

Report on the FCC and IC Testing of the
Aptiv Services US, LLC
Vehicle Radar. Model: FLR4S
In accordance with CFR 47, Part 95, Subpart M
and
ISED RSS-251, Issue 2



Product Service

Choose certainty.
Add value.

Prepared for: Aptiv Services US, LLC
5725 Innovation Drive
Troy, Michigan 48098
USA

FCC ID: L2CFLR4S
IC: 3432A-FLR4S

COMMERCIAL-IN-CONFIDENCE

Date: 2024-03-25
Document Number: TR-713312044-00 | Revision: 0

RESPONSIBLE FOR	NAME	DATE	SIGNATURE
Project Management	Alex Fink	2024-04-02	 SIGN-ID 901188
Authorised Signatory	Martin Steindl	2024-04-02	 SIGN-ID 901453

Signatures in this approval box have checked this document in line with the requirements of TÜV SÜD Product Service document control rules.

ENGINEERING STATEMENT

The measurements shown in this report were made in accordance with the procedures described on test pages. All reported testing was carried out on a sample equipment to demonstrate limited compliance with FCC 47 CFR Part 95, Subpart M and ISED Canada RSS-251. The sample tested was found to comply with the requirements defined in the applied rules.

RESPONSIBLE FOR	NAME	DATE	SIGNATURE
Testing	Alex Fink	2024-04-02	 SIGN-ID 901188

Laboratory Accreditation

DAkkS Reg. No. D-PL-11321-11-03

DAkkS Reg. No. D-PL-11321-11-04

Laboratory recognition

Registration No. BNetzA-CAB-16/21-15

ISED Canada test site registration

3050A-2

EXECUTIVE SUMMARY

A sample of this product was tested and found to be compliant with FCC 47 CFR Part 95, Subpart M (2018), ISED Canada RSS-251 Issue 2 (2018-06).

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Trade Register Munich
HRB 85742
VAT ID No. DE129484267
Information pursuant to Section 2(1)
DL-InfoV (Germany) at
www.tuev-sued.com/imprint

Managing Directors:
Walter Reithmaier (CEO)
Patrick van Welij

Phone: +49 (0) 9421 55 22-0
Fax: +49 (0) 9421 55 22-99
www.tuev-sued.de

TÜV SÜD Product Service GmbH
Äußere Frühlingsstraße 45
94315 Straubing
Germany



Summary

Prüfergebnisse / Test Results	Auftragsnummer / Order No. 454364295
Die Prüfungen wurden nach folgenden Vorschriften durchgeführt: <i>Tests were performed according to:</i> CFR 47, Part 95, Subpart M ISED RSS-251, Issue 2	
Durchgeführte Prüfung <i>Test performed</i>	Prüfergebnis <i>Test result</i>
Radiated Power	Pass
Occupied Bandwidth	Pass
Spurious Radiated Emissions	Pass
Frequency Stability	Pass

Bemerkungen / Remarks:

Die Prüfergebnisse beziehen sich ausschließlich auf das zur Prüfung vorgestellte Prüfmuster. Ohne schriftliche Genehmigung des Prüflabors darf der Prüfbericht auszugsweise nicht vervielfältigt werden. *The test results relate only to the individual item which has been tested. Without the written approval of the test laboratory this report may not be reproduced in extracts.*



^a

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1 Administrative Data

Application details

Applicant:	Aptiv Services US, LLC 5725 Innovation Drive Troy, Michigan 48098 USA
Contact person:	Mr. Dean FAROUKI
Intercompany contact:[RH2]	TÜV SÜD Product Service GmbH GMA Straubing Mr. Thomas Ring
Order number:	454364295
Receipt of EUT:	2024-01-16
Return of EUT:	---
Date(s) of test:	2024-02-08 to 2024-03-04
Note(s):	---
Responsible for testing:	Alex Fink
Responsible for test report:	Alex Fink
Test report checked by:	Martin Steindl

Report details

Report number:	TR-713312044-00
Revision:	0
Issue date:	2024-04-02



2 Details about the Test Laboratory

Details about the Test Laboratory

Company name:	TÜV SÜD Product Service GmbH
Address:	Äußere Frühlingstraße 45 D-94315 Straubing Germany
Laboratory accreditation:	DAkKS Registration No. D-PL-11321-11-03 DAkKS Registration No. D-PL-11321-11-04
Laboratory recognition:	Registration No. BNetzA-CAB-16/21-15
Industry Canada test site registration:	3050A-2
Contact:	Mr. Markus Biberger
	Phone: +49 9421 5522-0 Fax: +49 9421 5522-99



3 Description of the Equipment Under Test

Equipment characteristics	
Type designation:	FLR4S
Parts of the system:	Radar ECU
Options and accessories:	---
Type of equipment:	Vehicle Radar
Serial number:	---
Manufacturer:	Aptiv Services US, LLC
Hardware version:	PV
Software version:	24.00.08.23.43.03
Communication Protocol:	---
Build status:	---
Power supply:	Battery supply (regulated lead-acid) Nominal: 12.0 V DC Minimum: 6.5 V DC Maximum: 16.0 V DC Nominal frequency: N/A - DC
Highest internal frequency:	1.6 GHz (ADC/PLL clock) / 76.9 GHz (radio)

Marking Plate (draft)



Technical Description

The Equipment Under Test (EUT) was an Aptiv FLR4S. The EUT operates in the 76 GHz – 77 GHz band. The device employs a dynamic chirp modulated transmit array. Multiple receive antennas are used to determine target angular resolution through digital beam forming. The device is intended to be mounted at the front and rear corners of a vehicle. The EUT's normal operating voltage is DC 12 V

Antenna gain: 15.5 dBi

Modulation characteristics:

b. Non-pulsed radar

Type: FMCW

Modulation Type: Sawtooth

Sweep Bandwidth: 990 MHz

Sweep rate: 51.5 GHz/s

Sweep time: 19 ms (tx on)

Reset time (no transmission): 36 ms (tx off)



3.1 Modification Record

The table below details modifications made to the EUT during the test programme. The modifications incorporated during each test are recorded on the appropriate test pages.

<i>Modification State</i>	<i>Description of Modification still fitted to EUT</i>	<i>Modification Fitted By</i>	<i>Date</i>
Model: FLR4S - Serial Number: ---			
0	As supplied by the customer	Not Applicable	Not Applicable



4 Operation Mode and Configuration of EUT

Operation Mode(s)

Continuously Transmitting with modulation - 12.0 V DC power supply

List of ports and cables

No.	Description	Classification ¹	Cable type	Cable length	
				used	maximum ²
D1	DC 12 V supply	dc power	Unshielded	2 m	< 3 m
S1	Wiring harness (CAN)	signal/control port	Unshielded	2 m	< 3 m

List of devices connected to EUT

No.	Description	Type designation	Serial no. or ID	Manufacturer
---	---	---	---	---

List of support devices

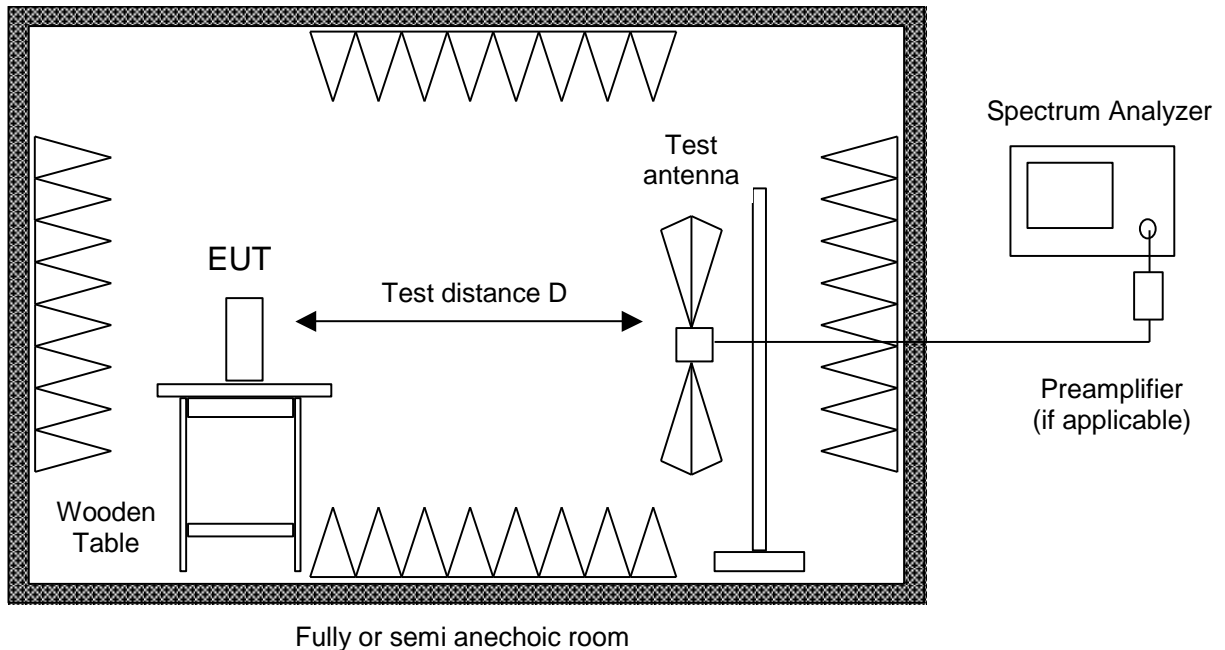
No.	Description	Type designation	Serial no. or ID	Manufacturer
1	CAN/LIN-Interface	VN1640A	---	Vector
2	Notebook	Precision 7510	---	Dell

¹ Ports shall be classified as ac power, dc power or signal/control port.

² As specified by applicant

5 Test Setups

Radiated Emission in Fully or Semi Anechoic Room



Radiated emission in fully or semi anechoic room is measured in the frequency range from 30 MHz to the maximum frequency as specified in CFR 47 Part 15 section 15.33.

Measurements are made in both the horizontal and vertical planes of polarization using a spectrum analyzer with the detector function set to peak and resolution as well as video bandwidth set to 100 kHz (below 1 GHz) or 1 MHz (above 1 GHz).

Testing up to 1 GHz is performed with a linear polarized logarithmic periodic antenna combined with a 4:1 broadband dipole ("Trilog broadband antenna"). For testing above 1 GHz horn antennas are used.

All tests below 8.2 GHz are performed at a test distance D of 3 meters. For higher frequencies the test distance may be reduced (e.g. to 1 meter) due to the sensitivity of the measuring instrument(s) and the test results are calculated according to CFR 47 Part 15 section 15.31(f)(1) using an extrapolation factor of 20 dB/decade. If required, preamplifiers are used for the whole frequency range. Special care is taken to avoid overload, using appropriate attenuators and filters, if necessary.

If the radiated emission limits are expressed in terms of the average value of the emission there also is a peak limit corresponding to 20 dB above the maximum permitted average limit. Additionally, if pulsed operation is employed, the average field strength is determined by averaging over one complete pulse train, including blanking intervals, as specified in CFR 47 Part 15 section 15.35(c). If the pulse train exceeds 0.1 second that 0.1 second interval during which the value of the emission is at its maximum is selected for calculation. The pulse train correction is added to the peak value of the emission to get the average value.

Hand-held or body-worn devices are rotated through three orthogonal axes to determine which attitude and configuration produces the highest emission relative to the limit and therefore shall be used for final testing.

During testing the EUT is rotated all around to find the maximum levels of emissions. Equipment and cables are placed and moved within the range of position likely to find their maximum emissions.

For final testing below 1 GHz a semi anechoic room complying with the NSA requirements of ANSI C63.4 for alternative test sites is used (see 0). If prescans are recorded in fully anechoic room they are indicated appropriately.

According to section 13 of KDB558074 the requirement for radiated emissions on the band edges was performed with a reduced bandwidth of 100 kHz instead of 1 MHz.

Radiated emission in the frequency range 9 kHz to 30 MHz is measured using an active loop antenna. First the whole spectrum of emission caused by the equipment is recorded at a distance of 3 meters in a fully or semi anechoic room with the detector of the spectrum analyzer or EMI receiver set to peak. This configuration is also used for recording the spectrum of intentional radiators.

Hand-held or body-worn devices are rotated through three orthogonal axes to determine which attitude and configuration produces the highest emission relative to the limit and therefore shall be used for final testing.

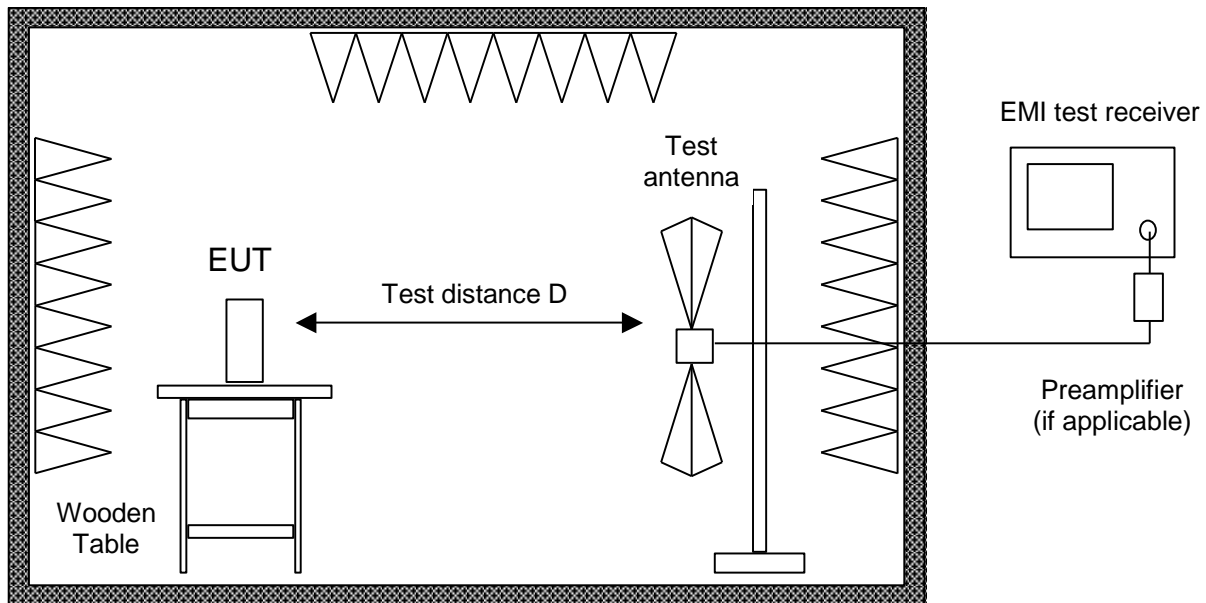
EUT is rotated all around to find the maximum levels of emissions. Equipment and cables are placed and moved within the range of position likely to find their maximum emissions.

If worst case emission of the EUT cannot be recorded with EUT in standard position and loop antenna in vertical polarization the EUT (or the radiating part of the EUT) is rotated by 90 degrees instead of changing the loop antenna to horizontal polarization. This procedure is selected to minimize the influence of the environment (e.g. effects caused by the floor especially with longer distances).

Final measurement is performed at a test distance D of 30 meters using an open field test site. In case the regulation requires testing at other distances, the result is extrapolated by either making measurements at an additional distance D of 10 meters to determine the proper extrapolation factor or by using the square of an inverse linear distance extrapolation factor (40 dB/decade). In cases of very low emissions measurements are performed at shorter distances and results are extrapolated to the required distance. The provisions of CFR 47 Part 15 sections 15.31(d) and (f)(2) apply. According to CFR 47 Part 15 section 15.209(d) final measurement is performed with detector function set to quasi-peak except for the frequency bands 9 to 90 kHz and 110 to 490 kHz where, for non-pulsed operation, average detector is employed.

If the radiated emission limits are expressed in terms of the average value of the emission there also is a peak limit corresponding to 20 dB above the maximum permitted average limit. Additionally, if pulsed operation is employed, the average field strength is determined by averaging over one complete pulse train, including blanking intervals, as specified in CFR 47 Part 15 section 15.35(c). If the pulse train exceeds 0.1 second that 0.1 second interval during which the value of the emission is at its maximum is selected for calculation. The pulse train correction is added to the peak value of the emission to get the average value.

Radiated Emission at Alternative Test Site



Alternate test site (semi anechoic room)

Radiated emission in the frequency range 30 MHz to 1 GHz is measured within a semi-anechoic room with groundplane complying with the NSA requirements of ANSI C63.4 for alternative test sites. A linear polarized logarithmic periodic antenna combined with a 4:1 broadband dipole ("Trilog broadband antenna") is used. The measurement bandwidth of the test receiver is set to 120 kHz with quasi-peak detector selected.

If the radiated emission limits are expressed in terms of the average value of the emission there also is a peak limit corresponding to 20 dB above the maximum permitted average limit. Additionally, if pulsed operation is employed, the average field strength is determined by averaging over one complete pulse train, including blanking intervals, as specified in CFR 47 Part 15 section 15.35(c). If the pulse train exceeds 0.1 second that 0.1 second interval during which the value of the emission is at its maximum is selected for calculation. The pulse train correction is added to the peak value of the emission to get the average value.

Hand-held or body-worn devices are tested in the position producing the highest emission relative to the limit as verified by prescans in fully anechoic room.

If no prescan in a fully anechoic room is used first a peak scan is performed in four positions to get the whole spectrum of emission caused by EUT with the measuring antenna raised and lowered from 1 to 4 m to find table position, antenna height and antenna polarization for the maximum emission levels.

Data reduction is applied to these results to select those levels having less margin than 10 dB to or exceeding the limit using subranges and limited number of maximums. Further maximization is following.

With detector of the test receiver set to quasi-peak final measurements are performed immediately after frequency zoom (for drifting disturbances) and maximum adjustment.

Equipment and cables are placed and moved within the range of position likely to find their maximum emissions.

In cases where prescans in a fully anechoic room are taken (e. g. if EUT is operating for a short time only or battery is discharged quickly) final measurements with quasi-peak detector are performed manually at frequencies indicated by prescan with EUT rotating all around and receiving antenna raising and lowering within 1 meter to 4 meters to find the maximum levels of emission.

Equipment and cables are placed and moved within the range of position likely to find their maximum emissions.



For measuring emissions of intentional radiators and receivers a test distance D of 3 meters is selected. Testing of unintentional radiators is performed at a distance of 10 meters. If limits specified for 3 meters shall be used for measurements performed at 10 meters distance the limits are calculated according to CFR 47 Part 15 section 15.31(d) and (f)(1) using an inverse linear-distance extrapolation factor of 20 dB/decade.



6 Referenced Regulations

<i>Publication</i>	<i>Title</i>
CFR 47, Part 2	Code of Federal Regulations Part 2 (Frequency allocation and radio treaty matters; General rules and regulations) of the Federal Communications Commission (FCC)
CFR 47, Part 95, Subpart M	Code of Federal Regulations Part 95 (Personal Radio Services), Subpart M (76 – 77 GHz Band Radar Service) of the Federal Communications Commission (FCC)
RSS-251, Issue 2	Vehicular Radar and Airport Fixed or Mobile Radar in the 76 – 81 GHz Frequency band
RSS-GEN, Issue 5 + Amendment 1 + Amendment 2	General Requirements for Compliance of Radio Apparatus
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

7 Measurement Uncertainty Values

The measurement uncertainty in the laboratory is less than or equal to the maximum measurement uncertainty according to EN 55016-4-2: 2011 + A1 + A2 + AC and CISPR16-4-2: 2011 + A1 + A2 + Cor1 (UCISPR). This normative regulation means that the measured value is also the value to be assessed in relation to the limit value.

For a 95% confidence level, the measurement uncertainties for defined systems are:

Radio Testing			
Test Name	kp	Expanded Uncertainty	Note
Occupied Bandwidth	2.0	±1.14 %	2
RF-Frequency error	1.96	±1 · 10 ⁻⁷	7
RF-Power, conducted carrier	2	±0.079 dB	2
RF-Power uncertainty for given BER	1.96	+0.94 dB / -1.05	7
RF power, conducted, spurious emissions	1.96	+1.4 dB / -1.6 dB	7
RF power, radiated			
25 MHz – 4 GHz	1.96	+3.6 dB / -5.2 dB	8
1 GHz – 18 GHz	1.96	+3.8 dB / -5.6 dB	8
18 GHz – 26.5 GHz	1.96	+3.4 dB / -4.5 dB	8
40 GHz – 170 GHz	1.96	+4.2 dB / -7.1 dB	8
Spectral Power Density, conducted	2.0	±0.53 dB	2
Maximum frequency deviation			
300 Hz – 6 kHz	2	±2,89 %	2
6 kHz – 25 kHz	2	±0.2 dB	2
Maximum frequency deviation for FM	2	±2,89 %	2
Adjacent channel power 25 MHz – 1 GHz	2	±2.31 %	2
Temperature	2	±0.39 K	4
(Relative) Humidity	2	±2.28 %	2
DC- and low frequency AC voltage			
DC voltage	2	±0.01 %	2
AC voltage up to 1 kHz	2	±1.2 %	2
Time	2	±0.6 %	2



Radio Interference Emission Testing			
Test Name	kp	Expanded Uncertainty	Note
Conducted Voltage Emission			
9 kHz to 150 kHz (50Ω/50μH AMN)	2	± 3.8 dB	1
150 kHz to 30 MHz (50Ω/50μH AMN)	2	± 3.4 dB	1
100 kHz to 200 MHz (50Ω/5μH AMN)	2	± 3.6 dB	1
Discontinuous Conducted Emission			
9 kHz to 150 kHz (50Ω/50μH AMN)	2	± 3.8 dB	1
150 kHz to 30 MHz (50Ω/50μH AMN)	2	± 3.4 dB	1
Conducted Current Emission			
9 kHz to 200 MHz	2	± 3.5 dB	1
Magnetic Fieldstrength			
9 kHz to 30 MHz (with loop antenna)	2	± 3.9 dB	1
9 kHz to 30 MHz (large-loop antenna 2 m)	2	± 3.5 dB	1
Radiated Emission			
Test distance 1 m (ALSE)			
9 kHz to 150 kHz	2	± 4.6 dB	1
150 kHz to 30 MHz	2	± 4.1 dB	1
30 MHz to 200 MHz	2	± 5.2 dB	1
200 MHz to 2 GHz	2	± 4.4 dB	1
2 GHz to 3 GHz	2	± 4.6 dB	1
Test distance 3 m			
30 MHz to 300 MHz	2	± 4.9 dB	1
300 MHz to 1 GHz	2	± 5.0 dB	1
1 GHz to 6 GHz	2	± 4.6 dB	1
Test distance 10 m			
30 MHz to 300 MHz	2	± 4.9 dB	1
300 MHz to 1 GHz	2	± 4.9 dB	1
Radio Interference Power			
30 MHz to 300 MHz	2	± 3.5 dB	1
Harmonic Current Emissions			4
Voltage Changes, Voltage Fluctuations and Flicker			4

Immunity Testing			
Test Name	kp	Expanded Uncertainty	Note
Electrostatic Discharges			4
Radiated RF-Field			
Pre-calibrated field level	2	+32.2 / -24.3 %	5
Dynamic feedback field level	2.05	+21.2 / -17.5 %	3
Electrical Fast Transients (EFT) / Bursts			4
Surges			4
Conducted Disturbances, induced by RF-Fields			
via CDN	2	+15.1 / -13.1 %	6
via EM clamp	2	+42.6 / -29.9 %	6
via current clamp	2	+43.9 / -30.5 %	6
Power Frequency Magnetic Field	2	+20.7 / -17.1 %	2
Pulse Magnetic Field			4
Voltage Dips, Short Interruptions and Voltage Variations			4
Oscillatory Waves			4
Conducted Low Frequency Disturbances			
Voltage setting	2	± 0.9 %	2
Frequency setting	2	± 0.1 %	2
Electrical Transient Transmission in Road Vehicles			4

Note 1:

The expanded uncertainty reported according to CISPR 16-4-2:2003-11 is based on a standard uncertainty multiplied by a coverage factor of $k_p = 2$, providing a level of confidence of $p = 95.45\%$

Note 2:

The expanded uncertainty reported according to UKAS Lab 34 (Edition 1, 2002-08) is based on a standard uncertainty multiplied by a coverage factor of $k_p = 2$, providing a level of confidence of $p = 95.45\%$

Note 3:

The expanded uncertainty reported according to UKAS Lab 34 (Edition 1, 2002-08) is based on a standard uncertainty multiplied by a coverage factor of $k_p = 2.05$, providing a level of confidence of $p = 95.45\%$

Note 4:

It has been demonstrated that the used test equipment meets the specified requirements in the standard with at least a 95% confidence.

Note 5:

The expanded uncertainty reported according to IEC 61000-4-3 is based on a standard uncertainty multiplied by a coverage factor of $k_p = 2$, providing a level of confidence of $p = 95.45\%$

Note 6:

The expanded uncertainty reported according to IEC 61000-4-6 is based on a standard uncertainty multiplied by a coverage factor of $k_p = 2$, providing a level of confidence of $p = 95.45\%$

Note 7:

The expanded uncertainty reported according to ETSI TR 100 028 V1.4.1 (all parts) is based on a standard uncertainty multiplied by a coverage factor of $k_p = 1.96$, providing a level of confidence of $p = 95.45\%$

Note 8:

The expanded uncertainty reported according to ETSI TR 102 273 V1.2.1 (all parts) is based on a standard uncertainty multiplied by a coverage factor of $k_p = 1.96$, providing a level of confidence of $p = 95.45\%$



8 Test Equipment used

<i>T-ID</i>	<i>Designation</i>	<i>Type</i>	<i>Last Cal.</i>	<i>Next Cal.</i>
18874	Horn antenna	3160-07	Verified	
18875	Horn antenna	3160-08	Verified	
19125	Horn antenna	3160-09	Verified	
19442	Horn antenna	3160-10	Verified	
39897	EMI test receiver	ESW44	2023-04	2024-04
19933	Double ridged horn antenna	HF907	2023-08	2025-08
19946	Horn antenna	24240-20	Verified	
20219	Signal and Spectrum Analysator	FSV40 for TS8997	2023-04	2024-04
22553	Waveguide mixer	FS-Z170	2023-06	2026-06
25849	Waveguide mixer	FS-Z60	2023-06	2026-06
25850	Waveguide mixer	FS-Z90	2023-06	2026-06
25851	Waveguide mixer	FS-Z110	2023-06	2026-06
27898	Horn antenna	26240-20	Verified	
27899	Horn antenna	27240-20	Verified	
36954	Harmonic Mixer	FS-Z220	2023-06	2026-06
36955	Harmonic Mixer	FS-Z325	2023-06	2026-06
37863	Horn antenna	30240-20 WG30	Verified	
37864	Horn antenna	32240-20 WG32	Verified	
38401	ULTRALOG Antenna	HL562E	2021-05	2024-05

Test software for: EMC32 V10.



9 Test Results

CFR 47, Part 2

<i>Section(s)</i>	<i>Test performed</i>	<i>Page</i>	<i>Test Result</i>
§ 2.202 (a); § 2.1049	Occupied Bandwidth	24	Test passed

CFR 47, Part 95, Subpart M,

<i>Section(s)</i>	<i>Test performed</i>	<i>Page</i>	<i>Test Result</i>
§ 95.3367 (a)	Radiated Power – Average	21	Test passed
§ 95.3367 (b)	Radiated Power – Peak	21	Test passed
§ 95.3379 (a)	Spurious Emissions	26	Test passed
§95.3379 (b)	Frequency Stability	38	Test passed



ISED RSS-GEN, Issue 5 + Amendment 1 + Amendment 2

<i>Section(s)</i>	<i>Test performed</i>	<i>Page</i>	<i>Test Result</i>
6.7	Occupied Bandwidth	24	Test passed

ISED RSS-251, Issue 2

<i>Section(s)</i>	<i>Test performed</i>	<i>Page</i>	<i>Test Result</i>
7	Occupied Bandwidth	24	Test passed
8	Average equivalent isotropically radiated power (e.i.r.p.)	21	Test passed
9	Peak (e.i.r.p.)	21	Test passed
10	Unwanted Emissions	26	Test passed
11	Frequency Stability	38	Test passed



9.1 Radiated Power

Date of Test	2024-02-19
Operator	Alex Fink
Test Site	Semi anechoic room, cabin no. 11

Test Result	
<input checked="" type="checkbox"/>	Passed
<input type="checkbox"/>	Not Passed

Barometric pressure:	989 hPa
Relative humidity:	32 %
Ambient temperature:	23 °C

Specifications:	Part 95, Subpart M, § 95.3367(a) and (b) RSS-251 Issue 2, Sections 8 and 9
Description:	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: Part 95, Subpart M, § 95.3367(a) and (b): 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. RSS-251 Issue 2, Sections 8 and 9: 8) The radar device's total average e.i.r.p. shall not exceed 50 dBm over the occupied bandwidth. 9) The radar device's peak e.i.r.p. spectral density shall not exceed 55 dBm/MHz
Operation mode:	Transmitting continuously on frequency with modulation.
Comment :	Test was performed as radiated test. The test distance was 3 m. A correction factor and mixer conversion loss table were used to account for the test antenna gain, free-space loss and external mixer loss.

Sample calculation of e.i.r.p. values:

$$\begin{aligned} \text{Final Value (dBm, e.i.r.p.)} = & \text{Reading Value (dBm)} + (\text{Antenna Gain Correction Factor (dB)} \\ & + \text{External Mixer Correction Factor (dB)} \\ & + \text{Cable Correction Factor (dB)} \\ & + \text{Free Space Loss Correction Factor (dB)}) \end{aligned}$$

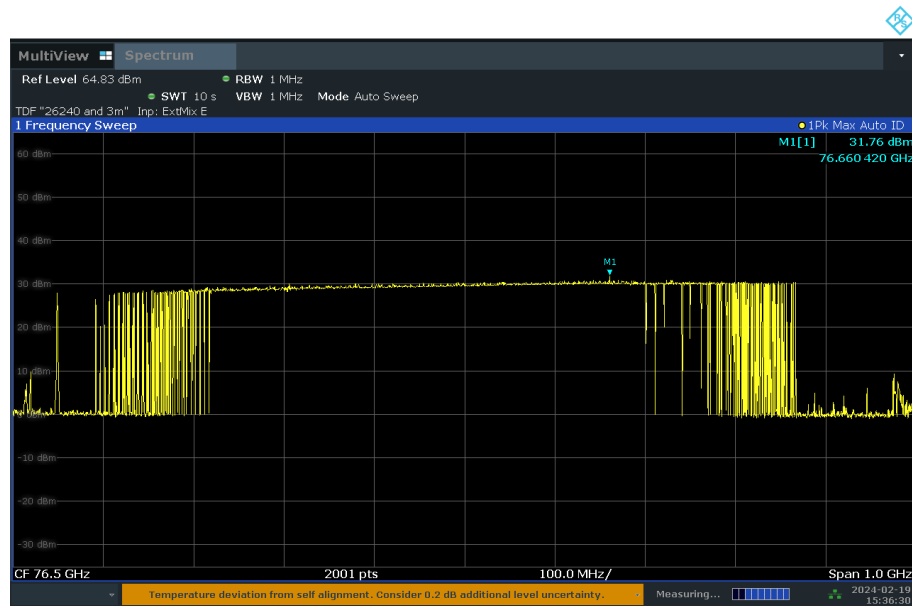


<i>Detector</i>	<i>Default mode</i>	<i>Limit</i>	<i>Note</i>
Average (peak value)	-2.65 dBm	50 dBm	1
Average (band function)	24.95 dBm	50 dBm	2
Peak	31.76 dBm	55 dBm	1 and 2

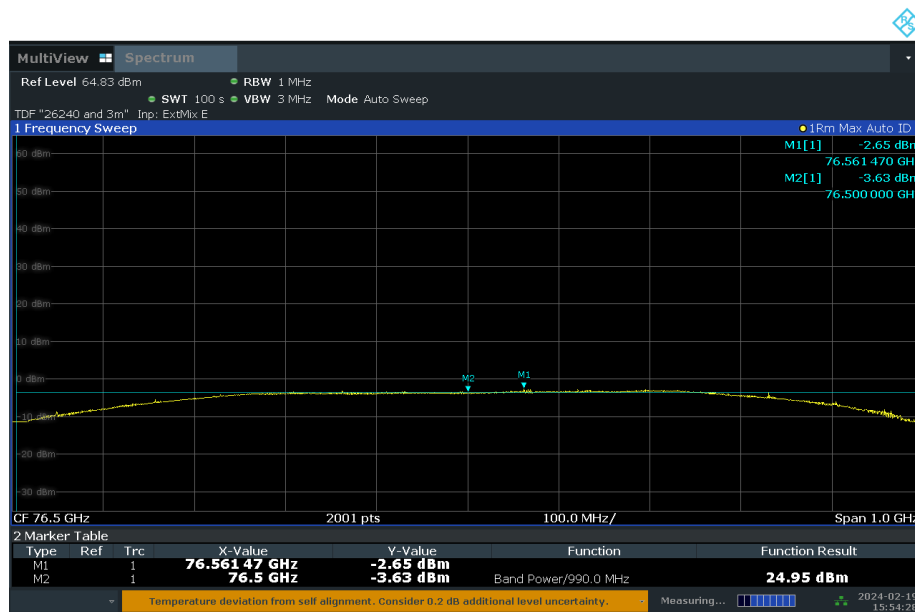
Note(s):

- 1 Applicable for FCC rules
- 2 Applicable for ISED rules

Plots taken during test



03:36:30 PM 02/19/2024



03:54:29 PM 02/19/2024

Operating mode – Continuously Transmitting - 12.0 V DC power supply



9.2 Occupied Bandwidth

Date of Test	2024-03-04
Operator	Alex Fink
Test Site	Semi anechoic room, cabin no. 11

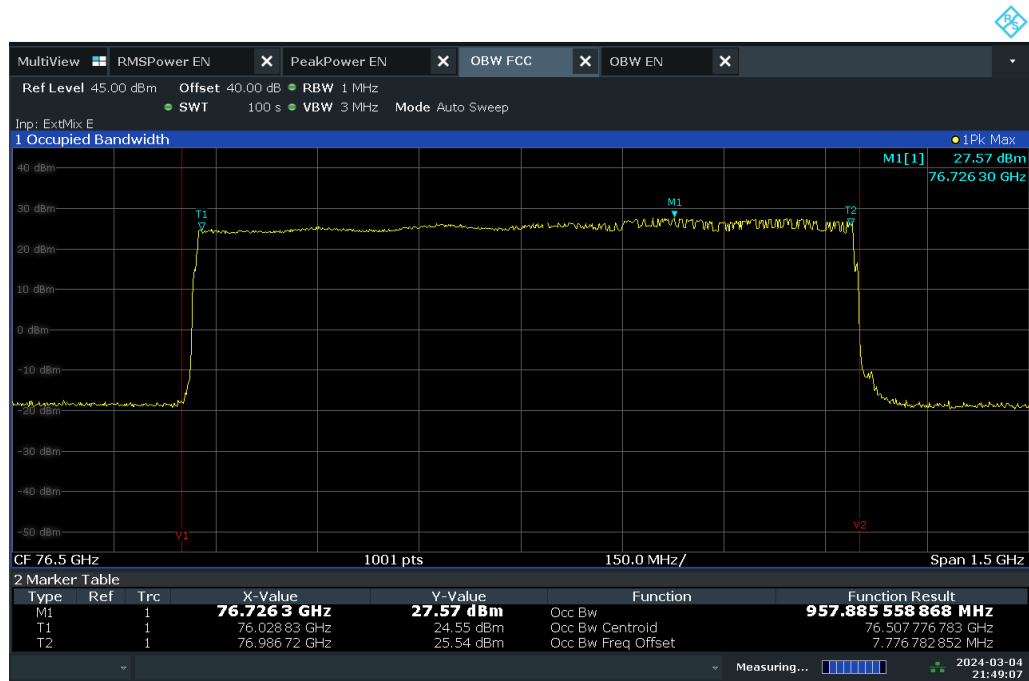
Test Result	
<input checked="" type="checkbox"/>	Passed
<input type="checkbox"/>	Not Passed

Barometric pressure:	989 hPa
Relative humidity:	32 %
Ambient temperature:	23 °C

Specifications:	CFR 47, Part 2, Clause 2.1049 and 2.202(a) RSS-GEN Issue 4, Section 6.6 RSS-251, Issue 2, Section 7
Description:	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.
Operation mode:	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.
Comment :	Transmitting continuously on frequency with modulation.

	Default mode	Limit	Note
f _L	76.02883 GHz	≥ 76 GHz	NA
f _H	76.98672 GHz	≤ 77 GHz	
99% bandwidth (f _H - f _L)	957.890 MHz	within 76-81 GHz band	NA

Note(s):	NA
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Operating mode - Continuously Transmitting - 12.0 V DC power supply



9.3 Spurious Radiated Emissions

Date of Test	2024-02-08 to 2024-02-23
Operator	Alex Fink
Test Site	Fully anechoic room, cabin no. 2 Semi anechoic room, cabin no. 11

Test Result	
<input checked="" type="checkbox"/>	Passed
<input type="checkbox"/>	Not Passed

Barometric pressure:	973 hPa
Relative humidity:	33 %
Ambient temperature:	23 °C

Specifications:	CFR 47, Part 95, Subpart M, § 95.3379(a) RSS-251 Issue 2, Section 10
Description:	The power density of any emissions outside the 76 – 81 GHz band shall consist solely of spurious emissions and shall not exceed the following: Radiated emissions below 40 GHz shall not exceed the field strength as shown in the Table 1. The power density of radiated of radiated emissions outside the 76 – 81 GHz band above 40 GHz shall not exceed the power density as shown in the tables on the next pages.
Operation mode:	This test was performed as radiated test in the frequency range 30 MHz to 300 GHz. No significant spurious emissions were observed. The test distance was 3 m in the frequency ranges 30 MHz to 1 GHz and 40 GHz to 110 GHz, 1 m in the frequency ranges 1GHz to 40 GHz and 110 GHz to 220 GHz and 0.5 m in the frequency range 220 GHz to 300 GHz.
Comment :	See plots for details.

Sample calculation of field final values:

$$\text{Final Value (dB}\mu\text{V/m)} = \text{Reading Value (dB}\mu\text{V)} + (\text{Antenna Correction Factor (dB/m)} + \text{Cable Correction Factor (dB)})$$

<i>Radiated emission limits 9 kHz – 40 GHz</i>		
<i>Frequency (MHz)</i>	<i>Field strength ($\mu\text{V}/\text{m}$)</i>	<i>Measurement distance (m)</i>
0.009 – 0.490	2400/f(kHz)	300
0.490 – 1.705	24000/f(kHz)	30
1.705 – 30	30	30
30 – 88	100	3
88 – 216	150	3
216 – 960	200	3
960 – 40000	500	3

Note(s):

- 1 In the emissions table the tighter limit applies at the band edges.
- 2 The limits are based on the frequency of the unwanted emissions and not the fundamental frequency. However, the level of any unwanted emission shall not exceed the level of the fundamental frequency.
- 3 The emissions limits shown in the table are based on measurement employing CISPR quasi-peak detector except for the frequency bands 9.0 – 90 kHz, 110.0 – 490 kHz, and above 1 GHz. Radiated emissions limits in these three bands are based on measurements employing an average detector with 1 MHz RBW.

Table 1: Radiated emission limits 9 kHz – 40 GHz

<i>Radiated emission limits 40 GHz – 231 GHz</i>		
<i>Frequency (GHz)</i>	<i>Power Density (pW/cm^2)</i>	<i>Measurement distance (m)</i>
40 – 200	600	3
above	1000	3

Note(s):

- 1 According to 47 CFR, Part 95, § 95.3379(a)(3) the spectrum shall be investigated up to 231 GHz.
- 2 The power density of 600 pW/cm² corresponds to a transmit power of -1.69 dBm, a field strength of 93.5 dB $\mu\text{V}/\text{m}$ for 3 m distance and 103.1 dB $\mu\text{V}/\text{m}$ for 1 m distance
- 3 The power density of 1000 pW/cm² corresponds to a field strength of 95.8 dB $\mu\text{V}/\text{m}$ for 3 m distance, 105.3 dB $\mu\text{V}/\text{m}$ for 1 m distance and 111.3 dB $\mu\text{V}/\text{m}$ for 0.5 m distance.

Table 2: FCC Radiated emission limits above 40 GHz



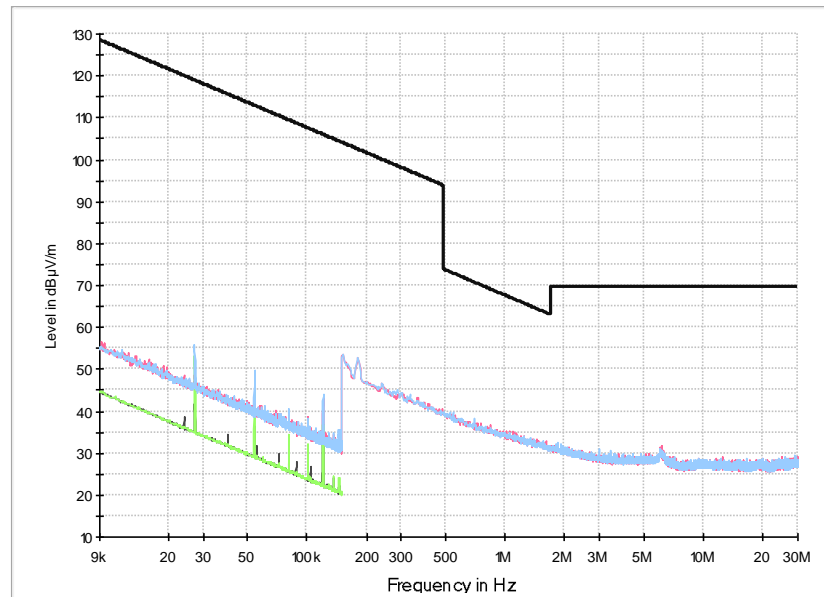
<i>Radiated emission limits 40 GHz – 162 GHz</i>		
<i>Frequency (GHz)</i>	<i>Limit (dBm/MHz e.i.r.p.)</i>	<i>Detector</i>
40 – 162	-30	RMS

Note(s):

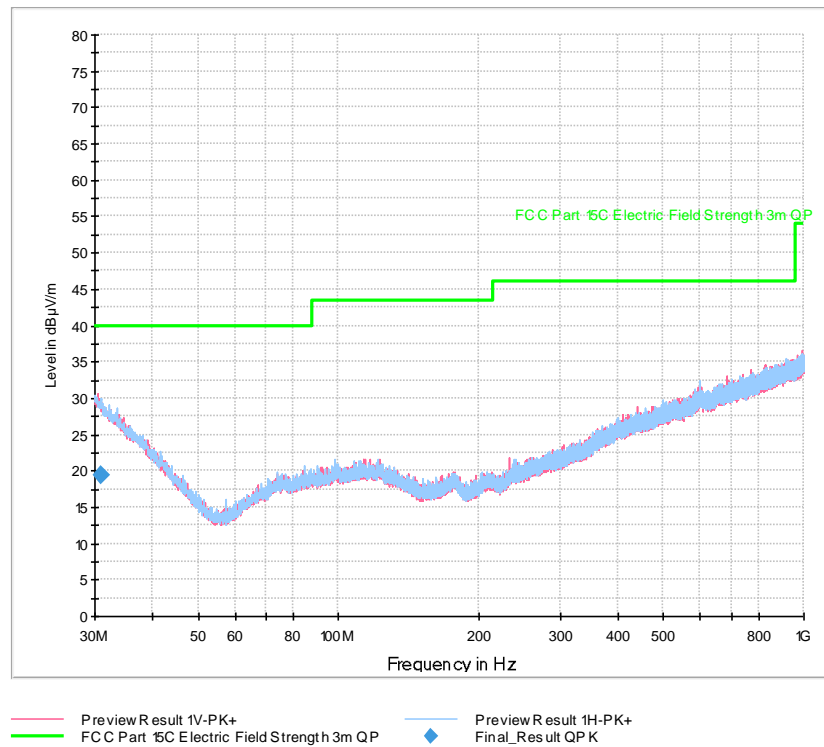
- For radar devices that operate solely in the 76 – 76 GHz Band (i.e. the occupied bandwidth is entirely contained in the 76 – 77 GHz band), an unwanted emissions limit of 0 dBm/MHz shall apply for the unwanted emission that fall in the 73.5 – 76 GHz band. Outside the 73.5 – 76 GHz band, the unwanted emission limits prescribed above shall apply.

Table 3: ISED Radiated emission limits above 40 GHz

Plots taken during measurement: Continuously Transmitting

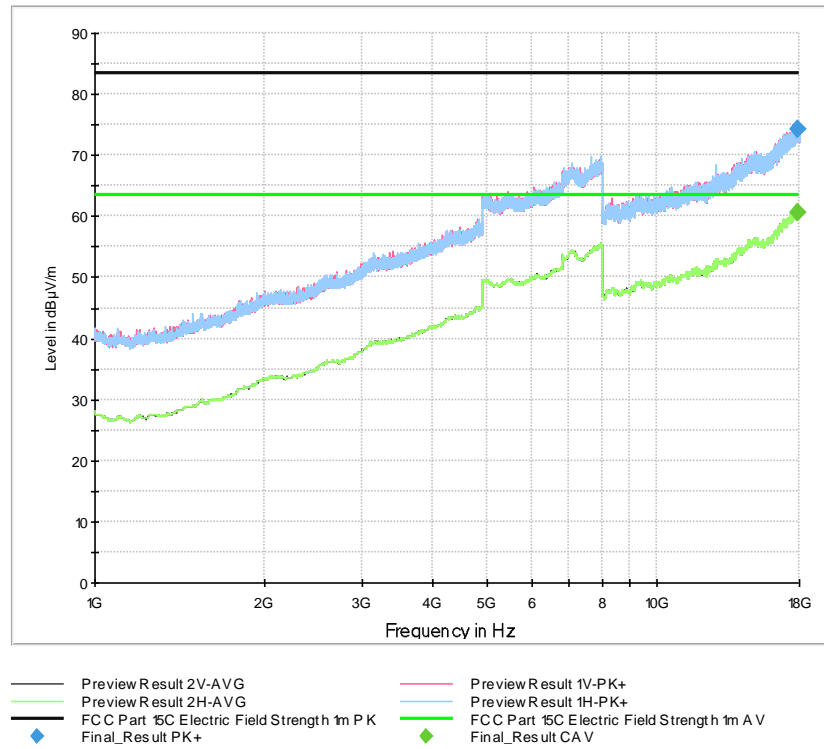


- Preview Result 2V-AVG
- Preview Result 1V-PK+
- Preview Result 2H-AVG
- Preview Result 1H-PK+
- FCC Part 15C Electric Field Strength 3m QP+AV (9k-30M)
- ◆ Final Result QP K
- ◆ Final Result CA V



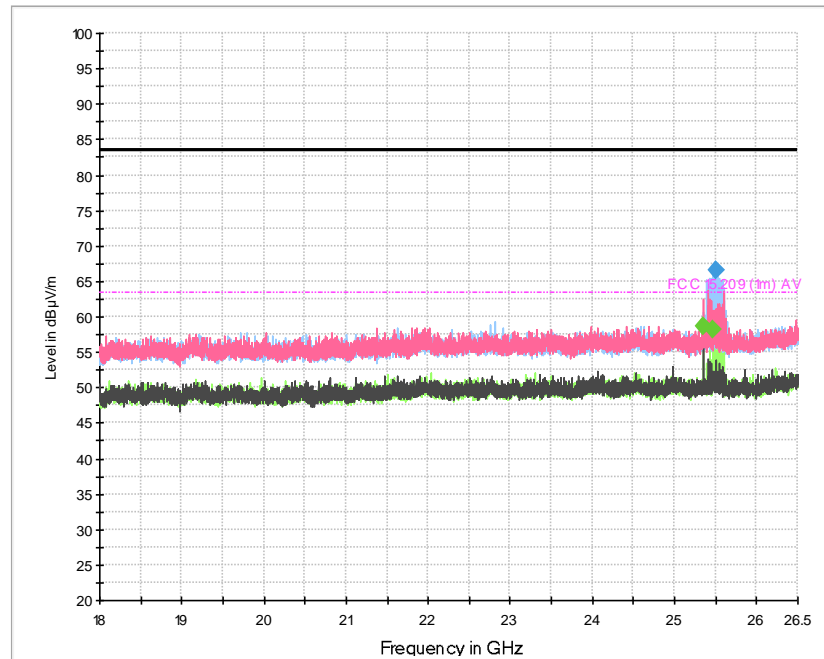
Final Results:

Frequency MHz	QuasiPeak dBµV/m	Limit dBµV/m	Margin dB	Meas. Time ms	Bandwidth kHz	Height cm	Pol	Azimuth deg	Corr. dB/m
31.050000	19.33	40.00	20.67	1000.0	120.000	150.0	V	9.0	24.6



Final Results:

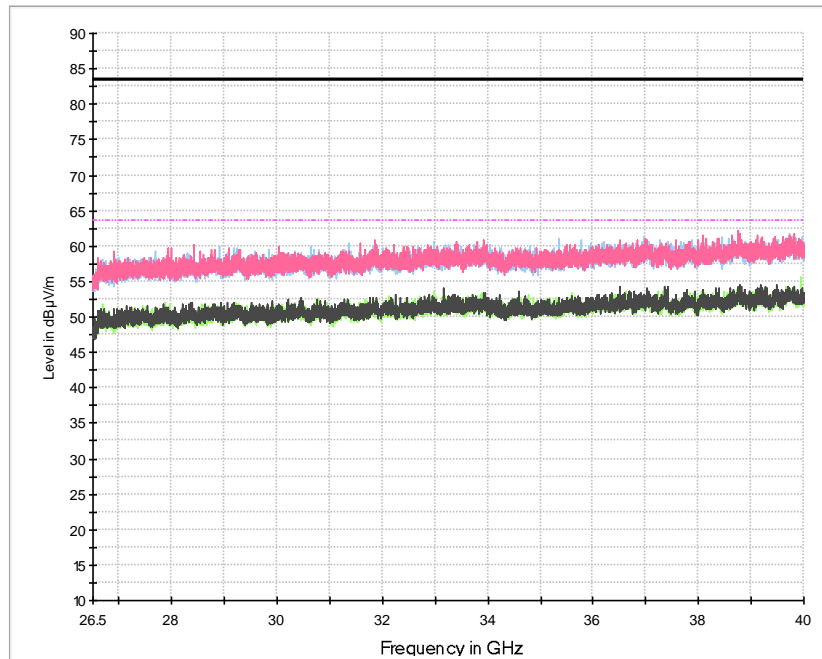
Frequency MHz	MaxPeak dBµV/m	CAverage dBµV/m	Limit dBµV/m	Margin dB	Meas. Time ms	Bandwidth kHz	Height cm	Pol	Azimuth deg	Corr. dB/m
17875.000000	---	60.74	63.50	2.76	1000.0	1000.000	125.0	V	132.0	58.9
17875.000000	74.24	---	83.50	9.27	1000.0	1000.000	125.0	V	132.0	58.9



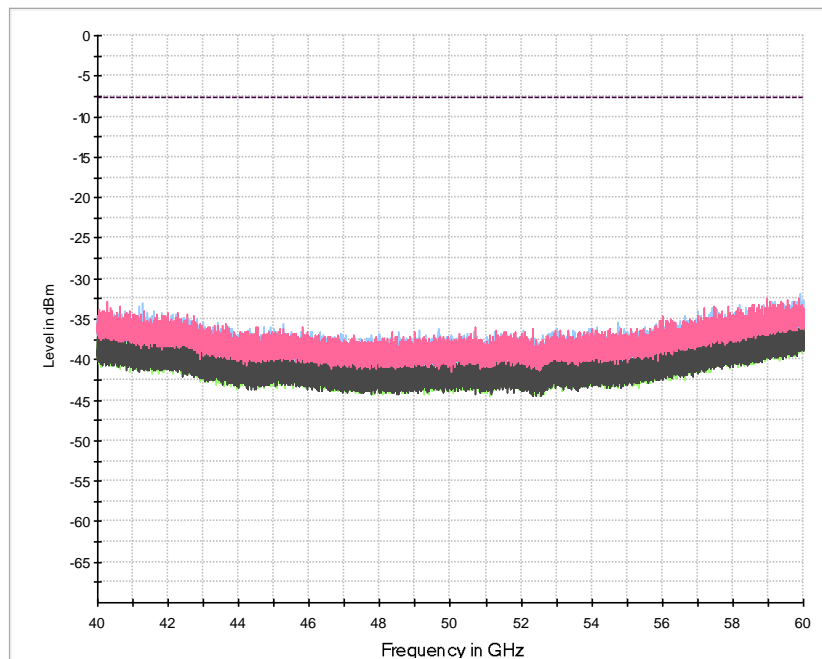
— Preview Result 2H-AVG — Preview Result 1H-PK+ — Preview Result 2V-AVG
— Preview Result 1V-PK+ — FCC 15.209 (1m) PK - - - FCC 15.209 (1m) AV
◆ Final_Result PK+ ◆ Final_Result AVG

Final Results:

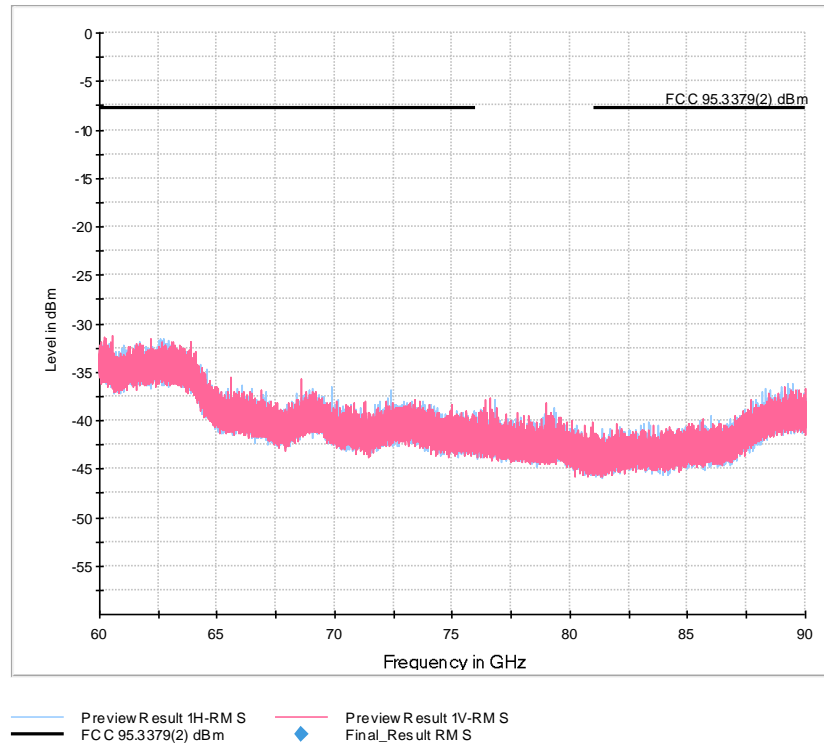
Frequency	MaxPeak	Average	Limit	Margin	Meas. Time	Bandwidth	Height	Pol	Azimuth	Corr.
MHz	dBµV/m	dBµV/m	dBµV/m	dB	ms	kHz	cm		deg	dB/m
25350.375000	---	58.59	63.50	4.91	2.5	1000.000	150.0	V	52.0	43
25475.750000	---	58.15	63.50	5.35	2.5	1000.000	150.0	H	176.0	43
25503.375000	66.53	---	83.50	16.97	2.5	1000.000	150.0	H	263.0	43

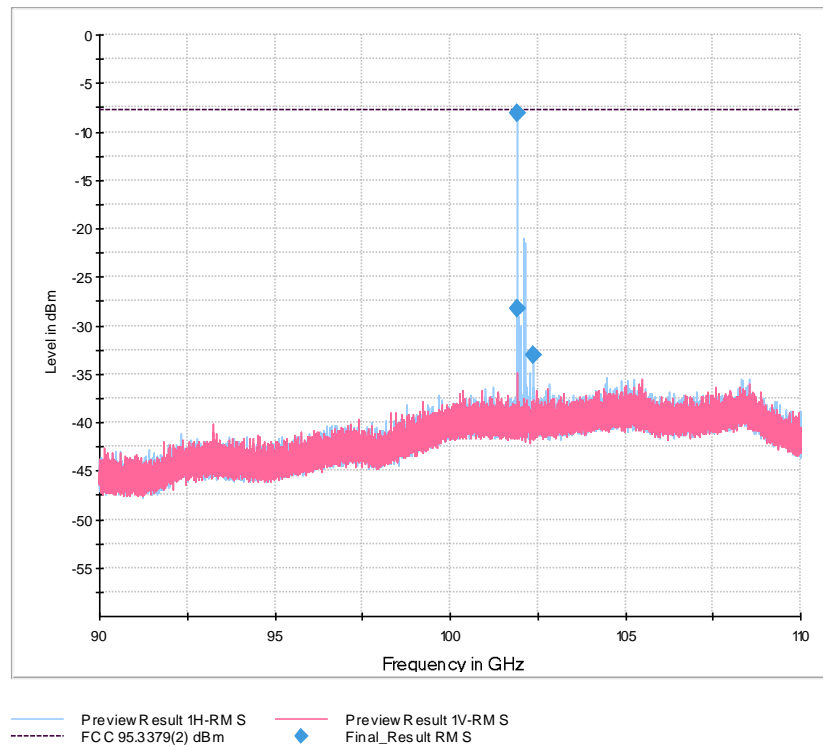


— Preview Result 2H-AVG — Preview Result 1H-PK+ — Preview Result 2V-AVG
— Preview Result 1V-PK+ — FCC 15.209 (1m) PK - - - FCC 15.209 (1m) AV
◆ Final_Result PK+ ◆ Final_Result AVG



— Preview Result 2H-RMS — Preview Result 1H-PK+ — Preview Result 2V-RMS
— Preview Result 1V-PK+ - - - FCC 95.3379(2) dBm ◆ Final_Result PK+
◆ Final_Result RMS

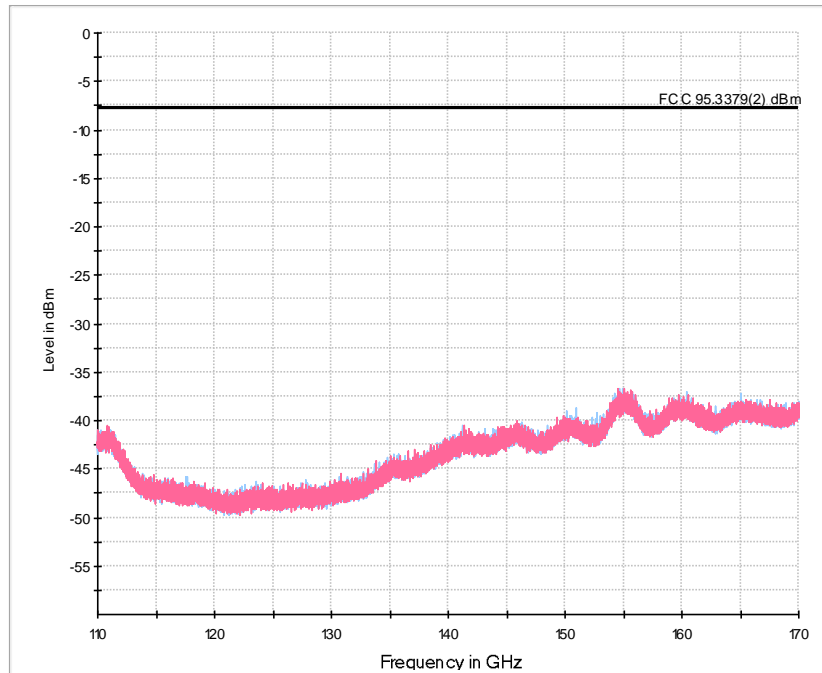




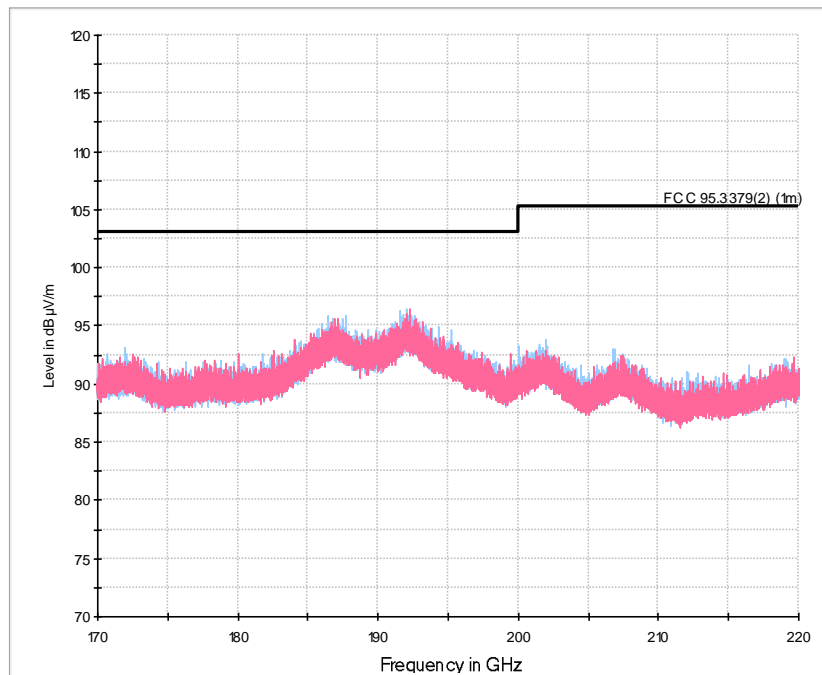
Final Results:

Frequency MHz	RMS dBm	Limit dBm	Margin dB	Meas. Time ms	Bandwidth kHz	Height cm	Pol	Azimuth deg	Corr. dB
101919.000000	-28.30 ^{#1}	-7.70	20.60	2.5	1000.000	150.0	H	20.0	-67
101940.000000	-8.02 ^{#1}	-7.70	0.32	2.5	1000.000	150.0	H	20.0	-67
102361.000000	-33.14 ^{#1}	-7.70	25.44	2.5	1000.000	150.0	H	343.0	-67

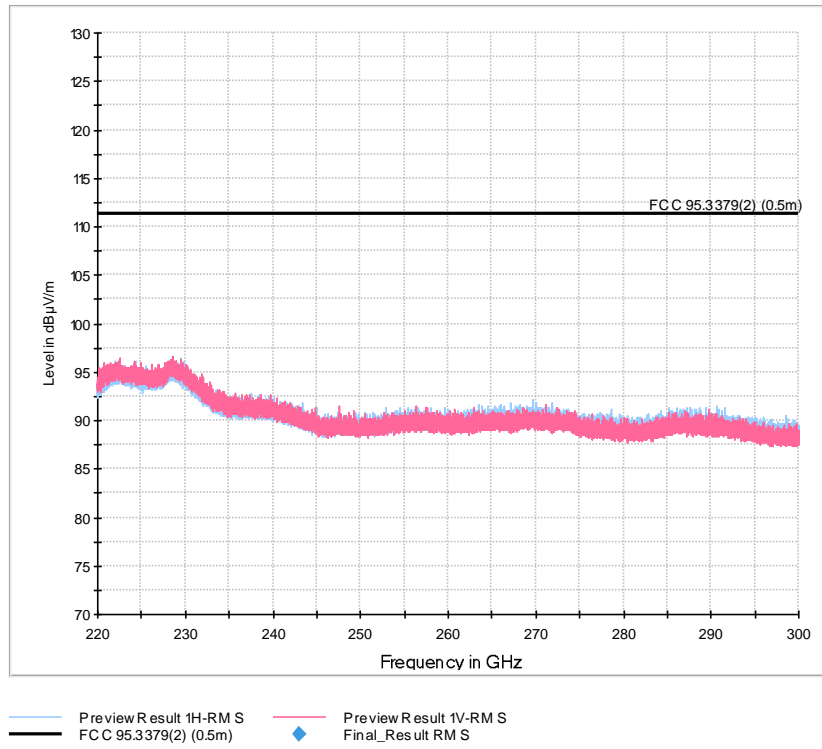
Note #1: emissions are mixing product



— Preview Result 1H-RM S — Preview Result 1V-RM S
— FCC 95.3379(2) dBm ◆ Final_Result RM S



— Preview Result 1H-PK+ — Preview Result 1V-PK+
— FCC 95.3379(2) (µm) ◆ Final_Result PK+





9.4 Frequency Stability

Date of Test	2024-03-04
Operator	Alex Fink
Test Site	Fully anechoic room, cabin no. 2 Climatic test chamber

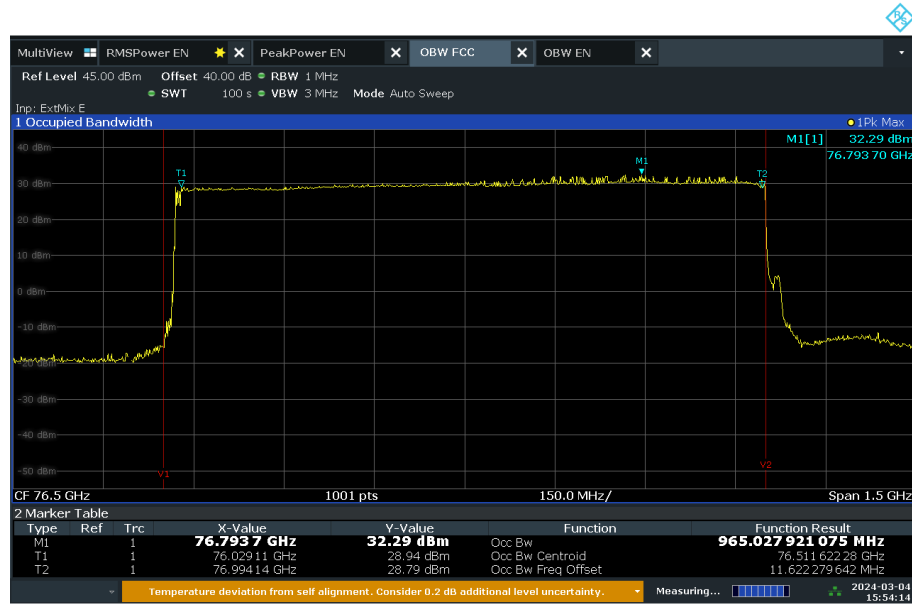
Prüfergebnis / Test Result	
<input checked="" type="checkbox"/>	Erfüllt / Passed
<input type="checkbox"/>	Nicht erfüllt / Not passed

Barometric pressure:	964 hPa
Relative humidity:	24 %
Ambient temperature:	24 °C

Specifications:	CFR 47, Part 95, Subpart M, §95.3379(b) RSS-251, Issue 2, Section 11
Description:	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 °C to 50 °C with a input voltage variation of 85 % to 115 % of rated input voltage unless justification is presented to demonstrate otherwise.
Operation mode:	Transmitting continuously
Comment :	See plots of tests for details.

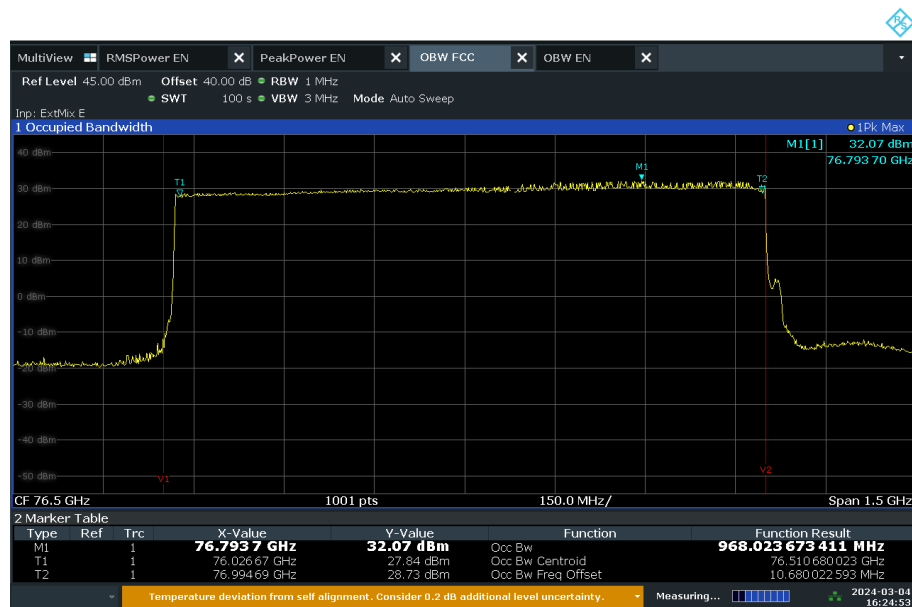
All emissions are within the 76 – 77 GHz frequency band.
 See plots for details

Plots taken during measurement



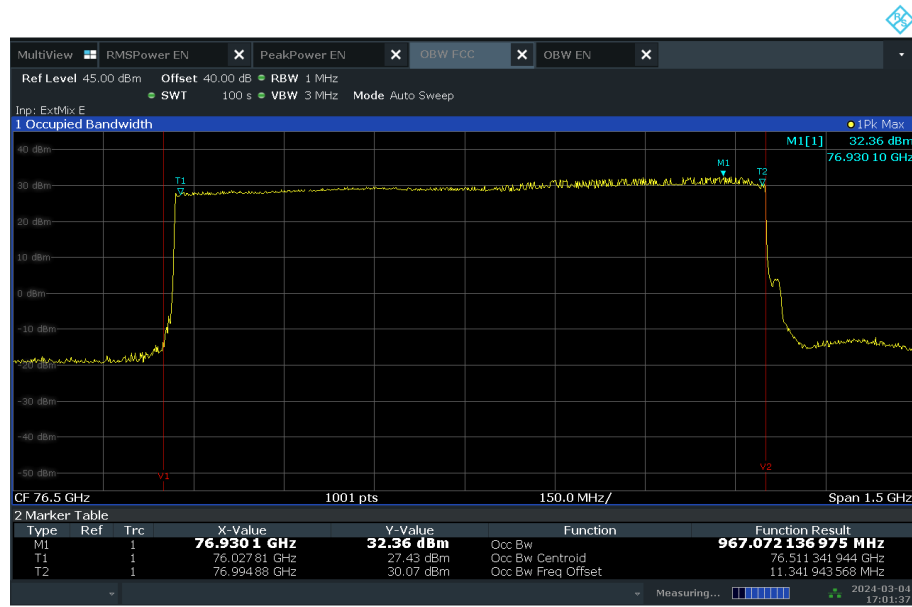
03:54:14 PM 03/04/2024

-40 °C, 12 V



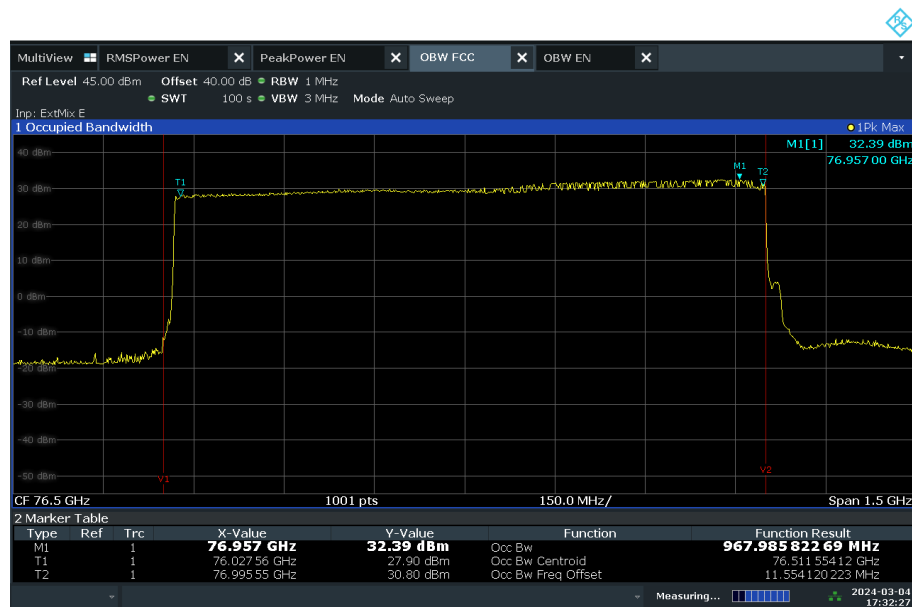
04:24:53 PM 03/04/2024

-30 °C, 12 V



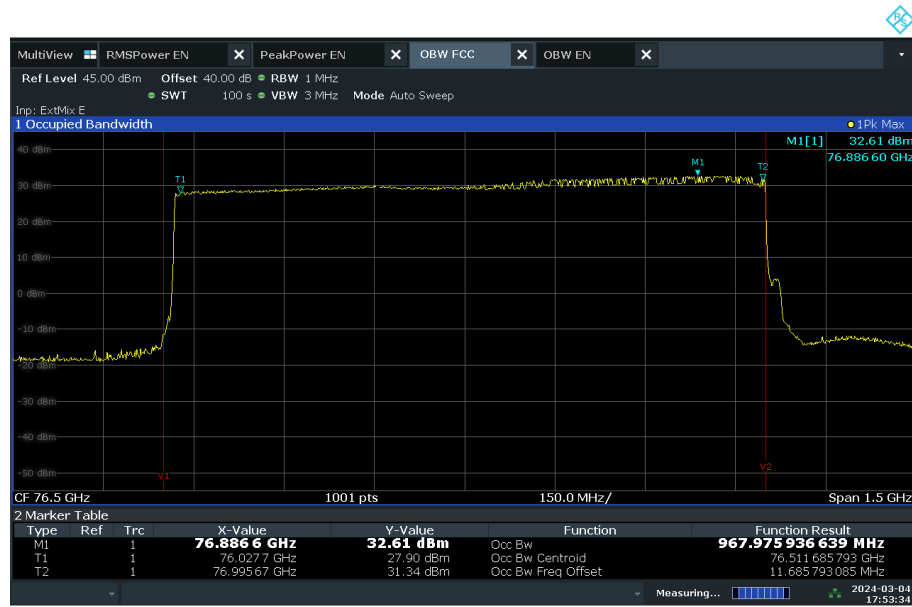
05:01:38 PM 03/04/2024

-20 °C, 12 V



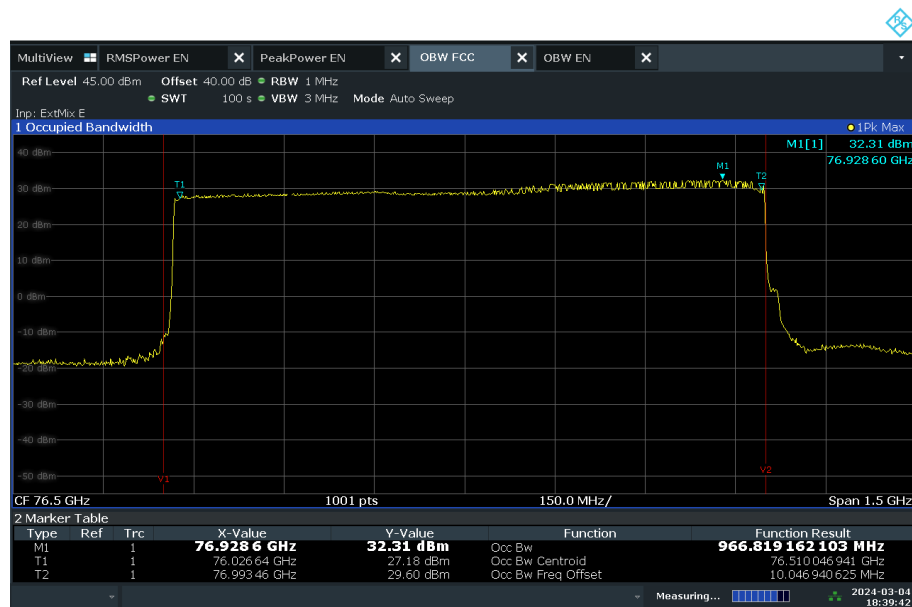
05:32:28 PM 03/04/2024

-10 °C, 12 V



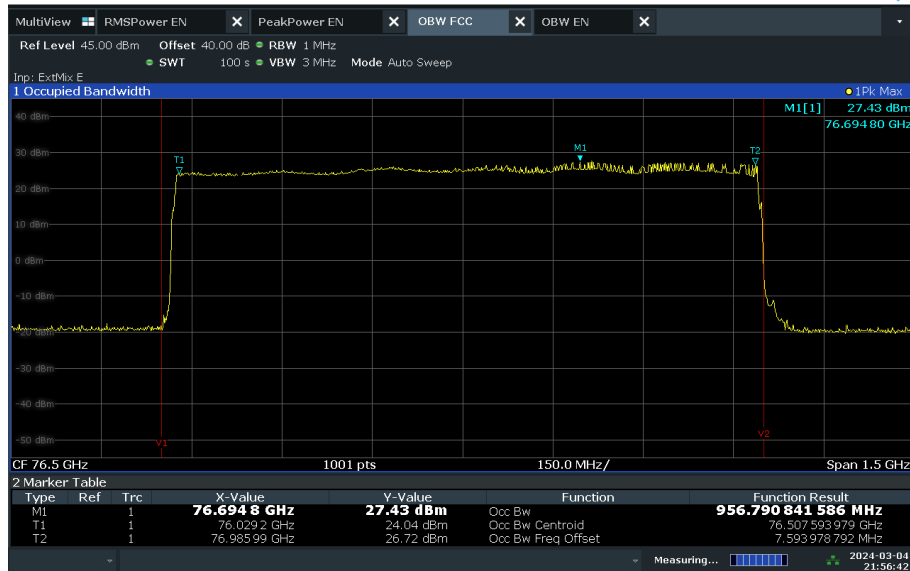
05:53:35 PM 03/04/2024

0 °C, 12 V



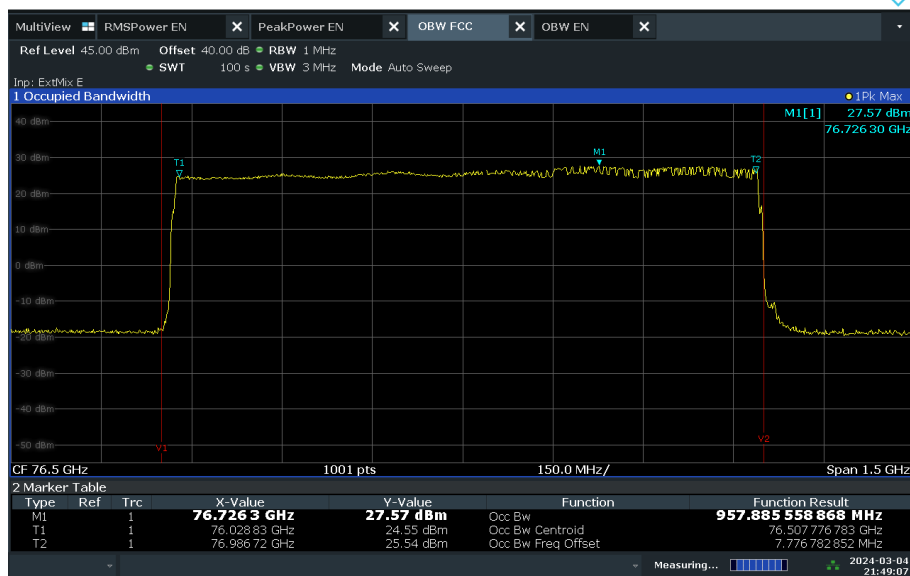
06:39:42 PM 03/04/2024

10 °C, 12 V



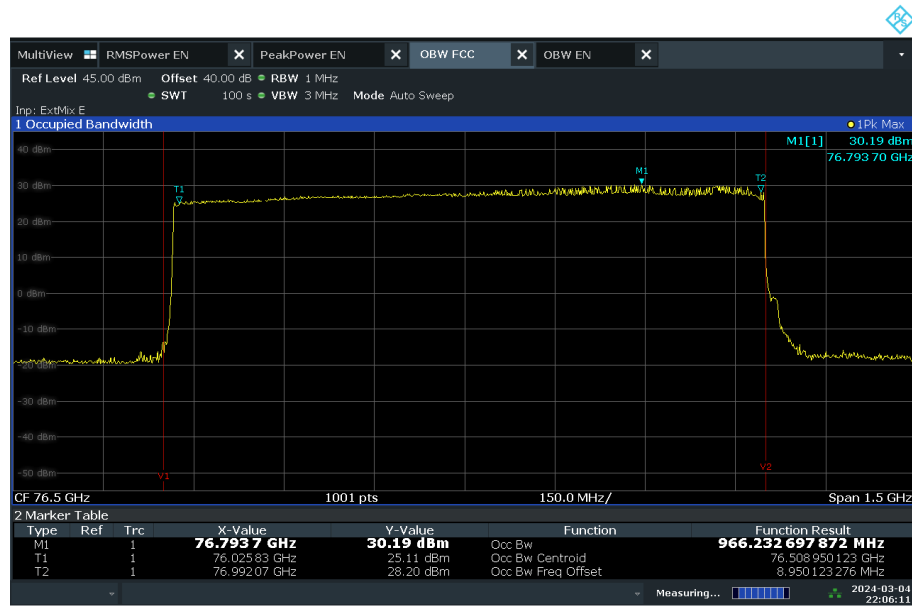
09:56:42 PM 03/04/2024

20 °C, 9 V



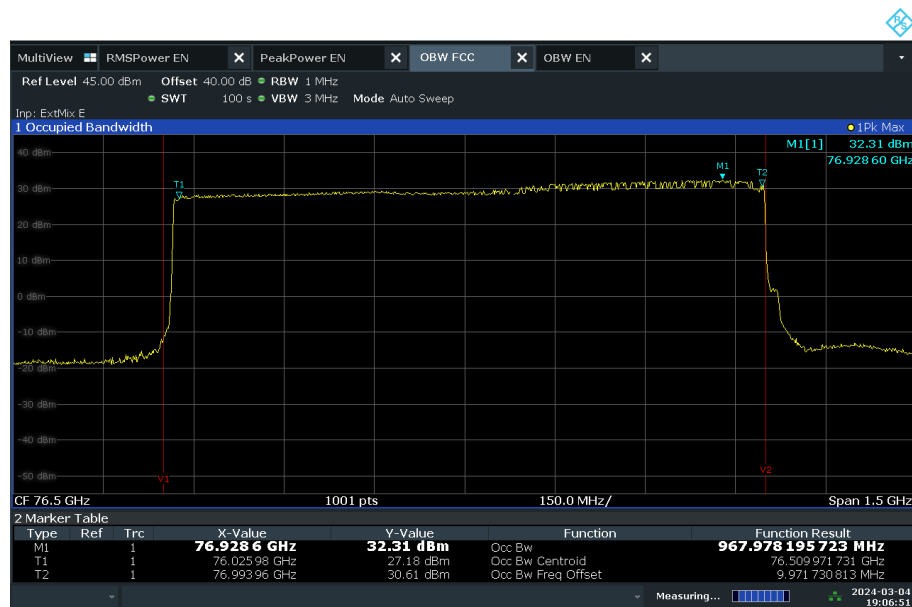
09:49:07 PM 03/04/2024

20 °C, 12 V



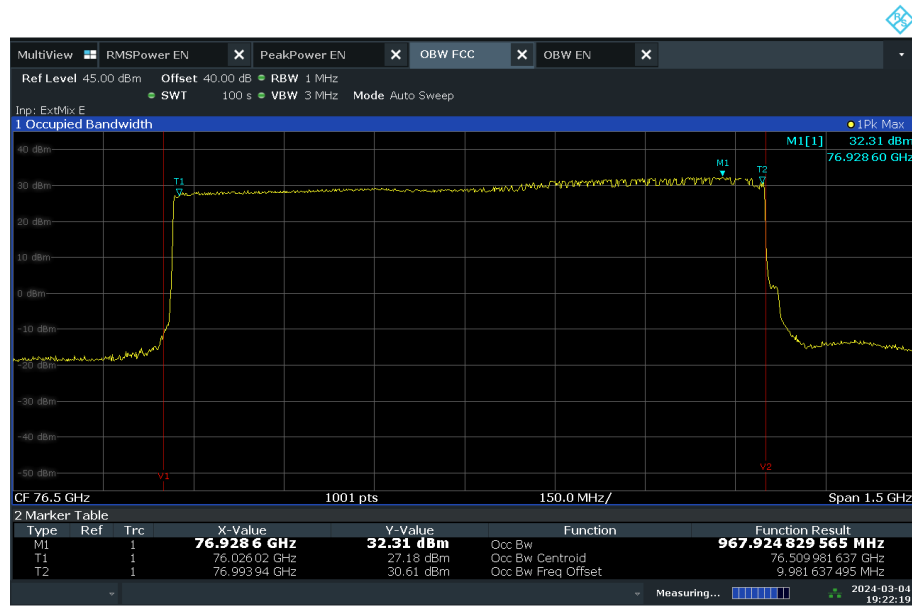
10:06:11 PM 03/04/2024

20 °C, 16 V



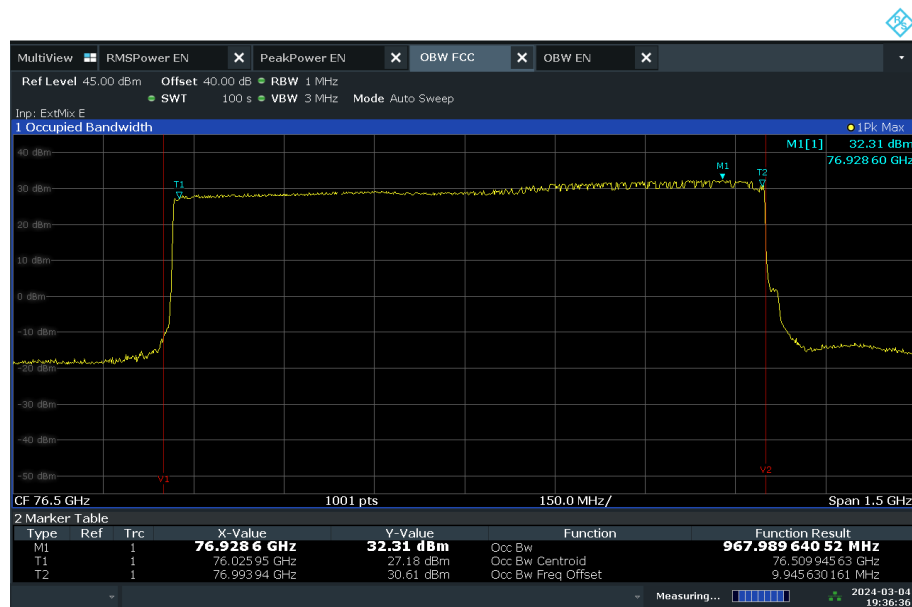
07:06:51 PM 03/04/2024

30 °C, 12 V



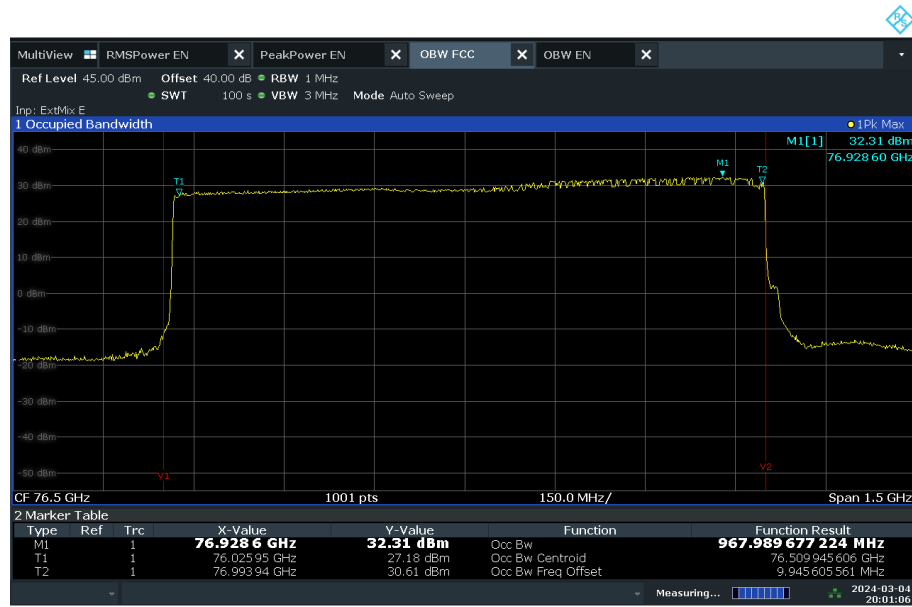
07:22:20 PM 03/04/2024

40 °C, 12 V



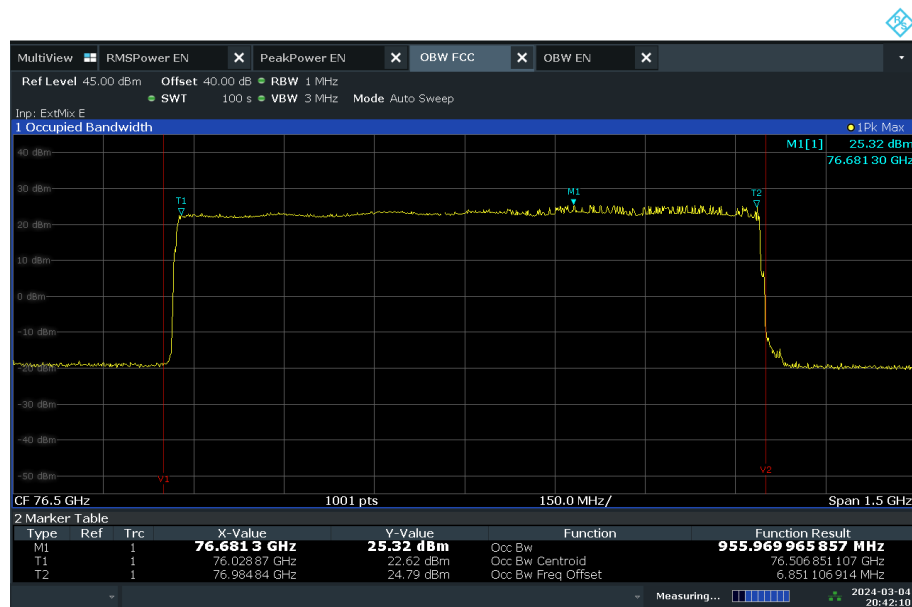
07:36:37 PM 03/04/2024

50 °C, 12 V



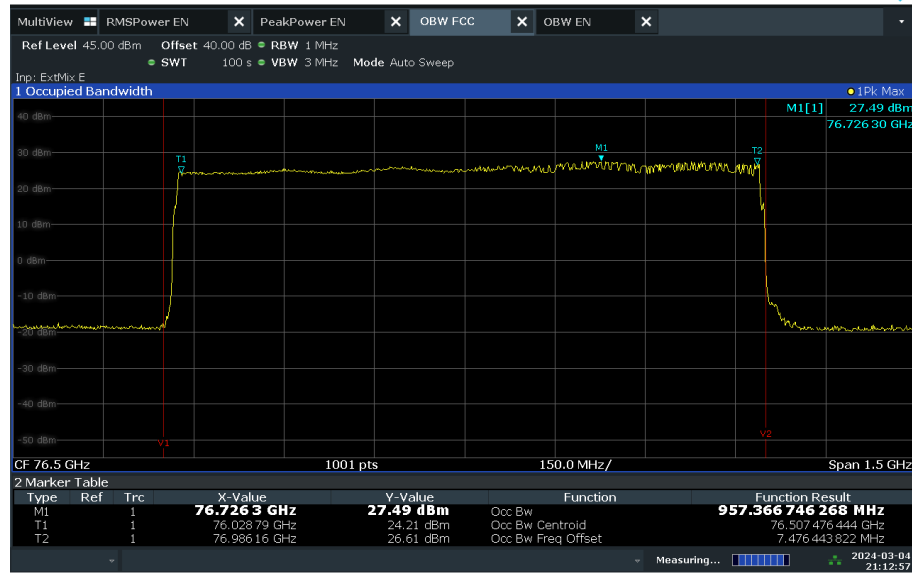
08:01:06 PM 03/04/2024

60 °C, 12 V



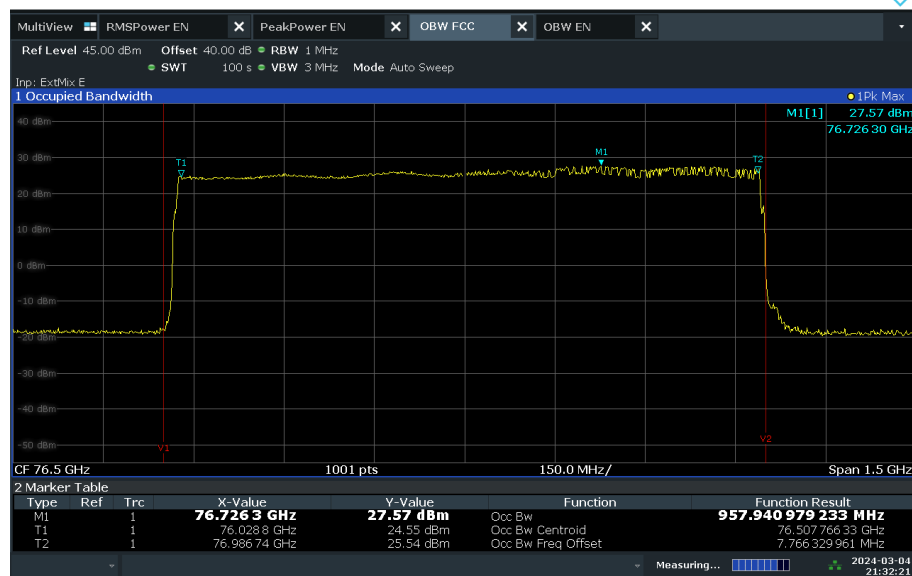
08:42:11 PM 03/04/2024

70 °C, 12 V



09:12:57 PM 03/04/2024

80 °C, 12 V



09:32:22 PM 03/04/2024

85 °C, 12 V



10 Revision History

Revision History			
<i>Edition</i>	<i>Date</i>	<i>Issued by</i>	<i>Modifications</i>
0	2024-04-02	Alex Fink	First Edition