EMC & RF Test Report

As per

RSS-247 Issue 2:2017
&
FCC Part 15 Subpart 15.247

Unlicensed Intentional Radiators

on the

Next-Generation Electronic Controller
Models: SR506-05 & ZVC406-5

Issued by: **TÜV SÜD Canada Inc.**
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Testing produced for

See Appendix A for full client & EUT details.

Innovation, Science and Economic Development Canada
Registration # 6844A-3

Testing Laboratory Certificate #2955.02

R-14023, G-20072
C-14498, T-20060

Registration # CA6844

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Report Scope

This report addresses the EMC verification testing and test results of the **Next-Generation Electronic Controller** and **Model: SR506-5 & ZVC406-5** and is herein referred to as EUT (Equipment Under Test). The EUT was tested for compliance against the following standards:

RSS-247 Issue 2:2017

FCC Part 15 Subpart C 15.247

Test procedures, results, justifications, and engineering considerations, if any, follow later in this report.

This report does not imply product endorsement by any government, accreditation agency, or TÜV SÜD Canada Inc.

Opinions or interpretations expressed in this report, if any, are outside the scope of TÜV SÜD Canada Inc. accreditations. Any opinions expressed do not necessarily reflect the opinions of TÜV SÜD Canada Inc., unless otherwise stated.

Summary

The results contained in this report relate only to the item(s) tested.

EUT:	**Next-Generation Electronic Controller** **Model: SR506-5 & ZVC406-5**
FCC Certification #, FCC ID:	2AW7V-93004022
Industry Canada Certification #, IC:	26602-93004022
EUT passed all tests performed	Yes
Tests conducted by	Min Xie
Report reviewed by	Amir Emami

For testing dates, see "Testing Environmental Conditions and Dates".

Test Results Summary

Standard/Method	Description	Class/Limit	Result
FCC 15.203	Antenna Requirement	Unique	Pass See Justification
FCC 15.205 RSS-GEN (Table 6)	Restricted Bands for Intentional Operation	QuasiPeak Average	Pass
FCC 15.207 RSS-GEN (Table 3)	Power Line Conducted Emissions	QuasiPeak Average	Pass
FCC 15.209 RSS-GEN (Table 4)	Spurious Radiated Emissions	QuasiPeak Average	Pass
FCC 15.247(a)2 RSS-247 5.2(a)	6 dB Bandwidth	> 500 kHz	Pass
FCC 15.247(b)2 RSS-247 5.4(d)	Max Output Power	< 1 Watt	Pass
FCC 15.247(b)4 RSS-247 5.4(d)	Antenna Gain	< 6 dBi	Pass See Justifications
FCC 15.247(d) RSS-247 5.5	Antenna Conducted Spurious	< 20 dBc	Pass
FCC 15.247(e) RSS-247 5.2(b)	Spectral Density	< 8 dBm (3 kHz BW)	Pass
Overall Result			**Pass**

If the product as tested or otherwise complies with the specification, the EUT is deemed to comply with the requirement and is deemed a ‘PASS’ grade. If not ‘FAIL’ grade will be issued. Note that ‘PASS’ / ‘FAIL’ grade is independent of any measurement uncertainties. A ‘PASS’ / ‘FAIL’ grade within measurement uncertainty is marked with a ‘*’.

Notes, Justifications, or Deviations

The following notes, justifications for tests not performed or deviations from the above listed specifications apply:

For the Antenna requirement specified in FCC 15.203 (RSS-247 section 5.4(d)), the unit uses a PCB antenna with 5.3 dBi which is less than the 6 dBi maximum gain.

For the Restricted Bands of operation, the EUT is designed to only operate between 2400 – 2483.5 MHz.

The EUT is not a hybrid system and FCC 15.247 (f) does not apply to it. However, the 15.247 (d) requirement of power density were met and are detailed later in this test report.

The Next-Generation Electronic Controller contains SR and ZVC series of controllers. The SR506-5 and ZVC406-5 models are the most populated models. The other models have depopulated relay output. The SR and ZVC have identical RF section.

All antenna conducted emissions were conducted with the ZVC model. Radiated and power line conducted emissions were performed on both models.

Sample Calculation(s)

Radiated Emission Test

E-Field Level = Received Signal + Antenna Factor + Cable Loss – Pre-Amp Gain
E-Field Level = 50dBµV + 10dB/m + 2dB – 20dB
E-Field Level = 42dBµV/m

Margin = Limit – E-Field Level
Margin = 50dBµV/m – 42dBµV/m
Margin = 8.0 dB (pass)

Power Line Conducted Emission Test

E-Field Level = Received Signal + Attenuation Factor + Cable Loss + LISN Factor
E-Field Level = 50dBµV + 10dB + 2.5dB + 0.5dB
E-Field Level = 63dBµV

Margin = Limit – E-Field Level
Margin = 73dBµV – 63dBµV
Margin = 10.0 dB (pass)

Applicable Standards, Specifications and Methods

ANSI C63.4:2014	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 For Testing Unlicensed Wireless Devices
CFR 47 FCC 15 Subpart C	Code of Federal Regulations – Radio Frequency Devices, Intentional Radiators
CISPR 32:2012	Electromagnetic Compatibility of Multimedia Equipment – Emission Requirements
FCC KDB 558074: 2019	FCC KDB 558074 Digital Transmission Systems, measurements and procedures
FCC KDB 447498: 2015	RF exposure procedures and equipment authorization policies for mobile and portable devices
ICES-003 Issue 6 2019	Digital Apparatus - Spectrum Management and Telecommunications Policy Interference-Causing Equipment Standard
RSS-GEN Issue 5 2019	General Requirements and Information for the Certification of Radio Apparatus
RSS-247 Issue 2:2017	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
ISO 17025:2017	General Requirements for the Competence of Testing and Calibration Laboratories

Document Revision Status

Revision	Date	Description	Initials
000	Mar 18, 2020	Initial release	MX
-	-	-	-

Definitions and Acronyms

The following definitions and acronyms are applicable in this report.
See also ANSI C63.14.

DTS – Digital Transmission System
LISN – Line Impedance Stabilization Network
NCR – No Calibration Required
NSA – Normalized Site Attenuation
N/A – Not Applicable
RF – Radio Frequency

AE – Auxiliary Equipment. A digital accessory that feeds data into or receives data from another device (host) that in turn, controls its operation.

Antenna Port – Port, other than a broadcast receiver tuner port, for connection of an antenna used for intentional transmission and/or reception of radiated RF energy.

BW – Bandwidth. Unless otherwise stated, this refers to the 6 dB bandwidth.

EMC – Electro-Magnetic Compatibility. The ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

EMI – Electro-Magnetic Immunity. The ability to maintain a specified performance when the equipment is subjected to disturbance (unwanted) signals of specified levels.

EUT – Equipment Under Test. A device or system being evaluated for compliance that is representative of a product to be marketed.

ITE – Information Technology Equipment. Has a primary function of entry, storage, display, retrieval, transmission, processing, switching, or control of data and/or telecommunication messages and which may be equipped with one or more ports typically for information transfer.

Testing Facility

Testing for EMC on the EUT was carried out at TÜV SÜD Canada testing lab near Toronto, Ontario. The testing lab has calibrated 3m semi-anechoic chambers which allow measurements on a EUT that has a maximum width or length of up to 2m and a height of up to 3m. The testing lab also has a calibrated 10m Open Area Test Site (OATS). The chambers are equipped with a turntable that is capable of testing devices up to 5000lb in weight and are equipped with a mast that controls the polarization and height of the antenna. Control of the mast occurs in the control room adjoining the shielded chamber. This facility is capable of testing products that are rated for single phase or 3-phase AC input and DC capability is also available. Radiated emission measurements are performed using a BiLog antenna and a Horn antenna where applicable. Conducted emissions, unless otherwise stated, are performed using a LISN and using the vertical ground plane if applicable.

Calibrations and Accreditations

The 3m semi-anechoic chamber is registered with Federal Communications Commission (FCC, CA6844), Innovation, Science and Economic Development Canada (ISED, 6844A-3) and Voluntary Control Council for Interference (VCCI, R-14023, G-20072, C-14498, and T-20060). This chamber was calibrated for Normalized Site Attenuation (NSA) using test procedures outlined in ANSI C63.4 "Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz". The chamber is lined with ferrite tiles and absorption cones to minimize any undesired reflections. The NSA data is kept on file at TÜV SÜD Canada. For radiated susceptibility testing, a 16 point field calibration has been performed on the chamber. The field uniformity data is kept on file at TÜV SÜD Canada. TÜV SÜD Canada Inc. is accredited to ISO 17025 by A2LA with Testing Certificate #2955.02. The laboratory's current scope of accreditation listing can be found as listed on the A2LA website. All measuring equipment is calibrated on an annual or biennial basis as listed for each respective test.

Testing Environmental Conditions and Dates

Following environmental conditions were recorded in the facility during time of testing

Date	Test	Initials	Temperature (ºC)	Humidity (%)	Pressure (kPa)
Feb. 17, 2021	Radiated Emissions	MX	22.4	10.1	98.7
Feb. 26, 2021	Antenna Conducted Emissions	MX	23.5	14.2	102.9
Feb. 24, 2021	Power Line Conducted Emissions	MX	21.0	23.7	98.8

Detailed Test Results Section

6dB Bandwidth of Digitally Modulated Systems

Purpose

The purpose of this test is to ensure that the bandwidth occupied exceeds a stated minimum. This helps ensure the utilization of the frequency allocation is sufficiently wide. This also helps prevent corruption of data by ensuring adequate data separation to distinguish the reception of the intended information.

Limits and Method

The limit is as specified in FCC Part 15.247(a)2 and RSS-247 5.2(a).

Systems using digital modulation techniques may operate in the 902 - 928 MHz, 2400 - 2483.5 MHz, and 5725 - 5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz. This should be measured with a 100 kHz RBW and a 300 kHz VBW.

The method is given in FCC KDB 558074 Section 8.1 and ANSI C63.10.

Results

The EUT passed.
The minimum 6 dB Bandwidth measured was 731 kHz
The maximum 99% Occupied Bandwidth was 1080 kHz.

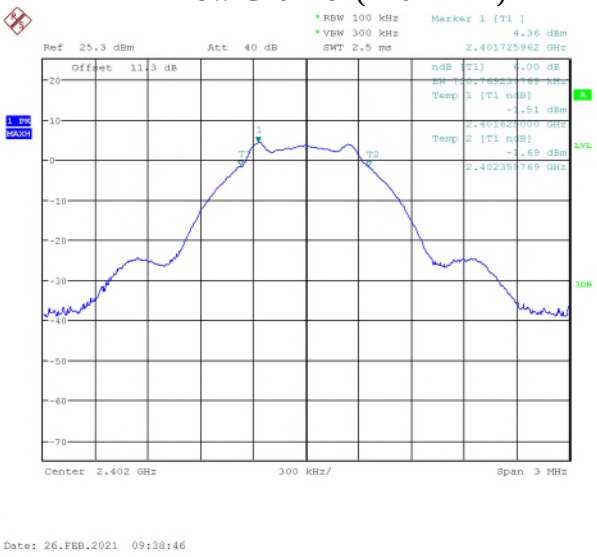
Channel	Frequency (MHz)	6 dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	0.731	1.07
Mid	2442	0.726	1.08
High	2480	0.745	1.08

Graphs

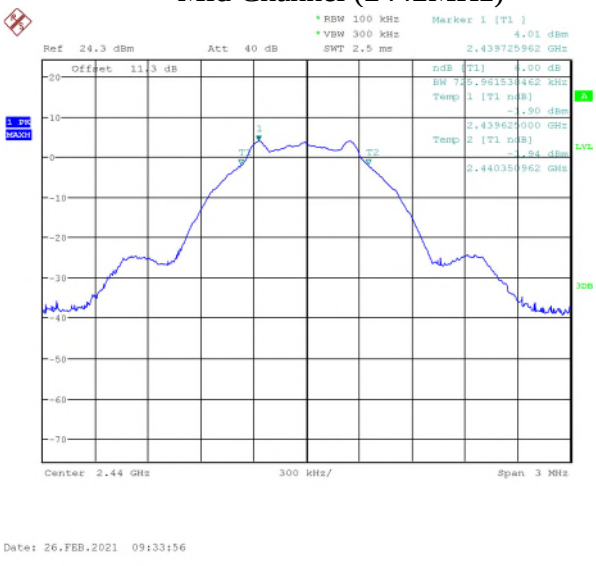
The graphs shown below show the OBW of the device during the conducted measurement operation of the EUT. This is measured by a max hold on the spectrum analyzer.

6dB Bandwidth

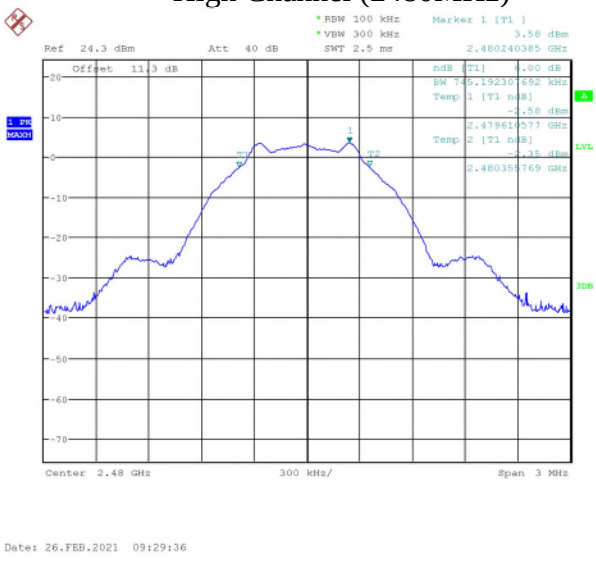
Low Channel (2402MHz)



Mid Channel (2442MHz)

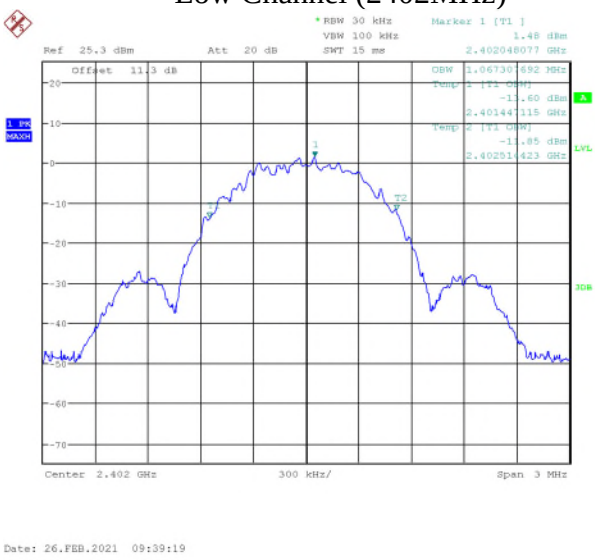


High Channel (2480MHz)

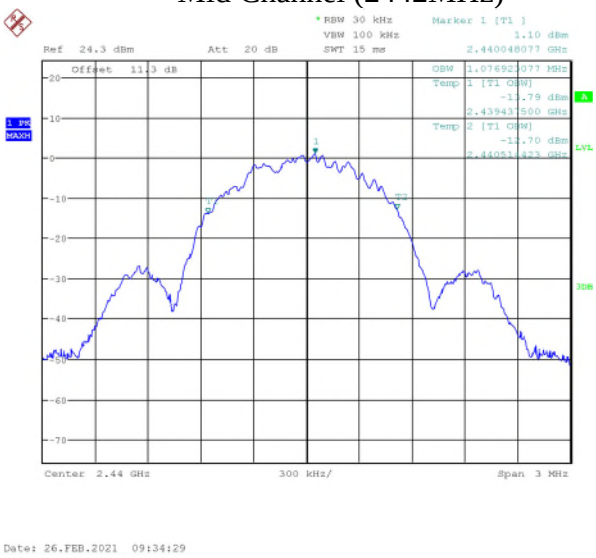


99% Bandwidth

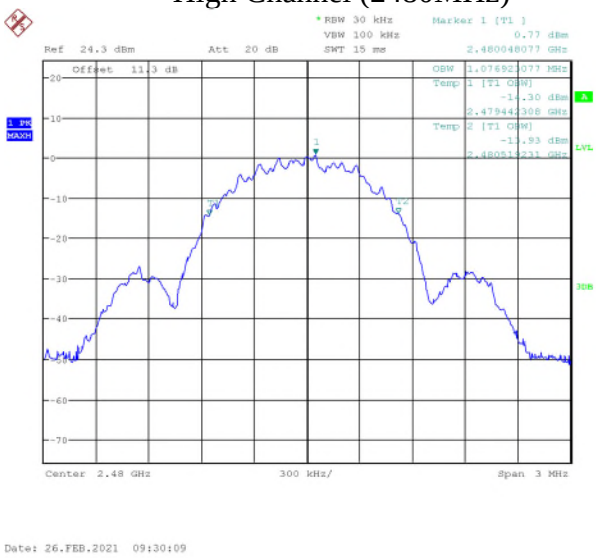
Low Channel (2402MHz)



Mid Channel (2442MHz)



High Channel (2480MHz)



Note: See ‘Appendix B – EUT & Test Setup Photos’ for photos showing the test set-up.

Test Equipment List

Equipment	Model No.	Manufacturer	Last Calibration Date	Next Calibration Date	Asset #
Signal Analyzer	FSQ 26	Rohde & Schwarz	Oct. 25, 2019	Oct. 25, 2021	GEMC 234
Attenuator 10 dB	8493B	Agilent	NCR	NCR	GEMC 133

Maximum Peak Envelope Conducted Power

Purpose

The purpose of this test is to ensure that the maximum power conducted to the radiating element does not exceed the limits specified. This ensures that if the end-user replaces the antenna, the maximum power does not exceed an amount which may create an excessive power level.

Limits and Method

The limits are defined in FCC Part 15.247(b) and RSS-247 5.4(d).
For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands, the peak limit is 1 watt (30 dBm).

The method is given in FCC KDB 558074 Section 9.1.2 and ANSI C63.10.

Results

The EUT passed.

Channel	Frequency (MHz)	Peak Power (dBm)	Peak Power (mW)
Low	2402	4.97	3.14
Mid	2442	4.62	2.90
High	2480	4.40	2.75

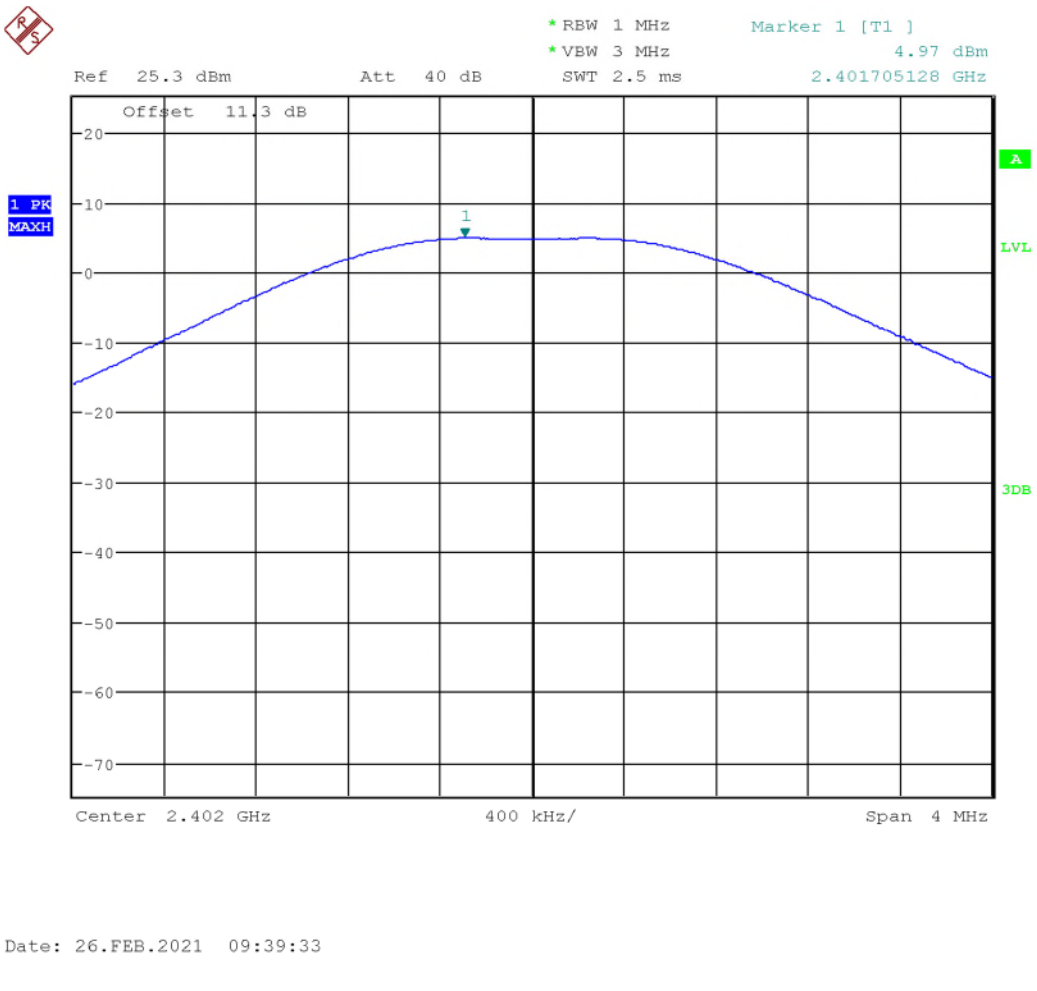
Note: The external attenuator and cable loss are accounted for as reference offset in the spectrum analyzer

Graphs

The graphs shown below show the peak power output of the device during the conducted measurement operation of the EUT. The measurement RBW is ≥ than the DTS bandwidth.

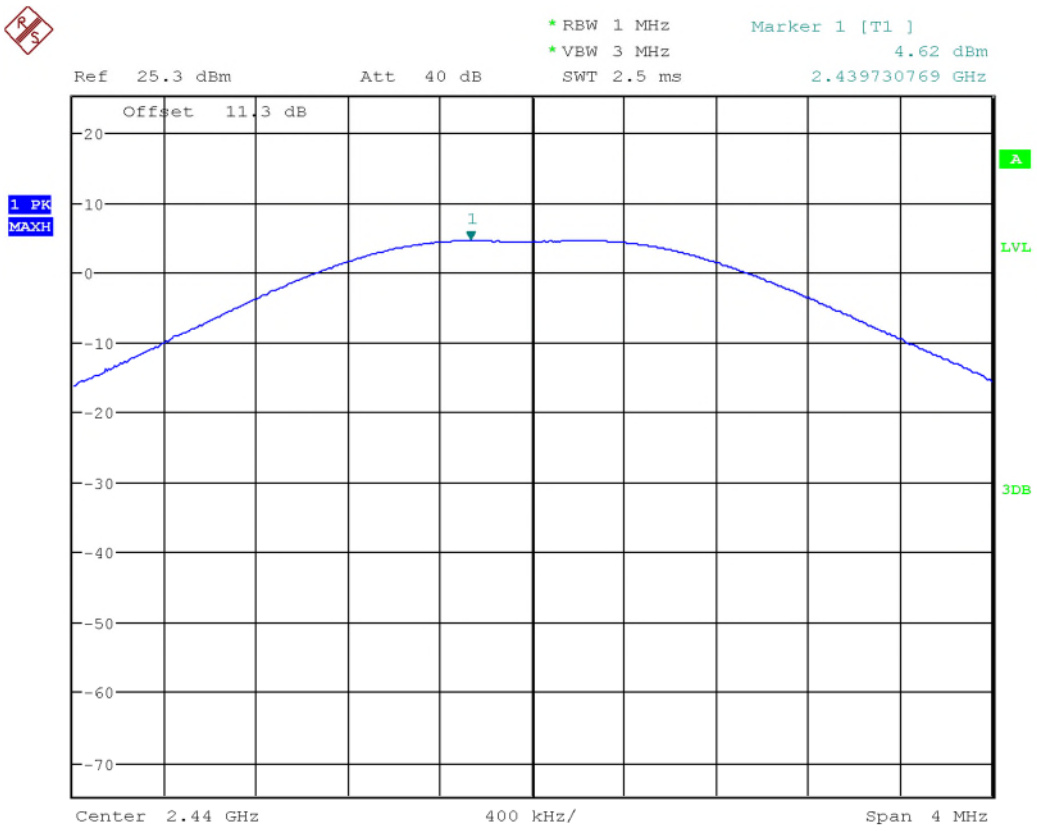
Peak Power

Low Channel

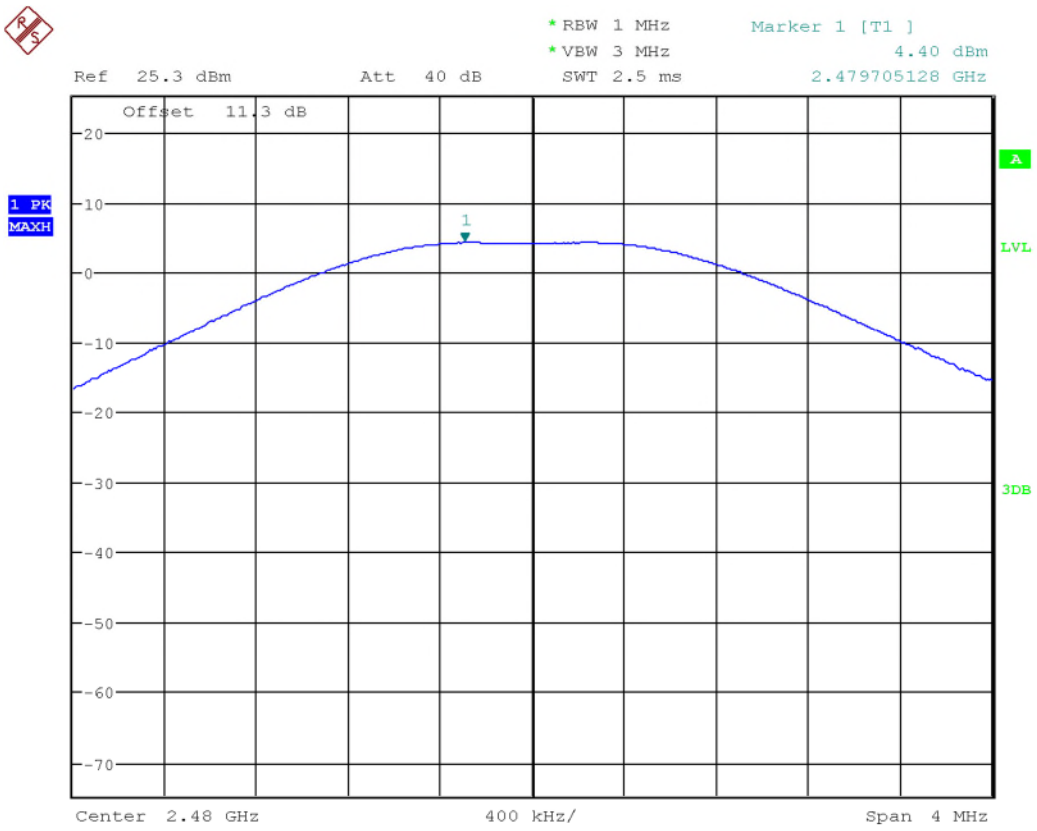


Peak Power

Mid Channel



Peak Power
High Channel



See 'Appendix B – EUT and Test Setup Photos' for photos showing the test set-up.

Test Equipment List

Equipment	Model No.	Manufacturer	Last Calibration Date	Next Calibration Date	Asset #
Signal Analyzer	FSQ 26	Rohde & Schwarz	Oct. 25, 2019	Oct. 25, 2021	GEMC 234
Attenuator 10 dB	8493B	Agilent	NCR	NCR	GEMC 133

Antenna Spurious Conducted Emissions (-20 dBc Requirement)

Purpose

The purpose of this test is to ensure that the maximum power conducted to the radiating element at frequencies outside of the authorized spectrum does not exceed the limits specified. This ensures that the only the intended signal is delivered to the radiating element.

Limits and Method

The limits are defined in 15.247(d) and RSS-247 5.5. In any 100 kHz band, the peak spurious harmonics emissions must be at least 20 dB below the fundamental. Spurious Conducted emissions are to be evaluated up to the 10^{th} harmonic. This -20 dBc requirement also applies at the 'band edge' or 2.4 GHz and 2.4835 GHz.

The method is given in FCC KDB 558074 Section 11 and ANSI C63.10

Results

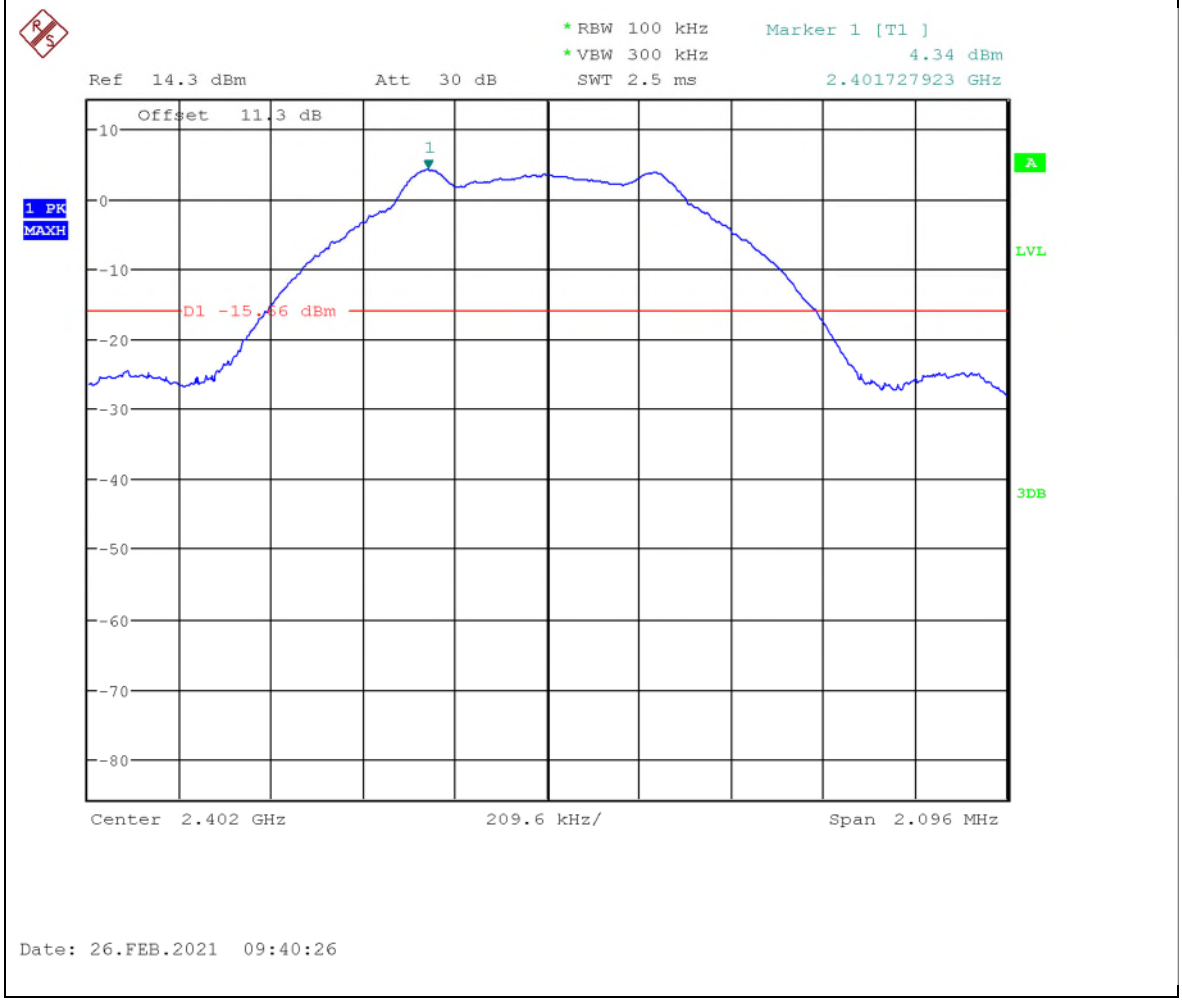
The EUT passed. Low, middle and high bands were measured. The worst case is presented as a graph for the spectrum. The -20 dBc requirement is shown for the lower band edge at 2.4 GHz in the low band and also for the higher band edge at 2.4835 GHz in the high band.

Graphs

The graphs shown below show the power output of the device during the conducted measurement operation of the EUT.

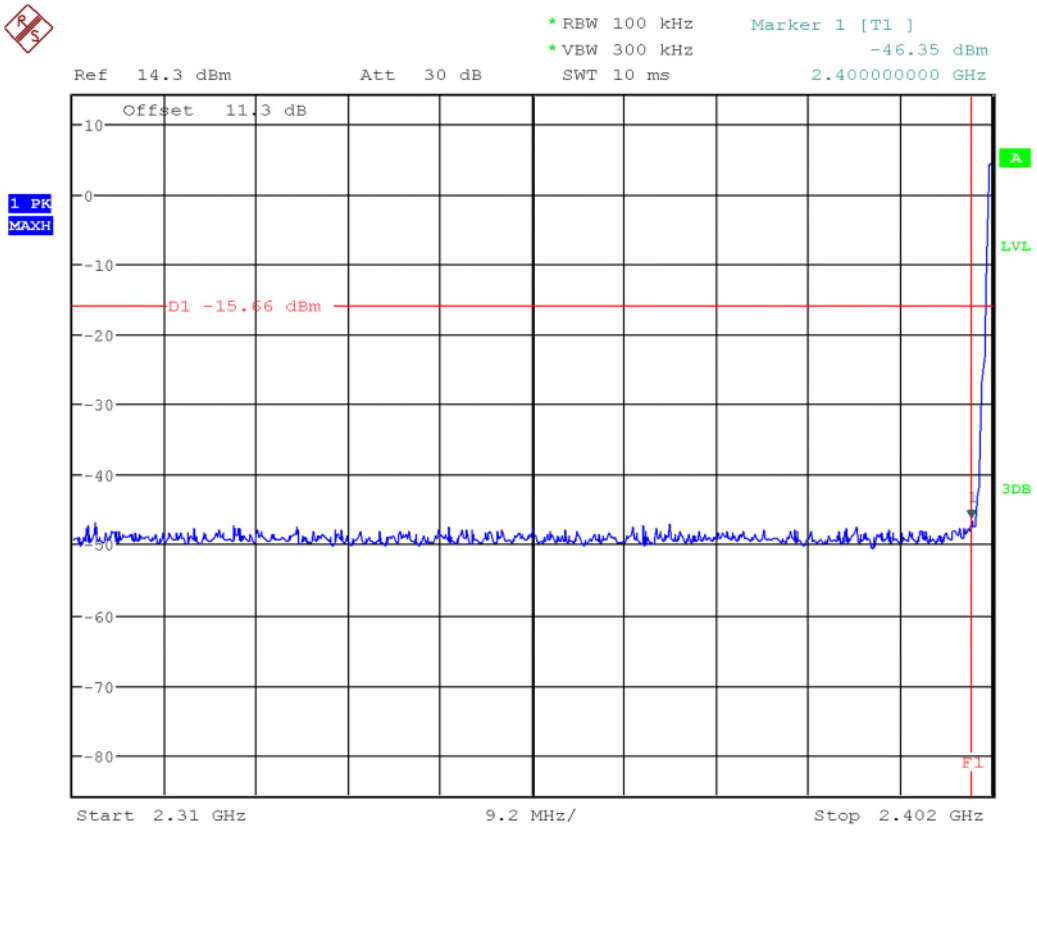
-20dBc

Reference Level: 4.34Bm



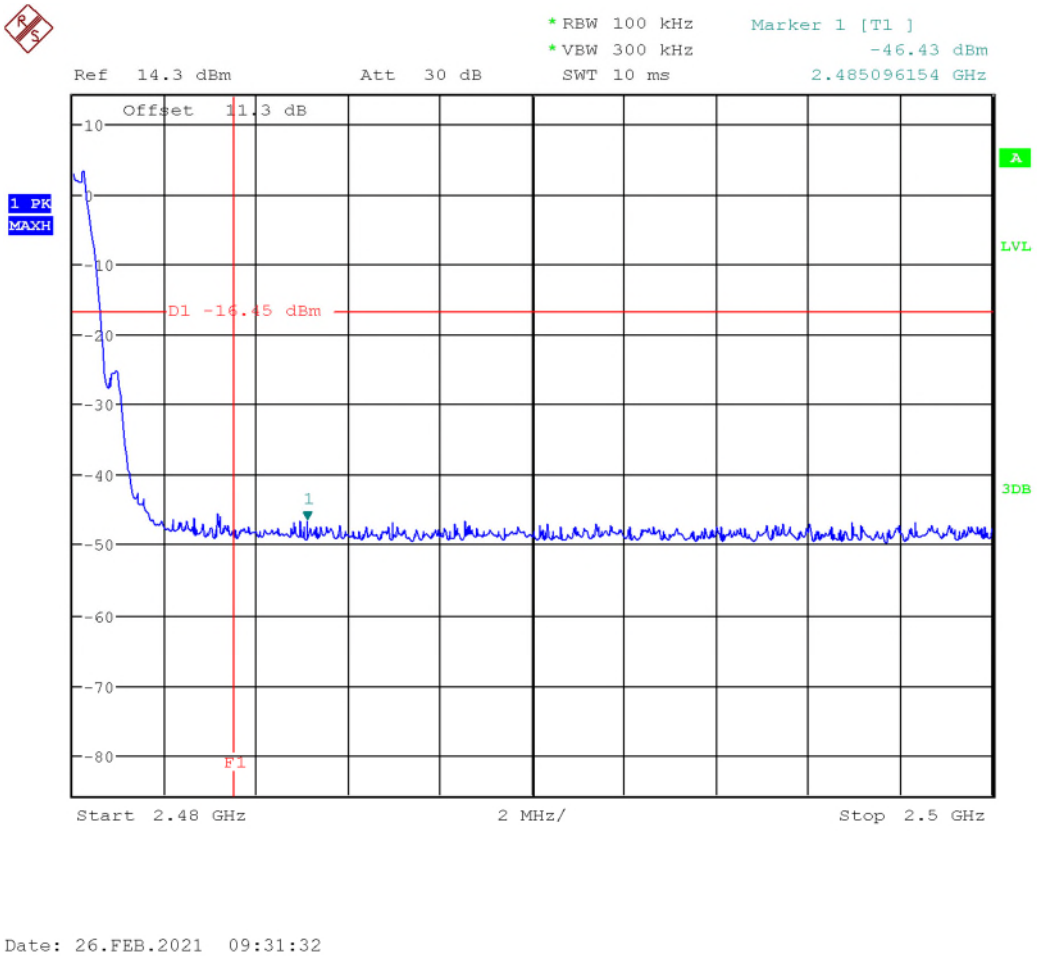
-20dBc

2400 MHz Band Edge



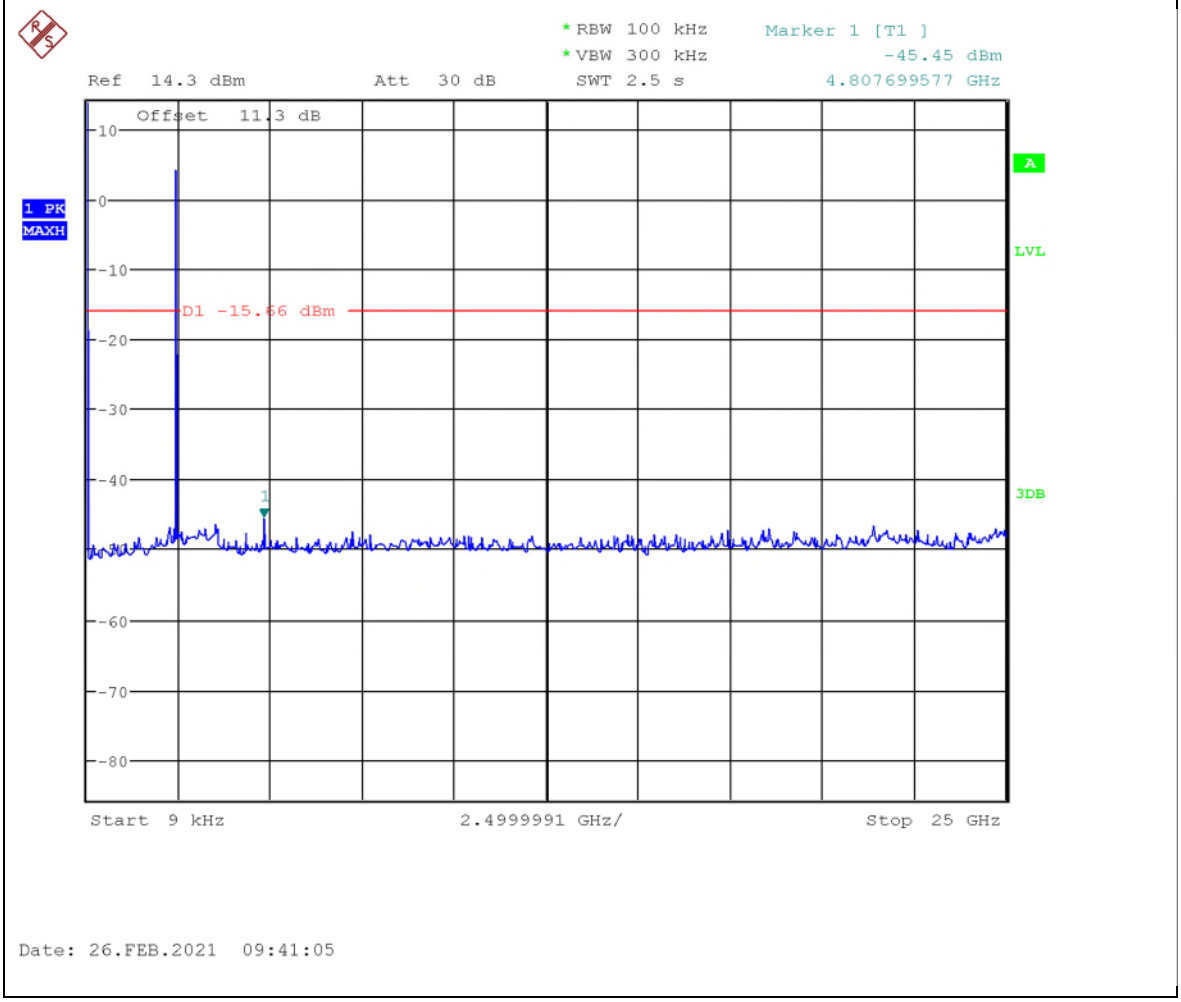
-20dBc

2483.5 MHz Band Edge



-20dBc

9kHz – 25GHz



See 'Appendix B – EUT and Test Setup Photos' for photos showing the test set-up.

Test Equipment List

Equipment	Model No.	Manufacturer	Last Calibration Date	Next Calibration Date	Asset #
Signal Analyzer	FSQ 26	Rohde & Schwarz	Oct. 25, 2019	Oct. 25, 2021	GEMC 234
Attenuator 10 dB	8493B	Agilent	NCR	NCR	GEMC 133

Transmitter Spurious Radiated Emissions

Purpose

The purpose of this test is to ensure that the RF energy unintentionally emitted from the EUT does not exceed the limits listed below as defined in the applicable test standard, as measured from a receiving antenna. This helps protect broadcast radio services such as television, FM radio, pagers, cellular telephones, emergency services, and so on, from unwanted interference.

Limits and Method

The method is as defined in FCC KDB 558074 Section 12.2 and ANSI C63.10.

The limits, as defined in 15.247(d) for unintentional radiated emissions, apply for those emissions that fall in the restricted bands, as defined in Section 15.205(a). These emissions must comply with the radiated emission limits specified in Section 15.209(a).

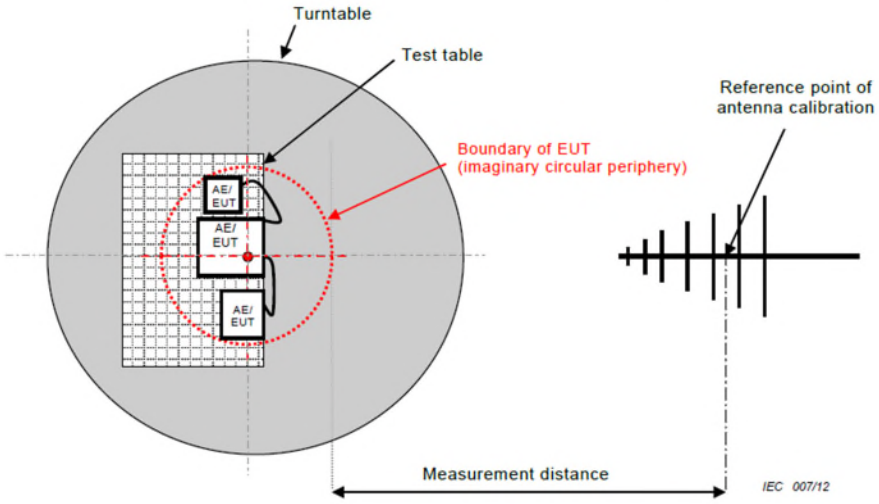
All unintentional emissions must also meet the 'Spurious Conducted Emissions' requirements of -20 dBc or greater. See also 'Antenna Spurious Conducted Emissions (-20dBc)' for further details.

Frequency	Field Strength Limit (µV/m)	Field Strength at 3m (dBµV/m)
0.009 MHz – 0.490 MHz	2400/F(kHz) [a] (at 300m)	128.5 to 93.8[a]
0.490 MHz – 1.705 MHz	24000/F(kHz)[a] (at 30m)	73.8 to 63.0[a]
1.705 MHz – 30 MHz	30[a] (at 30m)	69.5[a]
30 MHz – 88 MHz	100[a] (at 3m)	40.0[a]
88 MHz – 216 MHz	150[a] (at 3m)	43.5[a]
216 MHz – 960 MHz	200[a] (at 3m)	46.0[a]
Above 960 MHz	500[a] (at 3m)	54.0[a]
Above 1000 MHz	500[b] (at 3m)	54.0[b]
Above 1000 MHz	5 mV/m[c] (at 3m)	74.0[c]

[a]Limit is with Quasi Peak detector with bandwidths as defined in CISPR-16-1-1
[b]Limit is with 1 MHz measurement bandwidth and using an Average detector
[c]Limit is with 1 MHz measurement bandwidth and using a Peak detector

Based on ANSI C63.4 Section 4.2, if the Peak detector measurements do not exceed the Quasi-Peak limits, where defined, then the EUT is deemed to have passed the requirements.

Typical Radiated Emissions Setup



Measurement Uncertainty

The expanded measurement uncertainty is calculated in accordance with CISPR 16-4-2 and is ±5.67dB for 30MHz – 1GHz and ±4.58dB for 1GHz – 18GHz with a 'k=2' coverage factor and a 95% confidence level.

Preliminary Graphs

The graphs shown below are maximized peak measurement graphs measured with a resolution bandwidth greater than or equal to the final required detector over a full 0-360°. This peaking process is done as a worst case measurement and enables the detection of frequencies of concern for final measurement. For final measurements with the appropriate detector, where applicable, please refer to the tables under Final Measurements.

In accordance with FCC Part 15, Subpart A, Section 15.33, the device was scanned to the 10^{th} harmonic (a minimum of 24.835 GHz).

Devices scanned may be scanned at alternate test distances and in accordance with FCC Part 15, Subpart A, Section 15.31, an extrapolation factor of 20 dB/decade was used above 30 MHz and 40 dB/decade below 30 MHz. For example for 1 meter measurements, an extrapolation factor 9.5 dB from 20 Log (1m / 3m) is applied.

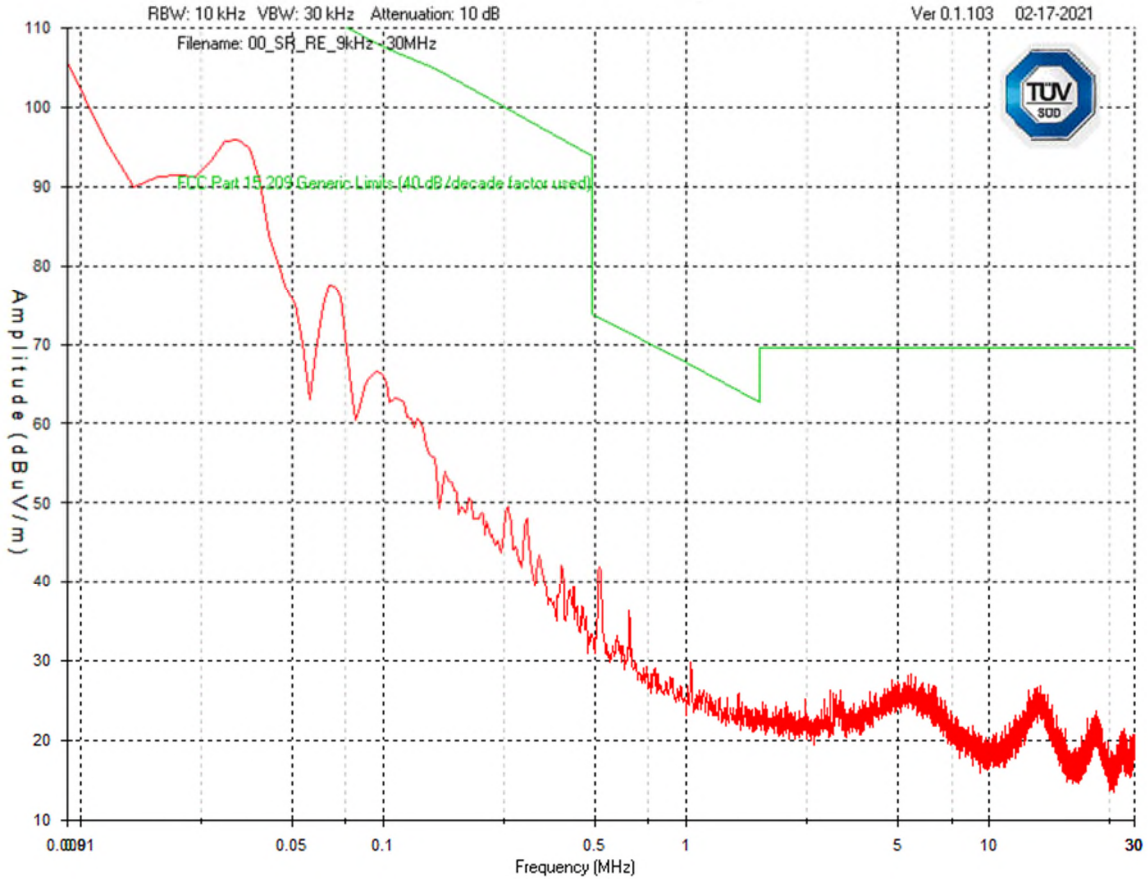
Peak output power for low, middle and high channels and each in three orthogonal axes were checked. The worst case was used for the spurious emissions which was on the high channel and in the Z-axis.

Band-edge measurement graphs are shown for illustration purposes. See final measurement section for all measurements.

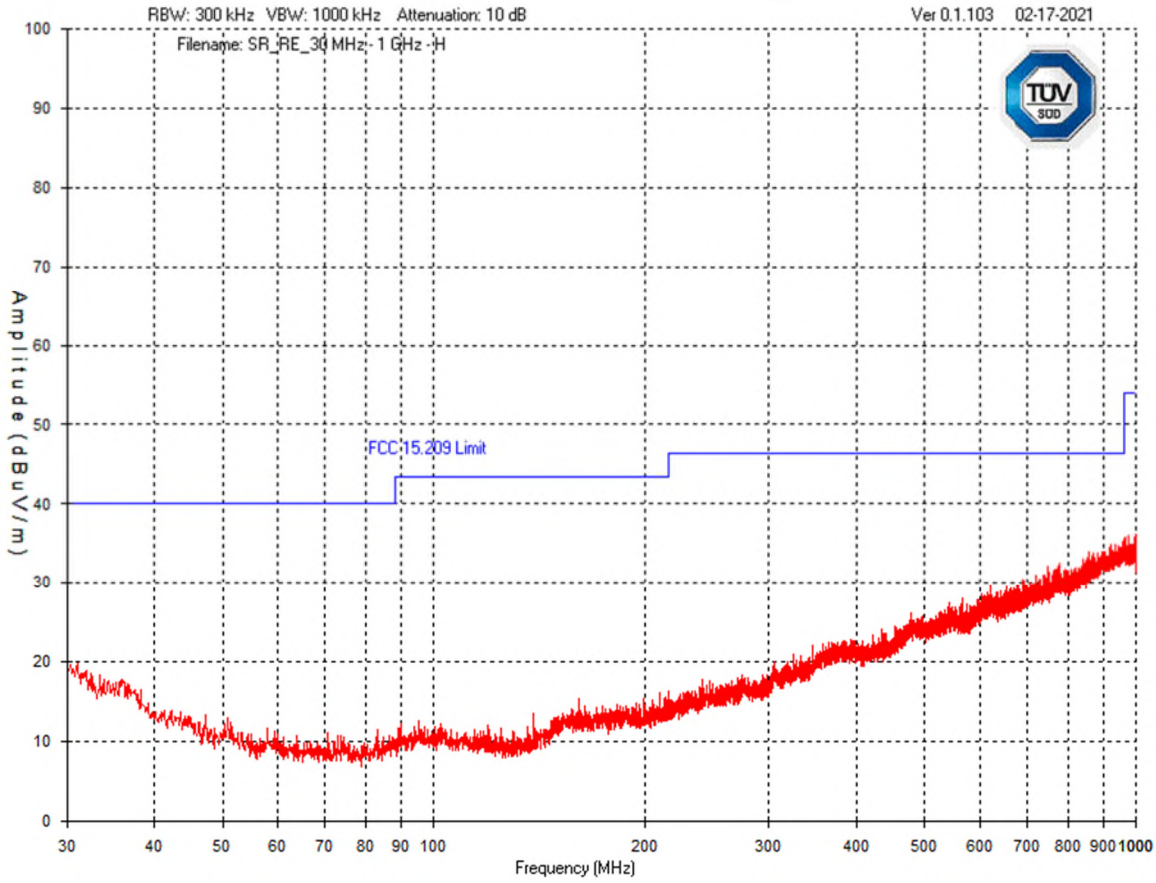
Both SR and ZVC models were tested for spurious emissions. The graphs presented are those of the SR model and it represents the worst case emissions.

Spurious Emissions

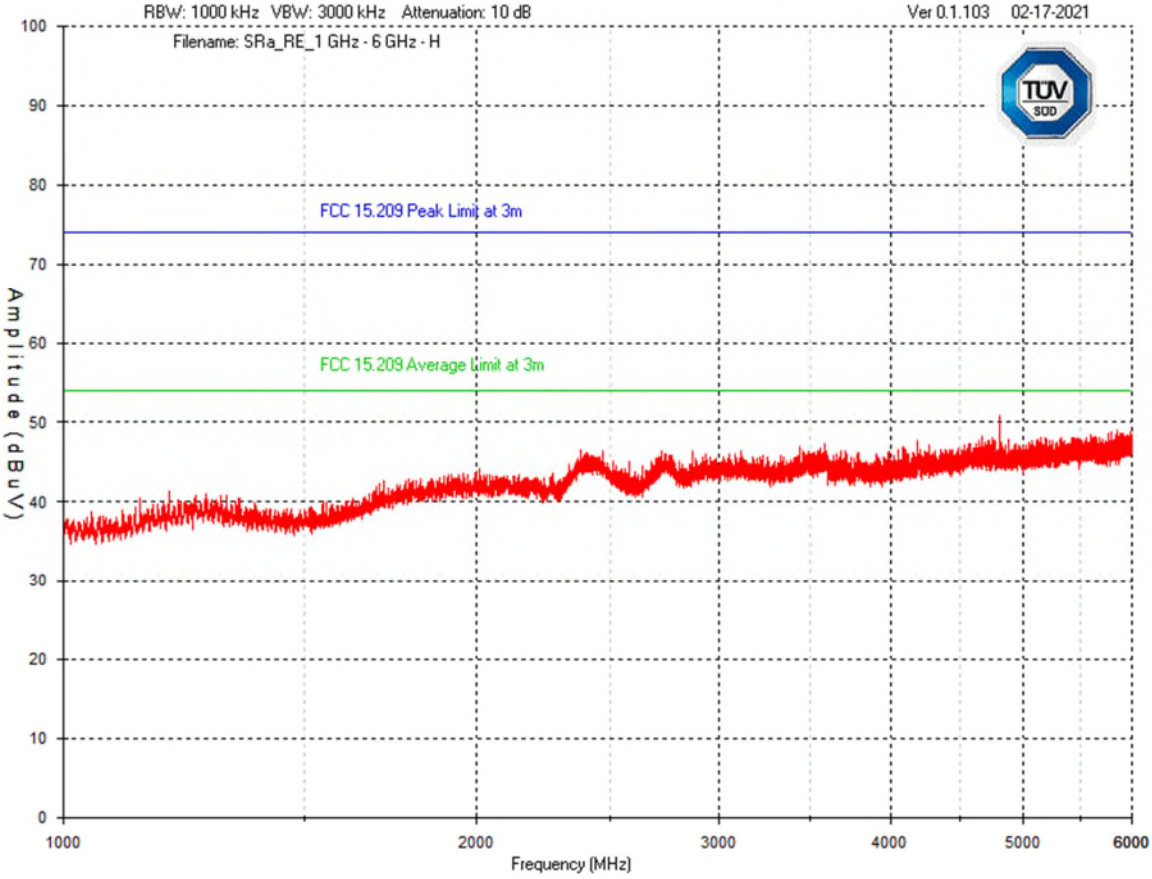
High Channel
9 kHz – 30 MHz
Peak Emission Graph



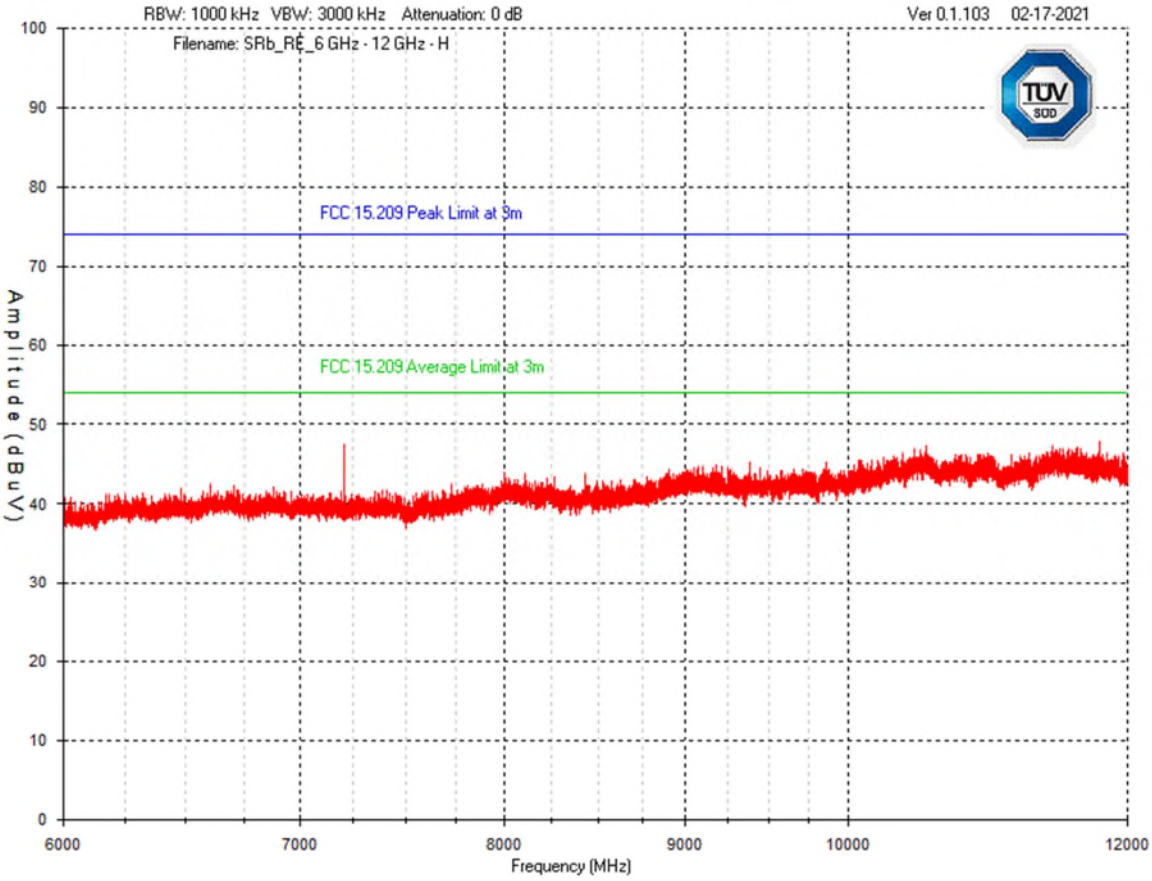
High Channel – 30 MHz – 1 GHz
Horizontal - Peak Emission Graph



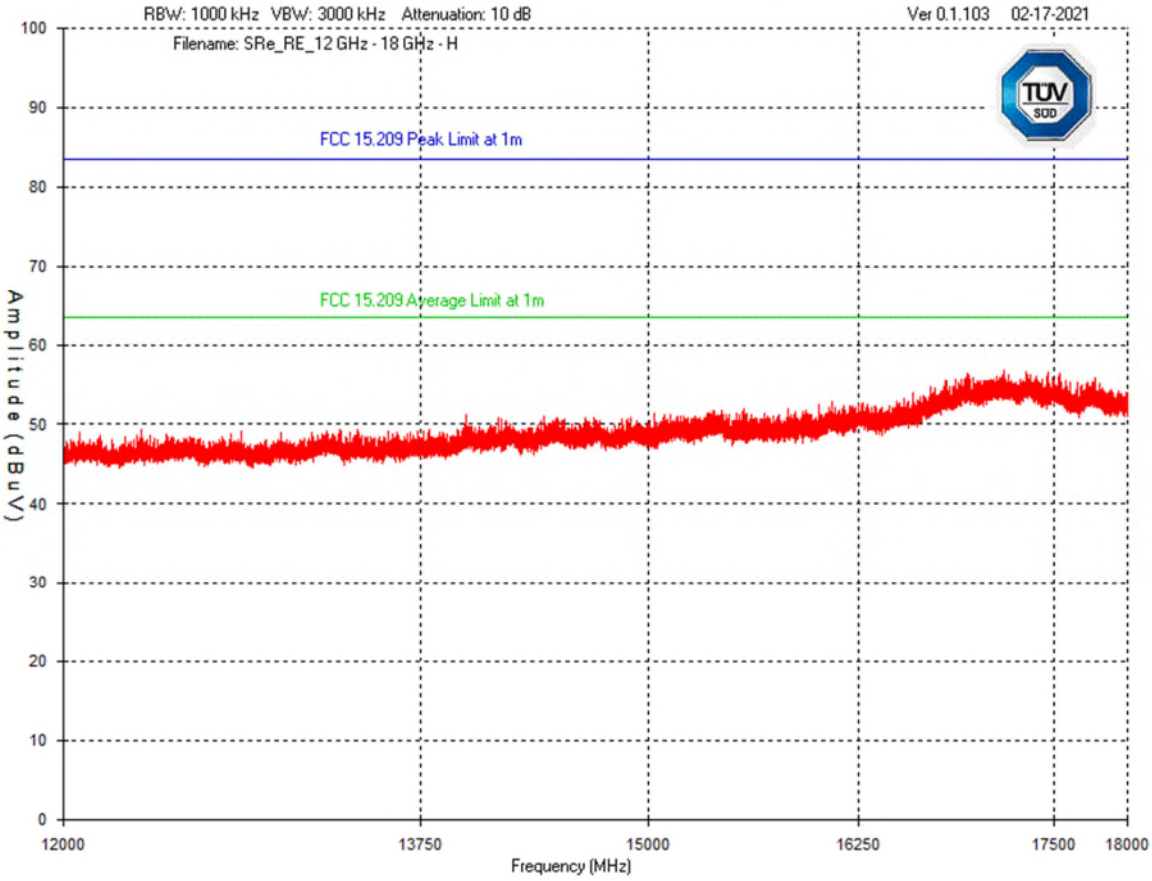
High Channel – 1 GHz – 6 GHz
Horizontal - Peak Emission Graph



High Channel – 6 GHz – 12 GHz
Horizontal - Peak Emission Graph

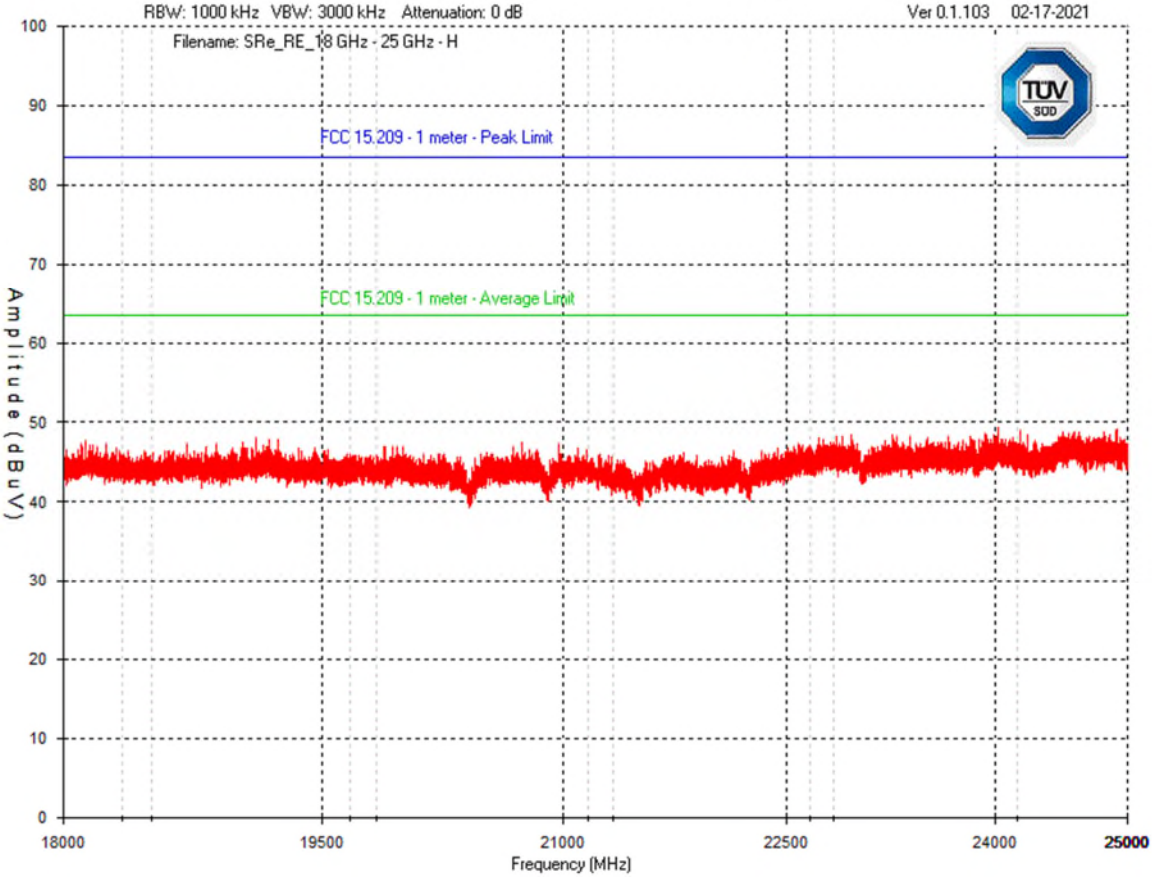


High Channel – 12 GHz – 18 GHz
Horizontal - Peak Emission Graph



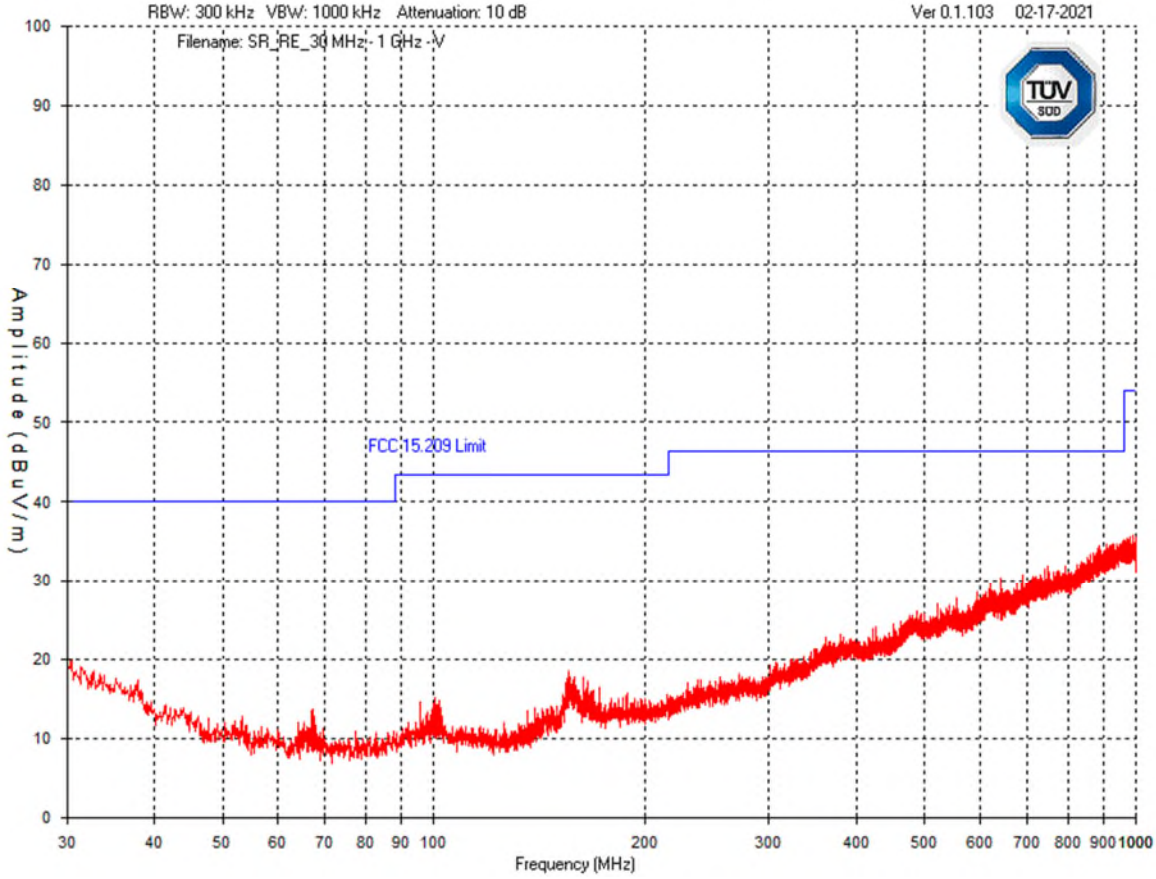
Plot was taken at a 1 meter distance. All emissions were noise floor of measurement instrument. No emissions were found in this frequency range.

High Channel – 18 GHz – 25 GHz
Horizontal - Peak Emission Graph

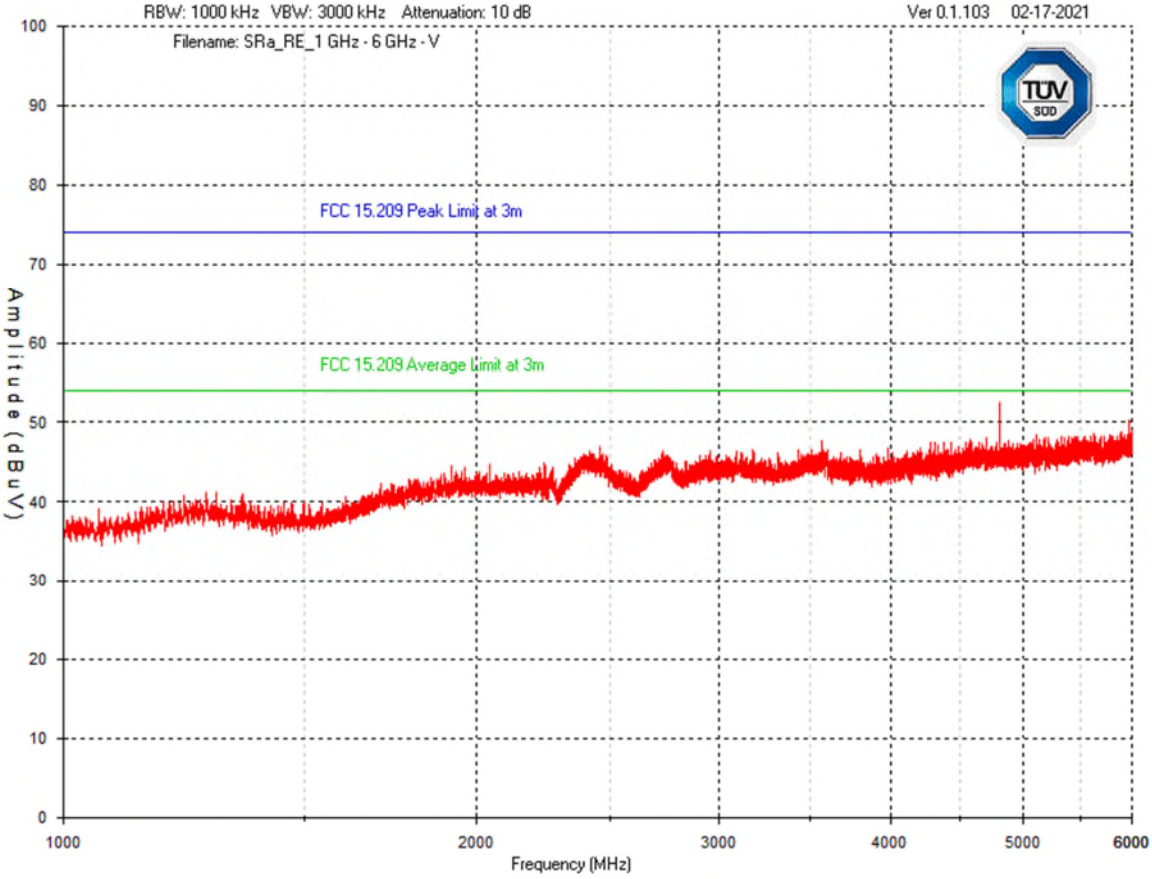


Plot was taken at a 1 meter distance. All emissions were noise floor of measurement instrument. No emissions were found in this frequency range.

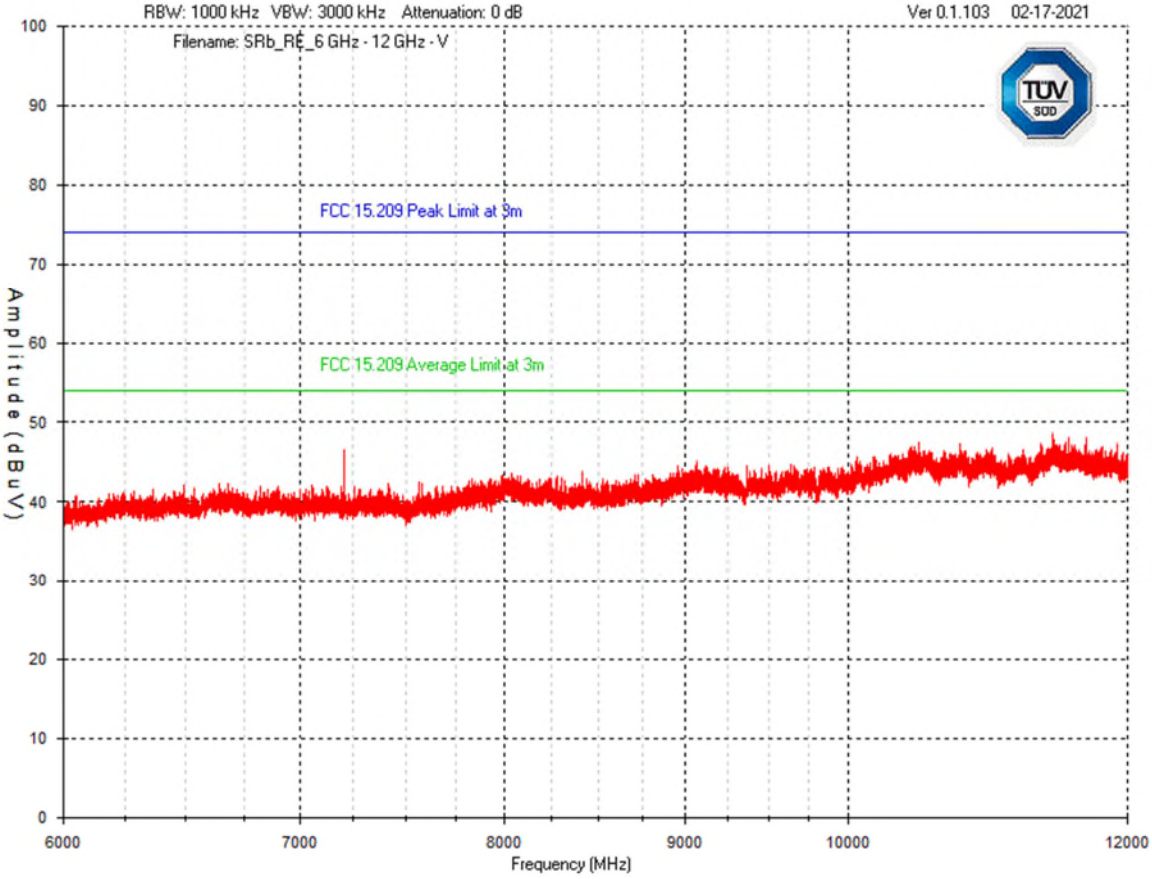
High Channel – 30 MHz – 1 GHz
Vertical - Peak Emission Graph



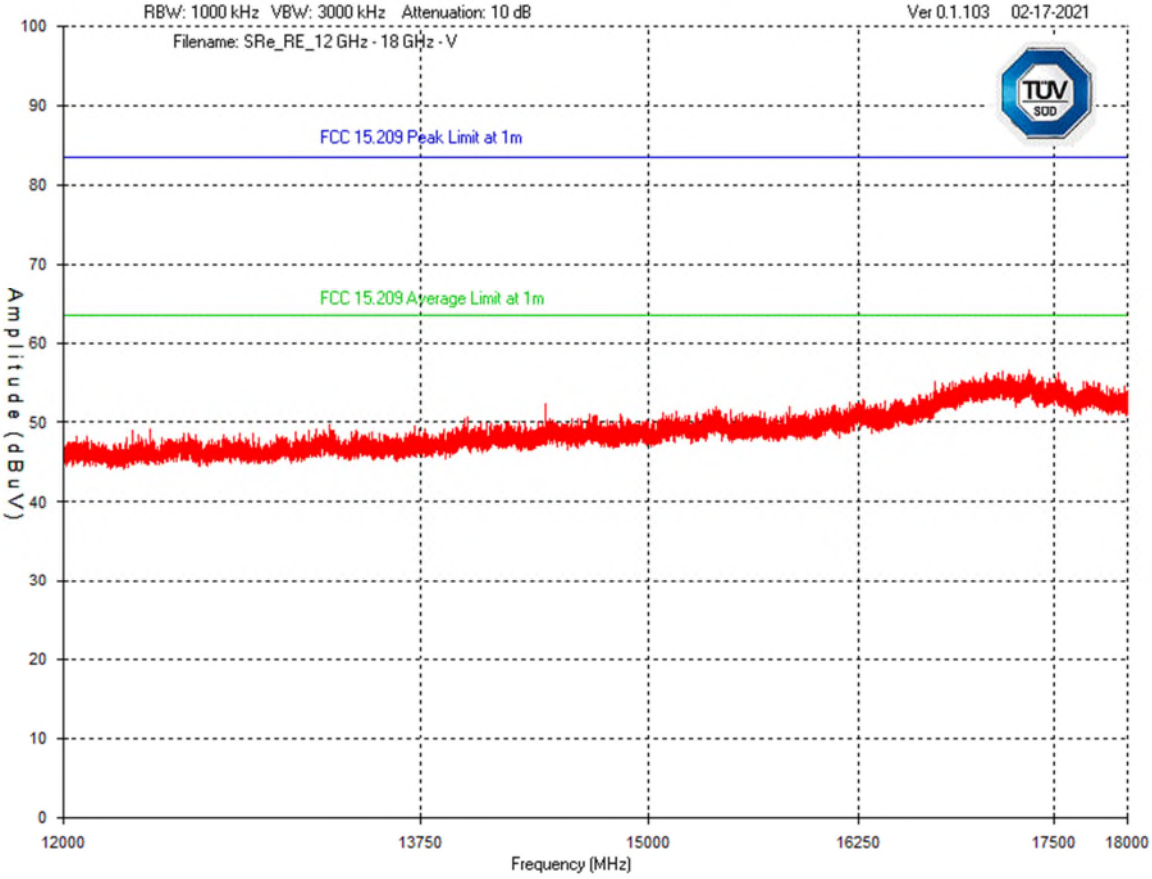
High Channel – 1 GHz – 6 GHz
Vertical - Peak Emission Graph



High Channel – 6 GHz – 12 GHz
Vertical - Peak Emission Graph

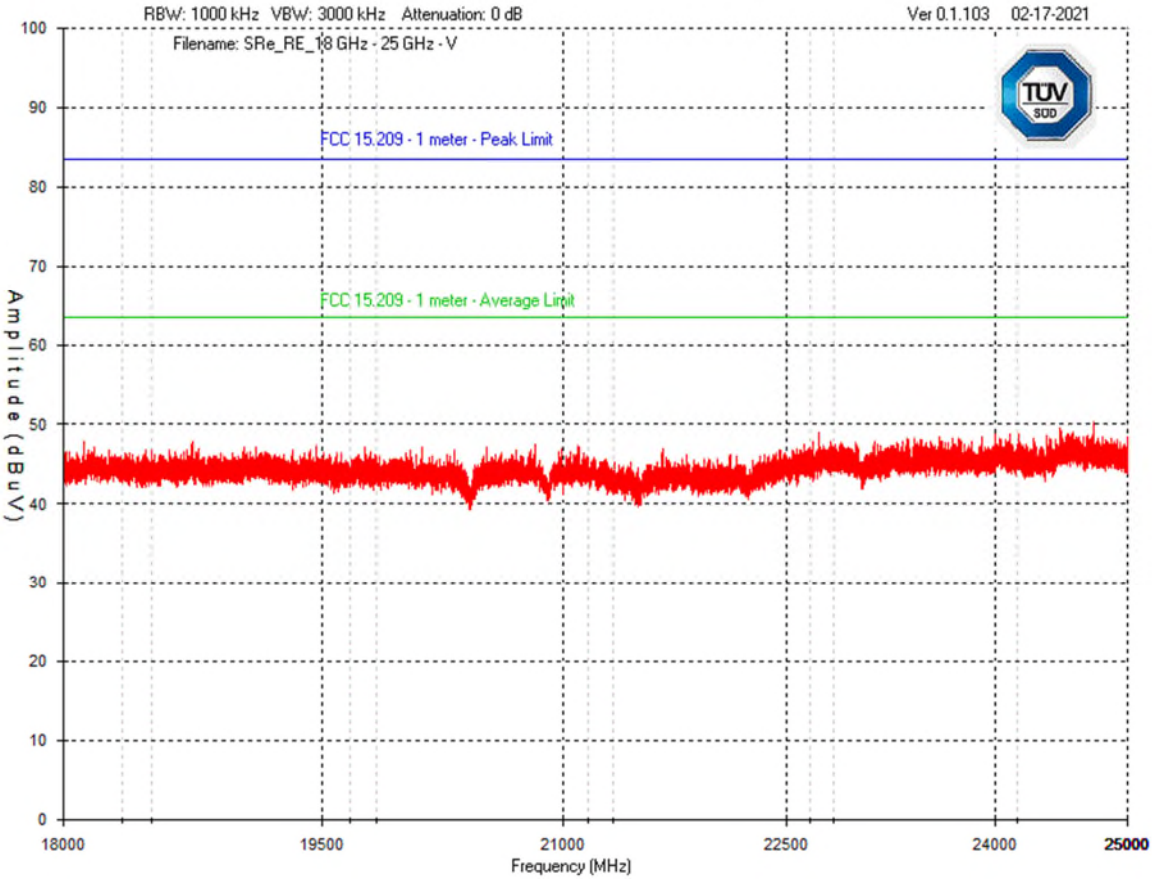


High Channel – 12 GHz – 18 GHz
Vertical - Peak Emission Graph



Plot was taken at a 1 meter distance. All emissions were noise floor of measurement instrument. No emissions were found in this frequency range.

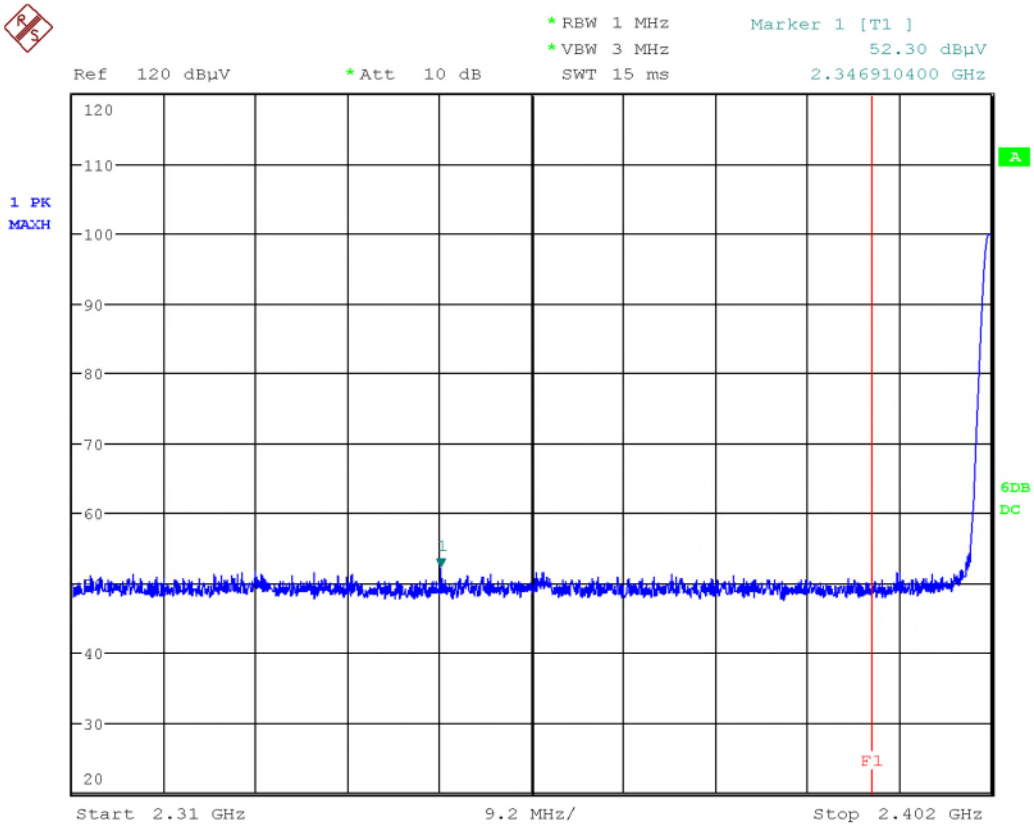
High Channel – 18 GHz – 25 GHz
Vertical - Peak Emission Graph



Plot was taken at a 1 meter distance. All emissions were noise floor of measurement instrument. No emissions were found in this frequency range.

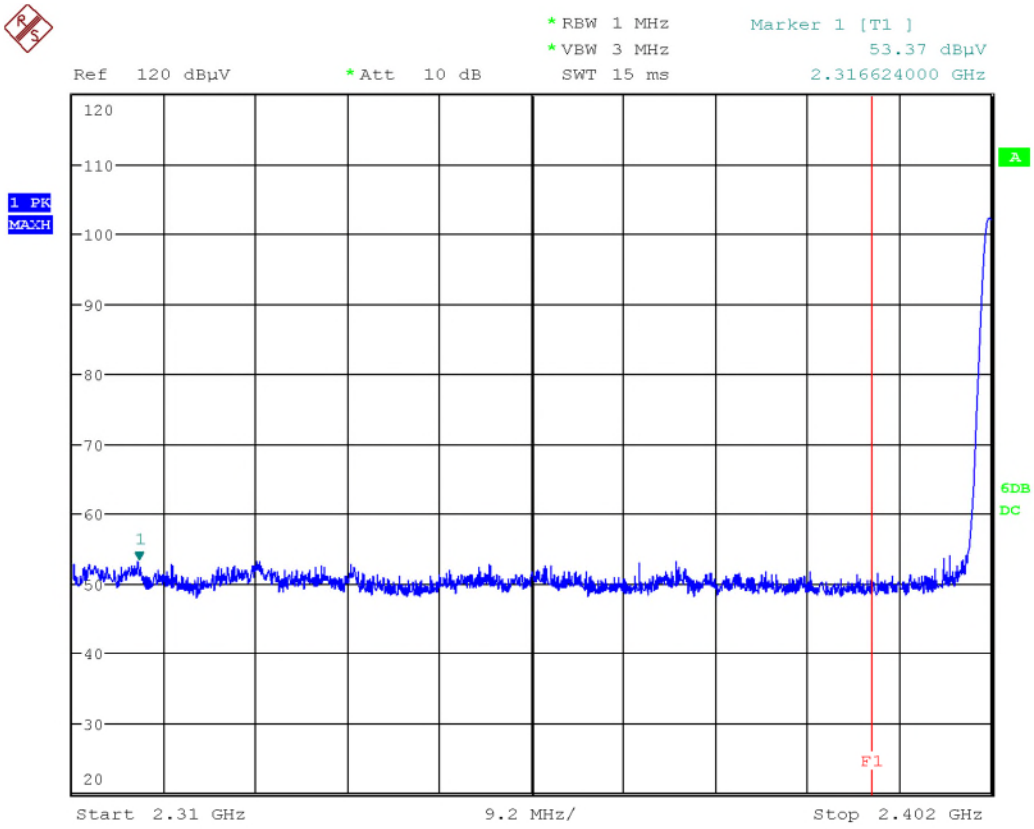
Band Edges

Band Edge – Low Channel
Horizontal - Peak Emission



Note: Restricted band Band Edge plot was taken at a 3m measurement distance. The marker shows the raw value. See the Final Measurements and Results section below for correct values.

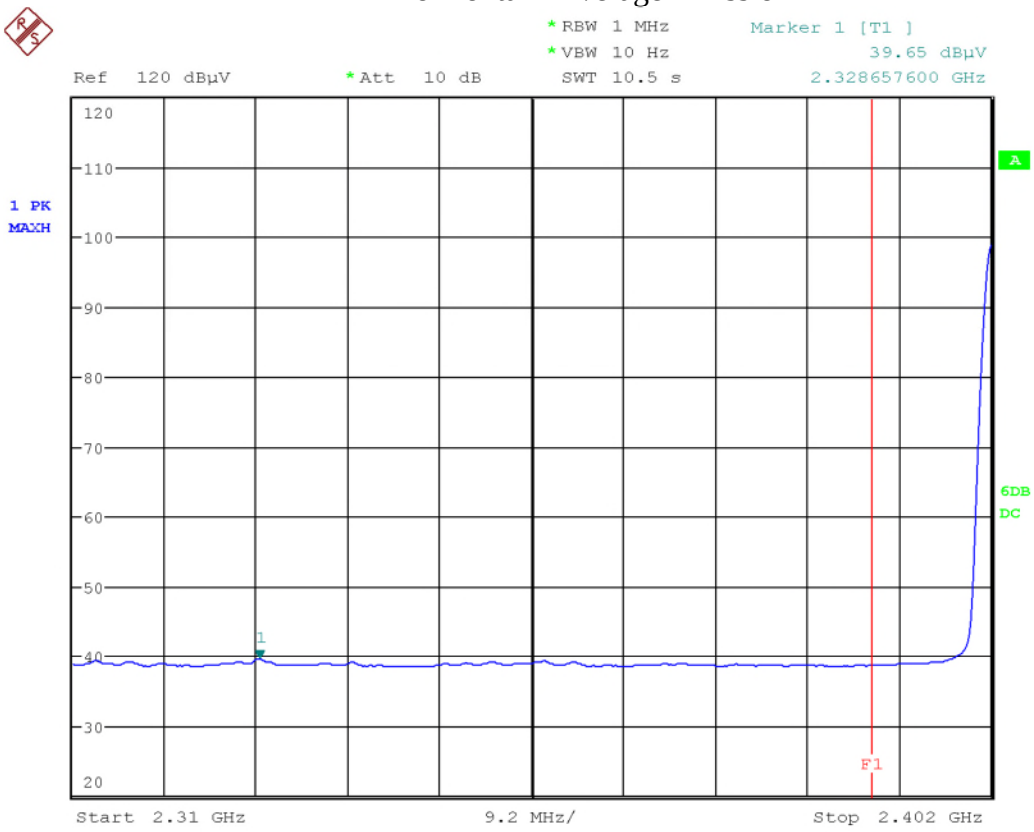
Band Edge – Low Channel
Vertical - Peak Emission



Date: 17.FEB.2021 17:02:53

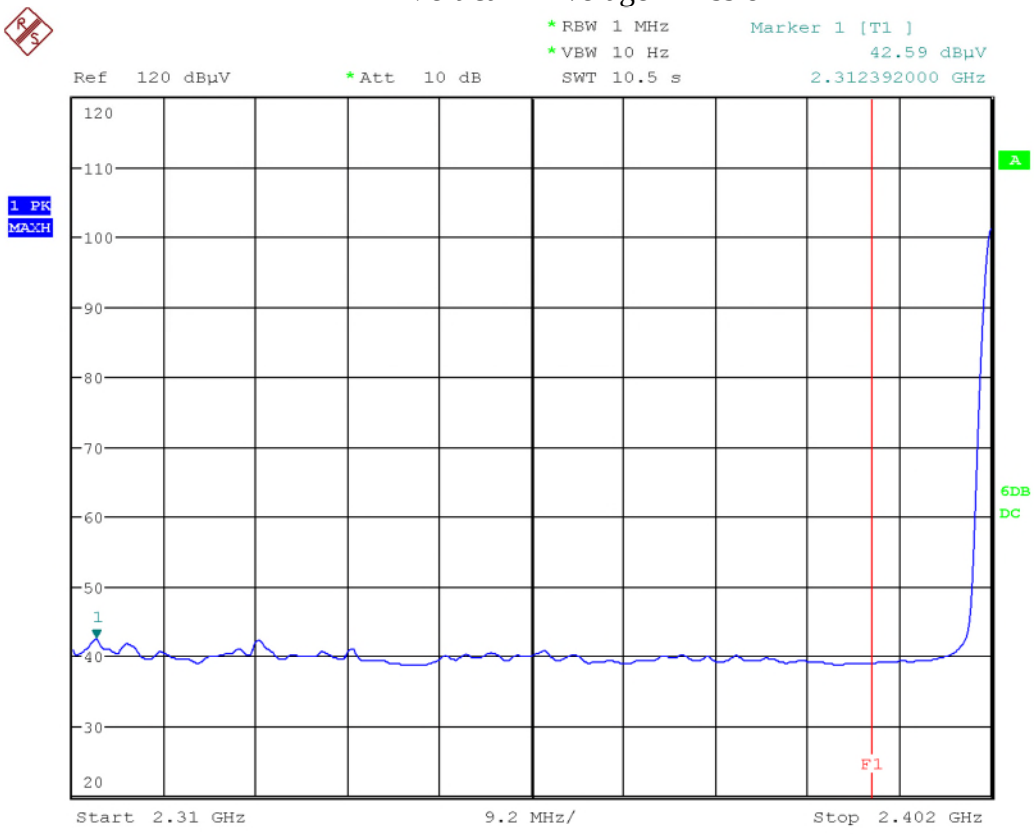
Note: Restricted band Band Edge plot was taken at a 3m measurement distance. The marker shows the raw value. See the Final Measurements and Results section below for correct values.

Band Edge – Low Channel
Horizontal - Average Emission



Note: Restricted band Band Edge plot was taken at a 3m measurement distance. The marker shows the raw value. See the Final Measurements and Results section below for correct values.

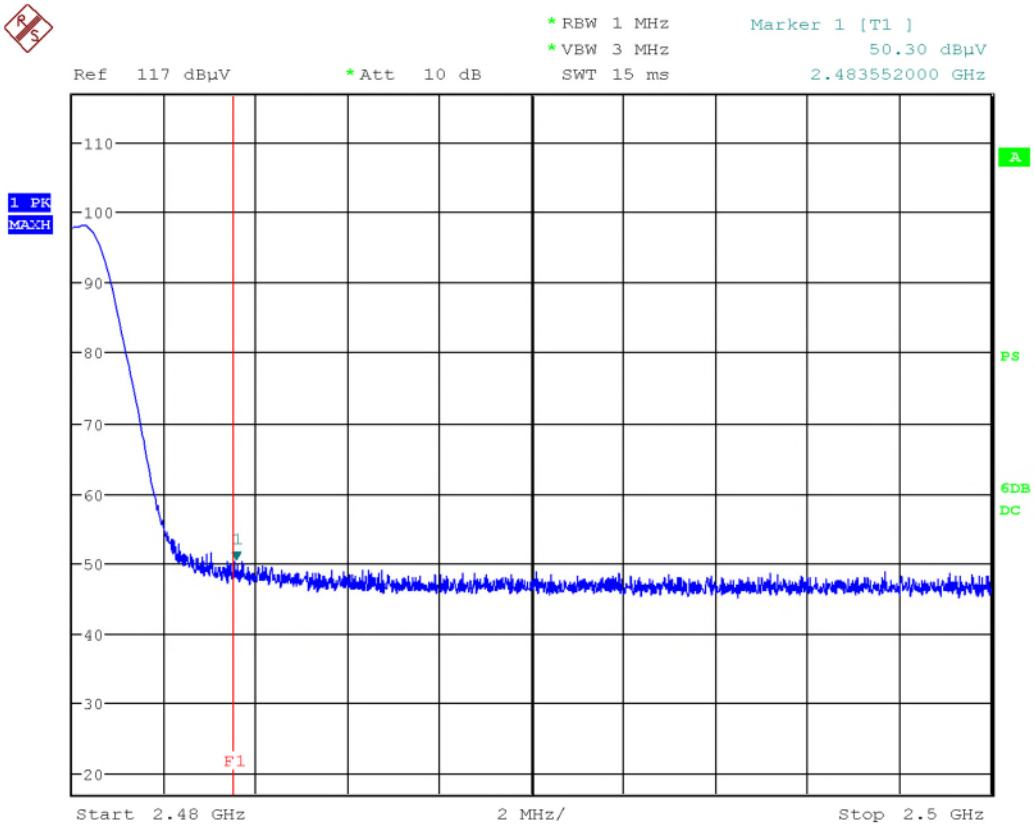
Band Edge – Low Channel
Vertical – Average Emission



Date: 17.FEB.2021 17:03:36

Note: Restricted band Band Edge plot was taken at a 3m measurement distance. The marker shows the raw value. See the Final Measurements and Results section below for correct values.

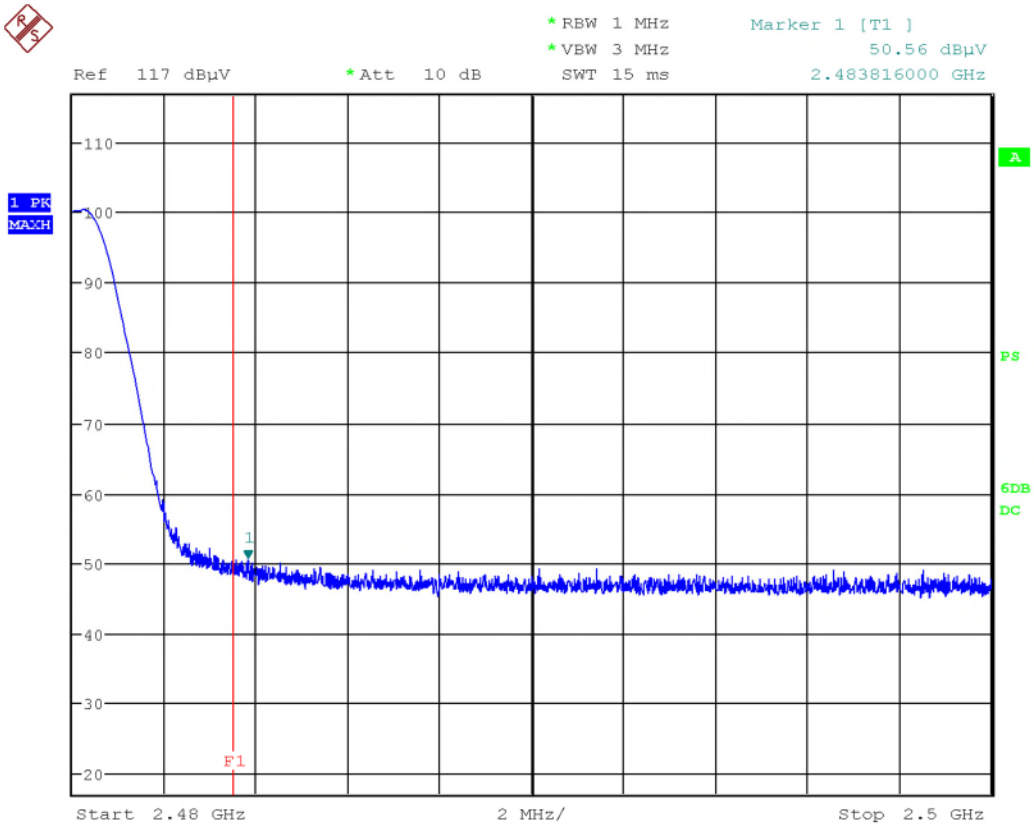
Band Edge – High Channel
Horizontal - Peak Emission



Date: 17.FEB.2021 17:31:24

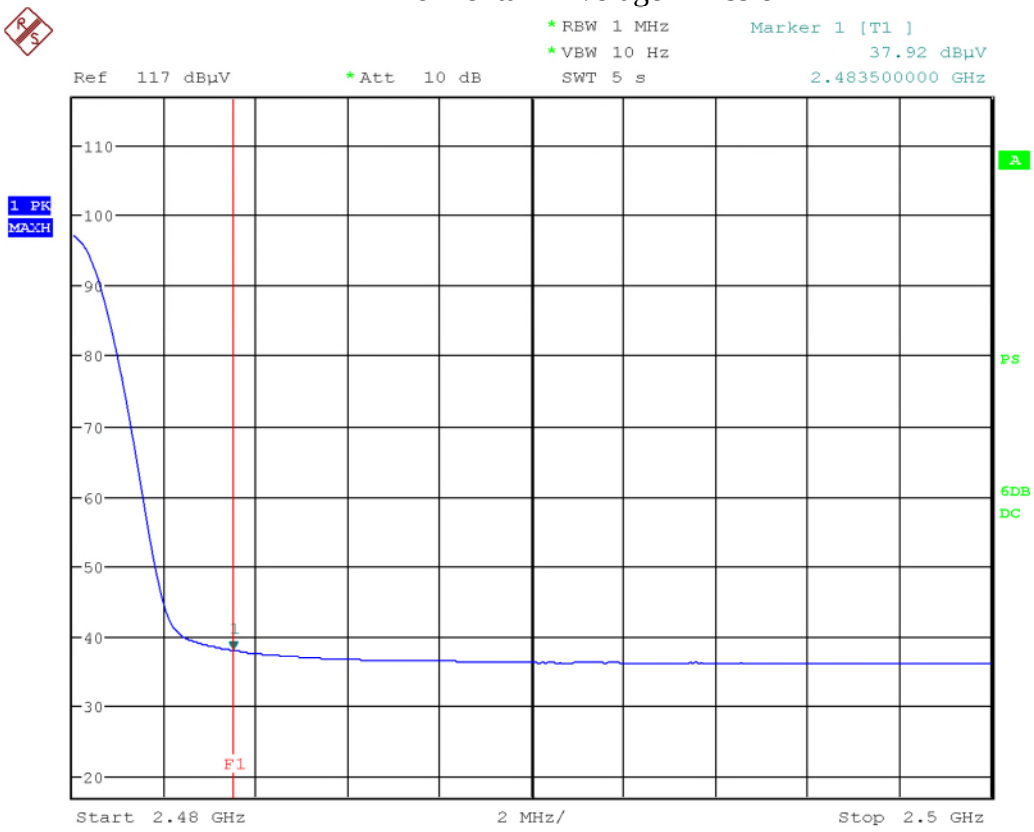
Note: Restricted band Band Edge plot was taken at a 3m measurement distance. The marker shows the raw value. See the Final Measurements and Results section below for correct values.

Band Edge – High Channel
Vertical - Peak Emission



Note: Restricted band Band Edge plot was taken at a 3m measurement distance. The marker shows the raw value. See the Final Measurements and Results section below for correct values.

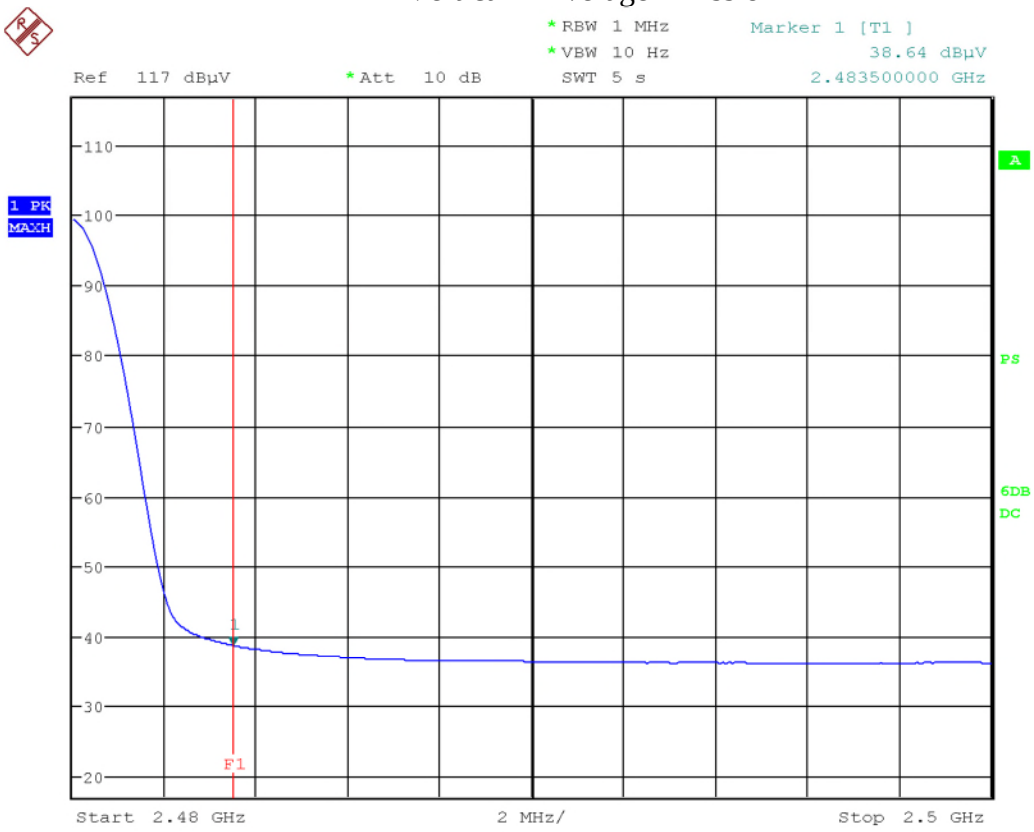
Band Edge – High Channel
Horizontal - Average Emission



Date: 17.FEB.2021 17:31:46

Note: Restricted band Band Edge plot was taken at a 3m measurement distance. The marker shows the raw value. See the Final Measurements and Results section below for correct values.

Band Edge – High Channel
Vertical – Average Emission



Date: 17.FEB.2021 17:37:18

Note: Restricted band Band Edge plot was taken at a 3m measurement distance. The marker shows the raw value. See the Final Measurements and Results section below for correct values.

Final Measurements and Results

The EUT passed. Low, middle, and high bands were measured.

In accordance with 15.247(d), only frequencies exceeding the 15.209 limit that occur within the bands listed in 15.205 need to be verified with a final detector.

The measurements were maximized by rotating the turn table over a full 0-360 rotation and the antenna height was varied from 1 m to 4 m.

Test Frequency (MHz)	Detection Mode	Antenna Polarity (Horz/Vert)	Received Signal (dBµV)	Antenna Factor (dB/m)	Cable Factor (dB)	Attenuator (dB)	Pre-Amp Gain (dB)	Level (dBµV/m)	Emission Limit (dBµV/m)	Margin (dB)	Result
Low Channel											
2402	Peak	Horz	100.0	32.0	4.7	0.0	-36.4	100.2			PASS
2402	Avg	Horz	99.0	32.0	4.7	0.0	-36.4	99.2			PASS
2402	Peak	Vert	102.3	32.0	4.7	0.0	-36.4	102.5			PASS
2402	Avg	Vert	101.3	32.0	4.7	0.0	-36.4	101.5			PASS
2346.9	Peak	Horz	52.3	31.9	4.6	0.0	-36.4	52.4	74.0	21.6	PASS
2328.7	Avg	Horz	39.7	31.8	4.6	0.0	-36.4	39.7	54.0	14.3	PASS
2316.6	Peak	Vert	53.4	31.8	4.6	0.0	-36.5	53.3	74.0	20.7	PASS
2312.4	Avg	Vert	42.6	31.8	4.6	0.0	-36.5	42.5	54.0	11.5	PASS
2498.2	Peak	Horz	48.6	32.2	4.7	0.0	-36.4	49.2	74.0	24.8	PASS
2491.6	Avg	Horz	37.0	32.2	4.7	0.0	-36.4	37.6	54.0	16.4	PASS
2497.6	Peak	Vert	50.0	32.2	4.7	0.0	-36.4	50.6	74.0	23.4	PASS
2497	Avg	Vert	38.0	32.2	4.7	0.0	-36.4	38.6	54.0	15.4	PASS
4804	Peak	Horz	46.8	34.2	7.0	0.0	-35.2	52.9	74.0	21.2	PASS
4804	Avg	Horz	39.0	34.2	7.0	0.0	-35.2	45.1	54.0	9.0	PASS
4804	Peak	Vert	48.2	34.2	7.0	0.0	-35.2	54.3	74.0	19.8	PASS
4804	Avg	Vert	40.6	34.2	7.0	0.0	-35.2	46.7	54.0	7.4	PASS
Mid Channel											
2442	Peak	Horz	98.5	32.2	4.7	0.0	-36.4	99.0			PASS
2442	Avg	Horz	97.5	32.2	4.7	0.0	-36.4	98.0			PASS
2442	Peak	Vert	100.7	32.2	4.7	0.0	-36.4	101.3			PASS
2442	Avg	Vert	99.7	32.2	4.7	0.0	-36.4	100.2			PASS
4884	Peak	Horz	46.8	34.1	7.1	0.0	-35.1	52.9	74.0	21.1	PASS
4884	Avg	Horz	38.8	34.1	7.1	0.0	-35.1	44.9	54.0	9.1	PASS
4884	Peak	Vert	45.5	34.1	7.1	0.0	-35.1	51.6	74.0	22.4	PASS
4884	Avg	Vert	35.2	34.1	7.1	0.0	-35.1	41.3	54.0	12.7	PASS
High Channel Z axis											
2480	Peak	Horz	98.2	32.2	4.7	0.0	-36.4	98.7			PASS
2480	Avg	Horz	97.1	32.2	4.7	0.0	-36.4	97.7			PASS
2480	Peak	Vert	100.5	32.2	4.7	0.0	-36.4	101.1			PASS
2480	Avg	Vert	99.4	32.2	4.7	0.0	-36.4	100.0			PASS
2351.9	Peak	Horz	50.5	31.9	4.6	0.0	-36.4	50.6	74.0	23.4	PASS
2352	Avg	Horz	43.3	31.9	4.6	0.0	-36.4	43.5	54.0	10.5	PASS
2352.4	Peak	Vert	54.2	31.9	4.6	0.0	-36.4	54.3	74.0	19.7	PASS
2352	Avg	Vert	47.8	31.9	4.6	0.0	-36.4	48.0	54.0	6.0	PASS
2483.6	Peak	Horz	50.3	32.2	4.7	0.0	-36.4	50.9	74.0	23.1	PASS
2483.5	Avg	Horz	37.9	32.2	4.7	0.0	-36.4	38.5	54.0	15.5	PASS
2483.8	Peak	Vert	50.6	32.2	4.7	0.0	-36.4	51.1	74.0	22.9	PASS
2483.5	Avg	Vert	38.6	32.2	4.7	0.0	-36.4	39.2	54.0	14.8	PASS

Test Equipment List

Equipment	Model No.	Manufacturer	Last Calibration Date	Next Calibration Date	Asset #
Spectrum Analyzer	ESU 40	Rohde & Schwarz	Jan. 15, 2020	Jan. 15, 2022	GEMC 233
Loop Antenna	EM 6879	Electro-Metrics	Nov 25, 2019	Nov 25, 2021	LAV4040
BiLog Antenna	3142-C	ETS-Lindgren	Mar. 01, 2019	Mar. 01, 2021	GEMC 137
Horn Antenna	3117	ETS-Lindgren	Feb. 17, 2020	Feb. 17, 2022	GEMC 340
Horn Antenna	WBH218HN	Q-par	Apr. 1, 2020	Apr. 1, 2022	GEMC 6375
Horn Antenna 18 - 26.5 GHz	SAS-572	A.H. Systems	Dec. 1, 2020	Dec. 1, 2022	GEMC 6371
Attenuator 6 dB	612-6-1	Meca Electronics, Inc	NCR	NCR	GEMC 287
Pre-Amp 9 kHz – 1 GHz	CPA9230	Chase	May 22, 2020	May 22, 2022	GEMC 301
Pre-Amp 1 – 26.5 GHz	HP 8449B	HP	Aug. 4, 2020	Aug. 4, 2022	GEMC 312
2.4GHz-2.5GHz Notch Filter	BRM50702	Micro-Tronics	NCR	NCR	GEMC 230
RF Cable 10m	LMR-400-10M-50Ω-MN-MN	LexTec	NCR	NCR	GEMC 274
RF Cable 2m	Sucoflex 104A	Huber+Suhner	NCR	NCR	GEMC 271
Emissions Software	0.1.103	TUV SUD Canada, Inc.	NCR	NCR	GEMC 58

FCC - 15.209 -Radiated Emissions_Rev1

Power Spectral Density

Purpose

The purpose of this test is to ensure that the maximum power spectral density to the radiating element does not exceed the limits specified. This ensures that the modulation is significantly wide enough, or low enough in power that it will allow for co-operation of other wireless devices operating within this frequency allocation.

Limits and Method

The limits are defined in 15.247(e) and RSS-247 5.2(b).

For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

The method is given in FCC KDB 558074 Section 10.2.

Results

The EUT passed. Low, middle and high bands were measured.

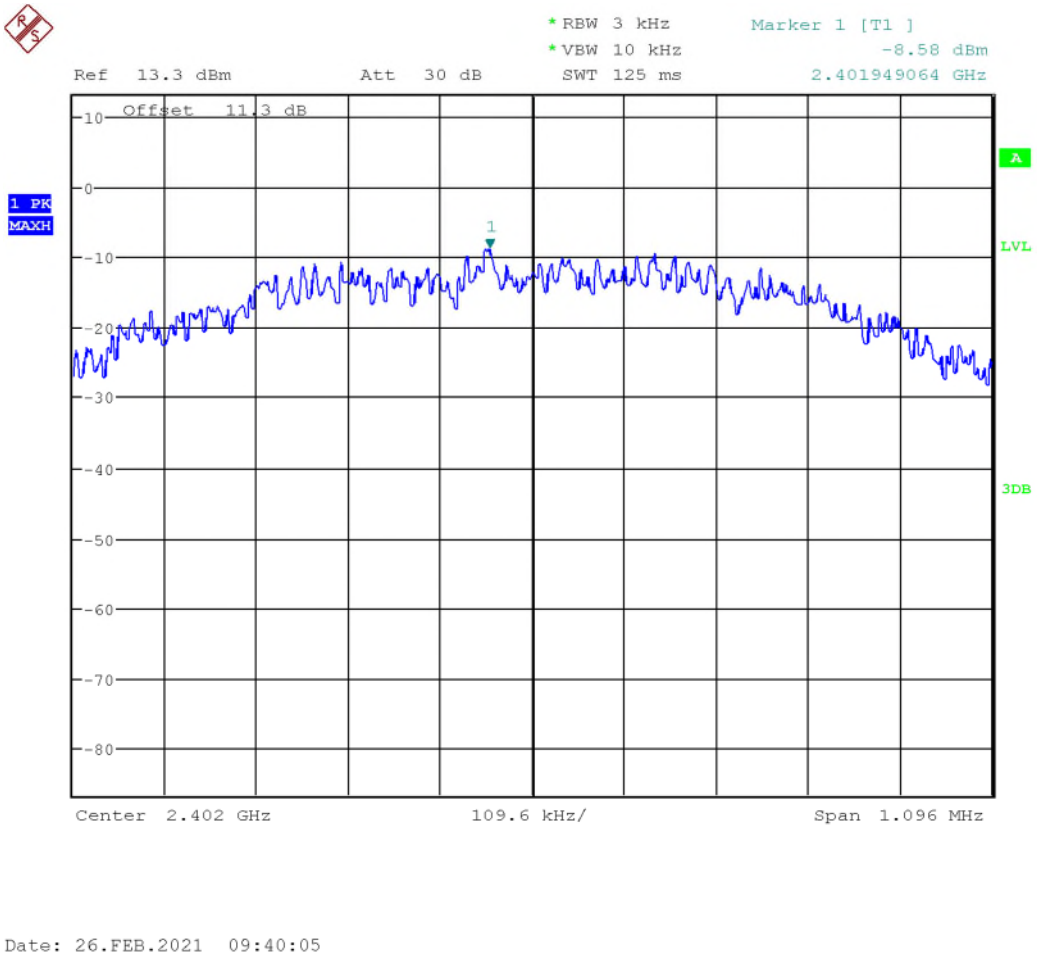
Channel	Frequency (MHz)	PSD (dBm)
Low	2402	-8.58
Mid	2442	-7.60
High	2480	-9.36

Graphs

The graphs shown below show the power spectral density of the device during the conducted measurement operation of the EUT. The external attenuator and cable loss are accounted for as reference offset in the spectrum analyzer.

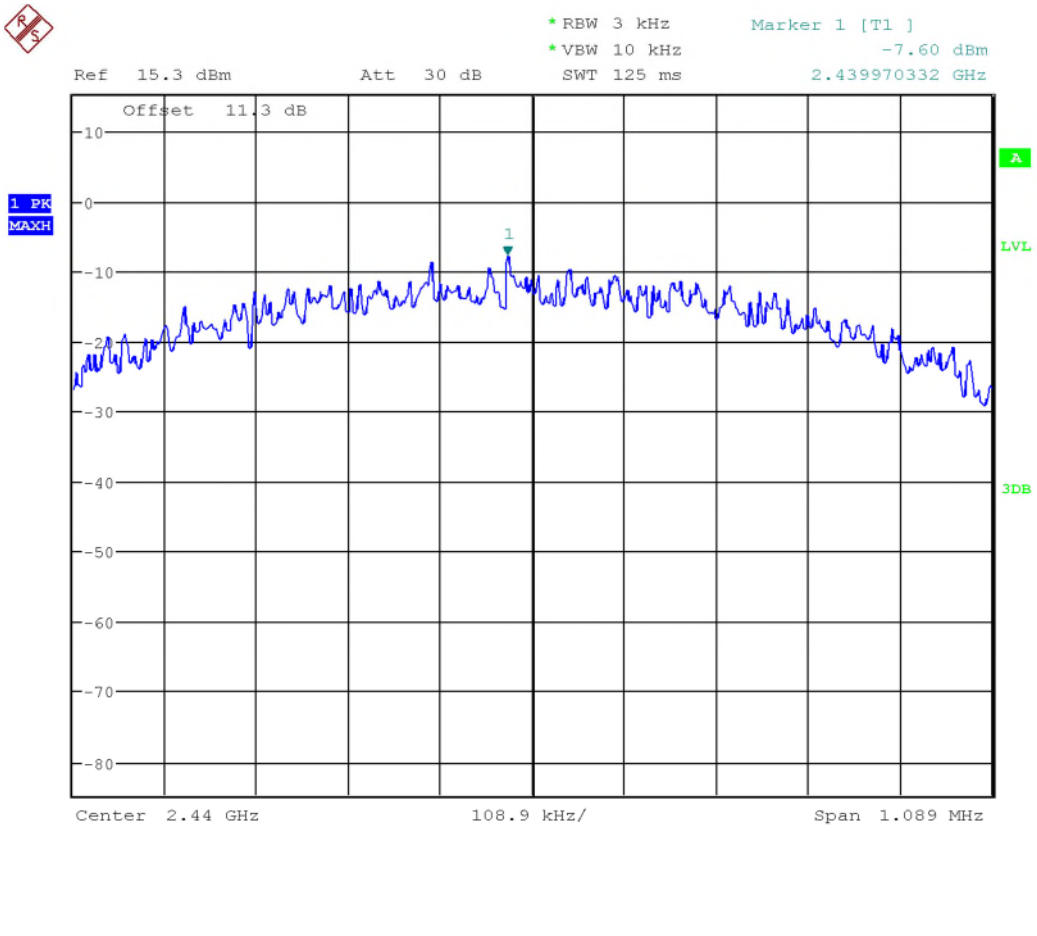
PSD

Low Channel

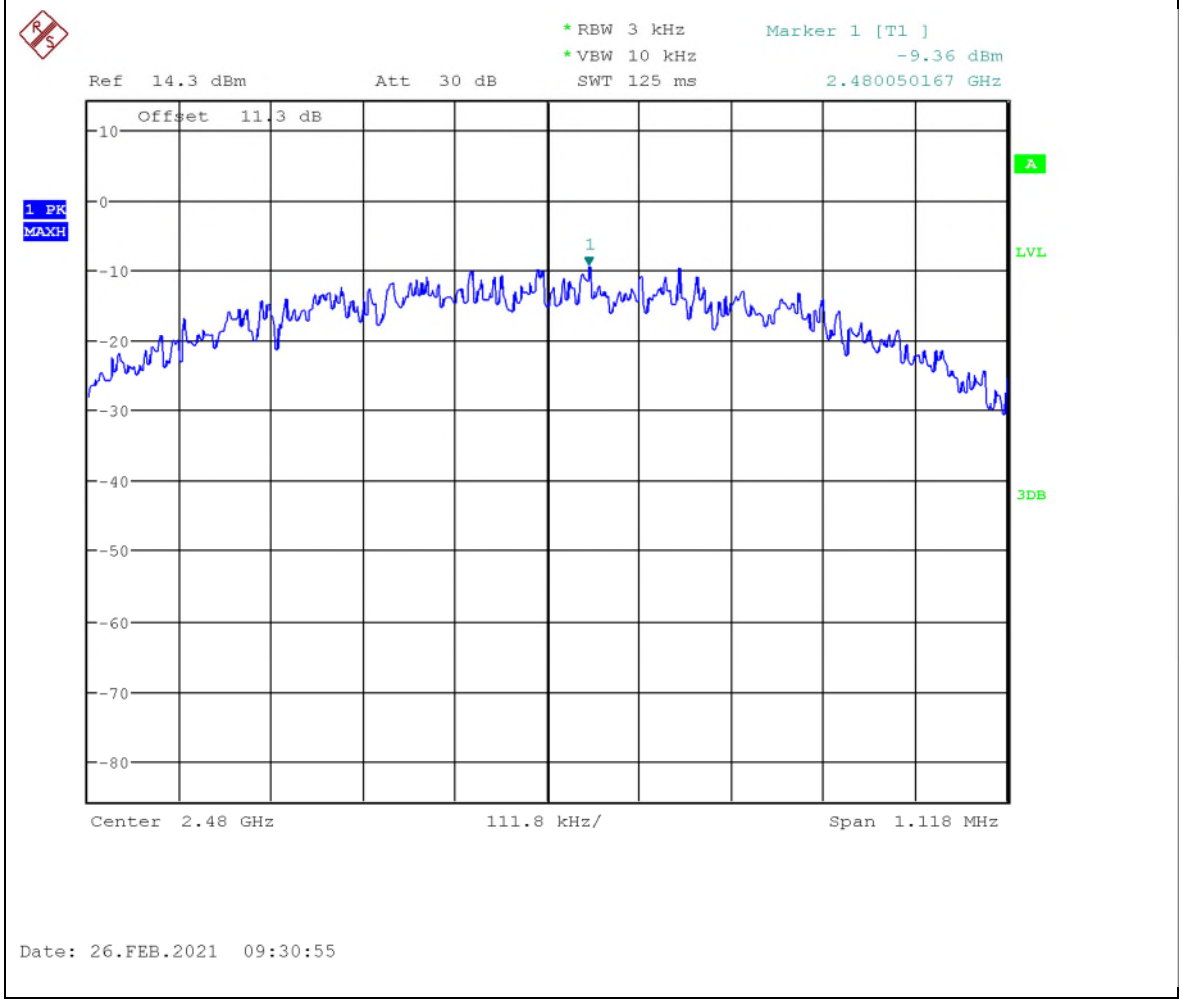


PSD

Mid Channel



PSD
High Channel



See 'Appendix B – EUT and Test Setup Photos' for photos showing the test set-up.

Test Equipment List

Equipment	Model No.	Manufacturer	Last Calibration Date	Next Calibration Date	Asset #
Signal Analyzer	FSQ 26	Rohde & Schwarz	Oct. 25, 2019	Oct. 25, 2021	GEMC 234
Attenuator 10 dB	8493B	Agilent	NCR	NCR	GEMC 133

Power Line Conducted Emissions

Purpose

The purpose of this test is to ensure that the RF energy unintentionally emitted from the EUT's power line does not exceed the limits listed below as defined in the applicable test standard and measured from a LISN. This helps protect lower frequency radio services such as AM radio, shortwave radio, amateur radio, maritime radio, CB radio, and so on, from unwanted interference.

Limits & Method

The method is as defined in ANSI C63.4. The limits are as defined in FCC Part 15 Section 15.207:

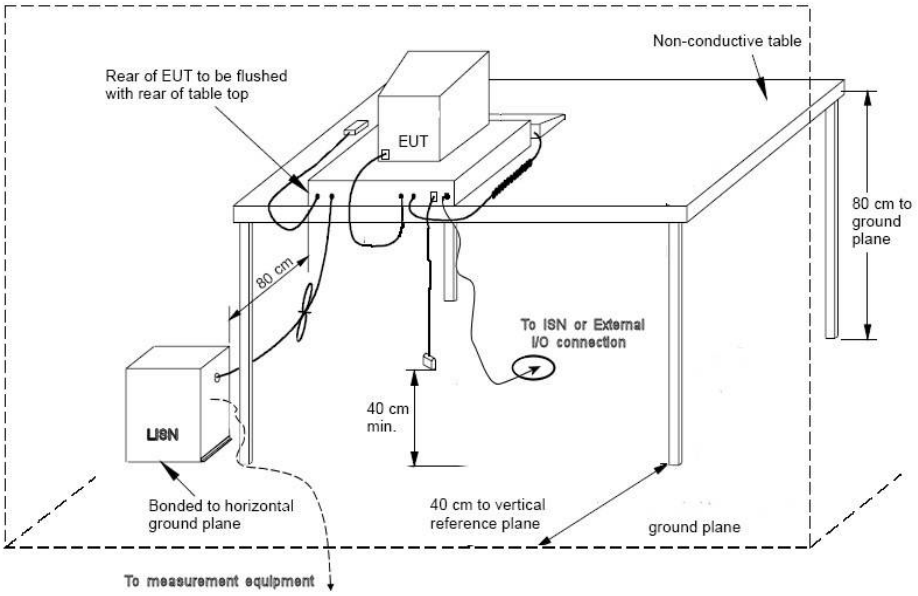
Average Limits		Quasi-Peak Limits	
150 kHz – 500 kHz	56 to 46* dBµV	150 kHz – 500 kHz	66 to 56* dBµV
500 kHz – 5 MHz	46 dBµV	500 kHz – 5 MHz	56 dBµV
5 MHz – 30 MHz	50 dBµV	5 MHz – 30 MHz	60 dBµV

* Decreases linearly with the logarithm of the frequency

Both Quasi-Peak and Average limits are applicable and each is specified as being measured with a resolution bandwidth of 9 kHz. For Quasi-Peak, a video bandwidth at least three times greater than the resolution bandwidth is used.

Based on ANSI C63.4 Section 4.2, if the Peak or Quasi-Peak detector measurements do not exceed the Average limits, then the EUT is deemed to have passed the requirements.

Typical Setup Diagram



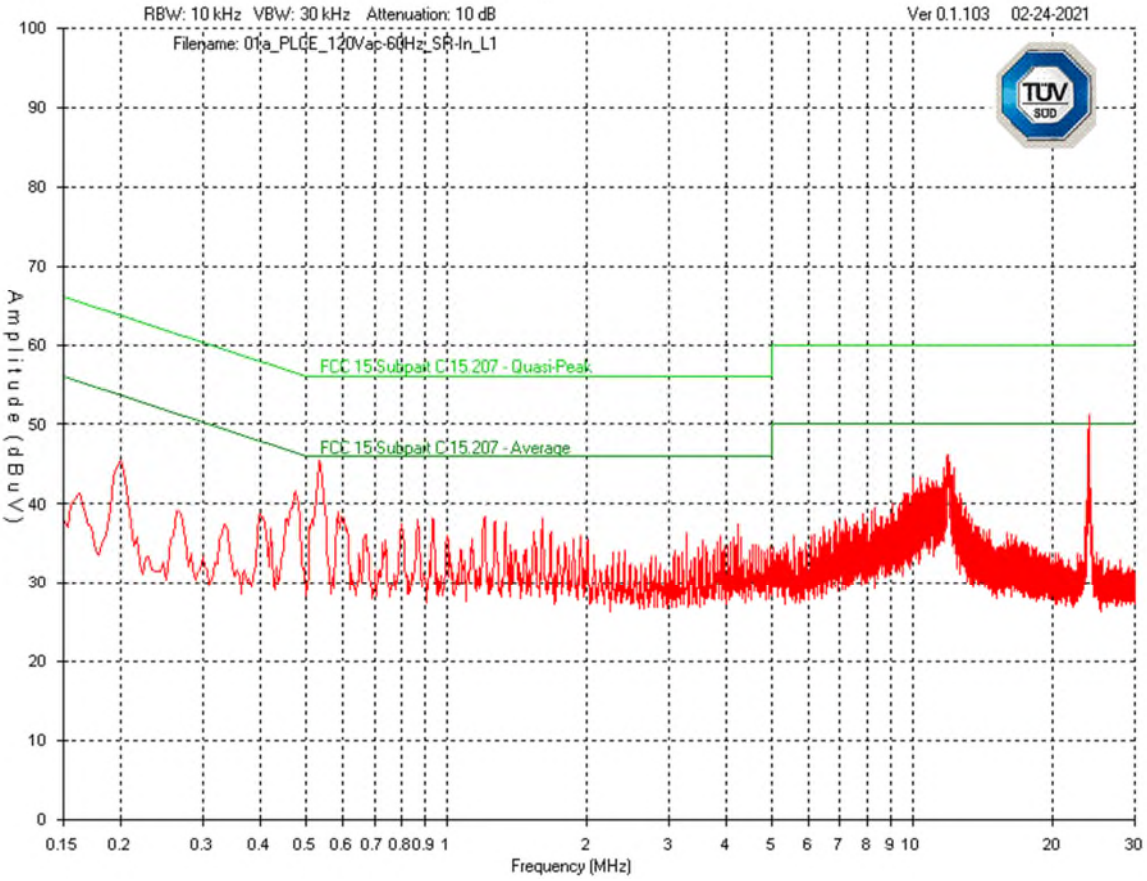
Measurement Uncertainty

The expanded measurement uncertainty is calculated in accordance with CISPR 16-4-2 and is ±2.27dB with a 'k=2' coverage factor and a 95% confidence level.

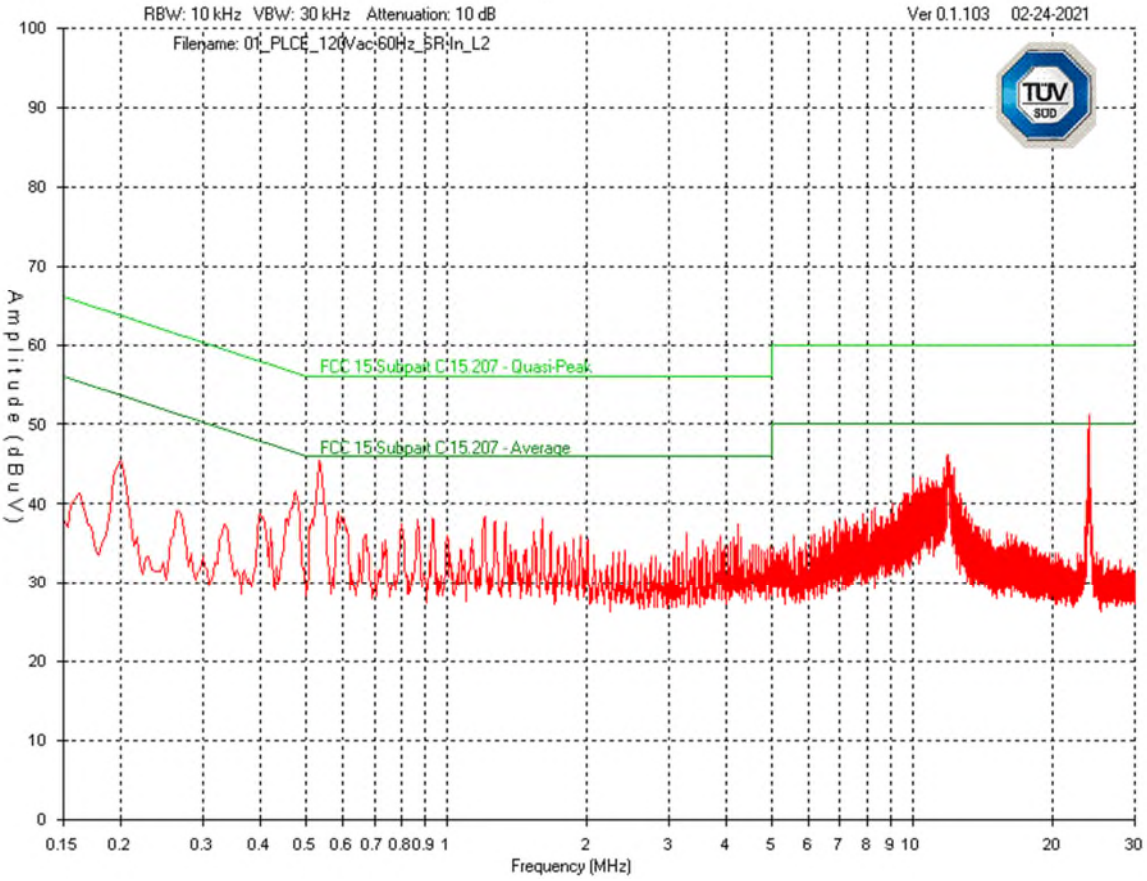
Preliminary Graphs

The graphs shown below are maximized peak measurement graphs measured with a resolution bandwidth greater than or equal to the final required detector. This peaking process is done as a worst-case measurement and enables the detection of frequencies of concern for final measurement. For final measurements with the appropriate detector, where applicable, please refer to the tables under Final Measurements.

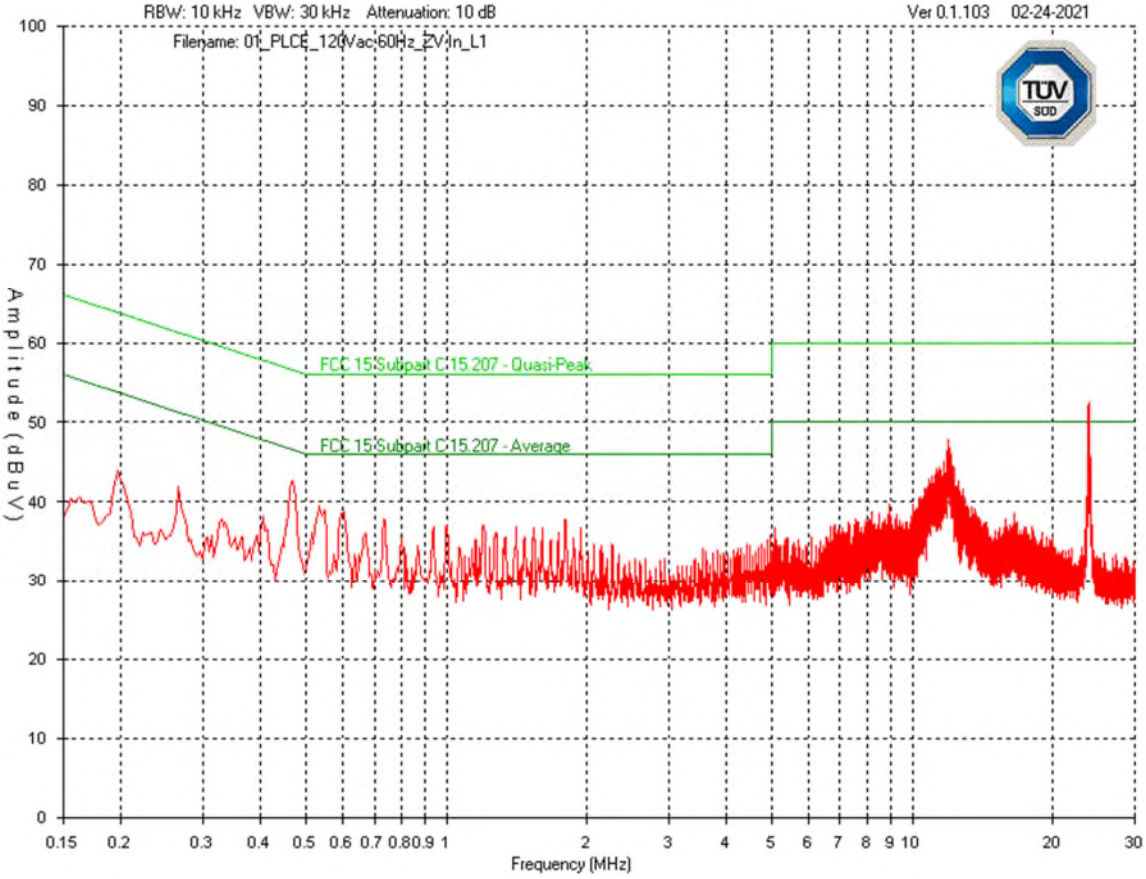
SR506-5
Line 1 (L1) – 120Vac 60Hz



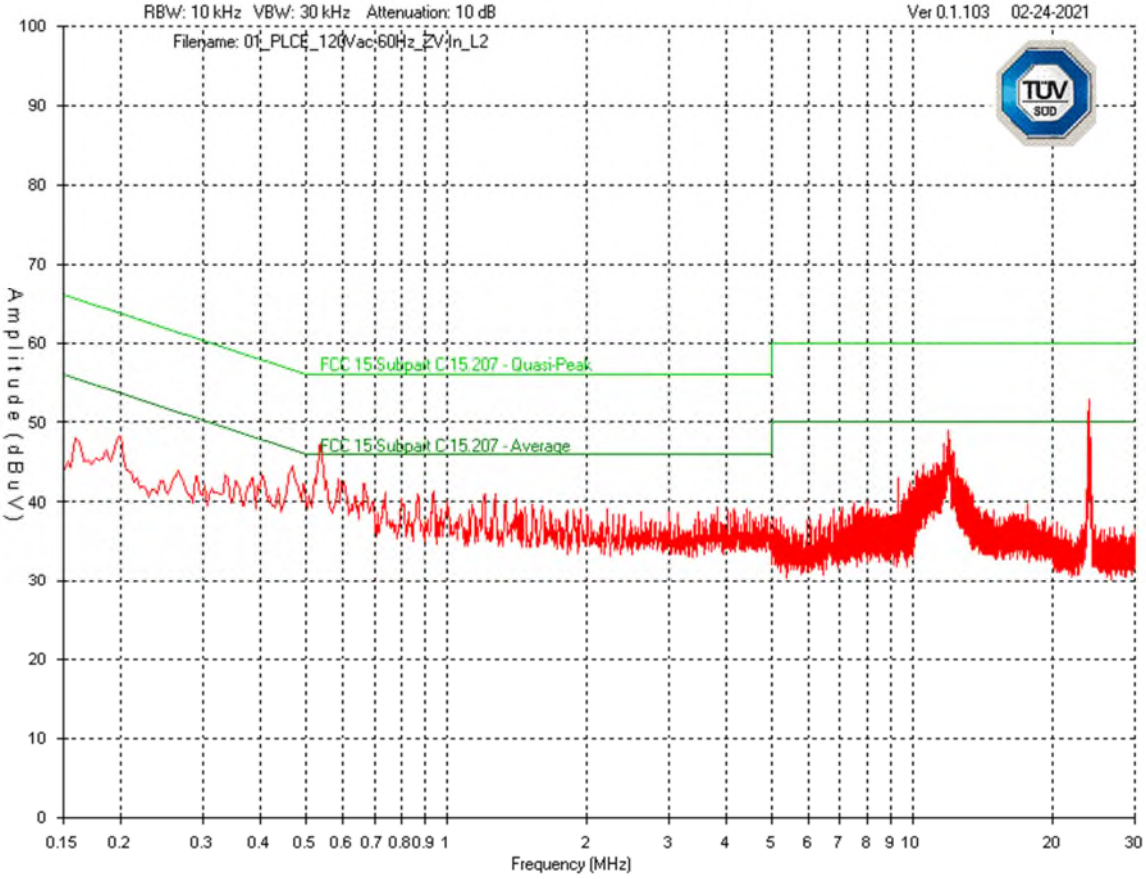
SR506-5
Line 2 (L2) – 120Vac 60Hz



ZVC406-5
Line 1 (L1) – 120Vac 60Hz



ZVC406-5
Line 2 (L2) – 120Vac 60Hz



Final Measurements

Product Category			15.207								
EUT			SR								
Supply			**120Vac 60Hz**								
Frequency (MHz)	**Detector**	**Received Signal (dBµV)**	**Atten Factor (dB)**	**Cable Factor (dB)**	**LISN Factor (dB)**	**Level (dBµV)**	**QP Limit (dBµV)**	**AVG Limit (dBµV)**	**QP Margin (dB)**	**AVG Margin (dB)**	**Test Result**
Line											
24.023	AVG	29.5	10	0.1	0.6	40.2	--	50.0	--	9.8	Pass
23.914	AVG	27.4	10	0.1	0.5	38.0	--	50.0	--	12.0	Pass
0.535	AVG	33.6	10	0.1	0.1	43.8	--	46.0	--	2.2	Pass
11.911	AVG	29.3	10	0.1	0.3	39.7	--	50.0	--	10.3	Pass
12.050	AVG	29.6	10	0.1	0.3	40.0	--	50.0	--	10.0	Pass
0.475	AVG	32.7	10	0.1	0.1	42.9	--	46.4	--	3.5	Pass
24.023	PEAK	40.5	10	0.1	0.6	51.2	60.0	--	8.8	--	Pass
23.914	PEAK	40.1	10	0.1	0.5	50.7	60.0	--	9.3	--	Pass
0.535	PEAK	35.5	10	0.1	0.1	45.7	56.0	--	10.3	--	Pass
11.911	PEAK	35.9	10	0.1	0.3	46.3	60.0	--	13.7	--	Pass
12.050	PEAK	35.3	10	0.1	0.3	45.7	60.0	--	14.3	--	Pass
0.475	PEAK	31.6	10	0.1	0.1	41.8	56.4	--	14.6	--	Pass
Neutral											
24.023	AVG	29.9	10	0.1	0.6	40.6	--	50.0	--	9.4	Pass
23.914	AVG	27.9	10	0.1	0.5	38.5	--	50.0	--	11.5	Pass
0.535	AVG	33.4	10	0.1	0.1	43.6	--	46.0	--	2.4	Pass
11.911	AVG	29.4	10	0.1	0.3	39.8	--	50.0	--	10.2	Pass
12.050	AVG	29.1	10	0.1	0.3	39.5	--	50.0	--	10.5	Pass
0.475	AVG	32.8	10	0.1	0.1	43.0	--	46.4	--	3.4	Pass
24.023	PEAK	40.6	10	0.1	0.6	51.3	60.0	--	8.7	--	Pass
23.914	PEAK	40.2	10	0.1	0.5	50.8	60.0	--	9.2	--	Pass
0.535	PEAK	35.4	10	0.1	0.1	45.6	56.0	--	10.4	--	Pass
11.911	PEAK	35.8	10	0.1	0.3	46.2	60.0	--	13.8	--	Pass
12.050	PEAK	35.0	10	0.1	0.3	45.4	60.0	--	14.6	--	Pass
0.475	PEAK	31.4	10	0.1	0.1	41.6	56.4	--	14.8	--	Pass

Average and Quasi-Peak Emissions Table

Product Category			15.207								
EUT			ZV								
Supply			**120Vac 60Hz**								
Frequency (MHz)	**Detector**	**Received Signal (dBµV)**	**Atten Factor (dB)**	**Cable Factor (dB)**	**LISN Factor (dB)**	**Level (dBµV)**	**QP Limit (dBµV)**	**AVG Limit (dBµV)**	**QP Margin (dB)**	**AVG Margin (dB)**	**Test Result**
Line											
23.924	AVG	31.6	10	0.1	0.6	42.3	--	50.0	--	7.7	Pass
11.964	AVG	31.1	10	0.1	0.3	41.5	--	50.0	--	8.5	Pass
12.070	AVG	27.8	10	0.1	0.3	38.2	--	50.0	--	11.8	Pass
0.468	AVG	29.9	10	0.1	0.1	40.1	--	46.5	--	6.4	Pass
24.186	AVG	19.9	10	0.1	0.6	30.6	--	50.0	--	19.4	Pass
0.535	AVG	29.7	10	0.1	0.1	39.9	--	46.0	--	6.1	Pass
23.924	PEAK	41.9	10	0.1	0.6	52.6	60.0	--	7.4	--	Pass
11.964	PEAK	37.6	10	0.1	0.3	48.0	60.0	--	12.0	--	Pass
12.070	PEAK	36.5	10	0.1	0.3	46.9	60.0	--	13.1	--	Pass
0.468	PEAK	32.5	10	0.1	0.1	42.7	56.5	--	13.8	--	Pass
24.186	PEAK	34.9	10	0.1	0.6	45.6	60.0	--	14.4	--	Pass
0.535	PEAK	29.4	10	0.1	0.1	39.6	56.0	--	16.4	--	Pass
Neutral											
23.917	AVG	30.5	10	0.1	0.5	41.1	--	50.0	--	8.9	Pass
0.538	AVG	30.1	10	0.1	0.1	40.3	--	46.0	--	5.7	Pass
11.957	AVG	31.6	10	0.1	0.3	42.0	--	50.0	--	8.0	Pass
24.140	AVG	27.2	10	0.1	0.6	37.9	--	50.0	--	12.1	Pass
12.183	AVG	26.7	10	0.1	0.3	37.1	--	50.0	--	12.9	Pass
0.936	AVG	20.5	10	0.1	0.1	30.7	--	46.0	--	15.3	Pass
1.208	AVG	22.7	10	0.1	0.1	32.9	--	46.0	--	13.1	Pass
10.243	AVG	23.2	10	0.1	0.2	33.5	--	50.0	--	16.5	Pass
23.917	PEAK	42.2	10	0.1	0.5	52.8	60.0	--	7.2	--	Pass
0.538	PEAK	37.1	10	0.1	0.1	47.3	56.0	--	8.7	--	Pass
11.957	PEAK	38.6	10	0.1	0.3	49.0	60.0	--	11.0	--	Pass
24.140	PEAK	37.4	10	0.1	0.6	48.1	60.0	--	11.9	--	Pass
12.183	PEAK	36.0	10	0.1	0.3	46.4	60.0	--	13.6	--	Pass
0.936	PEAK	31.3	10	0.1	0.1	41.5	56.0	--	14.5	--	Pass
1.208	PEAK	30.9	10	0.1	0.1	41.1	56.0	--	14.9	--	Pass

Note:

Peak = Peak measurement
AVG = Average measurement
QP = Quasi-Peak measurement

See 'Appendix B – EUT, Peripherals and Test Setup Photos' for photos showing the test set-up for the highest line conducted emission

Test Equipment List

Equipment	Model No.	Manufacturer	Last Calibration Date	Next Calibration Date	Asset #
Signal Analyzer	FSQ 26	Rohde & Schwarz	Oct. 25, 2019	Oct. 25, 2021	GEMC 234
LISN	FCC-LISN-50/250-16-2-01	FCC	Feb. 10, 2021	Feb. 10, 2023	GEMC 303
RF Cable 3m	LMR-400-3M-50Ω-MN-MN	LexTec	NCR	NCR	GEMC 276
Attenuator 10 dB	6N10W-10	Inmet	NCR	NCR	GEMC 350
Emissions Software	0.1.103	TUV SUD Canada, Inc.	NCR	NCR	GEMC 58

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Appendix A – EUT Summary

For further details for filing purposes, refer to filing package.

General EUT Description

Client	
Organization / Address	Taco, Inc. 1160 Cranston Street Cranston, RI 02920
Contact	Evan Cornell
Phone	401-942-8000
Email	EvaCor@TacoComfort.com
EUT Details	
EUT Name	Next-Generation Electronic Controls
Model	ZVC406-5; SR506-5
FCC ID	2AW7V-93004022
IC	26602-93004022
Equipment Category	HVAC Controller
Basic EUT Functionality	These devices are zone controllers intended for use with heating system. Each unit is provided in a Type 1 enclosure. The enclosure for the SR and ZVC series devices is comprised of a metallic base and polymeric cover. All models are intended to be permanently connected. Conduit knockouts are intended to accommodate connection to a permanent wiring system. These devices accept input from zone thermostats (or similar demand indicating devices). In response, these devices control external boiler (via the thermostat input), circulating pump(s) and zone valves (ZVC series), or zone circulating pumps (SR series). Each device is provided with (one or two) class 2 transformer(s) to supply the internal circuitry and external loads (i.e. zone valves). Models include circuitry to establish priority zones and operational schedules. Models include circuitry to provide expansion function (low voltage features). The SR50x-5 SKUs all use the same PCB, and are just different BOM assembly variants. The ZVC40x-5 SKUs all use the same PCB, and are just different BOM assembly variants.

	The radio circuitry (schematic and layout) are identical between both PCB types.
Input voltage range(s) (V)	110-126VAC
Frequency range(s) (Hz)	59-61Hz
Rated input current (A)	20A
Nominal power consumption (W)	20W
Connectors available on EUT	screw terminals for thermostat inputs, expansion, thermistor input (SR50x-5 only), zone outputs, auxiliary outputs, and boiler end-switch outputs
I/O cable description Specify length and type	thermostat inputs are typical household thermostat wiring, variable length relay outputs are typical household romex, variable length
Peripherals Required for Test	Laptop to configure the test firmware on the EUT via UART
Intentional Radiator Frequency	2400 – 2483.5 MHz for BLE applications as described above.
EUT Configuration	Wireless configured to transmit continuously with the following commands: - Tx Power: +4dBm (output_power pos4dBm) - Duty Cycle: Continuous (default) - start_tx_modulated_carrier - transmit_pattern (default)

Note: The EUT is considered to have been received the date of the commencement of the first test, unless otherwise stated. For a close-up picture of the EUT, see 'Appendix B – EUT and Test Setup Photos'.

Appendix B – EUT and Test Setup Photos

Refer to the files separate from this test report