EMC & RF Test Report

As per

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

Unlicensed Intentional Radiators

on the

Muse MU-03

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

InteraXon

See Appendix A for full client & EUT details.

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

Testing Laboratory Certificate #2955.02

R-4023, G-506 C-4498, T-1246

Registration # CA6844

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Report Scope

This report addresses the EMC verification testing and test results of the Muse model: **MU-03** from Interaxon Inc. This unit 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 15.247:2017

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 Model:	MU-03
FCC Certification #, FCC ID:	2ABZI-MU03
Industry Canada Certification #, IC:	11834A-MU03
EUT passed all tests performed	Yes
Tests conducted by	Raymond Lee Au

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 [α]
FCC 15.205 RSS-247 3.3 RSS-GEN (Table 7)	Restricted Bands for Intentional Operation	QuasiPeak Average	Pass [α]
FCC 15.207 RSS-GEN (Table 4)	Power Line Conducted Emissions	QuasiPeak Average	Pass
FCC 15.209 RSS-GEN (Tables 5 & 6)	Spurious Radiated Emissions & Band Edges	QuasiPeak Average	Pass
FCC 15.247(a)(2) RSS-247 5.2(a)	6 dB Bandwidth	≥ 500 kHz	Pass
FCC 15.247(b)(3) RSS-247 5.4(d)	Max Output Power	≤ 1 Watt (≤ 30 dBm)	Pass
RSS-247 5.4(d)	Max E.I.R.P Output	≤ 4 Watt (≤ 36 dBm)	Pass
FCC 15.247(b)(4) RSS-247 5.4(d)	Antenna Gain	≤ 6 dBi	Pass [α]
FCC 15.247(d) RSS-247 5.5	Antenna Spurious Conducted Emissions	≤ 20 dBc (100 kHz BW outside Tx band)	Pass
FCC 15.247(e) RSS-247 5.2(b)	Power Spectral Density	< 8 dBm (3 kHz BW)	Pass
FCC 15.247(i) RSS-102 (Table 1)	Maximum RF exposure	≤ 5 mm SAR exemption	Pass
Overall Result			**Pass**

[α] See *Notes, Justifications, or Deviations* section for more details.

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.

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, the unit uses a Johanson Technology part number 2450AT18B100 ceramic chip antenna, with 0.5 dBi peak gain, permanently soldered onto the PCB.

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.

The EUT was tested positioned in the three orthogonal axis. Worst case results are presented. See *Appendix B* for test photos.

The EUT's output is set to transmit continuously at 100% duty cycle at the maximum output power.

SAR assessment is applicable to the EUT. An assessment distance of ≤ 5 mm is applied. The device meets the SAR Test exemption criteria and no test is required. See RF Exposure exhibits for more details.

The EUT is a battery operated device with a battery rechargeable via a USB port. The radio is powered off while charging. Power line conducted emissions is performed while it is recharging using a representative support device (Lenovo ThinkPad 13 with Lenovo AC/DC Adapter model ADLX45NCC2A). Other tests were performed with the battery fully charged.

Sample Calculation(s)

Radiated Emission Test

Margin = Limit – (Received Signal + Antenna Factor + Cable Loss – Pre-Amp Gain)
Margin = 50.5dBµV/m – (50dBµV + 10dB + 2.5dB – 20dB)
Margin = 8.0 dB (pass)

Power Line Conducted Emission Test

Margin = Limit – (Received Signal + Attenuation Factor + Cable Loss + LISN Factor)
Margin = 73.0dBµV – (50dBµV + 10dB + 2.5dB + 0.5dB)
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:2017	Code of Federal Regulations – Radio Frequency Devices, Intentional Radiators
FCC KDB 558074: 2017	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
RSS-Gen Issue 5 2018	General Requirements and Information for the Certification of Radio Apparatus
RSS-102 Issue 5:2015	Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)
RSS-247 Issue 2:2017	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
ISO 17025:2005	General Requirements for the Competence of Testing and Calibration Laboratories

Document Revision Status

Revision 000 October 22, 2018
- Initial Release

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 labs near Toronto, Ontario. The testing lab consists of a 3m semi-anechoic chamber calibrated to be able to allow measurements on a EUT that has a maximum width or length of up to 2m and a height of up to 3m. The chamber is equipped with a turntable that is capable of testing devices up to 3300lb in weight. This facility is capable of testing products that are rated for 120Vac and 240Vac single phase, or devices that are rated for a 208Vac 3 phase input. DC capability is also available for testing. The chamber is 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. 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), Industry Canada (IC, 6844A-3) and Voluntary Control Council for Interference (VCCI, R-4023, G-506, C-4498, and T-1246). 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 #2555.01. 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 bi-annual 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)
Sept. 18, 2018	Restricted Bands for Intentional Operation	RA	24.2	50.6	101.1
Oct. 11, 2018	Power Line Conducted Emissions	RA	24.1	66.3	100.1
Sept. 18, 2018	Spurious Radiated Emissions & Band Edges	RA	24.2	50.6	101.1
Sept. 18, 2018	6 dB, 20dB, 99% Bandwidth	RA	24.2	50.6	101.1
Sept. 24, 2018	Max Output Power	RA	22.7	46.9	102.4
Sept. 18, 2018	Max E.I.R.P Output	RA	24.2	50.6	101.1
Sept. 24, 2018	Antenna Spurious Conducted Emissions	RA	22.7	46.9	102.4
Sept. 24, 2018	Power Spectral Density	RA	22.7	46.9	102.4

Detailed Test Results Section

6 dB and 99% Bandwidths

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 is measured with a 100 kHz RBW and a 300 kHz VBW.

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

There is no defined requirement for the 99% occupied bandwidth. It is included for informational purposes only.

Results

The EUT passed. The minimum 6 dB BW measured was 681.1 kHz and the maximum 99% Occupied Bandwidth was 1.0577 MHz.

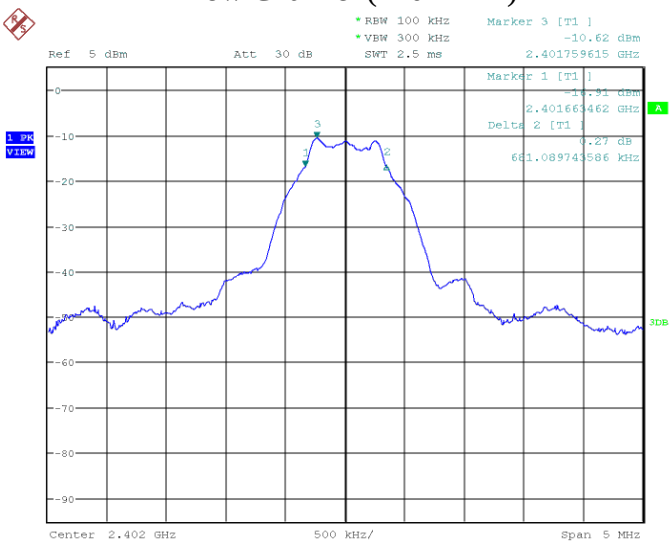
Channel	Frequency (MHz)	6 dB Bandwidth (MHz)	99% Bandwidth (MHz)
Low	2402	0.6811	1.0577
Mid	2440	0.6811	1.0577
High	2480	0.6972	1.0577

Graphs

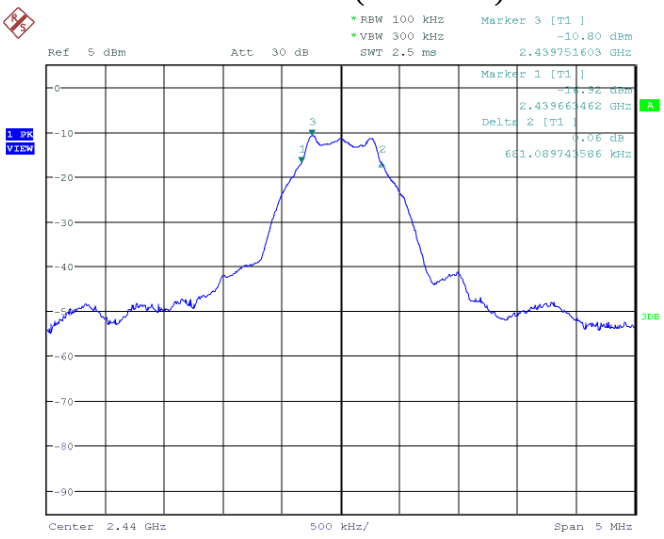
The graphs showed below show the OBW during the operation of the device. This is measured by a max hold on the spectrum analyzer and the highest resolution bandwidth that is sufficiently low to exhibit the 6 dB bandwidth of a channel during operation of the EUT. Max hold is performed for a duration of not less than 1 minute.

6dB Bandwidth

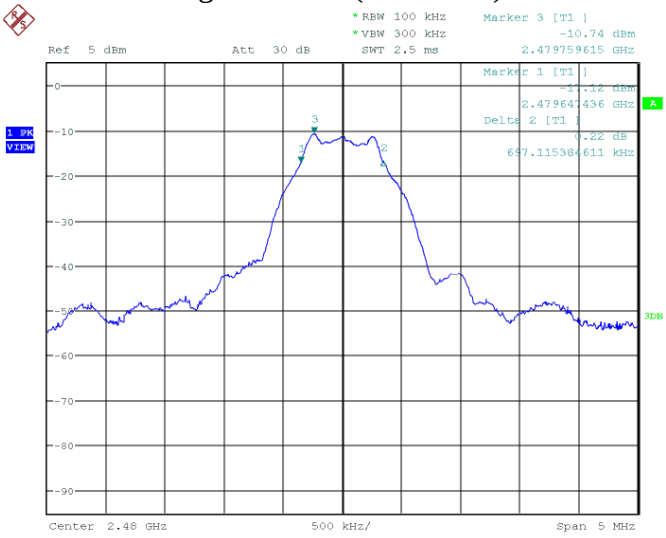
Low Channel (2402MHz)



Mid Channel (2440MHz)

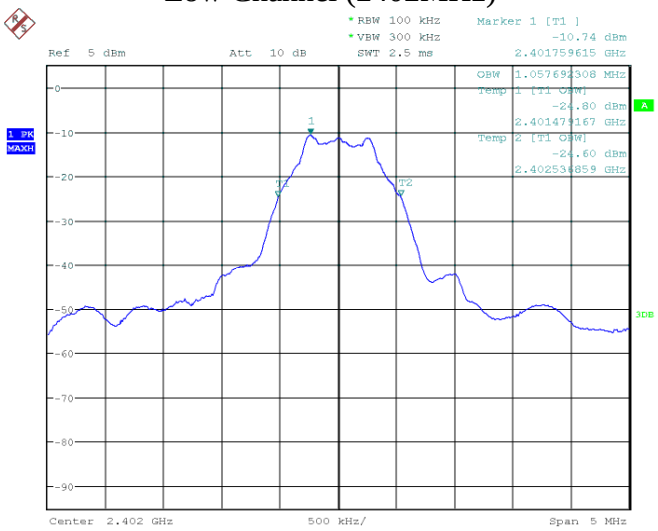


High Channel (2480MHz)

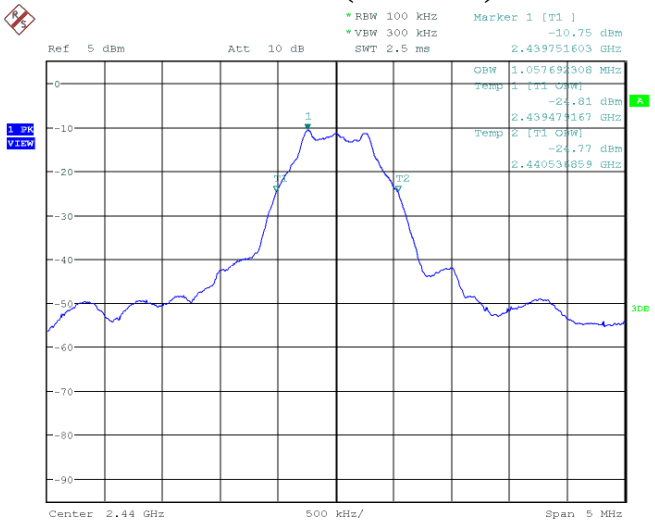


99% Bandwidth

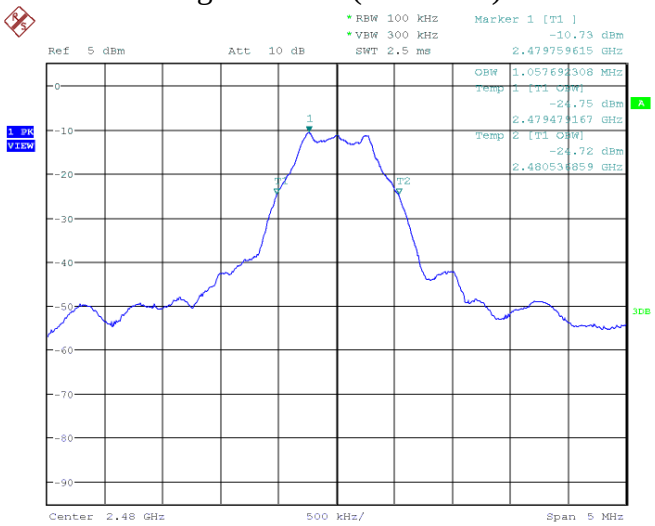
Low Channel (2402MHz)



Mid Channel (2440MHz)



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 #
Spectrum Analyzer	FSQ 26	Rohde & Schwarz	Feb 28, 2017	Feb 28, 2019	GEMC 234

Maximum Peak 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)(3) 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 (or 30 dBm = 125.2 dBµV at 3m distance). The E.I.R.P. limit is 4 watts (or 36 dBm = 131.2 dBµV at 3m distance).

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

Results

The EUT passed. The EUT was set to transmit at maximum power. Low, Middle and High Channels were measured. The following table shows the peak power:

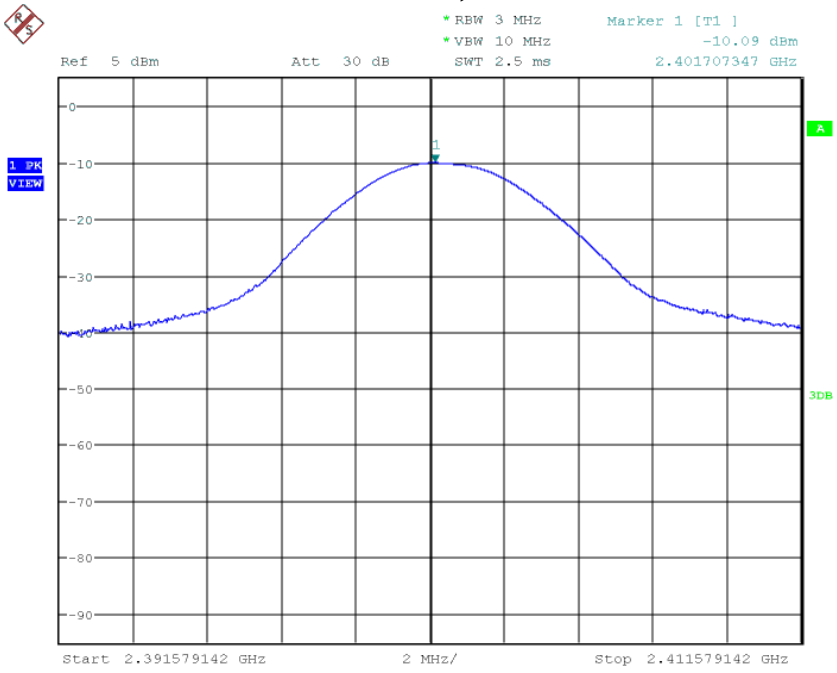
Test Frequency (MHz)	Channel	Measured Reading (dBm)	External Attenuator + Cable loss (dB)	Output Power (dBm)	Output Power (mW)	Output Limit (dBm)	Margin (dB)	Result
2402	Low	-10.09	10	-0.09	0.9795	30	30.09	Pass
2440	Mid	-10.08	10	-0.08	0.9817	30	30.08	Pass
2480	High	-10.06	10	-0.06	0.9863	30	30.06	Pass

Graphs

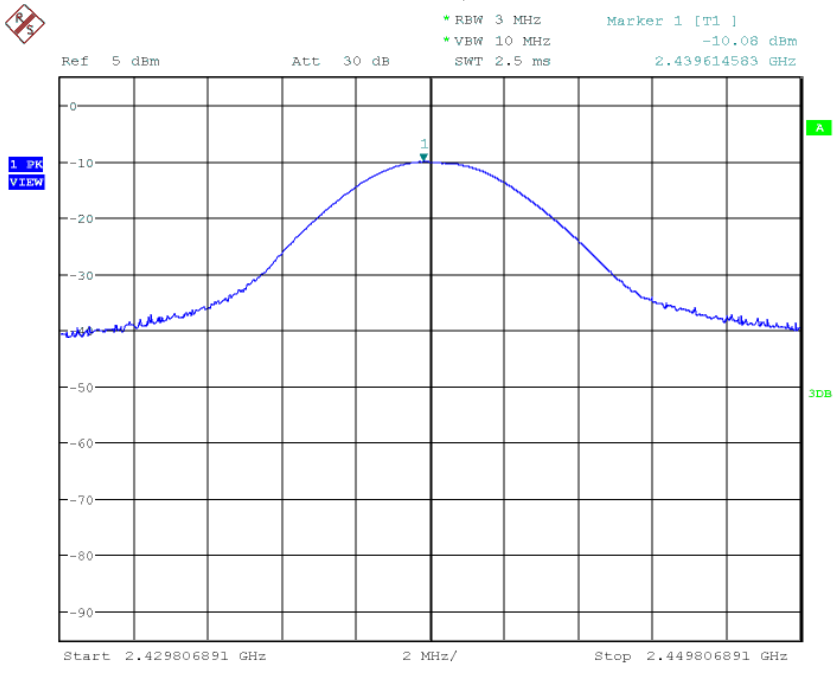
The plots shown below show the peak power output of the device during the antenna conducted measurements during transmit operation of the EUT. The measurement RBW is ≥ than the DTS bandwidth.

Note: 10 dB of attenuator + cable loss applicable when making measurements shown below.

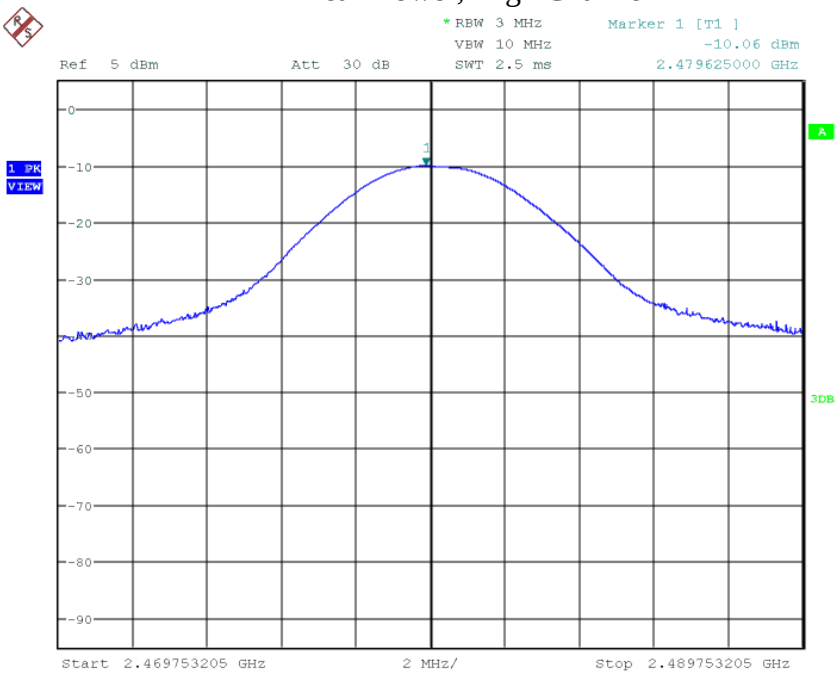
Peak Power, Low Channel



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 #
Spectrum Analyzer	FSQ 26	Rohde & Schwarz	Feb 28, 2017	Feb 28, 2019	GEMC 234

Maximum Peak E.I.R.P Output

Purpose

The purpose of this test is to ensure that the maximum power output does not exceed the limits specified when used with the antenna, which may provide gain. This ensures that the maximum power does not exceed an amount which may create an excessive power level.

Limits

The limits are defined in RSS-247 5.4(d).
For DTSs operating in the 2400-2483.5 MHz band, the peak E.I.R.P. limit is 4 Watts (or 36 dBm = 131.2 dBµV at a 3m distance).

Additionally, the peak conducted output power limit is 1 Watt. The analysis of this requirement is covered in the previous section.

Results

The EUT passed. The peak E.I.R.P. is -2.72 dBm (0.535 mW, 0.000535 W, or 92.48 dBµV/m at 3 m).

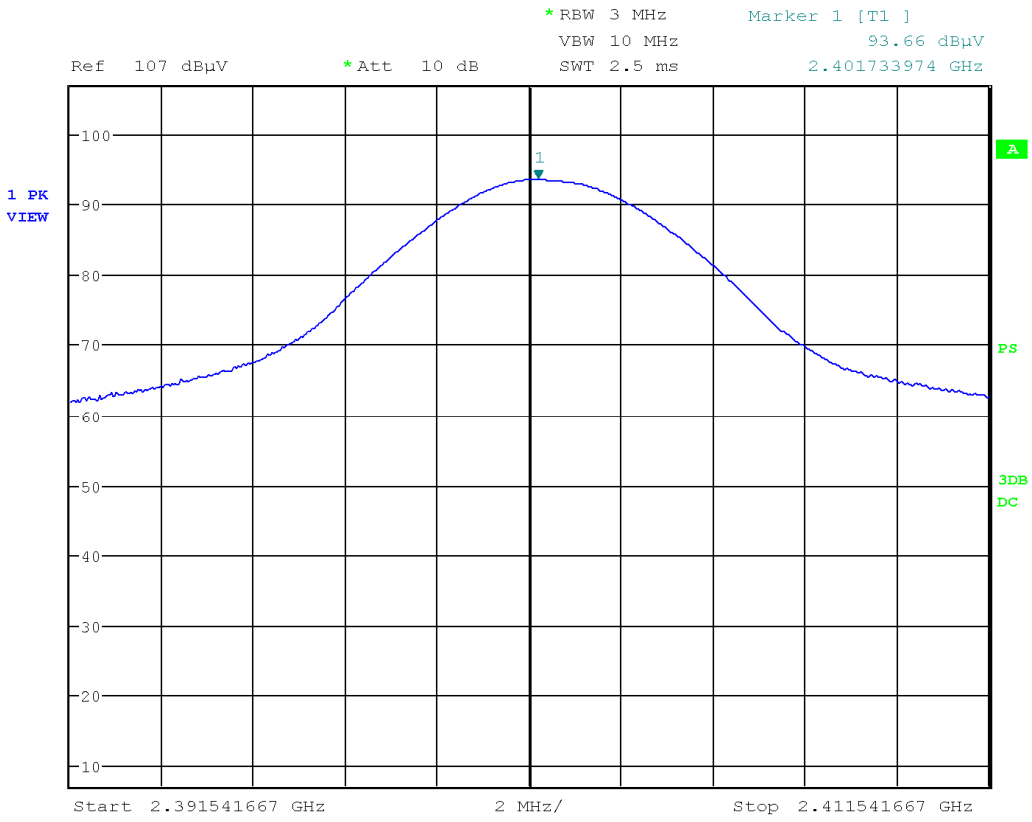
Emission Table & Plots

The table below shows the measured peak power output of the device. Peak measurements were made during transmit operation of the EUT with continuous modulated data at the maximum output power used by the manufacturer. Worst case plots are shown.

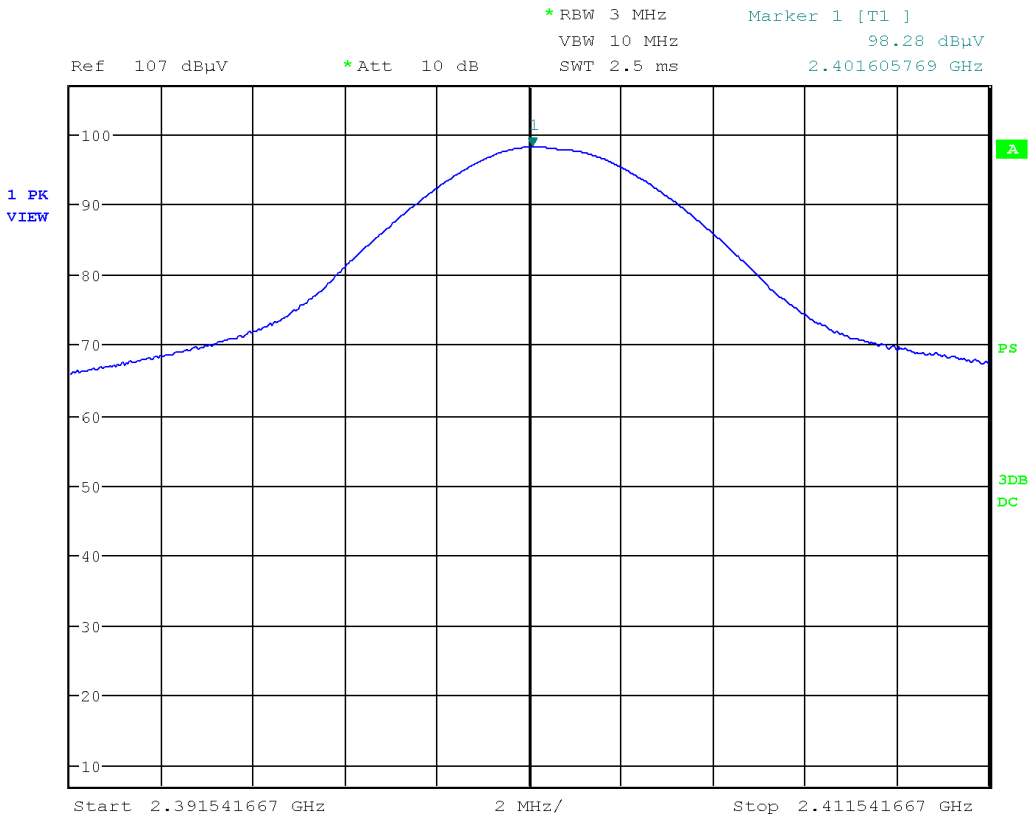
Table 2 – Max peak E.I.R.P. output

Test Frequency (MHz)	Channel	Antenna polarity	Received Reading dB(µV)	Antenna factor (dB)	Cable Loss (dB)	Pre-Amp Gain (dB)	Received signal at 3m (dBµV)	EIRP (dBm)	Emission limit dB(µV)	Margin dB(µV)	Result
2402	Low (37)	Vertical	93.66	26.6	3.6	-35.9	87.96	-7.24	131.2	43.24	Pass
2402	**Low (37)**	**Horizontal**	**98.28**	**26.5**	**3.6**	**-35.9**	**92.48**	**-2.72**	**131.2**	**38.72**	**Pass**
2440	Middle (17)	Vertical	92.66	26.4	3.6	-35.8	86.86	-8.34	131.2	44.34	Pass
2440	Middle (17)	Horizontal	97.3	26.5	3.6	-35.8	91.6	-3.6	131.2	39.6	Pass
2480	High (39)	Vertical	90.43	26.3	3.6	-35.8	84.53	-10.67	131.2	46.67	Pass
2480	High (39)	Horizontal	95.83	26.3	3.6	-35.8	89.93	-5.27	131.2	41.27	Pass

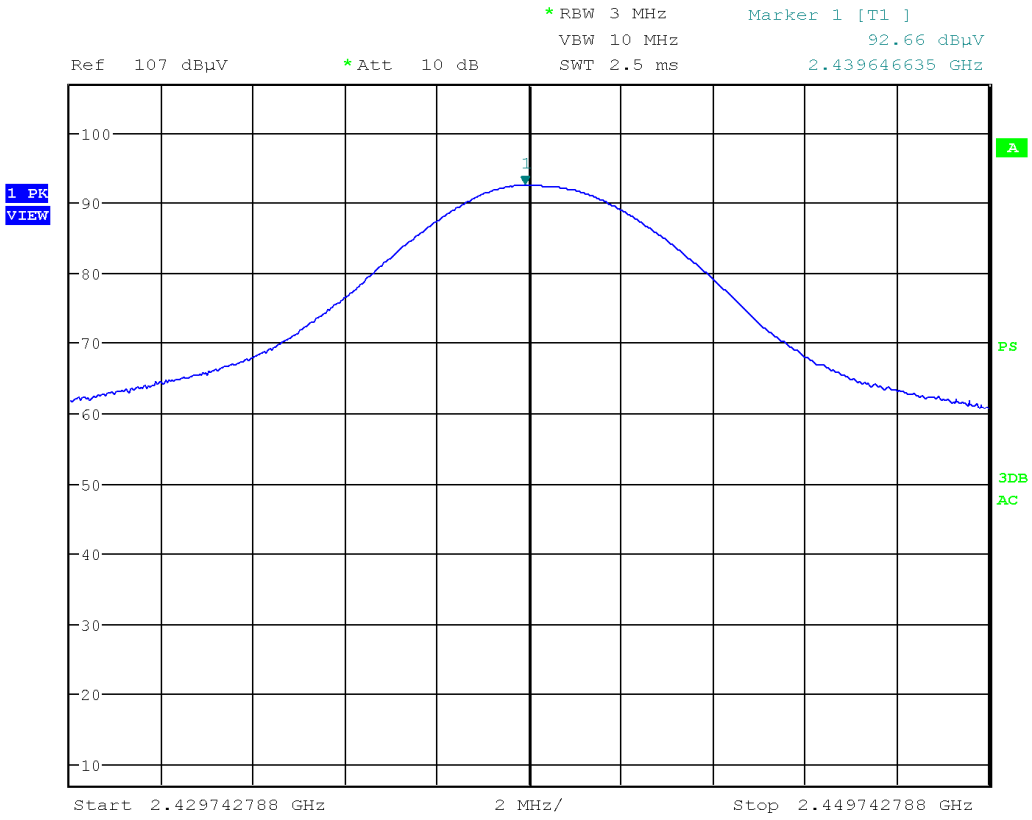
Low Channel 37
Vertical Antenna Polarity



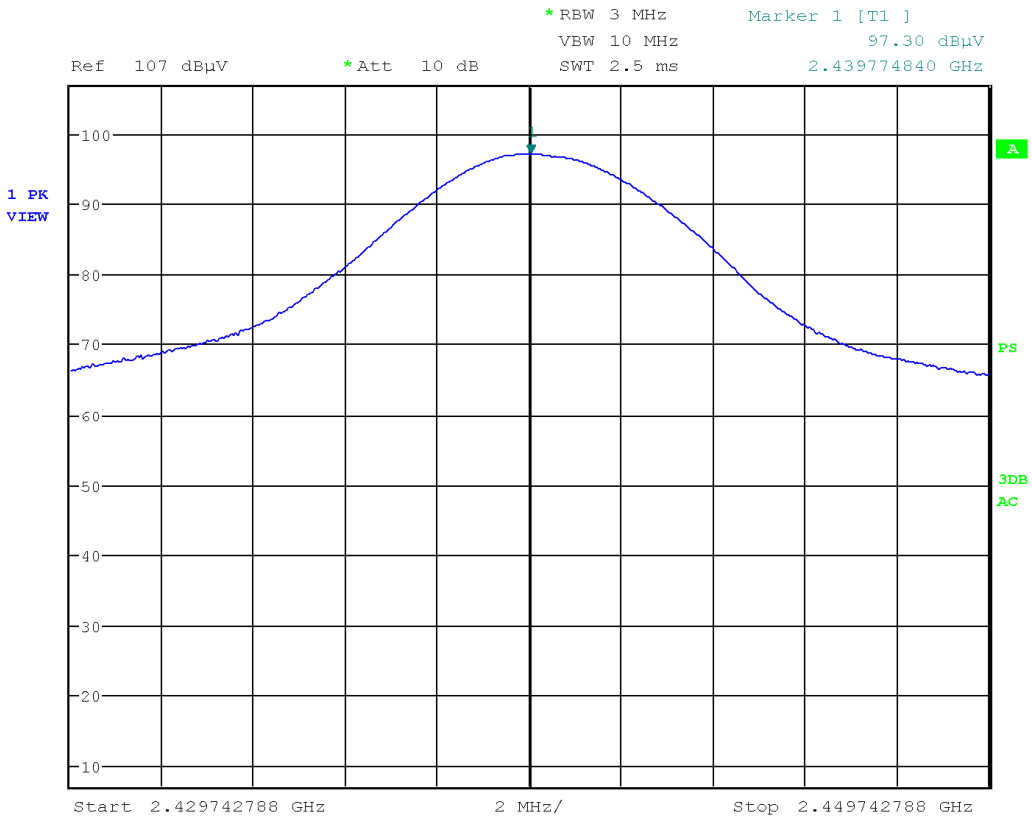
Low Channel 37
Horizontal Antenna Polarity



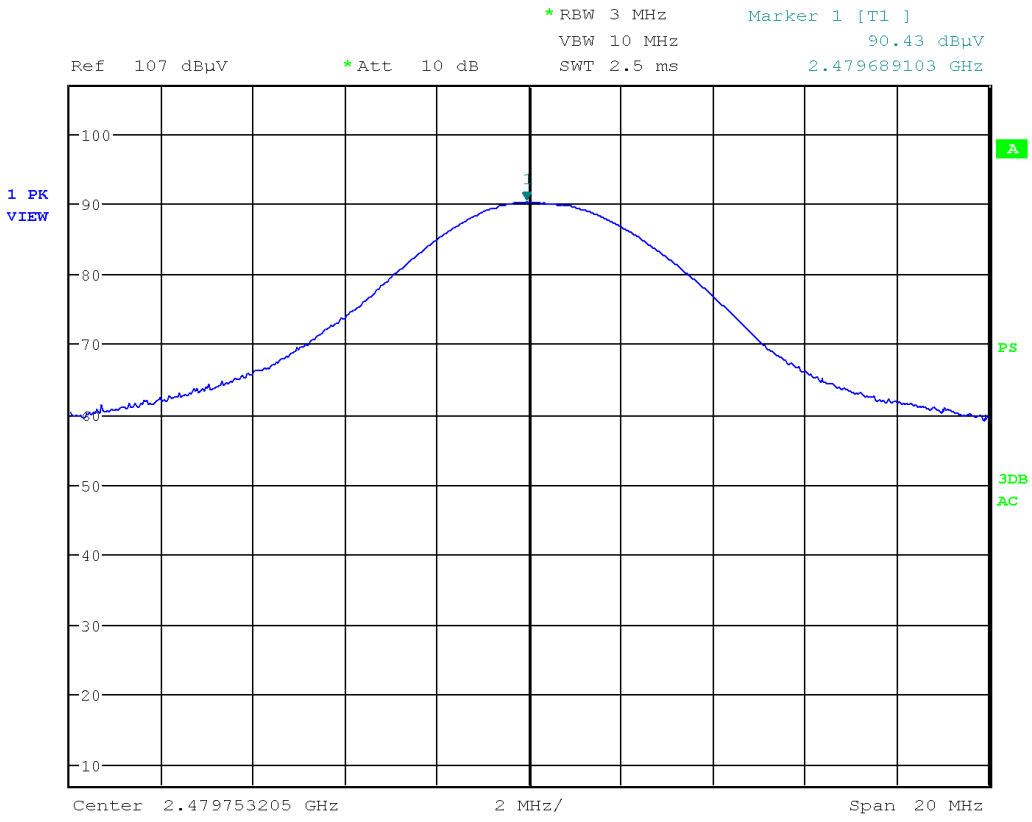
Middle Channel 17
Vertical Antenna Polarity



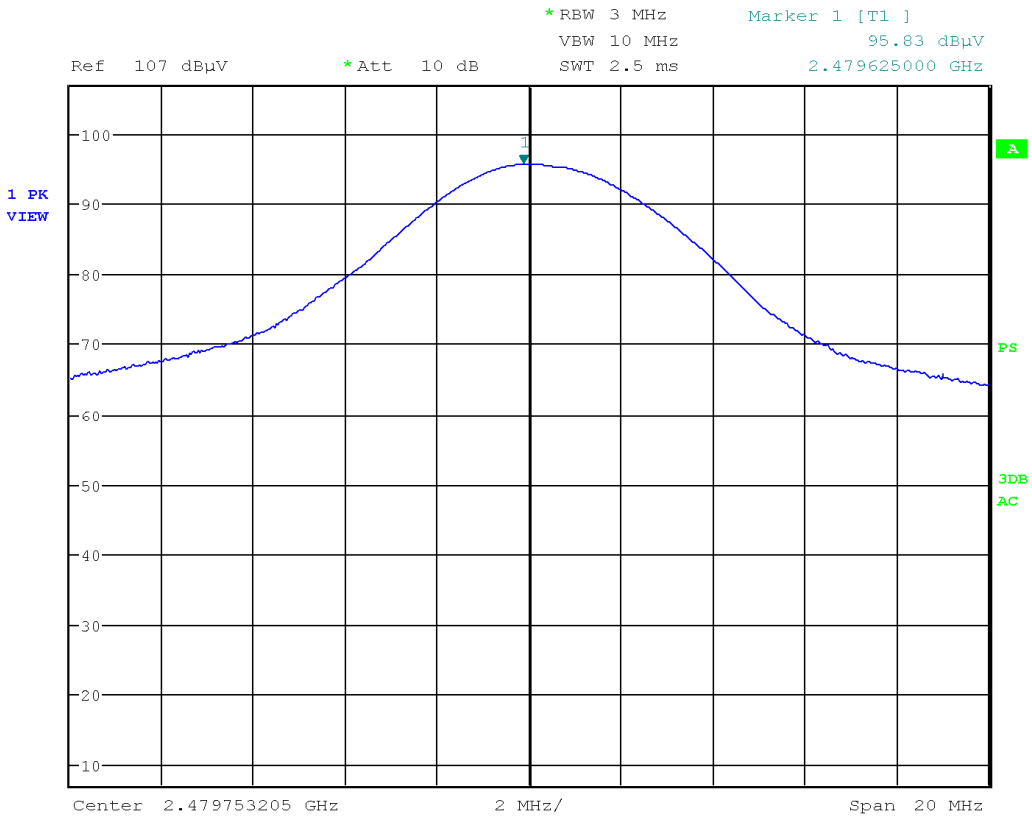
Middle Channel 17
Horizontal Antenna Polarity



High Channel 39
Vertical Antenna Polarity



High Channel 39
Horizontal Antenna Polarity



Note: See 'Appendix B – EUT & Test Setup Photographs' for photos showing the test set-up.

Test Equipment List

Equipment	Model No.	Manufacturer	Last Calibration Date	Next Calibration Date	Asset #
Spectrum Analyzer	ESU 40	Rohde & Schwarz	Jan. 12, 2018	Jan. 12, 2020	GEMC 233
Horn Antenna	WBH218HN	Q-par	Feb. 27, 2018	Feb. 27, 2020	GEMC 6375
Pre-Amp	HP 8449B	HP	Jun. 12, 2018	Jun. 12, 2020	GEMC 312
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

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 FCC Part 15.247(d) and RSS-247 5.5. In any 100 kHz band outside the frequency band in which the intentional radiator is operating, 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 Section 11 of FCC KDB 558074 and ANSI C63.10.

Results

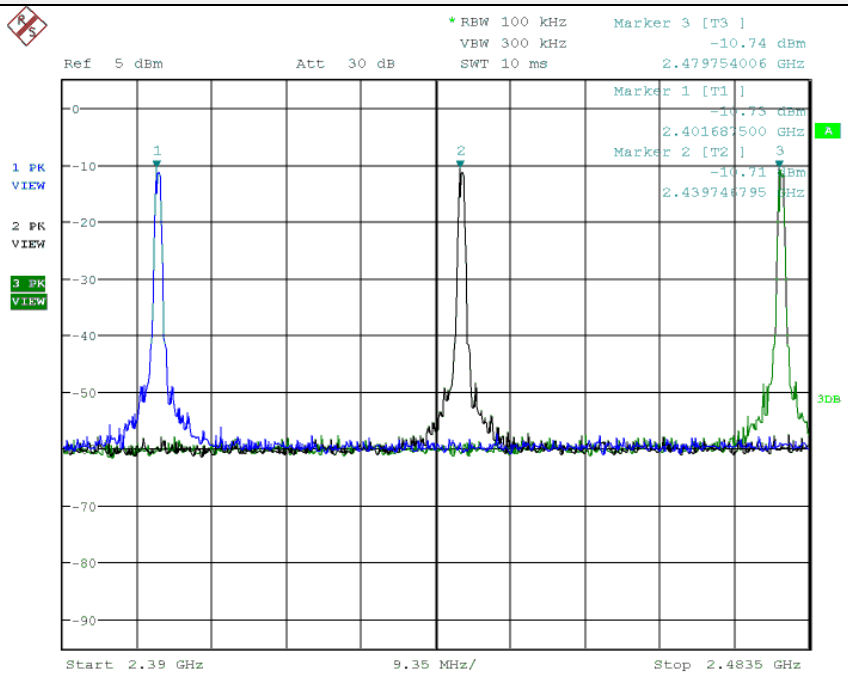
The EUT passed. Low, middle and high channels were measured against the -20 dBc requirement, with the band edge results shown at 2.4 GHz and 2.4835 GHz.

Graphs

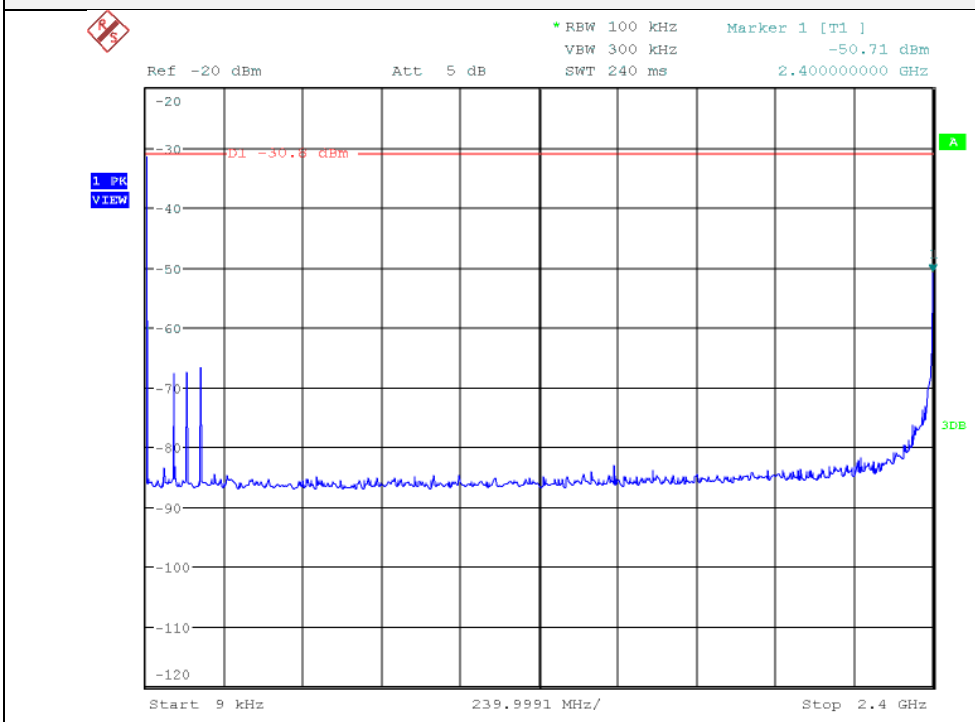
The graphs shown below are obtained during peak conducted power output of the device during transmit operation of the EUT at max output power, continuous transmission of data, at low middle and high channels. 10 dB of external attenuation is used during these measurements.

20dB below max fundamental in 100 kHz bandwidth is marked with line D1 at -30.8 dBm in subsequent plots.

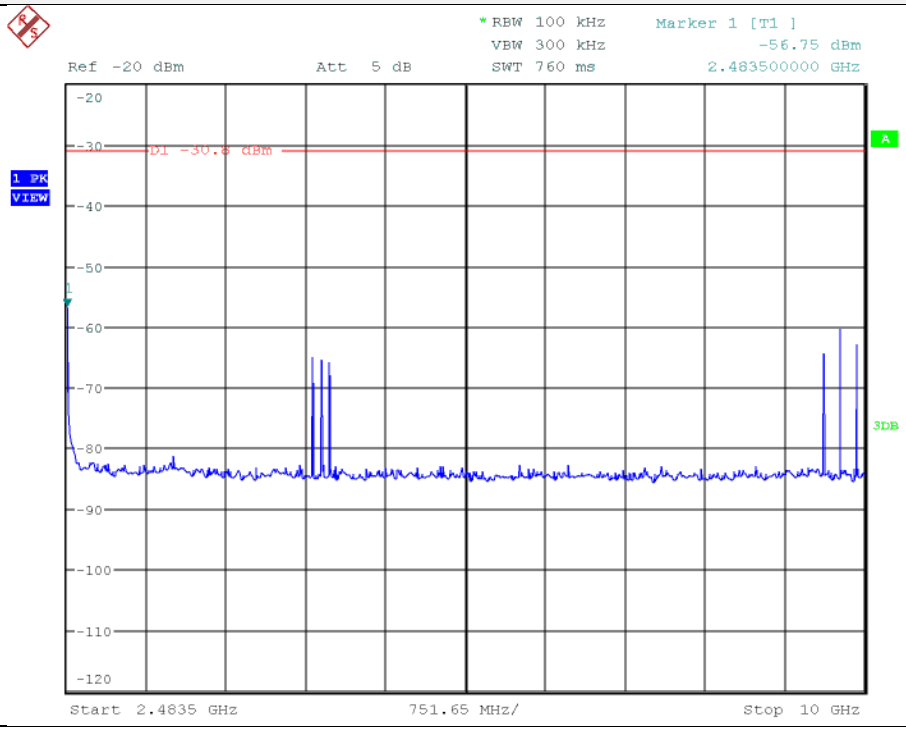
Max Fundamental Reference Level: -10.71 dBm



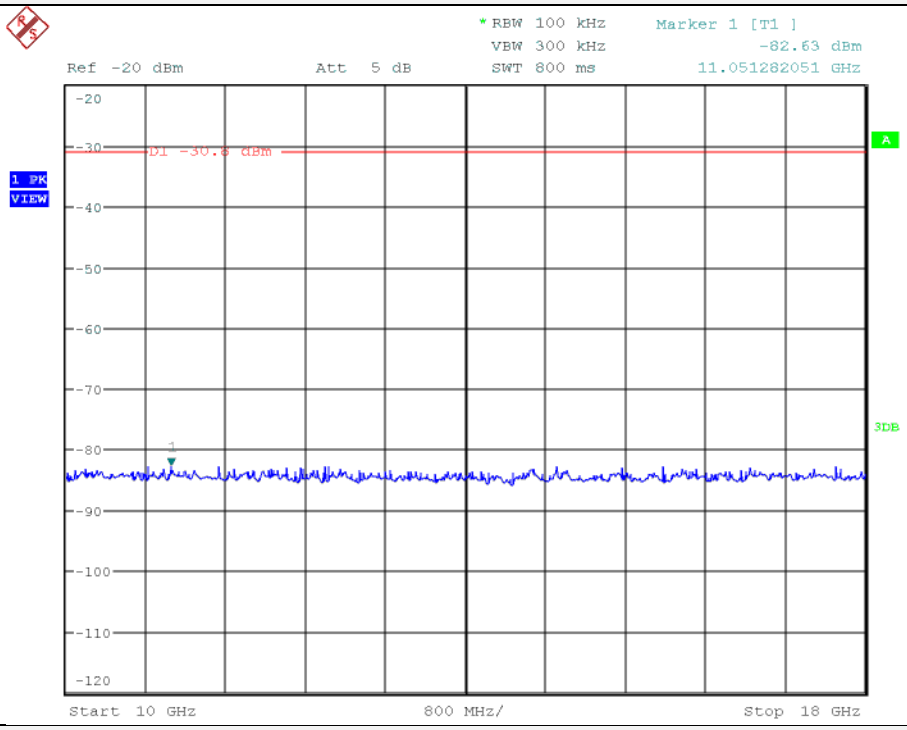
9 kHz – 2400 MHz



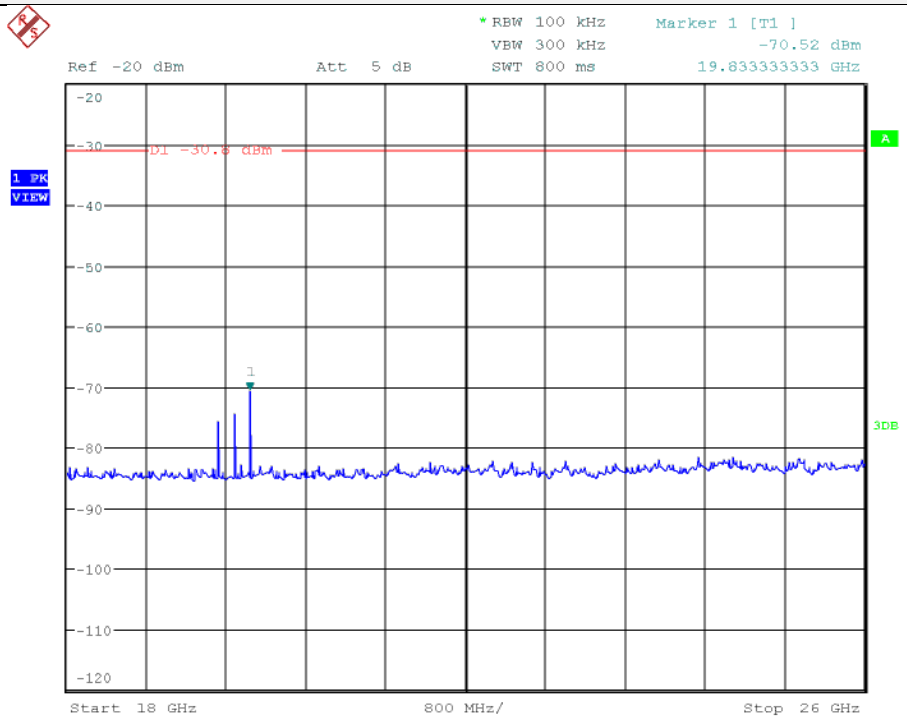
2483.5 MHz – 10 GHz



10 GHz – 18 GHz



18 GHz – 26 GHz



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Spectrum Analyzer	FSQ 26	Rohde & Schwarz	Feb 28, 2017	Feb 28, 2019	GEMC 234

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 (PSD) 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 Section 10.2 of FCC KDB 558074.

Results

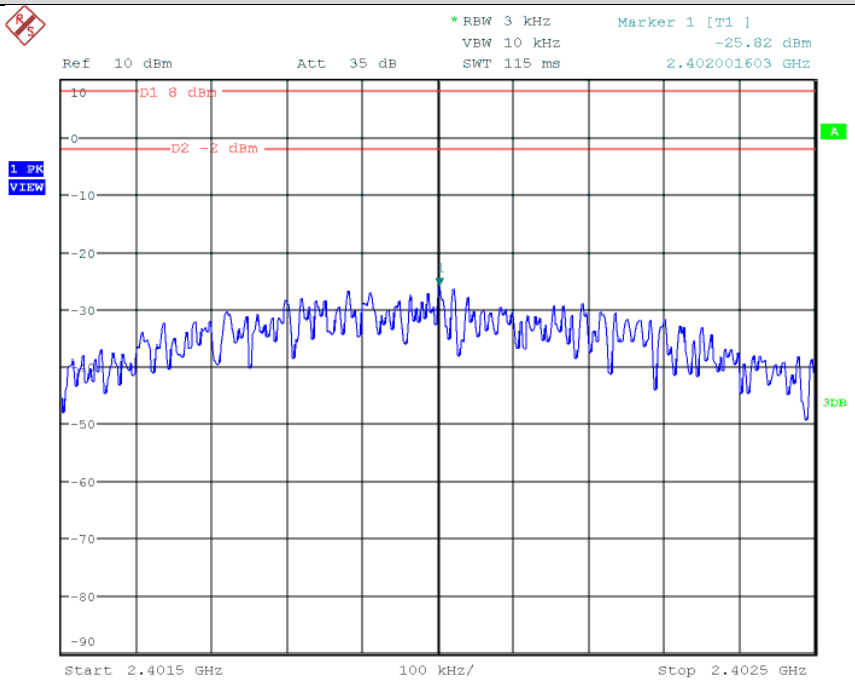
The EUT passed. Low, medium, and high channels were tested. The worst case value is -15.7 dBm as measured with a 3 kHz resolution bandwidth (peak power).

Test Frequency (MHz)	Channel	Measured Reading (dBm)	External Attenuator + Cable loss (dB)	Output Power (dBm)	Output Limit (dBm)	Margin (dB)	Result
2402	Low	-25.82	10	-15.82	8	23.82	Pass
2440	Mid	-25.94	10	-15.94	8	23.94	Pass
2480	High	-25.67	10	-15.67	8	23.67	Pass

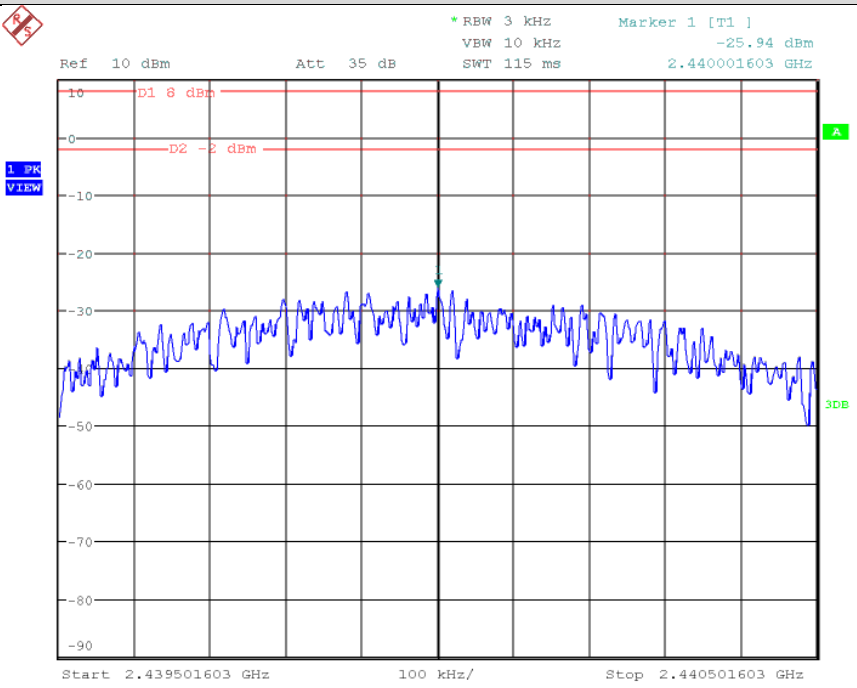
Graphs

The graphs shown below show the power spectral density conducted measurement of the device during transmit operation of the EUT with continuous modulated data. Low, middle, and high channels were investigated. An external attenuation and cable loss of 10dB are used. In the subsequent plots, line D2 is used to show the limit with this taken into account. Line D1 references the 8 dBm limit.

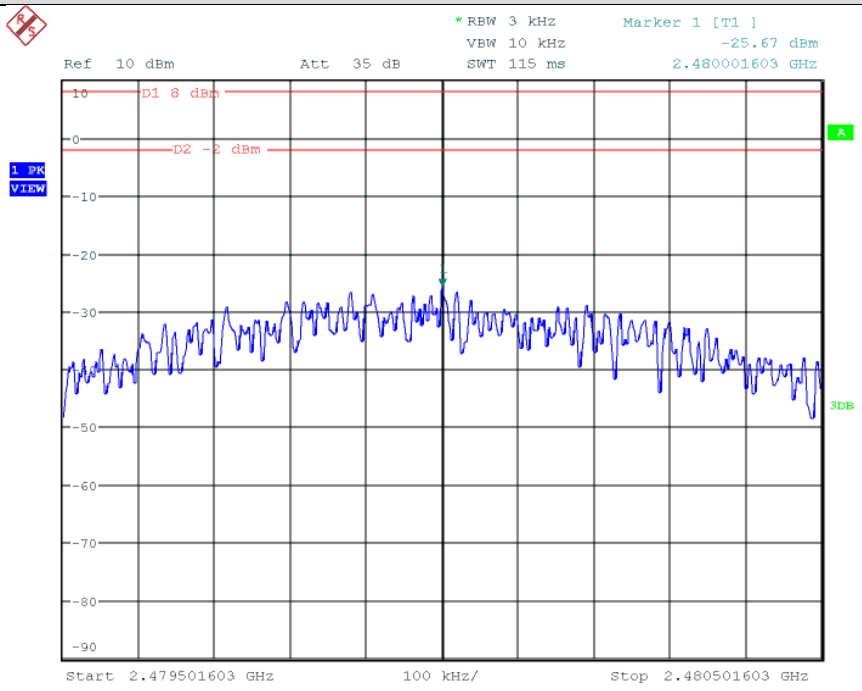
Low Channel (2402MHz)



Middle Channel (2440MHz)



High Channel (2480MHz)



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 #
Spectrum Analyzer	FSQ 26	Rohde & Schwarz	Feb 28, 2017	Feb 28, 2019	GEMC 234

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 defined in Section 12 of FCC KDB 558074 and ANSI C63.10.
The requirement is stated in FCC 15.247(d), and RSS-247 5.5.
The restricted bands are defined in 47 CFR FCC Part 15.205(a) and RSS-Gen (Table 7).
The limits are as defined in 47 CFR FCC Part 15.209 and RSS- Gen (Table 5 and Table 6).
The limits apply for emissions that fall within the restricted bands.

The limits for unintentional radiated emissions apply for those emissions that fall in the restricted bands. These limits are as follows:

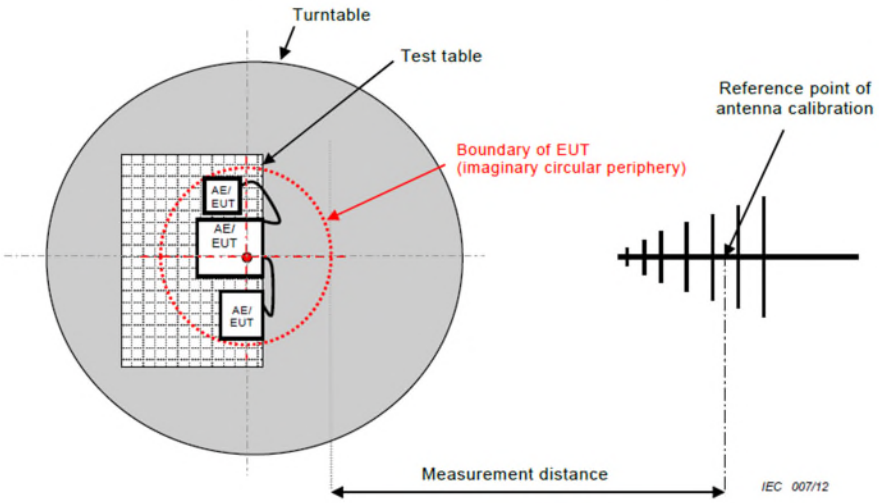
Frequency	Limit
0.009 MHz – 0.490 MHz	2400/F(kHz) uV/m at 300m[1]
0.490 MHz – 1.705 MHz	24000/F(kHz) uV/m at 30m[1]
1.705 MHz – 30 MHz	30 uV/m at 30m[1]
30 MHz – 88 MHz	100 uV/m (40.0 dBuV/m[1]) at 3m
88 MHz – 216 MHz	150 uV/m (43.5 dBuV/m[1]) at 3m
216 MHz – 960 MHz	200 uV/m (46.0 dBuV/m[1]) at 3m
Above 960 MHz	500 uV/m (54.0 dBuV/m[1]) at 3m
Above 1000 MHz	500 uV/m (54 dBuV/m[2]) at 3m
Above 1000 MHz	500 uV/m (74 dBuV/m[3]) at 3m

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

Additionally, all unintentional emissions must also meet the ‘Spurious Conducted Emissions’ requirements of -20 dBc or greater. See “Antenna Spurious Conducted Emissions (-20dBc Requirement)” section for further details.

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 ±4.25dB for 30MHz – 1GHz and ±4.93dB 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.

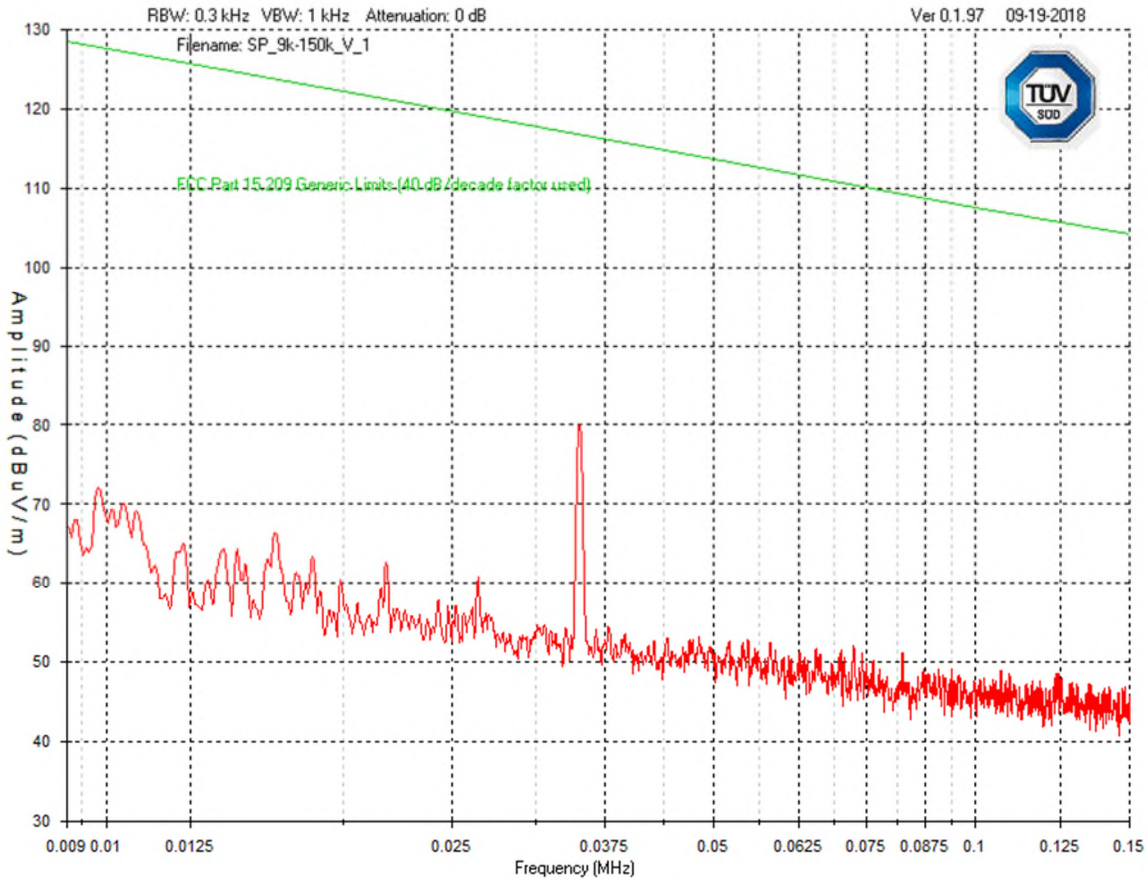
Devices scanned may be scanned at alternate test distances and in accordance with FCC Part 15, Subpart A, Section 15.31, an extrapolation factor of 20 dB/decade was used above 30 MHz and 40 dB/decade below 30 MHz. For example for 1 meter measurements, an extrapolation factor 9.5 dB from 20 Log (1m /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

Low, middle and high channels, in the three orthogonal axis were investigated. Worst case graphs are presented.

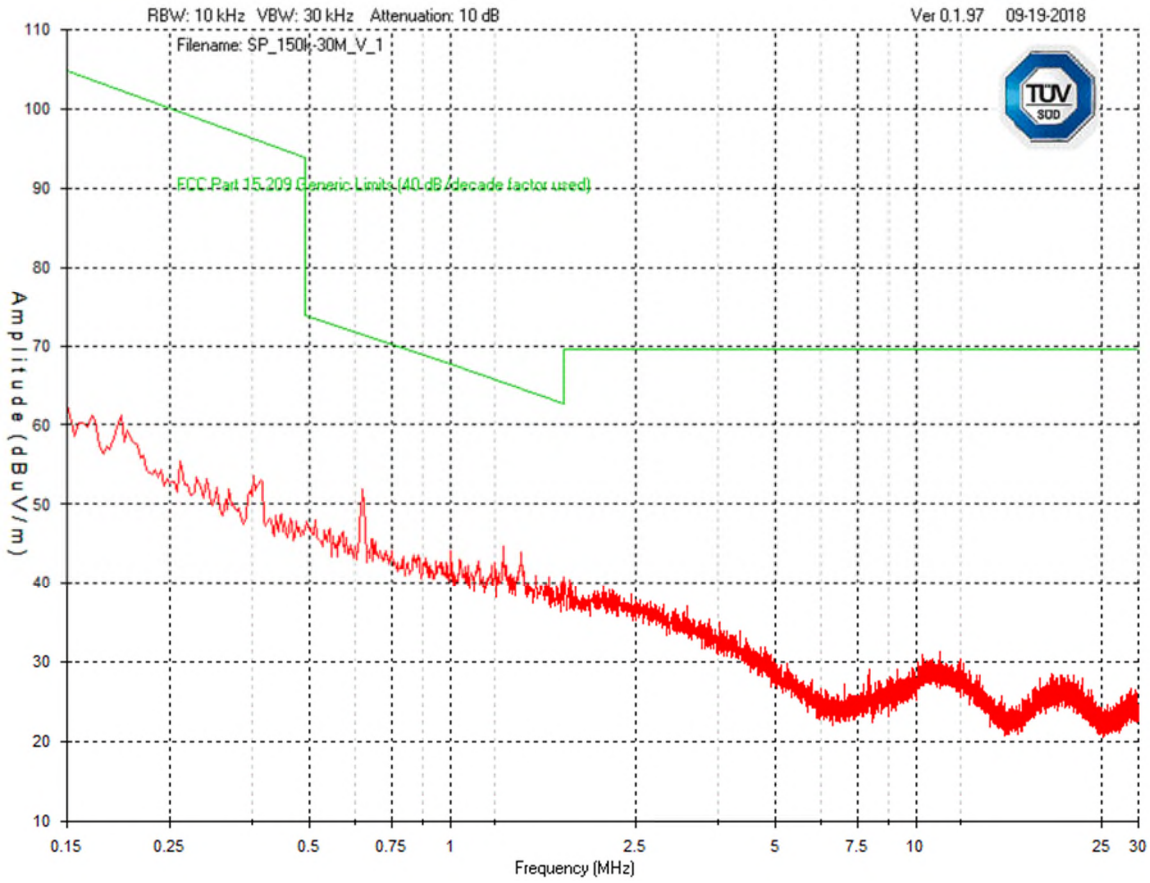
All transmitters in the EUT are on and transmitting continuous modulated data at the maximum power setting used by the manufacturer.

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

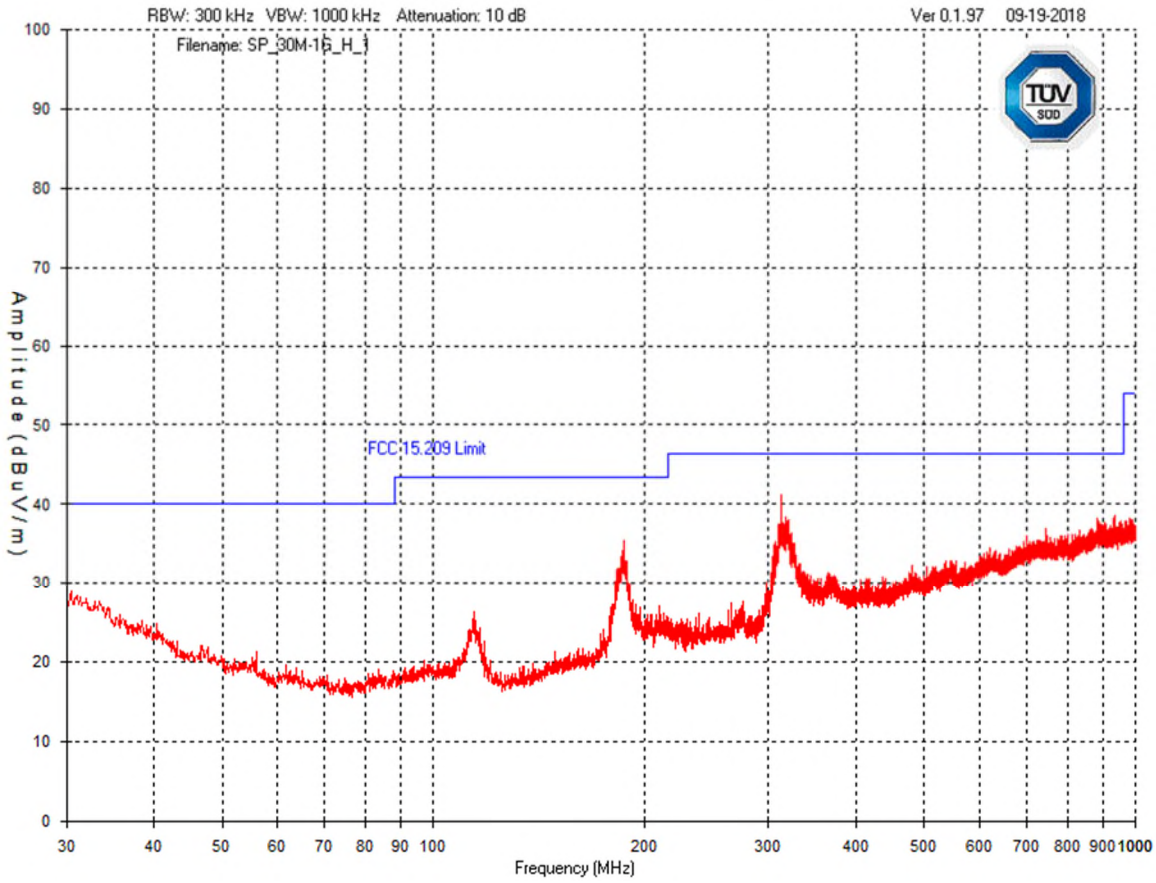
9 kHz – 150 kHz
Peak Emission Graph



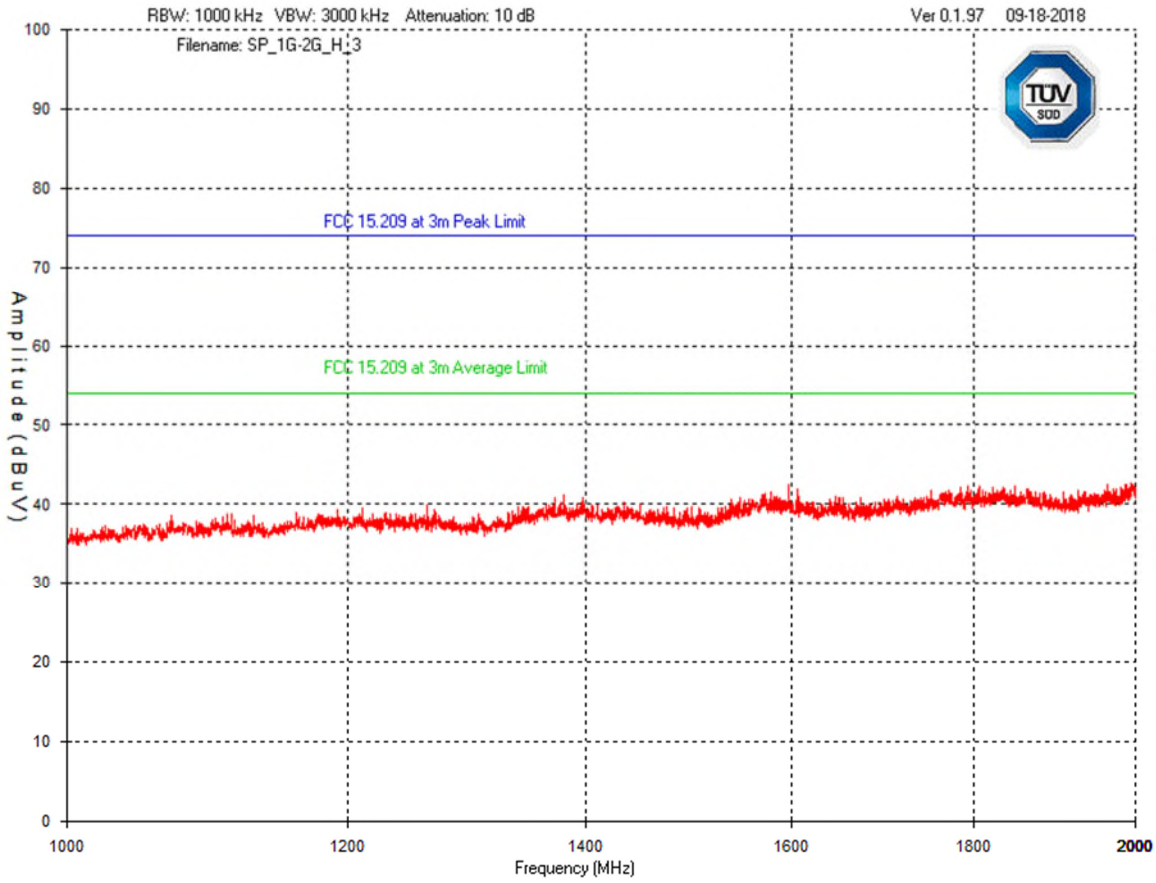
150 kHz – 30 MHz
Peak Emission Graph



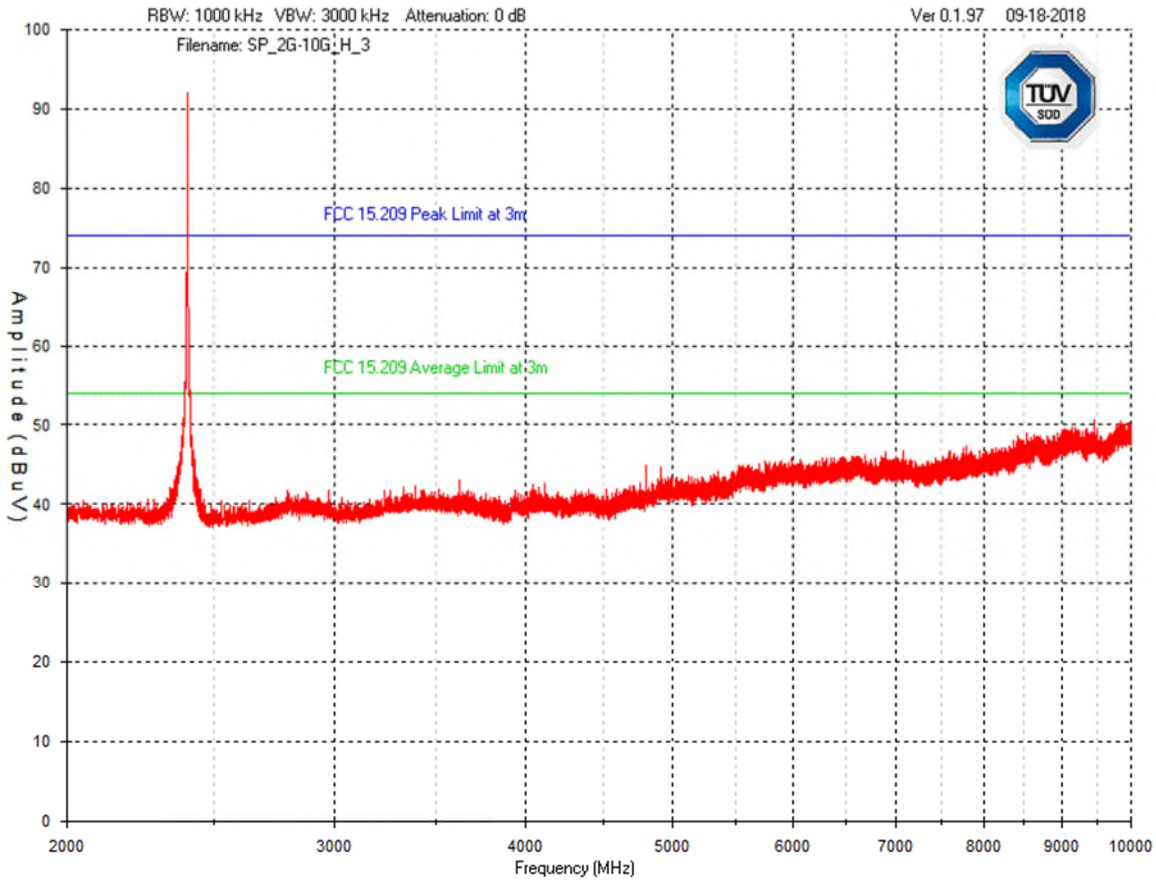
30 MHz – 1 GHz
Horizontal - Peak Emission Graph



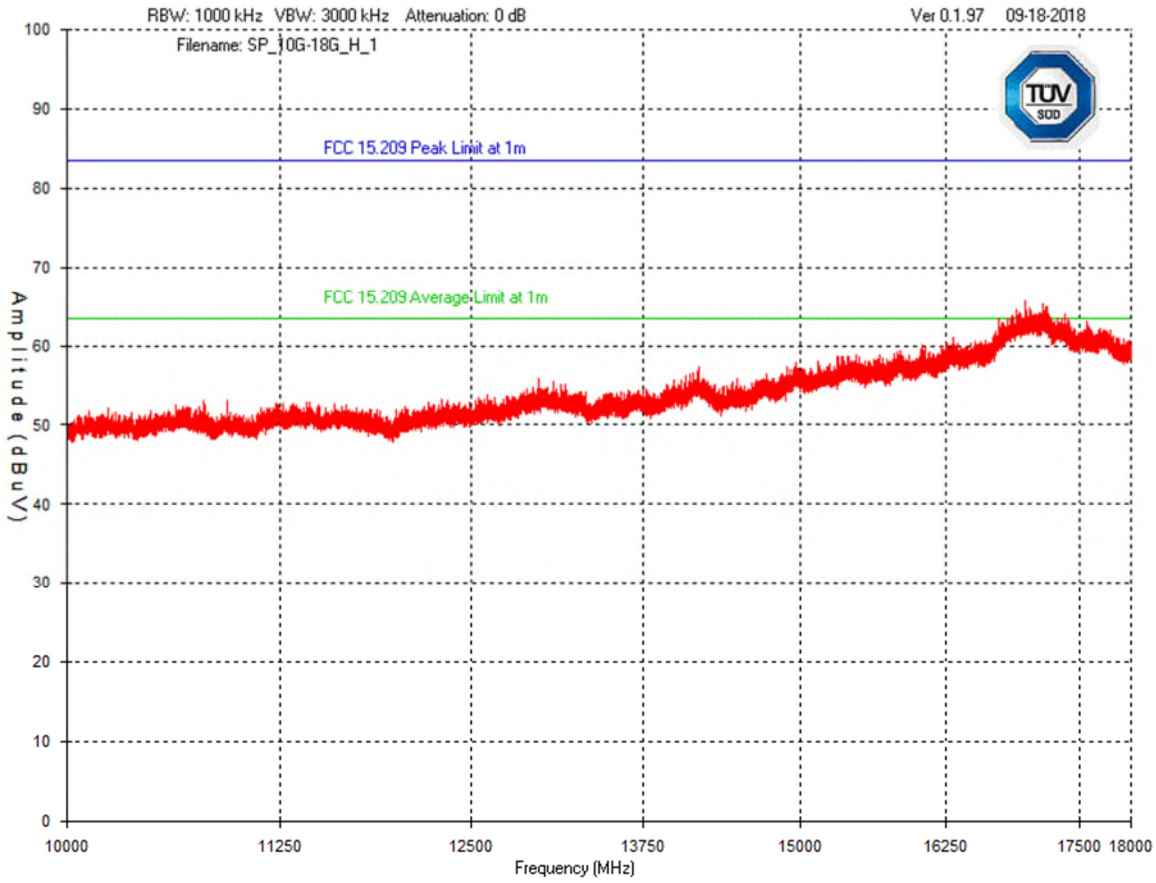
1 GHz – 2 GHz
Horizontal - Peak Emission Graph



2 GHz – 10 GHz
Horizontal - Peak Emission Graph

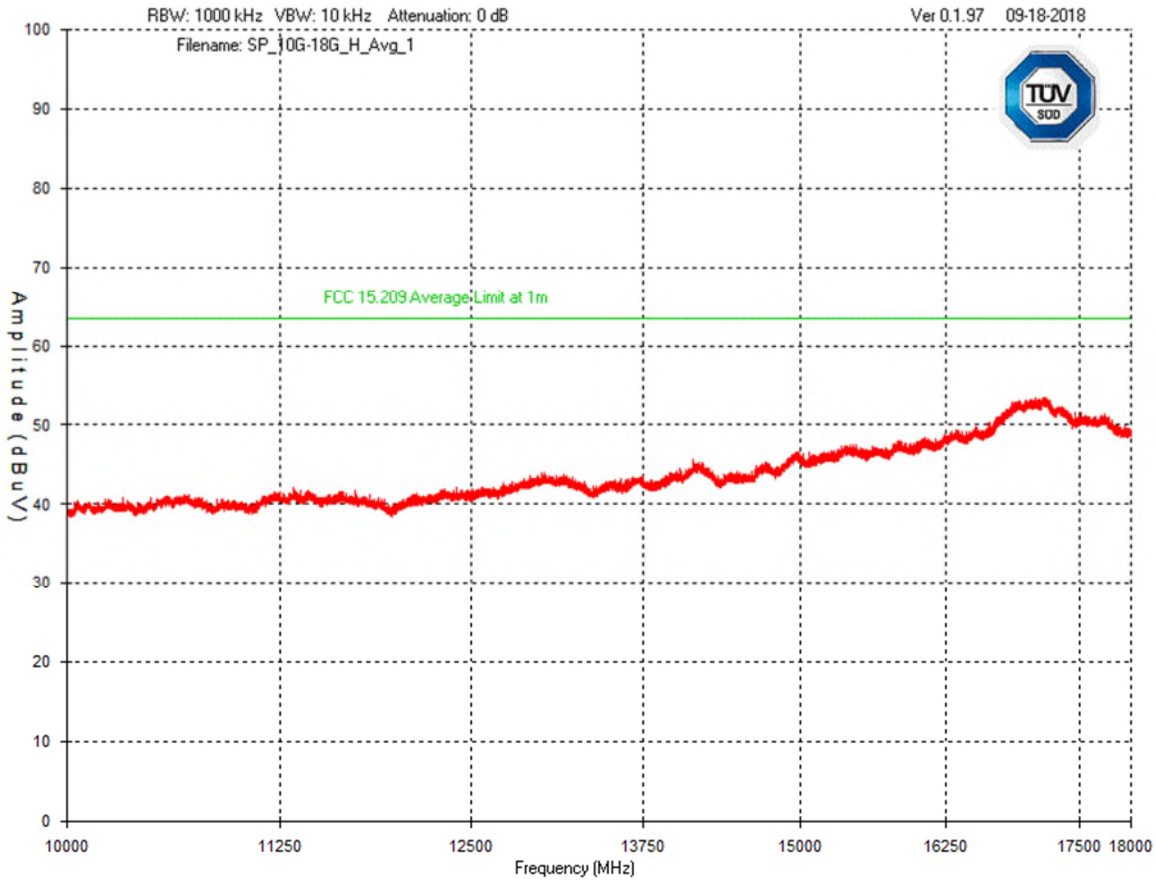


10 GHz – 18 GHz
Horizontal - Peak Emission Graph



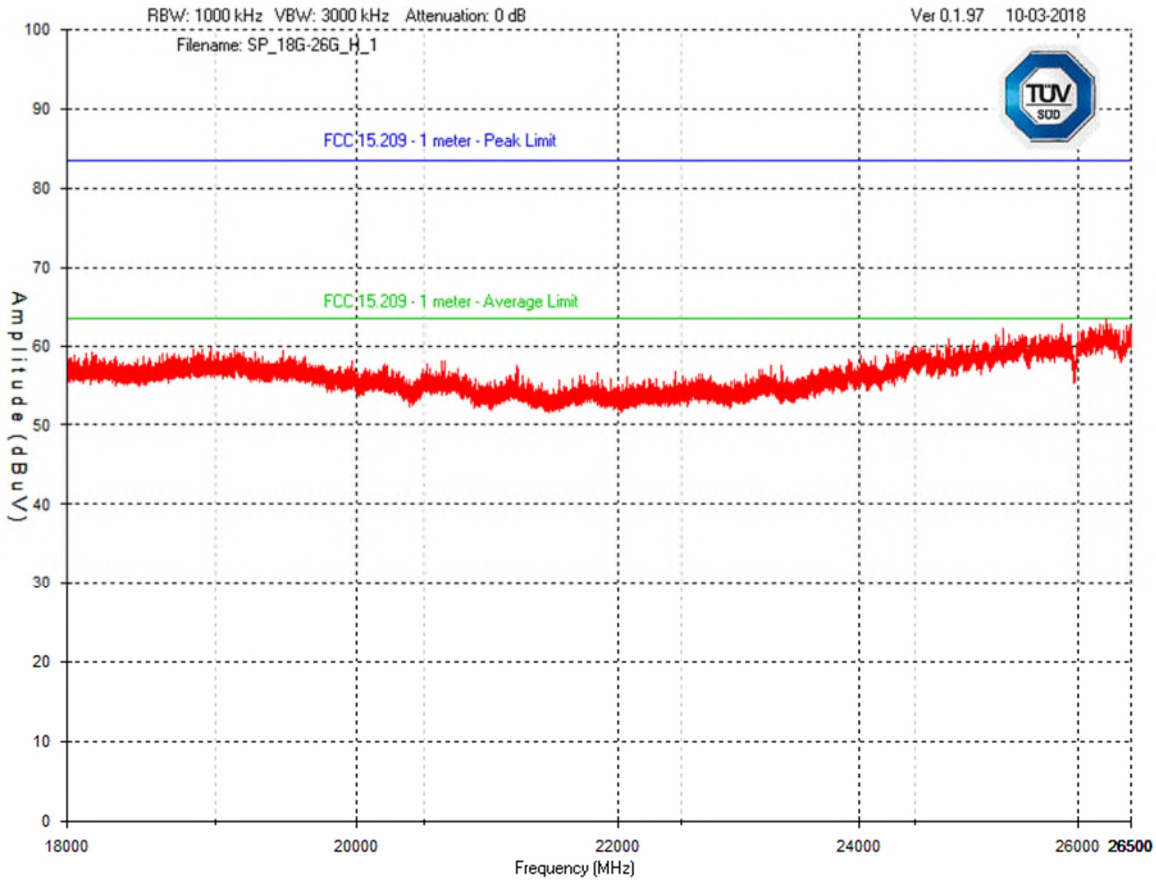
Plot was taken at a 1 meter distance.

10 GHz – 18 GHz
Horizontal - Average Emission Graph



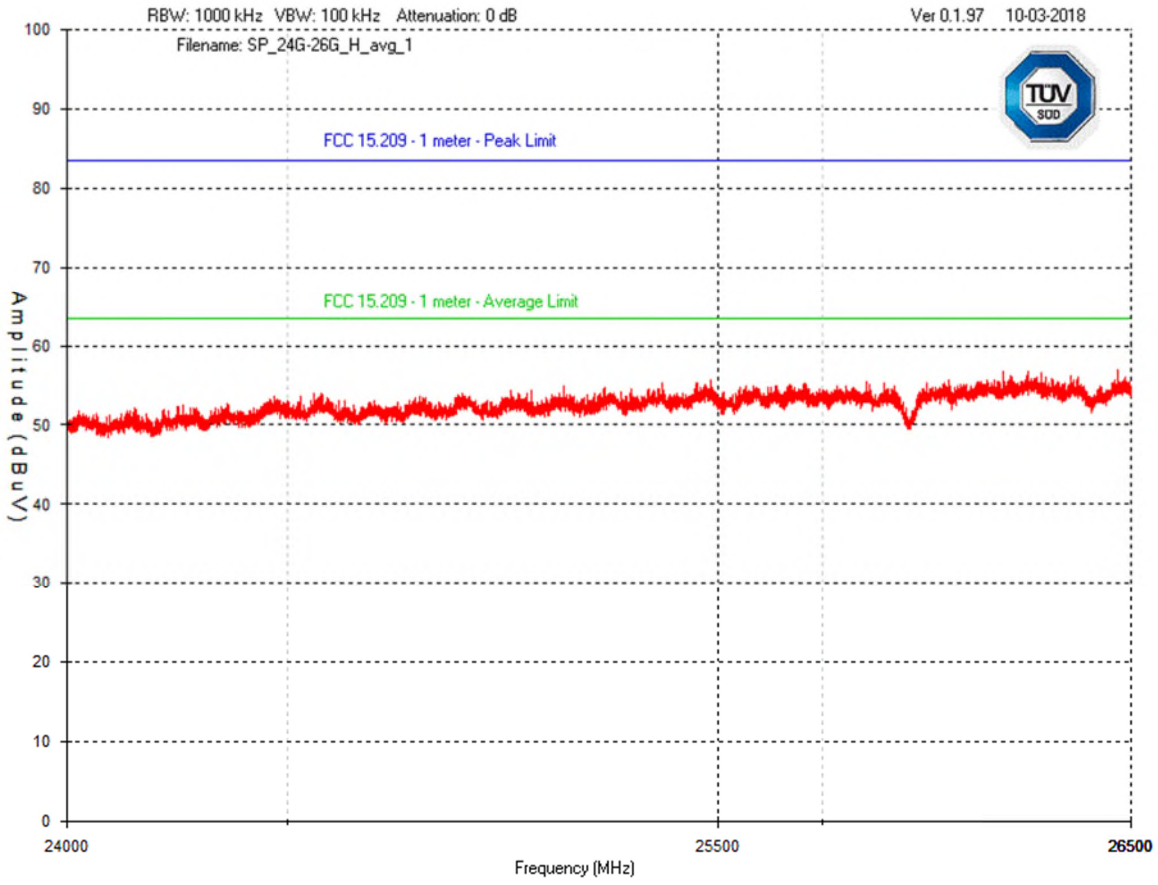
Plot was taken at a 1 meter distance.

18 GHz – 26.5 GHz
Horizontal - Peak Emission Graph



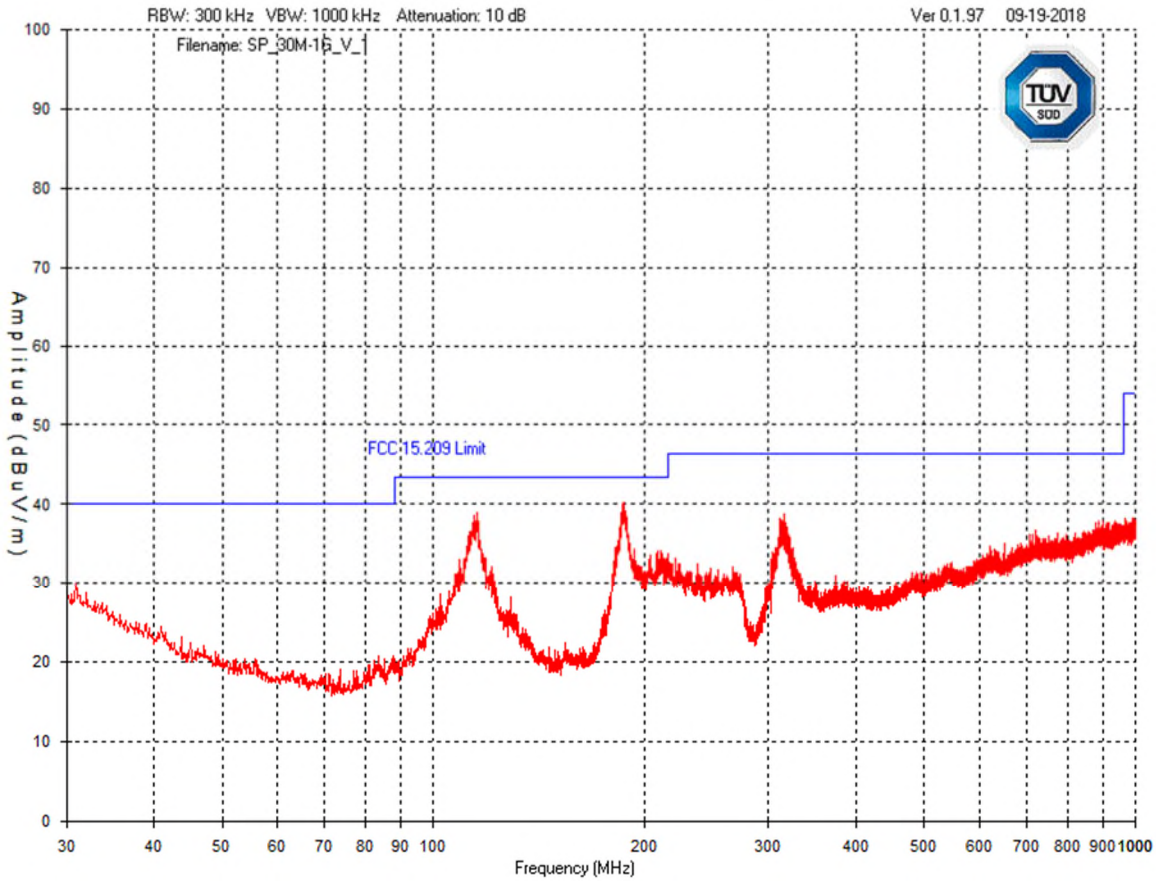
Plot was taken at a 1 meter distance.

24 GHz – 26.5 GHz
Horizontal - Average Emission Graph

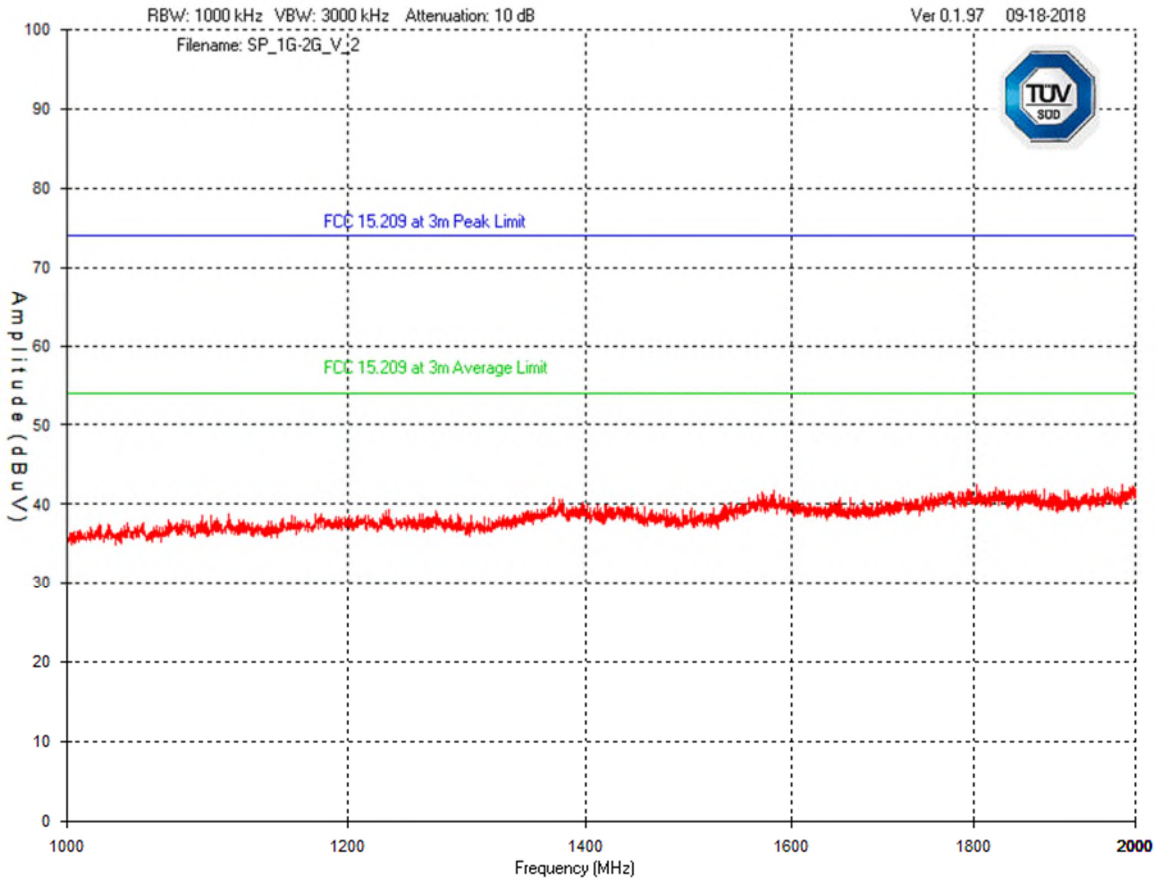


Plot was taken at a 1 meter distance.

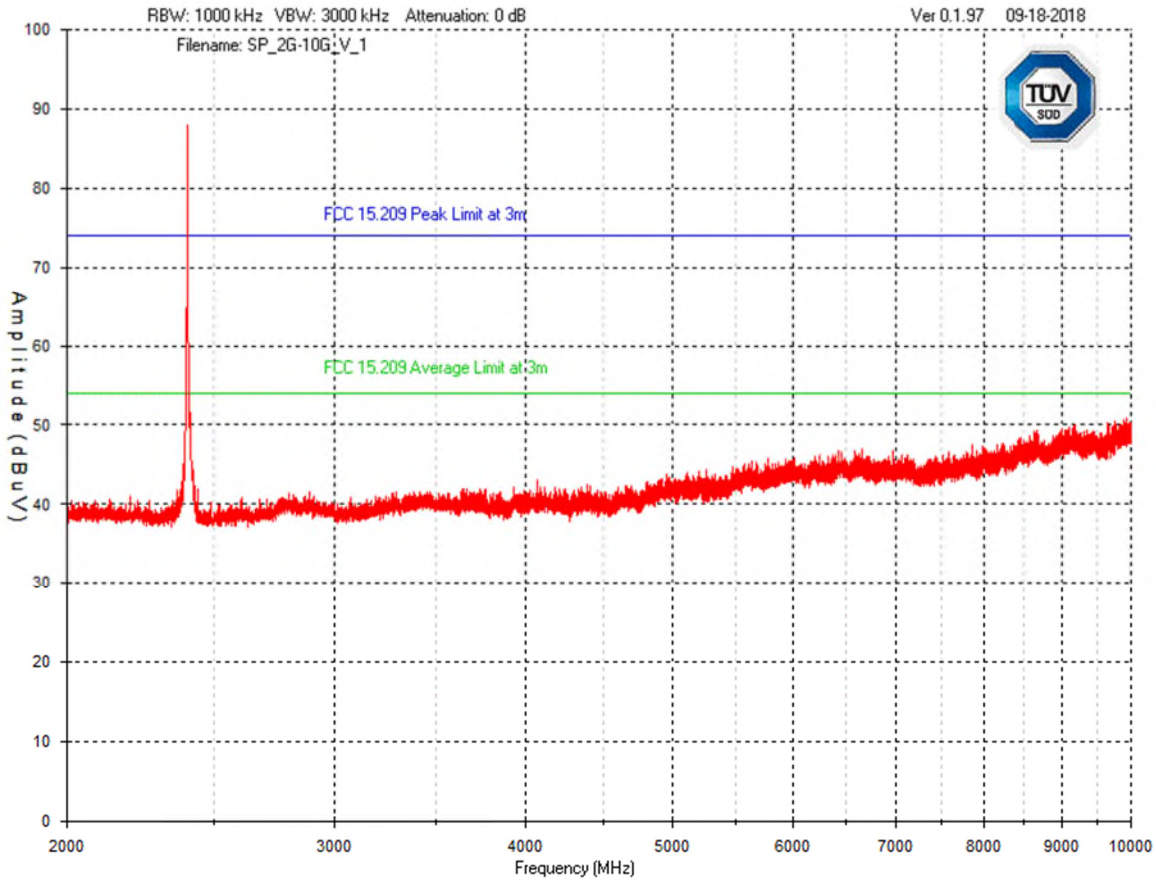
30 MHz – 1 GHz
Vertical - Peak Emission Graph



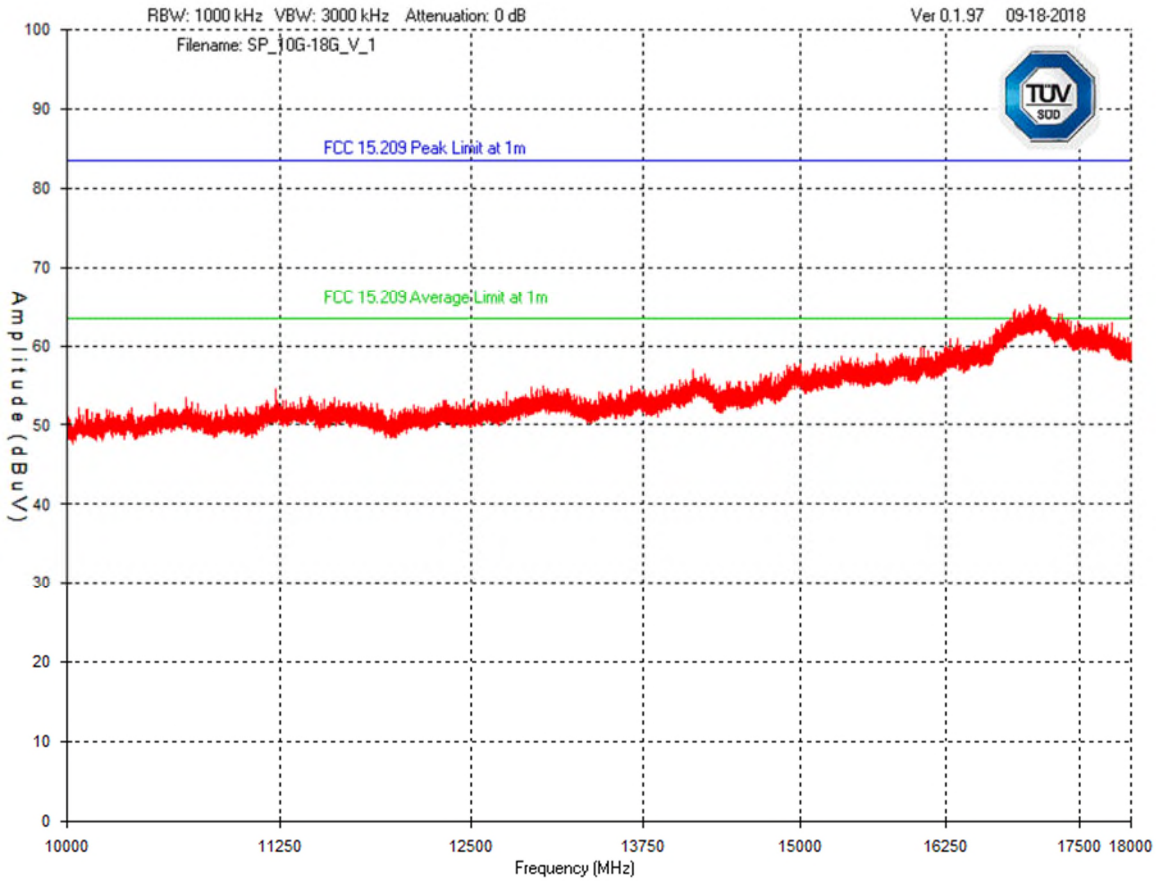
1 GHz – 2 GHz
Vertical - Peak Emission Graph



2 GHz – 10 GHz
Vertical - Peak Emission Graph

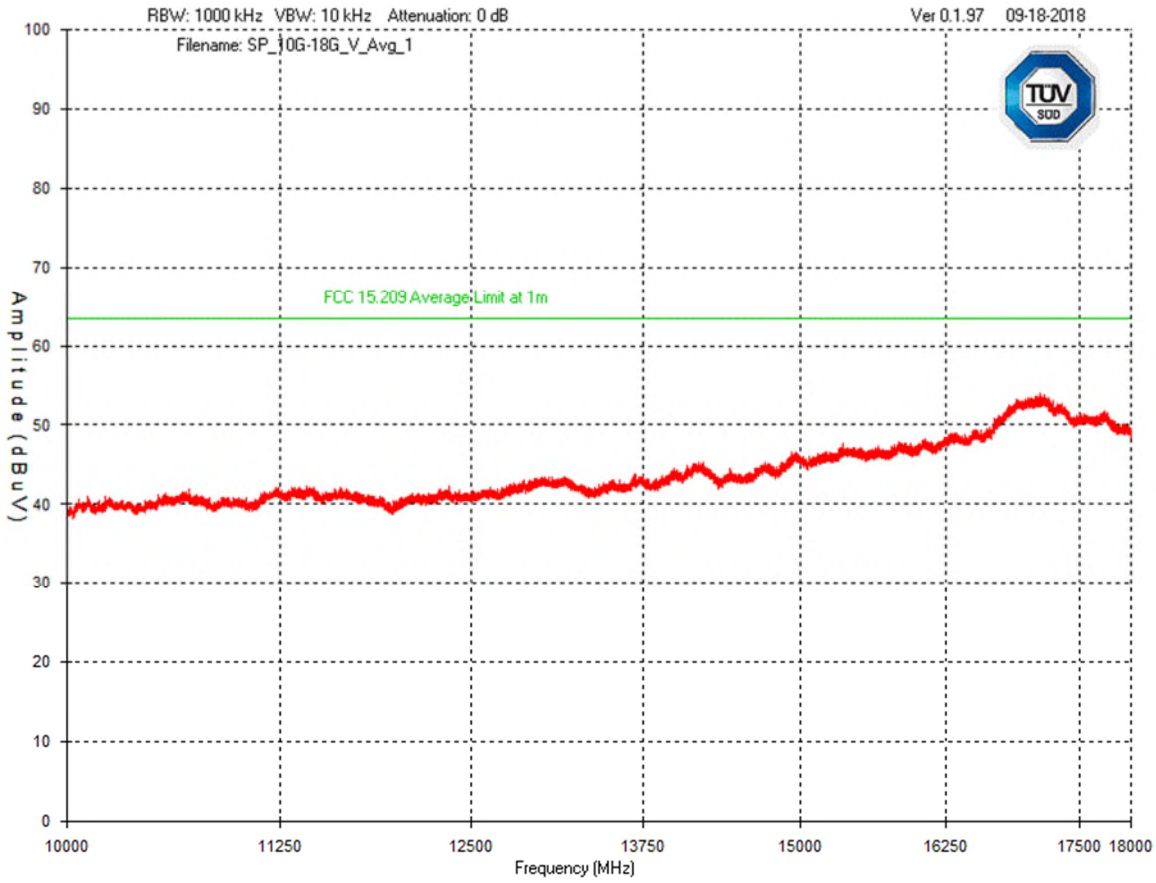


10 GHz – 18 GHz
Vertical - Peak Emission Graph



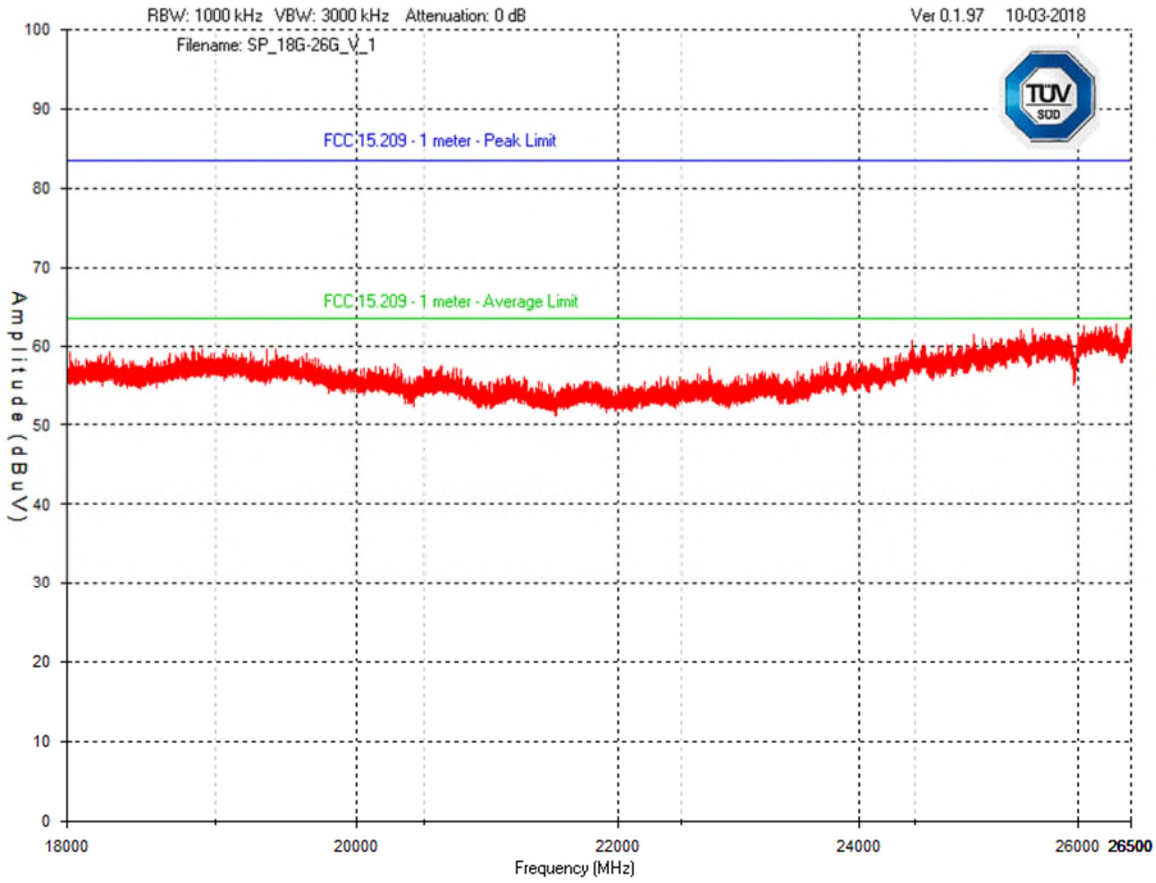
Plot was taken at a 1 meter distance.

10 GHz – 18 GHz
Vertical - Average Emission Graph



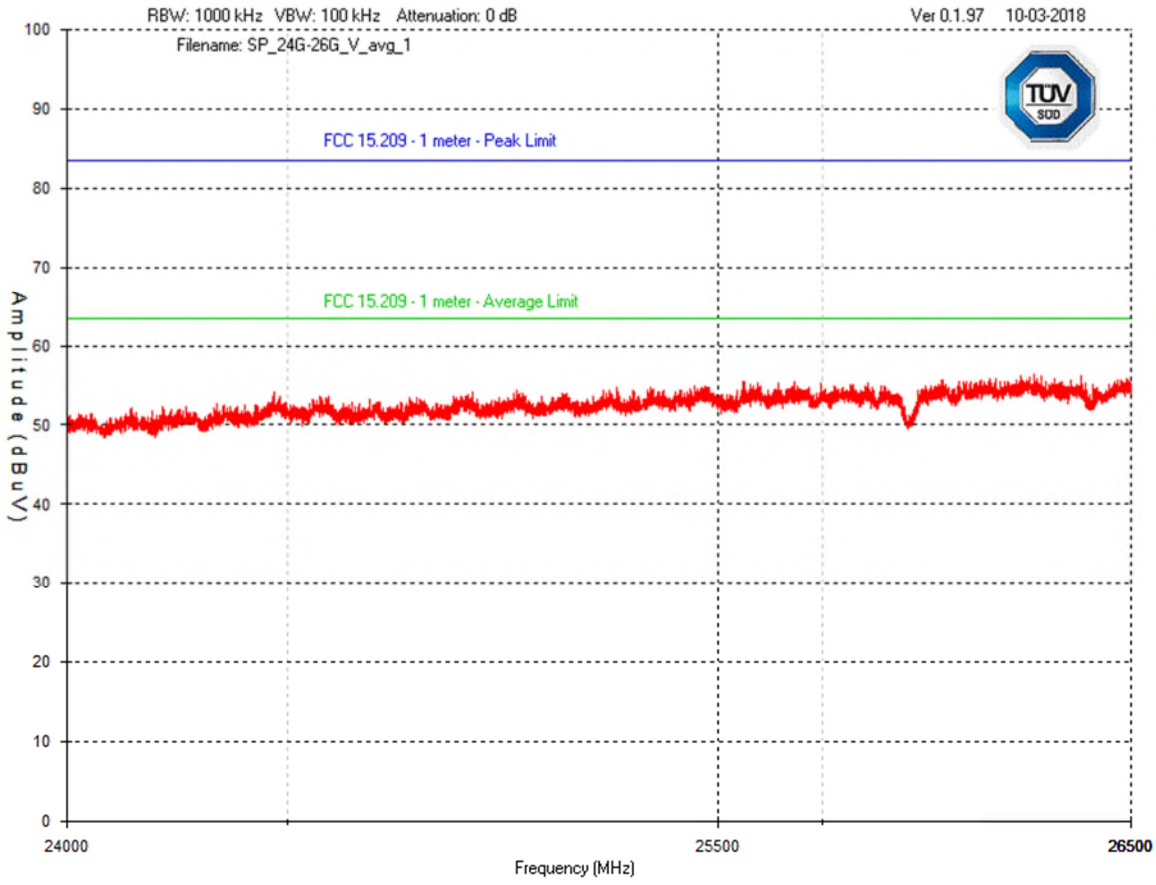
Plot was taken at a 1 meter distance.

18 GHz – 26.5 GHz
Vertical - Peak Emission Graph



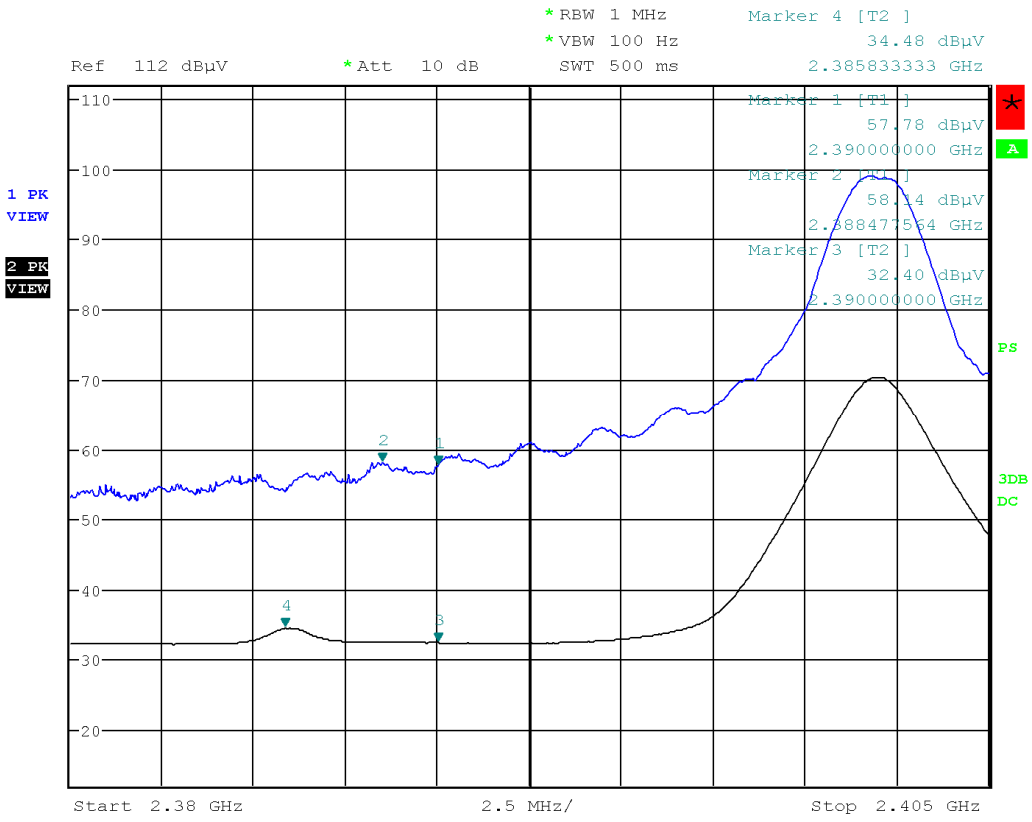
Plot was taken at a 1 meter distance.

24 GHz – 26.5 GHz
Vertical - Average Emission Graph



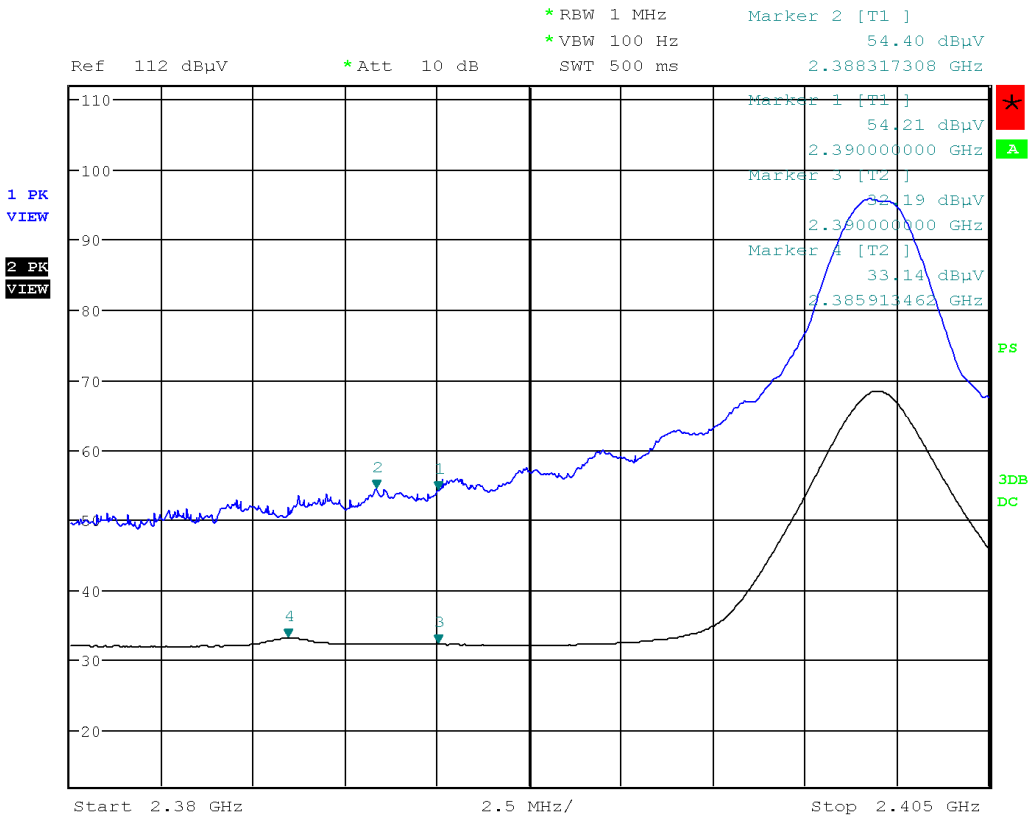
Plot was taken at a 1 meter distance.

Band Edge – Low Channel
Horizontal – Peak & Average Emissions



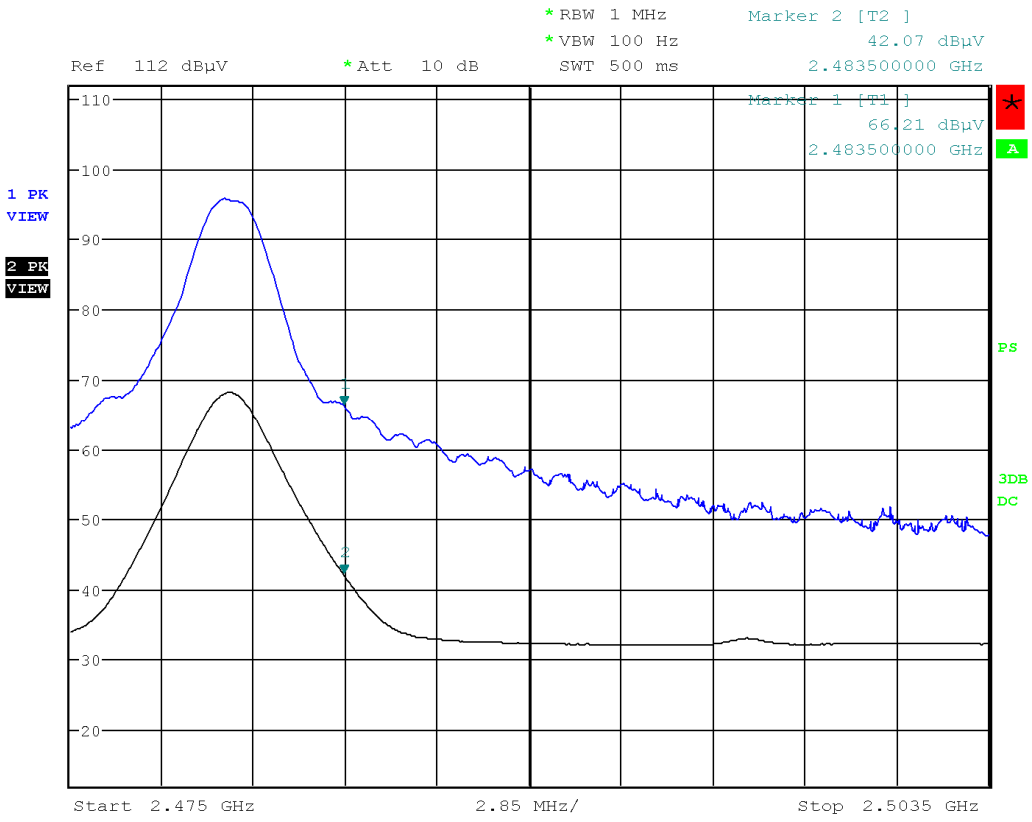
Note: Restricted band Band Edge plot was taken at a 3m measurement distance. The marker values do not have factors applied. See table in *Final Measurements and Results* for final factored values.

Band Edge – Low Channel
Vertical – Peak & Average Emissions



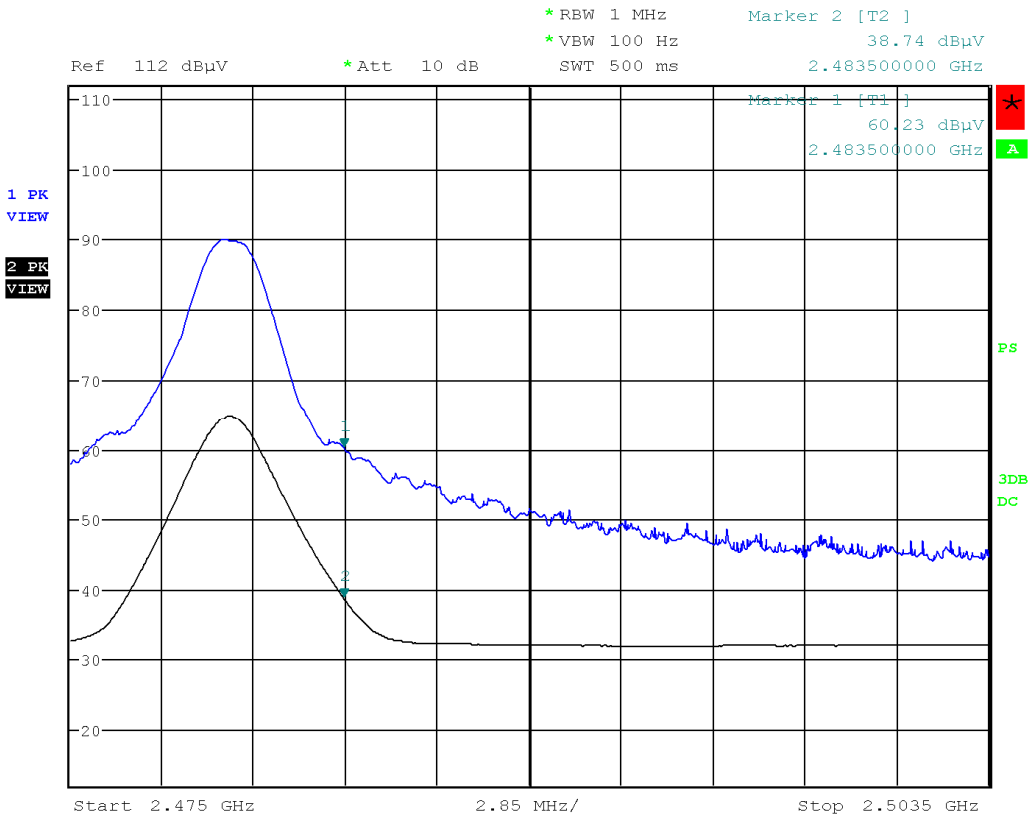
Note: Restricted band Band Edge plot was taken at a 3m measurement distance. The marker values do not have factors applied. See table in *Final Measurements and Results* for final factored values.

Band Edge – High Channel
Horizontal – Peak & Average Emissions



Note: Restricted band Band Edge plot was taken at a 3m measurement distance. The marker values do not have factors applied. See table in *Final Measurements and Results* for final factored values.

Band Edge – High Channel
Vertical – Peak & Average Emissions



Note: Restricted band Band Edge plot was taken at a 3m measurement distance. The marker values do not have factors applied. See table in *Final Measurements and Results* for final factored 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. Emissions outside the restricted bands were measured for informational purposes.

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.

Spurious Radiated Emissions Table

Frequency (MHz)	Detector	Received Signal (dBµV)	Antenna Factor (dB/m)	Atten Factor (dB)	Cable Factor (dB)	Pre-Amp (dB)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Pass/ Fail
Horizontal Antenna Polarization										
312.84	QP	34.7	13.7	6	1.3	-28.6	27.1	46.4	19.3	Pass
312.8	PEAL	48.9	13.7	6	1.3	-28.6	41.3	46.4	5.1	Pass
931.64	PEAK	34.8	23.4	6	2.6	-28.1	38.7	46.4	7.7	Pass
186.62	PEAK	47.3	9.8	6	1.0	-28.5	35.6	43.5	7.9	Pass
30.49	PEAK	34.6	16.5	6	0.4	-28.5	29.0	40.0	11.0	Pass
209.44	PEAK	38.2	10.4	6	1.0	-28.5	27.1	43.5	16.4	Pass
114.47	PEAK	40.7	7.3	6	0.8	-28.5	26.3	43.5	17.2	Pass
Vertical Antenna Polarization										
186.42	QP	39.6	9.7	6	1.0	-28.5	27.8	43.5	15.7	Pass
115.15	QP	40.9	7.2	6	0.8	-28.5	26.4	43.5	17.1	Pass
186.42	PEAK	52.1	9.7	6	1	-28.5	40.3	43.5	3.2	Pass
315.08	PEAK	46.4	13.7	6	1.3	-28.6	38.8	46.4	7.6	Pass
30.97	PEAK	35.5	16.6	6	0.4	-28.5	30.0	40.0	10.0	Pass
128.85	PEAK	43.4	6.5	6	0.9	-28.5	28.3	43.5	15.2	Pass
994.08	PEAK	33.8	23.7	6	2.8	-27.9	38.4	54.0	15.6	Pass

Restricted Band Edges Emissions Table

Test Frequency (MHz)	Detection Mode	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 Band Edge Measurements (2390 MHz) EUT Low Channel (37)										
Horizontal Antenna Polarity										
2390.00	Peak	57.8	26.6	3.6	0.0	-35.9	52.1	74.0	21.9	Pass
2390.00	Avg	32.4	26.6	3.6	0.0	-35.9	26.7	54.0	27.3	Pass
2388.48	Peak	58.1	26.6	3.6	0.0	-35.9	52.4	74.0	21.6	Pass
2385.83	Avg	34.5	26.6	3.6	0.0	-35.9	28.8	54.0	25.2	Pass
Vertical Antenna Polarity										
2390.00	Peak	54.2	26.6	3.6	0.0	-35.9	48.5	74.0	25.5	Pass
2390.00	Avg	32.2	26.6	3.6	0.0	-35.9	26.5	54.0	27.5	Pass
2388.32	Peak	54.4	26.6	3.6	0.0	-35.9	48.7	74.0	25.3	Pass
2385.91	Avg	33.1	26.6	3.6	0.0	-35.9	27.4	54.0	26.6	Pass
High Band Edge Measurements (2483.5 MHz) EUT High Channel (39)										
Horizontal Antenna Polarity										
2483.50	Peak	66.2	26.3	3.6	0.0	-35.8	60.3	74.0	13.7	Pass
2483.50	Avg	42.1	26.3	3.6	0.0	-35.8	36.2	54.0	17.8	Pass
Vertical Antenna Polarity										
2483.50	Peak	60.2	26.3	3.6	0.0	-35.8	54.3	74.0	19.7	Pass
2483.50	Avg	38.7	26.3	3.6	0.0	-35.8	32.8	54.0	21.2	Pass

Test Equipment List

Equipment	Model No.	Manufacturer	Last Calibration / Verification Date	Next Calibration / Verification Date	Asset #
Spectrum Analyzer	ESU 40	Rohde & Schwarz	Jan. 12, 2018	Jan. 12, 2020	GEMC 233
Loop Antenna 9 – 150 kHz	EM 6871	Electro-Metrics	Feb 13, 2017	Feb 13, 2019	GEMC 70
Loop Antenna 150 kHz – 30 MHz	EM 6872	Electro-Metrics	Feb 13, 2017	Feb 13, 2019	GEMC 71
BiLog Antenna 30 MHz – 2 GHz	3142-C	ETS	Oct. 5, 2016	Oct. 5, 2018	GEMC 8
Horn Antenna 2 – 18 GHz	WBH218HN	Q-par	Feb. 27, 2018	Feb. 27, 2020	GEMC 6375
Horn Antenna 18 – 26.5 GHz	SAS-572	A.H. Systems	Oct 11, 2016	Oct 11, 2018	GEMC 6371
Pre-Amp 9 kHz – 1 GHz	LNA 6901	Teseq	Feb. 2, 2017	Feb. 2, 2019	GEMC 168
Pre-Amp 1 – 26.5 GHz	HP 8449B	HP	Jun. 12, 2018	Jun. 12, 2020	GEMC 312
Attenuator 6 dB	612-6-1	Meca Electronics, Inc	NCR	NCR	GEMC 286
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	0.1.97	Global EMC	NCR	NCR	GEMC 58

FCC - 15.209 -Radiated Emissions_Rev1

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, as measured from a LISN. This helps protect lower frequency radio services such as AM radio, shortwave radio, amateur radio operators, maritime radio, CB radio, and so on, from unwanted interference.

Limits and Method

The limits are as defined in FCC 15.207 and RSS-Gen Table 4.
Method is as defined in ANSI C63.4

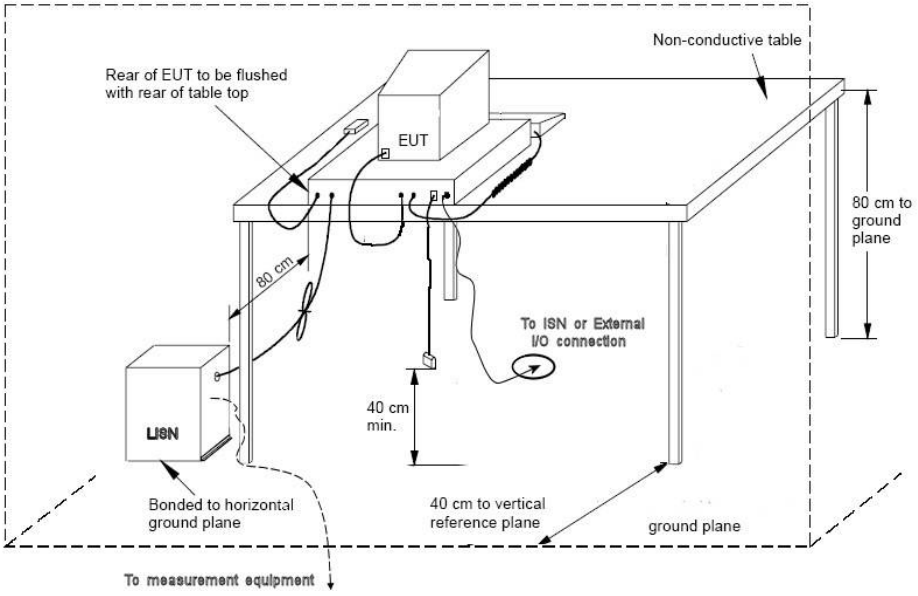
Average Limits		Quasi-Peak Limits	
150 kHz – 500 kHz	56 to 46* dBµV	150 kHz – 500 kHz	66 to 56* dBµV
500 kHz – 5 MHz	46 dBµV	500 kHz – 5 MHz	56 dBµV
5 MHz – 30 MHz	50 dBµV	5 MHz – 30 MHz	60 dBµV

* 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

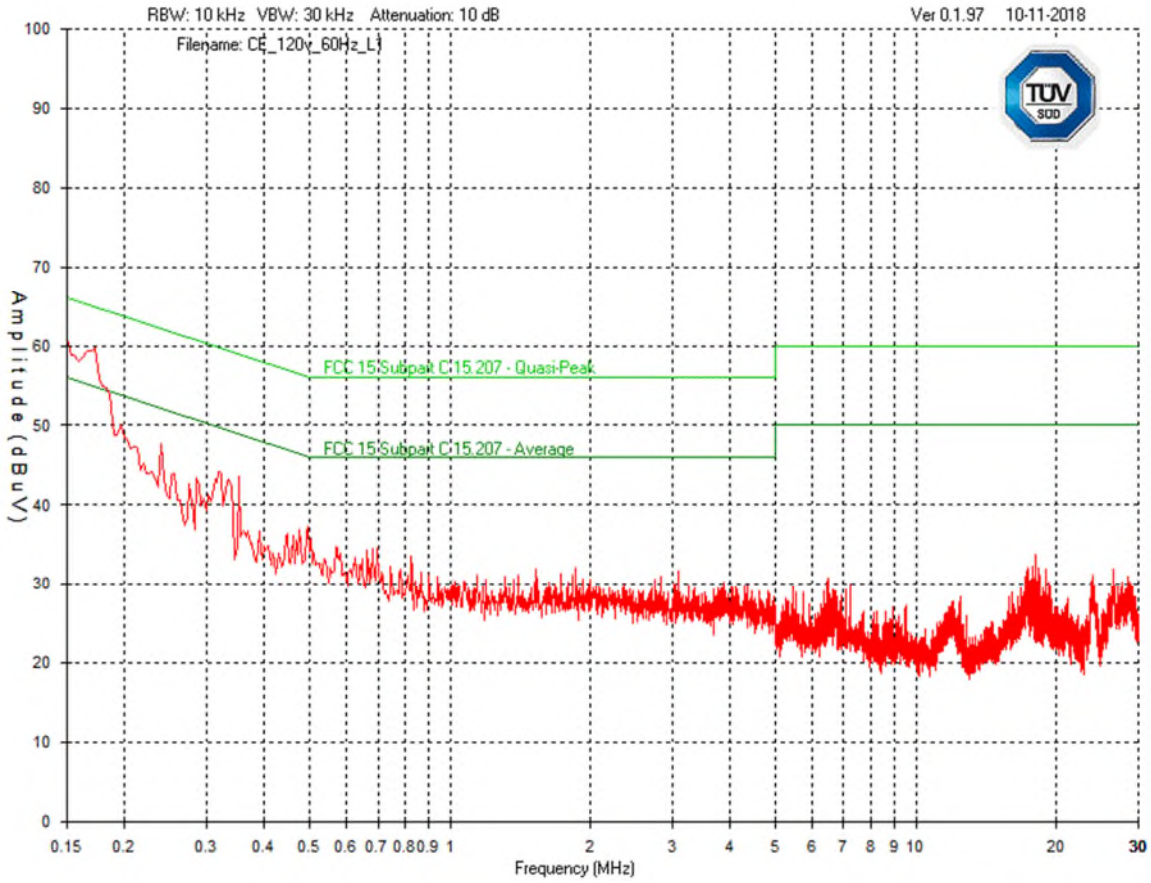
The expanded measurement uncertainty is calculated in accordance with CISPR 16-4-2 and is ±2.73dB with a 'k=2' coverage factor and a 95% confidence level.

Preliminary Graphs

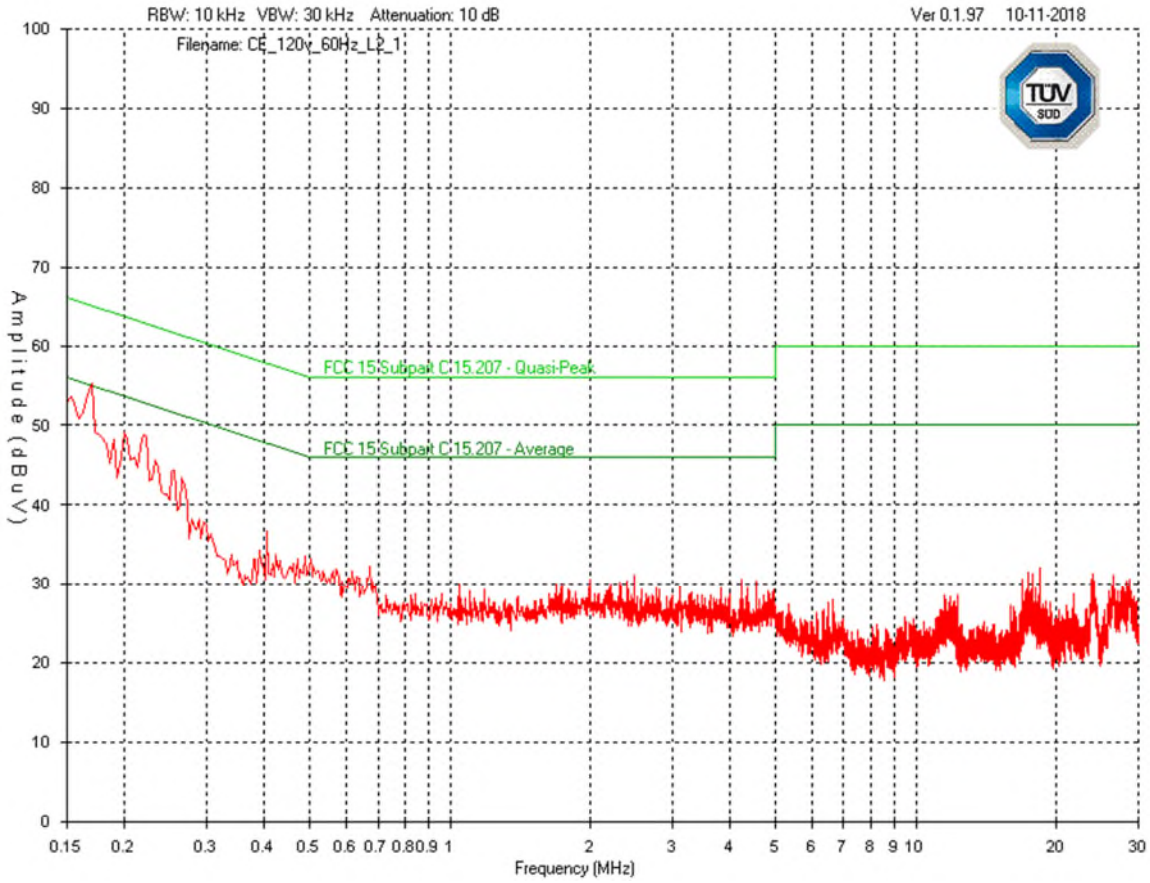
The graphs shown below are maximized peak measurement graphs measured with a resolution bandwidth greater than or equal to the final required detector. This peaking process is done as a worst case measurement and enables the detection of frequencies of concern for final measurement. For final measurements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

The EUT is a battery operated device with a battery rechargeable via a USB port. Power line conducted emissions is performed while it is recharging using a representative support device (Lenovo ThinkPad 13 with Lenovo AC/DC Adapter model ADLX45NCC2A).

Line 1 (L1) – 120Vac 60Hz



Line 2 (L2) – 120Vac 60Hz



Final Measurements

Power Line Conducted Emissions Table
120V, 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)	Pass/ Fail
Line											
0.173	AVG	27.5	10	0.0	0.0	37.5	--	54.8	--	17.3	Pass
0.150	AVG	29.9	10	0.0	0.0	39.9	--	54.8	--	14.9	Pass
0.188	AVG	26.8	10	0.0	0.0	36.8	--	54.8	--	18.0	Pass
0.352	AVG	16.5	10	0.1	0.0	26.6	--	48.9	--	22.3	Pass
0.319	AVG	17.2	10	0.1	0.0	27.3	--	49.7	--	22.4	Pass
0.495	PEAK	27.2	10	0.1	0.0	37.3	56.1	46.1	18.8	8.8	Pass
Neutral											
0.170	AVG	23.8	10	0.0	0.0	33.8	--	55.0	--	21.2	Pass
0.154	AVG	25.7	10	0.0	0.0	35.7	--	55.0	--	19.3	Pass
0.207	AVG	19.5	10	0.0	0.0	29.5	--	55.0	--	25.5	Pass
0.405	PEAK	26.6	10	0.1	0.0	36.7	57.7	47.7	21.0	11.0	Pass
2.485	PEAK	21.2	10	0.1	0.0	31.3	56.0	46.0	24.7	14.7	Pass
1.994	PEAK	20.6	10	0.1	0.0	30.7	56.0	46.0	25.3	15.3	Pass

Notes:

PEAK = Peak measurement
AVG = Average measurement

No Peak measurements were over Quasi-Peak limits.

See 'Appendix B – EUT, Peripherals 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 #
Spectrum Analyzer	ESL 6	Rohde & Schwarz	Dec. 27, 2017	Dec. 27, 2019	GEMC 160
LISN	FCC-LISN-50/250-16-2-01	FCC	Jan. 10, 2018	Jan. 10, 2020	GEMC 302
RF Cable 3m	LMR-400-3M-50Ω-MN-MN	LexTec	NCR	NCR	GEMC 276
Attenuator 10 dB	612-10-1	Meca Electronics, Inc.	NCR	NCR	GEMC 223
Emissions Software	0.1.97	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 / Manufacturer Details	
Organization / Address	Interaxon Inc. Suite 900, 555 Richmond St. West Toronto, Ontario Canada, M5V 3B1
Contact	Sam MacKenzie
Phone	416-598-8989
Email	sam.mackenzie@interaxon.ca
EUT (Equipment Under Test) Details	
EUT Name	Muse
EUT Model / SN (if known)	MU-03
EUT is powered using	Battery
Input voltage range(s) (V)	4.5-6 VDC
Rated input current (A)	100 mA
Nominal power consumption (W)	0.5 W
Transmits RF energy? (describe)	BLE, 2.4 Ghz
Basic EUT functionality description	A device worn on the head which measures brain activity.
I/O cable description	Standard USB cable. USB-A to microUSB-B. 1m length
Available connectors on EUT	microUSB B
Peripherals required to exercise EUT	Lenovo ThinkPad 13 and Lenovo AC/DC Adapter model ADLX45NCC2A (removed for radio testing).
Dimensions of product (approx..)	L: 143mm, W: 123mm, H: 60mm

Note the EUT is considered to have been received the date of the commencement of the first test, unless otherwise stated.

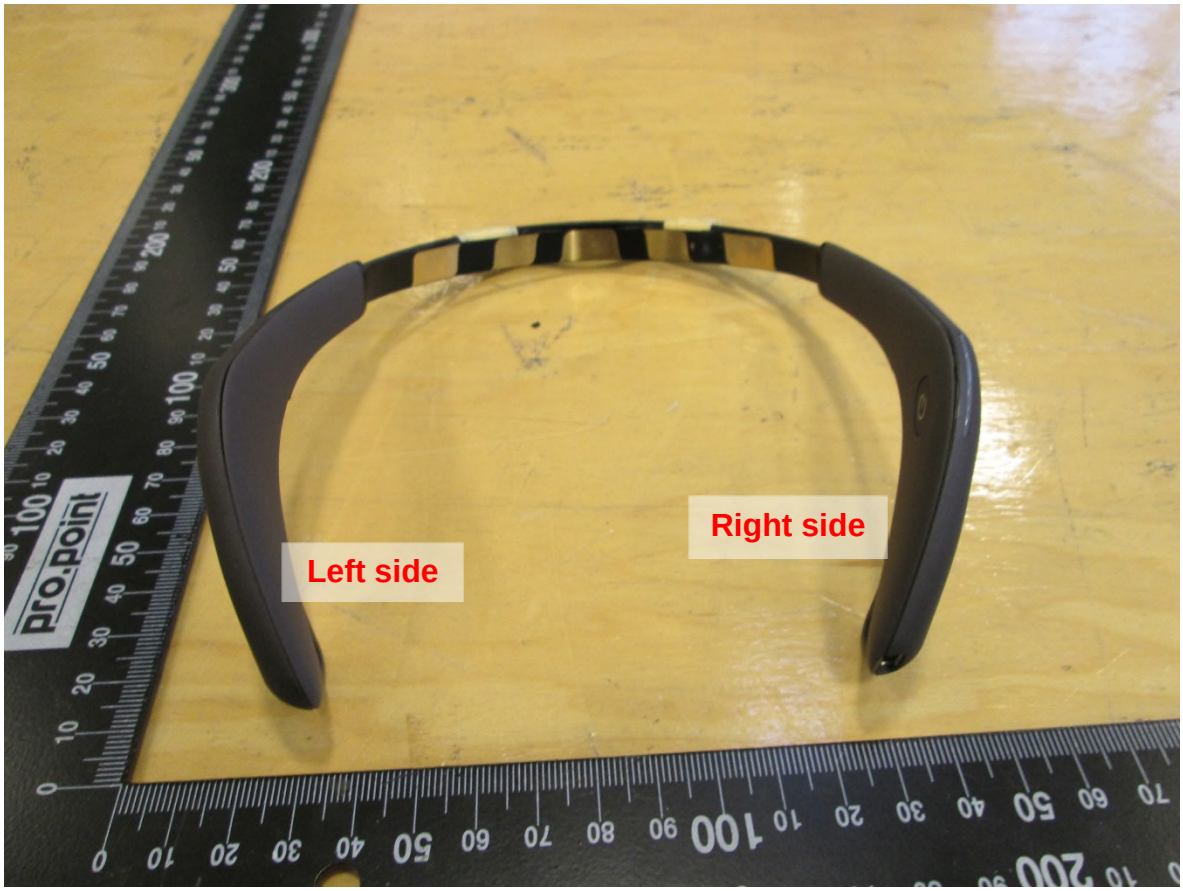
For a close-up picture of the EUT, see ‘Appendix B – EUT and Test Setup Photos’.

Appendix B – EUT and Test Setup Photos

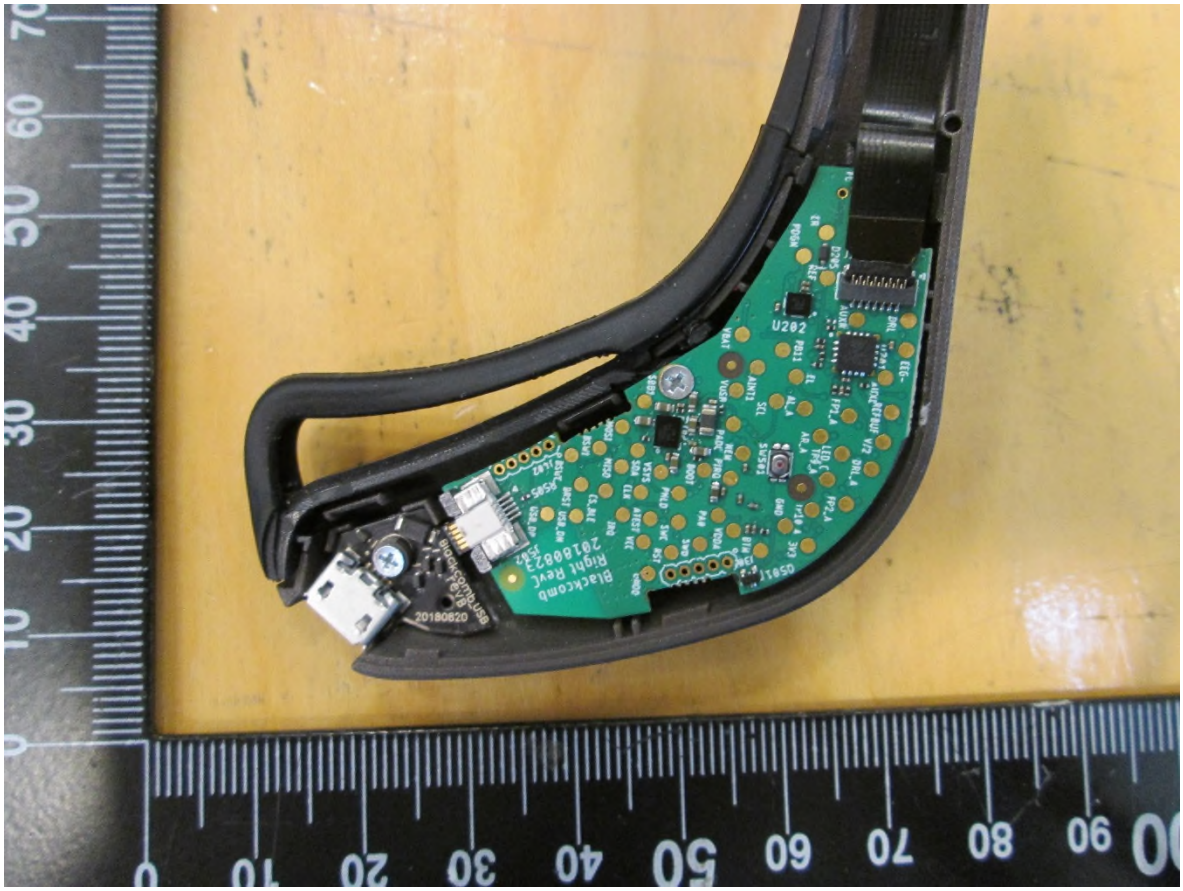
Note: These photos are for information purposes only.
Also refer to submitted files that are separate from this test report.

EUT – External view 1

EUT – External view 2

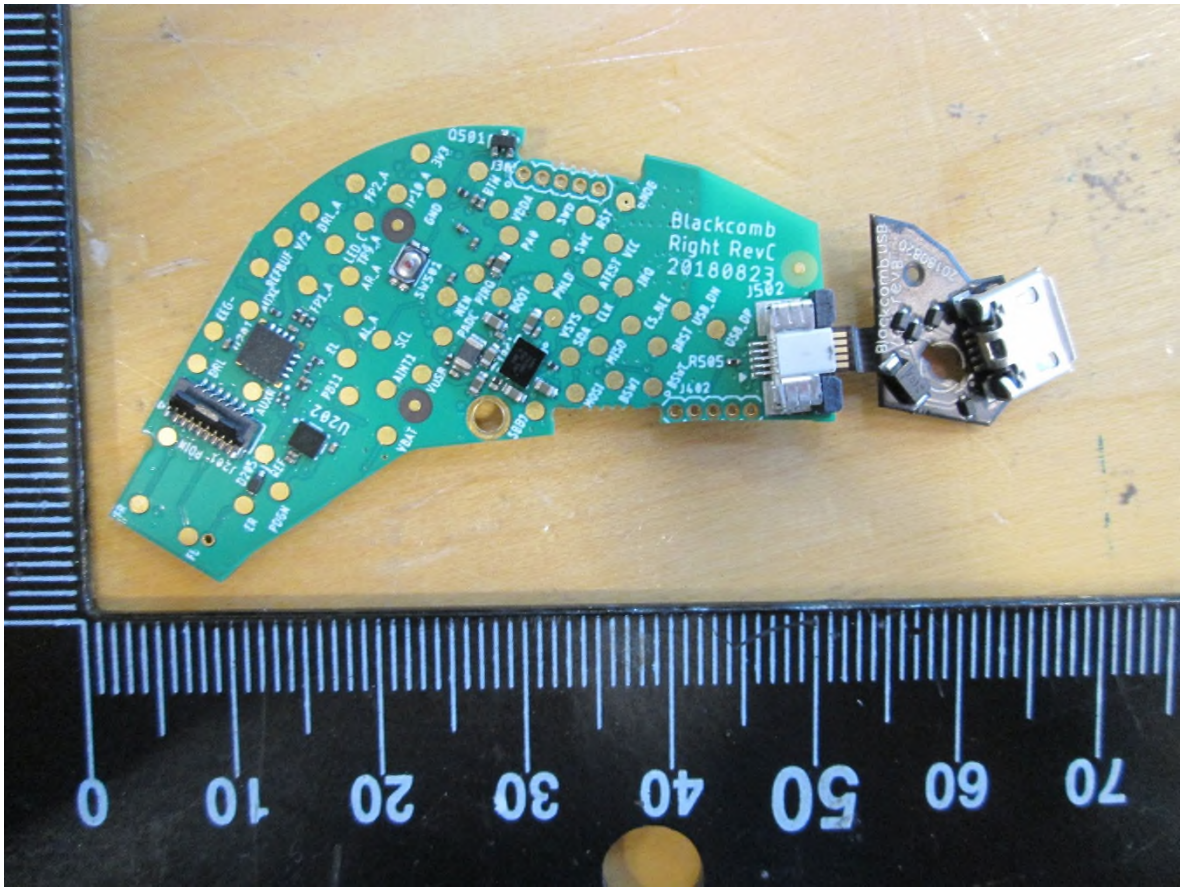


EUT – External view 3

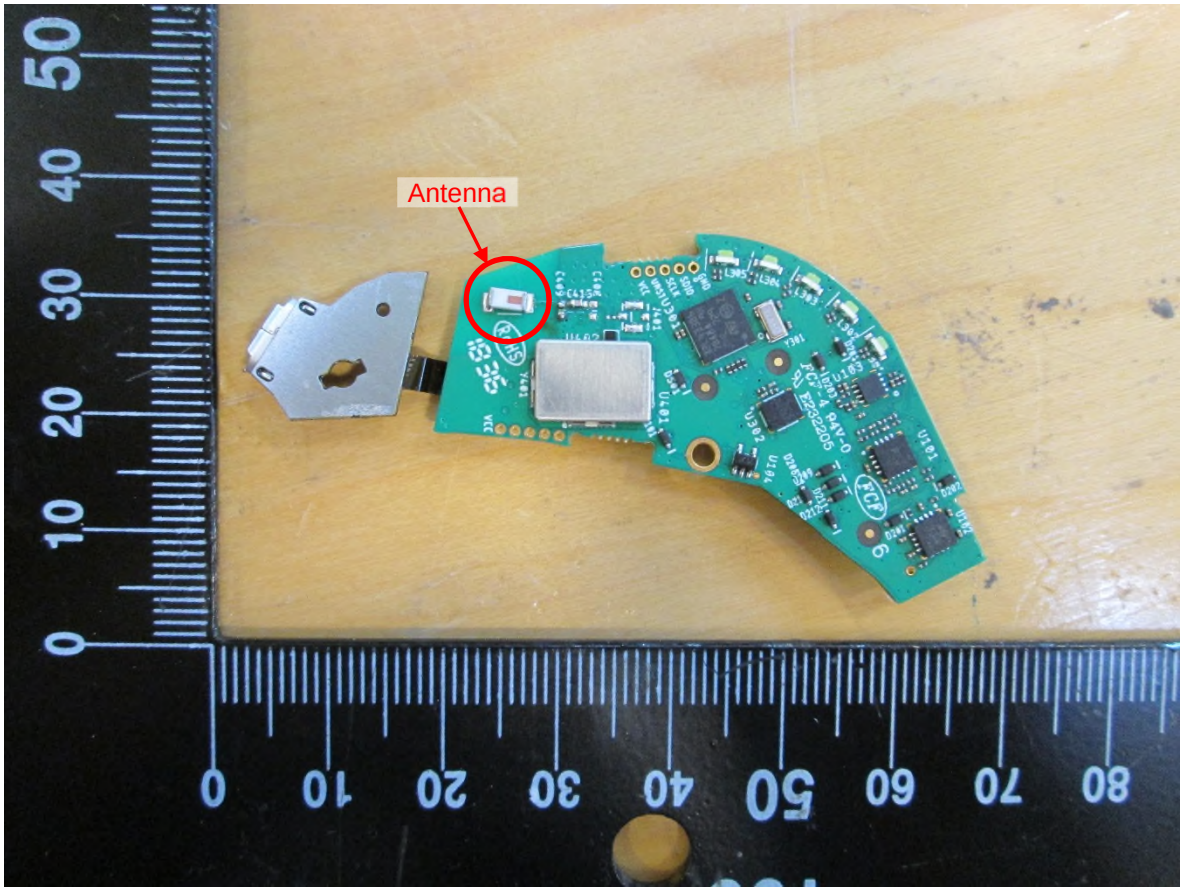


EUT – Internal view 1
Right side

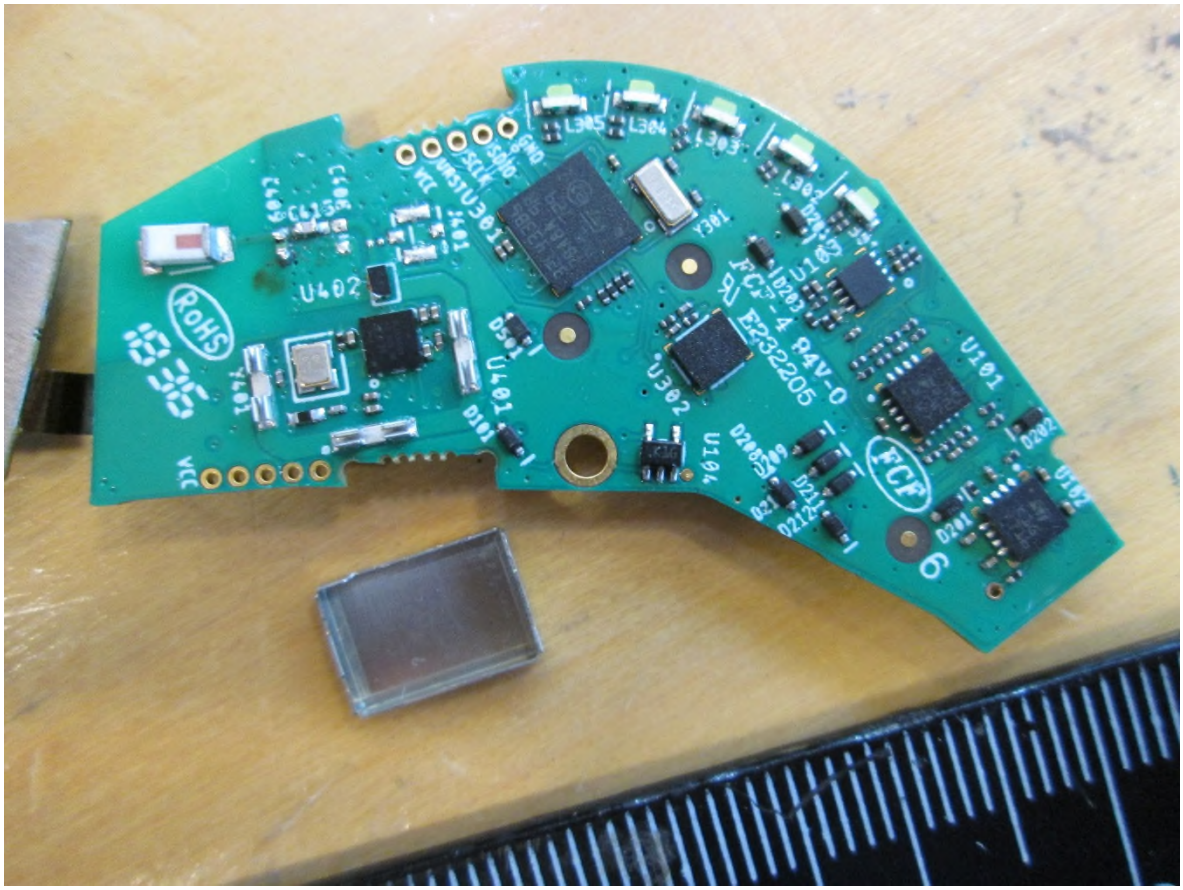
EUT – Internal view 2
Right side PCB removed from enclosure



EUT – Internal view 3
Right side PCB, side 1



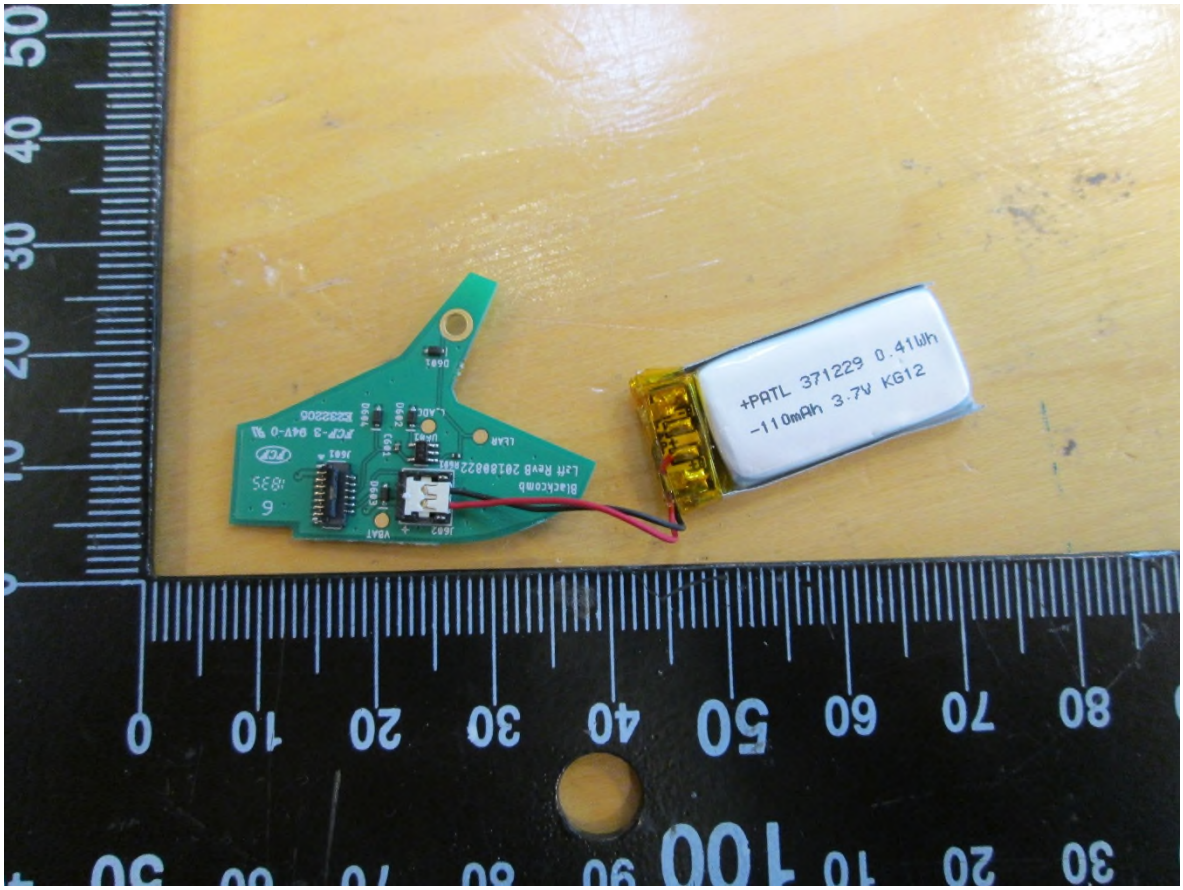
EUT – Internal view 4
Right side PCB, side 2



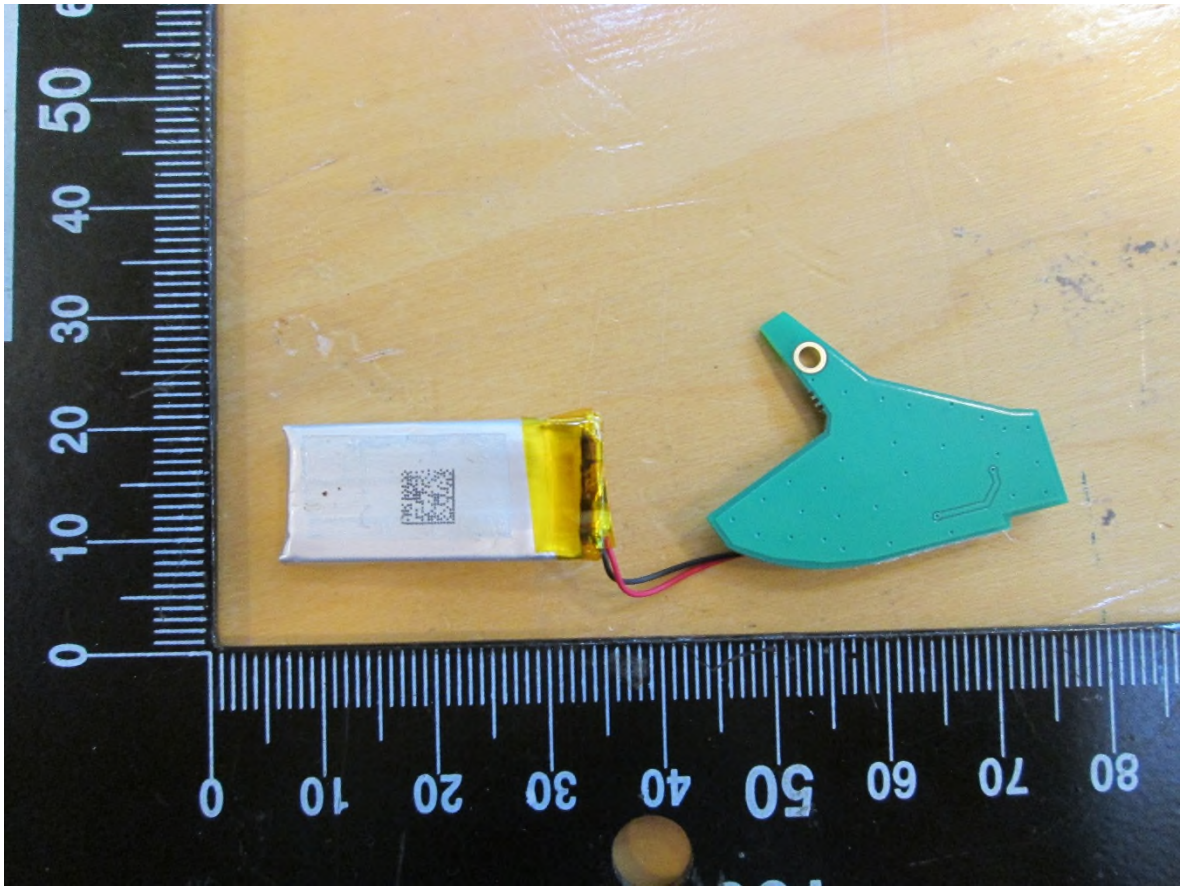
EUT – Internal view 5
Right side PCB, side 2, shield removed.

EUT – Internal view 6
Left side

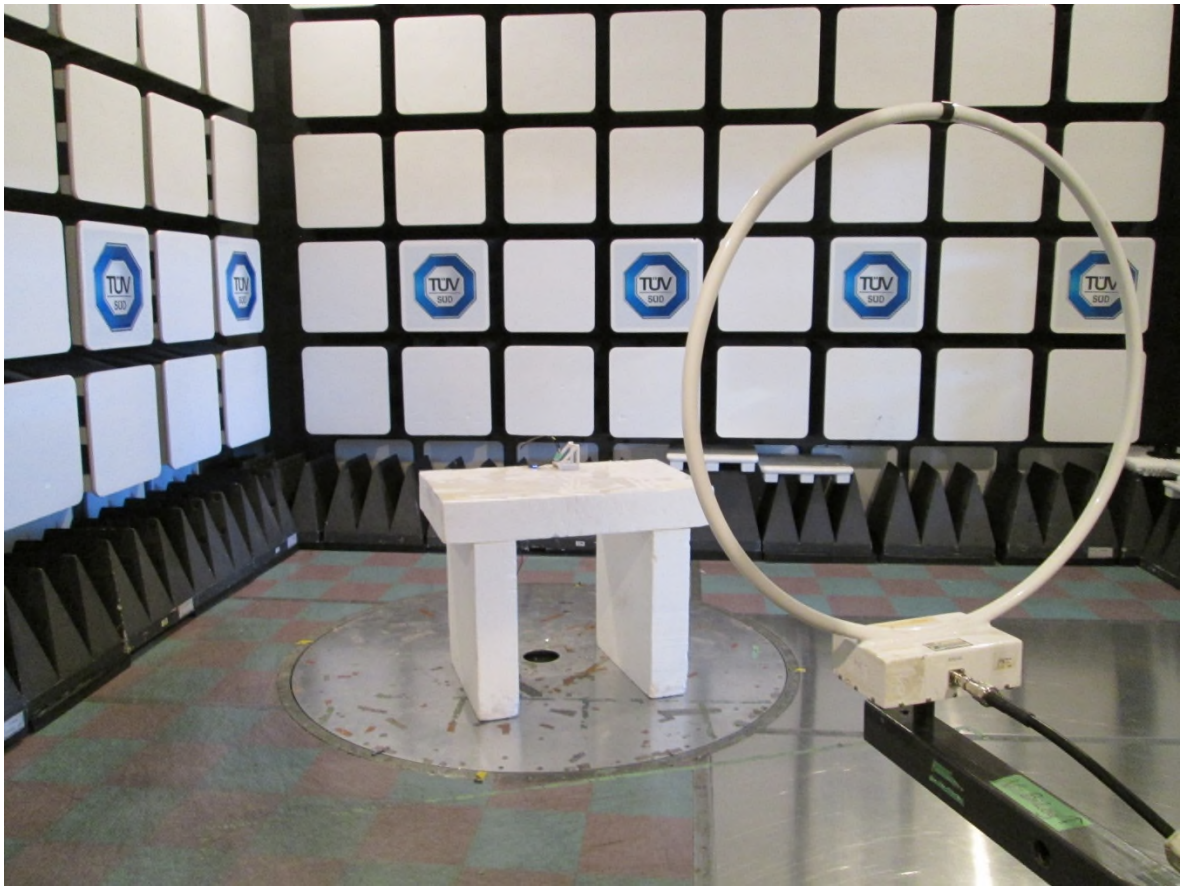
EUT – Internal view 7
Left side PCB removed from enclosure



EUT – Internal view 8
Left side PCB, side 1

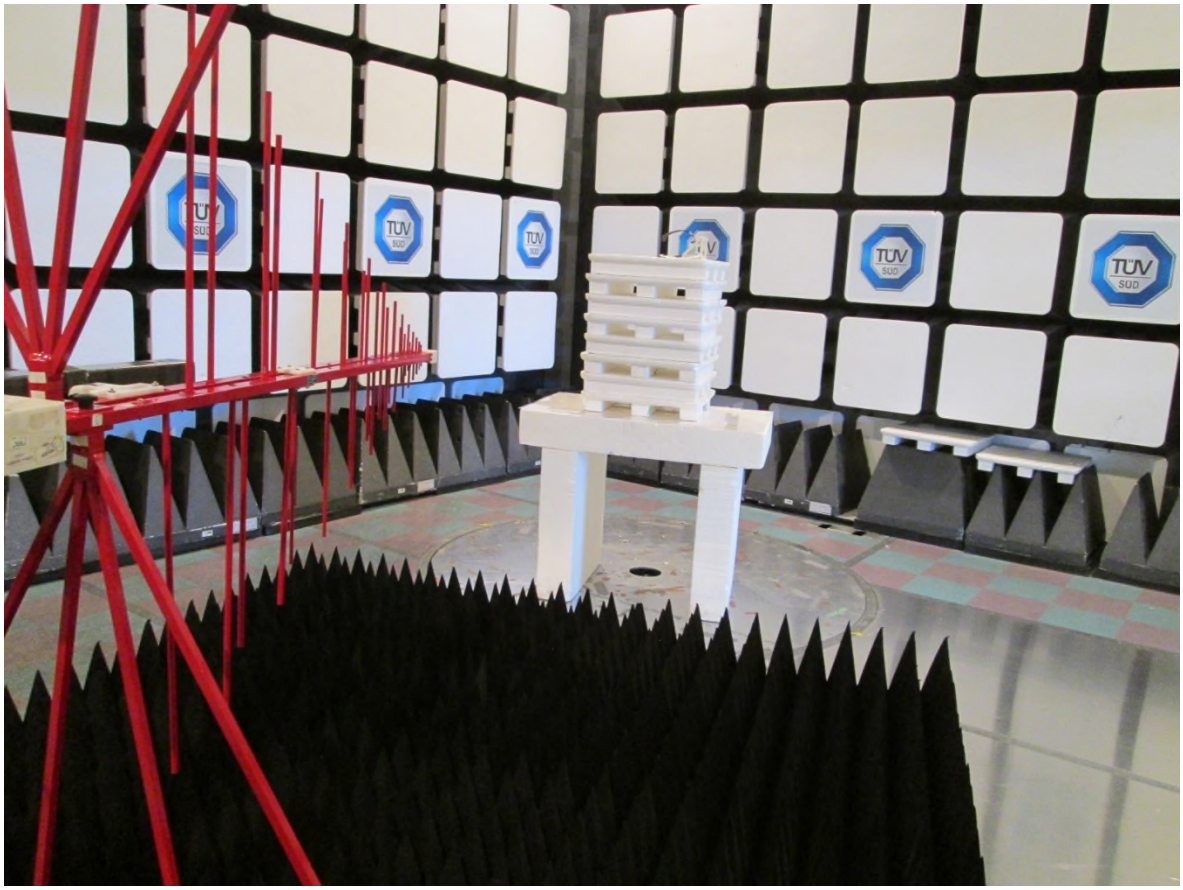


EUT – Internal view 9
Left side PCB, side 2

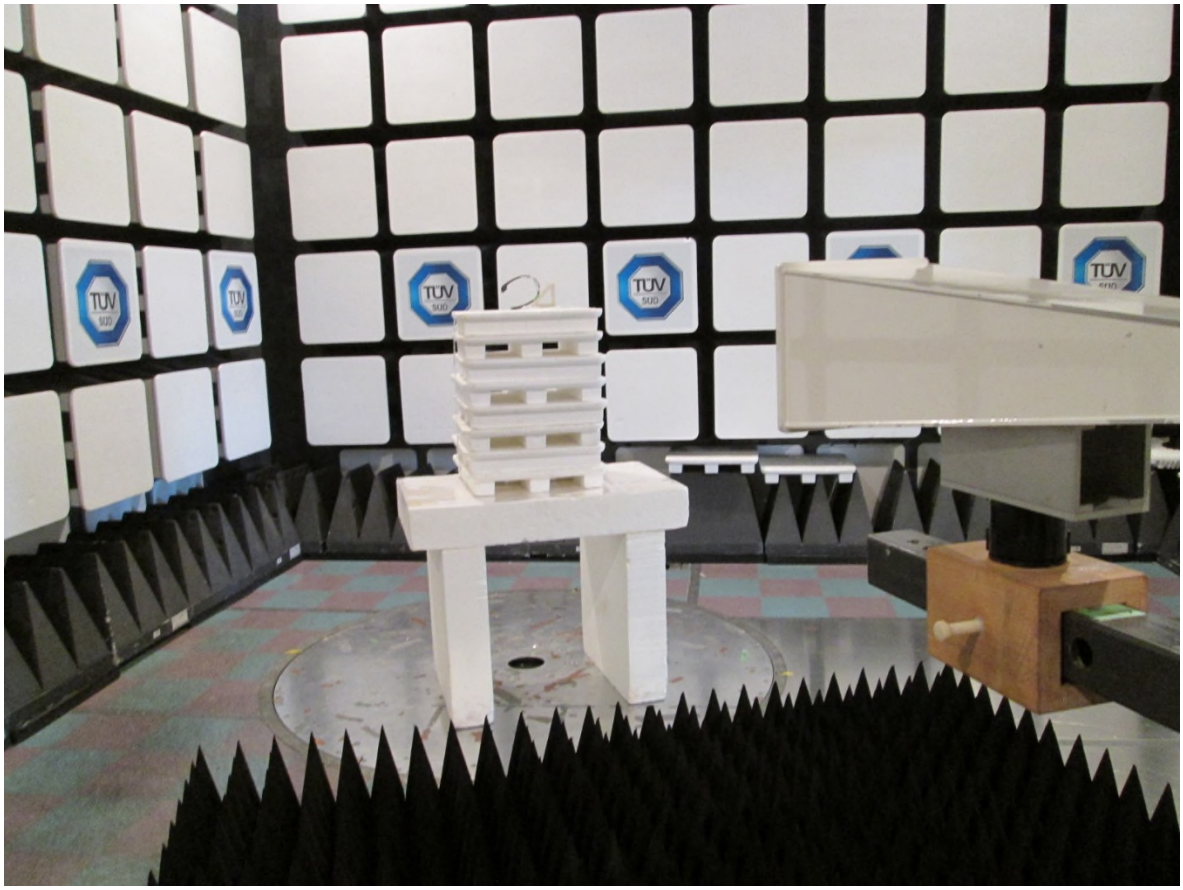


Test setup photo 1
Radiated measurements, 9 kHz – 30 MHz

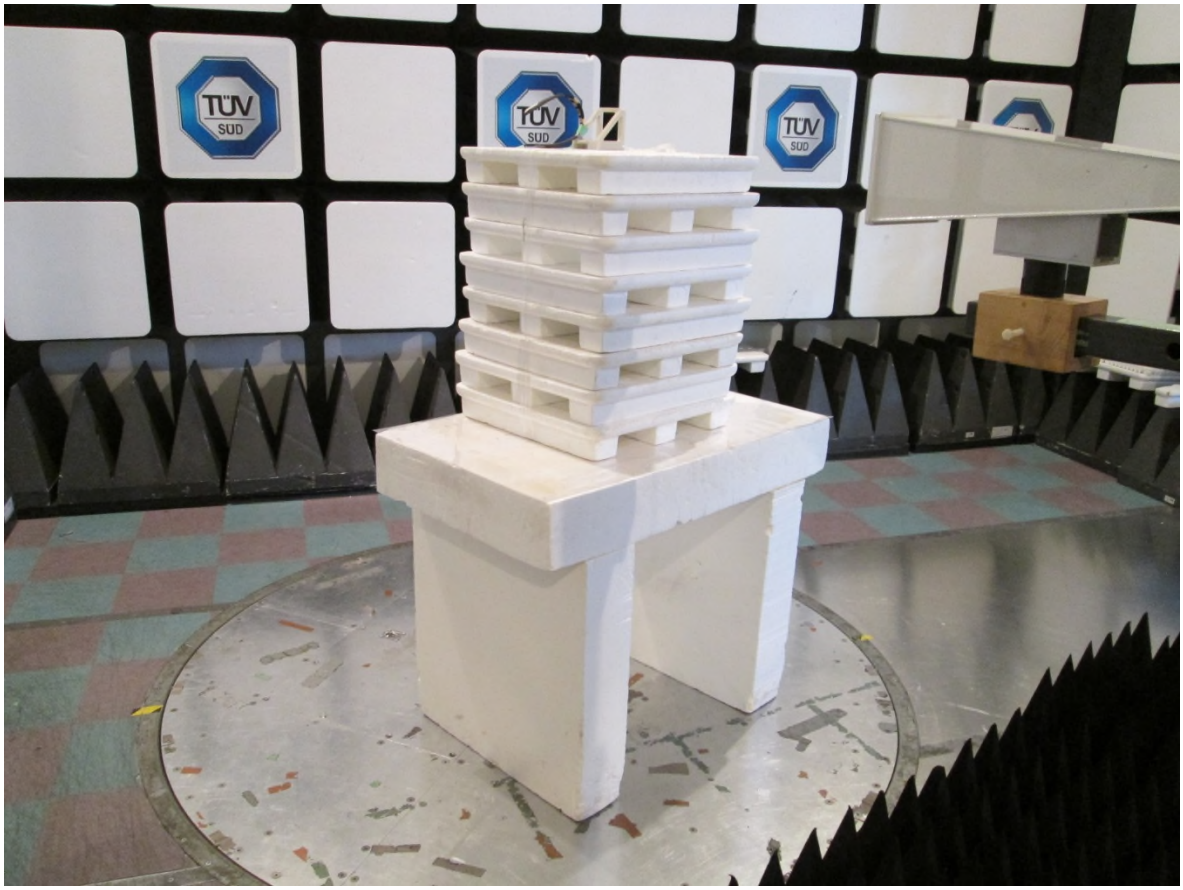
Test setup photo 2
Radiated measurements, 30 MHz – 1 GHz



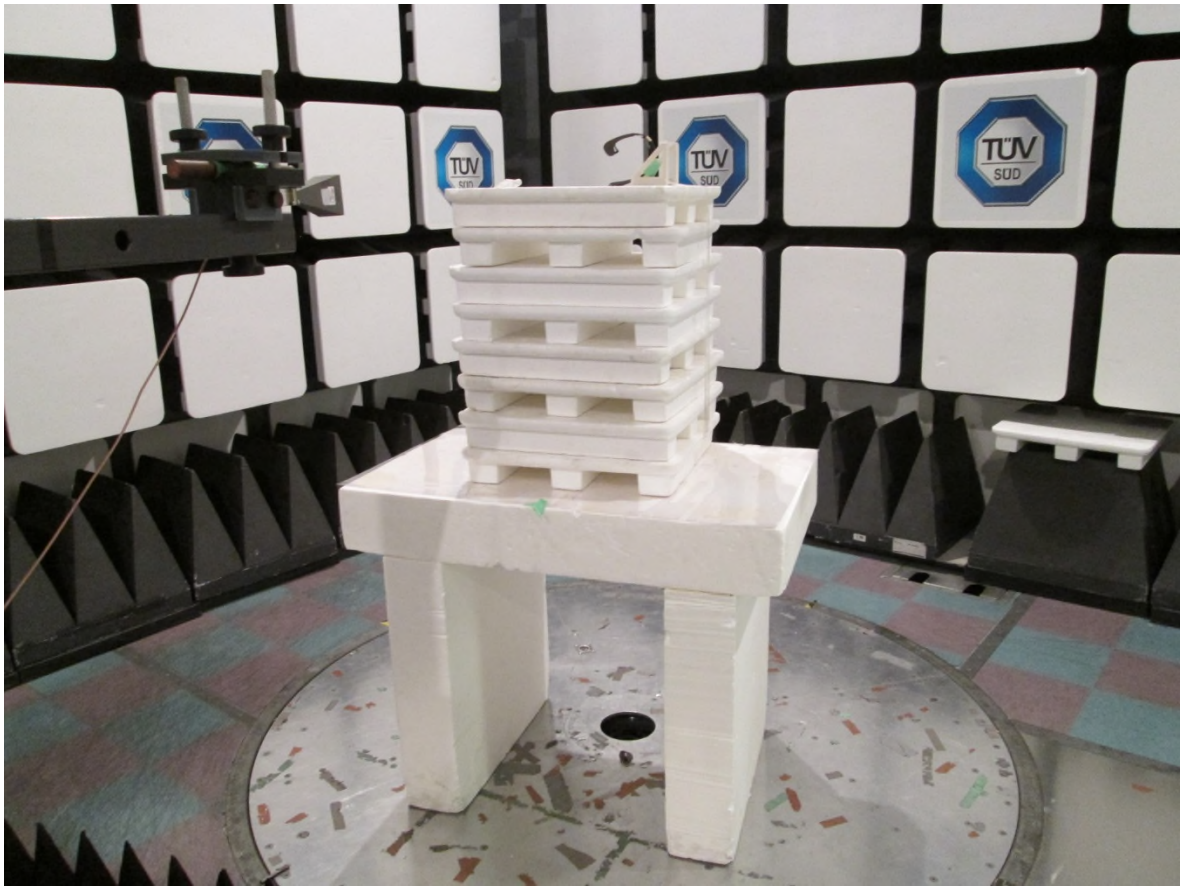
Test setup photo 3
Radiated measurements, 1 GHz – 2 GHz



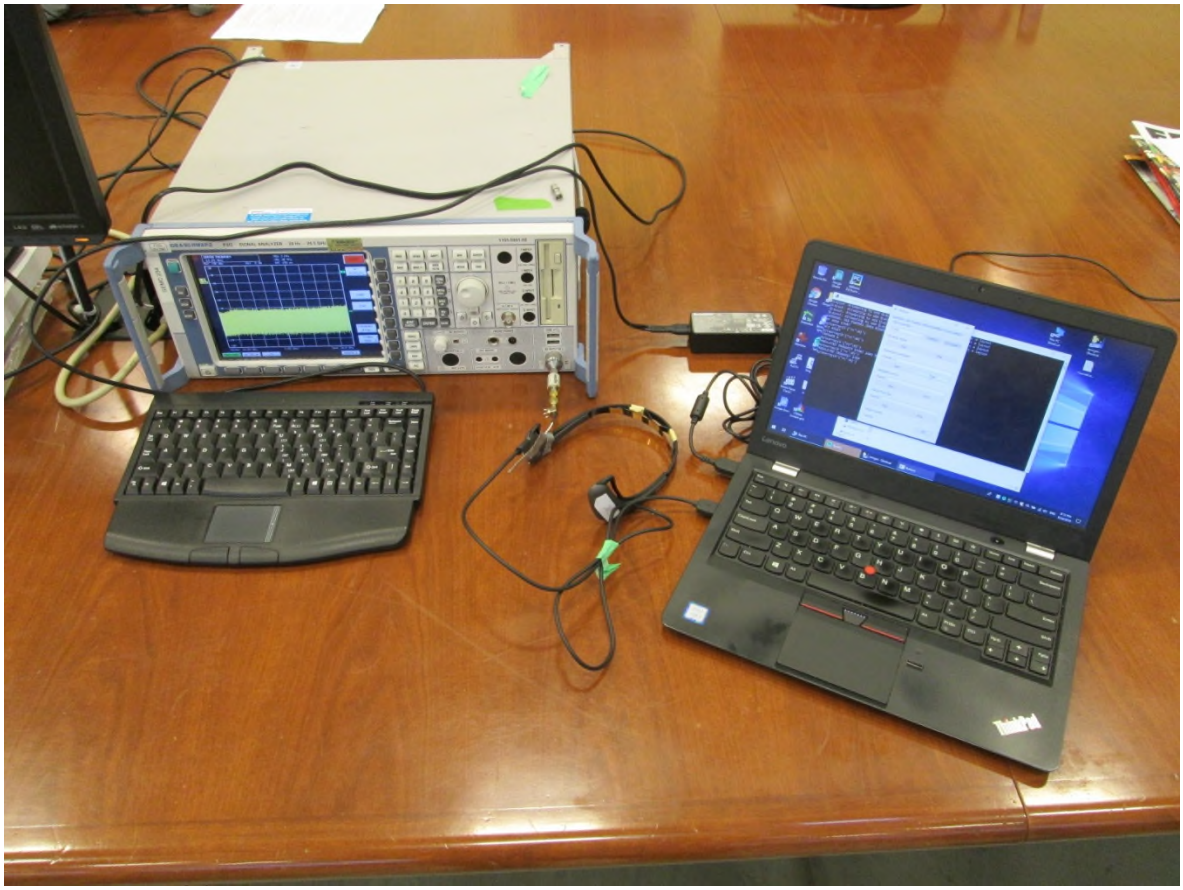
Test setup photo 4
Radiated measurements, 2 GHz – 10 GHz



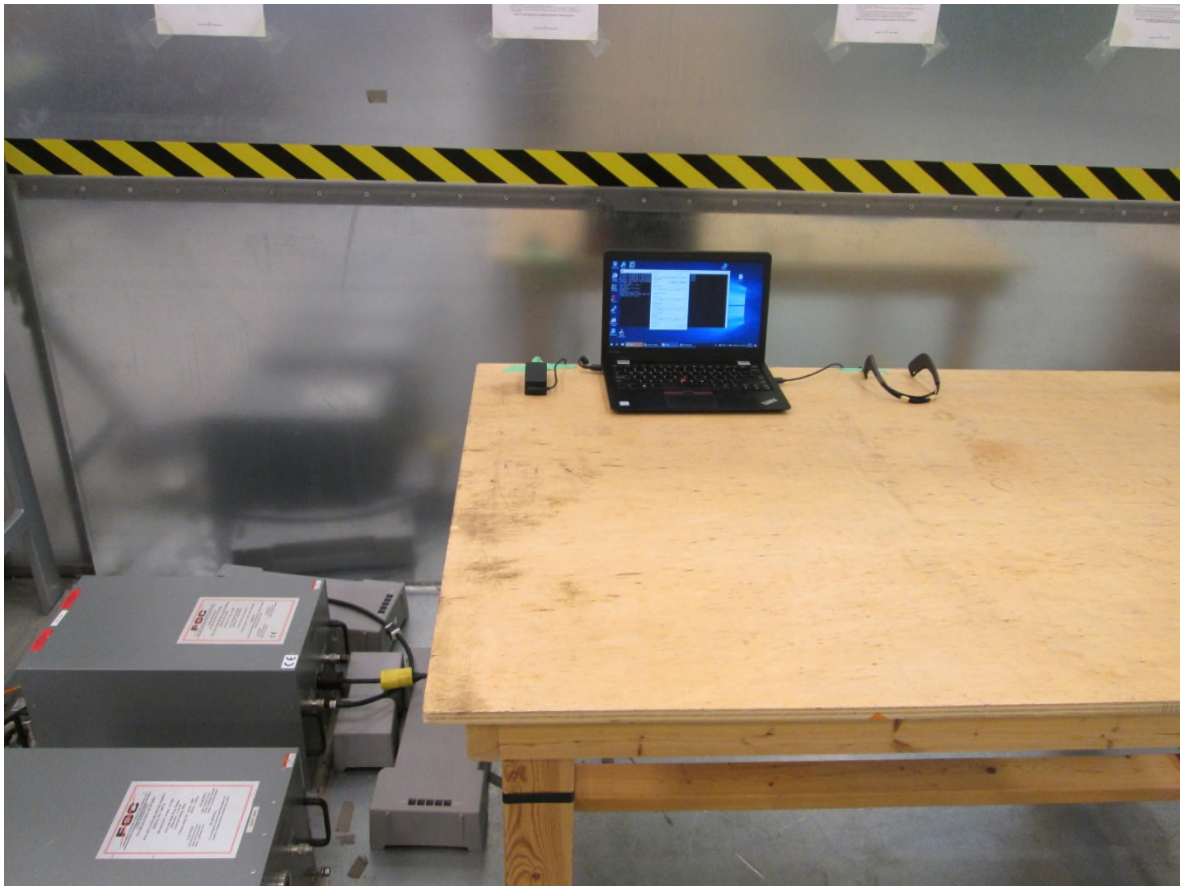
Test setup photo 5
Radiated measurements, 10 GHz – 18 GHz



Test setup photo 6
Radiated measurements, 18 GHz – 26.5 GHz



Test setup photo 7
Antenna conducted measurements



Test setup photo 8
Power line conducted emissions measurements