

Husqvarna AB
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SE-561 82 HUSKVARNA
SWEDEN

Equipment Authorization measurements on 2402-2480 MHz Transceiver Unit

Product name: Husqvarna Connectivity Device (HCD)

FCC ID: ZAS-HQ-CD1
IC: 23307-HQCD1

RISE Research Institutes of Sweden AB Electronics - EMC

Performed by



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Testing
ISO/IEC 17025

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Commission

The tests were performed to verify that the electromagnetic emission from the test object meets the requirements of listed standards.

Summary

Standard	Compliant	Remarks
FCC 47 CFR Part 15 C 15.247 Operation within the band 2400-2483.5 MHz	Yes	
ISED RSS-247 Issue 2, February 2017	Yes	
Duty cycle measurements	N/A	Note 1
15.247 (a) (2) / RSS-247 5.2 a) 6 dB bandwidth	Yes	
15.247 (b) (3) / RSS-247 5.4 d) Maximum peak conducted power	Yes	
15.247 (d) / RSS-247 5.5 20 dBc below fundamental	Yes	
15.247 (d) / RSS-247 5.5 Restricted bands of operation	Yes	
15.247 (e) / RSS-247 5.2 b) Power spectral density	Yes	
2.1049 / RSS-Gen 6.7 Occupied bandwidth	N/A	Note 1
2.1049 / RSS-247 5.5 Band Edge	Yes	
RF Exposure: 47 CFR 2.1093 Portable devices SAR test exclusion threshold/ RSS-102 2.5.1 Exemption from Routine Evaluation limits – SAR Evaluation	Yes	

Note 1: No limit specified in the Rules / standards.

Client

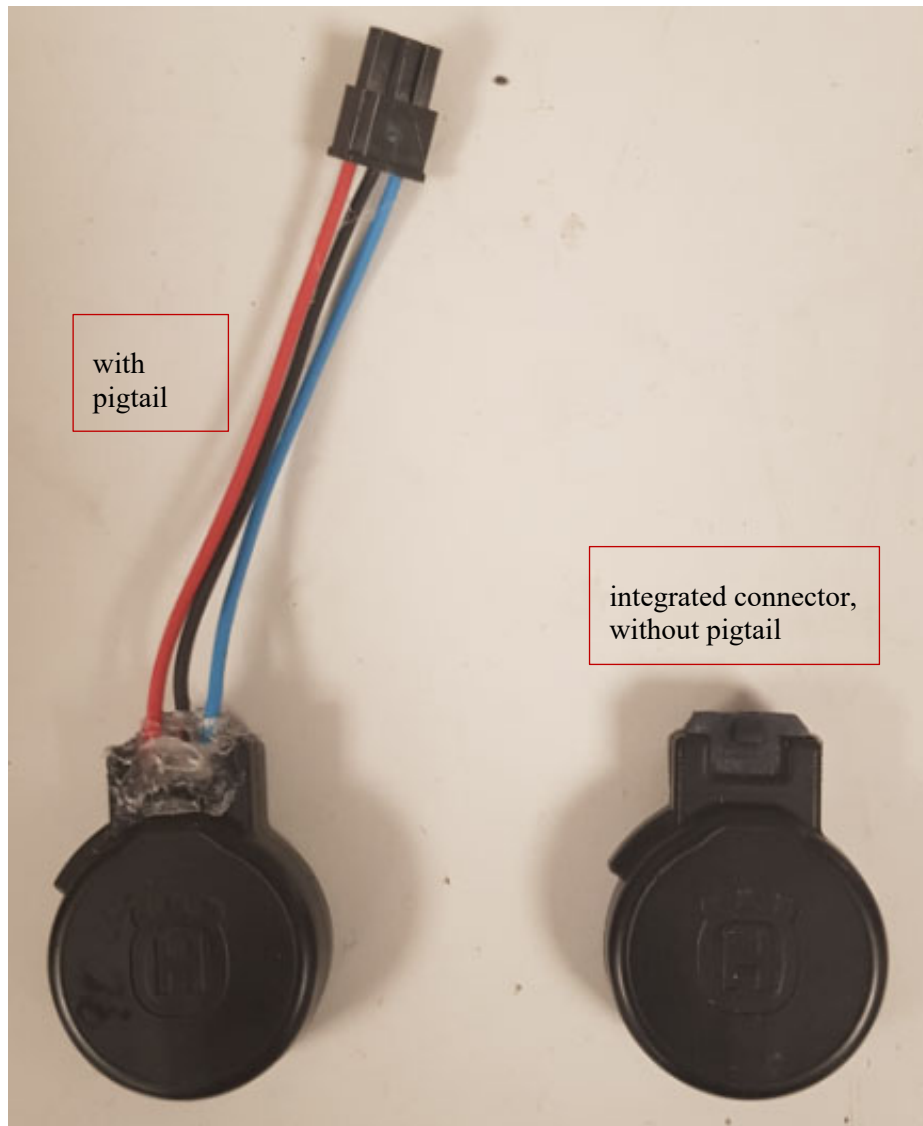
Therese Berg
Husqvarna AB
Drottninggatan 2
561 82 Huskvarna

Description of the EUT

The EUT is an accessory for use with Husqvarna combustion engine driven products. With this accessory installed, the user can get operating data from the associated product wirelessly via a Bluetooth (BLE) compatible device with the Husqvarna application software installed. There are two variants of the EUT, one with integrated connector and one with "pigtail". The housing of the EUT is moulded. The EUT is powered by its internal cell coin battery or by the engine management system of the combustion engine while running.

The two variants:

HVIN: 5.7.2-R5D (with pigtail) HVIN: 5.7.3-R5D (integrated connector)



Technical data:

Operational frequency range:	2402-2480 MHz
Antenna:	Integral onboard
Antenna manufacturer, model name:	Abracon/Proant PRO-OB-440
Antenna gain	5.2 dBi, Peak
Rated maximum Power:	0 dBm Peak, Conducted
Power tolerance:	±4 dB
Supported data rate:	1 Mbit/s
Modulation:	FSK
Supply voltage, internal battery/ combustion engine management system	3 VDC 5 – 15 VDC

List of used EUT samples

#101 – used in conducted tests

Samples used in radiated tests	
sample	HID-number in QR-code
#1	599581601OGJ2021365000244
#2	599581601OGJ2021365000213
#3	599581601OGJ2021365000015
#4	599581601OGJ2021365000299
#5	596816301OGJ2021263001540
#6	596816301OGJ2021263000857
#7	596816301OGJ2021263001366
#8	599581601OGJ2022012001041
#9	596816301OGJ2022024000543
#10	596816301OGJ2022024000642

Justification measurements

Justification measurements were performed with rotation of the EUT through three orthogonal axes to determine which orientation the EUT had the highest emission levels.

Operational test mode

The tests were performed at lowest (2402 MHz), middle (2440 MHz) and the highest (2480 MHz) channels.

Used test samples:

Sample #101 with temporary antenna connector was used for the conducted tests.

Radiated samples #1 to #10 were used for test in radiated mode, with internal antenna.

Since the radio was continuously transmitting, the internal battery ran out of power and therefore several devices had to be used as the battery could not be exchanged or charged, due to the moulded housing. The batteries were checked regularly before and after tests.

All the tests were performed with 100 % duty cycle (except for the duty cycle measurements) with normal modulation. The test equipment was connected to an external 10 MHz reference standard during measurements.

Ancillary and/or support equipment

Lap top PC, Dell with dedicated software	Client equipment
Software used during radio test: - Radiotest, Nordic's SDK 15.3	Client software

Orientations of the test object during the radiated measurements:

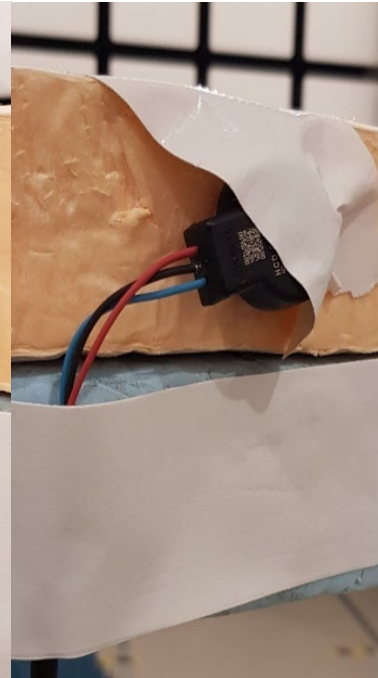
Pos 1



Pos 2



Pos 3



Pos 1b



Pos 2b



Pos 3b



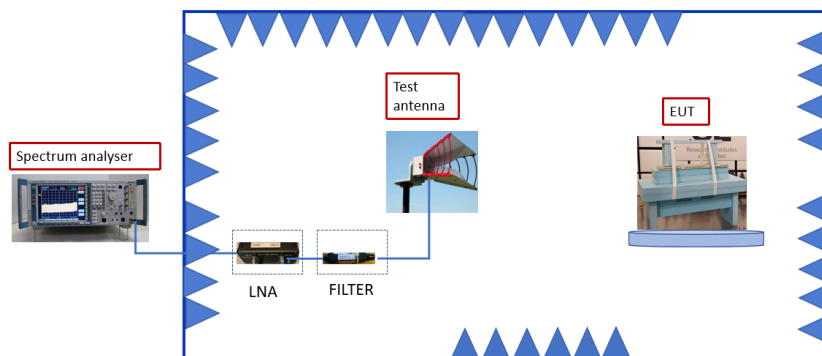
Measurement equipment

Item	Name	Inv.no	Cal.due date
Test site, SVSWR	Semi anechoic chamber, Edison	504114	2024-08-05
Test site, NSA	Semi anechoic chamber, Edison	504114	2023-04-14
Test Software	R&S EMC32	503889	
Spectrum Analyzer	R&S ESU 26	902210	2022-07-28
Attenuator	JFW 50HF-006 6 dB	BX61531	2022-09-22
Antenna	Teseq CBL 6143A	504079	2024-07-14
Antenna, Horn	ETS-Lindgren 3115	902212	2024-11-25
Antenna, Std.gain Horn	Flann 16240-20	503673	-
Antenna, Std.gain Horn	Flann 18240-20	503673	-
Antenna, Std.gain Horn	Flann 20240-20	BX92412	-
Antenna, Std.gain horn	Flann 22240-20	BX92413	-
RF Cable	Rosenberger Micro-coax Uniflex	504102	2023-03-24
RF Cable	Huber & Suhner SF106	504103	2023-03-24
RF Cable	Huber & Suhner SF106	504104	2023-03-24
RF Cable	Huber & Suhner Eacon 4C	BX91501	2023-06-17
RF Cable	Rosenberger F147AF015M2020	503697	2023-01-28
Preamplifier	Schwarzbeck BBV 9742	504085	2023-01-25
Preamplifier	Miteq MCN-JS42-00101800-30-10P	504160	2023-01-25
Preamplifier	Miteq JS4-18004000-30-5A	503278	2023-01-25
RF Filter, 3 GHz High Pass	Wainwright pass filter WHNX	901502	2023-06-08
Multimeter	Fluke 83	501522	2023-05-11
Thermohygrometer	Testo 625	504117	2023-06-30

Item	Name	Inv.no	Cal.due date
Test system	R&S TS8997	BX91608	2022-07-21
Test Software	R&S WMS32	BX62351	
Spectrum Analyzer	R&S FSQ26	BX50694	2022-07-21
Vector signal generator	R&S SMBV100A	BX62243	2022-07-21
Signal generator	R&S SMF100A	BX50695	2022-07-21
Power meter/Switch box	R&S OSP 120	BX60313	2023-07-21
RF Cable	-	BX50693	2023-06-30
RF Cable	-	BX81423	2023-04-22
RF Cable	-	BX50692	2023-06-30
RF Cable	-	BX50685	2023-07-05
Multimeter	Fluke 85 III	503418	2023-05-11
Thermohygrometer	Testo 615	503498	2023-06-30
Power supply	Keysight 3631A	503997	-

Item	Name	Inv.no	Cal.due date
Test site, SVSWR	Semi anechoic chamber, Tesla	503881	2024-09-20
Test site, NSA	Semi anechoic chamber, Tesla	503881	2022-12-11
Spectrum analyser	Rohde & Schwarz ESU40	901385	2022-07-23
Test Software	Rohde & Schwarz EMC32	BX62351	
RF cable	Huber & Suhner Eacon 4C	BX91490	2022-07-05
RF cable	Rosenberger UFB311A	503508	2022-09-13
RF cable	Rosenberger UFB311A	503509	2022-09-13
Antenna, Bilog	Teseq CBL6143A	BX92331	2022-09-12
Preamplifier	MicroComp Nordic MCN-JS42-00101800-28-10P	901545	2023-01-26
Preamplifier	Schwarzbeck BBV9744	BX52356	2023-01-26
Antenna, Horn	Emco 3115	502175	2024-07-02
Antenna, Std.gain Horn	Flann 16240-25	503939	-
Antenna, Std.gain Horn	Flann 18240-25	503900	-
Preamplifier	Miteq JS4-18004000-30-5A	503278	2023-01-25
Antenna, Std.gain horn	Flann 20240-20	BX92412	-
Antenna, Std.gain horn	Flann 22240-20	BX92413	-
Thermohygrometer	Testo Testo 625	504188	2023-06-30

Block diagram – radiated test



Note: tests above 1 GHz were done with absorbers on the floor, but tests below 1 GHz were done without absorbers on the floor.

LNA and filter are used according to need.

Sample calculation – radiated test

The transducer factors are stored in emission software/spectrum analyser as separate files and activated as applicable in the hardware setup, for each measurement configuration.

Radiated emission (dBuV/m):

General:

Final result (dBμV/m) = Spectrum analyser raw recording (dBμV) + Total Transducer Factor (dB/m)

Detailed:

The calculation of the measured radiated E-field signal level is given by:

$$E \text{ (dBuV/m)} = V \text{ (dBuV)} + Cl_1 \text{ (dB)} - \text{PAG (dB)} + \text{HPF (dB)} + Cl_2 \text{ (dB)} + \text{AF (dB/m)}$$

Where:

$E \text{ (dBuV/m)}$ = Measured E-field

$V \text{ (dBuV)}$ = Spectrum analyser raw recording

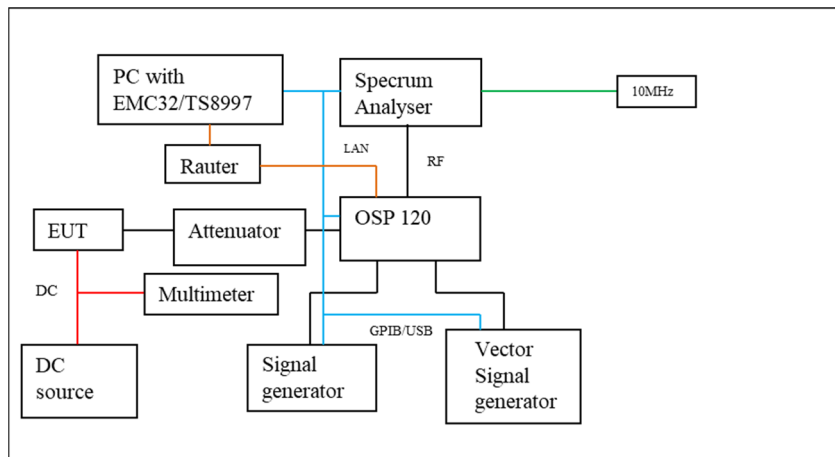
Cl_1 (dB) = Loss in cable 1
 PAG (dB) = PreAmplifier Gain
 HPF (dB) = High Pass Filter
 Cl_2 (dB) = Loss in cable 2
 AF (dB/m) = Antenna Factor

Calculation between electric field strength and EIRP was done using this equation (power in mW):

$$* E[dB\mu V/m] = 20 \cdot \log(10^6 \cdot \frac{\sqrt{30 \cdot P \cdot 10^{-3}}}{d})$$

For $d = 3$ m: $P[dBm] = E[dB\mu V/m] - 95.23$

Block diagram – conducted test



Sample calculation – conducted test

The internal losses in the base unit OSP-B157W8 are calibrated and internally saved. The measured values are corrected for those losses automatically by WMS32 without any action of the operator.

Transfer function of all equipment used during the test, (cables, filters, amplifiers, etc.), are saved as attenuations or transducer factors in the correction tables.

They are activated as applicable in the hardware setup and test template for actual measurement configuration.

General:

Final result (dBm) = Spectrum analyser raw recording (dBm) + Total Correction (dB)

Detailed:

The calculation of the measured signal level, (fundamental, harmonic, spurious...) is given by:

$$P_t \text{ (dBm)} = P_r \text{ (dBm)} + Cl_{int} \text{ (dB)} + Cl_{EUT} \text{ (dB)} + Cl_{SA} \text{ (dB)}$$

Where:

P_t (dBm) = Measured Power of the emission

P_r (dBm) = Spectrum analyzer raw recording

Cl_{int} (dB) = Internal losses in OSP-B157W8

Cl_{EUT} (dB) = Loss in cable and attenuator between EUT and OSP

Cl_{SA} (dB) = Loss in cable between OSP and spectrum analyser

Test facility

The used semi-anechoic chamber is compliant with ANSI C63.4. RISE is an ISO 17025 accredited test facility for Electromagnetic Compatibility (EMC) and Radio testing.

RISE is Recognized Lab under FCC (Designation number: SE0001) and ISED (CAB identifier: SE0002).

References

Measurements were done according to relevant parts of the following standards:

ANSI 63.4-2014

ANSI 63.10-2013

eCFR 47, part 15 C, January 2022

eCFR 47, 2.1049, January 2022

eCFR 47, 2.1093, January 2022

RSS-247, Issue 2

ISED Notice 2021-CEB0001. April 19, 2021

RSS-Gen Issue 5+A1

RSS-102 Issue 5

KDB 558074 D01 DTS Meas Guidance v05r02

KDB 447498 D01 General RF Exposure Guidance v06

Uncertainties

Measurement and test instrument uncertainties are described in the quality assurance documentation RISE – 3936. The uncertainties are calculated with a coverage factor $k=2$ (95% level of confidence). Compliancy evaluation is based on a shared risk principle with respect to the measurement uncertainty.

Method	Uncertainty
Duty cycle	1.3 %
6 dB bandwidth	2.6 %
Maximum conducted power	2.6 dB
Restricted bands of operation:	
Radiated emission, 30 – 1000 MHz	6.3 dB
Radiated emission, 1 – 6 GHz	5.2 dB
Radiated emission, 6 – 40 GHz	5.6 dB
Conducted Power spectral density	2.2 dB
RF Safety	2.6 dB
Occupied bandwidth	2.6 %

Reservation

The test results in this report apply only to the particular test object as declared in the report.

Delivery date of EUT

2022-01-11

Test engineers

Markel Bertilsson, Fredrik Isaksson and Ermin Pasalic, RISE

Test participants

Fredrik Moll, Husqvarna AB

Test results

Duty cycle measurements

Date 2022-01-11 and 12	Temperature 21 °C ± 2 °C	Humidity 15 % ± 5 %
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Test setup and procedure

Additional measurements/information were performed according to ANSI C63.10 clause 11.6 and KDB 558074 D01 clause 6.

Conducted measurements were performed at the temporary antenna connector.
The test was performed with continuous transmission and with normal (maximum) duty cycle.
Tested on sample #101.

Measurement equipment

Item	Name	Inv.no
Spectrum Analyzer	R&S FSQ26	BX50694
RF Cable	-	BX81423
Multimeter	Fluke 85 III	503418
Thermohygrometer	Testo 615	503498
Power supply	Keysight 3631A	503997

Remarks

No remarks.

Limits

No limit specified in the Rules / standards.

Results

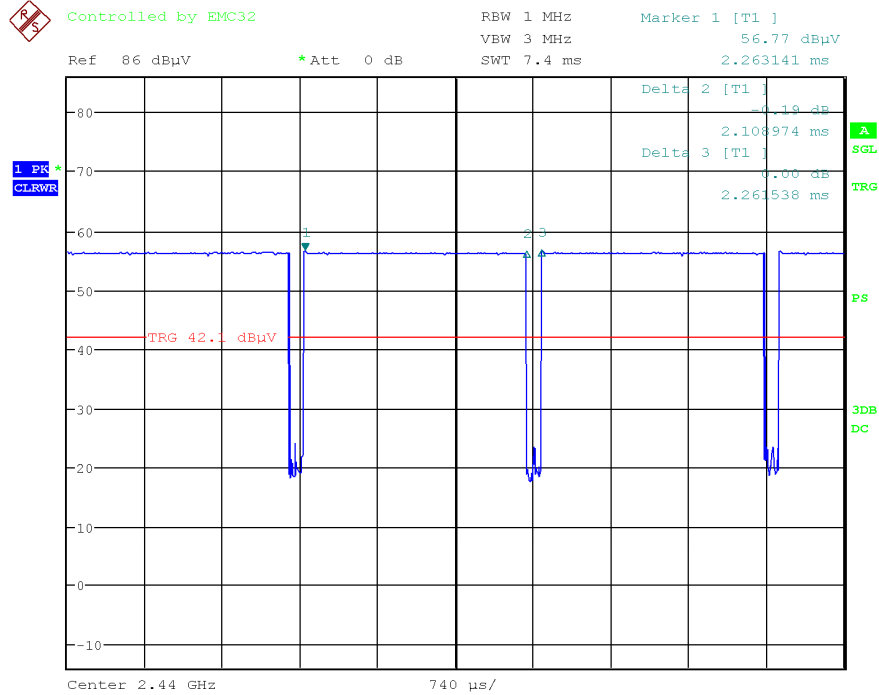
The duty cycle measurements can be found in the charts below:

Chart 1	2440 MHz	Normal duty cycle, measured 93.3 %
Chart 2	2440 MHz	Continuous transmission, duty cycle 100%

Test engineer Markel Bertilsson

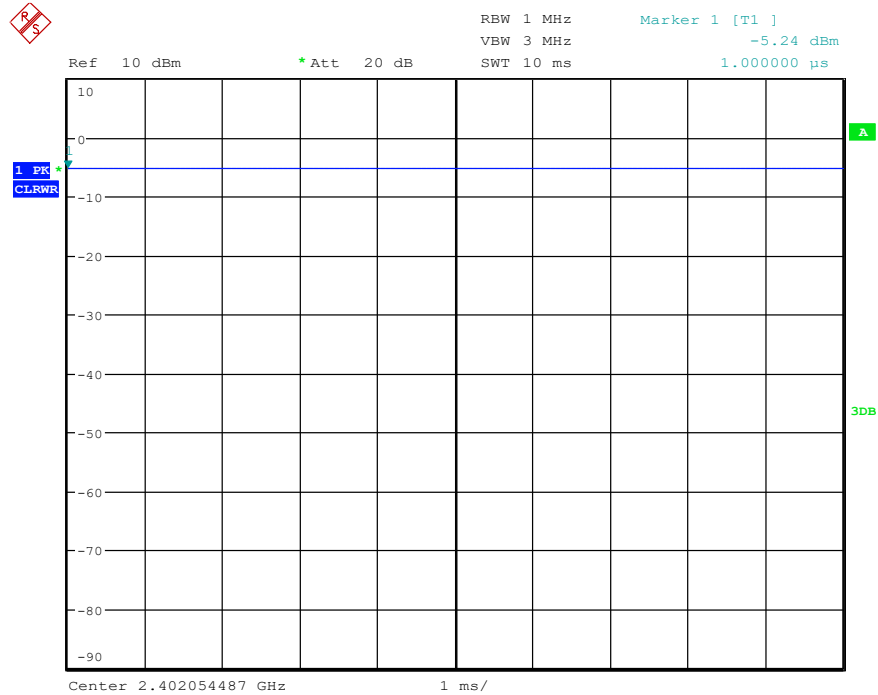
Compliant?	N/A
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Chart 1



Date: 12.JAN.2022 15:06:53

Chart 2



Date: 11.JAN.2022 10:45:16

6 dB / DTS bandwidth

Date 2022-01-11	Temperature 22 °C ± 2 °C	Humidity 20 % ± 5 %
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Test setup and procedure

The measurements were performed according to according to FCC 47 CFR part 15.247 (a) (2) / RSS-247 5.2 a) and ANSI C63.10, clause 11.8.

Conducted measurements were performed at the temporary antenna connector with continuous transmission (100% duty cycle) and with normal modulation. Tested on sample #101.

Measurement equipment

Item	Name	Inv.no
Test system	R&S TS8997	BX91608
Test Software	R&S WMS32	BX62351
Spectrum Analyzer	R&S FSQ26	BX50694
Vector signal generator	R&S SMBV100A	BX62243
Signal generator	R&S SMF100A	BX50695
Power meter/Switch box	R&S OSP 120	BX60313
RF Cable	-	BX50693
RF Cable	-	BX81423
RF Cable	-	BX50692
RF Cable	-	BX50685
Multimeter	Fluke 85 III	503418
Thermohygrometer	Testo 615	503498
Power supply	Keysight 3631A	503997

Limits

According to 47 CFR 15.247(a)(2), the minimum 6 dB/DTS bandwidth shall be at least 500 kHz.

According to RSS-247 5.2 a), the minimum 6 dB/DTS bandwidth shall be **at least 500 kHz**.

Results

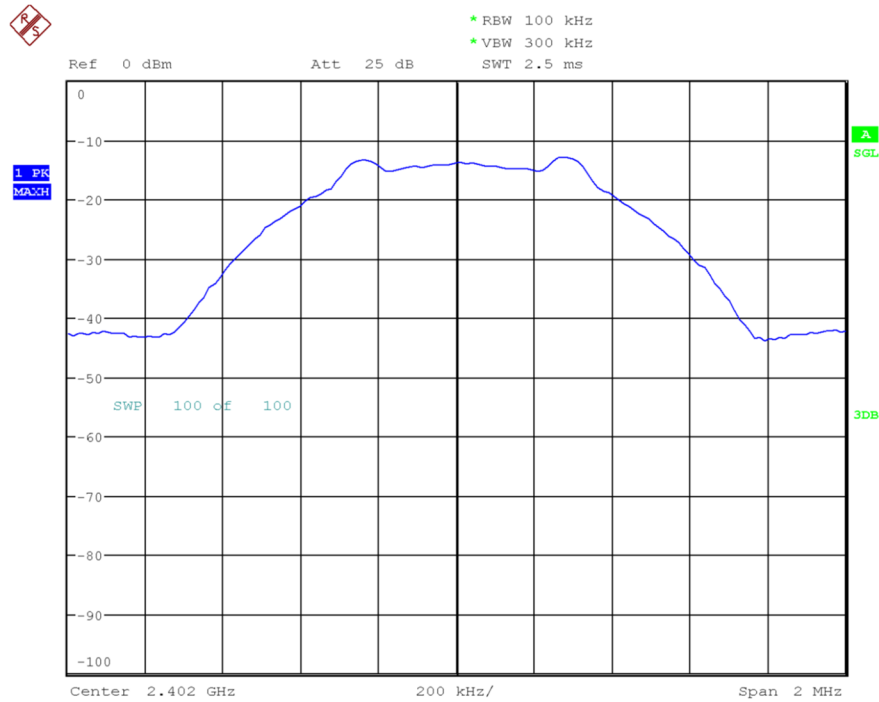
The 6 dB measurements can be found in the table and charts below:

Freq (MHz)	Bandwidth
2402	753 kHz
2440	740 kHz
2480	753 kHz

Test engineer Markel Bertilsson

Compliant?	Yes
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Chart to show settings for the measurement



Date: 20.JAN.2022 12:22:53

Maximum peak output power

Date	Temperature	Humidity
2022-01-20	23 °C ± 2 °C	20 % ± 5 %
2022-05-31	21 °C ± 2 °C	43 % ± 5 %
2022-07-01	22 °C ± 2 °C	32 % ± 5 %

Test setup and procedure

The measurements were performed according to FCC 47 CFR part 15.247 (b) (3) / RSS-247 5.4 d) and ANSI C63.10, clause 11.9.1.1 (peak) for radiated tests and for conducted tests clause 11.9.1.3 method PKPM1 (Peak) and 11.9.2.3.2, Method AVGPM-G (Average).

The test was performed with continuous transmission (100% duty cycle) and with normal modulation.

The test was performed both radiated and conducted, conducted tests were performed at the temporary antenna connector.

The maximum peak radiated output power measurements were performed radiated in the semi-anechoic chamber with EUT at 1.5 m height. The fundamental was scanned with peak-detector, the antenna height 1-4 m and the turntable were varied between 0-360 degrees for maximum response. The antenna distance during the measurements was 3.0 m.

Measurement equipment

Item	Name	Inv.no
Test system	R&S TS8997	BX91608
Test Software	R&S WMS32	BX62351
Spectrum Analyzer	R&S FSQ26	BX50694
Vector signal generator	R&S SMBV100A	BX62243
Signal generator	R&S SMF100A	BX50695
Power meter/Switch box	R&S OSP 120	BX60313
RF Cable	-	BX50693
RF Cable	-	BX81423
RF Cable	-	BX50692
RF Cable	-	BX50685
Multimeter	Fluke 85 III	503418
Thermohygrometer	Testo 615	503498
Power supply	Keysight 3631A	503997

Item	Name	Inv.no
Test site, SVSWR	Semi anechoic chamber, Tesla	503881
Spectrum analyser	Rohde & Schwarz ESU40	901385
Test Software	Rohde & Schwarz EMC32	BX62351
RF cable	Huber & Suhner Eacon 4C	BX91490
RF cable	Rosenberger UFB311A	503508
RF cable	Rosenberger UFB311A	503509
Antenna, Horn	Emco 3115	502175
Thermohygrometer	Testo Testo 625	504188

Item	Name	Inv.no
Test site, SVSWR	Semi anechoic chamber, Edison	504114
Test Software	R&S EMC32	503889
Spectrum Analyzer	R&S ESU 26	902210
Attenuator	JFW 50HF-006 6 dB	BX61531
Antenna, Horn	ETS-Lindgren 3115	902212
RF Cable	Rosenberger Micro-coax Uniflex	504102
RF Cable	Huber & Suhner SF106	504103
RF Cable	Huber & Suhner SF106	504104
RF Cable	Huber & Suhner Eacon 4C	BX91501
Multimeter	Fluke 83	501522
Thermohygrometer	Testo 625	504117

Limits

According to 47 CFR 15.247(b)(3), for systems using digital modulation in the 2400-2483.5 MHz band: 1 Watt (30 dBm).

According to RSS-247 5.4 d), for systems employing digital modulation techniques in the band 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1 Watt (30 dBm). The e.i.r.p. shall not exceed 4 W, except as provided in section 5.4(e).

Results**CONDUCTED**

Test sample #101

Maximum conducted output power

Without Pigtail, (Battery powered)

Freq (MHz)	3 V		Test system
	RMS (dBm)	Peak (dBm)	
2402	-1.2	-0.4	TS8997
2440	-2.0	-1.2	TS8997
2480	-2.3	-1.4	TS8997

With Pigtail, (extern DC source)

Freq (MHz)	5 V		10 V		15 V		Test system
	RMS (dBm)	Peak (dBm)	RMS (dBm)	Peak (dBm)	RMS (dBm)	Peak (dBm)	
2402	-1.3	-0.4	-1.3	-0.5	-1.3	-0.5	TS8997
2440	-2.0	-1.4	-2.1	-1.4	-2.1	-1.4	TS8997
2480	-2.4	-1.5	-2.4	-1.5	-2.5	-1.5	TS8997

RADIATED

Test sample #6, (Without Pigtail)

EUT pos: 1b

Max peak **radiated** output power (peak)

Freq (MHz)	Field at 3m (dBμV/m)	Peak (dBm)	Chart	Test Lab
2402	81.0	-14.2	Chart 1	Tesla
2440	80.9	-14.3	Chart 2	
2480	80.5	-14.7	Chart 3	

Test sample #8, (With Pigtail)

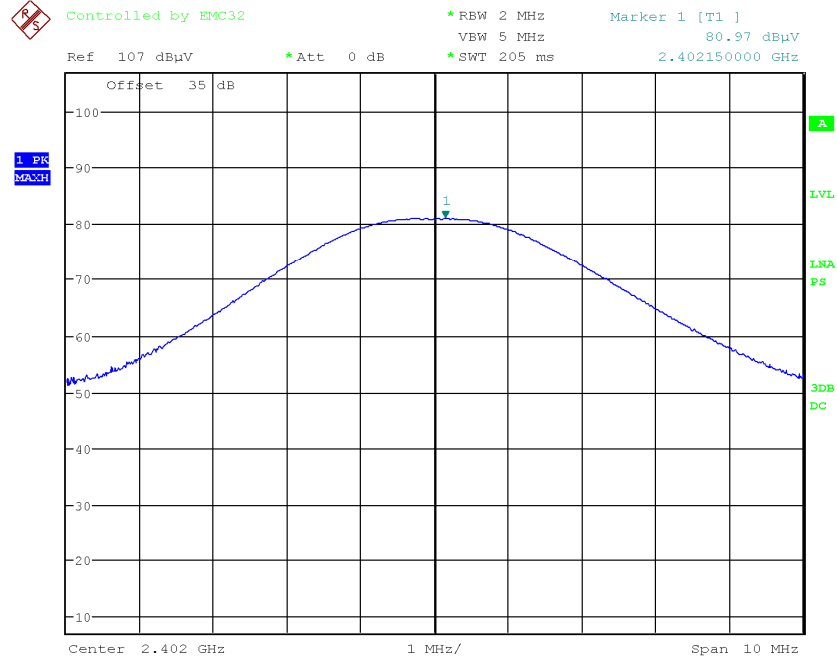
EUT pos: 3

Max peak **radiated** output power (peak)

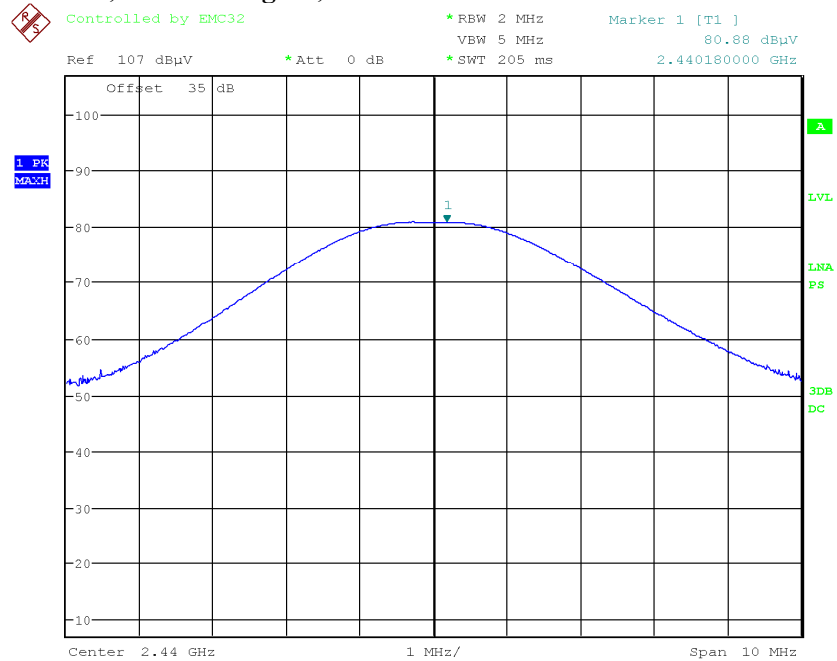
Freq (MHz)	Field at 3m (dBμV/m)	Peak (dBm)	Chart	Test Lab
2440	80.7	-14.5	Chart 4	Edison

Test engineer Markel Bertilsson and Ermin Pasalic

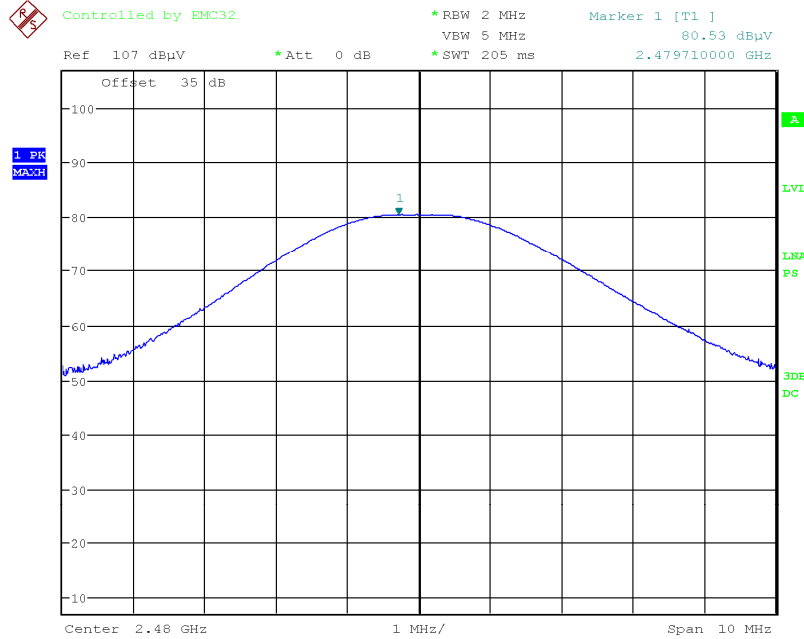
Compliant?	Yes
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Chart 1, Without Pigtail, 2402 MHz

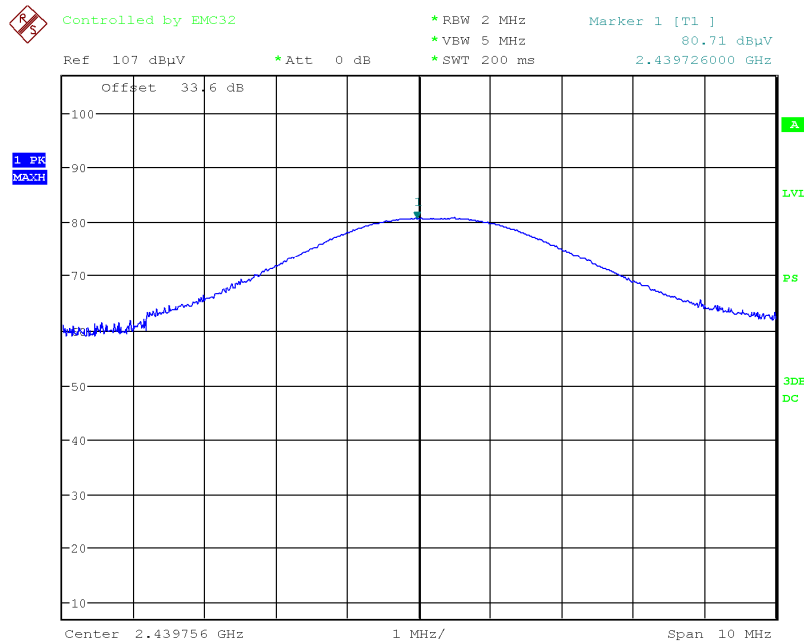
Date: 31.MAY.2022 15:36:35

Chart 2, Without Pigtail, 2440 MHz

Date: 31.MAY.2022 15:29:13

Chart 3, Without Pigtail, 2480 MHz

Date: 31.MAY.2022 15:42:15

Chart 4, With Pigtail, 2440 MHz

Date: 1.JUL.2022 12:32:17

Restricted bands of operation measurements and 20 dBc below fundamental/non restricted bands measurements

Date	Temperature	Humidity
2022-01-17 to 2022-01-19	21°C ± 2 °C	25 % ± 5 %
2022-05-31	21°C ± 2 °C	43 % ± 5 %
2022-06-30	23°C ± 2 °C	35 % ± 5 %
2022-07-02	22°C ± 2 °C	31 % ± 5 %

Test setup and procedure

The measurements were performed according to according to FCC 47 CFR part 15.247 (d) / RSS-247 5.5 and ANSI C63.10, clause 11.12. and clause 11.11.

The test was performed with continuous transmission (100% duty cycle) and with normal modulation.

The test of radiated emission was performed in a semi anechoic chamber. The measurements were performed with both horizontal and vertical polarizations of the antenna. The antenna distance was 3.0 m in the frequency range 30 MHz-18 GHz and 1.0 m in the frequency range 18-25 GHz.

The measurement procedure is as follows:

1. A pre-measurement is performed with peak detector. For measurement < 1 GHz the test object is measured in eight directions with the antenna at three heights, 1.0 m, 1.5 m and 2.0 m. For measurement between 1 GHz – 25 GHz the test object is measured in seventeen directions with the antenna at three heights, 1.0 m, 1.5 m and 2.0 m.
2. For measurements above 1 GHz, RF absorbers were covering an floor area to comply with site validation requirements according to CISPR 16-1-4:2010.
3. If the emission is close or above the limit during the pre-measurement, the test object is scanned 360 degrees and the antenna height scanned from 1 to 4 m for maximum response. Then the emission is measured with the quasi-peak detector on frequencies below 1 GHz and with the peak and average detector above 1 GHz.

The measurement was first performed with peak detector.

The following RBW were used:

30 MHz-1 GHz: RBW=120 kHz

1-25 GHz: RBW=1 MHz

Pictures of the test set-ups can be found in the photo section, in the end of the report.

Measurement equipment

Item	Name	Inv.no
Test site, SVSWR	Semi anechoic chamber, Edison	504114
Test site, NSA	Semi anechoic chamber, Edison	504114
Test Software	R&S EMC32	503889
Spectrum Analyzer	R&S ESU 26	902210
Attenuator	JFW 50HF-006 6 dB	BX61531
Antenna	Teseq CBL 6143A	504079
Antenna, Horn	ETS-Lindgren 3115	902212
Antenna, Std.gain Horn	Flann 16240-20	503673
Antenna, Std.gain Horn	Flann 18240-20	503673
Antenna, Std.gain Horn	Flann 20240-20	BX92412
Antenna, Std.gain horn	Flann 22240-20	BX92413
RF Cable	Rosenberger Micro-coax Uniflex	504102
RF Cable	Huber & Suhner SF106	504103
RF Cable	Huber & Suhner SF106	504104
RF Cable	Huber & Suhner Eacon 4C	BX91501
RF Cable	Rosenberger F147AF015M2020	503697
Preamplifier	Schwarzbeck BBV 9742	504085
Preamplifier	Miteq MCN-JS42-00101800- 30-10P	504160
Preamplifier	Miteq JS4-18004000-30-5A	503278
RF Filter, 3 GHz High Pass	Wainwright pass filter WHNX	901502
Multimeter	Fluke 83	501522
Thermohygrometer	Testo 625	504117

Item	Name	Inv.no
Test site, SVSWR	Semi anechoic chamber, Tesla	503881
Test site, NSA	Semi anechoic chamber, Tesla	503881
Spectrum analyser	Rohde & Schwarz ESU40	901385
Test Software	Rohde & Schwarz EMC32	BX62351
RF cable	Huber & Suhner Eacon 4C	BX91490
RF cable	Rosenberger UFB311A	503508
RF cable	Rosenberger UFB311A	503509
Antenna, Bilog	Teseq CBL6143A	BX92331
Preamplifier	MicroComp Nordic MCN-JS42-00101800-28-10P	901545
Preamplifier	Schwarzbeck BBV9744	BX52356
Preamplifier	Miteq JS4-18004000-30-5A	503278
Antenna, Horn	Emco 3115	502175
Antenna, Std.gain Horn	Flann 16240-25	503939
Antenna, Std.gain Horn	Flann 18240-25	503900
Antenna, Std.gain horn	Flann 20240-20	BX92412
Antenna, Std.gain horn	Flann 22240-20	BX92413
Thermohygrometer	Testo Testo 625	504188

Limits

According to 47 CFR 15.247(d), in any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in § 15.209(a) is not required. Radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a).

According to RSS-247 5.5, in any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean square averaging over a time interval, as permitted under Section A8.4(4), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

Results

The emission spectra measurement can be found in the charts below:

Chart 1	With pigtail, 30-1000 MHz, EUT operating at 2440 MHz, VP+HP, pos 3; Lab Edison, #4
Chart 2	With pigtail, 1-3 GHz, EUT operating at 2440 MHz, VP+HP, pos 3; Lab Edison, #3
Chart 3	With pigtail, 3-8.2 GHz, EUT operating at 2440 MHz, VP+HP, pos 3; Lab Edison, #3
Chart 4	With pigtail, 8.2-12.75 GHz, EUT operating at 2440 MHz, VP+HP, pos 3; Lab Edison, #2
Chart 5	With pigtail, 12.75-18 GHz, EUT operating at 2440 MHz, VP+HP, pos 3; Lab Edison, #2
Chart 6	With pigtail, 18-26 GHz, EUT operating at 2440 MHz, VP+HP, pos 3; Lab Edison, #4
Chart 7	Without pigtail, 30-1000 MHz, EUT operating at 2440 MHz, VP+HP, pos 1b; Lab Tesla, #7
Chart 8	Without pigtail, 1-3 GHz, EUT operating at 2440 MHz, VP+HP, pos 1b; Lab Tesla, #7
Chart 9	Without pigtail, 3-8.2 GHz, EUT operating at 2402 MHz, VP+HP, pos 1b; Lab Edison, #9
Chart 10	Without pigtail, 3-8.2 GHz, EUT operating at 2440 MHz, VP+HP, pos 1b; Lab Edison, #10
Chart 11	Without pigtail, 3-8.2 GHz, EUT operating at 2480 MHz, VP+HP, pos 1b; Lab Edison, #9

Note: Only worst-case plots are attached.

Final measurement results

With Pigtail:

2440 MHz, Chart 1

Frequency (MHz)	QuasiPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	MaxPeak (dBμV/m)	Pol.	Height (cm)	Azimuth (°)	Total TDF (dB/m)
41.759	18.69	40.00	21.31	25.33	V	102	45	23.3
43.077	17.79	40.00	22.21	24.07	V	100	200	22.7
45.719	16.87	40.00	23.13	22.92	V	162	186	21.4

2440 MHz, Chart 3

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	CAverage (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Pol.	Height (cm)	Azimuth (°)	Total TDF (dB/m)
7320.777	55.13	74.00	18.87	46.33	54.00	7.67	V	151	286	0.1

Without Pigtail:

2402MHz, Chart 9

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	CAverage (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Pol.	Height (cm)	Azimuth (°)	Total TDF (dB/m)
7205.275	56.65	74.0	17.35	47.60	54.0	6.40	V	118	264	1.1
7206.933	56.59	74.0	17.41	46.93	54.0	7.07	V	117	263	1.1

2440MHz, Chart 10

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	CAverage (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Pol.	Height (cm)	Azimuth (°)	Total TDF (dB/m)
7320.900	55.95	74.00	18.05	46.82	54.00	7.18	V	105	265	1.5

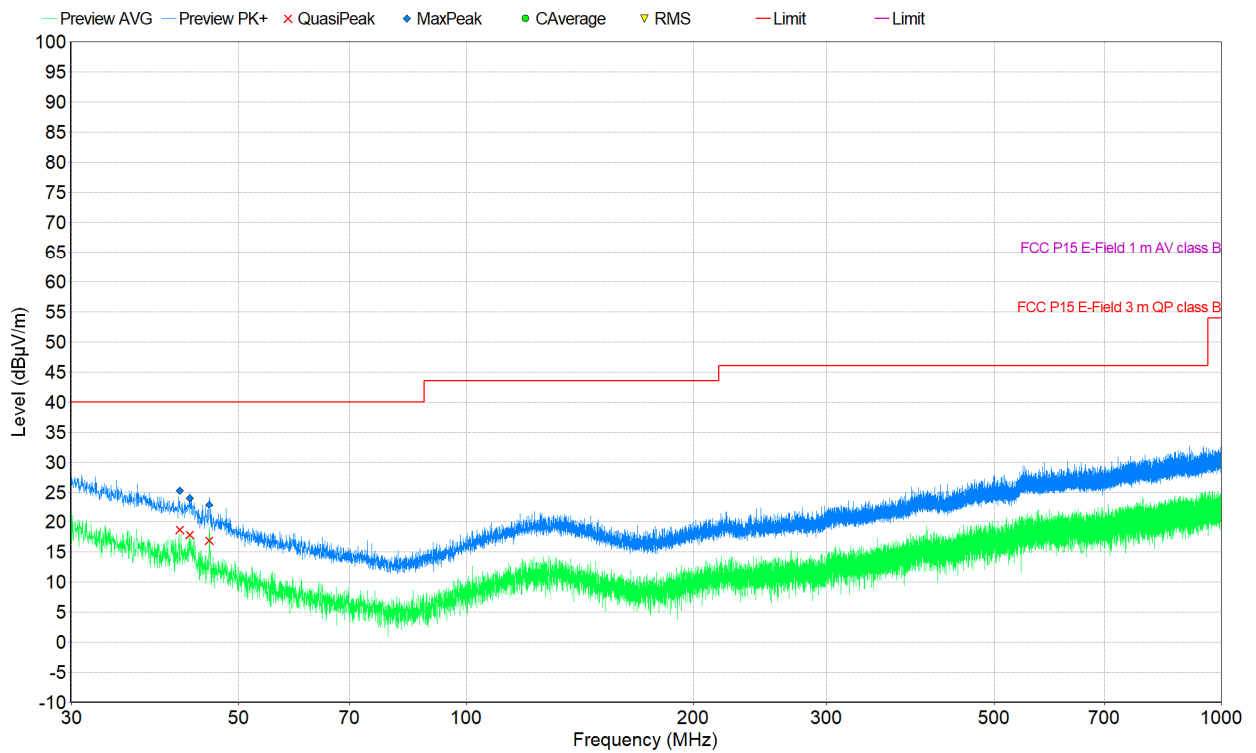
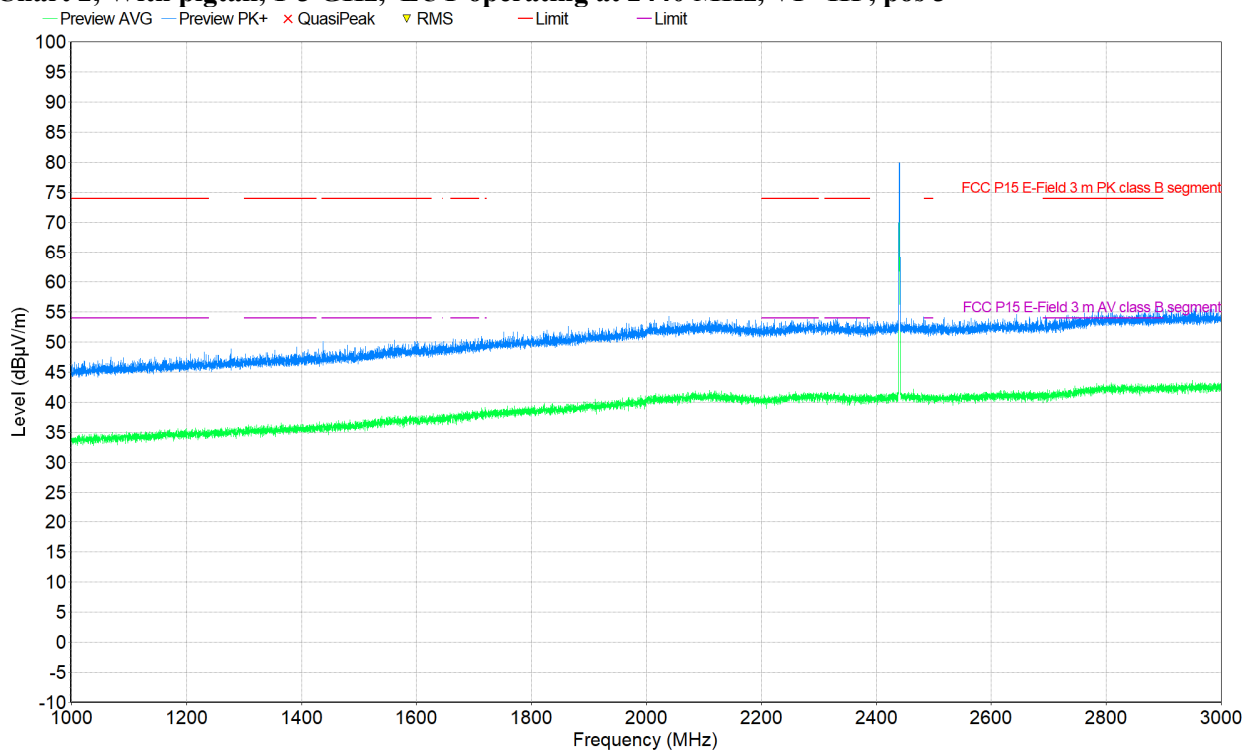
2480MHz, Chart 11

Frequency (MHz)	MaxPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	CAverage (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Pol.	Height (cm)	Azimuth (°)	Total TDF (dB/m)
7440.782	55.85	74.00	18.15	47.29	54.00	6.71	V	100	281	1.8
7440.983	55.24	74.00	18.76	45.66	54.00	8.34	V	103	282	1.8

Note: All emission levels are below limits specified in 15.209 and no need to apply 20 dBc requirement.

Test engineers Markel Bertilsson and Ermin Pasalic

Compliant?	Yes
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Chart 1, With pigtail, 30-1000 MHz, EUT operating at 2440 MHz, VP+HP, pos 3**Chart 2, With pigtail, 1-3 GHz, EUT operating at 2440 MHz, VP+HP, pos 3**

The emission above limit is the fundamental frequency, 2440 MHz, and shall be ignored.

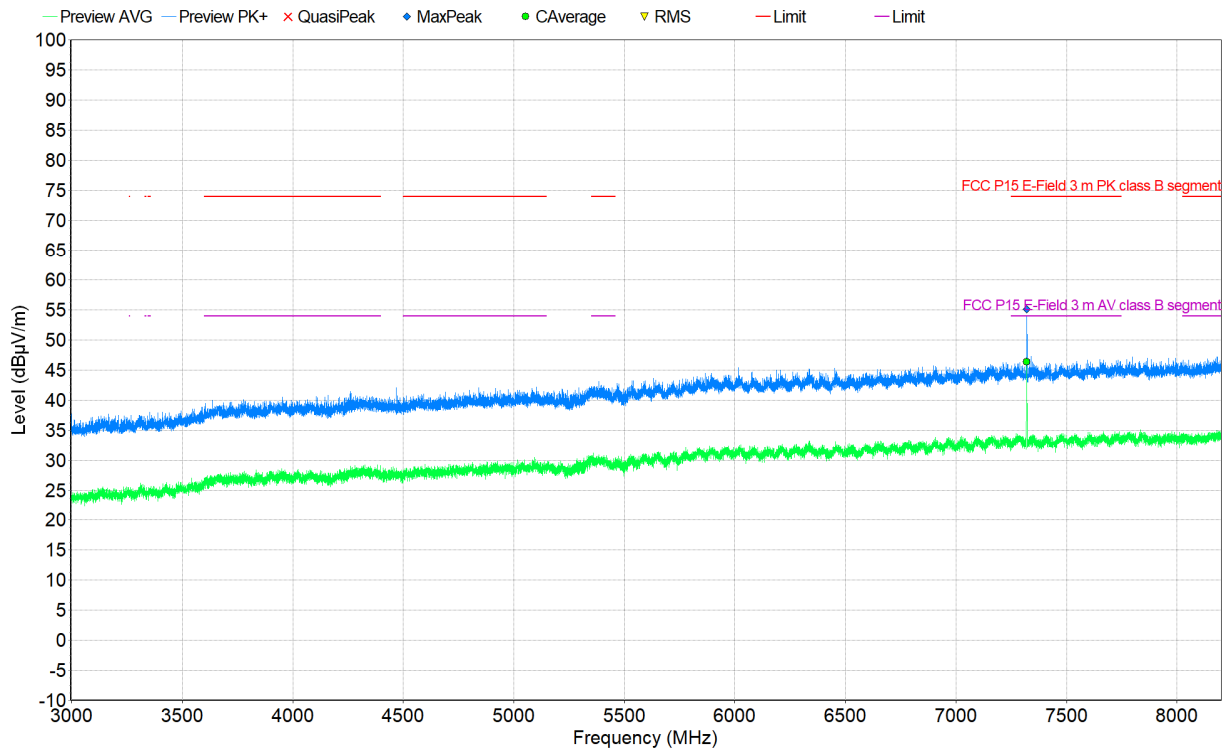
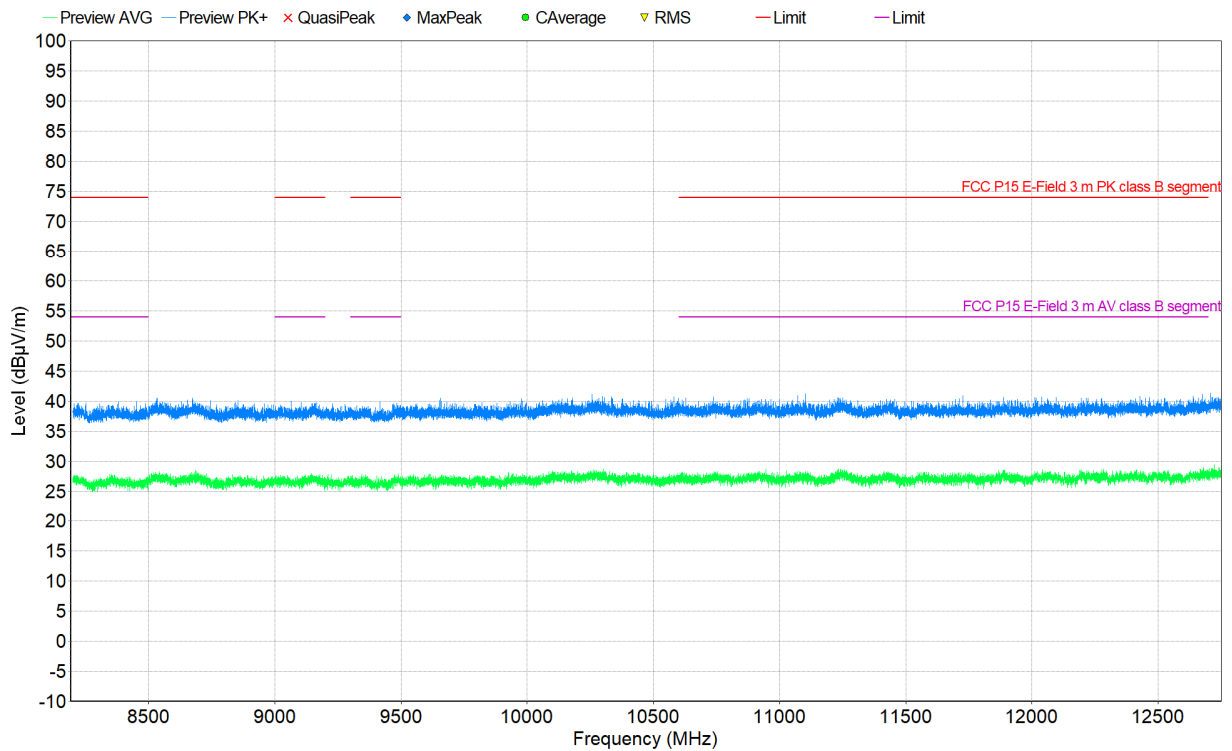
Chart 3, With pigtail, 3-8.2 GHz, EUT operating at 2440 MHz, VP+HP, pos 3**Chart 4, With pigtail, 8.2-12.75 GHz, EUT operating at 2440 MHz, VP+HP, pos 3**

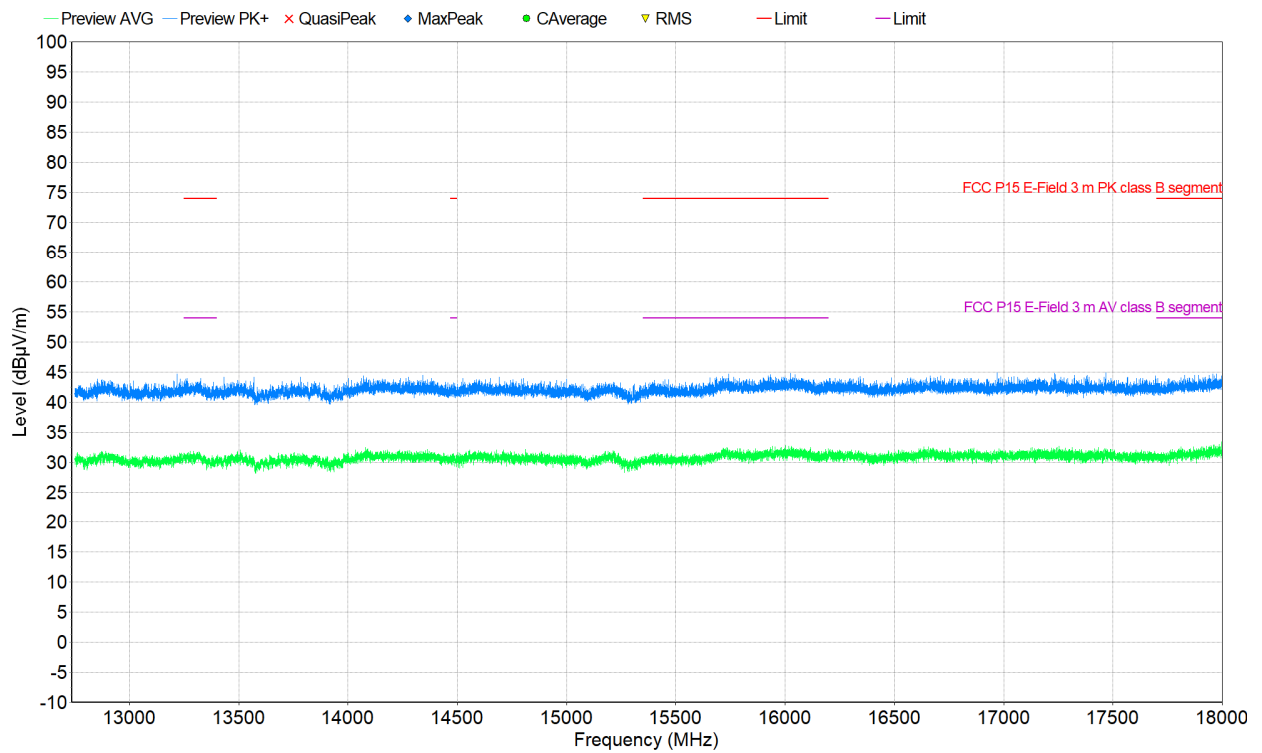
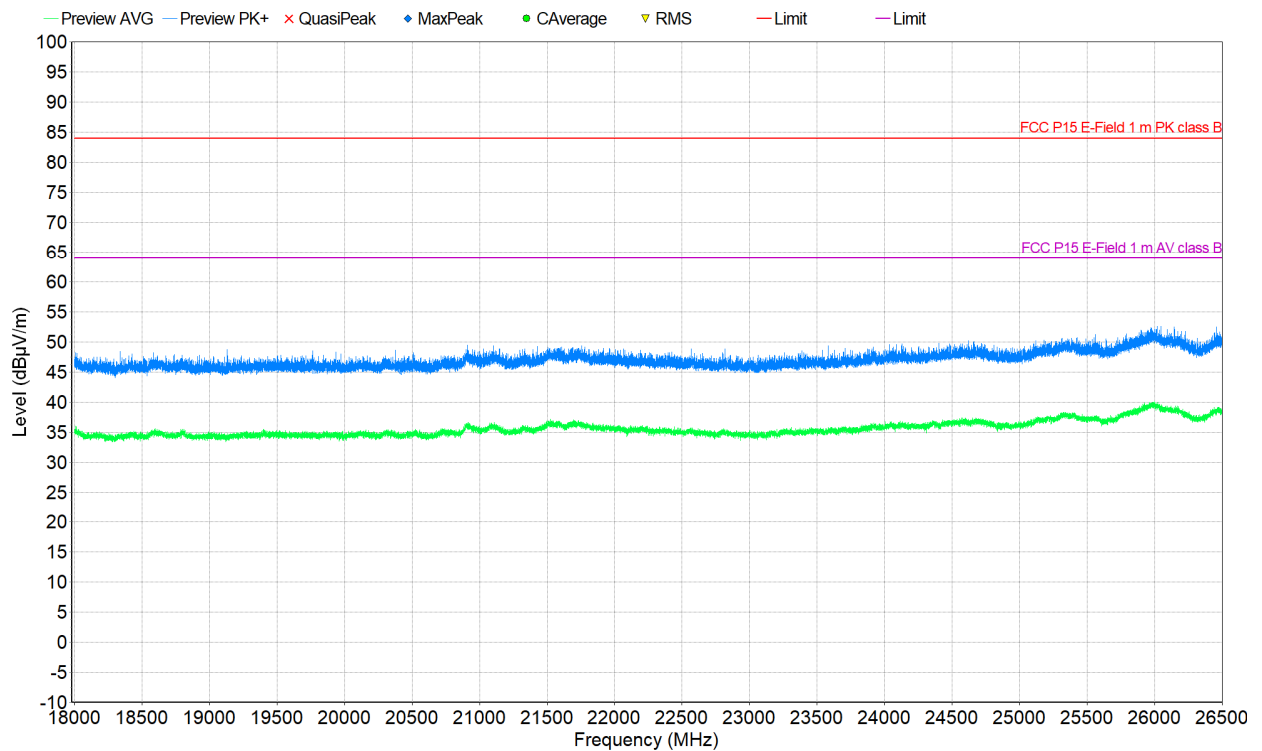
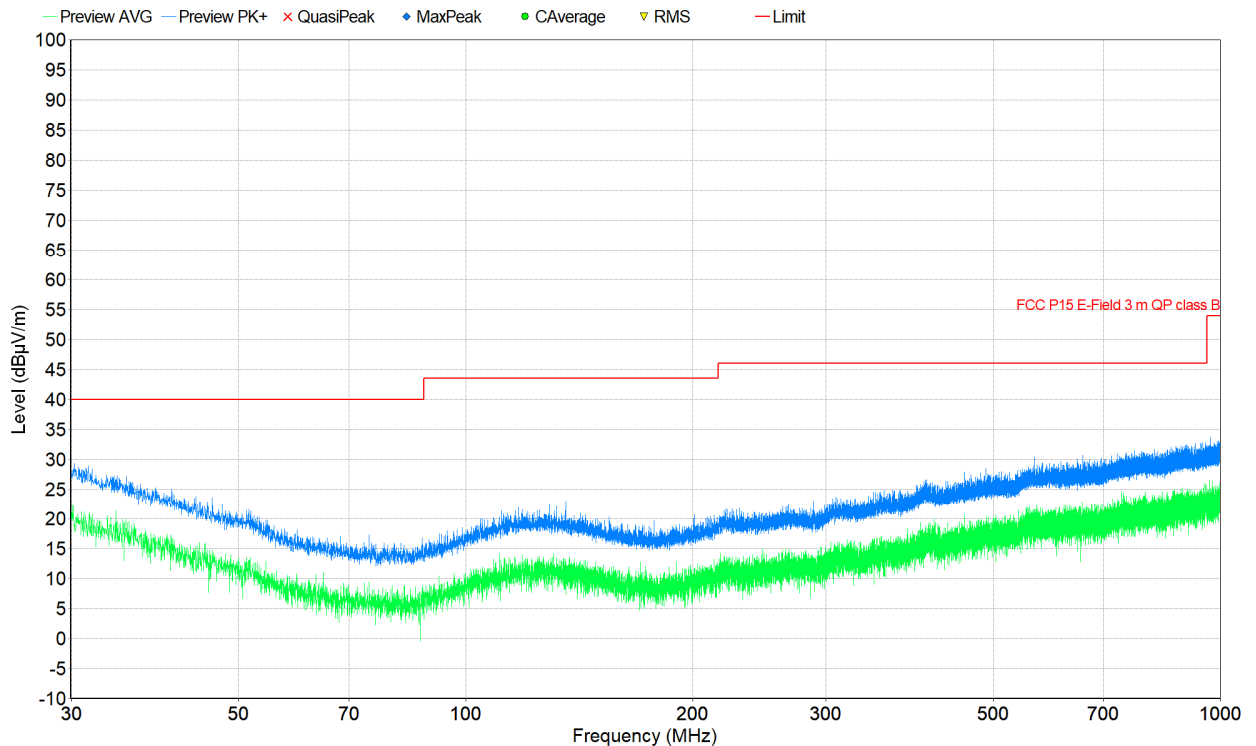
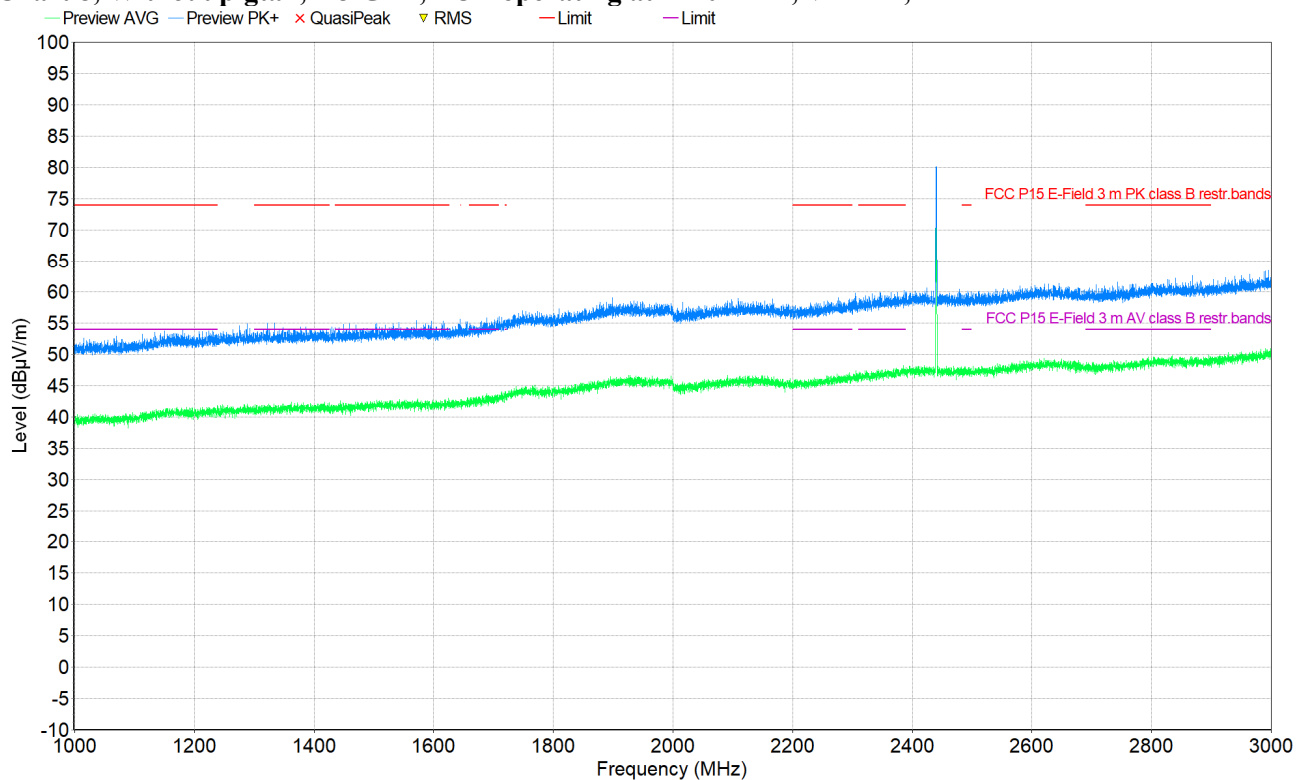
Chart 5, With pigtail, 12.75-18 GHz, EUT operating at 2440 MHz, VP+HP, pos 3**Chart 6, With pigtail, 18-26 GHz, EUT operating at 2440 MHz, VP+HP, pos 3**

Chart 7, Without pigtail, 30-1000 MHz, EUT operating at 2440 MHz, VP+HP**Chart 8, Without pigtail, 1-3 GHz, EUT operating at 2440 MHz, VP+HP;**

The emission above limit is the fundamental frequency, 2440 MHz, and shall be ignored.

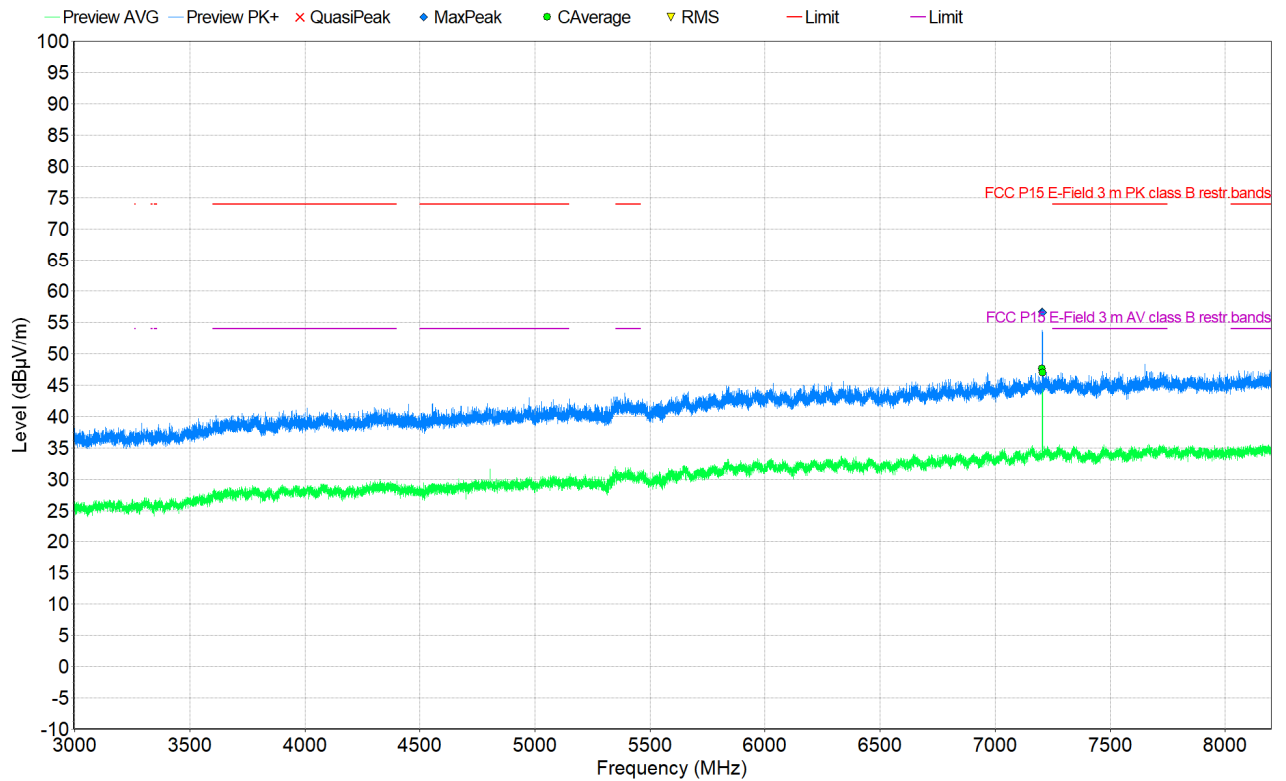
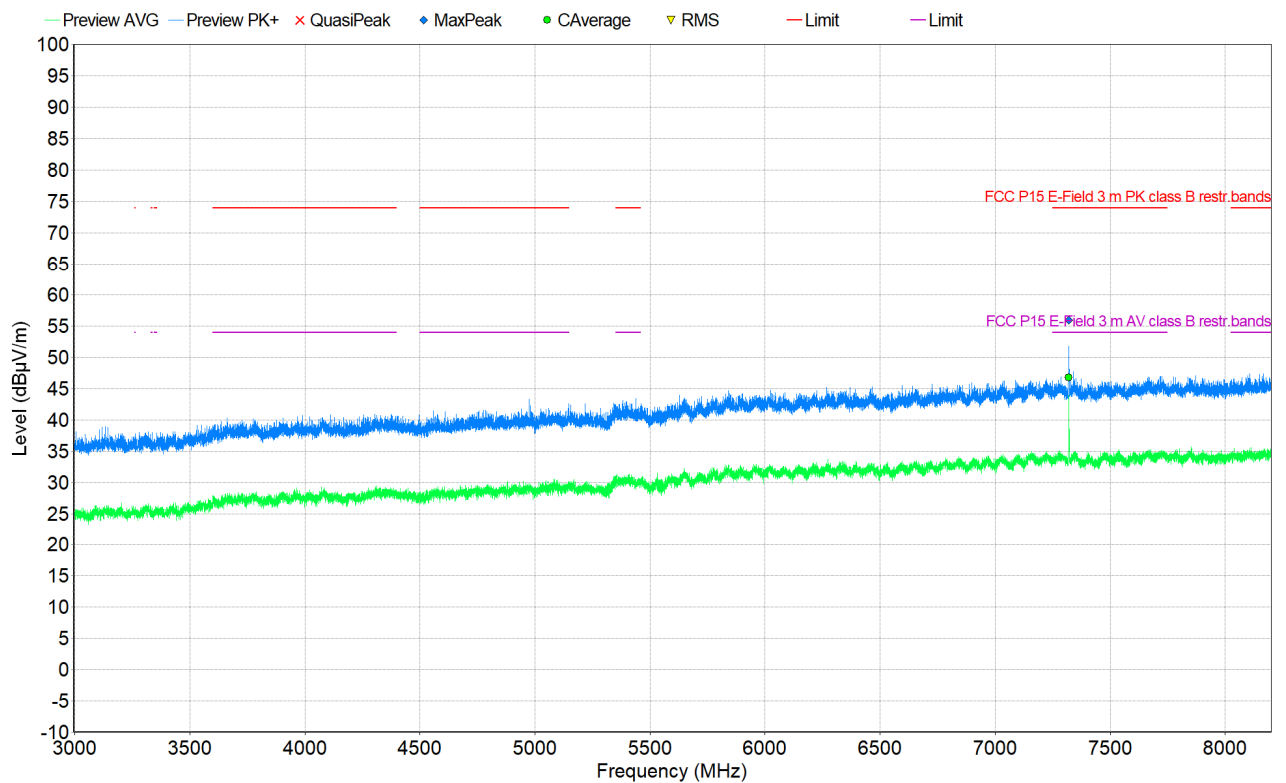
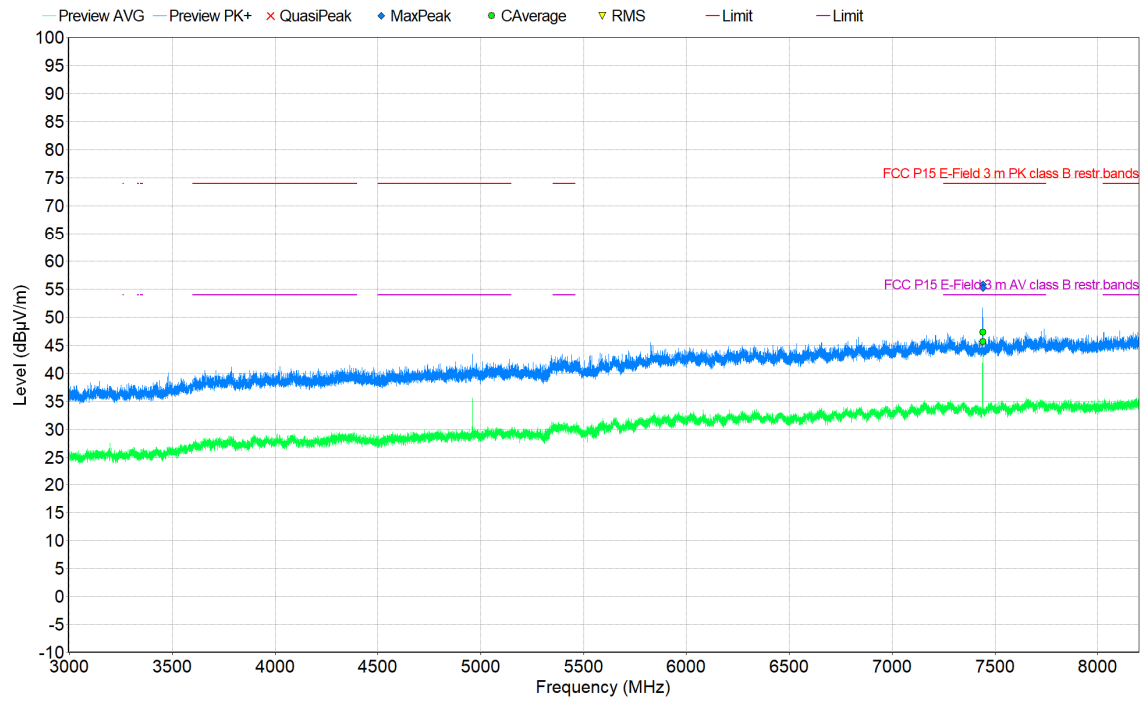
Chart 9, Without pigtail, 3-8.2 GHz, EUT operating at 2402 MHz, VP+HP**Chart 10, Without pigtail, 3-8.2 GHz, EUT operating at 2440 MHz, VP+HP**

Chart 11, Without pigtail, 3-8.2 GHz, EUT operating at 2480 MHz, VP+HP

Power spectral density

Limits

According to 47 CFR 15.247(e), 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.

According to RSS-247 5.2 b), the transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of Section 5.4 (d), (i.e. the power spectral density shall be determined using the same method as is used to determine the conducted output power).

According to ISED Notice 2021-CEB0001, April 19, 2021, Power spectral density (PSD) measurement shall be performed by using the correct detector as it relates to the methodology of measuring output power. PSD and output power shall be performed using the same detector methods.

Results

The measured peak output power is ≤ 0.4 dBm measured with 2 MHz bandwidth. Based on the output power measurement the power spectral density complies with the limit 8 dBm in any 3 kHz bandwidth.

Test engineer Ermin Pasalic

Compliant?	Yes
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Occupied bandwidth measurements

Date	Temperature	Humidity
2022-06-15	21 °C ± 2 °C	20 % ± 5 %

Test setup and procedure

The measurements were performed according to 47 CFR 2.1049 / RSS-Gen 6.7 and ANSI C63.10 cl. 6.9.3.

Radiated measurements were performed with continuous transmission (100% duty cycle) and with normal modulation.

Measurement equipment

Item	Name	Inv.no
Spectrum Analyzer	R&S FSQ26	BX50694
RF Cable		BX81423
Antenna, Horn	Emco 3115	502175
Multimeter	Fluke 85 III	503418
Thermohygrometer	Testo 615	503498

Limits

No limit specified in the Rules / standards.

Results

The OBW measurements can be found in the table/chart(s) below:

2402 MHz	OBW = 1.096 MHz (99%)	-
2440 MHz	OBW = 1.067 MHz (99%)	Chart 1 #7
2480 MHz	OBW = 1.072 MHz (99%)	-

Test engineers Markel Bertilsson, Ermin Pasalic

Compliant?	N/A
------------	-----

Band edge measurements

Date	Temperature	Humidity
2022-01-17	21 °C ± 2 °C	25 % ± 5 %
2022-01-18	21 °C ± 2 °C	25 % ± 5 %
2022-05-31	21 °C ± 2 °C	43 % ± 5 %

Test setup and procedure

The measurements were performed according to 47 CFR 2.1049 / RSS-247 5.5 and ANSI C63.10, see below which clauses that have been used.

The test was performed with continuous transmission (100% duty cycle) and with normal modulation.

The radiated measurements were performed in a semi anechoic chamber. The measurements were performed with the EUT-axis (if applicable), antenna position, polarization and the turntable in the position giving the highest level at the fundamental. The antenna distance was 3.0 m.

Both peak and average levels were measured during the test.

Measurement equipment

Item	Name	Inv.no
Test site, SVSWR	Semi anechoic chamber, Edison	504114
Test Software	R&S EMC32	503889
Spectrum Analyzer	R&S ESU 26	902210
Antenna, Horn	ETS-Lindgren 3115	902212
RF Cable	Rosenberger Micro-coax Uniflex	504102
RF Cable	Huber & Suhner SF106	504103
RF Cable	Huber & Suhner SF106	504104
RF Cable	Huber & Suhner Eacon 4C	BX91501
Multimeter	Fluke 83	501522
Thermohygrometer	Testo 625	504117

Item	Name	Inv.no
Test site, SVSWR	Semi anechoic chamber, Tesla	503881
Spectrum analyser	Rohde & Schwarz ESU40	901385
Test Software	Rohde & Schwarz EMC32	BX62351
RF cable	Huber & Suhner Eacon 4C	BX91490
RF cable	Rosenberger UFB311A	503508
RF cable	Rosenberger UFB311A	503509
Antenna, Horn	Emco 3115	502175
Thermohygrometer	Testo Testo 625	504188

Limits

Band edge at 2400 MHz:

According to 47 CFR 15.247(d), in any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.

According to RSS-247 5.5, in any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean square averaging over a time interval, as permitted under Section A8.4(4), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

Band edge at 2390 MHz and 2483.5 MHz:

In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a).

According to RSS-247 5.5, in any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean square averaging over a time interval, as permitted under Section A8.4(4), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

Results

Operation band 2400-2483.5 MHz

The band edge measurements with peak and average detector can be found in the table/chart(s) below.

	“Band edge” at 2390 MHz (limit=54.0 dBμV/m (Average)/ 74 dBμV/m (Peak)) (Restricted band)	
Chart 1	2402 MHz	Peak level at 2390 MHz = 47.3 dBμV/m (below average limit); Lab Edison, #5

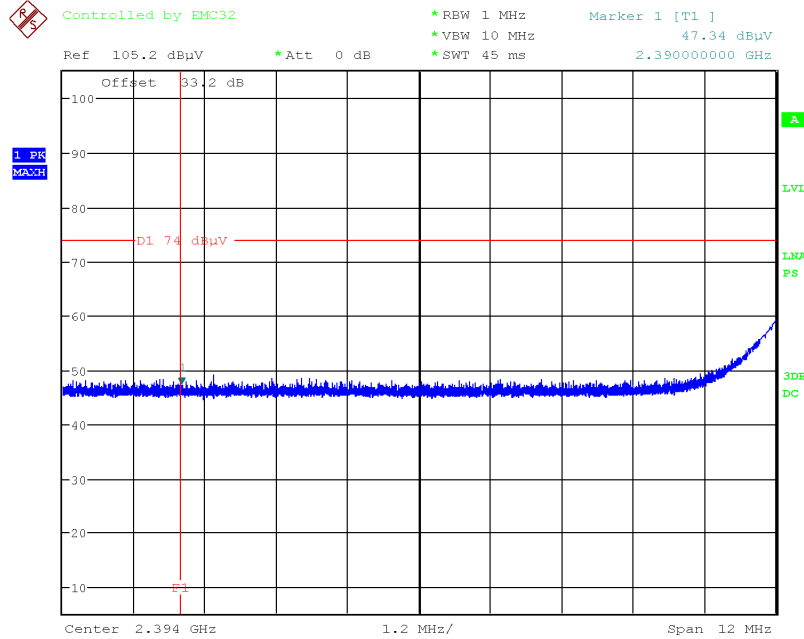
	Band edge at 2400 MHz (limit ≥ 20 dBc)	
Chart 2	2402 MHz	Peak level at fundamental in 100 kHz: 77.0 dBμV/m Peak level at 2400 MHz band edge in 100 kHz: 38.2 dBμV/m dBc at 2400 MHz: $77.0 - 38.2 = \mathbf{38.8}$ dBc; Lab Tesla, #7

	Band edge at 2483.5 MHz (limit=54.0 dBμV/m (Average)/ 74 dBμV/m (Peak)) (Restricted band)	
Chart 3	2480 MHz	Peak level at 2483.5 MHz = 47.6 dBμV/m (below average limit); Lab Edison, #5

Test engineer Markel Bertilsson

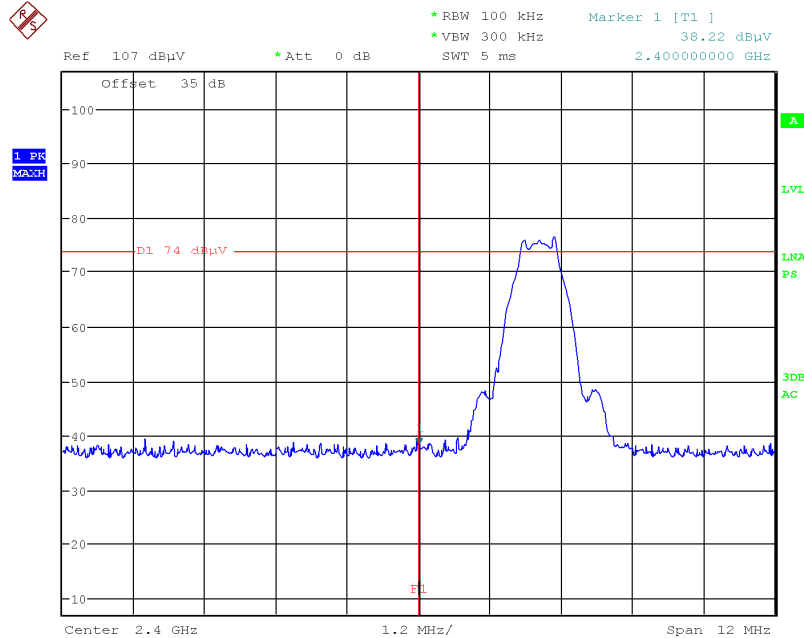
Compliant?	Yes
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Chart 1



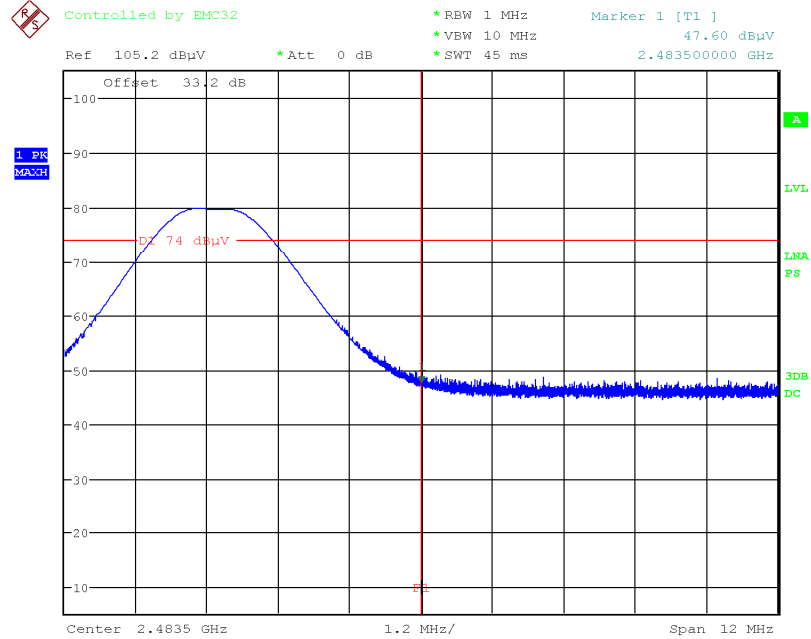
Date: 18.JAN.2022 16:21:03

Chart 2



Date: 31.MAY.2022 10:23:50

Chart 3



Date: 18.JAN.2022 16:35:46

RF exposure evaluation

Date	Temperature	Humidity
2022-04-08	22 °C ± 2 °C	33 % ± 5 %

Procedure

The measurements were performed according to 47 CFR 2.1093 Portable devices 47 CFR part 15.247 (i) / KDB 447498 / RSS-102 2.5.1

Systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy levels in excess limit for maximum permissible exposure. In accordance with 47 CFR Part 2 Subpart J, section 2.1093 and RSS-102 2.5.1 this device has been defined as a portable device to be used within 20 centimetres of the body of the user.

According to KDB 447498 D01 General RF Exposure Guidance v06.

The product is intended to be used at a distance of < 5 mm from the body.

Limits

47 CFR 2.1093 / KDB 447498 D01 General RF Exposure Guidance v06

4.3.1 Standalone SAR exclusion:

a) The 1-g and 10-g SAR test exclusion thresholds for 100 MHz to 6 GHz at test separation distances ≤ 50 mm are determined by:

$$[(\text{max. power of channel, including tune-up tolerance, mW}) / (\text{min. test separation distance, mm})] \times [\sqrt{f(\text{GHz})}] \leq 3.0 \text{ for 1-g SAR and } \leq 7.5 \text{ for 10-g extremity SAR, where}$$

- $f(\text{GHz})$ is the RF channel transmit frequency in GHz
- Power and distance are rounded to the nearest mW and mm before calculation
- The result is rounded to one decimal place for comparison

The test exclusions are applicable only when the minimum test separation distance is ≤ 50 mm and for transmission frequencies between 100 MHz and 6 GHz. When the minimum test separation distance is < 5 mm, a distance of 5 mm is applied to determine SAR test exclusion.

RSS-102 Issue 5 cl. 2.5.1 Exemption from Routine Evaluation Limits – SAR Evaluation

SAR evaluation is required if the separation distance between the user and/or bystander and the antenna and/or radiating element of the device is less than or equal to 20 cm, except when the device operates at or below the applicable output power level (adjusted for tune-up tolerance) for the specified separation distance defined in Table 1 in RSS-102.

Table 1: SAR evaluation – Exemption limits for routine evaluation based on frequency and separation distance

Frequency (MHz)	Exemption Limits (mW)
	At separation distance of ≤ 5 mm
2450	4 mW

Output power level shall be the higher of the maximum conducted or equivalent isotropically radiated power (e.i.r.p.) source-based, time-averaged output power. For controlled use devices where the 8 W/kg for 1 gram of tissue applies, the exemption limits for routine evaluation in Table 1 are multiplied by a factor of 5. For limb-worn devices where the 10-gram value applies, the exemption limits for routine evaluation in Table 1 are multiplied by a factor of 2.5. If the operating frequency of the device is between two frequencies located in Table 1, linear interpolation shall be applied for the applicable separation distance. For test separation distance less than 5 mm, the exemption limits for a separation distance of 5 mm can be applied to determine if a routine evaluation is required.

For medical implants devices, the exemption limit for routine evaluation is set at 1 mW. The output power of a medical implants device is defined as the higher of the conducted or e.i.r.p to determine whether the device is exempt from the SAR evaluation.

Results

Standalone SAR exclusion:

According to RSS-102 clause 2.5.1, Output power level shall be the higher of the maximum conducted or equivalent isotropically radiated power (e.i.r.p.) source-based, time-averaged output power.

Maximum measured radiated average output power from the Maximum peak output power measurements section above, at 2402 MHz was -14.2 dBm EIRP (81.0 dBuV/m@3m).

Note: The measurements were performed in field strength in dBμV/m. The EIRP level was then calculated by the formula $P = (E_{fd})^2 / 30 \times G$, with G as unity gain of 1.

Maximum measured conducted average output power from the Maximum peak output power measurements section above, at 2402 MHz was -1.2 dBm thus the conducted average output power was used for the RF exposure evaluation.

Step a):

The following formula was used to calculate the RF exposure SAR exclusion threshold,

$$Thld = \frac{P_{out} \sqrt{f}}{r} \text{ were,}$$

Thld= SAR exclusion threshold

Pout = Maximum output power measured with RMS detector, in mW

r = minimum test separation distance, in mm

f=frequency, in GHz

Frequency f, (GHz)	Rated power RMS (dBm) Note 1	Pout acc. to source- based time averaging (dBm) Note 2	RMS output power, tolerance added, Note 3	Distance r, (mm)	Exclusion threshold Thld	Limit Threshold 1-g SAR	Limit Threshold 10-g SAR
2.480	-0.8	-1.1	2.9 dBm =2 mW	5	0.63	< 3	< 7.5

Note 1: Rated peak output power is 0 dBm (Peak). The difference between power measured with peak detector and RMS detector was 0.8 dB, which is used for correction of rated output power (peak) to the RMS output power.

Note 2: The highest measured duty cycle (worst case acc. to the client) in normal operating mode was 93.3%, duty cycle correction (dB)=10 log duty cycle = -0.30 dB.

Note 3: According to KDB 447498 D01 and RSS-102 cl. 2.5.1 the RMS value shall be adjusted for power tolerance. The power tolerance declared by the client is ±4 dB.

Conversion from dBm to mW: $P_{mW} = 10^{(dBm/10)}$

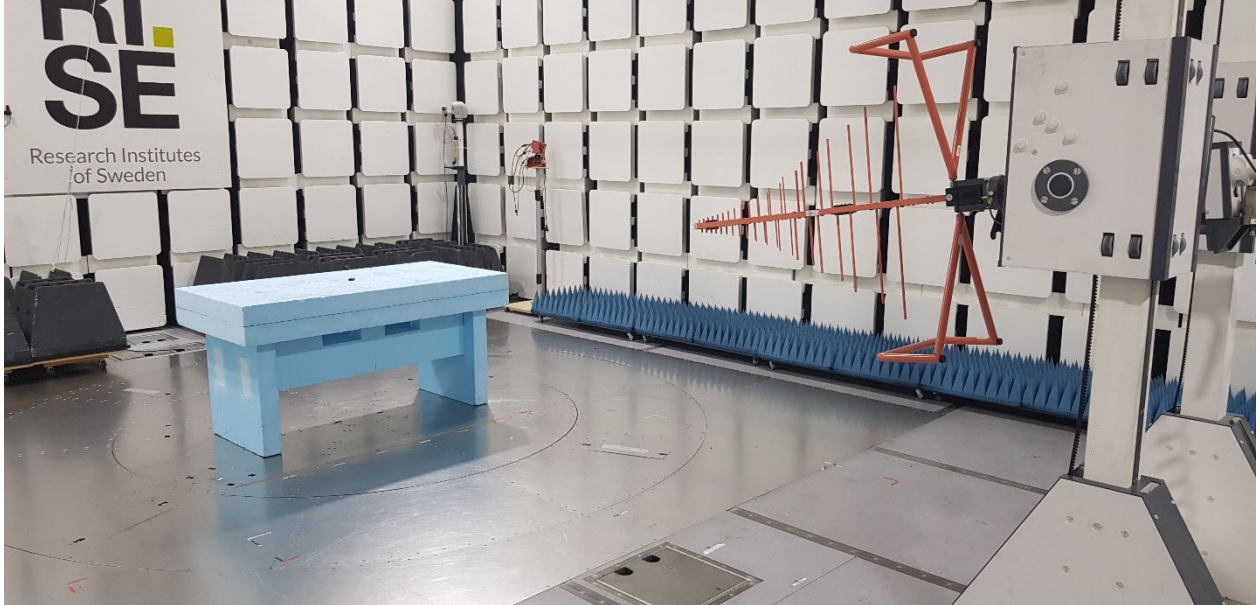
RMS output power including power tolerance correction and correction for duty cycle is 2 mW which is bellow limit of 4 mW at frequency 2480 MHz to exempt SAR evaluation of devices used at 5 mm or shorter to the body according to RSS-102 .

Test engineer Markel Bertilsson

Compliant?	Yes
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Photos

Test set-up: Below 1 GHz



Above 1 GHz



End of the report

Verification

Transaction 09222115557483836614

Document

P112377-F15C

Main document

45 pages

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Finalised on 2022-12-21 15:28:47 CET (+0100)

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Signed 2022-12-21 15:28:47 CET (+0100)

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