EKTOS
Testing & Reliability Services

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REPORT

issued by an Accredited Testing Laboratory

Date	Reference	Page
2018-03-16	P17-0042-2 rev 1	1 (46)

Moises Pacheco
Shape Robotics APS
Linde Alle 29 A
2850 Nærum
Denmark

DANAK TEST Reg.nr. 563

FCC Designation Number: DK0002

Test Report

of

Dongle DNG002
FCC ID: 2AOUEDNG002
according to

FCC 47 CFR, Part 15 Subpart C
15.249 Operation within the band 2400 - 2483.5 MHz

EKTOS Testing & Reliability Services A/S

Performed by

Søren Søltoft

Examined by

Ruben Hansen

Report no.:	P17-0042-2 rev 1	**Report date:**	2018-03-16
Test started:	2018-01-19	**Test ended:**	2018-03-14
Number of pages:	46	**Client contact:**	Moises Pacheco

Test laboratory:	EKTOS TRS A/S A. C. Meyers Vænge 15 2450 Copenhagen SV Denmark	**Client:**	Shape Robotics APS Linde Alle 29 A 2850 Nærum Denmark

Facility reg. no.	FCC Designation number: DK0002
Test specimen:	Dongle Model No: DNG002. FCC ID: 2AOUEDNG002
Test specification:	FCC 47 CFR Part 15 Subpart C 15.249 Operation within the band 2400 - 2483.5 MHz The tests relevant for the test specimens are listed in *section 1.1*.
Documentation:	P17-0042-2 rev 1 supersedes P17-0042-2 issued 2018-02-20. Changes: Duty cycle measurements repeated and Duty cycle correction factor used to demonstrate compliance with average limits. This test report must always be reproduced in full; reproduction of an excerpt only is subject to written approval of the testing laboratory. The complete test documentation is archived for 10 years at the testing laboratory.
Test results:	The test specimen complies with relevant parts of the test specifications. The test results relate only to the specimen tested.
Test personnel:	Søren Søltoft, Ruben Hansen

CONTENTS

Appendix

1 SUMMARY

See Appendix 1 for photos.
Emission measurements as specified below have been performed.

1.1 Test plan

Standard	Name of the test	Results
FCC 47 CFR Part 15C	15.249 Operation within the band 2400-2483.5 MHz	PASSED
15.35 (c)	Duty cycle measurement	-
15.249 (a)	Field strength of fundamental	PASSED
15.249 (d) (e)	Radiated emission	PASSED
15.207	AC conducted emission	PASSED
15.215 (c)	20 dB bandwidth	PASSED
2.1049	Occupied bandwidth	PASSED
2.1049	Band Edge	PASSED

PASSED The test was performed and the test specimen complies with the essential requirements in the standard.
FAILED The test was performed and the test specimen does not comply with the essential requirements in the standard.
REF The test is covered by a test in another report and/or on a similar test specimen.
NR The test is not relevant for the test specimen or has been waived by the manufacturer.

1.2 Test Specimen

Manufacturer	Shape Robotics
Name	Dongle
Model No.	DNG002
Test Software	Dongle_Firmware-6dbm_full_duty.hex
Supply voltage	5 VDC by USB

The Dongle contains electronics to control communication between a laptop and a Joint.
The Joint is an item containing two motor controlled joints, which enables the Joint to move.
The communication to Joint is via a 2.4 GHz radio link.
The communication between the Dongle and the laptop is via a USB cable, which also deliver power to the Dongle.
The Dongle also contains a Bluetooth radio, which is a pre certified module from RIGADO model BMD-100 with FCC ID: 2AA9B02 and IC: 12208A-02. This module is left out of the present test.

The 2.4 GHz radio used in both Joint and Dongle is the same module from ITEAD. The radio is based on a chipset from Nordic Semiconductor nRF24L01+.

The 2.4 GHz radio uses 6 pre-allocated frequencies in the range 2405 MHz to 2479 MHz.
The switching between the frequencies is done manually. (Pressing a button).
As the frequency range is greater than 10 MHz 3 frequencies are selected for test.

1. 2405 MHz
2. 2449 MHz
3. 2479 MHz

See photo 1 in appendix 1.

1.1 Auxiliary Equipment

1.1.1 Laptop

Manufacturer	Lenovo
Model	X220
Product ID	42903WG
Serial no.	R9-KVYB6 11/12
Software	Microsoft Windows 10 Professional
Details	-
Supply voltage	20 VDC from AC/DC power supply

1.1.2 AC/DC power supply for laptop

Manufacturer	Lenovo
Model	42T4424
Serial no.	11S42T4424Z1ZF3E15B6DA REV 05
Details	-
Supply voltage	100 – 240 VAC (120 VAC 60 Hz was used during tests)
Output voltage	20 VDC

1.1.3 AC/DC adaptor

Manufacturer	Shape Robotics
Model	UBP-008
Details	-
Supply voltage	100 – 240 VAC (120 VAC 60 Hz was used during tests)
Output voltage	5 VDC

See photo 2 in appendix 1.

1.2 I/O ports / cables to test specimen

I/O Port Cable	Type	Shielding	Cable length
USB	Std.	Shielded	40 cm

1.3 Test set-up

During test the test specimen was powered with 5 VDC via the USB cable, except during AC conducted emission were a laptop and a ACDC adaptor were used.

2 TESTS

2.1 Duty Cycle

Test specimen	Dongle DNG002
Test specification	47 CFR Part 15 Subpart C
Test method	ANSI C63.10:2013
Comments	None
Temperature / Humidity	22°C / 35%RH
Dates of measurements	2018-03-14
Test personnel	Ruben Hansen

2.1.1 Test setup

As it was not possibly to configure the 2.4 GHz radio module to 100 % duty cycle, a special test set up was made for the duty cycle measurement.

The worst case, during normal use, will be that the number of modules attached to the Dongle will go towards infinity. If that occurs the limiting factor will be the USB protocol since there is a 2 ms delay for each package.

For the test set up a Dongle was connected to a Laptop via USB cable and to a Joint via 2.4 GHz radio. At the laptop a special program was running. which was sending packages as fast as possible to the Joint via the Dongle and USB cable. The Joint was replying with full package. The package length was set to the maximal 32 Bytes.

The measurements were performed radiated with a small antenna placed next to the Dongle. There were a clear difference between the measured pulse level from the Dongle and the Joint.

See photo of test set up in appendix 1.

2.1.2 Test result

The duty cycle was measured at 2468.23 MHz.

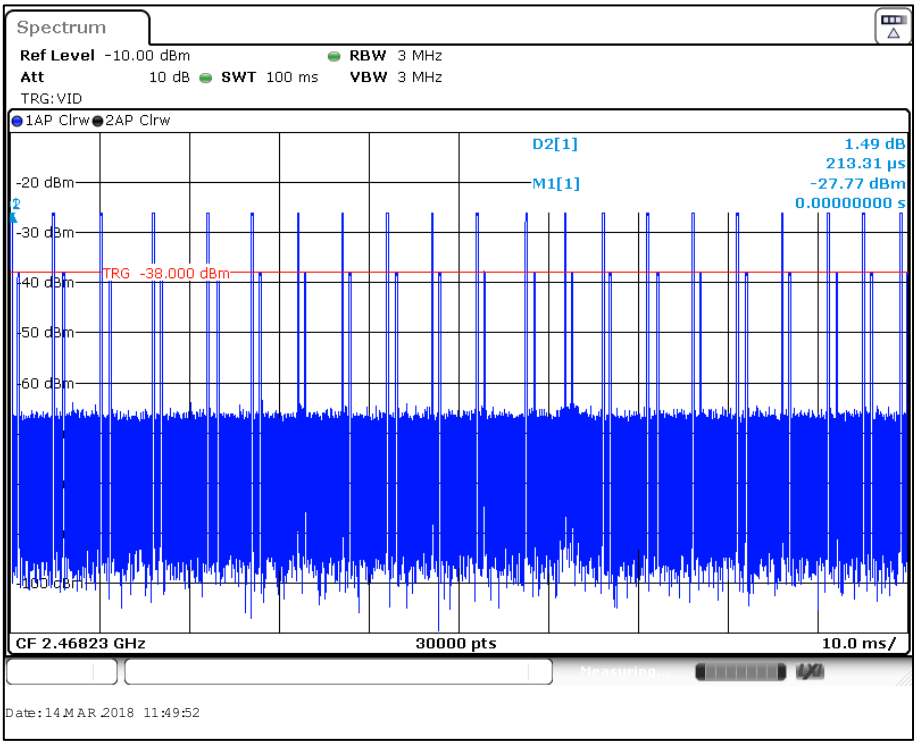

Figure 1. Duty Cycle.

The total pulse time was calculated in a spreadsheet based on the 30000 measurements points from the Analyzer.

Total pulse time [ms]	Period time [ms]	Duty cycle [%]	Duty cycle correction factor [dB]
4.67	100	4.69	-26.58

Table 1. Duty cycle.

2.1.3 Test equipment

Description	Supplier	Model	Tag no.	Cal. due date
Receiver EMI Test 10Hz-13.6GHz	Rohde & Schwarz	FSV 13	50092	2018-08-24

2.2 Field strength of fundamental

Test specimen	Dongle DNG002
Test specification	FCC 47 CFR Part 15.249
Test method	ANSI C63.10:2013
Frequency range	2400-2483.5 MHz
Limits	FCC 47 CFR Part 15.249 (a)
Comments	None
Temperature / Humidity	22°C / 37%RH
Dates of measurements	2018-01-26
Test personnel	Søren Søltoft

2.2.1 Test setup

The test was performed with maximal possible transmission and with normal modulation. See sec 2.1.

The radiated maximum peak output power measurements were performed in the semi-anechoic chamber.

The fundamental was scanned with peak detector with the EUT in 3 octagonal positions and the turntable was varied between 0-360 degrees for maximum response.

The antenna distance during the measurements was 3.0 m.

The EUT height above the reference ground plane was 1.5 m

See appendix 1 for photo of test set up and test specimen orientation

2.2.2 Test limit

Frequency range	Field strength limit	Field strength limit
2400 – 2483.5 MHz	50 mV/m	94 dBµV/m

Table 2. Field strength of fundamental limit.

2.2.3 Test results

Fundamental: 2405 MHz			
EUT axis	**Vertical**	**Vertical -90 deg.**	**Horizontal**
Antenna polarization	Horizontal	Vertical	Horizontal
Max. peak power	92.73 dBµV/m	90.95 dBµV/m	91.44 dBµV/m
Result	PASSED	PASSED	PASSED

Fundamental: 2449 MHz			
EUT axis	**Vertical**	**Vertical -90 deg.**	**Horizontal**
Antenna polarization	Horizontal	Vertical	Horizontal
Max. peak power	92.39 dBµV/m	90.81 dBµV/m	92.18 dBµV/m
Result	PASSED	PASSED	PASSED

Fundamental: 2479 MHz			
EUT axis	**Vertical**	**Vertical -90 deg.**	**Horizontal**
Antenna polarization	Horizontal	Vertical	Horizontal
Max. peak power	91.74 dBµV/m	91.38 dBµV/m	93.23 dBµV/m
Result	PASSED	PASSED	PASSED

The nominal voltage of 5 VDC were variated between 85% and 115% without any changes in output power.

2.2.4 Test equipment

Description	Supplier	Model	Tag no.	Cal. due date
Antenna Horn	Schwarzbeck	BBHA 9120 D	20777	2019-02-18
Analyzer 20Hz-26.5GHz	Rohde&Schwarz	ESI	20763	2018-09-05

2.3 Radiated emission

Test specimen	Dongle DNG002
Test specification	47 CFR Part 15.249 (d) (e)
Test method	ANSI C63.10:2013
Frequency range	30 MHz – 25 GHz
Limits	47 CFR Part 15.249 (a) and 15.209
Comments	None
Temperature / Humidity	21°C / 37%RH and 21°C / 40%RH
Dates of measurements	2018-01-19 and 2018-02-16
Test personnel	Søren Søltoft

2.3.1 Test setup

A measuring distance of 3 m was used during the tests.

The EUT was placed on a non-conductive table.

For measurements below 1 GHz. the height was 0.8 m and above 1 GHz the height was 1.5 m.

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 during the measurements was 3.0 m.

The measurement procedure is as follows:

1. A pre-measurement is performed with peak detector. The test object is measured in eight directions with the antenna in the frequency range 30-1000 MHz and in eighteen directions at frequencies above 1 GHz, with the antenna at three heights, 1.0 m, 1.5 m and 2.0 m. In the frequency range of 14 GHz to 25 GHz the measurement distance was 0.5 m.
2. 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 CISPR-average detector above 1 GHz.

The following RBW were used:

30 MHz-1 GHz: RBW = 120 kHz

1-25 GHz: RBW = 1 MHz

See appendix 1 for photo of test set up

2.3.2 Test results

2.3.2.1 Test result for Low channel 2405 MHz

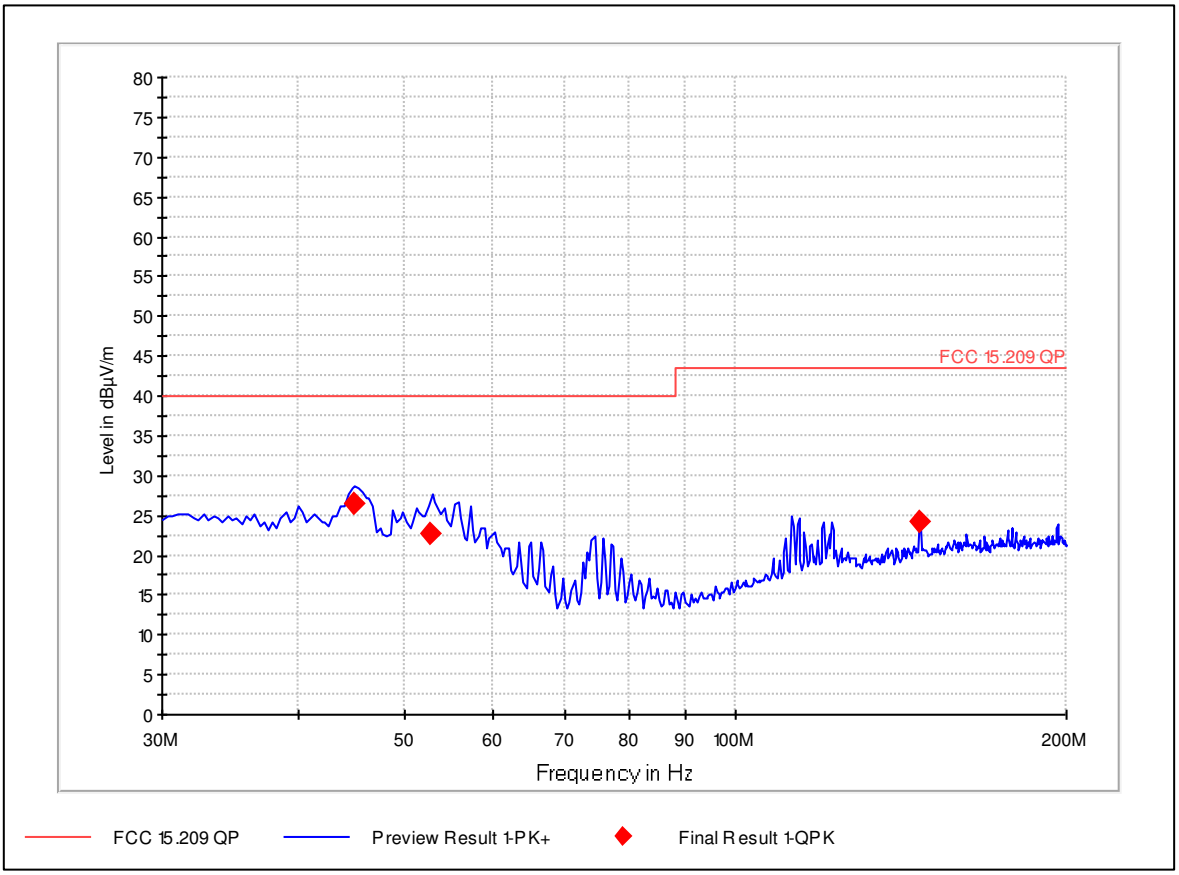

Figure 2. Radiated emission test results. 30 - 200 MHz.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
44.909980	26.4	120.0	149.2	V	95.0	13.6	40.0	PASSED
52.775651	22.7	120.0	99.7	V	98.0	17.3	40.0	PASSED
146.914389	24.0	120.0	100.1	V	53.0	19.5	43.5	PASSED

Table 3. Radiated emission test results. 30 - 200 MHz.

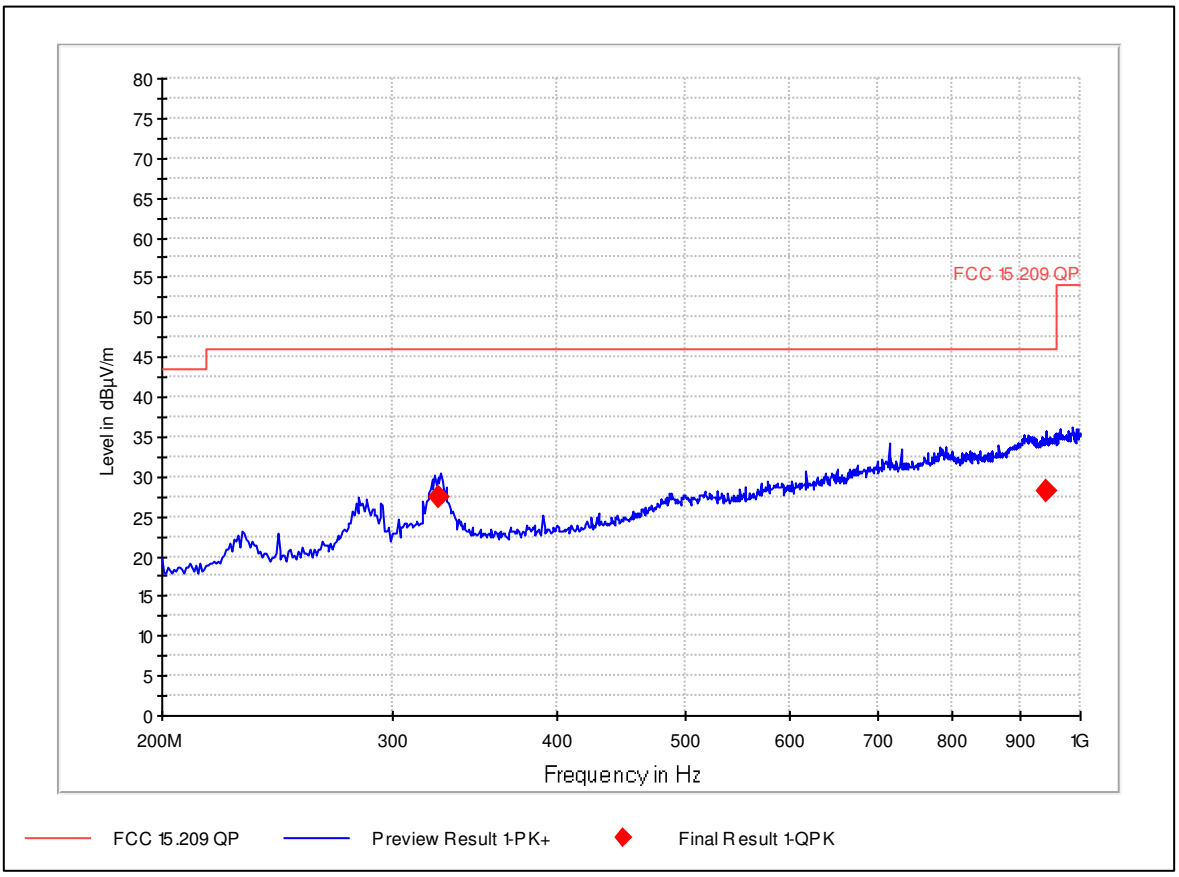

Figure 3. Radiated emission test results. 200 - 1000 MHz.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
325.361703	27.4	120.0	99.7	H	273.0	18.6	46.0	PASSED
941.112966	28.3	120.0	225.0	V	188.0	17.7	46.0	PASSED

Table 4. Radiated emission test results. 200 - 1000 MHz.

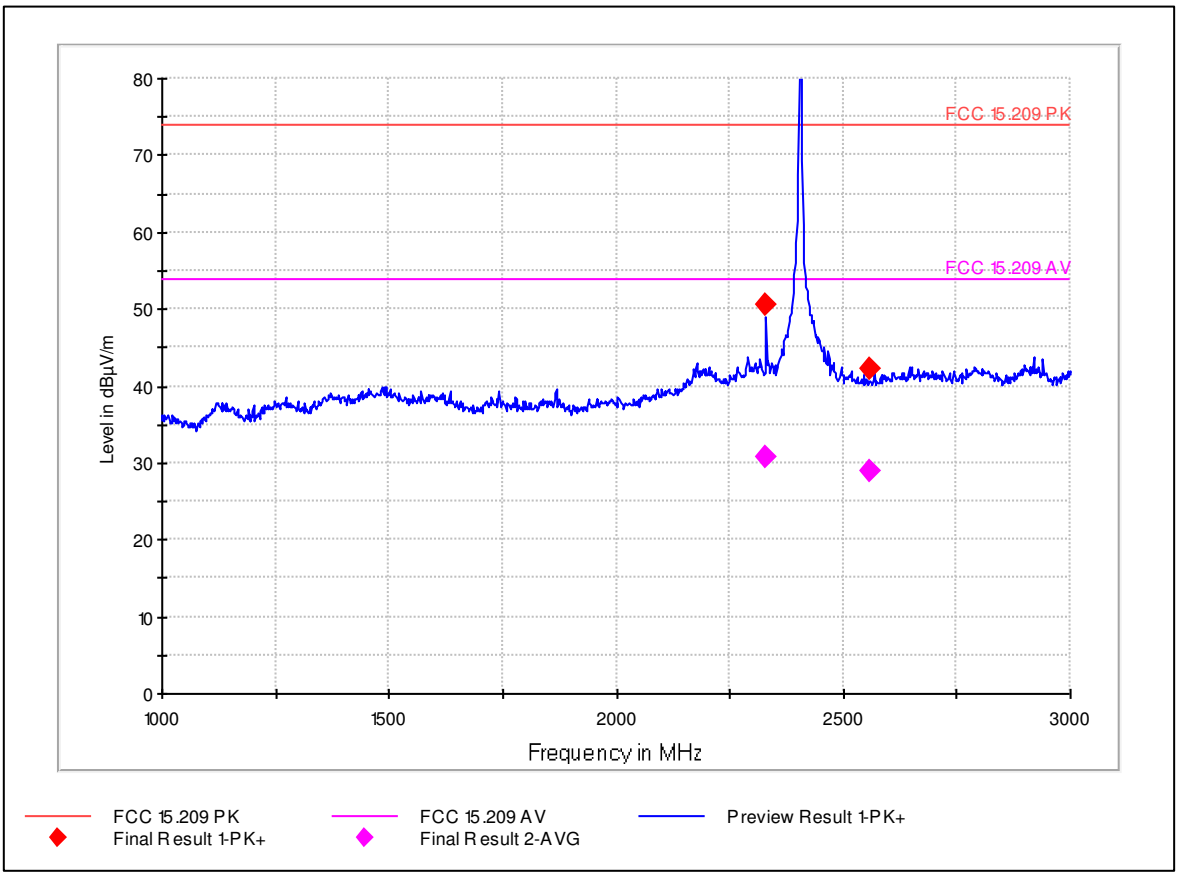

Figure 4. Radiated emission test results 1 - 3 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
2330.807823	50.7	1000	100.1	H	350.0	23.3	74.0	PASSED
2558.692777	42.3	1000	350.1	V	293.0	31.7	74.0	PASSED

Table 5. Radiated emission test results 1 - 3 GHz. Peak detector.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
2330.807823	30.7	1000	100.1	H	350.0	23.3	54.00	PASSED
2558.692777	28.9	1000	350.1	V	293.0	25.1	54.00	PASSED

Table 6. Radiated emission test results- 1 - 3 GHz. Average detector.

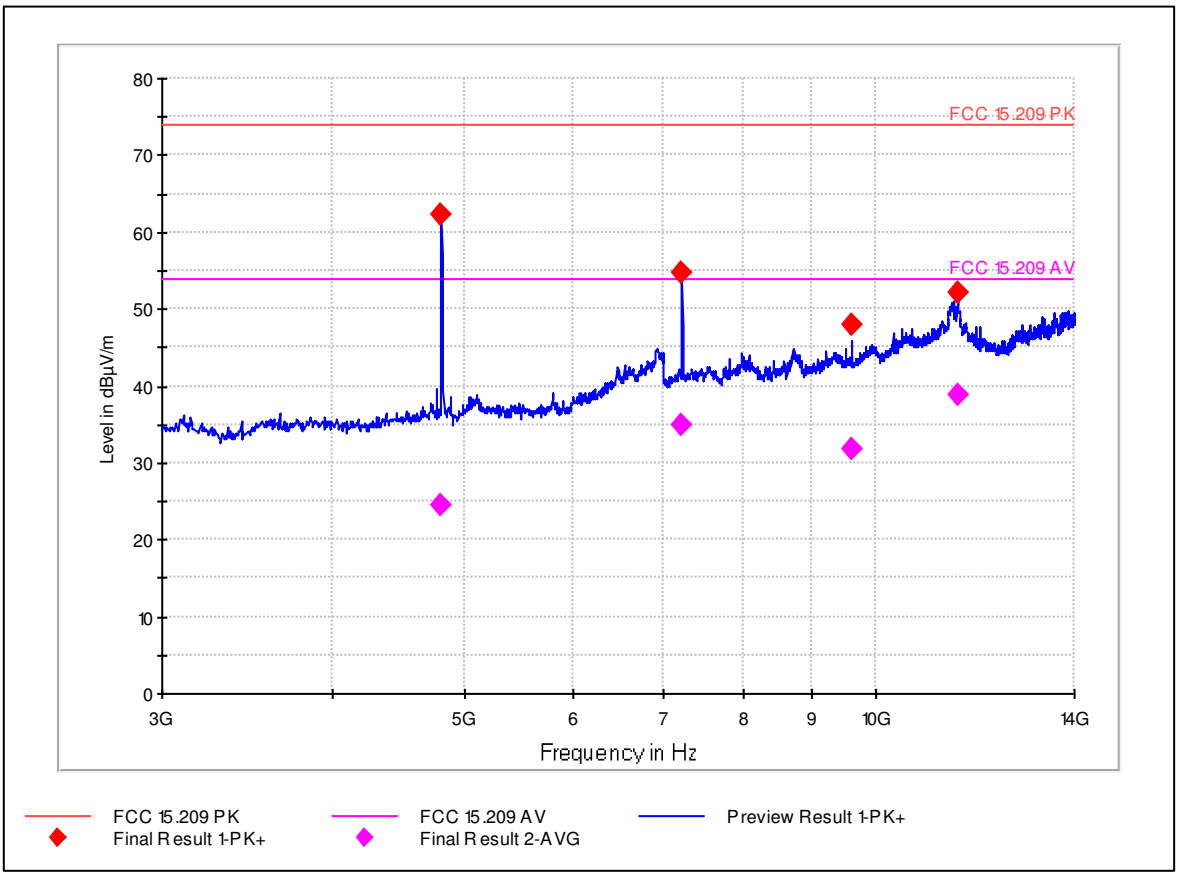

Figure 5. Radiated emission test results 3 - 14 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
4805.774234	62.2	1000	100.1	H	103.0	11.8	74.0	PASSED
7215.359854	54.8	1000	199.9	H	21.0	19.2	74.0	PASSED
9619.930493	47.8	1000	231.2	V	319.0	26.2	74.0	PASSED
11501.410486	52.1	1000	329.0	V	6.0	21.9	74.0	PASSED

Table 7. Radiated emission test results. 3 - 14 GHz. Peak detector.

The following frequencies are harmonic of the fundamental and thus pulsed.

The average value is calculated by correcting the Peak detector level with the Duty Cycle Correction Factor found in section 2.1.

Frequency [MHz]	Peak [dBuV/m]	Correction Factor [dB]	Average [dBuV/m]	Margin [dB]	Limit [dBuV/m]	Result
4805.774234	62.2	-26.58	35.62	18.38	54.0	PASSED
7215.359854	54.8	-26.58	28.22	25.78	54.0	PASSED
9619.930493	47.8	-26.58	21.22	32.78	54.0	PASSED

Table 8. Radiated emission test results 3 - 14 GHz. Average. Pulsed signal.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
11501.410486	39.0	1000.	329.0	V	6.0	15.0	54.0	PASSED

Table 9. Radiated emission test results 3 - 14 GHz. Average. Non pulsed signal.

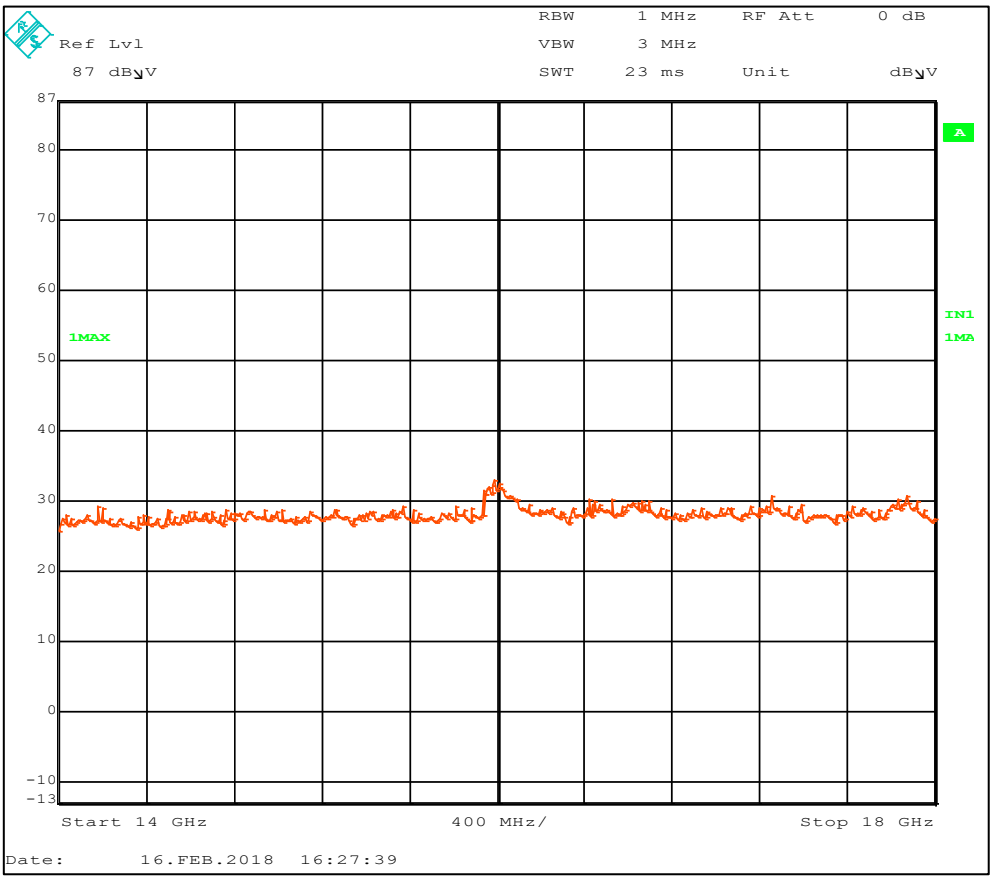

Figure 6 Radiated emission test results 14 - 18 GHz. Peak detector.

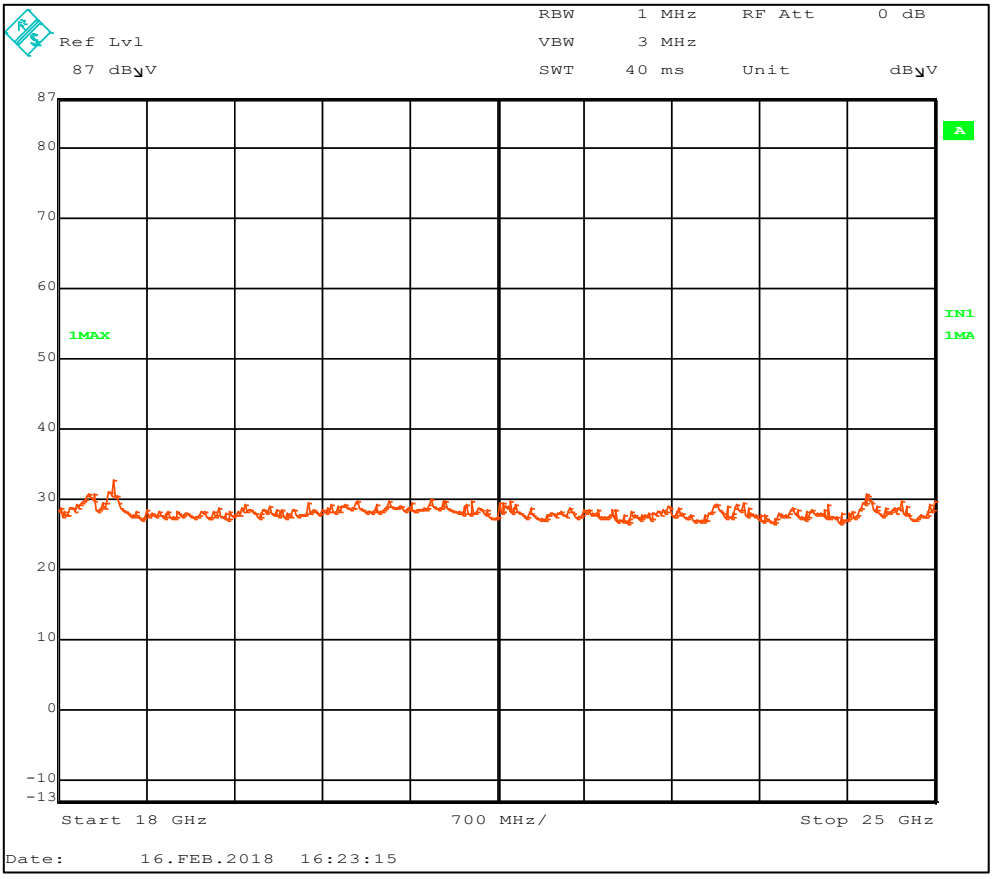

Figure 7. Radiated emission test results 18 - 25 GHz. Peak detector

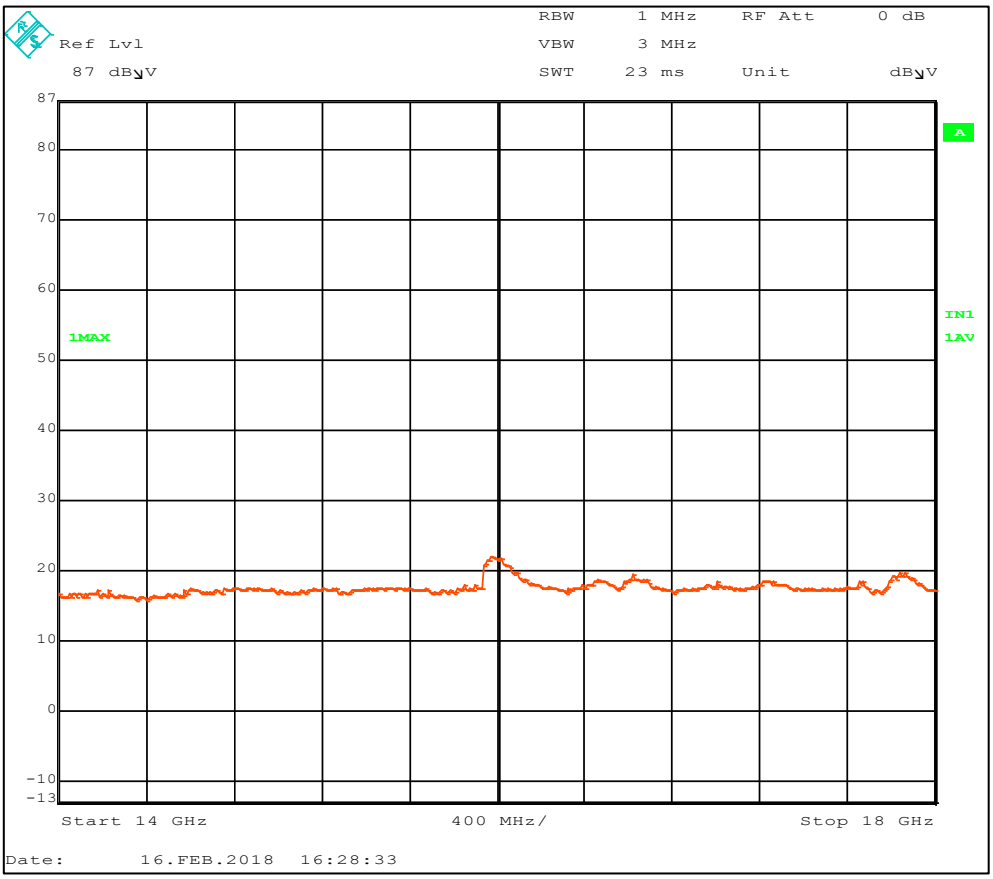

Figure 8. Radiated emission test results 14 - 18 GHz. Average detector.

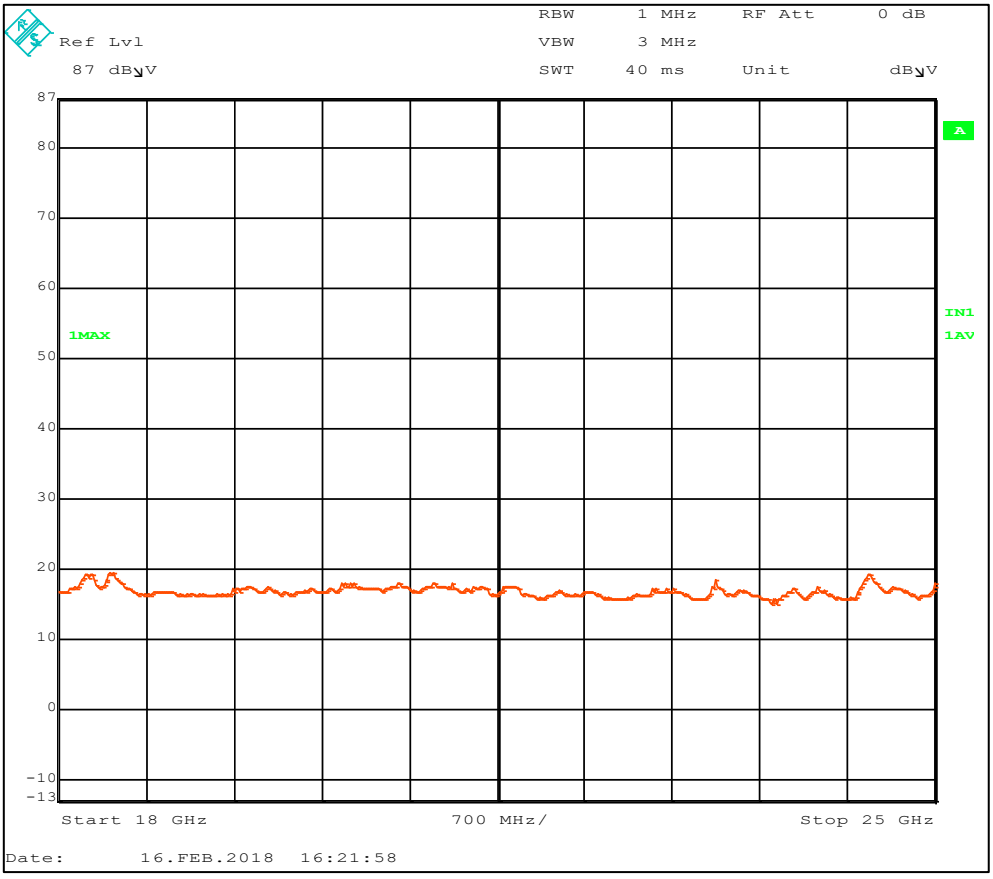

Figure 9. Radiated emission test results 18 - 25 GHz. Average detector.

Average Limit 3 m.	Peak limit 3 m	3 m / 0.5 m factor	Average Limit 0.5 m.	Peak limit 0.5 m
dBµV/m	dBµV/m	dB	dBµV/m	dBµV/m
53.98	73.98	15.56 dB	69.54	89.54

Table 10. Calculation of limit at 0.5 m.

Frequency	AF	Cable loss	Correction factor
GHz	dB/m	dB	dB/m
14	37,1	< 2	39.1
18	37,4	< 2	39.4
18	40.3	< 2	42.3
25	40.6	< 2	42.6

Table 11. Correction factors 14 – 25 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
-	-	-	-	-	-	-	89.54	PASSED

Table 12. Radiated emission test results. 14 - 25 GHz. Peak detector.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
-	-	-	-	-	-	-	69.54	PASSED

Table 13. Radiated emission test results 14 – 25 GHz. Average detector.

2.3.2.2 Test result for Middle channel 2449 MHz

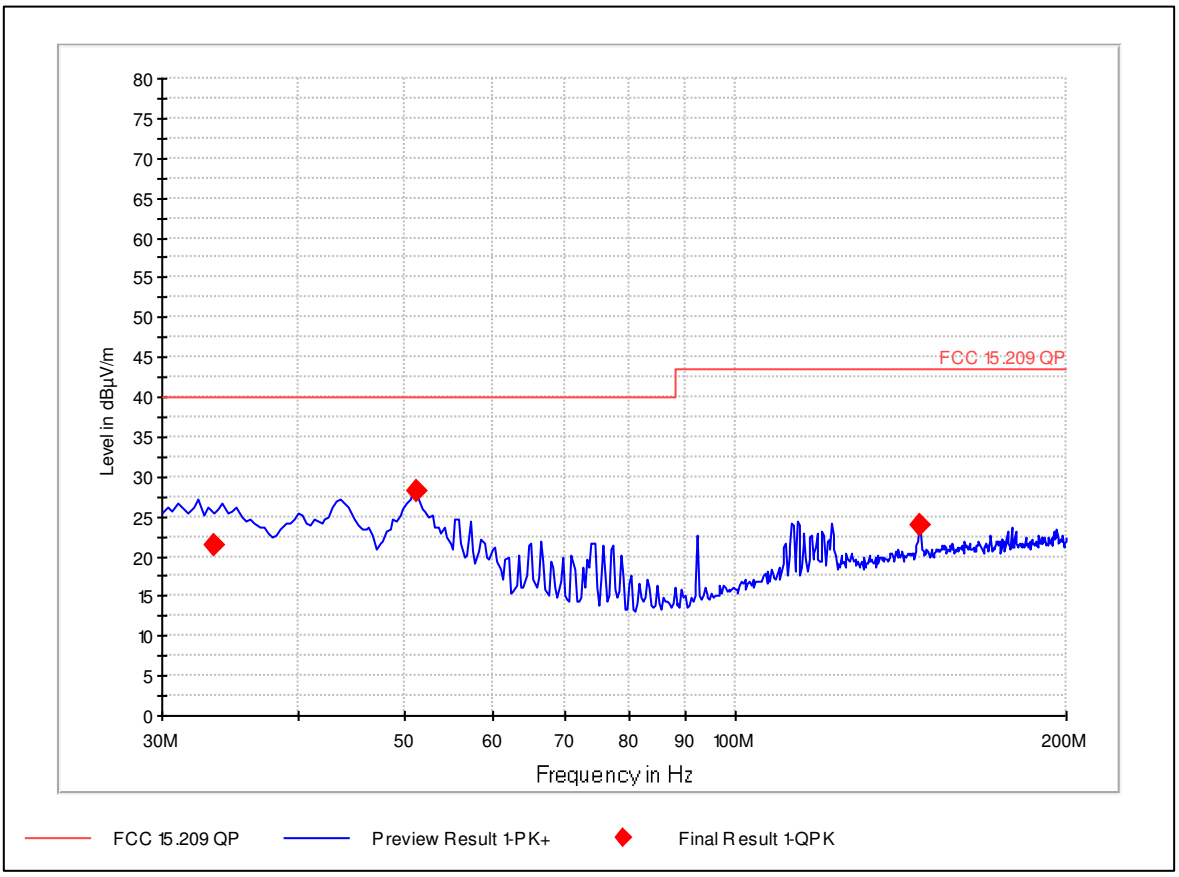

Figure 10. Radiated emission test results. 30 - 200 MHz.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
33.454770	21.3	120.0	297.1	V	90.0	18.7	40.0	PASSED
51.261563	28.1	120.0	319.0	V	172.0	11.9	40.0	PASSED
146.823707	23.9	120.0	99.7	V	46.0	19.6	43.5	PASSED

Table 14. Radiated emission test results. 30 - 200 MHz.

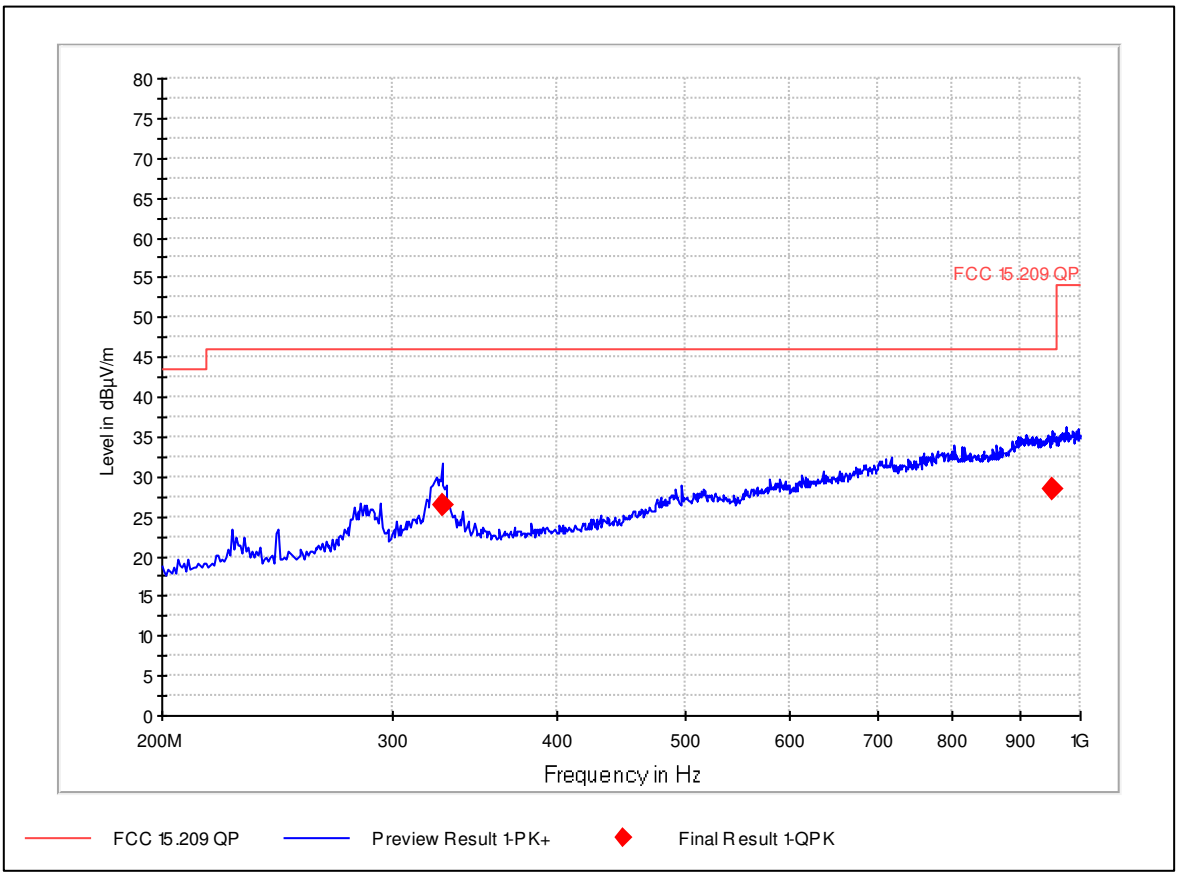

Figure 11. Radiated emission test results. 200 - 1000 MHz.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
326.593307	26.5	120.0	99.7	H	288.0	19.5	46.0	PASSED
952.435411	28.5	120.0	154.0	H	291.0	17.5	46.0	PASSED

Table 15. Radiated emission test results. 200 - 1000 MHz.

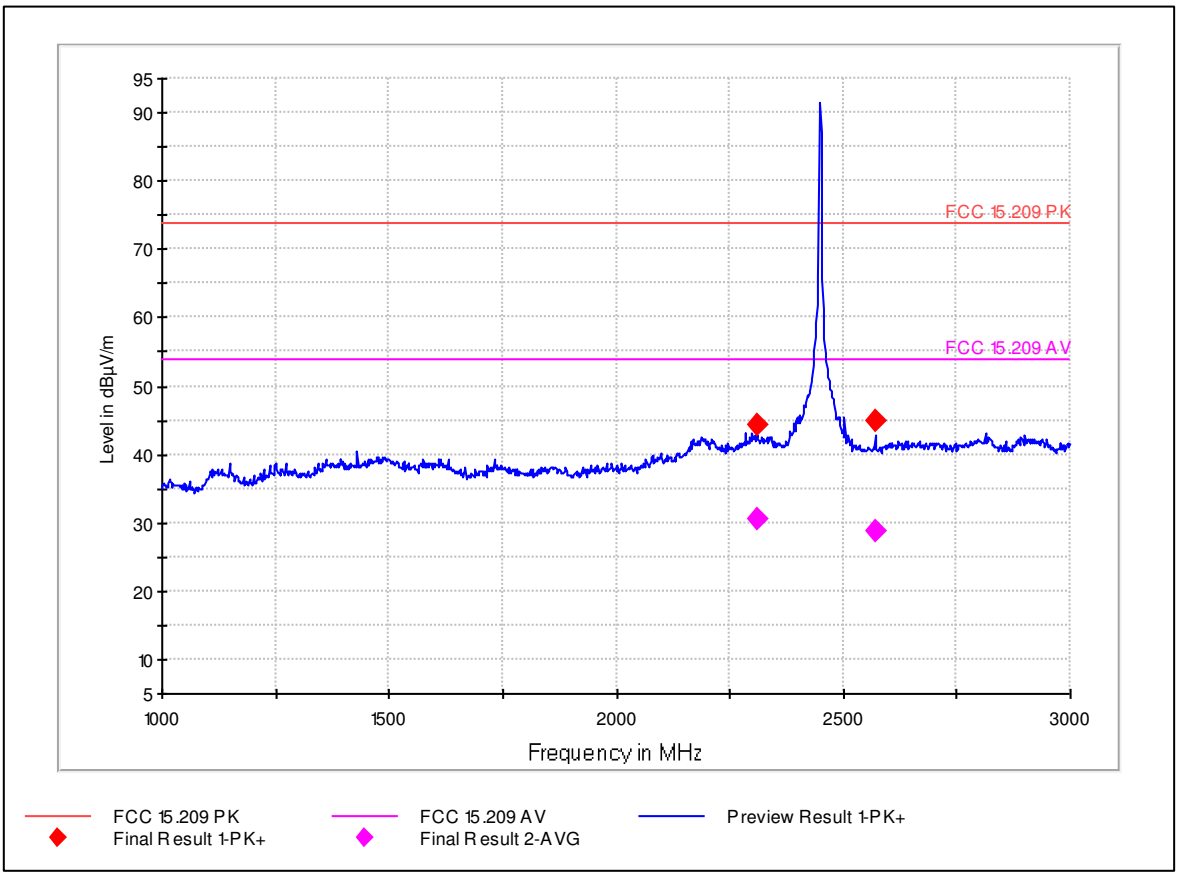

Figure 12. Radiated emission test results 1 - 3 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
2312.980227	44.2	1000	172.1	H	0.0	29.8	74.0	PASSED
2570.586785	45.0	1000	199.9	H	203.0	29.0	74.0	PASSED

Table 16. Radiated emission test results 1 - 3 GHz. Peak detector.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
2312.980227	30.5	1000	172.1	H	0.0	23.5	54.0	PASSED
2570.586785	28.9	1000	199.9	H	203.0	25.1	54.0	PASSED

Table 17. Radiated emission test results- 1 - 3 GHz. Average detector.

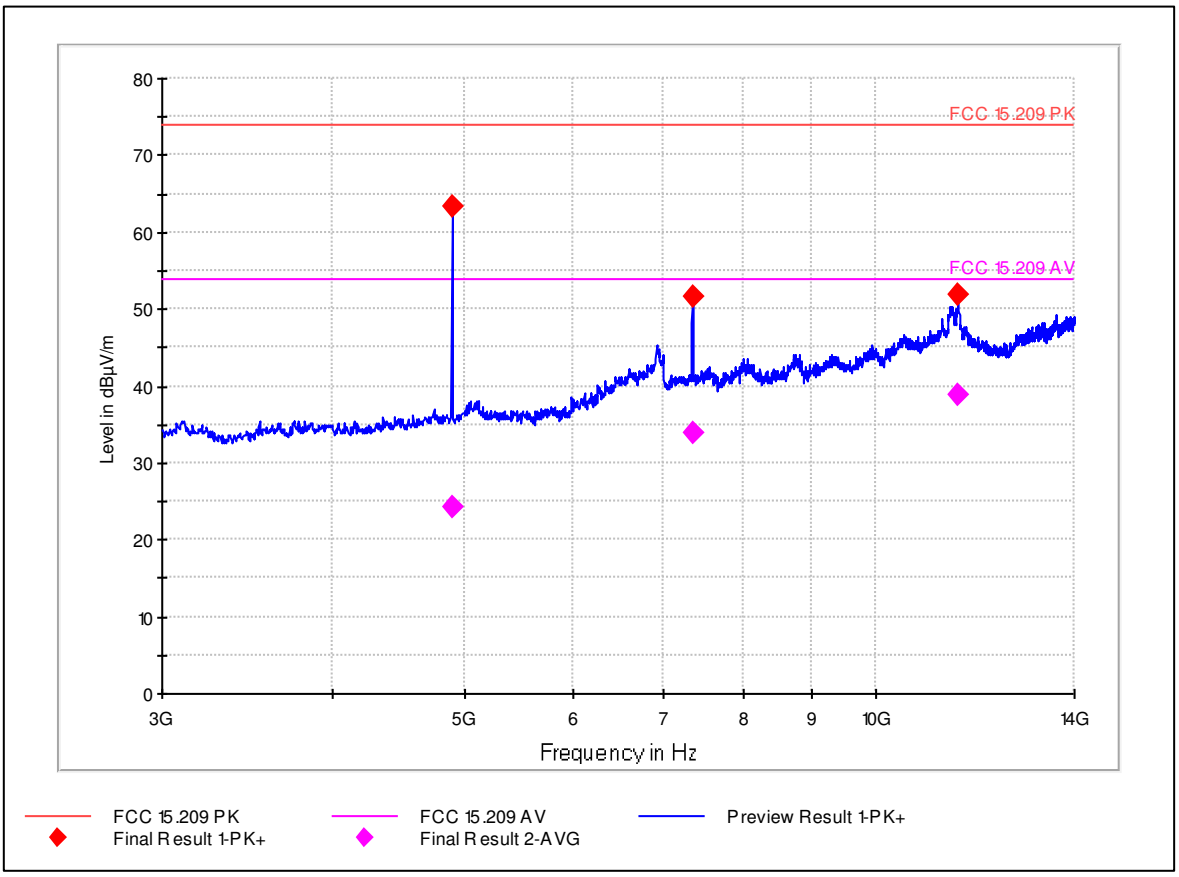

Figure 13. Radiated emission test results 3 - 14 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
4894.918575	63.3	1000	150.2	H	95.0	10.7	74.0	PASSED
7346.753895	51.6	1000	99.9	V	320.0	22.4	74.0	PASSED
11502.210486	51.9	1000	395.2	H	163.0	22.1	74.0	PASSED

Table 18. Radiated emission test results. 3 - 14 GHz. Peak detector.

The following frequencies are harmonic of the fundamental and thus pulsed.
The average value is calculated by correcting the Peak detector level with the Duty Cycle Correction Factor found in section 2.1.

Frequency [MHz]	Peak [dBuV/m]	Correction Factor [dB]	Average [dBuV/m]	Margin [dB]	Limit [dBuV/m]	Result
4894.918575	63.3	-26.58	36.72	17.28	54.0	PASSED
7346.753895	51.6	-26.58	25.02	28.98	54.0	PASSED

Table 19. Radiated emission test results 3 - 14 GHz. Average. Pulsed signal.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
11502.210486	38.8	1000	395.2	H	163.0	15.2	54.0	PASSED

Table 20. Radiated emission test results 3 - 14 GHz. Average. Non pulsed signal

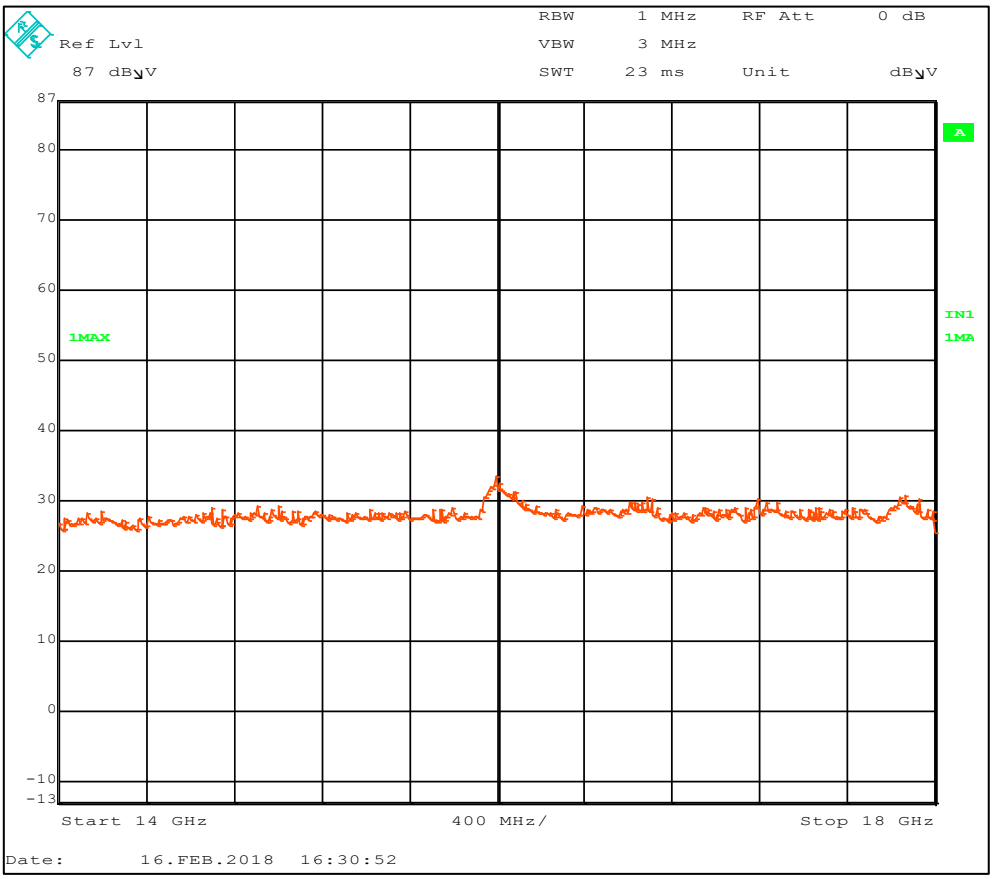

Figure 14. Radiated emission test results 14 - 18 GHz. Peak detector.

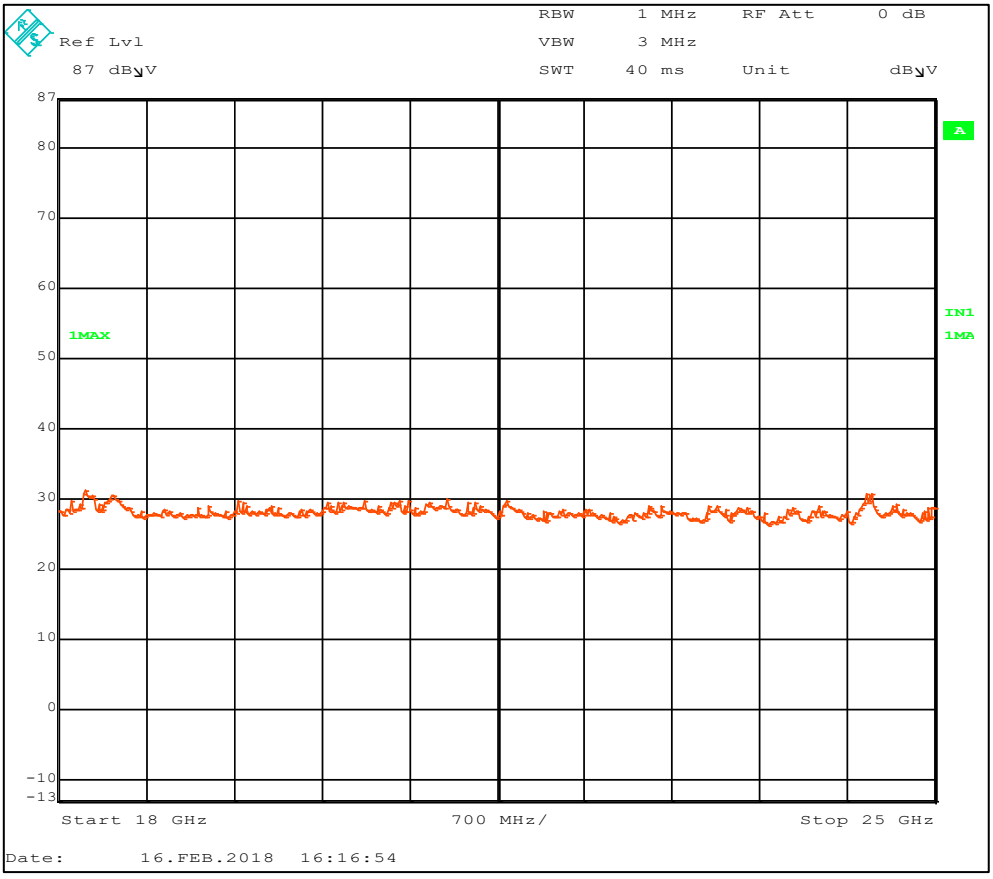

Figure 15. Radiated emission test results 18 - 25 GHz. Peak detector.

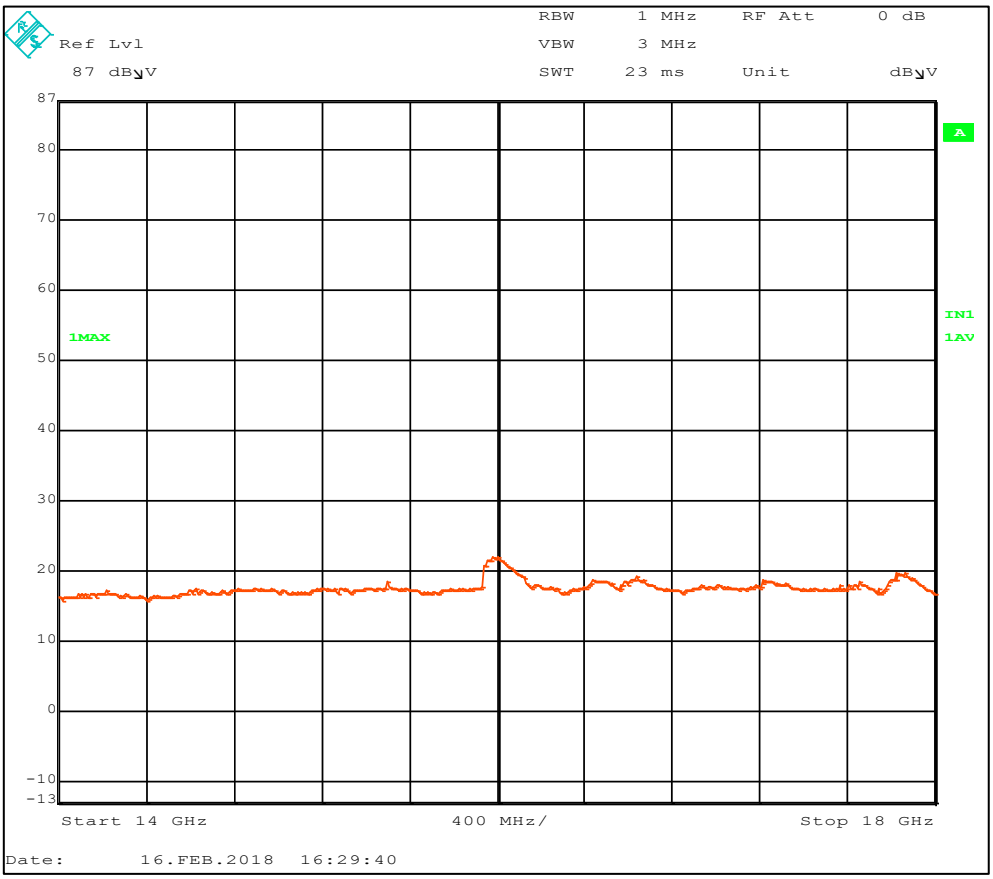

Figure 16. Radiated emission test results 18 - 25 GHz. Average detector.

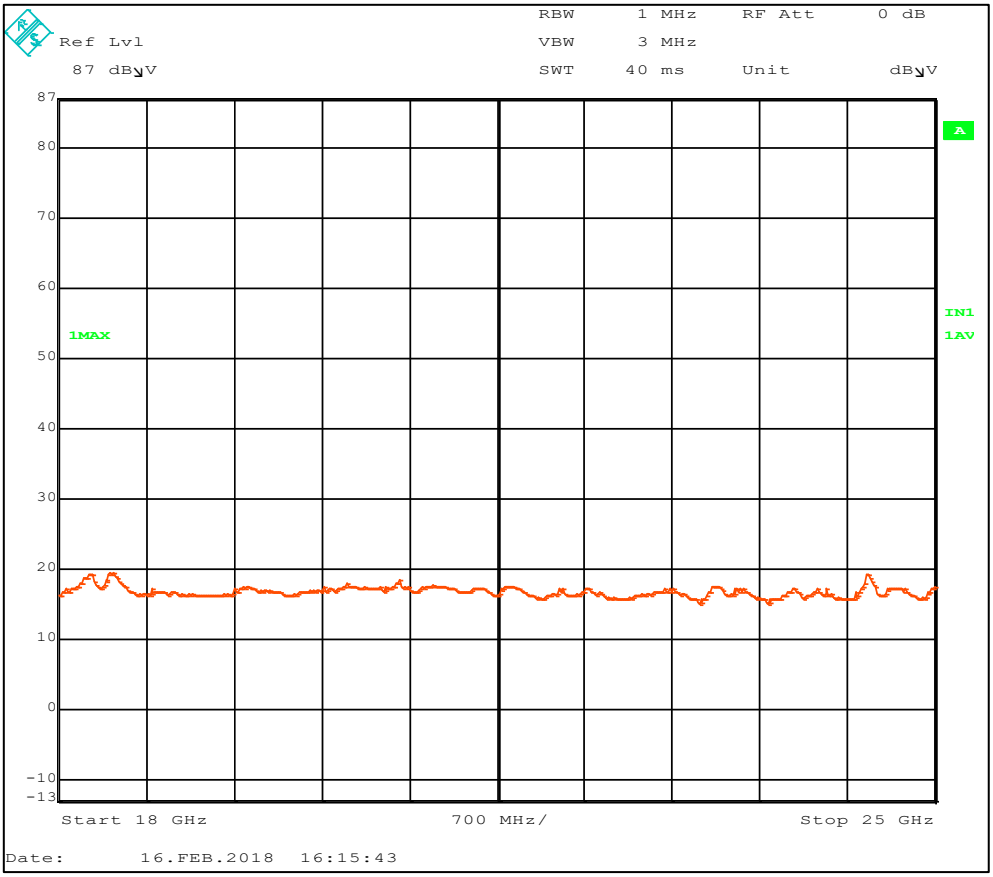

Figure 17. Radiated emission test results 18 - 25 GHz. Average detector.

Average Limit 3 m.	Peak limit 3 m	3 m / 0.5 m factor	Average Limit 0.5 m.	Peak limit 0.5 m
dBµV/m	dBµV/m	dB	dBµV/m	dBµV/m
53.98	73.98	15.56 dB	69.54	89.54

Table 21. Calculation of limit at 0.5 m.

Frequency	AF	Cable loss	Correction factor
GHz	dB/m	dB	dB/m
14	37,1	< 2	39.1
18	37,4	< 2	39.4
18	40.3	< 2	42.3
25	40.6	< 2	42.6

Table 22. Correction factors 14 – 25 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
-	-	-	-	-	-	-	89.54	PASSED

Table 23. Radiated emission test results. 14 - 25 GHz. Peak detector.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
-	-	-	-	-	-	-	69.54	PASSED

Table 24. Radiated emission test results 3 - 14 GHz. Average detector.

2.3.2.3 Test result for High channel 2479 MHz.

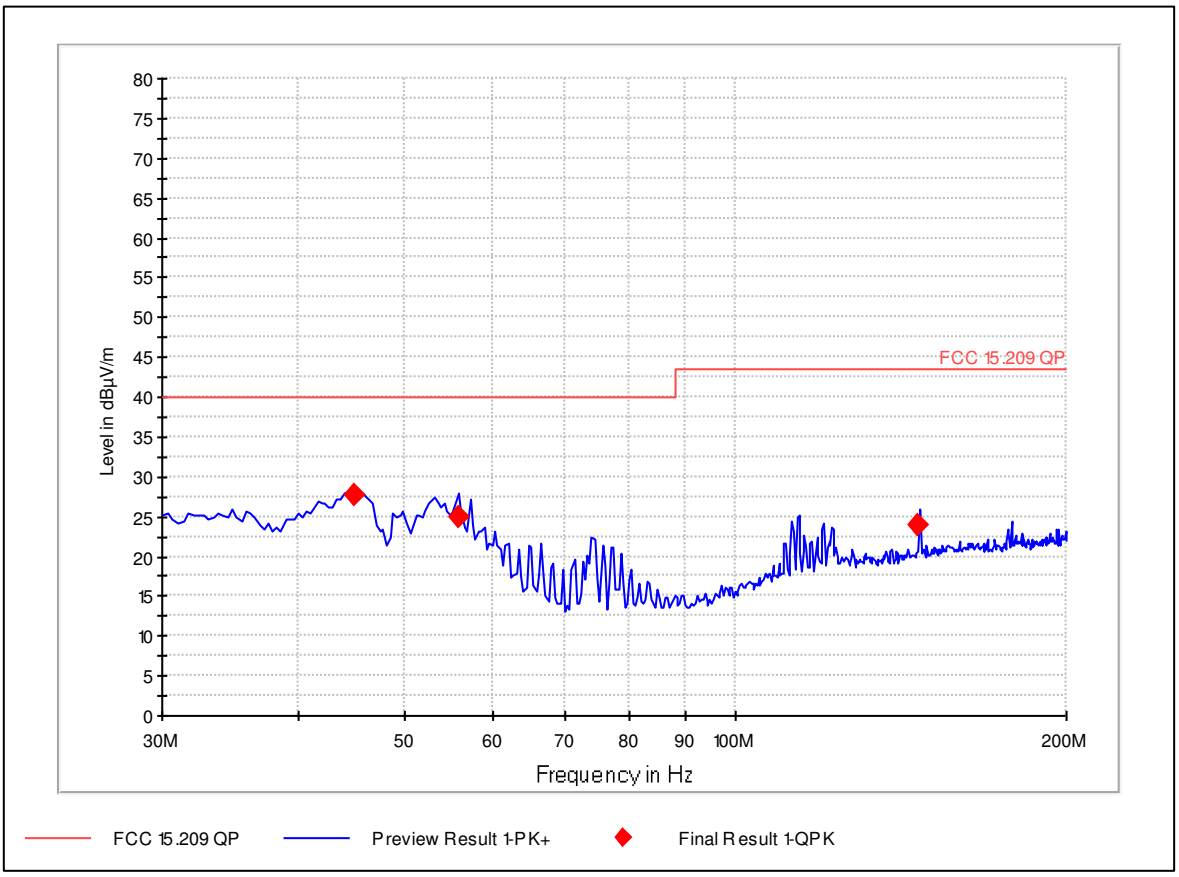

Figure 18. Radiated emission test results. 30 - 200 MHz.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
45.009980	27.7	120.0	162.7	V	4.0	12.3	40.0	PASSED
55.801784	25.0	120.0	100.0	V	307.0	15.0	40.0	PASSED
146.774389	23.9	120.0	100.1	V	45.0	19.6	43.5	PASSED

Table 25. Radiated emission test results. 30 - 200 MHz.

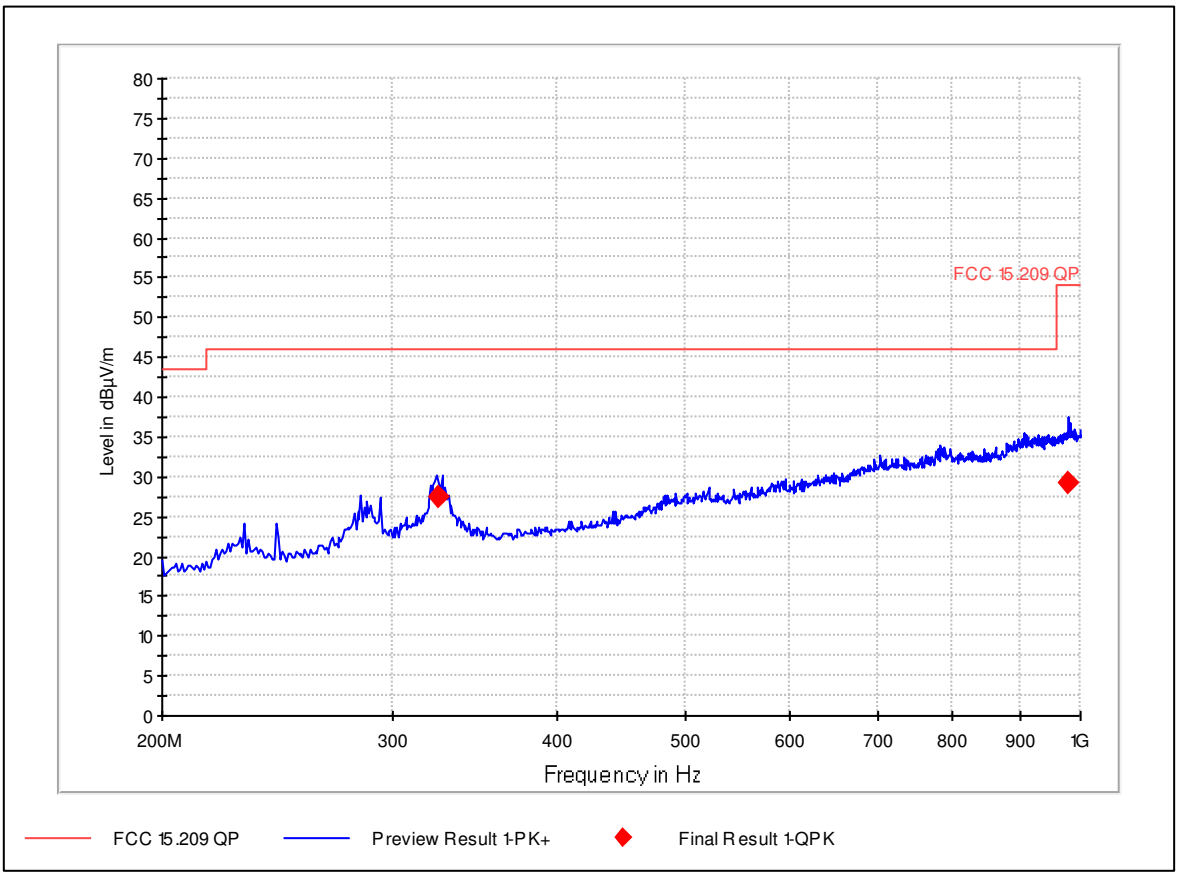

Figure 19. Radiated emission test results. 200 - 1000 MHz.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
324.576894	27.5	120.0	130.1	H	273.0	18.5	46.0	PASSED
979.489920	29.1	120.0	100.1	H	190.0	24.9	54.0	PASSED

Table 26. Radiated emission test results. 200 - 1000 MHz.

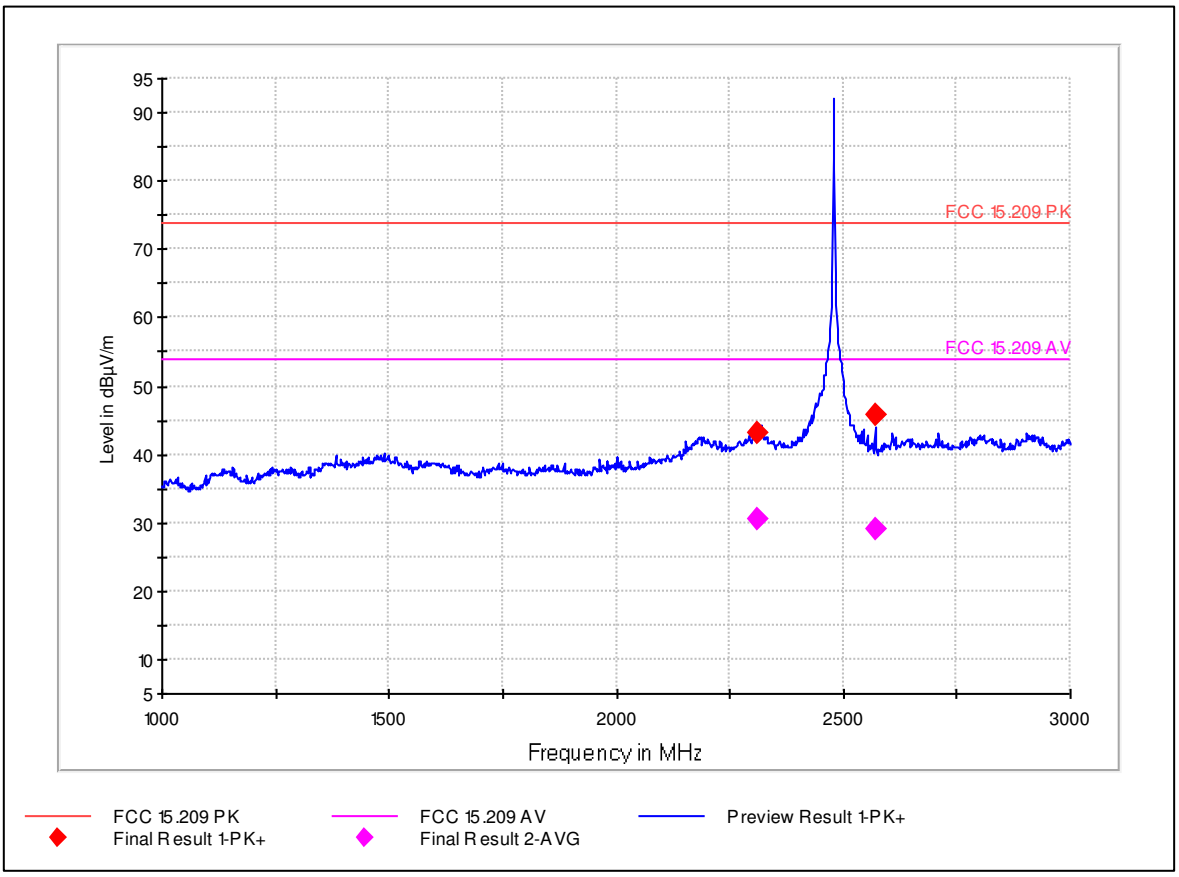

Figure 20. Radiated emission test results 1 - 3 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
2309.844275	43.3	1000	172.0	H	91.0	30.7	74.0	PASSED
2570.386785	45.9	1000	199.9	H	218.0	28.1	74.0	PASSED

Table 27. Radiated emission test results 1 - 3 GHz. Peak detector.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
2309.844275	30.6	1000	172.0	H	91.0	23.4	54.0	PASSED
2570.386785	29.1	1000	199.9	H	218.0	24.9	54.0	PASSED

Table 28. Radiated emission test results- 1 - 3 GHz. Average detector.

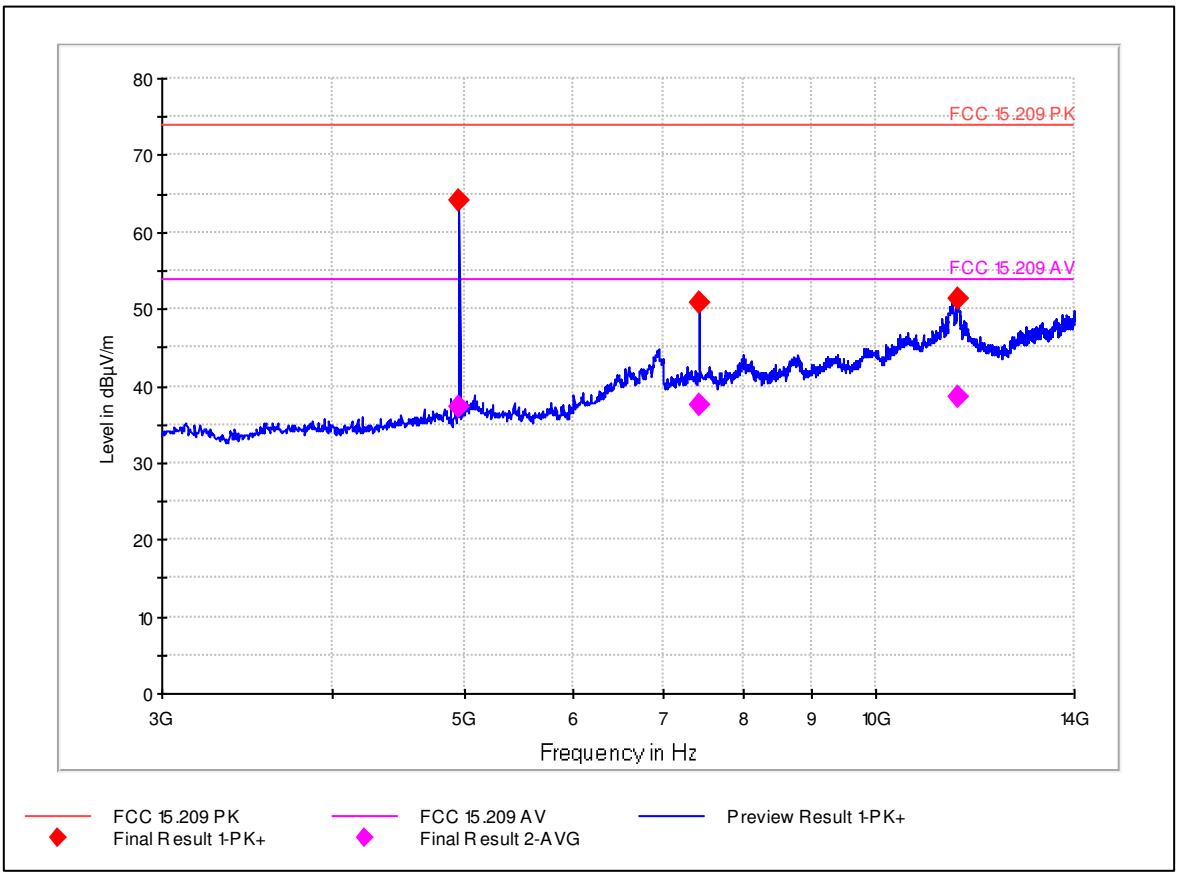

Figure 21. Radiated emission test results 3 - 14 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
4956.523336	64.2	1000	150.1	H	101.0	9.8	74.0	PASSED
7436.883256	50.7	1000	99.9	V	119.0	23.3	74.0	PASSED
11502.697004	51.2	1000	299.0	H	238.0	22.8	74.0	PASSED

Table 29. Radiated emission test results. 3 - 14 GHz. Peak detector.

The following frequencies are harmonic of the fundamental and thus pulsed.
The average value is calculated by correcting the Peak detector level with the Duty Cycle Correction Factor found in section 2.1.

Frequency [MHz]	Peak [dBuV/m]	Correction Factor [dB]	Average [dBuV/m]	Margin [dB]	Limit [dBuV/m]	Result
4956.523336	64.2	-26.58	37.62	16.38	54.0	PASSED
7436.883256	50.7	-26.58	24.12	29.88	54.0	PASSED

Table 30. Radiated emission test results 3 - 14 GHz. Average. Pulsed signal.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
11502.697004	38.5	1000	299.0	H	238.0	15.5	54.0	PASSED

Table 31. Radiated emission test results 3 - 14 GHz. Average. Non pulse signal

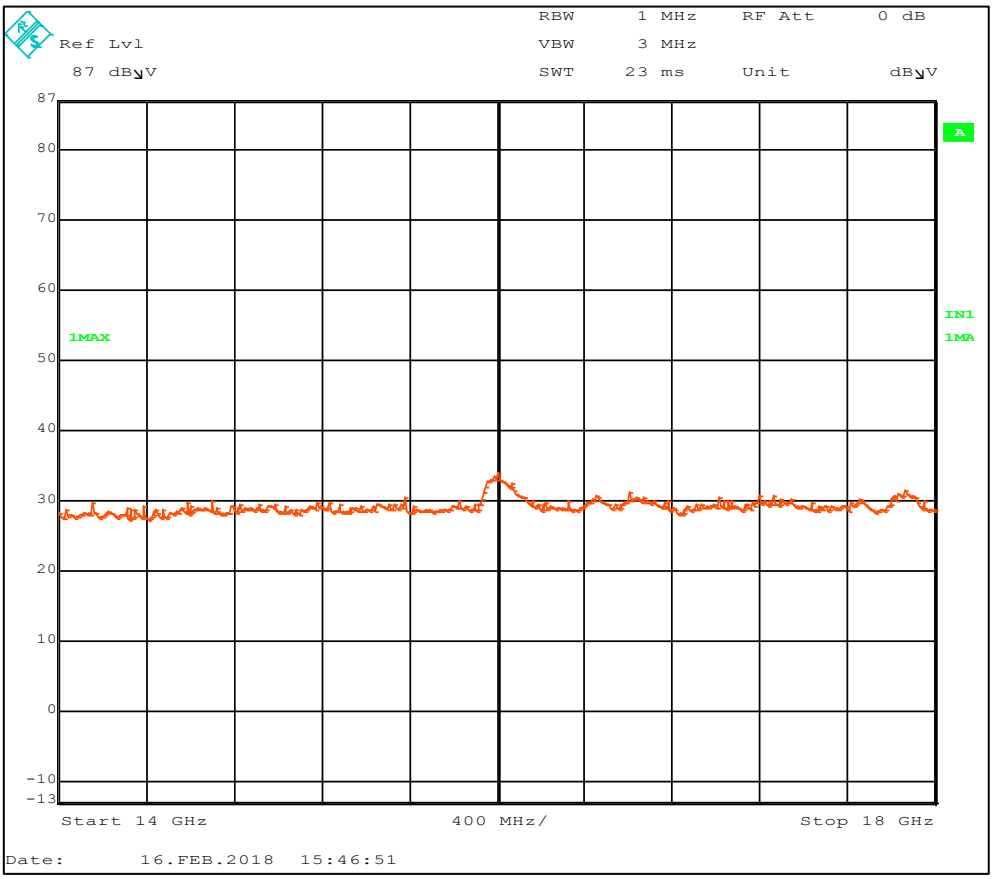

Figure 22. Radiated emission test results 14 - 18 GHz. Peak detector.

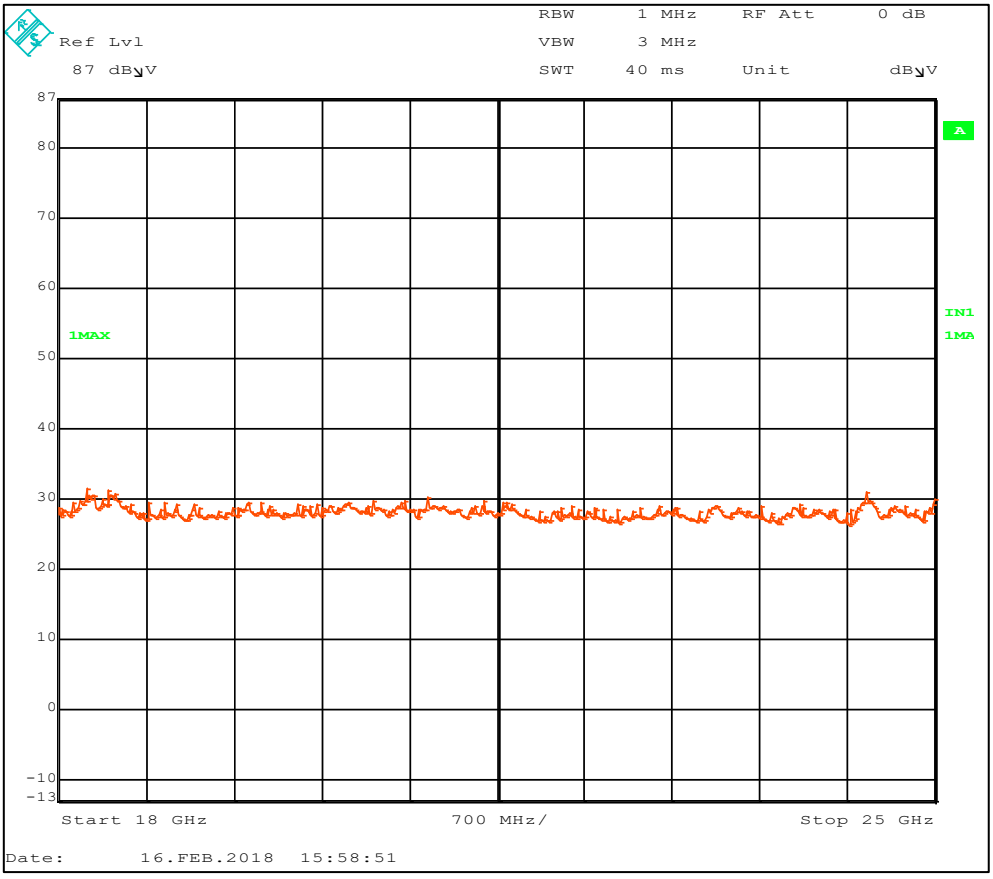

Figure 23. Radiated emission test results 18 - 25 GHz. Peak detector.

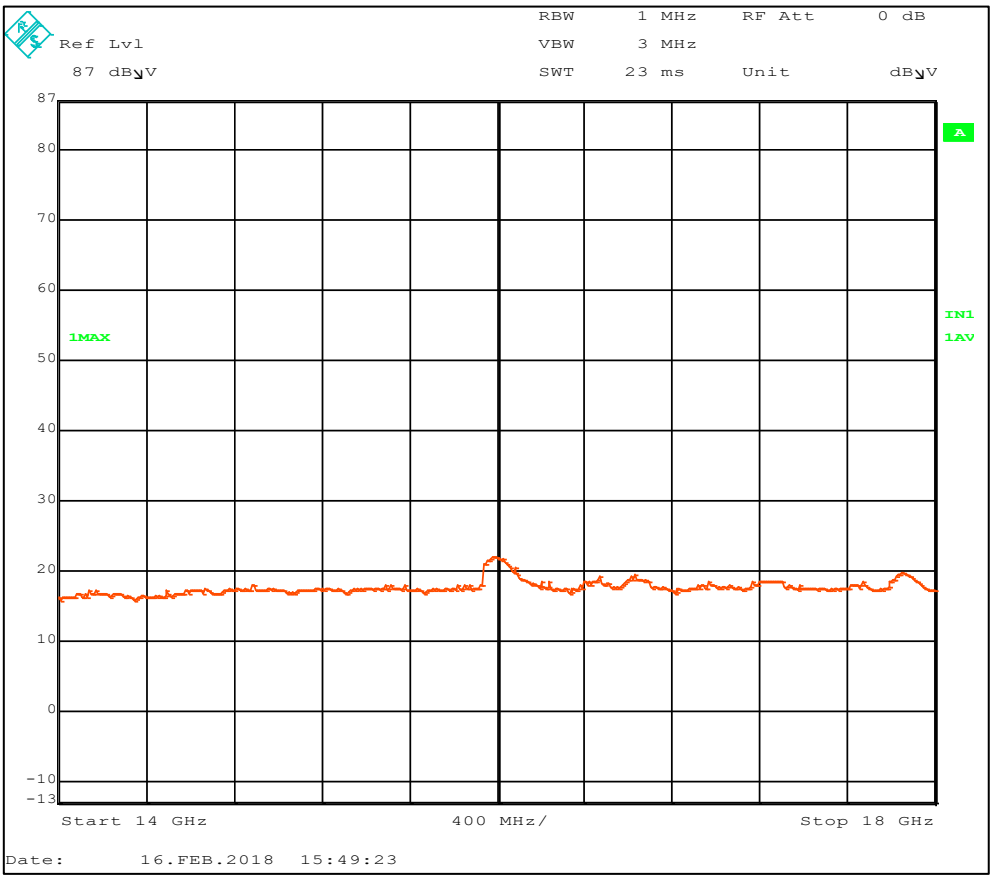

Figure 24. Radiated emission test results 14 - 18 GHz. Average detector.

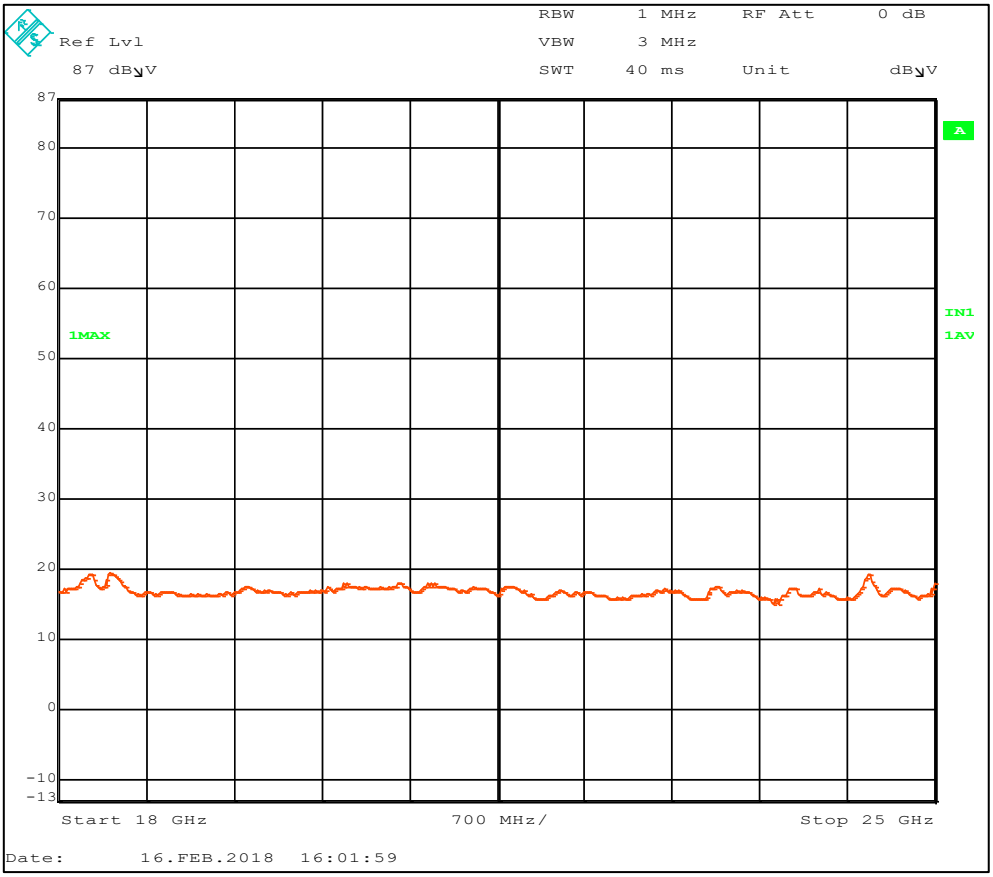

Figure 25. Radiated emission test results 18 - 25 GHz. Average detector.

Average Limit 3 m.	Peak limit 3 m	3 m / 0.5 m factor	Average Limit 0.5 m.	Peak limit 0.5 m
dBµV/m	dBµV/m	dB	dBµV/m	dBµV/m
53.98	73.98	15.56 dB	69.54	89.54

Table 32. Calculation of limit at 0.5 m.

Frequency	AF	Cable loss	Correction factor
GHz	dB/m	dB	dB/m
14	37,1	< 2	39.1
18	37,4	< 2	39.4
18	40.3	< 2	42.3
25	40.6	< 2	42.6

Table 33. Correction factors 14 – 25 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
-	-	-	-	-	-	-	89.54	PASSED

Table 34. Radiated emission test results. 14 - 25 GHz. Peak detector.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
-	-	-	-	-	-	-	69.54	PASSED

Table 35. Radiated emission test results 3 - 14 GHz. Average detector.

2.3.3 Test equipment

Description	Supplier	Model	Tag no.	Cal. due date
Antenna Biconical 30 - 300 MHz	ETS-LINDGREN	EMCO 3110B	13835	2019-02-20
Antenna Log Per 0.2 - 1 GHz	ETS-LINDGREN	3148	50083	2019-04-14
Antenna Horn	Schwarzbeck	BBHA 9120 D	20777	2019-02-18
Antenna Std gain Horn 12GHz-18GHz	Narda	639 + 609	17219	NA
Antenna Std gain Horn 18 - 26.5 GHz	Narda	638 + 4608B	17524	NA
Analyzer 20Hz-26.5GHz	Rohde&Schwarz	ESI	20763	2018-09-05

2.4 AC Conducted emission

Test specimen	Dongle DNG002
Test specification	47 CFR Part 15.207
Test method	ANSI C63.4:2014
Frequency range	0.15 - 30 MHz
Limits	47 CFR Part 15.207
Comments	none
Temperature / Humidity	22°C / 41%RH
Dates of measurements	2018-02-12
Test personnel	Søren Søltoft

2.4.1 Test setup

Measurements were performed with the test specimen powered from a USB port in a laptop and powered from a AC/DC adaptor while sending max power with max duty cycle at the middle channel (2449 MHz). In both set up the mains supply was 120 VAC 60 Hz.

See appendix 1 for photo of test set up

2.4.2 Test limits

Frequency (MHz)	Quasi-peak value (dBµV)	Average value (dBµV/m)
0.15-0.5	66-56*	56-46*
0.5-5	56	46
5-30	60	50

Table 36. Radiated emission limits.

Note *=Decreases with the logarithm of the frequency

2.4.3 Test results

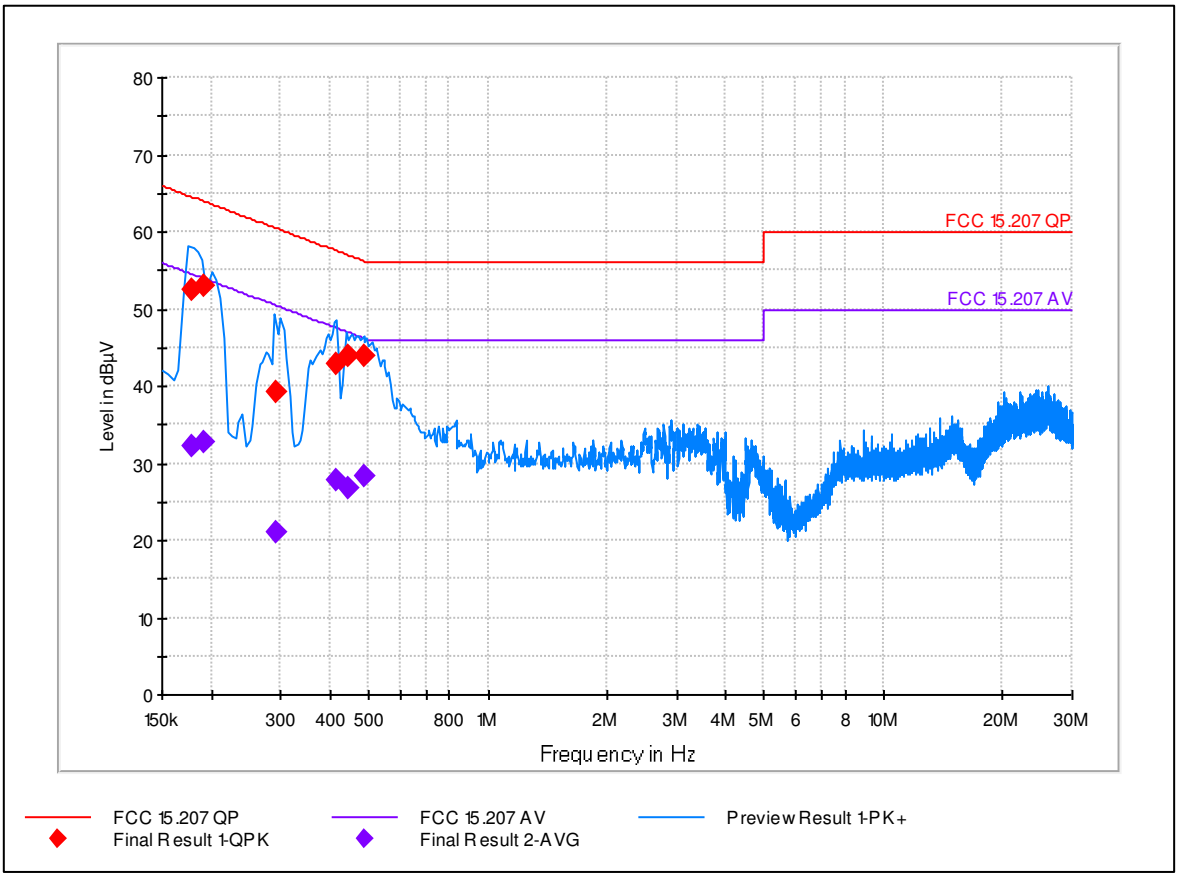

Figure 26. AC Conducted emission. Powered by laptop

Frequency [MHz]	QuasiPeak [dBuV]	BW [kHz]	Line	Margin [dB]	Limit [dBuV]	Result
0.178900	52.5	9.000	L1	12.00	64.50	PASSED
0.191200	53.1	9.000	N	10.90	64.00	PASSED
0.290100	39.2	9.000	N	21.30	60.50	PASSED
0.413800	42.8	9.000	N	14.80	57.60	PASSED
0.444800	43.8	9.000	N	13.10	57.00	PASSED
0.488800	43.8	9.000	N	12.40	56.20	PASSED

Table 37. AC Conducted emission. Powered by laptop. QuasiPeak detector.

Frequency [MHz]	Average [dBuV]	BW [kHz]	Line	Margin [dB]	Limit [dBuV]	Result
0.178900	32.3	9.000	L1	22.20	54.50	PASSED
0.191200	32.8	9.000	N	21.20	54.00	PASSED
0.290100	21.0	9.000	N	29.50	50.50	PASSED
0.413800	27.7	9.000	N	19.80	47.60	PASSED
0.444800	26.6	9.000	N	20.30	47.00	PASSED
0.488800	28.4	9.000	N	17.80	46.20	PASSED

Table 38. AC Conducted emission. Powered by laptop. Average detector.

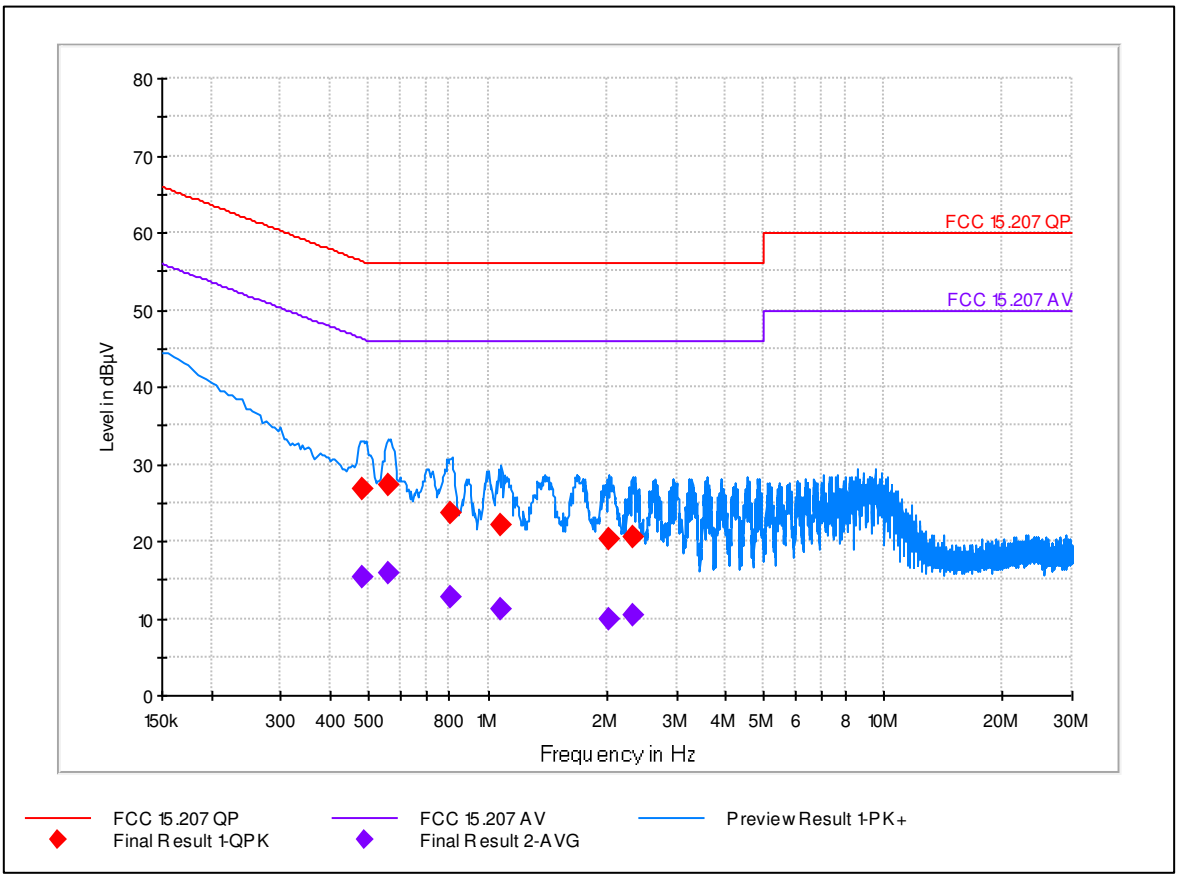

Figure 27. AC Conducted emission. Powered by AC/DC adaptor.

Frequency [MHz]	QuasiPeak [dBuV]	BW [kHz]	Line	Margin [dB]	Limit [dBuV]	Result
0.480300	26.7	9.000	N	29.60	56.30	PASSED
0.559700	27.4	9.000	N	28.60	56.00	PASSED
0.805100	23.7	9.000	N	32.30	56.00	PASSED
1.074000	22.1	9.000	N	33.90	56.00	PASSED
2.028000	20.2	9.000	N	35.80	56.00	PASSED
2.341600	20.5	9.000	N	35.50	56.00	PASSED

Table 39. AC Conducted emission. Powered by AC/DC adaptor. QuasiPeak detector.

Frequency [MHz]	Average [dBuV]	BW [kHz]	Line	Margin [dB]	Limit [dBuV]	Result
0.480300	15.3	9.000	N	31.10	46.30	PASSED
0.559700	15.8	9.000	N	30.20	46.00	PASSED
0.805100	12.7	9.000	N	33.30	46.00	PASSED
1.074000	11.2	9.000	N	34.80	46.00	PASSED
2.028000	9.9	9.000	N	36.10	46.00	PASSED
2.341600	10.4	9.000	N	35.60	46.00	PASSED

Table 40. AC Conducted emission. Powered by AC/DC adaptor. Average detector.

2.4.4 Test equipment

Description	Supplier	Model	Tag no.	Cal. due date
V-network Two Line	R&S	ESH3-Z5	20682	2019-01-22
Receiver EMI Test 20Hz-26.5GHz	Rohde&Schwarz	ESIB 26	18880	2018-09-05

2.5 20 dB bandwidth

Test specimen	Dongle DNG002
Test specification	47 CFR Part 15.215
Test method	ANSI C63.10:2013
Comments	none
Temperature / Humidity	22°C / 37%RH
Dates of measurements	2018-01-26
Test personnel	Søren Søltoft

2.5.1 Test setup

A measuring distance of 3 m was used during the tests.
The EUT was placed 1.5 m above ground on a non-conductive table.

See appendix 1 for photo of test set up

2.5.2 Test results

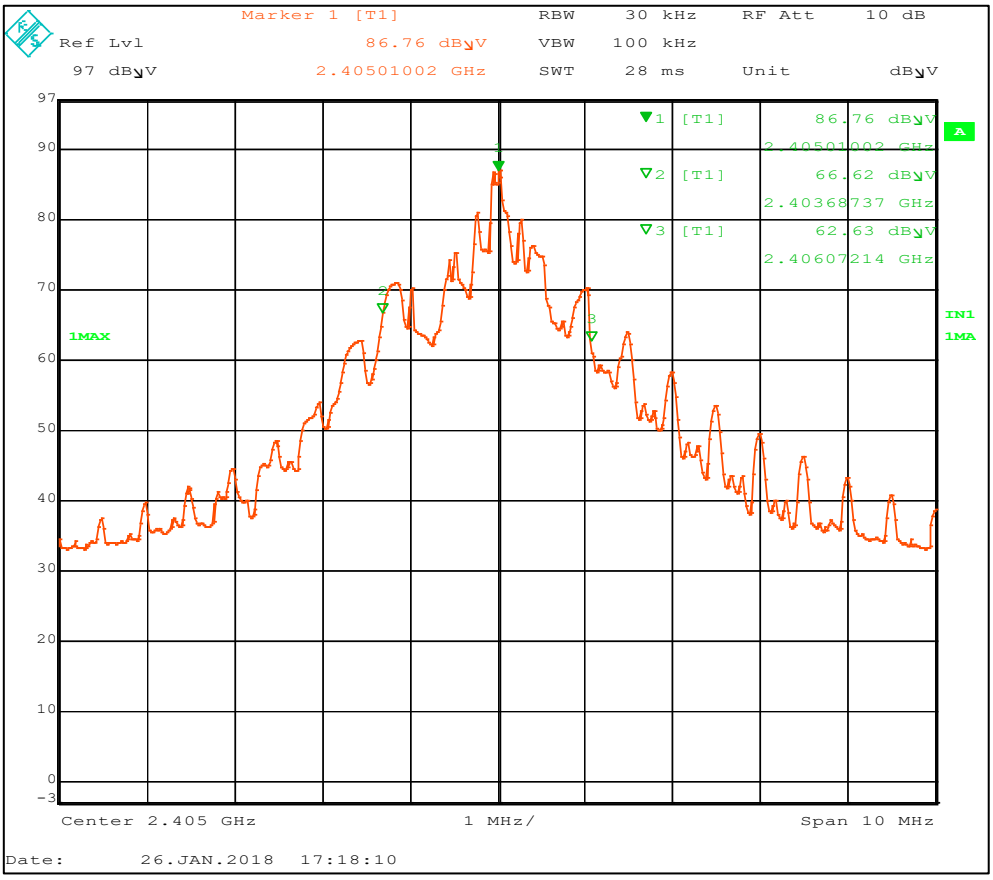

Figure 28. 20 dB bandwidth at 2405 MHz.

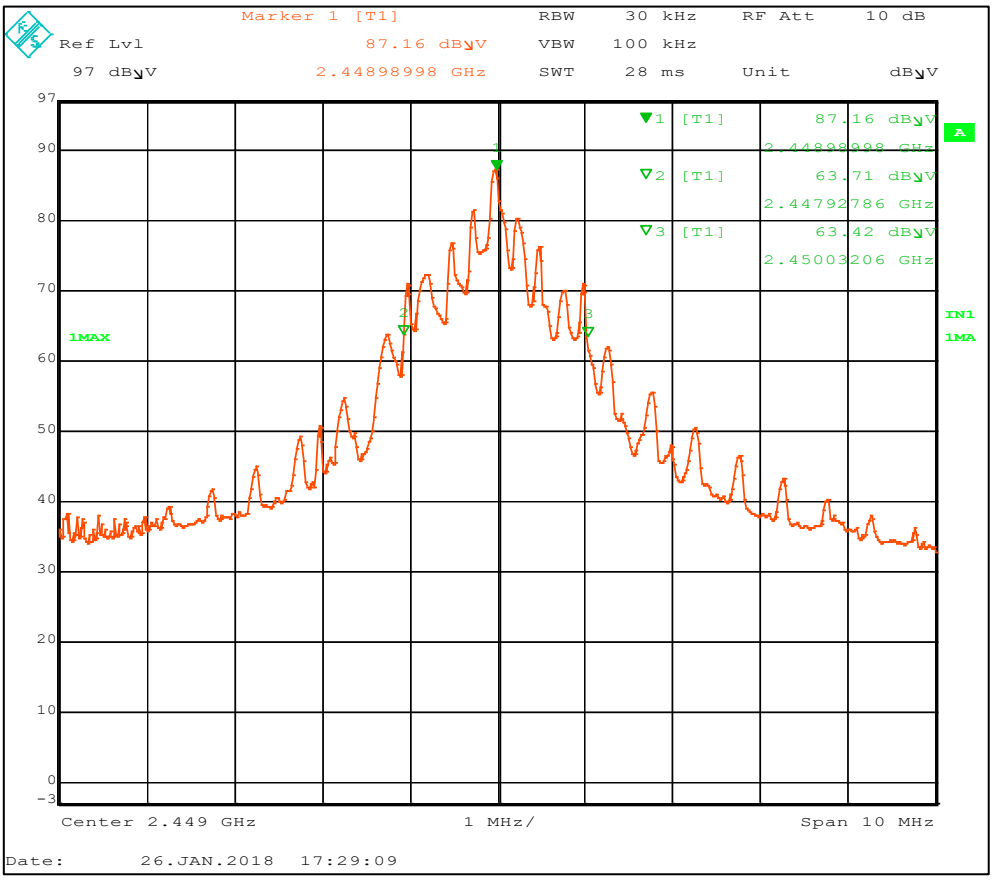

Figure 29. 20 dB bandwidth at 2449 MHz.

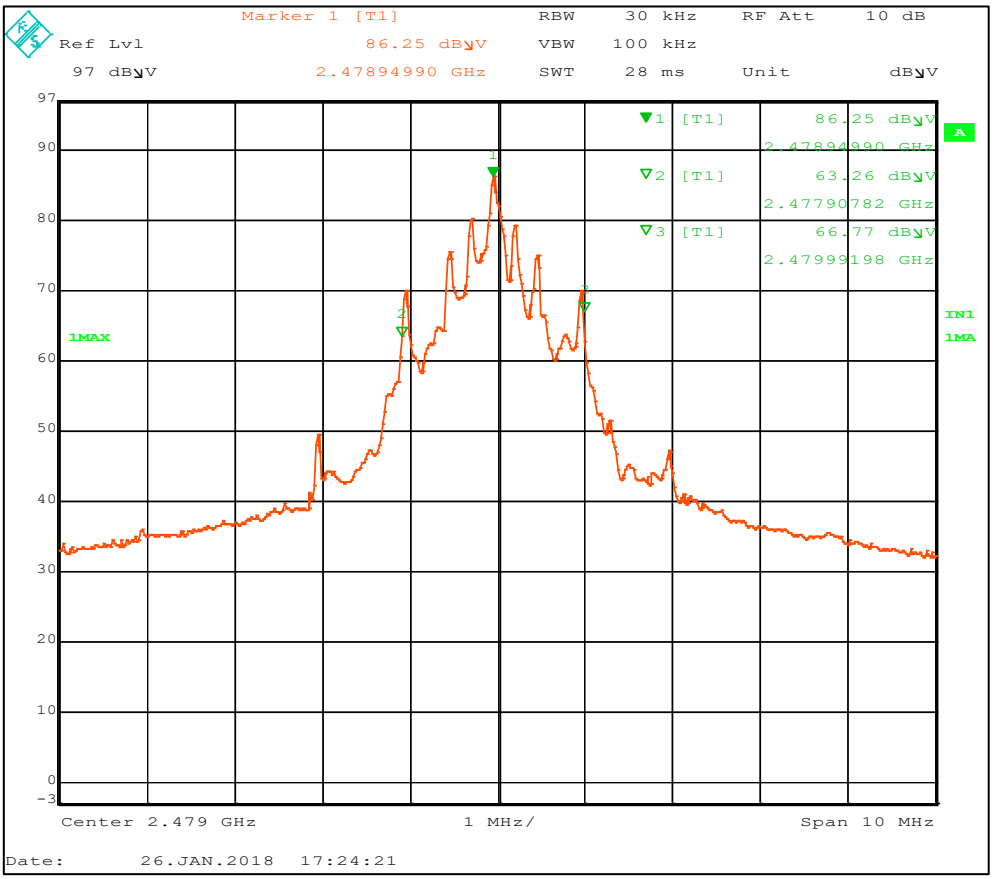

Figure 30. 20 dB bandwidth at 2479 MHz.

Frequency [MHz]	20 dB Bandwidth [MHz]	Result
2405	2.38477	PASSED
2449	2.1042	PASSED
2479	2.08416	PASSED

Table 41. 20 dB bandwidth results.

2.5.3 Test equipment

Description	Supplier	Model	Tag no.	Cal. due date
Antenna Horn	Schwarzbeck	BBHA 9120 D	20777	2019-02-18
Analyzer 20Hz-26.5GHz	Rohde&Schwarz	ESI	20763	2018-09-05

2.6 Occupied bandwidth

Test specimen	Dongle DNG002
Test specification	47 CFR 2.1049
Test method	ANSI C63.10:2013
Comments	none
Temperature / Humidity	22°C / 37%RH
Dates of measurements	2018-01-26
Test personnel	Søren Søltoft

2.6.1 Test setup

A measuring distance of 3 m was used during the tests.
The EUT was placed 1.5 m above ground on a non-conductive table.

See appendix 1 for photo of test set up

2.6.2 Test results

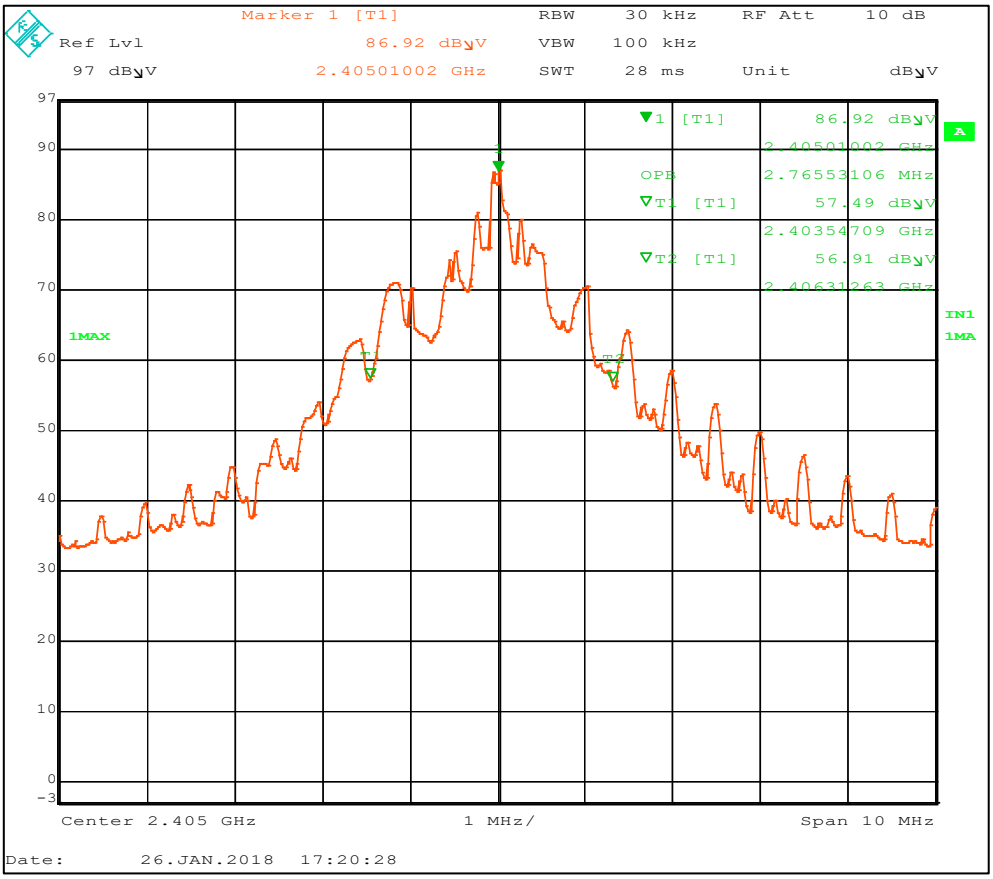

Figure 31. Occupied bandwidth 99% at 2405 MHz.

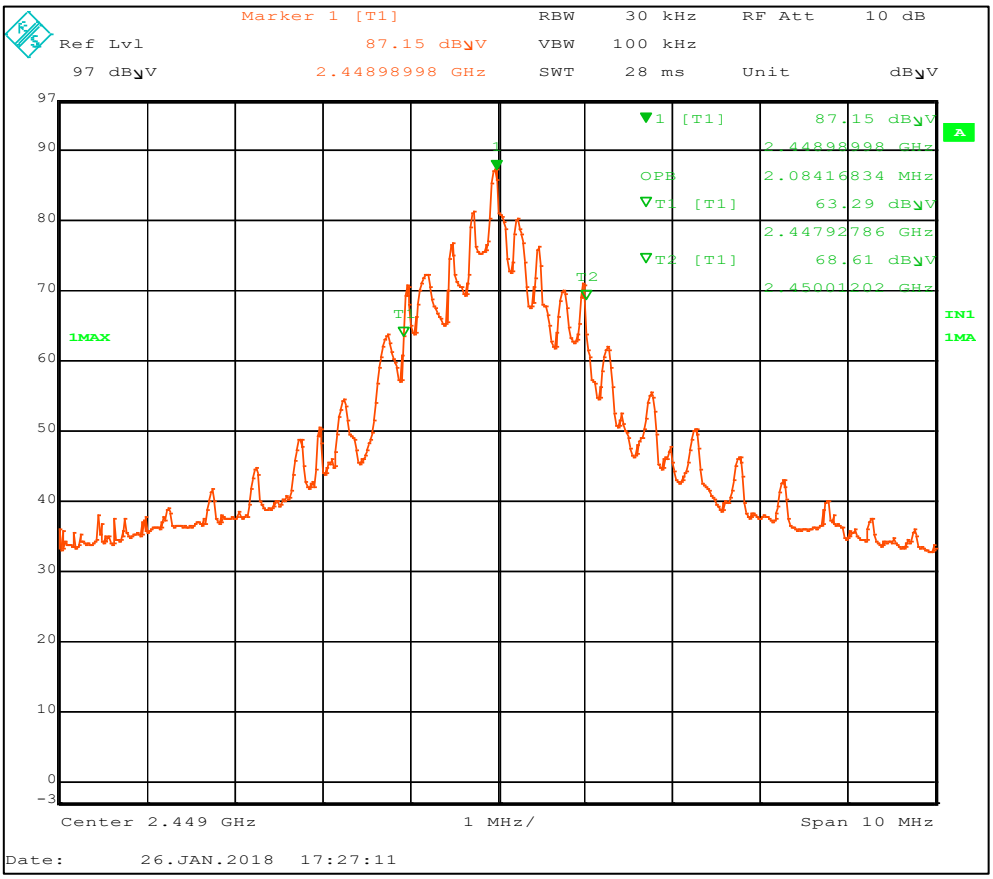

Figure 32. Occupied bandwidth 99% at 2449 MHz.

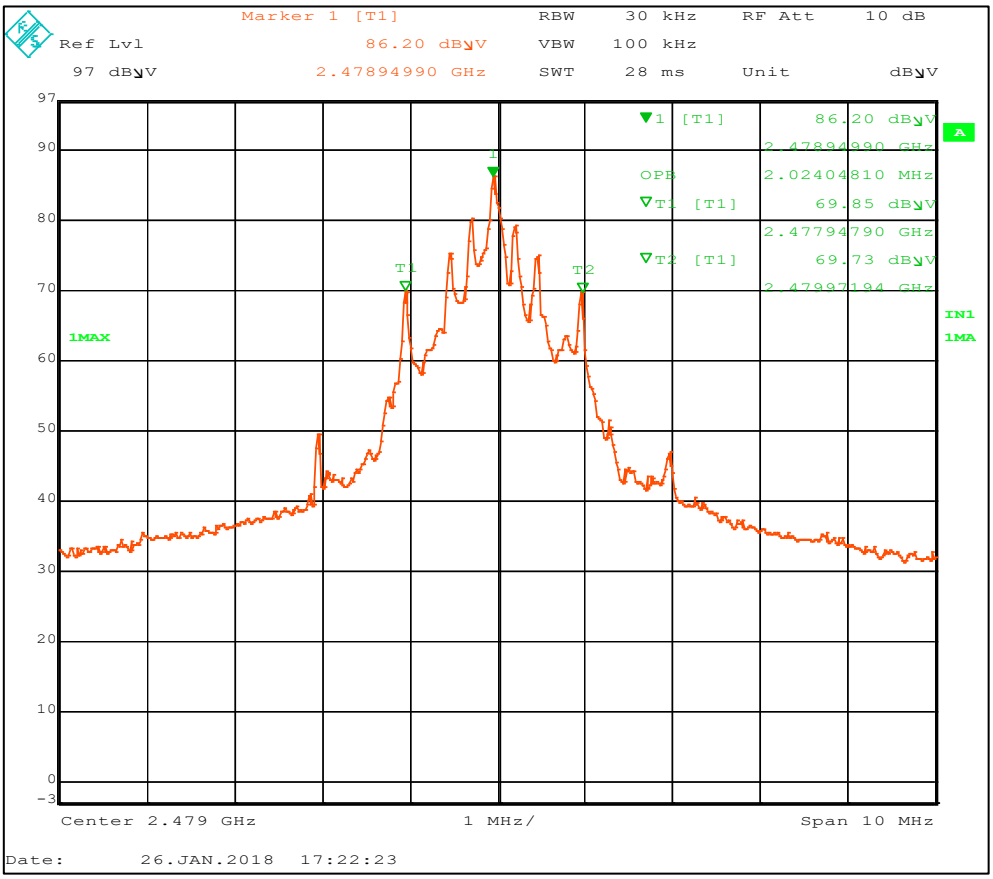

Figure 33. Occupied bandwidth 99% at 2479 MHz.

Frequency [MHz]	Occupied bandwidth 99% [MHz]	Result
2405	2,76553106	PASSED
2449	2,08416834	PASSED
2479	2,02404810	PASSED

Table 42. 20 dB bandwidth results.

2.6.3 Test equipment

Description	Supplier	Model	Tag no.	Cal. due date
Antenna Horn	Schwarzbeck	BBHA 9120 D	20777	2019-02-18
Analyzer 20Hz-26.5GHz	Rohde&Schwarz	ESI	20763	2018-09-05

Table 43. 20 dB bandwidth test equipment.

2.7 Band edge

Test specimen	Dongle DNG002
Test specification	47 CFR 2.1049
Test method	ANSI C63.10:2013
Comments	none
Temperature / Humidity	22°C / 37%RH
Dates of measurements	2018-01-26
Test personnel	Søren Søltoft

2.7.1 Test setup

A measuring distance of 3 m was used during the tests.

The EUT was placed 1.5 m above ground on a non-conductive table.

The turntable, antenna height and antenna polarity were adjusted for maximal radiated emission level.

The graphs are offset with the correction factor to show the maximal level.

See appendix 1 for photo of test set up

According to 15.205 the nearest restricted bands above and below the operational band are 2310 – 2390 MHz and 2483.5 – 2500 MHz. The measurements were made according to ANSI 63.10:2013 clause 6.10.5 Restricted-band band-edge measurements.

Limits according to 15.209.

2.7.2 Test results

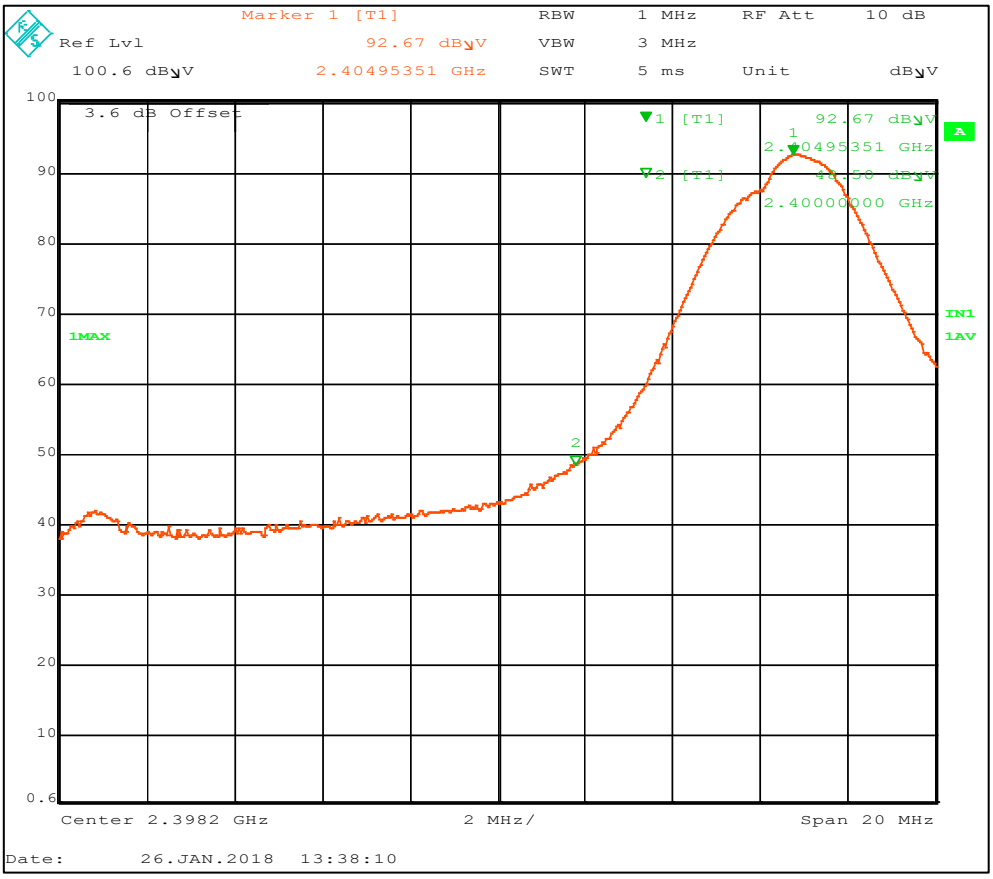

Figure 34. Band Edge Low channel 2405 MHz. Average detector.

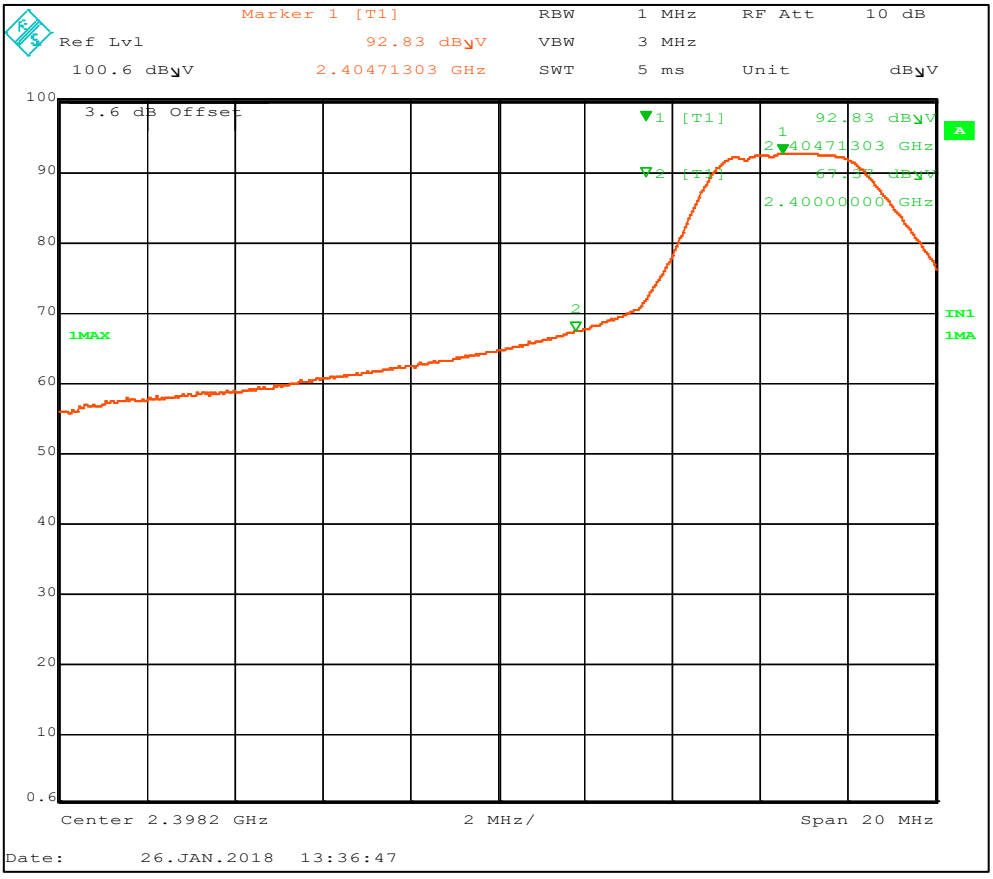

Figure 35. Band Edge Low channel 2405 MHz. Peak detector.

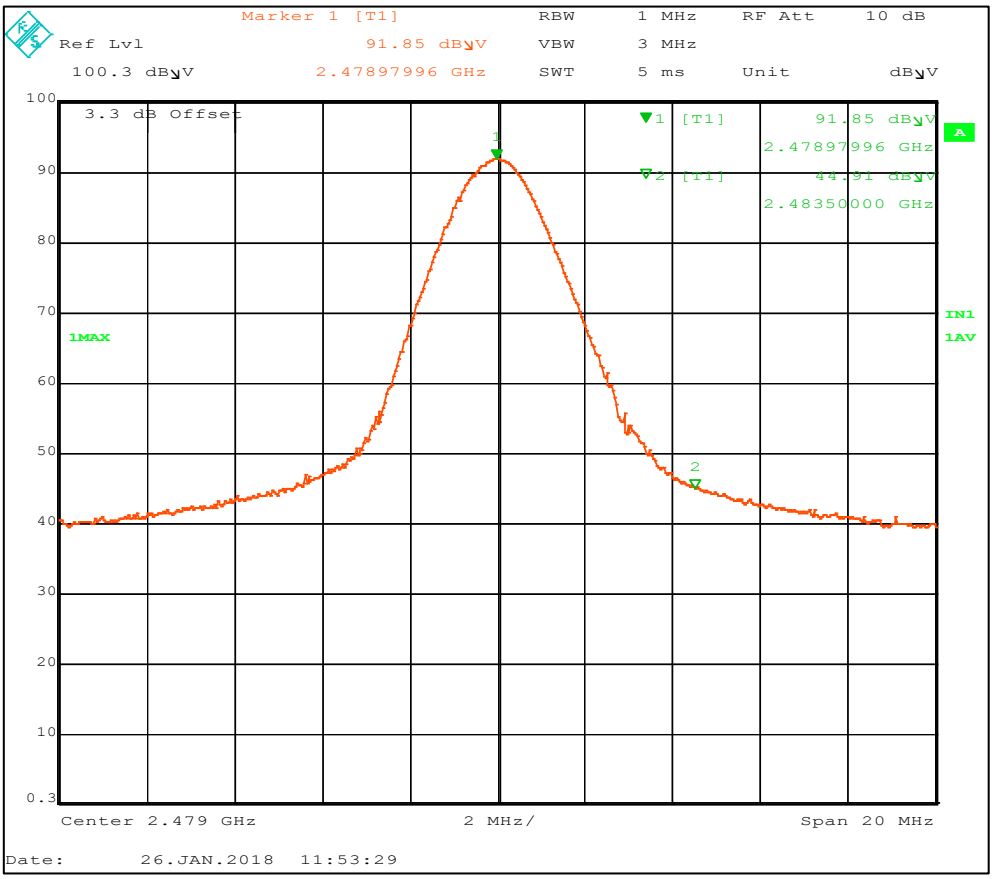

Figure 36 Band Edge High channel 2479 MHz. Average detector.

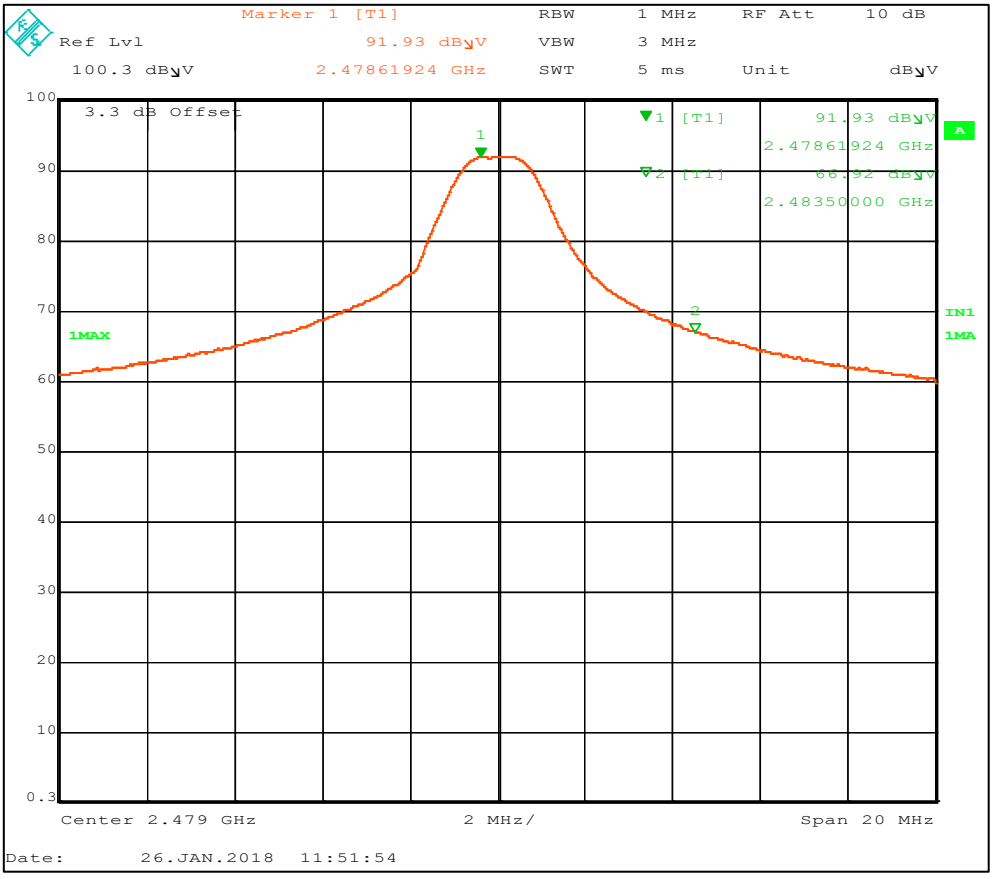

Figure 37. Band Edge High channel 2479 MHz. Peak detector.

The fundamental are pulsed, thus the average value is calculated by correcting the Peak detector level with the Duty Cycle Correction Factor found in section 2.1.

Channel Frequency	Detector	Band-Edge level	Margin	Limit	Result
[MHz]		[dBµV/m]	[dB]	[dBµV/m]	
2405	Average	40.79	13.21	54	PASSED
2405	Peak	67.37	6.63	74	PASSED
2479	Average	40.34	13.66	54	PASSED
2479	Peak	66.92	7.08	74	PASSED

Table 44. Band Edge results.

2.7.3 Test equipment

Description	Supplier	Model	Tag no.	Cal. due date
Antenna Horn	Schwarzbeck	BBHA 9120 D	20777	2019-02-18
Analyzer 20Hz-26.5GHz	Rohde & Schwarz	ESI	20763	2018-09-05

Table 45. Band Edge test equipment.

3 MEASURING UNCERTAINTIES

Compliancy evaluation is based on a shared risk principle with respect to the measurement uncertainty.

	Frequency [MHz]	Polarization	Expanded Uncertainty [dB] (k=2)
Radiated emission	30 - 200	Vertical	**4.59**
	200 - 1000	Vertical	**4.77**
	1000 - 18000	Vertical	**3.76**
	18000 - 25000	Vertical	**4.10**
	30 - 200	Horizontal	**4.57**
	200 - 1000	Horizontal	**4.86**
	1000 - 18000	Horizontal	**3.77**
	18000 - 25000	Horizontal	**4.11**
Conducted emission (CISPR 16-4)	0.01 - 30		**3.44**

Appendix 1 Photos

Photo 1. Dongle DNG002

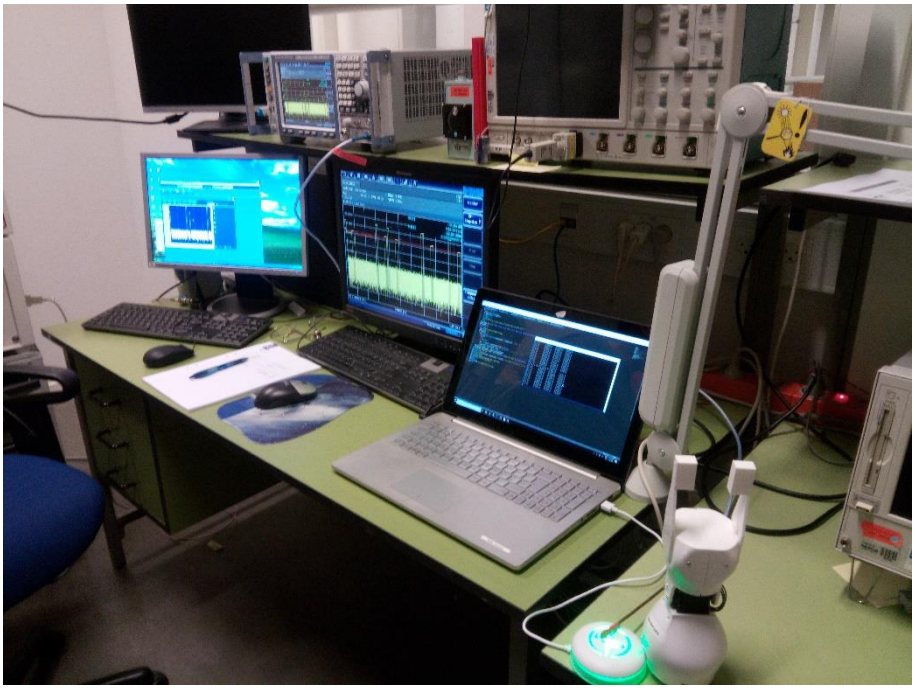

Photo 2. Duty cycle test set up.

Photo 3 - Radiated emission test setup for 30 - 200 MHz.

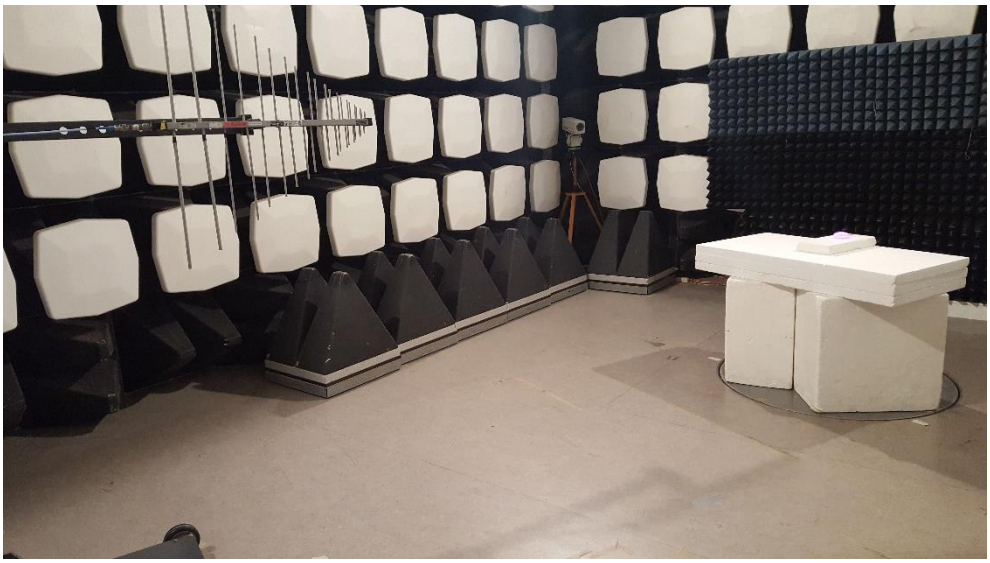

Photo 4 - Radiated emission test setup for 200 - 1000 MHz.

Photo 5 - Radiated emission test setup for 1 – 14 GHz.

Photo 6. Radiated emission test setup for 14 – 25 GHz. With ruler indicating distance.

Photo 7. Vertical orientation

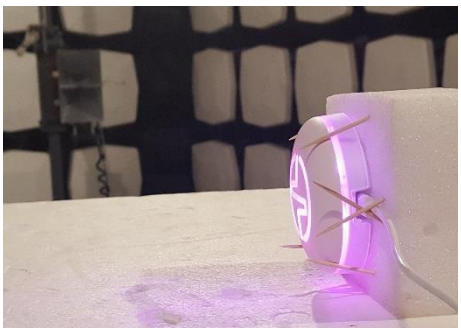

Photo 8. Vertical – 90 deg. orientation

Photo 9. Horizontal orientation.

Photo 10. AC Conducted emission test set up. Powered by laptop

Photo 11. AC Conducted emission test set up. Powered by AC/DC adaptor