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Date	Reference	Page
2019-01-18	P18-0129-1 rev. 1	1 (46)

Moises Pacheco
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DANAK
TEST Reg.nr. 563

FCC Designation
Number: DK0002

Test Report

of

Spin
FCC ID: 2AOUESPN001

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

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Report no.:	P18-0129-1 rev. 1	**Report date:**	2019-01-18
Test started:	2018-12-03	**Test ended:**	2018-12-12
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 Rugmarken 18 3520 Farum Denmark

Facility reg. nr.	FCC Designation number: DK0002
Test specimen:	Spin Model No: SPN001. FCC ID: 2AOUESPN001
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:	P18-0129-1 rev. 1 supersedes P18-0129-1 issued 2018-12-21. Changes: The client address has been changed. 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 David Busk

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Appendix

1 Photos

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	Spin
Model No.	SPN001
Hardware ver.	1.6
Test Software	Spin_fcc_const_carrier_modulated.hex
Supply voltage	5 VDC by USB or internal Li-ion battery

The Spin is an item containing two motor controlled wheels, which enables the Spin to rotate.
The movement is controlled by a PC program. The communication is performed via a 2.4 GHz radio link to a Dongle connected to a PC by a USB cable.
The Spin is powered by an internal Li-ion battery and charged via USB connector.
The 2.4 GHz radio used in both Spin and Dongle is the same type 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 2408 MHz to 2468 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. 2408 MHz
2. 2441 MHz
3. 2468 MHz

See photo 1 in appendix 1.

1.3 Auxiliary Equipment

1.3.1 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 in appendix 1.

1.4 I/O ports / cables to test specimen

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

1.5 Test set-up

During the tests the 2.4 GHz module (nRF24L01+) was set to transmit maximal power at one frequency, with the maximal duty cycle which was possible with normal modulation in test mode.

2 TESTS

2.1 Duty Cycle

Test specimen	Spin
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	2018-12-10
Test personnel	Søren Søltoft

2.1.1 Test setup

It was not possibly to configure the 2.4 GHz radio module to 100 % duty cycle.
The duty cycle was calculated from the total on time during a 100 ms period.
The measured duty cycle does not represents is higher than the duty cycle in normal mode.
The measurements were performed in a semi-anechoic chamber with absorber on floor

See photo of test set up in appendix 1.

2.1.2 Test result

The duty cycle was measured at 2441 MHz.

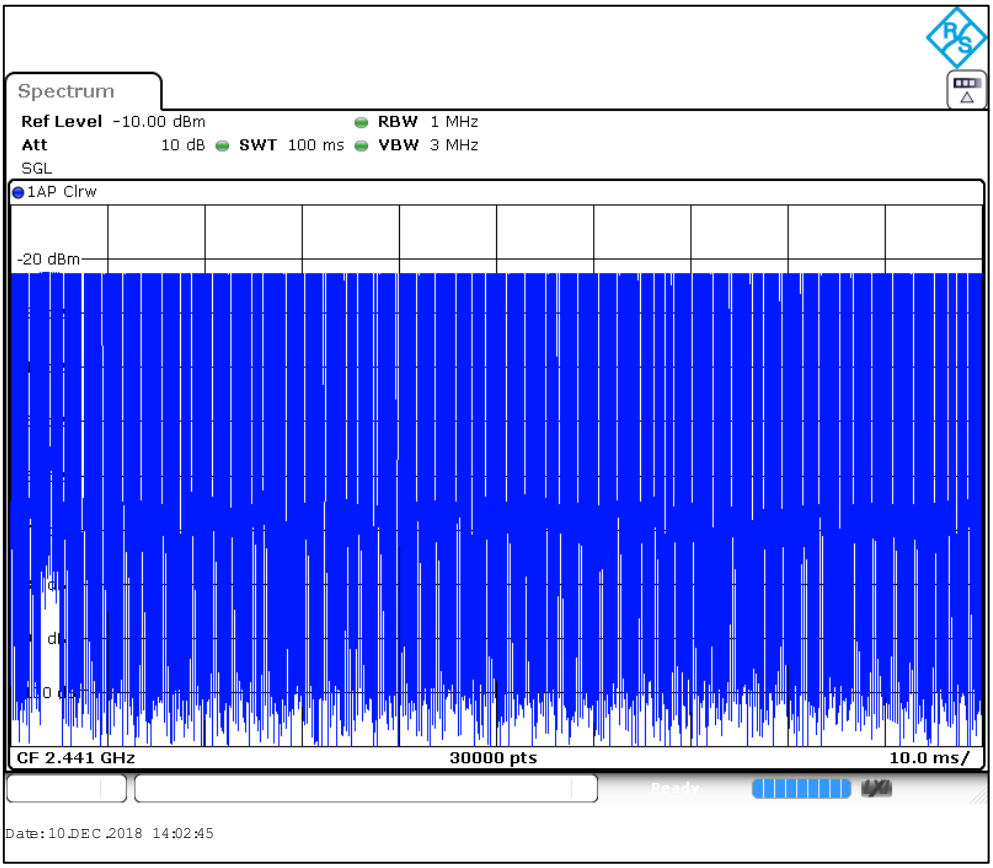

Figure 1. Duty Cycle.

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]
46.16	100	0.4616	-6.715

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	2019-08-24

2.2 Field strength of fundamental

Test specimen	Spin
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 / 39%RH
Dates of measurements	2018-12-03
Test personnel	Søren Søltoft

2.2.1 Test setup

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

The fundamental was scanned with peak detector with the EUT in 3 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: 2408 MHz			
EUT axis	**X**	**Y**	**Z**
Antenna polarization	Vertical	Horizontal	Vertical
Max. peak power	88.76 dBµV/m	89.6 dBµV/m	88.4 dBµV/m
Result	PASSED	PASSED	PASSED

Fundamental: 2441 MHz			
EUT axis	**X**	**Y**	**Z**
Antenna polarization	Vertical	Horizontal	Vertical
Max. peak power	89.54 dBµV/m	89.69 dBµV/m	87.87 dBµV/m
Result	PASSED	PASSED	PASSED

Fundamental: 2468 MHz			
EUT axis	**X**	**Y**	**Z**
Antenna polarization	Vertical	Horizontal	Vertical
Max. peak power	89.29 dBµV/m	88.65 dBµV/m	86.84 dBµV/m
Result	PASSED	PASSED	PASSED

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

The rated supply voltage were variated between 85% and 115% of range 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	2018-12-05

2.3 Radiated emission

Test specimen	Spin
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	22°C / 39%RH, 21°C / 39%RH, 22°C / 39%RH, 22°C / 37%RH, 21°C / 37%RH, 21°C / 37%RH
Dates of measurements	2018-12-03, 2018-12-04, 2018-12-05, 2018-12-06,2018-12-07, 2018-12-12
Test personnel	David Busk, 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 with absorbers on floor above 1 GHz. The measurements were performed with both horizontal and vertical polarizations of the antenna. The antenna distance during the measurements was 3.0 m.

The test specimen was tested in a combination of orientations and 3 frequencies.

The middle channel at 2441 MHz was tested in 3 orientations. The outer channels at 2408 MHz and 2468 MHz were tested in worst orientation found at the middle channel.

A pre-measurement was performed with peak detector. The test object was 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.

If the emission is close or above the limit during the pre-measurement, the test object was scanned 360 degrees and the antenna height scanned from 1 to 4 m for maximum response. Then the emission was 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 Middle channel 2441 MHz.

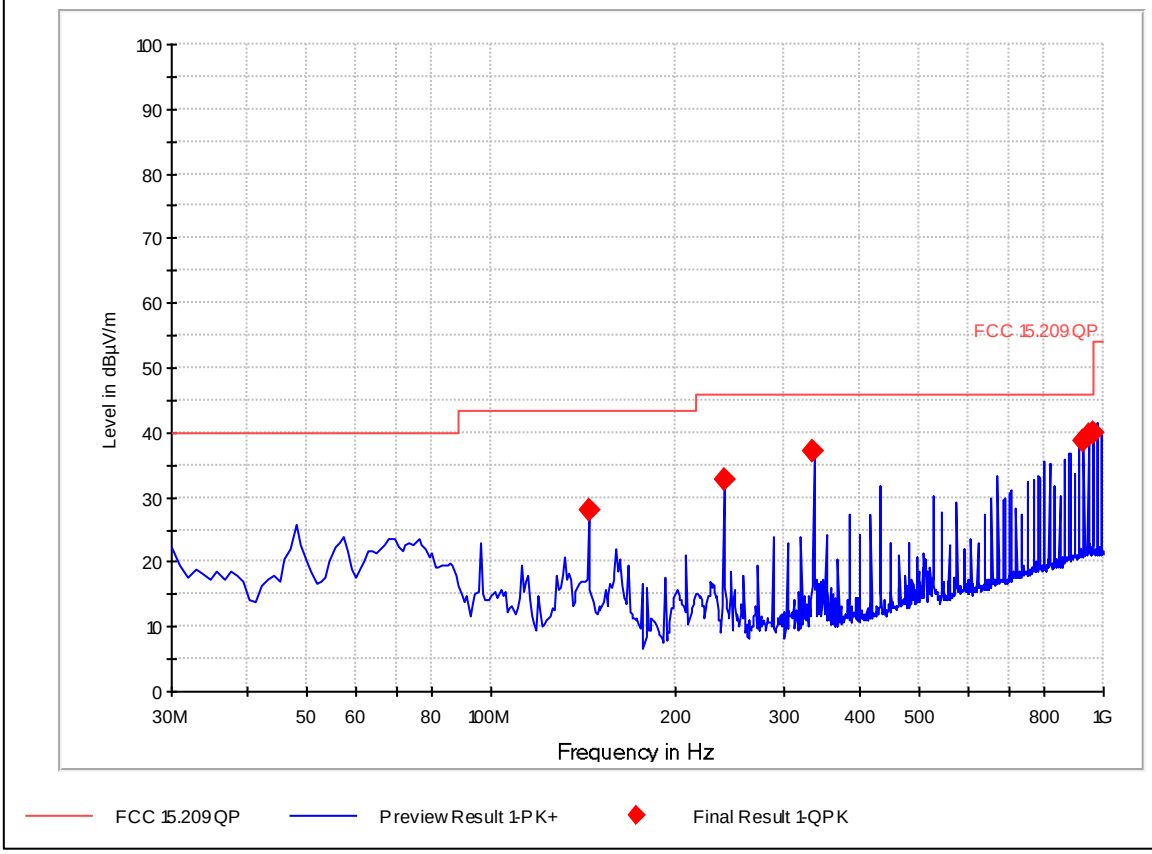

Figure 2. Radiated emission test results. 30 - 1000 MHz. X-axis.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
144.007936	28.0	120.0	99.8	V	54.0	15.5	43.5	PASSED
240.000080	32.6	120.0	99.8	V	256.0	13.4	46.0	PASSED
335.992224	37.3	120.0	99.8	H	257.0	8.7	46.0	PASSED
927.975711	38.8	120.0	100.1	V	183.0	7.2	46.0	PASSED
944.007776	39.6	120.0	99.8	V	177.0	6.4	46.0	PASSED
959.999840	39.9	120.0	100.1	V	168.0	6.1	46.0	PASSED

Table 3. Radiated emission test results. 30 - 1000 MHz. X-axis

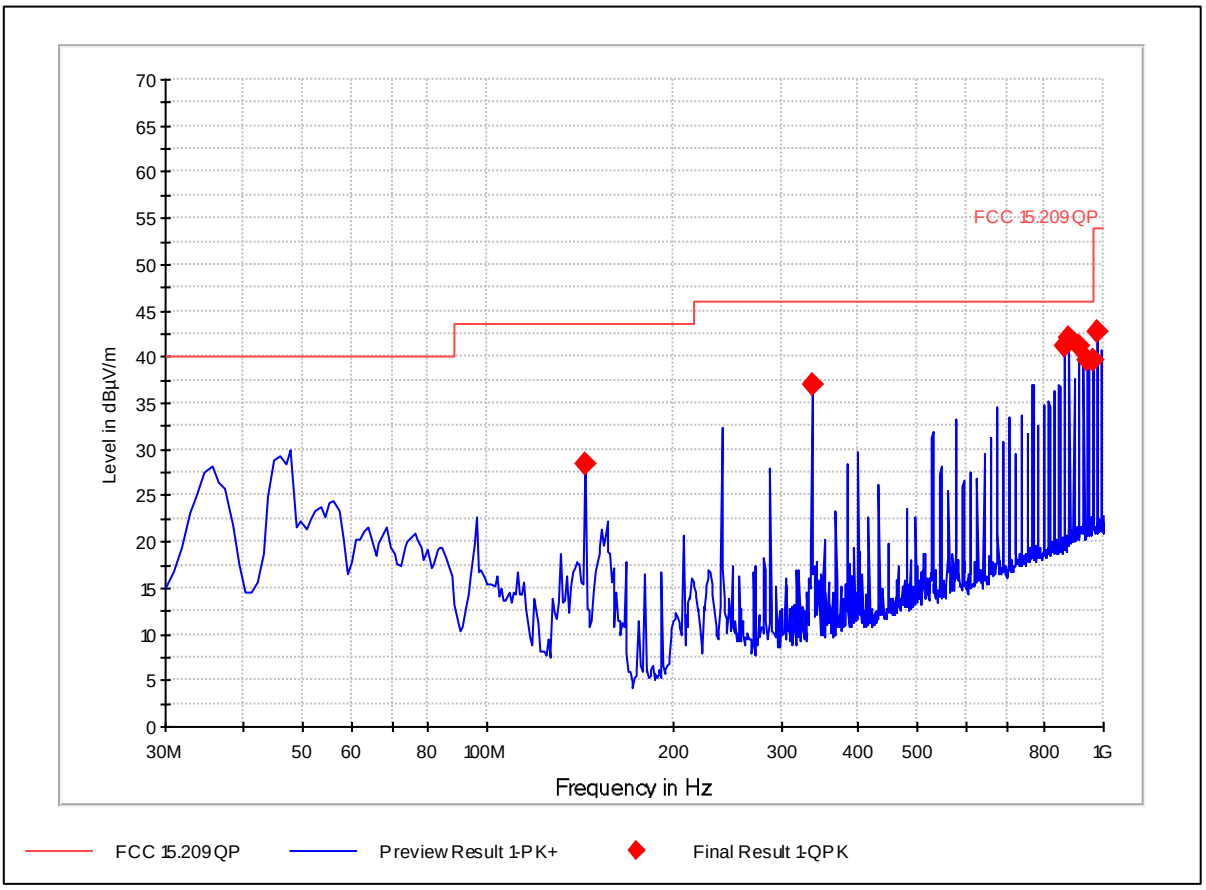

Figure 3. Radiated emission test results. 30 - 1000 MHz. Y-axis.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
144.007936	28.4	120.0	100.1	V	61.0	15.1	43.5	PASSED
335.992224	37.0	120.0	100.1	H	270.0	9.0	46.0	PASSED
864.007455	41.1	120.0	100.1	H	226.0	4.9	46.0	PASSED
879.999519	42.0	120.0	100.1	H	226.0	4.0	46.0	PASSED
911.983647	41.3	120.0	99.8	H	218.0	4.7	46.0	PASSED
944.007776	39.5	120.0	100.1	V	39.0	6.5	46.0	PASSED
959.999840	39.6	120.0	99.7	V	30.0	6.4	46.0	PASSED
975.991904	42.7	120.0	100.1	V	48.0	11.3	54.0	PASSED

Table 4. Radiated emission test results. 30 - 1000 MHz. Y-axis

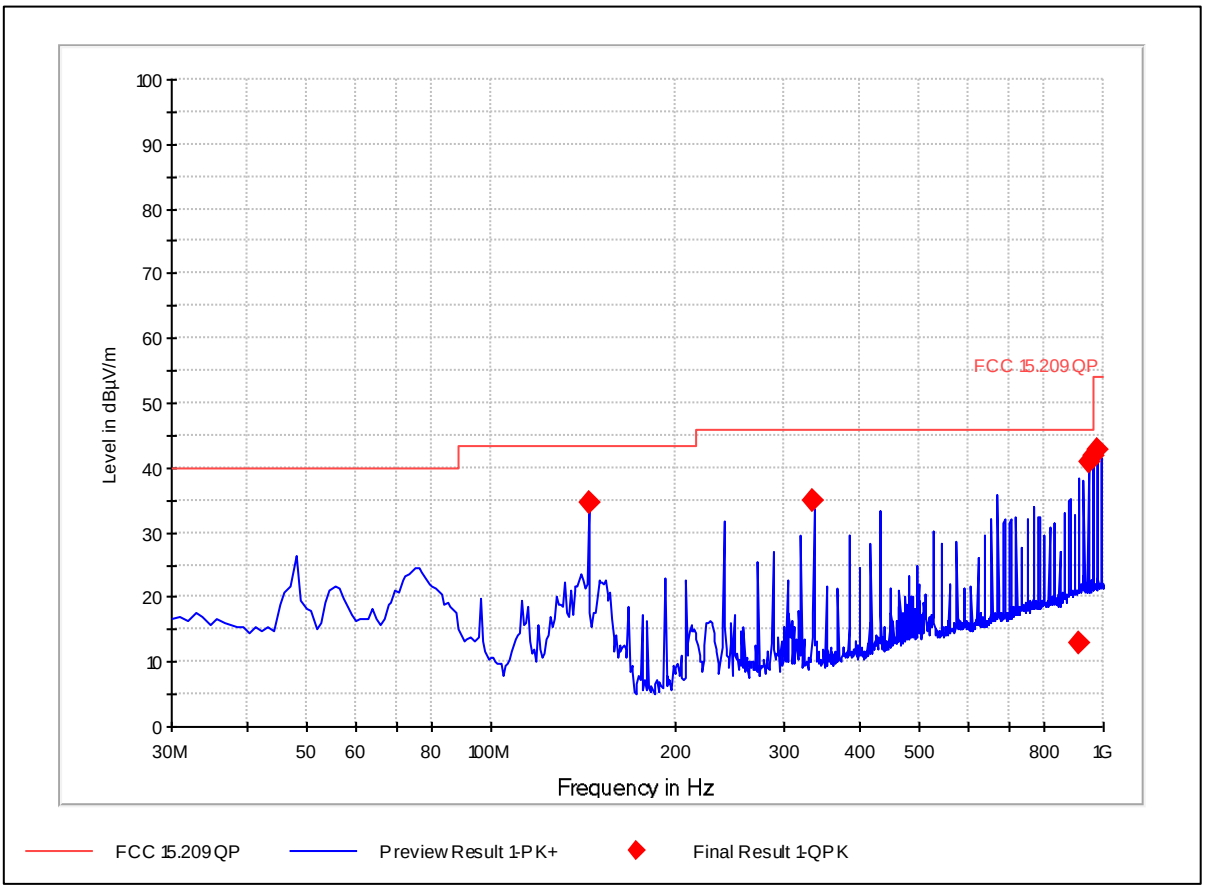

Figure 4. Radiated emission test results. 30 - 1000 MHz. Z-axis.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
144.007936	34.5	120.0	100.1	V	248.0	9.0	43.5	PASSED
335.992224	35.0	120.0	99.7	H	254.0	11.0	46.0	PASSED
913.425651	12.8	120.0	275.9	V	45.0	33.2	46.0	PASSED
944.007776	41.0	120.0	99.8	V	187.0	5.0	46.0	PASSED
959.999840	42.0	120.0	100.1	V	203.0	4.0	46.0	PASSED
975.991904	42.7	120.0	99.9	V	248.0	11.3	54.0	PASSED

Table 5. Radiated emission test results. 30 - 1000 MHz. Z-axis

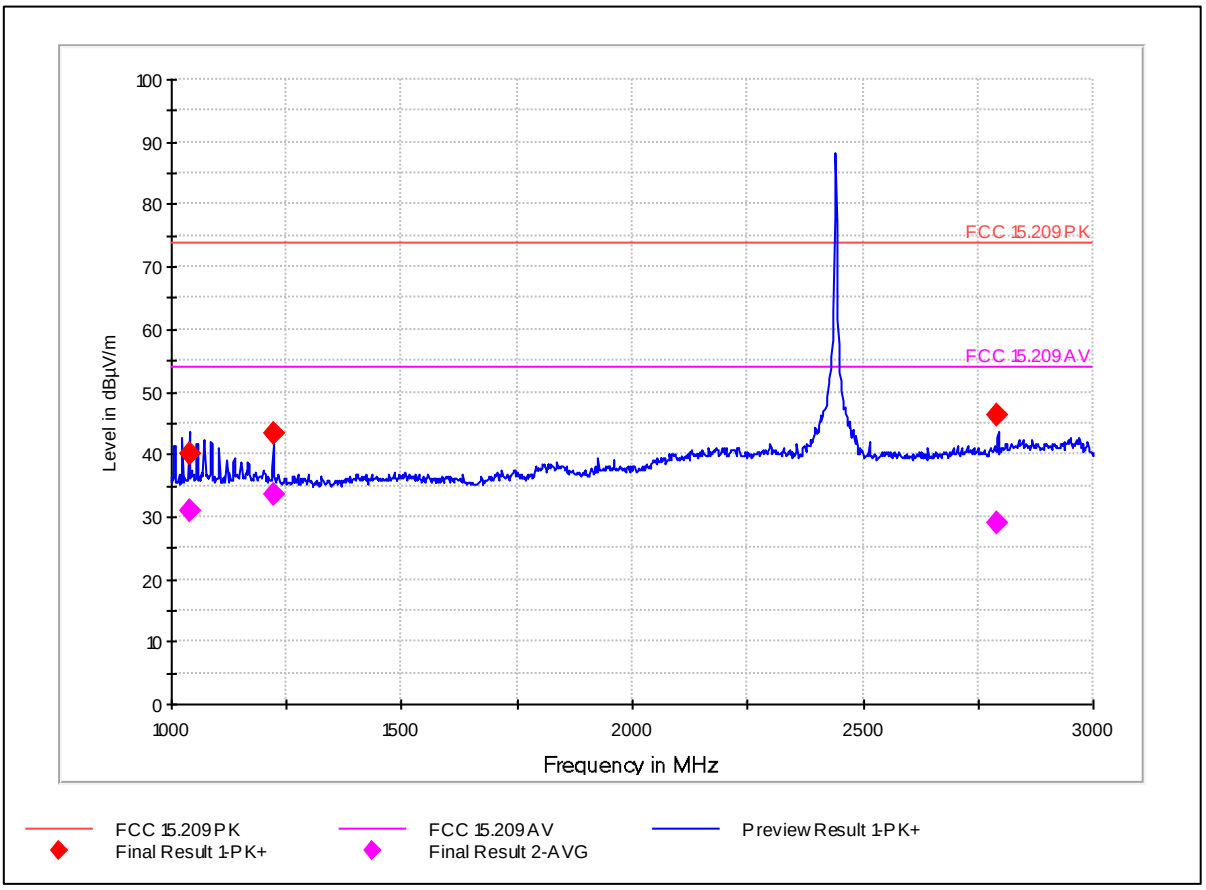

Figure 5. Radiated emission test results 1 - 3 GHz. X-axis

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
1039.976152	40.0	1000.	235.1	V	339.0	34.0	74.0	PASSED
1220.440882	43.2	1000.	150.1	V	266.0	30.8	74.0	PASSED
2791.687174	46.4	1000.	149.9	H	280.0	27.6	74.0	PASSED

Table 6. Radiated emission test results 1 - 3 GHz. Peak detector. X-axis.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
1039.976152	31.1	1000.	235.1	V	339.0	22.9	54.0	PASSED
1220.440882	33.5	1000.	150.1	V	266.0	20.5	54.0	PASSED
2791.687174	29.1	1000.	149.9	H	280.0	24.9	54.0	PASSED

Table 7. Radiated emission test results- 1 - 3 GHz. Average detector. X-axis.

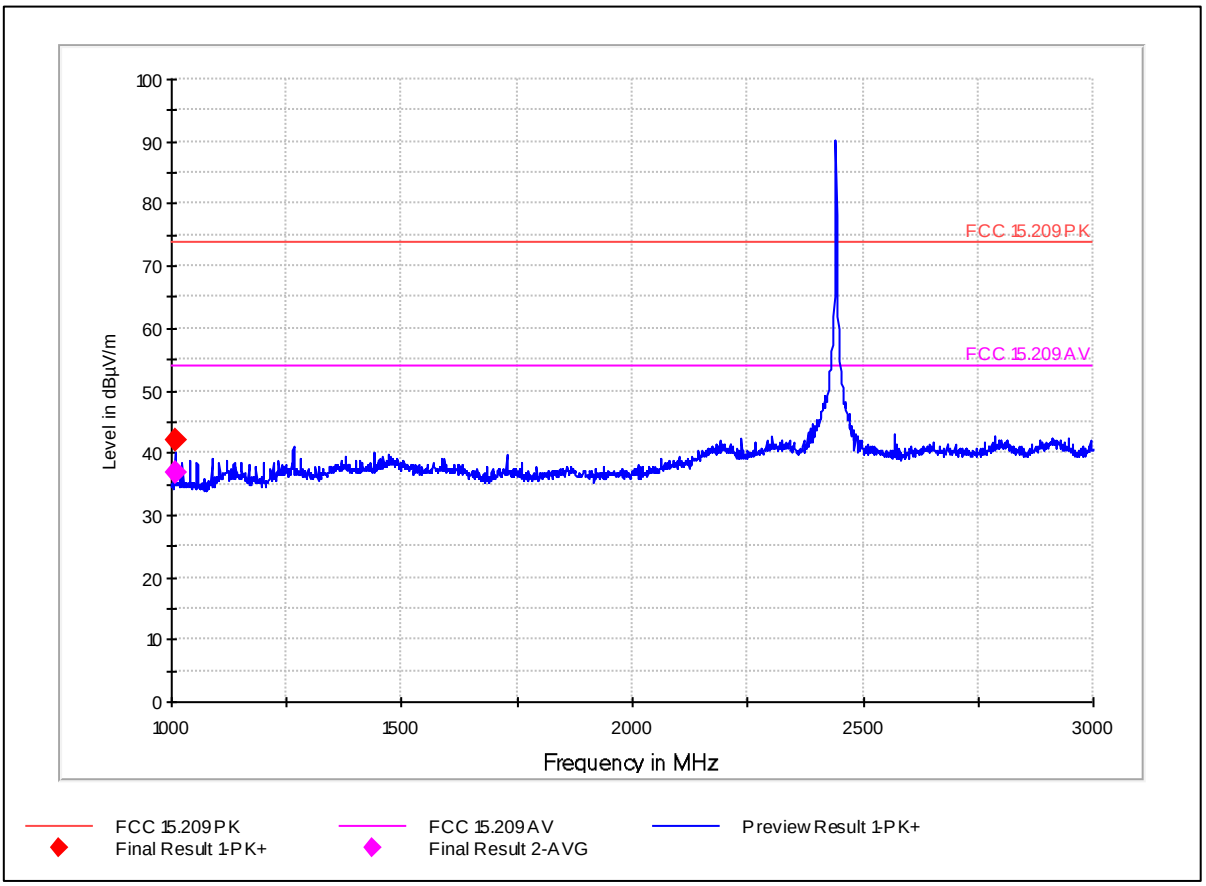

Figure 6. Radiated emission test results 1 - 3 GHz. Y-axis.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
1007.979028	42.2	1000.	150.0	H	149.0	31.8	74.0	PASSED

Table 8. Radiated emission test results 1 - 3 GHz. Peak detector. Y-axis.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
1007.979028	36.8	1000.	150.0	H	149.0	17.2	54.0	PASSED

Table 9. Radiated emission test results- 1 - 3 GHz. Average detector. Y-axis.

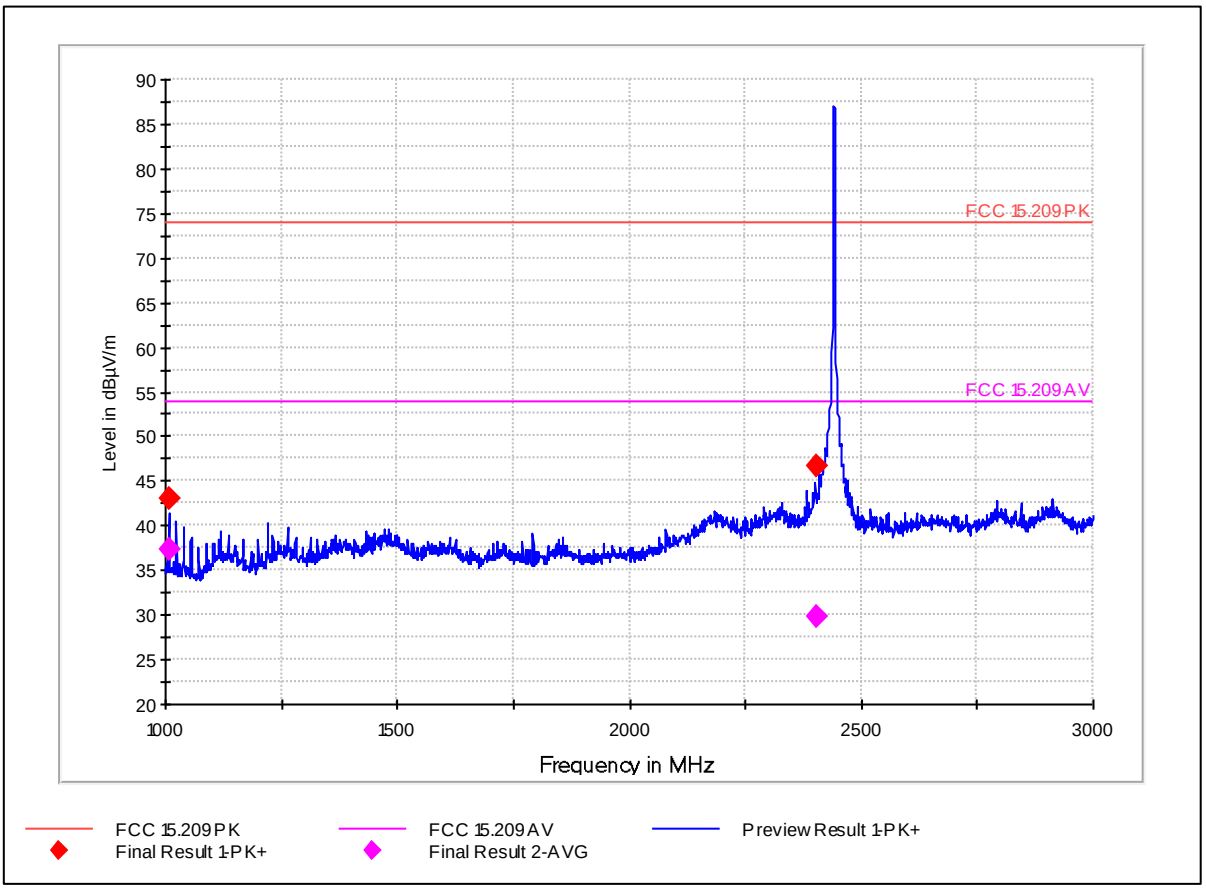

Figure 7. Radiated emission test results 1 - 3 GHz. Z-axis.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
1008.014028	43.0	1000.	127.0	V	270.0	31.0	74.0	PASSED
2403.501603	46.7	1000.	149.9	V	-11.0	27.3	74.0	PASSED

Table 10. Radiated emission test results 1 - 3 GHz. Peak detector. Z-axis.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
1008.014028	37.2	1000.	127.0	V	270.0	16.8	54.0	PASSED
2403.501603	29.8	1000.	149.9	V	-11.0	24.2	54.0	PASSED

Table 11. Radiated emission test results- 1 - 3 GHz. Average detector. Z-axis.

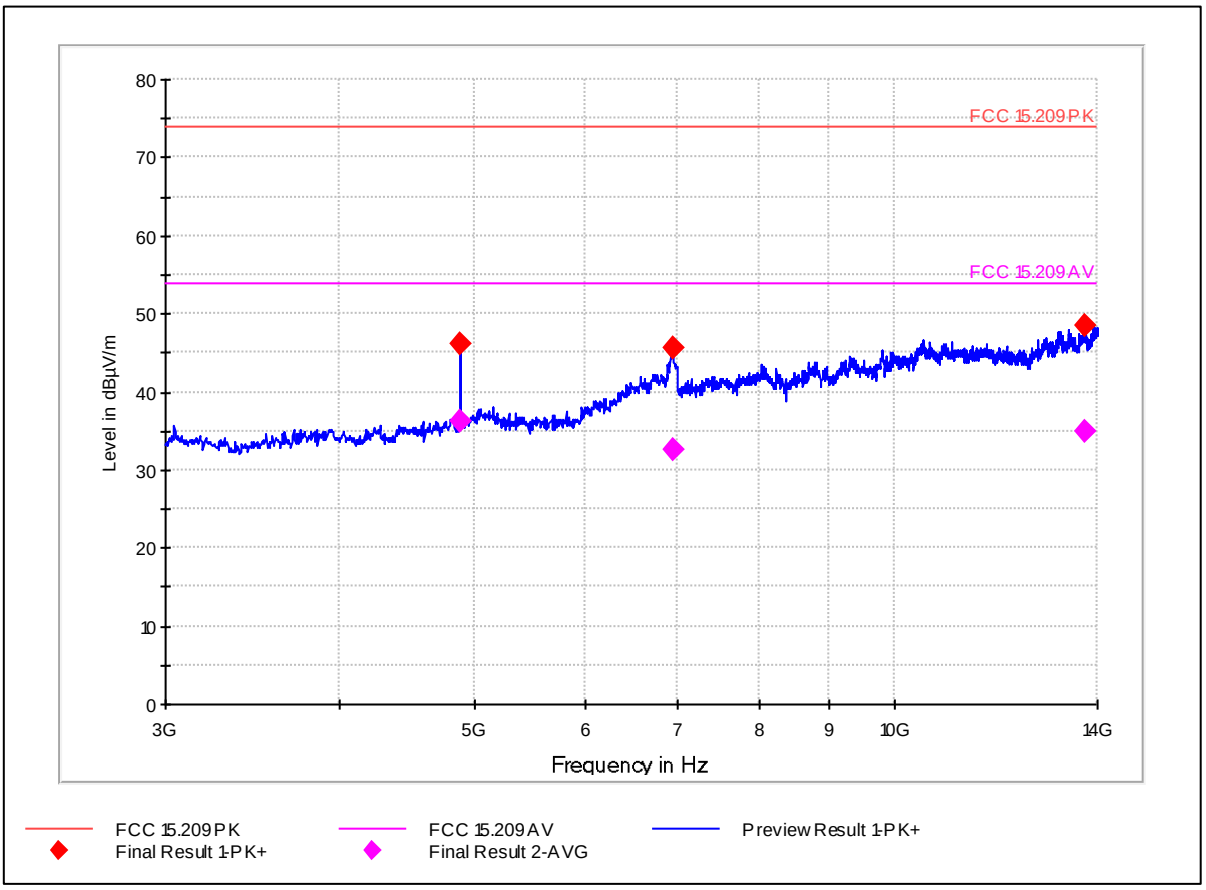

Figure 8. Radiated emission test results 3 - 14 GHz. X-axis.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
4881.748535	46.2	1000.	150.1	V	356.0	27.8	74.0	PASSED
6940.661651	45.5	1000.	386.1	H	122.0	28.5	74.0	PASSED
13721.916778	48.5	1000.	150.1	V	324.0	25.5	74.0	PASSED

Table 12. Radiated emission test results. 3 - 14 GHz. Peak detector. X-axis.

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
4881.748535	46.2	-6.715	39.49	14.51	54.0	PASSED

Table 13. Radiated emission test results 3 - 14 GHz. Average. Pulsed signal. X-axis.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
6940.661651	32.5	1000.	386.1	H	122.0	21.5	54.0	PASSED
13721.916778	35.0	1000.	150.1	V	324.0	19.0	54.0	PASSED

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

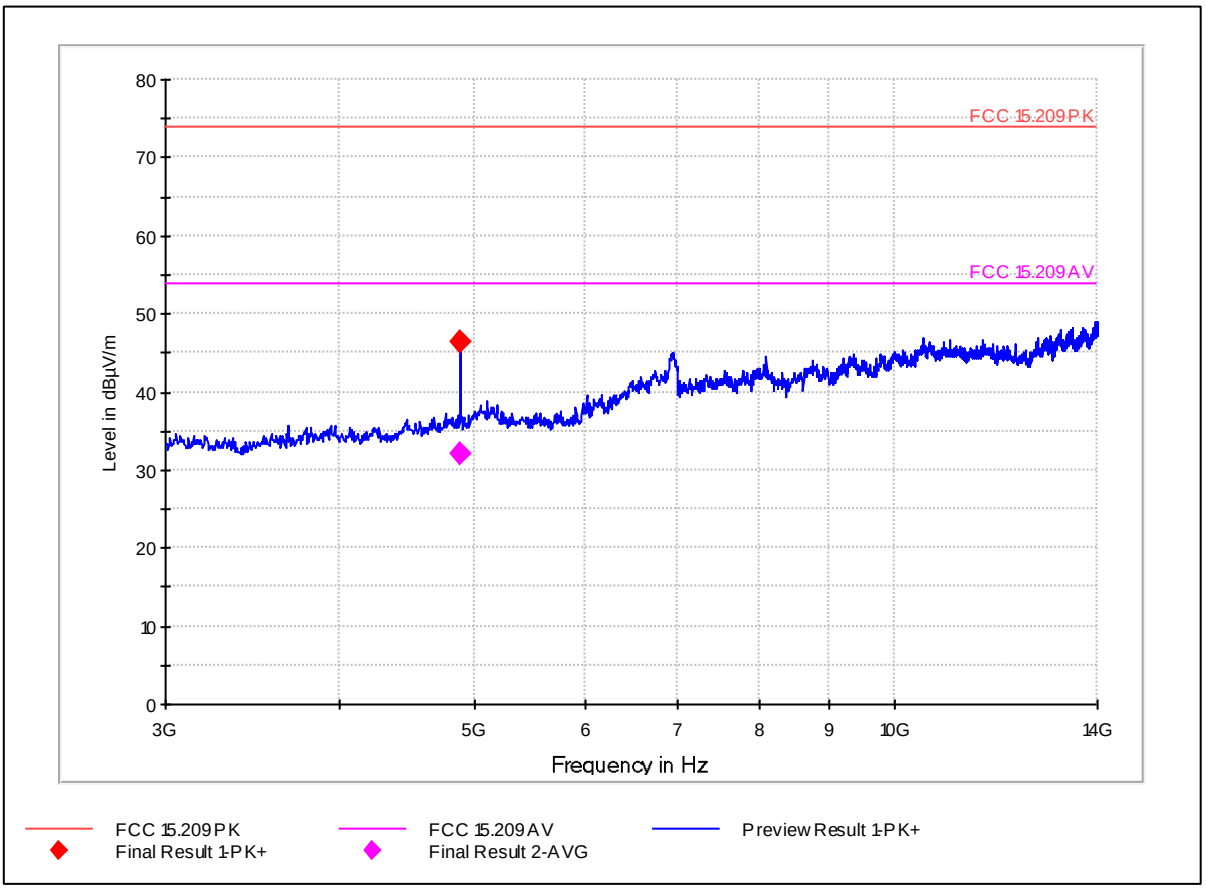

Figure 9. Radiated emission test results 3 - 14 GHz. Y-axis.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
4882.548535	46.4	1000.	150.1	H	0.0	27.6	74.0	PASSED

Table 15. Radiated emission test results. 3 - 14 GHz. Peak detector. Y-axis.

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
4882.548535	46.4	-6.715	39.69	14.32	54.0	PASSED

Table 16. Radiated emission test results 3 - 14 GHz. Average. Pulsed signal. Y-axis.

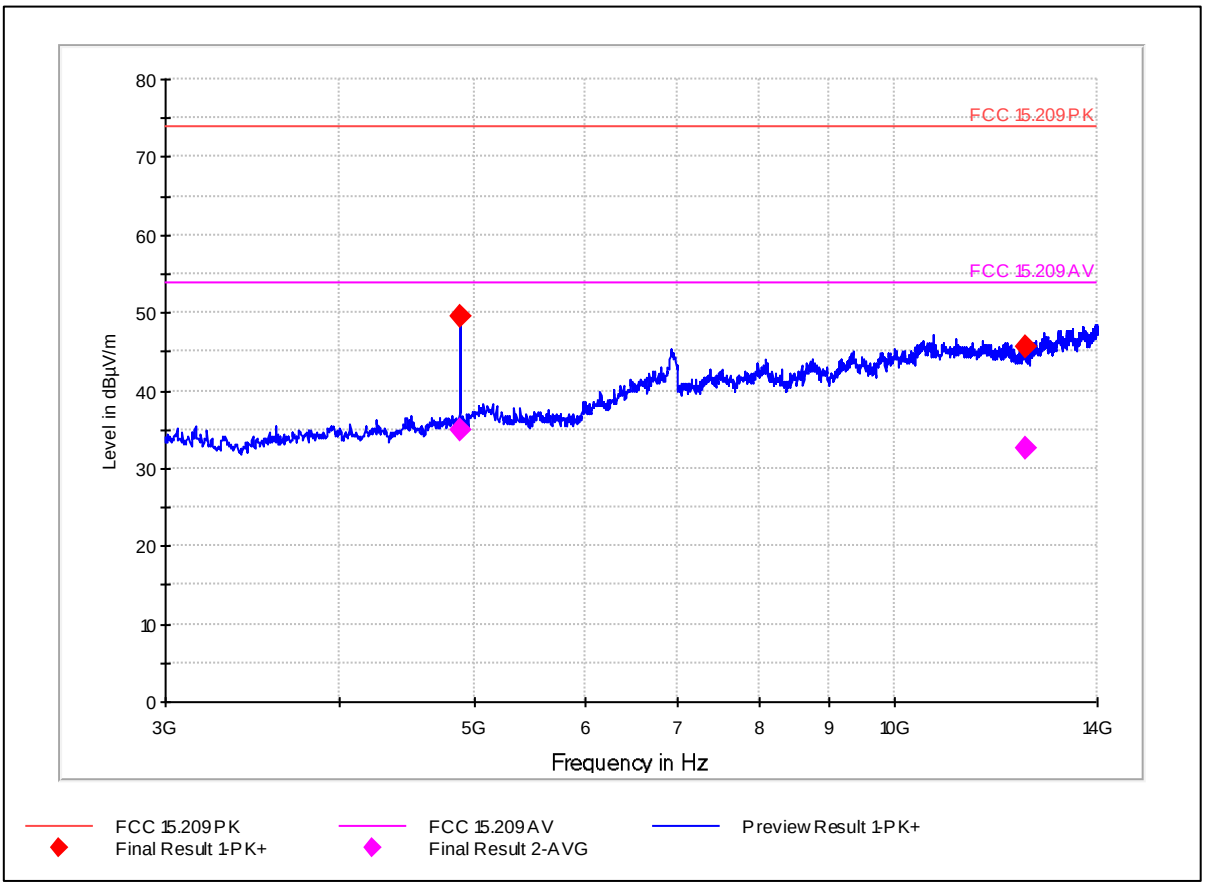

Figure 10. Radiated emission test results 3 - 14 GHz. Z-axis.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
4881.348535	49.5	1000.	150.1	H	43.0	24.5	74.0	PASSED
12421.051165	45.5	1000.	368.9	H	239.0	28.5	74.0	PASSED

Table 17. Radiated emission test results. 3 - 14 GHz. Peak detector. Z-axis.

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
4881.348535	49.5	-6.715	42.79	11.21	54.0	PASSED

Table 18. Radiated emission test results 3 - 14 GHz. Average. Pulsed signal. Z-axis.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
12421.051165	32.5	1000.	368.9	H	239.0	21.5	54.0	PASSED

Table 19. Radiated emission test results 3 - 14 GHz. Average. Non pulsed signal. Z-axis.

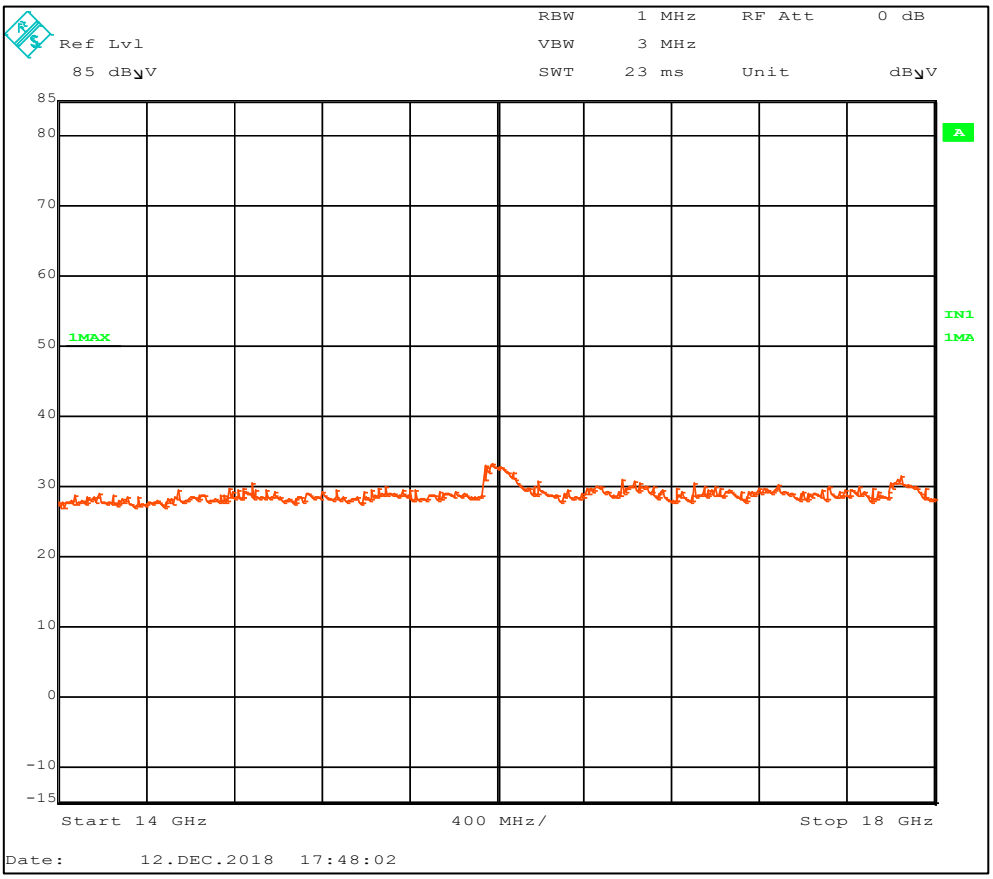

Figure 11 Radiated emission test results 14 - 18 GHz. Peak detector.

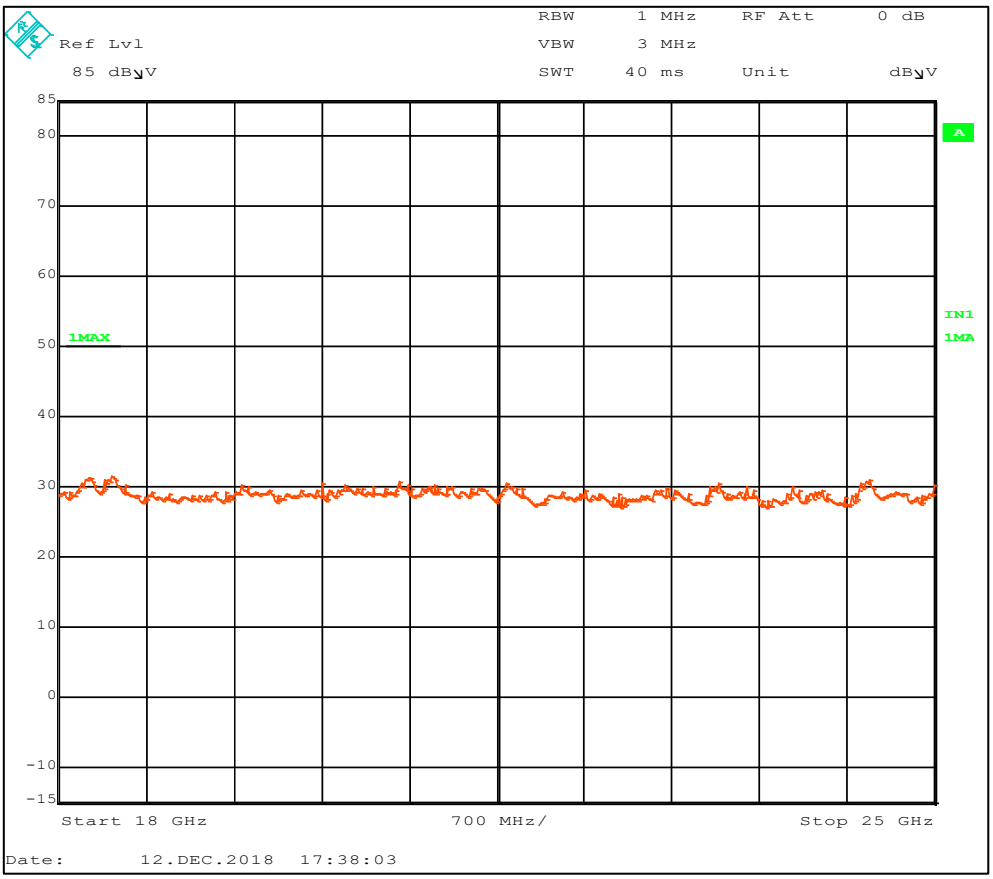

Figure 12. Radiated emission test results 18 - 25 GHz. Peak detector

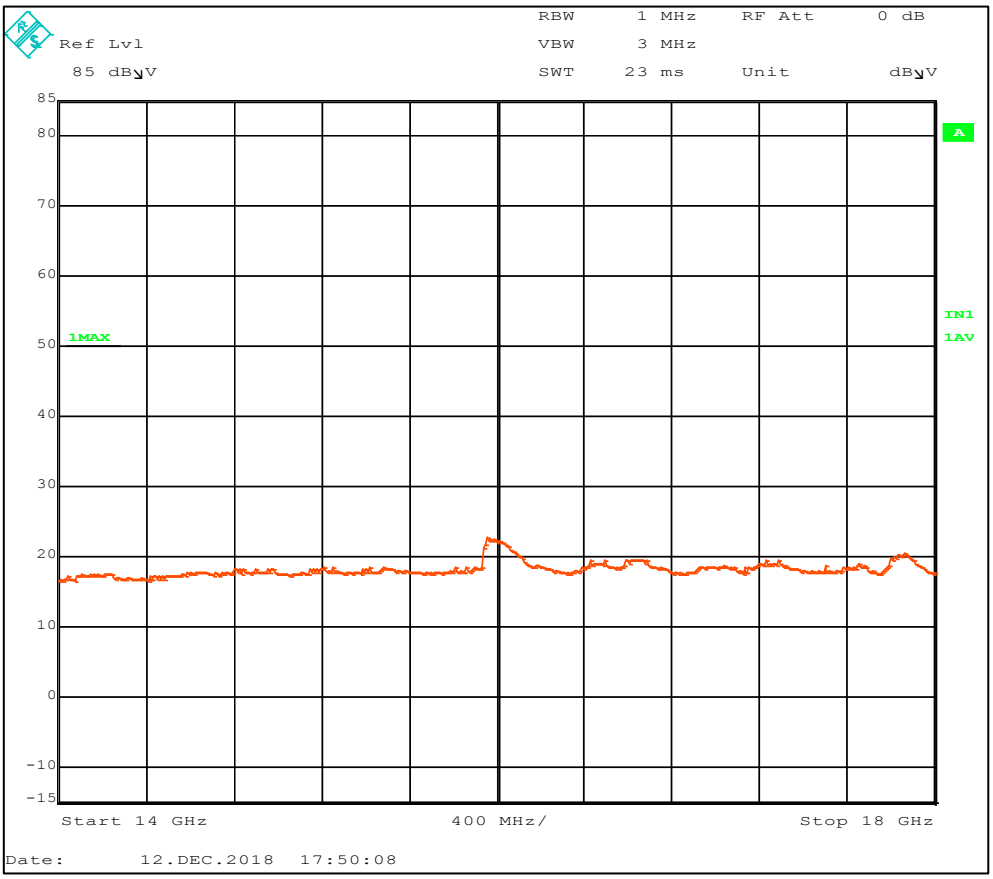

Figure 13. Radiated emission test results 14 - 18 GHz. Average detector.

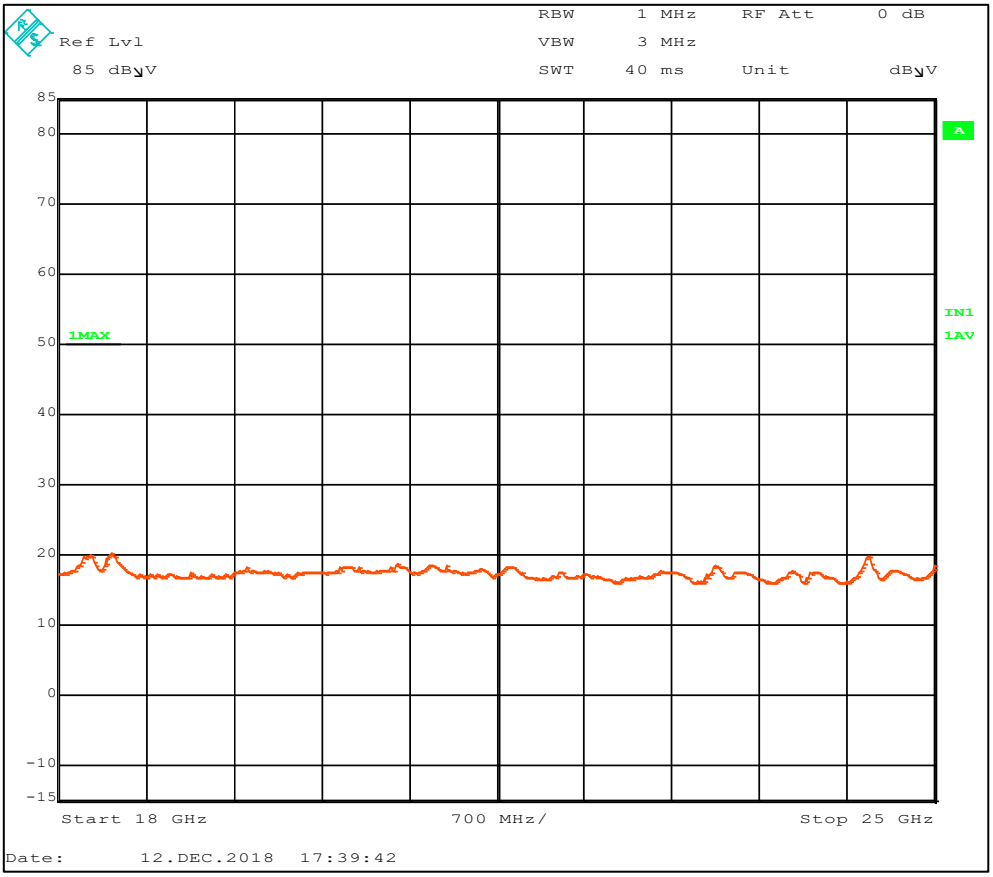

Figure 14. Radiated emission test results 18 - 25 GHz. Average detector.

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 20. 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 21. 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 22. 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 23. Radiated emission test results 14 – 25 GHz. Average detector.

2.3.2.2 Test result for Low channel 2408 MHz.

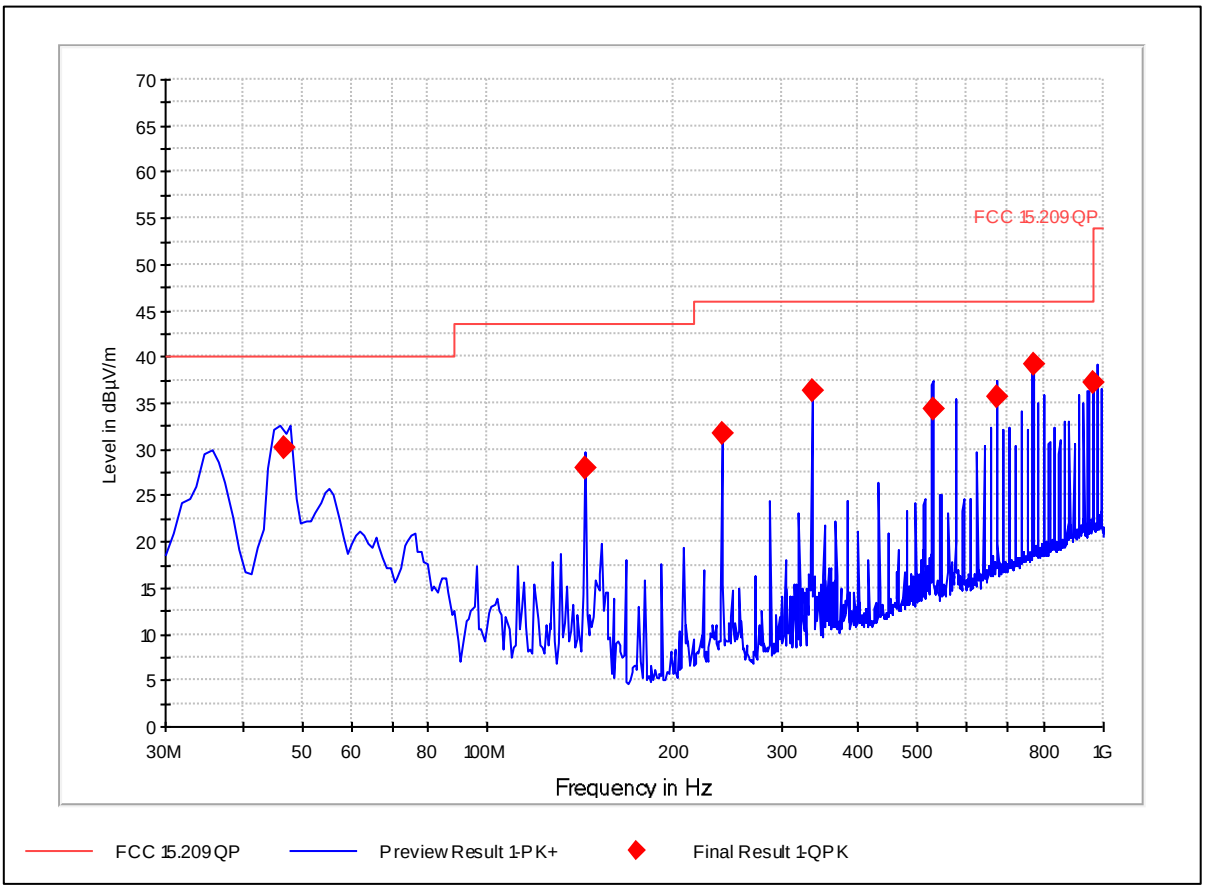

Figure 15. Radiated emission test results. 30 - 1000 MHz. Y-axis.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
46.732024	30.0	120.0	193.0	V	173.0	10.0	40.0	PASSED
143.997936	27.9	120.0	100.1	V	63.0	15.6	43.5	PASSED
240.000080	31.7	120.0	100.1	V	274.0	14.3	46.0	PASSED
336.002224	36.3	120.0	99.8	H	276.0	9.7	46.0	PASSED
528.006112	34.3	120.0	99.9	V	39.0	11.7	46.0	PASSED
671.994689	35.6	120.0	100.0	V	0.0	10.4	46.0	PASSED
767.997074	39.2	120.0	100.0	H	108.0	6.8	46.0	PASSED
959.989840	37.2	120.0	100.0	V	53.0	8.8	46.0	PASSED

Table 24. Radiated emission test results. 30 - 1000 MHz. Y-axis.

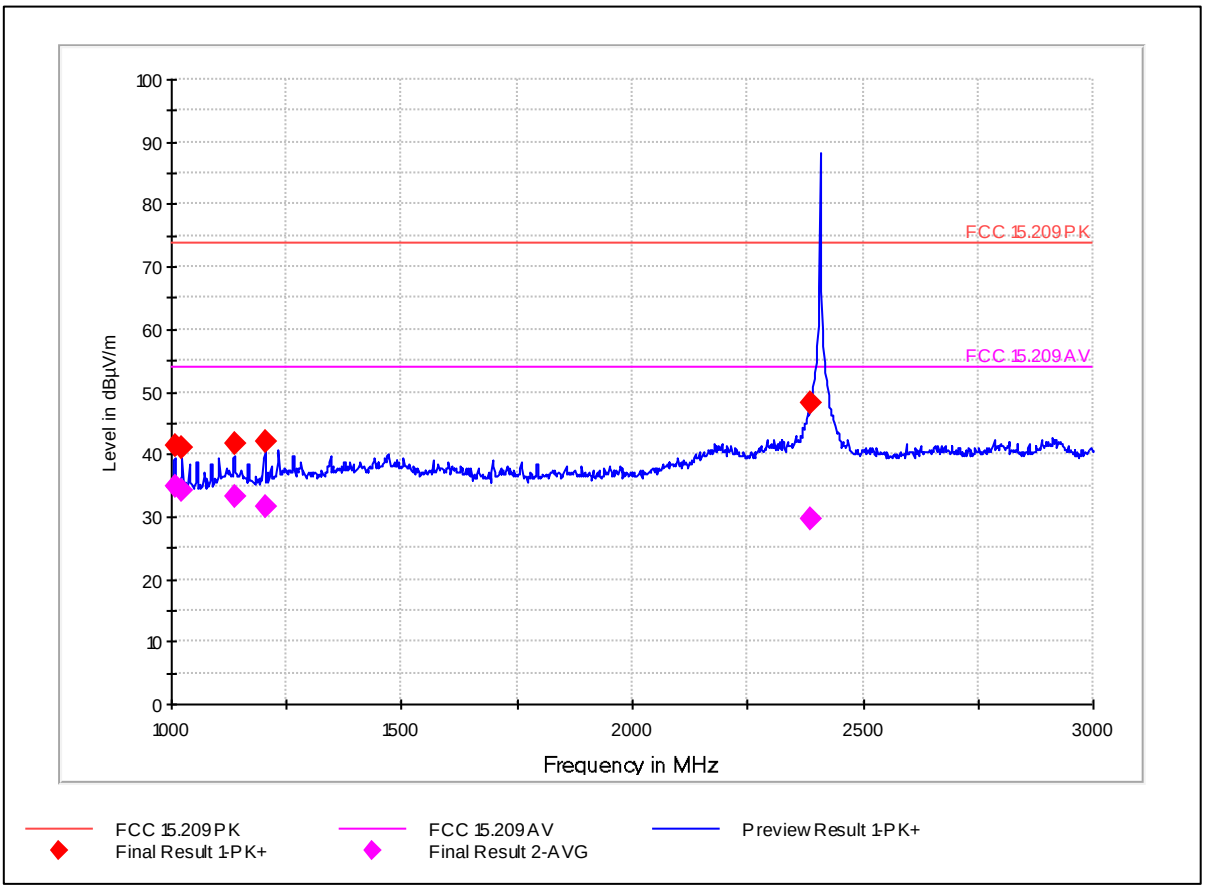

Figure 16. Radiated emission test results 1 - 3 GHz. X-axis.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
1008.016032	41.3	1000.	168.9	H	316.0	32.7	74.0	PASSED
1023.948096	41.2	1000.	150.1	V	53.0	32.8	74.0	PASSED
1136.072545	41.6	1000.	150.1	H	338.0	32.4	74.0	PASSED
1204.104810	42.2	1000.	150.1	V	76.0	31.8	74.0	PASSED
2385.261523	48.3	1000.	149.9	V	42.0	25.7	74.0	PASSED

Table 25. Radiated emission test results 1 - 3 GHz. Peak detector. X-axis.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
1008.016032	35.0	1000.	168.9	H	316.0	19.0	54.0	PASSED
1023.948096	34.3	1000.	150.1	V	53.0	19.7	54.0	PASSED
1136.072545	33.3	1000.	150.1	H	338.0	20.7	54.0	PASSED
1204.104810	31.6	1000.	150.1	V	76.0	22.4	54.0	PASSED
2385.261523	29.5	1000.	149.9	V	42.0	24.5	54.0	PASSED

Table 26. Radiated emission test results- 1 - 3 GHz. Average detector. X-axis.

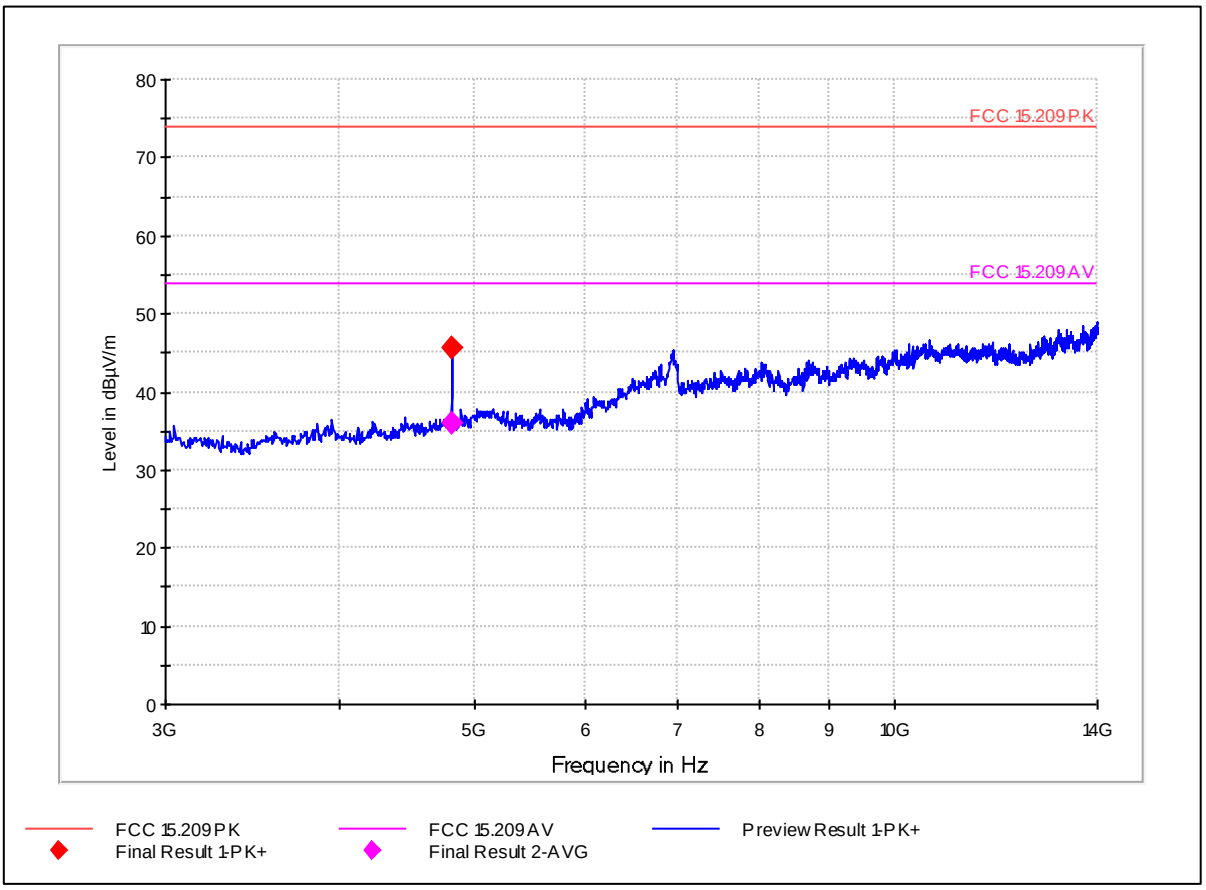

Figure 17. Radiated emission test results 3 - 14 GHz. X-axis.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
4816.144275	45.6	1000.	149.8	V	1.0	28.4	74.0	PASSED

Table 27. 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
4816.144275	45.6	-6.715	38.89	15.11	54.0	PASSED

Table 28. Radiated emission test results 3 - 14 GHz. Average. Pulsed signal.

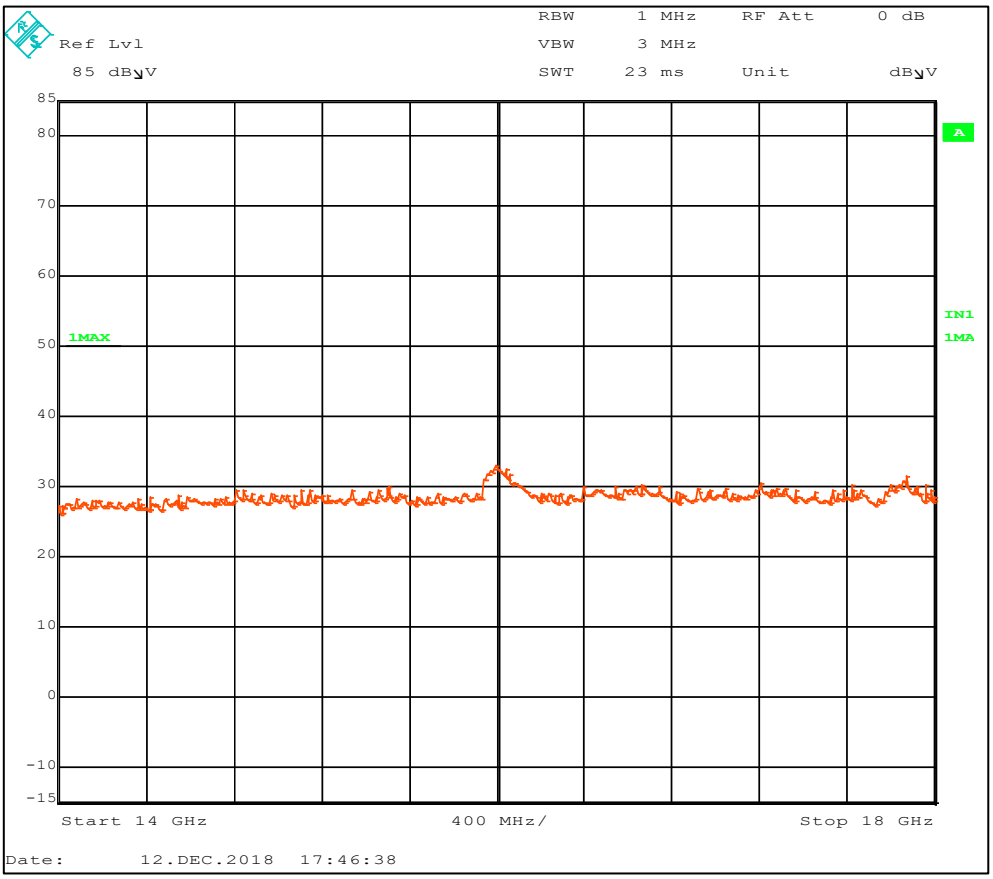

Figure 18. Radiated emission test results 14 - 18 GHz. Peak detector.

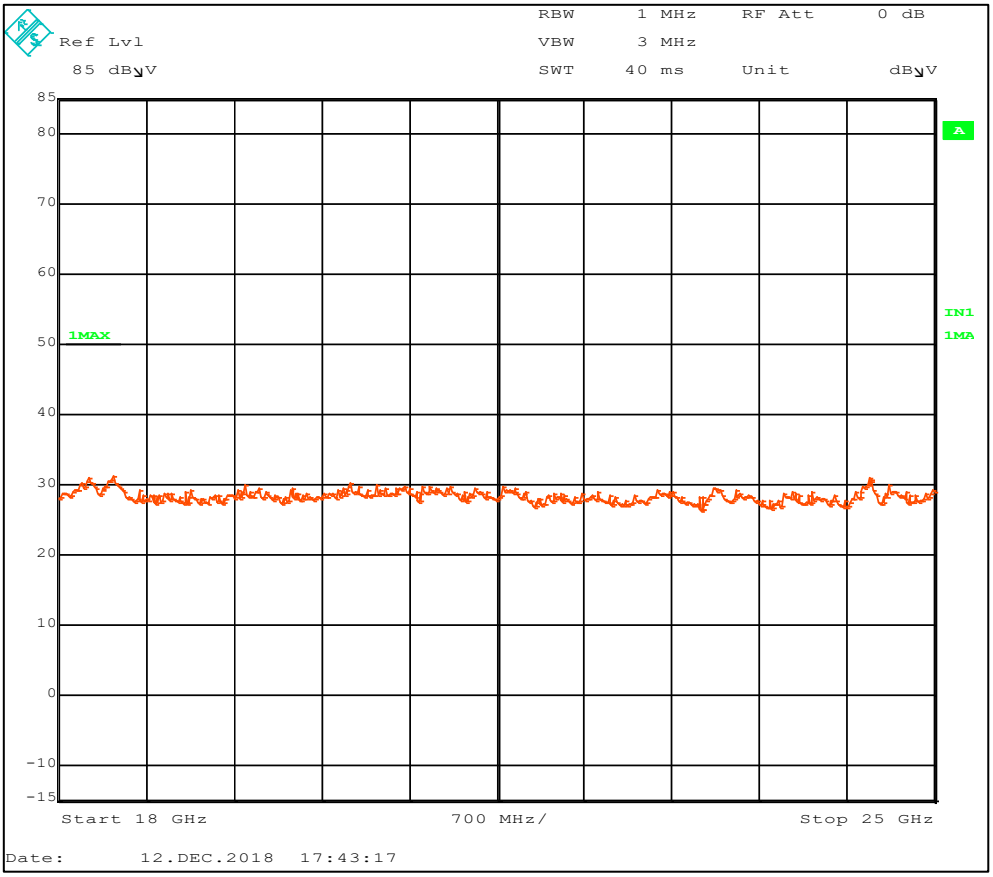

Figure 19. Radiated emission test results 18 - 25 GHz. Peak detector.

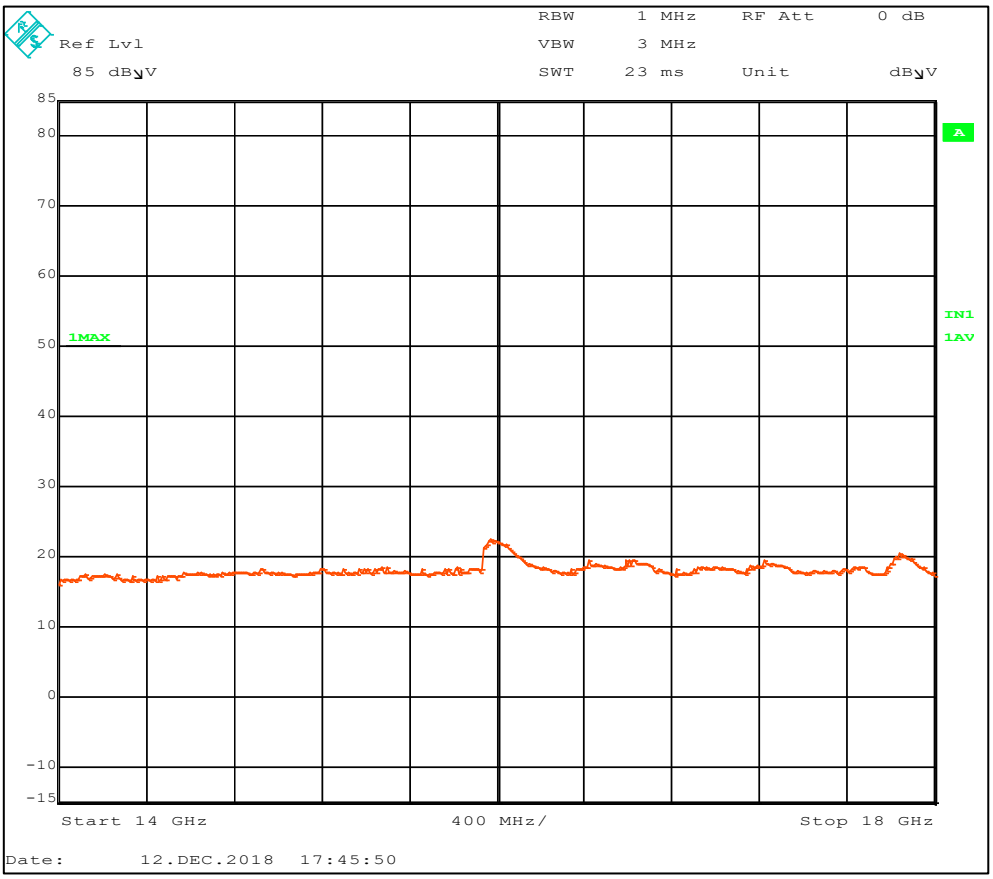

Figure 20. Radiated emission test results 14 - 18 GHz. Average detector.

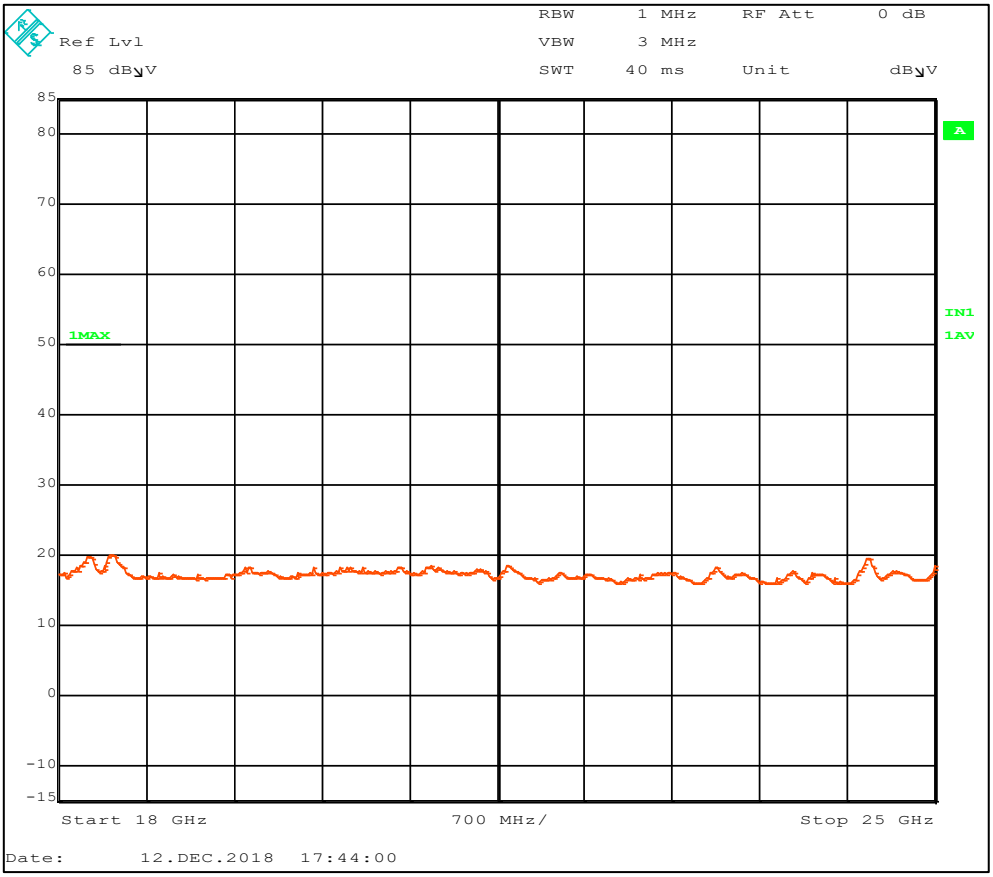

Figure 21. Radiated emission test results 18 - 25 GHz. Average detector.

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 29. 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 30. 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 31. 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 32. Radiated emission test results 14 – 25 GHz. Average detector.

2.3.2.3 Test result for High channel 2468 MHz.

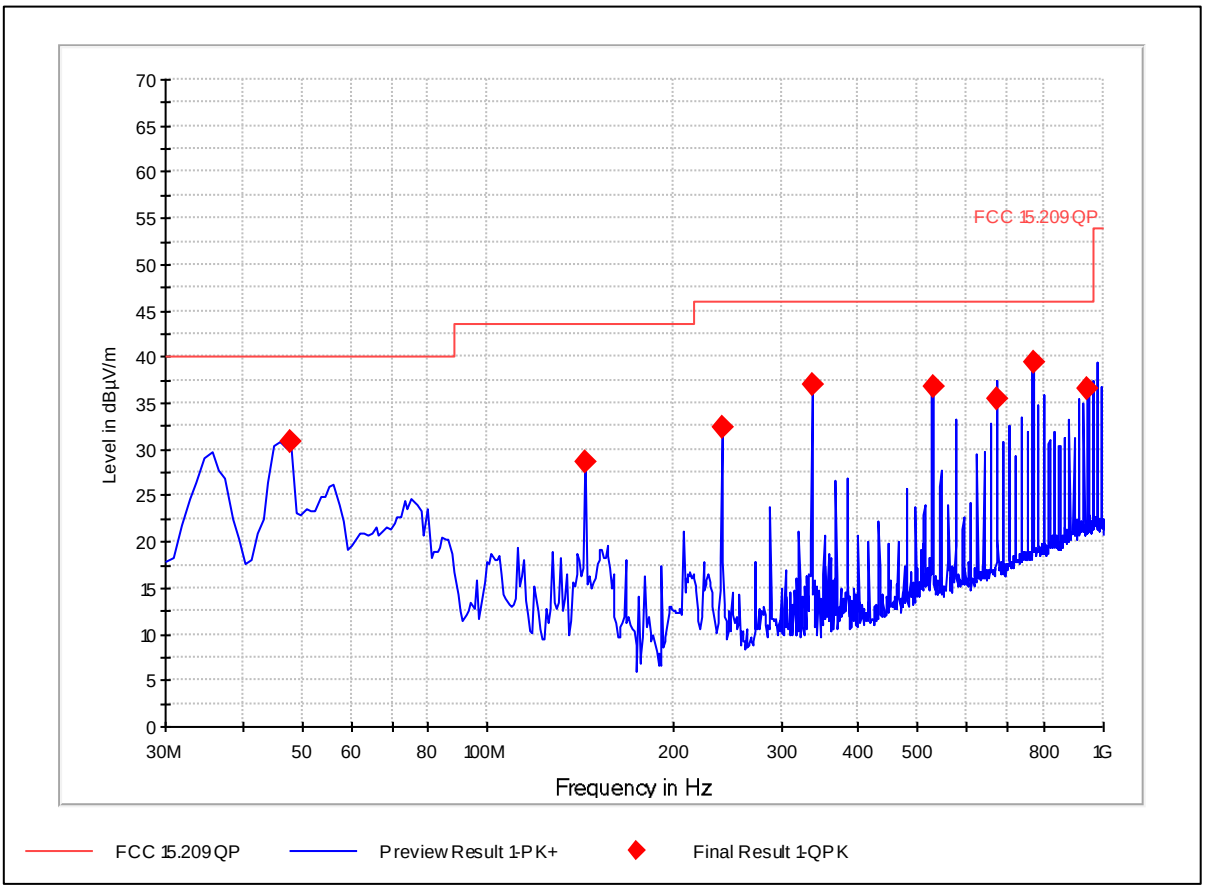

Figure 22. Radiated emission test results. 30 - 1000 MHz. Y-axis

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
47.995792	30.7	120.0	200.0	V	73.0	9.3	40.0	PASSED
143.997936	28.7	120.0	100.1	V	275.0	14.8	43.5	PASSED
240.000080	32.3	120.0	100.1	V	273.0	13.7	46.0	PASSED
336.002224	37.0	120.0	100.1	H	267.0	9.0	46.0	PASSED
527.996112	36.8	120.0	99.8	V	210.0	9.2	46.0	PASSED
671.994689	35.4	120.0	100.1	H	267.0	10.6	46.0	PASSED
767.997074	39.3	120.0	99.9	H	164.0	6.7	46.0	PASSED
943.987776	36.5	120.0	99.8	V	50.0	9.5	46.0	PASSED

Table 33. Radiated emission test results. 30 - 1000 MHz. Y-axis

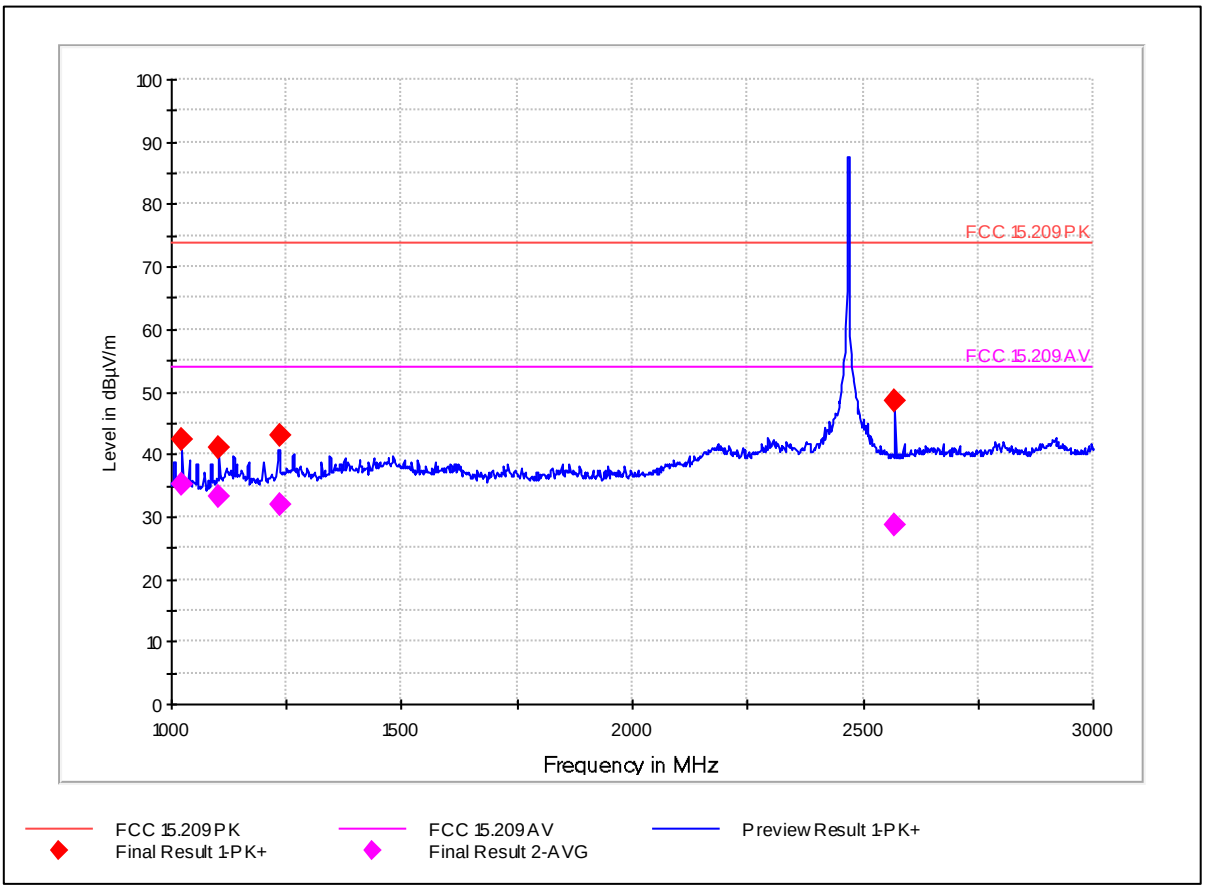

Figure 23. Radiated emission test results 1 - 3 GHz. X-axis.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
1024.048096	42.5	1000.	149.6	V	73.0	31.5	74.0	PASSED
1104.108417	41.0	1000.	150.1	V	146.0	33.0	74.0	PASSED
1234.068938	43.1	1000.	149.8	V	69.0	30.9	74.0	PASSED
2569.338277	48.6	1000.	150.1	V	23.0	25.4	74.0	PASSED

Table 34. Radiated emission test results 1 - 3 GHz. Peak detector. X-axis.

Frequency [MHz]	Average [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
1024.048096	35.3	1000.	149.6	V	73.0	18.7	54.0	PASSED
1104.108417	33.1	1000.	150.1	V	146.0	20.9	54.0	PASSED
1234.068938	32.1	1000.	149.8	V	69.0	21.9	54.0	PASSED
2569.338277	28.8	1000.	150.1	V	23.0	25.2	54.0	PASSED

Table 35. Radiated emission test results- 1 - 3 GHz. Average detector. X-axis.

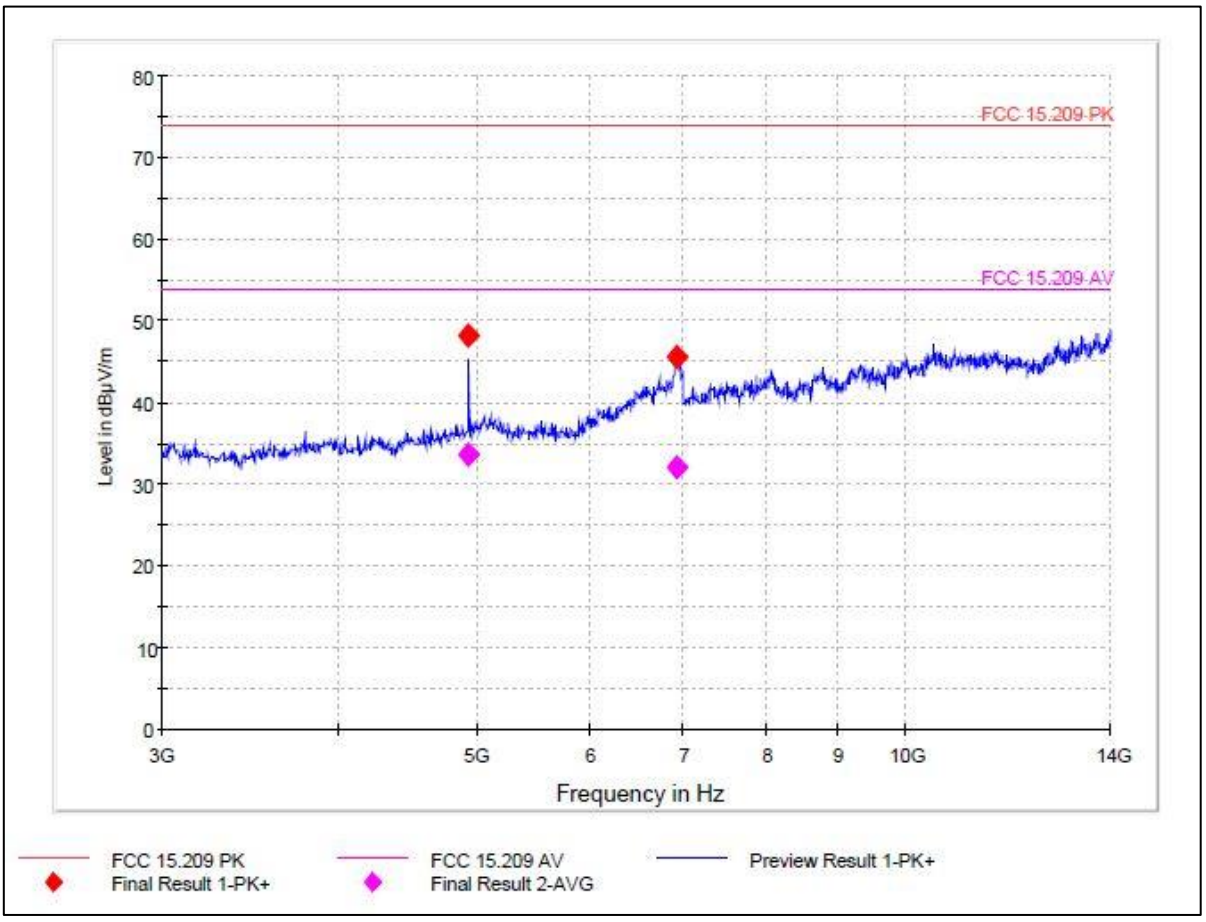

Figure 24. Radiated emission test results 3 - 14 GHz. X-axis

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
4935.383256	48.1	1000	205.9	V	121.0	25.9	74.0	PASSED
6929.401232	45.5	1000	149.9	H	174.0	28.5	74.0	PASSED

Table 36. 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
4935.383256	48.1	-6.715	41.39	12.61	54.0	PASSED

Table 37. 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
6929.401232	32.2	1000	149.9	H	174.0	28.5	74.0	PASSED

Table 38. Radiated emission test results 3 - 14 GHz. Average. Non pulsed signal.

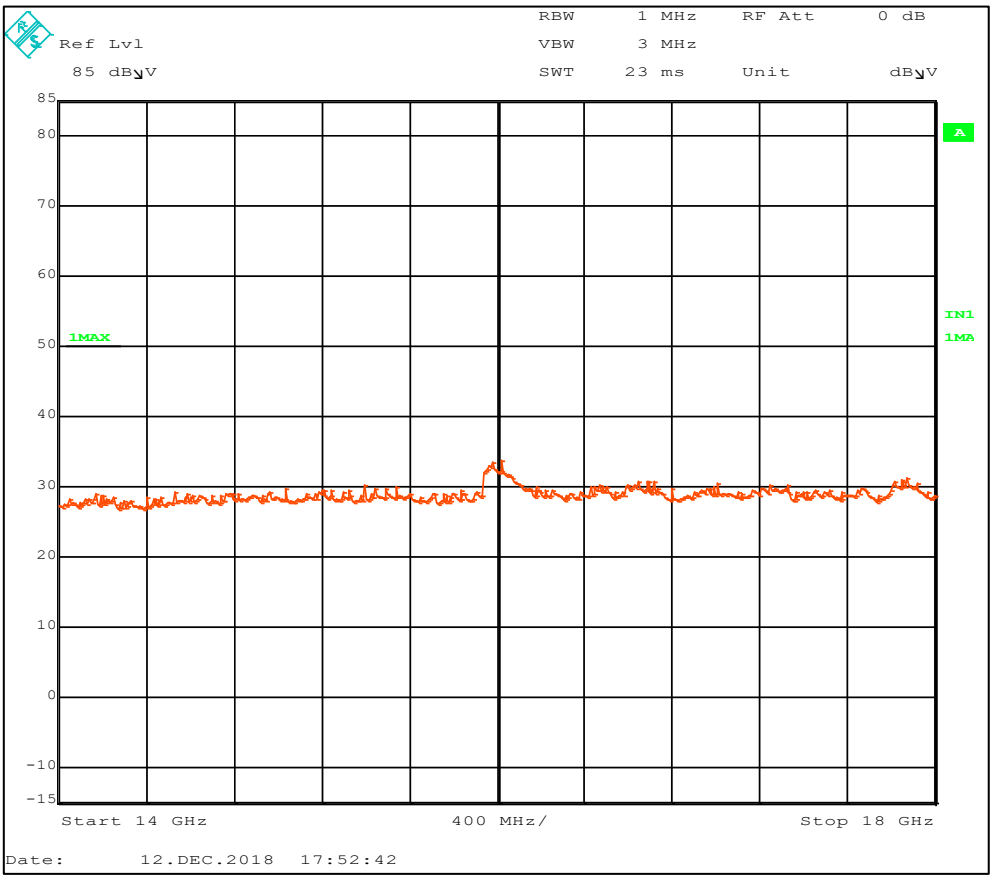

Figure 25. Radiated emission test results 14 - 18 GHz. Peak detector.

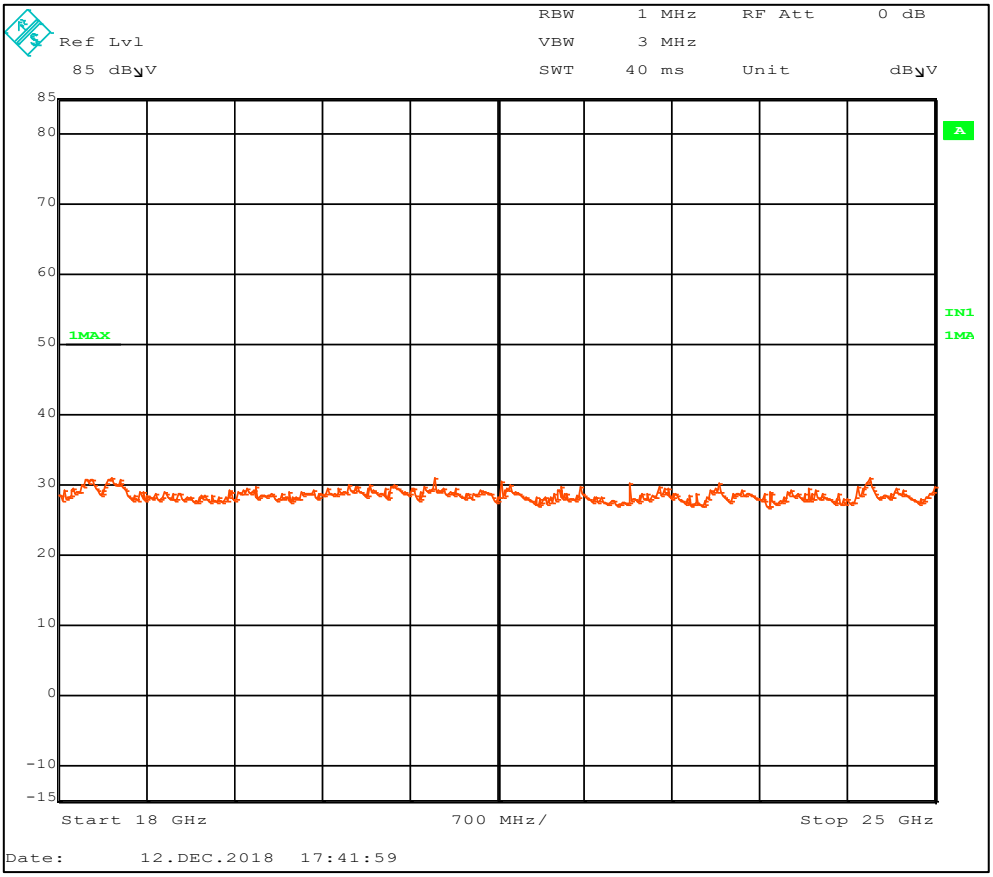

Figure 26. Radiated emission test results 18 - 25 GHz. Peak detector.

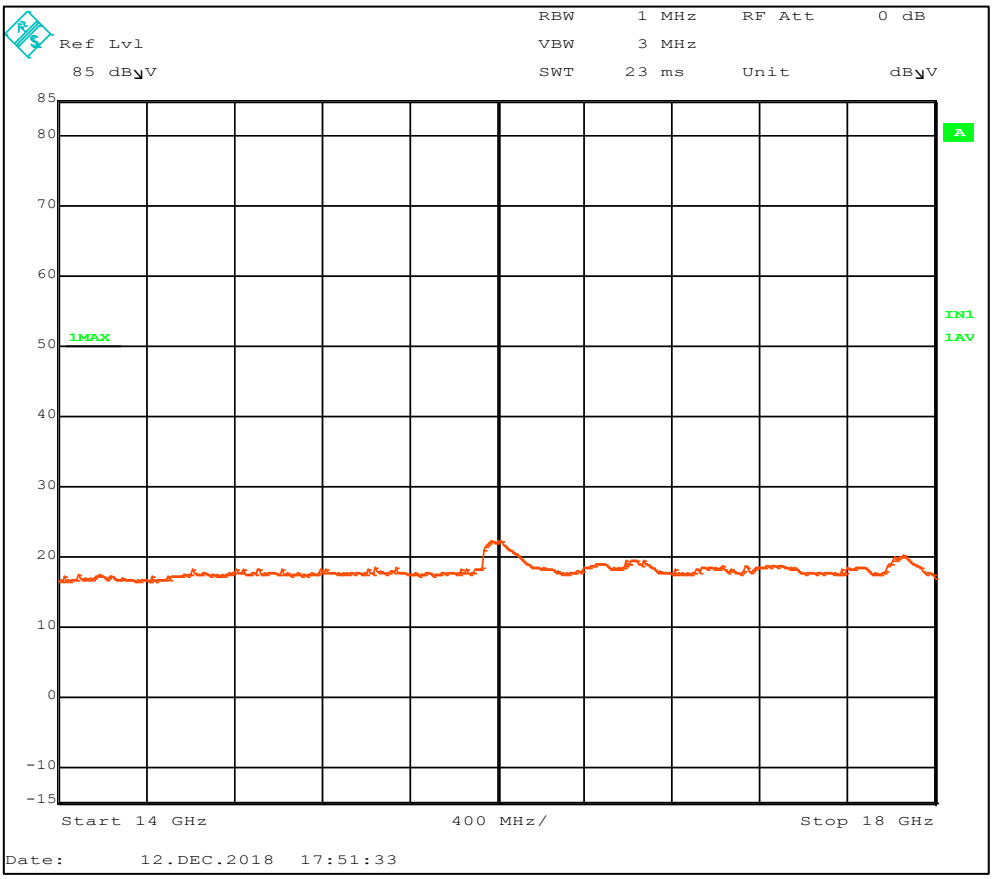

Figure 27. Radiated emission test results 14 - 18 GHz. Average detector.

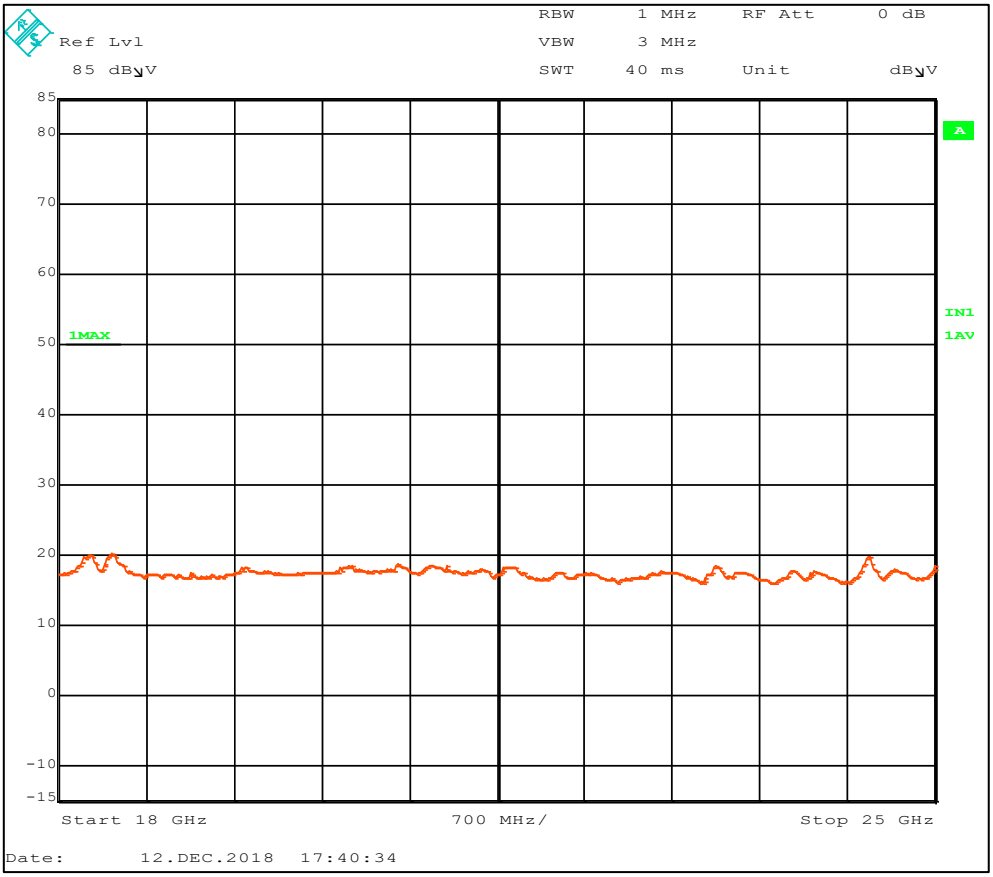

Figure 28. Radiated emission test results 18 - 25 GHz. Average detector.

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 39. 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 40. 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 41. 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 42. Radiated emission test results 3 - 14 GHz. Average detector.

2.3.3 Test equipment

Description	Supplier	Model	Tag no.	Cal. due date
Antenna, 30MHz-3GHz	Rohde & Schwarz	HL562	19830	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 26	20763	2018-12-05
Analyzer 20Hz-26.5GHz	Rohde & Schwarz	ESIB 26	18880	2019-09-24

2.4 AC Conducted emission

Test specimen	Spin
Test specification	47 CFR Part 15.207
Test method	ANSI C63.10:2013
Frequency range	0.15 - 30 MHz
Limits	47 CFR Part 15.207
Comments	None
Temperature / Humidity	22°C / 46%RH
Dates of measurements	2018-12-10
Test personnel	Søren Søltoft

2.4.1 Test setup

Measurements were performed with the test specimen powered from a AC/DC adaptor while sending max power with max duty cycle at the middle channel (2441 MHz). 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 43. Radiated emission limits.

Note *=Decreases with the logarithm of the frequency

2.4.3 Test results

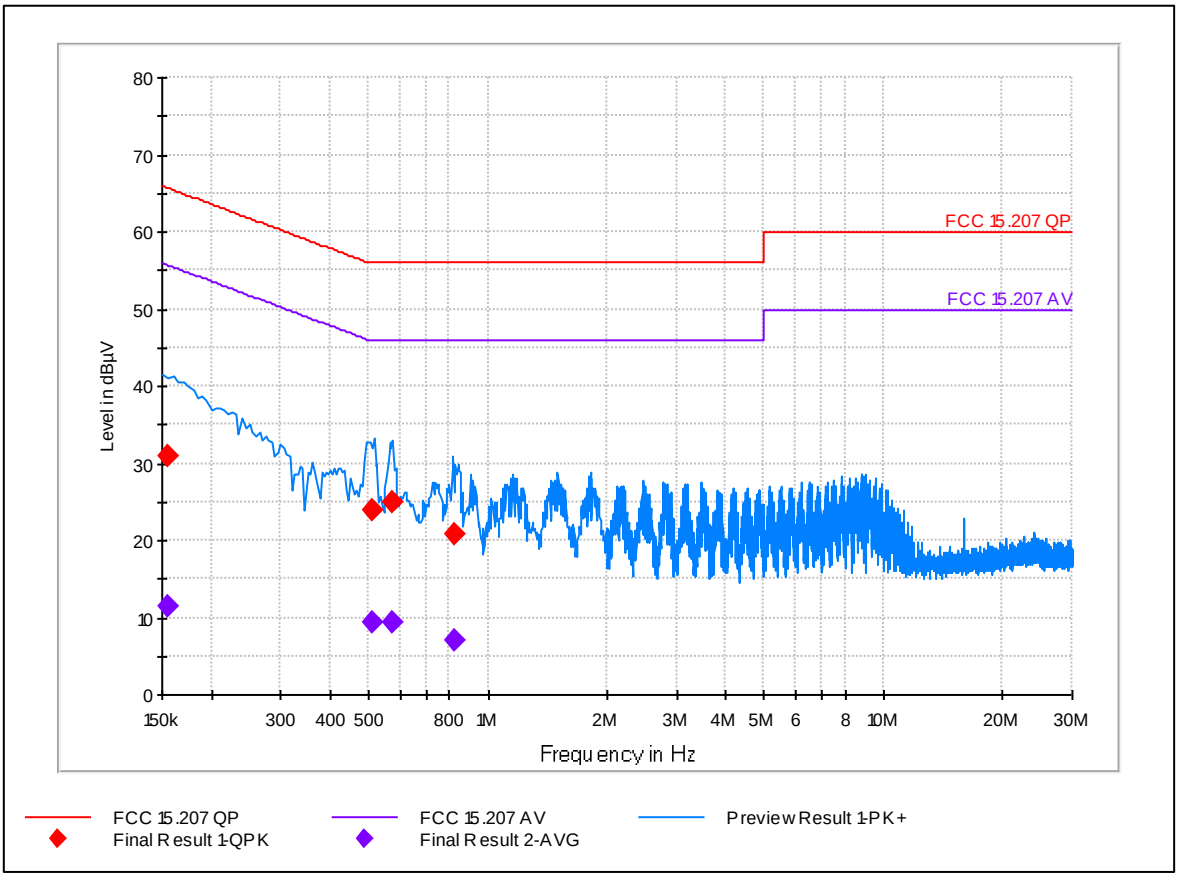

Figure 29. AC Conducted emission.

Frequency [MHz]	QuasiPeak [dBuV]	BW [kHz]	Line	Margin [dB]	Limit [dBuV]	Result
0.155200	31.0	9.000	N	34.70	65.70	PASSED
0.508900	23.8	9.000	L1	32.20	56.00	PASSED
0.572800	25.0	9.000	L1	31.00	56.00	PASSED
0.824800	20.8	9.000	L1	35.20	56.00	PASSED

Table 44. AC Conducted emission. Powered by laptop. QuasiPeak detector.

Frequency [MHz]	Average [dBuV]	BW [kHz]	Line	Margin [dB]	Limit [dBuV]	Result
0.155200	11.5	9.000	N	44.20	55.70	PASSED
0.508900	9.2	9.000	L1	36.80	46.00	PASSED
0.572800	9.5	9.000	L1	36.50	46.00	PASSED
0.824800	6.9	9.000	L1	39.10	46.00	PASSED

Table 45. AC Conducted emission. Powered by laptop. 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	2019-09-24

2.5 20 dB bandwidth

Test specimen	Spin
Test specification	47 CFR Part 15.215
Test method	ANSI C63.10:2013
Comments	None
Temperature / Humidity	21°C / 38%RH
Dates of measurements	2018-12-10
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

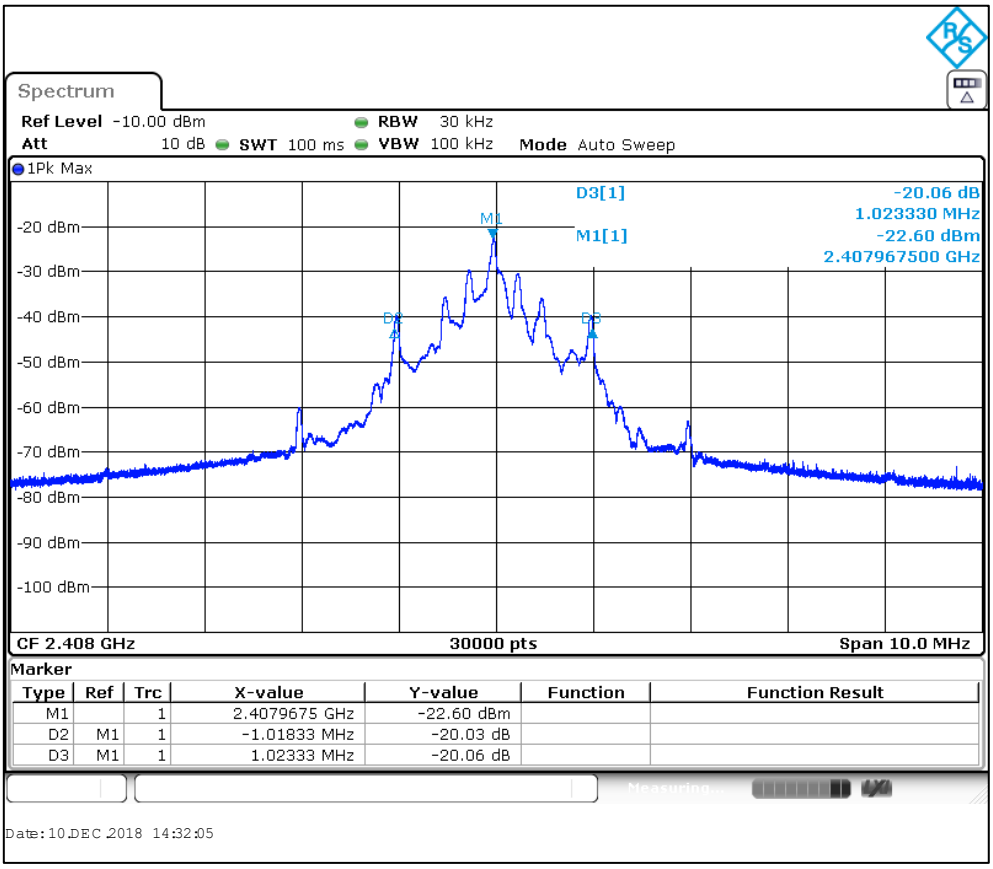

Figure 30. 20 dB bandwidth at 2408 MHz.

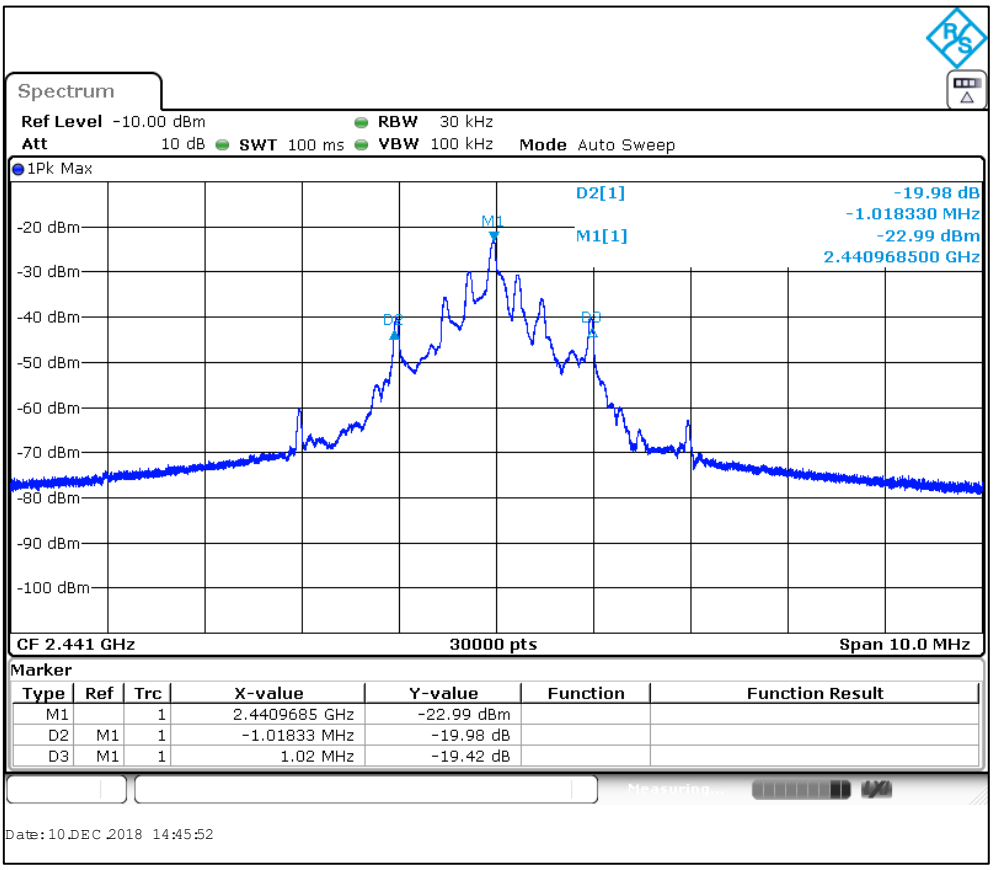

Figure 31. 20 dB bandwidth at 2441 MHz.

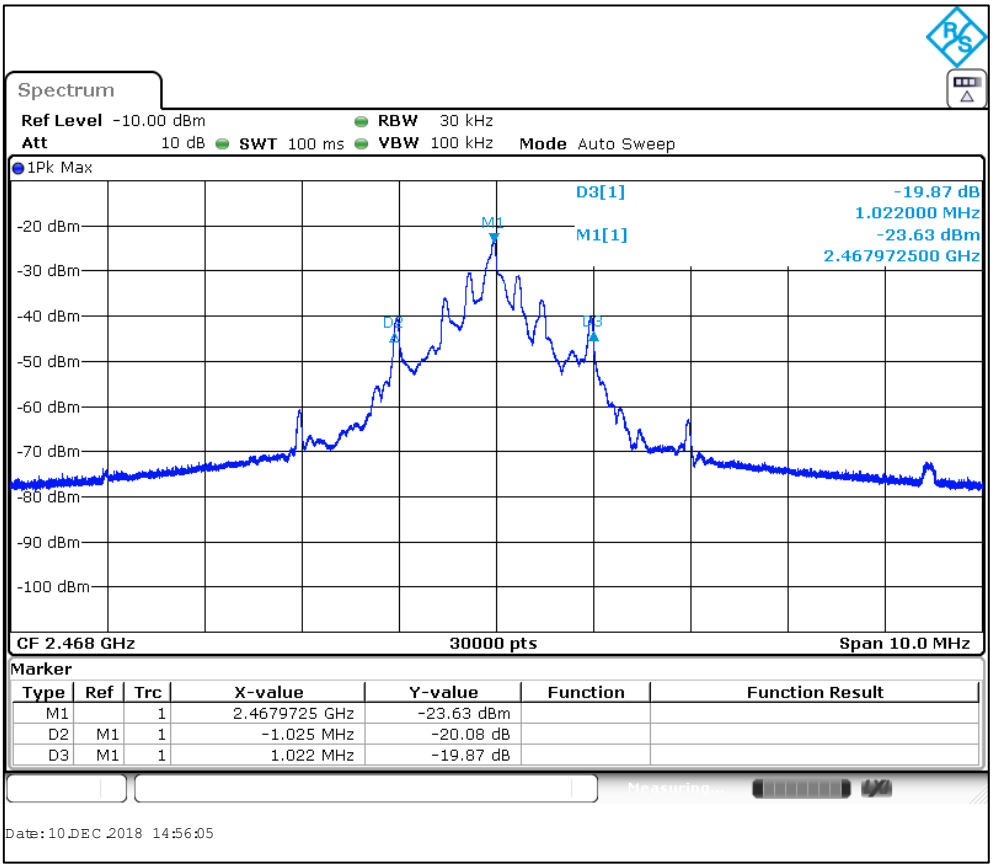

Figure 32. 20 dB bandwidth at 2468 MHz.

Frequency [MHz]	20 dB Bandwidth [MHz]	Result
2408	2.04166	PASSED
2441	2.03833	PASSED
2468	2.0470	PASSED

Table 46. 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 10Hz – 13.6GHz	Rohde & Schwarz	FSV 13	50092	2019-09-14

2.6 Occupied bandwidth

Test specimen	Spin
Test specification	47 CFR 2.1049
Test method	ANSI C63.10:2013
Comments	None
Temperature / Humidity	21°C / 38%RH
Dates of measurements	2018-12-10
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

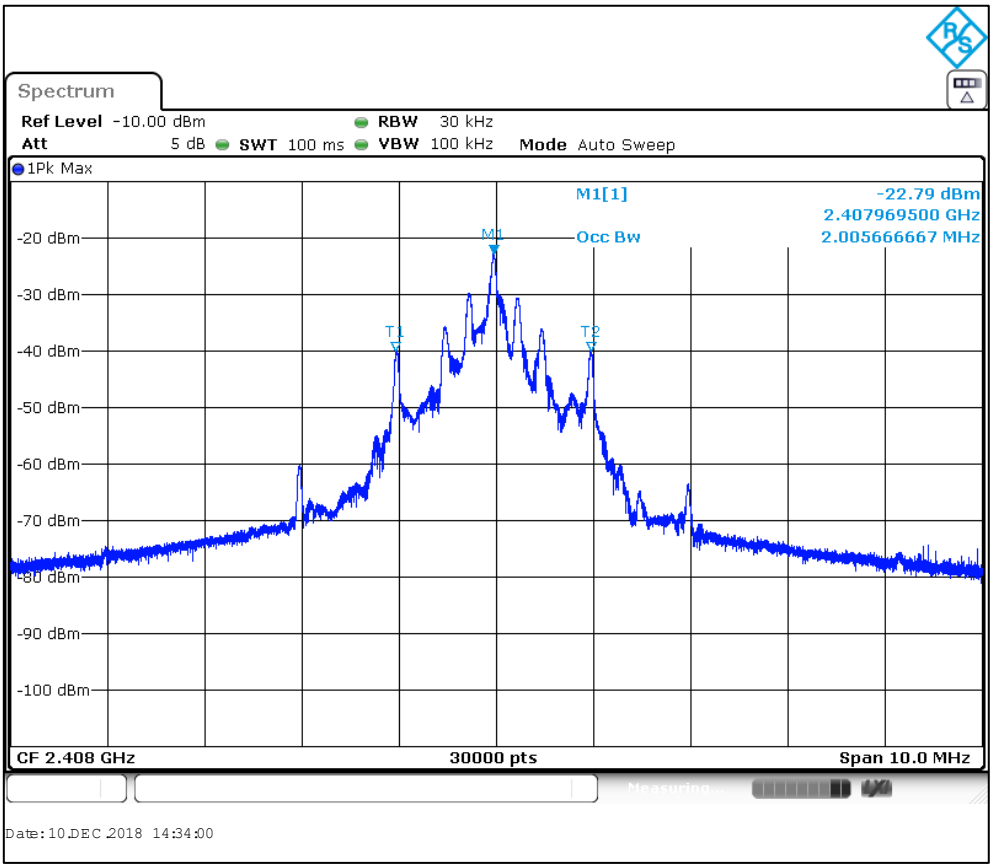

Figure 33. Occupied bandwidth 99% at 2408 MHz.

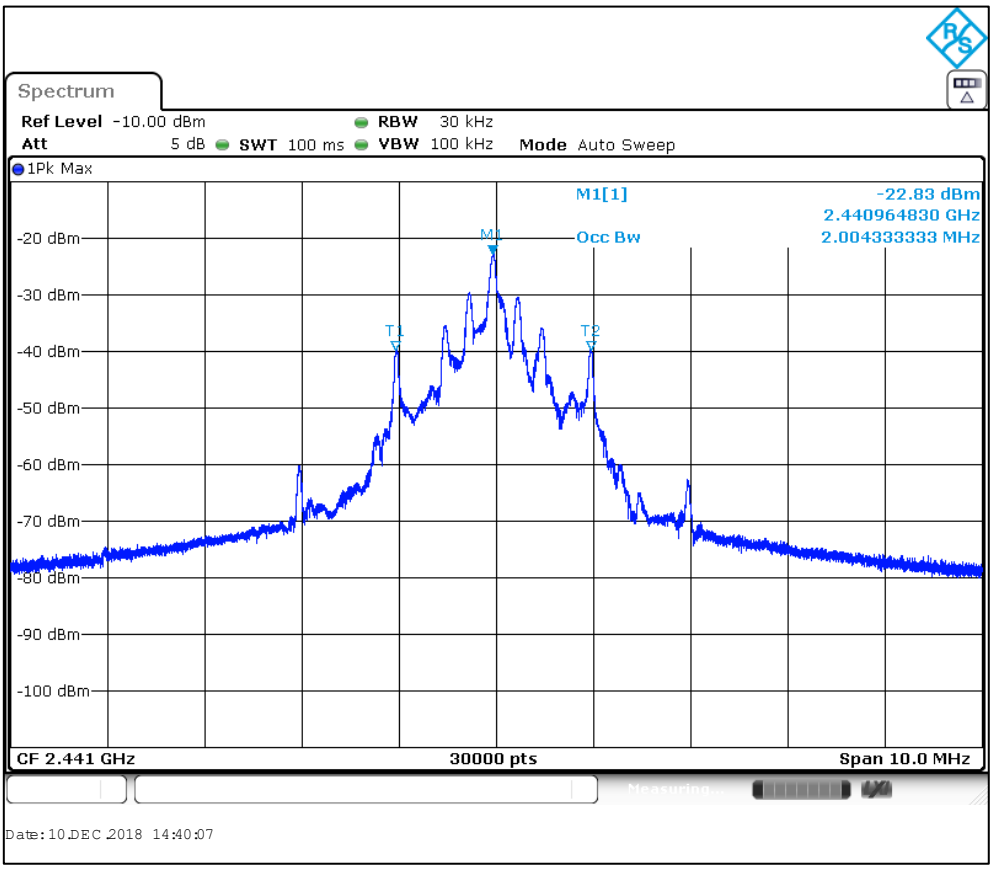

Figure 34. Occupied bandwidth 99% at 2441 MHz.

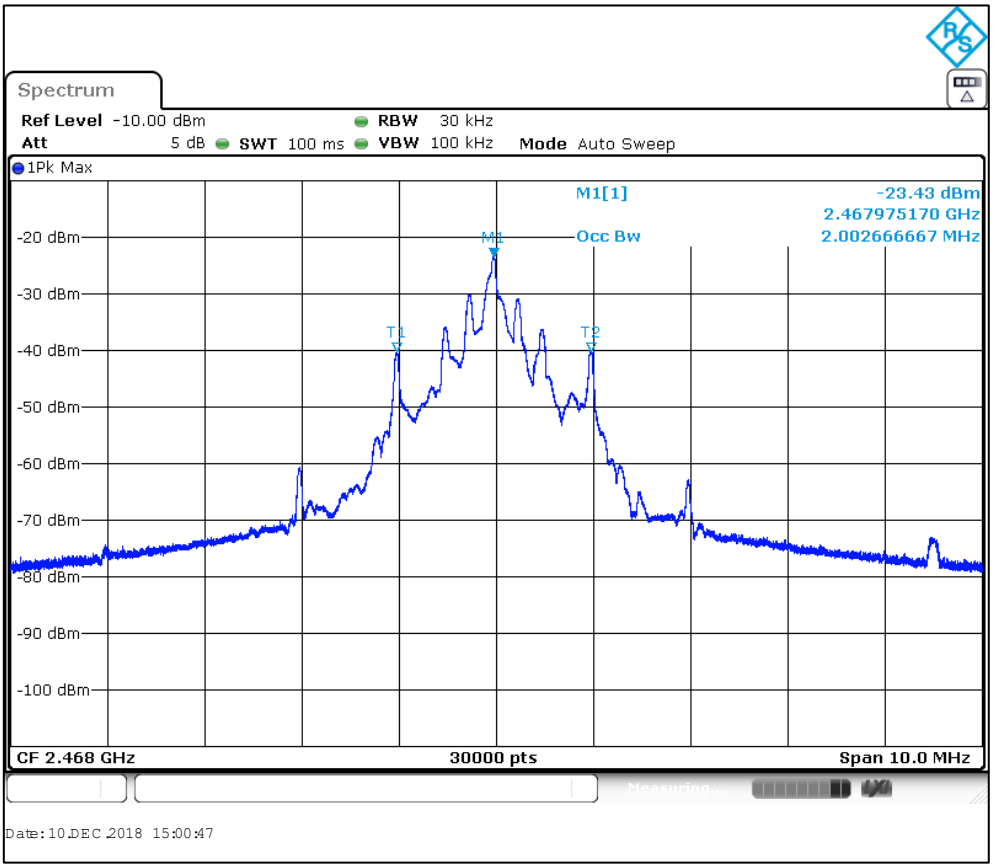

Figure 35. Occupied bandwidth 99% at 2468 MHz.

Frequency [MHz]	Occupied bandwidth 99% [MHz]	Result
2408	2.005667	PASSED
2441	2.004333	PASSED
2468	2.002667	PASSED

Table 47. 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 10Hz – 13.6GHz	Rohde & Schwarz	FSV 13	50092	2019-09-14

Table 48. 20 dB bandwidth test equipment.

2.7 Band edge

Test specimen	Spin
Test specification	47 CFR 2.1049
Test method	ANSI C63.10:2013
Comments	None
Temperature / Humidity	21°C / 37%RH
Dates of measurements	2018-12-07
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. Thus the low channel at 2405 MHz was tested according to ANSI 63.10:2013 clause 6.10.4 Authorized-band band-edge measurements and the high channel at 2479 MHz was tested 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

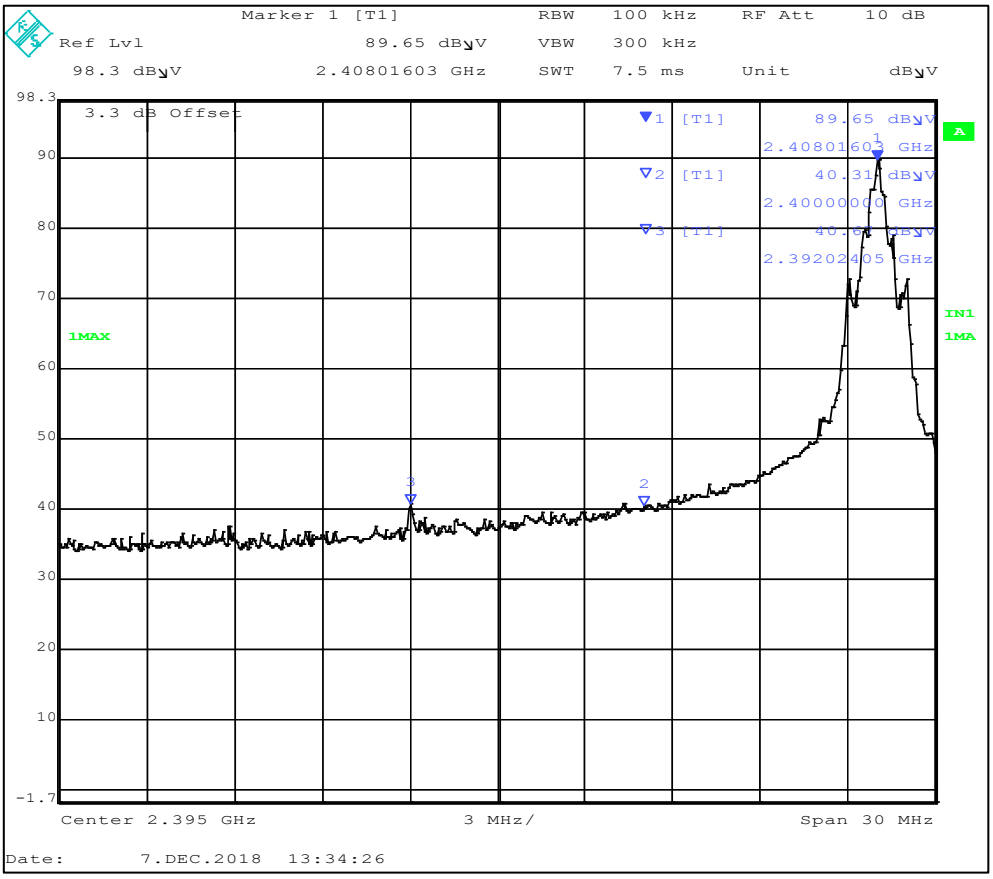

Figure 36. Band Edge Low channel 2405 MHz. Peak detector.

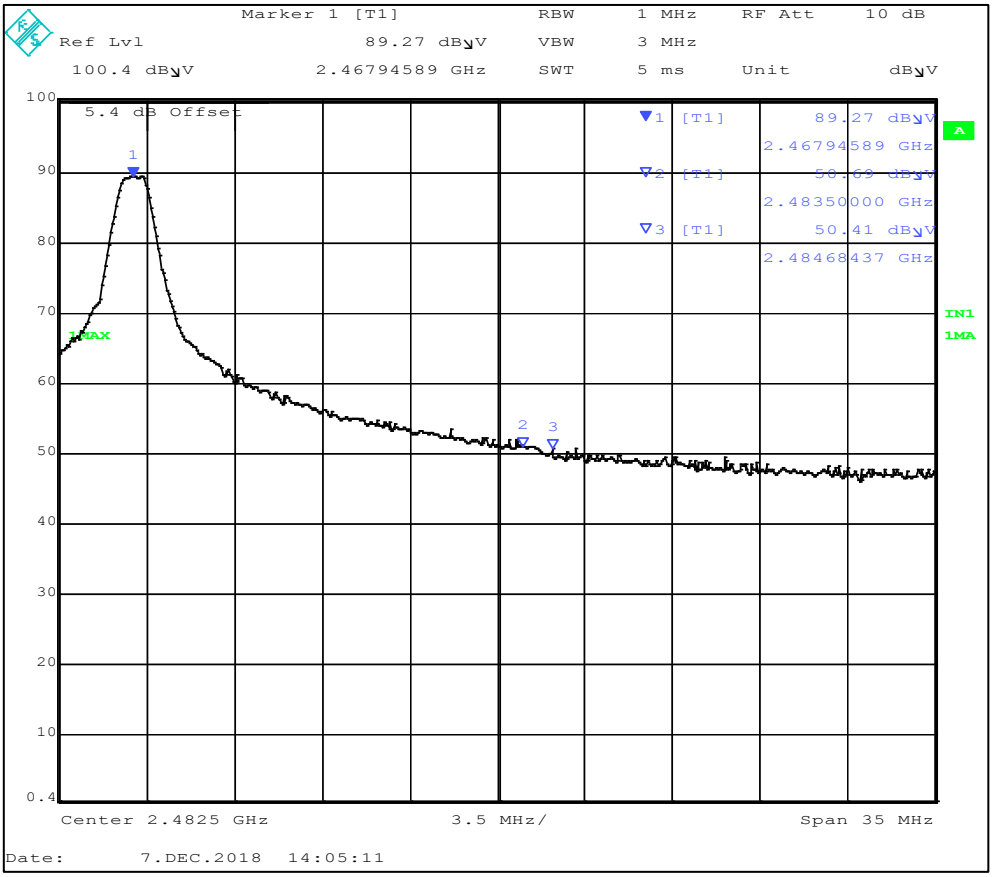

Figure 37. Band Edge High channel 2479 MHz. Peak detector.

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]	
2408	Peak	40.67	33.33	74	PASSED
2408	Average	33.96	20,04	54	PASSED
2468	Peak	50.69	23.31	74	PASSED
2468	Average	43.98	10.02	54	PASSED

Table 49. 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
Receiver, EMI 20Hz-26.5GHz	Rohde & Schwarz	ESIB 26	18880	2019-09-24

Table 50. 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**