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Date	Reference	Page
2018-03-19	P17-0042-4 rev 1	1 (43)

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DANAK
TEST Reg.nr. 563

FCC Designation
Number: DK0002

Test Report

of

Joint JNT002
FCC ID: 2AOUEJNT002
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.:	P17-0042-4 rev 1	**Report date:**	2018-03-19
Test started:	2018-01-26	**Test ended:**	2018-03-14
Number of pages:	43	**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. nr.	FCC Designation number: DK0002
Test specimen:	Joint Model No: JNT002. FCC ID: 2AOUEJNT002
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:	P17-0042-4 rev 1 supersedes P17-0042-4 issued 2018-02-26. 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

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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	Joint
Model No.	JNT002
Hardware ver.	2.3.4
Test Software	Joint_Firmware-idel-6dbm_full_duty.hex
Supply voltage	5 VDC by USB or internal Li-ion battery

The Joint is an item containing two motor controlled joints, which enables the Joint to move the top.
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 Joint is powered by an internal Li-ion battery and charged via USB connector.
The 2.4 GHz radio used in both Joint 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 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.

1.3 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 test the test specimen was powered with 5 VDC via the USB cable, except during AC conducted emission where the AC/DC adaptor was used.

During the tests, except the Duty Cycle test, 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.

2 TESTS

2.1 Duty Cycle

Test specimen	Joint JNT002
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 Joints 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.

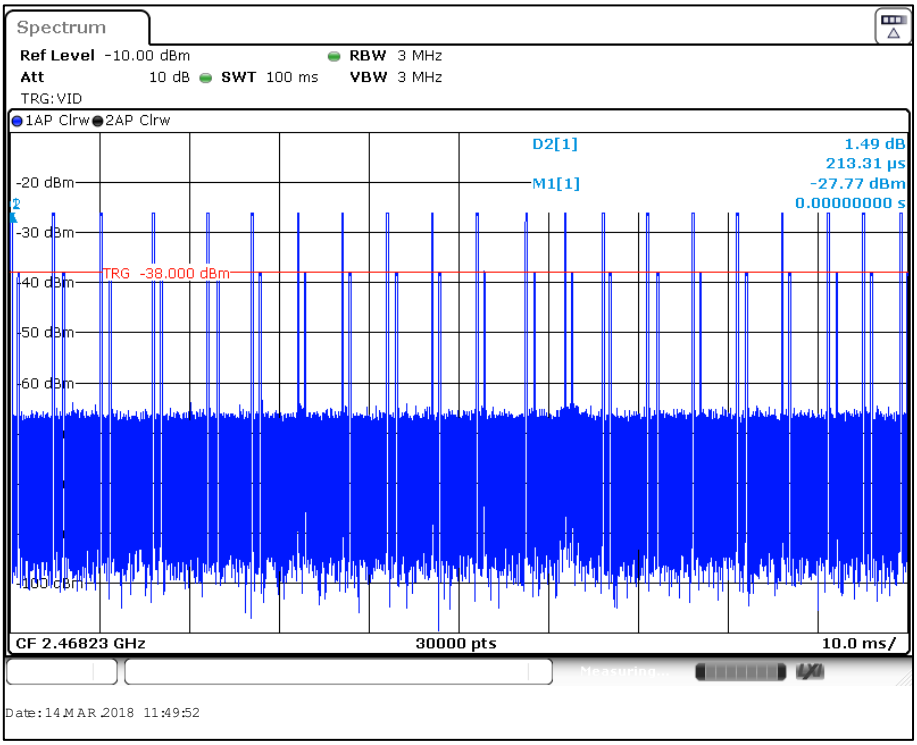

Figure 1. Duty Cycle.

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	4.67	-26.61

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	Joint JNT002
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 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 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	Horizontal	Vertical
Max. peak power	91,13 dBµV/m	90.51 dBµV/m	91.96 dBµV/m
Result	PASSED	PASSED	PASSED

Fundamental: 2449 MHz			
EUT axis	**Vertical**	**Vertical -90 deg.**	**Horizontal**
Antenna polarization	Horizontal	Horizontal	Horizontal
Max. peak power	90.67 dBµV/m	88.59 dBµV/m	89.88 dBµV/m
Result	PASSED	PASSED	PASSED

Fundamental: 2479 MHz			
EUT axis	**Vertical**	**Vertical -90 deg.**	**Horizontal**
Antenna polarization	Horizontal	Horizontal	Vertical
Max. peak power	88.87 dBµV/m	89.64 dBµV/m	89.76 dBµV/m
Result	PASSED	PASSED	PASSED

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

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	Joint JNT002
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	19°C / 42%RH, 20°C / 39%RH, 21°C / 38%RH
Dates of measurements	2018-02-08, 2018-02-09, 2018-02-23
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 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 3 different orientations and 3 frequencies.

At 2405 MHz the orientation was vertical, at 2449 MHz the orientation was vertical – 90 deg. and at 2479 MHz the orientation was horizontal.

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 Low channel 2405 MHz in vertical position.

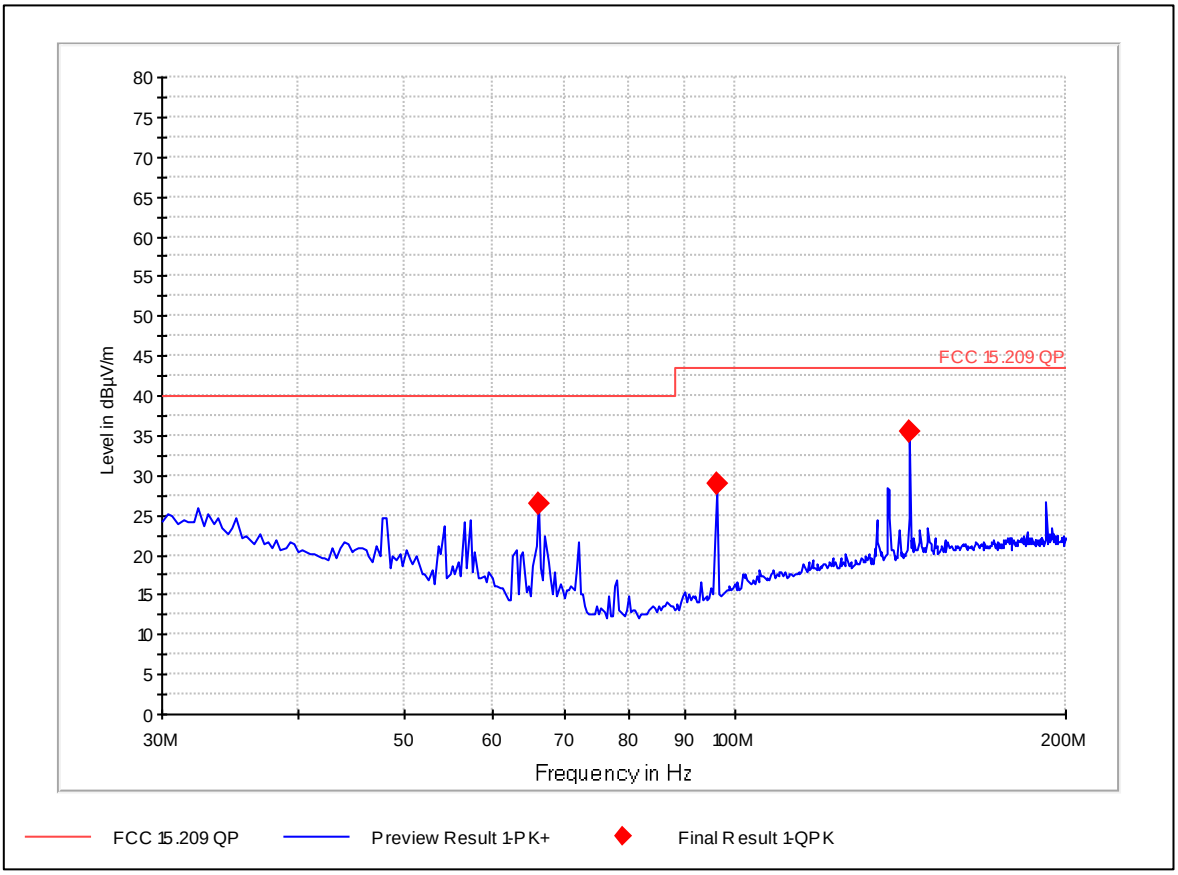

Figure 2. Radiated emission test results. 30 - 200 MHz.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
66.082224	26.4	120.0	100.1	V	19.0	13.6	40.0	PASSED
96.012184	28.9	120.0	100.1	V	350.0	14.6	43.5	PASSED
144.008257	35.5	120.0	99.9	V	41.0	8.0	43.5	PASSED

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

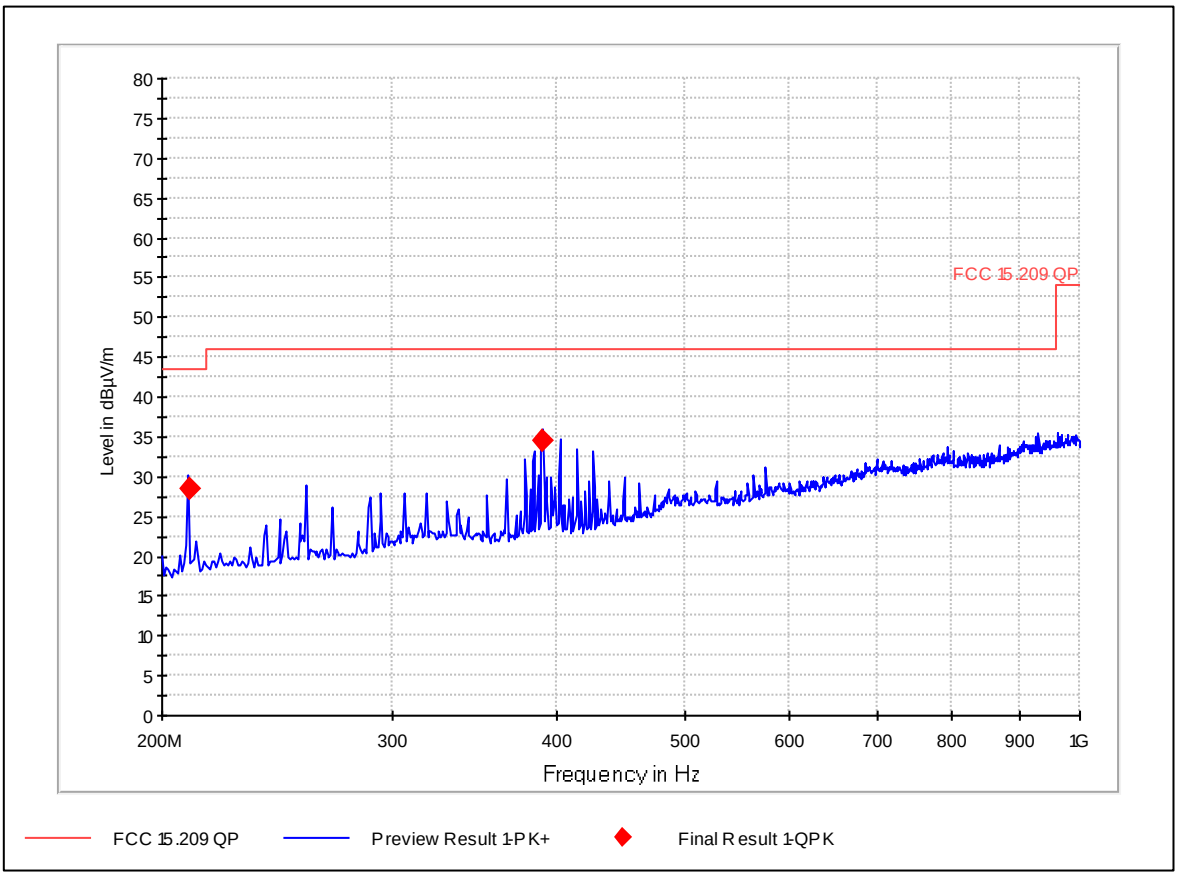

Figure 3. Radiated emission test results. 200 - 1000 MHz.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
210.079238	28.5	120.0	139.9	H	92.0	15.0	43.5	PASSED
390.229960	34.6	120.0	149.1	V	52.0	11.4	46.0	PASSED

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

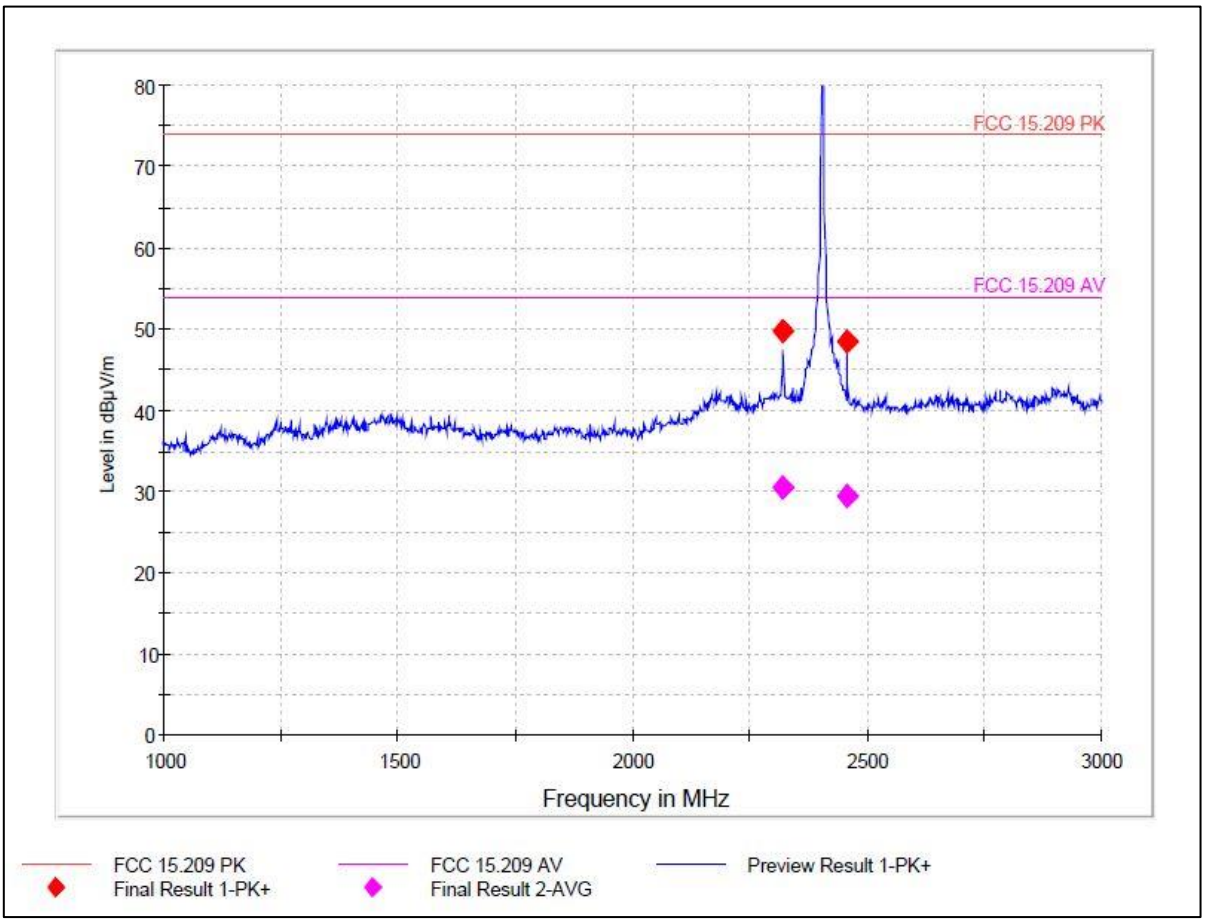

Figure 4. Radiated emission test results 1 - 3 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
2320.638283	49.8	1000	99.9	H	269.0	24.2	74.0	PASSED
2457.729328	48.4	1000	150.1	H	300.0	25.6	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
2320.638283	30.4	1000	99.9	H	269.0	23.6	54.0	PASSED
2457.729328	29.4	1000	150.1	H	300.0	24.6	54.0	PASSED

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

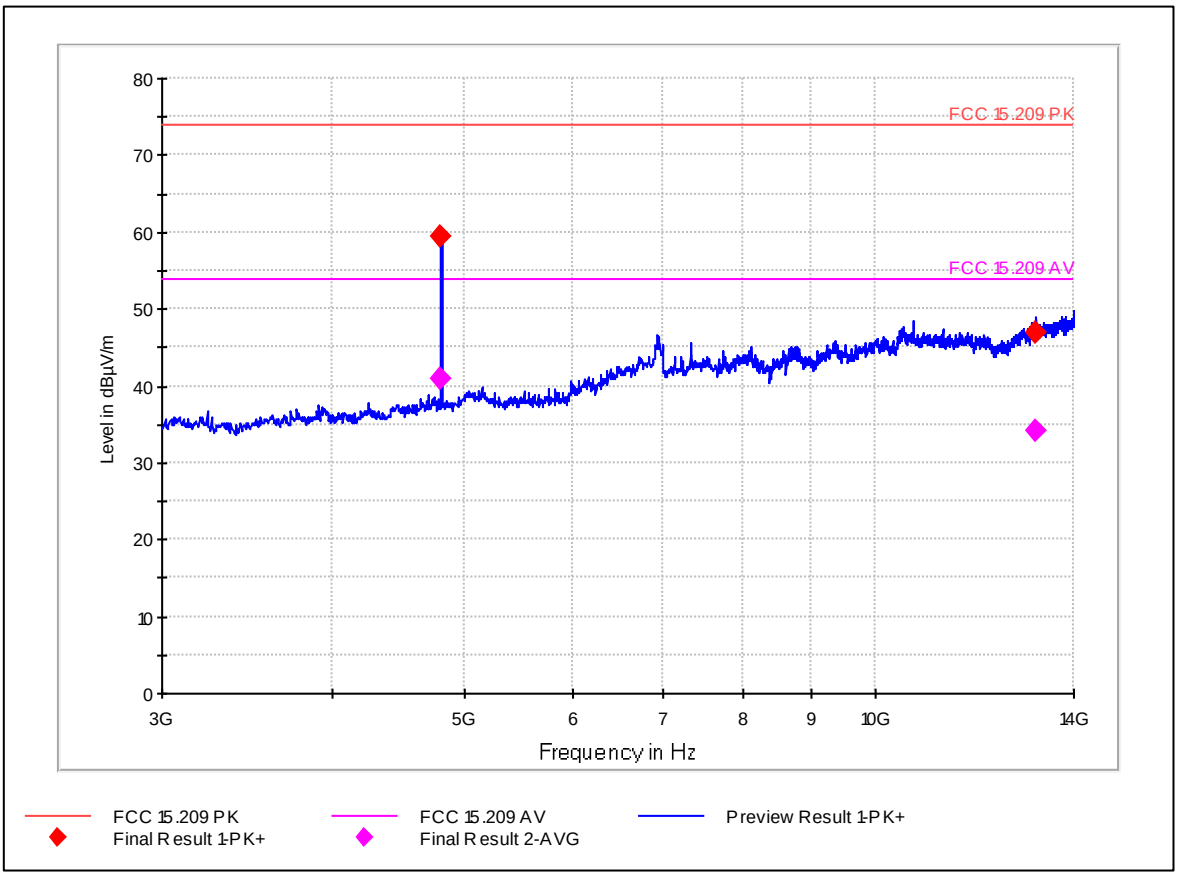

Figure 5. Radiated emission test results 3 - 14 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
4809.159255	59.3	1000	200.1	H	315.0	14.7	74.0	PASSED
13106.555093	47.0	1000	289.0	H	96.0	27.0	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
4809.159255	59.3	-26.61	32.69	21.31	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
13106.555093	34.2	1000	289.0	H	96.0	19.8	54.0	PASSED

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

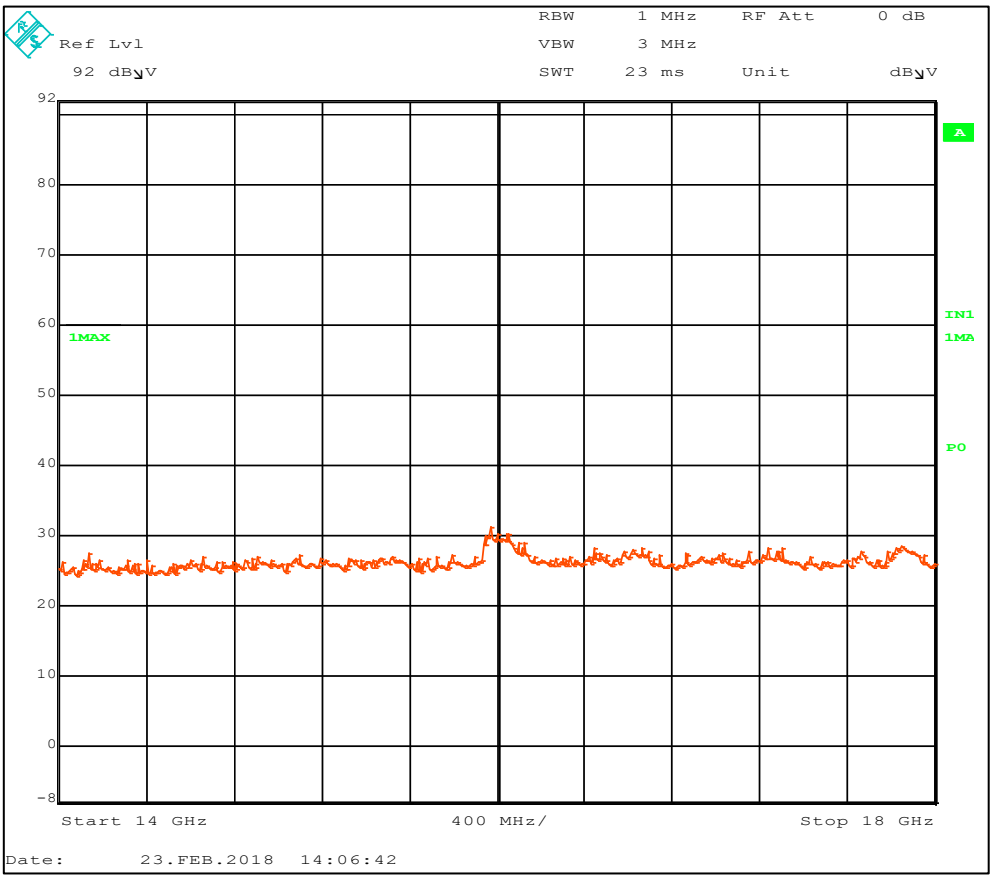

Figure 6 Radiated emission test results 14 - 18 GHz. Peak detector.

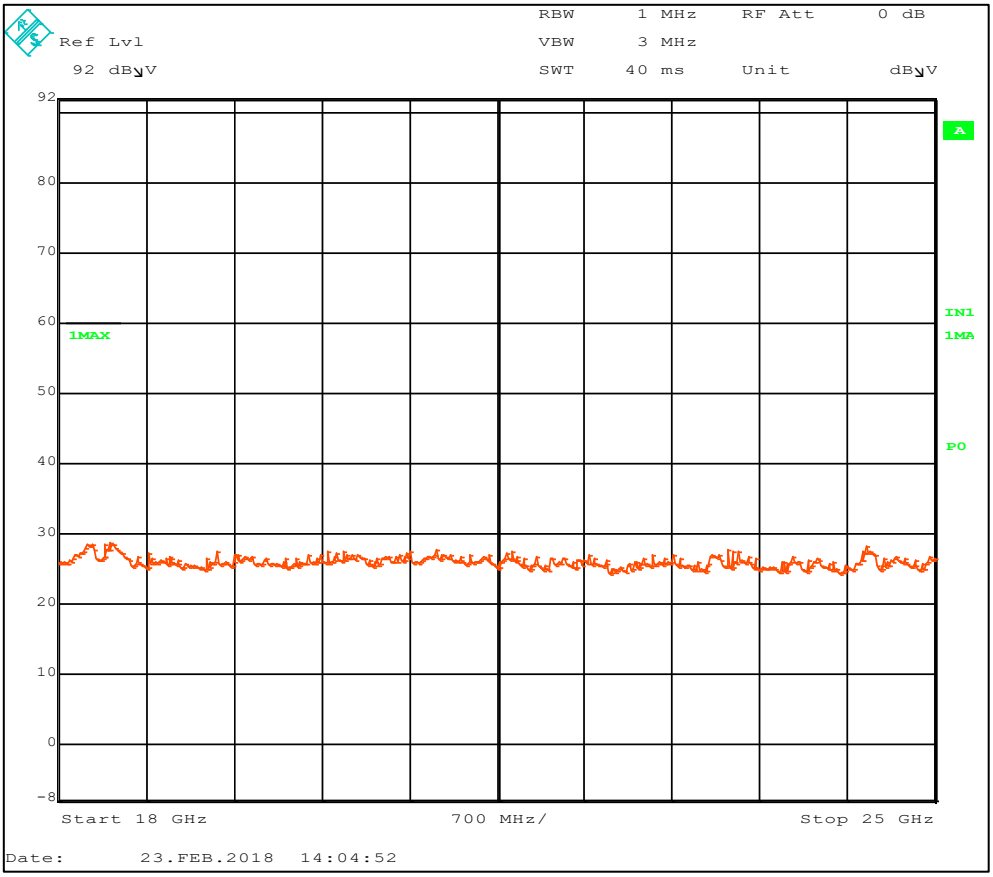

Figure 7. Radiated emission test results 18 - 25 GHz. Peak detector

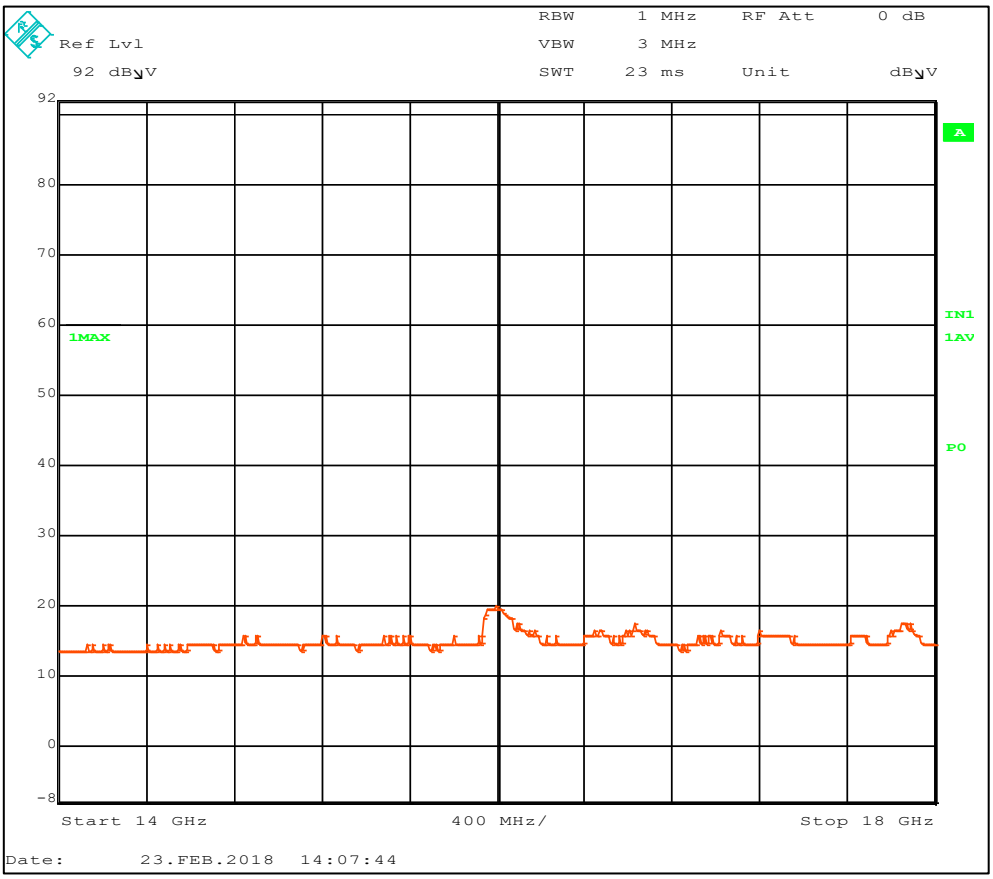

Figure 8. Radiated emission test results 14 - 18 GHz. Average detector.

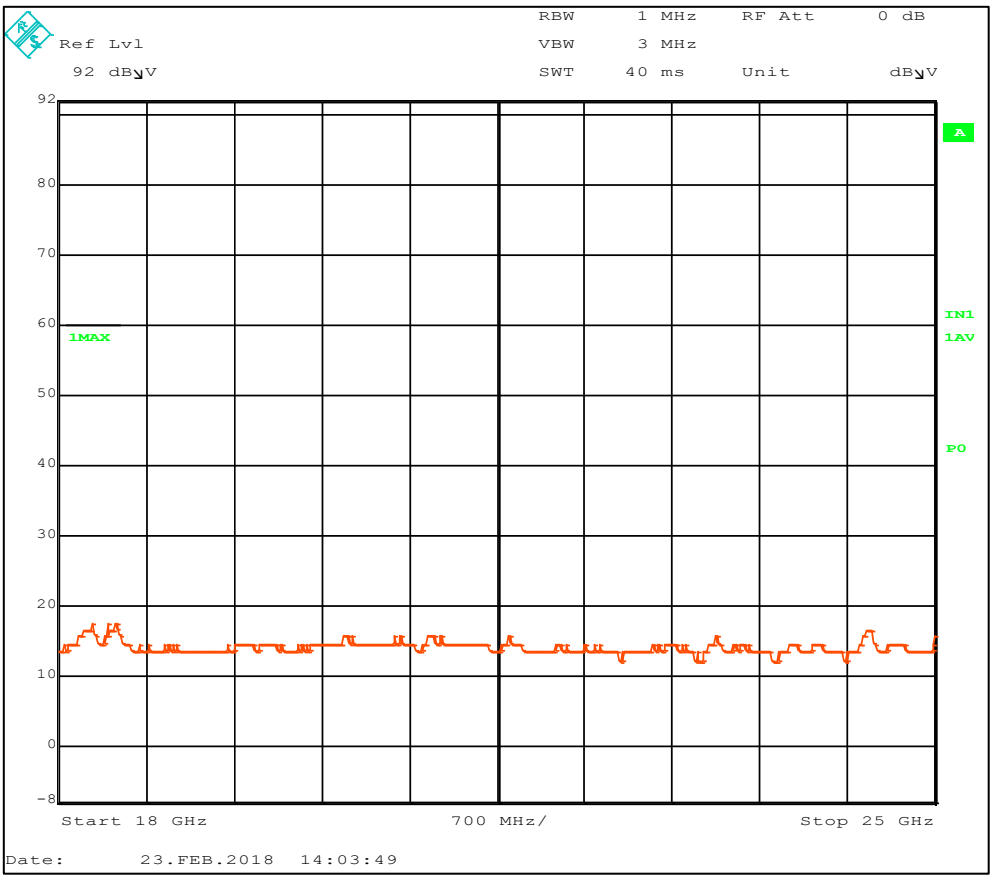

Figure 9. Radiated emission test results 18 - 25 GHz. Average detector.

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 in vertical -90 deg. position.

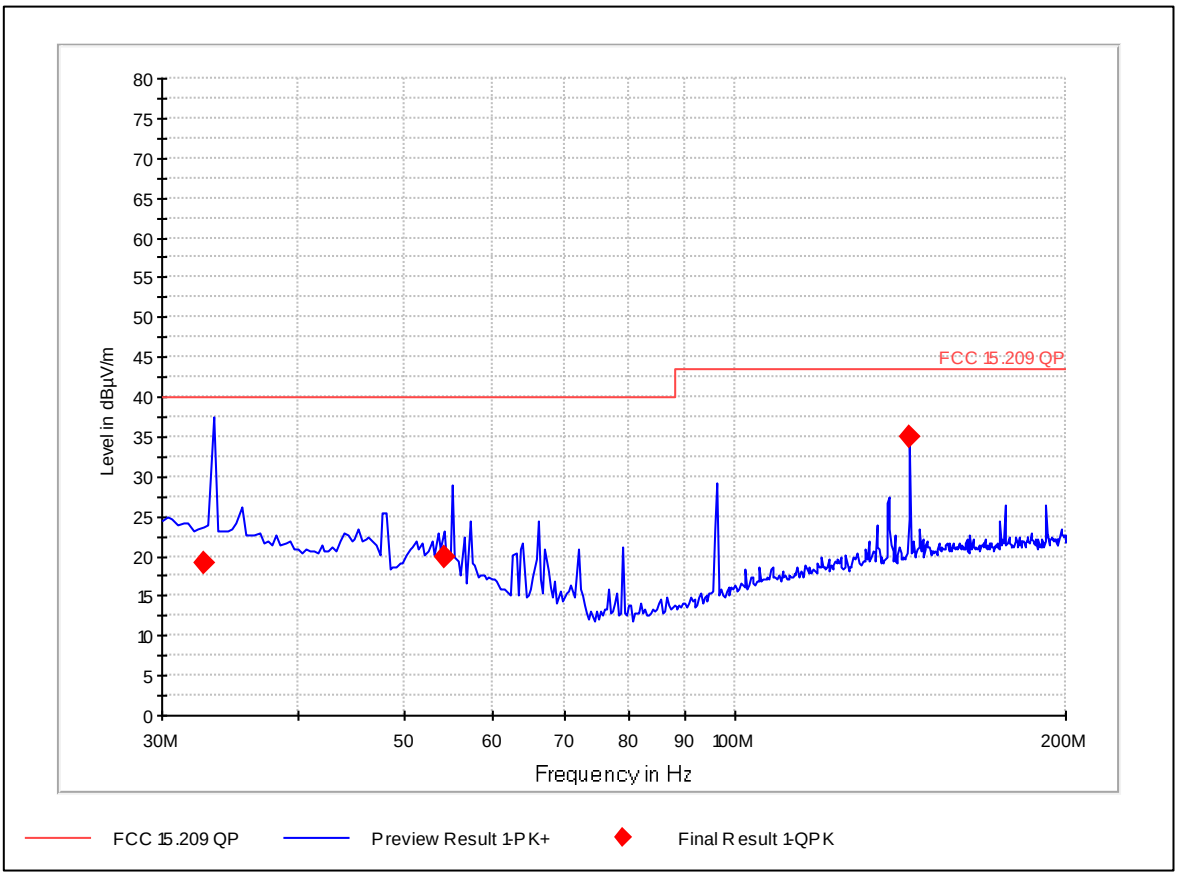

Figure 10. Radiated emission test results. 30 - 200 MHz.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
32.726814	19.1	120.0	148.1	V	230.0	20.9	40.0	PASSED
54.230421	19.9	120.0	162.8	V	156.0	20.1	40.0	PASSED
144.008257	34.9	120.0	99.9	V	0.0	8.6	43.5	PASSED

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

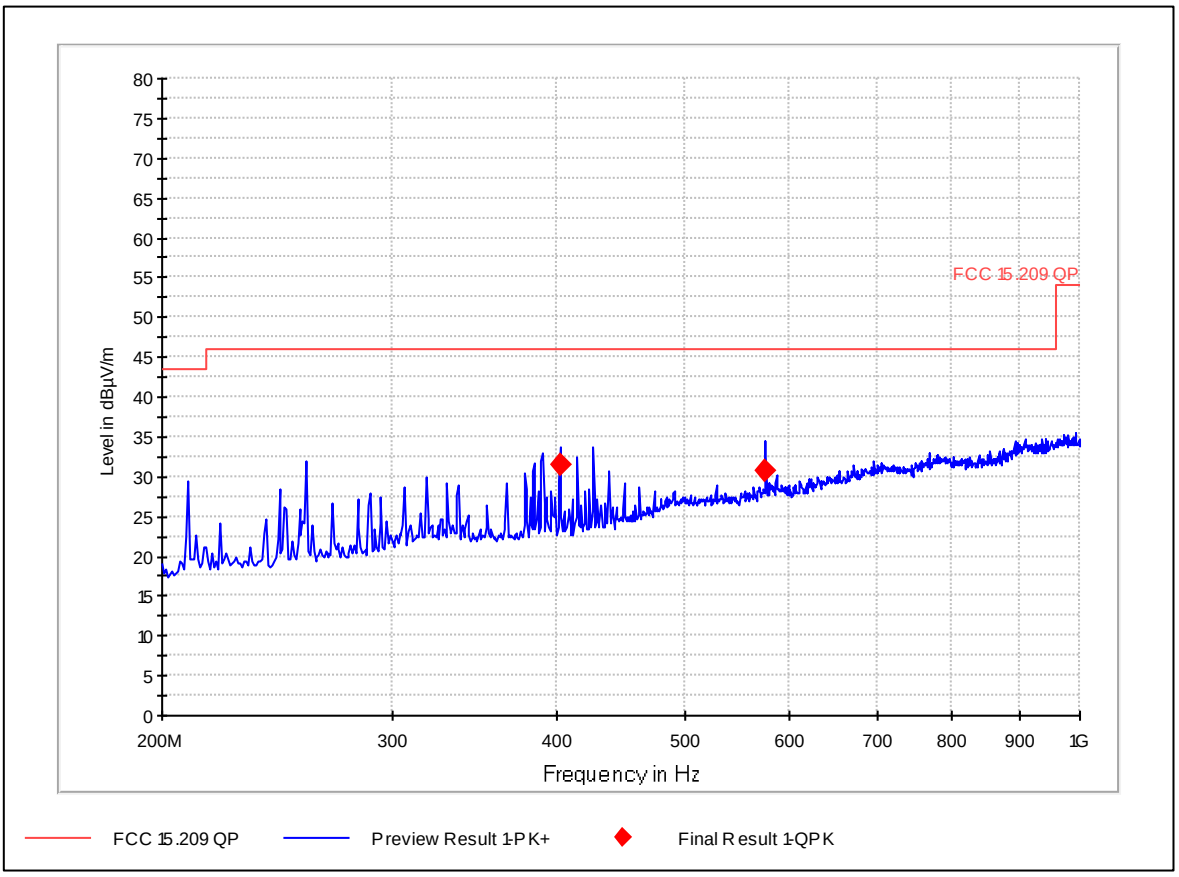

Figure 11. Radiated emission test results. 200 - 1000 MHz.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
402.084008	31.5	120.0	226.0	H	212.0	14.5	46.0	PASSED
575.991904	30.8	120.0	135.0	H	231.0	15.2	46.0	PASSED

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

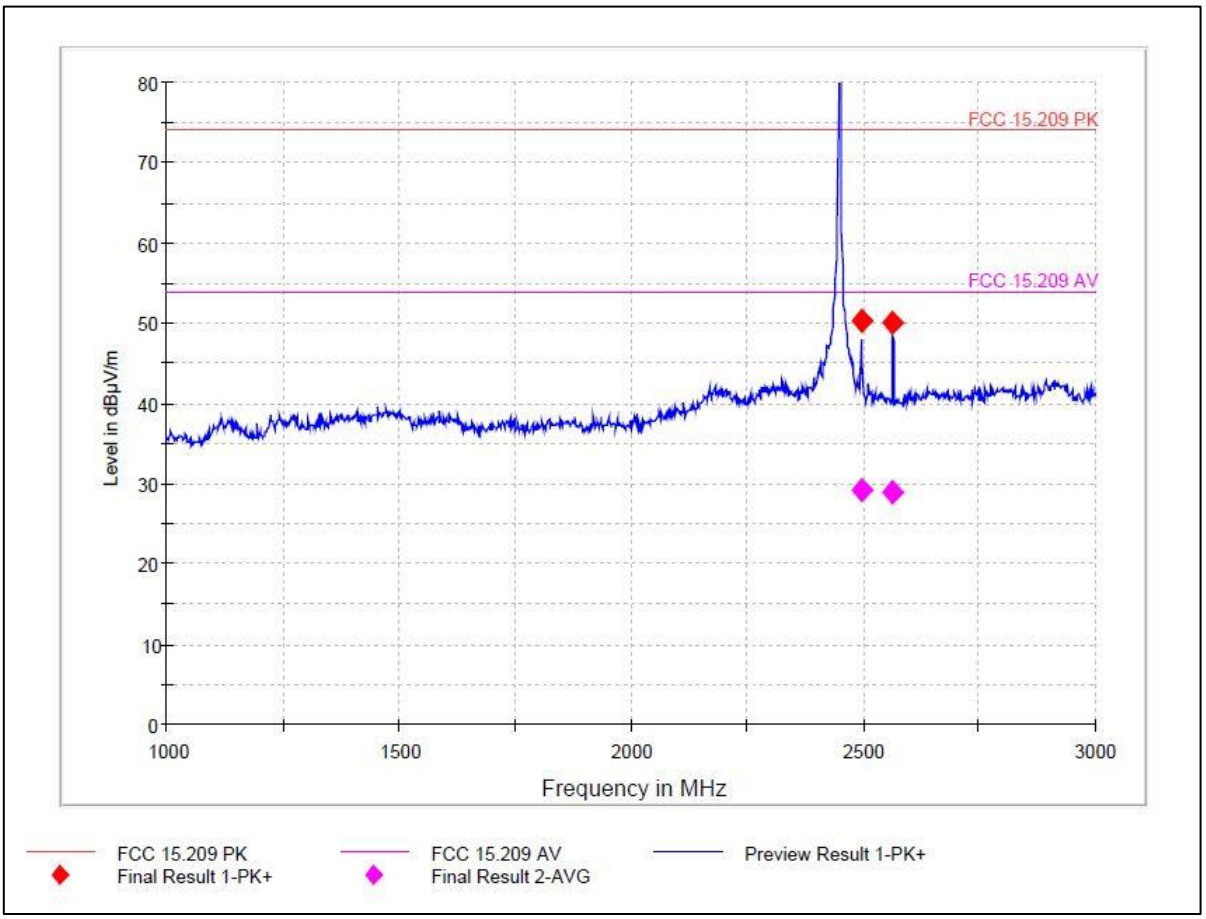

Figure 12. Radiated emission test results 1 - 3 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
2495.614980	50.3	1000.	150.1	V	257.0	23.7	74.0	PASSED
2564.010753	50.0	1000.	150.0	V	255.0	24.0	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
2495.614980	29.2	1000.	150.1	V	257.0	24.8	2495.614	PASSED
2564.010753	29.0	1000.	150.0	V	255.0	25.0	2564.010	PASSED

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

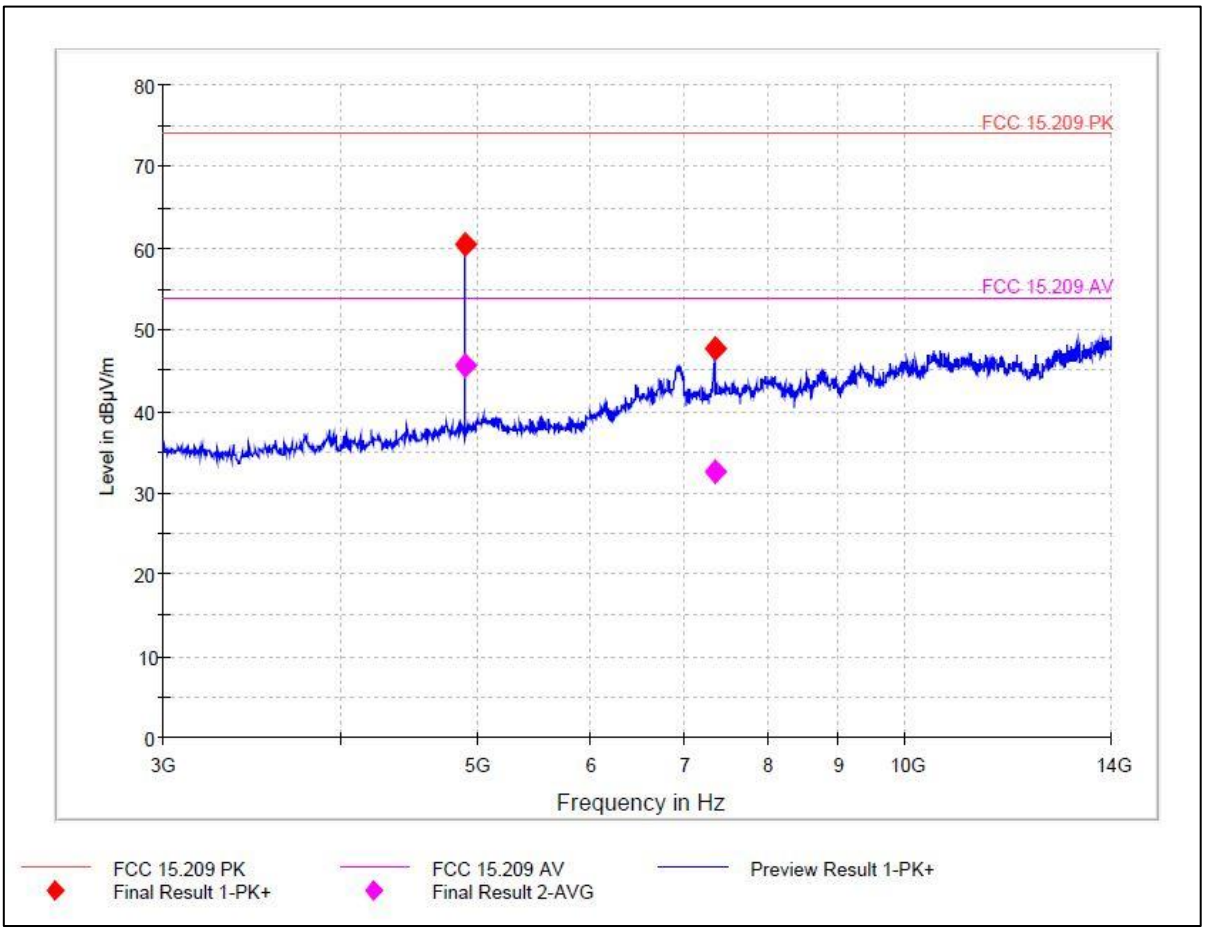

Figure 13. Radiated emission test results 3 - 14 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
4897.503595	60.3	1000	149.9	V	127.0	13.7	74.0	PASSED
7345.953895	47.8	1000	99.9	H	202.0	26.2	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
4897.503595	60.3	-26.61	33.69	20.31	54.0	PASSED
7345.953895	47.8	-26.61	21.19	32.81	54.0	PASSED

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

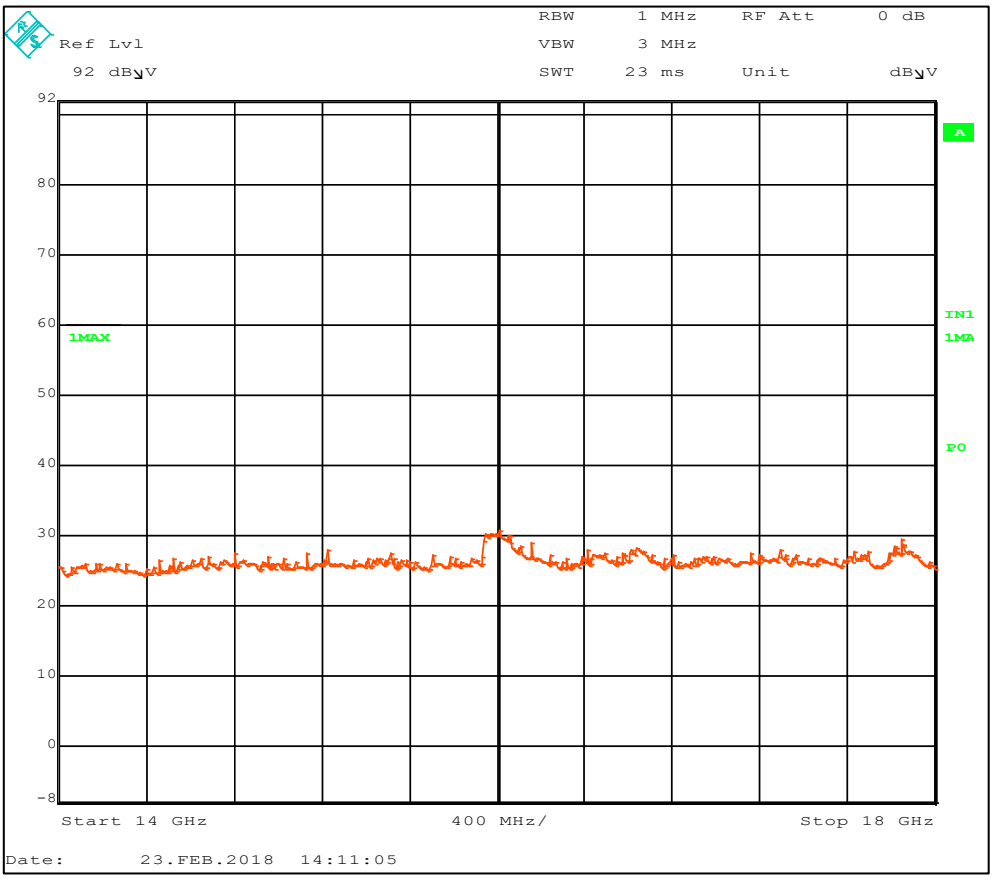

Figure 14. Radiated emission test results 14 - 18 GHz. Peak detector.

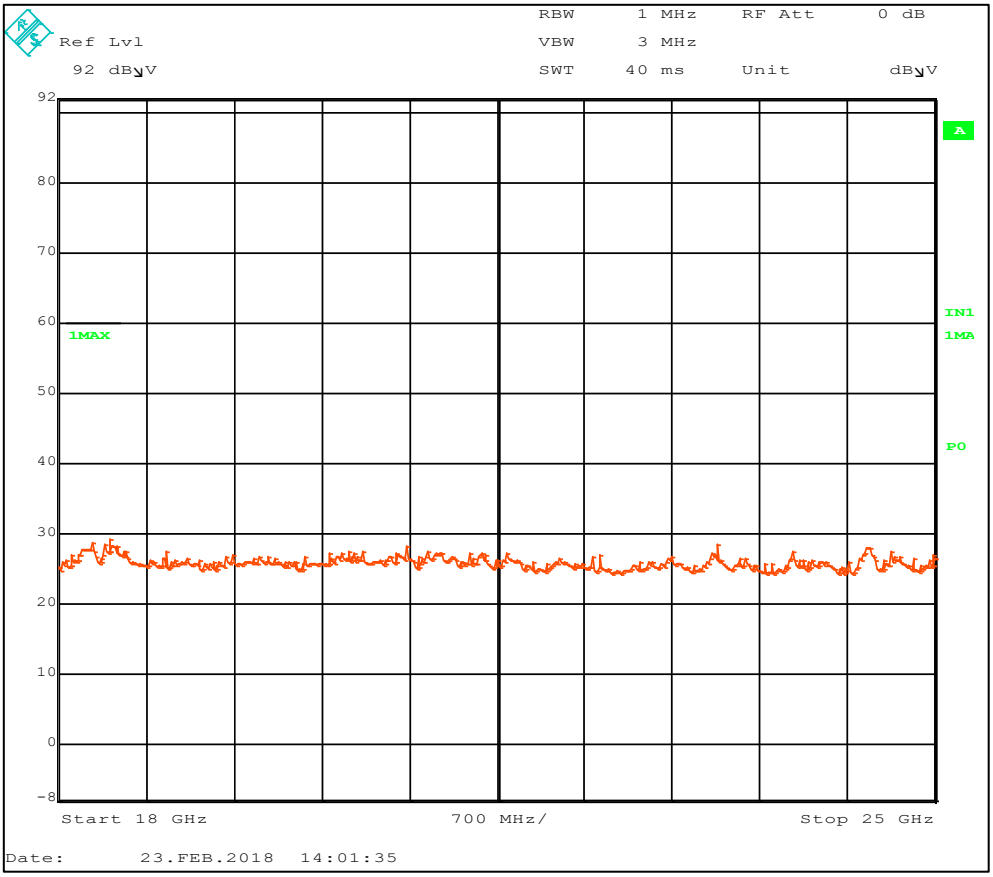

Figure 15. Radiated emission test results 18 - 25 GHz. Peak detector.

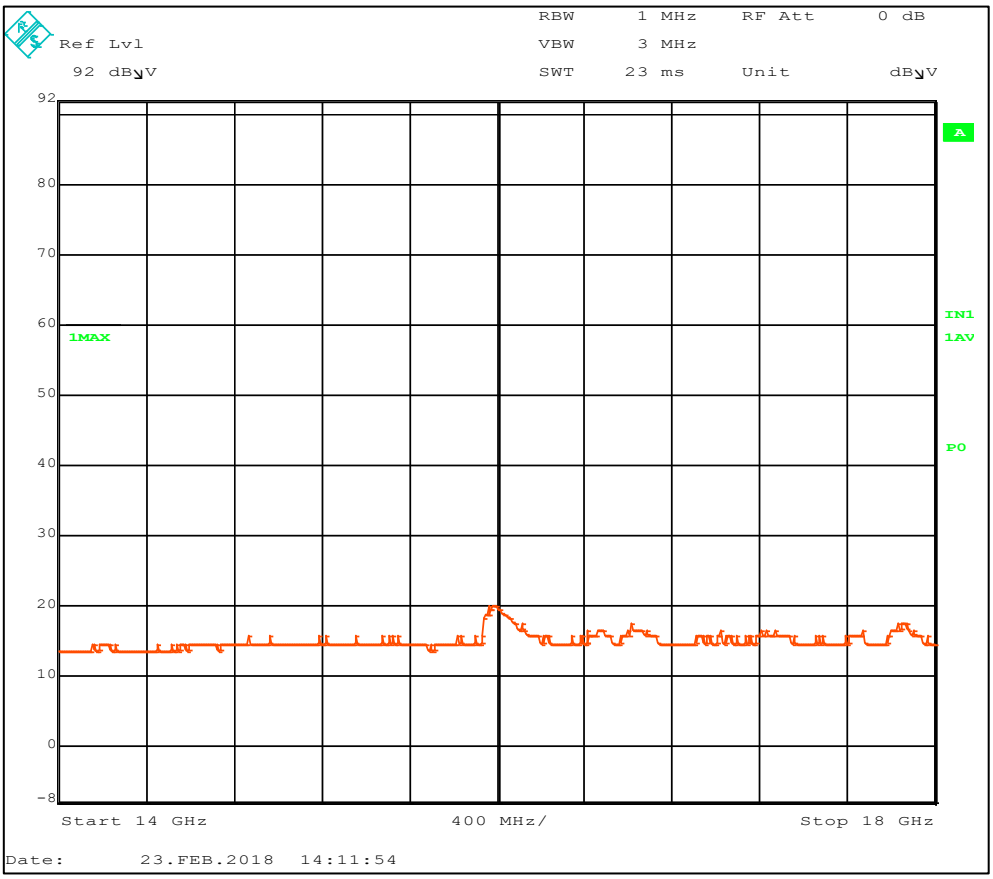

Figure 16. Radiated emission test results 18 - 25 GHz. Average detector.

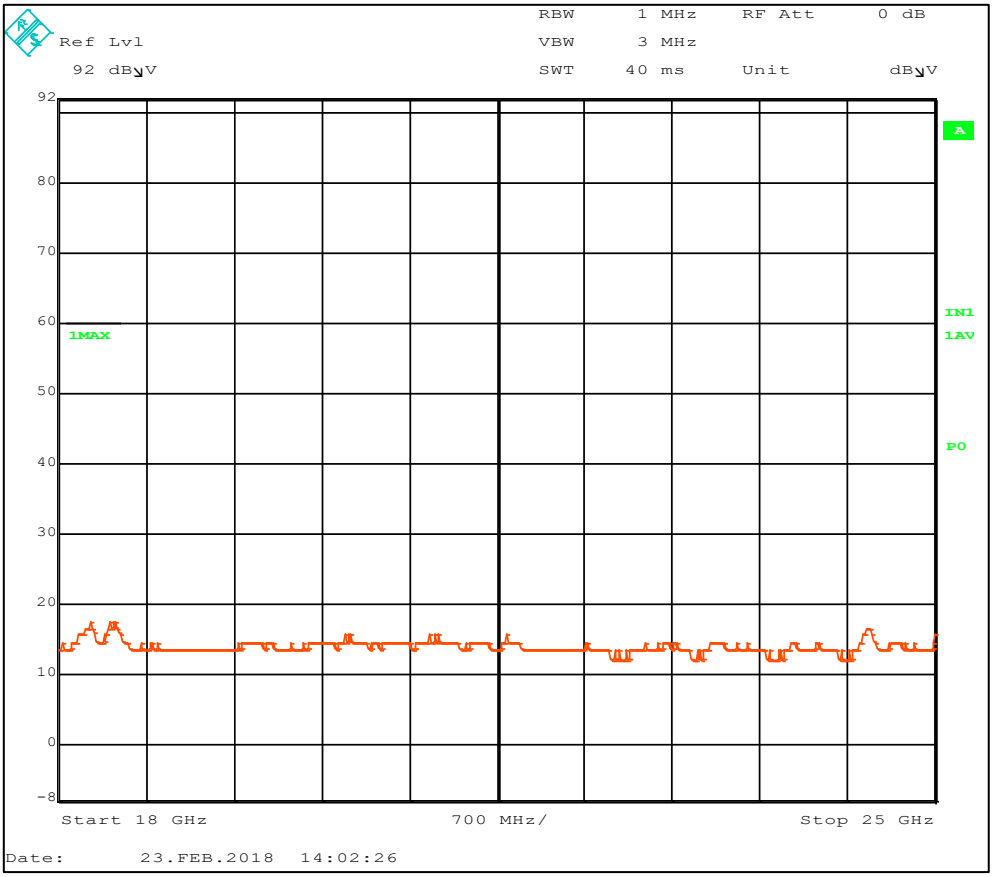

Figure 17. Radiated emission test results 18 - 25 GHz. Average detector.

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 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 3 - 14 GHz. Average detector.

2.3.2.3 Test result for High channel 2479 MHz in horizontal position

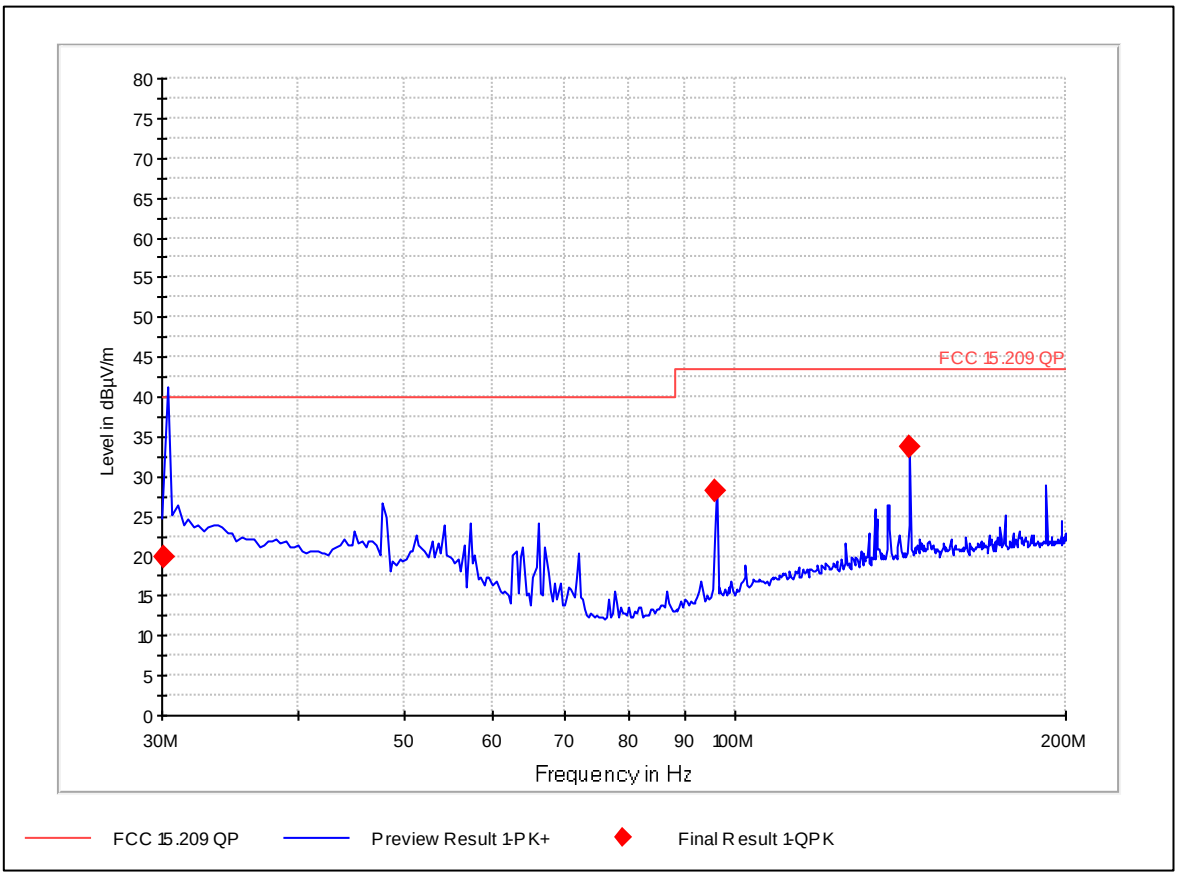

Figure 18. Radiated emission test results. 30 - 200 MHz.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
30.170000	19.9	120.0	309.1	H	190.0	20.1	40.0	PASSED
95.992184	28.3	120.0	99.9	V	136.0	15.2	43.5	PASSED
143.998257	33.8	120.0	99.9	V	42.0	9.7	43.5	PASSED

Table 24. Radiated emission test results. 30 - 200 MHz.

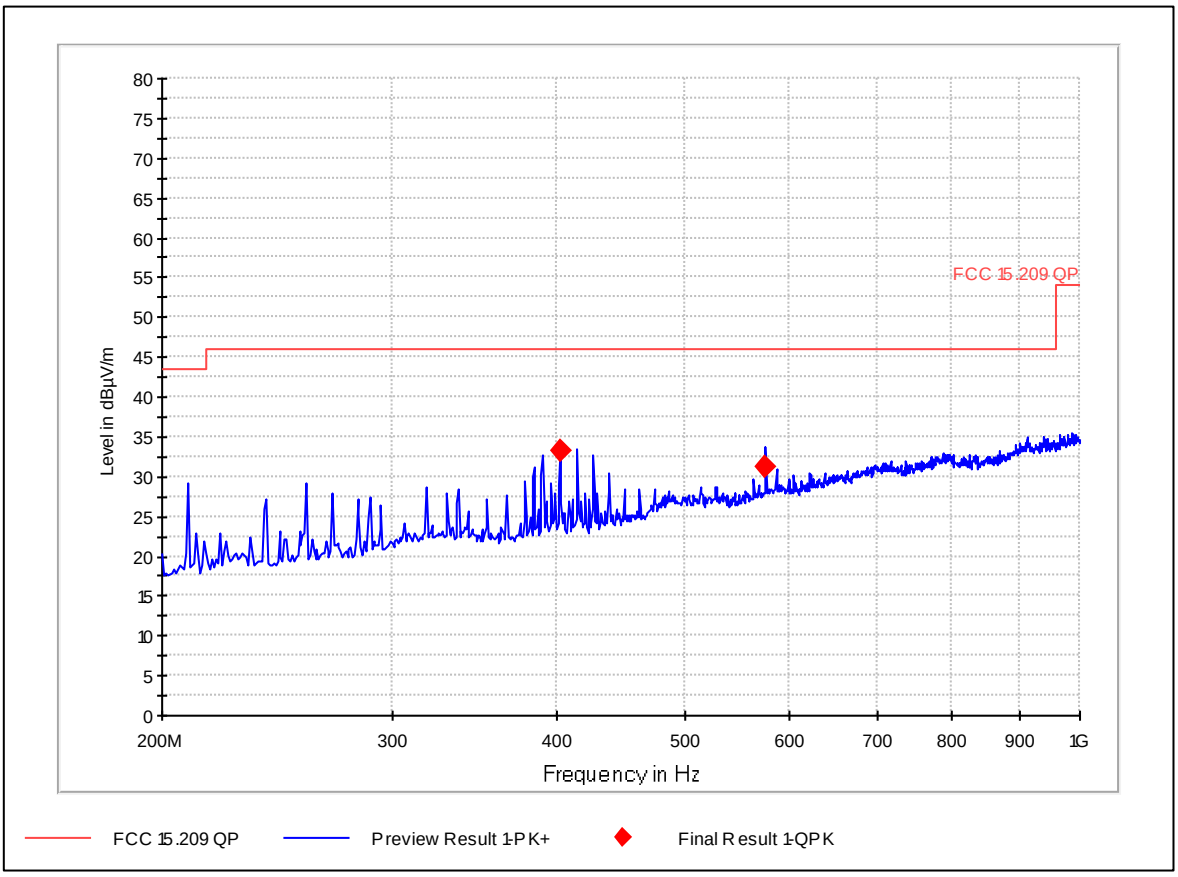

Figure 19. Radiated emission test results. 200 - 1000 MHz.

Frequency [MHz]	QP [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
402.074008	33.2	120.0	213.1	H	82.0	12.8	46.0	PASSED
575.991904	31.1	120.0	192.3	V	74.0	14.9	46.0	PASSED

Table 25. Radiated emission test results. 200 - 1000 MHz.

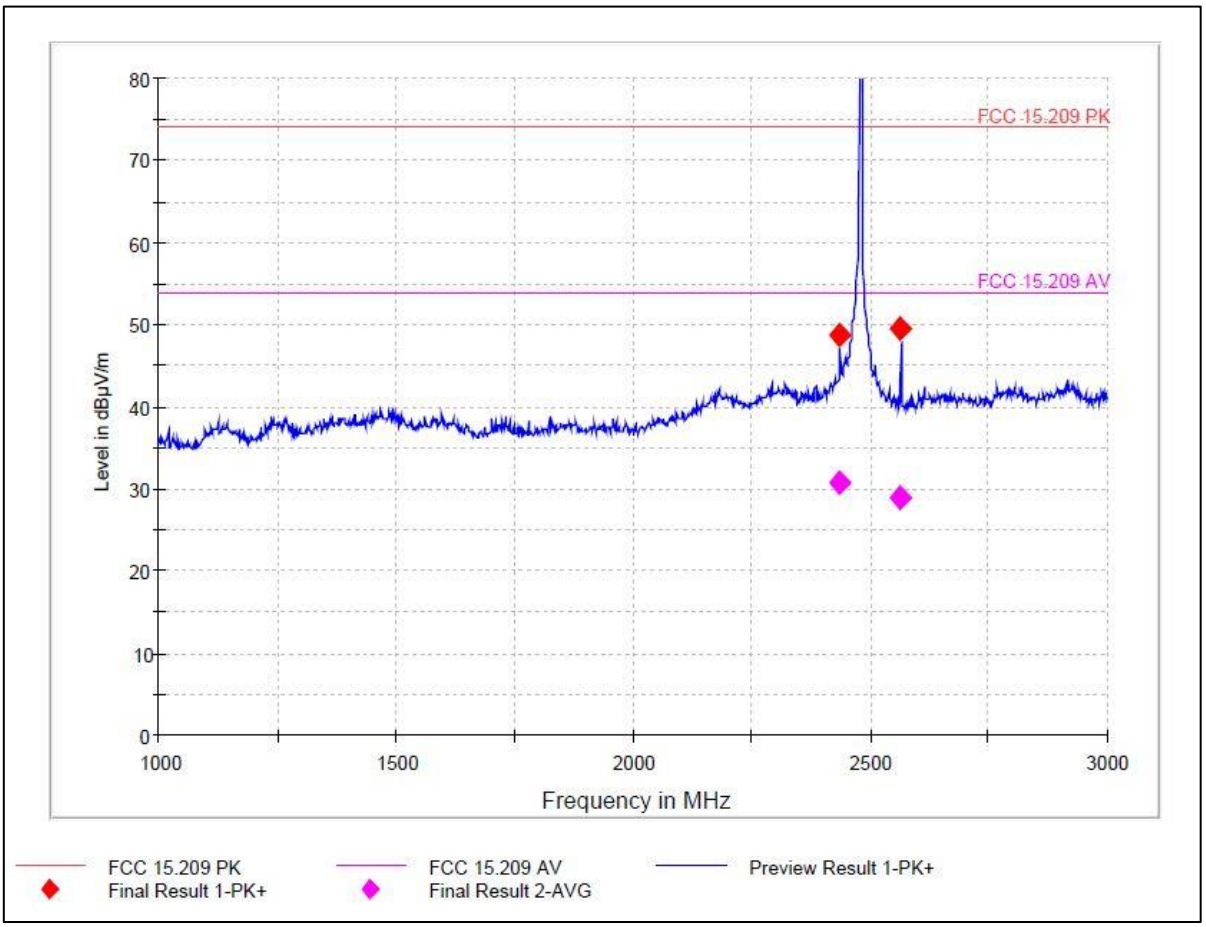

Figure 20. Radiated emission test results 1 - 3 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
2435.889248	48.8	1000.	199.6	H	0.0	25.2	74.0	PASSED
2564.404761	49.6	1000.	200.0	H	0.0	24.4	74.0	PASSED

Table 26. 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
2435.889248	30.7	1000.	199.6	H	0.0	23.3	54.0	PASSED
2564.404761	28.9	1000.	200.0	H	0.0	25.1	54.0	PASSED

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

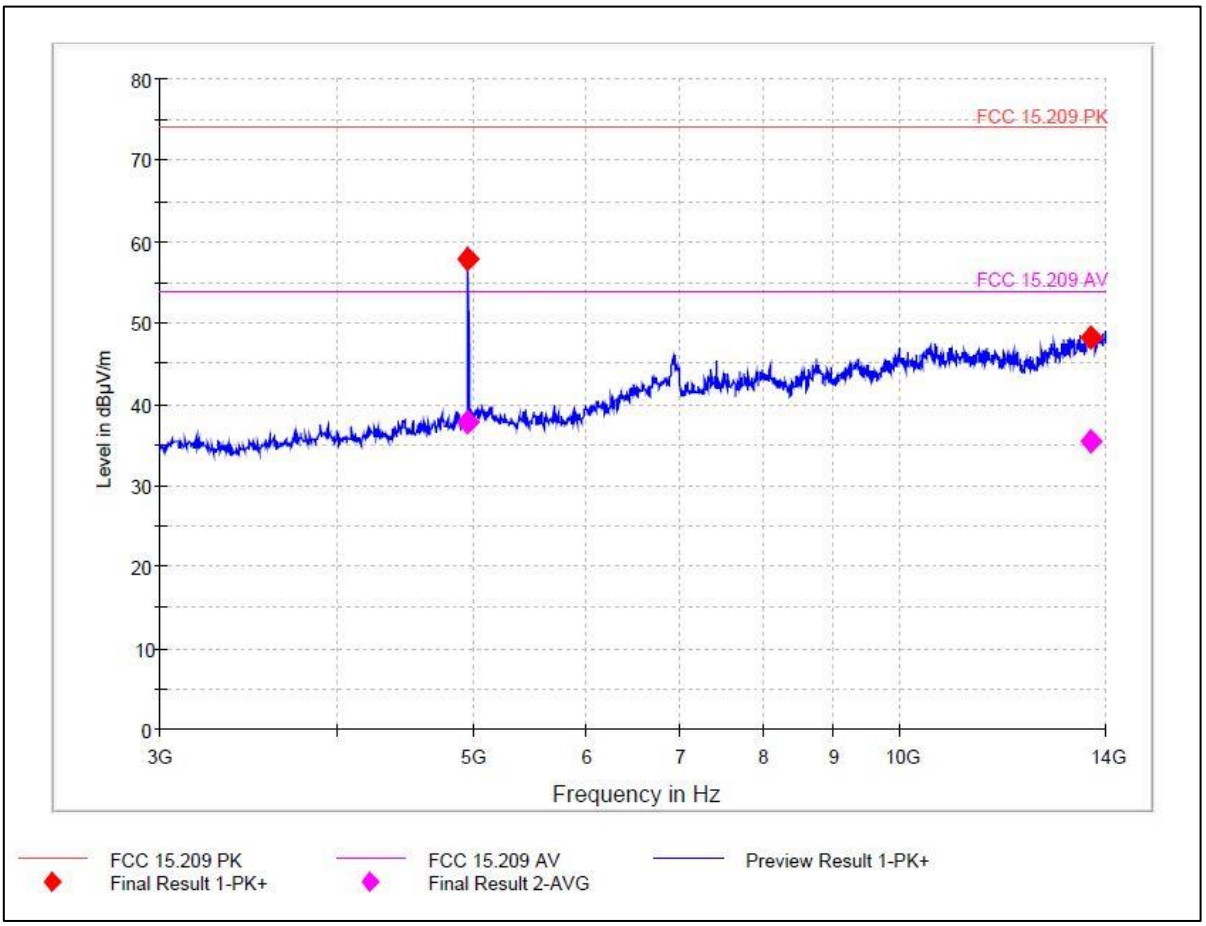

Figure 21. Radiated emission test results 3 - 14 GHz.

Frequency [MHz]	Peak [dBuV/m]	BW [kHz]	Height [cm]	Pol.	Azimuth [deg]	Margin [dB]	Limit [dBuV/m]	Result
4958.923336	57.9	1000	199.9	H	142.0	16.1	74.0	PASSED
13660.314647	48.1	1000	99.7	V	12.0	25.9	74.0	PASSED

Table 28. 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
4958.923336	57.9	-26.61	31.29	22.71	54.0	PASSED

Table 29. 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
13660.314647	35.4	1000.	99.7	V	12.0	18.6	54.0	PASSED

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

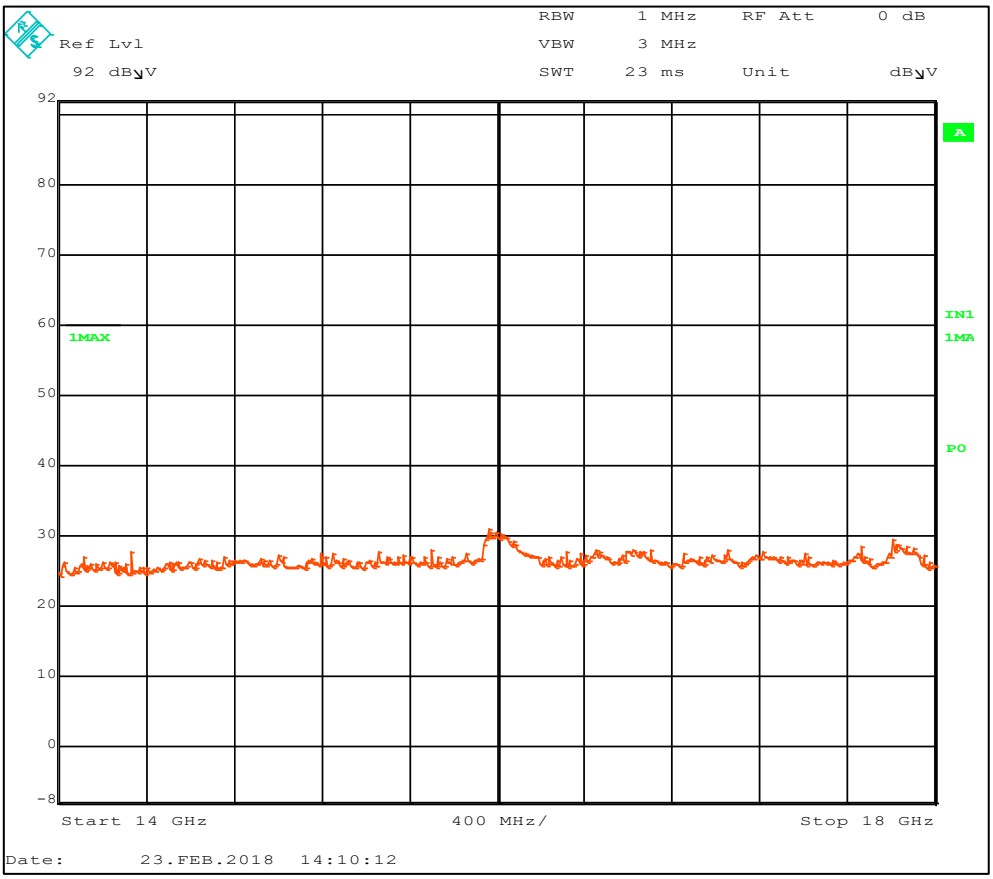

Figure 22. Radiated emission test results 14 - 18 GHz. Peak detector.

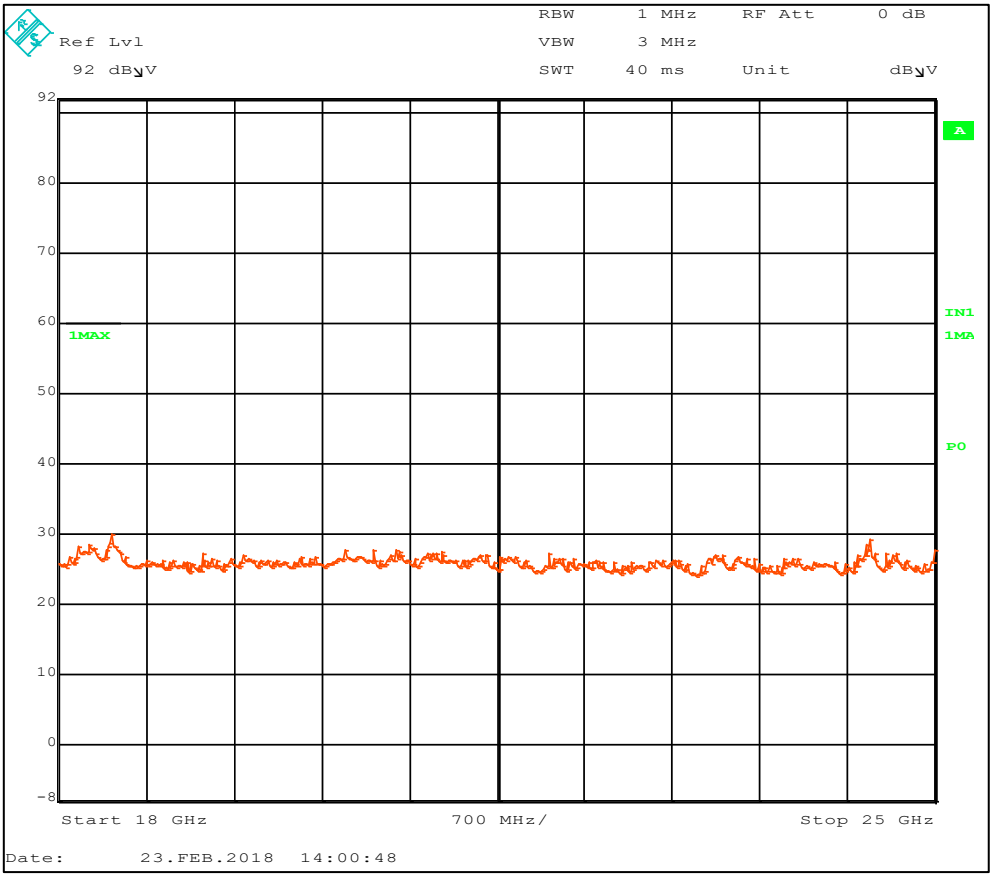

Figure 23. Radiated emission test results 18 - 25 GHz. Peak detector.

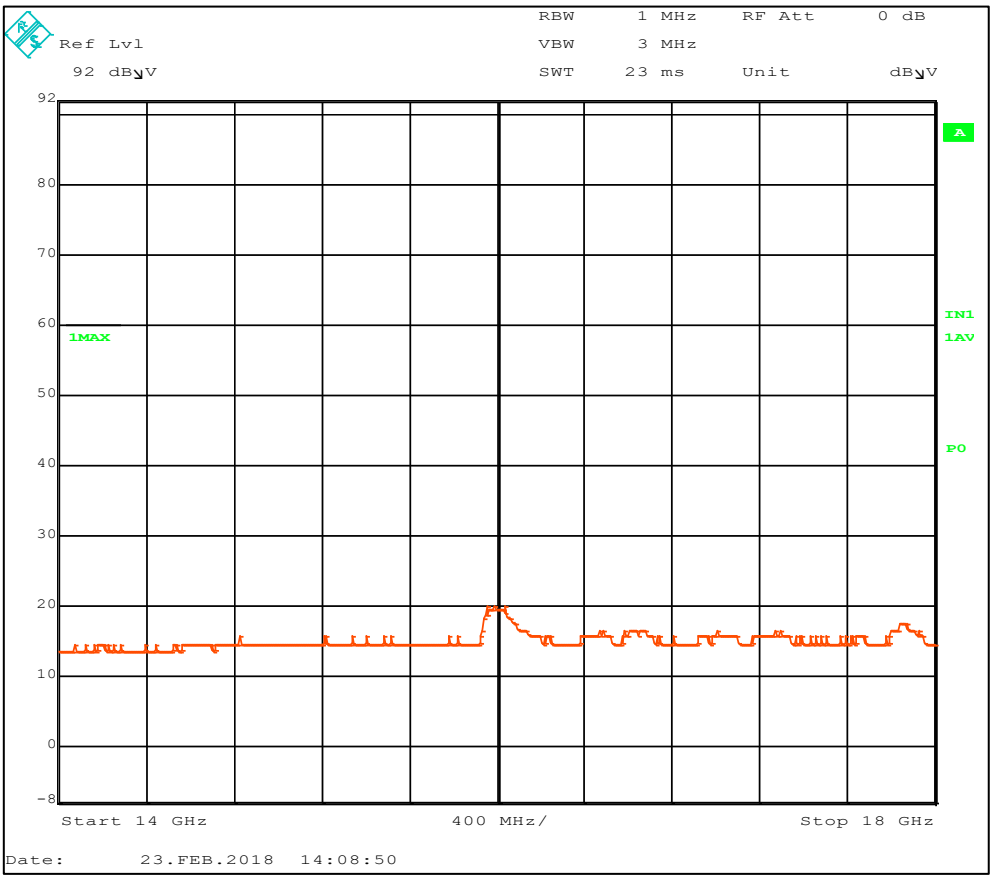

Figure 24. Radiated emission test results 14 - 18 GHz. Average detector.

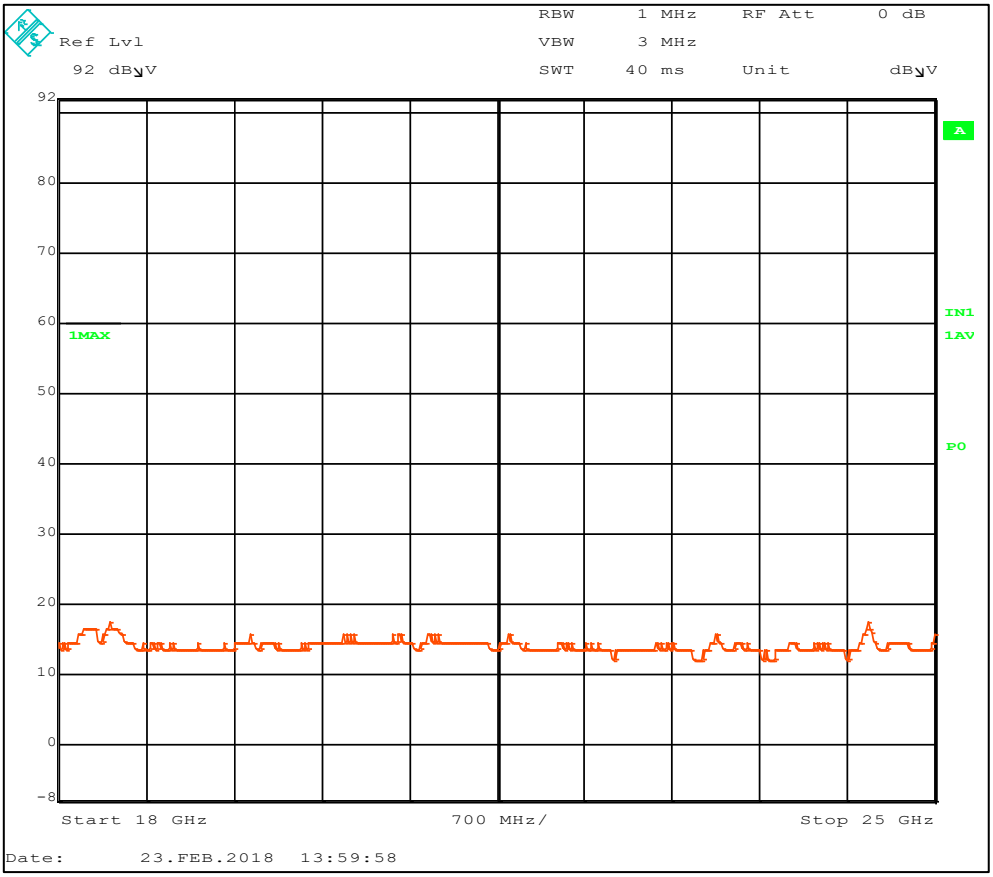

Figure 25. Radiated emission test results 18 - 25 GHz. Average detector.

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 31. 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 32. 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 33. 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 34. 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	Joint JNT002
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 AC/DC adaptor while sending max power with max duty cycle at the middle channel (2449 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 35. Radiated emission limits.

Note *=Decreases with the logarithm of the frequency

2.4.3 Test results

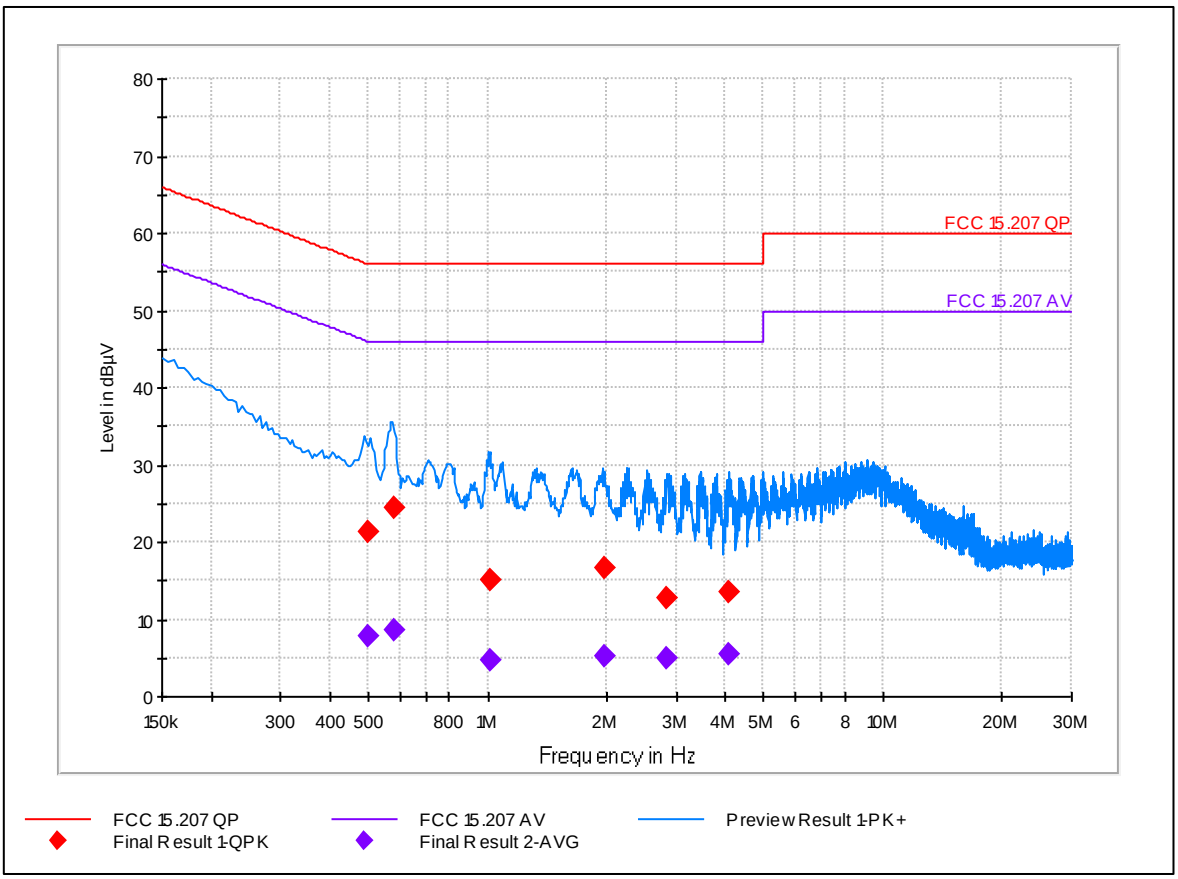

Figure 26. AC Conducted emission.

Frequency [MHz]	QuasiPeak [dBuV]	BW [kHz]	Line	Margin [dB]	Limit [dBuV]	Result
0.498900	21.3	9.000	N	34.70	56.00	PASSED
0.582500	24.4	9.000	N	31.60	56.00	PASSED
1.014700	15.1	9.000	N	40.90	56.00	PASSED
1.967800	16.6	9.000	N	39.40	56.00	PASSED
2.827700	12.6	9.000	N	43.40	56.00	PASSED
4.085200	13.4	9.000	N	42.60	56.00	PASSED

Table 36. AC Conducted emission. Powered by laptop. QuasiPeak detector.

Frequency [MHz]	Average [dBuV]	BW [kHz]	Line	Margin [dB]	Limit [dBuV]	Result
0.498900	7.9	9.000	N	38.10	46.00	PASSED
0.582500	8.6	9.000	N	37.40	46.00	PASSED
1.014700	4.7	9.000	N	41.30	46.00	PASSED
1.967800	5.3	9.000	N	40.70	46.00	PASSED
2.827700	4.9	9.000	N	41.10	46.00	PASSED
4.085200	5.5	9.000	N	40.50	46.00	PASSED

Table 37. 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	2018-09-05

2.5 20 dB bandwidth

Test specimen	Joint JNT002
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

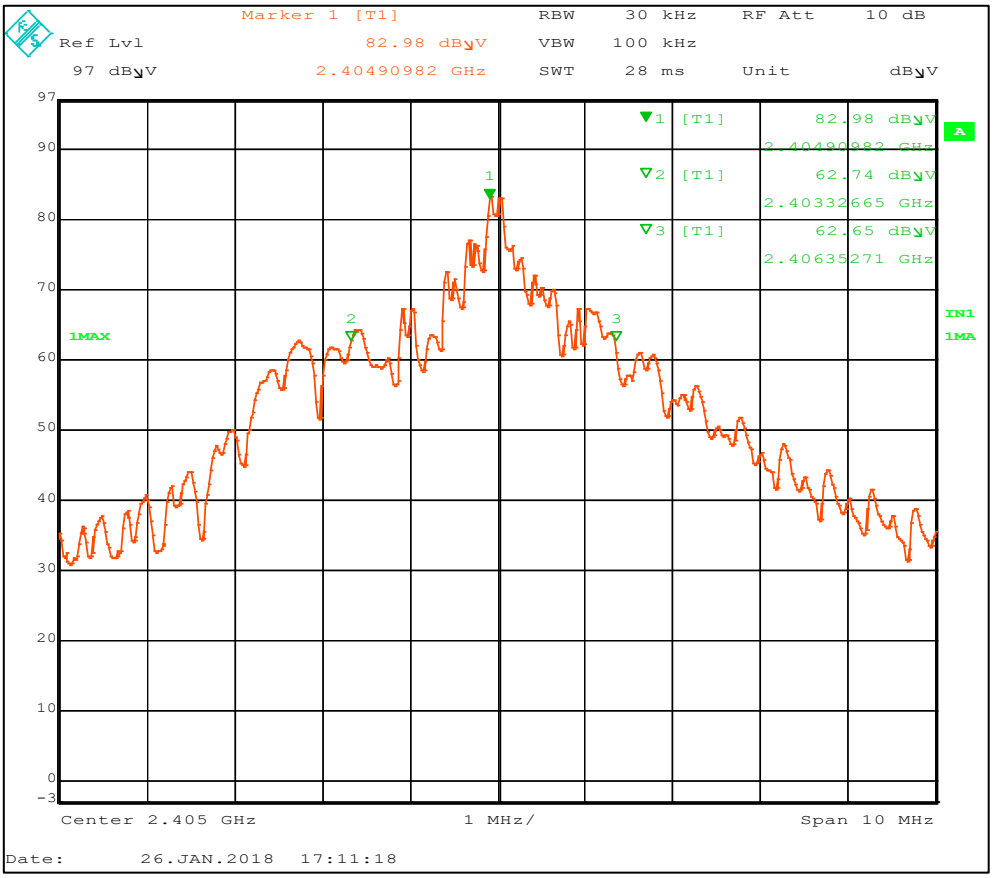

Figure 27. 20 dB bandwidth at 2405 MHz.

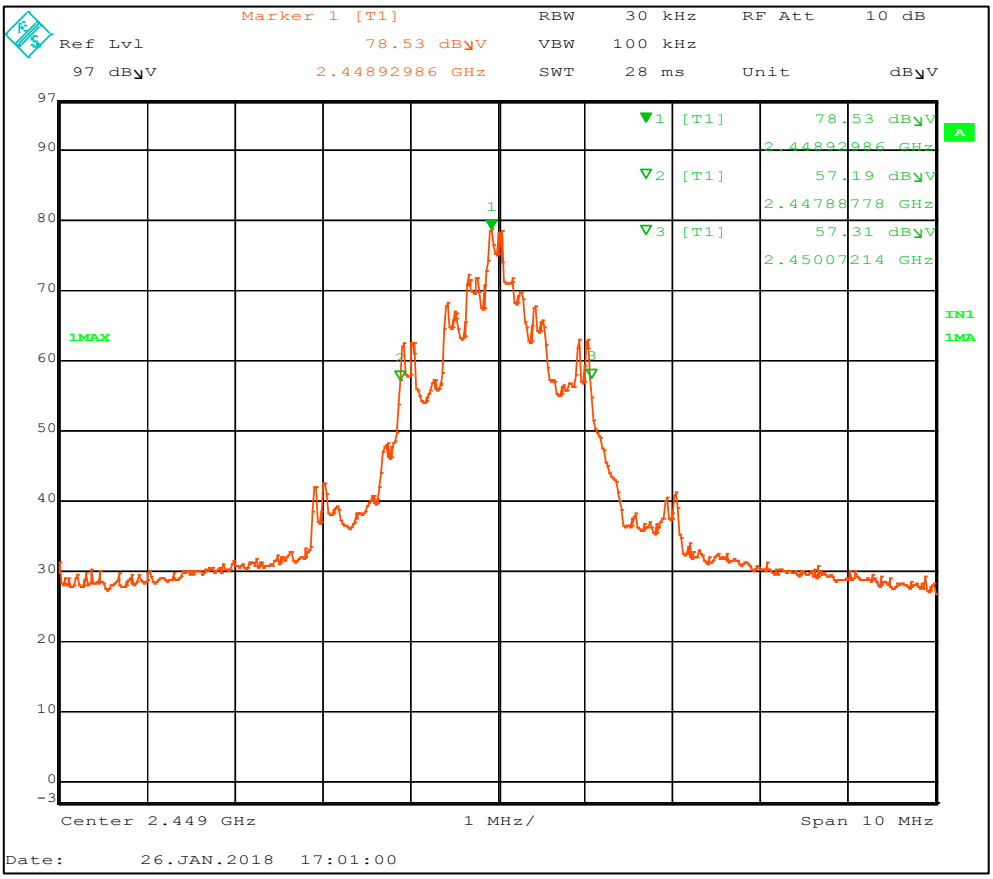

Figure 28. 20 dB bandwidth at 2449 MHz.

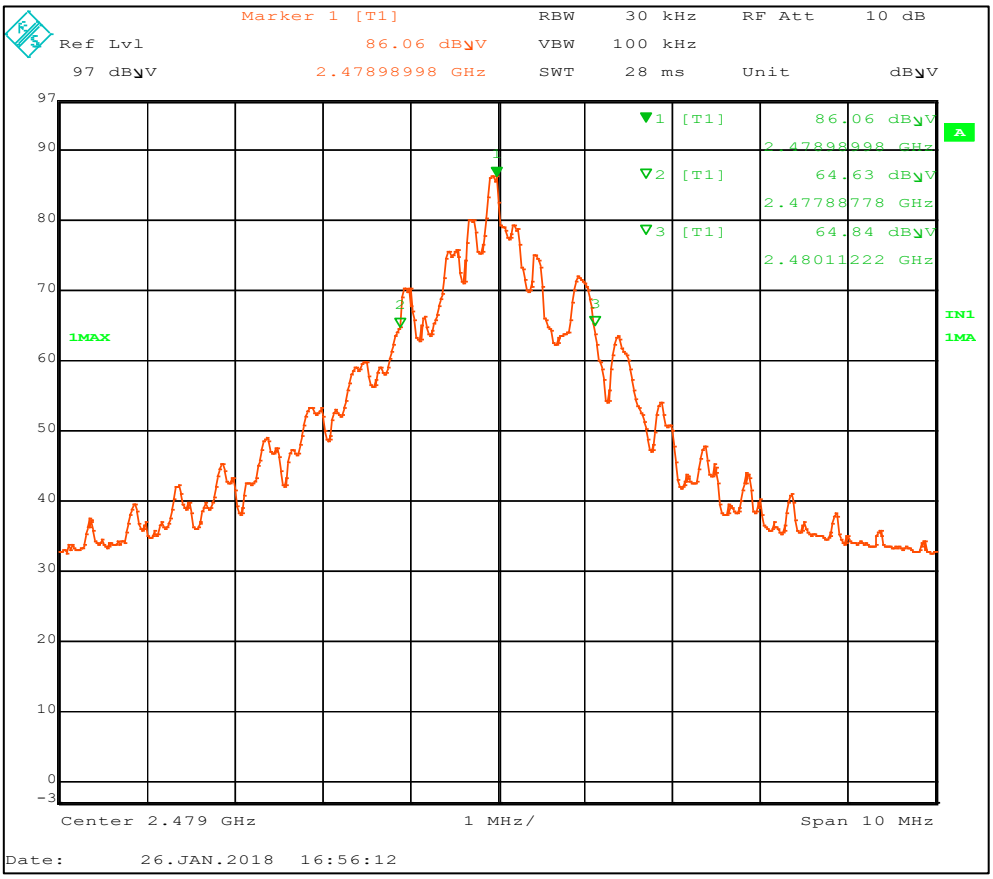

Figure 29. 20 dB bandwidth at 2479 MHz.

Frequency [MHz]	20 dB Bandwidth [MHz]	Result
2405	3.02606	PASSED
2449	2.18436	PASSED
2479	2.22444	PASSED

Table 38. 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	Joint JNT002
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

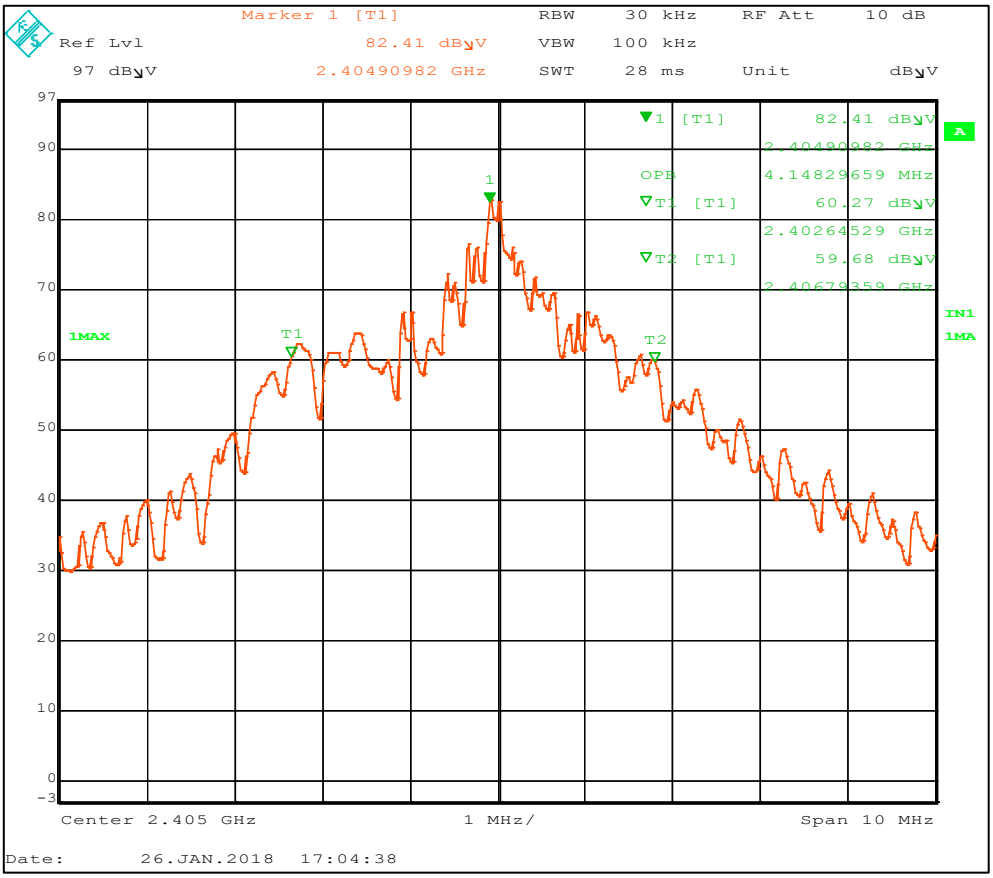

Figure 30. Occupied bandwidth 99% at 2405 MHz.

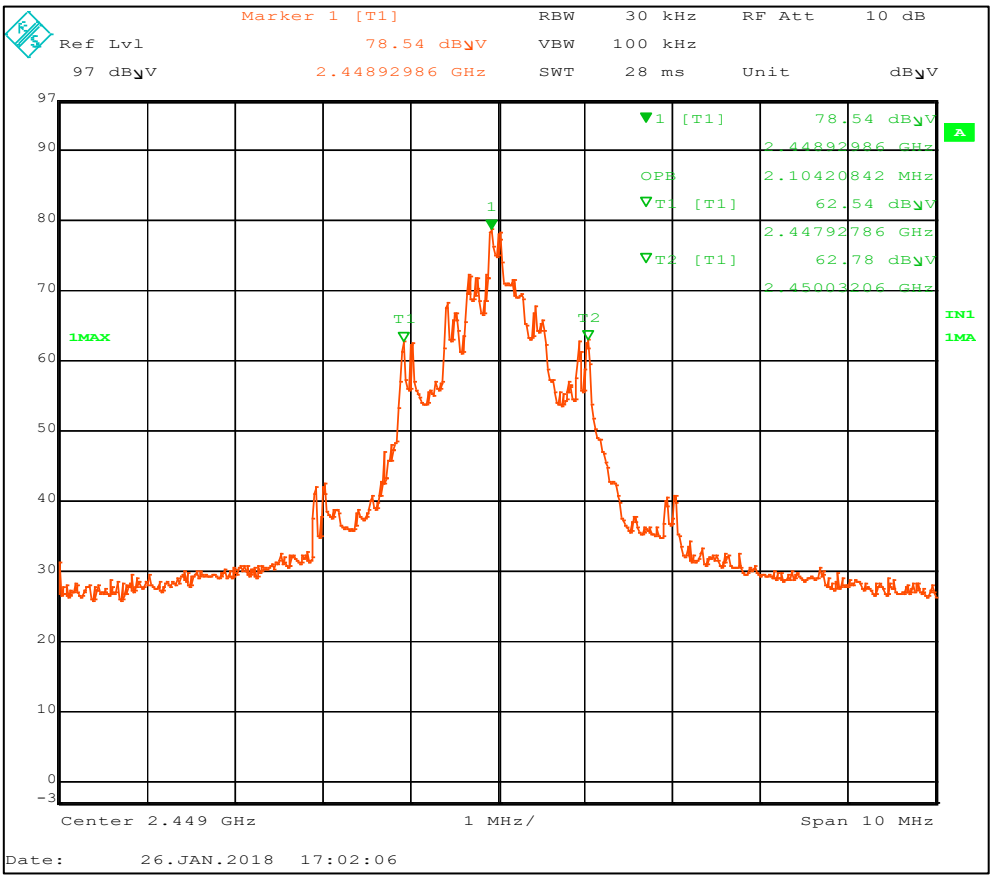

Figure 31. Occupied bandwidth 99% at 2449 MHz.

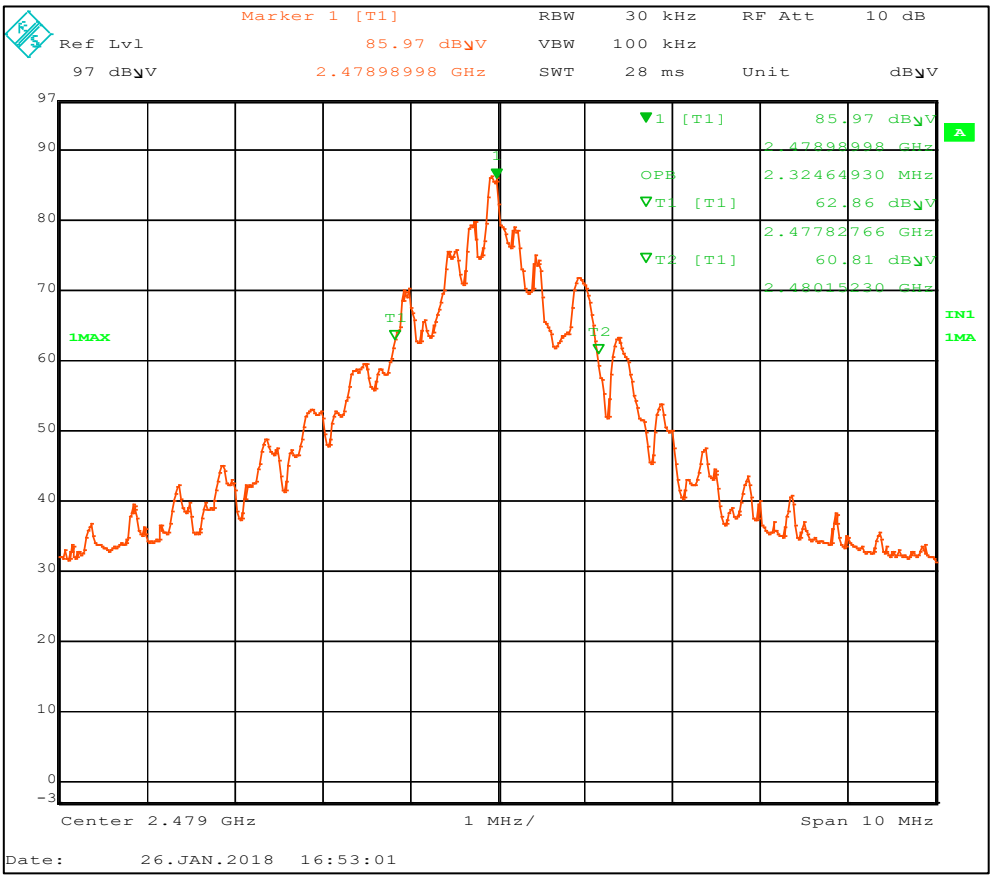

Figure 32. Occupied bandwidth 99% at 2479 MHz.

Frequency [MHz]	Occupied bandwidth 99% [MHz]	Result
2405	4.14829659	PASSED
2449	2.10420842	PASSED
2479	2.32464930	PASSED

Table 39. 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 40. 20 dB bandwidth test equipment.

2.7 Band edge

Test specimen	Joint JNT002
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. 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

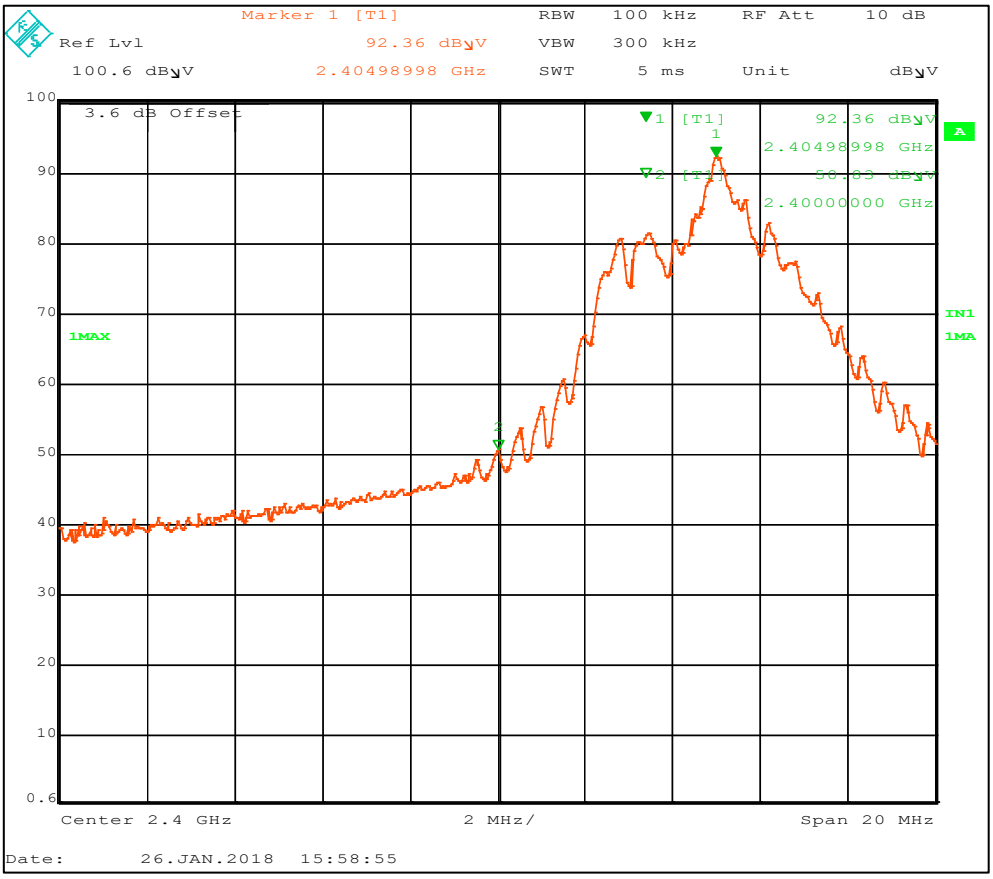

Figure 33. Band Edge Low channel 2405 MHz. Peak detector.

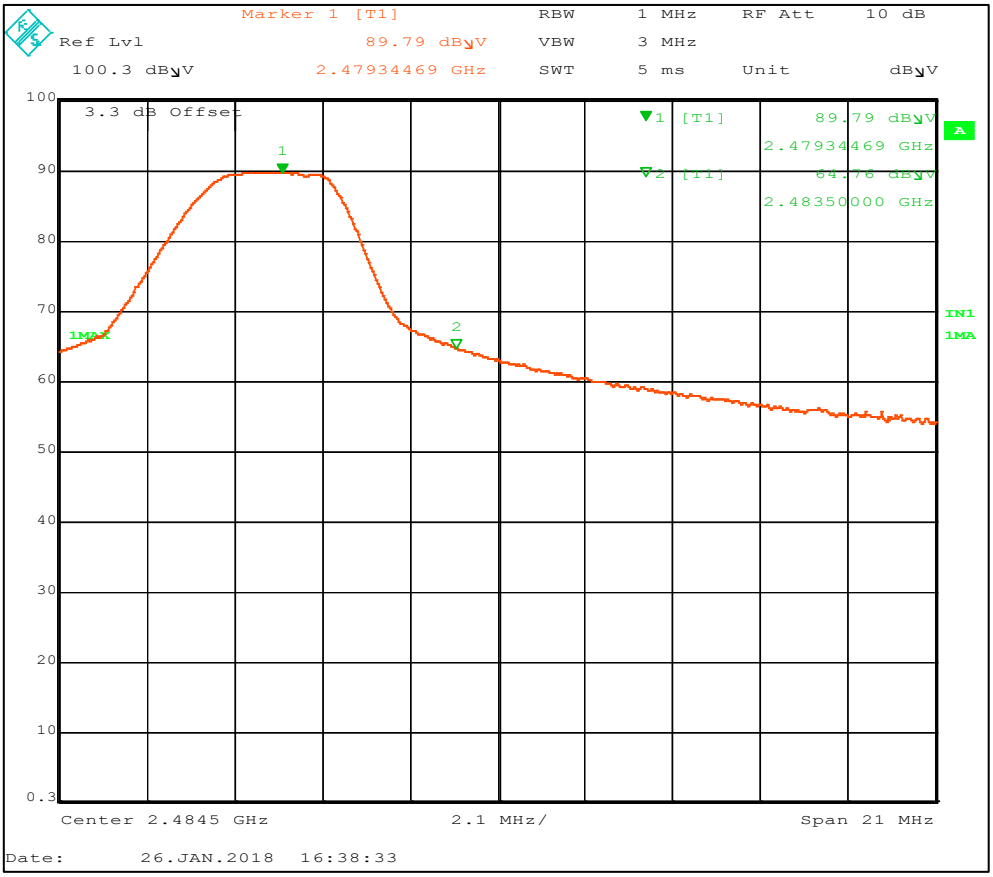

Figure 34. Band Edge High channel 2479 MHz. Peak detector.

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	Peak	50.83	23.17	74	PASSED
2405	Average	24.22	29.78	54	PASSED
2479	Peak	64.76	9.24	74	PASSED
2479	Average	38.15	15.85	54	PASSED

Table 41. 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 42. 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

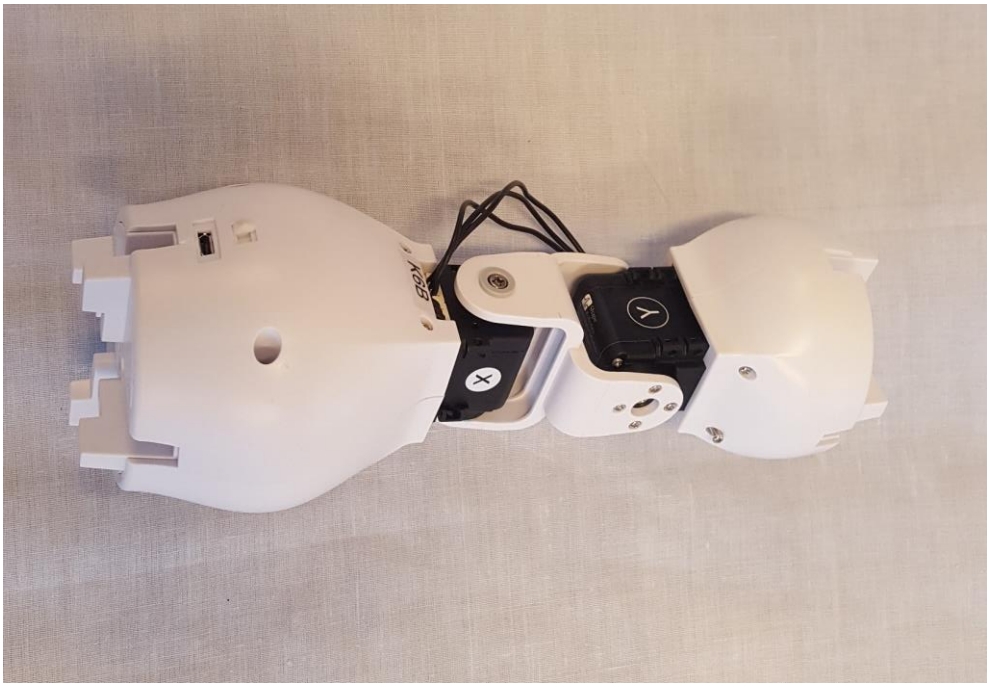

Photo 1. Joint JNT002.

Photo 2. AC/DC adaptor.

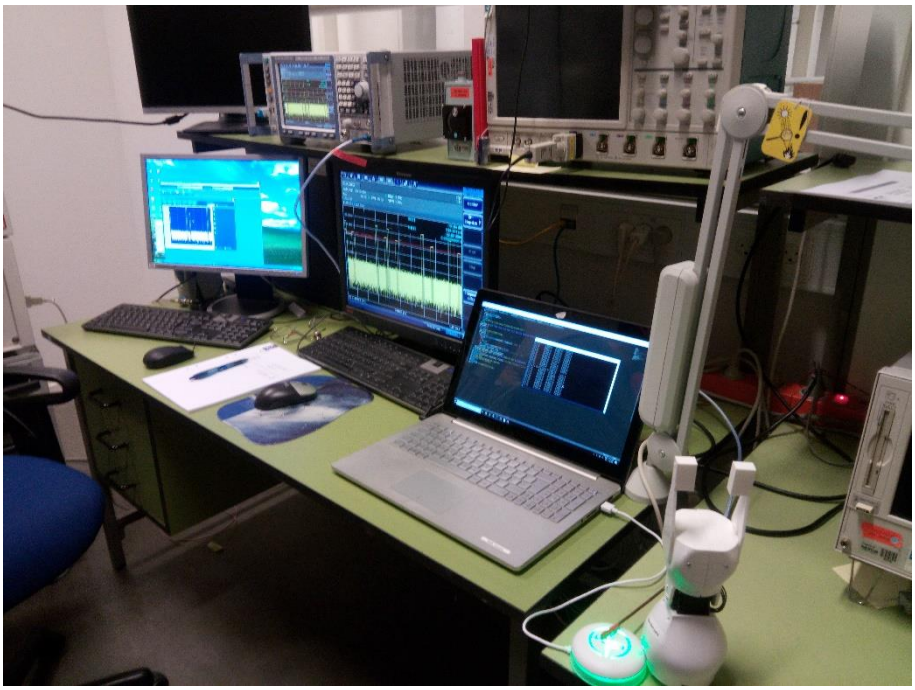

Photo 3. Duty cycle test set up.

Photo 4 - Radiated emission test setup for 30 - 200 MHz.

Photo 5 - Radiated emission test setup for 200 - 1000 MHz.

Photo 6 - Radiated emission test setup for 1 – 14 GHz.

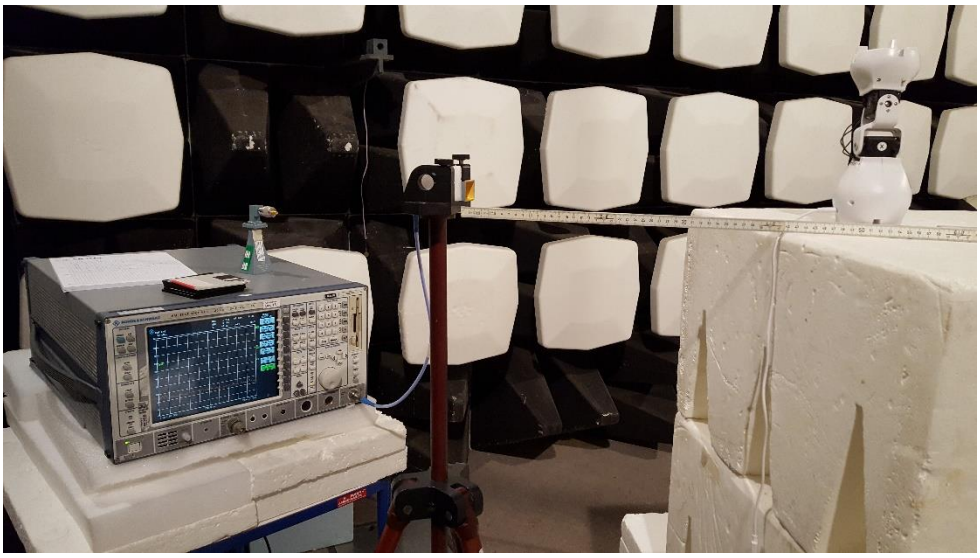

Photo 7. Radiated emission test setup for 14 – 25 GHz. With ruler indicating distance.

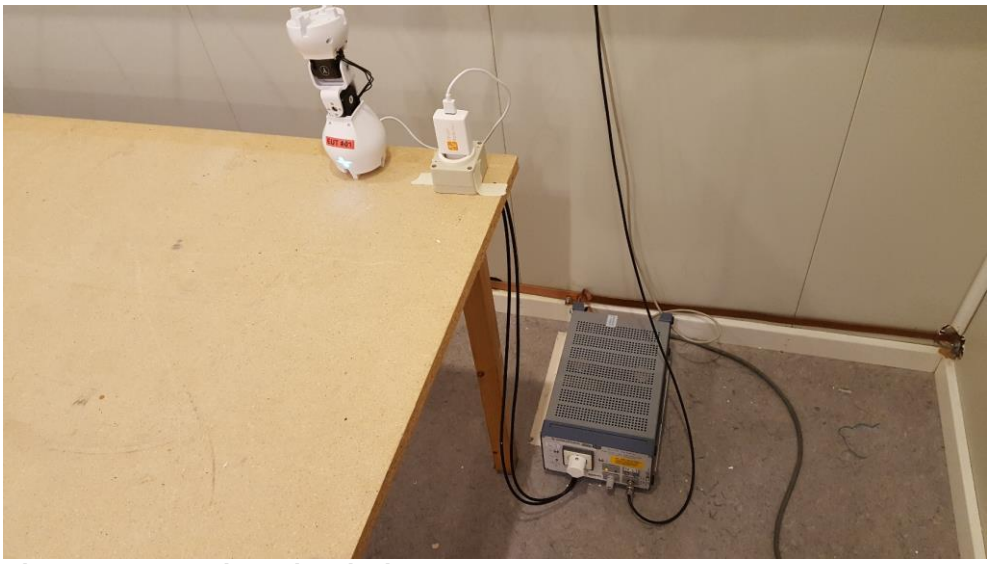

Photo 8. AC Conducted emission test set up.

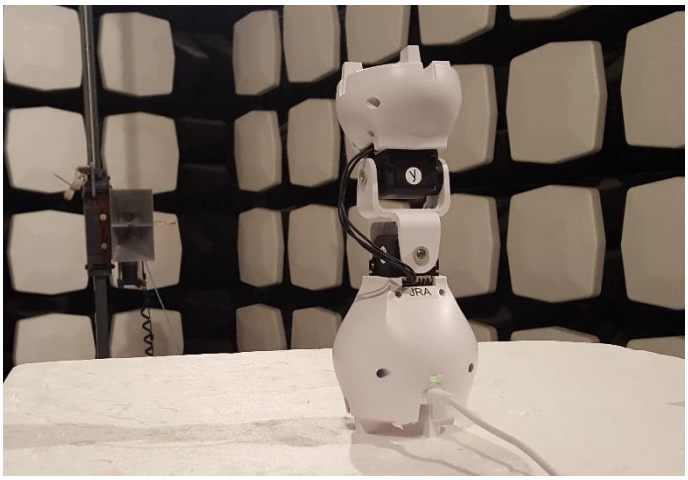

Photo 9. Vertical orientation

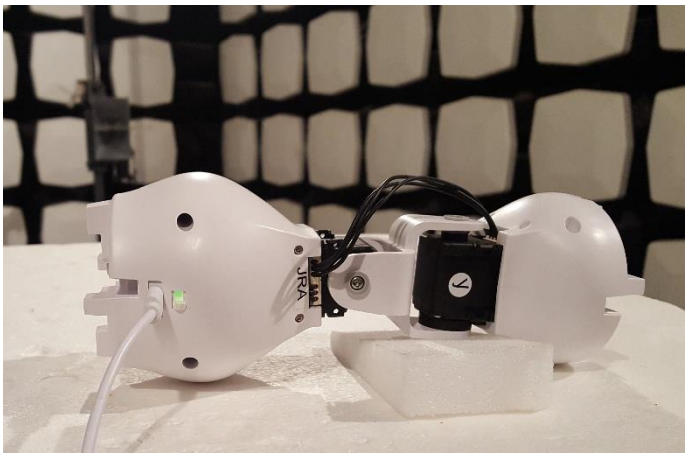

Photo 10. Vertical – 90 deg. orientation

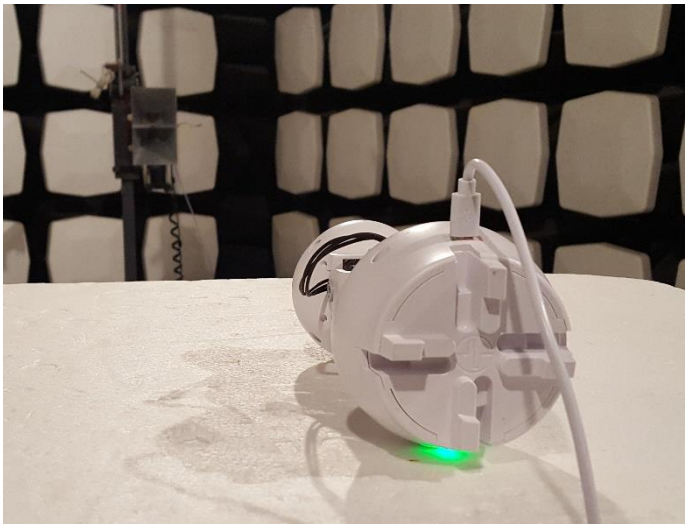

Photo 11. Horizontal orientation.