



Report No. 343081-01

FCC TEST REPORT / IC TEST REPORT

Product	Duplo Train / Bluetooth Low Energy (BLE) module		
Name and address of the applicant	Lego System A/S Aastvej 1, Billund, Denmark		
Name and address of the manufacturer	Lego System A/S Aastvej 1, Billund, Denmark		
Model	HUB NO.5		
Rating	6.0 Vdc		
Trademark	LEGO		
Serial number	/		
Additional information	2.4GHz, Bluetooth Low Energy (BLE).		
Tested according to	FCC Part 15.247 Frequency Hopping Transmitters / Digital Transmission Systems Industry Canada RSS-247, Issue 2 Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices		
Report number	343081-01		
Tested in period	2018-04-06 – 2018-04-18		
Issue date	2018-04-19		
Name and address of the testing laboratory	Nemko GmbH & Co. KG Reetzstraße 58 D-76327 Pfinztal Tel.: + 49 (0) 7240 – 63 - 0 Fax: + 49 (0) 7240 – 63 - 11	 Bundesnetzagentur BNetzA-CAB-17/21-17	FCC No: 973501 IC OATS: 10921A-1
 Prepared by [Dipl.-Ing. M. Korný]  Approved by [J. Stephansen]			

Template version: B

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1 INFORMATION

1.1 Test Item

Name :	LEGO DUPLO Train
FCC ID :	NPI28743
Industry Canada ID :	3072A-28743
Model/version :	HUB NO.5
Serial number :	/
Hardware identity and/or version:	-
Software identity and/or version :	-
Frequency Range :	2402 - 2480MHz
Tunable Bands :	None
Number of Channels :	40
Operating Modes :	Transceiver
Type of Modulation :	GFSK, 250kHz deviation
User Frequency Adjustment :	None
Output Power Radiated:	-1.2 dBm (e.i.r.p.)
Type of Power Supply :	6.0 Vdc (4 x AAA batteries)
Antenna Connector :	None (PCB antenna)
Antenna Diversity Supported :	No
Desktop Charger :	No

Description of Test Item

The devices tested are a system with a central HUB, which contains the radio functionality and 1 motor. The system can function independently or can be controlled by a remote device (iOS, Android or similar) running a dedicated App which is connected to the central HUB using BLE.

Theory of Operation

The module follows the Bluetooth low energy specification 4-0, operating in the 2.4GHz band

1.2 Normal test conditions

Temperature: 20 - 26 °C
Relative humidity: 45 - 55 %
Normal test voltage: 6.0 V dc(4 x 1.5 Vdc AAA batteries)

The values are the limit registered during the test period. All tests were performed with fully charged batteries.

1.3 Test Engineer(s)

Markus Korny

1.4 Description of modification for Modification Filing

Not applicable.

1.5 Family List Rational

Not Applicable.

1.6 Antenna Requirement

Is the antenna detachable?

☐ Yes ☒ No

If detachable, is the antenna connector non-standard?

☐ Yes ☐ No

Type of antenna connector: N/A

Ref. FCC §15.203

1.7 Worst-Case Configuration and Mode

Radiated Emissions was performed with the EUT set to transmit at the channel with the highest output power as worst-case scenario.

1.8 Comments

The output level is set to maximum in the software.

The radiated measurements are tested on three axes.

Four fully charged primary batteries are used.

All ports were populated during spurious emission measurements.

2 TEST REPORT SUMMARY

2.1 General

All measurements are traceable to national standards.

The tests were conducted for the purpose of demonstrating compliance with FCC CFR 47 Part 15, paragraph 15.247 and Industry Canada RSS-247 Issue 2.

Tests were performed in accordance with ANSI C63.4-2014 and ANSI C63.10-2013.

Radiated tests were performed in a semi-anechoic shielded room ($f < 1$ GHz) and a fully-anechoic shielded room ($f > 1$ GHz) at a measuring distance of 3m.

A description of the test facility is on file with the FCC and Industry Canada.

☒ New Submission

☒ Production Unit

☐ Class II Permissive Change

☐ Pre-production Unit

DTS Equipment Code

☐ Family Listing



THIS TEST REPORT APPLIES ONLY TO THE ITEM(S) AND CONFIGURATIONS TESTED.

Deviations from, additions to, or exclusions from the test specifications are described in "Summary of Test Data".

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2.2 Test Summary

Name of test	FCC Part 15 reference	RSS-247 Issue 2, RSS-GEN Issue 4 reference	Result
Supply Voltage Variations	15.31(e)	6.11 (RSS-GEN)	N/A ²
Number of Operating Frequencies	15.31(m)	5.1 (6) (RSS-247)	N/A
Antenna Requirement	15.203	8.3 (RSS-GEN)	Complies ¹
Power Line Conducted Emission	15.107(a) 15.207(a)	8.8 (RSS-GEN)	N/A ²
Channel Separation	15.247(a)(1)	5.1 (4) (RSS-247)	N/A
Pseudorandom Hopping Algorithm	15.247(a)(1)	5.1 (3) (RSS-247)	N/A
Time of Occupancy	15.247(a)(1)(iii)	5.1 (5) (RSS-247)	N/A
Occupied Bandwidth	15.247(a)(1)	5.1 (7) (RSS-247)	N/A
Occupied Bandwidth / 99% OCC-BW	N/A	6.6 (RSS-GEN)	-
Minimum 6 dB Bandwidth	15.247(a)(2)	5.2 (1) (RSS-247)	Complies
Peak Power Output	15.247(b)	5.4 (RSS-247)	Complies
Power Spectral Density	15.247(d)	5.2 (2) (RSS-247)	Complies
Spurious Emissions (Antenna Conducted)	15.247(c)	5.5 (RSS-247)	Complies ¹
Spurious Emissions (Radiated)	15.247(c) 15.109(a) 15.209(a)	5.5 (RSS-247) 6.13 (RSS-GEN) 8.9 (RSS-GEN)	Complies

¹ The tested equipment has integrated antennas only

² EUT is battery powered

- Only for information

3 TEST RESULTS

3.1 99 % Occupied Bandwidth

Para. No.: 6.6 RSS-Gen

Test Performed By: Markus Korny

Date of Test: 2018-04-06

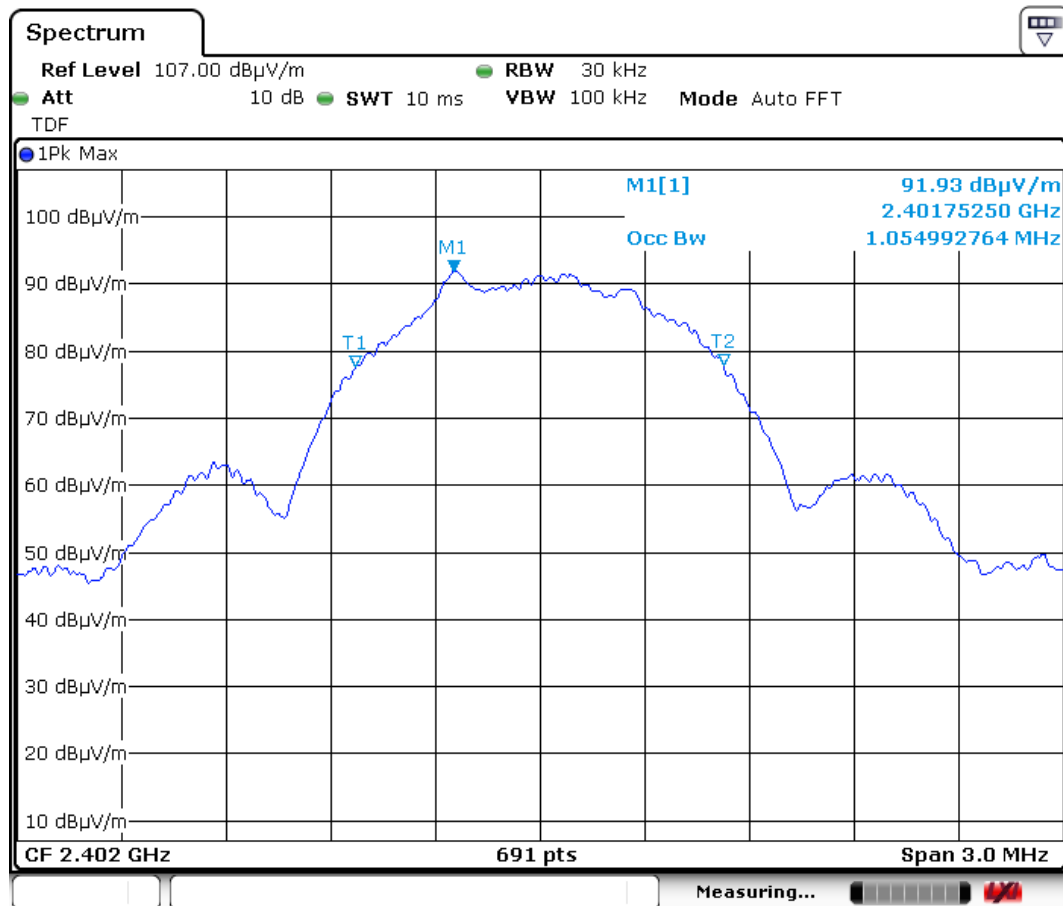
Test Results: Complies

Measurement Data:

99 % (kHz)
2402 MHz
1055

Requirements:

For information only



Date: 6.APR.2018 14:42:53

2402 MHz – 99% OCC BW

3.3 Minimum 6 dB Bandwidth

Para. No.: 15.247 (a)(2)

Test Performed By: Markus Korny

Date of Test: 2018-04-11

Test Results: Complies

Measurement Data:

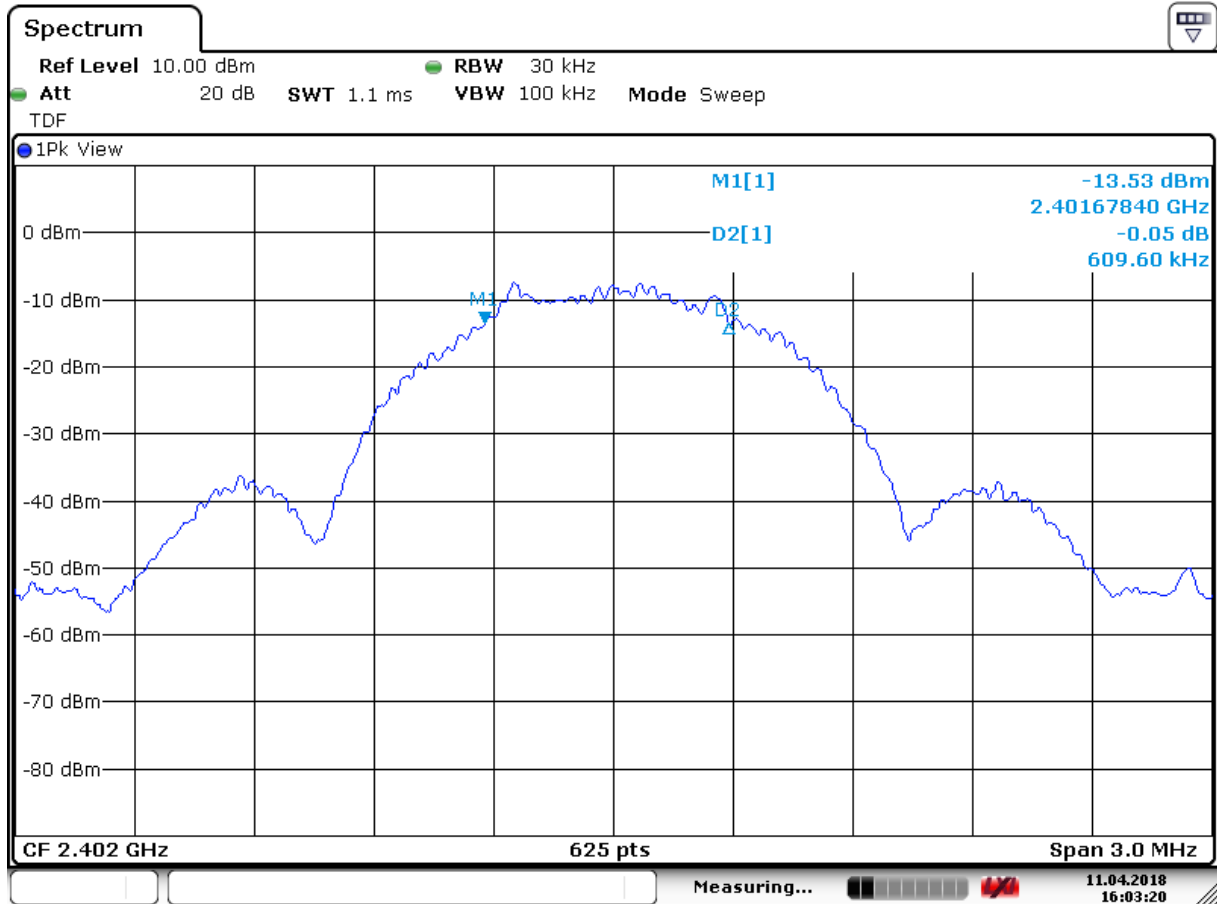
Measured 6 dB Bandwidth (kHz)		
2402 MHz, Ch 0	2440 MHz, Ch 19	2480 MHz, Ch 39
609.6	648.0	652.8

Fully charged battery is used

Requirements:

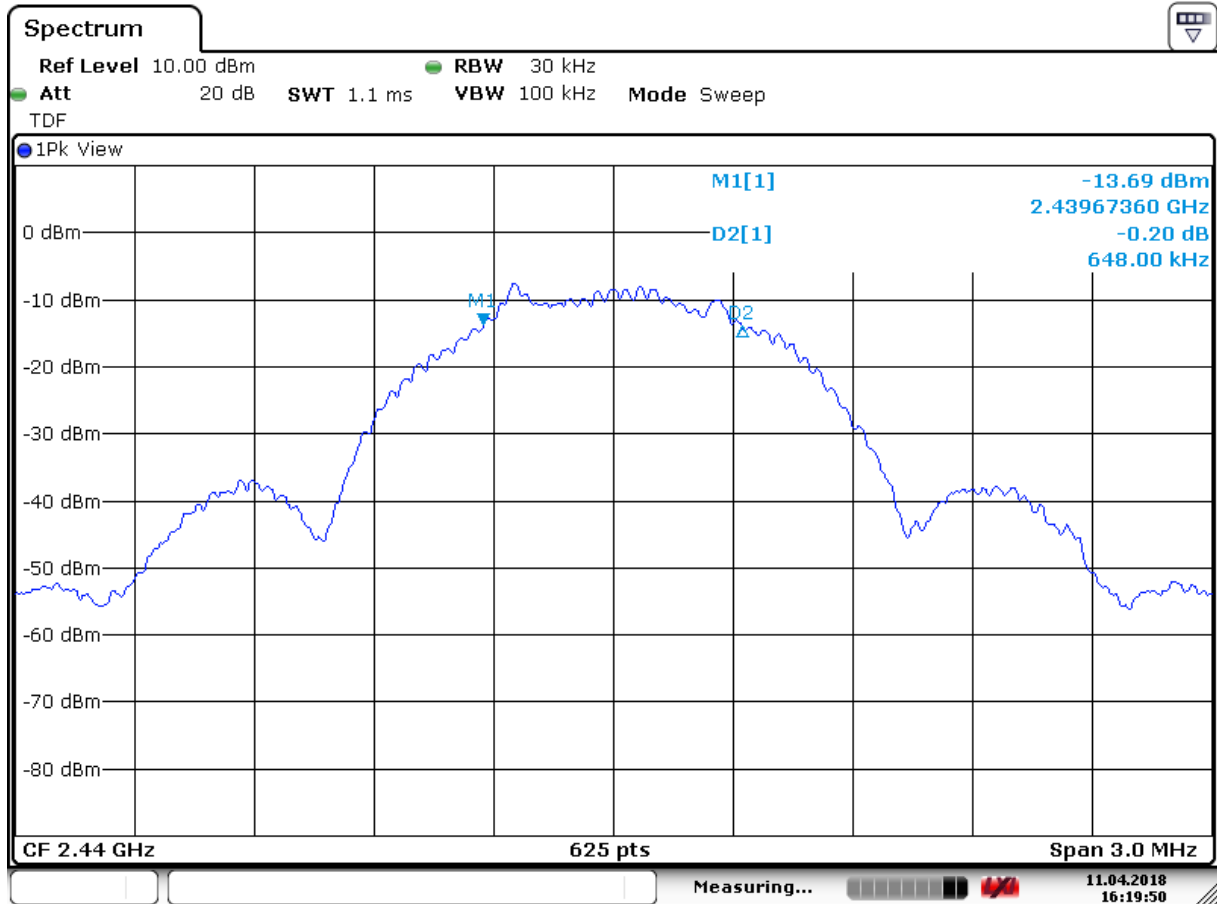
For Digital Transmission Systems in the 2400-2483.5 MHz band the minimum 6 dB bandwidth shall be at least 500 KHz.

No requirements for Frequency Hopping Systems.



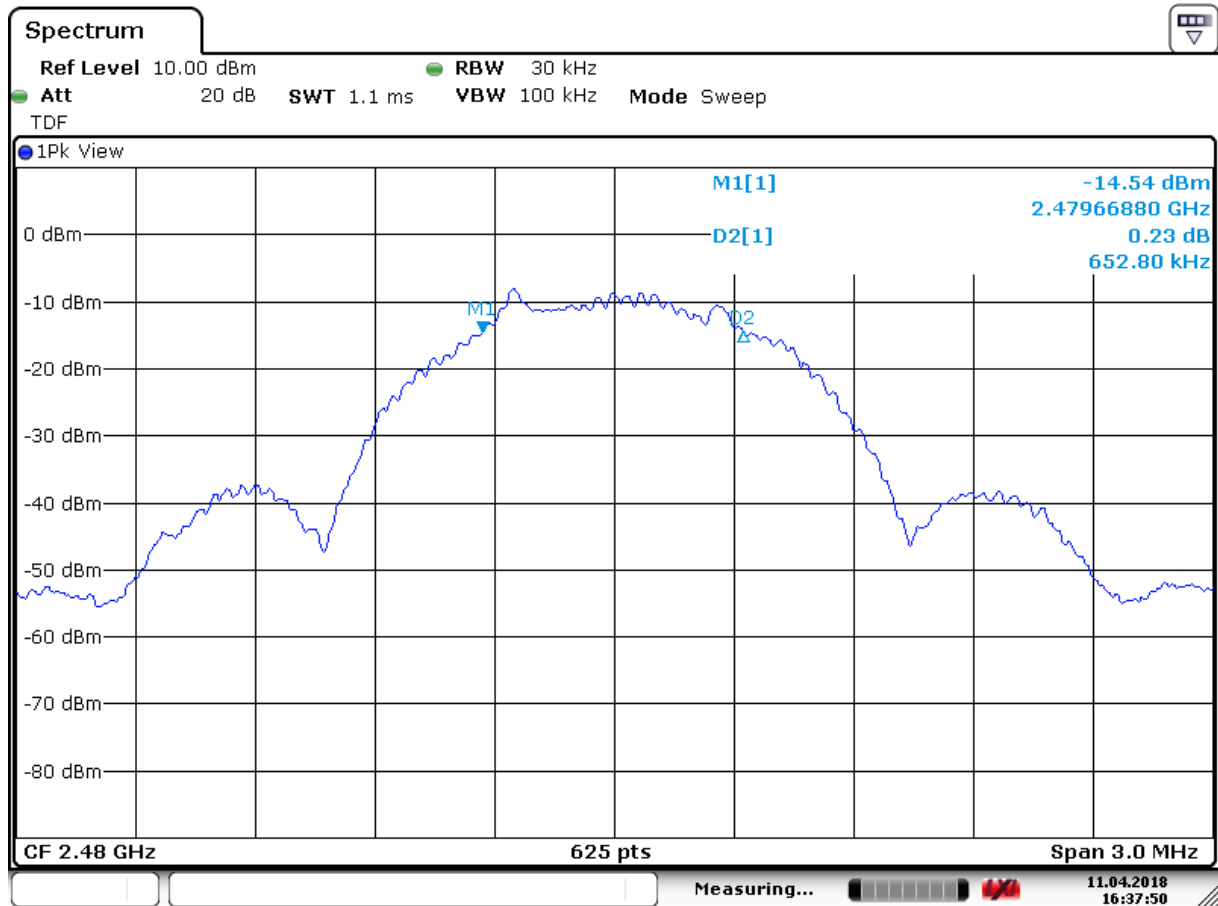
Date: 11.APR.2018 16:03:21

Ch2402MHz, 6 dB BW



Date: 11.APR.2018 16:19:51

Ch2440MHz, 6 dB BW



Date: 11.APR.2018 16:37:51

Ch2480MHz, 6 dB BW

3.4 Peak Power Output

Para. No.: 15.247 (b)

Test Performed By: Markus Korny	Date of Test: 2018-04-06 to 2018-04-11
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Test Results: Complies

Measurement Data:

RF channel	2402 MHz	2440 MHz	2480 MHz
Measured Maxium Field strength (dBμV/m) – HP	94.03	94.02	93.29
Calc. Radiated Power (dBm)	-1.20	-1.21	-1.94
Calc. Radiated Power (mW)	0.76	0.76	0.64
Measured Conducted Power (dBm)	-4.79	-5.37	-5.93
Measured Conducted Power (mW)	0.33	0.29	0.26
Calculated Antenna Gain (dBi)	3.6	4.2	4.0

Antenna gain = $10 \cdot \log(\text{EIRP} / \text{Conducted power})$ dBi

EIRP is calculated from measured field strength by the formulas in KDB 412172 D01 Determining ERP and EIRP v01.

The maximum field strength is obtained in XY plane and Vertical polarization

See attached graph.

Detachable antenna?

☐ Yes

☒ No

If detachable, is the antenna connector non-standard?

☐ Yes

☐ No

Type of antenna connector: N/A

Requirements:

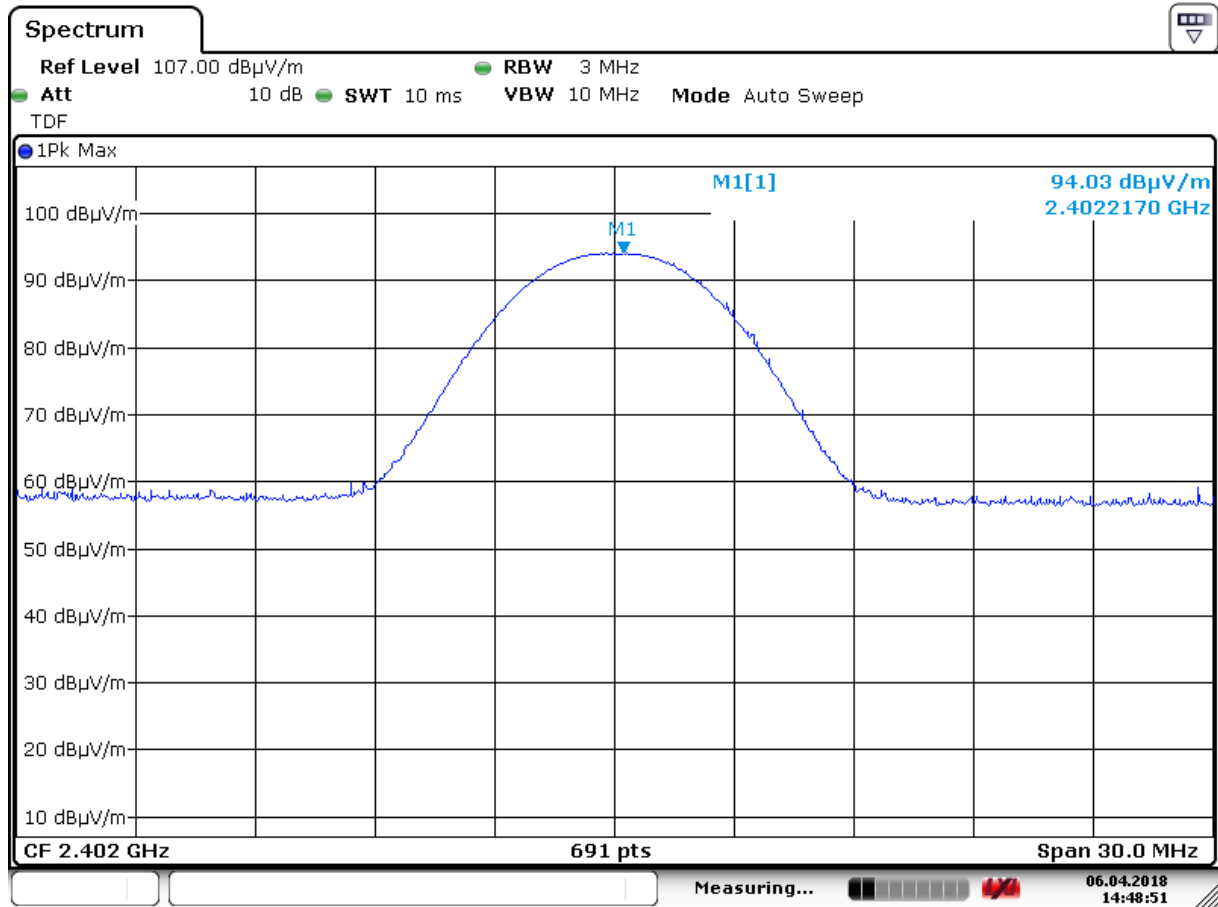
The maximum peak output power shall not exceed the following limits:

For frequency hopping systems employing at least 75 hopping channels: 1 Watt

For all other frequency hopping systems in the 2400 - 2483.5 MHz band: 0.125 Watts

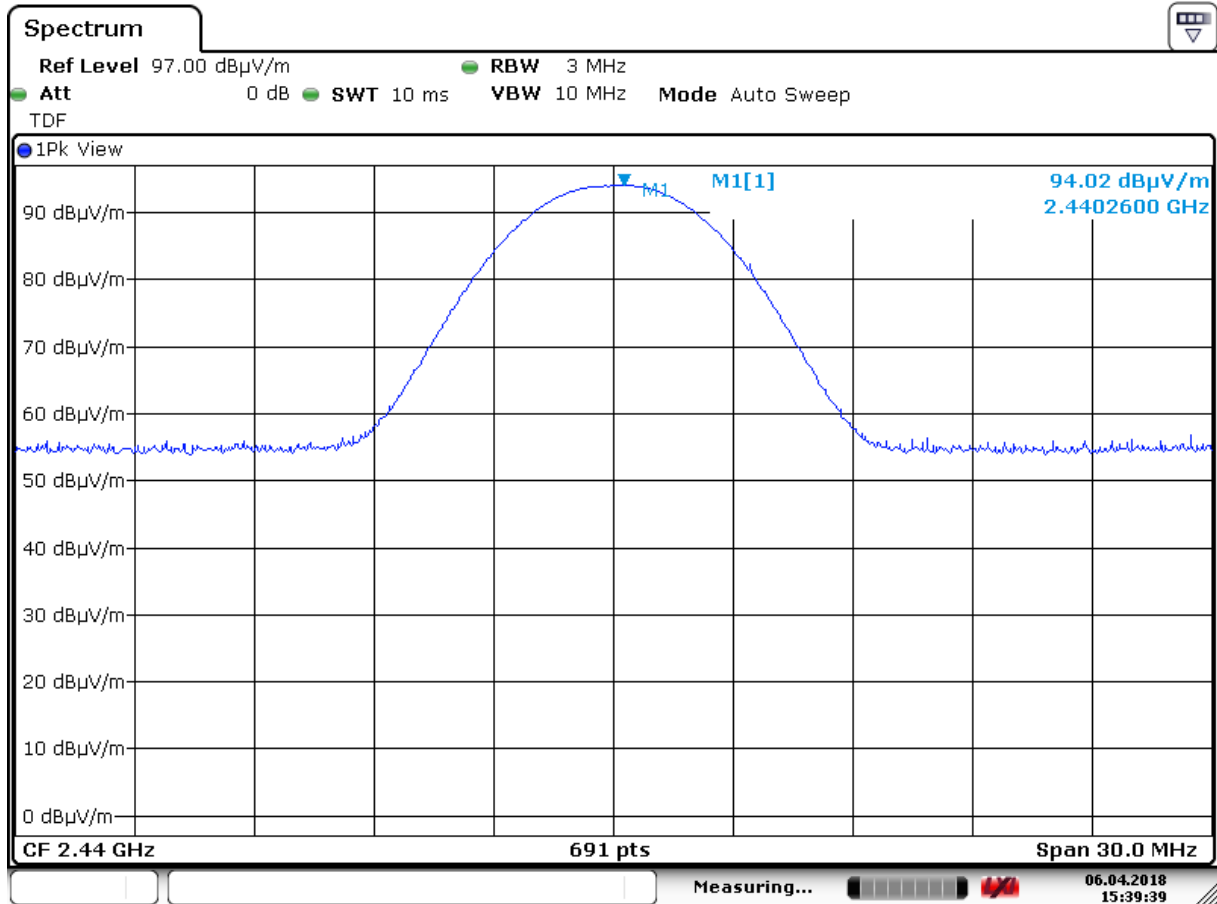
For Digital Transmission Systems in the 2400 - 2483.5 MHz band: 1 Watt

If transmitting antennas of directional gain greater than 6 dBi are used, the peak output power from the intentional radiator shall be reduced below the stated value above by the amount in dB that the directional gain of the antenna exceeds 6 dBi.



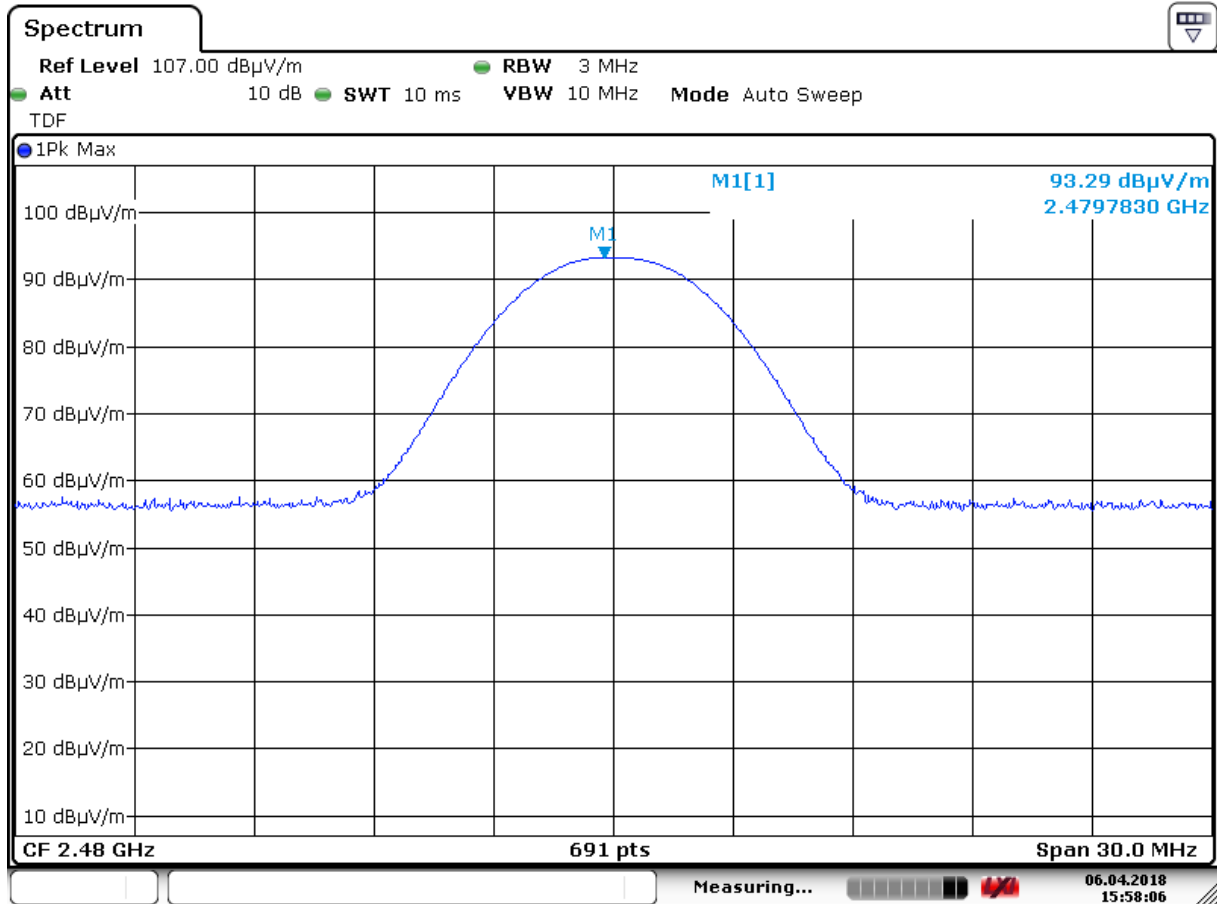
Date: 6.APR.2018 14:48:52

Radiated field strength, HP, 2402 MHz



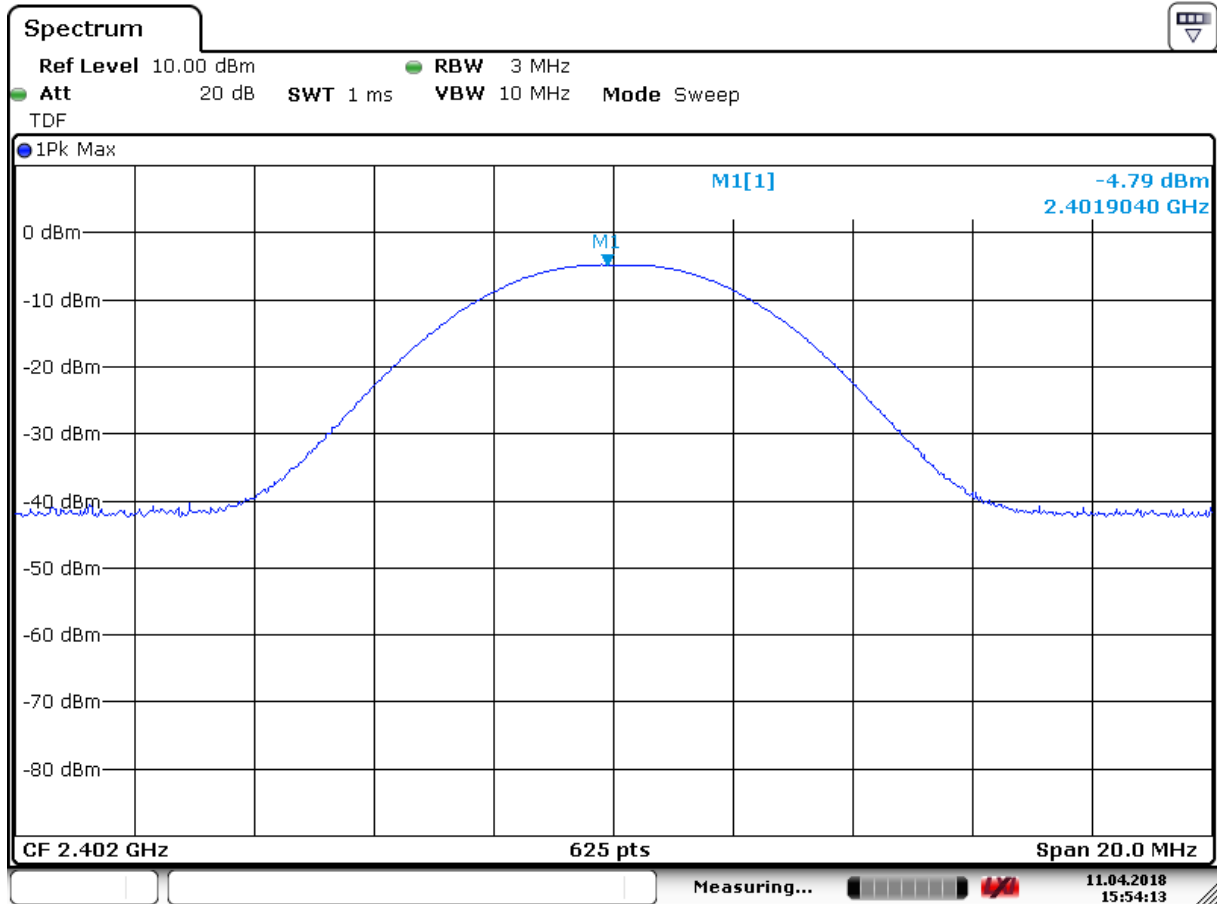
Date: 6.APR.2018 15:39:40

Radiated field strength, HP, 2440 MHz



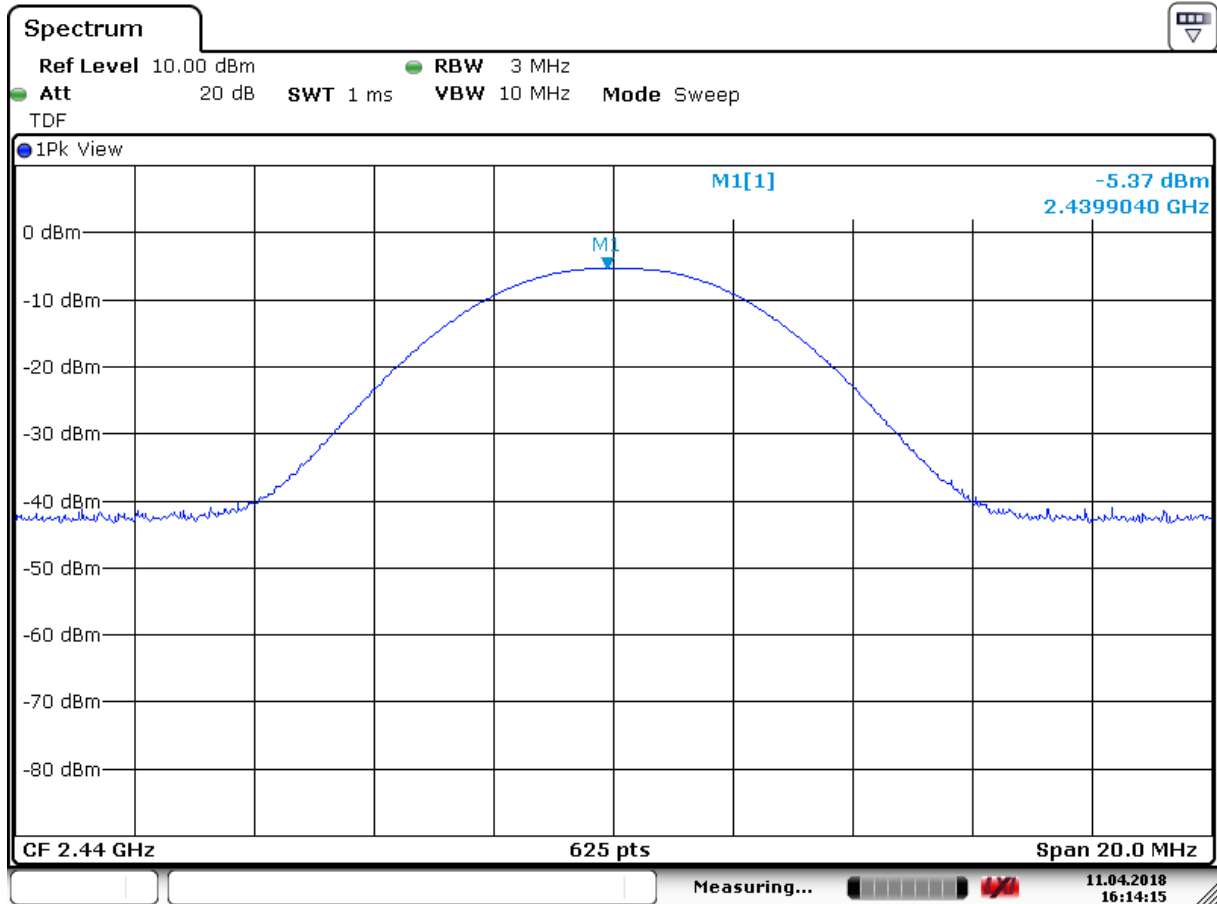
Date: 6.APR.2018 15:58:07

Radiated field strength, HP, 2480 MHz



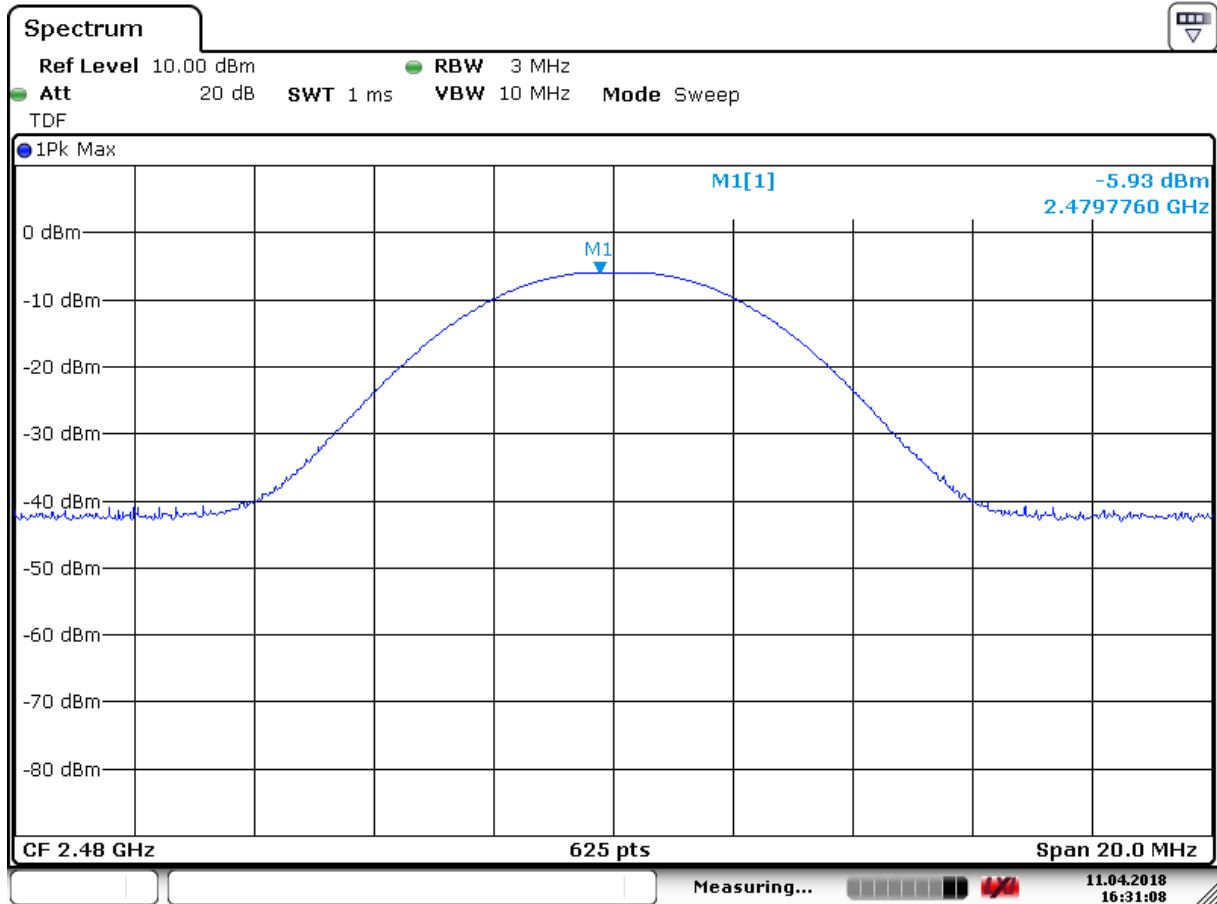
Date: 11.APR.2018 15:54:13

Conducted power – 2402MHz



Date: 11.APR.2018 16:14:16

Conducted power – 2440MHz



Date: 11.APR.2018 16:31:09

Conducted power – 2480MHz

3.5 Conducted Emissions at Antenna Connector

Para. No.: 15.247 (d)

RF conducted power to 25 GHz see attached plots.

Maximum RF level outside operating band:

RF ch 2402MHz: 37 dB/C, margin >10 dB

RF ch 2440MHz: 35 dB/C, margin >10 dB

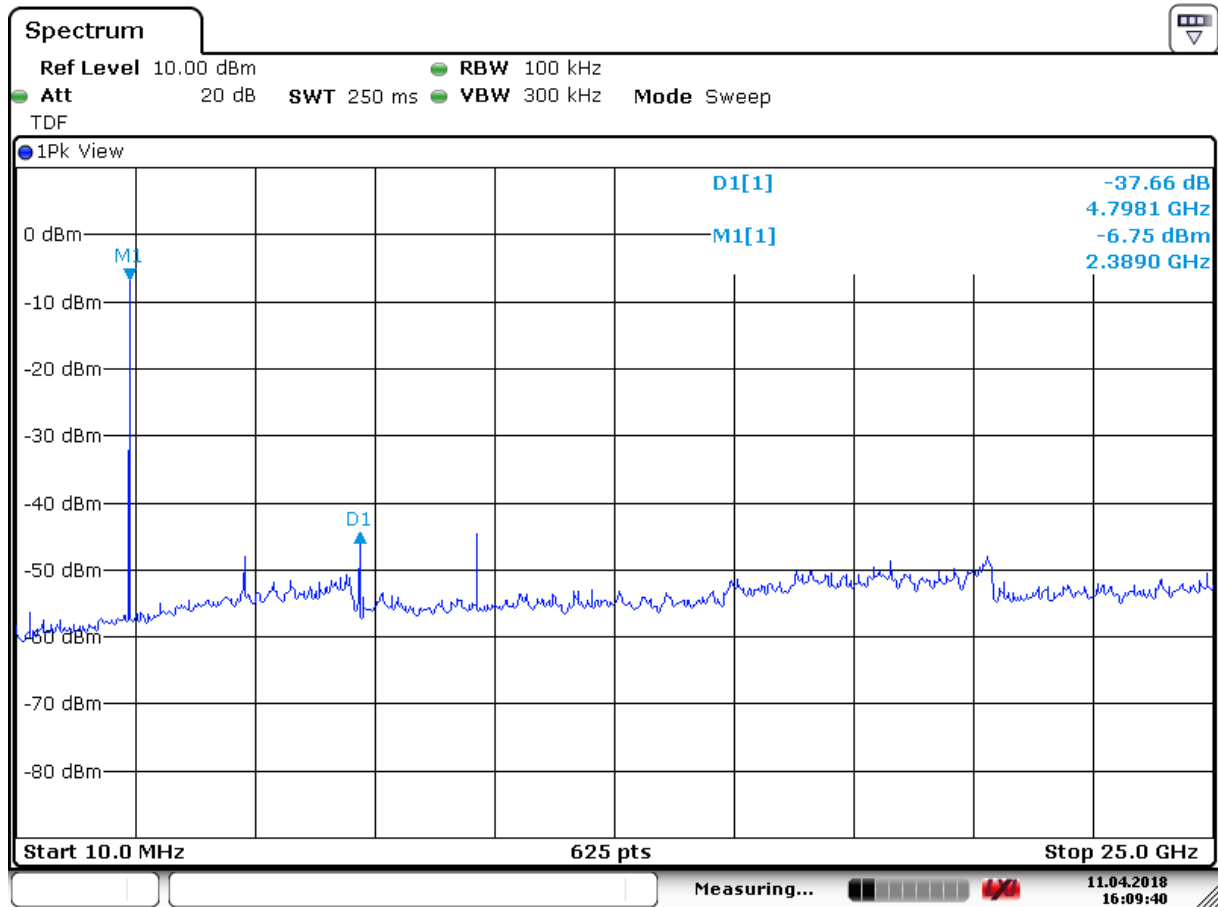
RF ch 2480MHz: 35 dB/C, margin >10 dB

Limit

Peak measurement	RMS averaging
20 dBc or more in 100 kHz bandwidth	30 dBc or more in 100 kHz bandwidth

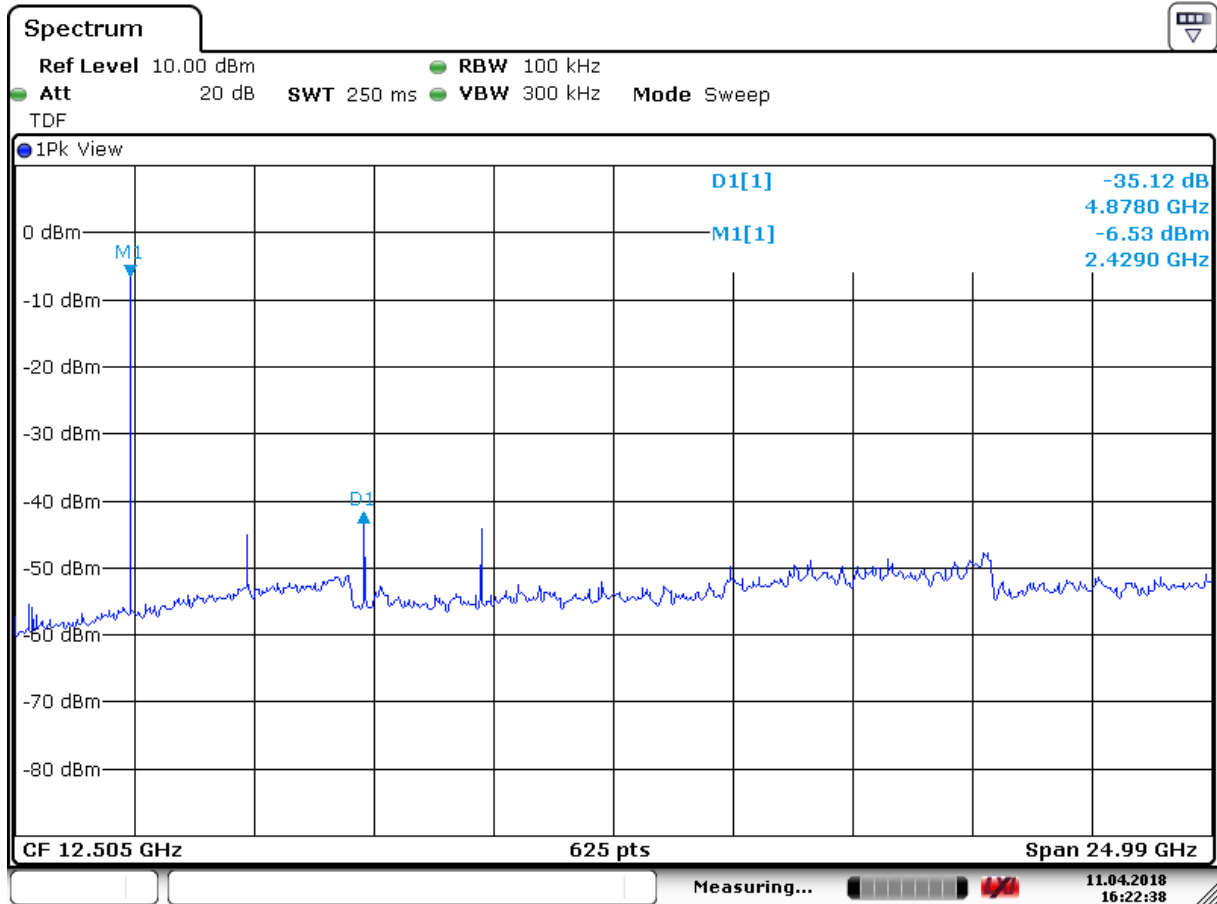
Detector type shall be the same as used for measuring Output Power.

Attenuation below the general limits specified in part 15.209(a) is not required.



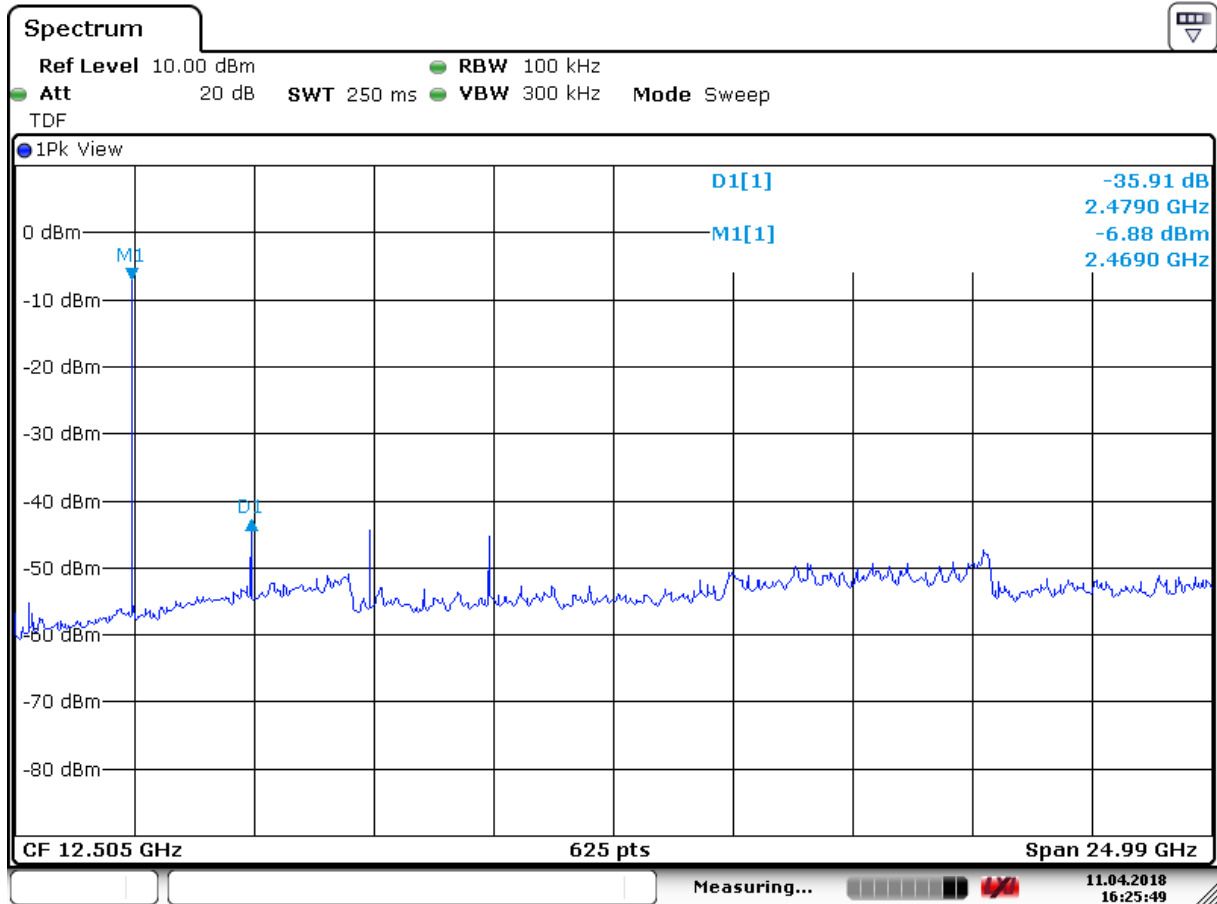
Date: 11.APR.2018 16:09:41

Conducted spurious emission 10MHz – 25GHz - ch2402MHz



Date: 11.APR.2018 16:22:39

Conducted spurious emission 10MHz – 25GHz - ch2440MHz



Date: 11.APR.2018 16:25:49

Conducted spurious emission 10MHz – 25GHz - ch2480MHz

3.6 Restricted Bands of operation

Restricted Bands of operation for FCC and ISSED are defined in FCC Part 15.205 and ISSED RSS-GEN, Issue 4 clause 8.10.

Generally, no fundamentals are allowed in the restricted bands and all emissions must comply with the limits in FCC 15.209 or RSS-GEN, Issue 4, clause 8.9.

FCC (MHz)	ISED (MHz)	FCC (GHz)	ISED (GHz)
0.090-0.110		0.96-1.24 1.3-1.427	0.96-1.427
0.495-0.505		1.435-1.6265	
2.1735-2.1905		1.6455-1.6465	
	3.020-3.026	1.660-1.710	
4.125-4.128		1.7188-1.7222	
4.17725-4.17775		2.2-2.3	
4.20725-4.20775		2.31-2.39	
	5.677-5.683	2.4835-2.5	
6.215-6.218		2.69-2.9	2.655-2.9
6.26775-6.26825		3.26-3.267	
6.31175-6.31225		3.332-3.339	
8.291-8.294		3.3458-3.358	
8.362-8.366		3.6-4.4	3.5-4.4
8.37625-8.38675		4.5-5.15	
8.41425-8.41475		5.35-5.46	
12.29-12.293		7.25-7.75	
12.51975-12.52025		8.025-8.5	
12.57675-12.57725		9.0-9.2	
13.36-13.41		9.3-9.5	
16.42-16.423		10.6-12.7	
16.69475-16.69525		13.25-13.4	
16.80425-16.80475		14.47-14.5	
25.5-25.67		15.35-16.2	
37.5-38.25		17.7-21.4	
73-74.6		22.01-23.12	
74.8-75.2		23.6-24.0	
108-121.94 123-138	108-138	31.2-31.8	
149.9-150.05		36.43-36.5	
156.52475-156.52525		Above 38.6	
156.7-156.9			
162.0125-167.17			
167.72-173.2			
240-285			
322-335.4			
399.9-410			
608-614			

Frequencies in **Bold** text are specific for FCC or ISSED, all other frequencies are common.

3.7 Spurious Emissions (Radiated)

Para. No.: 15.247 (c)

Test Performed By: Markus Korny	Date of Test: 2018-04-06 to 2018-04-12
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Test Results: Complies

Band-edge, @3m

Frequency	Measured Field Strength @3m, dBμV/m	Detector	Limit dBμV/m	Margin dB
2.39 GHz	51.34	PK	74	22.66
	/	AV	54	/
2.4835 GHz	50.70	PK	74	23.30
	/	AV	54	/

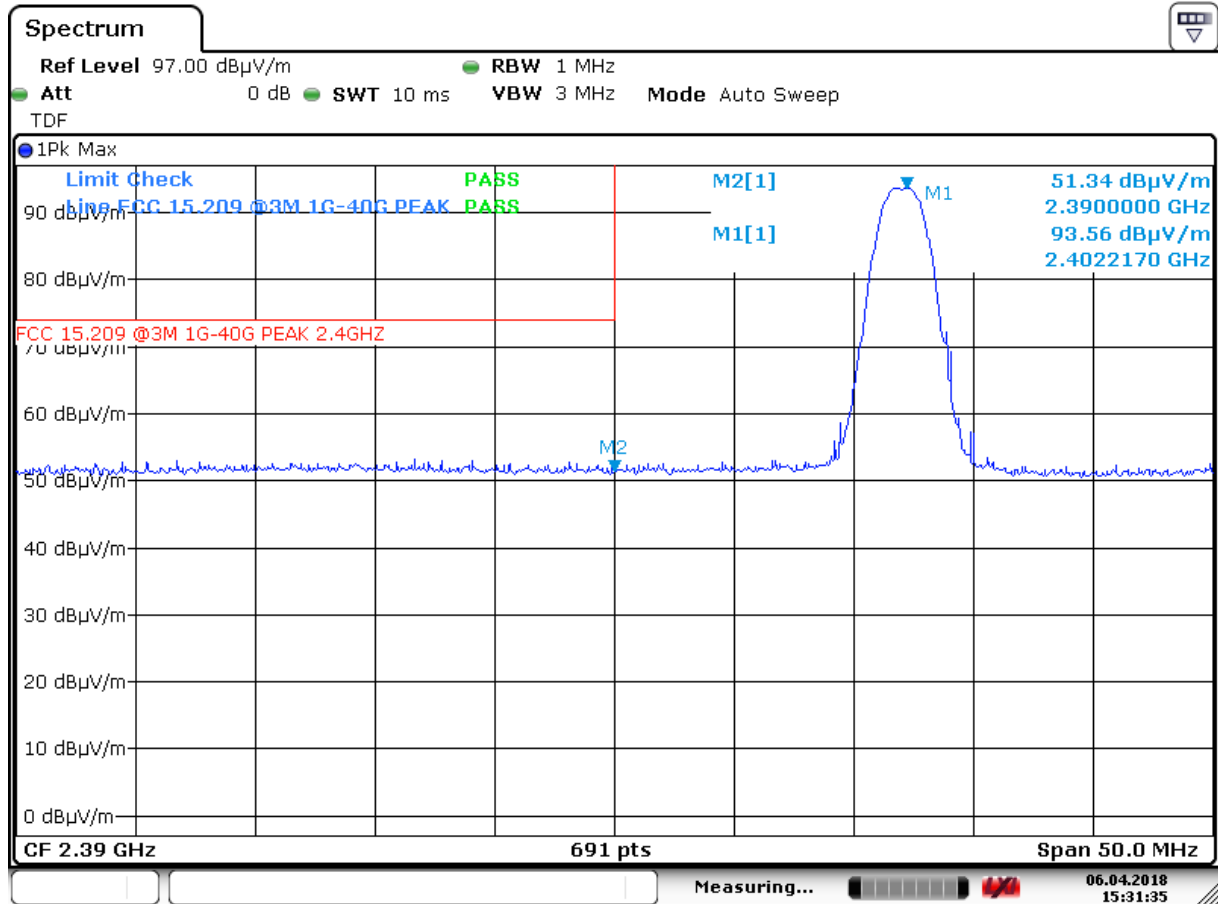
Average values are measured with Peak Detector and corrected for Duty Cycle.
See attached plots.

Duty Cycle Correction Factor Calculation:

Duty Cycle = On Time / (Period * Number of Channels) = $92 \mu\text{s} / (629 \mu\text{s} * 39) = 0.00375$

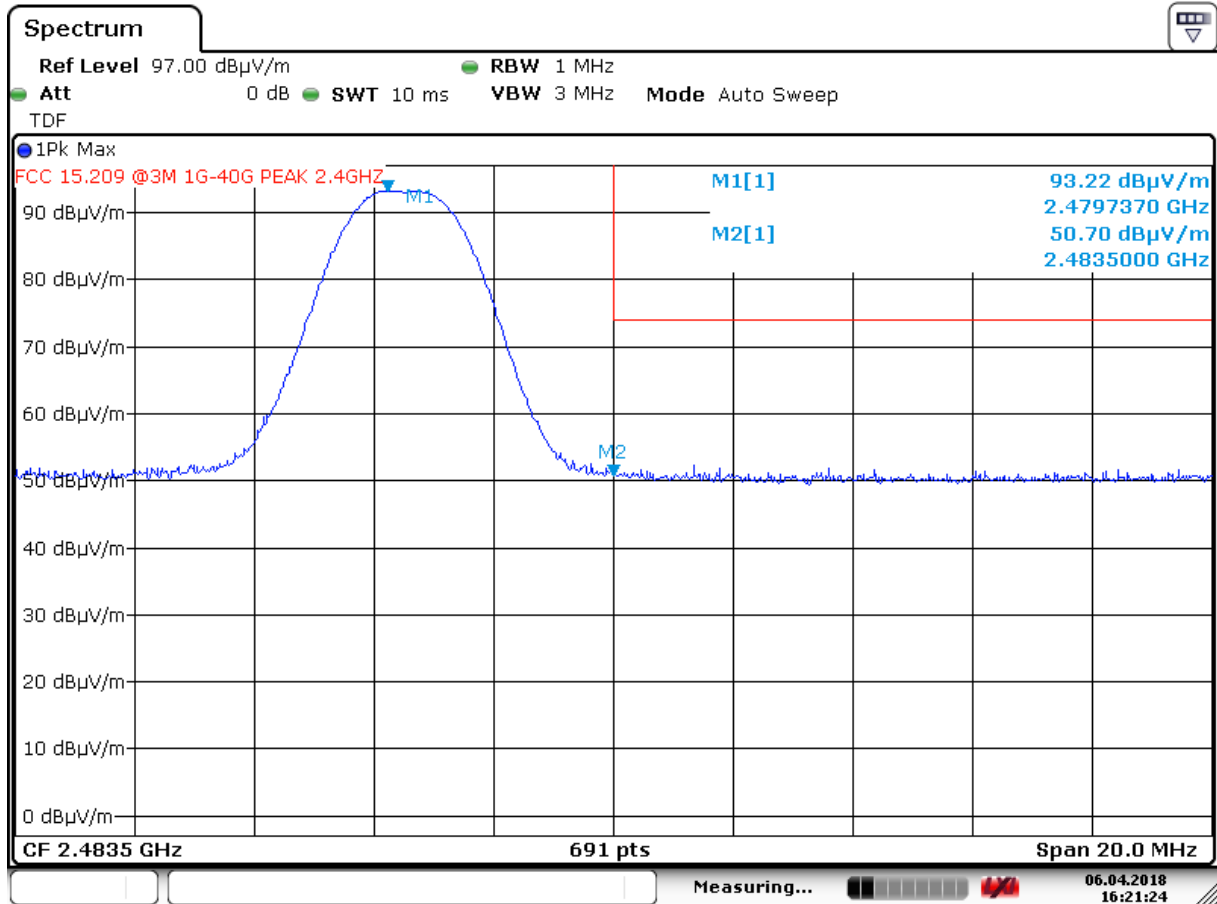
Duty Cycle Correction factor = $-20 \times \log(\text{Duty Cycle}) = 48.5 \text{ dB}$

Maximum allowed Duty Cycle Correction: 20 dB



Date: 6.APR.2018 15:31:36

Band Edge, 2390 MHz, Peak Detector



Date: 6.APR.2018 16:21:24

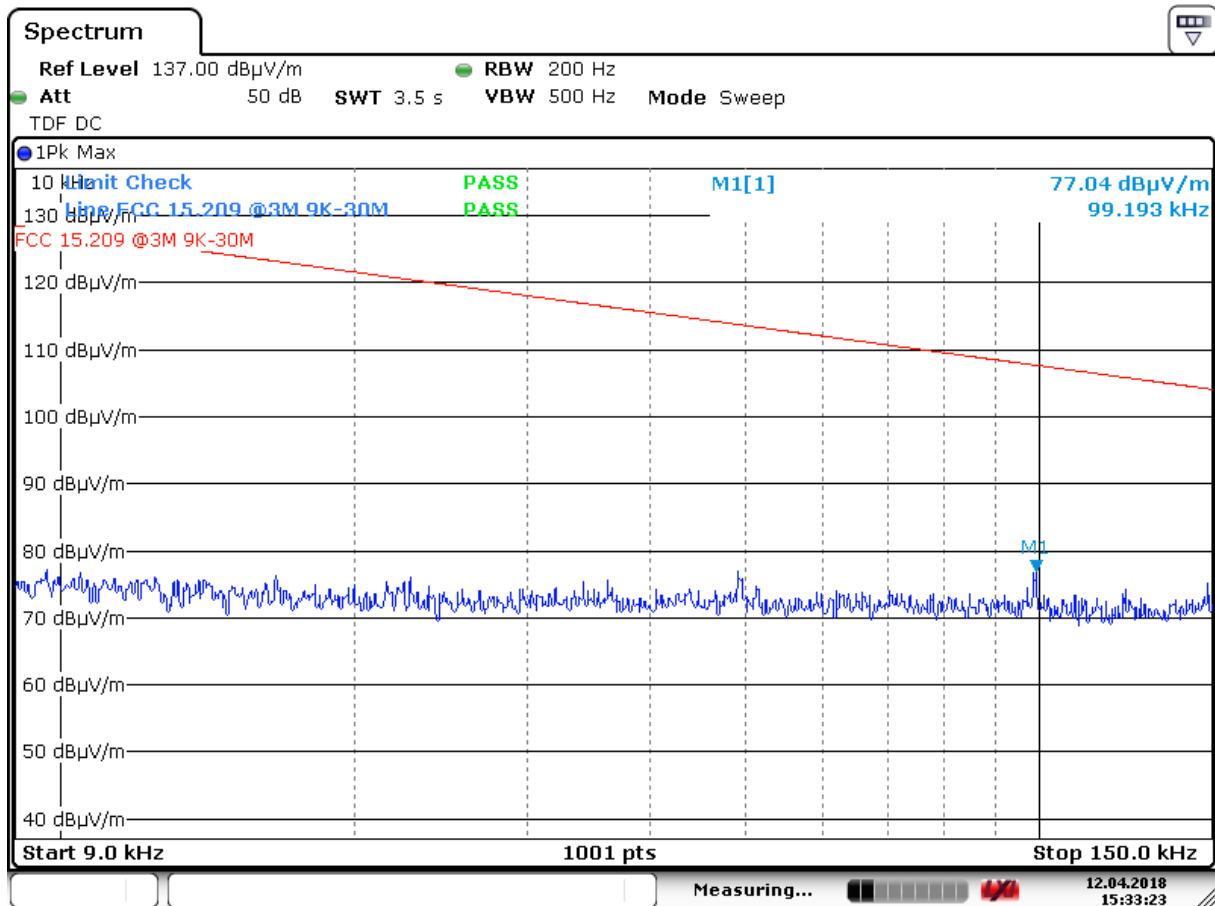
Band Edge, 2483.5 MHz, Peak Detector

Radiated emissions 10 kHz-30 MHz.

Measuring distance 3 m, measured with Peak detector.

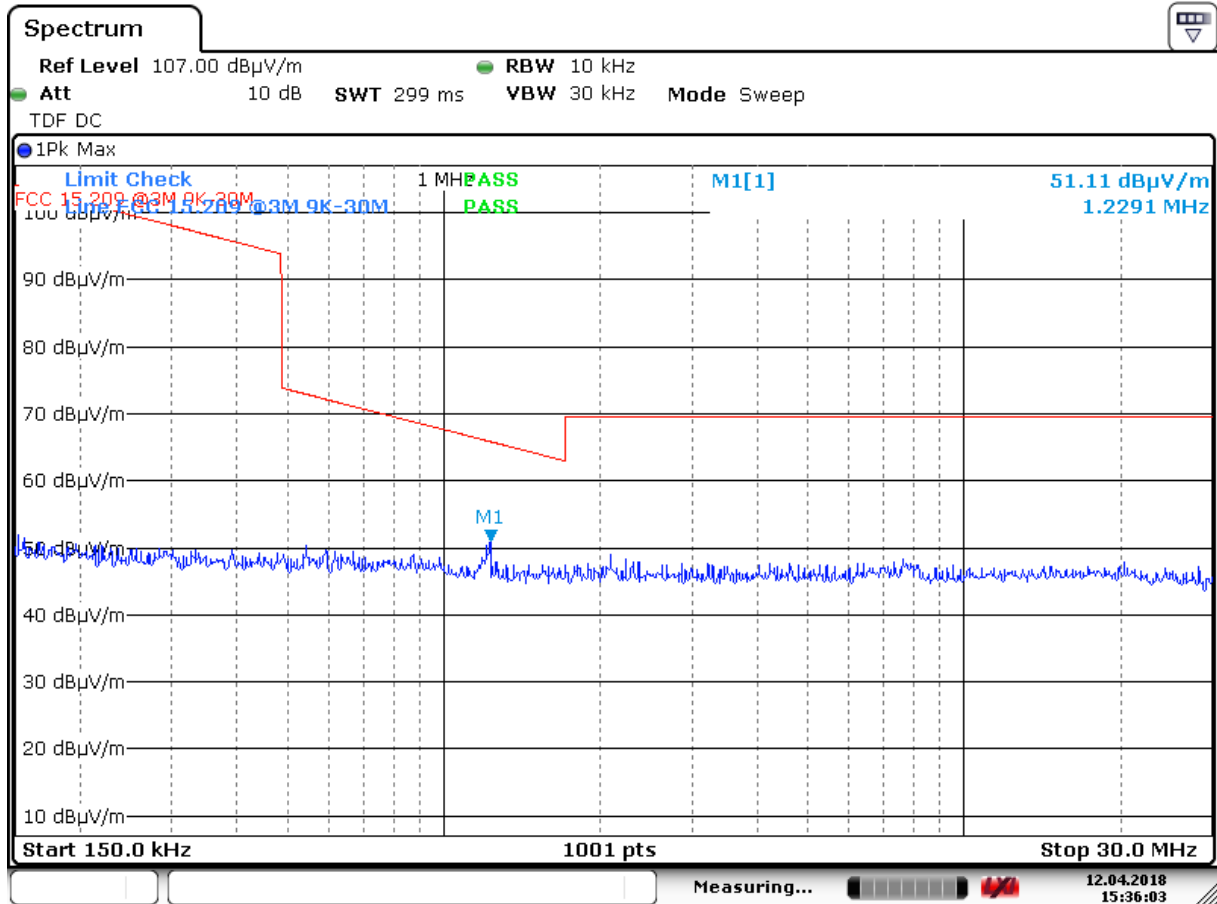
No component detected, see attached graph.

Limit is converted to 3 m using 40 dB / decade according to 15.31 (f) (2).



Date: 12.APR.2018 15:33:23

Radiated Emissions, 9 kHz – 150 kHz @3m



Date: 12.APR.2018 15:36:04

Radiated Emissions, 150 kHz - 30MHz @3m

Radiated emission 30 – 1000 MHz.

Detector: Quasi-Peak

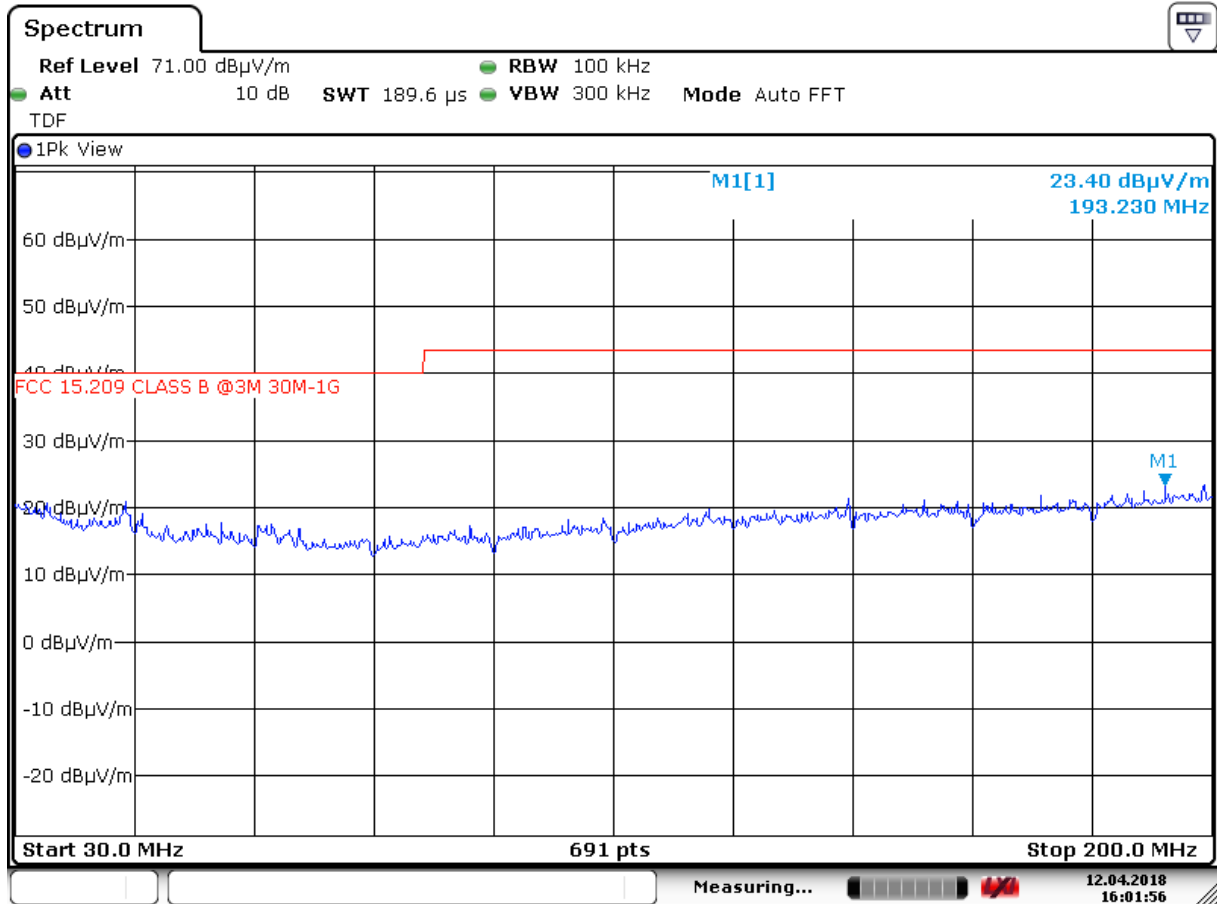
Measuring distance 3m.

Frequency	Operational condition	Detector	Field strength	Measuring distance	Limit FCC15.209	Margin
MHz			dBµV/m	metres	dBµV/m	dB
/	TX on	PK	/	3	40.0	/

See attached graphs.

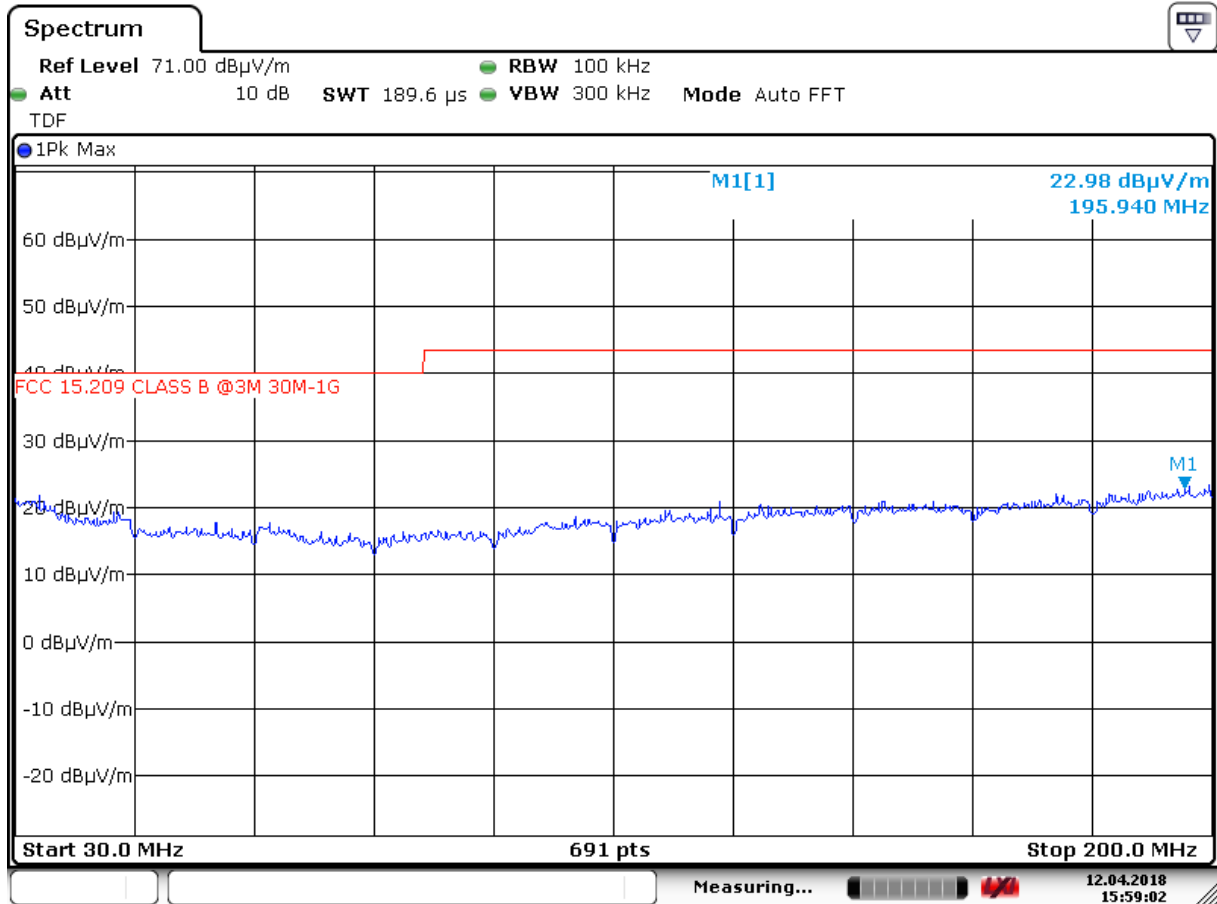
Requirements/Limit

FCC	Part 15.209 @ frequencies defined in §15.205	
ISED	RSS-GEN Issue 4, Clause 8.9 @ frequencies defined in clause 8.10	
	Radiated emission limit @3 meters	
Frequency (MHz)	Quasi Peak (µV/m)	Quasi Peak (dBµV/m)
30 – 88	100	40.0
88 – 216	150	43.5
216 – 960	200	46.0
Above 960	500	54.0



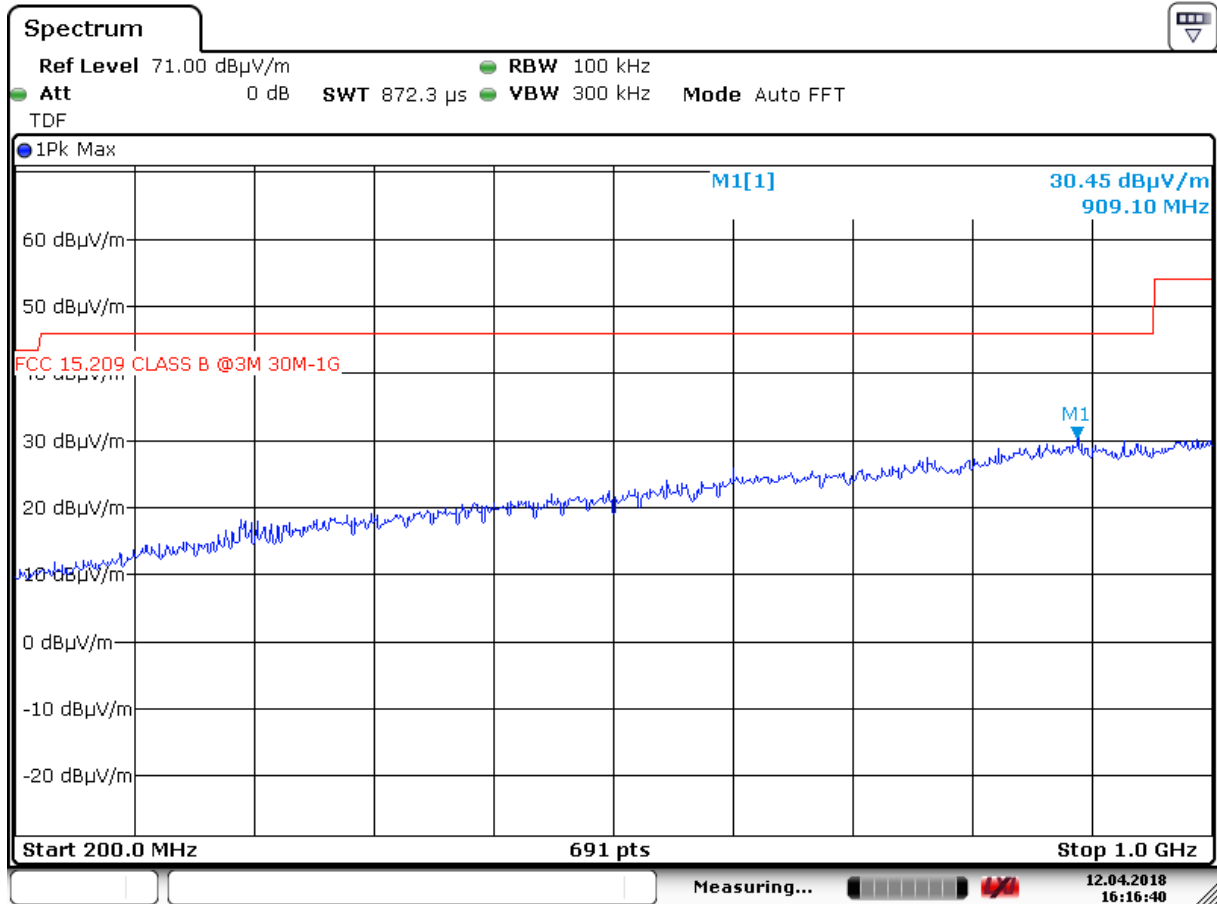
Date: 12.APR.2018 16:01:56

Radiated Emissions, 30 – 200 MHz, VP, @3m, PK scan



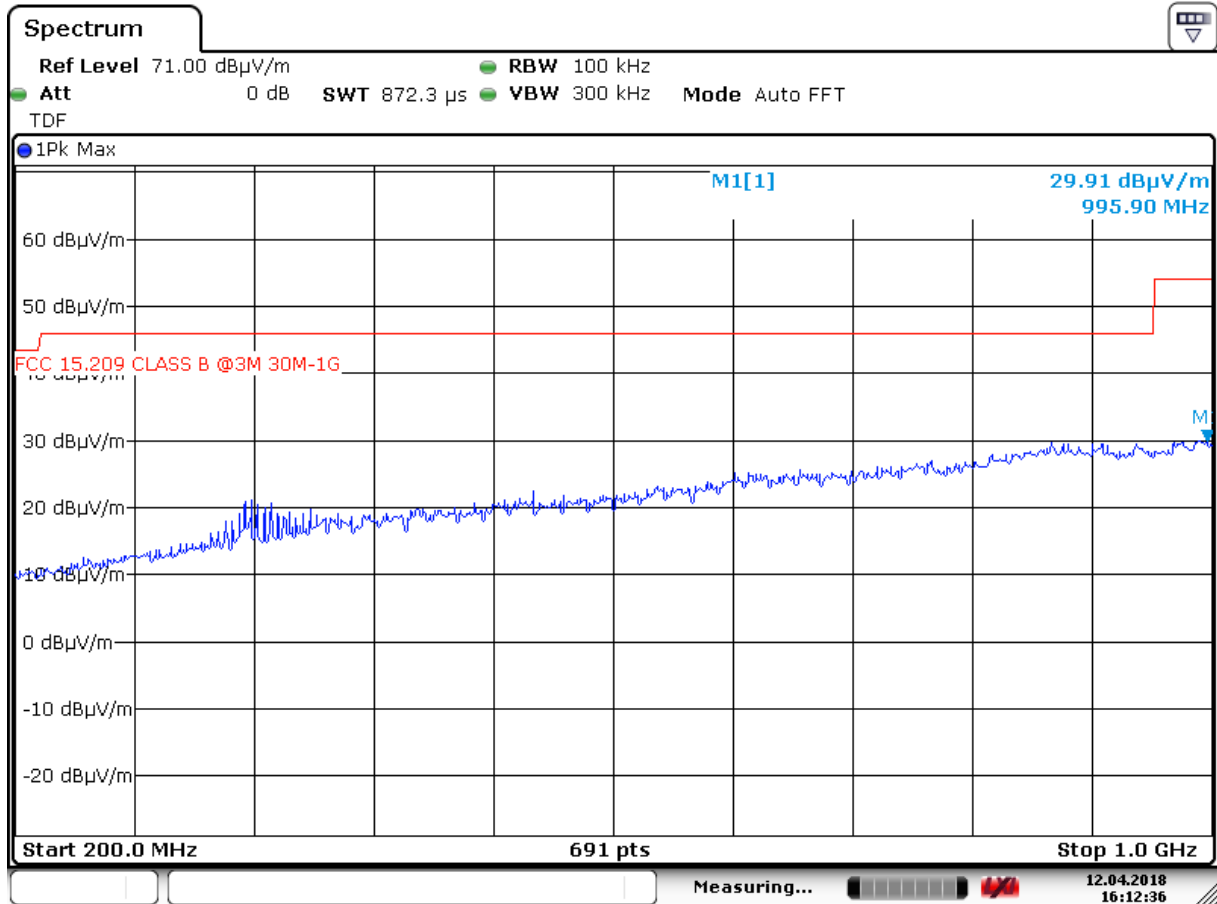
Date: 12.APR.2018 15:59:02

Radiated Emissions, 30 – 200 MHz, HP, @3m, PK scan



Date: 12.APR.2018 16:16:40

Radiated Emissions, 200 - 1000 MHz, VP, @3m, PK scan



Date: 12.APR.2018 16:12:37

Radiated Emissions, 200 - 1000MHz, HP, @3m, PK scan

Radiated Emissions, 1-25 GHz

Measuring distance: 3m (1 – 4 GHz)
Measuring distance: 1m (4 – 18 GHz)
Measuring distance: 3m (18 – 25 GHz)

A pre-scan was performed above 18 GHz and no spurious emissions were detected.

Peak Detector:

Frequency	RF channel	Dist. corr. factor	Field strength, Peak Detector	Duty cycle corr. factor	Limit	Margin
GHz	L,M,H	dB	dB μ V/m	dB	dB μ V/m	dB
17.848	L	0	61.50	0	74	12.50
Other freqs	L,M,H	/	< 54	0	74	>20

Average Detector:

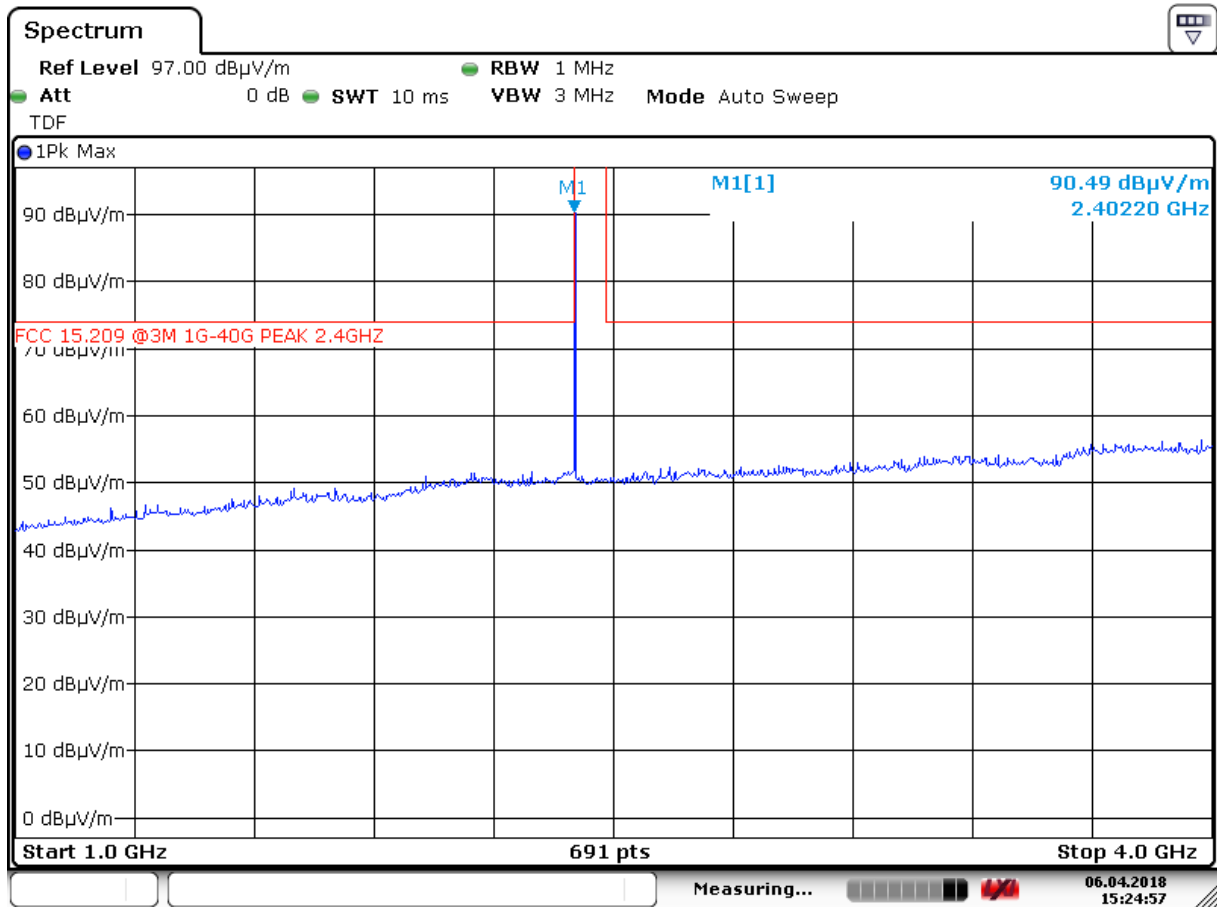
Frequency	RF channel	Dist. corr. factor	Field strength, Average Detector	Duty cycle corr. factor	Limit	Margin
GHz	L,M,H	dB	dB μ V/m	dB	dB μ V/m	dB
17.848	H	0	51.61	0	54	2.39
Other freqs	L,M,H	/	/	0	54	/

Tested according to KDB 558074 D01 DTS Meas Guidance v03r05, Section 12.2.5.2

Antenna factor, amplifier gain and cable loss are included in spectrum analyzer "Transducer factor".

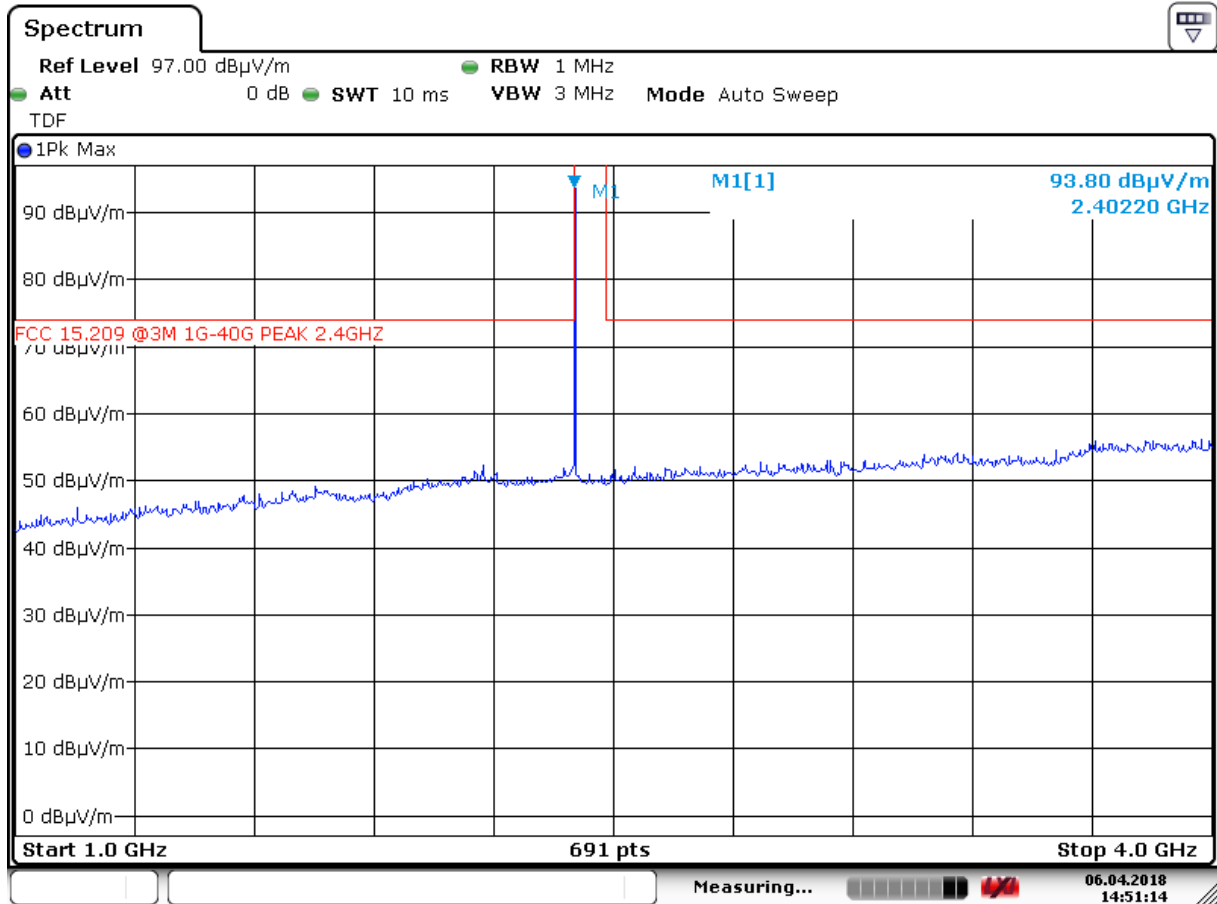
See plots.

No harmonics detected in the frequency range 1 – 25 GHz



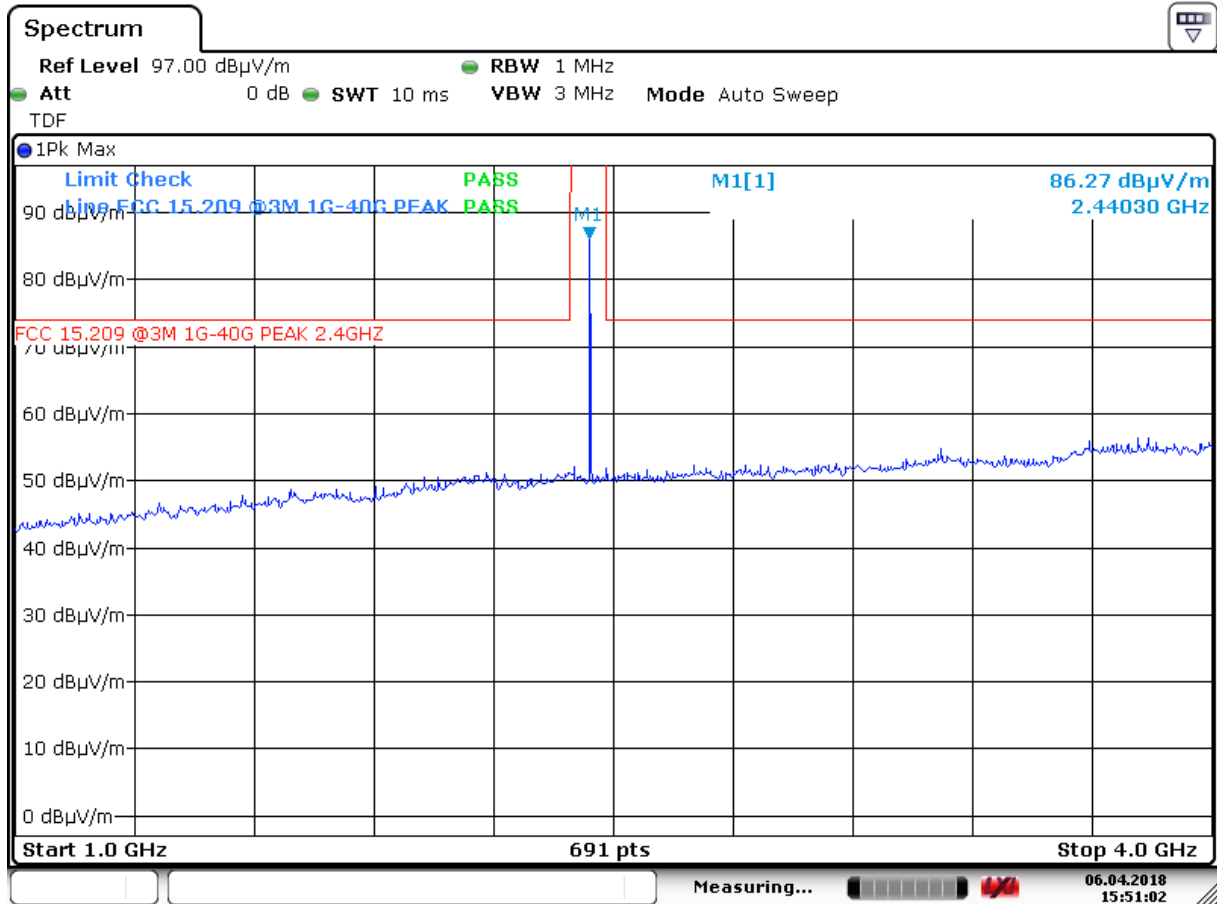
Date: 6.APR.2018 15:24:57

Radiated Emissions, 2402 MHz, 1 – 4 GHz, VP, @3m – Pre-scan



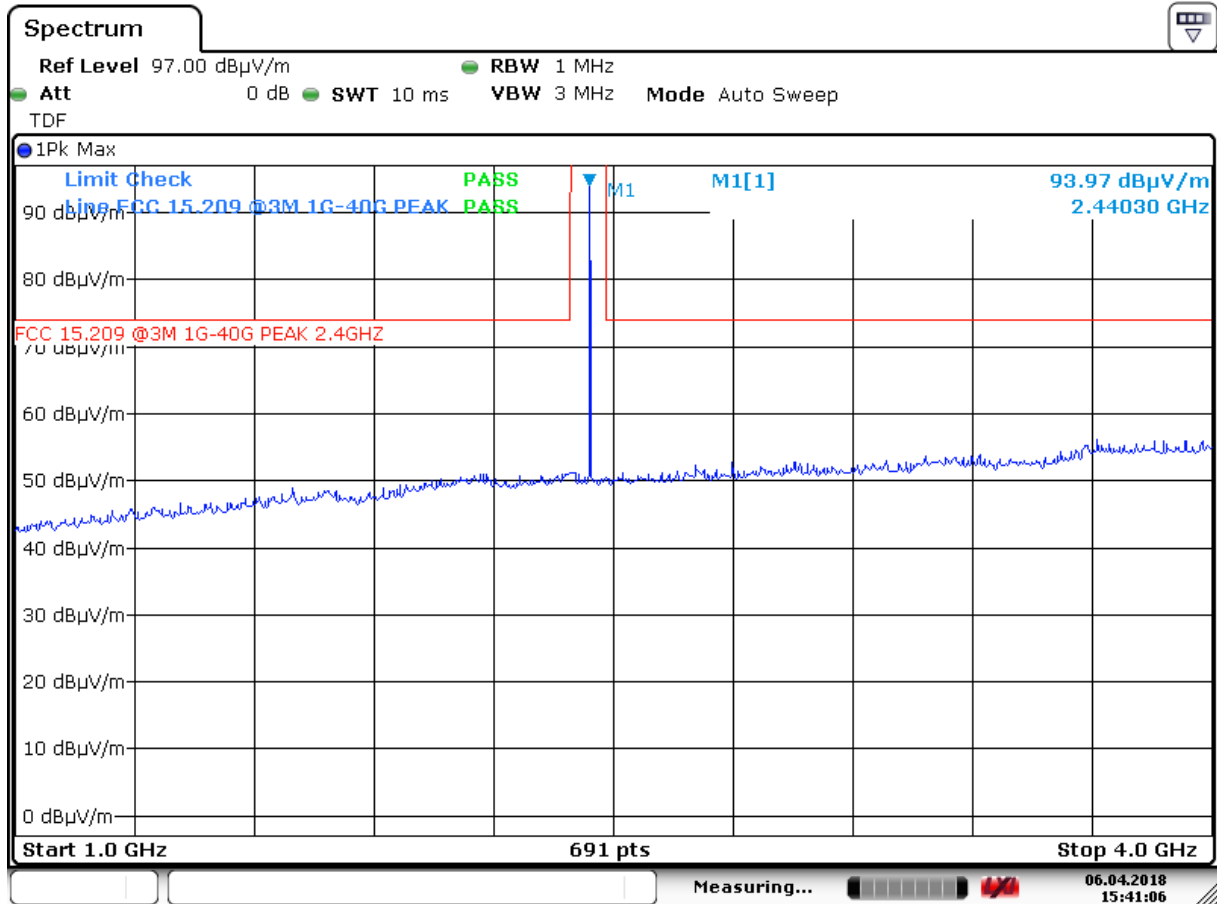
Date: 6.APR.2018 14:51:15

Radiated Emissions, 2402 MHz, 1 – 4 GHz, HP, @3m – Pre-scan



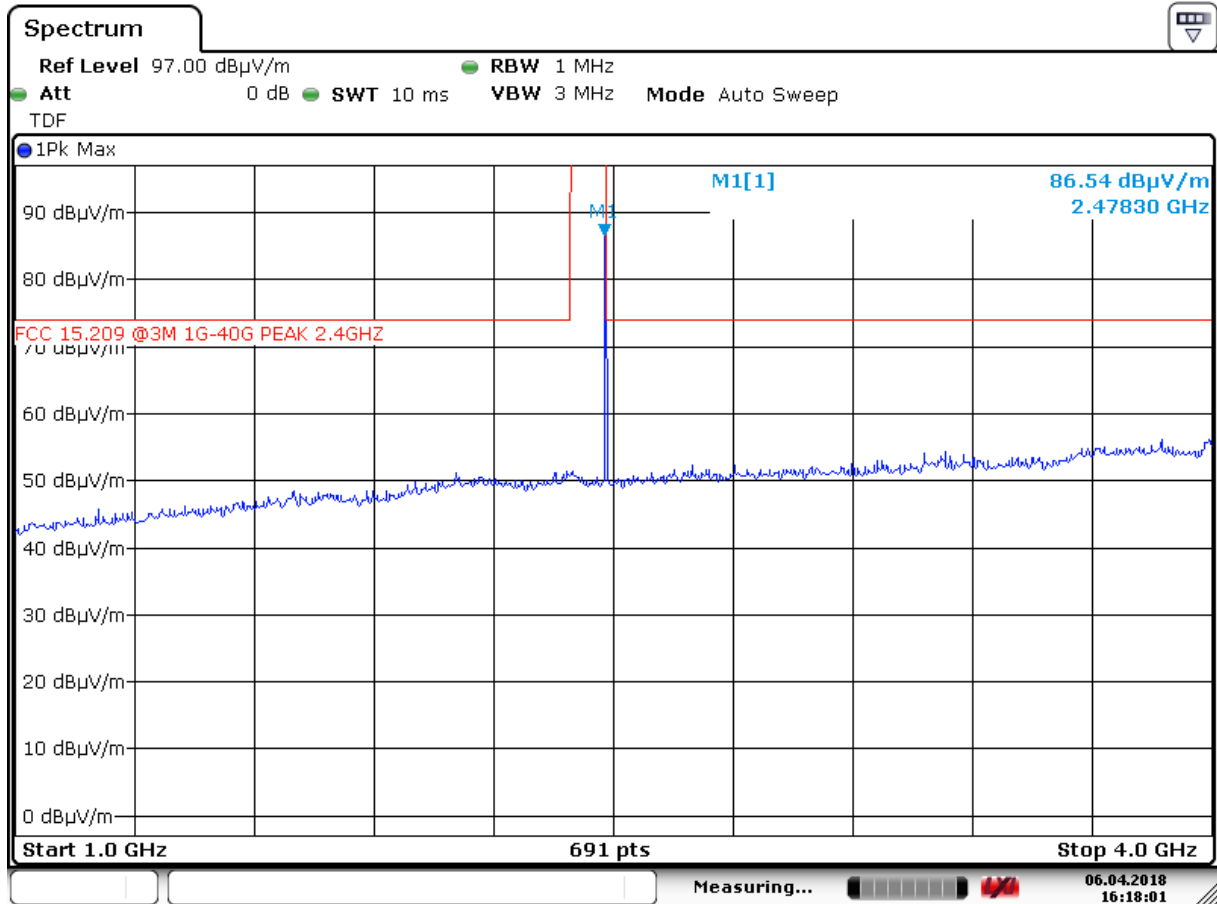
Date: 6.APR.2018 15:51:03

Radiated Emissions ch. 2440 MHz, 1 – 4 GHz, VP, @3m – Pre-scan



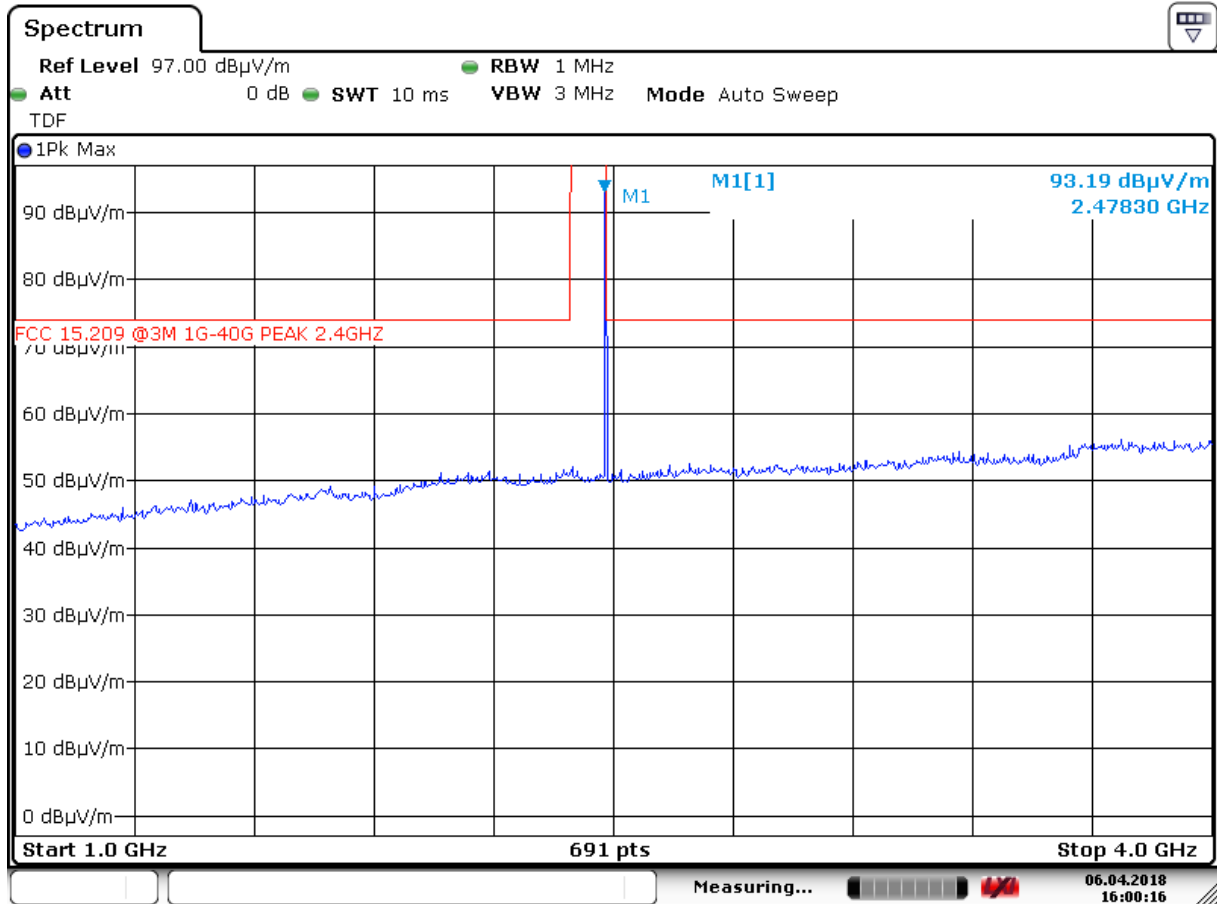
Date: 6.APR.2018 15:41:06

Radiated Emissions ch. 2440 MHz, 1 – 4 GHz, HP, @3m – Pre-scan



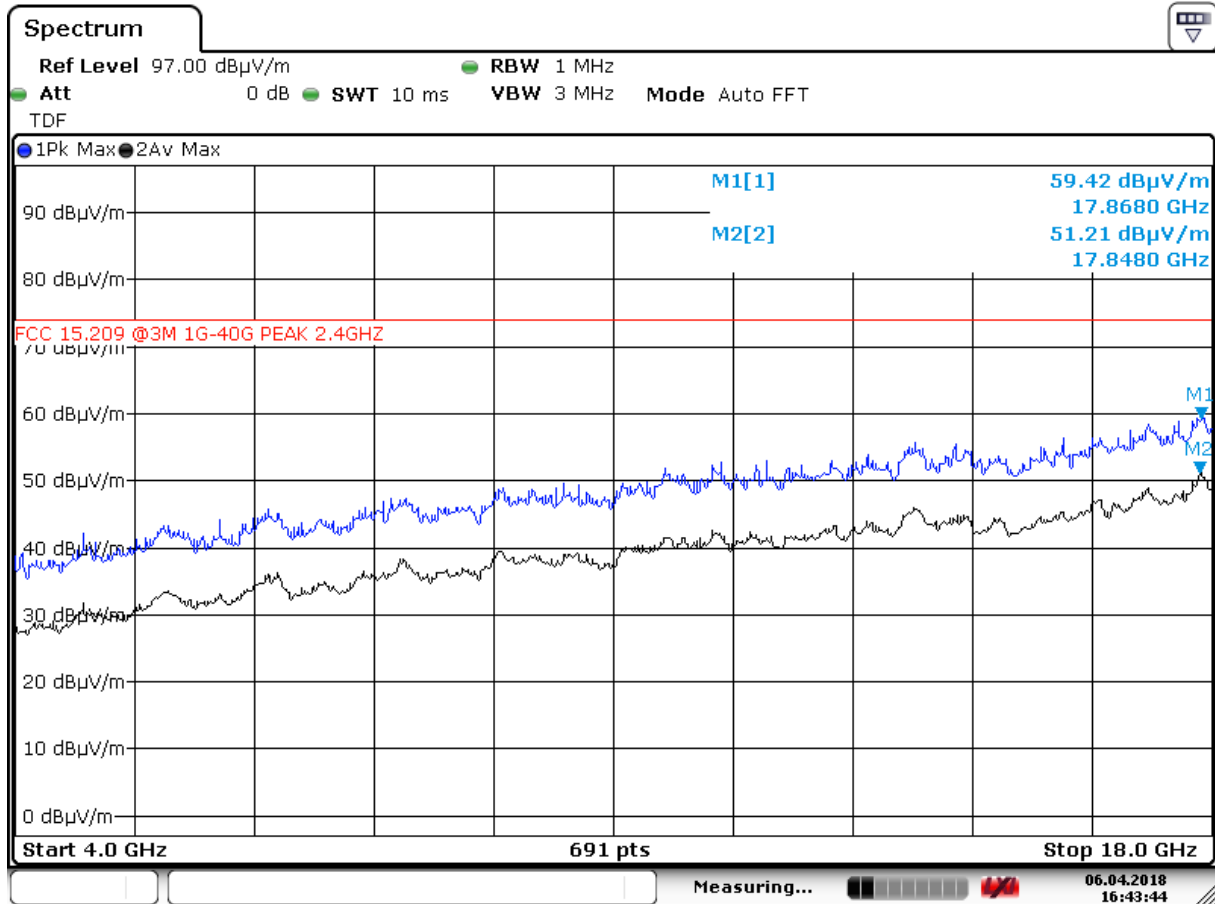
Date: 6.APR.2018 16:18:01

Radiated Emissions ch. 2480 MHz, 1 – 4 GHz, VP, @3m – Pre-scan



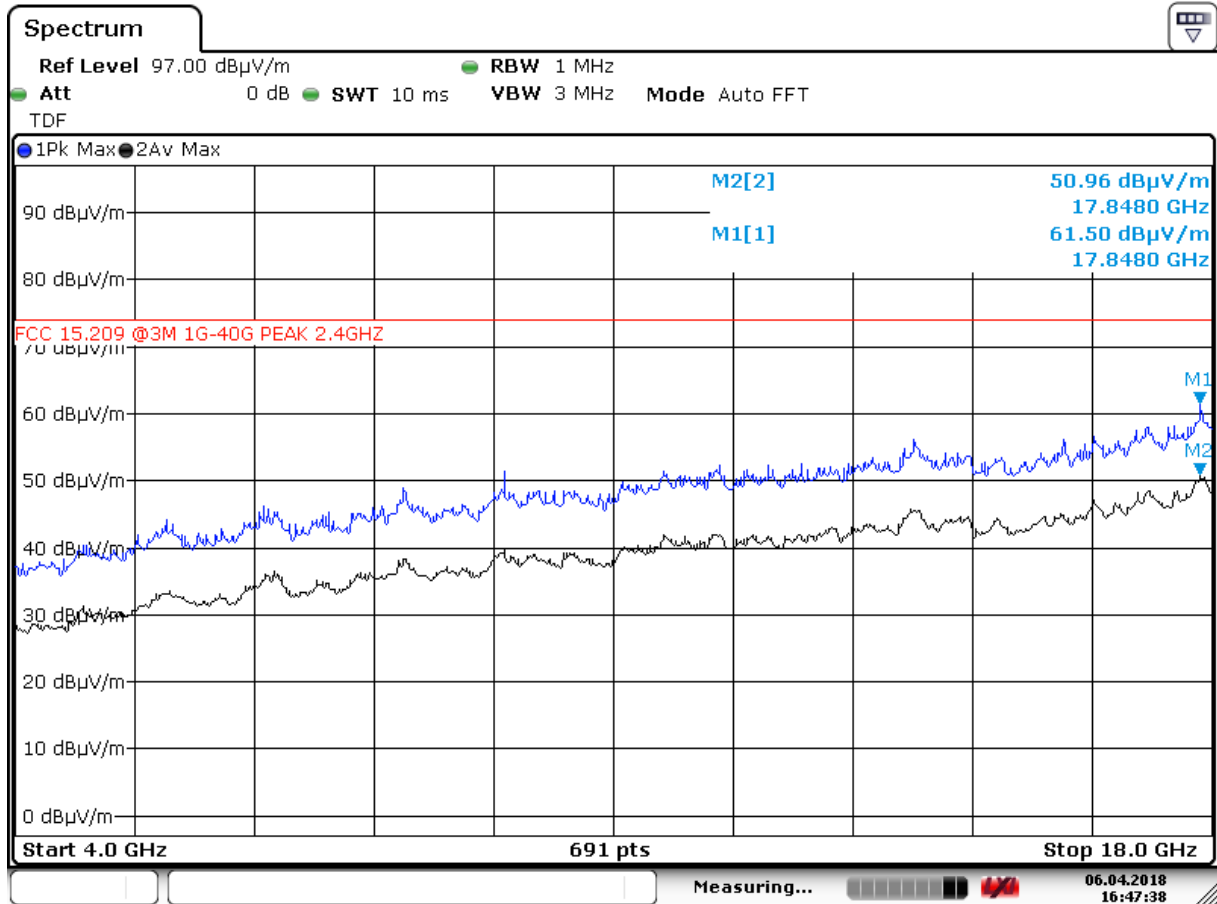
Date: 6.APR.2018 16:00:17

Radiated Emissions ch. 2480 MHz, 1 – 4 GHz, HP, @3m – Pre-scan



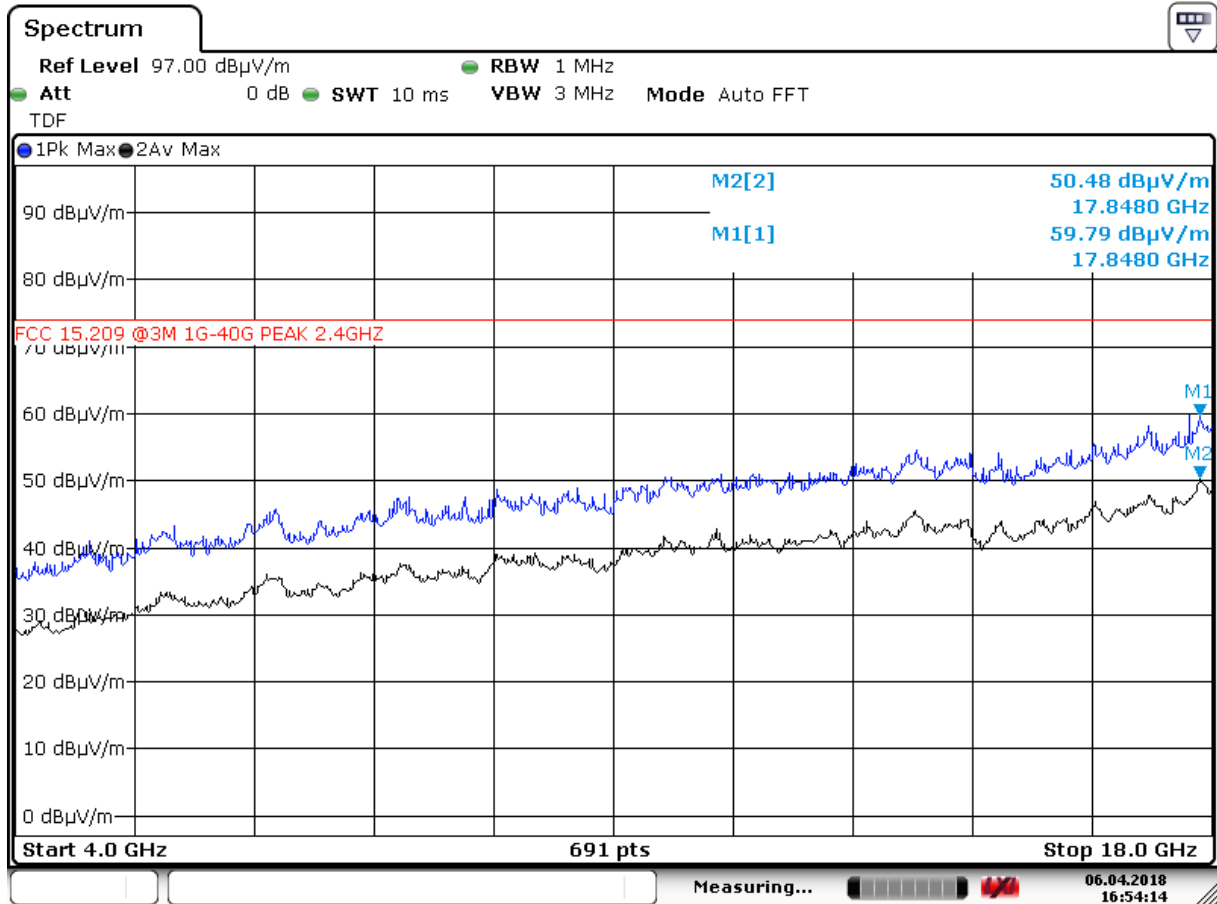
Date: 6.APR.2018 16:43:44

Radiated Emissions ch. 2402 MHz, 3 – 18 GHz, VP, @3m – Pre-scan



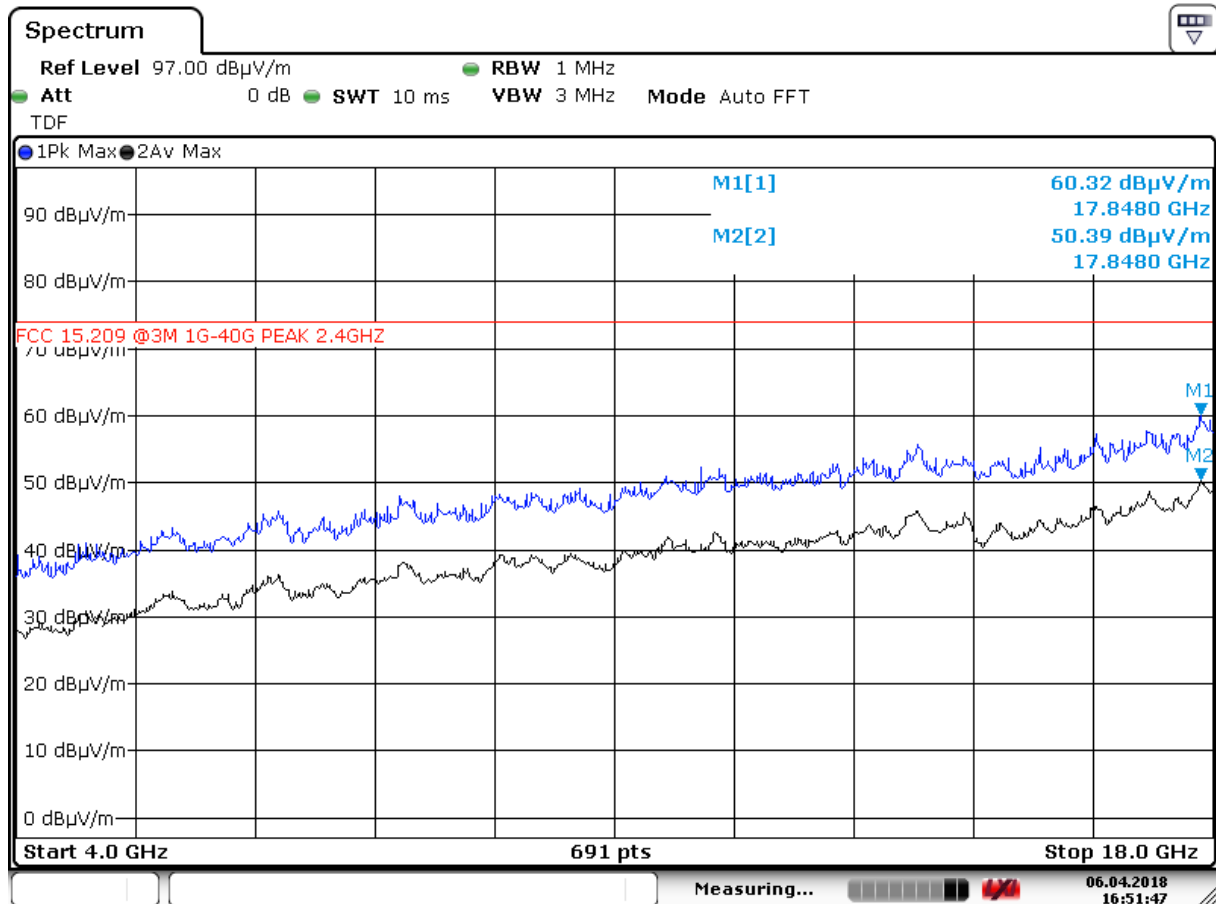
Date: 6.APR.2018 16:47:38

Radiated Emissions ch. 2402 MHz, 3 – 18 GHz, HP, @3m – Pre-scan



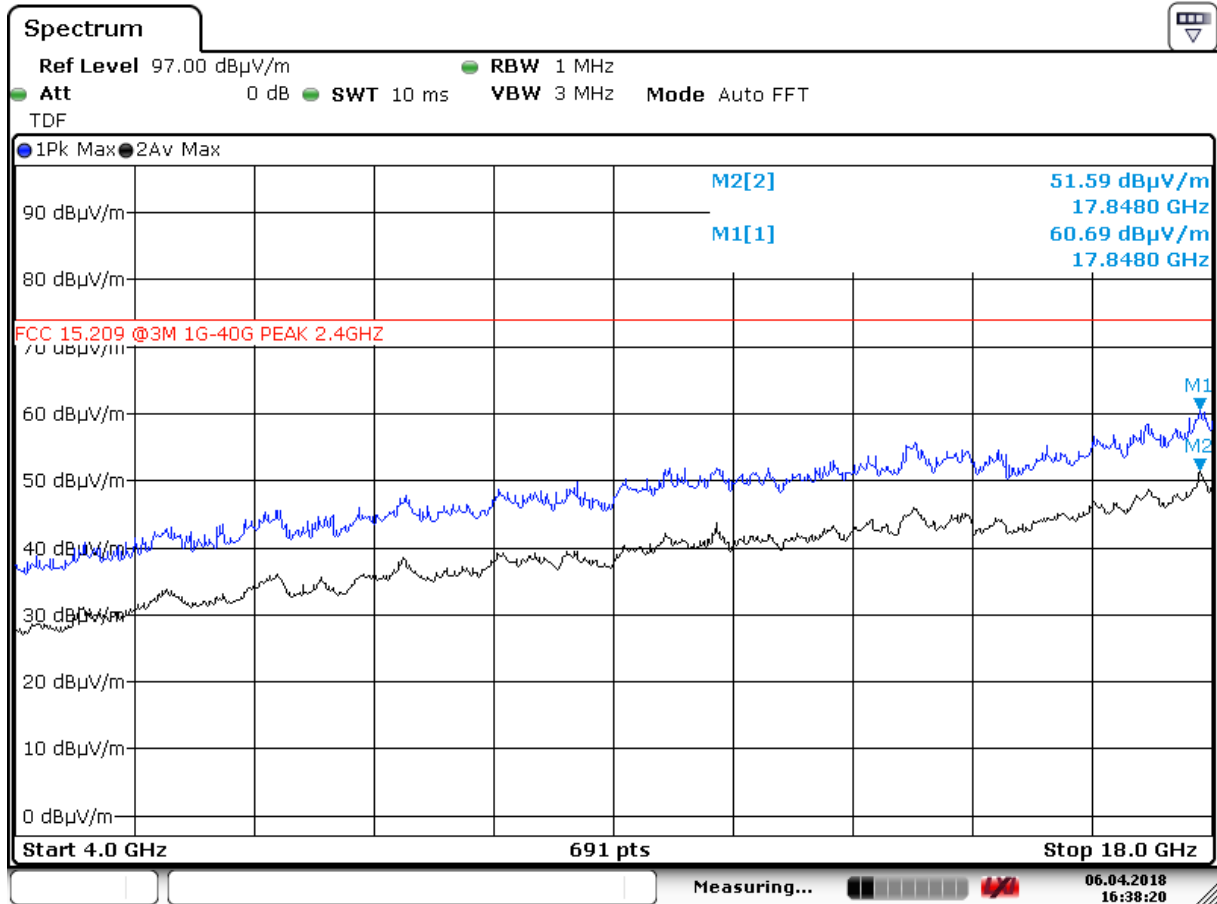
Date: 6.APR.2018 16:54:15

Radiated Emissions ch. 2440 MHz, 3 – 18 GHz, VP, @3m – Pre-scan



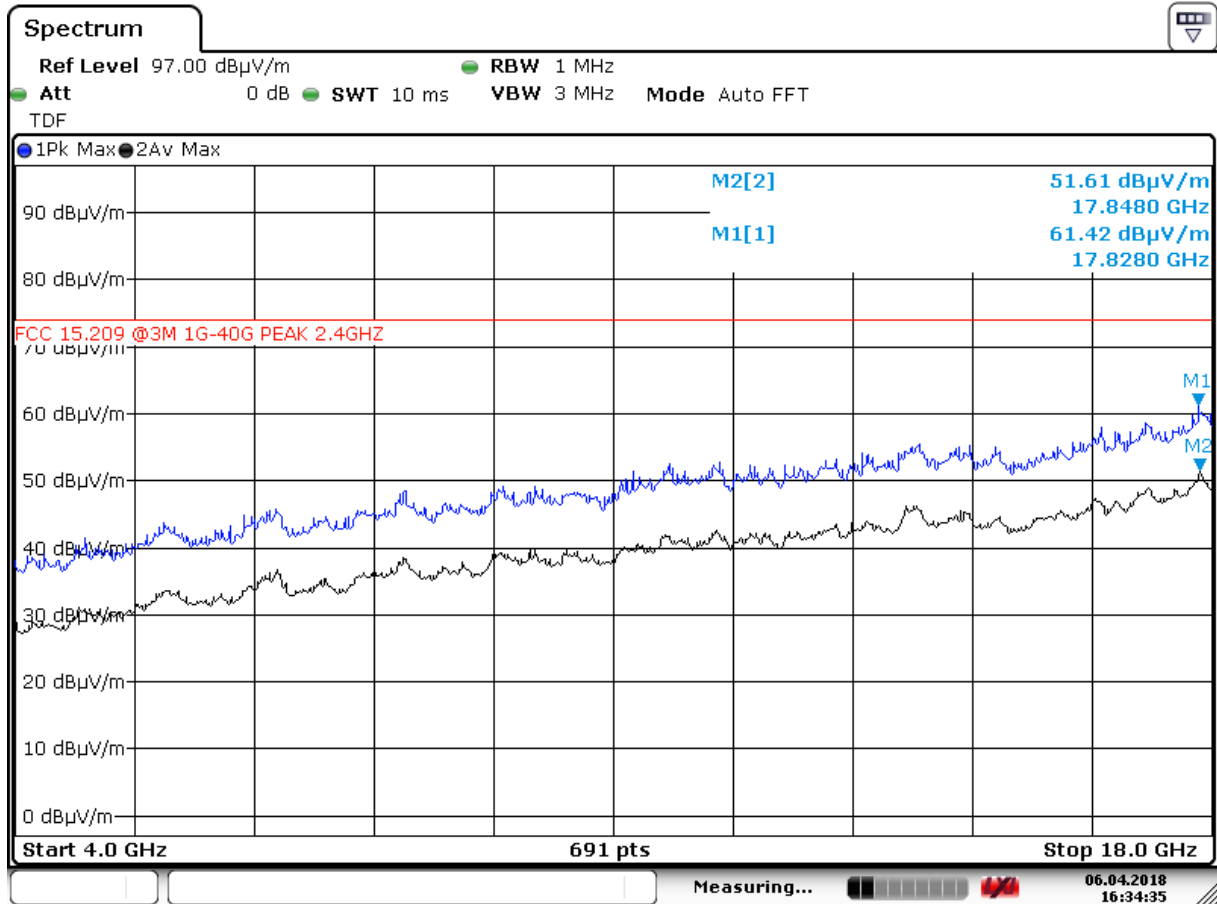
Date: 6.APR.2018 16:51:47

Radiated Emissions ch. 2440 MHz, 3 – 18 GHz, HP, @3m – Pre-scan



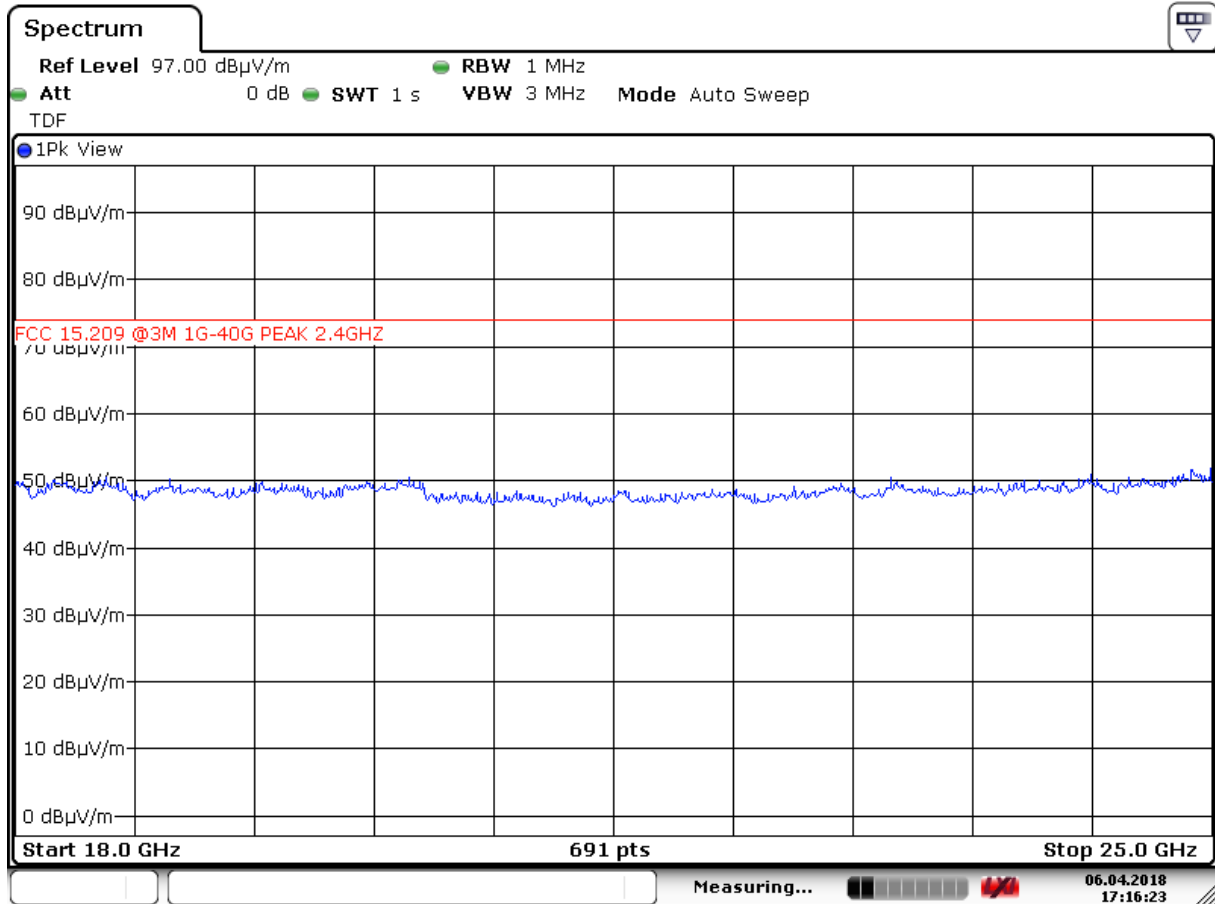
Date: 6.APR.2018 16:38:21

Radiated Emissions ch. 2480 MHz, 3 – 18 GHz, VP, @3m – Pre-scan



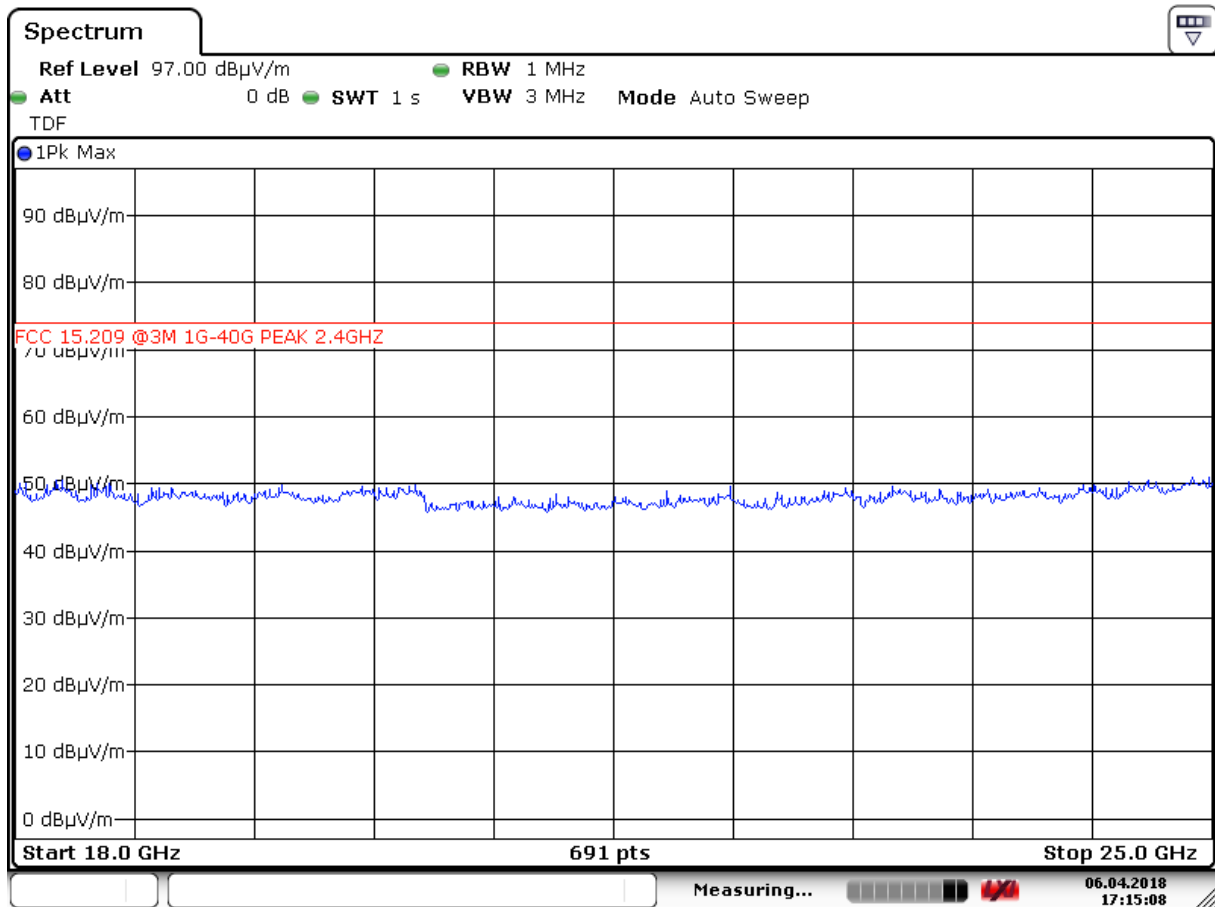
Date: 6.APR.2018 16:34:35

Radiated Emissions ch. 2480 MHz, 3 – 18 GHz, HP, @3m – Pre-scan



Date: 6.APR.2018 17:16:24

Radiated Emissions, 18 – 25 GHz, VP, @3m – Pre-scan



Date: 6.APR.2018 17:15:09

Radiated Emissions, 18 – 25 GHz, HP, @3m – Pre-scan

3.8 Power Spectral Density (PSD)

Para. No.: 15.247 (d)

Test Performed By: Markus Korny

Date of Test: 2018-04-18

Test Results: Passed

Measured and Calculated Data:

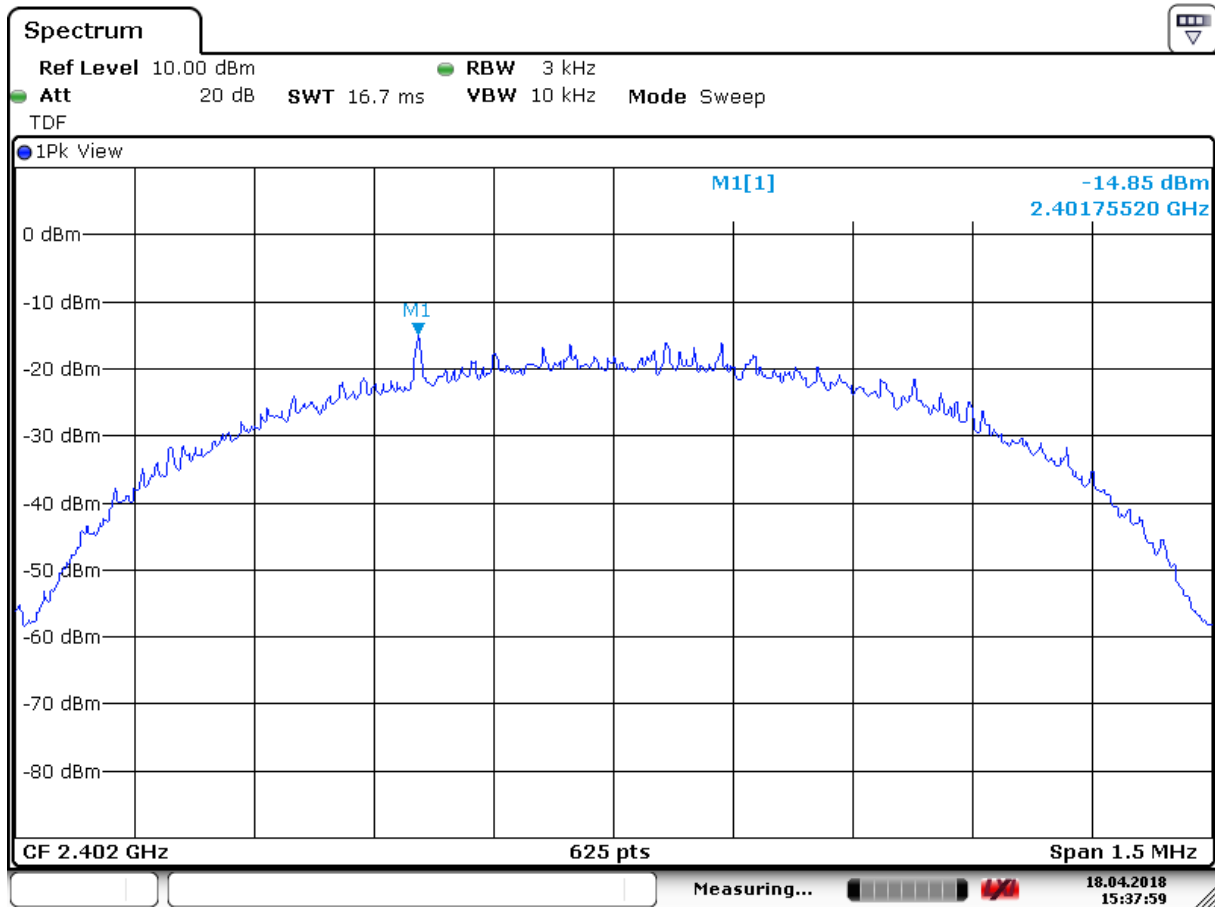
The measurement procedures PKPSD described in KDB 558074 D01 v03r05 was used.

	calculated peak PSD dBm
Power Spectral Density @2402 MHz	-14.85
Power Spectral Density @2440 MHz	-14.97
Power Spectral Density @2480 MHz	-15.35

Requirements:

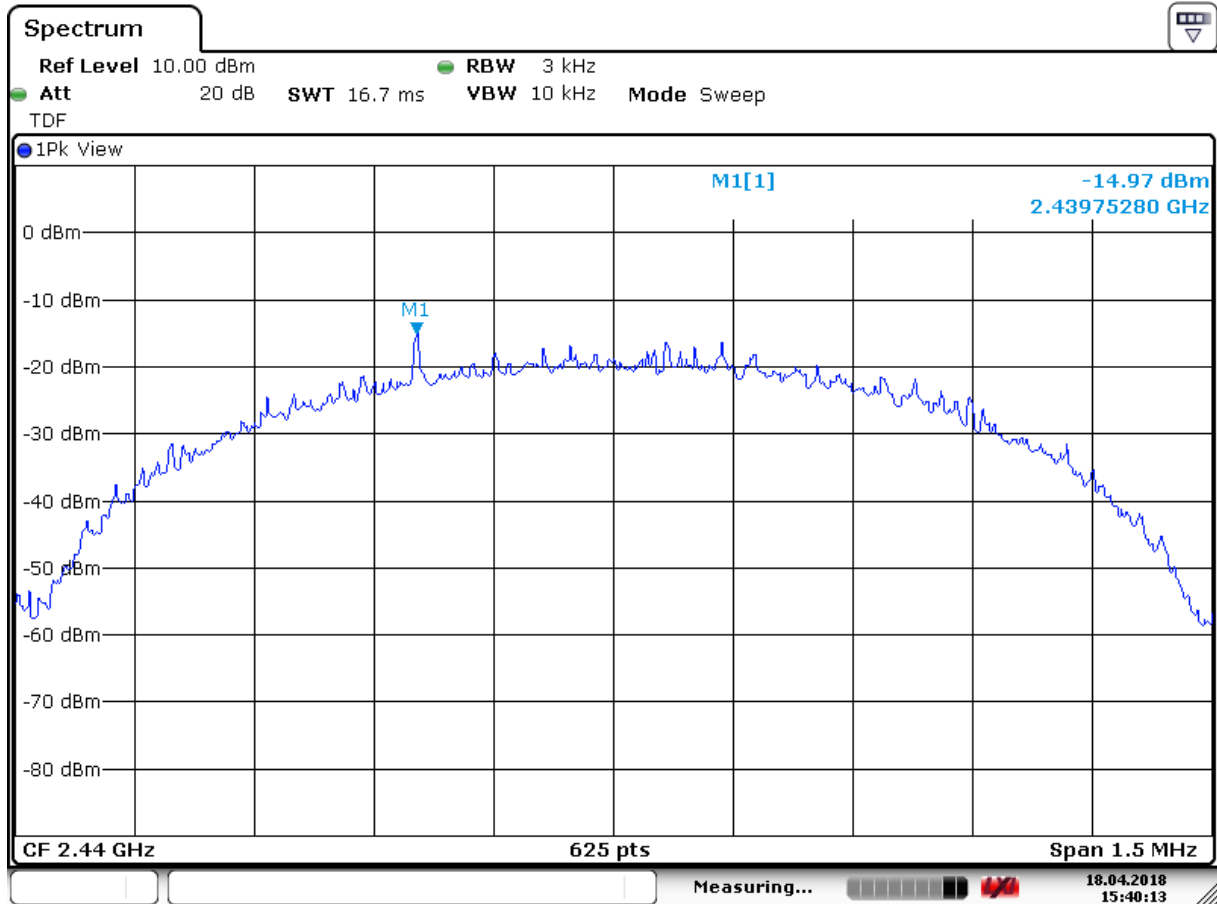
The Power Spectral Density of a Digital Transmission System shall be no greater than +8 dBm in any 3 kHz band

No requirements for Frequency Hopping Systems.



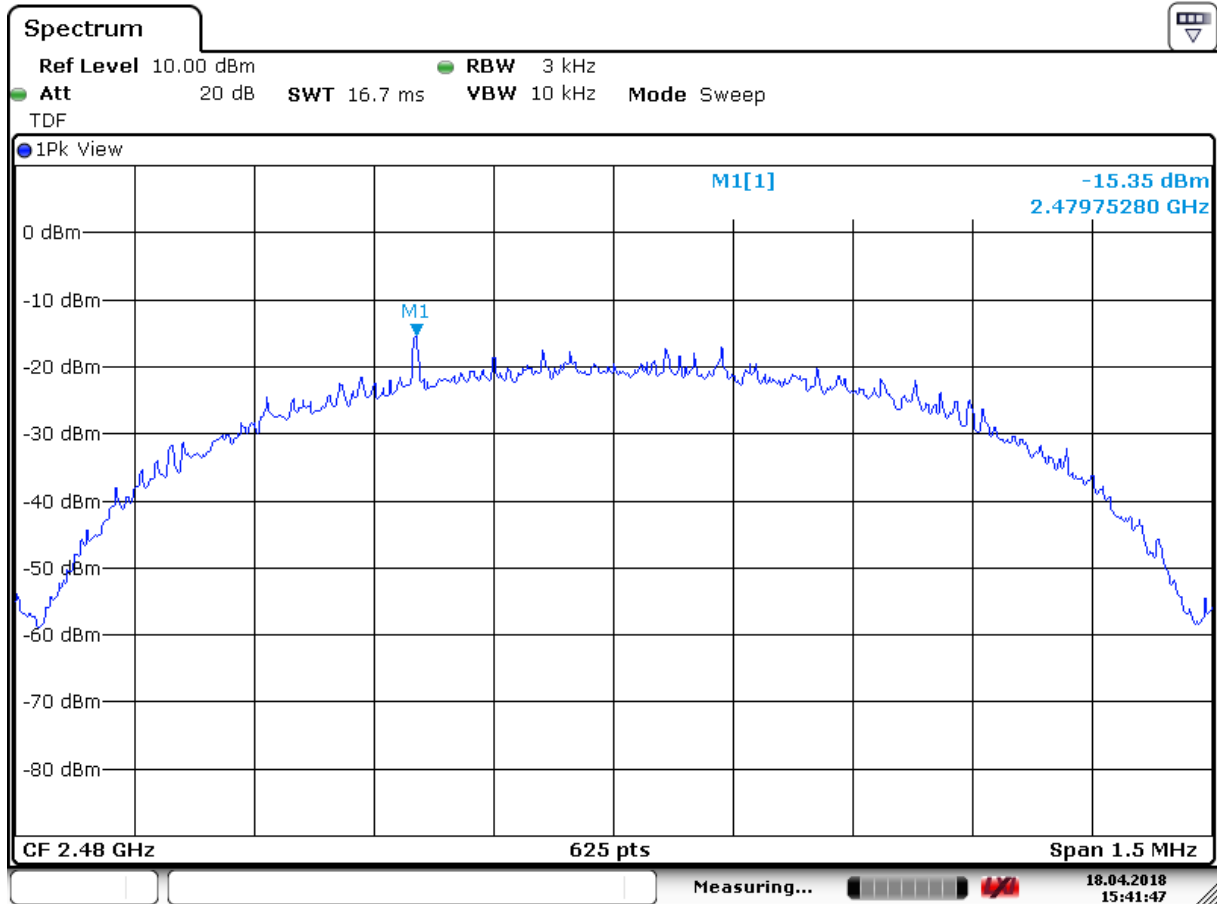
Date: 18.APR.2018 15:38:00

PSD Measurement - 2402MHz



Date: 18.APR.2018 15:40:14

PSD Measurement - 2440MHz



Date: 18.APR.2018 15:41:47

PSD Measurement - 2480MHz

4 Measurement Uncertainty

Measurement Uncertainty Values		
Test Item		Uncertainty
Output Power		±0.8 dB
Power Spectral Density		±0.8 dB
Out of Band Emissions, Conducted	< 3.6 GHz	±0.8 dB
	> 3.6 GHz	±1.2 dB
Spurious Emissions, Radiated	< 200 MHz	±4.77 dB
	200 MHz - 1 GHz	±5.02 dB
	1 GHz – 18 GHz	±4.94 dB
	> 18 GHz	±5.91 dB
Emission Bandwidth		±4 %
Power Line Conducted Emissions		±3.58 %
Spectrum Mask Measurements	Frequency	±5 %
	Amplitude	±1.0 dB
Frequency Error		±0.6 ppm
Temperature Uncertainty		±1 °C

All uncertainty values are expanded standard uncertainty to give a confidence level of 95%, based on coverage factor k=2

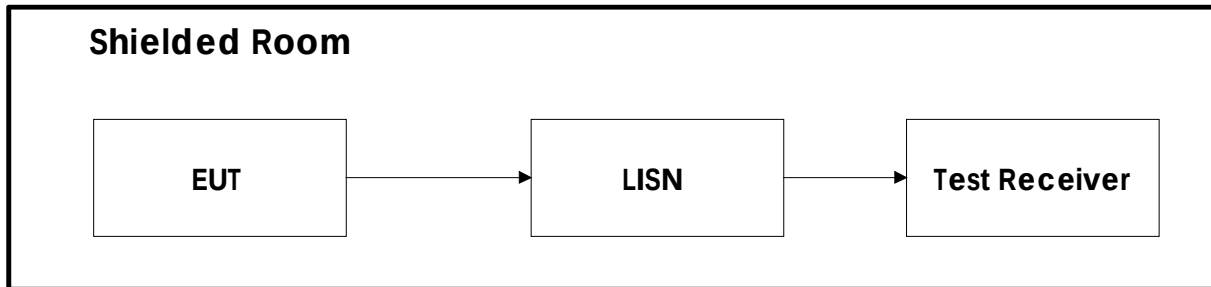
5 LIST OF TEST EQUIPMENT

To facilitate inclusion on each page of the test equipment used for related tests, each item of test equipment and ancillaries are identified (numbered) by the Test Laboratory.

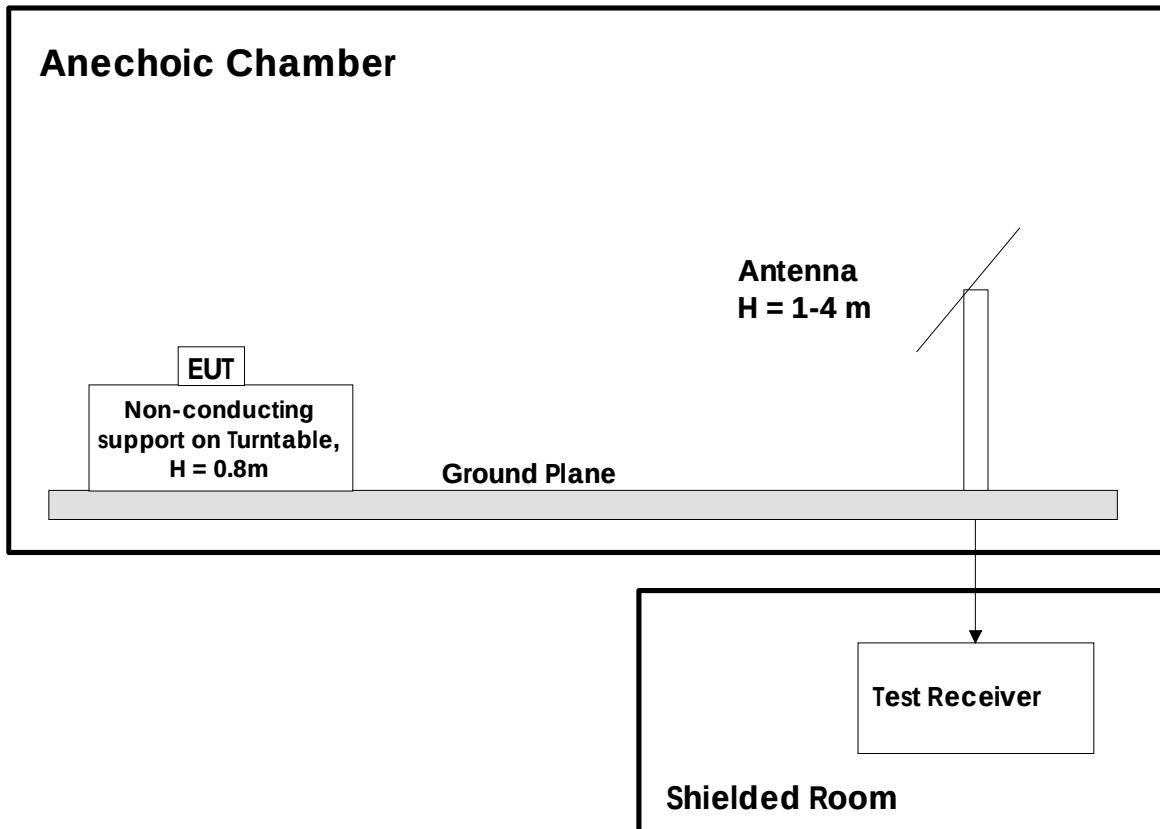
Ref No	Instrument/ ancillary	Manufacturer	Type of instrument/ ancillary	Cal. Date	Cal. Due
1-0039	Loop antenna	Rohde & Schwarz	HFH2-Z2	2017-09	2018-09
1-0040	Biconical antenna	Rohde & Schwarz	HK116	2015-08	2018-08
1-0055	LopPer antenna	Rohde & Schwarz	HL223	2015-08	2018-08
1-0080	Turntable	H. Deisel	DS 420	--	--
1-0256	Horn antenna	Schwarzbeck Mess-Elektronik	BBHA 9120	--	--
1-0361	Semi anechoic chamber	Reinhold & Mahla	3m	2017-06	2020-06
1-0364	Antenna cable 2	Kabelwerk Eupen	RF/Cord CMS / RG 214-N/7	2016-09	2019-09
1-0604	EMI test receiver	Rohde & Schwarz	ESU8	2017-09	2018-09
1-0611	Signal analyzer	Rohde & Schwarz	FSV 40	2017-09	2018-09
1-0614	Log.-per. antenna	Schwarzbeck Mess-Elektronik	STLP 9148 Stacked Log.-Per. Antenne	2016-11	2019-11
1-0615	Pre amplifier	Schwarzbeck Mess-Elektronik	BBV-9718 Broadband Preamplifier	2017-09	2018-09
1-0619	Coaxial cable (to SAC)	Huber+Suhner	SF106/2x11N-651/2m	2016-09	2019-09
1-0620	Antenna cable 3	Huber+Suhner	SF106/2x11N-651/3m	2016-09	2019-09
1-0771	Broadband Horn antenna	Schwarzbeck Mess-Elektronik	SHF-EHF Horn, 15-40GHz	2018-03	2021-03
1-0781	Pre amplifier	Schwarzbeck Mess-Elektronik	BBV 9721	2017-09	2018-09
1-0782	Antenna cable	Huber & Suhner	FB142A	2015-07	2018-07
1-0789	High Pass Filter	Mini Circuits	VHF-1320+ 1700-3800 MHz	2016-09	2019-09
1-0790	High Pass Filter	Mini Circuits	VHF-3100+ 3400-9900MHz	2016-09	2019-09
1-0791	High Pass Filter	Mini Circuits	VHF-740+ 900-2200MHz	2016-09	2019-09
1-0870	10 dB Attenuator	Mini Circuits	BW-N10W5+	2016-09	2019-09
1-0924	Cable 1m	---	SMA	2016-09	2019-09
1-0925	Cable 1m	---	SMA	2016-09	2019-09
1-0926	Cable 1m	Harbour Industries	SMA	2016-09	2019-09
1-0927	Cable 1m	Harbour Industries	SMA	2016-09	2019-09
1-0966	RF power meter	DARE	RPR3006W	2017-07	2018-07

6 BLOCK DIAGRAM

6.1 Power Line Conducted Emission



6.2 Test Site Radiated Emission



Measurements at 1GHz and above were performed with turntable height 1.5m and with the ground plane covered by absorbers.

Revision history

Version	Date	Comment	Sign
00	2018-04-19	First version	mk