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Wireless Test Report – 387256-4R2TRFWL

Applicant:

Ring LLC

Product name:

Ring

Model:

4HB1V9

FCC ID:

2AEUPBHABV002

Specifications:

FCC 47 CFR Part 15 Subpart E, §15.407

Unlicensed National Information Infrastructure Devises

Date of issue: July 9, 2020

Mark Libbrecht, EMC/Wireless Specialist	
Test engineer(s)	Signature
Kevin Rose, Wireless/EMC Specialist	
Reviewed by	Signature

Lab and Test location(s)

Company name	Nemko Canada Inc. (Cambridge)	
Facility	130 Saltsman Drive, Unit #1 Cambridge, ON Canada, N3E 0B2 Tel: +1 519 680 4811 Test Firm Registration Number: 332406	
Test site registration	**Organization**	**Designation Number**
	FCC/ISED	CA0101
Website	www.nemko.com	

Limits of responsibility

Note that the results contained in this report relate only to the items tested and were obtained in the period between the date of initial receipt of samples and the date of issue of the report.
This test report has been completed in accordance with the requirements of ISO/IEC 17025. All results contain in this report are within Nemko Canada's ISO/IEC 17025 accreditation.

Copyright notification

Table of contents

Section 1. Report summary

1.1 Applicant and manufacturer

Company name	Ring LLC
Address	1523 26th Street, Santa Monica, CA, United States, 90404

1.2 Test specifications

FCC 47 CFR Part 15, Subpart E, Clause 15.407	Unlicensed National Information Infrastructure Devises

1.3 Test methods

789033 D02 General UNII Test Procedures New Rules v02r01 (December 14, 2017)	Guidelines for Compliance Testing of Unlicensed National Information Infrastructure (U-NII) Devices Part 15, Subpart E
ANSI C63.10 v2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

1.4 Exclusions

TPC not applicable as maximum EIRP is less than 500 mW

1.5 Statement of compliance

In the configuration tested, the EUT was found compliant.

Testing was completed against all relevant requirements of the test standard or as per detailed in the section 1.3 Exclusions above. Results obtained indicate that the product under test complies in full with the requirements tested. The test results relate only to the items tested.

See “Summary of test results” for full details.

1.6 Test report revision history

Table 1.6-1: Test report revision history

Revision #	Date of issue	Details of changes made to test report
TRF	November 25, 2019	Original report issued
1RTRF	December 5, 2019	Update 40 MHz channel designator according to IEEE channel plan in section 3.5
R2TRF	July 9, 2020	Updated product model and description/theory of operation

Section 2. Summary of test results

2.1 Testing period

Test start date	November 8, 2019
Test end date	November 18, 2019

2.2 FCC Part 15 Subpart C, general requirements test results

Table 2.2-1: *FCC general requirements results*

Part	Test description	Verdict
§15.207(a)	Conducted limits	Pass
§15.31(e)	Variation of power source	Pass
§15.31(m)	Number of tested frequencies	Pass
§15.203	Antenna requirement	Pass

2.3 FCC Part 15 Subpart E, test results

Table 2.3-1: *FCC Part 15, Subpart E, results*

Part	Test description	Verdict
§15.403(i)	Emission bandwidth	Pass
§15.407(a)(2)	Power and density limits within 5.25–5.35 GHz and 5.47–5.725 GHz bands	Pass
§15.407(b)(3)	Undesirable emission limits for 5.47–5.725 GHz bands	Pass
§15.407(b)(6)	Conducted limits for U-NII devices using an AC power line	Pass
§15.407(g)	Frequency stability	Pass
§15.407(h)(2)[1]	Dynamic Frequency Selection (DFS)	Pass

Note: [1] See DFS Test results in separate test report, Reference ID: 387256-12TRFWL

Section 3. Equipment under test (EUT) details

3.1 Sample information

Receipt date	October 15, 2019
Nemko sample ID number	Item # 1 (conducted sample) and Item # 3 (radiated sample)

3.2 EUT information

Product name	Ring
Model	4HB1V9
Serial number	Item # 1 (conducted sample), Item # 2 (radiated sample)

3.3 Technical information

Frequency band	5470–5725 MHz
Frequency Min (MHz)	5500 (20 MHz), 5510 (40 MHz)
Frequency Max (MHz)	5700 (20 MHz), 5670 (40 MHz)
RF power Min (W),	N/A
RF power Max (W), Conducted	0.022 (13.4 dBm) 20 MHz, 0.022 (13.4 dBm) 40 MHz
Field strength, Units @ distance	N/A
Measured EBW (MHz) (26 dB)	19.6 (20MHz), 43.2 (40 MHz)
Calculated BW (kHz), as per TRC-43	N/A
Type of modulation	802.11a (20 MHz), 802.11n (40 MHz)
Emission classification (F1D, G1D, D1D)	W7D
Transmitter spurious, Units @ distance	5470 MHz, 64.9 dBµV/m (Peak) 51.7 dBµV/m (average) @ 3 m
Power requirements	5 V_{DC} (via external 100-240 VAC, 50/60 Hz power adapter)
Antenna information	Antenna Gain = 2.35 dBi Antenna type = Inverted F The EUT uses a unique antenna coupling/ non-detachable antenna to the intentional radiator.

3.4 Product description and theory of operation

Communications device using LTE, BLE, Wi-Fi, ZigBee, Z-Wave, and SimpleLink (TI1310) technologies.

3.5 EUT exercise details

The EUT was setup in continuous transmit state.
802.11a Power setting channel 100 = 16
802.11a Power setting channel 104, 116 and 136= 17
802.11a Power setting channel 140 = 15
802.11n Power setting for channel 102 =12
802.11n Power setting for channel 134 =13
802.11n Power setting for channel 142 (Straddle channel) = 16
802.11n Power setting for channel 110, 118 and 126 = 14

3.6 EUT setup diagram

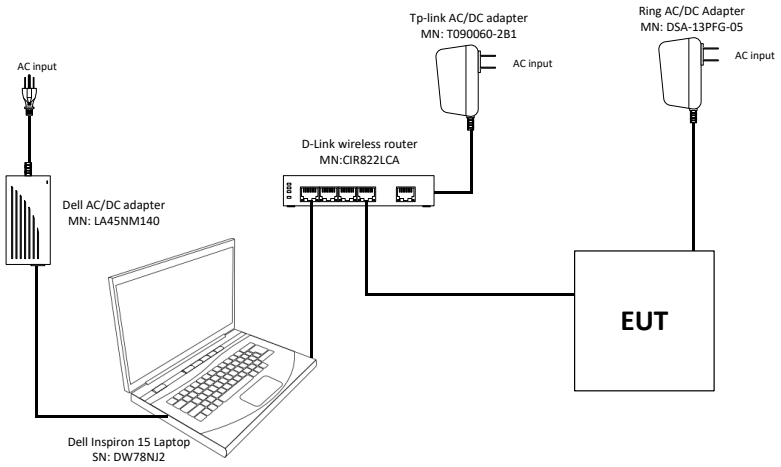


Figure 3.6-1: Setup diagram

3.7 EUT sub assemblies

Table 3.7-1: EUT sub assemblies

Description	Brand name	Model/Part number	Serial number
AC/DC Adapter	Ring	DSA-13PFG-05	BHAB11930DV047164
Laptop	Dell	Inspiron 15	DW78NJ2
Wireless router	D-Link	CIR822LCA	RZSC3IA001646

Section 4. Engineering considerations

4.1 Modifications incorporated in the EUT for compliance

There were no modifications performed to the EUT during this assessment.

4.2 Technical judgment

None

4.3 Deviations from laboratory tests procedures

No deviations were made from laboratory procedures.

Section 5. Test conditions

5.1 Atmospheric conditions

Temperature	15–30 °C
Relative humidity	20–75 %
Air pressure	860–1060 mbar

When it is impracticable to carry out tests under these conditions, a note to this effect stating the ambient temperature and relative humidity during the tests shall be recorded and stated.

5.2 Power supply range

The normal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. For the purpose of the present document, the nominal voltage shall be the declared voltage, or any of the declared voltages ±5 %, for which the equipment was designed.

Section 6. Measurement uncertainty

6.1 Uncertainty of measurement

UKAS Lab 34 and TIA-603-B have been used as guidance for measurement uncertainty reasonable estimations with regards to previous experience and validation of data. Nemko Canada, Inc. follows these test methods in order to satisfy ISO/IEC 17025 requirements for estimation of uncertainty of measurement for wireless products.

Measurement uncertainty budgets for the tests are detailed below. Measurement uncertainty calculations assume a coverage factor of K = 2 with 95% certainty.

Table 6.1-1: Measurement uncertainty

Test name	Measurement uncertainty, dB
All antenna port measurements	0.55
Conducted spurious emissions	1.13
Radiated spurious emissions	3.78
AC power line conducted emissions	3.55

Section 7. Test equipment

7.1 Test equipment list

Table 7.1-1: *Equipment list*

Equipment	Manufacturer	Model no.	Asset no.	Cal./Ver. cycle	Next cal./ver.
3 m EMI test chamber	TDK	SAC-3	FA003012	1 year	Nov. 12/19
Flush mount turntable	SUNAR	FM2022	FA003006	—	NCR
Controller	SUNAR	SC110V	FA002976	—	NCR
Antenna mast	SUNAR	TLT2	FA003007	—	NCR
Receiver/spectrum analyzer	Rohde & Schwarz	ESR26	FA002969	1 year	June 04/20
Spectrum analyzer	Rohde & Schwarz	FSW43	FA002971	1 year	June 21/20
Horn antenna (1–18 GHz)	ETS-Lindgren	3117	FA002911	1 year	Sept. 11/20
Preamp (1–18 GHz)	ETS-Lindgren	124334	FA002956	1 year	Sept. 26/20
Bilog antenna (30–2000 MHz)	SUNAR	JB1	FA003010	1 year	Sept. 17/20
50 Ω coax cable	Huber + Suhner	None	FA003047	1 year	Nov. 12/19
50 Ω coax cable	Huber + Suhner	None	FA003044	1 year	Nov. 12/19
Horn antenna (18-40 GHz)	ETS-Lindgren	3116B	FA002948	1 year	July 09/20
Two-line v-network	Rohde & Schwarz	ENV216	FA002964	1 year	June 20/20
50 Ω coax cable	Rohde & Schwarz	None	FA003074	1 year	Dec. 21/19
AC Power source	Chroma	61605	FA003034	—	VOU

Notes: NCR - no calibration required, VOU - verify on use

Section 8. Testing data

8.1 FCC 15.31(e) Variation of power source

8.1.1 Definitions and limits

FCC §15.31:

(e) For intentional radiators, measurements of the variation of the input power or the radiated signal level of the fundamental frequency component of the emission, as appropriate, shall be performed with the supply voltage varied between 85% and 115% of the nominal rated supply voltage. For battery operated equipment, the equipment tests shall be performed using a new battery.

8.1.2 Test date

Start date	November 13, 2019

8.1.3 Observations, settings and special notes

The testing was performed as per ANSI C63.10 Section 5.13.

a) Where the device is intended to be powered from an external power adapter, the voltage variations shall be applied to the input of the adapter provided with the device at the time of sale. If the device is not marketed or sold with a specific adapter, then a typical power adapter shall be used.
b) For devices where operating at a supply voltage deviating ±15% from the nominal rated value may cause damages or loss of intended function, test to minimum and maximum allowable voltage per manufacturer's specification and document in the report.
c) For devices with wide range of rated supply voltage, test at 15% below the lowest and 15% above the highest declared nominal rated supply voltage.
d) For devices obtaining power from an input/output (I/O) port (USB, firewire, etc.), a test jig is necessary to apply voltage variation to the device from a support power supply, while maintaining the functionalities of the device.

For battery-operated equipment, the equipment tests shall be performed using a variable power supply.

8.1.4 Test data

The EUT AC Input supply voltage was varied between 85% and 115% of the nominal rated supply voltage. No change to transmitter performance was observed.

8.2 FCC 15.31(m) Number of frequencies

8.2.1 Definitions and limits

FCC §15.31:

(m) Measurements on intentional radiators or receivers, other than TV broadcast receivers, shall be performed and, if required, reported for each band in which the device can be operated with the device operating at the number of frequencies in each band specified in the following table:

Table 8.2-1: Frequency Range of Operation

Frequency range over which the device operates (in each band)	Number of test frequencies required	Location of measurement frequency inside the operating frequency range
1 MHz or less	1	Center (middle of the band)
1–10 MHz	2	1 near high end, 1 near low end
Greater than 10 MHz	3	1 near high end, 1 near center and 1 near low end

Notes: "near" means as close as possible to or at the centre / low end / high end of the frequency range over which the device operates.

8.2.2 Test date

Start date	November 8, 2019

8.2.3 Observations, settings and special notes

Per ANSI C63.10 Subclause 5.6.2.1:

The number of channels tested can be reduced by measuring the center channel bandwidth first and then applying the following relaxations as appropriate:

a) For each operating mode, if the measured channel bandwidth on the middle channel is at least 150% of the minimum permitted bandwidth, then it is not necessary to measure the bandwidth on the high and low channels.
b) For multiple-input multiple-output (MIMO) systems, if the measured channel bandwidth on testing the middle channel exceeds the minimum permitted bandwidth by more than 50% on one transmit chain, then it is not necessary to repeat testing on the other chains.
c) If the measured channel bandwidth on the middle channel is less than 50% of the maximum permitted bandwidth, then it is not necessary to measure the bandwidth on the high and low channels.

Per ANSI C63.10 Subclause 5.6.2.2:

For devices with multiple operating modes, measurements on the middle channel can be used to determine the worst-case mode(s). The worst-case modes are as follows:

a) Band edge requirements—Measurements on the mode with the widest bandwidth can be used to cover the same channel (center frequency) on modes with narrower bandwidth that have the same or lower output power for each modulation family (e.g., OFDM and direct sequence spread spectrum).
b) Spurious emissions—Measure the mode with the highest output power and the mode with the highest output power spectral density for each modulation family (e.g., OFDM and direct sequence spread spectrum).
c) In-band PSD—Measurements on the mode with the narrowest bandwidth can be used to cover all modes within the same modulation family of an equal or lower output power provided the result is less than 50% of the limit.

8.2.4 Test data

Table 8.2-2: *Test channels selection 20 MHz channels*

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
5470	5725	255	5500	5580	5700

Table 8.2-3: *Test channels selection 40 MHz channels*

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
5470	5725	255	5510	5590	5710

8.3 FCC 15.203 Antenna requirement

8.3.1 Definitions and limits

FCC §15.203:

An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with §15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this part are not exceeded.

8.3.2 Test date

Start date	November 8, 2019

8.3.3 Observations, settings and special notes

None

8.3.4 Test data

- The EUT has an internal integrated antenna, non-detachable.
- The EUT will not be professionally installed

8.4 FCC 15.207(a) AC power line conducted emissions limits

8.4.1 Definitions and limits

FCC §15.207:

a) Except as shown in paragraphs (b) and (c) of this section, for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50 µH/50 Ω line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

ANSI: C63.10 subclause 6.2
If the EUT normally receives power from another device that in turn connects to the public utility ac power lines, measurements shall be made on that device with the EUT in operation to demonstrate that the device continues to comply with the appropriate limits while providing the EUT with power. If the EUT is
operated only from internal or dedicated batteries, with no provisions for connection to the public utility ac power lines (600 VAC or less) to operate the EUT (such as an adapter), then ac power-line conducted measurements are not required.
For direct current (dc) powered devices where the ac power adapter is not supplied with the device, an "off-the-shelf" unmodified ac power adapter shall be used. If the device is supposed to be installed in a host (e.g., the device is a module or PC card), then it is tested in a typical compliant host.

Table 8.4-1: *AC power line conducted emissions limit*

Frequency of emission, MHz	Conducted limit, dBµV	
	Quasi-peak	Average**
0.15–0.5	66 to 56*	56 to 46*
0.5–5	56	46
5–30	60	50

Notes: * - The level decreases linearly with the logarithm of the frequency.
** - A linear average detector is required.

8.4.2 Test date

Start date	November 11, 2019

8.4.3 Observations, settings and special notes

Port under test – Coupling device	AC Input – Artificial Mains Network (AMN)
EUT power input during test	5 V_{DC} (Powered via external power adapter @ 120 V_{AC} 60 Hz)
EUT setup configuration	Table top
Measurement details	– A preview measurement was generated with the receiver in continuous scan mode. Emissions detected within 10 dB or above the limit were re-measured with the appropriate detector against the correlating limit and recorded as the final measurement. No conducted emissions were overserved within 10 dB of limit. – The spectral plots have been corrected with transducer factors.

Receiver settings:

Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	Peak and Average (Preview measurement), Quasi-peak and CAverage (Final measurement)
Trace mode	Max Hold
Measurement time	– 100 ms (Peak and Average preview measurement) – 100 ms (Quasi-peak final measurement) – 160 ms (CAverage final measurement)

8.4.4 Test data

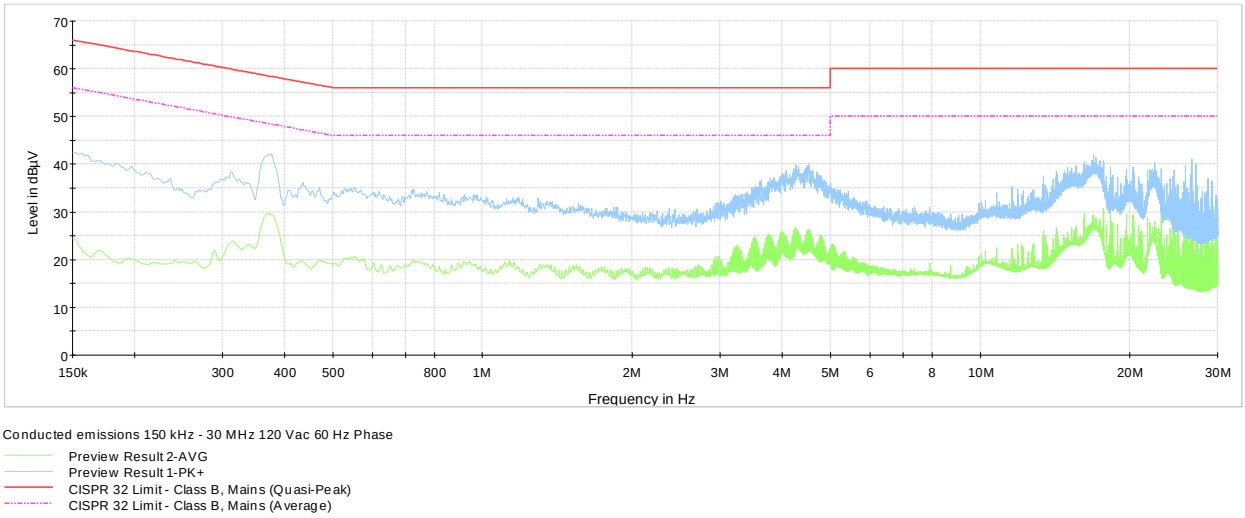


Figure 8.4-1: *AC power line conducted emissions – spectral plot on phase line*

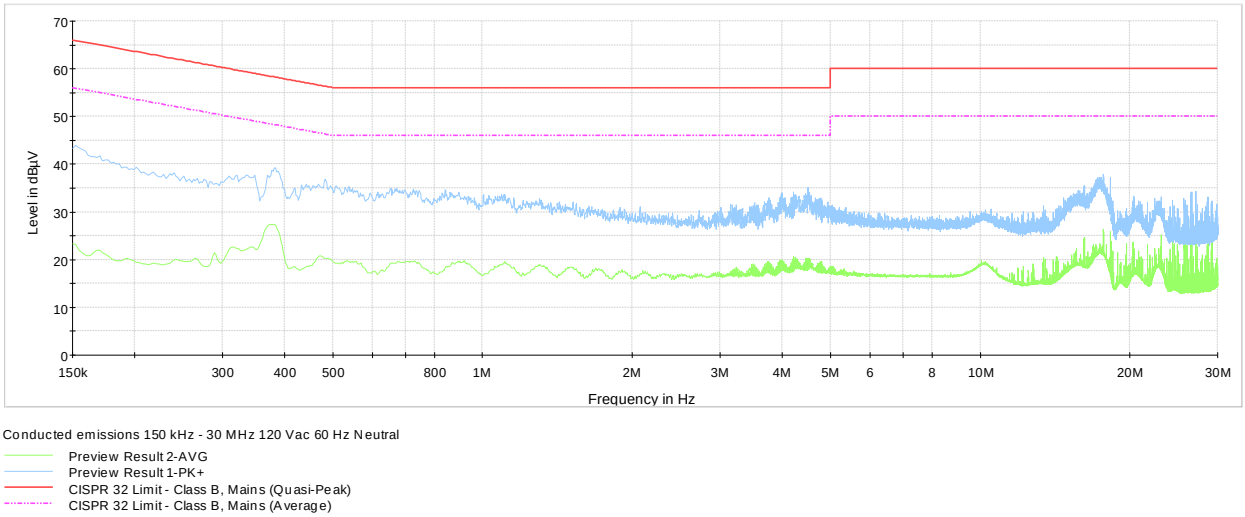


Figure 8.4-2: *AC power line conducted emissions – spectral plot on neutral line*

8.5 FCC 15.403(i) Emission bandwidth

8.5.1 Definitions and limits

For purposes of this subpart the emission bandwidth shall be determined by measuring the width of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, that are 26 dB down relative to the maximum level of the modulated carrier. Determination of the emissions bandwidth is based on the use of measurement instrumentation employing a peak detector function with an instrument resolution bandwidth approximately equal to 1.0 percent of the emission bandwidth of the device under measurement.

8.5.2 Test date

Start date	November 15, 2019

8.5.3 Observations, settings and special notes

Spectrum analyser settings for 26 dB EBW:

Resolution bandwidth	approximately 1% of the emission bandwidth
Video bandwidth	> RBW
Detector mode	Peak
Trace mode	Max Hold

Spectrum analyser settings for 99% OBW:

Resolution bandwidth:	1 – 5 % of OBW
Video bandwidth:	≥3 × RBW
Detector mode:	Peak
Trace mode:	Max Hold

8.5.4 Test data

Table 8.5-1: 26 dB bandwidth results

Modulation	Frequency, MHz	26 dB bandwidth, MHz
802.11a	5500	19.6
	5580	19.4
	5700	19.3
802.11n	5500	41.0
	5590	40.8
	5710	43.2

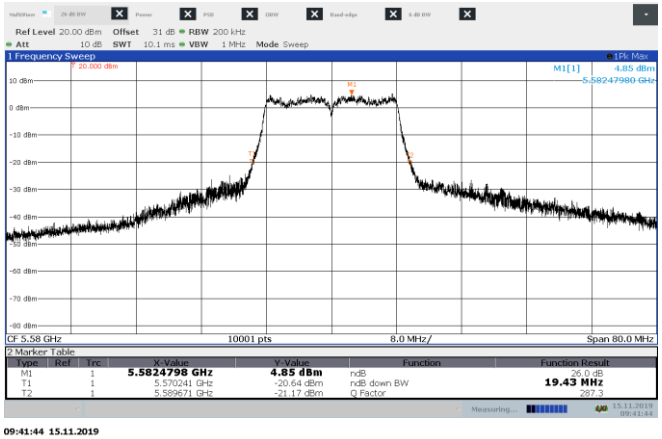


Figure 8.5-1: *26 dB bandwidth on 802.11a, sample plot*

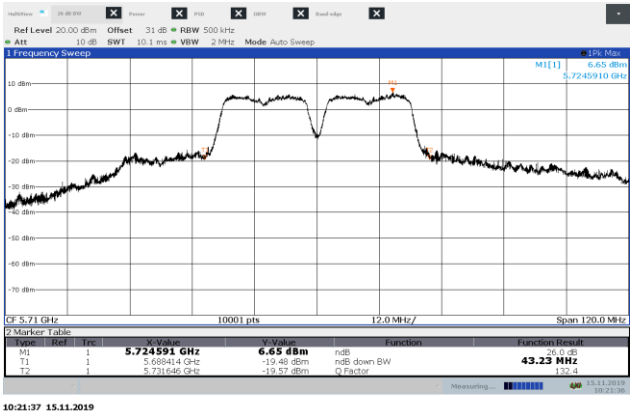


Figure 8.5-2: *26 dB bandwidth on 802.11n, sample plot*

8.5.4 Test data, continued

Table 8.5-2: 99 % bandwidth results

Modulation	Frequency, MHz	99 % occupied bandwidth, MHz
802.11a	5500	16.9
	5580	16.9
	5700	16.9
802.11n	5510	37.3
	5590	37.3
	5710	38.1

Note: 99% Occupied bandwidth is provided for information purposes only

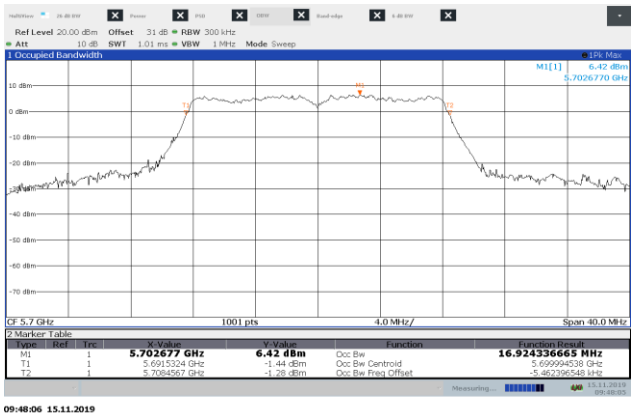


Figure 8.5-3: *99% Occupied bandwidth on 802.11a, sample plot*

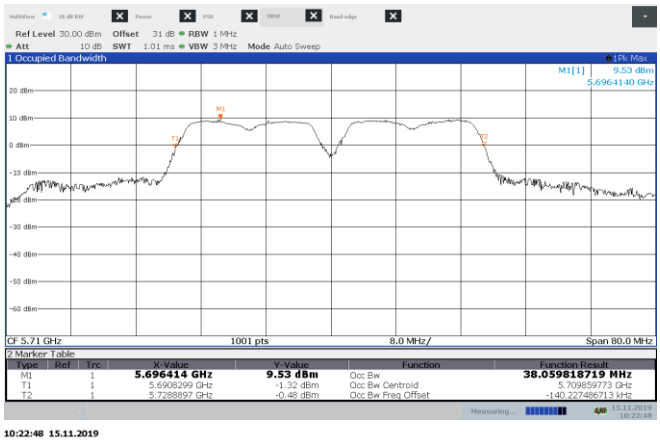


Figure 8.5-4: *99% Occupied bandwidth on 802.11n, sample plot*

8.6 FCC 15.407(a)(2) 5.470–5.725 GHz band output power and spectral density limits

8.6.1 Definitions and limits

The maximum conducted output power over the frequency bands of operation shall not exceed the lesser of 250 mW (24 dBm) or 11 dBm + 10 $\log_{10}$ (B), where B is the 26 dB emission bandwidth in megahertz. In addition, the maximum power spectral density shall not exceed 11 dBm in any 1 megahertz band. If transmitting antennas of directional gain greater than 6 dBi are used, both the maximum conducted output power and the maximum power spectral density shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

FCC §15.407(h)(1) Transmit power control (TPC).
U-NII devices shall employ a TPC mechanism. The U-NII device is required to have the capability to operate at least 6 dB below the mean EIRP value of 30 dBm. A TPC mechanism is not required for systems with an e.i.r.p. of less than 500 mW.

8.6.2 Test date

Start date	November 15, 2019

8.6.3 Observations, settings and special notes

EUT set to transmit continuously with duty cycle ≥ 98%.

KDB 789033 section E.2(b) method SA-1 referenced for power measurements
KDB 789033 section F.5 referenced for PSD measurements with reduced RBW, integrated over 1 MHz

The maximum measured 26 dB emission bandwidth for 802.11a was 19.6 MHz, and for 802.11n was 43.2 MHz.
FCC output power limit for 802.11a was calculated as follows: 11 dBm + 10 × log10 (19.6) = 23.9 dBm < 24 dBm, therefore the limit is 23.9 dBm
FCC output power limit for 802.11n was calculated as follows: 11 dBm + 10 × log10 (43.2) = 27.4 dBm > 24 dBm, therefore the limit is 24 dBm

Spectrum analyser settings for PSD:

Resolution bandwidth:	100 kHz
Video bandwidth:	≥3 × RBW
Detector mode:	RMS
Trace mode:	Average
Trace counts:	100

Spectrum analyser settings for Output Power:

Resolution bandwidth:	1 MHz
Video bandwidth:	≥3 × RBW
Detector mode:	RMS
Trace mode:	Average
Trace counts:	100

8.6.4 Test data

Table 8.6-1: *Output power measurements results*

Modulation	Frequency, MHz	Conducted output power, dBm	Power limit, dBm	Margin, dB
802.11a	5500	11.8	23.9	12.1
	5580	13.4	23.9	10.5
	5700	11.0	23.9	12.9
802.11n	5510	9.0	24.0	15.0
	5590	11.8	24.0	12.2
	5710	13.4	24.0	10.6

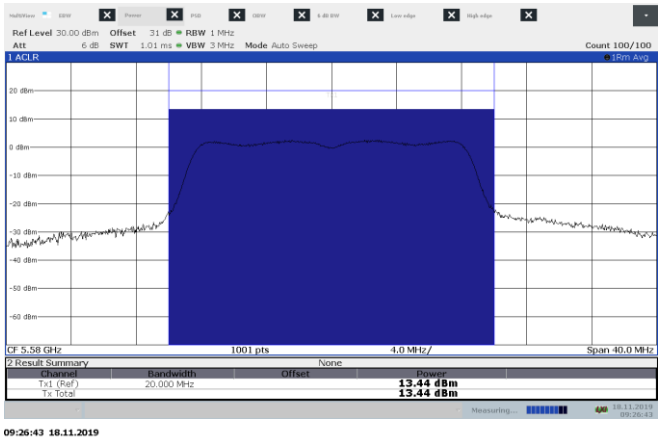


Figure 8.6-1: *Sample plot for power on 802.11a*

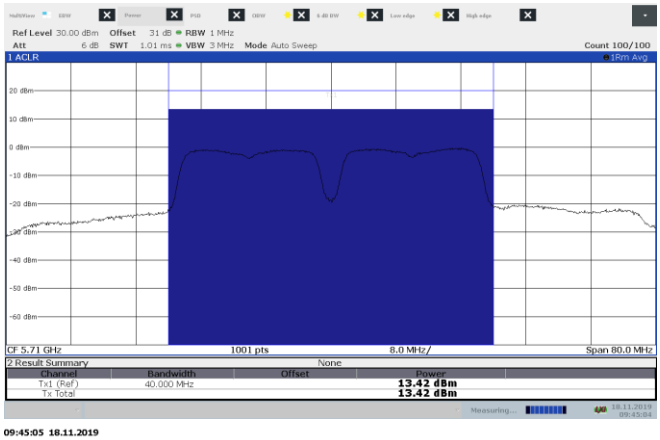


Figure 8.6-2: *Sample plot for power on 802.11n*

8.6.4 Test data, continued

Table 8.6-2: *PSD measurements results*

Modulation	Frequency, MHz	PSD, dBm/MHz	PSD limit, dBm/MHz	Margin, dB
802.11a	5500	0.4	11.0	10.6
	5580	2.2	11.0	8.8
	5700	-0.6	11.0	11.6
802.11n	5510	-4.8	11.0	15.8
	5590	-1.8	11.0	12.8
	5710	-0.5	11.0	11.5

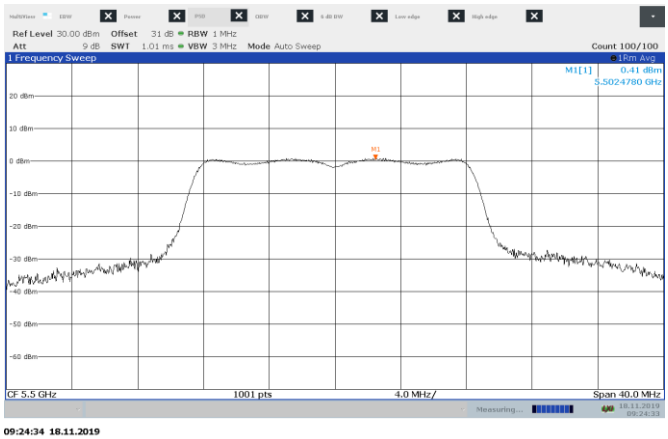


Figure 8.6-3: *Sample plot for PSD on 802.11a*

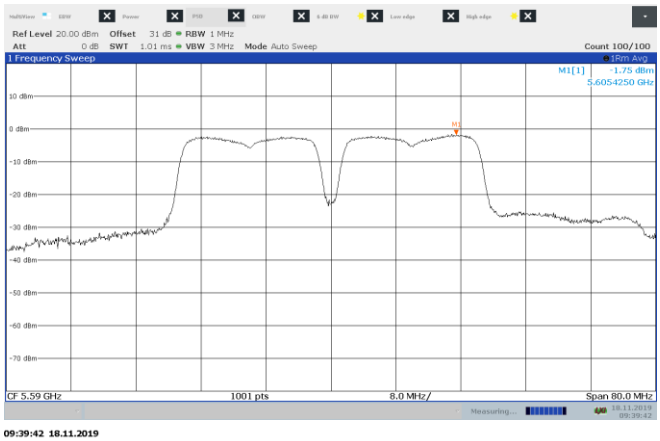


Figure 8.6-4: *Sample plot for PSD on 802.11n*

8.7 FCC 15.407(b) Undesirable (unwanted) emissions

8.7.1 Definitions and limits

FCC:

KDB 789033 III (B)(b)(iii)
Straddle channels 138, 142 and 144 are considered to be operating in both U-NII-2C and U-NII-3. The worst case out-of-band emission limit, i.e., −27 dBm/MHz peak EIRP, applies at the band edges. The band edges are considered to be 5.47 GHz and 5.85 GHz

(3) For transmitters operating in the 5.470–5.725 GHz band: all emissions outside of the 5.470–5.725 GHz band shall not exceed an EIRP of −27 dBm/MHz.
(5) The emission measurements shall be performed using a minimum resolution bandwidth of 1 MHz. A lower resolution bandwidth may be employed near the band edge, when necessary, provided the measured energy is integrated to show the total power over 1 MHz.
(6) Unwanted emissions below 1 GHz must comply with the general field strength limits set forth in § 15.209.
(7) The provisions of § 15.205 apply to intentional radiators operating under this section.
(8) When measuring the emission limits, the nominal carrier frequency shall be adjusted as close to the upper and lower frequency block edges as the design of the equipment permits.

Table 8.7-1: *FCC §15.209– Radiated emission limits*

Frequency, MHz	Field strength of emissions		Measurement distance, m
	µV/m	dBµV/m	
0.009–0.490	2400/F	$67.6 – 20 \times \log_{10}(F)$	300
0.490–1.705	24000/F	$87.6 – 20 \times \log_{10}(F)$	30
1.705–30.0	30	29.5	30
30–88	100	40.0	3
88–216	150	43.5	3
216–960	200	46.0	3
above 960	500	54.0	3

Notes: In the emission table above, the tighter limit applies at the band edges.
For frequencies above 1 GHz the limit on peak RF emissions is 20 dB above the maximum permitted average emission limit applicable to the equipment under test

Table 8.7-2: *FCC §15.205 restricted frequency bands*

MHz	MHz	MHz	GHz
0.090–0.110	16.42–16.423	399.9–410	4.5–5.15
0.495–0.505	16.69475–16.69525	608–614	5.35–5.46
2.1735–2.1905	16.80425–16.80475	960–1240	7.25–7.75
4.125–4.128	25.5–25.67	1300–1427	8.025–8.5
4.17725–4.17775	37.5–38.25	1435–1626.5	9.0–9.2
4.20725–4.20775	73–74.6	1645.5–1646.5	9.3–9.5
6.215–6.218	74.8–75.2	1660–1710	10.6–12.7
6.26775–6.26825	108–121.94	1718.8–1722.2	13.25–13.4
6.31175–6.31225	123–138	2200–2300	14.47–14.5
8.291–8.294	149.9–150.05	2310–2390	15.35–16.2
8.362–8.366	156.52475–156.52525	2483.5–2500	17.7–21.4
8.37625–8.38675	156.7–156.9	2690–2900	22.01–23.12
8.41425–8.41475	162.0125–167.17	3260–3267	23.6–24.0
12.29–12.293	167.72–173.2	3332–3339	31.2–31.8
12.51975–12.52025	240–285	3345.8–3358	36.43–36.5
12.57675–12.57725	322–335.4	3600–4400	Above 38.6
13.36–13.41			

8.7.2 Test date

Start date	November 13, 2019

8.7.3 Observations, settings and special notes

- The spectrum was searched from 30 MHz to 40 GHz.
  EUT was set to transmit with 100 % duty cycle.
- Radiated measurements from 30 MHz to 18 GHz were performed at a distance of 3 m.
- Radiated measurements from 18 to 40 GHz were performed at a distance of 30 cm.
- No transmitter related radiated emissions were detected below 1 GHz. Emissions detected within restricted bands that were close to the limit were found to be digital emissions.
- Conducted spurious EIRP emission limit line calculated as follows: -27 dBm EIRP – Antenna Gain (2.35 dBi) = -29.35 dBm

Spectrum analyzer settings for measurements below 1 GHz:

Detector mode	Peak or Quasi-Peak
Resolution bandwidth	100 kHz or 120 kHz
Video bandwidth	300 kHz
Trace mode	Max Hold

Spectrum analyser settings for peak measurements above 1 GHz:

Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Detector mode:	Peak
Trace mode:	Max Hold

Spectrum analyser for average radiated measurements in restricted bands above 1 GHz:

Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Detector mode:	RMS
Trace mode:	Power average
Number of averaging traces:	100

Spectrum analyzer settings for conducted band edge measurements:

Detector mode	Peak
Resolution bandwidth	100 kHz
Video bandwidth	300 kHz
Trace mode	Max Hold

8.7.4 Test data

Table 8.7-3: *Radiated field strength measurement results – Restricted Bands*

Modulation	Frequency, MHz	Peak Field strength, dBµV/m		Margin, dB	Average Field strength, dBµV/m		Margin, dB
		Measured	Limit		Measured	Limit	
802.11a	5460	63.7	74.00	10.3	50.2	54.00	3.8
802.11n	5460	64.9	74.00	9.1	51.7	54.00	2.3

Notes: Field strength includes correction factor of antenna, cable loss, amplifier, and attenuators where applicable.

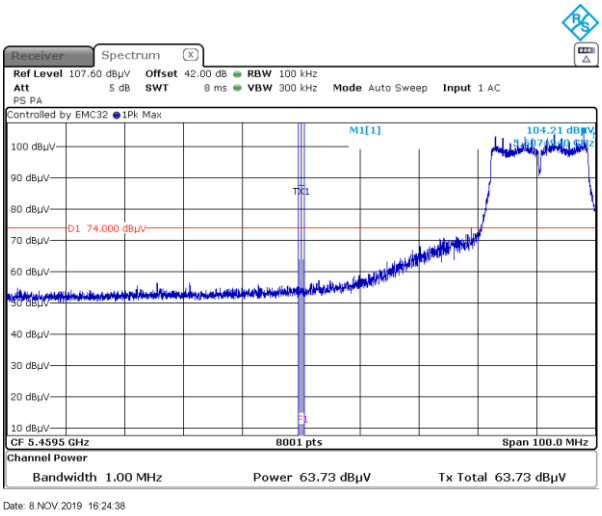


Figure 8.7-1: *Peak spurious emissions within restricted bands at 5.46 GHz, low channel, 802.11a*

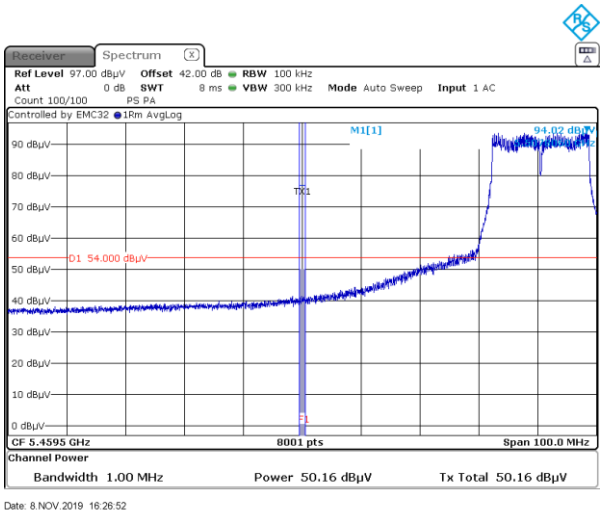


Figure 8.7-2: *Average spurious emissions within restricted bands at 5.46 GHz, low channel, 802.11a*

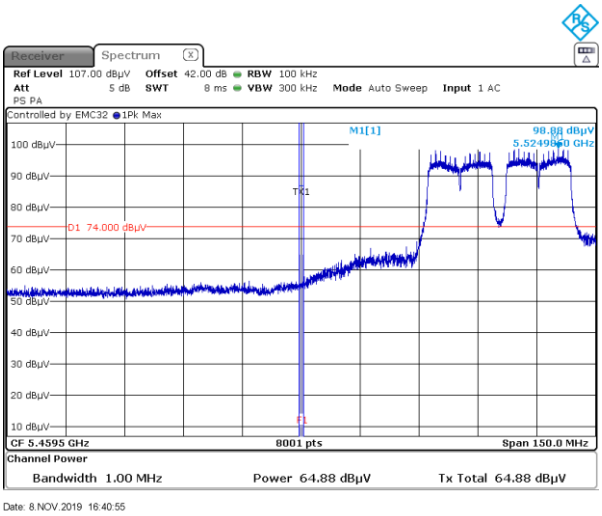


Figure 8.7-3: *Peak spurious emissions within restricted bands at 5.46 GHz, low channel, 802.11n*

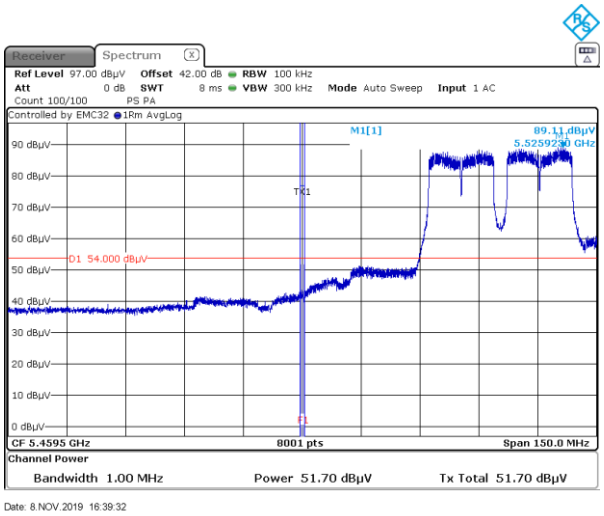


Figure 8.7-4: *Average spurious emissions within restricted bands at 5.46 GHz, low channel, 802.11n*

8.7.4 Test data, continued

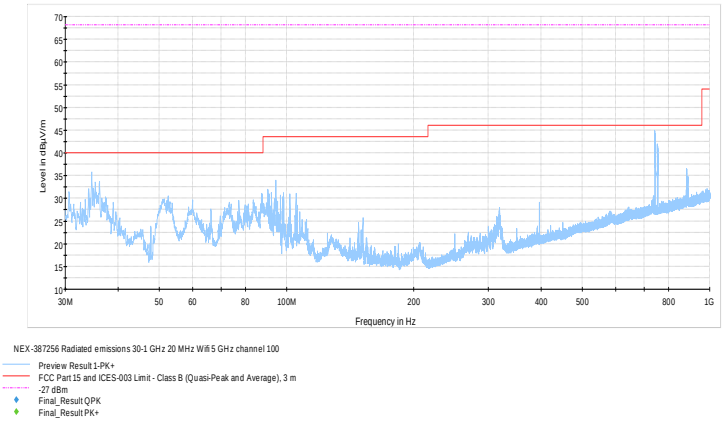


Figure 8.7-5: *Radiated spurious emission 30 MHz to 1 GHz, low channel, 802.11a*

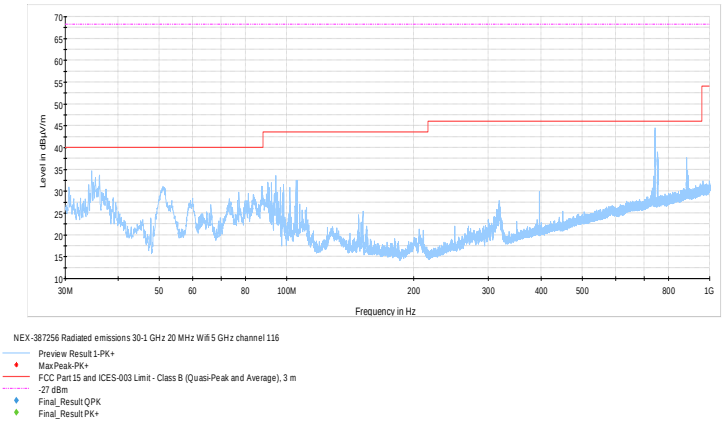


Figure 8.7-6: *Radiated spurious emission 30 MHz to 1 GHz, mid channel, 802.11a*

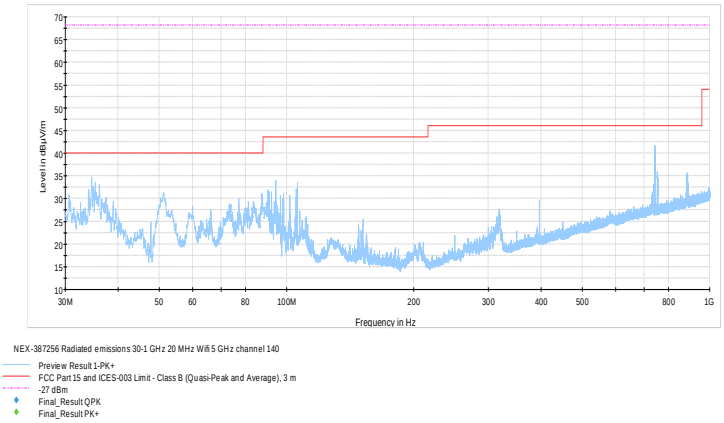


Figure 8.7-7: *Radiated spurious emission 30 MHz to 1 GHz, high channel, 802.11a*

8.7.4 Test data, continued

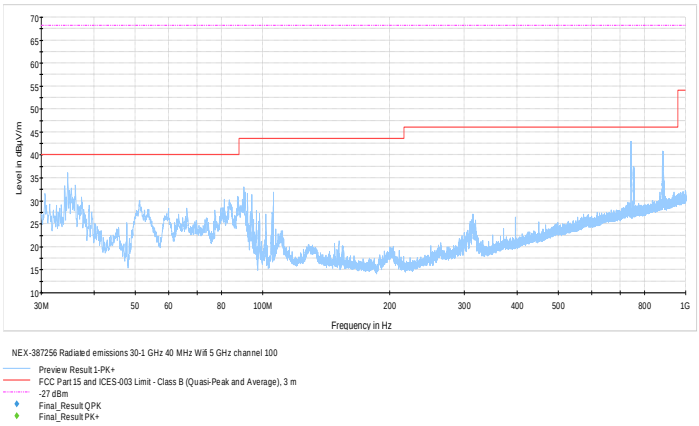


Figure 8.7-8: *Radiated spurious emission 30 MHz to 1 GHz, low channel, 802.11n*

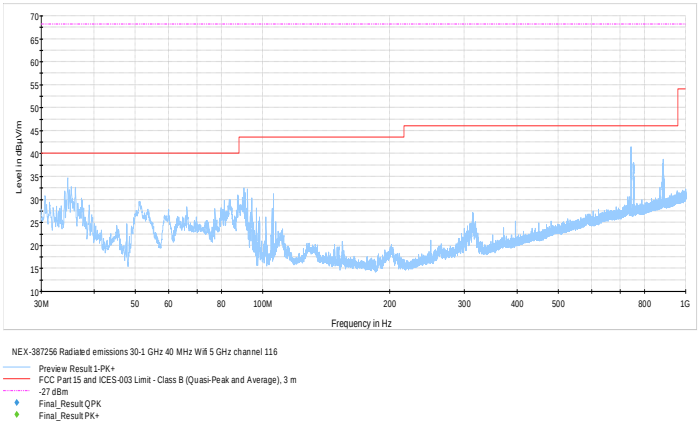


Figure 8.7-9: *Radiated spurious emission 30 MHz to 1 GHz, mid channel, 802.11n*

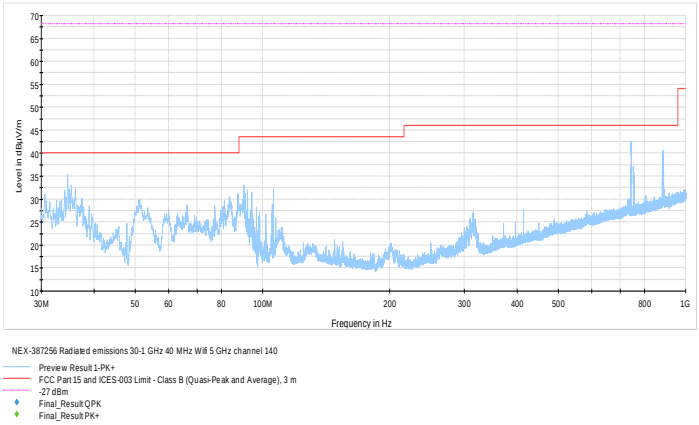


Figure 8.7-10: *Radiated spurious emission 30 MHz to 1 GHz, high channel, 802.11n*

8.7.4 Test data, continued

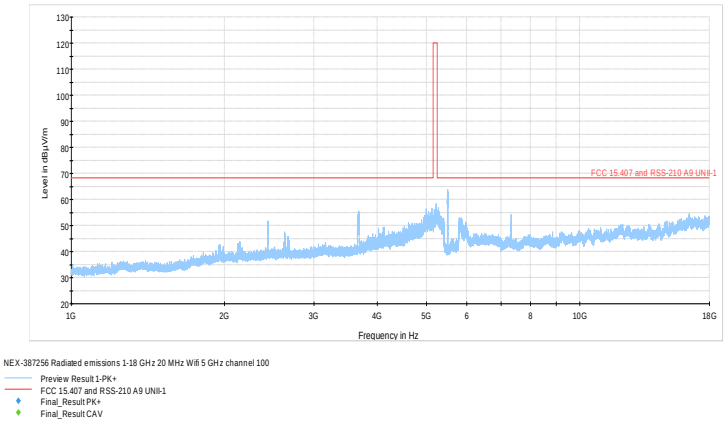


Figure 8.7-11: *Radiated spurious emission 1 to 18 GHz, low channel, 802.11a*

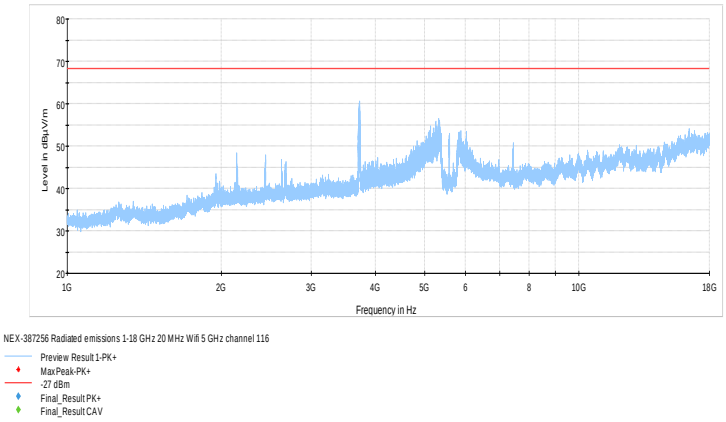


Figure 8.7-12: *Radiated spurious emission 1 to 18 GHz, mid channel, 802.11a*

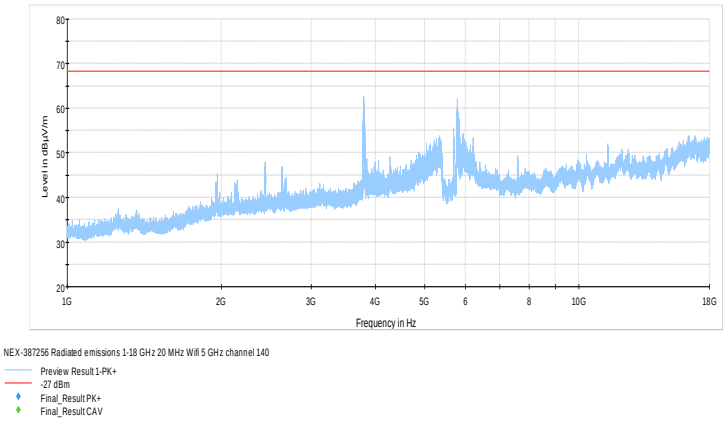


Figure 8.7-13: *Radiated spurious emission 1 to 18 GHz, high channel, 802.11a*

8.7.4 Test data, continued

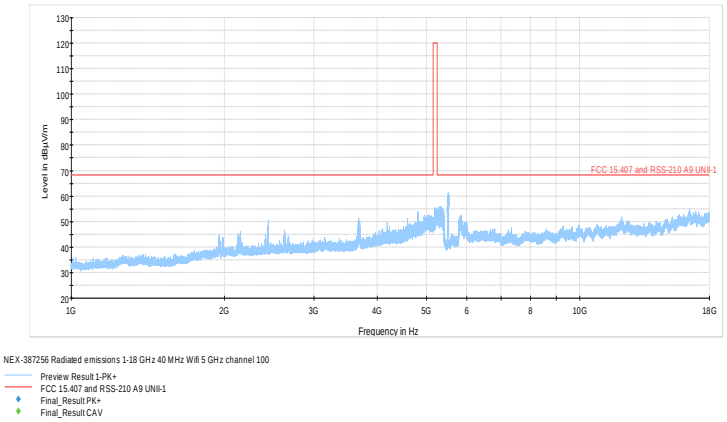


Figure 8.7-14: *Radiated spurious emission 1 to 18 GHz, low channel, 802.11n*

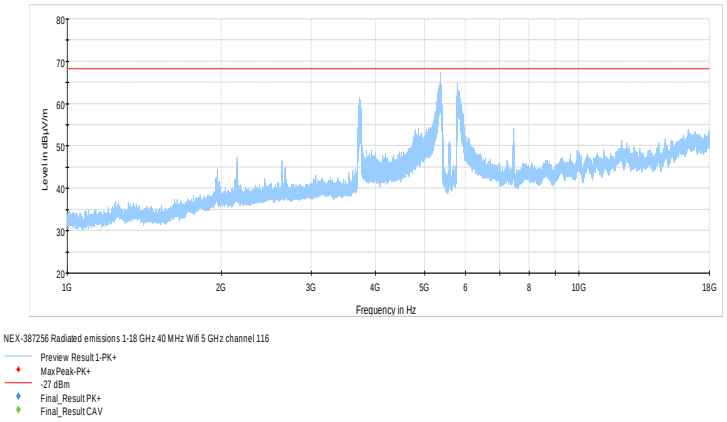


Figure 8.7-15: *Radiated spurious emission 1 to 18 GHz, mid channel, 802.11n*

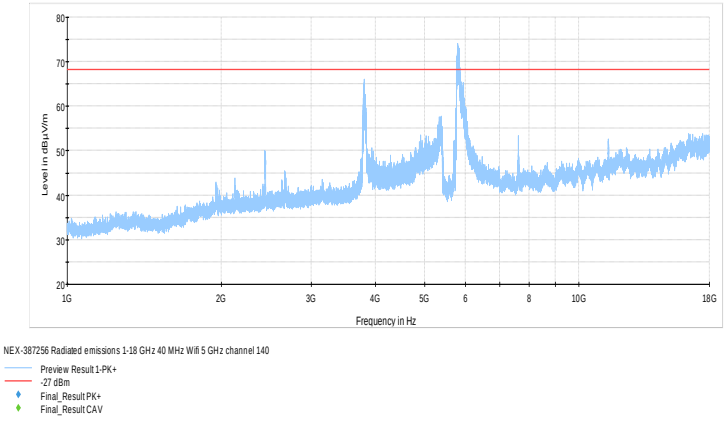


Figure 8.7-16: *Radiated spurious emission 1 to 18 GHz, high channel, 802.11n*

8.7.4 Test data, continued

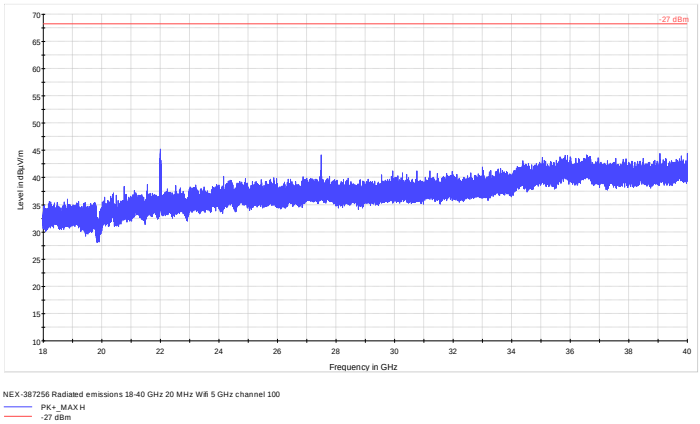


Figure 8.7-17: *Radiated spurious emission 18 to 40 GHz, low channel, 802.11a*

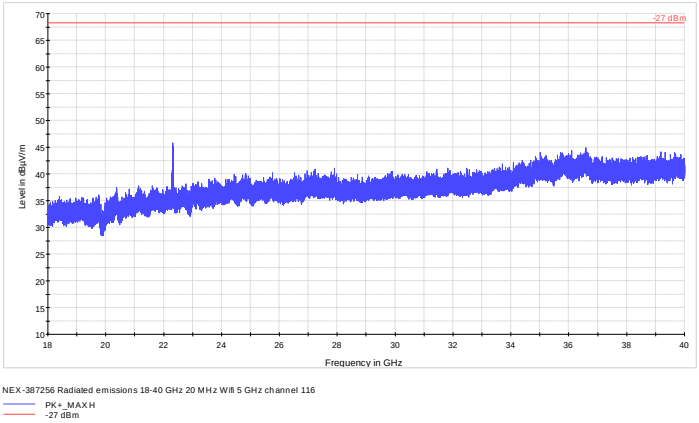


Figure 8.7-18: *Radiated spurious emission 18 to 40 GHz, mid channel, 802.11a*

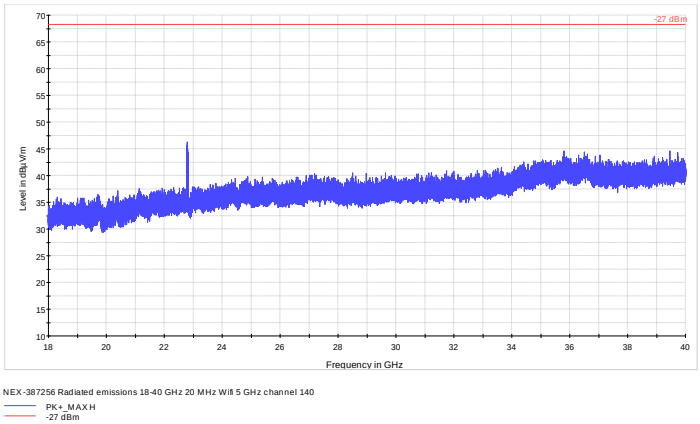


Figure 8.7-19: *Radiated spurious emission 18 to 40 GHz, high channel, 802.11a*

8.7.4 Test data, continued

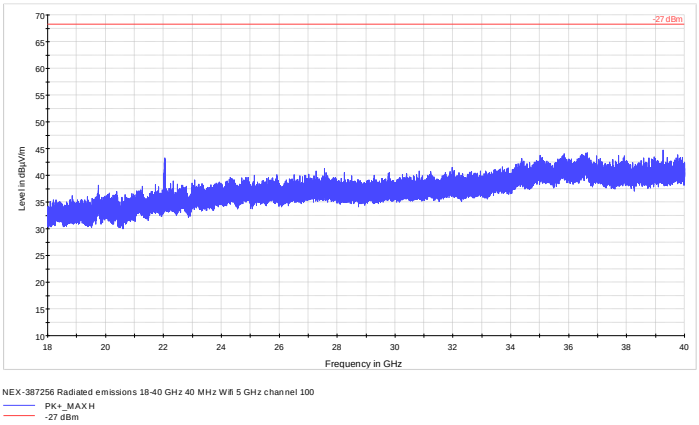


Figure 8.7-20: *Radiated spurious emission 18 to 40 GHz, low channel, 802.11n*

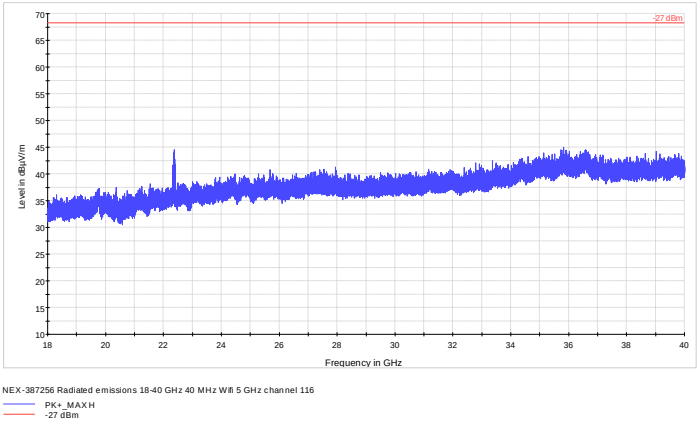


Figure 8.7-21: *Radiated spurious emission 18 to 40 GHz, mid channel, 802.11n*

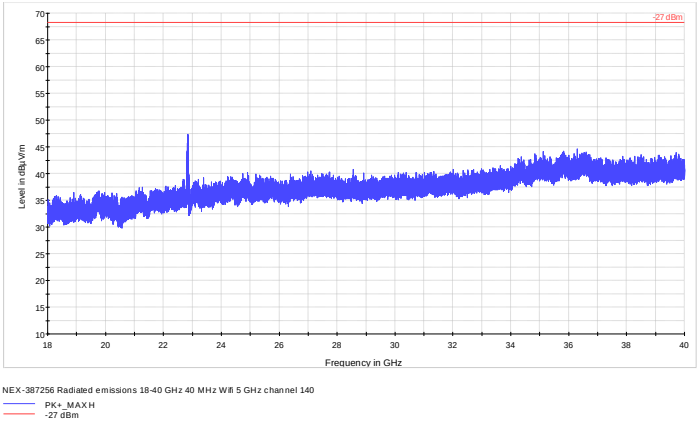


Figure 8.7-22: *Radiated spurious emission 18 to 40 GHz, high channel, 802.11n*

8.7.4 Test data, continued

Table 8.7-4: *Conducted band edge emissions low channel*

Channel	Modulation	Frequency, GHz	Emission strength, dBm/MHz	Antenna Gain, dBi	Emission strength EIRP, dBm/MHz	EIRP limit, dBm/MHz	Margin, dB
100	802.11a	5.47	-31.0	2.35	-28.65	-27	1.65
104	802.11n	5.47	-35.2	2.35	-32.85	-27	5.85
100	802.11n	5.47	-30.8	2.35	-28.45	-27	1.45
108	802.11n	5.47	-33.8	2.35	-31.45	-27	4.45

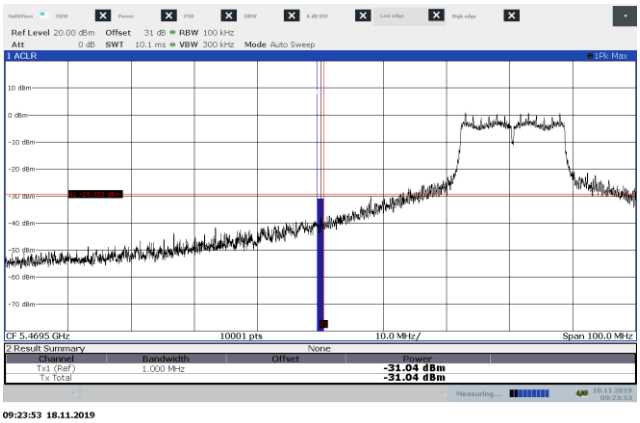


Figure 8.7-23: *Conducted band edge emissions 5.47 GHz, channel 100, 802.11a*

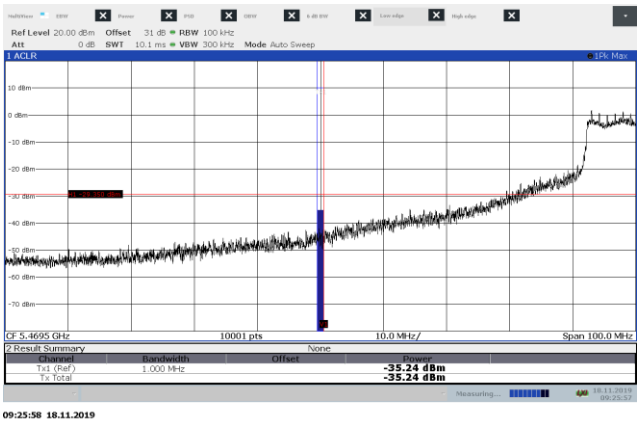


Figure 8.7-24: *Conducted band edge emissions 5.47 GHz, channel 104, 802.11a*

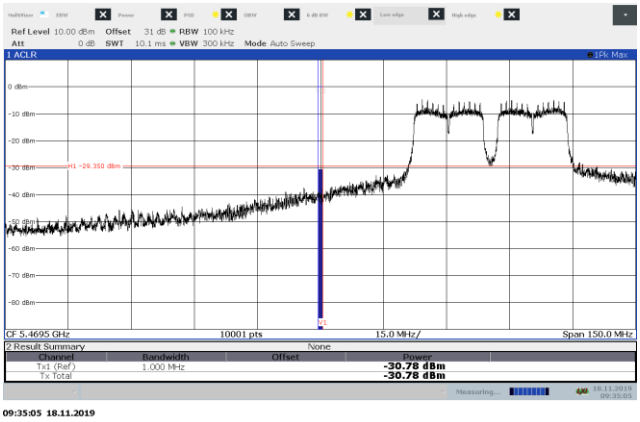


Figure 8.7-25: *Conducted band edge emissions 5.47 GHz, channel 100, 802.11n*

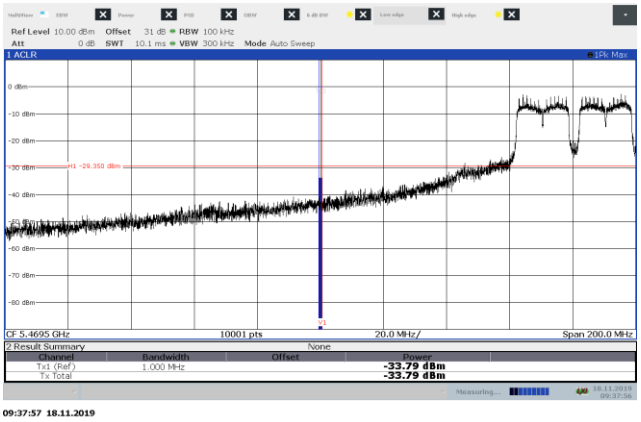


Figure 8.7-26: *Conducted band edge emissions 5.47 GHz, channel 108, 802.11n*

8.7.5 Test data, continued

Table 8.7-5: *Conducted band edge emissions high channel, 802.11a*

Channel	Modulation	Frequency, GHz	Emission strength, dBm/MHz	Antenna Gain, dBi	Emission strength EIRP, dBm/MHz	EIRP limit, dBm/MHz	Margin, dB
140	802.11a	5.725	-31.8	2.35	-29.45	-27	2.45
136	802.11a	5.725	-30.1	2.35	-27.75	-27	0.75

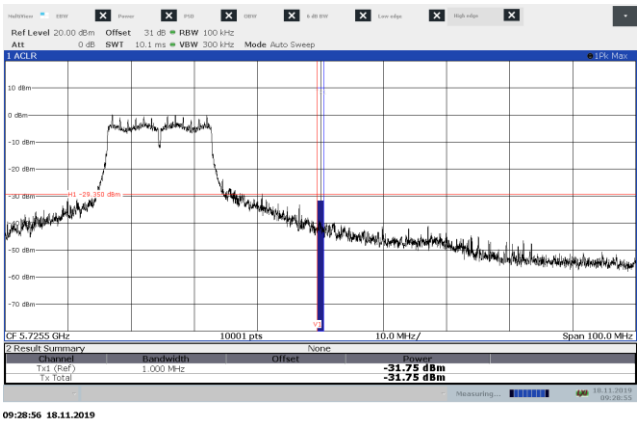


Figure 8.7-27: *Conducted band edge emissions 5.725 GHz, channel 140, 802.11a*

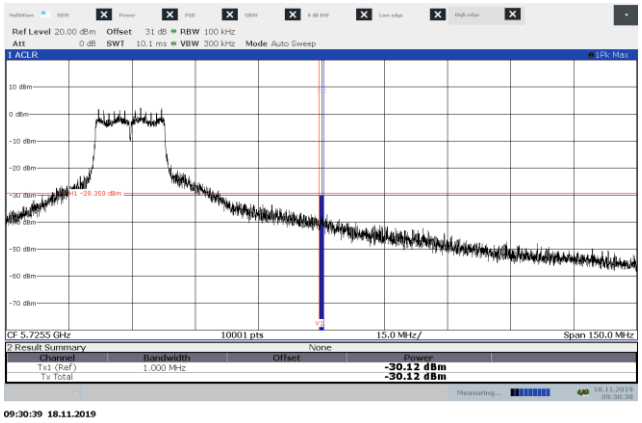


Figure 8.7-28: *Conducted band edge emissions 5.725 GHz, channel 136, 802.11a*

8.7.1 Test data, continued

Table 8.7-6: *Conducted band edge emissions high channel, 802.11n*

Channel	Modulation	Frequency, GHz	Emission strength, dBm/MHz	Antenna Gain, dBi	Emission strength EIRP, dBm/MHz	EIRP limit, dBm/MHz	Margin, dB
132	802.11n	5.725	-32.7	2.35	30.35	-27	3.35
136	802.11n	5.725	-31.3	2.35	28.95	-27	1.95
140	802.11n	5.85	-34.5	2.35	32.15	-27	5.15

Note: Channel 140 using 802.11n modulation is a straddle channel between U-NII-2C and U-NII-3 bands.

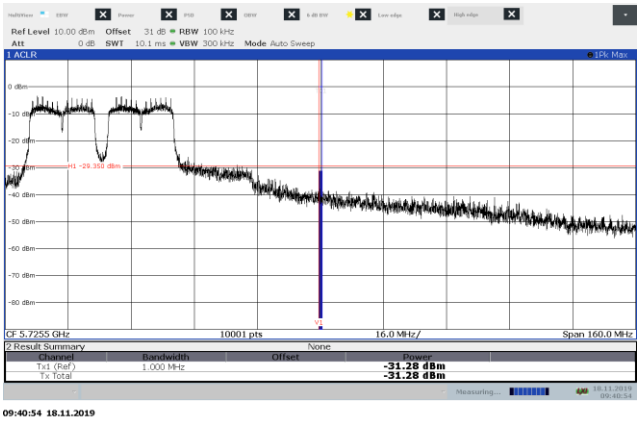


Figure 8.7-29: *Conducted band edge emissions 5.725 GHz, channel 136, 802.11n*

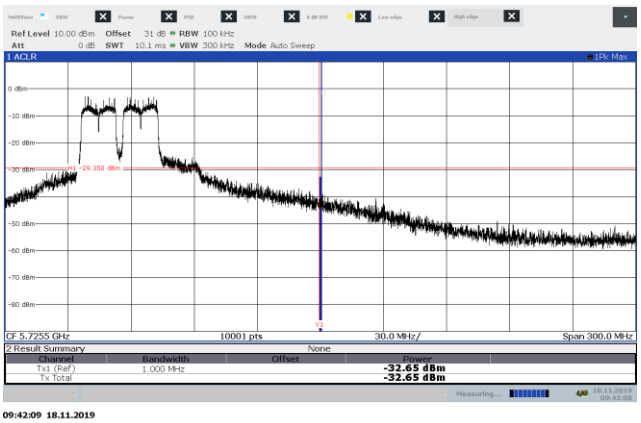


Figure 8.7-30: *Conducted band edge emissions 5.725 GHz, channel 132, 802.11n*

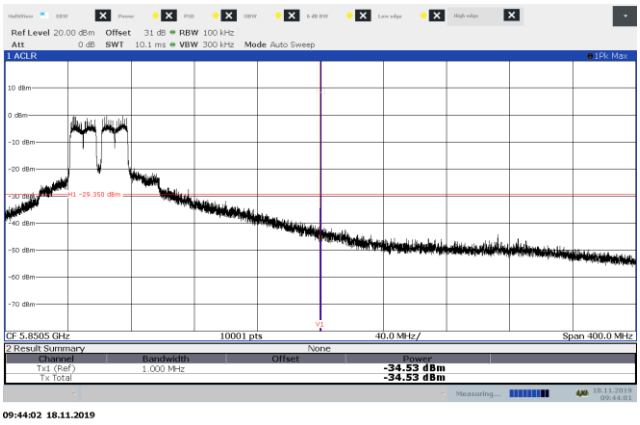


Figure 8.7-31: *Conducted band edge emissions 5.85 GHz, straddle channel 140, 802.11n*

8.7.4 Test data, continued

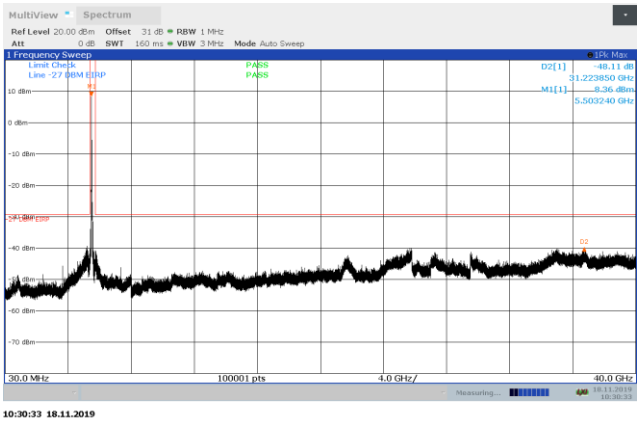


Figure 8.7-32: *Conducted spurious emissions 30 MHz – 40 GHz, low channel, 802.11a*

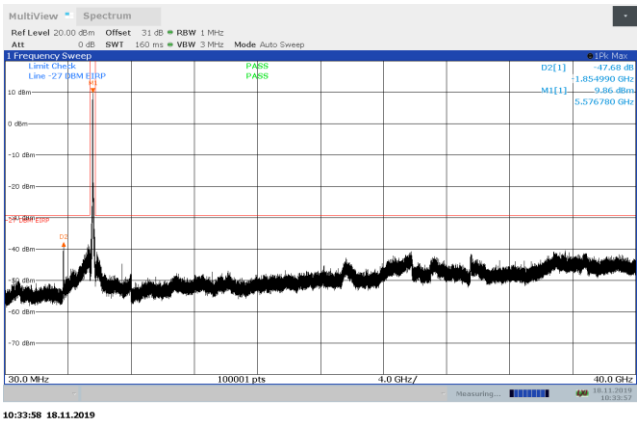


Figure 8.7-33: *Conducted spurious emissions 30 MHz – 40 GHz, mid channel, 802.11a*

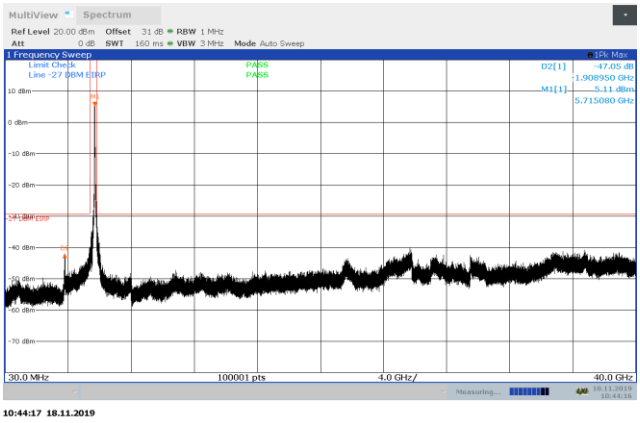


Figure 8.7-34: *Conducted spurious emissions 30 MHz – 40 GHz, high channel, 802.11a*

8.7.4 Test data, continued

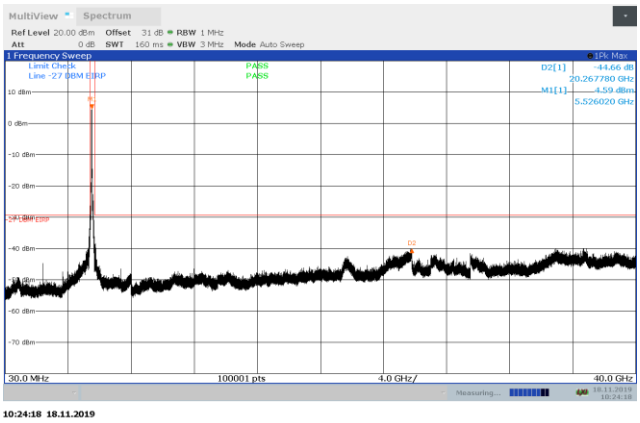


Figure 8.7-35: *Conducted spurious emissions 30 MHz – 40 GHz, low channel, 802.11n*

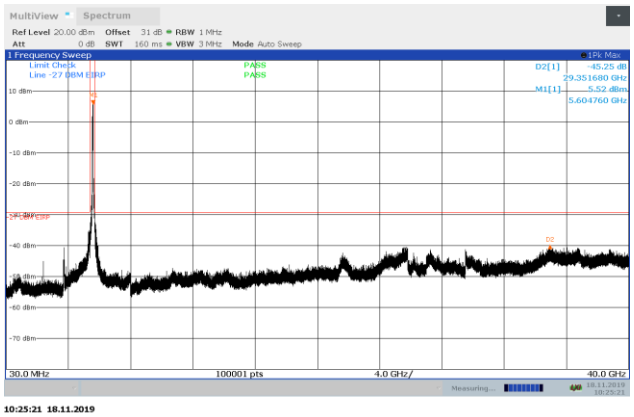


Figure 8.7-36: *Conducted spurious emissions 30 MHz – 40 GHz, mid channel, 802.11n*

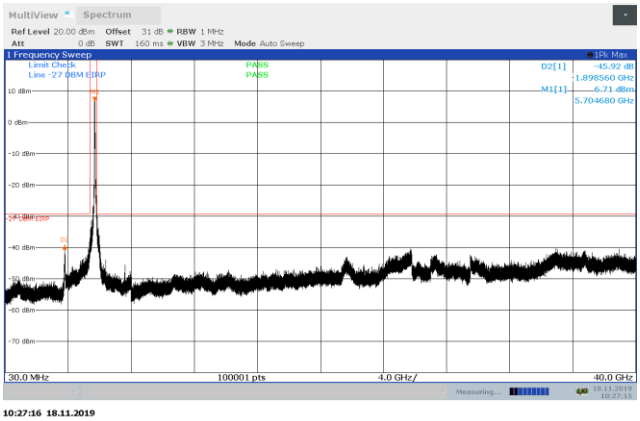


Figure 8.7-37: *Conducted spurious emissions 30 MHz – 40 GHz, high channel, 802.11n*

8.8 FCC 15.407(g) Frequency stability

8.8.1 Definitions and limits

Manufacturers of U-NII devices are responsible for ensuring frequency stability such that an emission is maintained within the band of operation under all conditions of normal operation as specified in the user's manual.

8.8.2 Test date

Start date	November 13, 2019

8.8.3 Observations, settings and special notes

Spectrum analyser settings:

Resolution bandwidth:	100 kHz
Video bandwidth:	300 kHz
Detector mode:	Peak
Trace mode:	Max Hold

8.8.4 Test data

Table 8.8-1: Frequency drift measurement

Test conditions	Frequency, Hz	Drift, Hz
+50 °C, Nominal	5499987194	-36194
+40 °C, Nominal	5499967152	-16152
+30 °C, Nominal	5499957110	-6110
+20 °C, +15 %	5499940500	10500
+20 °C, Nominal	5499951000	***Reference***
+20 °C, −15 %	5499941550	9450
+10 °C, Nominal	5499921220	29780
0 °C, Nominal	5499961648	-10648
−10 °C, Nominal	5499941900	9100
−20 °C, Nominal	5499971883	-20883
−30 °C, Nominal	5499991847	-40847

Table 8.8-2: Lower band edge drift calculation

Modulation	−26 dBc lower cross point, GHz	Max negative drift, Hz	Drifted lower cross point, GHz	Band edge, GHz	Margin, MHz
802.11a	5.490225	40847	5.490184153	5.47	20.2
802.11n	5.489542	40847	5.489501153	5.47	19.5

Notes: Drifted lower cross point = −26 dBc lower cross point – max negative drift.

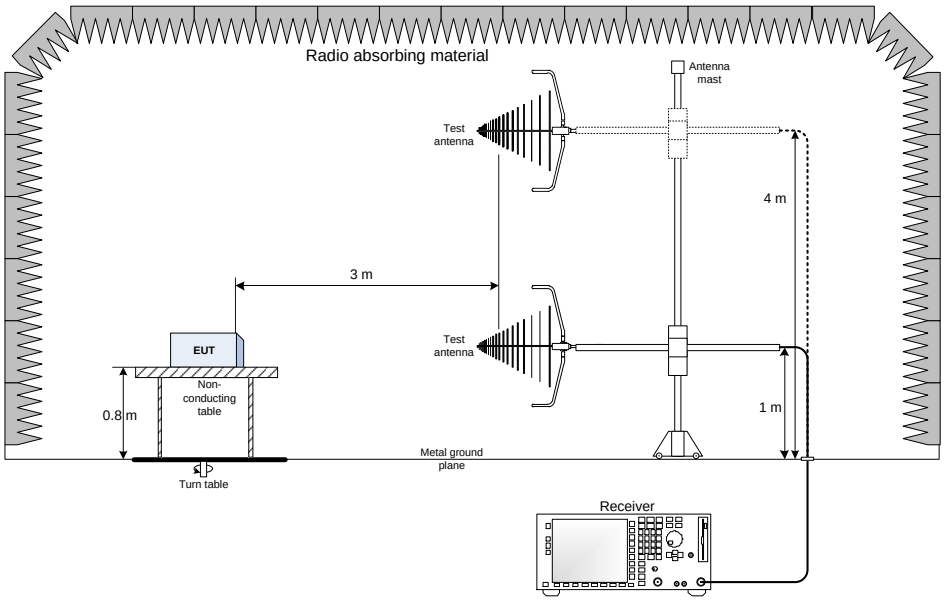
Table 8.8-3: Upper band edge drift calculation

Modulation	−26 dBc upper cross point, GHz	Max positive drift, Hz	Drifted upper cross point, GHz	Band edge, GHz	Margin, MHz
802.11a	5.709655	29780	5.70968478	5.725	15.3
802.11n	5.731646	29780	5.73167578	5.85	118.3

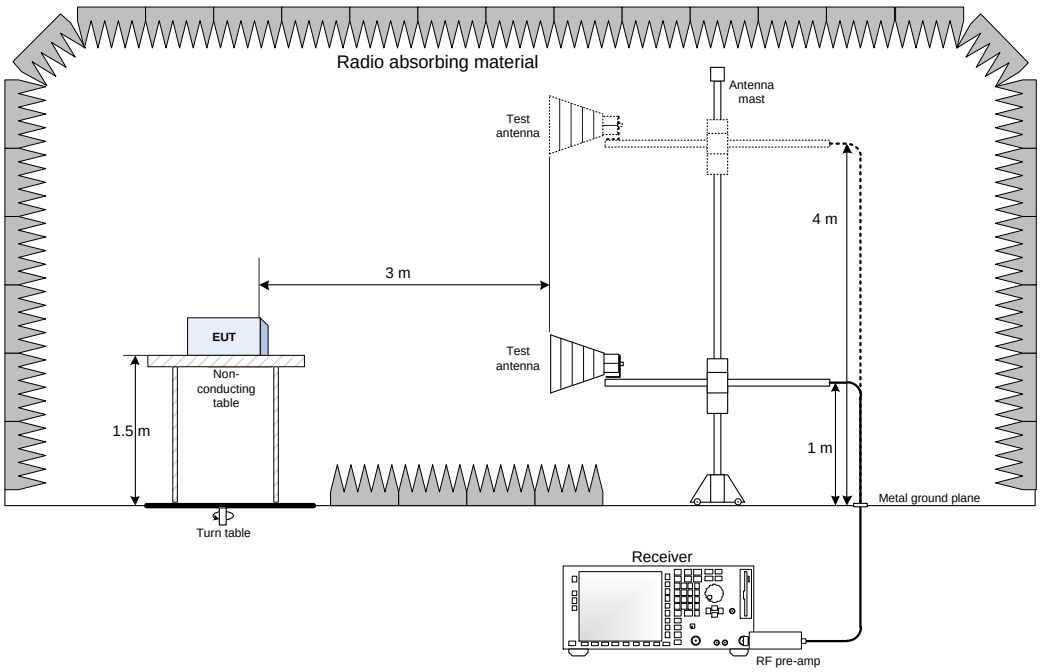
Notes: Drifted upper cross point = −26 dBc upper cross point + max positive drift.

Section 9. Block diagrams of test set-ups

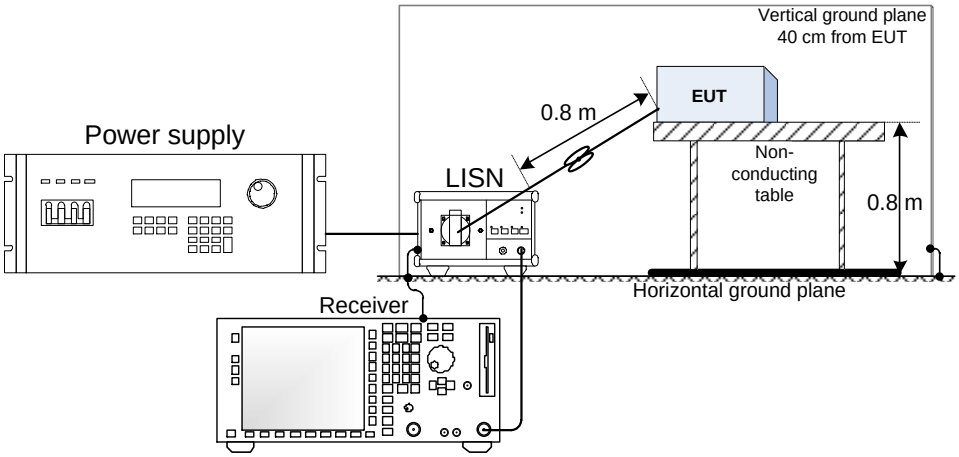
9.1 Radiated emissions set-up for frequencies below 1 GHz



9.2 Radiated emissions set-up for frequencies above 1 GHz



9.3 Conducted emissions set-up



9.4 Antenna port set-up