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Wireless Test Report – 387256-5R2TRFWL

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 Devices

Date of issue: July 9, 2020

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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.

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Section 1. Report summary

1.1 Applicant and manufacturer

Company name	Ring LLC
Address	1523 26 th 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 Devices
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1.3 Test specifications

789033 D02 General UNII Test Procedures New Rules v02r01 (Dec. 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 Statement of compliance

In the configuration tested, the EUT was found compliant.

Testing was completed against all relevant requirements of the test standard. 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.

1.5 Exclusions

None.

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	November 28, 2019	Update power levels in section 3.3
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

Notes: Only test pertaining to the EUT have been included in this table.

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)(3)	Power and density limits within 5.725–5.85 GHz band	Pass
§15.407(b)(4)	Undesirable emission limits for 5.725–5.85 GHz band	Pass
§15.407(b)(6)	Conducted limits for U-NII devices using an AC power line	Pass
§15.407(e)	Minimum 6 dB bandwidth of U-NII devices within the 5.725–5.85 GHz band	Pass
§15.407(g)	Frequency stability	Pass

Notes: Only test pertaining to the EUT have been included in this table.

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	5725–5850 MHz
Frequency Min (MHz)	5745 (20 MHz), 5755 (40 MHz)
Frequency Max (MHz)	5825 (20 MHz), 5795 (40 MHz)
RF power Min (W),	N/A
RF power Max (W), Conducted	0.021 (13.3 dBm) 20 MHz, 0.011 (10.3 dBm) 40 MHz
Field strength, Units @ distance	N/A
Measured 26 dB BW (MHz)	20.0 (20 MHz), 42.8 (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	67.2 dBμV/m @ 3 m, 3.8 GHz (peak)
Power requirements	5 V _{DC} (via external 100-240 VAC, 50/60 Hz power adapter)
Antenna information	Antenna gain: is 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.
Channel power setting for 802.11a = 17
Channel power setting for 802.11n = 13

3.6 EUT setup diagram

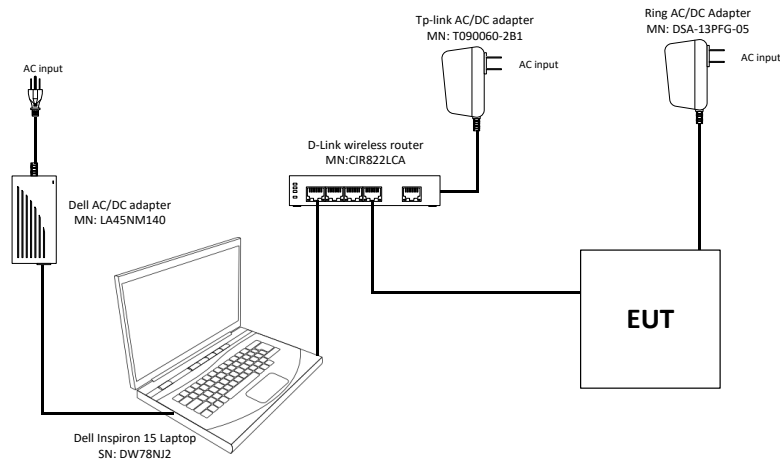


Figure 3.6-1: Setup diagram

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	86–106 kPa

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 $\pm 5\%$, 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
Preamplifier (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 8, 2019
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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 $\pm 15\%$ 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)

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:

- 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.
- 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.
- 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:

- 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).
- 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).
- 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
5725	5850	125	5745	5785	5825

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	High channel, MHz
5725	5850	125	5755	5795

Note: 40 MHz channels are limited to channels 151 and 159 for the 5725–5850 MHz band

8.3 FCC 15.203

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 11, 2019
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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 μ H/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, dB μ V	
	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.

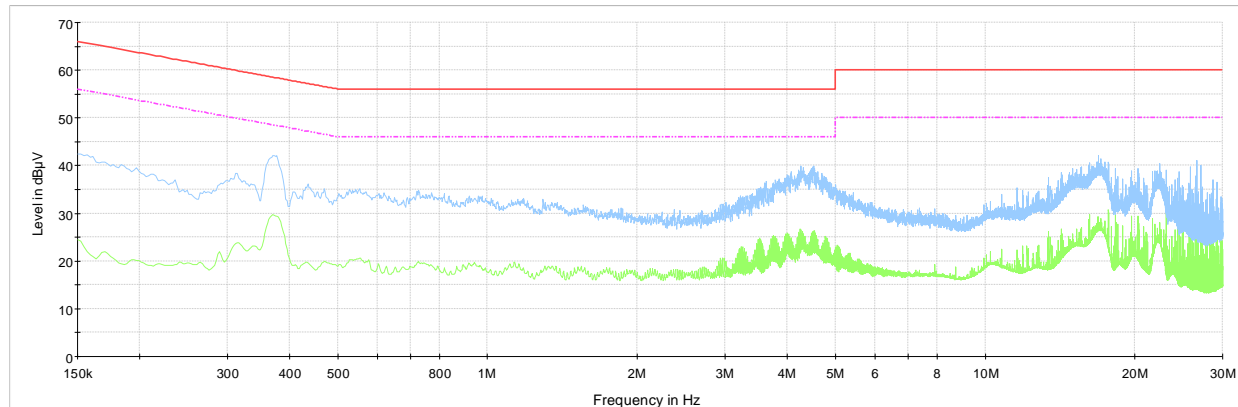
8.4.2 Test date

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	<ul style="list-style-type: none"> – 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	<ul style="list-style-type: none"> – 100 ms (Peak and Average preview measurement) – 100 ms (Quasi-peak final measurement) – 160 ms (CAverage final measurement)

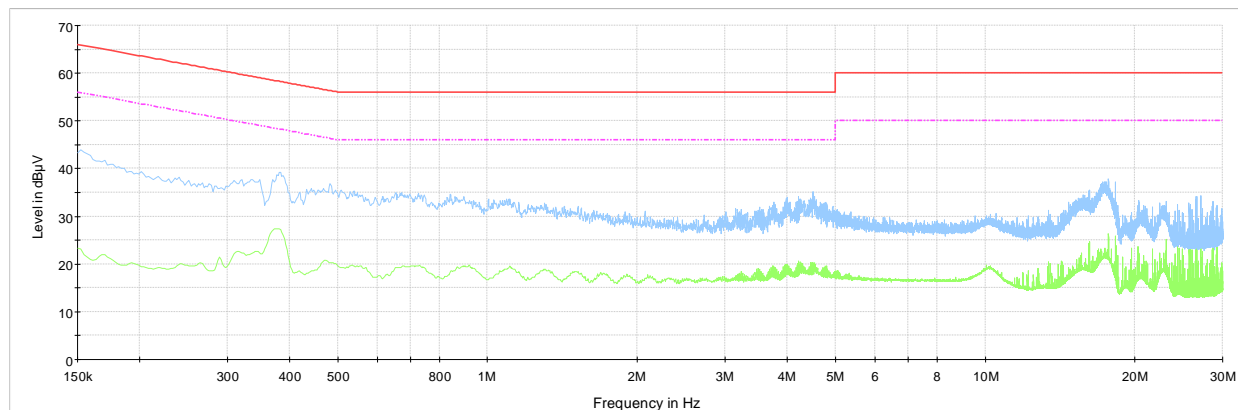
8.4.4 Test data



Conducted emissions 150 kHz - 30 MHz 120 Vac 60 Hz Phase

Preview Result 2-AVG
Preview Result 1-PK+
CISPR 32 Limit - Class B, Mains (Quasi-Peak)
CISPR 32 Limit - Class B, Mains (Average)

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



Conducted emissions 150 kHz - 30 MHz 120 Vac 60 Hz Neutral

Preview Result 2-AVG
Preview Result 1-PK+
CISPR 32 Limit - Class B, Mains (Quasi-Peak)
CISPR 32 Limit - Class B, Mains (Average)

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

8.5 FCC 15.407(e), Minimum 6 dB bandwidth

8.5.1 Definitions and limits

FCC:

15.407 (8)(e) Within the 5.725-5.85 GHz band, the minimum 6 dB bandwidth of U-NII devices shall be at least 500 kHz.

8.5.2 Test date

Start date	November 18, 2019
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8.5.3 Observations, settings and special notes

The test was performed as per KDB 789033, section C (2).

Spectrum analyser settings:

Resolution bandwidth	100 kHz
Video bandwidth	$\geq 3 \times \text{RBW}$
Frequency span	40 MHz for 20 MHz channel; 80 MHz for 40 MHz channel
Detector mode	Peak
Trace mode	Max Hold

8.5.4 Test data

Table 8.5-1: 6 dB bandwidth results

Modulation	Frequency, MHz	6 dB bandwidth, MHz	Minimum limit, MHz	Margin, MHz
802.11a	5745	16.6	0.50	16.1
	5785	16.6	0.50	16.1
	5825	16.6	0.50	16.1
802.11n	5755	33.3	0.50	32.8
	5795	32.4	0.50	31.9

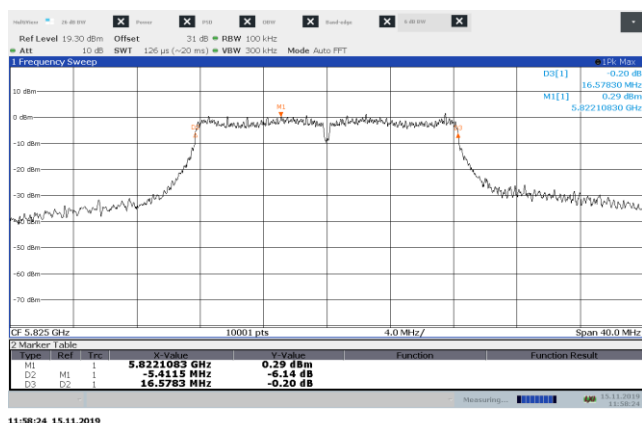


Figure 8.5-1: 6 dB bandwidth on 802.11a, sample plot

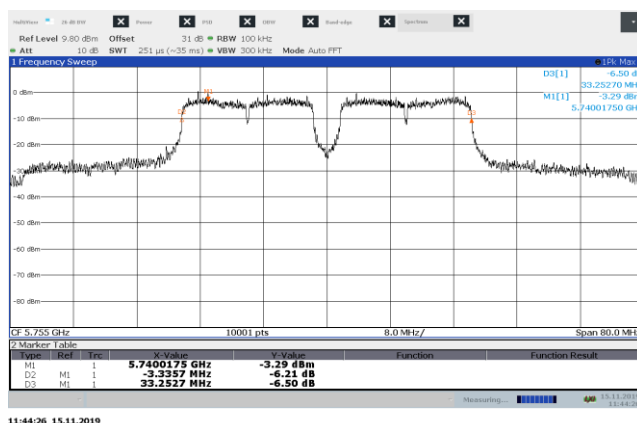


Figure 8.5-2: 6 dB bandwidth on 802.11n, sample plot

8.6 FCC 15.403(i) Emission bandwidth

8.6.1 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.

8.6.2 Test date

Start date November 13, 2019

8.6.3 Observations, settings and special notes

The test was performed as per KDB 789033, section C (1)

Spectrum analyser settings for 26 dB Bandwidth:

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

Spectrum analyser settings for Occupied Bandwidth:

Resolution bandwidth:	1 – 5 % of OBW
Video bandwidth:	$\geq 3 \times \text{RBW}$
Detector mode:	Peak
Trace mode:	Max Hold

Note: 99% Occupied bandwidth provided for information purposes only

8.6.4 Test data

Table 8.6-1: 26 dB bandwidth results

Modulation	Frequency, MHz	26 dB bandwidth, MHz
802.11a	5745	19.4
	5785	19.7
	5825	20.0
802.11n	5755	42.1
	5795	42.8

Table 8.6-2: 99 % bandwidth results

Modulation	Frequency, MHz	99 % occupied bandwidth, MHz
802.11a	5745	16.9
	5785	16.9
	5825	16.9
802.11n	5755	38.8
	5795	38.4

Section 8
Test name
Specification

Testing data
FCC 15.403(i) Emission bandwidth
FCC 15 Subpart E

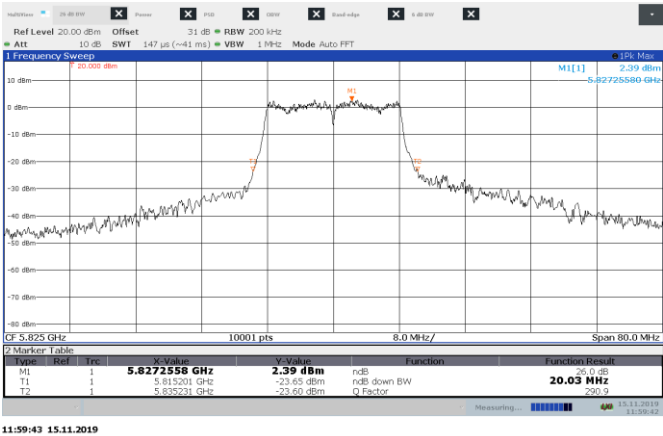


Figure 8.6-1: 26 dB bandwidth on 802.11a, sample plot

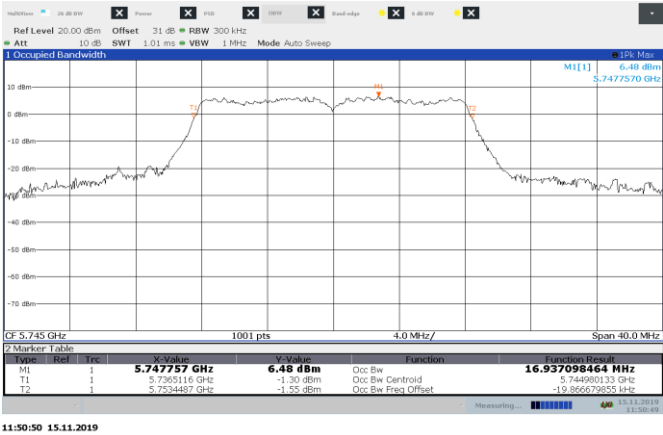


Figure 8.6-3: 99 % bandwidth on 802.11a, sample plot

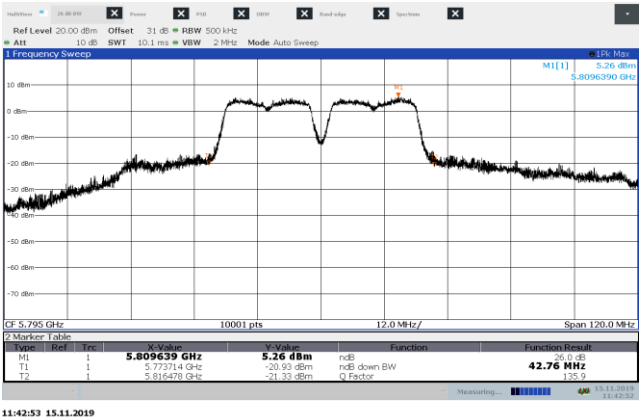


Figure 8.6-2: 26 dB bandwidth on 802.11n, sample plot

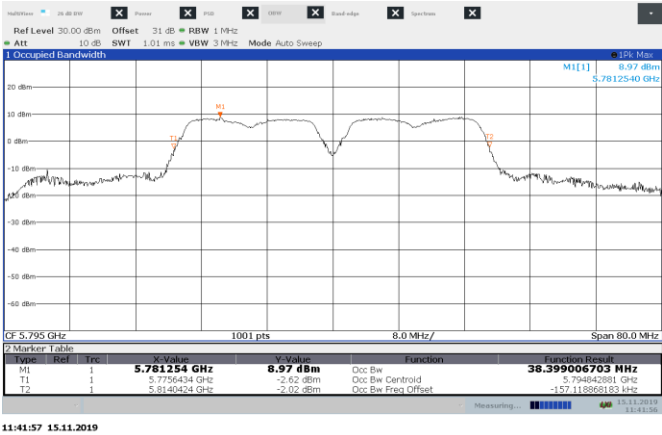


Figure 8.6-4: 99 % bandwidth on 802.11n, sample plot

8.7 FCC 15.407(a)(3) 5.725–5.85 GHz band output power and spectral density limits

8.7.1 Definitions and limits

For the band 5.725–5.85 GHz, the maximum conducted output power over the frequency band of operation shall not exceed 1 W. In addition, the maximum power spectral density shall not exceed 30 dBm in any 500-kHz 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. However, fixed point-to-point U-NII devices operating in this band may employ transmitting antennas with directional gain greater than 6 dBi without any corresponding reduction in transmitter conducted power. Fixed, point-to-point operations exclude the use of point-to-multipoint systems, omnidirectional applications, and multiple collocated transmitters transmitting the same information. The operator of the U-NII device, or if the equipment is professionally installed, the installer, is responsible for ensuring that systems employing high gain directional antennas are used exclusively for fixed, point-to-point operations.

8.7.2 Test date

Start date November 18, 2019

8.7.3 Observations, settings and special notes

EUT set to transmit continuously with duty cycle $\geq 98\%$.
KDB 789033 section E.2(b) method SA-1 referenced for power measurements
KDB 789033 section F referenced for PSD measurements

Spectrum analyser settings for PSD:

Resolution bandwidth:	500 kHz
Video bandwidth:	$\geq 3 \times \text{RBW}$
Detector mode:	RMS
Trace mode:	Average
Trace counts:	100

Spectrum analyser settings for Output Power:

Resolution bandwidth:	1 MHz
Video bandwidth:	$\geq 3 \times \text{RBW}$
Detector mode:	RMS
Trace mode:	Average
Trace counts:	100
Power Integration BW	EBW

8.7.4 Test data

Table 8.7-1: Output power measurements results

Modulation	Frequency, MHz	Conducted output power, dBm	Power limit, dBm	Margin, dB
802.11a	5745	13.3	30.0	16.7
	5785	12.5	30.0	17.5
	5825	12.0	30.0	18.0
802.11n	5755	10.3	30.0	19.7
	5795	9.6	30.0	20.4

Table 8.7-2: PSD measurements results

Modulation	Frequency, MHz	PSD, dBm/500 kHz	PSD limit, dBm/500 kHz	Margin, dB
802.11a	5745	-0.9	30.0	30.9
	5785	-1.2	30.0	31.2
	5825	-2.4	30.0	32.4
802.11n	5755	-6.8	30.0	36.8
	5795	-7.8	30.0	37.8

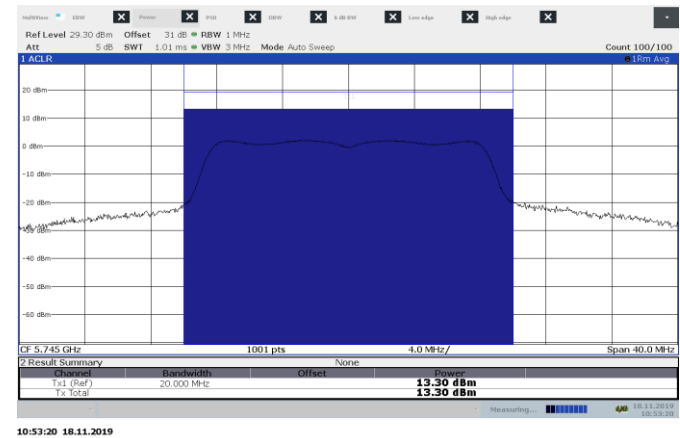


Figure 8.7-1: Sample plot for Power on 802.11a

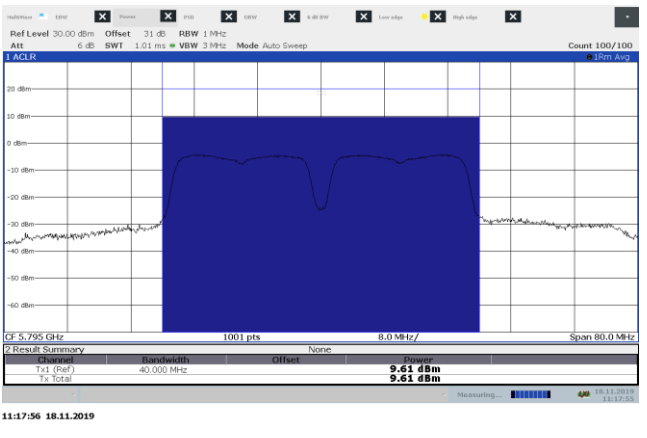


Figure 8.7-2: Sample plot for Power on 802.11n

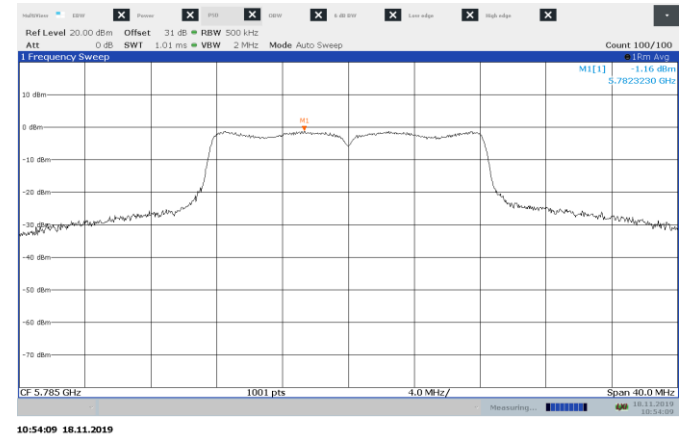


Figure 8.7-3: Sample plot for PSD on 802.11a

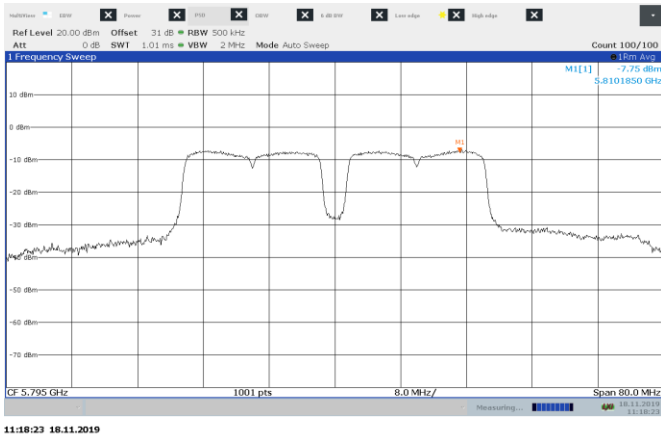


Figure 8.7-4: Sample plot for PSD on 802.11n

8.8 FCC 15.407(b) Undesirable (unwanted) emissions

8.8.1 Definitions and limits

FCC:

15.407 (4) For transmitters operating in the 5.725-5.85 GHz band:

(i) All emissions shall be limited to a level of -27 dBm/MHz at 75 MHz or more above or below the band edge increasing linearly to 10 dBm/MHz at 25 MHz above or below the band edge, and from 25 MHz above or below the band edge increasing linearly to a level of 15.6 dBm/MHz at 5 MHz above or below the band edge, and from 5 MHz above or below the band edge increasing linearly to a level of 27 dBm/MHz at the band edge.

Table 8.8-1: FCC §15.209– Radiated emission limits

Frequency, MHz	Field strength of emissions		Measurement distance, m
	$\mu\text{V/m}$	$\text{dB}\mu\text{V/m}$	
0.009–0.490	$2400/F$ (F in kHz)	$67.6 - 20 \times \log_{10}(F)$ (F in kHz)	300
0.490–1.705	$24000/F$ (F in kHz)	$87.6 - 20 \times \log_{10}(F)$ (F in kHz)	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 8.8-2: 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			

8.8.2 Test date

Start date	November 13, 2019
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8.8.3 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 30 MHz – 18 GHz were performed at a distance of 3 m.
- Radiated measurements 18 - 40 GHz were performed at a distance of 3 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 calculated as follows: Emission limit – Antenna Gain (2.35 dBi) = EIRP limit dBm/MHz

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 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 measurements above 1 GHz:

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

Spectrum analyser for band edge measurements above 1 GHz:

Resolution bandwidth:	1MHz
Video bandwidth:	3MHz
Detector mode:	RMS
Trace mode:	Average

8.8.4 Test data

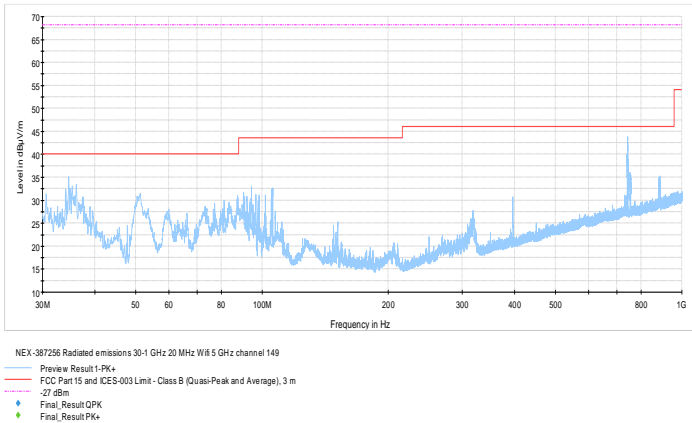


Figure 8.8-1: Radiated spurious emissions 30 MHz – 1 GHz low channel, 802.11a

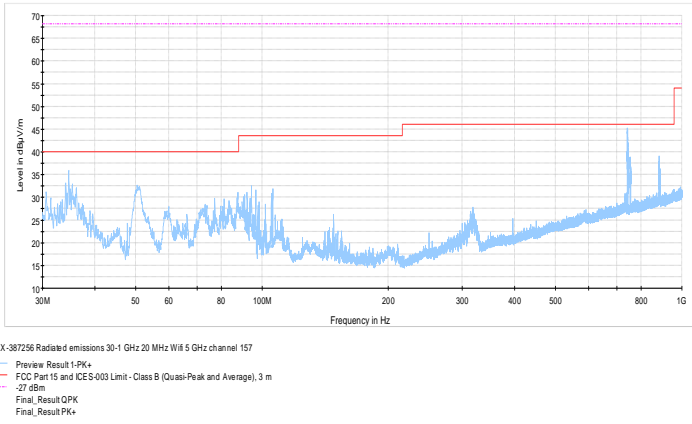


Figure 8.8-2: Radiated spurious emissions 30 MHz – 1 GHz mid channel, 802.11a

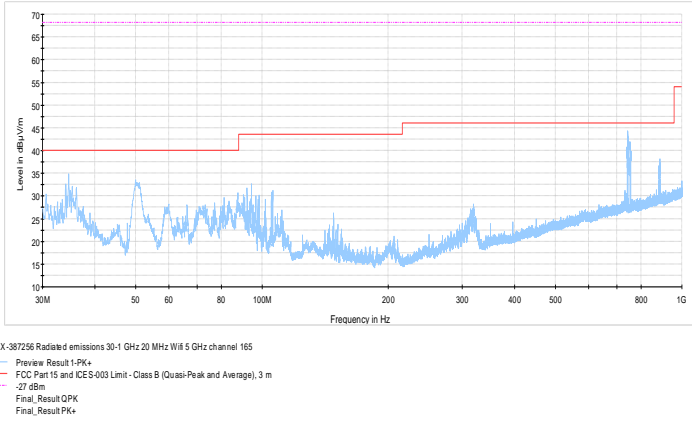


Figure 8.8-3: Radiated spurious emissions 30 MHz – 1 GHz high channel, 802.11a

8.8.4 Test data, continued

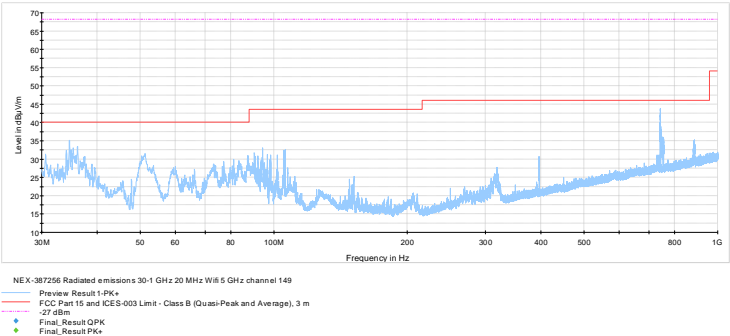


Figure 8.8-4: Radiated spurious emissions 30 MHz – 1 GHz low channel, 802.11n

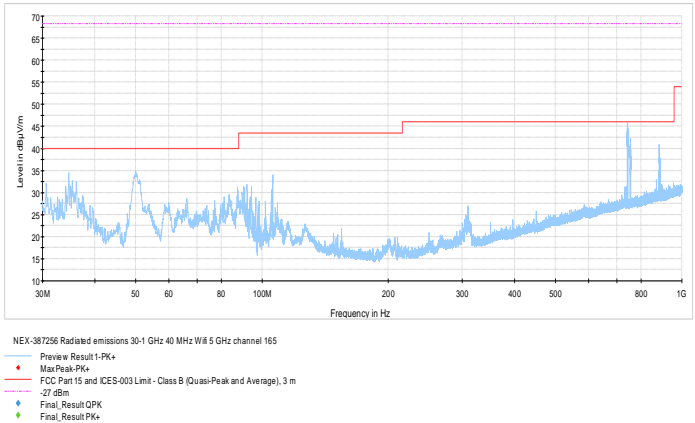


Figure 8.8-5: Radiated spurious emissions 30 MHz – 1 GHz high channel, 802.11n

8.8.4 Test data, continued

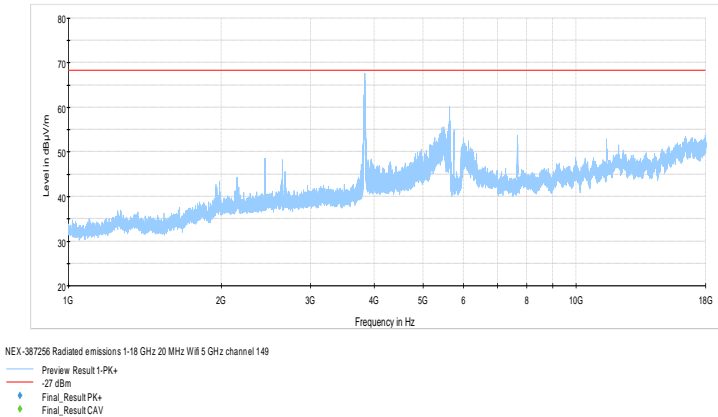


Figure 8.8-6: Radiated spurious emissions 1 - 18 GHz low channel, 802.11a

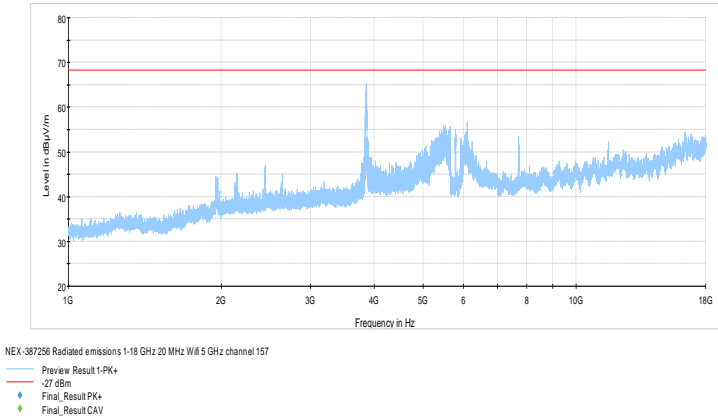


Figure 8.8-7: Radiated spurious emissions 1 - 18 GHz mid channel, 802.11a

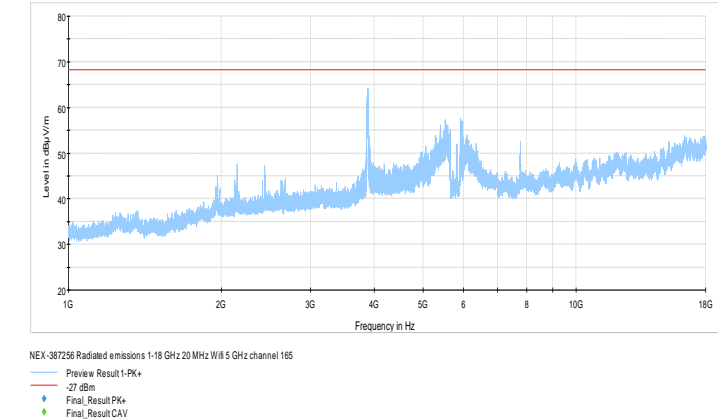


Figure 8.8-8: Radiated spurious emissions 1 - 18 GHz high channel, 802.11a

8.8.4 Test data, continued

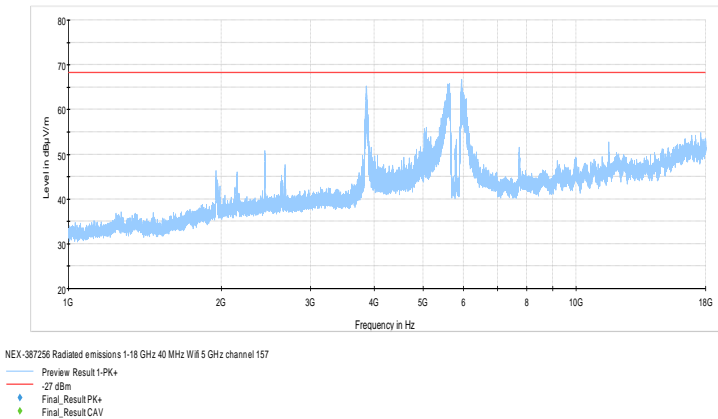


Figure 8.8-9: Radiated spurious emissions 1 - 18 GHz low channel, 802.11n

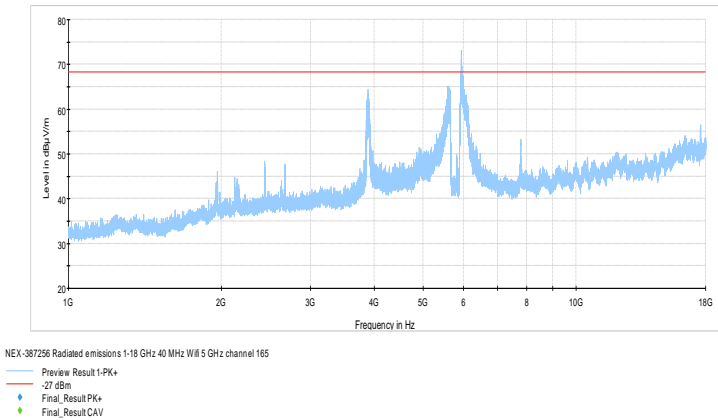


Figure 8.8-10: Radiated spurious emissions 1 - 18 GHz high channel, 802.11n

8.8.4 Test data, continued

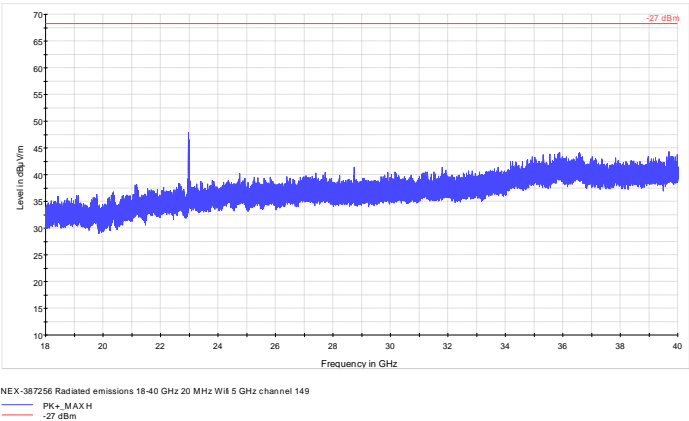


Figure 8.8-11: Radiated spurious emissions 18 - 40 GHz low channel, 802.11a

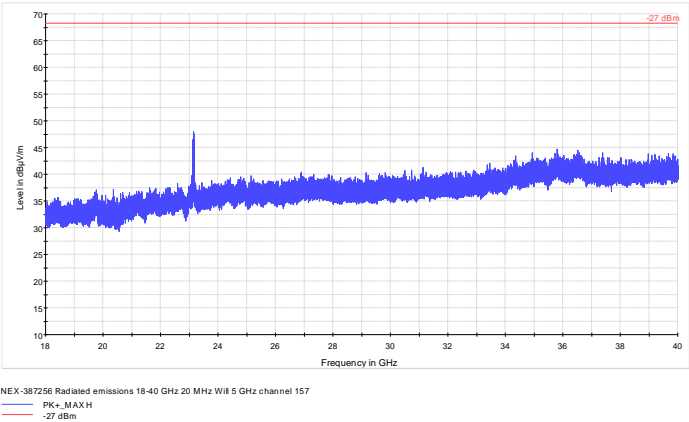


Figure 8.8-12: Radiated spurious emissions 18 - 40 GHz mid channel, 802.11a

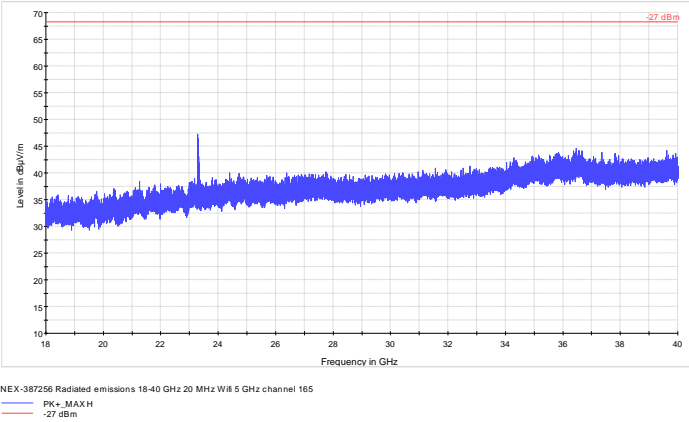


Figure 8.8-13: Radiated spurious emissions 18 - 40 GHz high channel, 802.11a

8.8.4 Test data, continued

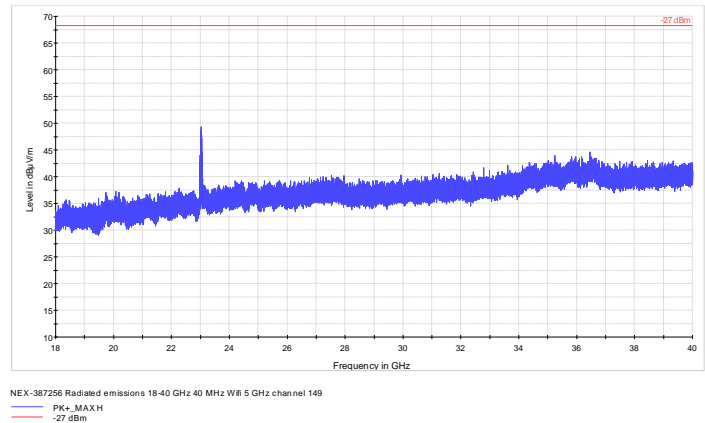


Figure 8.8-14: Radiated spurious emissions 18 - 40 GHz low channel, 802.11n

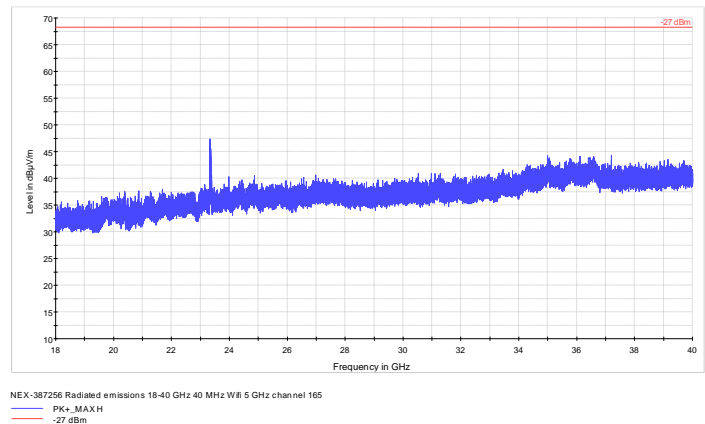


Figure 8.8-15: Radiated spurious emissions 18 - 40 GHz high channel, 802.11n

8.8.5 Test data, continued

Table 8.8-3: Conducted lower band edge emissions measurement results

Modulation	Frequency, MHz	PSD dBm/MHz	Antenna Gain, dBi	PSD dBm/MHz, EIRP	limit, dBm/MHz	Margin, dB
802.11a	5725	-10.9	2.35	-8.55	27.0	35.55
802.11a	5720	-17.9	2.35	-15.55	15.6	31.15
802.11a	5700	-23.2	2.35	-20.85	10.0	30.85
802.11a	5650	-32.9	2.35	-30.55	-27.0	3.55
802.11a	5634	-34.6	2.35	-32.25	-27.0	5.25
802.11n	5725	-17.4	2.35	-15.05	27.0	42.05
802.11n	5720	-16.1	2.35	-13.75	15.6	29.35
802.11n	5700	-23.9	2.35	-21.55	10.0	31.55
802.11n	5650	-32.5	2.35	-30.15	-27.0	3.15
802.11n	5620	-32.1	2.35	-29.75	-27.0	2.75



Figure 8.8-16: Conducted emissions at lower band edge measurement, 802.11a



Figure 8.8-17: Conducted emissions at lower band edge measurement, 802.11n

8.8.4 Test data, continued

Table 8.8-4: Conducted upper band edge emissions measurement results

Modulation	Frequency, MHz	PSD dBm/MHz	Antenna Gain, dBi	PSD dBm/MHz, EIRP	limit, dBm/MHz	Margin, dB
802.11a	5850	-15.5	2.35	-13.15	27.0	40.15
802.11a	5855	-18.5	2.35	-16.15	15.6	31.75
802.11a	5875	-23.4	2.35	-21.05	10.0	31.05
802.11a	5925	-35.5	2.35	-33.15	-27.0	6.15
802.11a	5937	-33.3	2.35	-30.95	-27.0	3.95
802.11n	5850	-22.3	2.35	-19.95	27.0	46.95
802.11n	5855	-21.9	2.35	-19.55	15.6	35.15
802.11n	5875	-25.9	2.35	-23.55	10.0	33.55
802.11n	5925	-32.4	2.35	-30.05	-27.0	3.05
802.11n	5931	-29.4	2.35	-27.05	-27.0	0.05



Figure 8.8-18: Conducted emissions at upper band edge measurement, 802.11a



Figure 8.8-19: Conducted emissions at upper band edge measurement, 802.11n

8.8.4 Test data, continued

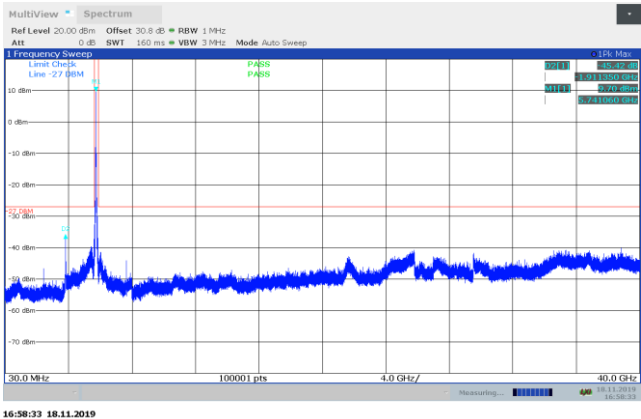


Figure 8.8-20: Conducted spurious emissions 30 MHz – 40 GHz low channel, 802.11a

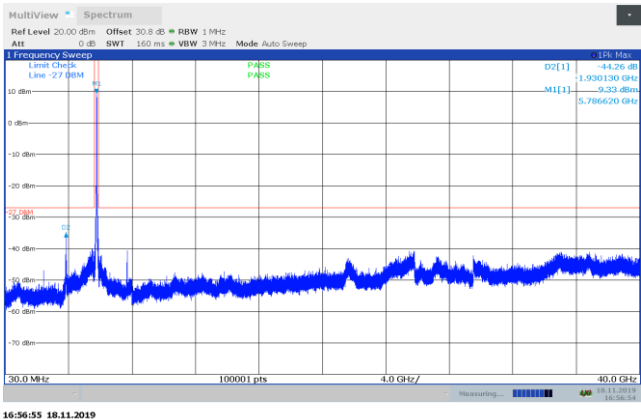


Figure 8.8-21: Conducted spurious emissions 30 MHz – 40 GHz mid channel, 802.11a

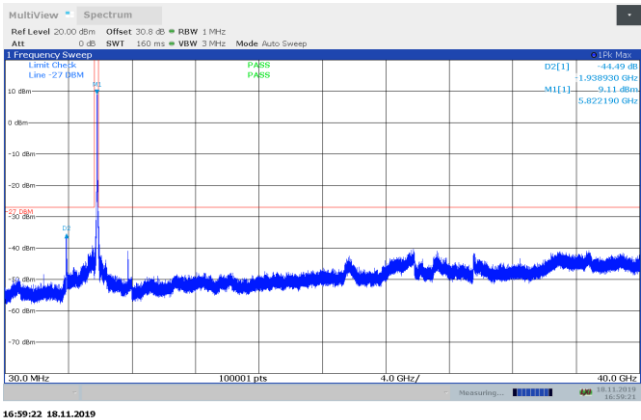


Figure 8.8-22: Conducted spurious emissions 30 MHz – 40 GHz high channel, 802.11a

8.8.4 Test data, continued

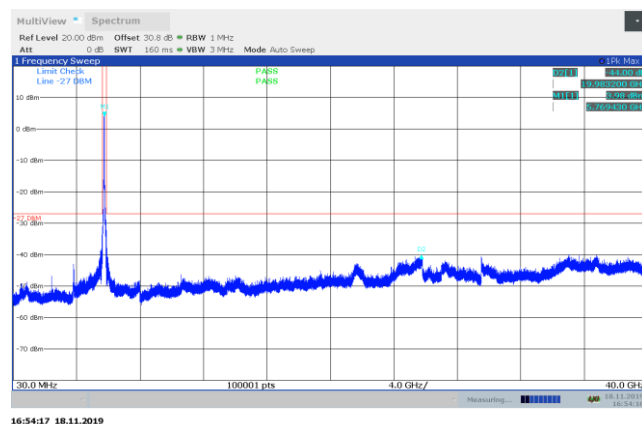


Figure 8.8-23: Conducted spurious emissions 30 MHz – 40 GHz low channel, 802.11n

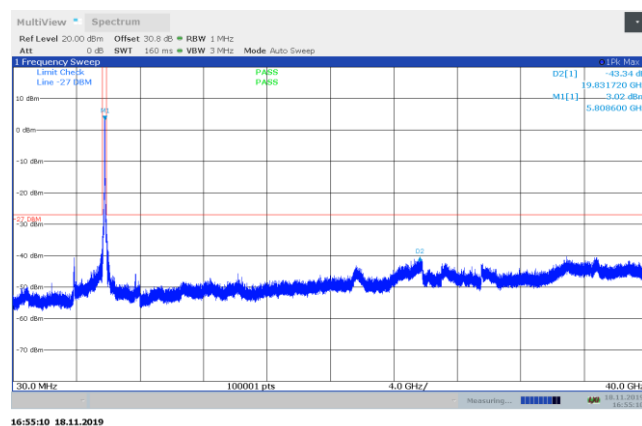


Figure 8.8-24: Conducted spurious emissions 30 MHz – 40 GHz high channel, 802.11n

8.9 FCC 15.407(g) Frequency stability

8.9.1 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.

8.9.2 Test date

Start date	November 13, 2019
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8.9.3 Observations, settings and special notes

Spectrum analyser settings:

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

8.9.4 Test data

Table 8.9-1: Frequency drift measurement Low channel

Test conditions	Frequency, Hz	Drift, Hz
+50 °C, Nominal	5744980133	-18990
+40 °C, Nominal	5744980133	-28030
+30 °C, Nominal	5744980133	-12680
+20 °C, +15 %	5744980133	5900
+20 °C, Nominal	5744980133	Reference
+20 °C, -15 %	5744980133	-12030
+10 °C, Nominal	5744931013	-49120
0 °C, Nominal	5744985633	-15500
-10 °C, Nominal	5744980133	-33000
-20 °C, Nominal	5744980133	7130
-30 °C, Nominal	5744980133	15310

Table 8.9-2: Lower band edge drift calculation

Modulation	26 dBc lower cross point, GHz	Max Negative drift, Hz	Drifted upper cross point, GHz	Band edge, GHz	Margin, MHz
802.11a	5.735273	49120	5.735223880	5.725	10.2
802.11n	5.733678	49120	5.733628880	5.725	8.6

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

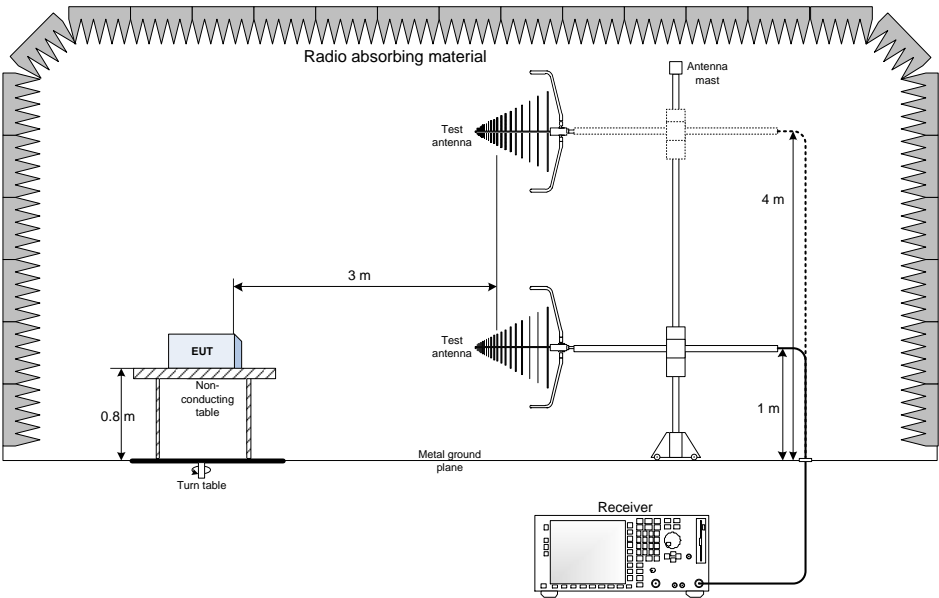
Table 8.9-3: Upper band edge drift calculation

Modulation	26 dBc upper cross point, GHz	Max positive drift, Hz	Drifted upper cross point, GHz	Band edge, GHz	Margin, MHz
802.11a	5.835231	15310	5.835246310	5.85	14.8
802.11n	5.816478	15310	5.816493310	5.85	33.5

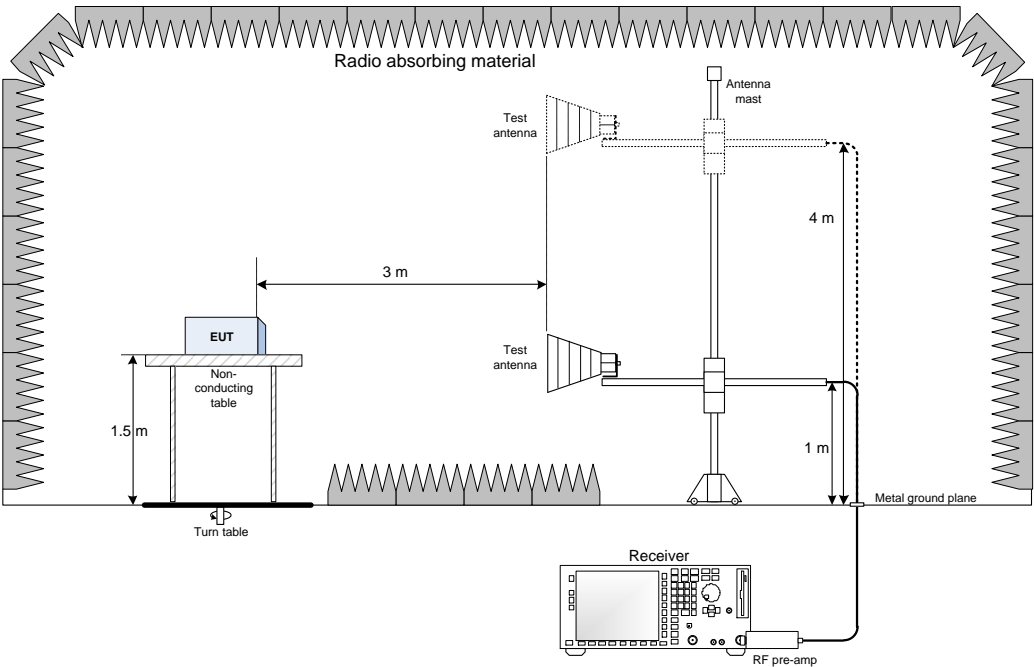
Notes: Drifted upper cross point = -26 dBc upper cross point + max positive drift.

Section 9. Block diagrams of test set-ups

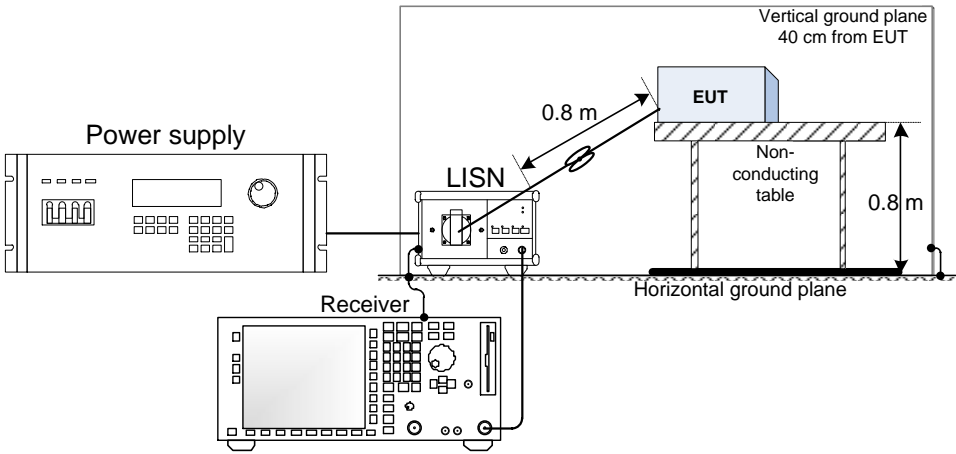
9.1 Radiated emissions set-up for frequencies below 1 GHz



9.2 Radiated emissions set-up for frequencies above 1 GHz



9.3 Conducted emissions set-up



9.4 Antenna port set-up

