ONE WORLD ○ OUR APPROVAL

Wireless Test Report – 1R368533-3TRFWL

Applicant:

Ring LLC

Product name:

Ring

Model:

Base Station NA

FCC ID:

2AEUPBHABN002

ISED Registration number:

20271-BHABN002

Specifications:

FCC 47 CFR Part 15 Subpart E, §15.407

Unlicensed National Information Infrastructure Devises

RSS-247, Issue 2, Feb 2017, Section 6

Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices, Section 6 Technical requirements for licence-exempt local area network devices and digital transmission systems operating in the 5 GHz band

Date of issue: April 2, 2019

Test engineer(s):	Mark Libbrecht, EMC/Wireless Specialist	Signature:	Mark Libbrecht
Reviewed by:	David Duchesne, Senior EMC/Wireless Specialist	Signature:	

Nemko Canada Inc., a testing laboratory, is accredited by the Standards Council of Canada. The tests included in this report are within the scope of this accreditation

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.

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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
RSS-247, Issue 2, Feb 2017	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

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

None.

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	March 29, 2019	Original report issued
R1	April 2, 2019	Removed model variant

Section 2. Summary of test results

2.1 Testing period

Test start date	February 1, 2019
Test end date	March 29, 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)(2)	Undesirable emission limits for 5.25–5.35 GHz band	Pass
§15.407(b)(6)	Conducted limits for U-NII devices using an AC power line	Pass [1]
§15.407(g)	Frequency stability	Pass
§15.407(h)(2)[2]	Dynamic Frequency Selection (DFS) for devices operating in the bands 5250–5350 MHz, 5470–5600 MHz and 5650–5725 MHz	Pass

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

[1] See results in section §15.207(a).

[2] See DFS Test results in separate test report, Reference ID: 368533-11TRFWL

2.4 ISED RSS-GEN, Issue 5, test results

Table 2.4-1: *RSS General requirements results*

Part	Test description	Verdict
6.7	Occupied Bandwidth	Pass
6.8	Antenna requirement	Pass
6.9	Number of tested frequencies	Pass
8.8	Power Line Conducted Emissions Limits for Licence-Exempt Radio Apparatus	Pass
8.11	Frequency stability	Pass

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

2.5 IC RSS-247, Issue 2, test results

Table 2.5-1: *RSS-247, Issue 2, results*

Section	Test description	Verdict
6.1[1]	Types of Modulation	Pass
6.2.2.1	Power limits for 5250–5350 MHz band	Pass
6.2.2.2	Unwanted emission limits for 5250–5350 MHz band	Pass
6.3[2]	Dynamic Frequency Selection (DFS) for devices operating in the bands 5250–5350 MHz, 5470–5600 MHz and 5650–5725 MHz	Pass

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

[1] The EUT employs digital modulations, such as: 802.11a and 802.11n

[2] See DFS Test results in separate test report, Reference ID: 368533-11TRFWL

Section 3. Equipment under test (EUT) details

3.1 Sample information

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

3.2 EUT information

Product name	Ring
Model	Base Station NA
Serial number	BHBN21851PG000046 (conducted), BHBN21851PG000052 (radiated)

3.3 Technical information

Applicant IC company number	20271
IC UPN number	20271-BHABN002
All used IC test site(s) Reg. number	332406
RSS number and Issue number	RSS-247 Issue 2, Feb 2017
Frequency band	5250–5350 MHz
Frequency Min (MHz)	5260 (20 MHz), 5270 (40 MHz)
Frequency Max (MHz)	5320 (20 MHz), 5310 (40 MHz)
RF power Min (W),	N/A
RF power Max (W), Conducted	0.018 (12.5 dBm) 20 MHz, 0.025 (13.9 dBm) 40 MHz
Field strength, Units @ distance	5350 MHz, 73.1 dBµV/m (Peak), 52.8 dBµV/m (Average) @ 3 m
Measured EBW (MHz) (26 dB)	20.0 (20 MHz), 43.1 (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	5350 MHz, 73.13 dBµV/m (Peak) 52.81 dBµV/m (Average) @ 3 m
Power requirements	5 V_{DC} (via external 100-240 VAC, 50/60 Hz power adapter)
Antenna information	Antenna Gain is 5.6 dBi (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 Hub for Home Security Products

3.5 EUT exercise details

The EUT was setup in continuous transmit state.
Channel power setting for 802.11a mid channels = 16
Channel power setting for 802.11n mid channels = 16
Channel power setting for 802.11a band edge @ 5350 MHz = 14
Channel power setting for 802.11n band edge @ 5350 MHz = 11

3.6 EUT setup diagram

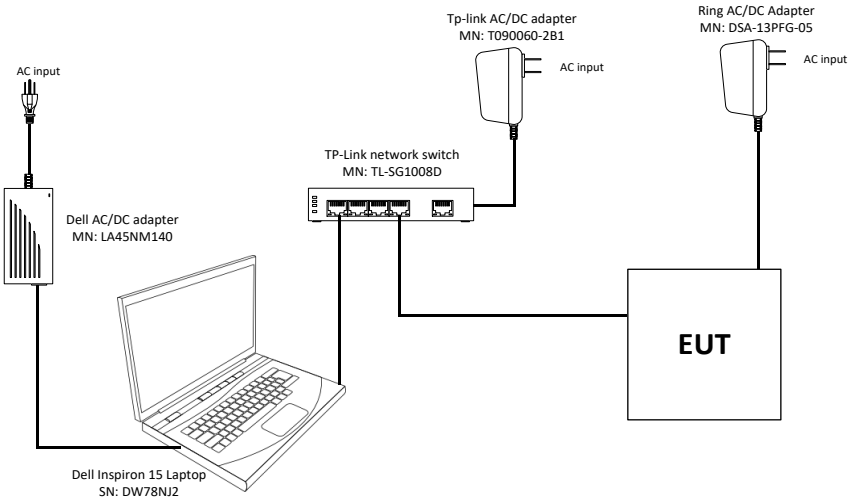


Figure 3.6-1: Setup diagram

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	BHAB11851DV000116
Laptop	Dell	Inspiron 15	DW78NJ2
Network switch	TP-Link	TL-SG1008D	2171682000263

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 ±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.	Serial no.	Asset no.	Cal./Ver. cycle	Next cal./ver.
3 m EMI test chamber	TDK	SAC-3		FA003012	1 year	Aug. 22/19
Flush mount turntable	SUNAR	FM2022		FA003006	—	NCR
Controller	SUNAR	SC110V	050118-1	FA002976	—	NCR
Antenna mast	SUNAR	TLT2	042418-5	FA003007	—	NCR
Receiver/spectrum analyzer	Rohde & Schwarz	ESR26	101367	FA002969	1 year	June 1/19
Spectrum analyzer	Rohde & Schwarz	FSW43	104437	FA002971	1 year	June 1/19
Horn antenna (1–18 GHz)	ETS-Lindgren	3117	00052793	FA002911	1 year	Aug. 16/19
Preamp (1–18 GHz)	ETS-Lindgren	124334	00224880	FA002956	1 year	Sept 18/19
Bilog antenna (30–2000 MHz)	SUNAR	JB1	A053018-2	FA003010	1 year	Sept. 6/19
50 Ω coax cable	Huber + Suhner	None	457630	FA003047	1 year	Nov 12/19
50 Ω coax cable	Huber + Suhner	None	457624	FA003044	1 year	Nov 12/19
Two-line v-network	Rohde & Schwarz	ENV216	101376	FA002964	1 year	Mar. 27/19
50 Ω coax cable	Rohde & Schwarz	None		FA003074	1 year	Dec. 21/19
AC Power source	Chroma	61605	616050002253	FA003034	—	VOU
filter 5150–5350 MHz	Microwave Circuits	N0452501	499784	FA003030	1 year	Oct. 1/19
Horn antenna (18-40 GHz)	ETS-Lindgren	3116B	00122305	FA002948	1 year	Apr. 18/19

Note: 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	February 14, 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) and RSS-Gen 6.9 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:

RSS-Gen Section 6.9:

Except where otherwise specified, measurements shall be performed for each frequency band of operation for which the radio apparatus is to be certified, with the device operating at the frequencies in each band of operation shown in table below. The frequencies selected for measurements shall be reported in the test report.

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	February 14, 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 BW

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
5250	5350	100	5260	5310	5320

Table 8.2-3: Test channels selection 40 MHz BW

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	High channel, MHz
5250	5350	100	5270	5310

8.3 FCC 15.203 and RSS-Gen 6.8 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.

RSS-Gen Section 6.8:

The applicant for equipment certification shall provide a list of all antenna types that may be used with the transmitter, where applicable (i.e. for transmitters with detachable antenna), indicating the maximum permissible antenna gain (in dBi) and the required impedance for each antenna. The test report shall demonstrate the compliance of the transmitter with the limit for maximum equivalent isotropically radiated power (e.i.r.p.) specified in the applicable RSS, when the transmitter is equipped with any antenna type, selected from this list.

For expediting the testing, measurements may be performed using only the antenna with highest gain of each combination of transmitter and antenna type, with the transmitter output power set at the maximum level. However, the transmitter shall comply with the applicable requirements under all operational conditions and when in combination with any type of antenna from the list provided in the test report.

8.3.2 Test date

Start date	February 13, 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) and RSS-Gen 8.8 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.

RSS-GEN Section 8.8:

A radio apparatus that is designed to be connected to the public utility (AC) power line shall ensure that the radio frequency voltage, which 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 table below.

Unless the requirements applicable to a given device state otherwise, for any radio apparatus equipped to operate from the public utility AC power supply either directly or indirectly (such as with a battery charger), the radio frequency voltage of emissions conducted back onto the AC power lines in the frequency range of 0.15 MHz to 30 MHz shall not exceed the limits shown in table below. The more stringent limit applies at the frequency range boundaries.

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	February 13, 2019

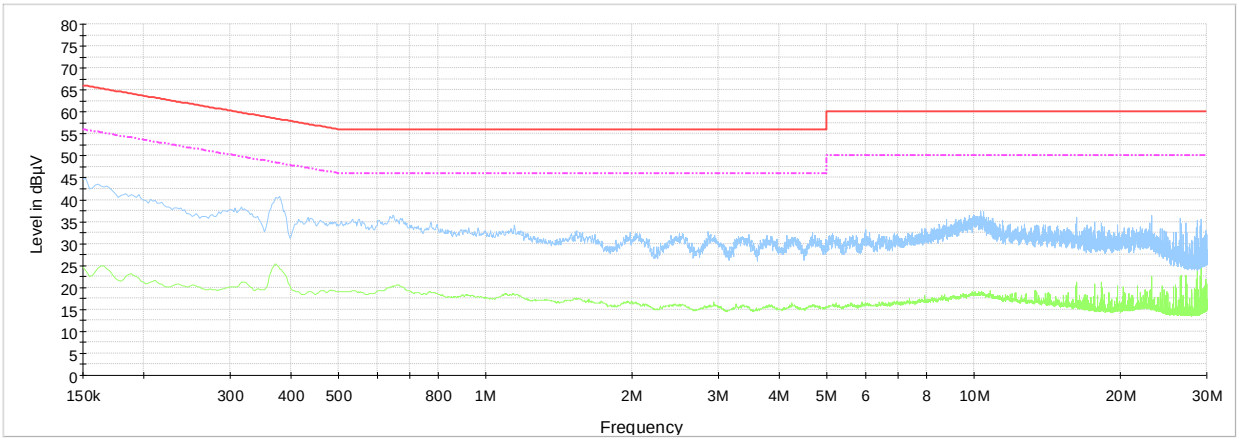
8.4.3 Observations, settings and special notes

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)

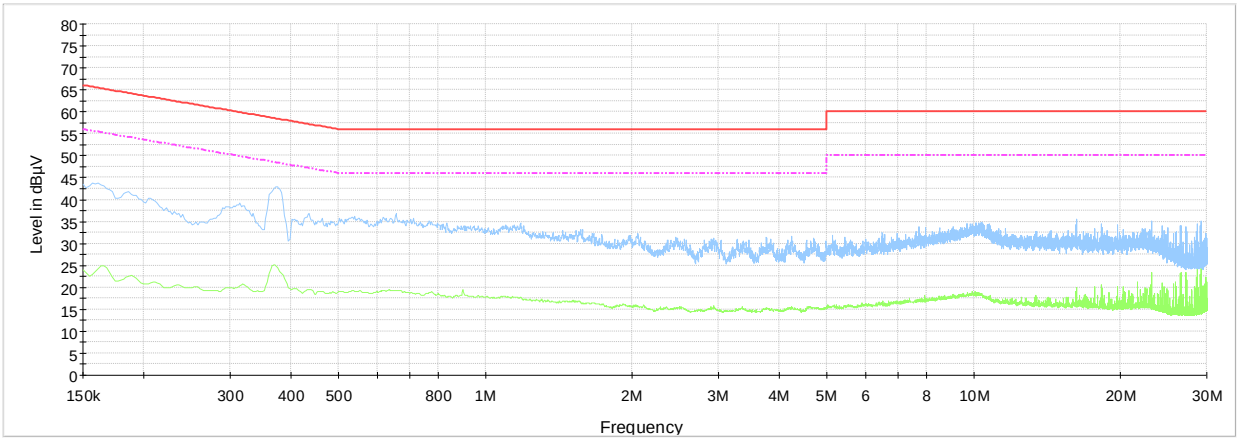
8.4.1 Test data



NEX368533 150 kHz - 30 MHz 120 VAC 60 Hz Line

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*



NEX368533 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 15.403(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	March 12, 2019

8.5.3 Observations, settings and special notes

Spectrum analyser settings:

Resolution bandwidth	approximately 1% of the emission bandwidth
Video bandwidth	> 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	5260	19.9
	5310	19.7
	5320	20.0
802.11n	5270	42.0
	5310	43.1

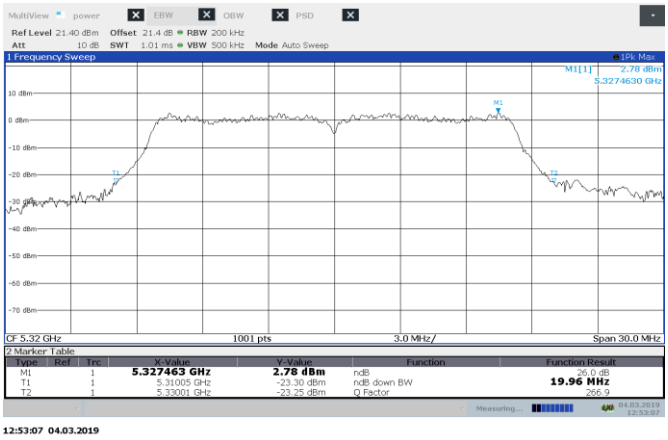


Figure 8.5-1: *26 dB bandwidth on 802.11a, sample plot*

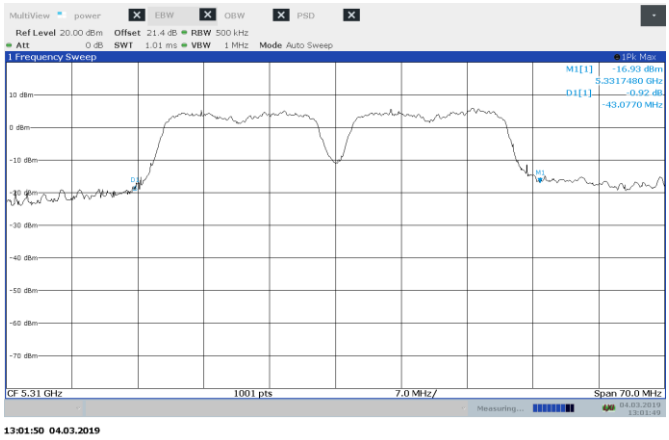


Figure 8.5-2: *26 dB bandwidth on 802.11n, sample plot*

8.6 RSS-Gen 6.7 Occupied bandwidth

8.6.1 Definitions and limits

The emission bandwidth (×dB) is defined as the frequency range between two points, one above and one below the carrier frequency, at which the spectral density of the emission is attenuated × dB below the maximum in-band spectral density of the modulated signal. Spectral density (power per unit bandwidth) is to be measured with a detector of resolution bandwidth in the range of 1% to 5% of the anticipated emission bandwidth, and a video bandwidth at least 3× the resolution bandwidth.

When the occupied bandwidth limit is not stated in the applicable RSS or reference measurement method, the transmitted signal bandwidth shall be reported as the 99% emission bandwidth, as calculated or measured.

8.6.2 Test date

Start date	March 12, 2019

8.6.3 Observations, settings and special notes

Spectrum analyser settings:

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

8.6.4 Test data

Table 8.6-1: *99 % bandwidth results*

Modulation	Frequency, MHz	99 % occupied bandwidth, MHz
802.11a	5260	17.0
	5310	16.9
	5320	16.9
802.11n	5270	41.3
	5310	38.4

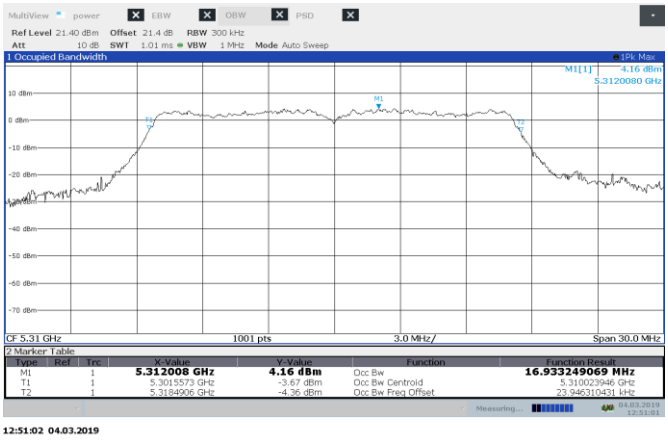


Figure 8.6-1: *99 % bandwidth on 802.11a, sample plot*

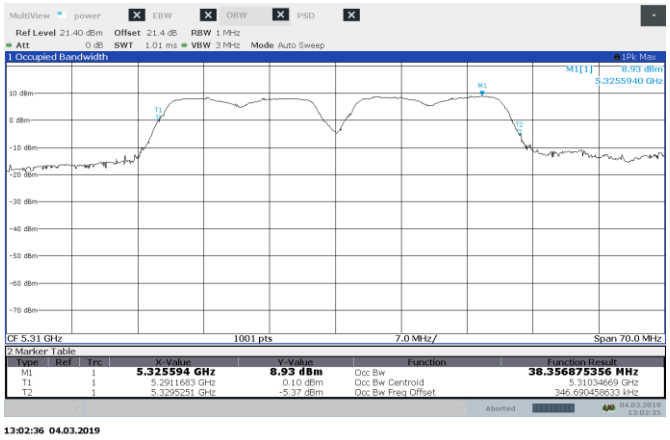


Figure 8.6-2: *99 % bandwidth on 802.11n, sample plot*

8.7 FCC 15.407(a)(2) and RSS-247 6.2.2(1) 5.25–5.35 GHz band output power and spectral density limits

8.7.1 Definitions and limits

FCC:
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.

IC:
The maximum conducted output power shall not exceed 250 mW (24 dBm) or 11 + 10 $\log_{10}$(B), dBm, whichever is less, where B is the 99% emission bandwidth in megahertz. The power spectral density shall not exceed 11 dBm in any 1.0 MHz band.

The maximum e.i.r.p. shall not exceed 1.0 W (30 dBm) or 17 + 10 $\log_{10}$ (B), dBm, whichever is less. B is the 99% emission bandwidth in megahertz. Note that devices with a maximum e.i.r.p. greater than 500 mW (27 dBm) shall implement TPC in order to have the capability to operate at least 6 dB below the maximum permitted e.i.r.p. of 1 W (30 dBm).

In addition to the above requirements, devices with a maximum e.i.r.p. greater than 200 mW (23 dBm) shall comply with the following e.i.r.p. at different elevations, where θ is the angle above the local horizontal plane (of the Earth) as shown below:

i.	−13 dBW/MHz	for 0° ≤ θ < 8°
ii.	−13 − 0.716 (θ-8) dBW/MHz	for 8° ≤ θ < 40°
iii.	−35.9 − 1.22 (θ-40) dBW/MHz	for 40° ≤ θ ≤ 45°
iv.	−42 dBW/MHz	for θ > 45°

8.7.2 Test date

Start date	March 4, 2019

8.7.3 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 20.0 MHz, and for 802.11n was 43.1 MHz
FCC output power limit for 802.11a was calculated as follows: 11 dBm + 10 × $\log_{10}$ (20) = 24 dBm, therefore the limit is 24 dBm
FCC output power limit for 802.11n was calculated as follows: 11 dBm + 10 × $\log_{10}$ (43.1) = 27.3 dBm > 24 dBm, therefore the limit is 24 dBm

The maximum measured 99 % occupied bandwidth for 802.11a was 17.0 MHz, and for 802.11n was 41.3 MHz.
IC output power limit for 802.11a was calculated as follows: 11 + 10 × Log_{10} (17.0) = 23.3 dBm < 24 dBm
IC output power limit for 802.11n was calculated as follows: 11 + 10 × Log_{10} (41.3) = 27.2 dBm > 24 dBm, therefore the limit is 24 dBm

IC EIRP limit for 802.11a was calculated as follows: 17 + 10 × Log_{10} (17.0) = 29.3 dBm < 30 dBm
IC EIRP limit for 802.11n was calculated as follows: 17 + 10 × Log_{10} (41.3) = 33.2 dBm > 30 dBm, therefore the limit is 30 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

8.7.4 Test data

Table 8.7-1: *Output power measurements results for FCC*

Modulation	Frequency, MHz	Conducted output power, dBm	Power limit, dBm	Margin, dB
802.11a	5260	12.3	24.0	11.7
	5310	12.5	24.0	11.5
	5320	8.9	24.0	15.1
802.11n	5270	13.9	24.0	10.1
	5310	7.2	24.0	16.8

Table 8.7-2: *PPSD measurements results for FCC*

Modulation	Frequency, MHz	PPSD, dBm/MHz	PPSD limit, dBm/MHz	Margin, dB
802.11a	5260	0.7	11.0	10.3
	5310	0.9	11.0	10.1
	5320	-3.4	11.0	14.4
802.11n	5270	-0.9	11.0	11.9
	5310	-7.8	11.0	18.8

Table 8.7-3: *Output power measurements results for IC*

Modulation	Frequency, MHz	Conducted output power, dBm	Conducted Output Power limit, dBm	Margin, dB
802.11a	5260	12.3	23.3	11.0
	5310	12.5	23.3	10.8
	5320	8.9	23.3	14.4
802.11n	5270	13.9	24.0	10.1
	5310	7.2	24.0	16.8

Table 8.7-4: *PSD measurements results for IC*

Modulation	Frequency, MHz	PSD, dBm/MHz	EIRP PSD limit, dBm/MHz	Margin, dB
802.11a	5260	0.7	11.0	10.3
	5310	0.9	11.0	10.1
	5320	-3.4	11.0	14.4
802.11n	5270	-0.9	11.0	11.9
	5310	-7.8	11.0	18.8

8.7-5: *EIRP measurements results for IC*

Modulation	Frequency, MHz	Conducted output power, dBm	Antenna gain, dBi	EIRP, dBm	EIRP limit, dBm	Margin, dB
802.11a	5260	12.3	5.6	17.9	29.3	11.4
	5310	12.5	5.6	18.1	29.3	11.2
	5320	8.9	5.6	14.5	29.3	14.8
802.11n	5270	13.9	5.6	19.5	30.0	10.5
	5310	7.2	5.6	12.8	30.0	17.2

8.7.4 Test data, continued

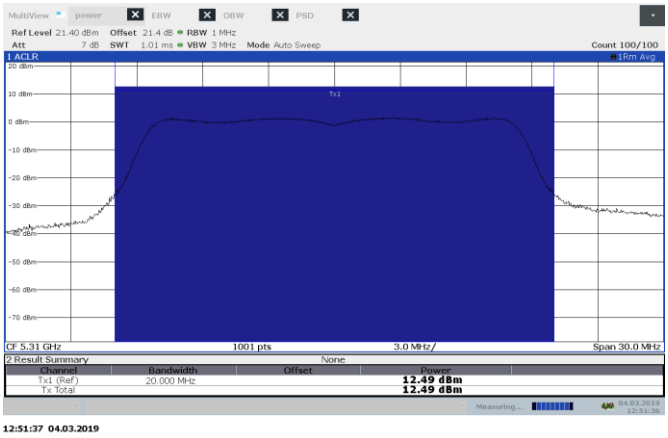


Figure 8.7-1: *Sample plot for power on 802.11a*

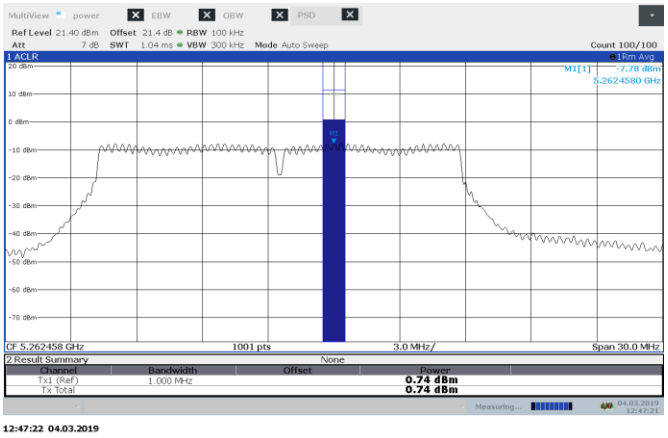


Figure 8.7-2: *Sample plot for PPSD on 802.11a*

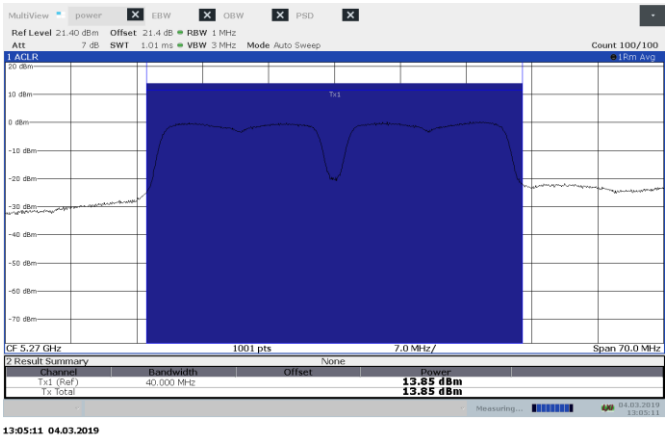


Figure 8.7-3: *Sample plot for power on 802.11n*

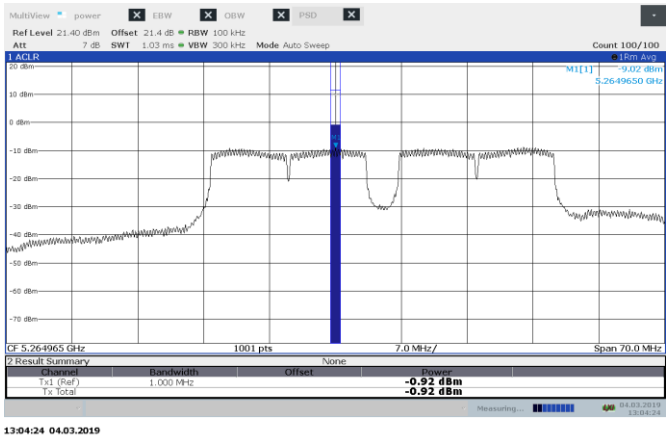


Figure 8.7-4: *Sample plot for PPSD on 802.11n*

8.8 FCC 15.407(b) and RSS-247 6.2.2(2) Undesirable (unwanted) emissions

8.8.1 Definitions and limits

FCC:
(2) For transmitters operating in the 5.25–5.35 GHz band: all emissions outside of the 5.15–5.35 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.

IC:
i) For devices with both operating frequencies and channel bandwidths contained within the band 5250–5350 MHz, the device shall comply with the following:

a) All emissions outside the band 5250–5350 MHz shall not exceed −27 dBm/MHz e.i.r.p. if the equipment is intended for outdoor use; or
b) All emissions outside the band 5150–5350 MHz shall not exceed −27 dBm/MHz e.i.r.p. and any emissions within the band 5150–5250 MHz shall meet the power spectral density limits of Section 6.2.1. The device shall be labelled “for indoor use only.”

ii) For devices with operating frequencies in the band 5250–5350 MHz but having a channel bandwidth that overlaps the band 5150–5250 MHz, the devices’ unwanted emission shall not exceed −27 dBm/MHz e.i.r.p. outside the band 5150–5350 MHz and its power shall comply with the spectral power density for operation within the band 5150–5250 MHz. The device shall be labelled “for indoor use only.”

RSS-Gen 8.10 Emissions falling within restricted frequency bands
Restricted bands, identified in

8.8.1 Definitions and limits, continued

Table 8.8-2, are designated primarily for safety-of-life services (distress calling and certain aeronautical bands), certain satellite downlinks, radio astronomy and some government uses. Except where otherwise indicated, the following restrictions apply:

a) fundamental components of modulation of licence-exempt radio apparatus shall not fall within the restricted bands of below;
b) unwanted emissions falling into restricted bands of below shall comply with the limits specified in RSS-Gen;
c) unwanted emissions not falling within restricted frequency bands shall either comply with the limits specified in the applicable RSS, or with those specified in RSS-Gen.

Table 8.8-1: *FCC §15.209 and RSS-Gen – Radiated emission limits*

Frequency, MHz	Field strength of emissions µV/m	dBµV/m	Measurement distance, m
0.009–0.490	2400/F *(F in kHz)*	67.6 – 20 × $\log_{10}$(F) *(F in kHz)*	300
0.490–1.705	24000/F *(F in kHz)*	87.6 – 20 × $\log_{10}$(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

8.8.2 Definitions and limits, continued

Table 8.8-2: *ISED restricted frequency bands*

MHz	MHz	MHz	GHz
0.090–0.110	12.57675–12.57725	399.9–410	7.25–7.75
0.495–0.505	13.36–13.41	608–614	8.025–8.5
2.1735–2.1905	16.42–16.423	960–1427	9.0–9.2
3.020–3.026	16.69475–16.69525	1435–1626.5	9.3–9.5
4.125–4.128	16.80425–16.80475	1645.5–1646.5	10.6–12.7
4.17725–4.17775	25.5–25.67	1660–1710	13.25–13.4
4.20725–4.20775	37.5–38.25	1718.8–1722.2	14.47–14.5
5.677–5.683	73–74.6	2200–2300	15.35–16.2
6.215–6.218	74.8–75.2	2310–2390	17.7–21.4
6.26775–6.26825	108–138	2483.5–2500	22.01–23.12
6.31175–6.31225	149.9–150.05	2655–2900	23.6–24.0
8.291–8.294	156.52475–156.52525	3260–3267	31.2–31.8
8.362–8.366	156.7–156.9	3332–3339	36.43–36.5
8.37625–8.38675	162.0125–167.17	3345.8–3358	Above 38.6
8.41425–8.41475	167.72–173.2	3500–4400	
12.29–12.293	240–285	4500–5150	
12.51975–12.52025	322–335.4	5350–5460	

Note: Certain frequency bands listed in

Definitions and limits, continued

Table 8.8-2 and above 38.6 GHz are designated for licence-exempt applications. These frequency bands and the requirements that apply to related devices are set out in the 200 and 300 series of RSSs.

Table 8.8-3: *FCC 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			

8.8.3 Test date

Start date	February 14, 2019

8.8.4 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 - 25 GHz were performed at a distance of 30 cm.
- Radiated measurements 25 – 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 line calculated as follows: -27 dBm EIRP – Antenna Gain (5.6 dBi) = -32.6 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

8.8.5 Test data

Table 8.8-4: *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	5350	69.5	74.00	4.5	49.8	54.00	3.3
802.11n	5350	73.1	74.00	0.9	52.8	54.00	1.2

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

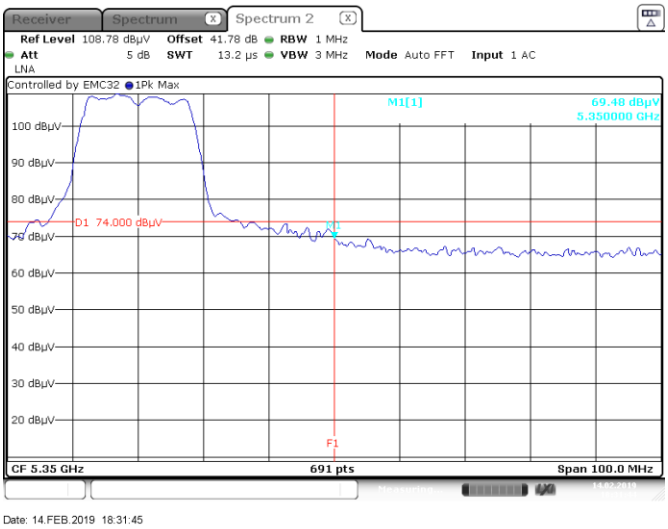


Figure 8.8-1: *Peak spurious emissions within restricted bands at high channel, 802.11a*

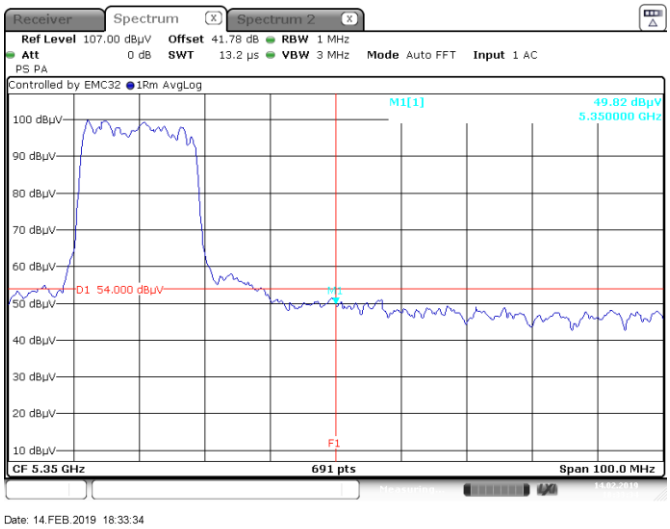


Figure 8.8-2: *Average spurious emissions within restricted bands at high channel, 802.11a*

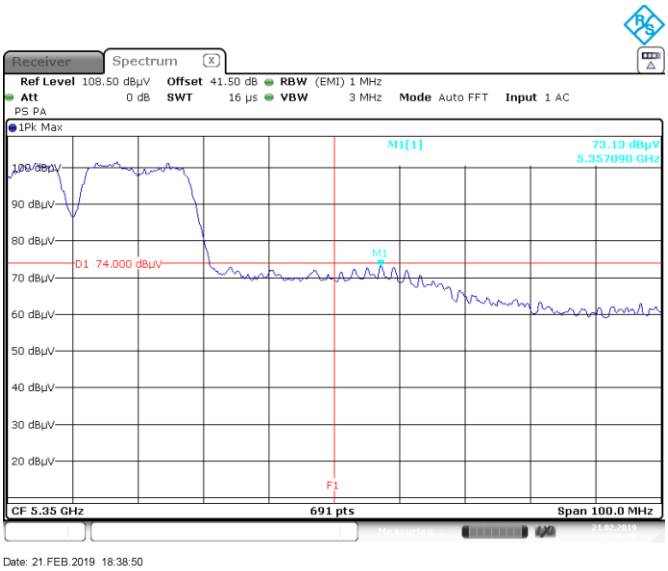


Figure 8.8-3: *Peak spurious emissions within restricted bands at high channel, 802.11n*

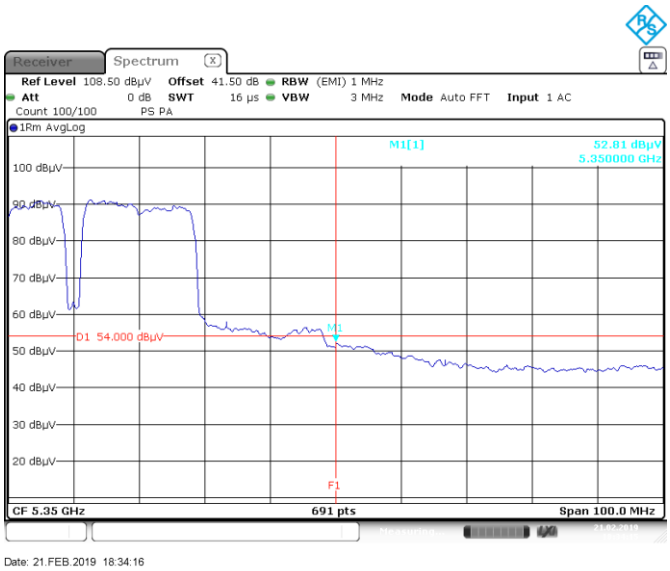


Figure 8.8-4: *Average spurious emissions within restricted bands at high channel, 802.11n*

8.8.6 Test data, continued

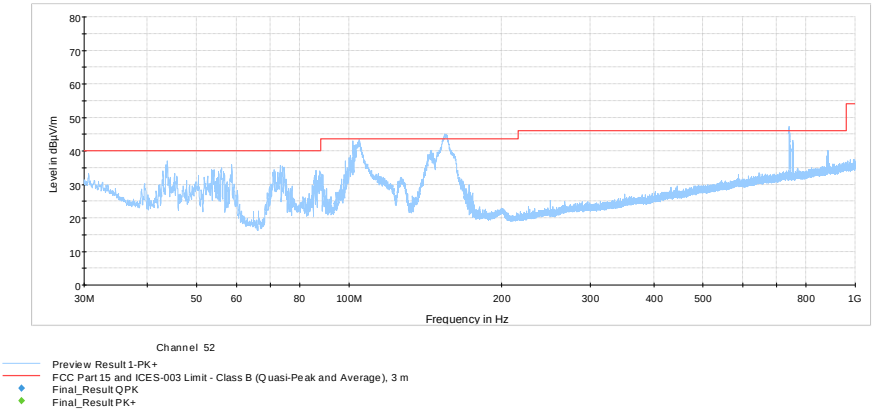


Figure 8.8-5: *Radiated spurious emissions 30 MHz – 1 GHz low channel, 802.11a*

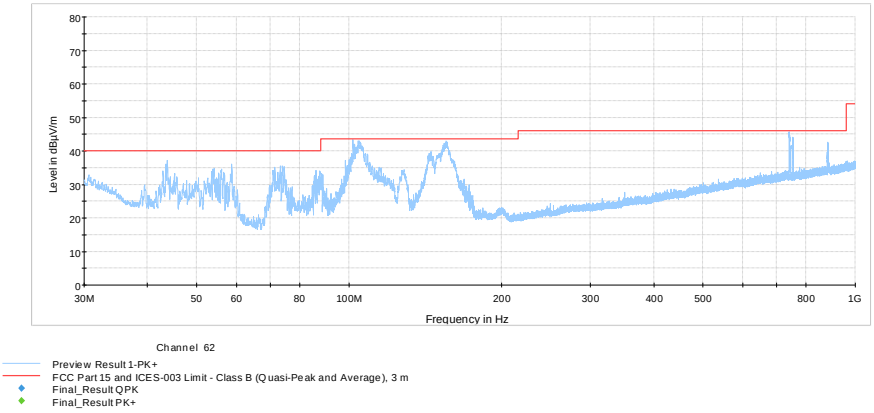


Figure 8.8-6: *Radiated spurious emissions 30 MHz – 1 GHz mid channel, 802.11a*

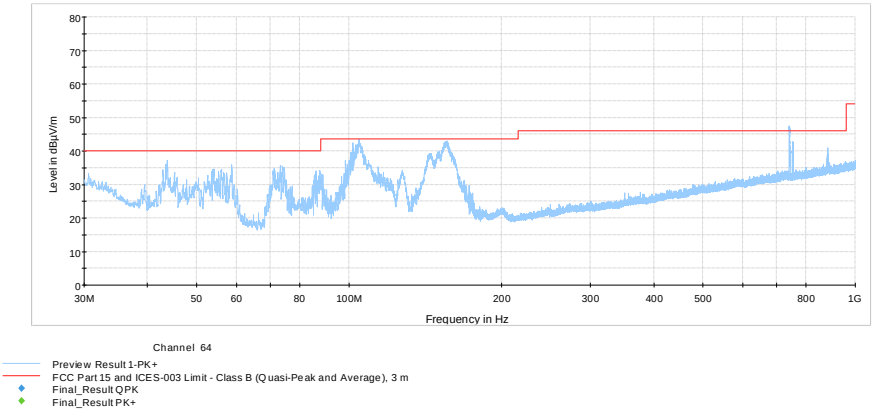


Figure 8.8-7: *Radiated spurious emissions 30 MHz – 1 GHz high channel, 802.11a*

8.8.4 Test data, continued

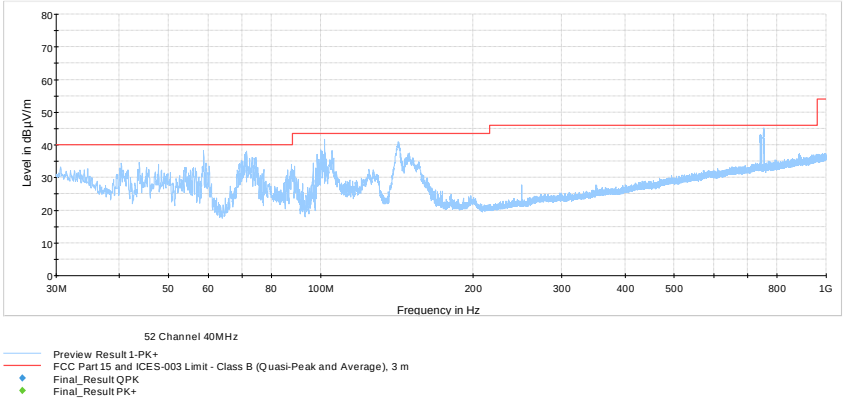


Figure 8.8-8: *Radiated spurious emissions 30 MHz – 1 GHz low channel, 802.11n*

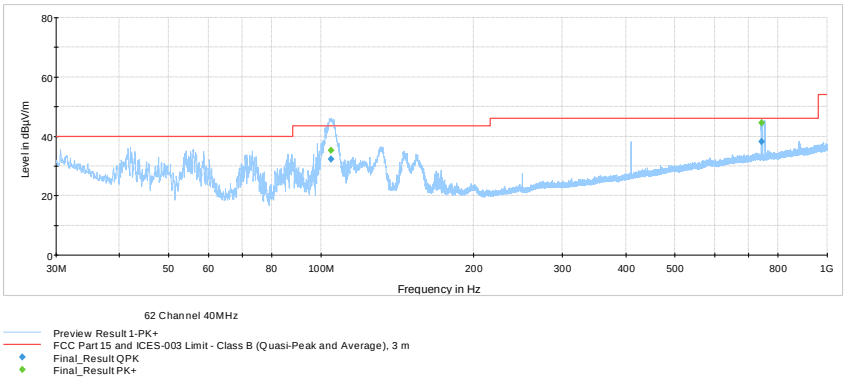


Figure 8.8-9: *Radiated spurious emissions 30 MHz – 1 GHz mid channel, 802.11n*

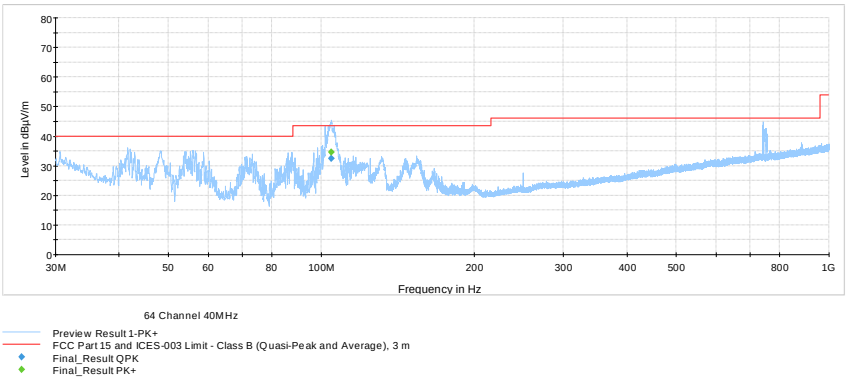


Figure 8.8-10: *Radiated spurious emissions 30 MHz – 1 GHz high channel, 802.11n*

8.8.4 Test data, continued

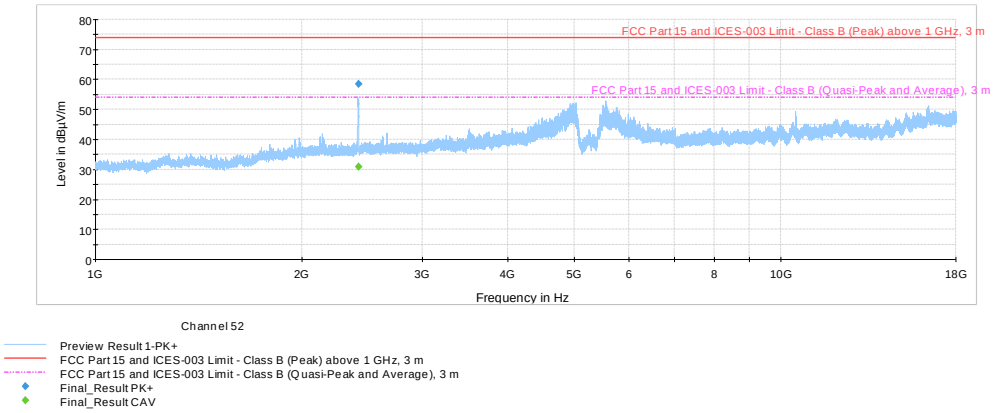


Figure 8.8-11: *Radiated spurious emissions 1 - 18 GHz low channel, 802.11a*

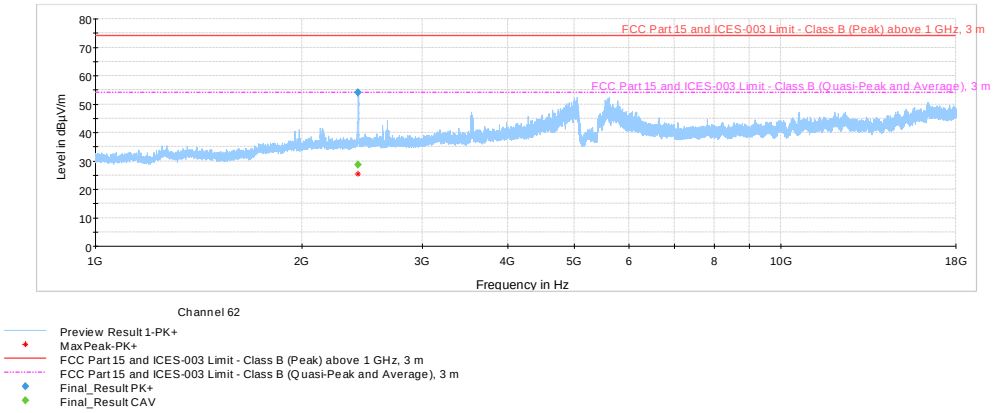


Figure 8.8-12: *Radiated spurious emissions 1 - 18 GHz mid channel, 802.11a*

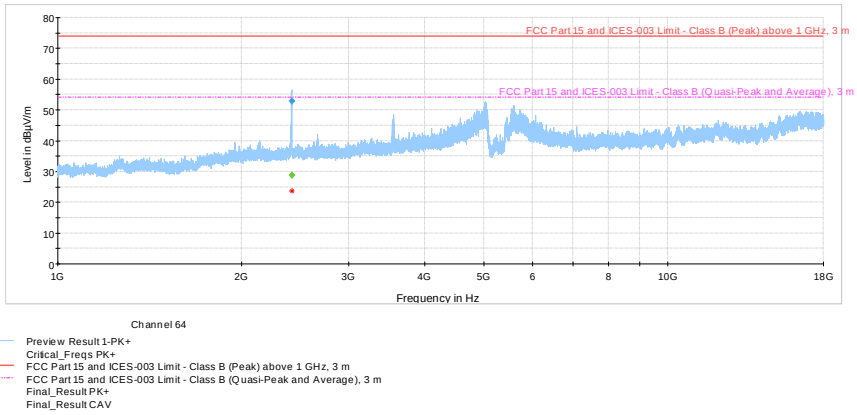


Figure 8.8-13: *Radiated spurious emissions 1 - 18 GHz high channel, 802.11a*

8.8.5 Test data, continued

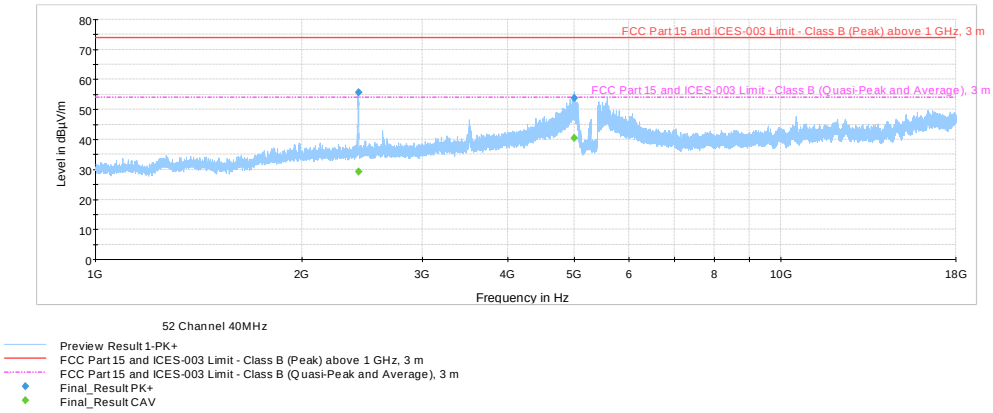


Figure 8.8-14: *Radiated spurious emissions 1 - 18 GHz low channel, 802.11n*

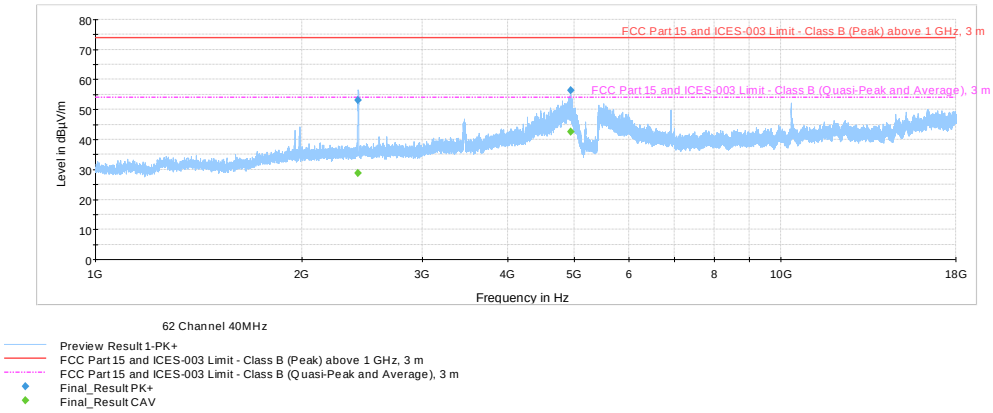


Figure 8.8-15*: Radiated spurious emissions 1 - 18 GHz mid channel, 802.11n*

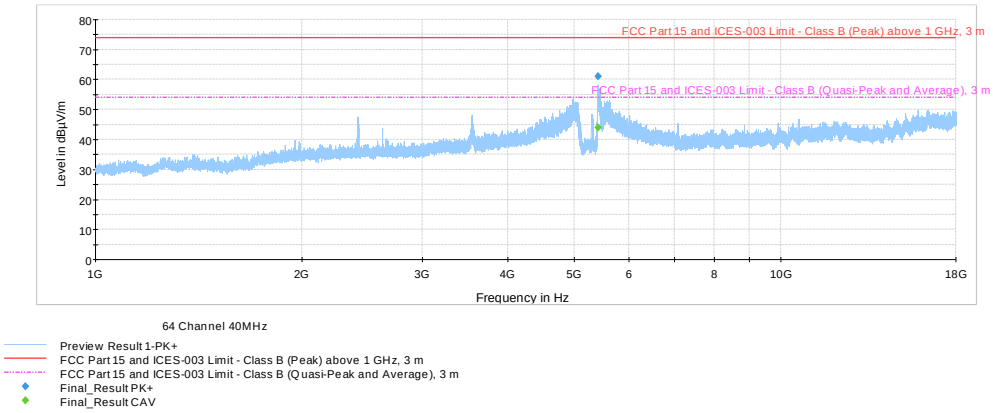


Figure 8.8-16: *Radiated spurious emissions 1 - 18 GHz high channel, 802.11n*

8.8.4 Test data, continued

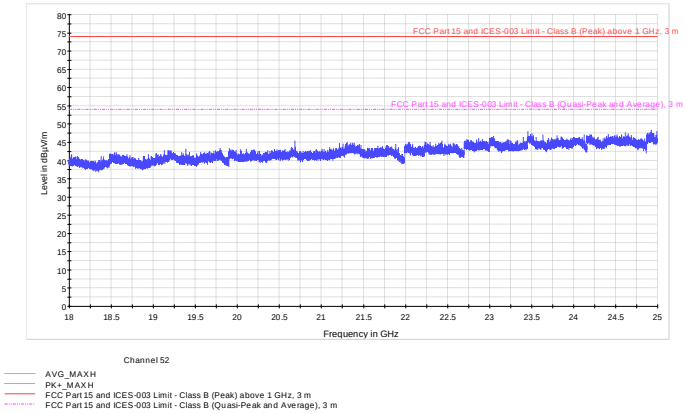


Figure 8.8-17: *Radiated spurious emissions 18 - 25 GHz low channel, 802.11a*

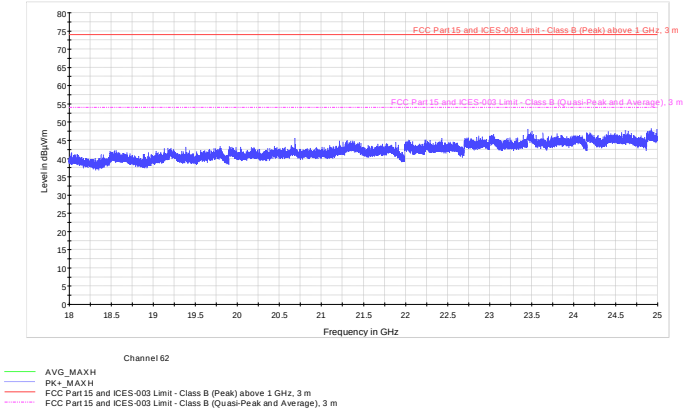


Figure 8.8-18: *Radiated spurious emissions 18 - 25 GHz mid channel, 802.11a*

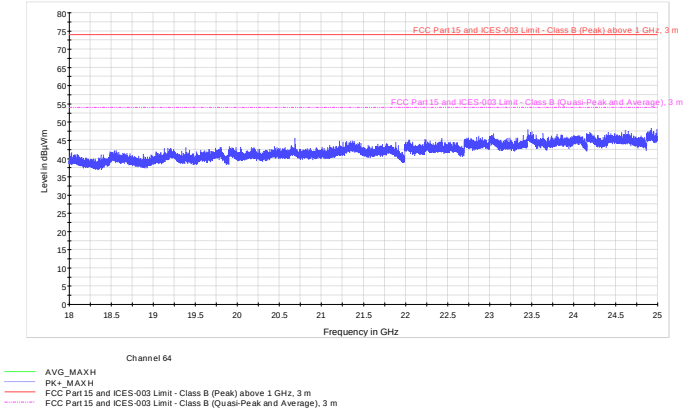


Figure 8.8-19: *Radiated spurious emissions 18 - 25 GHz high channel, 802.11a*

8.8.4 Test data, continued

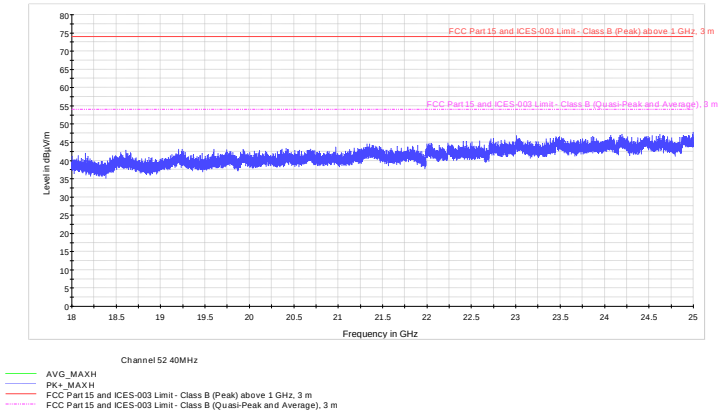


Figure 8.8-20: *Radiated spurious emissions 18 - 25 GHz low channel, 802.11n*

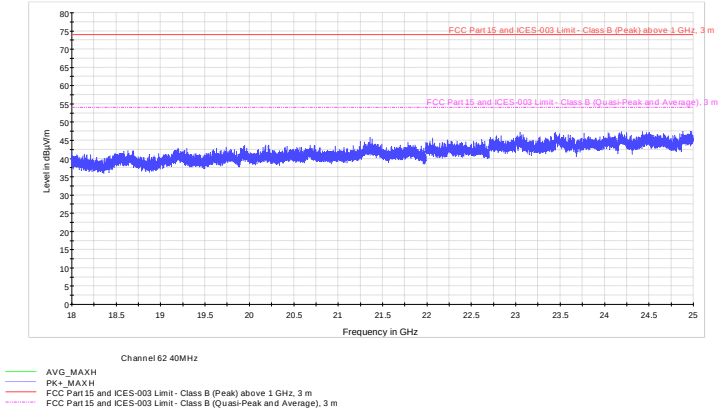


Figure 8.8-21: *Radiated spurious emissions 18 - 25 GHz mid channel, 802.11n*

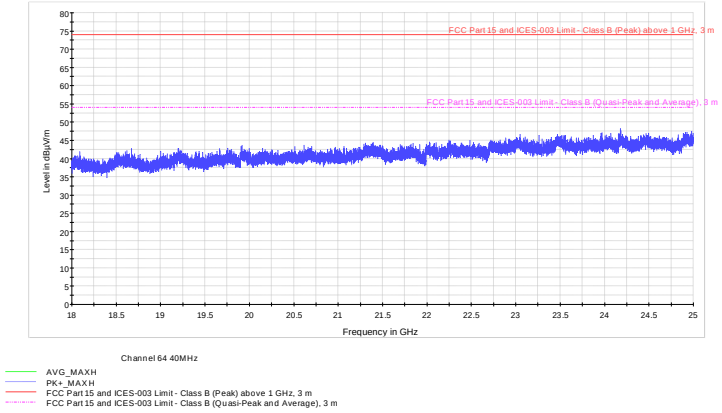


Figure 8.8-22: *Radiated spurious emissions 18 - 25 GHz high channel, 802.11n*

8.8.4 Test data, continued

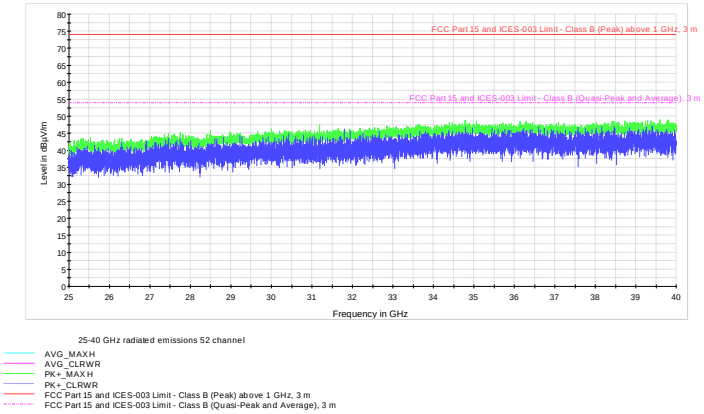


Figure 8.8-23: *Radiated spurious emissions 25 - 40 GHz low channel, 802.11a*

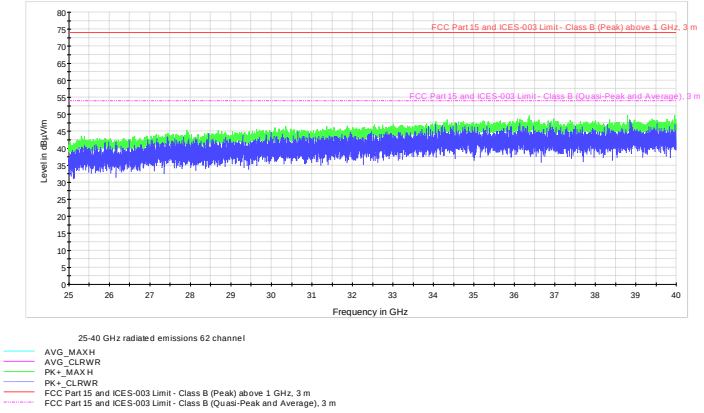


Figure 8.8-24: *Radiated spurious emissions 25 - 40 GHz mid channel, 802.11a*

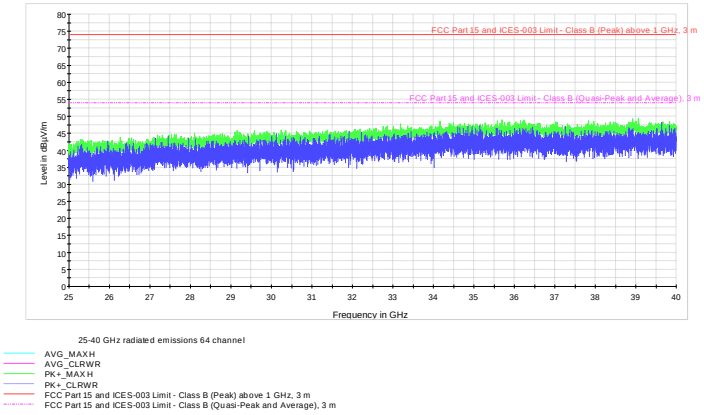


Figure 8.8-25: *Radiated spurious emissions 25 - 40 GHz high channel, 802.11a*

8.8.4 Test data, continued

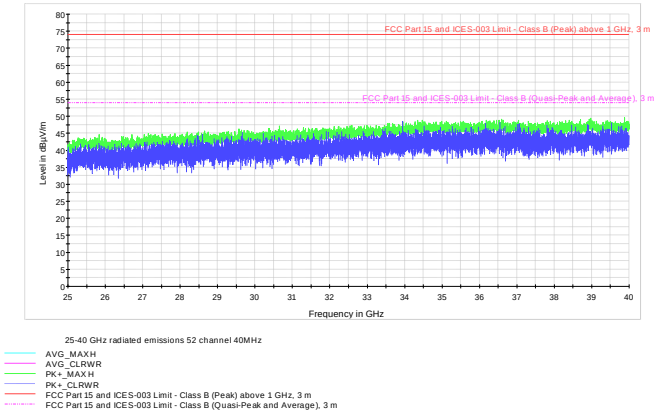


Figure 8.8-26: *Radiated spurious emissions 25 - 40 GHz low channel, 802.11n*

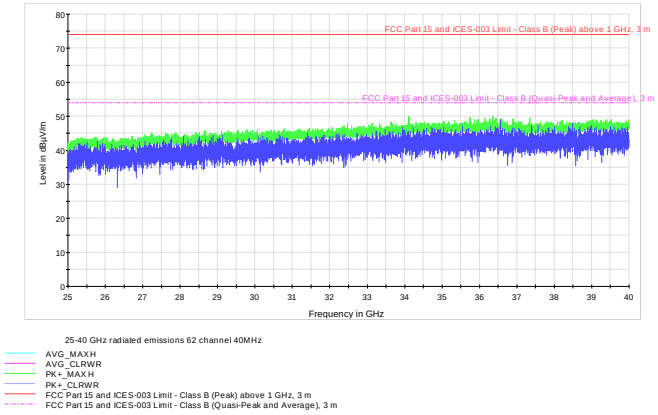


Figure 8.8-27: *Radiated spurious emissions 25 - 40 GHz mid channel, 802.11n*

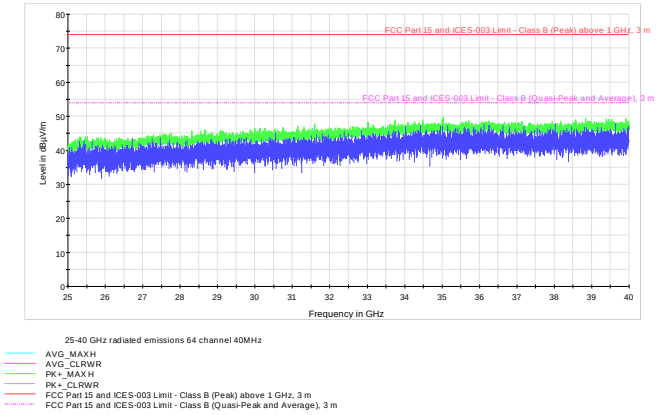


Figure 8.8-28: *Radiated spurious emissions 25 - 40 GHz high channel, 802.11n*

8.8.4 Test data, continued

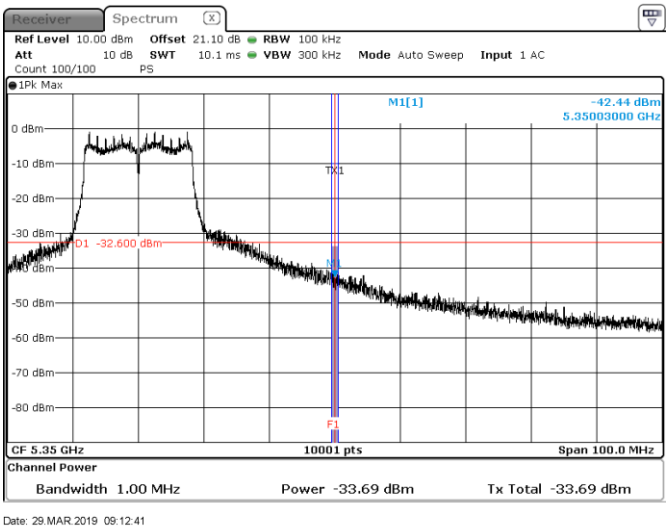


Figure 8.8-29: *Conducted emissions at band edge measurement, 802.11a*

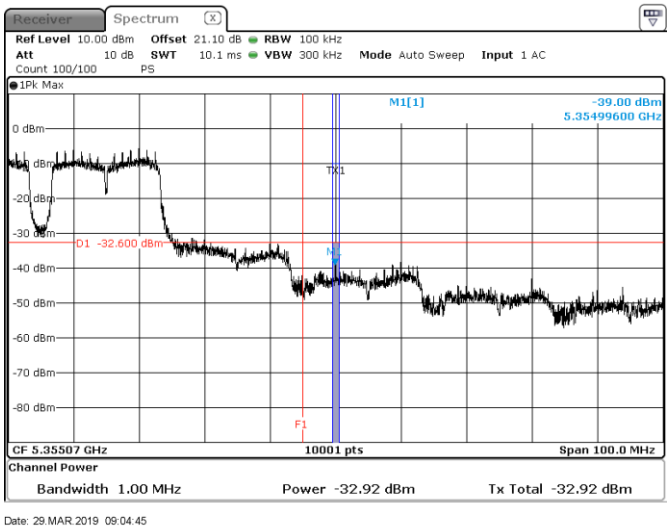


Figure 8.8-30: *Conducted emissions at band edge measurement, 802.11n*

Table 8.8-5: *Conducted band edge emissions at 5.15 GHz*

Channel	Modulation	Frequency, GHz	Emission strength, dBm / MHz	Antenna Gain	Emission strength EIRP, dBm / MHz	EIRP limit, dBm	Margin, dBm
64	802.11a	5.35	-33.7	5.6	-28.1	-27	1.1
64	802.11n	5.35	-32.9	5.6	-27.3	-27	0.3

8.8.4 Test data, continued

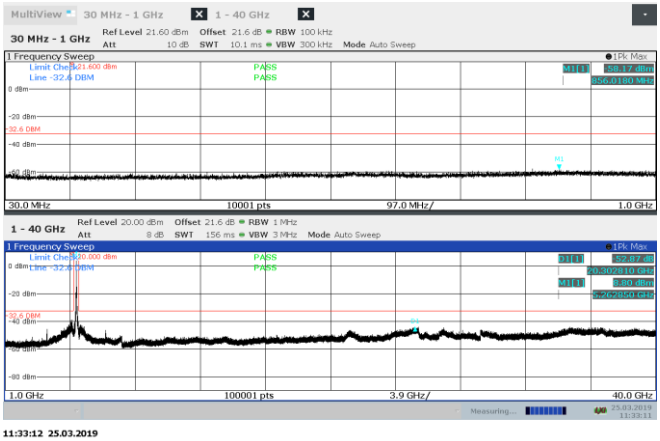


Figure 8.8-31: *Conducted spurious emissions 30 MHz – 40 GHz low channel, 802.11a*

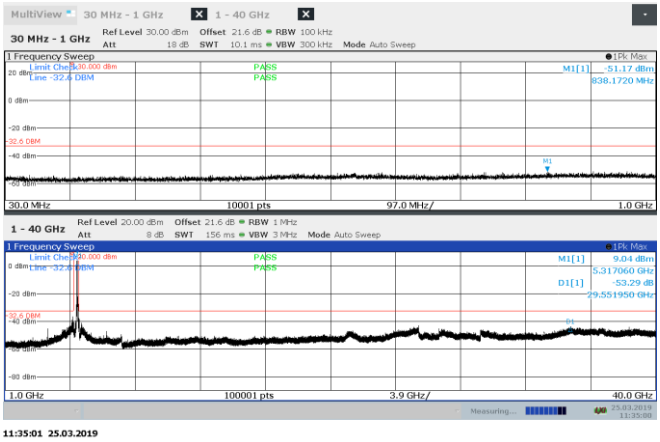


Figure 8.8-32: *Conducted spurious emissions 30 MHz – 40 GHz mid channel, 802.11a*

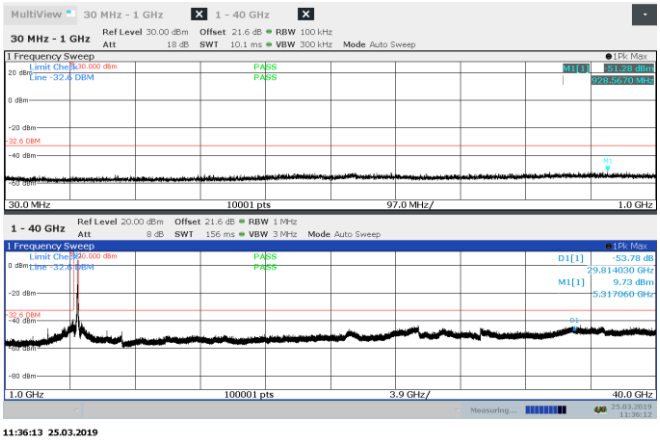


Figure 8.8-33: *Conducted spurious emissions 30 MHz – 40 GHz high channel, 802.11a*

8.8.4 Test data, continued

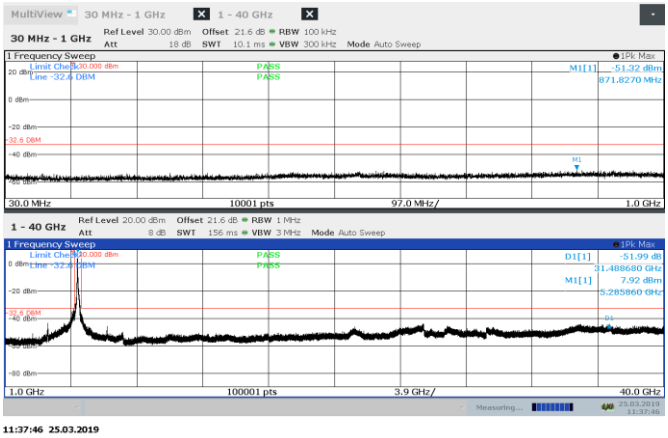


Figure 8.8-34: *Conducted spurious emissions 30 MHz – 40 GHz low channel, 802.11n*

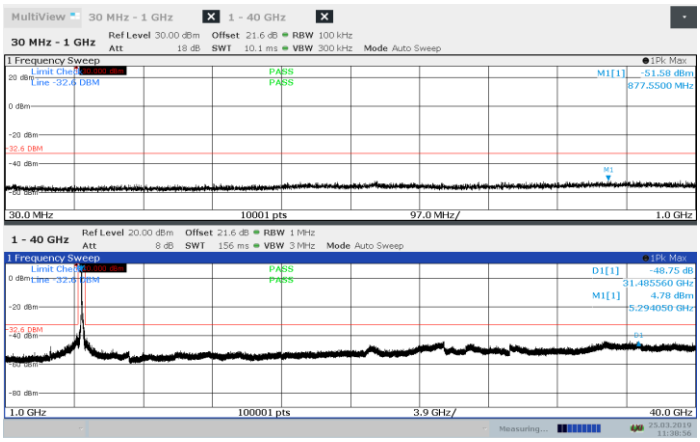


Figure 8.8-35: *Conducted spurious emissions 30 MHz – 40 GHz high channel, 802.11n*

8.9 FCC 15.407(g) and RSS-Gen 8.11 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	February 20, 2019

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*

Test conditions	Frequency, Hz	Drift, Hz
+50 °C, Nominal	5299994375	-11125
+40 °C, Nominal	5299986875	-18625
+30 °C, Nominal	5299998125	-7375
+20 °C, +15 %	5299998000	7500
+20 °C, Nominal	5300005500	***Reference***
+20 °C, −15 %	5300016750	-11250
+10 °C, Nominal	5300009375	3875
0 °C, Nominal	5299986875	-18625
−10 °C, Nominal	5300031875	26375
−20 °C, Nominal	5300005625	125
−30 °C, Nominal	5299960625	-44875

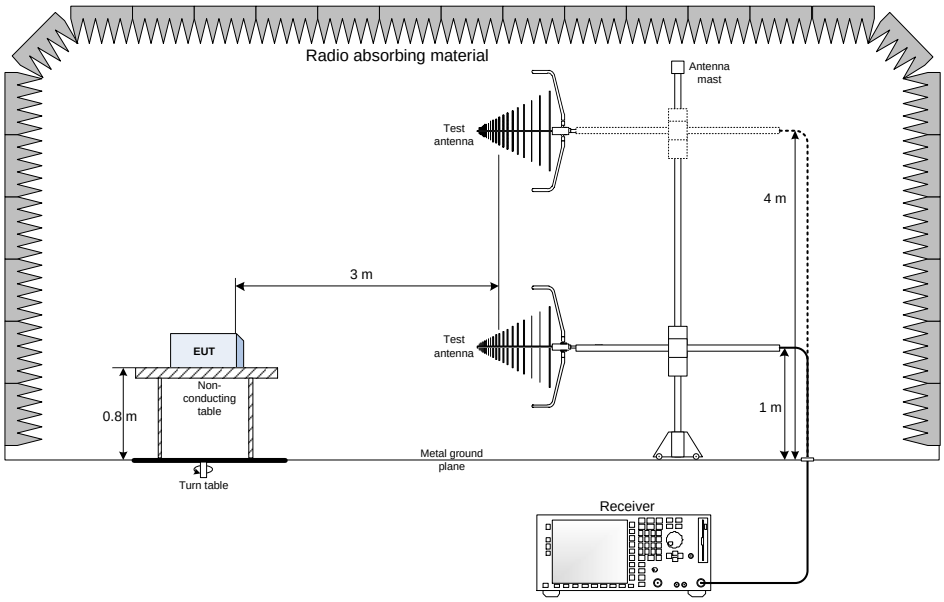
Table 8.9-2: *Upper band edge drift calculation*

Modulation	26 dBc upper cross point, GHz	Max positive drift, Hz	Drifted upper cross point, GHz	Band edge, GHz	Margin, MHz
802.11a	5.3300100	26375	5.330036375	5.35	20.0
802.11n	5.3317480	26375	5.331774375	5.35	18.2

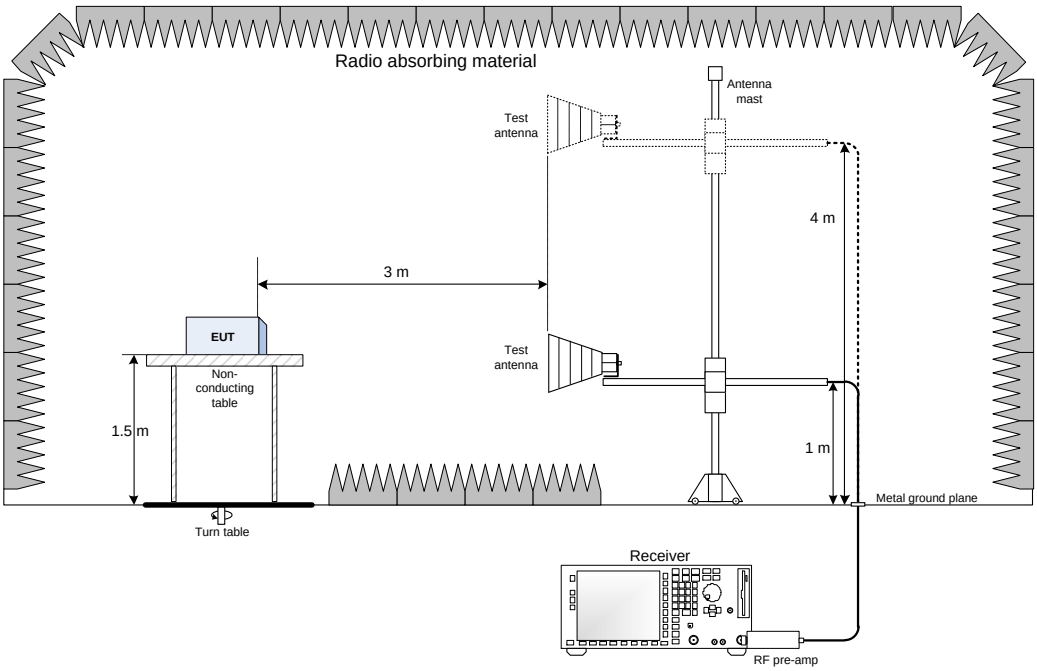
Notes: Drifted upper cross point = −26 dBc upper cross point + max positive drift.

Section 9. Block diagrams of test set-ups

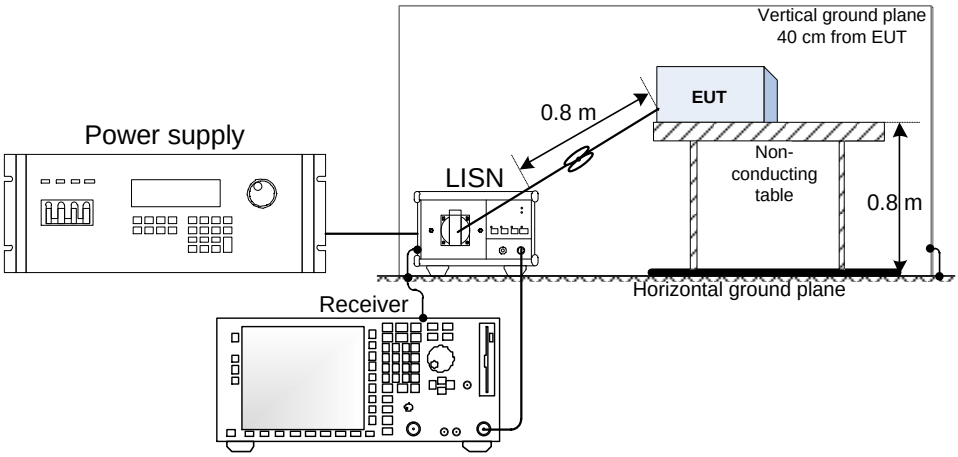
9.1 Radiated emissions set-up for frequencies below 1 GHz



9.2 Radiated emissions set-up for frequencies above 1 GHz



9.3 Conducted emissions set-up



9.4 Antenna port set-up