

RADIO TEST REPORT – 412143-1TRFWL

Type of assessment:

Final product testing

Applicant:

Alert Labs Inc.

Product name (type):

Sentree

Model:

ALF-000008-005**(3G cellular variant)**

Model variant:

ALF-000008-005L**(LTE cellular variant)**

FCC ID:

2AKXF-ALB050

IC Registration number:

22365-ALB050

Specifications:

- ◆ FCC 47 CFR Part 15 Subpart C, §15.247
- ◆ RSS-247, Issue 2, Feb 2017, Section 5

Date of issue: February 1, 2021

Tarek Elkholy, EMC/RF Specialist

Tested by



Signature

Mark Libbrecht, Deputy EMC/RF Lab Manager

Reviewed by



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 locations

Company name	Nemko Canada Inc.	
Facilities	<i>Cambridge site:</i> 1-130 Saltsman Drive Cambridge, Ontario Canada N3E 0B2 Tel: +1 519 650 4811	
Test site registration	Organization	Recognition numbers and location
	FCC/ISED	CA0101 (Cambridge)
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 contained in this report are within Nemko Canada's ISO/IEC 17025 accreditation.

Copyright notification

Nemko Canada Inc. authorizes the applicant to reproduce this report provided it is reproduced in its entirety and for use by the company's employees only. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties.

Nemko Canada Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

© Nemko Canada Inc.

Table of Contents

Table of Contents	3
Section 1 Report summary	4
1.1 Test specifications	4
1.2 Test methods	4
1.3 Exclusions	4
1.4 Statement of compliance	4
1.5 Test report revision history	4
Section 2 Engineering considerations	5
2.1 Modifications incorporated in the EUT for compliance	5
2.2 Technical judgment	5
2.3 Deviations from laboratory tests procedures	5
Section 3 Test conditions	6
3.1 Atmospheric conditions	6
3.2 Power supply range	6
Section 4 Measurement uncertainty	7
4.1 Uncertainty of measurement	7
Section 5 Information provided by the applicant	8
5.1 Disclaimer	8
5.2 Applicant	8
5.3 Manufacturer	8
5.4 EUT information	8
5.5 Technical information	9
5.6 EUT setup details	9
Section 6 Summary of test results	12
6.1 Testing location	12
6.2 Testing period	12
6.3 Sample information	12
6.4 FCC Part 15 Subpart C, general requirements test results	12
6.5 FCC Part 15 Subpart C, intentional radiators test results for digital transmission systems (DTS)	12
6.6 ISED RSS-Gen, Issue 5, test results	13
6.7 ISED RSS-247, Issue 2, test results for digital transmission systems (DTS)	13
Section 7 Test equipment	14
7.1 Test equipment list	14
Section 8 Testing data	15
8.1 FCC 15.31(e) Variation of power source	15
8.2 FCC 15.31(m) and RSS-Gen 6.9 Number of frequencies	16
8.3 FCC 15.203 and RSS-Gen, section 6.8 Antenna requirement	18
8.4 FCC 15.207(a) and RSS-Gen 8.8 AC power line conducted emissions limits	19
8.5 FCC 15.247(a)(2) and RSS-247 5.2(a) Minimum 6 dB bandwidth for DTS systems	23
8.6 FCC 15.247(b) and RSS-247 5.4(d) Transmitter output power and e.i.r.p. requirements for DTS in 900 MHz	26
8.7 FCC 15.247(d) and RSS-247 5.5 Spurious (out-of-band) unwanted emissions	30
8.8 FCC 15.247(e) and RSS-247 5.2(b) Power spectral density for digitally modulated devices	35
Section 9 Block diagrams of test set-ups	37
9.1 Radiated emissions set-up for frequencies below 1 GHz	37
9.2 Radiated emissions set-up for frequencies above 1 GHz	37
9.3 Conducted emissions set-up	38
9.4 Antenna port set-up	38

Section 1 Report summary

1.1 Test specifications

FCC 47 CFR Part 15, Subpart C, Clause 15.247	Operation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–585 MHz
RSS-247, Issue 2, Feb 2017, Section 5	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

1.2 Test methods

558074 D01 15.247 Meas Guidance v05r02 (April 2, 2019)	Guidance for compliance measurements on digital transmission system, frequency hopping spread spectrum system, and hybrid system devices operating under section 15.247 of the FCC rules.
ANSI C63.10 v2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
RSS-102, Issue 5, March 19, 2015	Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)

1.3 Exclusions

None.

1.4 Statement of compliance

In the configuration tested, the EUT was found compliant.

Testing was performed against all relevant requirements of the test standard except as noted in section 1.3 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.

1.5 Test report revision history

Table 1.5-1: Test report revision history

Revision #	Date of issue	Details of changes made to test report
TRF	February 1, 2021	Original report issued

Section 2 Engineering considerations

2.1 Modifications incorporated in the EUT for compliance

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

2.2 Technical judgment

None

2.3 Deviations from laboratory tests procedures

No deviations were made from laboratory procedures.

Section 3 Test conditions

3.1 Atmospheric conditions

Temperature	15 °C – 35 °C
Relative humidity	20 % – 75 %
Air pressure	86 kPa (860 mbar) – 106 kPa (1060 mbar)

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

3.2 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 4 Measurement uncertainty

4.1 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 4.1-1: Measurement uncertainty calculations for Radio

Test name	Measurement uncertainty, $\pm$ dB
All antenna port measurements	0.55
Occupied bandwidth	4.45
Conducted spurious emissions	1.13
Radiated spurious emissions	3.78
AC power line conducted emissions	3.55

Section 5 Information provided by the applicant

5.1 Disclaimer

This section contains information provided by the applicant and has been utilized to support the test plan. Inaccurate information provided by the applicant can affect the validity of the results contained within this test report. Nemko accepts no responsibility for the information contained within this section and the impact it may have on the test plan and resulting measurements.

5.2 Applicant

Company name	Alert Labs Inc.
Address	132 Queen Street South, Unit #2, Kitchener, Ontario, Canada N2G 1V9

5.3 Manufacturer

Company name	Alert Labs Inc.
Address	132 Queen Street South, Unit #2, Kitchener, Ontario, Canada N2G 1V9

5.4 EUT information

Product name	Sentree
Model	ALF-000008-005 (3G cellular variant)
Model variant(s)	ALF-000008-005L (LTE cellular variant)
Serial number	TD0.XXX.XXX.XXX (3G variant) TD2.XXX.XXX.XXX (LTE variant)
Part number	None
Operating conditions	Three test samples have been provided for radio testing. Each sample has been hardcoded to transmit data as quickly as possible on the low- (903MHz), mid- (915MHz), and high- (927.5MHz) frequencies in the 902 to 928MHz band. Once the power supply has been connected to the EUT, the LED on its front face will illuminate and the test sample will begin transmitting, within a few seconds, on the frequency marked on the enclosure of the EUT. The EUT was forced to transmit at its maximum possible duty cycle.
Product description and theory of operation	Sentree collects measurement data from sensors connected to the outdoor condenser unit of a central air conditioning or heat pump system and applies mathematical algorithms on the collected data to determine the health of the system. Sensors that are connected to the condenser are a current transformer attached to one of the AC mains electrical supply wires to measure the compressor current; 3 temperature sensors that will measure the ambient air temperature, the vapour temperature of the refrigerant ingress to the condenser unit, and the liquid temperature of the refrigerant egress from the condenser unit; 2 pressure sensors that measure the vapour pressure of the refrigerant ingress to the condenser unit and the liquid pressure of the refrigerant egress from the condenser unit. Sentree sends its collected data up to The Cloud via cellular radio module where it is processed. Sentree also contains a sub-1GHz radio module operating in the 915MHz band that communicates with Alert Labs companion devices.

5.5 Technical information

Applicant IC company number	22365
IC UPN number	ALB050
All used IC test site(s) Reg. number	24676
RSS number and Issue number	RSS-247 Issue 2, Feb 2017
Category of Wideband Data Transmission equipment	☐ Frequency Hopping Spread Spectrum (FHSS) equipment ☒ Other types of Wideband Data Transmission equipment (e.g. DSSS, OFDM, etc.).
Frequency band	902–928 MHz
Frequency Min (MHz)	903
Frequency Max (MHz)	927.5
RF power Max (W), Conducted	0.079 W; (19.0 dBm)
Field strength, dBμV/m @ 3 m	N/A
Measured BW (kHz), 6 dB Bandwidth	734.8
Type of modulation	Chirp spread spectrum
Emission classification	X1D
Transmitter spurious, dBμV/m @ 3 m	34.06 dBμV/m (Quasi Peak) @ 61.393 MHz
Power supply requirements	power converter Input: 90 - 264 V _{AC} , 50/60 Hz, Output: 12 V _{DC}
Antenna information	Printed helical PCB antenna, gain 0.01 dBi

5.6 EUT setup details

5.6.1 EUT Exercise and monitoring

Methods used to exercise the EUT and all relevant ports:

- The EUT was powered ON, the EUT power LED was ON through the whole test.

Configuration details:

- The EUT setup in a configuration that was expected to produce the highest amplitude emissions relative to the limit and that satisfy normal operation/installation practice by the end user.
- The type and construction of cables used in the measurement set-up were consistent with normal or typical use. Cables with mitigation features (for example, screening, tighter/more twists per length, ferrite beads) have been noted below:
 - None
- The EUT was setup in a manner that was consistent with its typical arrangement and use. The measurement arrangement of the EUT, local AE and associated cabling was representative of normal practice. Any deviations from typical arrangements have been noted below:
 - None

Monitoring details:

- The EUT was powered ON, the EUT power LED was ON and monitored through the whole test.

5.6 EUT setup details, continued

5.6.2 EUT test configuration

Table 5.6-1: EUT sub assemblies

Description	Brand name	Serial number, Part number, Model, Revision level
AC/DC adapter		SN: HB96P33072, MN: APV-16-12
Pressure sensor		SN: W1939843, MN: HDW-000040-003
Pressure sensor		SN: W1939692, MN: HDW-000040-003
Cable harness with three temperature sensors		None

Table 5.6-2: EUT interface ports

Description	Qty.
AC power input	1

Table 5.6-3: Inter-connection cables

Cable description	From	To	Length (m)
DC power input cable	AC/DC adapter	Sentree	3

5.6 EUT setup details, continued

5.6.2 EUT test configuration, continued



Figure 5.6-1: Radiated testing block diagram

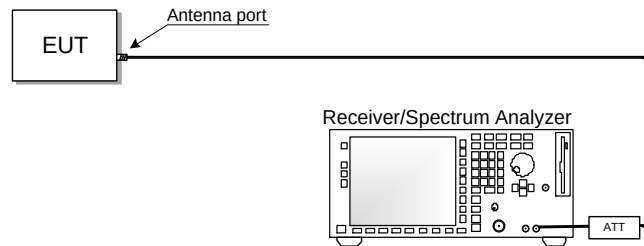


Figure 5.6-2: Antenna port testing block diagram

Section 6 Summary of test results

6.1 Testing location

Test location (s)	Cambridge
-------------------	-----------

6.2 Testing period

Test start date	January 8, 2021	Test end date	January 12, 2021
-----------------	-----------------	---------------	------------------

6.3 Sample information

Receipt date	December 24, 2020	Nemko sample ID number(s)	1, 2 and 3
--------------	-------------------	---------------------------	------------

6.4 FCC Part 15 Subpart C, general requirements test results

Table 6.4-1: FCC general requirements results

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

Notes: EUT is an AC powered device.

6.5 FCC Part 15 Subpart C, intentional radiators test results for digital transmission systems (DTS)

Table 6.5-1: FCC 15.247 results for DTS

Part	Test description	Verdict
§15.247(a)(2)	Minimum 6 dB bandwidth	Pass
§15.247(b)(3)	Maximum peak output power in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands	Pass
§15.247l(1)	Fixed point-to-point operation with directional antenna gains greater than 6 dBi	Not applicable
§15.247l(2)	Transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams	Not applicable
§15.247(d)	Spurious emissions	Pass
§15.247l	Power spectral density	Pass
§15.247(f)	Time of occupancy for hybrid systems	Not applicable

6.6 ISED RSS-Gen, Issue 5, test results

Table 6.6-1: RSS-Gen results

Part	Test description	Verdict
7.3	Receiver radiated emission limits	Not applicable
7.4	Receiver conducted emission limits	Not applicable
6.9	Operating bands and selection of test frequencies	Pass
8.8	AC power-line conducted emissions limits	Pass

Notes: ¹ According to sections 5.2 and 5.3 of RSS-Gen, Issue 5 the EUT does not have a stand-alone receiver neither scanner receiver, therefore exempt from receiver requirements.

EUT is an AC powered device.

6.7 ISED RSS-247, Issue 2, test results for digital transmission systems (DTS)

Table 6.7-1: RSS-247 results for DTS

Part	Test description	Verdict
5.2 (a)	Minimum 6 dB bandwidth	Pass
5.2 (b)	Maximum power spectral density	Pass
5.3	Hybrid Systems	
5.3 (a)	Digital modulation turned off	Not applicable
5.3 (b)	Frequency hopping turned off	Not applicable
5.4	Transmitter output power and e.i.r.p. requirements	
5.4 (d)	Systems employing digital modulation techniques	Pass
5.4 (e)	Point-to-point systems in 2400–2483.5 MHz and 5725–5850 MHz band	Not applicable
5.4 (f)	Transmitters which operate in the 2400–2483.5 MHz band with multiple directional beams	Not applicable
5.5	Unwanted emissions	Pass

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	April 10, 2021
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	November 12, 2021
Spectrum analyzer	Rohde & Schwarz	FSW43	FA002971	1 year	November 13, 2021
Victor Signal Generator	Rohde & Schwarz	SMW200A	FA002970	1 year	November 13, 2021
Bilog antenna (30–2000 MHz)	SUNAR	JB1	FA003010	1 year	March 17, 2021
Horn antenna (1–18 GHz)	ETS Lindgren	3117	FA002911	1 year	March 11, 2021
Preamp (1–18 GHz)	ETS Lindgren	124334	FA002956	1 year	March 11, 2021
50 Ω coax cable	Huber + Suhner	None	FA003047	1 year	December 17, 2021
50 Ω coax cable	Huber + Suhner	None	FA003044	1 year	December 17, 2021

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 References, definitions and limits

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 summary

Verdict	Pass		
Tested by	Tarek Elkholy	Test date	January 8, 2021

8.1.3 Observations, settings and special notes

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

- 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.
- 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.
- 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.
- 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

EUT Power requirements:	☒ AC	☐ DC	☐ Battery
If EUT is an AC or a DC powered, was the noticeable output power variation observed?	☐ YES	☒ NO	☐ N/A
If EUT is battery operated, was the testing performed using fresh batteries?	☐ YES	☐ NO	☒ N/A
If EUT is rechargeable battery operated, was the testing performed using fully charged batteries?	☐ YES	☐ NO	☒ N/A

8.2 FCC 15.31(m) and RSS-Gen 6.9 Number of frequencies

8.2.1 References, definitions and limits

FCC:

Measurements on intentional radiators or 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.

ISED:

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

Note: “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 summary

Verdict	Pass		
Tested by	Tarek Elkholy	Test date	January 8, 2021

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

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
902	928	24.5	903	915	927.5

8.3 FCC 15.203 and RSS-Gen, section 6.8 Antenna requirement

8.3.1 References, definitions and limits

FCC:

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.

FCC 15.247(b)(4)

The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

ISED:

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 summary

Verdict	Pass		
Tested by	Tarek Elkholy	Test date	January 8, 2021

8.3.3 Observations, settings and special notes

None

8.3.4 Test data

Must the EUT be professionally installed? ☒ YES ☐ NO
Does the EUT have detachable antenna(s)? ☐ YES ☒ NO
If detachable, is the antenna connector(s) non-standard? ☐ YES ☐ NO ☒ N/A

Table 8.3-1: Antenna information

Antenna type	Maximum gain	Connector type
helical PCB antenna, gain 0.01 dBi	0.01 dBi	Printed

8.4 FCC 15.207(a) and RSS-Gen 8.8 AC power line conducted emissions limits

8.4.1 References, definitions and limits

FCC:

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.

IC:

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: 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

Note: * - The level decreases linearly with the logarithm of the frequency.

** - A linear average detector is required.

8.4.2 Test summary

Verdict	Pass		
Tested by	Tarek Elkholy	Test date	January 12, 2021

8.4.3 Observations, settings and special notes

The EUT was set up as tabletop configuration per ANSI C63.10-2013 measurement procedure.

The spectral scan has been corrected with transducer factors (i.e. cable loss, LISN factors, and attenuators) for determination of compliance.

A preview measurement was generated with the receiver in continuous scan mode. Emissions detected within 6 dB or above limit were re-measured with the appropriate detector against the correlating limit and recorded as the final measurement.

The EUT was transmitting at its maximum allowable duty cycle.

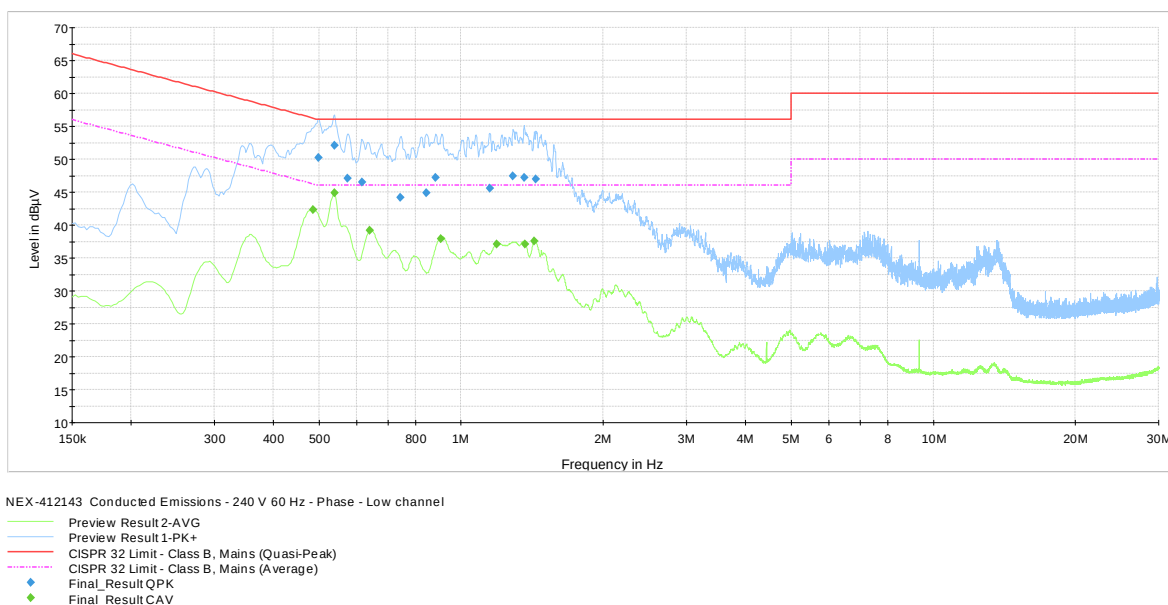
EMI Receiver settings for preview measurements:

Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	Peak and Average
Trace mode	Max Hold
Measurement time	1000 ms

Receiver settings for final measurements:

Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	Quasi-Peak and Average
Trace mode	Max Hold
Measurement time	1000 ms

8.4.4 Test data



Plot 8.4-1: Conducted emissions on phase line

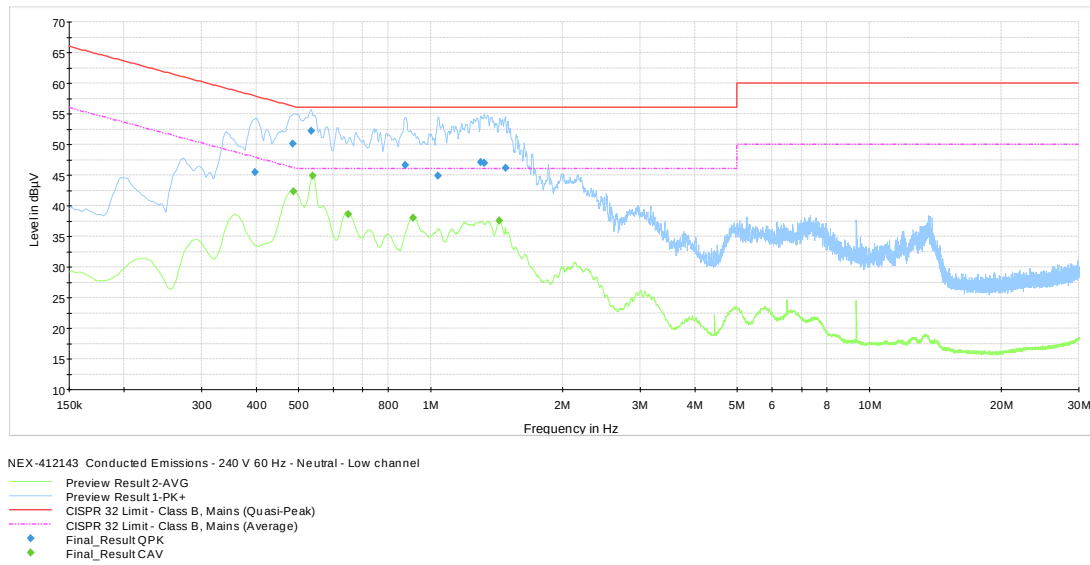
Table 8.4-2: Quasi-Peak conducted emissions results on phase line

Frequency, MHz	Q-Peak result, dBµV	Correction, dB	Margin, dB	Limit, dBµV
0.499	50.2	9.8	5.8	56.0
0.539	52.1	9.8	3.9	56.0
0.575	47.1	9.8	8.9	56.0
0.618	46.5	9.8	9.5	56.0
0.744	44.2	9.8	11.8	56.0
0.845	44.8	9.8	11.2	56.0
0.884	47.2	9.7	8.8	56.0
1.151	45.6	9.7	10.4	56.0
1.289	47.5	9.7	8.5	56.0
1.361	47.2	9.7	8.8	56.0
1.442	47.0	9.7	9.0	56.0

Note: 50.2 dBµV = 40.4 dBµV (receiver reading) + 3.6 dB (LISN factor IL) + 0.2 dB (cable loss) + 6 dB (attenuator)

Table 8.4-3: Average conducted emissions results on phase line

Frequency, MHz	Average result, dBµV	Correction, dB	Margin, dB	Limit, dBµV
0.5	42.4	9.8	3.9	46.2
0.5	44.9	9.8	1.1	46.0
0.6	39.1	9.8	6.9	46.0
0.9	38.0	9.7	8.0	46.0
1.2	37.1	9.7	8.9	46.0
1.4	37.1	9.7	8.9	46.0
1.4	37.6	9.7	8.4	46.0



Plot 8.4-2: Conducted emissions on neutral line

Table 8.4-4: Quasi-Peak conducted emissions results on neutral line

Frequency, MHz	Q-Peak result, dBµV	Correction, dB	Margin, dB	Limit, dBµV
0.4	45.5	9.7	12.5	57.9
0.5	50.2	9.8	6.1	56.2
0.5	52.2	9.8	3.8	56.0
0.9	46.6	9.7	9.4	56.0
1.0	44.9	9.7	11.1	56.0
1.3	47.1	9.7	8.9	56.0
1.3	47.0	9.7	9.0	56.0
1.5	46.1	9.7	9.9	56.0

Table 8.4-5: Average conducted emissions results on neutral line

Frequency, MHz	Average result, dBµV	Correction, dB	Margin, dB	Limit, dBµV
0.5	42.3	9.8	3.9	46.2
0.5	44.9	9.8	1.1	46.0
0.7	38.7	9.7	7.3	46.0
0.9	38.0	9.7	8.0	46.0
1.4	37.6	9.7	8.4	46.0

8.5 FCC 15.247(a)(2) and RSS-247 5.2(a) Minimum 6 dB bandwidth for DTS systems

8.5.1 References, definitions and limits

FCC:

Systems using digital modulation techniques may operate in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

ISED:

The minimum 6 dB bandwidth shall be 500 kHz.

RSS-GEN, Section 6.7:

6 dB bandwidth is defined as the frequency range between two points, one at the lowest frequency below and one at the highest frequency above the carrier frequency, at which the maximum power level of the transmitted emission is attenuated 6 dB below the maximum in-band power level of the modulated signal, where the two points are on the outskirts of the in-band emission.

For the 99% emission bandwidth, the trace data points are recovered and directly summed in linear power level terms. The recovered amplitude data points, beginning at the lowest frequency, are placed in a running sum until 0.5% of the total is reached, and that frequency recorded. The process is repeated for the highest frequency data points (starting at the highest frequency, at the right side of the span, and going down in frequency). This frequency is then recorded. The difference between the two recorded frequencies is the occupied bandwidth (or the 99% emission bandwidth).

8.5.2 Test summary

Verdict	Pass		
Tested by	Tarek Elkholy	Test date	January 8, 2021

8.5.3 Observations, settings and special notes

The test was performed as per KDB 558074, section 8.2 with reference to ANSI C63.10 subclause 11.8.

Spectrum analyser settings:

Resolution bandwidth	6 dB BW: 100 kHz; 99% OBW: 1–5% of OBW
Video bandwidth	$\geq 3 \times \text{RBW}$
Frequency span	2 MHz
Detector mode	Peak
Trace mode	Max Hold

8.5.4 Test data

Table 8.5-1: 99% occupied bandwidth results

Modulation	Frequency, MHz	99% occupied bandwidth, kHz
Chirp spread spectrum	903	0.611
	915	0.610
	927.5	0.612

Note: there is no 99% occupied bandwidth limit in the standard's requirements, the measurement results provided for information purposes only.

Table 8.5-2: 6 dB bandwidth results

Modulation	Frequency, MHz	6 dB bandwidth, MHz	Minimum limit, MHz	Margin, MHz
Chirp spread spectrum	903	0.705	0.500	0.205
	915	0.735	0.500	0.235
	927.5	0.705	0.500	0.205

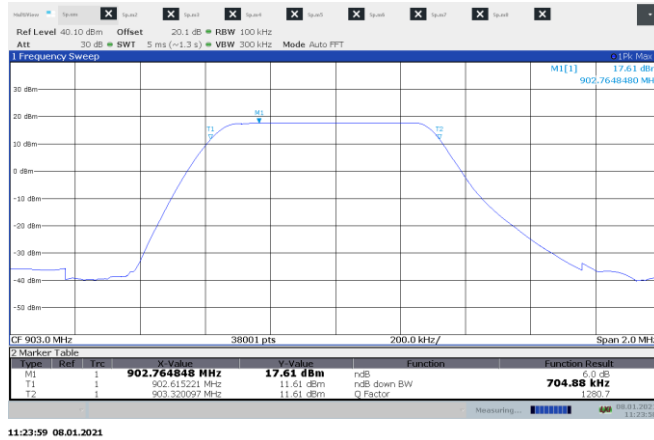


Figure 8.5-1: 6 dB bandwidth on 903 MHz

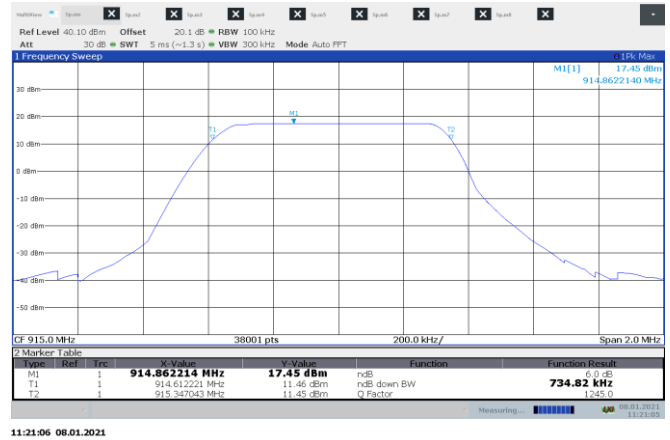


Figure 8.5-2: 6 dB bandwidth on 915 MHz

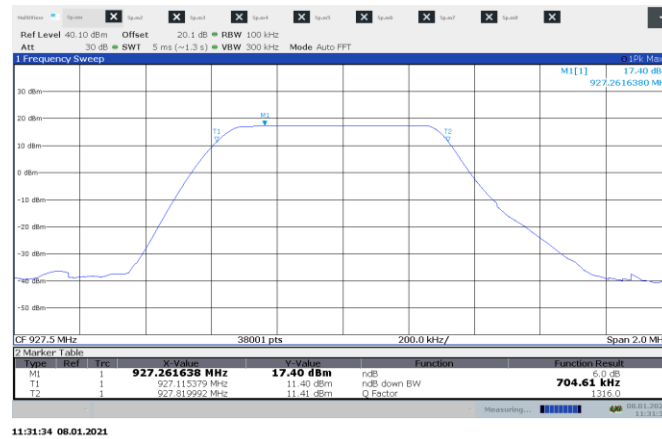
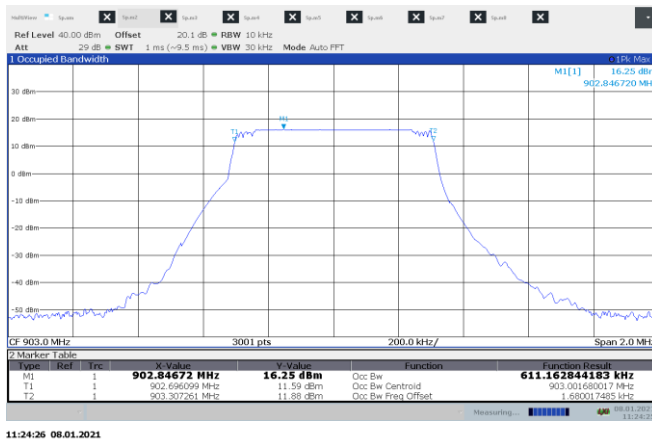
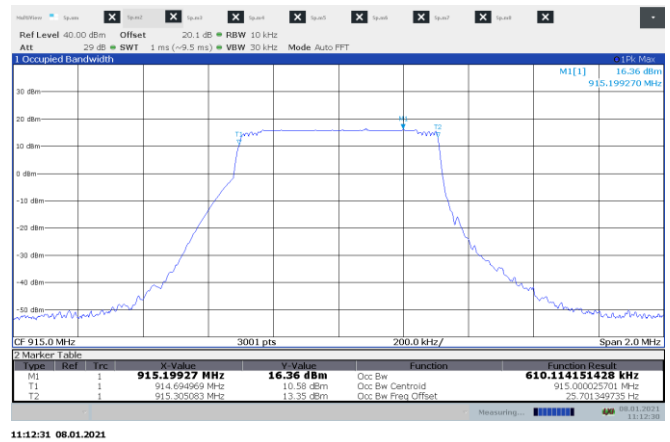
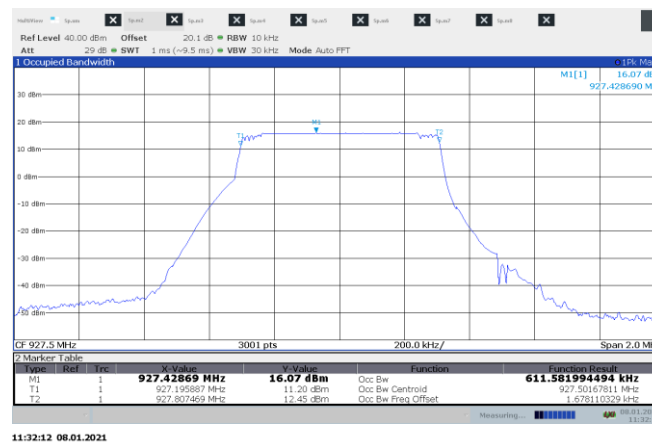


Figure 8.5-3: 6 dB bandwidth on 927.5 MHz


Figure 8.5-4: 99% occupied bandwidth on 903 MHz

Figure 8.5-5: 99% occupied bandwidth on 915 MHz

Figure 8.5-6: 99% occupied bandwidth on 927.5 MHz

8.6 FCC 15.247(b) and RSS-247 5.4(d) Transmitter output power and e.i.r.p. requirements for DTS in 900 MHz

8.6.1 References, definitions and limits

FCC:

- (b) The maximum peak conducted output power of the intentional radiator shall not exceed the following:
- (3) For systems using digital modulation in the 902–928 MHz band: 1 W (30 dBm). As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted output power. Maximum Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.
 - (4) The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.
- (c) Operation with directional antenna gains greater than 6 dBi.
- (1) Fixed point-to-point operation:
- (iii) Fixed, point-to-point operation, as used in paragraphs (c)(1)(i) and (c)(1)(ii) of this section, excludes the use of point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information. The operator of the spread spectrum or digitally modulated intentional radiator or, if the equipment is professionally installed, the installer is responsible for ensuring that the system is used exclusively for fixed, point-to-point operations. The instruction manual furnished with the intentional radiator shall contain language in the installation instructions informing the operator and the installer of this responsibility.

ISED:

- d. For DTSs employing digital modulation techniques operating in the 902–928 MHz band, the maximum peak conducted output power shall not exceed 1 W. The e.i.r.p. shall not exceed 4 W, except as provided in section 5.4(e).

As an alternative to a peak power measurement, compliance can be based on a measurement of the maximum conducted output power. The maximum conducted output power is the total transmit power delivered to all antennas and antenna elements, averaged across all symbols in the signalling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or transmitting at a reduced power level. If multiple modes of operation are implemented, the maximum conducted output power is the highest total transmit power occurring in any mode.

8.6.2 Test summary

Verdict	Pass		
Tested by	Tarek Elkholy	Test date	January 8, 2021

8.6.3 Observations, settings and special notes

- The test was performed as per KDB 558074, section 8.3 with reference to ANSI C63.10 subclause 11.9.1 (peak power) using Choose an item. subclause 11.9.2 (average power) using method AVGSA-2 (trace averaging across on- and off-times of the EUT transmissions, followed by duty cycle correction).

Spectrum analyser settings:

Resolution bandwidth	20 kHz
Video bandwidth	$\geq 3 \times \text{RBW}$
Frequency span	2 MHz
Detector mode	RMS
Trace mode	Average

8.6.4 Test data

Table 8.6-1: Output power and EIRP results (antenna port measurement)

Frequency, MHz	Conducted output power, dBm	Duty cycle corrected output power, dBm	Output power limit, dBm	Output power margin, dB	Antenna gain, dBi	EIRP, dBm	EIRP limit, dBm	EIRP margin, dB
903	5.6	18.4	30	11.6	0.01	18.4	36	17.6
915	6.2	19.0	30	11.0	0.01	19.0	36	17.0
927.5	5.7	18.5	30	11.5	0.01	18.5	36	17.5

Note: EIRP [dBm] = Conducted output power [dBm] + Antenna gain [dBi]

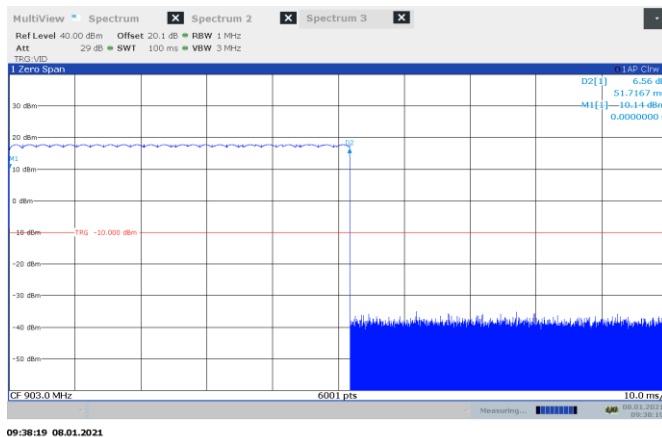


Figure 8.6-1: Pulse duration

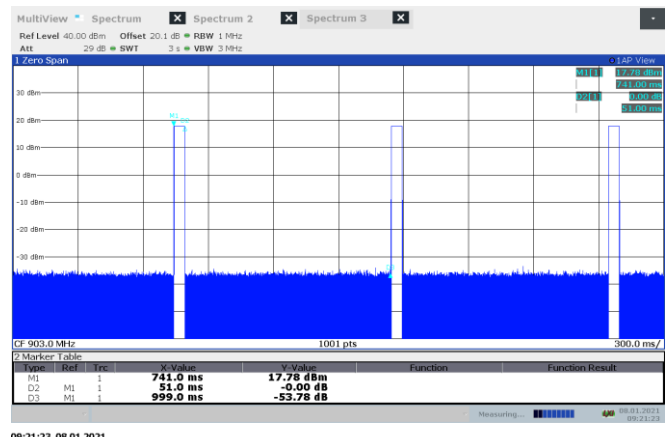


Figure 8.6-2: Duty cycle correction train

Duty cycle calculation: $10 \times \log_{10} [1/(T_{\text{on}}/\text{Observation period})] = 10 \times \log_{10} [1/(51.7 \text{ msec} / 999 \text{ msec})] = 12.8 \text{ dB}$

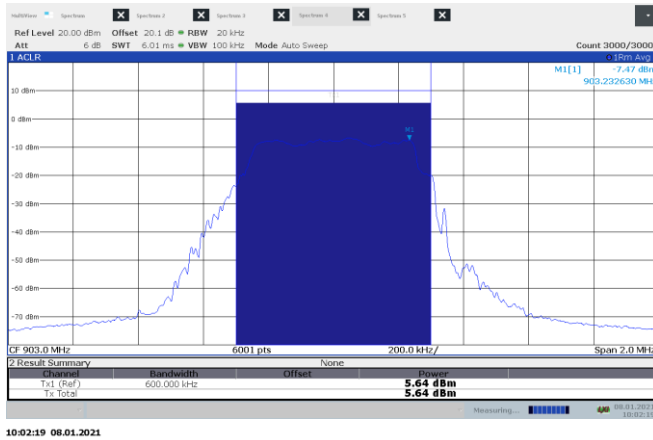


Figure 8.6-3: Output power on low channel

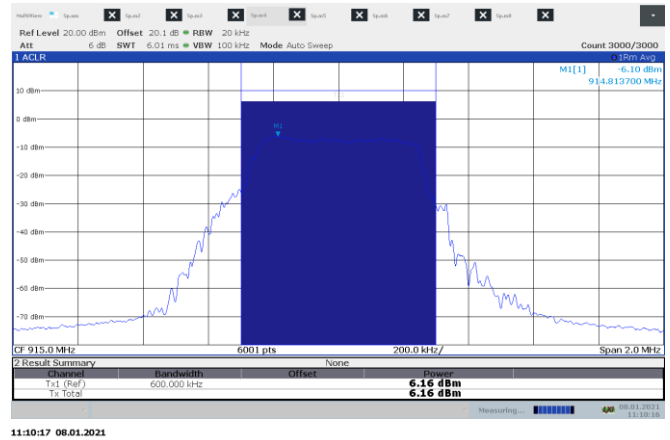


Figure 8.6-4: Output power on mid channel

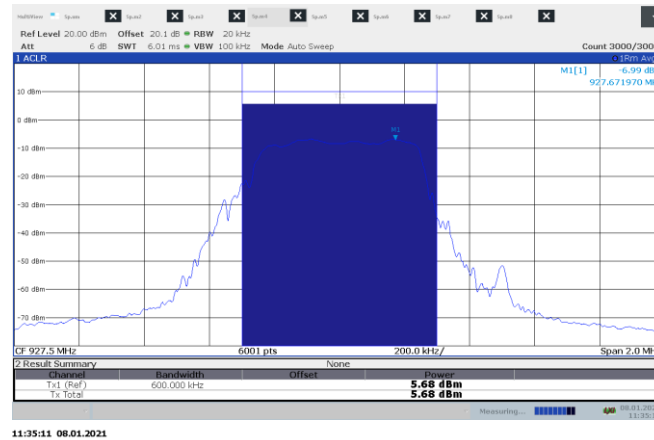


Figure 8.6-5: Output power on high channel

8.7 FCC 15.247(d) and RSS-247 5.5 Spurious (out-of-band) unwanted emissions

8.7.1 References, definitions and limits

FCC:

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

ISED:

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

Table 8.7-1: FCC §15.209 and RSS-Gen – Radiated emission limits

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

Notes: In the emission table above, the tighter limit applies at the band edges.

For frequencies above 1 GHz the limit on peak RF emissions is 20 dB above the maximum permitted average emission limit applicable to the equipment under test

Table 8.7-2: 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	
8.41425–8.41475	167.72–173.2	3500–4400	Above 38.6
12.29–12.293	240–285	4500–5150	
12.51975–12.52025	322–335.4	5350–5460	

Note: Certain frequency bands listed in Table 8.7-2 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 8.7-3: 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			

8.7.2 Test summary

Verdict	Pass		
Tested by	Tarek Elkholy	Test date	January 8, 2021

8.7.3 Observations, settings and special notes

As part of the current assessment, the test range of 9 kHz to 10th harmonic has been fully considered and compared to the actual frequencies utilized within the EUT. Since the EUT contains a transmitter in the GHz range, the EUT has been deemed compliant without formal testing in the 9 kHz to 30 MHz test range, therefore formal test results (tabular data and/or plots) are not provided within this test report.

Radiated measurements were performed at a distance of 3 m.

DTS emissions in non-restricted frequency bands test was performed as per KDB 558074, section 8.5 with reference to ANSI C63.10 subclause 11.11.

Since fundamental power was tested using maximum conducted (average) output power procedure to demonstrate compliance, the spurious emissions limit is -30 dBc/100 kHz.

DTS emissions in restricted frequency bands test was performed as per KDB 558074, section 8.6 with reference to ANSI C63.10 subclause 11.12.

DTS band-edge emission measurements test was performed as per KDB 558074, section 8.7 with reference to ANSI C63.10 subclause 11.13.

Average was calculated from peak results using duty cycle correction factor (DCCF).

Pulse width = 51.7 ms, Pulse repetition = 999 ms (1 pulses within 999 ms) $DCCF = 10 \times \log_{10} [1/(51.7 \text{ msec} / 999 \text{ msec})] = 12.8 \text{ dB}$

Any uninvestigated emissions exceeding the applicable limit lines noticed in the below 1 GHz radiated scans are not related to the EUT and were present in the ambient scan.

Spectrum analyser settings for radiated measurements within restricted bands below 1 GHz:

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

Spectrum analyser settings for peak radiated measurements within restricted bands above 1 GHz:

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

Spectrum analyser settings for average radiated measurements at band edges:

Resolution bandwidth:	100 kHz
Video bandwidth:	300 kHz
Detector mode:	RMS
Trace mode:	Average

Spectrum analyser settings for conducted spurious emissions measurements:

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

8.7.4 Test data



Figure 8.7-1: Band edge spurious emissions at 902 MHz

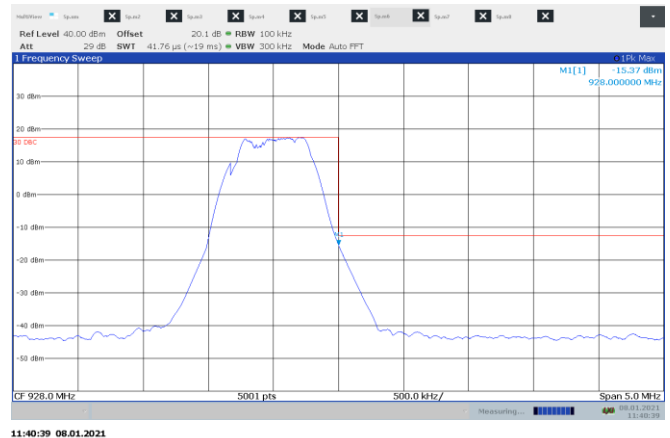


Figure 8.7-2: Band edge spurious emissions at 928 MHz

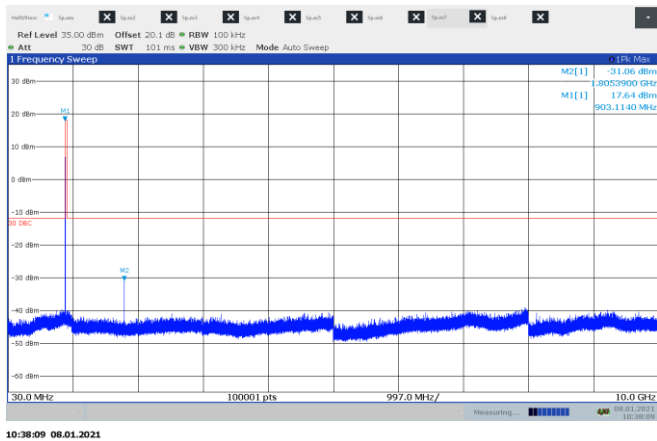


Figure 8.7-3: Conducted spurious emissions on low channel

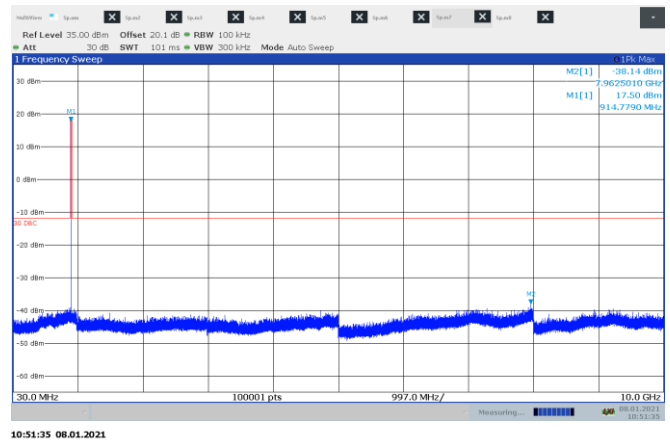


Figure 8.7-4: Conducted spurious emissions on mid channel

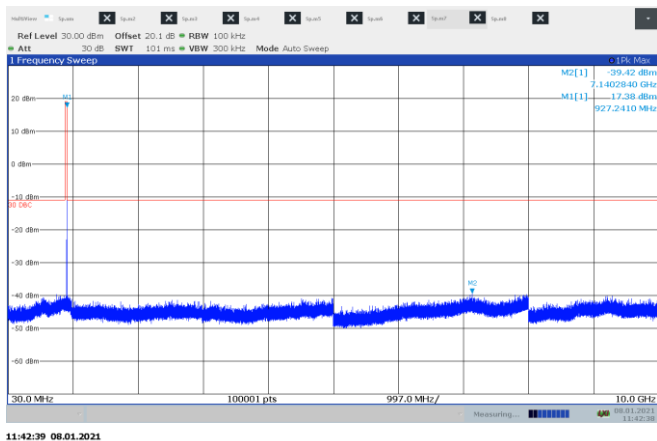


Figure 8.7-5: Conducted spurious emissions on high channel

8.7.4 Test data, continued

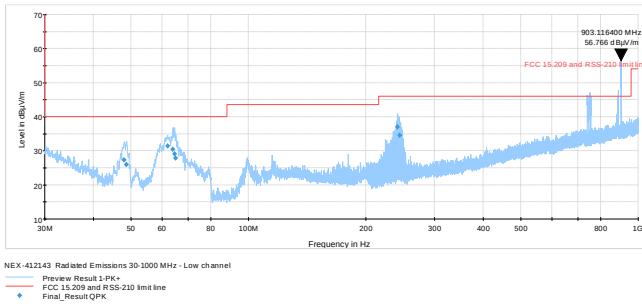


Figure 8.7-6: Radiated spurious emissions below 1 GHz on low channel

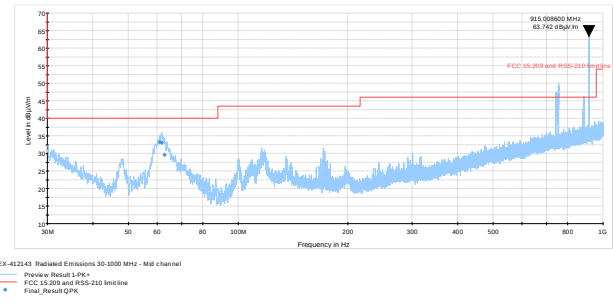


Figure 8.7-7: Radiated spurious emissions below 1 GHz on mid channel

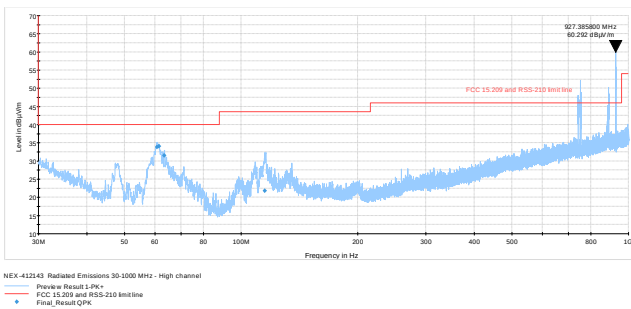


Figure 8.7-6: Radiated spurious emissions below 1 GHz on high channel

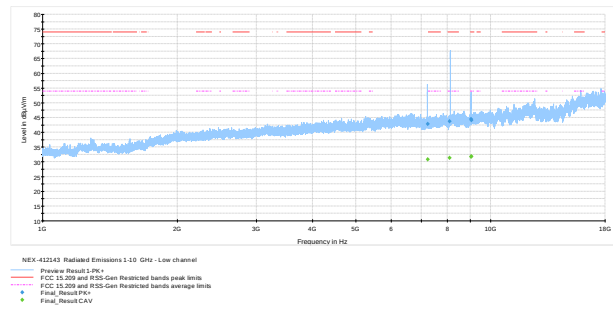


Figure 8.7-7: Radiated spurious emissions above 1 GHz on low channel

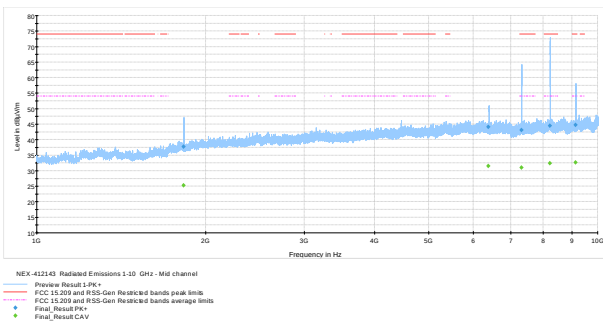


Figure 8.7-8: Radiated spurious emissions above 1 GHz on mid channel

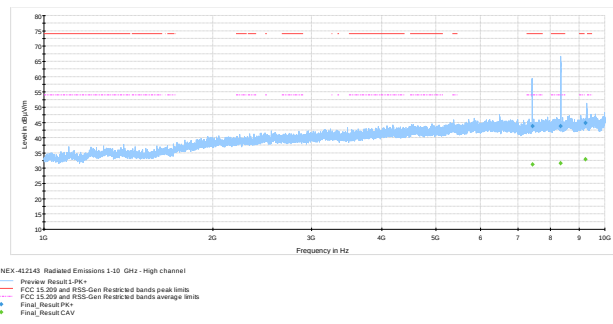


Figure 8.7-9: Radiated spurious emissions above 1 GHz on high channel

8.8 FCC 15.247(e) and RSS-247 5.2(b) Power spectral density for digitally modulated devices

8.8.1 References, definitions and limits

FCC:

For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.

(f) For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques. The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned-off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The power spectral density conducted from the intentional radiator to the antenna due to the digital modulation operation of the hybrid system, with the frequency hopping operation turned off, shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

ISED:

The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of section 5.4(d), (i.e. the power spectral density shall be determined using the same method as is used to determine the conducted output power).

5.3 Hybrid systems

Hybrid systems employ a combination of both frequency hopping and digital transmission techniques and shall comply with the following:

With the frequency hopping turned off, the digital transmission operation shall comply with the power spectral density requirements for digital modulation systems set out in of section 5.2(b) or section 6.2.4 for hybrid devices operating in the band 5725–5850 MHz.

8.8.2 Test summary

Verdict	Pass		
Tested by	Tarek Elkholy	Test date	January 8, 2021

8.8.3 Observations, settings and special notes

Power spectral density test was performed as per KDB 558074, section 8.4 with reference to ANSI C63.10 subclause 11.10.

The test was performed using method AVGPDS-2 (trace averaging across on- and off-times of the EUT transmissions, followed by duty cycle correction).

Spectrum analyser settings:

Resolution bandwidth:	$3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$
Video bandwidth:	$\geq 3 \times \text{RBW}$
Frequency span:	1.5 times the OBW (Average)
Detector mode:	RMS
Trace mode:	Average
Averaging sweeps number:	3000

8.8.4 Test data

Table 8.8-1: PSD results (antenna port measurement)

Frequency, MHz	PSD, dBm/10 kHz	Duty cycle corrected, PSD, dBm/10 kHz	PSD limit, dBm/10 kHz	Margin, dB
903	-11.6	1.2	8	6.8
915	-11.5	1.3	8	6.7
927.5	-12.3	0.5	8	7.5

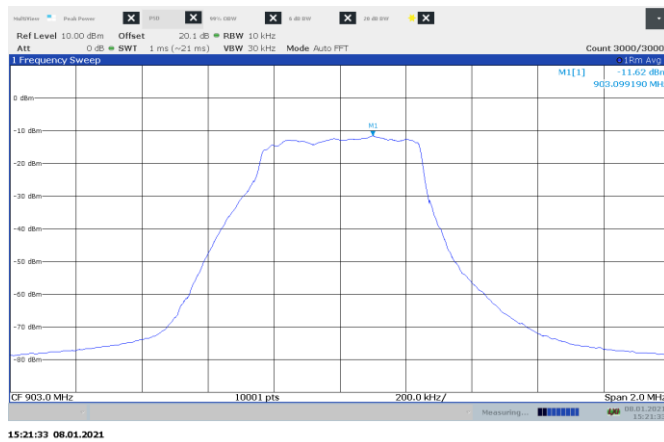


Figure 8.8-1: PSD on low channel

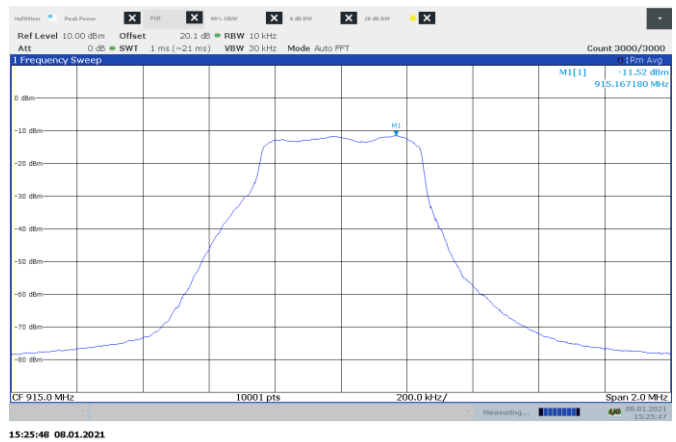


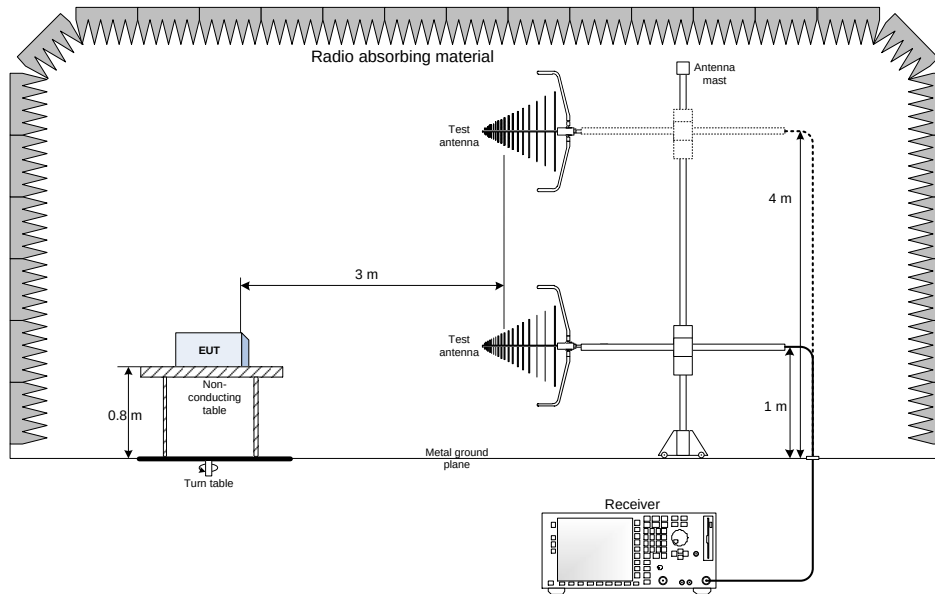
Figure 8.8-2: PSD on mid channel



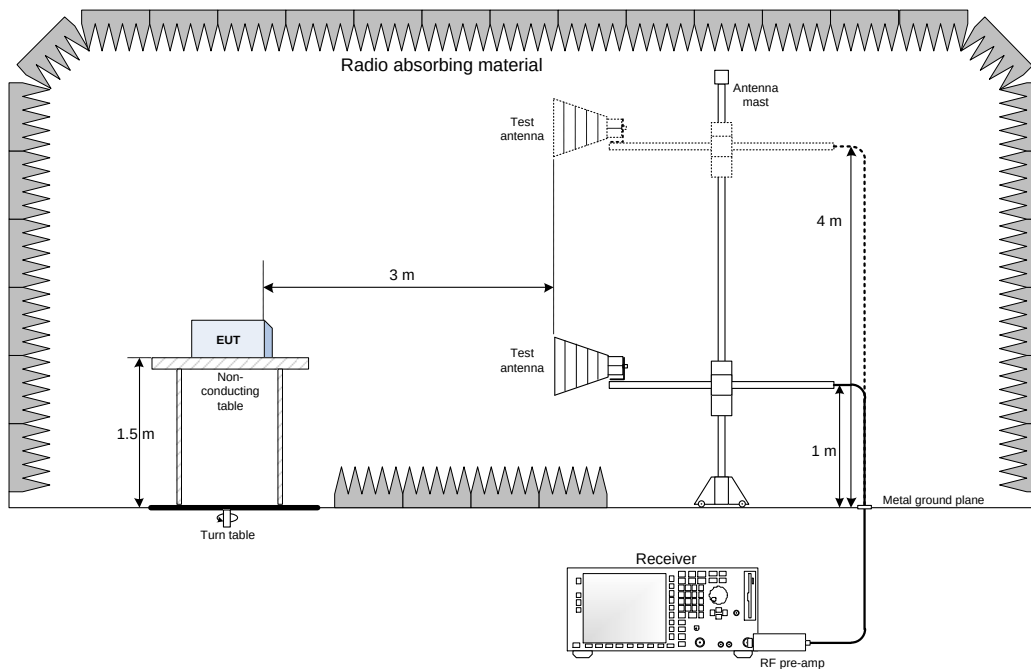
Figure 8.8-3: PSD on high channel

Section 9 Block diagrams of test set-ups

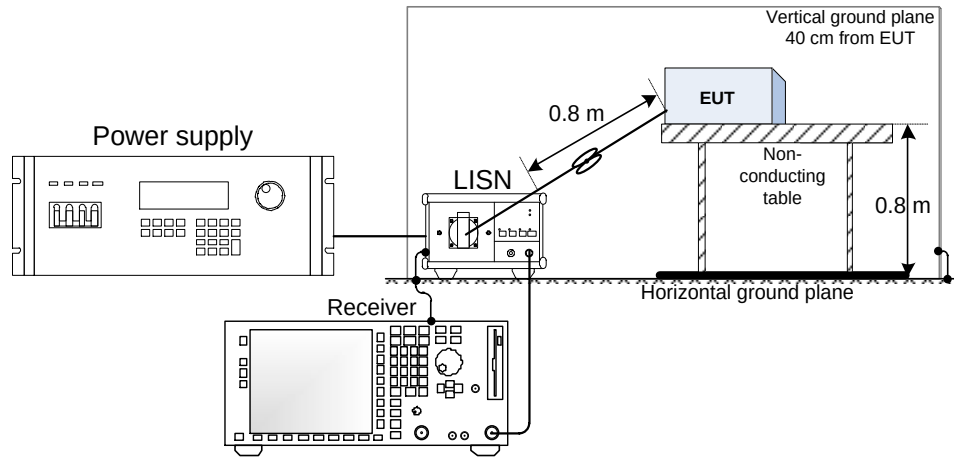
9.1 Radiated emissions set-up for frequencies below 1 GHz



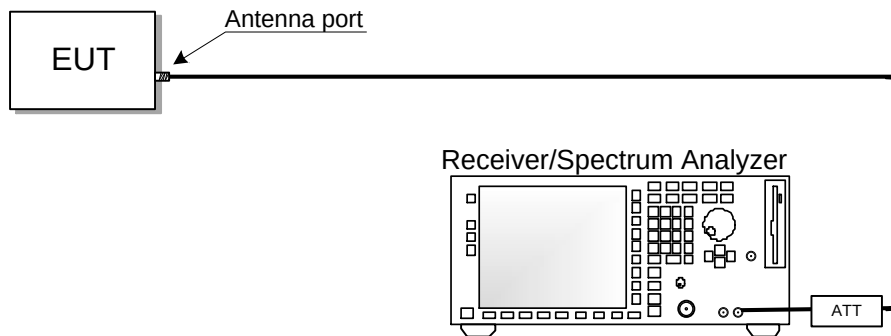
9.2 Radiated emissions set-up for frequencies above 1 GHz



9.3 Conducted emissions set-up



9.4 Antenna port set-up



End of the test report