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Test report

415157-1R1TRFWL

Date of issue: February 1, 2022

Applicant:
Sonendo Inc.

Product:
GentleWave

Model:
FG-012-00001

FCC ID #1: N6C-SXPCEAC2

Specifications:

- FCC 47 CFR Part 15, Subpart C – §15.225
  Operation within the band 13.110-14.010 MHz
- RSS-210, Issue 10, December 2019
  License-Exempt Radio Apparatus: Category I Equipment
- RSS-Gen, Issue 5, Amendment 1, March 2019
  General Requirements for Compliance of Radio Apparatus

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

Test location

Company name	Nemko USA, Inc.
Address	2210 Faraday Ave, Suite 150
City	Carlsbad
Province	California
Postal code	92008
Country	USA
Telephone	+1 760 444 3500
Website	www.nemko.com
FCC Site Number	Test Firm Registration Number: 392943 Designation Number: US5058
ISED Test Site	2040B-3

Tested by	David Hewitt, EMC Specialist
Reviewed by	James Cunningham, EMC/MIL/WL Supervisor
Review date	February 1, 2022
Reviewer signature	

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 USA's ISO/IEC 17025 accreditation. This report must not be used by the client to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the U.S. Government.

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Section 1. Report summary

1.1 Applicant and manufacturer

Company name	Sonendo Inc.
Address	26061 Merit Circle, Suite 102
City	Laguna Hills
Province/State	CA
Postal/Zip code	92653
Country	USA

1.2 Test specifications

FCC 47 CFR Part 15, Subpart C, Clause 15.225	Operation within the band 13.110-14.010 MHz
RSS-210, Issue 10	License-Exempt Radio Apparatus: Category I Equipment
RSS-Gen, Issue 5, Amendment 1, March 2019	General Requirements for Compliance of Radio Apparatus

1.3 Test methods

ANSI C63.4-2014	American National Standard for Methods of Measurement of Radio- Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz
ANSI C63.10-2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

1.4 Statement of compliance

In the configuration tested, the EUT was found compliant.

Testing was performed against all relevant requirements of the test standard. Results obtained indicate that the product under test complies in full with the requirements tested. The test results relate only to the items tested.

See “Summary of test results” for full details.

1.5 Exclusions

None

1.6 Test report revision history

Revision #	Details of changes made to test report
415157-1TRFWL	Original report issued
415157-1R1TRFWL	Corrected product and model name

Section 2. Summary of test results

2.1 FCC Part 15 Subpart C, general requirements test results

Part	Test description	Verdict
§15.207(a)	Conducted limits	Pass
§15.31(e)	Variation of power source	Pass
§15.203[1]	Antenna requirement	Pass
§15.215	20 dB bandwidth	Pass

Notes: [1] The Antenna is internal to device or with unique antenna coupling.

2.2 FCC Part 15 Subpart C, intentional radiators test results

Part	Test description	Verdict
§15.225(a)	Field strength within 13.553–13.567 MHz band	Pass
§15.225(b)	Field strength within 13.410–13.553 MHz and 13.567–13.710 MHz bands	Pass
§15.225(c)	Field strength within 13.110–13.410 MHz and 13.710–14.010 MHz bands	Pass
§15.225(d)	Field strength outside 13.110–14.010 MHz band	Pass
§15.225(e)	Frequency tolerance of carrier signal	Pass

Notes: [1] None

2.3 IC RSS-GEN, Issue 4, test results

Part	Test description	Verdict
7.3[1]	Receiver radiated emission limits	Not applicable
7.4[1]	Receiver conducted emission limits	Not applicable
8.8	Power Line Conducted Emissions Limits for License-Exempt Radio Apparatus	Pass
8.10	Restricted Frequency Bands	Pass
6.6[2]	Occupied bandwidth	Pass
6.11[2]	Transmitter frequency stability	Pass

Note: [1] According to sections 5.2 and 5.3 of RSS-Gen, Issue 4, the EUT does not have a stand-alone receiver nor is it a scanner receiver, and is therefore exempt from receiver requirements.

2.4 IC RSS-210, Issue 9, test results

Part	Test description	Verdict
B.6 (a)	The field strength within the band 13.553–13.567 MHz.	Pass
B.6 (b)	The field strength within the bands 13.410–13.553 MHz and 13.567–13.710 MHz	Pass
B.6 (c)	The field strength within the bands 13.110–13.410 MHz and 13.710–14.010 MHz.	Pass
B.6 (d)	The field strength outside the band 13.110–14.010 MHz.	Pass
B.6[1]	Carrier frequency stability shall be maintained to ±0.01% (±100 ppm)	Pass

Note: [1] None.

Section 3. Equipment under test (EUT) details

3.1 Sample information

Receipt date	March 17, 2021
Nemko sample ID number	NEx: 415157

3.2 EUT information

Product name	GentleWave
Model	FG-012-00001
Model variant	None
Serial number	None
FCC ID	N6C-SXPCEAC2

3.3 Technical information

All used IC test site(s) Reg. number	2040B-3
RSS number and Issue number	RSS-210, Issue 10, December 2019
Frequency band	13.110 – 14.010 MHz
Frequency Min (MHz)	13.564 MHz
Frequency Max (MHz)	13.564 MHz
Field strength, Units @ distance	71.77 dBµV/m @ 3m QP
Measured BW (kHz) (20 dB)	240.385 kHz
Measured BW (kHz) (99%)	1.034 MHz
Transmitter spurious, Units @ distance	34.75 dBµV/m @ 3m QP
Power requirements	100-240VAC, 50/60Hz
Type of modulation	ASK
Emission classification	A2D
Antenna information	The EUT uses a unique antenna coupling/ non-detachable antenna to the intentional radiator.

3.4 Product description and theory of operation

The Sonendo GentleWave™ System is intended to be used by a licensed, trained dental professional for cleaning and irrigation of root canals. The Sonendo GentleWave X (Laguna) Console utilizes a combination of sound (byproduct of high pressure), circulation, and chemistry to clean root canals, auxiliary canals, and tubules.

3.5 EUT exercise details

EUT is powered on and set into a test mode that allows the RFID reader to transmit once per second. This is the fastest repetition of the RFID transmitter available.

3.6 EUT setup diagram

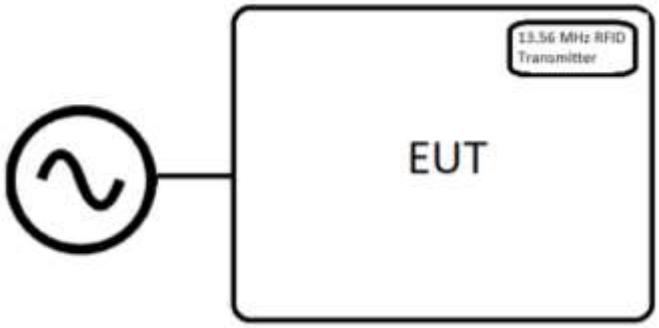

Figure 3.6-1: EUT setup diagram

3.7 EUT sub assemblies

Table 3.7-1: EUT sub assemblies

Description	Brand name	Model/Part number	Serial number
--	--	--	--

Table 3.7-2: Support equipment

Description	Brand name	Model/Part number	Serial number	Rev.
None	--	--	--	--

Section 4. Engineering considerations

4.1 Modifications incorporated in the EUT

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

4.2 Technical judgment

None

4.3 Deviations from laboratory tests procedures

The following deviations were made:

During carrier frequency stability testing at various temperatures, the EUT froze and stopped operating at -20°C. But, per manufacture declaration: the EUT contains fluids, including distilled water, and is not intended to operate in sub-zero environments. Therefore, the inability to gather frequency stability data at temperatures that the EUT could operate within is used as justification to not to include that data point in this report.

Section 5. Test conditions

5.1 Atmospheric conditions

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

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

5.2 Power supply range

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

Section 6. Measurement uncertainty

6.1 Uncertainty of measurement

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

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	1.38

Section 7. Test Data

7.1 Field strength of spurious emissions

7.1.1 Definitions and limits

FCC:

a. The field strength of any emissions within the band 13.553-13.567 MHz shall not exceed 15,848 microvolts/meter at 30 meters.
b. Within the bands 13.410-13.553 MHz and 13.567-13.710 MHz, the field strength of any emissions shall not exceed 334 microvolts/meter at 30 meters.
c. Within the bands 13.110-13.410 MHz and 13.710-14.010 MHz the field strength of any emissions shall not exceed 106 microvolts/meter at 30 meters.
d. The field strength of any emissions appearing outside of the 13.110-14.010 MHz band shall not exceed the general radiated emission limits in § 15.209.

ISED:

The field strength of any emission shall not exceed the following limits:

a. 15.848 mV/m (84 dBµV/m) at 30 m, within the band 13.553-13.567 MHz;
b. 334 µV/m (50.5 dBµV/m) at 30 m, within the bands 13.410-13.553 MHz and 13.567-13.710 MHz;
c. 106 µV/m (40.5 dBµV/m) at 30 m, within the bands 13.110-13.410 MHz and 13.710-14.010 MHz; and
d. RSS-Gen general field strength limits for frequencies outside the band 13.110-14.010 MHz.

Table 7.1-1: **FCC §15.209 and RSS-Gen – Radiated emission limits**

Frequency, MHz	Field strength of emissions µV/m	Field strength of emissions dBµV/m	Measurement distance, 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 7.1-2: IC restricted frequency bands

MHz	MHz	MHz	GHz
0.090–0.110	12.51975–12.52025	399.9–410	5.35–5.46
2.1735–2.1905	12.57675–12.57725	608–614	7.25–7.75
3.020–3.026	13.36–13.41	960–1427	8.025–8.5
4.125–4.128	16.42–16.423	1435–1626.5	9.0–9.2
4.17725–4.17775	16.69475–16.69525	1645.5–1646.5	9.3–9.5
4.20725–4.20775	16.80425–16.80475	1660–1710	10.6–12.7
5.677-5.683	25.5–25.67	1718.8–1722.2	13.25–13.4
6.215–6.218	37.5–38.25	2200–2300	14.47–14.5
6.26775–6.26825	73–74.6	2310–2390	15.35–16.2
6.31175–6.31225	74.8–75.2	2655–2900	17.7–21.4
8.291–8.294	108–138	3260–3267	22.01–23.12
8.362–8.366	156.52475–156.52525	3332–3339	23.6–24.0
8.37625–8.38675	156.7–156.9	3345.8–3358	31.2–31.8
8.41425–8.41475	240–285	3500–4400	36.43–36.5
12.29–12.293	322–335.4	4500–5150	Above 38.6

Note: Certain frequency bands listed in Table 8.3-2 and above 38.6 GHz are designated for low-power license-exempt applications. These frequency bands and the requirements that apply to the devices are set out in this Standard

Table 7.1-3: 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			

7.1.2 Test summary

Verdict	Pass		
Test date	March 17, 2021	Temperature	20 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1011 mbar
Test location	10m semi anechoic chamber	Relative humidity	36 %

7.1.3 Observations, settings, and special notes

In order to investigate the spectrum from the lowest radio frequency signal generated in the device to the tenth harmonic of the highest fundamental frequency, per 47 CFR § 15.33 (a)-1, radiated emissions were measured from 9 kHz to 150 MHz.

7.1.4 Setup details

Spectrum analyzer settings for radiated measurements within restricted bands from 9 kHz to 30 MHz:

Resolution bandwidth	200 Hz from 9 – 150 kHz, 9 kHz from 150 kHz – 30 MHz
Video bandwidth	600 Hz and 30 kHz respectively
Detector mode	– Peak (Preview measurement) – Quasi-peak (Final measurement)
Trace mode	Max Hold
Measurement time	– 100 ms (Peak preview measurement) – 15000 ms (Quasi-peak final measurement)

Spectrum analyzer settings for radiated measurements within restricted bands from 30 – 1000 MHz:

Resolution bandwidth	120 kHz
Video bandwidth	300 kHz
Detector mode	– Peak (Preview measurement) – Quasi-peak (Final measurement)
Trace mode	Max Hold
Measurement time	– 100 ms (Peak preview measurement) – 5000 ms (Quasi-peak final measurement)

7.1.4 Setup details, continued

Table 7.1-4: Radiated disturbance equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI Test Receiver	Rohde & Schwarz	ESU40	E1131	1 yr	3 Dec 2021
System Controller	Sunoc Sciences	SC104V	E1129	NCR	NCR
Active Loop H Field Antenna	Hewlett Packard	6502	E1267	1 yr	4 Dec 2021
Bilog antenna	Schaffner-Chase	CBL6111C	1480	1 yr	28 Oct 2021

Notes: None

Table 7.1-5: Radiated disturbance test software details

Manufacturer of Software	Details
Rohde & Schwarz	EMC32 V10.00.00

Notes: None

7.1.5 Testing data

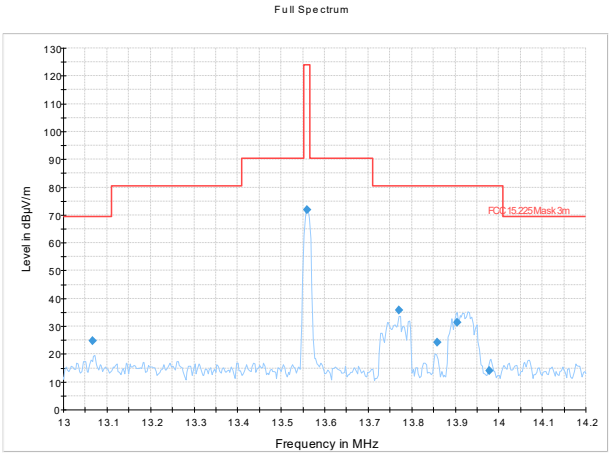

Figure 7.1.1: Radiated spurious emissions, 13.11-14.01 MHz (3m at 0°)

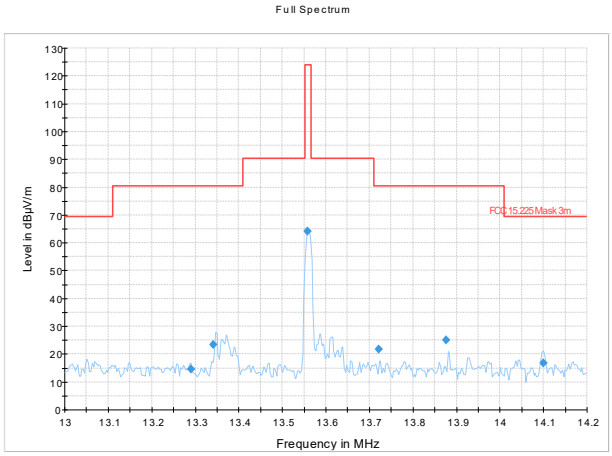

Figure 7.1.2: Radiated spurious emissions, 13.11-14.01 MHz (3m at 90°)

Table 7.1-6: Radiated field strength measurement results 13-14.2 MHz (Test antenna at 0°)

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Pol	Azimuth (deg)	Corr. (dB)
13.067565	24.72	69.54	44.83	15000.0	9.000	0°	0.0	10.9
13.559105	71.77	124.00	52.23	15000.0	9.000	0°	10.0	10.9
13.771040	35.78	80.51	44.72	15000.0	9.000	0°	357.0	10.9
13.858635	24.36	80.51	56.15	15000.0	9.000	0°	-1.0	10.9
13.904380	31.30	80.51	49.21	15000.0	9.000	0°	0.0	10.9
13.977990	14.00	80.51	66.51	15000.0	9.000	0°	329.0	10.9

Notes: [1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factors = antenna factor ACF (dB) + cable loss (dB) − amplifier gain (dB)
[3] The maximum measured value observed over a period of 15 seconds was recorded.

Table 7.1-7: Radiated field strength measurement results 13-14.2 MHz (Test antenna at 90°)

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Pol	Azimuth (deg)	Corr. (dB)
13.289470	14.56	80.51	65.95	15000.0	9.000	90°	337.0	10.9
13.342185	23.40	80.51	57.10	15000.0	9.000	90°	327.0	10.9
13.557105	64.20	124.00	59.80	15000.0	9.000	90°	325.0	10.9
13.721280	21.71	80.51	58.80	15000.0	9.000	90°	317.0	10.9
13.876500	25.15	80.51	55.36	15000.0	9.000	90°	321.0	10.9
14.100405	16.85	69.54	52.69	15000.0	9.000	90°	334.0	10.9

Notes: [1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factors = antenna factor ACF (dB) + cable loss (dB) − amplifier gain (dB)
[3] The maximum measured value observed over a period of 15 seconds was recorded.

7.1.5 Testing data, continued

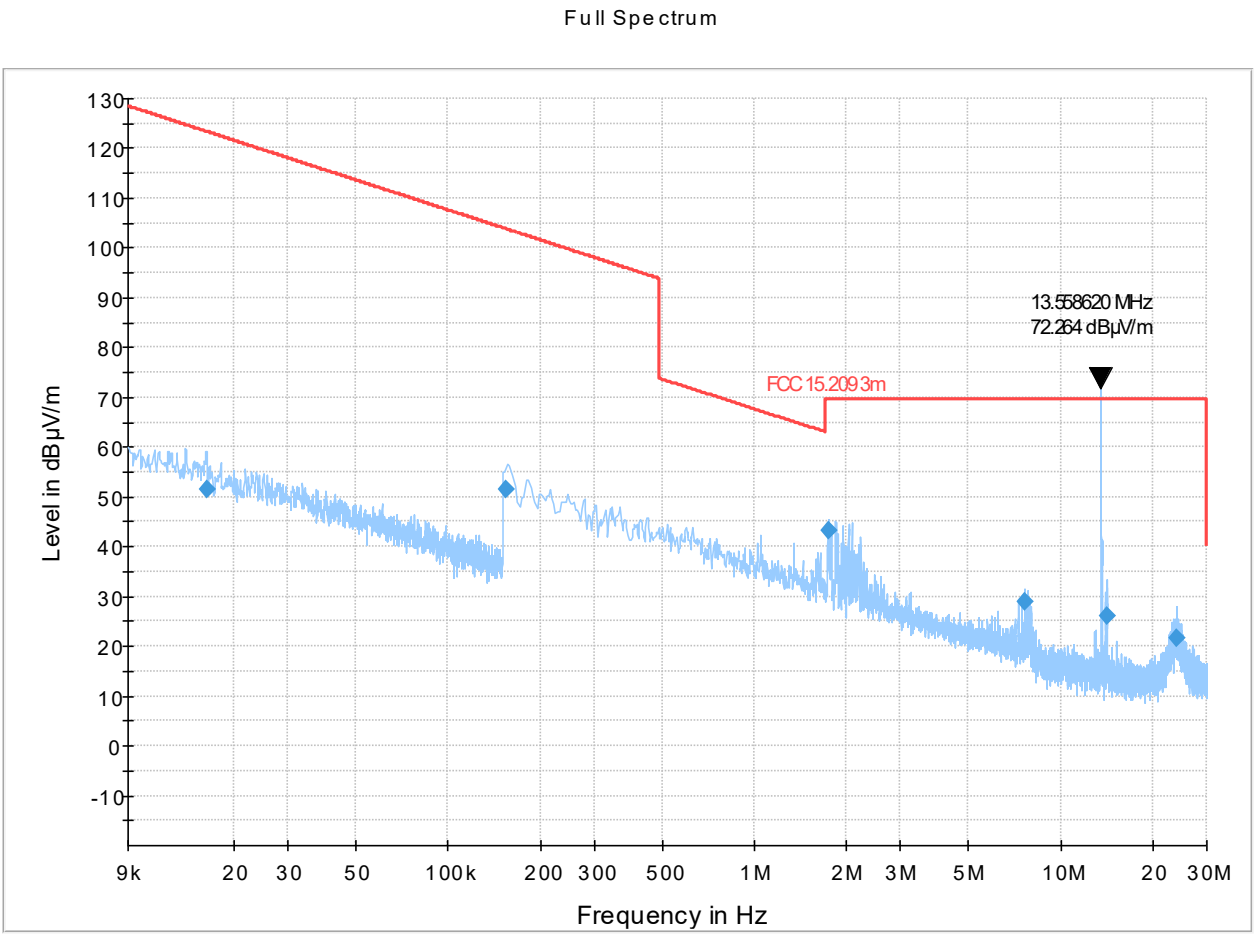

Figure 7.1-3: Radiated spurious emissions, 9 kHz-30 MHz at 0°

Table 7.1-8: Radiated disturbance (Quasi-Peak) results

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Pol	Azimuth (deg)	Corr. (dB)
0.016242	51.37	123.38	72.01	15000.0	0.200	0°	271.0	15.7
0.154455	51.62	103.82	52.20	15000.0	9.000	0°	70.0	10.2
1.738505	43.33	69.50	26.17	15000.0	9.000	0°	0.0	10.5
7.654805	28.97	69.50	40.53	15000.0	9.000	0°	0.0	10.7
14.197925	26.24	69.50	43.26	15000.0	9.000	0°	10.0	11.0
23.807595	21.55	69.50	47.95	15000.0	9.000	0°	192.0	10.0

Notes:
[1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factors = antenna factor ACF (dB) + cable loss (dB) – amplifier gain (dB)
[3] The maximum measured value observed over a period of 15 seconds was recorded.
[4] The 13.56 MHz signal is the transmitter fundamental, and not measured against FCC 15.209 limits.

7.1.5 Testing data, continued

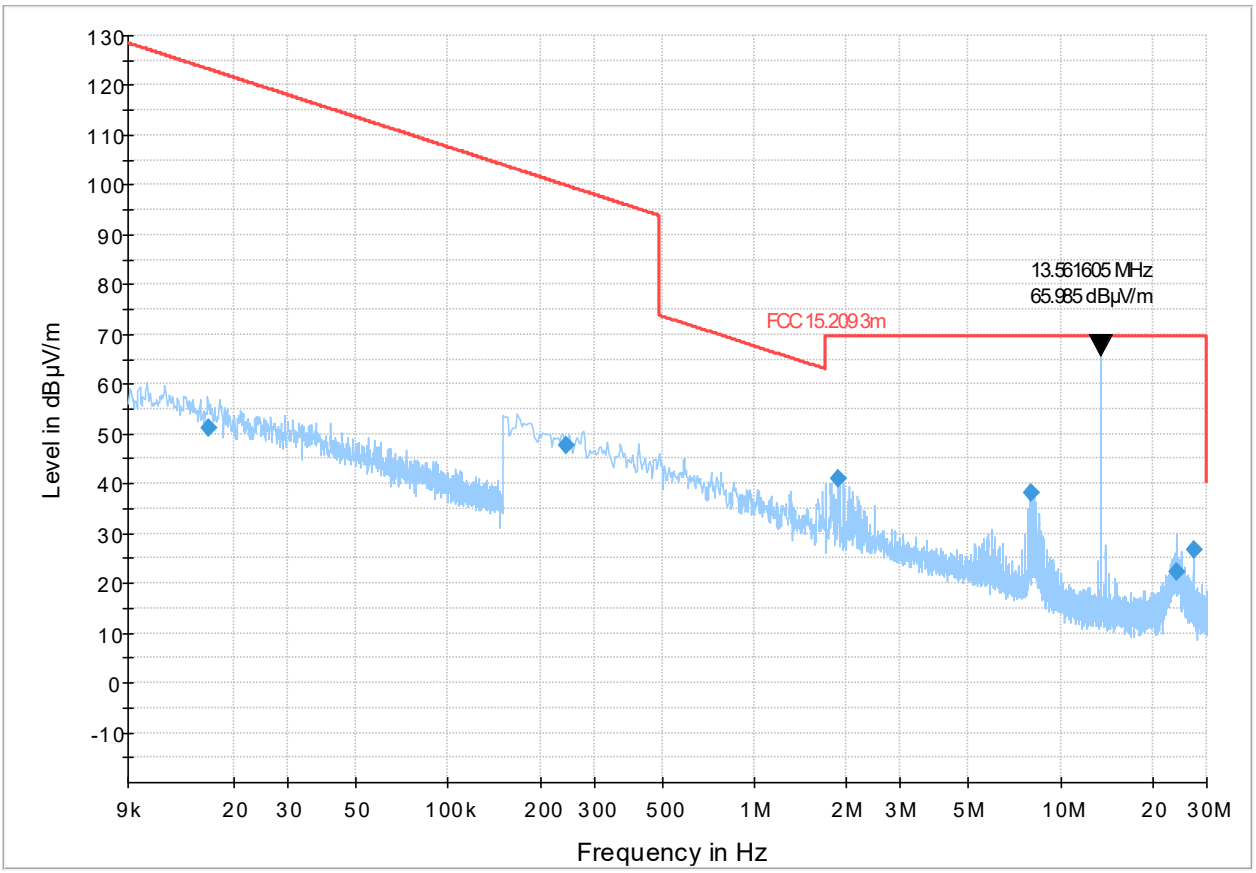

Figure 7.1-4: Radiated spurious emissions, 9 kHz-30 MHz at 90°

Table 7.1-9: Radiated disturbance (Quasi-Peak) results

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Pol	Azimuth (deg)	Corr. (dB)
0.016462	51.12	123.26	72.14	15000.0	0.200	90°	9.0	15.6
0.244035	47.60	99.85	52.26	15000.0	9.000	90°	214.0	10.1
1.885800	41.03	69.50	28.47	15000.0	9.000	90°	322.0	10.5
7.987125	38.06	69.50	31.44	15000.0	9.000	90°	347.0	10.6
24.013605	22.36	69.50	47.14	15000.0	9.000	90°	66.0	10.0
27.118975	26.67	69.50	42.83	15000.0	9.000	90°	260.0	9.2

Notes:
[1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factors = antenna factor ACF (dB) + cable loss (dB) – amplifier gain (dB)
[3] The maximum measured value observed over a period of 15 seconds was recorded.
[4] The 13.56 MHz signal is the transmitter fundamental, and not measured against FCC 15.209 limits.

7.1.5 Testing data, continued

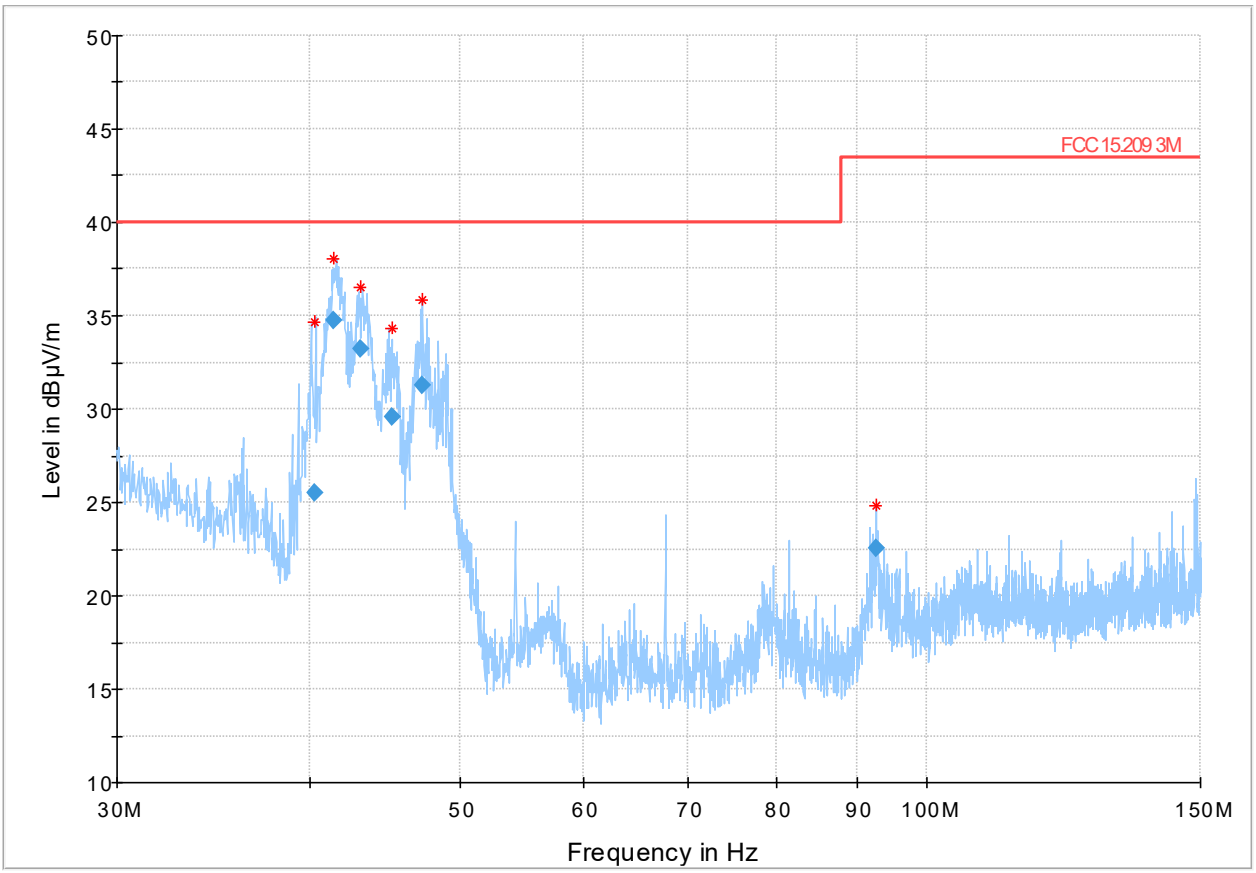

Figure 7.1-5: Radiated spurious emissions, 30 MHz – 150 MHz

Table 7.1-10: Radiated disturbance (Quasi-Peak) results

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
40.203333	25.50	40.00	14.50	5000.0	120.000	160.2	V	286.0	18.9
41.403000	34.75	40.00	5.25	5000.0	120.000	98.0	V	0.0	18.3
43.084333	33.21	40.00	6.79	5000.0	120.000	109.0	V	60.0	17.4
45.118000	29.60	40.00	10.40	5000.0	120.000	108.7	V	108.0	16.4
47.213667	31.28	40.00	8.72	5000.0	120.000	98.0	V	0.0	15.5
92.689667	22.52	43.50	20.98	5000.0	120.000	109.0	V	199.0	15.3

Notes:
[1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factors = antenna factor ACF (dB) + cable loss (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.
[4] The spectral plot is a summation of a vertical and horizontal scan.
[5] The spectrum was investigated from the lowest radio frequency signal generated in the device to the tenth harmonic of the highest fundamental frequency.

7.2 Conducted emissions

7.2.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.207 / ANSI C63.4: 2014

(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 ohms 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.

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

*Decreases with the logarithm of the frequency

(b) The limit shown in paragraph (a) of this section shall not apply to carrier current systems operating as intentional radiators on frequencies below 30 MHz. In lieu thereof, these carrier current systems shall be subject to the following standards:

a. For carrier current system containing their fundamental emission within the frequency band 535-1705 kHz and intended to be received using a standard AM broadcast receiver: no limit on conducted emissions.
b. For all other carrier current systems: 1000 µV within the frequency band 535-1705 kHz, as measured using a 50 µH/50 ohms LISN.
c. Carrier current systems operating below 30 MHz are also subject to the radiated emission limits in §15.205, §15.209, §15.221, §15.223, or §15.227, as appropriate.

(c) Measurements to demonstrate compliance with the conducted limits are not required for devices which only employ battery power for operation and which do not operate from the AC power lines or contain provisions for operation while connected to the AC power lines. Devices that include, or make provisions for, the use of battery chargers which permit operating while charging, AC adapters or battery eliminators or that connect to the AC power lines indirectly, obtaining their power through another device which is connected to the AC power lines, shall be tested to demonstrate compliance with the conducted limits.

7.2.2 Conducted Emissions Test summary

Verdict	Pass		
Test date	March 17, 2021	Temperature	23 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1009 mbar
Test location	Ground Plane	Relative humidity	36 %

7.2.3 Notes

None

7.2.4 Setup details

Port under test	AC Mains
EUT setup configuration	Floor standing
Measurement details	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.

Receiver settings:

Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	– Peak (Preview measurement) – Quasi-peak and CAverage (Final measurement)
Trace mode	Max Hold
Measurement time	– 100 ms (Peak preview measurement) – 5000 ms (Quasi-peak final measurement) – 5000 ms (CAverage final measurement)

Table 7.2-1: Conducted disturbance at mains port equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI Test Receiver	Rohde & Schwarz	ESCI7	E1026	1 yr	24 Feb 2022
Transient Limiter	Hewlett Packard	11947A	684	1 yr	26 Apr 2021
Two Line V-Network	Rohde & Schwarz	ENV216	E1019	1 yr	4 Aug 2021

Notes: None

Table 7.2-2: Conducted disturbance at mains port test software details

Manufacturer of Software	Details
Rohde & Schwarz	EMC 32 V10.65.10

Notes: None

7.2.5 Conducted Emissions Test data

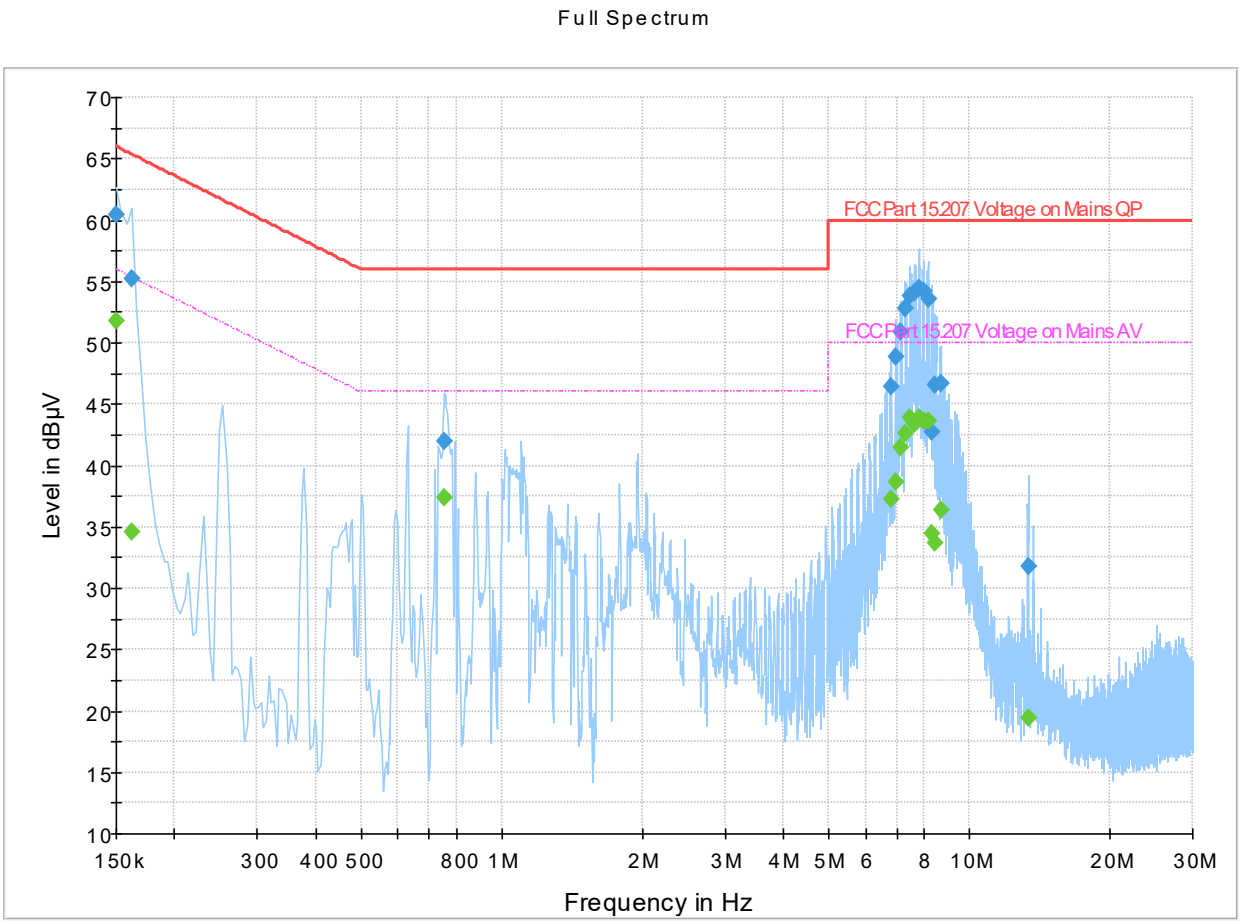

Figure 7.2.1: Conducted spurious emissions, 150 kHz-30 MHz

The spectral plot has been corrected with transducer factors. (i.e. cable loss, LISN factors, and transient limiters)

Table 7.2-3 Conducted disturbance at AC mains results (Quasi-Peak and Average)

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.150000	---	51.77	56.00	4.23	5000.0	9.000	N	ON	19.6
0.150000	60.49	---	66.00	5.51	5000.0	9.000	N	ON	19.6
0.162000	55.20	---	65.36	10.16	5000.0	9.000	L1	ON	19.6
0.162000	---	34.63	55.36	20.73	5000.0	9.000	L1	ON	19.6
0.754000	42.03	---	56.00	13.97	5000.0	9.000	N	ON	19.4
0.754000	---	37.41	46.00	8.60	5000.0	9.000	N	ON	19.4
6.786000	46.46	---	60.00	13.54	5000.0	9.000	L1	ON	19.3
6.786000	---	37.27	50.00	12.73	5000.0	9.000	L1	ON	19.3
6.978000	---	38.69	50.00	11.31	5000.0	9.000	N	ON	19.3
6.978000	48.81	---	60.00	11.19	5000.0	9.000	N	ON	19.3
7.130000	50.94	---	60.00	9.06	5000.0	9.000	N	ON	19.3
7.130000	---	41.50	50.00	8.50	5000.0	9.000	N	ON	19.3
7.306000	52.77	---	60.00	7.23	5000.0	9.000	L1	ON	19.3
7.306000	---	42.59	50.00	7.41	5000.0	9.000	L1	ON	19.3
7.470000	53.77	---	60.00	6.23	5000.0	9.000	L1	ON	19.3

7.470000	---	43.86	50.00	6.14	5000.0	9.000	L1	ON	19.3
7.634000	54.08	---	60.00	5.92	5000.0	9.000	L1	ON	19.3
7.634000	---	43.41	50.00	6.59	5000.0	9.000	L1	ON	19.3
7.826000	---	43.87	50.00	6.13	5000.0	9.000	L1	ON	19.3
7.826000	54.49	---	60.00	5.51	5000.0	9.000	L1	ON	19.3
7.970000	---	43.59	50.00	6.41	5000.0	9.000	L1	ON	19.3
7.970000	54.25	---	60.00	5.75	5000.0	9.000	L1	ON	19.3
8.150000	---	43.59	50.00	6.41	5000.0	9.000	L1	ON	19.4
8.150000	53.55	---	60.00	6.45	5000.0	9.000	L1	ON	19.4
8.278000	42.69	---	60.00	17.31	5000.0	9.000	N	ON	19.3
8.278000	---	34.47	50.00	15.53	5000.0	9.000	N	ON	19.3
8.454000	46.58	---	60.00	13.42	5000.0	9.000	N	ON	19.4
8.454000	---	33.64	50.00	16.36	5000.0	9.000	N	ON	19.4
8.678000	---	36.38	50.00	13.62	5000.0	9.000	L1	ON	19.4
8.678000	46.74	---	60.00	13.26	5000.0	9.000	L1	ON	19.4
13.350000	31.80	---	60.00	28.20	5000.0	9.000	L1	ON	20.0
13.350000	---	19.44	50.00	30.56	5000.0	9.000	L1	ON	20.0

Notes: [1] Result (dBμV) = receiver/spectrum analyzer value (dBμV) + correction factor (dB)
[2] Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + transient limiter (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.

7.3 Carrier frequency stability

7.3.1 References

47 CFR § 15.225 - Operation within the band 13.110-14.010 MHz

e) The frequency tolerance of the carrier signal shall be maintained within ±0.01% of the operating frequency over a temperature variation of −20 degrees to + 50 degrees C at normal supply voltage, and for a variation in the primary supply voltage from 85% to 115% of the rated supply voltage at a temperature of 20 degrees C. For battery operated equipment, the equipment tests shall be performed using a new battery.

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b) The carrier frequency stability shall not exceed ±100 ppm

7.3.2 Carrier frequency stability Test Summary

Verdict	Pass		
Test date	March 18, 2021	Temperature	21 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1011 mbar
Test location	Ground Plane	Relative humidity	42 %

7.3.3 Notes

The following testing deviations were made: During carrier frequency stability testing at various temperatures, the EUT froze and stopped operating at -20°C. But, per manufacture declaration: the EUT contains fluids, including distilled water, and is not intended to operate in sub-zero environments. Therefore, the inability to gather frequency stability data at temperatures that the EUT could not operate within is used as justification to not to include that data point in this report.

7.3.4 Test Methods

ANSI C63.10-2013: §6.8.1 Frequency stability with respect to ambient temperature
§6.8.2 Frequency stability when varying supply voltage

Table 7.3-1: Occupied bandwidth equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI Test Receiver	Rohde & Schwarz	ESU40	E1121	1 yr	1 Dec 2021
Active Loop H Field Antenna	Hewlett-Packard	6502	E1267	1 yr	4 Dec 2021
Variac	Shanghai China	TDGC	S1043	NCR	NCR
Multimeter	Fluke	111	809	1 yr	14 Oct 2021
Environmental Chamber	Thermotron	WP-605	S1033	1 yr	3 Aug 2021
Digital Thermometer	Fluke	54-2	S1203	1 yr	9 Sep 2021

Notes: None

7.3.5 Test results

Temp (C°)	Voltage	Measured Carrier Frequency (F_M) (MHz)	Variation (MHz)	Deviation from F_R (%)
+50	Nominal (120 Vac)	13.564012821	0.000000	0.0000
+40	Nominal (120 Vac)	13.564012821	0.000000	0.0000
+30	Nominal (120 Vac)	13.564012821	0.000000	0.0000
+20	Nominal (120 Vac)	13.564012821	0.000000	0.0000
+20	85% Nominal (102 Vac)	13.564012821	0.000000	0.0000
+20	115% Nominal (138 Vac)	13.564012821	0.000000	0.0000
+10	Nominal (120 Vac)	13.564012821	0.000000	0.0000
+0	Nominal (120 Vac)	13.564012821	0.000000	0.0000
-10	Nominal (120 Vac)	13.564012821	0.000000	0.0000
-20	Nominal (120 Vac)	Could not be measured	Undefined	Undefined

Notes: The measured frequency variation was calculated at each temperature and supply voltage by finding the difference between the Reference Carrier Frequency (F_R) (taken at +20C, 120 V_{AC} 60 Hz) and the Measured Carrier Frequency (F_M). The frequency deviation was then calculated by finding the percentage difference of the frequency variation in relation to the Reference Carrier Frequency.

$$Variation = F_R - F_M \quad \text{and} \quad Deviation\ (\%) = \frac{Variation}{F_R} \times 100$$

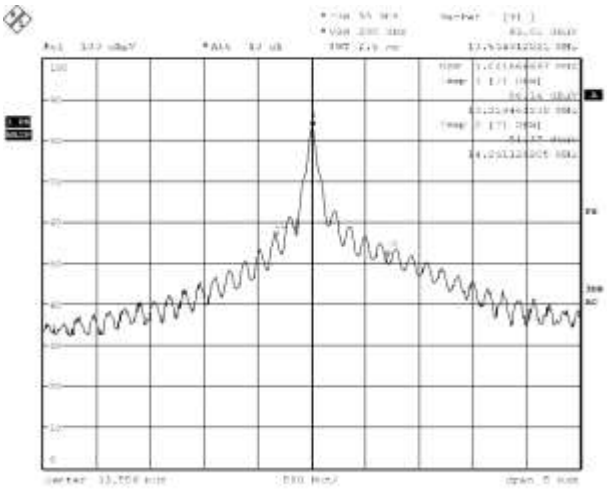


Figure 7.3-1: +50°C, 120 V_{AC} 60 Hz (nominal voltage)

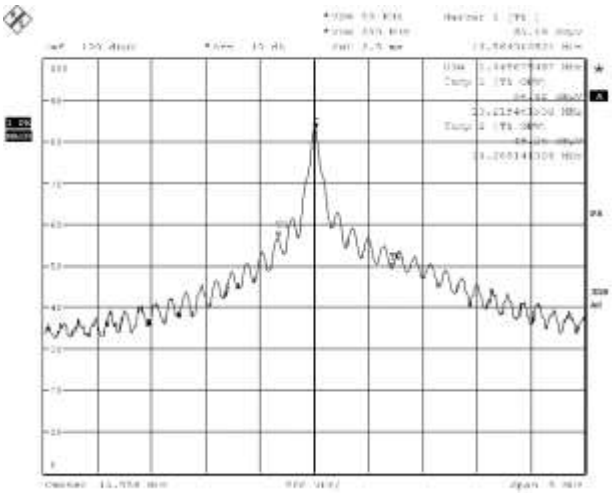


Figure 7.3-2: +40°C, 120 V_{AC} 60 Hz (nominal voltage)

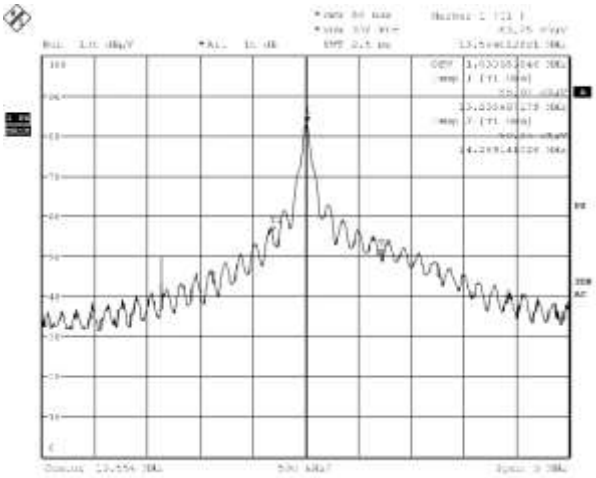


Figure 7.3-3: +30°C, 120 V_{AC} 60 Hz (nominal voltage)

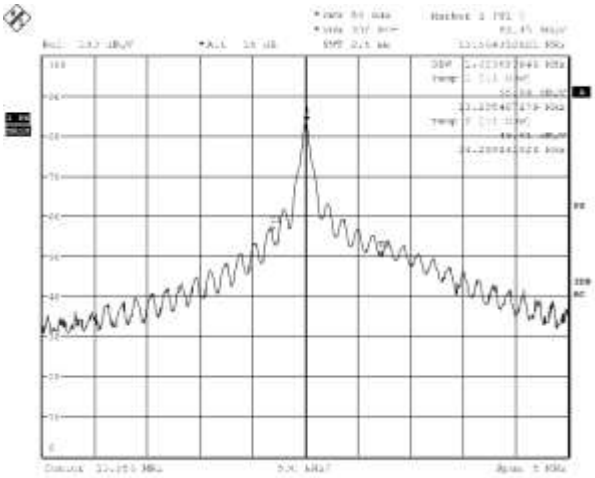


Figure 7.3-4: +20°C, 120 V_{AC} 60 Hz (Reference Carrier Frequency)

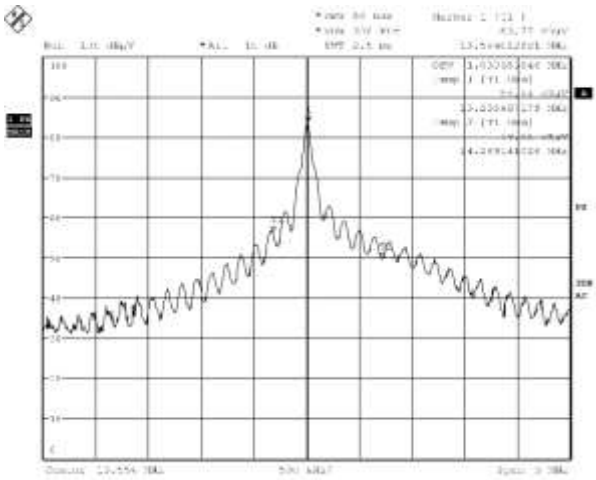


Figure 7.3-5: +20°C, 102 V_{AC} 60 Hz (nominal voltage - 15%)

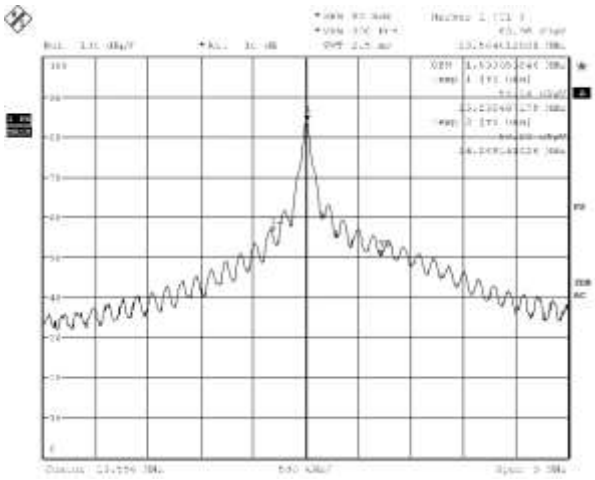


Figure 7.3-6: +20°C, 138 V_{AC} 60 Hz (nominal voltage + 15%)

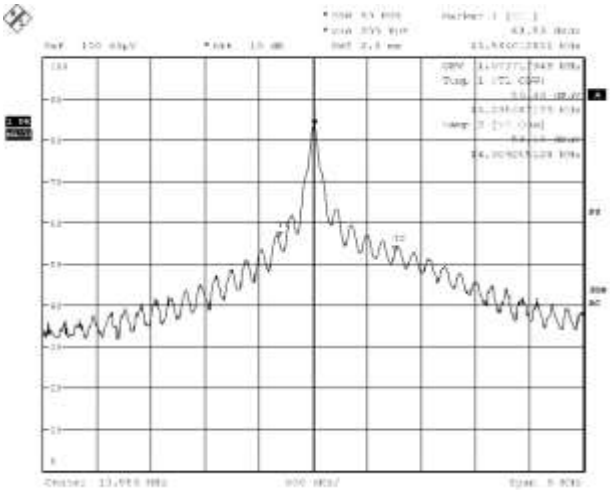


Figure 7.3-7: +10°C, 120 V_{AC} 60 Hz (nominal voltage)

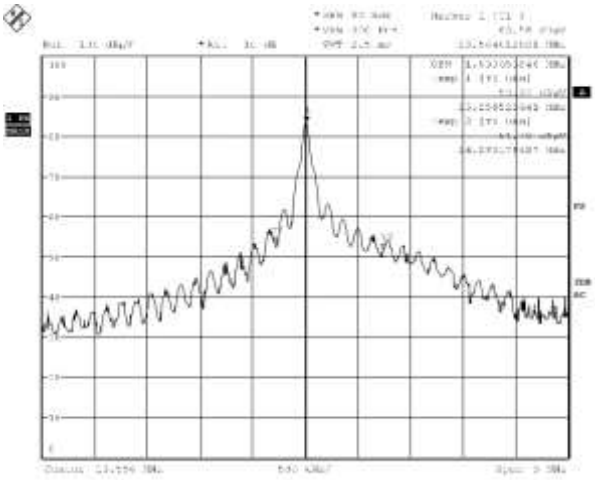


Figure 7.3-8: 0°C, 120 V_{AC} 60 Hz (nominal voltage)

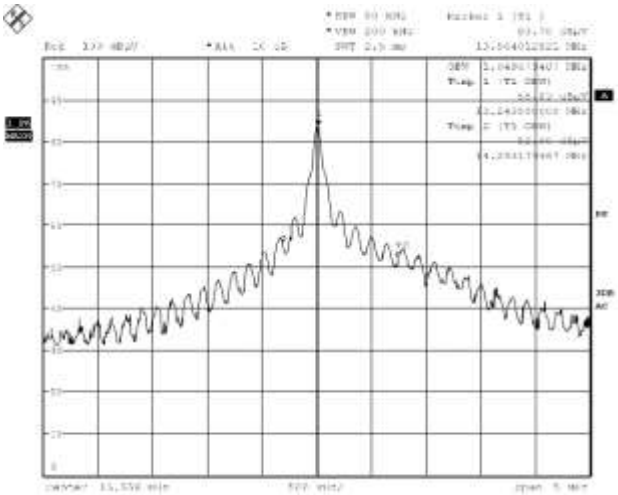


Figure 7.3-9: -10°C, 120 V_{AC} 60 Hz (nominal voltage)

Unable to obtain data due to non-operation of EUT at sub-zero temperatures.
See test deviation notes.

Figure 7.3-10: -20°C, 120 V_{AC} 60 Hz (nominal voltage)

7.4 Occupied Bandwidth: 99% OBW and 20 dB Bandwidth

7.4.1 References

RSS-Gen — 6.7 Occupied bandwidth (or 99% emission bandwidth) and x dB bandwidth

The occupied bandwidth or the "99% emission bandwidth" is defined as the frequency range between two points, one above and the other below the carrier frequency, within which 99% of the total transmitted power of the fundamental transmitted emission is contained. The occupied bandwidth shall be reported for all equipment in addition to the specified bandwidth required in the applicable RSSs.

In some cases, the "x dB bandwidth" is required, which 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 x 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.

The following conditions shall be observed for measuring the occupied bandwidth and x dB bandwidth:

The transmitter shall be operated at its maximum carrier power measured under normal test conditions.
The span of the spectrum analyzer shall be set large enough to capture all products of the modulation process, including the emission skirts, around the carrier frequency, but small enough to avoid having other emissions (e.g. on adjacent channels) within the span.
The detector of the spectrum analyzer shall be set to "Sample". However, a peak, or peak hold, may be used in place of the sampling detector since this usually produces a wider bandwidth than the actual bandwidth (worst-case measurement). Use of a peak hold (or "Max Hold") may be necessary to determine the occupied / x dB bandwidth if the device is not transmitting continuously.
The resolution bandwidth (RBW) shall be in the range of 1% to 5% of the actual occupied / x dB bandwidth and the video bandwidth (VBW) shall not be smaller than three times the RBW value. Video averaging is not permitted.
Note: It may be necessary to repeat the measurement a few times until the RBW and VBW are in compliance with the above requirement.

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).

47 CFR § 15.215 - Additional provisions to the general radiated emission limitations.

c) Intentional radiators operating under the alternative provisions to the general emission limits, as contained in §§ 15.217 through 15.257 and in subpart E of this part, must be designed to ensure that the 20 dB bandwidth of the emission, or whatever bandwidth may otherwise be specified in the specific rule section under which the equipment operates, is contained within the frequency band designated in the rule section under which the equipment is operated. In the case of intentional radiators operating under the provisions of subpart E, the emission bandwidth may span across multiple contiguous frequency bands identified in that subpart. The requirement to contain the designated bandwidth of the emission within the specified frequency band includes the effects from frequency sweeping, frequency hopping and other modulation techniques that may be employed as well as the frequency stability of the transmitter over expected variations in temperature and supply voltage. If a frequency stability is not specified in the regulations, it is recommended that the fundamental emission be kept within at least the central 80% of the permitted band in order to minimize the possibility of out-of-band operation.

7.4.2 Notes

None

7.4.3 Test Summary

Test date	March 18, 2021	Temperature	20 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1011 mbar
Test location	Wireless workbench	Relative humidity	42 %

7.4.4 Setup Details

Spectrum analyzer settings:

	99% Occupied Bandwidth measurement	20 dB Bandwidth measurement
Resolution bandwidth	50 kHz	50 kHz
Video bandwidth	200 kHz	200 kHz
Frequency span	5 MHz	5 MHz
Detector mode	Peak	Peak
Trace mode	Max Hold	Max Hold

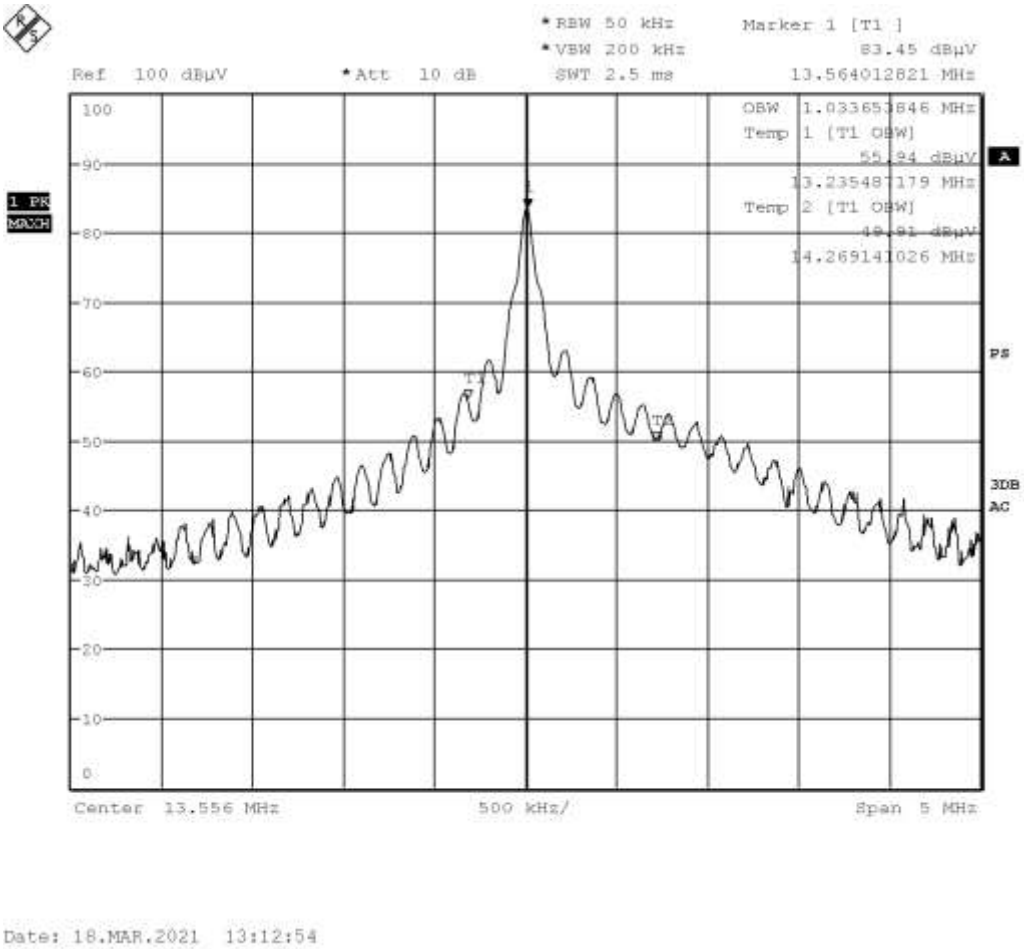
Table 7.4-1: Occupied bandwidth equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI Test Receiver	Rohde & Schwarz	ESU40	E1121	1 yr	1 Dec 2021
Active Loop H Field Antenna	Hewlett-Packard	6502	E1267	1 yr	4 Dec 2021

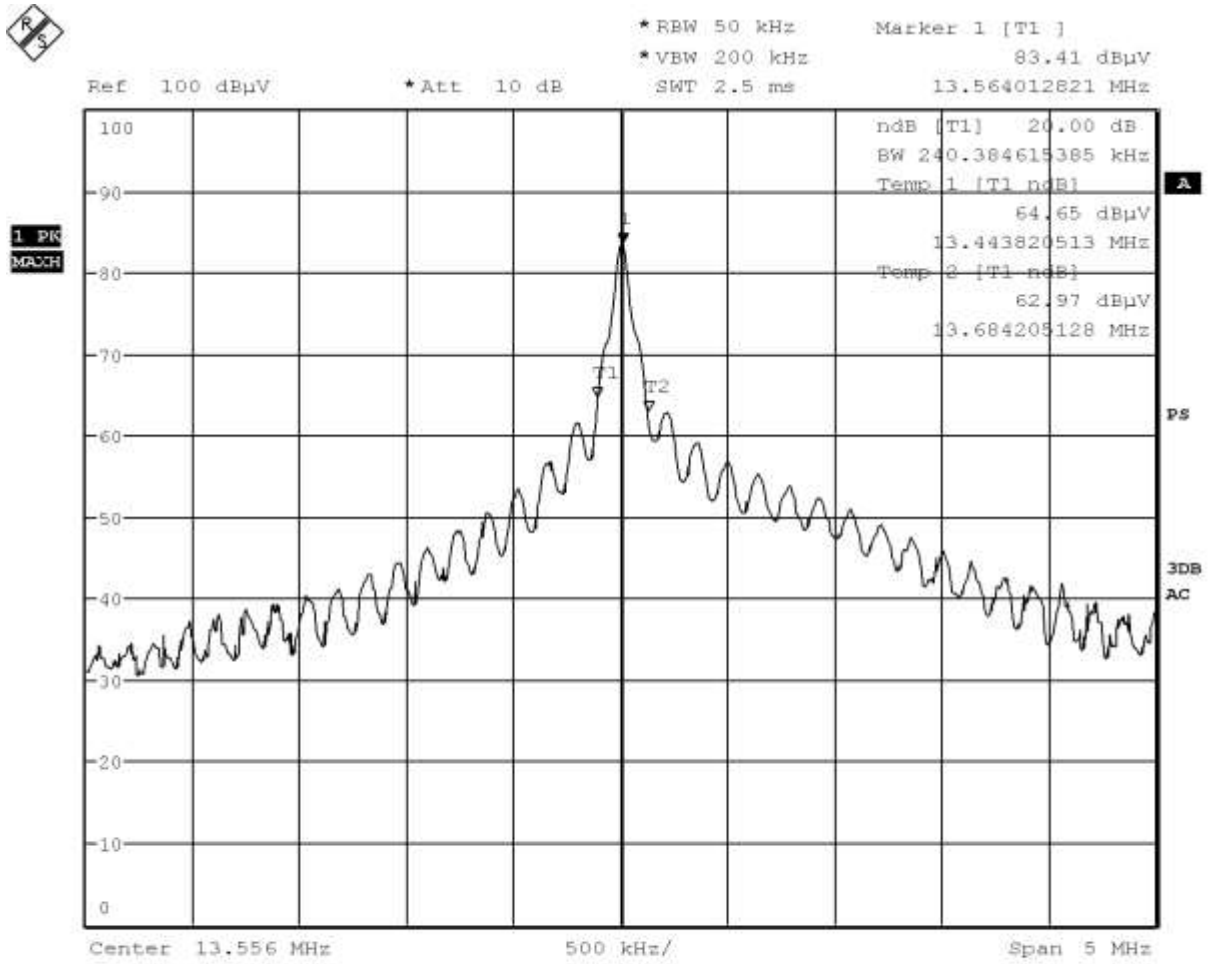
Notes: None

7.4.5 Test Data

99% Occupied Bandwidth



20 dB Bandwidth



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Section 8. Block diagrams of test setups

8.1 Radiated emissions set-up

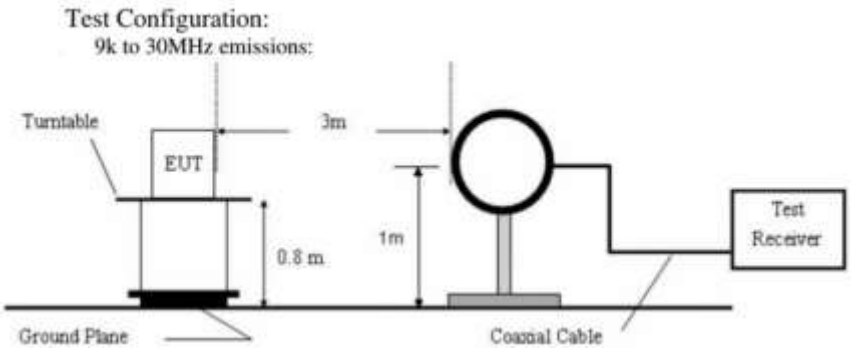

Figure 8.1-1: Radiated Emissions Test Setup – 9 kHz to 30 MHz

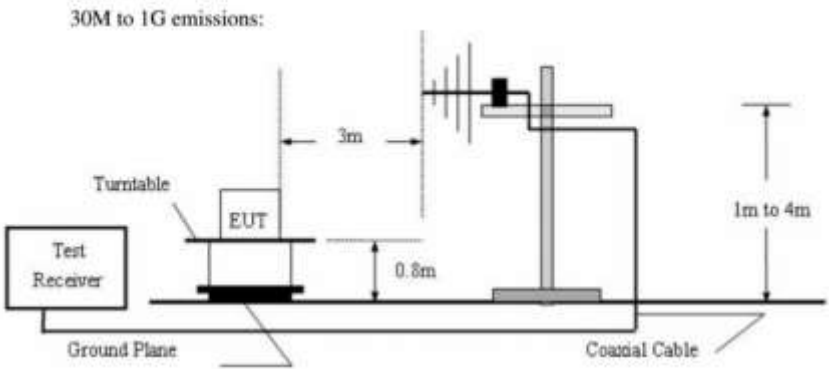

Figure 8.1-2: Radiated Emissions Test Setup – 30 to 150 MHz

8.2 Conducted emissions set-up

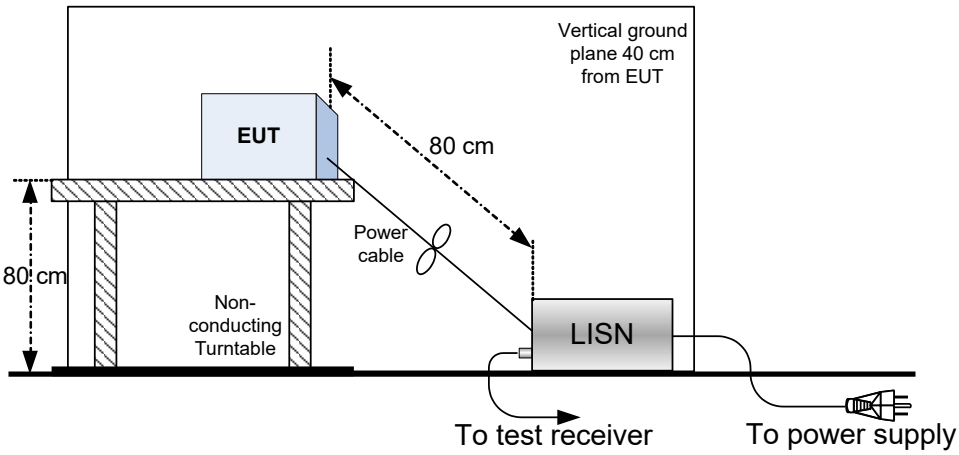

Figure 8.2-2: Conducted Emissions Test Setup – 150 kHz to 30 MHz