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Test report

REP015991-2TRFWL

Date of issue: September 28, 2023

Applicant:
Cubic Transportation System

Product:
Platform Validator

Model:
Validator 3 – Base Unit + 4G LTE Capability Utilizing New Antenna

Specifications:

- FCC 47 CFR Part 15, Subpart C – §15.207
  Conducted limits
- FCC 47 CFR Part 15, Subpart C – §15.209
  Radiated emission limits; general requirements

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

Lab and test locations

Company name	Nemko USA Inc.
Address	2210 Faraday Ave, Suite 150
City	Carlsbad
State	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	Chenhao Ma Wireless test technician
Reviewed by	James Cunningham, EMC/WL Manager
Review date	September 28, 2023
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 ANAB, NIST, or any agency of the U.S. Government.

Copyright notification

Table of Contents

Section 1 Report summary

1.1 Applicant

Company name	Cubic Transportation Systems
Address	9233 Balboa Ave.
City	San Diego
Province/State	CA
Postal/Zip code	92123
Country	United States

1.2 Manufacture

Company name	Cubic Transportation Systems
Address	9233 Balboa Ave.
City	San Diego
Province/State	CA
Postal/Zip code	92123
Country	United States

1.3 Test specifications

FCC 47 CFR Part 15, Subpart C – §15.207	Conducted limits.
FCC 47 CFR Part 15, Subpart C – §15.209	Radiated emission limits; general requirements.

1.4 Test methods

ANSI C63.10-2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

1.5 Exclusions

None

1.6 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.

1.7 Test report revision history

Table 1.7-1: Test report revision history

Revision #	Details of changes made to test report
REP015991-1TRFWL	Original report issued

Notes: None

Section 2 Summary of test results

2.1 Radiated and Conducted Emissions in simultaneous transmission.

Table 2.1-1: FCC 47 CFR Part 15, Subpart C §15.207 & §15.209

Test description	Verdict
FCC 15.209 - Radiated disturbance	Pass
FCC 15.207 - Conducted disturbance	Pass

Notes: None

Section 3 Equipment under test (EUT) details

3.1 Sample information

Receipt date	September 7, 2023
Nemko sample ID number	PRJ0040288

3.2 EUT information

Product name	Bus Validator
Model	Validator 3.0
Serial number	N/A
Trade Name	N/A

3.3 Technical information

Power requirements	24VDC (230VAC50Hz for AC/DC adapter) and PoE
Description/theory of operation	The device is to be used by public transit operators to collect fares for journeys through contactless media i.e., contactless bankcard (EMV), contactless token card (e.g. ISO14443 type A and B) and barcode (QR code on printed media or phone).
Operational frequencies band	NFC band (13.56 MHz) 2.4GHz and 5GHz Wi-Fi (802.11a/b/g/n/ac) Bluetooth (5.0 including BLE) 4G LTE.
Software details	Validator 3 Qualification Software

3.4 EUT exercise and monitoring details

EUT description of the methods used to exercise the EUT and all relevant ports:

- With the use of supporting devices, the EUT was exercising the main peripherals (Bluetooth, Wi-Fi, Cellular, sensors, LCD, NFC, audio, etc.) through an automated test script within the EUT software.
- 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.
- The EUT was setup in a manner that was consistent with its typical arrangement and use. The measurement arrangement of the EUT, local ancillary equipment and associated cabling was representative of normal practice.
- Automated test script within the EUT went through an infinite loop of toggling the following in series below:
  - Wi-Fi (sending packets to raspberry pi)
  - Ethernet (sending packets to raspberry pi)
  - Cellular (toggling specific website) - not applicable to these tests
  - MicroSD (every 1 second)
  - Internal temperature (every 5 seconds)
  - Proximity (every 2 seconds)
  - NFC (every 1 second) - not applicable to these tests
  - Backlight (every 0.5 second)
  - Camera (every 5 seconds)
  - Bluetooth scan (every 15 seconds)
  - GPS (every 3 seconds) - not applicable to these tests

  The unit was connected thru RJ32-Serial-USB adapter to the laptop.
  Using Tera-Term software: Serial COM4, Speed = 115200

EUT setup/configuration rationale:

- 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 ancillary equipment and associated cabling was representative of normal practice. Any deviations from typical arrangements have been noted below:
  - None

3.5 EUT setup diagram

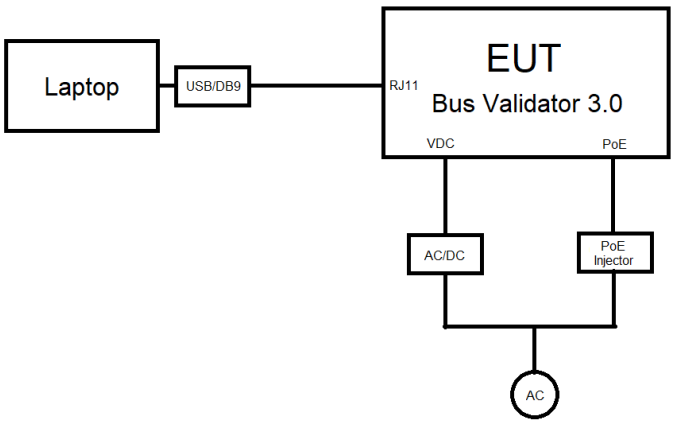

Figure 3.5-1: Setup diagram

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

No deviations were made from laboratory procedures.

Section 5 Test conditions

5.1 Atmospheric conditions

Temperature	21.4 °C
Relative humidity	55.7 %
Air pressure	86–106 kPa

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

5.2 Power supply range

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

Section 6 Measurement uncertainty

6.1 Uncertainty of measurement

Nemko USA Inc. has calculated measurement uncertainty and is documented in EMC/MUC/001 "Uncertainty in EMC measurements." Measurement uncertainty was calculated using the methods described in CISPR 16-4-2 Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-2: Uncertainties, statistics, and limit modelling – Measurement instrumentation uncertainty. The expression of Uncertainty in EMC testing. Measurement uncertainty calculations assume a coverage factor of K=2 with 95% certainty.

Table 6.1-1: Measurement uncertainty calculations

Measurement		U_{cispr} dB	U_{lab} dB
Conducted disturbance at AC mains and other port power using a V-AMN	9 kHz to 150 kHz	3.8	2.9
	150 kHz to 30 MHz	3.4	2.3
Conducted disturbance at telecommunication port using AAN	150 kHz to 30 MHz	5.0	4.3
Conducted disturbance at telecommunication port using CVP	150 kHz to 30 MHz	3.9	2.9
Conducted disturbance at telecommunication port using CP	150 kHz to 30 MHz	2.9	1.4
Conducted disturbance at telecommunication port using CP and CVP	150 kHz to 30 MHz	4.0	3.1
Radiated disturbance (electric field strength in a SAC)	30 MHz to 1 GHz	6.3	5.5
Radiated disturbance (electric field strength in a FAR)	1 GHz to 6 GHz	5.2	4.7
Radiated disturbance (electric field strength in a FAR)	6 GHz to 18 GHz	5.5	5.0

Notes: Compliance assessment:

If U_{lab} is less than or equal to U_{cispr} then:

- compliance is deemed to occur is no measured disturbance level exceeds the disturbance limit.
- non-compliance is deemed to occur if any measured disturbance level exceeds the disturbance limit.

If U_{lab} is greater than U_{cispr} then:

- compliance is deemed to occur is no measured disturbance level, increased by (U_{lab} - U_{cispr}), exceeds the disturbance limit.
- non-compliance is deemed to occur if any measured disturbance level, increased by (U_{lab} - U_{cispr}), exceeds the disturbance limit.

V-AMN: V type artificial mains network
AAN: Asymmetric artificial network
CP: Current probe
CVP: Capacitive voltage probe
SAC: Semi-anechoic chamber
FAR: Fully anechoic room

Section 7 Test Equipment

Table 6.1-1: Test Equipment List

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI Test Receiver	Rohde & Schwarz	ESU40	E1121	08-23-2023	08-23-2024
EMI Test Receiver	Rohde & Schwarz	ESCI 7	E1026	17-04-2023	17-04-2024
System controller	Sunol Sciences	SC104V	E1191	NCR	NCR
DRG Horn (medium)	ETS-Lindgren	3117-PA	E1160	13-02-2023	13-02-2024
Antenna, DRWG	EMCO	3115	0529	NCR	NCR
Wideband radio comm tester	Rohde & Schwarz	CMW500	E1161	NCR	NCR
High Pass Filter	Wainwright Instruments	WHKX12-900-1000-1500	E1211	NCR	NCR
Notch filter	Micro-Tonics	BRM50702-02	E1142	NCR	NCR
Tunable Notch	K&L	3TNF-1000/2000-N/N	1059	VOU	VOU

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

Table 6.1-2: Test Software

Manufacturer of Software	Details
Rohde & Schwarz	EMC 32 V10.20.01 (AC conducted emissions)
Rohde & Schwarz	EMC 32 V10.60.15 (radiated emissions)

Notes: None

Section 8 Testing data

8.1 Radiated emission limits; Intentional Radiators.

8.1.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.209 / ANSI C63.4: 2014

(a) Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

(b)

Frequency (MHz)	Field strength (microvolts/meter)	Measurement distance (meters)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	30
30-88	100**	3
88-216	150**	3
216-960	200**	3
Above 960	500	3

**Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this section shall not be located in the frequency bands 54-72 MHz, 76-88 MHz, 174-216 MHz or 470-806 MHz, however, operation within these frequency bands is permitted under other sections of this part, e.g., §§15.231 and 15.241.

(c) In the emission table above, the tighter limit applies at the band edges.

(d) The level of any unwanted emissions from an intentional radiator operating under these general provisions shall not exceed the level of the fundamental emission. For intentional radiators which operate under the provisions of other sections within this part and which are required to reduce their unwanted emissions to the limits specified in this table, the limits in this table are based on the frequency of the unwanted emission and not the fundamental frequency. However, the level of any unwanted emissions shall not exceed the level of the fundamental frequency.

(e) The emission limits shown in the above table are based on measurements employing a CISPR quasi-peak detector except for the frequency bands 9-90 kHz, 110-490 kHz and above 1000 MHz Radiated emission limits in these three bands are based on measurements employing an average detector.

(f) The provisions in §§15.31, 15.33, and 15.35 for measuring emissions at distances other than the distances specified in the above table, determining the frequency range over which radiated emissions are to be measured, and limiting peak emissions apply to all devices operated under this part.

(g) In accordance with §15.33(a), in some cases the emissions from an intentional radiator must be measured to beyond the tenth harmonic of the highest fundamental frequency designed to be emitted by the intentional radiator because of the incorporation of a digital device. If measurements above the tenth harmonic are so required, the radiated emissions above the tenth harmonic shall comply with the general radiated emission limits applicable to the incorporated digital device, as shown in §15.109 and as based on the frequency of the emission being measured, or, except for emissions contained in the restricted frequency bands shown in §15.205, the limit on spurious emissions specified for the intentional radiator, whichever is the higher limit. Emissions which must be measured above the tenth harmonic of the highest fundamental frequency designed to be emitted by the intentional radiator and which fall within the restricted bands shall comply with the general radiated emission limits in §15.109 that are applicable to the incorporated digital device.

8.1.2 Test summary

Verdict	Pass		
Test date	September 5, 2023	Temperature	22 °C
Test engineer	Chenhao Ma. Wireless test technician	Air pressure	1004 mbar
Test location	3m semi anechoic chamber	Relative humidity	55.2 %

8.1.3 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 30MHz to 26.5GHz

8.1.4 Setup details

EUT setup configuration	Table top
Test facility	3 m Semi anechoic chamber
Measuring distance	3 m
Antenna height variation	1–4 m
Turn table position	0–360°
Measurement details	A preview measurement was generated with receiver in continuous scan or sweep mode while the EUT was rotated and antenna adjusted to maximize radiated emission. 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/spectrum analyzer settings for frequencies below 1 GHz:

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)

Receiver/spectrum analyzer settings for frequencies above 1 GHz:

Resolution bandwidth	1 MHz
Video bandwidth	3 MHz
Detector mode	Peak (Preview measurement) Peak and CAverage (Final measurement)
Trace mode	Max Hold
Measurement time	– 100 ms (Peak preview measurement) – 5000 ms (Peak and CAverage final measurement)

8.1.5 Setup details, continued

Table 8.1-1: Radiated disturbance equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI Test Receiver	Rohde & Schwarz	ESU40	E1121	08-23-2023	08-23-2024
System controller	Sunol Sciences	SC104V	E1191	NCR	NCR
DRG Horn (medium)	ETS-Lindgren	3117-PA	E1160	13-02-2023	13-02-2024
Antenna, DRWG	EMCO	3115	0529	NCR	NCR
Wideband radio comm tester	Rohde & Schwarz	CMW500	E1161	NCR	NCR
High Pass Filter	Wainwright Instruments	WHKX12-900-1000-1500	E1211	NCR	NCR
Notch filter	Micro-Tonics	BRM50702-02	E1142	NCR	NCR
Tunable Notch	K&L	3TNF-1000/2000-N/N	1059	VOU	VOU

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

Table 8.1-2: Radiated disturbance test software details

Manufacturer of Software	Details
Rohde & Schwarz	EMC32 V10.35.10

Notes: None

8.1.6 Test data Radiated Emissions 30MHz-26.5GHz (BLE and RFID Wi-Fi LTE modules transmitting simultaneously)

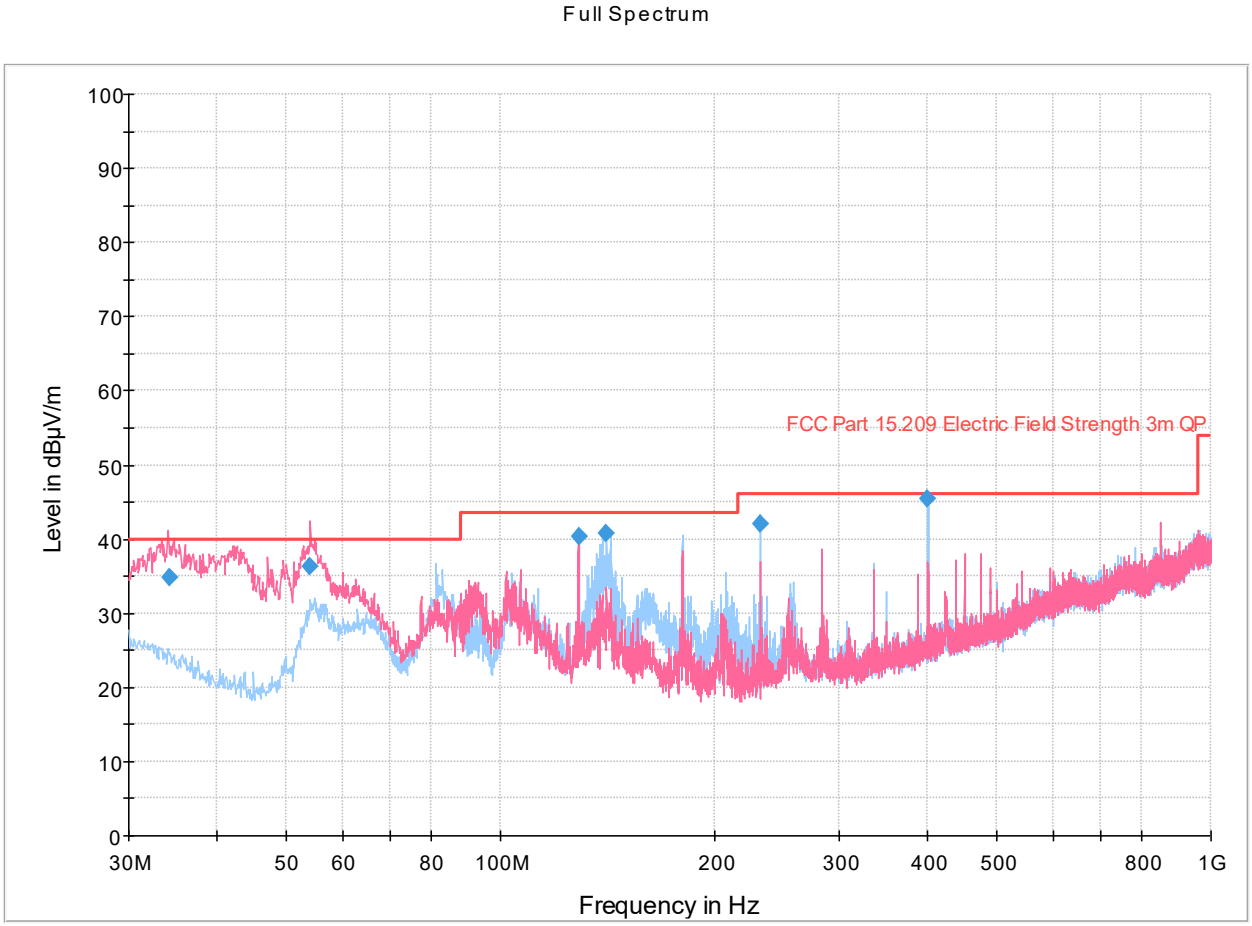

Figure 8.1-1: RE 30-1000MHz Multi transmit LTE band2, Wi-Fi Bluetooth, NFC module.

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
34.234000	34.89	40.00	5.11	5000.0	120.000	120.0	V	134.0	22.8
53.936000	36.26	40.00	3.74	5000.0	120.000	107.0	V	309.0	13.3
128.923000	40.33	43.50	3.17	5000.0	120.000	228.0	H	101.0	18.4
141.202000	40.73	43.50	2.77	5000.0	120.000	201.0	H	252.0	18.7
232.034000	42.05	46.00	3.95	5000.0	120.000	100.0	H	101.0	18.0
399.958000	45.53	46.00	0.47	5000.0	120.000	100.0	H	136.0	24.3

Table 8.1-3: Radiated emission result of multi-transmit.

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 5 seconds was recorded.
[4] The spectral plot is a summation of a vertical and horizontal scan.

8.1.6 Test data Radiated Emissions 30MHz-26.5GHz, continued

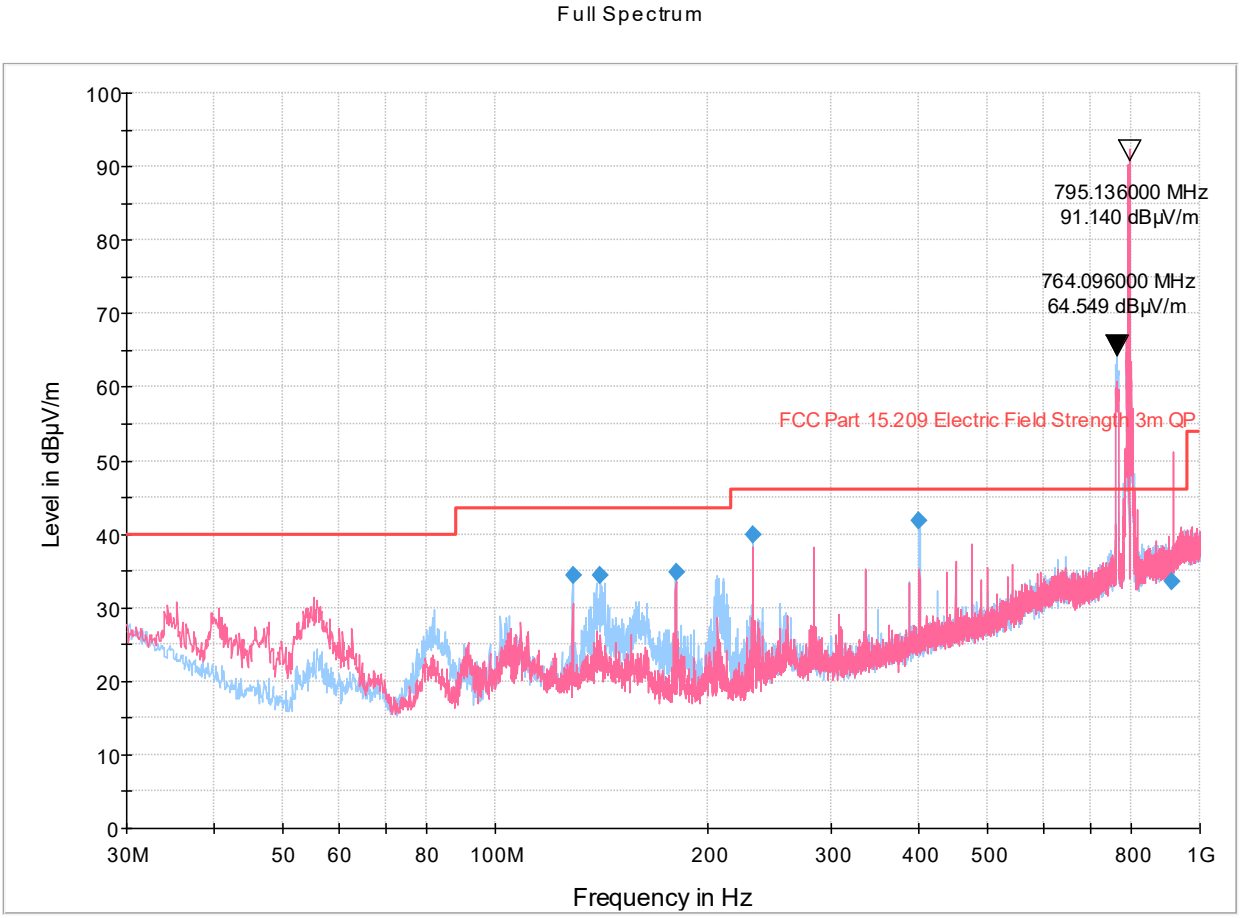

Figure 8.1-2: RE 30-1000MHz Multi transmit LTE band14, Wi-Fi Bluetooth, NFC module

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
128.883000	34.33	43.50	9.17	5000.0	120.000	227.0	H	100.0	18.4
141.202000	34.37	43.50	9.13	5000.0	120.000	191.0	H	239.0	18.7
180.447000	34.75	43.50	8.75	5000.0	120.000	185.0	H	220.0	16.4
232.034000	39.92	46.00	6.08	5000.0	120.000	100.0	H	115.0	18.0
399.958000	41.85	46.00	4.15	5000.0	120.000	100.0	H	131.0	24.3
913.731000	33.63	46.00	12.37	5000.0	120.000	142.0	V	250.0	33.8

Table 8.1-4: Radiated emission result of multi-transmit.

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 5 seconds was recorded.
[4] The spectral plot is a summation of a vertical and horizontal scan.
Emissions at 764 MHz and 791 MHz are attributable to the LTE band 14 uplink and downlink and are not assessed against the limits.

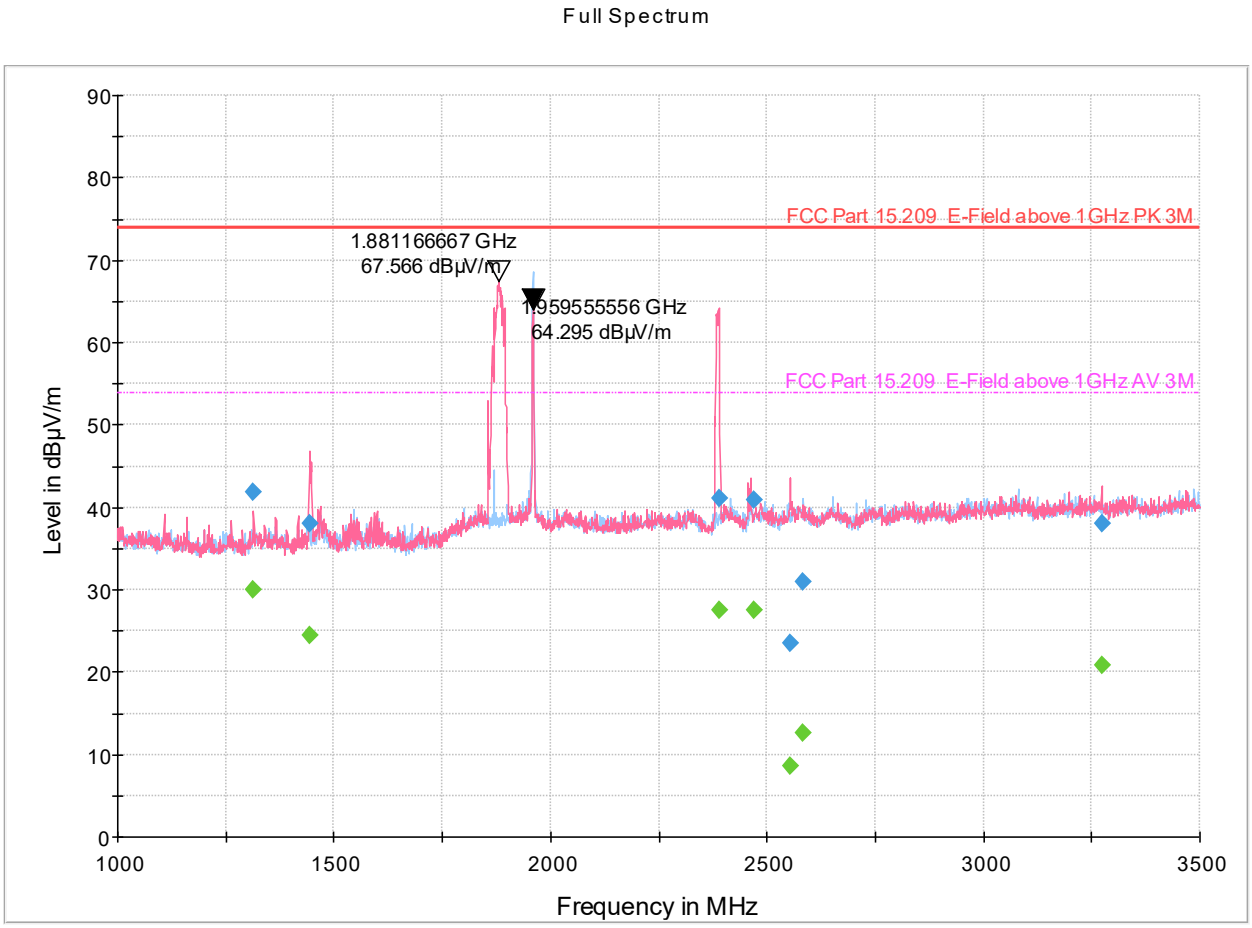

Figure 8.1-3: RE 1-3.5GHz Multi transmit LTE band2, Wi-Fi Bluetooth, NFC module.

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1314.100000	41.92	---	73.90	31.98	5000.0	1000.000	104.0	V	33.0	-10.4
1314.100000	---	29.97	53.90	23.93	5000.0	1000.000	104.0	V	33.0	-10.4
1444.833333	---	24.47	53.90	29.43	5000.0	1000.000	200.0	V	148.0	-10.0
1444.833333	38.01	---	73.90	35.89	5000.0	1000.000	200.0	V	148.0	-10.0
2391.788889	---	27.45	53.90	26.45	5000.0	1000.000	203.0	V	232.0	-4.3
2391.788889	41.02	---	73.90	32.88	5000.0	1000.000	203.0	V	232.0	-4.3
2469.200000	---	27.48	53.90	26.42	5000.0	1000.000	275.0	V	168.0	-4.0
2469.200000	40.96	---	73.90	32.94	5000.0	1000.000	275.0	V	168.0	-4.0
2552.555556	---	8.60	53.90	45.30	5000.0	1000.000	247.0	V	0.0	-3.7
2552.555556	23.51	---	73.90	50.39	5000.0	1000.000	247.0	V	0.0	-3.7
2581.577778	31.01	---	73.90	42.89	5000.0	1000.000	151.0	H	312.0	-3.8
2581.577778	---	12.58	53.90	41.32	5000.0	1000.000	151.0	H	312.0	-3.8
3275.677778	---	20.82	53.90	33.08	5000.0	1000.000	136.0	V	334.0	-1.7
3275.677778	38.12	---	73.90	35.79	5000.0	1000.000	136.0	V	334.0	-1.7

Table 8.1-5: Radiated emission result of multi-transmit.

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 5 seconds was recorded.
[4] The spectral plot is a summation of a vertical and horizontal scan.
Emissions at 1881 MHz and 1960 MHz are attributable to the LTE band 2 uplink and downlink and are not assessed against the limits.

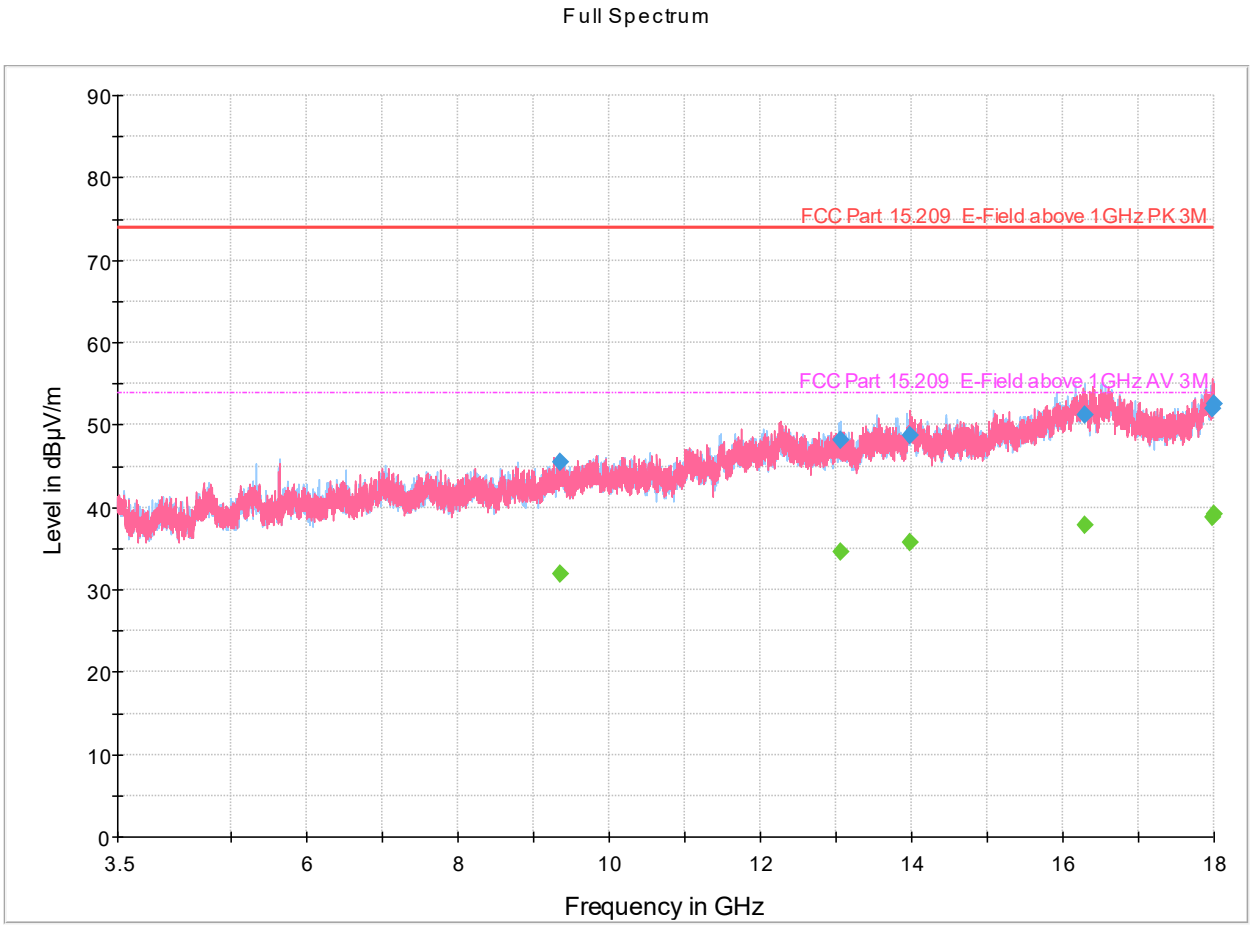

Figure 8.1-4 1: RE 3.5-18GHz Multi transmit LTE band2, Wi-Fi Bluetooth, NFC module.

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
9348.422222	45.46	---	73.90	28.44	5000.0	1000.000	194.0	V	235.0	9.1
9348.422222	---	31.82	53.90	22.08	5000.0	1000.000	194.0	V	235.0	9.1
13070.622222	---	34.50	53.90	19.40	5000.0	1000.000	128.0	H	137.0	16.1
13070.622222	48.17	---	73.90	25.73	5000.0	1000.000	128.0	H	137.0	16.1
13982.944444	---	35.65	53.90	18.25	5000.0	1000.000	270.0	V	103.0	17.5
13982.944444	48.79	---	73.90	25.11	5000.0	1000.000	270.0	V	103.0	17.5
16285.255556	51.29	---	73.90	22.61	5000.0	1000.000	388.0	H	214.0	22.7
16285.255556	---	37.83	53.90	16.07	5000.0	1000.000	388.0	H	214.0	22.7
17984.777778	---	38.80	53.90	15.10	5000.0	1000.000	219.0	V	10.0	24.3
17984.777778	51.93	---	73.90	21.97	5000.0	1000.000	219.0	V	10.0	24.3
17991.177778	---	39.15	53.90	14.75	5000.0	1000.000	327.0	V	173.0	24.7
17991.177778	52.53	---	73.90	21.37	5000.0	1000.000	327.0	V	173.0	24.7

Table 8.1-6: Radiated emission result of multi-transmit.

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 5 seconds was recorded.
[4] The spectral plot is a summation of a vertical and horizontal scan.

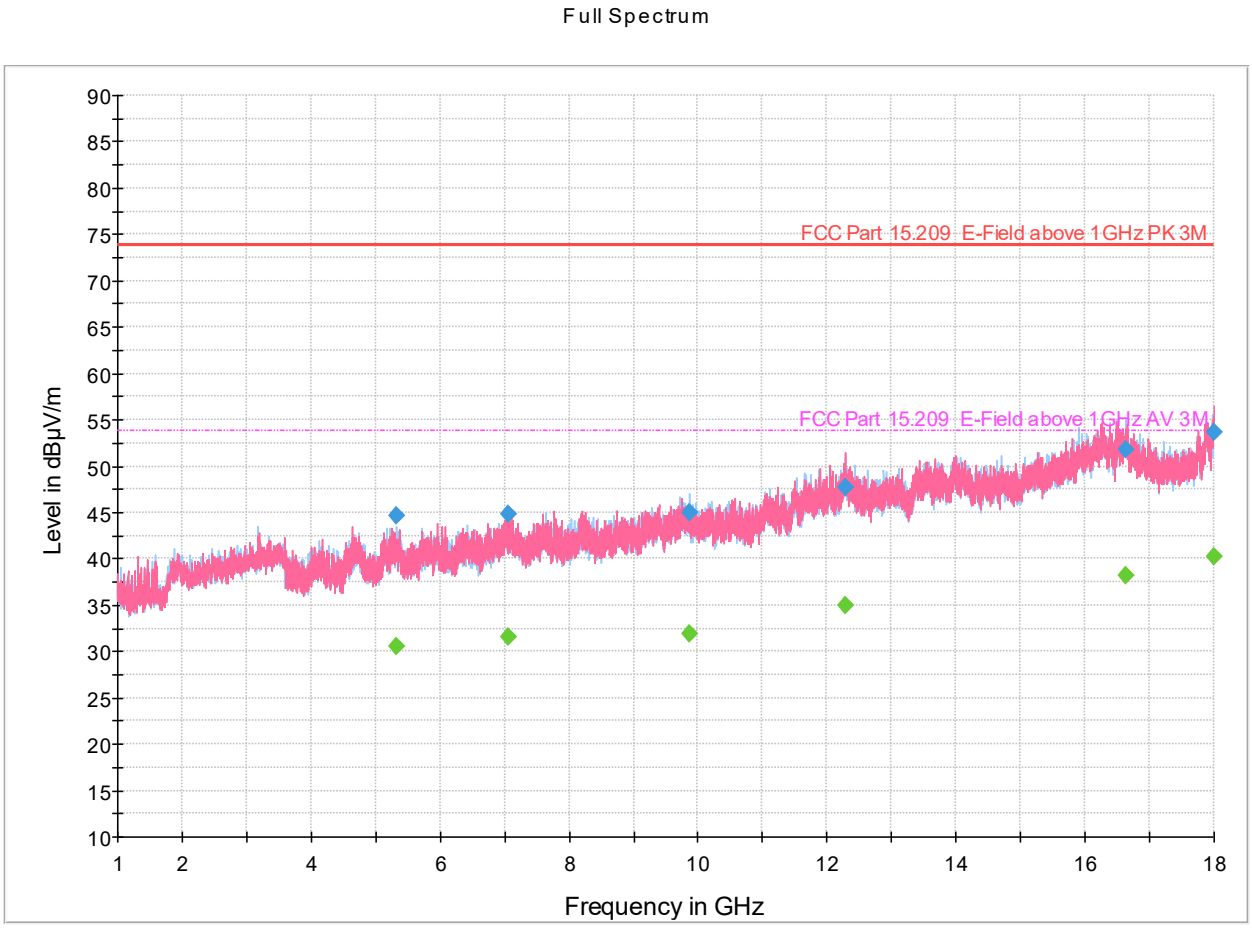

Figure 8.1-5: RE 1-18GHz Multi transmit LTE band14, Wi-Fi Bluetooth, NFC module.

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
5324.466667	---	30.62	53.90	23.28	5000.0	1000.000	235.0	H	356.0	3.1
5324.466667	44.61	---	73.90	29.29	5000.0	1000.000	235.0	H	356.0	3.1
7066.711111	44.82	---	73.90	29.08	5000.0	1000.000	274.0	H	33.0	4.8
7066.711111	---	31.55	53.90	22.35	5000.0	1000.000	274.0	H	33.0	4.8
9866.766667	44.96	---	73.90	28.94	5000.0	1000.000	194.0	H	0.0	10.6
9866.766667	---	31.90	53.90	22.00	5000.0	1000.000	194.0	H	0.0	10.6
12273.355556	47.76	---	73.90	26.14	5000.0	1000.000	310.0	V	186.0	15.4
12273.355556	---	34.89	53.90	19.01	5000.0	1000.000	310.0	V	186.0	15.4
16625.911111	51.74	---	73.90	22.16	5000.0	1000.000	260.0	H	33.0	22.9
16625.911111	---	38.26	53.90	15.64	5000.0	1000.000	260.0	H	33.0	22.9
17998.800000	---	40.19	53.90	13.71	5000.0	1000.000	258.0	V	350.0	25.2
17998.800000	53.57	---	73.90	20.33	5000.0	1000.000	258.0	V	350.0	25.2

Table 8.1-7: Radiated emission result of multi-transmit.

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 5 seconds was recorded.
[4] The spectral plot is a summation of a vertical and horizontal scan.

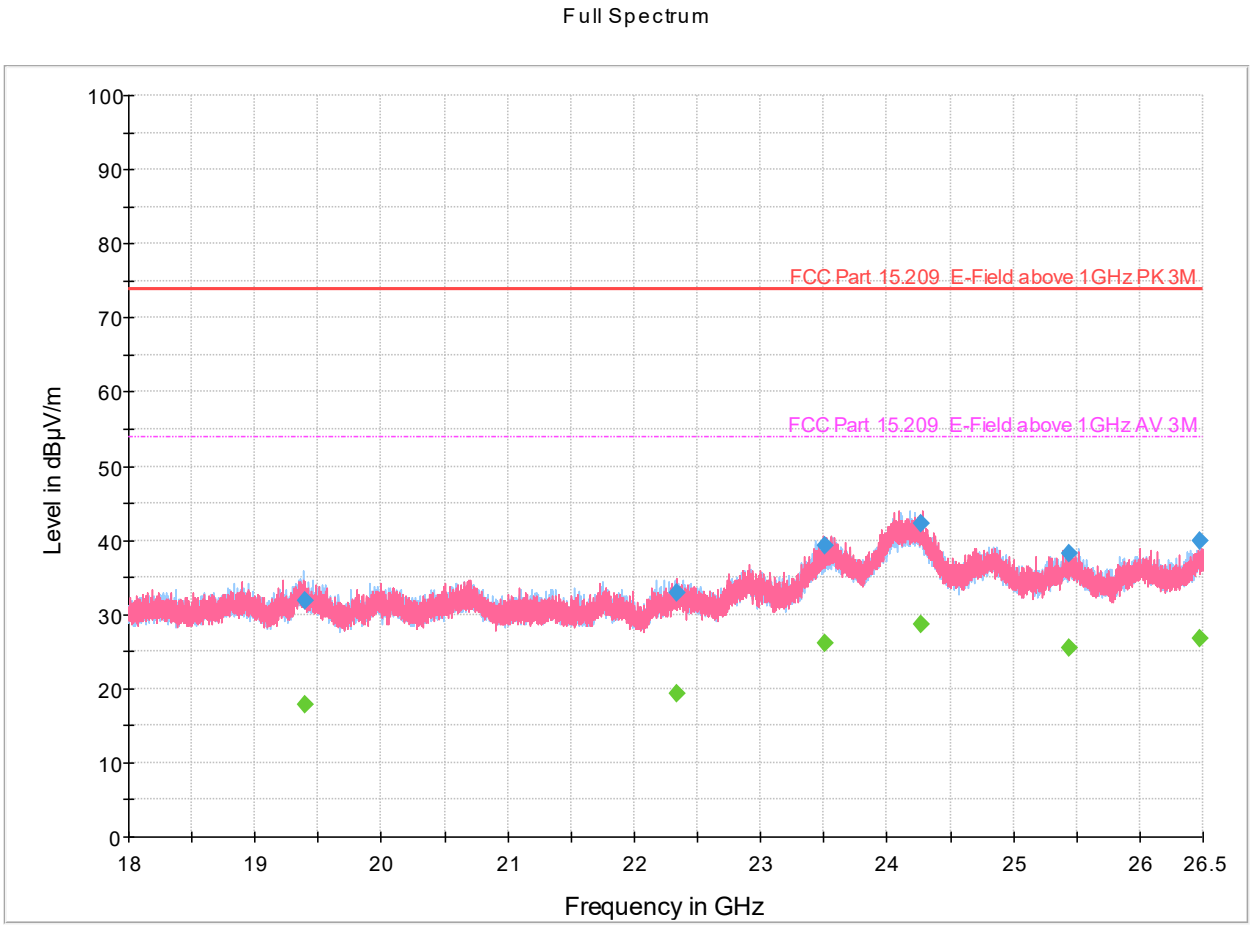

Figure 8.1-6: RE 18-26.5GHz Multi transmit LTE band2, Wi-Fi Bluetooth, NFC module.

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
19392.718750	31.88	---	73.90	42.02	5000.0	1000.000	134.0	H	11.0	16.6
19392.718750	---	17.85	53.90	36.05	5000.0	1000.000	134.0	H	11.0	16.6
22336.012500	32.95	---	73.90	40.95	5000.0	1000.000	225.0	V	90.0	17.6
22336.012500	---	19.32	53.90	34.58	5000.0	1000.000	225.0	V	90.0	17.6
23508.081250	39.34	---	73.90	34.56	5000.0	1000.000	388.0	V	55.0	23.2
23508.081250	---	26.07	53.90	27.83	5000.0	1000.000	388.0	V	55.0	23.2
24272.106250	42.15	---	73.90	31.75	5000.0	1000.000	100.0	V	326.0	26.7
24272.106250	---	28.62	53.90	25.28	5000.0	1000.000	100.0	V	326.0	26.7
25435.700000	38.25	---	73.90	35.65	5000.0	1000.000	361.0	H	254.0	21.7
25435.700000	---	25.50	53.90	28.40	5000.0	1000.000	361.0	H	254.0	21.7
26473.787500	39.98	---	73.90	33.92	5000.0	1000.000	114.0	H	104.0	23.3
26473.787500	---	26.80	53.90	27.10	5000.0	1000.000	114.0	H	104.0	23.3

Table 8.1-8: Radiated emission result of multi-transmit.

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 5 seconds was recorded.
[4] The spectral plot is a summation of a vertical and horizontal scan.

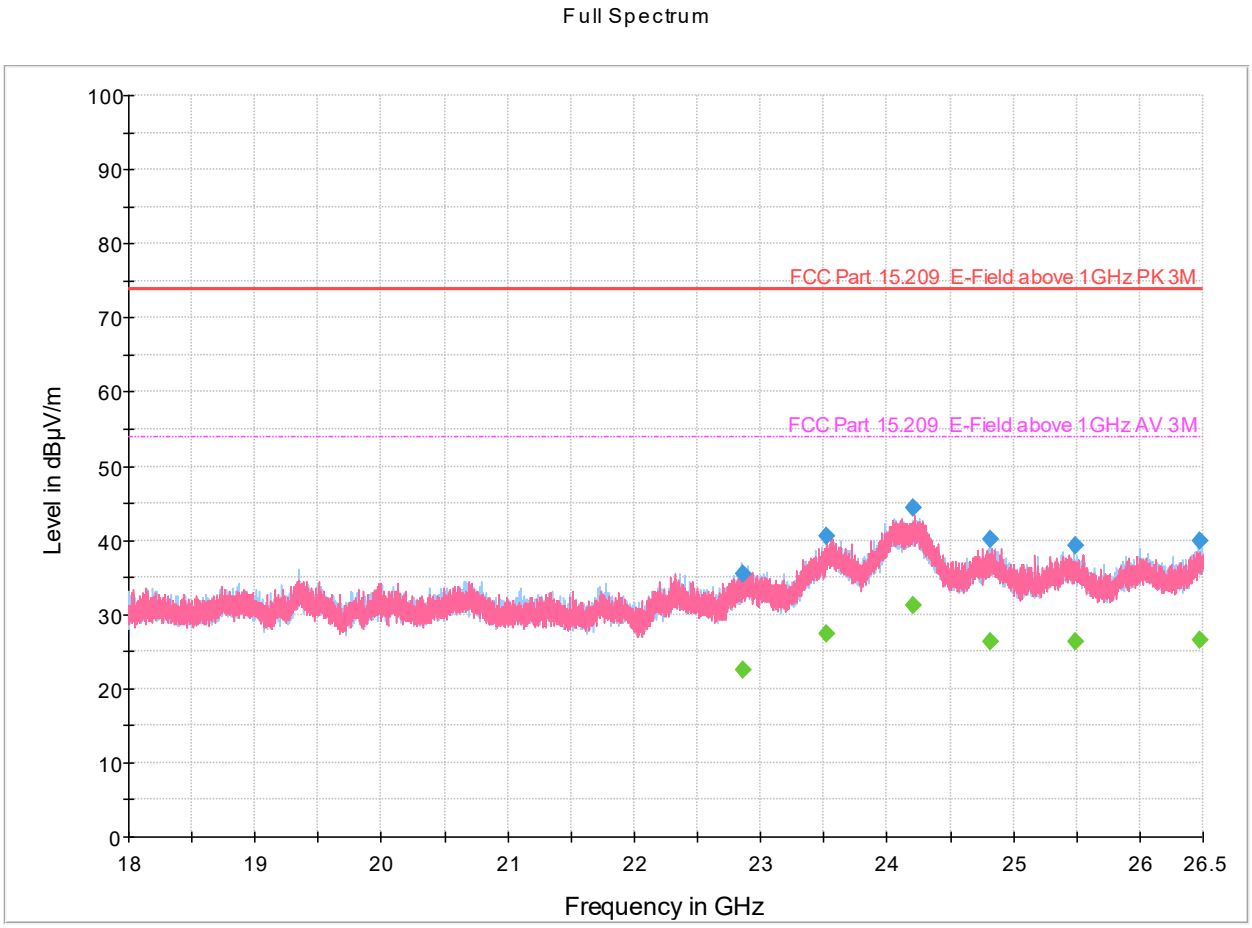

Figure 8.1-7: RE 18-26.5GHz Multi transmit LTE band 14, Wi-Fi Bluetooth, NFC module.

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
22862.406250	35.54	---	73.90	38.36	5000.0	1000.000	144.0	H	115.0	19.0
22862.406250	---	22.55	53.90	31.35	5000.0	1000.000	144.0	H	115.0	19.0
23522.300000	---	27.48	53.90	26.42	5000.0	1000.000	131.0	V	56.0	23.3
23522.300000	40.61	---	73.90	33.29	5000.0	1000.000	131.0	V	56.0	23.3
24211.125000	---	31.27	53.90	22.63	5000.0	1000.000	327.0	V	44.0	27.1
24211.125000	44.29	---	73.90	29.61	5000.0	1000.000	327.0	V	44.0	27.1
24822.400000	40.10	---	73.90	33.80	5000.0	1000.000	193.0	H	241.0	22.3
24822.400000	---	26.27	53.90	27.63	5000.0	1000.000	193.0	H	241.0	22.3
25489.987500	---	26.34	53.90	27.56	5000.0	1000.000	362.0	H	78.0	21.9
25489.987500	39.22	---	73.90	34.68	5000.0	1000.000	362.0	H	78.0	21.9
26472.000000	---	26.45	53.90	27.45	5000.0	1000.000	365.0	H	224.0	23.3
26472.000000	39.96	---	73.90	33.94	5000.0	1000.000	365.0	H	224.0	23.3

Table 8.1-9: Radiated emission result of multi-transmit.

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 5 seconds was recorded.
[4] The spectral plot is a summation of a vertical and horizontal scan.

8.1.7 Radiated Emissions Setup photos

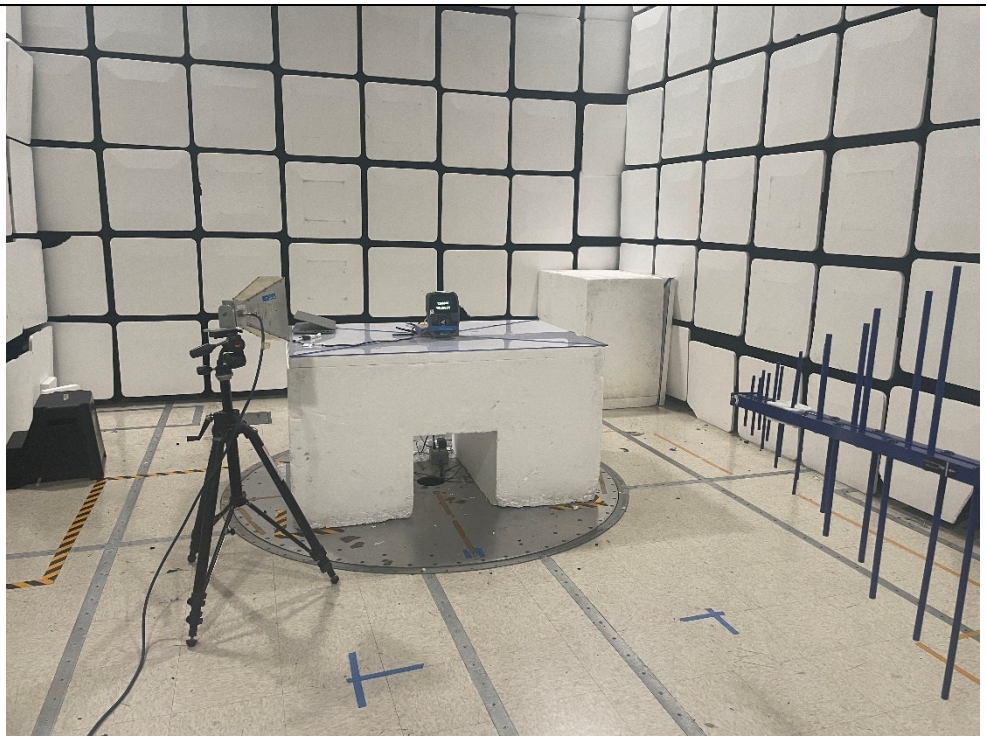

Figure 8.1.8 Radiated emissions 30-1000 MHz (Front)

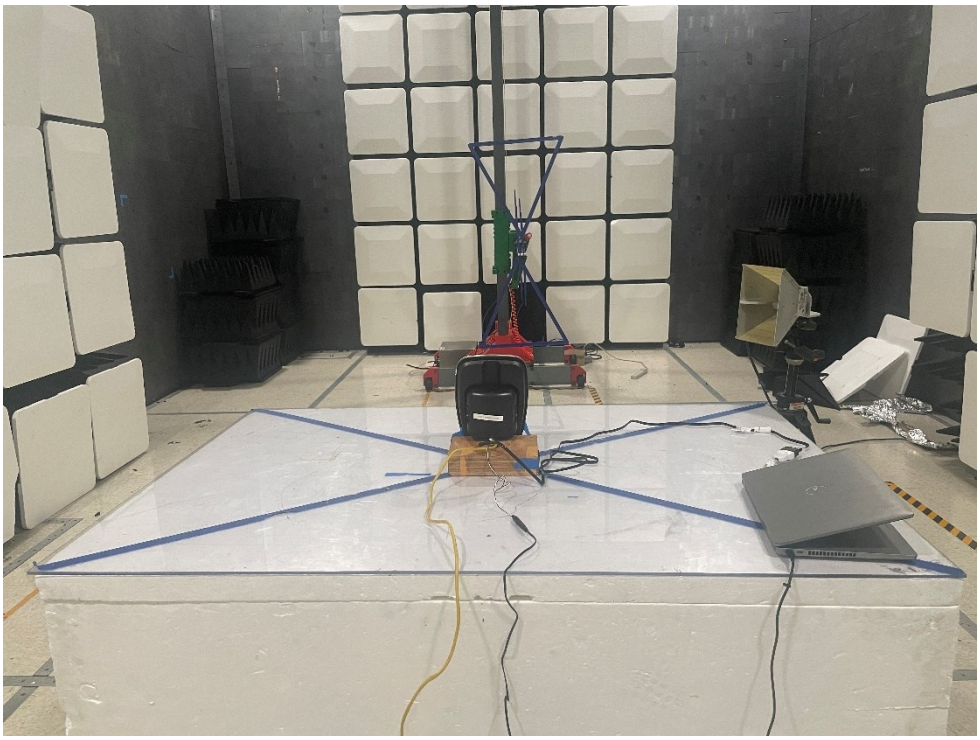

Figure 8.1.9 Radiated emissions 30-1000 MHz (Back)

Figure 8.1.10 Radiated emissions 1-18 GHz (Front)

Figure 8.1.11 Radiated emissions 1-18 GHz (Back)

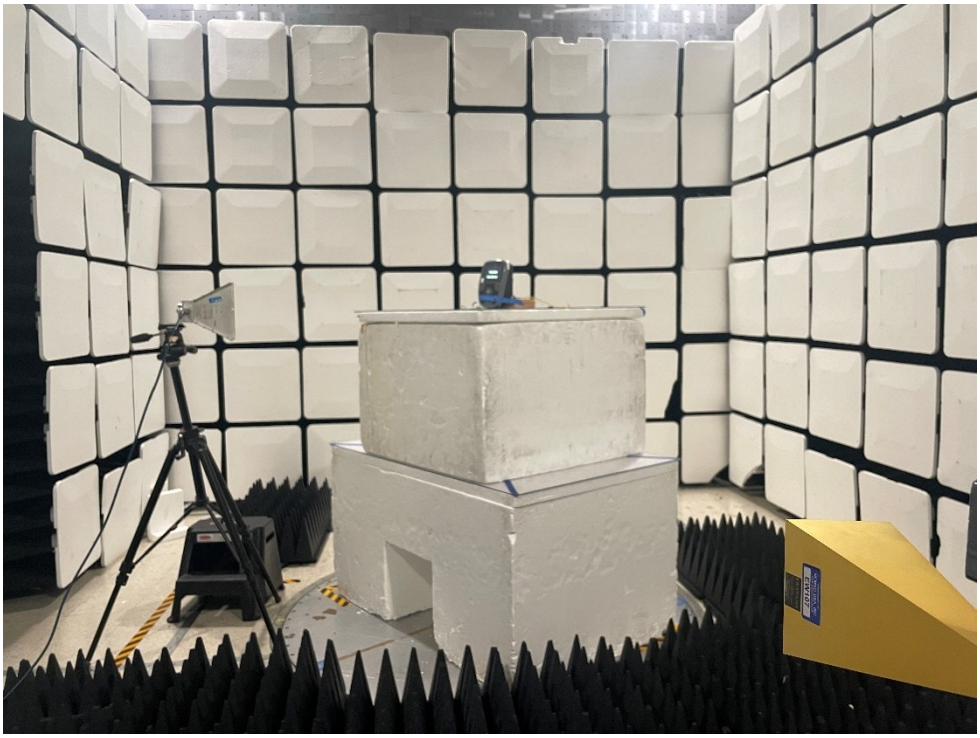

Figure 8.1.12 Radiated emissions 18-26.5 GHz (Front)

Figure 8.1.13 Radiated emissions 18-26.5 GHz (Back)

8.2 Conducted limits.

8.2.1 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.

8.2.2 Conducted limits

Verdict	Pass		
Test date	September 7, 2023	Temperature	21.6 °C
Test engineer	Chenhao Ma Wireless test technician	Air pressure	1002 mbar
Test location	Ground Plane	Relative humidity	48.7 %

8.2.3 Notes

None

8.2.4 Setup details

Port under test	AC Mains Input
EUT setup configuration	Table top
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 8.2-1: Conducted disturbance at mains port equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI Test Receiver	Rohde & Schwarz	ESCI 7	E1026	17-04-2023	17-04-2024
10dB transmit limiter	HP	11947A	E1159	02-27-2023	02-27-2024
Two Line V-Network	Rohde & Schwarz	ENV216	E1020	01-02-2023	01-02-2024

Notes: None

Table 8.2-2: Conducted disturbance at mains port test software details

Manufacturer of Software	Details
Rohde & Schwarz	EMC 32 V10.20.01

Notes: None

8.2.5 Conducted Emissions Test data

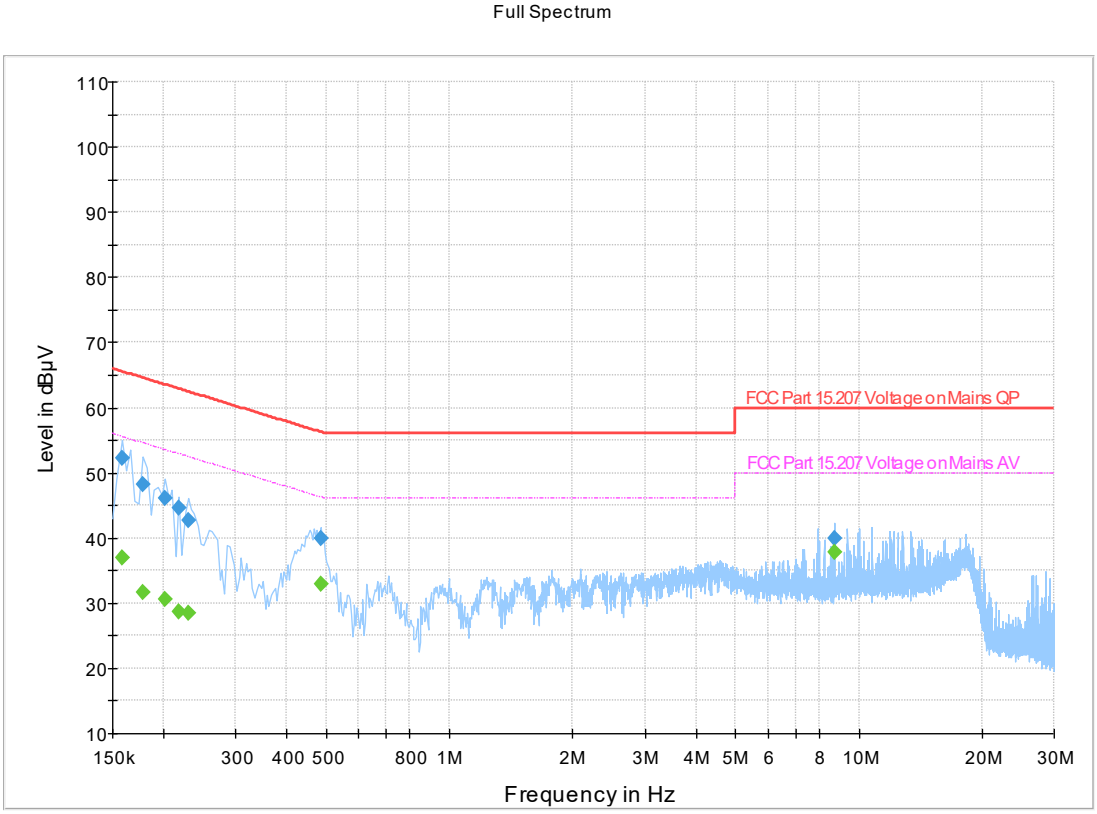

Figure 8.2-1 Multi Transmit conduct emission test

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

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.158000	---	37.00	55.57	18.57	5000.0	9.000	L1	ON	19.5
0.158000	52.19	---	65.57	13.38	5000.0	9.000	L1	ON	19.5
0.178000	---	31.61	54.58	22.96	5000.0	9.000	L1	ON	19.5
0.178000	48.14	---	64.58	16.44	5000.0	9.000	L1	ON	19.5
0.202000	---	30.56	53.53	22.97	5000.0	9.000	L1	ON	19.5
0.202000	46.15	---	63.53	17.38	5000.0	9.000	L1	ON	19.5
0.218000	---	28.67	52.90	24.22	5000.0	9.000	L1	ON	19.5
0.218000	44.54	---	62.90	18.35	5000.0	9.000	L1	ON	19.5
0.230000	---	28.44	52.45	24.01	5000.0	9.000	L1	ON	19.4
0.230000	42.78	---	62.45	19.67	5000.0	9.000	L1	ON	19.4
0.486000	---	32.97	46.24	13.27	5000.0	9.000	L1	ON	19.4
0.486000	39.88	---	56.24	16.36	5000.0	9.000	L1	ON	19.4
8.718000	---	37.85	50.00	12.15	5000.0	9.000	N	ON	19.7
8.718000	39.83	---	60.00	20.17	5000.0	9.000	N	ON	19.7

Table 8.2-3 Conducted disturbance at AC mains results (Quasi-Peak and Average)

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)

8.2.6 Conducted Emissions Setup photos

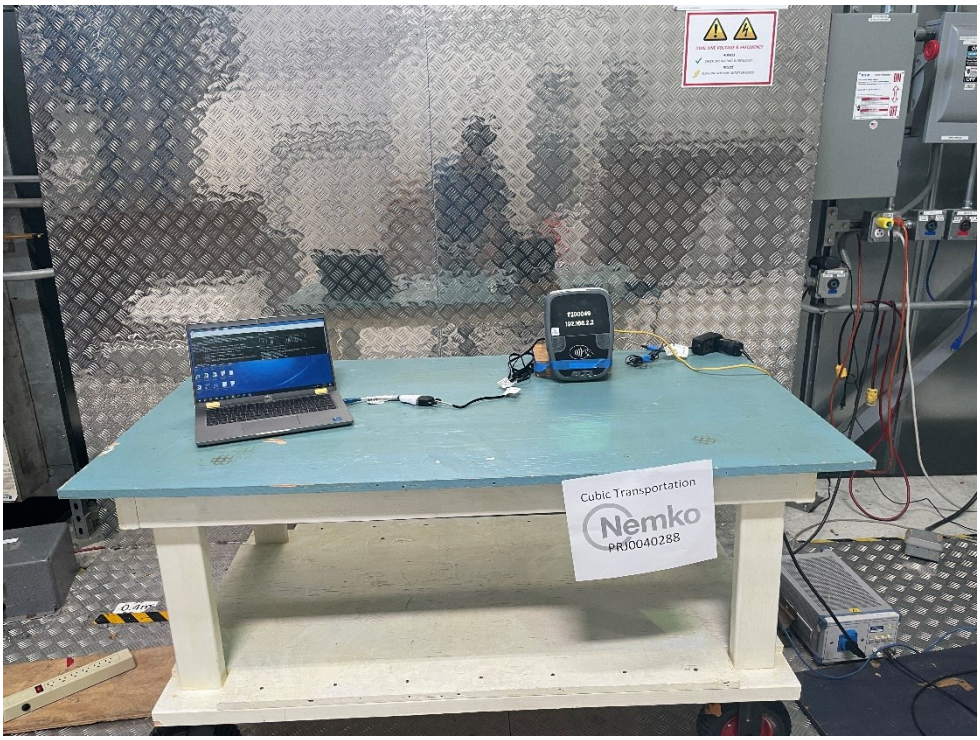

Figure 8.2.1 Conducted disturbance at AC mains port setup photo (Front)

Figure 8.2.2 Conducted disturbance at AC mains port setup photo (Back)

Section 9 Block diagrams of test set-ups

9.1 Radiated emissions set-up

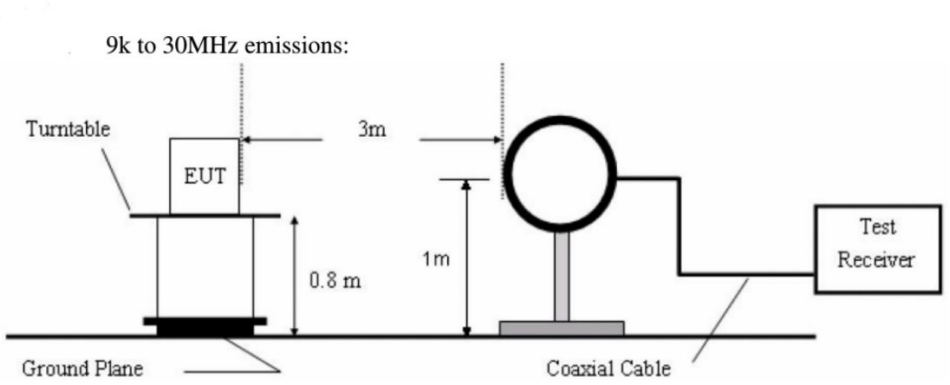

Figure 9.1.1 Radiated emissions, 9 kHz to 30 MHz setup

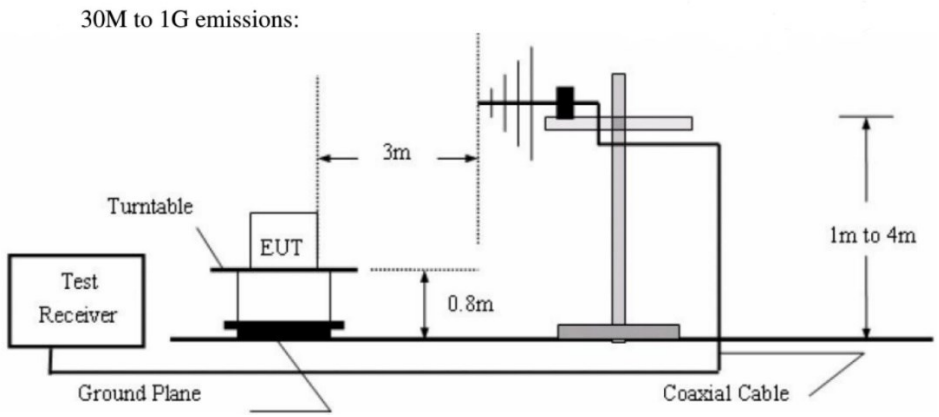

Figure 9.1.2 Radiated emissions, 30 to 1000 MHz setup

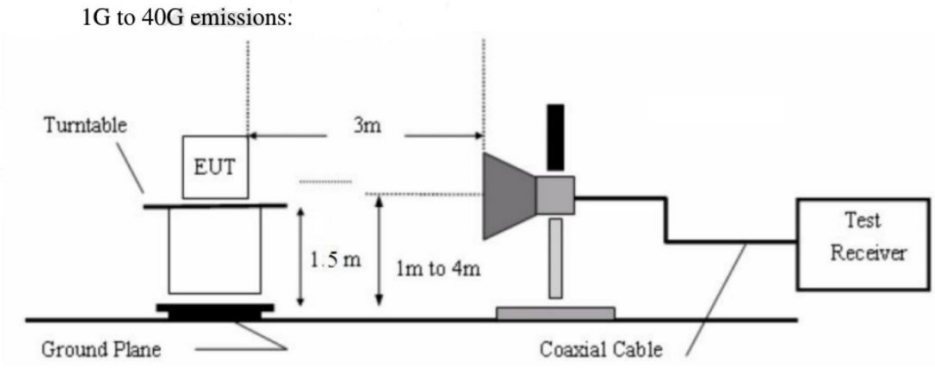

Figure 9.1.3 Radiated emissions, 1 to 40 GHz setup

9.2 Conducted emissions set-up

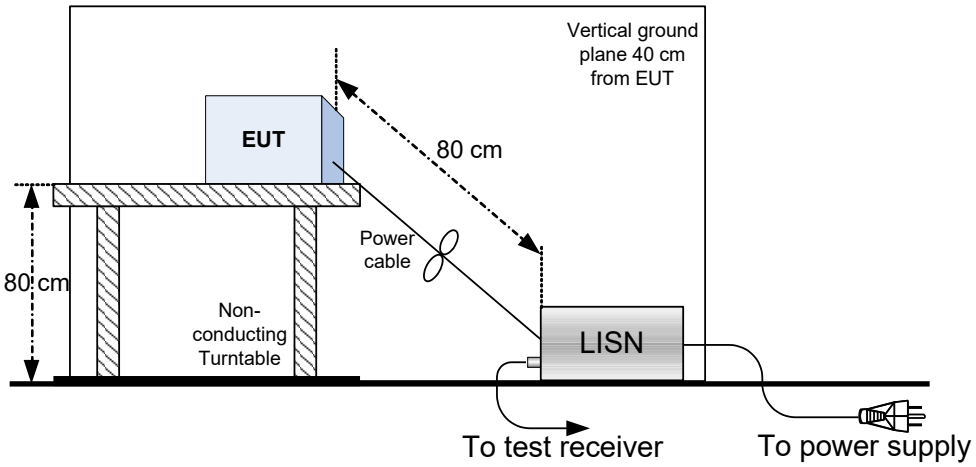

Figure 9.2.1 Conducted emissions, 150 kHz-30 MHz, setup