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FCC/ISED Test Report

Prepared for: **701x**

Address: **700 Main Avenue**
Fargo, North Dakota 58103, USA

Product: **cTAG**

Test Report No: **R20220914-20-01-E1D**

Approved by:

Nic S. Johnson, NCE
Technical Manager
iNARTE Certified EMC Engineer #EMC-003337-NE

DATE: **16 December 2022**

Total Pages: **27**

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TESTING LABORATORY
CERTIFICATE NO. 1953.01

REVISION PAGE

Rev. No.	Date	Description
0	31 October 2022	Original – NJohnson Prepared by BWinter
A	15 November 2022	Rev A – Njohnson Prepared by BWinter Correct page header error on page 2. Correct tables on pages 15, 17, and 19. Remove extraneous statement on pages 15, 17, and 19. Change tables 2, 4, 6 to include a duty cycle correction factor. Add correction factors to restricted band edge measurements.
B	30 November 2022	Rev B – Njohnson Prepared by BWinter Add plot that confirms continuous transmit. Add plot that demonstrates a large delta between peak and average measurements on the 2nd harmonic of the higher frequency channel.
C	8 December 2022	Duty cycle measurements were measured from a sample operating in the worse-case production transmit mode. All average measurements were replaced with peak measurements – DCCF. NJ
D	16 December 2022	Duty cycle has been updated throughout the report-KV

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1.0 SUMMARY OF TEST RESULTS

The EUT has been tested according to the following specifications:

(1) US Code of Federal Regulations, Title 47, Part 15 using ANSI C63.10-2013.

SUMMARY			
Requirement	**Test Type and Limit**	**Result**	**Remark**
FCC 15.203	Unique Antenna Requirement	Pass	Surface Mount antenna
FCC 15.209	Receiver Radiated Emissions	Pass	Meets the requirement of the limit.
FCC 15.209 FCC 15.249(a)	Transmitter Radiated Emissions	Pass	Meets the requirement of the limit.

2.0 EUT DESCRIPTION

2.1 EQUIPMENT UNDER TEST

Summary

The Equipment Under Test (EUT) was a cTag animal tracking device manufactured by 701x. It has a Bluetooth radio that operates in 2400 MHz -2483.5 MHz band, and it has transmit and receive capabilities.

EUT	cTag
EUT Received	9/26/2022
EUT Tested	9/26/2022 - 10/24/2022
Serial No.	017F-D9CD, 017F-1468, 017F-1374
Operating Band	2400 – 2483.5 MHz
Device Type	BTLE
Power Supply	CR2477 3.3V Lithium coin cell

NOTE: For more detailed features description, please refer to the manufacturer's specifications or user's manual.

2.2 DESCRIPTION OF TEST MODES

The EUT operates on, and was tested at the frequencies below:

Channel	Frequency
1	2402 MHz
2	2440 MHz
3	2480 MHz

These are the only three representative channels tested in the frequency range according to FCC Part 15.31. See the operational description for a list of all channel frequency and designations.

This EUT was set to transmit in a worst-case scenario with modulation on. The unit could be programmed to transmit continuously on the low, mid or high frequency channel.

The EUT was tested for spurious emissions while running off of battery power.

2.3 DESCRIPTION OF SUPPORT UNITS

None

3.0 LABORATORY DESCRIPTION

3.1 LABORATORY DESCRIPTION

All testing was performed at the following Facility:

The Nebraska Center for Excellence in Electronics (NCEE Labs)
4740 Discovery Drive
Lincoln, NE 68521

A2LA Certificate Number:	1953.01
FCC Accredited Test Site Designation No:	US1060
Industry Canada Test Site Registration No:	4294A-1
NCC CAB Identification No:	US0177

Environmental conditions varied slightly throughout the tests.

3.2 TEST PERSONNEL

No.	PERSONNEL	TITLE	ROLE
1	Blake Winter	EMC Test Engineer	Testing
2	Ethan Schmidt	Test Tech/Intern	Supervised Testing
3	Nic Johnson	Technical Manager	Review of Results

Notes:
All personnel are permanent staff members of NCEE Labs. No testing or review was sub-contracted or performed by sub-contracted personnel.

3.3 TEST EQUIPMENT

DESCRIPTION AND MANUFACTURER	MODEL NO.	SERIAL NO.	LAST CALIBRATION DATE	CALIBRATION DUE DATE
Keysight MXE Signal Analyzer (26.5GHz)	N9038A	MY56400083	July 19, 2022	July 19, 2024
Keysight MXE Signal Analyzer (44GHz)	N9038A	MY59050109	July 19, 2022	July 19, 2024
SunAR RF Motion**	JB1	A082918-1	July 26, 2022	July 26, 2024
EMCO Horn Antenna	3115	6416	July 28, 2021	July 28, 2023
Rohde & Schwarz Preamplifier*	TS-PR18	3545700803	April 4, 2022	April 4, 2024
Trilithic High Pass Filter*	6HC330	23042	April 22, 2022	April 22, 2024
MiniCircuits High Pass Filter*	VHF-1320+	15542	April 4, 2022	April 4, 2024
ETS – Lindgren- VSWR on 10m Chamber	10m Semi-anechoic chamber-VSWR	4740 Discovery Drive	July 30, 2020	July 30, 2023
NCEE Labs-NSA on 10m Chamber	10m Semi-anechoic chamber-NSA	NCEE-001	May 24, 2022	May 24, 2025
TDK Emissions Lab Software	V11.25	700307	NA	NA
RF Cable (preamplifier to antenna)*	MFR-57500	01-07-002	April 4, 2022	April 4, 2024
RF Cable (antenna to 10m chamber bulkhead)*	FSCM 64639	01E3872	September 24, 2021	September 24, 2023
RF Cable (10m chamber bulkhead to control room bulkhead)*	FSCM 64639	01E3864	September 24, 2021	September 24, 2023
RF Cable (control room bulkhead to test receiver)*	FSCM 64639	01F1206	September 24, 2021	September 24, 2023
N connector bulkhead (10m chamber)**	PE9128	NCEEBH1	September 24, 2021	September 24, 2023
N connector bulkhead (control room)**	PE9128	NCEEBH2	September 24, 2021	September 24, 2023

*Internal Characterization

**2-year calibration cycle

Notes:
All equipment is owned by NCEE Labs and stored permanently at NCEE Labs facilities.

4.0 DETAILED RESULTS

4.1 DUTY CYCLE CORRECTION FACTOR

Duty cycle measurement:

The EUT was tested with production software in order to measure the duty cycle during normal operation. An ipod was connected to the EUT using BluefruitConnect app. The manufacturer has stated that the mode measured was the worse-case. The duty cycle measurement was performed per 1 MHz of spectrum. In this case it covered one channel since the channel spacing is greater than 1 MHz.

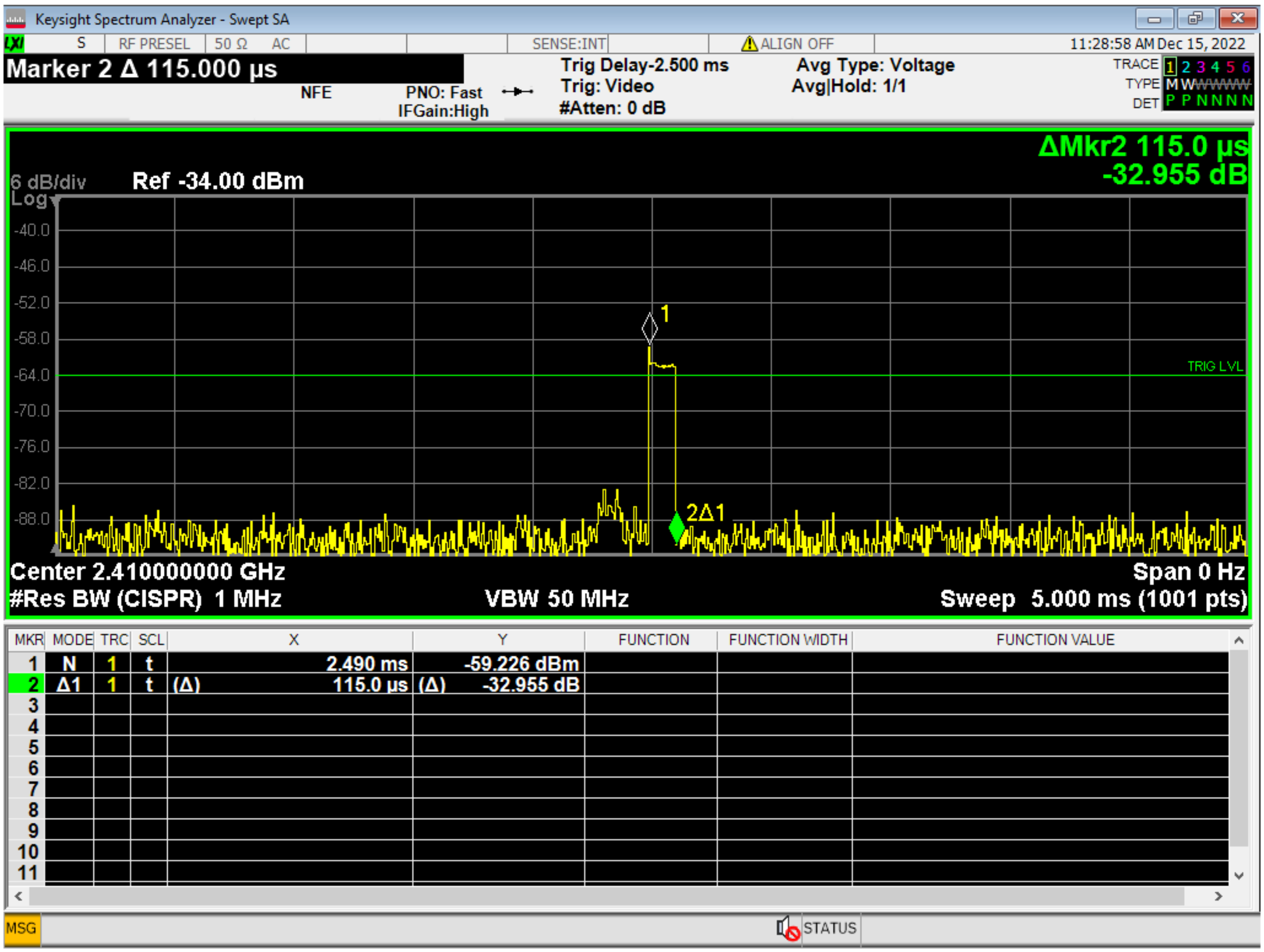

Figure 1 – Duty Cycle/On Time

Worst case On time =115 µs=0.115 ms

Worst case Period >100 ms

Duty cycle correction factor (DCCF) = 20log(0.115/100) = -58.786

Duty cycle correction factor is applied to the peak measurements to report the average value in Section 4.2

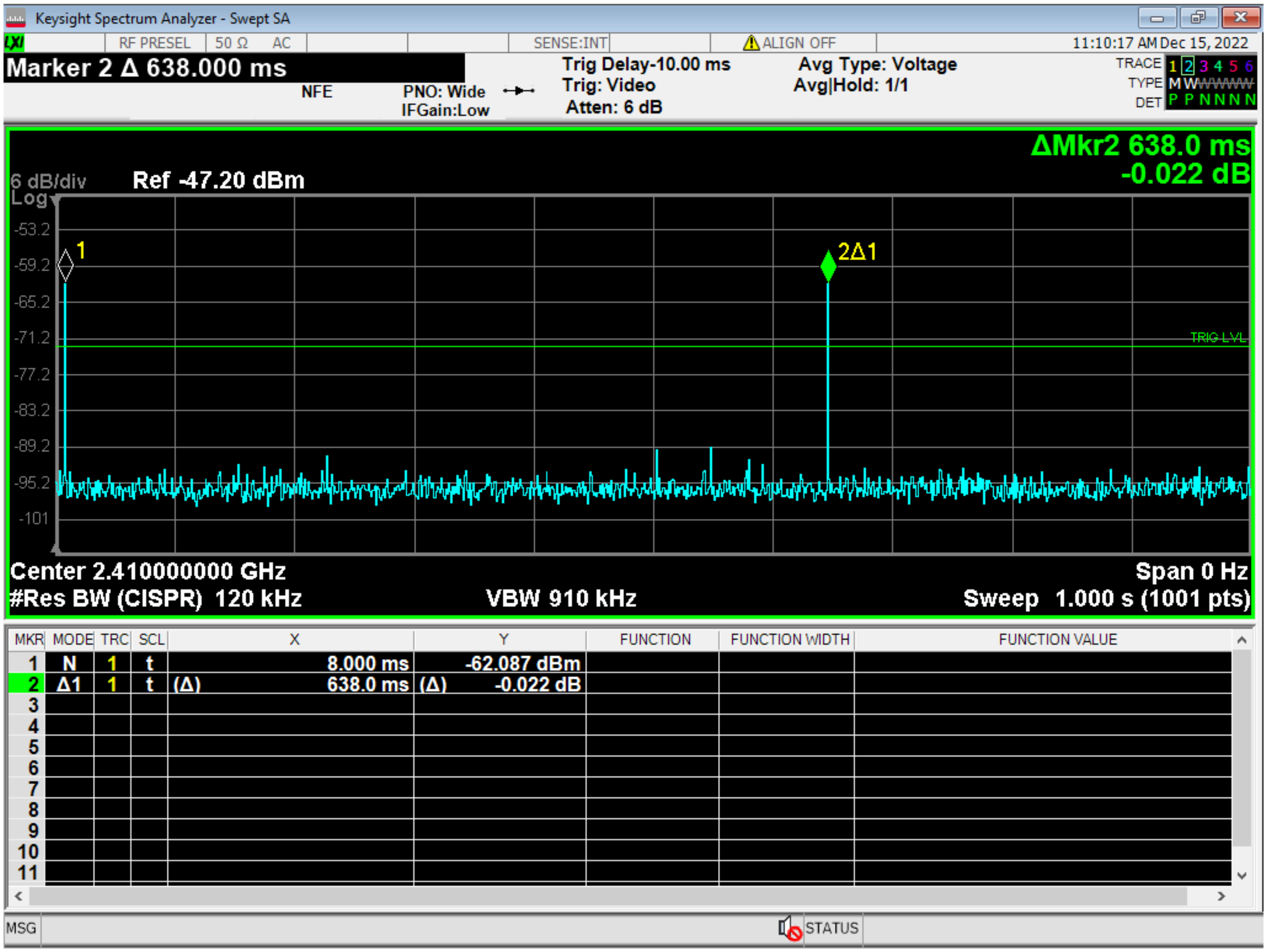

Figure 2 – Period

4.2 RADIATED EMISSIONS

Test Method: ANSI C63.10-2013, Section 6.5, 6.6

Limits for radiated emissions measurements:

Emissions radiated outside of the specified bands shall be applied to the limits in 15.209 as follows:

FREQUENCIES (MHz)	FIELD STRENGTH (µV/m)	MEASUREMENT DISTANCE (m)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	3
30-88	100	3
88-216	150	3
216-960	200	3
Above 960	500	3

NOTE:
1. The lower limit shall apply at the transition frequencies.
2. Emission level (dBuV/m) = 20 * log * Emission level (µV/m).
3. As shown in 15.35(b), for frequencies above 1000MHz, the field strength limits are based on average detector, however, the peak field strength of any emission shall not exceed the maximum permitted average limits by more than 20dB under any condition of modulation.
4. The EUT was tested for spurious emissions while running off of battery power.

Test procedures:

a. The EUT was placed on the top of a rotating table above the ground plane in a 10-meter semi-anechoic chamber. The table was rotated 360 degrees to determine the position of the highest radiation. The table was 0.8m high for measurements form 30MHz-1Ghz and 1.5m for measurements from 1GHz and higher.

b. The EUT was set 3 meters away from the interference-receiving antenna, which was mounted on the top of a variable-height antenna tower.

c. The antenna was a broadband antenna, and its height is varied from one meter to four meters above the ground to determine the maximum value of the field strength. Both horizontal and vertical polarizations of the antenna are used to make the measurement.

d. For each suspected emission, the EUT was arranged to maximize its emissions and then the antenna height was varied from 1 meter to 4 meters and the rotating table was turned from 0 degrees to 360 degrees to find the maximum emission reading.

e. The test-receiver system was set to use a peak detector with a specified resolution bandwidth. For spectrum analyzer measurements, the composite maximum of several analyzer sweeps was used for final measurements.

f. If the emission level of the EUT in peak mode was 10dB lower than the limit specified, then testing could be stopped and the peak values of the EUT would be reported. Otherwise, the emissions that did not have 10 dB margin would be re-tested one by one using peak, quasi-peak or average method as specified and then reported in a data sheet.

g. The EUT was maximized in all 3 orthogonal positions. The results are presented for the axis that had the highest emissions.

NOTE:
1. The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 120kHz for Peak detection (PK) and Quasi-peak detection (QP) at frequencies below 1GHz.

2. The resolution bandwidth 1 MHz for all measurements and at frequencies above 1GHz, A peak detector was used for all measurements above 1GHz. Measurements were made with an EMI Receiver.

Deviations from test standard:

No deviation.

Test setup:

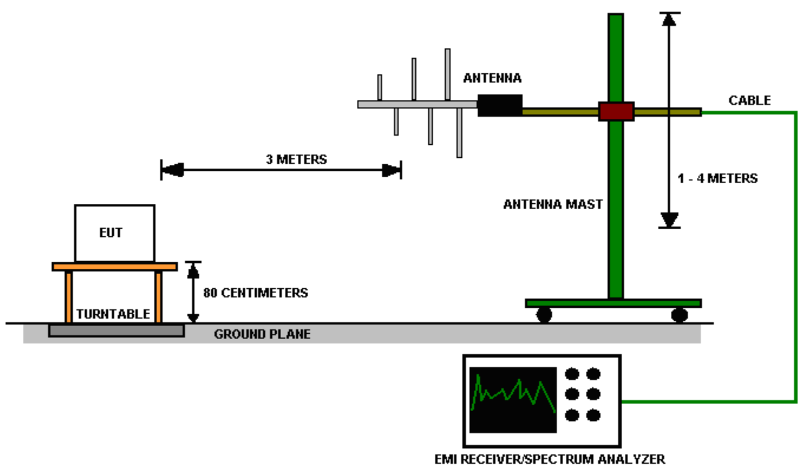

Figure 3 - Radiated Emissions Test Setup

EUT operating conditions
The EUT was powered by a 3.3V coin cell battery and set to transmit continuously on the lowest and highest frequency channels.

Test results:

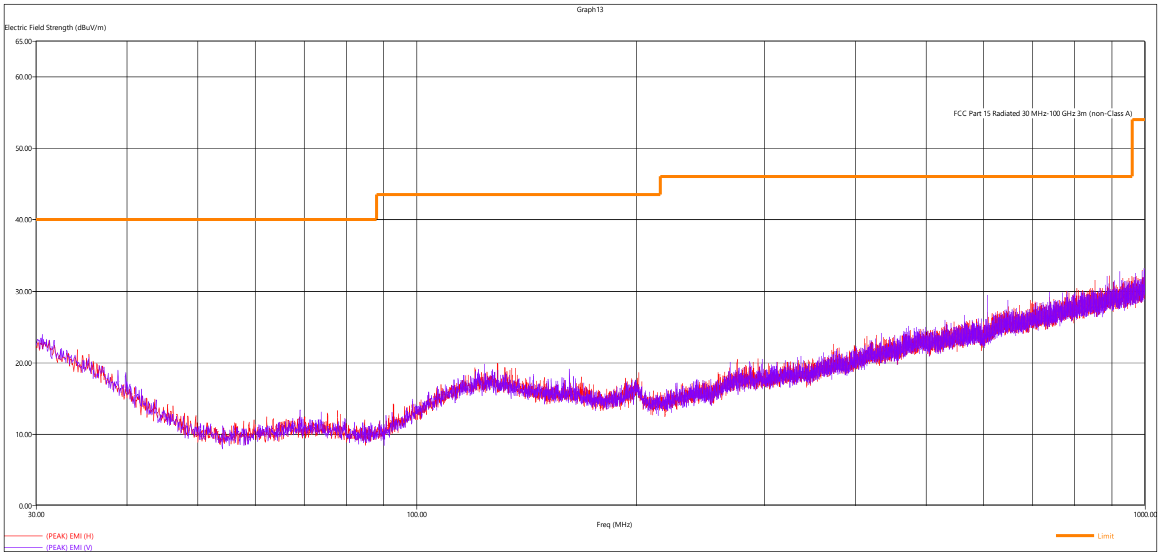

Figure 4 - Radiated Emissions Plot, Receive

REMARKS:
1. Emission level (dBuV/m) = Raw Value (dBuV) + Correction Factor (dB)
2. Correction Factor (dB/m) = Antenna Factor (dB/m) + Cable Factor (dB)
3. The other emission levels were very low against the limit.
4. Margin value = Emission level – Limit value

No measurements 30MHz – 18GHz were within 10dB of the limits, and no emissions are listed in tables.

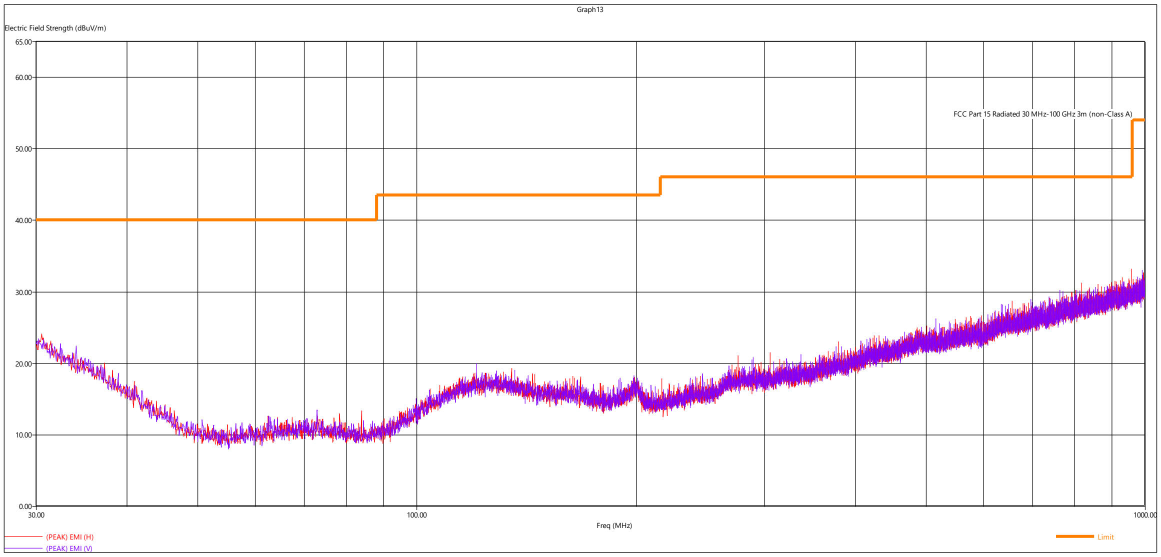

Figure 5 - Radiated Emissions Plot, Low Channel

REMARKS:
1. Emission level (dBuV/m) = Raw Value (dBuV) + Correction Factor (dB)
2. Correction Factor (dB/m) = Antenna Factor (dB/m) + Cable Factor (dB)
3. The other emission levels were very low against the limit.
4. Margin value = Emission level – Limit value

No measurements in the frequency range 30MHz – 1GHz were within 10dB of the limits, and no emissions in the 30MHz – 1GHz frequency range are listed in the tables.

Table 1 - Radiated Emissions Peak Measurements, Low Channel

Frequency	PK Level	PK Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2401.638000	89.42	113.98	24.56	399	175	H	X
4804.350000	58.16	73.98	15.82	394	182	V	X
7206.690000	59.83	73.98	14.15	532	178	H	X
9608.776000	62.54	73.98	11.44	133	179	H	X

The EUT was maximized in all 3 orthogonal axes. The worst-case is shown in the table above.

Table 2 - Radiated Emissions Average Measurements*, Low Channel

Frequency	AV Level	AV Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2401.638000	30.634	93.98	63.346	399	175	H	X
4804.350000	-0.626	53.98	54.606	394	182	V	X
7206.690000	1.04396	53.98	52.936	532	178	H	X
9608.776000	3.75396	53.98	50.226	133	179	H	X

The EUT was maximized in all 3 orthogonal axes. The worst-case is shown in the table above.

*The radiated emission average measurement Field Strength (FS) is the peak radiated emission measurement + the Duty Cycle Correction Factor from section 4.1. FS(corrected) = FS(Peak) + DCCF.

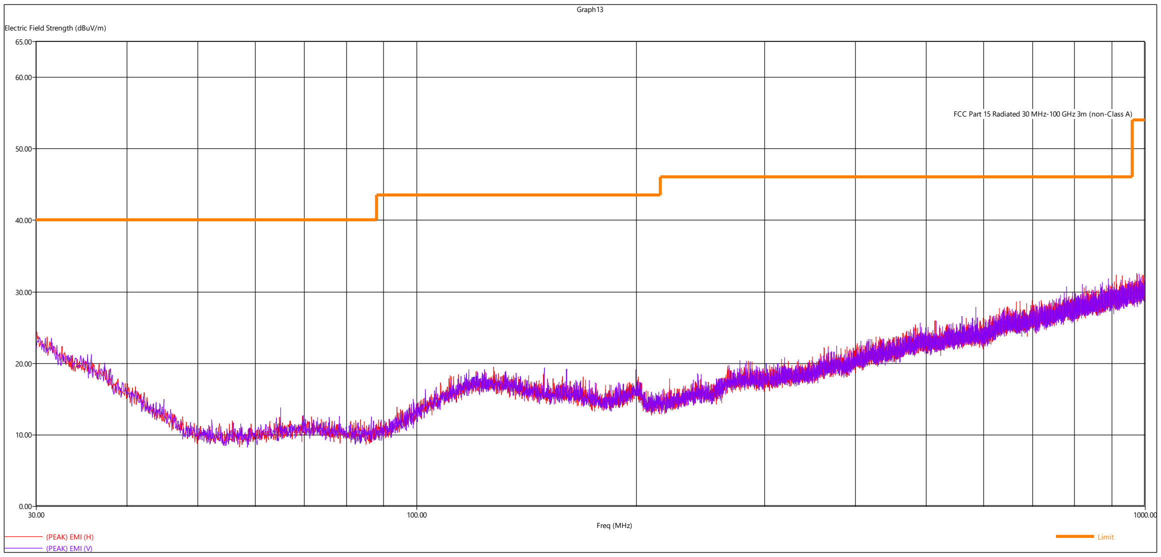

Figure 6 - Radiated Emissions Plot, Mid Channel

REMARKS:
1. Emission level (dBuV/m) = Raw Value (dBuV) + Correction Factor (dB)
2. Correction Factor (dB/m) = Antenna Factor (dB/m) + Cable Factor (dB)
3. The other emission levels were very low against the limit.
4. Margin value = Emission level – Limit value

No measurements in the frequency range 30MHz – 1GHz were within 10dB of the limits, and no emissions in the 30MHz – 1GHz frequency range are listed in the tables.

Table 3 - Radiated Emissions Peak Measurements, Mid Channel

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2439.698000	91.35	113.98	22.63	387.00	182.00	H	X
4880.344000	57.19	73.98	16.79	434.00	180.00	V	X
7318.810000	53.54	73.98	20.44	560.00	182.00	H	X
9760.702000	59.95	73.98	14.03	483.00	212.00	H	X

The EUT was maximized in all 3 orthogonal axes. The worst-case is shown in the table above.

Table 4 - Radiated Emissions Average Measurements*, Mid Channel

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	dBµV/m	dBµV/m	dB	cm.	deg.		
2439.698000	32.564	93.98	61.416	387	182	H	X
4880.344000	-1.596	53.98	55.576	434	180	V	X
7318.810000	-5.246	53.98	59.226	560	182	H	X
9760.702000	1.16396	53.98	52.816	483	212	H	X

The EUT was maximized in all 3 orthogonal axes. The worst-case is shown in the table above.

*The radiated emission average measurement Field Strength (FS) is the peak radiated emission measurement + the Duty Cycle Correction Factor from section 4.1. FS(corrected) = FS(Peak) + DCCF.

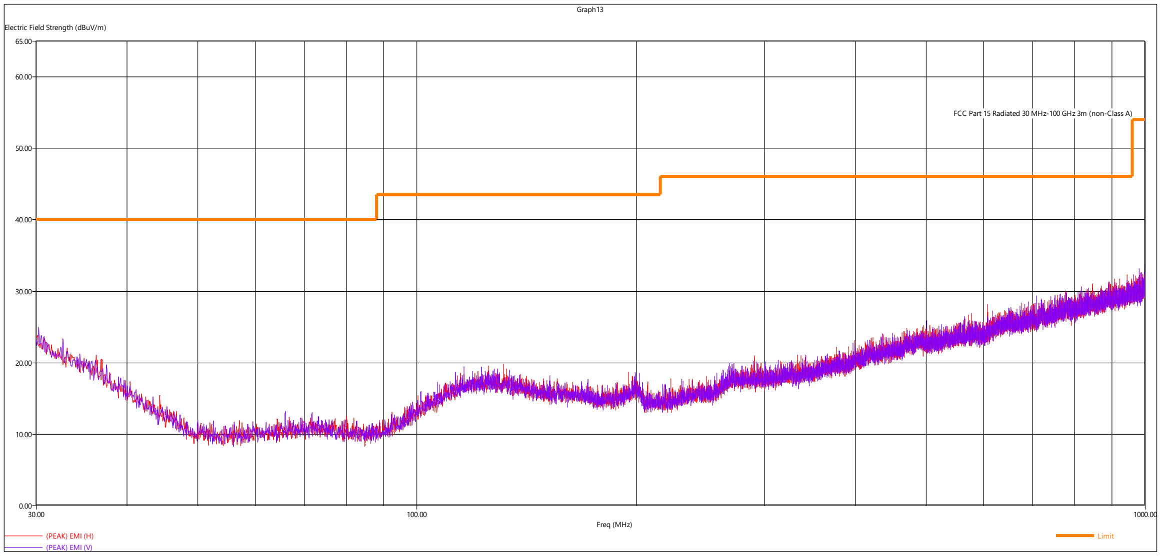

Figure 7 - Radiated Emissions Plot, High Channel

REMARKS:
1. Emission level (dBuV/m) = Raw Value (dBuV) + Correction Factor (dB)
2. Correction Factor (dB/m) = Antenna Factor (dB/m) + Cable Factor (dB)
3. The other emission levels were very low against the limit.
4. Margin value = Emission level – Limit value.

No measurements in the frequency range 30MHz – 1GHz were within 10dB of the limits, and no emissions in the 30MHz – 1GHz frequency range are listed in the tables.

Table 5 - Radiated Emissions Peak Measurements, High Channel

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	**dBµV/m**	**dBµV/m**	**dB**	**cm.**	**deg.**		
2479.728000	91.54	113.98	22.44	485	167	H	X
9919.432000	55.96	73.98	18.02	496	259	H	X
4960.344000	64.04	73.98	9.94	448	180	V	X

The EUT was maximized in all 3 orthogonal axes. The worst-case is shown in the table above.

Table 6 - Radiated Emissions Average Measurements*, High Channel

Frequency	Level	Limit	Margin	Height	Angle	Pol	Axis
MHz	**dBµV/m**	**dBµV/m**	**dB**	**cm.**	**deg.**		
2479.728000	32.754	93.98	61.226	485	167	H	X
9919.432000	-2.826	53.98	56.806	496	259	H	X
4960.344000	5.25396	53.98	48.726	448	180	V	X

The EUT was maximized in all 3 orthogonal axes. The worst-case is shown in the table above.

**The radiated emission average measurement Field Strength (FS) is the peak radiated emission measurement + the Duty Cycle Correction Factor from section 4.1. FS(corrected) = FS(Peak) + DCCF.

Restricted band edge plots:

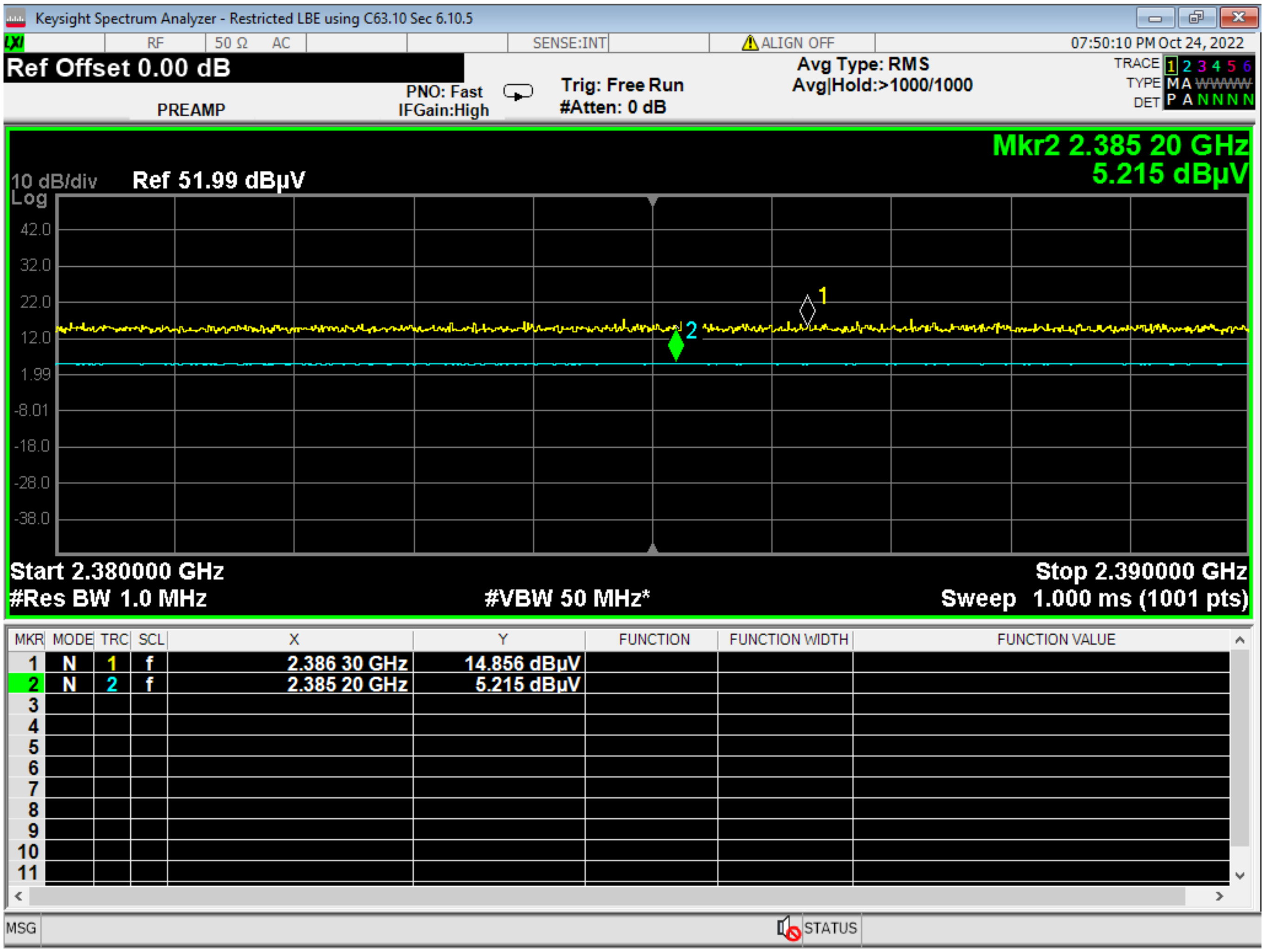

Figure 8 – Restricted Lower Band Edge, Uncorrected

The corrected lower band edge uses the following equation:

FS(corrected) = FS(uncorrected) + CL + AF.

FS(peak) = 14.86dBuV/m + 8.56dB + 27.53dB = 50.95dBuV/m. AV Limit = 53.98dBuV/m. Margin = 3.03dB

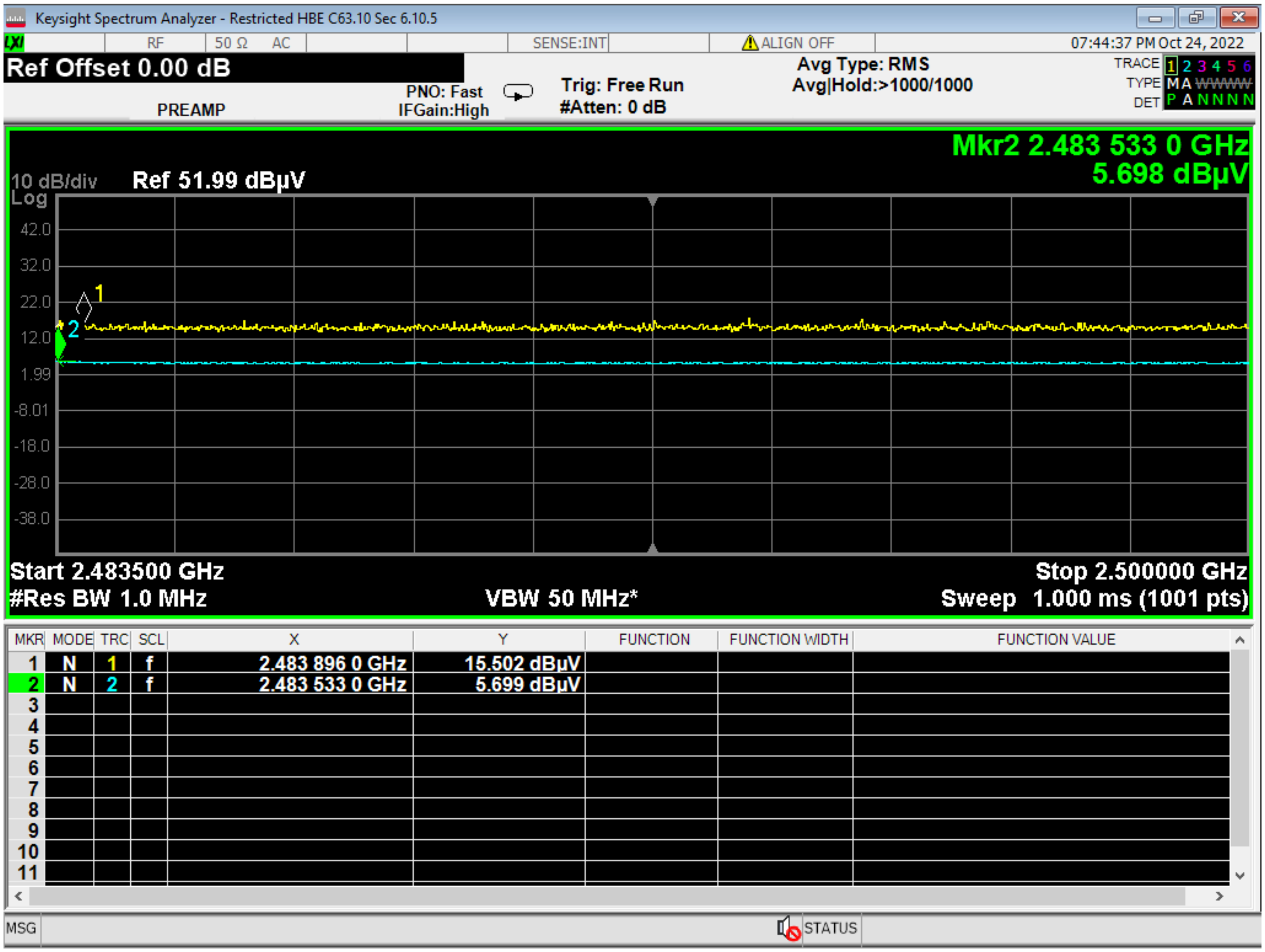

Figure 9 – Restricted Upper Band Edge, Uncorrected

The corrected upper band edge Field Strength (FS) uses the following equation, with Cable Loss (CL) and Antenna Factor (AF):

FS(corrected) = FS(uncorrected) + CL + AF.

FS(peak) = 15.50dBuV/m + 8.85dB + 27.66dB = 52.01dBuV/m. AV Limit = 53.98dBuV/m. Margin = 1.97dB

APPENDIX A: SAMPLE CALCULATION

Radiated Emissions

The field strength is calculated in decibels (dB) by adding the Antenna Factor and Cable Factor, and subtracting the Amplifier Gain (if any) from the measured reading. The basic equation with a sample calculation is as follows:

$$FS = R + AF - (-CF + AG)$$

where FS = Field Strength

R = Receiver Amplitude Receiver reading in dBµV

AF = Antenna Factor

CF = Cable Attenuation Factor

AG = Preamplifier Amplifier Gain

Assume a receiver reading of 55.00 dBµV is obtained. The Antenna Factor of 12.00 and a Cable Factor of 1.10 is added. The Amplifier Gain of 20 dB is subtracted, giving a field strength of 48.10 dBµV/m.

FS = 55.00 + 12.00 – (-1.10 + 20.00) = 48.1 dBµV/m

The 48.1 dBµV/m value can be mathematically converted to its corresponding level in µV/m.

Level in µV/m = Common Antilogarithm [(48.1 dBµV/m)/20]= 254.1 µV/m

Conducted Emissions

Receiver readings are compared directly to the conducted emissions limits in decibels (dB) by adding the cable loss and LISN insertion loss to the receiver reading. The basic equations with a sample calculation is as follows;

$$FS = R + IL - (-CF)$$

where V = Conducted Emissions Voltage Measurement

R = Receiver reading in dBµV

IL = LISN Insertion Loss

CF = Cable Attenuation Factor

APPENDIX B – MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels apply to tests performed in this test report:

Test	**Frequency Range**	**NCEE Labs Uncertainty Value (dB)**	**Maximum Uncertainty Values per** **CISPR 16-4-2:2011/A1:2018**
Radiated Emissions, 3m	30MHz - 1GHz	4.19	5.34
Radiated Emissions, 3m	1GHz – 18GHz	5.08	5.48

Expanded uncertainty values are calculated to a confidence level of 95%.

NCEE Labs meets the maximum uncertainty requirements per CISPR 16-4-2:2011/A1:2018, and therefore does not require a minimum passing margin to state that an EUT is less than the field strength limits of the applicable CISPR, IEC or EN limit per CISPR 16-4-2:2011/A1:2018, Section 4.1.

NCEE Labs employs tilting when testing at 3m test distance. The maximum uncertainty associated with this method is used.

Maximum uncertainty values show the worse-case of all test distances used.

REPORT END