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FCC/ISED Test Report

Prepared for: **TORO Company**

Address: **8111 Lyndale Ave S,**
Bloomington Minnesota, USA

Product: **Nova Gen. 2**

Test Report No: **R20241011-73-E5** **Rev: A**

Approved by:

Fox Lane

Fox Lane,
EMC Test Engineer

DATE: **February 5, 2025**

Total Pages: **31**

ilac-MRA A2LA ACCREDITED
TESTING LABORATORY
CERTIFICATE NO. 1953.01

REVISION PAGE

Rev. No.	Date	Description
0	2 January 2025	Issued by FLane Prepared by Flane / ESchmidt
A	5 February 2025	Updated Company Name– FL

CONTENTS

1.0 SUMMARY OF TEST RESULTS

The worst-case measurements were reported in this report. Summary of test results presented in this report correspond to the following section:

The EUT has been tested according to the following specifications:

(1) US Code of Federal Regulations, Title 47, Part 15
(2) ISED RSS-Gen, Issue 5
(3) ISED RSS-247, Issue 3

APPLIED STANDARDS AND REGULATIONS		
Standard Section	**Test Type**	**Result**
FCC Part 15.35 RSS Gen, Issue 5, Section 6.10	Duty Cycle	Pass
FCC Part 15.209 RSS-Gen Issue 5, Section 7.3	Receiver Radiated Emissions	Pass
FCC Part 15.209 (restricted bands), 15.247 (unrestricted) RSS-247 Issue 3 Section 5.5, RSS-Gen Issue 5, Section 8.9	Transmitter Radiated Emissions	Pass
FCC Part 15.209, 15.247(d) RSS-247 Issue 3 Section 5.5	Band Edge Measurement	Pass

2.0 EUT DESCRIPTION

2.1 EQUIPMENT UNDER TEST

Summary and Operating Condition:

EUT	Nova Gen. 2
IC	3575A-NVG2
FCC ID	OF7-NVG2
EUT Received	2 December 2024
EUT Tested	2 December 2024- 26 December 2024
Serial No.	324000100
Operating Band	2400 – 5850 MHz
Device Type	☒ GMSK ☐ GFSK ☒ BT LE ☒ BT EDR 2MB ☒ BT EDR 3MB ☒ 802.11x
Power Supply / Voltage	Powered by 12VDC Marine Battery

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

2.2 DESCRIPTION OF TEST MODES

The operating range of the EUT is dependent on the device type found in section 2.1:

Channel	Frequency
Low	2412 MHz
Mid	2437 MHz
High	2462 MHz

These are the only representative channels tested in the frequency range according to FCC Part 15.31 and RSS-Gen Table A1. See the operational description for a list of all channel frequencies and designations.

2.3 DESCRIPTION OF SUPPORT UNITS

None

3.0 LABORATORY AND GENERAL TEST 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
NCC CAB Identification No:	US0177

Environmental conditions varied slightly throughout the tests:

Relative humidity of 35 ± 4%
Temperature of 22 ± 3° Celsius

3.2 TEST PERSONNEL

No.	PERSONNEL	TITLE	ROLE
1	Fox Lane	Test Engineer	Testing and Report
2	Ethan Schmidt	Test Engineer	Testing and Report

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 (44GHz)	N9038A	MY59050109	July 17, 2024	July 18, 2026
Keysight MXE Signal Analyzer (26.5GHz)	N9038A	MY56400083	July 17, 2024	July 18, 2026
SunAR RF Motion	JB1	A082918-1	July 17, 2024	July 17, 2025
EMCO Horn Antenna	3117	29616	June 12, 2024	June 12, 2025
Agilent Preamp*	87405A	3207A01475	May 2, 2024	May 2, 2026
ETS Red Preamplifier (Orange)*	3115-PA	00218576	January 22, 2024	January 22, 2026
Trilithic High Pass Filter*	6HC330	23042	June 5, 2023	June 5, 2025
ETS – Lindgren- VSWR on 10m Chamber	10m Semi-anechoic chamber-VSWR	4740 Discovery Drive	May 15, 2024	May 15, 2027
NCEE Labs-NSA on 10m Chamber*	10m Semi-anechoic chamber-NSA	NCEE-001	May 22, 2024	May 22, 2026
RF Cables (3m Ant. to Control room Bulkhead)	MFR-57500	1E3874	June 5, 2023	June 5, 2025
RF Cable (antenna to 10m chamber bulkhead)*	FSCM 64639	01E3872	June 5, 2023	June 5, 2025
RF Cable (10m chamber bulkhead to control room bulkhead)*	FSCM 64639	01E3874	June 5, 2023	June 5, 2025
RF Cable (control room bulkhead to test receiver)*	FSCM 64639	01F1206	June 5, 2023	June 5, 2025
N connector bulkhead (10m chamber)*	PE9128	NCEEBH1	June 5, 2023	June 5, 2025
N connector bulkhead (control room)*	PE9128	NCEEBH2	June 5, 2023	June 5, 2025
TDK Emissions Lab Software	V11.25	700307	NA	NA

*Internal Characterization

Notes:

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

3.4 GENERAL TEST PROCEDURE AND SETUP FOR RADIO MEASUREMNTS

Measurement type presented in this report (Please see the checked box below):

Conducted ☐

The conducted measurements were performed by connecting the output of the transmitter directly into a spectrum analyzer using an impedance matched cable and connector soldered to the EUT in place of the antenna. The information regarding resolution bandwidth, video bandwidth, span and the detector used can be found in the graphs provided in Appendix C. All the radio measurements were performed using the sections from ANSI C63.10, details about the section used can be found in the spectrum analyzer titles on the graph.

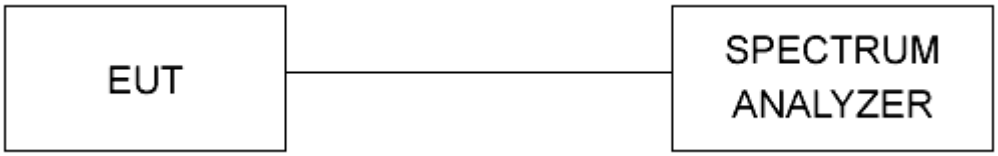


Figure 1 - Bandwidth Measurements Test Setup

Radiated ☒

All the radiated measurements were taken at a distance of 3m from the EUT. The information regarding resolution bandwidth, video bandwidth, span and the detector used can be found in the graphs provided in Appendix C. All the radio measurements were performed using the sections from ANSI C63.10, details about the section used can be found in the spectrum analyzer titles on the graph.

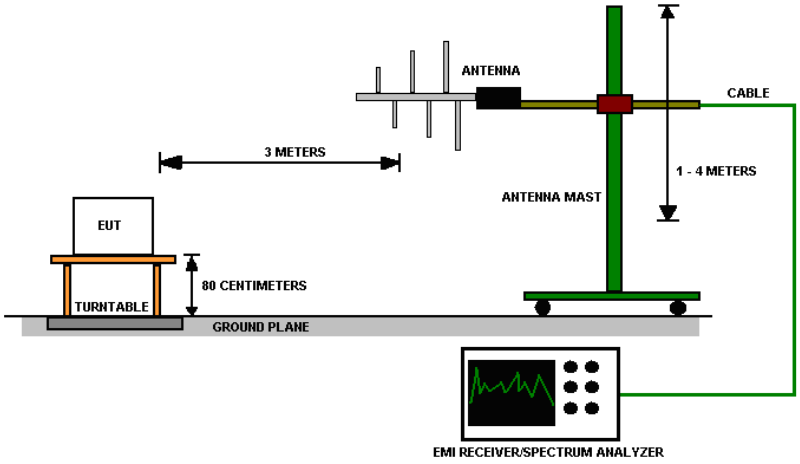


Figure 2 - Radiated Emissions Test Setup

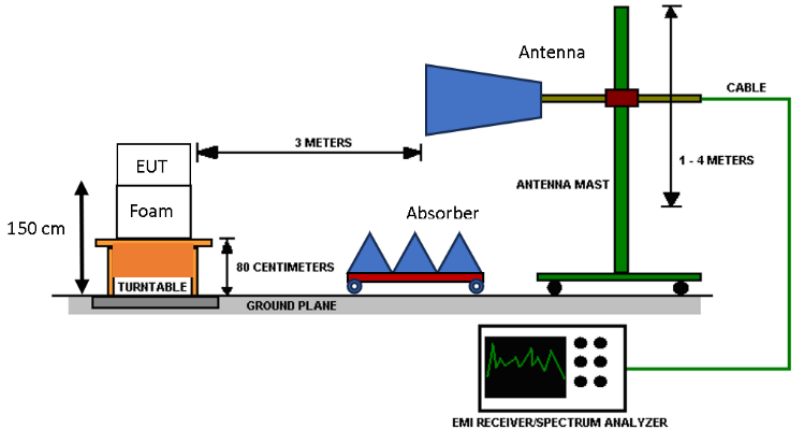


Figure 3 - Radiated Emissions Test Setup, >1GHz

4.0 RESULTS

Radiated Peak Restricted Band-Edge, Low Data Rate							
Channel	**Mode**	**Band edge /Measurement Frequency (MHz)**	**Highest out of band level (dBuV/m @ 3m)**	**Measurement Type**	**Limit (dBuV/m @ 3m)**	**Margin (dB)**	**Result**
Low	802.11b	2390	55.3	Peak	73.98	18.68	PASS
Low	802.11g	2390	67.891	Peak	73.98	6.089	PASS
Low	802.11n	2390	66.411	Peak	73.98	7.569	PASS
High	802.11b	2483.5	57.49	Peak	73.98	16.49	PASS
High	802.11g	2483.5	69.303	Peak	73.98	4.677	PASS
High	802.11n	2483.5	68.83	Peak	73.98	5.15	PASS
*Limit shown is the peak limit taken from FCC Part 15.209							

Radiated Average Restricted Band-Edge, Low Data Rate									
Ch	**Mode**	**Band edge /Measurement Frequency (MHz)**	**Raw Avg out of band level (dBuV/m @ 3m)**	**DCCF**	**Corrected Highest out of band level (dBuV/m @ 3m)**	**Detector**	**Limit (dBuV/m @ 3m)**	**Margin (dB)**	**Result**
Low	802.11b	2390	43.583	0.051	43.634	Average	53.98	10.346	PASS
Low	802.11g	2390	49.432	0.322	49.754	Average	53.98	4.226	PASS
Low	802.11n	2390	48.124	0.342	48.466	Average	53.98	5.514	PASS
High	802.11b	2483.5	48.226	0.051	48.277	Average	53.98	5.703	PASS
High	802.11g	2483.5	49.769	2.367	52.136	Average	53.98	1.844	PASS
High	802.11n	2483.5	51.967	0.342	52.309	Average	53.98	1.671	PASS
Limit shown is the average limit taken from FCC Part 15.209 Highest out of band level = Raw peak out of band level - DCCF (as per C63.10 Sec. 11.12.2.5.2) *See section 4.3									

Radiated Peak Restricted Band-Edge, Low Data Rate							
CHANNEL	**Mode**	**Band edge /Measurement Frequency (MHz)**	**Highest out of band level (dBuV/m @ 3m)**	**Measurement Type**	**Limit (dBuV/m @ 3m)**	**Margin (dB)**	**Result**
Low	802.11b	2390	55.39	Peak	73.98	18.59	PASS
Low	802.11g	2390	68.529	Peak	73.98	5.451	PASS
Low	802.11n	2390	69.622	Peak	73.98	4.358	PASS
High	802.11b	2483.5	58.09	Peak	73.98	15.89	PASS
High	802.11g	2483.5	69.42	Peak	73.98	4.56	PASS
High	802.11n	2483.5	71.231	Peak	73.98	2.749	PASS
*Limit shown is the peak limit taken from FCC Part 15.209							

Radiated Average Restricted Band-Edge, Low Data Rate									
CH	**Mode**	**Band edge /Measurement Frequency (MHz)**	**Raw Avg out of band level (dBuV/m @ 3m)**	**DCCF**	**Corrected Highest out of band level (dBuV/m @ 3m)**	**Detector**	**Limit (dBuV/m @ 3m)**	**Margin (dB)**	**Result**
Low	802.11b	2390	43.481	0.544	44.025	Average	53.98	9.955	PASS
Low	802.11g	2390	49.742	0.322	50.064	Average	53.98	3.916	PASS
Low	802.11n	2390	48.361	2.524	50.885	Average	53.98	3.095	PASS
High	802.11b	2483.5	47.205	0.544	47.749	Average	53.98	6.231	PASS
High	802.11g	2483.5	49.235	2.367	51.602	Average	53.98	2.378	PASS
High	802.11n	2483.5	50.791	2.524	53.315	Average	53.98	0.665	PASS
Limit shown is the average limit taken from FCC Part 15.209 Highest out of band level = Raw peak out of band level - DCCF (as per C63.10 Sec. 11.12.2.5.2) *See section 4.3									

4.1 DUTY CYCLE

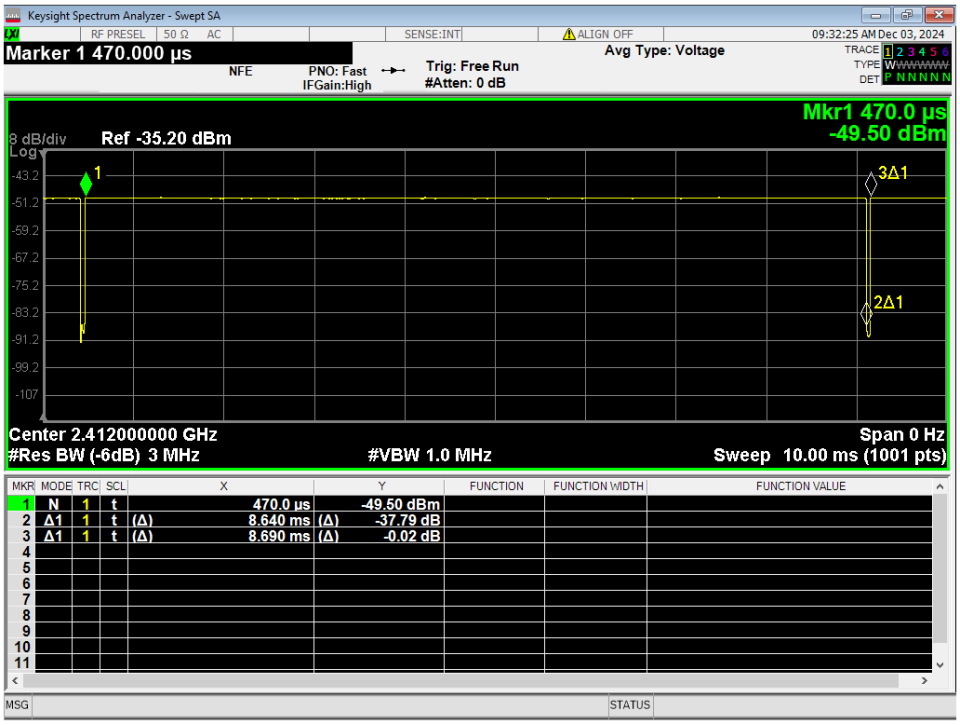


Figure 4 – Duty Cycle, 802.11b 1MB

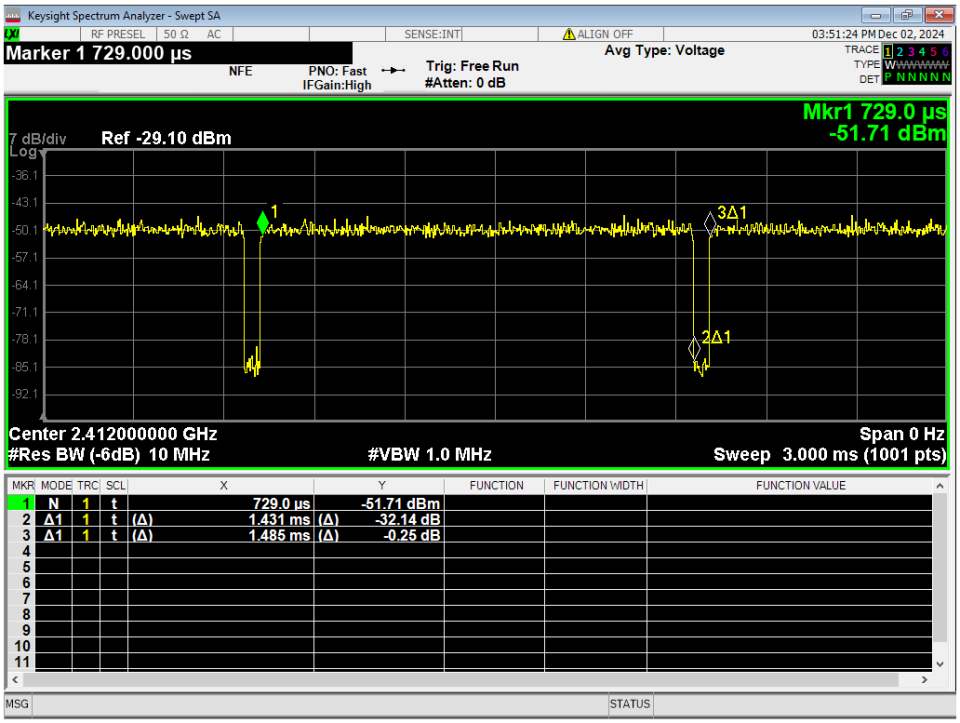


Figure 5 – Duty Cycle, 802.11g 6MB

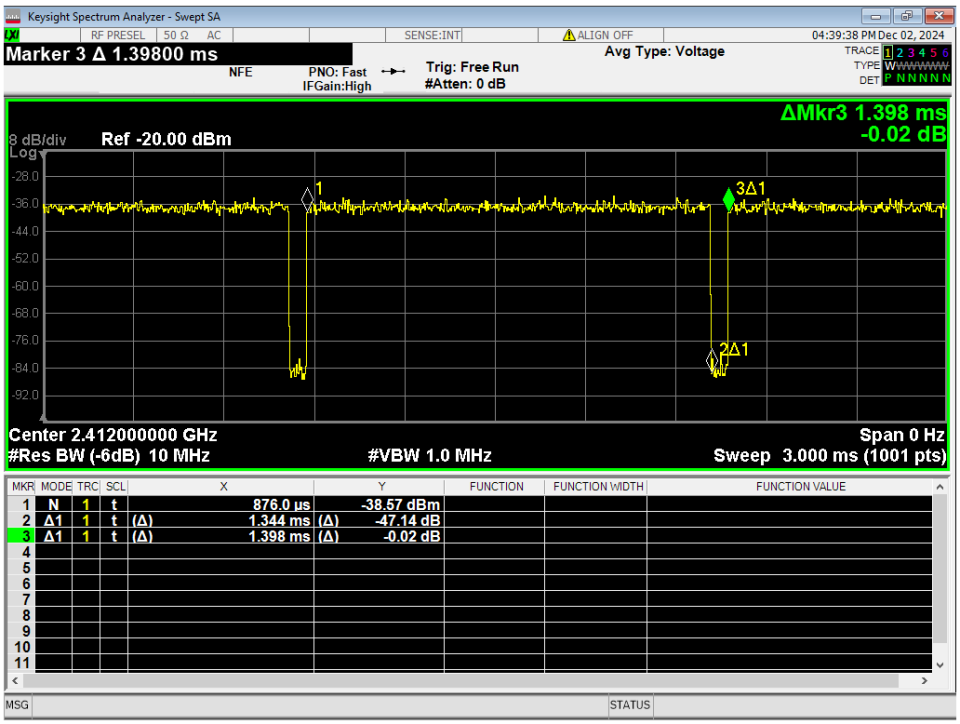


Figure 6 – Duty Cycle, 802.11n MCS0

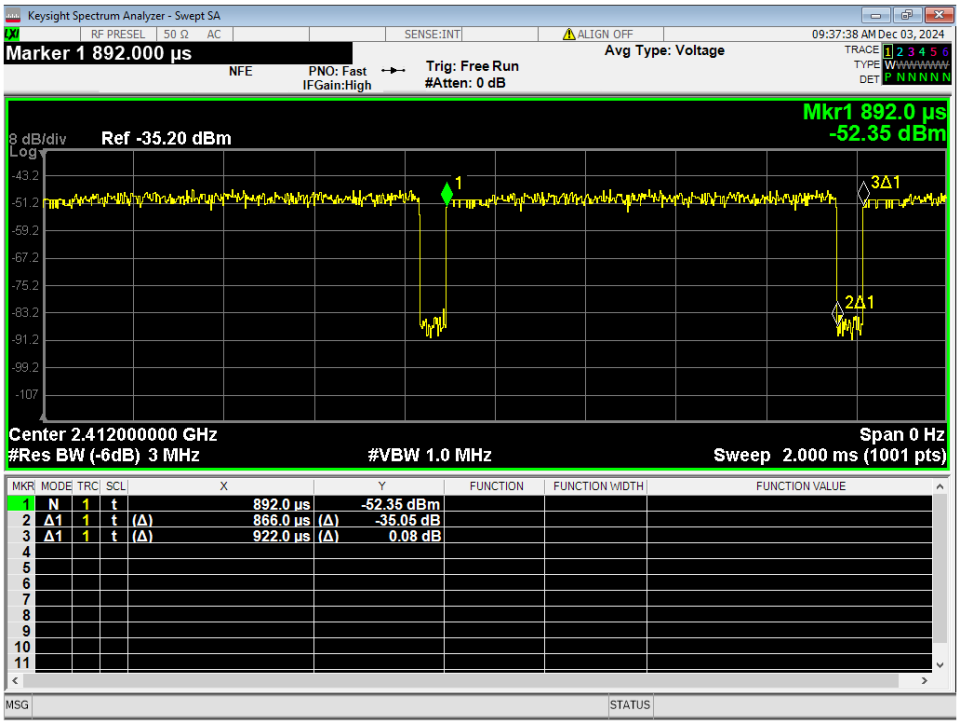


Figure 7 – Duty Cycle, 802.11b 11MB

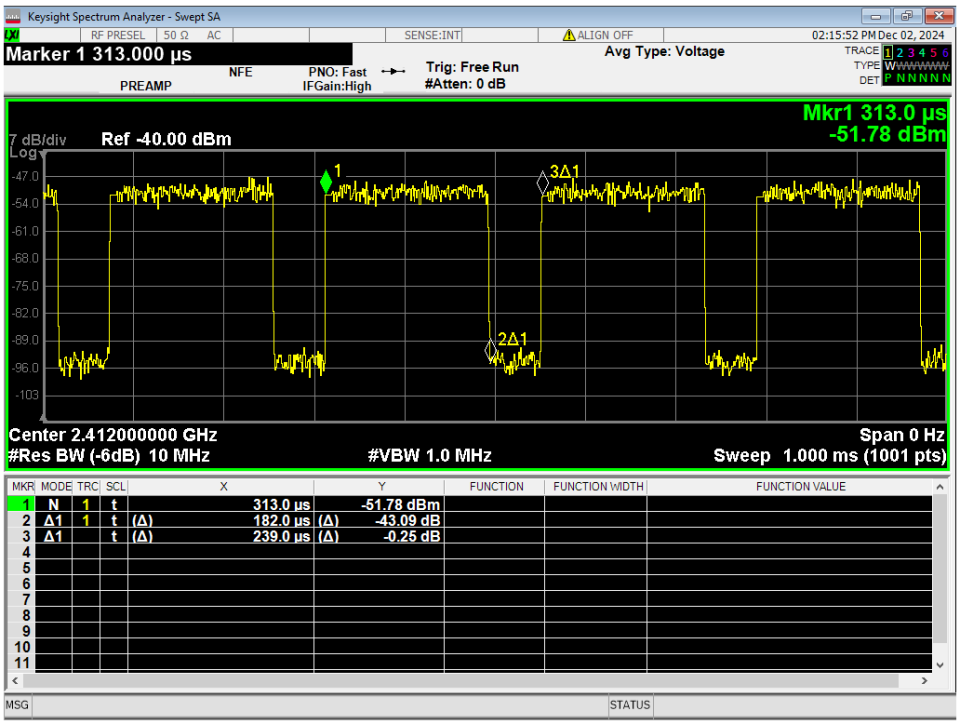


Figure 8 – Duty Cycle, 802.11g 54MB

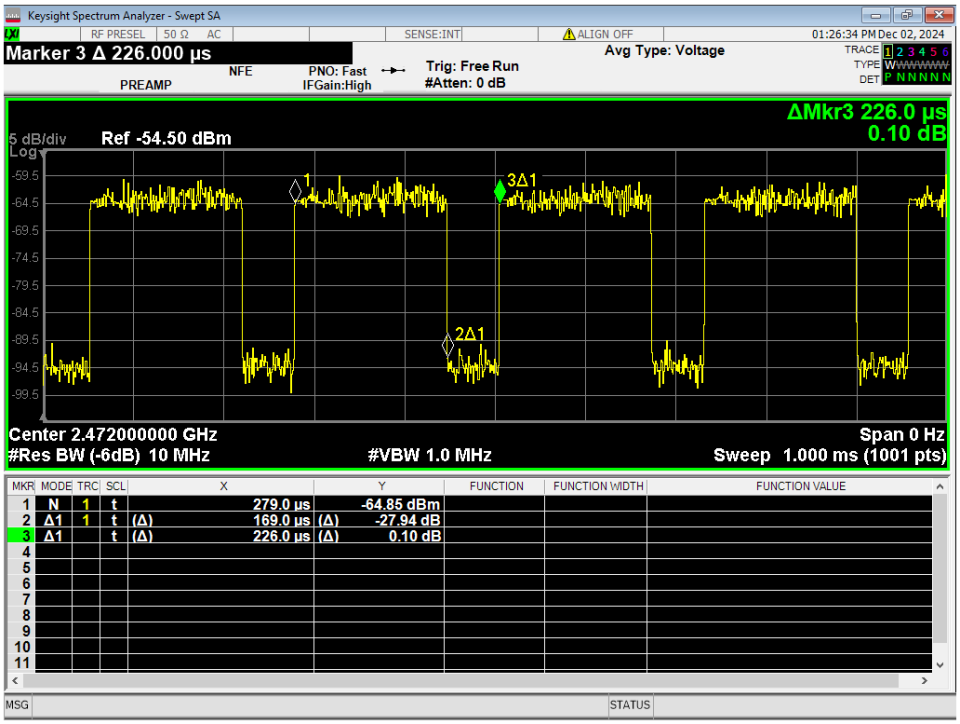


Figure 9 – Duty Cycle, 802.11n MCS7

The following duty cycle and duty cycle correction factors (DCCF) were used where applicable.

Duty Cycle correction factor (for emissions) = 20 * log(1 / Duty cycle)
Duty Cycle correction factor (for power) = 10*log(1 / Duty Cycle)

Duty Cycle for 802.11b 1MB: **0.994**
Duty Cycle correction factor (for emissions) for 802.11b 1MB: **0.051dB**
Duty Cycle correction factor (for power) for 802.11b 1MB: **0.025dB**

Duty Cycle for 802.11g 6MB: **0.964**
Duty Cycle correction factor (for emissions) for 802.11g 6MB: **0.322dB**
Duty Cycle correction factor (for power) for 802.11g 6MB: **0.161dB**

Duty Cycle for 802.11n MCS0: **0.961**
Duty Cycle correction factor (for emissions) for 802.11n MCS0: **0.342dB**
Duty Cycle correction factor (for power) for 802.11n MCS0: **0.171dB**

Duty Cycle for 802.11b 11MB: **0.939**
Duty Cycle correction factor (for emissions) for 802.11b 11MB: **0.544dB**
Duty Cycle correction factor (for power) for 802.11b 11MB: **0.272dB**

Duty Cycle for 802.11g 54MB: **0.762**
Duty Cycle correction factor (for emissions) for 802.11g 54MB: **2.367dB**
Duty Cycle correction factor (for power) for 802.11g 54MB: **1.183dB**

Duty Cycle for 802.11n MCS7: **0.748**
Duty Cycle correction factor (for emissions) for 802.11n MCS7: **2.524dB**
Duty Cycle correction factor (for power) for 802.11n MCS7: **1.262dB**

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 followed:

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 and external USB power. The worse-case emissions were produced while running off of USB power, so results from this mode are presented.

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 from 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.

EUT operating conditions
Details can be found in section 2.1 of this report.

Test results:

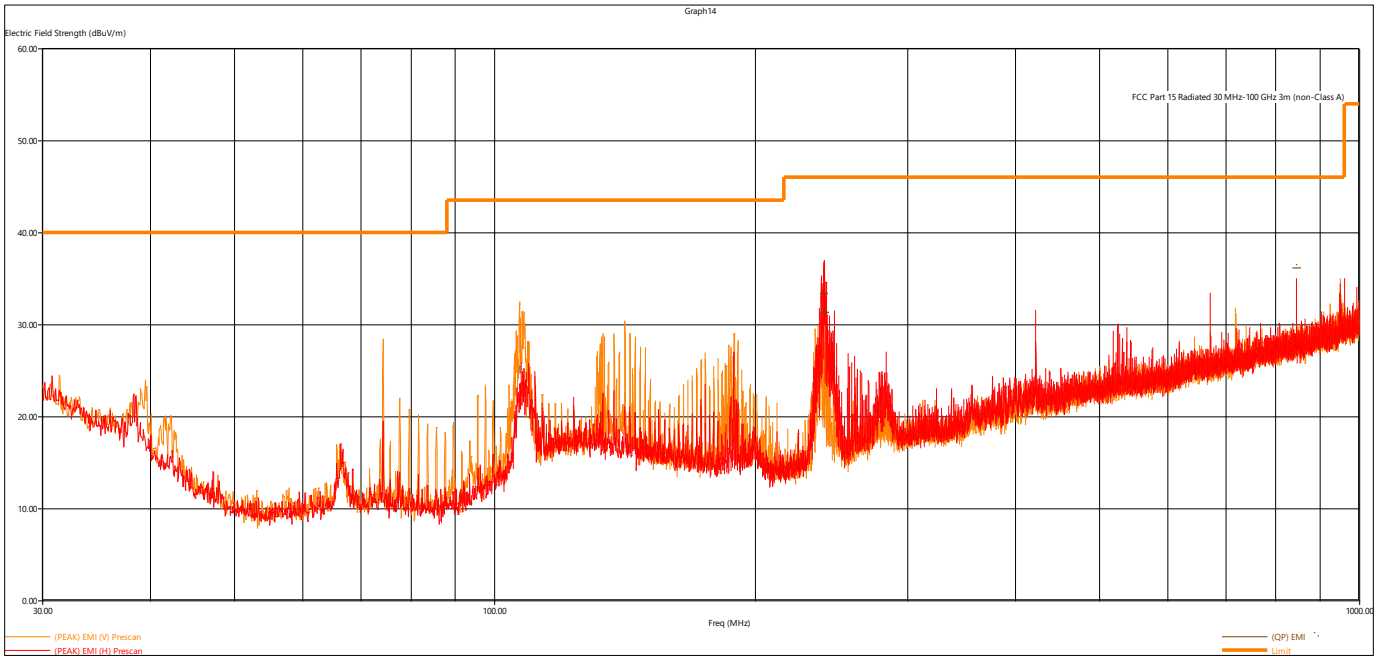


Figure 10 - Radiated Emissions Plot, Receive

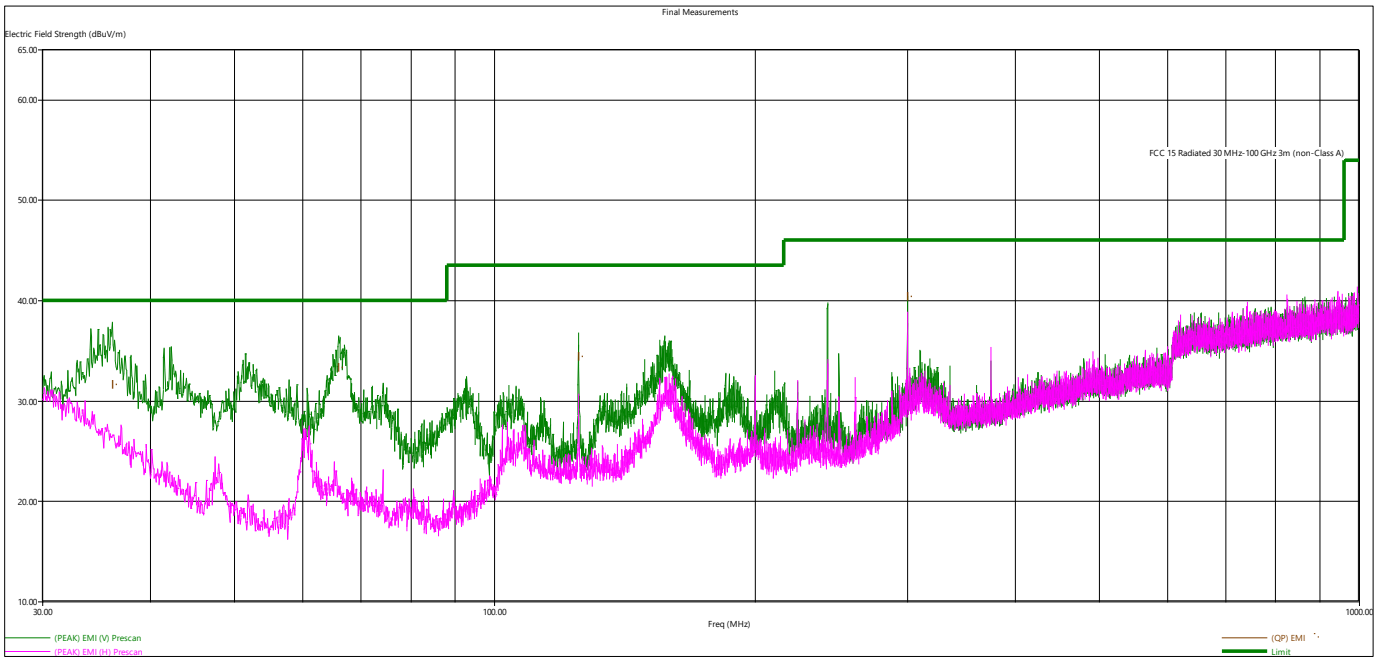


Figure 11 - Radiated Emissions Plot, 802.11b 1MB

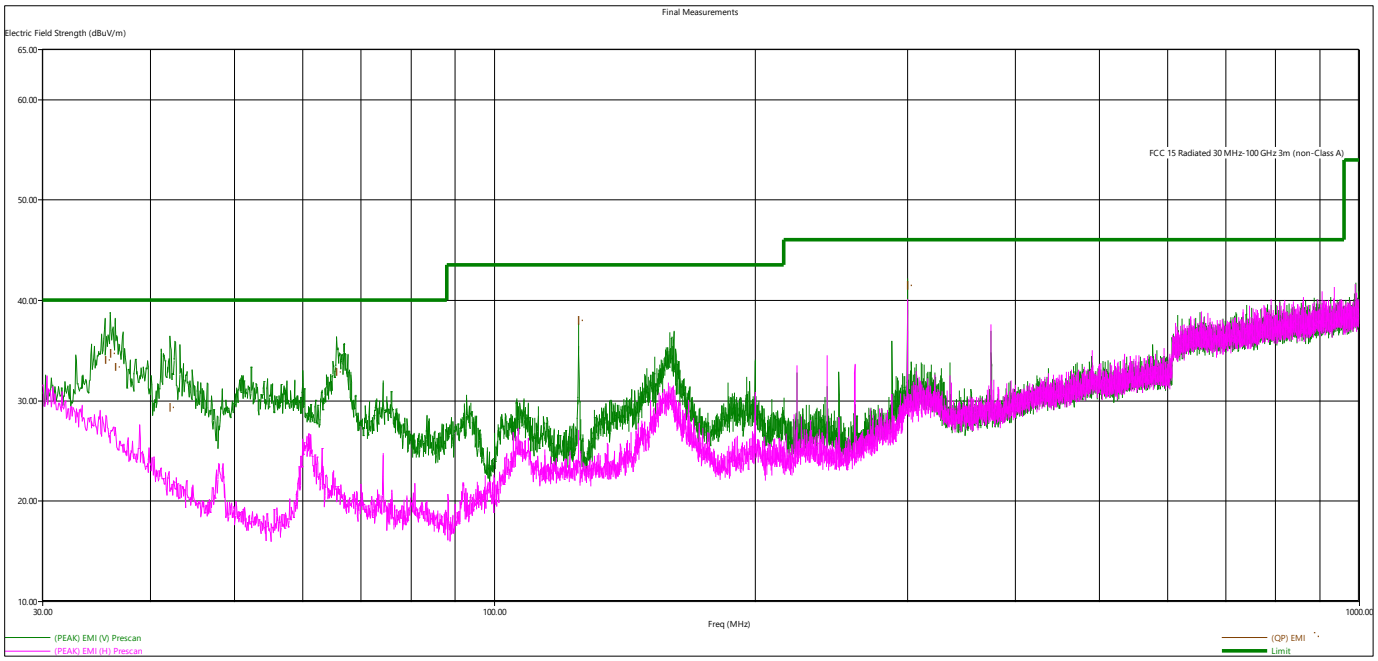


Figure 12 - Radiated Emissions Plot, 802.11n MCS0

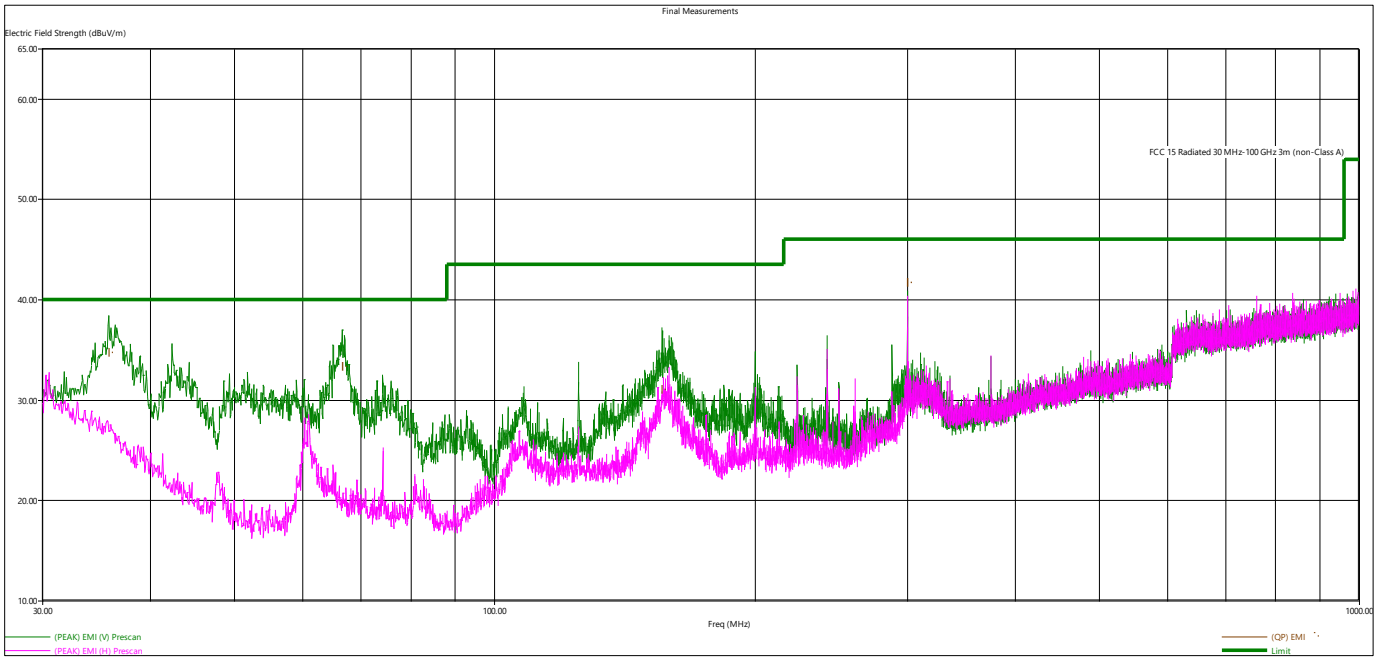


Figure 13 - Radiated Emissions Plot, 802.11b 11MB

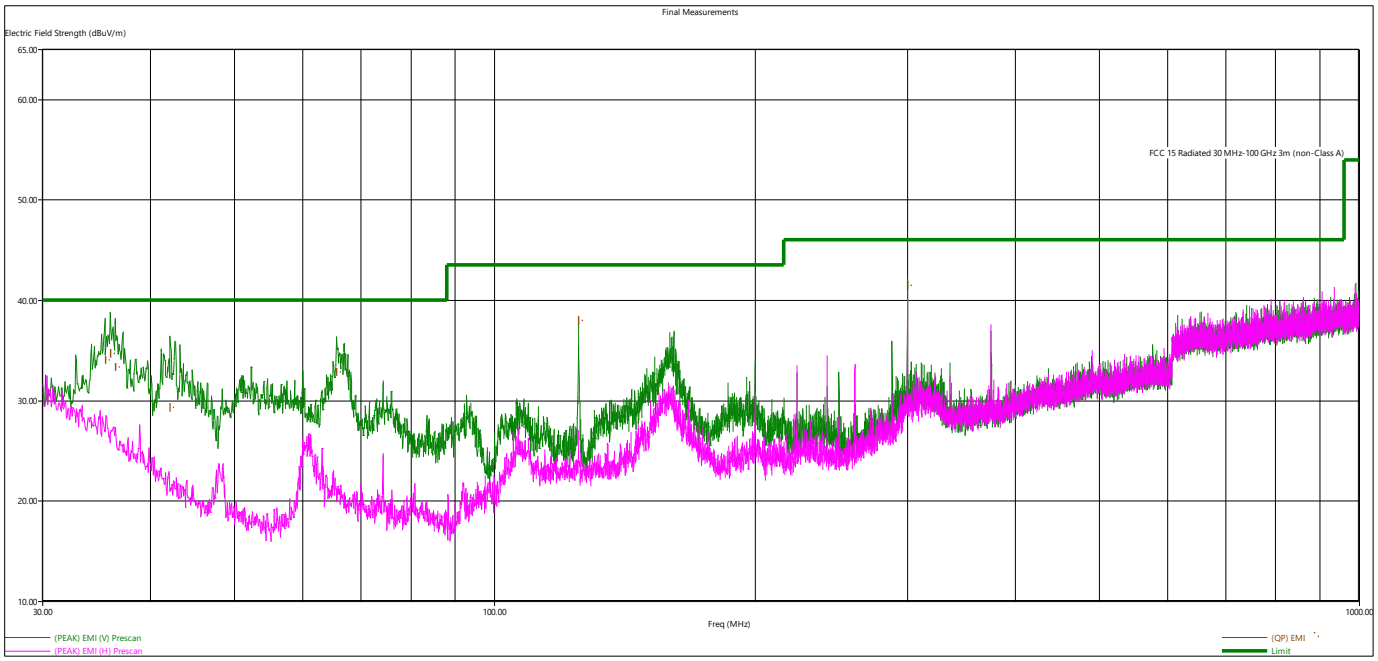


Figure 14 - Radiated Emissions Plot, 802.11g 54MB

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 = Limit value - Emission level

Quasi-Peak Measurements, 30MHz – 1GHz								
Frequency	**Level**	**Limit**	**Margin**	**Height**	**Angle**	**Pol**	**Channel**	**Modulation**
MHz	**dBµV/m**	**dBµV/m**	**dB**	**cm.**	**deg.**			
36.320880	31.57	40.00	8.43	138.61	52.50	V	Low	B 1MB
66.011520	33.30	40.00	6.70	109.77	186.50	V	Low	B 1MB
124.981680	34.33	43.52	9.19	103.74	188.75	V	Low	B 1MB
300.016080	40.38	46.02	5.64	114.73	202.25	V	Low	B 1MB
35.356320	33.97	40.00	6.03	104.94	302.25	V	Low	N MCS0
35.975280	34.64	40.00	5.36	105.71	358.50	V	Low	N MCS0
36.357360	33.25	40.00	6.75	114.01	213.25	V	Low	N MCS0
42.129360	29.27	40.00	10.73	155.56	261.75	V	Low	N MCS0
65.635920	32.81	40.00	7.19	111.74	140.25	V	Low	N MCS0
124.993200	37.95	43.52	5.57	112.76	170.00	V	Low	N MCS0
300.008160	41.40	46.02	4.62	109.41	202.50	V	Low	N MCS0
35.800560	34.71	40.00	5.29	130.97	352.25	V	Low	B 11MB
66.504479	33.30	40.00	6.70	108.88	173.75	V	Low	B 11MB
156.117600	30.96	43.52	12.56	107.74	164.25	V	Low	B 11MB
300.027840	41.68	46.02	4.34	105.00	183.00	V	Low	B 11MB
35.356320	33.97	40.00	6.03	104.94	302.25	V	Low	N MCS0
35.975280	34.64	40.00	5.36	105.71	358.50	V	Low	N MCS0
36.357360	33.25	40.00	6.75	114.01	213.25	V	Low	N MCS0
42.129360	29.27	40.00	10.73	155.56	261.75	V	Low	N MCS0
65.635920	32.81	40.00	7.19	111.74	140.25	V	Low	N MCS0
124.993200	37.95	43.52	5.57	112.76	170.00	V	Low	N MCS0
300.008160	41.40	46.02	4.62	109.41	202.50	V	Low	N MCS0

The EUT was maximized in all 3 orthogonal axes. The worst-case is shown in the plot and table above.
All other measurements were found to be at least 6 dB below the limit.
Intermodulation was investigated with pre-certified module, **FCC ID: R17LE910CXNF**, no emissions above measurement sensitivity were found and were not tabulated.
*All measurements above 1GHz were found to be at least 6 dB below the limit.

4.3 BAND EDGES

Test Method: All the radio measurements were performed using the sections from ANSI C63.10, details about the section used can be found in the spectrum analyzer titles on the graph.

Limits of band-edge measurements:
For FCC Part 15.247 Device:
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c))

Test procedures:
The highest emissions level beyond the band-edge was measured and recorded. All band edge measurements were evaluated to the general limits in Part 15.209. More details can be found in section 3.4 of this report.

Deviations from test standard:
No deviation.

Test setup:
Test setup details can be found in section 3.4 of this report.

EUT operating conditions:
Details can be found in section 2.1 of this report.

Test results:
Pass
Comments:
1. All the band edge plots can be found in Appendix C.
2. If the device falls under FCC Part 15.247 (Details can be found in summary of test results), compliance is shown in the unrestricted band edges by showing minimum delta of 20 dB between peak and the band edge.
3. The restricted band edge compliance is shown by comparing it to the general limit defined in Part 15.209.
4. Tabulated data is listed in section 4.0.

APPENDIX A: SAMPLE CALCULATION

Field Strength Calculation

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

FS = RA + AF – (-CF + AG) + AV

where FS = Field Strength

RA = Receiver Amplitude

AF = Antenna Factor

CF = Cable Attenuation Factor

AG = Amplifier Gain

AV = Averaging Factor (if applicable)

Assume a receiver reading of 55 dBμV is obtained. The Antenna Factor of 12 and a Cable Factor of 1.1 is added. The Amplifier Gain of 20 dB is subtracted, giving a field strength of 48.1 dBμV/m.

FS = 55 + 12 – (-1.1 + 20) + 0 = 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

AV is calculated by the taking the 20*log(T_{on}/100) where T_{on} is the maximum transmission time in any 100ms window.

EIRP Calculations

In cases where direct antenna port measurement is not possible or would be inaccurate, output power is measured in EIRP. The maximum field strength is measured at a specified distance and the EIRP is calculated using the following equation;

EIRP (Watts) = [Field Strength (V/m) x antenna distance (m)]^2 / 30

Power (watts) = 10^[Power (dBm)/10] / 1000

Voltage (dBμV) = Power (dBm) + 107 (for 50Ω measurement systems)

Field Strength (V/m) = 10^[Field Strength (dBμV/m) / 20] / 10^6

Gain = 1 (numeric gain for isotropic radiator)

Conversion from 3m field strength to EIRP (d=3):

EIRP = [FS(V/m) x d^2]/30 = FS [0.3] for d = 3

EIRP(dBm) = FS(dBμV/m) – 10(log 10^9)+ 10log[0.3] = FS(dBμV/m) - 95.23

10log(10^9) is the conversion from micro to milli

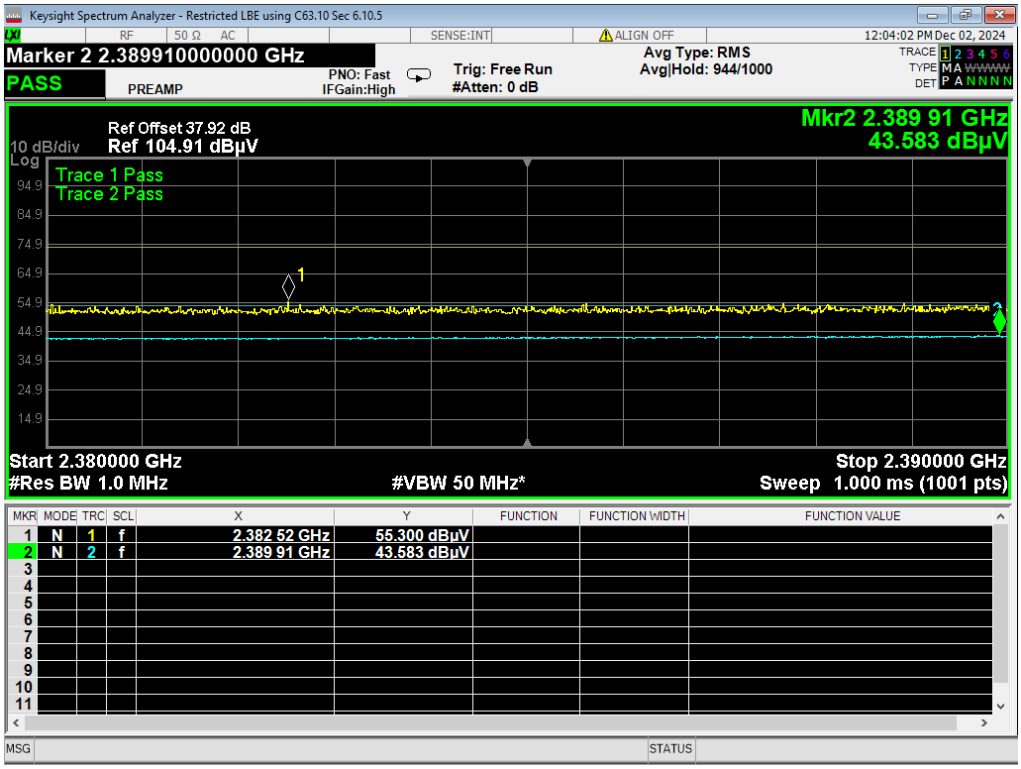
APPENDIX B – MEASUREMENT UNCERTAINTY

NCEE Labs does not add uncertainty levels to measurement levels
Where relevant, the following measurement uncertainty levels have been for tests performed in this test report:

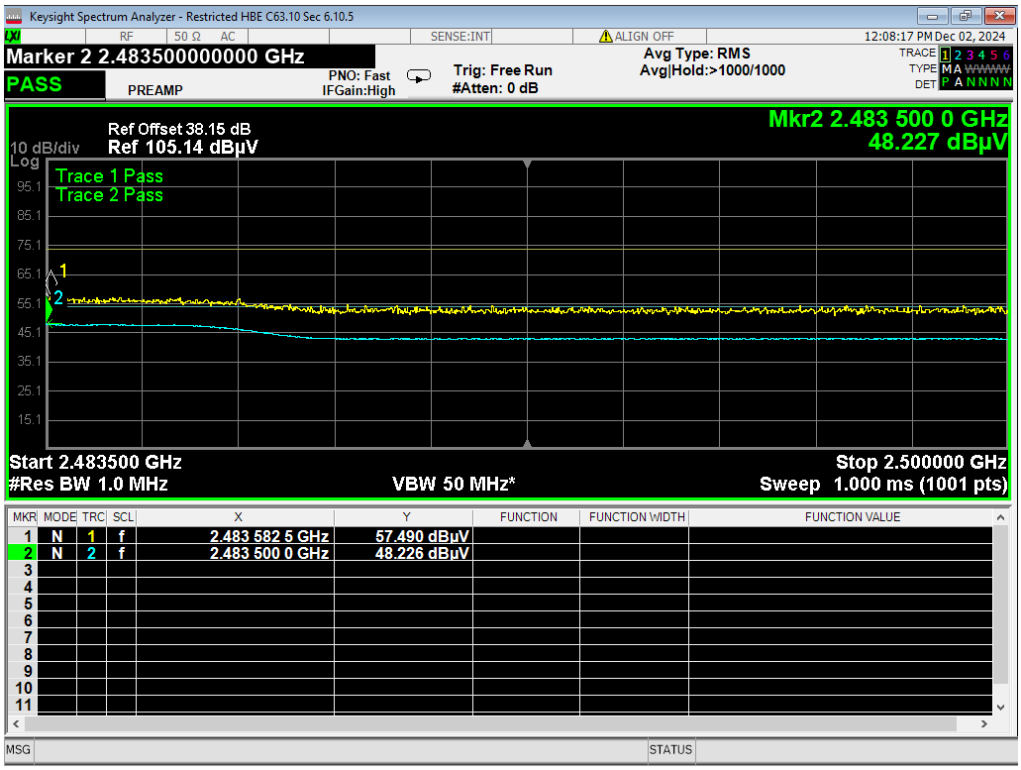
Test	Frequency Range	Uncertainty Value (dB)
Radiated Emissions, 3m	30MHz - 1GHz	±4.31
Radiated Emissions, 3m	1GHz - 18GHz	±5.08
Emissions limits, conducted	30MHz – 18GHz	±3.03

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

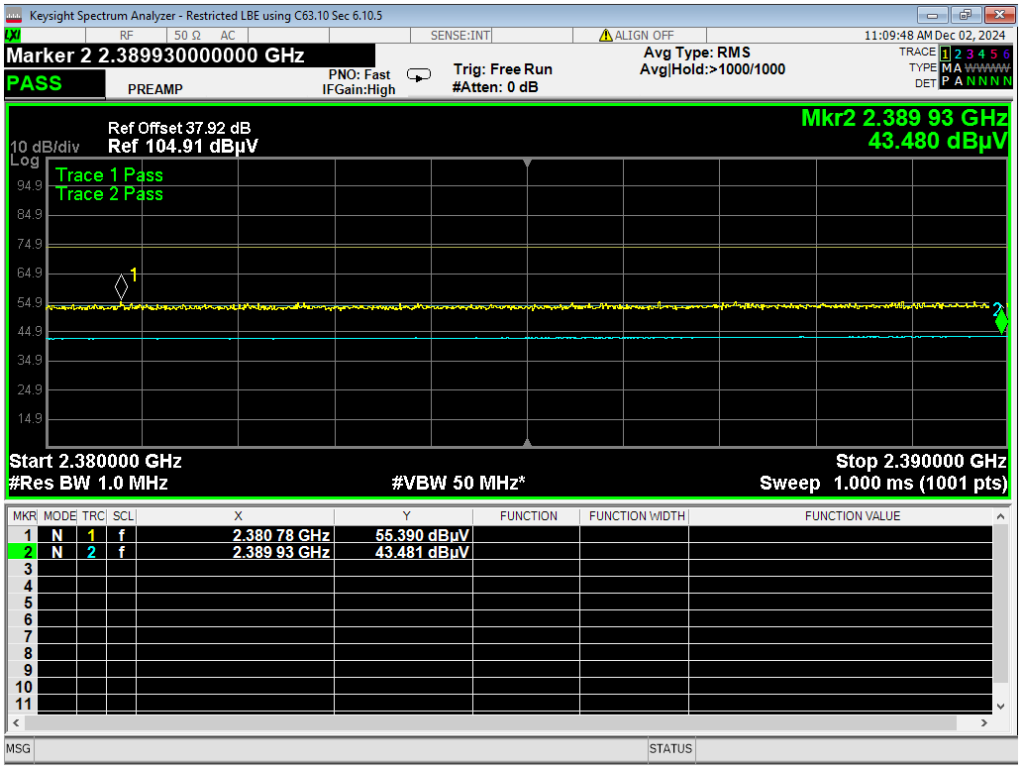
APPENDIX C – GRAPHS AND TABLES



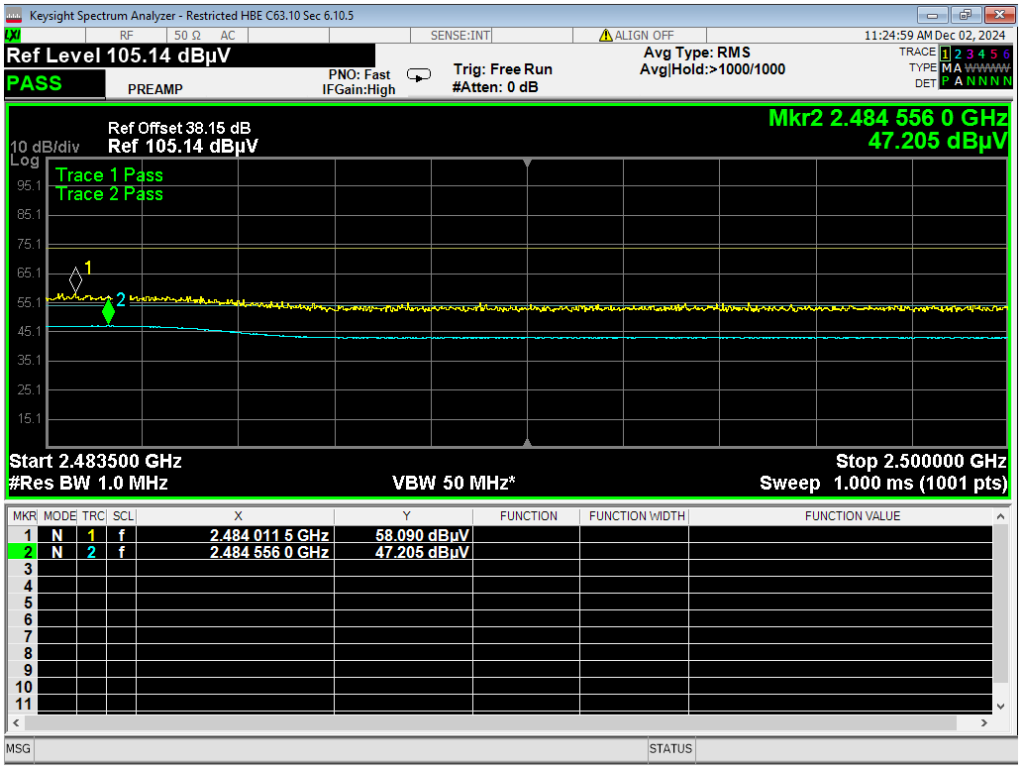
01 LBE Restricted, Wifi B 1MB, pwr18



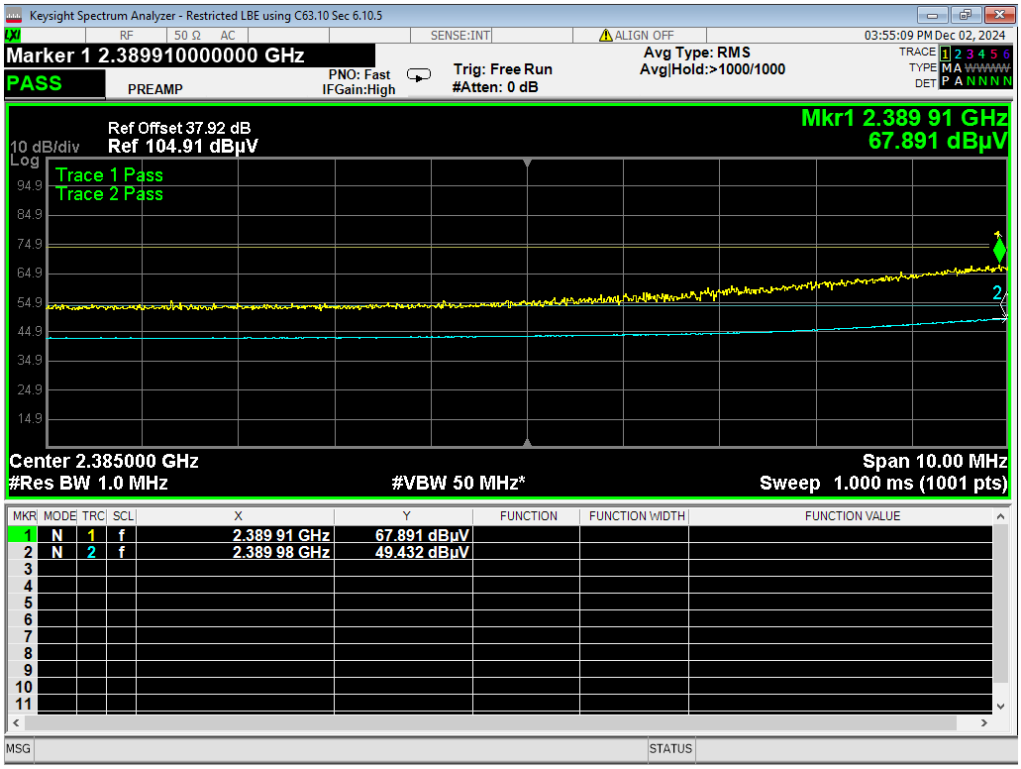
02 HBE Restricted, Wifi B 1MB, pwr15



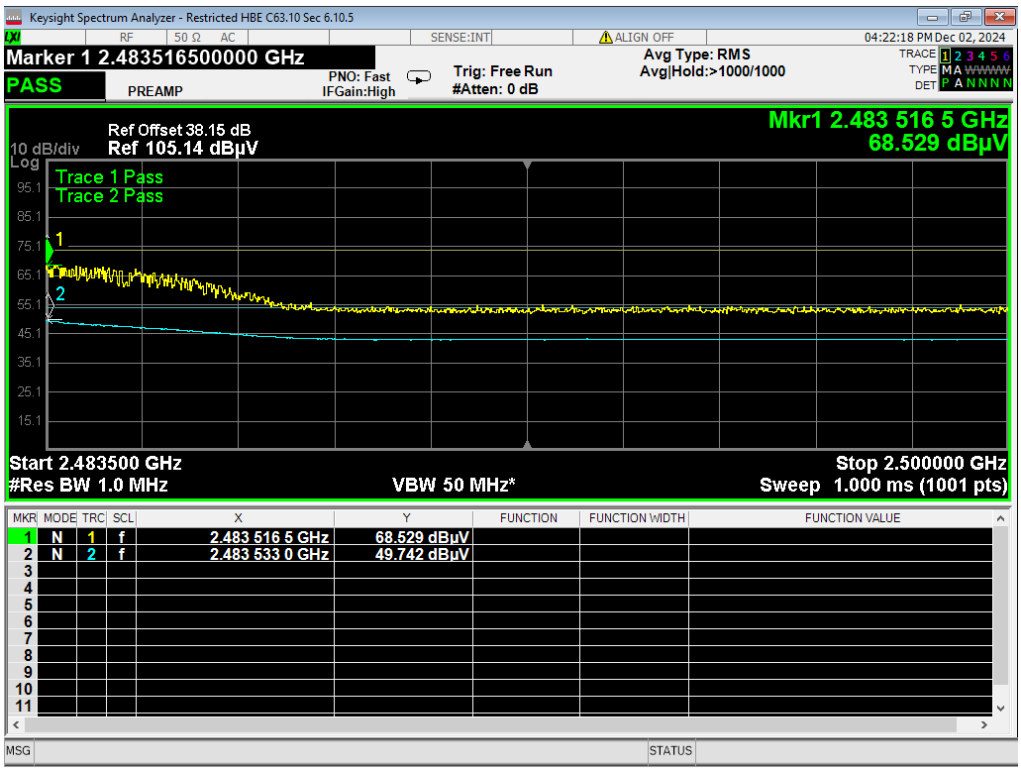
03 LBE Restricted, Wifi B 11MB, pwr18



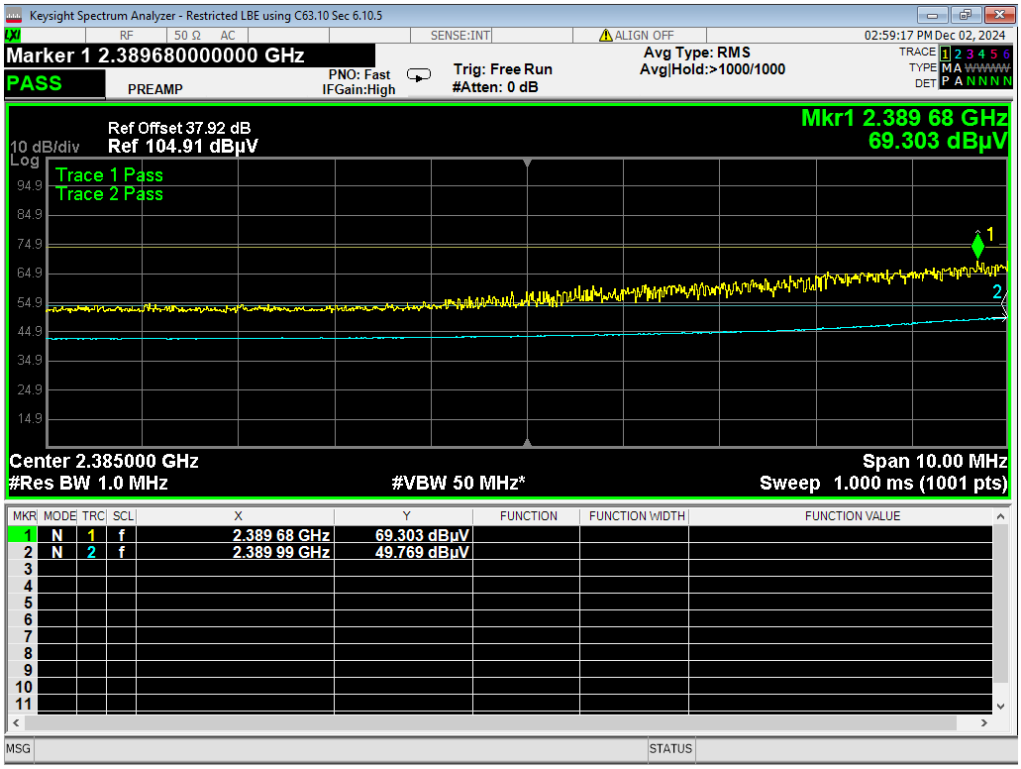
04 HBE Restricted, Wifi B 11MB, pwr15



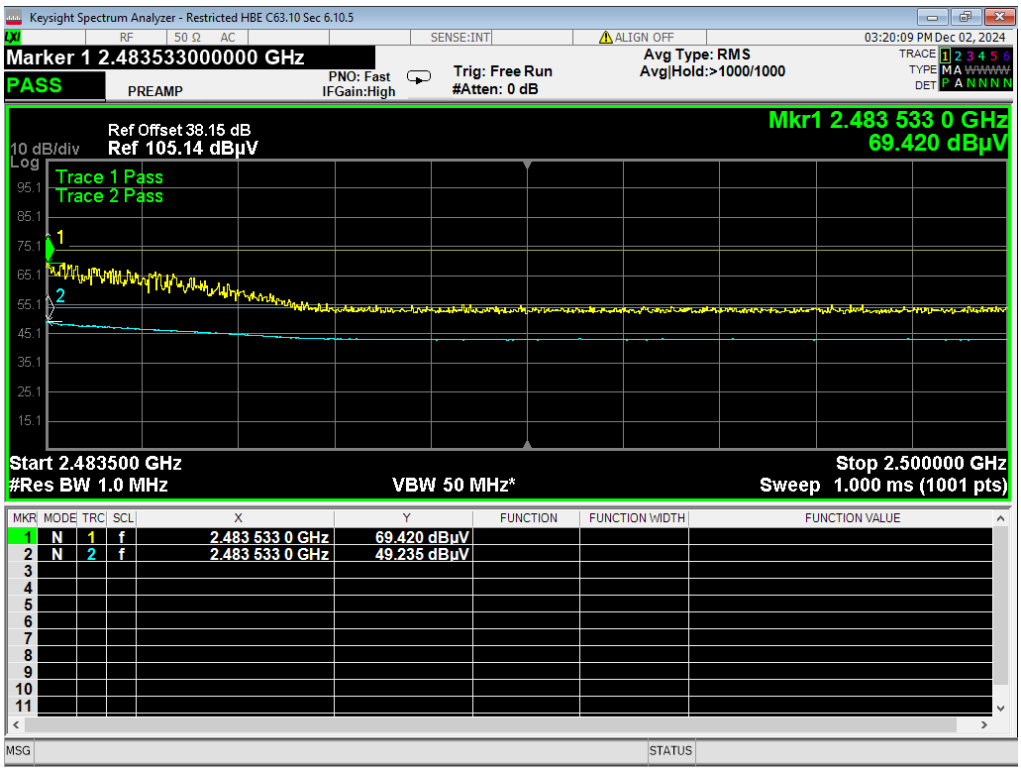
05 LBE Restricted, Wifi G 6MB, pwr15



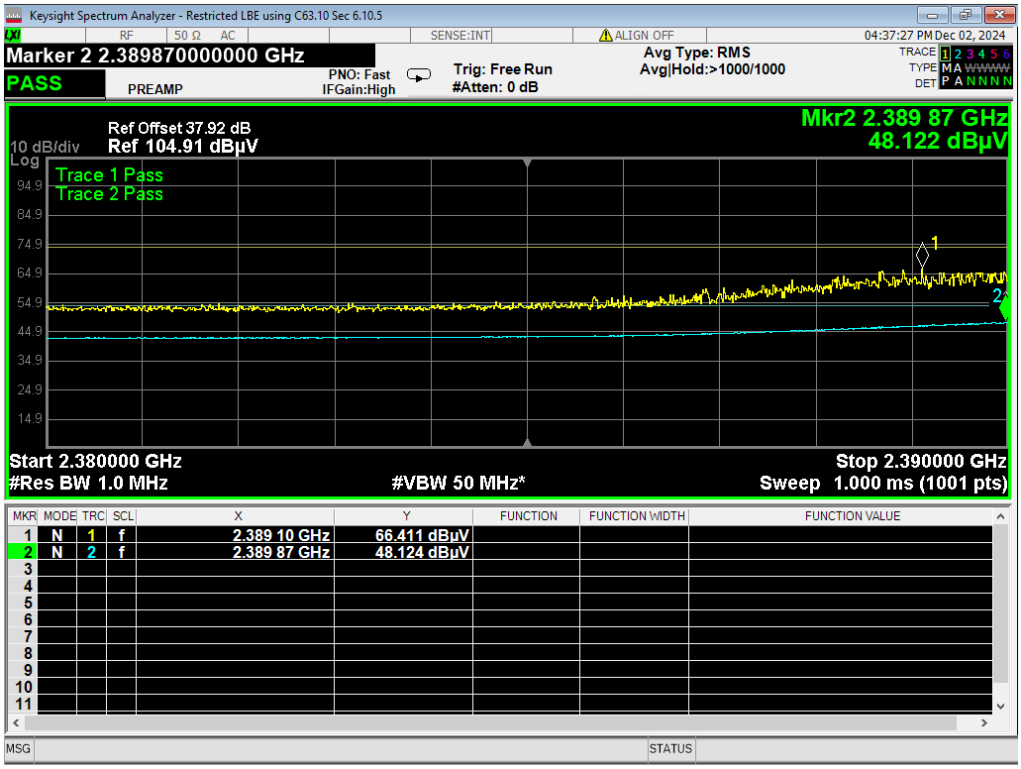
06 HBE Restricted, Wifi G 6MB, pwr12



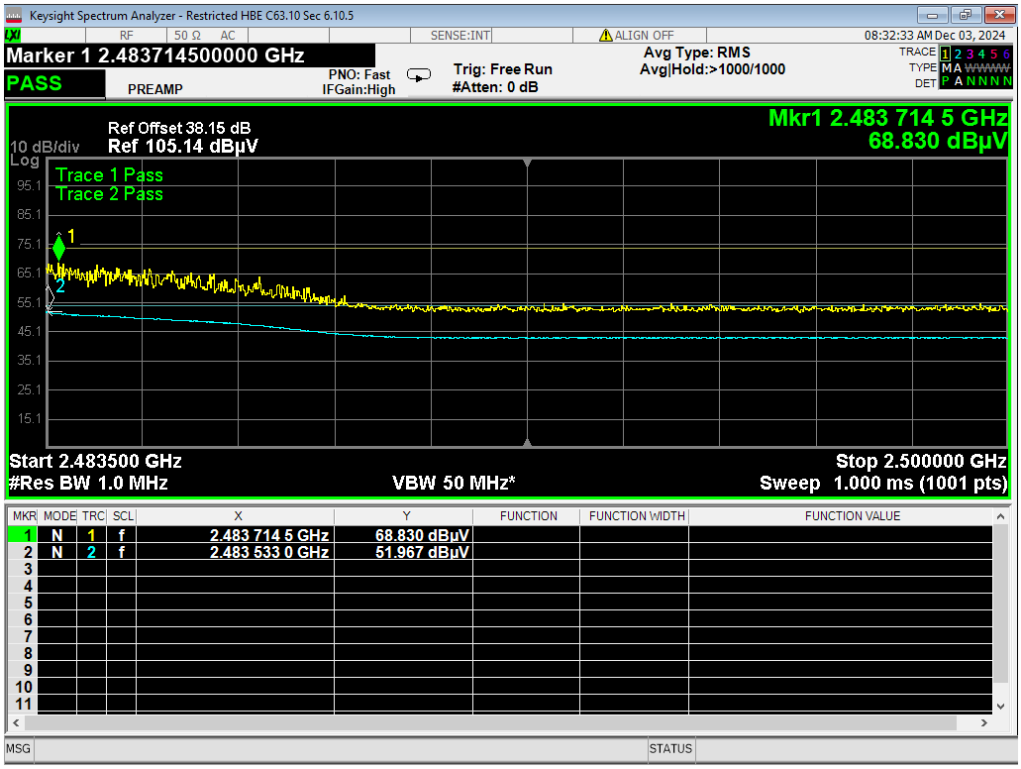
07 LBE Restricted, Wifi G 54MB, pwr15



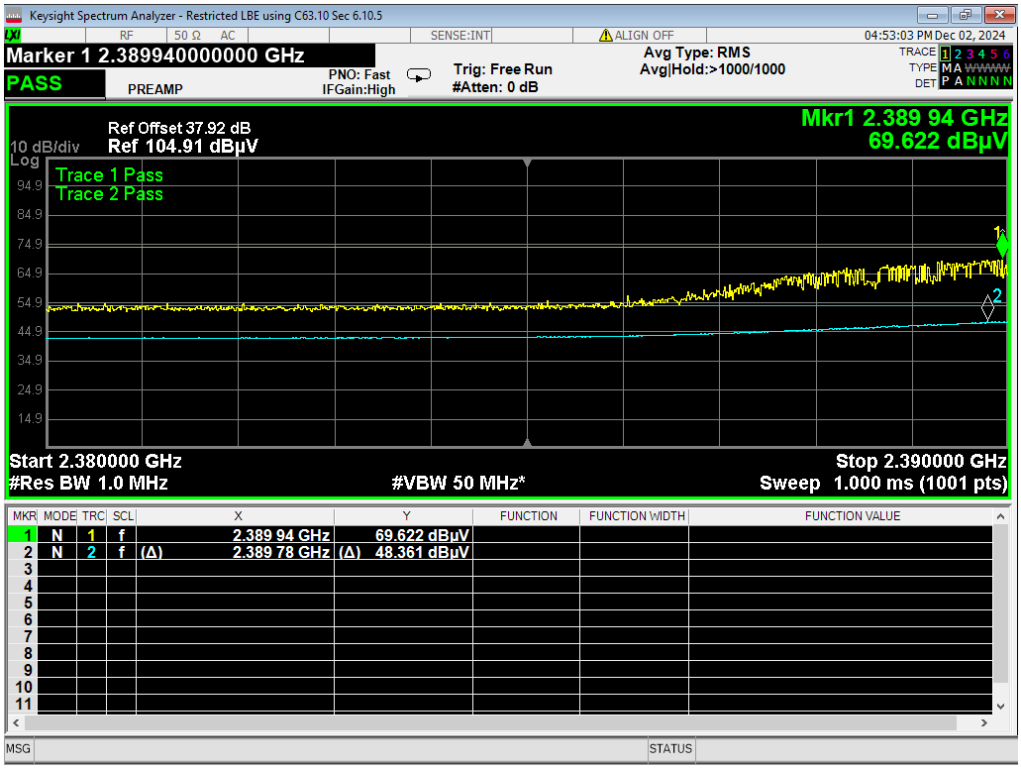
08 HBE Restricted, Wifi G 54MB, pwr12



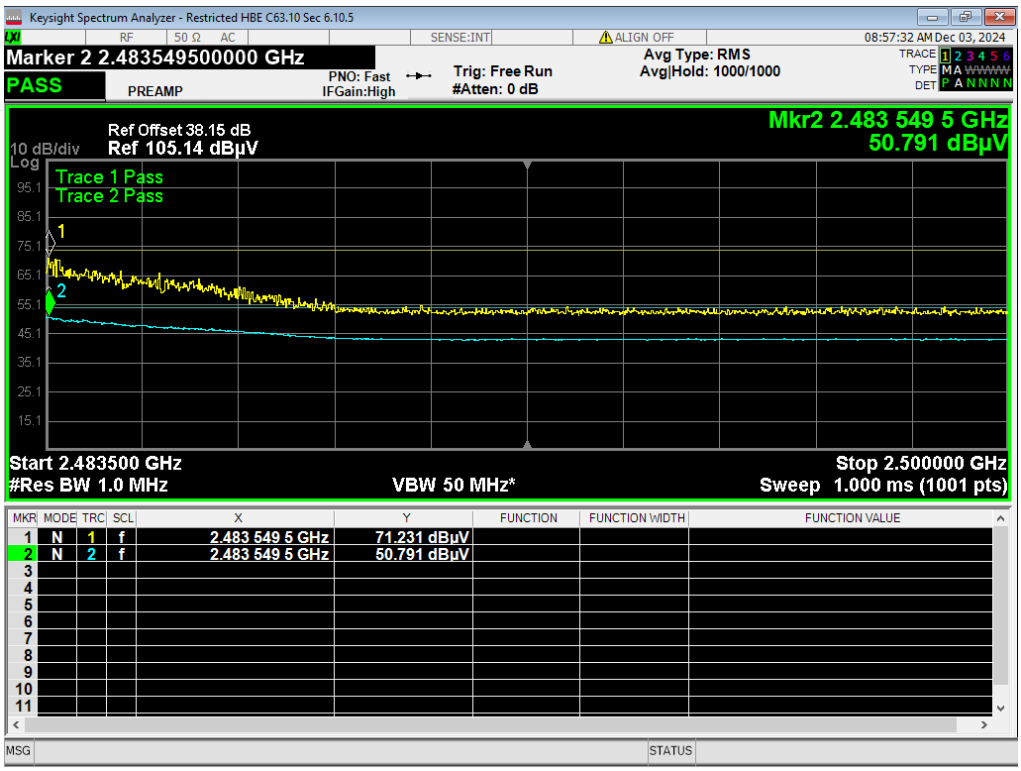
09 LBE Restricted, Wifi N MCS0, pwr14



10 HBE Restricted, Wifi N MCS0, pwr12



11 LBE Restricted, Wifi N MCS7, pwr14



12 HBE Restricted, Wifi N MCS7, pwr12

REPORT END