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FCC/ISED Test Report

Prepared for: **Appareo**

Address: **1810 NDSU Research Circle**
Fargo, ND 58102

Product: **AT-130**

Test Report No: **R20200702-20-E1B**

Approved by:

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

DATE: **5 February 2021**

Total Pages: **30**

REVISION PAGE

Rev. No.	Date	Description
0	28 October 2020	Original – NJohnson Prepared by KVepuri/FLane
A	13 January 2021	1. Table under section 4.0 is updated. 2. Appendix C is updated with the tables for band edge measurements.
B	5 February 2021	1. Corrected DCCF and updated reported average values accordingly

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

FCC Part 15.249

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-210, Issue 10

SUMMARY			
Requirement	**Test Type and Limit**	**Result**	**Remark**
FCC 15.203	Unique Antenna Requirement	Pass	PCB Antenna
FCC 15.35 RSS-Gen, 6.10	Duty cycle of pulsed emissions	N/A	Not required
NA	Maximum Peak Output Power	N/A	Informational Purpose Only
NA	Minimum Bandwidth	N/A	Informational Purpose Only
FCC 15.209 RSS-Gen, 7.1	Receiver Radiated Emissions	Pass	Meets the requirement of the limit.
FCC 15.209 RSS-Gen, 8.9 RSS-210 A1.2 FCC 15.249(a)	Transmitter Radiated Emissions	Pass	Meets the requirement of the limit.
FCC 15.209, 15.205, 15.249(d) RSS-Gen, 8.9 RSS-210, 5.5	Band Edge Measurement	Pass	Meets the requirement of the limit.
FCC 15.207 RSS-Gen. 8.8	Conducted AC Emissions	N/A	Battery Powered Device

2.0 EUT DESCRIPTION

2.1 EQUIPMENT UNDER TEST

Summary and Operating Condition:

EUT	MN: AT-130
EUT Received	9 October 2020
EUT Tested	16 October 2020- 27 October 2020
Serial No.	000075
Operating Band	2400 – 2483.5 MHz
Device Type	☒ BLE
Power Supply / Voltage	3.6 VDC Primary Lithium-Thionyl Chloride 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:

For Bluetooth Transmissions:

Channel	Frequency
Low	2402 MHz
Mid	2440/2441 MHz
High	2480 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 frequency and designations.

2.3 DESCRIPTION OF SUPPORT UNITS

The EUT was tested with the plastic back removed. In order to achieve continuous transmission and control of test firmware, an evaluation board was connected to the EUT during testing. To change modes, the board was plugged into a PC via USB. Testing was performed to ensure the removal of the back cover and the addition of the evaluation board did not effect the results by more than 1 dB.

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-1
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	Nic Johnson	Technical Manager	Review/editing
2	Karthik Vepuri	Test Engineer	Testing and report
3	Fox Lane	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

Notes:

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

DESCRIPTION AND MANUFACTURER	MODEL NO.	SERIAL NO.	LAST CALIBRATION DATE	CALIBRATION DUE DATE
Keysight MXE Signal Analyzer (26.5GHz)	N9038A	MY56400083	May 5, 2020	May 5, 2022
Keysight EXA Signal Analyzer	N9010A	MY56070862	December 14, 2018	December 14, 2020***
SunAR RF Motion	JB1	A091418	March 6, 2020	March 6, 2021
EMCO Horn Antenna	3115	6415	March 16, 2020	March 16, 2022
EMCO Horn Antenna	3116	2576	March 9, 2020	March 9, 2022
Rohde & Schwarz Preamplifier**	TS-PR18	3545700803	April 14, 2020	April 14, 2022
Trilithic High Pass Filter*	6HC330	23042	April 14, 2020	April 14, 2022
MiniCircuits High Pass Filter*	VHF-1320+	15542	April 14, 2020	April 14, 2022
RF Cable (preamplifier to antenna)*	MFR-57500	01-07-002	April 14, 2020	April 14, 2022
RF Cable (antenna to 10m chamber bulkhead)*	FSCM 64639	01E3872	April 14, 2020	April 14, 2022
RF Cable (10m chamber bulkhead to control room bulkhead)*	FSCM 64639	01E3874	April 14, 2020	April 14, 2022
RF Cable (control room bulkhead to test receiver)*	FSCM 64639	01F1206	April 14, 2020	April 14, 2022
N connector bulkhead (10m chamber)*	PE9128	NCEEBH1	April 14, 2020	April 14, 2022
N connector bulkhead (control room)*	PE9128	NCEEBH2	April 14, 2020	April 14, 2022
TDK Emissions Lab Software	V11.25	700307	NA	NA

*Internal Characterization

**2-year calibration cycle

*** Extended Cal

3.4 GENERAL TEST PROCEDURE AND SETUP FOR RADIO MEASUREMNTS

Measurement type presented in this report

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 the 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.

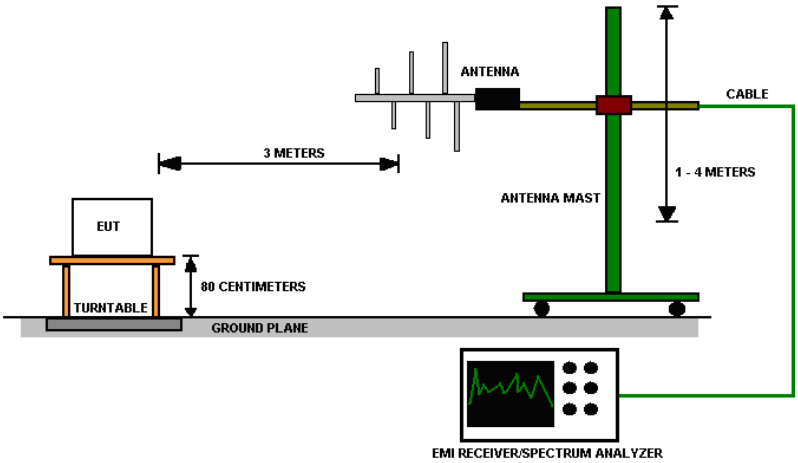


Figure 1 - Radiated Emissions Test Setup

4.0 RESULTS

DTS Radio B2:I35Measurements							
CHANNEL	**Transmitter**	**Occupied Bandwidth (kHz)**	**6 dB Bandwidth (kHz)**	**OUTPUT POWER - EIRP (dBm)**	**PEAK OUTPUT POWER (mW)**	**PSD (dBm)**	**RESULT**
Low	BLE	1090.90	NA	-2.87	0.516	NA	PASS
Mid	BLE	1087.80	NA	-4.648	0.343	NA	PASS
High	BLE	1111.00	NA	-6.274	0.236	NA	PASS
Occupied Bandwidth = N/A; 6 dB Bandwidth Limit = N/A				Peak Output Power Limit = NA; PSD Limit = N/A			

Output Power EIRP Correction							
CHANNEL	**Measurement**	**Raw SA uncorrected value (dBm)**	**Antenna Factor (dB)**	**Cable Loss (dB)**	**Corrected Level (dB)**	**3m EIRP conversion***	**EIRP (dBm)**
Low	Output Power	-48.98	28.38	5.96	-14.64	11.77	-2.87
Mid	Output Power	-50.64	28.32	5.90	-16.42	11.77	-4.65
High	Output Power	-52.41	28.39	5.98	-18.04	11.77	-6.27
* 107 (dBm to dBuV Conversion) - 95.23(EIRP Conversion from 3m) =11.77; Corrected Level= Raw SA Value+ Antenna Factor+ Cable Loss; EIRP=Corrected Value+3 m EIRP conversion;							

Unrestricted Band-Edge							
CHANNEL	**Mode**	**Band edge /Measurement Frequency (MHz)**	**Highest out of band level (dBuV/m @ 3m)**	**Measurement Type**	**Limit (dBuV/m @ 3m)***	**Margin**	**Result**
Low	BLE	2400.00	55.92	Peak	73.98	18.06	PASS
High	BLE	2483.50	50.22	Peak	73.98	23.76	PASS
Low	BLE	2400.00	49.63	Average**	53.98	4.35	PASS
High	BLE	2483.50	43.93	Average**	53.98	10.05	PASS
*Limit shown is taken from FCC Part 15.209; Plots in Appendix C shows uncorrected measurements **Average = Peak – DCCF (-5.51 dB per Section 4.3)							

Band Edge Corrections							
CHANNEL	**Measurement**	**Band edge /Measurement Frequency (MHz)**	**Measurement Type**	**Raw SA uncorrected level (dBuV)**	**Antenna Factor (dB)**	**Cable Loss (dB)**	**Corrected Level (dBuV)**
Low	Band Edge	2400.00	Peak	21.58	28.38	5.96	55.92
High	Band Edge	2483.50	Peak	15.85	28.39	5.98	50.22
Plots in Appendix C shows uncorrected measurements; Corrected Level= Raw SA level + Antenna Factor + Cable Loss;							

4.1 OUTPUT POWER

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 power measurements:
For FCC Part 15.249 Device:
For Informational Purposes only
.
Test procedures:
Details can be found in section 3.4 of this report.

Deviations from test standard:
No deviation.

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 output power plots can be found in the Appendix C.
2. All data is in the table in results section 4.0.
3. All the measurements were found to be compliant.

4.2 BANDWIDTH

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 bandwidth measurements:

For FCC Part 15.249 Device:
For Informational Purposes only

Test procedures:
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:

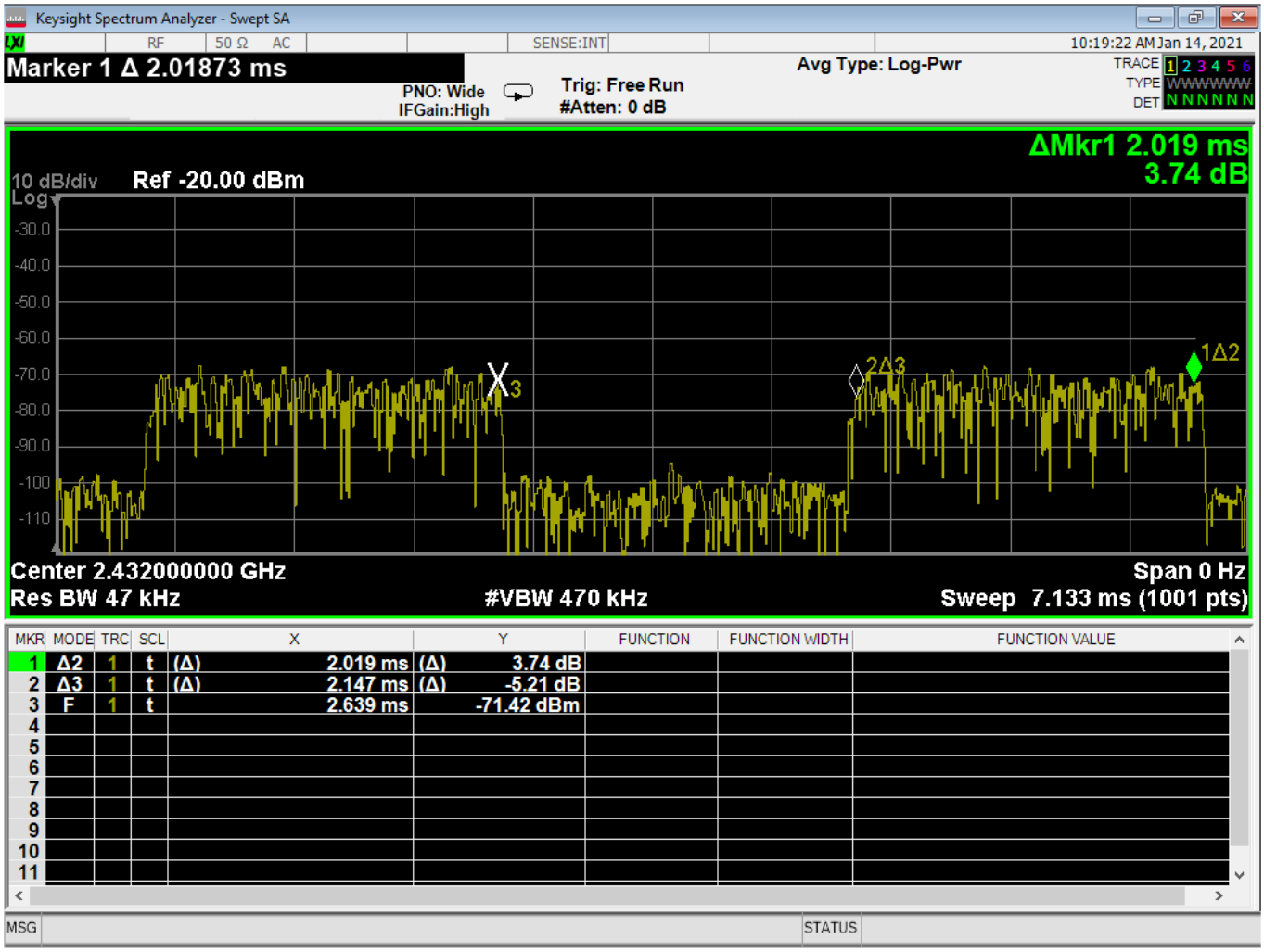
Pass

Comments:

1. All the bandwidth plots can be found in the Appendix C.
2. All data is in the table in results section 4.0.
3. All the measurements were found to be compliant.

4.3 DUTY CYCLE

Test Method: Since the device featured pulsed emissions, a duty cycle correction factor was applied to peak measurements to calculate the average measurement per ANSI C63.10-2013, Section 7.5.



Duty cycle = 2.019 / (2.019 + 2.147) = 48.5%

Duty Cycle Correction Factor (DCCF) = 20 x log(0.485) = **-6.29 dB**

4.4 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.

h. Emissions were investigated with the 2.4 GHz radio radios transmitting simultaneously with the pre-certified cellular radio to detect any potential intermodulation products. No additional emissions were found within the labs measurement sensitivity as a result of the simultaneous transmissions. The cellular radio was tested in the PCS band (1850.0 – 1915.0 MHz) and Part 90 / 27 band (699 – 716 MHz).

Test setup:

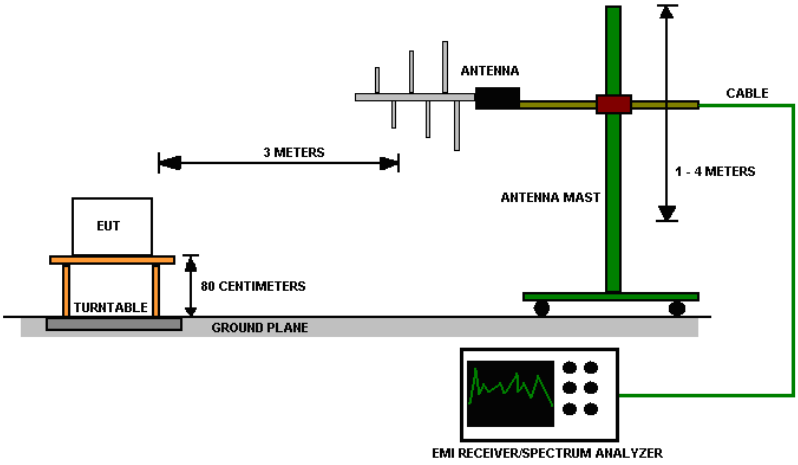


Figure 2 - Radiated Emissions Test Setup

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:

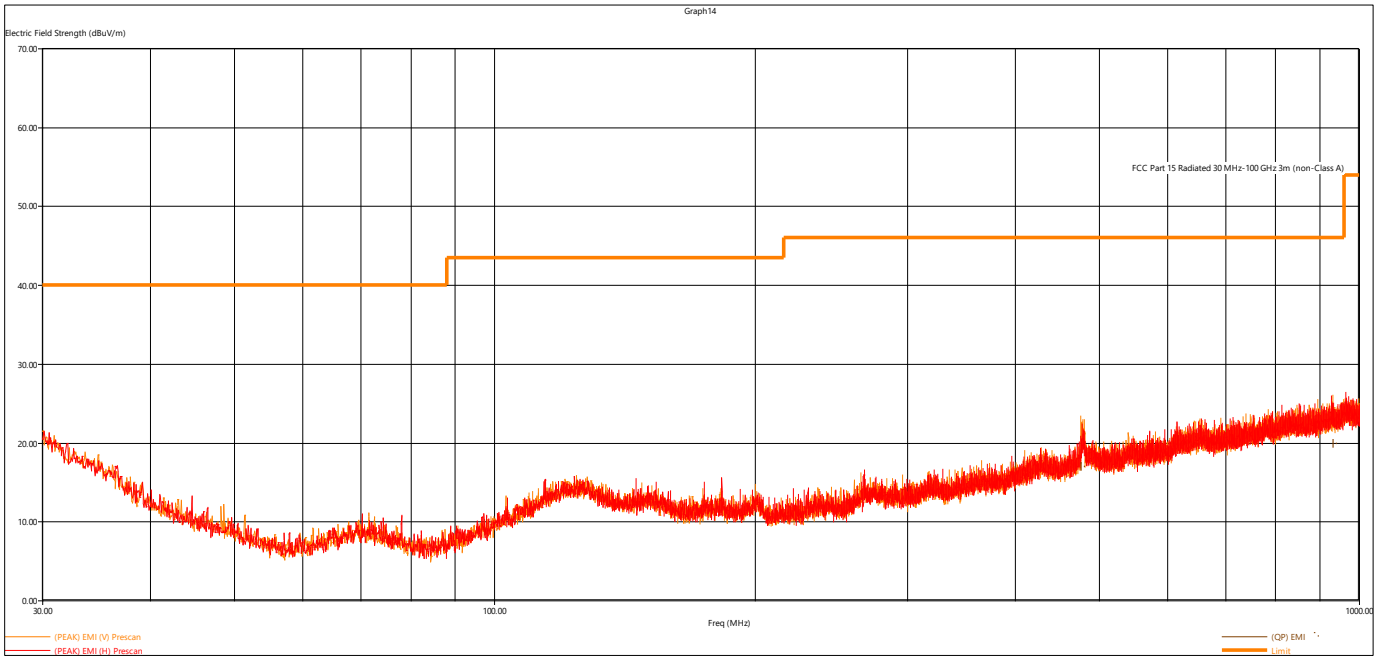


Figure 3 - Radiated Emissions Plot, Receive

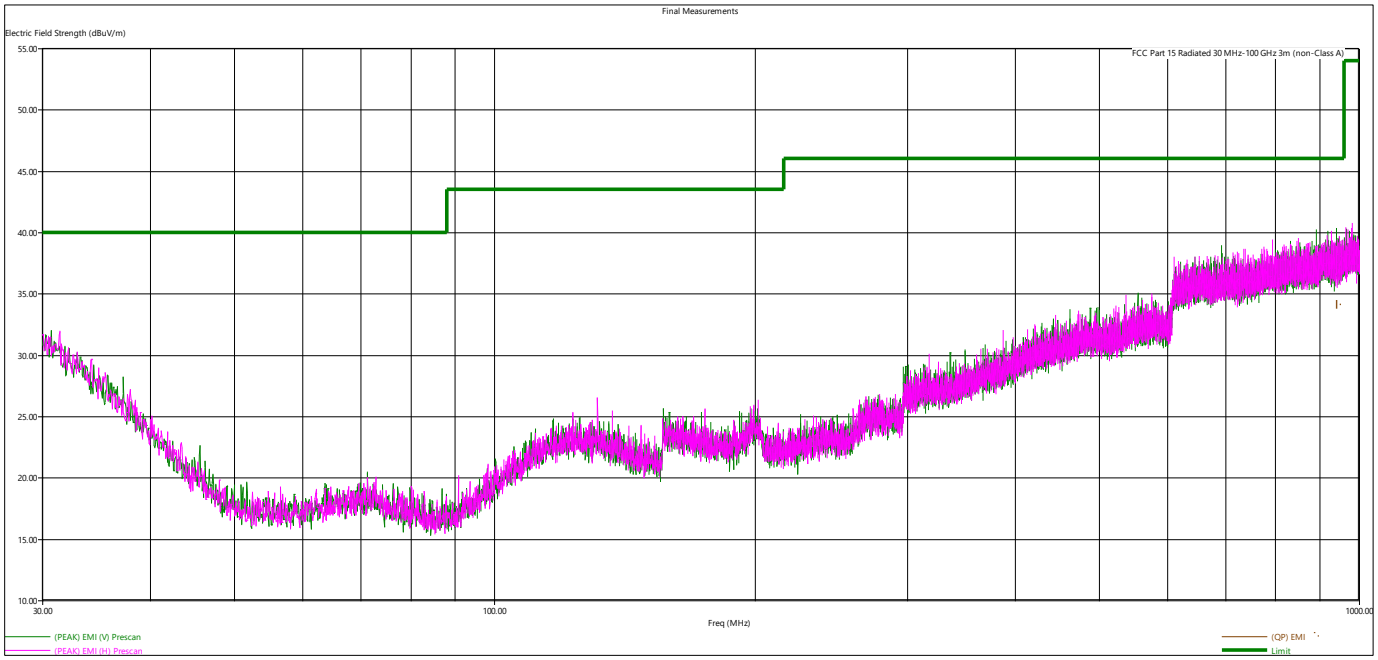


Figure 4 - Radiated Emissions Plot, Low Channel, Worst Case

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

Quasi-Peak Measurements, BLE								
Frequency	Level	Limit	Margin	Height	Angle	Pol	Mode	Modulation
MHz	dBµV/m	dBµV/m	dB	cm.	deg.			
476.543280	16.93	46.02	29.09	160.00	23.00	V	Receive	BLE
931.291920	19.91	46.02	26.11	175.00	360.00	V	Receive	BLE

Quasi-Peak Measurements, BLE, Transmit Mode								
Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel	Modulation
MHz	dBµV/m	dBµV/m	dB	cm.	deg.			
941.35248	34.05	46.02	11.97	278	75	V	Low	BLE

Peak Measurements, BLE, Transmit Mode								
Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel	Modulation
MHz	dBµV/m	dBµV/m	dB	cm.	deg.			
2402.406000	92.14	113.98	21.84	209	150	H	Low	BLE
2440.358000	90.41	113.98	23.57	128	9	H	Mid	BLE
2479.892000	88.28	113.98	25.70	156	7	H	High	BLE
4804.682000	51.51	73.98	22.47	187	155	H	Low	BLE
4880.526000	51.20	73.98	22.78	214	145	H	Mid	BLE
4960.874000	50.46	73.98	23.52	213	328	H	High	BLE

Average Measurements, BLE, Transmit Mode								
Frequency	Level	Limit	Margin	Height	Angle	Pol	Channel	Modulation
MHz	dBµV/m	dBµV/m	dB	cm.	deg.			
2402.406000	87.95	93.98	6.03	209	150	H	Low	BLE
2440.360000	86.54	93.98	7.44	128	9	H	Mid	BLE
2479.892000	83.80	93.98	10.18	156	7	H	High	BLE
4804.682000	44.87	53.98	9.11	187	155	H	Low	BLE
4880.526000	43.82	53.98	10.16	214	145	H	Mid	BLE
4960.874000	42.23	53.98	11.75	213	328	H	High	BLE

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

4.5 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 15.249 Device:
For emissions outside of the allowed band of operation, the emission level needs to be 50dB under the maximum fundamental field strength. However, if the emissions fall within one of the restricted bands from 15.205 the field strength levels need to be under that of the limits in 15.209.

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 the Appendix C.
2. All data is in the table in results section 4.0.
3. If the device falls under FCC Part 15.249 (Details can be found in summary of test results), compliance is shown in the unrestricted band edges by showing the compliance to 15.209 Limits.
4. The restricted band edge compliance is shown by comparing to the general limit defined in Part 15.209. The limit shown in the graph accounts for the antenna gain of the device.
5. The compliance was shown in unrestricted band comparing the highest out of band measurements to FCC Part 15.209 Limits.

APPENDIX A: SAMPLE CALCULATION

Field Strength Calculation

The field strength is calculated 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 = 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

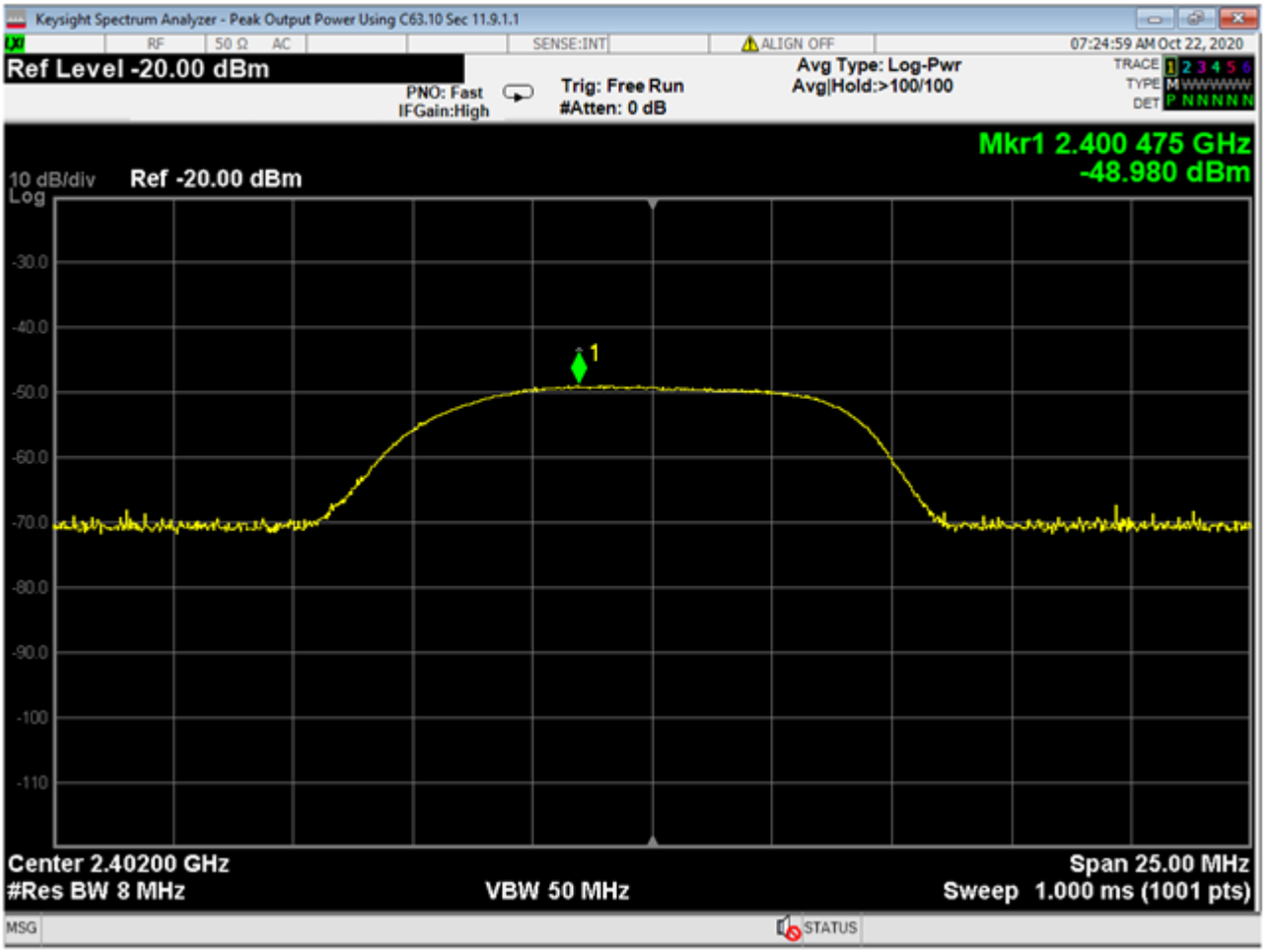
APPENDIX B – MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been for tests performed in this test report:

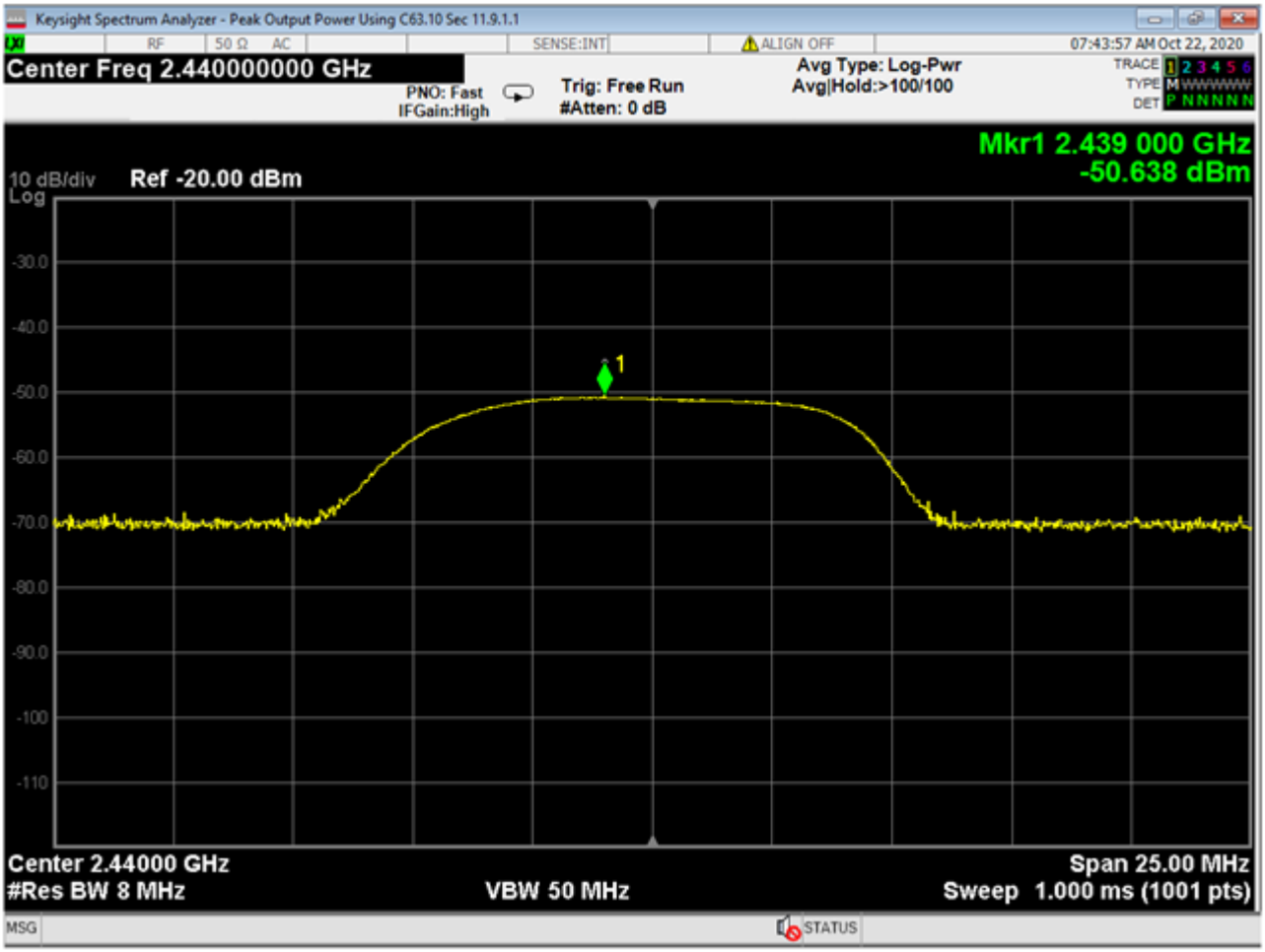
Test	Frequency Range	Uncertainty Value (dB)
Radiated Emissions, 3m	30MHz - 1GHz	3.82
Radiated Emissions, 3m	1GHz - 18GHz	4.44
Emissions limits, conducted	30MHz – 18GHz	±3.30 dB

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

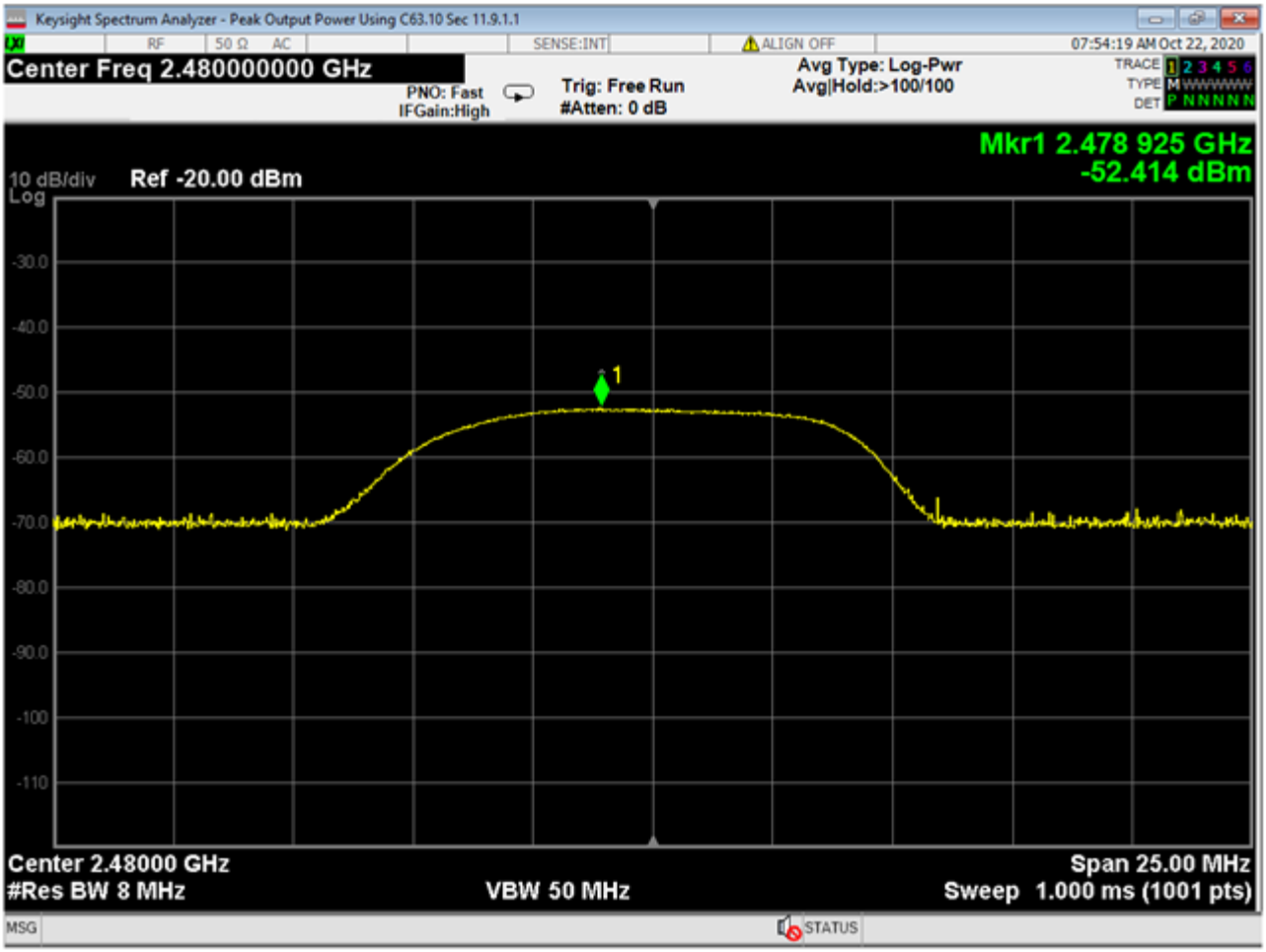
APPENDIX C – GRAPHS AND TABLES



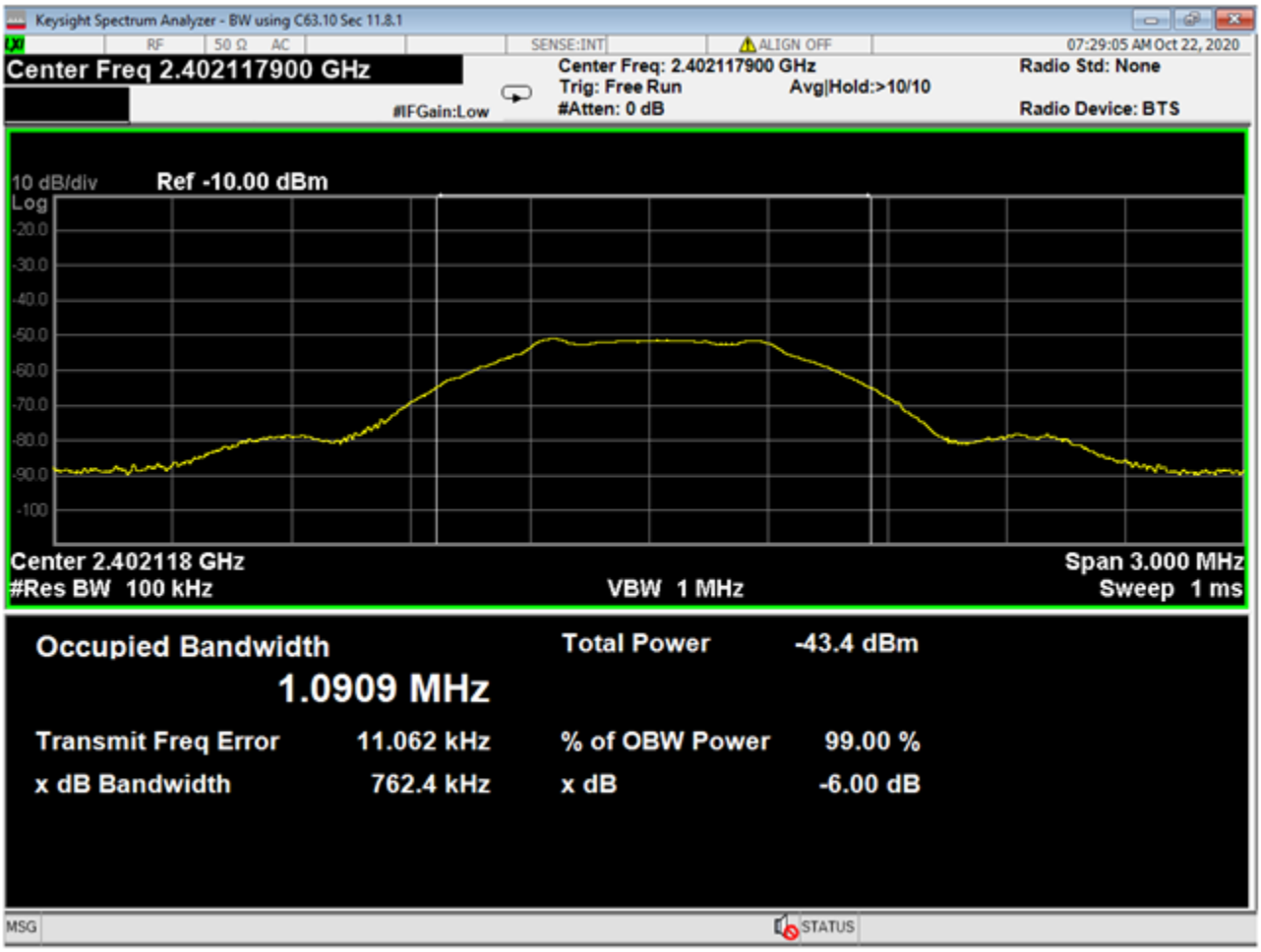
Low Channel Power



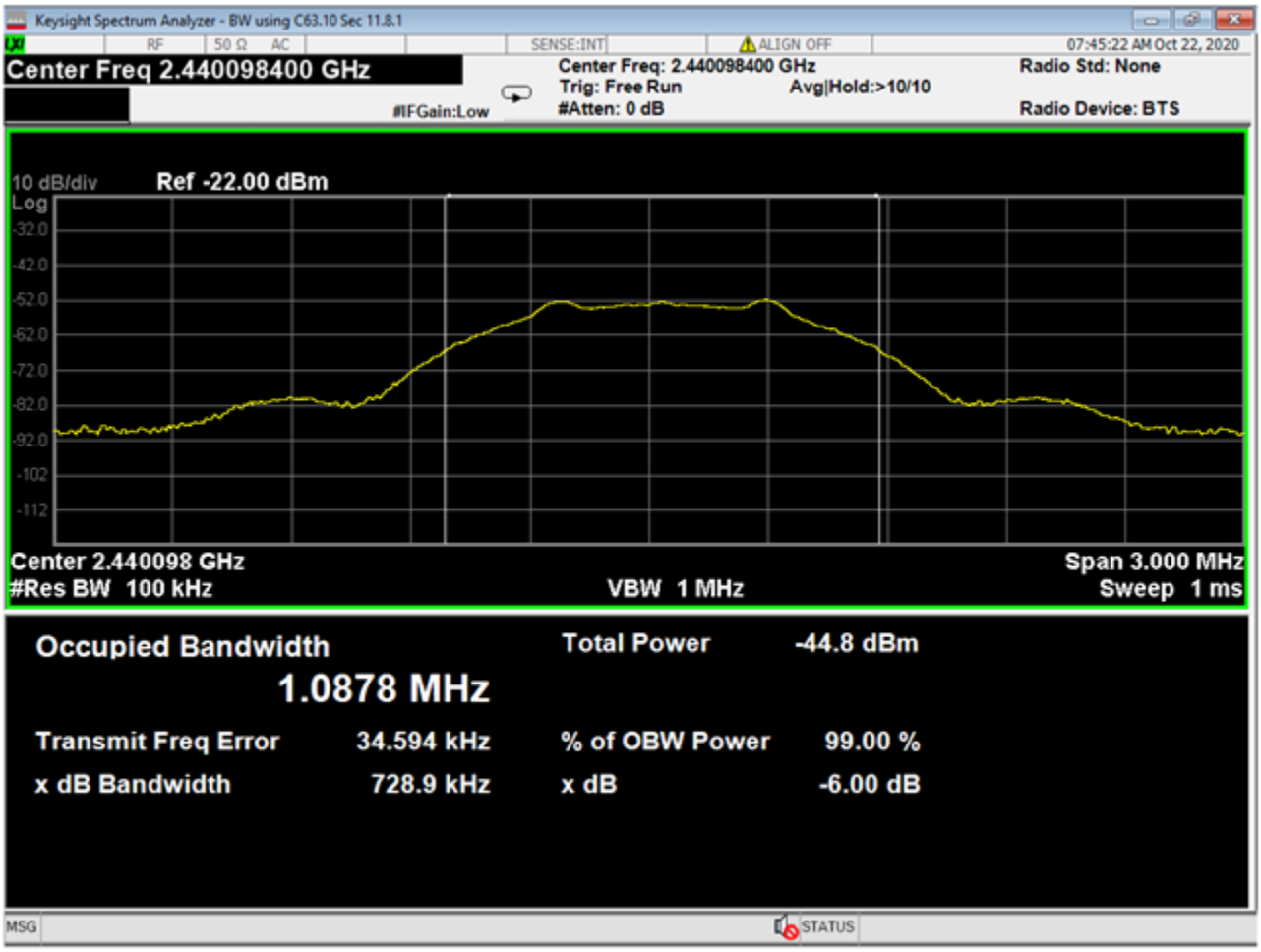
Mid Channel Power



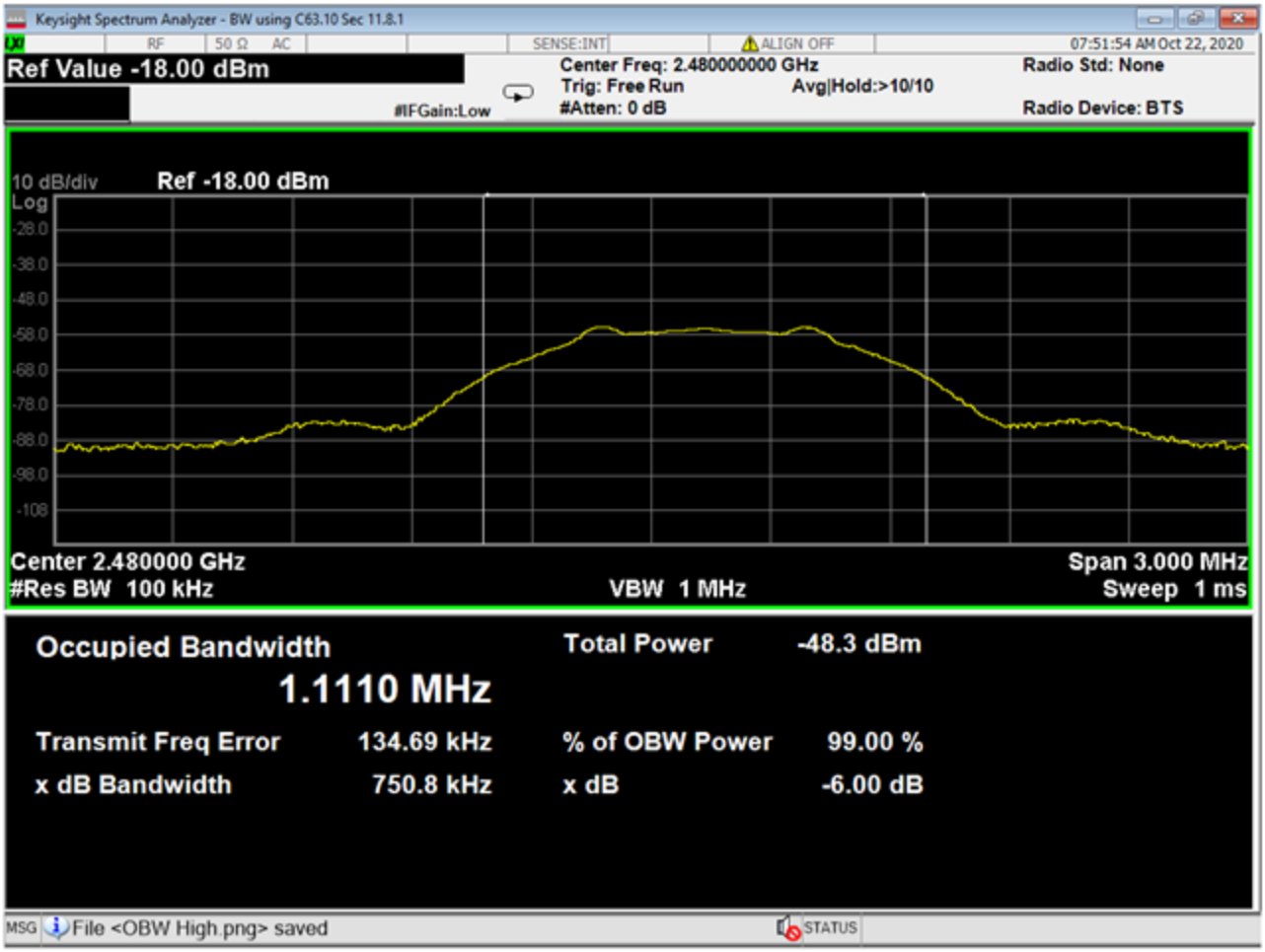
High Channel Power



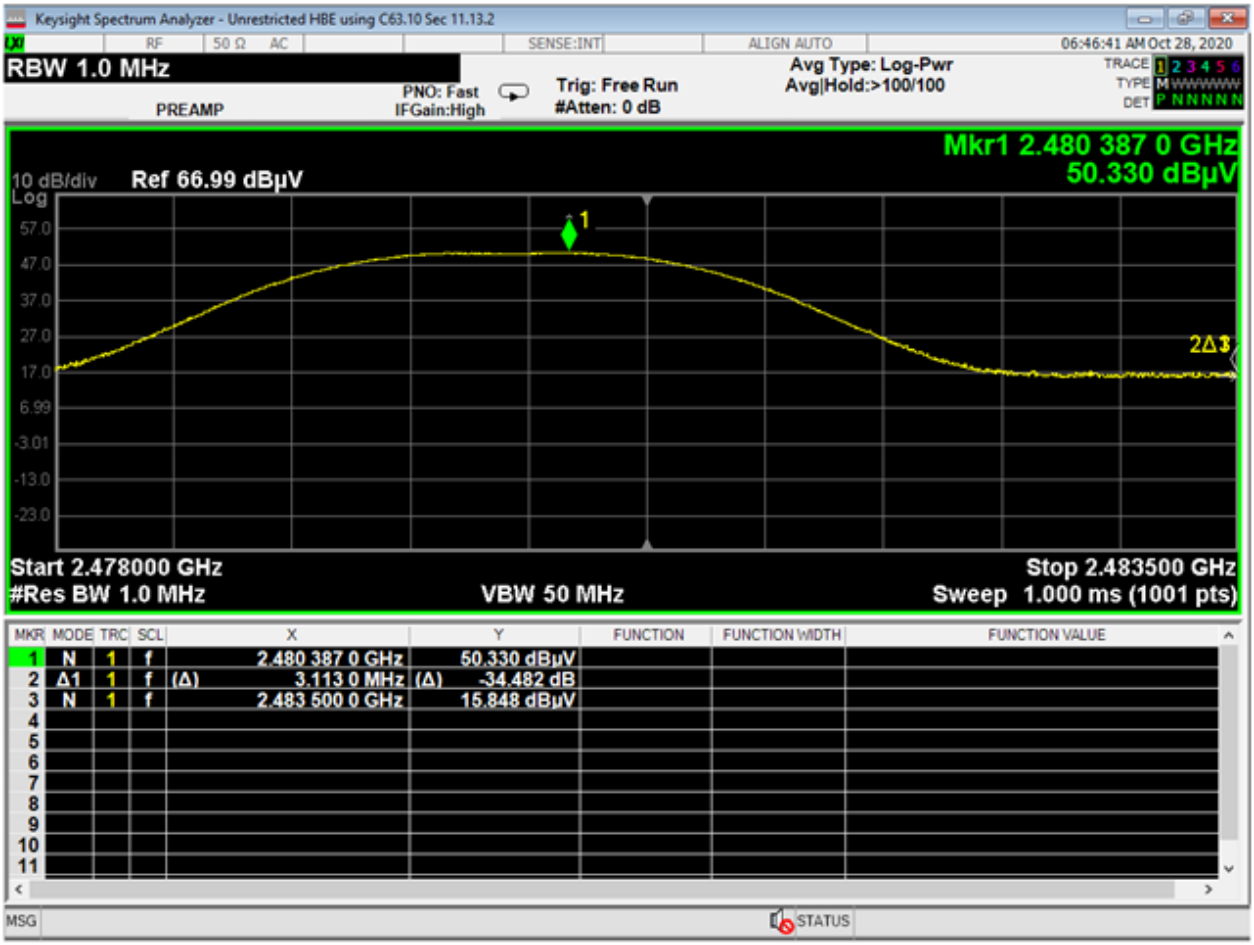
Bandwidth - Low Channel



Bandwidth - Mid Channel

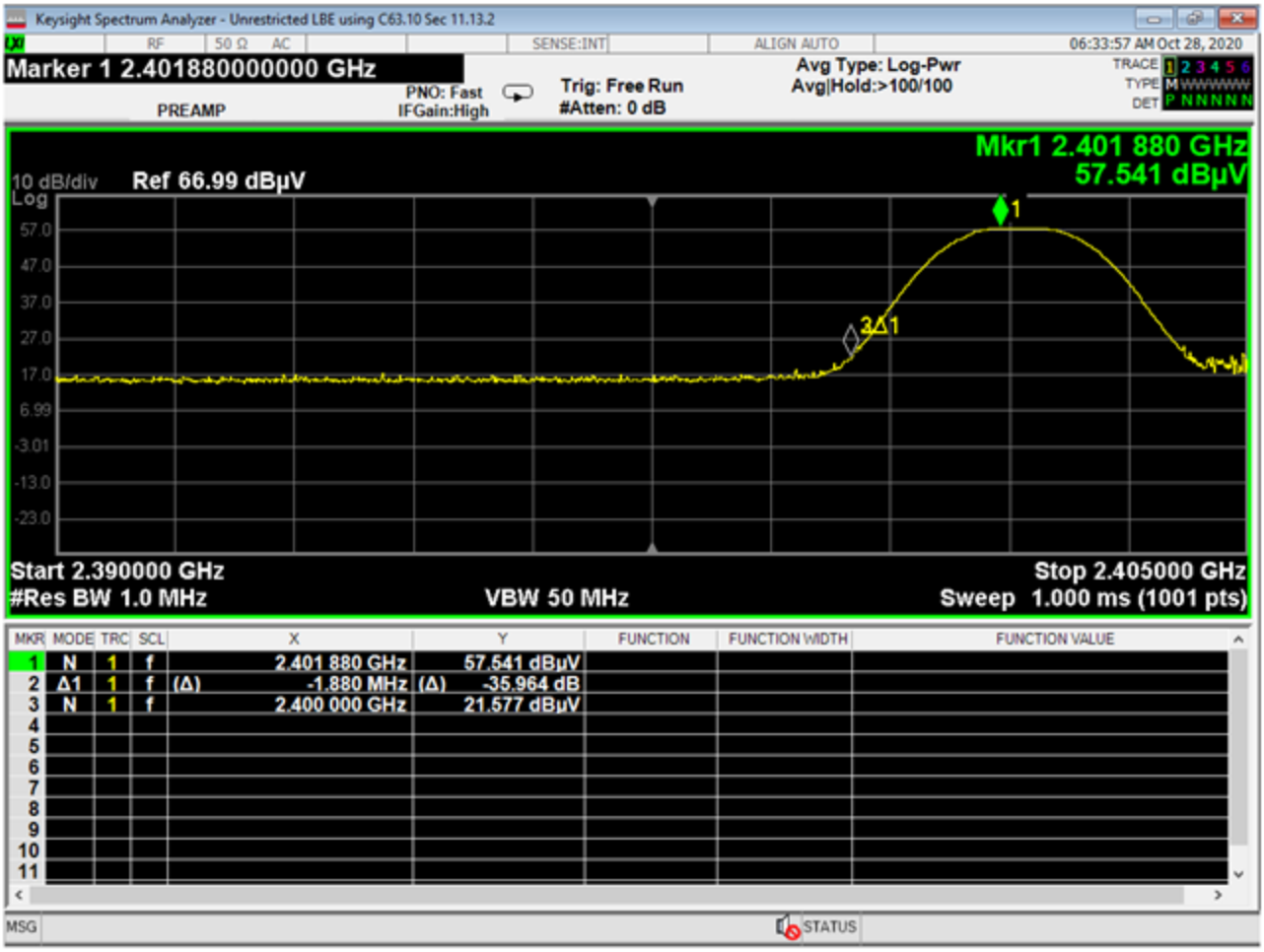


Bandwidth - High Channel



Higher Band Edge Peak

Unrestricted Band-Edge							
CHANNEL	**Mode**	**Band edge /Measurement Frequency (MHz)**	**Highest out of band level (dBuV/m @ 3m)**	**Measurement Type**	**Limit (dBuV/m @ 3m)**	**Margin**	**Result**
High	BLE	2483.50	50.22	Peak	73.98	23.76	PASS
High	BLE	2483.50	43.93	Avg**	53.98	10.05	PASS
*Limit shown is taken from FCC Part 15.209; Plots in Appendix C shows uncorrected measurements **Avg = peak - DCCF							
Band Edge Corrections							
CHANNEL	**Measurement**	**Band edge /Measurement Frequency (MHz)**	**Measurement Type**	**Raw SA uncorrected value (dBuV)**	**Antenna Factor (dB)**	**Cable Loss (dB)**	**Corrected Level (dBuV)**
High	Band Edge	2483.50	Peak	15.85	28.39	5.98	50.22
Plots shows uncorrected measurements; Corrected Level= Raw SA level + Antenna Factor + Cable Loss;							



Lower Band Edge Peak

Unrestricted Band-Edge							
CHANNEL	**Mode**	**Band edge /Measurement Frequency (MHz)**	**Highest out of band level (dBuV/m @ 3m)**	**Measurement Type**	**Limit (dBuV/m @ 3m)**	**Margin**	**Result**
Low	BLE	2400.00	55.917	Peak	73.98	18.06	PASS
Low	BLE	2400.00	49.63	Avg**	53.98	4.35	PASS
*Limit shown is taken from FCC Part 15.209; Plots shows uncorrected measurements **Avg = peak - DCCF							
Band Edge Corrections							
CHANNEL	**Measurement**	**Band edge /Measurement Frequency (MHz)**	**Measurement Type**	**Raw uncorrected value (dBuV)**	**Antenna Factor (dB)**	**Cable Loss (dB)**	**Corrected Level (dBuV)**
Low	Band Edge	2400.00	Peak	21.58	28.38	5.96	55.92
Plots shows uncorrected measurements; Corrected Level= Raw SA level + Antenna Factor + Cable Loss;							

REPORT END