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FCC/ISED Test Report

Prepared for: **Garmin International, Inc.**

Address: **1200 E. 151st Street**
Olathe, Kansas, 66062, USA

Product: **A04659**

Test Report No: **R20220628-20-E1A**

Approved by:

Mahendra Karthik Vepuri, NCE
EMC Test Engineer,
iNARTE Certified EMC Engineer #EMC-041453-E

DATE: **January 3, 2023**

Total Pages: **60**

REVISION PAGE

Rev. No.	Date	Description
0	19 December 2022	Original – KVepuri Reviewed by KVepuri Prepared by FLane, GLarsen
A	3 January 2023	Page 6 was modified-KV

CONTENTS

1.0 SUMMARY OF TEST RESULTS

FCC Part 15.247 ☒

The EUT has been tested according to the following specifications:

(1) US Code of Federal Regulations, Title 47, Part 15

APPLIED STANDARDS AND REGULATIONS		
Standard Section	**Test Type**	**Result**
FCC Part 15.35	Duty Cycle	Pass
FCC Part 15.247(b)(3)	Peak output power	Pass
FCC Part 15.247(a)(2)	Bandwidth	Pass
FCC Part 15.209	Receiver Radiated Emissions	Pass
FCC Part 15.209 (restricted bands), 15.247 (unrestricted)	Transmitter Radiated Emissions	Pass
FCC Part 15.247(e)	Power Spectral Density	Pass
FCC Part 15.209, 15.247(d)	Band Edge Measurement	Pass
FCC Part 15.207	Conducted Emissions	Pass

2.0 EUT DESCRIPTION

2.1 EQUIPMENT UNDER TEST

Summary and Operating Condition:

Equipment under test is a transceiver manufactured by Garmin International Inc.

EUT	A04659
FCC ID:	IPH-04659
EUT Received	21 July 2022
EUT Tested	21 July 2022 - 20 September 2022
Serial No.	3424308878 (Conducted Unit) 3424308866 (Radiated Unit)
Operating Band	2400 – 2483.5 MHz
Device Type	☒ GMSK ☒ GFSK ☐ BT BR ☐ BT EDR 2MB ☐ BT EDR 3MB ☐ 802.11x
Power Supply / Voltage	Internal Battery/ 5VDC Charger: Garmin (Phi Hong) MN: LACA046 (Representative Power Supply)
Antenna Gain (dBi)*	+0.43

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

*See Section 4.9 for more details.

2.2 DESCRIPTION OF TEST MODES

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

The EUT was powered by 5 VDC. It was set to transmit continuously on the 3 different channels of its operating range where available. A ferrite was placed on the charging cable adjacent to the USB-C connector FairRite (0431164951). EUT was investigated with both a short VHF antenna (122mm) and a long VHF antenna (340mm). Data was reported from both.

For GFSK/GMSK 1MB Transmissions:

Channel	Frequency
Low	2402 MHz
Mid	2440 MHz
High	2480 MHz

For GMSK 2MB Transmissions:

Channel	Frequency
Low	2404 MHz
Mid	2440 MHz
High	2478 MHz

These are the only 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.

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	Karthik Vepuri	Test Engineer	Review/editing
2	Fox Lane	Test Engineer	Testing and report
3	Blake Winter	Test Engineer	Testing
4	Grace Larsen	Test Engineer	Testing and report
5	Ethan Schmidt	Test Technician	Testing

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 19, 2022	July 19, 2024
Keysight MXE Signal Analyzer (26.5GHz)***	N9038A	MY56400083	July 19, 2022	July 19, 2024
Keysight EXA Signal Analyzer**	N9010A	MY56070862	July 20, 2021	July 20, 2023
SunAR RF Motion	JB1	A091418-1	July 26, 2022	July 26, 2023
ETS EMCO Red Horn Antenna	3115	00218655	July 21, 2022	July 21, 2023
Rohde & Schwarz Preamplifier*	TS-PR18	3545700803	March 21, 2022	March 21, 2024
8447F POT H64 Preamplifier	8447F POT H64	3113AD4667	March 21, 2022	March 21, 2024
Trilithic High Pass Filter*	6HC330	23042	March 21, 2022	March 21, 2024
TDK Emissions Lab Software	V11.25	700307	NA	NA
RF Cable (preamplifier to antenna)*	MFR-57500	01-07-002	March 21, 2022	March 21, 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 Cal Cycle

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 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.

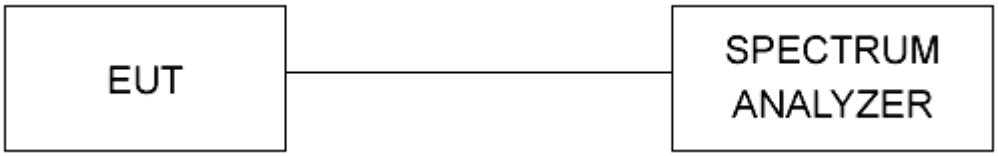


Figure 1 - Bandwidth Measurements Test Setup

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 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.

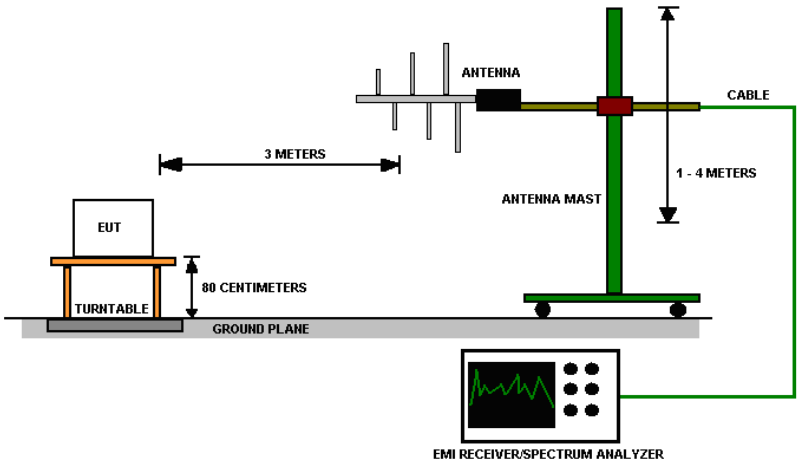


Figure 2 - Radiated Emissions Test Setup

4.0 RESULTS

DTS Radio Measurements							
CHANNEL	**Transmitter**	**Occupied Bandwidth (kHz)**	**6 dB Bandwidth (kHz)**	**PEAK OUTPUT POWER (dBm)**	**PEAK OUTPUT POWER (mW)**	**PSD (dBm)**	**RESULT**
Low	ANT GFSK	1361.80	861.70	2.672	1.850	-15.545	PASS
Mid	ANT GFSK	1879.40	962.80	5.505	3.552	-10.545	PASS
High	ANT GFSK	1534.60	941.10	1.773	1.504	-15.305	PASS
Low	BLE 1Mb	1428.70	868.50	2.643	1.838	-15.738	PASS
Mid	BLE 1Mb	1317.80	811.90	5.407	3.473	-12.087	PASS
High	BLE 1Mb	1345.70	850.70	1.761	1.500	-15.239	PASS
Low	BLE 2Mb	2741.30	1606.00	5.848	3.844	-12.876	PASS
Mid	BLE 2Mb	2628.70	1482.00	5.716	3.729	-12.462	PASS
High	BLE 2Mb	2661.10	1488.00	2.062	1.608	-16.768	PASS
Occupied Bandwidth Limit = N/A; 6 dB Bandwidth Limit > 500 kHz				Peak Output Power Limit = 30 dBm; PSD Limit = 8 dBm			

Unrestricted Band-Edge							
CHANNEL	**Mode**	**Band edge /Measurement Frequency (MHz)**	**Relative Highest out of band level (dBuV)**	**Relative Fundamental (dBuV)**	**Delta (dB)**	**Min Delta (dB)**	**Result**
Low	BLE 1MB	2400.00	66.980	107.990	41.010	20.00	PASS
Low	BLE 2MB	2400.00	68.367	108.941	40.574	20.00	PASS
Low	ANT GFSK	2400.00	66.621	108.043	41.422	20.00	PASS
High	BLE 1MB	2483.50	53.374	106.284	52.911	20.00	PASS
High	BLE 2MB	2483.50	62.111	104.892	42.781	20.00	PASS
High	ANT GFSK	2483.50	56.446	106.801	50.354	20.00	PASS

Peak Restricted 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	GMSK 1MB	2390.00	51.88	Peak	73.98	22.10	PASS
Low	GMSK 2MB	2390.00	52.67	Peak	73.98	21.31	PASS
Low	GFSK	2390.00	52.10	Peak	73.98	21.88	PASS
High	GMSK 1MB	2483.50	55.46	Peak	73.98	18.52	PASS
High	GMSK 2MB	2483.50	57.39	Peak	73.98	16.59	PASS
High	GFSK	2483.50	57.12	Peak	73.98	16.86	PASS
*Limit shown is the peak limit taken from FCC Part 15.209							

Average Restricted 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	GMSK 1MB	2390.00	39.99	Average	53.98	13.99	PASS
Low	GMSK 2MB	2390.00	42.25	Average	53.98	11.74	PASS
Low	GFSK	2390.00	39.96	Average	53.98	14.02	PASS
High	GMSK 1MB	2483.50	44.33	Average	53.98	9.65	PASS
High	GMSK 2MB	2483.50	49.27	Average	53.98	4.71	PASS
High	GFSK	2483.50	45.98	Average	53.98	8.00	PASS
*Limit shown is the average limit taken from FCC Part 15.209							

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 15.247 Device:
The maximum allowed peak output power is 30 dBm / 1000 mW.

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 the measurements were found to be compliant.
3. Compiled values can be found in the Results section, 4.0.

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 15.247 Device:
The 99% occupied bandwidth is for informational purpose only. The 6dB bandwidth of the signal must be greater than 500 kHz.

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 the measurements were found to be compliant.

4.3 DUTY CYCLE

Test Method:

All Modulations/transmitters were provided and tested with a duty cycle of >98%.

4.4 POWER SPECTRAL DENSITY

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 15.247 Device:
The maximum PSD allowed is 8 dBm.

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 Power Spectral Density (PSD) plots can be found in the Appendix C.
2. All the measurements were found to be compliant.
3. The measurements are reported on the graph.

4.5 CONDUCTED SPURIOUS EMISSIONS

Test Method: ANSI C63.10-2013, Section 7.8.8

Limits of spurious emissions:

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 was measured and recorded. All spurious measurements were evaluated to 20dB below the fundamental. 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:

The highest value measured was 3.848 dBm at the fundamental frequency. All other values were at least 20 dB lower. Please note the green line shown in the plots is a reference line, not a limit line.

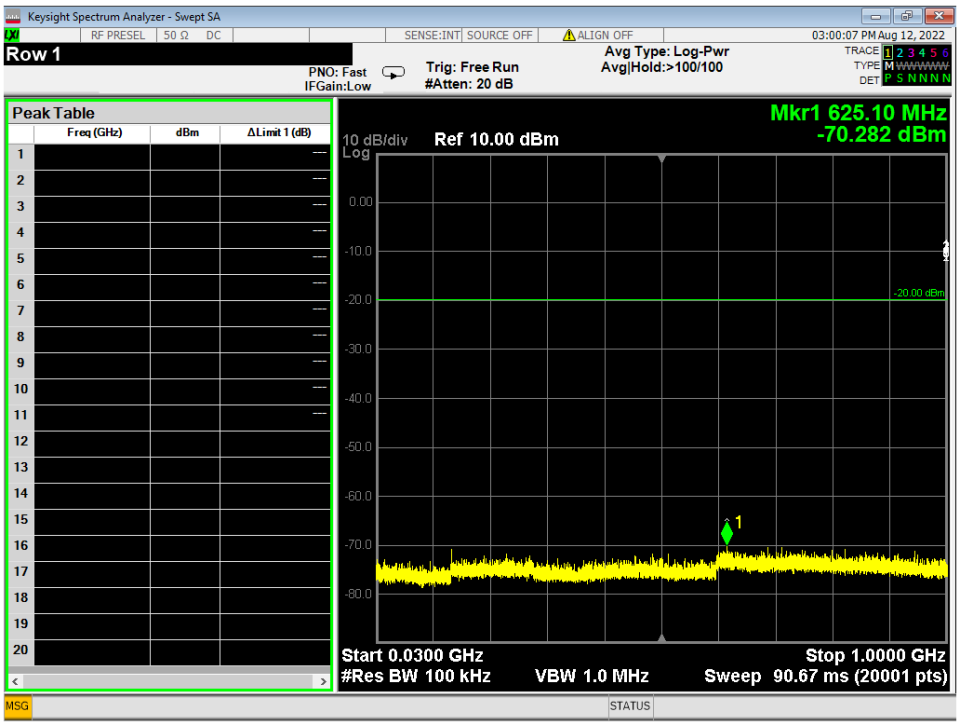


Figure 3 - Radiated Emissions Plot, GFSK, 30M – 1G

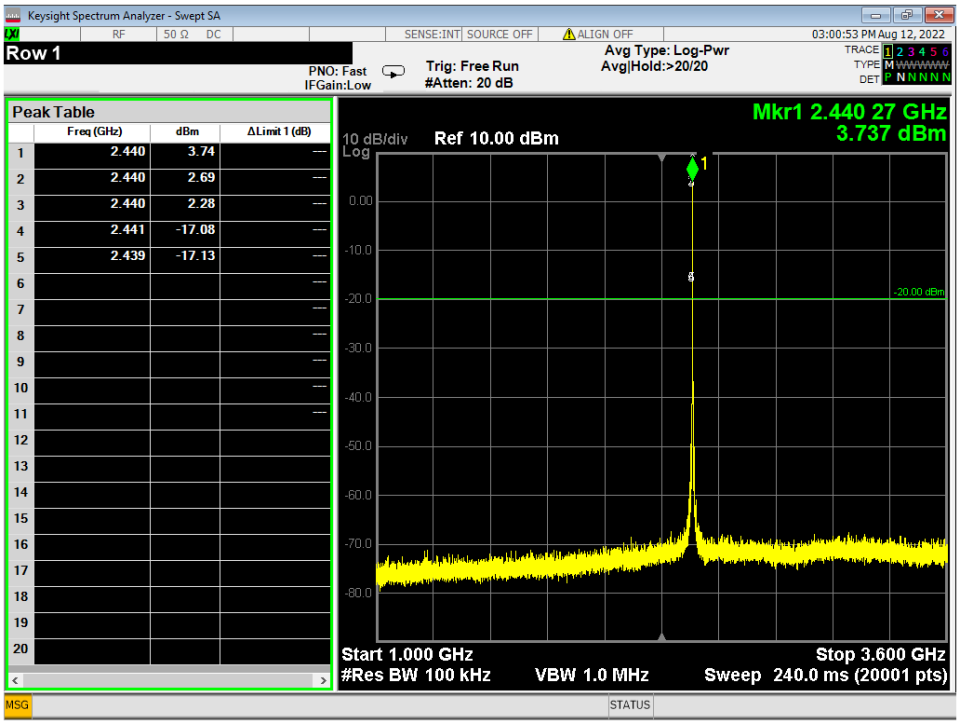


Figure 4 - Radiated Emissions Plot, GFSK, 1G – 3.6G

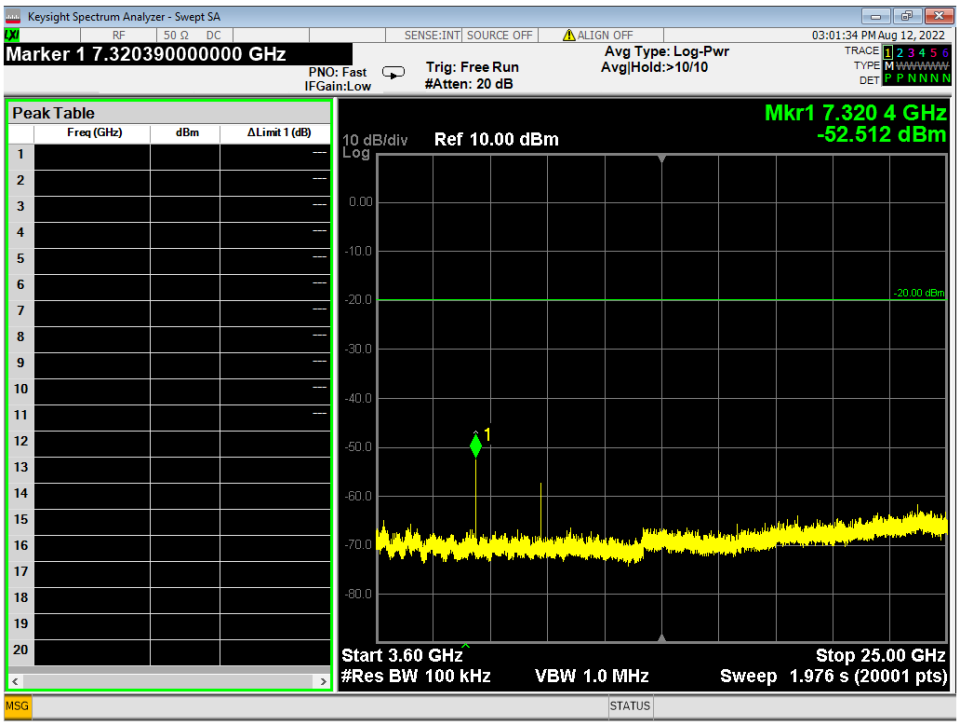


Figure 5 - Radiated Emissions Plot, GFSK, 3.6G – 25G

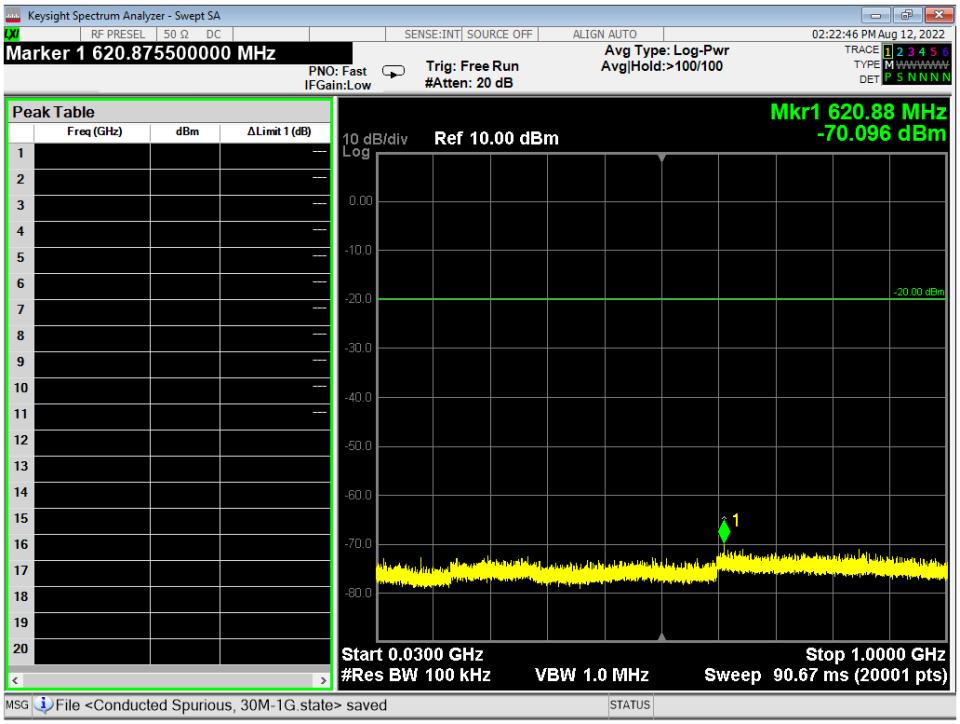


Figure 6 - Radiated Emissions Plot, GMSK 1MB, 30M – 1G

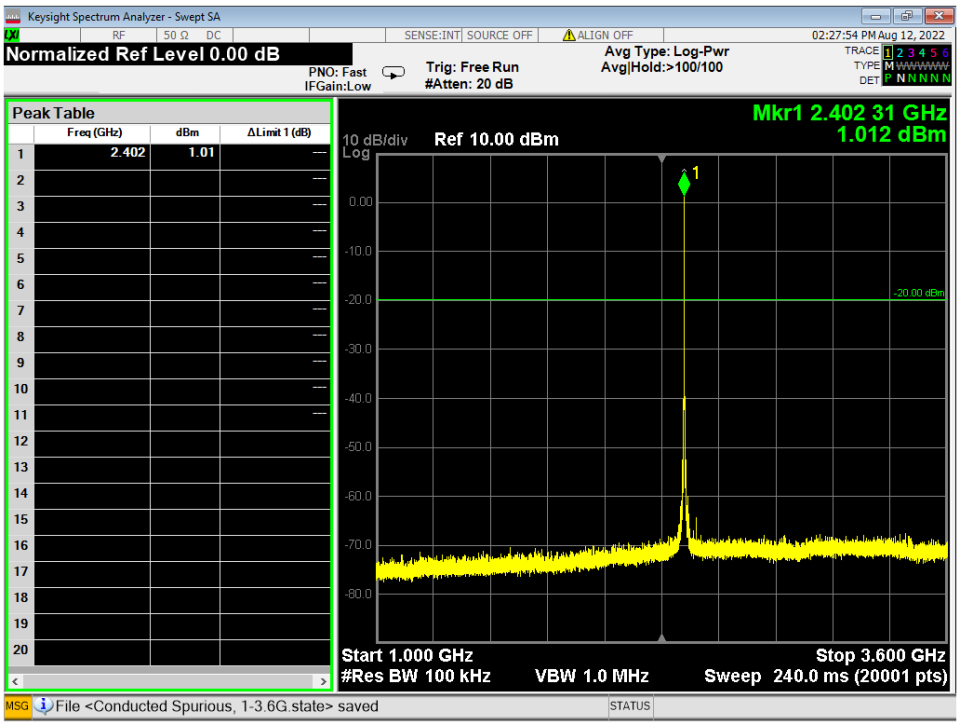


Figure 7 - Radiated Emissions Plot, GMSK 1MB, 1G – 3.6G

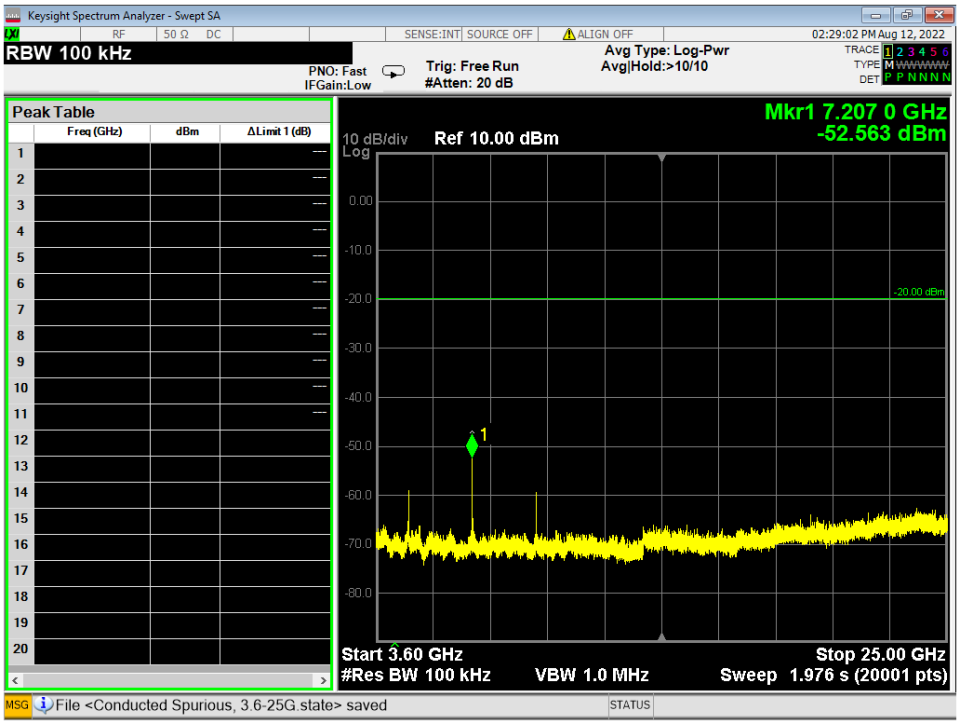


Figure 8 - Radiated Emissions Plot, GMSK 1MB, 3.6G – 25G

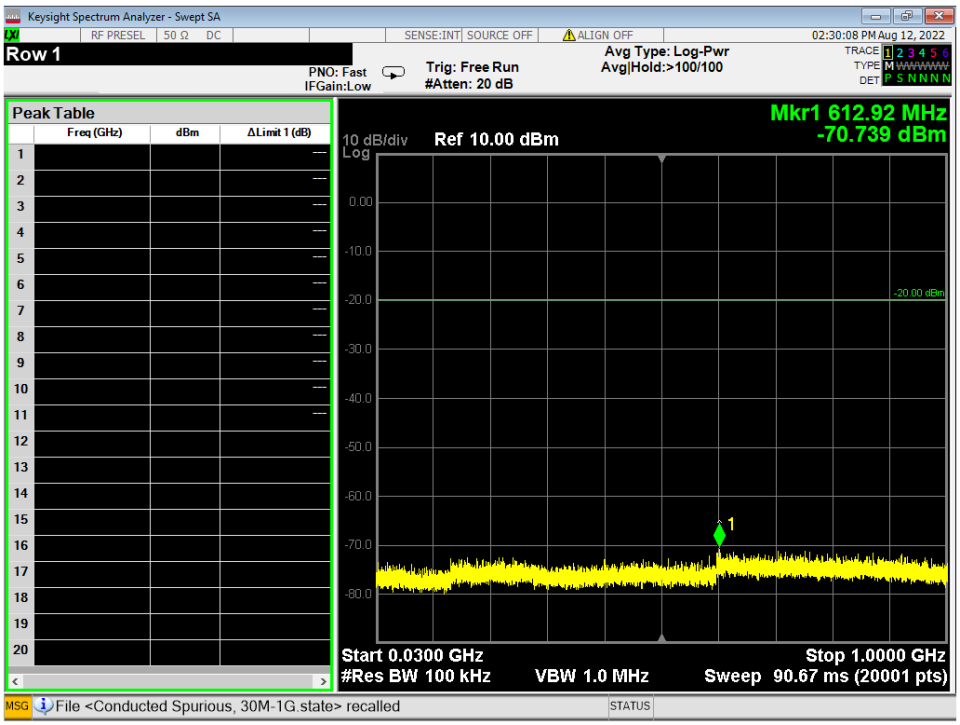


Figure 9 - Radiated Emissions Plot, GMSK 2MB, 30M – 1G

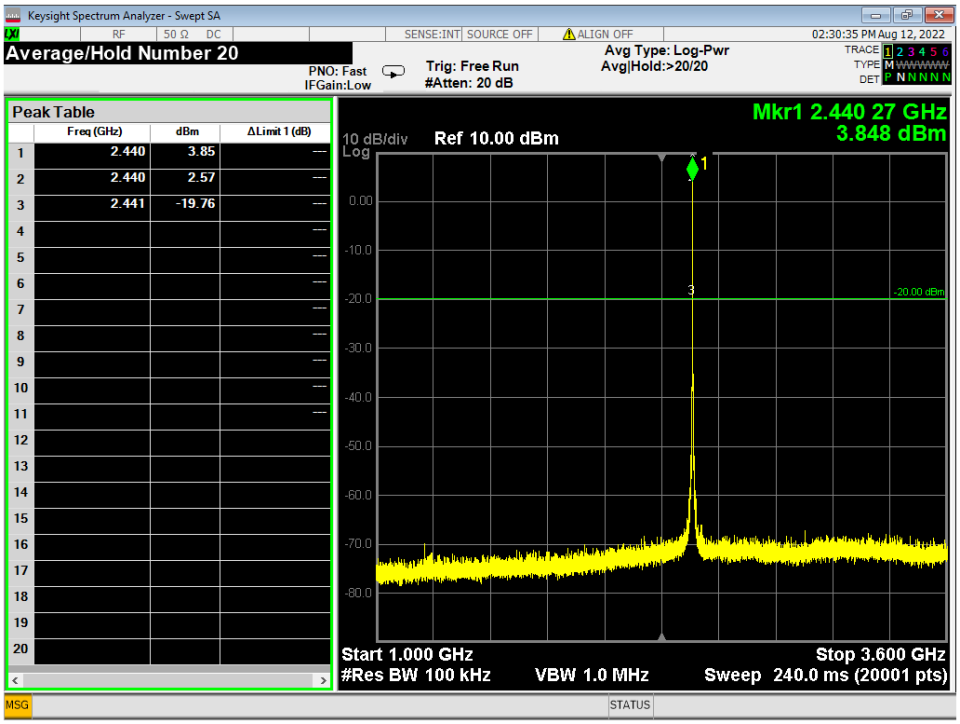


Figure 10 - Radiated Emissions Plot, GMSK 2MB, 1G – 3.6G

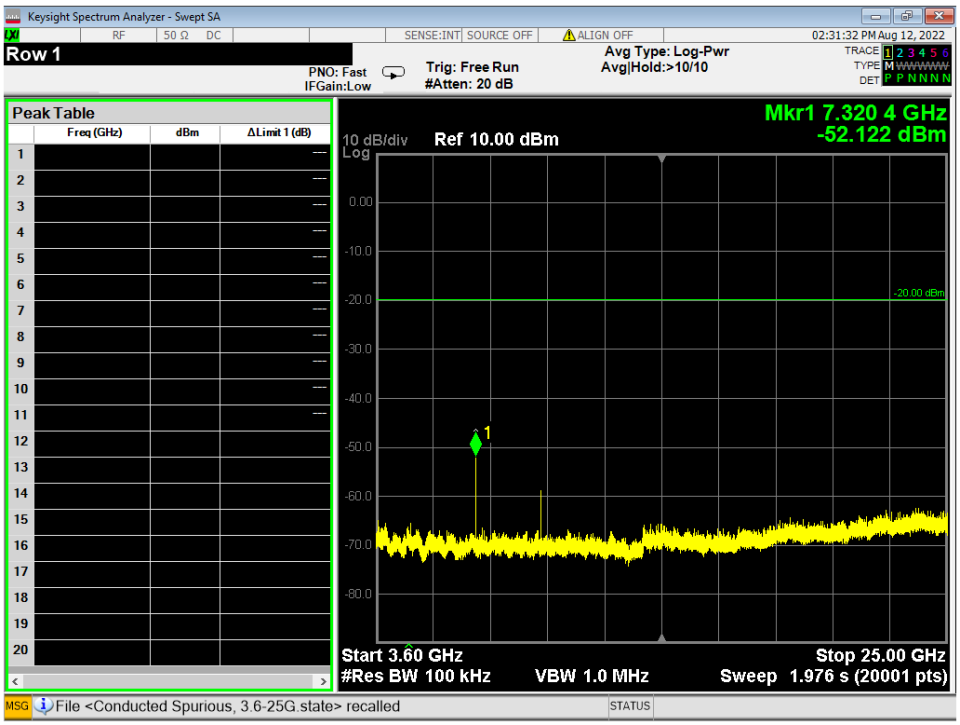


Figure 11 - Radiated Emissions Plot, GMSK 2MB, 3.6G – 25G

4.6 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.

Test setup:

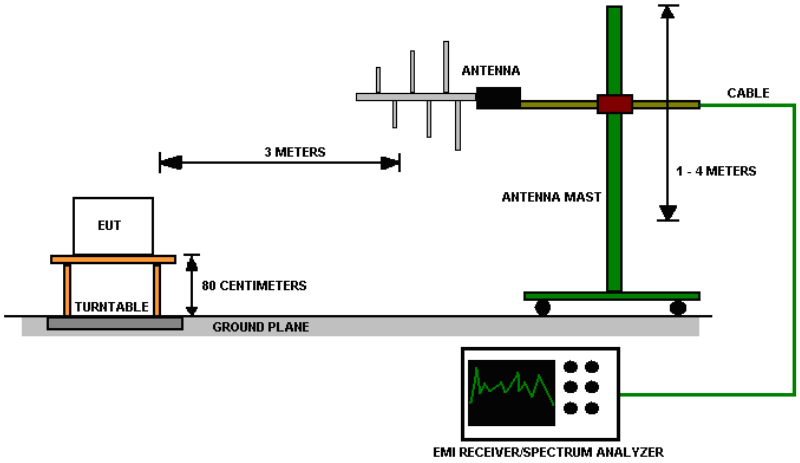


Figure 12 - Radiated Emissions Test Setup

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:

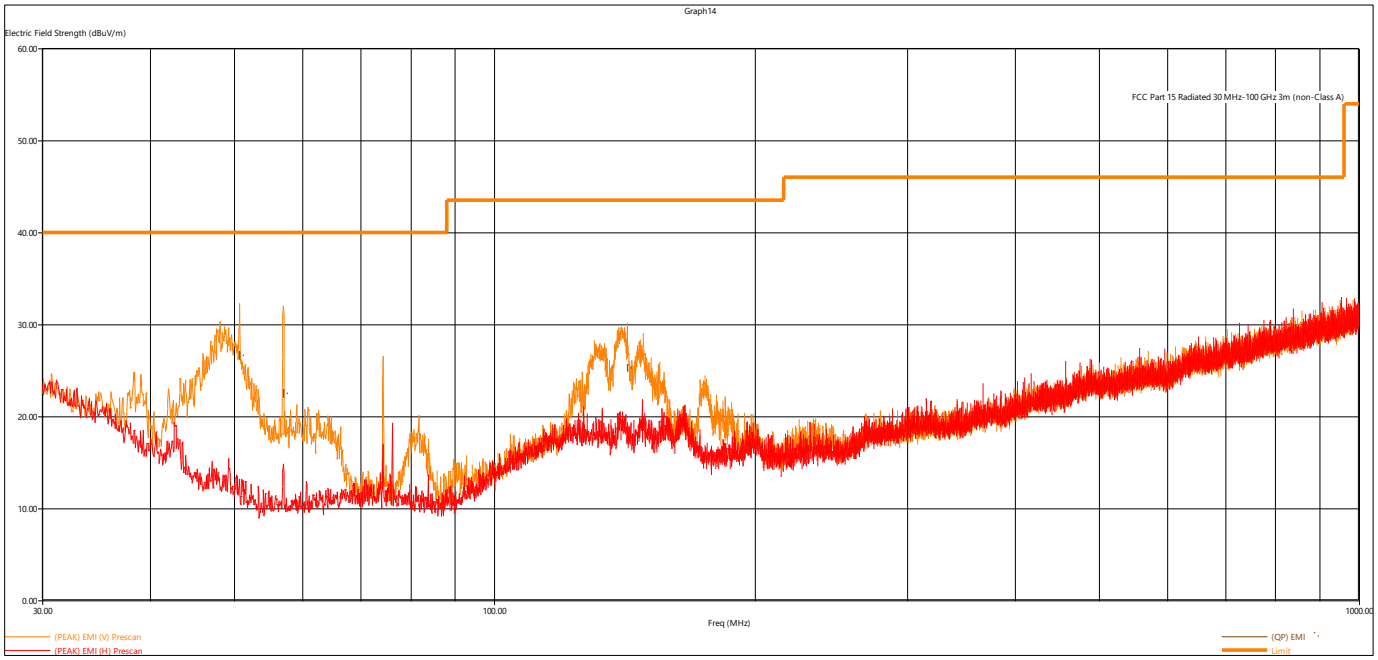


Figure 13 - Radiated Emissions Plot, Receive, Short Antenna

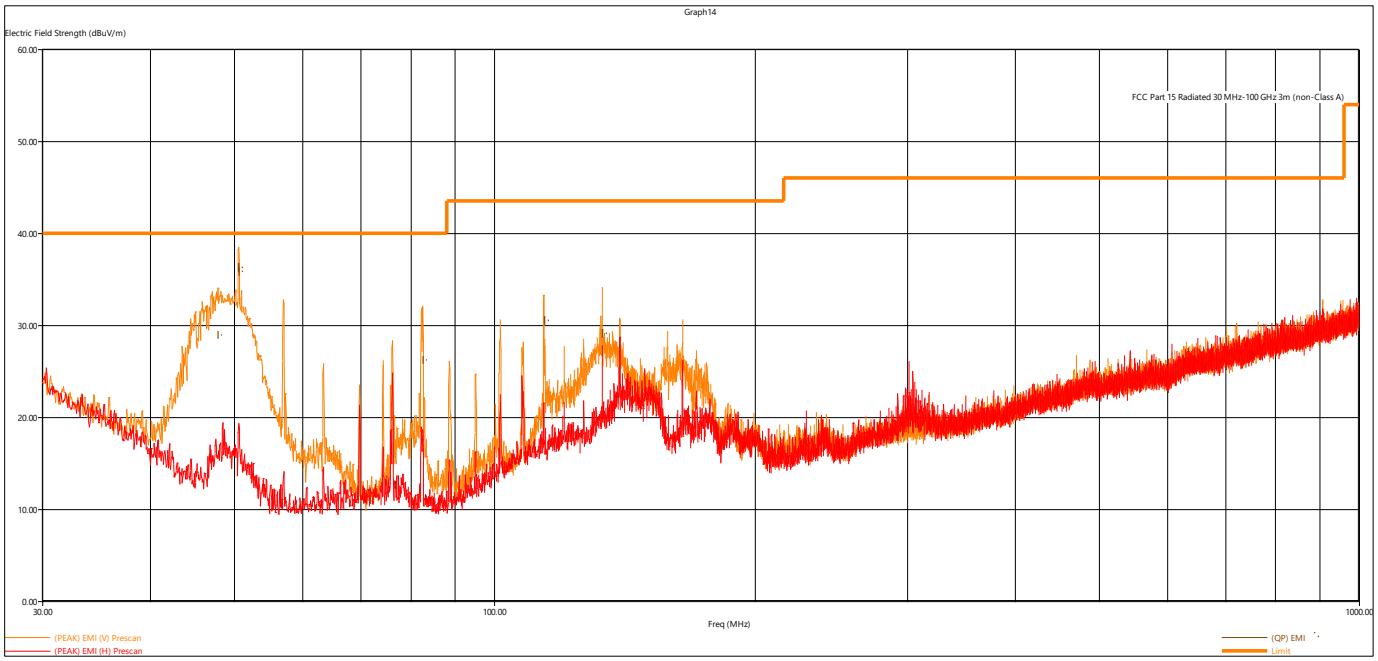


Figure 14 - Radiated Emissions Plot, GFSK, Short Antenna

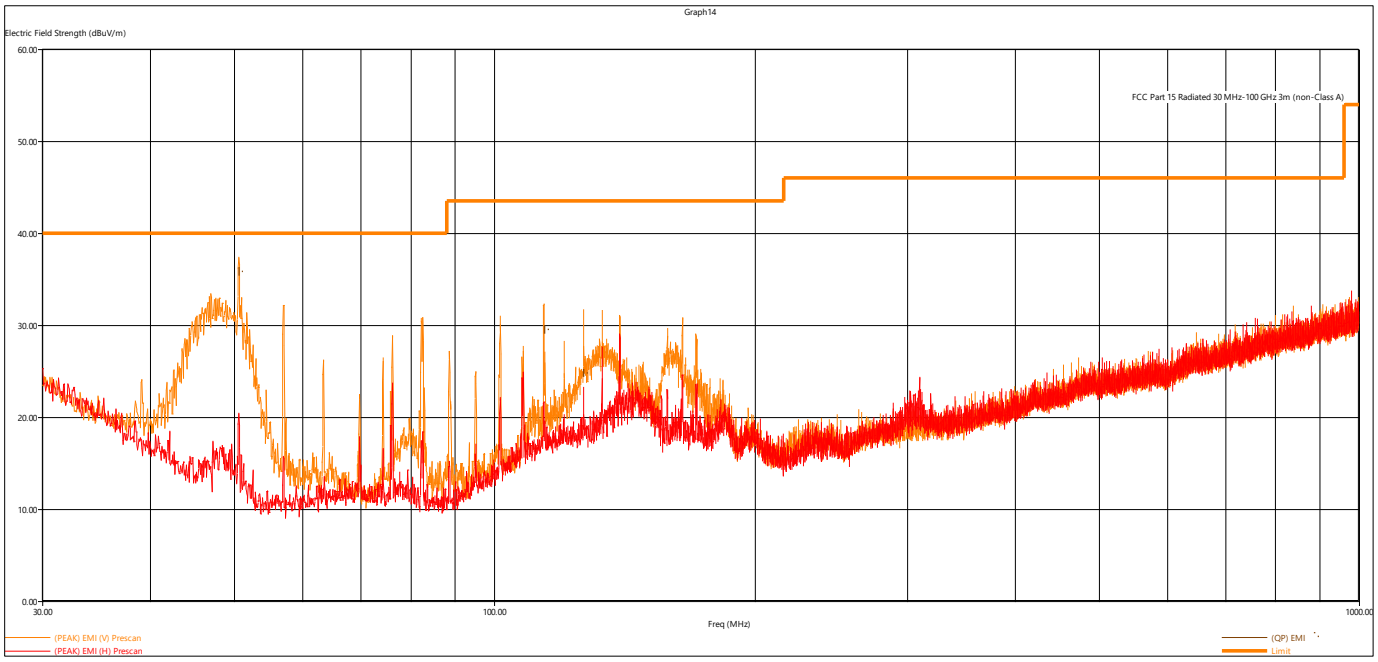


Figure 15 - Radiated Emissions Plot, GMSK 1MB, Short Antenna

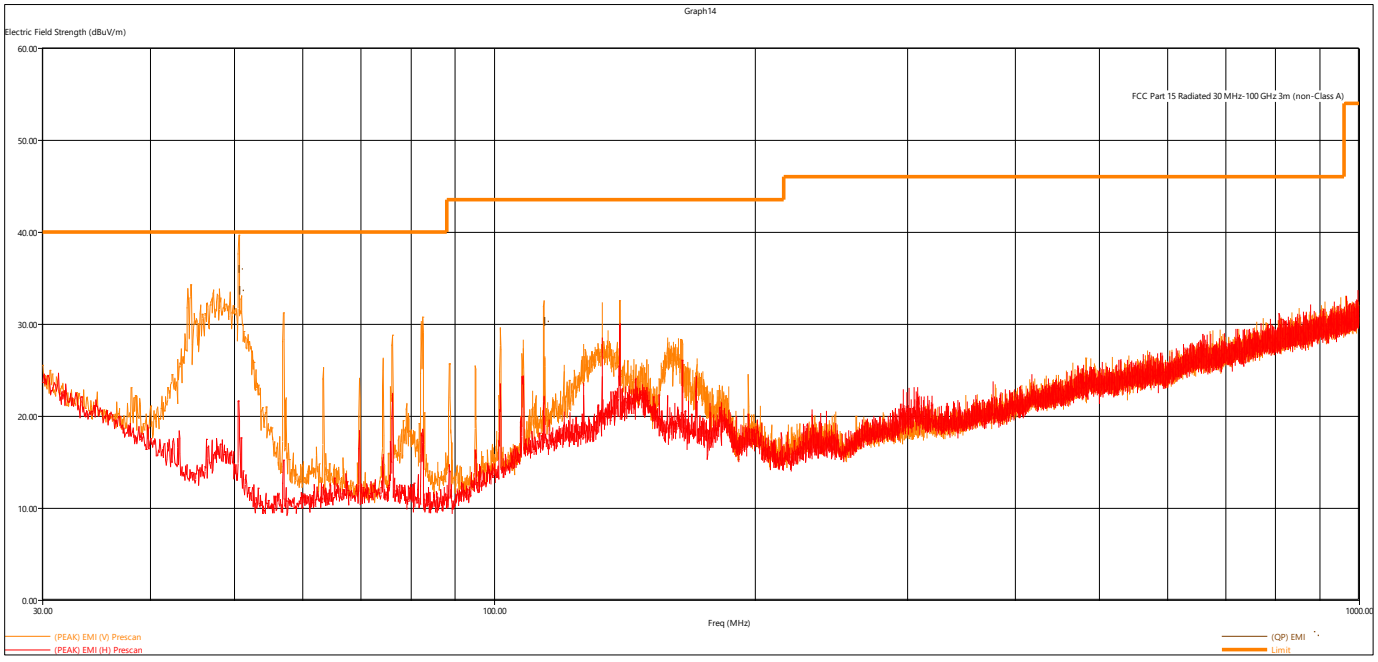


Figure 16 - Radiated Emissions Plot, GMSK 2MB, Short Antenna

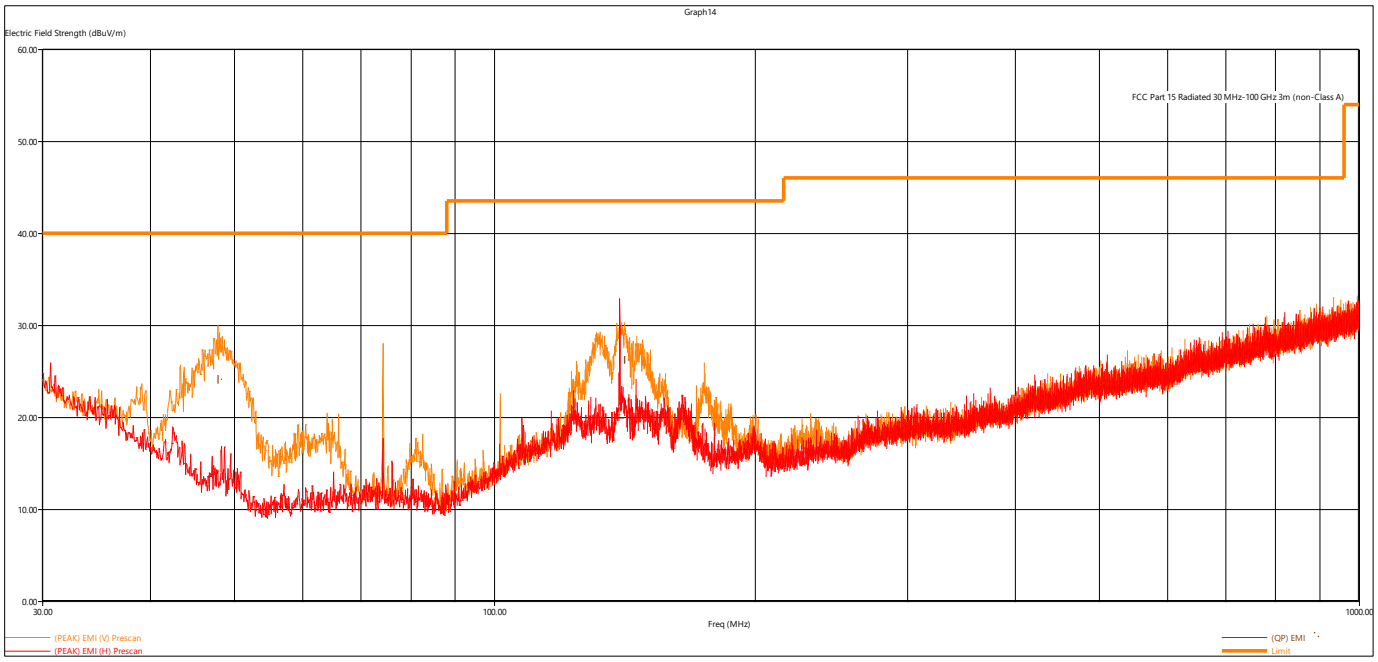


Figure 17 - Radiated Emissions Plot, Receive, Long Antenna

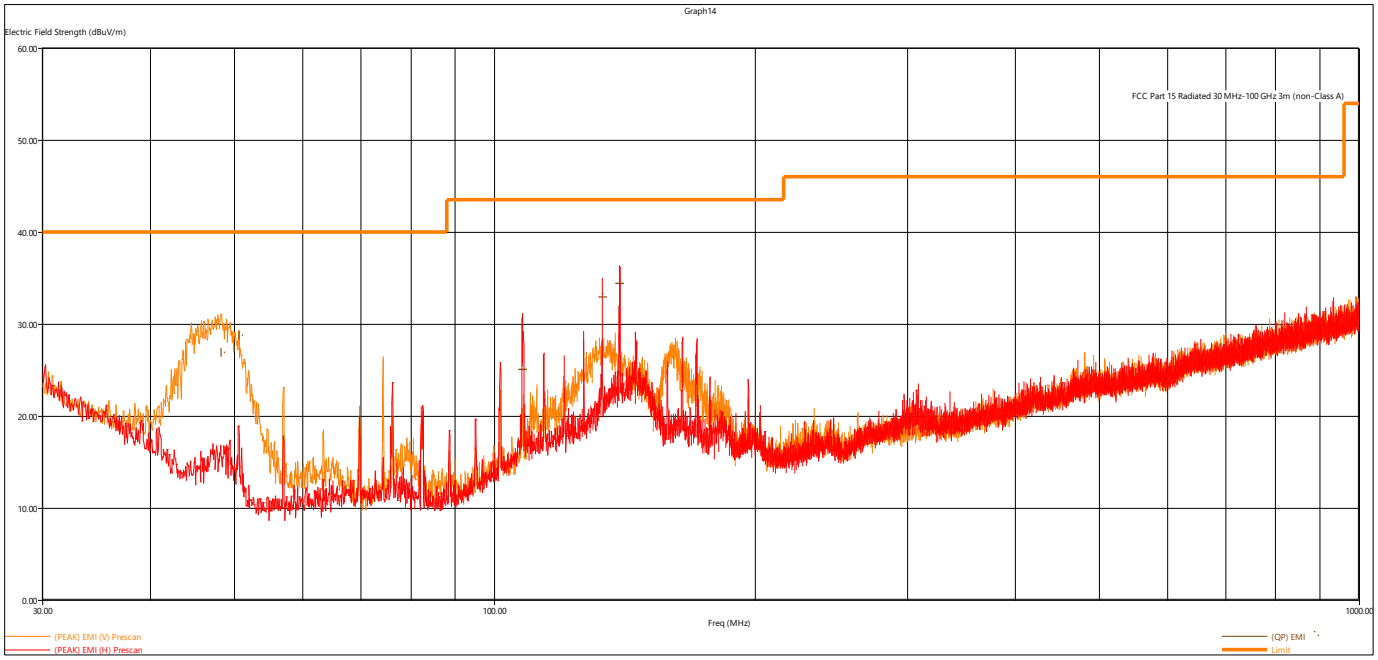


Figure 18 - Radiated Emissions Plot, GFSK, Long Antenna

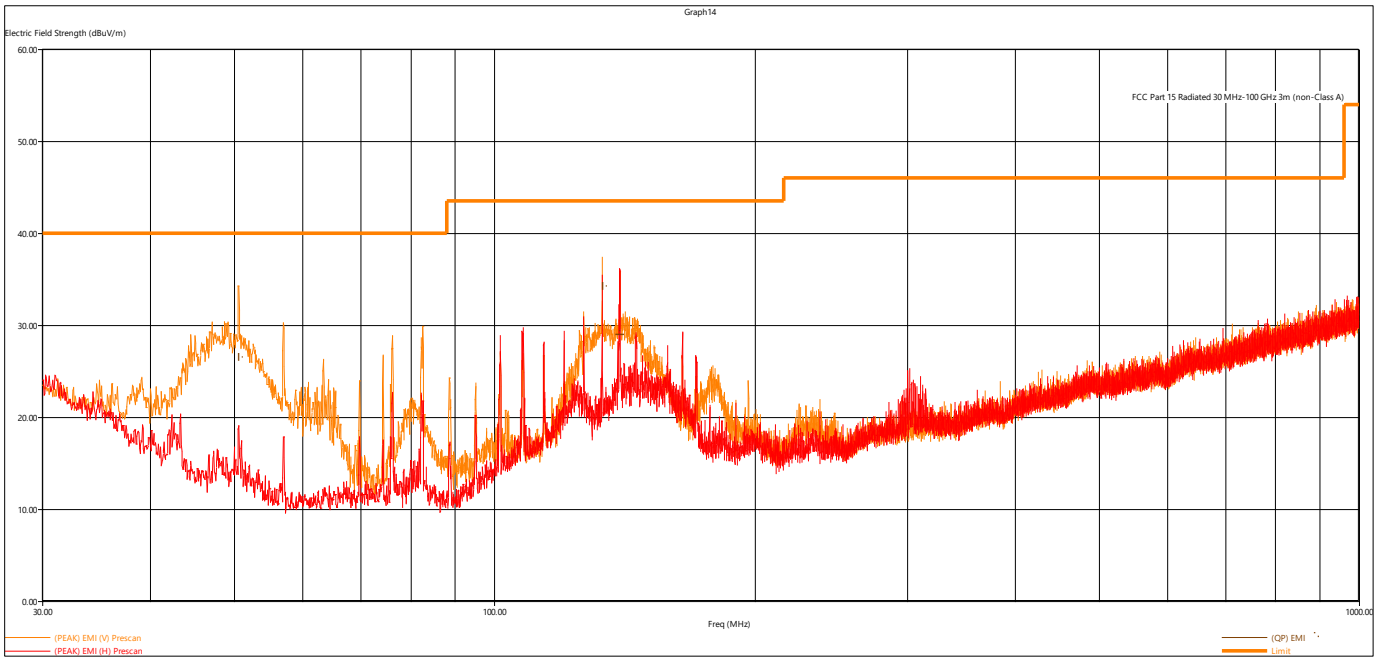


Figure 19 - Radiated Emissions Plot, GMSK 1MB, Long Antenna

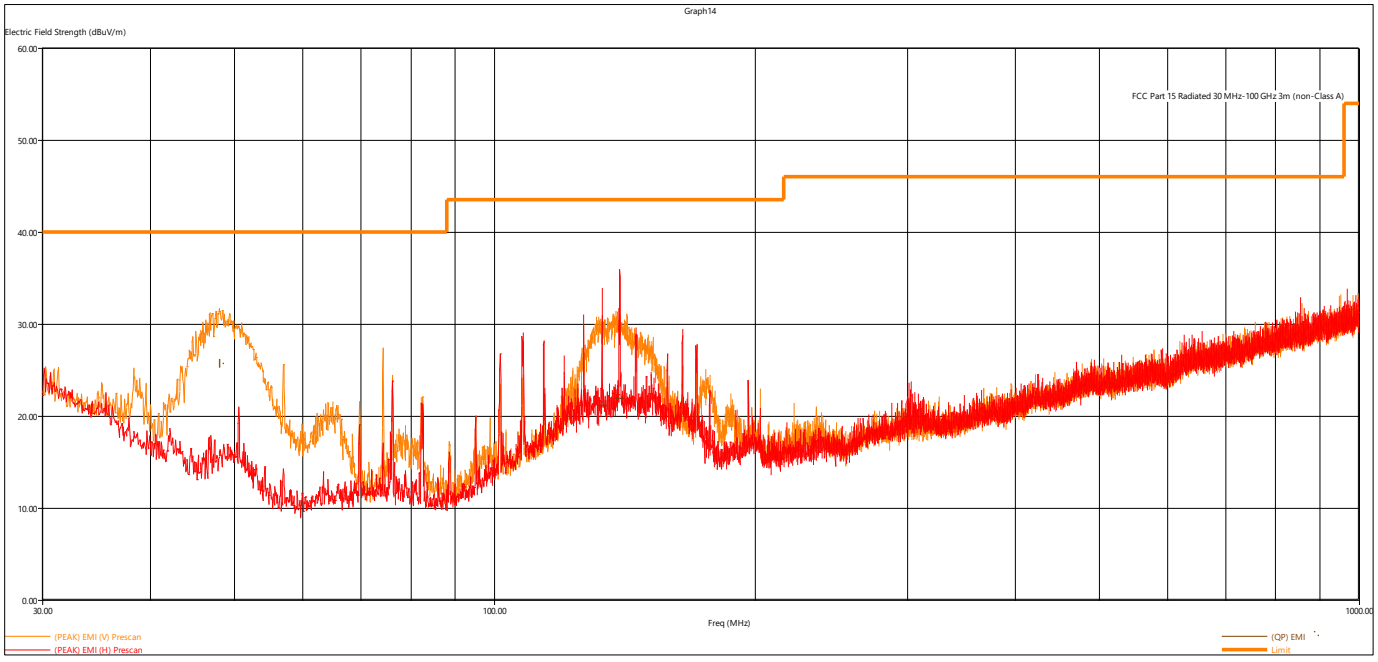


Figure 20 - Radiated Emissions Plot, GMSK 2MB, Long Antenna

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, GMSK-GFSK								
Frequency	**Level**	**Limit**	**Margin**	**Height**	**Angle**	**Pol**	**EUT Antenna**	**Modulation**
MHz	**dBµV/m**	**dBµV/m**	**dB**	**cm.**	**deg.**			
47.97024	28.89	40	11.11	119	221	V	Short	GFSK
47.796	24.03	40	15.97	105	193	V	Long	Receive
48.03456	25.62	40	14.38	126	226	V	Long	GMSK 2MB
48.15264	26.85	40	13.15	112	226	V	Long	GFSK
50.418	26.49	40	13.51	100	0	V	Long	GMSK 1MB
50.45688	28.69	40	11.31	127	21	V	Long	GFSK
50.54928	26.56	40	13.44	127	271	V	Short	Receive
50.56632	**36.27**	**40**	**3.73**	**111**	**357**	**V**	**Short**	**GFSK**
50.63688	35.79	40	4.21	109	62	V	Short	GFSK
50.63736	35.9	40	4.10	100	0	V	Short	GMSK 2MB
50.67384	33.6	40	6.40	100	5	V	Short	GMSK 2MB
50.6856	35.8	40	4.20	159	53	V	Short	GMSK 1MB
56.90832	22.43	40	17.57	163	336	V	Short	Receive
82.4352	26.17	40	13.83	154	10	V	Short	GFSK
107.4581	24.99	43.52	18.53	253	68	H	Long	GFSK
113.7386	30.25	43.52	13.27	100	70	V	Short	GMSK 2MB
113.9018	29.42	43.52	14.10	110	64	V	Short	GMSK 1MB
113.9083	30.47	43.52	13.05	111	159	V	Short	GFSK
126.7018	24.74	43.52	18.78	134	152	V	Short	GMSK 1MB
132.931	29.1	43.52	14.42	115	200	V	Short	GFSK
132.9521	21.07	43.52	22.45	235	281	H	Long	GMSK 2MB
132.9914	32.89	43.52	10.63	184	64	H	Long	GFSK
133.1316	34.22	43.52	9.30	100	180	V	Long	GMSK 1MB
139.3452	19.81	43.52	23.71	202	52	H	Long	Receive
139.3524	34.35	43.52	9.17	252	89	H	Long	GFSK
139.5804	28.92	43.52	14.6	211	68	H	Long	GMSK 1MB
139.661	21.86	43.52	21.66	209	82	H	Long	GMSK 2MB
141.1922	26.2	43.52	17.32	107	109	V	Long	Receive
142.1422	25.21	43.52	18.31	118	76	V	Short	Receive

Peak Measurements, GMSK-GFSK								
Frequency	**Level**	**Limit**	**Margin**	**Height**	**Angle**	**Pol**	**Channel**	**Modulation**
MHz	**dBµV/m**	**dBµV/m**	**dB**	**cm.**	**deg.**			
2402.160	98.73	NA	NA	177	337	H	Low	GMSK 1MB
2440.240	104.49	NA	NA	137	347	H	Mid	GMSK 1MB
2479.774	98.55	NA	NA	242	353	H	High	GMSK 1MB
2404.456	102.82	NA	NA	222	3	H	Low	GMSK 2MB
2440.456	104.57	NA	NA	139	351	H	Mid	GMSK 2MB
4881.048	49.20	73.98	24.78	305	334	H	Mid	GMSK 2MB
2477.504	98.73	NA	NA	241	350	H	High	GMSK 2MB
2402.264	99.31	NA	NA	139	348	H	Low	GFSK
2440.278	104.70	NA	NA	135	351	H	Mid	GFSK
2479.714	99.29	NA	NA	131	352	H	High	GFSK

The EUT was maximized in all 3 orthogonal axes. The worst-case is shown in the plot and table above. All other emissions found to be at least 6dB below the limit line. System Noise floor was at least 6 dB below the limit line throughout the test range.

Average Measurements, GMSK-GFSK								
Frequency	**Level**	**Limit**	**Margin**	**Height**	**Angle**	**Pol**	**Channel**	**Modulation**
MHz	**dBµV/m**	**dBµV/m**	**dB**	**cm.**	**deg.**			
2402.160	96.46	NA	NA	177	337	H	Low	GMSK 1MB
2440.240	101.94	NA	NA	137	347	H	Mid	GMSK 1MB
2479.774	96.22	NA	NA	242	353	H	High	GMSK 1MB
2404.456	97.23	NA	NA	222	3	H	Low	GMSK 2MB
2440.456	98.87	NA	NA	139	351	H	Mid	GMSK 2MB
4881.048	39.64	53.98	14.34	305	334	H	Mid	GMSK 2MB
2477.504	92.53	NA	NA	241	350	H	High	GMSK 2MB
2402.264	96.67	NA	NA	139	348	H	Low	GFSK
2440.278	101.63	NA	NA	135	351	H	Mid	GFSK
2479.714	95.87	NA	NA	131	352	H	High	GFSK

The EUT was maximized in all 3 orthogonal axes. The worst-case is shown in the plot and table above. All other emissions found to be at least 6dB below the limit line. System Noise floor was at least 6 dB below the limit line throughout the test range.

4.7 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 the 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 to the general limit defined in Part 15.209. The limit shown in the graph accounts for the antenna gain of the device.

4.8 CONDUCTED AC MAINS EMISSIONS

Test Method: ANSI C63.10-2013, Section(s) 6.2

Limits for conducted emissions measurements:

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

Notes:
1. The lower limit shall apply at the transition frequencies.
2. The limit decreases in line with the logarithm of the frequency in the range of 0.15 to 0.50 MHz
3. All emanations from a class A/B digital device or system, including any network of conductors and apparatus connected thereto, shall not exceed the level of field strengths specified above.

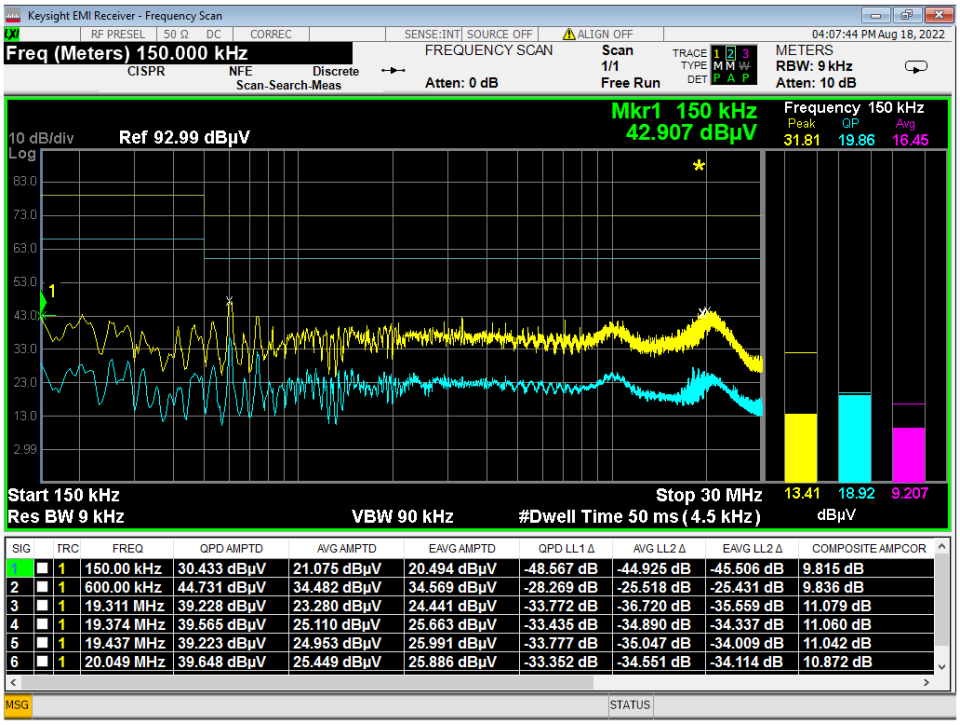
Test Procedures:

a. The EUT was placed 0.8m above a ground reference plane and 0.4 meters from the conducting wall of a shielded room with EUT being connected to the power mains through a line impedance stabilization network (LISN). The LISN provides 50 ohm/ 50uH of coupling impedance for the measuring instrument.
b. Both lines of the power mains connected to the EUT were checked for maximum conducted interference as well as the ground.
c. The frequency range from 150 kHz to 30 MHz was searched. Emission levels over 10dB under the prescribed limits are not reported.
d. Results were compared to the 15.207 limits.

Deviation from the test standard:
No deviation

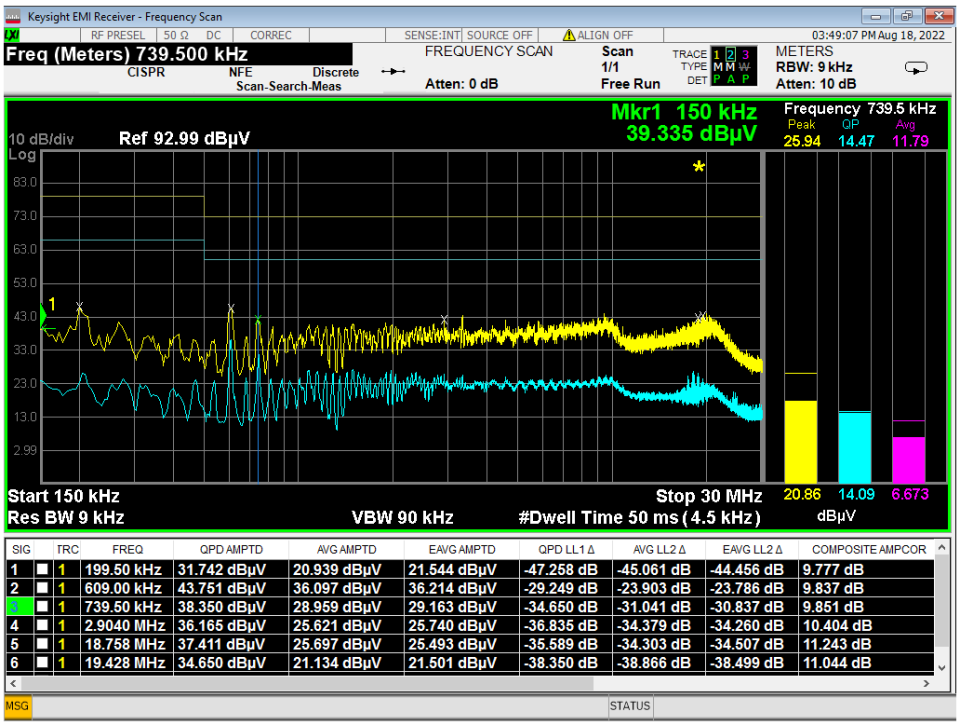
EUT operating conditions:
Details can be found in section 2.1 of this report.
.

Test Results:



SIG	TRC	FREQ	QPD AMPTD	AVG AMPTD	EAVG AMPTD	QPD LL1 Δ	AVG LL2 Δ	EAVG LL2 Δ	COMPOSITE AMPCOR
1	1	150.00 kHz	30.433 dBµV	21.075 dBµV	20.494 dBµV	-48.567 dB	-44.925 dB	-45.506 dB	9.815 dB
2	1	600.00 kHz	44.731 dBµV	34.482 dBµV	34.569 dBµV	-28.269 dB	-25.518 dB	-25.431 dB	9.836 dB
3	1	19.311 MHz	39.228 dBµV	23.280 dBµV	24.441 dBµV	-33.772 dB	-36.720 dB	-35.559 dB	11.079 dB
4	1	19.374 MHz	39.565 dBµV	25.110 dBµV	25.663 dBµV	-33.435 dB	-34.890 dB	-34.337 dB	11.060 dB
5	1	19.437 MHz	39.223 dBµV	24.953 dBµV	25.991 dBµV	-33.777 dB	-35.047 dB	-34.009 dB	11.042 dB
6	1	20.049 MHz	39.648 dBµV	25.449 dBµV	25.886 dBµV	-33.352 dB	-34.551 dB	-34.114 dB	10.872 dB

Figure 21 - Conducted Emissions Plot, Line, TX



SIG	TRC	FREQ	QPD AMPTD	AVG AMPTD	EAVG AMPTD	QPD LL1 Δ	AVG LL2 Δ	EAVG LL2 Δ	COMPOSITE AMPCOR
1	1	199.50 kHz	31.742 dBµV	20.939 dBµV	21.544 dBµV	-47.258 dB	-45.061 dB	-44.456 dB	9.777 dB
2	1	609.00 kHz	43.751 dBµV	36.097 dBµV	36.214 dBµV	-29.249 dB	-23.903 dB	-23.786 dB	9.837 dB
3	1	739.50 kHz	38.350 dBµV	28.959 dBµV	29.163 dBµV	-34.650 dB	-31.041 dB	-30.837 dB	9.851 dB
4	1	2.9040 MHz	36.165 dBµV	25.621 dBµV	25.740 dBµV	-36.835 dB	-34.379 dB	-34.260 dB	10.404 dB
5	1	18.758 MHz	37.411 dBµV	25.697 dBµV	25.493 dBµV	-35.589 dB	-34.303 dB	-34.507 dB	11.243 dB
6	1	19.428 MHz	34.650 dBµV	21.134 dBµV	21.501 dBµV	-38.350 dB	-38.866 dB	-38.499 dB	11.044 dB

Figure 22 - Conducted Emissions Plot, Neutral, TX

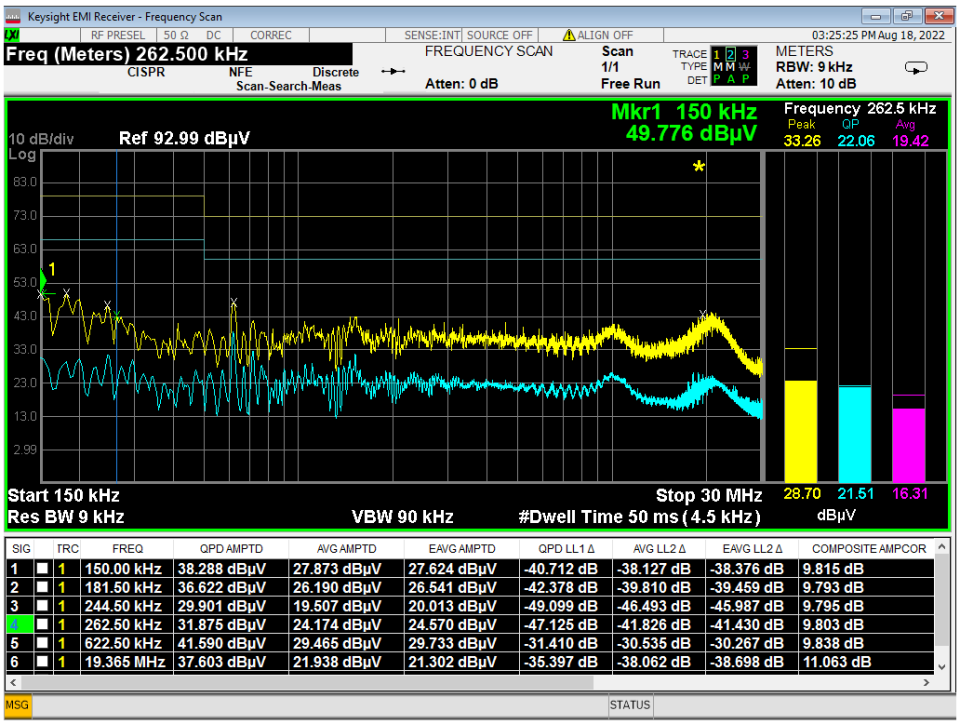


Figure 23 - Conducted Emissions Plot, Line, IDLE

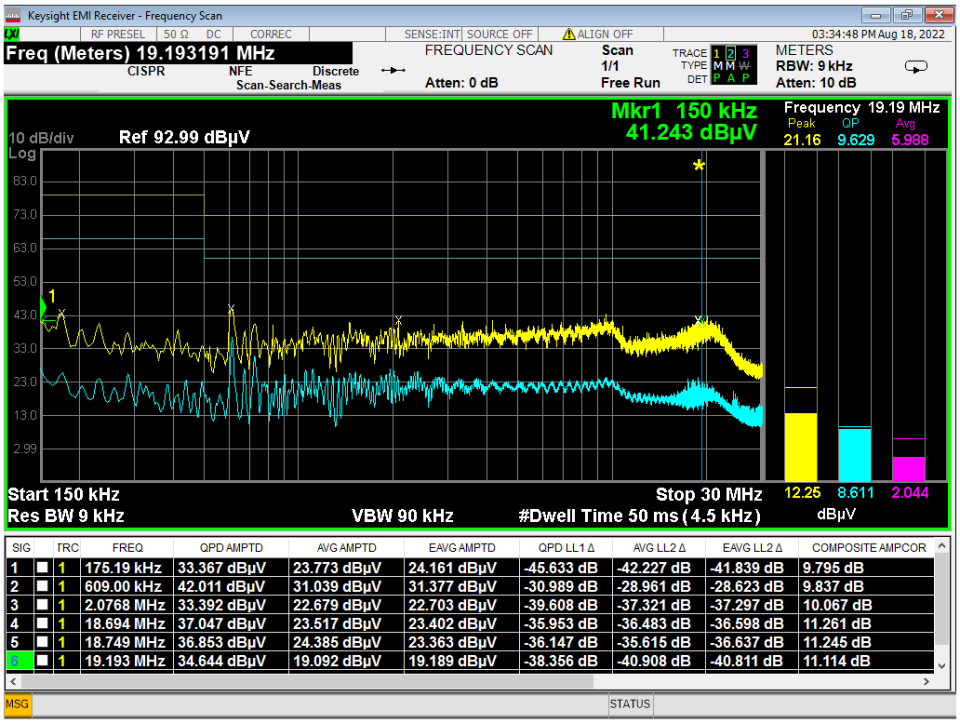


Figure 24 - Conducted Emissions Plot, Neutral, IDLE

4.9 ANTENNA GAIN

Test procedures:
Device's conducted power was measured, and the same measurement was repeated through a substitution method measurement at 3m test distance.

Test setup:
Details can be found in section 2.1 of this report.

EUT operating conditions:
Details can be found in section 2.1 and 2.2 of this report.

Test results:

Antenna Gain:
Radiated Average Substitution method – Conducted Average Power = Antenna gain
19.54 dBm – 19.11 dBm = +0.43 **dBi**

Comments:

1. Device was compared only on the highest power modulation/transmitter and the results were used for all other modulations/transmitters within that frequency band that use the same antenna (2400 – 2483.5 MHz band)
2. Results were taken from 802.11x family of transmitters, see report R20220628-20-E3 for further plots/details

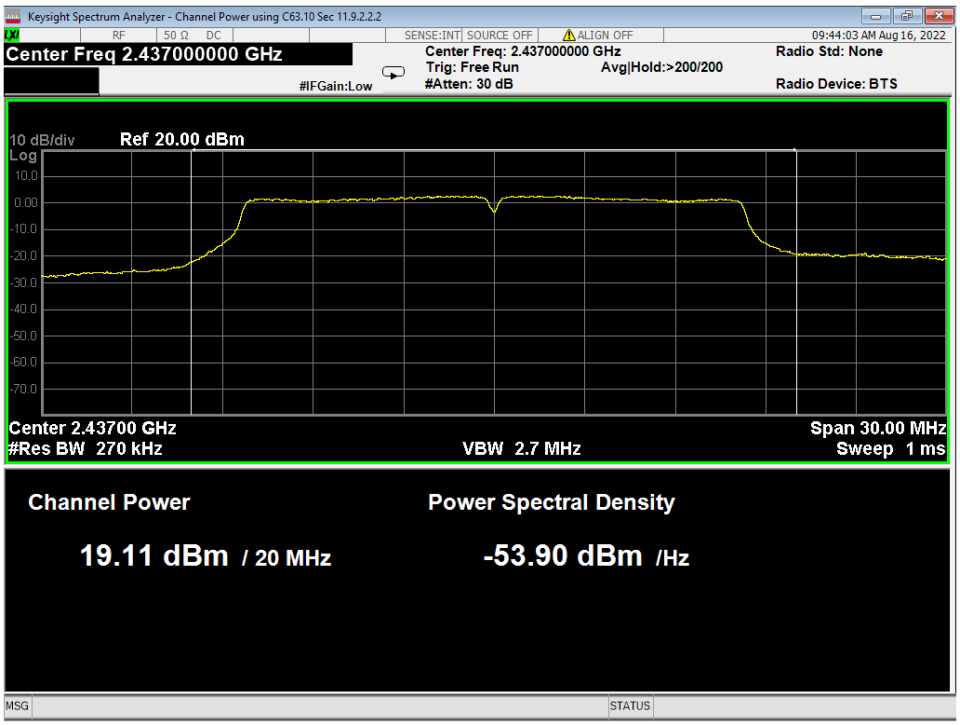


Figure 25 – Conducted Average Power Measurement, 802.11g 6MB

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

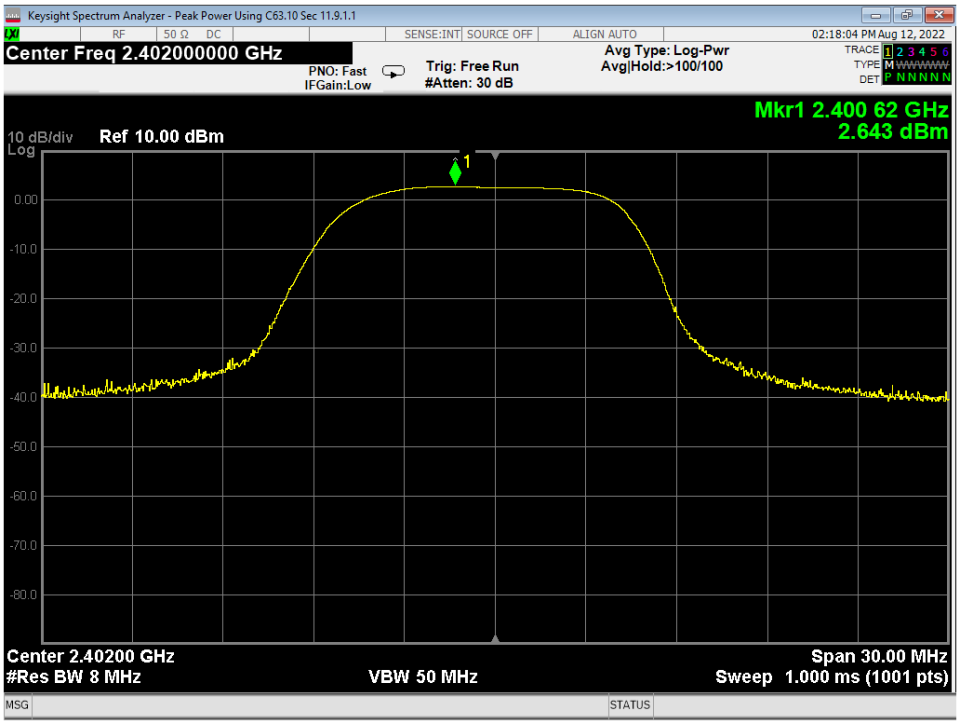
APPENDIX B – MEASUREMENT UNCERTAINTY

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

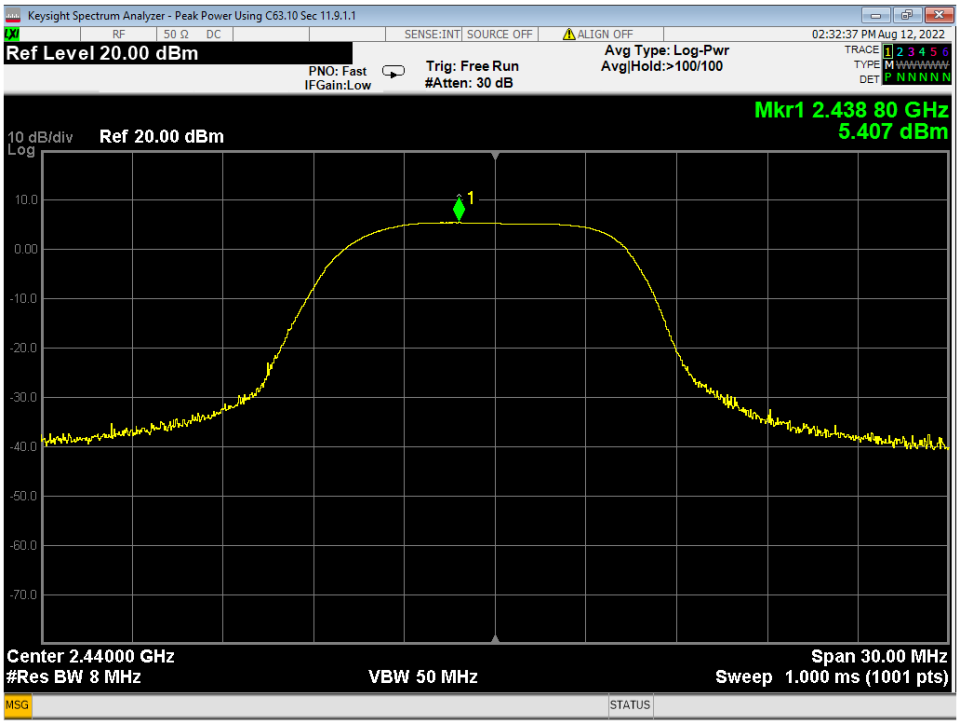
Test	Frequency Range	Uncertainty Value (dB)
Radiated Emissions, 3m	30MHz - 1GHz	±4.31
Radiated Emissions, 3m	1GHz - 18GHz	±5.08
Emissions limits, conducted	150kHz – 30MHz	±3.03

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

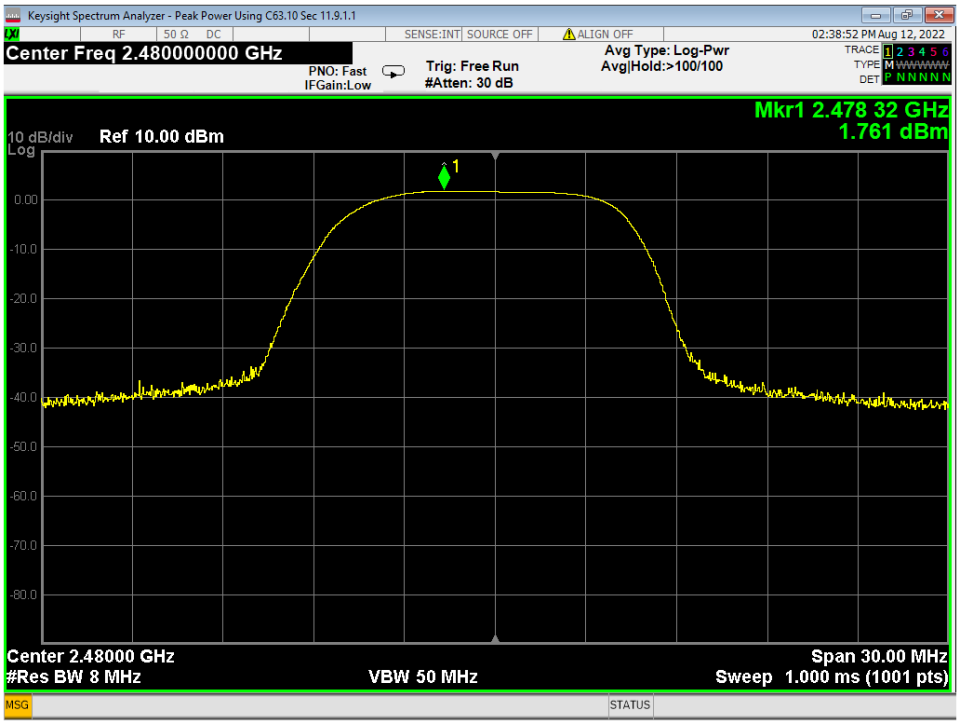
APPENDIX C – GRAPHS AND TABLES



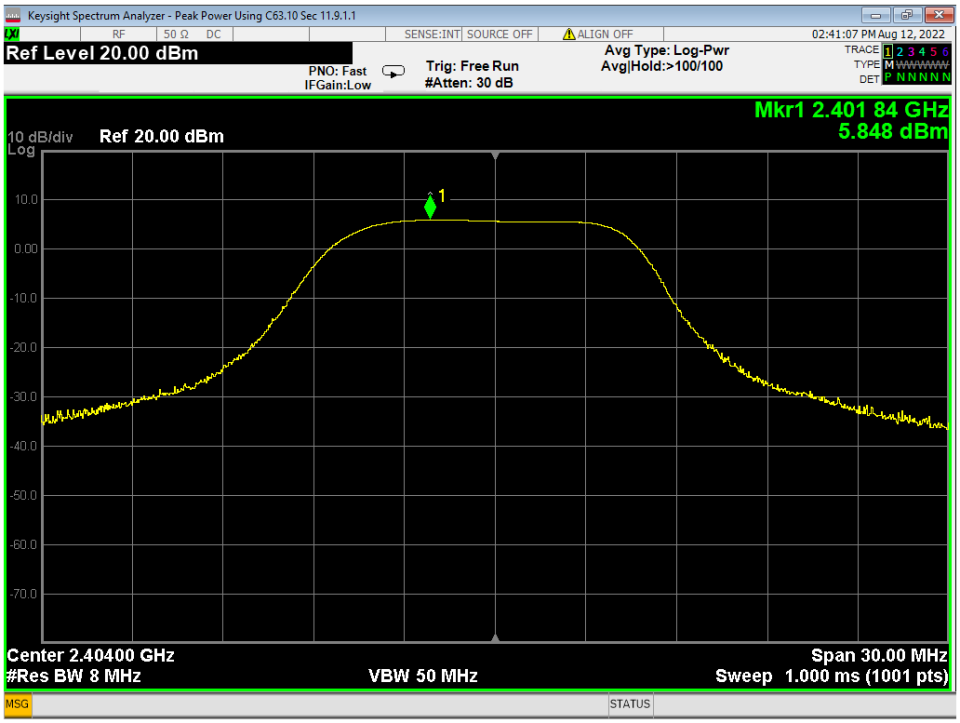
1 Peak Power, Low Channel, GMSK 1MB



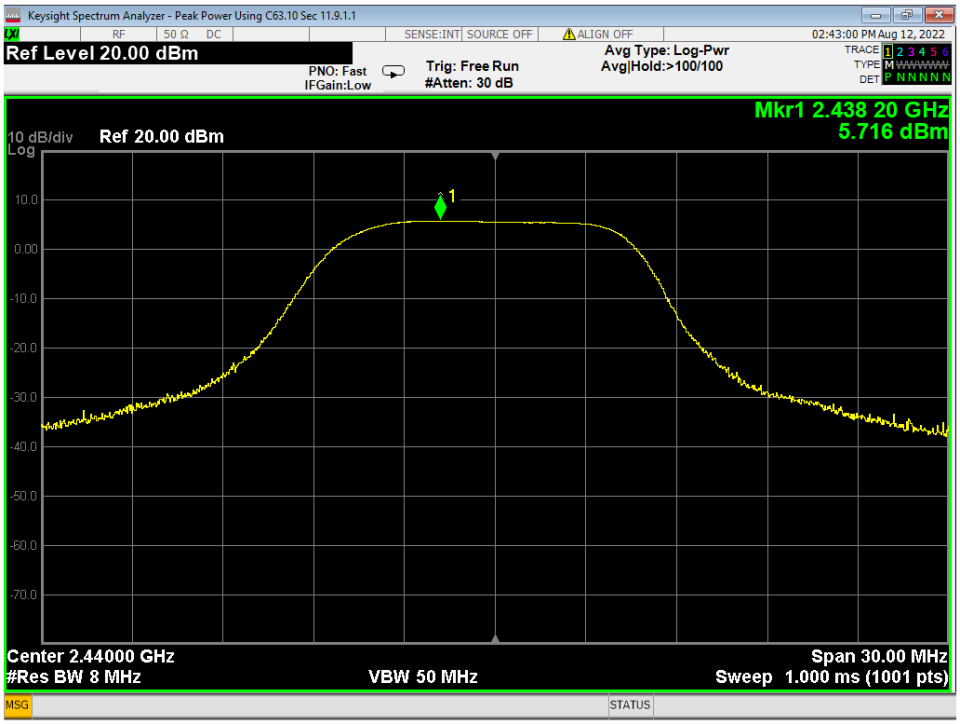
2 Peak Power, Mid Channel, GMSK 1MB



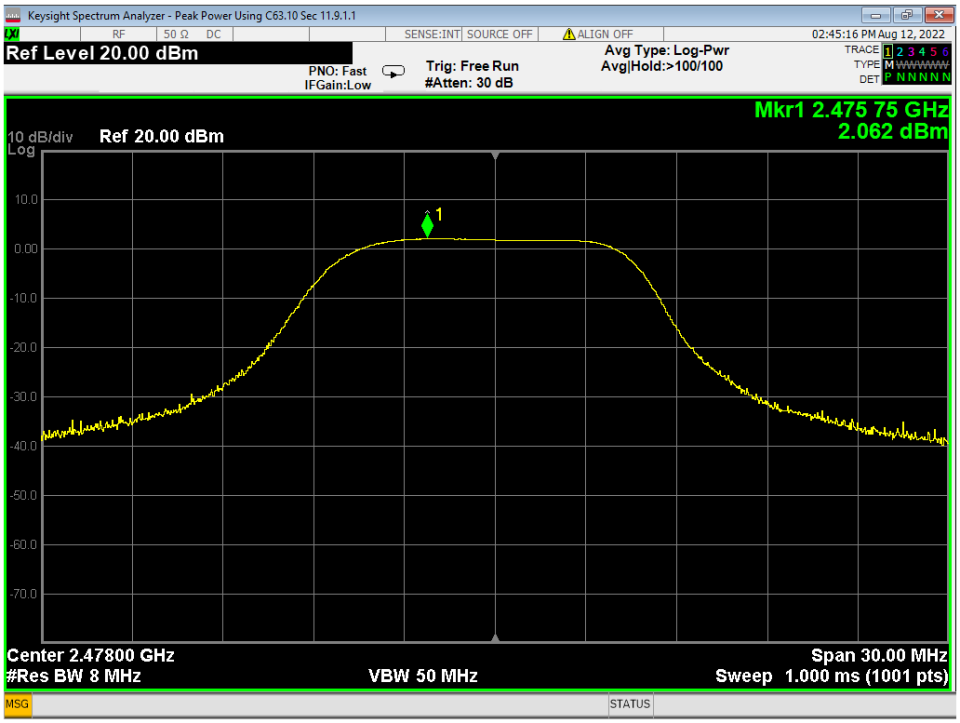
3 Peak Power, High Channel, GMSK 1MB



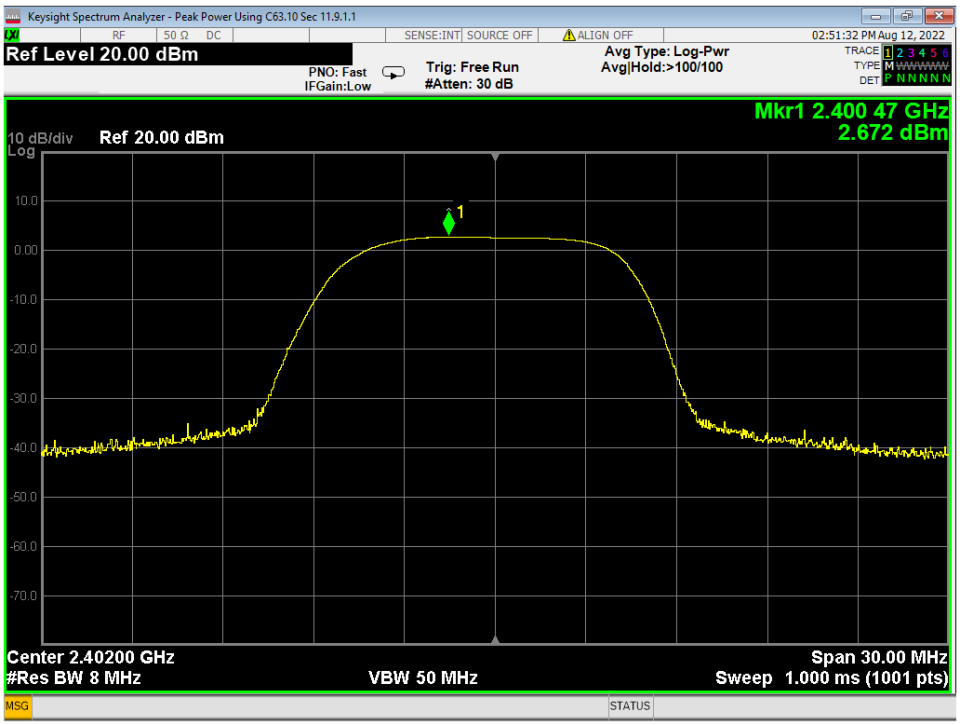
4 Peak Power, Low Channel, GMSK 2MB



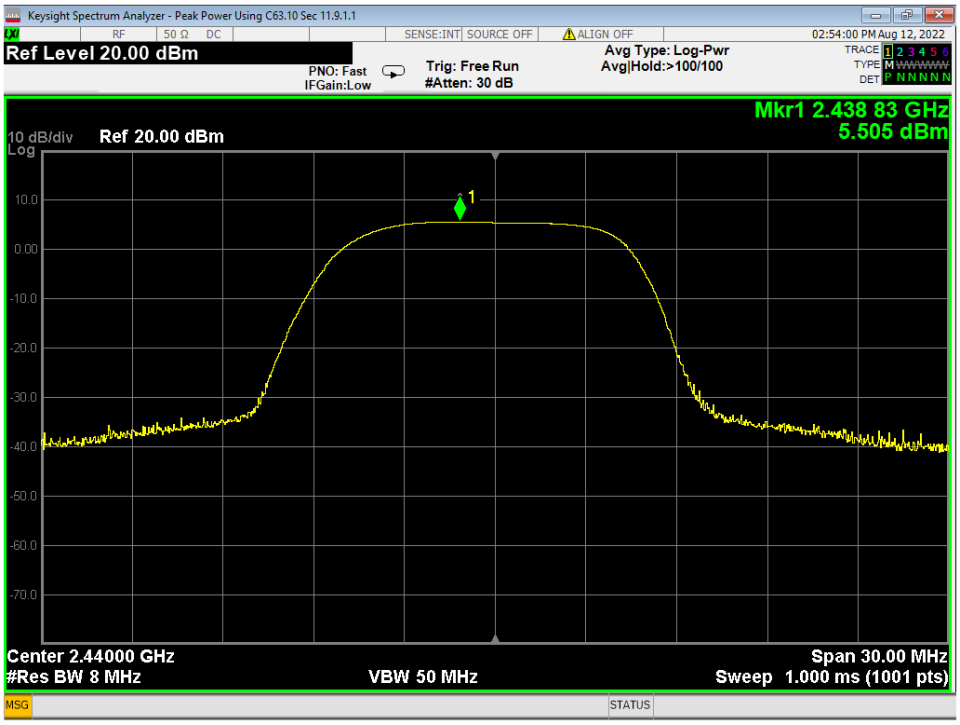
5 Peak Power, Mid Channel, GMSK 2MB



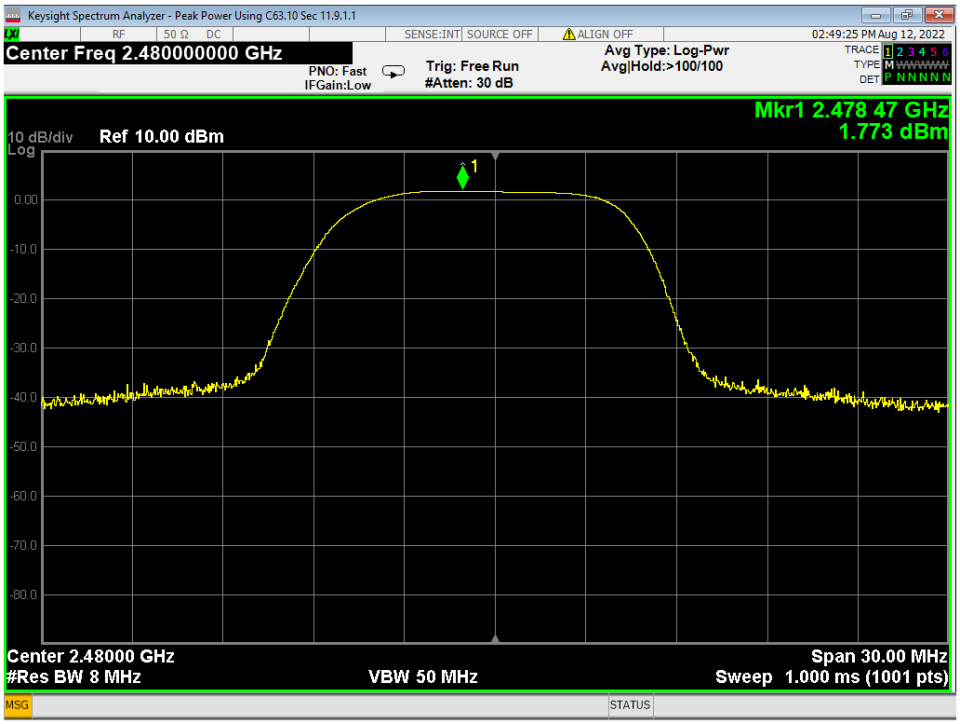
6 Peak Power, High Channel, GMSK 2MB



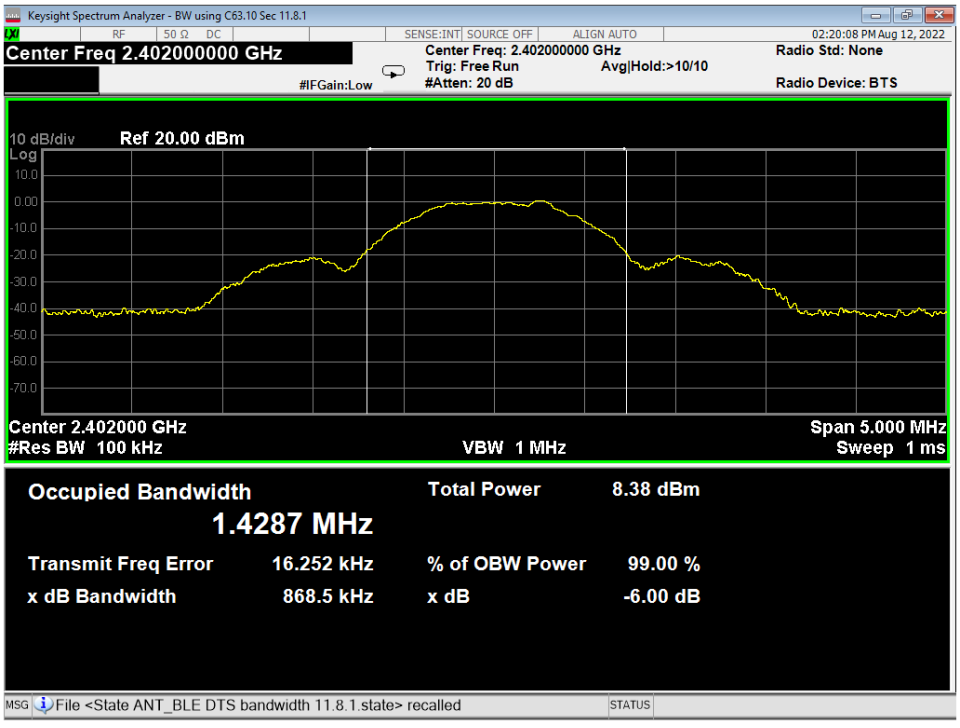
7 Peak Power, Low Channel, GFSK



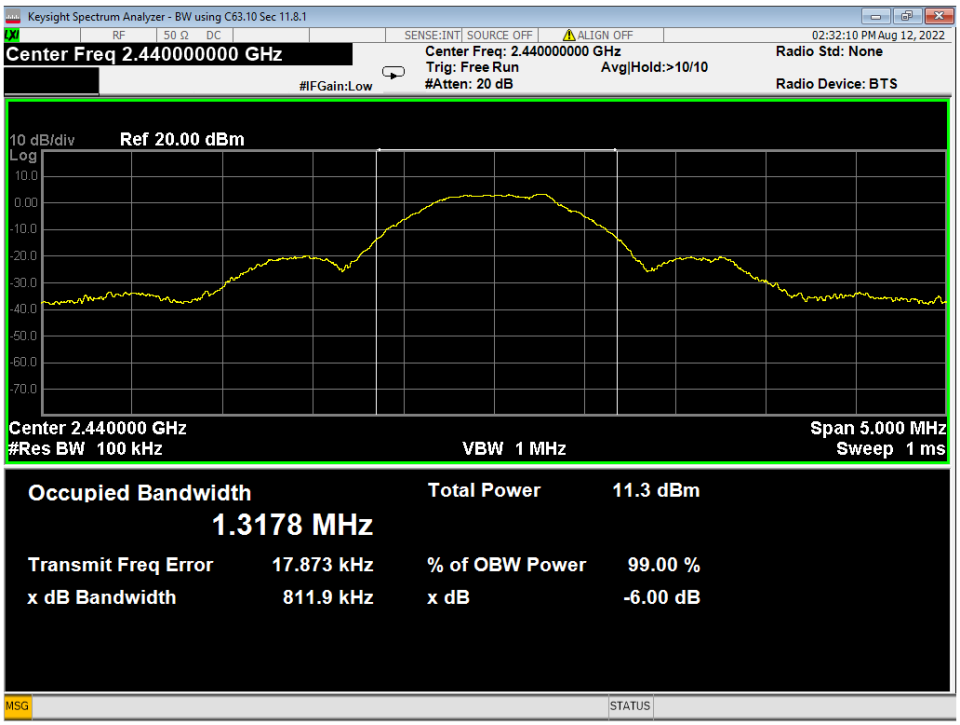
8 Peak Power, Mid Channel, GFSK



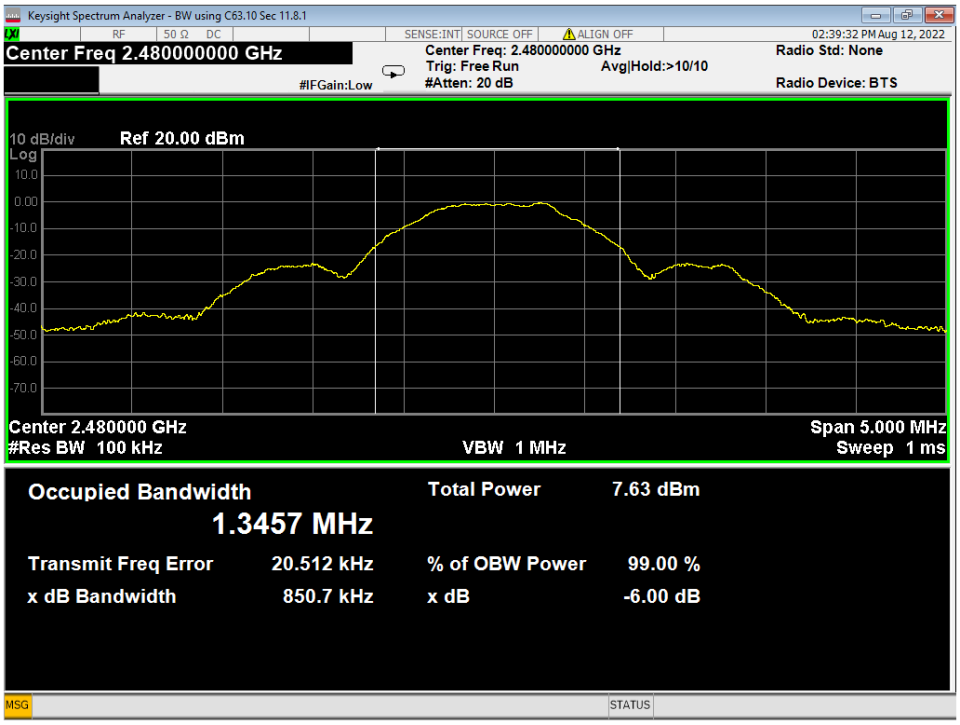
9 Peak Power, High Channel, GFSK



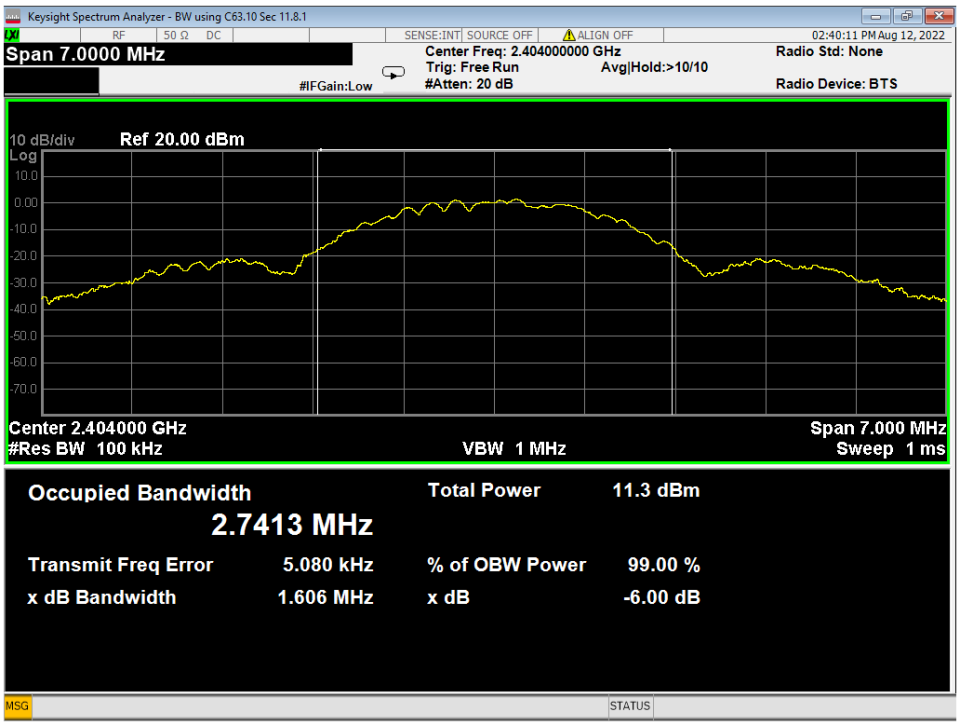
10 Bandwidth, Low Channel, GMSK 1MB



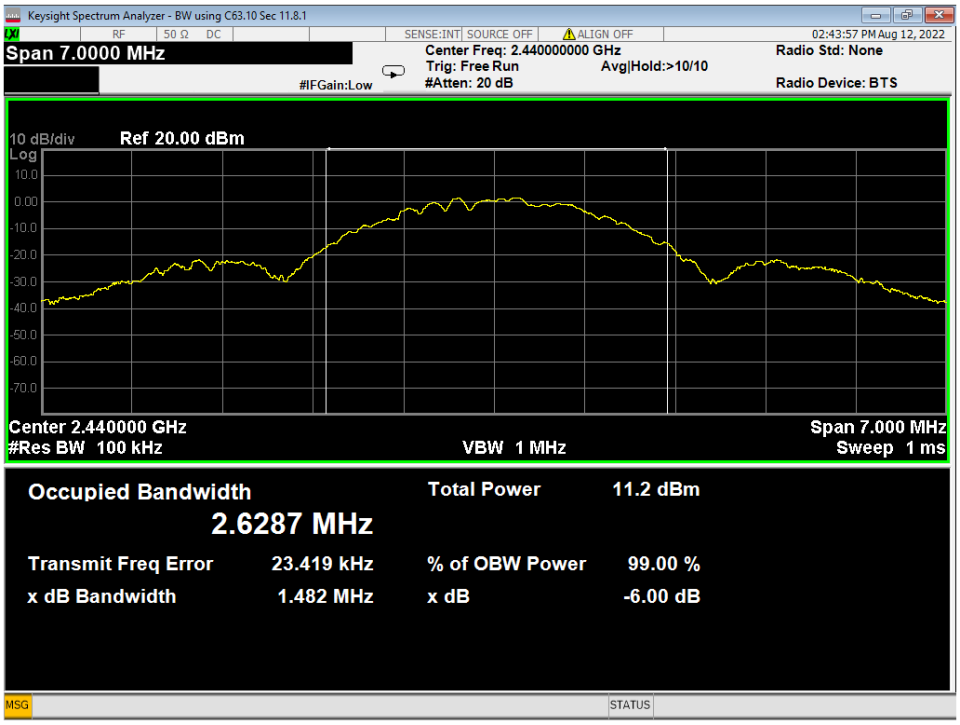
11 Bandwidth, Mid Channel, GMSK 1MB



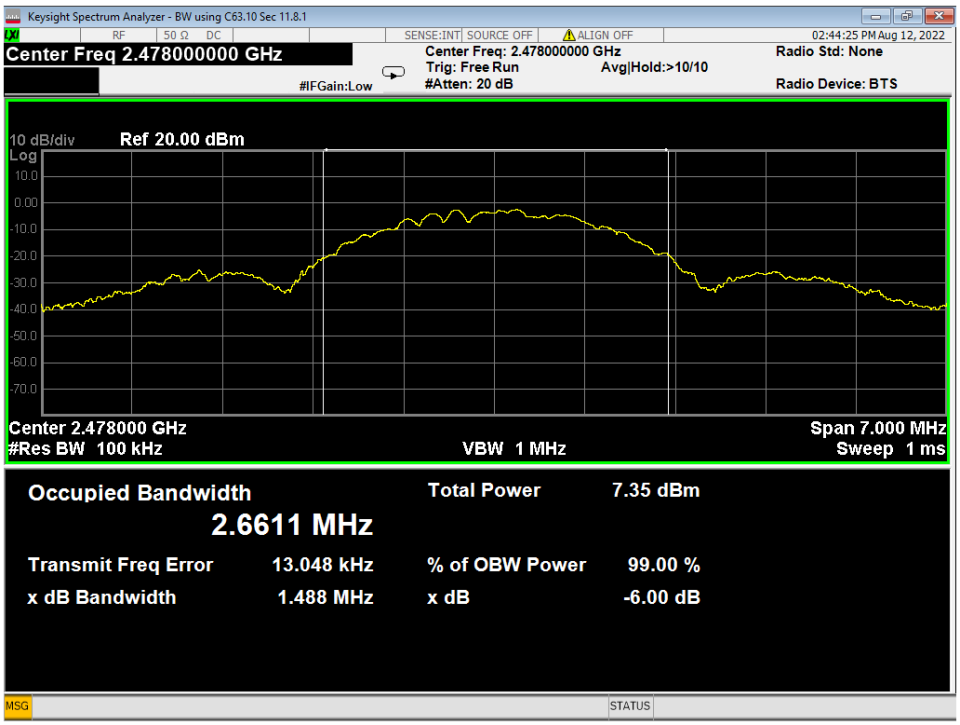
13 Bandwidth, High Channel, GMSK 1MB



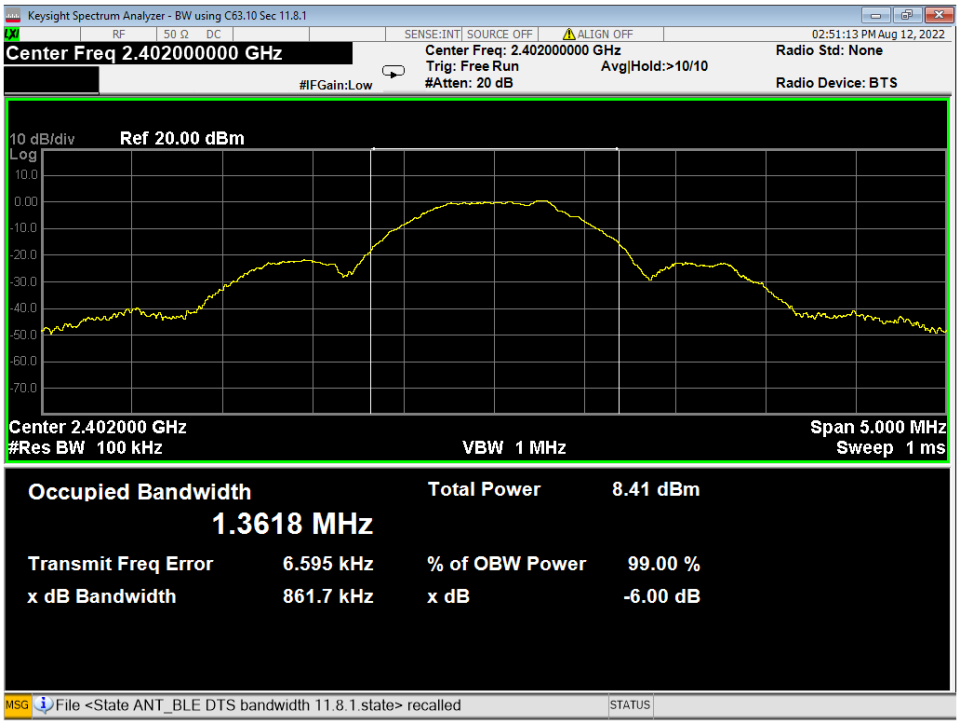
14 Bandwidth, Low Channel, GMSK 2MB



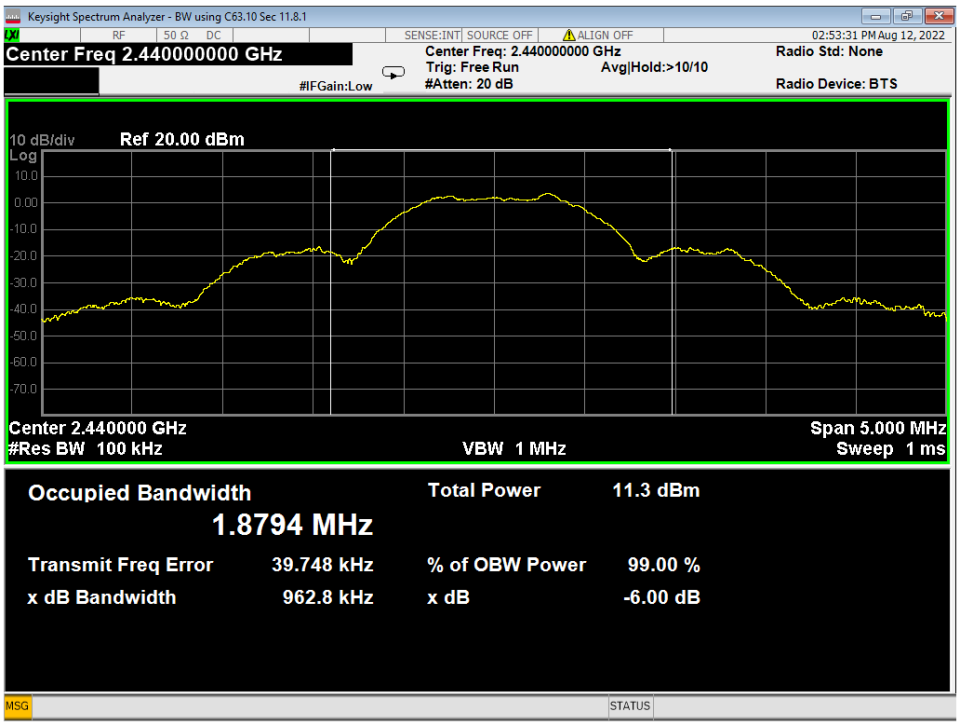
15 Bandwidth, Mid Channel, GMSK 2MB



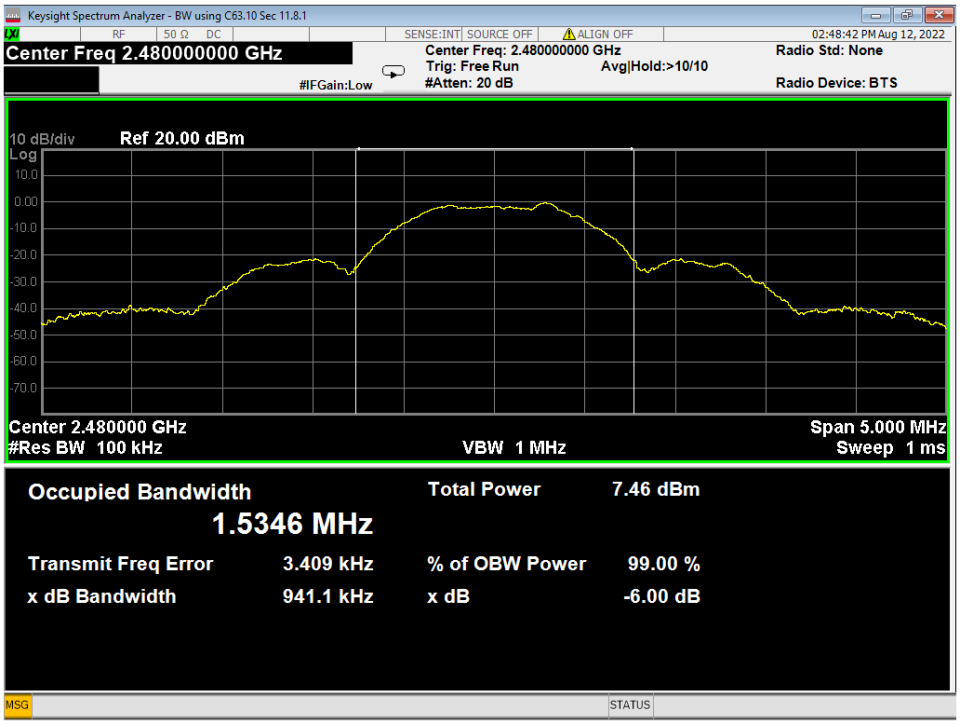
16 Bandwidth, High Channel, GMSK 2MB



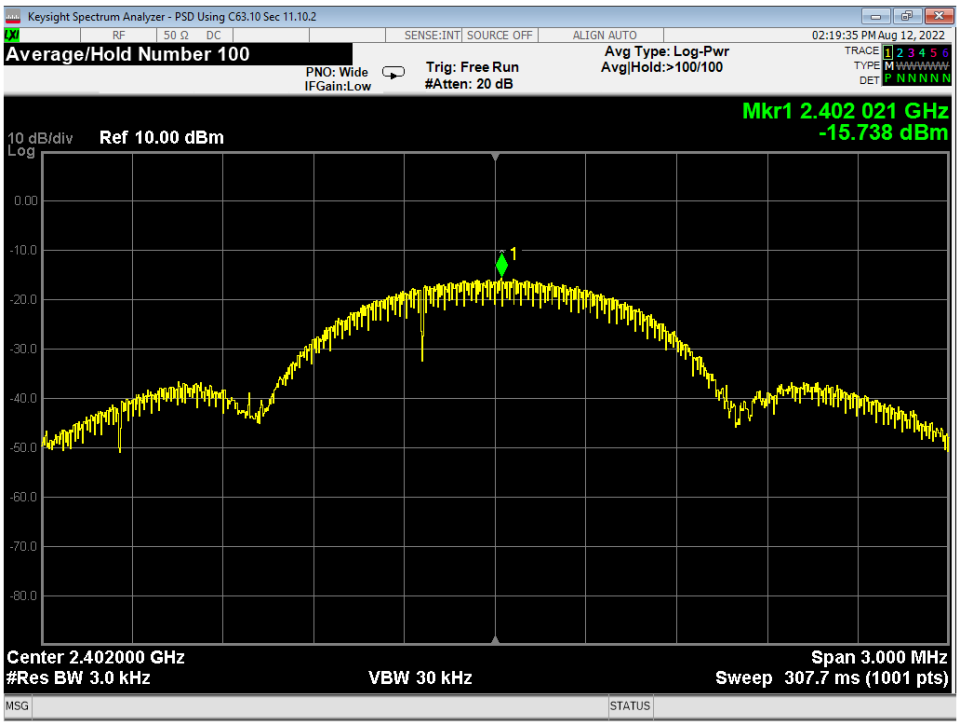
17 Bandwidth, Low Channel, GFSK



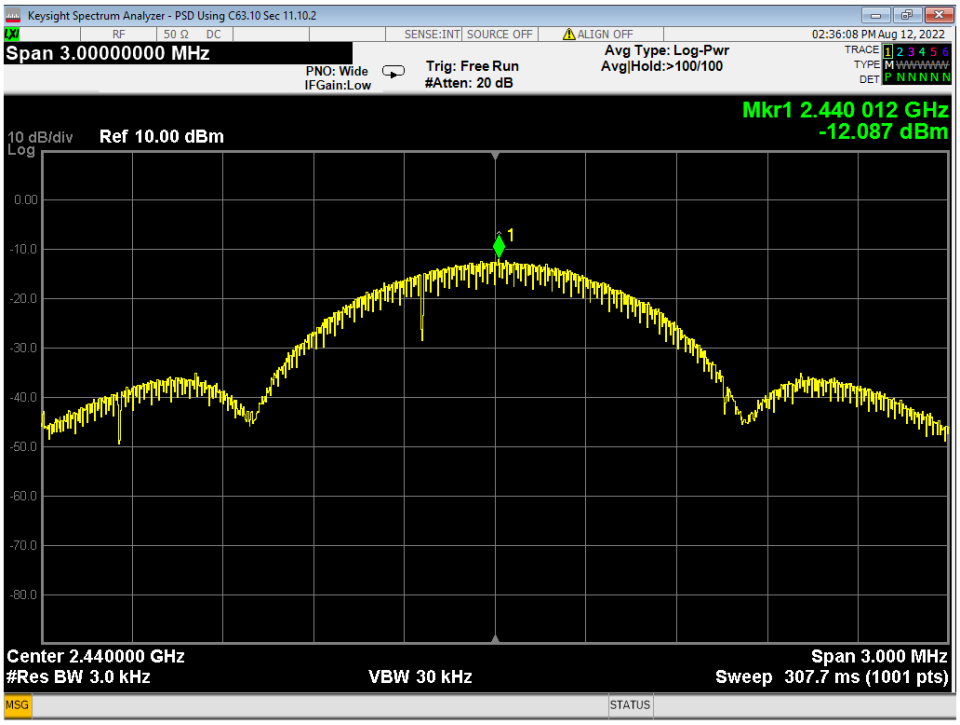
18 Bandwidth, Mid Channel, GFSK



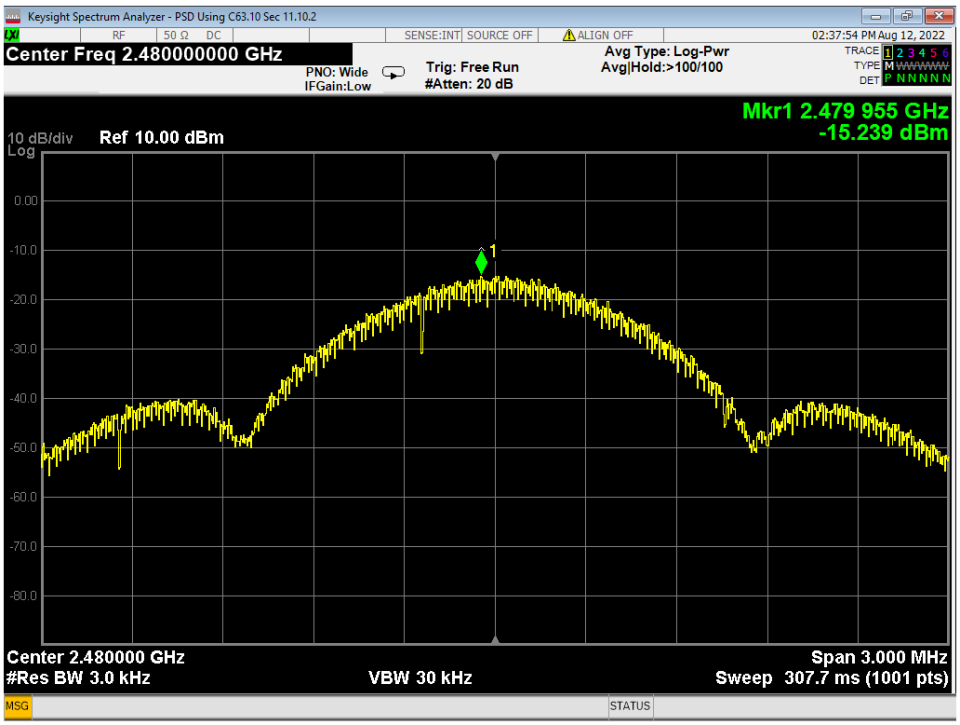
19 Bandwidth, High Channel, GFSK



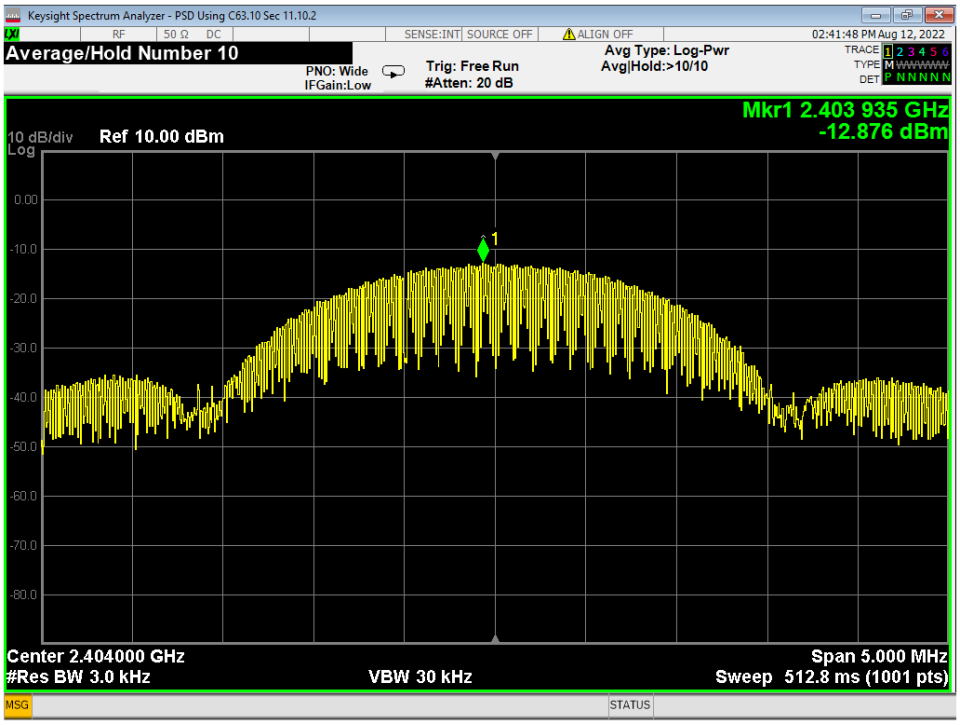
20 PSD, Low Channel, GMSK 1MB



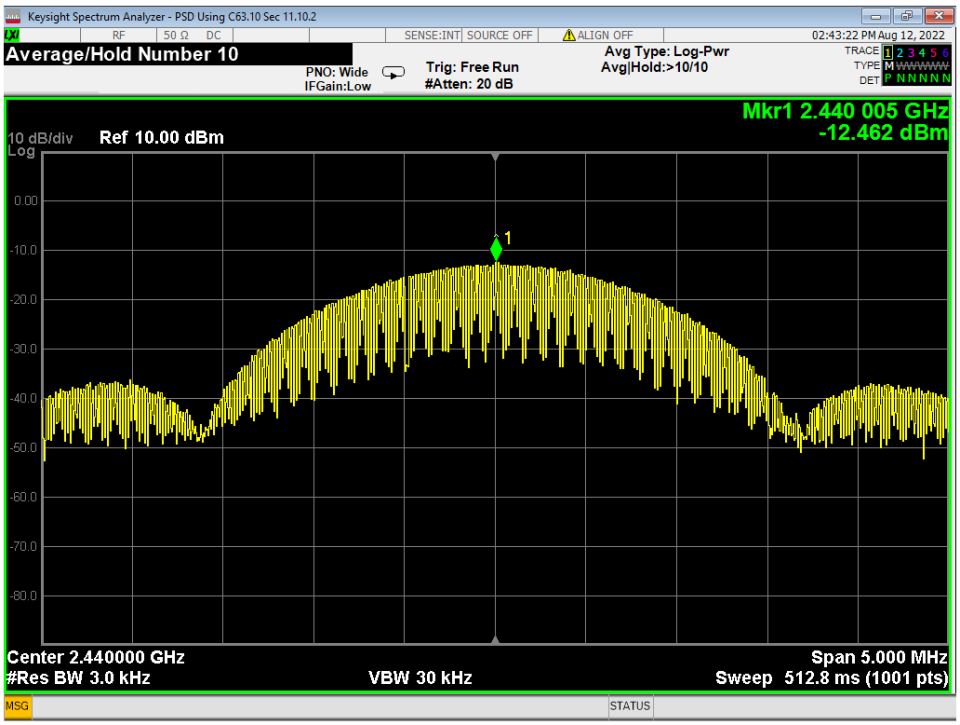
21 PSD, Mid Channel, GMSK 1MB



22 PSD, High Channel, GMSK 1MB



23 PSD, Low Channel, GMSK 2MB



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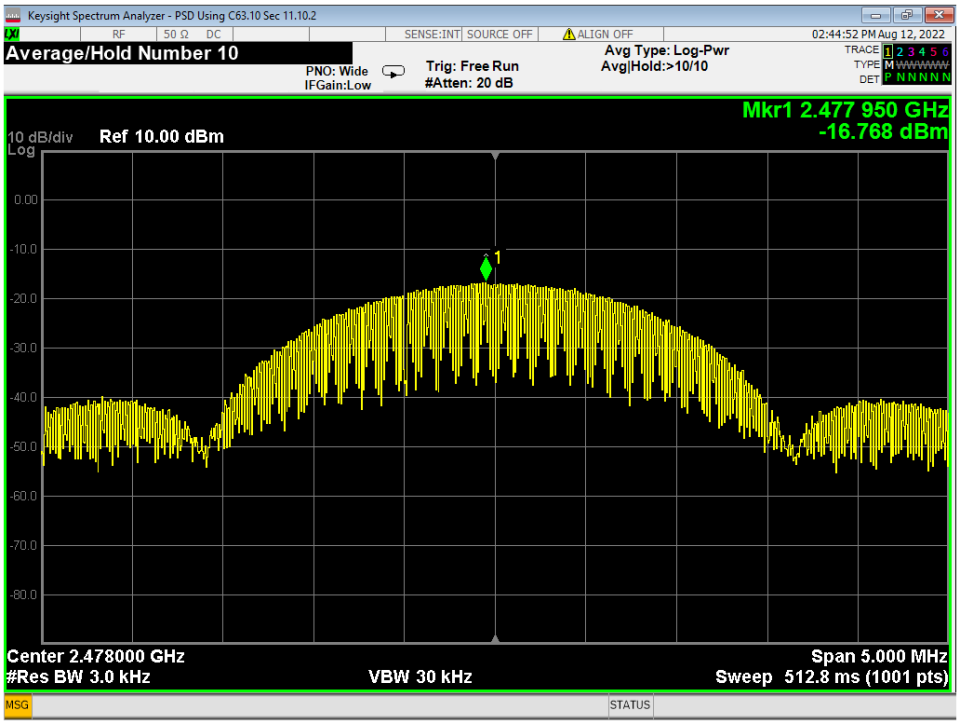

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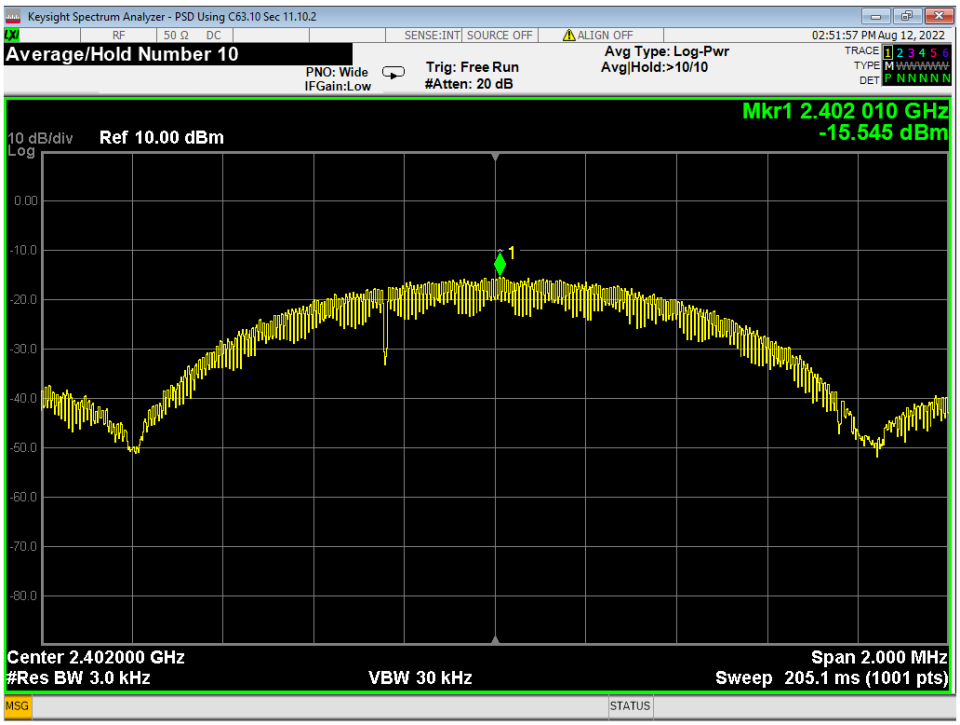
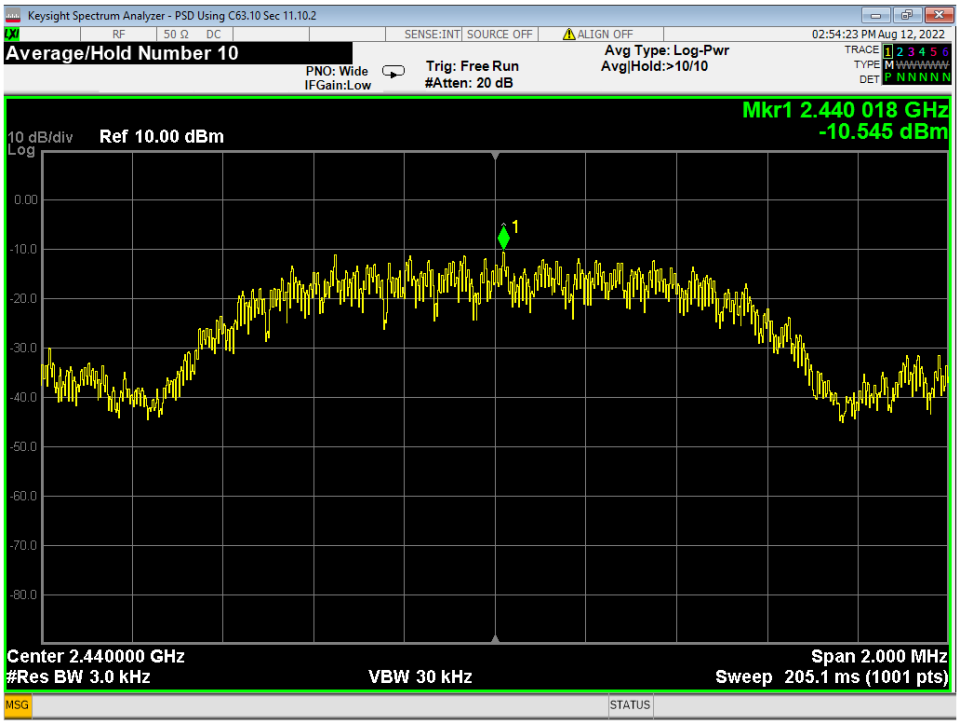
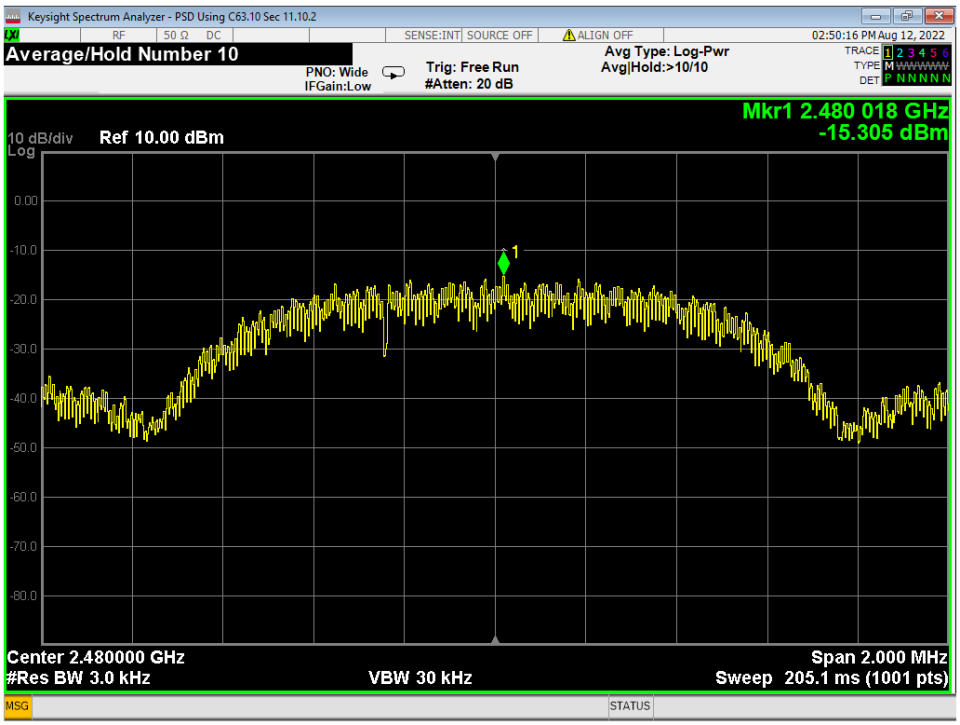


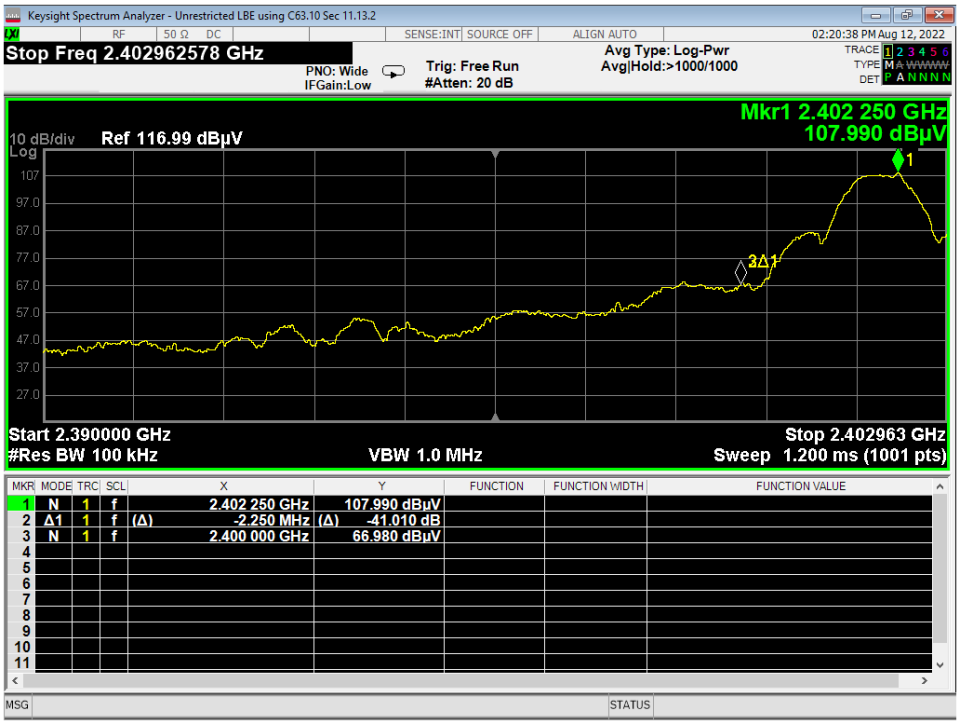
26 PSD, Low Channel, GFSK



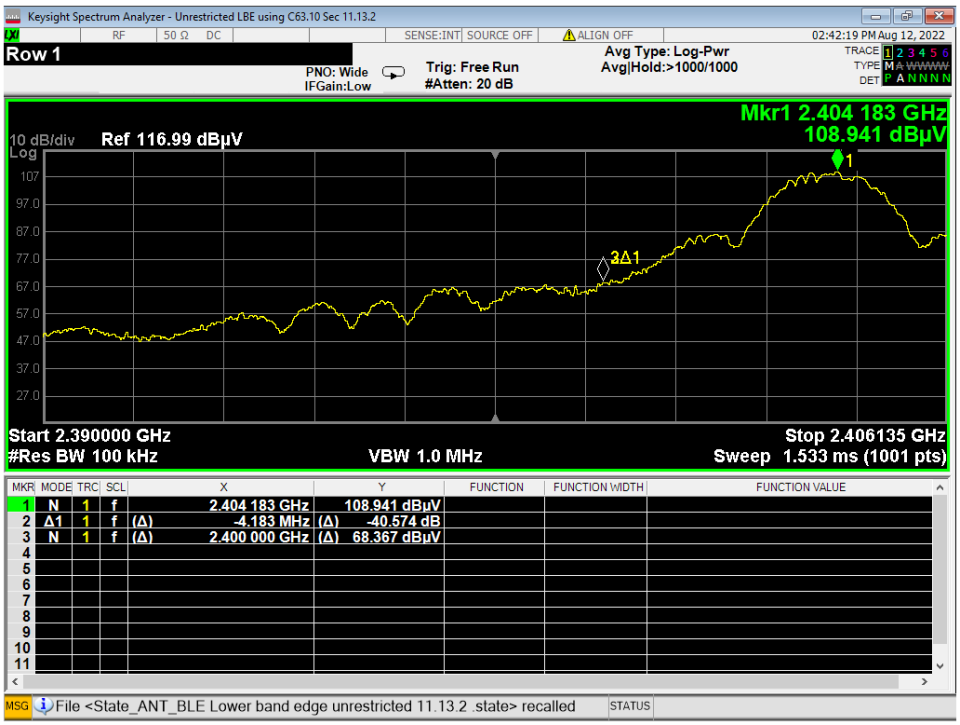
27 PSD, Mid Channel, GFSK



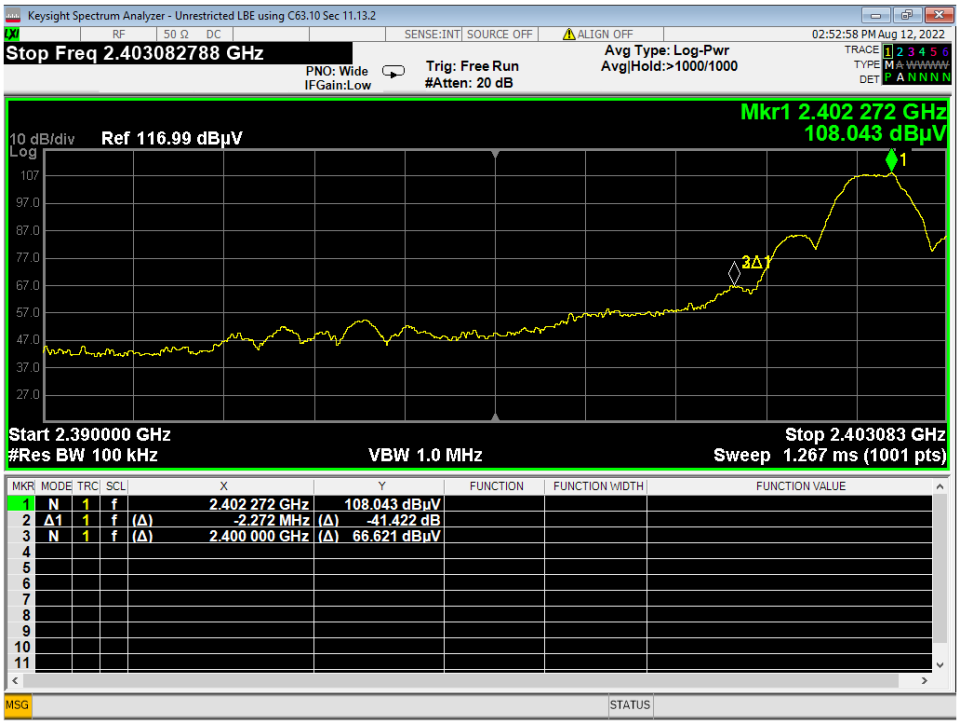
28 PSD, High Channel, GFSK



29 LBE, Unrestricted, GMSK 1MB



30 LBE, Unrestricted, GMSK 2MB



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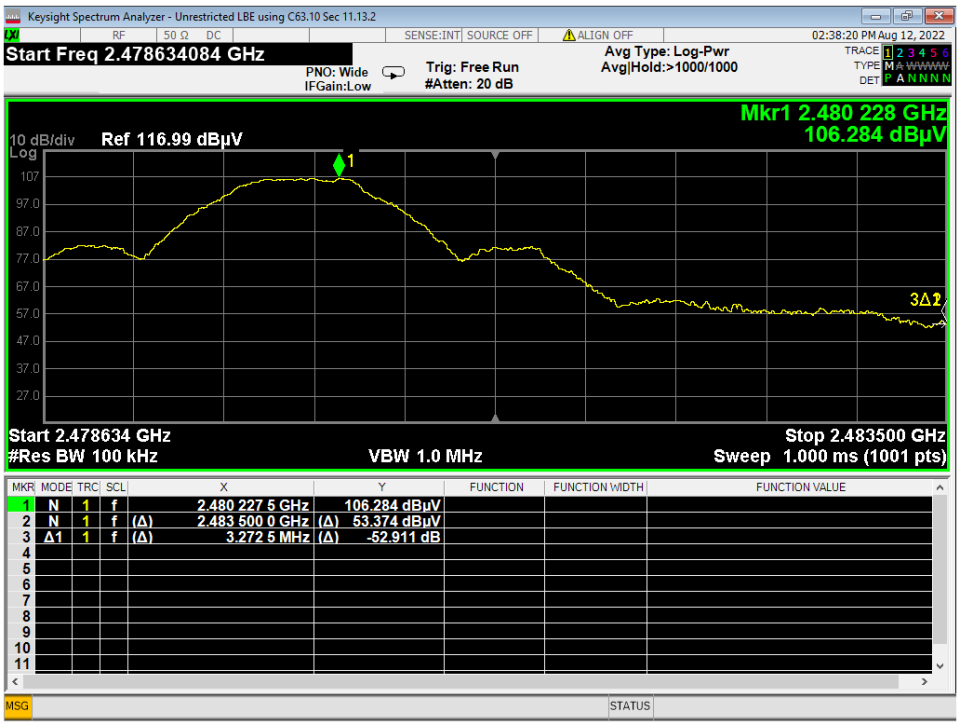

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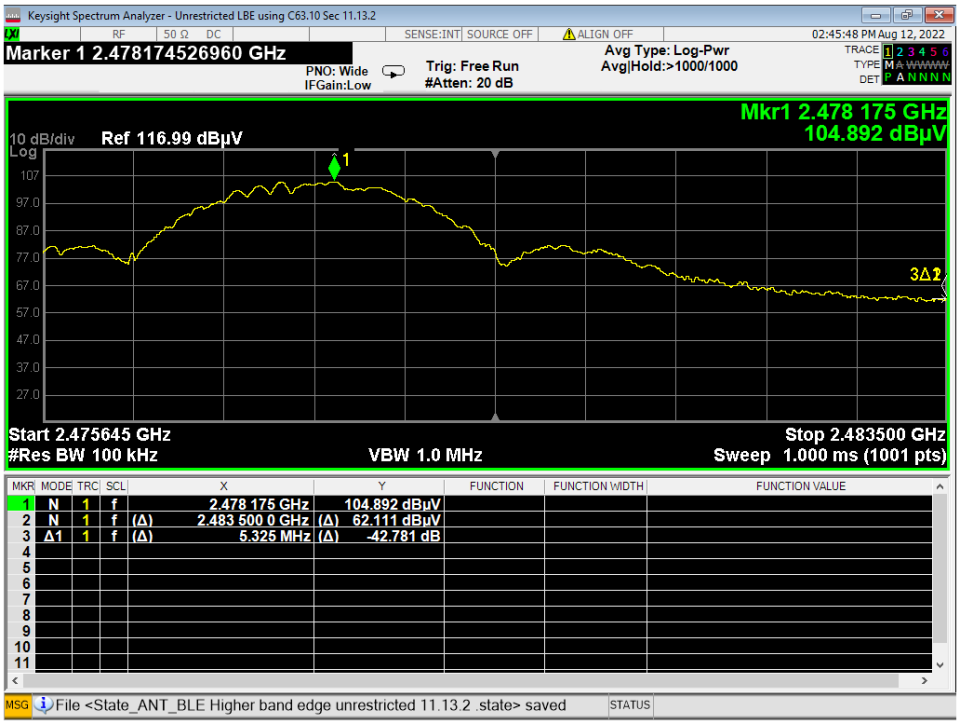

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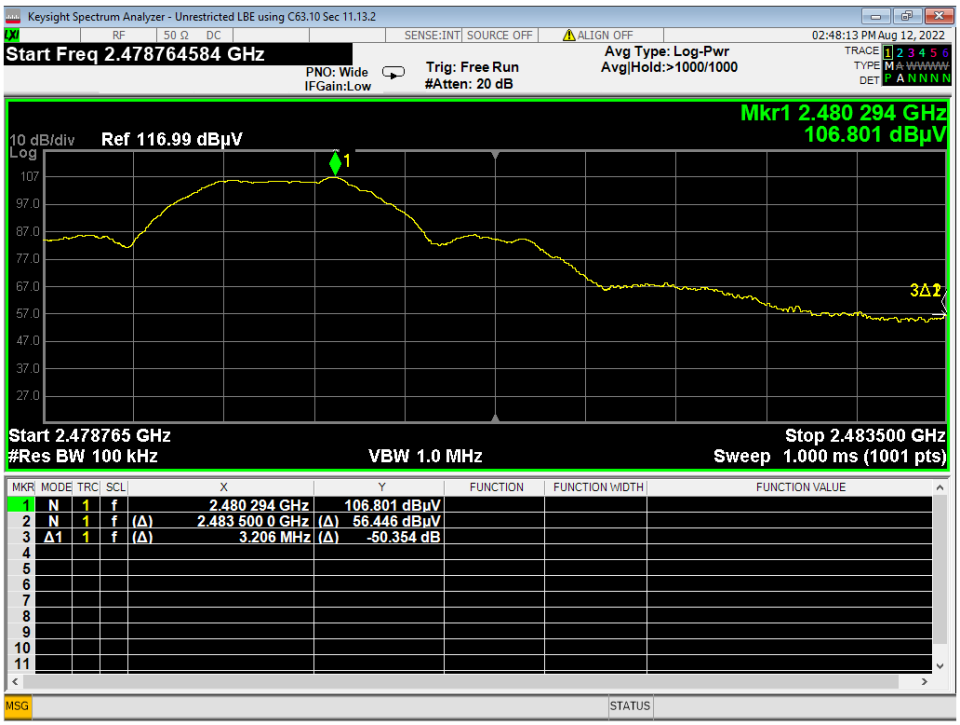

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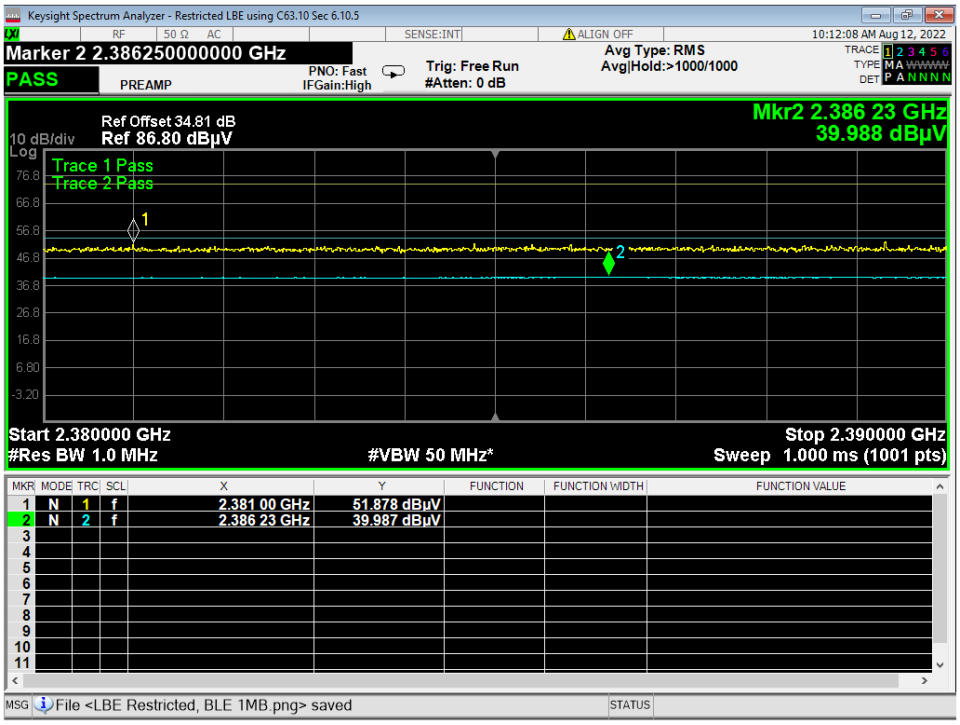
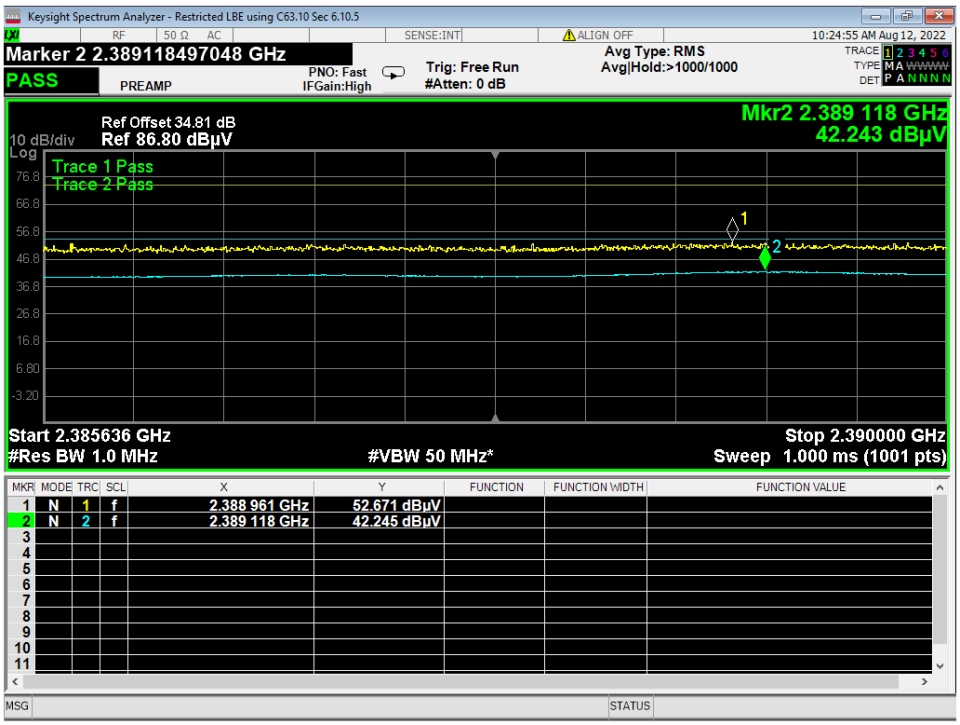
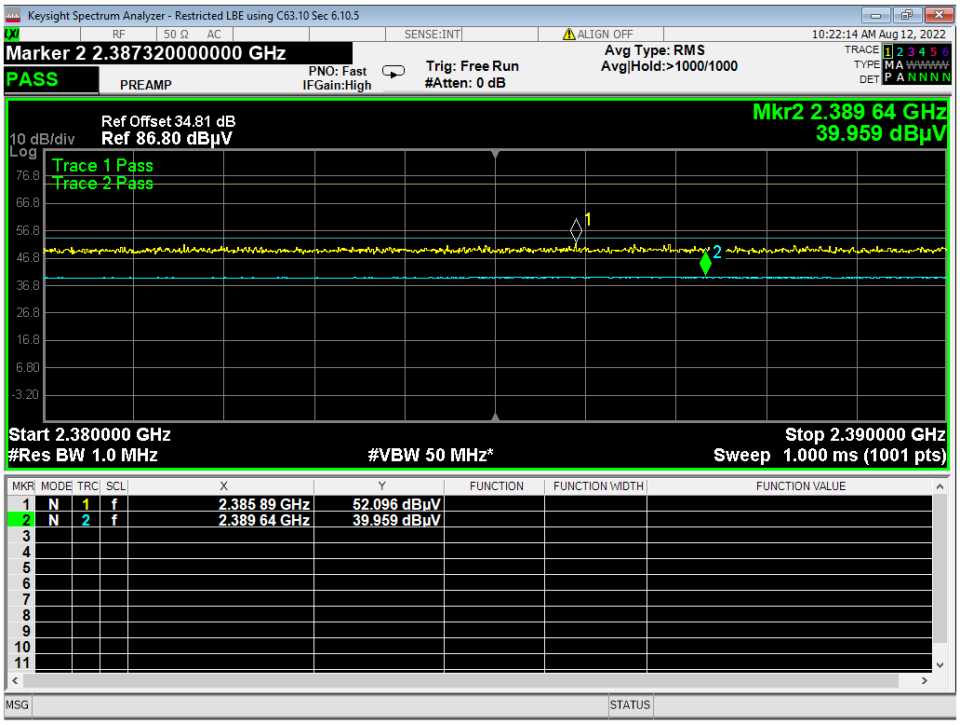


35 LBE, Restricted, GMSK 1MB



36 LBE, Restricted, GMSK 2MB



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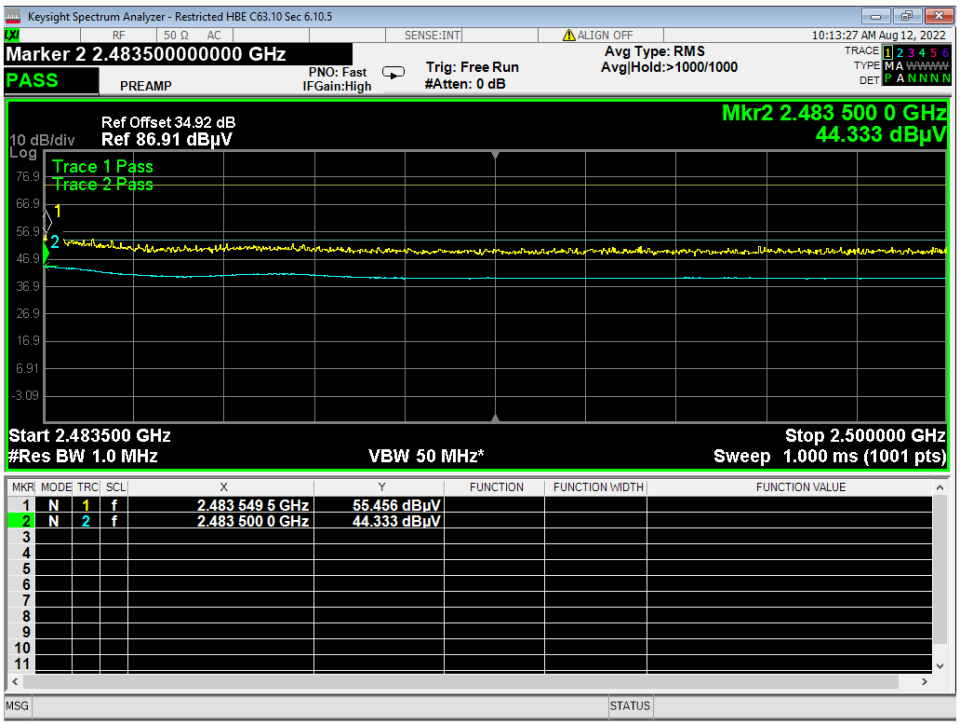

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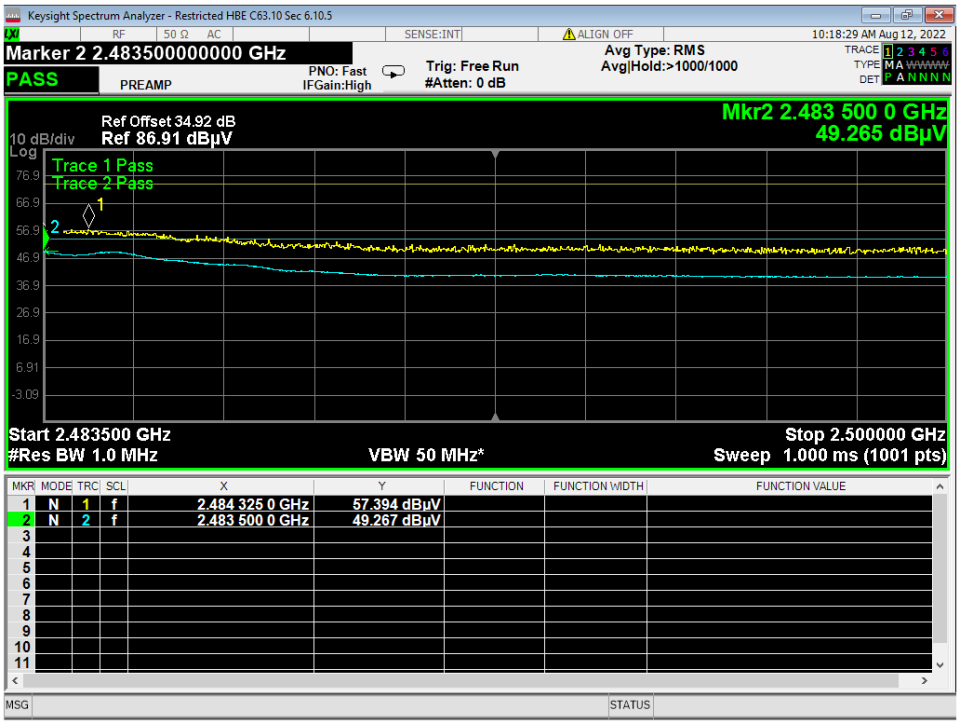

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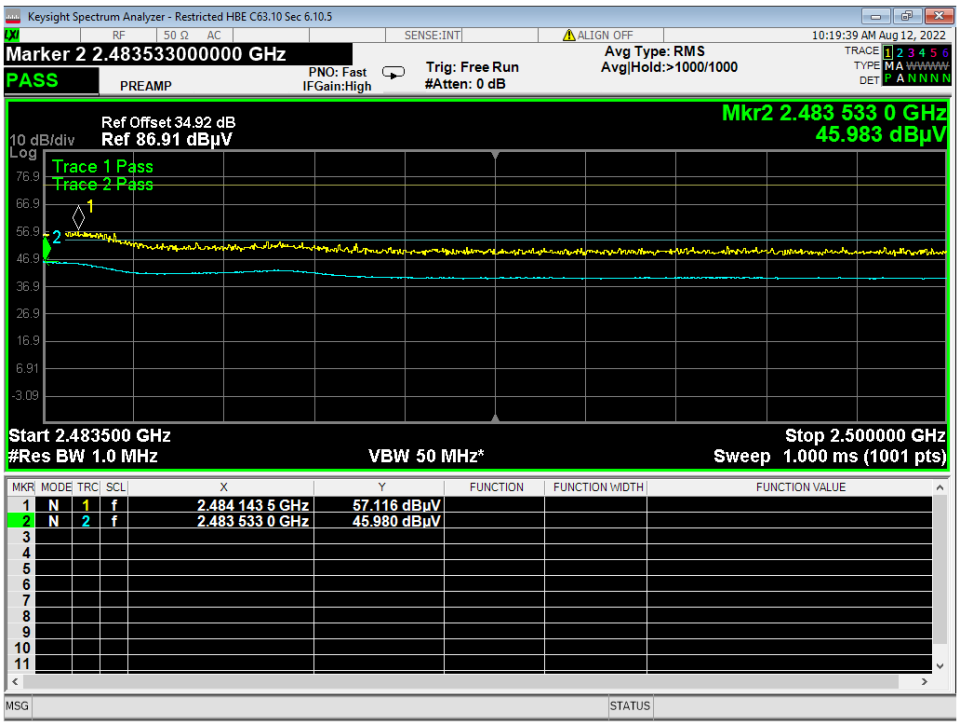

40 HBE, Restricted, GFSK

REPORT END