TEST REPORT

Report Number: R15374786-E3

Applicant	:	Microsoft Corporation 1 Microsoft Way Redmond, WA 98052-8300, USA
Model	:	HWB-Q93
FCC ID	:	C3K00002101
IC	:	3048A-00002101
EUT Description	:	Wireless Module
Test Standard(s)	:	FCC 47 CFR PART 15 SUBPART C: 2024 ISED RSS-247 ISSUE 3: 2023 ISED RSS-GEN ISSUE 5 + A1 + A2: 2021

Date Of Issue:
2025-01-10

Prepared by:
UL LLC
12 Laboratory Dr.
Research Triangle Park, NC 27709 U.S.A.
TEL: (919) 549-1400

ACCREDITED
CERT #0751.06

REPORT REVISION HISTORY

Rev.	Issue Date	Revisions	Revised By
V1	2024-11-25	Initial Issue	Charles Moody
V2	2024-12-30	Revised Section 6.5 and Section 9.10 to include Test Methodology and Sample Calculations	Charles Moody
V3	2025-01-10	Revised Antenna Gain Statement in Section 6.3 and Added Note Regarding Equipment Calibration in Section 7	Charles Moody

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

TABLE OF CONTENTS

REPORT REVISION HISTORY 2

TABLE OF CONTENTS 3

1. ATTESTATION OF TEST RESULTS 5

2. TEST RESULTS SUMMARY 6

3. TEST METHODOLOGY 6

4. FACILITIES AND ACCREDITATION 6

5. DECISION RULES AND MEASUREMENT UNCERTAINTY 7

5.1. METROLOGICAL TRACEABILITY 7

5.2. DECISION RULES 7

5.3. MEASUREMENT UNCERTAINTY 7

5.4. SAMPLE CALCULATION 7

6. EQUIPMENT UNDER TEST 8

6.1. EUT DESCRIPTION 8

6.2. MAXIMUM OUTPUT POWER 8

6.3. DESCRIPTION OF AVAILABLE ANTENNAS 8

6.4. SOFTWARE AND FIRMWARE 9

6.5. WORST-CASE CONFIGURATION AND MODE 9

6.6. DESCRIPTION OF TEST SETUP 10

7. TEST AND MEASUREMENT EQUIPMENT 11

8. MEASUREMENT METHODS 13

9. ANTENNA PORT TEST RESULTS 15

9.1. ON TIME AND DUTY CYCLE 15

9.2. 20 dB BANDWIDTH 16

9.2.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION 17

9.2.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION 19

9.3. 99% BANDWIDTH 21

9.3.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION 21

9.3.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION 23

9.4. HOPPING FREQUENCY SEPARATION 25

9.4.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION 25

9.4.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION 27

9.5. NUMBER OF HOPPING CHANNELS 29

9.5.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION 29

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

9.5.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION....34

9.6. AVERAGE TIME OF OCCUPANCY....38
9.6.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION....39
9.6.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION....43

9.7. OUTPUT POWER....47
9.7.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION....48
9.7.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION....49
9.7.3. BLUETOOTH ENHANCED DATA RATE DQPSK MODULATION....50

9.8. AVERAGE POWER....51
9.8.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION....52
9.8.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION....52
9.8.3. BLUETOOTH ENHANCED DATA RATE DQPSK MODULATION....52

9.9. CONDUCTED SPURIOUS EMISSIONS....53
9.9.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION....54
9.9.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION....58

9.10. CONDUCTED SPURIOUS EMISSIONS – RESTRICTED BAND....62
9.10.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION....63

10. UNWANTED EMISSIONS....69

10.1. TRANSMITTER ABOVE 1 GHz....71
10.1.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION....71
10.1.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION....89

10.2. WORST CASE BELOW 30MHZ....101
10.2.1. CHAIN 0....101
10.2.2. CHAIN 1....103
10.2.3. 2TX MIMO....105

10.3. WORST CASE BELOW 1 GHZ....107
10.3.1. CHAIN 0....107
10.3.2. CHAIN 1....109
10.3.3. 2TX MIMO....111

10.4. WORST CASE 18-26 GHZ....113
10.4.1. CHAIN 0....113
10.4.2. CHAIN 1....115
10.4.3. 2TX MIMO....117

11. SETUP PHOTOS....119

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

1. ATTESTATION OF TEST RESULTS

COMPANY NAME: Microsoft Corporation
1 Microsoft Way
Redmond, WA 98052-8300, USA

EUT DESCRIPTION: Wireless Module

MODEL: HWB-Q93

SERIAL NUMBER: 6-19, 6-25, 6-28

SAMPLE RECEIPT DATE: 2024-06-20 TO 2024-10-10

DATE TESTED: 2024-10-07 TO 2024-11-25

APPLICABLE STANDARDS	
STANDARD	**TEST RESULTS**
CFR 47 Part 15 Subpart C: 2024	Refer to Section 2
ISED RSS-247 Issue 3: 2023	Refer to Section 2
ISED RSS-GEN Issue 5 + A1 + A2: 2021	Refer to Section 2

UL LLC tested the above equipment in accordance with the requirements set forth in the above standards. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. It is the manufacturer's responsibility to assure that additional production units of this model are manufactured with identical electrical and mechanical components. All samples tested were in good operating condition throughout the entire test program. Measurement Uncertainties are published for informational purposes only and were not taken into account unless noted otherwise.

This document may not be altered or revised in any way unless done so by UL LLC and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL LLC will constitute fraud and shall nullify the document.

Approved & Released For
UL LLC By:

Brian Kiewra
Project Engineer
Consumer, Medical and IT Segment
UL LLC

Prepared By:

Charles Moody
Senior Project Engineer
Consumer, Medical and IT Segment
UL LLC

2. TEST RESULTS SUMMARY

This report contains data/info provided by the customer which can impact the validity of results. UL LLC is only responsible for the validity of results after the integration of the data provided by the customer.
Below is a list of the data/info provided by the customer:

1) Antenna gain and type (see section 6.3)

FCC Clause	ISED Clause	Requirement	Result	Comment
See Comment		Duty Cycle	Reporting purposes only	Per ANSI C63.10, Section 11.6.
See Comment	RSS-GEN 6.7	20dB BW/99% OBW	Reporting purposes only	ANSI C63.10 Sections 6.9.2 and 6.9.3
15.247 (a)(1)	RSS-247 (5.1) (b)	Hopping Frequency Separation	Compliant	None
15.247 (a)(1)(iii)	RSS-247 (5.1) (d)	Number of Hopping Channels		
15.247 (a)(1)(iii)	RSS-247 (5.1) (d)	Average Time of Occupancy		
15.247 (b)(1)	RSS-247 (5.4) (b)	Output Power		
See Comment		Average Power	Reporting purposes only	Per ANSI C63.10, Section 11.9.2.3.2.
15.247 (d)	RSS-247 (5.5)	Conducted Spurious Emissions	Compliant	None
15.209, 15.205	RSS-GEN 8.9, 8.10	Radiated Emissions		
15.207	RSS-Gen 8.8	AC Mains Conducted Emissions	Not Performed	See Note 1

NOTE 1: AC Mains emissions testing was not performed since the EUT is a radio module that is powered through a DC internal power supply.

3. TEST METHODOLOGY

The tests documented in this report were performed in accordance with FCC 47 CFR Part 2, FCC 47 CFR Part 15, ANSI C63.10-2020, KDB 558074 D01 15.247 Meas Guidance v05r02, KDB 414788 D01 Radiated Test Site v01r01, RSS-GEN Issue 5 + A1 + A2, and RSS-247 Issue 3.

4. FACILITIES AND ACCREDITATION

UL LLC is accredited A2LA, certification # 0751.06, for all testing performed within the scope of this report. Testing was performed at the locations noted below.

	Address	ISED CABID	ISED Company Number	FCC Registration
☐	Building: 12 Laboratory Dr RTP, NC 27709, U.S.A	US0067	2180C	825374
☒	Building: 2800 Perimeter Park Dr. Suite B Morrisville, NC 27560, U.S.A		27265	

5. DECISION RULES AND MEASUREMENT UNCERTAINTY

5.1. METROLOGICAL TRACEABILITY

All test and measuring equipment utilized to perform the tests documented in this report are calibrated on a regular basis, with a maximum time between calibrations of one year or the manufacturers' recommendation, whichever is less, and where applicable is traceable to recognized national standards.

5.2. DECISION RULES

The Decision Rule is based on Simple Acceptance in accordance with ISO Guide 98-4:2012 Clause 8.2. (Measurement uncertainty is not taken into account when stating conformity with a specified requirement.)

5.3. MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been estimated for tests performed on the apparatus:

PARAMETER	UNCERTAINTY
Radio Frequency (Spectrum Analyzer)	141.2 Hz
Occupied Channel Bandwidth	1.22%
RF output power, conducted	1.3 dB (PK) 0.45 dB (AV)
Power Spectral Density, conducted	2.47 dB
Unwanted Emissions, conducted	1.94 dB
All emissions, radiated	6.01 dB
Conducted Emissions (0.150-30MHz) - LISN	3.40 dB
Temperature	0.57°C
Humidity	3.39%
DC Supply voltages	1.70%
Time	3.39%

Uncertainty figures are valid to a confidence level of 95%.

5.4. SAMPLE CALCULATION

RADIATED EMISSIONS

Where relevant, the following sample calculation is provided:
Field Strength (dBuV/m) = Measured Voltage (dBuV) + Antenna Factor (dB/m) + Cable Loss (dB) – Preamp Gain (dB)
36.5 dBuV + 18.7 dB/m + 0.6 dB – 26.9 dB = 28.9 dBuV/m

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

6. EQUIPMENT UNDER TEST

6.1. EUT DESCRIPTION

The EUT is a Wireless Module. This report covers the emissions testing of the BT radio.

6.2. MAXIMUM OUTPUT POWER

The transmitter has a maximum peak conducted output power as follows:

Frequency Range (MHz)	Mode	Output Power (dBm)	Output Power (mW)
2402 - 2480	Basic GFSK	19.66	92.47
2402 - 2480	Enhanced DQPSK	19.59	90.99
2402 - 2480	Enhanced 8PSK	20.19	104.47

Note: GFSK, DQPSK, 8PSK average Power were all investigated, The GFSK and 8PSK power are the worst case. Testing is based on these modes to showing compliance. For average power data please refer to section 9.8.

6.3. DESCRIPTION OF AVAILABLE ANTENNAS

The antenna(s) gain and type, as provided by the manufacturer' are as follows:

Low Gain Antenna:

Chain	Frequency (MHz)	Gain (dBi)	Type
0	2400-2483.5	3.6	PIFA
1	2400-2483.5	3.6	
(Uncorrelated)	2400-2483.5	3.6	
(Correlated)	2400-2483.5	6.61	

Mid Gain Antenna:

Chain	Frequency (MHz)	Gain (dBi)	Type
0	2400-2483.5	4.4	PIFA
1	2400-2483.5	4.4	
(Uncorrelated)	2400-2483.5	4.4	
(Correlated)	2400-2483.5	7.41	

High Gain Antenna:

Chain	Frequency (MHz)	Gain (dBi)	Type
0	2400-2483.5	6.1	PIFA
1	2400-2483.5	6.1	
(Uncorrelated)	2400-2483.5	6.1	
(Correlated)	2400-2483.5	9.11	

Antenna gains for MIMO operations are calculated using the formulae from KDB 662911 D01 Multiple Transmitter Output v02r01 section F. As the two antennas have the same gain equations 2)a)(i) and 2)a)(ii) for correlated and uncorrelated transmissions respectively are used.

Correlated directional gain = G_{ANT} + 10 log(N_{ANT}) dBi, where N_{ANT} = 2 for a 2x2 MIMO device

Uncorrelated directional gain = G_{ANT}

6.4. SOFTWARE AND FIRMWARE

The EUT firmware installed during testing was 10.0.22621.1.

The test utility software used during testing was Qualcomm Radio Control Toolkit Version 4.0.118.1.

6.5. WORST-CASE CONFIGURATION AND MODE

All conducted emissions testing was performed as SISO to cover MIMO as a worst case, power-per-chain, mode. Output power was measured on SISO C0, SISO C1, and MIMO.

Radiated emissions below 1GHz and above 18GHz were performed with the EUT set to transmit at the channel with the highest power for SISO C0, SISO C1 or MIMO, as a worst-case mode.

Band edge was performed with the EUT set to transmit at the highest power on low and high channels. Testing was performed using a conducted restricted band edge setup. A traditional restricted band edge scan (C63.10 Section 11.12.2.2) was ran on chain 0 and chain 1, each operating in SISO mode as a worst-case scenario unless otherwise noted within the report. The data was then summed together accounting for the high gain antenna gain (worst-case). To compare this data to the average limit, a correction factor of -25 dB (see section 9.1) based on the protocol limited correction factor for DH3 modulation. An example band edge scan and has been included for each mode for reference. The summed tabular and plot data has been included for each scan.

NOTE: High gain was used in all the testing as a worst-case since the power for all antenna gains was the same.

Radiated spurious emissions between 1GHz and 18GHz were performed with the EUT set to transmit on low, mid, and high channels at the worst-case power mode for SISO C0 and SISO C1, and at the worst-case average power mode for MIMO. These modes were found to be GFSK for all modes.

The fundamental of the EUT was investigated in three orthogonal orientations X,Y,Z, it was determined that Z orientation was worst-case orientation for SISO C0, SISO C1, and MIMO; therefore, all final radiated testing was performed with the antennas in Z orientation.

Worst-case data rates and packet sizes as determined by power measurements were:

GFSK mode: DH3
QPSK mode : 2-DH1
8PSK mode: 3-DH3

6.6. DESCRIPTION OF TEST SETUP

SUPPORT EQUIPMENT

Support Equipment List				
Description	**Manufacturer**	**Model**	**Serial Number**	**FCC ID**
NUC	Intel	NuC	BTAN3160022Z/ BTAN322009FE/ BTAN331003QS/ BTAN331002VK	N/A
Intel NUC Charger	Chicony Power Technology	A17-120P2A	0432-05LT1002333012523	N/A

I/O CABLES

I/O Cable List						
Cable No.	**Port**	**# of Identical Ports**	**Connector Type**	**Cable Type**	**Cable Length (m)**	**Remarks**
1	Ribbon	1	Ribbon	Unshielded	3>	Connects EUT to NUC
2	DC Mains	1	Barrel	Unshielded	3>	Connects NUC to DC Adaptor

TEST SETUP

Test software exercised the radio card.

SETUP DIAGRAMS

Please refer to R15374786-EP1 for setup diagrams

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

7. TEST AND MEASUREMENT EQUIPMENT

The following test and measurement equipment was utilized for the tests documented in this report:

Test Equipment Used - Wireless Conducted Measurement Equipment

Equipment ID	Description	Manufacturer	Model Number	Last Cal.	Next Cal.
	Common Equipment				
	Conducted Room 1				
90416	Spectrum Analyzer	Keysight Technologies	N9030A	2024-09-23	2025-09-23
**206459	Spectrum Analyzer	Rohde & Schwarz	FSW	2023-11-15	2024-11-15
179892	Environmental Meter	Fisher Scientific	15-077-963	2024-08-12	2025-08-12
SOFTEMI	Antenna Port Software	UL	Version 2024.2.23	NA	NA
Power Software	Boonton Power Analyzer	Boonton	Version 3.0.13.0	NA	NA
	Conducted Room 2				
90410	Spectrum Analyzer	Keysight Technologies	N9030A	2024-06-14	2025-06-14
248881	Environmental Meter	Control Company	06-662-4	2024-04-10	2026-04-10
SOFTEMI	Antenna Port Software	UL	Version 2024.2.23	NA	NA
Power Software	Boonton Power Analyzer	Boonton	Version 3.0.13.0	NA	NA
	Additional Equipment used				
245262	Conducted Switch Box	UL	CSB	2024-02-20	2025-02-20

**NOTE: This equipment was used for testing while equipment was still in calibration.

Test Equipment Used - Radiated Disturbance Emissions Test Equipment (Morrisville – Chamber 4)

Equip. ID	Description	Manufacturer/Brand	Model Number	Last Cal.	Next Cal.
	1-18 GHz				
89509	Double-Ridged Waveguide Horn Antenna, 1 to 18 GHz	ETS Lindgren	3117	2023-05-23	2025-05-23
	Gain-Loss Chains				
207640	Gain-loss string: 1-18GHz	Various	Various	2024-05-22	2025-05-22
	Receiver & Software				
197955	Spectrum Analyzer	Rohde & Schwarz	ESW44	2024-04-16	2025-04-16
SOFTEMI	EMI Software	UL	Version 9.5 (18 Oct 2021)		
	Additional Equipment used				
241204	Environmental Meter	Fisher Scientific	15-077-963	2023-09-05	2025-09-05
**170112	10dB, DC-18GHz, 5W	Mini-Circuits	BW-N10W5	2023-11-09	2024-11-09

**NOTE: This equipment was used for testing while equipment was still in calibration.

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

Test Equipment Used - Radiated Disturbance Emissions Test Equipment (Morrisville – Chamber 1)

Equip. ID	Description	Manufacturer	Model Number	Last Cal.	Next Cal.
	0.009-30MHz				
135144	Active Loop Antenna	ETS-Lindgren	6502	2024-10-02	2025-10-02
	30-1000 MHz				
90629	Hybrid Broadband Antenna	Sunol Sciences Corp.	JB3	2024-01-30	2026-01-30
	1-18 GHz				
135143	Double-Ridged Waveguide Horn Antenna, 1 to 18 GHz	ETS Lindgren	3117	2024-02-07	2026-02-07
	18-40 GHz				
204704	Horn Antenna, 18-26.5GHz	Com-Power	AH-826	2023-07-20	2025-07-20
	Gain-Loss Chains				
91974	Gain-loss string: 0.009-30MHz	Various	Various	2024-05-08	2025-05-08
91976	Gain-loss string: 25-1000MHz	Various	Various	2024-05-08	2025-05-08
91979	Gain-loss string: 1-18GHz	Various	Various	2024-05-08	2025-05-08
135999	Gain-loss string: 18-40GHz	Various	Various	2024-05-08	2025-05-08
	Receiver & Software				
197954	Spectrum Analyzer	Rohde & Schwarz	ESW44	2024-03-05	2025-03-05
81018	Spectrum Analyzer	Agilent	E4446A	2024-07-31	2025-07-31
SOFTEMI	EMI Software	UL	Version 9.5 (18 Oct 2021)		
	Additional Equipment used				
241205	Environmental Meter	Fisher Scientific	15-077-963	2023-09-05	2025-09-05
**170112	10dB Pad, DC-18GHz, 5W	Mini-Circuits	BW-N10W5+	2023-11-09	2024-11-09

**NOTE: This equipment was used for testing while equipment was still in calibration.

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

8. MEASUREMENT METHODS

On Time and Duty Cycle: ANSI C63.10-2020 Section 11.6

Occupied BW (20dB): ANSI C63.10-2020 Section 6.9.2

Occupied BW (99%): ANSI C63.10-2020 Section 6.9.3

Carrier Frequency Separation: ANSI C63.10-2020 Section 7.8.2

Number of Hopping Frequencies: ANSI C63.10-2020 Section 7.8.3

Time of Occupancy (Dwell Time): ANSI C63.10-2020 Section 7.8.4

Peak Output Power: ANSI C63.10-2020 Section 7.8.5

Conducted Spurious Emissions: ANSI C63.10-2020 Section 7.8.8

Conducted Band-Edge: ANSI C63.10-2020 Section 6.10.4

Radiated Band-edge: ANSI C63.10-2020 Section 6.10.5

Radiated Spurious Emissions: ANSI C63.10-2020 Sections 6.3 to 6.6

9. ANTENNA PORT TEST RESULTS

9.1. ON TIME AND DUTY CYCLE

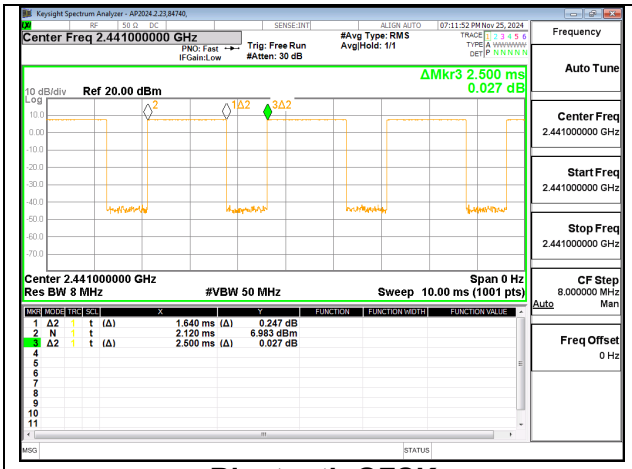
LIMITS

None; for reporting purposes only.

PROCEDURE

ANSI C63.10, Section 11.6 : Zero-Span Spectrum Analyzer Method.

Mode	ON Time B (msec)	Period (msec)	Duty Cycle x (linear)	Duty Cycle (%)	1/T Minimum VBW (kHz)
Bluetooth GFSK	1.640	2.500	0.656	65.60	0.610
Bluetooth 8PSK	1.630	2.500	0.652	65.20	0.613



Bluetooth GFSK

Bluetooth 8PSK

Note: The DCCF used was calculated based on the worst case on-time when the device transmits DH3 ackets and operates on 20 channels (3/1600 s per hop = 1.875 ms per channel). In this mode, the device will have a maximum of 3 hops on a channel in 100ms or 3x 1.875 ms = 5.625 ms on any channel. Therefore, 20log(5.625 / 100) = - 25dB.

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

9.2. 20 dB BANDWIDTH

LIMITS

None; for reporting purposes only.

TEST PROCEDURE

The transmitter output is connected to a spectrum analyzer. The RBW is set to ≥ 1% of the 20 dB bandwidth. The VBW is set to ≥ RBW. The sweep time is coupled.

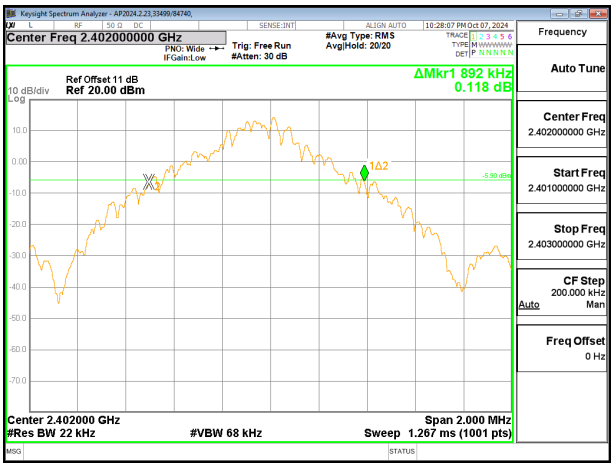
RESULTS

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

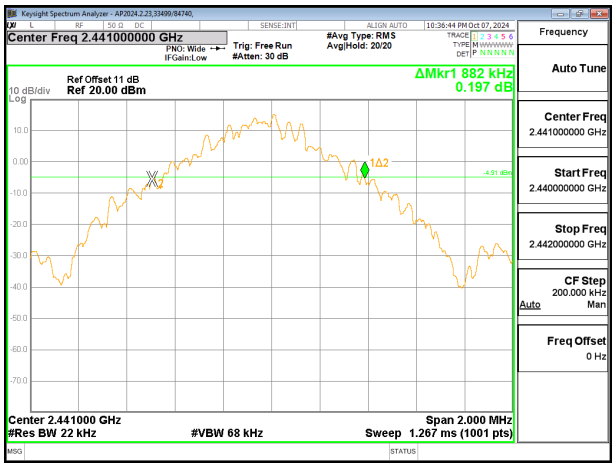
9.2.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION

Chain 0

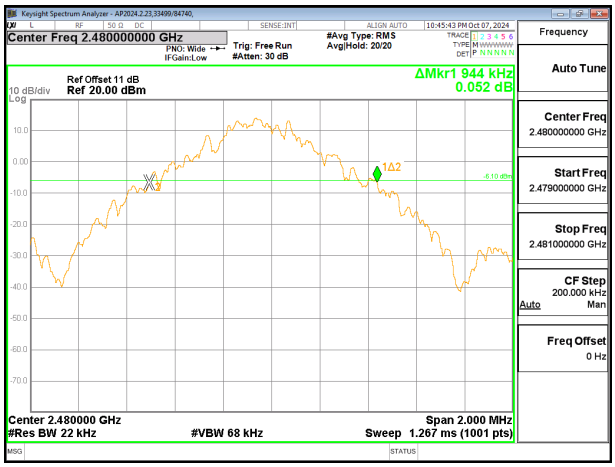
Channel	Frequency (MHz)	20dB Bandwidth (MHz)
Low	2402	0.892
Mid	2441	0.882
High	2480	0.944



LOW CHANNEL



MID CHANNEL

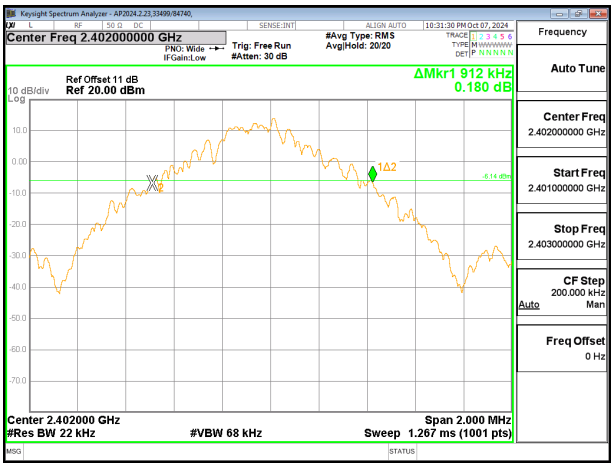


HIGH CHANNEL

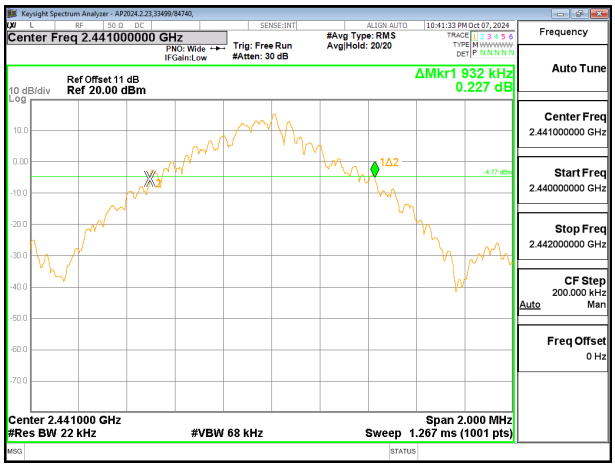
UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

Chain 1

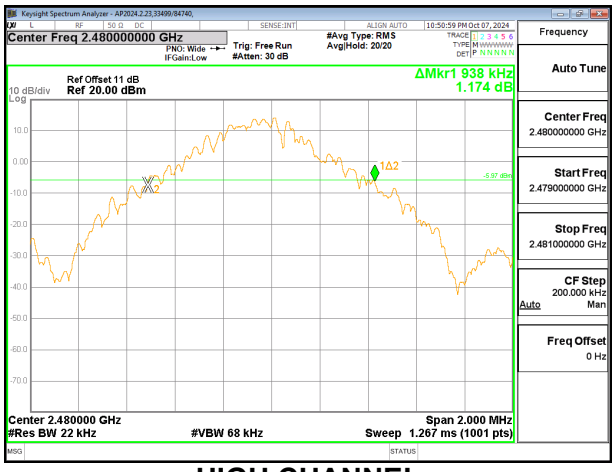
Channel	Frequency (MHz)	20dB Bandwidth (MHz)
Low	2402	0.912
Mid	2441	0.932
High	2480	0.938



LOW CHANNEL



MID CHANNEL



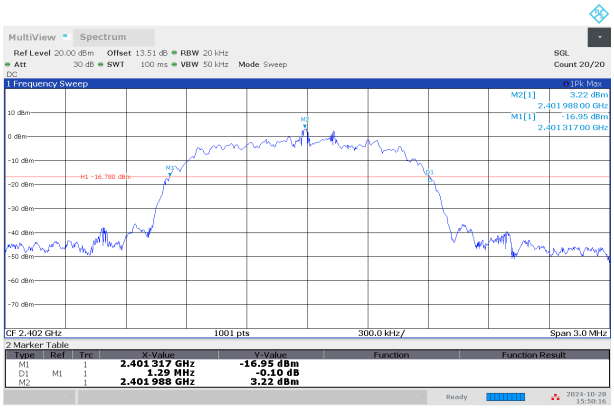
HIGH CHANNEL

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

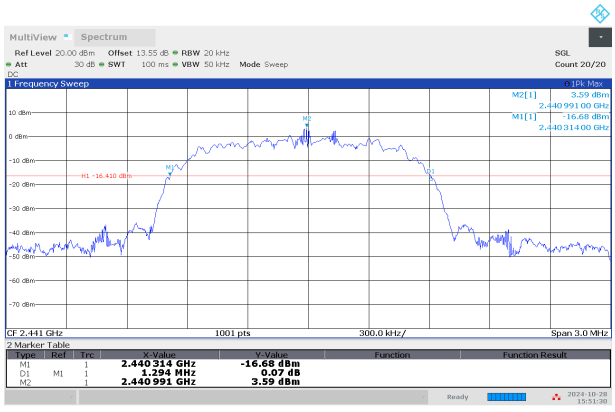
9.2.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION

Chain 0

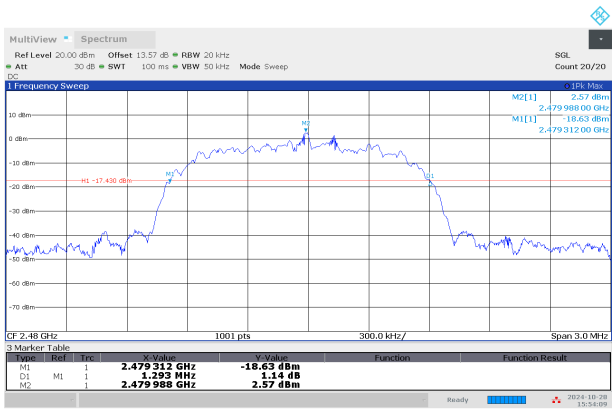
Channel	Frequency (MHz)	20dB Bandwidth (MHz)
Low	2402	1.290
Mid	2441	1.294
High	2480	1.293



LOW CHANNEL



MID CHANNEL

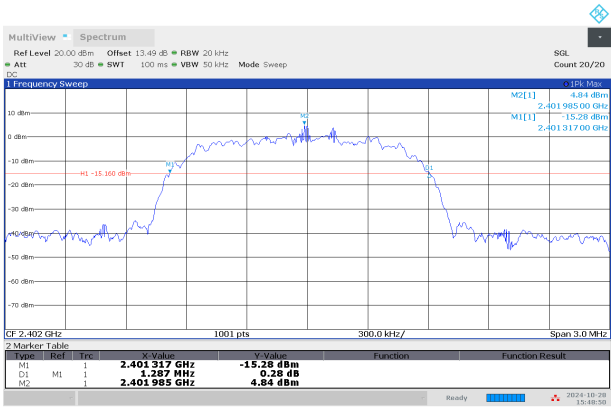


HIGH CHANNEL

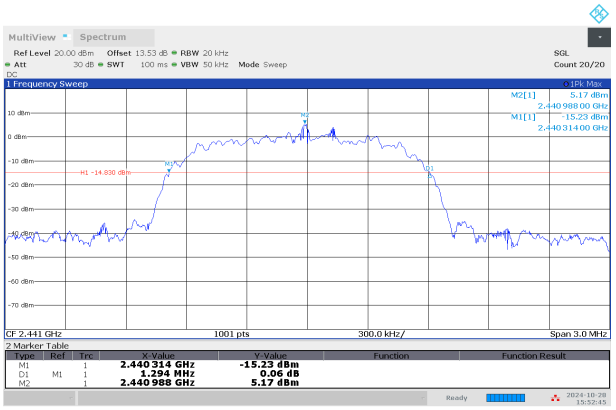
UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

Chain 1

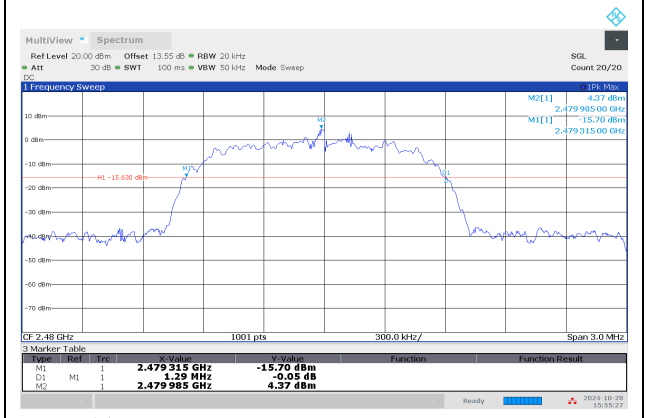
Channel	Frequency (MHz)	20dB Bandwidth (MHz)
Low	2402	1.287
Mid	2441	1.294
High	2480	1.290



LOW CHANNEL



MID CHANNEL



HIGH CHANNEL

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

9.3. 99% BANDWIDTH

LIMITS

None; for reporting purposes only.

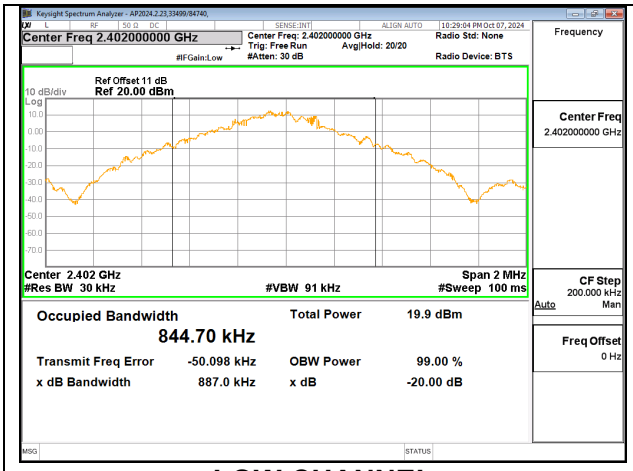
TEST PROCEDURE

The transmitter output is connected to a spectrum analyzer. The RBW is set to 1-5% of the 99% bandwidth. The VBW is set to ≥ RBW. The sweep time is coupled.

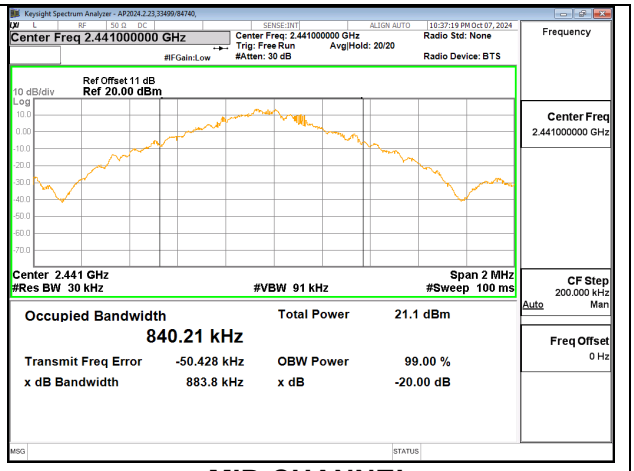
9.3.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION

CHAIN 0

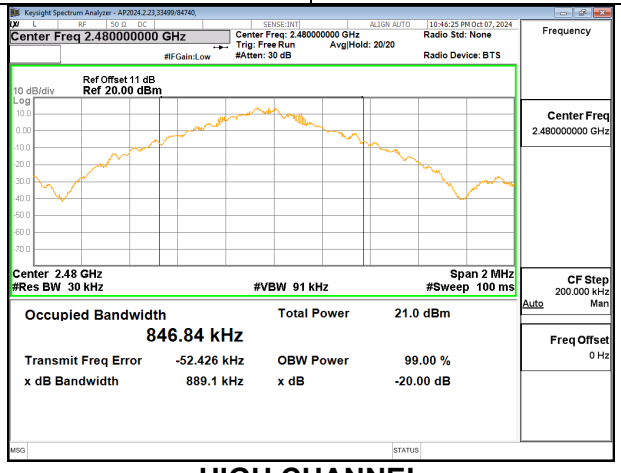
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low	2402	0.84470
Mid	2441	0.84021
High	2480	0.84684



LOW CHANNEL



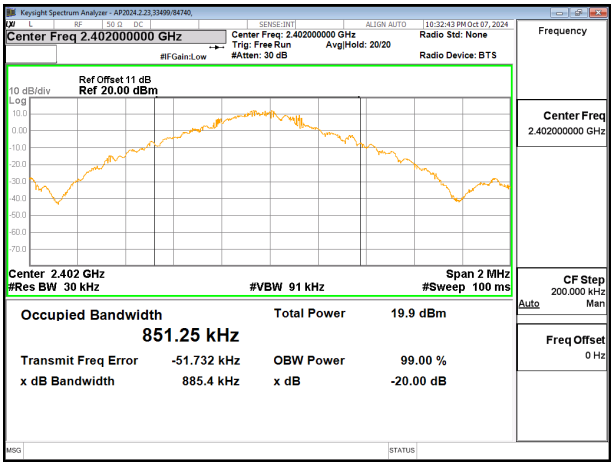
MID CHANNEL



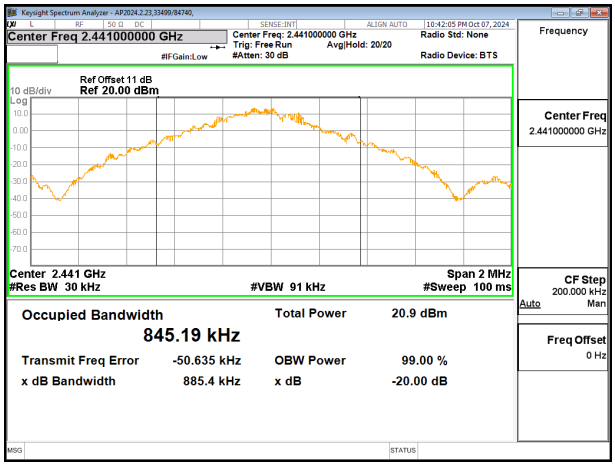
HIGH CHANNEL

CHAIN 1

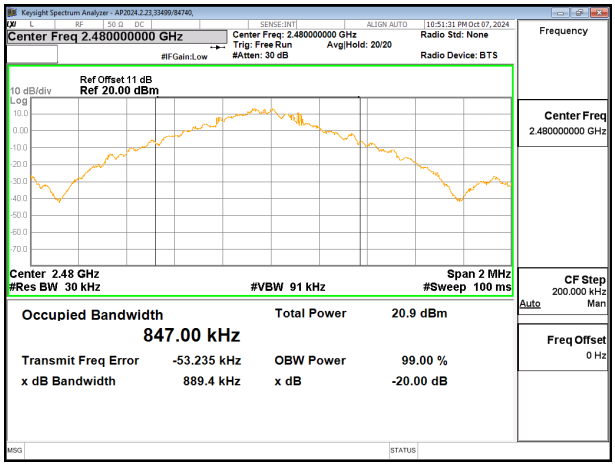
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low	2402	0.85125
Mid	2441	0.84519
High	2480	0.84700



LOW CHANNEL



MID CHANNEL



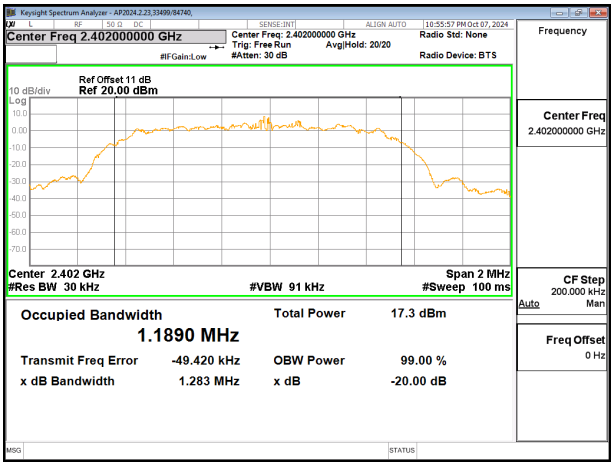
HIGH CHANNEL

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

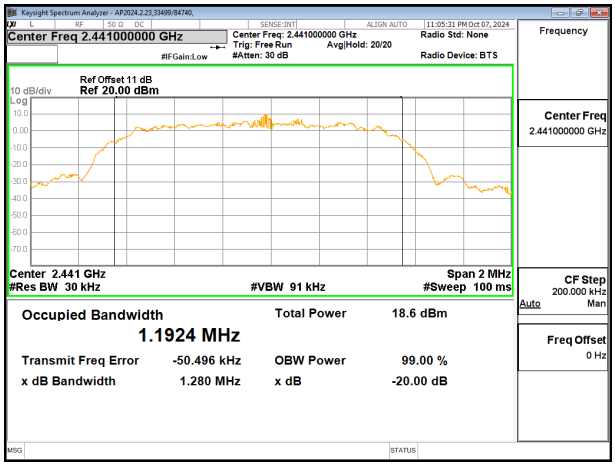
9.3.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION

CHAIN 0

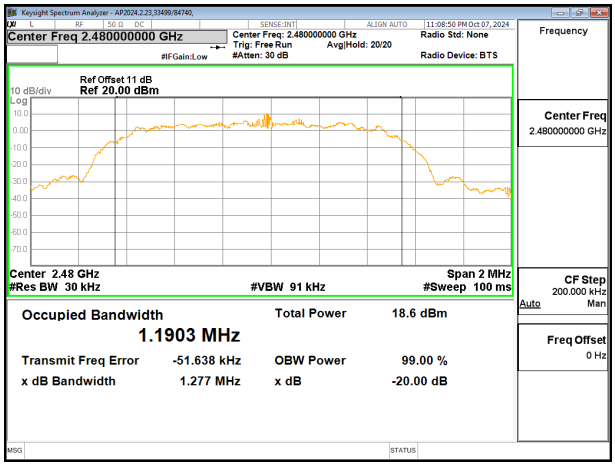
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low	2402	1.1890
Mid	2441	1.1924
High	2480	1.1903



LOW CHANNEL



MID CHANNEL

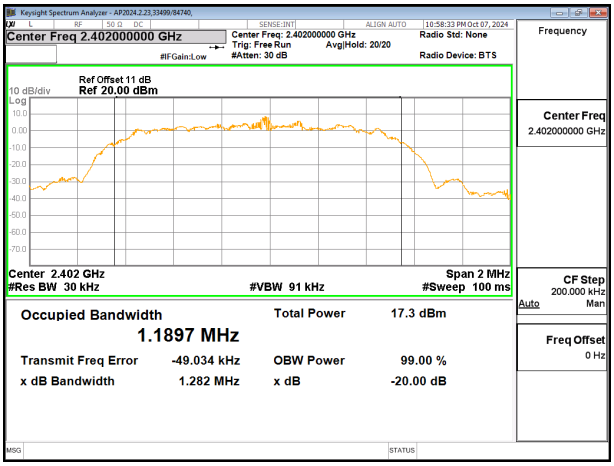


HIGH CHANNEL

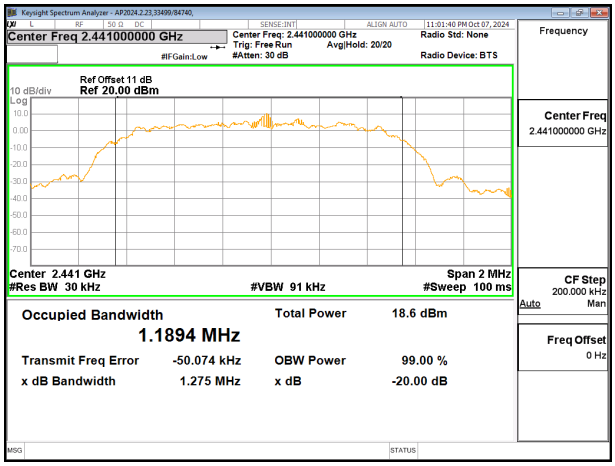
UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

CHAIN 1

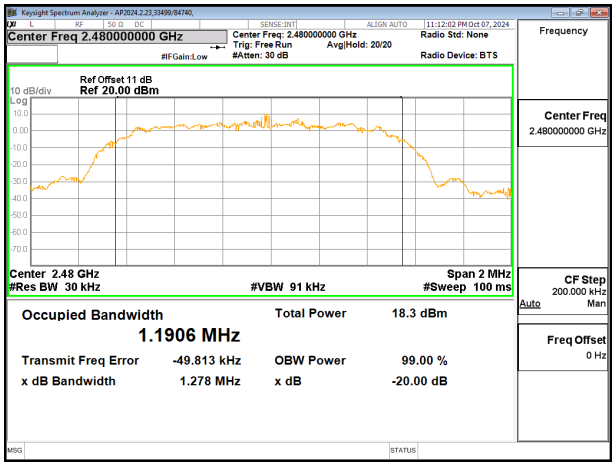
Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low	2402	1.1897
Mid	2441	1.1894
High	2480	1.1906



LOW CHANNEL



MID CHANNEL



HIGH CHANNEL

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

9.4. HOPPING FREQUENCY SEPARATION

LIMITS

FCC §15.247 (a) (1)
RSS-247 (5.1) (b)

Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hoping channel, whichever is greater.

Alternatively, frequency hopping systems operating in the 2400-2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW.

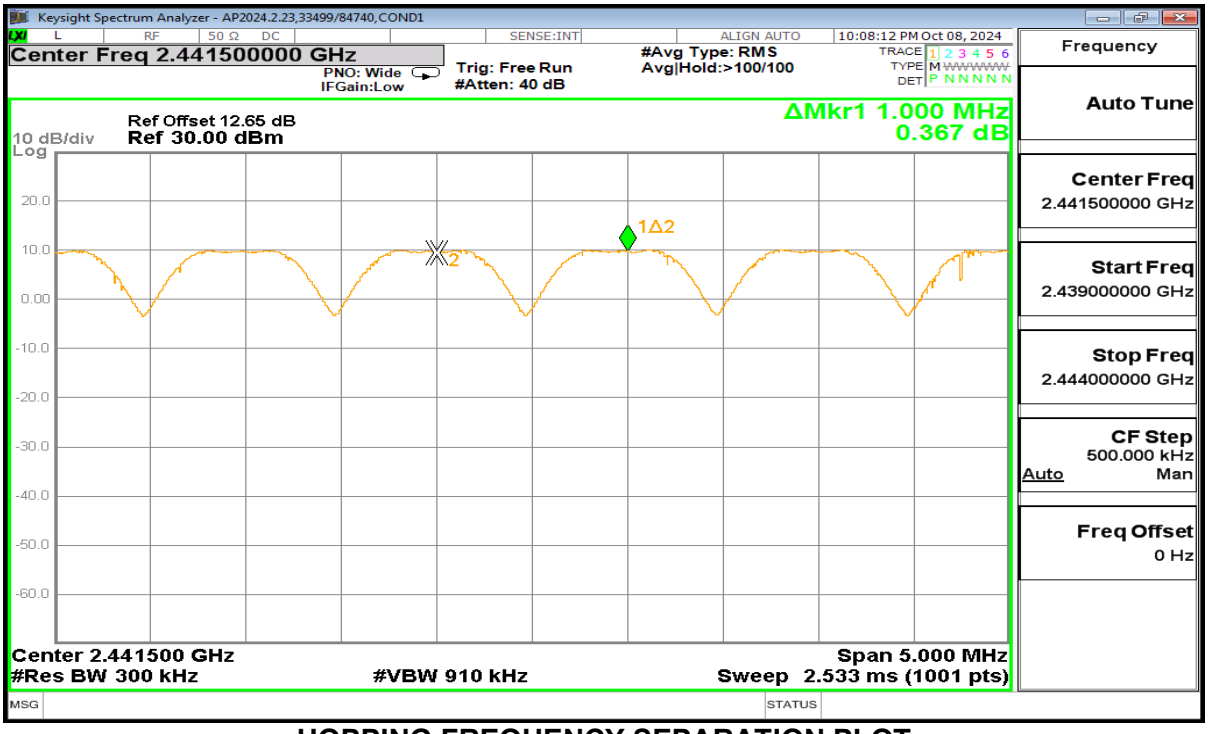
TEST PROCEDURE

The transmitter output is connected to a spectrum analyzer. The RBW is set to 300 kHz and the VBW is set to VBW >= RBW. The sweep time is coupled.

RESULTS

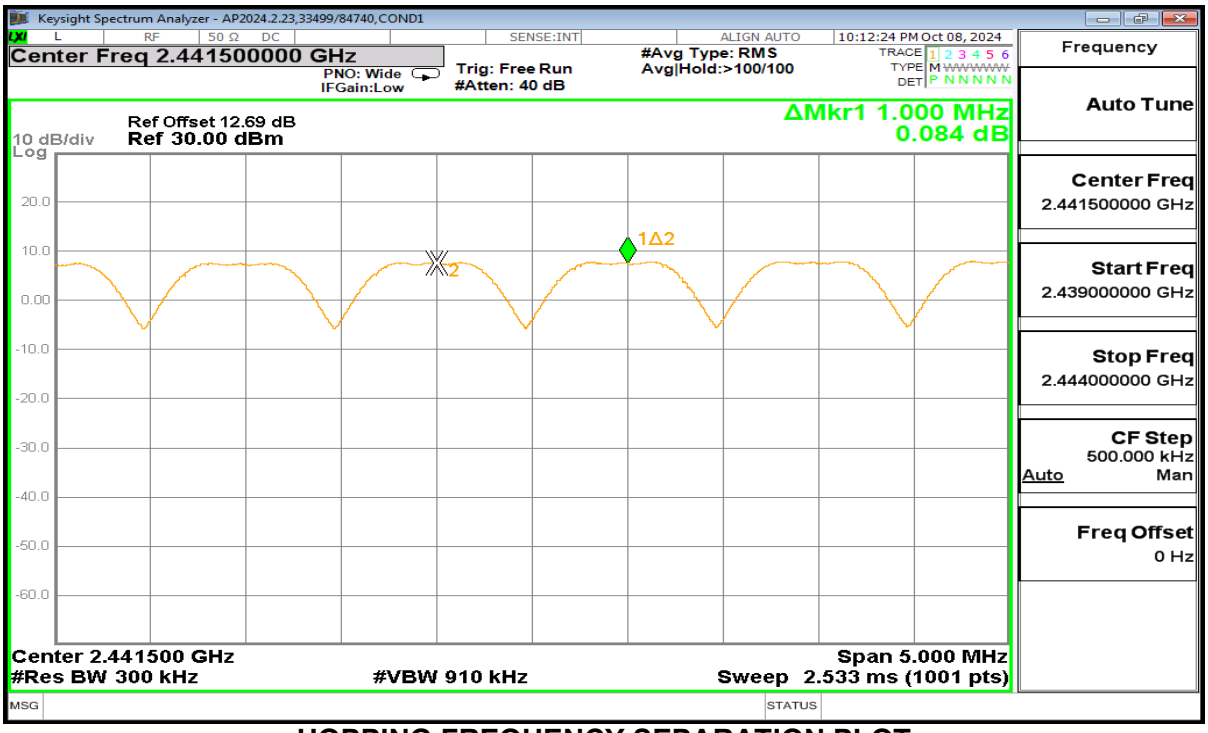
9.4.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION

Chain 0



HOPPING FREQUENCY SEPARATION PLOT

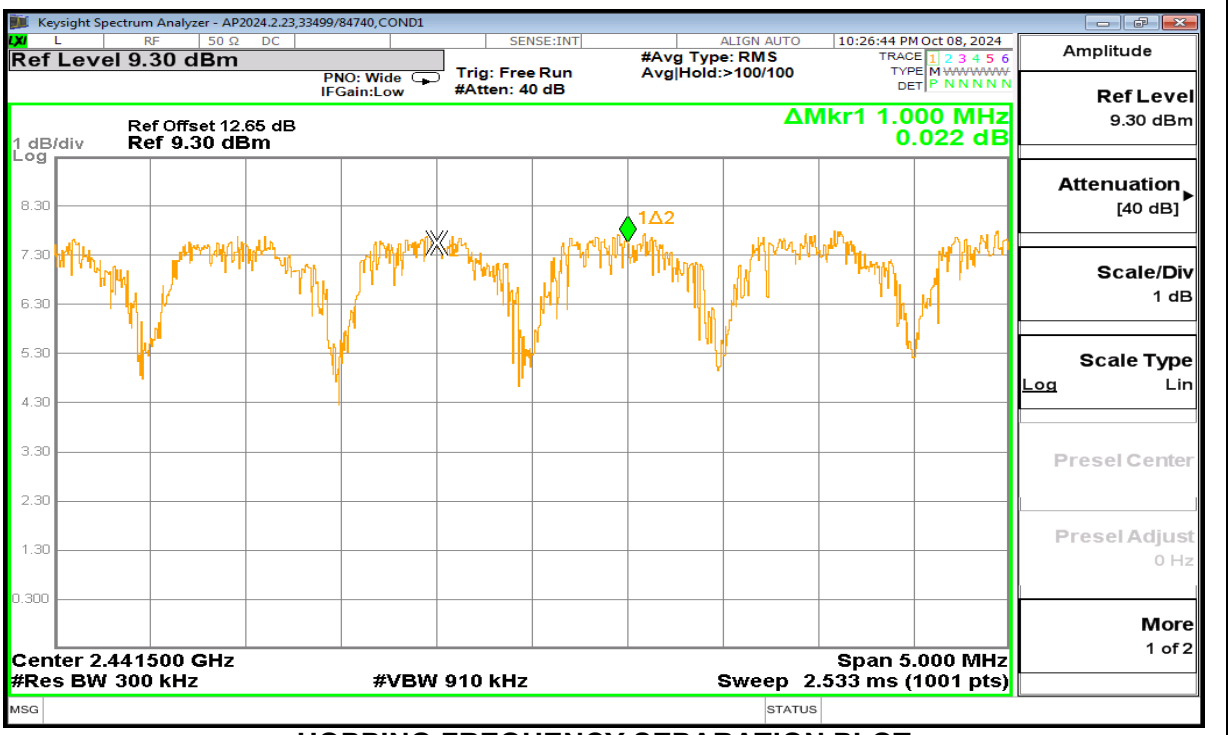
Chain 1



HOPPING FREQUENCY SEPARATION PLOT

9.4.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION

Chain 0



HOPPING FREQUENCY SEPARATION PLOT

Since output power is <125mW (21dBm), Separation can be > 2/3 20dB BW

Output Power (dBm)	Separation (MHz)	20dB BW (MHz)	2/3 dB BW (MHz)	Margin (MHz)
20.62	1.000	1.294	0.863	-0.137

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

Chain 1

HOPPING FREQUENCY SEPARATION PLOT

Since output power is <125mW (21dBm), Separation can be > 2/3 20dB BW

Output Power (dBm)	Separation (MHz)	20dB BW (MHz)	2/3 dB BW (MHz)	Margin (MHz)
20.62	1.000	1.294	0.863	-0.137

9.5. NUMBER OF HOPPING CHANNELS

LIMITS

FCC §15.247 (a) (1) (iii)
RSS-247 (5.1) (d)

Frequency hopping systems in the 2400 – 2483.5 MHz band shall use at least 15 non-overlapping channels.

TEST PROCEDURE

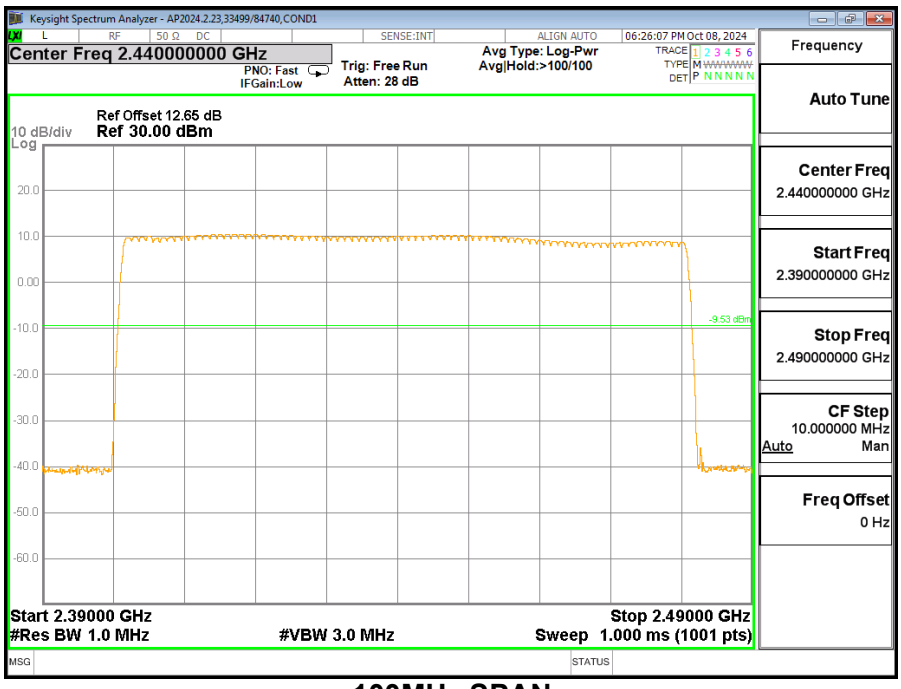
The transmitter output is connected to a spectrum analyzer. The span is set to cover the entire authorized band, in either a single sweep or in multiple contiguous sweeps. The RBW is set to a maximum of 1 % of the span. The analyzer is set to Max Hold.

RESULTS

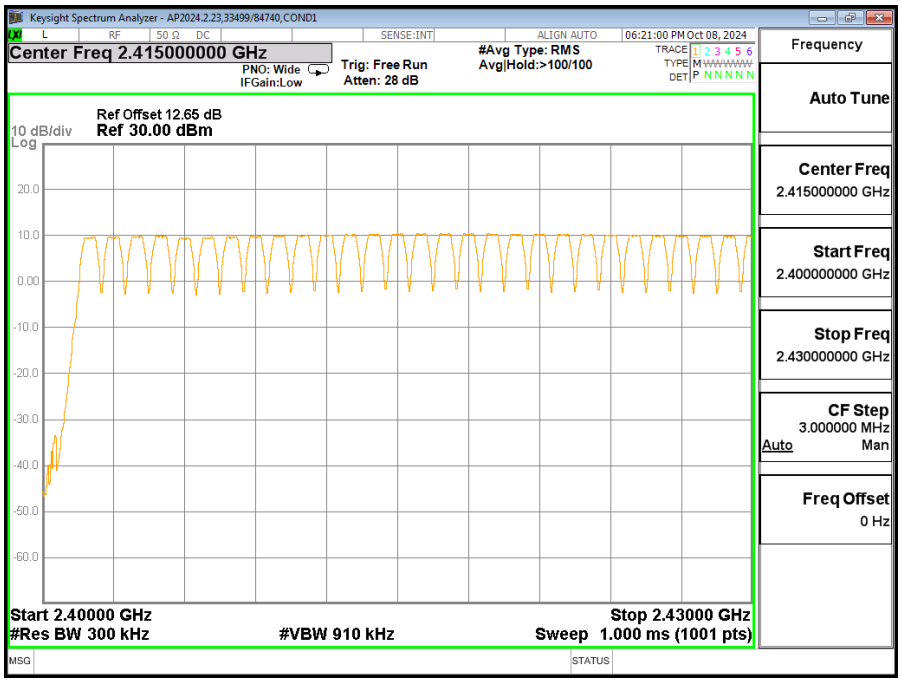
Normal Mode: 79 Channels Observed

9.5.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION

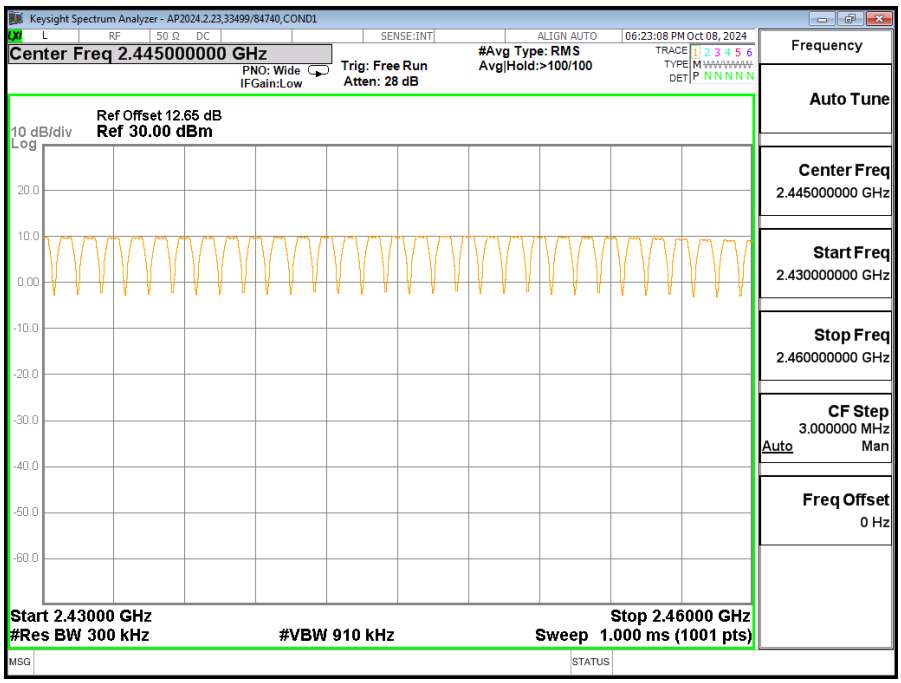
Chain 0



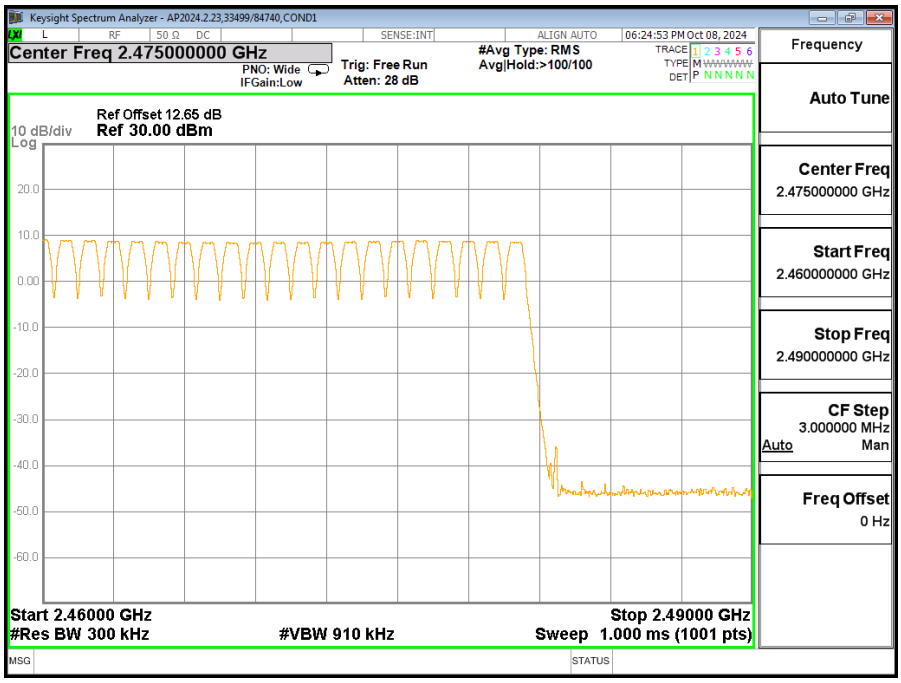
100MHz SPAN



30MHz SPAN, SEGMENT 1 OF 3

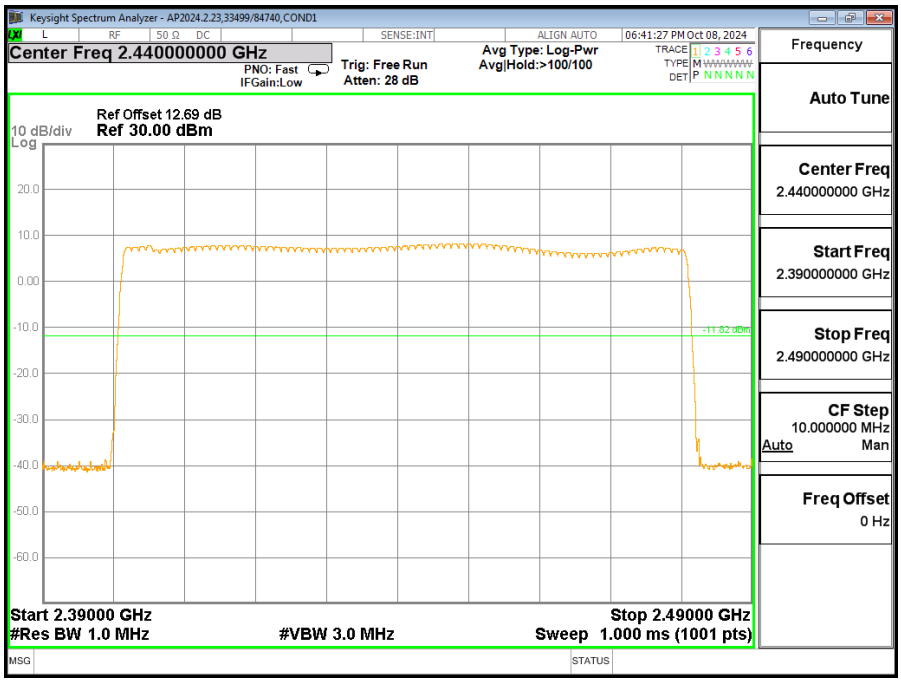


30MHz SPAN, SEGMENT 2 OF 3

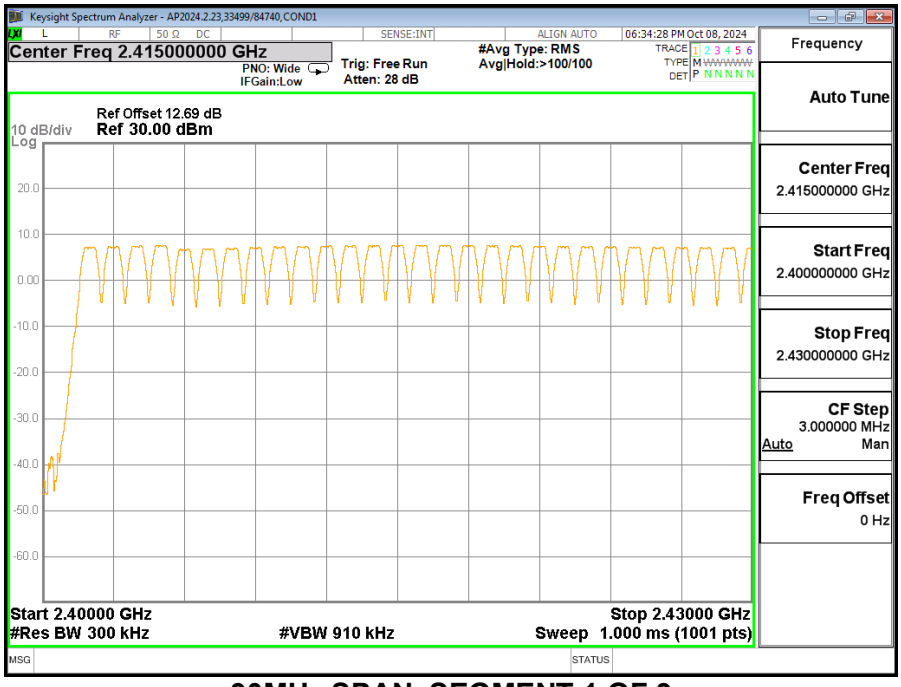


30MHz SPAN, SEGMENT 3 OF 3

Chain 1

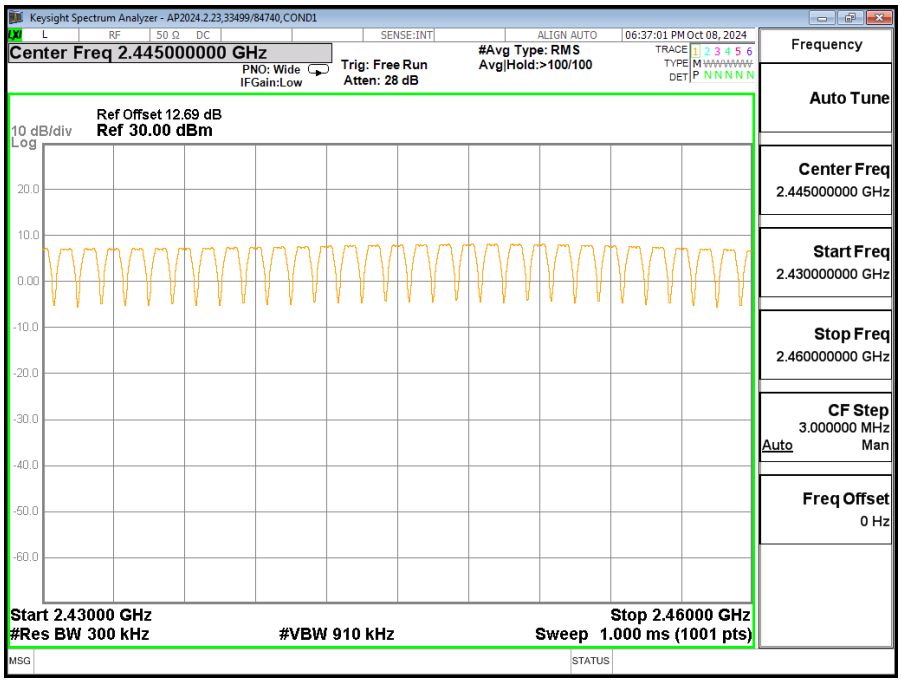


100MHz SPAN

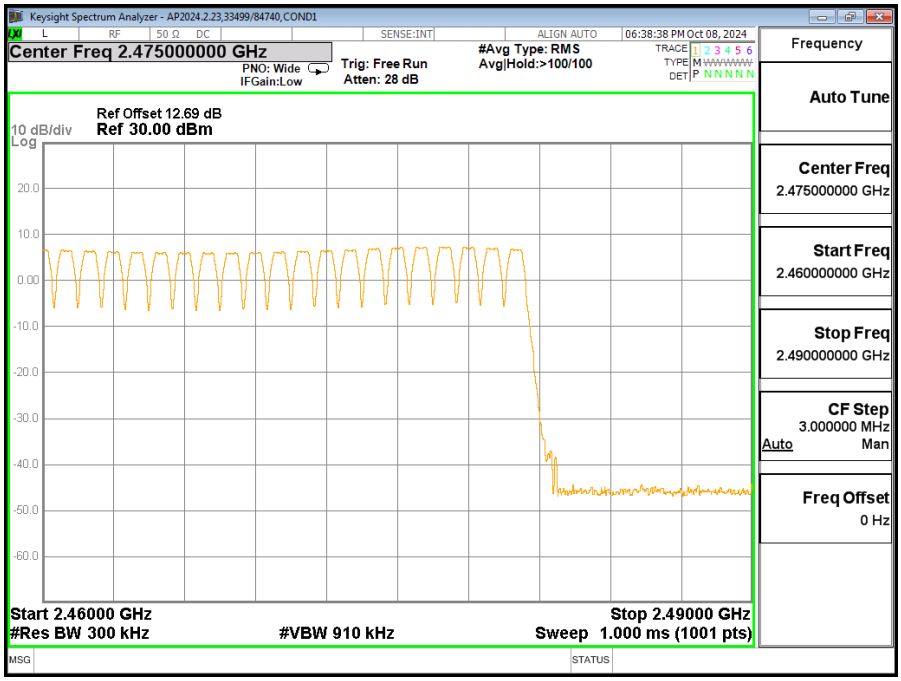


30MHz SPAN, SEGMENT 1 OF 3

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400



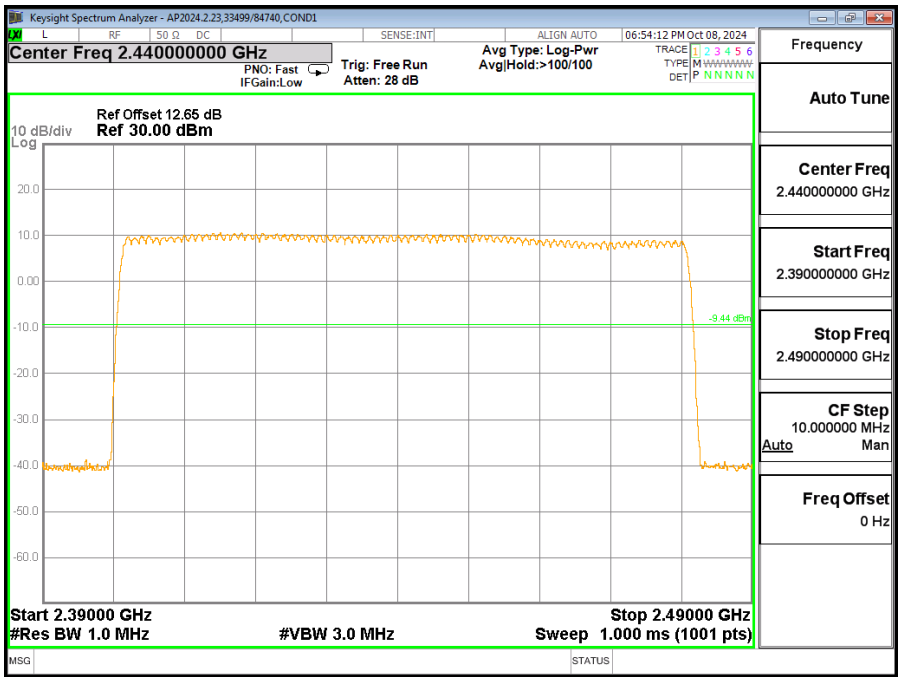
30MHz SPAN, SEGMENT 2 OF 3



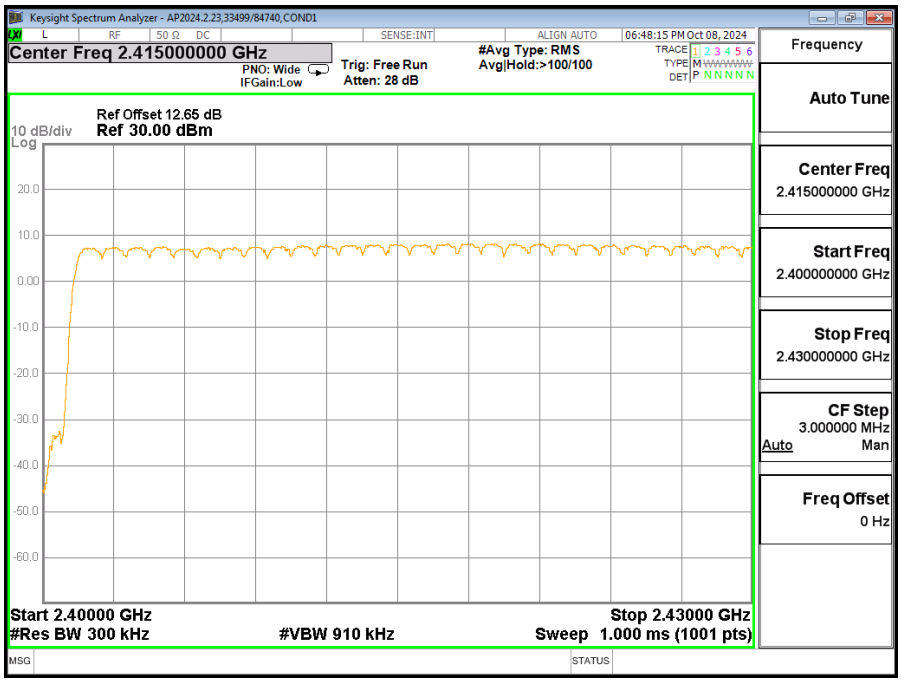
30MHz SPAN, SEGMENT 3 OF 3

9.5.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION

Chain 0

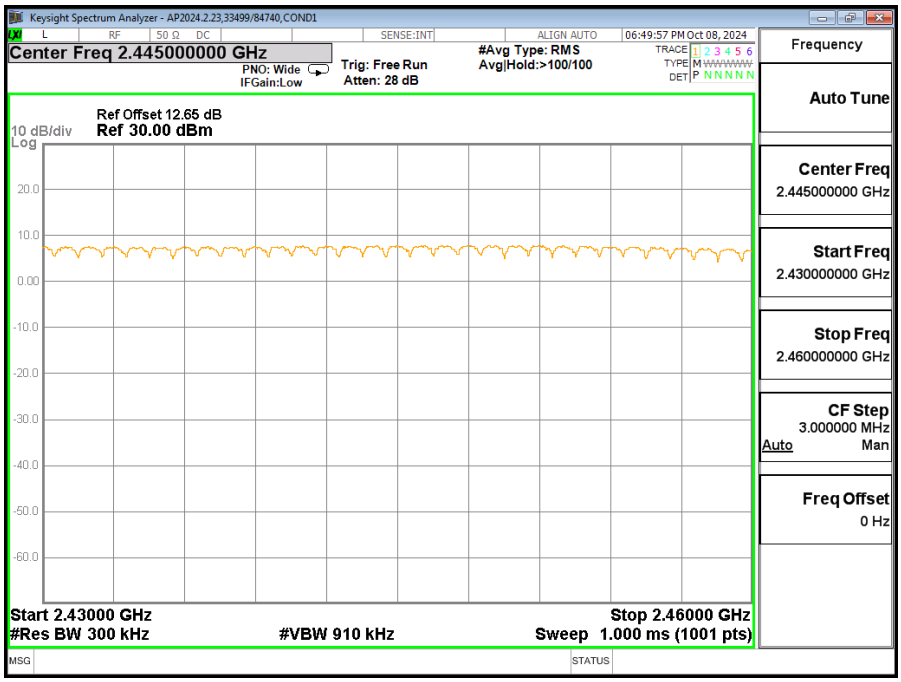


100MHz SPAN

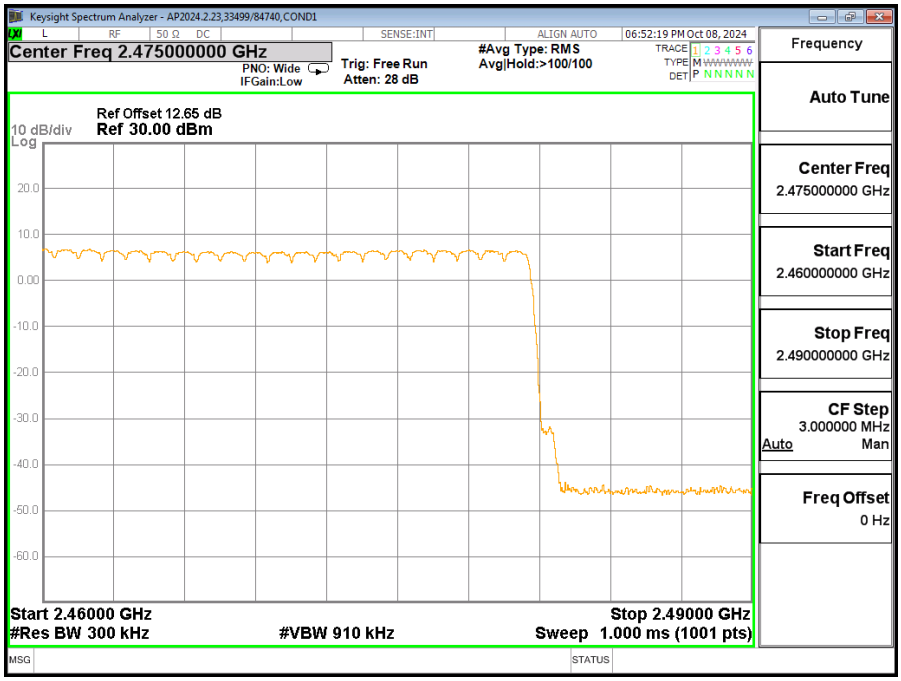


30MHz SPAN, SEGMENT 1 OF 3

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400



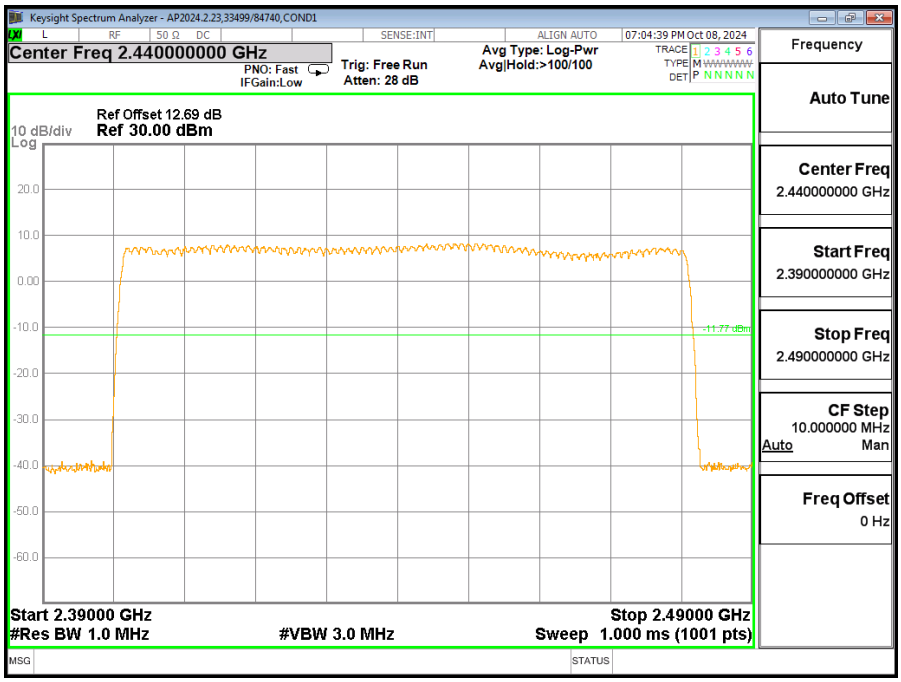
30MHz SPAN, SEGMENT 2 OF 3



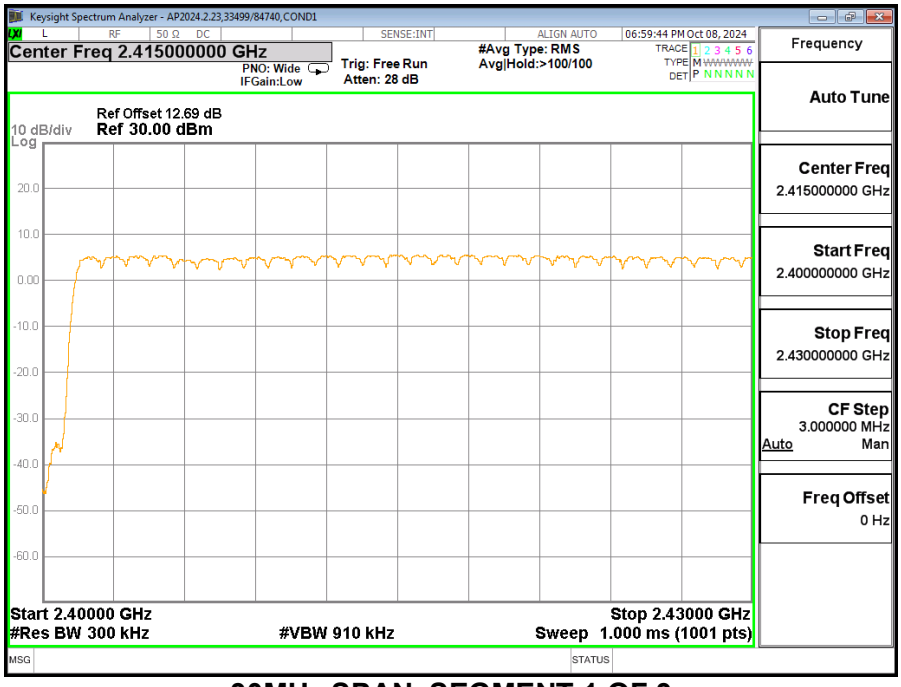
30MHz SPAN, SEGMENT 3 OF 3

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

Chain 1

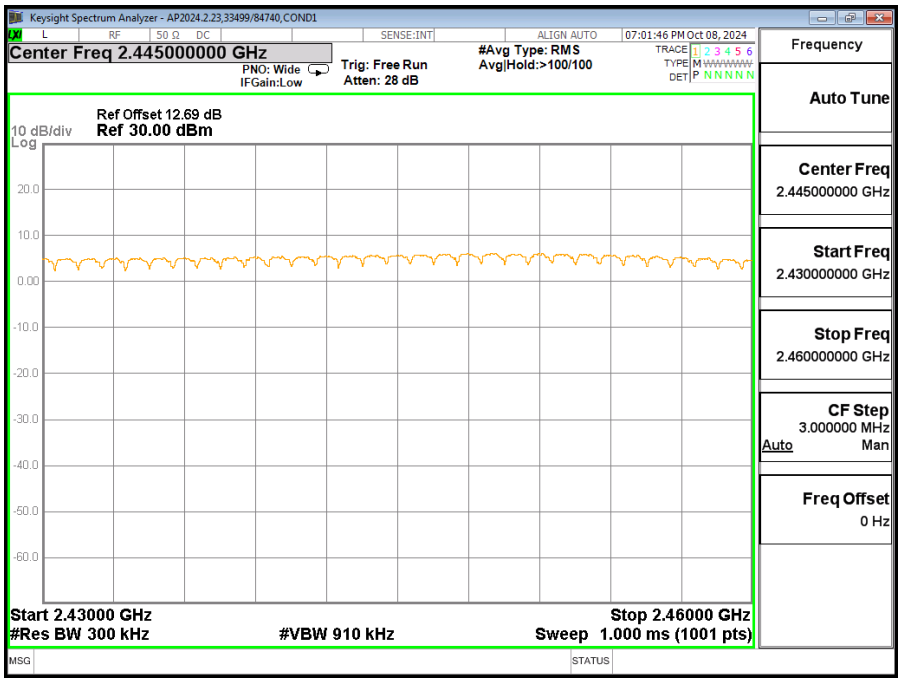


100MHz SPAN

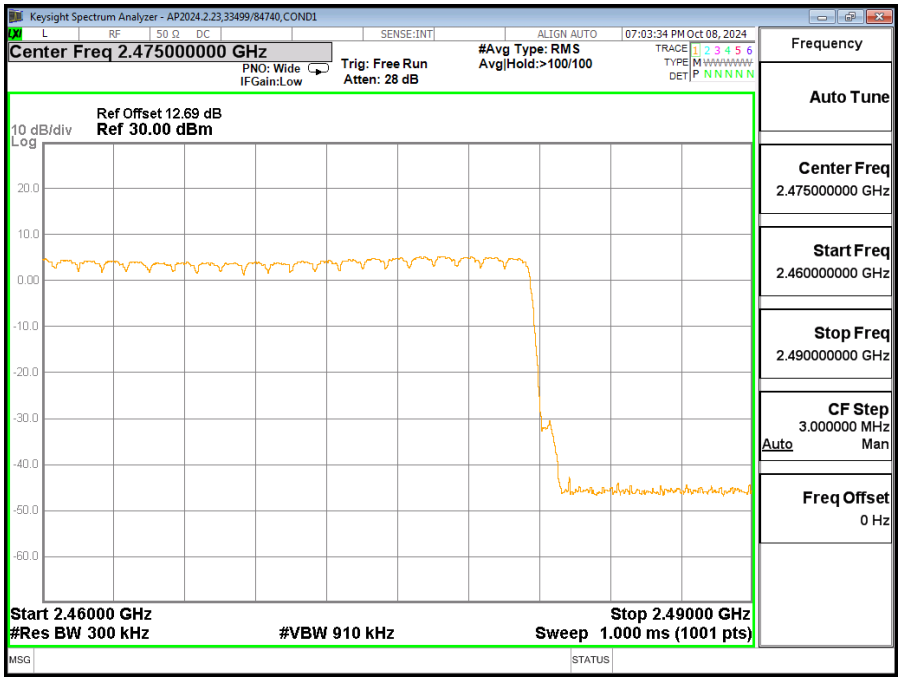


30MHz SPAN, SEGMENT 1 OF 3

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400



30MHz SPAN, SEGMENT 2 OF 3



30MHz SPAN, SEGMENT 3 OF 3

9.6. AVERAGE TIME OF OCCUPANCY

LIMITS

FCC §15.247 (a) (1) (iii)
RSS-247 (5.1) (d)

The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed.

TEST PROCEDURE

The transmitter output is connected to a spectrum analyzer. The span is set to 0 Hz, centered on a single, selected hopping channel. The width of a single pulse is measured in a fast scan. The number of pulses is measured in a 3.16 second scan, to enable resolution of each occurrence.

The average time of occupancy in the specified 31.6 second period (79 channels * 0.4 s) is equal to 10 * (# of pulses in 3.16 s) * pulse width.

For AFH mode, the average time of occupancy in the specified 8 second period (20 channels * 0.4 seconds) is equal to 10 * (# of pulses in 0.8 s) * pulse width.

RESULTS

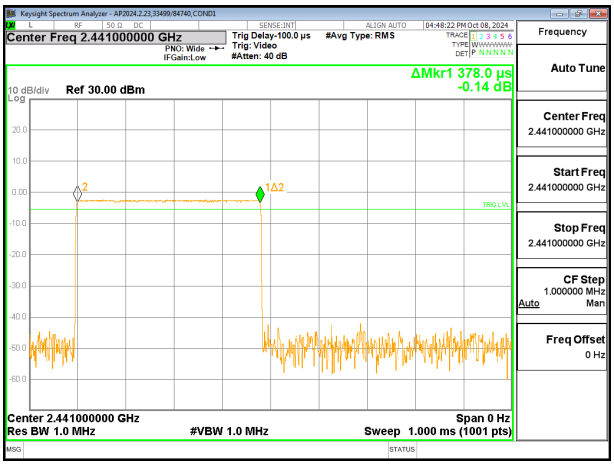
UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

9.6.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION

Chain 0

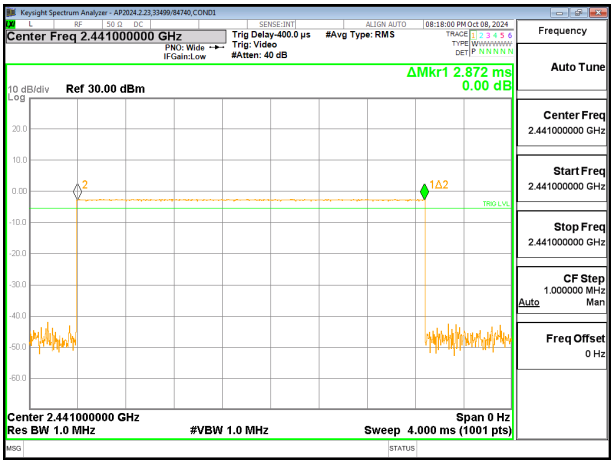
DH Packet	Pulse Width (msec)	Number of Pulses in 3.16 seconds	Average Time of Occupancy (sec)	Limit (sec)	Margin (sec)
GFSK Normal Mode					
DH1	0.378	30	0.1134	0.4	-0.2866
DH3	1.630	20	0.3260	0.4	-0.0740
DH5	2.872	9	0.2585	0.4	-0.1415
DH Packet	Pulse Width (sec)	Number of Pulses in 0.8 seconds	Average Time of Occupancy (sec)	Limit (sec)	Margin (sec)
GFSK AFH Mode					
DH1	0.378	7.5	0.02835	0.4	-0.3717
DH3	1.630	5	0.08150	0.4	-0.3185
DH5	2.872	2.25	0.06462	0.4	-0.3354

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400



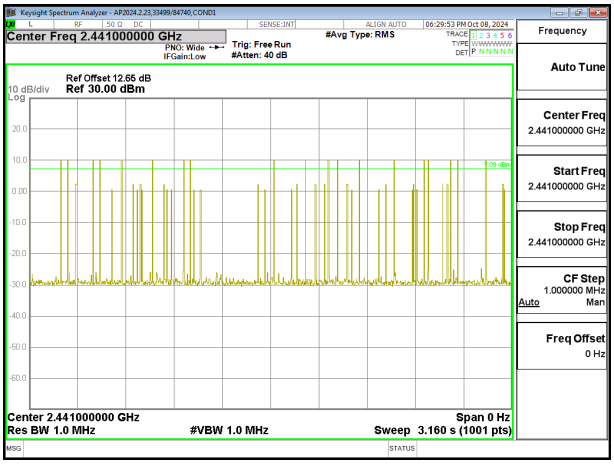
PULSE WIDTH – DH1

PULSE WIDTH – DH3



PULSE WIDTH – DH5

NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – DH1



NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – DH3

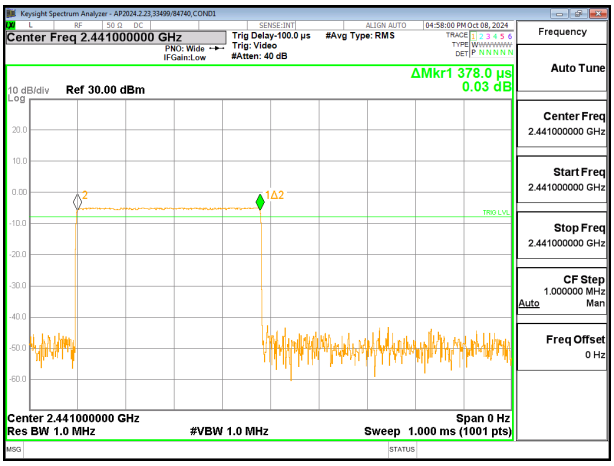
NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – DH5

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

Chain 1

DH Packet	Pulse Width (msec)	Number of Pulses in 3.16 seconds	Average Time of Occupancy (sec)	Limit (sec)	Margin (sec)
GFSK Normal Mode					
DH1	0.378	32	0.1210	0.4	-0.2790
DH3	1.630	17	0.2771	0.4	-0.1229
DH5	2.872	9	0.2585	0.4	-0.1415
DH Packet	Pulse Width (sec)	Number of Pulses in 0.8 seconds	Average Time of Occupancy (sec)	Limit (sec)	Margin (sec)
GFSK AFH Mode					
DH1	0.378	8	0.03024	0.4	-0.3698
DH3	1.630	4.25	0.06928	0.4	-0.3307
DH5	2.872	2.25	0.06462	0.4	-0.3354

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

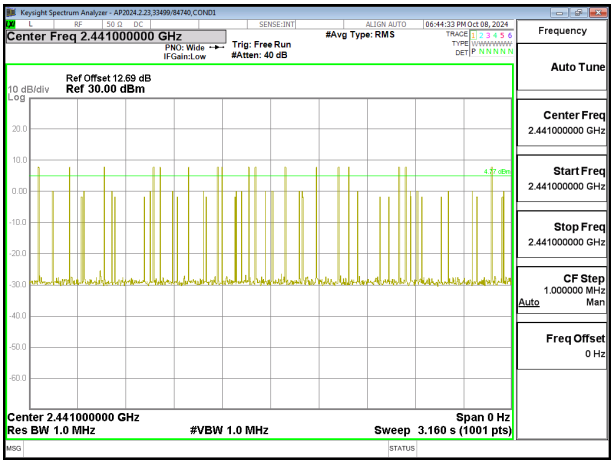


PULSE WIDTH – DH1

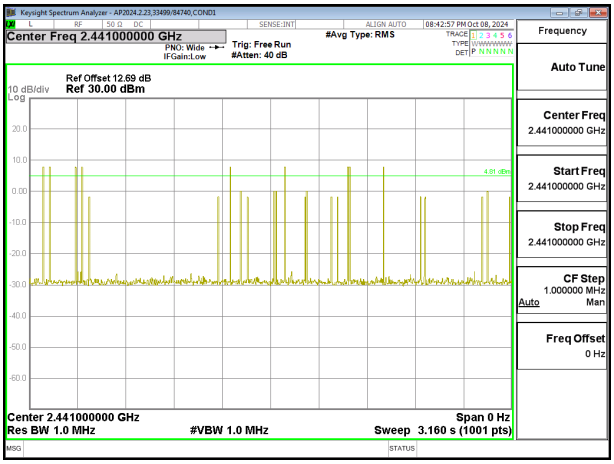
PULSE WIDTH – DH3

PULSE WIDTH – DH5

NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – DH1



NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – DH3



NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – DH5

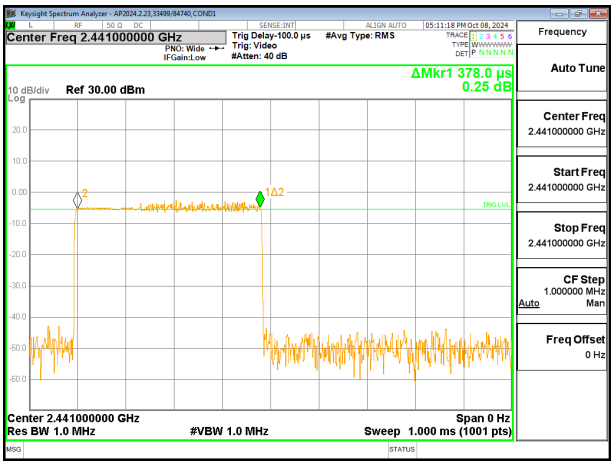
9.6.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION

Chain 0

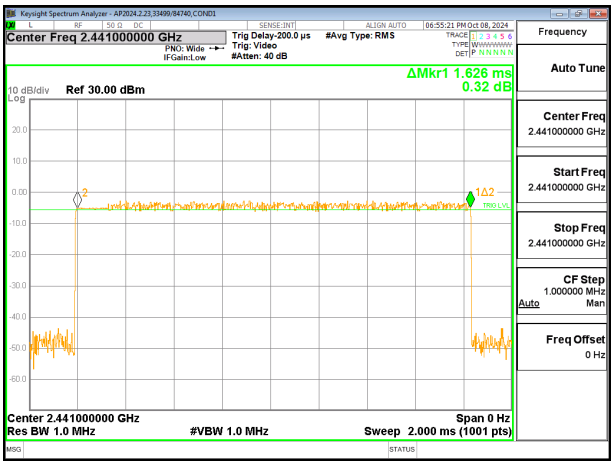
DH Packet	Pulse Width (msec)	Number of Pulses in 3.16 seconds	Average Time of Occupancy (sec)	Limit (sec)	Margin (sec)
8PSK Normal Mode					
3DH1	0.378	31	0.11718	0.4	-0.2828
3DH3	1.626	19	0.30894	0.4	-0.0911
3DH5	2.872	9	0.25848	0.4	-0.1415

Note: for AFH(8PSK) mode, please refer to the results of AFH(GFSK) mode; the channel selection and hopping rate are the same for both EDR and Basic Rate operation, data for Basic Rate demonstrates compliance with channel occupancy when AFH is employed.

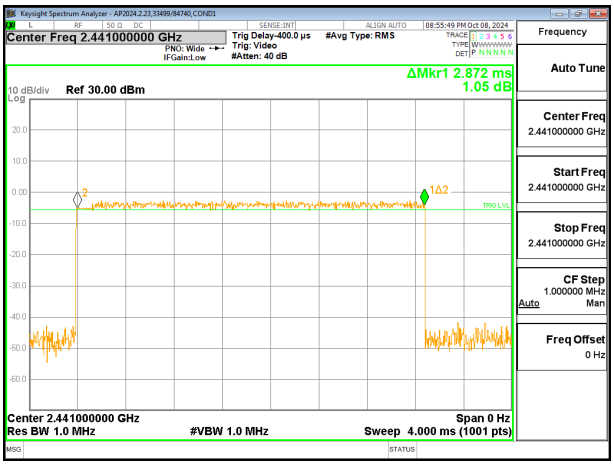
UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400



PULSE WIDTH – 3DH1



PULSE WIDTH – 3DH3



PULSE WIDTH – 3DH5

NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – 3DH1

NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – 3DH3

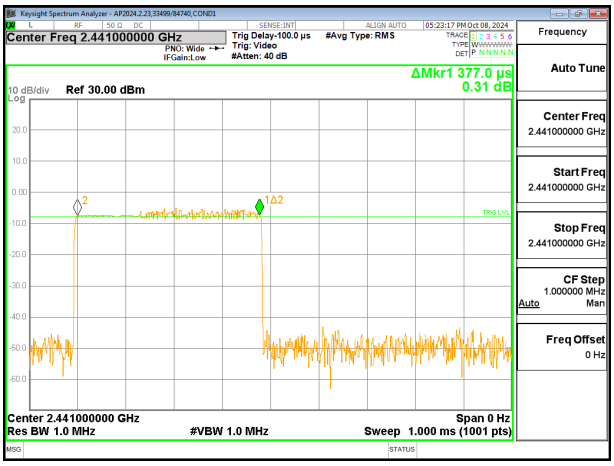
NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – 3DH5

Chain 1

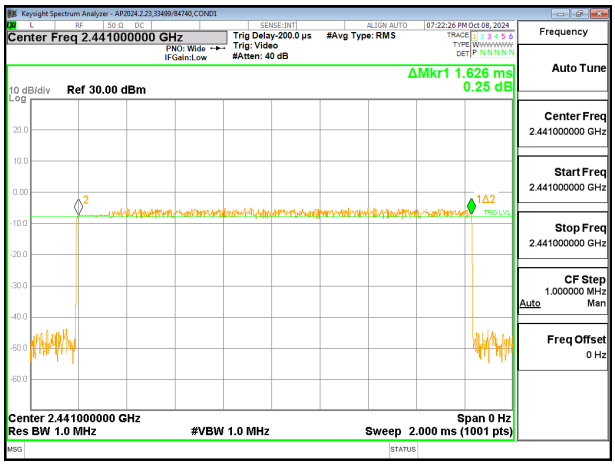
DH Packet	Pulse Width (msec)	Number of Pulses in 3.16 seconds	Average Time of Occupancy (sec)	Limit (sec)	Margin (sec)
8PSK Normal Mode					
3DH1	0.377	32	0.12064	0.4	-0.2794
3DH3	1.626	17	0.27642	0.4	-0.1236
3DH5	2.872	11	0.31592	0.4	-0.0841

Note: for AFH(8PSK) mode, please refer to the results of AFH(GFSK) mode; the channel selection and hopping rate are the same for both EDR and Basic Rate operation, data for Basic Rate demonstrates compliance with channel occupancy when AFH is employed.

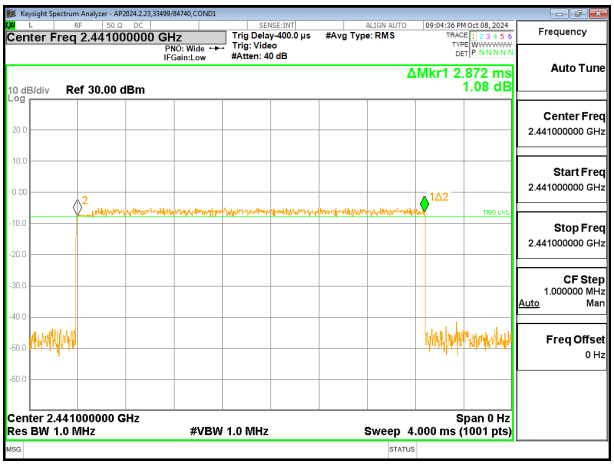
UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400



PULSE WIDTH – 3DH1



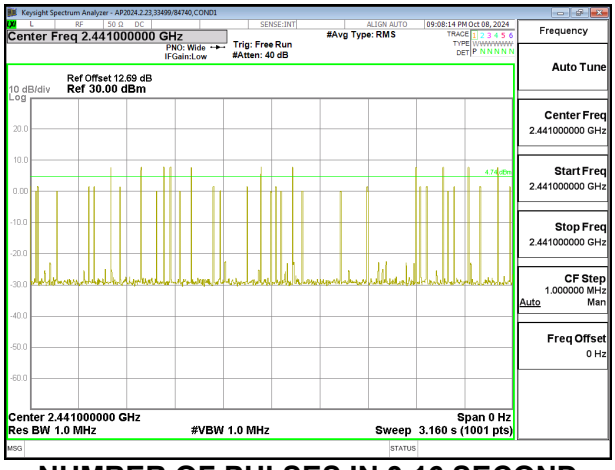
PULSE WIDTH – 3DH3



PULSE WIDTH – 3DH5

NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – 3DH1

NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – 3DH3



NUMBER OF PULSES IN 3.16 SECOND OBSERVATION PERIOD – 3DH5

9.7. OUTPUT POWER

LIMITS

§15.247 (b) (1)
RSS-247 (5.4) (b)

The maximum SISO antenna gain is greater than 6 dBi, therefore the limit, 21dBm, is reduced by the amount of the gain >6dB, in this case 0.1 dB. For MIMO, the gain is also >6dBi. Therefore the limit is reduced by the amount of gain >6dBi, 3.11 dB.

For frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725-5850 MHz band: 1 watt. For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 watts. The EUT supports AFH thus the limit used is 125 mW for all modes.

TEST PROCEDURE

The transmitter output is connected to a wideband RF power meter.

The cable assembly insertion loss of 11.04 dB for C0 (including 9.72 dB pad and 1.32 dB EUT cable) and 11 dB for C1 (9.68 dB pad and 1.32 dB EUT) was entered as an offset in the power meter

RESULTS

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

9.7.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION

Chain 0

Tested By:	33499/84740
Date:	2024-10-07

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	18.27	20.9	-2.63
Middle	2441	19.39	20.9	-1.51
High	2480	19.54	20.9	-1.36

Chain 1

Tested By:	33499/84740
Date:	2024-10-07

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	17.96	20.9	-2.94
Middle	2441	19.66	20.9	-1.24
High	2480	19.45	20.9	-1.45

2Tx

Tested By:	107116/85501
Date:	2024-10-14

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	16.94	20.9	-3.96
Middle	2441	17.2	20.9	-3.7
High	2480	15.88	20.9	-5.02

9.7.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION

Chain 0

Tested By:	33499/84740
Date:	2024-10-07

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	18.91	20.9	-1.99
Middle	2441	19.77	20.9	-1.13
High	2480	19.91	20.9	-0.99

Chain 1

Tested By:	33499/84740
Date:	2024-10-07

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	18.46	20.9	-2.44
Middle	2441	20.06	20.9	-0.84
High	2480	20.19	20.9	-0.71

2Tx

Tested By:	107116/85501
Date:	2024-10-14

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	16.66	20.9	-4.24
Middle	2441	16.91	20.9	-3.99
High	2480	15.91	20.9	-4.99

9.7.3. BLUETOOTH ENHANCED DATA RATE DQPSK MODULATION

Chain 0

Tested By:	33499/84740
Date:	2024-10-07

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	18.34	20.9	-2.56
Middle	2441	19.31	20.9	-1.59
High	2480	19.59	20.9	-1.31

Chain 1

Tested By:	33499/84740
Date:	2024-10-07

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	17.92	20.9	-2.98
Middle	2441	19.51	20.9	-1.39
High	2480	19.47	20.9	-1.43

2Tx

Tested By:	107116/85501
Date:	2024-10-14

Channel	Frequency (MHz)	Output Power (dBm)	Limit (dBm)	Margin (dB)
Low	2402	16.22	20.9	-4.68
Middle	2441	16.46	20.9	-4.44
High	2480	15.49	20.9	-5.41

9.8. AVERAGE POWER

LIMITS

None; for reporting purposes only

TEST PROCEDURE

The transmitter output is connected to a wideband gated RF power meter.

The cable assembly insertion loss of 11.04 dB for C0 (including 9.72 dB pad and 1.32 dB EUT cable) and 11 dB for C1 (9.68 dB pad and 1.32 dB EUT) was entered as an offset in the power meter.

RESULTS

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

9.8.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION

Tested By:	33499/44389, 107716/85501
Date	2024-10-07, 2024-10-14

Channel	Frequency (MHz)	Average Power SISO Chain 0 (dBm)	Average Power SISO Chain 1 (dBm)	Average Power MIMO 2Tx (dBm)
Low	2402	17.95	17.62	16.54
Middle	2441	18.95	19.36	16.81
High	2480	19.11	19.05	15.48

9.8.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION

Tested By:	33499/44389, 107716/85501
Date	2024-10-07, 2024-10-14

Channel	Frequency (MHz)	Average Power SISO Chain 0 (dBm)	Average Power SISO Chain 1 (dBm)	Average Power MIMO 2Tx (dBm)
Low	2402	15.25	14.82	13.61
Middle	2441	16.02	16.42	13.85
High	2480	16.27	16.40	13.04

9.8.3. BLUETOOTH ENHANCED DATA RATE DQPSK MODULATION

Tested By:	33499/44389, 107716/85501
Date	2024-10-07, 2024-10-14

Channel	Frequency (MHz)	Average Power SISO Chain 0 (dBm)	Average Power SISO Chain 1 (dBm)	Average Power MIMO 2Tx (dBm)
Low	2402	15.22	14.90	13.62
Middle	2441	15.68	16.47	13.87
High	2480	16.43	16.13	13.02

9.9. CONDUCTED SPURIOUS EMISSIONS

LIMITS

FCC §15.247 (d)
RSS-247 5.5

Limit = -20 dBc

TEST PROCEDURE

The transmitter output is connected to a spectrum analyzer. The resolution bandwidth is set to 100 kHz.The video bandwidth is set to 300 kHz.

The spectrum from 30 MHz to 26 GHz is investigated with the transmitter set to the lowest, middle, and highest channels with hopping disabled.

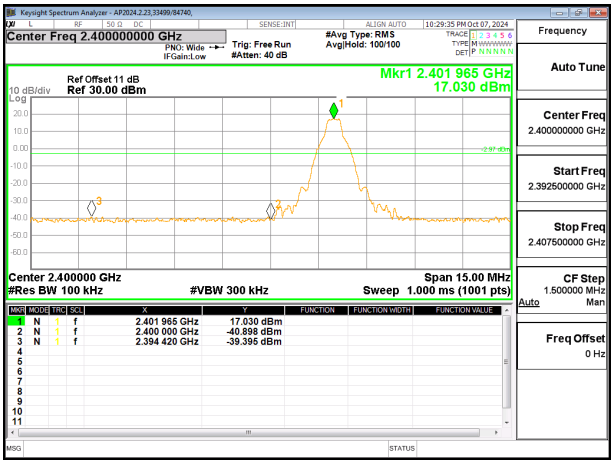
The bandedges at 2.4 and 2.4835 GHz are investigated with the transmitter set to the normal hopping mode and with hopping disabled.

RESULTS

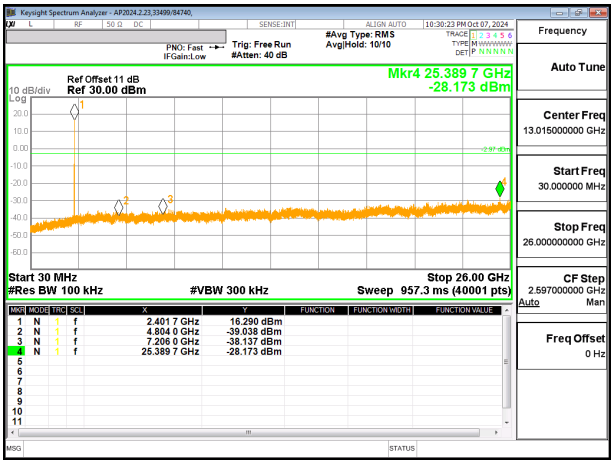
UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

9.9.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION

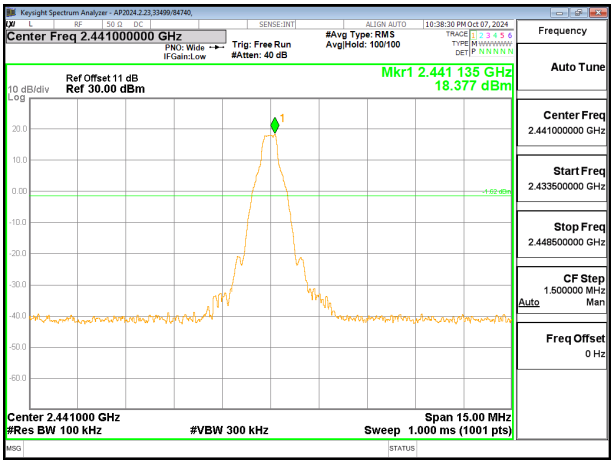
Chain 0 SPURIOUS EMISSIONS, NON-HOPPING



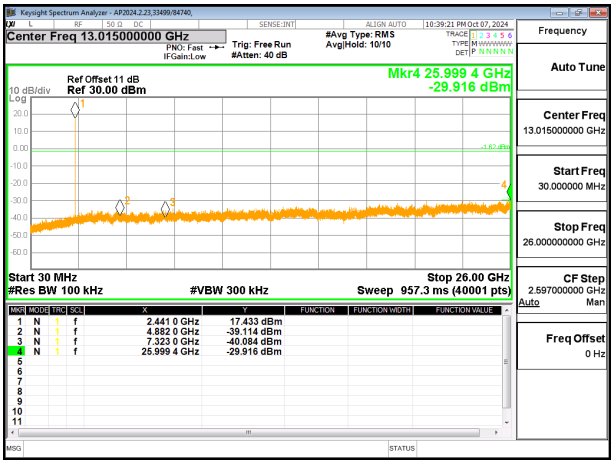
LOW CHANNEL BANDEDGE



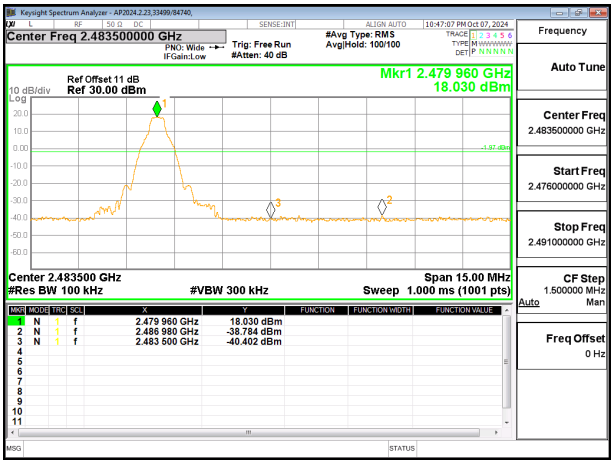
OUT-OF-BAND LOW CHANNEL



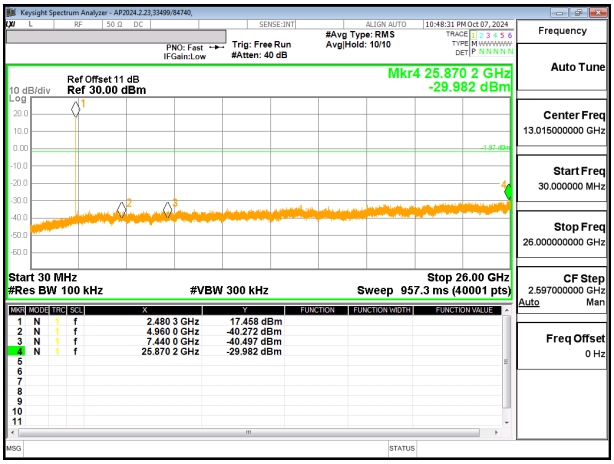
IN-BAND REFERENCE LEVEL



OUT-OF-BAND MID CHANNEL

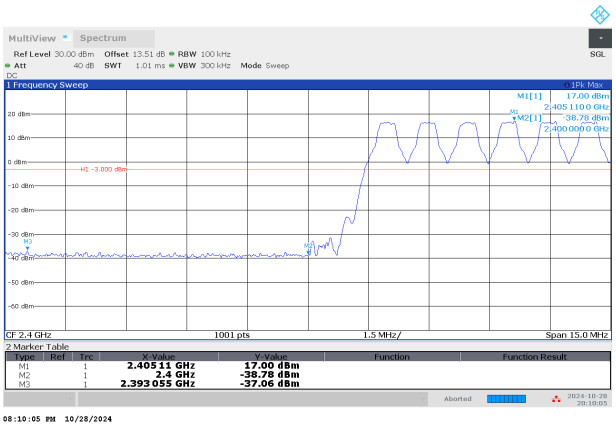


HIGH CHANNEL BANDEDGE

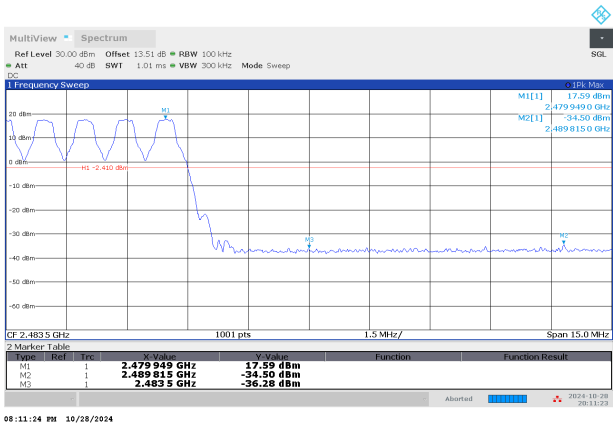


OUT-OF-BAND HIGH CHANNEL

Chain 0 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



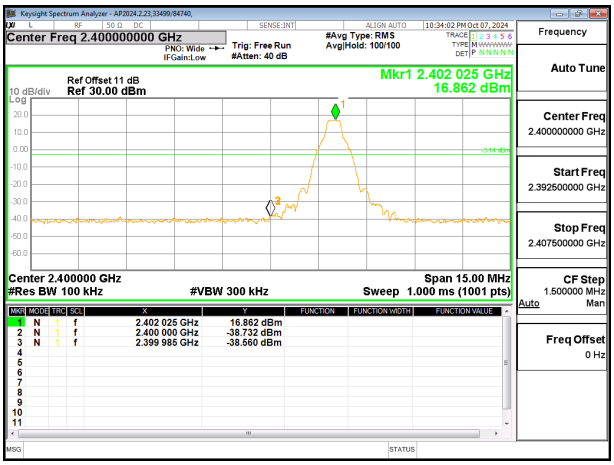
LOW BANDEDGE



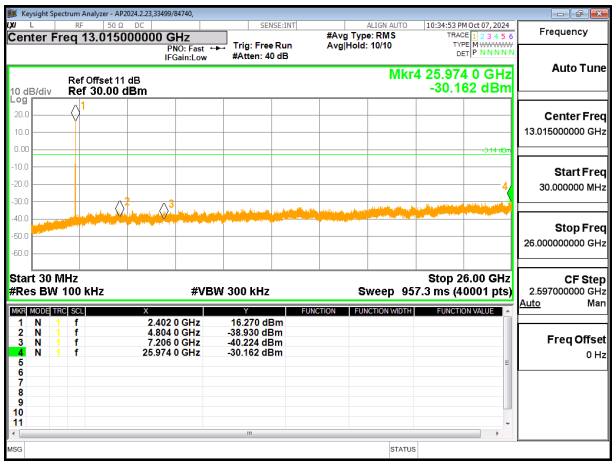
HIGH BANDEDGE

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

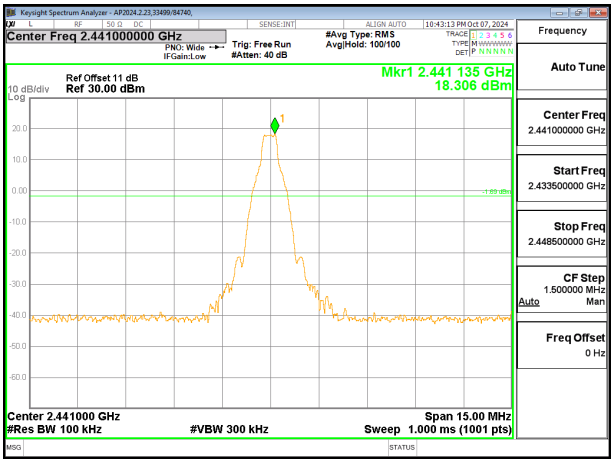
Chain 1 SPURIOUS EMISSIONS, NON-HOPPING



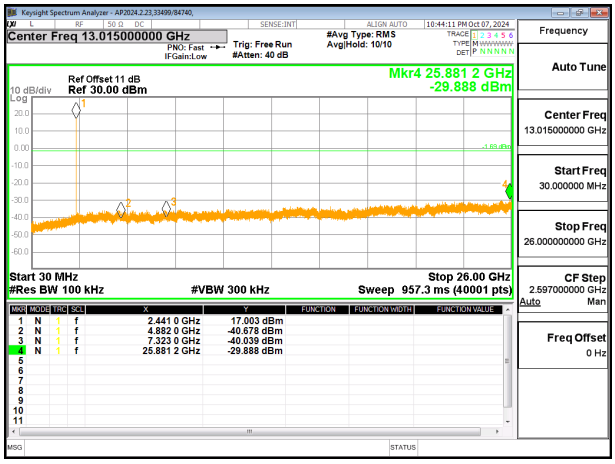
LOW CHANNEL BANDEDGE



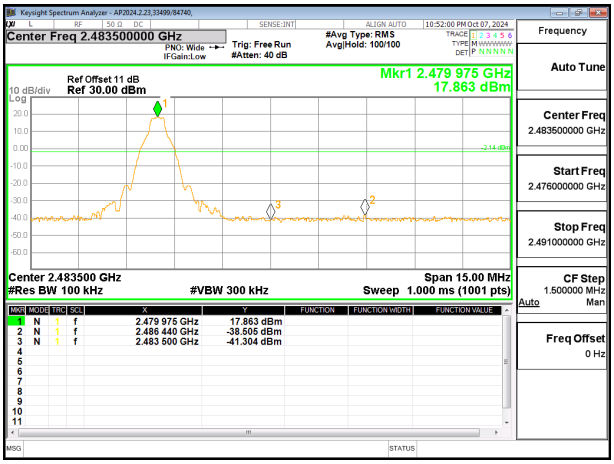
OUT-OF-BAND LOW CHANNEL



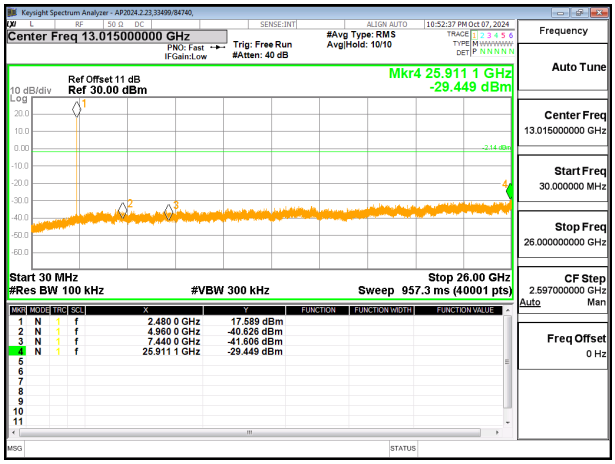
IN-BAND REFERENCE LEVEL



OUT-OF-BAND MID CHANNEL



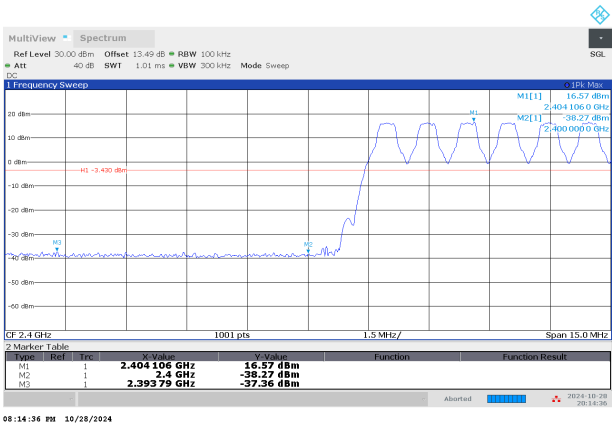
HIGH CHANNEL BANDEDGE



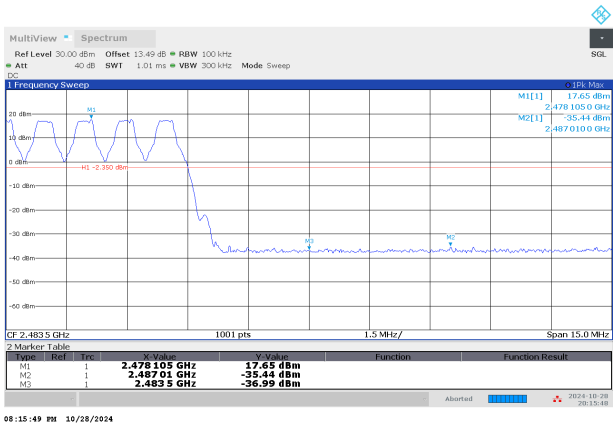
OUT-OF-BAND HIGH CHANNEL

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

Chain 1 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



LOW BANDEDGE

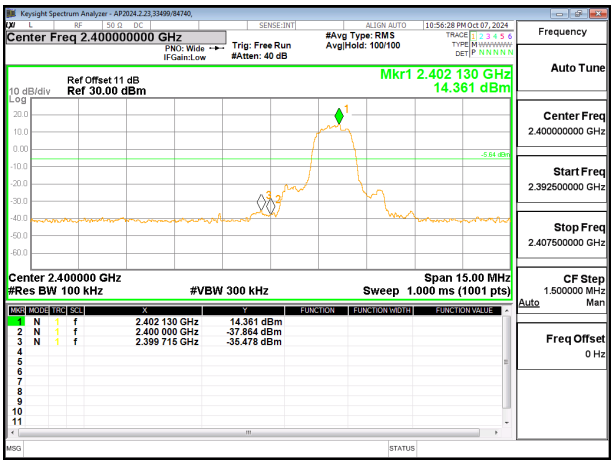


HIGH BANDEDGE

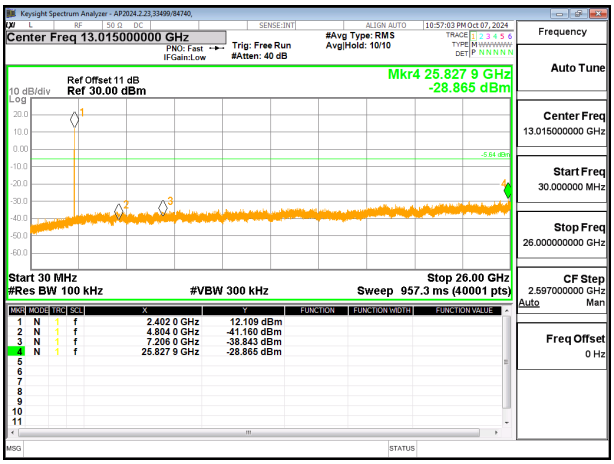
UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

9.9.2. BLUETOOTH ENHANCED DATA RATE 8PSK MODULATION

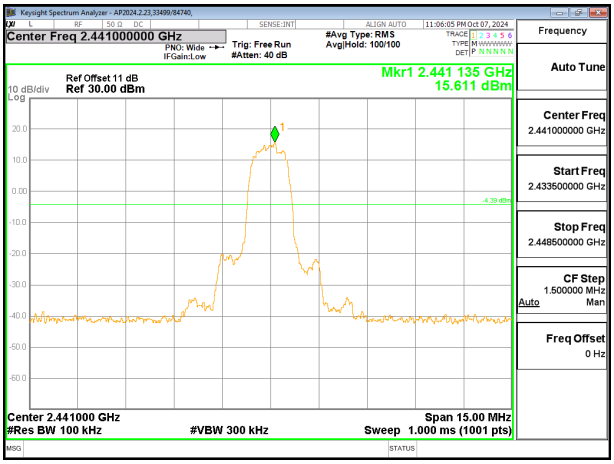
Chain 0 SPURIOUS EMISSIONS, NON-HOPPING



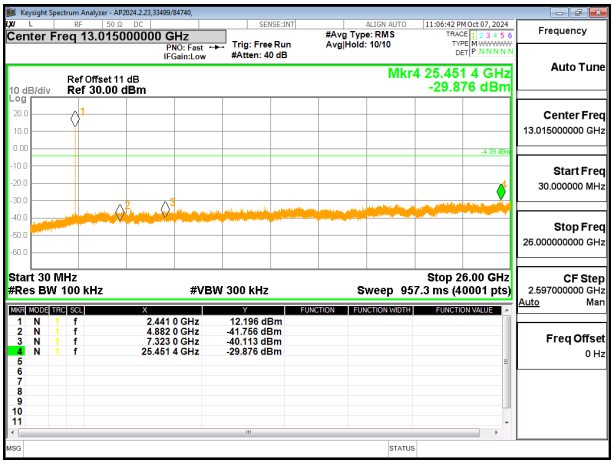
LOW CHANNEL BANDEDGE



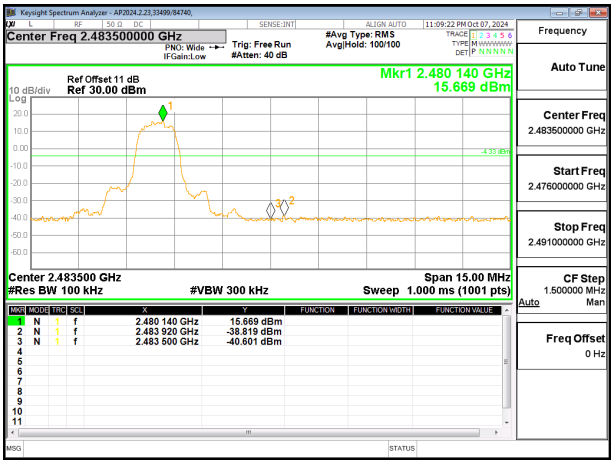
OUT-OF-BAND LOW CHANNEL



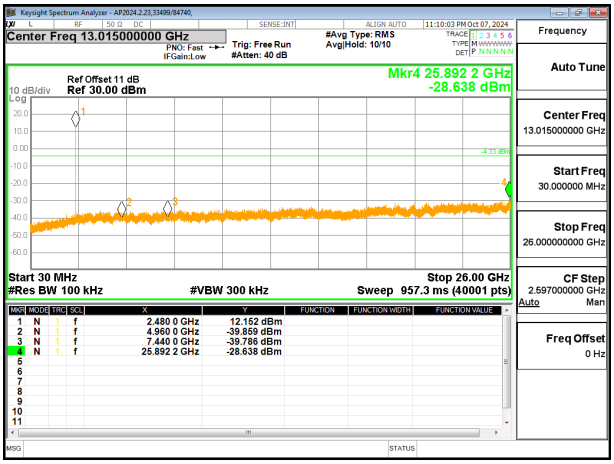
IN-BAND REFERENCE LEVEL



OUT-OF-BAND MID CHANNEL

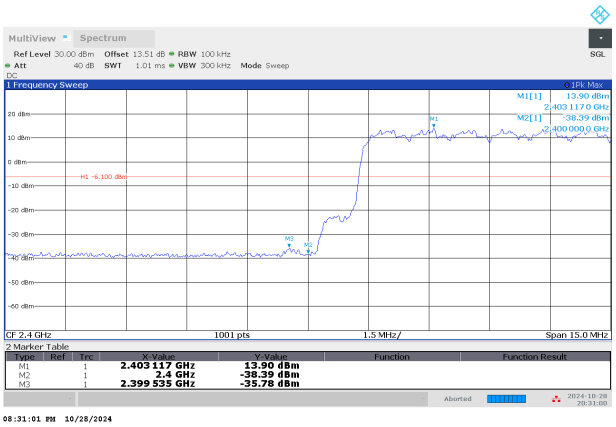


HIGH CHANNEL BANDEDGE

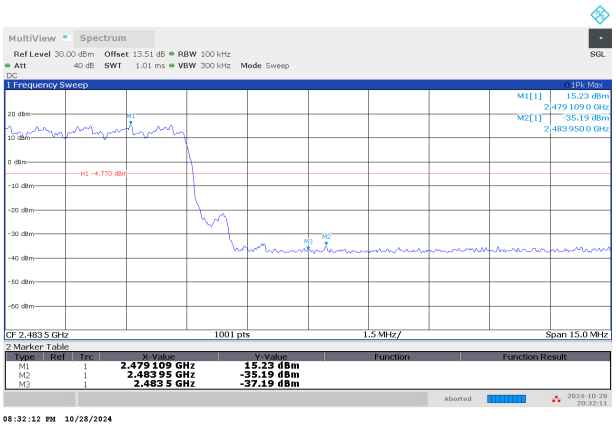


OUT-OF-BAND HIGH CHANNEL

Chain 0 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



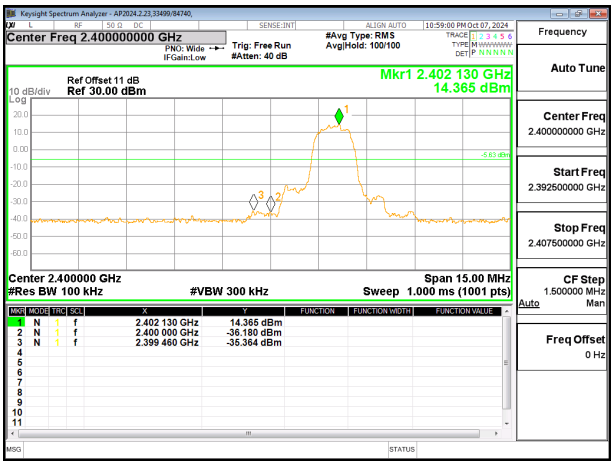
LOW BANDEDGE



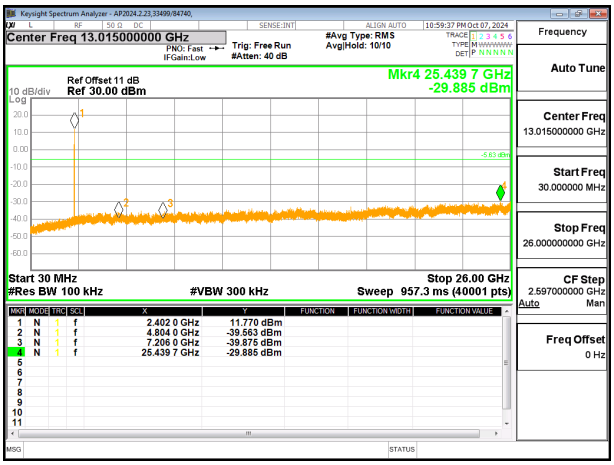
HIGH BANDEDGE

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

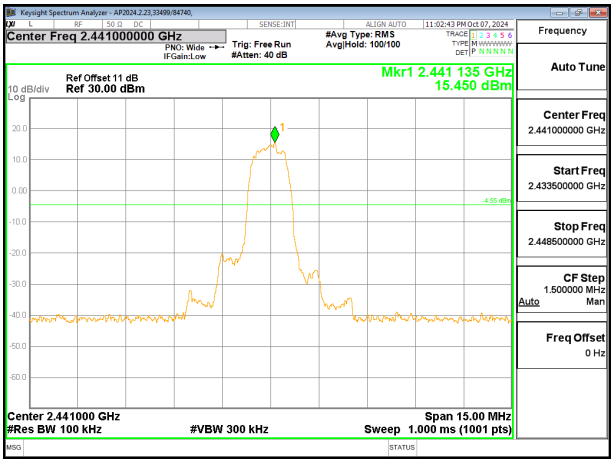
Chain 1 SPURIOUS EMISSIONS, NON-HOPPING



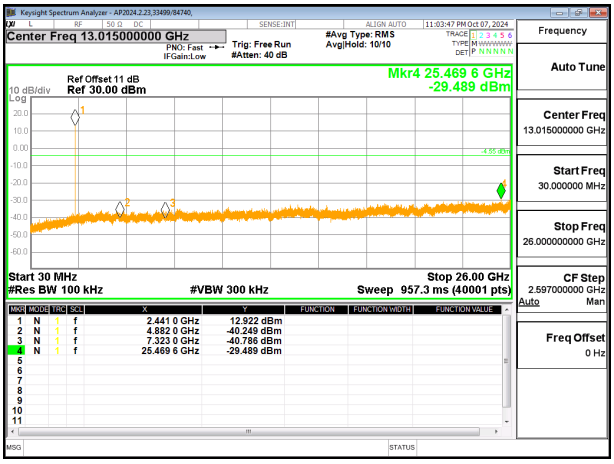
LOW CHANNEL BANDEDGE



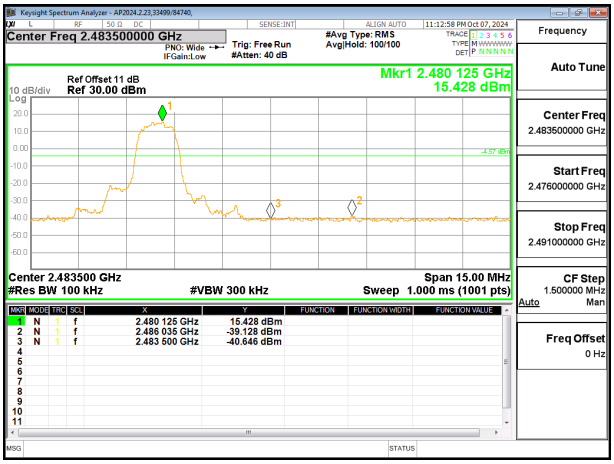
OUT-OF-BAND LOW CHANNEL



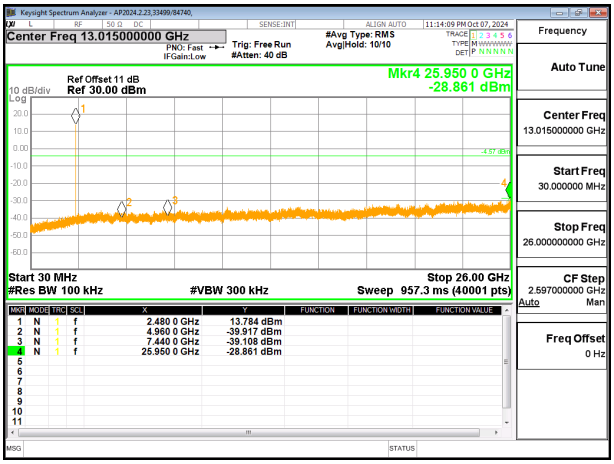
IN-BAND REFERENCE LEVEL



OUT-OF-BAND MID CHANNEL



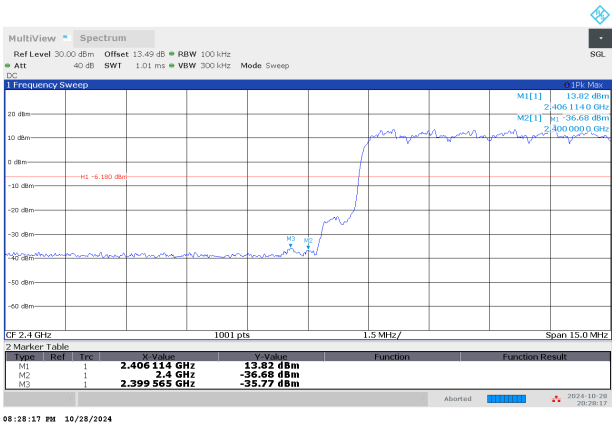
HIGH CHANNEL BANDEDGE



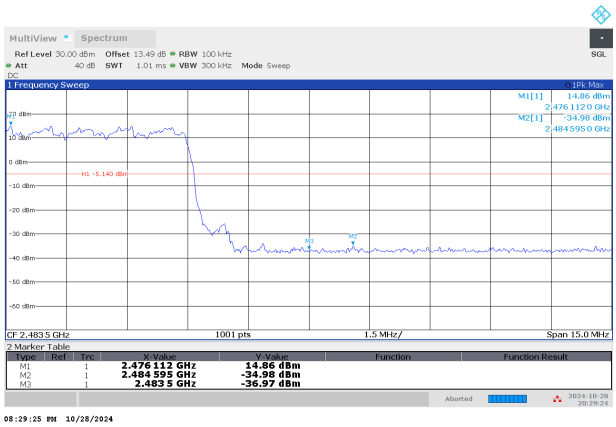
OUT-OF-BAND HIGH CHANNEL

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

Chain 1 SPURIOUS BANDEDGE EMISSIONS WITH HOPPING ON



LOW BANDEDGE



HIGH BANDEDGE

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

9.10. CONDUCTED SPURIOUS EMISSIONS – RESTRICTED BAND

LIMITS

FCC §15.205 and §15.209
RSS-GEN, Section 8.9 and 8.10.

Frequency Range (MHz)	Field Strength Limit (uV/m) at 3 m	Field Strength Limit (dBuV/m) at 3 m
Above 960	500	54

TEST PROCEDURE

Conducted measurements were made for this test.

For final measurements above 1 GHz the resolution bandwidth is set to 1 MHz; the video bandwidth is set to 3 MHz

Band edge was performed with the EUT set to transmit at the highest power on low and high channels. Testing was performed using a conducted restricted band edge setup as described in ANSI C63.10: 2020 section 7.8.8.4. A traditional restricted band edge scan (C63.10 Section 11.12.2.2) was ran on chain 0 and chain 1, each operating in SISO mode as a worst-case scenario unless otherwise noted within the report. The data was then summed together accounting for the high gain antenna gain (worst-case). To compare this data to the average limit, a correction factor of -25 dB (see section 9.1) based on the protocol limited correction factor for DH3 modulation. An example band edge scan and has been included for each mode for reference. The summed tabular and plot data has been included for each scan. A sample calculation of this test method can be seen below:

Meter Pk Chain 0 Reading = -60 dBm, Meter Pk Chain 1 Reading = -60 dBm. Correlated antenna gain = 9.11 dBi.

Pk E-Field = 10log[10^(Pk C0 Reading/10) + 10^(Pk C1 Reading/10)]+ Correlated Antenna Gain – 20log(Measurement distance) +104.8

Pk E-Field = 10log[10^(-60/10)+10^(-60/10)] + 9.11 - 20log(3) + 104.8
Pk E-Field = 47.38

Average E-Field = Pk E-Field – 25dB
Average E-Field = 22.38

Summed bandedge plots are included for all measurements. Only one representative of the per chain bandedge measurement was included per mode to be representative for the other measurements.

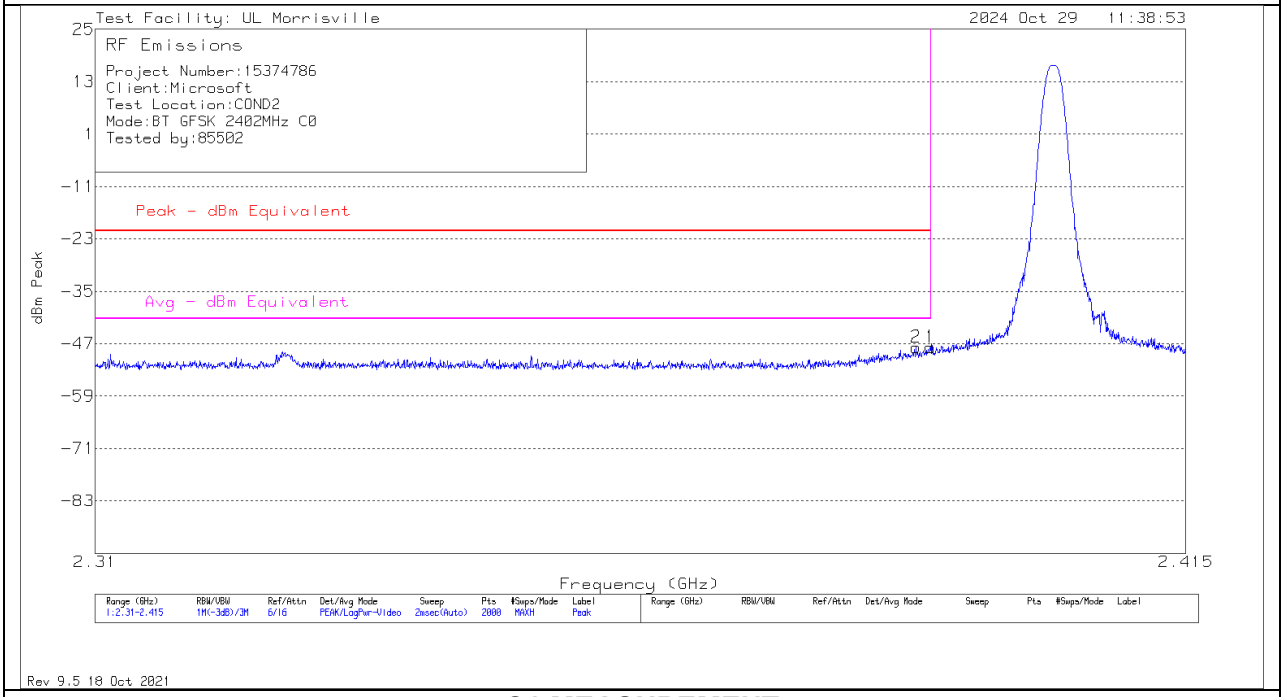
UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

Chain 0

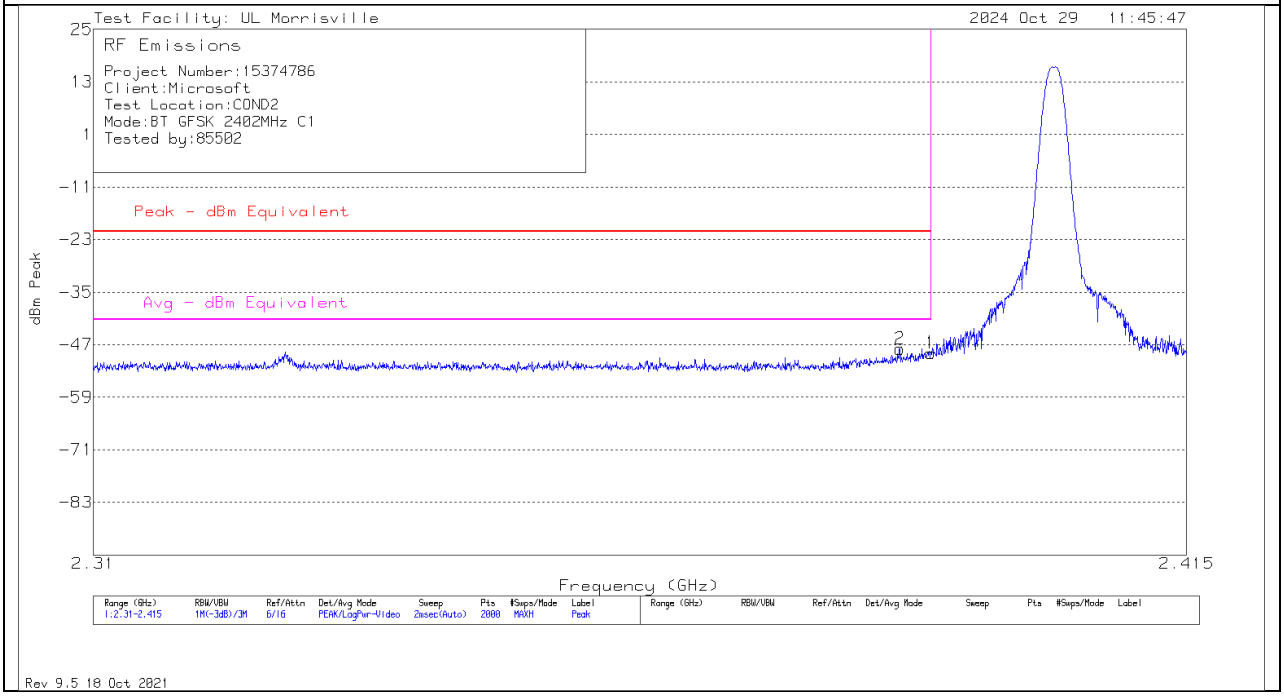
9.10.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION

BANDEDGE (LOW CHANNEL) CONDUCTED RESTRICTED METHOD

C0 MEASUREMENT

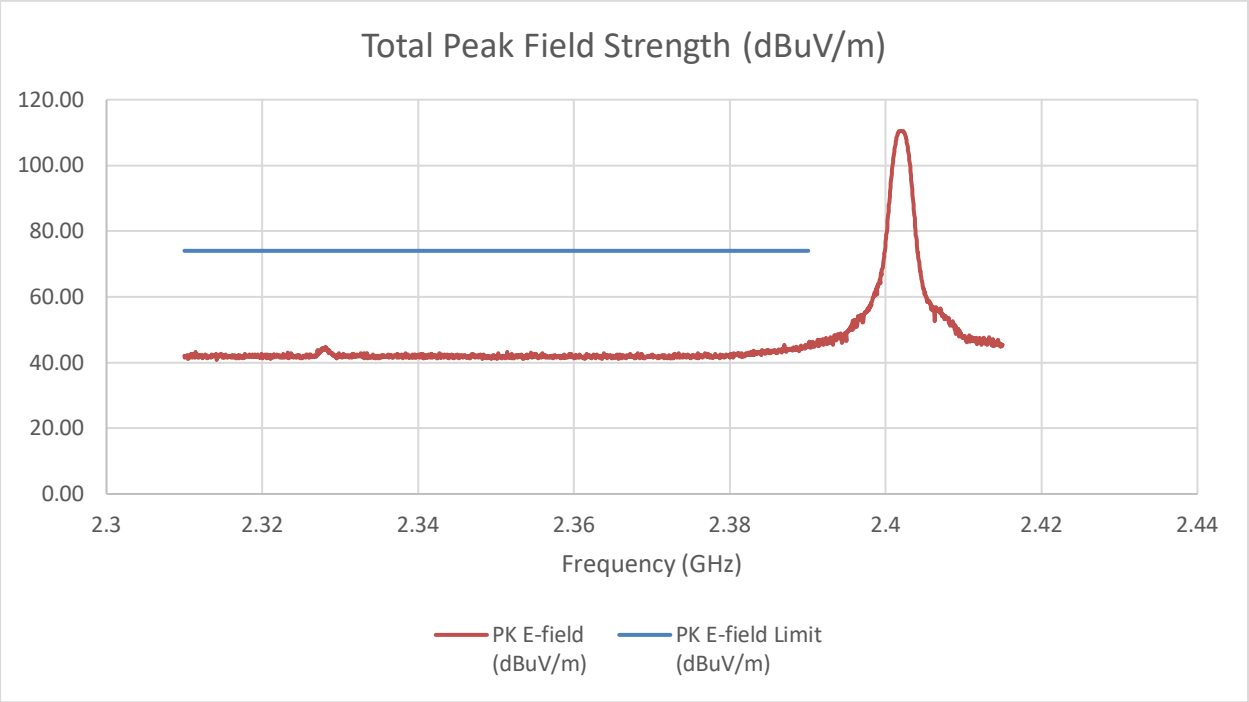


C1 MEASUREMENT



UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

SUMMED BANDEDGE DATA (Pk)



Summed Pk and Average Data at Restricted Band

Frequency (GHz)	Meter PK Reading Chain 0 (dBm)	Meter PK Reading Chain 1 (dBm)	PK EIRP (dBm)	PK E-field (dBuV/m)	PK E-field Limit (dBuV/m)	Margin (dB)
2.390	-62.79	-62.41	-50.48	44.78	74	-29.22

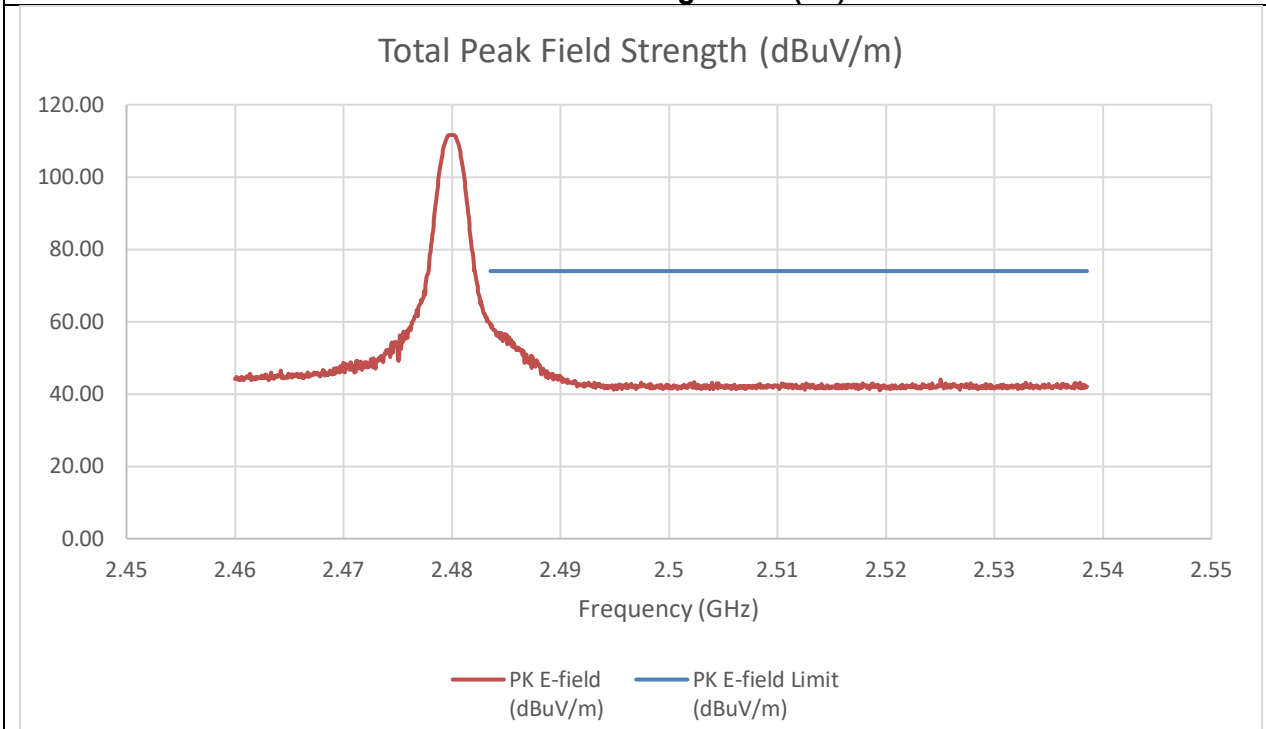
Frequency (GHz)	Calculated Av Reading Chain 0 (dBm)	Calculated Av Reading Chain 1 (dBm)	AV EIRP (dBm)	AV E-field (dBuV/m)	AV E-field Limit (dBuV/m)	Margin (dB)
2.390	-87.79	-87.41	-75.48	19.78	54	-34.22

An array gain of 9.11 dBi was used in the calculation of the summed data.

NOTE: Average measurement not included in the tabular data since the average measurement is made by applying the protocol limited duty cycle correction factor of -25 dB to the peak measurements.

BANDEDGE (HIGH CHANNEL) CONDUCTED RESTRICTED METHOD

Summed Bandedge Data (Pk)



Summed Pk and Average Data at Restricted Band

Frequency (GHz)	Meter PK Reading Chain 0 (dBm)	Meter PK Reading Chain 1 (dBm)	PK EIRP (dBm)	PK E-field (dBuV/m)	PK E-field Limit (dBuV/m)	Margin (dB)
2.4835	-50.21	-46.88	-36.11	59.14	74	-14.86

Frequency (GHz)	Calculated Av Reading Chain 0 (dBm)	Calculated Av Reading Chain 1 (dBm)	AV EIRP (dBm)	AV E-field (dBuV/m)	AV E-field Limit (dBuV/m)	Margin (dB)
2.4835	-75.21	-71.88	-61.11	34.14	54	-19.86

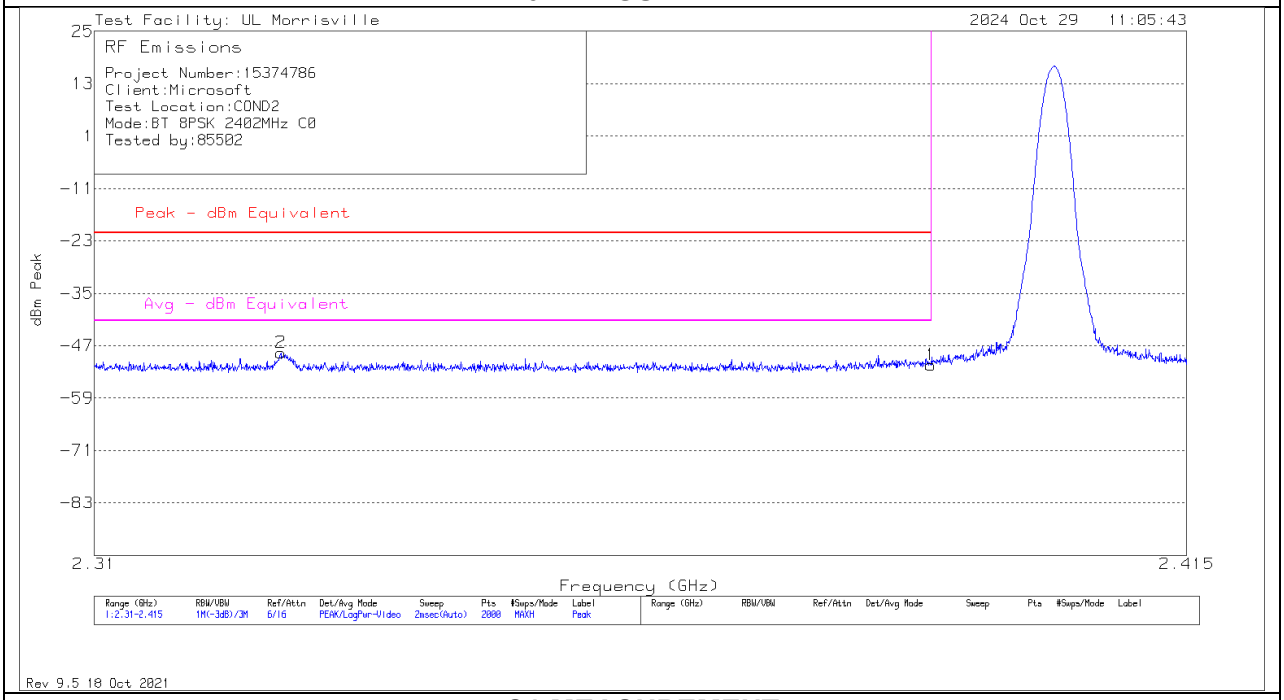
An array gain of 9.11 dBi was used in the calculation of the summed data.

NOTE: Average measurement not included in the tabular data since the average measurement is made by applying the protocol limited duty cycle correction factor of -25 dB to the peak measurements.

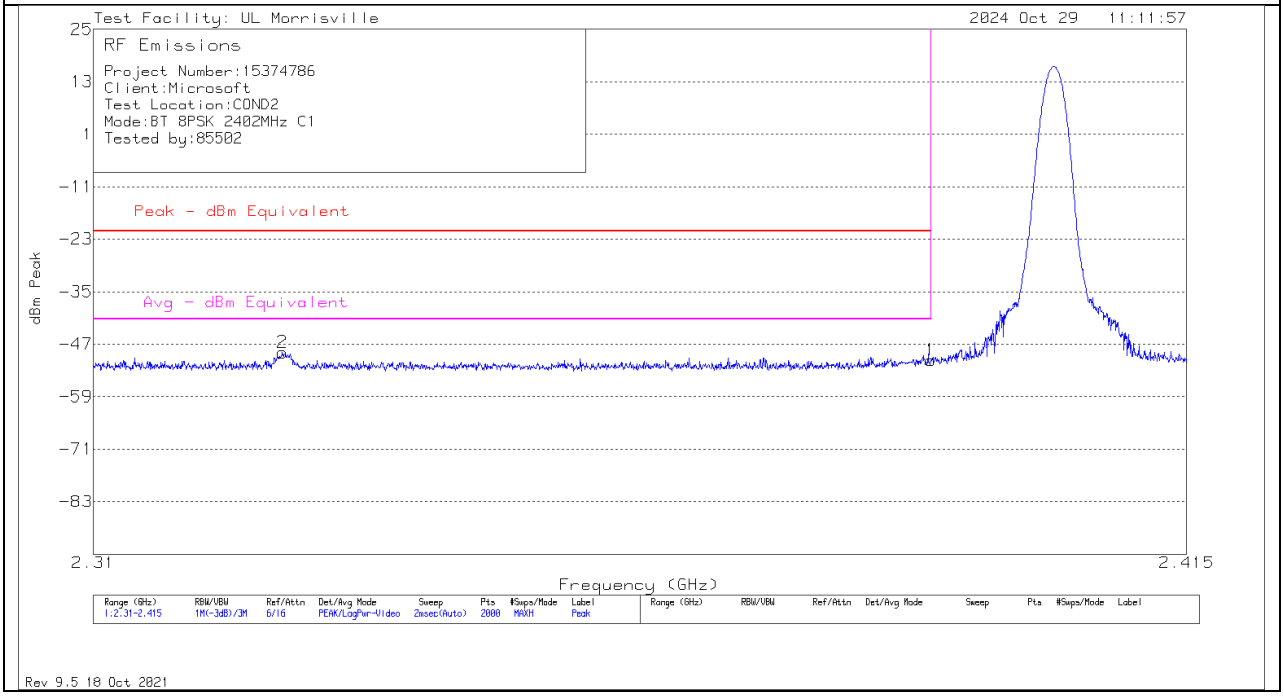
UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

BANDEDGE (LOW CHANNEL) CONDUCTED RESTRICTED METHOD

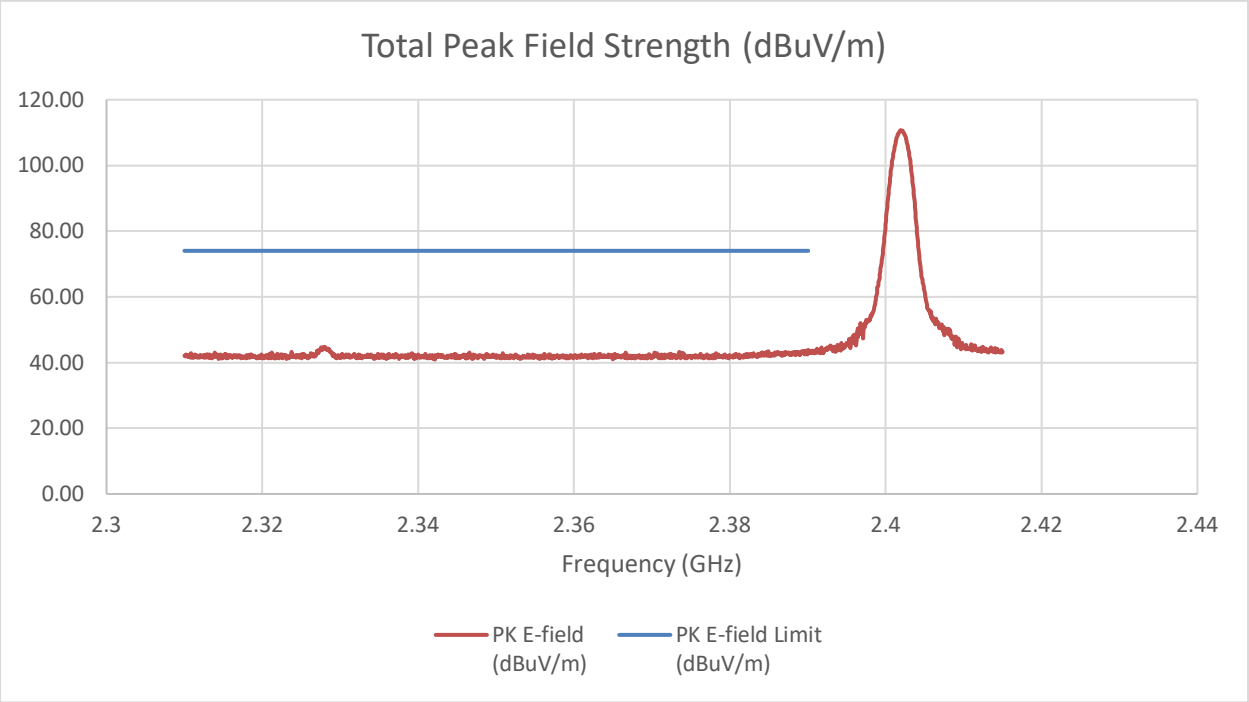
C0 MEASUREMENT



C1 MEASUREMENT



SUMMED BANDEDGE DATA (Pk)



Summed Pk and Average Data at Restricted Band

Frequency (GHz)	Meter PK Reading Chain 0 (dBm)	Meter PK Reading Chain 1 (dBm)	PK EIRP (dBm)	PK E-field (dBuV/m)	PK E-field Limit (dBuV/m)	Margin (dB)
2.390	-63.08	-64.25	-51.51	43.75	74	-30.25

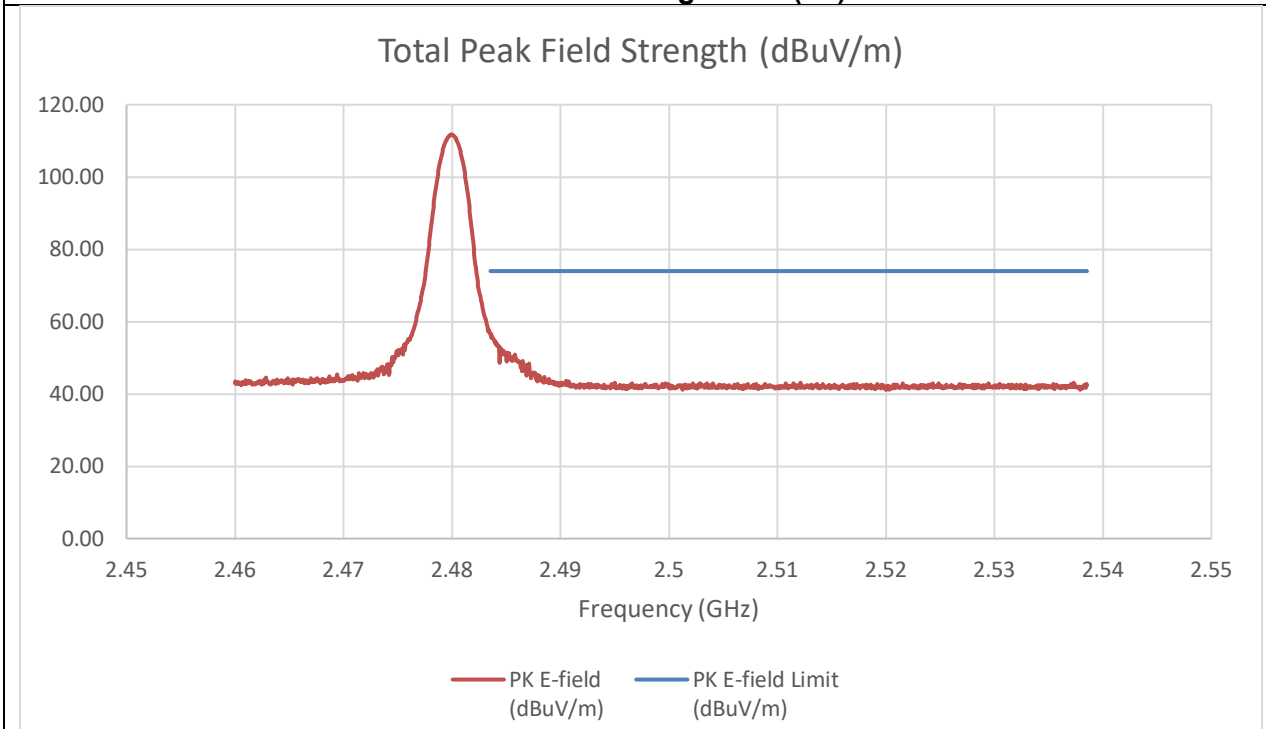
Frequency (GHz)	Calculated Av Reading Chain 0 (dBm)	Calculated Av Reading Chain 1 (dBm)	AV EIRP (dBm)	AV E-field (dBuV/m)	AV E-field Limit (dBuV/m)	Margin (dB)
2.390	-88.08	-89.25	-76.51	18.75	54	-35.25

An array gain of 9.11 dBi was used in the calculation of the summed data.

NOTE: Average measurement not included in the tabular data since the average measurement is made by applying the protocol limited duty cycle correction factor of -25 dB to the peak measurements.

BANDEDGE (HIGH CHANNEL) CONDUCTED RESTRICTED METHOD

Summed Bandedge Data (Pk)



Summed Pk and Average Data at Restricted Band

Frequency (GHz)	Meter PK Reading Chain 0 (dBm)	Meter PK Reading Chain 1 (dBm)	PK EIRP (dBm)	PK E-field (dBuV/m)	PK E-field Limit (dBuV/m)	Margin (dB)
2.4835	-51.13	-50.27	-38.56	56.70	74	-17.30

Frequency (GHz)	Calculated Av Reading Chain 0 (dBm)	Calculated Av Reading Chain 1 (dBm)	AV EIRP (dBm)	AV E-field (dBuV/m)	AV E-field Limit (dBuV/m)	Margin (dB)
2.4835	-76.13	-75.27	-63.56	31.70	54	-22.30

An array gain of 9.11 dBi was used in the calculation of the summed data.

NOTE: Average measurement not included in the tabular data since the average measurement is made by applying the protocol limited duty cycle correction factor of -25 dB to the peak measurements.

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

10. UNWANTED EMISSIONS

LIMITS

FCC §15.205 and §15.209

RSS-GEN, Section 8.9 and 8.10.

Frequency Range (MHz)	Field Strength Limit (uV/m) at 3 m	Field Strength Limit (dBuV/m) at 3 m
0.009-0.490	2400/F(kHz) @ 300 m	-
0.490-1.705	24000/F(kHz) @ 30 m	-
1.705 - 30	30 @ 30m	-
30 - 88	100	40
88 - 216	150	43.5
216 - 960	200	46
Above 960	500	54

TEST PROCEDURE

The EUT is placed on a non-conducting table 80 cm above the ground plane for measurement below 1GHz; 1.5 m above the ground plane for measurement above 1GHz. The antenna to EUT distance is 3 meters. The EUT is configured in accordance with ANSI C63.10. The EUT is set to transmit in a continuous mode.

For measurements below 1 GHz the resolution bandwidth is set to 100 kHz for peak detection measurements or 120 kHz for quasi-peak detection measurements in the 30-1000MHz range, 9kHz for peak and/or quasi-peak detection measurements in the 0.15-30MHz range and 200Hz for peak and/or quasi-peak detection measurements in the 9 to 150kHz range. Peak detection is used unless otherwise noted as quasi-peak or average (9-90kHz and 110-490kHz).

For pre-scans and final measurements above 1 GHz the resolution bandwidth is set to 1 MHz; the video bandwidth is set to 3 MHz for peak measurements.

The spectrum from 1 GHz to 18 GHz is investigated with the transmitter set to the lowest, middle, and highest channels in each applicable band. Below 1GHz and above 18GHz emissions, the channel with the highest average output power for SISO and MIMO modes were tested

The frequency range of interest is monitored at a fixed antenna height and EUT azimuth. The EUT is rotated through 360 degrees to maximize emissions received. The antenna is scanned from 1 to 4 meters above the ground plane to further maximize the emission. Measurements are made with the antenna polarized in both the vertical and the horizontal positions.

3D antenna use - For below 30MHz testing, investigation was done on three antenna orientations (parallel, perpendicular, and ground-parallel).

Base on FCC 15.31 (f) (2): measurements may be performed at a distance closer than that specified in the regulations; however, an attempt should be made to avoid making measurements in the near field.

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

KDB 414788 Open Field Site(OFS) and Chamber Correlation Justification

OFS and chamber correlation testing had been performed and chamber measured test result is the worst case test result.

KDB 558074 D01 15.247 Meas Guidance v05r02

Use of a duty cycle correction factor (DCCF) is permitted for calculating average radiated field strength emission levels for an FHSS device in 15.247. This DCCF can be applied when the field strength limit (e.g., within a Government Restricted band) and the conditions specified in Section 15.35(c) can be satisfied. The average radiated field strength is calculated by subtracting the DCCF from the maximum radiated field strength level as determined through measurement. The maximum radiated field strength level represents the worst-case (maximum amplitude) RMS measurement of the emission(s) during continuous transmission (i.e., not including any time intervals during which the transmitter is off or is transmitting at a reduced power level). It is also acceptable to apply the DCCF to a measurement performed with a peak detector instead of the specified RMS power averaging detector. Note that Section 15.35(c) specifies that the DCCF shall represent the worst-case (greatest duty cycle) over any 100 msec transmission period.

Note: The DCCF used was calculated based on the worst case on-time when the device transmits DH3 (worst-case power mode) packets and operates on 20 channels (3/1600 s per hop = 1.875 ms per channel). In this mode, the device will have a maximum of 3 hops on a channel in 100ms or 3x 1.875 ms = 5.625 ms on any channel. Therefore, 20log(5.625 / 100) = -25dB. This value was subtracted from the peak measurement to obtain a calculated average value.

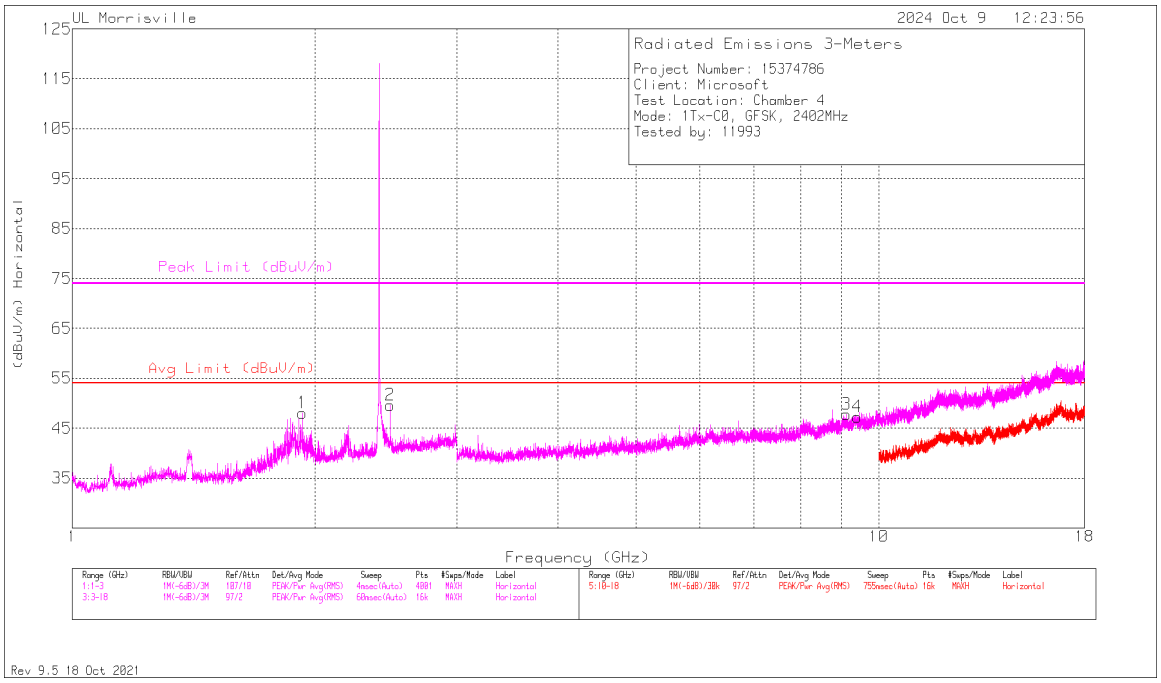
UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

10.1. TRANSMITTER ABOVE 1 GHz

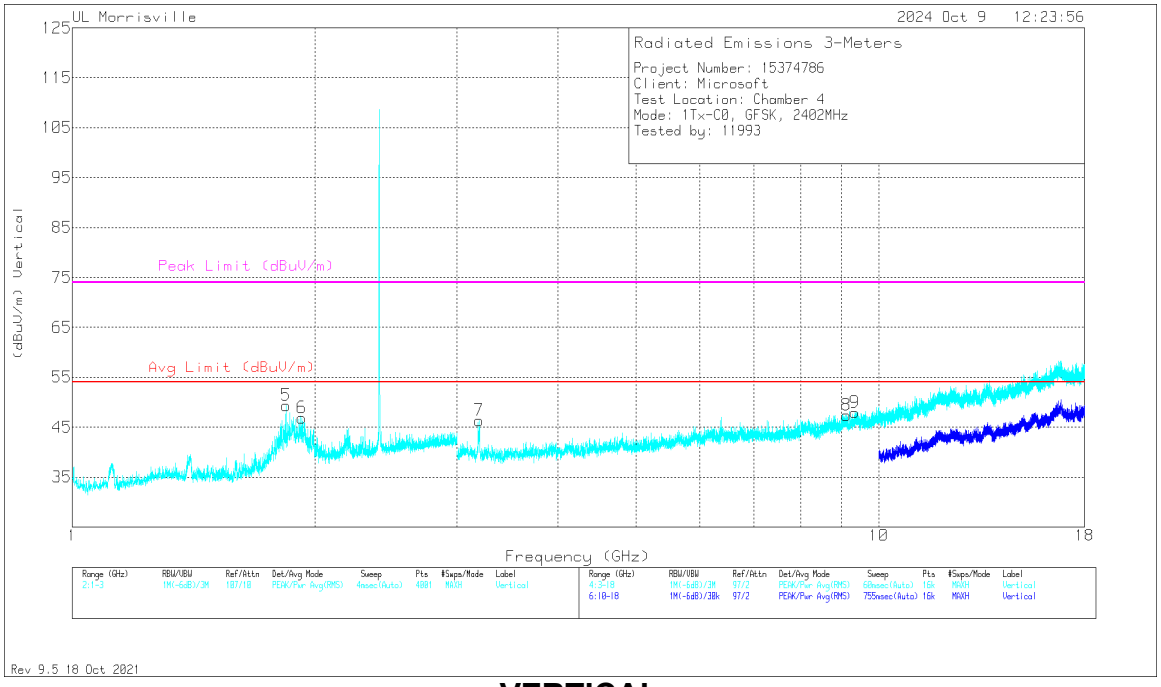
10.1.1. BLUETOOTH BASIC DATA RATE GFSK MODULATION

HARMONICS AND SPURIOUS EMISSIONS (CHAIN 0)

LOW CHANNEL RESULTS



HORIZONTAL



VERTICAL

RADIATED EMISSIONS

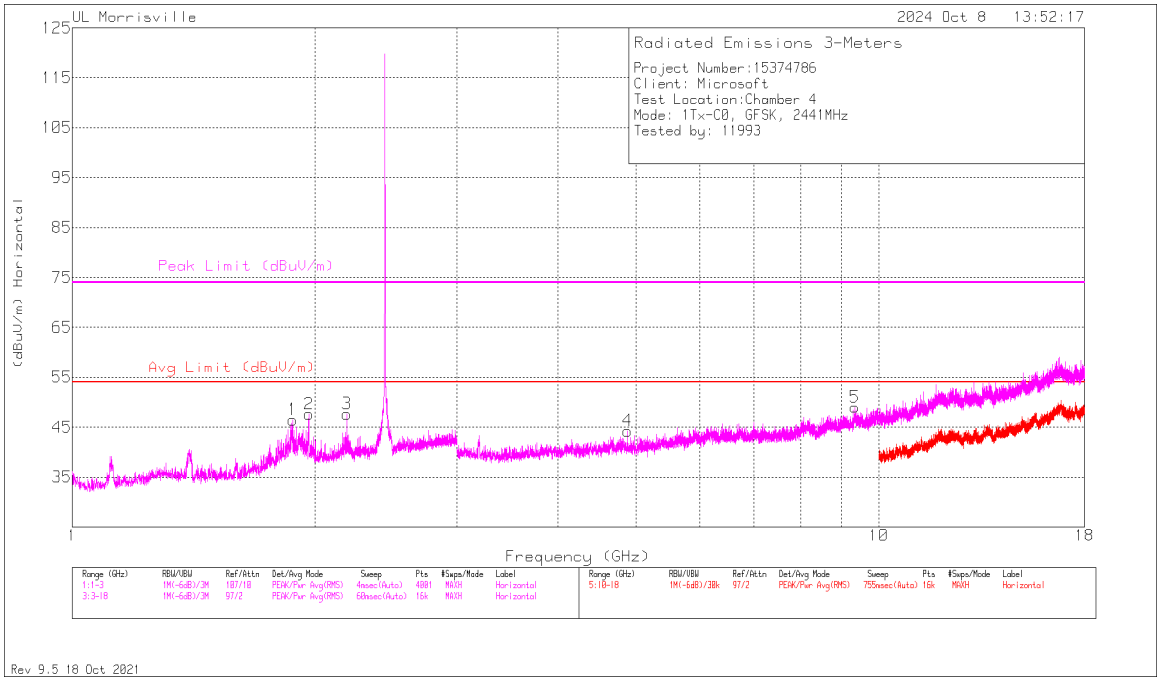
Marker	Frequency (GHz)	Meter Reading (dBuV)	Det	89509 ACF (dB/m)	Gain/Loss (dB)	DC Corr (dB)	Corrected Reading (dBuV/m)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)	Azimuth (Degs)	Height (cm)	Polarity
1	** 1.9285	40.79	Pk	30.7	-23.5	-	47.99	54	-6.01	74	-26.01	0-360	100	H
5	** 1.83974	47.81	PK2	30.4	-23.8	-	54.41	-	-	74	-19.59	315	388	V
5	** 1.83974	47.81	PK2	30.4	-23.8	-25	29.41	54	-24.59	-	-	315	388	V
6	** 1.925	39.66	Pk	30.7	-23.5	-	46.86	54	-7.14	74	-27.14	0-360	200	V
3	* ** 9.12469	36.12	Pk	36.3	-24.7	-	47.72	54	-6.28	74	-26.28	0-360	100	H
4	* ** 9.41063	35.85	Pk	36.6	-25.2	-	47.25	54	-6.75	74	-26.75	0-360	100	H
8	* ** 9.12094	35.75	Pk	36.3	-24.7	-	47.35	54	-6.65	74	-26.65	0-360	200	V
9	* ** 9.34031	35.66	Pk	36.5	-24.2	-	47.96	54	-6.04	74	-26.04	0-360	200	V
2	2.479	40.14	Pk	32.3	-22.8	-	49.64	-	-	-	-	0-360	100	H
7	3.19781	47.64	Pk	32.8	-34.1	-	46.34	-	-	-	-	0-360	200	V

* - indicates frequency in CFR47 Pt 15 / IC RSS-Restricted Band
** - indicates frequency in Taiwan NCC LP0002 Restricted Band
Pk - Peak detector
PK2 - Maximum Peak

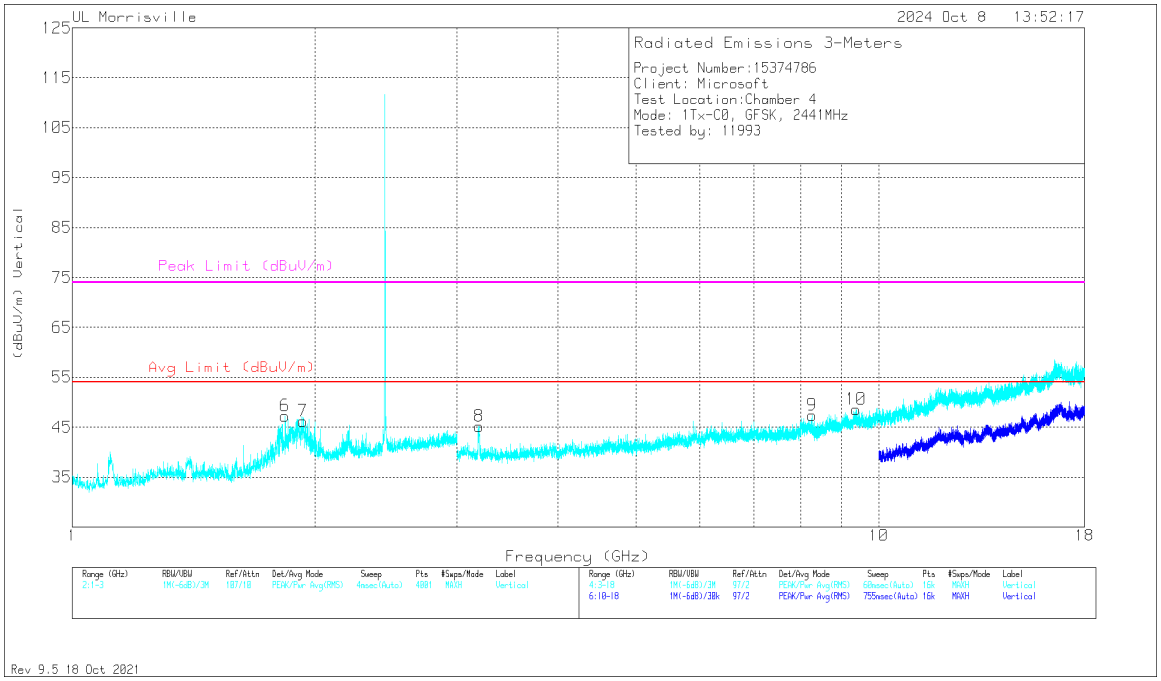
NOTE: Average measurement not included in the tabular data since the average measurement is made by applying the protocol limited duty cycle correction factor of -25 dB to the peak measurements.

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

MID CHANNEL RESULTS



HORIZONTAL



VERTICAL

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

RADIATED EMISSIONS

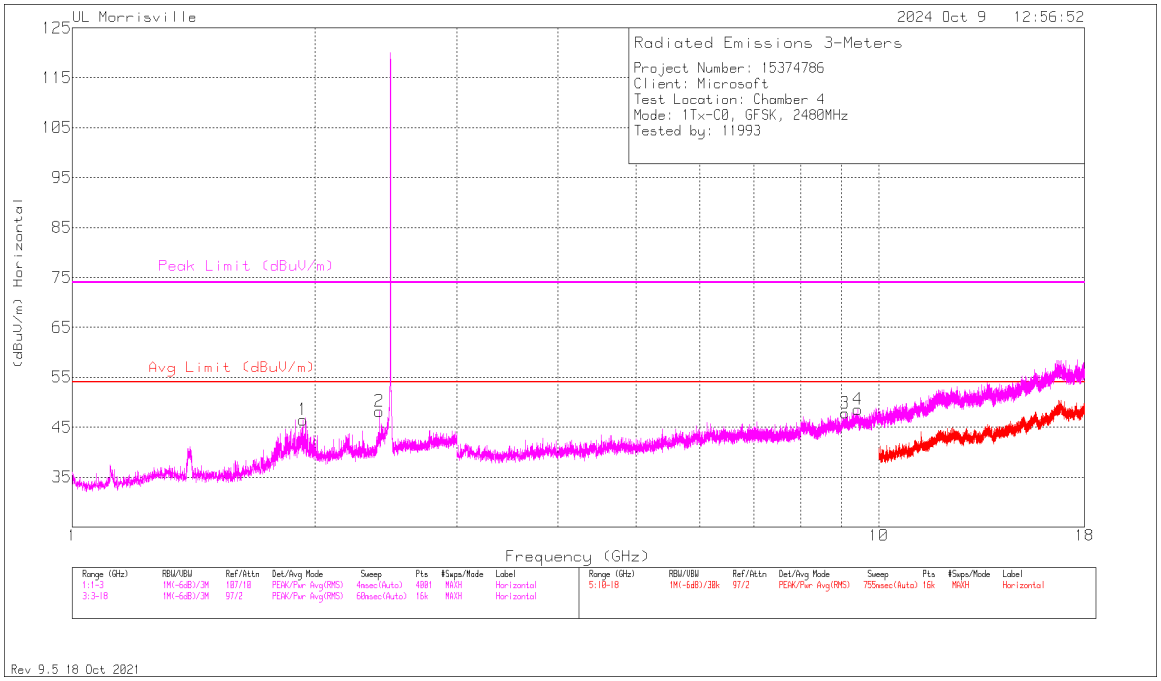
Marker	Frequency (GHz)	Meter Reading (dBuV)	Det	89509 ACF (dB/m)	Gain/Loss (dB)	DC Corr (dB)	Corrected Reading (dBuV/m)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)	Azimuth (Degs)	Height (cm)	Polarity
1	** 1.877	39.48	Pk	30.7	-23.7	-	46.48	54	-7.52	74	-27.52	0-360	100	H
2	** 1.9665	40.18	Pk	30.9	-23.5	-	47.58	54	-6.42	74	-26.42	0-360	100	H
6	** 1.8365	40.7	Pk	30.4	-23.8	-	47.3	54	-6.7	74	-26.7	0-360	200	V
7	** 1.9315	39.02	Pk	30.7	-23.5	-	46.22	54	-7.78	74	-27.78	0-360	200	V
4	* ** 4.88156	41.23	Pk	34	-31	-	44.23	54	-9.77	74	-29.77	0-360	100	H
5	* ** 9.33654	36.8	PK2	36.5	-24.2	-	49.1	-	-	74	-24.9	319	378	H
5	* ** 9.33654	36.8	PK2	36.5	-24.2	-25	24.1	54	-29.9	-	-	319	378	H
9	* ** 8.26969	37.94	Pk	35.8	-26.4	-	47.34	54	-6.66	74	-26.66	0-360	200	V
10	* ** 9.37719	37.46	PK2	36.6	-24.8	-	49.26	-	-	74	-24.74	96	229	V
10	* ** 9.37719	37.46	PK2	36.6	-24.8	-25	24.26	54	-29.74	-	-	96	229	V
3	2.191	39.28	Pk	31.6	-23.2	-	47.68	-	-	-	-	0-360	100	H
8	3.19406	46.43	Pk	32.8	-34.1	-	45.13	-	-	-	-	0-360	200	V

* - indicates frequency in CFR47 Pt 15 / IC RSS-Restricted Band
** - indicates frequency in Taiwan NCC LP0002 Restricted Band
Pk - Peak detector
PK2 - Maximum Peak

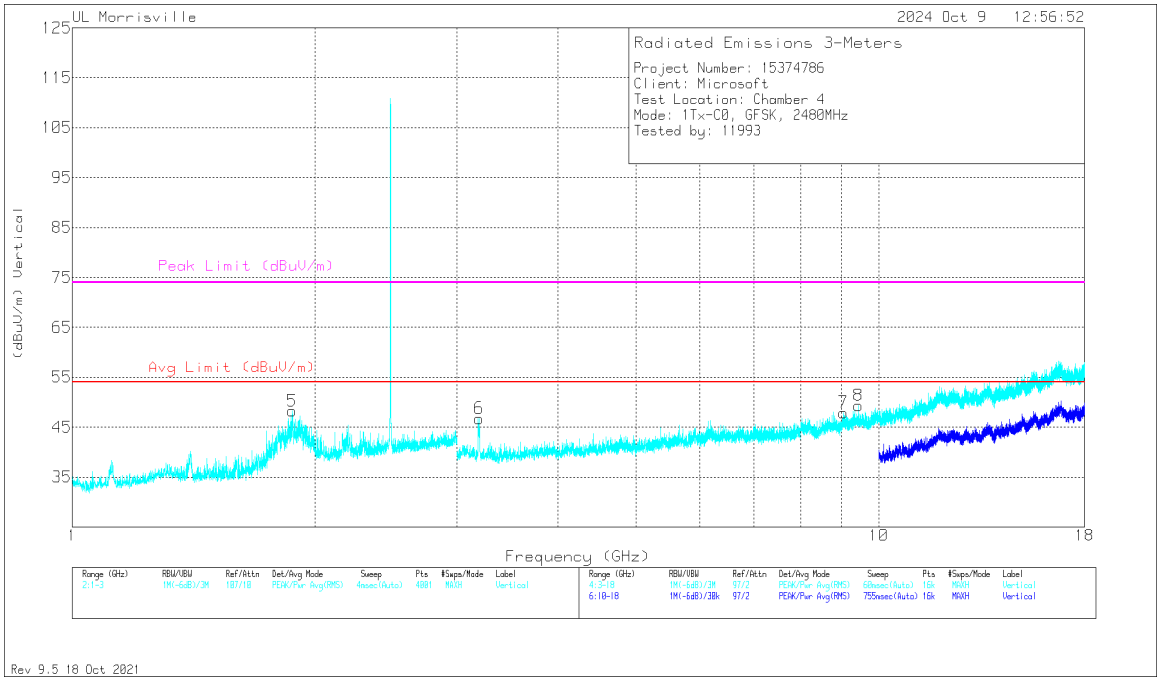
NOTE: Average measurement not included in the tabular data since the average measurement is made by applying the protocol limited duty cycle correction factor of -25 dB to the peak measurements.

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

HIGH CHANNEL RESULTS



HORIZONTAL



VERTICAL

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400

RADIATED EMISSIONS

Marker	Frequency (GHz)	Meter Reading (dBuV)	Det	89509 ACF (dB/m)	Gain/Loss (dB)	DC Corr (dB)	Corrected Reading (dBuV/m)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)	Azimuth (Degs)	Height (cm)	Polarity
1	** 1.9315	39.29	Pk	30.7	-23.5	-	46.49	54	-7.51	74	-27.51	0-360	100	H
5	** 1.87585	47.26	PK2	30.7	-23.7	-	54.26	-	-	74	-19.74	302	206	V
5	** 1.87585	47.26	PK2	30.7	-23.7	-25	29.26	54	-24.74	-	-	302	206	V
3	* ** 9.08156	36.13	Pk	36.3	-24.6	-	47.83	54	-6.17	74	-26.17	0-360	100	H
4	* ** 9.41814	37.27	PK2	36.6	-25.1	-	48.77	-	-	74	-25.23	208	146	H
4	* ** 9.41814	37.27	PK2	36.6	-25.1	-25	23.77	54	-30.23	-	-	208	146	H
7	* ** 9.04781	35.66	Pk	36.2	-24	-	47.86	54	-6.14	74	-26.14	0-360	200	V
8	* ** 9.43816	37.1	PK2	36.7	-25.1	-	48.7	-	-	74	-25.3	252	155	V
8	* ** 9.43816	37.1	PK2	36.7	-25.1	-25	23.7	54	-30.3	-	-	252	155	V
2	2.4035	39.27	Pk	31.9	-23	-	48.17	-	-	-	-	0-360	100	H
6	3.19406	48.04	Pk	32.8	-34.1	-	46.74	-	-	-	-	0-360	200	V

* - indicates frequency in CFR47 Pt 15 / IC RSS-Restricted Band
** - indicates frequency in Taiwan NCC LP0002 Restricted Band
Pk - Peak detector
PK2 - Maximum Peak

NOTE: Average measurement not included in the tabular data since the average measurement is made by applying the protocol limited duty cycle correction factor of -25 dB to the peak measurements.

UL LLC
12 Laboratory Drive, Research Triangle Park, NC 27709; USA TEL:(919) 549-1400