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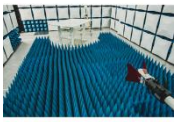

MEASUREMENT REPORT
FCC PART 15.247 / ISED RSS-247 Bluetooth

Applicant Name:
Apple Inc.
One Apple Park Way
Cupertino, CA 95014
United States

Date of Testing:
11/04/2022-01/16/2023
Test Site/Location:
Element Materials Technology Morgan Hill, CA, USA
Test Report Serial No.:
1C2211040069-01.BCG

FCC ID:	**BCGA2871**
IC:	**579C-A2871**
APPLICANT:	**Apple Inc.**

Application Type:	Certification
Model/HVIN:	A2871
EUT Type:	Wireless Earbud
Max. RF Output Power:	32.584 mW (15.13 dBm) Peak Conducted
Frequency Range:	2402 – 2480MHz
Type of Modulation:	GFSK, π/4-DQPSK, 8DPSK
FCC Classification:	FCC Part 15 Spread Spectrum Transmitter (DSS)
FCC Rule Part(s):	Part 15 Subpart C (15.247)
ISED Specification:	RSS-247 Issue 2
Test Procedure(s):	ANSI C63.10-2013

This equipment has been shown to be capable of compliance with the applicable technical standards as indicated in the measurement report and was tested in accordance with the measurement procedures specified in ANSI C63.10-2013. Test results reported herein relate only to the item(s) tested.

I attest to the accuracy of data. All measurements reported herein were performed by me or were made under my supervision and are correct to the best of my knowledge and belief. I assume full responsibility for the completeness of these measurements and vouch for the qualifications of all persons taking them.

RJ Ortanez
Executive Vice President

ACCREDITED
CERT #2041.02

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1.0 INTRODUCTION

1.1 Scope

Measurement and determination of electromagnetic emissions (EMC) of radio frequency devices including intentional and/or unintentional radiators for compliance with the technical rules and regulations of the Federal Communications Commission and the Innovation, Science and Economic Development Canada.

1.2 Element Materials Technology Morgan Hill Test Location

These measurement tests were conducted at the Element Materials Technology Morgan Hill facility located at 18855 Adams Court, Morgan Hill, CA 95037. The measurement facility is compliant with the test site requirements specified in ANSI C63.4-2014 and KDB 414788 D01 v01r01.

1.3 Test Facility / Accreditations

Measurements were performed at Element Materials Technology located in Morgan Hill, CA 95037, U.S.A.

- Element Materials Technology Morgan Hill is an ISO 17025-2017 accredited test facility under the American Association for Laboratory Accreditation (A2LA) with Certificate number 2041.02 for Specific Absorption Rate (SAR), Hearing Aid Compatibility (HAC) testing, where applicable, and Electromagnetic Compatibility (EMC) testing for FCC and Innovation, Science, and Economic Development Canada rules.

- Element Washington DC LLC TCB is a Telecommunication Certification Body (TCB) accredited to ISO/IEC 17065-2012 by A2LA (Certificate number 2041.03) in all scopes of FCC Rules and ISED Standards (RSS).

- Element Materials Technology Morgan Hill facility is a registered (22831) test laboratory with the site description on file with ISED.

- Element Materials Technology Morgan Hill is a Recognized U.S. Certification Assessment Body (CAB # US0110) for ISED Canada as designated by NIST under the U.S. and Canada Mutual Recognition Agreements (MRAs)

2.0 PRODUCT INFORMATION

2.1 Equipment Description

The Equipment Under Test (EUT) is the **Apple Wireless Right Earbud FCC ID: BCGA2871 and IC: 579C-A2871**. The test data contained in this report pertains only to the emissions due to the EUT's Bluetooth transmitter.

- This Bluetooth module has been tested by manufacturer and the following were confirmed:
  - A) The hopping sequence is pseudorandom
  - B) All channels are used equally on average
  - C) The receiver input bandwidth equals the transmit bandwidth
  - D) The receiver hops in sequence with the transmit signal
- 15.247(g): In accordance with the Bluetooth Industry Standard, the system is designed to comply with all of the regulations in Section 15.247 when the transmitter is presented with a continuous data (or information) system.
- 15.247(h): In accordance with the Bluetooth Industry Standard, the system does not coordinate its channels selection/ hopping sequence with other frequency hopping systems for the express purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters.
- 15.247(h): The EUT employs Adaptive Frequency Hopping (AFH) which identifies sources of interference namely devices operating in 802.11 WLAN and excludes them from the list of available channels. The process of re-mapping reduces the number of test channels from 79 channels to a minimum number of 20 channels.

Test Device Serial No.: FL6JL05W24FH, FL6JL0AC24FH, FL6JQ04224FH, FL6JN0KP24FH

2.2 Device Capabilities

This device contains the following capabilities:

Bluetooth (1x, EDR, LE1M, LE2M)

Ch.	Frequency (MHz)
00	2402
:	:
39	2441
:	:
78	2480

Table 2-1. Bluetooth Frequency/ Channel Operations

Note: This device is capable of operating in hopping and non-hopping mode. The EUT can hop between 79 different channels in the 2400 – 2483.5MHz band. The maximum achievable duty cycles for all modes were determined based on measurements performed on a spectrum analyzer in zero-span mode with RBW = 8MHz, VBW = 50MHz, and detector = peak per the guidance of Section 6.0 b) of KDB 558074 D01 v05r02 and ANSI C63.10-2013. The RBW and VBW were both greater than 50/T, where T is the minimum transmission duration, and the number of sweep points across T was greater than 100. The duty cycles are as follows:

Measured Duty Cycles	
BLE Mode	**Duty Cycle (%)**
GFSK	76.7
8DPSK	76.8

Table 2-2. Measured Duty Cycles

2.3 Antenna Description

Following antenna gain provided by manufacturer was used for testing.

Frequency [GHz]	Antenna Gain (dBi)
2.4	-6.35

Table 2-3. Highest Antenna Gain

2.4 Test Support Equipment

1	Apple MacBook Pro	Model:	A2141	S/N:	C02DV7VKMD6T
	w/ AC/DC Adapter	Model:	A2166	S/N:	N/A
2	HAM UART Cable	Model:	N/A	S/N:	A670206HW00026316
	w/ USB-C Adapter	Model:	N/A	S/N:	N/A
3	Beats Charging Case	Model:	N/A	S/N:	FL6JQ00X24FJ
4	Apple USB-C Cable	Model:	N/A	S/N:	N/A
	w/ AC/DC Adapter	Model:	A2305	S/N:	C4H0106004QPF4FAD

Table 2-4. Test Support Equipment List

2.5 Test Configuration

The EUT was tested per the guidance of ANSI C63.10-2013. ANSI C63.10-2013 was also used to reference the appropriate EUT setup for radiated spurious emissions testing and AC line conducted testing. See Sections 3.2 for AC line conducted emissions test setups, 3.3 for radiated emissions test setups, and 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, and 7.8 for antenna port conducted emissions test setups.

For emissions from 1GHz – 18GHz, low, mid, and high channels were tested with highest power and worst case configuration. The emissions below 1GHz and above 18GHz were tested with the highest transmitting power and the worst case channel.

The EUT was manipulated through four orthogonal planes of X-orientation (flatbed), Y-orientation (landscape), Z up-orientation (portrait-up), and Z down-orientation (portrait-down) during the testing. Only the worst case emissions were reported in this test report.

For AC line conducted and radiated test below 1GHz, following configuration were investigated and the worst case was reported.

- EUT charged by charging case and powered by AC/DC adapter with USB-C cable
- EUT charged by charging case and powered by host PC with USB-C cable

π/4-DQPSK has been investigated and confirmed as not the worst case.

2.6 Software and Firmware

The test was conducted with firmware version 2A81 installed on the EUT.

2.7 EMI Suppression Device(s)/Modifications

No EMI suppression device(s) were added and no modifications were made during testing.

3.0 DESCRIPTION OF TESTS

3.1 Evaluation Procedure

The measurement procedure described in the American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices (ANSI C63.10-2013) was used in the measurement of the EUT**.**

Deviation from measurement procedure…….....None

3.2 AC Line Conducted Emissions

The line-conducted facility is located inside a 7m x 3.66m x 2.7m shielded enclosure. The shielded enclosure is manufactured by AP Americas. The shielding effectiveness of the shielded room is in accordance with MIL-Std-285 or NSA 65-5. A 1m x 1.5m wooden table 80cm high is placed 40cm away from the vertical wall and 80cm away from the sidewall of the shielded room. Two 10kHz-30MHz, 50Ω/50μH Line-Impedance Stabilization Networks (LISNs) are bonded to the shielded room floor. Power to the LISNs is filtered by external high-current high-insertion loss power line filters. The external power line filter is an EPCOS 2X60A Power Line Filter (100dB Attenuation, 14kHz-18GHz) and the two EPCOs 2X48A filters (100dB Minimum Insertion Loss, 14kHz – 10GHz). These filters attenuate ambient signal noise from entering the measurement lines. These filters are also bonded to the shielded enclosure.

The EUT is powered from one LISN and the support equipment is powered from the second LISN. If the EUT is a DC-powered device, power will be derived from the source power supply it normally will be powered from and this supply line(s) will be connected to the second LISN. All interconnecting cables more than 1 meter were shortened to a 1 meter length by non-inductive bundling (serpentine fashion) and draped over the back edge of the test table. All cables were at least 40cm above the horizontal reference groundplane. Power cables for support equipment were routed down to the second LISN while ensuring that the cables were not draped over the second LISN.

Sufficient time for the EUT, support equipment, and test equipment was allowed in order for them to warm up to their normal operating condition. The RF output of the LISN was connected to the spectrum analyzer and exploratory measurements were made to determine the frequencies producing the maximum emission from the EUT. The spectrum was scanned from 150kHz to 30MHz with a spectrum analyzer. The detector function was set to peak mode for exploratory measurements while the bandwidth of the analyzer was set to 10kHz. The EUT, support equipment, and interconnecting cables were arranged and manipulated to maximize each emission. Once the worst case emissions have been identified, the one EUT cable configuration/arrangement and mode of operation that produced these emissions is used for final measurements on the same test site. The analyzer is set to CISPR quasi-peak and average detectors with a 9kHz resolution bandwidth for final measurements.

Line conducted emissions test results are shown in Section 7.11. Automated test software was used to perform the AC line conducted emissions testing. Automated measurement software utilized is Rohde & Schwarz EMC32, Version 10.50.40.

3.3 Radiated Emissions

The radiated test facilities consisted of an indoor 3 meter semi-anechoic chamber used for final measurements and exploratory measurements, when necessary. The measurement area is contained within the semi-anechoic chamber which is shielded from any ambient interference. The test site inside the chamber is a 6m x 5.2m elliptical, obstruction-free area in accordance with Figure 5.7 of Clause 5 in ANSI C63.4-2014. Absorbers are arranged on the floor between the turn table and the antenna mast in such a way so as to maximize the reduction of reflections for measurements above 1GHz. An 80cm tall test table made of Styrodur is placed on top of the turn table. For measurements above 1GHz, an additional Styrodur pedestal is placed on top of the test table to bring the total table height to 1.5m.

Per KDB 414788 D01 v01r01, radiated emission test sites other than open-field test sites (e.g., shielded anechoic chambers), may be employed for emission measurements below 30MHz if characterized so that the measurements correspond to those obtained at an open-field test site. To determine test site equivalency, a reference sample transmitting at 149kHz was measured on an open field test site (asphalt with no ground plane) and then measured in the 3m semi-anechoic chamber. A calibrated 60cm loop antenna was rotated about its vertical axis while the reference device was rotated through the X, Y and Z axis in order to capture the worst case level. A maximum deviation of 2.77dB at 149kHz was measured when comparing the 3 meter semi-anechoic chamber to the open field site.

For all measurements, the spectrum was scanned through all EUT azimuths and from 1 to 4 meter receive antenna height using a broadband antenna from 30MHz up to the upper frequency shown in 15.33 depending on the highest frequency generated or used in the device or on which the device operates or tunes. For frequencies above 1GHz, linearly polarized double ridge horn antennas were used. For frequencies below 30MHz, a calibrated loop antenna was used. When exploratory measurements were necessary, they were performed at 1 meter test distance inside the semi-anechoic chamber using broadband antennas, broadband amplifiers, and spectrum analyzers to determine the frequencies and modes producing the maximum emissions. Sufficient time for the EUT, support equipment, and test equipment was allowed in order for them to warm up to their normal operating condition. The test set-up was placed on top of the 1 x 1.5 meter table. The EUT, support equipment, and interconnecting cables were arranged and manipulated to maximize each emission. Appropriate precaution was taken to ensure that all emissions from the EUT were maximized and investigated. The system configuration, mode of operation, turntable azimuth, and receive antenna height was noted for each frequency found.

Final measurements were made in the semi-anechoic chamber using calibrated, linearly polarized broadband and horn antennas. The test setup was configured to the setup that produced the worst case emissions. The spectrum analyzer was set to investigate all frequencies required for testing to compare the highest radiated disturbances with respect to the specified limits. The turntable containing the EUT was rotated through 360 degrees and the height of the receive antenna was varied 1 to 4 meters and stopped at the azimuth and height producing the maximum emission. Each emission was maximized by changing the orientation of the EUT through four orthogonal planes and changing the polarity of the receive antenna, whichever produced the worst-case emissions.

3.4 Environmental Conditions

The temperature is controlled within range of 15ºC to 35ºC. The relative humidity is controlled within range of 10% to 75%. The atmospheric pressure is monitored within the range 86-106kPa (860-1060mbar).

4.0 ANTENNA REQUIREMENTS

Excerpt from §15.203 of the FCC Rules/Regulations:
"An intentional radiator antenna shall be designed to ensure that no antenna other than that furnished by the responsible party can be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section."

- The antennas of the EUT are **permanently attached.**
- There are no provisions for connection to an external antenna.

Conclusion:

The EUT complies with the requirement of §15.203.

5.0 MEASUREMENT UNCERTAINTY

The measurement uncertainties shown below were calculated in accordance with the requirements of ANSI C63.23-2012. All measurement uncertainty values are shown with a coverage factor of k = 2 to indicate a 95% level of confidence. The measurement uncertainty shown below meets or exceeds the U_{CISPR} measurement uncertainty values specified in CISPR 16-4-2 and, thus, can be compared directly to specified limits to determine compliance.

Contribution	Expanded Uncertainty (±dB)
Conducted Bench Top Measurements	1.77
Line Conducted Disturbance	2.70
Radiated Disturbance (<30MHz)	4.38
Radiated Disturbance (30MHz - 1GHz)	4.75
Radiated Disturbance (1 - 18GHz)	5.20
Radiated Disturbance (>18GHz)	4.72

6.0 TEST EQUIPMENT CALIBRATION DATA

Test Equipment Calibration is traceable to the National Institute of Standards and Technology (NIST). Measurements antennas used during testing were calibrated in accordance to the requirements of ANSI C63.5-2017.

Manufacturer	Model	Description	Cal Date	Cal Interval	Cal Due	Serial #
Agilent	N9020A	MXA Signal Analyzer	4/26/2022	Annual	4/26/2023	MY56470202
Keysight Technologies	N9030A	PXA Signal Analyzer	6/10/2022	Annual	6/10/2023	MY49430244
Keysight Technologies	N9040B	UXA Spectrum Analyzer	2/2/2022	Annual	2/2/2023	US57212289
Anritsu	MA2411B	Pulse Power Sensor	8/1/2022	Annual	8/1/2023	1027293
Anritsu	MA2411B	Pulse Power Sensor	5/19/2022	Annual	5/19/2023	1911106
Anritsu	ML2496A	Power Meter	10/17/2022	Annual	10/17/2023	2002005
ETS-Lindgren	3117	Double Ridged Guide Horn Antenna (1-18 GHz)	5/24/2022	Annual	5/24/2023	240049
Schwarzbeck	VULB9162	Biconilog Antenna - (30MHz-6GHz)	10/21/2021	Annual	7/27/2023	00358
Rohde & Schwarz	HFH-2Z2	9kHz - 30MHz Loop Antenna	4/13/2022	Annual	4/13/2023	100546
Rohde & Schwarz	ENV216	Two-Line V-Network	1/14/2022	Annual	1/14/2023	101364
Rohde & Schwarz	FSVA3044	Signal Analyzer 44GHz	5/12/2022	Annual	5/12/2023	101098
Rohde & Schwarz	FSV40	Signal Analyzer 40GHz	3/4/2022	Annual	3/4/2023	101619
Rohde & Schwarz	FSW43	Signal and Spectrum Analyzer 2Hz to 43GHz	5/19/2022	Annual	5/19/2023	104093
Rohde & Schwarz	FSW67	Signal and Spectrum Analyzer (2Hz-67GHz)	4/21/2022	Annual	4/21/2023	101366
Rohde & Schwarz	TS-PR18	Pre Amplifier 1-18GHz	1/6/2022	Annual	1/6/2023	101639
Rohde & Schwarz	TS-PR1	Preamplifier - Antenna System; 30MHz - 1GHz	4/18/2022	Annual	4/18/2023	102081
Rohde & Schwarz	180-442A-KF	Horn (Small)	1/19/2022	Annual	1/19/2023	T058701-2
Rohde & Schwarz	TS-PR1840	Pre Amplifier 18-40GHz	4/18/2022	Annual	4/18/2023	100050

Table 6-1. Test Equipment List

Notes:

For equipment listed above that has a calibration date or calibration due date that falls within the test date range, care was taken to ensure that this equipment was used after the calibration date and before the calibration due date.

7.0 TEST RESULTS

7.1 Summary

Company Name: Apple Inc.

FCC ID: BCGA2871

IC: 579C-A2871

Method/System: Frequency Hopping Spread Spectrum (FHSS)

Number of Channels: 79

FCC Part Section(s)	RSS Section(s)	Test Description	Test Limit	Test Condition	Test Result	Reference
15.247(a)(1)	RSS-247 [5.1(a)]	20dB Bandwidth	N/A	CONDUCTED	N/A	Section 7.2
2.1049	RSS-Gen [6.7]	Occupied Bandwidth	N/A		N/A	Section 7.2
15.247(b)(1)	RSS-247 [5.4(b)]	Peak Transmitter Output Power	< 1 Watt if ≥ 75 non-overlapping channels used		PASS	Section 7.3
15.247(a)(1)	RSS-247 [5.1(b)]	Channel Separation	Min. of 25kHz or the 20dB BW of the hopping channel, whichever is greater		PASS	Section 7.5
15.247(a)(1)(iii)	RSS-247 [5.1(d)]	Time of Occupancy	< 0.4 sec in 31.6 sec period		PASS	Section 7.6
15.247(a)(1)(iii)	RSS-247 [5.1(d)]	Number of Channels	> 15 Channels		PASS	Section 7.7
15.247(d)	RSS-247 [5.5]	Band Edge / Out-of-Band Emissions	> 20dBc		PASS	Section 7.4 Section 7.8
15.205 15.209	RSS-Gen [8.9]	General Field Strength Limits (Restricted Bands and Radiated Emission Limits)	Emissions in restricted bands must meet the radiated limits detailed in 15.209 (RSS-247 limits)	RADIATED	PASS	Section 7.9, Section 7.9.1, Section 7.10
15.207	RSS-Gen [8.8]	AC Conducted Emissions 150kHz – 30MHz	< FCC 15.207 limits (RSS-Gen [8.8] limits)	LINE CONDUCTED	PASS	Section 7.11

Table 7-1. Summary of Test Results

Notes:

1) All modes of operation and data rates were investigated. The test results shown in the following sections represent the worst case emissions.
2) The analyzer plots shown in this section were all taken with a correction table loaded into the analyzer. The correction table was used to account for the losses of the cables and attenuators used as part of the system to connect the EUT to the analyzer at all frequencies of interest.
3) All antenna port conducted emissions testing was performed on a test bench with the antenna port of the EUT connected to the spectrum analyzer through calibrated cables, attenuators, and couplers.
4) For conducted spurious emissions, automated test software was used to measure emissions and capture the corresponding plots necessary to show compliance. The measurement software utilized is Element "BT Auto," Version 4.0.
5) For radiated band edge, automated test software was used to measure emissions and capture the corresponding plots necessary to show compliance. The measurement software utilized is Element "Chamber Automation," Version 1.3.2.

7.2 Bandwidth Measurement

§2.1049; §15.247 (a.1); RSS-247 [5.1(a)]; RSS-Gen [6.7]

Test Overview and Limit

The bandwidth at 20dB down from the highest in-band spectral density is measured with a spectrum analyzer connected to the receive antenna while the EUT is operating in transmission mode at the appropriate frequencies.

The occupied bandwidth, that is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission shall be measured. All modes of operation were investigated and the worst case configuration results are reported in this section.

Test Procedure Used

ANSI C63.10-2013 – Subclause 6.9.2
RSS-Gen [6.7]

Test Settings

1. The signal analyzers' automatic bandwidth measurement capability of the spectrum analyzer was used to perform the 99% occupied bandwidth and the 20dB bandwidth measurement. The "X" dB bandwidth parameter was set to X = 20. The bandwidth measurement was not influenced by any intermediate power nulls in the fundamental emission.
2. RBW = 1 – 5% OBW
3. VBW ≥ 3 x RBW
4. Reference level set to keep signal from exceeding maximum input mixer level for linear operation.
5. Detector = Peak
6. Trace mode = max hold
7. Sweep = auto couple
8. The trace was allowed to stabilize
9. If necessary, steps 2 – 7 were repeated after changing the RBW such that it would be within 1 – 5% of the 99% occupied bandwidth observed in Step 7

Test Setup

The EUT and measurement equipment were set up as shown in the diagram below.

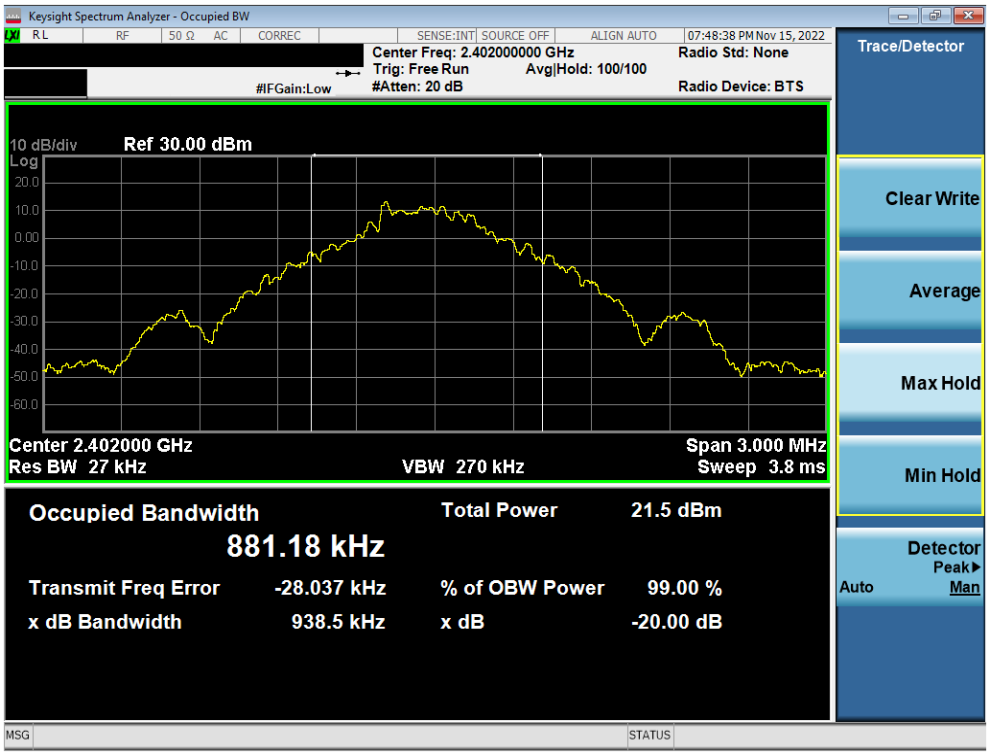
Figure 7-1. Test Instrument & Measurement Setup

Test Notes

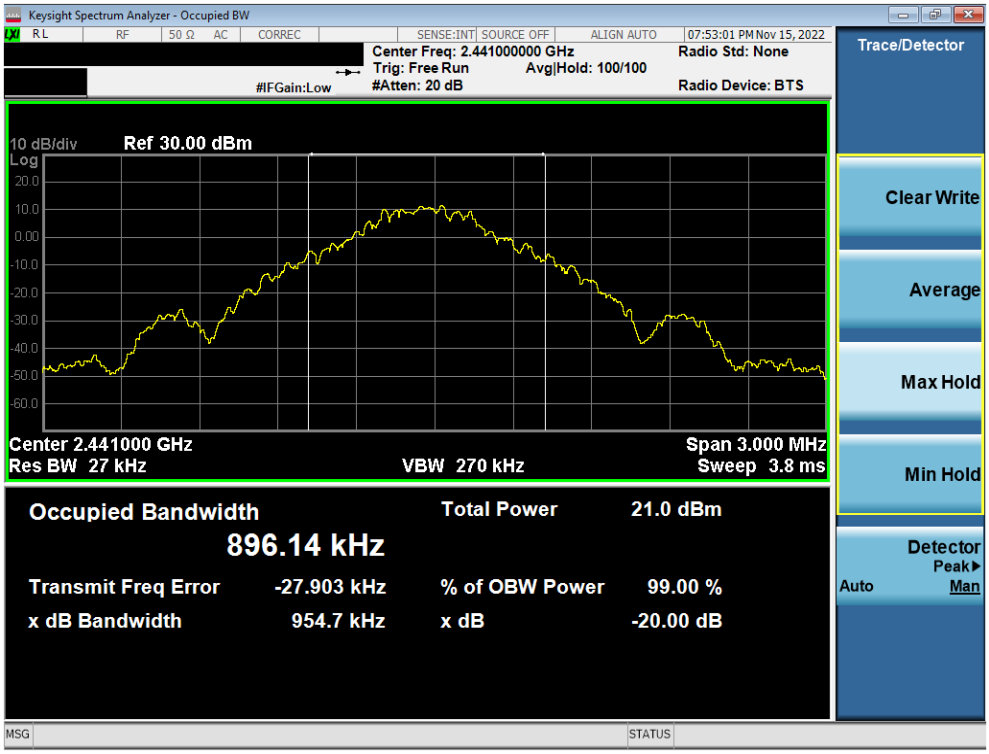
All supported modulation have been tested on the unit and only worst-case configuration is reported.

Frequency [MHz]	Data Rate [Mbps]	Mod.	Channel No.	Measured 99% Occupied Bandwidth [kHz]	Measured 20dB Bandwidth [kHz]
2402	1.0	GFSK	0	881.18	938.50
2441	1.0	GFSK	39	896.14	954.70
2480	1.0	GFSK	78	891.44	938.40
2402	3.0	8DPSK	0	1197.90	1285.00
2441	3.0	8DPSK	39	1190.10	1249.00
2480	3.0	8DPSK	78	1192.70	1255.00

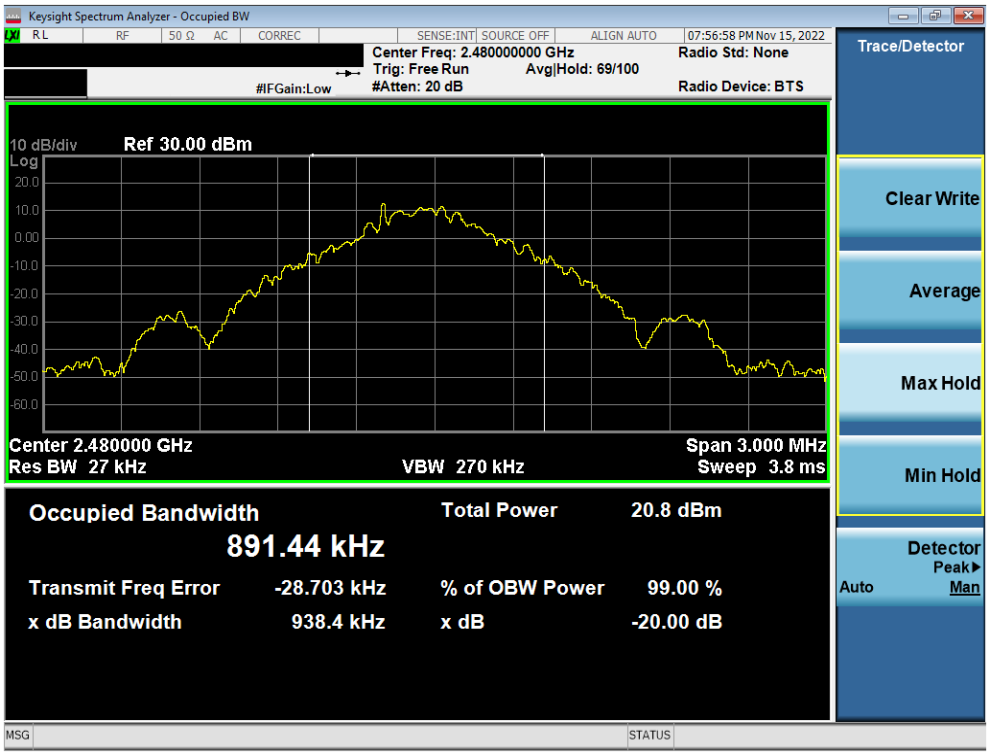
Table 7-2. 20dB BW and 99% OBW Measurements



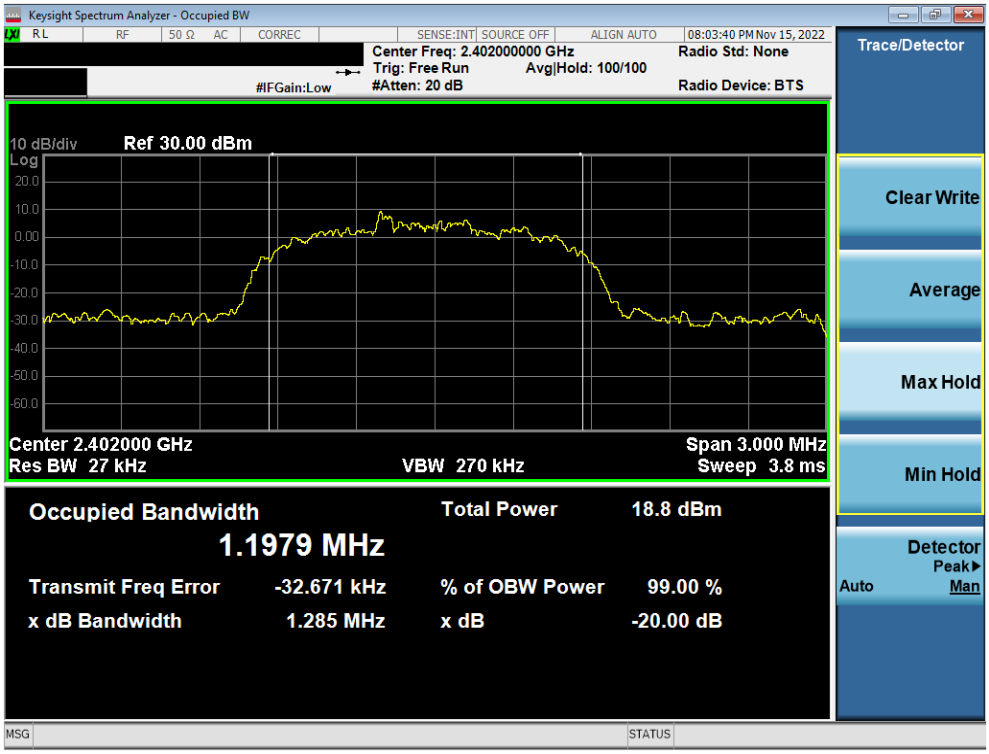
Plot 7-1. 20dB BW and 99% OBW Plot (Bluetooth, GFSK – 2402MHz)



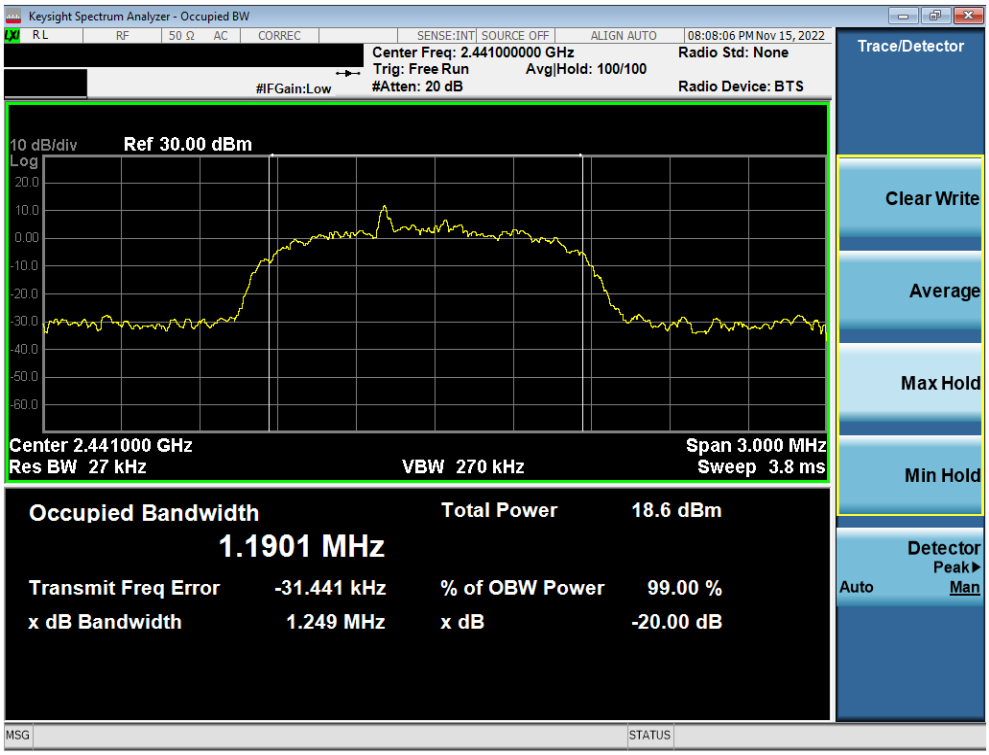
Plot 7-2. 20dB BW and 99% OBW Plot (Bluetooth, GFSK – 2441MHz)



Plot 7-3. 20dB BW and 99% OBW Plot (Bluetooth, GFSK – 2480MHz)



Plot 7-4. 20dB BW and 99% OBW Plot (Bluetooth, 8DPSK – 2402MHz)



Plot 7-5. 20dB BW and 99% OBW Plot (Bluetooth, 8DPSK – 2441MHz)

Plot 7-6. 20dB BW and 99% OBW Plot (Bluetooth, 8DPSK – 2480MHz)

7.3 Output Power Measurement

§15.247 (b.1); RSS-247 [5.4(b)]

Test Overview and Limits

Measurement is made while the EUT is operating in non-hopping transmission mode. Peak and Average power measurements are performed using a broadband power meter with a pulse sensor.

The maximum peak conducted output power of frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 non-overlapping hopping channels is 1 watt

The conducted output power limit on paragraph above is based on the use of antennas with directional gains that do not exceed 6 dBi. If transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

For FHSS operating in the band 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1.0 W if the hopset uses 75 or more hopping channels. The e.i.r.p. shall not exceed 4 W.

Test Procedure Used

ANSI C63.10-2013 – Section 7.8.5
ANSI C63.10-2013 – Section 11.9.2.3.2 method AVGPM-G

Test Settings

Peak Power Measurement

The maximum peak conducted output power may be measured using a broadband peak RF power meter. The power meter shall have a video bandwidth that is greater than the occupied bandwidth.

Method AVGPM-G (Average Power Measurement)

Average power measurements were performed only when the EUT was transmitting at its maximum power control level using a broadband power meter with a pulse sensor. The power meter implemented triggering and gating capabilities which were set up such that power measurements were recorded only during the ON time of the transmitter. The trace was averaged over 100 traces to obtain the final measured average power.

Test Setup

The EUT and measurement equipment were set up as shown in the diagram below.

Figure 7-2. Test Instrument & Measurement Setup for Peak and Average Power Measurement

Note

All supported modulations have been tested and π/4-DQPSK was found not as the worst case modulation so only GFSK and 8DPSK is reported.

Peak Output Power Measurement

Frequency [MHz]	Data Rate [Mbps]	Mod.	Channel No.	Peak Conducted Power		Conducted Power Limit [dBm]	Conducted Power Margin [dB]	Ant. Gain [dBi]	EIRP [dBm]	EIRP Limit [dBm]	EIRP Margin [dB]
				[dBm]	[mW]						
2402	1.0	GFSK	0	15.13	32.584	30.00	-14.87	-6.35	8.78	36.02	-27.24
2441	1.0	GFSK	39	15.05	31.989	30.00	-14.95	-6.35	8.70	36.02	-27.32
2480	1.0	GFSK	78	14.90	30.903	30.00	-15.10	-6.35	8.55	36.02	-27.47
2402	3.0	8DPSK	0	12.55	17.989	30.00	-17.45	-6.35	6.20	36.02	-29.82
2441	3.0	8DPSK	39	12.73	18.750	30.00	-17.27	-6.35	6.38	36.02	-29.64
2480	3.0	8DPSK	78	12.43	17.498	30.00	-17.57	-6.35	6.08	36.02	-29.94

Table 7-3. Peak Conducted Output Power Measurements

7.3.1 Average Output Power Measurement

Frequency [MHz]	Data Rate [Mbps]	Mod.	Channel No.	Avg Conducted Power		Conducted Power Limit [dBm]	Conducted Power Margin [dB]	Ant. Gain [dBi]	EIRP [dBm]	EIRP Limit [dBm]	EIRP Margin [dB]
				[dBm]	[mW]						
2402	1.0	GFSK	0	13.85	24.266	30.00	-16.15	-6.35	7.50	36.02	-28.52
2441	1.0	GFSK	39	13.78	23.878	30.00	-16.22	-6.35	7.43	36.02	-28.59
2480	1.0	GFSK	78	13.69	23.388	30.00	-16.31	-6.35	7.34	36.02	-28.68
2402	3.0	8DPSK	0	8.75	7.499	30.00	-21.25	-6.35	2.40	36.02	-33.62
2441	3.0	8DPSK	39	8.97	7.889	30.00	-21.03	-6.35	2.62	36.02	-33.40
2480	3.0	8DPSK	78	8.70	7.413	30.00	-21.30	-6.35	2.35	36.02	-33.67

Table 7-4. Average Conducted Output Power Measurements

Sample e.i.r.p. Calculation:

At 2402MHz, the average conducted output power was calculated to be 13.85 dBm with directional gain of -6.35 dBi.

e.i.r.p. (dBm) = Conducted Power (dBm) + Ant gain (dBi)

13.85 dBm + (-6.35) dBi = 7.50 dBm

7.4 Conducted Authorized Band Edge

§15.247 (d); RSS-247 [5.5]

Test Overview and Limits

EUT operates in hopping and non-hopping transmission mode. Measurement is taken at the highest point located outside of the emission bandwidth. ***The maximum permissible out-of-band emission level is 20 dBc.***

Test Procedure Used

ANSI C63.10-2013 – Section 6.10.4

Test Settings

1. Start and stop frequency were set such that the band edge would be placed in the center of the plot
2. Span was set large enough so as to capture all out of band emissions near the band edge
3. RBW = 100kHz
4. VBW = 300kHz
5. Detector = Peak
6. Number of sweep points ≥ 2 x Span/RBW
7. Trace mode = max hold
8. Sweep time = auto couple
9. The trace was allowed to stabilize

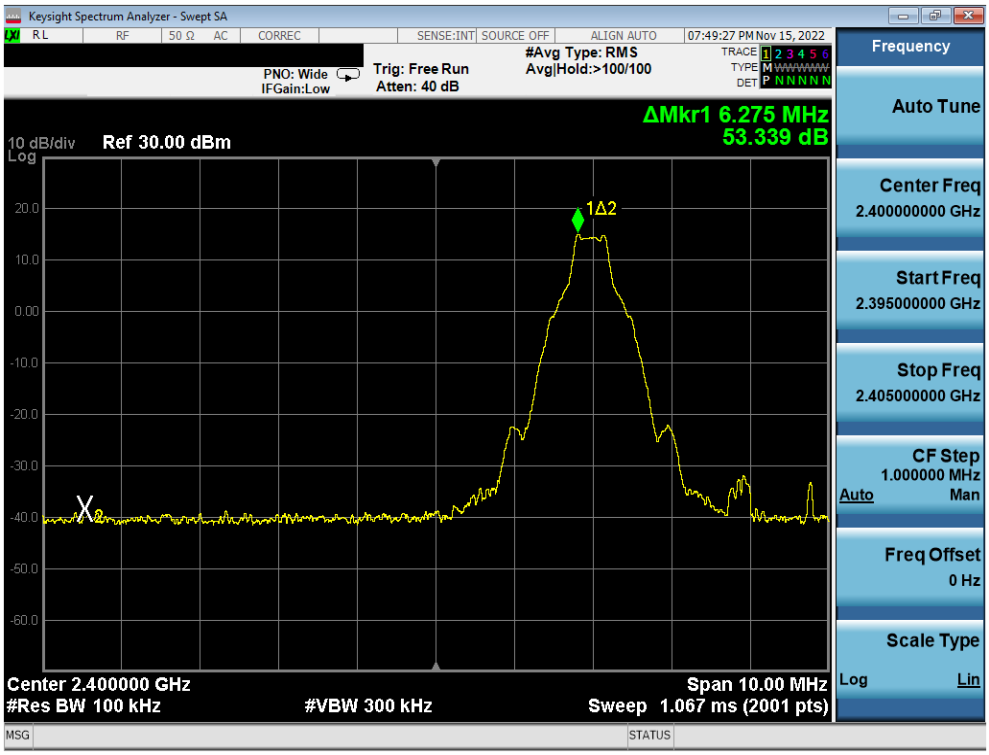
Test Setup

The EUT and measurement equipment were set up as shown in the diagram below.

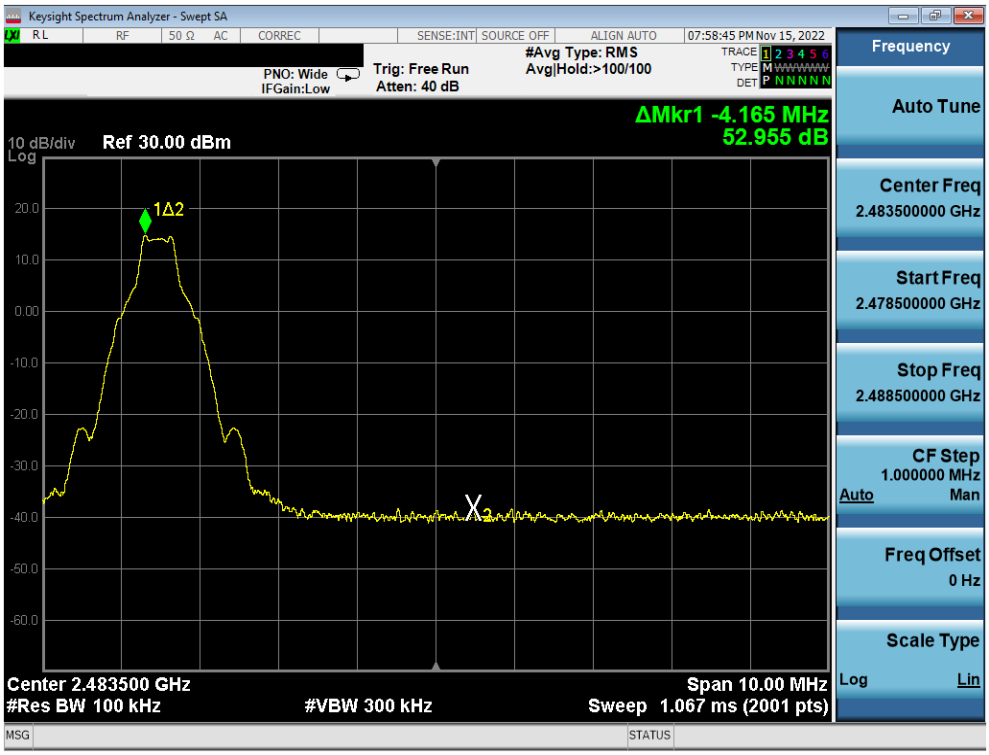
Figure 7-3. Test Instrument & Measurement Setup

Test Notes

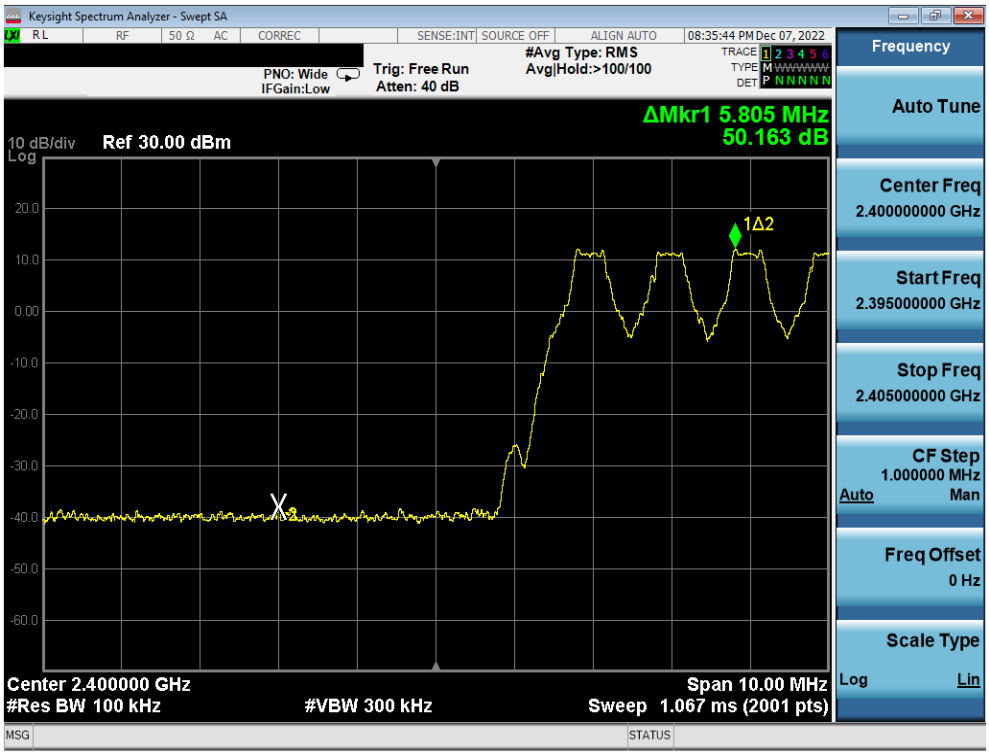
1. Out of band conducted spurious emissions at the band edge were investigated for all data rates in hopping and non-hopping modes. The worst case emissions were found with the EUT transmitting at 3 Mbps. Band Edge emissions were also investigated with the EUT transmitting in all data rates. Plots of the worst case emissions are shown below.
2. All supported modulation have been tested on the unit and only worst case configuration is reported.



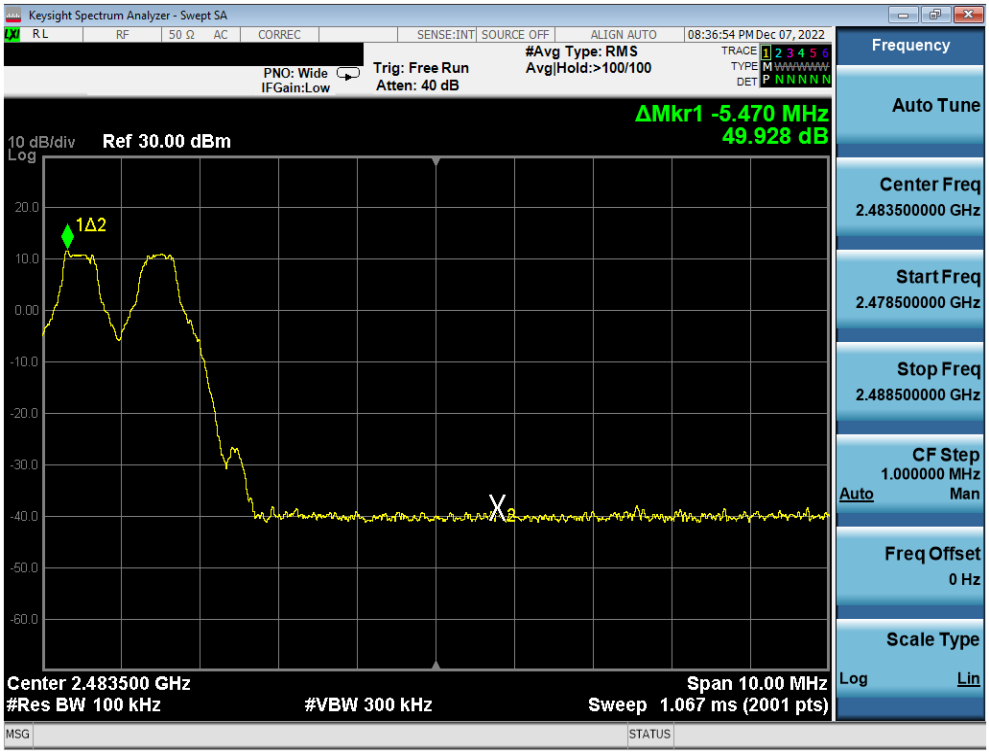
Plot 7-7. Band Edge Plot (Bluetooth with Hopping Disabled, GFSK, 2.4GHz)



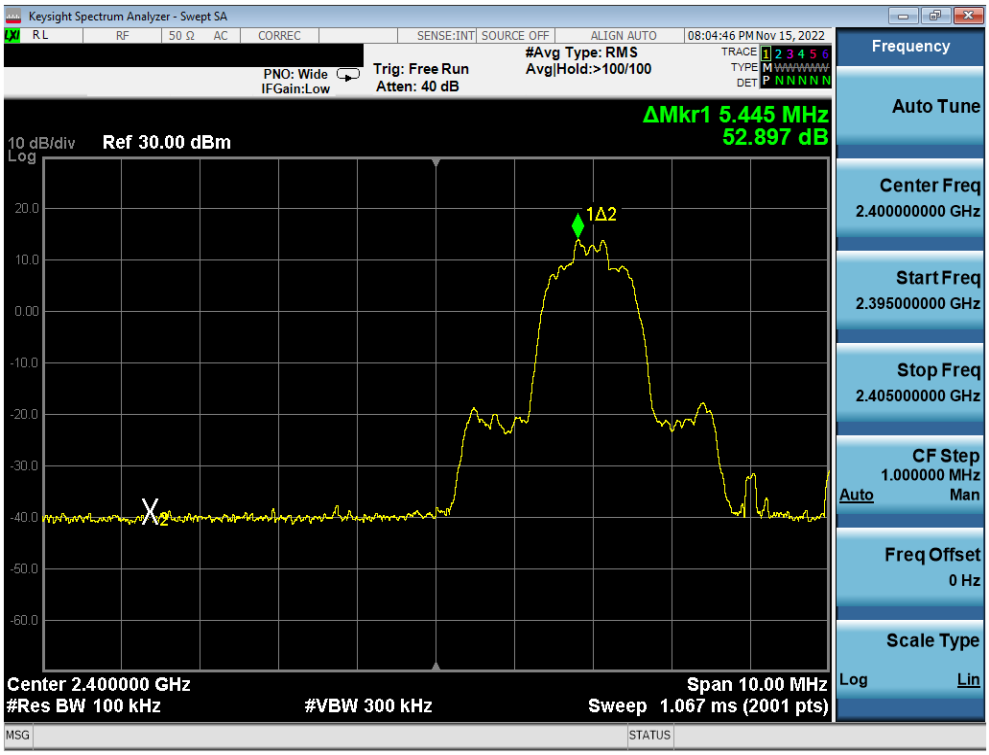
Plot 7-8. Band Edge Plot (Bluetooth with Hopping Disabled, GFSK, 2.4GHz)



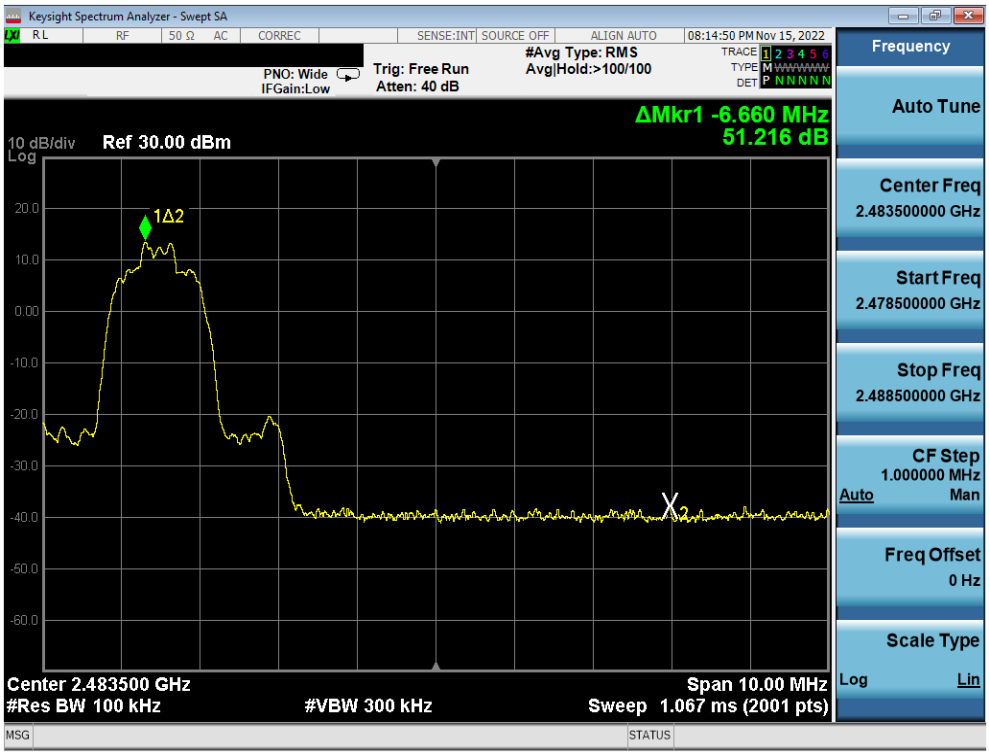
Plot 7-9. Band Edge Plot (Bluetooth with Hopping Enabled, GFSK, 2.4GHz)



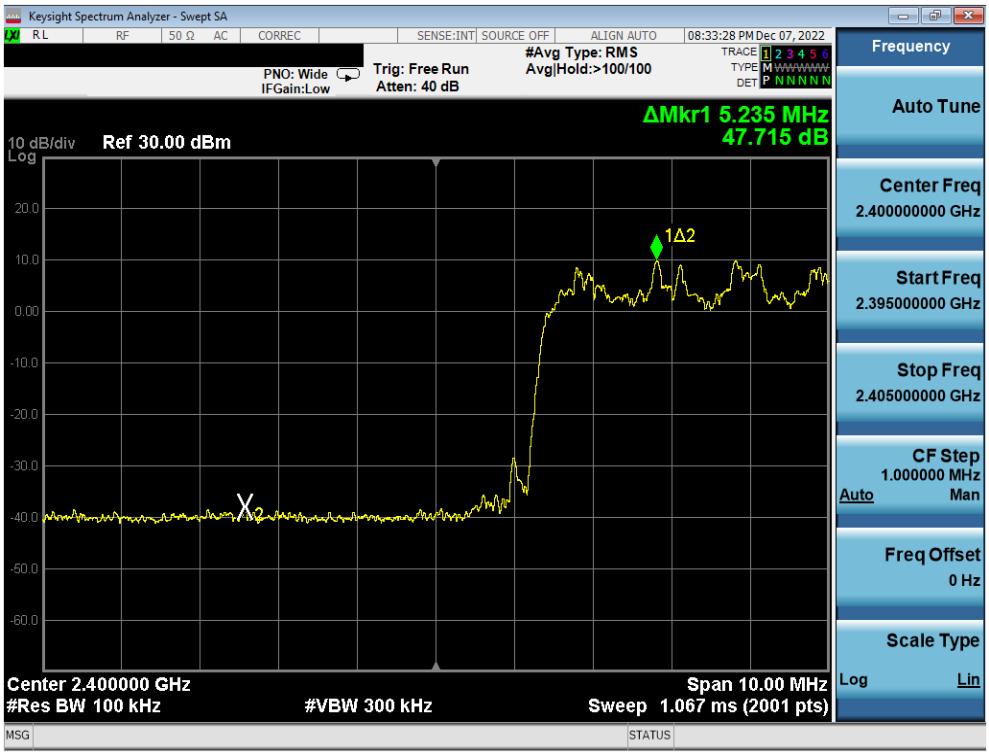
Plot 7-10. Band Edge Plot (Bluetooth with Hopping Enabled, GFSK, 2.4GHz)



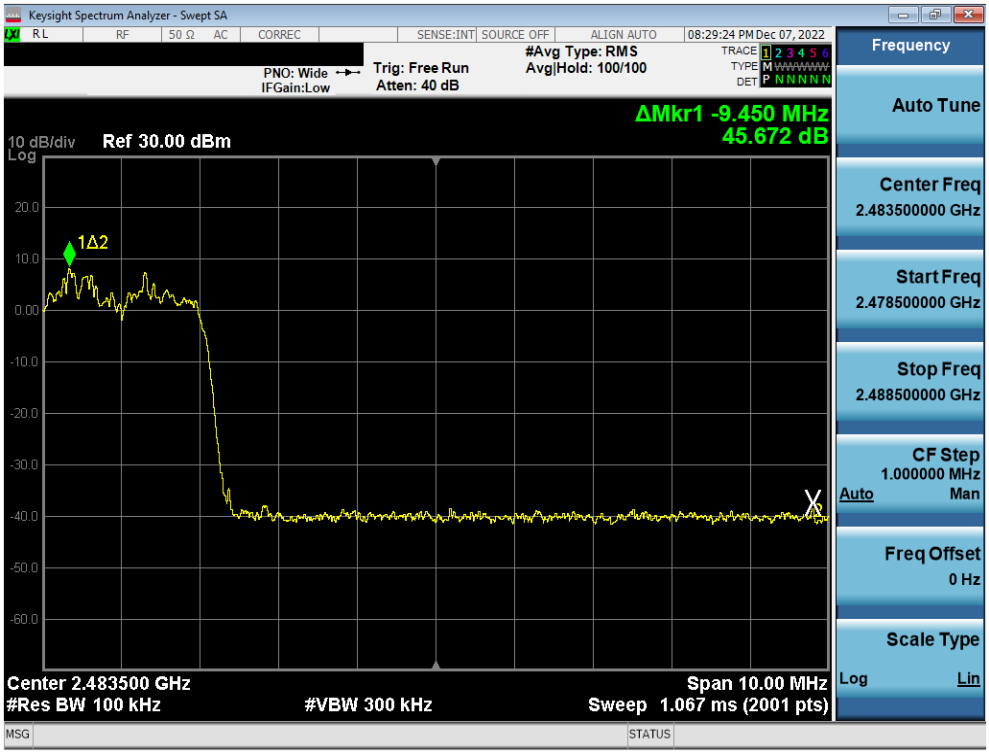
Plot 7-11. Band Edge Plot (Bluetooth with Hopping Disabled, 8DPSK, 2.4GHz)



Plot 7-12. Band Edge Plot (Bluetooth with Hopping Disabled, 8DPSK, 2.4GHz)



Plot 7-13. Band Edge Plot (Bluetooth with Hopping Enabled, 8DPSK, 2.4GHz)



Plot 7-14. Band Edge Plot (Bluetooth with Hopping Enabled, 8DPSK, 2.4GHz)

7.5 Carrier Frequency Separation

§15.247 (a.1); RSS-247 [5.1(b)]

Test Overview and Limit

Measurement is made with EUT operating in hopping mode. ***The minimum permissible channel separation for this system is 2/3 the value of the 20dB BW.***

Test Procedure Used

ANSI C63.10-2013 – Section 7.8.2

Test Settings

1. Span = Wide enough to capture peaks of two adjacent channels
2. RBW = 30% of channel spacing. Adjust as necessary to best identify center of each individual channel
3. VBW ≥ RBW
4. Sweep = Auto
5. Detector = Peak
6. Trace mode = max hold
7. The trace was allowed to stabilize.
8. Marker-delta function used to determine separation between peaks of the adjacent channels

Test Setup

The EUT and measurement equipment were set up as shown in the diagram below.

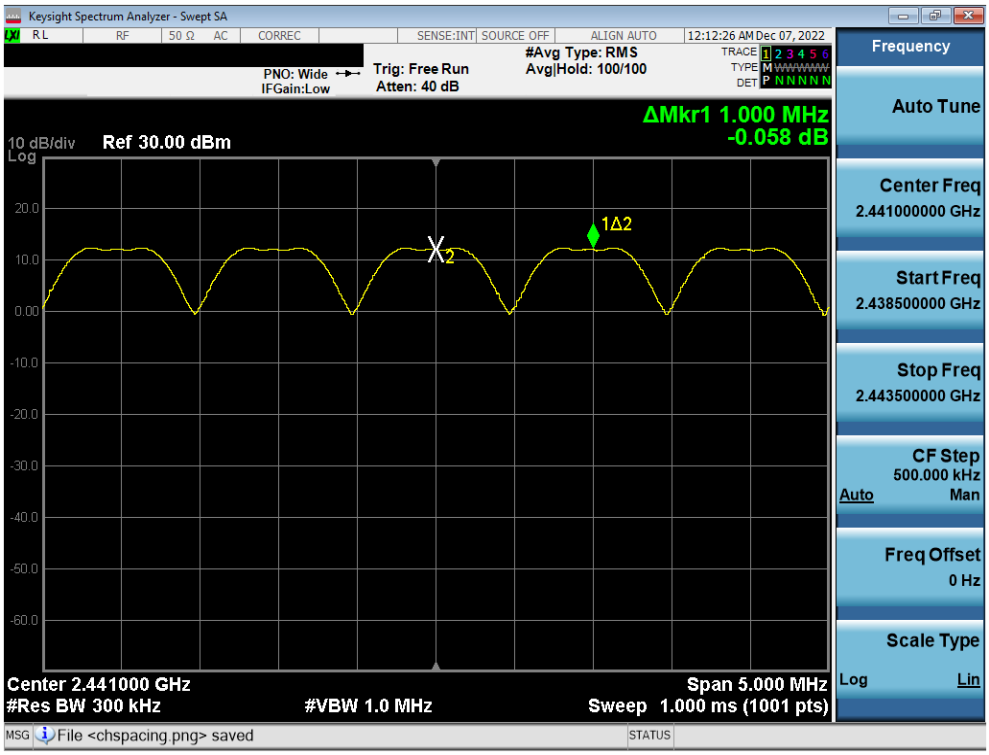
Figure 7-4. Test Instrument & Measurement Setup

Test Notes

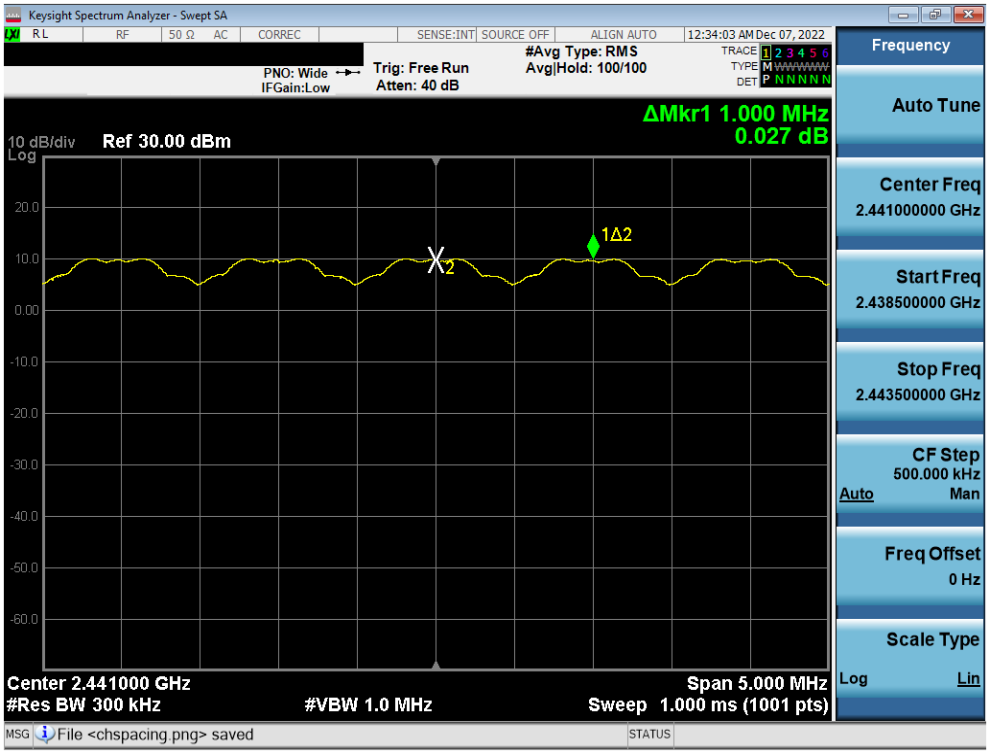
1. The EUT complies with the minimum channel separation requirement when it is operating in 1x/EDR mode using 79 channels.
2. All supported modulation have been tested on the unit and only worst case configuration is reported.

Frequency [MHz]	Data Rate [Mbps]	Mod.	Channel No.	Measured Channel Separation [MHz]	Min. Channel Separation [MHz]	Pass / Fail
2441	1.0	GFSK	39	1.000	0.636	Pass
2441	3.0	8DPSK	39	1.000	0.833	Pass

Table 7-5. Minimum Channel Separation



Plot 7-15. Channel Spacing Plot (Bluetooth, GFSK,2.4GHz)



Plot 7-16. Channel Spacing Plot (Bluetooth, 8DPSK, 2.4GHz)

7.6 Time of Occupancy

§15.247 (a.1.iii); RSS-247 [5.1(d)]

Test Overview and Limit

Measurement is made while EUT is operating in hopping mode with the spectrum analyzer set to zero span. ***The maximum permissible time of occupancy is 400 ms within a period of 400ms multiplied by the number of hopping channels employed.***

Test Procedure Used

ANSI C63.10-2013 – Section 7.8.4

Test Settings

1. Span = zero span, centered on a hopping channel
2. RBW ≤ channel spacing and >> 1/T, where T is expected dwell time per channel
3. Sweep = as necessary to capture entire dwell time. Second plot may be required to demonstrate two successive hops on a channel
4. Trigger is set with appropriate trigger delay to place pulse near the center of the plot
5. Detector = peak
6. Trace mode = max hold
7. Marker-delta function used to determine transmit time per hop

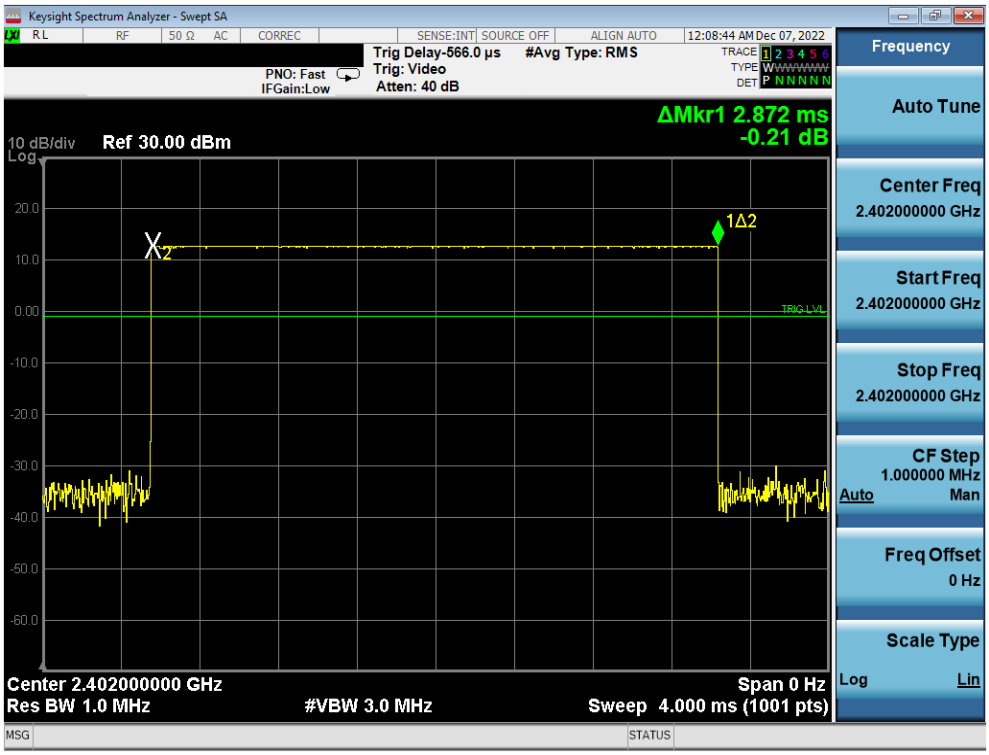
Test Setup

The EUT and measurement equipment were set up as shown in the diagram below.

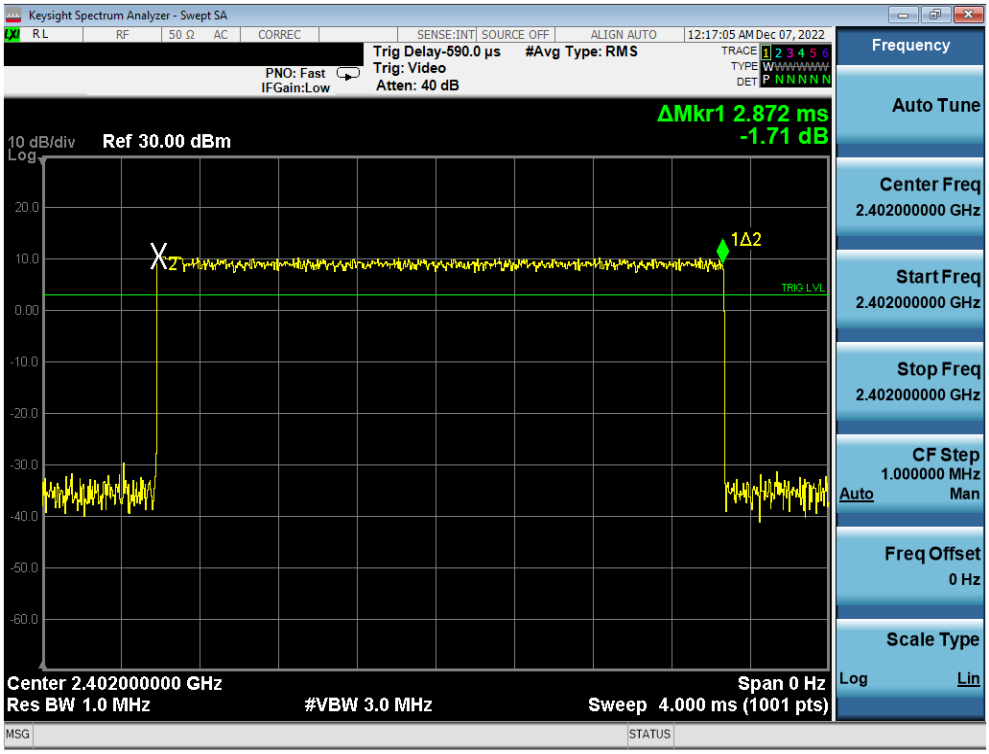
Figure 7-5. Test Instrument & Measurement Setup

Test Notes

All supported modulation have been tested on the unit and only worst case configuration is reported.



Plot 7-17. Time of Occupancy Plot (Bluetooth, GFSK, 2.4GHz)



Plot 7-18. Time of Occupancy Plot (Bluetooth, 8DPSK, 2.4GHz)

Bluetooth Time of Occupancy Calculation

Typically, Bluetooth 1x/EDR mode has a channel hopping rate of 1600 hops/s. Since 1x/EDR modes use 5 transmit and 1 receive slot, for a total of 6 slots, the Bluetooth transmitter is actually hopping at a rate of 1600 / 6 = 266.67 hops/s/slot

- 400ms x 79 hopping channels = 31.6 sec (Time of Occupancy Limit)
- Worst case BT has 266.67 hops/second (for 1x/EDR modes with DH5 operation)
- 266.67 hops/second / 79 channels = 3.38 hops/second (# of hops/second on one channel)
- 3.38 hops/second/channel x 31.6 seconds = 106.67 hops (# hops over a 31.6 second period)
- 106.67 hops x 2.872 ms/channel = 306.36 ms (worst case dwell time for one channel in 1x/EDR modes)

With AFH, the number of channels is reduced to a minimum of 20 channels and the channel hopping rate is reduced by 50% to 800 hops/s. AFH mode also uses 6 total slots so the Bluetooth transmitter hops at a rate of 800 / 6 = 133.3 hops/s/slot

- 400ms x 20 hopping channels = 8 sec (Time of Occupancy Limit)
- Worst case BT has 133.3 hops/second/slot (for AFH mode with DH5 operation)
- 133.3 hops/s / 20 channels = 6.67 hops/second (# of hops/second on one channel)
- 6.67 hops/s / channel x 8 seconds = 53.34 hops (# hops over a 8 second period)
- 53.34 hops x 2.872 ms/channel = 153.19 ms (worst case dwell time for one channel in AFH mode)

Test Result

The measured worst case dwell time is below the limit of 0.4s.

7.7 Number of Hopping Channels

§15.247 (a.1.iii); RSS-247 [5.1(d)]

Test Overview and Limit

Measurement is made while EUT is operating in hopping mode. ***This frequency hopping system must employ a minimum of 15 hopping channels.***

Test Procedure Used

ANSI C63.10-2013 – Section 7.8.3

Test Settings

1. Span = frequency of band of operation (divided into two plots)
2. RBW < 30% of channel spacing or 20dB bandwidth, whichever is smaller.
3. VBW ≥ RBW
4. Sweep = auto
5. Detector = peak
6. Trace mode = max hold
7. Trace was allowed to stabilize

Test Setup

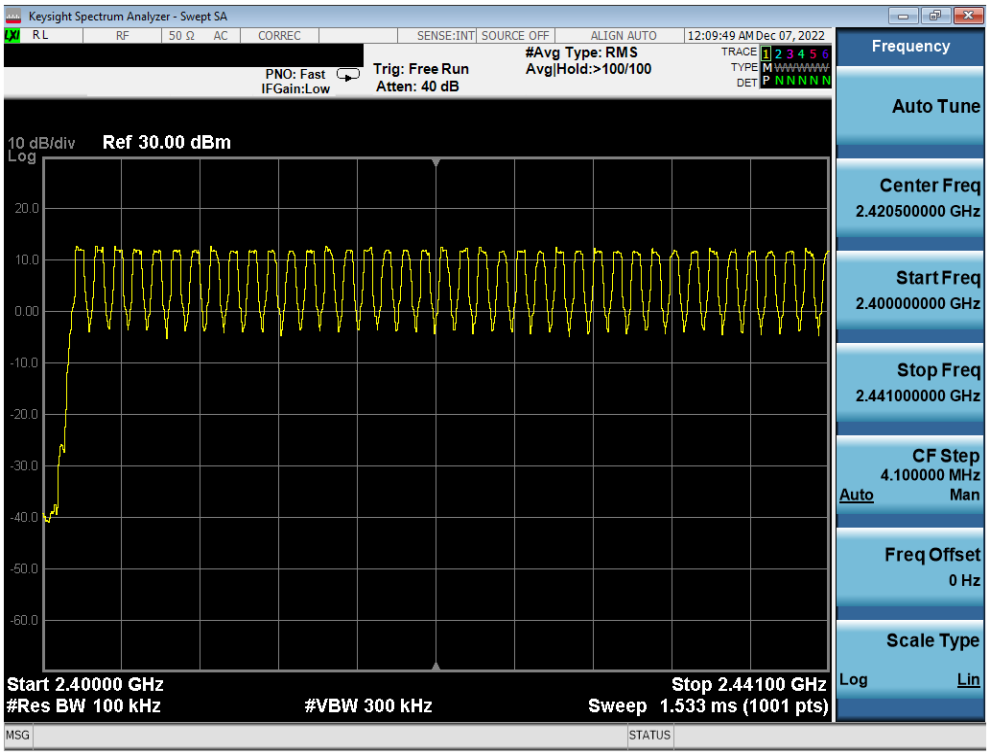
The EUT and measurement equipment were set up as shown in the diagram below.

Figure 7-6. Test Instrument & Measurement Setup

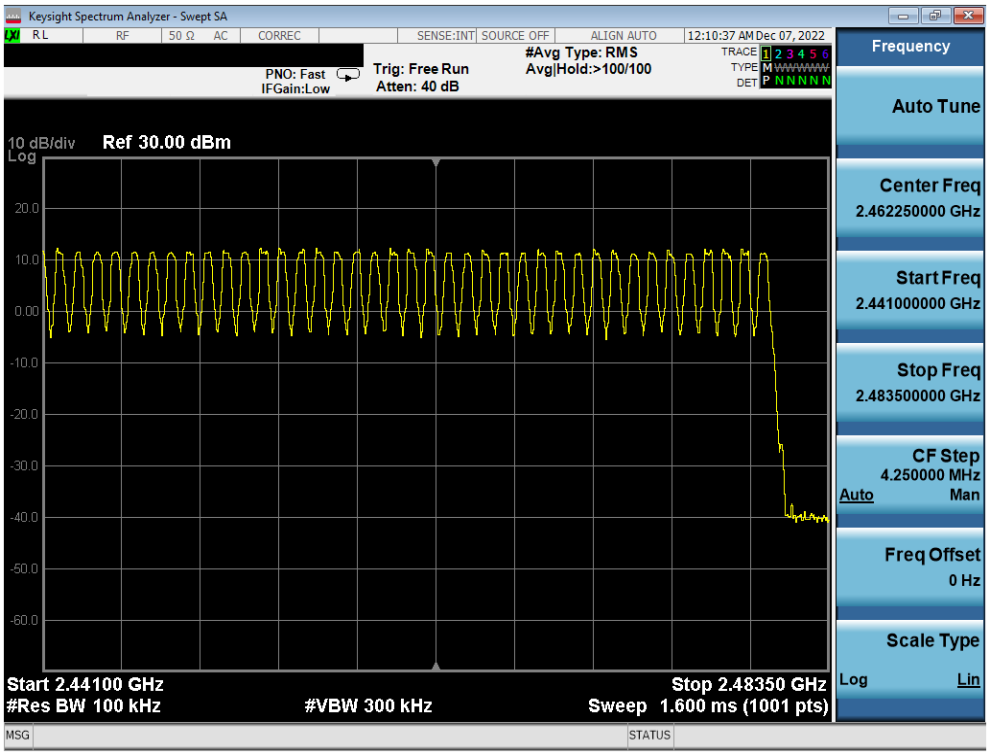
Test Notes

1. The frequency spectrum was broken up into two sub-ranges to clearly show all of the hopping frequencies. In AFH mode, this device operates using 20 channels so the requirement for minimum number of hopping channels is satisfied.

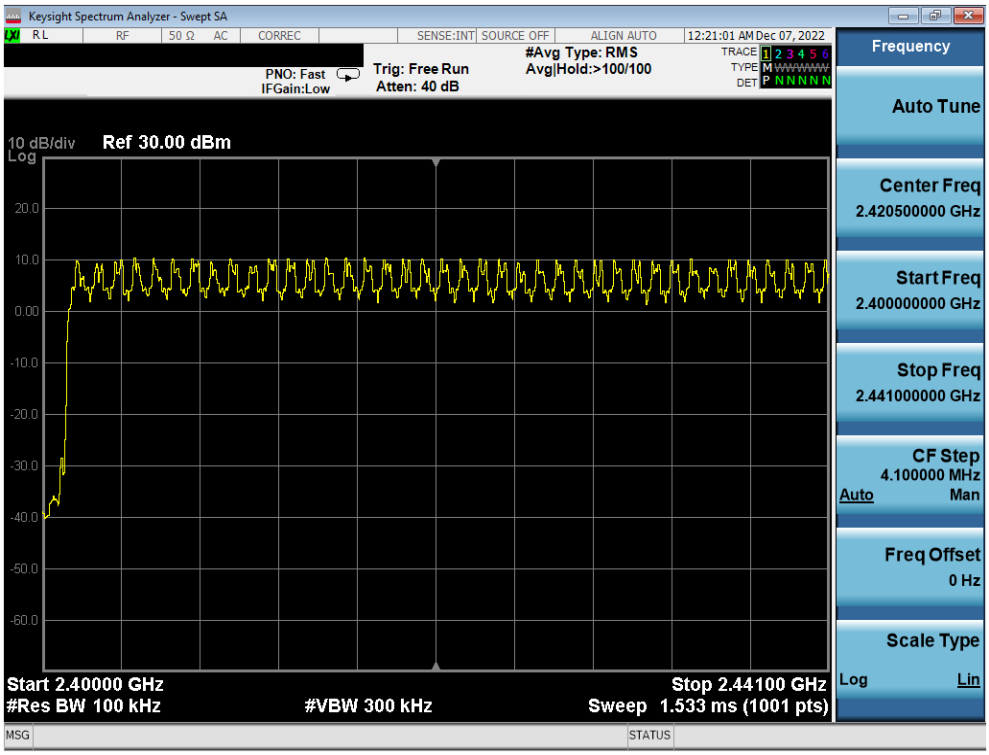
2. All supported modulation have been tested on the unit and only worst case configuration is reported.



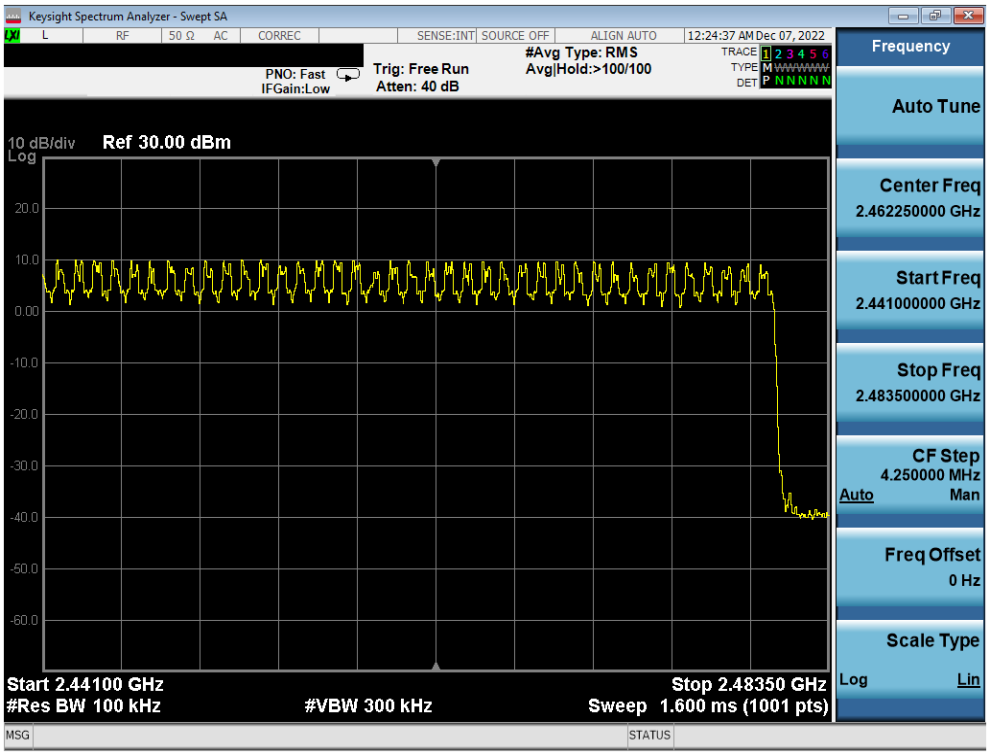
Plot 7-19. Low End Spectrum Channel Hopping Plot (Bluetooth, GFSK, 2.4GHz)



Plot 7-20. High End Spectrum Channel Hopping Plot (Bluetooth, GFSK, 2.4GHz)



Plot 7-21. Low End Spectrum Channel Hopping Plot (Bluetooth, 8DPSK, 2.4GHz)



Plot 7-22. High End Spectrum Channel Hopping Plot (Bluetooth, 8DPSK, 2.4GHz)

7.8 Conducted Spurious Emissions

§15.247 (d); RSS-247 [5.5]

Test Overview and Limit

Conducted out-of-band spurious emissions were investigated from 30MHz up to 25GHz to include the 10th harmonic of the fundamental transmit frequency. ***The maximum permissible out-of-band emission level is 20 dBc.***

Test Procedure Used

ANSI C63.10-2013 – Section 7.8.8

Test Settings

1. Start frequency was set to 30MHz and stop frequency was set to 25GHz (separated into two plots per channel)
2. RBW = 1MHz* (See note below)
3. VBW = 3MHz
4. Detector = Peak
5. Trace mode = max hold
6. Sweep time = auto couple
7. The trace was allowed to stabilize

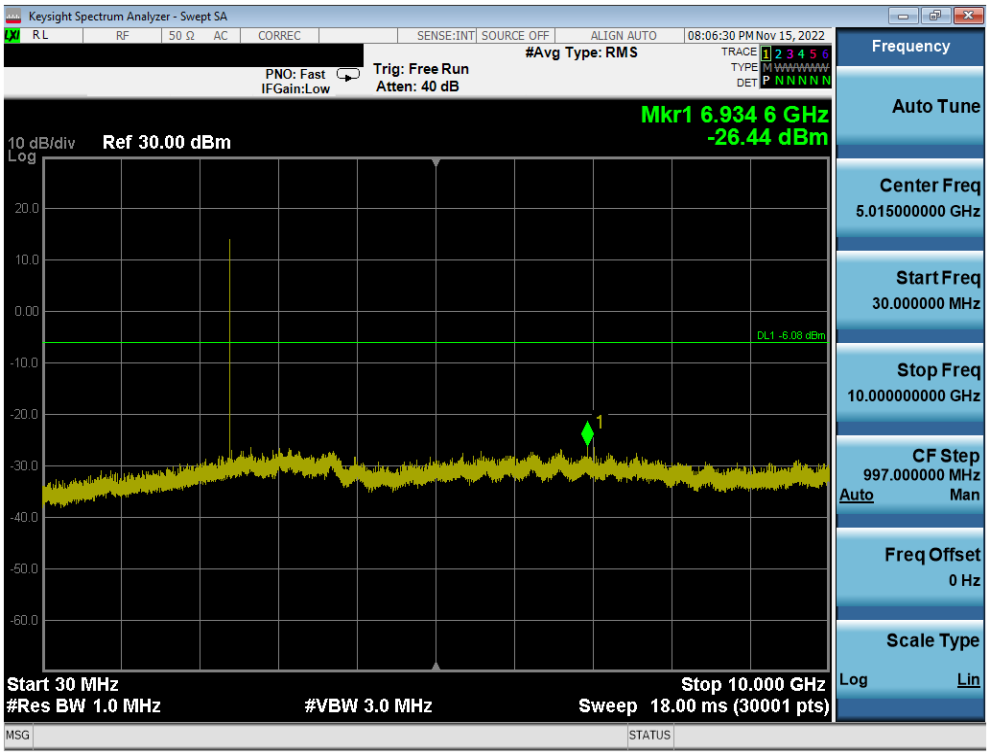
Test Setup

The EUT and measurement equipment were set up as shown in the diagram below.

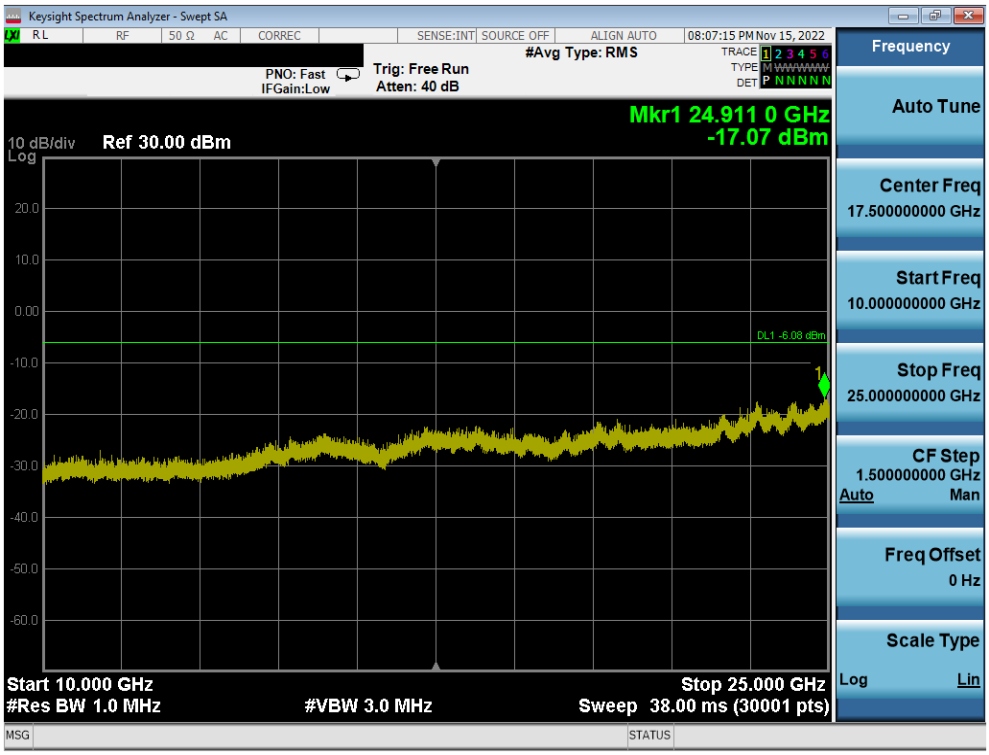
Figure 7-7. Test Instrument & Measurement Setup

Test Notes

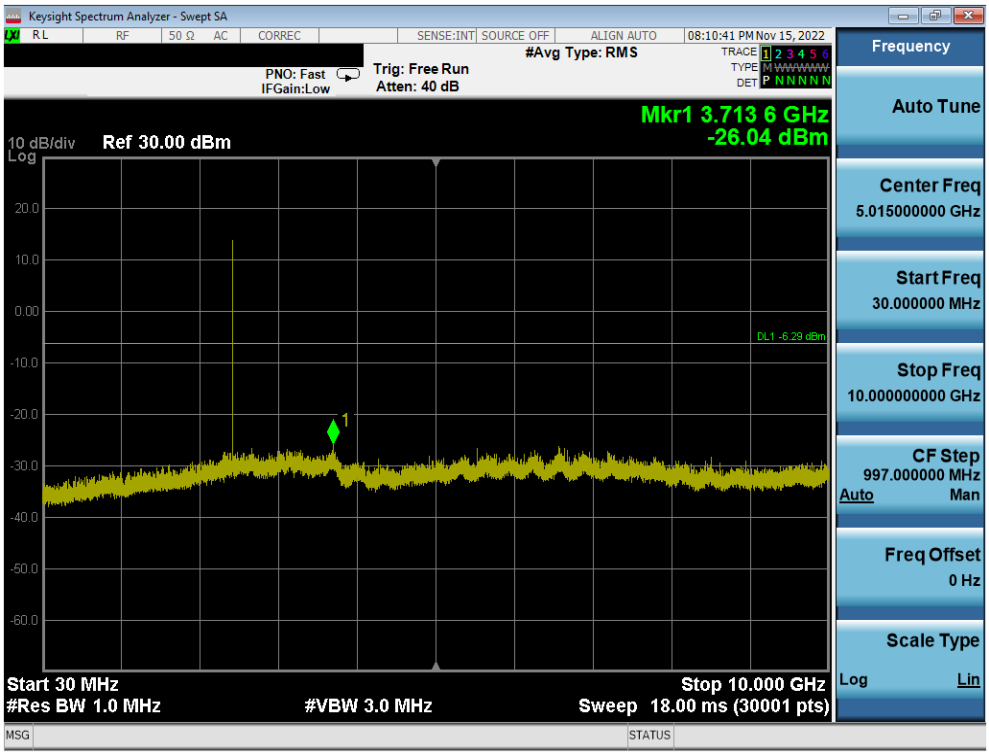
1. Out-of-band conducted spurious emissions were investigated for all data rates and the worst case emissions were found with the EUT transmitting at 1Mbps. The display line shown in the following plots is the limit at 20dB below the fundamental emission level measured in a 100kHz bandwidth. However, the traces in the following plots are measured with a 1MHz RBW to reduce test time, so the display line may not necessarily appear to be 20dB below the level of the fundamental in a 1MHz bandwidth.
2. The unit was tested with all possible modes and only the highest emission is reported.



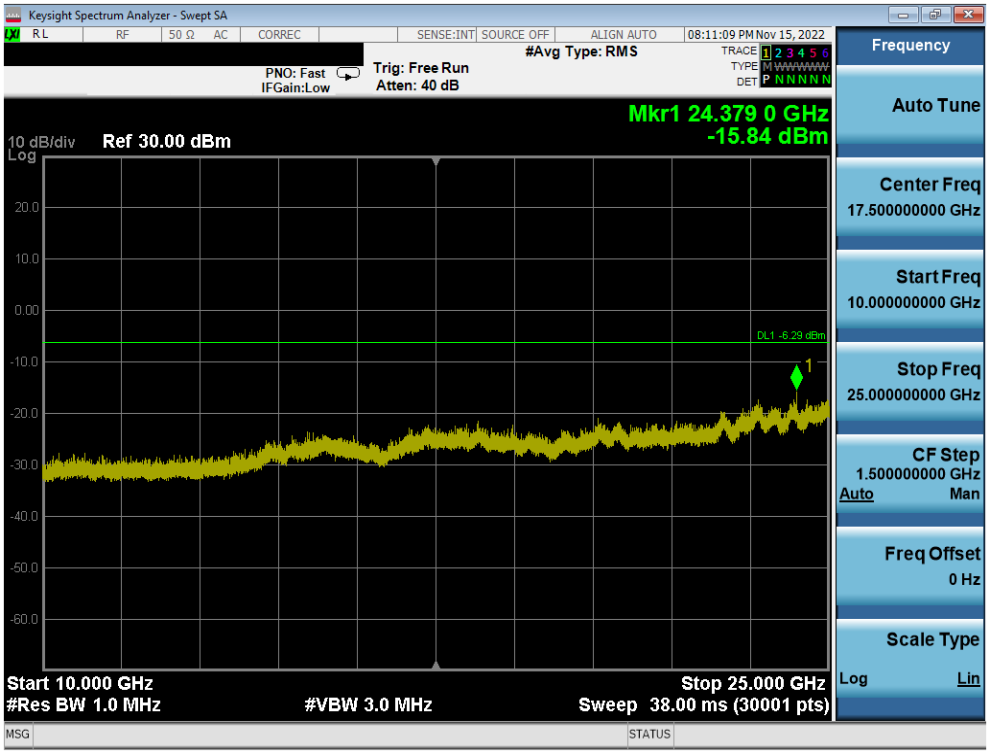
Plot 7-23. Conducted Spurious Plot (Bluetooth, GFSK – 2402MHz)



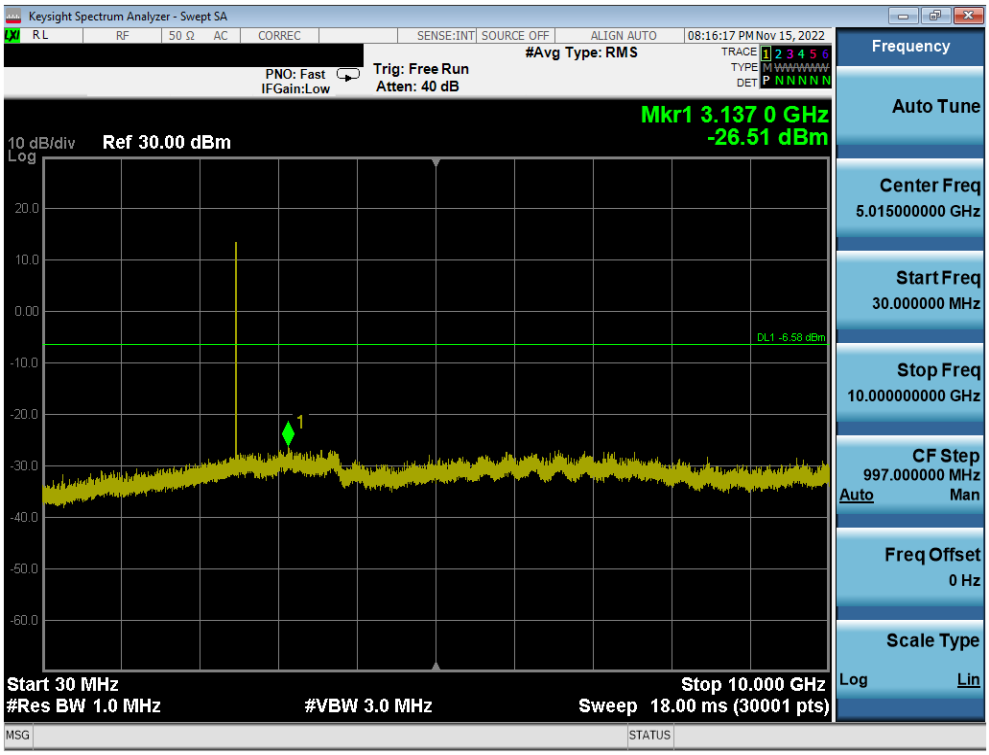
Plot 7-24. Conducted Spurious Plot (Bluetooth, GFSK – 2402MHz)



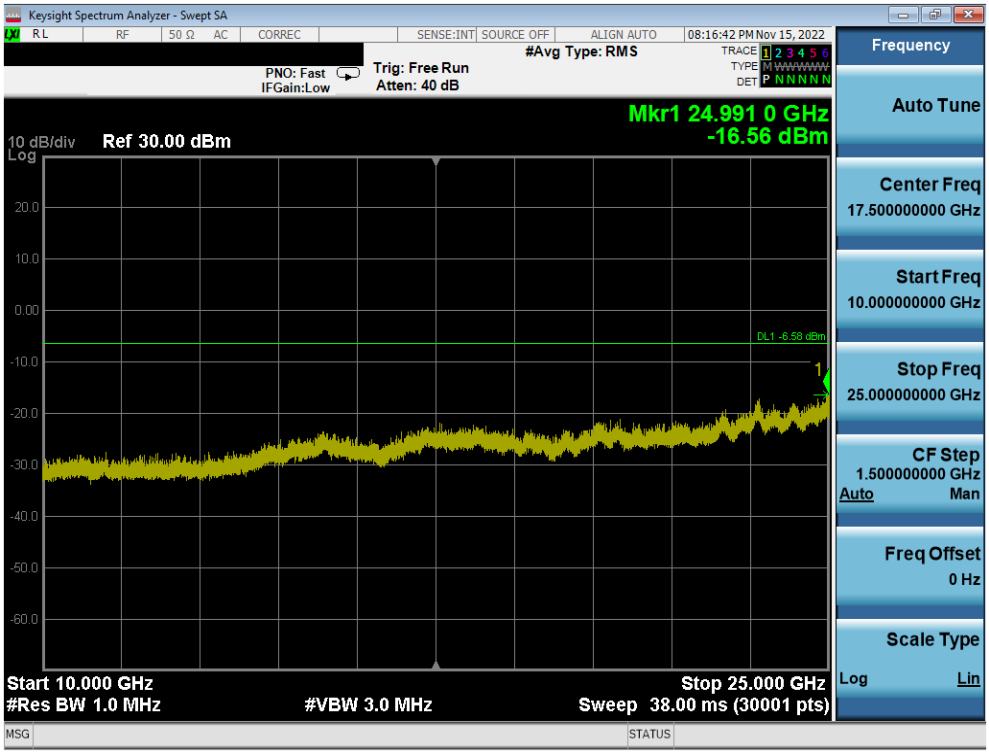
Plot 7-25. Conducted Spurious Plot (Bluetooth, GFSK – 2441MHz)



Plot 7-26. Conducted Spurious Plot (Bluetooth, GFSK - 2441MHz)



Plot 7-27. Conducted Spurious Plot (Bluetooth, GFSK – 2480MHz)



Plot 7-28. Conducted Spurious Plot (Bluetooth, GFSK – 2480MHz)

7.9 Radiated Spurious Emissions – Above 1GHz

§15.205 §15.209 §15.247 (d); RSS-Gen [8.9]

Test Overview and Limit

All out of band radiated spurious emissions are measured with a spectrum analyzer connected to a receive antenna while the EUT is operating at maximum power and at the appropriate frequencies. Only the radiated emissions of the configuration that produced the worst case emissions are reported in this section.

All out of band emissions appearing in a restricted band as specified in Section 15.205 of the Title 47 CFR and Table 7 of RSS-Gen (8.10) must not exceed the limits shown in Table 7-6 per Section 15.209 and RSS-Gen (8.9).

Frequency	Field Strength [μV/m]	Measured Distance [Meters]
Above 960.0 MHz	500	3

Table 7-6. Radiated Limits

Test Procedure Used

ANSI C63.10-2013 – Section 6.6.4.3

Test Settings

Peak Field Strength Measurements

1. Analyzer center frequency was set to the frequency of the radiated spurious emission of interest
2. RBW = 1MHz
3. VBW = 3MHz
4. Detector = peak
5. Sweep time = auto couple
6. Trace mode = max hold
7. Trace was allowed to stabilize

Test Setup

The EUT and measurement equipment were set up as shown in the diagram below.

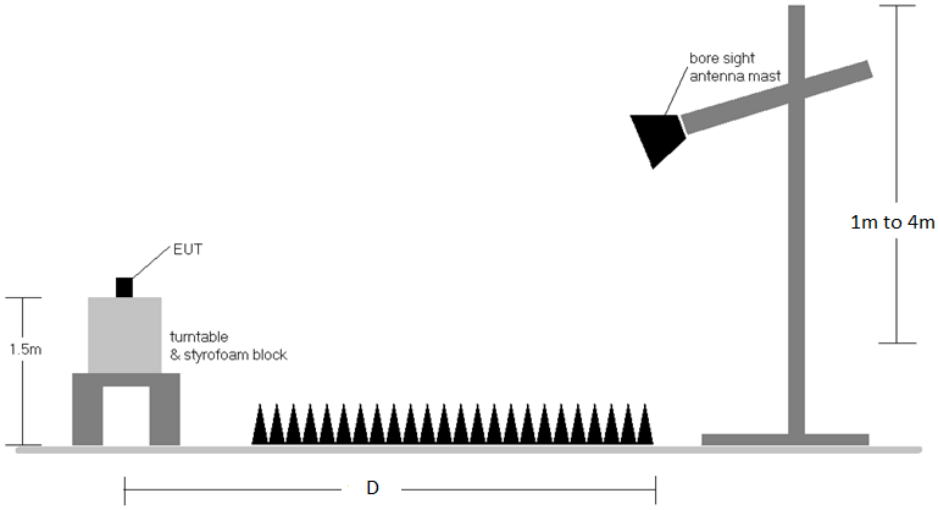


Figure 7-8. Radiated Test Setup >1GHz

Test Notes

1. All emissions lying in restricted bands specified in §15.205 and Section 8.10 of RSS-Gen are below the limit shown in Table 7-6.
2. The antenna is manipulated through typical positions, polarity and length during the tests. The EUT is manipulated through three orthogonal planes.
3. This unit was tested with its standard battery.
4. The spectrum is measured from 9kHz to the 10th harmonic and the worst-case emissions are reported.
5. The wide spectrum spurious emissions plots shown on the following pages are used only for the purpose of emission identification. Any emissions found to be within 20dB of the limit are fully investigated and the results are shown in this section.
6. D is the measurement test distance and emissions 1-18GHz were measured at a 3 meters test distance while emissions above 18GHz were measured at a 1 meter test distance with the application of a distance correction factor.
7. The "-" shown in the following RSE tables are used to denote a noise floor measurement.
8. All supported modulation have been tested on the unit and only worst case configuration is reported.
9. Average emissions were not reported since the duty cycle correction factor was greater than 20dB.

Sample Calculation

- Field Strength Level $[dB\mu V/m]$ = Analyzer Level $[dBm]$ + 107 + AFCL $[dB/m]$
- AFCL $[dB/m]$ = Antenna Factor $[dB/m]$ + Cable Loss $[dB]$ – Preamplifier Gain $[dB]$
- Margin $[dB]$ = Field Strength Level $[dB\mu V/m]$ – Limit $[dB\mu V/m]$

Duty Cycle Correction Factor Calculation

- Channel hop rate = 800 hops/second (AFH Mode)
- Adjusted channel hop rate for DH5 mode **=** 133.33 hops/second
- Time per channel hop **=** 1 / 133.33 hops/second = 7.50 ms
- Time to cycle through all channels = 7.50 x 20 channels = 150 ms
- Number of times transmitter hits on one channel = 100 ms / 150 ms = 1 time(s)
- Worst case dwell time = 7.5 ms

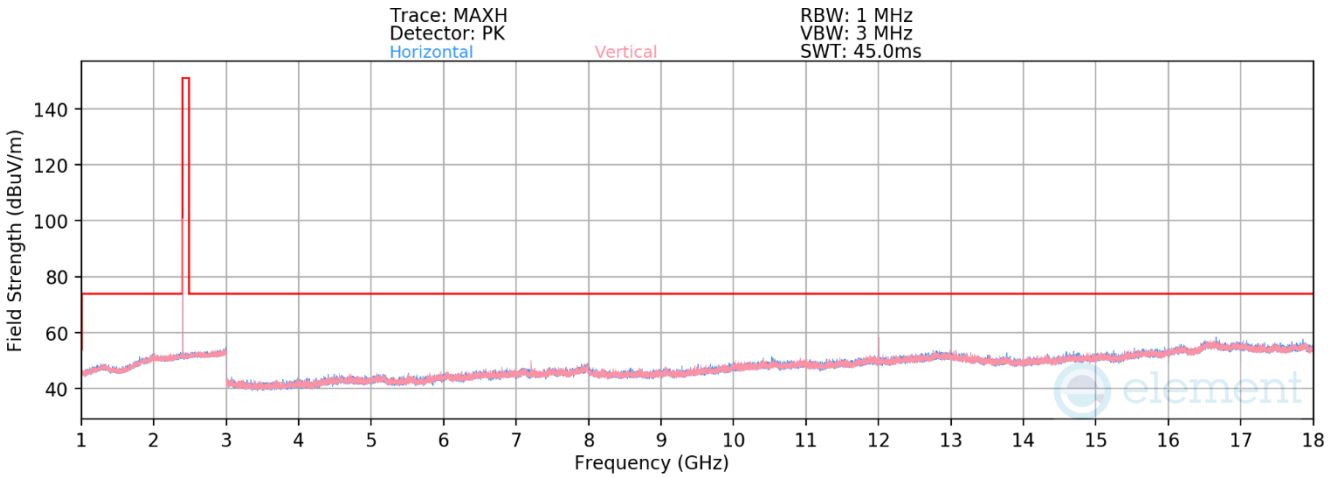
Duty cycle correction factor = $20\log_{10}(7.5ms/100ms)$ = -22.5 dB

Average Emission Calculation

- Average Emission = Measured Peak Emissions $[dB\mu V/m]$ – Duty Cycle Correction Factor $[dB]$

Radiated Spurious Emission Measurements (1 – 18GHz)

§15.205 §15.209 §15.247 (d); RSS-Gen [8.9]

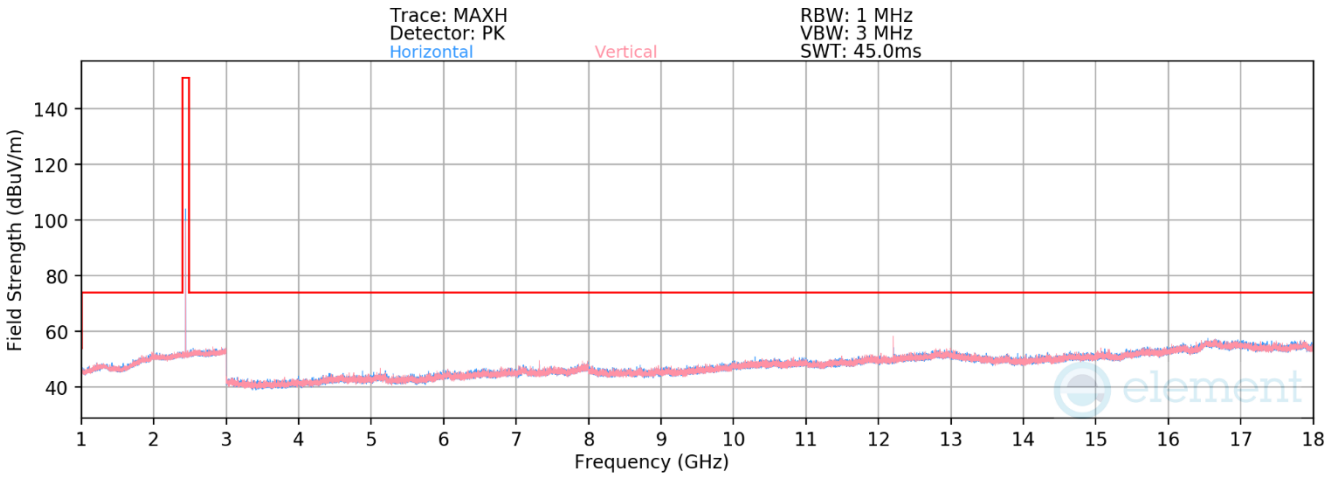


Plot 7-29. Radiated Spurious Emissions above 1GHz (BT GFSK – 2402MHz)

Bluetooth Mode:	GFSK
Data Rate:	1Mbps
Distance of Measurements:	3 Meters
Operating Frequency:	2402MHz

Frequency [MHz]	Detector	Ant. Pol. [H/V]	Antenna Height [cm]	Turntable Azimuth [degree]	Analyzer Level [dBm]	AFCL [dB/m]	Field Strength [dBµV/m]	Limit [dBµV/m]	Margin [dB]
4804.00	Peak	H	102	123	-63.34	4.09	47.75	73.98	-26.23
12010.00	Peak	V	103	61	-66.29	17.34	58.05	73.98	-15.93

Table 7-7. Radiated Measurements

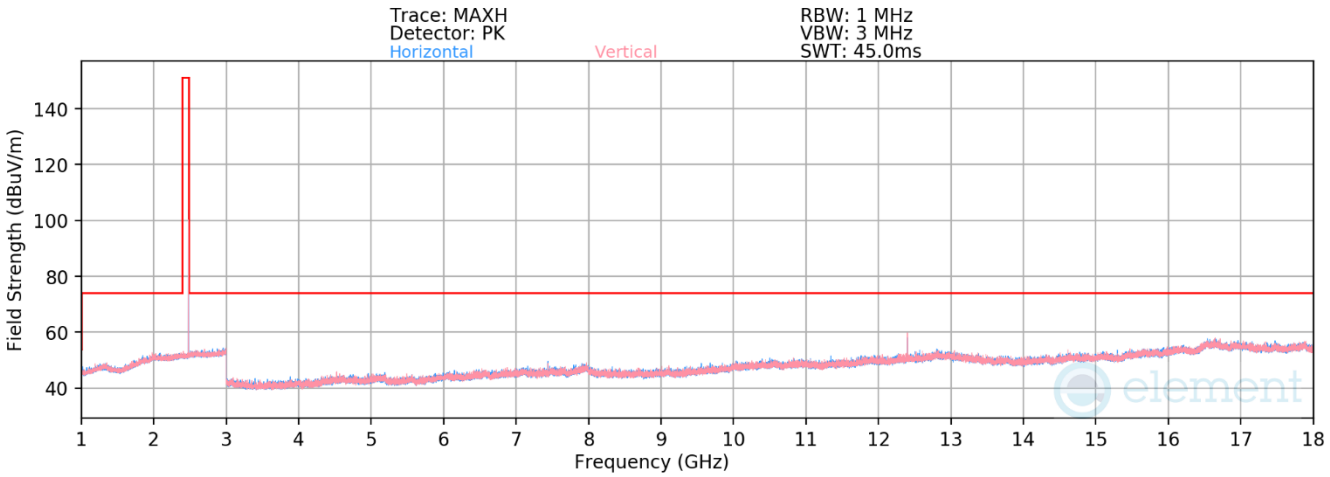


Plot 7-30. Radiated Spurious Emissions above 1GHz (BT GFSK – 2441MHz)

Bluetooth Mode:	GFSK
Data Rate:	1Mbps
Distance of Measurements:	3 Meters
Operating Frequency:	2441MHz

Frequency [MHz]	Detector	Ant. Pol. [H/V]	Antenna Height [cm]	Turntable Azimuth [degree]	Analyzer Level [dBm]	AFCL [dB/m]	Field Strength [dBµV/m]	Limit [dBµV/m]	Margin [dB]
4882.00	Peak	H	348	178	-65.11	4.65	46.54	73.98	-27.44
7323.00	Peak	H	393	169	-62.38	8.85	53.47	73.98	-20.51
12205.00	Peak	V	102	320	-60.73	17.80	64.07	73.98	-9.91

Table 7-8. Radiated Measurements



Plot 7-31. Radiated Spurious Emissions above 1GHz (BT GFSK – 2480MHz)

Bluetooth Mode:	GFSK
Data Rate:	1Mbps
Distance of Measurements:	3 Meters
Operating Frequency:	2480MHz

Frequency [MHz]	Detector	Ant. Pol. [H/V]	Antenna Height [cm]	Turntable Azimuth [degree]	Analyzer Level [dBm]	AFCL [dB/m]	Field Strength [dBµV/m]	Limit [dBµV/m]	Margin [dB]
4960.00	Peak	V	102	229	-62.89	3.92	48.03	73.98	-25.95
7440.00	Peak	H	153	71	-63.78	8.40	51.62	73.98	-22.36
12400.00	Peak	V	102	135	-60.96	13.32	59.36	73.98	-14.62

Table 7-9. Radiated Measurements

Radiated Spurious Emission Measurements (Above 18GHz)

§15.209; RSS-Gen [8.9]

18:55:40 16.01.2023

Plot 7-32. Radiated Spurious Emissions above 18GHz (BT GFSK - 2441MHz, Pol. H)

18:39:47 16.01.2023

Plot 7-33. Radiated Spurious Emissions above 18GHz (BT GFSK - 2441MHz, Pol. V)

Frequency [GHz]	Detector	Ant. Pol. [H/V]	Positioner [degree]	Turntable Azimuth [degree]	Analyzer Level [dBm]	AFCL [dB/m]	Dist. Corr. Factor [dB]	Field Strength [dBµV/m]	Limit [dBµV/m]	Margin [dB]
21.95	Peak	V	15	118	-40.78	-7.36	-9.54	49.32	73.98	-24.66

Table 7-10. Radiated Spurious Emissions Above 18GHz Measurements

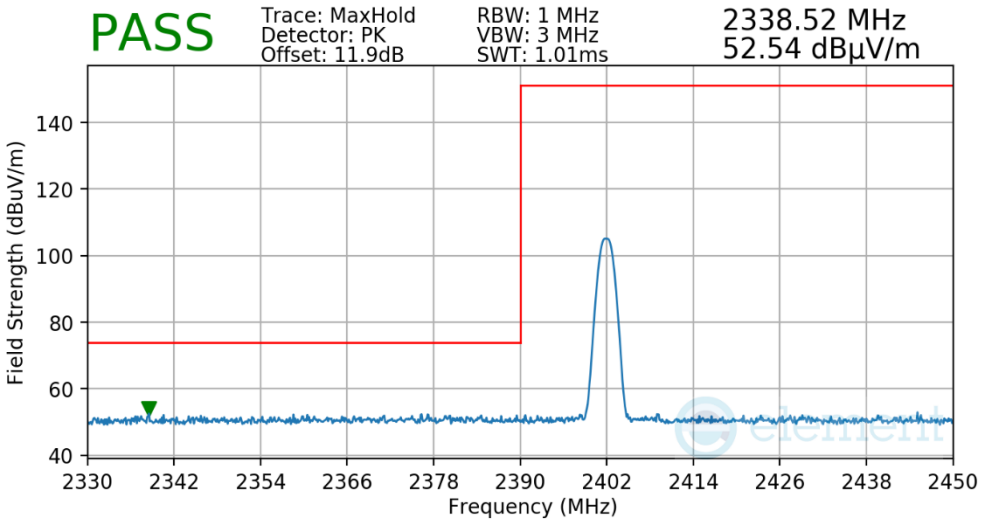
7.9.1 Radiated Restricted Band Edge Measurements

§15.205 §15.209 §15.247 (d); RSS-Gen [8.9]

Bluetooth Mode: GFSK

Measurement Distance: 3 Meters

Operating Frequency: 2402MHz

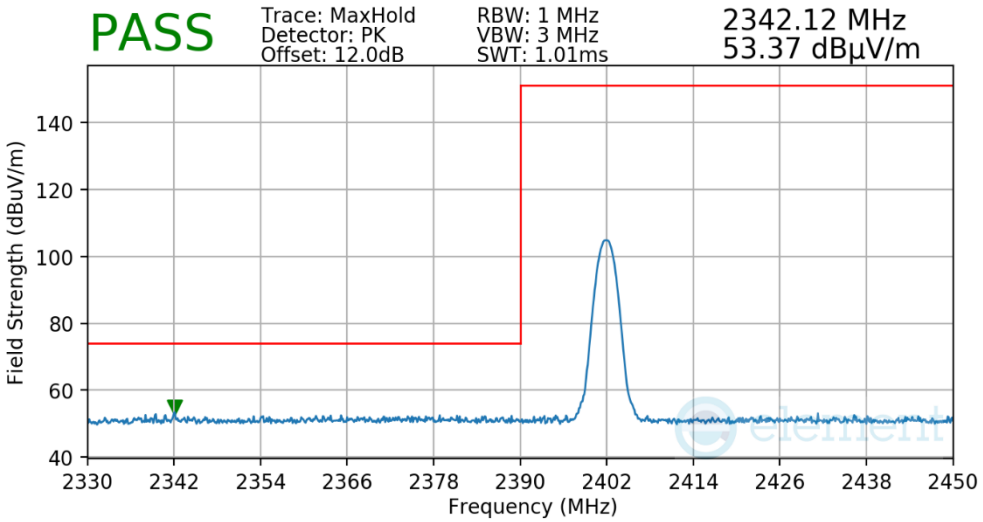


Plot 7-34. Radiated Restricted Lower Band Edge Measurement

Bluetooth Mode: 8DPSK

Measurement Distance: 3 Meters

Operating Frequency: 2402MHz

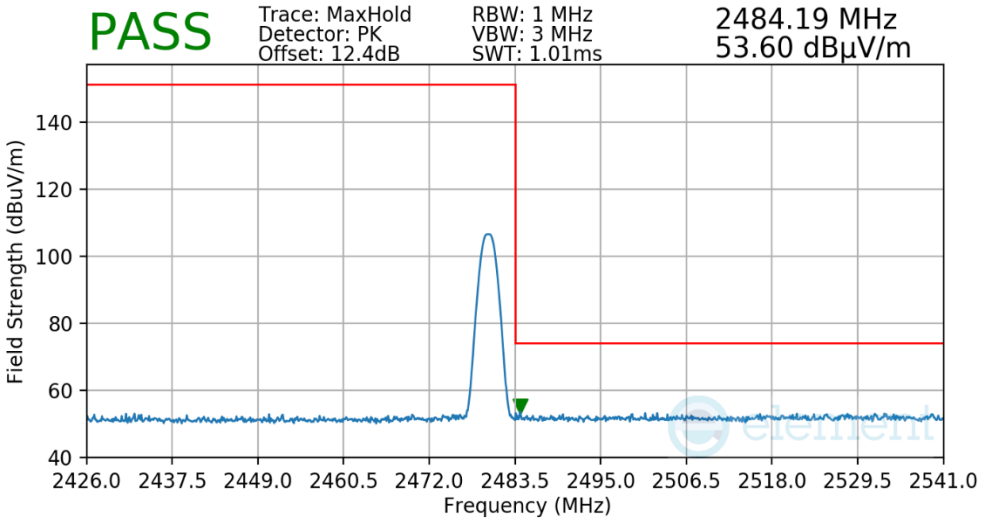


Plot 7-35. Radiated Restricted Lower Band Edge Measurement

Bluetooth Mode: GFSK

Measurement Distance: 3 Meters

Operating Frequency: 2480MHz

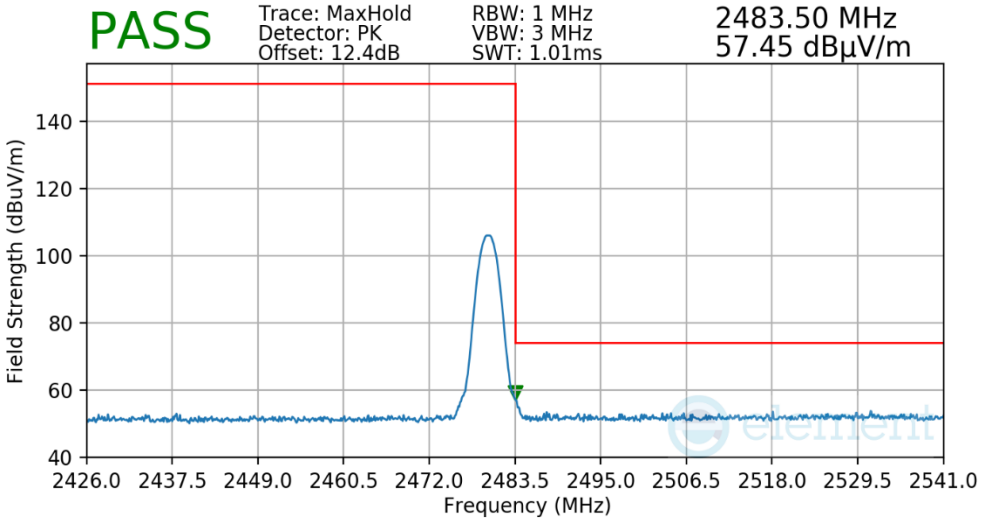


Plot 7-36. Radiated Restricted Upper Band Edge Measurement

Bluetooth Mode: 8DPSK

Measurement Distance: 3 Meters

Operating Frequency: 2480MHz



Plot 7-37. Radiated Restricted Upper Band Edge Measurement

7.10 Radiated Spurious Emissions – Below 1GHz

§15.209; RSS-Gen [8.9]

Test Overview and Limit

All out of band radiated spurious emissions are measured with a spectrum analyzer connected to a receive antenna while the EUT is operating at its maximum duty cycle, at maximum power, and at the appropriate frequencies. All data rates and modes were investigated for radiated spurious emissions. Only the radiated emissions of the configuration that produced the worst case emissions are reported in this section.

All out of band emissions appearing in a restricted band as specified in Section 15.205 of the Title 47 CFR and Table 7 of RSS-Gen (8.10) must not exceed the limits shown in Table 7-11 per Section 15.209 and RSS-Gen (8.9).

Frequency	Field Strength [µV/m]	Measured Distance [Meters]
0.009 – 0.490 MHz	2400/F (kHz)	300
0.490 – 1.705 MHz	24000/F (kHz)	30
1.705 – 30.00 MHz	30	30
30.00 – 88.00 MHz	100	3
88.00 – 216.0 MHz	150	3
216.0 – 960.0 MHz	200	3
Above 960.0 MHz	500	3

Table 7-11. Radiated Limits

Test Procedures Used

ANSI C63.10-2013

Test Settings

Quasi-Peak Field Strength Measurements

1. Analyzer center frequency was set to the frequency of the radiated spurious emission of interest
2. RBW = 120kHz (for emissions from 30MHz – 1GHz)
3. Detector = quasi-peak
4. Sweep time = auto couple
5. Trace mode = max hold
6. Trace was allowed to stabilize

Peak Field Strength Measurements

1. Analyzer center frequency was set to the frequency of the radiated spurious emission of interest
2. RBW = 120kHz (for emissions from 30MHz – 1GHz)
3. VBW = 300kHz
4. Detector = peak
5. Sweep time = auto couple
6. Trace mode = max hold
7. Trace was allowed to stabilize

Test Setup

The EUT and measurement equipment were set up as shown in the diagrams below.

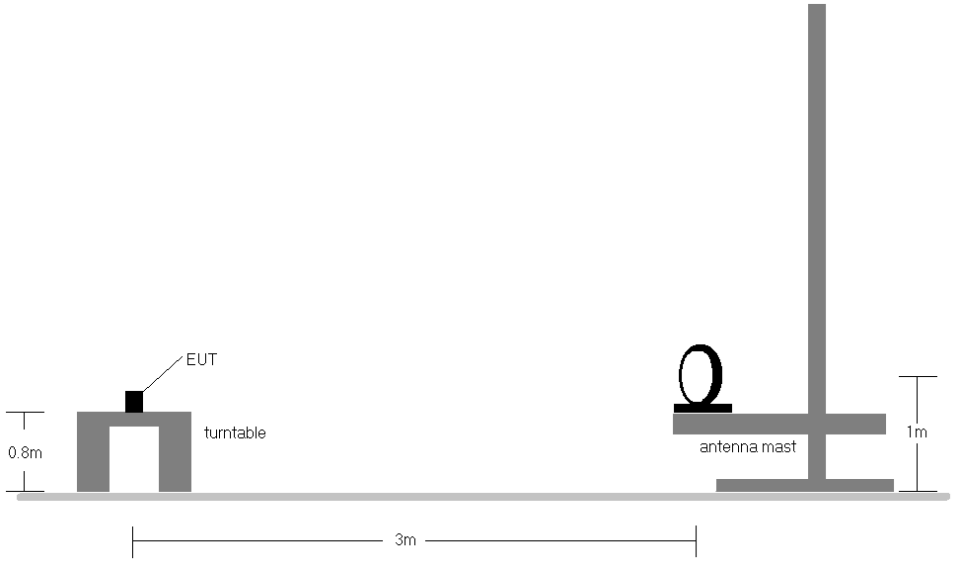


Figure 7-9. Radiated Test Setup < 30MHz

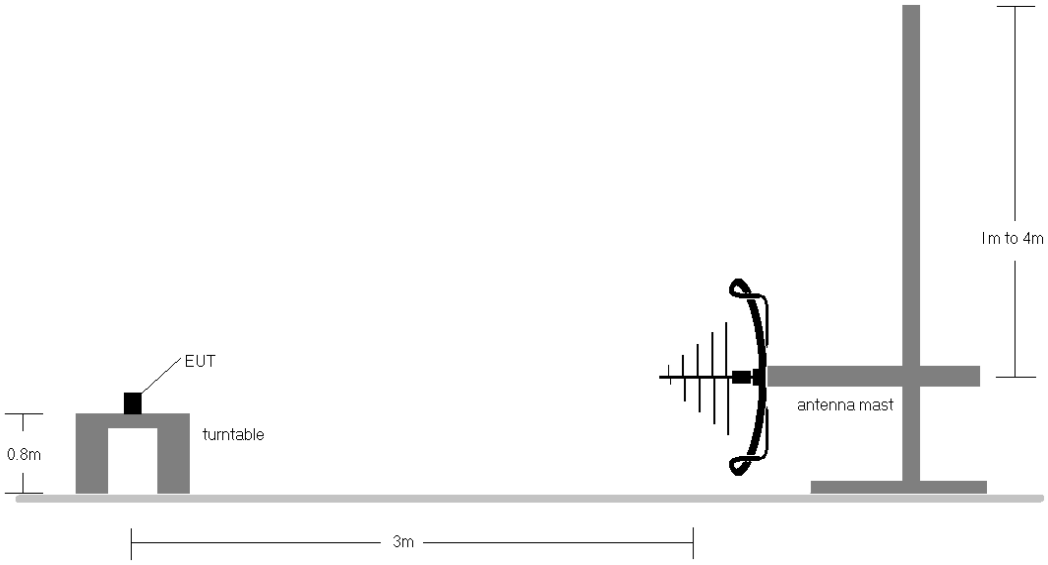


Figure 7-10. Radiated Test Setup < 1GHz

Test Notes

1. All emissions lying in restricted bands specified in §15.205 and RSS-Gen (8.10) are below the limit shown in Table 7-11.
2. The broadband receive antenna is manipulated through vertical and horizontal polarizations during the tests. The EUT is manipulated through three orthogonal planes. For below 30MHz the loop antenna was positioned in 3 orthogonal planes (X front, Y side, Z top) to determine the orientation resulting in the worst case emissions.
3. This unit was tested with its standard battery.
4. The spectrum is investigated using a peak detector and final measurements are recorded using CISPR quasi peak detector on emissions that were within 6dB of the limit.
5. Emissions were measured at a 3 meter test distance.
6. Emissions are investigated while operating on the center channel of the mode, band, and modulation that produced the worst case results during the transmitter spurious emissions testing.
7. No spurious emissions were detected within 20dB of the limit below 30MHz.
8. The results recorded using the broadband antenna is known to correlate with the results obtained by using a tuned dipole with an acceptable degree of accuracy. The VSWR for the measurement antenna was found to be less than 2:1.
9. All supported modulation have been tested on the unit and only worst case configuration is reported.
10. Both configurations below were investigated, and the worst case has been reported.
    a. EUT charged by charging case and powered by AC/DC adaptor with USB-C cable.
    b. EUT charged by charging case and powered by host PC with USB-C cable.

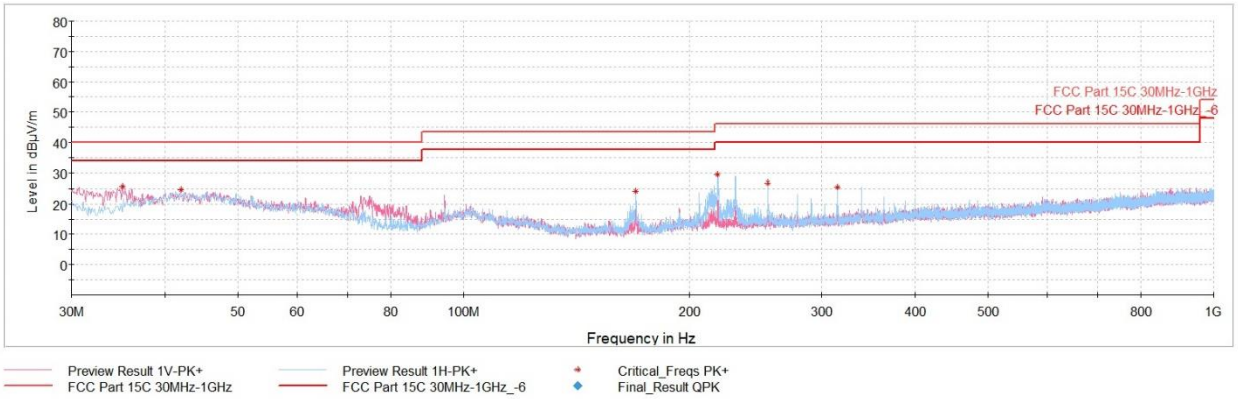
Sample Calculations

Determining Spurious Emissions Levels

- Field Strength Level $_{[dB\mu V/m]}$ = Analyzer Level $_{[dBm]}$ + 107 + AFCL $_{[dB/m]}$
- AFCL $_{[dB/m]}$ = Antenna Factor $_{[dB/m]}$ + Cable Loss $_{[dB]}$ – Preamplifier Gain $_{[dB]}$
- Margin $_{[dB]}$ = Field Strength Level $_{[dB\mu V/m]}$ – Limit $_{[dB\mu V/m]}$

Radiated Spurious Emissions Measurements (Below 1GHz)

§15.209; RSS-Gen [8.9]



Plot 7-38. Radiated Spurious Emissions Below 1GHz (GFSK – Ch.39, with AC/DC Adapter and USB-C cable)

Frequency [MHz]	Detector	Ant. Pol. [H/V]	Antenna Height [cm]	Turntable Azimuth [degree]	Analyzer Level [dBm]	AFCL [dB/m]	Field Strength [dBµV/m]	Limit [dBµV/m]	Margin [dB]
35.0925	Max-Peak	V	100	238	-62.69	-18.69	25.62	40.00	-14.38
41.9795	Max-Peak	H	300	159	-65.85	-16.37	24.78	40.00	-15.22
169.4375	Max-Peak	H	100	228	-62.48	-20.26	24.26	43.52	-19.26
217.8405	Max-Peak	H	100	90	-59.86	-17.63	29.51	46.02	-16.51
254.1185	Max-Peak	H	100	264	-63.96	-16.20	26.84	46.02	-19.18
314.7920	Max-Peak	H	100	296	-66.76	-14.82	25.42	46.02	-20.60

Table 7-12. Radiated Spurious Emissions Below 1GHz (GFSK – Ch.39 with AC/DC Adapter and USB-C cable)

7.11 AC Line-Conducted Emissions Measurement

§15.207; RSS-Gen [8.8]

Test Overview and Limit

All AC line conducted spurious emissions are measured with a receiver connected to a grounded LISN while the EUT is operating at its maximum duty cycle, at maximum power, and at the appropriate frequencies. All data rates and modes were investigated for AC Line conducted spurious emissions. Only the conducted emissions of the configuration that produced the worst case emissions are reported in this section.

All conducted emissions must not exceed the limits shown in the table below, per Section 15.207 and RSS-Gen (8.8).

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

Table 7-13. Conducted Limits

*Decreases with the logarithm of the frequency.

Test Procedures Used

ANSI C63.10-2013, Section 6.2

Test Settings

Quasi-Peak Measurements

1. Analyzer center frequency was set to the frequency of the spurious emission of interest
2. RBW = 9kHz (for emissions from 150kHz – 30MHz)
3. Detector = quasi-peak
4. Sweep time = auto couple
5. Trace mode = max hold
6. Trace was allowed to stabilize

Average Measurements

1. Analyzer center frequency was set to the frequency of the spurious emission of interest
2. RBW = 9kHz (for emissions from 150kHz – 30MHz)
3. Detector = RMS
4. Sweep time = auto couple
5. Trace mode = max hold
6. Trace was allowed to stabilize

Test Setup

The EUT and measurement equipment were set up as shown in the diagram below.

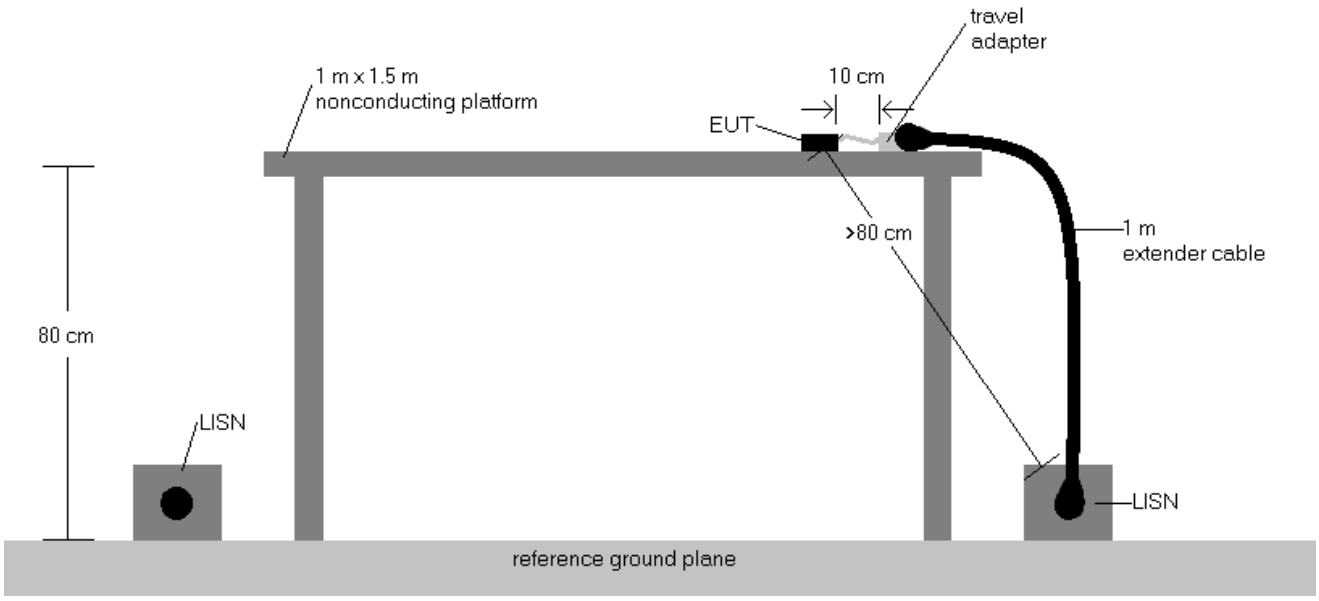
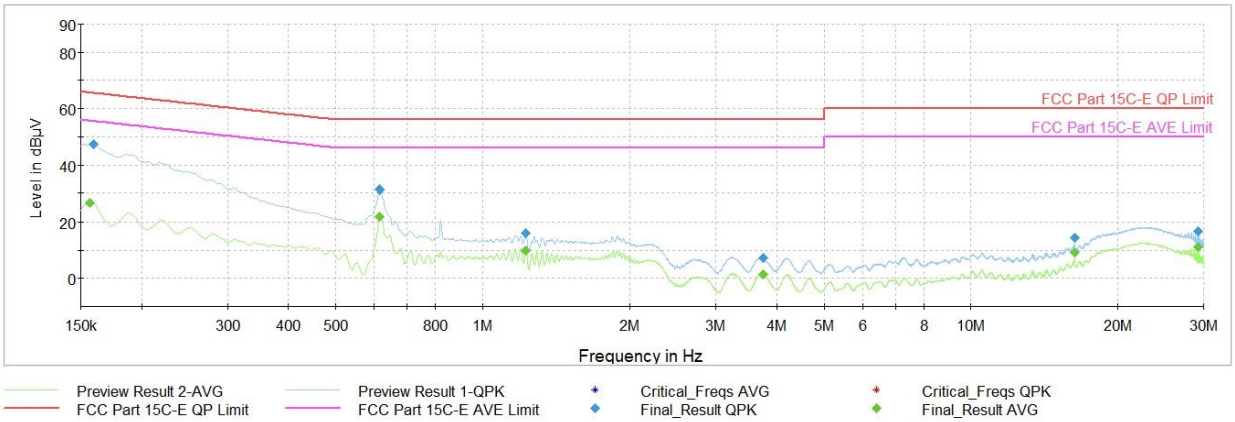


Figure 7-11. Test Instrument & Measurement Setup

Test Notes

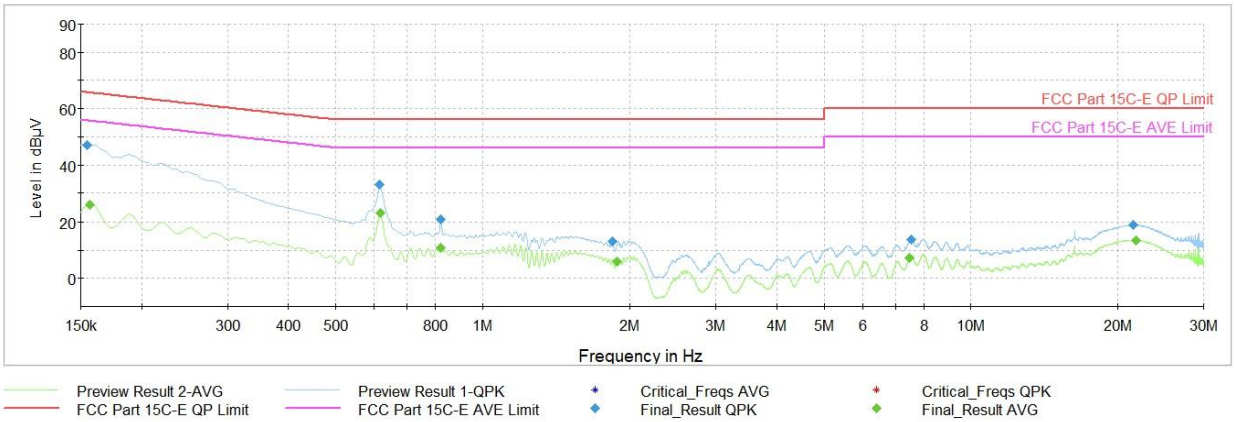
1. All modes of operation were investigated and the worst-case emissions are reported. The emissions found were not affected by the choice of channel used during testing.
2. Both configurations below were investigated, and the worst case has been reported.
    a. EUT charged by charging case and powered by AC/DC adaptor with USB-C cable
    b. EUT charged by charging case and powered by host PC with USB-C cable
3. The limit for an intentional radiator from 150kHz to 30MHz are specified in Part 15.207 and RSS-Gen (8.8).
4. Corr. (dB) = Cable loss (dB) + LISN insertion factor (dB)
5. QP/AV Level (dBμV) = QP/AV Analyzer/Receiver Level (dBμV) + Correction Factor (dB)
6. Margin (dB) = QP/AV Level (dBμV) - QP/AV Limit (dBμV)
7. Traces shown in plot are made using a quasi peak and average detectors.
8. Deviations to the Specifications: None.



Plot 7-39. AC Line-Conducted Test Plot (L1, GFSK – 2480MHz, with host PC and USB-C cable)

Frequency [MHz]	Process State	QuasiPeak [dBµV]	Average [dBµV]	Limit [dBµV]	Margin [dB]	Line	PE
0.157	FINAL	---	26.94	55.63	-28.69	L1	GND
0.159	FINAL	47.3	---	65.52	-18.27	L1	GND
0.616	FINAL	---	21.86	46.00	-24.14	L1	GND
0.616	FINAL	31.5	---	56.00	-24.50	L1	GND
1.226	FINAL	15.9	---	56.00	-40.09	L1	GND
1.228	FINAL	---	10.01	46.00	-35.99	L1	GND
3.743	FINAL	7.2	---	56.00	-48.83	L1	GND
3.750	FINAL	---	1.51	46.00	-44.49	L1	GND
16.332	FINAL	14.3	---	60.00	-45.69	L1	GND
16.332	FINAL	---	9.28	50.00	-40.72	L1	GND
29.234	FINAL	---	11.23	50.00	-38.77	L1	GND
29.234	FINAL	16.8	---	60.00	-43.24	L1	GND

Table 7-14. AC Line-Conducted Test Data (L1, GFSK – 2480MHz, with host PC and USB-C cable)



Plot 7-40. AC Line-Conducted Test Plot (N, GFSK – 2480MHz, with host PC and USB-C cable)

Frequency [MHz]	Process State	QuasiPeak [dBµV]	Average [dBµV]	Limit [dBµV]	Margin [dB]	Line	PE
0.155	FINAL	46.9	---	65.75	-18.86	N	GND
0.157	FINAL	---	26.25	55.63	-29.39	N	GND
0.616	FINAL	32.9	---	56.00	-23.13	N	GND
0.618	FINAL	---	23.08	46.00	-22.92	N	GND
0.821	FINAL	---	10.79	46.00	-35.21	N	GND
0.821	FINAL	20.9	---	56.00	-35.08	N	GND
1.838	FINAL	13.2	---	56.00	-42.83	N	GND
1.878	FINAL	---	6.08	46.00	-39.92	N	GND
7.465	FINAL	---	7.12	50.00	-42.88	N	GND
7.539	FINAL	13.6	---	60.00	-46.38	N	GND
21.514	FINAL	18.8	---	60.00	-41.16	N	GND
21.755	FINAL	---	13.52	50.00	-36.48	N	GND

Table 7-15. AC Line-Conducted Test Data (N, GFSK – 2480MHz, with host PC and USB-C cable)

8.0 CONCLUSION

The data collected relate only to the item(s) tested and show that the **Apple Wireless Right Earbud FCC ID: BCGA2871 and IC: 579C-A2871** is in compliance with Part 15 Subpart C (15.247) of the FCC Rules and RSS-247 of the Innovation, Science and Economic Development Canada Rules.