

MEASUREMENT REPORT

FCC PART 15.247 / ISSED RSS-247 Bluetooth

Applicant Name:

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

Date of Testing:

6/7/2022 - 8/23/2022

Test Site/Location:

Element Washington DC LLC Morgan Hill, CA, USA

Test Report Serial No.:

1C2204080015-01.BCG

FCC ID:

BCG-A2698

IC:

579C-A2698

APPLICANT:

Apple Inc.

Application Type:

Certification

Model/HVIN:

A2698

EUT Type:

Wireless Earbud

Max. RF Output Power:

17.947 mW (12.54 dBm) Peak Conducted

Frequency Range:

2402 – 2480MHz & 5731 – 5844MHz

Type of Modulation:

GFSK, $\pi/4$ -DQPSK, 8DPSK

FCC Classification:

FCC Part 15 Spread Spectrum Transmitter (DSS)

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



FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 1 of 77

V 10.4 5/21/2021

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TABLE OF CONTENTS

1.0	INTRODUCTION	3
1.1	Scope	3
1.2	Element Washington DC LLC Test Location	3
1.3	Test Facility / Accreditations	3
2.0	PRODUCT INFORMATION	4
2.1	Equipment Description	4
2.2	Device Capabilities	4
2.3	Antenna Description	5
2.4	Test Support Equipment	6
2.5	Test Configuration	6
2.6	Software and Firmware	6
2.7	EMI Suppression Device(s)/Modifications	6
3.0	DESCRIPTION OF TESTS	7
3.1	Evaluation Procedure	7
3.2	AC Line Conducted Emissions	7
3.3	Radiated Emissions	8
3.4	Environmental Conditions	8
4.0	ANTENNA REQUIREMENTS	9
5.0	MEASUREMENT UNCERTAINTY	10
6.0	TEST EQUIPMENT CALIBRATION DATA	11
7.0	TEST RESULTS	12
7.1	Summary	12
7.2	Bandwidth Measurement	13
7.3	Output Power Measurement	20
7.3.1	Peak Output Power Measurement	21
7.3.2	Average Output Power Measurement	22
7.4	Conducted Authorized Band Edge	23
7.5	Carrier Frequency Separation	30
7.6	Time of Occupancy	34
7.7	Number of Hopping Channels	38
7.8	Conducted Spurious Emissions	42
7.9	Radiated Spurious Emissions – Above 1GHz	51
7.9.1	Radiated Restricted Band Edge Measurements	61
7.10	Radiated Spurious Emissions – Below 1GHz	65
7.11	AC Line-Conducted Emissions Measurement	70
8.0	CONCLUSION	76
9.0	APPENDIX A	77

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 2 of 77

V 10.4 5/21/2021

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 Washington DC LLC Test Location

These measurement tests were conducted at the Element Washington DC LLC 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 Washington DC LLC located in Morgan Hill, CA 95037, U.S.A.

- Element Washington DC LLC 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 Washington DC LLC facility is a registered (22831) test laboratory with the site description on file with ISED.

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 3 of 77

V 10.4 5/21/2021

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2.0 PRODUCT INFORMATION

2.1 Equipment Description

The Equipment Under Test (EUT) is the **Apple Wireless Right Earbud FCC ID: BCG-A2698 and IC: 579C-A2698**. 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) 79 channels can be used at a time for hopping
 - C) The receiver input bandwidth equals the transmit bandwidth
 - D) The receiver hops in sequence with the transmit signal
 - E) Narrowband UNII can only hop within the same UNII band and cannot hop between bands
- 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.

Test Device Serial No.: HM6HR0VK18JP, HM6HQ1KT18JP, HM6HV19918JP

2.2 Device Capabilities

This device contains the following capabilities:

Bluetooth (1x, EDR, LE1M, LE2M, HDR4, HDR8, HDRp4, HDRp8), NB UNII (1x, LE2M, HDR4, HDR8, HDRp4, HDRp8)

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

Table 2-1. Bluetooth Frequency/ Channel Operations

Ch.	Frequency (MHz)
Low	5731
:	:
Mid	5788
:	:
High	5844

Table 2-2. Bluetooth Frequency/ Channel Operations

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 4 of 77

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 and 5725 – 5850MHz bands. 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		
Mode	Frequency (MHz)	Duty Cycle [%]
GFSK	2402 - 2480	76.6
	5731 - 5844	75.3

Table 2-3. Measured Duty Cycles

1. Additionally, this device is sold together in the same package as a system with FCC ID / IC: BCG-A2699 / 579C-A2699 and FCC ID / IC: BCG-A2700 / 579C-A2700. Co-Tx configurations were tested, and the worst case has been included in the RF BTLE Report.

2.3 Antenna Description

Following antenna gains provided by manufacturer were used for testing.

Frequency [MHz]	Antenna Gain (dBi)
2402 – 2480	-1.2
5731 – 5844	-4.6

Table 2-4. Highest Antenna Gains

See Appendix A for full antenna specs sheet.

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 5 of 77

V 10.4 5/21/2021

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2.4 Test Support Equipment

1	Apple Macbook	Model:	A2141	S/N:	C02DV7VGMD6T
	w/ AD/DC Adapter	Model:	A2164	S/N:	N/A
2	Apple Airpod Charging Case	Model:	A2700	S/N:	GHQ7JH6VWH
	Apple Airpod (Left)	Model:	A2699	S/N:	HM6HR0P518JQ
3	Apple Lightning Cable	Model:	N/A	S/N:	N/A
	W/ AD/DC Adapter	Model:	A2305	S/N:	C4H0106004QPF4FAD
4	HAM UART Cable	Model:	N/A	S/N:	F7514HMN0031983

Table 2-5. 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 three orthogonal planes of X-orientation (flatbed), Y-orientation (landscape), and Z-orientation (portrait) 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 adaptor with lightning cable.
- EUT charged by charging case and powered by host PC with lightning cable.

$\pi/4$ -DQPSK has been investigated and confirmed as not the worst case.

2.6 Software and Firmware

The test was conducted with firmware version 5A335 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.

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 6 of 77

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 ground plane. 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 7.12. 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.

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 7 of 77

V 10.4 5/21/2021

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

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 8 of 77

V 10.4 5/21/2021

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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.

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 9 of 77

V 10.4 5/21/2021

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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 (\pm 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

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 10 of 77

V 10.4 5/21/2021

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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
Anritsu	MA2411B	Pulse Power Sensor	11/30/2021	Annual	11/30/2022	1726261
Anritsu	MA2411B	Pulse Power Sensor	5/19/2022	Annual	5/19/2023	1911106
Anritsu	ML2495A	Power Meter	12/6/2021	Annual	12/6/2022	1039008
Anritsu	ML2496A	Power Meter	11/29/2021	Annual	11/29/2022	1840005
ETS-Lindgren	3117	Double Ridged Guide Horn Antenna (1-18 GHz)	5/24/2022	Annual	5/24/2023	240049
ETS-Lindgren	3142E	Biconilog Antenna - (30MHz-6GHz)	10/21/2021	Annual	10/21/2022	208204
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	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
Rohde & Schwarz	HFH2-Z2	Loop Antenna	4/3/2022	Annual	4/3/2023	100546

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.

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 11 of 77

V 10.4 5/21/2021

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7.0 TEST RESULTS

7.1 Summary

Company Name: Apple Inc.
 FCC ID: BCG-A2698
 IC: 579C-A2698
 Method/System: Frequency Hopping Spread Spectrum (FHSS)

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)] RSS-247 [5.4(c)]	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)(ii)	RSS-247 [5.1(e)]	Time of Occupancy	< 0.4 sec in 30 sec period in 5725–5850MHz band		PASS	Section 7.7
15.247(a)(1)(iii)	RSS-247 [5.1(d)]		< 0.4 sec in 31.6 sec period in 2400–2483.5MHz band			
15.247(a)(1)(ii)	RSS-247 [5.1(e)]	Number of Channels	> 75 Channels in 5725–5850MHz band		PASS	Section 7.6
15.247(a)(1)(iii)	RSS-247 [5.1(d)]		> 15 Channels in 2400–2483.5MHz band			
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 7.10
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.

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 12 of 77

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. $VBW \geq 3 \times RBW$
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

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 13 of 77

V 10.4 5/21/2021

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.

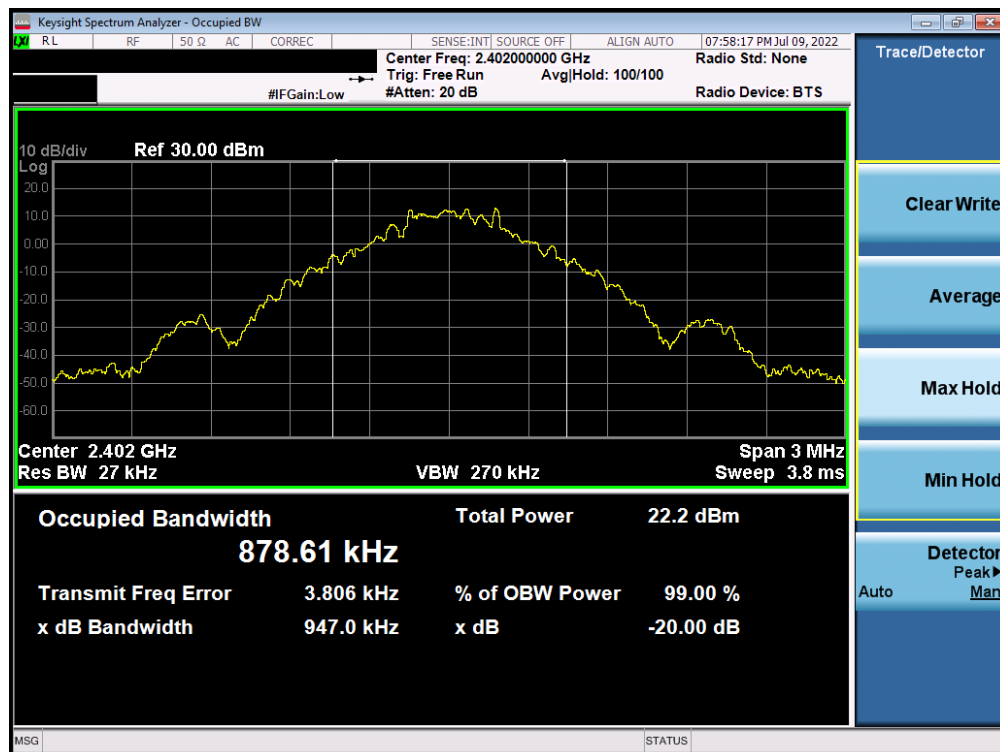
Frequency [MHz]	Data Rate [Mbps]	Mod.	Measured 99% Occupied Bandwidth [kHz]	Measured 20dB Bandwidth [kHz]
2402	1.0	GFSK	878.61	947.00
2441	1.0	GFSK	879.75	947.60
2480	1.0	GFSK	876.35	938.10
2402	3.0	8DPSK	1160.60	1233.00
2441	3.0	8DPSK	1148.80	1190.00
2480	3.0	8DPSK	1159.40	1225.00
5731	1.0	GFSK	955.33	1083.00
5788	1.0	GFSK	955.91	1085.00
5844	1.0	GFSK	956.44	1085.00

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

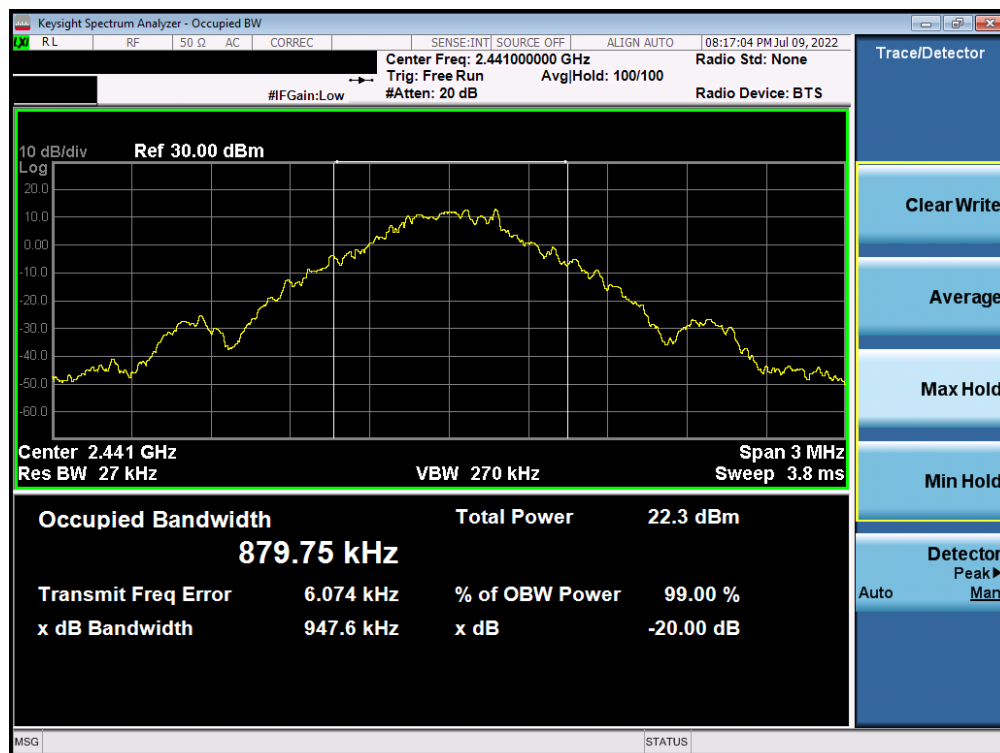
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 14 of 77

V 10.4 5/21/2021

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Plot 7-1. 20dB BW and 99% OBW Plot (Bluetooth, GFSK – Ch. 0)

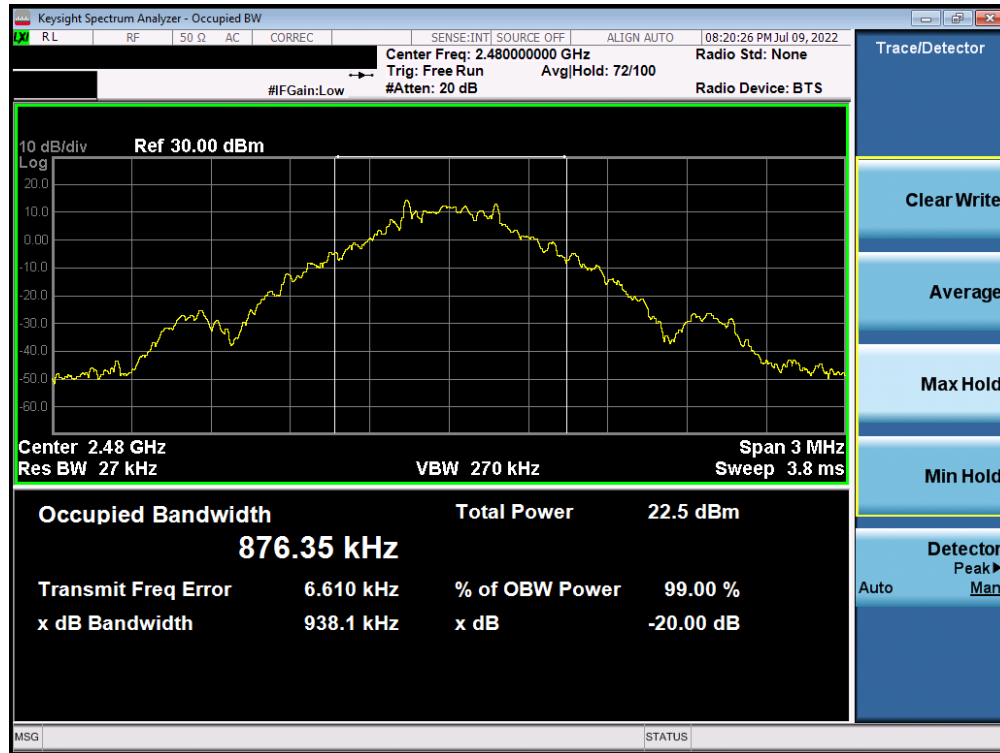


Plot 7-2. 20dB BW and 99% OBW Plot (Bluetooth, GFSK – Ch. 39)

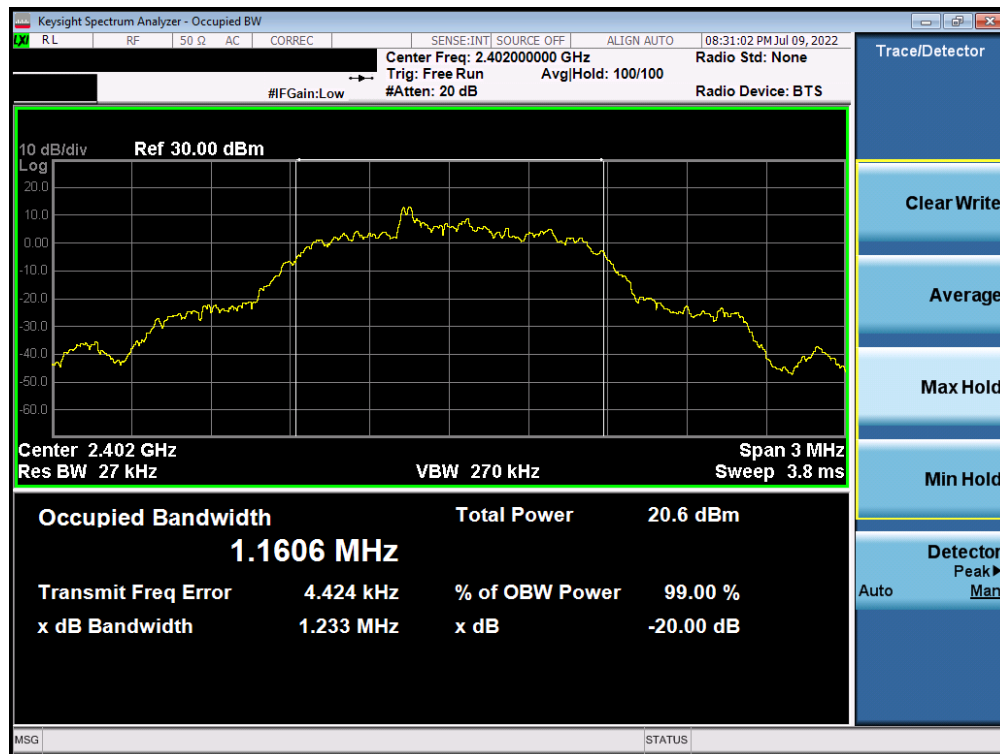
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 15 of 77

V 10.4 5/21/2021

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Plot 7-3. 20dB BW and 99% OBW Plot (Bluetooth, GFSK – Ch. 78)

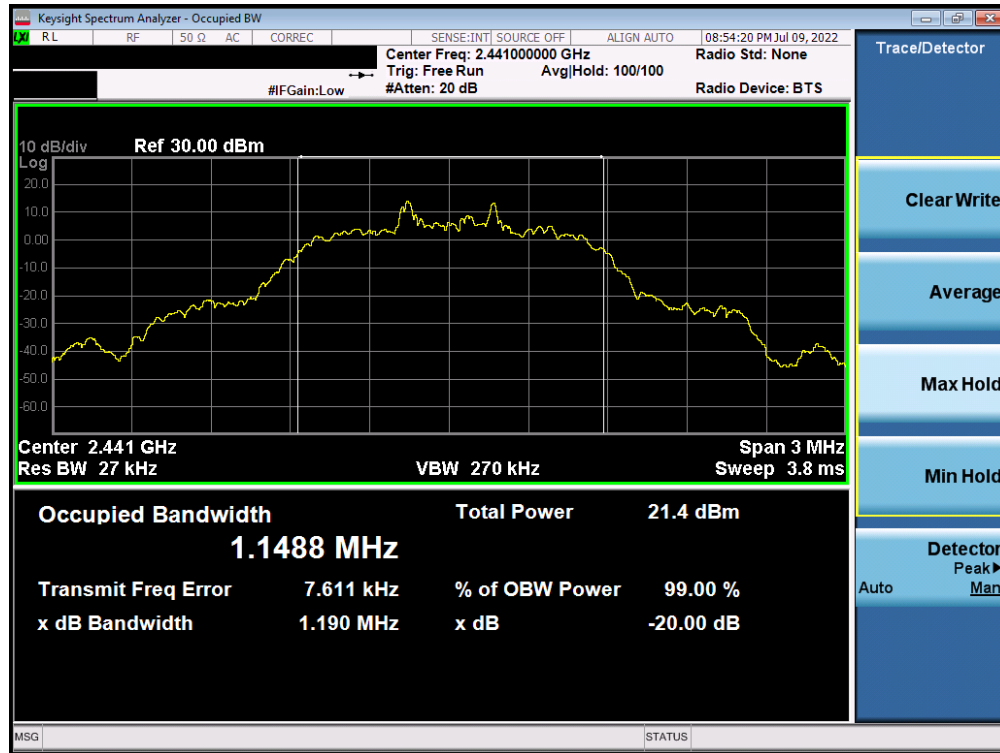


Plot 7-4. 20dB BW and 99% OBW Plot (Bluetooth, 8DPSK – Ch. 0)

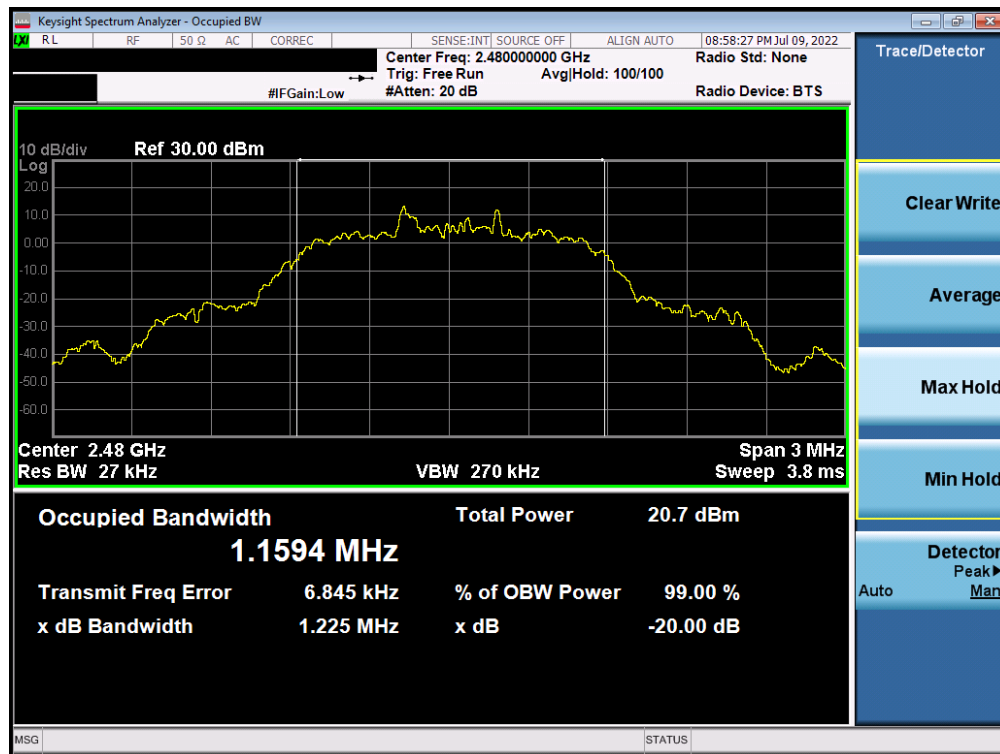
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 16 of 77

V 10.4 5/21/2021

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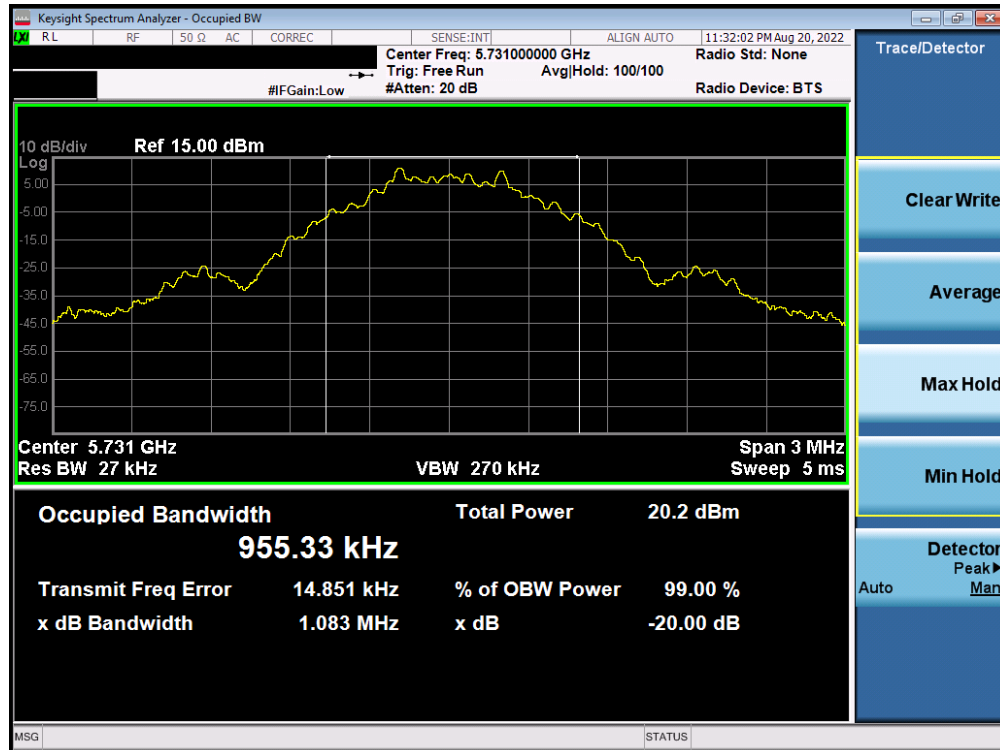


Plot 7-5. 20dB BW and 99% OBW Plot (Bluetooth, 8DPSK – Ch. 39)

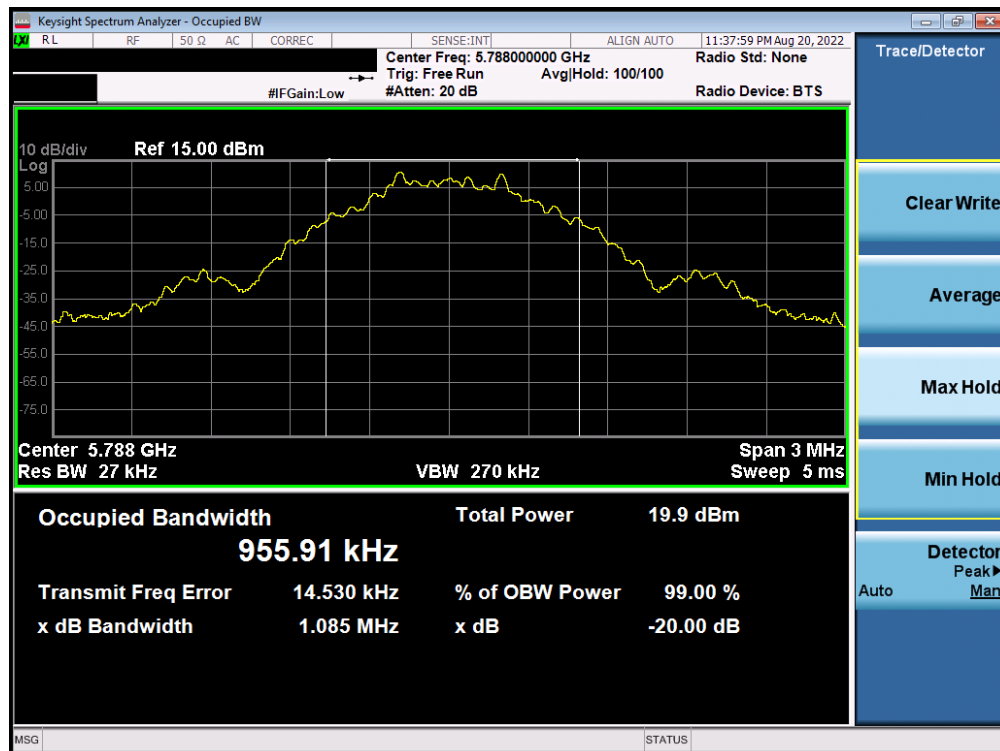


Plot 7-6. 20dB BW and 99% OBW Plot (Bluetooth, 8DPSK – Ch. 78)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 17 of 77



Plot 7-7. 20dB BW and 99% OBW Plot (Bluetooth, GFSK – 5731MHz)



Plot 7-8. 20dB BW and 99% OBW Plot (Bluetooth, GFSK – 5788MHz)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 18 of 77



Plot 7-9. 20dB BW and 99% OBW Plot (Bluetooth, GFSK – 5844MHz)

FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 19 of 77

V 10.4 5/21/2021

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7.3 Output Power Measurement

§15.247 (b.1); RSS-247 [5.4(b)]; RSS-247 [5.4(c)]

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 and 5725-5850 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 bands 2400-2483.5 MHz and 5725-5850 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 $\pi/4$ -DQPSK was found not as the worst case modulation so only GFSK and 8DPSK is reported.

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 20 of 77

V 10.4 5/21/2021

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7.3.1 Peak Output Power Measurement

Frequency [MHz]	Data Rate [Mbps]	Mod.	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	12.40	17.378	30.00	-17.60	-1.20	11.20	36.02	-24.82
2441	1.0	GFSK	12.54	17.947	30.00	-17.46	-1.20	11.34	36.02	-24.68
2480	1.0	GFSK	12.47	17.660	30.00	-17.53	-1.20	11.27	36.02	-24.75
2402	3.0	8DPSK	12.38	17.298	30.00	-17.62	-1.20	11.18	36.02	-24.84
2441	3.0	8DPSK	12.52	17.865	30.00	-17.48	-1.20	11.32	36.02	-24.70
2480	3.0	8DPSK	12.46	17.620	30.00	-17.54	-1.20	11.26	36.02	-24.76
5731	1.0	GFSK	10.45	11.092	30.00	-19.55	-4.60	5.85	36.02	-30.17
5788	1.0	GFSK	10.36	10.864	30.00	-19.64	-4.60	5.76	36.02	-30.26
5844	1.0	GFSK	10.54	11.324	30.00	-19.46	-4.60	5.94	36.02	-30.08

Table 7-3. Peak Conducted Output Power Measurements

FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 21 of 77

V 10.4 5/21/2021

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7.3.2 Average Output Power Measurement

Frequency [MHz]	Data Rate [Mbps]	Mod.	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	12.36	17.219	30.00	-17.64	-1.20	11.16	36.02	-24.86
2441	1.0	GFSK	12.50	17.783	30.00	-17.50	-1.20	11.30	36.02	-24.72
2480	1.0	GFSK	12.43	17.498	30.00	-17.57	-1.20	11.23	36.02	-24.79
2402	3.0	8DPSK	9.36	8.630	30.00	-20.64	-1.20	8.16	36.02	-27.86
2441	3.0	8DPSK	9.50	8.913	30.00	-20.50	-1.20	8.30	36.02	-27.72
2480	3.0	8DPSK	9.43	8.770	30.00	-20.57	-1.20	8.23	36.02	-27.79
5731	1.0	GFSK	10.39	10.940	30.00	-19.61	-4.60	5.79	36.02	-30.23
5788	1.0	GFSK	10.31	10.740	30.00	-19.69	-4.60	5.71	36.02	-30.31
5844	1.0	GFSK	10.49	11.194	30.00	-19.51	-4.60	5.89	36.02	-30.13

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 12.36 dBm with gain of -1.20 dBi.

$$\text{e.i.r.p. (dBm)} = \text{Conducted Power (dBm)} + \text{Ant gain (dBi)}$$

$$12.36 \text{ dBm} + -1.2 \text{ dBi} = 11.16 \text{ dBm}$$

FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 22 of 77

V 10.4 5/21/2021

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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 $\geq 2 \times \text{Span/RBW}$
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

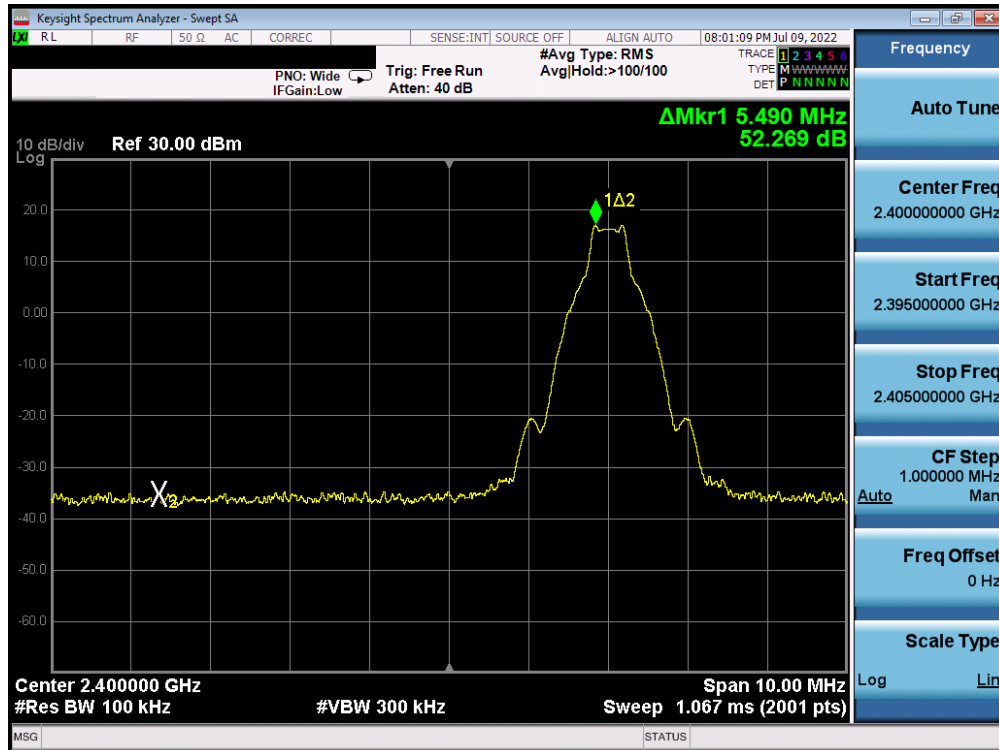
Test Notes

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.

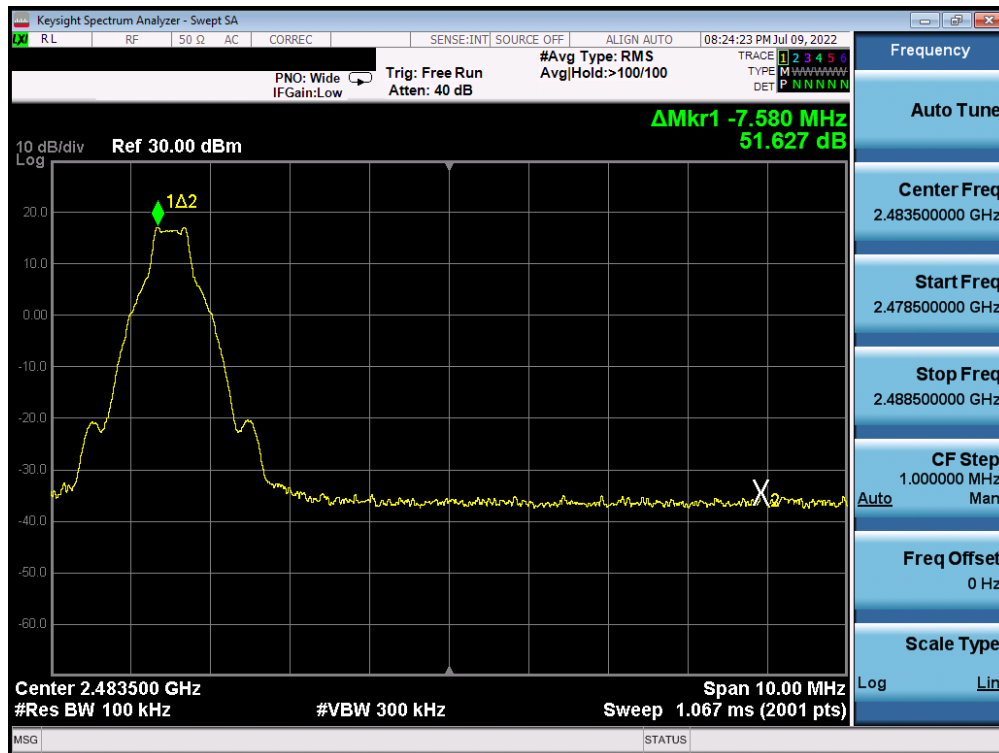
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 23 of 77

V 10.4 5/21/2021

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

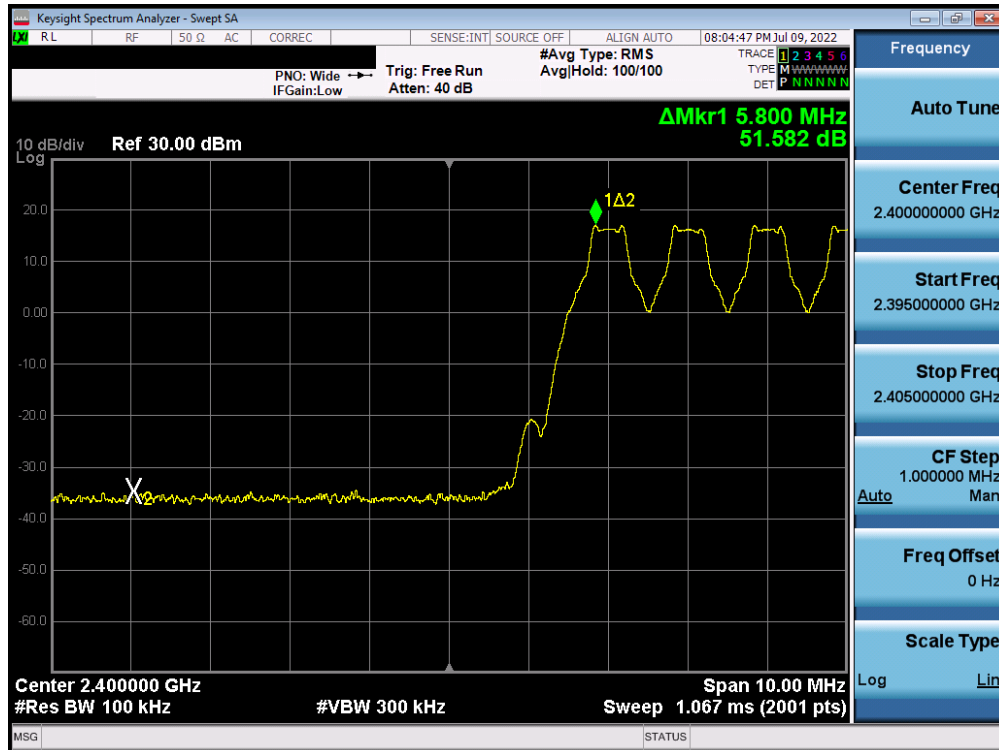


Plot 7-11. Band Edge Plot (Bluetooth with Hopping Disabled, GFSK, 2.4GHz)

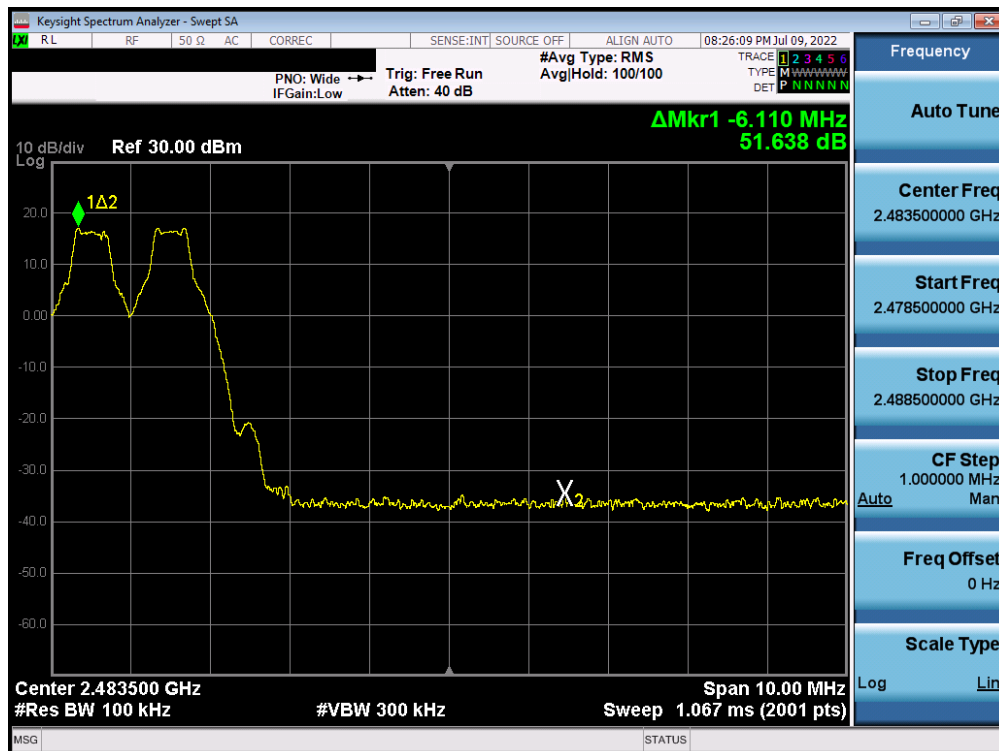
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 24 of 77

V 10.4 5/21/2021

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Plot 7-12. Band Edge Plot (Bluetooth with Hopping Enabled, GFSK, 2.4GHz)

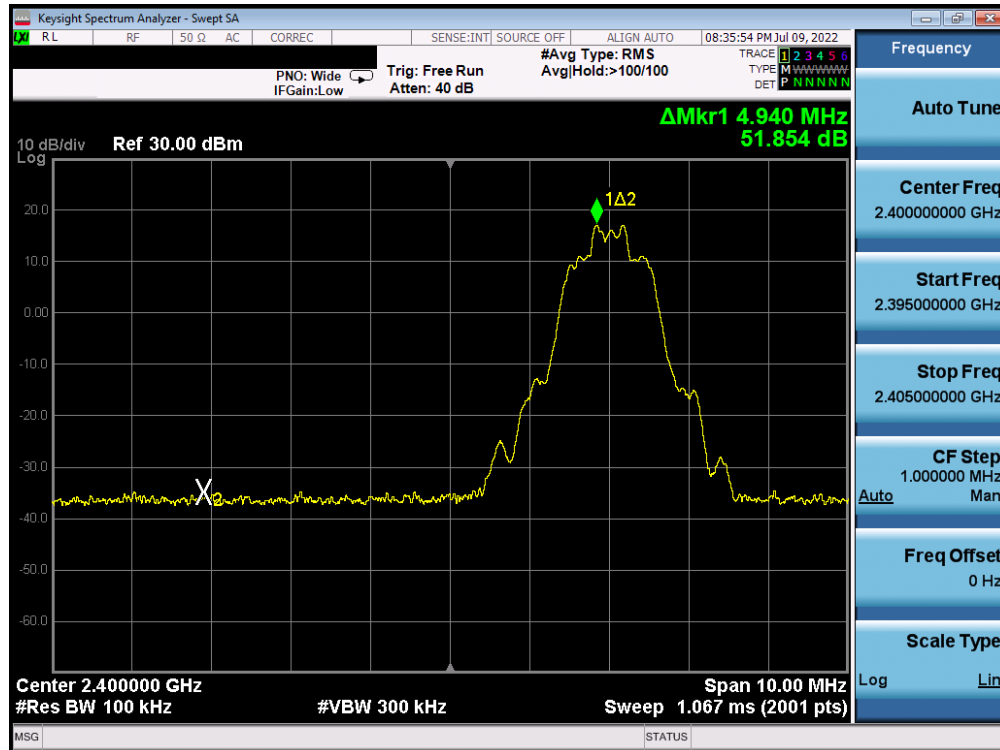


Plot 7-13. Band Edge Plot (Bluetooth with Hopping Enabled, GFSK, 2.4GHz)

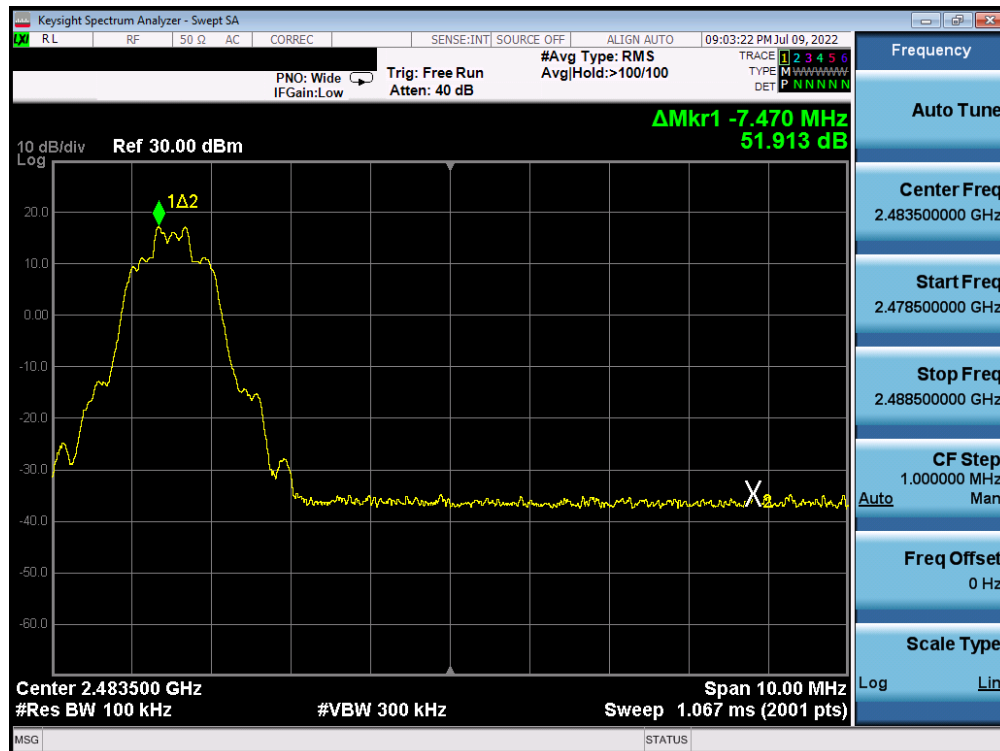
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 25 of 77

V 10.4 5/21/2021

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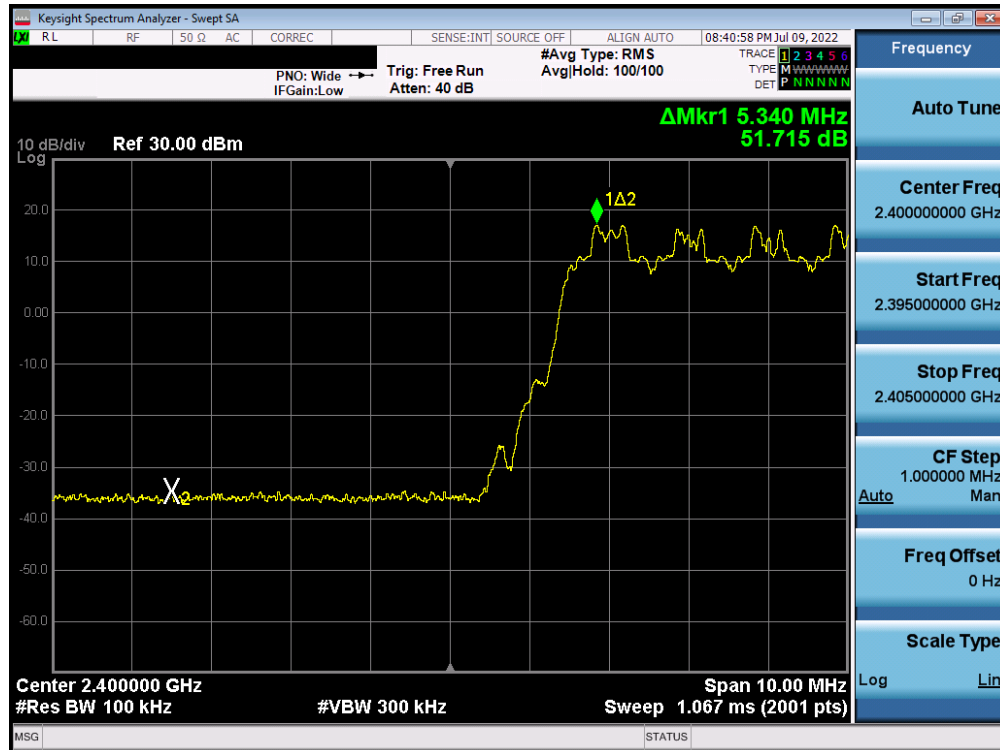


Plot 7-14. Band Edge Plot (Bluetooth with Hopping Disabled, 8DPSK, 2.4GHz)

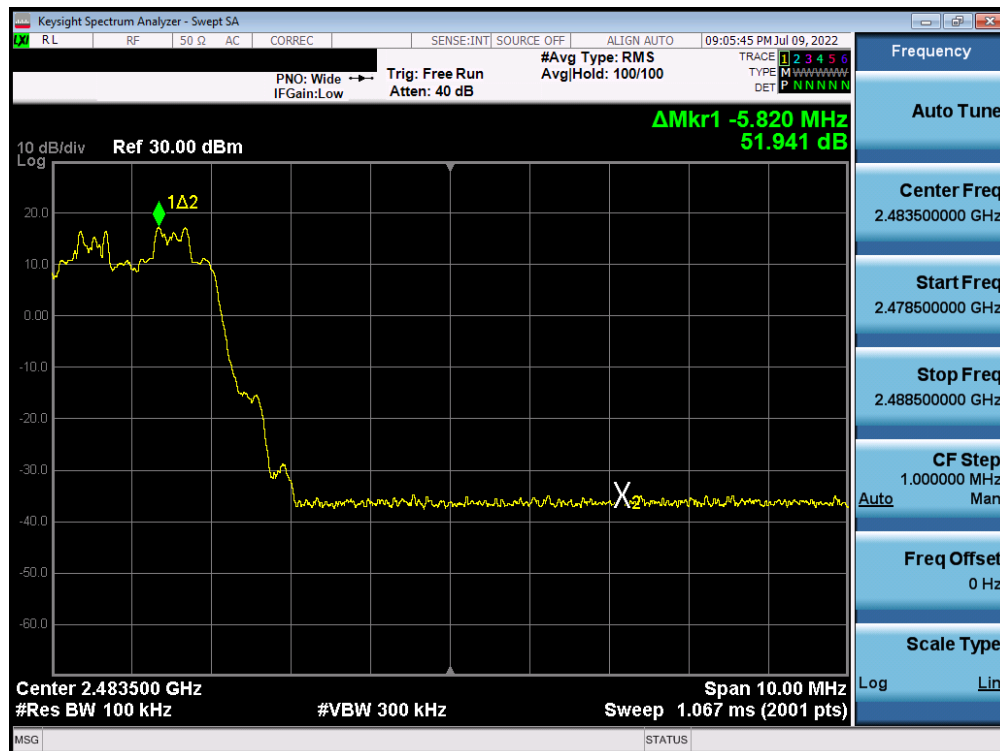


Plot 7-15. Band Edge Plot (Bluetooth with Hopping Disabled, 8DPSK, 2.4GHz)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 26 of 77

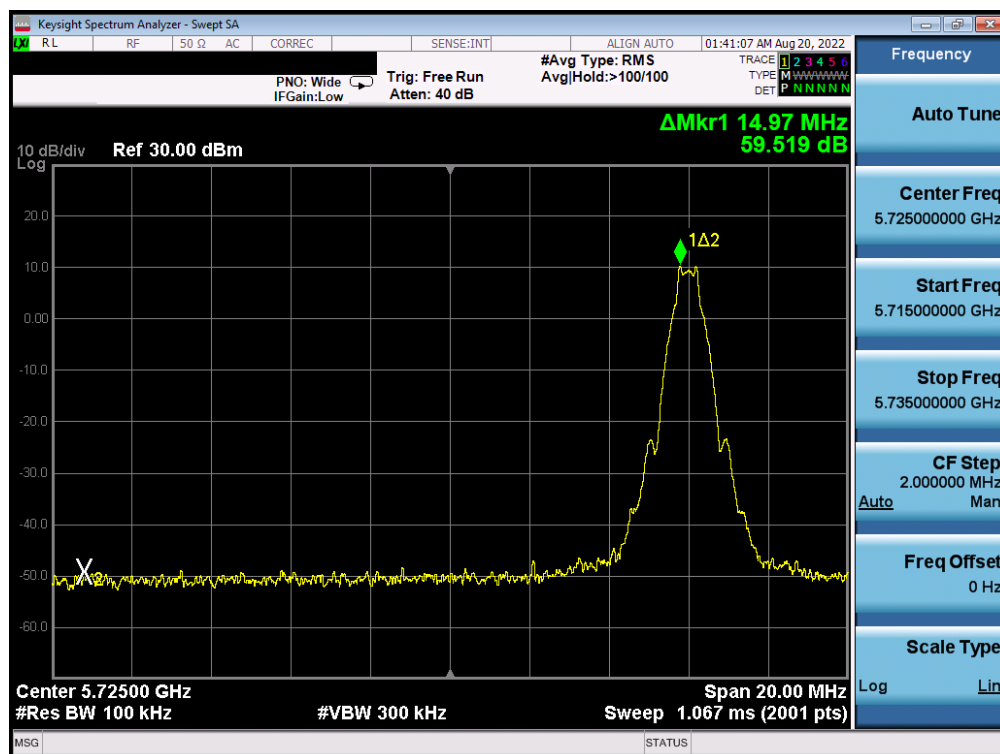


Plot 7-16. Band Edge Plot (Bluetooth with Hopping Enabled, 8DPSK, 2.4GHz)

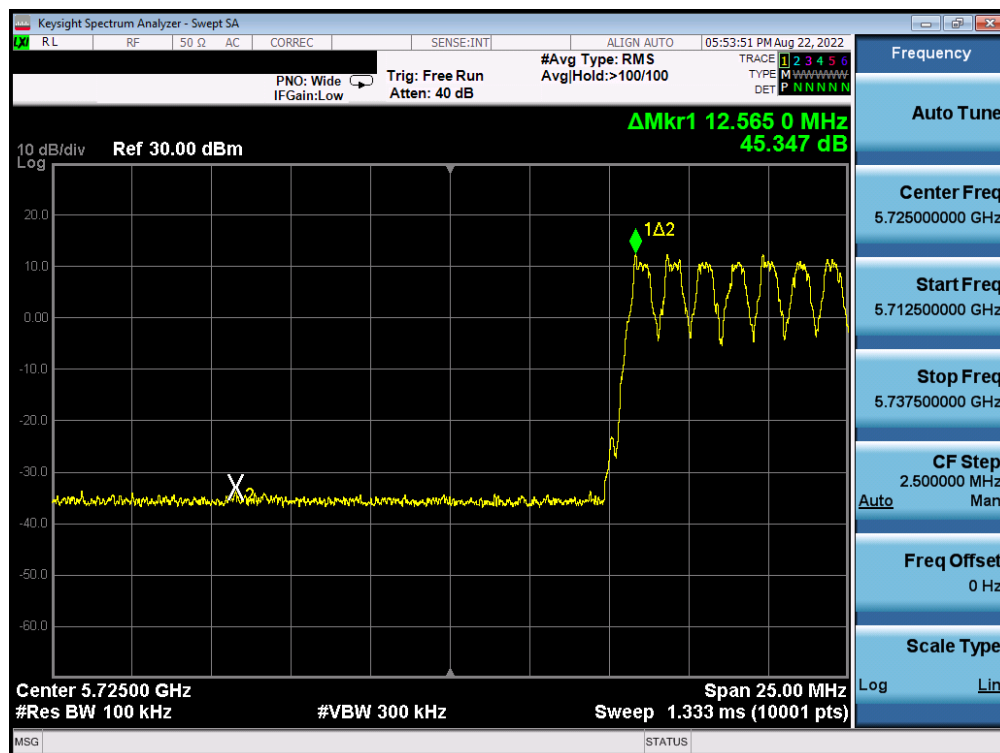


Plot 7-17. Band Edge Plot (Bluetooth with Hopping Enabled, 8DPSK, 2.4GHz)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 27 of 77



Plot 7-18. Band Edge Plot (Bluetooth with Hopping Disabled, GFSK, 5.8GHz)

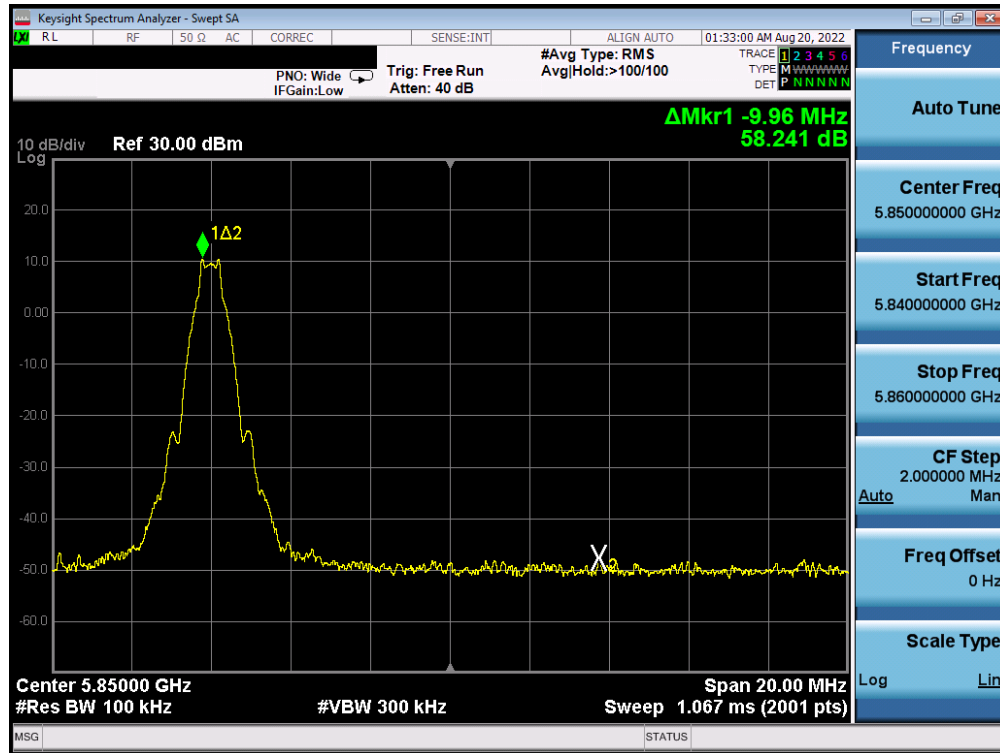


Plot 7-19. Band Edge Plot (Bluetooth with Hopping Enabled, GFSK, 5.8GHz)

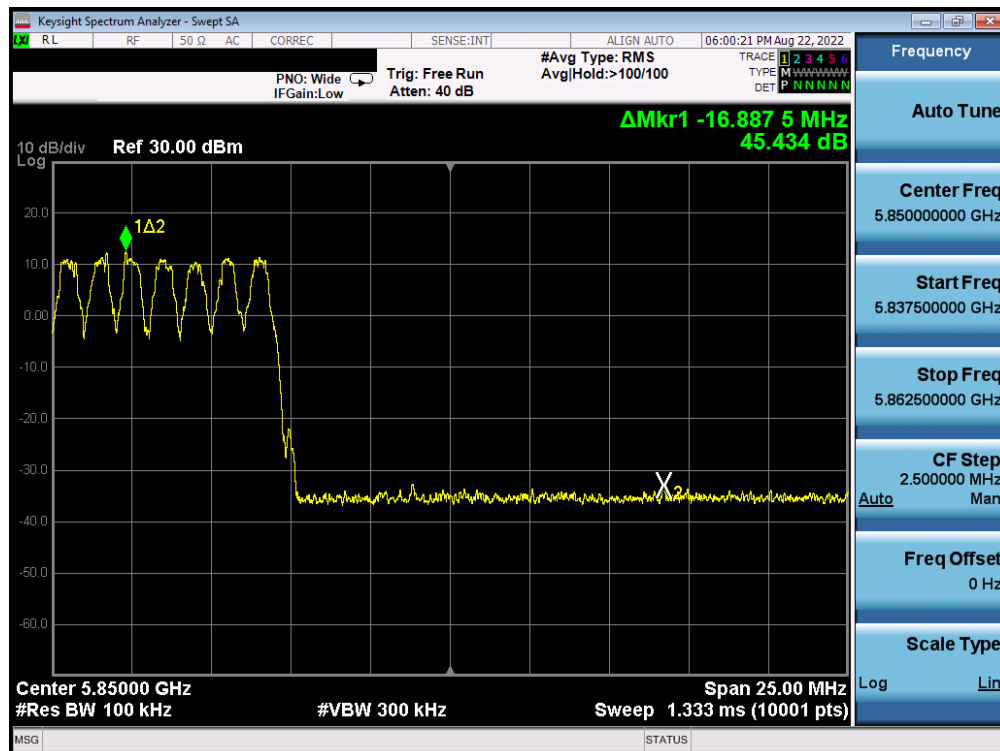
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 28 of 77

V 10.4 5/21/2021

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Plot 7-20. Band Edge Plot (Bluetooth with Hopping Disabled, GFSK, 5.8GHz)



Plot 7-21. Band Edge Plot (Bluetooth with Hopping Enabled, GFSK, 5.8GHz)

FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 29 of 77

V 10.4 5/21/2021

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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 \geq 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.

FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 30 of 77

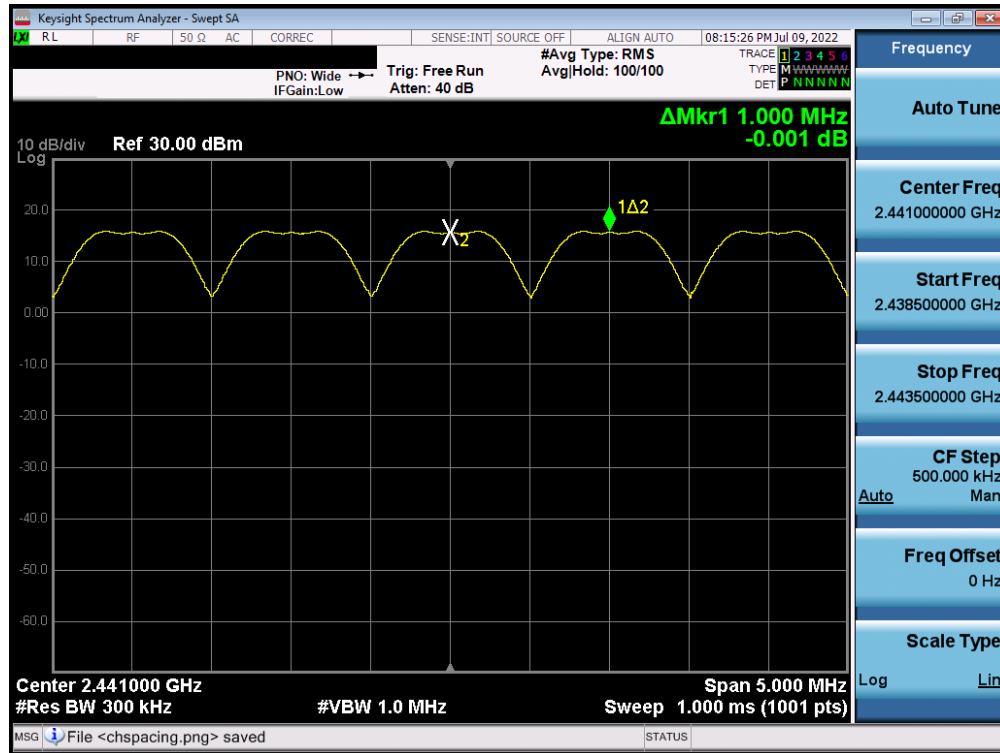
Frequency [MHz]	Data Rate [Mbps]	Mod.	Measured Channel Separation [MHz]	Min. Channel Separation [MHz]	Pass / Fail
2441	1.0	GFSK	1.000	0.6317	Pass
2441	3.0	8DPSK	1.000	0.7933	Pass
5788	1.0	GFSK	1.000	0.7233	Pass

Table 7-5. Minimum Channel Separation

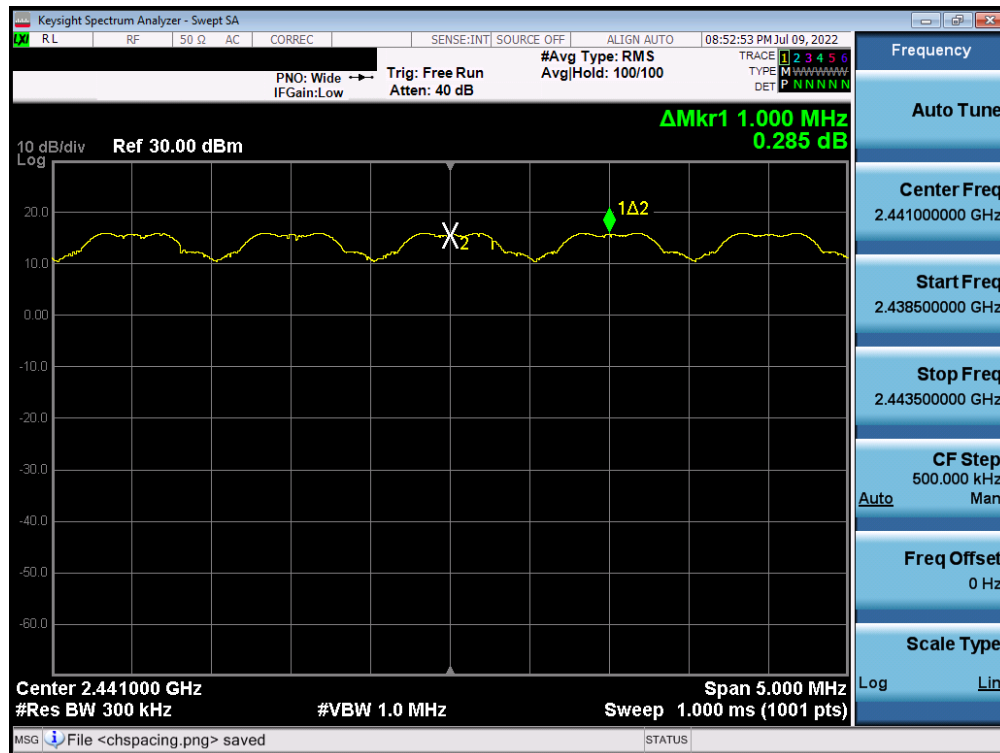
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 31 of 77

V 10.4 5/21/2021

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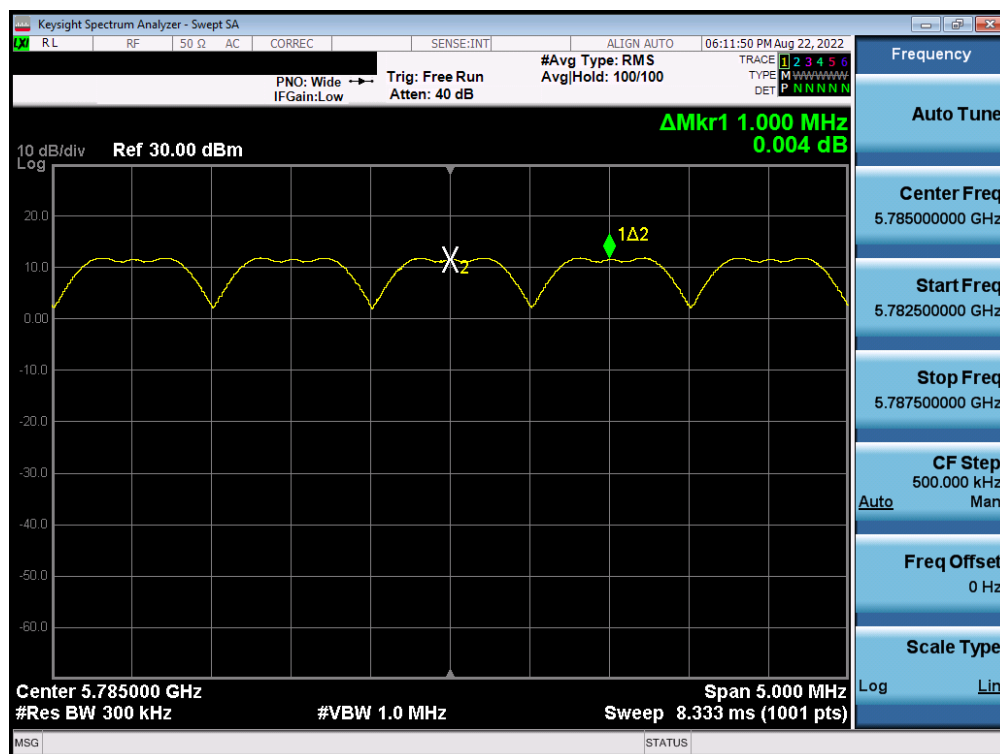


Plot 7-22. Channel Spacing Plot (Bluetooth, GFSK, 2.4GHz)



Plot 7-23. Channel Spacing Plot (Bluetooth, 8DPSK, 2.4GHz)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 32 of 77



Plot 7-24. Channel Spacing Plot (Bluetooth, GFSK, 5.8GHz)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 33 of 77

V 10.4 5/21/2021

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7.6 Time of Occupancy

§15.247 (a.1.ii); §15.247 (a.1.iii); RSS-247 [5.1(d)]; RSS-247 [5.1(e)]

Test Overview and Limit

Measurement is made while EUT is operating in hopping mode with the spectrum analyzer set to zero span.

In the 2400-2483.5 MHz band, the maximum permissible time of occupancy is 400ms within a period of 400ms multiplied by the number of hopping channels employed.

In the 5725-5850 MHz band, the maximum permissible time of occupancy is 400ms within a period of 30s.

Test Procedure Used

ANSI C63.10-2013 – Section 7.8.4

Test Settings

1. Span = zero span, centered on a hopping channel
2. RBW \leq channel spacing and $\gg 1/T$, 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

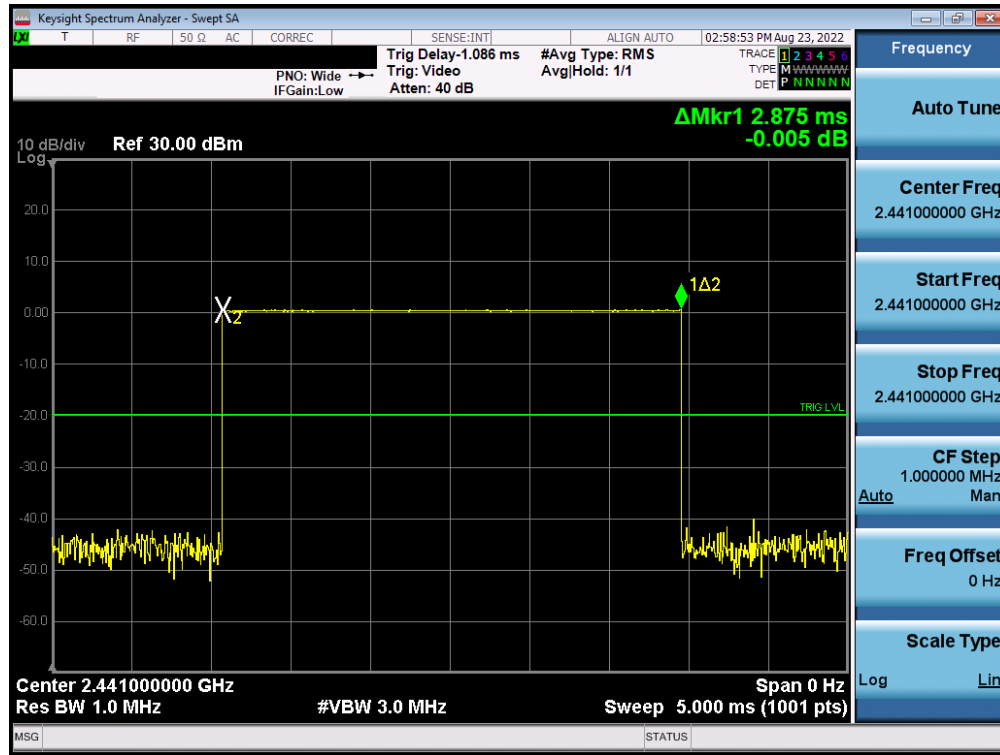
Test Notes

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

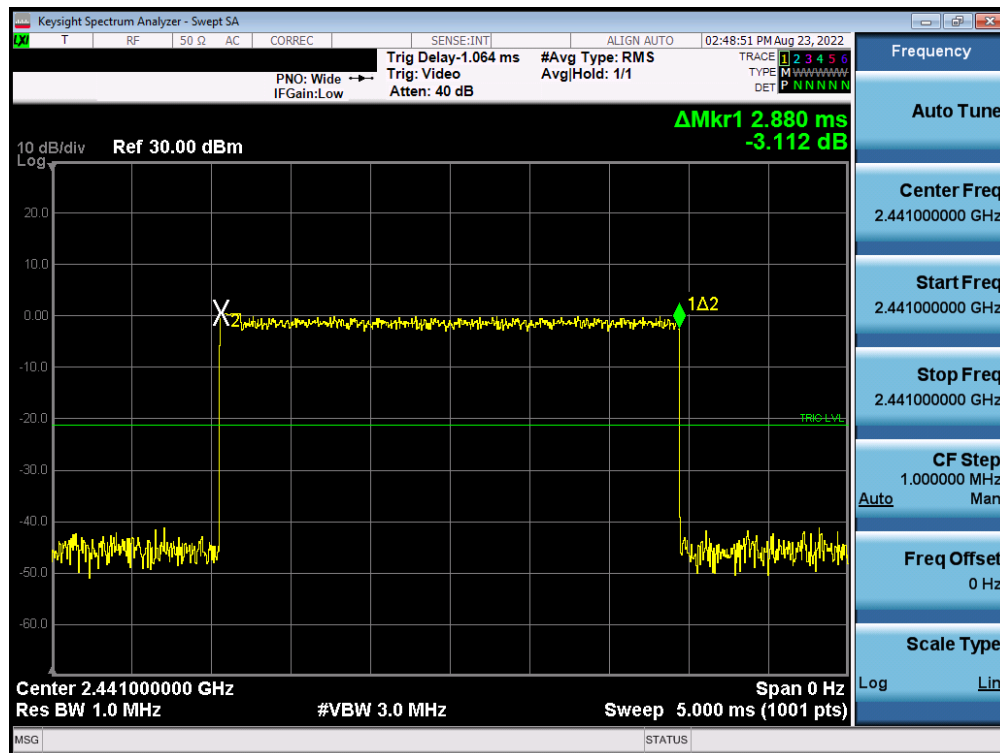
FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 34 of 77

V 10.4 5/21/2021

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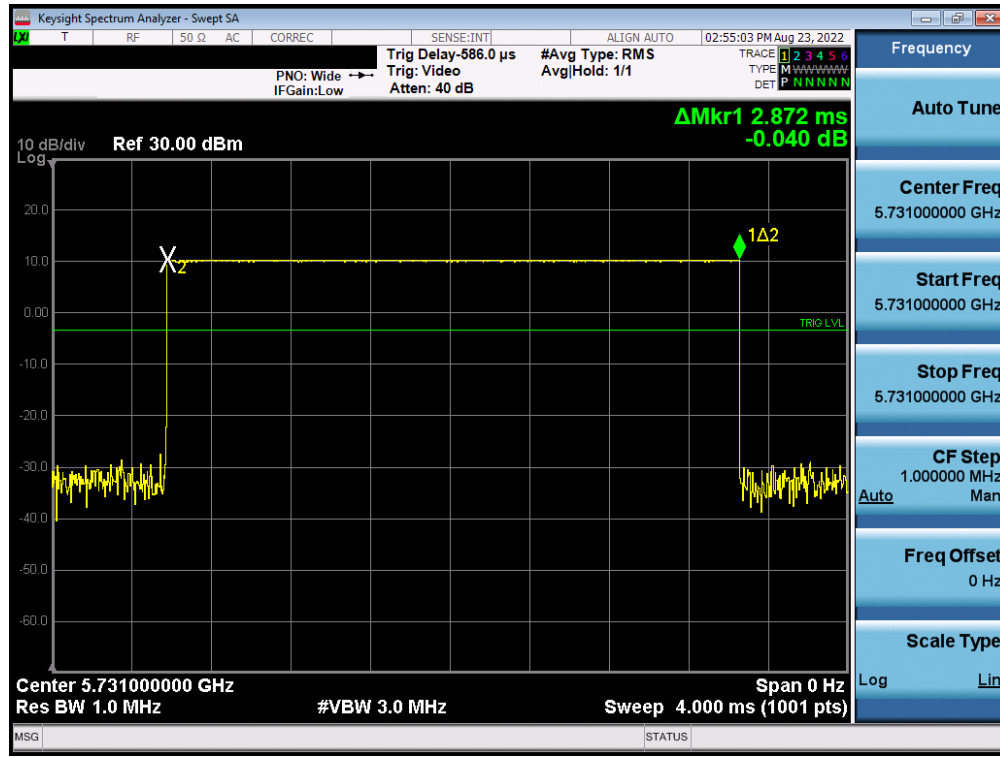


Plot 7-25. Time of Occupancy Plot (Bluetooth, GFSK, 2.4GHz)



Plot 7-26. Time of Occupancy Plot (Bluetooth, 8DPSK, 2.4GHz)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 35 of 77



Plot 7-27. Time of Occupancy Plot (Bluetooth, QPSK, 5.8GHz)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 36 of 77

V 10.4 5/21/2021

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

- $400\text{ms} \times 79$ hopping channels = 31.6 sec (Time of Occupancy Limit)
- Worst case BT has 266.67 hops/second (for 1x/EDR modes with DH5 operation)
- $266.67 \text{ hops/second} / 79 \text{ channels} = 3.38 \text{ hops/second}$ (# of hops/second on one channel)
- $3.38 \text{ hops/second/channel} \times 31.6 \text{ seconds} = 106.67 \text{ hops}$ (# hops over a 31.6 second period)
- $106.67 \text{ hops} \times 2.880 \text{ ms/channel} = 307.210 \text{ ms}$ (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

- $400\text{ms} \times 20$ hopping channels = 8 sec (Time of Occupancy Limit)
- Worst case BT has 133.3 hops/second/slot (for AFH mode with DH5 operation)
- $133.3 \text{ hops/s} / 20 \text{ channels} = 6.67 \text{ hops/second}$ (# of hops/second on one channel)
- $6.67 \text{ hops/s} / \text{channel} \times 8 \text{ seconds} = 53.34 \text{ hops}$ (# hops over a 8 second period)
- $53.34 \text{ hops} \times 2.880 \text{ ms/channel} = 153.619 \text{ ms}$ (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.

FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 37 of 77

V 10.4 5/21/2021

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7.7 Number of Hopping Channels

§15.247 (a.1.ii); §15.247 (a.1.iii); RSS-247 [5.1(d)]; RSS-247 [5.1(e)]

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 in the 2400-2483.5 MHz band and a minimum of 75 hopping channels in the 5725-5850 MHz band.***

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 modulations have been tested on the unit and only worst case configuration is reported.

FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 38 of 77

V 10.4 5/21/2021

Keysight Spectrum Analyzer - Swept SA

08:12:45 PM Jul 09, 2022

R.L. RF 50 Ω AC CORREC SENSE:INT SOURCE OFF ALIGN AUTO

PNO: Fast IF Gain: Low Trig: Free Run Atten: 40 dB #Avg Type: RMS Avg/Hold: >100/100

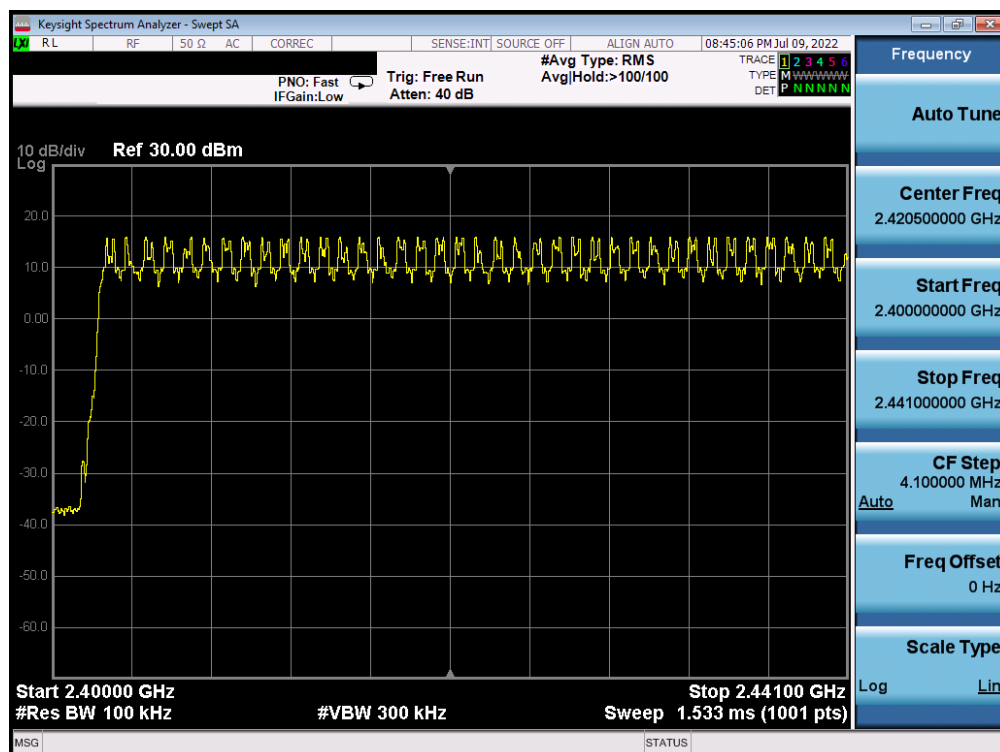
TRAC 1 2 3 4 5 6 TYPE M DET P NNNNN

10 dB/div Log Ref 30.00 dBm

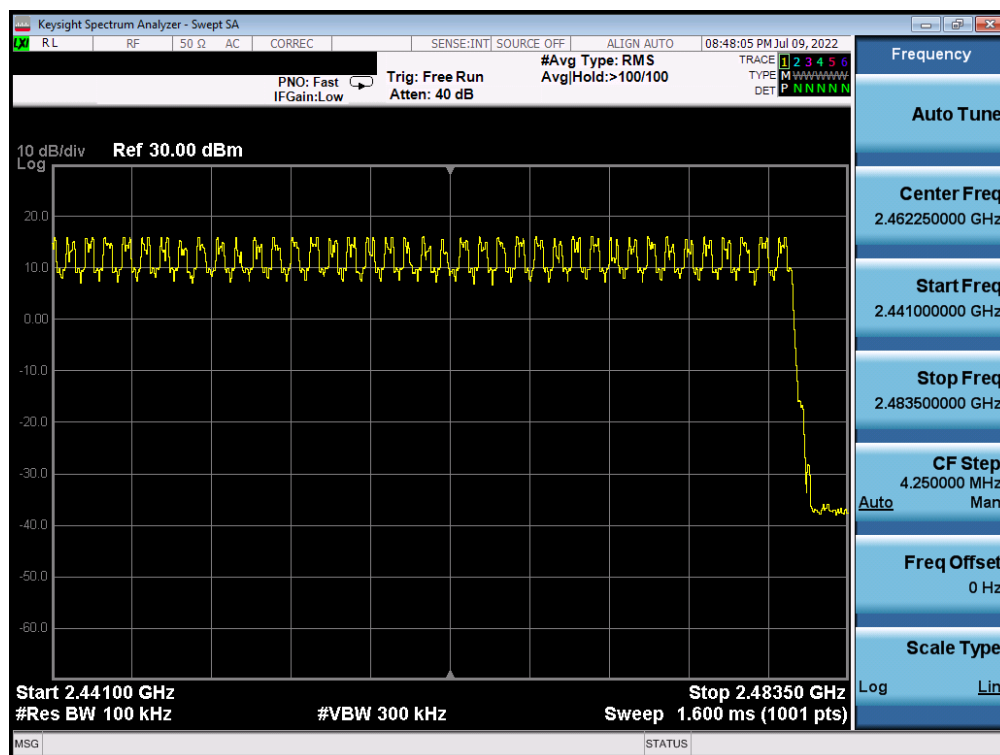
Start 2.44100 GHz Stop 2.48350 GHz

#Res BW 100 kHz #VBW 300 kHz Sweep 1.600 ms (1001 pts)

Frequency Auto Tune Center Freq 2.462250000 GHz Start Freq 2.441000000 GHz Stop Freq 2.483500000 GHz CF Step 4.250000 MHz Auto Man Freq Offset 0 Hz Scale Type Log Lin



Plot 7-30. Low End Spectrum Channel Hopping Plot (Bluetooth, 8DPSK, 2.4GHz)

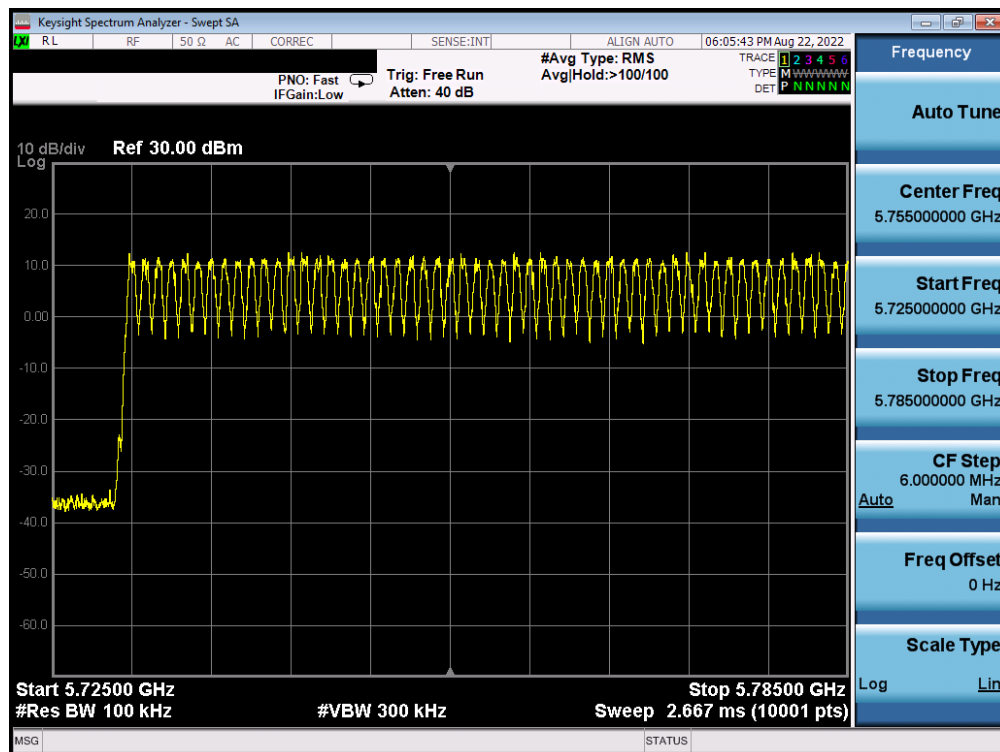


Plot 7-31. High End Spectrum Channel Hopping Plot (Bluetooth, 8DPSK, 2.4GHz)

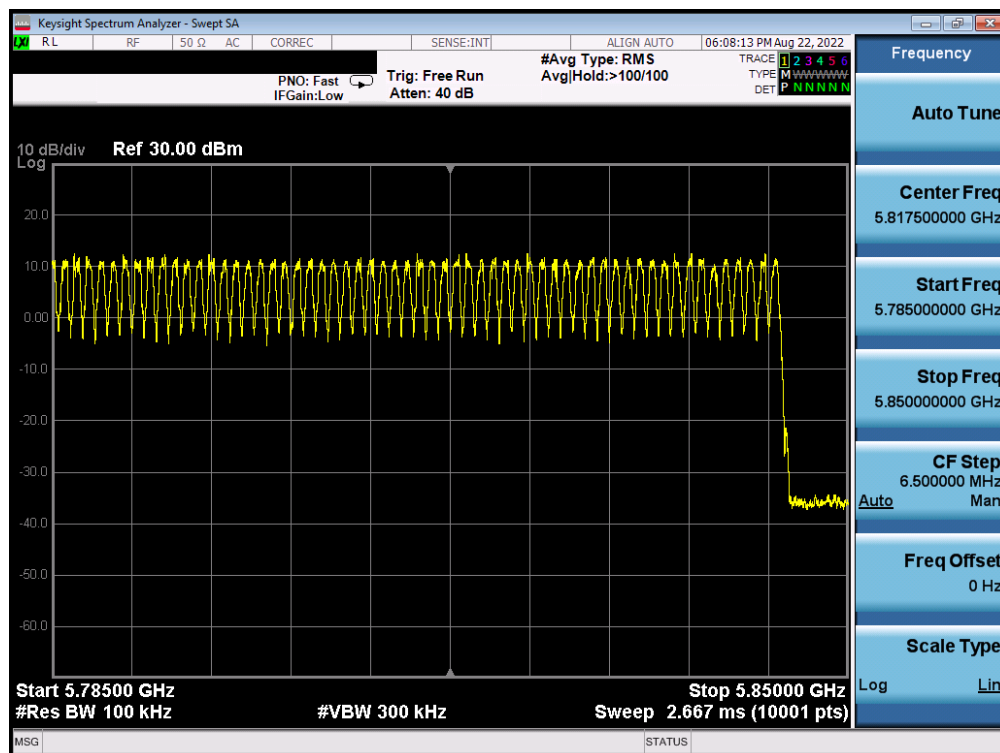
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 40 of 77

V 10.4 5/21/2021

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Plot 7-32. Low End Spectrum Channel Hopping Plot (Bluetooth, GFSK, 5.8GHz)



Plot 7-33. High End Spectrum Channel Hopping Plot (Bluetooth, GFSK, 5.8GHz)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 41 of 77

V 10.4 5/21/2021

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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 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 for the 2400-2483.5 MHz band (separated into two plots per channel) and 30MHz to 40GHz for the 5725-5850 MHz band (separated into three 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

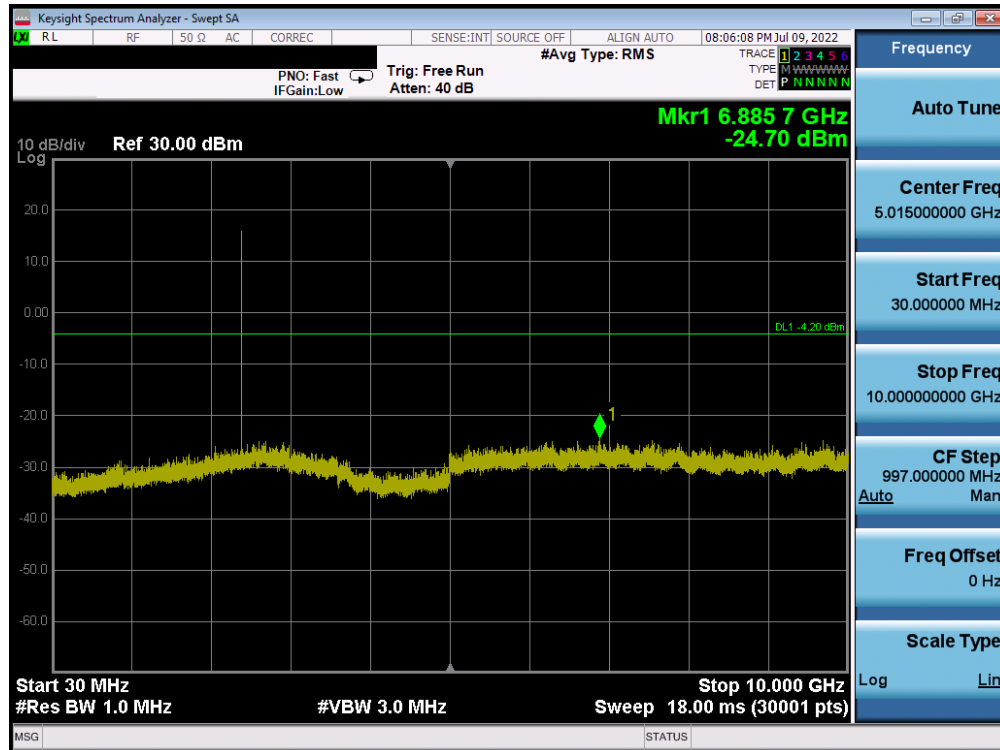
Test Notes

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 mode and only the highest emission is reported.

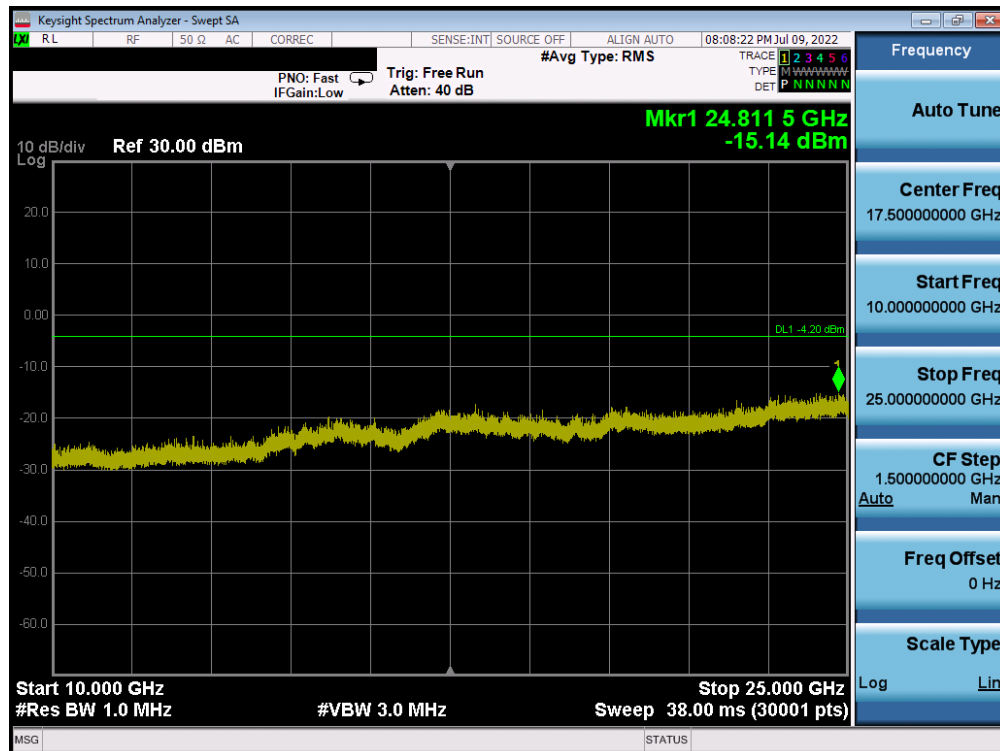
FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 42 of 77

V 10.4 5/21/2021

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Plot 7-34. Conducted Spurious Plot (Bluetooth, GFSK – 2402MHz)

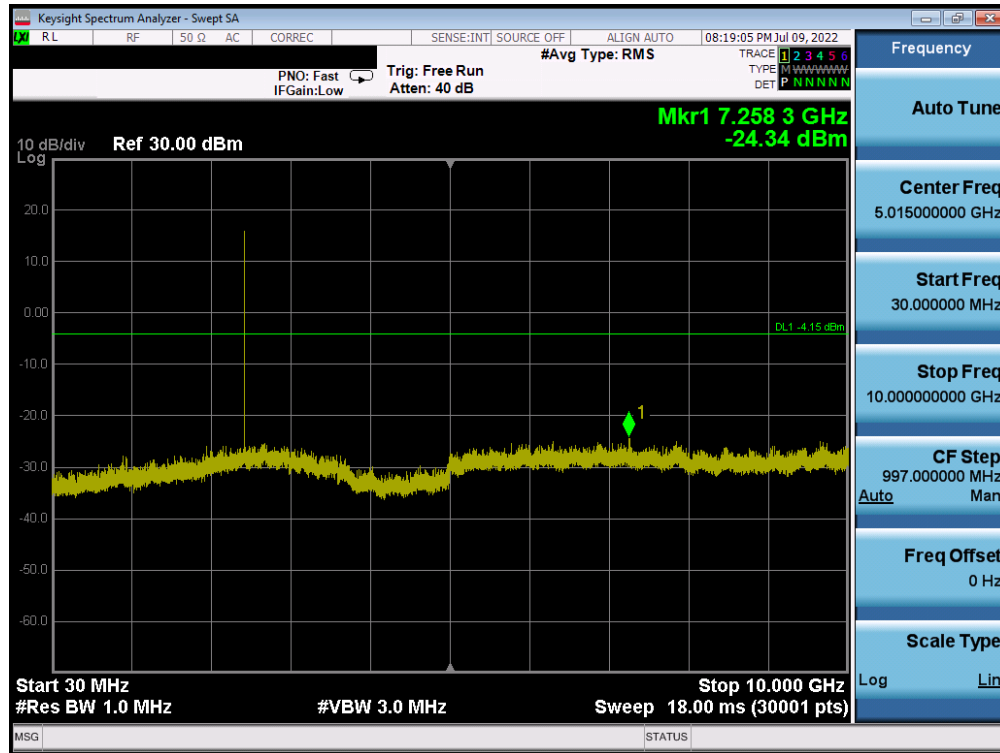


Plot 7-35. Conducted Spurious Plot (Bluetooth, GFSK – 2402MHz)

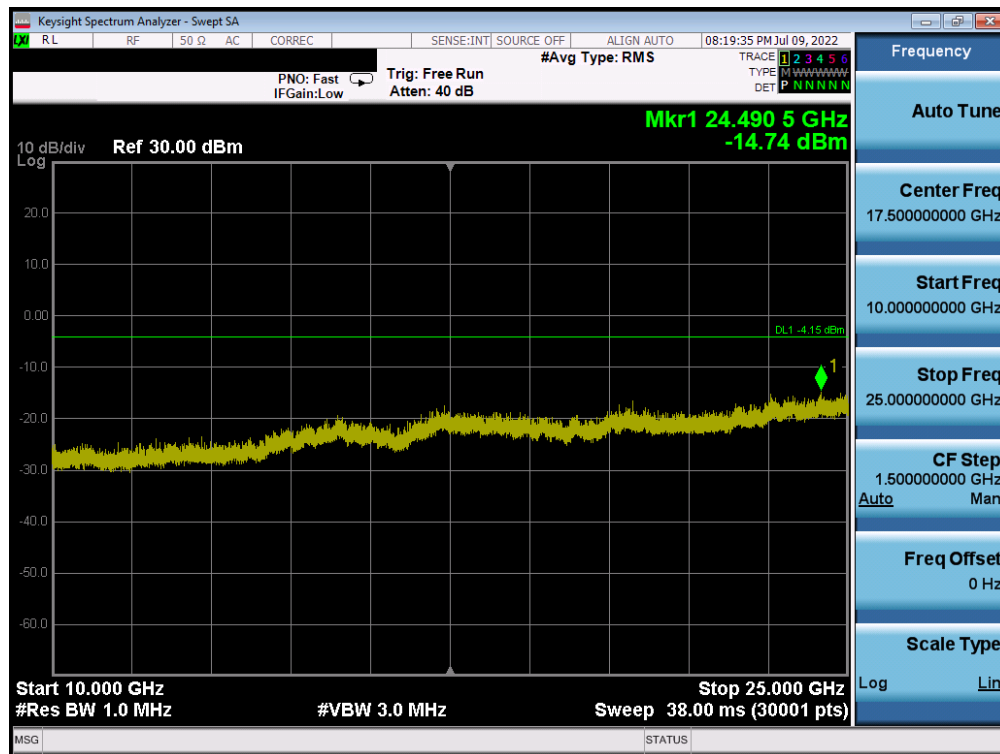
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 43 of 77

V 10.4 5/21/2021

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Plot 7-36. Conducted Spurious Plot (Bluetooth, GFSK – 2441MHz)

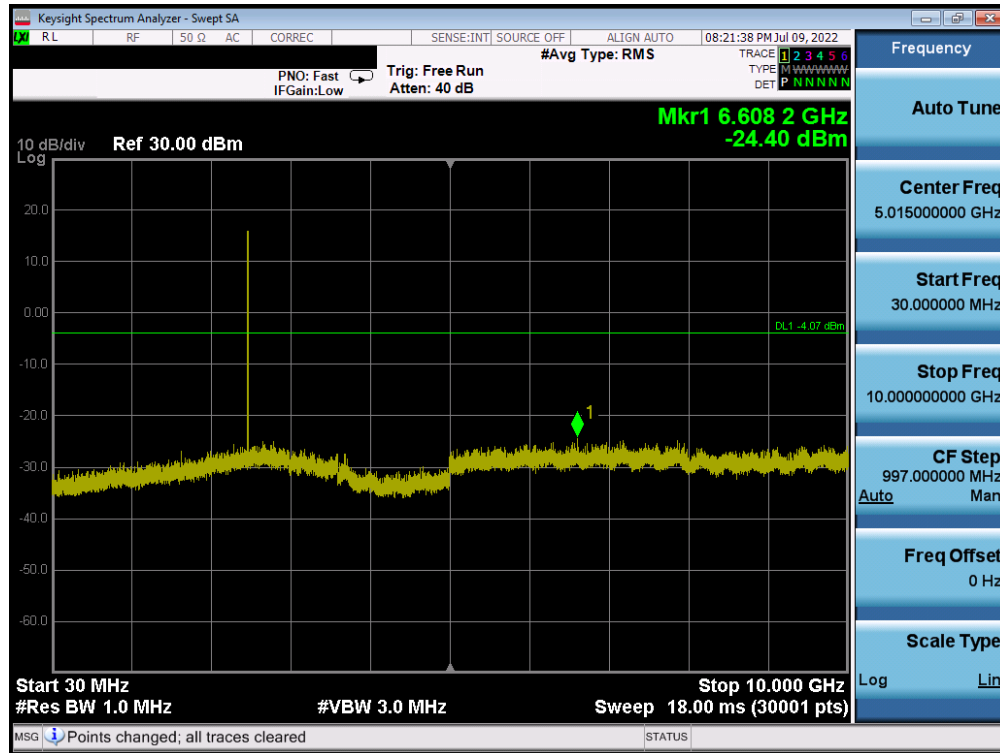


Plot 7-37. Conducted Spurious Plot (Bluetooth, GFSK – 2441MHz)

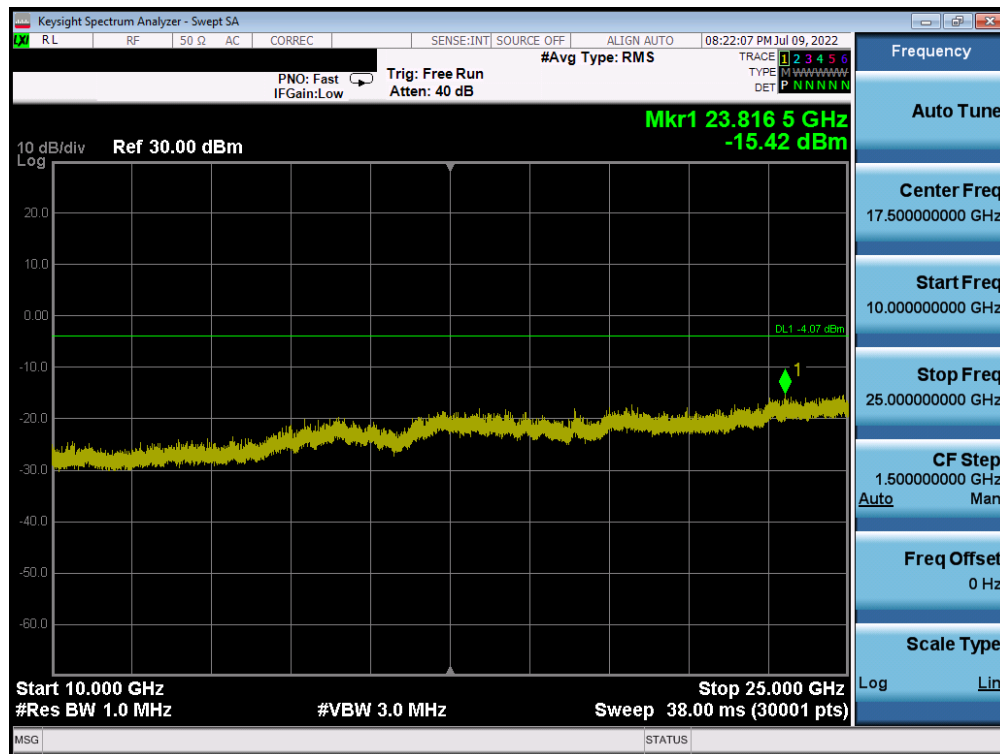
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 44 of 77

V 10.4 5/21/2021

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Plot 7-38. Conducted Spurious Plot (Bluetooth, GFSK – 2480MHz)

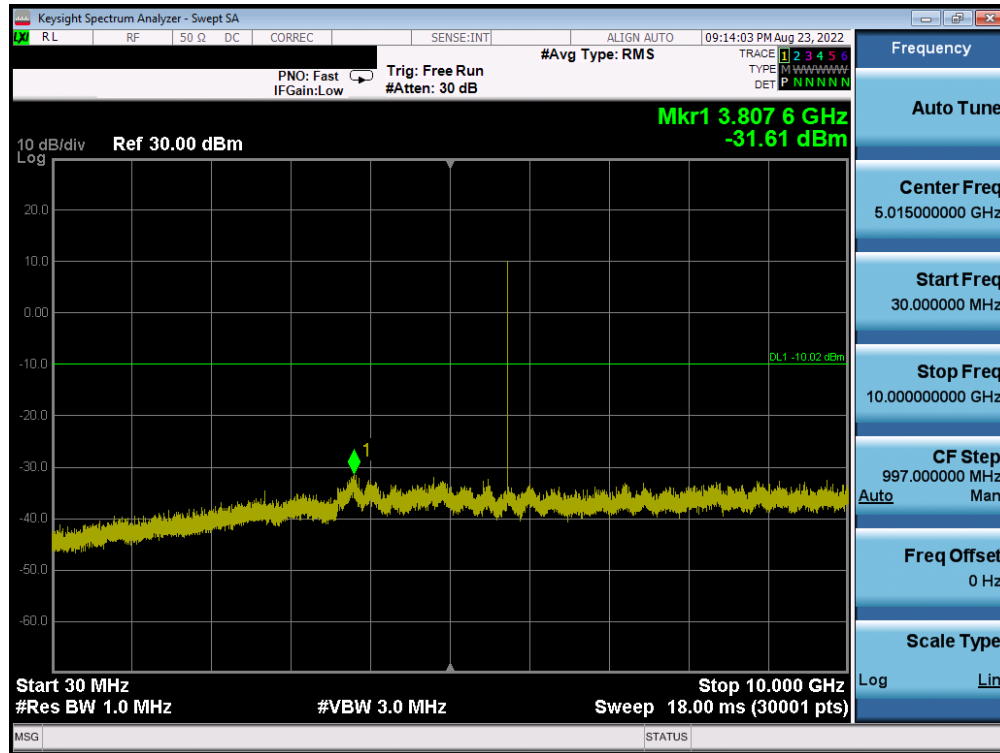


Plot 7-39. Conducted Spurious Plot (Bluetooth, GFSK – 2480MHz)

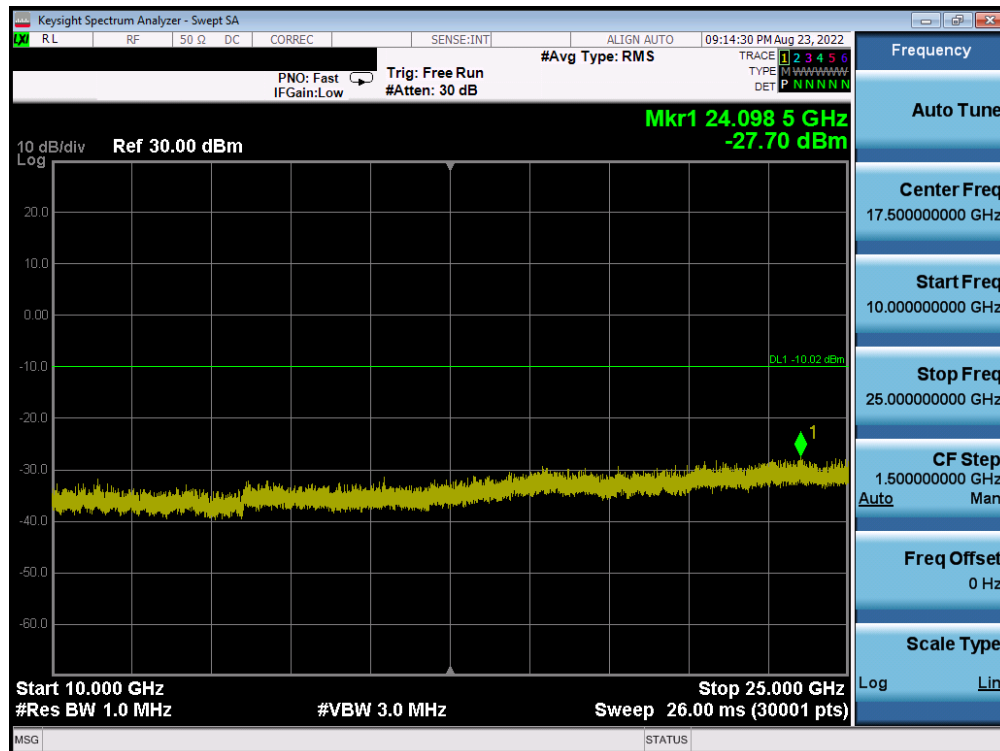
FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 45 of 77

V 10.4 5/21/2021

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Plot 7-40. Conducted Spurious Plot (Bluetooth, GFSK – 5731MHz)

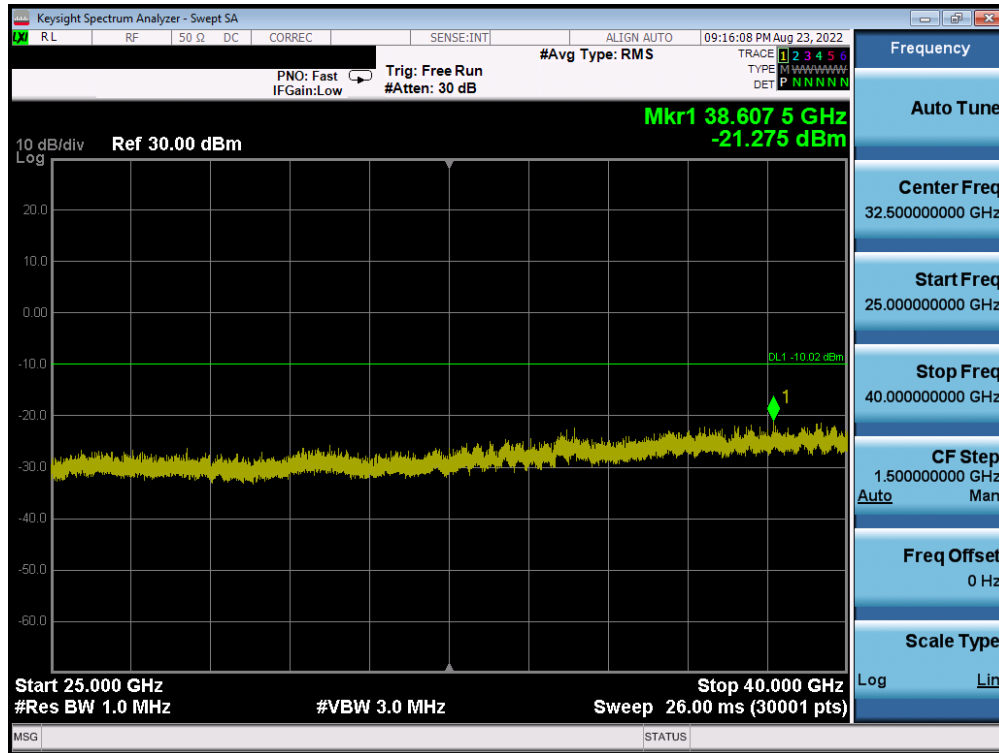


Plot 7-41. Conducted Spurious Plot (Bluetooth, GFSK – 5731MHz)

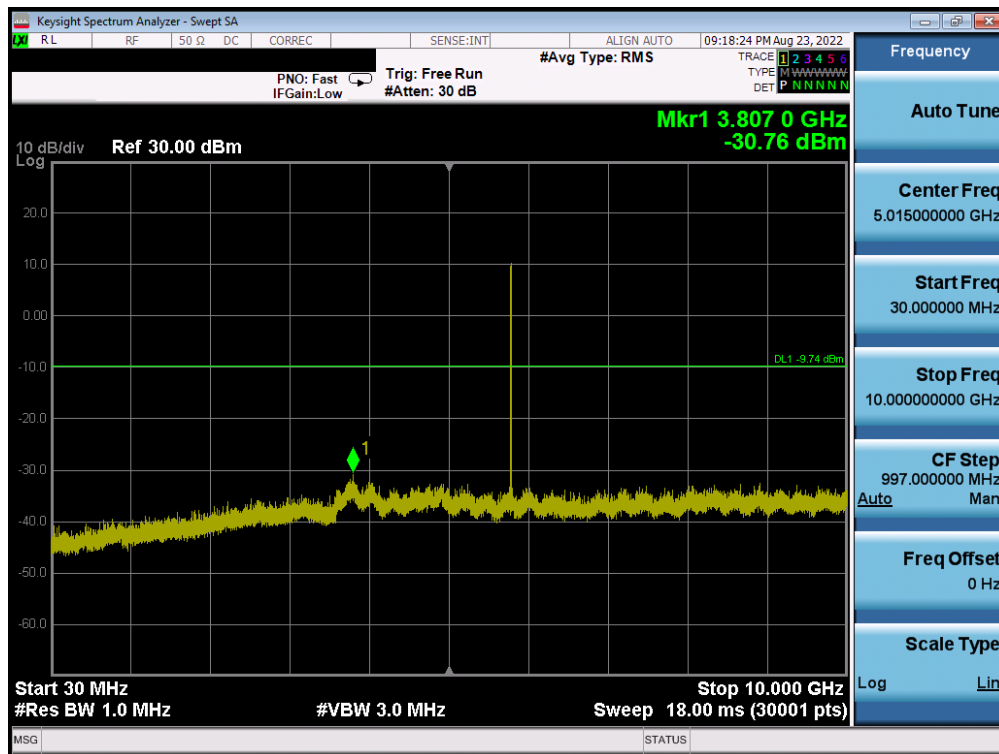
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 46 of 77

V 10.4 5/21/2021

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Plot 7-42. Conducted Spurious Plot (Bluetooth, GFSK – 5731MHz)

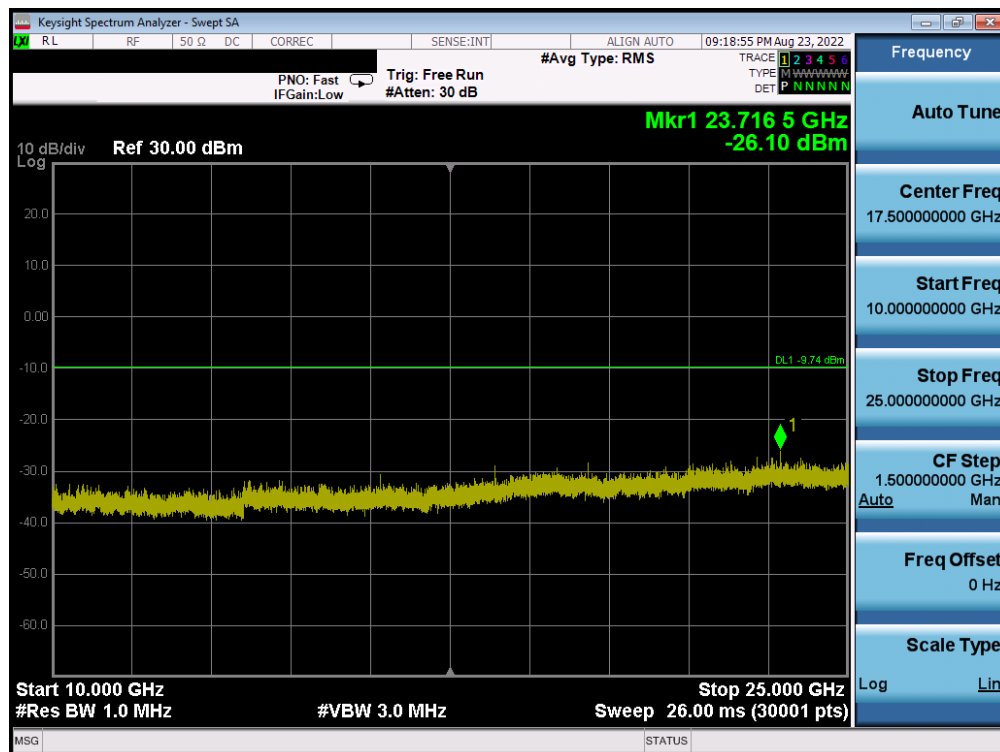


Plot 7-43. Conducted Spurious Plot (Bluetooth, GFSK – 5788MHz)

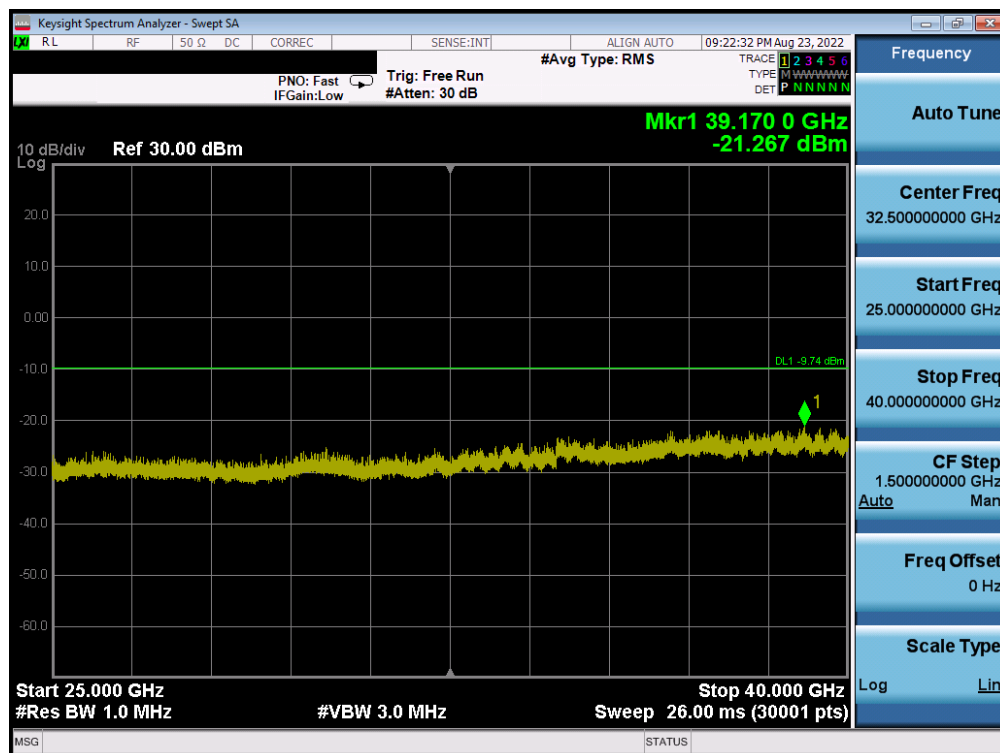
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 47 of 77

V 10.4 5/21/2021

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Plot 7-44. Conducted Spurious Plot (Bluetooth, GFSK – 5788MHz)

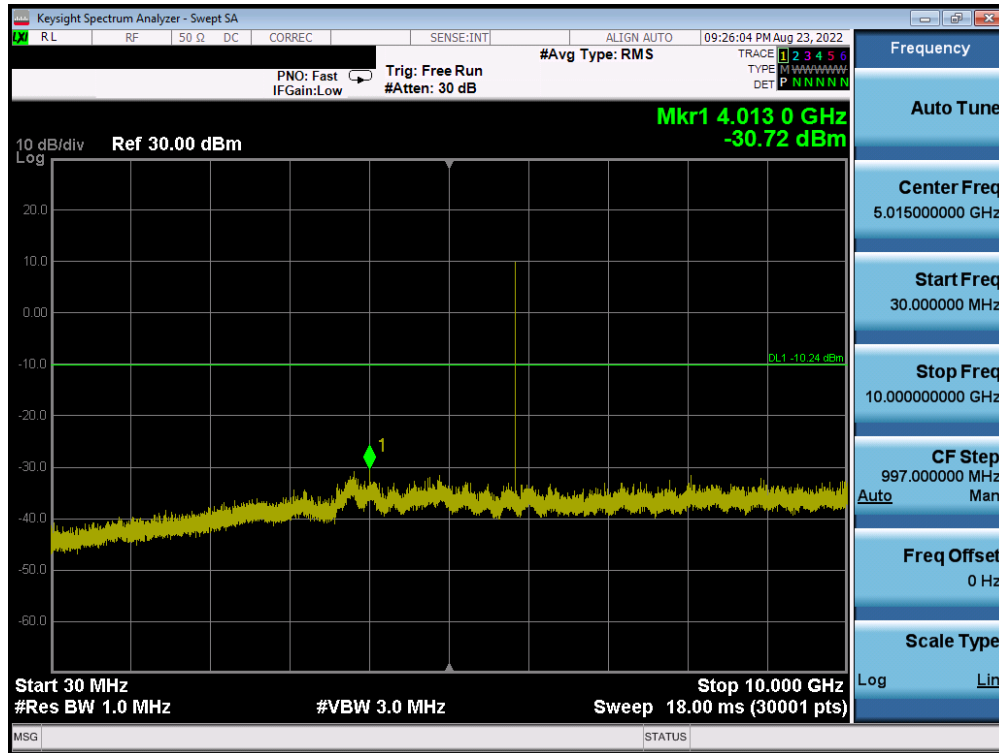


Plot 7-45. Conducted Spurious Plot (Bluetooth, GFSK – 5788MHz)

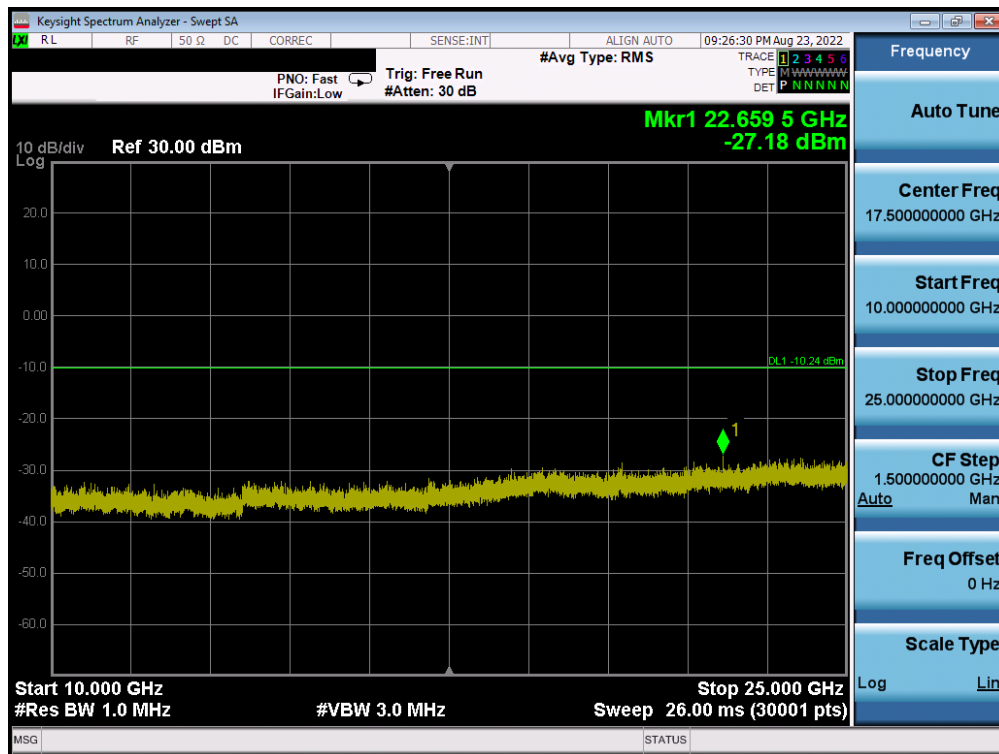
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 48 of 77

V 10.4 5/21/2021

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Plot 7-46. Conducted Spurious Plot (Bluetooth, GFSK – 5844MHz)

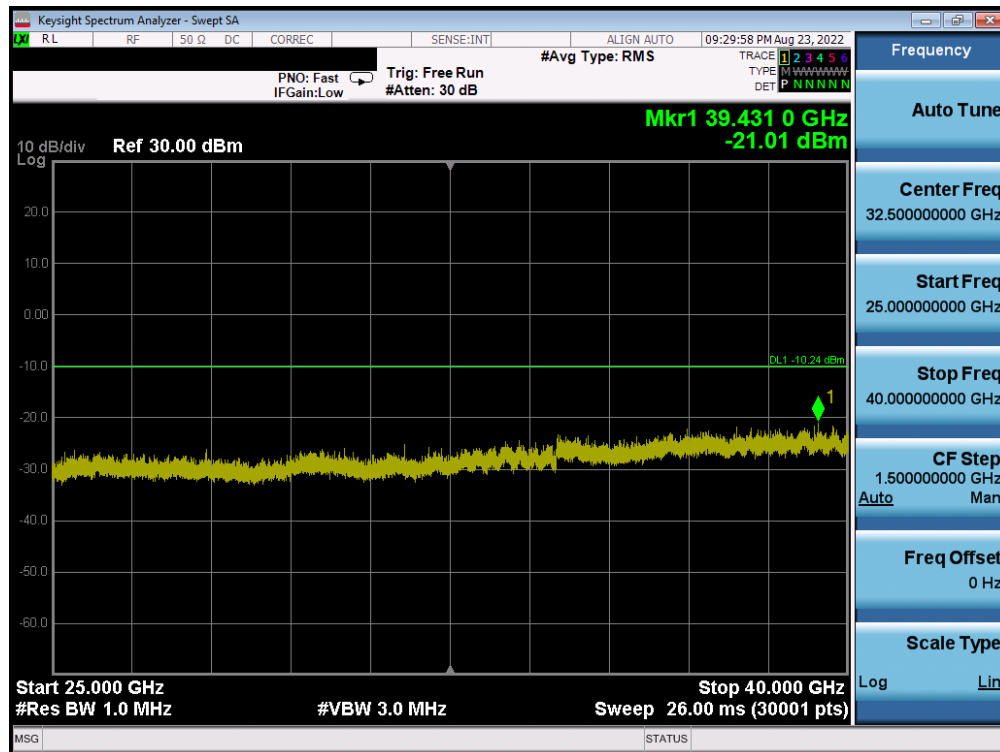


Plot 7-47. Conducted Spurious Plot (Bluetooth, GFSK – 5844MHz)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 49 of 77

V 10.4 5/21/2021

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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 [$\mu\text{V/m}$]	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

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 51 of 77

V 10.4 5/21/2021

Test Setup

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

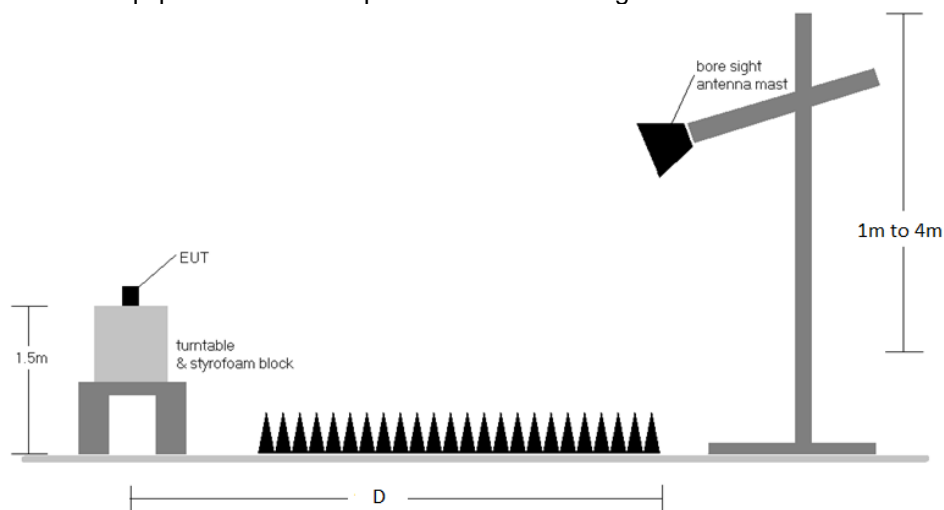


Figure 7-8. Radiated Test Setup >1GHz

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 and power schemes 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.

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 52 of 77

V 10.4 5/21/2021

Sample Calculation

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

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 = $1 / 133.33 \text{ hops/second} = 7.50 \text{ ms}$
- Time to cycle through all channels = $7.50 \times 20 \text{ channels} = 150 \text{ ms}$
- Number of times transmitter hits on one channel = $100 \text{ ms} / 150 \text{ ms} = 1 \text{ time(s)}$
- Worst case dwell time = 7.5 ms

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

Average Emission Calculation

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

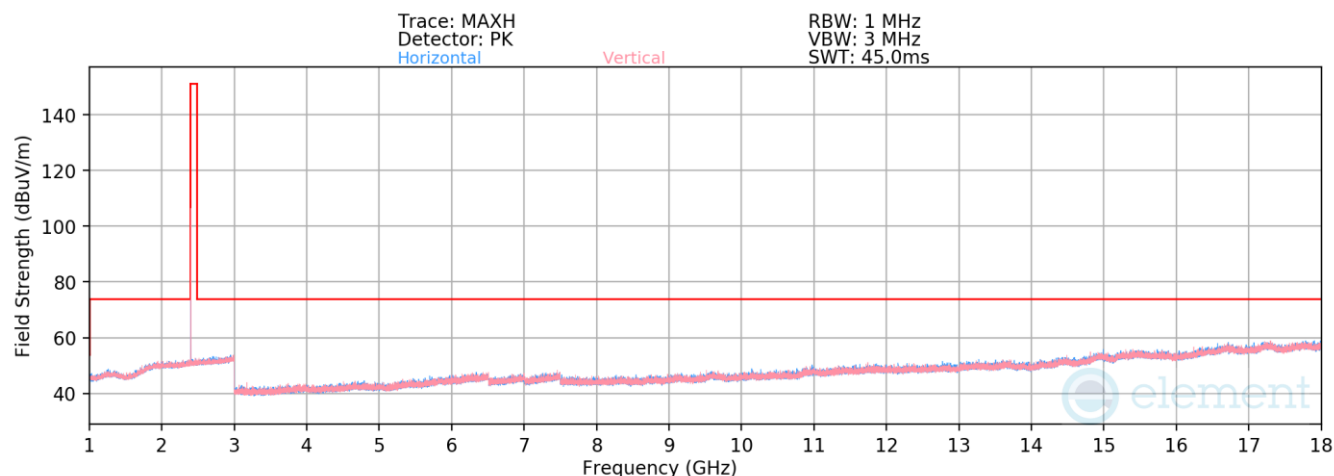
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 53 of 77

V 10.4 5/21/2021

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Radiated Spurious Emission Measurements (1 – 18GHz)

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



Plot 7-49. Radiated Spurious Emissions above 1GHz (BT GFSK – 2402MHz)

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

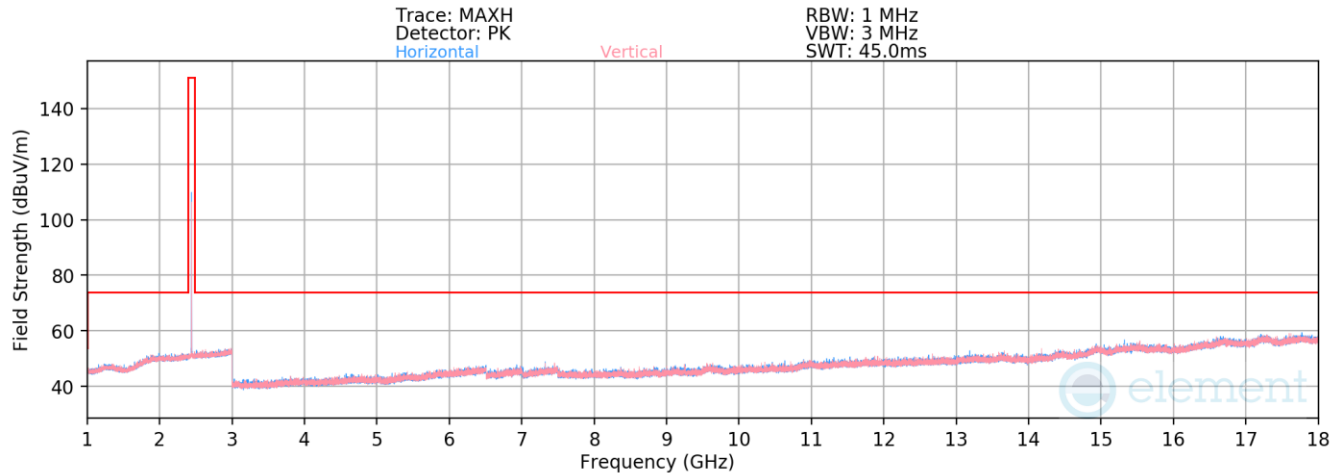
Frequency [MHz]	Detector	Ant. Pol. [H/V]	Antenna Height [cm]	Turntable Azimuth [degree]	Analyzer Level [dBm]	AFCL [dB/m]	Field Strength [dBuV/m]	Limit [dBuV/m]	Margin [dB]
4804.00	Peak	H	340	105	-68.18	4.71	43.53	73.98	-30.44
12010.00	Peak	H	-	-	-71.92	13.17	48.25	73.98	-25.73

Table 7-7. Radiated Measurements

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 54 of 77

V 10.4 5/21/2021

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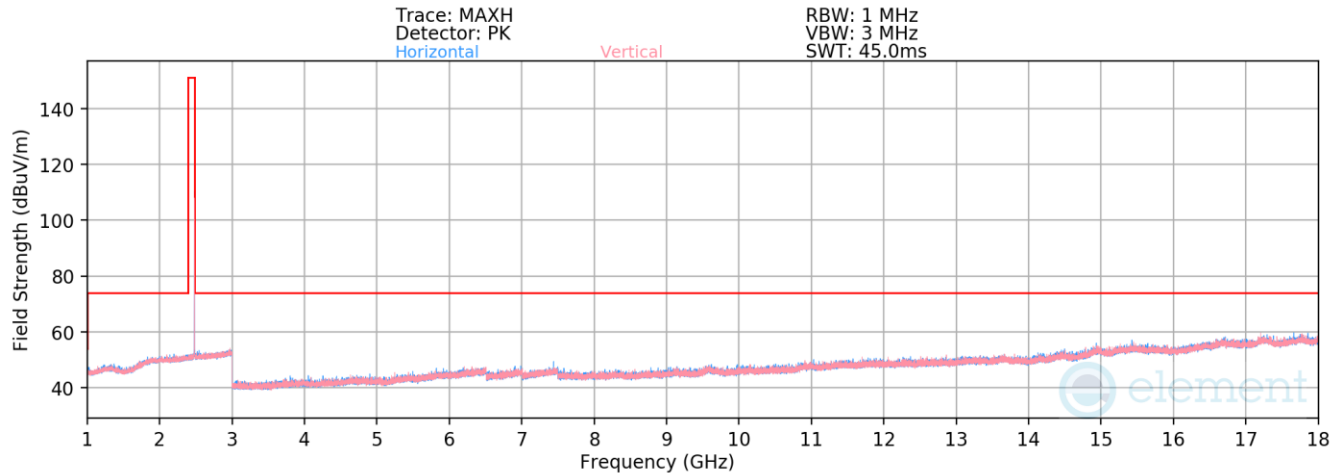
Plot 7-50. Radiated Spurious Emissions above 1GHz (BT GFSK – 2441MHz)

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 [dBuV/m]	Limit [dBuV/m]	Margin [dB]
4882.00	Peak	H	318	139	-68.28	4.51	43.23	73.98	-30.75
7323.00	Peak	H	167	368	-65.52	8.24	49.72	73.98	-24.25
12205.00	Peak	H	-	-	-72.24	13.22	47.98	73.98	-26.00

Table 7-8. Radiated Measurements

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 55 of 77



Plot 7-51. Radiated Spurious Emissions above 1GHz (BT GFSK – 2480MHz)

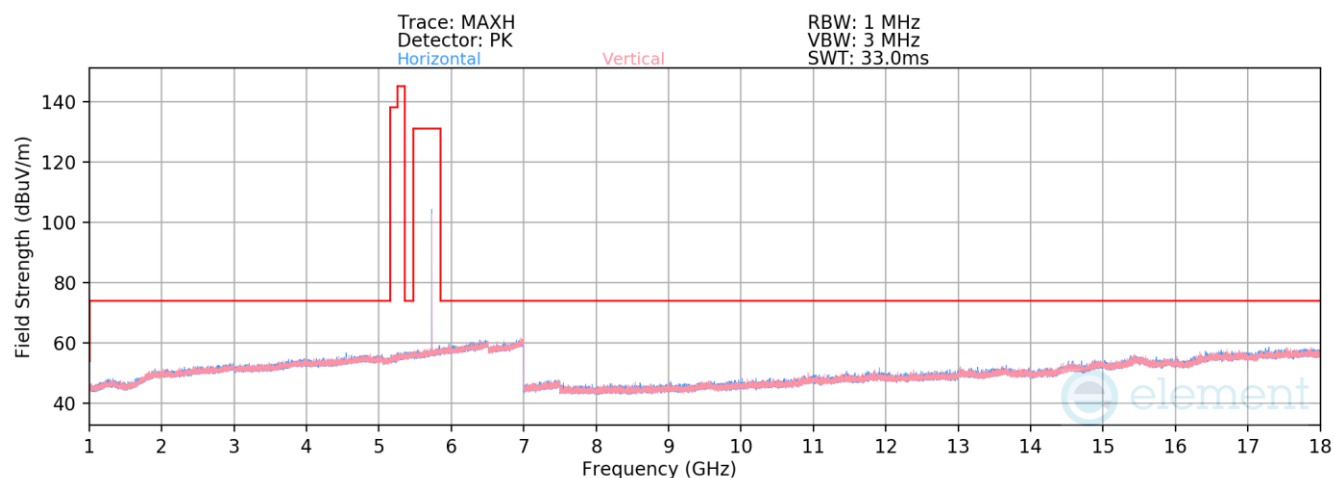
Bluetooth Mode: GFSK
Data Rate: 1Mbps
Distance of Measurements: 3 Meters
Operating Frequency: 2480MHz

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	304	187	-68.30	4.75	43.45	73.98	-30.53
7440.00	Peak	V	109	46	-67.23	8.40	48.17	73.98	-25.81
12400.00	Peak	V	-	-	-71.66	13.32	48.66	73.98	-25.32

Table 7-9. Radiated Measurements

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 56 of 77

V 10.4 5/21/2021



Plot 7-52. Radiated Spurious Emissions above 1GHz (BT GFSK – 5731MHz)

Bluetooth Mode: GFSK
Data Rate: 1Mbps
Distance of Measurements: 3 Meters
Operating Frequency: 5731MHz

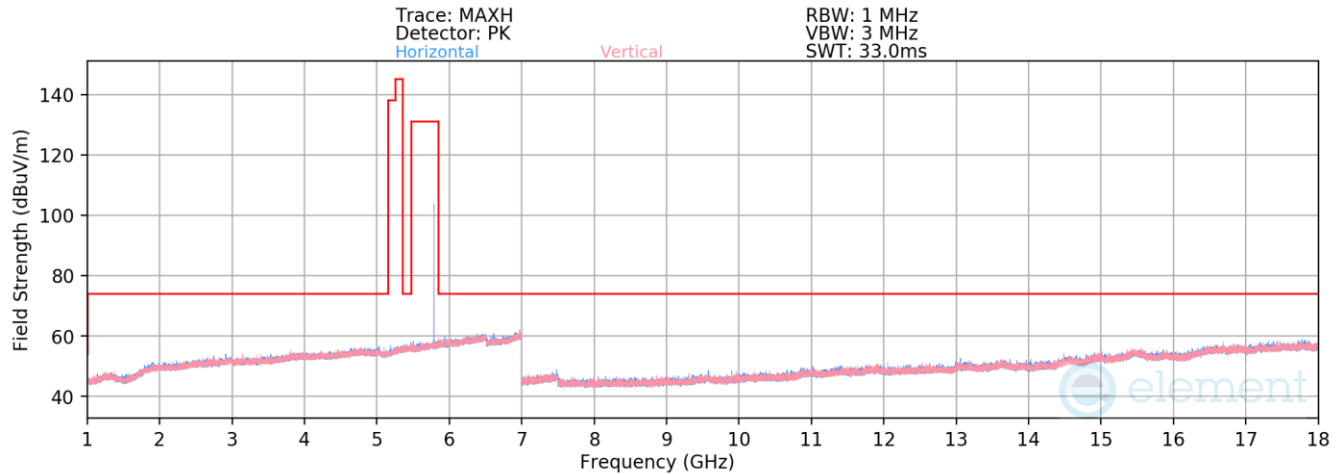
Frequency [MHz]	Detector	Ant. Pol. [H/V]	Antenna Height [cm]	Turntable Azimuth [degree]	Analyzer Level [dBm]	AFCL [dB/m]	Field Strength [dBμV/m]	Limit [dBμV/m]	Margin [dB]
11462.00	Peak	-	-	-	-70.67	12.46	48.79	73.98	-25.19
17193.00	Peak	H	109	329	-73.35	21.81	55.46	68.23	-12.77

Table 7-10. Radiated Measurements

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 57 of 77

V 10.4 5/21/2021

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Plot 7-53. Radiated Spurious Emissions above 1GHz (BT GFSK – 5788MHz)

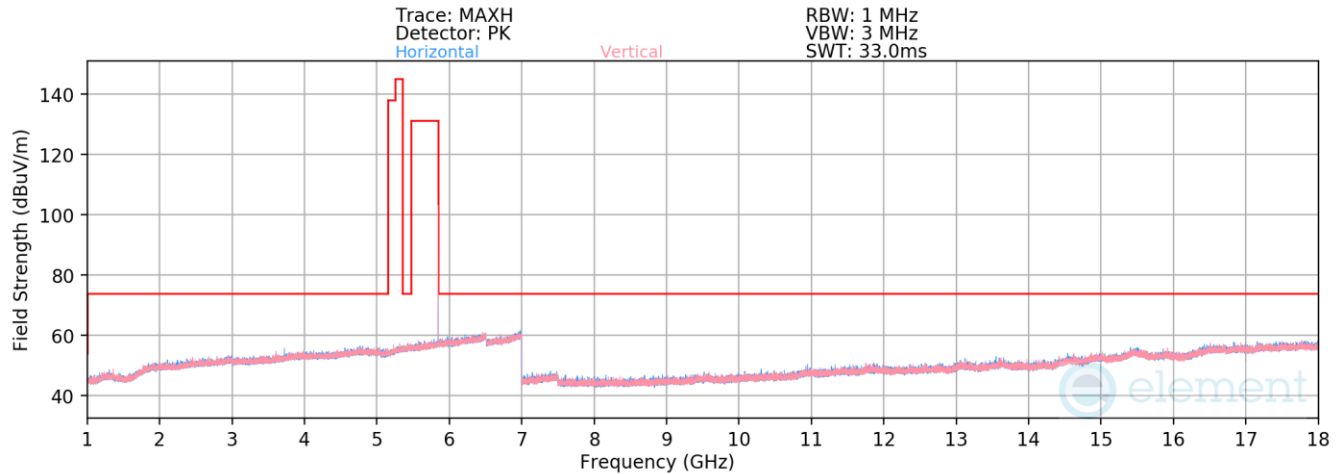
Bluetooth Mode: GFSK
Data Rate: 1Mbps
Distance of Measurements: 3 Meters
Operating Frequency: 5788MHz

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]
11576.00	Peak	H	102	26	-71.30	12.45	48.15	73.98	-25.83
17364.00	Peak	H	236	218	-72.75	21.74	55.99	68.23	-12.24

Table 7-11. Radiated Measurements

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 58 of 77

V 10.4 5/21/2021



Plot 7-54. Radiated Spurious Emissions above 1GHz (BT GFSK – 5844MHz)

Bluetooth Mode: GFSK
Data Rate: 1Mbps
Distance of Measurements: 3 Meters
Operating Frequency: 5844MHz

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]
11688.00	Peak	H	326	47	-71.34	12.45	48.11	73.98	-25.87
17532.00	Peak	H	109	22	-73.80	22.69	55.89	68.23	-12.34

Table 7-12. Radiated Measurements

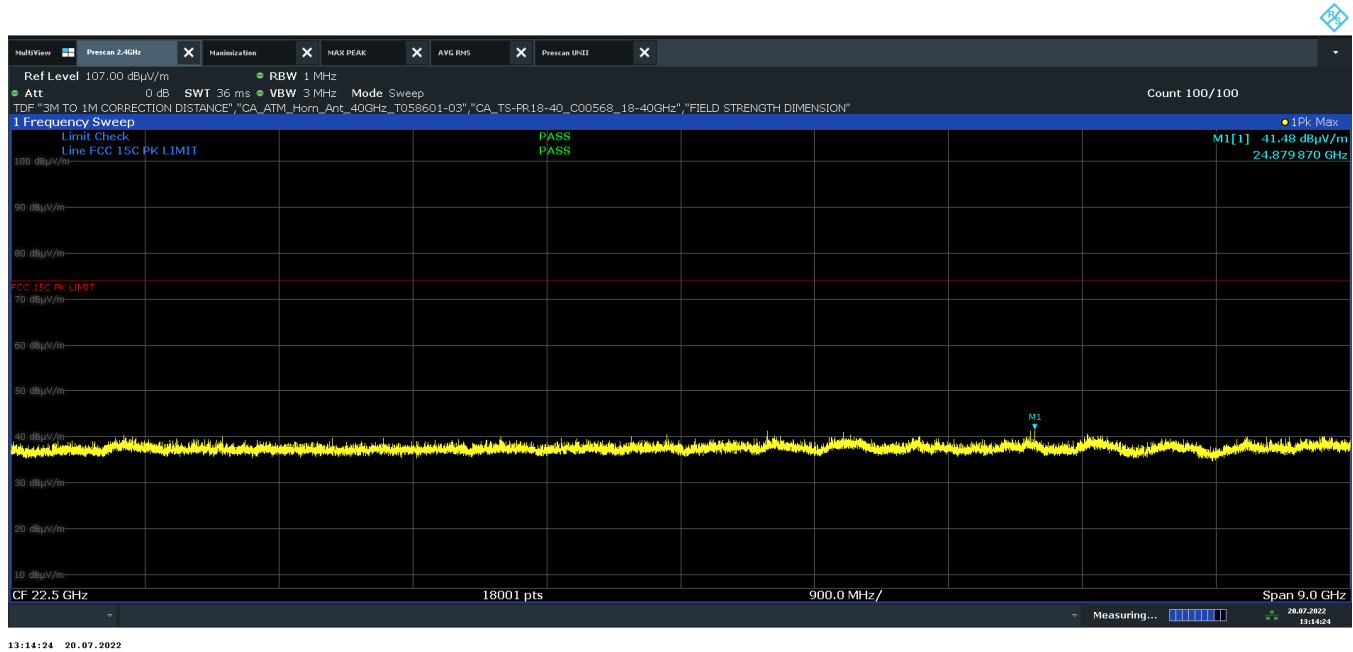
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 59 of 77

V 10.4 5/21/2021

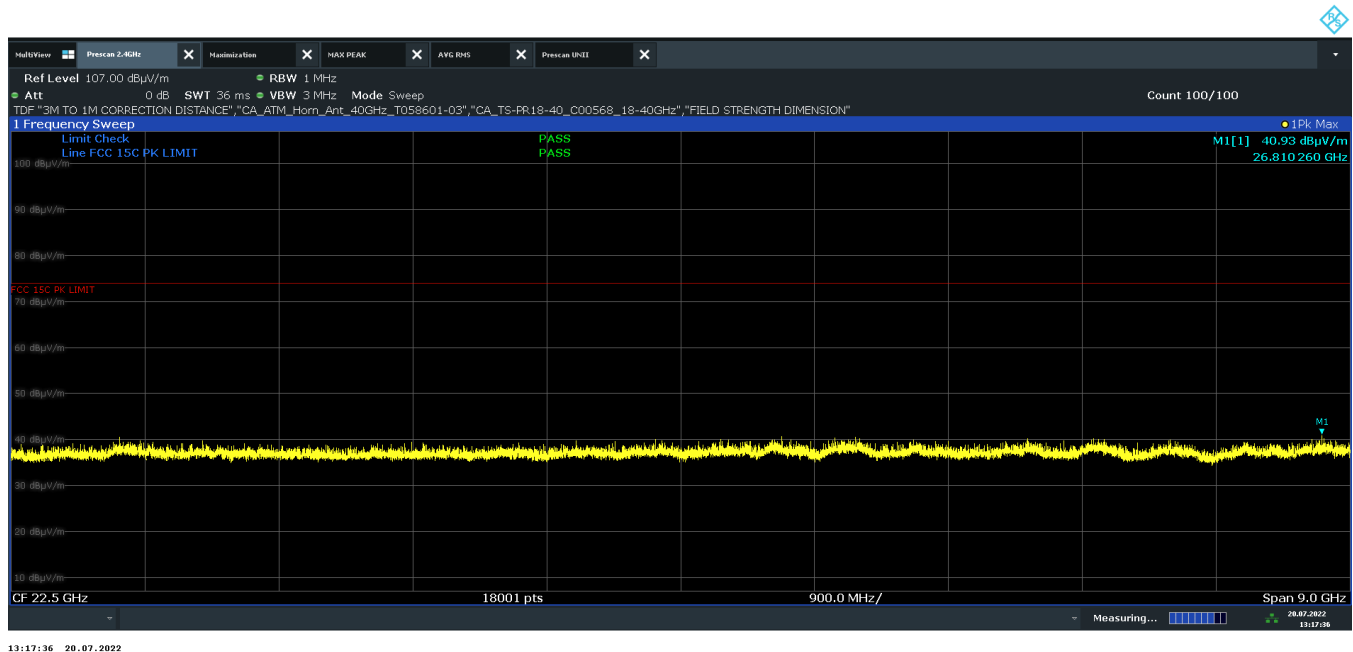


Radiated Spurious Emission Measurements (Above 18GHz)

\$15.209; RSS-Gen [8.9]



Plot 7-55. Radiated Spurious Emissions above 18GHz (BT GFSK - 2441MHz, Pol. H)

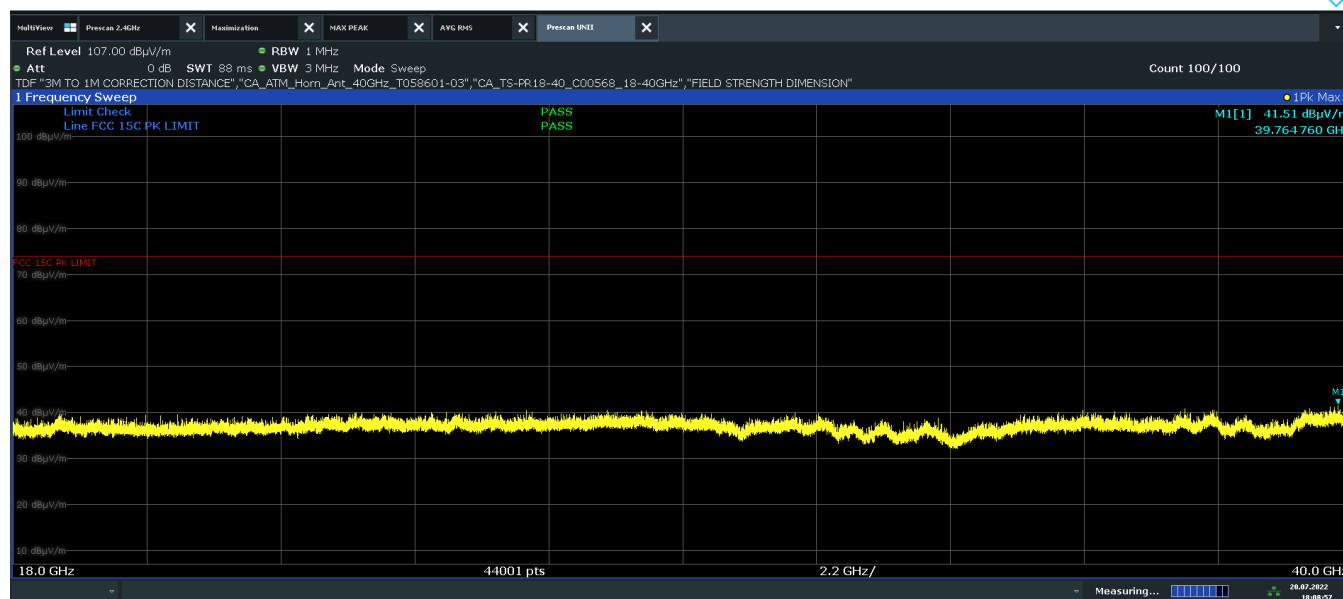


Plot 7-56. Radiated Spurious Emissions above 18GHz (BT GFSK - 2441MHz, Pol. V)

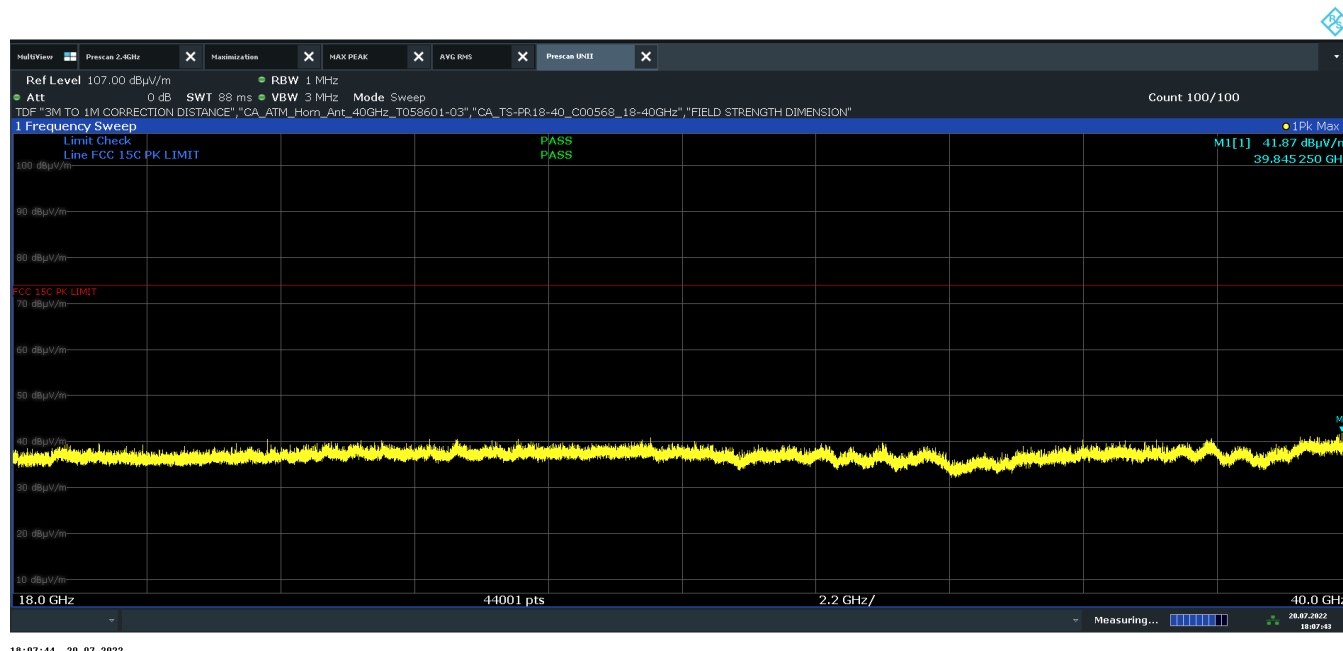
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 60 of 77

V 10.4 5/21/2021

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Plot 7-57. Radiated Spurious Emissions above 18GHz (BT GFSK - 5788MHz, Pol. H)



Plot 7-58. Radiated Spurious Emissions above 18GHz (BT GFSK - 5788MHz, Pol. V)

FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 61 of 77

V 10.4 5/21/2021

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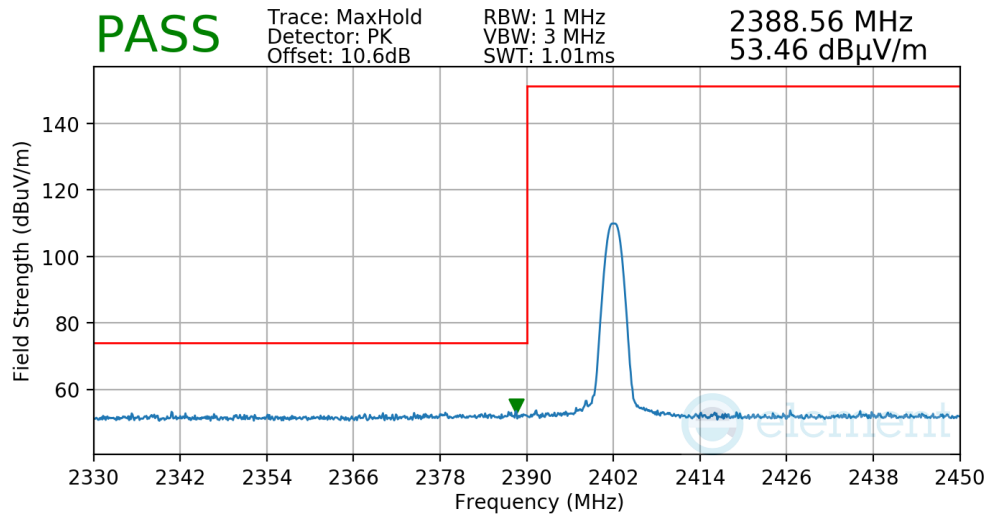
7.9.1 Radiated Restricted Band Edge Measurements

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

Bluetooth Mode: GFSK

Measurement Distance: 3 Meters

Operating Frequency: 2402MHz

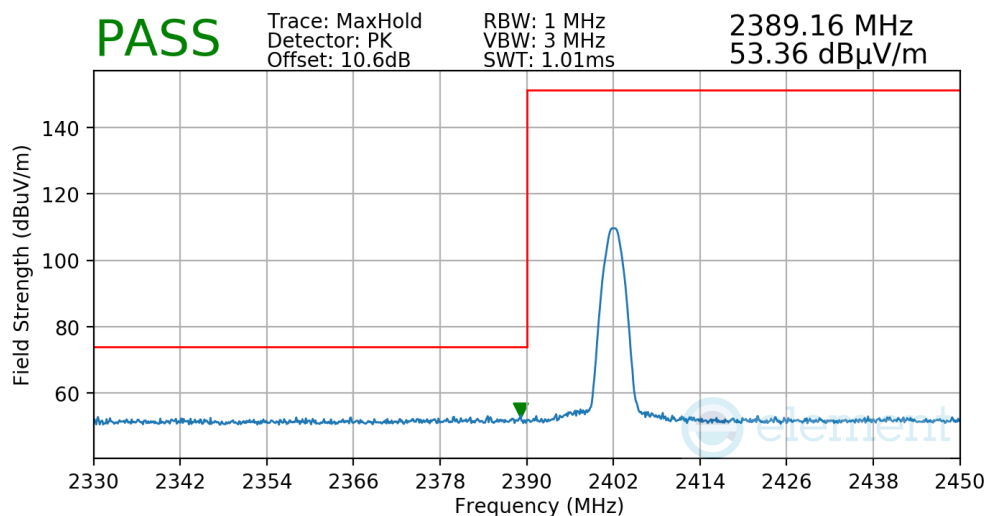


Plot 7-59. Radiated Restricted Lower Band Edge Measurement

Bluetooth Mode: 8DPSK

Measurement Distance: 3 Meters

Operating Frequency: 2402MHz



Plot 7-60. Radiated Restricted Lower Band Edge Measurement

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 62 of 77

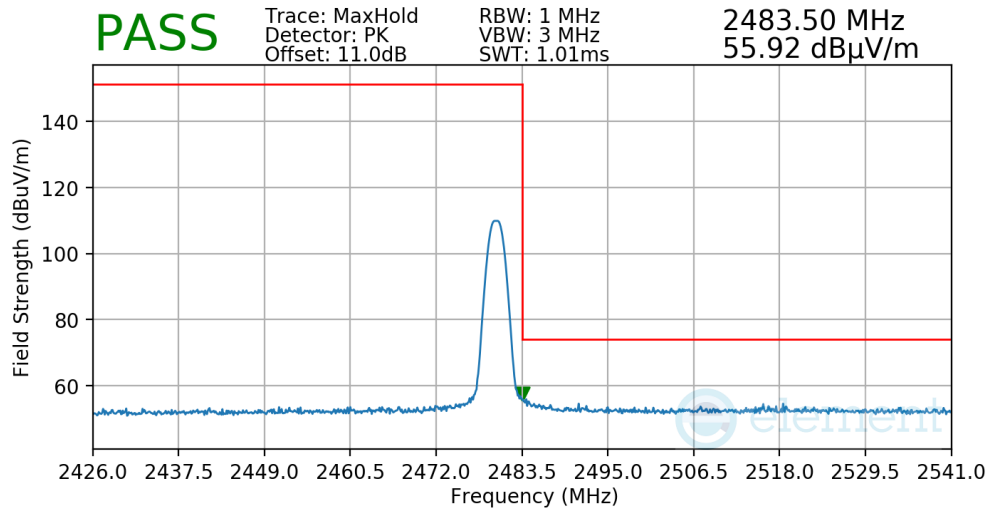
V 10.4 5/21/2021

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Bluetooth Mode: GFSK

Measurement Distance: 3 Meters

Operating Frequency: 2480MHz

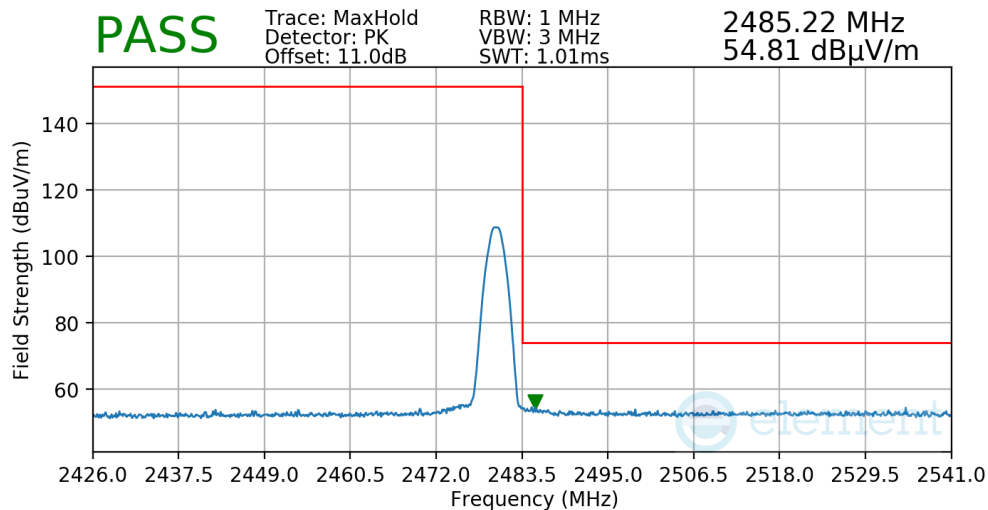


Plot 7-61. Radiated Restricted Upper Band Edge Measurement

Bluetooth Mode: 8DPSK

Measurement Distance: 3 Meters

Operating Frequency: 2480MHz



Plot 7-62. Radiated Restricted Upper Band Edge Measurement

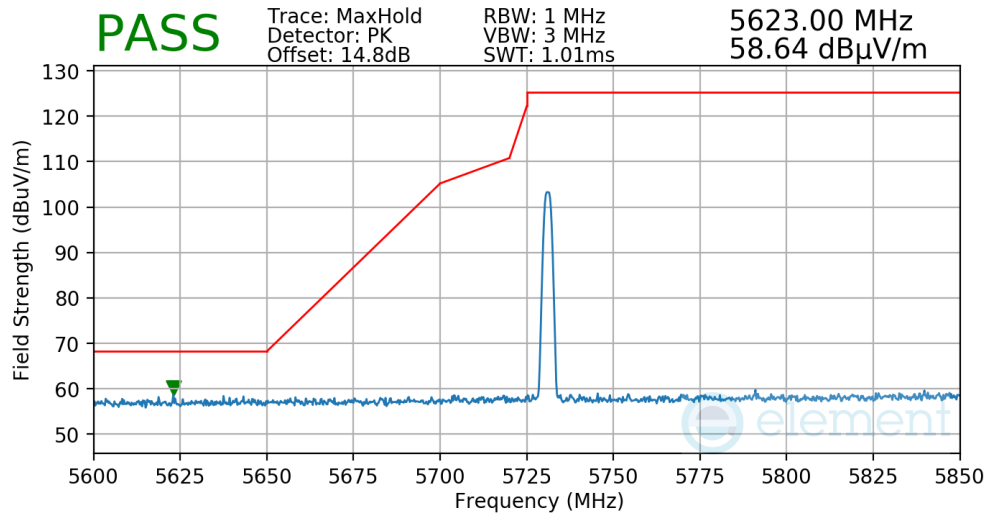
FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud		Page 63 of 77

V 10.4 5/21/2021

Bluetooth Mode: GFSK

Measurement Distance: 3 Meters

Operating Frequency: 5731MHz

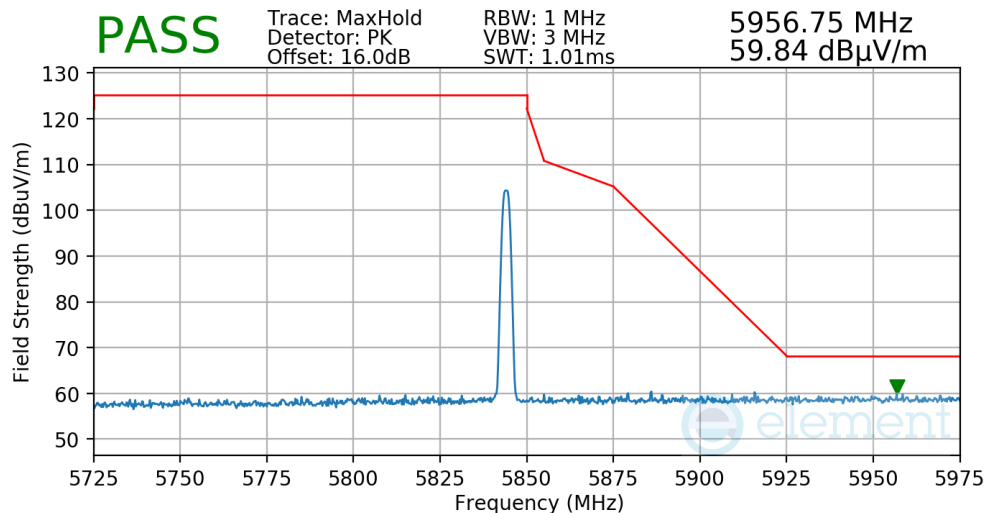


Plot 7-63. Radiated Restricted Lower Band Edge Measurement

Bluetooth Mode: GFSK

Measurement Distance: 3 Meters

Operating Frequency: 5844MHz



Plot 7-64. Radiated Restricted Upper Band Edge Measurement

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 64 of 77

V 10.4 5/21/2021

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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 7-13 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 7-13. 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

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 65 of 77

V 10.4 5/21/2021

Test Setup

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

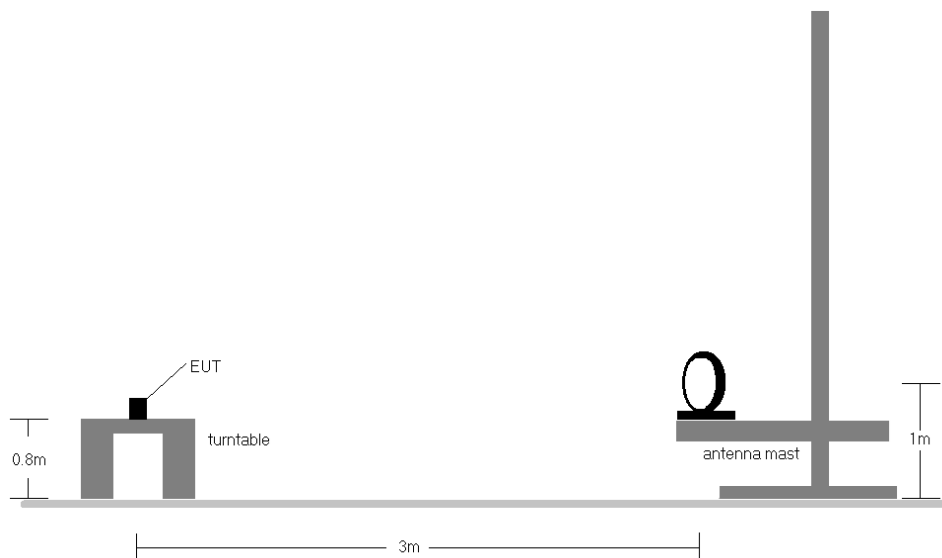


Figure 7-9. Radiated Test Setup < 30MHz

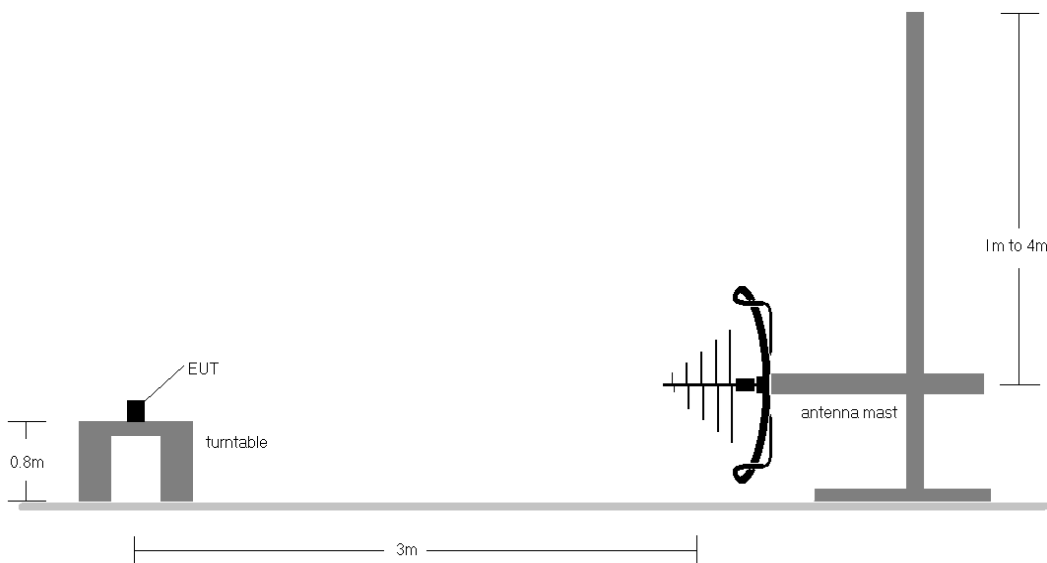


Figure 7-10. Radiated Test Setup < 1GHz

FCC ID: BCG-A2698 IC: 579C-A2698	 MEASUREMENT REPORT (CERTIFICATION)		Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 66 of 77

V 10.4 5/21/2021

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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 7-13.
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 lightning cable.
 - b. EUT charged by charging case and powered by host PC with lightning cable.

Sample Calculations

Determining Spurious Emissions Levels

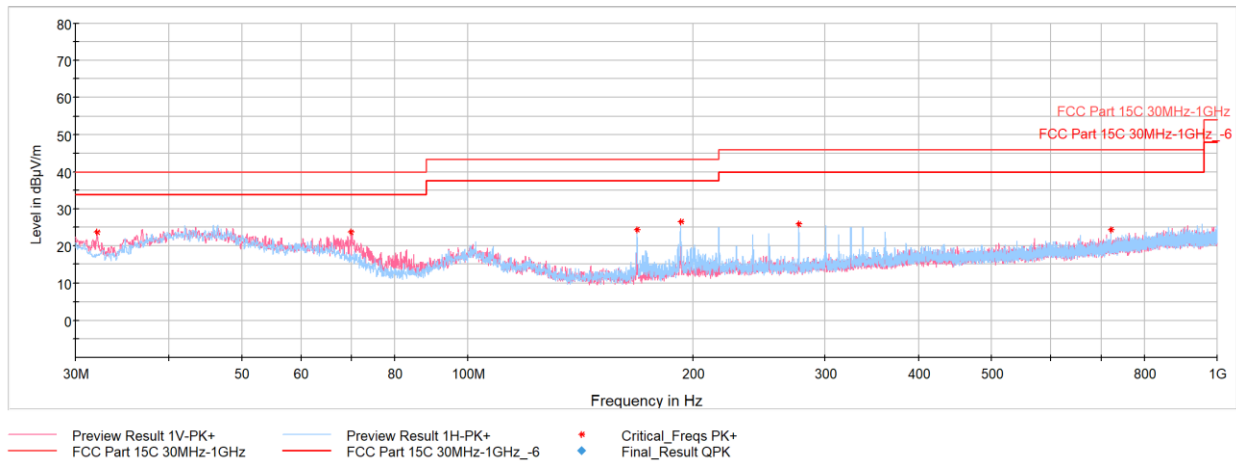
- Field Strength Level $_{[dB\mu V/m]} = \text{Analyzer Level}_{[dBm]} + 107 + \text{AFCL}_{[dB/m]}$
- $\text{AFCL}_{[dB/m]} = \text{Antenna Factor}_{[dB/m]} + \text{Cable Loss}_{[dB]} - \text{Preamplifier Gain}_{[dB]}$
- $\text{Margin}_{[dB]} = \text{Field Strength Level}_{[dB\mu V/m]} - \text{Limit}_{[dB\mu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

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 67 of 77

V 10.4 5/21/2021

Radiated Spurious Emissions Measurements (Below 1GHz)

§15.209; RSS-Gen [8.9]



Plot 7-65. Radiated Spurious Emissions Below 1GHz (GFSK – 2441MHz) with AC/DC Adapter and lightning cable

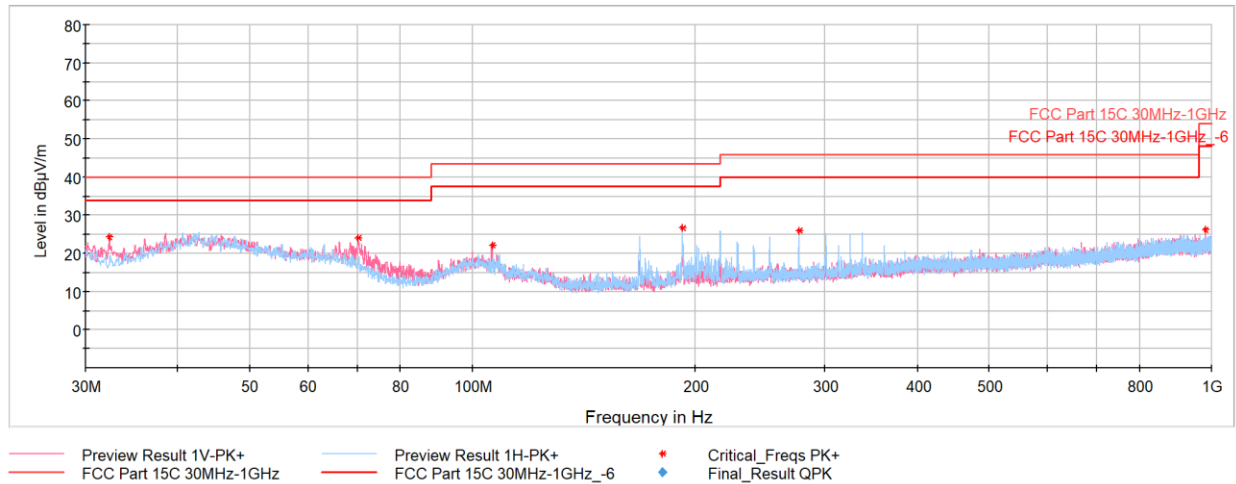
Frequency [MHz]	Detector	Ant. Pol. [H/V]	Antenna Height [cm]	Turntable Azimuth [degree]	Analyzer Level [dBm]	AFCL [dB/m]	Field Strength [dBμV/m]	Limit [dBμV/m]	Margin [dB]
32.04	Max Peak	V	100	347	-63.49	-19.86	23.65	40.00	-16.35
69.92	Max Peak	V	100	193	-62.96	-20.25	23.79	40.00	-16.21
168.18	Max Peak	H	200	63	-62.35	-20.33	24.32	43.52	-19.20
192.33	Max Peak	H	200	98	-62.35	-18.09	26.56	43.52	-16.96
276.62	Max Peak	H	100	245	-65.33	-15.76	25.91	46.02	-20.11
721.32	Max Peak	H	100	15	-75.56	-7.01	24.43	46.02	-21.59

Table 7-14. Radiated Spurious Emissions Below 1GHz (GFSK – 2441MHz) with AC/DC Adapter and lightning cable

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 68 of 77

V 10.4 5/21/2021

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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]
32.33	Max Peak	V	100	136	-63.00	-19.79	24.21	40.00	-15.79
70.16	Max Peak	V	100	146	-62.65	-20.33	24.02	40.00	-15.98
106.44	Max Peak	V	100	96	-66.28	-18.58	22.14	43.52	-21.38
192.28	Max Peak	H	200	83	-62.28	-18.10	26.62	43.52	-16.90
276.57	Max Peak	H	100	217	-65.36	-15.76	25.88	46.02	-20.14
981.52	Max Peak	V	100	193	-77.14	-3.66	26.20	53.98	-27.78

Table 7-15. Radiated Spurious Emissions Below 1GHz (GFSK – 5788MHz) with AC/DC Adapter and lightning cable

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 69 of 77

V 10.4 5/21/2021

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 7-16. 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

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 70 of 77

V 10.4 5/21/2021

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Test Setup

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

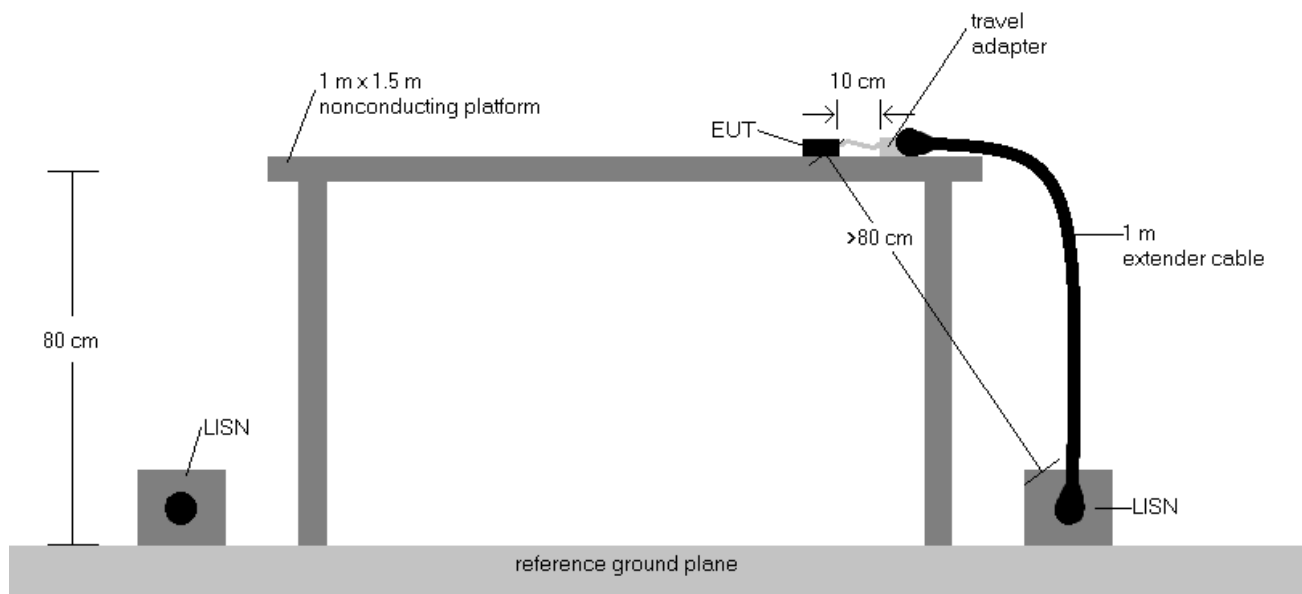


Figure 7-11. Test Instrument & Measurement Setup

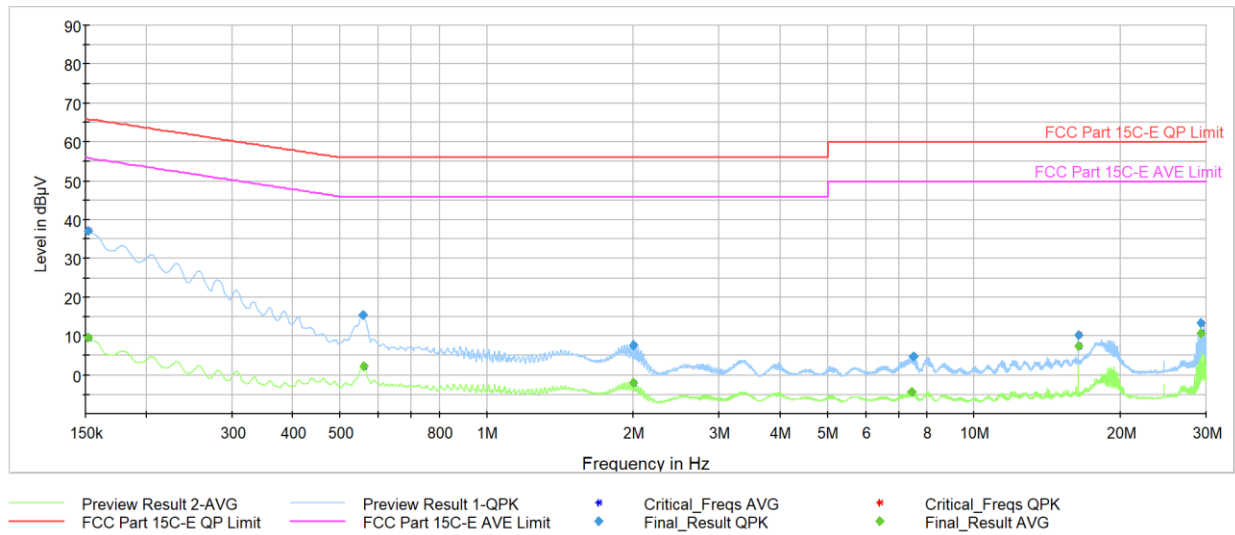
Test Notes

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 lightning cable.
 - b. EUT charged by charging case and powered by host PC with lightning cable.
3. The limit for an intentional radiator from 150kHz to 30MHz are specified in Part 15.207 and RSS-Gen (8.8).
4. $\text{Corr. (dB)} = \text{Cable loss (dB)} + \text{LISN insertion factor (dB)}$
5. $\text{QP/AV Level (dB}\mu\text{V)} = \text{QP/AV Analyzer/Receiver Level (dB}\mu\text{V)} + \text{Correction Factor (dB)}$
6. $\text{Margin (dB)} = \text{QP/AV Level (dB}\mu\text{V)} - \text{QP/AV Limit (dB}\mu\text{V)}$
7. Traces shown in plot are made using a quasi peak and average detectors.
8. Deviations to the Specifications: None.

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 71 of 77

V 10.4 5/21/2021

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Plot 7-67. AC Line-Conducted Plot (L1, GFSK – 2441MHz, with host PC and lightning cable)

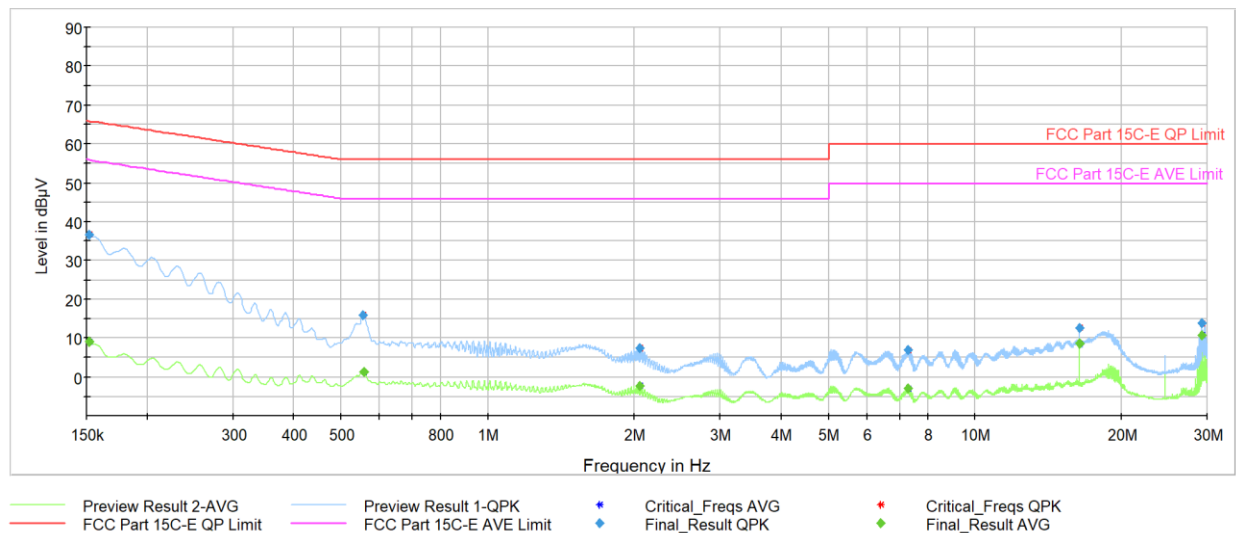
Frequency [MHz]	Process State	QuasiPeak [dBµV]	Average [dBµV]	Limit [dBµV]	Margin [dB]	Line	PE
0.152	FINAL	—	9.58	55.88	-46.29	L1	GND
0.152	FINAL	37.2	—	65.88	-28.67	L1	GND
0.557	FINAL	15.4	—	56.00	-40.61	L1	GND
0.560	FINAL	—	2.22	46.00	-43.78	L1	GND
1.995	FINAL	7.8	—	56.00	-48.20	L1	GND
1.995	FINAL	—	-1.93	46.00	-47.93	L1	GND
7.454	FINAL	—	-4.26	50.00	-54.26	L1	GND
7.505	FINAL	4.9	—	60.00	-55.10	L1	GND
16.384	FINAL	—	7.40	50.00	-42.60	L1	GND
16.386	FINAL	10.3	—	60.00	-49.75	L1	GND
29.182	FINAL	—	10.64	50.00	-39.36	L1	GND
29.182	FINAL	13.3	—	60.00	-46.67	L1	GND

Table 7-17. AC Line-Conducted Data (L1, GFSK – 2441MHz, with host PC and lightning cable)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 72 of 77

V 10.4 5/21/2021

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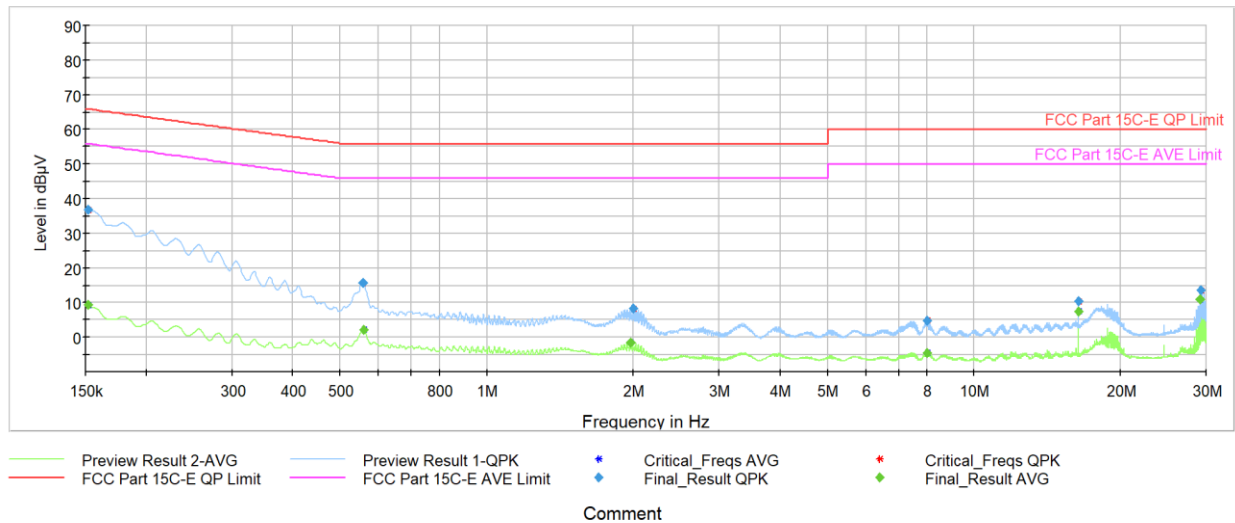


Plot 7-68. AC Line-Conducted Plot (N, GFSK – 2441MHz, with host PC and lightning cable)

Frequency [MHz]	Process State	QuasiPeak [dBµV]	Average [dBµV]	Limit [dBµV]	Margin [dB]	Line	PE
0.152	FINAL	—	9.19	55.88	-46.69	N	GND
0.152	FINAL	36.8	—	65.88	-29.12	N	GND
0.555	FINAL	15.9	—	56.00	-40.15	N	GND
0.557	FINAL	—	1.33	46.00	-44.67	N	GND
2.047	FINAL	7.6	—	56.00	-48.44	N	GND
2.047	FINAL	—	-2.24	46.00	-48.24	N	GND
7.276	FINAL	—	-2.91	50.00	-52.91	N	GND
7.301	FINAL	6.9	—	60.00	-53.07	N	GND
16.406	FINAL	12.6	—	60.00	-47.39	N	GND
16.406	FINAL	—	8.53	50.00	-41.47	N	GND
29.177	FINAL	13.9	—	60.00	-46.15	N	GND
29.180	FINAL	—	10.76	50.00	-39.24	N	GND

Table 7-18. AC Line-Conducted Data (N, GFSK – 2441MHz, with host PC and lightning cable)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 73 of 77



Plot 7-69. AC Line-Conducted Plot (L1, GFSK – 5788MHz, with host PC and lightning cable)

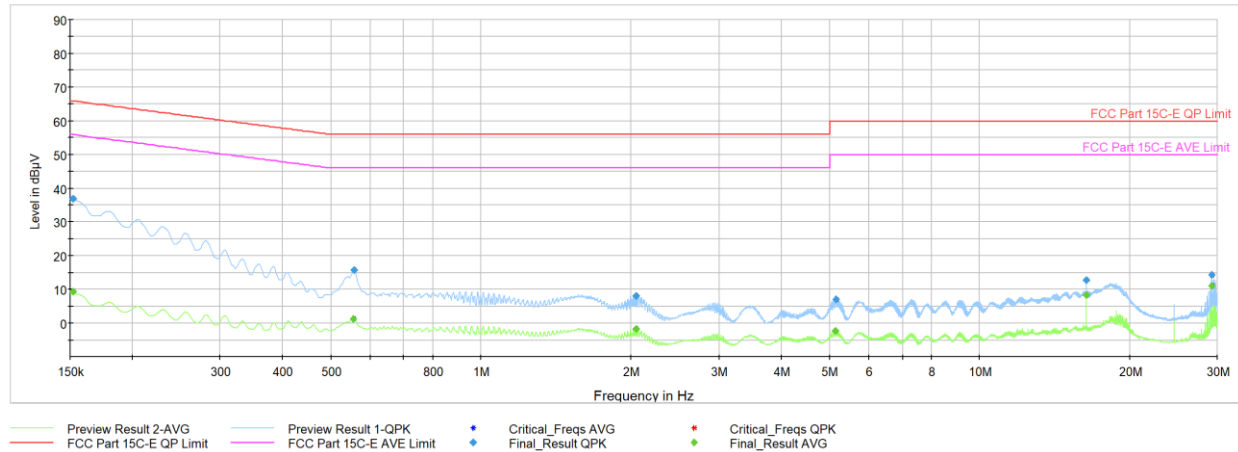
Frequency [MHz]	Process State	QuasiPeak [dBµV]	Average [dBµV]	Limit [dBµV]	Margin [dB]	Line	PE
0.152	FINAL	—	9.35	55.88	-46.52	L1	GND
0.152	FINAL	36.9	—	65.88	-28.95	L1	GND
0.557	FINAL	15.6	—	56.00	-40.42	L1	GND
0.560	FINAL	—	2.22	46.00	-43.78	L1	GND
1.968	FINAL	—	-1.65	46.00	-47.65	L1	GND
1.995	FINAL	8.2	—	56.00	-47.76	L1	GND
8.012	FINAL	—	-4.37	50.00	-54.37	L1	GND
8.014	FINAL	4.7	—	60.00	-55.31	L1	GND
16.370	FINAL	10.4	—	60.00	-49.56	L1	GND
16.373	FINAL	—	7.39	50.00	-42.61	L1	GND
29.168	FINAL	—	10.99	50.00	-39.01	L1	GND
29.171	FINAL	13.5	—	60.00	-46.48	L1	GND

Table 7-19. AC Line-Conducted Data (L1, GFSK – 5788MHz, with host PC and lightning cable)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 74 of 77

V 10.4 5/21/2021

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Plot 7-70. AC Line-Conducted Plot (N, GFSK – 5788MHz, with host PC and lightning cable)

Frequency [MHz]	Process State	QuasiPeak [dBµV]	Average [dBµV]	Limit [dBµV]	Margin [dB]	Line	PE
0.152	FINAL	—	9.31	55.88	-46.57	N	GND
0.152	FINAL	37.0	—	65.88	-28.90	N	GND
0.555	FINAL	—	1.26	46.00	-44.74	N	GND
0.557	FINAL	15.8	—	56.00	-40.16	N	GND
2.047	FINAL	—	-1.66	46.00	-47.66	N	GND
2.047	FINAL	8.2	—	56.00	-47.79	N	GND
5.132	FINAL	—	-2.27	50.00	-52.27	N	GND
5.156	FINAL	7.1	—	60.00	-52.86	N	GND
16.384	FINAL	12.8	—	60.00	-47.19	N	GND
16.384	FINAL	—	8.40	50.00	-41.60	N	GND
29.175	FINAL	—	11.20	50.00	-38.80	N	GND
29.175	FINAL	14.3	—	60.00	-45.75	N	GND

Table 7-20. AC Line-Conducted Data (N, GFSK – 5788MHz, with host PC and lightning cable)

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 75 of 77

V 10.4 5/21/2021

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8.0 CONCLUSION

The data collected relate only to the item(s) tested and show that the **Apple Wireless Right Earbud FCC ID: BCG-A2698 and IC: 579C-A2698** 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.

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 76 of 77

V 10.4 5/21/2021

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9.0 APPENDIX A

Antenna gains provided by manufacturer.

Frequency MHz)	H (dBi)	V (dBi)
2402	-10.5	-2.6
2441	-9.6	-1.5
2480	-9.1	-1.2
5150	-7.5	-2.6
5250	-6.6	-1.7
5725	-7.5	-5.0
5850	-6.8	-4.6
5925	-5.7	-3.7
5987	-3.8	-2.0
6113	-3.3	-1.3
6176	-3.2	-1.7
6238	-4.0	-2.9
6301	-4.7	-3.2
6425	-5.2	-3.2

Table 9-1. Antenna Gains

FCC ID: BCG-A2698 IC: 579C-A2698		MEASUREMENT REPORT (CERTIFICATION)	Approved by: Technical Manager
Test Report S/N: 1C2204080015-01.BCG	Test Dates: 6/7/2022 - 8/23/2022	EUT Type: Wireless Earbud	Page 77 of 77

V 10.4 5/21/2021

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