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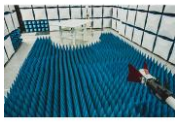


MEASUREMENT REPORT
FCC PART 15.247 / ISED RSS-247 Bluetooth

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

Date of Testing:
5/20/2024 - 7/01/2024
Test Report Issue Date:
9/3/2024
Test Site/Location:
Element Materials Technology Morgan Hill, CA, USA
Test Report Serial No.:
1C2405200017-07-R2.BCG

FCC ID:	**BCGA2993**
IC:	**579C-A2993**
APPLICANT:	**Apple Inc.**

Application Type:	Certification
Model/HVIN:	A2993
EUT Type:	Tablet Device
Max. RF Output Power:	103.039 mW (20.13 dBm) Peak Conducted
Frequency Range:	2402 – 2480MHz
Type of Modulation:	GFSK, π/4-DQPSK, 8DPSK
FCC Classification:	FCC Part 15 Spread Spectrum Transmitter (DSS)
FCC Rule Part(s):	Part 15 Subpart C (15.247)
ISED Specification:	RSS-247 Issue 3
Test Procedure(s):	ANSI C63.10-2020

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 C63.10-2020. Test results reported herein relate only to the item(s) tested.

This revised Test Report (S/N: 1C2405200017-07-R2.BCG) supersedes and replaces the previously issued test report on the same subject device for the same type of testing as indicated. Please discard or destroy the previously issued test report(s) and dispose accordingly.

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

Prepared by: WKR000007358

Reviewed by: WKR000005849

ACCREDITED
CERT #2041.02

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Scope

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

1.2 Element Materials Technology Test Location

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

1.3 Test Facility / Accreditations

Measurements were performed at Element Materials Technology.

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

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

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

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

2.0 PRODUCT INFORMATION

2.1 Equipment Description

The Equipment Under Test (EUT) is the **Apple Tablet Device FCC ID: BCGA2993 and IC: 579C-A2993**. The test data contained in this report pertains only to the emissions due to the EUT's Bluetooth transmitter.

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

Test Device Serial No.: F2DC65676T, QRQXC0F4VX, QM1447F0Y2, CWNWRCFHJ9, TD7K46CKPJ, H9HH590003X00003MW, H9HH5L0000Z0000R50

2.2 Device Capabilities

This device contains the following capabilities:

802.11b/g/n/ax WLAN, 802.11a/n/ac/ax UNII, 802.11a/ax WIFI 6E, Bluetooth (1x, EDR, LE1M, LE2M, HDR4, HDR8), NB UNII (1x, HDR4, HDR8), WPT, 802.15.4

This device supports BT Beamforming.

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

Table 2-1. Bluetooth Frequency/ Channel Operations

Note: This device is capable of operating in hopping and non-hopping mode. The EUT can hop between 79 different channels in the 2400 – 2483.5MHz band. The maximum achievable duty cycles for all modes were determined based on measurements performed on a spectrum analyzer in zero-span mode with RBW = 8MHz, VBW = 50MHz, and detector = peak per the guidance of Section 6.0 b) of KDB 558074 D01 v05r02 and ANSI C63.10-2020. 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						
Bluetooth Mode			Duty Cycle [%]			
			Antenna WF8	Antenna WF7	Antenna WF2	TxBF
2.4 GHz	GFSK	ePA	100.0	100.0	N/A	100.0
		iPA	100.0	100.0	100.0	100.0
	8PSK	ePA	100.0	100.0	N/A	100.0
		iPA	100.0	100.0	100.0	100.0
	π/4-DQPSK	ePA	100.0	100.0	N/A	100.0
		iPA	100.0	100.0	100.0	100.0

Table 2-2. Measured Duty Cycles

This device supports simultaneous transmission operations, which allows for multiple transmitters to transmit simultaneously on the same antenna. The table below shows all configurations possible.

Antenna	Simultaneous Tx Config	Wifi 2GHz	Bluetooth	Thread	Wifi 5GHz	Wifi 6GHz	NB UNII
		802.11 b/g/n/ax	BDR, EDR, HDR4/8, LE1/2M	802.15.4	802.11 a/n/ac/ax	802.11 a/ax	BDR, HDR4/8
WF2	Config 1	✗	✓	✗	✗	✓	✗
WF2	Config 2	✗	✓	✗	✓	✗	✗
WF2	Config 3	✗	✗	✓	✗	✓	✗
WF2	Config 4	✗	✗	✓	✓	✗	✗

Table 2-3. Simultaneous Transmission Configurations

✓ = Support; × = Not Support

Note:

Specific 2.4GHz Wi-Fi antenna that can only transmit simultaneously with 2.4GHz Bluetooth antenna is listed in the SAR test report. For BT (2.4GHz), in both connected and disconnected modes, and Wi-Fi (2.4GHz) - Wi-Fi max power will not exceed minimum of (13.5dBm, SAR max cap, Reg max cap) power. Bluetooth can simultaneously transmit with IEEE 802.11a/n/ac/ax 5/6 GHz on separate antenna.

2.3 Antenna Description

Following antenna gains provided by manufacturer were used for testing.

Frequency [GHz]	Antenna Gain (dBi)		
	Antenna WF8	Antenna WF7	Antenna WF2
2.4	0.7	0.8	-8.6

Table 2-4. Highest Antenna Gain

2.4 Test Support Equipment

1	Apple MacBook Pro	Model:	A2141	S/N:	C02H604EQ05D
	w/AC/DC Adapter	Model:	A2166	S/N:	C4H042705ZNPM0WA6
2	Apple USB-C Cable	Model:	Spartan	S/N:	GXK1336018XKTR024
3	USB-C Cable	Model:	A246C	S/N:	DWH80115BK826GV19
	w/ AC Adapter	Model:	A2305	S/N:	C4H95160004PF4F4V
4	Apple Pencil	Model:	A2538	S/N:	KJ26TCFXJW
5	DC Power Supply	Model:	KPS3010D	S/N:	N/A

Table 2-5. Test Support Equipment List

2.5 Test Configuration

The EUT was tested per the guidance of ANSI C63.10-2020. ANSI C63.10-2020 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.

There are two vendors of the WiFi/Bluetooth radio modules, variant 1 and variant 2. Both radio modules have the same mechanical outline, same on-board antenna matching circuit, identical antenna structure, and are built and tested to conform to the same specifications and to operate within the same tolerances. The worst case configuration was found between the two variants. The EUT was also investigated with and without charger.

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 powered by AC/DC adaptor via USB-C cable with wire charger
- EUT powered by host PC via USB-C cable with wire charger

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

All possible simultaneous transmission configurations have been investigated and the worst case config has been reported.

Description	UNII	Bluetooth
Antenna	Antenna WF2	Antenna WF2
Channel	36	78
Operating Frequency (MHz)	5180	2480
Mode/Modulation	802.11n	GFSK iPa

Table 2-6. Worst Case Simultaneous Transmission Configuration

2.6 Software and Firmware

The test was conducted with firmware version 22A312 installed on the EUT.

2.7 EMI Suppression Device(s)/Modifications

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

3.0 DESCRIPTION OF TESTS

3.1 Evaluation Procedure

The measurement procedure described in the American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices (ANSI C63.10-2020) was used in the measurement of the EUT**.**

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

3.2 AC Line Conducted Emissions

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

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

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

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

3.3 Radiated Emissions

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

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

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

Final measurements were made in the semi-anechoic chamber using calibrated, linearly polarized broadband and horn antennas. The test setup was configured to the setup that produced the worst case emissions. The spectrum analyzer was set to investigate all frequencies required for testing to compare the highest radiated disturbances with respect to the specified limits. The turntable containing the EUT was rotated through 360 degrees and the height of the receive antenna was varied 1 to 4 meters and stopped at the azimuth and height producing the maximum emission. Each emission was maximized by changing the orientation of the EUT through 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 15ºC to 35ºC. The relative humidity is controlled within range of 10% to 75%. The atmospheric pressure is monitored within the range 86-106kPa (860-1060mbar).

4.0 ANTENNA REQUIREMENTS

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

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

Conclusion:

The EUT complies with the requirement of §15.203.

5.0 MEASUREMENT UNCERTAINTY

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

Contribution	Expanded Uncertainty (±dB)
Conducted Bench Top Measurements	2.07
AC Line Conducted Disturbance	1.91
Radiated Disturbance (<30MHz)	4.12
Radiated Disturbance (30MHz - 1GHz)	4.85
Radiated Disturbance (1 - 18GHz)	5.08
Radiated Disturbance (>18GHz)	5.22

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 Number
Agilent Technologies	N9030A	3Hz-26.5GHz PXA Signal Analyzer	10/18/2023	Annual	10/18/2024	MY55330128
Anritsu	ML2495A	Power Meter	7/8/2024	Annual	7/8/2025	1039008
Anritsu	MA2411B	Pulse Power Sensor	7/1/2024	Annual	7/1/2025	1911105
Anritsu	MA2411B	Pulse Power Sensor	11/8/2023	Annual	11/8/2024	1027293
ATM	180-442A-KF	20dB Nominal Gain Horn Antenna	3/14/2024	Annual	3/14/2025	T058701-01
ETS-Lindgren	3117	Double Ridged Guide Antenna (1-18 GHz)	4/9/2024	Annual	4/9/2025	00218555
Fairview Microwave/MCL	FMCA1975-36/BW-K10-2W44+	30MHz-40GHz Conducted Cable/Attenuator *	6/10/2024	Annual	6/10/2025	-
Keysight Technology	N9040B	UXA Signal Analyzer	5/28/2024	Annual	5/28/2025	MY57212015
Rohde & Schwarz	TS-PR18	Pre-Amplifier (1GHz - 18GHz)	8/15/2023	Annual	8/15/2024	101639
Rohde & Schwarz	TS-PR18	Pre-Amplifier (1GHz - 18GHz)	8/14/2024	Annual	8/15/2025	101648
Rohde & Schwarz	FSV40	Signal Analyzer (10Hz-40GHz)	5/29/2024	Annual	5/29/2025	101619
Rohde & Schwarz	ESW44	EMI Test Receiver	5/1/2024	Annual	5/1/2025	101867
Rohde & Schwarz	TS-PR8	Pre-Amplifier (30MHz - 8GHz)	7/3/2024	Annual	7/3/2025	102356
Rohde & Schwarz	TS-PR1840	Pre-Amplifier (18GHz - 40GHz)	6/10/2024	Annual	6/10/2025	100057
Rohde & Schwarz	HFH2-Z2	Loop Antenna	6/21/2024	Annual	6/21/2025	100519
Rohde & Schwarz	ENV216	Two-Line V-Network	4/24/2024	Annual	4/24/2025	101364
Schwarzbeck	VULB 9162	Bilog Antenna (30MHz - 6GHz)	4/29/2024	Annual	4/29/2025	00304

Table 6-1. Test Equipment List

Notes:

1. 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.
2. * denotes passive equipment that have been internally verified/calibrated.

7.0 TEST RESULTS

7.1 Summary

Company Name: Apple Inc.

FCC ID: BCGA2993

IC: 579C-A2993

Method/System: Frequency Hopping Spread Spectrum (FHSS)

Number of Channels: 79

FCC Part Section(s)	RSS Section(s)	Test Description	Test Limit	Test Condition	Test Result	Reference
15.247(a)(1)	RSS-247 [5.1(a)]	20dB Bandwidth	N/A	CONDUCTED	N/A	Section 7.2
2.1049	RSS-Gen [6.7]	Occupied Bandwidth	N/A		N/A	Section 7.2
15.247(b)(1)	RSS-247 [5.4(b)]	Peak Transmitter Output Power	< 1 Watt if ≥ 75 non-overlapping channels used		PASS	Section 7.3
15.247(a)(1)	RSS-247 [5.1(b)]	Channel Separation	> 2/3 of 20 dB BW for systems with Output Power < 125mW		PASS	Section 7.5
15.247(a)(1)(iii)	RSS-247 [5.1(d)]	Time of Occupancy	< 0.4 sec in 31.6 sec period		PASS	Section 7.6
15.247(a)(1)(iii)	RSS-247 [5.1(d)]	Number of Channels	> 15 Channels		PASS	Section 7.7
15.247(d)	RSS-247 [5.5]	Band Edge / Out-of-Band Emissions	> 20dBc		PASS	Section 7.4, 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, 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 "Conducted Automation" Version 1.1.0.
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 3.0.0.

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 C63.10-2020 – Subclause 6.9.2
RSS-Gen [6.7]

Test Settings

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

Test Setup

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

Figure 7-1. Test Instrument & Measurement Setup

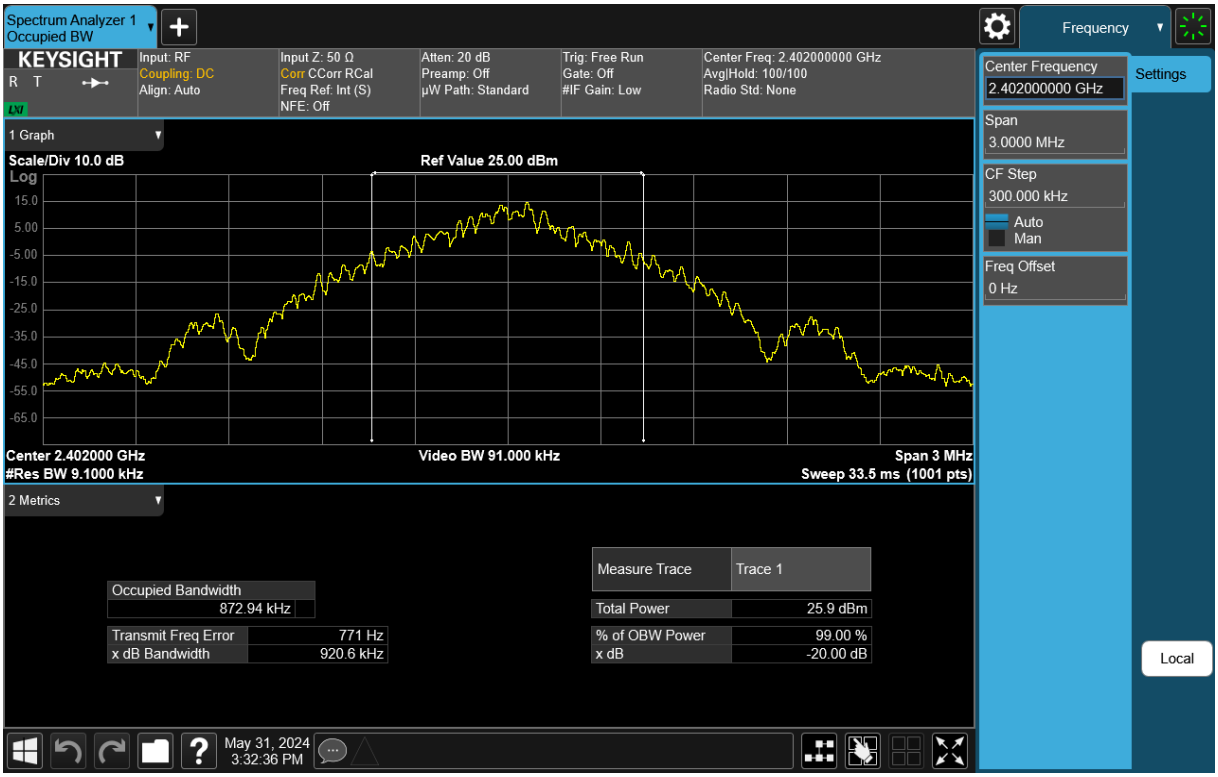
Test Notes

All supported modulation, antenna (including TxBF mode) and power schemes have been tested on the unit and only worst case configuration is reported.

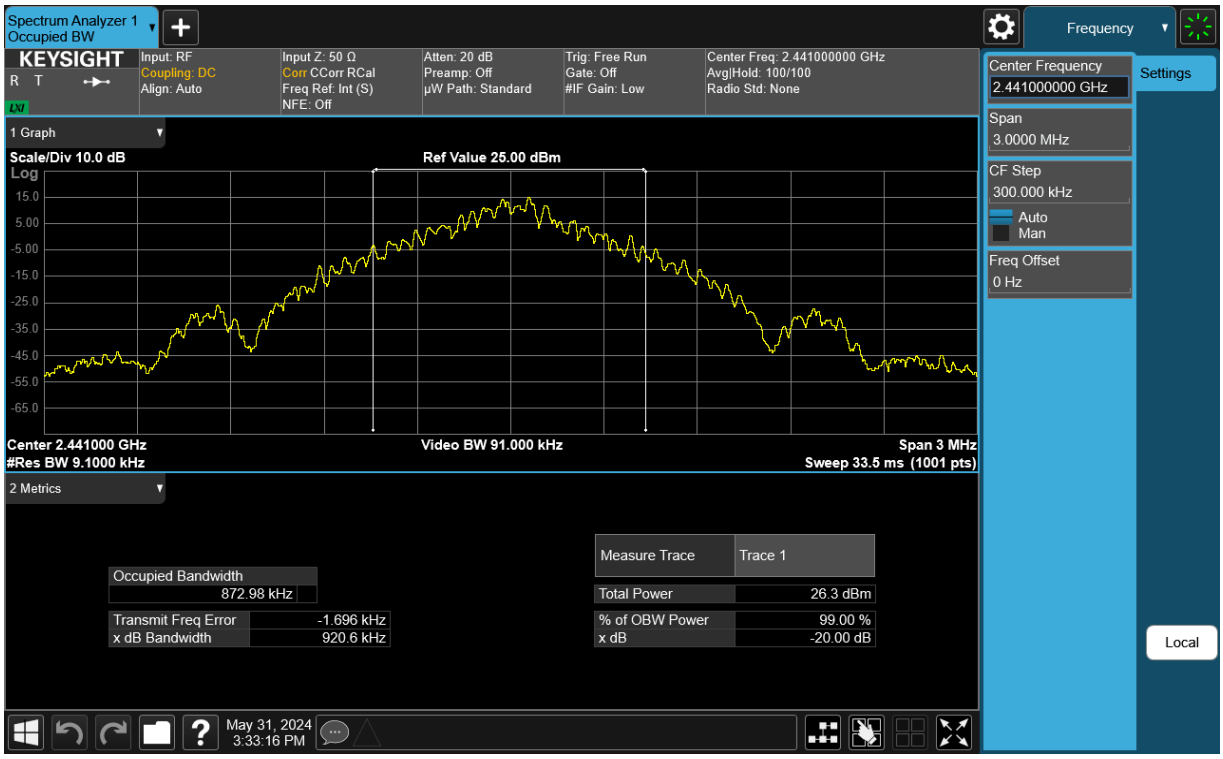
Antenna WF8

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Measured 99% Occupied Bandwidth [kHz]	Measured 20dB Bandwidth [kHz]
2402	1.0	GFSK	ePA	0	872.94	920.64
2441	1.0	GFSK	ePA	39	872.98	920.56
2480	1.0	GFSK	ePA	78	872.65	920.42
2402	3.0	8DPSK	ePA	0	1207.90	1345.66
2441	3.0	8DPSK	ePA	39	1208.37	1346.33
2480	3.0	8DPSK	ePA	78	1208.64	1346.59

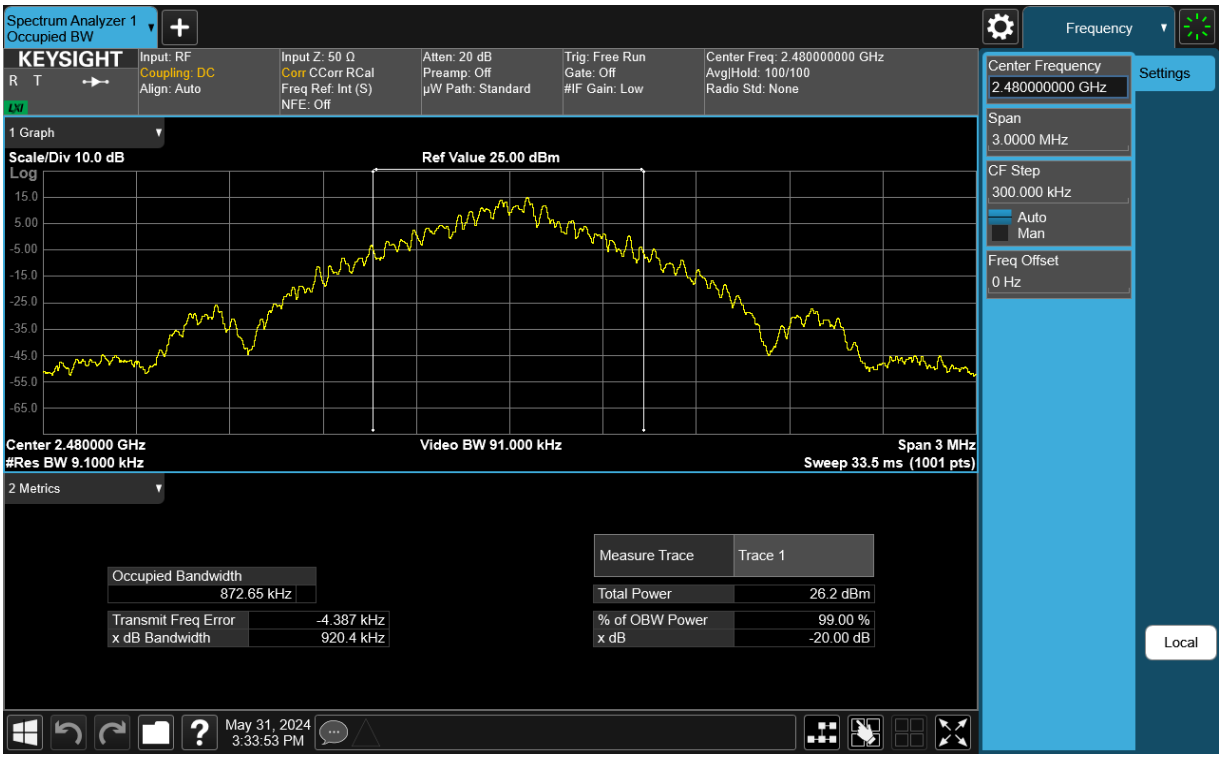
Table 7-2. 20dB BW and 99% OBW Measurements Antenna WF8



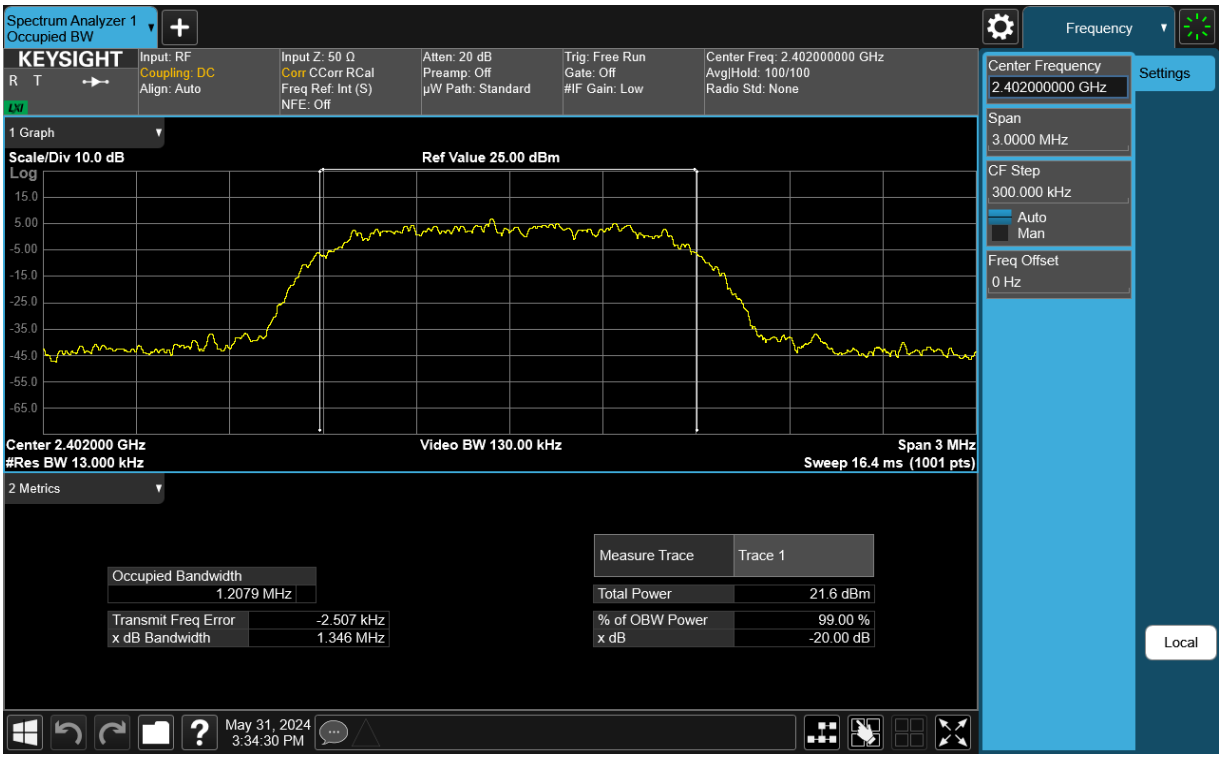
Plot 7-1. 20dB BW and 99% OBW Plot Antenna WF8 (Bluetooth, GFSK, ePA – Ch. 0)



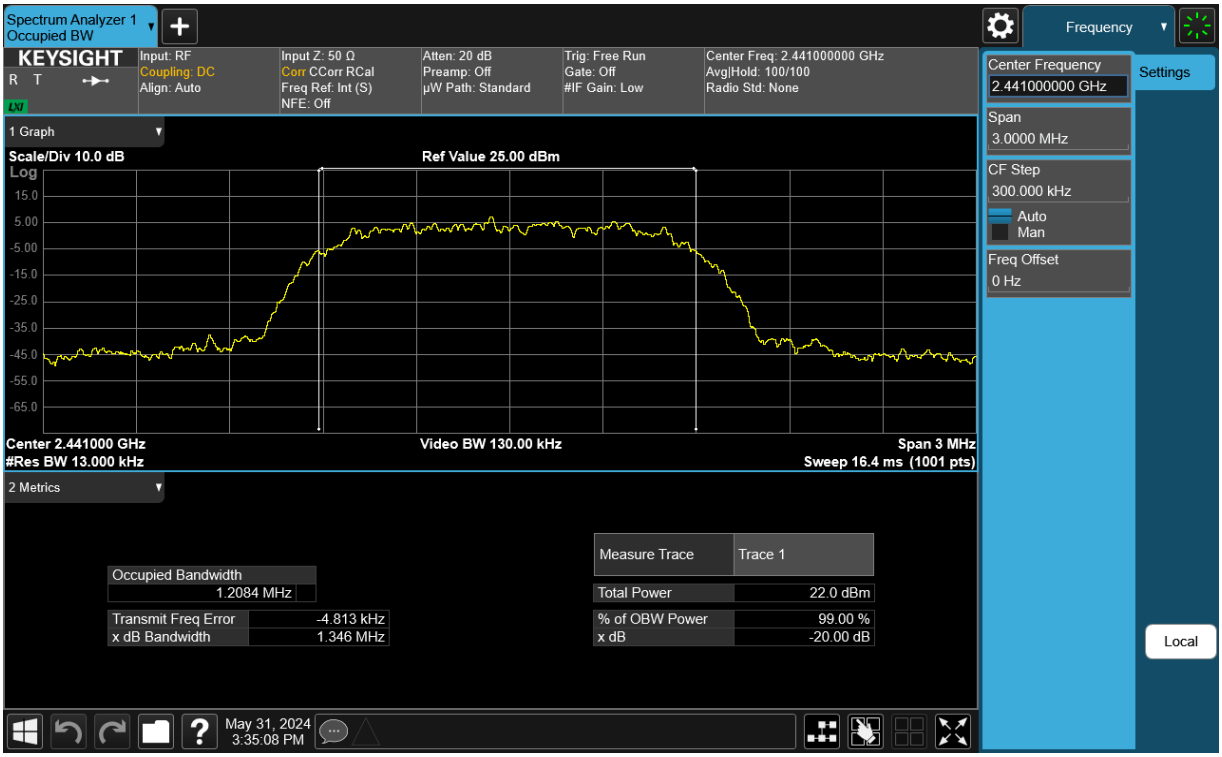
Plot 7-2. 20dB BW and 99% OBW Plot Antenna WF8 (Bluetooth, GFSK, ePA – Ch. 39)



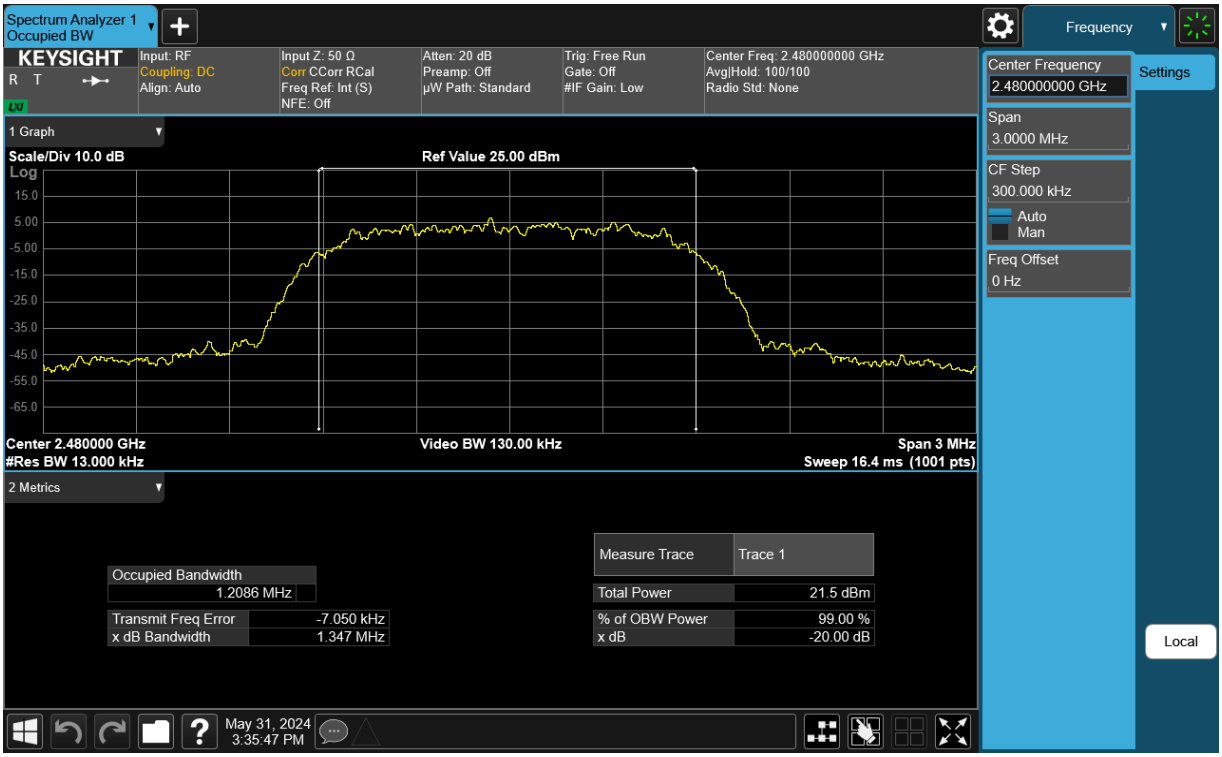
Plot 7-3. 20dB BW and 99% OBW Plot Antenna WF8 (Bluetooth, GFSK, ePA – Ch. 78)



Plot 7-4. 20dB BW and 99% OBW Plot Antenna WF8 (Bluetooth, 8DPSK, ePA – Ch. 0)



Plot 7-5. 20dB BW and 99% OBW Plot Antenna WF8 (Bluetooth, 8DPSK, ePA – Ch. 39)

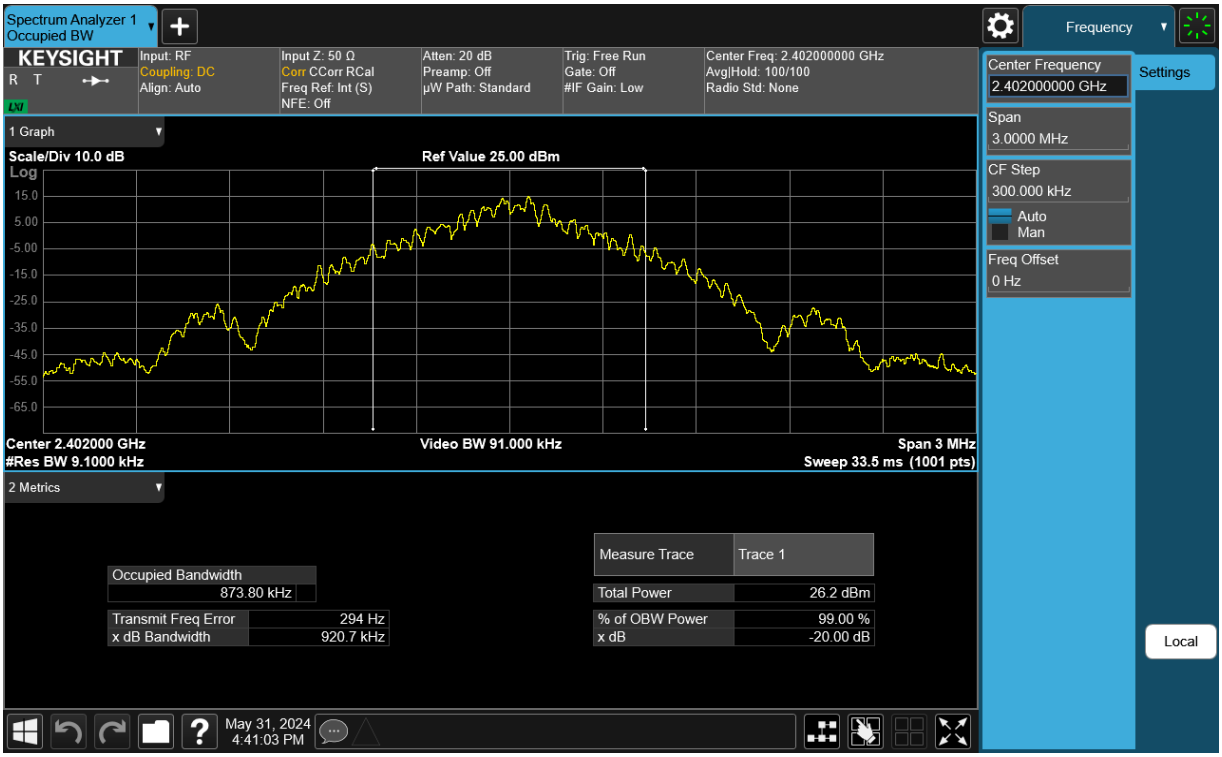


Plot 7-6. 20dB BW and 99% OBW Plot Antenna WF8 (Bluetooth, 8DPSK, ePA – Ch. 78)

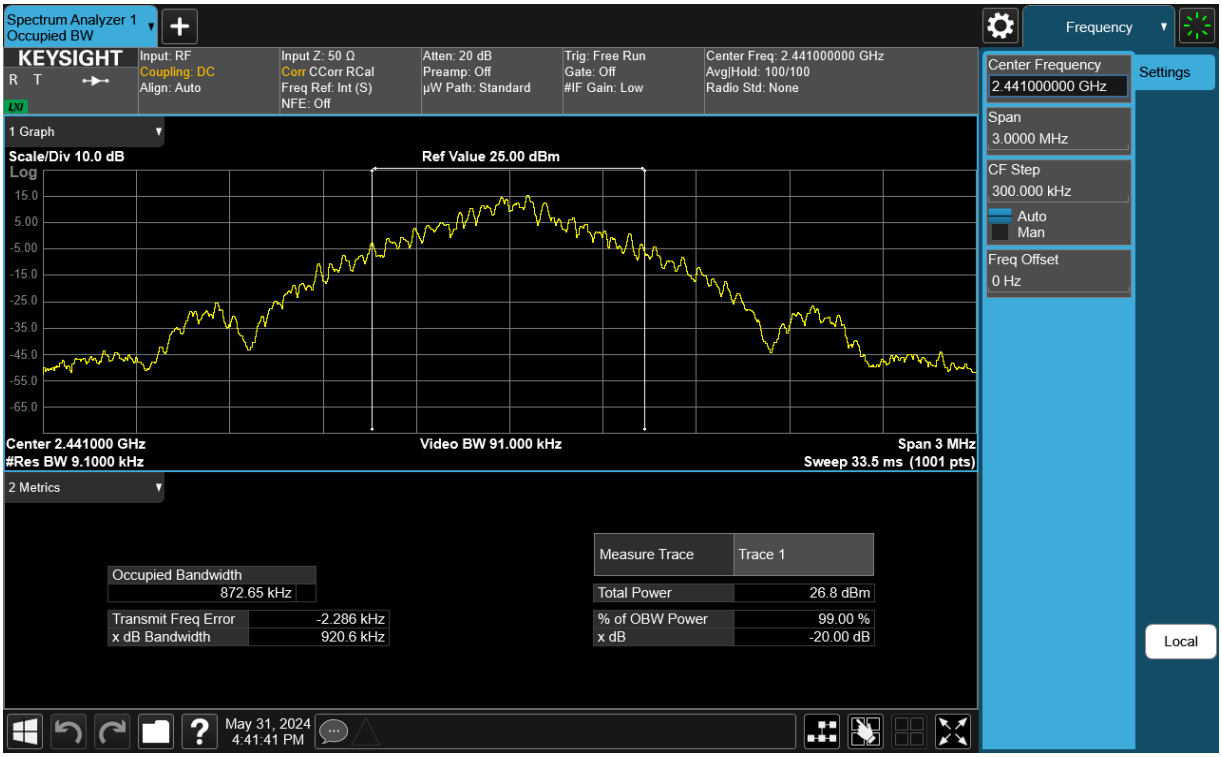
Antenna WF7

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Measured 99% Occupied Bandwidth [kHz]	Measured 20dB Bandwidth [kHz]
2402	1.0	GFSK	ePA	0	873.80	920.72
2441	1.0	GFSK	ePA	39	872.65	920.64
2480	1.0	GFSK	ePA	78	873.03	920.61
2402	3.0	8DPSK	ePA	0	1208.43	1345.61
2441	3.0	8DPSK	ePA	39	1209.16	1346.68
2480	3.0	8DPSK	ePA	78	1209.18	1346.66

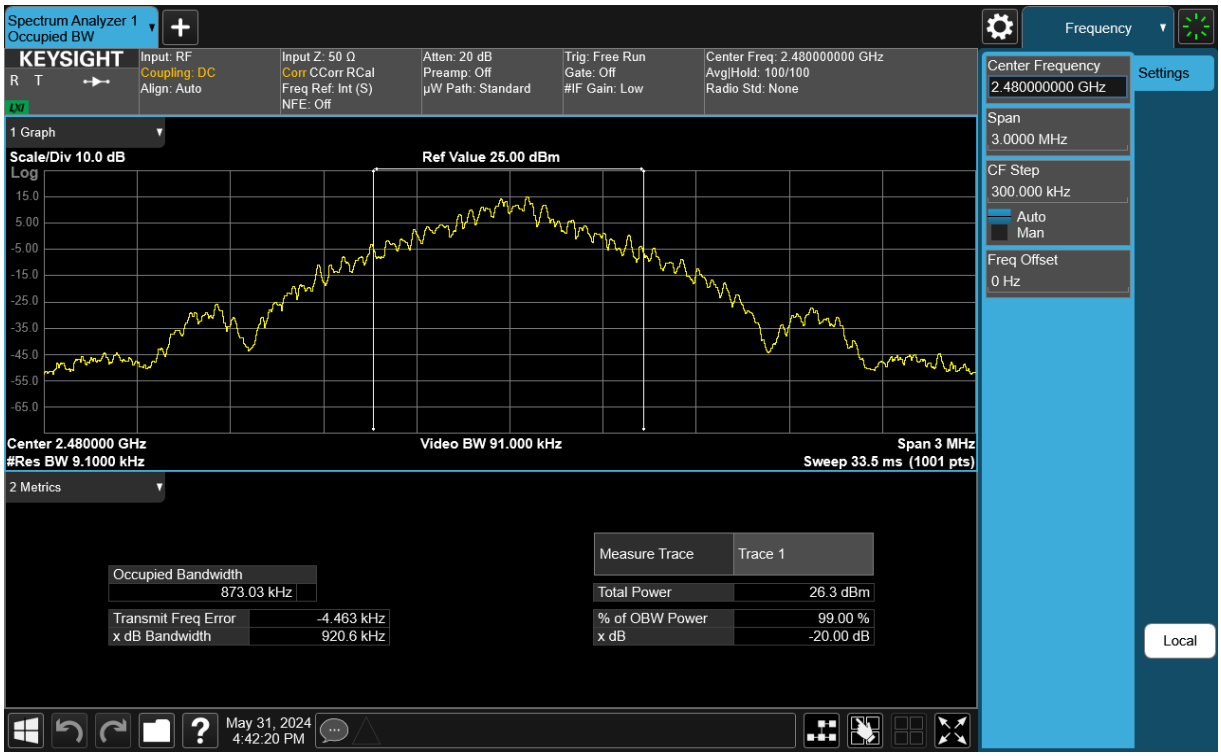
Table 7-3. 20dB BW and 99% OBW Bandwidth Measurements Antenna WF7



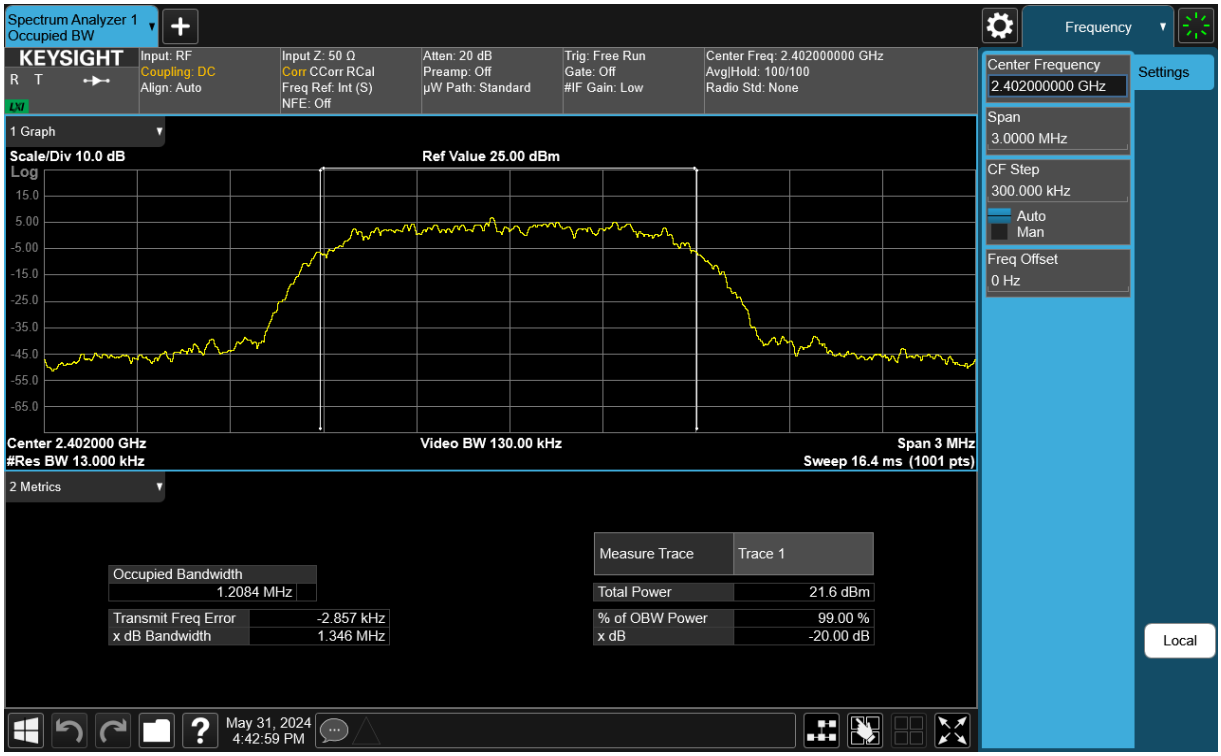
Plot 7-7. 20dB BW and 99% OBW Plot Antenna WF7 (Bluetooth, GFSK, ePA – Ch. 0)



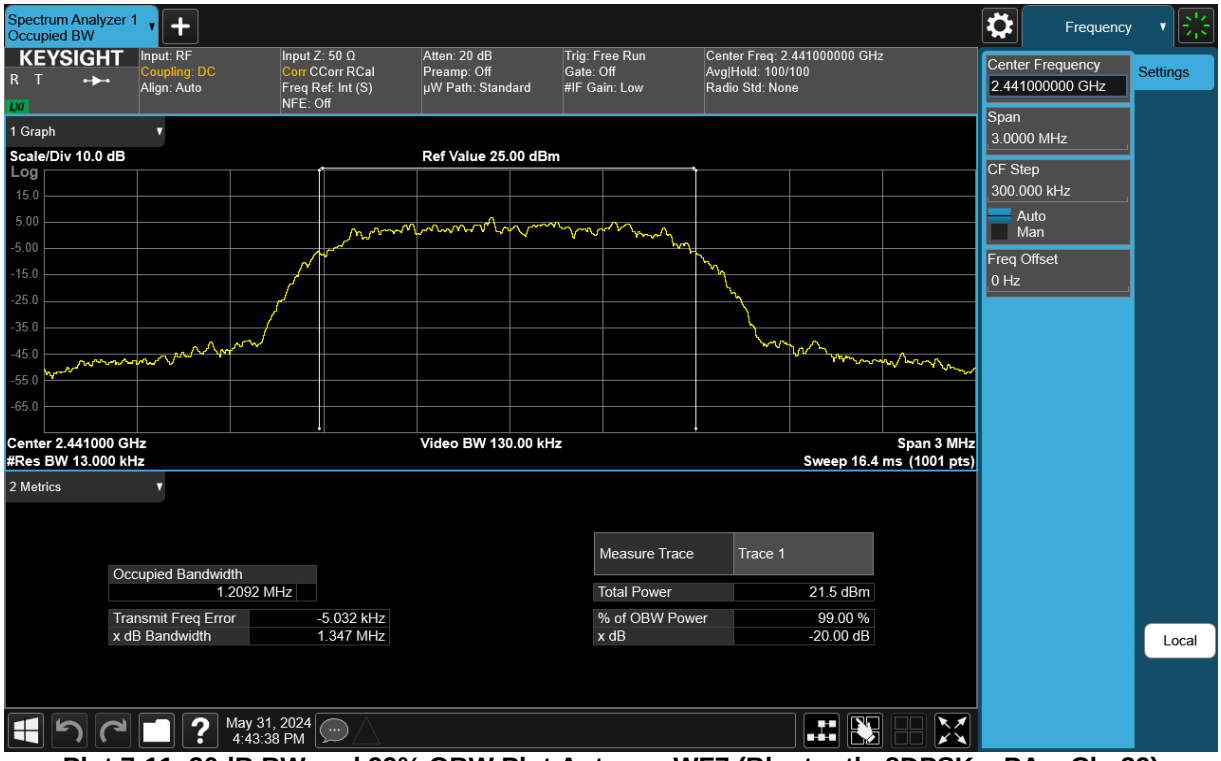
Plot 7-8. 20dB BW and 99% OBW Plot Antenna WF7 (Bluetooth, GFSK, ePA – Ch. 39)



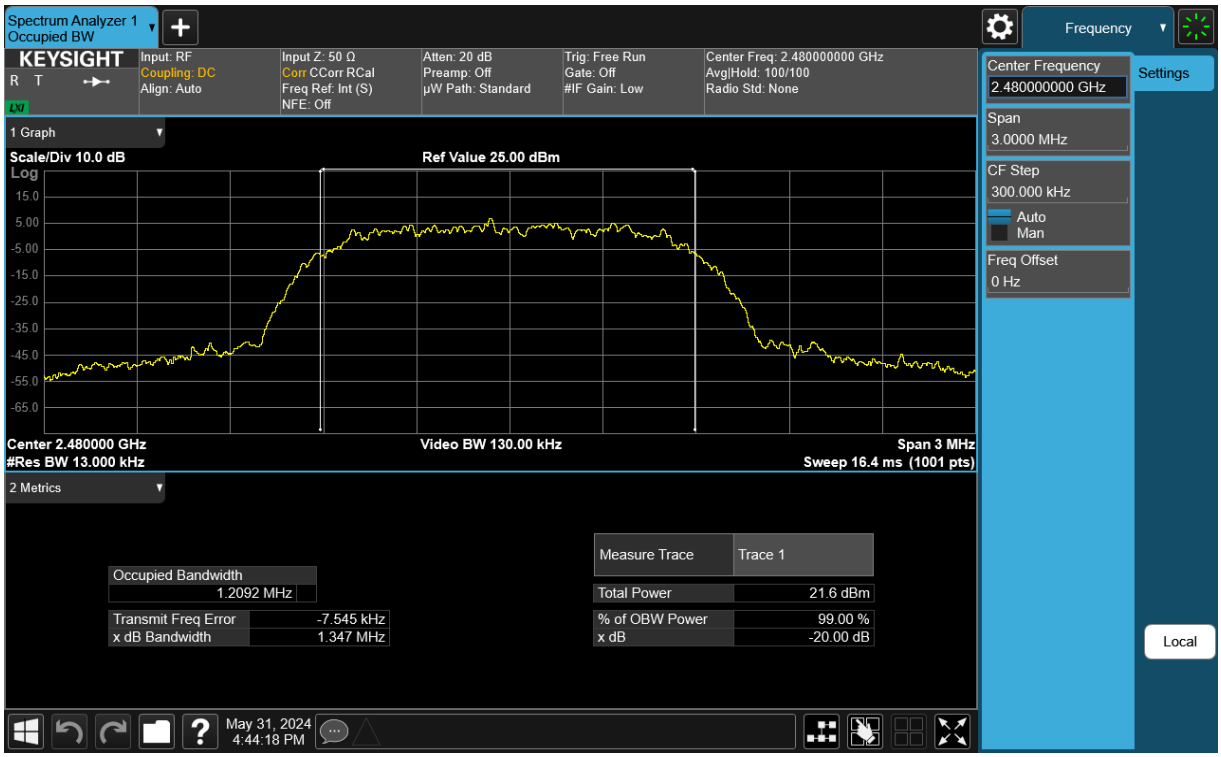
Plot 7-9. 20dB BW and 99% OBW Plot Antenna WF7 (Bluetooth, GFSK, ePA – Ch. 78)



Plot 7-10. 20dB BW and 99% OBW Plot Antenna WF7 (Bluetooth, 8DPSK, ePA – Ch. 0)



Plot 7-11. 20dB BW and 99% OBW Plot Antenna WF7 (Bluetooth, 8DPSK, ePA – Ch. 39)

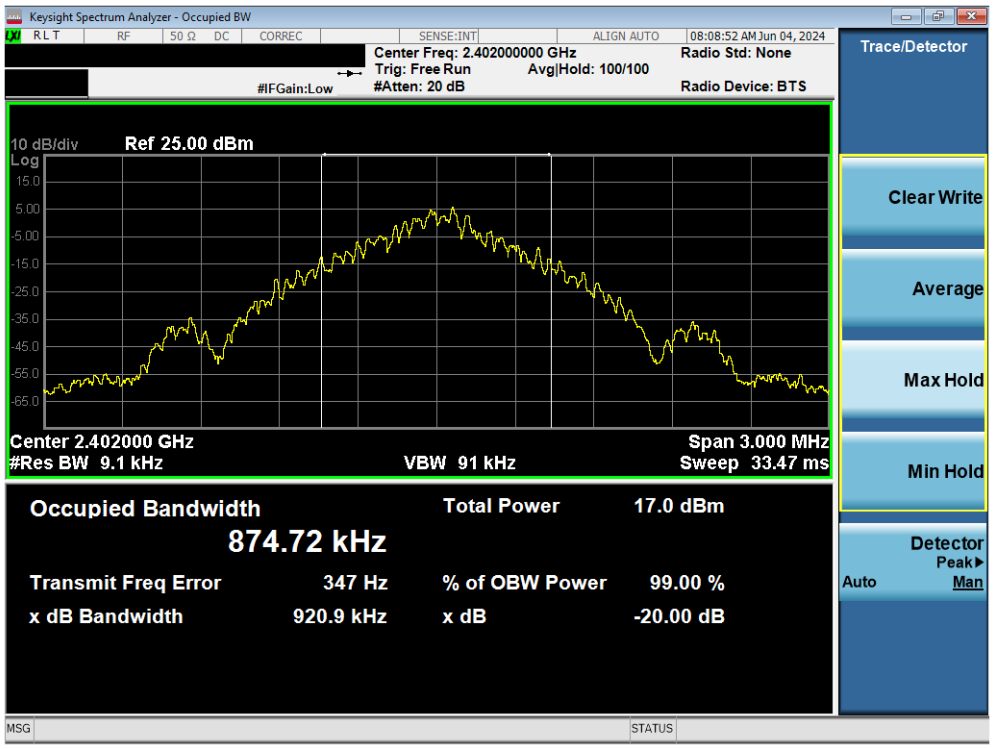


Plot 7-12. 20dB BW and 99% OBW Plot Antenna WF7 (Bluetooth, 8DPSK, ePA – Ch. 78)

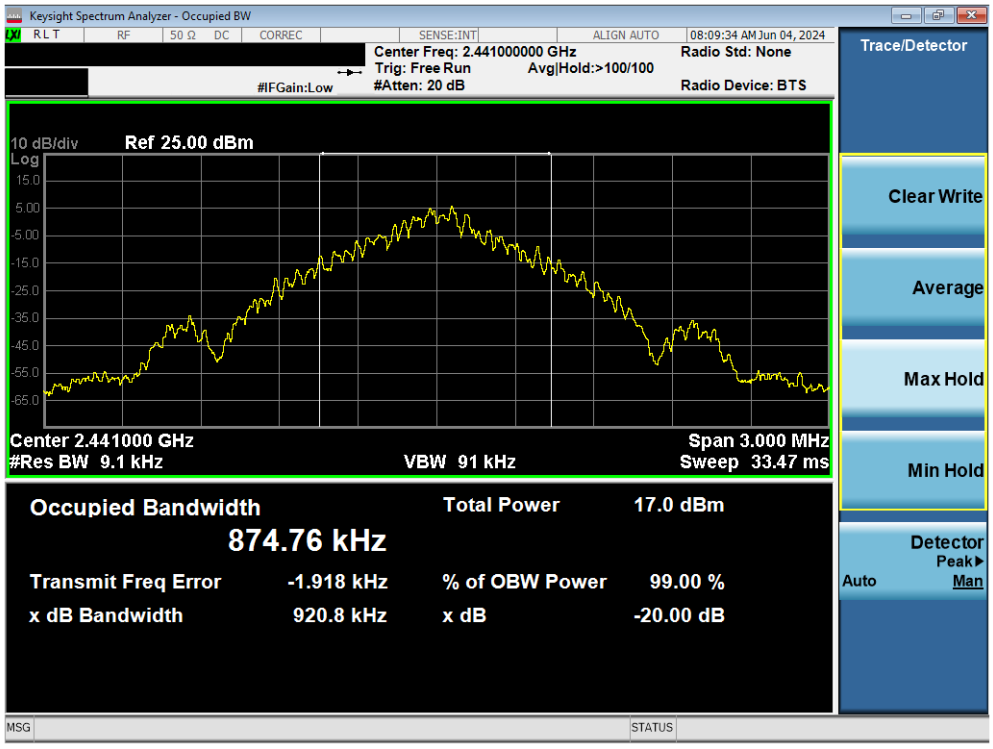
Antenna WF2

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Measured 99% Occupied Bandwidth [kHz]	Measured 20dB Bandwidth [kHz]
2402	1.0	GFSK	iPA	0	874.72	920.94
2441	1.0	GFSK	iPA	39	874.76	920.77
2480	1.0	GFSK	iPA	78	874.35	920.59
2402	3.0	8DPSK	iPA	0	1212.98	1348.74
2441	3.0	8DPSK	iPA	39	1213.28	1349.48
2480	3.0	8DPSK	iPA	78	1213.71	1349.63

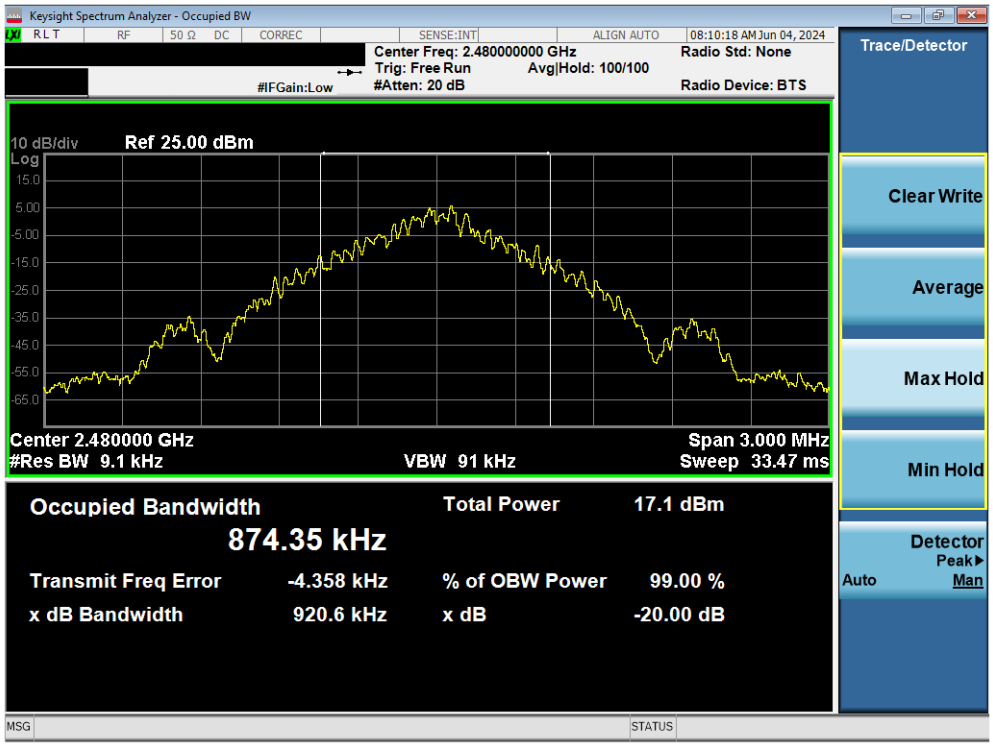
Table 7-4. 20dB BW and 99% OBW Bandwidth Measurements Antenna WF2



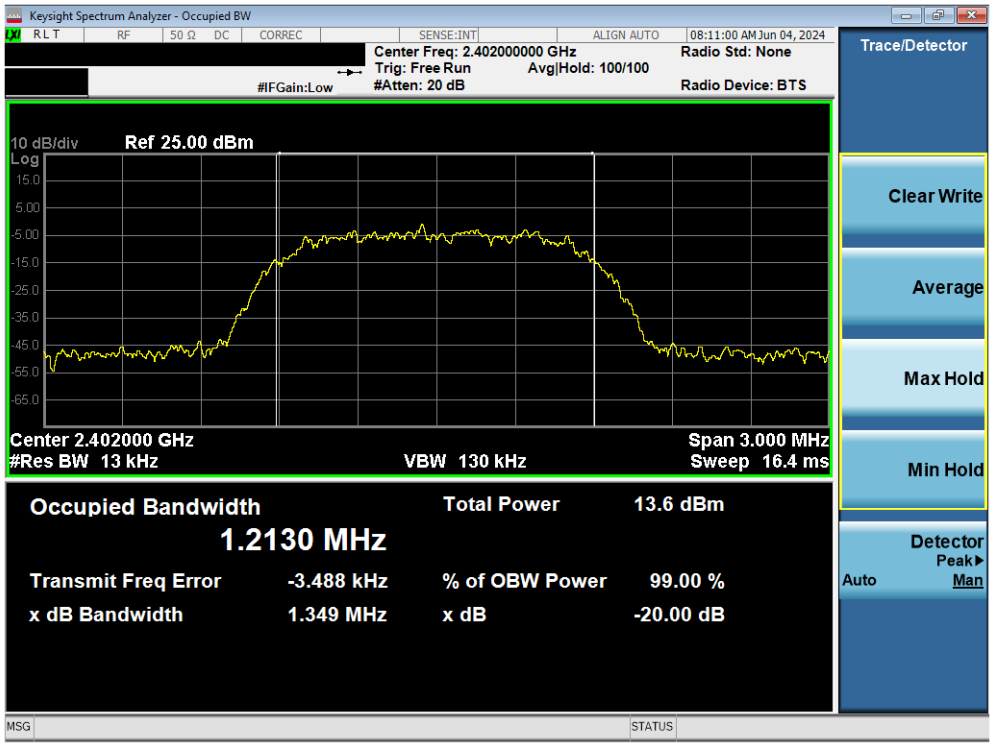
Plot 7-13. 20dB BW and 99% OBW Plot Antenna WF2 (Bluetooth, GFSK, iPA – Ch. 0)



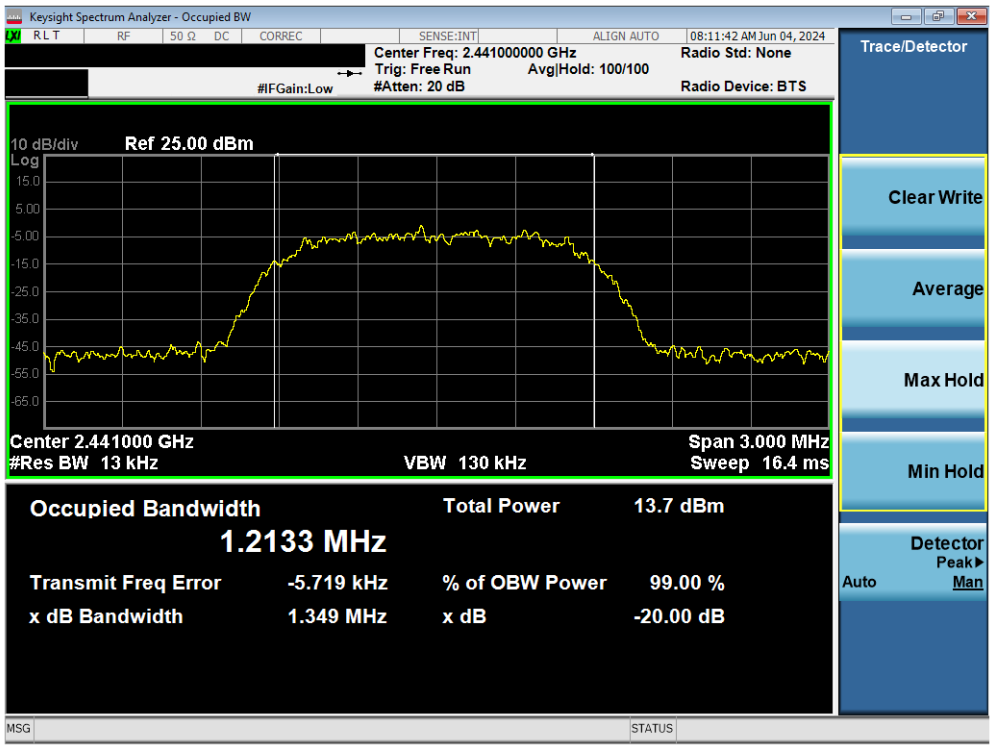
Plot 7-14. 20dB BW and 99% OBW Plot Antenna WF2 (Bluetooth, GFSK, iPA – Ch. 39)



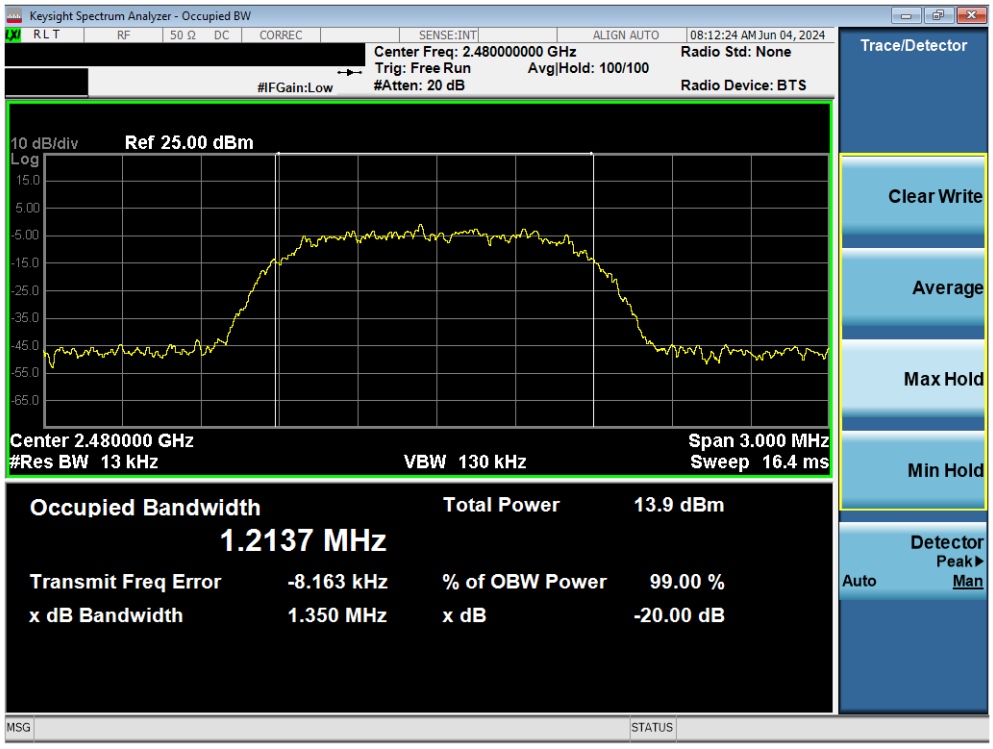
Plot 7-15. 20dB BW and 99% OBW Plot Antenna WF2 (Bluetooth, GFSK, iPA – Ch. 78)



Plot 7-16. 20dB BW and 99% OBW Plot Antenna WF2 (Bluetooth, 8DPSK, iPA – Ch. 0)



Plot 7-17. 20dB BW and 99% OBW Plot Antenna WF2 (Bluetooth, 8DPSK, iPA – Ch. 39)



Plot 7-18. 20dB BW and 99% OBW Plot Antenna WF2 (Bluetooth, 8DPSK, iPA – Ch. 78)

7.3 Output Power Measurement

§15.247 (b.1); RSS-247 [5.4(b)]

Test Overview and Limits

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

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

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

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

Test Procedure Used

ANSI C63.10-2020 – Subclause 7.8.5
ANSI C63.10-2020 – Subclause 11.9.2.3.2 Method AVGPM-G
ANSI C63.10-2020 – Subclause 14.4 Measure-and-Sum Technique

Test Settings

Peak Power Measurement

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

Method AVGPM-G (Average Power Measurement)

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

Test Setup

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

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

Note

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

7.3.1 Peak Output Power Measurement

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Peak Conducted Power		Conducted Power Limit [dBm]	Conducted Power Margin [dB]	Ant. Gain [dBi]	EIRP [dBm]	EIRP Limit [dBm]	EIRP Margin [dB]
					[dBm]	[mW]						
2402	1.0	GFSK	ePA	0	19.71	93.541	30.00	-10.29	0.70	20.41	36.02	-15.61
2441	1.0	GFSK	ePA	39	19.54	89.950	30.00	-10.46	0.70	20.24	36.02	-15.78
2480	1.0	GFSK	ePA	78	19.36	86.298	30.00	-10.64	0.70	20.06	36.02	-15.96
2402	1.0	GFSK	iPA	0	12.34	17.140	30.00	-17.66	0.70	13.04	36.02	-22.98
2441	1.0	GFSK	iPA	39	12.34	17.140	30.00	-17.66	0.70	13.04	36.02	-22.98
2480	1.0	GFSK	iPA	78	12.38	17.298	30.00	-17.62	0.70	13.08	36.02	-22.94
2402	3.0	8DPSK	ePA	0	18.17	65.615	30.00	-11.83	0.70	18.87	36.02	-17.15
2441	3.0	8DPSK	ePA	39	18.12	64.863	30.00	-11.88	0.70	18.82	36.02	-17.20
2480	3.0	8DPSK	ePA	78	18.03	63.533	30.00	-11.97	0.70	18.73	36.02	-17.29
2402	3.0	8DPSK	iPA	0	10.93	12.388	30.00	-19.07	0.70	11.63	36.02	-24.39
2441	3.0	8DPSK	iPA	39	11.01	12.618	30.00	-18.99	0.70	11.71	36.02	-24.31
2480	3.0	8DPSK	iPA	78	11.36	13.677	30.00	-18.64	0.70	12.06	36.02	-23.96

Table 7-5. Peak Conducted Output Power Measurements Antenna WF8

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Peak Conducted Power		Conducted Power Limit [dBm]	Conducted Power Margin [dB]	Ant. Gain [dBi]	EIRP [dBm]	EIRP Limit [dBm]	EIRP Margin [dB]
					[dBm]	[mW]						
2402	1.0	GFSK	ePA	0	19.69	93.111	30.00	-10.31	0.80	20.49	36.02	-15.53
2441	1.0	GFSK	ePA	39	19.56	90.365	30.00	-10.44	0.80	20.36	36.02	-15.66
2480	1.0	GFSK	ePA	78	19.65	92.257	30.00	-10.35	0.80	20.45	36.02	-15.57
2402	1.0	GFSK	iPA	0	12.80	19.055	30.00	-17.20	0.80	13.60	36.02	-22.42
2441	1.0	GFSK	iPA	39	12.85	19.275	30.00	-17.15	0.80	13.65	36.02	-22.37
2480	1.0	GFSK	iPA	78	12.82	19.143	30.00	-17.18	0.80	13.62	36.02	-22.40
2402	3.0	8DPSK	ePA	0	17.83	60.674	30.00	-12.17	0.80	18.63	36.02	-17.39
2441	3.0	8DPSK	ePA	39	17.73	59.293	30.00	-12.27	0.80	18.53	36.02	-17.49
2480	3.0	8DPSK	ePA	78	17.84	60.814	30.00	-12.16	0.80	18.64	36.02	-17.38
2402	3.0	8DPSK	iPA	0	11.62	14.521	30.00	-18.38	0.80	12.42	36.02	-23.60
2441	3.0	8DPSK	iPA	39	11.59	14.421	30.00	-18.41	0.80	12.39	36.02	-23.63
2480	3.0	8DPSK	iPA	78	11.44	13.932	30.00	-18.56	0.80	12.24	36.02	-23.78

Table 7-6. Peak Conducted Output Power Measurements Antenna WF7

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Peak Conducted Power		Conducted Power Limit [dBm]	Conducted Power Margin [dB]	Ant. Gain [dBi]	EIRP [dBm]	EIRP Limit [dBm]	EIRP Margin [dB]
					[dBm]	[mW]						
2402	1.0	GFSK	iPA	0	11.75	14.962	30.00	-18.25	-8.60	3.15	36.02	-32.87
2441	1.0	GFSK	iPA	39	11.95	15.668	30.00	-18.05	-8.60	3.35	36.02	-32.67
2480	1.0	GFSK	iPA	78	11.99	15.812	30.00	-18.01	-8.60	3.39	36.02	-32.63
2402	3.0	8DPSK	iPA	0	10.82	12.078	30.00	-19.18	-8.60	2.22	36.02	-33.80
2441	3.0	8DPSK	iPA	39	10.91	12.331	30.00	-19.09	-8.60	2.31	36.02	-33.71
2480	3.0	8DPSK	iPA	78	10.95	12.445	30.00	-19.05	-8.60	2.35	36.02	-33.67

Table 7-7. Peak Conducted Output Power Measurements Antenna WF2

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Peak Conducted Power						Conducted Power Limit [dBm]	Conducted Power Margin [dB]	Directional Ant. Gain [dBi]	EIRP [dBm]	EIRP Limit [dBm]	EIRP Margin [dB]
					Antenna WF8		Antenna WF7		Summed							
					[dBm]	[mW]	[dBm]	[mW]	[dBm]	[mW]						
2402	1.0	GFSK	ePA	0	17.11	51.404	16.89	48.865	20.01	100.231	30.00	-9.99	3.76	23.77	36.02	-12.25
2441	1.0	GFSK	ePA	39	17.00	50.119	16.83	48.195	19.92	98.175	30.00	-10.08	3.76	23.68	36.02	-12.34
2480	1.0	GFSK	ePA	78	17.06	50.816	17.18	52.240	20.13	103.039	30.00	-9.87	3.76	23.89	36.02	-12.13
2402	1.0	GFSK	iPA	0	12.20	16.596	12.74	18.793	15.49	35.400	30.00	-14.51	3.76	19.25	36.02	-16.77
2441	1.0	GFSK	iPA	39	12.31	17.022	12.68	18.535	15.51	35.563	30.00	-14.49	3.76	19.27	36.02	-16.75
2480	1.0	GFSK	iPA	78	12.24	16.749	13.16	20.701	15.74	37.497	30.00	-14.26	3.76	19.50	36.02	-16.52
2402	3.0	8DPSK	ePA	0	16.46	44.259	16.25	42.170	19.37	86.497	30.00	-10.63	3.76	23.13	36.02	-12.89
2441	3.0	8DPSK	ePA	39	16.31	42.756	16.32	42.855	19.33	85.704	30.00	-10.67	3.76	23.09	36.02	-12.93
2480	3.0	8DPSK	ePA	78	16.37	43.351	16.26	42.267	19.32	85.507	30.00	-10.68	3.76	23.08	36.02	-12.94
2402	3.0	8DPSK	iPA	0	11.31	13.521	11.49	14.093	14.41	27.606	30.00	-15.59	3.76	18.17	36.02	-17.85
2441	3.0	8DPSK	iPA	39	11.23	13.274	11.42	13.868	14.34	27.164	30.00	-15.66	3.76	18.10	36.02	-17.92
2480	3.0	8DPSK	iPA	78	11.15	13.032	11.40	13.804	14.29	26.853	30.00	-15.71	3.76	18.05	36.02	-17.97

Table 7-8. Peak Conducted Output Power Measurements TxBF

7.3.2 Average Output Power Measurement

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Avg Conducted Power		Conducted Power Limit [dBm]	Conducted Power Margin [dB]	Ant. Gain [dBi]	EIRP [dBm]	EIRP Limit [dBm]	EIRP Margin [dB]
					[dBm]	[mW]						
2402	1.0	GFSK	ePA	0	19.45	88.105	30.00	-10.55	0.70	20.15	36.02	-15.87
2441	1.0	GFSK	ePA	39	19.29	84.918	30.00	-10.71	0.70	19.99	36.02	-16.03
2480	1.0	GFSK	ePA	78	19.13	81.846	30.00	-10.87	0.70	19.83	36.02	-16.19
2402	1.0	GFSK	iPA	0	12.17	16.482	30.00	-17.83	0.70	12.87	36.02	-23.15
2441	1.0	GFSK	iPA	39	12.18	16.520	30.00	-17.82	0.70	12.88	36.02	-23.14
2480	1.0	GFSK	iPA	78	12.21	16.634	30.00	-17.79	0.70	12.91	36.02	-23.11
2402	3.0	8DPSK	ePA	0	14.90	30.903	30.00	-15.10	0.70	15.60	36.02	-20.42
2441	3.0	8DPSK	ePA	39	14.91	30.974	30.00	-15.09	0.70	15.61	36.02	-20.41
2480	3.0	8DPSK	ePA	78	14.85	30.549	30.00	-15.15	0.70	15.55	36.02	-20.47
2402	3.0	8DPSK	iPA	0	8.01	6.324	30.00	-21.99	0.70	8.71	36.02	-27.31
2441	3.0	8DPSK	iPA	39	8.07	6.412	30.00	-21.93	0.70	8.77	36.02	-27.25
2480	3.0	8DPSK	iPA	78	8.46	7.015	30.00	-21.54	0.70	9.16	36.02	-26.86

Table 7-9. Average Conducted Output Power Measurements Antenna WF8

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Peak Conducted Power		Conducted Power Limit [dBm]	Conducted Power Margin [dB]	Ant. Gain [dBi]	EIRP [dBm]	EIRP Limit [dBm]	EIRP Margin [dB]
					[dBm]	[mW]						
2402	1.0	GFSK	ePA	0	19.40	87.096	30.00	-10.60	0.80	20.20	36.02	-15.82
2441	1.0	GFSK	ePA	39	19.30	85.114	30.00	-10.70	0.80	20.10	36.02	-15.92
2480	1.0	GFSK	ePA	78	19.38	86.696	30.00	-10.62	0.80	20.18	36.02	-15.84
2402	1.0	GFSK	iPA	0	12.64	18.365	30.00	-17.36	0.80	13.44	36.02	-22.58
2441	1.0	GFSK	iPA	39	12.68	18.535	30.00	-17.33	0.80	13.48	36.02	-22.55
2480	1.0	GFSK	iPA	78	12.63	18.323	30.00	-17.37	0.80	13.43	36.02	-22.59
2402	3.0	8DPSK	ePA	0	14.62	28.973	30.00	-15.38	0.80	15.42	36.02	-20.60
2441	3.0	8DPSK	ePA	39	14.54	28.445	30.00	-15.47	0.80	15.34	36.02	-20.69
2480	3.0	8DPSK	ePA	78	14.65	29.174	30.00	-15.35	0.80	15.45	36.02	-20.57
2402	3.0	8DPSK	iPA	0	8.81	7.603	30.00	-21.19	0.80	9.61	36.02	-26.41
2441	3.0	8DPSK	iPA	39	8.75	7.499	30.00	-21.25	0.80	9.55	36.02	-26.47
2480	3.0	8DPSK	iPA	78	8.60	7.244	30.00	-21.40	0.80	9.40	36.02	-26.62

Table 7-10. Average Conducted Output Power Measurements Antenna WF7

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Avg Conducted Power		Conducted Power Limit [dBm]	Conducted Power Margin [dB]	Ant. Gain [dBi]	EIRP [dBm]	EIRP Limit [dBm]	EIRP Margin [dB]
					[dBm]	[mW]						
2402	1.0	GFSK	iPA	0	11.57	14.355	30.00	-18.43	-8.60	2.97	36.02	-33.05
2441	1.0	GFSK	iPA	39	11.78	15.066	30.00	-18.22	-8.60	3.18	36.02	-32.84
2480	1.0	GFSK	iPA	78	11.83	15.241	30.00	-18.18	-8.60	3.23	36.02	-32.80
2402	3.0	8DPSK	iPA	0	7.88	6.138	30.00	-22.12	-8.60	-0.72	36.02	-36.74
2441	3.0	8DPSK	iPA	39	7.96	6.252	30.00	-22.04	-8.60	-0.64	36.02	-36.66
2480	3.0	8DPSK	iPA	78	8.00	6.310	30.00	-22.00	-8.60	-0.60	36.02	-36.62

Table 7-11. Average Conducted Output Power Measurements Antenna WF2

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Average Conducted Power						Conducted Power Limit [dBm]	Conducted Power Margin [dB]	Directional Ant. Gain [dBi]	EIRP [dBm]	EIRP Limit [dBm]	EIRP Margin [dB]
					Antenna WF8		Antenna WF7		Summed							
					[dBm]	[mW]	[dBm]	[mW]	[dBm]	[mW]						
2402	1.0	GFSK	ePA	0	16.85	48.417	16.59	45.604	19.74	94.189	30.00	-10.26	3.76	23.50	36.02	-12.52
2441	1.0	GFSK	ePA	39	16.75	47.315	16.54	45.082	19.65	92.257	30.00	-10.35	3.76	23.41	36.02	-12.61
2480	1.0	GFSK	ePA	78	16.84	48.306	16.91	49.091	19.88	97.275	30.00	-10.12	3.76	23.64	36.02	-12.38
2402	1.0	GFSK	iPA	0	12.03	15.959	12.58	18.113	15.32	34.041	30.00	-14.68	3.76	19.08	36.02	-16.94
2441	1.0	GFSK	iPA	39	12.15	16.406	12.51	17.824	15.34	34.198	30.00	-14.66	3.76	19.10	36.02	-16.92
2480	1.0	GFSK	iPA	78	12.06	16.069	13.00	19.953	15.56	35.975	30.00	-14.44	3.76	19.32	36.02	-16.70
2402	3.0	8DPSK	ePA	0	13.22	20.989	13.04	20.137	16.14	41.115	30.00	-13.86	3.76	19.90	36.02	-16.12
2441	3.0	8DPSK	ePA	39	13.10	20.417	13.12	20.512	16.12	40.926	30.00	-13.88	3.76	19.88	36.02	-16.14
2480	3.0	8DPSK	ePA	78	13.18	20.797	13.06	20.230	16.13	41.020	30.00	-13.87	3.76	19.89	36.02	-16.13
2402	3.0	8DPSK	iPA	0	8.45	6.998	8.65	7.328	11.56	14.322	30.00	-18.44	3.76	15.32	36.02	-20.70
2441	3.0	8DPSK	iPA	39	8.33	6.808	8.57	7.194	11.46	13.996	30.00	-18.54	3.76	15.22	36.02	-20.80
2480	3.0	8DPSK	iPA	78	8.24	6.668	8.56	7.178	11.41	13.836	30.00	-18.59	3.76	15.17	36.02	-20.85

Table 7-12. Average Conducted Output Power Measurements TxBF

Note:

Per ANSI C63.10-2020 and KDB 662911 D01 v02r01 Section E)1), the conducted powers at Antenna WF8 and Antenna WF7 were first measured separately during TxBF transmission as shown in the section above. The measured values were then summed in linear power units then converted back to dBm.

Per ANSI C63.10-2020 Subclause 14.6.3, the directional gain is calculated using the following formula, where G_N is the gain of the nth antenna and N_{ANT}, the total number of antennas used.

$$\text{Directional gain} = 10 \log[(10^{G_1/20} + 10^{G_2/20} + \ldots + 10^{G_N/20})^2 / N_{ANT}] \text{ dBi}$$

Sample TxBF Calculation:

At 2402MHz, the average conducted output power was measured to be 16.85 dBm for Antenna WF8 and 16.59 dBm for Antenna WF7.

Antenna WF8 + Antenna WF7 = TxBF

(16.85dBm + 16.59 dBm) = (48.417 mW + 45.604 mW) = 94.189 mW = 19.74 dBm

Sample e.i.r.p. Calculation:

At 2402MHz, the average conducted output power was calculated to be 19.74 dBm with antenna gain of 3.76 dBi.

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

19.74 dBm + 3.76 dBi = 23.50 dBm

7.4 Conducted Authorized Band Edge

§15.247 (d); RSS-247 [5.5]

Test Overview and Limits

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

Test Procedure Used

ANSI C63.10-2020 – Section 6.10.4

Test Settings

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

Test Setup

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

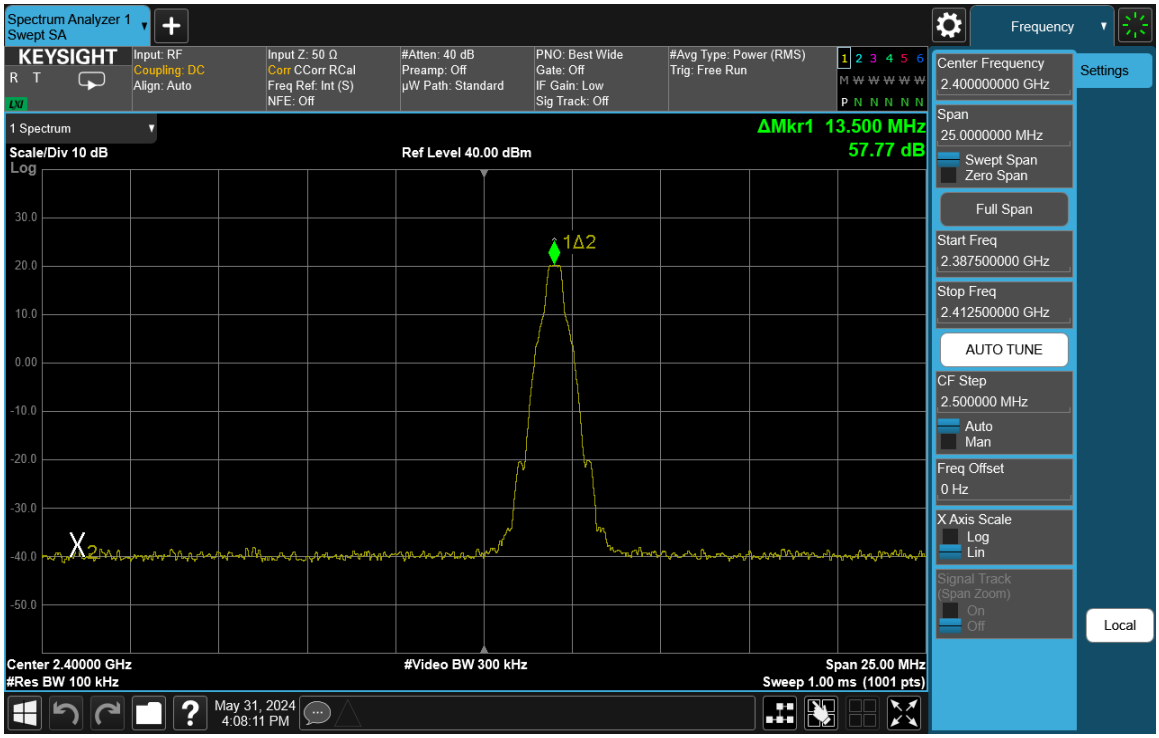
Figure 7-3. Test Instrument & Measurement Setup

Test Notes

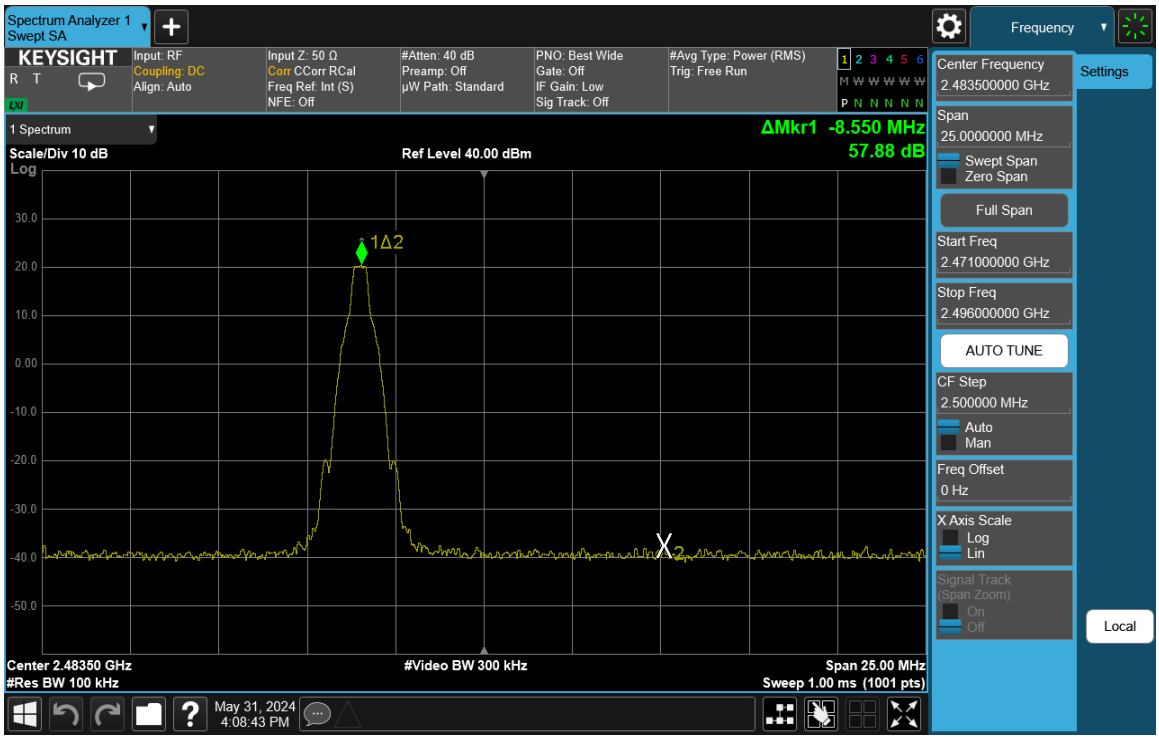
1. Out of band conducted spurious emissions at the band edge were investigated for all data rates in hopping and non-hopping modes. The worst case emissions were found with the EUT transmitting at 3 Mbps. Band edge emissions were also investigated with the EUT transmitting in all data rates. Plots of the worst case emissions are shown below.

2. All supported modulation, antenna (including TxBF mode) and power schemes have been tested on the unit and only worst case configuration is reported.

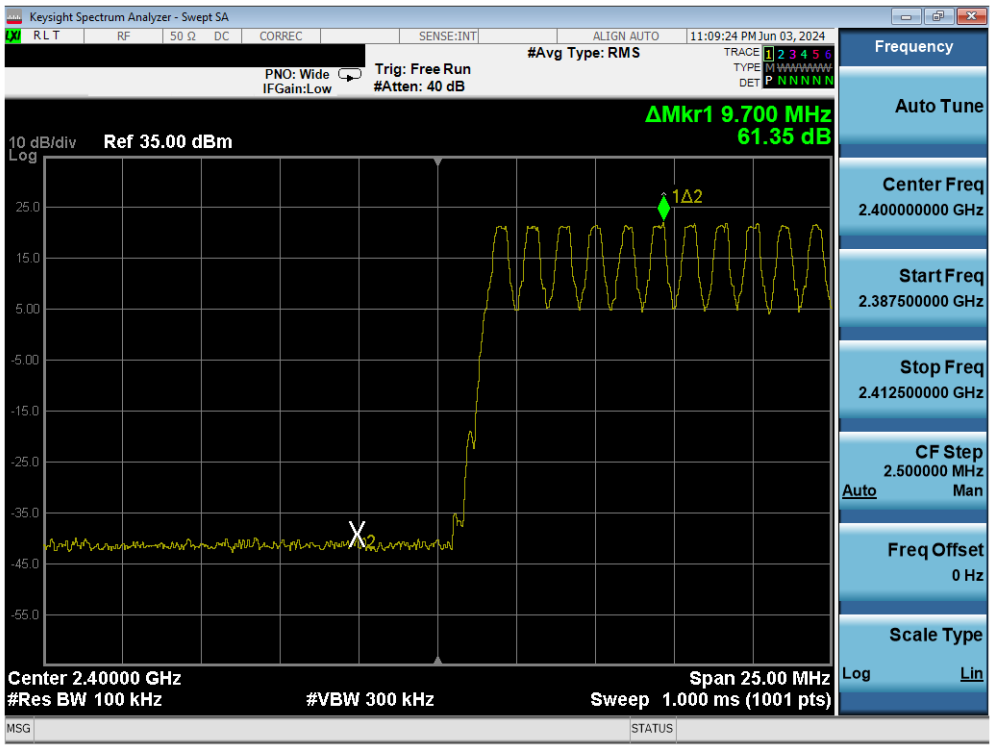
Antenna WF8



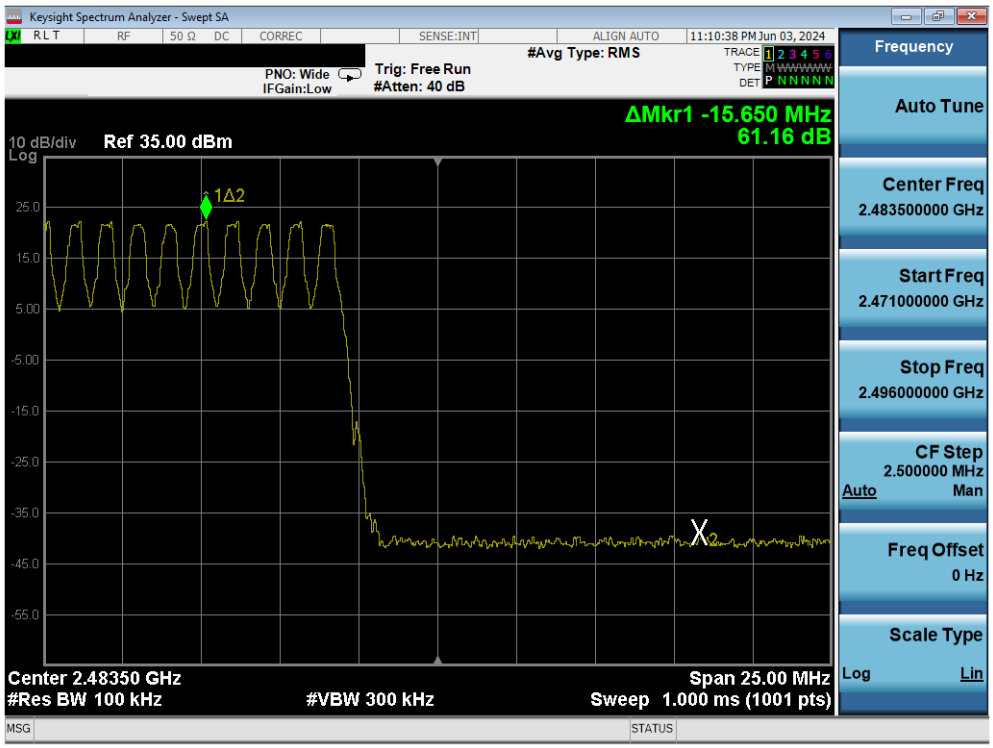
Plot 7-19. Band Edge Plot Antenna WF8 (Bluetooth with Hopping Disabled, GFSK, ePA – Ch. 0)



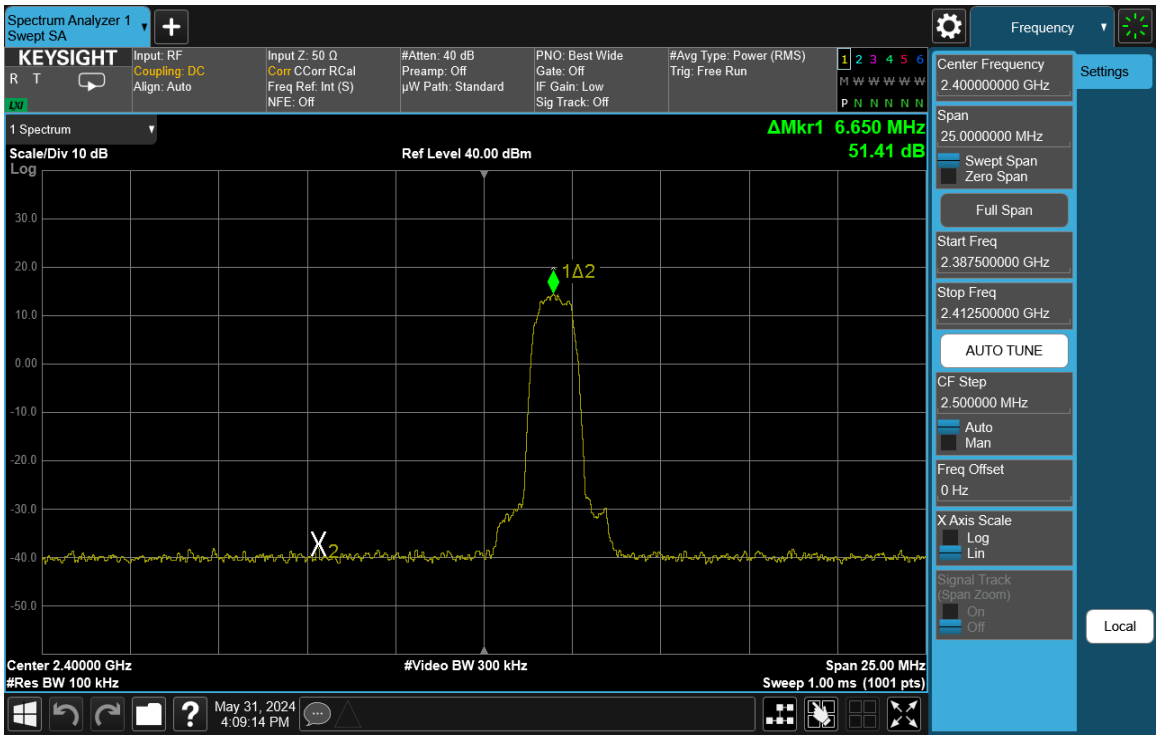
Plot 7-20. Band Edge Plot Antenna WF8 (Bluetooth with Hopping Disabled, GFSK, ePA – Ch. 78)



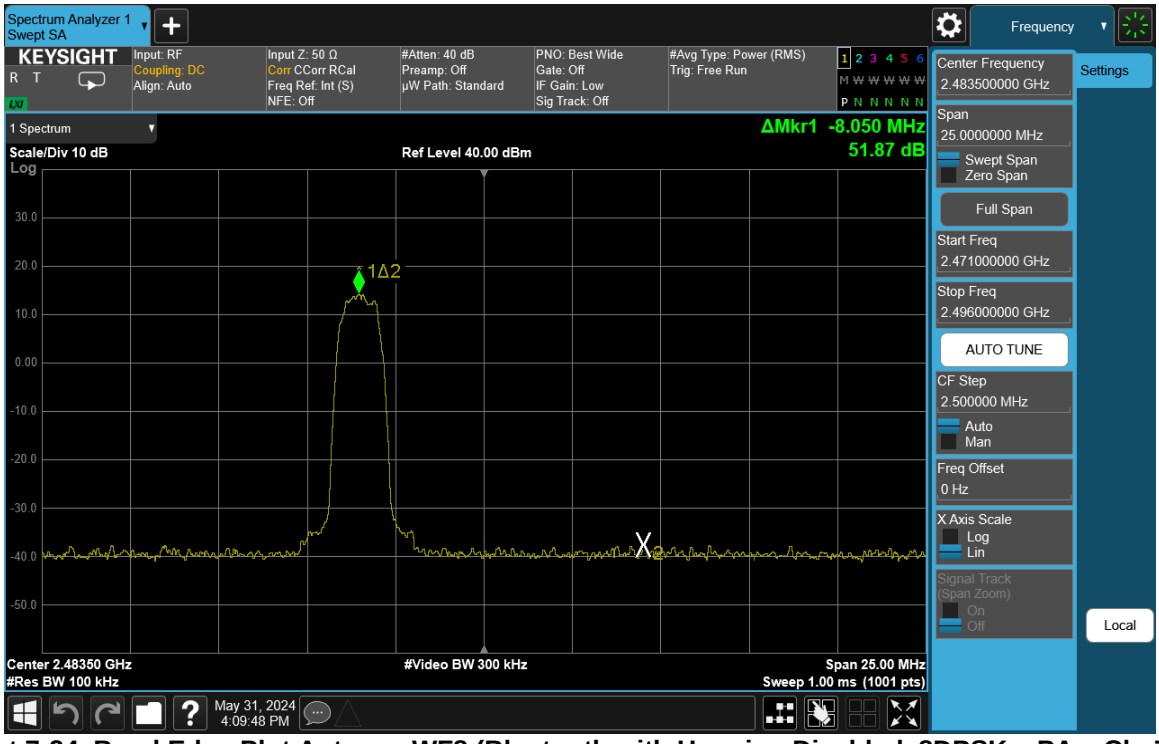
Plot 7-21. Band Edge Plot Antenna WF8 (Bluetooth with Hopping Enabled, GFSK, ePA)



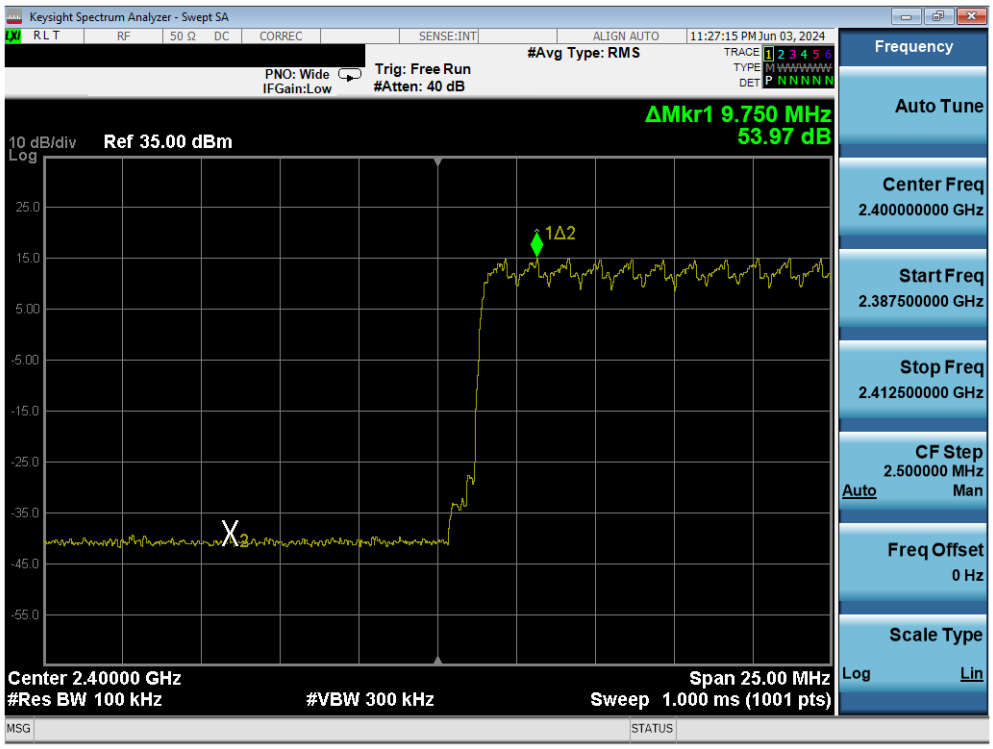
Plot 7-22. Band Edge Plot Antenna WF8 (Bluetooth with Hopping Enabled, GFSK, ePA)



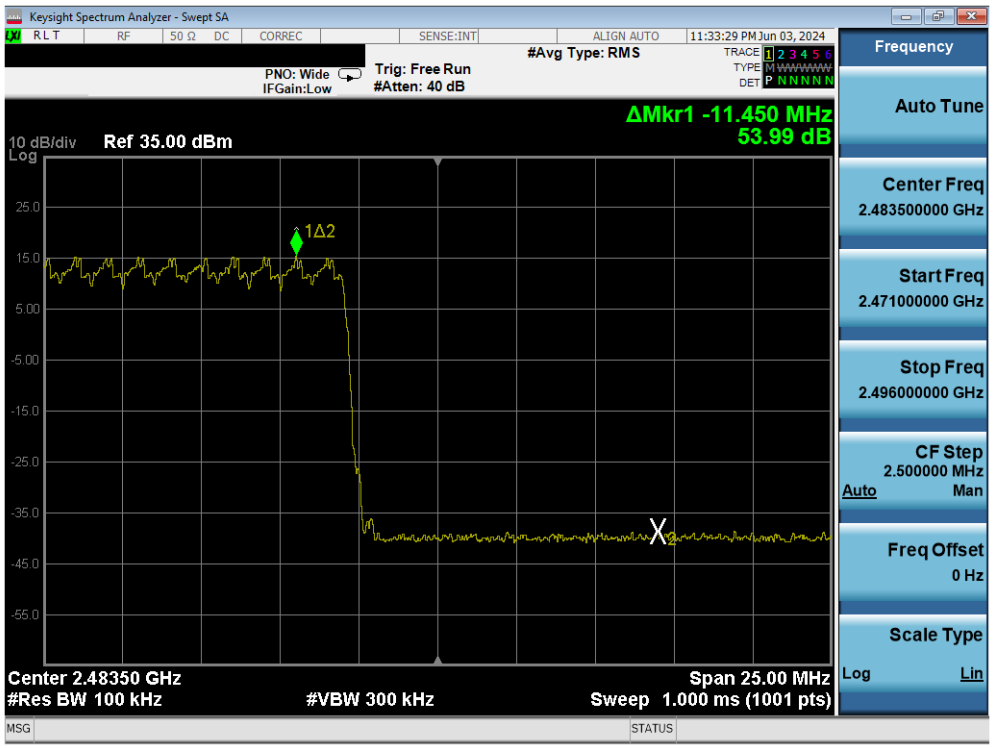
Plot 7-23. Band Edge Plot Antenna WF8 (Bluetooth with Hopping Disabled, 8DPSK, ePA – Ch. 0)



Plot 7-24. Band Edge Plot Antenna WF8 (Bluetooth with Hopping Disabled, 8DPSK, ePA – Ch. 78)

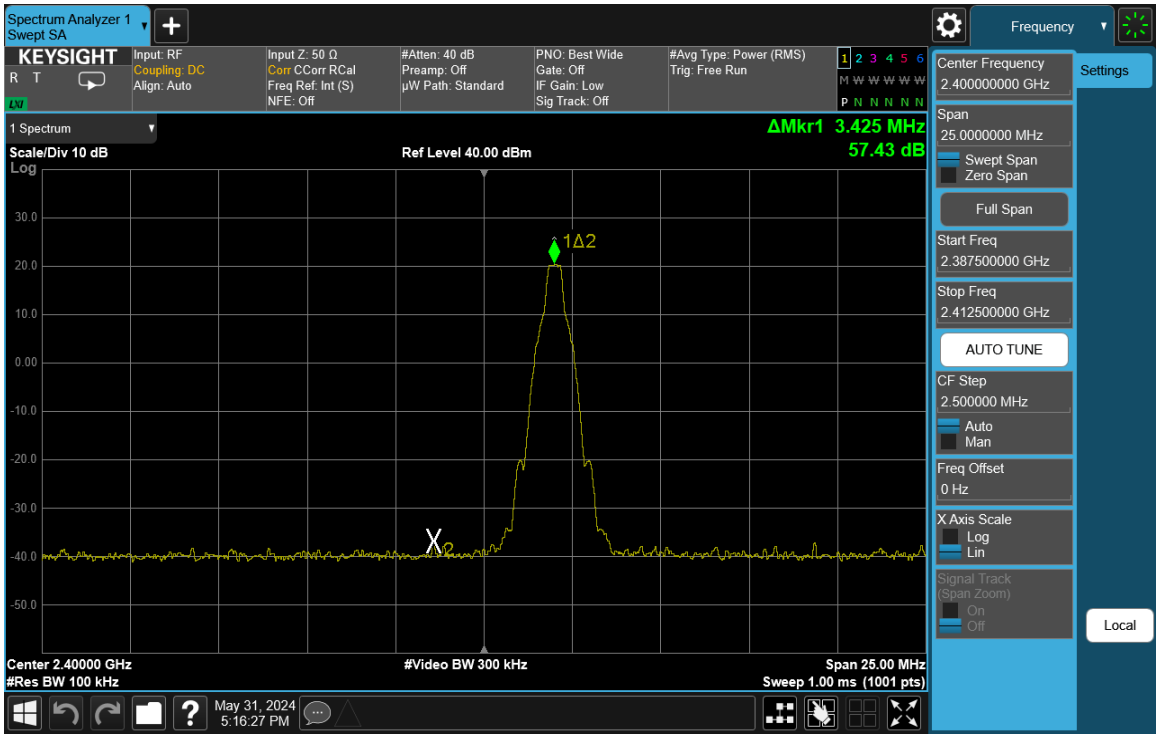


Plot 7-25. Band Edge Plot Antenna WF8 (Bluetooth with Hopping Enabled, 8DPSK, ePA)

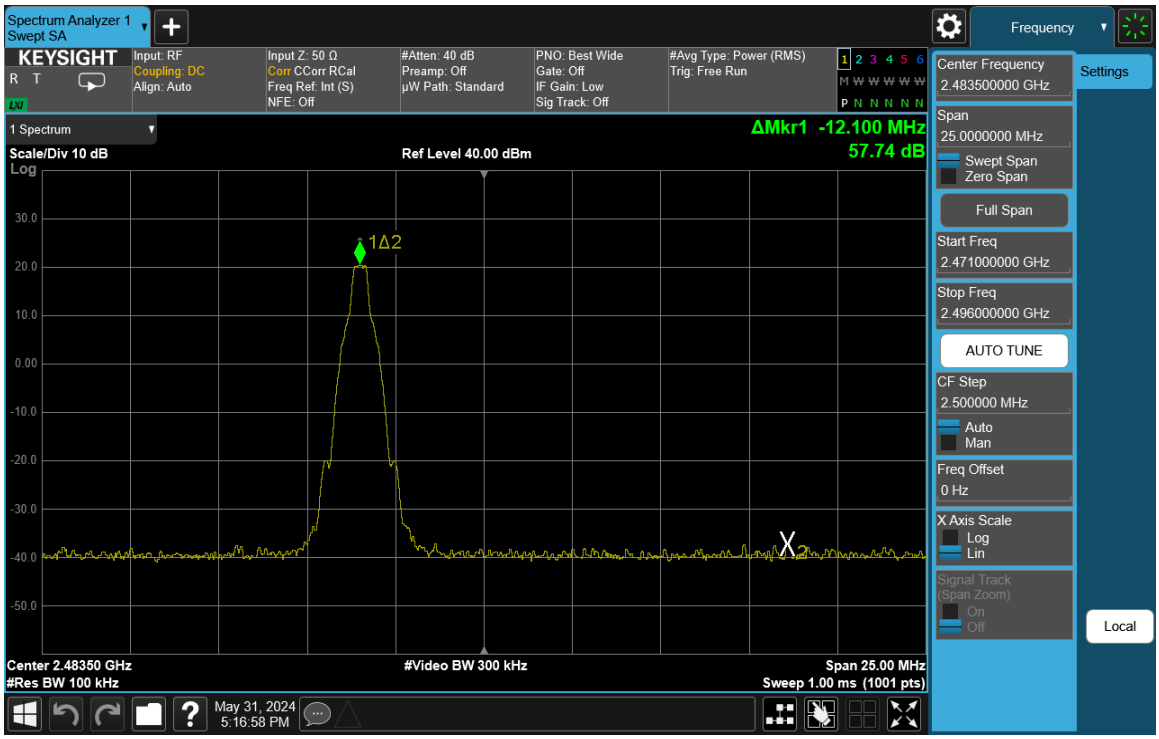


Plot 7-26. Band Edge Plot Antenna WF8 (Bluetooth with Hopping Enabled, 8DPSK, ePA)

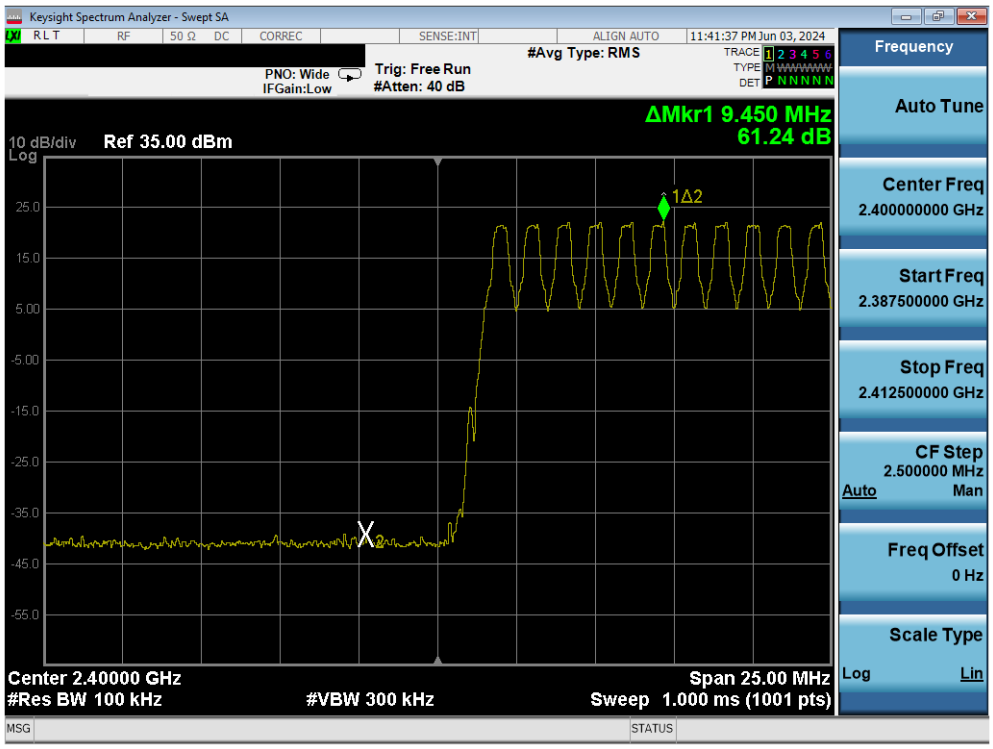
Antenna WF7



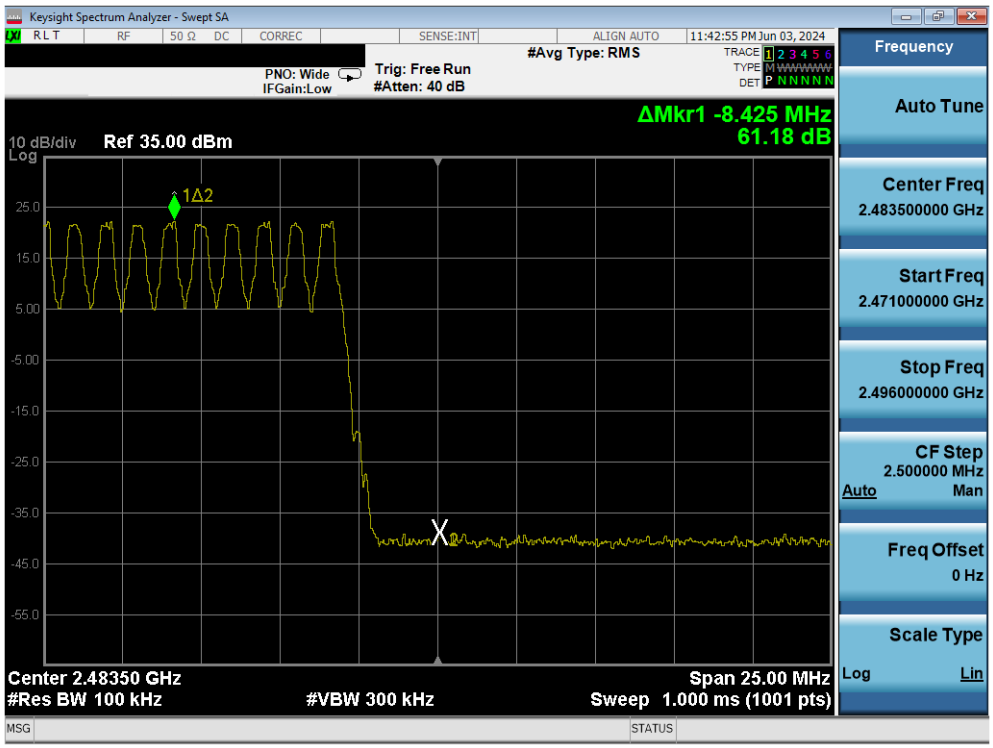
Plot 7-27. Band Edge Plot Antenna WF7 (Bluetooth with Hopping Disabled, GFSK, ePA – Ch. 0)



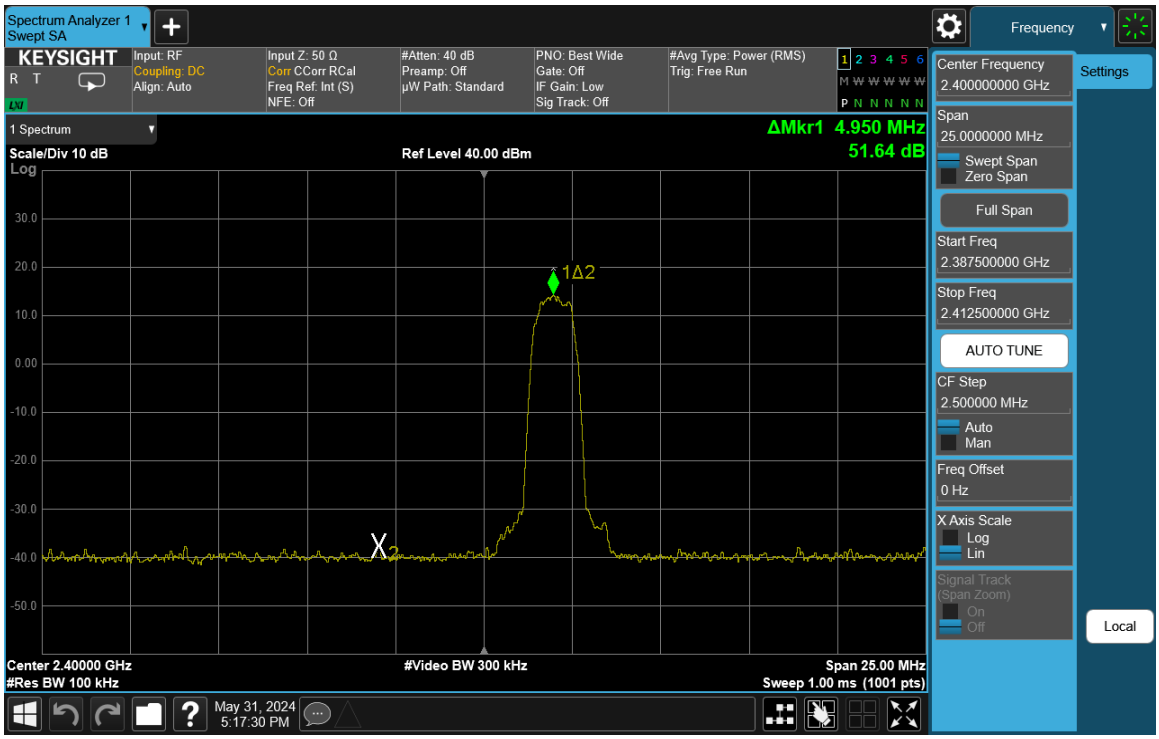
Plot 7-28. Band Edge Plot Antenna WF7 (Bluetooth with Hopping Disabled, GFSK, ePA – Ch. 78)



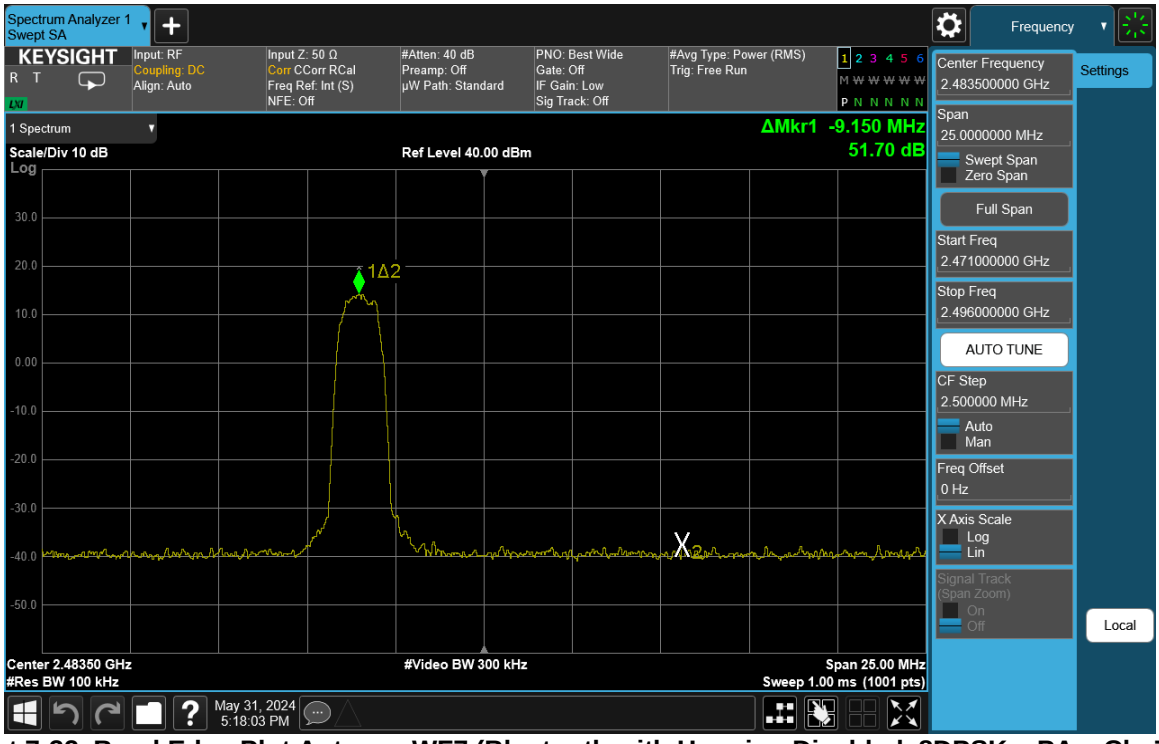
Plot 7-29. Band Edge Plot Antenna WF7 (Bluetooth with Hopping Enabled, GFSK, ePA)



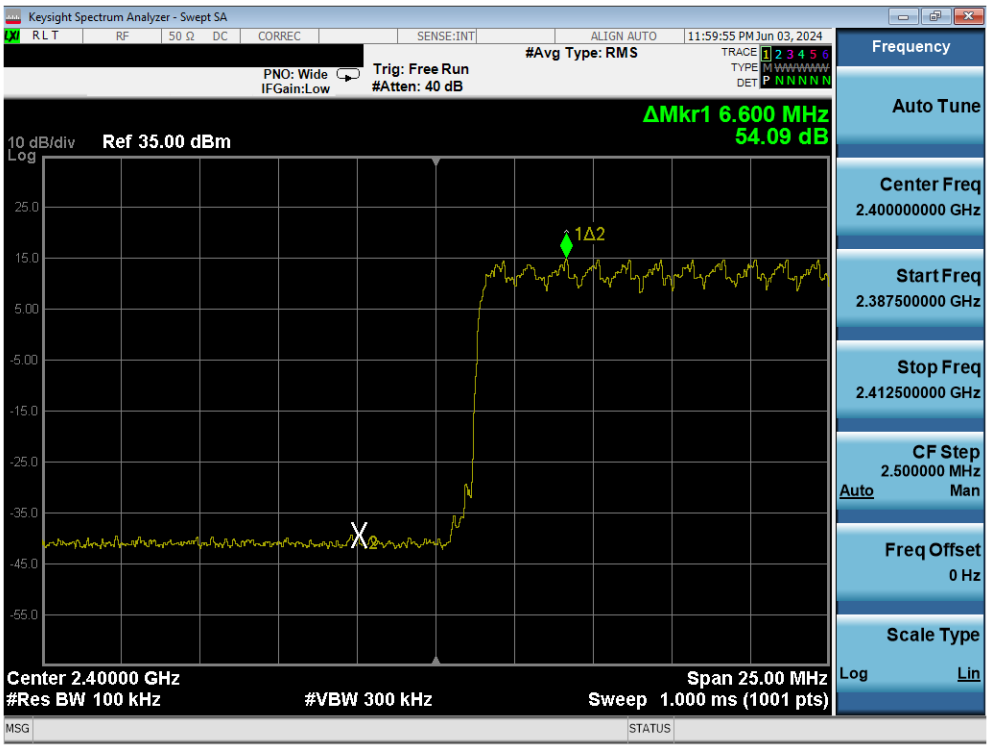
Plot 7-30. Band Edge Plot Antenna WF7 (Bluetooth with Hopping Enabled, GFSK, ePA)



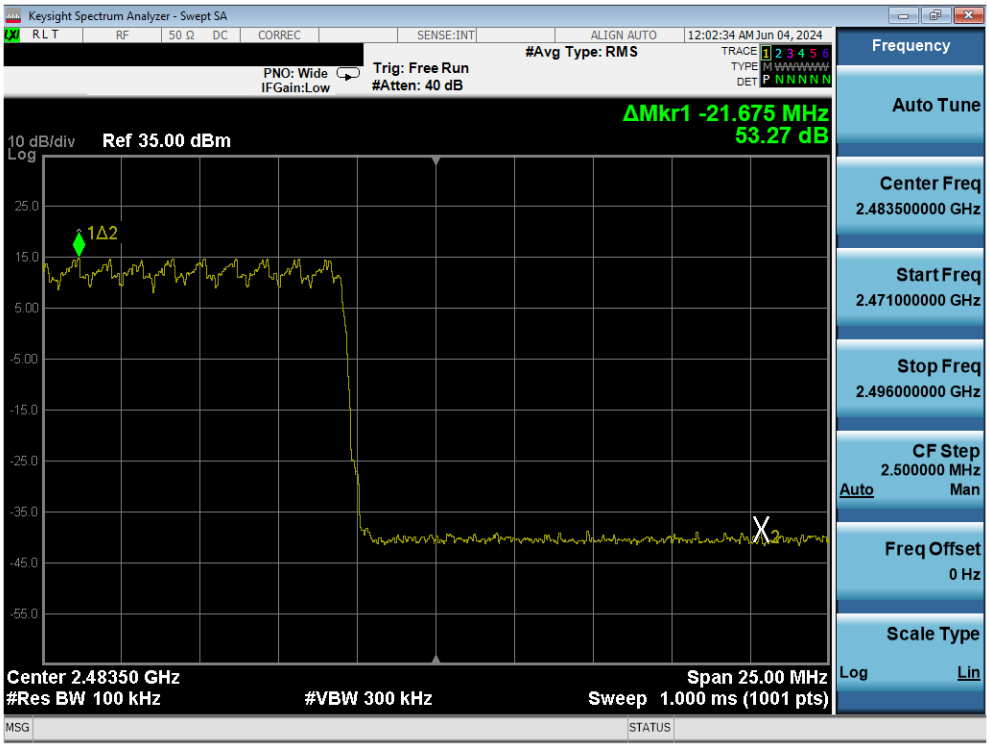
Plot 7-31. Band Edge Plot Antenna WF7 (Bluetooth with Hopping Disabled, 8DPSK, ePA – Ch. 0)



Plot 7-32. Band Edge Plot Antenna WF7 (Bluetooth with Hopping Disabled, 8DPSK, ePA – Ch. 78)

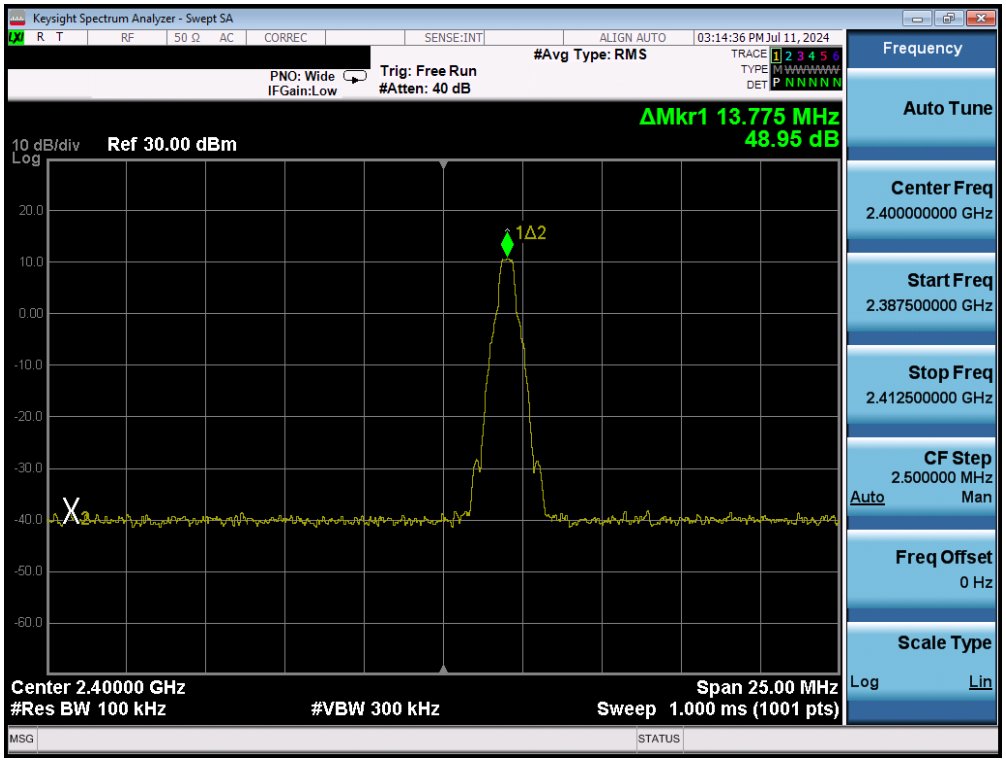


Plot 7-33. Band Edge Plot Antenna WF7 (Bluetooth with Hopping Enabled, 8DPSK, ePA)

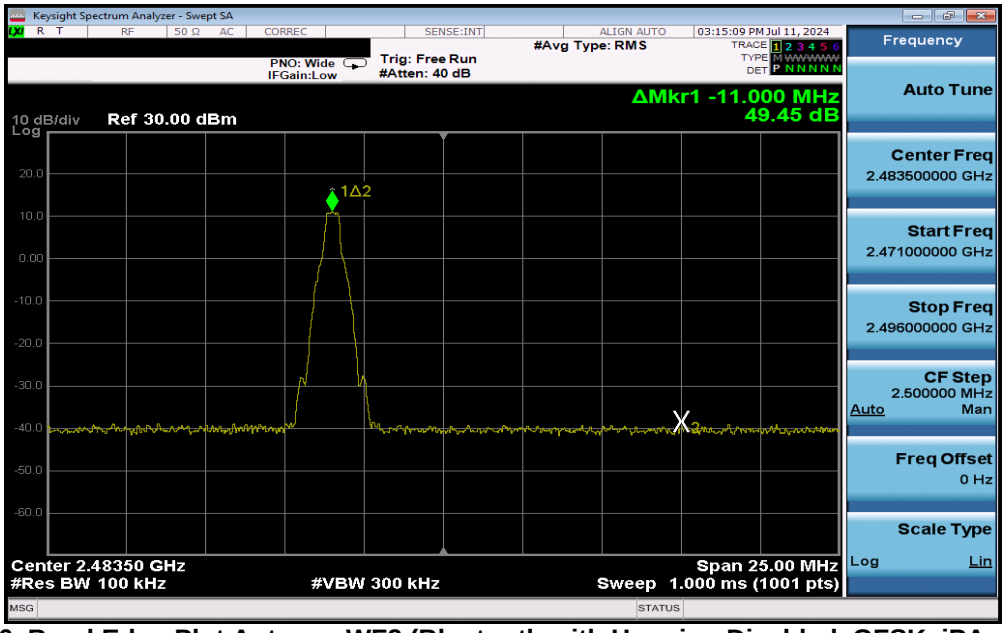


Plot 7-34. Band Edge Plot Antenna WF7 (Bluetooth with Hopping Enabled, 8DPSK, ePA)

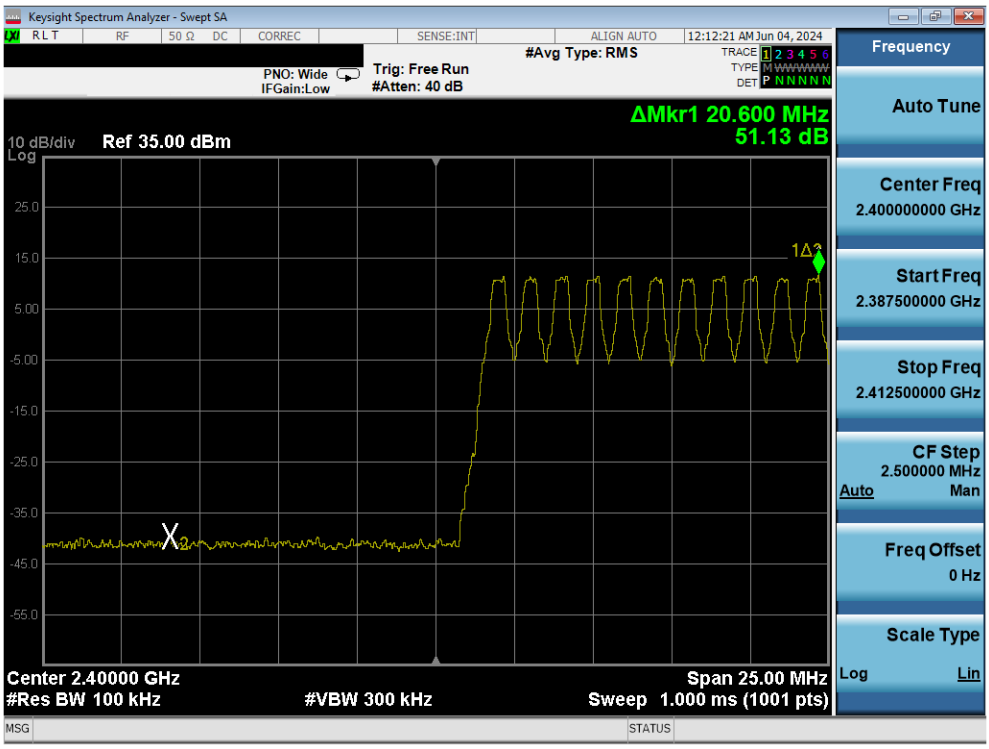
Antenna WF2



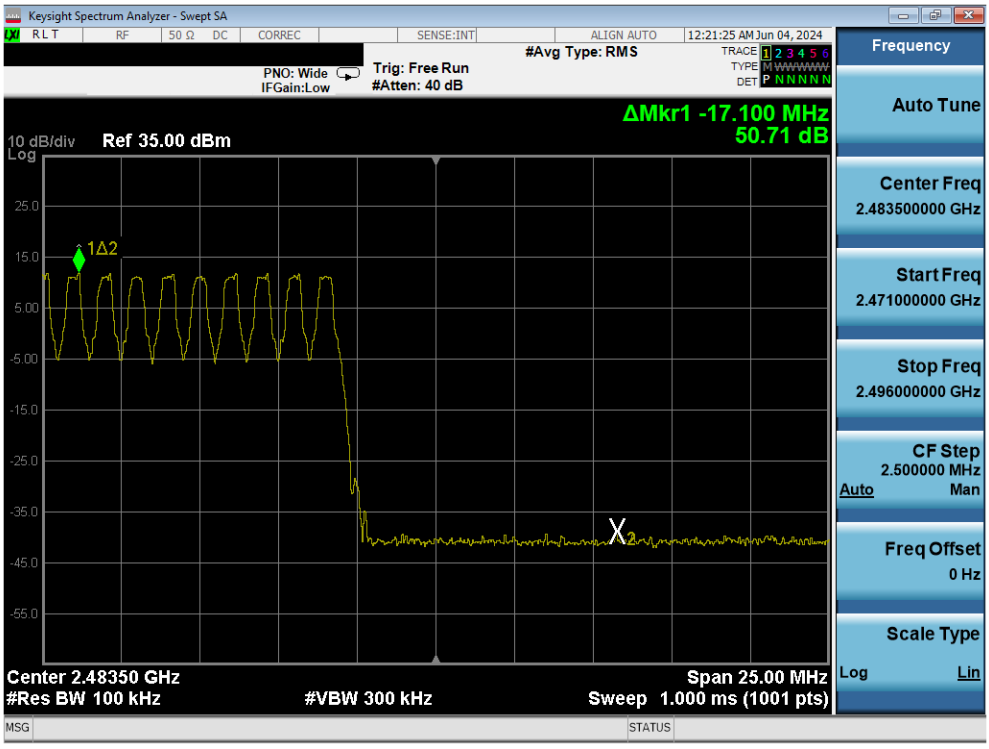
Plot 7-35. Band Edge Plot Antenna WF2 (Bluetooth with Hopping Disabled, GFSK, iPA – Ch. 0)



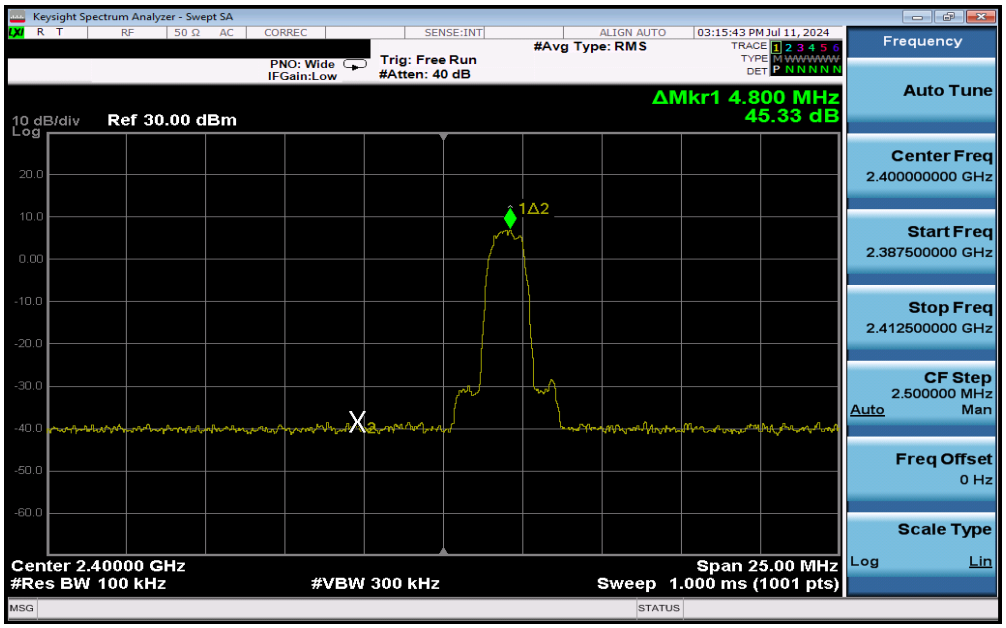
Plot 7-36. Band Edge Plot Antenna WF2 (Bluetooth with Hopping Disabled, GFSK, iPA – Ch. 78)



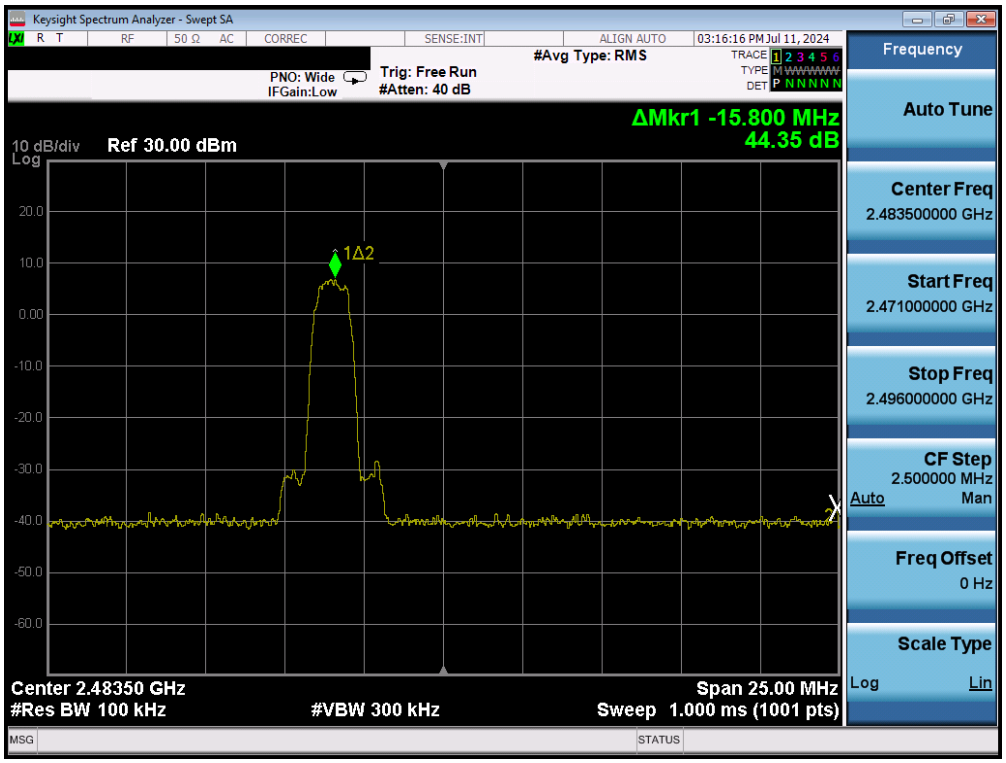
Plot 7-37. Band Edge Plot Antenna WF2 (Bluetooth with Hopping Enabled, GFSK, iPA)



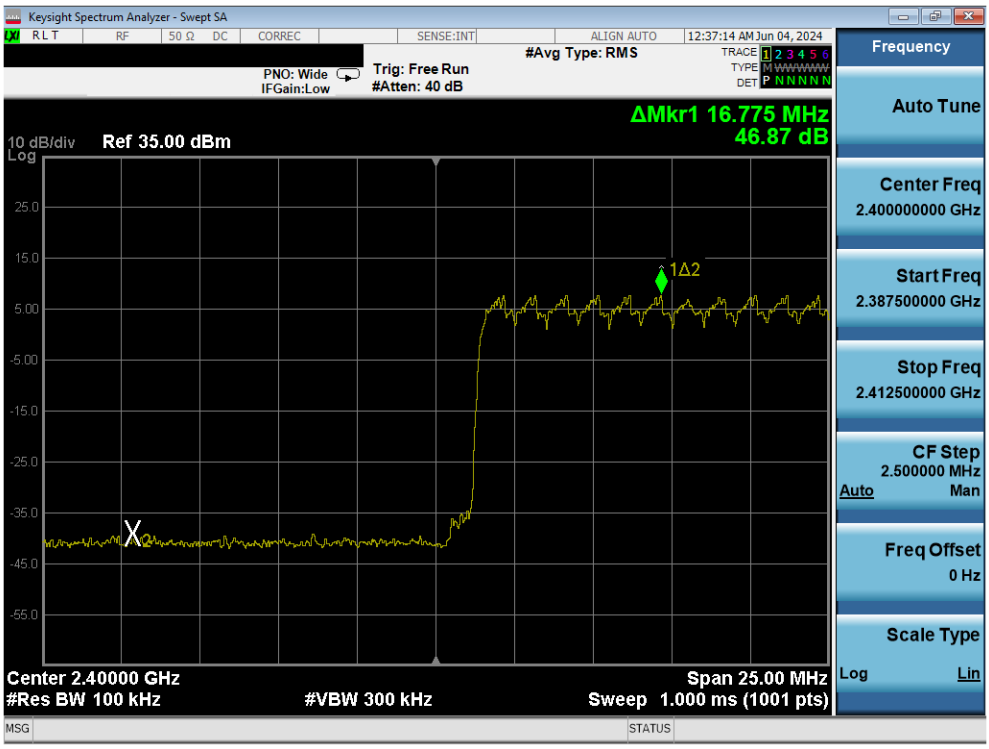
Plot 7-38. Band Edge Plot Antenna WF2 (Bluetooth with Hopping Enabled, GFSK, iPA)



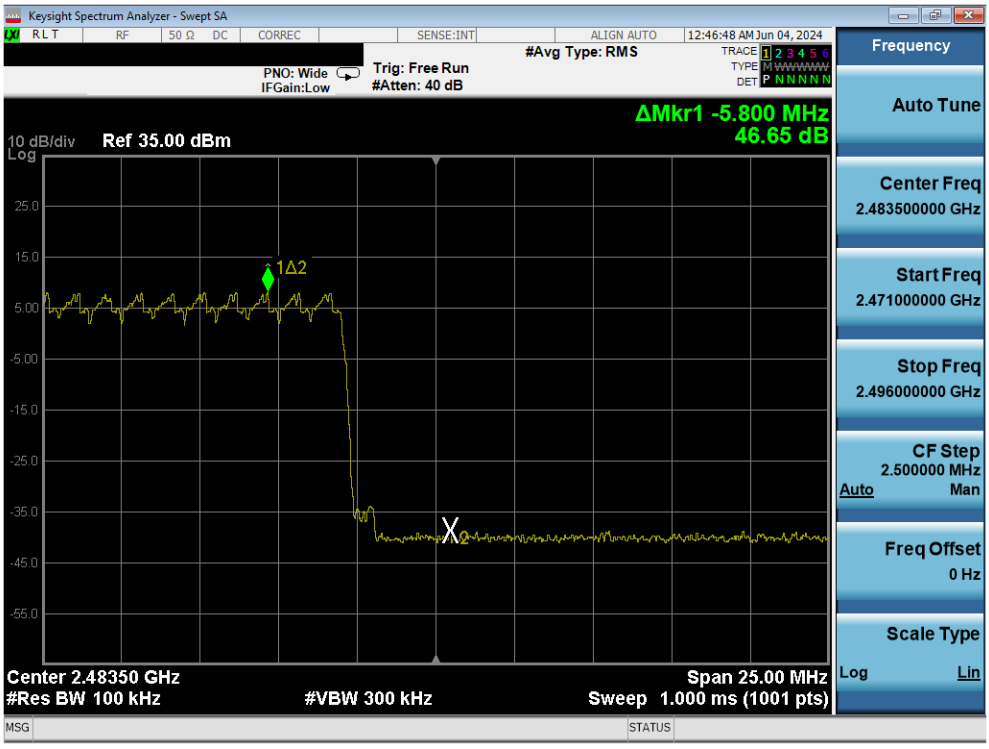
Plot 7-39. Band Edge Plot Antenna WF2 (Bluetooth with Hopping Disabled, 8DPSK, iPA – Ch. 0)



Plot 7-40. Band Edge Plot Antenna WF2 (Bluetooth with Hopping Disabled, 8DPSK, iPA – Ch. 78)



Plot 7-41. Band Edge Plot Antenna WF2 (Bluetooth with Hopping Enabled, 8DPSK, iPA)



Plot 7-42. Band Edge Plot Antenna WF2 (Bluetooth with Hopping Enabled, 8DPSK, iPA)

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 C63.10-2020 – Section 7.8.2

Test Settings

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

Test Setup

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

Figure 7-4. Test Instrument & Measurement Setup

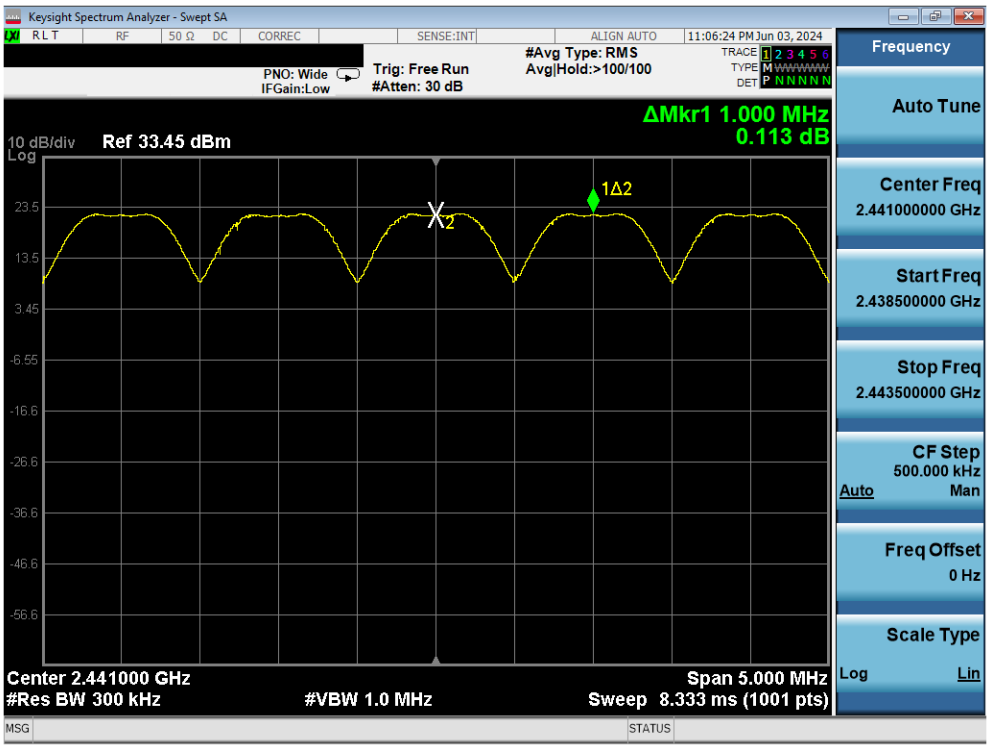
Test Notes

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

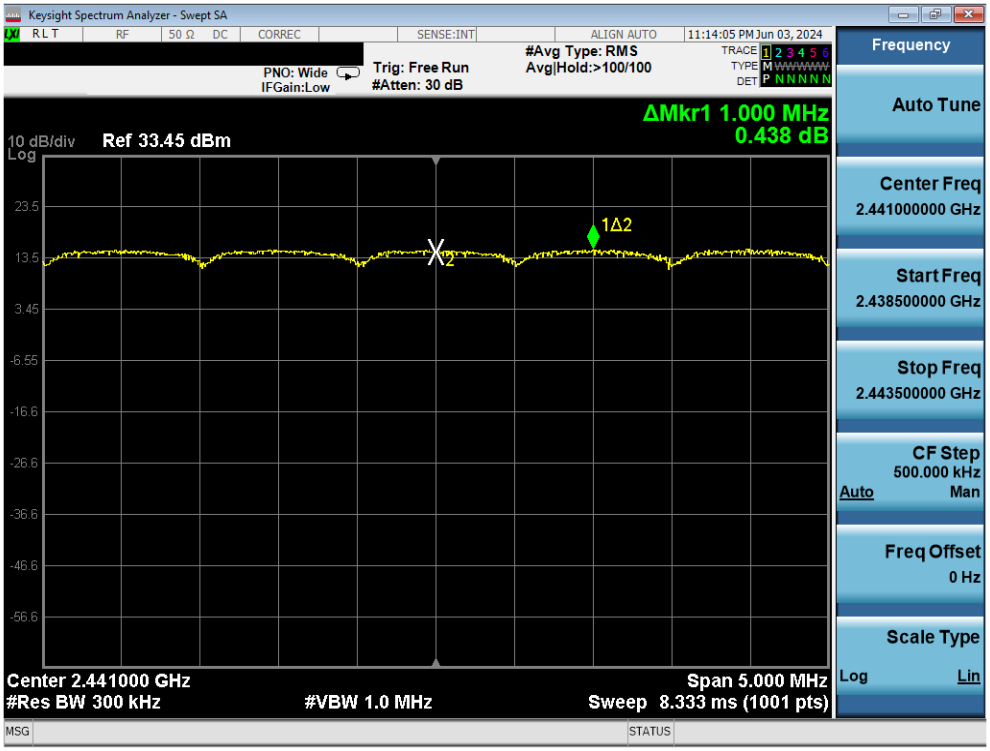
Antenna WF8

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Measured Channel Separation [MHz]	Min. Channel Separation [MHz]	Pass/Fail
2441	1.0	GFSK	ePA	39	1.00	0.61	Pass
2441	3.0	8DPSK	ePA	39	1.00	0.90	Pass

Table 7-13. Minimum Channel Separation Antenna WF8



Plot 7-43. Channel Spacing Plot Antenna WF8 (Bluetooth, GFSK, ePA)

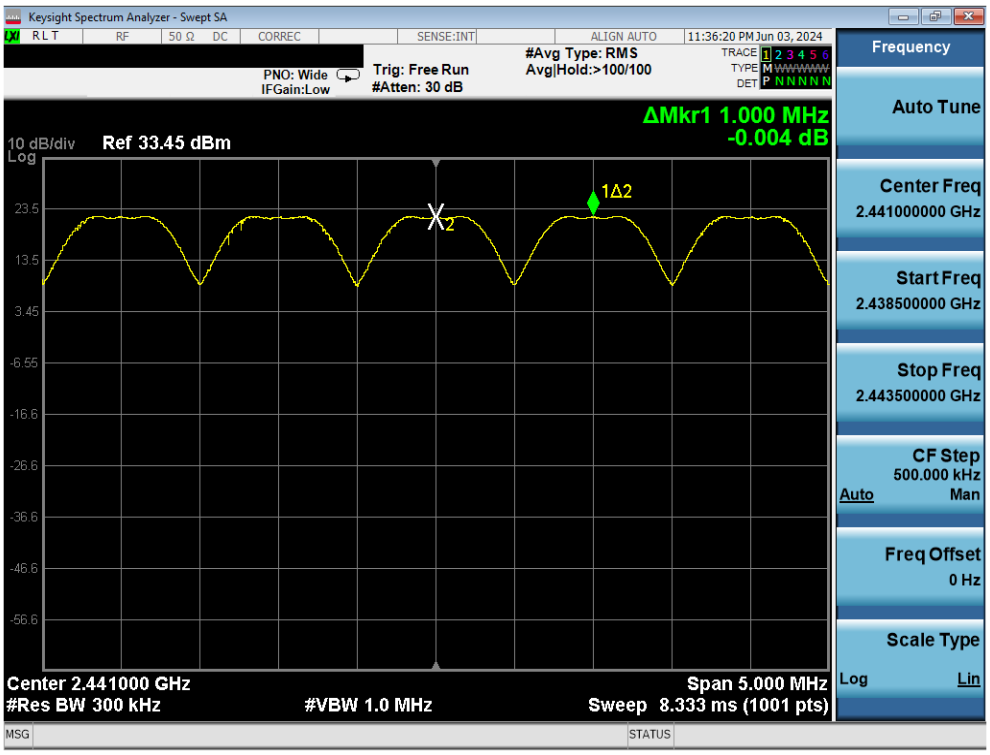


Plot 7-44. Channel Spacing Plot Antenna WF8 (Bluetooth, 8DPSK, ePA)

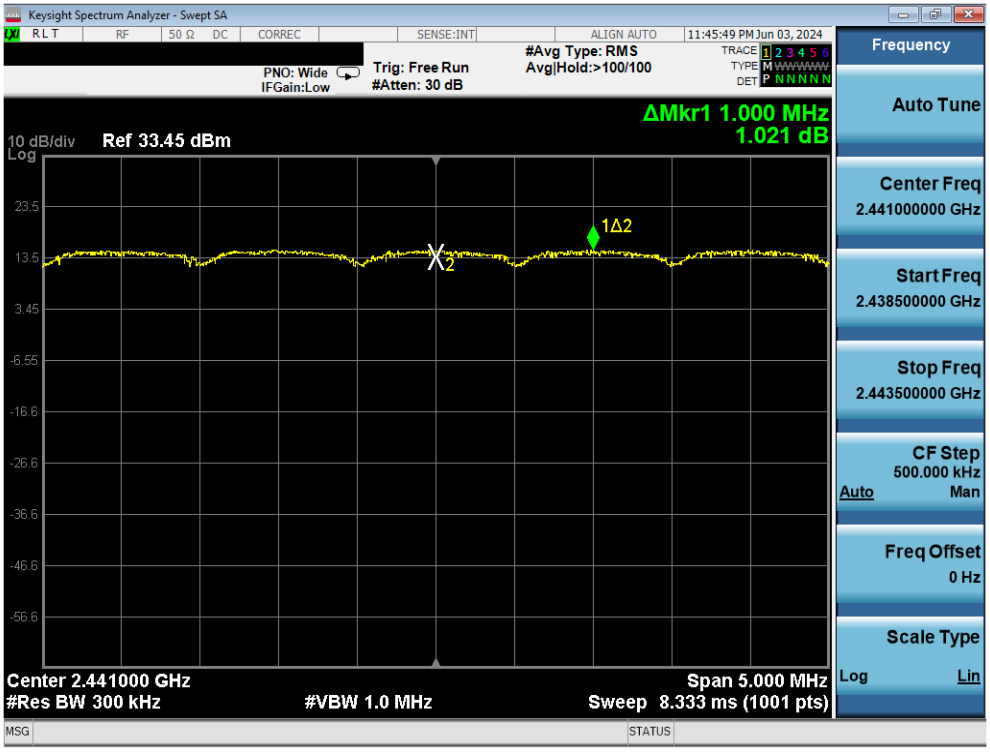
Antenna WF7

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Measured Channel Separation [MHz]	Min. Channel Separation [MHz]	Pass/Fail
2441	1.0	GFSK	ePA	39	1.00	0.61	Pass
2441	3.0	8DPSK	ePA	39	1.00	0.90	Pass

Table 7-14. Minimum Channel Separation Antenna WF7



Plot 7-45. Channel Spacing Plot Antenna WF7 (Bluetooth, GFSK, ePA)

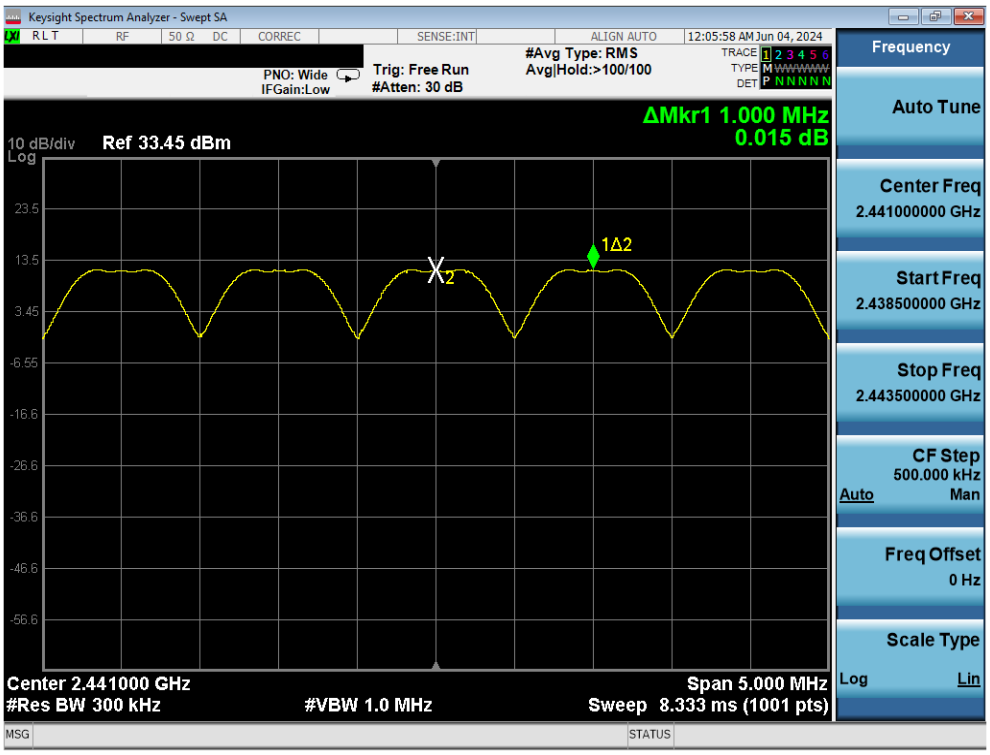


Plot 7-46. Channel Spacing Plot Antenna WF7 (Bluetooth, 8DPSK, ePA)

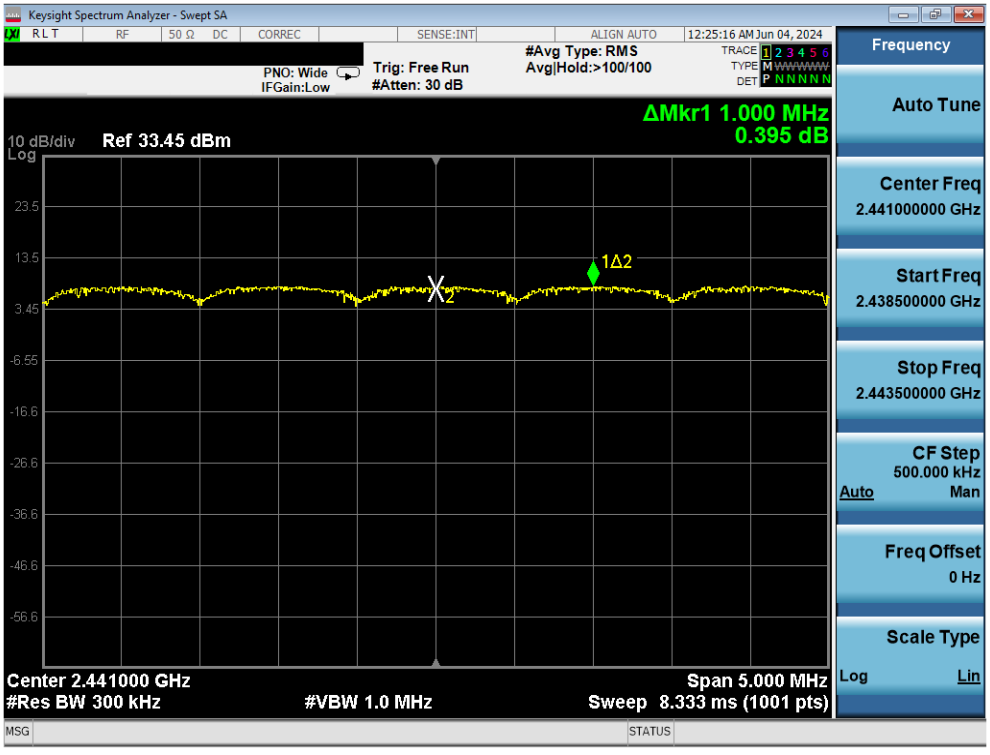
Antenna WF2

Frequency [MHz]	Data Rate [Mbps]	Mod.	Power Scheme	Channel No.	Measured Channel Separation [MHz]	Min. Channel Separation [MHz]	Pass/Fail
2441	1.0	GFSK	iPA	39	1.00	0.61	Pass
2441	3.0	8DPSK	iPA	39	1.00	0.90	Pass

Table 7-15. Minimum Channel Separation Antenna WF2



Plot 7-47. Channel Spacing Plot Antenna WF2 (Bluetooth, GFSK, iPA)



Plot 7-48. Channel Spacing Plot Antenna WF2 (Bluetooth, 8DPSK, iPA)

7.6 Time of Occupancy

§15.247 (a.1.iii); RSS-247 [5.1(d)]

Test Overview and Limit

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

Test Procedure Used

ANSI C63.10-2020 – Section 7.8.4

Test Settings

1. Span = zero span, centered on a hopping channel
2. RBW ≤ channel spacing and >> 1/T, where T is expected TOC per channel
3. Sweep = as necessary to capture entire TOC. 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

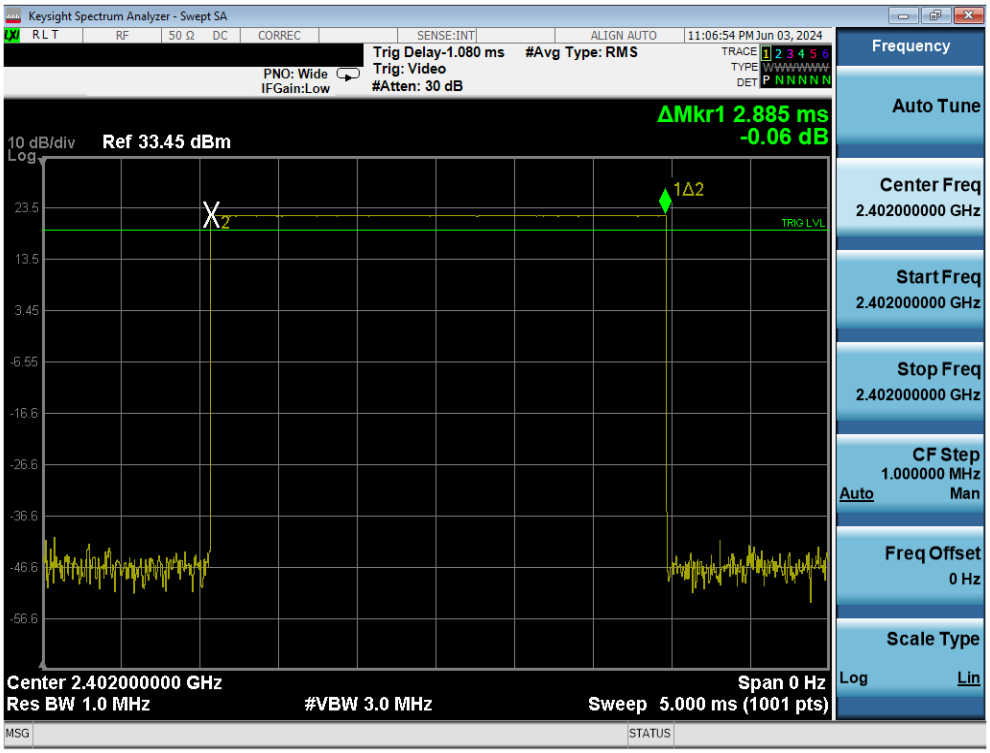
The EUT and measurement equipment were set up as shown in the diagram below.

Figure 7-5. Test Instrument & Measurement Setup

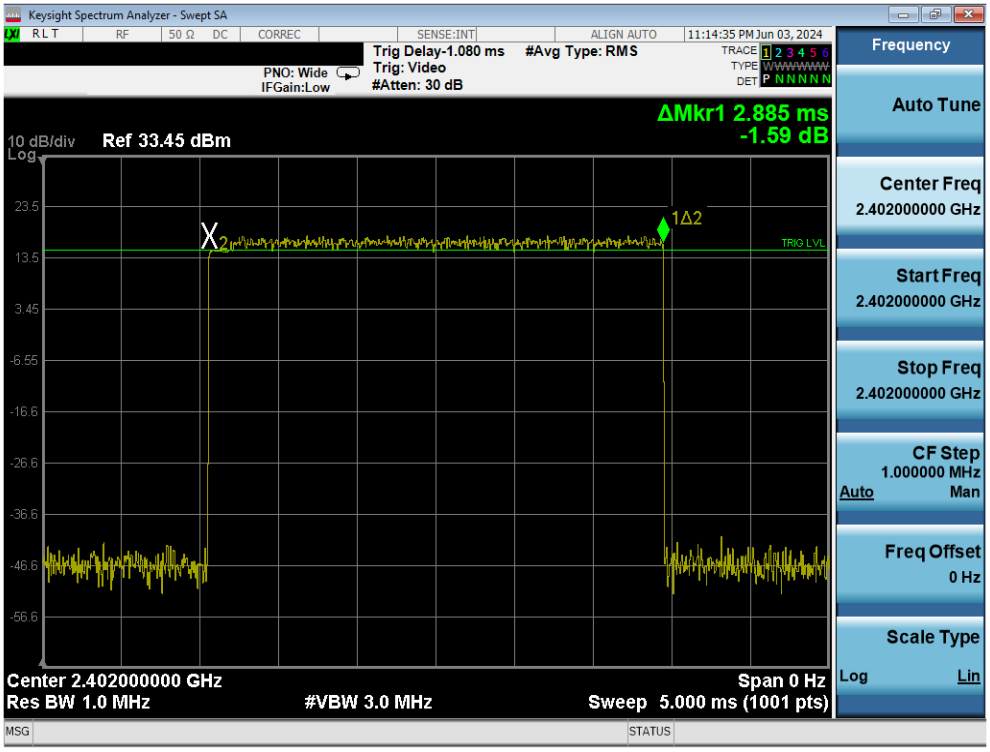
Test Notes

All supported modulation, antenna (including TxBF mode) and power schemes have been tested on the unit and only worst case configuration is reported.

Antenna WF8

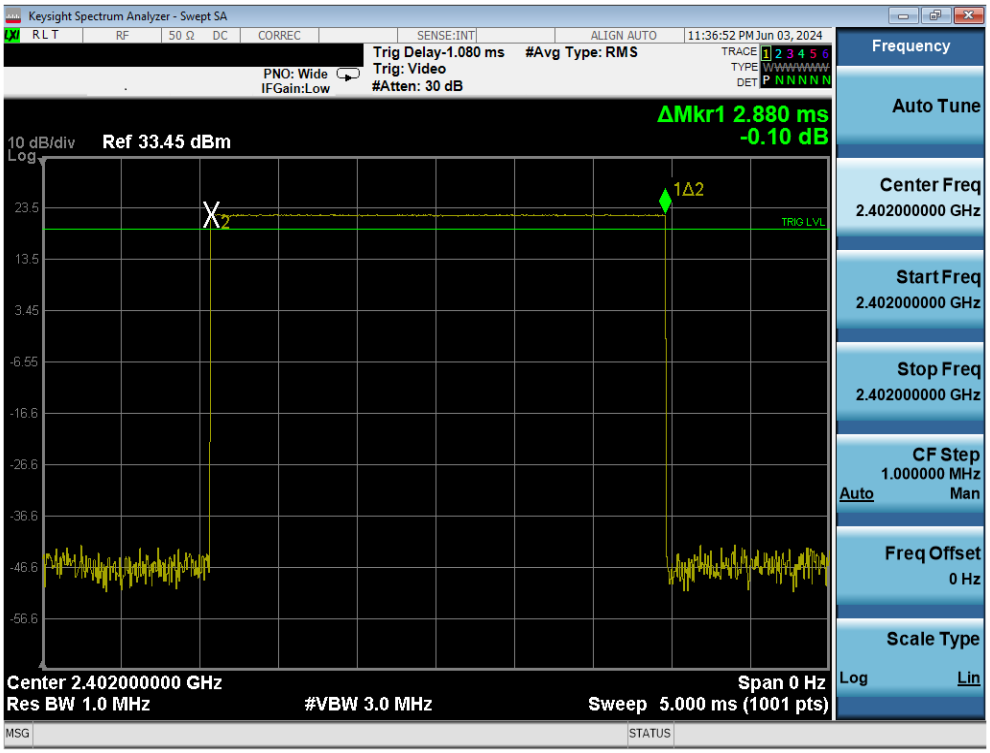


Plot 7-49. Time of Occupancy Plot Antenna WF8 (Bluetooth, GFSK, ePA)

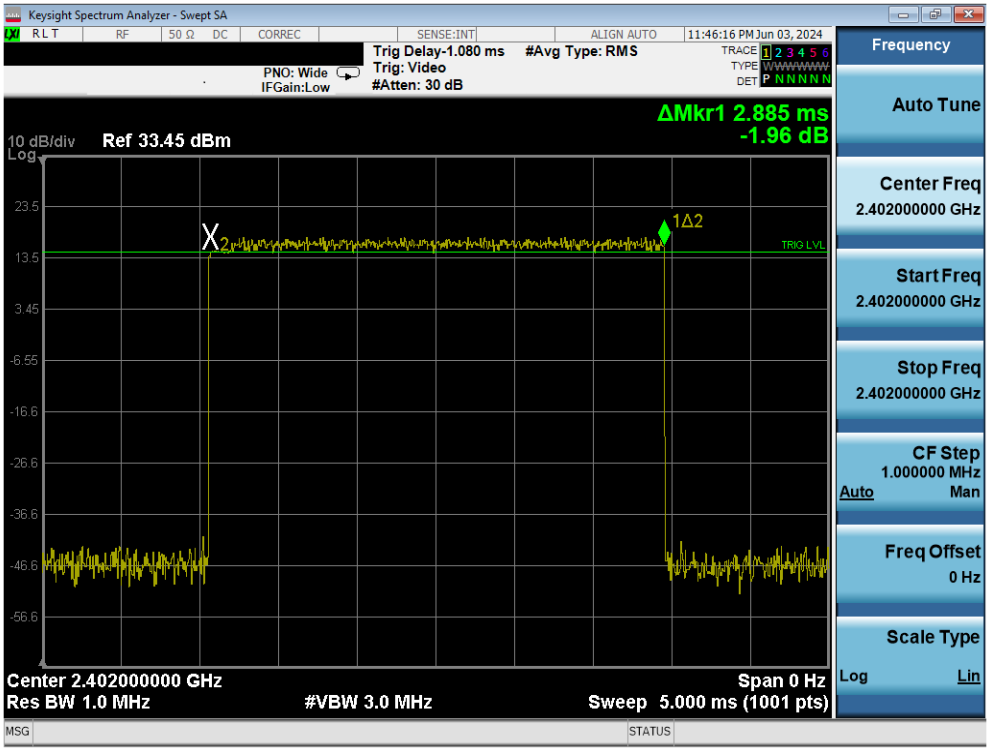


Plot 7-50. Time of Occupancy Plot Antenna WF8 (Bluetooth, 8DPSK, ePA)

Antenna WF7

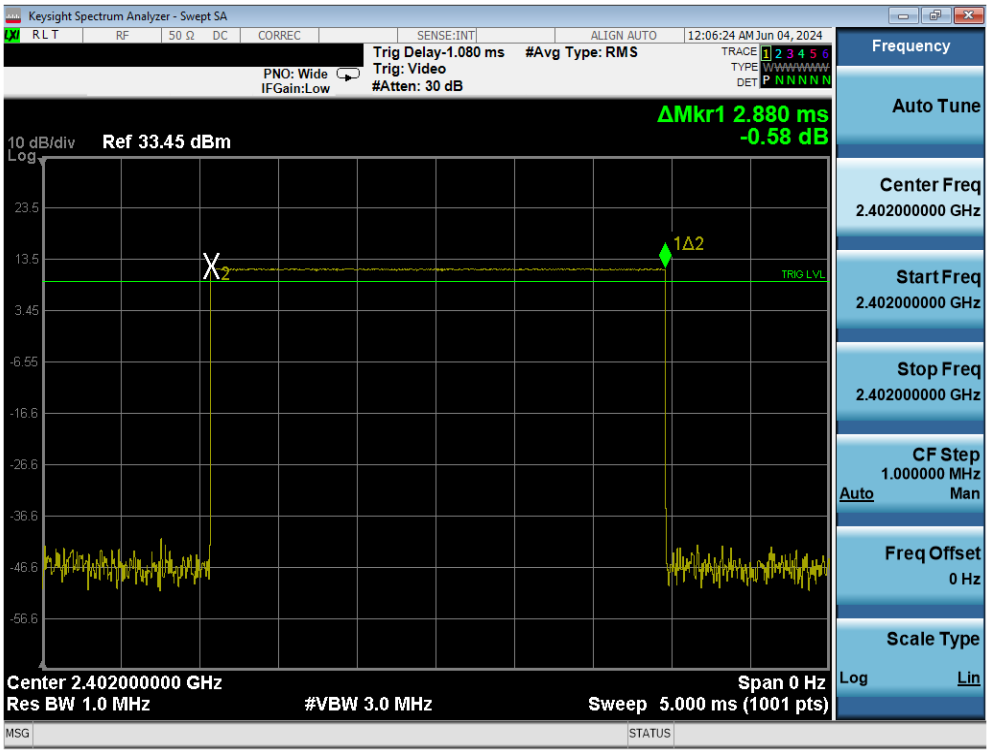


Plot 7-51. Time of Occupancy Plot Antenna WF7 (Bluetooth, GFSK, ePA)

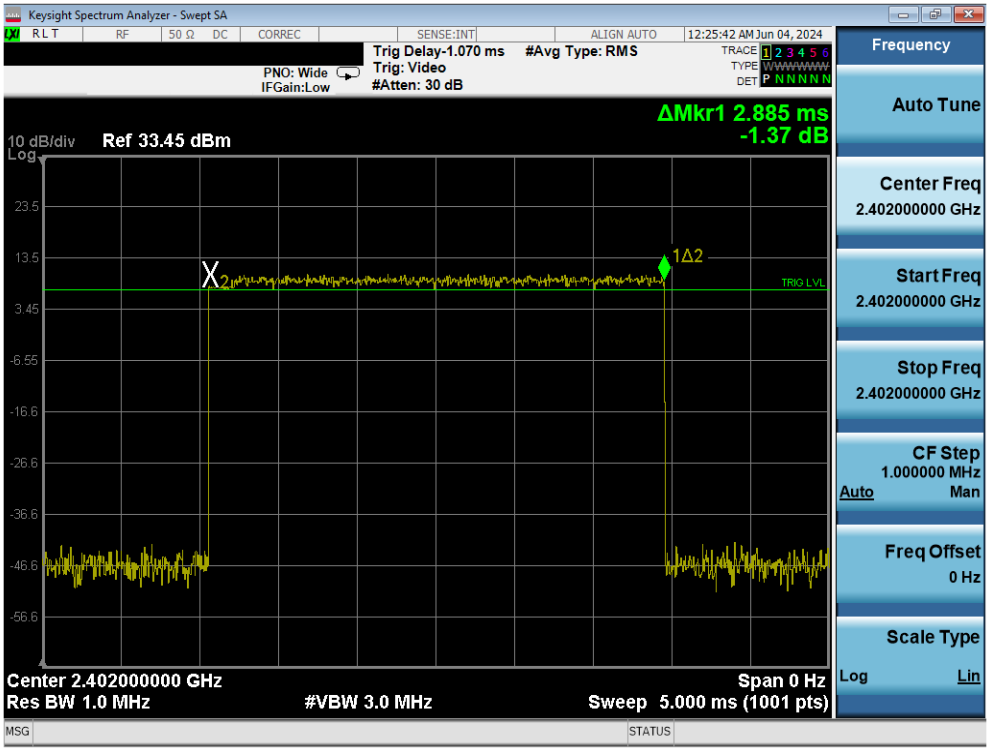


Plot 7-52. Time of Occupancy Plot Antenna WF7 (Bluetooth, 8DPSK, ePA)

Antenna WF2



Plot 7-53. Time of Occupancy Plot Antenna WF2 (Bluetooth, GFSK, iPA)



Plot 7-54. Time of Occupancy Plot Antenna WF2 (Bluetooth, 8DPSK, iPA)

Bluetooth Time of Occupancy Calculation

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

- 400ms x 79 hopping channels = 31.6 sec (Time of Occupancy Limit)
- Worst case BT has 266.67 hops/second (for 1x/EDR modes with DH5 operation)
- 266.67 hops/second / 79 channels = 3.38 hops/second (# of hops/second on one channel)
- 3.38 hops/second/channel x 31.6 seconds = 106.81 hops (# hops over a 31.6 second period)
- 106.81 hops x 2.89 ms/channel = 308.68 ms (worst case dwell time for one channel in 1x/EDR modes)

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

- 400ms x 20 hopping channels = 8 sec (Time of Occupancy Limit)
- Worst case BT has 133.3 hops/second/slot (for AFH mode with DH5 operation)
- 133.3 hops/s / 20 channels = 6.67 hops/second (# of hops/second on one channel)
- 6.67 hops/s / channel x 8 seconds = 53.36 hops (# hops over a 8 second period)
- 53.36 hops x 2.89 ms/channel = 154.21 ms (worst case dwell time for one channel in AFH mode)

Test Result

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

7.7 Number of Hopping Channels

§15.247 (a.1.iii); RSS-247 [5.1(d)]

Test Overview and Limit

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

Test Procedure Used

ANSI C63.10-2020 – Section 7.8.3

Test Settings

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

Test Setup

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

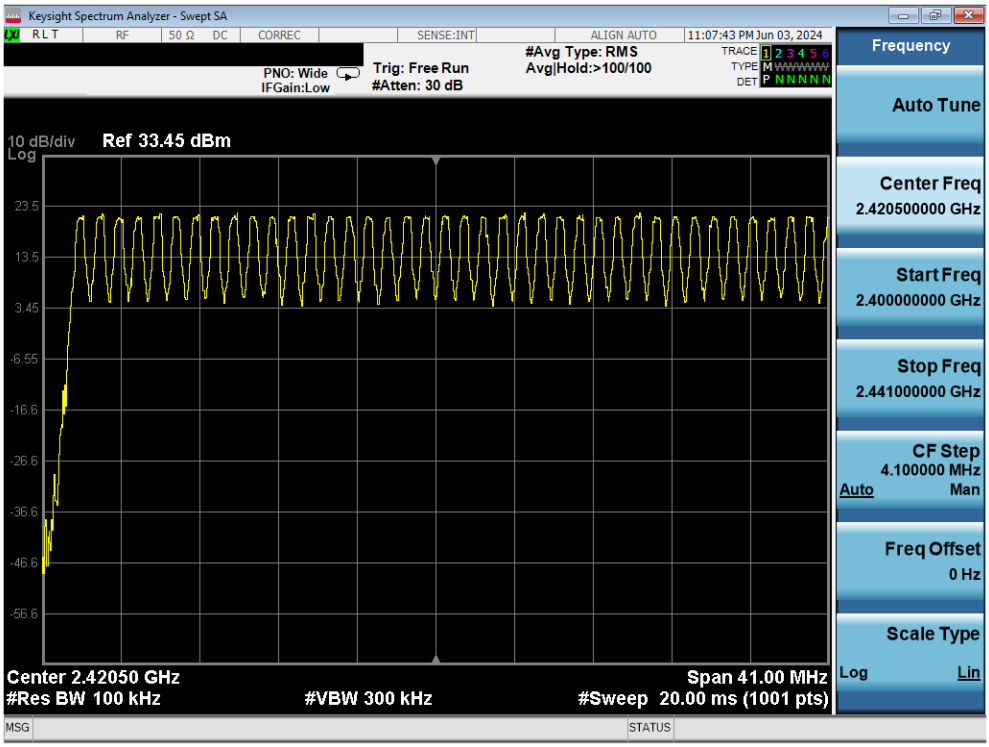
Figure 7-6. Test Instrument & Measurement Setup

Test Notes

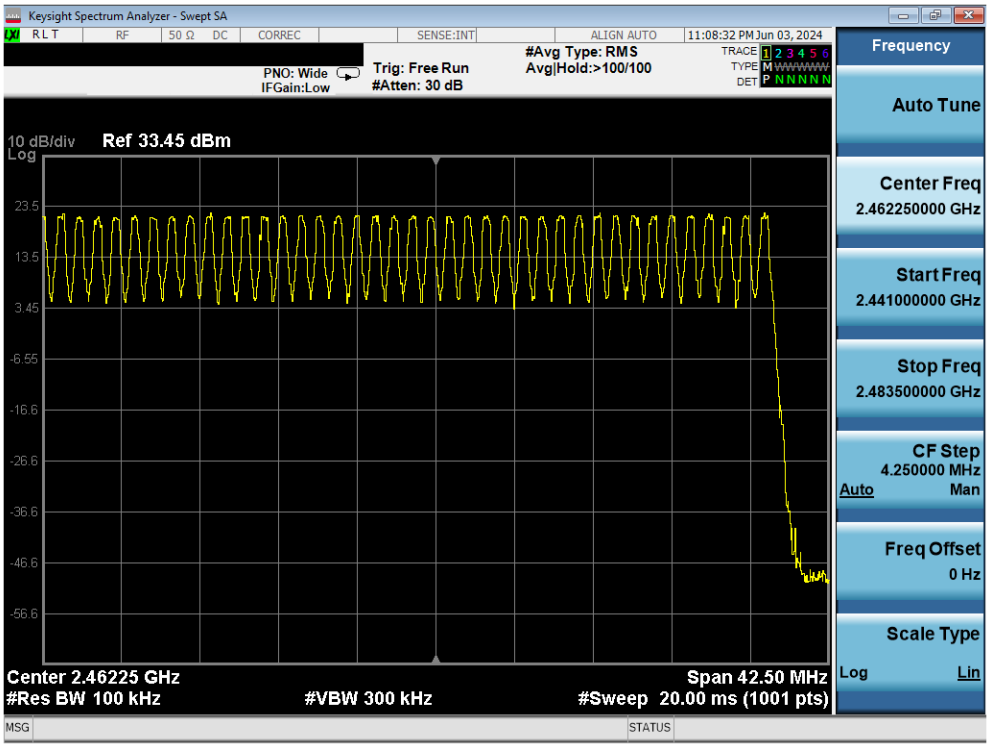
1. The frequency spectrum was broken up into two sub-ranges to clearly show all of the hopping frequencies. In AFH mode, this device operates using 20 channels so the requirement for minimum number of hopping channels is satisfied.

2. All supported modulation, antenna (including TxBF mode) and power schemes have been tested on the unit and only worst case configuration is reported.

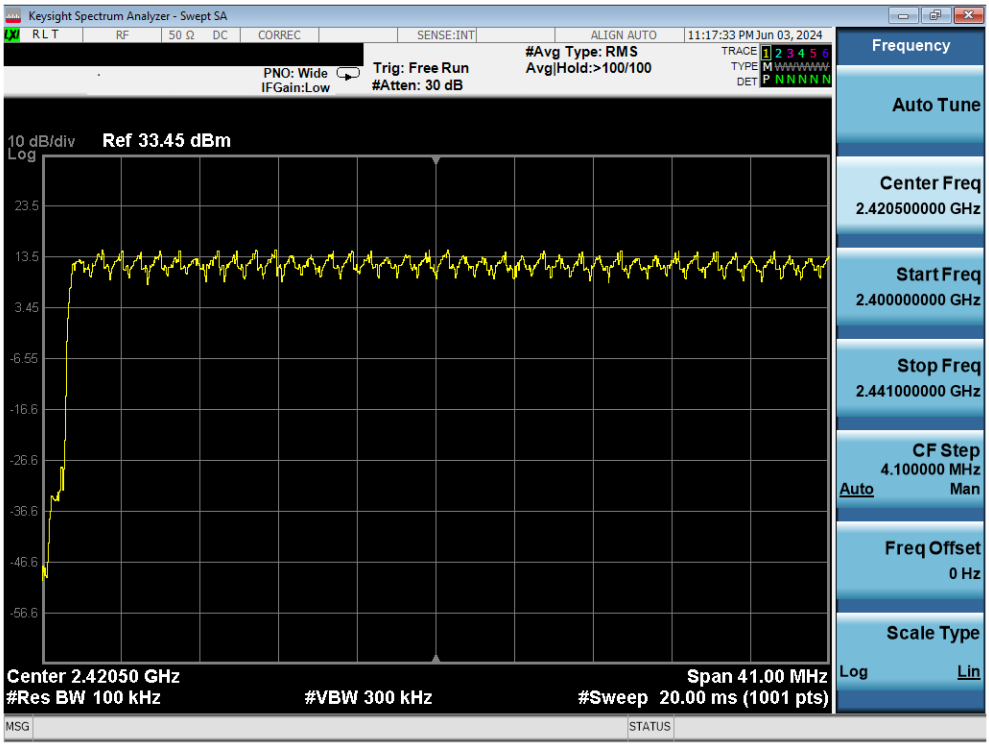
Antenna WF8



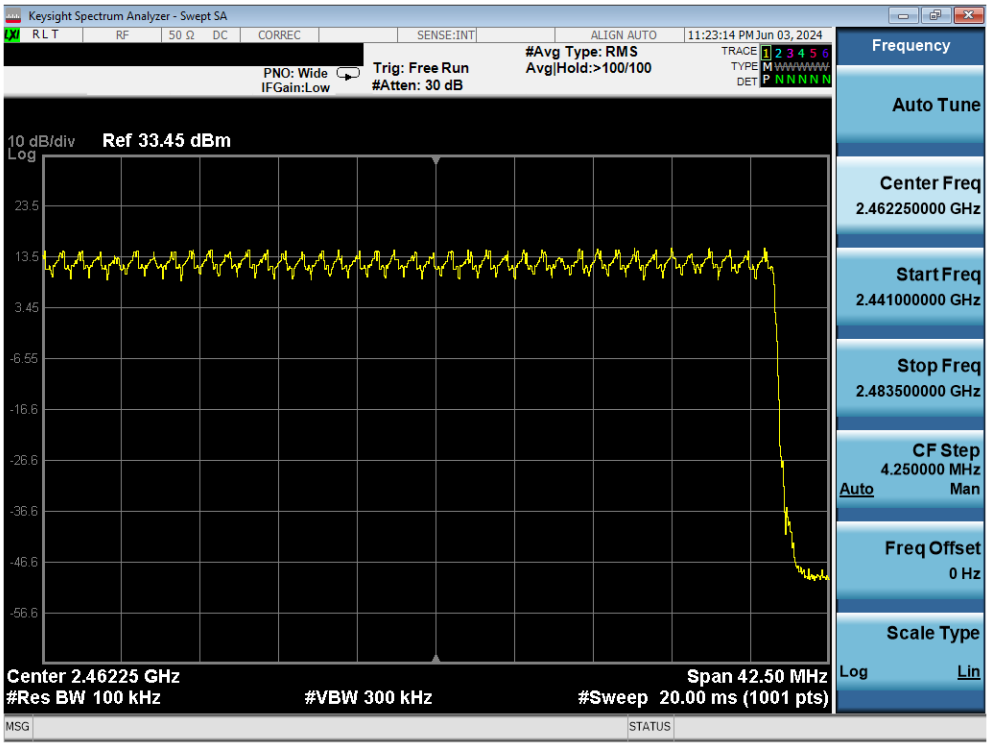
Plot 7-55. Low End Spectrum Channel Hopping Plot Antenna WF8 (Bluetooth, GFSK, ePA)



Plot 7-56. High End Spectrum Channel Hopping Plot Antenna WF8 (Bluetooth, GFSK, ePA)

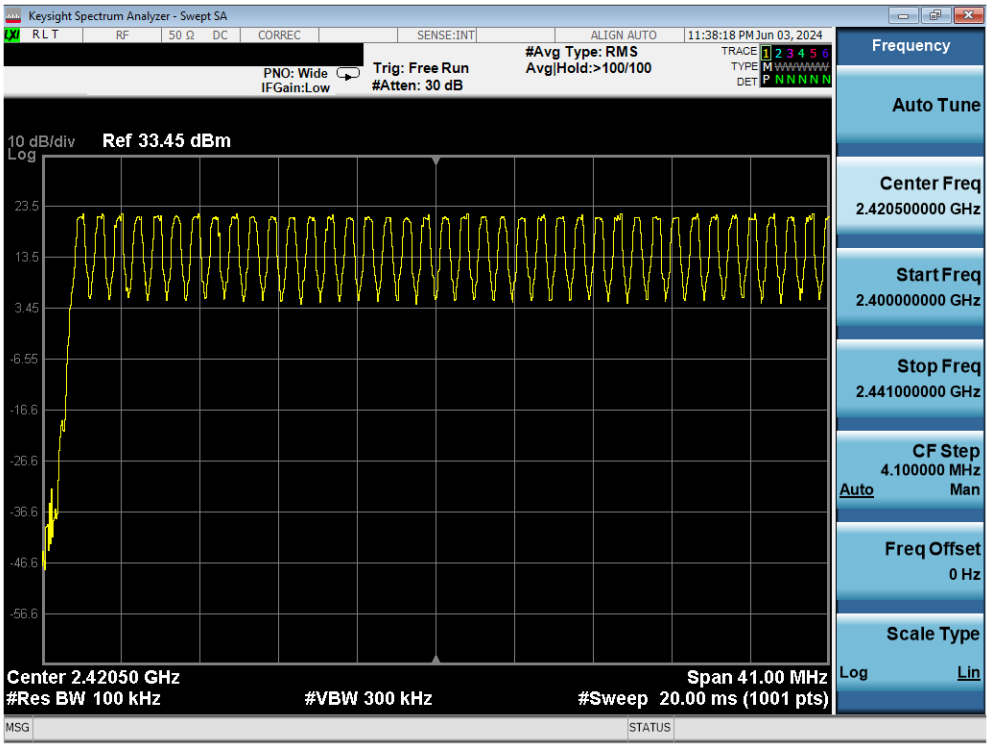


Plot 7-57. Low End Spectrum Channel Hopping Plot Antenna WF8 (Bluetooth, 8DPSK, ePA)

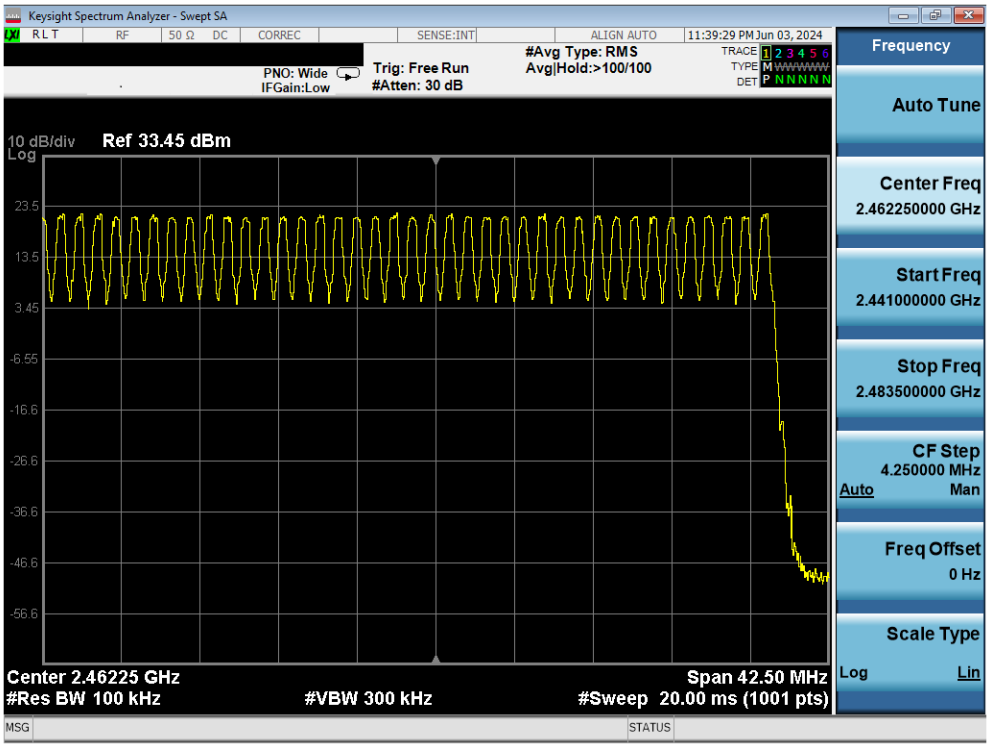


Plot 7-58. High End Spectrum Channel Hopping Plot Antenna WF8 (Bluetooth, 8DPSK, ePA)

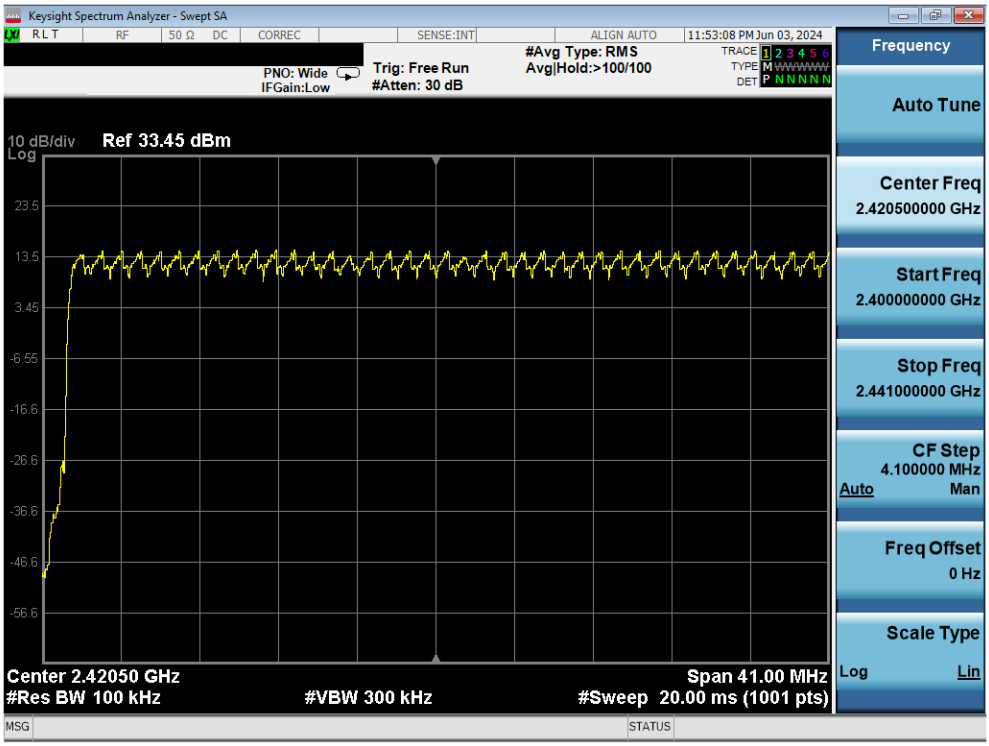
Antenna WF7



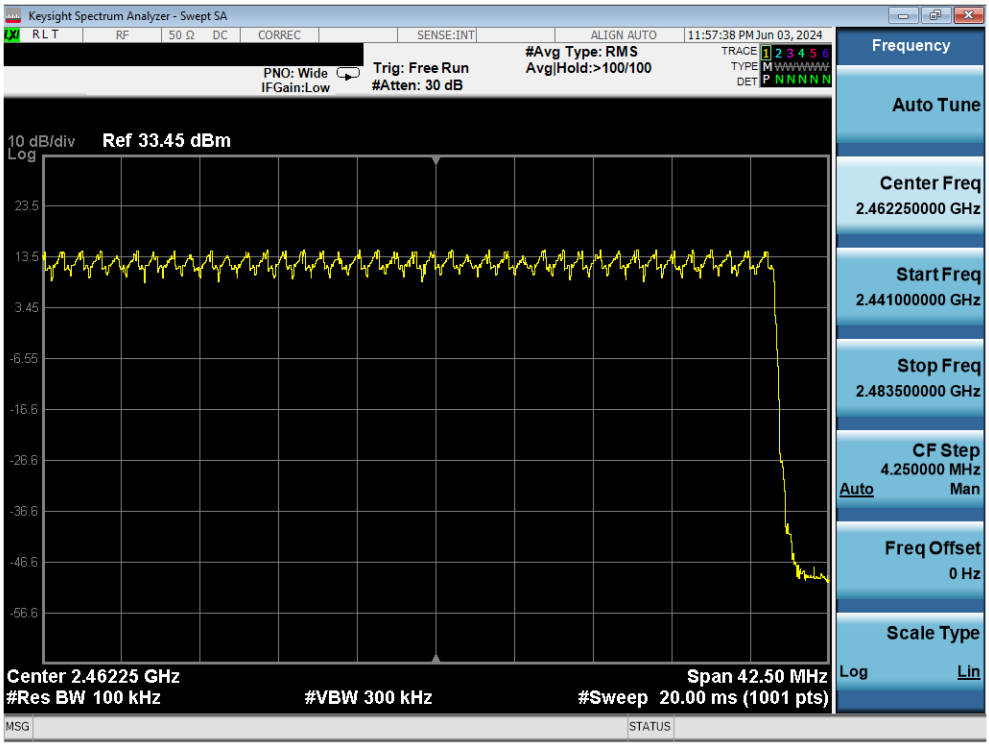
Plot 7-59. Low End Spectrum Channel Hopping Plot Antenna WF7 (Bluetooth, GFSK, ePA)



Plot 7-60. High End Spectrum Channel Hopping Plot Antenna WF7 (Bluetooth, GFSK, ePA)

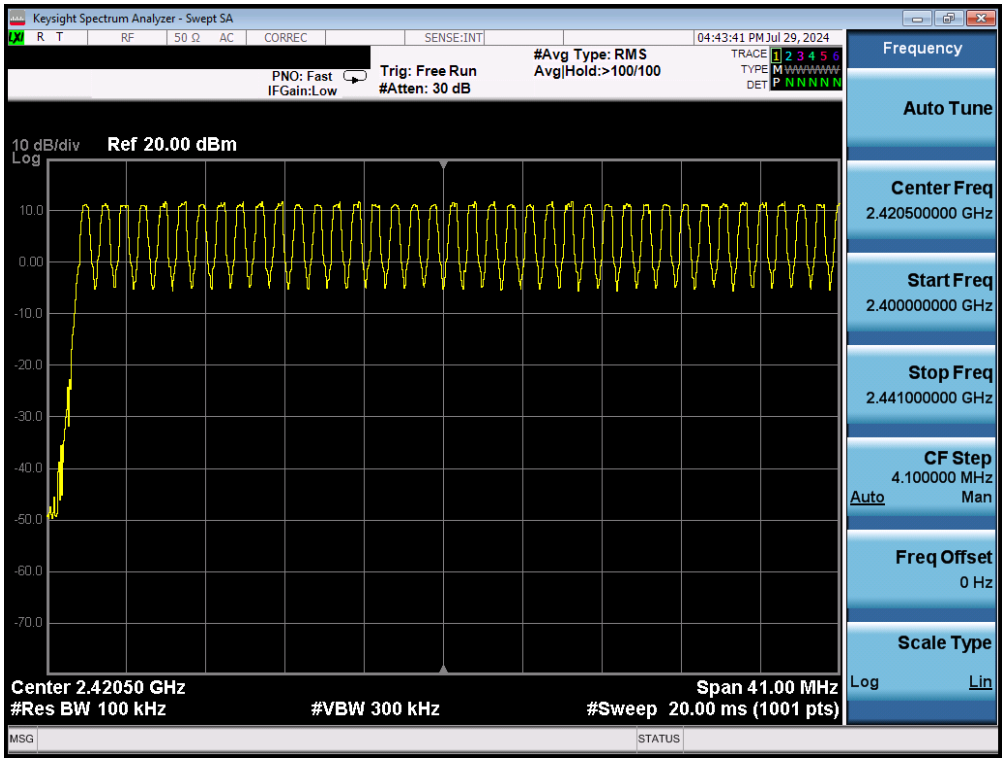


Plot 7-61. Low End Spectrum Channel Hopping Plot Antenna WF7 (Bluetooth, 8DPSK, ePA)

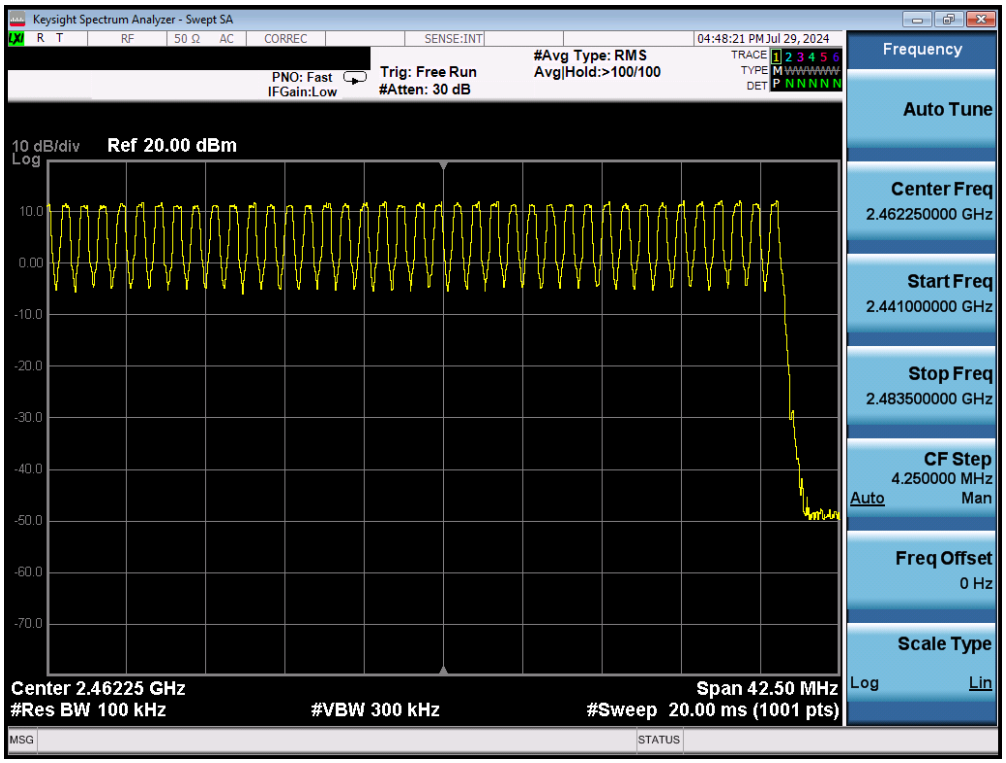


Plot 7-62. High End Spectrum Channel Hopping Plot Antenna WF7 (Bluetooth, 8DPSK, ePA)

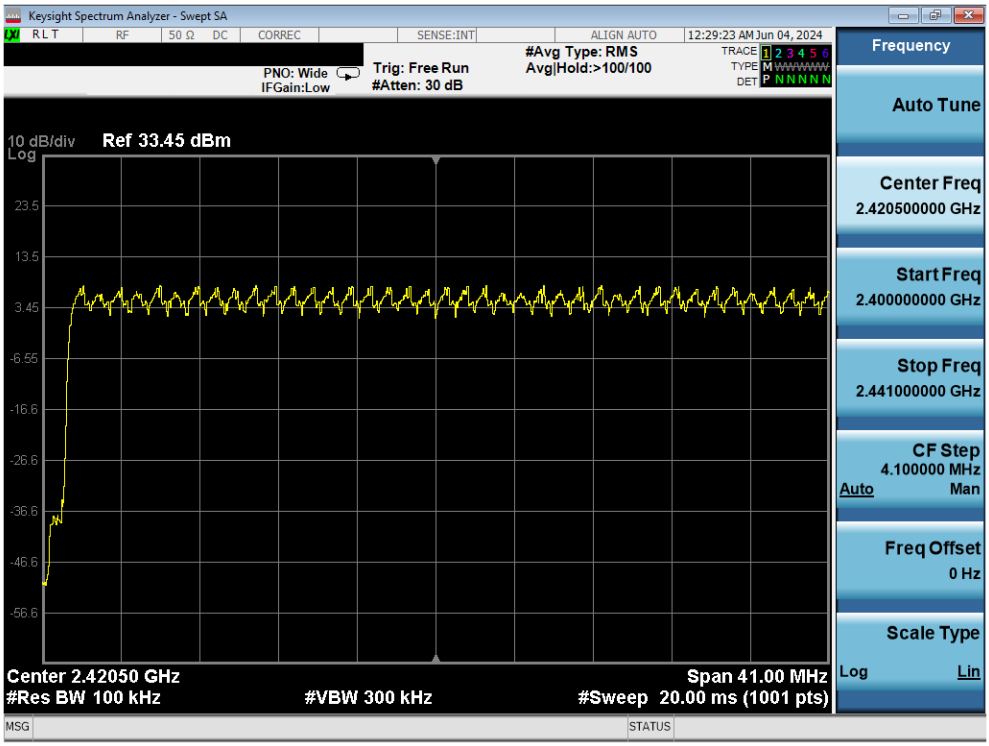
Antenna WF2



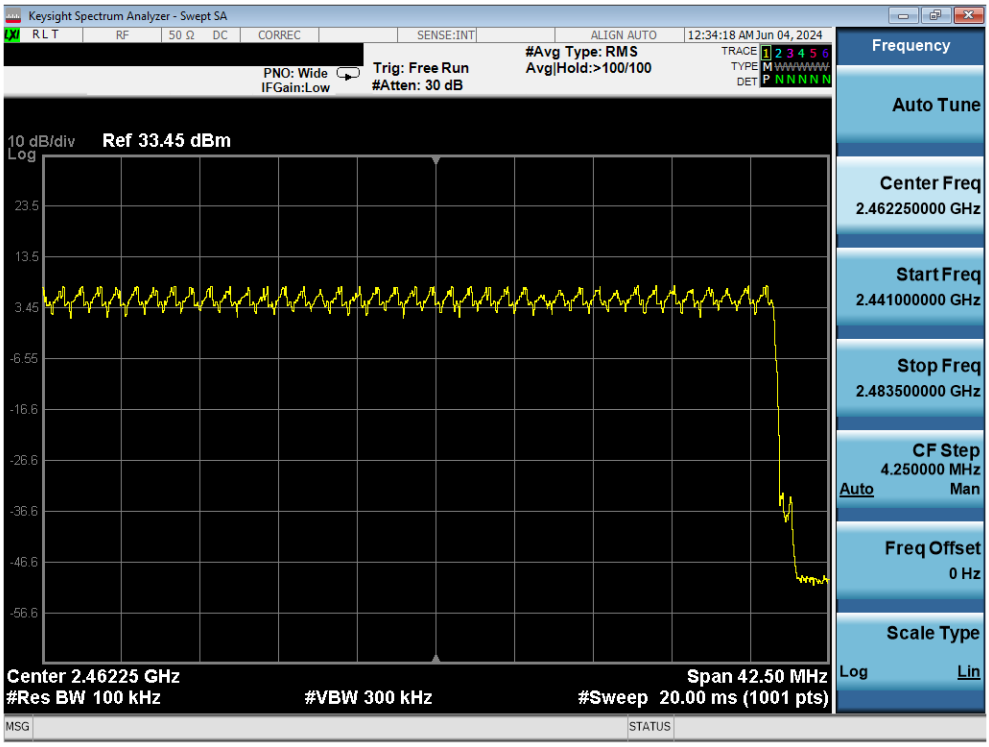
Plot 7-63. Low End Spectrum Channel Hopping Plot Antenna WF2 (Bluetooth, GFSK, iPA)



Plot 7-64. High End Spectrum Channel Hopping Plot Antenna WF2 (Bluetooth, GFSK, iPA)



Plot 7-65. Low End Spectrum Channel Hopping Plot Antenna WF2 (Bluetooth, 8DPSK, iPA)



Plot 7-66. High End Spectrum Channel Hopping Plot Antenna WF2 (Bluetooth, 8DPSK, iPA)

7.8 Conducted Spurious Emissions

§15.247 (d); RSS-247 [5.5]

Test Overview and Limit

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

Test Procedure Used

ANSI C63.10-2020 – Section 7.8.8

Test Settings

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

Test Setup

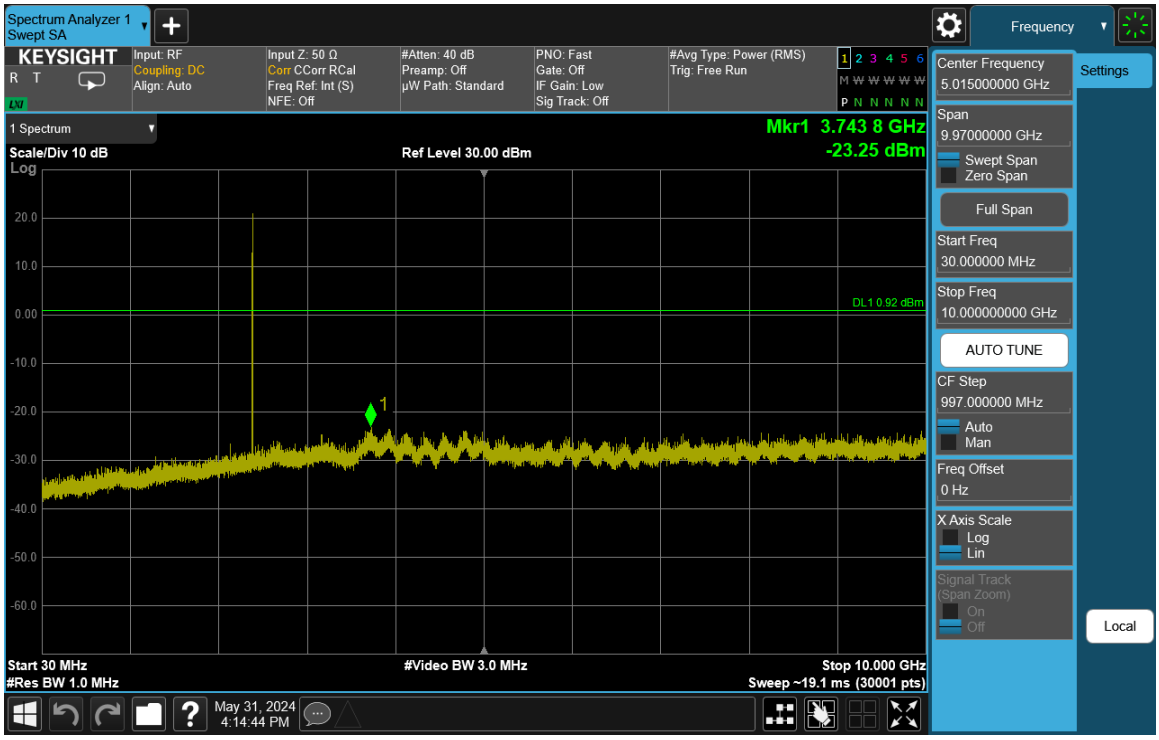
The EUT and measurement equipment were set up as shown in the diagram below.

Figure 7-7. Test Instrument & Measurement Setup

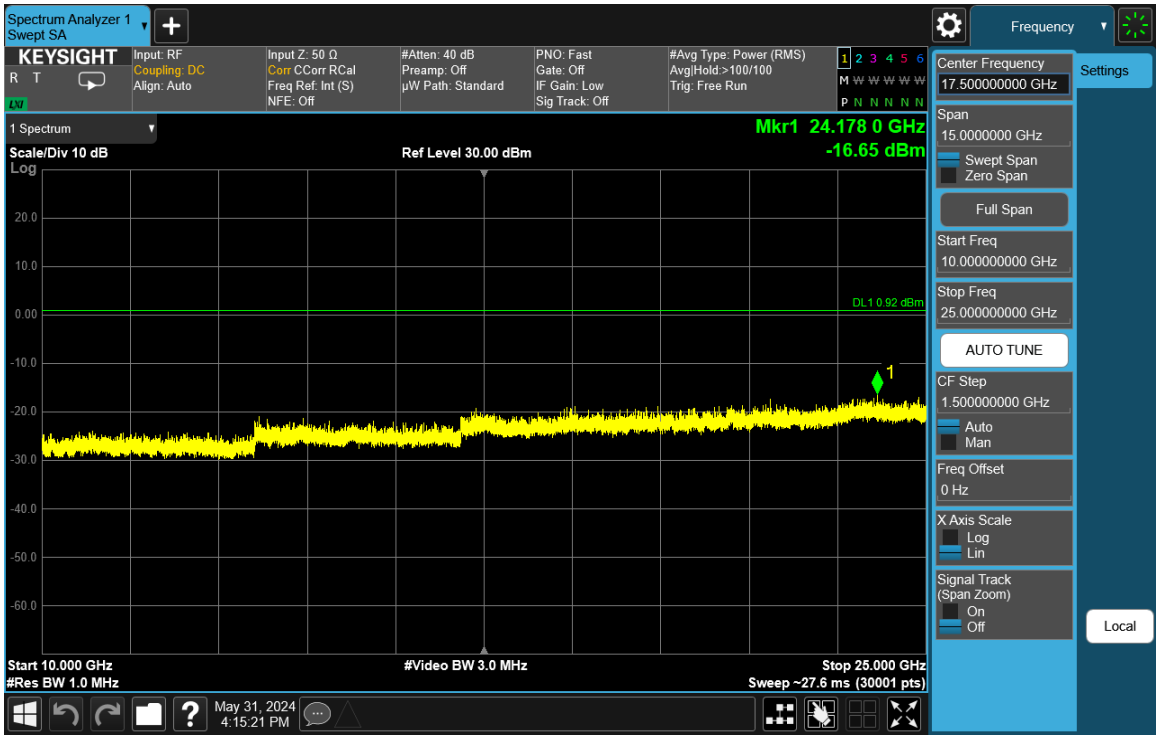
Test Notes

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

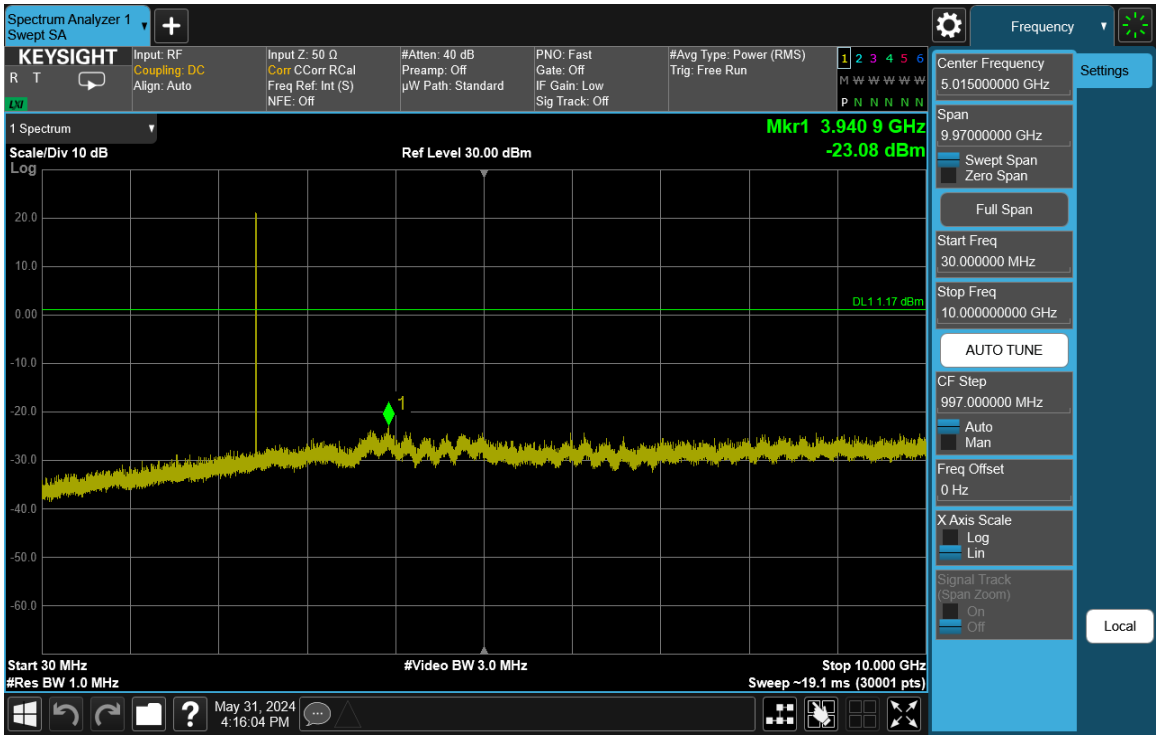
Antenna WF8



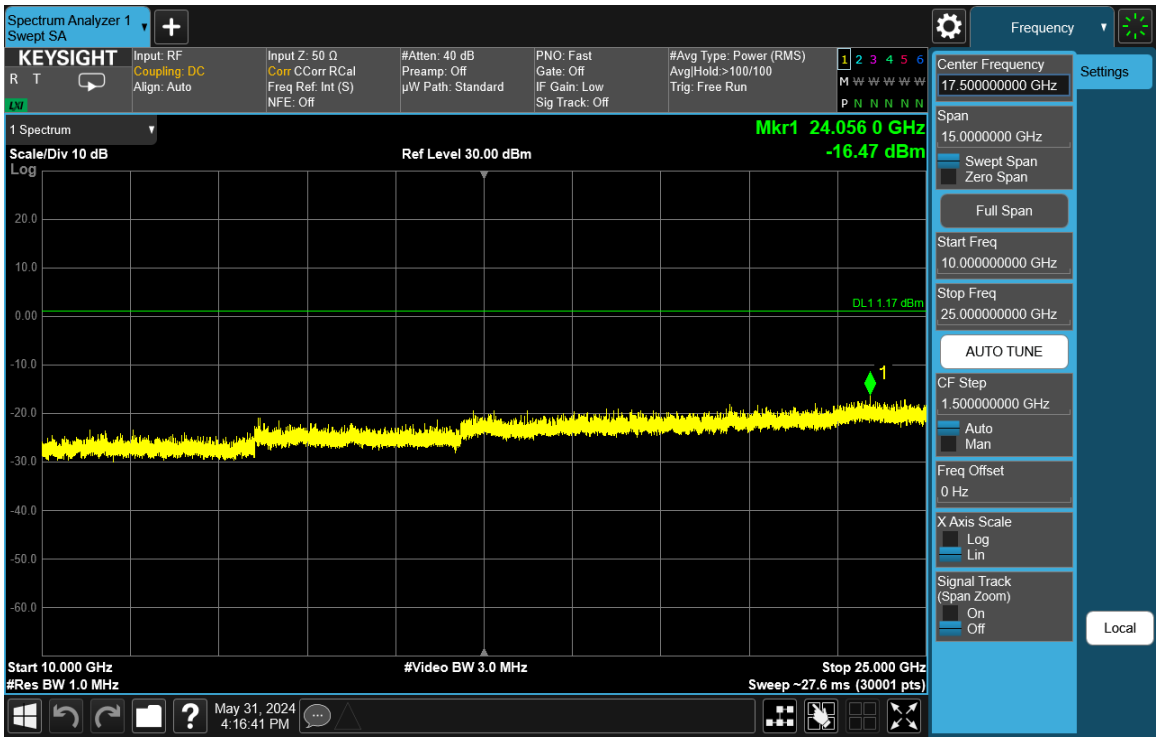
Plot 7-67. Conducted Spurious Plot Antenna WF8 (Bluetooth, GFSK, ePA – Ch. 0)



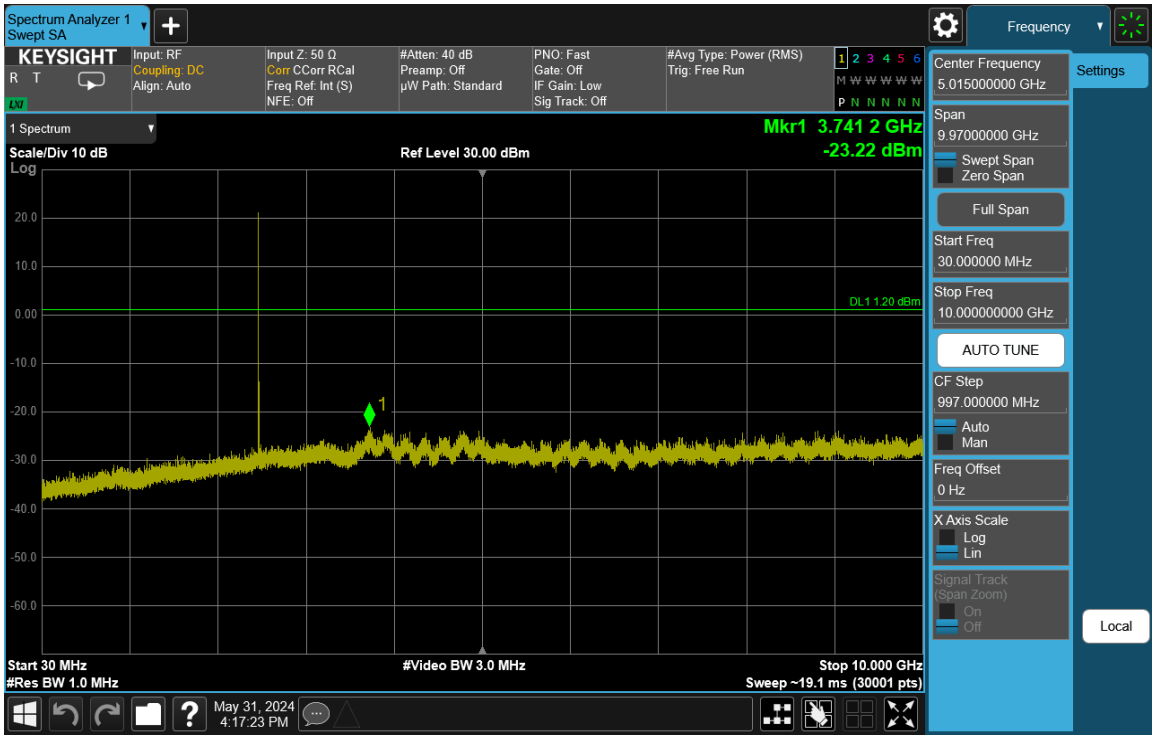
Plot 7-68. Conducted Spurious Plot Antenna WF8 (Bluetooth, GFSK, ePA – Ch. 0)



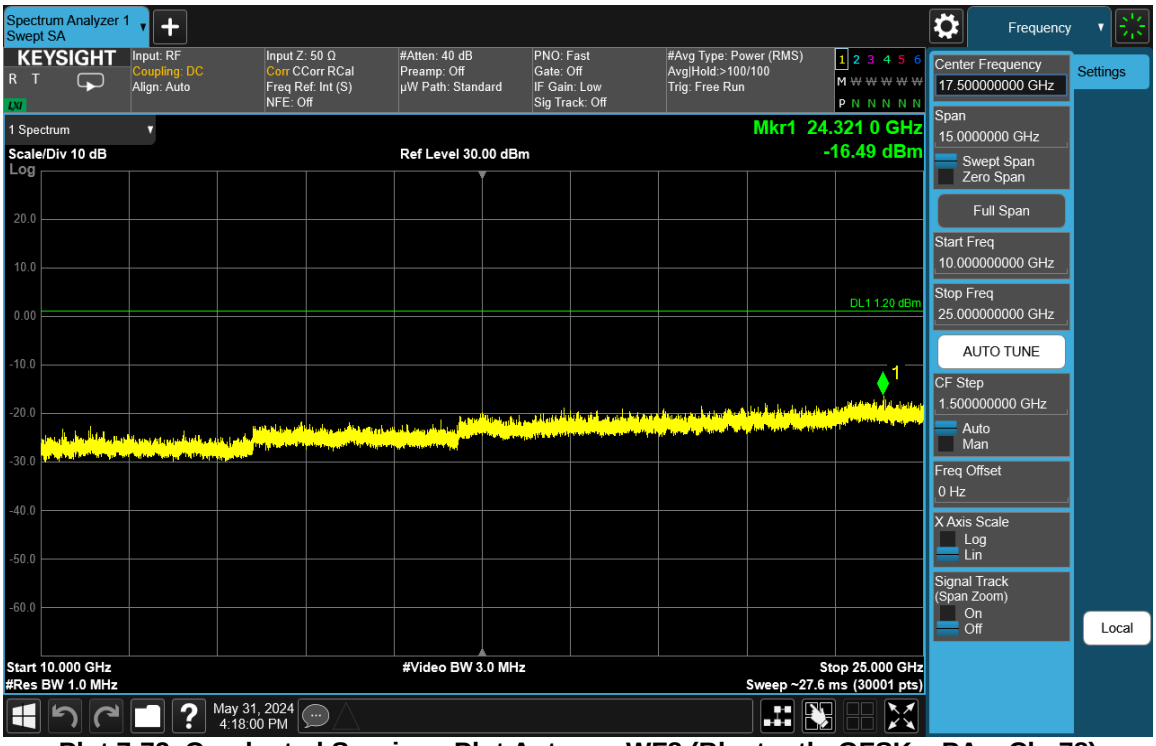
Plot 7-69. Conducted Spurious Plot Antenna WF8 (Bluetooth, GFSK, ePA – Ch. 39)



Plot 7-70. Conducted Spurious Plot Antenna WF8 (Bluetooth, GFSK, ePA Ch. 39)



Plot 7-71. Conducted Spurious Plot Antenna WF8 (Bluetooth, GFSK, ePA – Ch. 78)



Plot 7-72. Conducted Spurious Plot Antenna WF8 (Bluetooth, GFSK, ePA – Ch. 78)