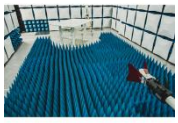
Element Materials Technology
(Formerly PCTEST)
18855 Adams Court, Morgan Hill, CA 95037 USA
Tel. 408.538.5600
http://www.element.com



# 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:**
10/25/2024 - 1/14/2025
**Test Report Issue Date:**
1/24/2025
**Test Site/Location:**
Element Materials Technology, Morgan Hill, CA, USA
**Test Report Serial No.:**
1C2410210076-07.BCG

| | |
|---|---|
| **FCC ID:** | **BCGA3354** |
| **IC:** | **579C-A3354** |
| **APPLICANT:** | **Apple Inc.** |

| | |
|---|---|
| **Application Type:** | Certification |
| **Model/HVIN:** | A3354 |
| **EUT Type:** | Tablet Device |
| **Max. RF Output Power:** | 30.269 mW (14.81 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.

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

RJ Ortanez
Executive Vice President

ACCREDITED
CERT #2041.02

# 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 located in Morgan Hill, CA 95037, U.S.A.**

- 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: BCGA3354 and IC: 579C-A3354**. 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.:** LCM6C3J3GN, C5G6DF4TJX, X7WY7H45F6, J0V7G4XLJ6, H9HHAD0006G0000VYN

## 2.2 Device Capabilities

This device contains the following capabilities:

802.11b/g/n/ax WLAN, 802.11a/n/ac/ax UNII, Bluetooth (1x, EDR, LE1M, LE2M)

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

**Table 2-1. Bluetooth Frequency/ Channel Operations**

**Note:** This device is capable of operating in hopping and non-hopping mode. The EUT can hop between 79 different channels in the 2400 – 2483.5MHz band. The maximum achievable duty cycles for all modes were determined based on measurements performed on a spectrum analyzer in zero-span mode with RBW = 8MHz, VBW = 50MHz, and detector = peak per the guidance of Section 6.0 b) of KDB 558074 D01 v05r02 and ANSI C63.10-2020. 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 WF7b |
| 2.4 GHz | GFSK | iPA | 100.0 | 100.0 |
| | 8PSK | iPA | 100.0 | 100.0 |
| | π/4-DQPSK | iPA | 100.0 | 100.0 |

**Table 2-2. Measured Duty Cycles**

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

| Antenna | Simultaneous Tx Config | Bluetooth 2.4GHz | WLAN | WIFI 5GHz |
|---|---|---|---|---|
| | | BDR, EDR, LE1/2M | 802.11 b/g/n/ax | 802.11 a/n/ac/ax |
| Ant WF8 | Config 1 | ✓ | × | ✓ |
| Ant WF8 | Config 2 | × | ✓ | ✓ |

**Table 2-3. Simultaneous Transmission Configurations**

✓ = Support; × = Not Support

**Note:**

All the above simultaneous transmission configurations have been tested and the worst-case configuration was found to be Config 1.

Specific 2.4 GHz Wi-Fi antenna that can only transmit simultaneously with 2.4 GHz Bluetooth antenna is listed in the SAR test report. For BT (2.4 GHz), in both connected and disconnected modes, and Wi-Fi (2.4 GHz) – 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 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 WF7b |
| 2.4 | 1.2 | 0.4 |

**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 | 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.

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.

Both Antenna WF8 and WF7b supports two signal paths (Dedicated and Common) to a single port via a splitter, with Common path power equal to or lower than Dedicated path power.

| Description | Bluetooth | UNII |
|---|---|---|
| Antenna | Antenna WF8 | Antenna WF8 |
| Channel | 78 | 36 |
| Operating Frequency (MHz) | 2480 | 5180 |
| Mode/Modulation | GFSK iPA | 802.11n |

**Table 2-6. Worst Case Simultaneous Transmission Configuration**

## 2.6 Software and Firmware

The test was conducted with firmware version 22D8 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 |
| 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 with the requirements of ANSI C63.5-2017.

| Manufacturer | Model | Description | Cal Date | Cal Interval | Cal Due | Serial Number |
|---|---|---|---|---|---|---|
| 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 | 10/21/2024 | Annual | 10/21/2025 | 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 RF Cable/Attenuator * | 6/10/2024 | Annual | 6/10/2025 | - |
| Keysight Technology | N9040B | UXA Signal Analyzer | 5/28/2024 | Annual | 5/28/2025 | MY57212015 |
| Keysight Technology | N9030A | PXA Signal Analyzer | 7/11/2024 | Annual | 7/11/2025 | MY49430244 |
| Rohde & Schwarz | TS-PR18 | Pre-Amplifier (1GHz - 18GHz) | 3/1/2024 | Annual | 3/1/2025 | 102145 |
| Rohde & Schwarz | TS-PR18 | Pre-Amplifier (1GHz - 18GHz) | 8/14/2024 | Annual | 8/14/2025 | 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: BCGA3354

IC: 579C-A3354

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 Section 7.8 |
| 15.205 15.209 | RSS-Gen [8.9] | General Field Strength Limits (Restricted Bands and Radiated Emission Limits) | Emissions in restricted bands must meet the radiated limits detailed in 15.209 (RSS-247 limits) | RADIATED | PASS | Section 7.9, Section 7.9.2, 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 "Conducted Automation," Version 1.1.1.
5. For radiated testing, 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 3.1.0.

## 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.

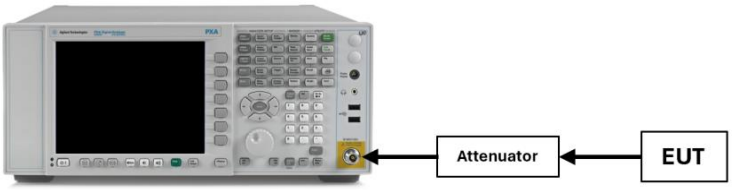



**Figure 7-1. Test Instrument & Measurement Setup**

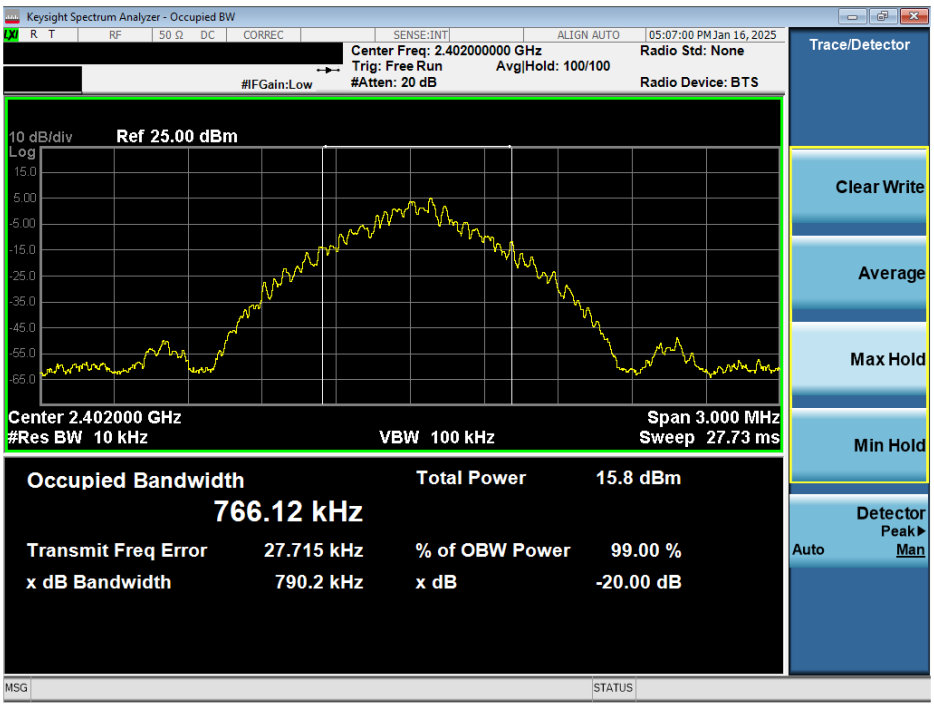
## Test Notes

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

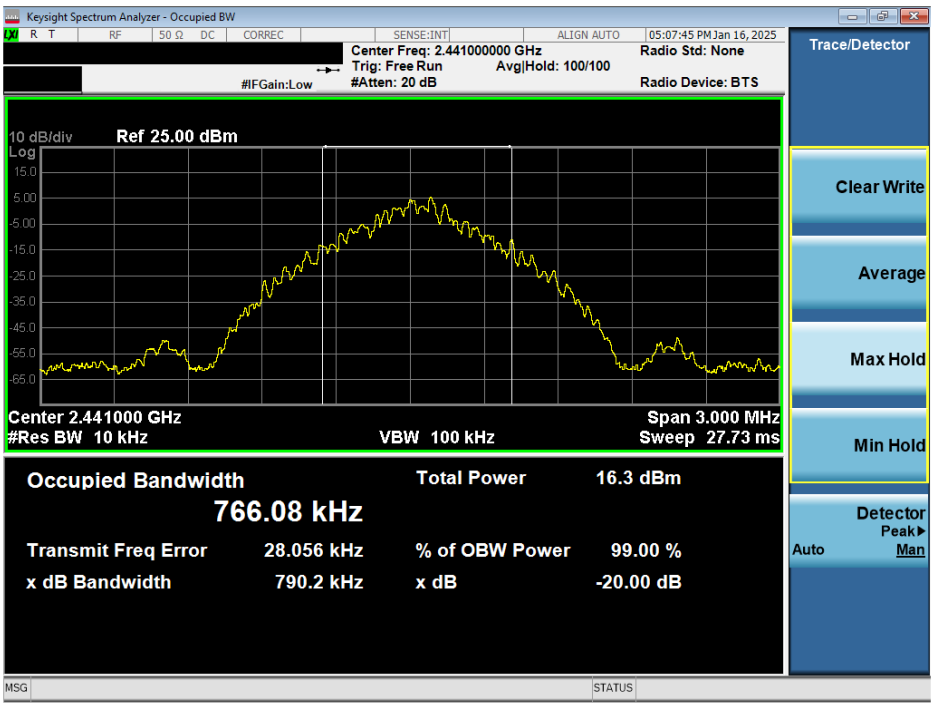
## Antenna WF8 (Common)

| 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 | 766.12 | 790.18 |
| 2441 | 1.0 | GFSK | iPA | 39 | 766.08 | 790.19 |
| 2480 | 1.0 | GFSK | iPA | 78 | 766.28 | 790.36 |
| 2402 | 3.0 | 8DPSK | iPA | 0 | 1193.74 | 1317.58 |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 1193.32 | 1317.59 |
| 2480 | 3.0 | 8DPSK | iPA | 78 | 1193.14 | 1316.26 |

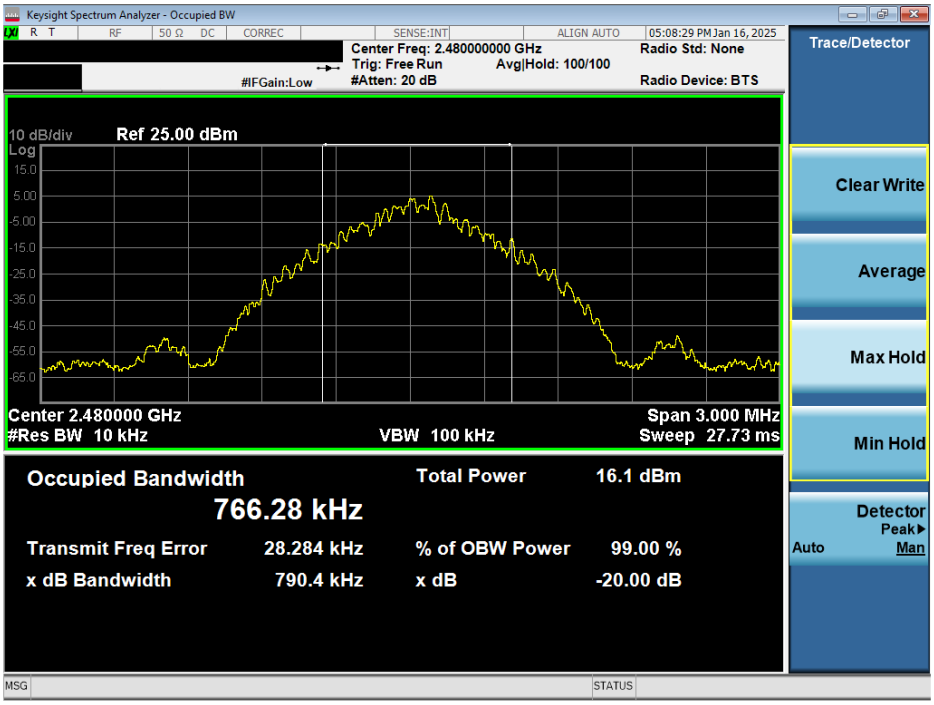
**Table 7-2. 20dB BW and 99% OBW Measurements Antenna WF8 (Common)**



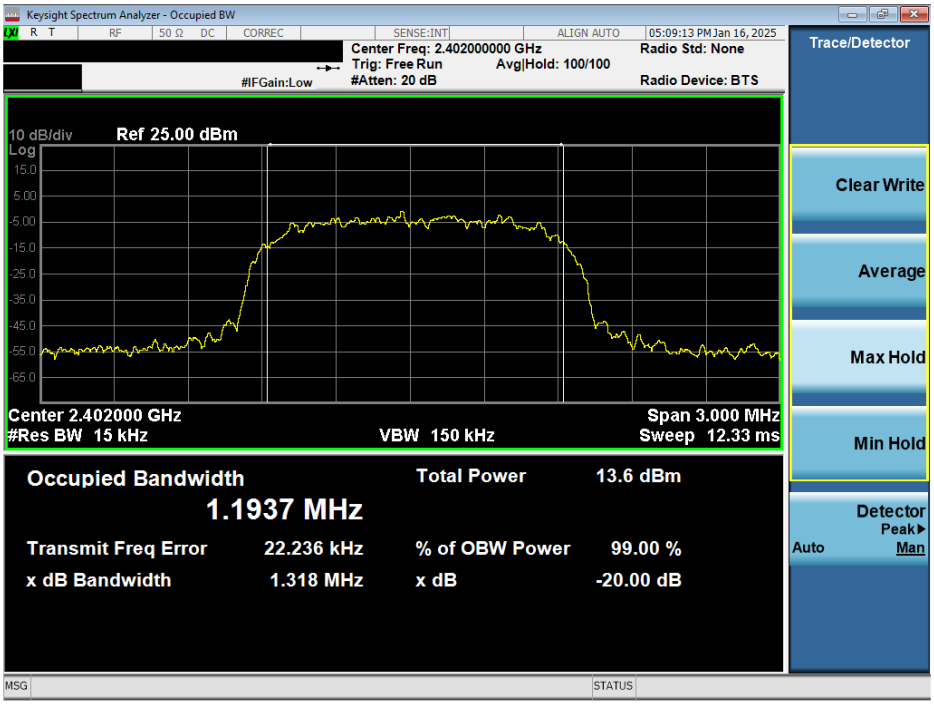

**Plot 7-1. 20dB BW and 99% OBW Plot Antenna WF8 (Common) (Bluetooth, GFSK, iPA – Ch. 0)**



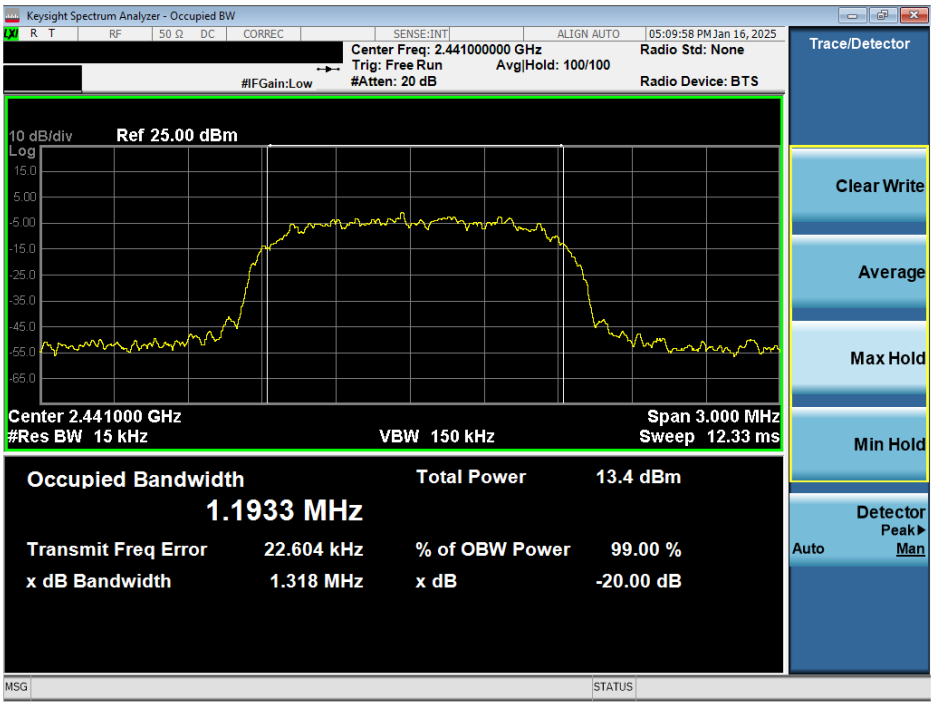

**Plot 7-2. 20dB BW and 99% OBW Plot Antenna WF8 (Common) (Bluetooth, GFSK, iPA – Ch. 39)**



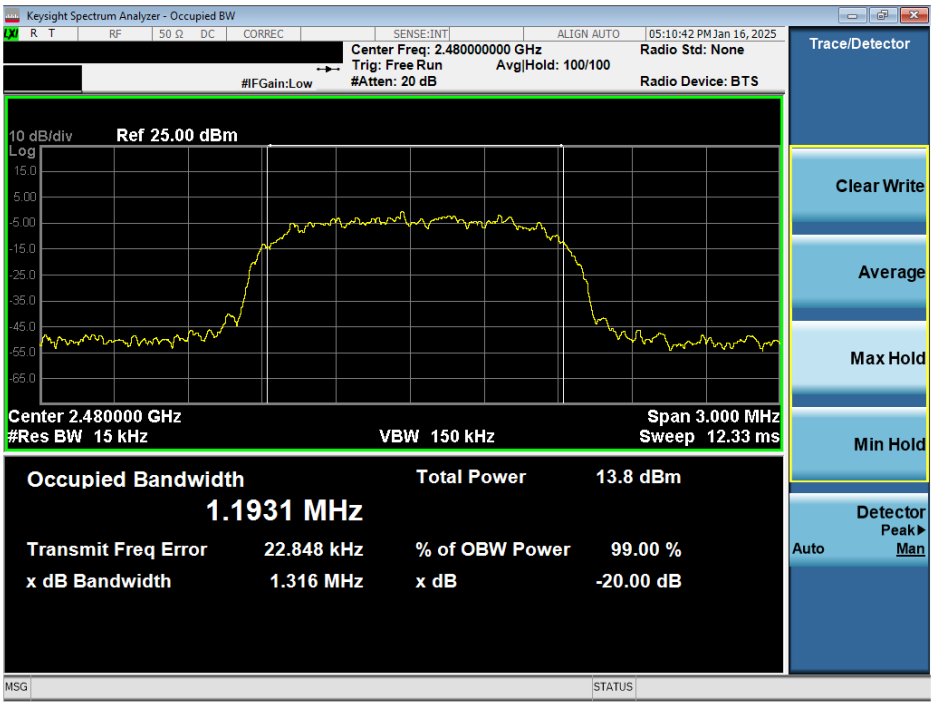

**Plot 7-3. 20dB BW and 99% OBW Plot Antenna WF8 (Common) (Bluetooth, GFSK, iPA – Ch. 78)**




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




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

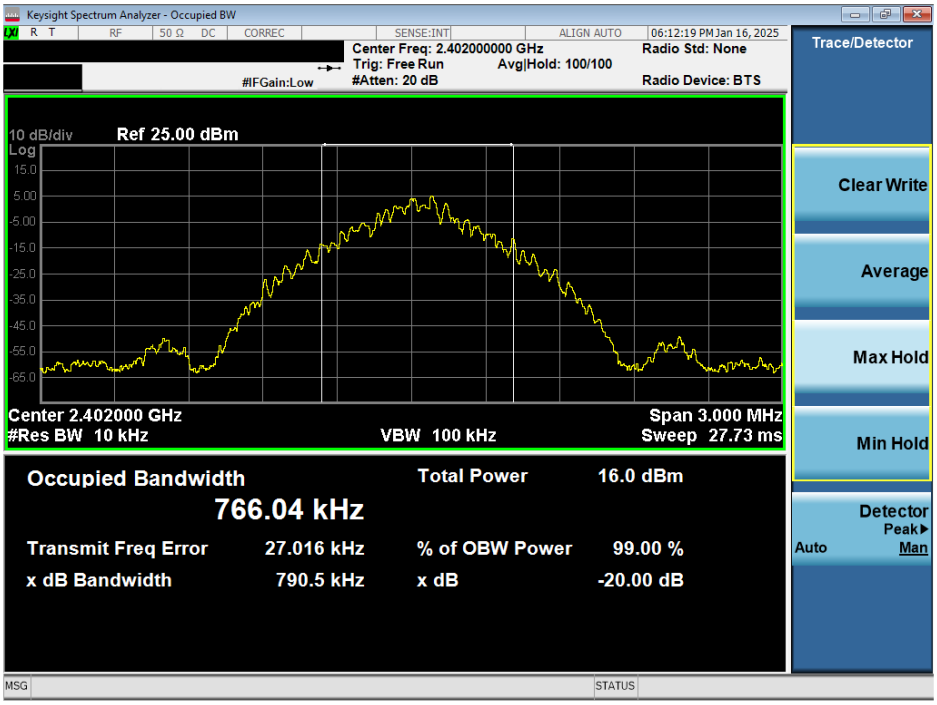



**Plot 7-6. 20dB BW and 99% OBW Plot Antenna WF8 (Common) (Bluetooth, 8DPSK, iPA – Ch. 78)**

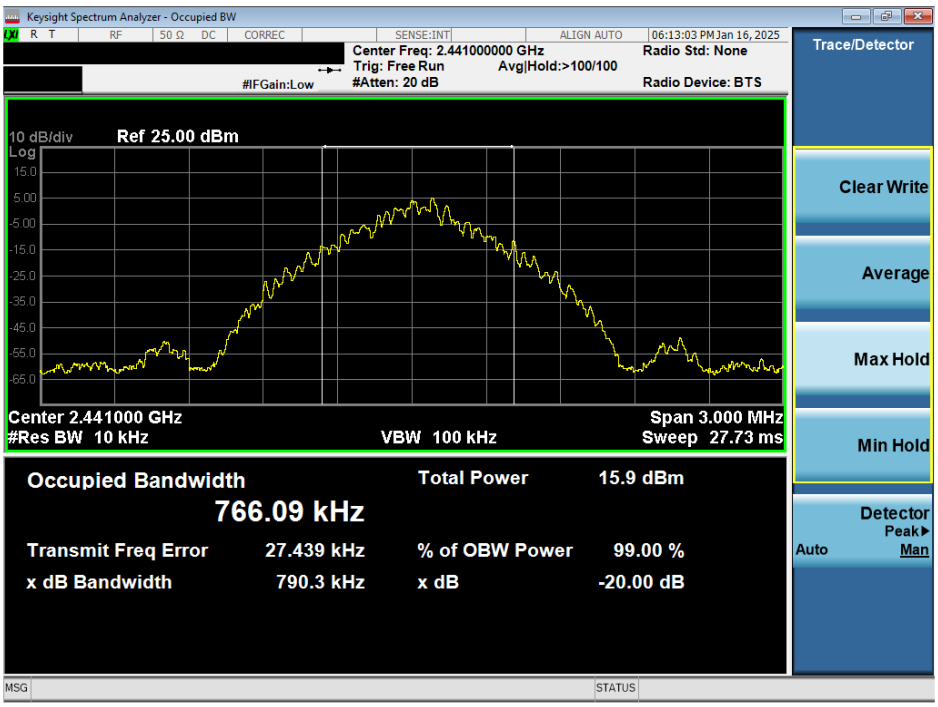
## Antenna WF7b (Common)

| 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 | 766.04 | 790.47 |
| 2441 | 1.0 | GFSK | iPA | 39 | 766.09 | 790.27 |
| 2480 | 1.0 | GFSK | iPA | 78 | 766.24 | 790.24 |
| 2402 | 3.0 | 8DPSK | iPA | 0 | 1193.79 | 1317.72 |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 1193.55 | 1317.72 |
| 2480 | 3.0 | 8DPSK | iPA | 78 | 1193.43 | 1317.38 |

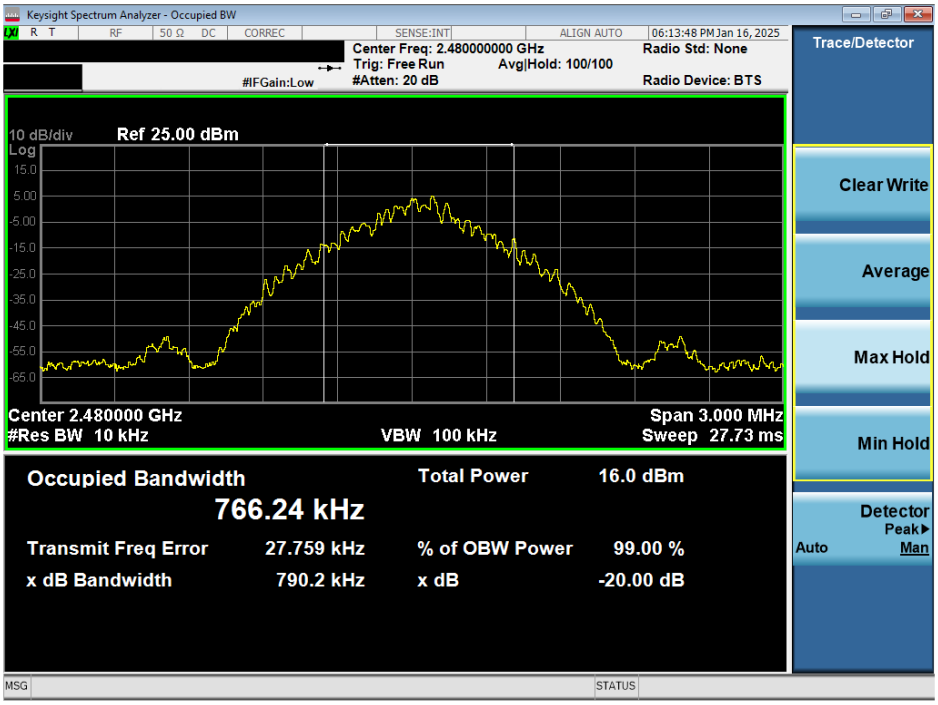
**Table 7-3. 20dB BW and 99% OBW Bandwidth Measurements Antenna WF7b (Common)**



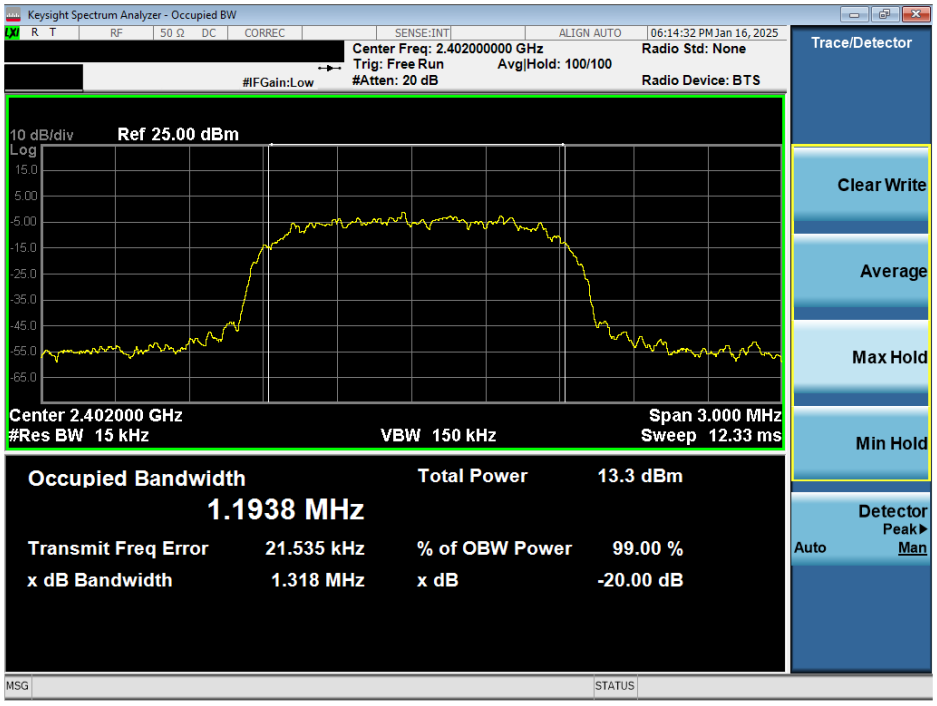

**Plot 7-7. 20dB BW and 99% OBW Plot Antenna WF7b (Common) (Bluetooth, GFSK, iPA – Ch. 0)**



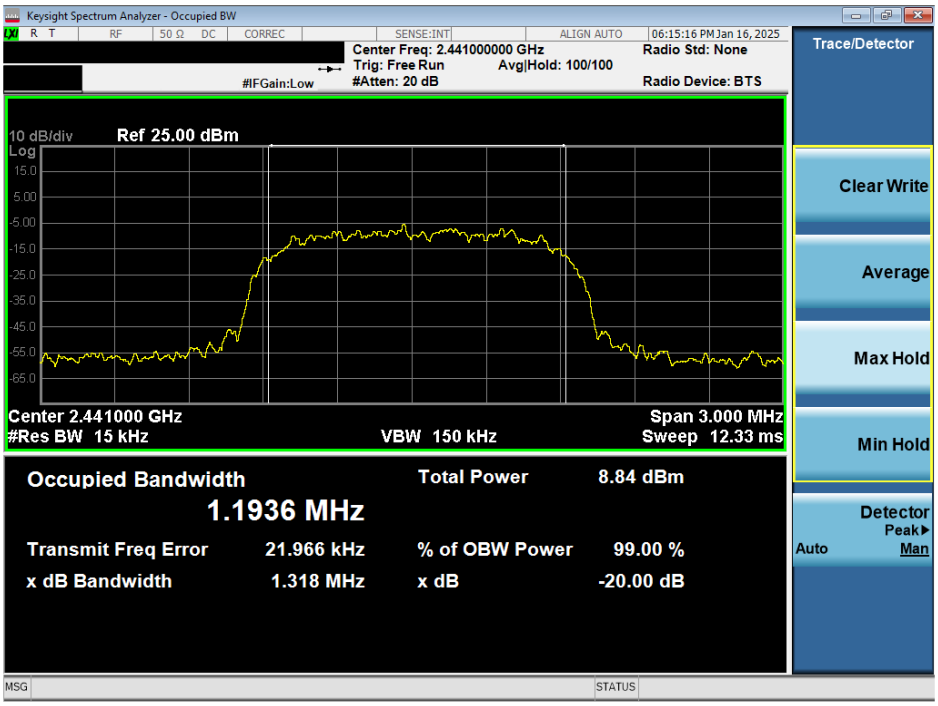

**Plot 7-8. 20dB BW and 99% OBW Plot Antenna WF7b (Common) (Bluetooth, GFSK, iPA – Ch. 39)**



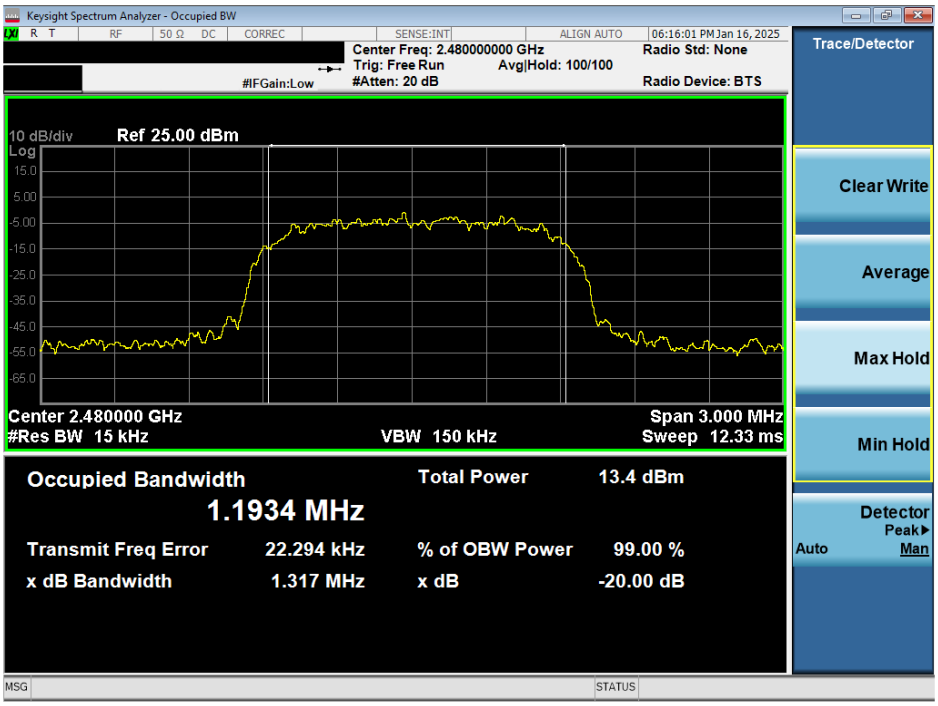

**Plot 7-9. 20dB BW and 99% OBW Plot Antenna WF7b (Common) (Bluetooth, GFSK, iPA – Ch. 78)**




**Plot 7-10. 20dB BW and 99% OBW Plot Antenna WF7b (Common) (Bluetooth, 8DPSK, iPA – Ch. 0)**




**Plot 7-11. 20dB BW and 99% OBW Plot Antenna WF7b (Common) (Bluetooth, 8DPSK, iPA – Ch. 39)**

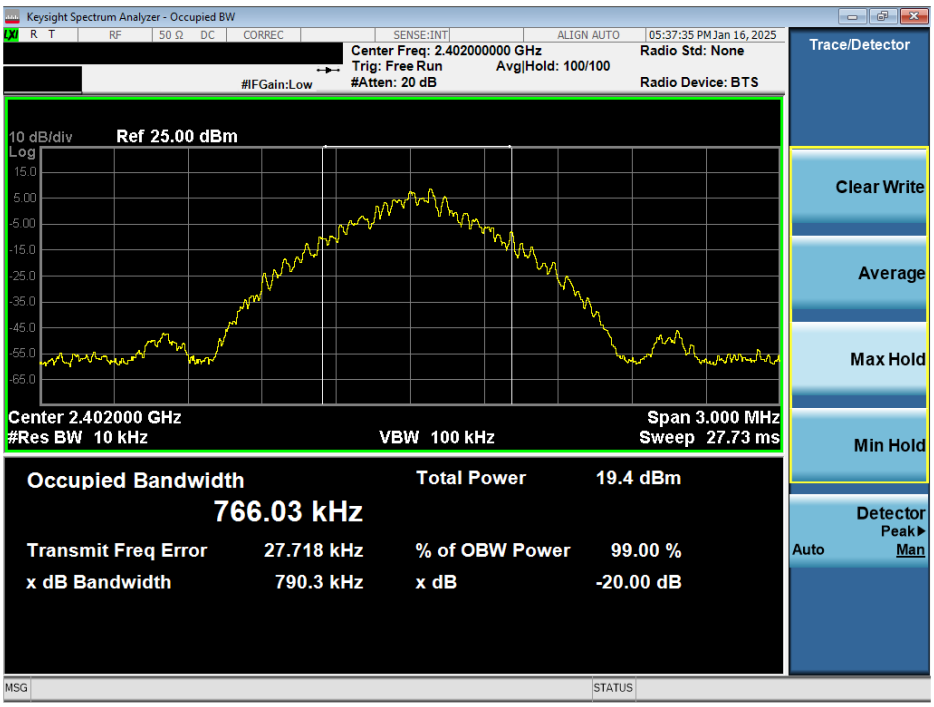



**Plot 7-12. 20dB BW and 99% OBW Plot Antenna WF7b (Common) (Bluetooth, 8DPSK, iPA – Ch. 78)**

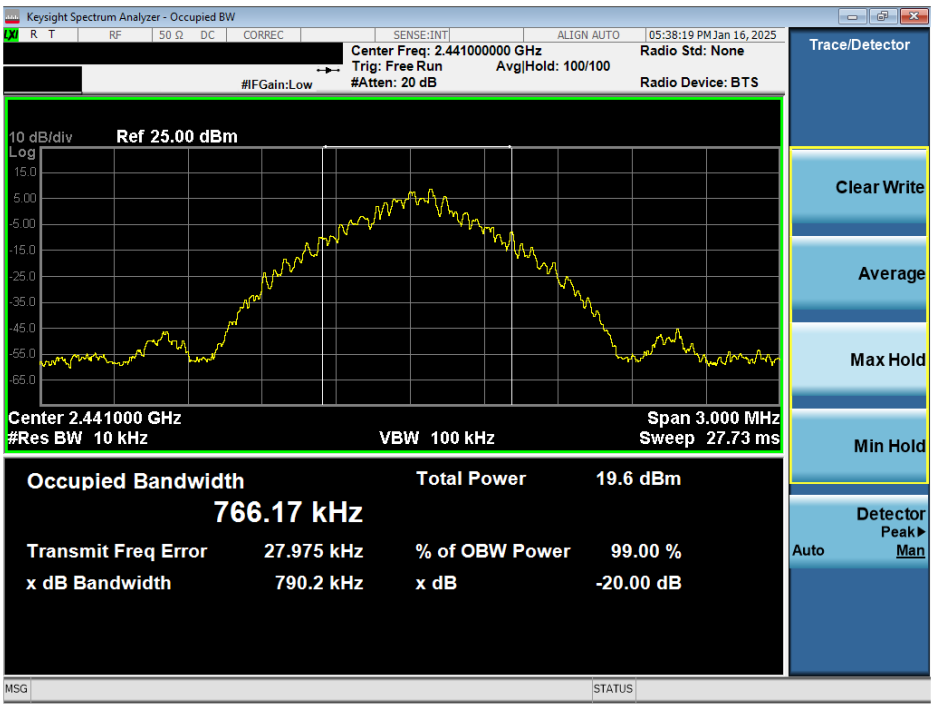
## Antenna WF8 (Dedicated)

| 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 | 766.03 | 790.28 |
| 2441 | 1.0 | GFSK | iPA | 39 | 766.17 | 790.20 |
| 2480 | 1.0 | GFSK | iPA | 78 | 766.30 | 790.47 |
| 2402 | 3.0 | 8DPSK | iPA | 0 | 1193.73 | 1317.59 |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 1193.84 | 1317.33 |
| 2480 | 3.0 | 8DPSK | iPA | 78 | 1193.92 | 1317.41 |

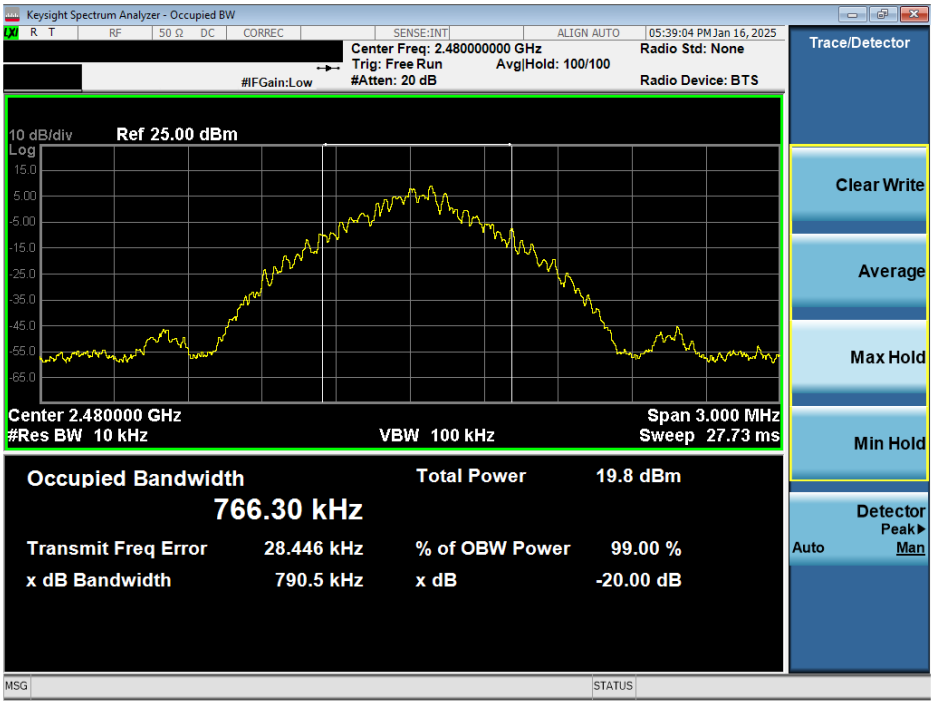
**Table 7-4. 20dB BW and 99% OBW Measurements Antenna WF8 (Dedicated)**



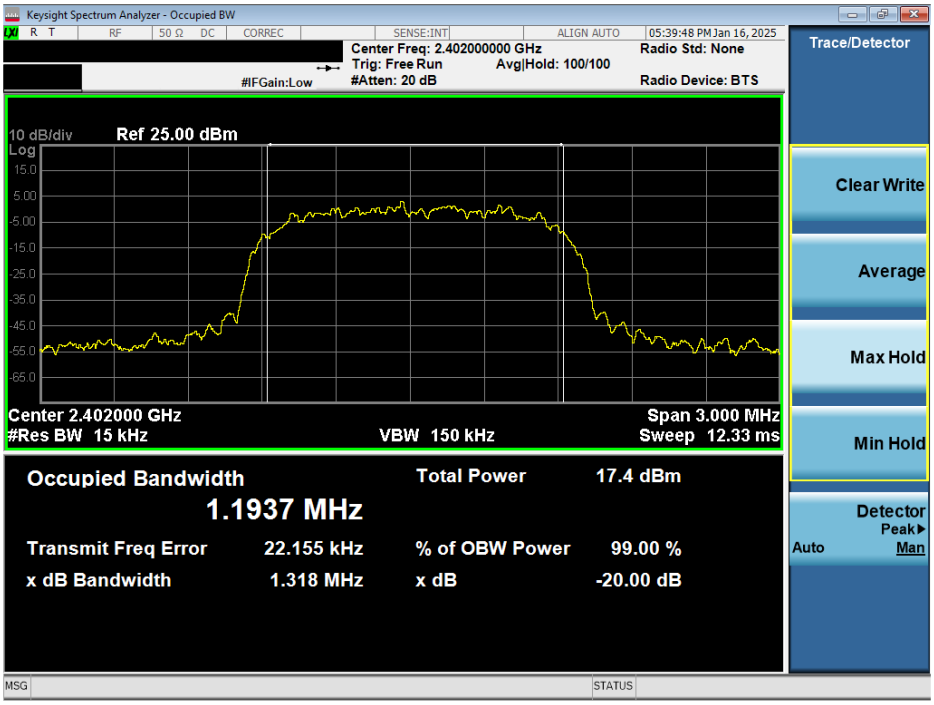

**Plot 7-13. 20dB BW and 99% OBW Plot Antenna WF8 (Dedicated) (Bluetooth, GFSK, iPA – Ch. 0)**



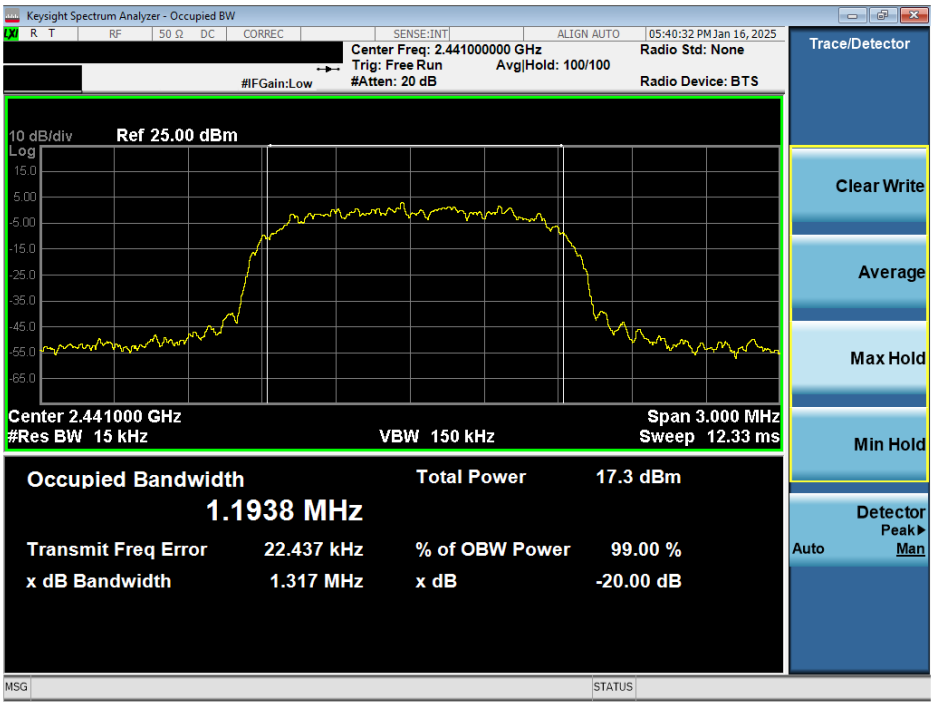

**Plot 7-14. 20dB BW and 99% OBW Plot Antenna WF8 (Dedicated) (Bluetooth, GFSK, iPA – Ch. 39)**



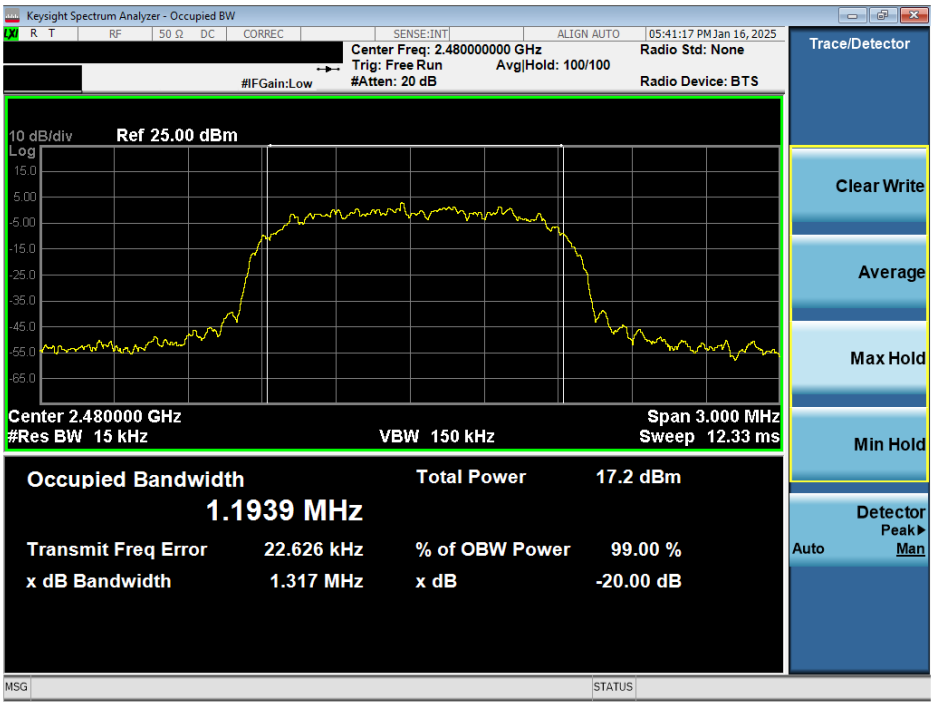

**Plot 7-15. 20dB BW and 99% OBW Plot Antenna WF8 (Dedicated) (Bluetooth, GFSK, iPA – Ch. 78)**




**Plot 7-16. 20dB BW and 99% OBW Plot Antenna WF8 (Dedicated) (Bluetooth, 8DPSK, iPA – Ch. 0)**




**Plot 7-17. 20dB BW and 99% OBW Plot Antenna WF8 (Dedicated) (Bluetooth, 8DPSK, iPA – Ch. 39)**

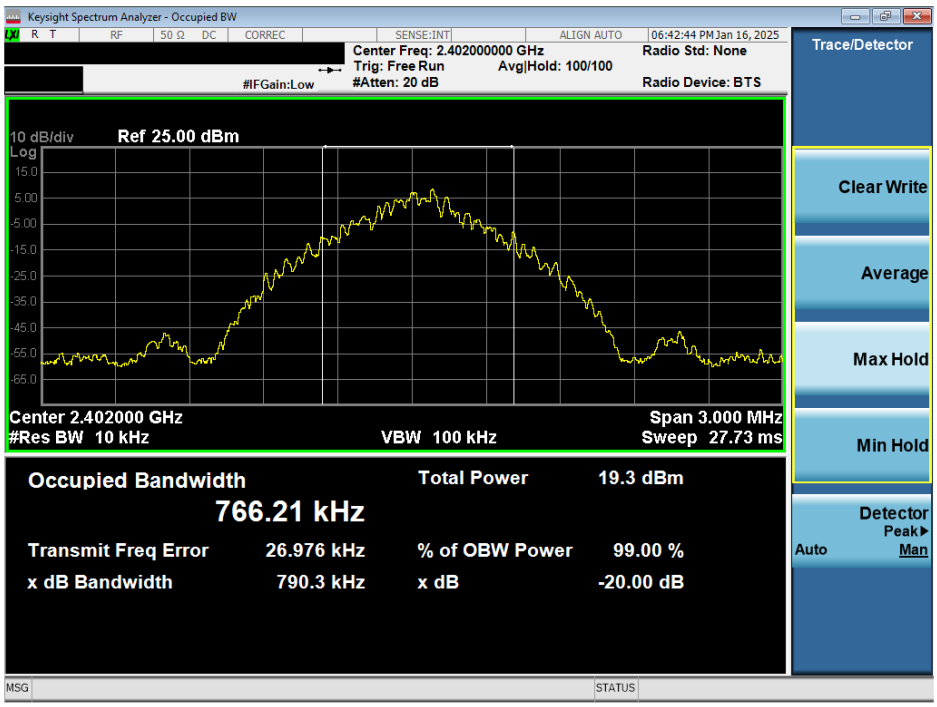



**Plot 7-18. 20dB BW and 99% OBW Plot Antenna WF8 (Dedicated) (Bluetooth, 8DPSK, iPA – Ch. 78)**

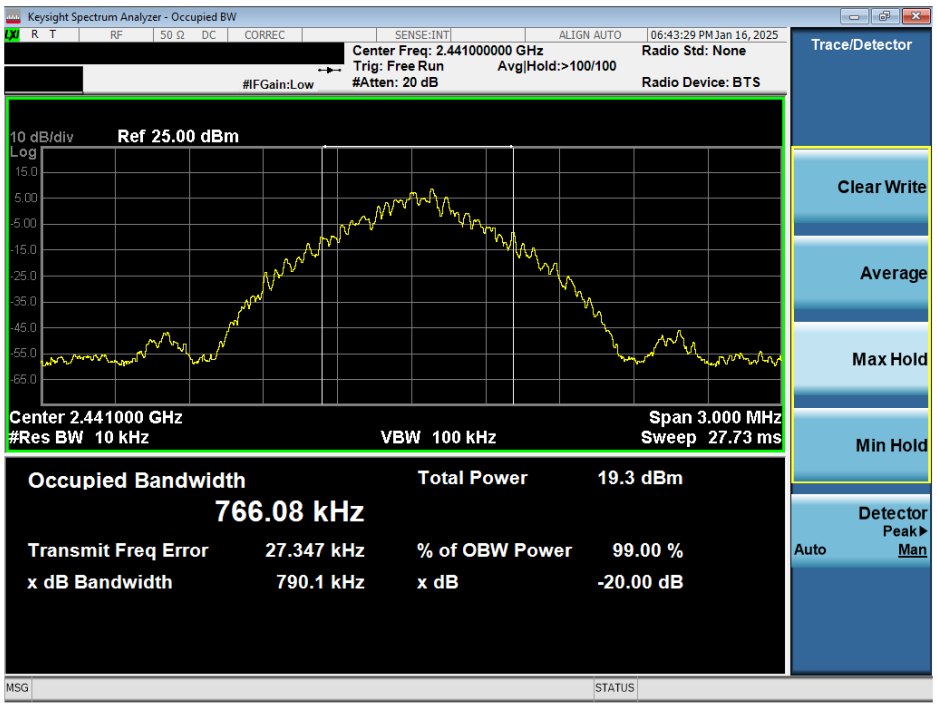
## Antenna WF7b (Dedicated)

| 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 | 766.21 | 790.31 |
| 2441 | 1.0 | GFSK | iPA | 39 | 766.08 | 790.14 |
| 2480 | 1.0 | GFSK | iPA | 78 | 766.54 | 790.26 |
| 2402 | 3.0 | 8DPSK | iPA | 0 | 1194.21 | 1318.35 |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 1194.08 | 1318.27 |
| 2480 | 3.0 | 8DPSK | iPA | 78 | 1193.85 | 1317.59 |

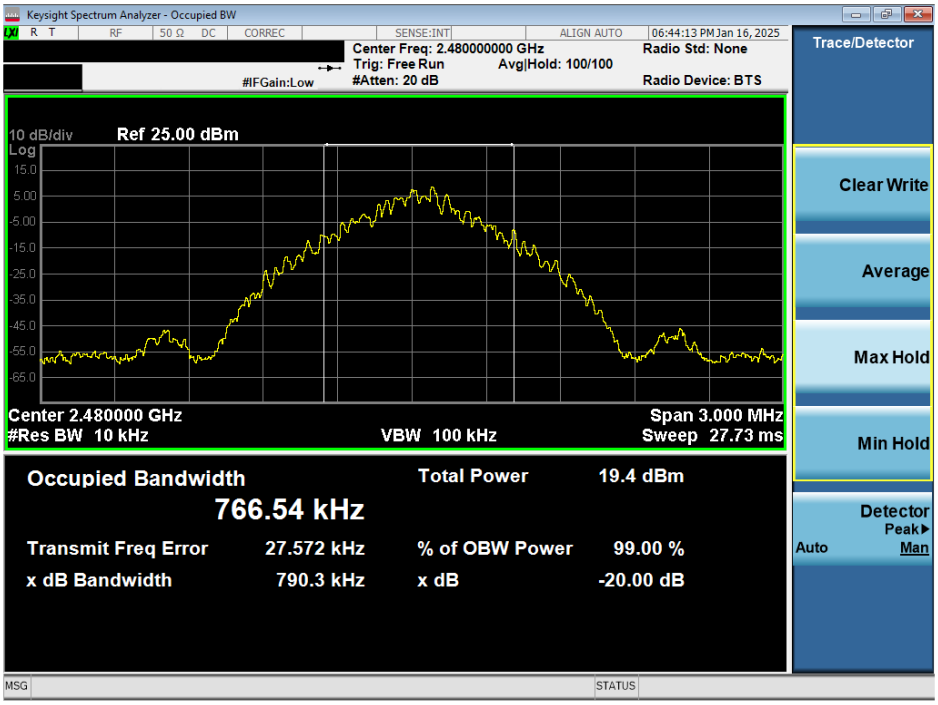
**Table 7-5. 20dB BW and 99% OBW Bandwidth Measurements Antenna WF7b (Dedicated)**



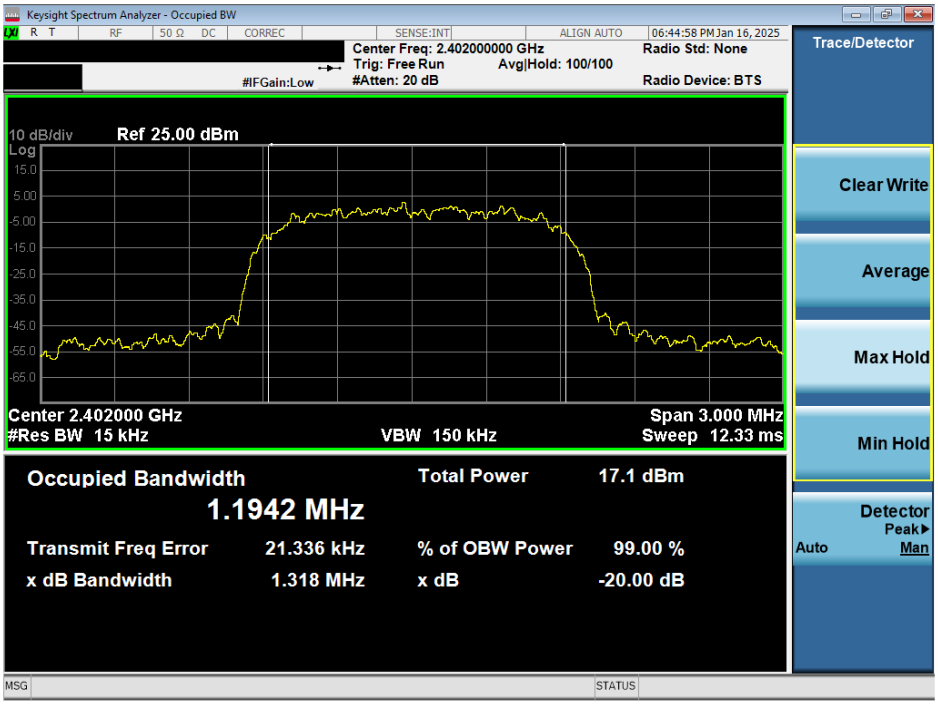

**Plot 7-19. 20dB BW and 99% OBW Plot Antenna WF7b (Dedicated) (Bluetooth, GFSK, iPA – Ch. 0)**



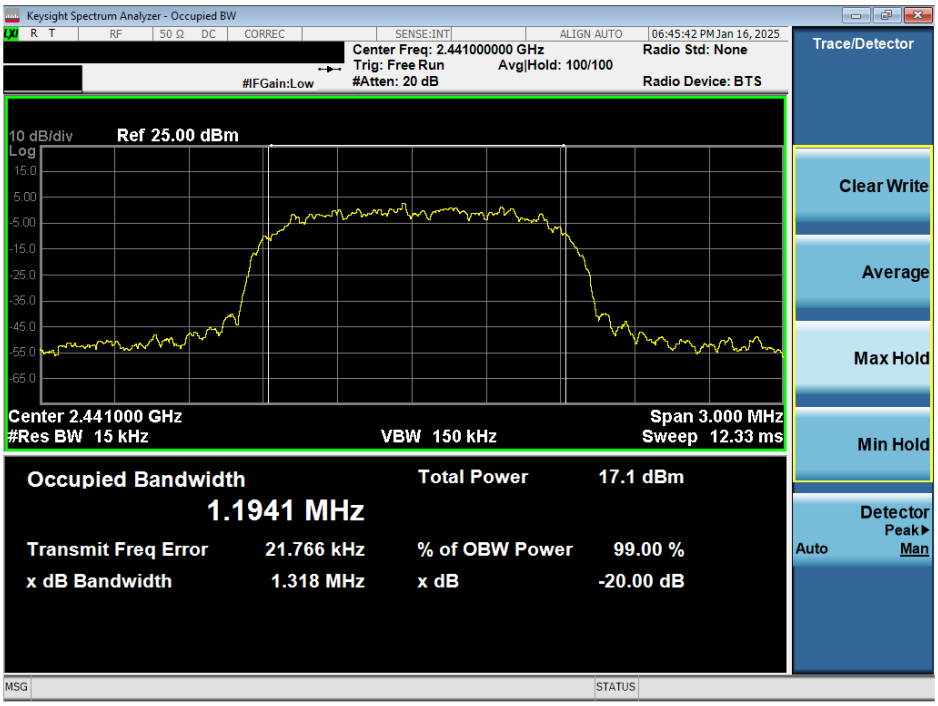

**Plot 7-20. 20dB BW and 99% OBW Plot Antenna WF7b (Dedicated) (Bluetooth, GFSK, iPA – Ch. 39)**



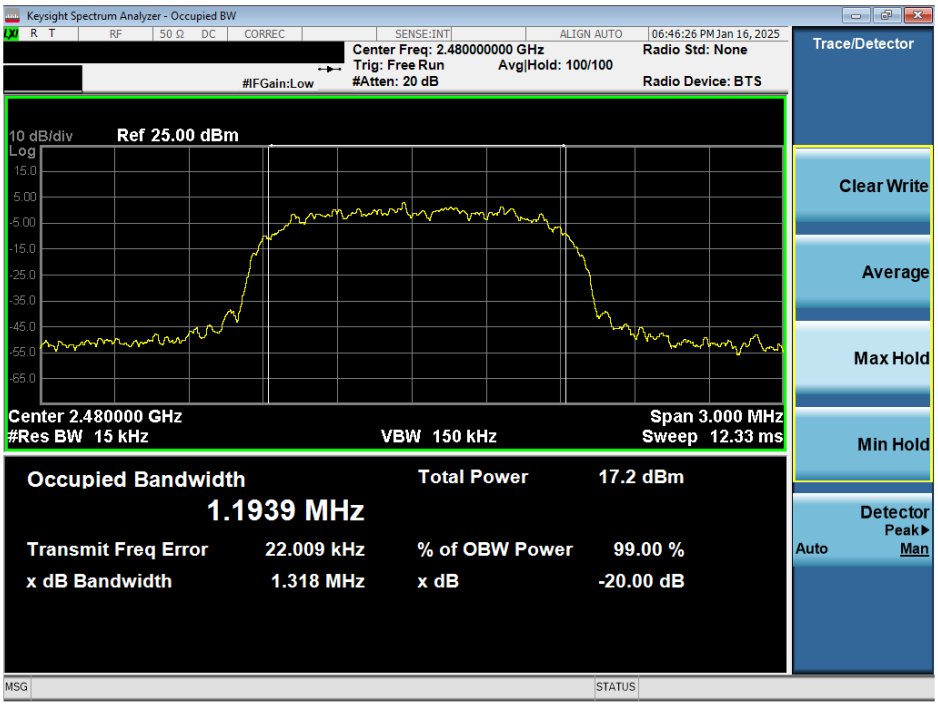

**Plot 7-21. 20dB BW and 99% OBW Plot Antenna WF7b (Dedicated) (Bluetooth, GFSK, iPA – Ch. 78)**




**Plot 7-22. 20dB BW and 99% OBW Plot Antenna WF7b (Dedicated) (Bluetooth, 8DPSK, iPA – Ch. 0)**




**Plot 7-23. 20dB BW and 99% OBW Plot Antenna WF7b (Dedicated) (Bluetooth, 8DPSK, iPA – Ch. 39)**




**Plot 7-24. 20dB BW and 99% OBW Plot Antenna WF7b (Dedicated) (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 11.9.1.2 PKPM1 Peak Power Method
ANSI C63.10-2020 – Subclause 11.9.2.3.2 Method AVGPM-G

**Test Settings**

**Peak Power Measurement**

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

**Method AVGPM-G (Average Power Measurement)**

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

**Test Setup**

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


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

**Note**

All supported modulations have been tested and π/4-DQPSK was found not to be 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 | iPA | 0 | 10.82 | 12.078 | 30.00 | -19.18 | 1.20 | 12.02 | 36.02 | -24.00 |
| 2441 | 1.0 | GFSK | iPA | 39 | 11.14 | 13.002 | 30.00 | -18.86 | 1.20 | 12.34 | 36.02 | -23.68 |
| 2480 | 1.0 | GFSK | iPA | 78 | 11.04 | 12.706 | 30.00 | -18.96 | 1.20 | 12.24 | 36.02 | -23.78 |
| 2402 | 3.0 | 8DPSK | iPA | 0 | 11.09 | 12.853 | 30.00 | -18.91 | 1.20 | 12.29 | 36.02 | -23.73 |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 11.18 | 13.122 | 30.00 | -18.82 | 1.20 | 12.38 | 36.02 | -23.64 |
| 2480 | 3.0 | 8DPSK | iPA | 78 | 11.35 | 13.646 | 30.00 | -18.66 | 1.20 | 12.55 | 36.02 | -23.48 |

**Table 7-6. Peak Conducted Output Power Measurements Antenna WF8 (Common)**

| 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 | 10.85 | 12.162 | 30.00 | -19.15 | 0.40 | 11.25 | 36.02 | -24.77 |
| 2441 | 1.0 | GFSK | iPA | 39 | 11.00 | 12.589 | 30.00 | -19.00 | 0.40 | 11.40 | 36.02 | -24.62 |
| 2480 | 1.0 | GFSK | iPA | 78 | 10.96 | 12.474 | 30.00 | -19.04 | 0.40 | 11.36 | 36.02 | -24.66 |
| 2402 | 3.0 | 8DPSK | iPA | 0 | 10.85 | 12.162 | 30.00 | -19.15 | 0.40 | 11.25 | 36.02 | -24.77 |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 11.31 | 13.521 | 30.00 | -18.69 | 0.40 | 11.71 | 36.02 | -24.31 |
| 2480 | 3.0 | 8DPSK | iPA | 78 | 11.06 | 12.764 | 30.00 | -18.94 | 0.40 | 11.46 | 36.02 | -24.56 |

**Table 7-7. Peak Conducted Output Power Measurements Antenna WF7b (Common)**

| 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 | 14.39 | 27.479 | 30.00 | -15.61 | 1.20 | 15.59 | 36.02 | -20.43 |
| 2441 | 1.0 | GFSK | iPA | 39 | 14.58 | 28.708 | 30.00 | -15.42 | 1.20 | 15.78 | 36.02 | -20.24 |
| 2480 | 1.0 | GFSK | iPA | 78 | 14.63 | 29.040 | 30.00 | -15.37 | 1.20 | 15.83 | 36.02 | -20.19 |
| 2402 | 3.0 | 8DPSK | iPA | 0 | 14.68 | 29.376 | 30.00 | -15.33 | 1.20 | 15.88 | 36.02 | -20.15 |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 14.81 | 30.269 | 30.00 | -15.19 | 1.20 | 16.01 | 36.02 | -20.01 |
| 2480 | 3.0 | 8DPSK | iPA | 78 | 14.45 | 27.861 | 30.00 | -15.55 | 1.20 | 15.65 | 36.02 | -20.37 |

**Table 7-8. Peak Conducted Output Power Measurements Antenna WF8 (Dedicated)**

| 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 | 14.45 | 27.861 | 30.00 | -15.55 | 0.40 | 14.85 | 36.02 | -21.17 |
| 2441 | 1.0 | GFSK | iPA | 39 | 14.48 | 28.054 | 30.00 | -15.52 | 0.40 | 14.88 | 36.02 | -21.14 |
| 2480 | 1.0 | GFSK | iPA | 78 | 14.53 | 28.379 | 30.00 | -15.47 | 0.40 | 14.93 | 36.02 | -21.09 |
| 2402 | 3.0 | 8DPSK | iPA | 0 | 14.70 | 29.512 | 30.00 | -15.30 | 0.40 | 15.10 | 36.02 | -20.92 |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 14.49 | 28.119 | 30.00 | -15.51 | 0.40 | 14.89 | 36.02 | -21.13 |
| 2480 | 3.0 | 8DPSK | iPA | 78 | 14.81 | 30.269 | 30.00 | -15.19 | 0.40 | 15.21 | 36.02 | -20.81 |

**Table 7-9. Peak Conducted Output Power Measurements Antenna WF7b (Dedicated)**

## 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 | iPA | 0 | 10.51 | 11.246 | 30.00 | -19.49 | 1.20 | 11.71 | 36.02 | -24.31 |
| 2441 | 1.0 | GFSK | iPA | 39 | 10.82 | 12.078 | 30.00 | -19.18 | 1.20 | 12.02 | 36.02 | -24.00 |
| 2480 | 1.0 | GFSK | iPA | 78 | 10.71 | 11.776 | 30.00 | -19.29 | 1.20 | 11.91 | 36.02 | -24.11 |
| 2402 | 3.0 | 8DPSK | iPA | 0 | 7.77 | 5.984 | 30.00 | -22.24 | 1.20 | 8.97 | 36.02 | -27.06 |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 7.81 | 6.039 | 30.00 | -22.19 | 1.20 | 9.01 | 36.02 | -27.01 |
| 2480 | 3.0 | 8DPSK | iPA | 78 | 7.96 | 6.252 | 30.00 | -22.04 | 1.20 | 9.16 | 36.02 | -26.86 |

**Table 7-10. Average Conducted Output Power Measurements Antenna WF8 (Common)**

| 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 | 10.54 | 11.324 | 30.00 | -19.46 | 0.40 | 10.94 | 36.02 | -25.08 |
| 2441 | 1.0 | GFSK | iPA | 39 | 10.68 | 11.695 | 30.00 | -19.32 | 0.40 | 11.08 | 36.02 | -24.94 |
| 2480 | 1.0 | GFSK | iPA | 78 | 10.63 | 11.561 | 30.00 | -19.37 | 0.40 | 11.03 | 36.02 | -24.99 |
| 2402 | 3.0 | 8DPSK | iPA | 0 | 7.52 | 5.649 | 30.00 | -22.48 | 0.40 | 7.92 | 36.02 | -28.10 |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 7.95 | 6.237 | 30.00 | -22.05 | 0.40 | 8.35 | 36.02 | -27.67 |
| 2480 | 3.0 | 8DPSK | iPA | 78 | 7.68 | 5.861 | 30.00 | -22.32 | 0.40 | 8.08 | 36.02 | -27.94 |

**Table 7-11. Average Conducted Output Power Measurements Antenna WF7b (Common)**

| 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 | 14.09 | 25.645 | 30.00 | -15.91 | 1.20 | 15.29 | 36.02 | -20.73 |
| 2441 | 1.0 | GFSK | iPA | 39 | 14.27 | 26.730 | 30.00 | -15.73 | 1.20 | 15.47 | 36.02 | -20.55 |
| 2480 | 1.0 | GFSK | iPA | 78 | 14.32 | 27.040 | 30.00 | -15.68 | 1.20 | 15.52 | 36.02 | -20.50 |
| 2402 | 3.0 | 8DPSK | iPA | 0 | 11.36 | 13.677 | 30.00 | -18.65 | 1.20 | 12.56 | 36.02 | -23.47 |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 11.50 | 14.125 | 30.00 | -18.50 | 1.20 | 12.70 | 36.02 | -23.32 |
| 2480 | 3.0 | 8DPSK | iPA | 78 | 11.12 | 12.942 | 30.00 | -18.88 | 1.20 | 12.32 | 36.02 | -23.70 |

**Table 7-12. Average Conducted Output Power Measurements Antenna WF8 (Dedicated)**

| 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 | 14.13 | 25.882 | 30.00 | -15.87 | 0.40 | 14.53 | 36.02 | -21.49 |
| 2441 | 1.0 | GFSK | iPA | 39 | 14.16 | 26.062 | 30.00 | -15.85 | 0.40 | 14.56 | 36.02 | -21.47 |
| 2480 | 1.0 | GFSK | iPA | 78 | 14.21 | 26.363 | 30.00 | -15.79 | 0.40 | 14.61 | 36.02 | -21.41 |
| 2402 | 3.0 | 8DPSK | iPA | 0 | 11.43 | 13.900 | 30.00 | -18.57 | 0.40 | 11.83 | 36.02 | -24.19 |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 11.18 | 13.122 | 30.00 | -18.82 | 0.40 | 11.58 | 36.02 | -24.44 |
| 2480 | 3.0 | 8DPSK | iPA | 78 | 11.47 | 14.028 | 30.00 | -18.53 | 0.40 | 11.87 | 36.02 | -24.15 |

**Table 7-13. Average Conducted Output Power Measurements Antenna WF7b (Dedicated)**

**Sample e.i.r.p. Calculation:**

At 2402MHz, the average conducted output power was calculated to be 10.51 dBm with antenna gain of 1.20 dBi.

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

10.51 dBm + 1.20 dBi = 11.71 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.

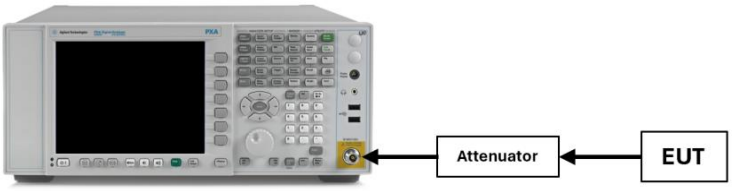


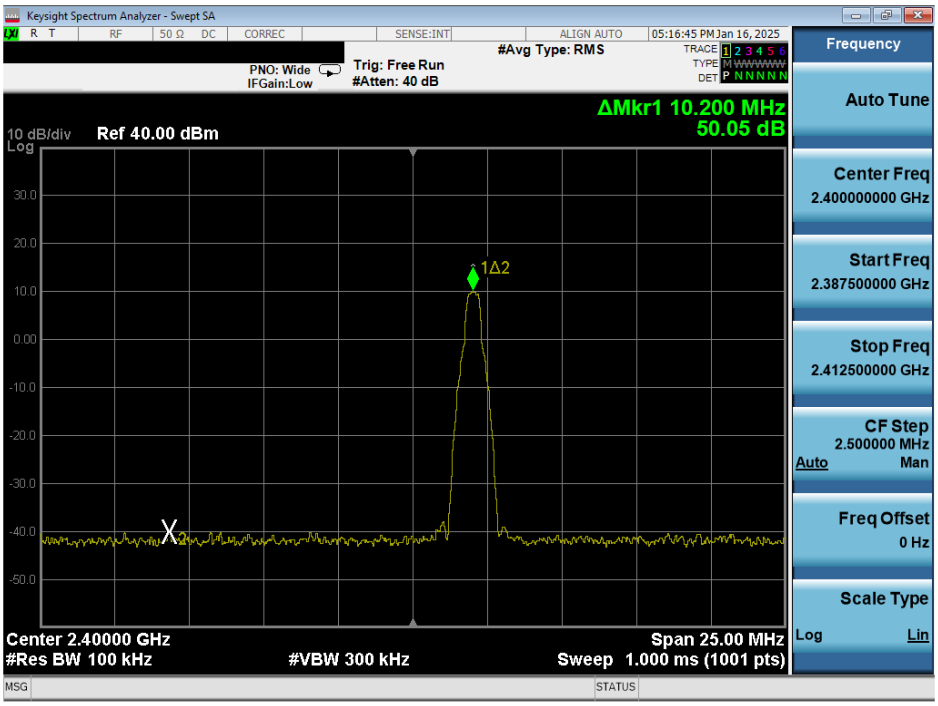

**Figure 7-3. Test Instrument & Measurement Setup**

### Test Notes

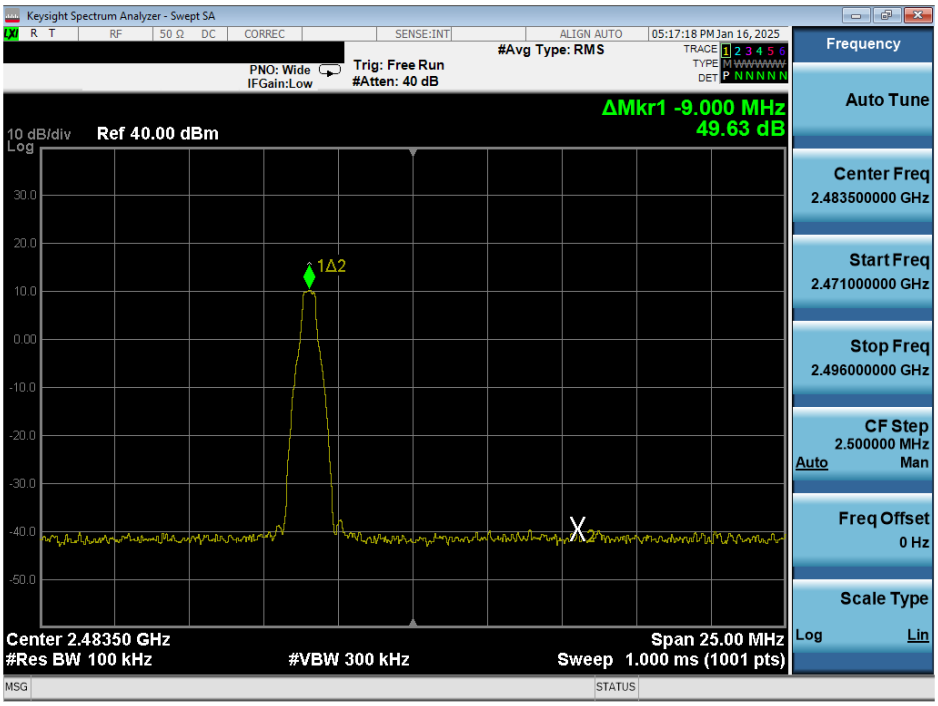
1. Out of band conducted spurious emissions at the band edge were investigated for all data rates in hopping and non-hopping modes. The worst case emissions were found with the EUT transmitting at 3 Mbps. Band edge emissions were also investigated with the EUT transmitting in all data rates. Plots of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

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

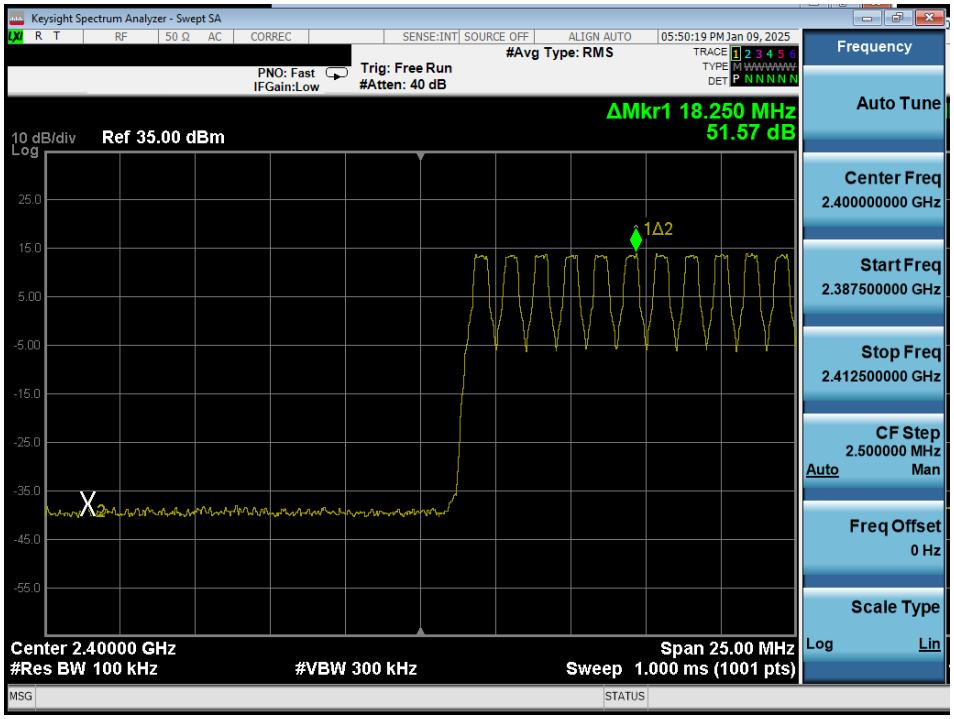
## Antenna WF8 (Common)



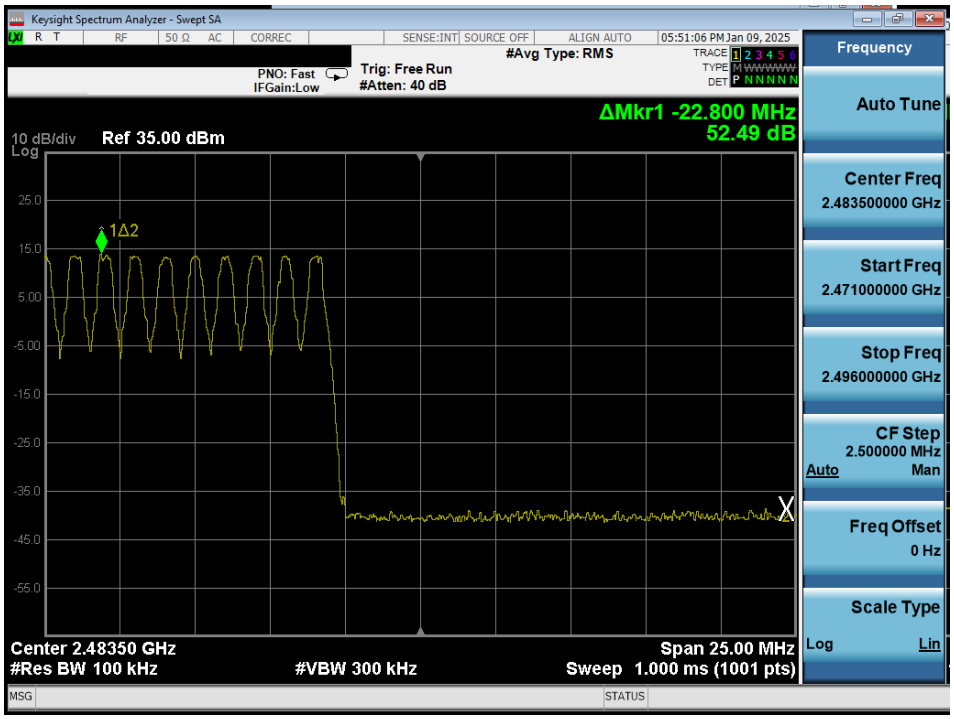

**Plot 7-25. Band Edge Plot Antenna WF8 (Common) (Bluetooth with Hopping Disabled, GFSK, iPA – Ch. 0)**



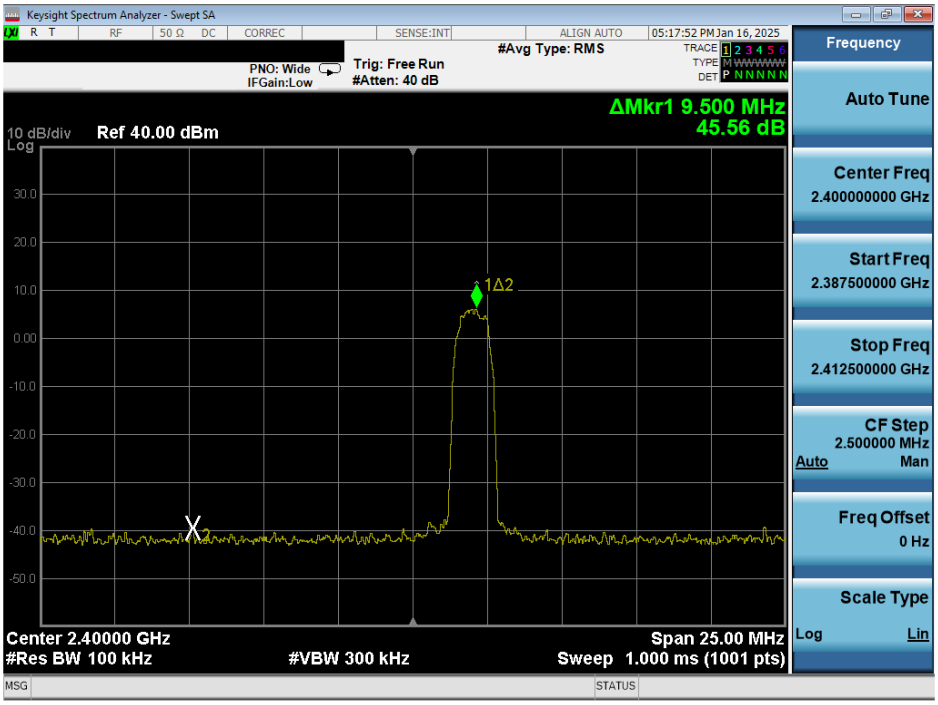

**Plot 7-26. Band Edge Plot Antenna WF8 (Common) (Bluetooth with Hopping Disabled, GFSK, iPA – Ch. 78)**



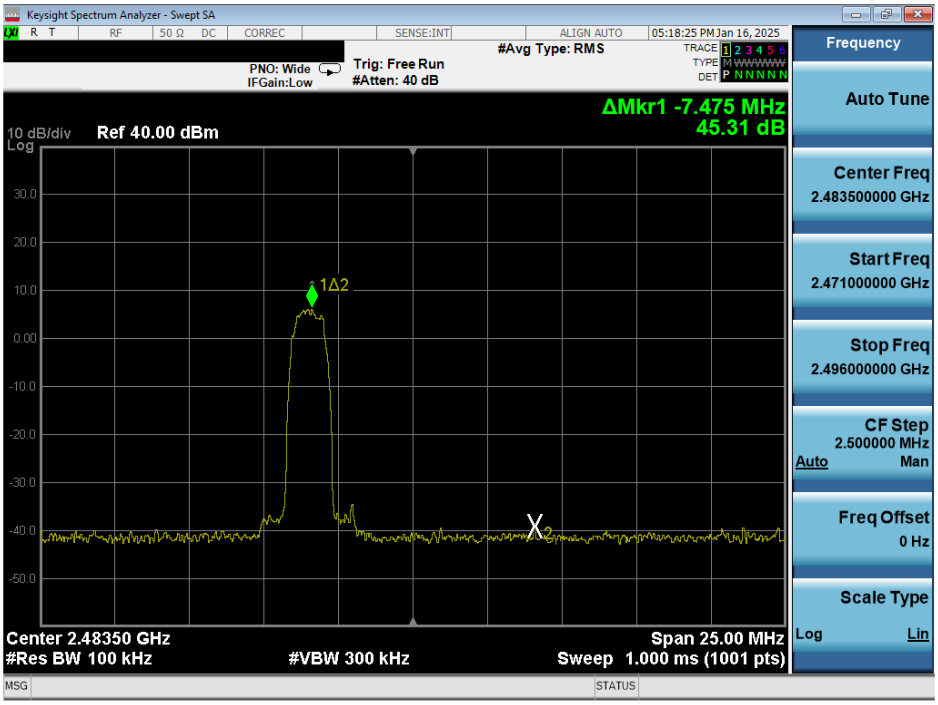

**Plot 7-27. Band Edge Plot Antenna WF8 (Common) (Bluetooth with Hopping Enabled, GFSK, iPA)**



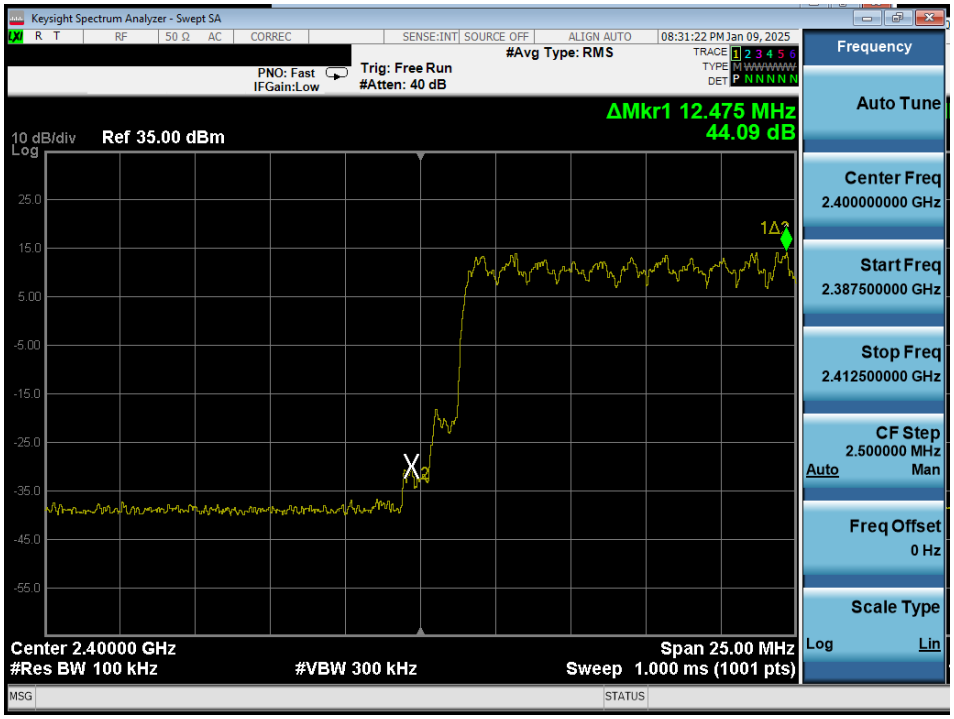

**Plot 7-28. Band Edge Plot Antenna WF8 (Common) (Bluetooth with Hopping Enabled, GFSK, iPA)**



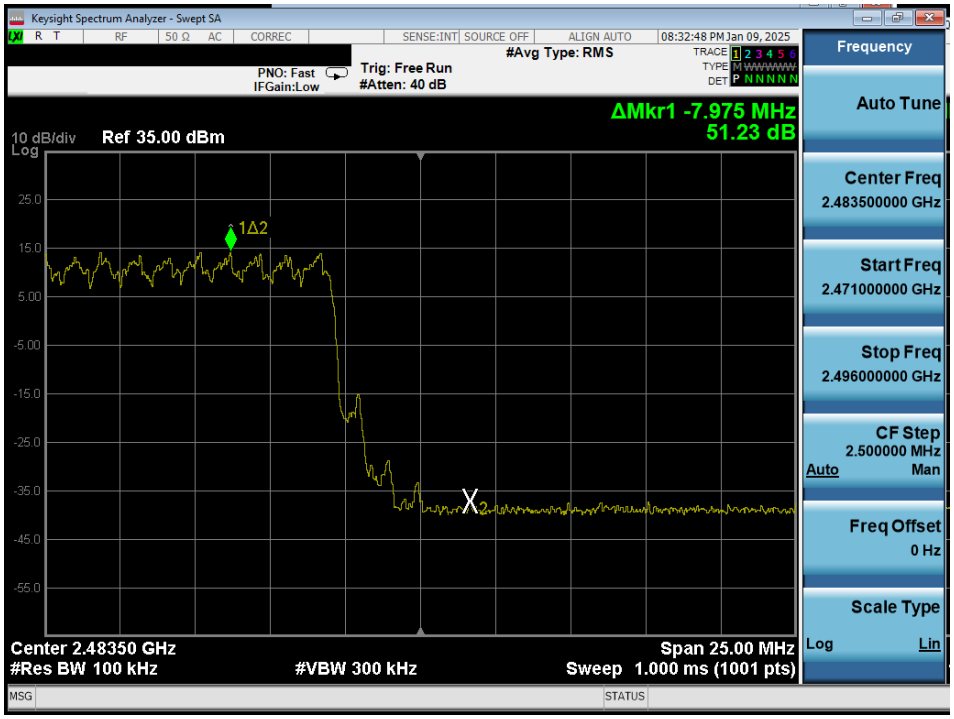

**Plot 7-29. Band Edge Plot Antenna WF8 (Common) (Bluetooth with Hopping Disabled, 8DPSK, iPA – Ch. 0)**




**Plot 7-30. Band Edge Plot Antenna WF8 (Common) (Bluetooth with Hopping Disabled, 8DPSK, iPA – Ch. 78)**

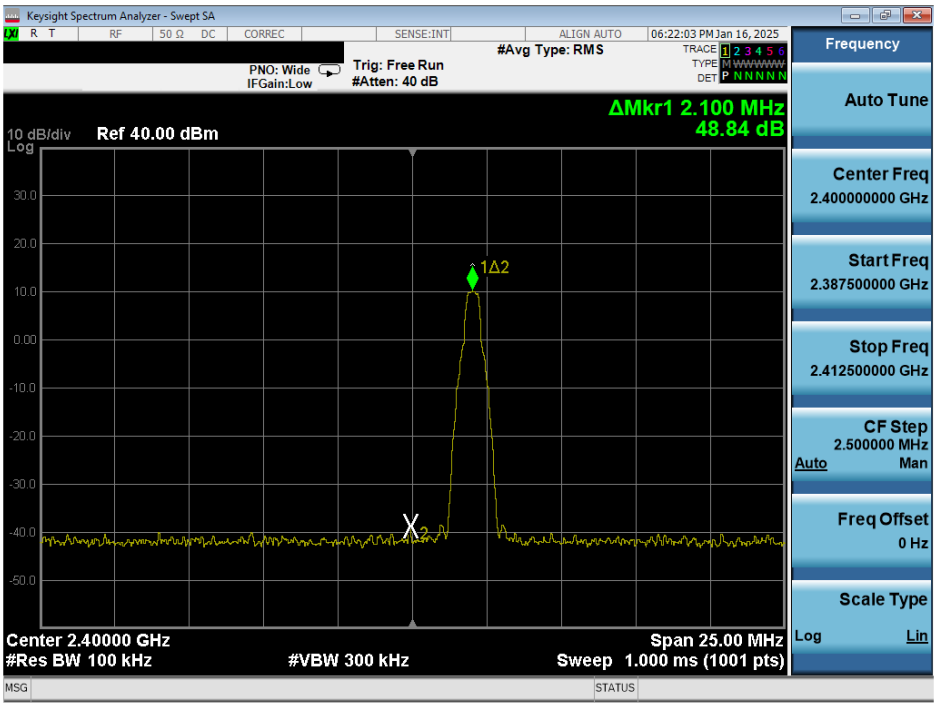



**Plot 7-31. Band Edge Plot Antenna WF8 (Common) (Bluetooth with Hopping Enabled, 8DPSK, iPA)**

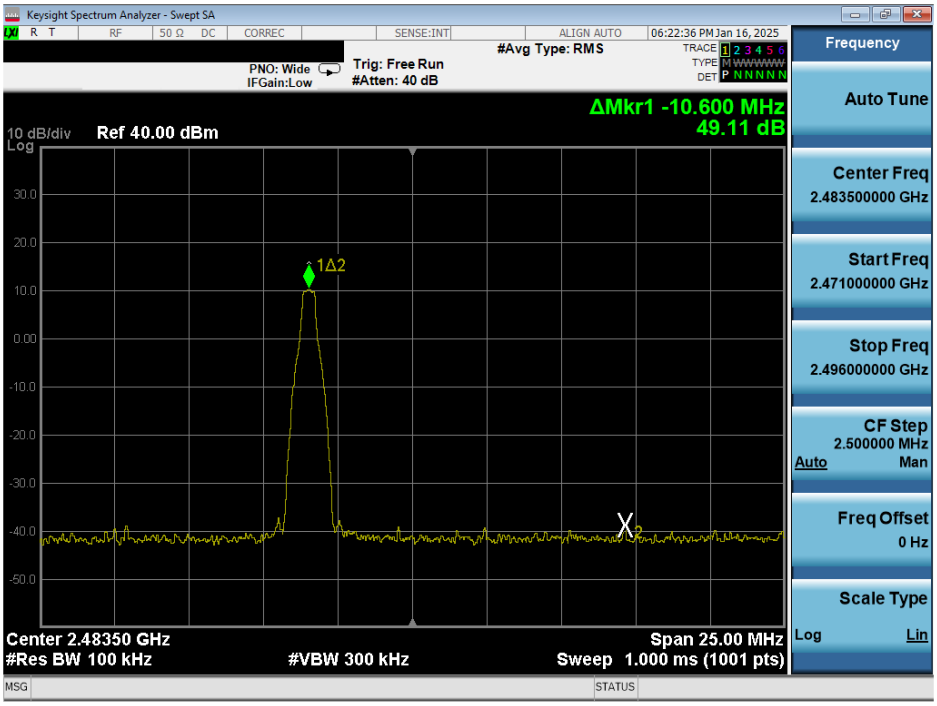



**Plot 7-32. Band Edge Plot Antenna WF8 (Common) (Bluetooth with Hopping Enabled, 8DPSK, iPA)**

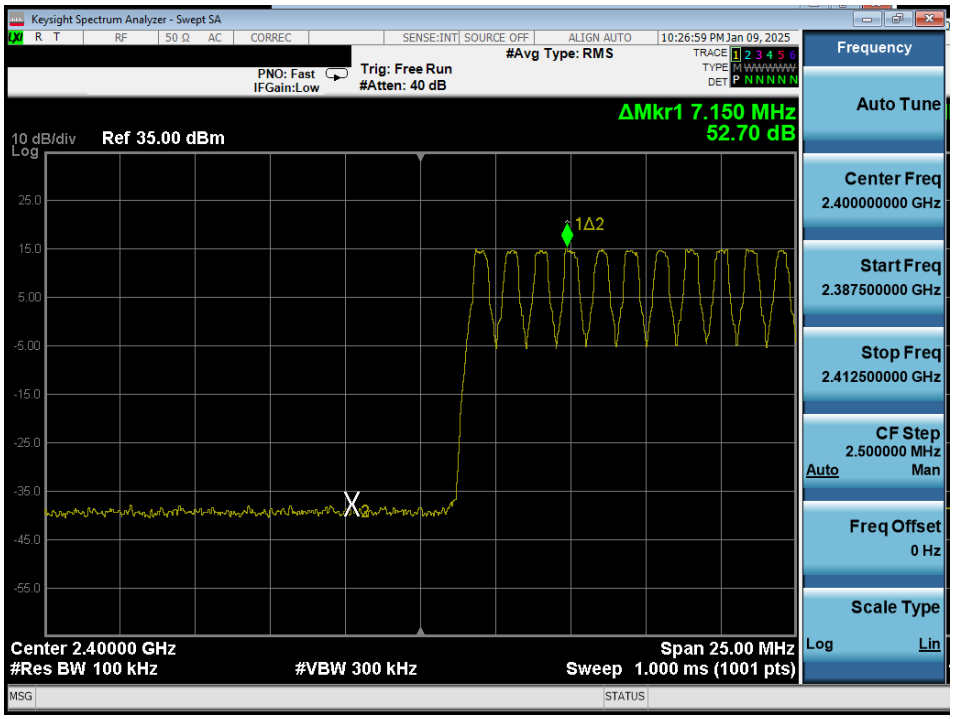
## Antenna WF7b (Common)



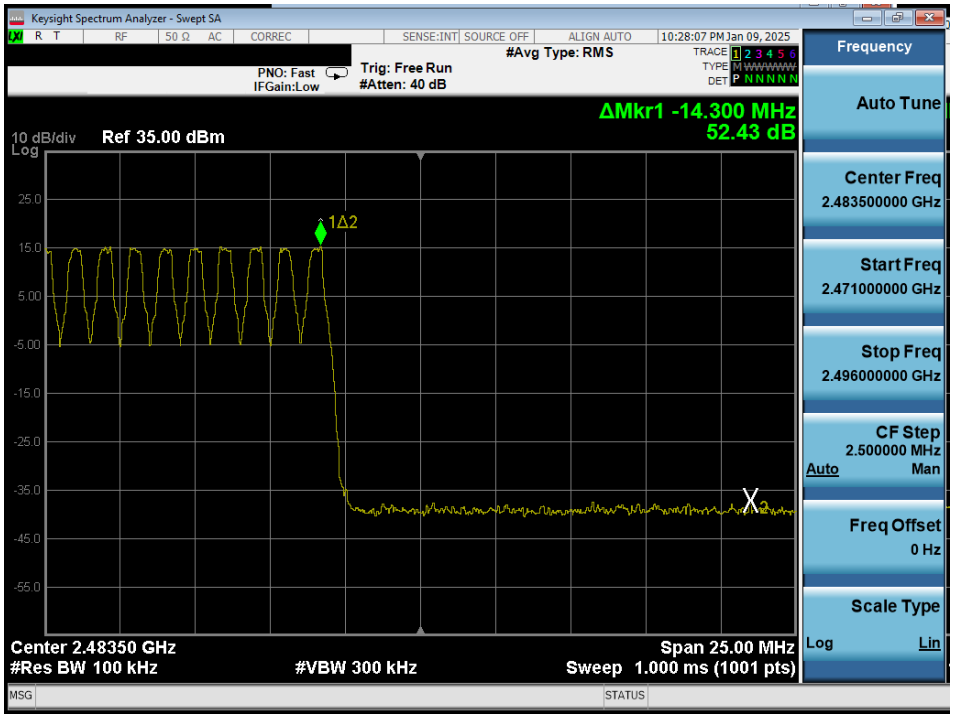

**Plot 7-33. Band Edge Plot Antenna WF7b (Common) (Bluetooth with Hopping Disabled, GFSK, iPA – Ch. 0)**



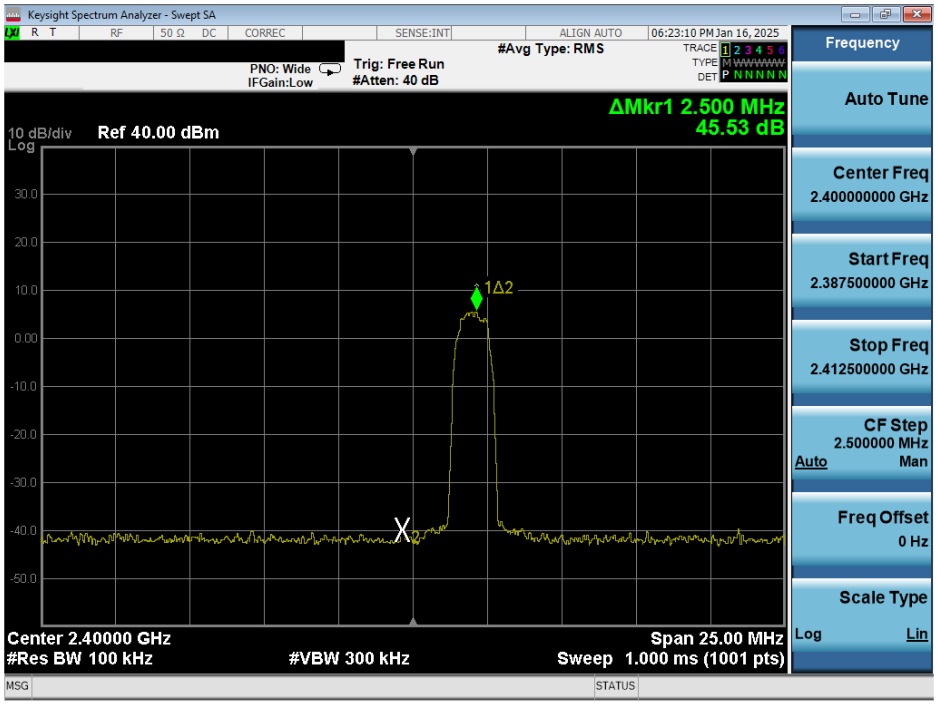

**Plot 7-34. Band Edge Plot Antenna WF7b (Common) (Bluetooth with Hopping Disabled, GFSK, iPA – Ch. 78)**



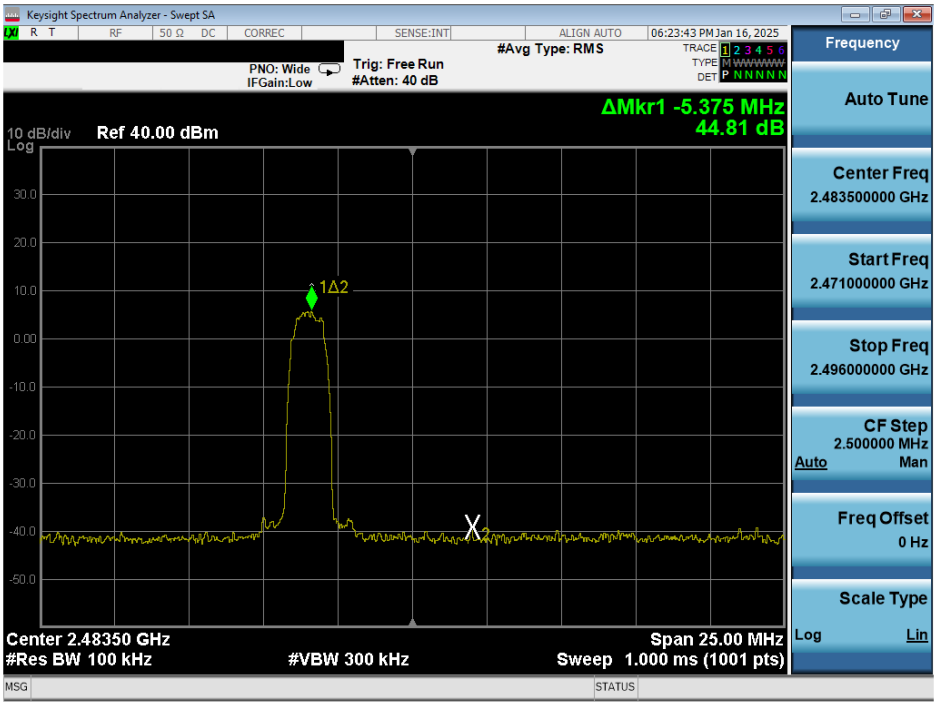

**Plot 7-35. Band Edge Plot Antenna WF7b (Common) (Bluetooth with Hopping Enabled, GFSK, iPA)**



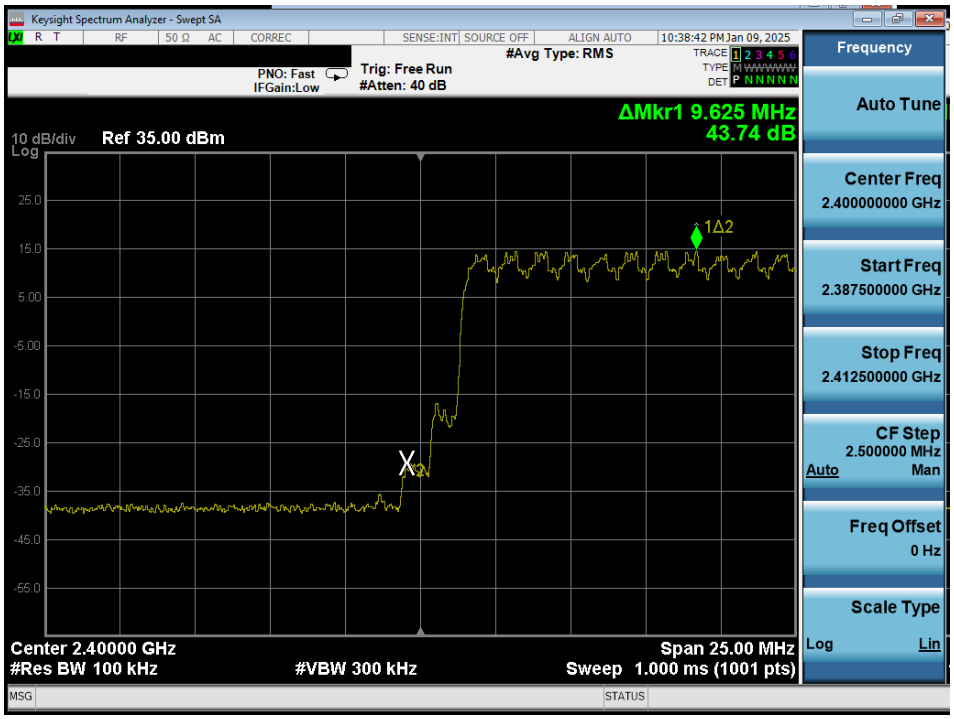

**Plot 7-36. Band Edge Plot Antenna WF7b (Common) (Bluetooth with Hopping Enabled, GFSK, iPA)**



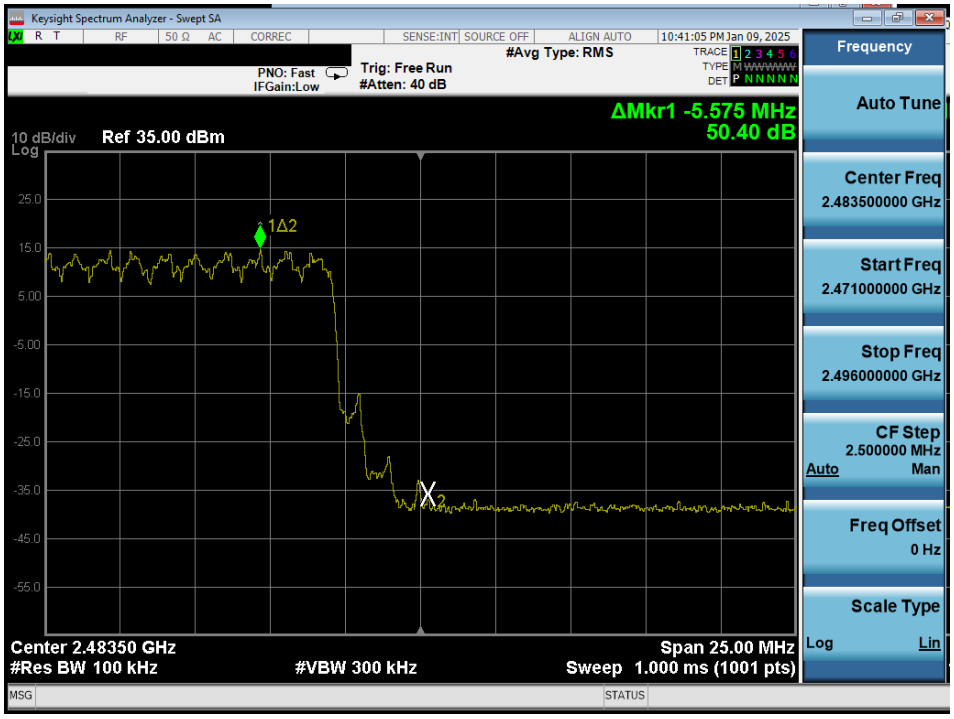

**Plot 7-37. Band Edge Plot Antenna WF7b (Common) (Bluetooth with Hopping Disabled, 8DPSK, iPA – Ch. 0)**




**Plot 7-38. Band Edge Plot Antenna WF7b (Common) (Bluetooth with Hopping Disabled, 8DPSK, iPA – Ch. 78)**

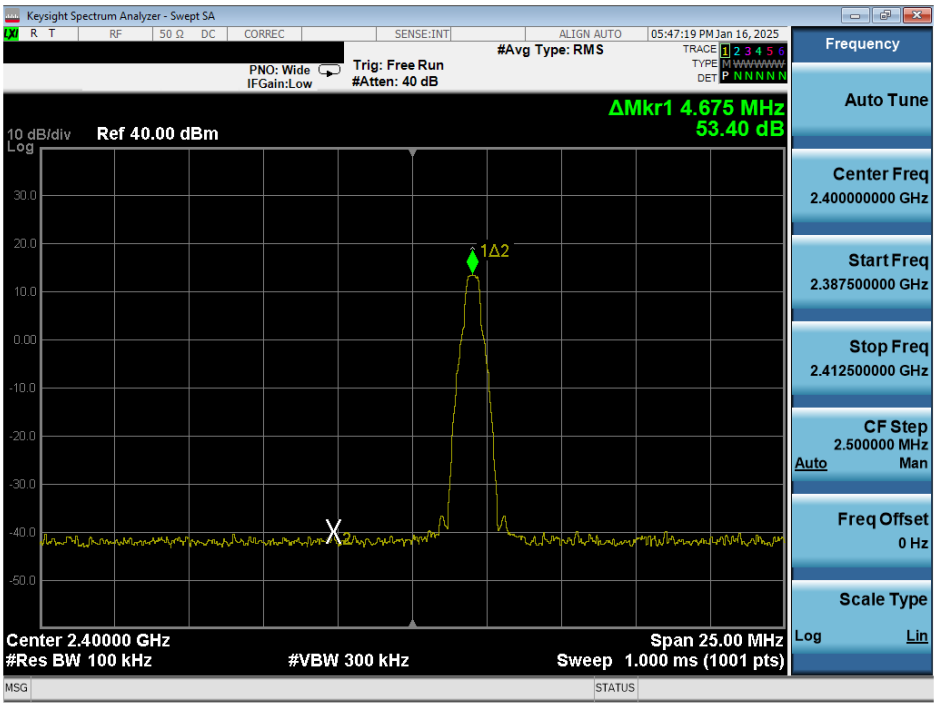



**Plot 7-39. Band Edge Plot Antenna WF7b (Common) (Bluetooth with Hopping Enabled, 8DPSK, iPA)**

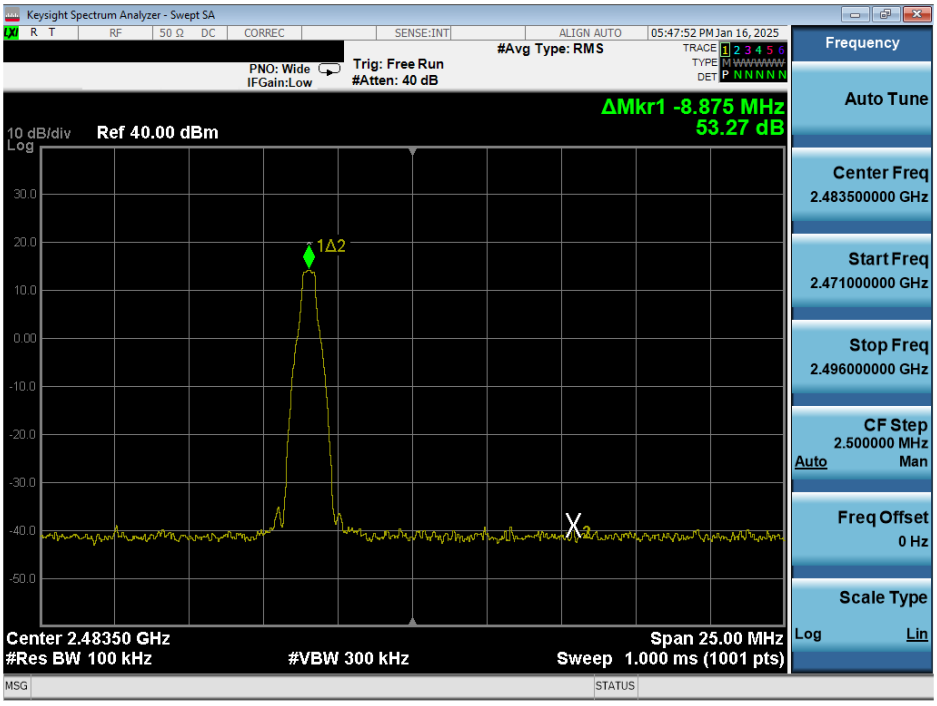



**Plot 7-40. Band Edge Plot Antenna WF7b (Common) (Bluetooth with Hopping Enabled, 8DPSK, iPA)**

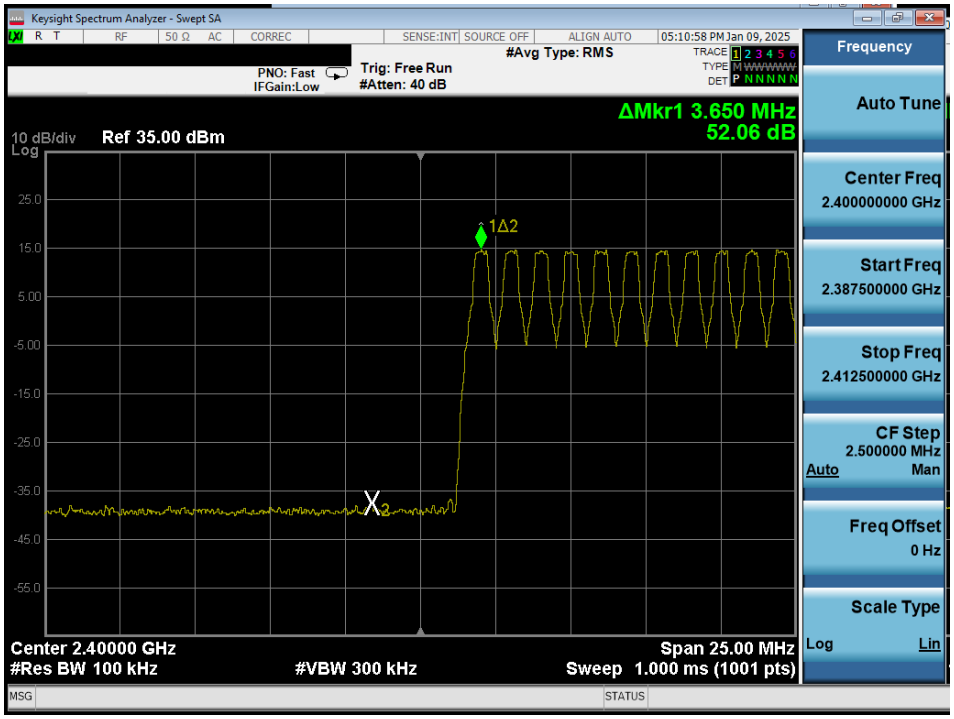
## Antenna WF8 (Dedicated)



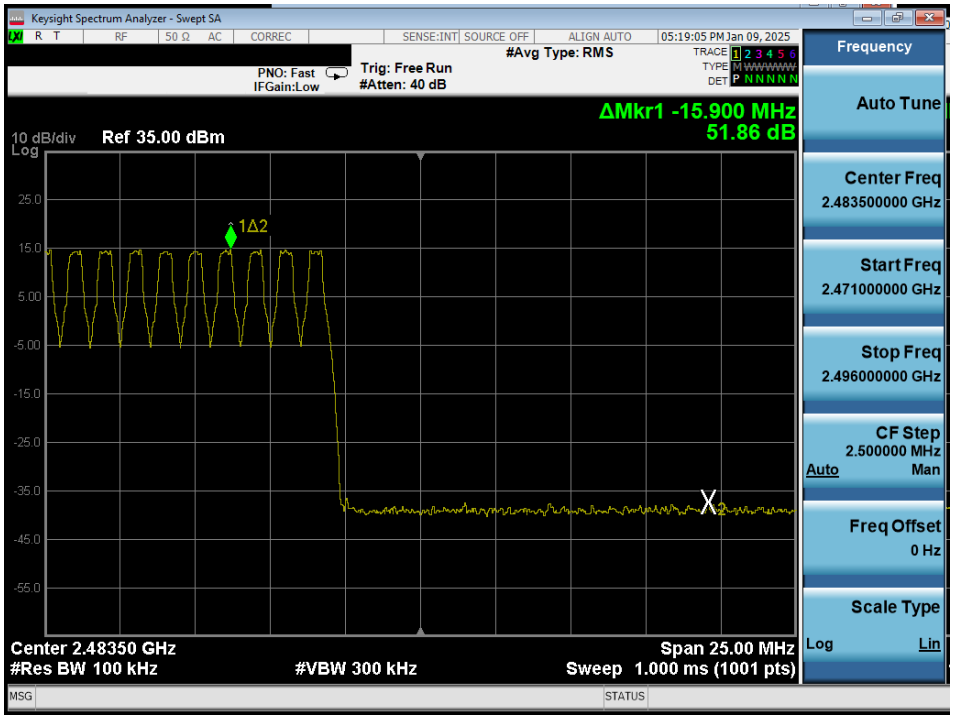

**Plot 7-41. Band Edge Plot Antenna WF8 (Dedicated) (Bluetooth with Hopping Disabled, GFSK, iPA – Ch. 0)**



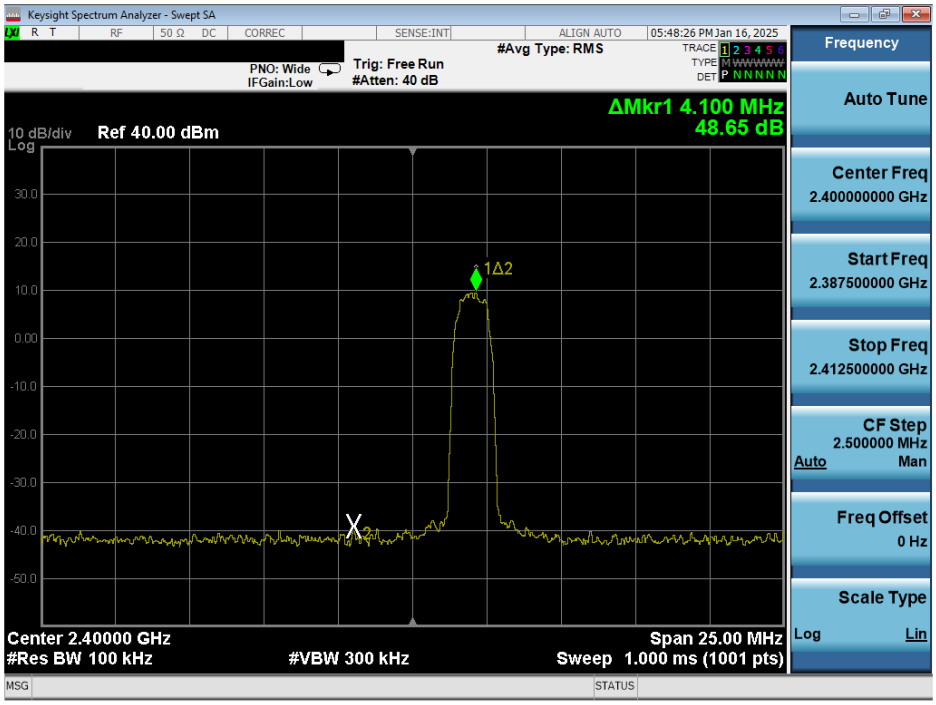

**Plot 7-42. Band Edge Plot Antenna WF8 (Dedicated) (Bluetooth with Hopping Disabled, GFSK, iPA – Ch. 78)**



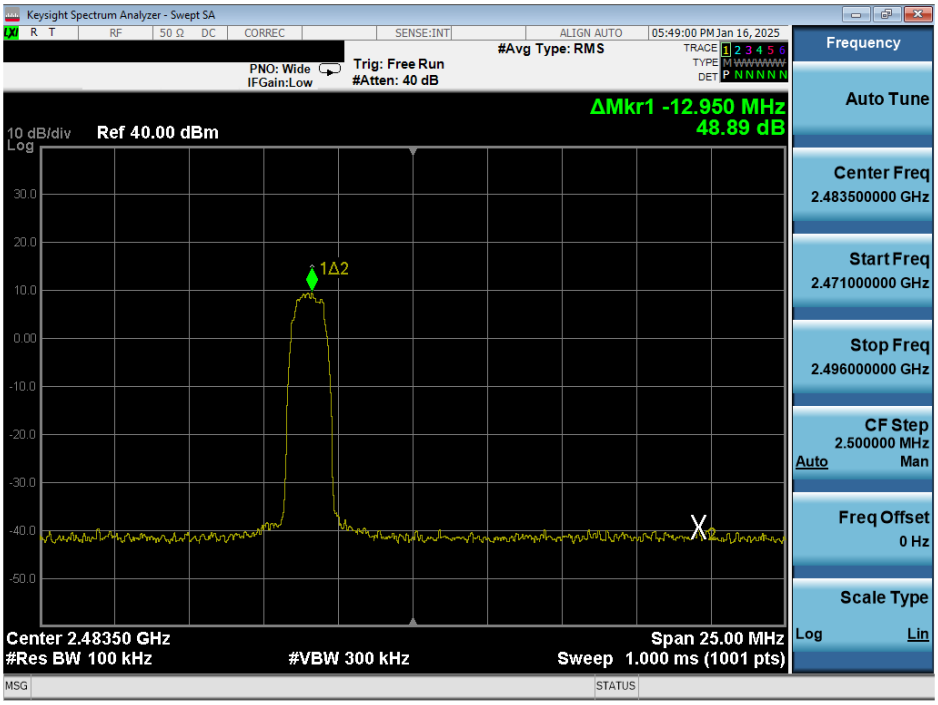

**Plot 7-43. Band Edge Plot Antenna WF8 (Dedicated) (Bluetooth with Hopping Enabled, GFSK, iPA)**



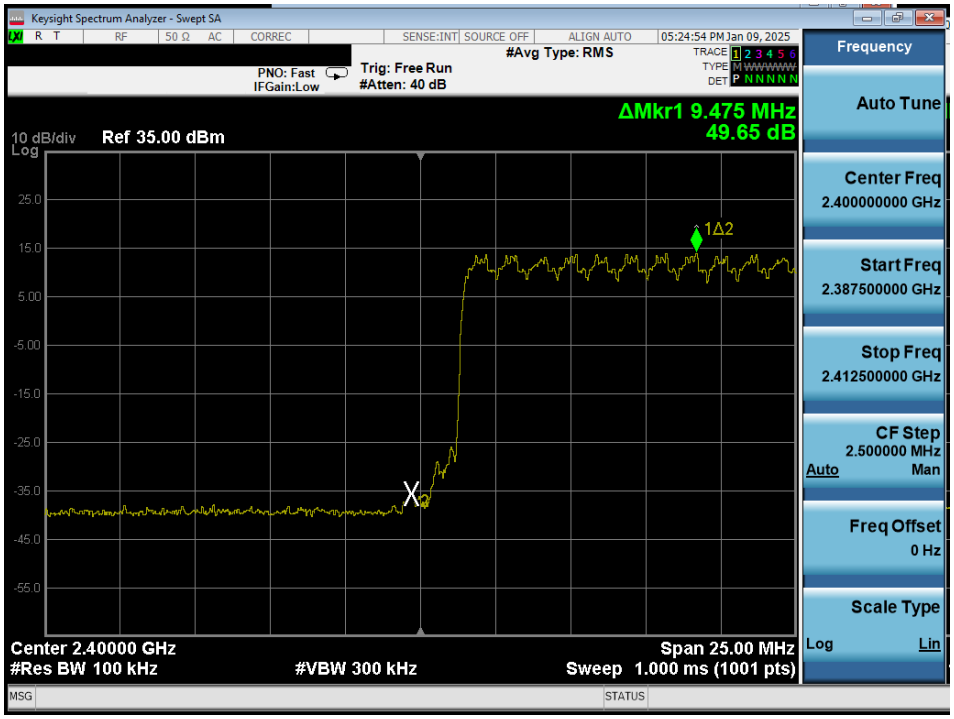

**Plot 7-44. Band Edge Plot Antenna WF8 (Dedicated) (Bluetooth with Hopping Enabled, GFSK, iPA)**



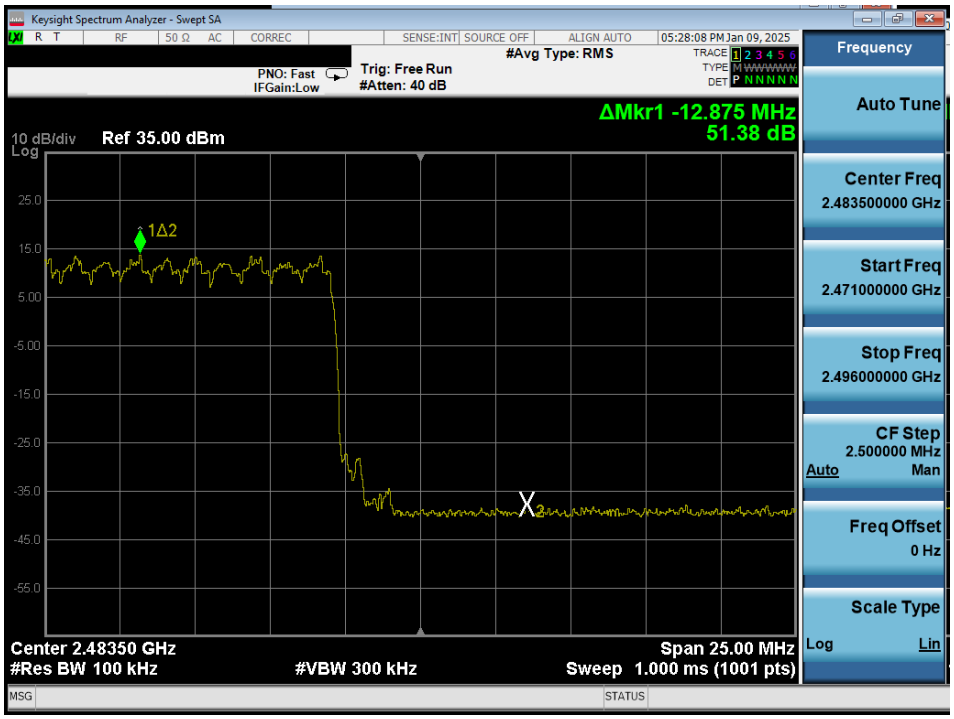

**Plot 7-45. Band Edge Plot Antenna WF8 (Dedicated) (Bluetooth with Hopping Disabled, 8DPSK, iPA – Ch. 0)**




**Plot 7-46. Band Edge Plot Antenna WF8 (Dedicated) (Bluetooth with Hopping Disabled, 8DPSK, iPA – Ch. 78)**

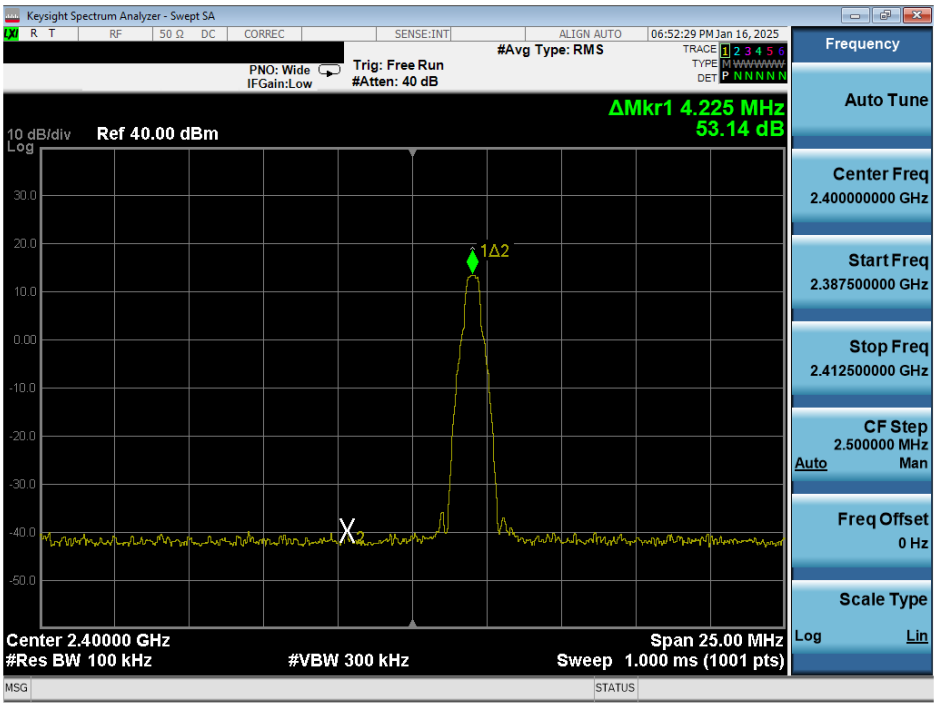



**Plot 7-47. Band Edge Plot Antenna WF8 (Dedicated) (Bluetooth with Hopping Enabled, 8DPSK, iPA)**

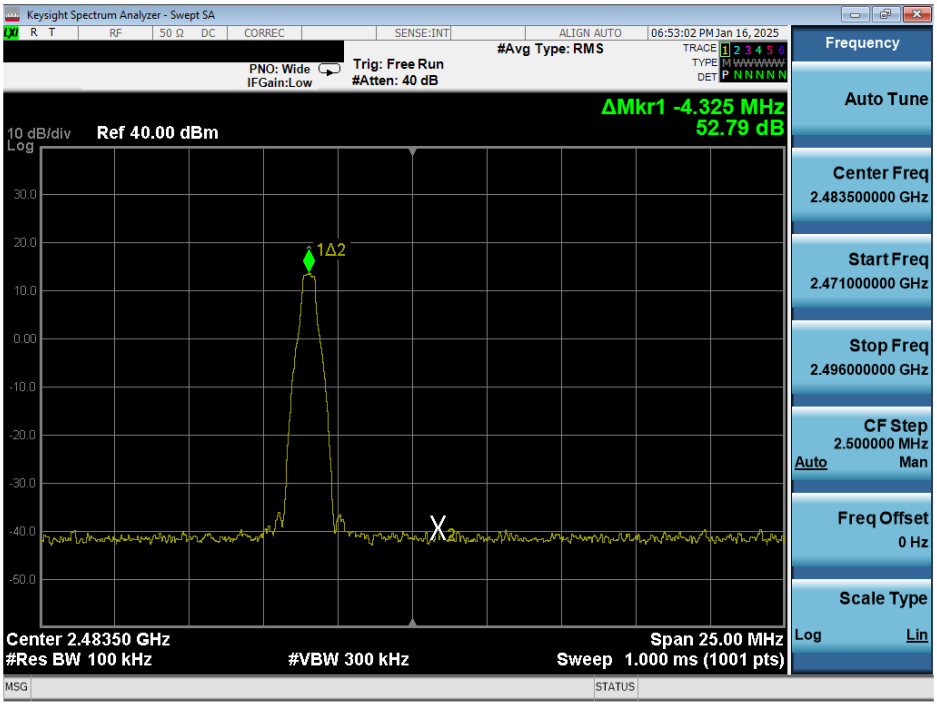



**Plot 7-48. Band Edge Plot Antenna WF8 (Dedicated) (Bluetooth with Hopping Enabled, 8DPSK, iPA)**

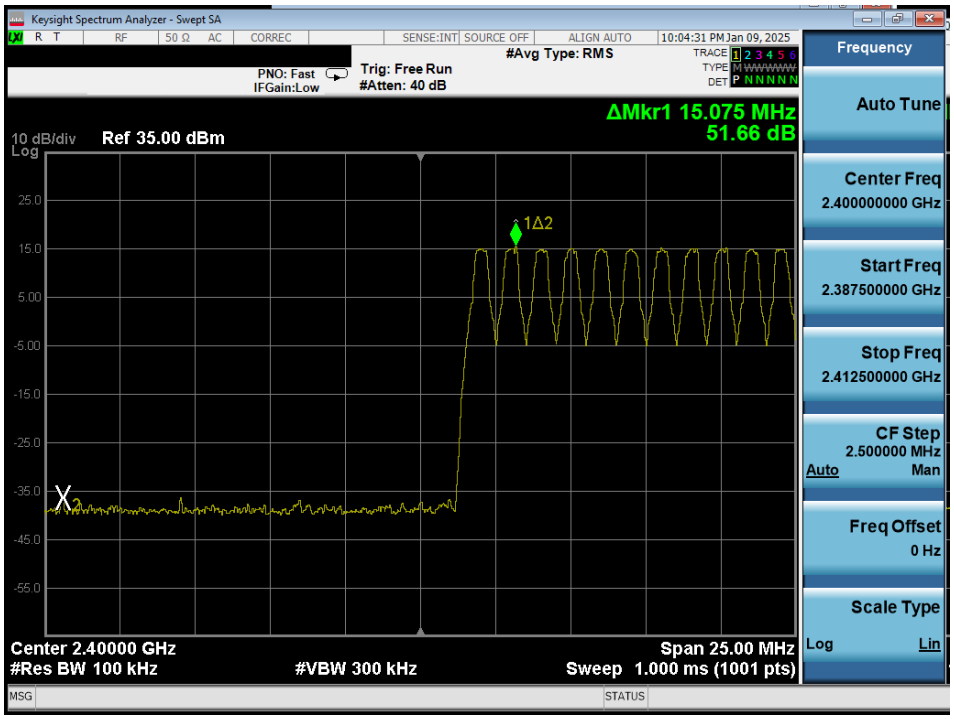
## Antenna WF7b (Dedicated)



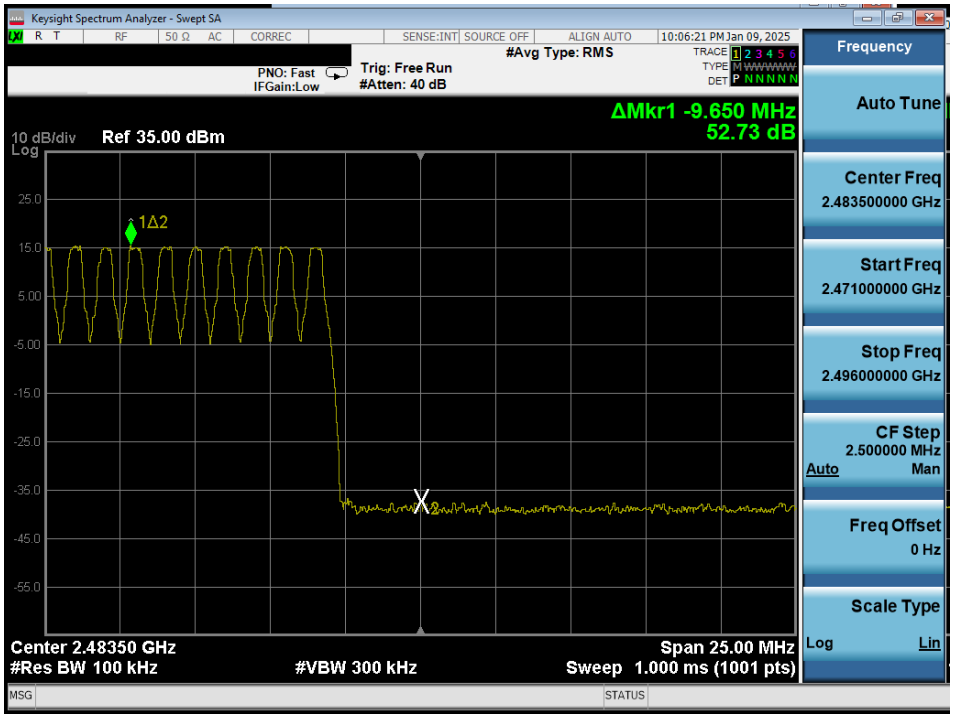

**Plot 7-49. Band Edge Plot Antenna WF7b (Dedicated) (Bluetooth with Hopping Disabled, GFSK, iPA – Ch. 0)**



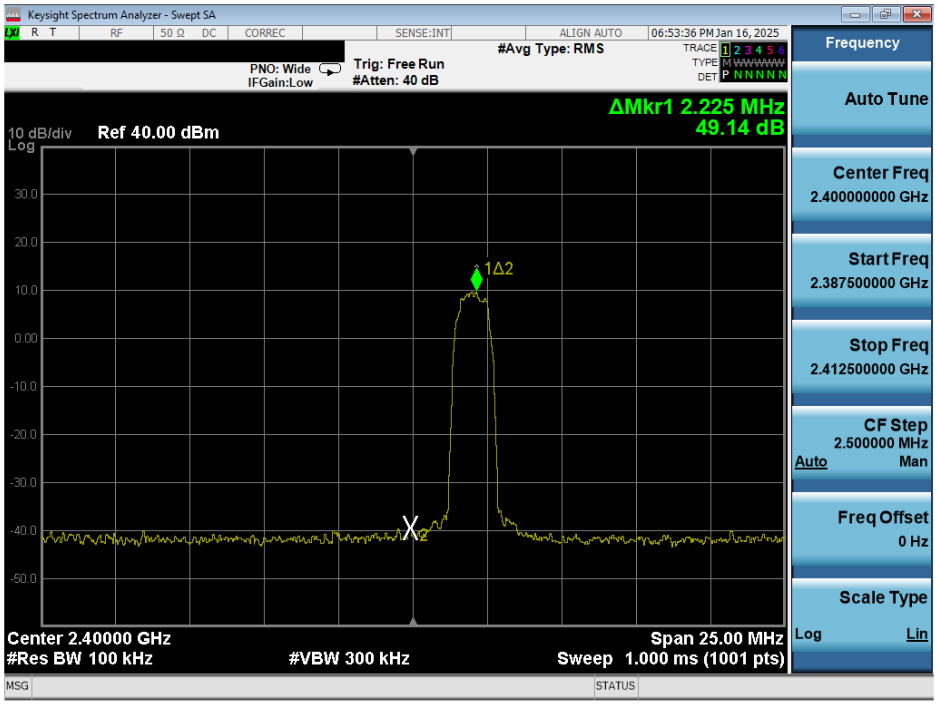

**Plot 7-50. Band Edge Plot Antenna WF7b (Dedicated) (Bluetooth with Hopping Disabled, GFSK, iPA – Ch. 78)**



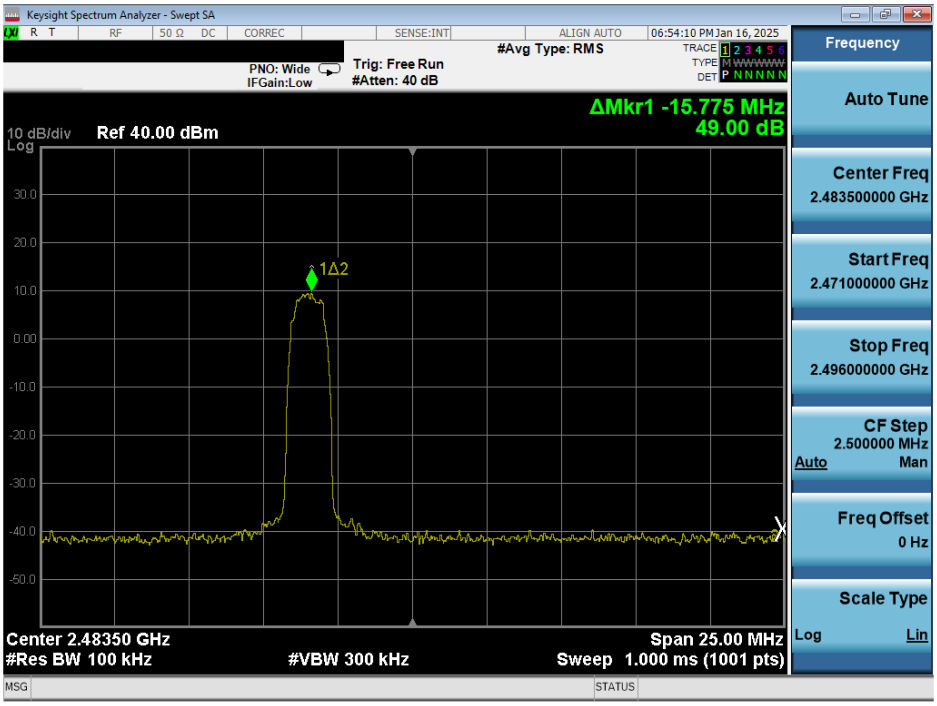

**Plot 7-51. Band Edge Plot Antenna WF7b (Dedicated) (Bluetooth with Hopping Enabled, GFSK, iPA)**



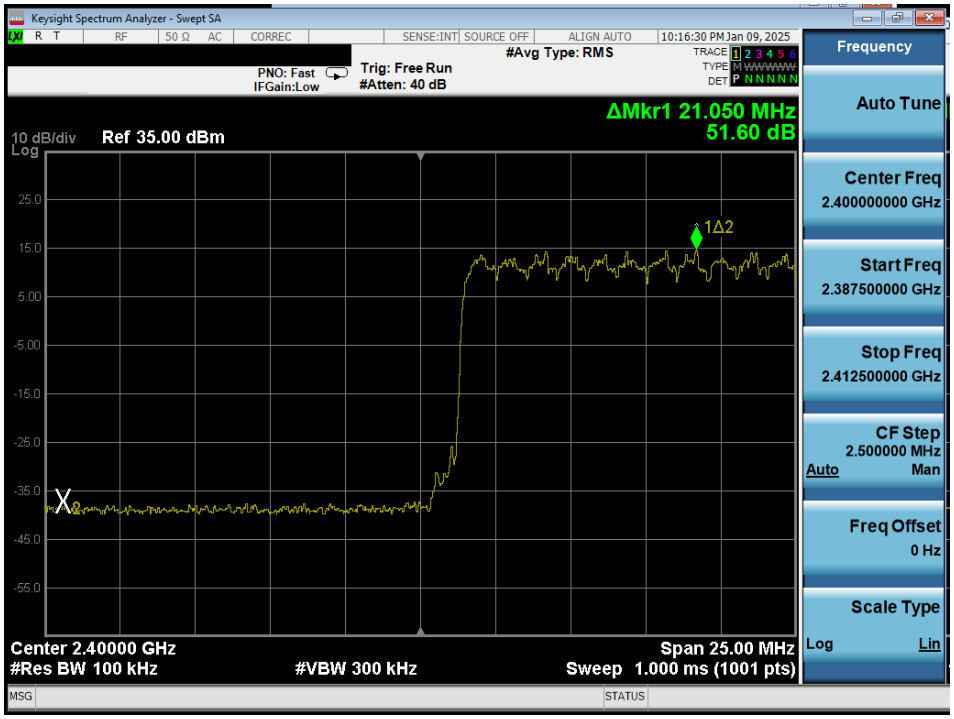

**Plot 7-52. Band Edge Plot Antenna WF7b (Dedicated) (Bluetooth with Hopping Enabled, GFSK, iPA)**



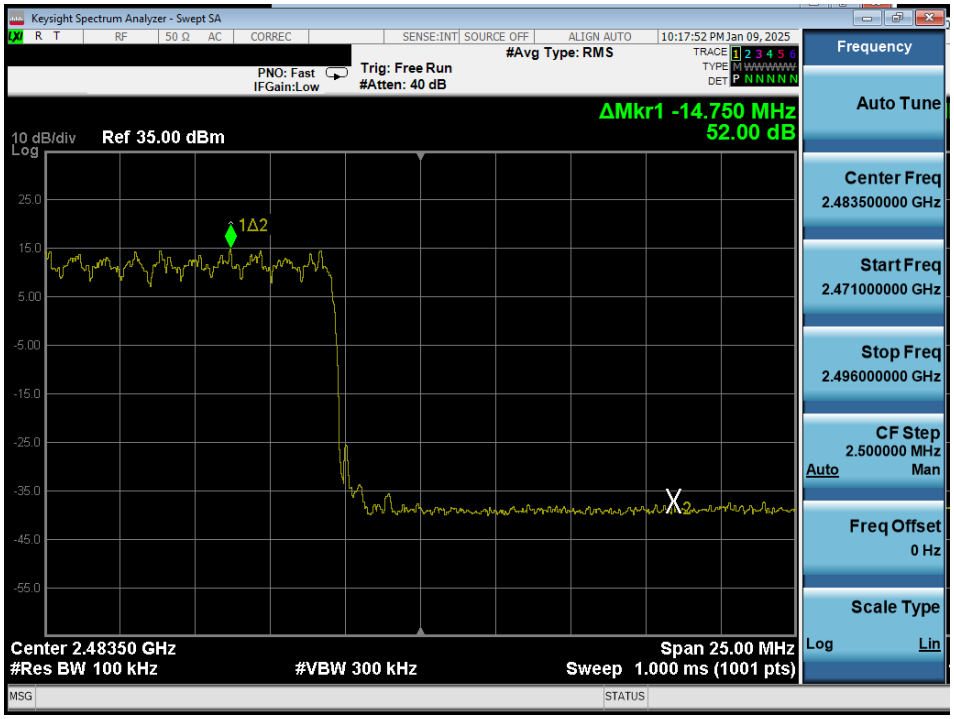

**Plot 7-53. Band Edge Plot Antenna WF7b (Dedicated) (Bluetooth with Hopping Disabled, 8DPSK, iPA – Ch. 0)**




**Plot 7-54. Band Edge Plot Antenna WF7b (Dedicated) (Bluetooth with Hopping Disabled, 8DPSK, iPA – Ch. 78)**




**Plot 7-55. Band Edge Plot Antenna WF7b (Dedicated) (Bluetooth with Hopping Enabled, 8DPSK, iPA)**




**Plot 7-56. Band Edge Plot Antenna WF7b (Dedicated) (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.

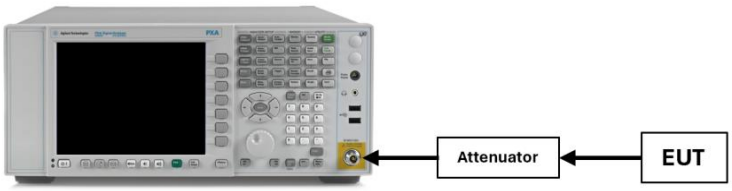



**Figure 7-4. Test Instrument & Measurement Setup**

### Test Notes

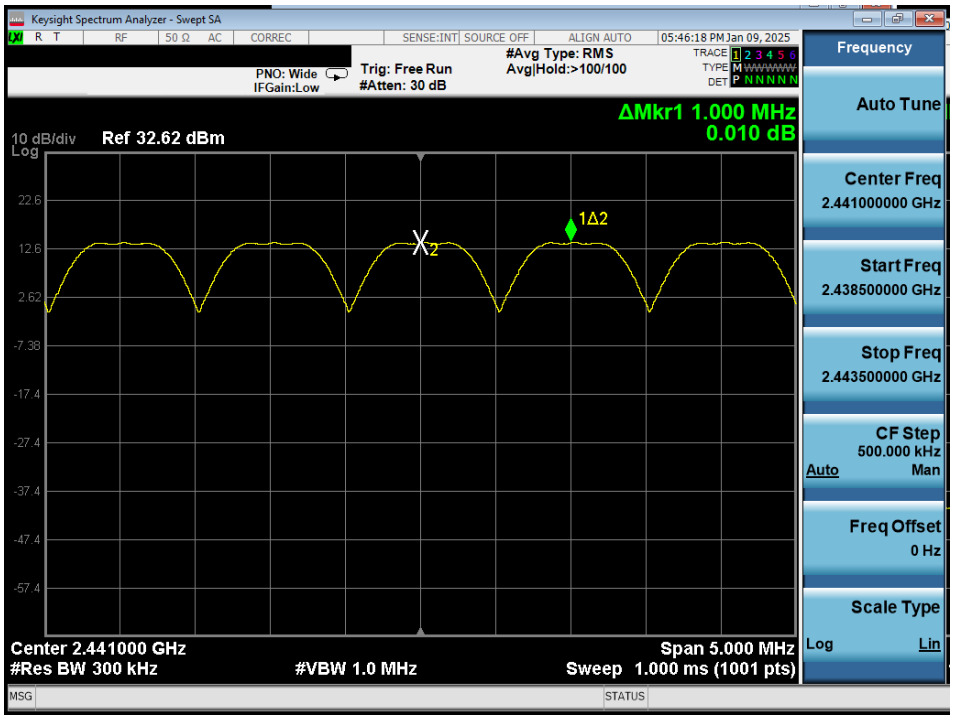
1. The EUT complies with the minimum channel separation requirement when it is operating in 1x/EDR mode using 79 channels.

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

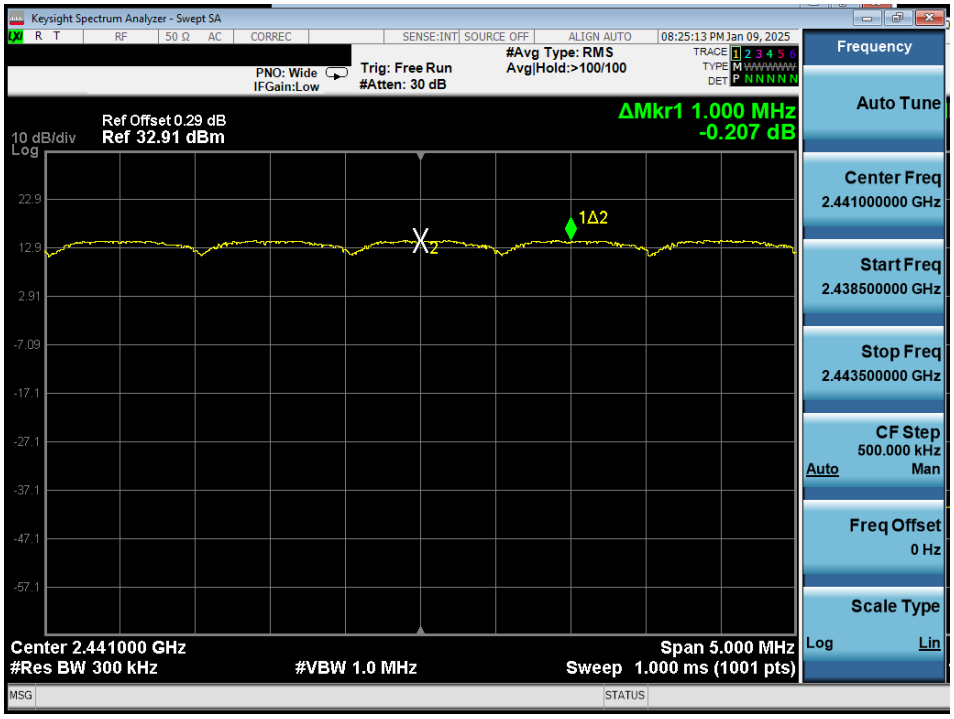
## Antenna WF8 (Common)

| 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 | 0.53 | Pass |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 1.00 | 0.88 | Pass |

**Table 7-14. Minimum Channel Separation Antenna WF8 (Common)**




**Plot 7-57. Channel Spacing Plot Antenna WF8 (Common) (Bluetooth, GFSK, iPA)**

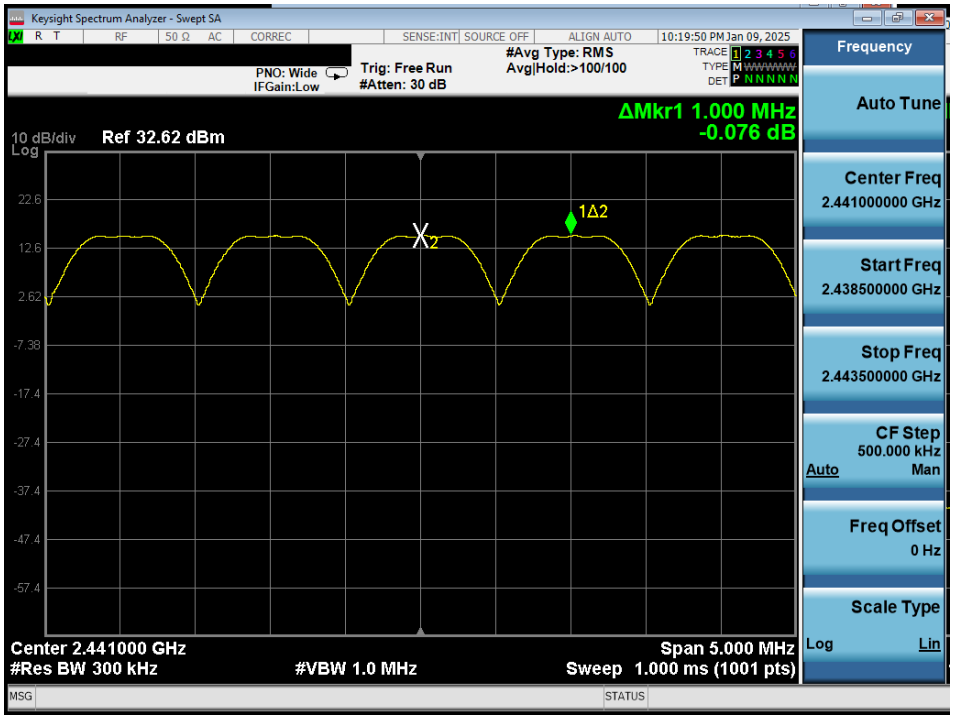



**Plot 7-58. Channel Spacing Plot Antenna WF8 (Common) (Bluetooth, 8DPSK, iPA)**

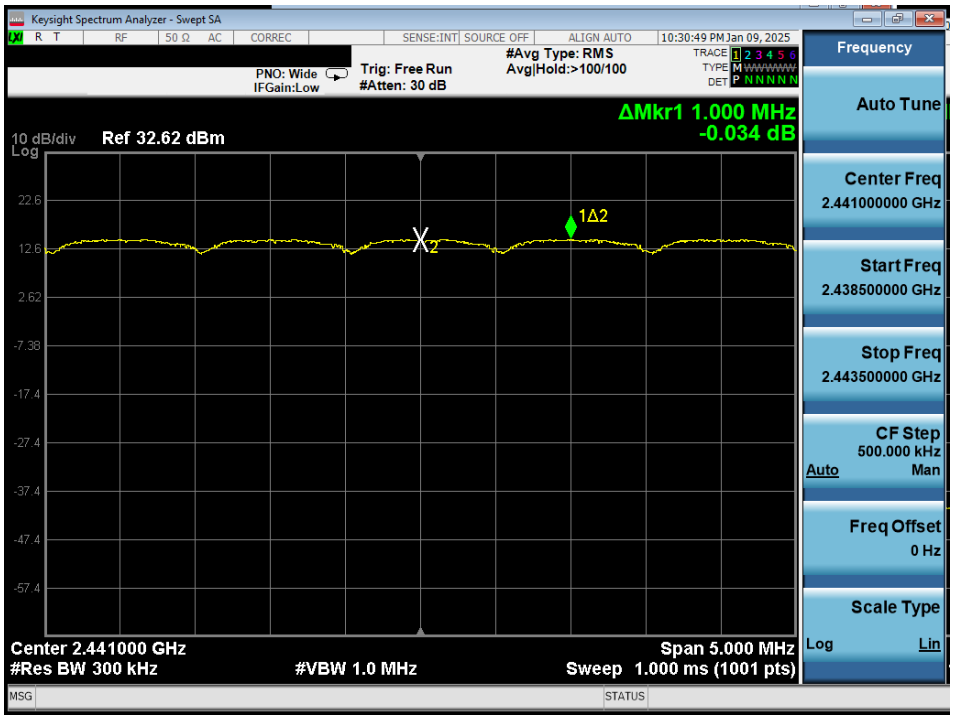
## Antenna WF7b (Common)

| Frequency [MHz] | Data Rate [Mbps] | Mod. | Power Scheme | Channel No. | Measured Channel Separation [kHz] | Min. Channel Separation [kHz] | Pass/Fail |
|---|---|---|---|---|---|---|---|
| 2441 | 1.0 | GFSK | iPA | 39 | 1.00 | 0.53 | Pass |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 1.00 | 0.88 | Pass |

**Table 7-15. Minimum Channel Separation Antenna WF7b (Common)**




**Plot 7-59. Channel Spacing Plot Antenna WF7b (Common) (Bluetooth, GFSK, iPA)**

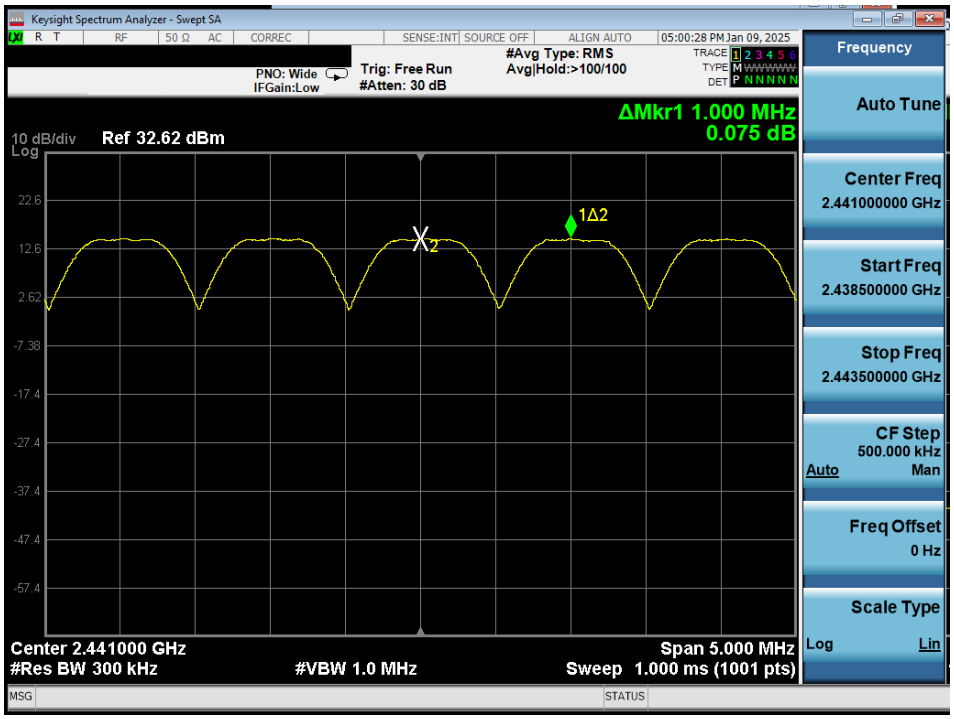



**Plot 7-60. Channel Spacing Plot Antenna WF7b (Common) (Bluetooth, 8DPSK, iPA)**

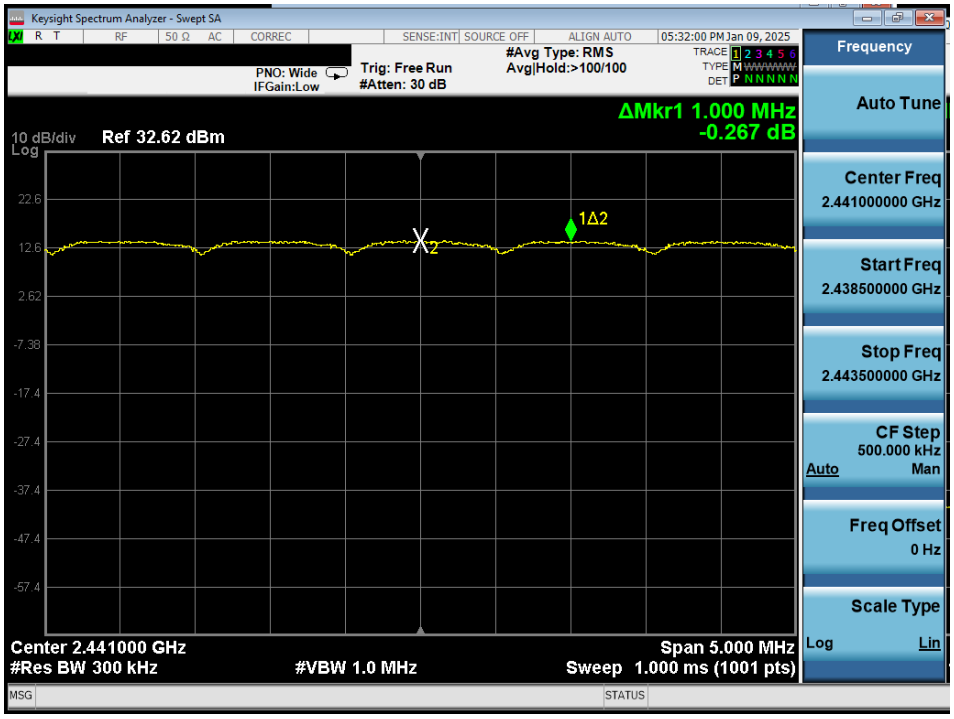
## Antenna WF8 (Dedicated)

| Frequency [MHz] | Data Rate [Mbps] | Mod. | Power Scheme | Channel No. | Measured Channel Separation [kHz] | Min. Channel Separation [kHz] | Pass/Fail |
|---|---|---|---|---|---|---|---|
| 2441 | 1.0 | GFSK | iPA | 39 | 1.00 | 0.53 | Pass |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 1.00 | 0.88 | Pass |

**Table 7-16. Minimum Channel Separation Antenna WF8 (Dedicated)**




**Plot 7-61. Channel Spacing Plot Antenna WF8 (Dedicated) (Bluetooth, GFSK, iPA)**

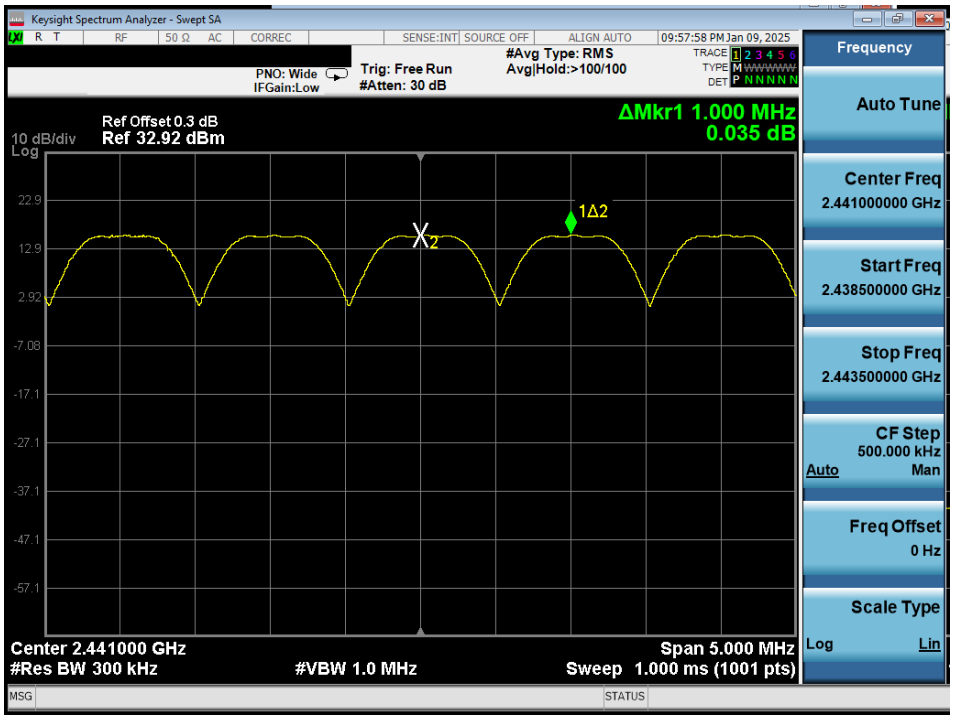



**Plot 7-62. Channel Spacing Plot Antenna WF8 (Dedicated) (Bluetooth, 8DPSK, iPA)**

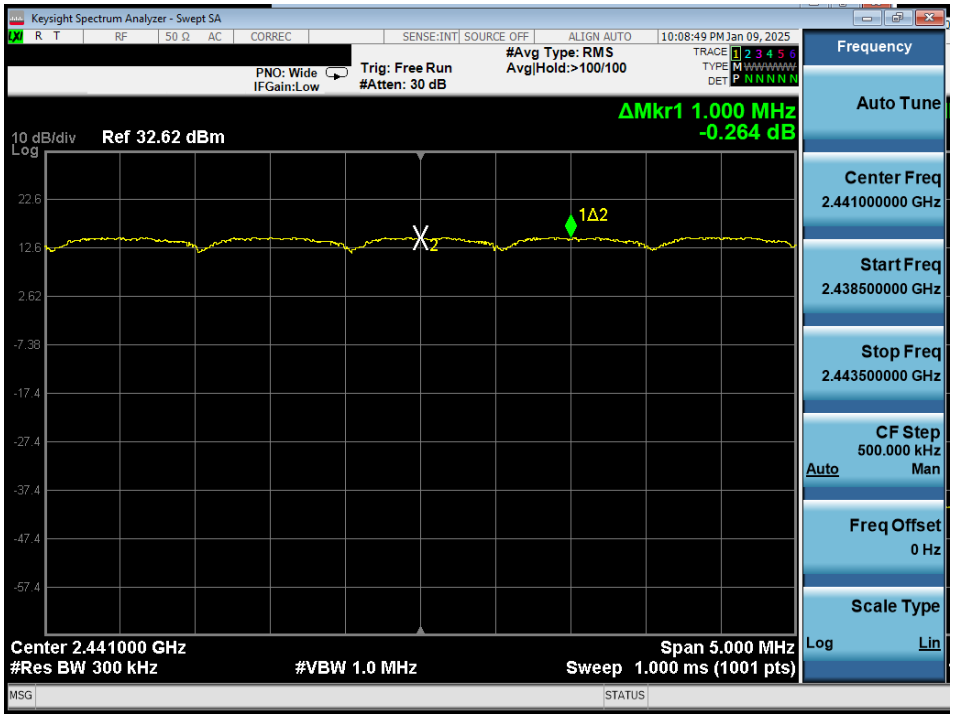
## Antenna WF7b (Dedicated)

| Frequency [MHz] | Data Rate [Mbps] | Mod. | Power Scheme | Channel No. | Measured Channel Separation [kHz] | Min. Channel Separation [kHz] | Pass/Fail |
|---|---|---|---|---|---|---|---|
| 2441 | 1.0 | GFSK | iPA | 39 | 1.00 | 0.53 | Pass |
| 2441 | 3.0 | 8DPSK | iPA | 39 | 1.00 | 0.88 | Pass |

**Table 7-17. Minimum Channel Separation Antenna WF7b (Dedicated)**




**Plot 7-63. Channel Spacing Plot Antenna WF7b (Dedicated) (Bluetooth, GFSK, iPA)**




**Plot 7-64. Channel Spacing Plot Antenna WF7b (Dedicated) (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 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.

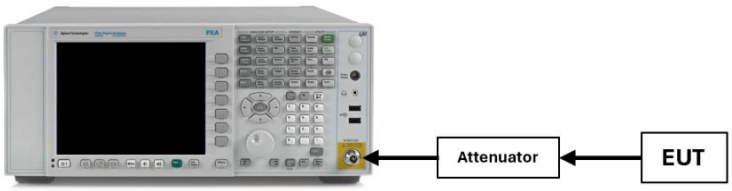
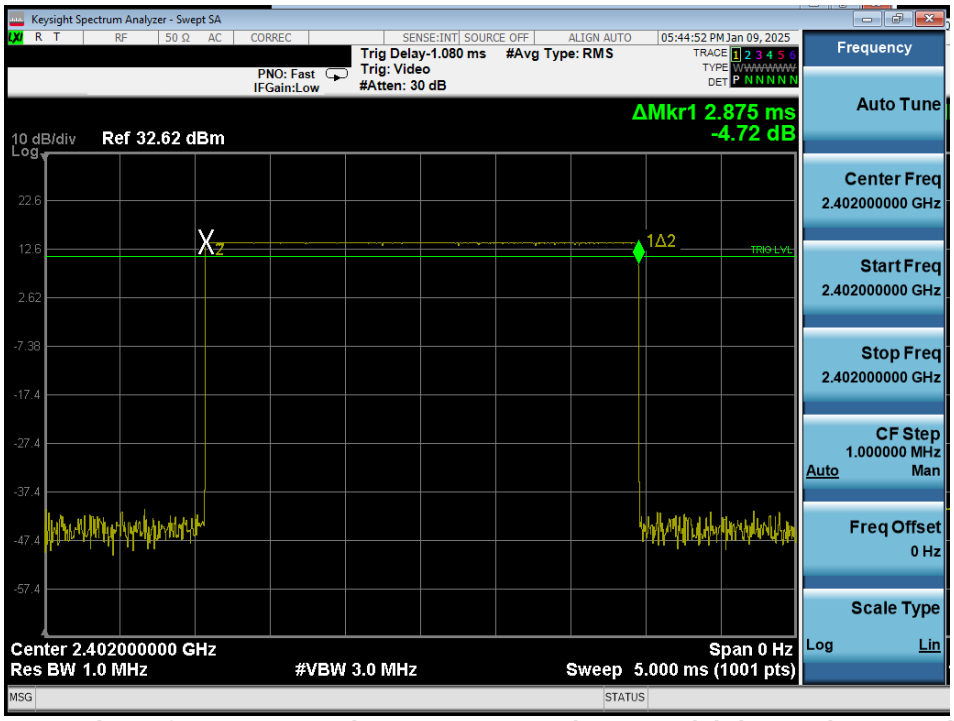



**Figure 7-5. Test Instrument & Measurement Setup**

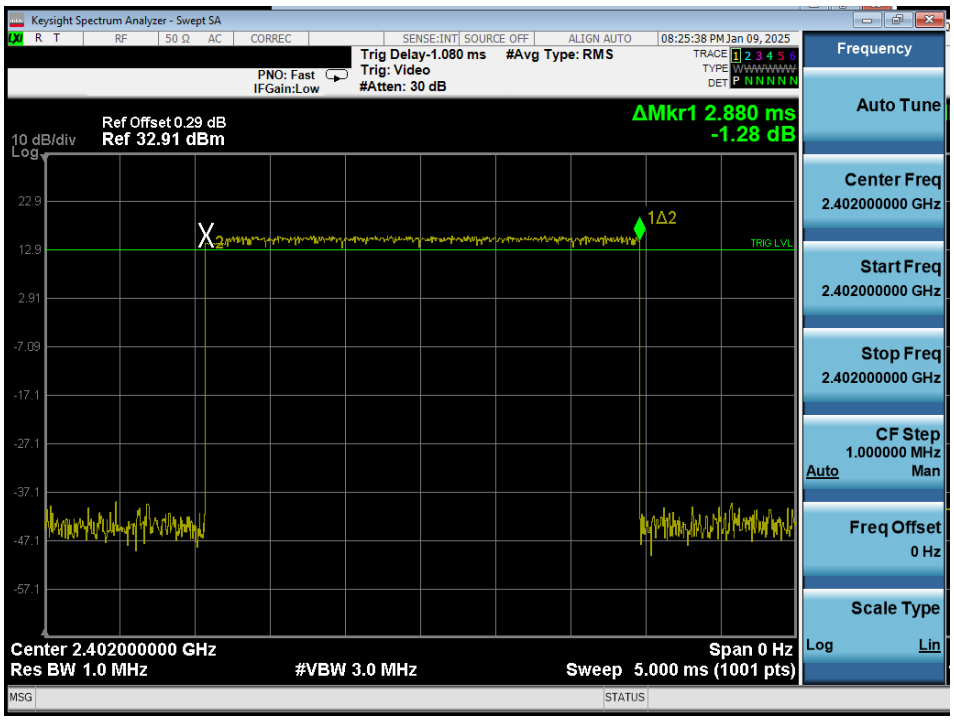
### Test Notes

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

## Antenna WF8 (Common)

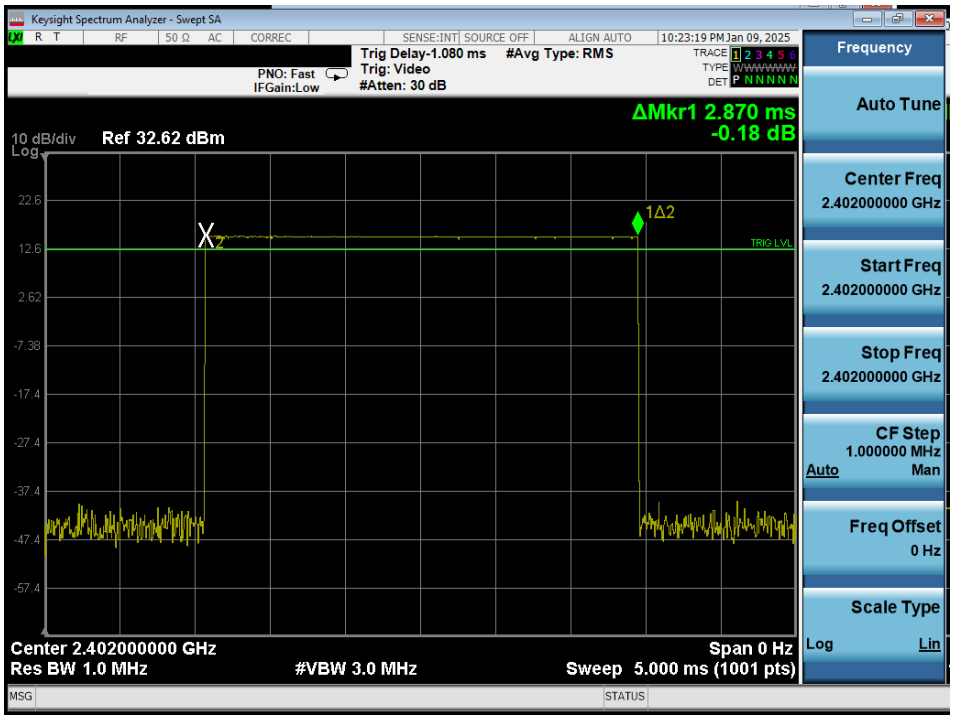



**Plot 7-65. Time of Occupancy Plot Antenna WF8 (Common) (Bluetooth, GFSK, iPA)**

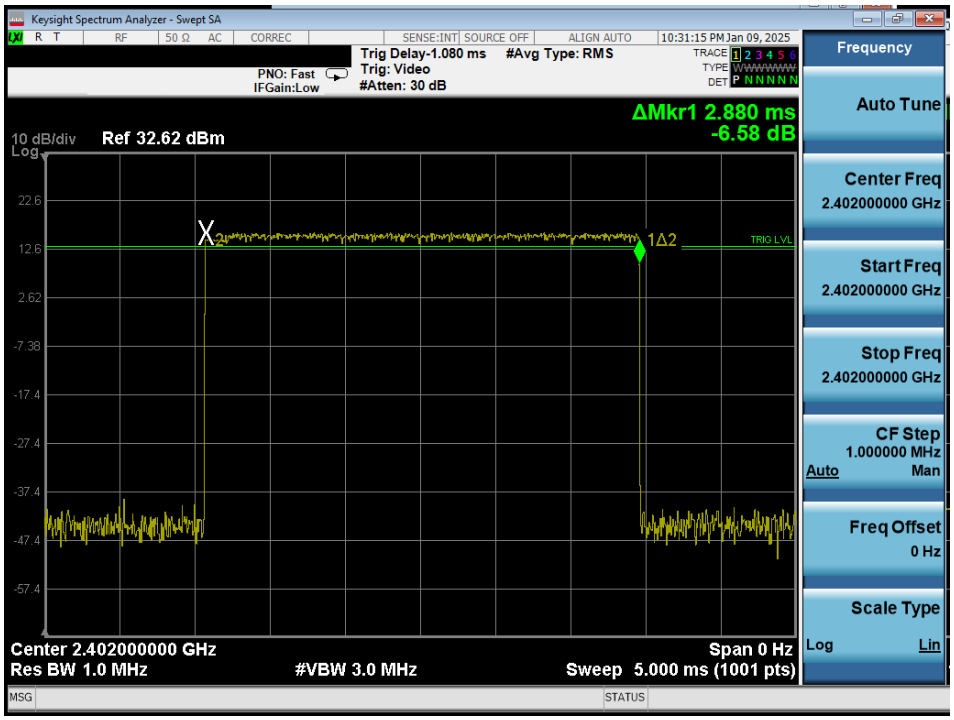



**Plot 7-66. Time of Occupancy Plot Antenna WF8 (Common) (Bluetooth, 8DPSK, iPA)**

## Antenna WF7b (Common)

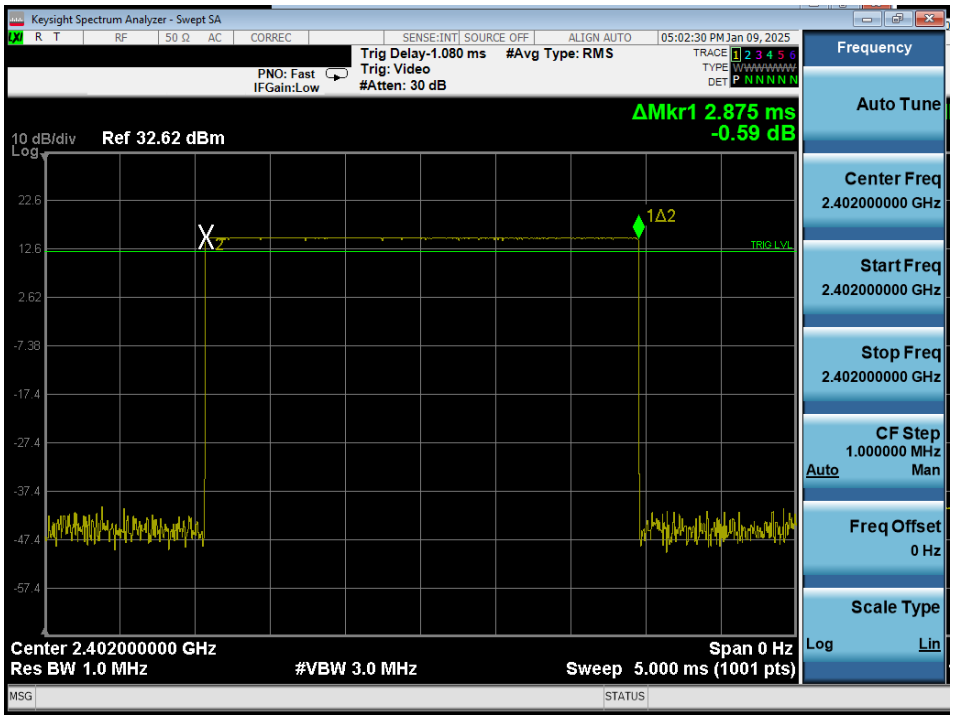



**Plot 7-67. Time of Occupancy Plot Antenna WF7b (Common) (Bluetooth, GFSK, iPA)**

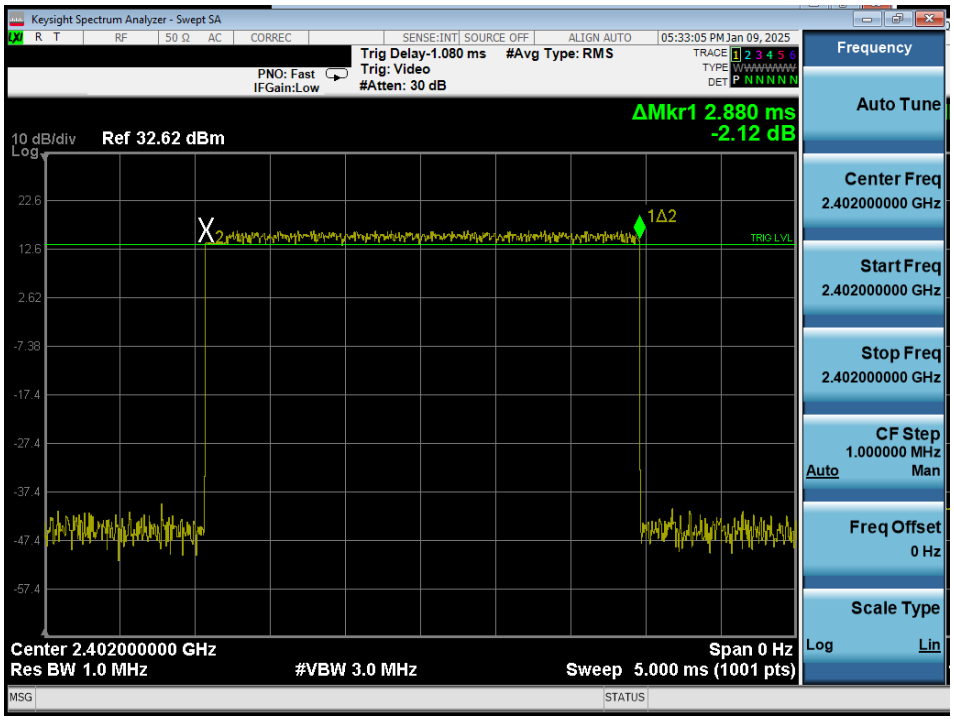



**Plot 7-68. Time of Occupancy Plot Antenna WF7b (Common) (Bluetooth, 8DPSK, iPA)**

## Antenna WF8 (Dedicated)

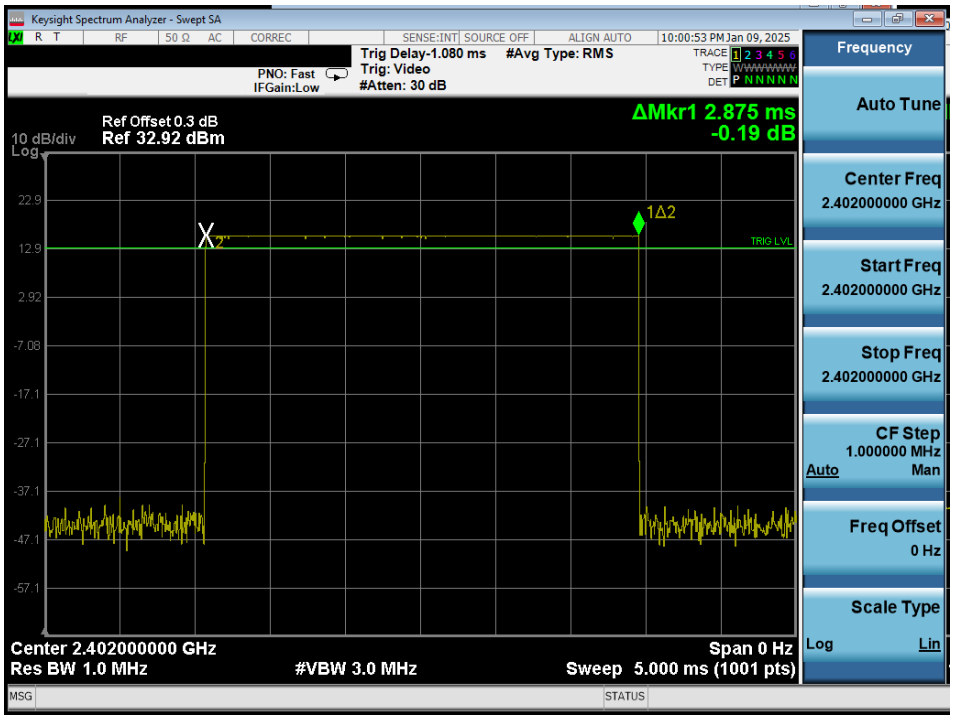



**Plot 7-69. Time of Occupancy Plot Antenna WF8 (Dedicated) (Bluetooth, GFSK, iPA)**

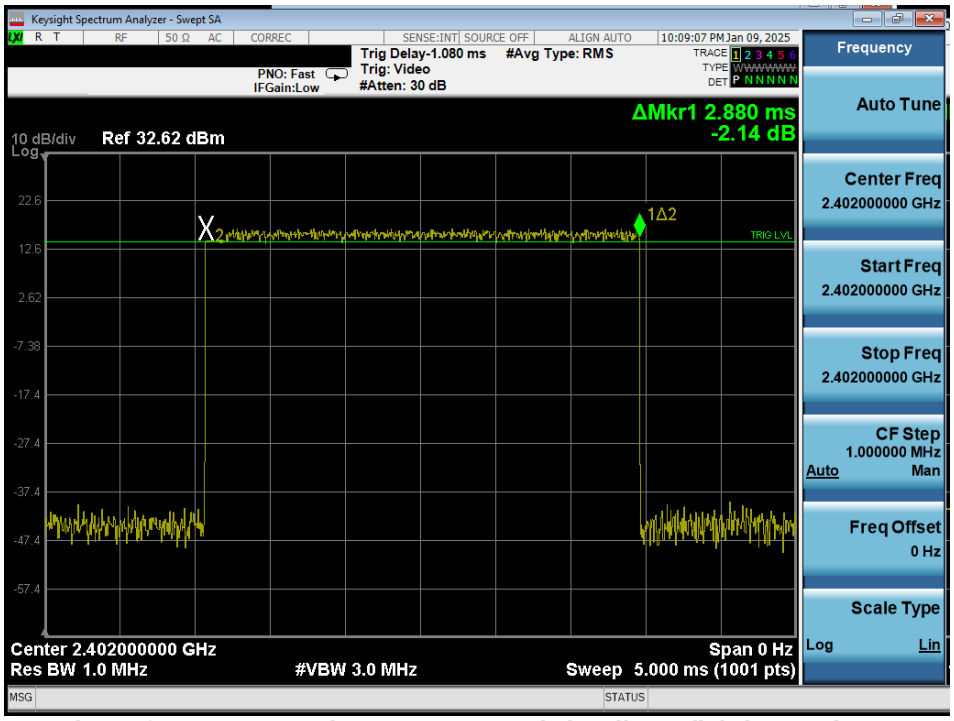



**Plot 7-70. Time of Occupancy Plot Antenna WF8 (Dedicated) (Bluetooth, 8DPSK, iPA)**

## Antenna WF7b (Dedicated)




**Plot 7-71. Time of Occupancy Plot Antenna WF7b (Dedicated) (Bluetooth, GFSK, iPA)**




**Plot 7-72. Time of Occupancy Plot Antenna WF7b (Dedicated) (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 = 106.67 hops (# hops over a 31.6 second period)
- 106.67 hops x 2.88 ms/channel = 307.21 ms (worst case dwell time for one channel in 1x/EDR modes)

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

- 400ms x 20 hopping channels = 8 sec (Time of Occupancy Limit)
- Worst case BT has 133.3 hops/second/slot (for AFH mode with DH5 operation)
- 133.3 hops/s / 20 channels = 6.67 hops/second (# of hops/second on one channel)
- 6.67 hops/s / channel x 8 seconds = 53.34 hops (# hops over a 8 second period)
- 53.34 hops x 2.88 ms/channel = 153.62 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.

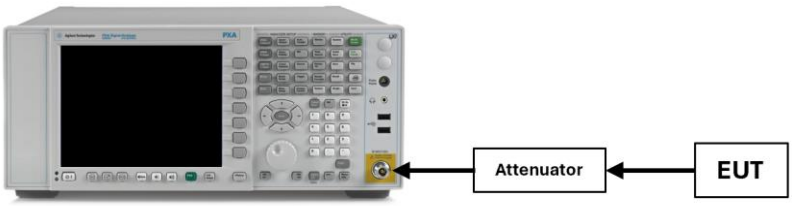


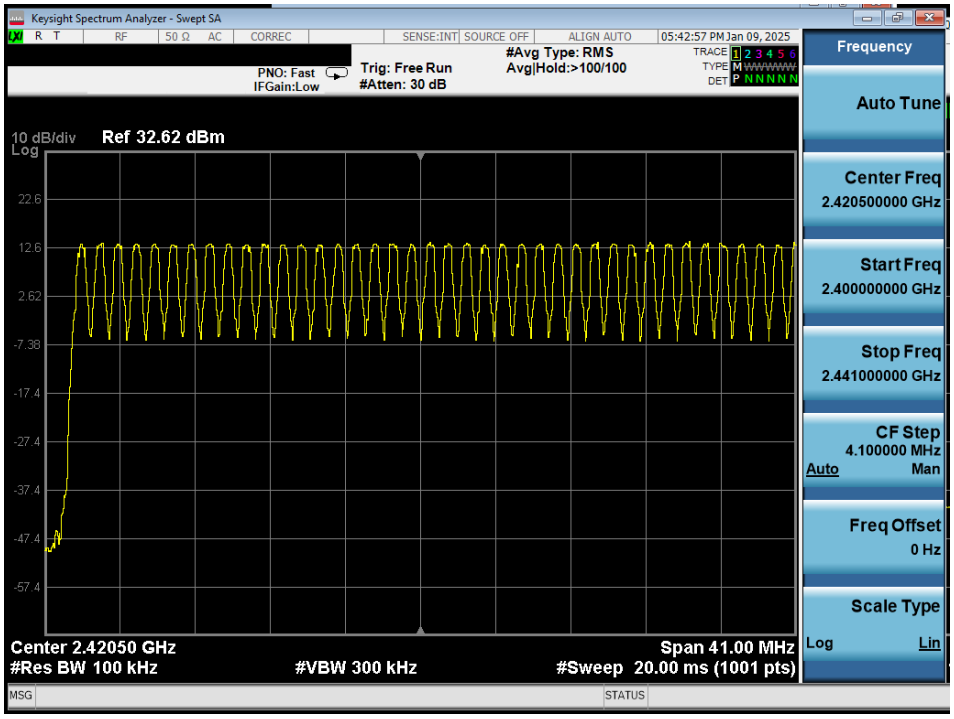

**Figure 7-6. Test Instrument & Measurement Setup**

### Test Notes

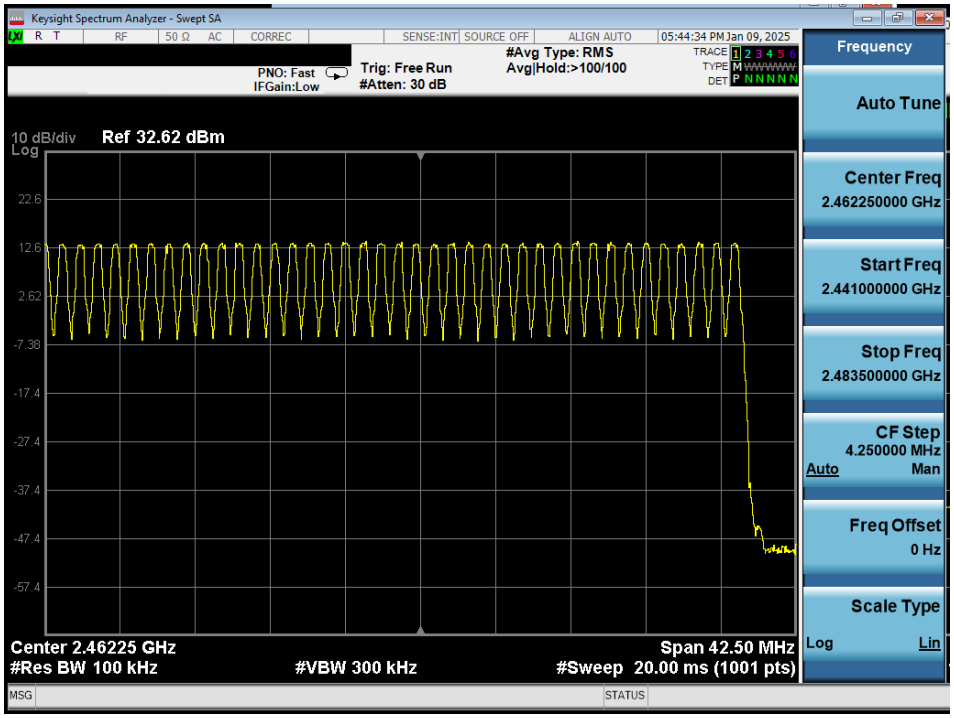
1. The frequency spectrum was broken up into two sub-ranges to clearly show all of the hopping frequencies. In AFH mode, this device operates using 20 channels so the requirement for minimum number of hopping channels is satisfied.

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

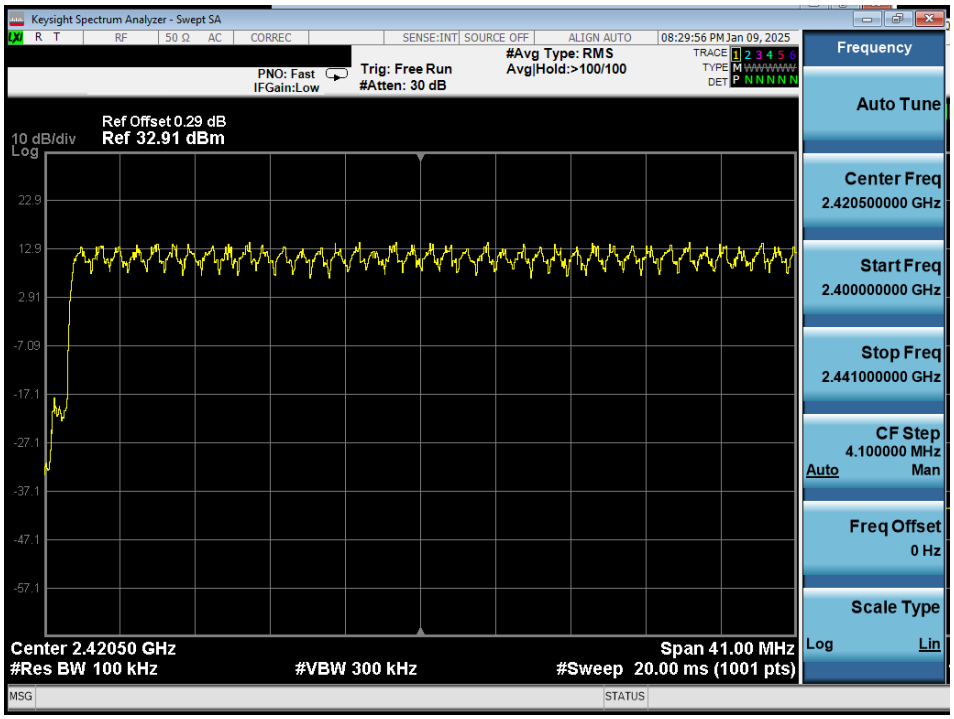
## Antenna WF8 (Common)



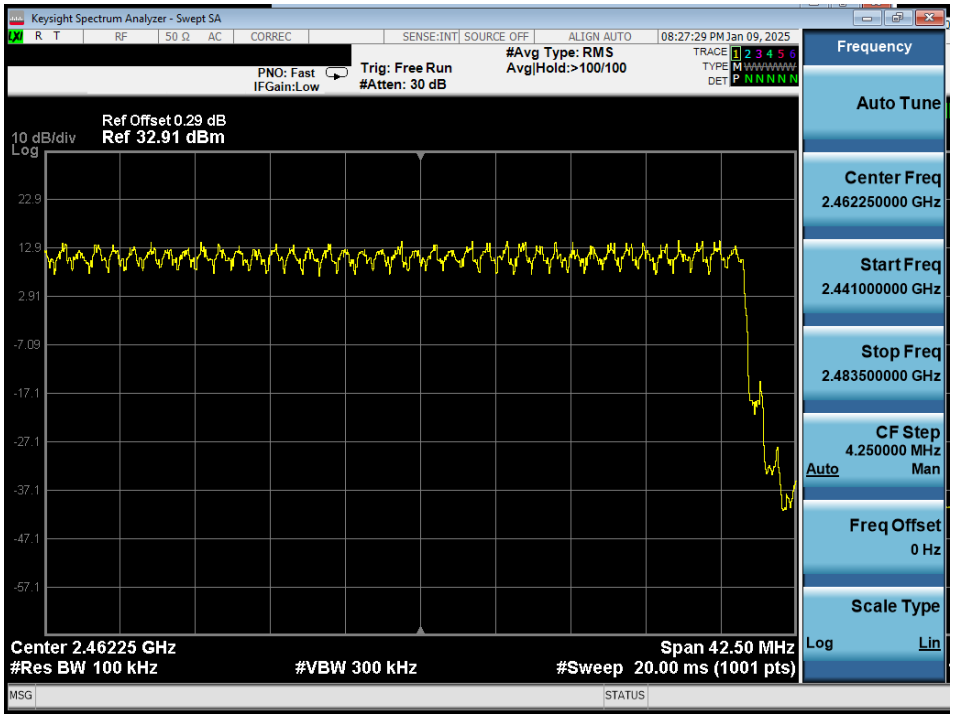

**Plot 7-73. Low End Spectrum Channel Hopping Plot Antenna WF8 (Common) (Bluetooth, GFSK, iPA)**




**Plot 7-74. High End Spectrum Channel Hopping Plot Antenna WF8 (Common) (Bluetooth, GFSK, iPA)**

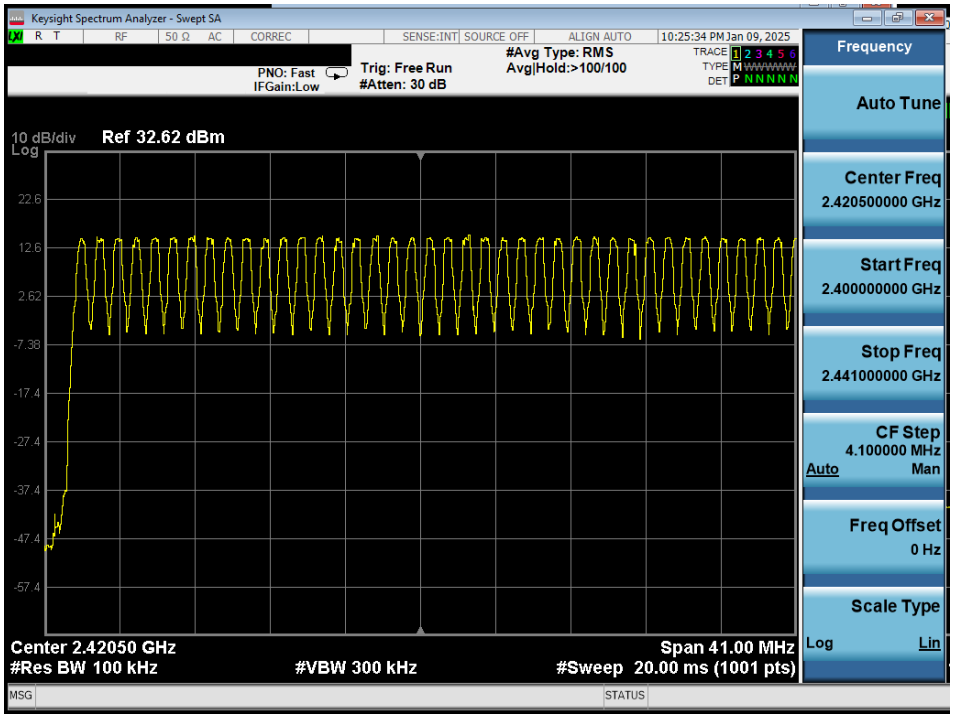



**Plot 7-75. Low End Spectrum Channel Hopping Plot Antenna WF8 (Common) (Bluetooth, 8DPSK, iPA)**

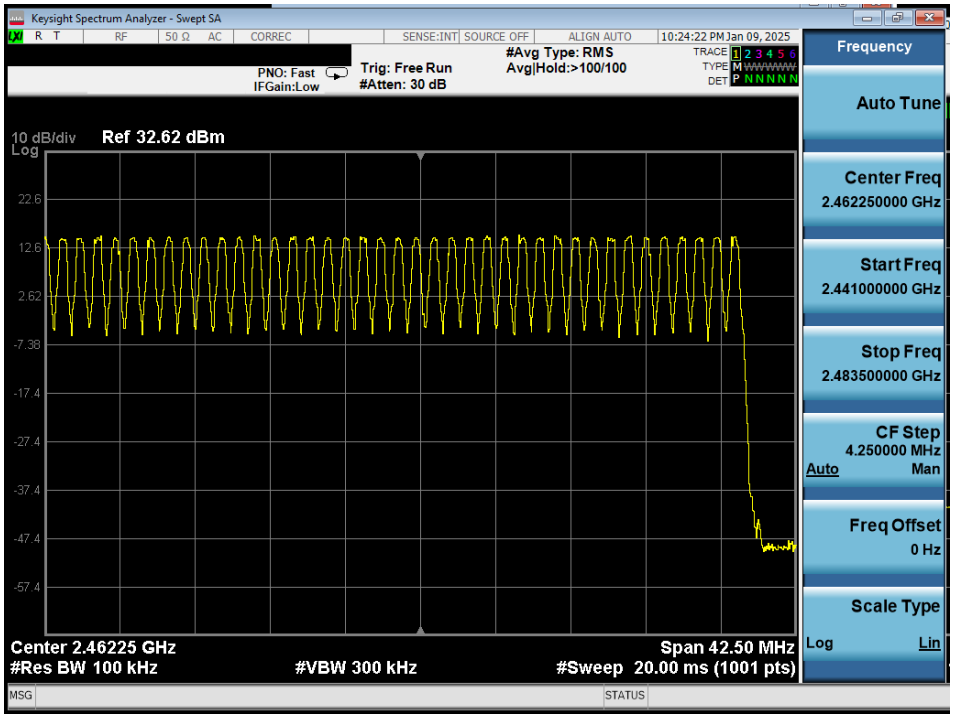



**Plot 7-76. High End Spectrum Channel Hopping Plot Antenna WF8 (Common) (Bluetooth, 8DPSK, iPA)**

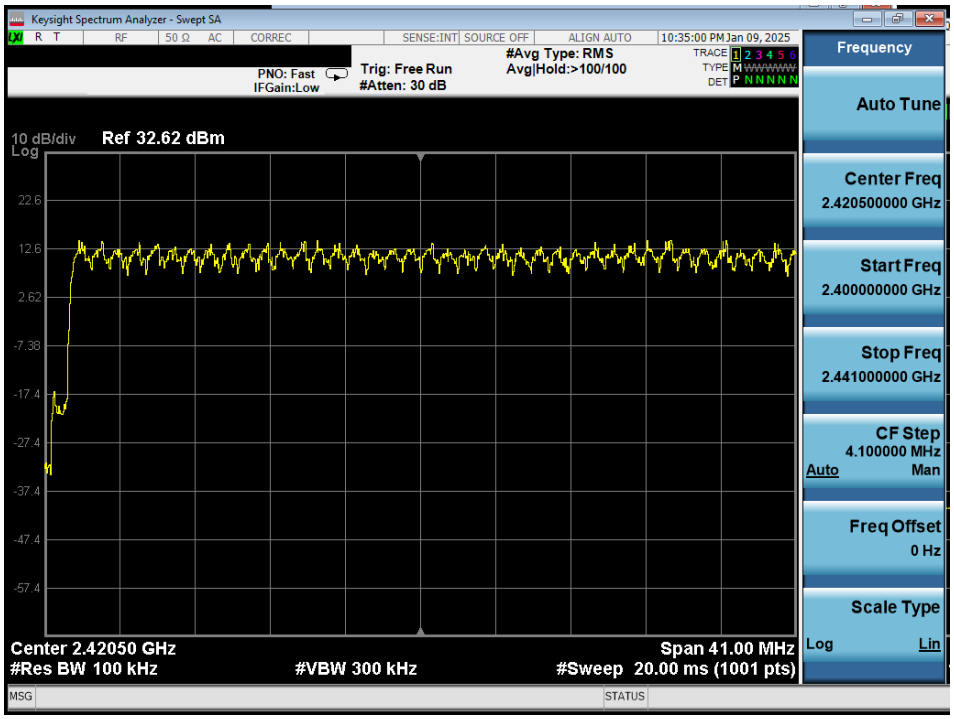
## Antenna WF7b (Common)



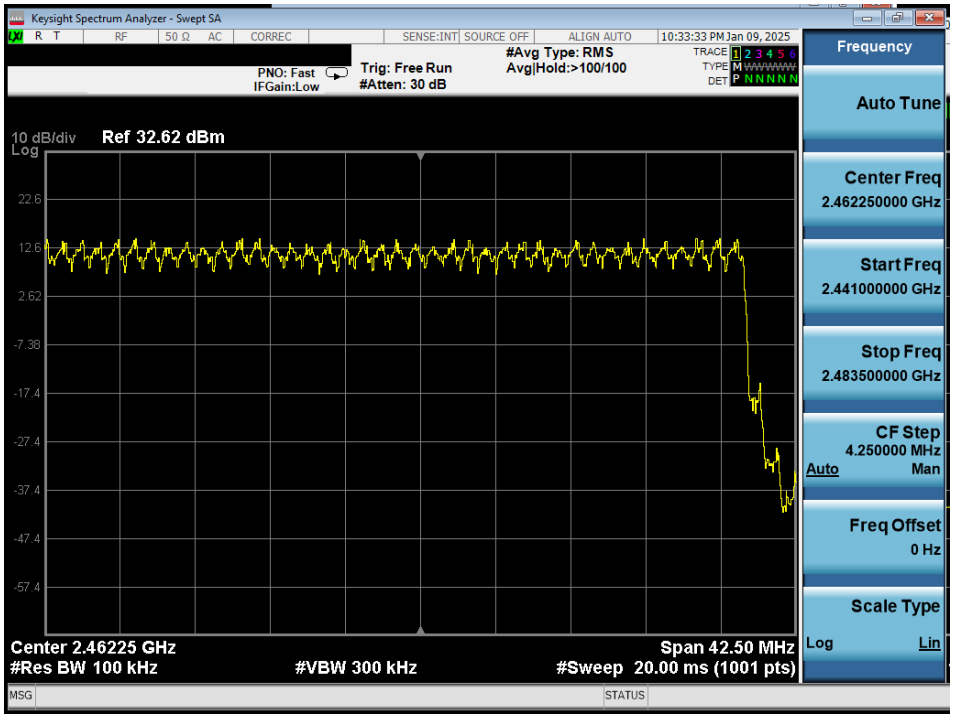

**Plot 7-77. Low End Spectrum Channel Hopping Plot Antenna WF7b (Common) (Bluetooth, GFSK, iPA)**




**Plot 7-78. High End Spectrum Channel Hopping Plot Antenna WF7b (Common) (Bluetooth, GFSK, iPA)**

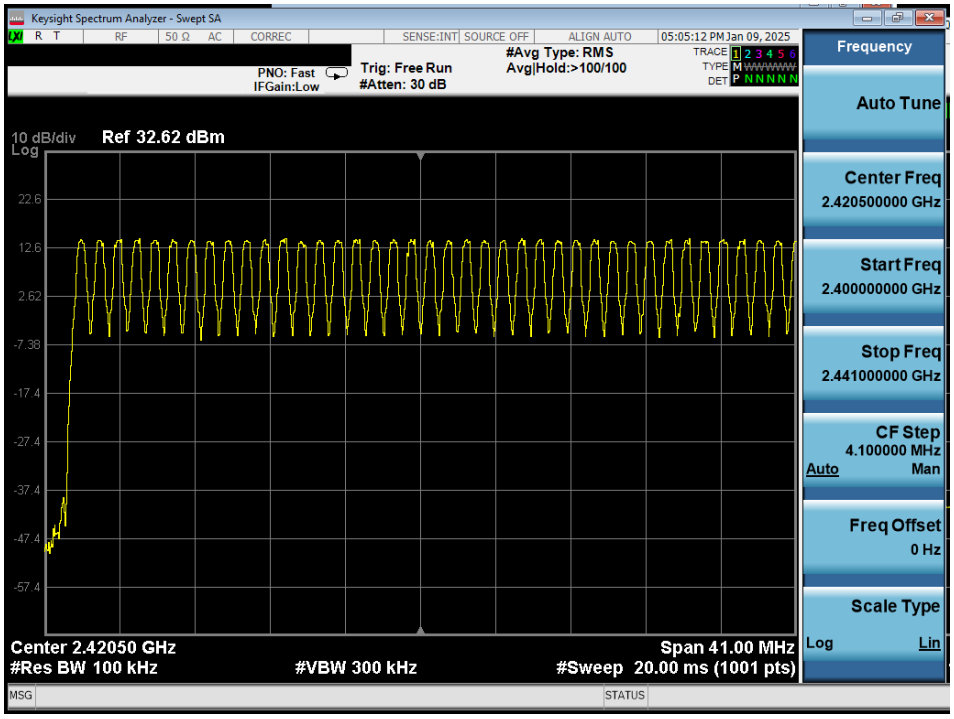



**Plot 7-79. Low End Spectrum Channel Hopping Plot Antenna WF7b (Common) (Bluetooth, 8DPSK, iPA)**

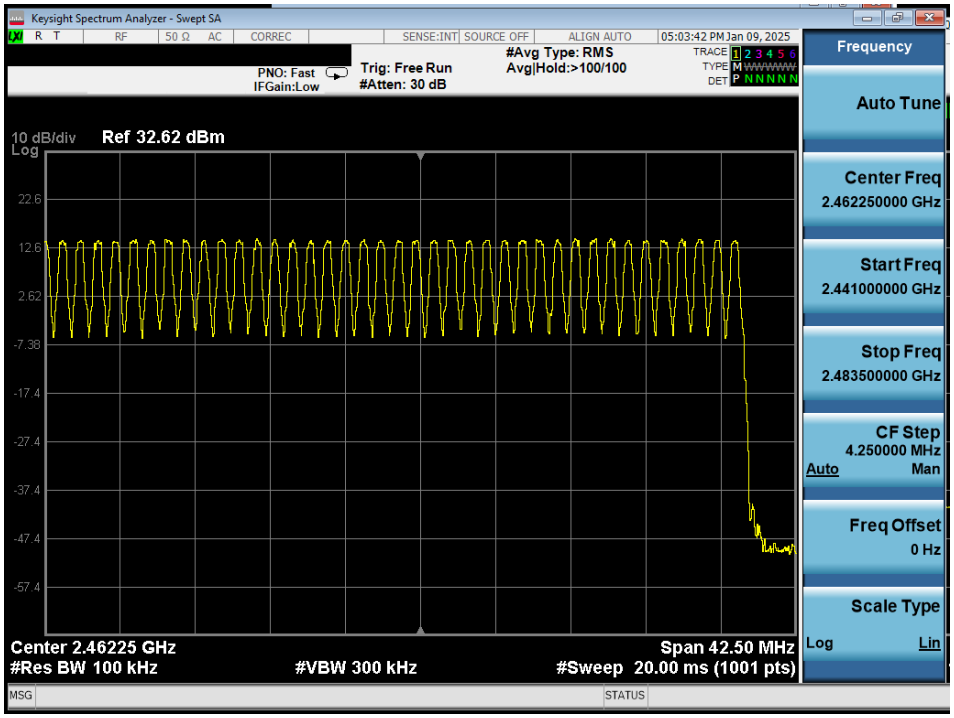



**Plot 7-80. High End Spectrum Channel Hopping Plot Antenna WF7b (Common) (Bluetooth, 8DPSK, iPA)**

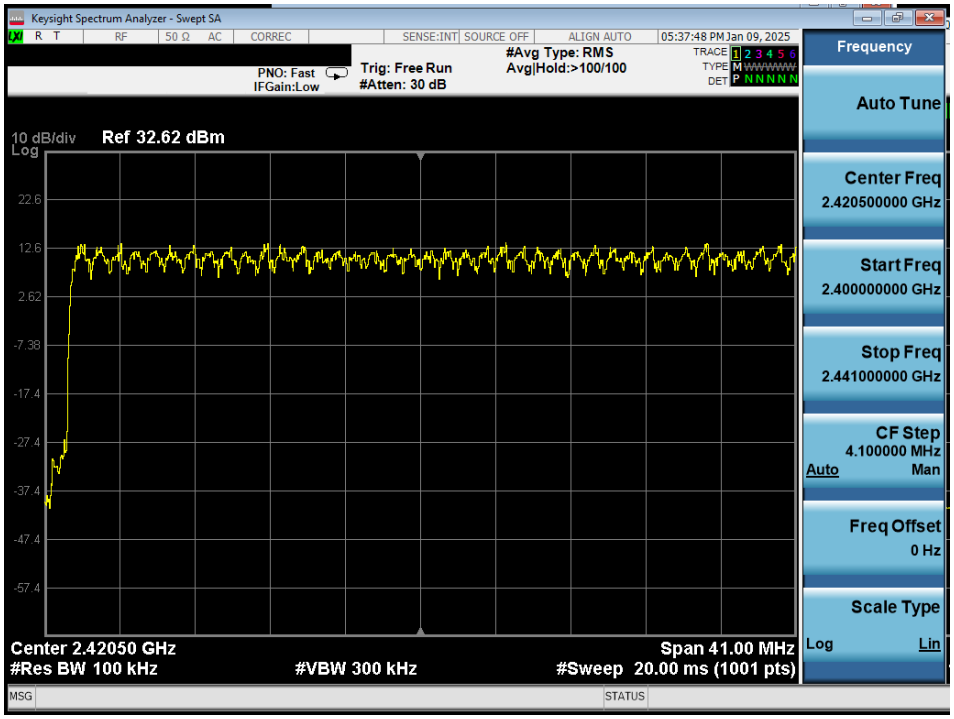
## Antenna WF8 (Dedicated)



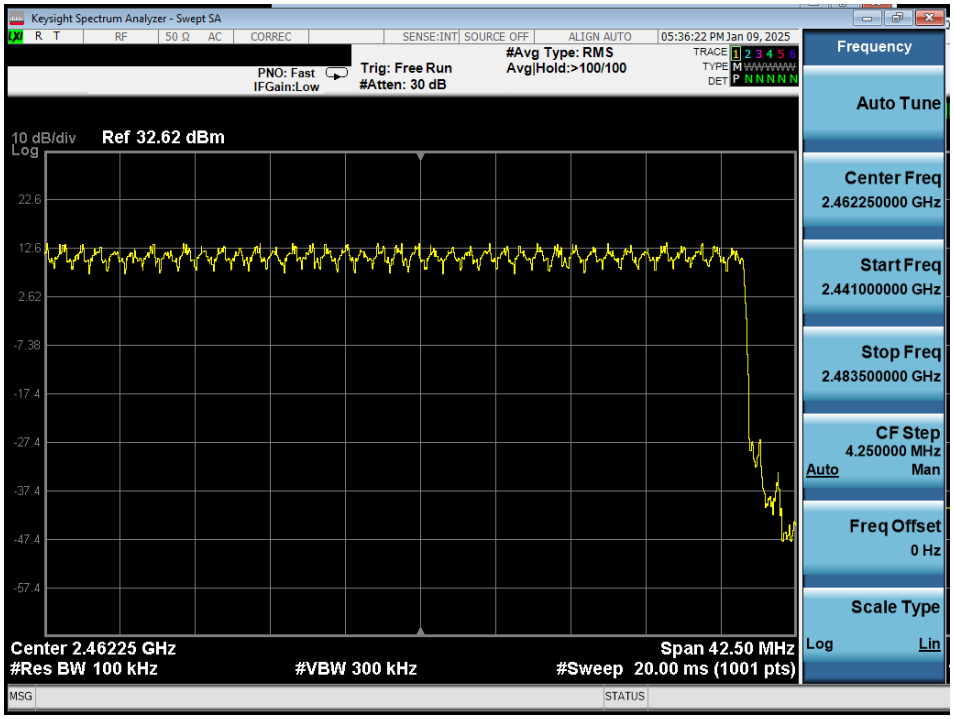

**Plot 7-81. Low End Spectrum Channel Hopping Plot Antenna WF8 (Dedicated) (Bluetooth, GFSK, iPA)**




**Plot 7-82. High End Spectrum Channel Hopping Plot Antenna WF8 (Dedicated) (Bluetooth, GFSK, iPA)**

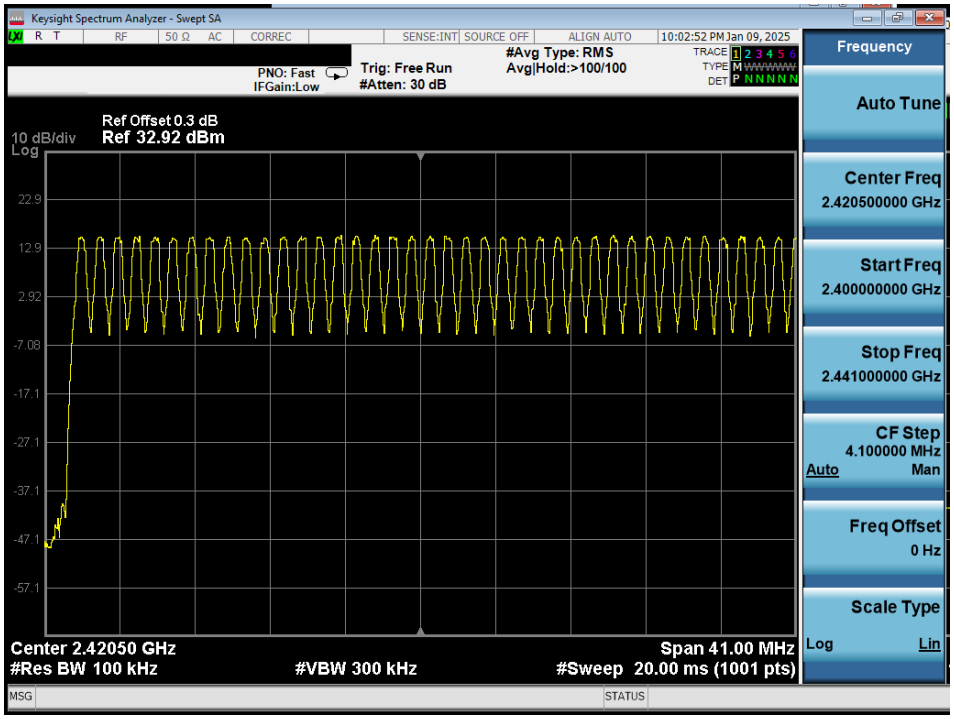



**Plot 7-83. Low End Spectrum Channel Hopping Plot Antenna WF8 (Dedicated) (Bluetooth, 8DPSK, iPA)**

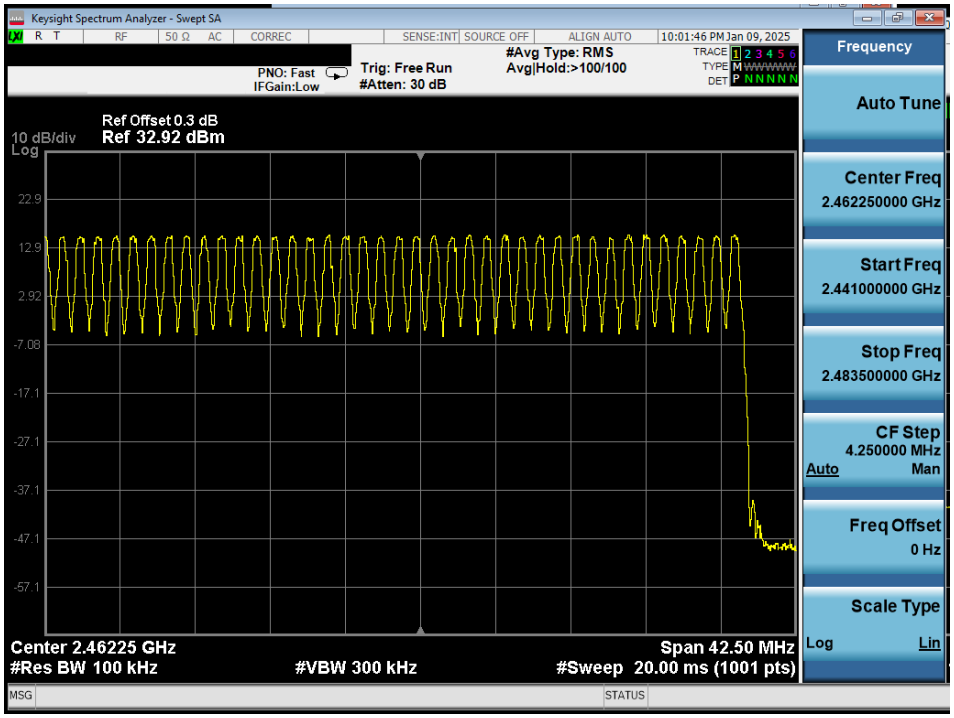



**Plot 7-84. High End Spectrum Channel Hopping Plot Antenna WF8 (Dedicated) (Bluetooth, 8DPSK, iPA)**

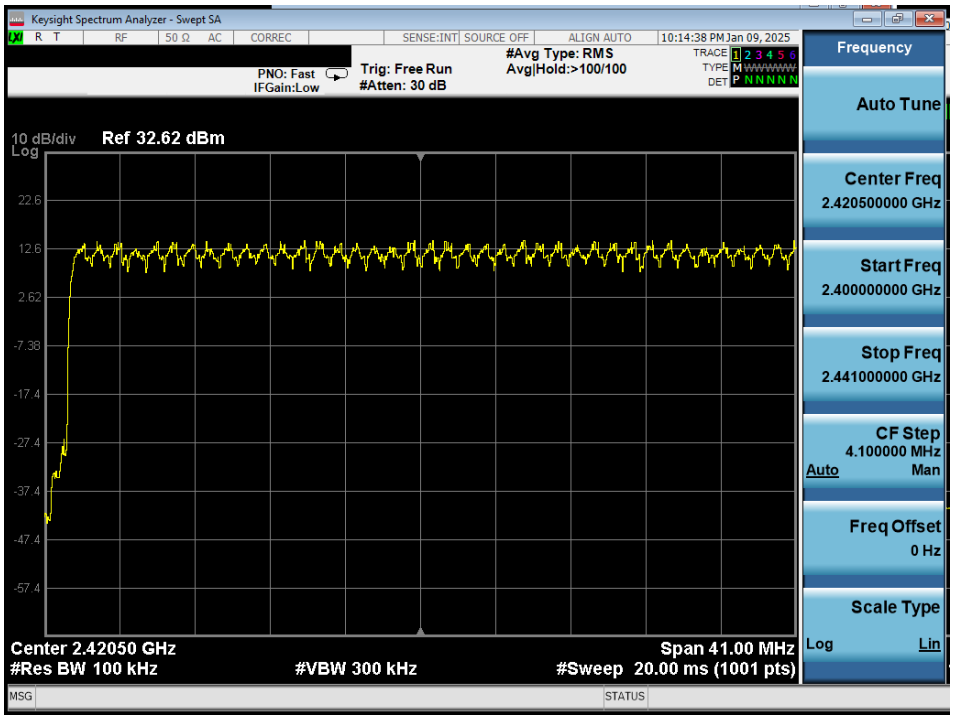
## Antenna WF7b (Dedicated)



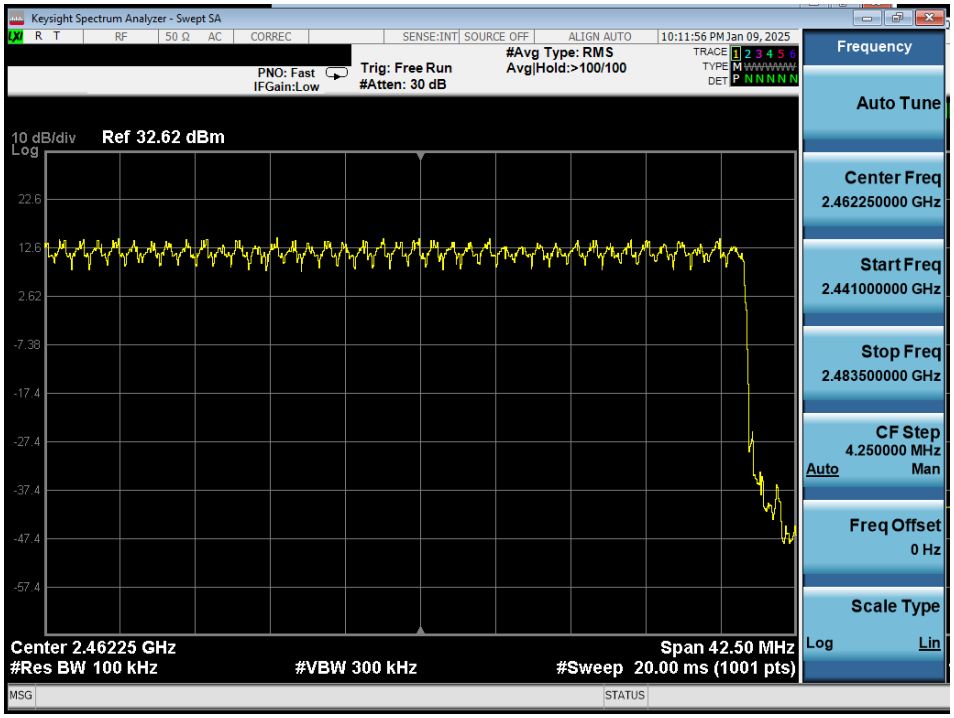

**Plot 7-85. Low End Spectrum Channel Hopping Plot Antenna WF7b (Dedicated) (Bluetooth, GFSK, iPA)**




**Plot 7-86. High End Spectrum Channel Hopping Plot Antenna WF7b (Dedicated) (Bluetooth, GFSK, iPA)**




**Plot 7-87. Low End Spectrum Channel Hopping Plot Antenna WF7b (Dedicated) (Bluetooth, 8DPSK, iPA)**




**Plot 7-88. High End Spectrum Channel Hopping Plot Antenna WF7b (Dedicated) (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.

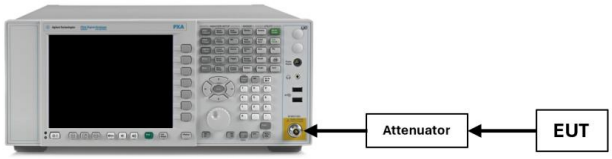



**Figure 7-7. Test Instrument & Measurement Setup**

### 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 only the highest emission is reported.