Test Report 2023-096

Version C
Issued 4 June 2024

Project GCL-0296
Model Identifier: A03996
Primary Test Standard(s)
CFR 47, FCC Part 15.249
RSS-210 Issue 10 Amd 1

Garmin Compliance Lab
Garmin International
1200 E 151st Street
Olathe Kansas 66062 USA

Client-supplied Information
FCC ID: IPH-03996
IC ID: 1792A-03996

ACCREDITED
CERTIFICATE #6162.01

See section 6 of this report regarding the presence or absence of accreditation logos or marks on this cover page.

1. Summary

The equipment or product described in section 5 of this report was tested at the Garmin Compliance Lab according to standards listed in section 6. This report focuses on the 2.4 GHz ANT transceiver(s). Test records within this report may include data for the other 2.4 GHz DTS transmitter, but DTS radio compliance is fully addressed in separate reports. The results for ANT are as follows.

Parameter	Description	Key Performance Values	Result	Data starts at page
Radio Modulation	Summary of the kinds of communication this radio can achieve, as stated by the client. [RSS-GEN at Annex A item 10b]	Digitally modulated spread spectrum at rates as high as 1 Mbps.	Reported	N/A
Restricted Bands	The radio must not emit in certain designated restricted frequency bands above a set of limit values. [15.205; RSS-210 at 7.1]	Emissions in the restricted bands were at least 7.79 dB below the applicable limits.	PASS	11
Carrier and Harmonic Emissions	The field strength from the radio carrier and its harmonics must meet specific limits at a 3 m test distance. [15.249(a); RSS-210 at B.10]	The limit is 50 mV/m (94 dBuV/m) in the carrier band, and 0.5 mV/m (54 dBuV/m) at all other frequencies. This sample demonstrated 7.70 dB of margin or greater.	PASS	15
Frequency Stability	The radio tuning must be robust over a range of temperature and supply voltage conditions. [RSS-Gen at 6.11]	Radio emissions remained within the allowed radio band under all environmental conditions tested.	PASS	28
Other Bandwidths	Regulatory agencies also require the reporting of signal bandwidths using alternate processes. [2.202; RSS-GEN at 6.7]	These values are reported but have no actual performance requirements.	Reported	32

NT (Not Tested) means the requirement may or may not be applicable, but the relevant measurement or test was not performed as part of this test project.
N/A (Not Applicable) means the lab judged that the test sample is exempt from the requirement.

Table 1: Summary of results

Report Organization

For convenience of the reader, this report is organized as follows:

1. Summary
2. Test Background
3. Report History and Approval
4. Test Sample Modifications and Special Conditions
5. Description of Equipment Tested
6. Test Standards Applied
7. Measurement Instrumentation Uncertainty
8. Selected Examples of Calculations
9. Environmental Conditions During Test
10. Immunity Performance Criteria

Annex: Test records are provided for each type of test, following the order and page numbering stated in the summary table. Concluding notes appear on the final page of this report.

Due to confidentiality, certain material (such as test setup photographs) has been removed from this report and placed in GCL Test Report 2023-094. That report is treated as a part of this document by way of this reference.

2. Test Background

2.1 The test lab

The testing reported here was performed at the Garmin Compliance Lab, an organization within Garmin International, located at 1200 E 151st St, Olathe Kansas, USA. The contact telephone number is +1.913.397.8200.

2.2 The client

The testing was performed on behalf of the Garmin design group, a separate organization located at 1200 E 151st St, Olathe Kansas, USA. Witnesses from the business group included: None.

2.3 Other information

Test Sample received: 22 May 2023
Test Start Date: 21 Aug 2023
Test End Date: 08 Dec 2023

The data in this test report apply only to the specific samples tested.
Upon receipt all test samples were believed to be properly assembled and ready for testing.

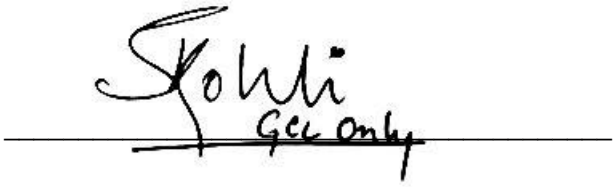
3. Report History and Approval

This report was written by Majid Farah and initially issued on 12 Jan 2024 as Version A. Majid Farah created version B on 24 May 2024 updating the product description and replacing references to RSS-247 with RSS-210. This report was written by Majid Farah and issued on 4 June 2024 as Version C with update on section 2.

Report Technical Review:

David Arnett
Technical Lead EMC Engineer

Report Approval:



Shruti Kohli
Manager Test and Measurement (EMC, Reliability and Calibration)

4. Test Sample Modifications and Special Conditions

The following special conditions or usage attributes were judged during test to be necessary to achieve compliance with one or more of the standards listed in section 6 of this report:
None

The following modifications to the test sample(s) were made, and are judged necessary to achieve compliance with one or more of the standards listed in section 6 of this report:

Modification 1: Firmware version changed from V0.78 to V7.78
Detailed Description: A Software upgrade applied to address required compliance test modes and to develop a GUI application (S1 compliance test tool) to be used by the compliance test engineers.
Date applied: 9/18/2023

Reason for this modification: The new software provides access to required modes/radio channels of EUT when it is using during various compliance tests which may need EUT to be connected to a companion device.

The following tests were performed without this modification being present, and the presence or absence of the modification is judged by the lab and client to have no significant effect on these specific tests: Transmit Power
Modification 2: Firmware version changed from V7.78 to V7.79
Detailed Description: Power adjusted to a lower level for IEEE 802.11 b mode only
Date applied: 12/08/23

Reason for this modification: Measured power spectral density for IEEE 802.11 b mode was over the ETSI EN 300 328 limit.

The following tests were performed without this modification being present, and the presence or absence of the modification is judged by the lab and client to have no significant effect on the compliance results of these specific tests: RF Bandwidth, Power Spectral Density, Voltage & Temperature stability, Rx spurious emissions, or any tests related to other radio services other than IEEE 802.11 b.

5. Description of the Equipment Tested

5.1 Unique Identification

Product Model	A03996
Serial Numbers Tested	443220641, 443220748

This product tested is a Transceiver/AP for multiple types of diving purposes.

The client affirmed that the test samples will be representative of production in all relevant aspects.

5.2 Key Parameters

EUT Input Power:	5 Vdc 2A, Internal battery 3.7 Vdc
I/O Ports:	USB
Radio Transceivers:	IEEE 802.11 b/g/n, Bluetooth Low Energy, ANT
Radio Receivers:	GPS L1, GLONASS
Acoustic Transceiver:	Subwave
Primary Functions:	Data collection and communication
Typical use:	Portable in multiple orientations or on floor
Highest internal frequency:	2.484 GHz
Firmware Revision	V0.78, V7.78, V7.79 (See section 4)

5.3 Operating modes

During test, the EUT was operated in one or more of the following modes.

Mode 1: M1 (BleT). Bluetooth Low Energy radio transmitting consistently on a selected channel at 1 Mbps or 2 Mbps

Mode 2: M2 (BleL). Bluetooth Low Energy radio is paired to a companion device, transmitting and receiving data on various channels in accordance with the protocol, and maintaining the paired relationship.

Mode 3: M3 (AntT). ANT radio transmitting consistently on a selected channel.

Mode 4: M4 (AntL). ANT radio is paired to a companion device, transmitting and receiving data in accordance with the protocol, and maintaining the paired relationship.

Mode 6: M6 (Gnss). The Global Navigation Satellite System receiver is monitoring the GNSS bands, attempting to detect a constellation and determine location. Unless otherwise noted, the EUT was provided simulated GNSS signals representing one of more constellation types. In addition, the EUT may have been reporting signal levels and satellite data to an attached computer to monitor link health.

Mode 7: M7 (All Tx off). This means all radio transmitters turned off.

Mode 8: M8 (WifiT). The IEEE 802.11 b/g/n radio was transmitting consistently on a selected channel, with a specified modulation type, and data rate.

Mode 9: M9 (WifiL). The IEEE 802.11 b/g/n radio is paired to a companion device, transmitting and receiving data on a selected channel in accordance with the protocol, and maintaining the paired relationship.

Mode 12: M12 (All Tx on). This means the radio was tested in modes M1, M3, M8 and M14 if applicable.

Mode 13: M13 (All Rx on). This means the radio was tested in Receiver mode only if applicable.

Mode 14: M14 (Subwave L). The EUT was linked to a companion device thru Subwave.

Mode 15: M15 (Normal). The EUT was working in normal operational mode with charging cable attached or not.

Mode 16: M16 (WifiSub). The EUT was working in normal operational mode and linked or connected to companion devices thru Subwave and IEEE 802.11 b/g/n radio.

5.4 EUT Arrangement

During test, the EUT components and associated support equipment were selected including the following arrangement sets. Associated support equipment cand be a laptop or a power adaptor.

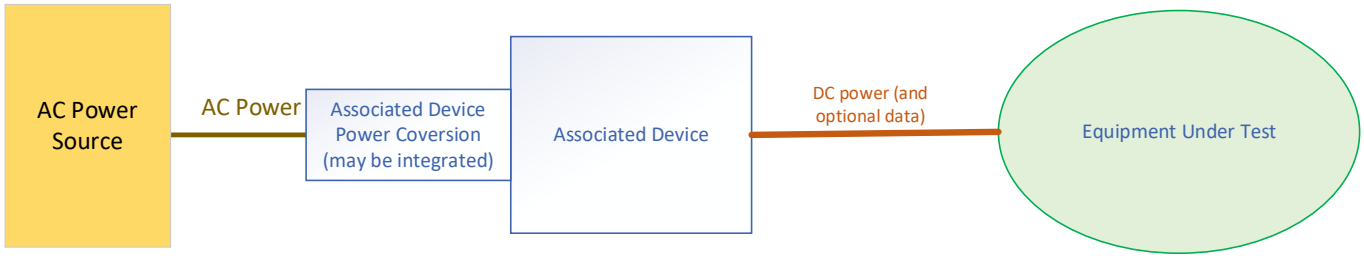
Arrangement 1: A1 (Standalone). The test sample operates from its battery and no external physical connections. No block diagram is needed for this arrangement.

Arrangement 2: A2 (laptop). The test sample is attached to a laptop that provides dc power to the sample over a cable may it used or not used for data transfer.

Arrangement 3: A3 (GNSS). The test sample is attached to a laptop that provides dc power to the sample over a cable. The laptop using a software to collect received data from the test sample.

Arrangement 4: A4 (PwrSupply). The test sample is attached to a variable dc power supply over a cable.

Arrangement 5: A5 (PwrA). The test sample is attached to a dc power adaptor with USB A port over a cable.



This interconnect drawing is not to scale.
It does not indicate the placement of devices.

Figure 1: Block diagram of equipment for arrangements A2, A3, A4, A5

5.5 Associated Equipment (AE) used

Description	Manufacturer	Model	Serial Number
Laptop Computer	Dell	Latitude 5410	5VSPFB3
Laptop Power Supply	Dell	HA65NM191	None
AC/DC Power adaptor	Phihong technology	PSAF10R-050Q	P183100844A1
ANT companion device	Garmin	T1	28811
Subwave companion device	Garmin	T1	10162
nRF52840 USB dongle	Nordic	400250	PCA10059

Table 2: List of associated equipment that may have been used during test

5.6 Cables used

Description	From	To	Length	EMC Treatment
USB Clip	Power and/or Data source	EUT	114 cm	None

Table 3: List of cables that may have been used during test

6 Test Standards Applied

6.1. Accredited Standards

The following test or measurement standards were applied and are within the scope of the lab's accreditation. All results in this report that cite these standards are presented as Accredited results consistent with ISO/IEC 17025.

AS/NZS 4268: 2017
CFR 47, FCC Part 15.249
ANSI C63.10: 2013 and ANSI C63.10: 2020
RSS-GEN Issue 5 Amd 2
RSS-210 Issue 10 Amd 1

6.2. Non-accredited Standards

The following test or measurement standards were applied and are either outside the scope of the lab's accreditation, or were performed in such a way that results are not presented as being fully accredited.

None.

6.3 Variances

The following variances were applied to standards cited in this section.

Where different test standards cover the same test parameter or phenomenon, and the standards have compatible differences, the stricter of the requirements is typically applied. For example, a consolidated limit may be applied to emission tests selecting the strictest of the limits at each frequency. Likewise, if one standard requires a vertical antenna sweep with boresighting and another does not, swept motion with boresighting will typically be used as it is the more stringent requirement.

6.4 Laboratory Accreditation

The Garmin Compliance Lab, an organization within Garmin International, is registered with the US Federal Communication Commission as US1311. The lab is recognized by the Canada Department of Innovation, Science, and Economic Development (ISED) under CAB identifier US0233.

The Garmin Compliance Lab, an organization within Garmin International, is accredited by A2LA, Certificate No. 6162.01. The presence of the A2LA logo on the cover of this report indicates this is an accredited ISO/IEC 17025 test report. If the logo is absent, this report is not issued as an accredited report. Other marks and symbols adjacent to the A2LA logo are accreditation co-operations of which A2LA is a member under a mutual recognition agreement, and to which the Garmin Compliance Lab has been sublicensed.

7 Measurement Instrumentation Uncertainty

The lab has analyzed the sources of measurement instrumentation uncertainty. The analysis concludes that the actual measurement values cited in this report are accurate within the U_{LAB} intervals shown below with approximately 95% statistical confidence. Where the report shows a judgment that a test sample passes a test against a published limit based on these measured values, that judgment has a statistical confidence of 97.5% or greater. Measurement Instrumentation Uncertainty is one component of over-all measurement uncertainty, and other uncertainty components are not considered as part of this analysis.

The primary benchmark for measurement instrumentation uncertainty (MIU) in an electromagnetic compatibility (EMC) test lab is the set of U_{CISPR} values published in CISPR 16-4-2. In all cases where a U_{CISPR} value is published by CISPR, the analysis shows that U_{LAB} – this lab's estimated MIU – is better than the U_{CISPR} benchmark.

The secondary benchmark for MIU in an EMC lab performing radio transceiver tests is a set of uncertainty limit values published in various ETSI standards. In this report, U_{ETSI} is the most restrictive of the values found in the ETSI EN standards listed in section 5 of this report. The analysis principles are described in the ETSI TR documents listed there. In most cases U_{LAB} is better than the U_{ETSI} benchmark. Where U_{LAB} exceeds the U_{ETSI} benchmark cited here, that entry is preceded by an asterisk. When required by the ETSI EN standards, excess uncertainty will be added to the measurand before comparison to a limit. In an individual test report, staff may re-evaluate that excess uncertainty based on the uncertainty of the method used and the uncertainty limits of the actual ETSI EN standard being applied, and the revised uncertainty values will be shown in the test report.

Some measurement uncertainties analyzed and reported here are not addressed in CISPR 16-4-2 or the ETSI standards, as indicated by the entry 'None.'

Test Type		**U_{LAB}**	**U_{CISPR}**	**U_{ETSI}**
Conducted DC voltage		0.09% + 2 x LSDPV	None	1%
Conducted AC voltage below 500 Hz		1.0% + 3 x LSDPV	None	2%
Conducted Emissions, Mains Voltage		0.10% + 10 mV	None	None
Conducted Emissions, Mains Current		0.10% + 3 mA	None	None
Conducted Emissions, Mains Power		0.15% + 100 mW	None	None
Conducted Emissions, Power Mains, 9 kHz to 150 kHz		1.49 dB	3.8 dB	None
Conducted Emissions, Power Mains, 150 kHz to 30 MHz		1.40 dB	3.4 dB	None
Conducted Emissions, Cat 6 LCL, 150 kHz to 30 MHz		2.80dB	5 dB	None
Conducted Emissions, Cat 5 LCL, 150 kHz to 30 MHz		3.21 dB	5 dB	None
Conducted Emissions, Cat 3 LCL, 150 kHz to 30 MHz		4.24 dB	5 dB	None
Radiated Emissions, below 30 MHz		0.88 dB	None	6 dB
Radiated Emissions, 30 MHz to 1000 MHz		2.77 dB	6.3 dB	6 dB
Radiated Emissions, 1 GHz to 18 GHz		2.60 dB	5.2 & 5.5 dB	6 dB
Radiated Emissions, 18 GHz to 26.5 GHz		2.73 dB	None	6 dB
*Radio Signal Frequency Accuracy		*1.55 x 10^-7	None	1.0 x 10^-7
Radio Signal Occupied Bandwidth		0.95%	None	5%
Radio Power or Power Spectral Density		0.98 dB	None	1 dB
Temperature		0.38 °C	None	1 °C
Barometric Pressure		0.38 kPA	None	None
Relative Humidity		2.85% RH	None	±5% RH
Signal Timing	The greater of these three...	0.63 usec 0.01% of value 0.5 x LSDPV	None	None

Note: *LSDPV stands for the Least Significant Digit Place Value reported. In the value 1470 msec, the least significant digit is the 7. It has a 10 msec place value. The LSDPV is thus 10 msec and the maximum error due to roundoff would be 5 msec. If the time value were reported as 147<u>0</u> msec, the underscore indicates that the 0 is a significant figure and the error due to roundoff would be 0.5 msec. All digits provided to the right of a decimal point radix are significant.*

8 Selected Example Calculations

Certain regulators require samples of the calculations that lead from the raw measurement to the final result for AC Mains conducted and unintended radiated emissions. The assumption is that the lab performs raw measurements, then adds, subtracts, multiplies, or divides based on transducer factors, amplifier gains, and losses in the signal transmission path. In this lab, our CISPR 16 Receiver does not work that way. The calibration factors and losses and gains are provided to the receiver as detailed data files. These factors are applied in the RF measurement path prior to the detector. But as a step in the lab measurement process, staff frequently verify that these factors are applied correctly. They make a measurement with the factors applied inside the receiver, then they disable the factors and remeasure the result manually adding in the various relevant factors.

The transmission loss is measured including the combined losses and gains of preamplifiers, cables, and any band-selective filters. In many cases above 1 GHz it is a negative value, indicating that the preamplifier gain is greater than these other losses.

Here are examples of these calculations. The data in these examples was not taken as part of this project:

8.1 AC Mains conducted emissions at 22 MHz

(Raw measurement) + (AMN factor) + (transmission loss) = Result

(7.145 dBuV) + (9.812 dB) + (0.216 dB) = 17.173 dBuV

8.2 Radiated Emissions at 630 MHz

(Raw measurement) + (Antenna factor) + (transmission loss) = Result

(2.25 dBuV) + (27.80 dB/m) + (2.89 dB) = 32.94 dBuV/m

8.3 Radiated Emissions at 2.7 GHz

(Raw measurement) + (Antenna factor) + (transmission loss) = Result

(43.72 dBuV) + (32.22 dB/m) + (-36.09 dB) = 39.85 dBuV/m

9 Environmental Conditions During Test

Environmental conditions in the test lab were monitored during the test period. Temperature and humidity are controlled by an air handling system. As information to the reader, the conditions were observed at the values or within the ranges noted below. For any tests where environmental conditions are critical to test results and require further constraints or details, the test records in the annex may provide more specific information.

Temperature:	20.5 to 24.8 °C
Relative Humidity:	19.9% to 55.7% (non-condensing)
Barometric Pressure	96.3 to 99.5 kPa

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
Barometer	Traceable	6453	221702700	3-Aug-2022	1-Aug-2024

Table 4: Environmental monitoring device

10 Immunity Performance Criteria

If this report includes immunity tests then results have been categorized as Performance Criteria A, B, C, or D. The standards that the lab applied will define the details for A, B, and C, as well as which criterion is required for each type of test. They will also define the electrical stresses that were applied during each test. In a very general sense the observed criteria noted in this report are as follows:

Criterion A. The stress applied did not alter product operation. This criterion is generally used for 'continuous' stresses that can be present for a long time in the places the product will be used, or that can appear often, even though they may come and go over time.

Criterion B. The stress applied altered product operation, but the product self-recovered so that the user would not have to try to figure out how to restore it to full operation. This criterion is generally used for 'transient' stresses that appear briefly and occasionally, but are usually not present in the places the product will be used.

Criterion C. The stress applied altered product operation, but the user could restore it to full operation, for example by power cycling the product. This criterion is generally used for 'transient' stresses that appear briefly and only rarely in the places the product will be used.

Criterion D. This is not an official criterion in the standards, because it would be a failure of the requirements. This indication in a test record means the product was affected in a way that the user might not be able to correct. The effect could include some degree of hardware damage, or it could include loss of program files or data files necessary for operation.

Repeatability is an issue in all EMC immunity work. When the product operation changes unexpectedly during a test, and the change would fail the requirements of the standard, this is an anomaly. The test operator needs to determine whether the anomaly was a result of the applied electrical stress. The investigation is done by repeating the section of the test where the anomaly occurred three times. If the same or a similar anomaly occurs in any of the three repeat trials, it is confirmed as a response to the stress. If not, the anomaly is judged unreproducible and is not considered when judging the A, B, or C observed performance. Since there is usually no ability to confirm a Criterion D anomaly, these are usually treated as Criterion D upon a single occurrence.

Tests that require Criterion B performance will be judged to Pass if criteria A or B is observed. Similarly, tests that require Criterion C performance will be judged to Pass if criteria A, B, or C is observed.

ANNEX

The remainder of this report is an Annex containing individual test data records. These records are the basis for the judgments summarized in section 1 of this report. The Annex ends with a set of concluding notes regarding use of the report.

Test Record
Radiated Emission Test RE03
Project GCL0296

Test Date(s)	7 Nov 2023
Test Personnel	David Kerr
Product Model	A03996
Serial Number tested	443220641
Operating Mode	M3 (AntT)
Arrangement	A1 (Standalone)
Input Power	Battery 5 Vdc
Test Standards:	FCC Part 15, ANSI C63.10 (as noted in Section 6 of the report)
Frequency Range:	Restricted Bands (2200-2300 MHz, 2310-2390 MHz, 2483.5-2500 MHz)
Pass/Fail Judgment:	**PASS**
Test record created by:	**Aditya Prakash**
Date of this record:	**7 Nov 2023**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 26 GHz	Keysight	N9048B	MY59290135	27-Sep-2023	1-Oct-2024
Antenna, Horn, 1-18 GHz	ETS Lindgren	3117	259208	7-Jun-2023	1-Jun-2024
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	16-Nov-2022	16-Nov-2025
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10720	16-Jan-2023	15-Jan-2026
Preamplifier, 500 MHz 18 GHz	Com-Power	PAM-118A	18040133	Calibration	Not Required
Wifi Filter	K&L	8NSL26-2437/E82.2-0/0	1	Calibration	Not Required

Table RE03.1: Test Equipment Used

Software Used
N9048B Keysight PXE firmware version A.33.03
RE Signal Maximization Tool v2023Jul14.xlsx
FCC Restricted Band 2p4GHz Template v1b 2023Jun20.xlsx

Test Data

This restricted band investigation began with a benchtop setup wherein the emissions in the restricted bands were observed from a modified test sample with an RF output cable replacing the onboard antenna. The actual emission levels within restricted bands in many of the test sample's available transmission modes are too low to be reliably measured in the radiated environment. By applying the required peak and average detectors and bandwidths to the signals direct from the transmitter, lab staff identified the worst-case operational modes. These were then measured using an unmodified unit in the required radiated environment.

The radiated emission test began with a preliminary scan in each restricted band at multiple turntable angles, antenna heights, and both antenna polarizations. For test standards that require reorienting the test sample, further preliminary scans were taken in those alternate orientations typically described as X, Y, and Z. Subsequent testing was done using on the orientation(s) producing the highest result relative to the test limit. Final field strength measurements were taken in that set of positions.

Restricted band measurements in the lower and upper bands were made while the transmitter was tuned to its only allowed frequency of 2460 MHz.

At azimuth angle 0° the 'front' reference mark of the turntable is pointed Southward. At 90° the reference mark points West. At -90° it points East. At -7° the turntable reference mark is pointed directly at the antenna. The designation of the X, Y, and Z orientations of the test sample are sample dependent, so these are reported by use of photographs.

The tables show the selected final measurement data between the FCC restricted bands. It includes a the strongest emissions observed relative to the test limit, along with other data points of interest. Where a data point is highlighted is yellow, this is an aid to indicate the data point(s) with the least margin to the test limit. A positive margin value indicates that the emission was below the test limit. The test limit is the FCC restricted band Class B Limit at 3m.

Frequency	Avg Limit	Pk Limit	Avg Level	Pk Level	Av Margin	Pk Margin	Azimuth	Height	Polarity
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	---
2332	54	74	46.208	56.505	7.792	17.495	74	2518	HORZ

Table RE03.2: FCC restricted bands from 2200 to 2390 MHz

Frequency	Avg Limit	Pk Limit	Avg Level	Pk Level	Av Margin	Pk Margin	Azimuth	Height	Polarity
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	---
2483.5	54	74	37.695	56.721	16.305	17.279	82	2266	HORZ

Table RE03.3: FCC restricted band from 2483.5 to 2500 MHz

The graphs below show the background spectrum observed during pre-scan, as well as the final data points from the table above.

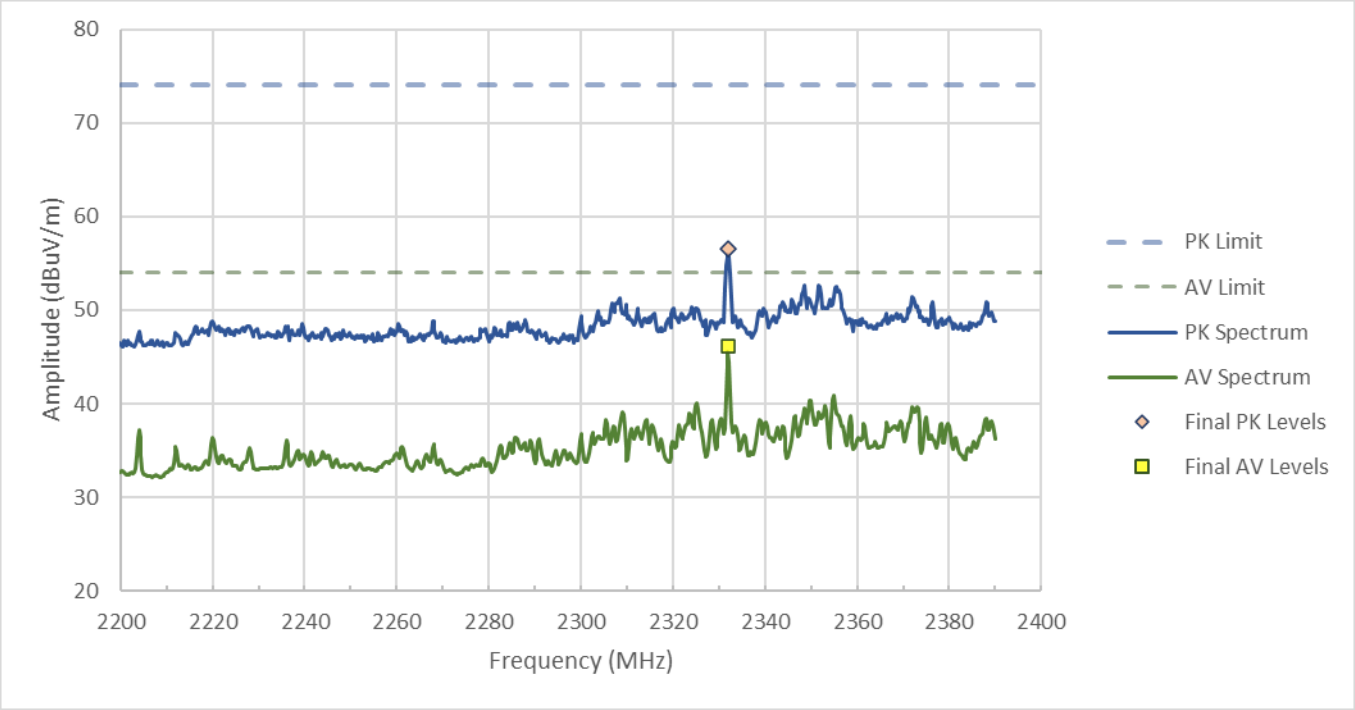


Figure RE03.1: FCC restricted band spectral data from 2200 to 2390 MHz

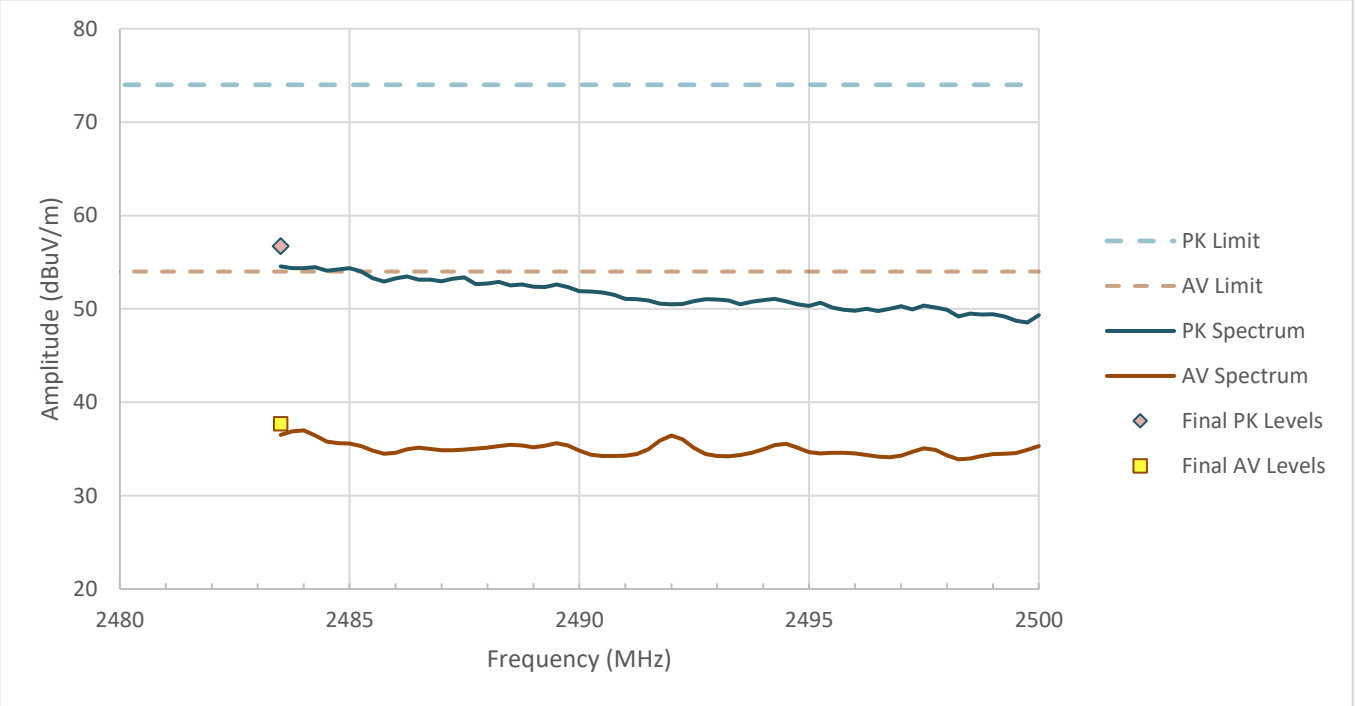


Figure RE03.2: FCC restricted band spectral data from 2483.5 to 2500 MHz

Setup Photographs

The following photographs show the EUT configured and arranged in the manner in which it was measured.

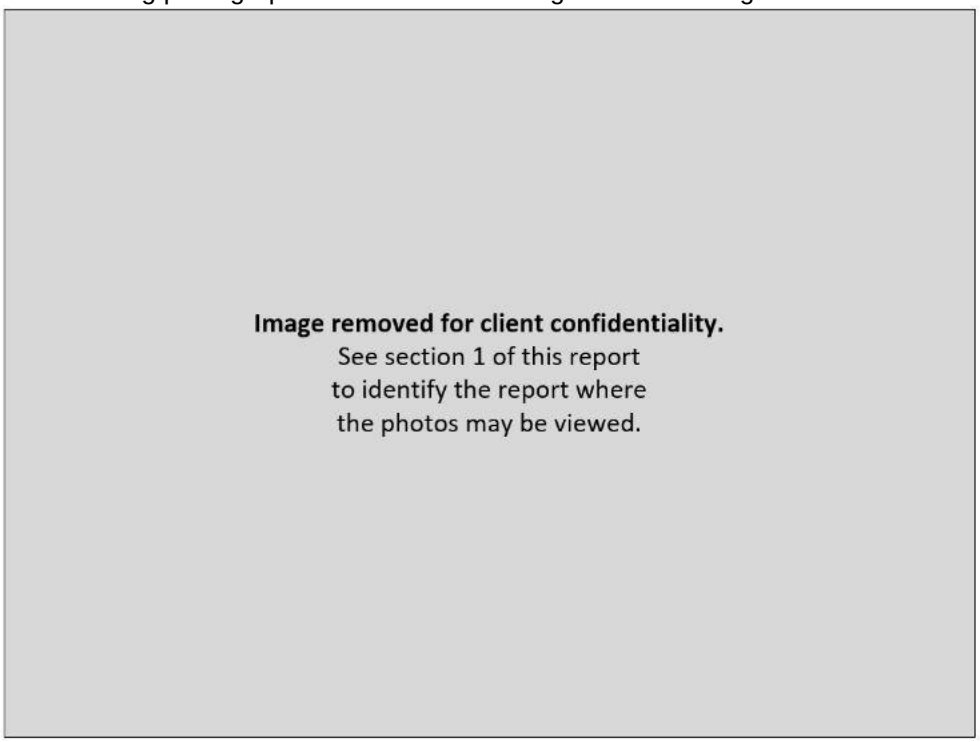


Figure RE03.3: EUT test setup, primary view

Figure RE03.3: EUT test setup, reverse view

This line is the end of the test record.

Test Record
Radiated Emission Test RE13
Project GCL0296

Test Date(s)	28 Nov 2023
Test Personnel	David Kerr
Product Model	A03996
Serial Number tested	443220641
Operating Mode	M3 (AntT)
Arrangement	A1 (Standalone)
Input Power	Battery 5 Vdc
Test Standards:	FCC 15.249, (as noted in Section 6 of the report).
Frequency Range:	30 MHz to 1000 MHz
Pass/Fail Judgment:	**Pass**
Test record created by:	**David A Kerr**
Date of this record:	**28 Nov 2023**

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 26 GHz	Keysight	N9048B	MY59290135	27-Sep-2023	1-Oct-2024
Antenna, Biconilog, 30M-6 GHz	ETS Lindgren	3142E	233204	7-Nov-2023	1-Nov-2025
SAC 3m, below 1 GHz	Frankonia	SAC3	F199004	7-Nov-2022	7-Nov-2025
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10720	16-Jan-2023	15-Jan-2026

Table RE13.1: Test Equipment Used

Software Used: Keysight PXE software A.32.06, EPX test software Version 2023.01.001

Test Data

The radiated emission test process began with a preliminary scan at multiple turntable angles, antenna heights, and both antenna polarizations. For test standards that require reorienting the test sample, further preliminary scans were taken in those alternate orientations typically described as X, Y, and Z. Subsequent testing was done using on the orientation(s) producing the highest result relative to the test limit. Where the test standard requires cable manipulation, this was done at one of more likely worst case frequencies selected by the test personnel while observing the receiver display. At each of the frequencies selected for final measurements, the turntable angle, antenna height, and antenna polarization were explored to find the worst-case settings. Final field strength measurements were taken in that set of positions. Full maximization was not performed at frequencies that are noise floor measurements included per the test standard requirements.

At azimuth angle 180° the 'front' reference mark of the turntable is pointed Southward. At 270° the reference mark points West. At 90° it points East. At 173° the turntable reference mark is pointed directly at the antenna. The designation of the X, Y, 4nd Z orientations of the test sample are sample dependent, so these are reported by use of photographs.

The table shows the selected final measurement data between 30 MHz and 1 GHz. It includes at least the six strongest emissions observed relative to the test limit, along with other data points of interest. Where a data point is highlighted is yellow, this is an aid to indicate the data point(s) with the least margin to the test limit. A positive margin value indicates that the emission was below the test limit. The test limit is the FCC Class B Limit at 3m

Frequency	Pol.	Reading	Factor	Level	Limit	Margin	Height	Angle
MHz		dB(µV)	dB(1/m)	dB(µV/m)	dB(µV/m)	dB	cm	deg
		QP		QP	QP	QP		
293.370	H	16.1	21.5	37.6	46.0	8.4	100.0	109.0
201.600	H	6.2	18.9	25.1	40.0	14.9	145.2	227.0
705.600	V	4.0	33.4	37.4	46.0	8.6	143.4	179.0
504.000	V	6.0	28.8	34.8	46.0	11.2	100.0	122.0
428.220	V	4.9	26.9	31.8	46.0	14.2	118.0	214.0
765.000	V	0.1	33.6	33.7	46.0	12.3	375.5	216.0

Table RE13.2: Emission summary (ANT Ch 60 GFSK)

The graph below shows the background spectrum observed during pre-scan, as well as the final data points from the table above.

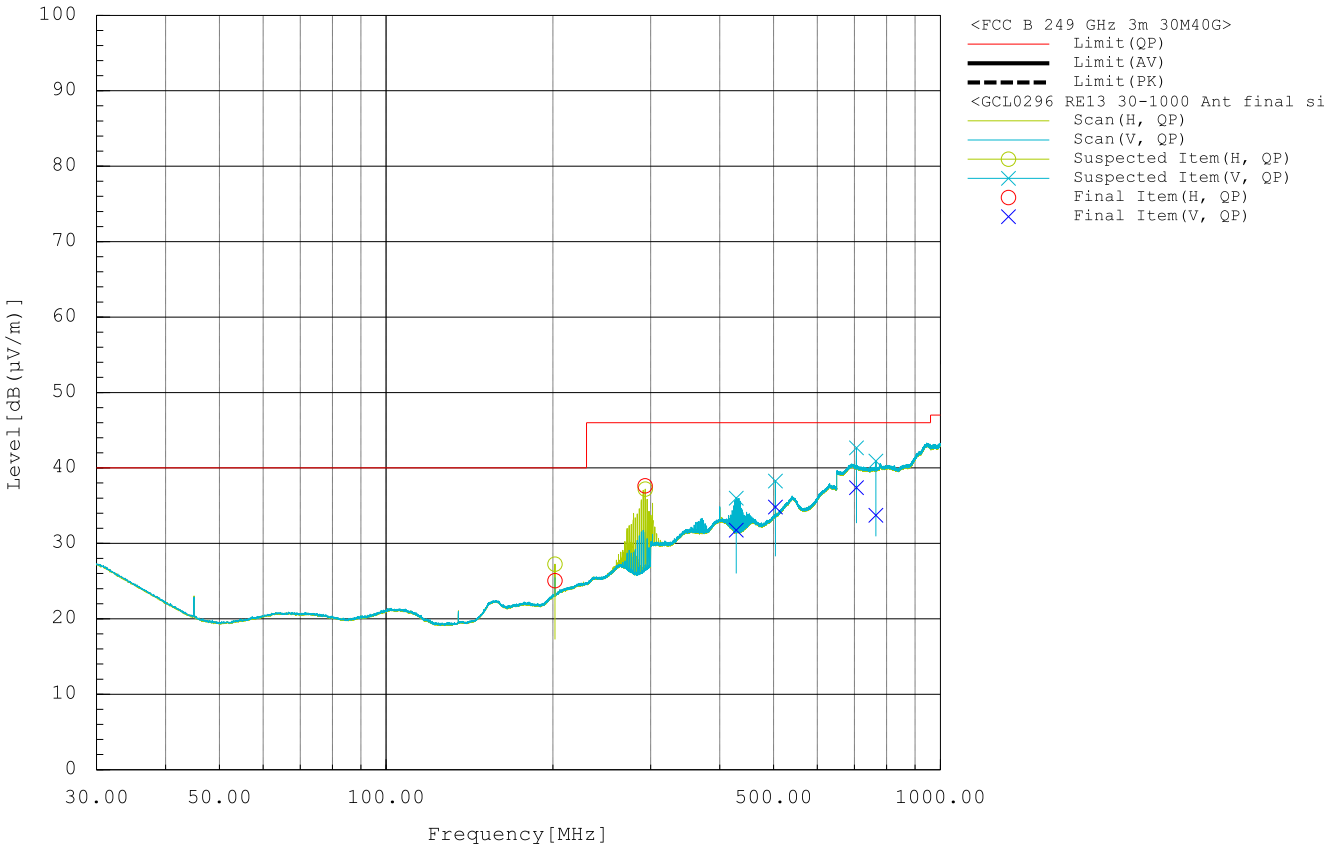


Figure RE13.1: Spectral data (Ant ch 60 GFSK)

Setup Photographs
The following photographs show the EUT configured and arranged in the manner in which it was measured.

Figure RE13.2: EUT test setup, front view

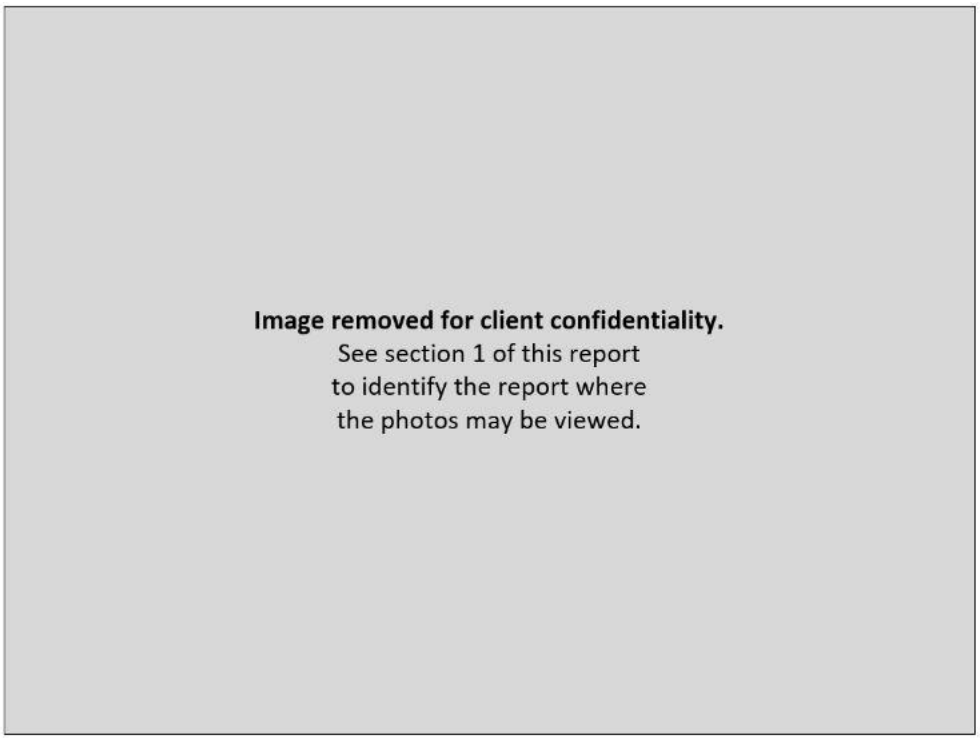


Figure RE13.3: EUT test setup, reverse view

This line is the end of the test record.

Test Record
Radiated Emission Test RE14
Project GCL0296

Test Date(s)	01 Nov 2023
Test Personnel	David Kerr
Product Model	A03996
Serial Number tested	4433220641
Operating Mode	M3 (AntT)
Arrangement	A1 (Standalone)
Input Power	Battery 5 Vdc
Test Standards:	FCC Part 15, ANSI C63.10 (as noted in Section 6 of the report).
Frequency Range:	1 GHz to 18 GHz
Pass/Fail Judgment:	**PASS**
Test record created by:	**David A Kerr**
Date of this record:	**01 Nov 2023**

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 26 GHz	Keysight	N9048B	MY59290135	27-Sep-2023	1-Oct-2024
Antenna, Horn, 1-18 GHz	ETS Lindgren	3117	259208	7-Jun-2023	1-Jun-2024
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	16-Nov-2022	16-Nov-2025
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10720	16-Jan-2023	15-Jan-2026
Preamplifier, 500 MHz 18 GHz	Com-Power	PAM-118A	18040133	Calibration	Not Required
Wifi Filter	K&L	8NSL26-2437/E82.2-0/0	1	Calibration	Not Required
GPS Filter	K&L	WSN-00445	7	Calibration	Not Required

Table RE14.1: Test Equipment Used

Software Used: Keysight PXE software A.33.03, EPX test software Version 2023.01.001

Test Data

The radiated emission test process began with a preliminary scan at multiple turntable angles, antenna heights, and both antenna polarizations. For test standards that require reorienting the test sample, further preliminary scans were taken in those alternate orientations typically described as X, Y, and Z. Subsequent testing was done using on the orientation(s) producing the highest result relative to the test limit. Where the test standard requires cable manipulation, this was done at one of more likely worst case frequencies selected by the test personnel while observing the receiver display. At each of the frequencies selected for final measurements, the turntable angle, antenna height, and antenna polarization were explored to find the worst-case settings. Final field strength measurements were taken in that set of positions. Full maximization was not performed at frequencies that are noise floor measurements included per the test standard requirements.

In the 6 GHz to 18 GHz frequency range, pre-scan spectral data was taken at 1 meter and extrapolated to a 3 meter distance. Final measurements were made at 3 meters.

At azimuth angle 180° the 'front' reference mark of the turntable is pointed Southward. At 270° the reference mark points West. At 90° it points East. At 173° the turntable reference mark is pointed directly at the antenna. The

designation of the X, Y, and Z orientations of the test sample are sample dependent, so these are reported by use of photographs.

The table shows the selected final measurement data between 1 GHz and 18 GHz. It includes at least the six strongest emissions observed relative to the test limit, along with other data points of interest. Where a data point is highlighted is yellow, this is an aid to indicate the data point(s) with the least margin to the test limit. A positive margin value indicates that the emission was below the test limit. The test limit is FCC Class B Limit at 3m.

Frequency	Pol.	Reading		Factor	Level		Limit		Margin		Height	Angle
MHz		dB(µV)		dB(1/m)	dB(µV/m)		dB(µV/m)		dB		cm	deg
		CAV	PK		CAV	PK	AV	PK	CAV	PK		
2460.000	H	103.1	104.1	-1.4	101.7	102.7	94.0	114.0	-7.7	11.3	285.5	265.0
2460.000	H	103.5	104.4	-1.4	102.1	103.0	94.0	114.0	-8.1	11.0	287.9	269.0
2588.000	H	46.7	56.5	-1.2	45.5	55.3	54.0	74.0	8.5	18.7	105.6	254.0

Table RE14.2: Emission summary (1 - 3.2 GHz)

Frequency	Pol.	Reading		Factor	Level		Limit		Margin		Height	Angle
MHz		dB(µV)		dB(1/m)	dB(µV/m)		dB(µV/m)		dB		cm	deg
		CAV	PK		CAV	PK	AV	PK	CAV	PK		
5896.000	V	33.2	50.5	9.2	42.4	59.7	54.0	74.0	11.6	14.3	224.7	45.0
4099.750	H	34.0	50.5	4.4	38.4	54.9	54.0	74.0	15.6	19.1	118.2	207.0
5991.000	H	32.8	50.0	10.0	42.8	60.0	54.0	74.0	11.2	14.0	100.0	299.0

Table RE14.3: Emission summary (3.2 – 6 GHz)

Frequency	Pol.	Reading		Factor	Level		Limit		Margin		Height	Angle
MHz		dB(µV)		dB(1/m)	dB(µV/m)		dB(µV/m)		dB		cm	deg
		CAV	PK		CAV	PK	AV	PK	CAV	PK		
17071.500	V	25.7	40.9	25.4	51.1	66.3	54.0	74.0	2.9	7.7	268.0	226.0
9843.500	H	28.3	42.8	15.2	43.5	58.0	54.0	74.0	10.5	16.0	148.3	119.0
11225.500	H	27.1	40.6	18.9	46.0	59.5	54.0	74.0	8.0	14.5	292.5	12.0
17071.500	H	25.7	40.7	25.4	51.1	66.1	54.0	74.0	2.9	7.9	311.9	43.0

Table RE14.4: Emission summary (6 – 18 GHz)

The graph below shows the background spectrum observed during pre-scan, as well as the final data points from the table above.

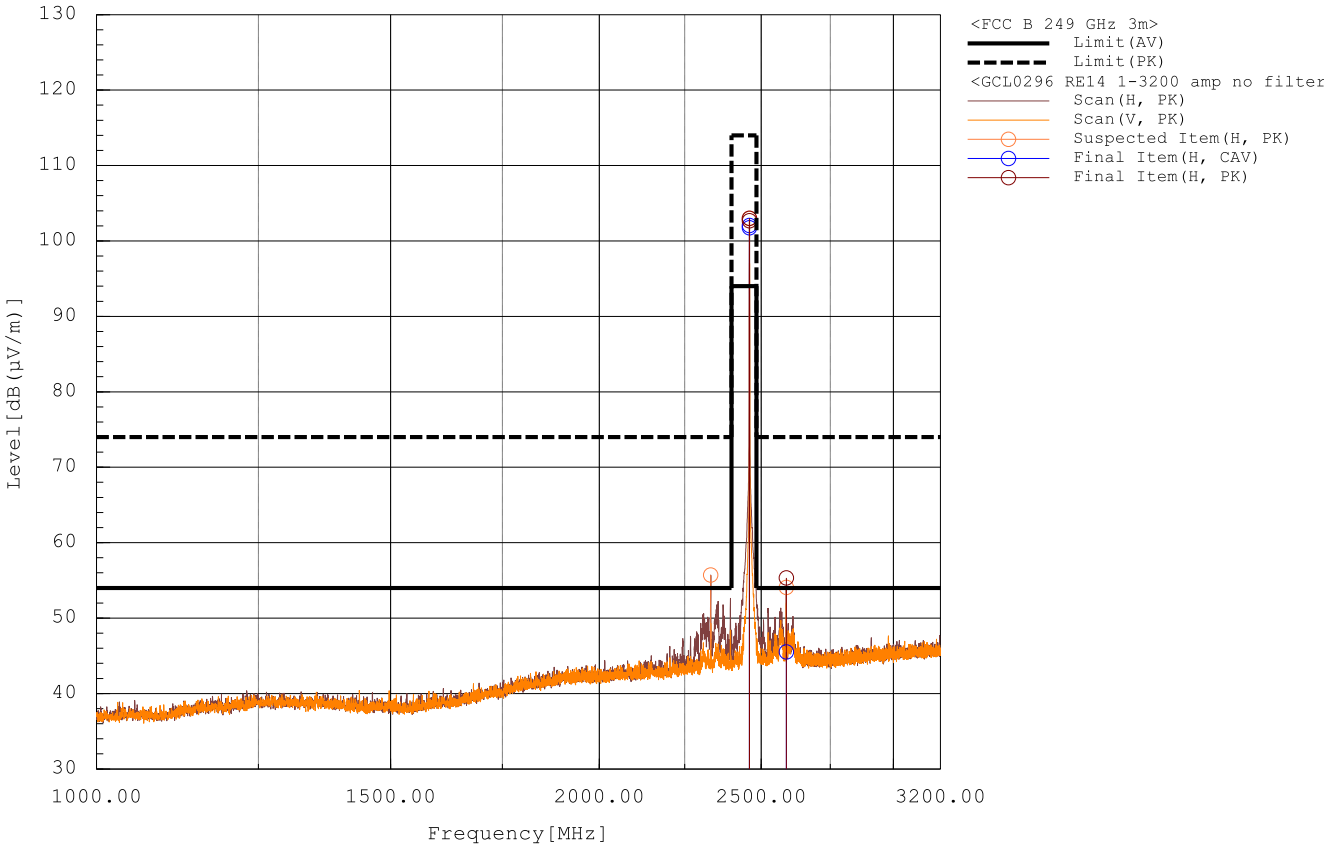


Figure RE14.1: Spectral data (1 - 3.2 GHz)

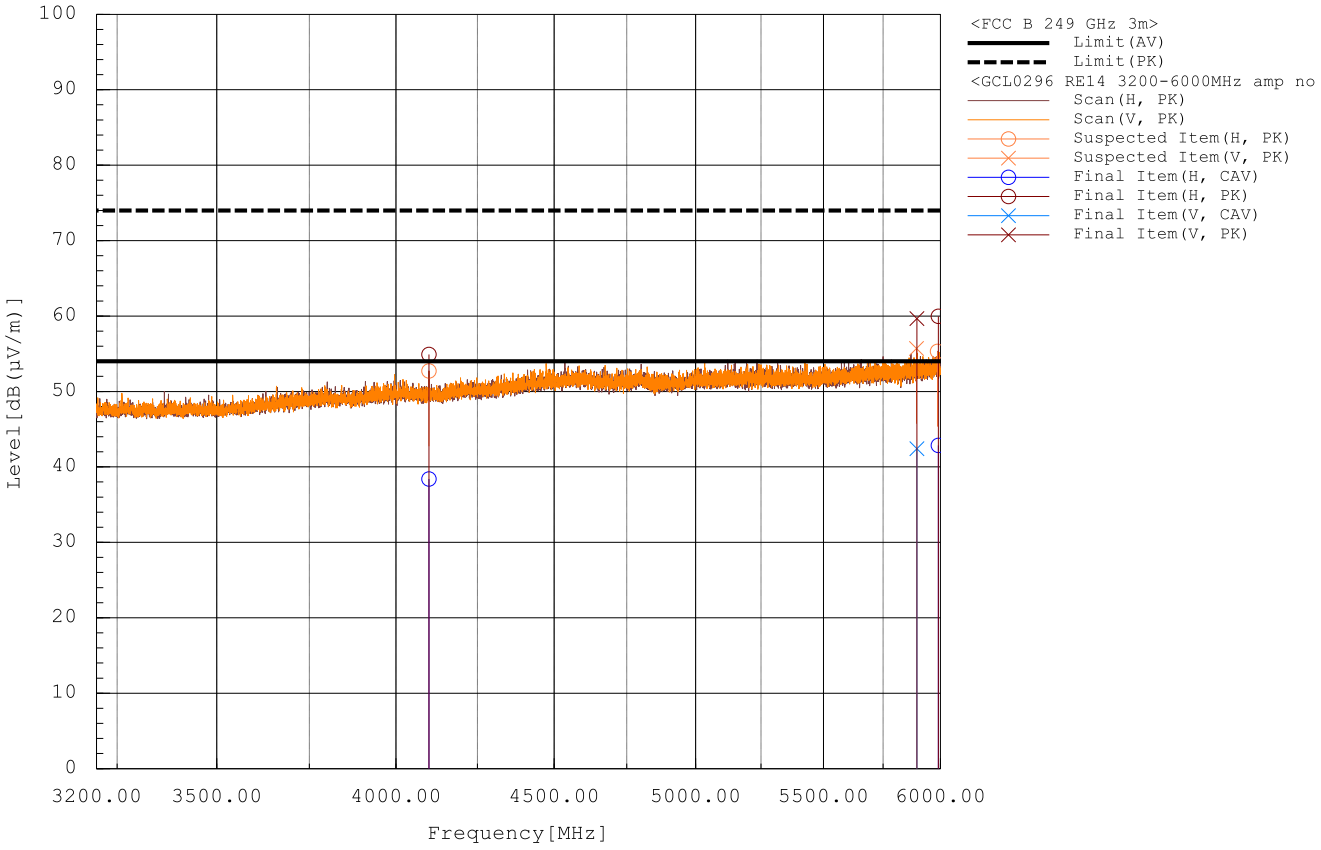


Figure RE14.2: Spectral data (3.2 – 6 GHz)

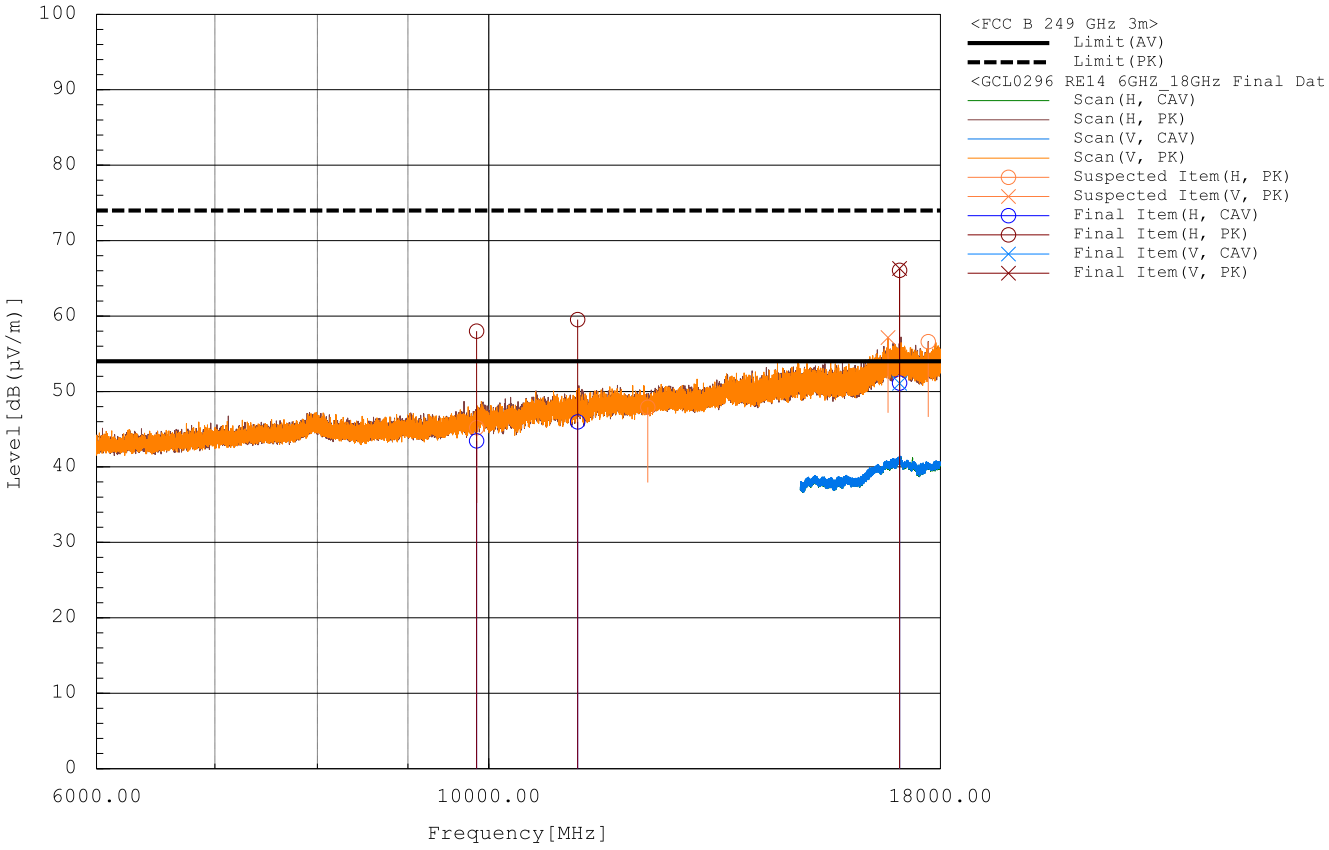


Figure RE14.3: Spectral data (6 to 18 GHz)

Setup Photographs
The following photographs show the EUT configured and arranged in the manner in which it was measured.

Figure RE14.4 EUT test setup, front view

Figure RE14.5: EUT test setup, reverse view

This line is the end of the test record.

Test Record
Radiated Emission Test RE15
Project GCL0296

Test Date(s)	16 Nov 2023
Test Personnel	Jim Solum
Product Model	A03996
Serial Number tested	443220641
Operating Mode	M3 (AntT)
Arrangement	A1 (Satndalone)
Input Power	Internal battery
Test Standards:	FCC Part 15, ANSI C63.4 (as noted in Section 6 of the report).
Frequency Range:	18 GHz to 26 GHz
Pass/Fail Judgment:	**PASS**
Test record created by:	**Aditya Prakash**
Date of this record:	**17 Nov 2023**

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
Antenna, Horn, 10-40 GHz	ETS Lindgren	3116C	00259186	23-Mar-2023	1-Apr-2024
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	16-Nov-2022	16-Nov-2025
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10720	16-Jan-2023	15-Jan-2026
Preamplifier, 18 Ghz to 40 Ghz	Com-Power	PAM-840A	461364	Calibration	Not Required
PXE Receiver 44GHz	Keysight	N9048B	MY62220146	3-Jun-2023	3-Jun-2024

Table RE15.1: Test Equipment Used

Software Used: Keysight PXE software A.35.06
RE Signal Maximization Tool v2023Jul14.xlsx
RE 18G to 26G 1 meter Data AnalysisV1 2022Oct12.xlsx

Test Data

The radiated emission test process began with a preliminary scan at multiple turntable angles, antenna heights, and both antenna polarizations. For test standards that require reorienting the test sample, further preliminary scans were taken in those alternate orientations typically described as X, Y, and Z. Subsequent testing was done using on the orientation(s) producing the highest result relative to the test limit. Where the test standard requires cable manipulation, this was done at one of more likely worst case frequencies selected by the test personnel while observing the receiver display. At each of the frequencies selected for final measurements, the turntable angle, antenna height, and antenna polarization were explored to find the worst-case settings. Final field strength measurements were taken in that set of positions. Full maximization was not performed at frequencies that are noise floor measurements included per the test standard requirements.

In the 18 GHz to 26.5 GHz frequency range, pre-scan spectral data was taken at 1 meter and extrapolated to a 3 meter distance. Final measurements were made at 3 meters.

At azimuth angle 0° the 'front' reference mark of the turntable is pointed Southward. At 90° the reference mark points West. At -90° it points East. At -7° the turntable reference mark is pointed directly at the antenna. The designation of the X, Y, and Z orientations of the test sample are sample dependent, so these are reported by use of photographs.

The table shows the selected final measurement data between 18 GHz and 26 GHz. It includes at least the six strongest emissions observed relative to the test limit, along with other data points of interest. Where a data point is highlighted is yellow, this is an aid to indicate the data point(s) with the least margin to the test limit. A positive margin value indicates that the emission was below the test limit. The test limit is the Composite FCC Class B Limit at 3m. Any unintentional radio emission limits are not applied to intentional radio signals.

Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Antenna Polarity
19680.000	54.00	74.00	45.00	58.20	9.00	15.80	0	1500	HORZ
22140.000	54.00	74.00	44.90	58.90	9.10	15.10	0	1500	HORZ
24600.000	54.00	74.00	45.20	58.30	8.80	15.70	0	1500	HORZ

Table RE15.2: Emission summary

The graph below shows the background spectrum observed during pre-scan, as well as the final data points from the table above.

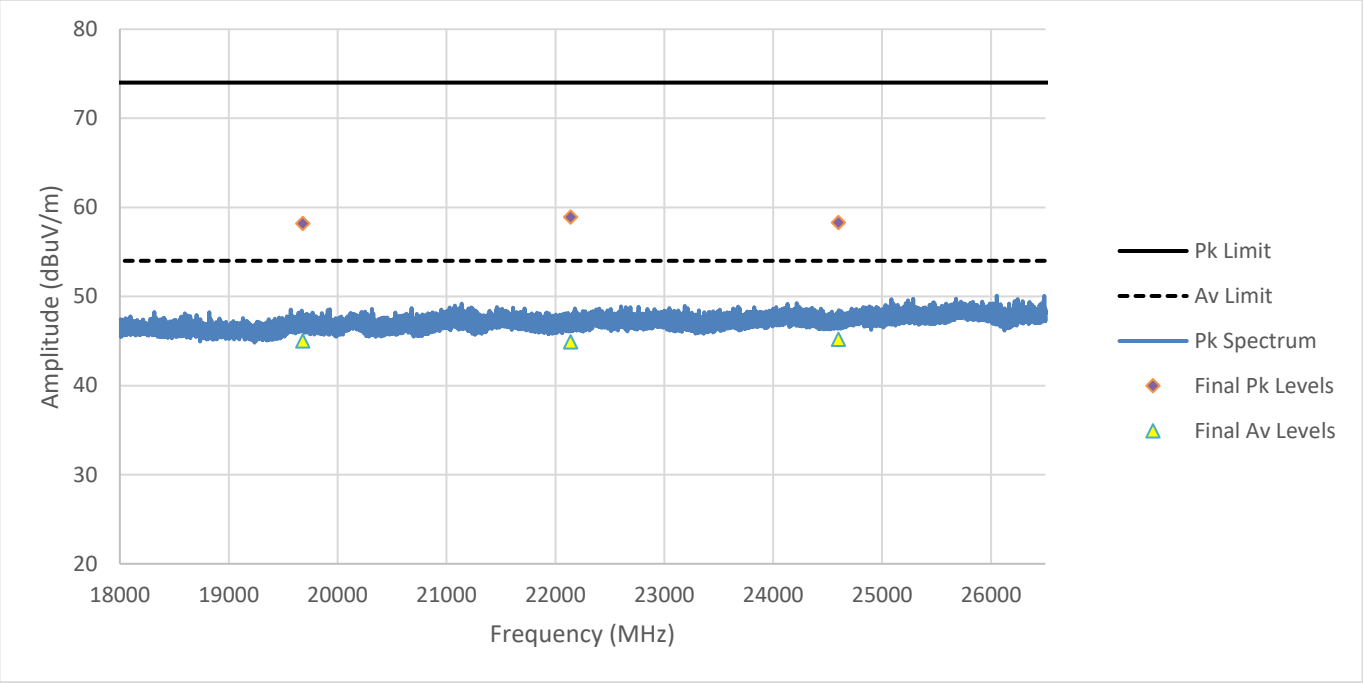


Figure RE15.1: Spectral data

Setup Photographs

The following photographs show the EUT configured and arranged in the manner in which it was measured.

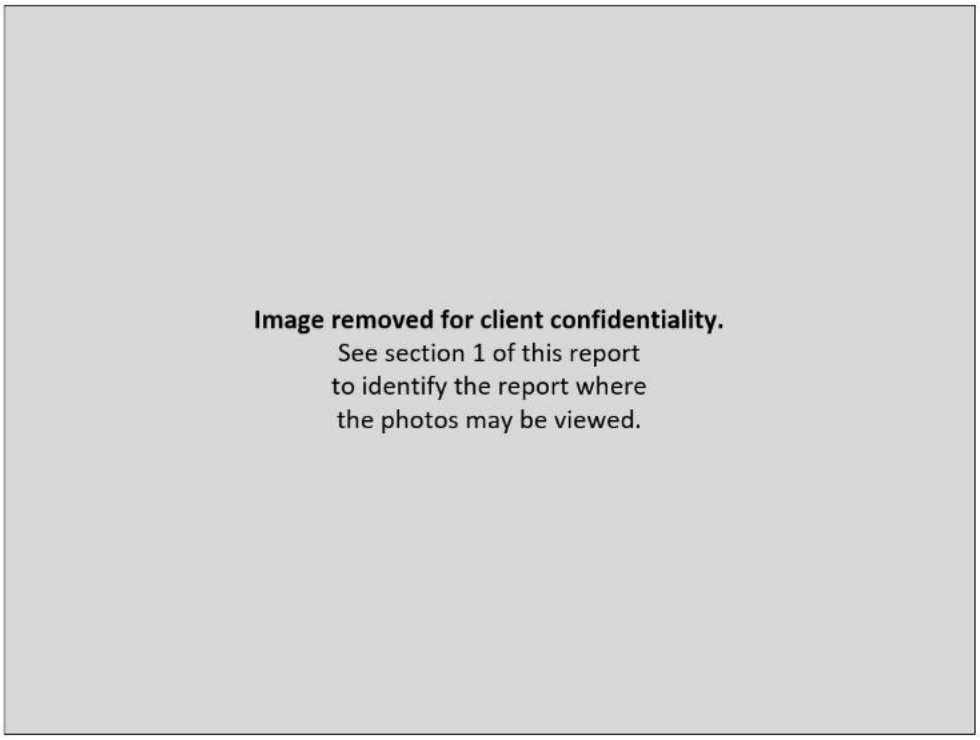


Figure RE15.2: EUT test setup, front view

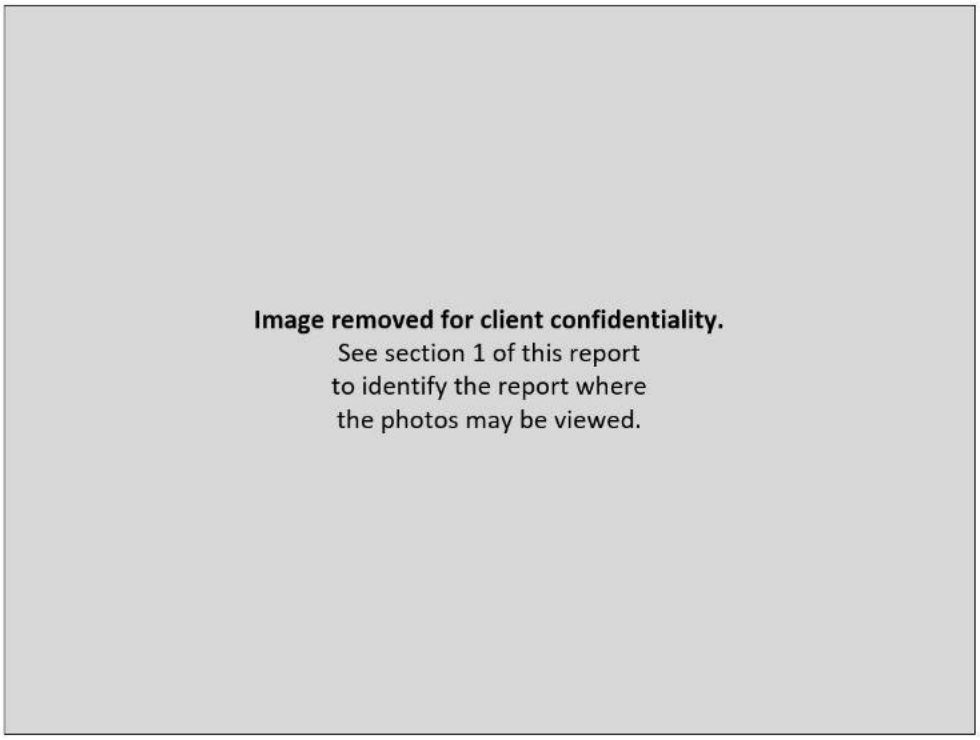


Figure RE15.3: EUT test setup, reverse view

This line is the end of the test record.

Author's note:

In following test record, TR25, Transmitter Stability in Extreme Conditions is shown for Bluetooth Low Energy (BLE). ANT only operates on channel 60 (2460 MHz) in this product, but BLE is using a wider channel set of 2402-2480 MHz. Since the EUT uses same circuitry for BLE and ANT, the lab judged that the test sample could be tested more conclusively in BLE mode. The result for BLE is firm evidence that the ANT radio also meets the stability requirement.

Test Record
Transmitter Stability in Extreme Conditions
Test IDs TR25
Project GCL-0296

Test Date(s)	05 Dec 2023
Test Personnel	Jim Solum
Product Model	A03996
Serial Number tested	443220748
Operating Mode	M1 (BleT)
Arrangement	A2 (laptop)
Nominal Input Power	5 Vdc
Test Standards:	FCC part 15, RSS-GEN, ANSI C63.10 (as noted in Section 6 of the report)
Radio Protocol	BLE (Bluetooth Low Energy)
Pass/Fail Judgment:	**PASS**
Test record created by:	**Jim Solum**
Date this record:	**12 Dec 2023**

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 44GHz	Keysight	N9048B	MY62220139	30-Jan-2023	1-Feb-2024
Thermometer	Thermco	ACCD370P	220608121	26-Aug-2022	1-Sep-2024
Barometer	Traceable	6453	221702700	3-Aug-2022	1-Aug-2024
DMM Multimeter	FLUKE	79 III	71740743	5-Apr-2023	1-Apr-2024
Programmable DC power source	Keithley	2260B-30-72 720 W	1411917	21-Apr-2023	15-Apr-2024
Thermal Chamber	Tenney	T2RC	32774-02	Calibration	Not Required

Table TR25.1: Equipment used

Software Used: PXE Software Revision A.33.03, FrequencyStabilityAnalysistemplateV1.xlsx

Test Method

The standards cited require observation of the stability for transmission frequency and/or power at certain environmental extremes. The reference is performance on nominal input voltage and a temperature of 20 °C. Where the standards cited here impose different limits or conditions, the most stringent limits and conditions have been applied.

The acceptance criterion is that the 6 dBc Occupied Bandwidth of the modulated signal should remain within the 2400-2483.5 MHz radio band.

The modes utilized include those that showed emissions closest to the band edge during prior bandwidth testing.

Test Data

The test sample(s) were subjected to extreme conditions and performed as shown below. Yellow highlights indicate the highest level for a protocol, for which an image of the spectrum is also provided. In the spectral plots, the data

sets have been combined to present the low and high channel results side by side. Orange diamond markers indicate the spectral peak, which the black square markers are at the 2400 MHz or 2483.5 MHz band edge.

Tx Mode	Temp	Volts	Low Ch.	High Ch.
Bluetooth	˚C	Vdc	dBc	dBc
BLE 1 Mbps	50	5	29.3	35.4
BLE 1 Mbps	40	5	30.8	38.6
BLE 1 Mbps	30	5	31.2	33.5
BLE 1 Mbps	20	5	29.0	32.1
BLE 1 Mbps	10	5	32.4	41.1
BLE 1 Mbps	0	5	32.3	30.8
BLE 1 Mbps	-10	5	28.0	30.4
BLE 1 Mbps	-20	5	32.7	29.1

Table TR25.2 Difference between peak and band edge levels for BLE 1 transmissions during temperature variations

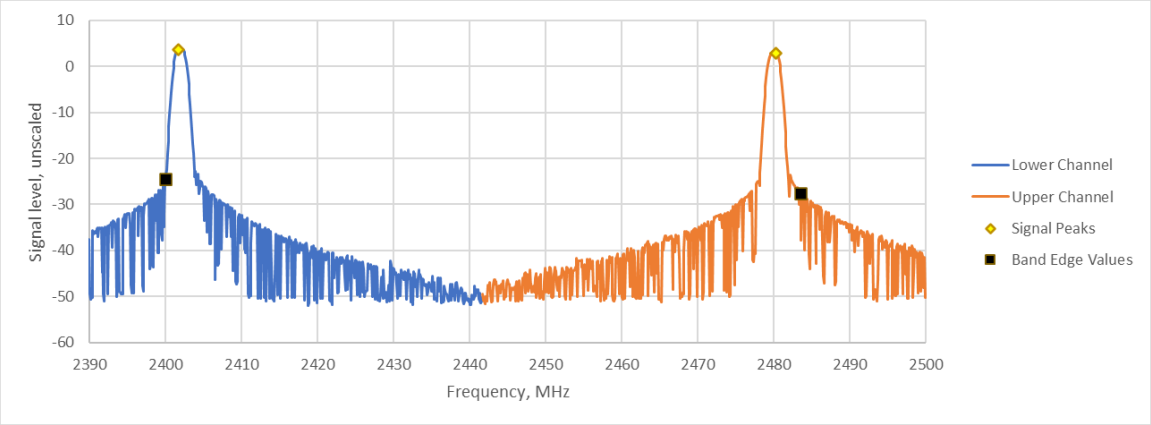


Figure TR27.1: Spectral data for BLE 1 at -10°C which represent low and high channel

Tx Mode	Temp	Volts	Low Ch.	High Ch.
Bluetooth	˚C	Vdc	dBc	dBc
BLE 1 Mbps	20	4.25	29.6	46.1
BLE 1 Mbps	20	5	29	32.1
BLE 1 Mbps	20	5.75	29.4	32.7

Table TR25.3 Difference between peak and band edge levels for BLE 1 transmissions at 20°C during voltage variations

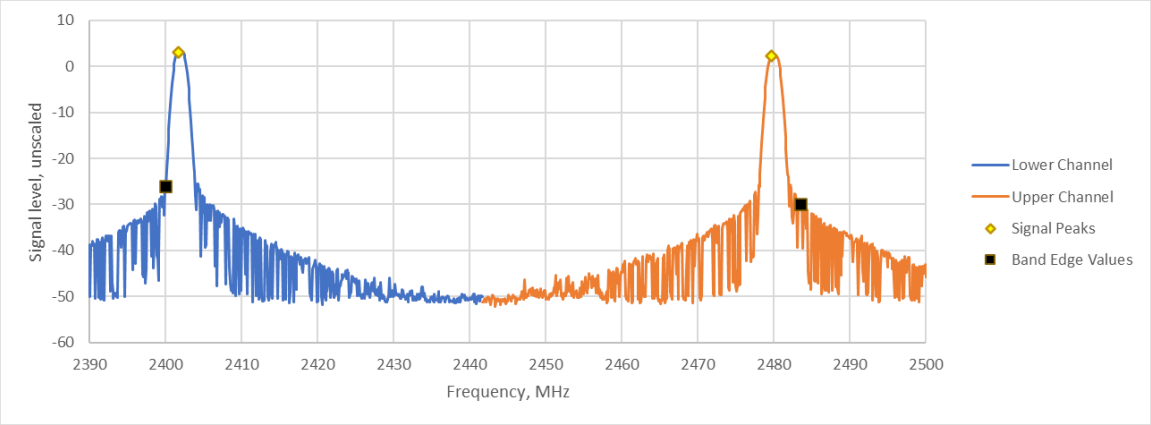


Figure TR25.2: Spectral data for BLE 1 at 20 °C and 5 Vdc which represent low and high channel

Setup Block Diagram

The following block diagrams show the EUT configured and arranged in the manner which it was measured.

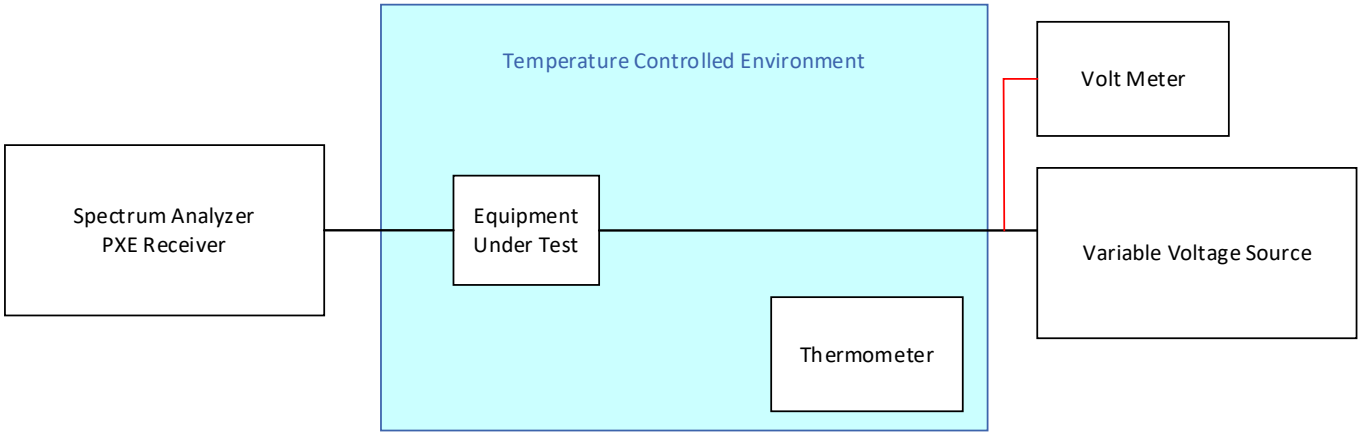


Figure TR25.3: Schematic drawing of the test equipment setup

This line is the end of the test record.

Test Record
Transmitter Bandwidth Tests
Test IDs TR03
Project GCL-0296

Test Date(s)	2-3 Nov 2023
Test Personnel	Jim Solum
Product Model	A03996
Serial Number tested	443220748
Operating Mode	M12 (All Tx on)
Arrangement	A2 (laptop)
Input Power	5Vdc
Test Standards:	FCC Part 2.202, FCC Part 15, ANSI C63.10, TRC-43, RSS-GEN (as noted in Section 6 of the report).
Radio Protocol	Bluetooth Low Energy (BLE), ANT, IEEE 802.11b/g/n
Radio Band	2400 to 2483.5 MHz

Pass/Fail Judgment: **Reported**

Test record created by: **Jim Solum**
Date of this record: **20 Nov 2023**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 44GHz	Keysight	N9048B	MY62220146	3-Jun-2023	3-Jun-2024

Table TR03.1: List of test equipment used

Test Software Used: Keysight PXE firmware A.35.06

Test Method

During this test the transmitter output is fed directly, or through RF attenuators, to the spectrum analyzer. The analyzer has a built-in capability to identify the minimum bandwidth that contains a specified portion of the total power observed, and also identify parameters such as the edge frequencies for that bandwidth and the center frequency error. The spectrum is scanned many times so that the varied effects of modulation are appropriately assessed. Since the focus is on the relative distribution of energy across a range of frequencies, the absolute amplitudes recorded during this test are not relevant and may not include cable losses or attenuation factors.

For BLE operating at 2 Mbps, the lowest operating frequency was 2404 MHz, and the highest operating frequency was 2478 MHz. The ANT radio operates only at 2460 MHz. For all other non-WiFi radios reported here, the lowest operating frequency was 2402 MHz, and the highest operating frequency was 2480 MHz.

Test Setup

This block diagram shows the test equipment setup.

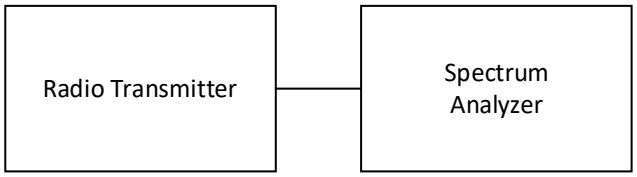


Figure TR03.1: Test setup

Test Data

The data for each test is summarized below, followed by the spectral data for each case highlighted in yellow.

The analysis threshold for the Occupied Bandwidth test was the bandwidth containing 99% of the observed power. The standards cited do not limit the Occupied Bandwidth (OBW) for all transmitter types. In such cases an OBW limit stated below may be inapplicable. Instead, the distance from the edge of the occupied band to the edge of the allocated frequency band may be more pertinent.

	2402 (04)	2440	2480 (78)
BLE 1 Mbps	**1.053**	**1.056**	**1.055**
BLE 2 Mbps	**2.060**	**2.063**	**2.071**
ANT 2460 (Ch 60)		**0.988**	

Table TR03.2: Summary of bandwidth data in MHz for BLE and ANT modes

	Ch1	Ch6	Ch11
B1	13.503	13.664	13.543
B2	13.512	13.628	13.529
B5.5	13.091	13.162	13.089
B11	13.320	13.389	13.315
G6	17.277	17.522	17.279
G9	17.266	17.496	17.277
G12	16.963	17.069	16.948
G18	16.927	17.080	16.963
G24	16.901	16.969	16.955
G36	16.859	16.901	16.843
G48	16.839	16.878	16.862
G54	16.857	16.879	16.854
NMCS0	18.163	18.341	18.175
NMCS1	17.937	18.065	17.967
NMCS2	17.975	18.060	17.942
NMCS3	17.959	18.028	17.974
NMCS4	17.985	17.990	17.970
NMCS5	17.904	17.911	17.910
NMCS6	17.904	17.931	17.869
NMCS7	17.881	17.914	17.881

Table TR03.3: Summary of bandwidth data in MHz for IEEE 802.11 WiFi modes

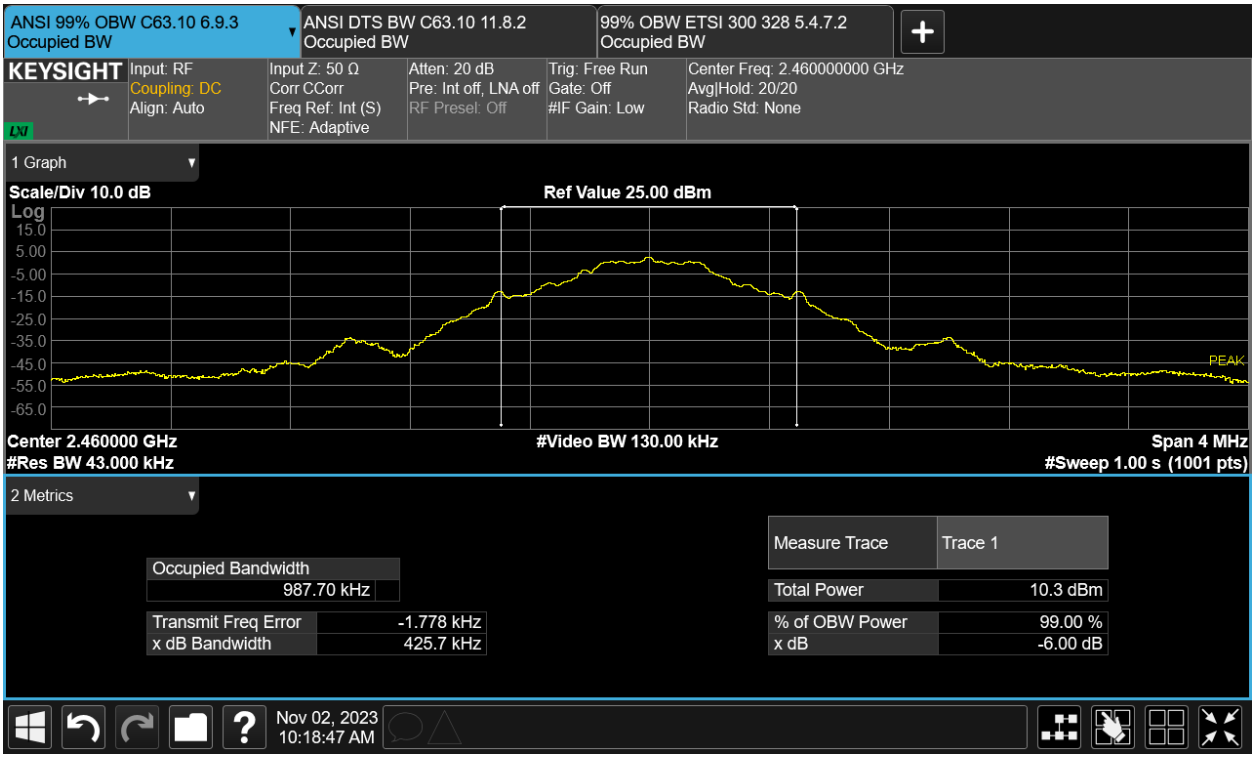


Figure TR03.2: Bandwidth data for ANT at channel (2460 MHz)

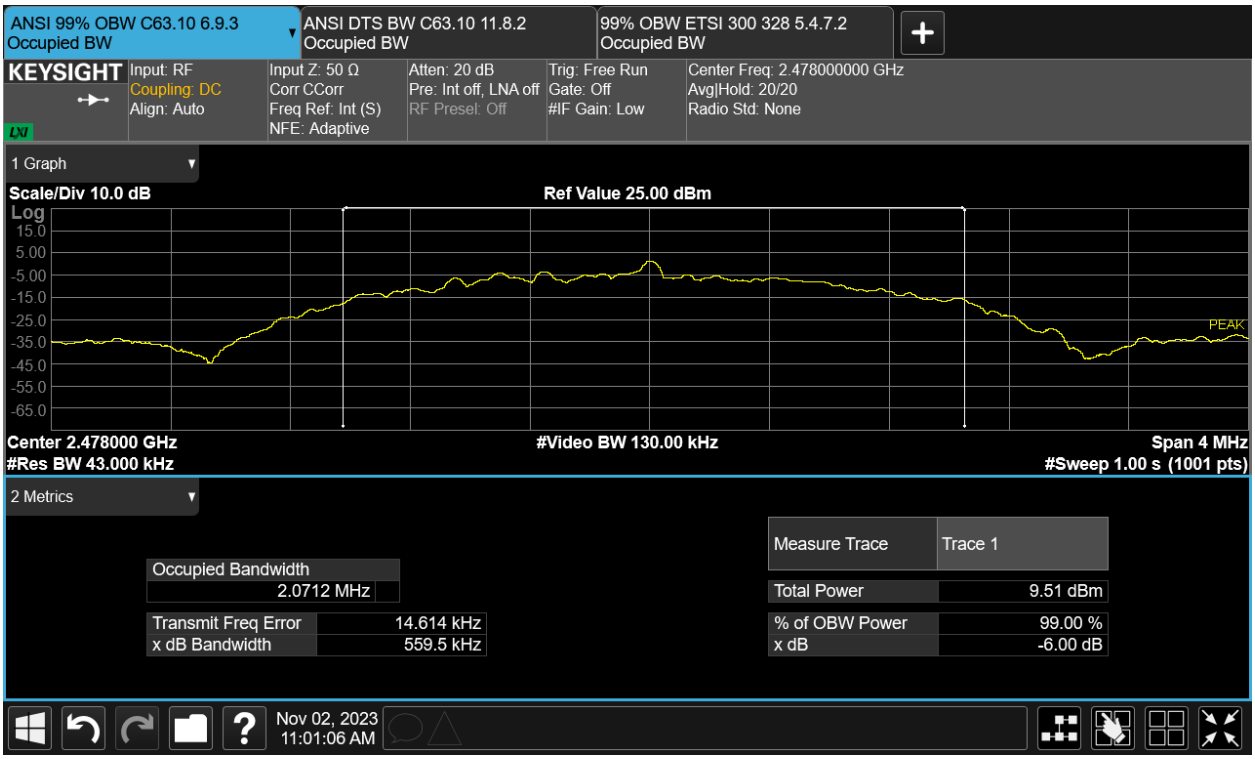


Figure TR03.3: Bandwidth data for BLE 2 at high channel (2478 MHz)

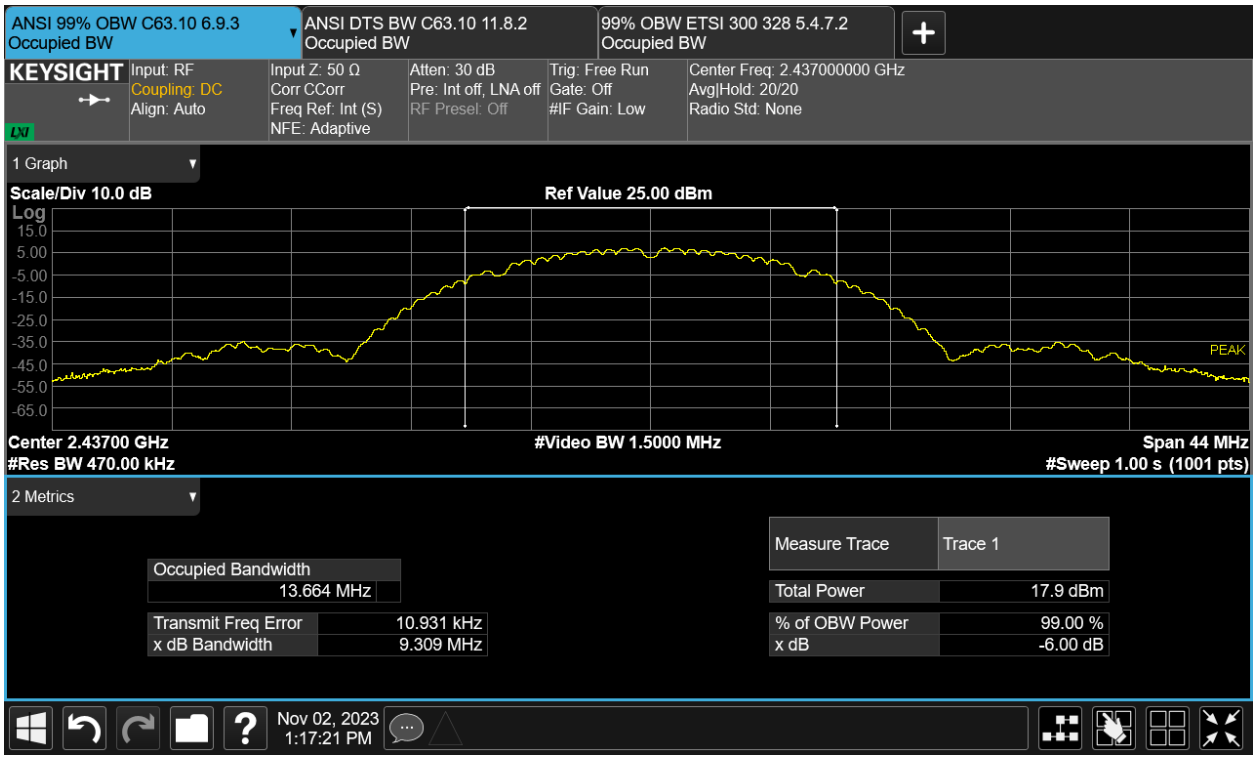


Figure TR03.4: Bandwidth data for 802.11b 1 Mbps at channel 6

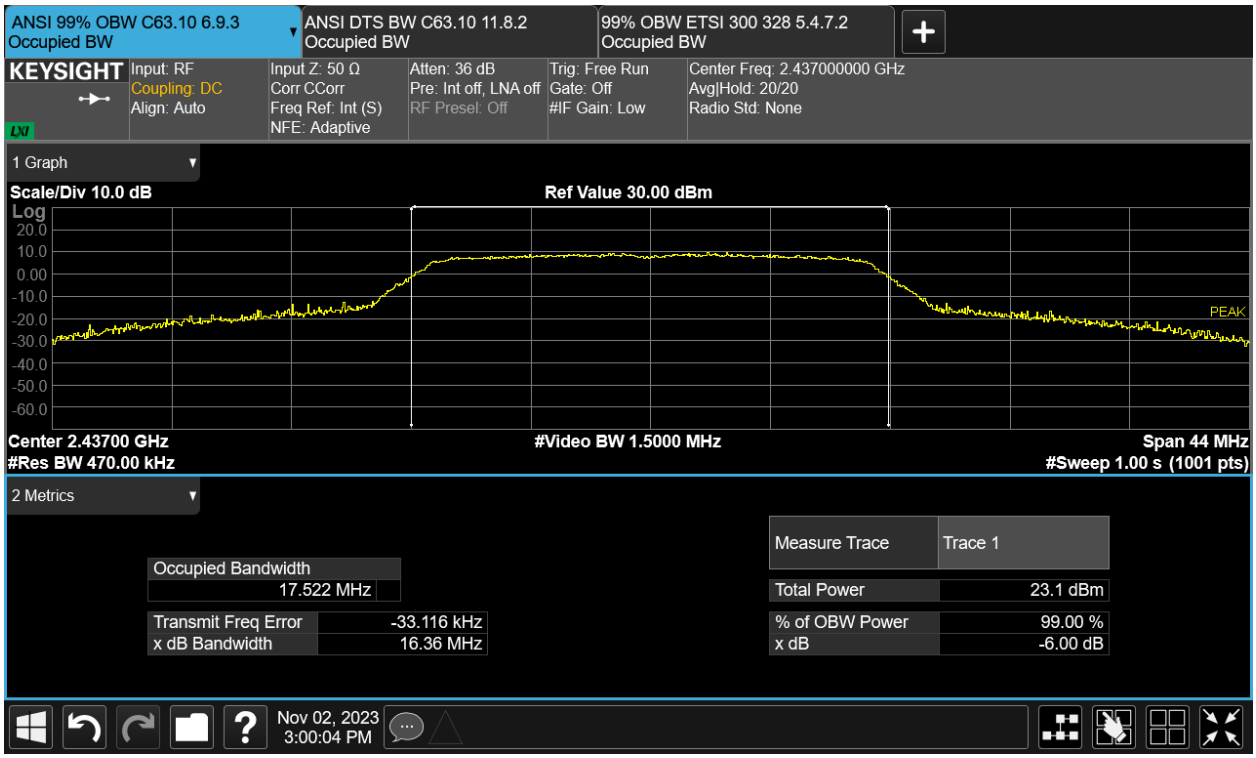


Figure TR03.5: Bandwidth data for 802.11g 6 Mbps at channel 6

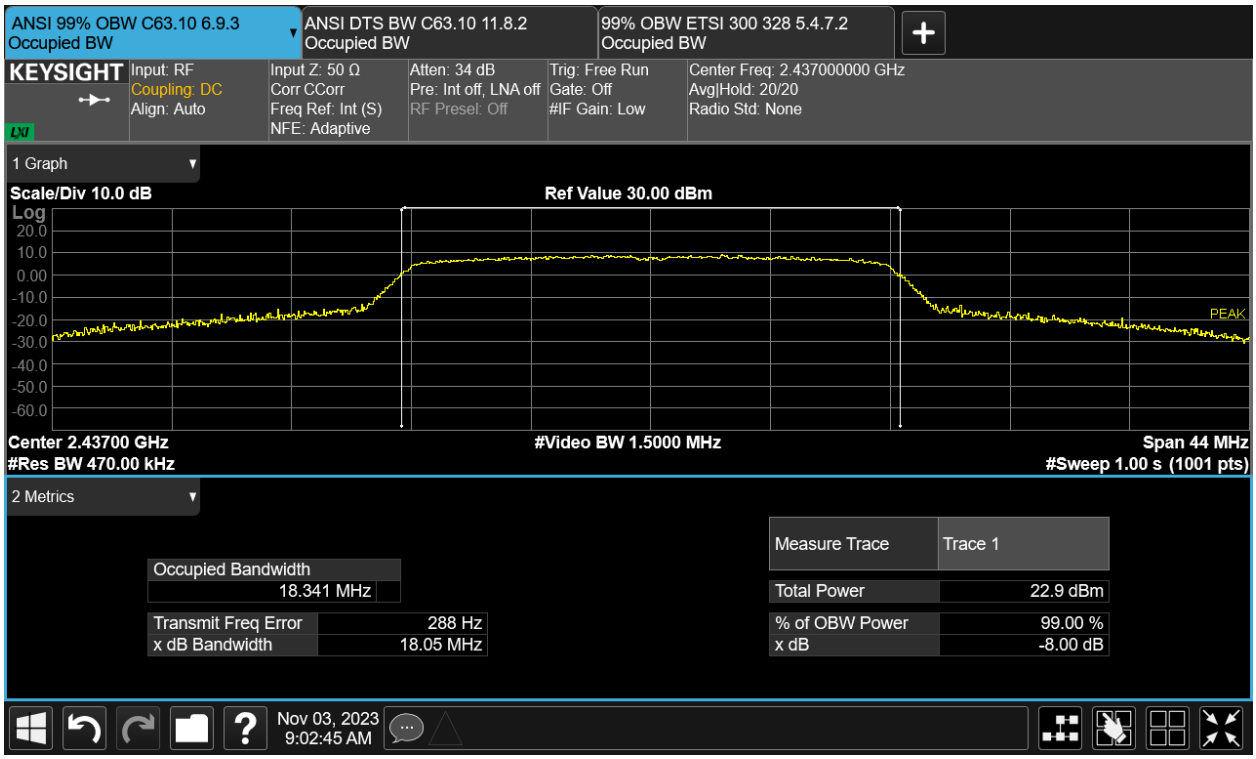


Figure TR03.6: Bandwidth data for 802.11n MCS0 at channel 6

Necessary Bandwidth Calculations

The Necessary Bandwidth is a theoretical value based on the specifications for a communication protocol, rather than the hardware implementation and a subsequent lab measurement. The analysis methods in FCC Part 2.202 and TRC-43 are the same for Bluetooth, ANT, and IEEE 802.11b WiFi. However, they differ for IEEE 802.11g and 11n systems because the Canadian TRC-43 standard provides different analysis methods for Orthogonal Frequency Division Multiplexing systems (OFDM). The tables below will show the analysis for most of the radios signals as a combined approach, then separately analyze the results for IEEE 802.11g and n systems. The tables below may include radio protocols that are not part of the product being evaluated.

The radio modulation schemes for Ant, for the various Bluetooth protocols, and for IEEE 802.11 b WiFi are a mix of Phase Shift Key (PSK) and Quadrature Amplitude Modulation (QAM) techniques. The Necessary Bandwidth calculations use the equations from 47CFR Part 2.202(g) table section 6. We have set the variable K=1, which leaves the equation for both PSK and QAM as:

$$B_N = 2R / Log_2(S)$$

where B_N is the Necessary Bandwidth, R is the bit rate, and S is the number of signaling states.

Radio Type	R Mbps	K	S	LogBase2 of (S)	BN (MHz)
ANT / ANT+	1	1	2	1	2

Table TR**03**.101: Necessary Bandwidth for ANT and ANT+ Radio Protocols (FCC and TRC-43)

Radio Type	Sub-type	Method	R Mbps	K	S	LogBase2 of (S)	BN (MHz)
Bluetooth	BR	GFSK	1	1	2	1	2
	EDR2	Pi/4 DPSK	2	1	4	2	2
	EDR3	8DPSK	3	1	8	3	2
BLE	1Mbps	GFSK	1	1	2	1	2
	2Mbps	DQPSK	2	1	4	2	2

Table TR03.102: Necessary Bandwidth for Bluetooth Radio Protocols (FCC and TRC-43)

Radio Type	Sub-type	R Mbps	K	S	LogBase2 of (S)	BN (MHz)
802.11 b	1	1	1	2	1	2
	2	2	1	4	2	2
	5.5	5.5	1	4	2	5.5
	11	11	1	4	2	11

Table TR**03**.103: Necessary Bandwidth for IEEE 802.11 b Radio Protocol (FCC and TRC-43)

Radio Type	Sub-type	R Mbps	K	S	LogBase2 of (S)	BN (MHz)
802.11 g	6	6	1	2	1	12
	9	9	1	2	1	18
	12	12	1	4	2	12
	18	18	1	4	2	18
	24	24	1	16	4	12
	36	36	1	16	4	18
	48	48	1	64	6	16
	54	54	1	64	6	18
802.11 n	MCS0	7.2	1	2	1	14.4
	MCS1	14.4	1	4	2	14.4
	MCS2	21.7	1	4	2	21.7
	MCS3	28.9	1	16	4	14.5
	MCS4	43.3	1	16	4	21.7
	MCS5	57.8	1	64	6	19.3
	MCS6	65	1	64	6	21.7
	MCS7	72.2	1	64	6	24.1

Table TR03.104: Necessary Bandwidth for IEEE 802.11 g and n 20 MHz Radio Protocols (FCC)

As a note, the bit rate for IEEE 802.11 n WiFi is calculated based on the IEEE standard's short guard interval of 400 nsec. If only the long guard interval of 800 nsec were implemented, the bit rate for MCS7would decrease to 65 Mbps for a Necessary Bandwidth of 21.7 MHz.

The TRC-43 method for OFDM signals simply multiplies the number of subcarriers, K, and the subcarrier spacing, N_S. In both cases, Ns is 312.5 kHz. The count of subcarriers includes nulls. So for example, 802.11 n uses 4 pilot subcarriers, 52 data subcarriers, and one null suppressed subcarrier in the middle for 57 total subcarrier channels.

$B_N = N_S * K$

Radio Type	Ns (MHz)	K	BN (MHz)
802.11g	0.3125	53	16.6
802.11n	0.3125	57	17.8

Table TR03.105: Necessary Bandwidth for IEEE 802.11 g and n 20 MHz Radio Protocols (TRC-43)

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Concluding Notes

This report stands as an integrated record of the tests performed and must be copied or distributed in its complete form. The reproduction of selected pages or sections separate from the complete report would require specific approval from the manager of the Garmin Compliance Lab.

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