Test Report 2024-060

Version A
Issued 4 Jun 2024

Project GCL-0460
Model Identifier: A04881
Primary Test Standard(s):
CFR 47, FCC Part 15.247
RSS-247 Issue 3

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

Client-supplied Information

FCC ID:	IPH-04881
IC ID:	1792A-04881

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 Bluetooth Low Energy (BLE) transceiver(s). Test records within this report may include data for the ANT transmitter, but ANT is addressed in a separate report. The results 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 2 Mbps.	Reported	N/A
Hopping Channels	The radio manages it use of channels appropriately. [15.247(a)(1); RSS-247 at 5.1]	N/A	N/A	N/A
DTS Bandwidth	The nature of the radio signal is broadband, being at least 500 kHz wide. [15.247(a)(2); RSS-247 at 5.2(a)]	The 6dB bandwidth is 722.9 kHz or greater.	PASS	12
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	15
Transmit Power	The peak transmit power presented to the antenna is no greater than 1 Watt or 30 dBm. The effective radiated power is limited to 4 Watts or 36 dBm EIRP. [15.247(b); RSS-247 at 5.4(d)]	The maximum transmit power is 4.43 dBm or 2.77 mW.	PASS	20
Antenna Gain	The radio should not focus too much energy on any direction. Unless additional rules are applied, the antenna gain is no greater than 6 dBi. [15.247(b)(4) and (c)]	NT. The client stated that maximum antenna gain was -1.915 dBi and will document antenna gain separately.	NT	NT
Unwanted Emissions (Conducted Spurious)	The radio should not provide too much radio energy to the antenna at frequencies beyond its intended frequency band. [15.247(d); RSS-247 at 5.5]	Emissions outside the band must be reduced by at least 20 dB from in-band levels. The measured reduction was at least 51.03 dB.	PASS	24
Restricted Bands	The radio must not emit in certain designated restricted frequency bands above a set of limit values. [15.247(d) and 15.205; RSS-247 at 3.3]	Emissions in the restricted bands were at least 11.27 dB below the applicable limits.	PASS	28

Power Spectral Density	The radio must not focus too much radio energy on a narrow frequency band. [15.247(e); RSS-247 at 5.2(b)]	The limit is 8 dBm in a 3 kHz band. The strongest emission level was -12.19 dBm in a band of at least 3 kHz.	PASS	34
Hybrid Systems	A radio that is both frequency hopping and digitally modulated should satisfy a combination of system rules. [15.247(f); RSS-247 at 5.3]	N/A. The radios described in this report are not subject to the Hybrid System rules.	N/A	N/A
Frequency Hopping Rules	Frequency hopping systems have additional functional requirements. [15.247(g) and (h); RSS-247 at 5.1]	N/A. The radios described in this report are not subjected to the Frequency Hopping rules.	N/A	N/A
Radio Safety	The radio emissions must meet public health & safety guidelines related to human exposure. [15.247(i) and 1.1307; RSS-Gen at 3.4]	NT. Client will report radio energy safety results separately.	NT	NT
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	36
Unintended Radiated Emissions	Radio emissions that this device may generate via its structures and connected cables that are not necessary for its operation and that may affect other radio communication	9.5 dB of margin to limit. Appropriate for use in homes, offices, and industrial facilities. [Class B]	PASS	39
AC Mains Conducted Emissions	Radio emissions that this device may generate via its ac power network connections that are not necessary for its operation and that may affect radio communication.	29.31 dB of margin. Appropriate for use in homes, offices, and industrial facilities. [Class B]	PASS	47

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 set-up photographs) has been removed from this report and placed in GCL Test Report 2024-088. 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: 03 Apr 2024
Test Start Date: 09 Apr 2024
Test End Date: 17 May 2024

The data in this test report applies 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 4 Jun 2024 as Version A.

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
Detailed Description: A change of firmware from Version 1.11 to 2.03
Date applied: 7 May 2024
Reason for this modification:
This modification was performed only on sample serial number 469824622 prior to ANT Receiver blocking testing.
This change allowed test staff to adjust the ANT radio to test on the high and low channels.
The client stated this firmware change only affects the ANT test page. Based on the client's statement GCL judged the presence of this modification has no effect on any other tests.

Modification 2
Detailed Description: A change of firmware from Version 2.03 to 2.04
Date applied: 8 May 2024
Reason for this modification:
This modification was performed only on sample serial number 469824622 prior to BLE receiver testing.
The modified allowed the unit to show the tuned receiver frequency.
The client stated this firmware change only affects the BLE test page. Based on the client's statement GCL judged the presence of this modification has no effect on any other tests.

5. Description of the Equipment Tested

5.1 Unique Identification

Product Model	A04881
Serial Numbers Tested	469824622, 469824478

This product tested is a mobile device for collecting and sharing data with the user and nearby electronic devices.

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
I/O Ports:	USB
Radio Transceivers:	Bluetooth Low Energy, ANT
Radio Receivers:	GPS L1, Galileo E1, BeiDou, GLONASS
Primary Functions:	Data collection and communication
Typical use:	Portable in multiple orientations
Highest internal frequency:	2.484 GHz
Firmware Revision	2.04 (see also section 4 of this report)

5.3 Operating modes

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

Mode 3: M3 (BleTx). Bluetooth Low Energy radio transmitting consistently on a selected channel at 1 Mbps or 2 Mbps

Mode 4: M4 (BleLnk). 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 5: M5 (AntTx). ANT radio transmitting consistently on a selected channel.

Mode 6: M6 (AntTnk). ANT radio is paired to a companion device, transmitting and receiving data in accordance with the protocol, and maintaining the paired relationship.

Mode 9: M9 (RxBtBlA). The radio was set to receive 2.4 GHz signals but not transmitted in Bluetooth, Bluetooth low energy or ANT.

Mode 13: M13 (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 15: M15 (Normal). EUT is in normal operational mode (User mode) if some Transmitters are on during normal operational mode exclude radiations on those frequency.

Mode 19: M19 (ML1). The EUT is actively linked to more than one companion device through different radios which is mostly used mode during immunity tests.

5.4 EUT Arrangement

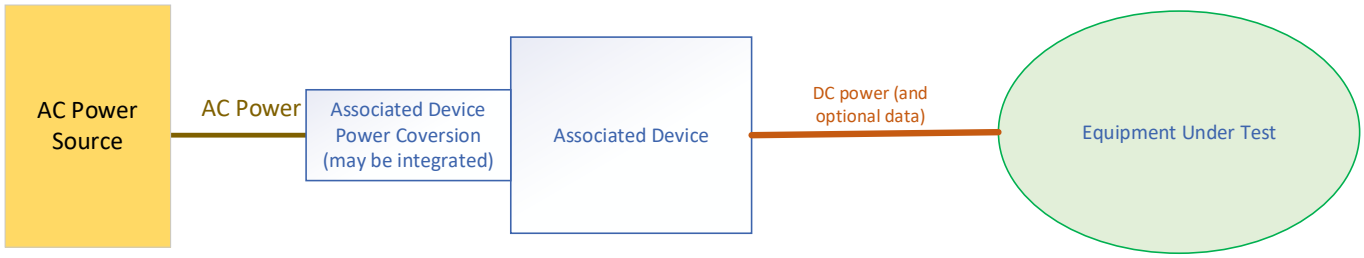
During the test, the EUT components and associated support equipment were selected including the following arrangement sets.

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

Arrangement 2: A2 (Upwr). The test sample is attached to a Mains-powered device connected that provides dc power to the sample over a cable but no user data. See the block diagram in Figure 1.

Arrangement 3: A3 (Udata). The test sample is attached to a Mains-powered device connected that provides dc power to the sample and user data over a cable. See the block diagram in Figure 1.

Arrangement 4: A4 (Udc). The test sample is attached to a Mains-powered device connected that provides dc power to the sample and may or may not provide user data. This arrangement is specified in the test plan to provide staff flexibility when the presence or absence of data on the cable is not pertinent. See the block diagram in Figure 1.



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

5.5 Associated Equipment (AE) used

Description	Manufacturer	Model	Serial/Part Number
USB C power adaptor	Phihong (Garmin)	AQ27A-59CFA	362-00118-00
Tablet	Apple	iPad Pro 11 inch	DMPZ7582KD6L
Laptop	Dell	Latitude 5410	5VSPFB3
Power Supply	Dell	HA65NM191	0BD-7TC0-A02
Phone	Samsung	SM-J700T	R58H8080GJF

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

5.6 Cables used

Description	From	To	Length	EMC Treatment
USB C to custom cable	Power and/or Data source	EUT	0.5m	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 15.247
ANSI C63.10: 2013 and ANSI C63.10: 2020
RSS-GEN Issue 5 Amd 2
RSS-247 Issue 3

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.

TRC-43 Issue 3

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:	20.3 to 23 °C
Relative Humidity:	27.7% to 55.8% (non-condensing)
Barometric Pressure	96.1 to 96.3 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 fails 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 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
Transmitter Bandwidth Tests
Test IDs TR06, TR07
Project GCL0460

Test Date(s)	09 Apr 2024
Test Personnel	Majid Farah
Product Model	A04881
Serial Number tested	469824622
Operating Mode	M3 (BleTx)
Arrangement	A4 (Udc)
Input Power	5 Vdc
Test Standards:	FCC Part 15, ANSI C63.10, RSS-GEN (as noted in Section 6 of the report).
Radio Protocol	Bluetooth Low Energy (BLE), ANT
Radio Band	2400 to 2483.5 MHz
Pass/Fail Judgment:	**Reported**
Test record created by:	**Majid Farah**
Date of this record:	**18 Apr 2024**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 44GHz	Keysight	N9048B	MY62220139	13-Mar-2024	15-Mar-2025

Table TR06.1: List of test equipment used

Test Software Used: Keysight PXE firmware A.33.03

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.

Test Setup

This block diagram shows the test equipment setup.

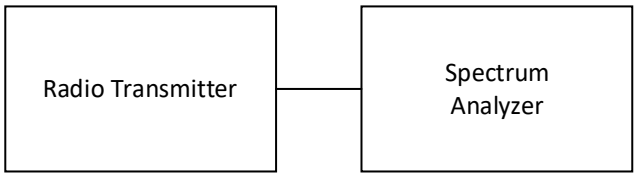


Figure TR06.1: Test setup

Test Data

The data for each test is summarized below, followed by the spectral data for each case highlighted in yellow. For BLE operating at 2 Mbps, the lowest operating frequency was 2404 MHz, and the highest operating frequency was 2478 MHz. For all other radios reported here, the lowest operating frequency was 2402 MHz, and the highest operating frequency was 2480 MHz.

The DTS Bandwidth is measured using a spectrum analyzer operating with a defined resolution bandwidth. The analysis finds the smallest continuous range of frequencies containing all emissions within 6 dB of the highest value. The requirement is that the DTS Bandwidth be greater than 500 kHz. As such the lowest measured bandwidth is the worst case and is highlighted. BLE radios are judged to have met this requirement. ANT is not part of this 15.247 report scope.

		2402 (04)	2440	2480 (78)
BLE	1 Mbps	**722.90**	**723.10**	**726.90**
BLE	2 Mbps	**1174.00**	**1172.00**	**1180.00**

Table TR06.2: Summary of DTS bandwidth data in kHz for BLE

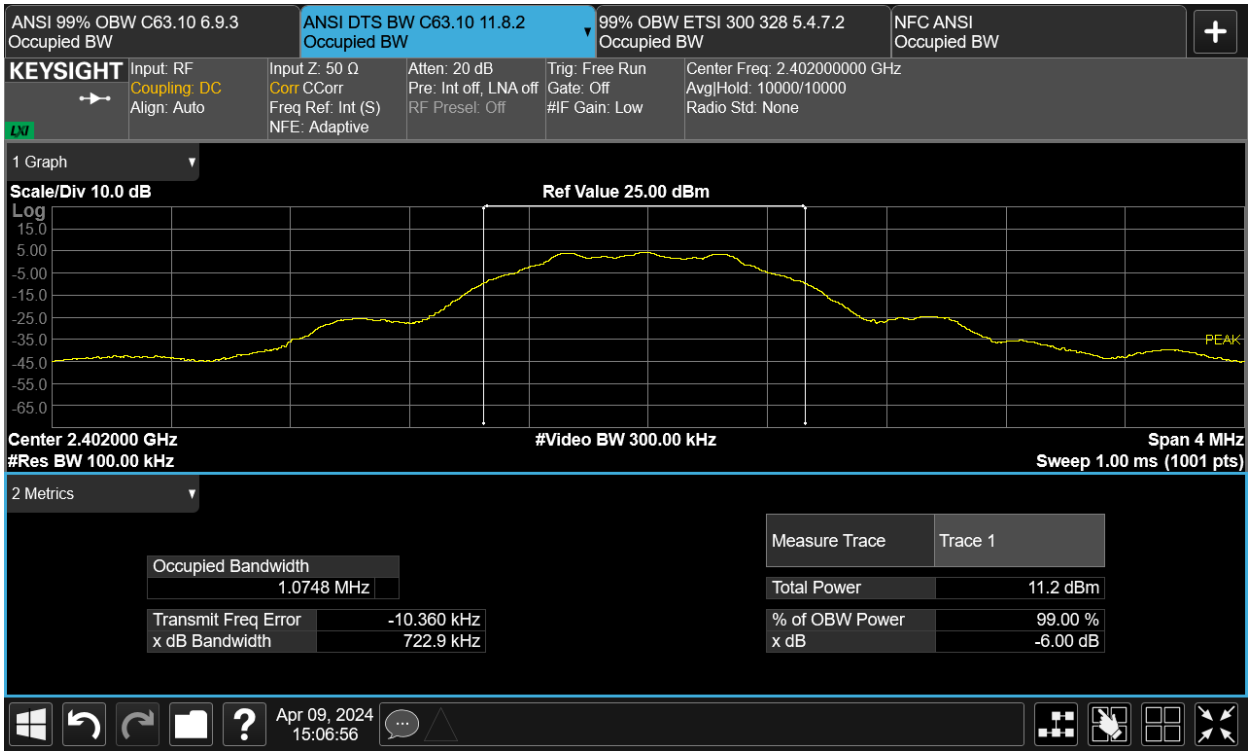


Figure TR06.2: Bandwidth data for BLE 1 Mbps at 2402 MHz

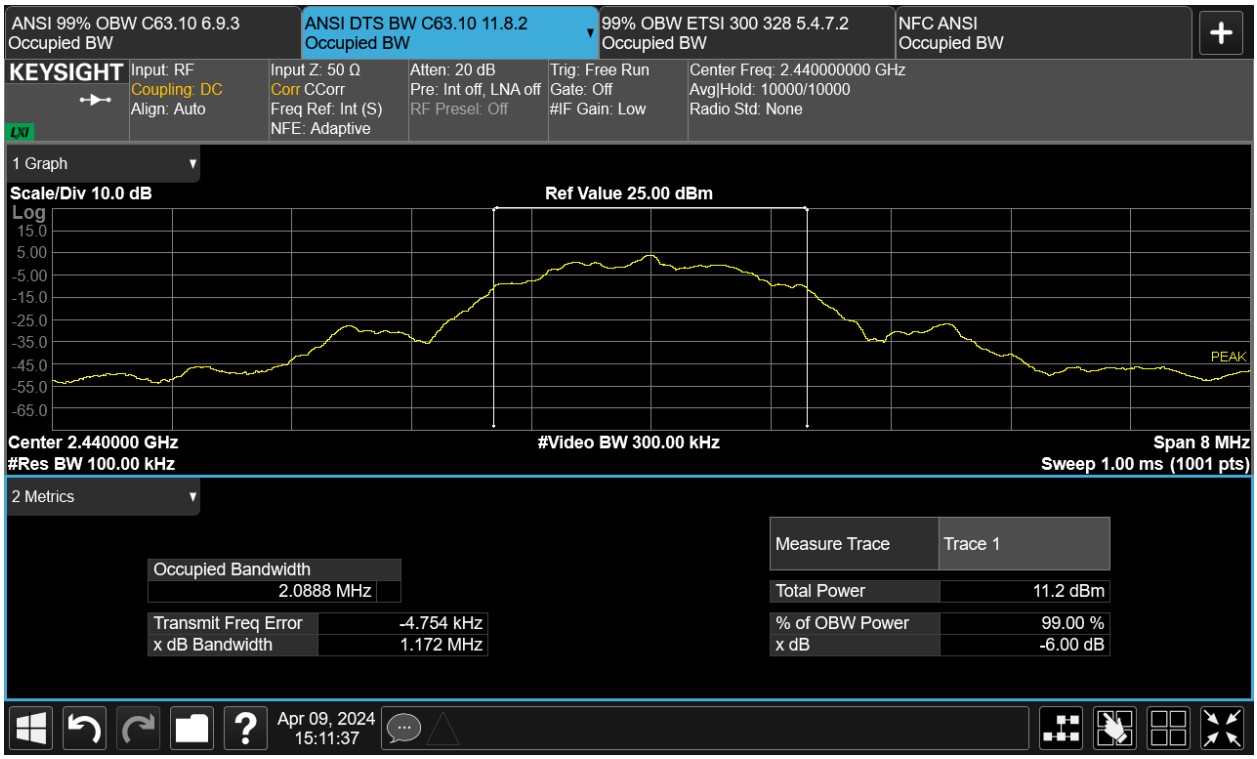


Figure TR06.3: Bandwidth data for BLE 2 Mbps at 2440 MHz

This line is the end of the test record.

Test Record
Transmitter Bandwidth Tests
Test IDs TR10, TR11
Project GCL0460

Test Date(s)	09 Apr 2024
Test Personnel	Majid Farah
Product Model	A04881
Serial Number tested	469824622
Operating Mode	M3 (BleTx)
Arrangement	A4 (Udc)
Input Power	5 Vdc
Test Standards:	FCC Part 2.202, ANSI C63.10, TRC-43, RSS-GEN (as noted in Section 6 of the report).
Radio Protocol	Bluetooth Low Energy (BLE), ANT
Radio Band	2400 to 2483.5 MHz
Pass/Fail Judgment:	**Reported**
Test record created by:	**Majid Farah**
Date of this record:	**18 Apr 2024**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 44GHz	Keysight	N9048B	MY62220139	13-Mar-2024	15-Mar-2025

Table TR10.1: List of test equipment used

Test Software Used: Keysight PXE firmware A.33.03

Background
There are regulatory requirements to present two additional types of bandwidth analyses: 99% Occupied Bandwidth and Necessary Bandwidth. There are no limits or functional requirements around these data, beyond a reporting requirement. The contents of this test record are for information, and do not affect compliance of the devices that are the subject of this report.

For BLE operating at 2 Mbps, the lowest operating frequency was 2404 MHz, and the highest operating frequency was 2478 MHz. For all other Bluetooth, BLE, and ANT 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.

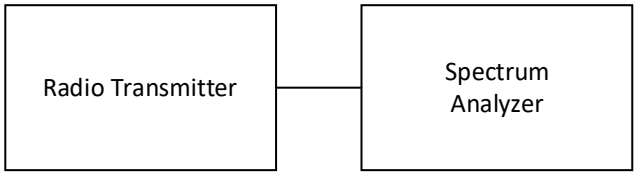


Figure TR10.1: Test setup

Occupied Bandwidth, 99% 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 percentage of the total power observed. The spectrum is scanned hundreds of 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.

Occupied Bandwidth, 99% Test Data

The data for each type of bandwidth is summarized below, followed by the spectral data for the cases highlighted in yellow. The analysis threshold for this test was the bandwidth containing 99% of the observed power using the ANSI C63.10 method. The standards require testing a frequency near the bottom, middle, and top of the band. The measured bandwidth data have MHz as their units of measure.

Mode	Speed	2402 (04)	2442	2480 (78)
BLE	1 Mbps	**1.0456**	**1.0480**	**1.0480**
BLE	2 Mbps	**2.0467**	**2.0480**	**2.0515**
ANT	Fixed	**983.60**	**984.39**	**986.19**

Table TR10.2: Summary of 99% bandwidth data in MHz for ANT and BLE modes

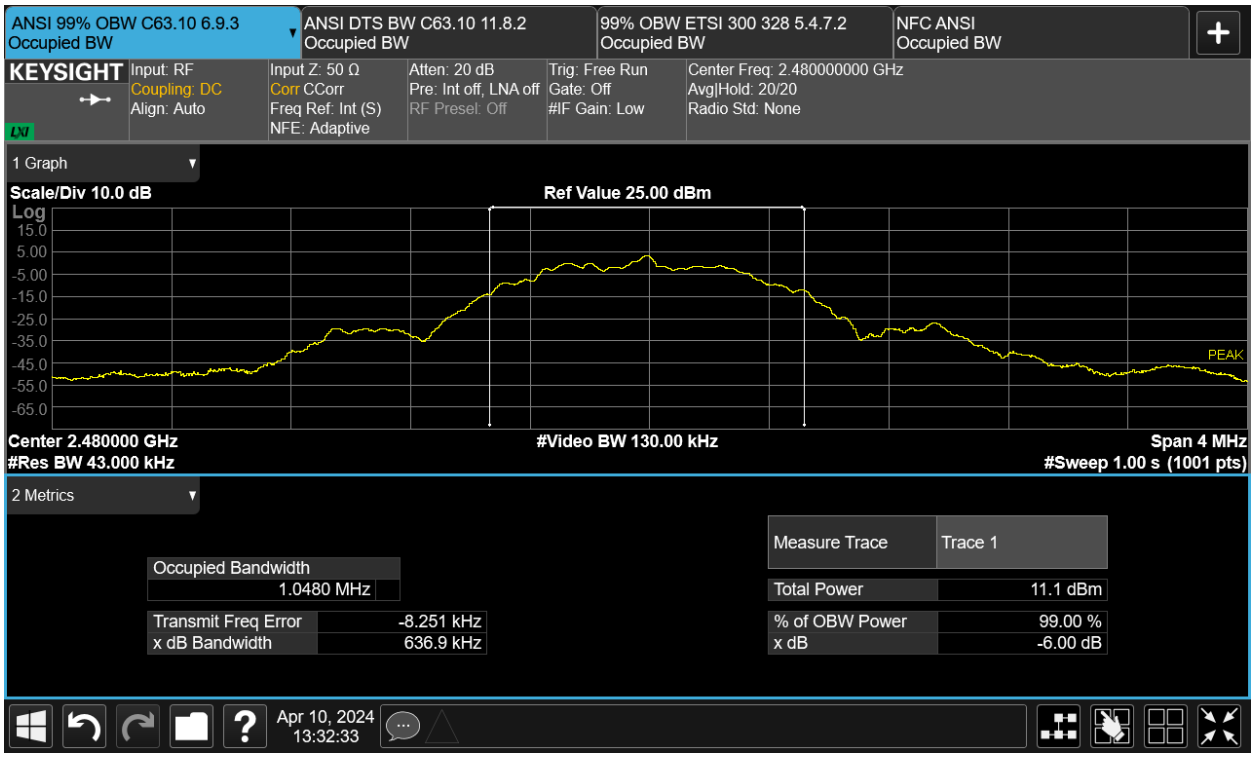


Figure TR10.2: Bandwidth data for BLE 1 Mbps at 2480 MHz

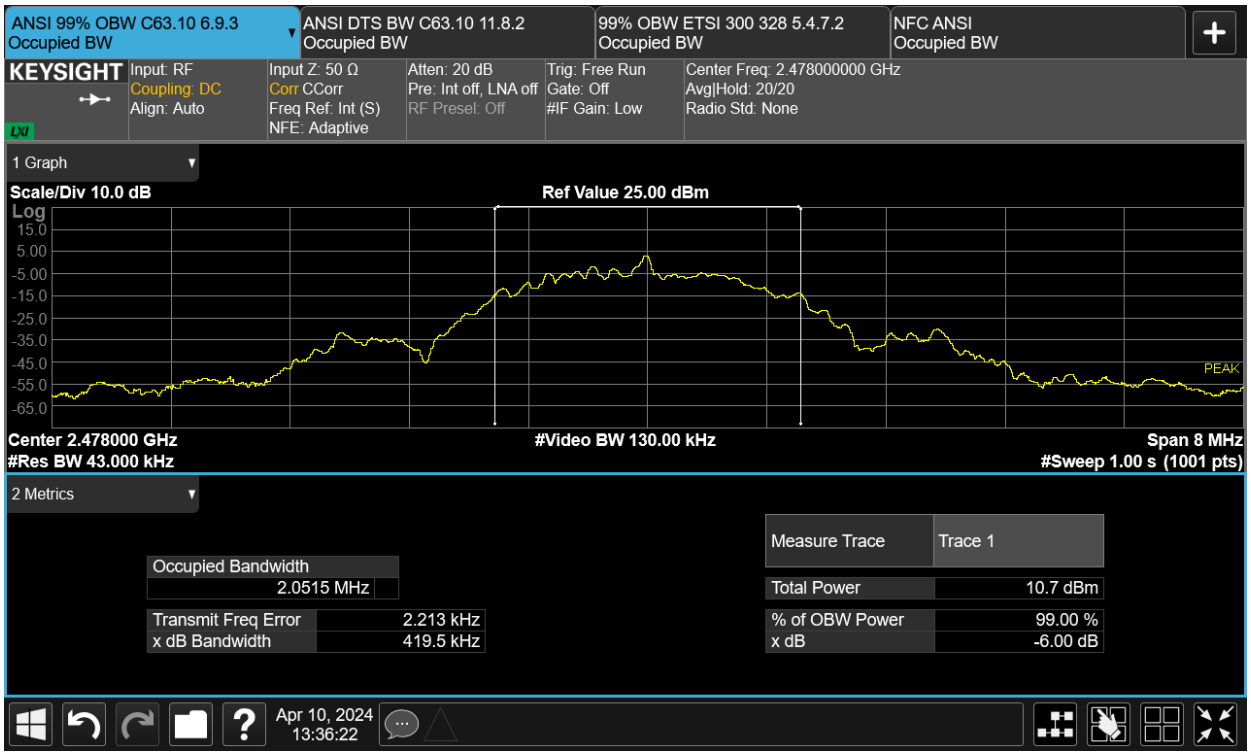


Figure TR10.3: Bandwidth data for BLE 2 Mbps at 2478 MHz

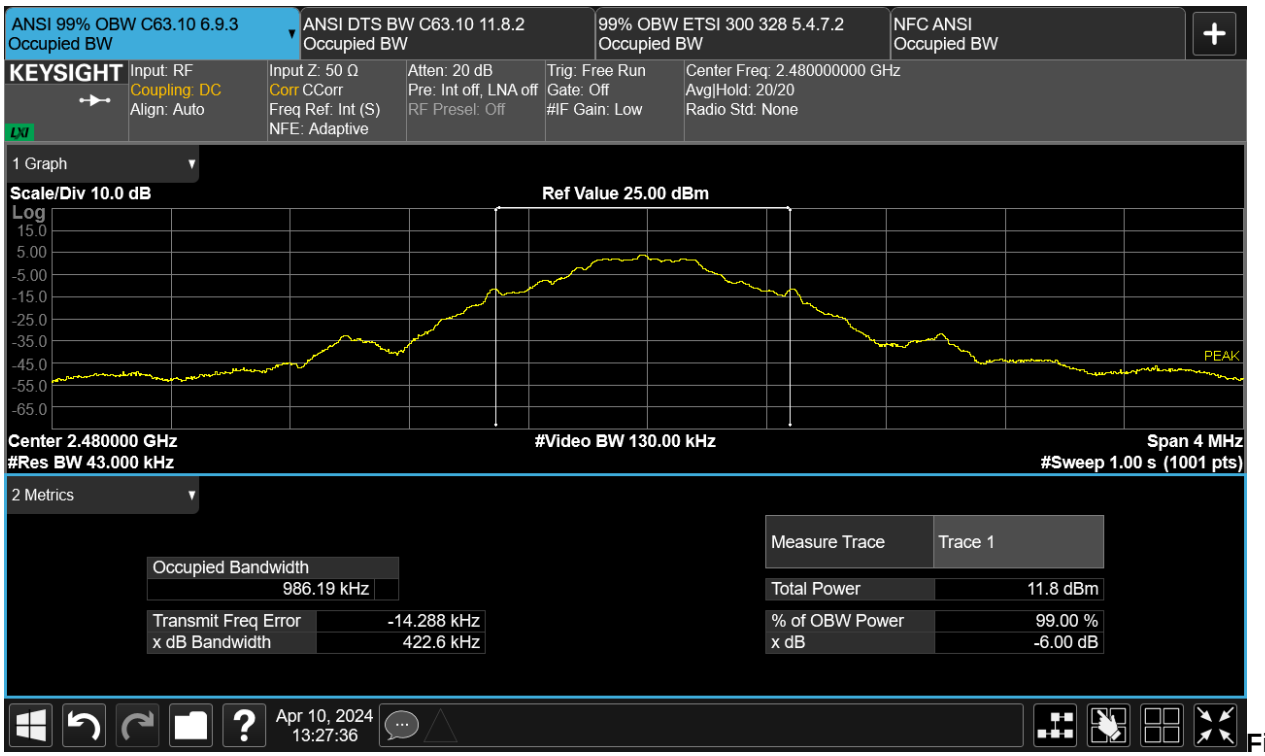


Figure TR10.4: Bandwidth data for ANT at 2480 MHz

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 BN 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 TR10.101: 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 TR10.102: 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 TR10.103: 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 TR10.104: 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 TR10.105: Necessary Bandwidth for IEEE 802.11 g and n 20 MHz Radio Protocols (TRC-43)

This line is the end of the test record.

Test Record
Transmitter Power, Duty Cycle and RF Exposure
Test IDs TR02, TR03
Project GCL0460

Test Date(s)	09 Apr 2024
Test Personnel	Majid Farah
Product Model	A04881
Serial Number tested	469824622
Operating Mode	M3 (BleTx), M5 (AntTx)
Arrangement	A4 (Udc)
Input Power	5 Vdc
Test Standards:	FCC Part 15, ANSI C63.10, ETSI EN 300 328, RSS-GEN, RSS-247, FCC Part 1.1310, FCC Part 2.1093, RSS-GEN, RSS-102, IEC/EN 62311, and IEC/EN 62479 (as noted in Section 6 of the report)
Antenna Gain	Maximum -1.915 dBi, as reported by the client
Radio Protocol	BLE (Bluetooth Low Energy), ANT
Separation distance	5 cm, distance from EUT to user as reported by the client
Pass/Fail Judgment:	**PASS**
RF exposure:	**EXEMPT from further detailed analysis**
Test record created by:	**Majid Farah**
Date of this record:	**29 Apr 2024**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
RF Power Sensor	Rohde&Schwarz	NRP8S	109927	7-Jul-2023	1-Jul-2024

Table TR02.1: List of test equipment used

Software used: Rohde & Schwarz Power Viewer V11.3; TimePowerAnalysisSpreadsheetv11.xls, RFExposurev1.xls

Test Method
The basic test standards provide options for the time evaluation test method. The following test methods were applied.

ETSI EN 300 328:	5.4.2.2.1.3
ANSI C63.10:	11.9.1.3

Transmit Power Data

Each measurement is conducted from the antenna port with the transmitter on a specified channel and in a selected transmission protocol. Where standards cited here apply harmonized test methods and different limits, the stricter limit has applied. In this case, the ANSI method finds the highest value (numerical peak) and applies the 30 dBm limit from the US and Canadian standards. By contrast, the ETSI method reports the highest numerical average observed during any transmission burst and applies a 20 dBm EIRP limit. All values met the respective limits with more than 10 dB of margin. The results are shown below.

Frequency	(MHz)	2402	2404	2440	2478	2480	ETSI Limit(dBm eirp)
BT Low Energy	1 Mbps	**2.31**	**NT**	**2.26**	**NT**	**2.22**	**20**
BT Low Energy	2 Mbps	**NT**	**1.68**	**1.64**	**1.59**	**NT**	**20**
ANT	----	**2.40**	**NT**	**2.36**	**NT**	**2.32**	**20**

Table TR02.2: Transmit Power Summary in dBm EIRP with ETSI analytical methods

ANT transmits at 2402 MHz at the highest level in room temperature and it was nominated to be tested for power stability vs temperature. The table below shows ANT transmission (2402 MHz) power vs temperature at nominal and hot and cold temperature extremes.

Tx Mode	Temp	Power	Limit	Result
	˚C	dBm EIRP	dBm EIRP	
ANT	60	2.18	20	Pass
ANT	20	2.88	20	Pass
ANT	-20	3.59	20	Pass

Table TR02.3: ANT 2402 MHz Transmit Power Summary in dBm EIRP with ETSI analytical methods

Frequency	(MHz)	2402	2404	2440	2478	2480	ANSI Limit(dBm)
BT Low Energy	1 Mbps	**4.43**	**NT**	**4.39**	**NT**	**4.33**	**21**
BT Low Energy	2 Mbps	**NT**	**4.42**	**4.39**	**4.34**	**NT**	**21**
ANT	----	**4.41**	**NT**	**4.36**	**NT**	**4.32**	**21**

Table TR02.4: Transmit Power Summary in dBm with ANSI C63.10 analytical methods

RF Exposure Test Background

RF Exposure testing typically takes one of three routes: exemption from routine evaluation by analysis, calculation of exposure, or determination of specific absorption rate (SAR). SAR applies at transmission frequencies below 6 GHz used closer than 20 cm unless an exemption can be applied. Clients whose products require SAR measurements are required to seek detailed RF exposure evaluation elsewhere.

The exemption and exposure calculation paths both rely on a combination of measured values and detail provided by the client. Examples of measured values are:

- RF power delivered to an antenna, which is measured with a fast diode-based RF power meter
- Electric or magnetic field components at a distance, measured on a radio test range at 3 m distance
- RF signal short term duty cycle, which is embedded in the RF power meter or electric/magnetic field data

Note that the RF power meter data set analyzed and reported in this section is the same data set used for the analysis in the RF Power and Timing section of this test record.

Examples of detail provided by the client are:

- Antenna gain in the peak direction, referenced to an ideal isotropic antenna
- The separation distance between the product under test and a user or other person
- The power tolerance attributable to factory tune-up procedures
- Usage rates
- If worn, whether it placed on the body (head or torso) or a limb (arm, hand, leg, foot)

The standards typically allow power to be averaged in linear power units over a period of 6 minutes. That is divided into two distinct factors: duty cycle and usage rates. The RF power meter reads peak power levels over a measurement duration of up to 1 second. Embedded in that data set is a short-term duty cycle that is attributable to the types of signals being transmitted, and the low-level radio protocol details. It deals with sub-second timing. The usage rate is a factor based on how often and how long a product could transmit and is often based on user behaviors. Usage rate analyzes what happens over several seconds or minutes of time. These two factors are multiplied to determine the complete 6-minute time averaging factor.

The ‘tuned time averaged EIRP power’ is the product of: the linear transmitter output power that the lab measured which includes the embedded duty cycle; the usage rate; 1 plus the tune-up tolerance; and any positive antenna gain expressed as a linear factor. Since the lab’s measurement instrumentation uncertainty is within the allowed limits, no uncertainty adjustment is applied.

The calculation of exposure goes by two names. The preferred name is Exposure Reference Level (ERL), though the older name in some standards is Maximum Permissible Exposure (MPE). This record speaks of Exposure or ERL to cover both terms.

When ERL is calculated, ‘power density at distance’ divides the power just calculated by the surface area of a sphere having a radius equal to the separation distance. The exposure ratio is the power density at the exposure distance divided by the exposure reference level (ERL). The ERL is calculated based on formulas provided in the standards, usually RSS-102 which is stricter. For convenience of the reader, the distance is also calculated at which the user would experience radiofrequency energy at the exposure reference level.

The analysis below deals with the most stringent requirements among the standards cited and may impose limits stricter than any particular standard. Different radio services in the device under test may be subject to different rules. To pass the requirement, the unit must be exempt from routine evaluation, or the exposure ratio must be no greater than 1.

RF Exposure Results

Each measurement is conducted from the antenna port with the transmitter on a specified channel and in a selected transmission protocol. The data record length is 100 msec for the Bluetooth-like protocols.

The analytical method reports the power in linear units, such as milliwatt, where the level is averaged over the measurement record. In addition, short-time duty cycle is reported since this is a portion of the over-all 6-minute time averaging result, but this factor is not double-counted in the final result for tuned time-averaged EIRP power. The key question addressed is whether the transmitters require further detailed analysis as described in the standards, or whether the exposure levels are so low that they are exempt from that further analysis.

Where standards cited here apply harmonized test methods and different limits, the stricter limit has applied. The results are shown below.

Frequency	(MHz)	2402	2404	2440	2478	2480
BT Low Energy	1 Mbps	**1.13**	**NT**	**1.11**	**NT**	**1.10**
BT Low Energy	2 Mbps	**NT**	**0.61**	**0.60**	**0.60**	**NT**
ANT	----	**2.57**	**NT**	**2.55**	**NT**	**2.52**

Table TR02.5: Transmit Power Summary in mW with RF Exposure analytical methods

Frequency	(MHz)	2402	2404	2440	2478	2480
BT Low Energy	1 Mbps	**0.467**	**NT**	**0.467**	**NT**	**0.467**
BT Low Energy	2 Mbps	**NT**	**0.280**	**0.280**	**0.280**	**NT**
ANT	----	**0.964**	**NT**	**0.963**	**NT**	**0.964**

Table TR02.6: Duty cycle embedded in power measurements

Parameter	Unit	Value
Radio type	---	**BLE**
Lowest Tx frequency	MHz	2402
Highest Tx frequency	MHz	2480
Separation distance	cm	0.5
Tx power to antenna	mW	1.13
Duty cycle embedded above	unitless	0.467
Antenna gain (unused if neg)	dBi	-1.915
Usage Rate	unitless	1.000
6-min time averaging factor	unitless	0.467
Tune-up tolerance	%	10.0
Tuned time-averaged EIRP power	**mW**	**1.2**
Controlled Environment?	----	No
Basic exemption level	mW	3.9
Body/Limb use	----	Body worn
Body/Limb multiplier	unitless	1
Final exemption level	**mW**	**3.9**
Judgment:		**Exempt**

Table TR02.7: Analysis of whether Bluetooth Low Energy results meet the exemption level

Parameter	Unit	Value
Radio type	---	**ANT**
Lowest Tx frequency	MHz	2402
Highest Tx frequency	MHz	2480
Separation distance	cm	0.5
Tx power to antenna	mW	2.57
Duty cycle embedded above	unitless	0.964
Antenna gain (unused if neg)	dBi	-1.915
Usage Rate	unitless	1.000
6-min time averaging factor	unitless	0.964
Tune-up tolerance	%	10.0
Tuned time-averaged EIRP power	**mW**	**2.8**
Controlled Environment?	----	No
Basic exemption level	mW	3.9
Body/Limb use	----	Body worn
Body/Limb multiplier	unitless	1
Final exemption level	**mW**	**3.9**
Judgment:		**Exempt**

Table TR02.8: Analysis of whether ANT results meet the exemption level

Setup Diagram

The following block diagrams show how the EUT, and test equipment is arranged for the test.

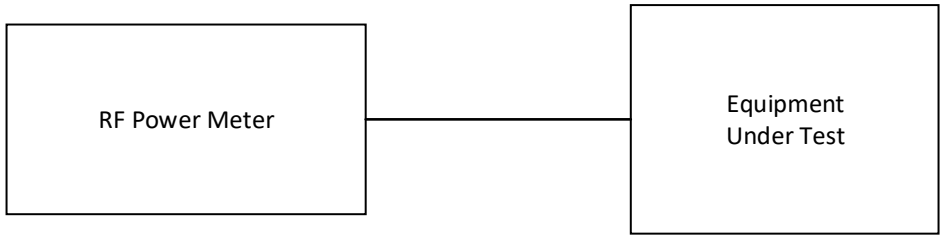


Figure TR02.1: Test equipment setup

This line is the end of the test record.

Test Record
Conducted Spurious Emissions
Test IDs TR27
Project GCL-0460

Test Date(s)	30 Apr 2024
Test Personnel	Jim Solum
Product Model	A04881
Serial Number tested	469824622
Operating Mode	M3 (BleTx)
Arrangement	A4 (Udc)
Input Power	5 Vdc
Test Standards:	FCC Part 15, ANSI C63.10, RSS-GEN, RSS-247 (as noted in Section 6 of the report).
Pass/Fail Judgment:	**PASS**
Test record created by:	**Jim Solum**
Date of this test record:	**03 May 2024**

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 44GHz	Keysight	N9048B	MY62220139	13-Mar-2024	15-Mar-2025

Table TR27.1: Test equipment used

Software used: Keysight PXE software A.33.03.

Test Method

The basic test standards provide options for the test method. The following test methods were applied.
ANSI C63.10: 11.11.2 and 11.11.3

Test Setup

This block diagram shows the test equipment setup.

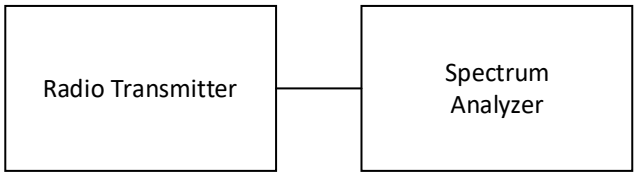


Figure TR27.1: Test setup

Test Data

The conducted spurious emission test measures the strength of intentional and unintentional radio signals conducted from the transmitter to the antenna across a wide range of frequencies. It does not evaluate whether intentional signals meet specific limits. Rather, it ensures that magnitudes unintentional signals are sufficiently reduced relative to the intentional signal to satisfy the requirements of the relevant standards.

This measurement requires that a coaxial feed line from the transmitter is available as a connector exterior to the test sample. This feed line and connector may be a part of the shipping product, or it may be a special modification to the product for testing purposes. The connector is attached via laboratory cables to the measurement instrument. The results have been adjusted to account for the losses in the laboratory cables. Where feasible, the losses of any added feed lines are also included in that adjustment.

Data is collected using the required detector function(s) across the frequency range. The instrument uses a 100 kHz bandwidth detector.

The data table below shows the final measurement data which may be at harmonics of the carrier, or at frequencies that represent one of the highest data points measured.

For BLE operating at 2 Mbps, the lowest operating frequency was 2404 MHz, and the highest operating frequency was 2478 MHz. For BLE, operating at 1 Mbps, the lowest operating frequency was 2402 MHz, and the highest operating frequency was 2480 MHz.

The peak level of the fundamental is also identified. The harmonics or spurious emissions must be reduced from this fundamental level by 20 dBc. This harmonic limit is calculated and used to determine compliance. A reduction from the carrier that is greater than 20 is a passing result. The minimum margin from the peak level for each mode are highlighted in yellow.

Data plots are provided for the worst-case data sets. One plot shows the spectrum at the carrier, and another shows the spectrum across the band. On this second plot, a green reference line is at approximately the 20 dBc maximum spurious emission level.

		2402 (04)	2440	2480 (78)
BLE	1 Mb	51.11	52.99	53.71
	2 Mb	51.03	52.17	53.50

Table TR27.2: Results Summary in dBc

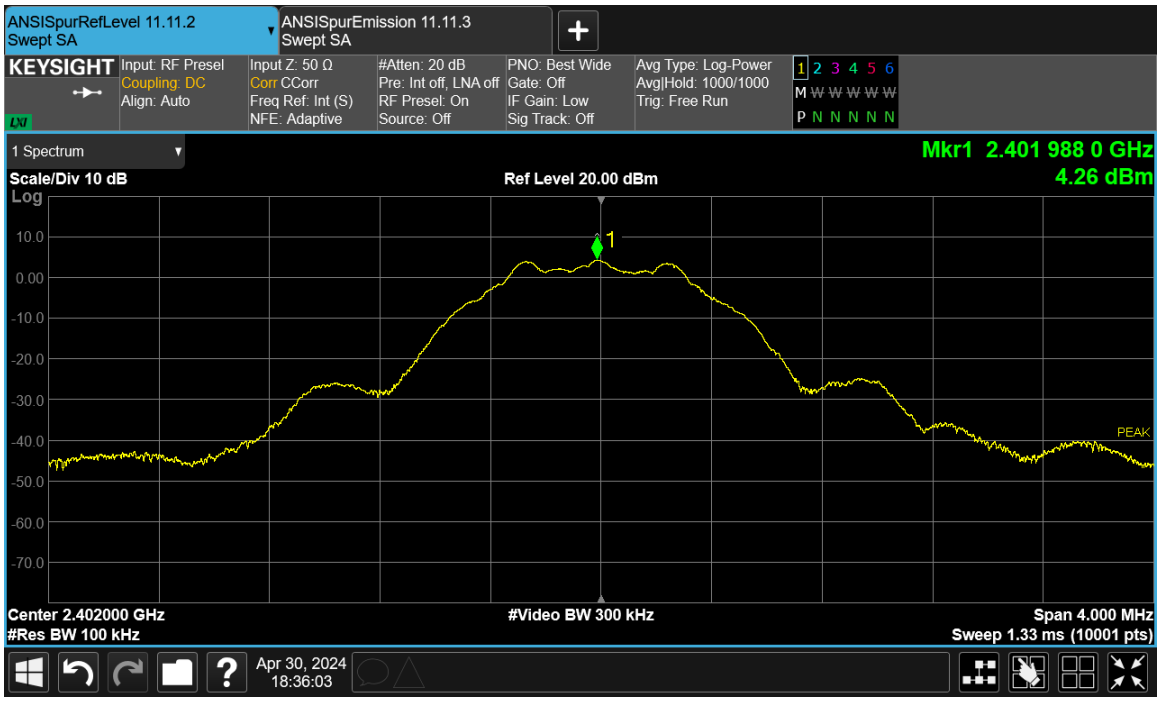


Figure TR27.2: Reference level measurement for Bluetooth BLE 1 Mbps at 2402 MHz

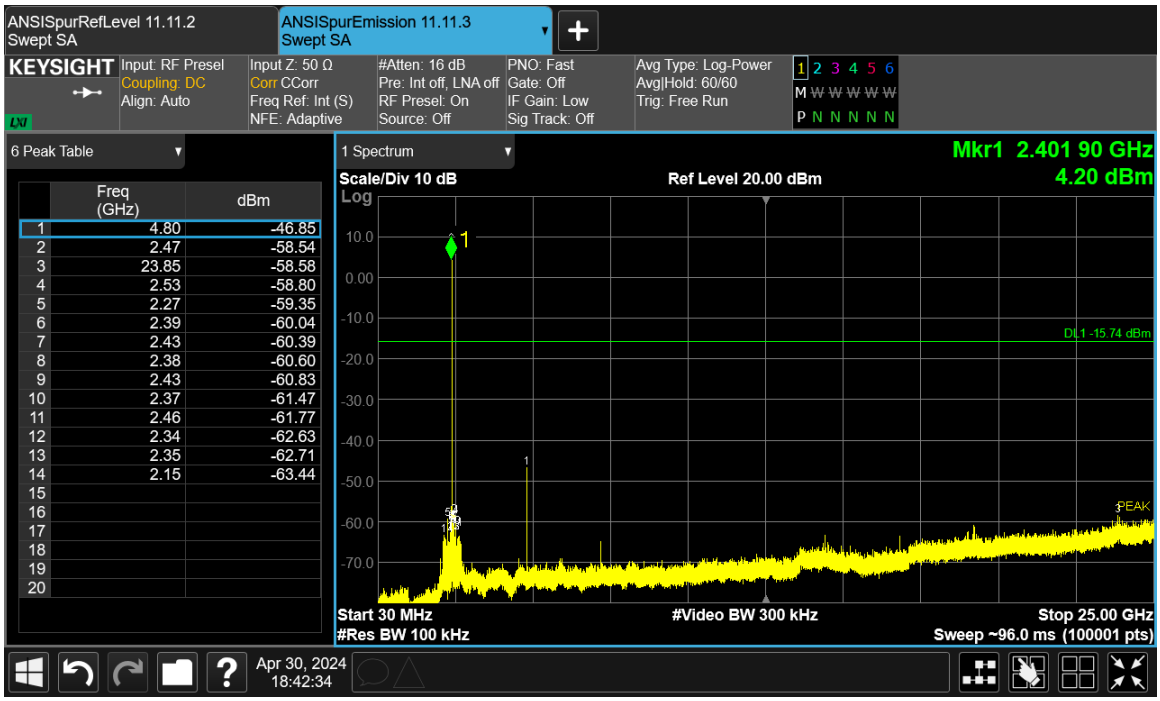


Figure TR27.3: Spectral data for Bluetooth BLE 1 Mbps at 2402 MHz

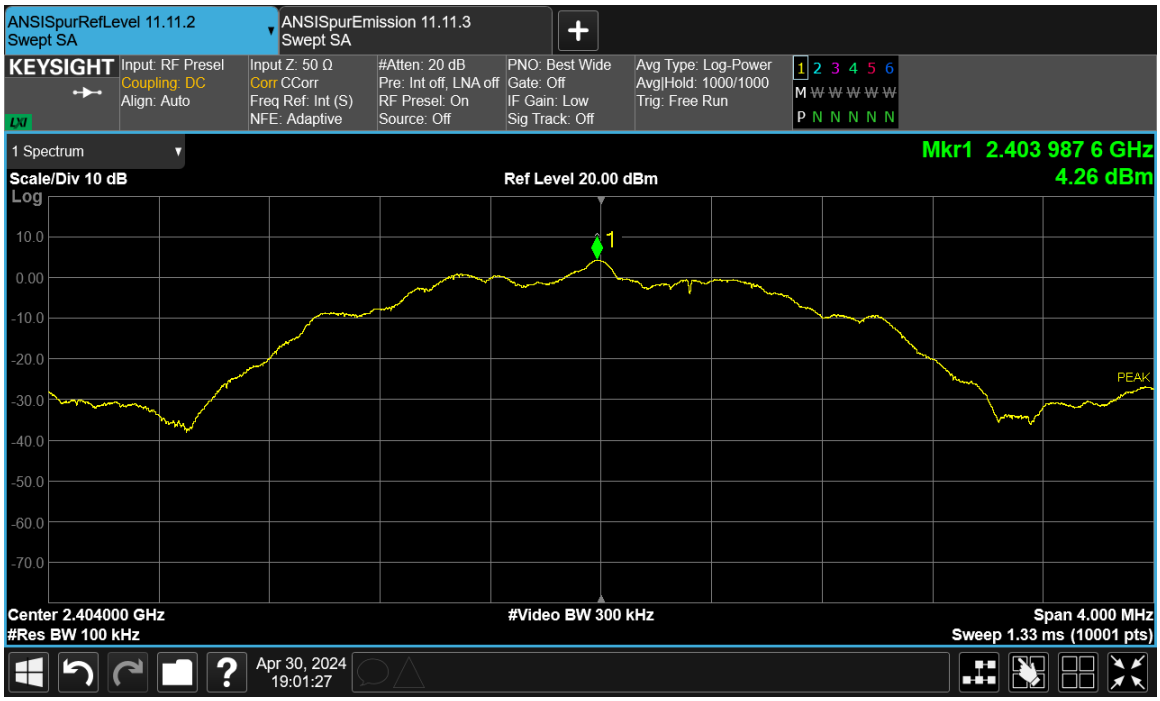


Figure TR27.4: Reference level measurement for Bluetooth BLE 2 Mbps at 2404 MHz

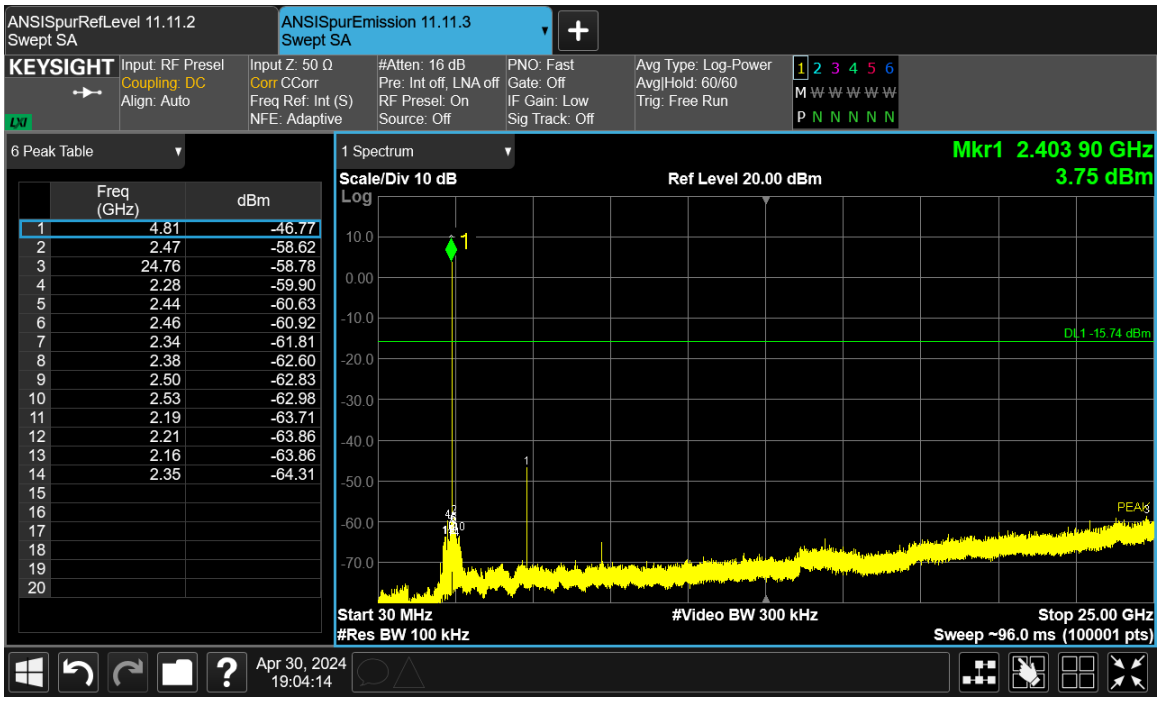


Figure TR27.5 Spectral data for Bluetooth BLE 2 Mbps at 2404 MHz

This line is the end of the test record.

Test Record
Radiated Emission Test RE03
Project GCL0460

Test Date(s)	25 Apr 2024
Test Personnel	David Kerr
Product Model	A04881
Serial Number tested	469824478
Operating Mode	M3 (BleTx)
Arrangement	A2 (Upwr)
Input Power	USB 5 Vdc
Test Standards:	FCC Part 15, ANSI C63.10, RSS-Gen (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:	**Andy Heier**
Date of this record:	**29 Apr 2024**

Original record, Version A.

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	00259208	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	10721	30-Aug-2023	1-Sep-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
Keysight PXE receiver software A.32.06, RE Signal Maximization Tool v2023Jul14

Test Data

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 band were made while the transmitter was tuned to its lowest frequency of 2402 MHz for the 1 Mbps data rate, and 2404 MHz for the 2 Mbps data rate. Measurements in the upper band were made while the transmitter was tuned to its highest frequency of 2480 MHz for the 1 Mbps data rate, and 2478 MHz for the 2 Mbps data rate.

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 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)	---
2390	54	74	35.075	50.852	18.925	23.148	115	3632	HORZ
2274	54	74	35.359	49.09	18.641	24.91	115	3632	HORZ

Table RE03.2: FCC restricted bands from 2200 to 2390 MHz (1 Mbps Orientation Y)

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	36.818	62.723	17.182	11.277	95	4000	VERT
2483.5	54	74	36.802	62.604	17.198	11.396	95	4000	VERT

Table RE03.3: FCC restricted band from 2483.5 to 2500 MHz (1 Mbps Orientation Z)

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)	---
2390	54	74	35.075	50.852	18.925	23.148	115	3632	HORZ
2274	54	74	35.359	49.09	18.641	24.91	115	3632	HORZ

Table RE03.4: FCC restricted bands from 2200 to 2390 MHz (2 Mbps Orientation Y)

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	36.818	62.723	17.182	11.277	95	4000	VERT
2483.5	54	74	36.802	62.604	17.198	11.396	95	4000	VERT

Table RE03.5: FCC restricted band from 2483.5 to 2500 MHz (2 Mbps Orientation Z)

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

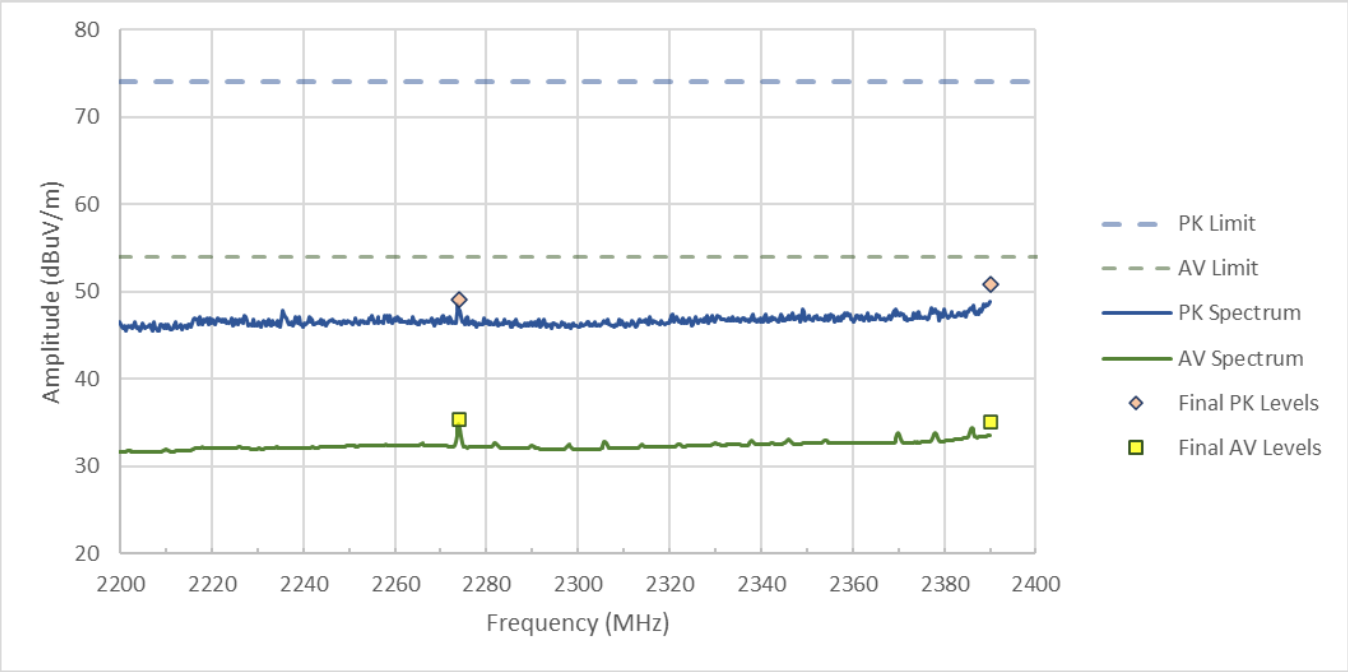


Figure RE03.1: FCC restricted band spectral data from 2200 to 2390 MHz (1 Mbps)

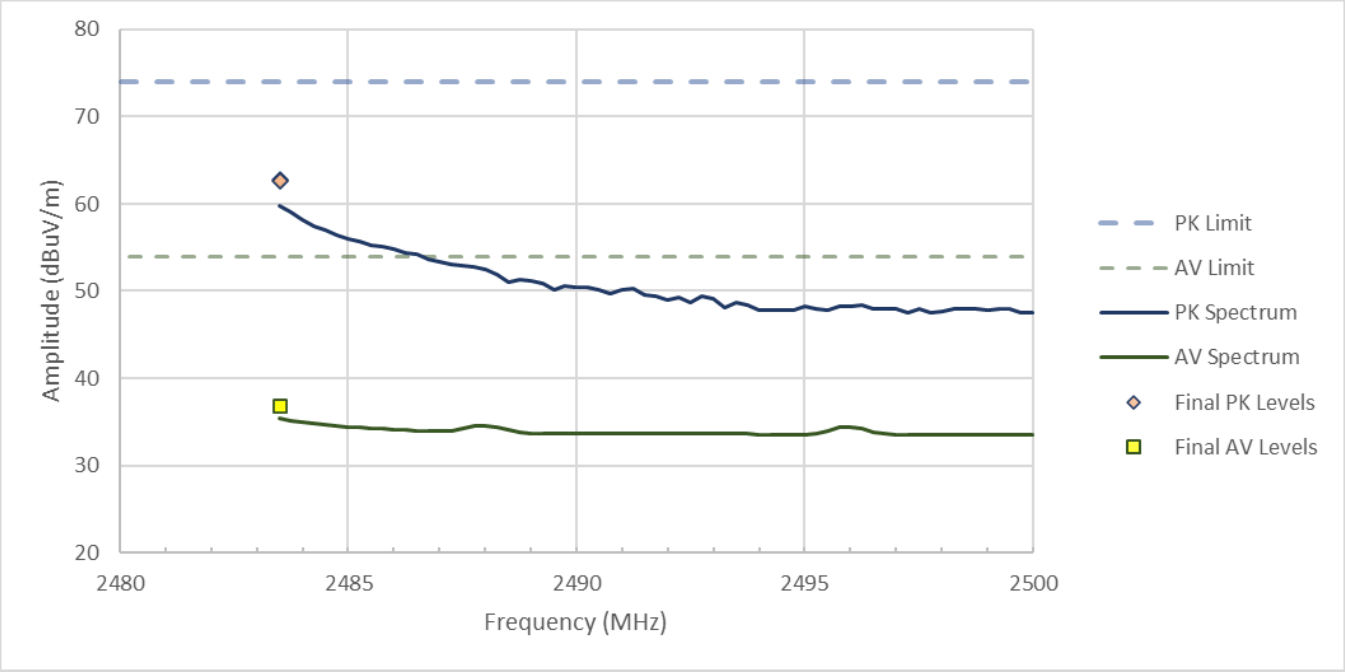


Figure RE03.2: FCC restricted band spectral data from 2483.5 to 2500 MHz (1 Mbps)

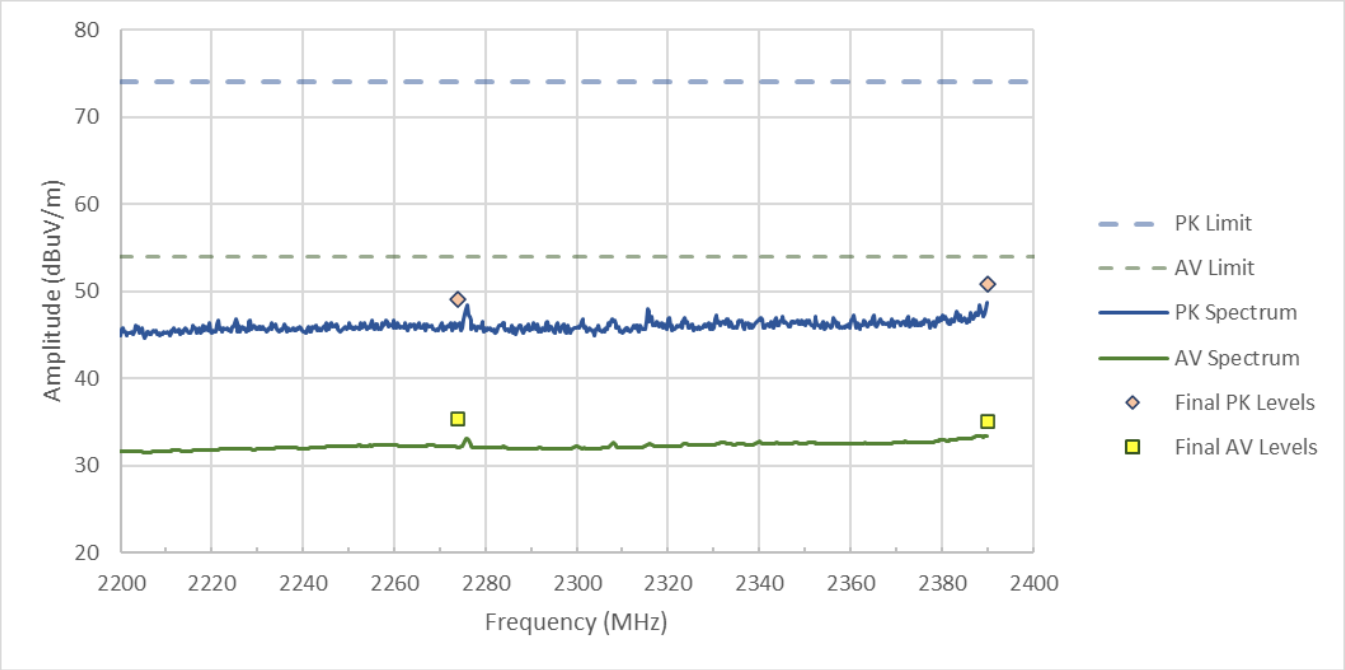


Figure RE03.3: FCC restricted band spectral data from 2200 to 2390 MHz (2 Mbps)

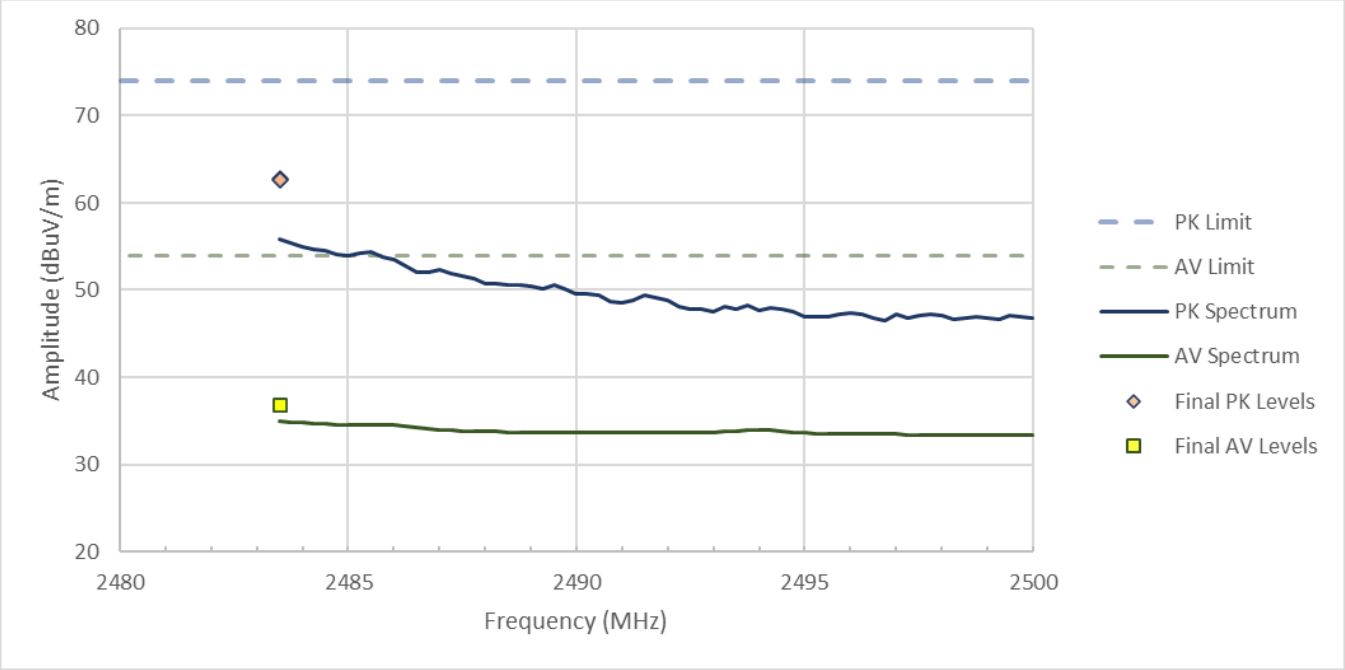


Figure RE03.4: FCC restricted band spectral data from 2483.5 to 2500 MHz (2 Mbps)

Setup Photographs

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

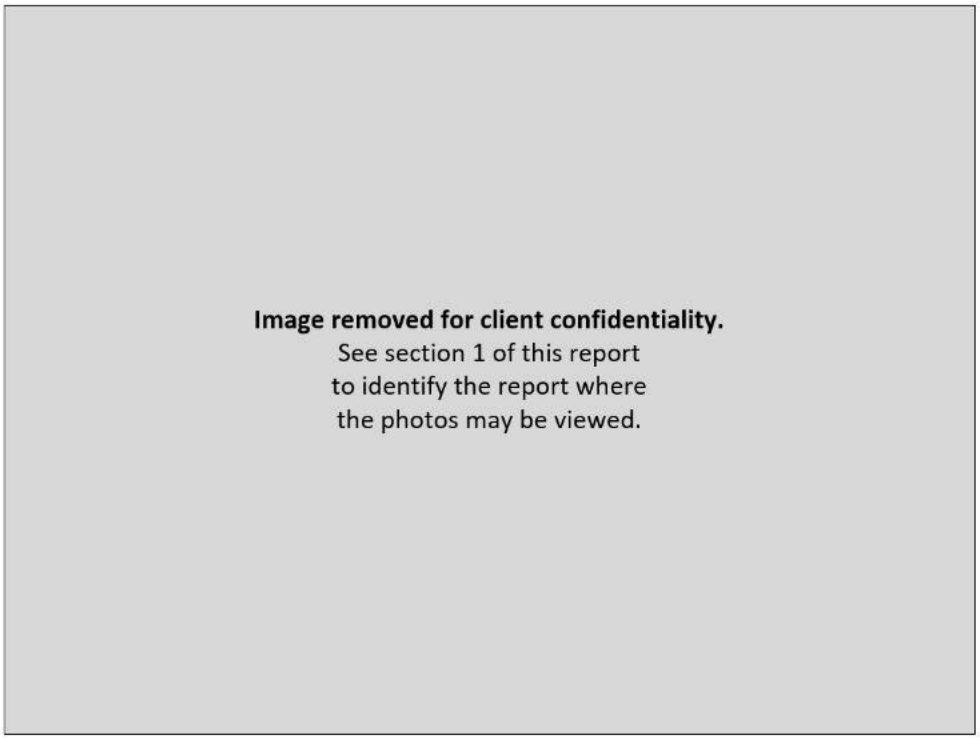


Figure RE03.5: EUT test setup, primary view (Orientation Y)

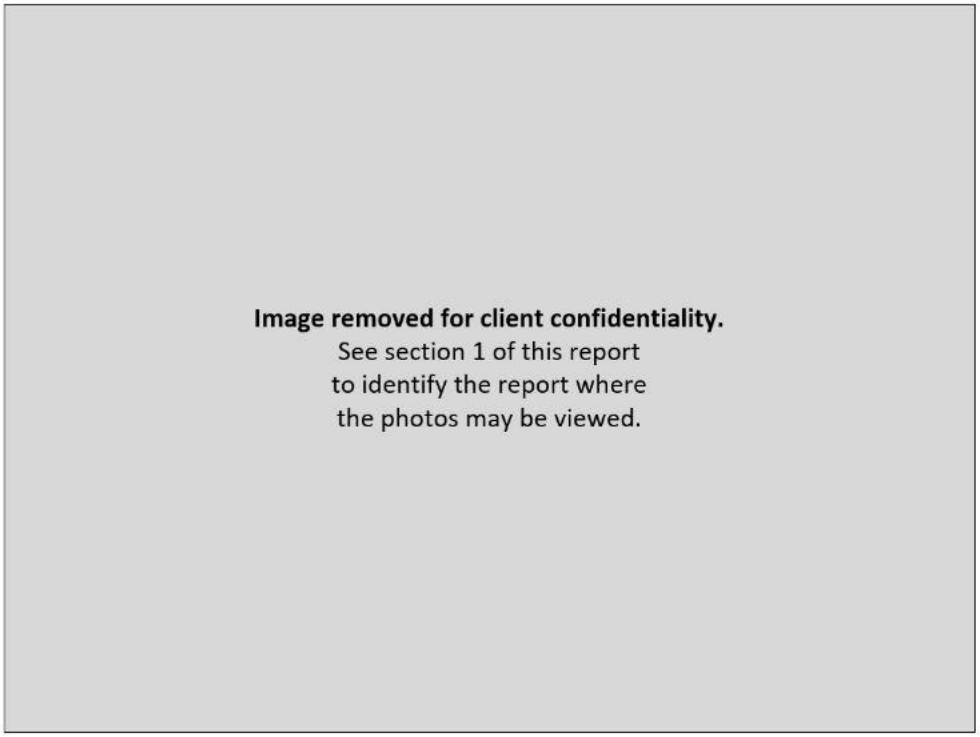


Figure RE03.6: EUT test setup, reverse view (Orientation Y)

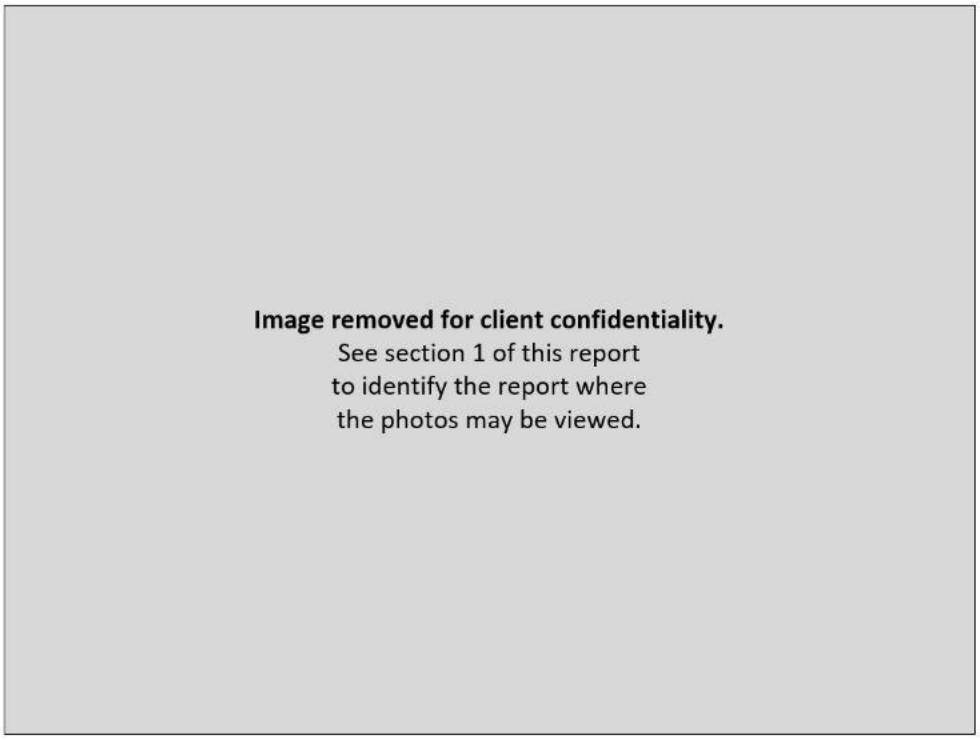


Figure RE03.7: EUT test setup, primary view (Orientation Z)

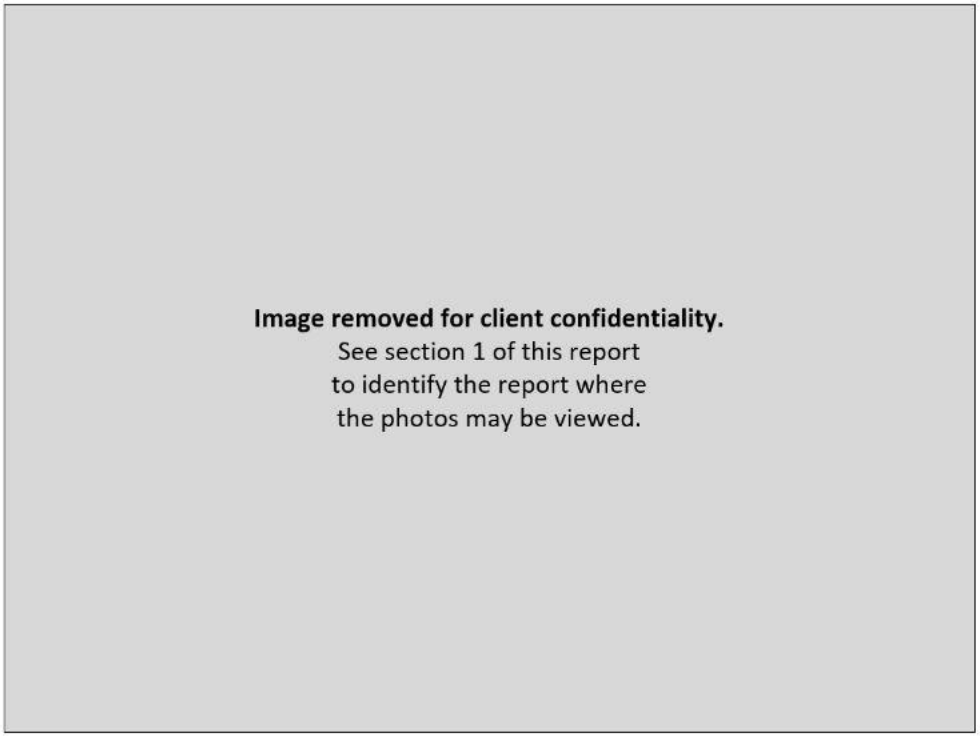


Figure RE03.8: EUT test setup, primary view (Orientation Z)

This line is the end of the test record.

Test Record
Transmitter Power Spectral Density
Test IDs TR19
Project GCL-0460

Test Date(s)	19 Apr 2023
Test Personnel	Majid Farah
Product Model	A04881
Serial Number tested	469824622
Operating Mode	M3 (BleTx)
Arrangement	A4 (Udc)
Input Power	5Vdc
Test Standards:	FCC Part 15, ANSI C63.10, RSS-247, (as noted in Section 6 of the report).
Antenna Gain	-1.915 dBi, as reported by the client
Radio Protocol	Bluetooth Low Energy (BLE)
Pass/Fail Judgment:	**PASS**
Test record created by:	**Jim Solum**
Date of this record:	**29 Apr 2023**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
MXE Receiver 8.4 GHz	Keysight	N9038B	MY63460112	28-Feb-2024	1-Mar-2025

Table TR19.1: Test equipment used

Software Used: Keysight PXE software A.37.02

Test Method

The basic test standards provide options for the test method. The following test methods were applied.

ANSI C63.10: PKPSD (11.10.2)

Test Setup

This block diagram shows the test equipment setup.

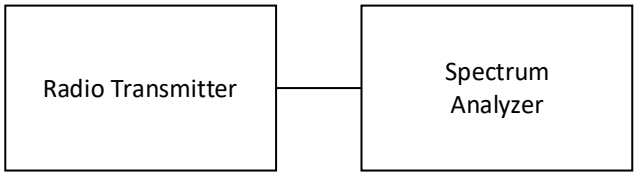


Figure TR19.1: Test setup

Test Data

Each measurement is conducted from the antenna port with the transmitter on a specified channel and in a selected transmission protocol. The results include the effects of any measurement cable losses. Results reported are in units of dBm/Bandwidth and do not include the effect of antenna gain. The standard limit is 8 dBm / 3 kHz and meeting the limit with higher resolution bandwidths is permitted. All data met the limit using a 3 kHz resolution bandwidth.

For BLE operating at 2 Mbps, the lowest operating frequency was 2404 MHz, and the highest operating frequency was 2478 MHz. For BLE operating at 1 Mbps, the lowest operating frequency was 2402 MHz, and the highest operating frequency was 2480 MHz.

The highest PSD levels for each mode are highlighted in yellow, and graphical results are provided for those cases.

	2402 (04)	2440	2480 (78)
BLE 1 Mbps	**-12.29**	**-12.27**	**-12.19**
BLE 2 Mbps	**-13.73**	**-13.74**	**-13.81**

Table TR19.2: Summary of results in dBm / 3 kHz

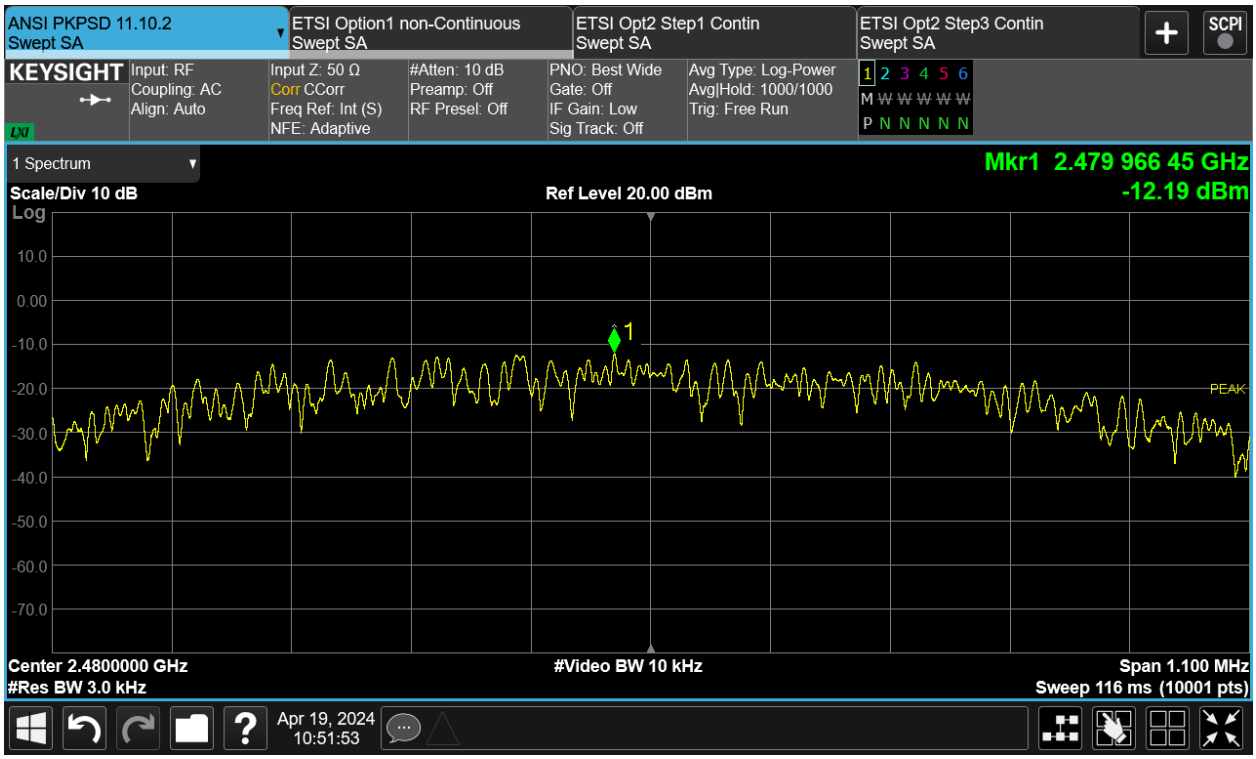


Figure TR19.2: Test data for BLE 1 Mbps, 2480 MHz

This line is the end of the test record.

Test Record
Transmitter Stability in Extreme Conditions
Test IDs TR43
Project GCL-0460

Test Date(s)	15 Oct 2023
Test Personnel	Majid Farah
Product Model	A04881
Serial Number tested	469824622
Operating Mode	M3 (BleTx)
Arrangement	A4 (Udc)
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), ANT
Pass/Fail Judgment:	**PASS**
Test record created by:	**Majid Farah**
Date this record:	**02 May 2024**

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
MXE Receiver 8.4 GHz	Keysight	N9038B	MY63460112	28-Feb-2024	1-Mar-2025
Thermometer	Thermco	ACCD370P	210607316	21-Sep-2023	15-Sep-2024
Barometer	Traceable	6453	221702700	3-Aug-2022	1-Aug-2024
Programmable DC power source	Keithley	2260B-30-72 720 W	1411917	21-Apr-2023	21-May-2024
Thermal Chamber	Tenney	T2RC	32774-02	Calibration	Not Required

Table TR43.1: Equipment used

Software Used: PXE Software Revision A.37.02

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. Markers 1 and 3 indicate the spectral peak while markers 2 and 4 are at the 2400 MHz or 2483.5 MHz band edge. Markers 2 and 4 in the table below spectral data show differences to Markers 1 and 3.

Tx Mode	Temp	Volts	Low Ch.	High Ch.
	˚C	Vdc	dBc	dBc
BLE 1Mbps	60	5	33.88	34.29
BLE 1Mbps	50	5	32.84	33.67
BLE 1Mbps	40	5	32.36	36.83
BLE 1Mbps	30	5	32.11	33.65
BLE 1Mbps	20	5	30.93	32.96
BLE 1Mbps	10	5	29.75	32.94
BLE 1Mbps	0	5	33.63	32.59
BLE 1Mbps	-10	5	28.07	31.76
BLE 1Mbps	-20	5	30.47	32.43

Table TR43.2 Difference between peak and band edge levels for BLE 1 Mbps transmissions during temperature variations

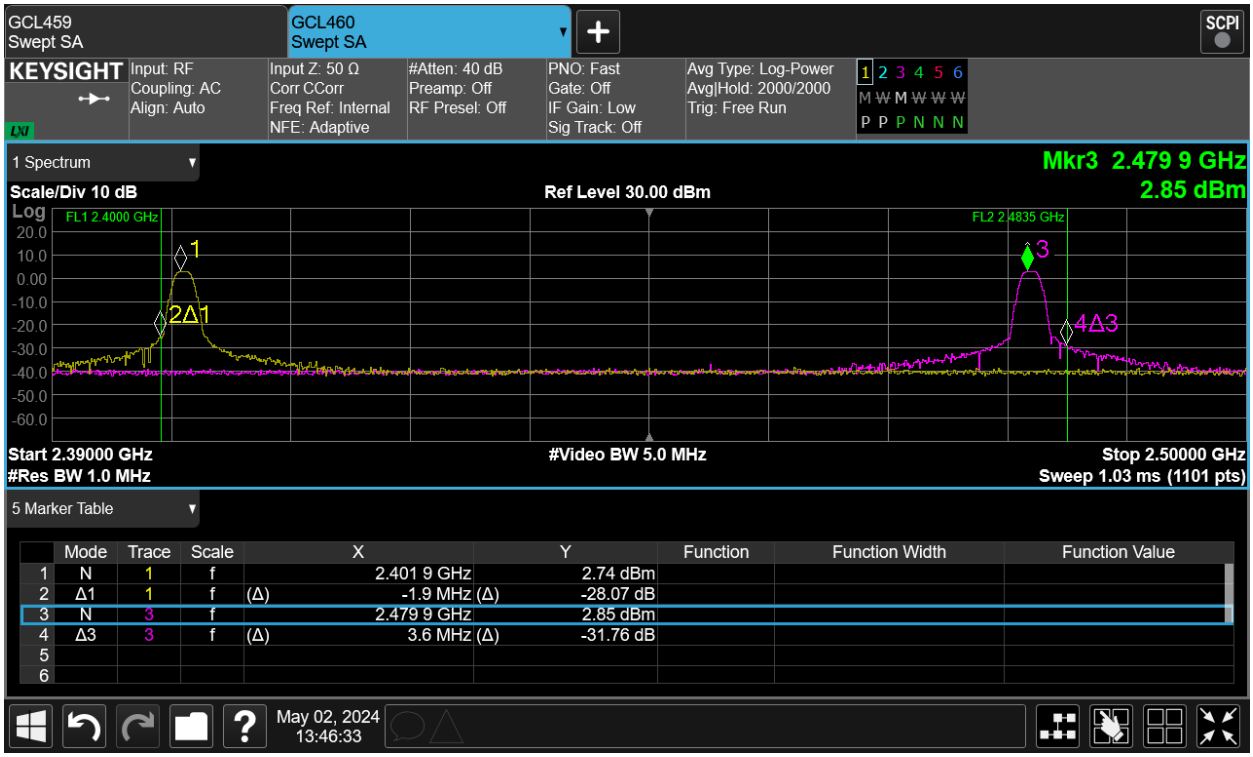


Figure TR43.1: Spectral data for BLE 1 Mbps at -10 °C which represent low and high channel

Tx Mode	Temp	Volts	Low Ch.	High Ch.
	˚C	Vdc	dBc	dBc
BLE 1Mbps	20	4.25	30.57	32.39
BLE 1Mbps	20	5	30.93	32.96
BLE 1Mbps	20	5.75	31.20	32.68

Table TR43.3 Difference between peak and band edge levels for BLE 1 Mbps transmissions at 20 °C during voltage variations

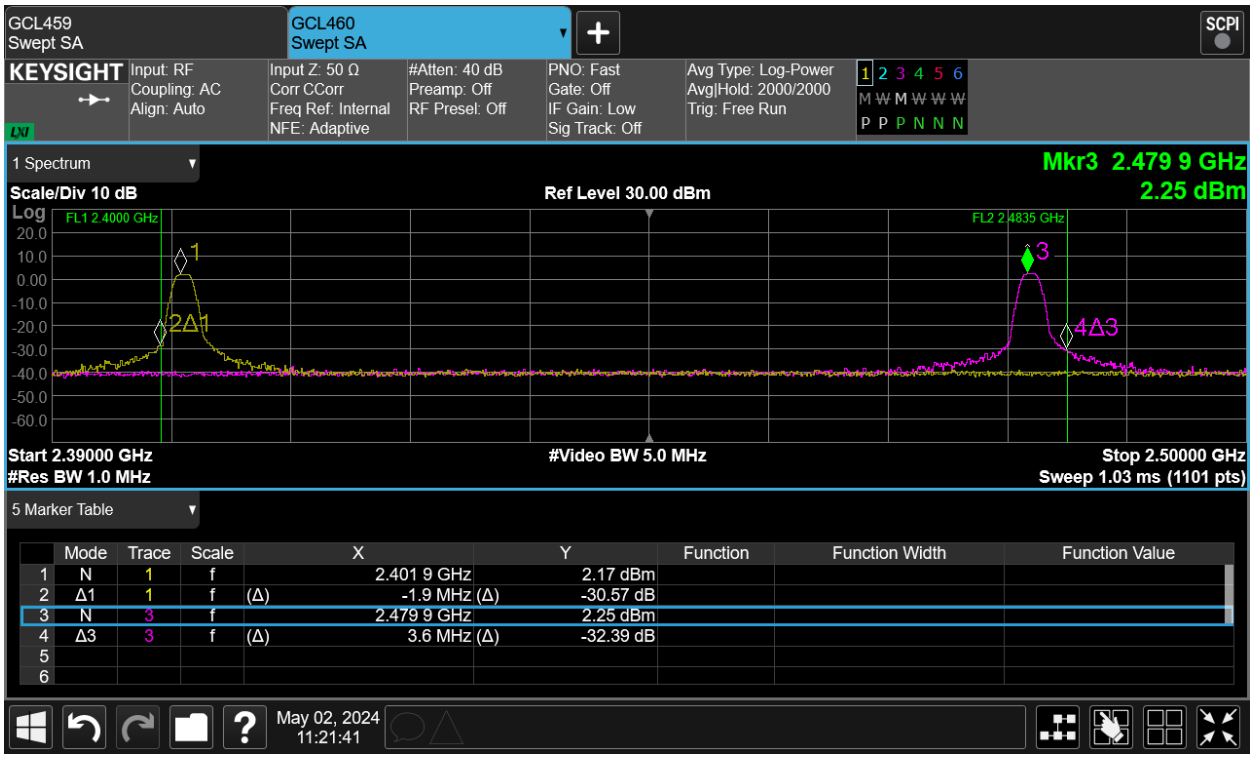


Figure TR43.2: Spectral data for BLE 1 Mbps at 20 °C which represent low and high channel at 4.25 V

Setup Block Diagram

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

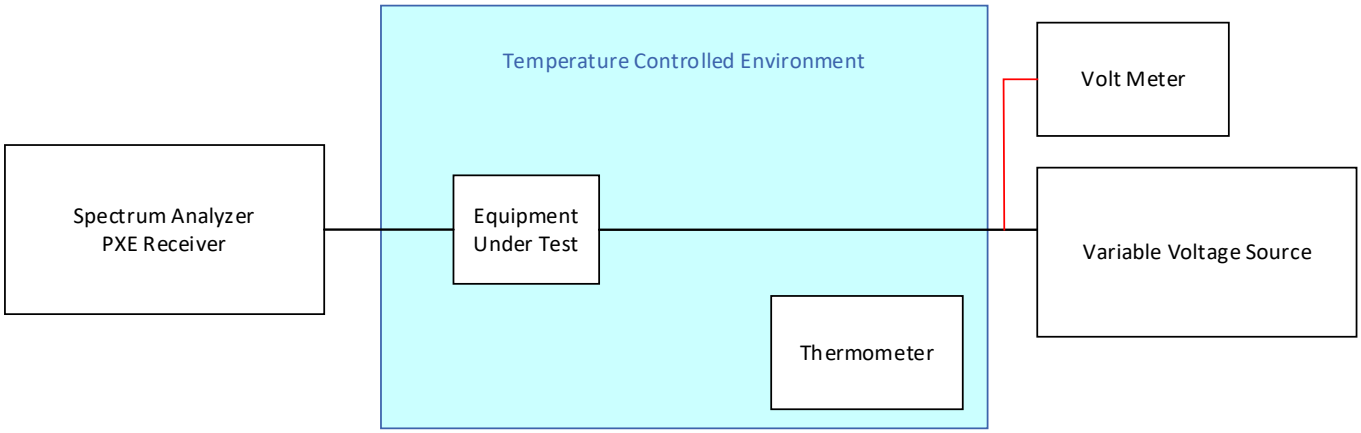


Figure TR43.3: Schematic drawing of the test equipment setup

This line is the end of the test record.

Test Record
Radiated Emission Test RE05
Project GCL0460

Test Date(s)	25 Apr 2024
Test Personnel	David Kerr
Product Model	A04881
Serial Number tested	469824478
Operating Mode	M3 (BleTx)
Arrangement	A2 (Upwr)
Input Power	USB 5 Vdc
Test Standards:	FCC Part 15, RSS-Gen, ANSI C63.10 (as noted in Section 6 of the report).
Frequency Range:	1 GHz to 2.2 GHz
Pass/Fail Judgment:	**PASS**
Test record created by:	**David A Kerr**
Date of this record:	**25 Apr 2024**

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	227596	14-Sep-2023	14-Sep-2025
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
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

Table RE05.1: Test Equipment Used

Software Used: Keysight PXE receiver 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, 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 2.2 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. Unintentional radio emission limits are not applied to intentional radio signals.

In this test, fewer than six emissions were observed within 20 dB of the limit.

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		
2138.000	V	32.7	46.0	-1.2	31.5	44.8	54.0	74.0	22.5	29.2	281.9	78.0

Table RE05.2: Emission summary (BLE 1Mbps 2402MHz)

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		
2176.000	V	32.8	46.6	-1.2	31.6	45.4	54.0	74.0	22.4	28.6	364.9	257.0

Table RE05.3: Emission summary (BLE 1Mbps 2440MHz)

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		
2137.250	V	32.7	46.0	-1.2	31.5	44.8	54.0	74.0	22.5	29.2	338.5	287.0

Table RE05.4: Emission summary (BLE 1Mbps 2480MHz)

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

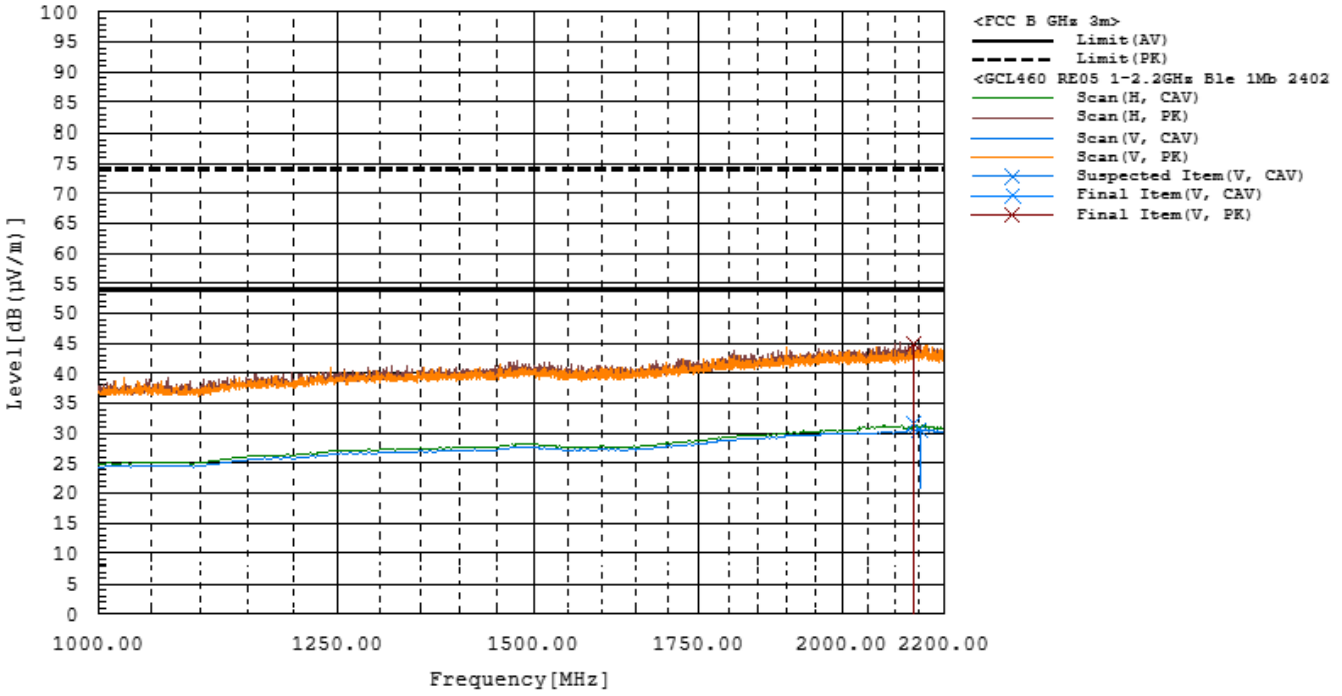


Figure RE05.1: Spectral data (BLE 1 Mbps 2402MHz)

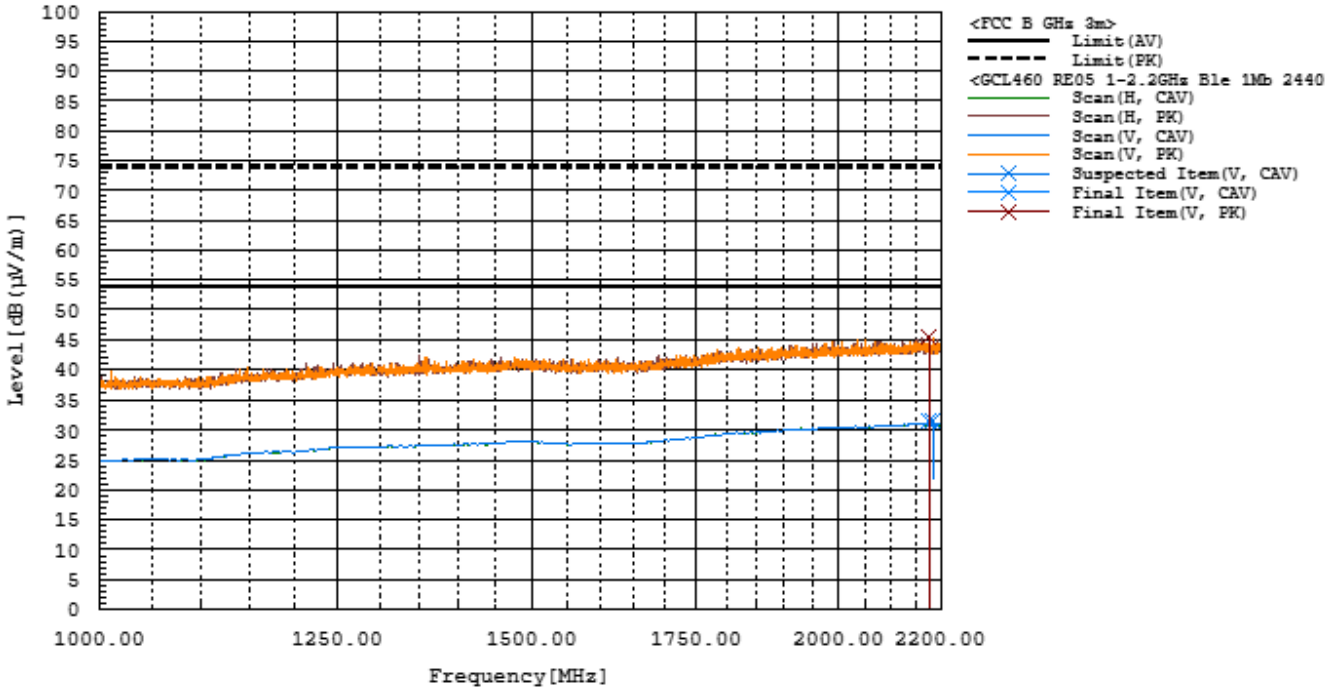


Figure RE05.2: Spectral data (BLE 1 Mbps 2440MHz)

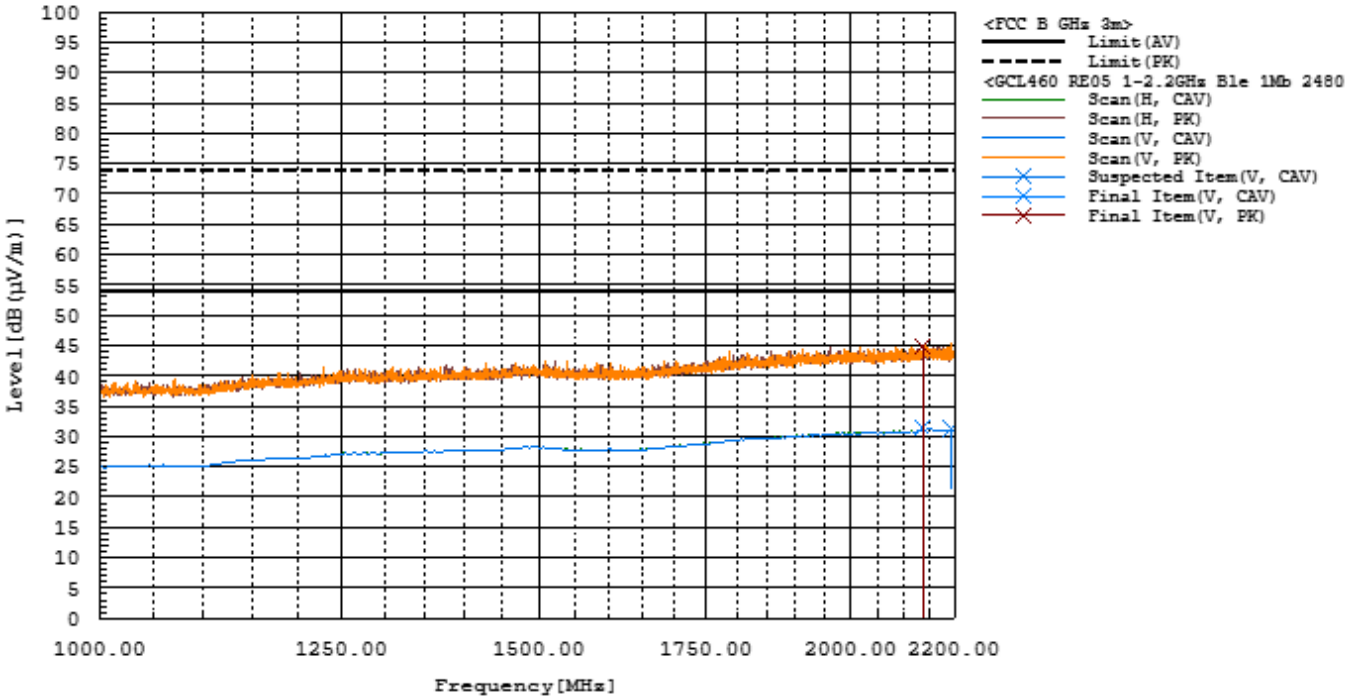


Figure RE05.3: Spectral data (BLE 1 Mbps 2480MHz)

Setup Photographs

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

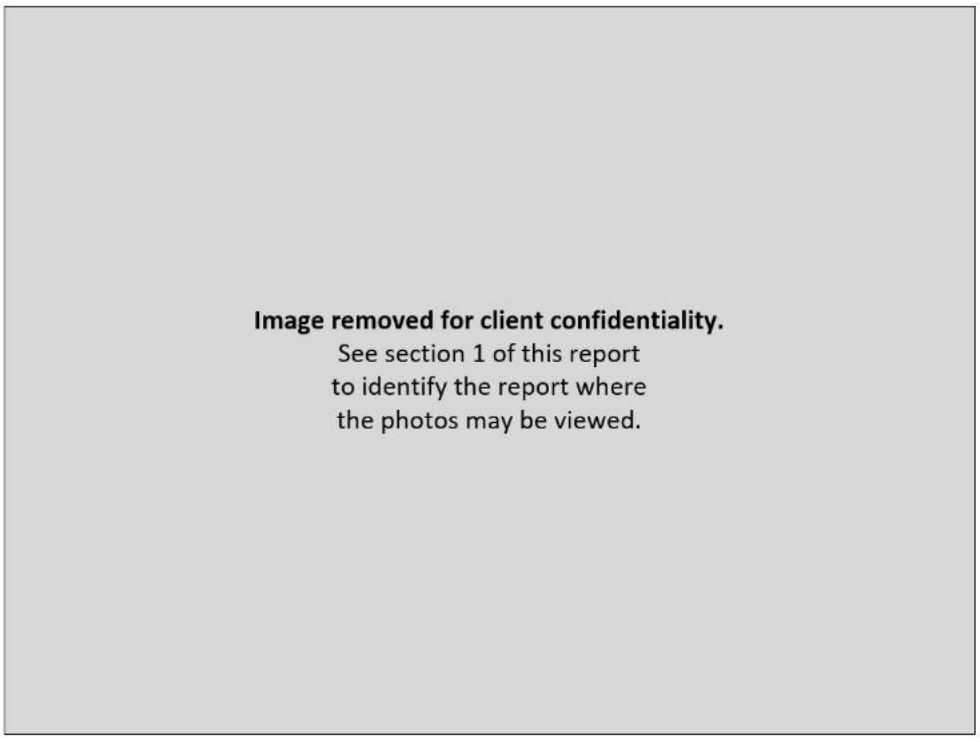


Figure RE05.4: EUT test setup, front view (Y orientation)

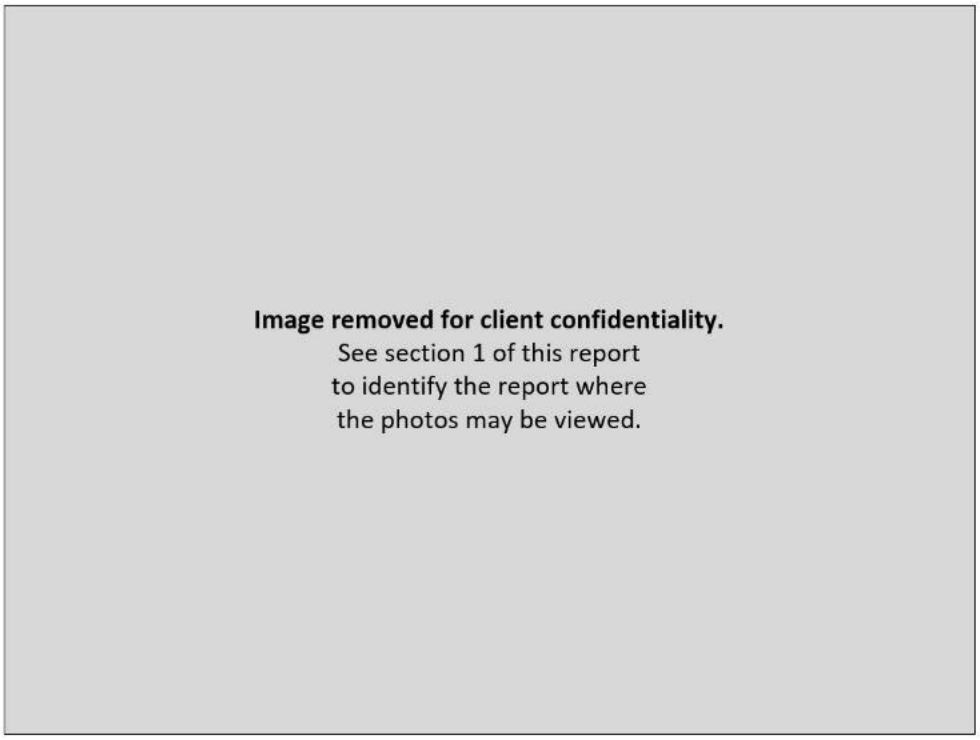


Figure RE05.5: EUT test setup, reverse view (Y orientation)

This line is the end of the test record.

Test Record
Radiated Emission Test RE07
Project GCL0460

Test Date(s)	18 Apr 2024
Test Personnel	Jim Solum
Product Model	A04881
Serial Number tested	469824478
Operating Mode	M3 (BleTx)
Arrangement	A2 (Upwr)
Input Power	5 Vdc
Test Standards:	FCC Part 15, ANSI C63.10, RSS-247 (as noted in Section 6 of the report).
Frequency Range:	30 MHz to 1000 MHz
Pass/Fail Judgment:	**PASS**
Test record created by:	**Jim Solum**
Date of this record:	**19 Apr 2024**

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	2-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 RE07.1: 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, 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 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. Unintentional radio emission limits are not applied to intentional radio signals.

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		
39.690	V	11.4	17.6	29.0	40.0	11.0	100.0	313.0
44.970	H	2.5	15.3	17.8	40.0	22.2	362.3	329.0
49.590	V	13.8	14.1	27.9	40.0	12.1	100.0	169.0
536.040	V	-0.4	30.9	30.5	46.0	15.5	153.0	341.0
779.550	V	-0.1	34.1	34.0	46.0	12.0	298.6	351.0
945.360	H	-0.1	36.6	36.5	46.0	9.5	387.8	233.0

Table RE07.2: Emission summary

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

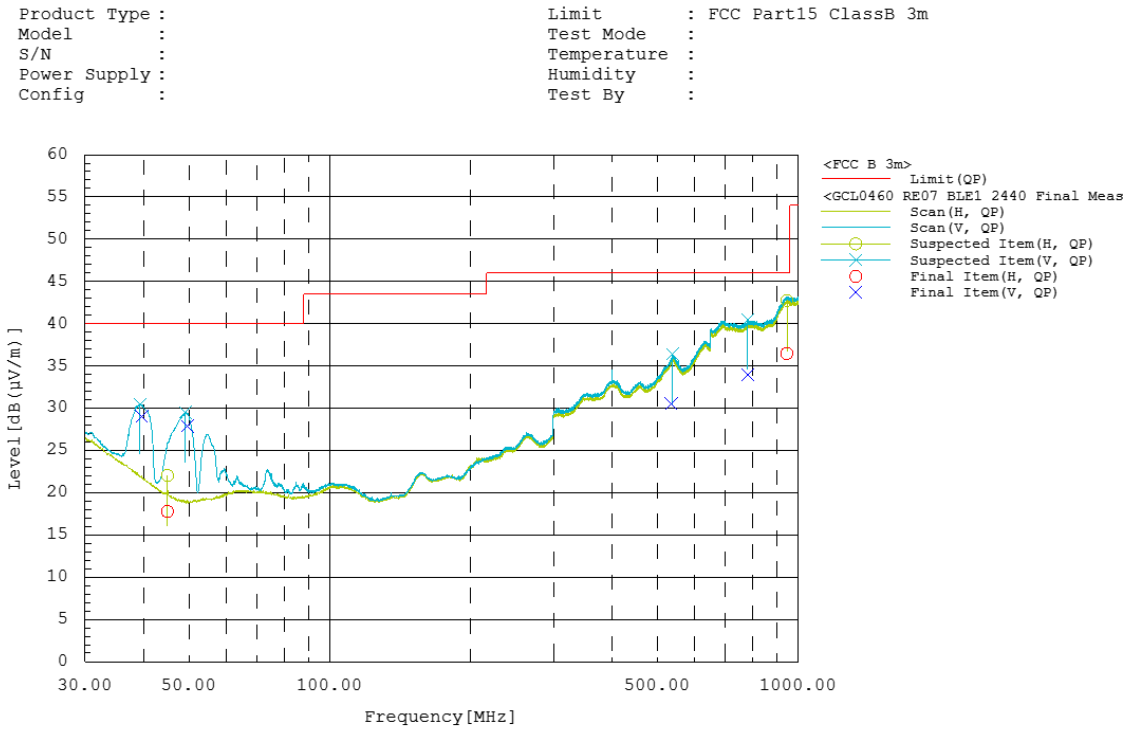


Figure RE07.1: Spectral data

Setup Photographs

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

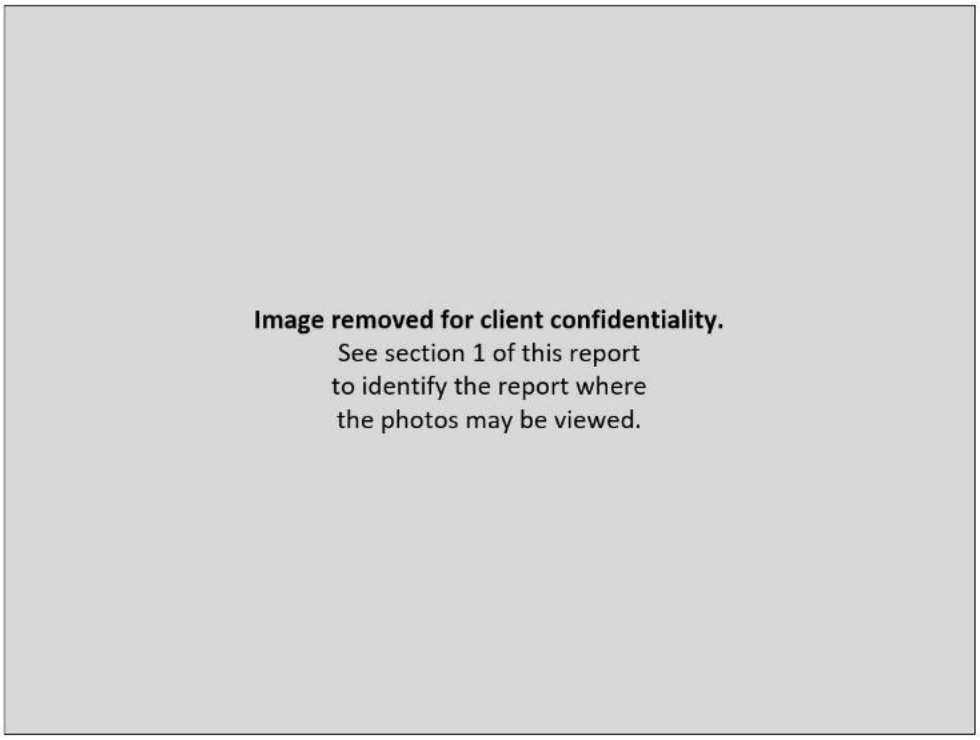


Figure RE07.2: EUT test setup, front view (Z orientation)

Figure RE07.3: EUT test setup, reverse view (Z orientation)

This line is the end of the test record.

Test Record
Conducted Emissions Mains Test CE01
Project GCL0460

Test Date(s)	16 May 2024
Test Personnel	Aditya Prakash
Product Model	A04881
Serial Number tested	469824478
Operating Mode	M3 (BleTx)
Arrangement	A2 (Upwr)
Input Power	115 V/ 60 Hz
Test Standards:	FCC Part 15, ANSI C63.10, RSS-247 (as noted in Section 6 of the report).
Frequency Range:	150 kHz to 30 MHz
Pass/Fail Judgment:	**PASS**
Test record created by:	**Andy Heier**
Date of this record:	**23 May 2024**

Original record, Version A.

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 44GHz	Keysight	N9048B	MY62220139	13-Mar-2024	15-Mar-2025
LISN multiline; 15A to 9kHz	Com-Power	LI-215A	192027	19-Feb-2024	15-Feb-2027

Table CE01.1: Test Equipment Used

Software Used
Keysight PXE software A.33.03; CE Mains 150kHz to 30M Data Analysis V2 2021Jun10.xlsx

Test Data

The conducted emission test process began with a set of preliminary scans on both power conductors using both Quasi-Peak and Average detectors across the frequency range. Where the test standard requires cable manipulation, one or more likely worst-case frequencies selected by the test personnel. Cables were manipulated to find the maximal signal strength while observing the receiver levels at those selected frequencies. At each of the frequencies selected for final measurements, Quasi-peak and Average detector readings were taken on each conductor.

The table shows the selected final measurement data. It includes at least the six strongest emissions observed relative to the limit lines, along with other data points of interest. The yellow highlight indicates the data points with the least margin to the quasi-peak detector limit and the average detector limit. A positive margin value indicates that the emission was below the test limit. The test limit is the Composite FCC/CISPR Class B Limit.

In this test, fewer than six emissions were observed within 20 dB of the limit.

Frequency (kHz)	QP Limit (dBuV)	AV Limit (dBuV)	L1 QP (dBuV)	L2 QP (dBuV)	L1 AV (dBuV)	L2 AV (dBuV)	QP Margin (dB)	AV Margin (dB)
164	65.28	55.28	25.36	21.79	21.20	17.59	39.92	34.09
436	57.14	47.14	23.71	20.50	17.59	14.78	33.43	29.55
1673	56.00	46.00	22.37	21.00	16.69	15.82	33.63	29.31

Table CE01.2: Emission summary (BLE)

The graph below shows preliminary scan data as continuous curves. Superimposed are the final measurement data points reported in the table above.

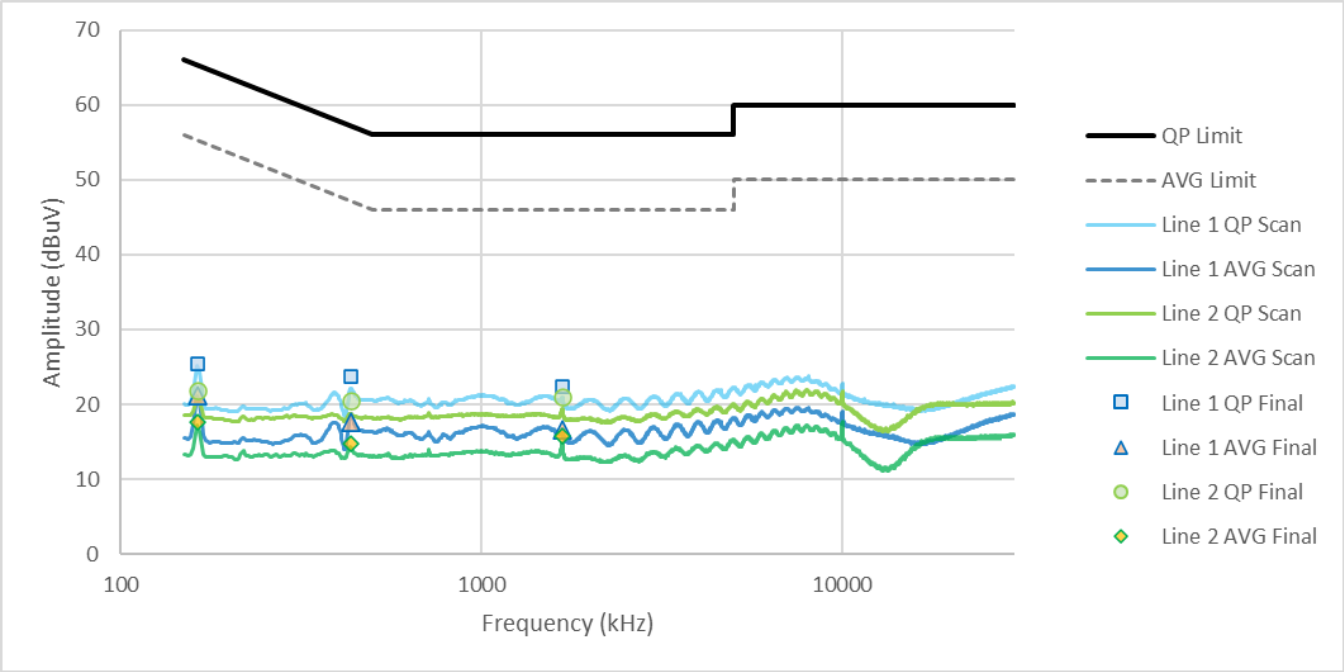


Figure CE01.1: Spectral data (BLE)

Setup Photographs

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

Figure CE01.2: Test setup, front view

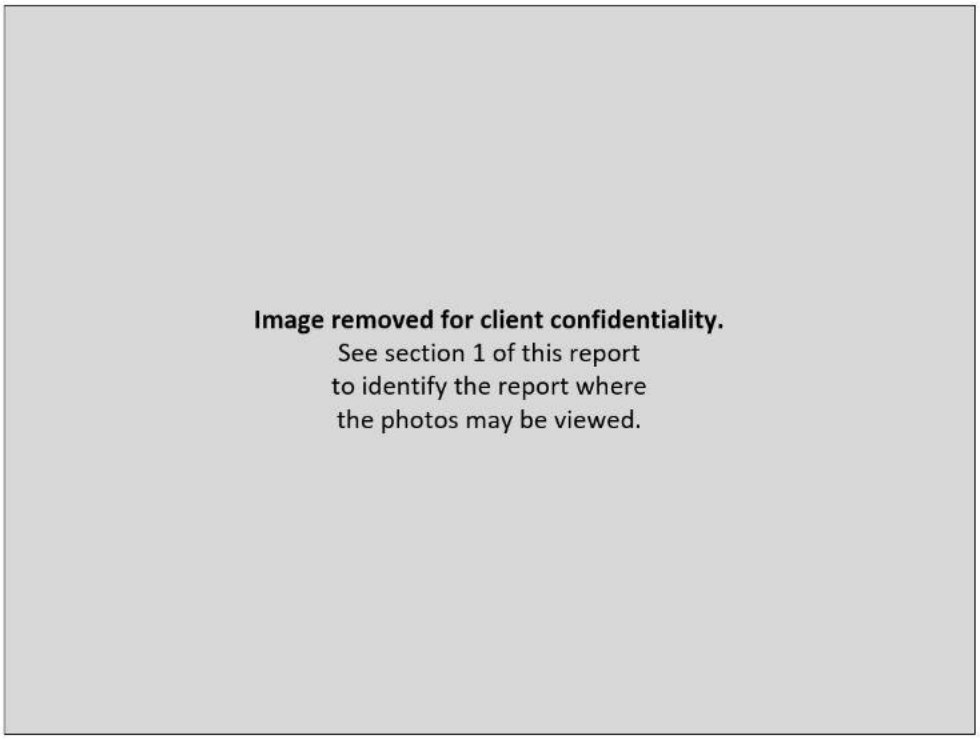


Figure CE01.3: Test setup, side view

This line is the end of the test record.

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.

This is the final page of the report.