Test Report 2024-177

Version C
Issued 17 Jan 2024

Project GCL-0635
Model Identifier A04896
Primary Test Standard
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-04896
IC ID:	1792A-04896

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 Bluetooth Low Energy (BLE) transceiver. Test records within this report may include data for the ANT transmitter, but ANT is addressed in a separate report (GCL Test Report 2024-178). 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 its 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 706.7 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 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 7.76 dBm or 5.97 mW.	PASS	20
Antenna Gain	The radio should not focus too much energy in 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 the antenna gain was 1.6 dBi and will document antenna gain separately.	NT	NT
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 11.6 dB below the applicable limits.	PASS	23
Power Spectral Density	The radio must not focus too much radio energy in 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 -8.39 dBm in a band of at least 3 kHz.	PASS	28
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 subjected 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]	NT	NT	NT
Unwanted Emissions (Radiated Spurious)	While transmitting, the radiated emissions must not be too strong. [15.209, RSS-Gen at 8.9]	Emissions other than the fundamental and harmonics must meet the 'Class B' limits. The measured emissions had at least 4.6 dB of margin. Preliminary testing and PSD data identified BLE 1 Mbps as the worst case modulation.	PASS	31
Unwanted Emissions (Mains Conducted)	While transmitting, the emissions conducted into the power mains must not be too strong. [15.207, RSS-Gen at 8.8]	N/A	N/A	N/A

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

<u>Report Organization</u>
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
11. 3m RF Chamber Block Diagrams

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 2024-174. 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:	24 Sep 2024
Test Start Date:	25 October 2024
Test End Date:	17 January 2025

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 Aditya Prakash and initially issued on 10 Dec 2024 as Version A. On December 17 2024, version B was created to update the 99% occupied bandwidth data. Version C, issued on 17 Jan 2024, updated the data for Transmit Power, DTS Bandwidth, and Power Spectral Density. Conducted spurious emission data was removed. In addition, the sample serial number was corrected for the Transmitter bandwidth test (TR10).

Report Technical Review: GCL Only

David Arnett
Technical Lead EMC Engineer

Report Approval: GCL Only

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:
None

5. Description of the Equipment Tested

5.1 Unique Identification

Product Model	A04896
Serial Numbers Tested	3490522727, 3490522799, 4196561404

This product tested is digital device and data transceiver.

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

5.2 Key Parameters

EUT Input Power:	3 Vdc battery
I/O Ports:	None
Radio Transceivers:	Bluetooth Low Energy, ANT
Radio Receivers:	None
Primary Functions:	Text
Typical use:	Body worn
Highest internal frequency:	2.480 GHz
Firmware Revision	2.41.1

5.3 Operating modes

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

Mode 1: M3 (BleTx). BLE in transmit mode
Mode 2: M4 (BleLnk). BLE linked to companion device.
Mode 3: M5 (AntTx). ANT in transmit mode
Mode 4: M6 (AntLnk). ANT linked to companion device.

5.4 EUT Arrangement

During 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 powered by 3 Vdc power supply. The EUT had a special interconnect that allowed us to replace the battery with a special contact. It provided the desired voltage to the product battery terminals for longer periods of time adequate for testing. This arrangement only exists for lab testing, not for field use. See the block diagram in Figure 1.

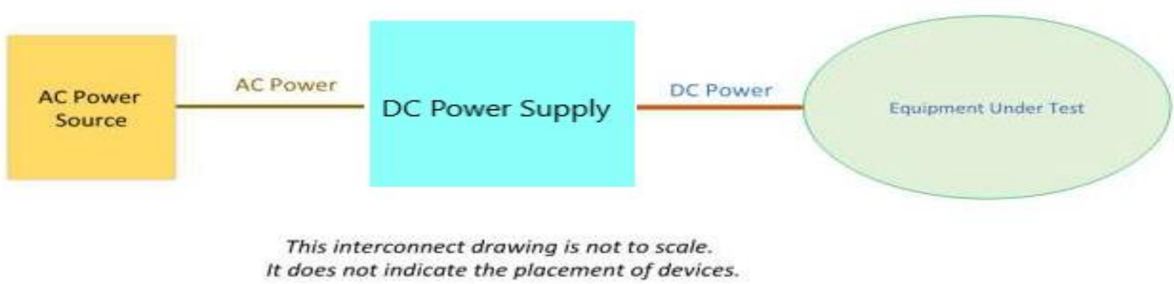

Figure 1: Block diagram of equipment arrangement A2

5.5 Associated Equipment (AE) used

Description	Manufacturer	Model	Serial Number
Chest Strap	Garmin	013-00271-B1	None

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

A 1 Megaohm resistor assembly with wires and attachment clips was connected across the sensor pads of the chest strap. It simulated the typical skin resistance necessary for the test sample to turn on and operate.

5.6 Cables used

None

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: 2020, and ANSI C63.10: 2020 +Cor 1: 2023
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.

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 µsec 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 dBµV) + (9.812 dB) + (0.216 dB) = 17.173 dBµV

8.2 Radiated Emissions at 630 MHz

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

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

8.3 Radiated Emissions at 2.7 GHz

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

(43.72 dBµV) + (32.22 dB/m) + (-36.09 dB) = 39.85 dBµV/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:	19.8 to 21.2 °C
Relative Humidity:	42.4% to 55% (non-condensing)
Barometric Pressure	96.5 to 99.2 kPa

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
Barometer	Traceable	6453	240300703	9-Apr-2024	9-Apr-2027

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.

11. 3m RF Chamber Block Diagrams

The 3m chamber has three basic configurations which are shown in the figures below. These figures are not to scale.

Figure 1 shows a semi anechoic setup which is typically used for frequencies below 1 GHz. In this example, the antenna is mounted on a mast capable of 1-4 m elevation changes. If a preamplifier or RF filter is used, they are located at or just below floor level. The receiver is outside the chamber, typically in an adjacent separate shielded room.

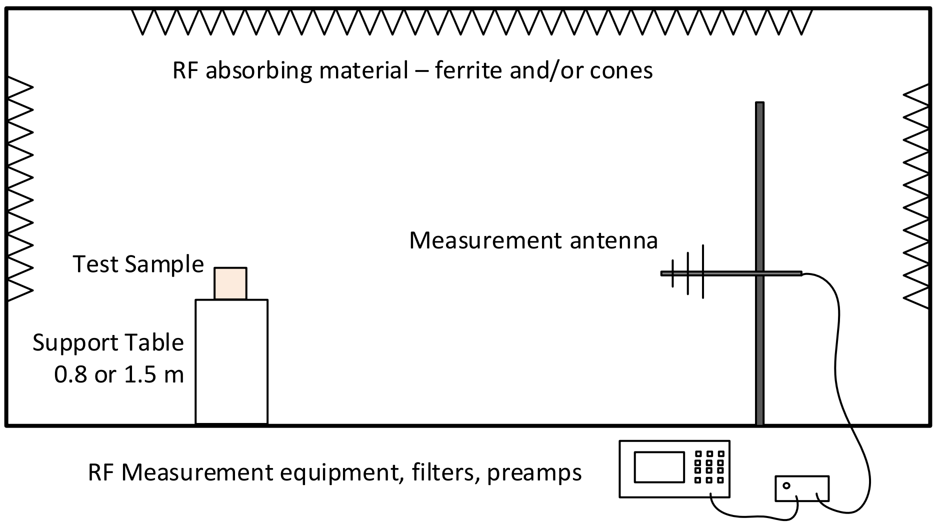

Figure 1: Typical configuration for measurements below 1 GHz

Figure 2 shows an FSOATS setup which is typically used for frequencies above 1 GHz but below an upper limit such as 14 or 18 GHz. In this example, the antenna is mounted on a mast capable of 1-4 m elevation changes and bore sighting. If a preamplifier or RF filter is used, they are located at or just below floor level. The receiver is outside the chamber, typically in an adjacent separate shielded room.

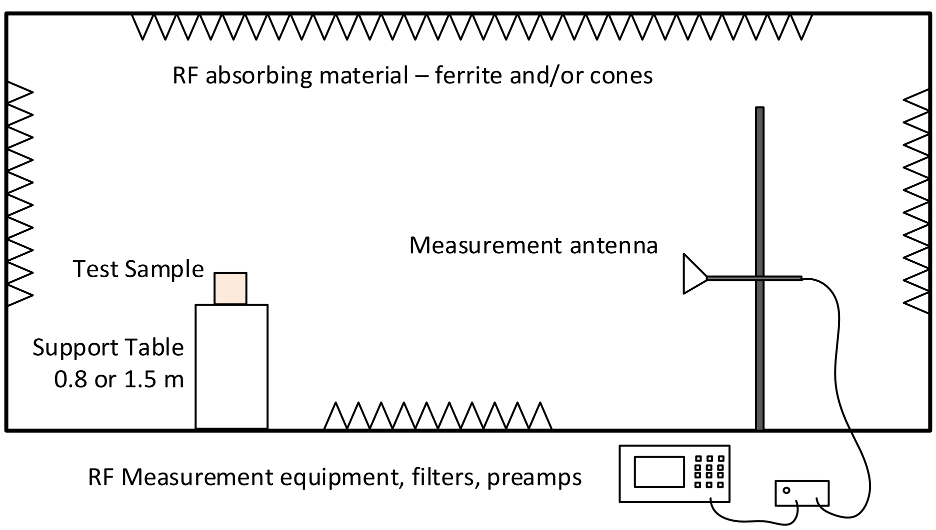

Figure 2: Typical configuration for measurements between 1 GHz and 14 GHz

Figure 3 shows an alternate FSOATS setup which is typically used for frequencies above 14 GHz. In this example, the antenna is mounted on a mast capable of 1-4 m elevation changes and bore sighting. A preamplifier is located on the mast just behind the antenna. The receiver is located in the chamber near floor level but outside the antenna beam. The receiver may be operated manually by an operator in the chamber and or remotely via an Ethernet connection.

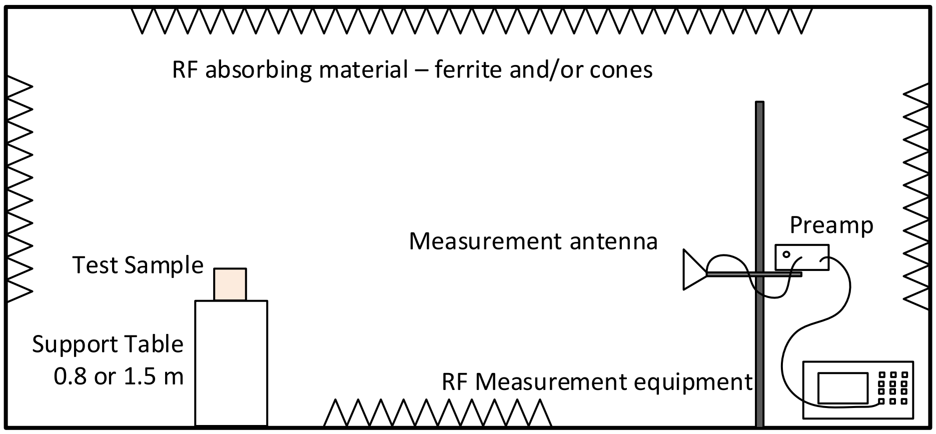

Figure 3: Typical configuration for measurements above 14 GHz

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 TR71
Project GCL-0635

Test Date(s)	17 Jan 2025
Test Personnel	Majid Farah
Product Model	A04896
Serial Number tested	4196561404
Operating Mode	M3 (BleTx)
Arrangement	A2 (Pwr)
Input Power	3 Vdc
Test Standards:	FCC Part 15, ANSI C63.10, RSS-GEN, RSS-247 (as noted in Section 6 of the report).
Radio Protocol	Bluetooth Low Energy (BLE)
Radio Band	2400 to 2483.5 MHz
Pass/Fail Judgment:	**PASS**
Test record created by:	Majid Farah
Date of this record:	17 Jan 2025

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 44GHz	Keysight	N9048B	MY62220139	21-Oct-2024	21-Oct-2025

Table TR71.1: List of test equipment used

Test Software Used: Keysight PXE software 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.

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

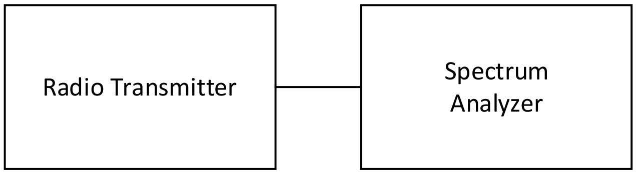

Figure TR71.1: Test setup

Test Data

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

The 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 worst case. All radios reported here are judged to have met this requirement.

	2402 (04)	2440	2480 (78)
BLE 1 Mbps	**706.7**	**708.1**	**714.8**
BLE 2 Mbps	**1156.0**	**1154.0**	**1149.0**

Table TR71.2: Summary of bandwidth data in kHz for BLE mode

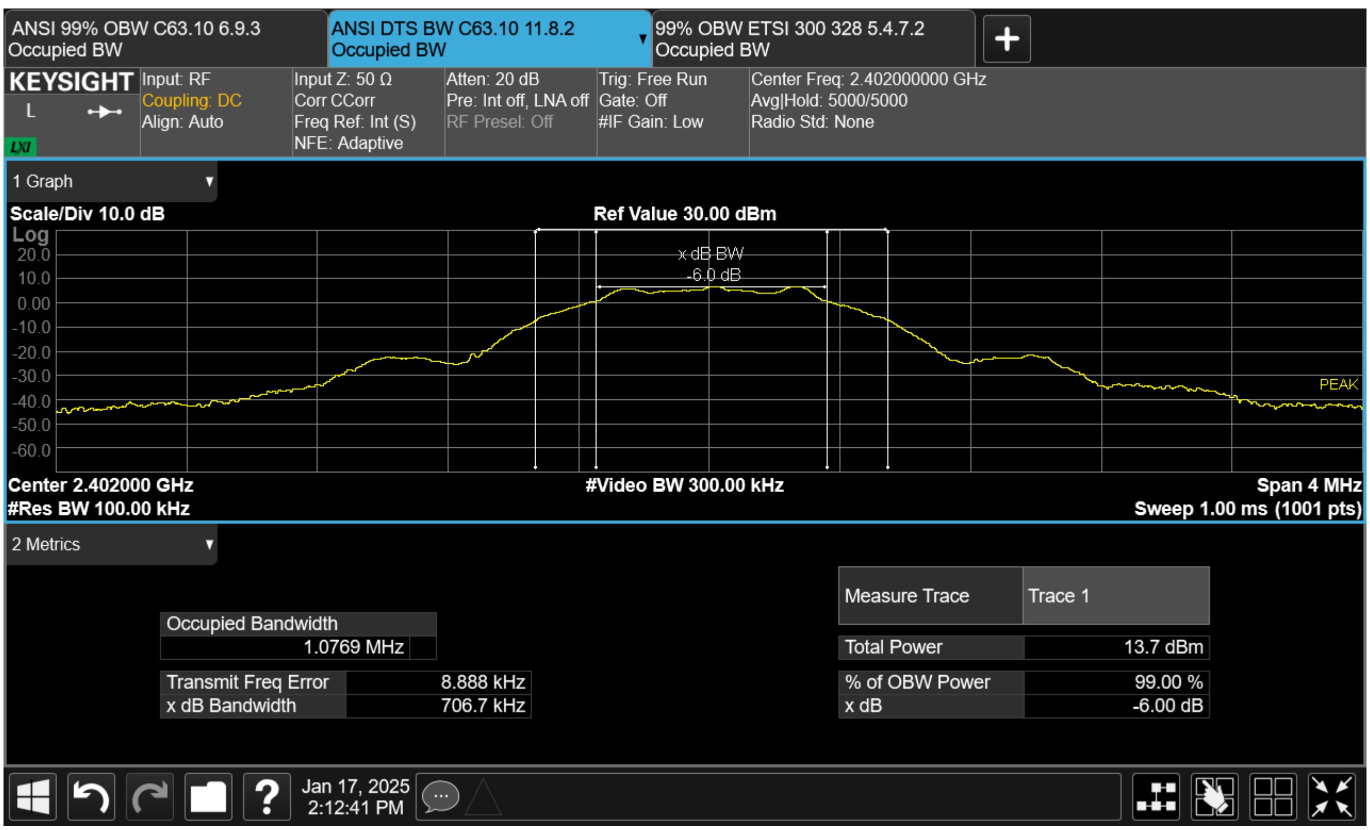

Figure TR71.2: Bandwidth data for BLE 1 Mbps at 2402 MHz

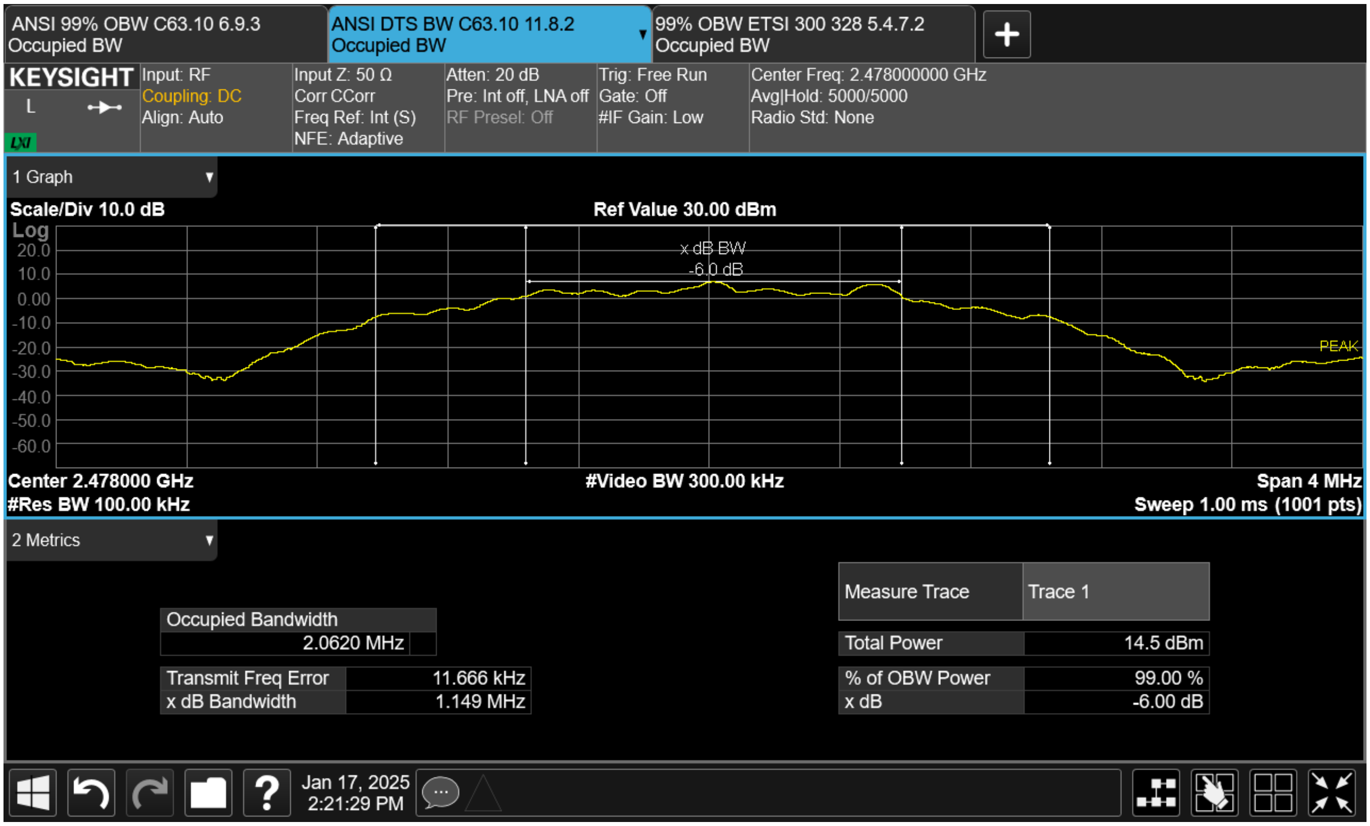

Figure TR71.3: Bandwidth data for BLE 2 Mbps at 2478 MHz

This line is the end of the test record.

Test Record
Transmitter Bandwidth Tests
Test IDs TR10
Project GCL0635

Test Date(s)	16 December 2024
Test Personnel	Jim Solum
Product Model	A04896
Serial Number tested	3490522727
Operating Mode	M3 (BleTx)
Arrangement	A2 (Pwr)
Input Power	USB 3 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)
Radio Band	2480 to 2483.5 MHz
Pass/Fail Judgment:	**Reported**
Test record created by:	Aditya Prakash
Date of this record:	17 Jan 2025

Original record, Version was created on 1 November 2024 by Vladimir Tolstik. On 17 December, version B of this record was created by Aditya Prakash to address to corrections and updating new data in the record. Version C, issued on 17 Jan 2025, corrected the sample serial number.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 26 GHz	Keysight	N9048B	MY59290135	24-Oct-2024	24-Oct-2025
Antenna, Horn, 1-18 GHz	ETS Lindgren	3117	00259208	30-May-2024	30-May-2026
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	7-Mar-2023	7-Mar-2026
DMM Multimeter	Fluke	79 III	71740743	11-Apr-2024	11-Apr-2027
Regulated DC power supply	Triplett	PS305	C233005744	Calibration	Not Required

Table TR10.1 Equipment Used

Software used: Keysight PXE software A.32.06

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 photograph shows the test equipment setup. See also section 11 of the report, figure 2.

Image removed for client confidentiality.
See section 1 of this report
to identify the report where
the photos may be viewed.

Figure TR10.1: Test setup

Occupied Bandwidth, 99% Test Method
Since the focus is on the relative distribution of energy across a range of frequencies, having a good signal to noise ratio is important but the absolute amplitude is not as critical. At the 2402 MHz carrier frequency, the turntable angle, antenna height, and antenna polarization were explored to find the worst-case settings. Occupied bandwidth measurements for all frequencies were taken in that set of spatial positions: table azimuth 110 degrees clockwise from the position shown in the figure TR10.1; Antenna elevation 2.29 m, receive antenna polarity vertical.

During this test the measuring antenna output is fed directly to the spectrum analyzer. Since this was a measurement of the carrier, no preamplifier or filter were used. 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.

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 are in bold font and have MHz as their units of measure.

(MHz)	2402 (04)	2440	2480 (78)
BLE 1 Mbps	**1.046**	**1.049**	**1.049**
BLE 2 Mbps	**2.038**	**2.038**	**2.045**

Table TR10.2: Summary of 99% Occupied Bandwidth Data for BLE modes

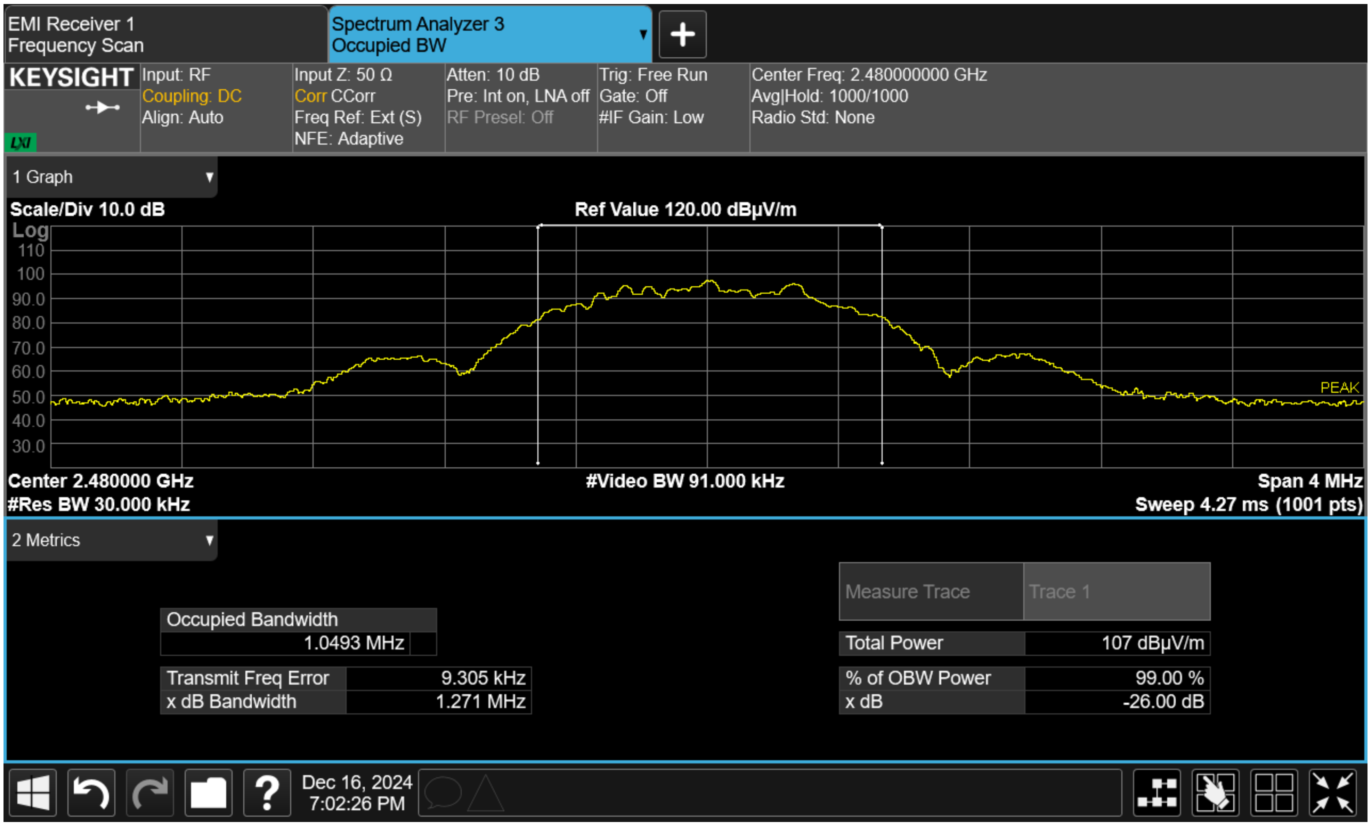

Figure TR10.2: Occupied bandwidth data for BLE 1 Mbps at high channel (2480 MHz)

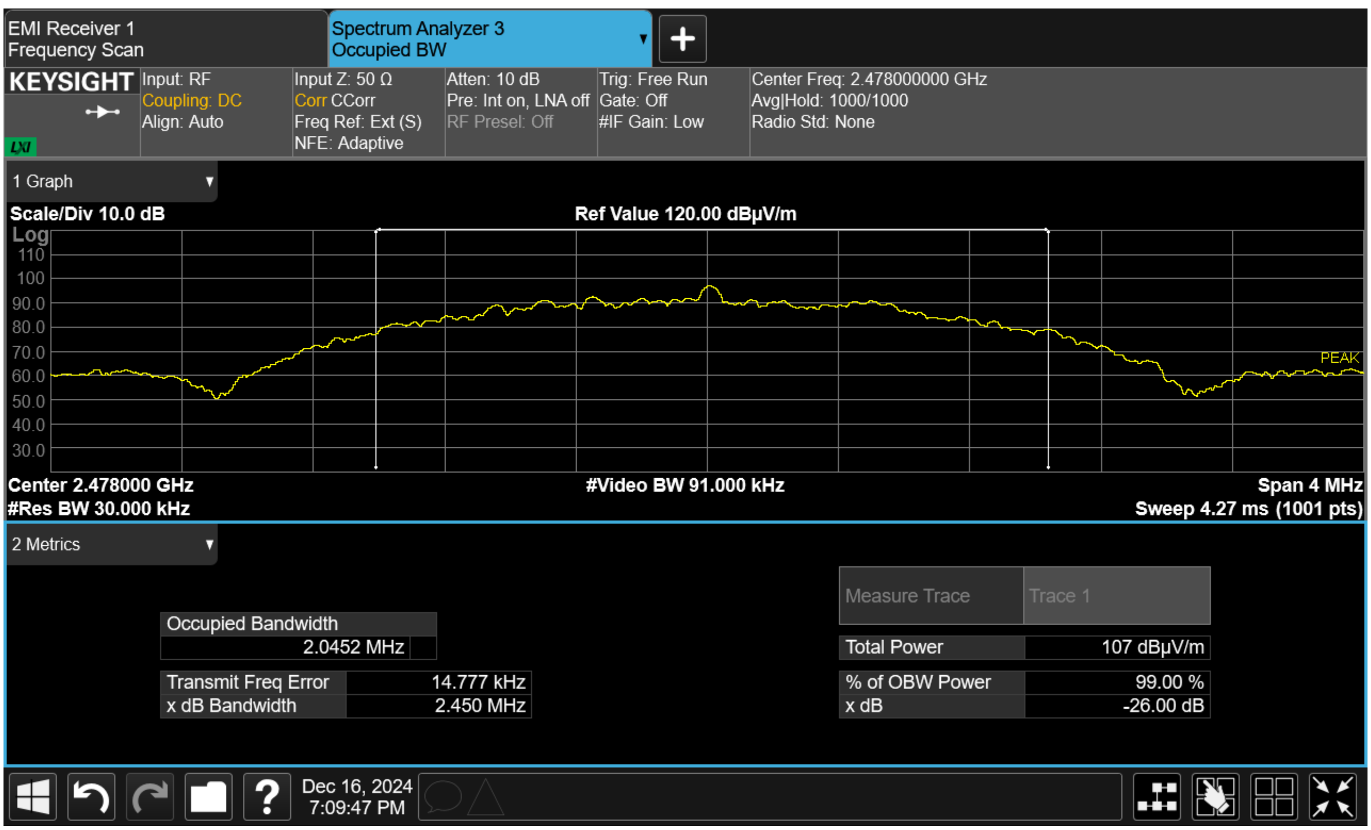

Figure TR10.3: Occupied bandwidth data for BLE 2 Mbps at high channel (2478 MHz)

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 NFC, 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.

NFC (Near Field Communication) at 13.56 MHz uses continuous wave telegraphy without tone modulation. The bit rate 'B' in the FCC and TRC equations is split into two parts here. B is the baud rate. C is a coding factor. C=1 for Miller encoding where the transition speed is as high as the bit rate, or C=2 for Manchester encoding where the transition speed is as high as twice the bit rate). K is a factor set to 3 for non-fading circuits under the standards. The Necessary Bandwidth, B_N is then:

$$B_N = BCK$$

Radio Type	B (kbaud)	C	K	B_N (kHz)
NFC A	106	1	3	318.0
NFC B	212	2	3	1272.0
NFC B	424	2	3	2544.0

Table TR10.100: Necessary Bandwidth for NFC

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)	B_N (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)	B_N (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)	B_N (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)	B_N (MHz)
802.11 a/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/ac	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
	MCS8	86.7	1	256	8	21.7

Table TR10.104: Necessary Bandwidth for IEEE 802.11 a, g, n, and ac 20 MHz Radio Protocols (FCC)

Radio Type	Sub-type	R Mbps	K	S	LogBase2 of (S)	B_N (MHz)
802.11 n/ac	MCS0	15	1	2	1	30.0
	MCS1	30	1	4	2	30.0
	MCS2	45	1	4	2	45.0
	MCS3	60	1	16	4	30.0
	MCS4	90	1	16	4	45.0
	MCS5	120	1	64	6	40.0
	MCS6	135	1	64	6	45.0
	MCS7	150	1	64	6	50.0
	MCS8	180	1	256	8	45.0
	MCS9	200	1	256	8	50.0

Table TR10.105: Necessary Bandwidth for IEEE 802.11 n and ac 40 MHz Radio Protocols (FCC)

As a note, the bit rate for IEEE 802.11 n or ac 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 rates would decrease by a small amount.

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	Mode	N_S (MHz)	K	B_N (MHz)
802.11a/g	20 MHz	0.3125	53	16.6
802.11n/ac	20 MHz	0.3125	57	17.8
802.11n/ac	40 MHz	0.3125	117	36.6

Table TR10.106: Necessary Bandwidth for IEEE 802.11 a, g, n, and ac Radio Protocols (TRC-43)

This line is the end of the test record.

Test Record
Transmitter Power, Duty Cycle
Test IDs TR61a
Project GCL0635

Test Date(s)	15 Jan 2025
Test Personnel	Majid Farah
Product Model	A04896
Serial Number	4196561404
Operating Mode	M3 (BleTx)
Arrangement	A2 (Pwr)
Input Power	3 Vdc
Test Standards:	FCC Part 15, ANSI C63.10, RSS-GEN, RSS-247, (as noted in Section 6 of the report).
Antenna Gain	1.6 dBi, as reported by the client
Radio Protocol	Bluetooth Low Energy
Pass/Fail Judgment:	PASS
Test record created by:	Vladimir Tolstik
Date of this record:	16 Jan 2025

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
RF Power Sensor	Rohde&Schwarz	NRP8S	109927	18-Jul-2024	18-Jul-2026
Regulated DC power supply	Triplett	PS305	C233005744	Calibration	Not Required

Table TR61a.1: List of test equipment used

Software used: Rohde & Schwarz Power Viewer V11.3; TimePowerAnalysisSpreadsheetV12a.xls

Test Method

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

ANSI C63.10: 11.9.2.3.2 (Gated average power with broadband power meter)

Under the ETSI standard, the parameters of duty cycle, transmitter timing, or medium utilization are typically not required for adaptive transceivers or transceivers emitting at 10 dBm EIRP or less, so those results will typically be omitted from the data set. Duty Cycle data will be included if it is relevant to test methods used for other standards such as Average Detector methods in the ANSI standards that apply duty cycle correction or certain kinds of analysis under the RF exposure standards.

Transmit Power and Timing Data

Each measurement is made 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 more strict limit has applied.

This test record will show results based on one or more of the following methods of analyzing the same set of raw power data vs. time. The ANSI peak power method looks for the highest power in the data record, with results in dBm units. The ANSI gated average power method determines the average power in the data record but only during times when the transmitter is keyed on, with results in dBm units. Under the US and Canadian rules a limit of 30 dBm is applied independent of which ANSI method is used. The ETSI 300 328 method looks at the individual transmission bursts within the data record and reports the power level from the burst with the for the highest average power. The ETSI result is presented in dBm EIRP units, and a 20 dBm EIRP limit is applied. The RF exposure analysis asks for the average power observed over the entire data record time, with results in linear power units such as milliwatts. RF exposure limits are not addressed in this test record. Many of the these standards also care about duty cycle, the portion of the time when the transmitter was actually transmitting. That is presented as a percentage, and no limit applies. All of these results are drawn from the same trace of Tx power data. The results are shown below.

ANSI Power

Frequency	(MHz)	2402	2404	2440	2478	2480
BT Low Energy	1 Mbps	**7.39**	**NT**	**7.58**	**NT**	**7.76**
BT Low Energy	2 Mbps	**NT**	**7.32**	**7.49**	**7.67**	**NT**

Table TR61a.2: Transmit Power, ANSI method, in dBm

The following figures show the gate settings used for the test cases highlighted in yellow in Table TR61a.2. Gate setting diagrams may not be included for radio modes where the duty cycle reported in Table TR61a.4 below is greater than 98%, since ANSI C63.10 treats these as continuous transmissions.

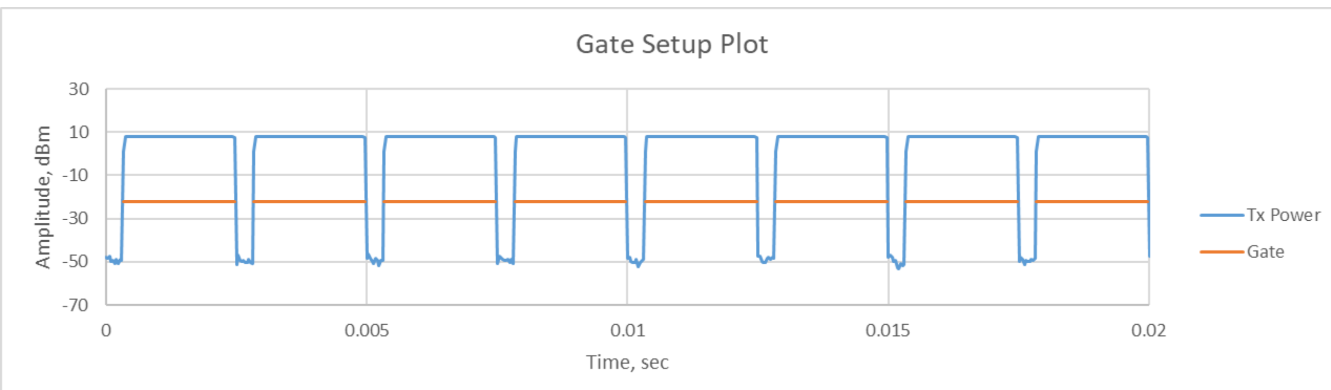

Figure TR61a.1: Gate setting diagram for BLE Radio, 1 Mbps modulation, 2480 MHz

Other Power Analyses

Frequency	(MHz)	2402	2404	2440	2478	2480
BT Low Energy	1 Mbps	**4.75**	**NT**	**4.97**	**NT**	**5.18**
BT Low Energy	2 Mbps	**NT**	**3.18**	**3.32**	**3.45**	**NT**

Table TR61a.3: Transmit Power, RF exposure method, in mW

Frequency	(MHz)	2402	2404	2440	2478	2480
BT Low Energy	1 Mbps	**86.7%**	**NT**	**86.7%**	**NT**	**86.7%**
BT Low Energy	2 Mbps	**NT**	**57.8%**	**58.3%**	**58.3%**	**NT**

Table TR61a.4: Duty cycle for each radio mode

Setup Diagram

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

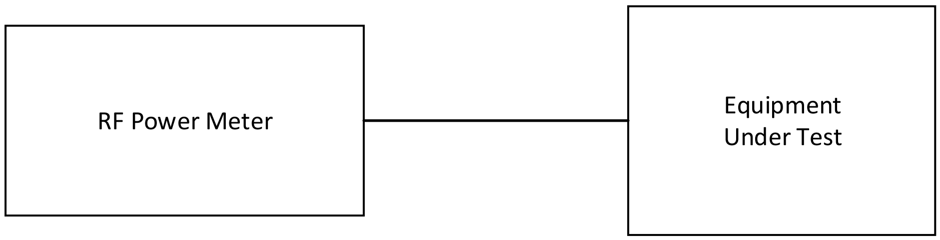

Figure TR61a.2: Test equipment setup

This line is the end of the test record.

Test Record
Radiated Emission Test RE03
Project GCL0635

Test Date(s) 29 Oct 2024
Test Personnel David Kerr

Product Model A04896
Serial Number tested 3490522727

Operating Mode M3 (BleTx)
Arrangement A2(Pwr)
Input Power 3 V DC

Test Standards: FCC Part 15.247; RSS-247; RSS-GEN; 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: David A Kerr
Date of this record: 29 Oct 2024

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 26 GHz	Keysight	N9048B	MY59290135	24-Oct-2024	24-Oct-2025
Antenna, Horn, 1-18 GHz	ETS Lindgren	3117	259208	30-May-2024	30-May-2026
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	7-Mar-2023	7-Mar-2026
Tape measure, 1” x 33’	Lufkin	PHV1410CMEN	10721	30-Aug-2023	1-Sep-2026
DMM Multimeter 87V	Fluke	87V	63490051	21-Jun-2024	21-Jun-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
Regulated DC power supply	TRIPLETT	PS305	C233005744	Calibration	Not Required

Table RE03.1: Test Equipment Used

Software Used
Keysight PXE receiver software A.32.06, RE Signal Maximization Tool v2024Jul31.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 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 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)	---
2389.50	54.00	74.00	33.63	50.97	20.37	23.03	-142.00	1220.00	VERT
2370.00	54.00	74.00	38.82	49.29	15.18	24.71	-142.00	1220.00	VERT

Table RE03.2: FCC restricted bands from 2200 to 2390 MHz (BLE, 1Mb)

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)	---
2483.50	54.00	74.00	39.89	62.84	14.11	11.16	43.00	1164.00	VERT
2488.00	54.00	74.00	40.62	52.62	13.38	21.38	43.00	1164.00	VERT

Table RE03.3: FCC restricted band from 2483.5 to 2500 MHz (BLE, 1Mb)

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)	---
2390.00	54.00	74.00	34.95	51.73	19.05	22.27	-142.00	1220.00	VERT
2370.00	54.00	74.00	36.31	49.67	17.69	24.33	-142.00	1220.00	VERT

Table RE03.4: FCC restricted bands from 2200 to 2390 MHz (BLE, 2Mb)

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)	---
2483.50	54.00	74.00	43.74	62.84	10.26	11.16	43.00	1164.00	VERT
2483.50	54.00	74.00	43.74	62.57	10.27	11.43	43.00	1164.00	VERT

Table RE03.5: FCC restricted band from 2483.5 to 2500 MHz (BLE, 2Mb)

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

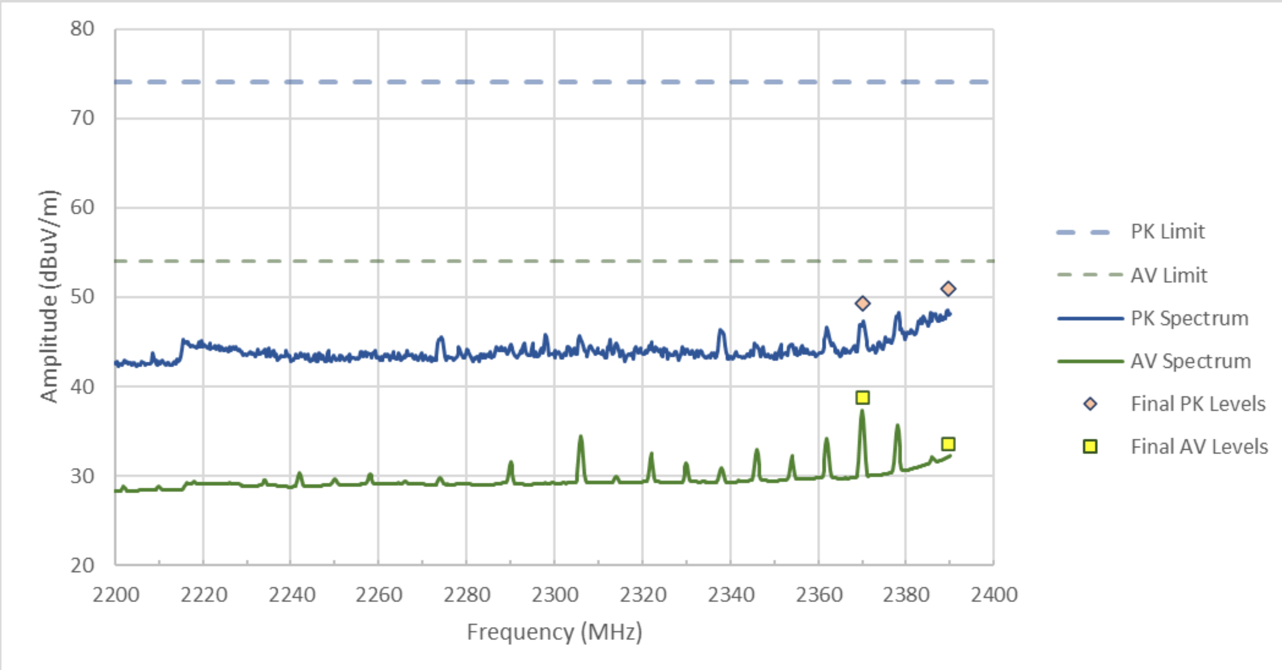

Figure RE03.1: FCC restricted band spectral data from 2200 to 2390 MHz (BLE, 1Mb)

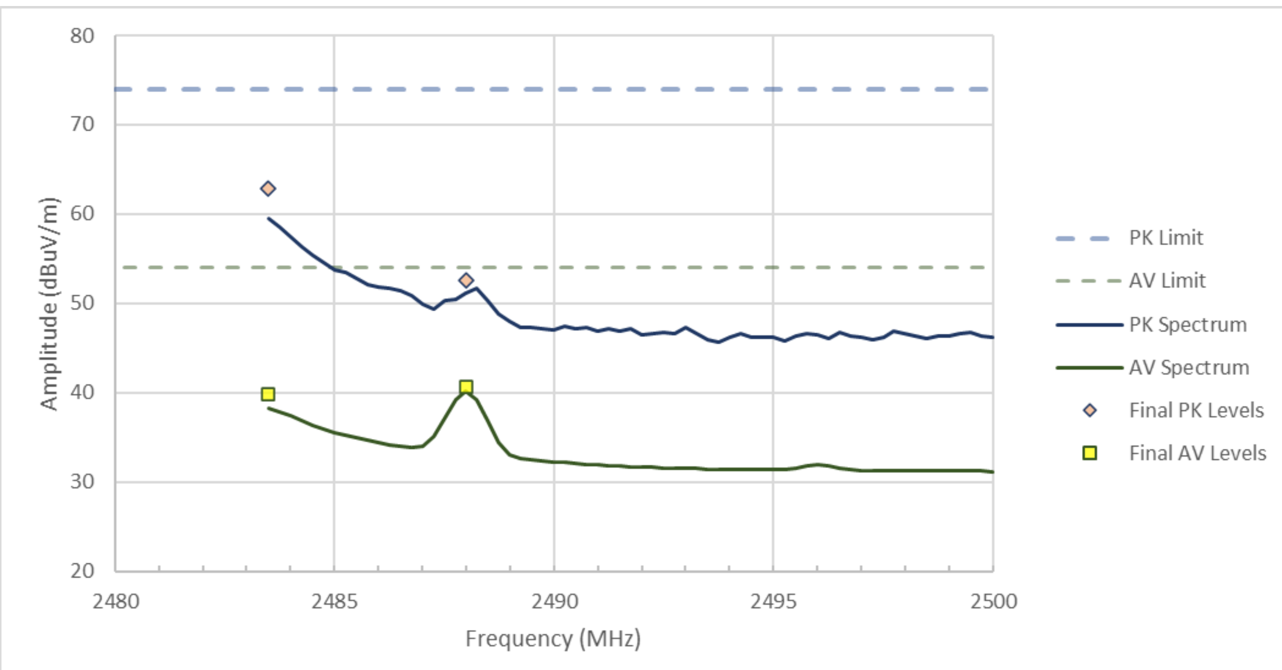

Figure RE03.2: FCC restricted band spectral data from 2483.5 to 2500 MHz (BLE, 1Mb)

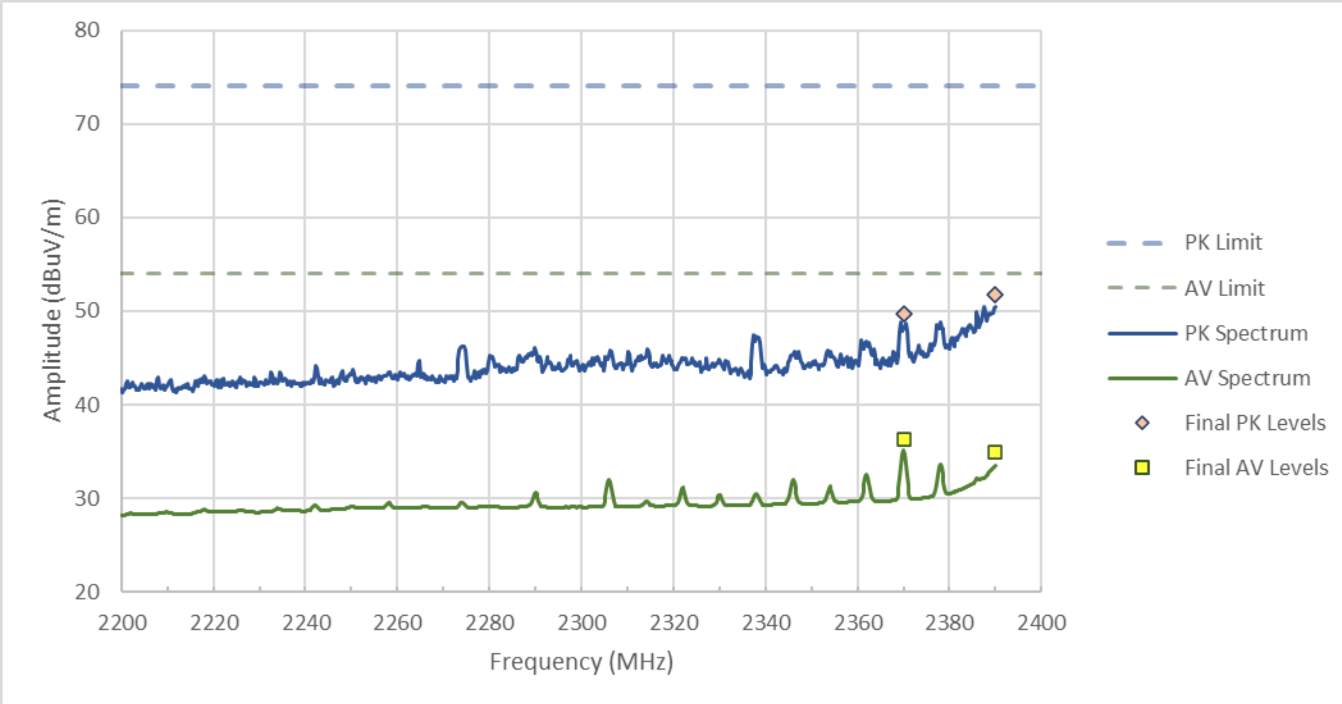

Figure RE03.3: FCC restricted band spectral data from 2200 to 2390 MHz (BLE, 2Mb)

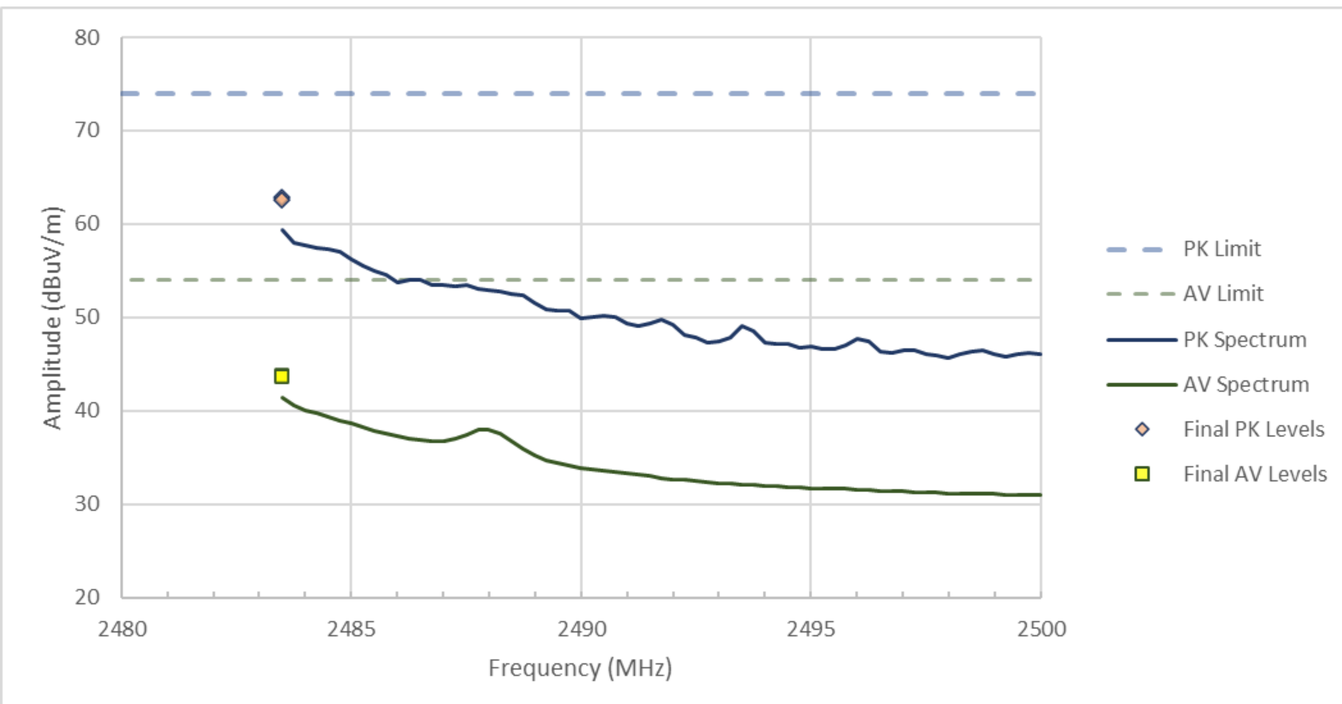

Figure RE03.4: FCC restricted band spectral data from 2483.5 to 2500 MHz (BLE, 2Mb)

Setup Photographs

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

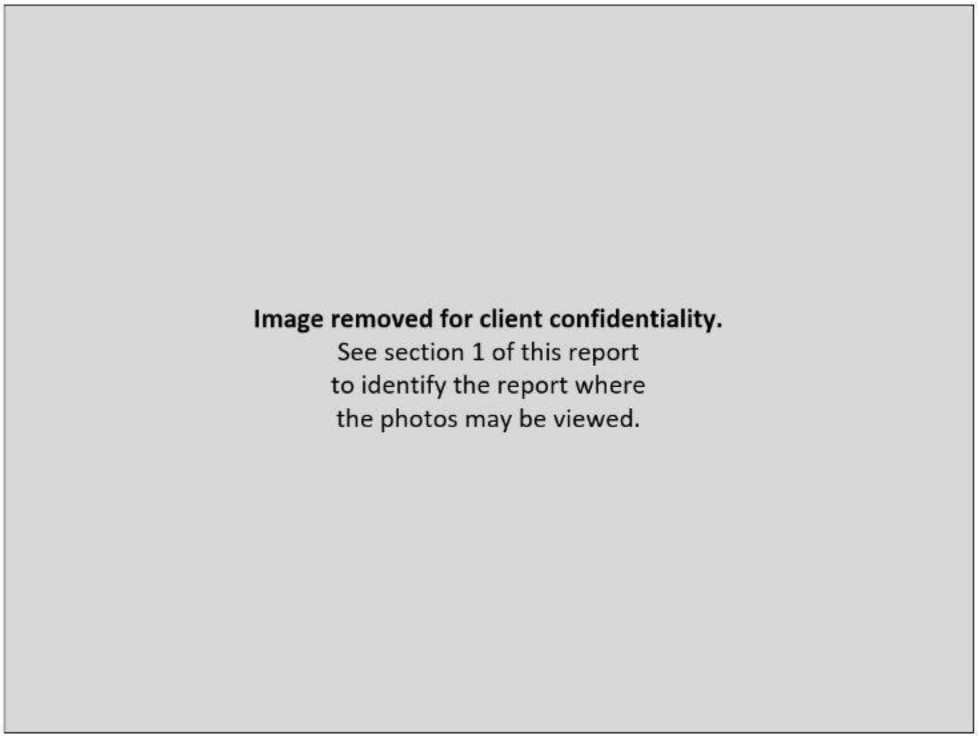

Figure RE03.5: EUT test setup, primary view (X orientation)

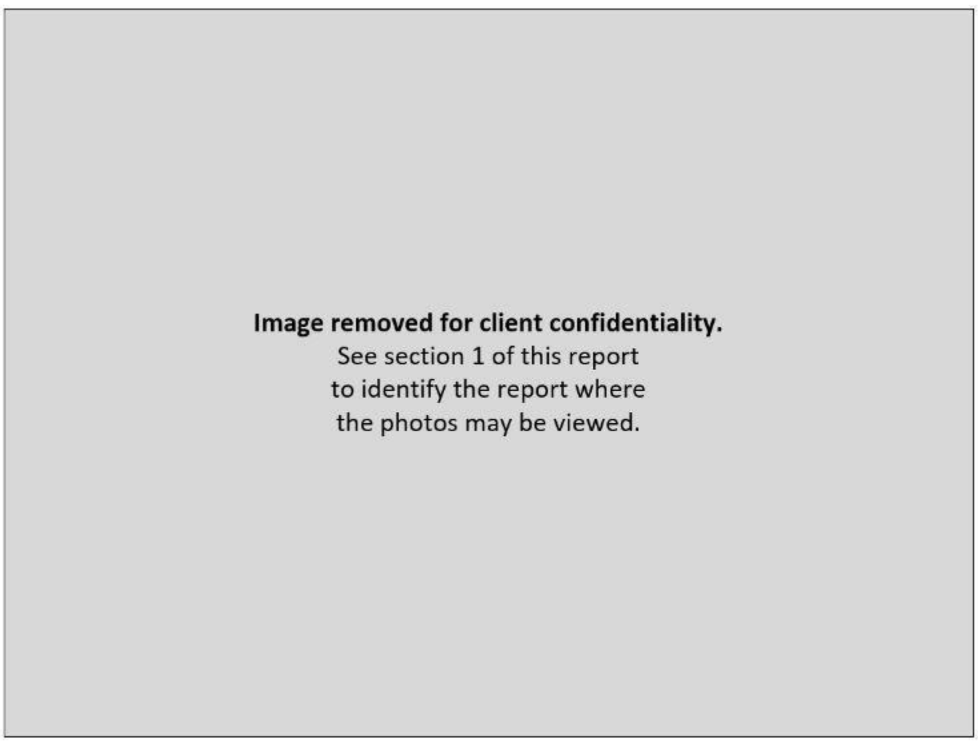

Figure RE03.6: EUT test setup, reverse view (X orientation)

This line is the end of the test record.

Test Record
Transmitter Power Spectral Density
Test IDs TR63
Project GCL-0635

Test Date(s) 15 Jan 2025
Test Personnel Majid Farah

Product Model A04896
Serial Number tested 4196561404

Operating Mode M3 (BleTx)
Arrangement A2 (Pwr)
Input Power 3 Vdc

Test Standards: FCC Part 15, ANSI C63.10, RSS-GEN, RSS-247 (as noted in Section 6 of the report).

Antenna Gain + 1.6 dBi, as reported by the client
Radio Protocol Bluetooth Low Energy (BLE)

Pass/Fail Judgment: PASS

Test record created by: Vladimir Tolstik
Date of this record: 15 Jan 2025

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 44 GHz	Keysight	N9048B	MY62220139	21-Oct-2024	21-Oct-2025

Table TR63.1: 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: PKPSD (11.10.2)

Test Setup

This block diagram shows the test equipment setup.

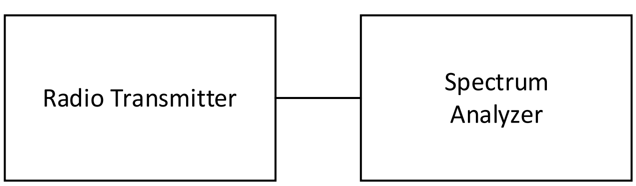

Figure TR63.1: Test setup

Test Data

Each measurement is made 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 a wider 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 all other Bluetooth, BLE, and ANT radios reported here, 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	**-8.56**	**-8.46**	**-8.39**
BLE 2 Mbps	**-10.34**	**-10.18**	**-10.06**

Table TR63.2: Summary of results in dBm / 3 kHz

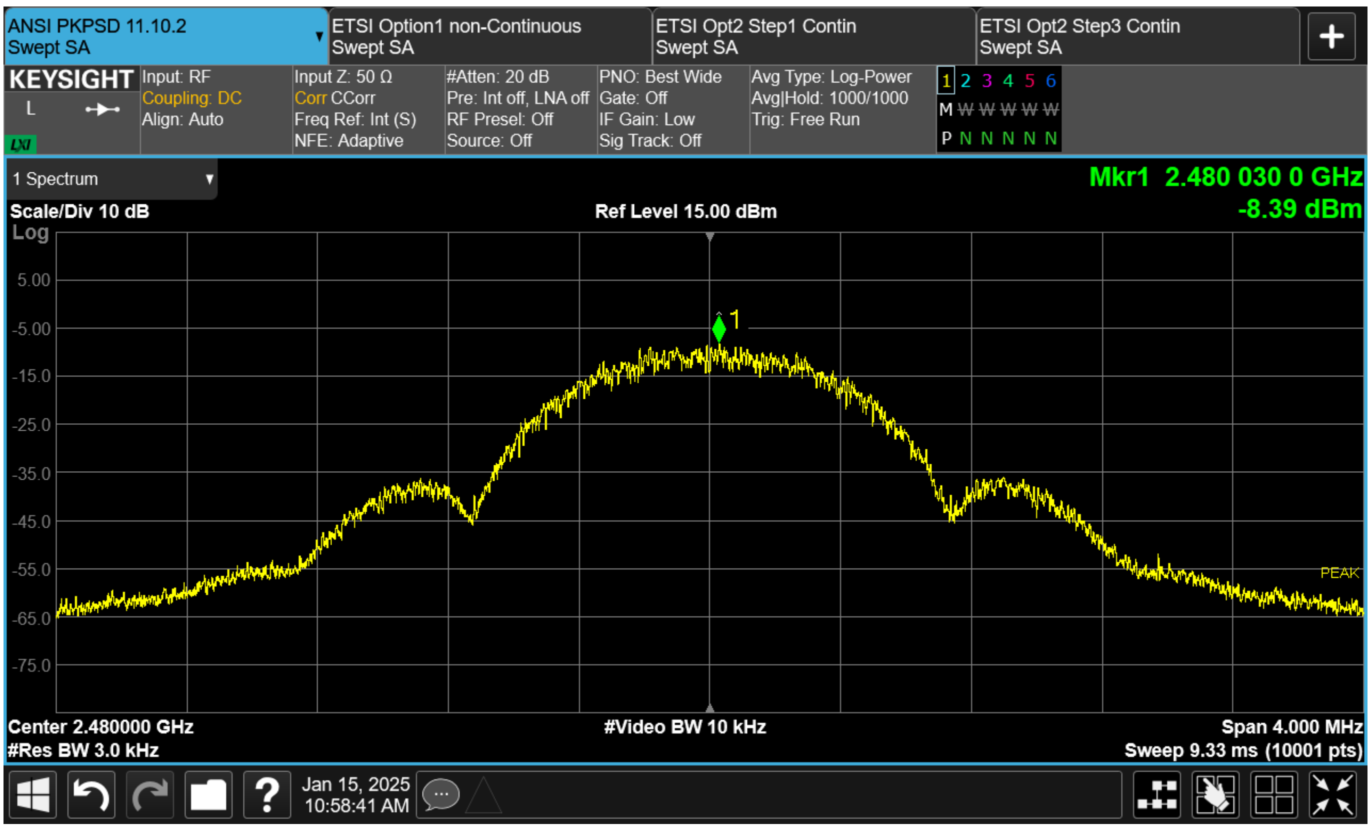

Figure TR63.2: Test data for BLE 1 Mbps at 2480 MHz

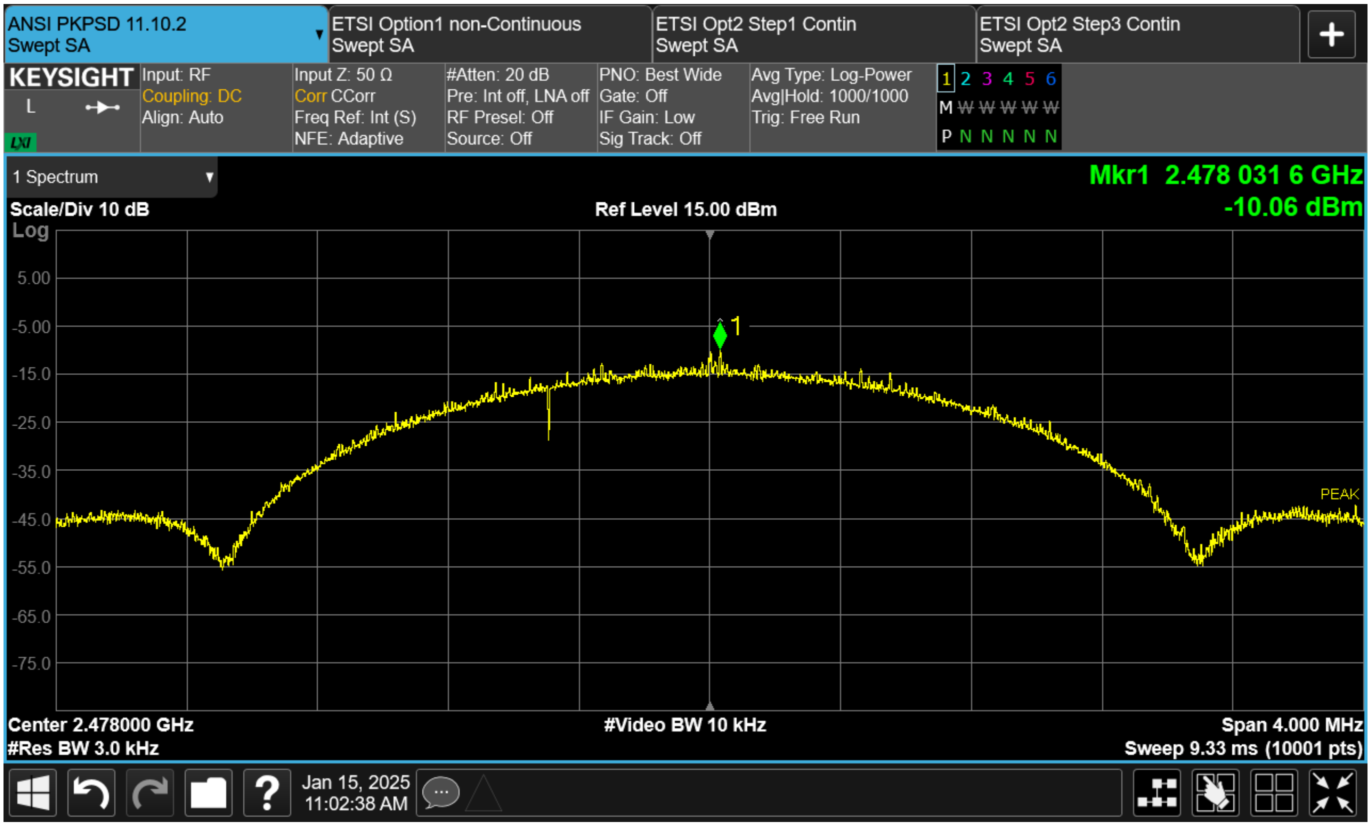

Figure TR63.3: Test data for BLE 2 Mbps at 2478 MHz

This line is the end of the test record.

Test Record
Radiated Emission Test RE20
Project GCL0635

Test Date(s) 11 Nov 2024
Test Personnel David Kerr

Product Model A04896
Serial Number tested 3490522727

Operating Mode M3 (BleTx) (2402MHz)
Arrangement A2(Pwr)
Input Power 3 Vdc

Test Standards: FCC Part 15.247; RSS-247; RSS-GEN; ANSI C63.10 (as noted in Section 6 of the report).

Frequency Range: 9 kHz to 30 MHz
Pass/Fail Judgment: **PASS**

Test record created by: David A Kerr
Date of this record: 11 Nov 2024

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 26 GHz	Keysight	N9048B	MY59290135	24-Oct-2024	24-Oct-2025
Loop antenna, amplified	Schwarzbeck	FMZB 1519B	174	18-Jul-2024	18-Jul-2026
SAC 3m, below 1 GHz	Frankonia	SAC3	F199004	25-Jan-2023	25-Jan-2026
Tape measure, 1” x 33’	Lufkin	PHV1410CMEN	10721	30-Aug-2023	1-Sep-2026
Regulated DC power supply	TRIPLETT	PS305	C233005744	Calibration	Not Required
DMM Multimeter 87V	Fluke	87V	63490051	21-Jun-2024	21-Jun-2025

Table RE20.1: Test Equipment Used

Software Used: Keysight PXE software A.32.06, 9k` to 30M XYZ_orientations_TemplateV7.xlsm, 150k to 30M Signal Maximization Tool V1 2021Mar17.xlsx

Test Data

For test standards that require reorienting the test sample, preliminary scans were taken in those alternate orientations to find the orientation that produced that largest field at the receive antenna. With intentional radiators, that highest field is usually found at the carrier frequency. The alternate orientations are typically described as X, Y, and Z and explained with a photograph. Subsequent testing was done using on the orientation identified in this way.

The radiated emission test process continued with a preliminary scan at multiple turntable angles, and in the three loop antenna polarizations. The loop antenna was positioned at a 1.5 m height. 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 loop was set to the worst case orientation for that frequency and the turntable angle was 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 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 9 kHz and 30 MHz. 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. Any 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. The relevant emissions were measured, including one or more noise floor signals as judged appropriate to the spectrum.

Freq.	Level	Detector	Limit	Margin	Peak Level	Pk Limit	Pk Margin	Antenna	Table
MHz	dBuV/m	Type	dBuV/m	dB	dBuV/m	dBuV/m	dB	Orientation	Azimuth, deg
0.0486	37.22	Avg	113.87	76.65	45.95	133.87	87.93	Z	97
0.0562	30.77	Avg	112.61	81.84	40.54	132.61	92.06	Z	180
0.13335	23.96	Avg	105.10	81.15	33.29	125.10	91.81	Z	-132
0.13795	23.27	Avg	104.81	81.54	32.51	124.81	92.30	Y	118
24.835	20.82	QP	69.54	48.72	29.31	None	None	X	70

Table RE20.2: Emission summary

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

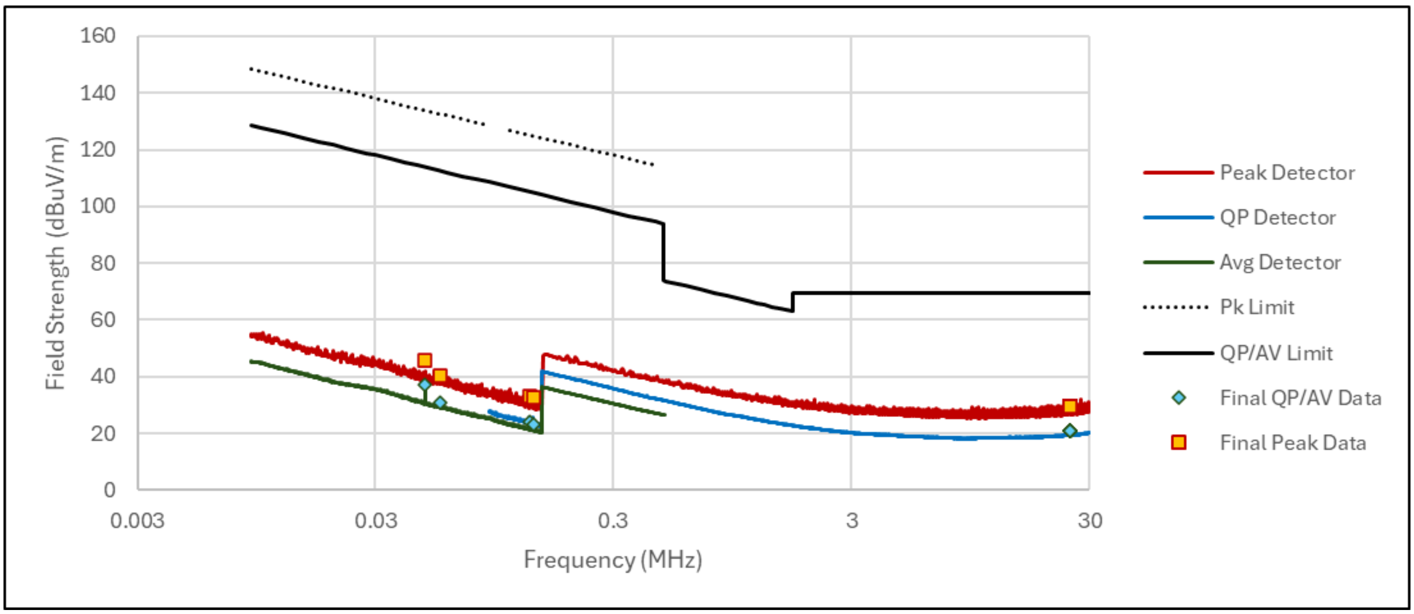

Figure RE20.1: Spectral data

Setup Photographs

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

Image removed for client confidentiality.
See section 1 of this report
to identify the report where
the photos may be viewed.

Figure RE20.2: EUT test setup, first view

Image removed for client confidentiality.
See section 1 of this report
to identify the report where
the photos may be viewed.

Figure RE20.3: EUT test setup, second view (X orientation)

Image removed for client confidentiality.
See section 1 of this report
to identify the report where
the photos may be viewed.

Figure RE20.4: EUT test setup, second view (Y orientation)

Image removed for client confidentiality.
See section 1 of this report
to identify the report where
the photos may be viewed.

Figure RE20.5: EUT test setup, second view (Z orientation)

This line is the end of the test record.

Test Record
Radiated Emission Test RE41
Project GCL0635

Test Date(s)	11 Nov 2024
Test Personnel	David Kerr
Product Model	A04896
Serial Number tested	3490522727
Operating Mode	M3 (BleTx) (2402MHz)
Arrangement	A2(Pwr)
Input Power	3 Vdc
Test Standards:	FCC Part 15.247; RSS-247; RSS-GEN; ANSI C63.10 (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:	11 Nov 2024

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 26 GHz	Keysight	N9048B	MY59290135	24-Oct-2024	24-Oct-2025
Antenna, Biconilog, 30M-6 GHz	ETS Lindgren	3142E	233201	18-Jul-2024	18-Jul-2026
SAC 3m, below 1 GHz	Frankonia	SAC3	F199004	25-Jan-2023	25-Jan-2026
Tape measure, 1” x 33’	Lufkin	PHV1410CMEN	10721	30-Aug-2023	1-Sep-2026
Regulated DC power supply	TRIPLETT	PS305	C233005744	Calibration	Not Required
DMM Multimeter 87V	Fluke	87V	63490051	21-Jun-2024	21-Jun-2025

Table RE41.1: Test Equipment Used

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

Test Data

For test standards that require reorienting the test sample, preliminary scans were taken in those alternate orientations to find the orientation that produced that largest field at the receive antenna. With intentional radiators, that highest field is usually found at the carrier frequency. The alternate orientations are typically described as X, Y, and Z and explained with a photograph. Subsequent testing was done using on the orientation identified in this way.

The radiated emission test process continued with a preliminary scan at multiple turntable angles, antenna heights, and both antenna polarizations. 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. Any 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		
43.920	V	4.6	15.2	19.8	40.0	20.2	100.0	134.0
54.750	V	6.0	13.5	19.5	40.0	20.5	104.4	148.0
71.160	V	7.4	14.0	21.4	40.0	18.6	116.5	0.0
88.710	V	3.7	14.1	17.8	43.5	25.7	143.4	0.0
148.500	V	4.6	16.4	21.0	43.5	22.5	108.3	303.0
940.890	V	0.8	34.6	35.4	46.0	10.6	232.6	208.0

Table RE41.2: Emission summary

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

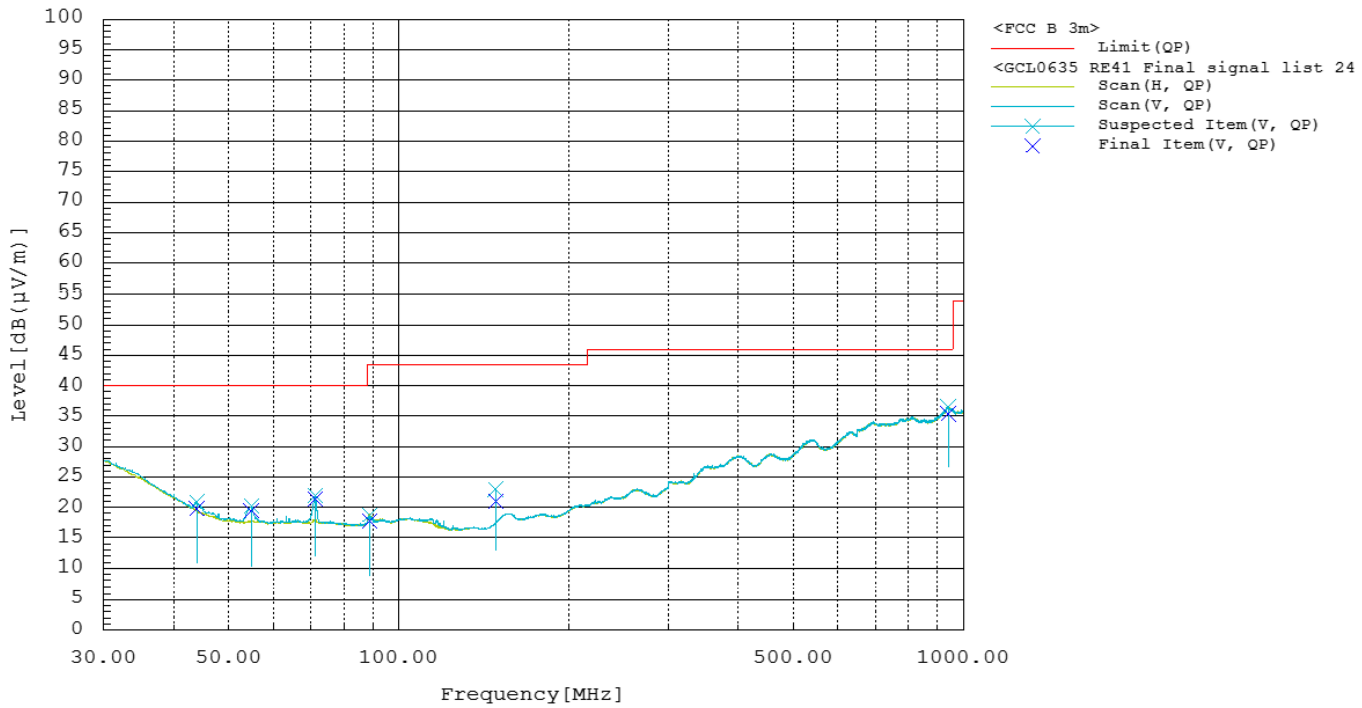

Figure RE41.1: Spectral data

Setup Photographs

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

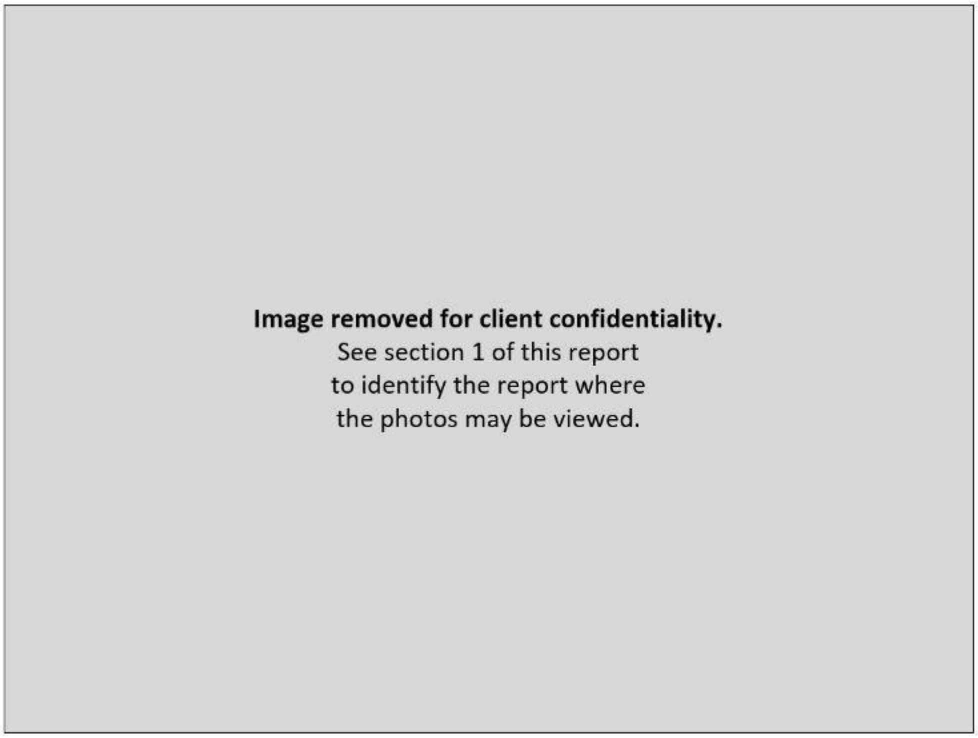

Figure RE41.2: EUT test setup, first view (X orientation)

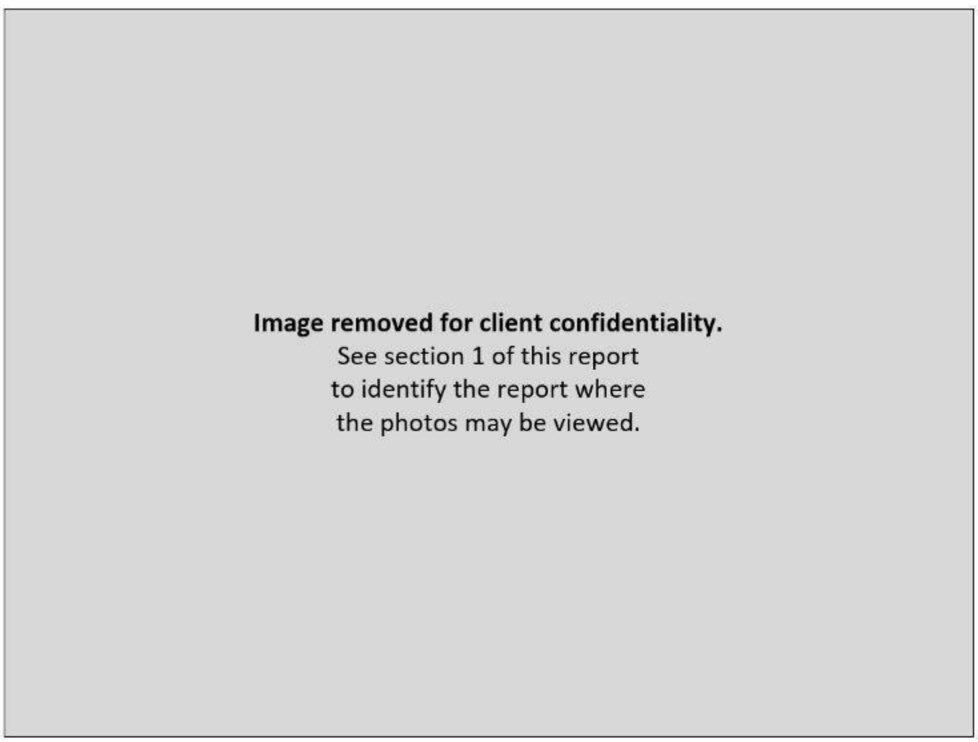

Figure RE41.3: EUT test setup, second view (X orientation)

This line is the end of the test record.

Test Record
Radiated Emission Test RE11
Project GCL0635

Test Date(s)	31 Oct 2024
Test Personnel	David Kerr
Product Model	A04896
Serial Number tested	3490522727
Operating Mode	M3 (BleTx) (2402MHz, 2440MHz, 2480MHz)
Arrangement	A2(Pwr)
Input Power	3 V DC
Test Standards:	FCC Part 15.247; RSS-247; RSS-GEN; ANSI C63.10 (as noted in Section 6 of the report).
Frequency Range:	1 GHz to 14 GHz
Pass/Fail Judgment:	**PASS**
Test record created by:	David A Kerr
Date of this record:	31 Oct 2024

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 26 GHz	Keysight	N9048B	MY59290135	24-Oct-2024	24-Oct-2025
Antenna, Horn, 1-18 GHz	ETS Lindgren	3117	00259208	30-May-2024	30-May-2026
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	7-Mar-2023	7-Mar-2026
Tape measure, 1 in x 33 ft	Lufkin	PHV1410CMEN	10720	16-Jan-2023	15-Jan-2026
DMM Multimeter	Fluke	87V	63490051	21-Jun-2024	21-Jun-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
3 GHz High Pass filter	Anatech Electronics	0K0R2	01	Calibration	Not Required
Regulated DC power supply	Triplett	PS305	C233005744	Calibration	Not Required

Table RE11.1: Test Equipment Used

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

Test Data

For test standards that require reorienting the test sample, preliminary scans were taken in those alternate orientations to find the orientation that produced that largest field at the receive antenna. With intentional radiators, that highest field is usually found at the carrier frequency. The alternate orientations are typically described as X, Y, and Z and explained with a photograph. Subsequent testing was done using on the orientation identified in this way.

The radiated emission test process continued with a preliminary scan at multiple turntable angles, antenna heights, and both antenna polarizations. 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 1 GHz to 3.2 GHz frequency range, a Chebyshev 'Wifi' notch filter covering the 2.4 GHz ISM band was placed in series just before the preamplifier to ensure it operated in its linear range. This filter is accounted for in the system loss, so it appears in the prescan plots as high noise floor levels from 2400 – 2483 MHz. These are not failing emissions. A 3 GHz high pass filter was applied during testing between 3.2 GHz and 14 GHz to similarly protect the preamplifier.

In the 1 GHz to 14 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 14 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. Any 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
		CAV	PK		CAV	PK	AV	PK	CAV	PK		
1722.480	H	32.0	45.4	-6.1	25.9	39.3	54.0	74.0	28.1	34.7	374.8	190.0
1727.760	V	32.1	45.7	-6.1	26.0	39.6	54.0	74.0	28.0	34.4	314.0	288.0
2273.800	V	33.2	48.5	-3.5	29.7	45.0	54.0	74.0	24.3	29.0	220.3	294.0
4803.260	V	33.5	47.2	3.2	36.7	50.4	54.0	74.0	17.3	23.6	302.9	107.0
7206.800	V	42.4	52.6	7.0	49.4	59.6	54.0	74.0	4.6	14.4	336.8	40.0
9608.000	V	27.8	41.4	10.7	38.5	52.1	54.0	74.0	15.5	21.9	272.5	87.0
12010.640	H	32.5	45.2	14.1	46.6	59.3	54.0	74.0	7.4	14.7	379.8	301.0

Table RE11.2: Emission summary (2402 MHz)

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		
1731.720	V	32.1	46.2	-6.0	26.1	40.2	54.0	74.0	27.9	33.8	331.7	292.0
2375.880	V	37.2	52.9	-3.3	33.9	49.6	54.0	74.0	20.1	24.4	100.0	311.0
2503.480	V	34.0	49.3	-2.5	31.5	46.8	54.0	74.0	22.5	27.2	300.2	176.0
4880.000	V	33.3	46.4	2.8	36.1	49.2	54.0	74.0	17.9	24.8	274.7	81.0
7319.120	V	39.8	51.0	6.9	46.7	57.9	54.0	74.0	7.3	16.1	351.4	34.0
9760.000	V	28.7	42.2	10.3	39.0	52.5	54.0	74.0	15.0	21.5	100.0	66.0
12201.260	V	30.8	44.1	15.3	46.1	59.4	54.0	74.0	7.9	14.6	391.1	12.0

Table RE11.3: Emission summary (2440 MHz)

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		
1722.920	V	32.3	46.0	-6.1	26.2	39.9	54.0	74.0	27.8	34.1	252.2	44.0
2351.680	V	36.5	52.8	-3.5	33.0	49.3	54.0	74.0	21.0	24.7	210.2	298.0
2607.760	H	34.7	50.3	-2.6	32.1	47.7	54.0	74.0	21.9	26.3	333.1	235.0
4959.860	V	34.1	46.9	2.9	37.0	49.8	54.0	74.0	17.0	24.2	242.7	109.0
7439.000	V	38.2	50.0	7.1	45.3	57.1	54.0	74.0	8.7	16.9	313.6	11.0
9920.000	V	28.4	42.1	11.2	39.6	53.3	54.0	74.0	14.4	20.7	377.9	34.0
12401.060	H	32.8	44.8	14.6	47.4	59.4	54.0	74.0	6.6	14.6	371.3	297.0

Table RE11.4: Emission summary (2480 MHz)

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

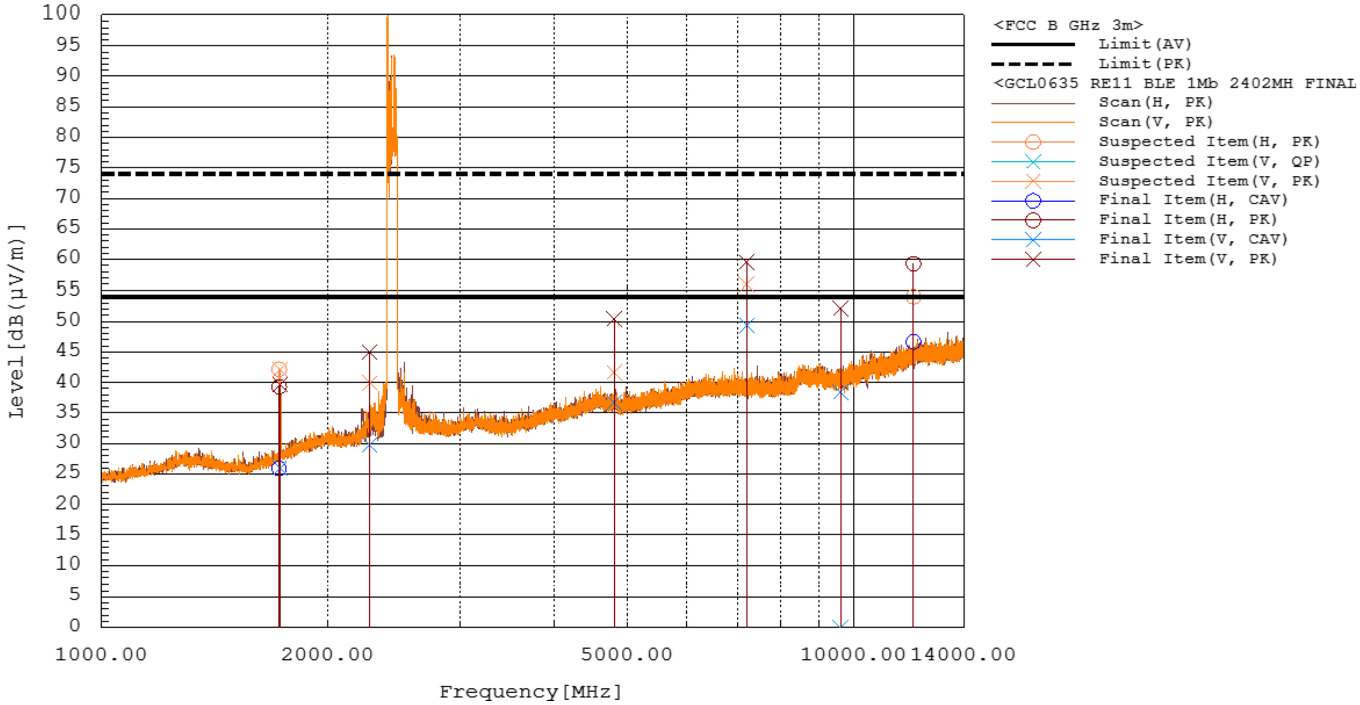

Figure RE11.1: Spectral data (2402 MHz)

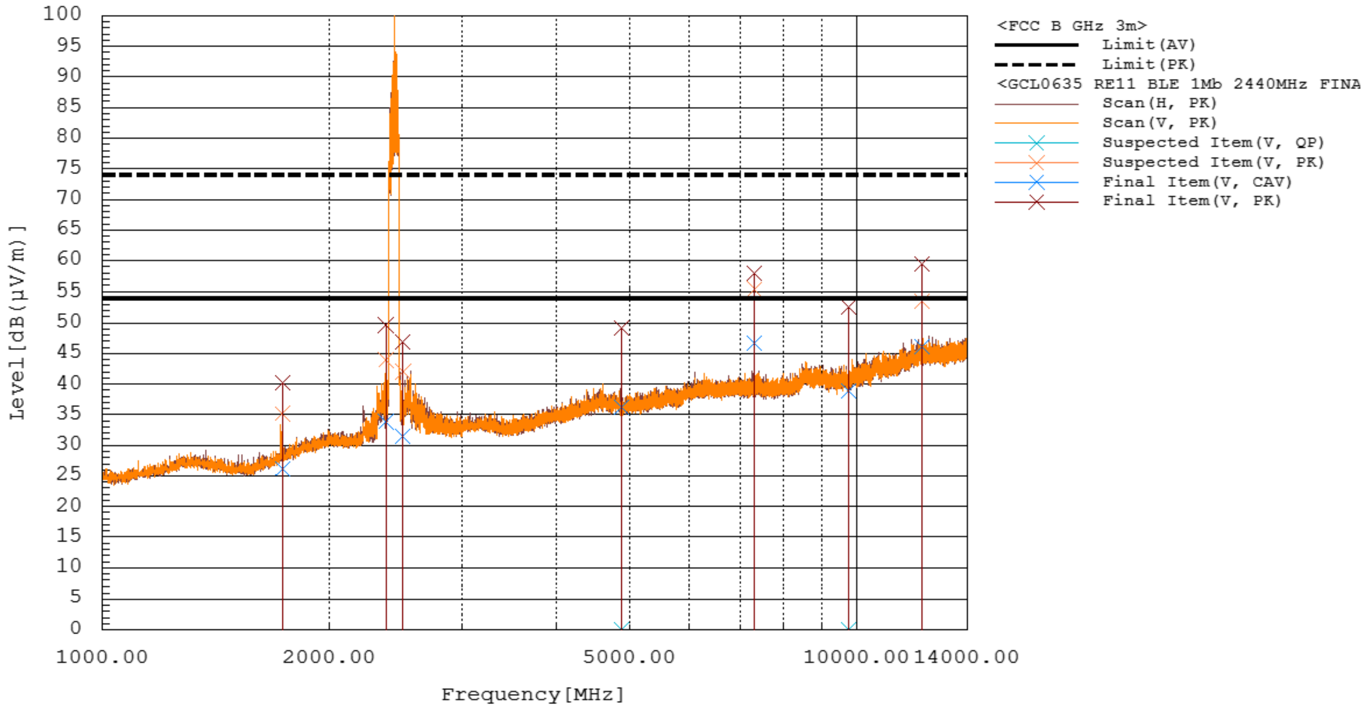

Figure RE11.2: Spectral data (2440 MHz)

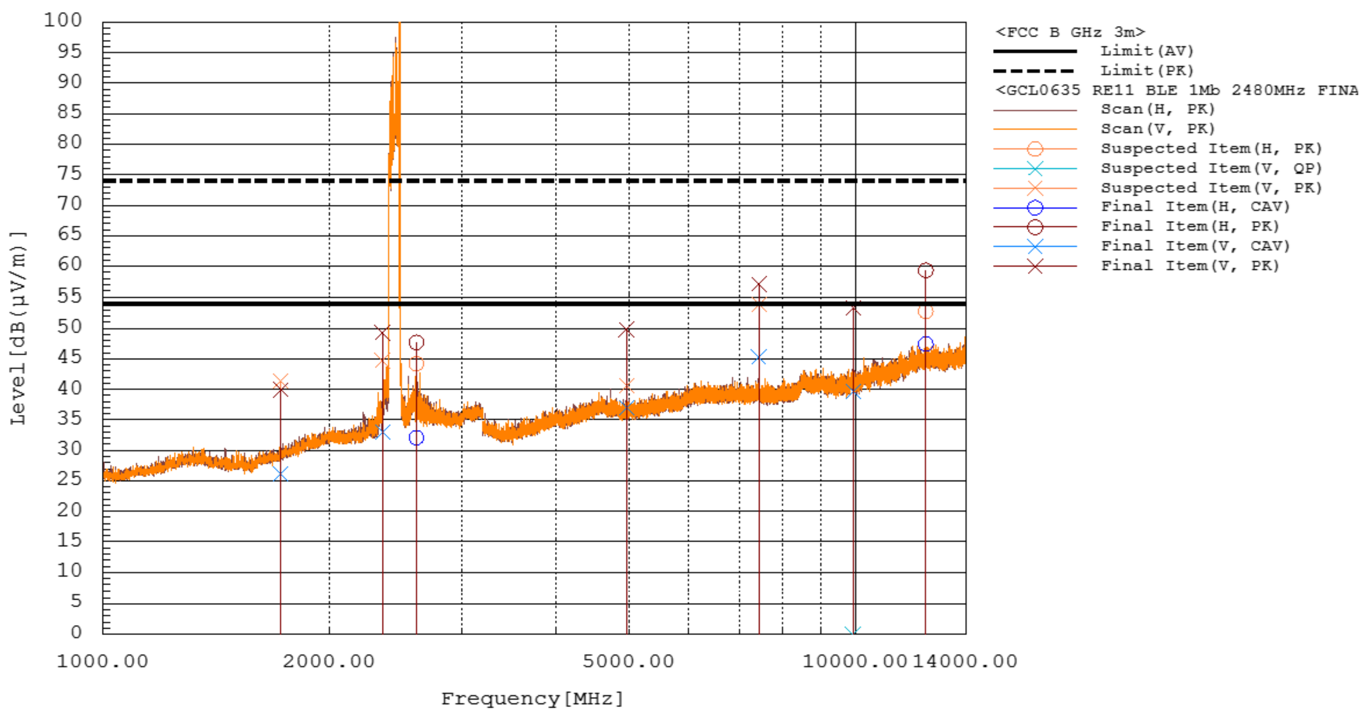

Figure RE11.3: Spectral data (2480 MHz)

Setup Photographs

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

Image removed for client confidentiality.
See section 1 of this report
to identify the report where
the photos may be viewed.

Figure RE11.4: EUT test setup, first view (X orientation)

Image removed for client confidentiality.
See section 1 of this report
to identify the report where
the photos may be viewed.

Figure RE11.5: EUT test setup, second view (X orientation)

This line is the end of the test record.

Test Record
Radiated Emission Test RE14
Project GCL0635

Test Date(s) 04 Nov 2024
Test Personnel David Kerr

Product Model A04896
Serial Number tested 3490522727

Operating Mode M3 (BleTx) (2402MHz, BLE 1Mb)
Arrangement A2(Pwr)
Input Power 3 Vdc

Test Standards: FCC Part 15.247; RSS-247; RSS-GEN; ANSI C63.10 (as noted in Section 6 of the report).

Frequency Range: 14 GHz to 25 GHz
Pass/Fail Judgment: **PASS**

Test record created by: David A Kerr
Date of this record: 04 Nov 2024

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 44 GHz	Keysight	N9048B	MY62220139	21-Oct-2024	21-Oct-2025
Antenna, Horn, 10-40 GHz	ETS Lindgren	3116C	00259186	29-Apr-2024	29-Apr-2026
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	7-Mar-2023	7-Mar-2026
Tape measure, 1 in x 33 ft	Lufkin	PHV1410CMEN	10720	16-Jan-2023	15-Jan-2026
Preamplifier, 14 GHz to 40 GHz	Com-Power	PAM-840A	461364	Calibration	Not Required
Regulated DC power supply	Triplett	PS305	C233005744	Calibration	Not Required

Table RE14.1: Test Equipment Used

Software Used: Keysight PXE software A.39.28, EPX test software Version 2023.01.001

Test Data

For test standards that require reorienting the test sample, preliminary scans were taken in those alternate orientations to find the orientation that produced that largest field at the receive antenna. With intentional radiators, that highest field is usually found at the carrier frequency. The alternate orientations are typically described as X, Y, and Z and explained with a photograph. Subsequent testing was done using on the orientation identified in this way.

The radiated emission test process continued with a preliminary scan at multiple turntable angles, antenna heights, and both antenna polarizations. 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 14 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 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 14 GHz and 25 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. Any 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
		CAV	PK		CAV	PK	AV	PK	CAV	PK		
14083.850	V	14.1	28.2	27.8	41.9	56.0	54.0	74.0	12.1	18.0	400.0	82.0
14412.000	V	14.8	28.7	26.4	41.2	55.1	54.0	74.0	12.8	18.9	379.8	0.0
16814.000	V	20.5	34.6	21.6	42.1	56.2	54.0	74.0	11.9	17.8	400.0	351.0
19216.000	V	23.2	36.8	18.9	42.1	55.7	54.0	74.0	11.9	18.3	400.0	87.0
21618.000	V	22.8	36.3	19.8	42.6	56.1	54.0	74.0	11.4	17.9	400.0	75.0
24020.000	V	21.6	35.4	21.7	43.3	57.1	54.0	74.0	10.7	16.9	400.0	281.0

Table RE14.2: Emission summary (BLE 2402MHz 1Mb)

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

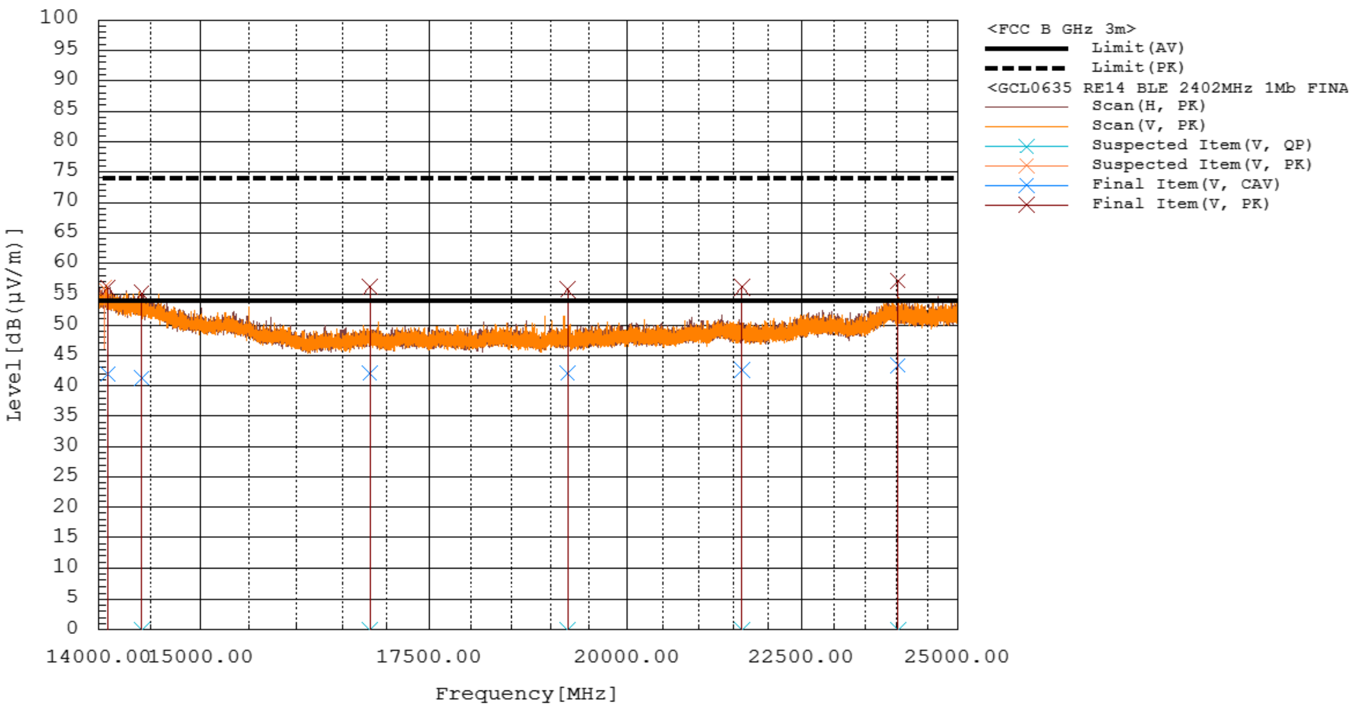

Figure RE14.1: Spectral data at 1 meter (BLE 2402MHz 1Mb)

Setup Photographs

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

Image removed for client confidentiality.
See section 1 of this report
to identify the report where
the photos may be viewed.

Figure RE14.2: EUT test setup, first view (X orientation)

Image removed for client confidentiality.
See section 1 of this report
to identify the report where
the photos may be viewed.

Figure RE14.3: EUT test setup, second view (X orientation)

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.