Test Report 2024-130

Version A
Issued 15 Aug 2024

Project GCL-0461
Model Identifier: A04882
Primary Test Standard(s):
CFR 47, FCC Part 15.249
RSS-210 Issue 11

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

Client-supplied Information

FCC ID:	IPH-04882
IC ID:	1792A-04882

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

1. Summary

The equipment or product described in section 5 of this report was tested at the Garmin Compliance Lab according to standards listed in section 6. This report focuses on the 2.4 GHz ANT transceiver(s) and limited to 1 GHz to 25 GHz band. Test records within this report may include data for the Bluetooth Low Energy (BLE) transceiver(s), but BLE is addressed in a separate report. In the frequency stability test record and AC mains conducted emissions, the BLE transmitter was used to show compliance for both BLE and ANT. 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 1 Mbps.	Reported	NT
Restricted Bands	The radio must not emit in certain designated restricted frequency bands above a set of limit values. [15.205; RSS-210 at 7.1]	Emissions in the restricted bands were at least 15.76 dB below the applicable limits.	PASS	14
Carrier and Harmonic Emissions	The field strength from the radio carrier and its harmonics must meet specific limits at a 3 m test distance. Other unwanted emissions also must meet what is commonly called the Class B limit. [15.249(a); RSS-210 at B.10]	The limit is 50 mV/m (94 dBuV/m) in the carrier band, and 0.5 mV/m (54 dBuV/m) at all other frequencies. This sample demonstrated 12.0 dB of margin or greater. At other non-harmonic frequencies, unwanted emissions had at least 3.1 dB of margin.	PASS	18
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	33
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	38
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]	Emissions other than the fundamental and harmonics must meet the 'Class B' limits. The measured emissions had at least 20.17 dB of margin.	PASS	41

NT (Not Tested) means the requirement may or may not be applicable, but the relevant measurement or test was not performed as part of this test project.

N/A (Not Applicable) means the lab judged that the test sample is exempt from the requirement.

Table 1: Summary of results

Report Organization

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

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

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

Due to confidentiality, certain material (such as test setup photographs) has been removed from this report and placed in GCL Test Report 2024-135. 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: 29 May 2024
Test Start Date: 07 Jun 2024
Test End Date: 11 Jul 2024

The data in this test report apply only to the specific samples tested.

Upon receipt all test samples were believed to be properly assembled and ready for testing.

3. Report History and Approval

This report was written by Majid Farah and initially issued on 15 Aug 2024 as Version A.

Report Technical Review:

Majid Farah
Senior 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 2.09 to 2.11
Date applied: 20 Jun 2024
Reason for this modification:
This modification was performed on all samples due to a connectivity issue between EUT and companion device during BLE Receiver blocking testing. 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	A04882
Serial Numbers Tested	3475112672, 3475112460

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 (BLE), ANT, NFC
Radio Receivers:	GPS L1, GPS L5, Galileo E1, Galileo E5a/b, BeiDou, GLONASS
Primary Functions:	Data collection and communication
Typical use:	Portable in multiple orientations
Highest internal frequency:	2.484 GHz
Firmware Revision	2.11 (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 (AntLnk). 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 11: M11 (NfcTag). The NFC radio was transmitting and actively linked to a passive NFC tag.

Mode 12: M12 (NfcLnk). The NFC radio was transmitting and actively linked to an NFC card reader.

Mode 13: M13 (GnssY). 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 14: M14 (NfcIdle). The NFC Radio was powered, but not transmitting or linked to any devices.

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 17: M13 (GnssN). The Global Navigation Satellite System receiver is monitoring the GNSS bands, attempting to detect a constellation and determine location. The EUT is in GNSS receiving mode but no GNSS signal provided.

Mode 19: M19 (ML1). Multiple link, combining modes M4 & M6. The EUT is actively paired to both a BLE and an ANT companion device, used for Immunity tests.

Mode 20: M20 (ML2). Multiple link, combining modes M12 & M13. The EUT is actively linked to a NFC card reader and the specified satellite system, used for immunity tests.

5.4 EUT Arrangement

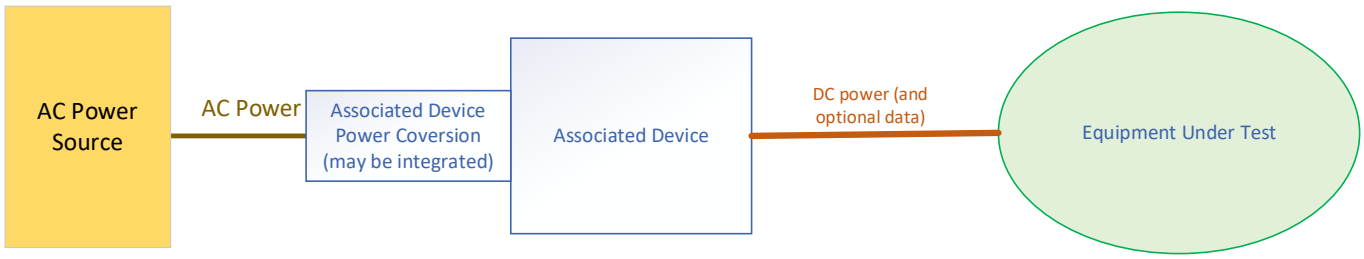
During test, the EUT components and associated support equipment were selected including the following arrangement sets.

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 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

Arrangement 5: A5 (NFCp) The test sample is placed near an NFC Card Reader or NFC tag. The NFC Card Reader is connected to a laptop computer. The test sample is powered by a device that does not include data over the cable, just as with A2. For clarity, test sample is NOT powered by, or connected to, the laptop computer that powers the NFC Card Reader.

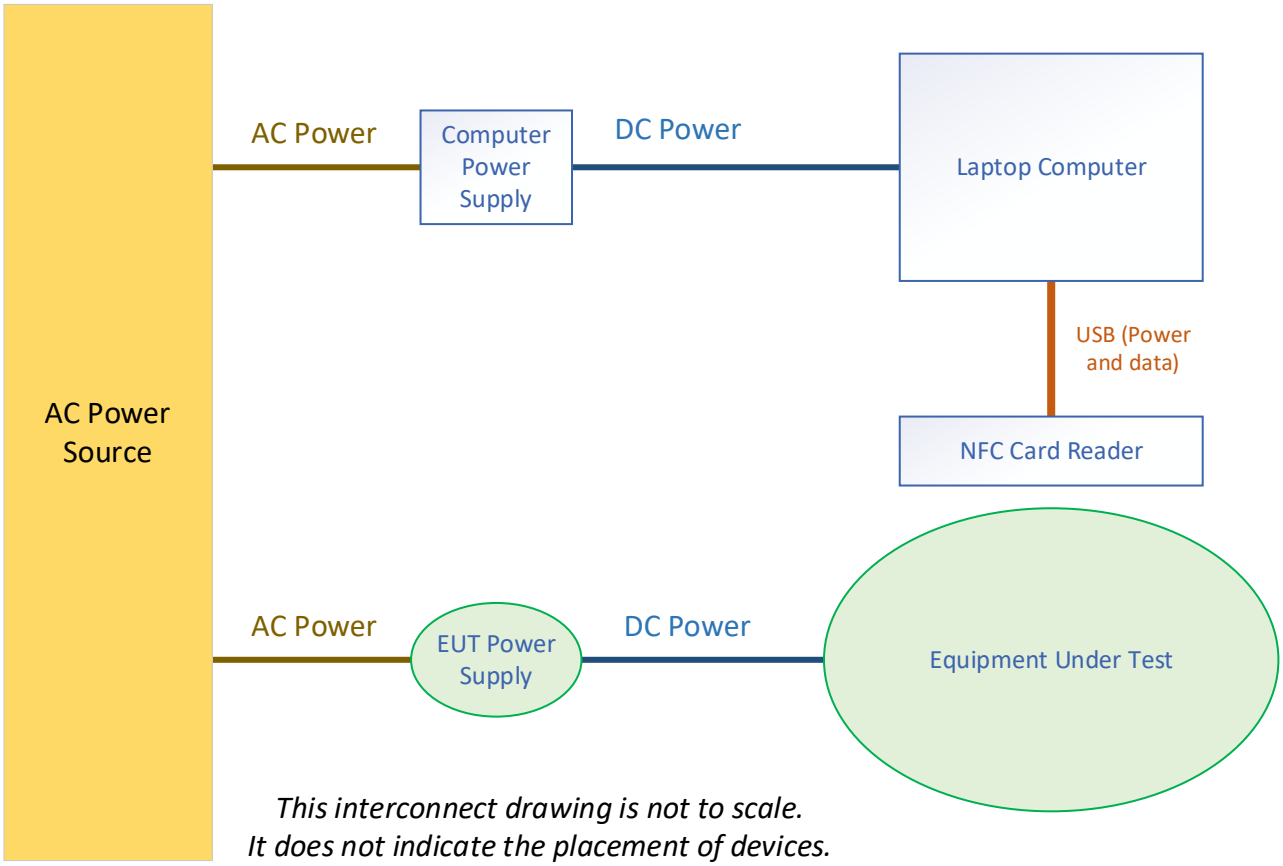


Figure 2: Block diagram of equipment arrangement A5

Arrangement 6: A6 (NFCu) The test sample is placed near an NFC Card Reader or NFC tag. The NFC Card Reader is connected to a laptop computer. The test sample is powered by its own batteries rather than an external power source. Either NFC Card reader or NFC tag can be used during test.

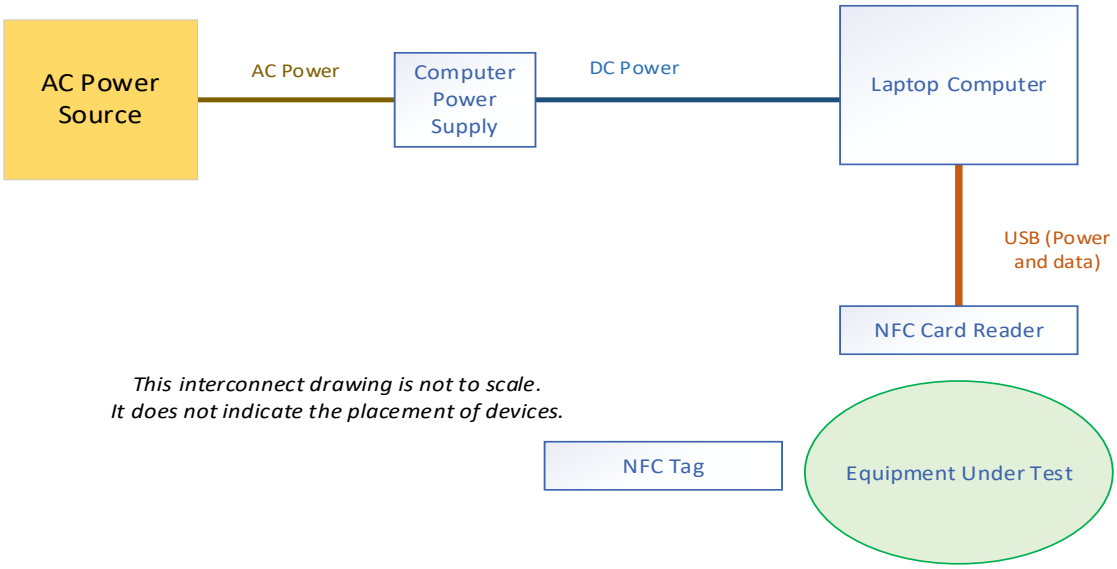


Figure 3: Block diagram of equipment arrangement A6

5.5 Associated Equipment (AE) used

Description	Manufacturer	Model	Serial Number
USB C power adaptor	Phihong (Garmin)	AQ27A-59CFA	362-00118-00
Laptop	Dell	Precision 5540	3JYG33
Power Supply	Dell	HA130PM130	CN-0V363H-CH200-78G-0DC1-A01
Laptop	Dell	Latitude 5410	5VSPFB3
Power Supply	Dell	HA65NM191	CN-0H374X-CH200-0BD-7TC0-A020BD-7TC0-A02
Phone	Samsung	SM-G973U (S10)	RF8MC0W9XVR
NFC Card Reader	ACS	ACR1252U-M1	RR554-118449
NFC Tag	SANPOPO	NTAG215	PD-STICKER-B-30
Auxiliary device	Garmin	A04883	3477207518

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 15.249
ANSI C63.10: 2020, and ANSI C63.10: 2020 +Cor 1: 2023
RSS-GEN Issue 5 Amd 2
RSS-210 Issue 11

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.

FCC Part 2.202
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:	19.8 to 22.5 °C
Relative Humidity:	42.3% to 60% (non-condensing)
Barometric Pressure	96.7 to 98.9 kPa

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

Table 4: Environmental monitoring device

10 Immunity Performance Criteria

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

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

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

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

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

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

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

ANNEX

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

Test Record
Radiated Emission Test RE04
Project GCL0461

Test Date(s)	19 June 2024
Test Personnel	David Kerr
Product Model	A04882
Serial Number tested	3475112672
Operating Mode	M5 (AntTx)
Arrangement	A2 (Upwr)
Input Power	USB 5 Vdc
Test Standards:	FCC Part 15, ANSI C63.10, RSS-210, 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:	David A Kerr
Date of this record:	20 June 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
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	16-Nov-2022	16-Nov-2025
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10720	16-Jan-2023	15-Jan-2026
Preamplifier, 500 MHz 18 GHz	Com-Power	PAM-118A	18040133	Calibration	Not Required
Wifi Filter	K&L	8NSL26-2437/E82.2-0/0	1	Calibration	Not Required

Table RE04.1: Test Equipment Used

Software Used
Keysight PXE receiver software A.32.06, RE Signal Maximization Tool v2023Jul14.xlsx, FCC Restricted Band 2p4GHz Data Analysis Template v1b 2023Jun20.xlsx.

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. 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.

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)	---
2390	54	74	34.417	50.596	19.583	23.404	-160	1003	VERT
2370	54	74	38.234	49.162	15.766	24.838	-160	1003	VERT

Table RE04.2: FCC restricted bands from 2200 to 2390 MHz (ANT, X orientation)

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	35.889	56.753	18.111	17.247	-156	1019	VERT
2483.5	54	74	35.936	56.545	18.064	17.455	-156	1019	VERT

Table RE04.3: FCC restricted band from 2483.5 to 2500 MHz (ANT, X orientation)

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

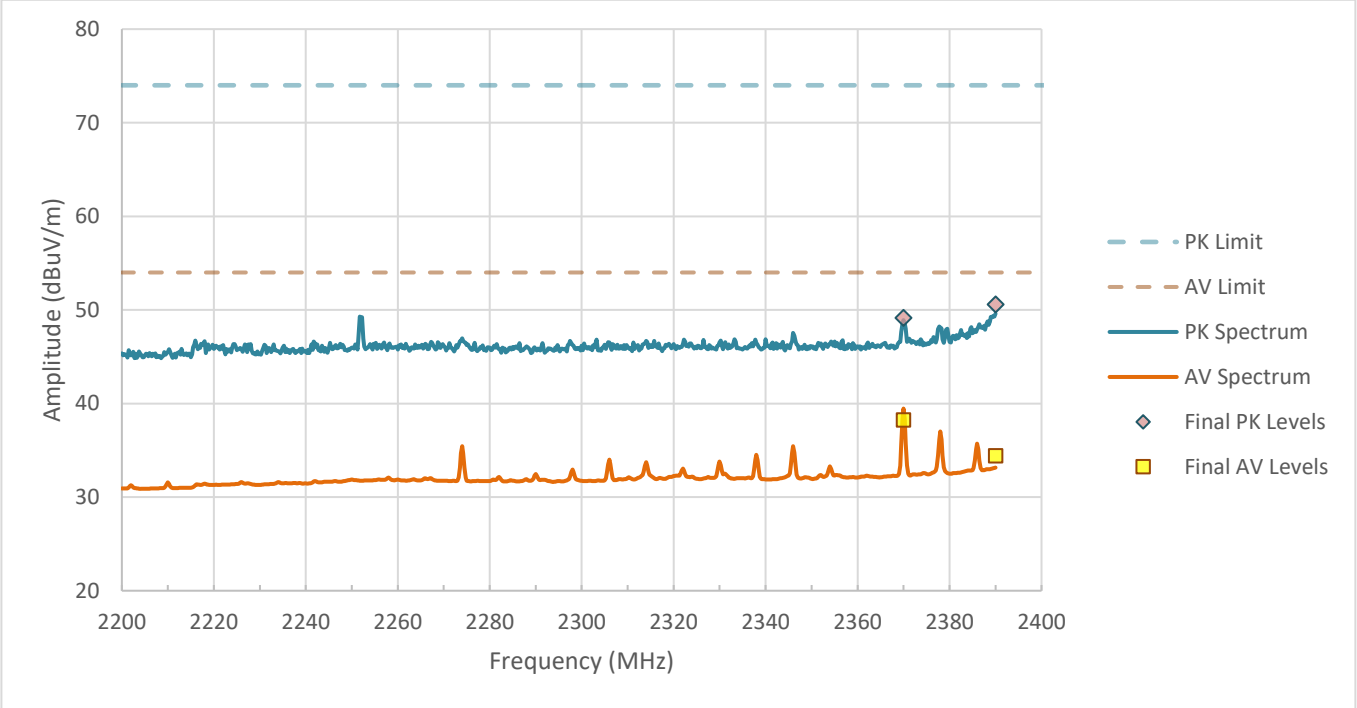


Figure RE04.1: FCC restricted band spectral data from 2200 to 2390 MHz (ANT, X orientation)

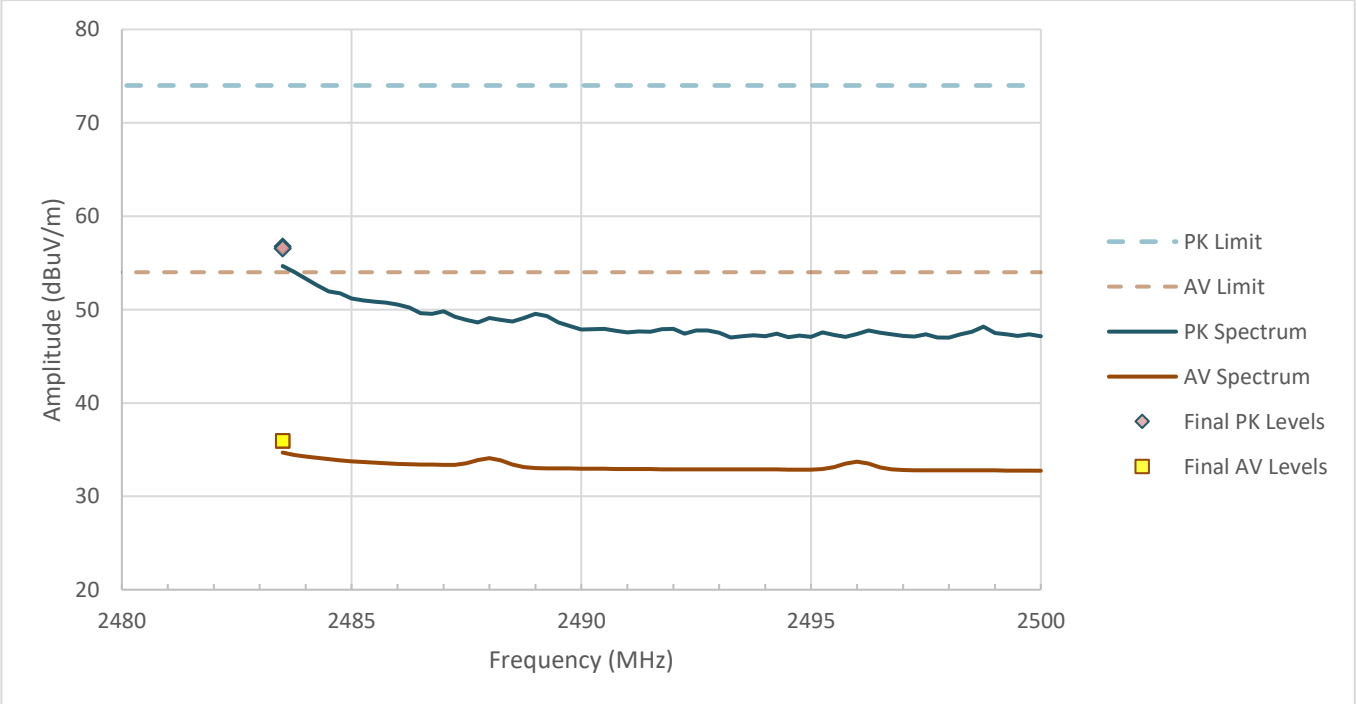


Figure RE04.2: FCC restricted band spectral data from 2483.5 to 2500 MHz (ANT, X orientation)

Setup Photographs

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

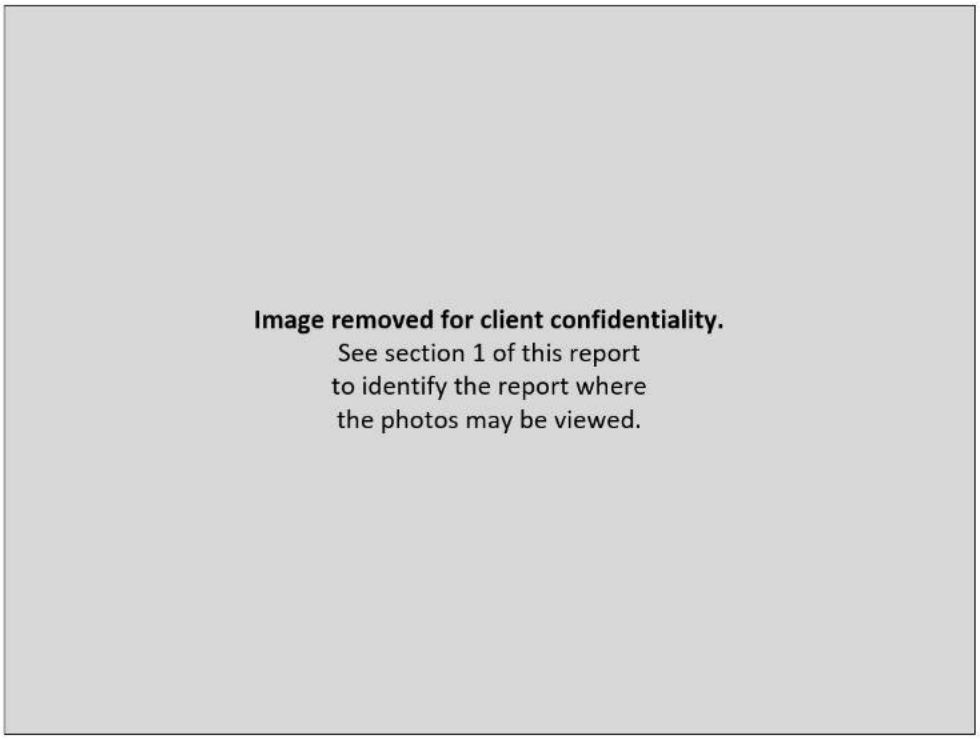


Figure RE04.3: EUT test setup, primary view

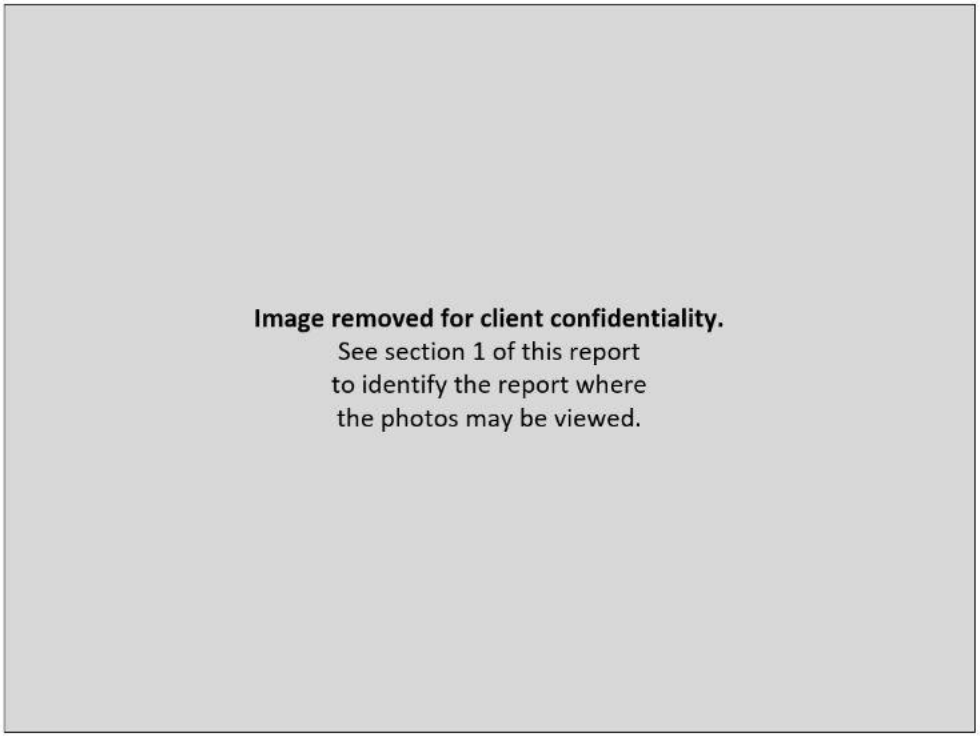


Figure RE04.4: EUT test setup, reverse view

This line is the end of the test record.

Test Record
Radiated Emission Test RE24
Project GCL0461

Test Date(s)	24 Jun 2024
Test Personnel	Vladimir Tolstik assisted by Dave Kerr and Jim Solum
Product Model	A04882
Serial Number tested	3475112672
Operating Mode	M5 (AntTx)
Arrangement	A2 (Upwr)
Input Power	USB 5 Vdc
Test Standards:	FCC Part 15, ANSI C63.10, RSS-210 (as noted in Section 6 of the report).
Frequency Range:	1000 MHz to 3200 MHz
Pass/Fail Judgment:	**PASS**
Test record created by:	Vladimir Tolstik
Date of this record:	24 Jun 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	00227596	14-Sep-2023	14-Sep-2025
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	16-Nov-2022	16-Nov-2025
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10720	16-Jan-2023	15-Jan-2026
Preamplifier, 500 MHz 18 GHz	Com-Power	PAM-118A	18040133	Calibration	Not Required
3 GHz High Pass filter	Anatech Electronics	0K0R2	01	Calibration	Not Required
RF Power Sensor	Rohde&Schwarz	NRP8S	109927	7-Jul-2023	1-Jul-2024

Table RE24.1: 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 1000 MHz and 3200 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.

The test sample was transmitting with a 96.3% duty cycle during this test. The duty cycle was measured using a fast diode detector RF power sensor and calculated according to ANSI C63.10. The client states that the maximum duty cycle for the ANT protocol is 13%. The CISPR Average detector has a square law response for signal pulses with these ANT timing parameters. In the data tables below, the Average detector values for the carrier frequencies have been adjusted downward by 17.6 dB, which comes from 20 * log (13% / 96.3%). The Peak detector values are not reduced for duty cycle, nor were the other emissions adjusted for duty cycle.

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		
2402.000	V	41.3	60.0	40.7	82.0	100.7	94.0	114.0	12.0	13.3	100.0	17.0
3065.000	V	7.8	25.4	43.1	50.9	68.5	54.0	74.0	3.1	5.5	317.9	187.0

Table RE24.2: Emission summary (X orientation, ANT 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		
2440.250	V	35.8	55.9	40.9	76.7	96.8	94.0	114.0	17.3	17.2	193.8	13.0
3050.000	V	7.8	24.5	43.1	50.9	67.6	54.0	74.0	3.1	6.4	313.2	358.0

Table RE24.3: Emission summary(X orientation, ANT 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		
2479.750	V	34.9	55.0	41.2	76.1	96.2	94.0	114.0	17.9	17.8	100.0	12.0
3050.000	V	7.8	25.5	43.1	50.9	68.6	54.0	74.0	3.1	5.4	116.4	0.0

Table RE24.4: Emission summary (X orientation, ANT 2480MHz)

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

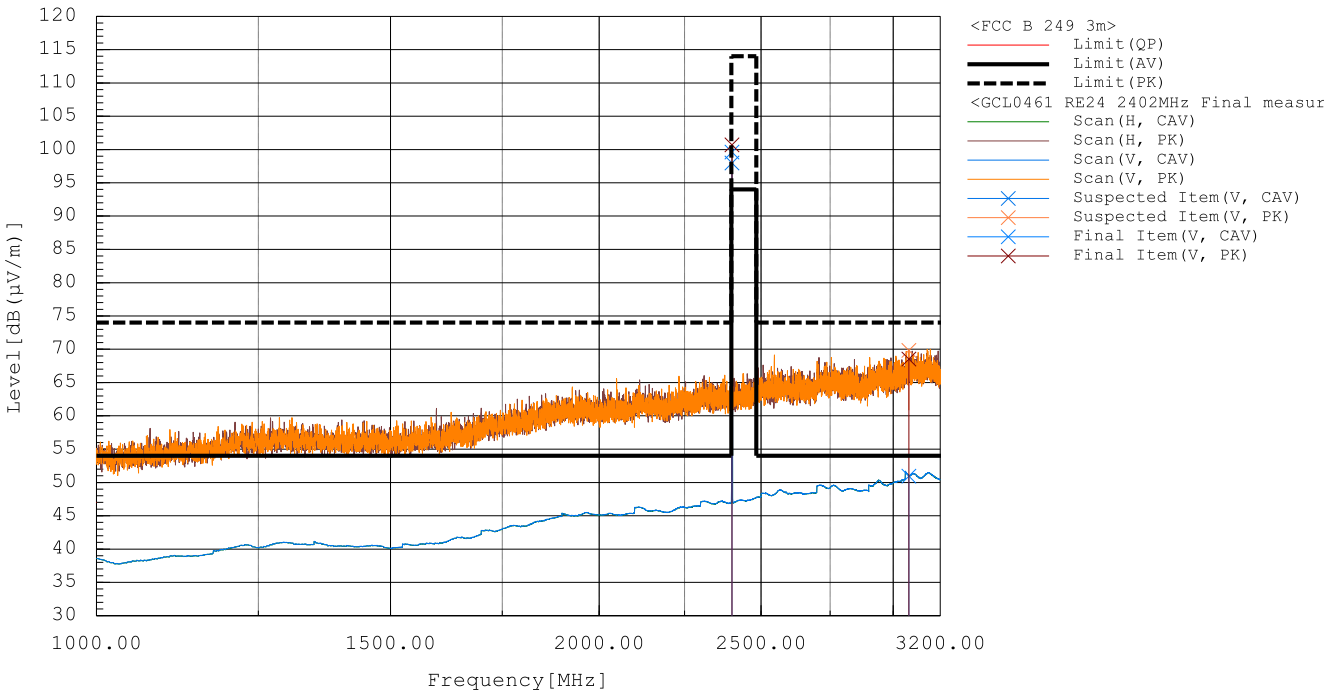


Figure RE24.1: Spectral data (X orientation, ANT 2402MHz)

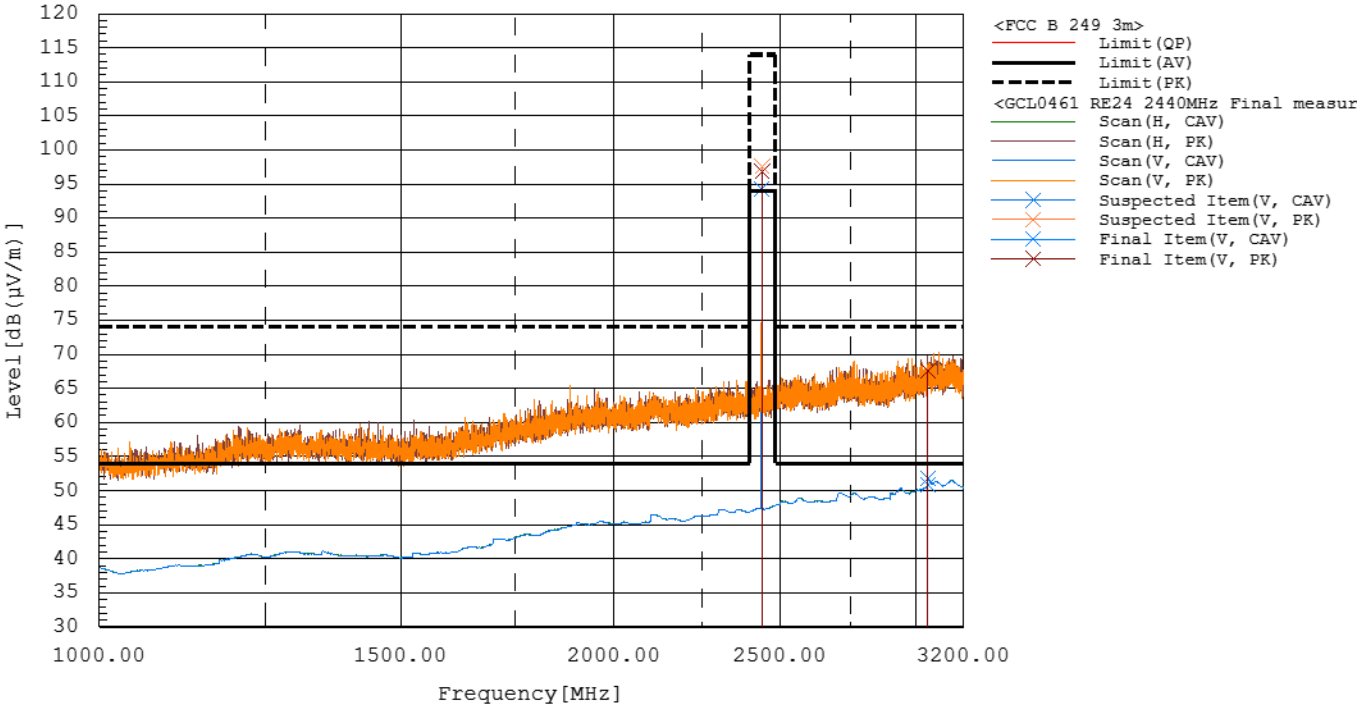


Figure RE24.2: Spectral data (X orientation, ANT 2440MHz)

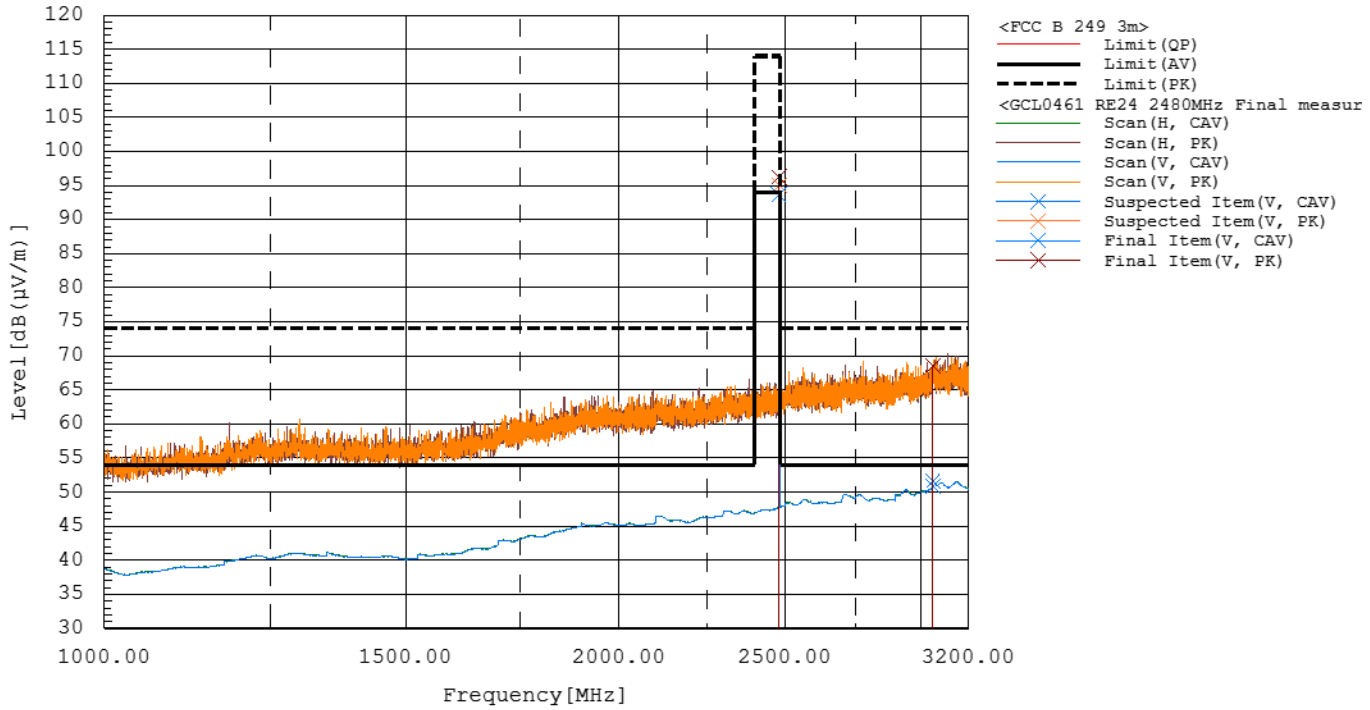


Figure RE24.3: Spectral data (X orientation, ANT 2480MHz)

Setup Photographs

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

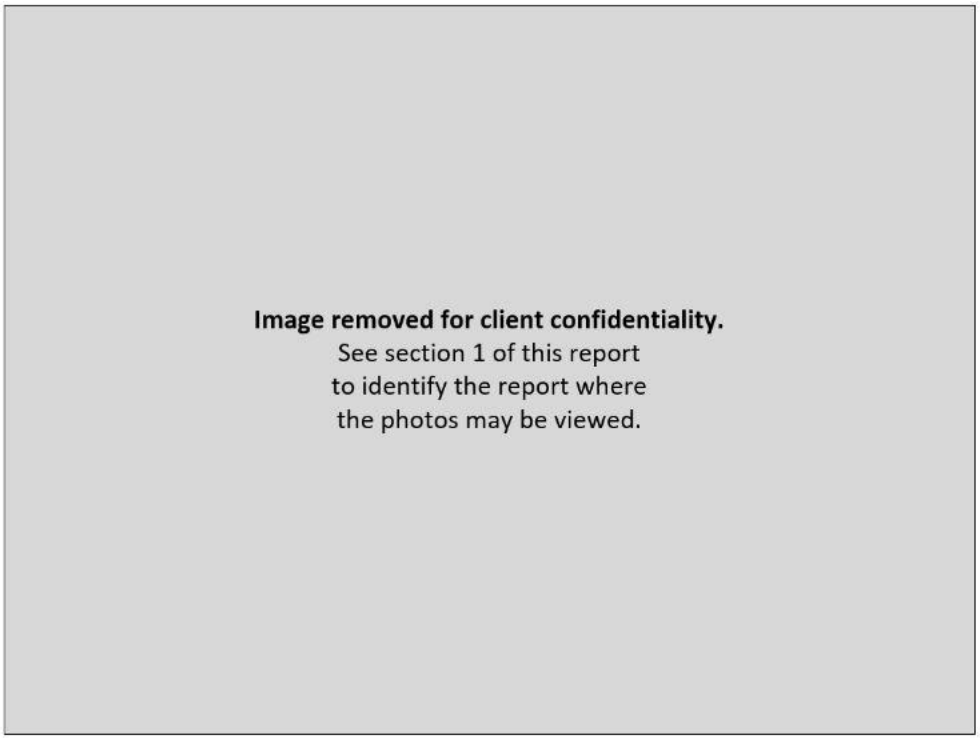


Figure RE24.4: EUT test setup, first view

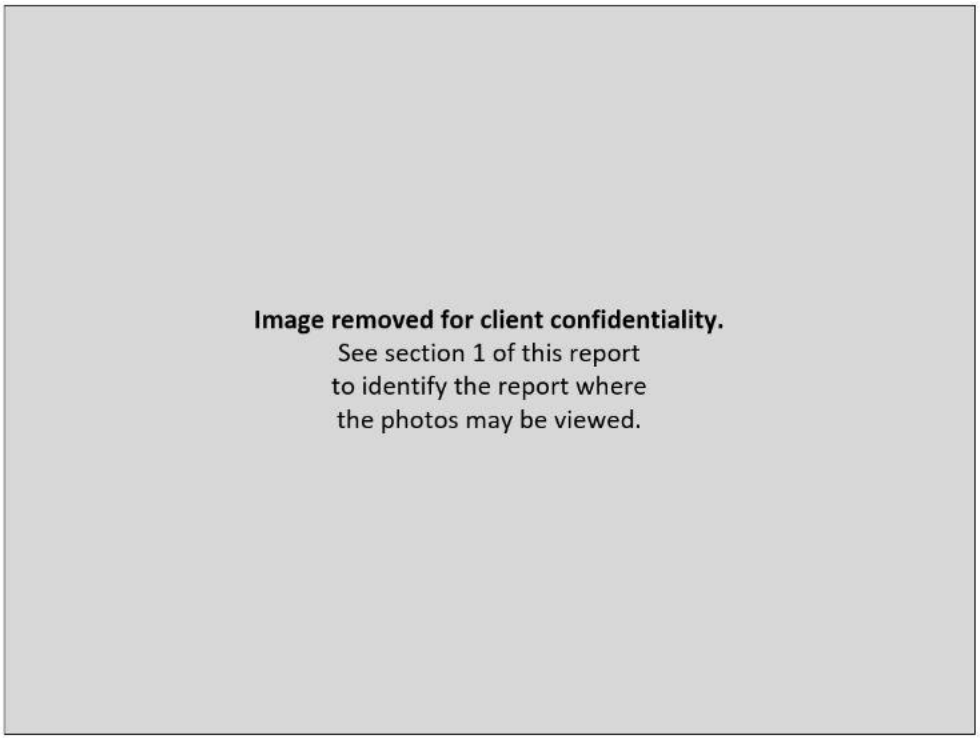


Figure RE24.5: EUT test setup, second view

This line is the end of the test record.

Test Record
Duty Cycle Effects SP01

Test Date	19 Jan 2023
Test Personnel	David Arnett
Product Model	A04600
Serial Number tested	3431708548
Operating Mode	Special: ANT Transmit per the sample studied
Arrangement	Special: USB Powered per the sample studied
Input Power	5V dc

Test record created by: **David Arnett**
Date of this test record: **27 Jan 2023**
Original record, Version A, created 27 Jan 2023.
Version B was created on 29 May 2024 for use in general test projects.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
RF Power Sensor	Rohde&Schwarz	NRP8S	109927	13-Jul-2022	15-Jul-2023
PXE 44GHz	Keysight	N9048B	MY59500016	2-Feb-2022	2-Feb-2023

Table SP01.1: Test equipment used

Test Software used: Keysight MXE System Code rev. A.33.03, R&S Power Viewer V11.3

Background

The question this test record addresses is how the radiated emission results above 1 GHz are affected by a change in transmission duty cycle. This is a general question related to the dynamics of the ANT transmission protocol and the CISPR detectors, not a specific product. As such this test record is relevant to many Garmin products other than the specific model used in the study.

ANSI C63.10 at various locations (such as 11.9.2.2.5.j) indicates that adjustment of measured average values using the measured duty cycle (D) is to be based on a linear law: 10 log(1/D). However, CISPR 16-1-1:2019 shows that a CISPR Average detector has square law pulse repetition response: 20 log(1/D). See, for example, figure 9 of CISPR 16-1-1, showing that a change in pulse repetition by a factor of 10 results in a 20 dB change in the instrument reading. The same figure shows that the reading of a CISPR peak detector should not be affected by the pulse repetition rate. This assumes the pulses are of sufficient duration to be detected.

The test application software in the test sample has two relevant modes for ANT radio transmissions. One is the regular ANT transmit test mode which produces near-continuous data. This is the operating mode used during radiated emission tests. The other is Packet mode which produces packets of a fixed length at a specified rate. That rate is expressed in units of packets-per-Hertz. These modes can be used to understand how the ANT duty cycle affects the Average Detector emission results, and whether it follows a linear or square law response.

Test Data
The client for the January 2023 project reported that the ANT radio protocol has a maximum duty cycle of 13.8%, which is much lower than the duty cycle used during radiated emission testing. The test modes discussed above allow a range of duty cycles to be evaluated above and below this protocol-limited value.

The duty cycles available in the various modes were first evaluated using the NRP8S, which is a fast diode RF power meter. This sample was one of the modified units providing a coaxial output from the transmitter rather than using the internal antenna. The packet length in Packet mode was measured at 156 usec, and duty cycles were measured for each available setting. The transmit power level from this sample was then evaluated in the same modes in a conducted manner by feeding the transmitter output through a coaxial cable to the input of the PXE Receiver. Data was recorded at the carrier frequency using peak and average detectors as they are usually set up

in a CISPR-compliant receiver during radiated emission tests above 1 GHz. All amplitude data in dBm units were then normalized to the Peak detector level as measured at the maximum duty cycle.

The resulting duty cycle and normalized amplitude data are presented in Table SP01.2.

Packet Rate (Hz)	Duty Cycle (%)	Peak (dB)	Avg (db)
Ant Tx Mode	96.300%	0	-1.2
255	3.978%	0	-27.98
128	1.997%	0	-33.89
64	0.998%	0.1	-39.69
32	0.499%	0	-45.4
16	0.250%	0.1	-50.62
8	0.125%	0	-55.42
4	0.062%	0.1	-58.95
2	0.031%	0	-61.33
1	0.016%	0.1	-61.99

Table SP01.2: Duty Cycle and Normalized Amplitude for ANT transmitter

Figure SP01.1 below plots this data along with the curves for the linear law response in ANSI C63.10 (green) and the square law response for a CISPR 16-1-1 Average detector (yellow). The average data is observed to follow the square law response for duty cycles above 0.5%, and the Peak detector data is unaffected by the duty cycle.

The orange triangles in the plot show the factors that were used in January 2023 for converting measured data in ANT Transmit test mode to the levels one would find when ANT has the maximum duty cycle permitted by the radio protocol. For comparison of data to a peak detector limit, that adjustment was 0 dB. For comparison of data to an average detector limit, that change was 20 * log (13.8% / 96.3%) or -16.83 dB.

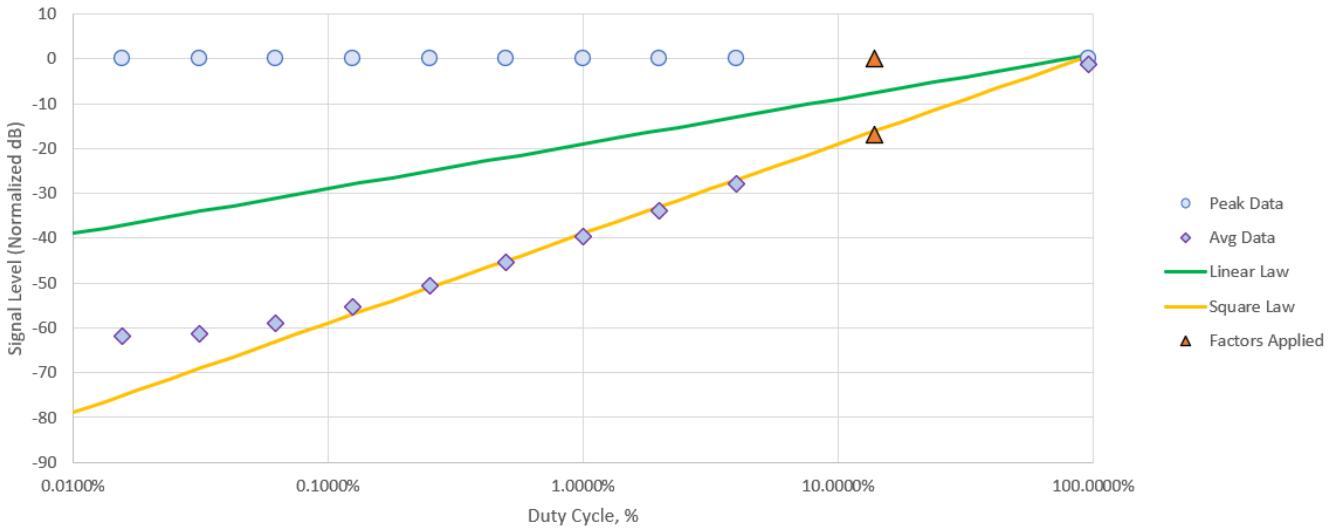


Figure SP01.1: Normalized Amplitude for ANT transmitter and linear or square law references

The Garmin Compliance lab uses this general result for projects involving ANT transmitter field measurements. The actual duty cycle, d_r, is measured for the test mode that will be used during radiated emission testing. The client reports the maximum duty cycle that the unit can produce in actual usage, d_u. Radiated emission data that has been measured using a CISPR Average detector can be reduced using $20*\log_{10}(d_u/d_r)$ before comparing against a limit. Radiated emission data measured using a Peak detector is not reduced but is reported as measured.

This line is the end of the test record.

Test Record
Radiated Emission Test RE25
Project GCL0461

Test Date(s)	26 Jun 2024, 27 Jun 2024
Test Personnel	Vladimir Tolstik assisted by David Kerr and Jim Solum
Product Model	A04882
Serial Number tested	3475112672
Operating Mode	M5 (AntTx)
Arrangement	A2 (Upwr)
Input Power	USB 5 Vdc
Test Standards:	FCC Part 15, RSS-210 (as noted in Section 6 of the report).
Frequency Range:	3200 MHz to 18000 MHz
Pass/Fail Judgment:	**PASS**
Test record created by:	David A Kerr
Date of this record:	27 Jun 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	00227596	14-Sep-2023	14-Sep-2025
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	16-Nov-2022	16-Nov-2025
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10720	16-Jan-2023	15-Jan-2026
Preamplifier, 500 MHz 18 GHz	Com-Power	PAM-118A	18040133	Calibration	Not Required
3 GHz High Pass filter	Anatech Electronics	0K0R2	01	Calibration	Not Required

Table RE25.1: 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.

In the 3.2 GHz to 18 GHz frequency range, pre-scan spectral data was taken at 1 meter and extrapolated to a 3 meter distance. Final measurements were made at 3 meters.

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

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

The table shows the selected final measurement data between 3.2 GHz and 18 GHz. It includes at least the six strongest emissions observed relative to the test limit, along with other data points of interest. Where a data point is highlighted is yellow, this is an aid to indicate the data point(s) with the least margin to the test limit. A positive margin value indicates that the emission was below the test limit. The test limit is 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		
4804.000	H	35.3	46.8	7.1	42.4	53.9	54.0	74.0	11.6	20.1	250.5	0.0
7205.500	H	33.5	45.9	11.4	44.9	57.3	54.0	74.0	9.1	16.7	327.2	303.0
9608.000	H	27.8	42.3	15.1	42.9	57.4	54.0	74.0	11.1	16.6	328.9	315.0
12010.000	H	27.5	42.7	18.2	45.7	60.9	54.0	74.0	8.3	13.1	211.9	162.0
14412.000	H	26.2	41.7	20.9	47.1	62.6	54.0	74.0	6.9	11.4	191.9	298.0
16814.000	H	25.7	40.9	24.6	50.3	65.5	54.0	74.0	3.7	8.5	369.1	284.0

Table RE25.2: Emission summary (X orientation, 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		
4880.000	H	31.6	45.3	6.6	38.2	51.9	54.0	74.0	15.8	22.1	366.6	331.0
7319.500	H	33.8	46.1	11.7	45.5	57.8	54.0	74.0	8.5	16.2	296.7	29.0
9760.000	H	28.9	42.3	14.9	43.8	57.2	54.0	74.0	10.2	16.8	317.4	287.0
12200.000	H	26.9	40.6	19.0	45.9	59.6	54.0	74.0	8.1	14.4	355.3	252.0
14640.000	H	26.4	40.7	21.4	47.8	62.1	54.0	74.0	6.2	11.9	377.9	267.0
17080.000	H	25.5	40.2	24.6	50.1	64.8	54.0	74.0	3.9	9.2	268.8	324.0

Table RE25.3: Emission summary (X orientation, 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		
4960.000	V	31.9	45.3	6.7	38.6	52.0	54.0	74.0	15.4	22.0	112.6	0.0
7440.000	V	33.1	45.3	11.7	44.8	57.0	54.0	74.0	9.2	17.0	100.0	0.0
9920.000	V	29.4	43.8	16.0	45.4	59.8	54.0	74.0	8.6	14.2	108.6	343.0
12400.000	V	27.8	41.3	18.8	46.6	60.1	54.0	74.0	7.4	13.9	207.5	33.0
14880.000	V	26.2	40.5	21.6	47.8	62.1	54.0	74.0	6.2	11.9	333.8	354.0
17360.000	V	25.6	40.6	24.1	49.7	64.7	54.0	74.0	4.3	9.3	302.7	263.0

Table RE25.4: Emission summary (X orientation, 2480MHz)

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

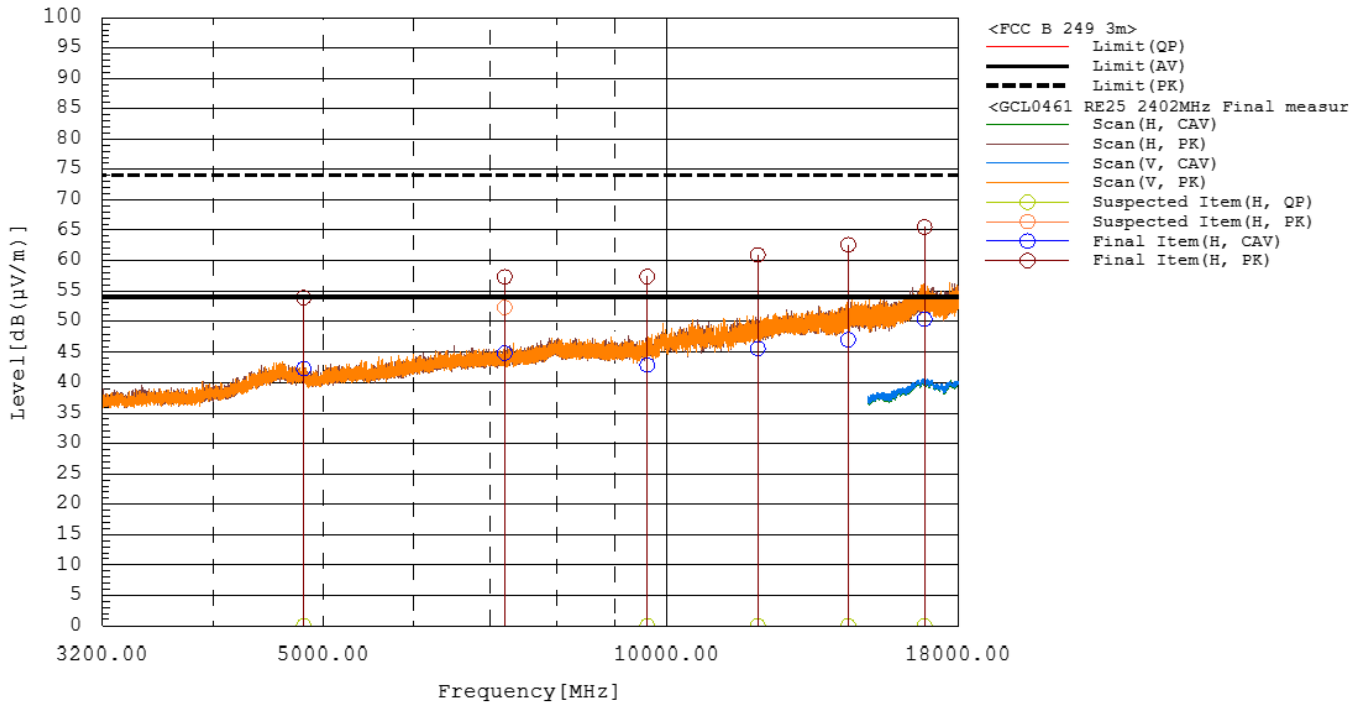


Figure RE25.1: Spectral data (X orientation, 2402MHz)

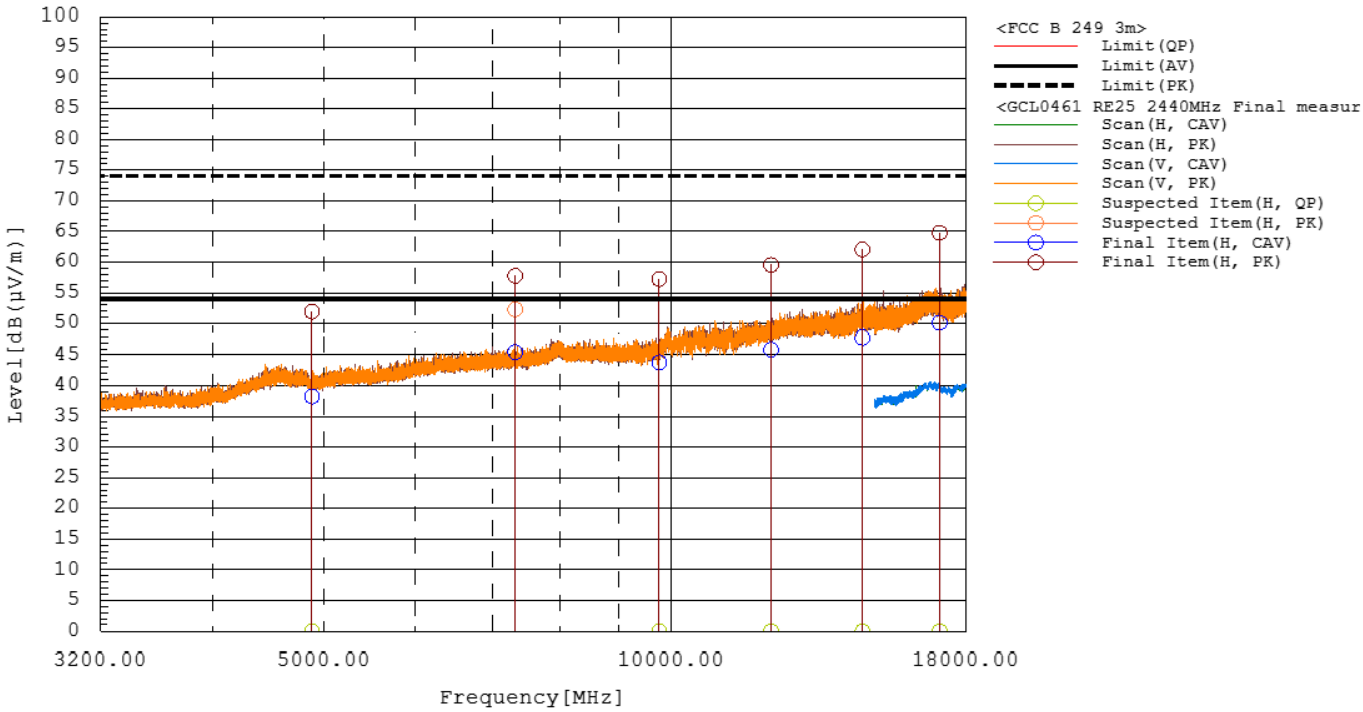


Figure RE25.2: Spectral data (X orientation, 2440MHz)

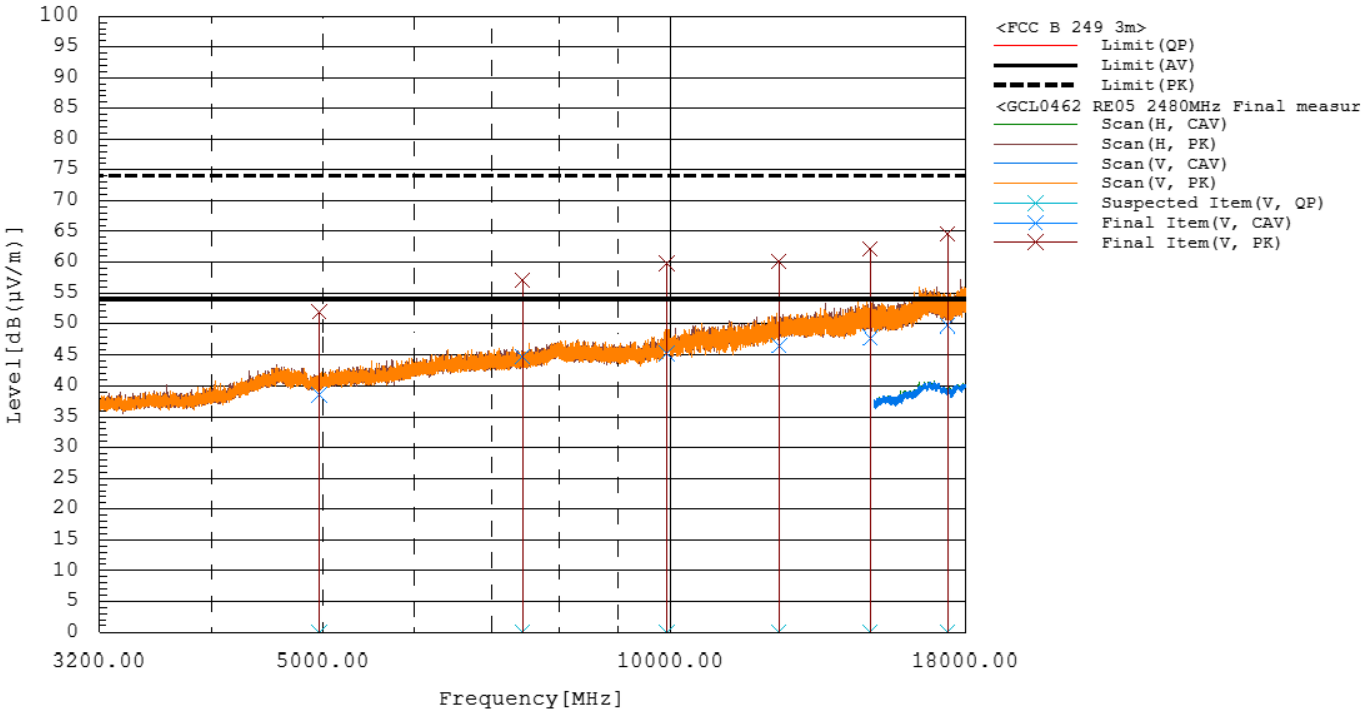


Figure RE25.3: Spectral data (X orientation, 2480MHz)

Setup Photographs

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

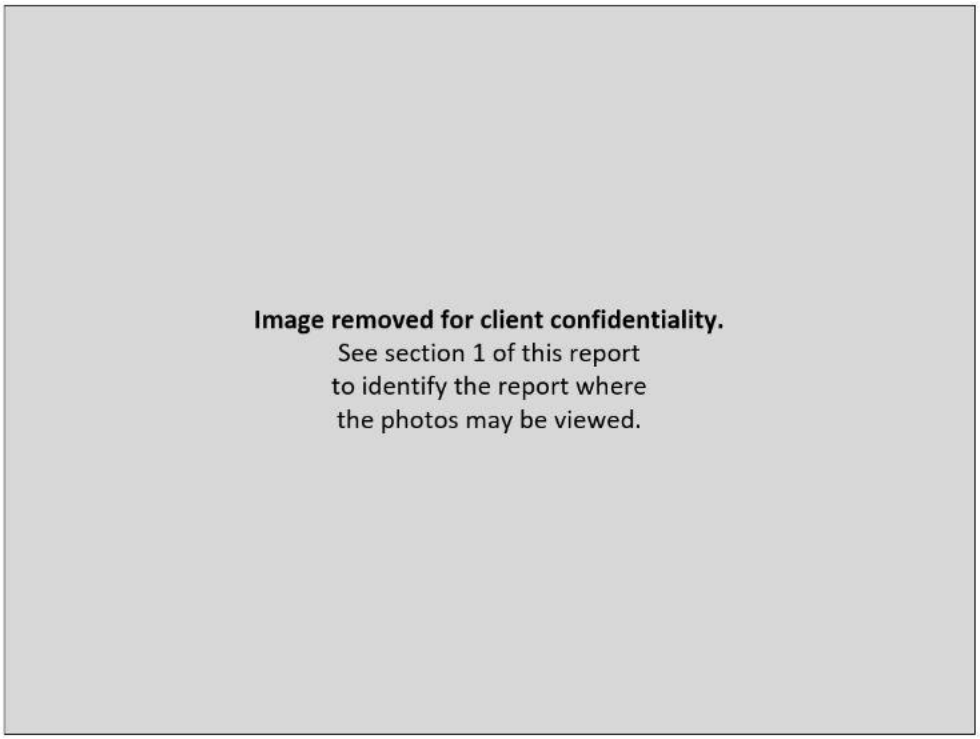


Figure RE25.4: EUT test setup, first view (X orientation)

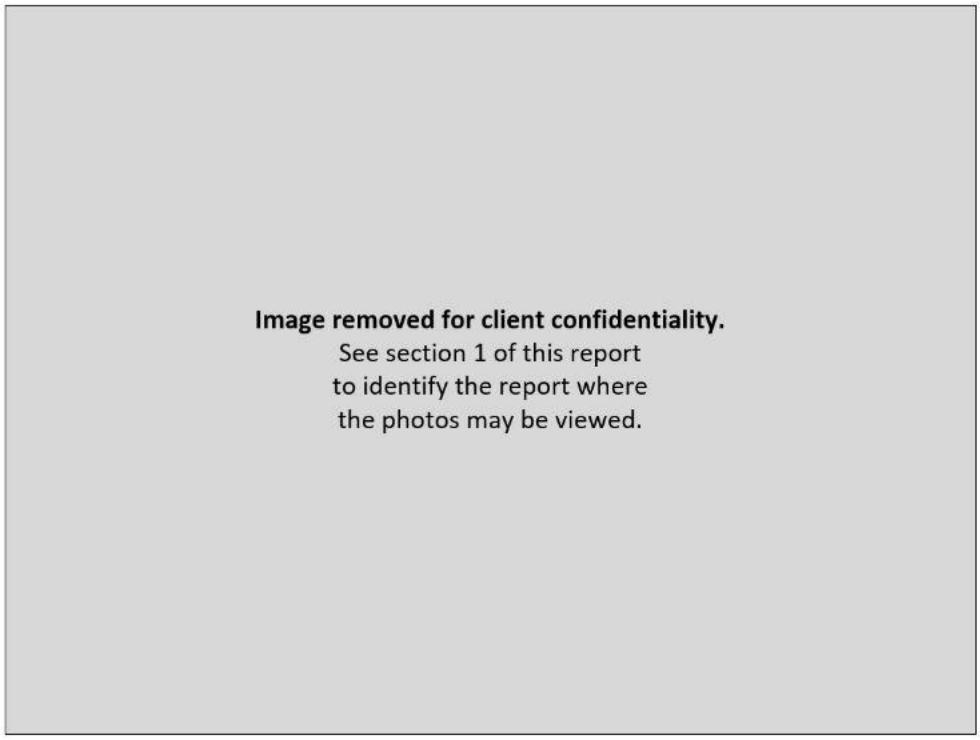


Figure RE25.5: EUT test setup, second view (X orientation)

This line is the end of the test record.

Test Record
Radiated Emission Test RE26
Project GCL0461

Test Date(s)	5 Jul 2024
Test Personnel	David Kerr, Aditya Prakash
Product Model	A04882
Serial Number tested	3475112672
Operating Mode	M5 (AntTx)
Arrangement	A2 (Upwr)
Input Power	5 Vdc
Test Standards:	FCC Part 15, ANSI C63.4, ICES-003, ANSI C63.10, ANSI C63.26, AS/NZS 4268, RSS-210 (as noted in Section 6 of the report).
Frequency Range:	18 GHz to 25 GHz
Pass/Fail Judgment:	**PASS**
Test record created by:	Aditya Prakash
Date of this record:	8 Jul 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
Antenna, Horn, 10-40 GHz	ETS Lindgren	3116C	00227673	14-Sep-2023	15-Sep-2025
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	16-Nov-2022	16-Nov-2025
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10720	16-Jan-2023	15-Jan-2026
Preamplifier, 18 Ghz to 40 Ghz	Com-Power	PAM-840A	461364	Calibration	Not Required
3 GHz High Pass filter	Anatech Electronics	0K0R2	01	Calibration	Not Required

Table RE26.1: Test Equipment Used

Software Used: Keysight PXE software A.33.03, RE Signal Maximization Tool v2021Feb25.xlsx, RE 18G to 44G Data AnalysisV2.xlsx

Test Data

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

In the 18 GHz to 25 GHz frequency range, pre-scan spectral data was taken at 1 meter and extrapolated to a 3 meter distance. Final measurements were made at 3 meters.

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

The table shows the selected final measurement data between 18 GHz and 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 Composite 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.

Frequency	Avg Limit	Avg Level	Pk Level	Av Margin	Azimuth	Height	Polarity
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(degree)	(mm)	---
19520.000	54.0	43.8	58.7	10.2	-114	1081	HORZ
21960.000	54.0	44.6	58.2	9.4	-65	1646	HORZ
24400.000	54.0	44.8	58.5	9.2	74	1321	HORZ

Table RE26.2: Emission summary

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

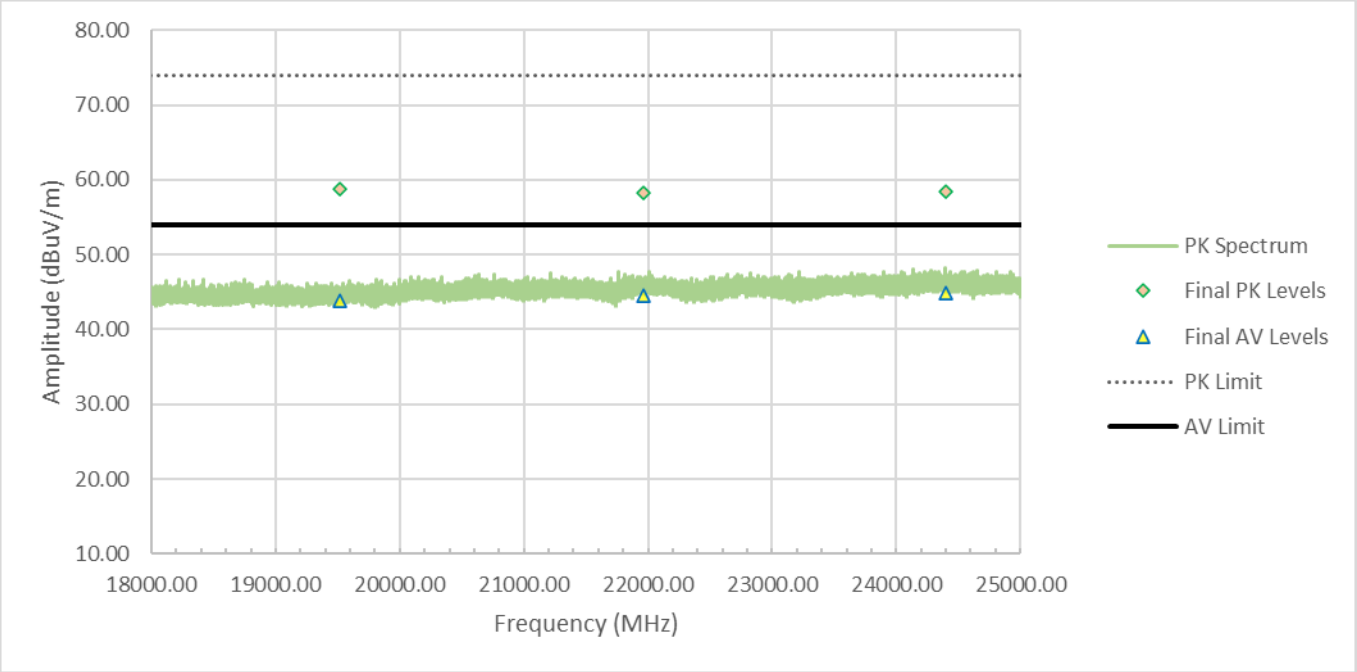


Figure RE26.1: Spectral data

Setup Photographs

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

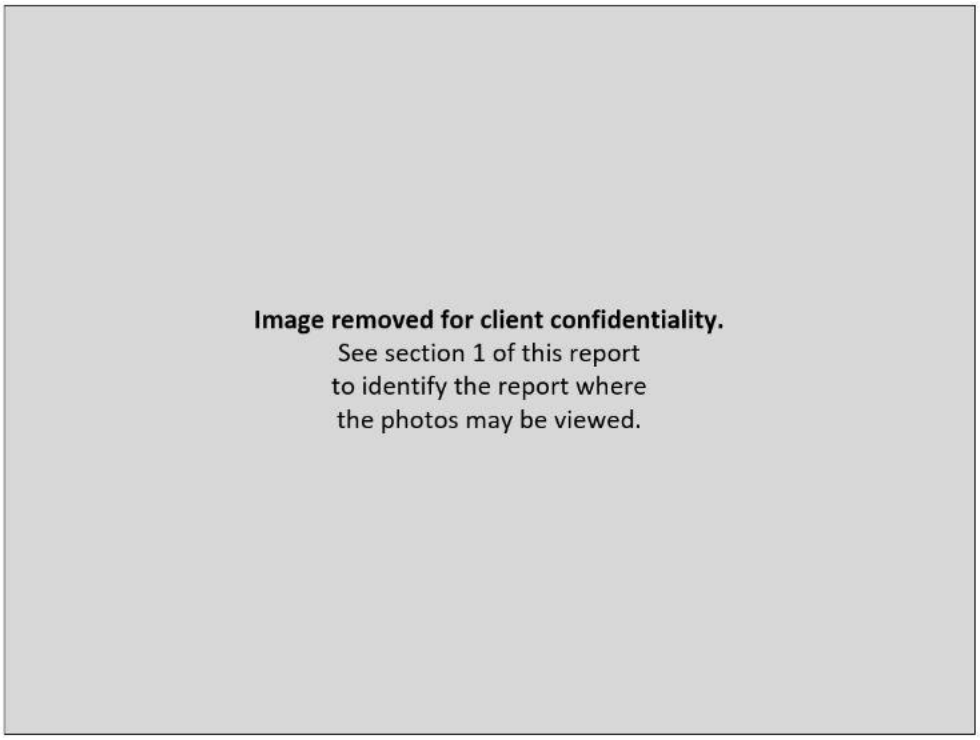


Figure RE26.2: EUT test setup, first view

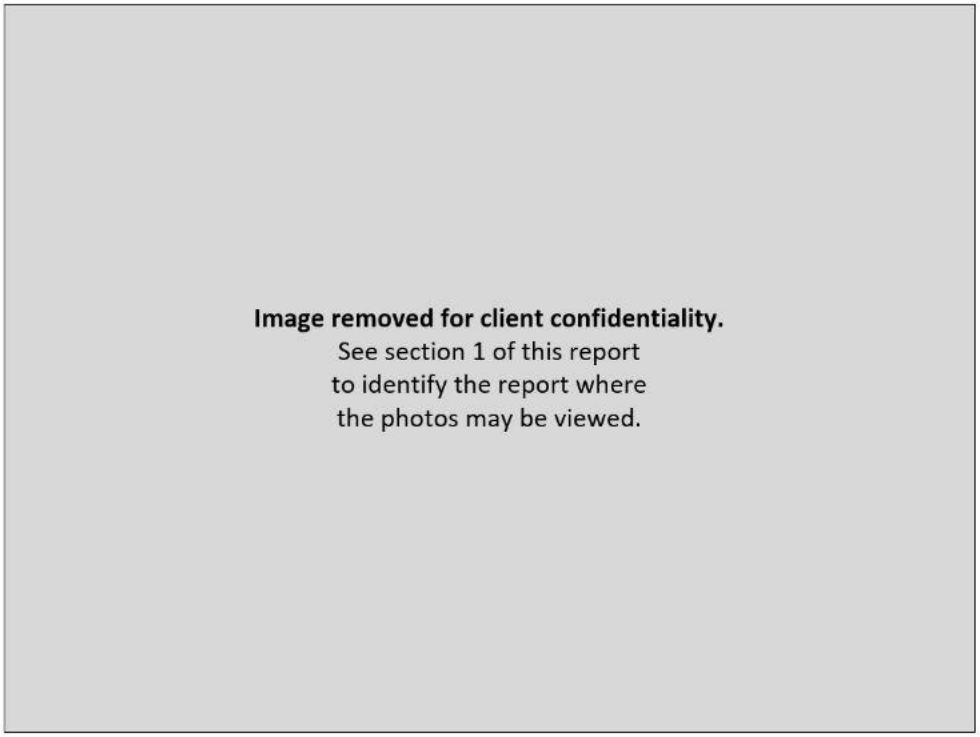


Figure RE26.3: EUT test setup, second view

This line is the end of the test record.

Test Record
Transmitter Bandwidth Tests
Test IDs TR10, TR11
Project GCL0461

Test Date(s)	26 Jun 2024
Test Personnel	Majid Farah
Product Model	A04882
Serial Number tested	3475112460
Operating Mode	M3 (BleTx), M5 (AntTx)
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:	**28 Jun 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.

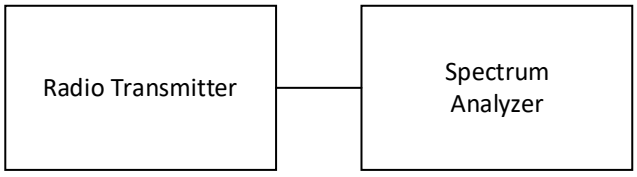


Figure TR10.1: Test setup

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	**1.0503**	**1.0506**	**1.0531**
BLE	2 Mbps	**2.0525**	**2.0517**	**2.0559**
ANT	Fixed	**0.9868**	**0.9866**	**0.9874**

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

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

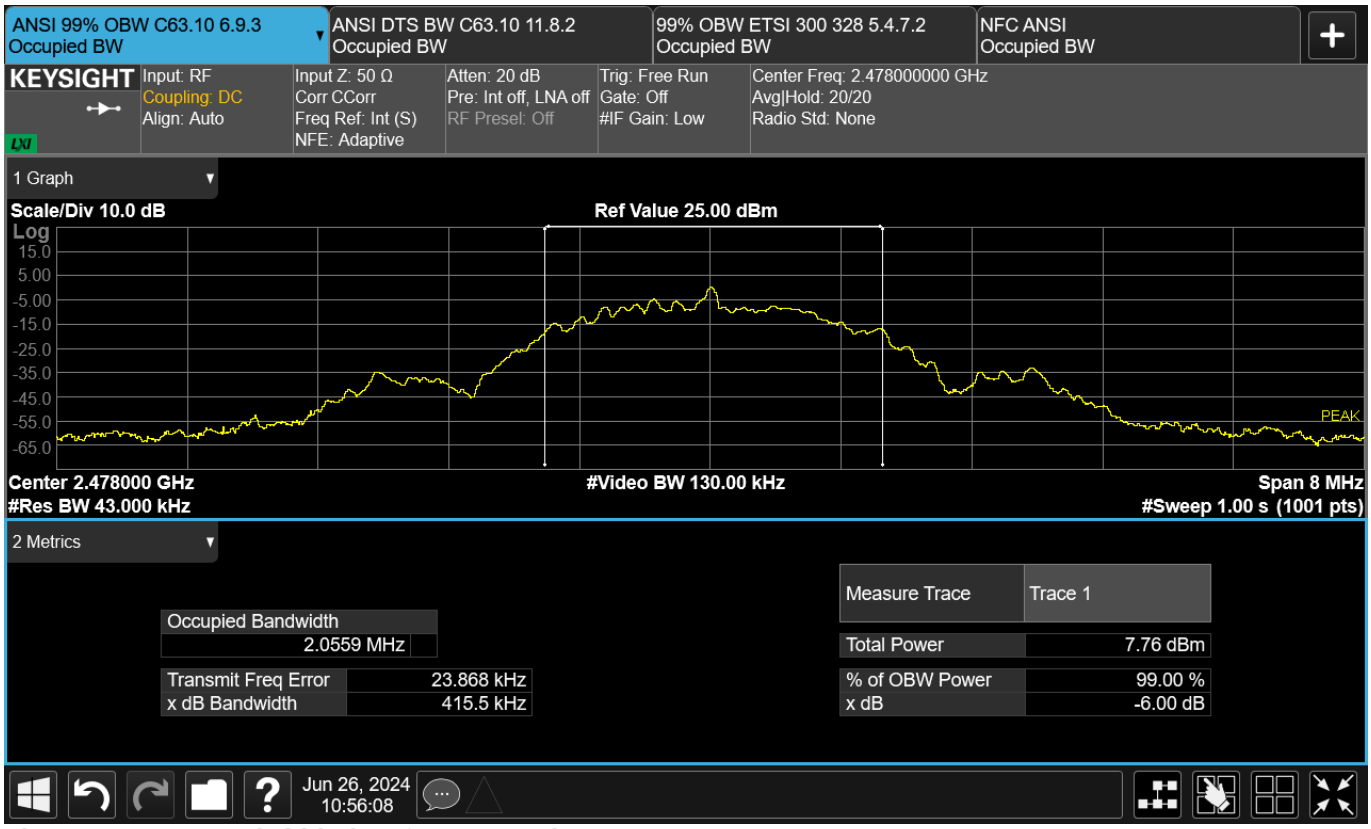


Figure TR10.3: Bandwidth data for BLE 2 Mbps at 2478 MHz

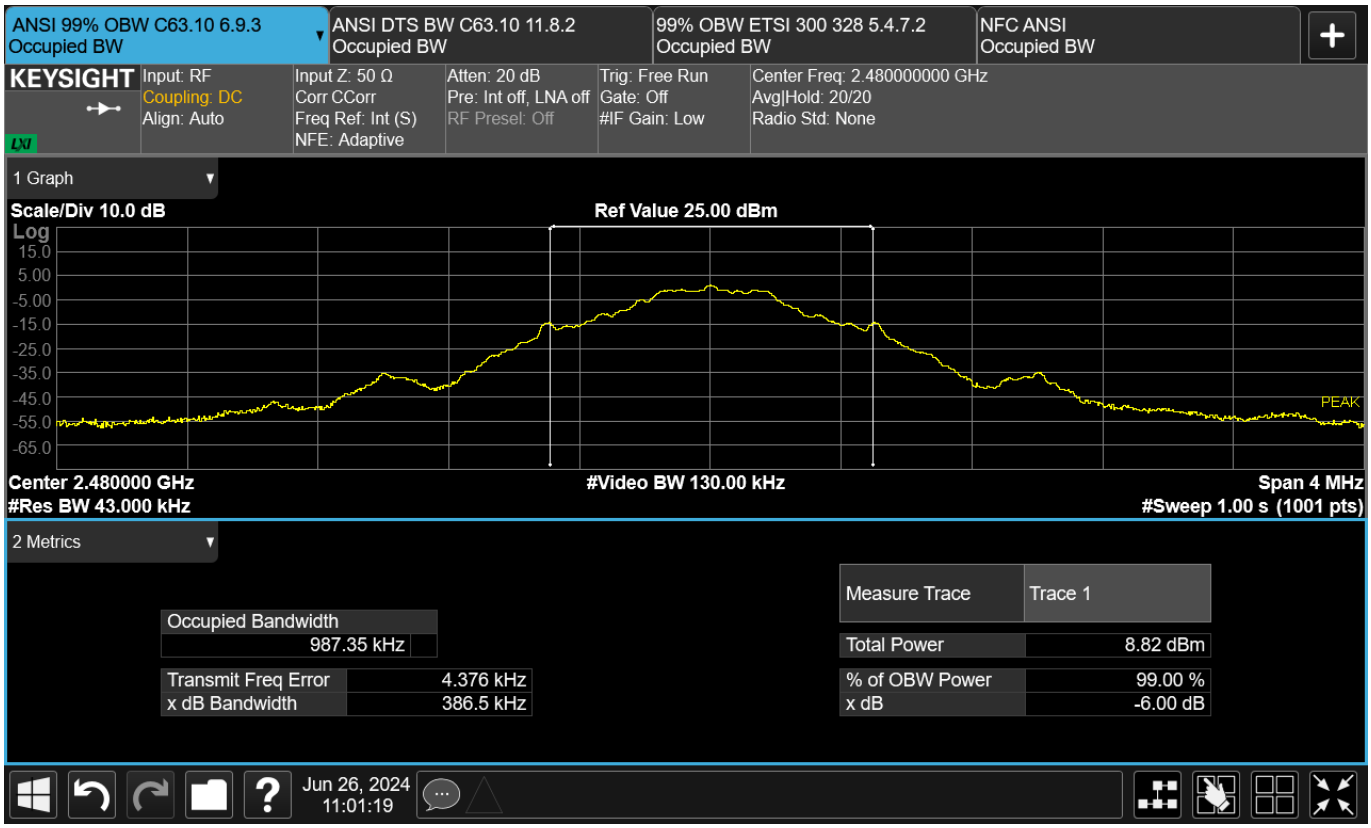


Figure TR10.4: Bandwidth data for ANT at 2480 MHz

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

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

Table 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 Stability in Extreme Conditions
Test IDs TR43
Project GCL-0461

Test Date(s)	01 Jul 2024
Test Personnel	Vladimir Tolstik supervised by Majid Farah
Product Model	A04882
Serial Number tested	3475112460
Operating Mode	M3 (BleTx)
Arrangement	A4 (Udc)
Nominal Input Power	USB 5 Vdc
Test Standards:	FCC part 15, RSS-GEN, ANSI C63.10 (as noted in Section 6 of the report)
Radio Protocol	BLE (Bluetooth Low Energy)
Pass/Fail Judgment:	**PASS**
Test record created by:	Jim Solum
Date this record:	02 Jul 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
Thermal Chamber	Tenney	T2RC	32774-02	Calibration	Not Required
DMM Multimeter 87V	Fluke	87V	63490051	21-Jun-2024	21-Jun-2025

Table TR43.1: Equipment used

Software Used: MXE 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.
Bluetooth	˚C	Vdc	dBc	dBc
BLE 1 Mbps	60	5	-32.76	-39.06
BLE 1 Mbps	50	5	-33.33	-39.72
BLE 1 Mbps	40	5	-33.59	-38.82
BLE 1 Mbps	30	5	-33.88	-39.17
BLE 1 Mbps	20	5	-33.22	-37.81
BLE 1 Mbps	10	5	-33.97	-38.57
BLE 1 Mbps	0	5	-33.62	-38.65
BLE 1 Mbps	-10	5	-34.52	-37.90
BLE 1 Mbps	-20	5	-34.96	-36.66

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

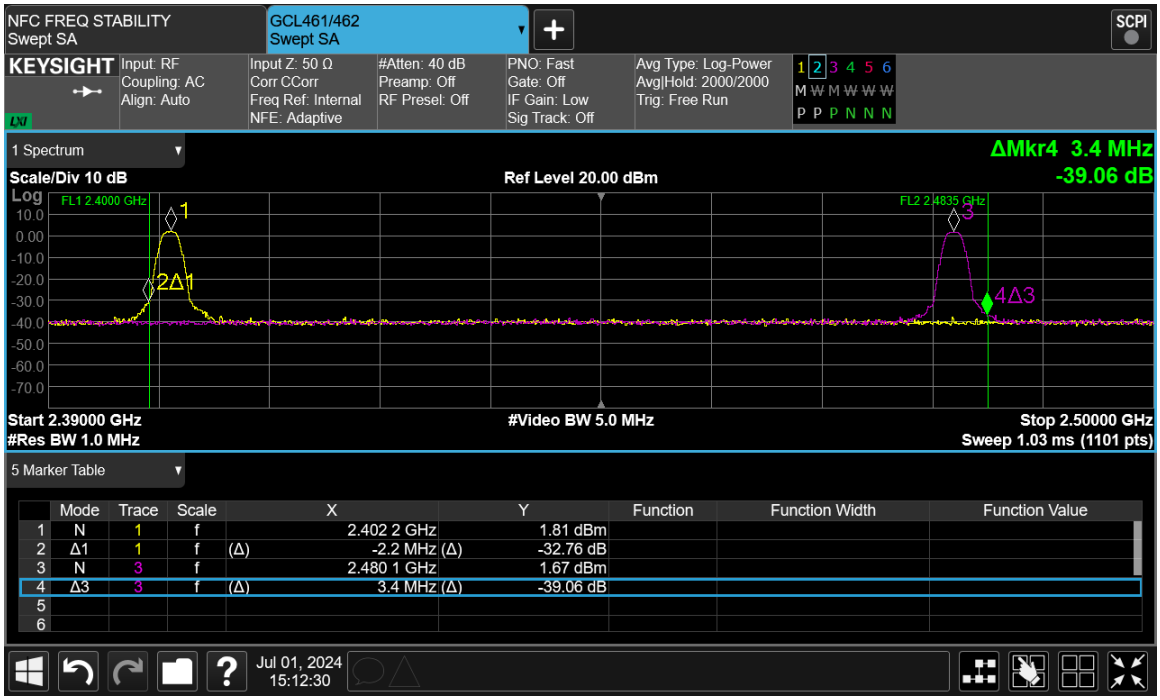


Figure TR43.1: Spectral data for BLE 1 Mbps at 60 °C which represent low and high channel

Tx Mode	Temp	Volts	Low Ch.	High Ch.
Bluetooth	˚C	Vdc	dBc	dBc
BLE 1 Mbps	20	4.25	-33.97	-38.88
BLE 1 Mbps	20	5	-33.22	-37.81
BLE 1 Mbps	20	5.75	-33.19	-38.01

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

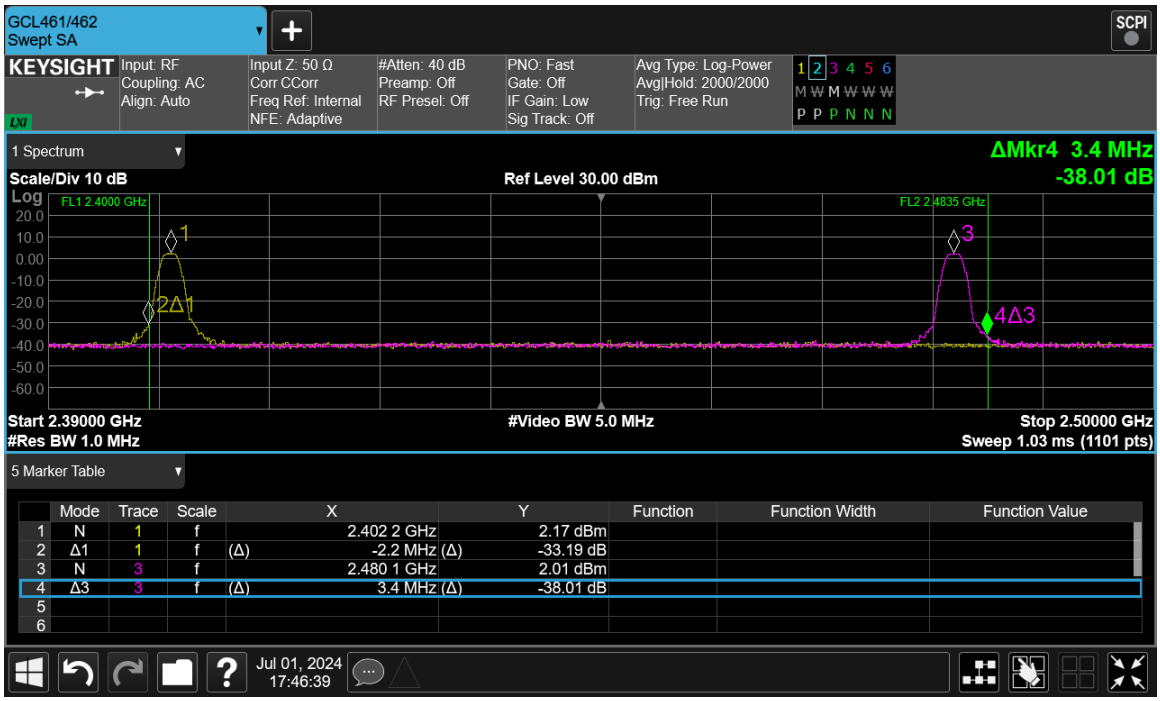


Figure TR43.2: Spectral data for BLE 1 Mbps at 20 °C which represent low and high channel at 5.75 V

Setup Block Diagram

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

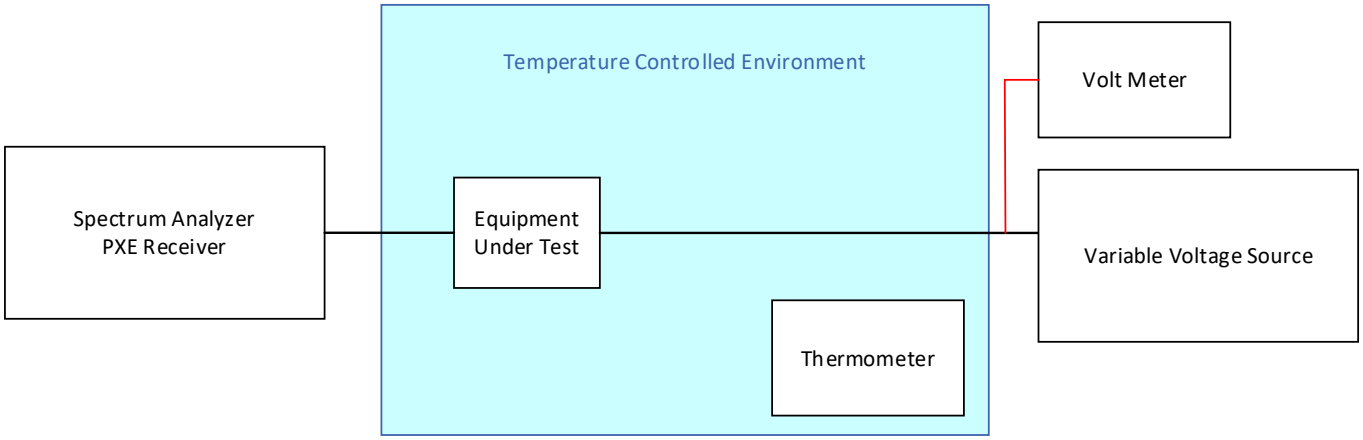


Figure TR43.3: Schematic drawing of the test equipment setup

This line is the end of the test record.

Test Record
Conducted Emissions Mains Test CE01
Project GCL0461

Test Date(s)	01 July 2024
Test Personnel	David Arnett assisted by Andy Heier
Product Model	A04882
Serial Number tested	3475112672
Operating Mode	M3 (BleTx)
Arrangement	A2 (Upwr)
Input Power	120 Vac 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:	David Arnett, Andy Heier
Date of this record:	1 July 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
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10721	30-Aug-2023	1-Sep-2026
LISN multiline; 20A 50uH	Com-Power	LIN-120C	20160005	3-Apr-2024	1-Apr-2027

Table CE01.1: Test Equipment Used

Software Used
Keysight PXE software A.33.03; CE Mains 150k to 30M Data Analysis V3 2024May23.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 indicate 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.

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)
150	66.00	56.00	34.86	34.35	24.40	23.99	31.14	31.60
164	65.28	55.28	32.12	31.91	27.20	27.02	33.16	28.09
1676	56.00	46.00	29.93	29.13	25.83	25.13	26.07	20.17
8086	60.00	50.00	28.82	28.18	23.98	23.10	31.18	26.02
10001	60.00	50.00	30.03	29.84	26.21	25.92	29.97	23.79
27348	60.00	50.00	29.64	29.71	24.57	24.51	30.29	25.43

Table CE01.2: Emission summary

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

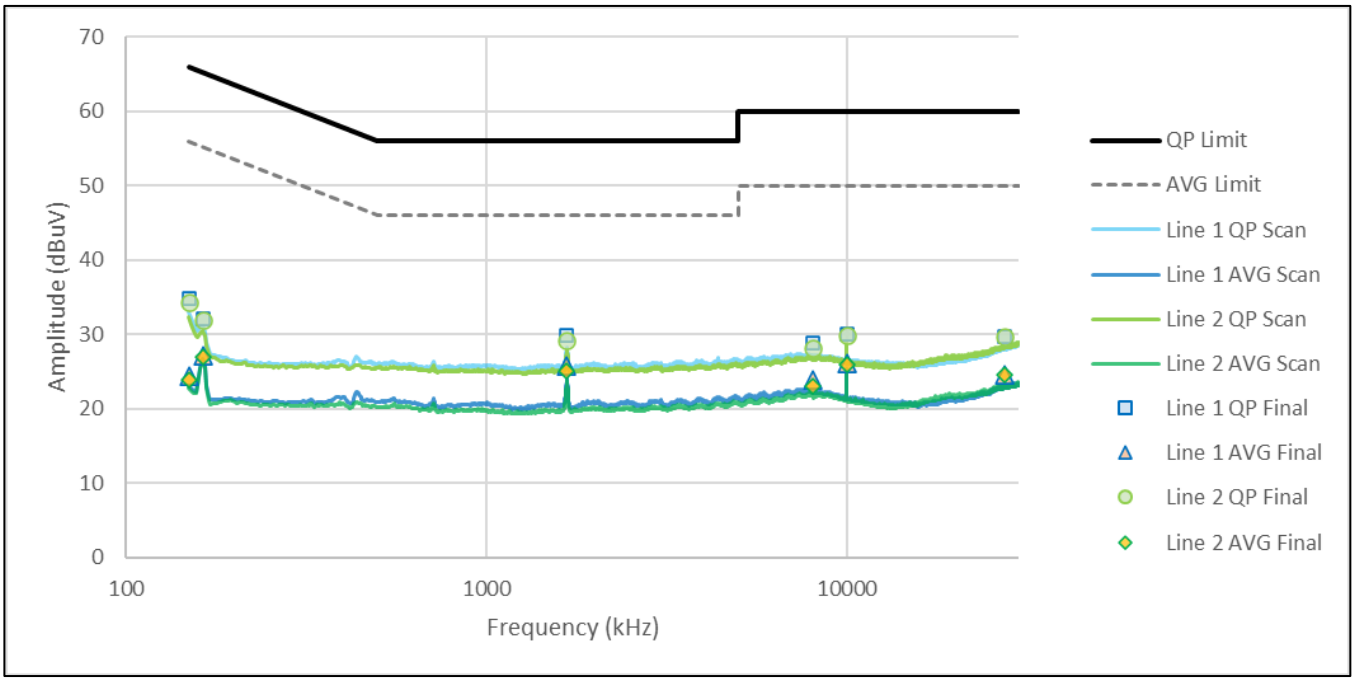


Figure CE01.1: Spectral data

Setup Photographs

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

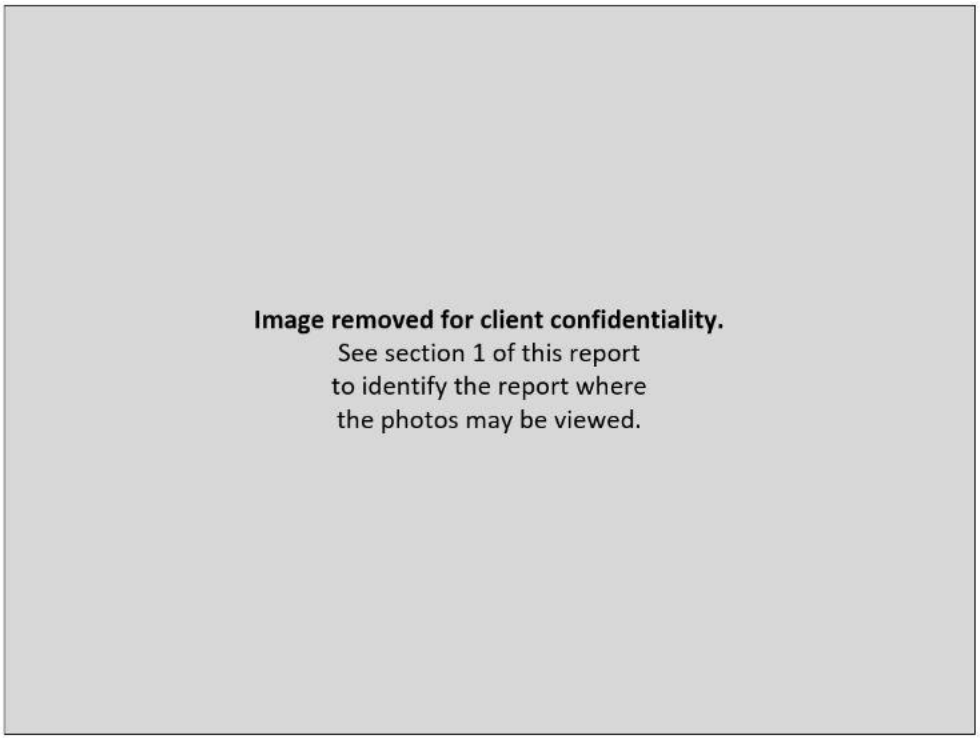


Figure CE01.2: Test setup, first view

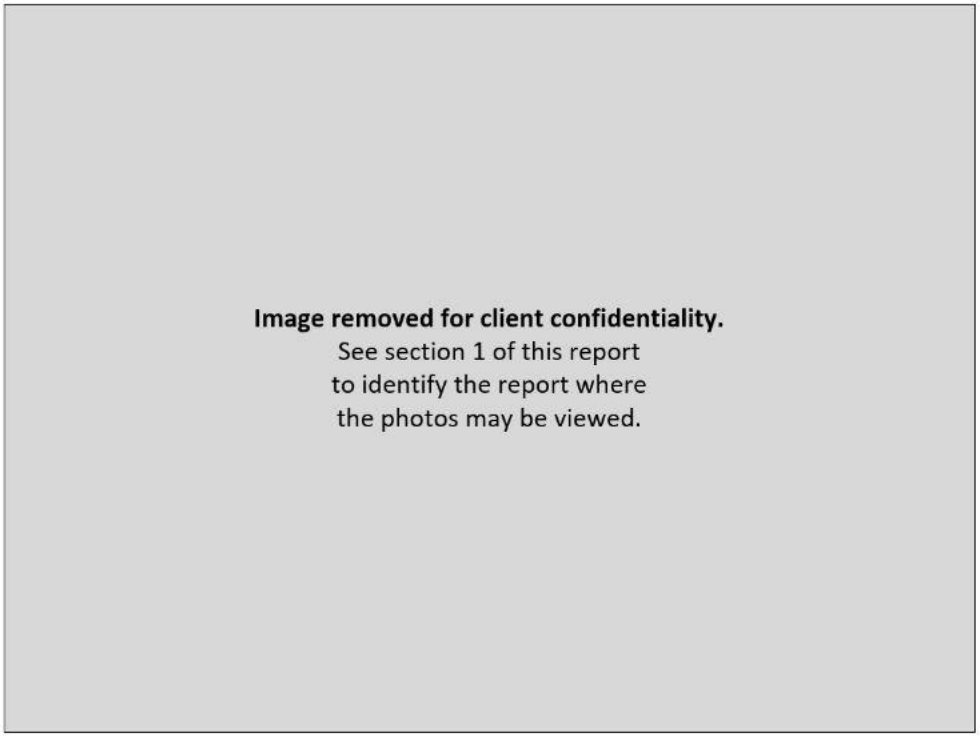


Figure CE01.3: Test setup, second view

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.