Test Report 2022-032

Version C
Issued 27 Mar 2023

Project GCL-0305
Model Identifier A04600
Primary Test Standard
FCC part 15
RSS-210 Issue 10
ICES-003 Issue 7

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

Client-supplied Information
FCC ID: IPH-04600
IC ID: 1792A-04600

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. The results are as follows.

Parameter	Description	Key Performance Values	Result	Data starts at page
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 21.48 dB below the applicable limits.	PASS	10
Carrier and Harmonic Emissions	The field strength from the radio carrier and its harmonics must meet specific limits at a 3 m test distance. [15.249(a); RSS-210 at B.10]	The limit is 50 mV/m (94 dBuV/m) in the carrier band, and 0.5 mV/m (54 dBuV/m) at all other frequencies. This sample demonstrated 9.40 dB of margin or greater.	PASS	15
Frequency Stability	The radio tuning must be robust over a range of temperature and supply voltage conditions. [RSS-Gen at 6.11]	Radio emissions remained within the allowed radio band under all environmental conditions tested.	PASS with caveat	32
Other Bandwidths	Bandwidth values are presented for 99% Occupied Bandwidth and Necessary Bandwidth	There are requirements to report these numbers, but they do not have performance limits.	Reported	36

NT (Not Tested) means the requirement is or may 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:

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

Due to confidentiality, certain material (such as test setup photographs) has been removed from this report and placed in GCL Test Report 2023-040. That report is treated as a part of this document by way of this reference.

2. Test Background

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.

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.

Test Sample received:	23 Nov 2022
Test Start Date:	28 Nov 2022
Test End Date:	01 Feb 2023

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

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

3. Report History and Approval

This report was written by Majid Farah and initially issued on 03 Feb 2023 as Version A.
Version B was released on 1 Mar 2023. The FCC ID and IC ID numbers were added to the cover page per client request, and removed some data regarding radios that are not within the subject of this report.. Updates were made to the frequency axes of figures 14.1 through 14.6 and figures 15.1 through 15.6.
Version C issued 27 Mar 2023 transferred additional sensitive materials to GCL Test Report 2023-040.

Report Technical Review: ______________________

David Arnett
Technical Lead EMC Engineer

Report Approval: ______________________

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

4. Test Sample Modifications and Special Conditions

The following special conditions or usage attributes were found 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) made and are 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	A04600
Serial Numbers Tested	3431708344, 3431708548, 3431708479, 3431708421, 3431708497

[Material removed for confidentiality. See section 1 of this report to identify the report where the material may be viewed]

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

5.2 Key Parameters

EUT Input Power:	5 Vdc
I/O Ports:	USB
Radio Transceivers:	Bluetooth Low Energy, ANT/ANT+, NFC
Radio Receivers:	GNSS
Highest internal frequency:	2.484 GHz
Firmware Revision	1201

[Material removed for confidentiality. See section 1 of this report to identify the report where the material may be viewed]

5.3 Operating modes

During test, the EUT was operated in the following modes.

Mode 2: M2 (NFC-L). EUT linked to NFC reader pad and transmit data
Mode 5: M5 (BLE Tx). EUT in test mode-BLE Tx always On
Mode 6: M6 (BLE-L). EUT linked to companion device through BLE
Mode 7: M7 (GNSS). EUT in GNSS test mode
Mode 8: M8 (ANT Tx). EUT in test mode- ANT Tx always On
Mode 9: M9 (ANT-L). EUT linked to companion device through ANT
Mode 10: M10 (ALL). all relevant radios On
Mode 11: M11 (BLE Rx). EUT in test mode- BLE Rx always On for Rx spurious emission test

5.4 EUT Arrangement

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

Arrangement 1: A1 (PwrA) EUT powered up through a DC power supply with a type A USB connection

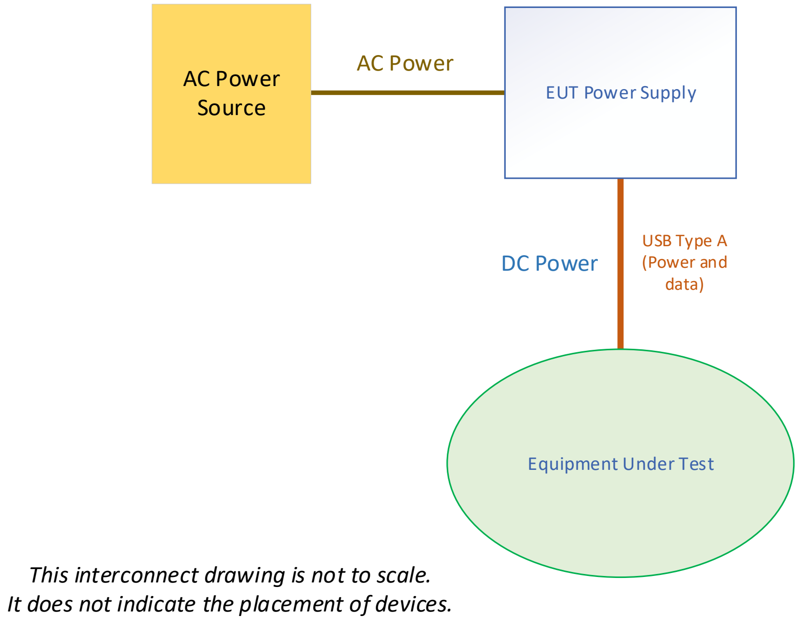

Figure 1: Block diagram of equipment arrangement A1

Arrangement 2: A2 (NFC) EUT Powered up through arrangement A1, A3 or A4 in NFC mode and near to an NFC reader device

Arrangement 3: A3 (PwrPc) EUT Powered up through USB port of a Laptop

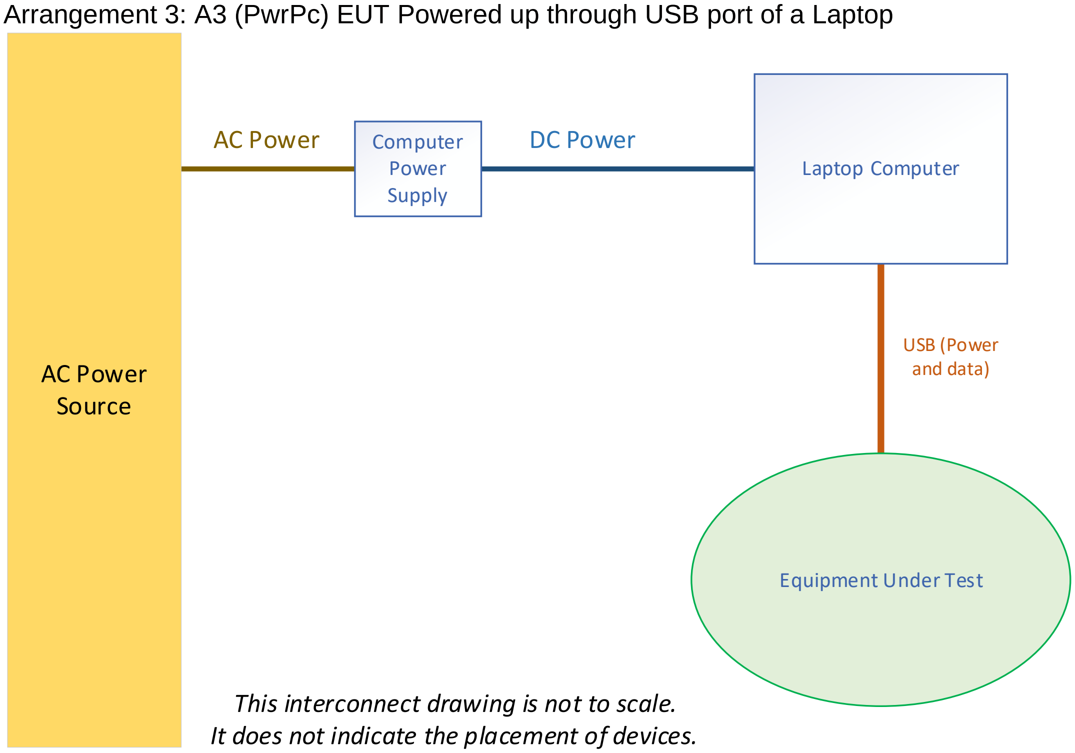

Figure 2: Block diagram of equipment arrangement A3

Arrangement 4: A4 (Standalone) EUT Powered up through internal battery

5.5 Associated Equipment (AE) used

Description	Manufacturer	Model	Serial Number
Smartwatch	Garmin	A04112	3400414926
Laptop	Dell	Latitude 5410	5VSPFB3
Laptop power supply	Dell	65 W	CN-oH374X-CH200-OBD-7TC0-A02
NFC reader	ACS	ACR1252	RR554-086776
USB Power type A	Garmin	PSAF10R-050Q	362-00096-00
iPad	Apple	iPad Pro (11-inch)	DMPZ7582KD6L
Smartwatch	Garmin	A04600	3423419439

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

5.6 Cables used

Description	From	To	Length	EMC Treatment
USB	Type A	Special	50 cm	None

Table 3: List of cable 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.

FCC Part 15.249, Subpart B
ANSI C63.4: 2014
ANSI C63.10: 2013
ICES-003 Issue 7: 2020
RSS-GEN Issue 5 Amd 2
RSS-210 Issue 10 Amd 1

6.2. Non-accredited Standards

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

FCC Part 2.202
TRC-43

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.

The ANT and Bluetooth Low Energy (BLE) transmissions use the same hardware and differ on in matters of protocol. Since BLE emissions are stronger than ANT emissions, certain spurious emission tests using BLE transmissions are also use to demonstrate compliance of the ANT transmitter.

During tests of radiated harmonic emissions, the data are adjusted downward 16.83 dB before comparison to the Average Detector limit. This adjustment is intended to compensate for the maximum possible transmitter duty cycle. The adjustment value is calculated using 20 log(1/D) where D is the duty cycle. ANSI C63.10 would seem to prefer any adjustment be based on 10 log(1/D). The details around this choice are discussed more fully in Test Record SP01 which appears at about page 30. No adjustment is made when comparing data to a Peak Detector limit, consistent with ANSI C63.10.

6.4 Laboratory Accreditation

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

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

7 Measurement Instrumentation Uncertainty

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

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

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

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

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

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

8 Selected Example Calculations

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

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

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

8.1 AC Mains conducted emissions at 22 MHz

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

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

8.2 Radiated Emissions at 630 MHz

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

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

8.3 Radiated Emissions at 2.7 GHz

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

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

9 Environmental Conditions During Test

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

Temperature:	20.0 to 23.9 °C
Relative Humidity:	33.8% to 57.9% (non-condensing)
Barometric Pressure	96.0 to 99.7 kPa

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 RE09
Project GCL0305

Test Date(s) 28 Nov 2022 – 29 Nov 2022
Test Personnel David Kerr, Jim Solum (Assisted)

Product Model A04600
Serial Number tested 3431708344

Operating Mode M8 (Ant Tx)
Arrangement A1 (PwrA)
Input Power USB 5 Vdc

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

Frequency Range: FCC Restricted Bands (2200-2390MHz, 2483.5-2500MHz)
Pass/Fail Judgment: PASS

Test record created by: David Kerr, Jim Solum
Date of this record: 05 DEC 2022

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver	Keysight	N9048B	MY59290135	21-Sep-2022	15-Sep-2023
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	4-Nov-2021	4-Nov-2024
Antenna, Horn, 1-18 GHz	ETS Lindgren	3117	00227596	27-Aug-2021	1-Sep-2023
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 Electro	0K0R2	01	Calibration	Not Required
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10721	15-Aug-2022	15-Aug-2023
Barometer	Traceable	6453	221702700	3-Aug-2022	1-Aug-2024

Table RE09.1: Test Equipment Used

Software Used
Keysight PXE N9048B Firmware version A.32.06.
RE Signal Maximization Tool v2021Feb25.xlsx
FCC Restricted Band 2p4GHz Template v1 2022Sep08.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.

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	EUT
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	---	Orientation
2216	54	74	32.019	47.376	21.981	26.624	-144	3582	HORZ	X
2390	54	74	32.515	46.455	21.485	27.545	-29	4000	HORZ	X

Table RE09.2: FCC restricted band from 2200 to 2390 MHz

Frequency	Avg Limit	Pk Limit	Avg Level	Pk Level	Av Margin	Pk Margin	Azimuth	Height	Polarity	EUT
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	---	Orientation
2491	54	74	31.086	45.135	22.914	28.865	59	2300	HORZ	Z
2483.5	54	74	31.493	45.106	22.507	28.894	-122	2679	VERT	Z

Table RE09.3: FCC restricted band from 2483.5 to 2500 MHz

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

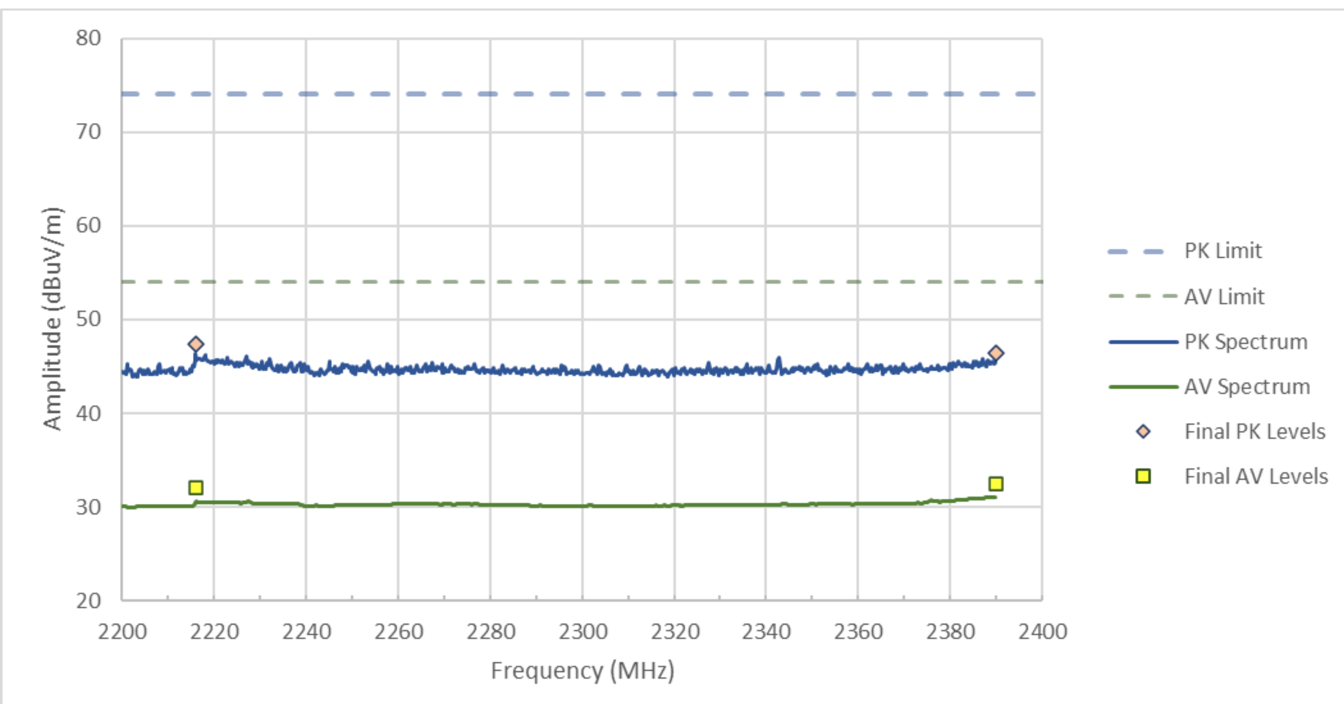

Figure RE09.1: : FCC restricted band spectral data from 2200 to 2390 MHz

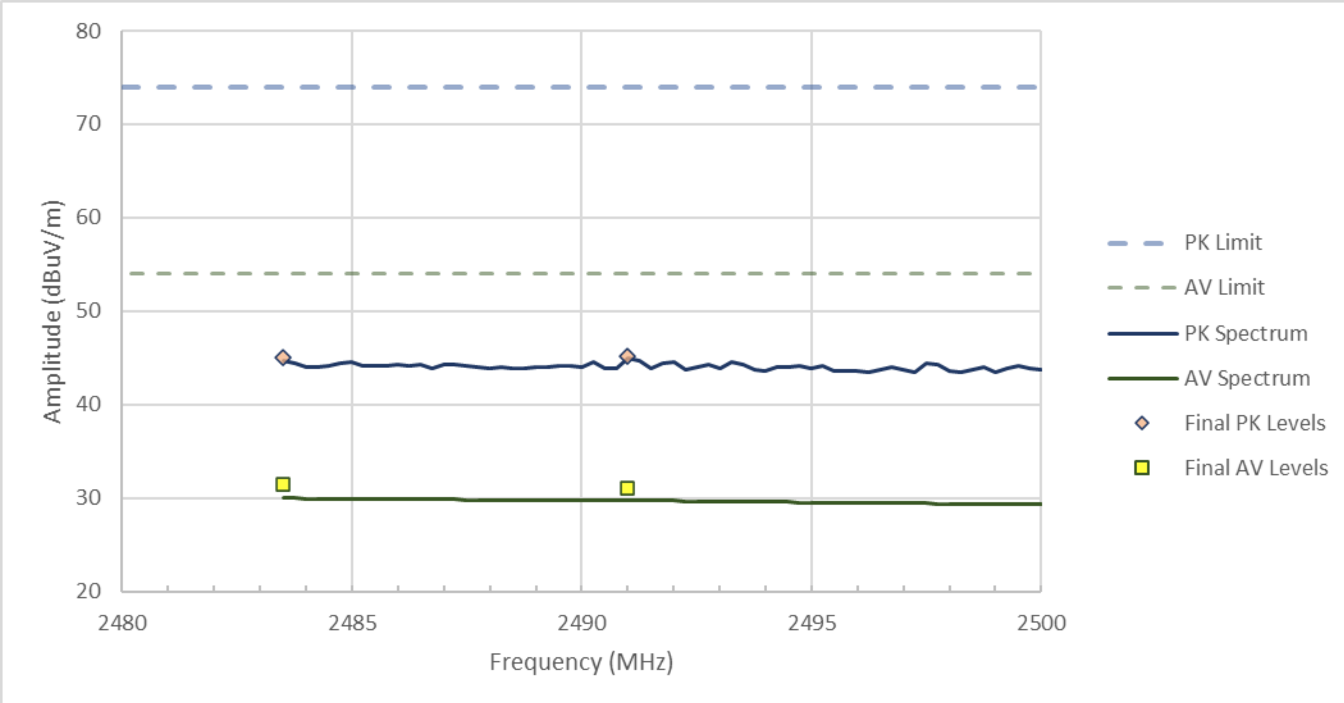

Figure RE09.2: FCC restricted band spectral data from 2483.5 to 2500 MHz

Setup Photographs

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

Figure RE09.3: Z orientation front of EUT

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

Figure RE09.4: Z orientation rear of EUT

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

Figure RE09.5: X orientation front of EUT

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

Figure RE09.6: X orientation rear of EUT

This line is the end of the test record.

Test Record
Radiated Emission Test RE01
Project GCL0305

Test Date(s)	07 Dec 2022
Test Personnel	David Kerr
Product Model	A04600
Serial Number tested	3431708344
Operating Mode	M5 (BLE Tx)
Arrangement	A1 (PwrA)
Input Power	USB 5 Vdc
Test Standards:	FCC Part 15, ANSI C63.10, CISPR 32, EN 55032, AS/NZS 4268, RSS-210 (as noted in Section 6 of the report).
Frequency Range:	30 MHz to 1000 MHz
Pass/Fail Judgment:	**PASS**
Test record created by:	**David Kerr, Jim Solum**
Date of this record:	**08 Dec 2022**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
Antenna, Biconilog, 30M-6 GHz	ETS Lindgren	3142E	00233201	19-Jul-2022	15-Jul-2024
SAC 3m, below 1 GHz	Frankonia	SAC3	F199004	25-Oct-2021	25-Oct-2024
PXE Receiver	Keysight	N9048B	MY59290135	21-Sep-2022	15-Sep-2023
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10721	15-Aug-2022	15-Aug-2023
Barometer	Traceable	6453	221702700	3-Aug-2022	1-Aug-2024

Table RE01.1: Test Equipment Used

Software Used

Keysight PXE N9048B Firmware version A.32.06
RE Signal Maximization Tool v2021Feb25.xlsx
RE 30M to 1G Data Analysis Template V3 2022May10.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.

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 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 Composite FCC/CISPR Class B Limit at 3m.

Frequency (MHz)	Limit (dBuV/m)	Measured (dBuV/m)	Margin (dB)	Azimuth (degree)	Height (mm)	Antenna Polarity
30.120	40.0	27.4	12.6	0	1000	*
95.700	40.0	18.9	21.1	-68	1012	VERT
404.100	46.0	24.2	21.8	0	1000	*
687.780	46.0	30.8	15.2	0	1000	*
851.550	46.0	30.3	15.7	0	1000	*
944.130	46.0	33.9	12.1	-38	3616	HORZ

Table RE01.2: Emission summary

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

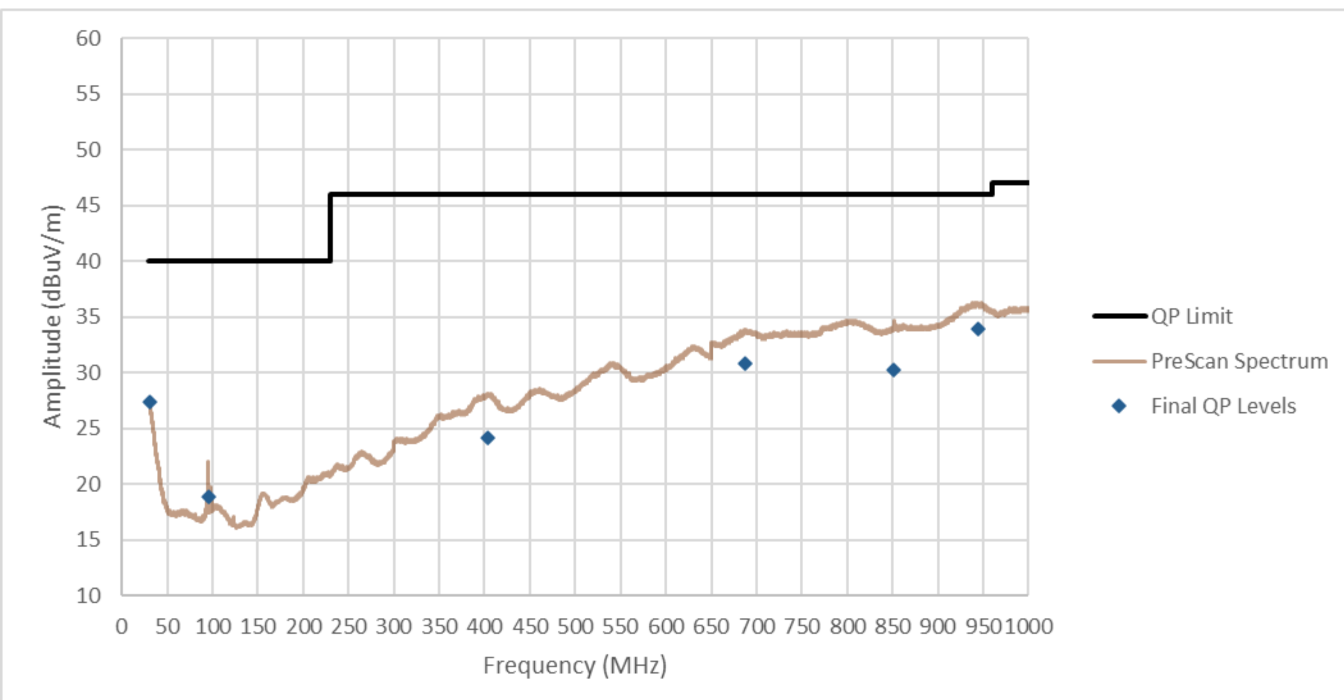

Figure RE01.1: Spectral data

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 RE01.2: Front EUT test setup

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

Figure RE01.3: Rear EUT test setup
This line is the end of the test record.

Test Record
Radiated Emission Test RE14
Project GCL0305

Test Date(s) 17 - 19 Jan 2023
Test Personnel Christian Shepherd

Product Model A04600
Serial Number tested 3431708344

Operating Mode M8 (Ant Tx)
Arrangement A1 (PwrA)
Input Power USB 5 Vdc

Test Standards: FCC Part 15 C (as noted in Section 6 of the report).

Frequency Range: 1 GHz to 18 GHz
Pass/Fail Judgment: PASS

Test record created by: Christian Shepherd
Date of this record: 23 Jan 2023

Original record, Version A released 23 Jan 2023.
Version B released 27 Feb 2023 adjusted the frequency scale on figures 14.1 through 14.6.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver	Keysight	N9048B	MY59290135	21-Sep-2022	15-Sep-2023
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	4-Nov-2021	4-Nov-2024
Antenna, Horn, 1-18 GHz	ETS Lindgren	3117	00227596	27-Aug-2021	1-Sep-2023
Preamplifier, 500 MHz 18 GHz	Com-Power	PAM-118A	18040133	Calibration	Not Required
Tape measure, 1” x 33’	Lufkin	PHV1410CMEN	10721	15-Aug-2022	15-Aug-2023
Barometer	Traceable	6453	221702700	3-Aug-2022	1-Aug-2024

Table RE14.1: Test equipment used

Software Used
PXE Software Revision A.32.06

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 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 1 GHz and 18 GHz. Final measurements were performed for three ANT frequencies on the EUT: 2402 MHz (Low Channel), 2442 MHz (Middle Channel), and 2480 MHz (High Channel). Each table includes at least six of 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 Class B Limit at 3m.

For the ANT test mode, the EUT is operating in a 'continuous' mode with a 96.3% duty cycle. The client reports that the ANT protocol has a maximum duty cycle of 13.8%. The duty cycle adjustment applied subtracts 16.83 dB from the measured data when comparing against average limits. No adjustment is applied when comparing measured data against peak limits. See test record SP01 for further details.

Frequency	Avg Limit	Pk Limit	Avg Level	Adjusted Avg Level	Pk Level	Av Margin	Pk Margin	Azimuth	Height	Ant.	EUT
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	Polarity	Polarity
2402.00	94.00	114.00	97.60	80.77	97.80	13.23	16.20	137	1071	HORZ	Z
4804.00	54.00	74.00	35.70	18.87	49.50	35.13	24.50	137	1071	HORZ	Z
7206.00	54.00	74.00	40.20	23.37	54.10	30.63	19.90	137	1071	HORZ	Z
9608.00	54.00	74.00	42.90	26.07	57.00	27.93	17.00	137	1071	HORZ	Z
12010.00	54.00	74.00	45.80	28.97	60.10	25.03	13.90	137	1071	HORZ	Z
14412.00	54.00	74.00	47.50	30.67	61.40	23.33	12.60	137	1071	HORZ	Z
16814.00	54.00	74.00	50.90	34.07	64.60	19.93	9.40	137	1071	HORZ	Z

Table RE14.2: Low Channel Emission summary

Frequency	Avg Limit	Pk Limit	Avg Level	Adjusted Avg Level	Pk Level	Av Margin	Pk Margin	Azimuth	Height	Ant.	EUT
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	Polarity	Polarity
2442.00	94.00	114.00	96.80	79.97	97.00	14.03	17.00	-70	1438	VERT	X
4884.00	54.00	74.00	35.80	18.97	49.50	35.03	24.50	-70	1438	VERT	X
7326.00	54.00	74.00	40.10	23.27	53.50	30.73	20.50	-70	1438	VERT	X
9768.00	54.00	74.00	43.40	26.57	57.20	27.43	16.80	-70	1438	VERT	X
12210.00	54.00	74.00	45.80	28.97	59.50	25.03	14.50	-70	1438	VERT	X
14652.00	54.00	74.00	48.10	31.27	61.60	22.73	12.40	-70	1438	VERT	X
17094.00	54.00	74.00	50.80	33.97	64.20	20.03	9.80	-70	1438	VERT	X

Table RE14.3: Middle Channel Emission summary

Frequency	Avg Limit	Pk Limit	Avg Level	Adjusted Avg Level	Pk Level	Av Margin	Pk Margin	Azimuth	Height	Ant.	EUT
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	Polarity	Polarity
2480.00	94.00	114.00	97.80	80.97	98.00	13.03	16.00	-70	1438	VERT	X
4960.00	54.00	74.00	36.00	19.17	49.80	34.83	24.20	-70	1438	VERT	X
7440.00	54.00	74.00	40.50	23.67	54.00	30.33	20.00	-70	1438	VERT	X
9920.00	54.00	74.00	42.90	26.07	56.90	27.93	17.10	-70	1438	VERT	X
12400.00	54.00	74.00	46.00	29.17	60.30	24.83	13.70	-70	1438	VERT	X
14880.00	54.00	74.00	48.20	31.37	61.90	22.63	12.10	-70	1438	VERT	X
17360.00	54.00	74.00	50.60	33.77	64.50	20.23	9.50	-70	1438	VERT	X

Table RE14.4: High Channel Emission summary

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

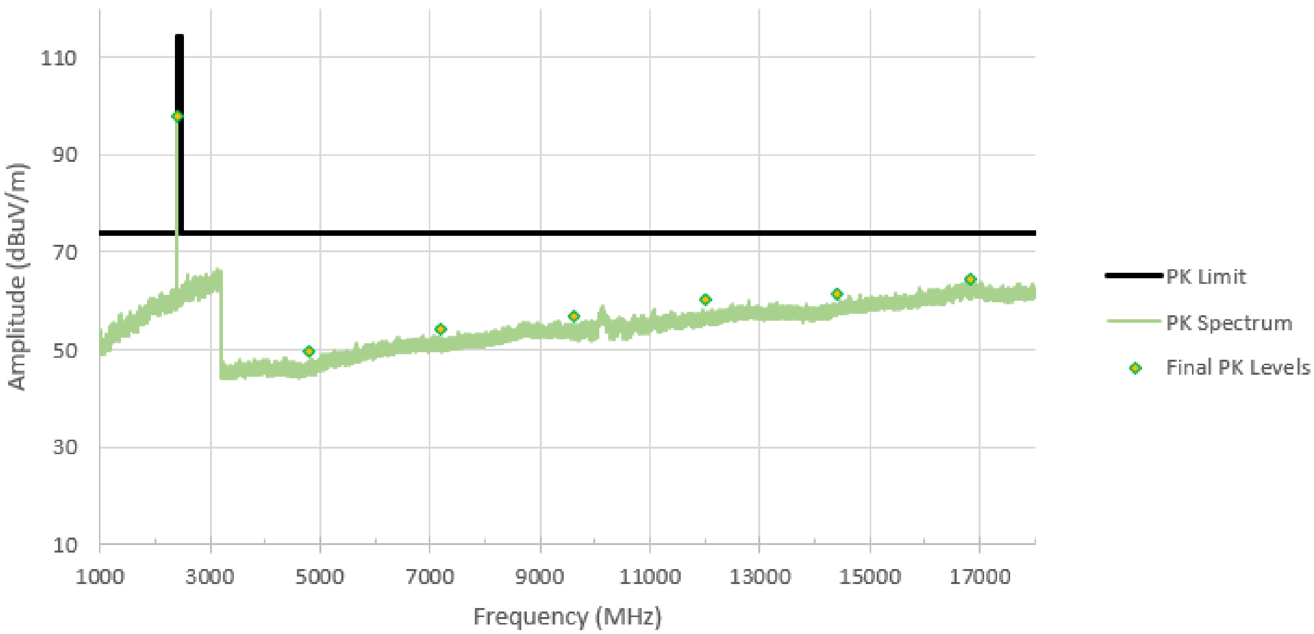

Figure RE14.1: Low Channel Final Peak Level Data

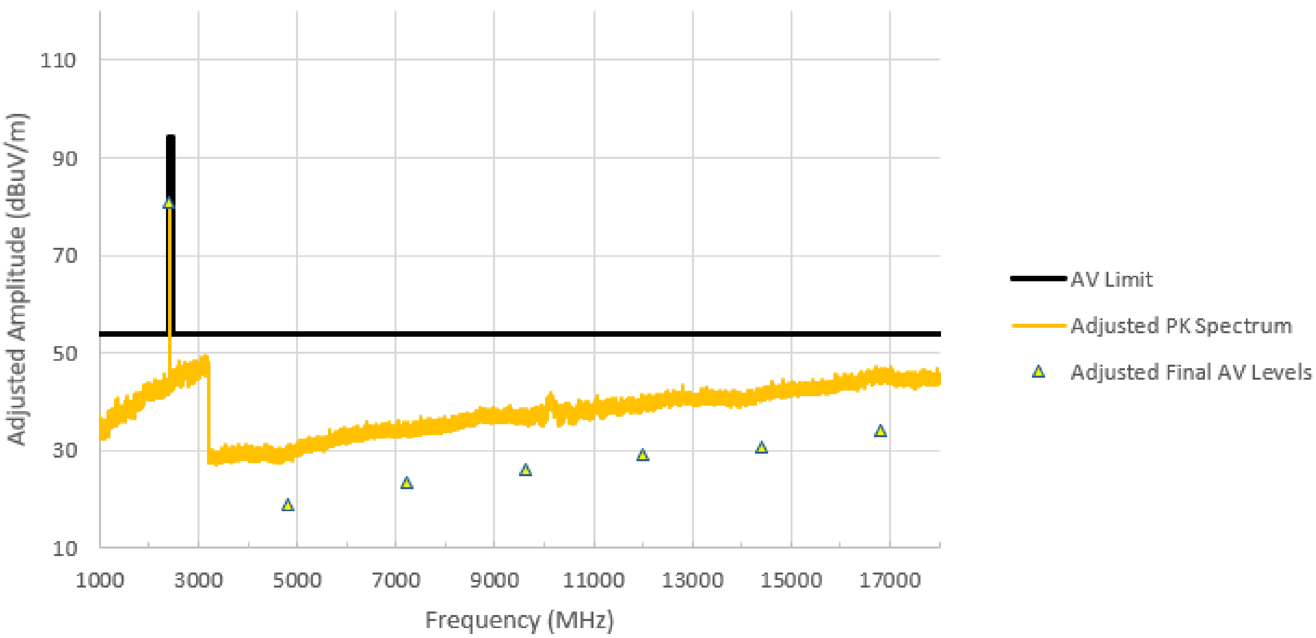

Figure RE14.2: Low Channel Final Adjusted Average Level Data

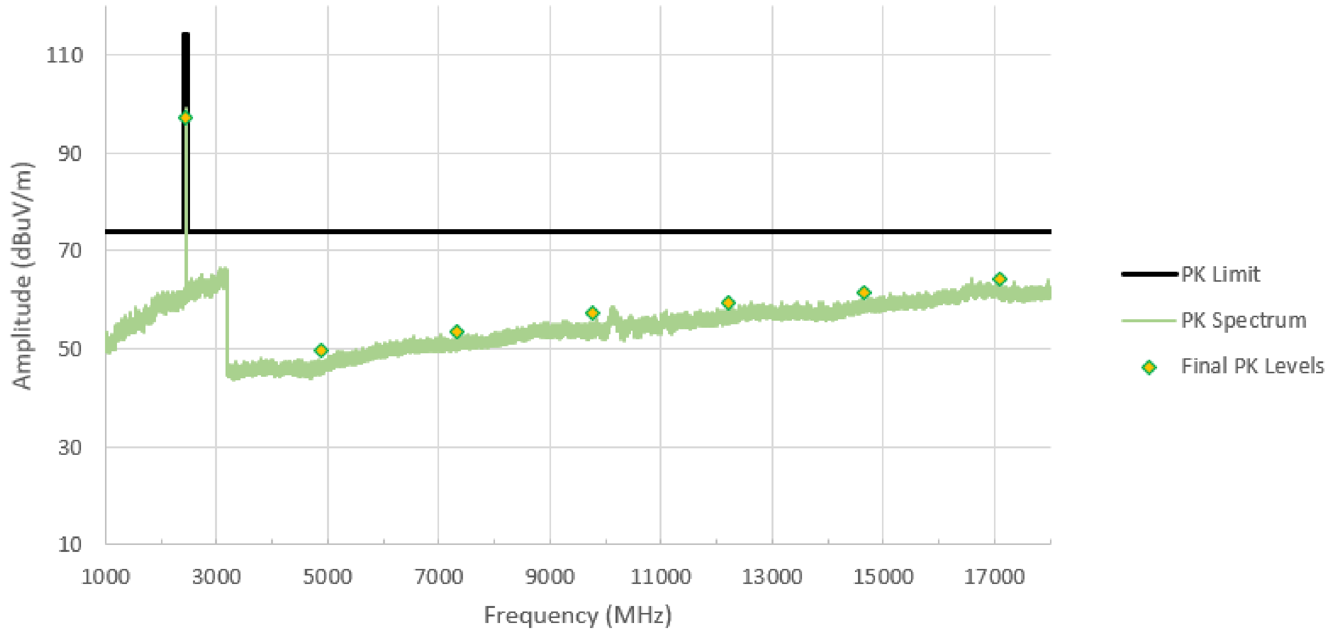

Figure RE14.3: Middle Channel Final Peak Level Data

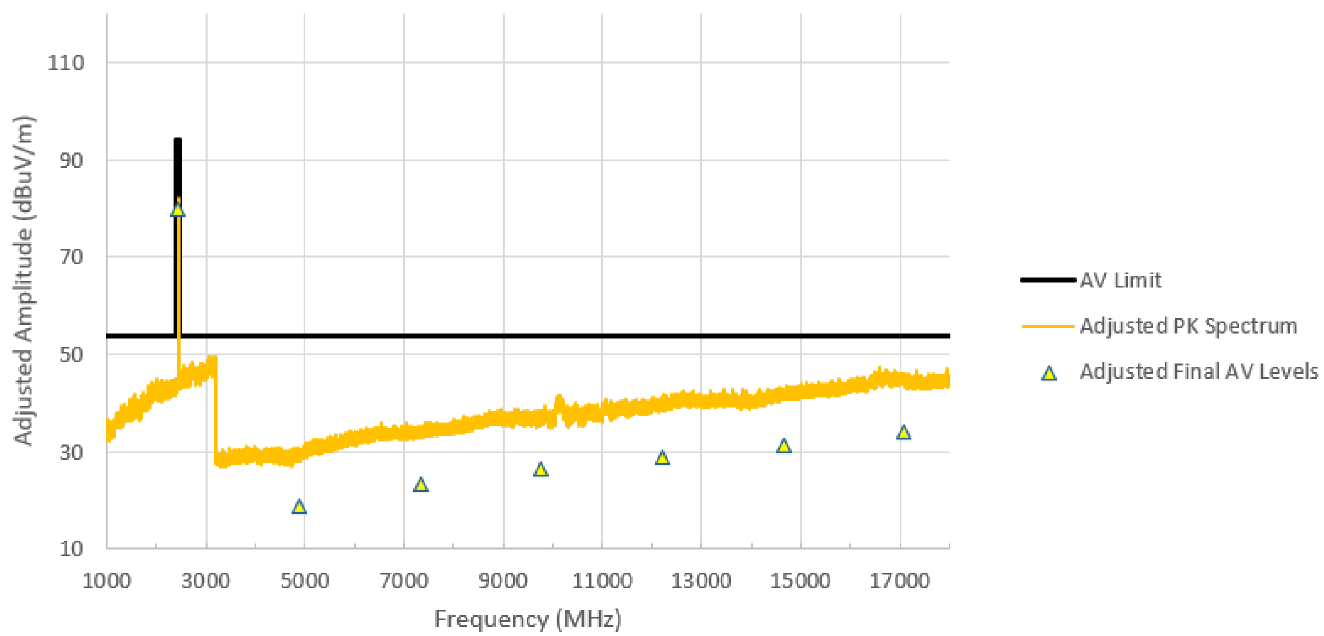

Figure RE14.4: Middle Channel Final Adjusted Average Level Data

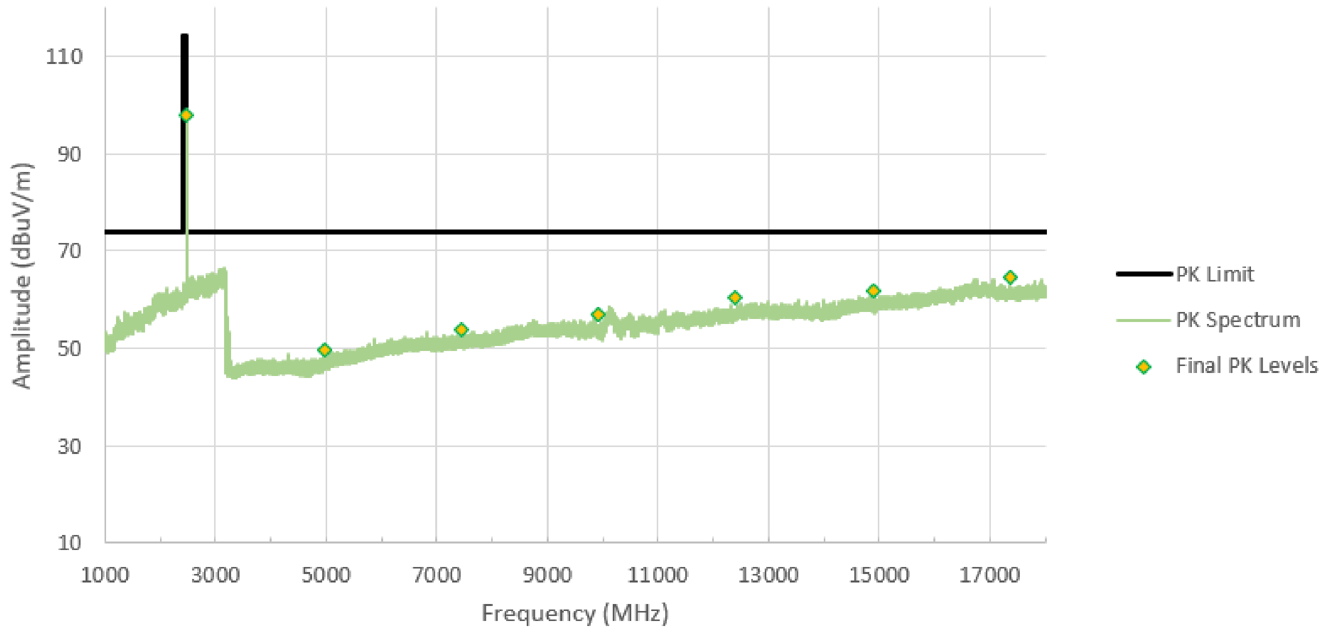

Figure RE14.5: High Channel Final Peak Level Data

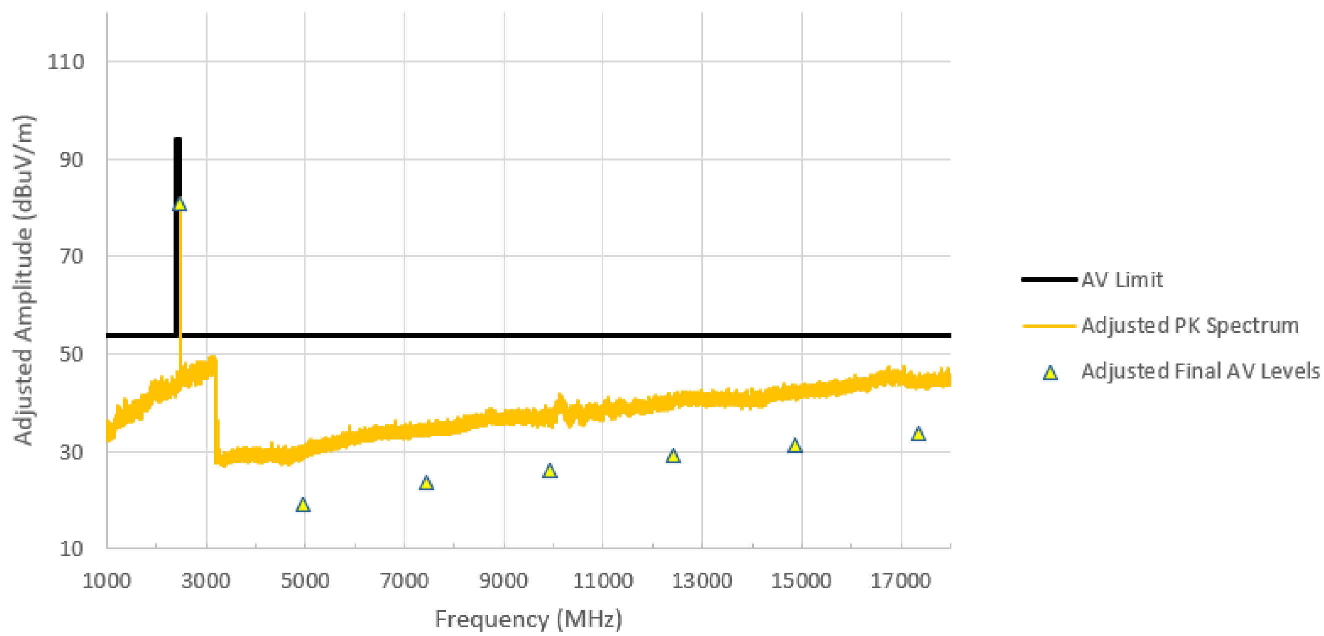

Figure RE14.6: High Channel Final Adjusted Average Level Data

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 RE14.7: EUT Z orientation test setup

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

Figure RE14.8: EUT X orientation test setup

This line is the end of the test record.

Test Record
Radiated Emission Test RE15
Project GCL0305

Test Date(s)	20 Jan 2023
Test Personnel	Christian Shepherd
Product Model	A04600
Serial Number tested	3431708344
Operating Mode	M8 (Ant Tx)
Arrangement	A1 (PwrA)
Input Power	USB 5 Vdc
Test Standards:	FCC Part 15 C (as noted in Section 6 of the report).
Frequency Range:	18 GHz to 26.5 GHz
Pass/Fail Judgment:	**PASS**
Test record created by:	**Christian Shepherd**
Date of this record:	**27 Jan 2023**

Original record, Version A, was released 27 Jan 2023.
Version B released 27 Feb 2023 adjusts the frequency scale on figures 15.1 through 15.6.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	4-Nov-2021	4-Nov-2024
Antenna, Horn, 10-40 GHz	ETS Lindgren	3116C	00227673	26-Aug-2021	1-Sep-2023
Preamplifier, 18 Ghz to 40 Ghz	Com-Power	PAM-840A	461364	Calibration	Not Required
Tape measure, 1” x 33’	Lufkin	PHV1410CMEN	10721	15-Aug-2022	15-Aug-2023
PXE 44GHz	Keysight	N9048B	MY59500016	2-Feb-2022	2-Feb-2023
Barometer	Traceable	6453	221702700	3-Aug-2022	1-Aug-2024

Table RE15.1: Test Equipment Used

Software Used
PXE Software Revision A.33.03

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 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 1 GHz and 18 GHz. Final measurements were performed for three ANT frequencies on the EUT: 2402 MHz (Low Channel), 2442 MHz (Middle Channel), and 2480 MHz (High Channel). Each table includes the harmonics of the ANT frequencies in the selected frequency range. 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.

For the ANT test mode, the EUT is operating in a 'continuous' mode with a 96.3% duty cycle. The client reports that the ANT protocol has a maximum duty cycle of 13.8%. The duty cycle adjustment applied subtracts 16.83 dB from the measured data when comparing against average limits. No adjustment is applied when comparing measured data against peak limits. See test record SP01 for further details.

Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Adjusted Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Ant. Polarity	EUT Polarity
19216.00	54.00	74.00	43.40	26.57	56.60	27.43	17.40	137	1071	HORZ	Z
21618.00	54.00	74.00	44.60	27.77	57.80	26.23	16.20	137	1071	HORZ	Z
24020.00	54.00	74.00	45.20	28.37	58.80	25.63	15.20	137	1071	HORZ	Z
26422.00	54.00	74.00	44.60	27.77	58.40	26.23	15.60	137	1071	HORZ	Z

Table RE15.2: Low Channel Emission Summary

Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Adjusted Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Ant. Polarity	EUT Polarity
19536.00	54.00	74.00	43.20	26.37	57.60	27.63	16.40	-70	1438	VERT	X
21978.00	54.00	74.00	43.50	26.67	56.90	27.33	17.10	-70	1438	VERT	X
24420.00	54.00	74.00	44.10	27.27	58.10	26.73	15.90	-70	1438	VERT	X

Table RE15.3: Middle Channel Emission Summary

Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Adjusted Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Ant. Polarity	EUT Polarity
19840.00	54.00	74.00	42.80	25.97	55.90	28.03	18.10	-70	1438	VERT	X
22320.00	54.00	74.00	43.80	26.97	57.50	27.03	16.50	-70	1438	VERT	X
24800.00	54.00	74.00	44.30	27.47	57.60	26.53	16.40	-70	1438	VERT	X

Table RE15.4: High Channel Emission Summary

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

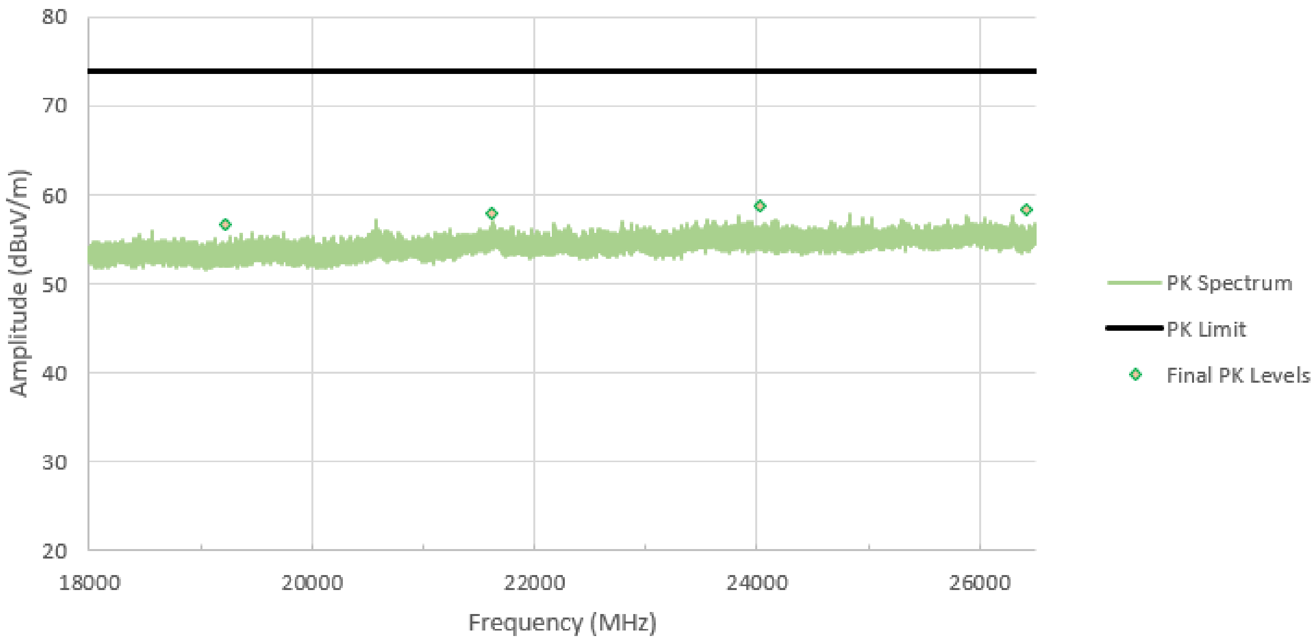

Figure RE15.1: Low Channel Final Peak Level Data

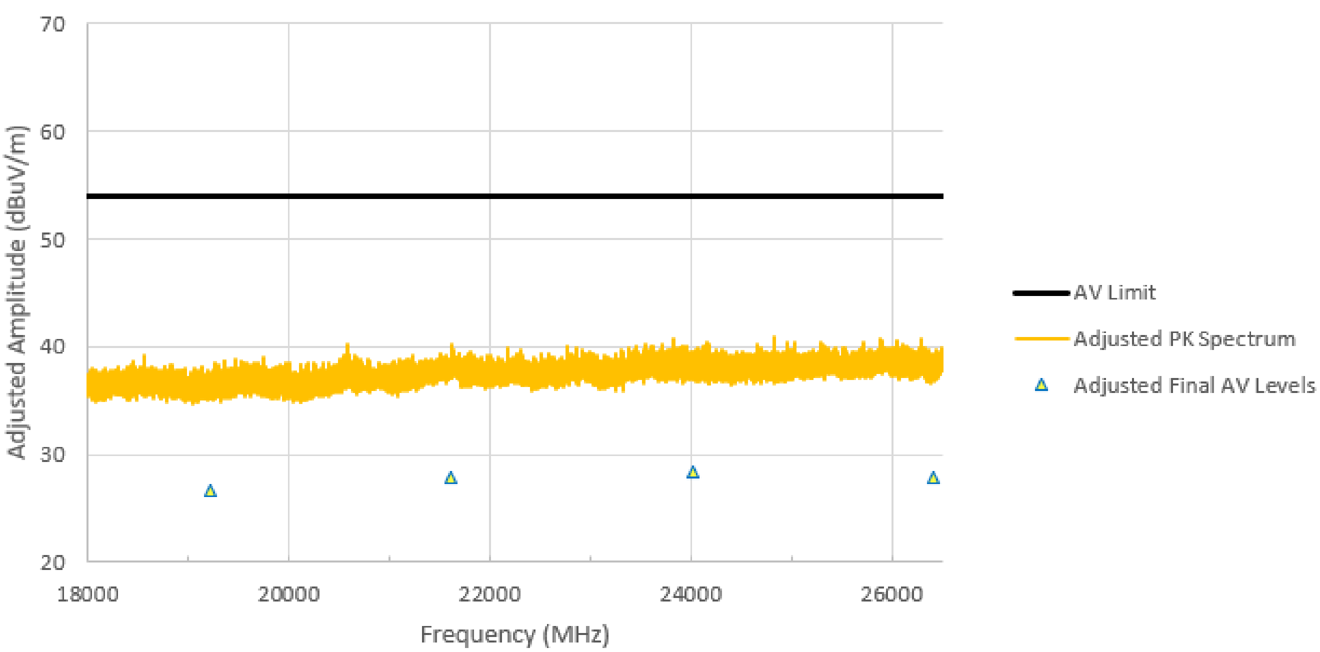

Figure RE15.2: Low Channel Final Adjusted Average Level Data

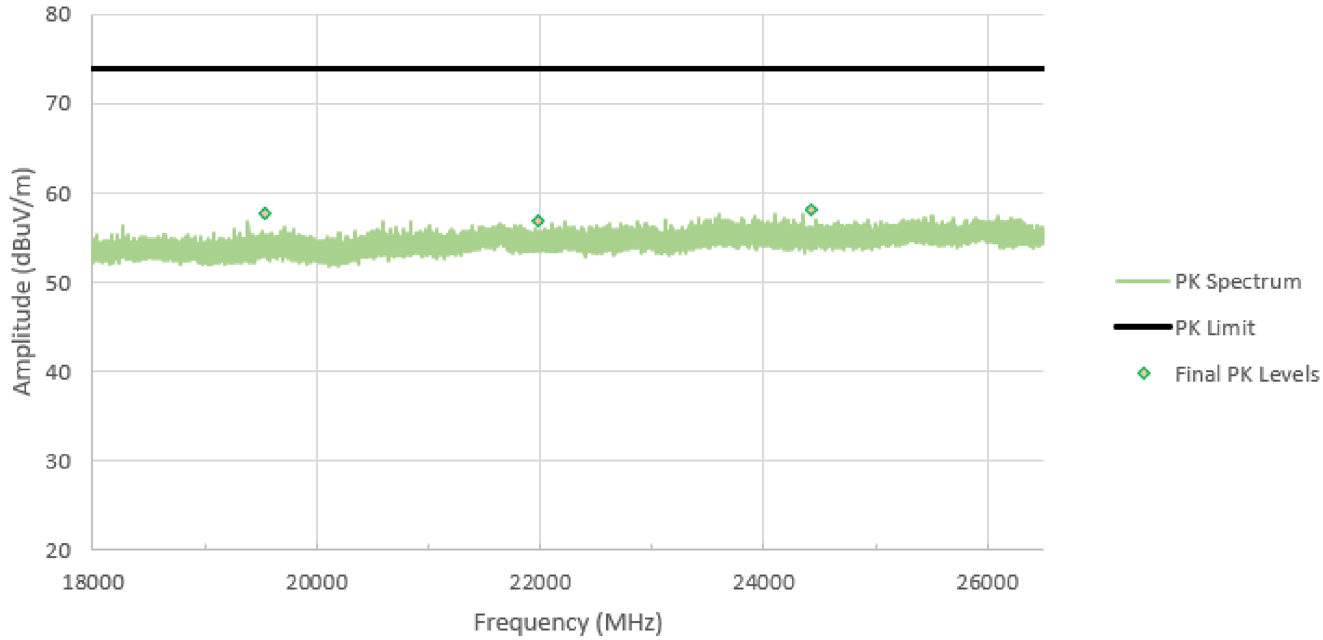

Figure RE15.3: Middle Channel Final Peak Level Data

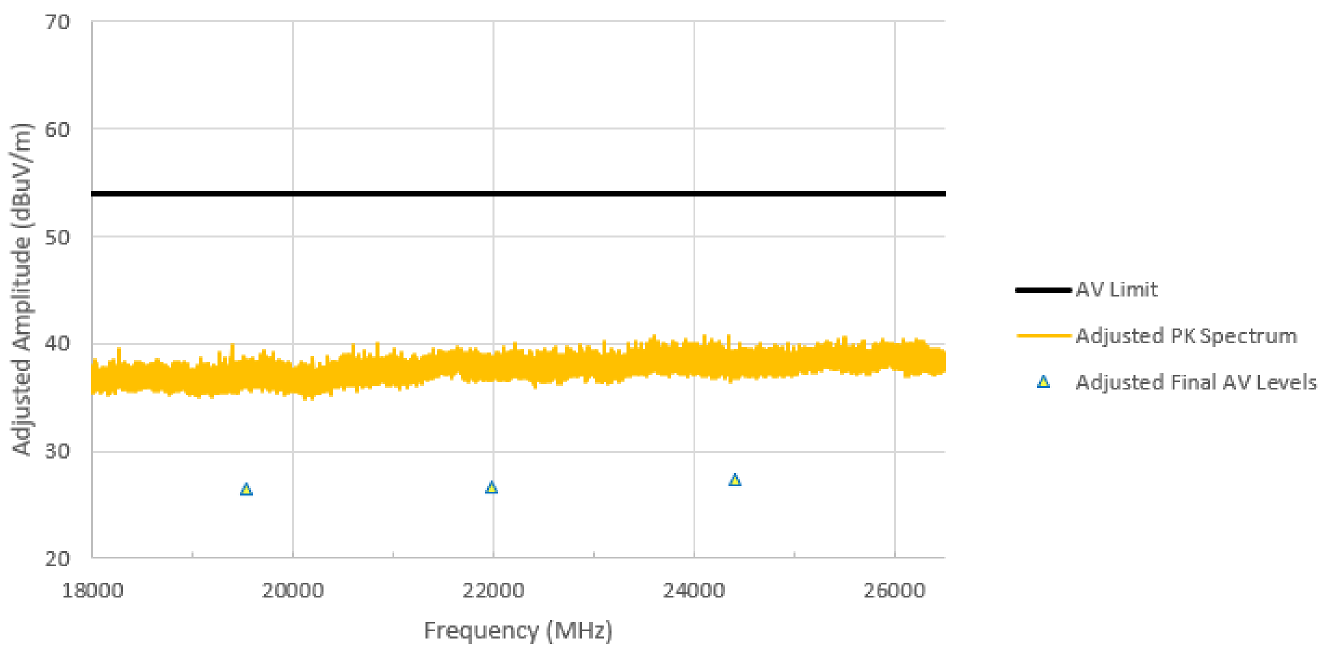

Figure RE15.4: Middle Channel Final Adjusted Average Level Data

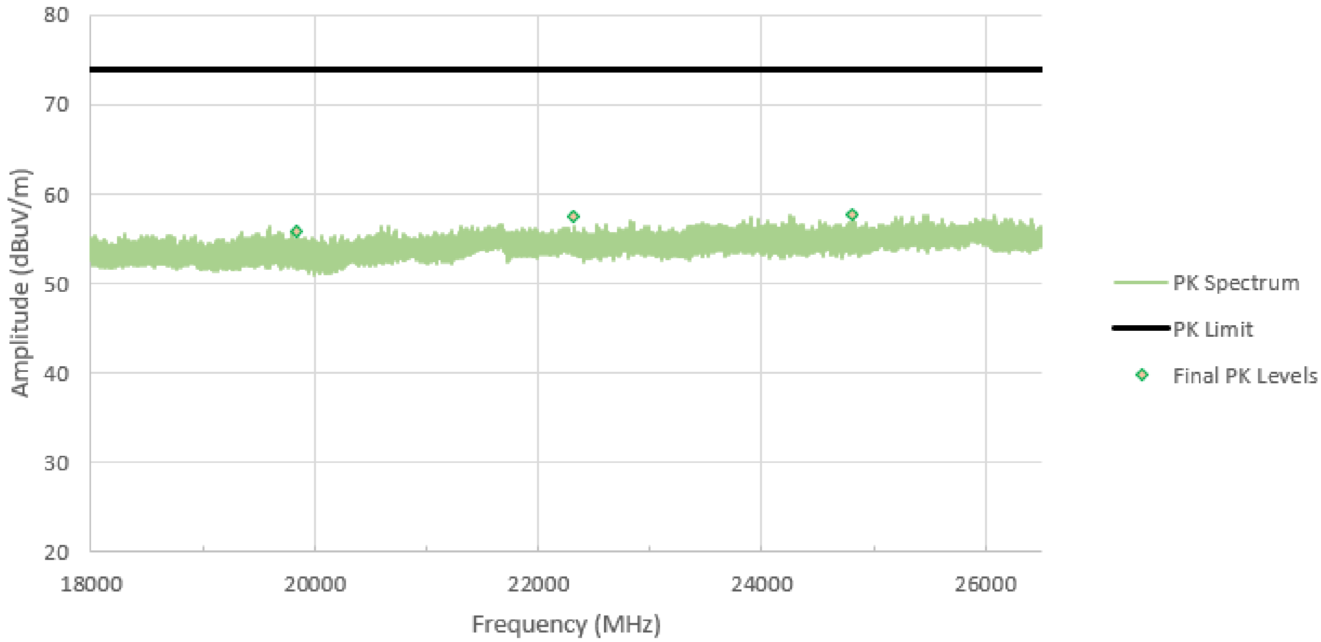

Figure RE15.5: High Channel Final Peak Level Data

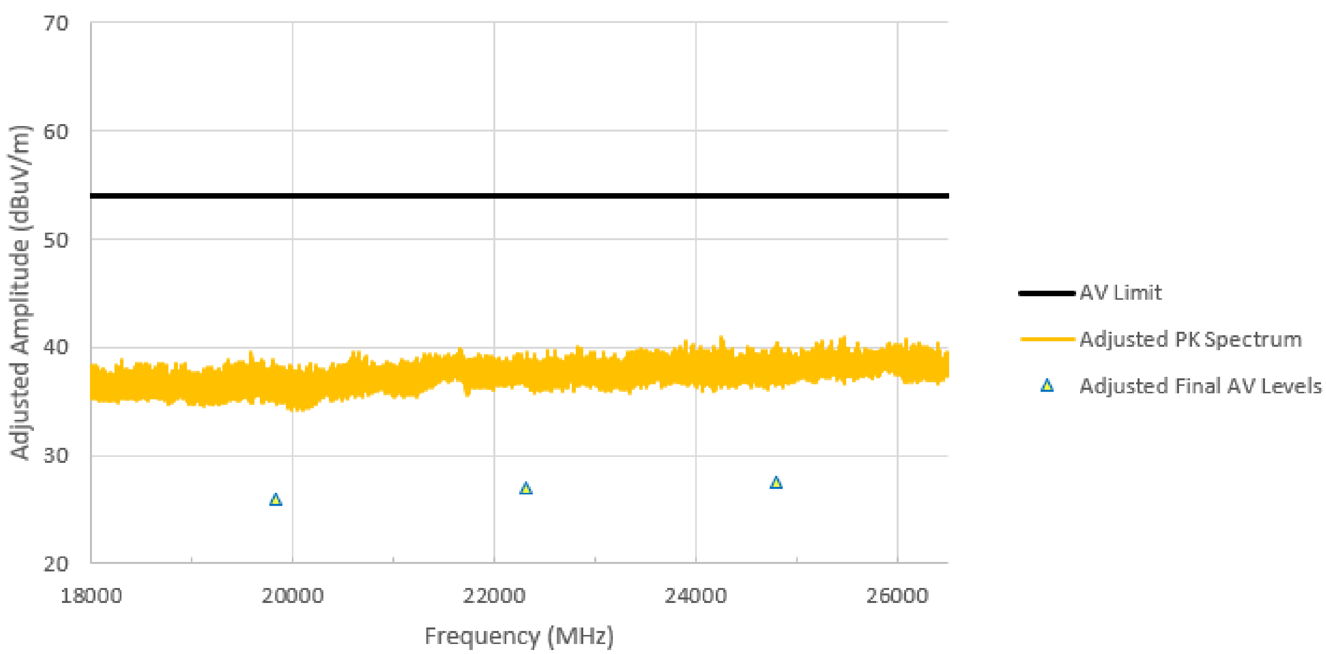

Figure RE15.6: High Channel Final Adjusted Average Level Data

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 RE15.7: EUT Z orientation test setup

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

Figure RE15.8: EUT X orientation test setup

This line is the end of the test record.

Test Record
Duty Cycle Effects SP01
Project GCL0305

Test Date(s) 19 Jan 2023
Test Personnel David Arnett

Product Model A04600
Serial Number tested 3431708548

Operating Mode M8 (ANT Tx)
Arrangement A1 (PwrA)
Input Power 5V dc

Test Standards: None

Pass/Fail Judgment: Reported

Test record created by: David Arnett
Date of this test record: 27 Jan 2023
Original record, Version A.

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.

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 reported that the ANT radio protocol has a maximum duty cycle of 13.8%, which is much lower than the duty cycle 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 during radiated emission tests above 1 GHz. All amplitude data in dBm units was 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 can be used 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 is 0 dB. For comparison of data to an average detector limit, that ratio is 20 * log(13.8% / 96.3%) or -16.83 dB.

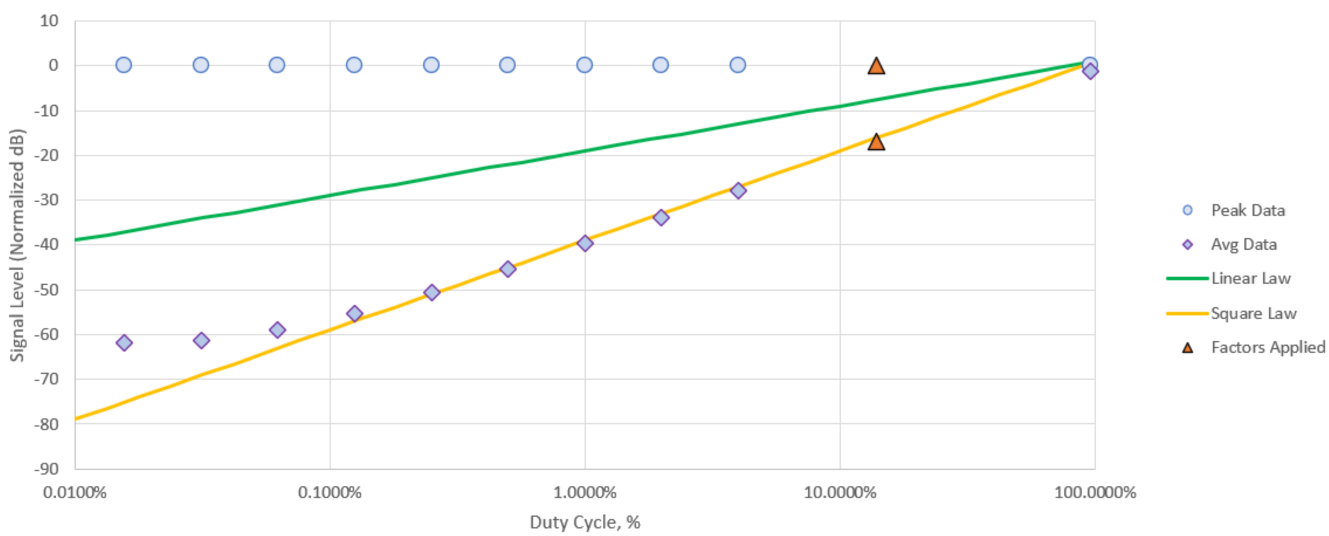

Figure SP01.1: Normalized Amplitude for ANT transmitter and linear or square law references

This line is the end of the test record.

Test Record

Transmitter Frequency Stability
Test IDs TR18
Project GCL-0305

Test Date(s)	12 - 13 Jan 2023
Test Personnel	Majid Farah and Jim Solum supervised by David Arnett
Product Model	A04600
Serial Number tested	3431708497 and 3431708344
Operating Mode	M8 (ANT Tx)
Arrangement	A1 (PwrA)
Nominal Input Power	5 Vdc
Test Standards:	FCC part 15, RSS-GEN, RSS-210, ANSI C63.10 (as noted in Section 6 of the report)
Radio Protocol	ANT/ANT+

Pass/Fail Judgment: **PASS**

Test record created by: **Majid Farah and David Arnett**
Date this record: **28 Feb 2023**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
DMM Multimeter	FLUKE	79 III	71740743	18-Apr-2022	15-Apr-2023
Signal analyzer PXE Receiver	Keysight	N9048B	MY59290135	21-Sep-2022	15-Sep-2023
Thermometer	Thermco	ACCD370P	210607316	11-Aug-2021	15-Aug-2023
Barometer	Traceable	6453	221702700	3-Aug-2022	1-Aug-2024
Programmable DC power source	Keithley	2260B-30-72 720 W	14911917	6-Nov-2021	15-Feb-2023
Thermal Chamber	TPS	T2RC	611000116	21-Apr-22	15-Apr-2024
Near Field Probe set	Com-Power	PS-400	151679	Calibration	Not Required
NFC Reader	acs	ACR1252	RR554-086776	Calibration	Not Required

Table TR18.1: Equipment used

Software Used: PXE Software Revision A.32.06, FrequencyStabilityAnalysistemplateV1.xlsx

Test Method

The RSS-GEN standard requires a frequency stability test with variations in temperature and supply voltage, but RSS-247 does not provide further guidance on this test. RSS-GEN suggests one possible criterion for unlicensed transmitters could be that the carrier remains in the central 80% of the frequency band. However, the Bluetooth and ANT protocols have carriers that are intentionally closer to the band edge. The basic concept applied here is that the 6 dBc Occupied Bandwidth of the modulated signal should remain within the 2400-2483.5 MHz radio band. To evaluate this, the peak carrier level and the level at the band edge are compared to ensure that signal at the band edge is reduced at least 6 dB across the specified range of voltages and temperatures. The data is reported in terms of dBc as a positive value, meaning we report the ratio between the peak carrier signal level and the level at the band edge to demonstrate that the resulting intentional signals remained within the allowed band.

BLE and ANT use channel plan with a minimum transmission center frequency at 2402 MHz and a maximum at 2480 MHz. Although BLE has two data rate mode 1 Mbps and 2 Mbps and ANT has 1 Mbps.

The test sample was placed in a thermal chamber and connected to an appropriate dc power source. The sample has appropriate output to be use for conducted measurement. The analyzer was set up to detect radio signals from the test sample.

The test temperatures range is from +50 °C to -20 °C by 10 °C decrement at each test step for nominal input voltage (5 V). For the voltage variation test at +20 °C, the voltage is to be varied 15% above and below nominal input voltage. Data was taken at 5 Vdc and 15% lower at 4.25 Vdc plus 15% higher at 5.75 Vdc.

The test sample was placed in a thermal chamber and connected to an appropriate dc power source. A near-field probe was placed near the sample then connected by a cable to the PXE analyzer. The analyzer was set up to detect radio signals from the test sample in a way to read carrier frequency with high resolution. The Standard indicated carrier frequency stability shall not exceed 0.01% of operation frequency.

The test temperatures range is from +50 °C to -20 °C by 10 °C decrement at each test step for nominal input voltage (5 V). The NFC carrier frequency was recorded four times at each temperature by 2, 5 and 10 minutes interval from first record. For the voltage variation test at +20 °C, the voltage is to be varied 15% above and below nominal input voltage. Data was taken at 5 Vdc and 15% lower at 4.25 Vdc plus 15% higher at 5.75 Vdc.

Test Data

The various standards 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 apply different limits or conditions, the most stringent limits and conditions have been applied.

During BLE and ANT test mode, each measurement is made conducted from the antenna port of the sample with the transmitter continuously “ON” at a specified channel and in a selected transmission protocol. The amplitude results are unscaled and may not include the effects such as cable losses. Such effects are minimal when comparing two nearby data points in a single spectral scan.

Yellow highlight indicates the highest level for a protocol, for which an image of the spectrum is also provided. In the spectral plots, the data sets have been combined to present the low and high channel results side by side. Orange diamond markers indicate the spectral peak, which the black square markers are at the 2400 MHz or 2483.5 MHz band edge.

Tx Mode	Temp	Volts	Low Ch.	High Ch.
	˚C	Vdc	dBc	dBc
ANT	50	5	34.3	40.9
ANT	40	5	34.3	39
ANT	30	5	34.2	37.9
ANT	20	5	34.7	37
ANT	10	5	41.1	37.4
ANT	0	5	34.9	34.9
ANT	-10	5	35	34.3
ANT	-20	5	34.5	33.9

Table TR18.4 Difference between peak and band edge levels for ANT transmissions during temperature variations

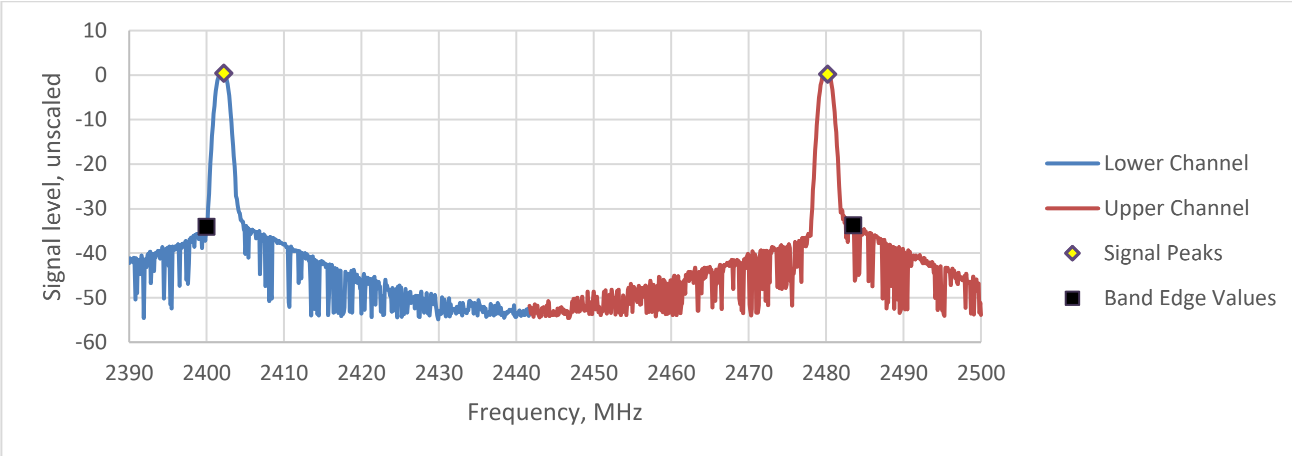

Figure TR18.3: Spectral data for ANT at -20 °C

Tx Mode	Temp	Volts	Low Ch.	High Ch.
	˚C	Vdc	dBc	dBc
ANT	20	4.25	34.9	37.3
ANT	20	5	34.7	37
ANT	20	5.75	36.5	40.3

Table TR18.5 Difference between peak and band edge levels for ANT transmissions at 20 °C during voltage variations

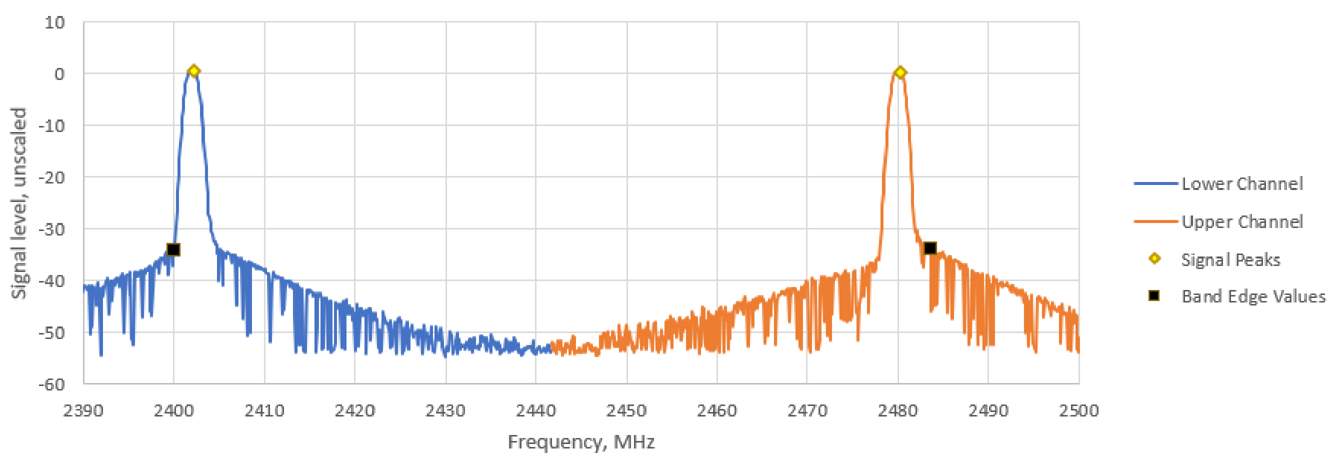

Figure TR18.4: Spectral data for ANT at 20 °C and 5 Vdc

Setup Block Diagram

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

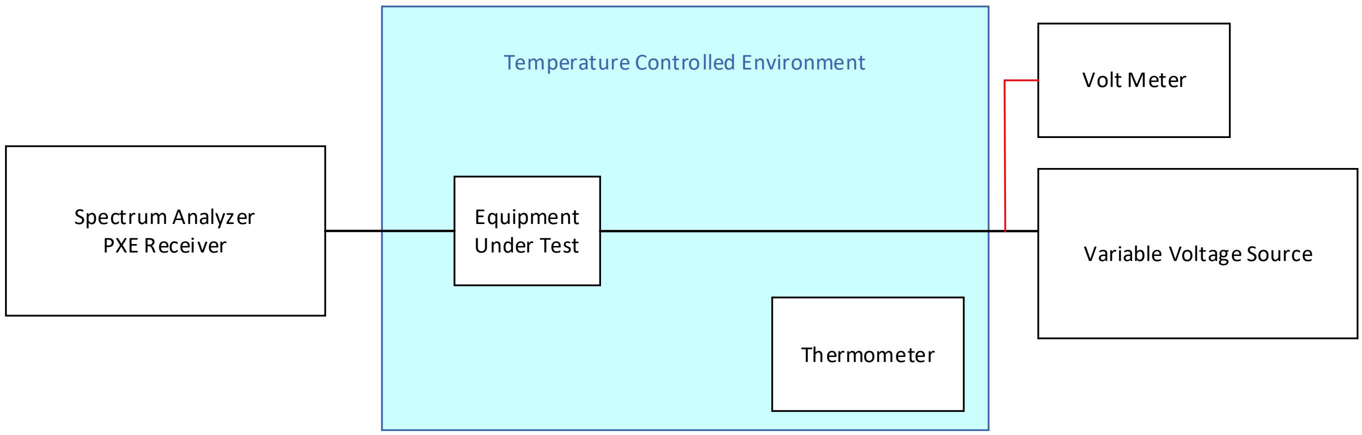

Figure TR18.5: Schematic drawing of the test equipment setup for BLE and ANT

This line is the end of the test record.

Test Record
Other Bandwidth Tests
Test IDs TR9B
Project GCL-0305

Test Date(s)	12 Jan 2021
Test Personnel	David Arnett
Product Model	A04600
Serial Number tested	3431708548
Operating Mode	M8 (ANT Tx)
Arrangement	A1 (PwrA)
Input Power	5V dc
Test Standards:	FCC Part 2.202, ANSI C63.10, TRC-43, RSS-GEN (as noted in Section 6 of the report).
Radio Protocol	ANT
Radio Band	2480 to 2483.5 MHz
Pass/Fail Judgment:	**Reported**
Test record created by:	**David Arnett**
Date of this record:	**25 Jan 2023**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE 44GHz	Keysight	N9048B	MY59500016	2-Feb-2022	2-Feb-2023

Table TR9B.1

Test Software used: Keysight MXE System Code rev. 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.

Test Setup

This block diagram shows the test equipment setup.

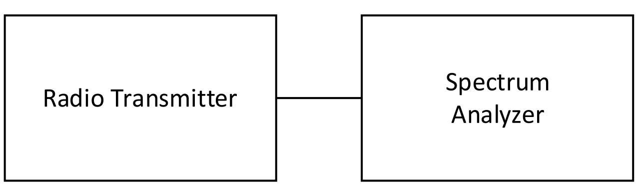

Figure TR9B.1: Test setup

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

The channel frequencies for ANT are 2402, 2442, and 2480 MHz. These are called the Low, Mid, and High frequencies.

	ANT
Low	990.3
Mid	992.6
High	991.4
Mean	991.4
Unit	kHz

Table TR9B.2: Summary of 99% Occupied Bandwidth Data, ANT mode

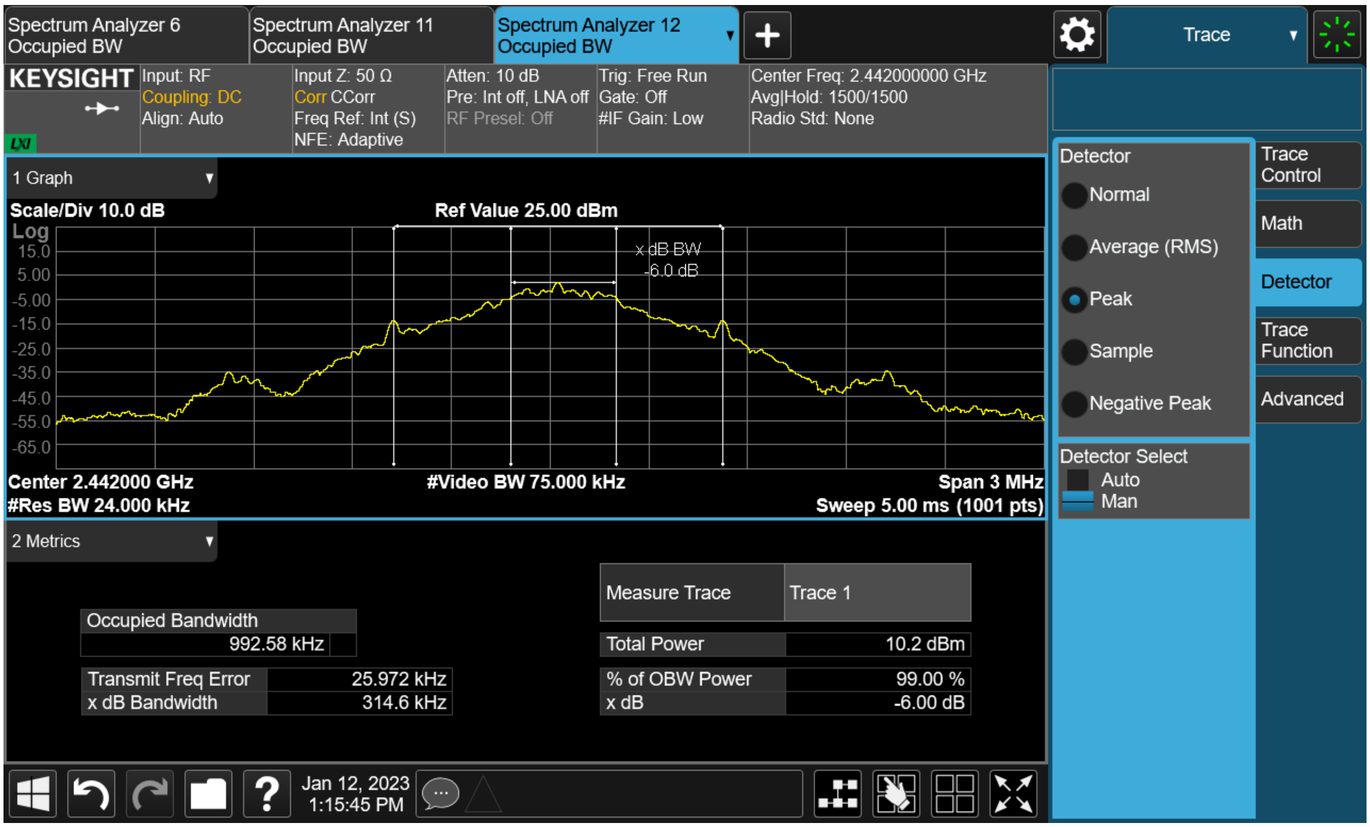

Figure TR9B.1: Occupied bandwidth data for ANT at mid channel (2442 MHz)

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 TR9B.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 TR9B.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 TR9B.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 TR9B.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 TR9B.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.

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.