Test Report 2023-039

Version A
Issued 23 Aug 2023

Project GCL-0315
Model Identifier A04770
Primary Test Standard

FCC Part 15.247
RSS-247 Issue 2 Amd 1

Garmin Compliance Lab

Garmin International
1200 E 151st Street
Olathe Kansas 66062 USA

Client-supplied Information

FCC ID: IPH-04770
IC ID: 1792A-04770

ACCREDITED
CERTIFICATE #6162.01

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

1. Summary

The equipment or product described in section 5 of this report was tested at the Garmin Compliance Lab according to standards listed in section 6. This report focuses on the 2.4 GHz transceiver(s). The results are as follows.

Parameter	**Description**	**Key Performance Values**	**Result**	**Data starts at page**
Hopping Channels	The radio manages it use of channels appropriately. [15.247(a)(1); RSS-247 at 5.1]	N/A. The radios described in this report are not subjected to the Frequency Hopping rules.	N/A	N/A
DTS Bandwidth	The nature of the radio signal is broadband, being at least 500 kHz wide. [15.247(a)(2); RSS-247 at 5.2(a)]	The 6dB bandwidth is 694.1 kHz or greater.	PASS	10
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	13
Transmit Power	The peak transmit power presented to the antenna is no greater that 1 Watt or 30 dBm. The effective radiated power is limited to 4 Watts or 36 dBm EIRP. [15.247(b); RSS-247 at 5.4(d)]	The maximum transmit power is 5.7 dBm.	PASS	16
Antenna Gain	The radio should not focus too much energy in any direction. Unless additional rules are applied, the antenna gain is no greater than 6 dBi. [15.247(b)(4) and (c)]	NT. The client stated that the maximum antenna gain was -0.3 dBi and will document antenna gain separately.	NT	NT
Unwanted Emissions (Conducted Spurious)	The radio should not provide too much radio energy to the antenna at frequencies beyond its intended frequency band. [15.247(d); RSS-247 at 5.5]	Emissions outside the band must be reduced at least 20 dB from in-band levels. The measured reduction was at least 36.30 dB.	PASS	18
Restricted Bands	The radio must not emit in certain designated restricted frequency bands above a set of limit values. [15.247(d) and 15.205; RSS-247 at 3.3]	Emissions in the restricted bands were at least 8.417 dB below the applicable limits.	PASS	22
Power Spectral Density	The radio must not focus too much radio energy in a narrow frequency band. [15.247(e); RSS-247 at 5.2(b)]	The limit is 8 dBm in a 3 kHz band. The strongest emission level was -11.16 dBm in a band of at least 3 kHz.	PASS	26

Hybrid Systems	A radio that is both frequency hopping and digitally modulated should satisfy a combination of system rules. [15.247(f); RSS-247 at 5.3]	N/A. The radios described in this report are not subjected to the Hybrid System rules.	N/A	N/A
Frequency Hopping Rules	Frequency hopping systems have additional functional requirements. [15.247(g) and (h); RSS-247 at 5.1]	N/A. The radios described in this report are not subjected to the Frequency Hopping rules.	N/A	N/A
Radio Safety	The radio emissions must meet public health & safety guidelines related to human exposure. [15.247(i) and 1.1307; RSS-Gen at 3.4]	NT. Client will report radio energy safety results separately.	NT	NT
Frequency Stability	The radio tuning must be robust over a range of temperature and supply voltage conditions. [RSS-Gen at 6.11]	Radio emissions remained within the allowed radio band under all environmental conditions tested.	PASS	28

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

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

Table 1: Summary of results

Report Organization

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

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

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

Due to confidentiality, certain material (such as test setup photographs) has been removed from this report and placed in GCL Test Report 2023-041. 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: 22 Jun 2023
Test Start Date: 23 Jul 2023
Test End Date: 03 Aug 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 23 Aug 2023 as Version A.

Report Technical Review: ____________________

David Arnett
Technical Lead EMC Engineer

Report Approval: ____________________

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

4. Test Sample Modifications and Special Conditions

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

The following modifications to the test sample(s) were made, and are judged necessary to achieve compliance with one or more of the standards listed in section 6 of this report:
None

5. Description of the Equipment Tested

5.1 Unique Identification

Product Model	A04770
Serial Numbers Tested	817000237, 817000223

This product tested is a transceiver for multiple types of diving purposes.

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

5.2 Key Parameters

EUT Input Power:	Battery operated 3 Vdc
I/O Ports:	None
Radio Transceivers:	Bluetooth Low Energy, ANT
Radio Receivers:	None
Primary Functions:	Sharing data between different devices
Typical use location:	Body worn
Highest internal frequency:	2.484 GHz
Firmware Revision	V0.98

5.3 Operating modes

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

Mode 1: M1 (ANT Tx). EUT in test mode and ANT Tx always On.
Mode 2: M2 (ANT Lnk). EUT linked to companion device through ANT.
Mode 3: M3 (BLE Tx). EUT in test mode and BLE Tx always On.
Mode 4: M4 (BLE Lnk). EUT linked to companion device through BLE.
Mode 5: M5 (All Tx off). EUT in test mode and all transmitters turned off.
Mode 6: M6 (All Tx on). EUT in test mode and all transmitters are always On.
Mode 7: M7 (All Rx on). EUT in test mode and in receiver mode only.

5.4 EUT Arrangement

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

Arrangement 1: A1 (Standalone) EUT powered up through internal battery

Arrangement 2: A2 (PwrSupply) EUT powered up through an adjustable DC power supply

5.5 Associated Equipment (AE) used

Description	Manufacturer	Model	Serial Number
USB ANT stick	Garmin	010-01058-00	R203-JN6016

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

5.6 Cables used

Description	From	To	Length	EMC Treatment
Battery interrupter	Power supply	Battery compartment	1.5 m	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, Subpart C
ANSI C63.10: 2013
RSS-GEN Issue 5 Amd 2
RSS-247 Issue 2

6.2. Non-accredited Standards

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

TRC-43 Issue 3

6.3 Variances

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

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

6.4 Laboratory Accreditation

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

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

7 Measurement Instrumentation Uncertainty

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

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

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

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

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

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

8 Selected Example Calculations

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

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

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

8.1 AC Mains conducted emissions at 22 MHz

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

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

8.2 Radiated Emissions at 630 MHz

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

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

8.3 Radiated Emissions at 2.7 GHz

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

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

9 Environmental Conditions During Test

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

Temperature: 21.9 to 22.9 °C
Relative Humidity: 43.2% to 53.1% (non-condensing)
Barometric Pressure 97.4 to 98.5 kPa

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

Table 4: Environmental monitoring device

10 Immunity Performance Criteria

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

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

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

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

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

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

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

ANNEX

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

Test Record
Transmitter DTS Bandwidth Tests
Test IDs TR02
Project GCL-0315

Test Date(s) 26 Jul, 2 Aug 2023
Test Personnel Majid Farah, (2 Aug) Jim Solum supervised by Majid Farah

Product Model A04770
Serial Number tested 817000237

Operating Mode M3 (BLE Tx)
Arrangement A1 (Standalone)
Input Power Battery operated 3 Vdc

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

Radio Protocol Bluetooth Low Energy (BLE)
Radio Band 2480 to 2483.5 MHz

Pass/Fail Judgment: PASS

Test record created by: Jim Solum
Date of this record: 2 Aug 2023
Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 44GHz	Keysight	N9048B	MY62220139	30-Jan-2023	1-Feb-2024

Table TR02.1: List of test equipment used

Test Software Used: Keysight PXE firmware A.33.03

Test Method

During this test the transmitter output is fed directly, or through RF attenuators, to the spectrum analyzer. The analyzer has a built-in capability to identify the minimum bandwidth that contains a specified portion of the total power observed, and also identify parameters such as the edge frequencies for that bandwidth and the center frequency error. The spectrum is scanned many times so that the varied effects of modulation are appropriately assessed. Since the focus is on the relative distribution of energy across a range of frequencies, the absolute amplitudes recorded during this test are not relevant and may not include cable losses or attenuation factors. The channel frequencies for BLE at 1 Mbps are 2402, 2442, and 2480 MHz. The channel frequencies for BLE at 2 Mbps are 2404, 2442, and 2478 MHz. These are called the Low, Mid, and High frequencies.

Test Setup

This block diagram shows the test equipment setup.

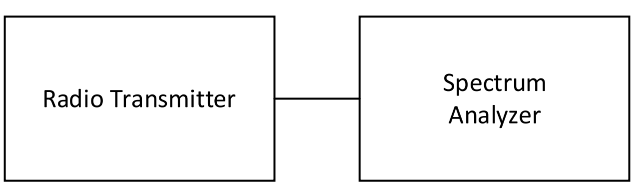


Figure TR02.1: Test setup

Test Data

The DTS Bandwidth is measured using a spectrum analyzer operating with a defined resolution bandwidth. The analysis finds the smallest continuous range of frequencies containing all emissions within 6 dB of the highest value. The requirement is that the DTS Bandwidth be greater than 500 kHz. As such the lowest measured bandwidth is worst case. All radios reported here are judged to have met this requirement.

The data for each test is summarized in the table below. The spectral data is also provided for each case.

Mode	Speed	Low	Mid	High	Unit
BLE	1 Mb	**694.2**	**694.1**	**707.5**	**KHz**
BLE	2 Mb	**1147**	**1145**	**1147**	**KHz**

Table TR02.2: Summary of DTS Bandwidth test results for ANSI method

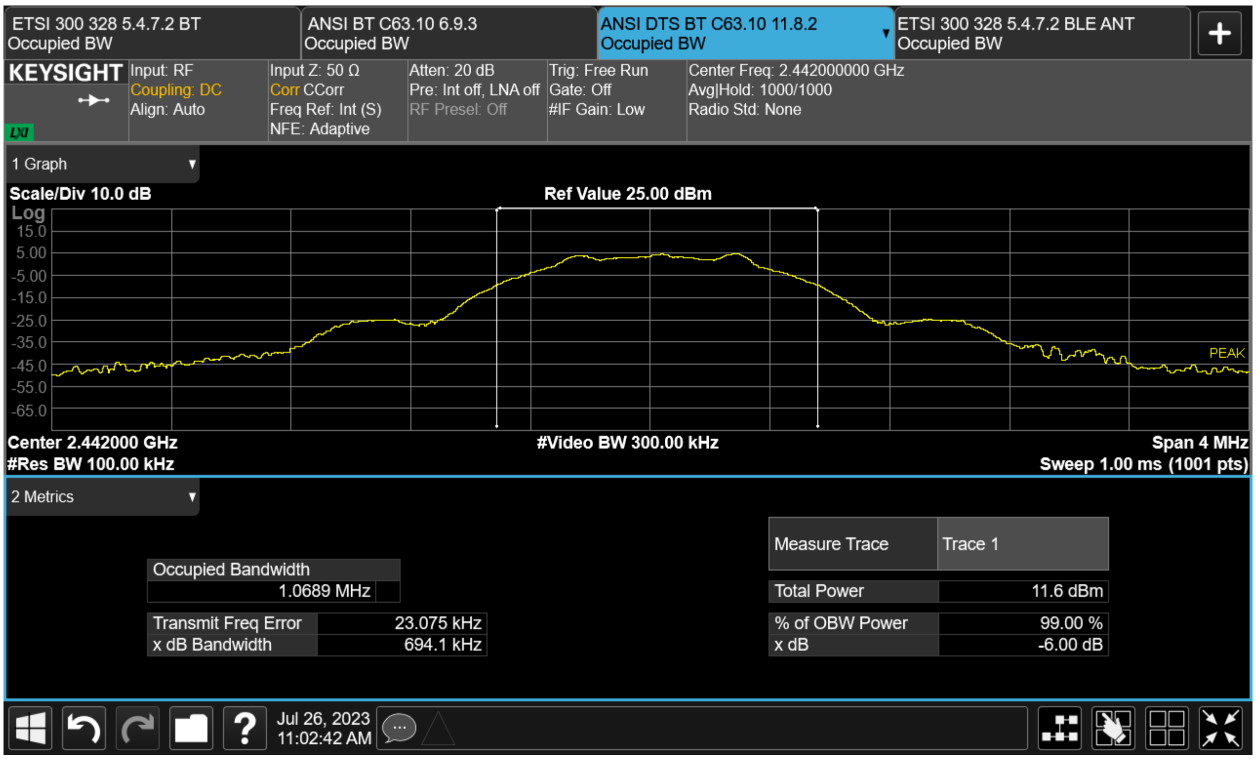


Figure TR02.2: Spectral data for BLE 1 Mbps on the Mid frequency.

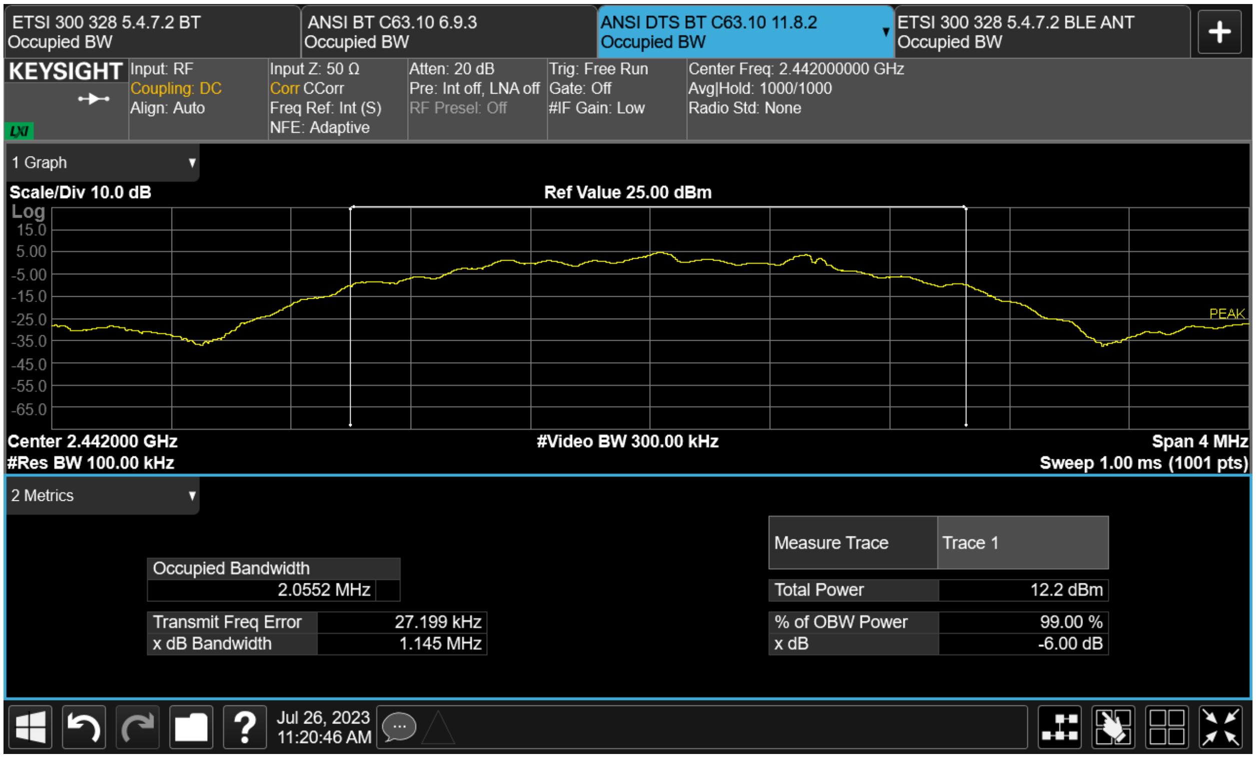


Figure TR02.3: Spectral data for BLE 2 Mbps on the Mid frequency.

This line is the end of the test record.

Test Record
Transmitter Bandwidth Tests
Test IDs TR003
Project GCL-0315

Test Date(s) 26 Jul, 2 Aug 2023
Test Personnel Majid Farah, (2 Aug) Jim Solum supervised by Majid Farah

Product Model A04770
Serial Number tested 817000237

Operating Mode M1 (ANT Tx), M3 (BLE Tx)
Arrangement A1 (Standalone)
Input Power Battery

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 2480 to 2483.5 MHz

Pass/Fail Judgment: Reported
This record includes all transmitters that are part of this report, as well as transmitters that are not part of this report.

Test record created by: Jim Solum
Date of this record: 3 Aug 2023
Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 44GHz	Keysight	N9048B	MY62220139	30-Jan-2023	1-Feb-2024

Table TR03.1

Test Software used: Keysight PXE 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.

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

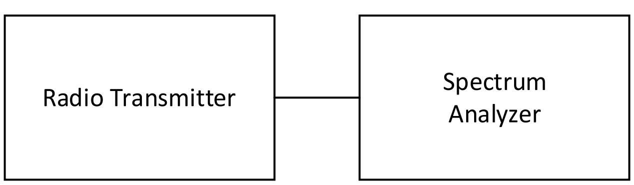


Figure TR03.1: Test setup

Occupied Bandwith, 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 Bandwith, 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 Mb	**1.041**	**1.045**	**1.048**
BLE	2 Mb	**2.030**	**2.034**	**2.038**
ANT	Fixed	**0.981**	**0.984**	**0.986**

Table TR03.2: Summary of 99% Occupied Bandwidth Data for BLE and ANT modes

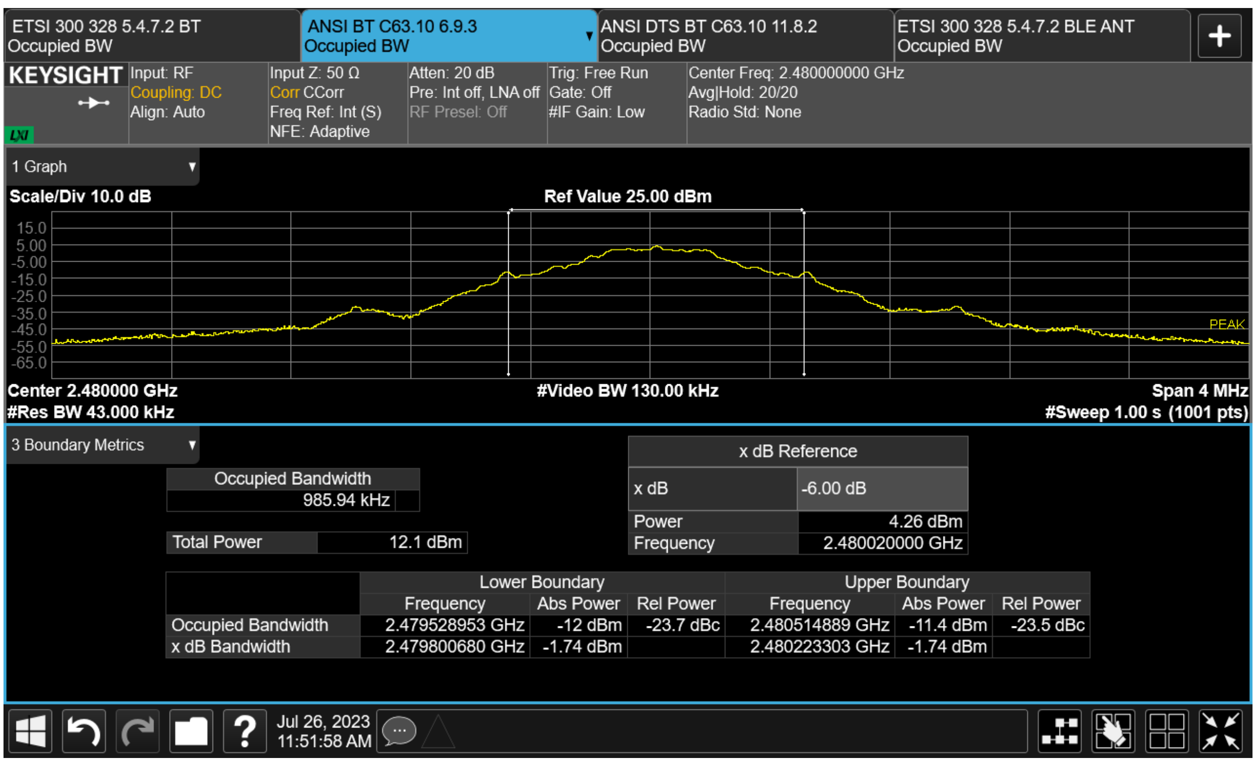


Figure TR03.2: Occupied bandwidth data for ANT at 2480 MHz

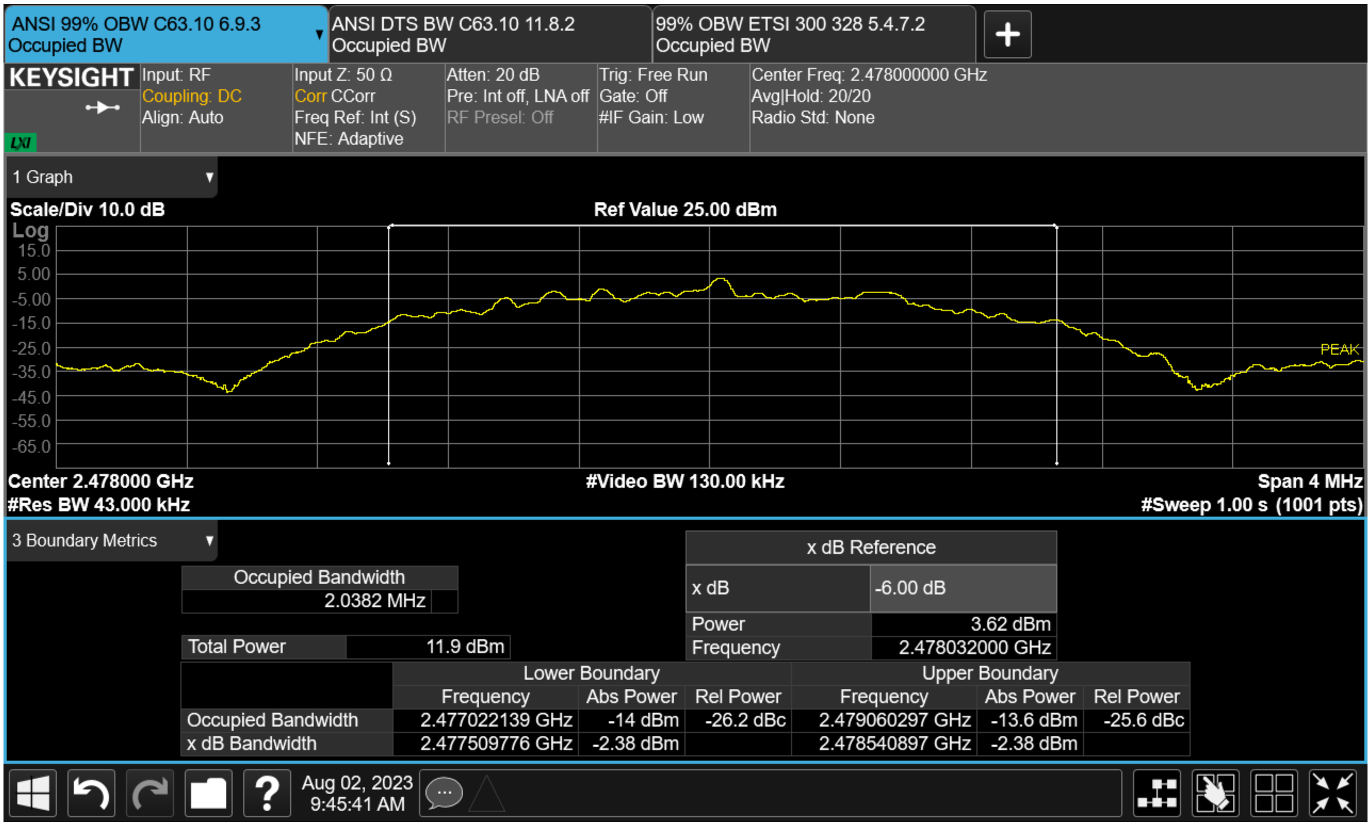


Figure TR03.3: Occupied bandwidth data for BLE 2 Mbps at 2478 MHz

Necessary Bandwidth Calculations

The Necessary Bandwidth is a theoretical value based on the specifications for a communication protocol, rather than the hardware implementation and a subsequent lab measurement. The analysis methods in FCC Part 2.202 and TRC-43 are the same for Bluetooth, ANT, and IEEE 802.11b WiFi. The tables below may include radio protocols that are not part of the product being evaluated.

The radio modulation schemes for Ant, and 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 TR03.101: Necessary Bandwidth for ANT and ANT+ Radio Protocols (FCC and TRC-43)

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

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

This line is the end of the test record.

Test Record

Transmitter Power
Test IDs TR01
Project P0315

Test Date(s) 23 Jul 2023
Test Personnel Majid Farah

Product Model A04770
Serial Number tested 817000237

Operating Mode M1 (ANT Tx), M3 (BLE Tx)
Arrangement A1 (Standalone)
Input Power Battery

Test Standards: FCC Part 15, ANSI C63.10, ETSI EN 300 328, RSS-GEN, RSS-247 (as noted in Section 6 of the report).

Antenna Gain -0.3 dBi, as reported by the client
Radio Protocol Bluetooth Low Energy, ANT

Pass/Fail Judgment: PASS
This record includes all transmitters that are part of this report, as well as transmitters that are not part of this report.

Test record created by: Jim Solum
Date of this record: 9 Aug 2023
Original record, Version A.

Test Equipment Used

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

Table TR01.1: List of test equipment used

Software used: Rohde & Schwarz Power Viewer V11.3, TimePowerAnalysisSpreadsheetv10.xls

Test Method
The basic test standards provide options for the time evaluation test method. The following test methods were applied.
ETSI EN 300 328: 5.4.2.2.1.3
ANSI C63.10: 11.9.1.3

The parameters of duty cycle, transmitter timing, or medium utilization are typically not required for adaptive transceivers or transceivers emitting at 10 dBm EIRP or less, so those results will be omitted from the data set.

Transmit Power and Timing Data
Each measurement is made conducted from the antenna port with the transmitter on a specified channel and in a selected transmission protocol. The data record length is 100 msec for the Bluetooth-like protocols. Where standards cited here apply harmonized test methods and different limits, the more strict limit has applied. The results are shown below.

There are two separate analyses performed on the data set from the broadband fast diode power sensor. Under the ANSI method, the analysis reports the peak value of power observed, in dBm units. Under the ETSI method, each transmission burst is analyzed to find the burst with the highest average power, antenna gain is added, and the resulting unit is dBm EIRP. Both analyses will be reported, even though the report in which this record appears may not need each of these methods.

The results are shown below. Yellow highlighted cells indicate the highest power value for each radio protocol. Bluetooth Low Energy at the 2 Mbps data has its lowest and highest channel frequencies set at 2404 MHz and 2478 MHz. The lowest and highest operating channel frequencies for the other protocols are 2402 MHz and 2480 MHz.

Frequency (Mhz)	2402 (04)	2442	2478 (80)	ANSI Limit (dBm)
ANT	5.5	5.6	5.5	30
BLE 1Mbps	5.5	5.6	5.5	30
BLE 2Mbps	5.5	5.7	5.5	30

Table TR01.2: Transmit Power Summary in dBm with ANSI C63.10 analytical methods

Frequency (Mhz)	2402 (04)	2442	2480 (78)	ETSI Limit (dBm EIRP)
ANT	5.08	5.21	5.05	20
BLE 1Mbps	5.1	5.22	5.05	20
BLE 2Mbps	5.08	5.19	5.05	20

Table TR01.3: Transmit Power Summary in dBm EIRP with ETSI analytical methods

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

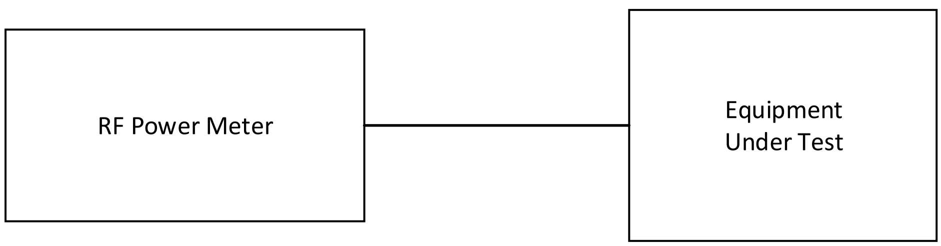


Figure TR01.1: Test equipment setup

This line is the end of the test record.

Test Record
Conducted Spurious Emissions
Test IDs TR11
Project GCL-0315

Test Date(s)	26 Jul 2023
Test Personnel	Majid Farah
Product Model	A04770
Serial Number tested	817000237
Operating Mode	M3 (BLE Tx)
Arrangement	A1 (Standalone)
Input Power	3.0 Vdc battery operated
Test Standards:	FCC Part 15, ANSI C63.10, RSS-GEN, RSS-247 (as noted in Section 6 of the report).
Pass/Fail Judgment:	**PASS**
Test record created by:	**Jim Solum**
Date of this test record:	**3 Aug 2023**

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
Signal analyzer PXE Receiver 44GHz	Keysight	N9048B	MY62220139	30-Jan-2023	1-Feb-2024

Table TR11.1: Test equipment used

Software used: Keysight PXE software A.33.03.

Test Method

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

Test Setup

This block diagram shows the test equipment setup.

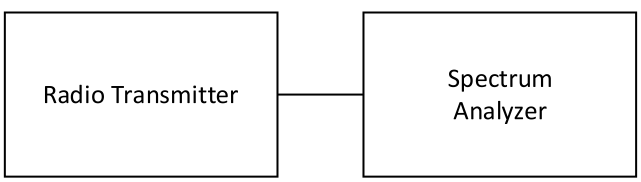


Figure TR11.1: Test setup

Test Data

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

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

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

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

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

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

		2402	2404	2442	2478	2480
BLE	1 Mb	**37.22**	**NT**	**37.22**	**NT**	**36.30**
BLE	2 Mb	**NT**	**37.98**	**36.42**	**37.88**	**NT**

Table TR11.2: Results Summary
NT: (Not tested) means the requirement is or may not be applicable by EUT or it is not required by standards.

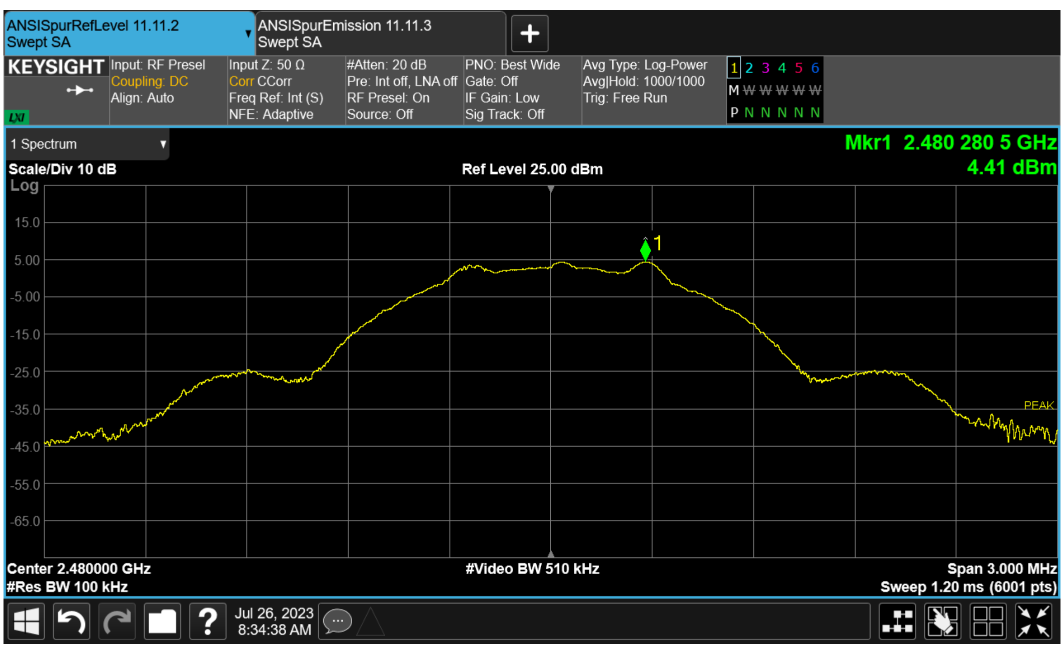


Figure TR11.2: Reference level measurement for BLE 1 Mbps at 2480 MHz

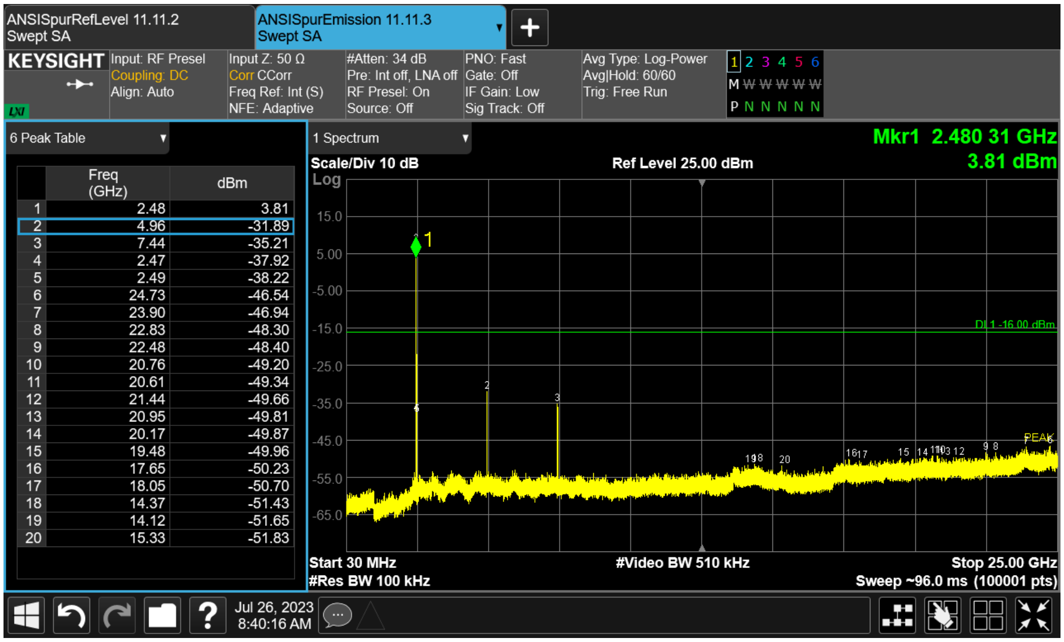


Figure TR11.3: Spectral data for BLE 1 Mbps at 2480 MHz

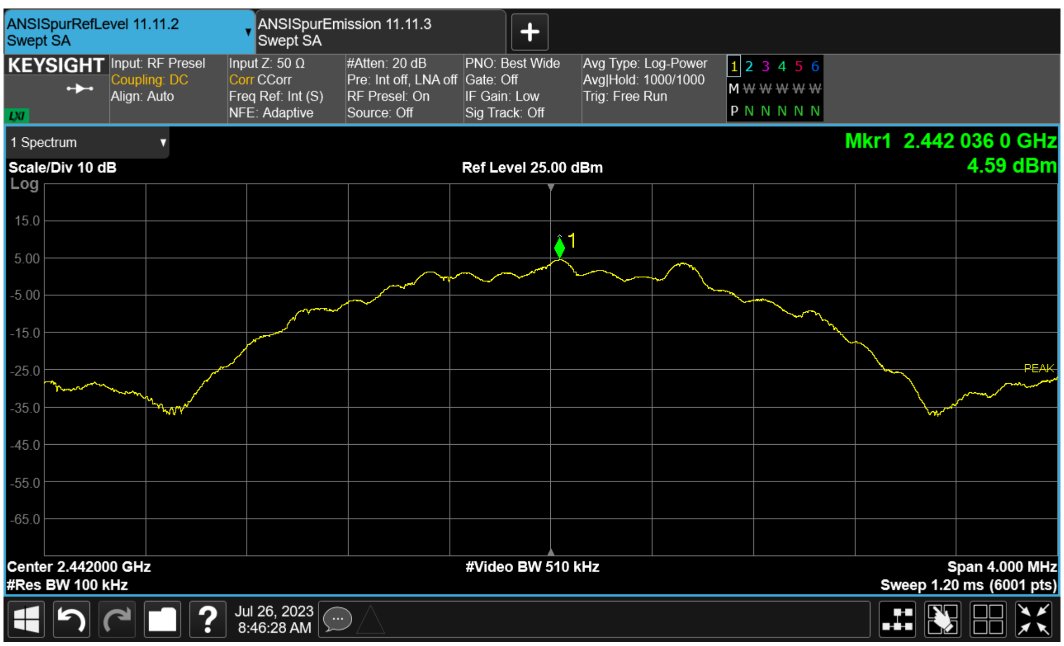
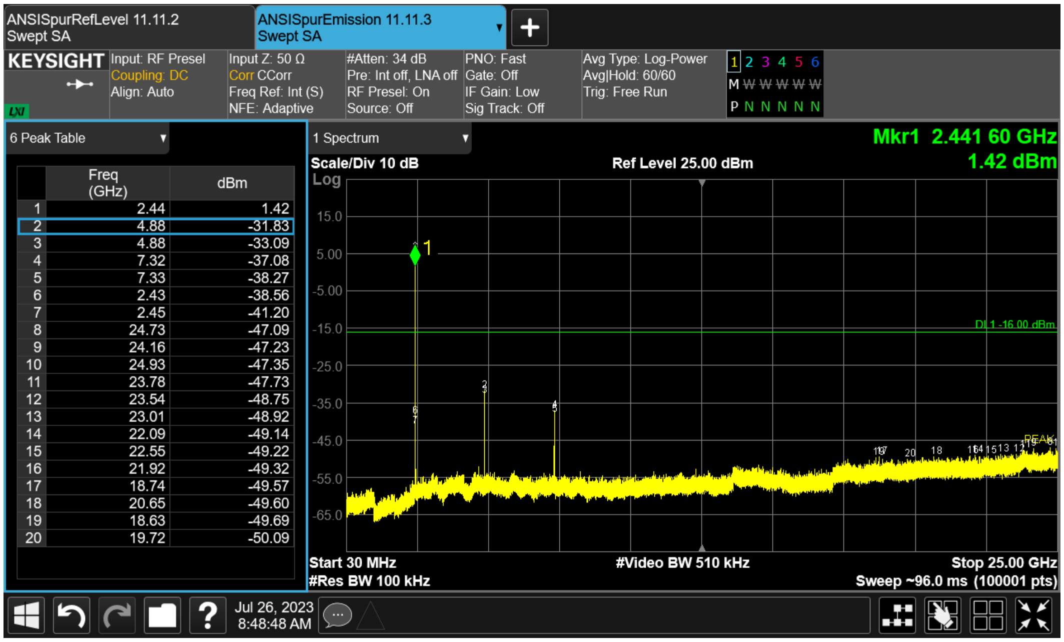


Figure TR11.4: Reference level measurement for BLE 2 Mbps at 2442 MHz



	Freq (GHz)	dBm
1	2.44	1.42
2	4.88	-31.83
3	4.88	-33.09
4	7.32	-37.08
5	7.33	-38.27
6	2.43	-38.56
7	2.45	-41.20
8	24.73	-47.09
9	24.16	-47.23
10	24.93	-47.35
11	23.78	-47.73
12	23.54	-48.75
13	23.01	-48.92
14	22.09	-49.14
15	22.55	-49.22
16	21.92	-49.32
17	18.74	-49.57
18	20.65	-49.60
19	18.63	-49.69
20	19.72	-50.09

Figure TR11.5: Spectral data for BLE 2 Mbps at 2442 MHz

This line is the end of the test record.

Test Record
Radiated Emission Test RE02
Project GCL0315

Test Date(s)	25 Jul 2023
Test Personnel	David Kerr
Product Model	A04770
Serial Number tested	817000223
Operating Mode	M3 (BLE Tx)
Arrangement	A1 (Standalone)
Input Power	Battery 3 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:	**Aditya Prakash**
Date of this record:	**28 Jul 2023**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 26 GHz	Keysight	N9048B	MY59290135	21-Sep-2022	15-Sep-2023
Antenna, Horn, 1-18 GHz	ETS Lindgren	3117	00227596	27-Aug-2021	1-Sep-2023
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	16-Nov-2022	16-Nov-2025
Preamplifier, 500 MHz 18 GHz	Com-Power	PAM-118A	18040133	Calibration	Not Required
Wifi Filter	K&L	8NSL26-2437/E82.2-0/0	1	Calibration	Not Required
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10720	16-Jan-2023	15-Jan-2026

Table RE02.1: Test Equipment Used

Software Used
Software Used
Keysight PXE N9048B Firmware version A.32.06
RE Signal Maximization Tool v2023Jul14.xlsx
FCC Restricted Band 2p4GHz Template v1b 2023Jun20.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.

Restricted band measurements in the lower band were made while the transmitter was tuned to its lowest frequency of 2404 MHz for the 2 Mbps data rate. Measurements in the upper band were made while the transmitter was tuned to its highest frequency of 2478 MHz for the 2 Mbps data rate.

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

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

Frequency	Avg Limit	Pk Limit	Avg Level	Pk Level	Av Margin	Pk Margin	Azimuth	Height	Polarity
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	---
2337.8	54	74	32.893	49.094	21.107	24.906	-73	3396	HORZ
2390	54	74	33.19	46.734	20.81	27.266	-73	3396	HORZ

Table RE02.2: FCC restricted band from 2200 to 2390 MHz (BLE 2 Mbps)

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)	---
2497.5	54	74	43.638	56.032	10.362	17.968	-168	1516	HORZ
2488	54	74	45.583	55.721	8.417	18.279	-168	1516	HORZ

Table RE02.3: FCC restricted band from 2483.5 to 2500 MHz (BLE 2 Mbps)

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

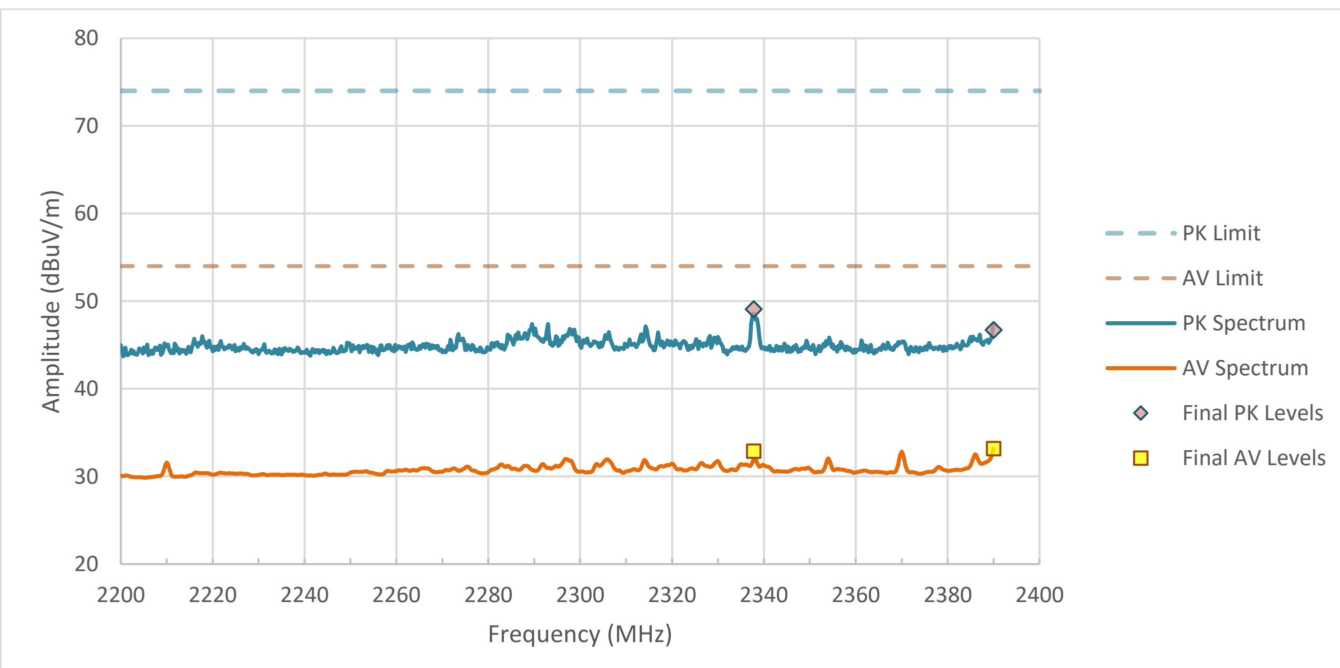


Figure RE02.1: FCC restricted band spectral data from 2200 to 2390 MHz (BLE 2 Mbps)

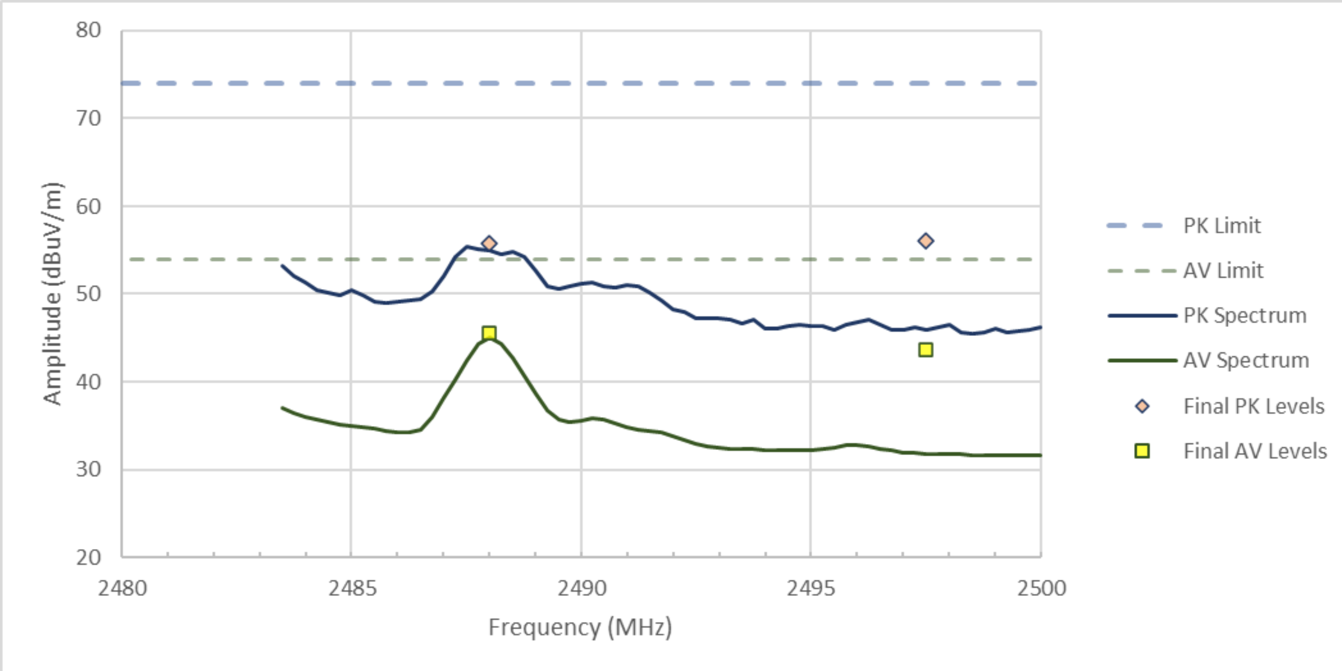


Figure RE02.2: FCC restricted band spectral data from 2483.5 to 2500 MHz (BLE 2 Mbps)

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 RE02.3: EUT test setup, Front View (Y Orientation)

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

Figure RE02.4: EUT test setup, reverse View (Y Orientation)

This line is the end of the test record.

Test Record

Transmitter Power Spectral Density
Test IDs TR07
Project GCL-0315

Test Date(s)	26 Jul 2023
Test Personnel	Majid Farah
Product Model	A04770
Serial Number tested	817000237
Operating Mode	M3 (BLE Tx)
Arrangement	A1 (Standalone)
Input Power	3.0 Vdc battery operated
Test Standards:	FCC Part 15, ANSI C63.10, RSS-GEN, RSS-210, RSS-247, (as noted in Section 6 of the report).
Antenna Gain	-0.3 dBi, as reported by the client
Radio Protocol	Bluetooth Low Energy (BLE)
Pass/Fail Judgment:	**PASS**
Test record created by:	**Jim Solum**
Date of this record:	**1 Aug 2023**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 44GHz	Keysight	N9048B	MY62220139	30-Jan-2023	1-Feb-2024

Table TR07.1: Test equipment used

Software Used: Keysight PXE software A.33.03

Test Method

The basic test standards provide options for the test method. The following test methods were applied.
ANSI C63.10: PKPSD (11.10.2)

Test Setup

This block diagram shows the test equipment setup.

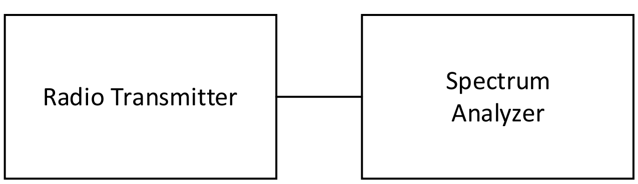


Figure TR07.1: Test setup

Test Data

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

All data met the limit using a 3 kHz resolution bandwidth. The highest PSD levels for each mode are highlighted in yellow, and graphical results are provided for those cases.

		2402 (04)	2442	2480 (78)
BLE	1 Mb	-11.21	-11.16	-11.71
BLE	2 Mb	-12.83	-12.64	-12.92

Table TR07.2: Summary of results

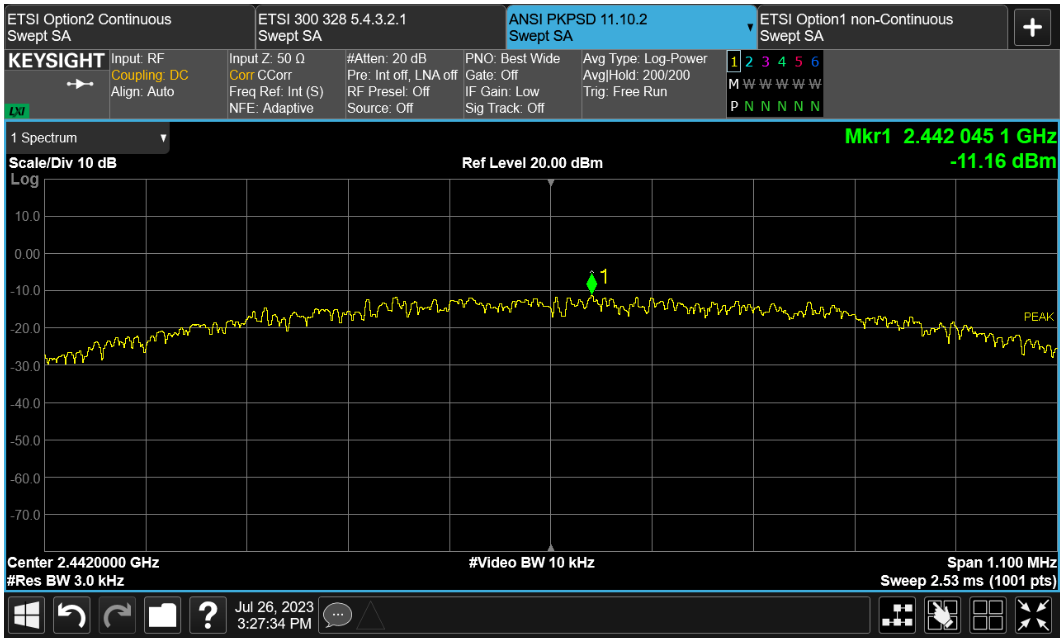


Figure TR07.2: Test data for BLE at 1 Mbps, 2442 MHz

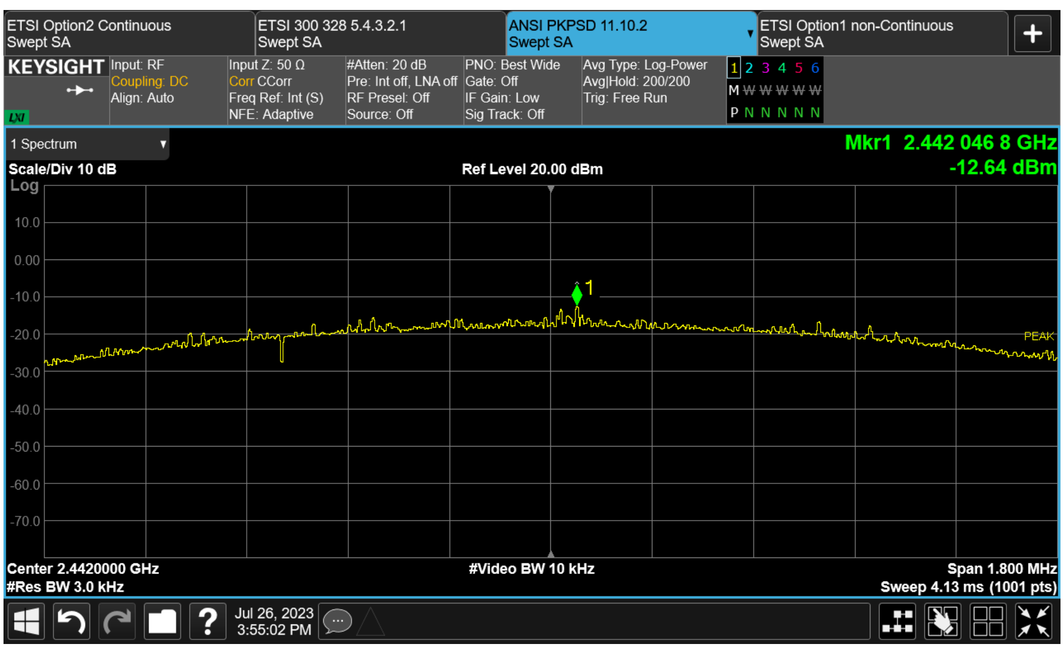


Figure TR07.3: Test data for BLE at 2 Mbps, 2442 MHz

This line is the end of the test record.

Test Record

Transmitter Frequency Stability
Test IDs TR16, TR17
Project GCL-0315

Test Date(s)	27 Jul 2023
Test Personnel	Jim Solum supervised Majid Farah
Product Model	A04770
Serial Number tested	817000237
Operating Mode	M1 (ANT Tx), M3 (BLE Tx)
Arrangement	A2 (PwrSupply)
Nominal Input Power	3 Vdc
Test Standards:	FCC part 15, RSS-GEN, ANSI C63.10 (as noted in Section 6 of the report)
Radio Protocol	BLE (Bluetooth Low Energy), ANT
Pass/Fail Judgment:	**PASS**
Test record created by:	**Jim Solum**
Date this record:	**3 Aug 2023**

Original record, Version A.

Test Equipment

Description	**Make**	**Model #**	**Serial #**	**Last Cal/Ver**	**Next Due**
DMM Multimeter	FLUKE	79 III	71740743	5-Apr-2023	1-Apr-2024
PXE Receiver 44GHz	Keysight	N9048B	MY62220139	30-Jan-2023	1-Feb-2024
Thermometer	Thermco	ACCD370P	210607316	11-Aug-2021	15-Aug-2023
Barometer	Traceable	6453	221702700	3-Aug-2022	1-Aug-2024
Thermal Chamber	TPS	T2RC	32774-02	Calibration	Not Required
Programmable DC power source	Keithley	2260B-30-72	1411917	21-Apr-2023	15-Apr-2024

Table TR16.1: Equipment used

Software Used: PXE Software Revision A.33.03, 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.

Bluetooth Low Energy and ANT use channel plans with a minimum transmission center frequency at 2402 MHz and a maximum at 2480 MHz. Additional information regarding Bluetooth Low Energy (BLE) and ANT technologies is provided in the following table.

	First Channel	Last Channel	Channel spacing	Data rate
	MHz	MHz	MHz	Mb/s
BLE 1 Mbps	2402	2480	2	1
BLE 2 Mbps	2404	2478	2	2
ANT	2402	2402	1	60 Kb/s

Table TR16.2 BLE and ANT overview

The test sample was placed in a thermal chamber and connected to an appropriate dc power source. The sample has an appropriate output to be used 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 (3 V). For the voltage variation test at +20 °C, the voltages were varied between the marginal battery levels. Data was taken at 3 Vdc and at the lower marginal limit of 2.5 Vdc plus the higher marginal limit of 3.2 Vdc. The lower/higher marginal limit of battery voltage was provided by the client.

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 to different limits or conditions, the most stringent limits and conditions have been applied.

During Bluetooth, BLE and ANT test mode, each measurement is made conducted from the antenna port of the sample with the transmitter continuous “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 highlights indicate the highest level(s) for a protocol, for which an image of the spectrum is also provided. In the spectral plots, the data sets have been combined to present the low and high channel results side by side. Orange diamond markers indicate the spectral peak, which the black square markers are at the 2400 MHz or 2483.5 MHz band edge.

Tx Mode	Temp	Volts	Low Ch.	High Ch.
Bluetooth	˚C	Vdc	dBc	dBc
BLE 1 Mbps	50	3	29.6	47.3
BLE 1 Mbps	40	3	30.2	44.8
BLE 1 Mbps	30	3	29.8	45.4
BLE 1 Mbps	20	3	29.8	45.3
BLE 1 Mbps	10	3	30.0	44.0
BLE 1 Mbps	0	3	30	44.8
BLE 1 Mbps	-10	3	29.6	44.2
BLE 1 Mbps	-20	3	30.7	42.9

Table TR16.3 Difference between peak and band edge levels for BLE 1Mbps transmissions during temperature variations

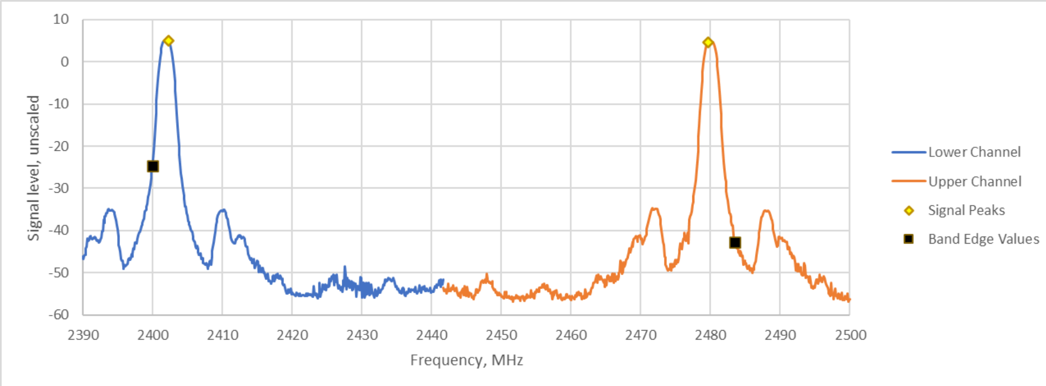


Figure TR16.1: Spectral data for BLE 1Mbps at 50 °C

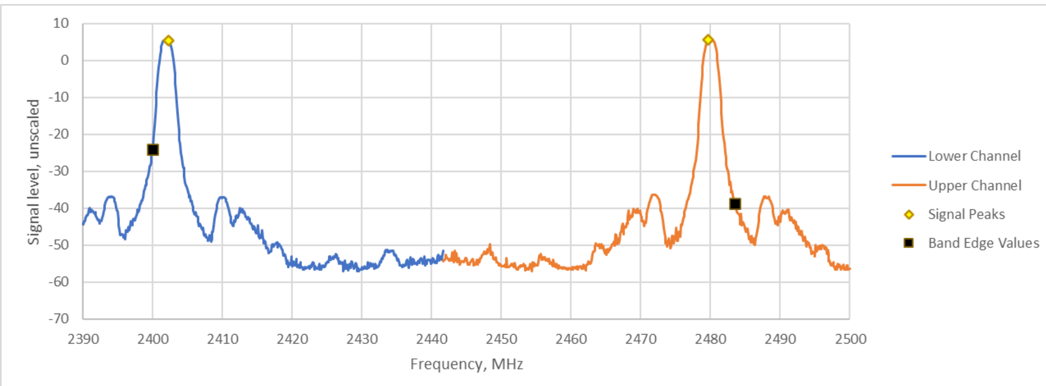


Figure TR16.2: Spectral data for BLE 1Mbps at -10 °C

Tx Mode	Temp	Volts	Low Ch.	High Ch.
Bluetooth	˚C	Vdc	dBc	dBc
BLE 1 Mbps	20	3.2	30.2	46.9
BLE 1 Mbps	20	3	29.8	45.3
BLE 1 Mbps	20	2.5	30.8	45.3

Table TR16.4 Difference between peak and band edge levels for BLE 1 Mbps transmissions at 20 °C during voltage variations

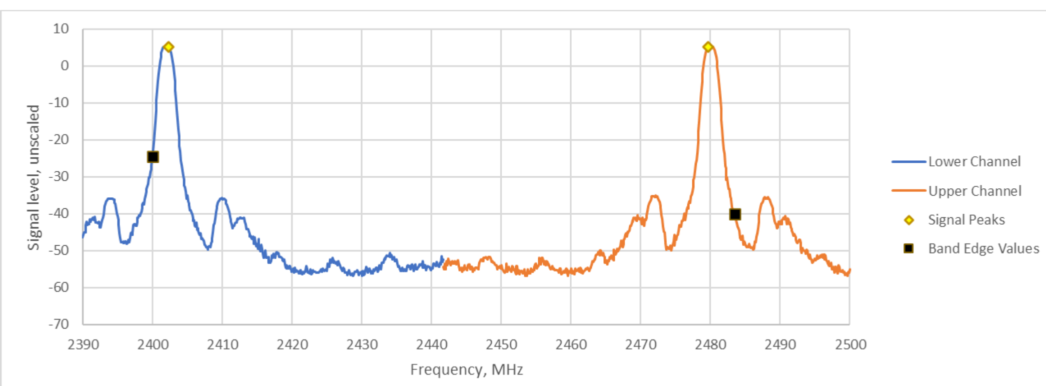


Figure TR16.3: Spectral data for BLE 1 Mbps at 20 °C and 3 Vdc

Tx Mode	Temp	Volts	Low Ch.	High Ch.
	˚C	Vdc	dBc	dBc
BLE 2 Mbps	50	3	46.3	47
BLE 2 Mbps	40	3	45.3	47.9
BLE 2 Mbps	30	3	45.5	46.7
BLE 2 Mbps	20	3	46.4	47.7
BLE 2 Mbps	10	3	46.2	48.1
BLE 2 Mbps	0	3	46.9	48.3
BLE 2 Mbps	-10	3	46.2	47.3
BLE 2 Mbps	-20	3	47.2	49.2

Table TR16.5 Difference between peak and band edge levels for BLE 2 Mbps transmissions during temperature variations

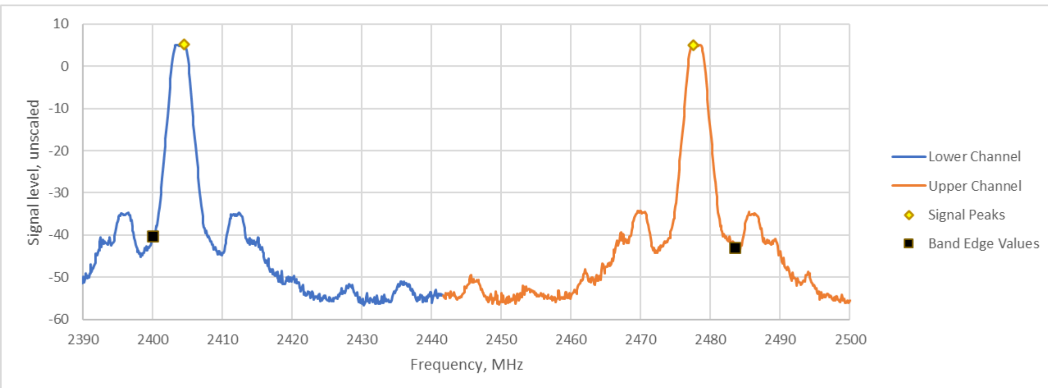


Figure TR16.4: Spectral data for BLE 2 Mbps at 40 °C

Tx Mode	Temp	Volts	Low Ch.	High Ch.
	˚C	Vdc	dBc	dBc
BLE 2 Mbps	20	3.2	47	48.1
BLE 2 Mbps	20	3	46.4	47.7
BLE 2 Mbps	20	2.5	46.1	47.8

Table TR16.6 Difference between peak and band edge levels for BLE 2 Mbps transmissions at 20 °C during voltage variations

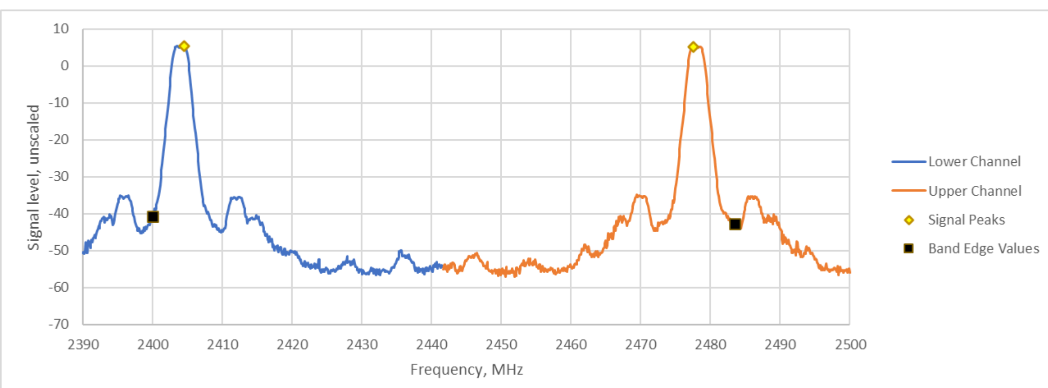


Figure TR16.5: Spectral data for BLE 2 Mbps at 20 °C and 2.5 Vdc

Tx Mode	Temp	Volts	Low Ch.	High Ch.
	˚C	Vdc	dBc	dBc
ANT	50	3	29.8	45.8
ANT	40	3	29.9	45.5
ANT	30	3	30.3	43.8
ANT	20	3	30.4	45
ANT	10	3	29.8	46.1
ANT	0	3	30	45.8
ANT	-10	3	29.8	44.1
ANT	-20	3	30	44.7

Table TR16.7 Difference between peak and band edge levels for ANT transmissions during temperature variations

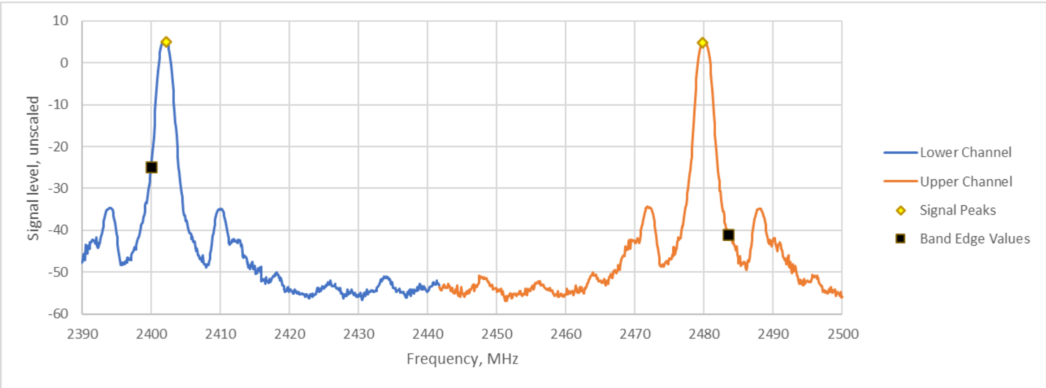


Figure TR16.6: Spectral data for ANT Mbps at 50 °C

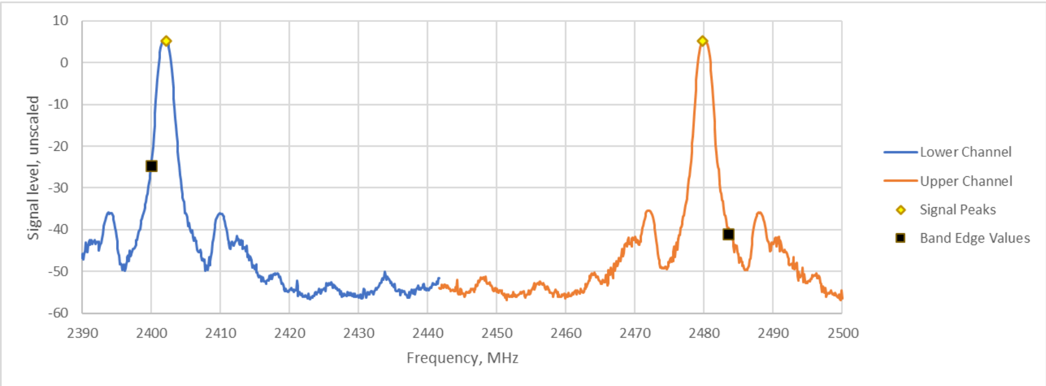


Figure TR16.7: Spectral data for ANT Mbps at 10 °C

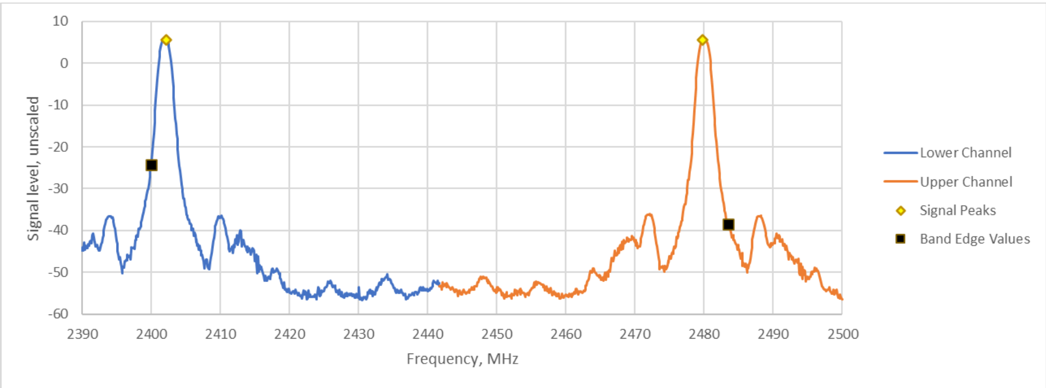


Figure TR16.8: Spectral data for ANT Mbps at -10 °C

Tx Mode	Temp	Volts	Low Ch.	High Ch.
	˚C	Vdc	dBc	dBc
ANT	20	3.2	30.3	44.2
ANT	20	3	30.4	45
ANT	20	2.5	30.7	44.8

Table TR16.8 Difference between peak and band edge levels for ANT transmissions at 20 °C during voltage variations

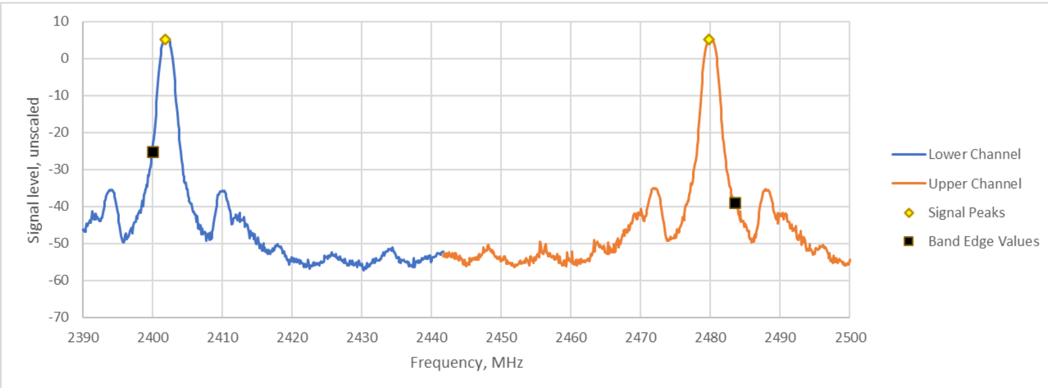


Figure TR16.9: Spectral data for ANT Mbps at 20°C and 3.2 Vdc

Setup Block Diagram

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

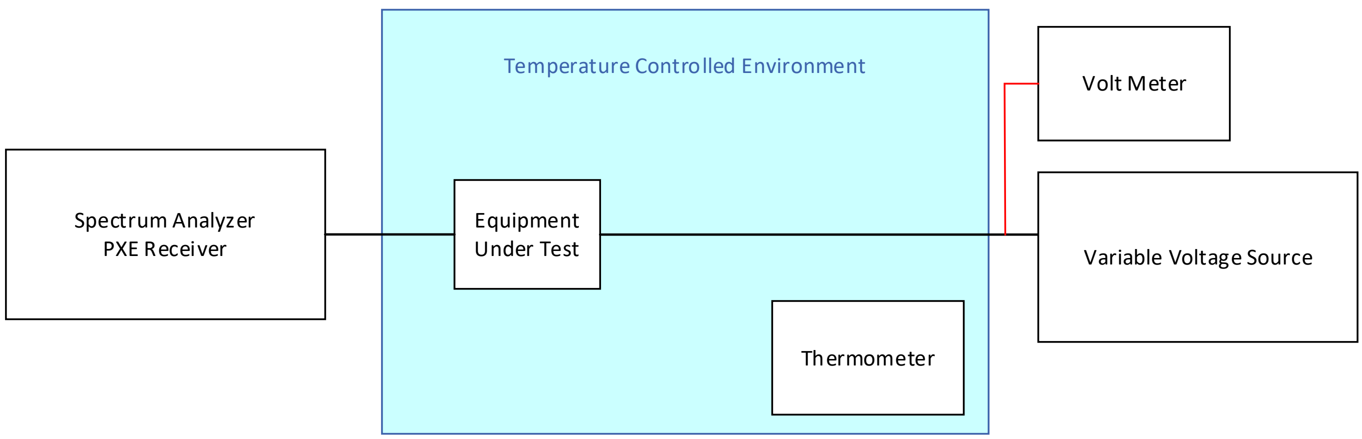


Figure TR16.10: Schematic drawing of the test equipment setup for BLE and ANT

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.