

Test Report 2023-032

Version B
Issued 14 July 2023

Project GCL-0385
Model Identifier: A04724
Primary Test Standards
CFR 47, FCC Part 15.247
RSS-247 Issue 2

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

Client-supplied Information

FCC ID: IPH-04724
IC ID: 1792A-04724



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 its 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 516 kHz or greater.	PASS	12
Other Bandwidths	Regulatory agencies also require the reporting of signal bandwidths using alternate processes. [2.202; RSS-GEN at 6.7]	These values are reported but have no actual performance requirements.	Reported	19
Transmit Power	The peak transmit power presented to the antenna is no greater than 1 Watt or 30 dBm. The effective radiated power is limited to 4 Watts or 36 dBm EIRP. [15.247(b); RSS-247 at 5.4(d)]	The maximum transmit power is 19.67 dBm or 92.7 mW.	PASS	26
Antenna Gain	The radio should not focus too much energy in any direction. Unless additional rules are applied, the antenna gain is no greater than 6 dBi. [15.247(b)(4) and (c)]	NT. The client stated that the antenna gain was 0.37 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 39 dB.	PASS	31
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 0.3 dB below the applicable limits.	PASS	41
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 5.55 dBm in a band of at least 3 kHz.	PASS	64

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	73
AC Mains Conducted Emissions	Radio emissions that this device may generate via long connected cables that are not necessary for its operation and that may affect other radio communication	9.66 dB of margin. Appropriate for use in homes, offices, and industrial facilities. [Class B]	PASS	83
Unintended Radiated Emissions	Radio emissions that this device may generate via its structures and connected cables not necessary for its operation and that may affect other radio communication	12.2 dB of margin. Appropriate for use in homes, offices, and industrial facilities. [Class B]	PASS	86

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:

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

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 2023-034. 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: 6 Apr 2023
Test Start Date: 11 May 2023
Test End Date: 9 Jun 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 David Arnett and initially issued on 6 July 2023 as Version A. Version B issued 14 July 2023 to correct editorial errors identified during TCB review.

Report Technical Review:



David Arnett
Technical Lead EMC Engineer

Report Approval:



Shrutli 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:

Modification 1

Detailed Description: Update of unit software from version 2.14 to version 2.15

Date applied: 22 May 2023

Reason for this modification: The new software changed the transmit power for WiFi Channel 13 under particular conditions.

Radiated emission and transmit power tests performed on 22 May or earlier that did not involve WiFi channel 13 were performed using firmware version 2.14 and are unaffected by this change. Radiated emission and transmit power tests performed on 22 May or earlier that included channel 13 but not the particular conditions affected by this change were likewise performed using firmware version 2.14 and are unaffected by this change. All other tests used version 2.15.

5. Description of the Equipment Tested

5.1 Unique Identification

Product Model A04724
Serial Numbers Tested 441084880, 441085073, 441085328

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

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

5.2 Key Parameters

EUT Input Power: 5 Vdc
I/O Ports: USB
Radio Transceivers: IEEE 802.11 b/g/n, Bluetooth, Bluetooth Low Energy, ANT, NFC
Radio Receivers: GPS L1, Galileo E1, BeiDou, GLONASS
Primary Functions: Data collection and communication
Typical use location: Mobile, in variable orientation
Highest internal frequency: 2.484 GHz
Firmware Revision 2.14, 2.15 (see section 4)

5.3 Operating modes

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

Mode 1: M1 (BLE Tx). Bluetooth Low Energy radio transmitting consistently on a selected channel at 1 Mbps or 2 Mbps

Mode 2: M2 (BLE Link). Bluetooth Low Energy radio is paired to a companion device, transmitting and receiving data on various channels in accordance with the protocol, and maintaining the paired relationship.

Mode 3: M3 (ANT Tx). ANT radio transmitting consistently on a selected channel.

Mode 4: M4 (ANT Link). ANT radio is paired to a companion device, transmitting and receiving data in accordance with the protocol, and maintaining the paired relationship.

Mode 5: M5 (NFC). The NFC 13.56 MHz transceiver is in Card Emulation mode, and is actively linked to a companion NFC Reader.

Mode 6: M6 (GNSS). The Global Navigation Satellite System receiver is monitoring the GNSS bands, attempting to detect a constellation and determine location. Unless otherwise noted, the EUT was provided simulated GNSS signals representing one of more constellation types. In addition, the EUT may have been reporting signal levels and satellite data to an attached computer to monitor link health.

Mode 7: Void – not used.

Mode 8: M8 (WiFi Tx). The IEEE 802.11 b/g/n radio was transmitting consistently on a selected channel, with a specified modulation type, and data rate.

Mode 9: M9 (BLE Link). The IEEE 802.11 b/g/n radio is paired to a companion device, transmitting and receiving data on a selected channel in accordance with the protocol, and maintaining the paired relationship.

Mode 10: M10 (BT Tx). Bluetooth, sometimes called Bluetooth Classic, radio is transmitting consistently on a selected channel sending data using the BR (Basic Rate of 1 Mbps), EDR2 (Extended Data Rate of 2 Mbps) or EDR3 (Extended Data Rate of 3 Mbps) modulation types.

Mode 11: M11 (BT Link). Bluetooth Classic radio is paired to a companion device, transmitting and receiving data on various channels in accordance with the protocol, and maintaining the paired relationship.

Mode 12: M12 (All2.4). This means the radio was tested in modes M1, M3, M8, and M10.

Mode 13: M13 (Rx 2.4). The radio was set to receive 2.4 GHz signals but not transmit. In this situation, it was specifically looking for Bluetooth Low Energy signals which cover the 2.4 GHz band and represent a worst-case scenario.

5.4 EUT Arrangement

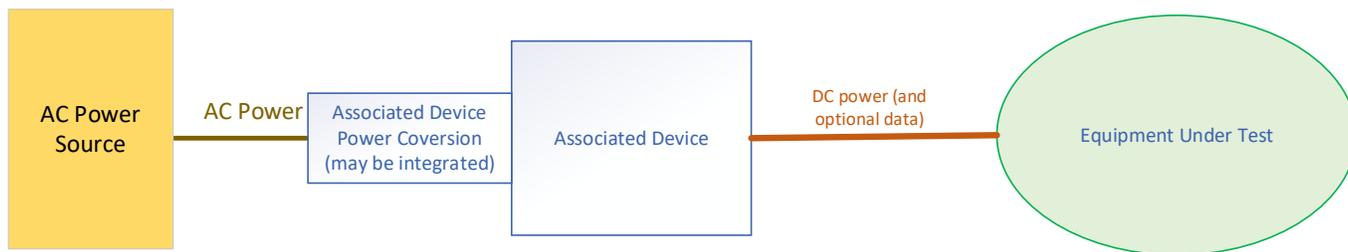
During test, the EUT components and associated support equipment were selected including the following arrangement sets.

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

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

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

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



*This interconnect drawing is not to scale.
It does not indicate the placement of devices.*

Figure 1: Block diagram of equipment for arrangements A2, A3, A4

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

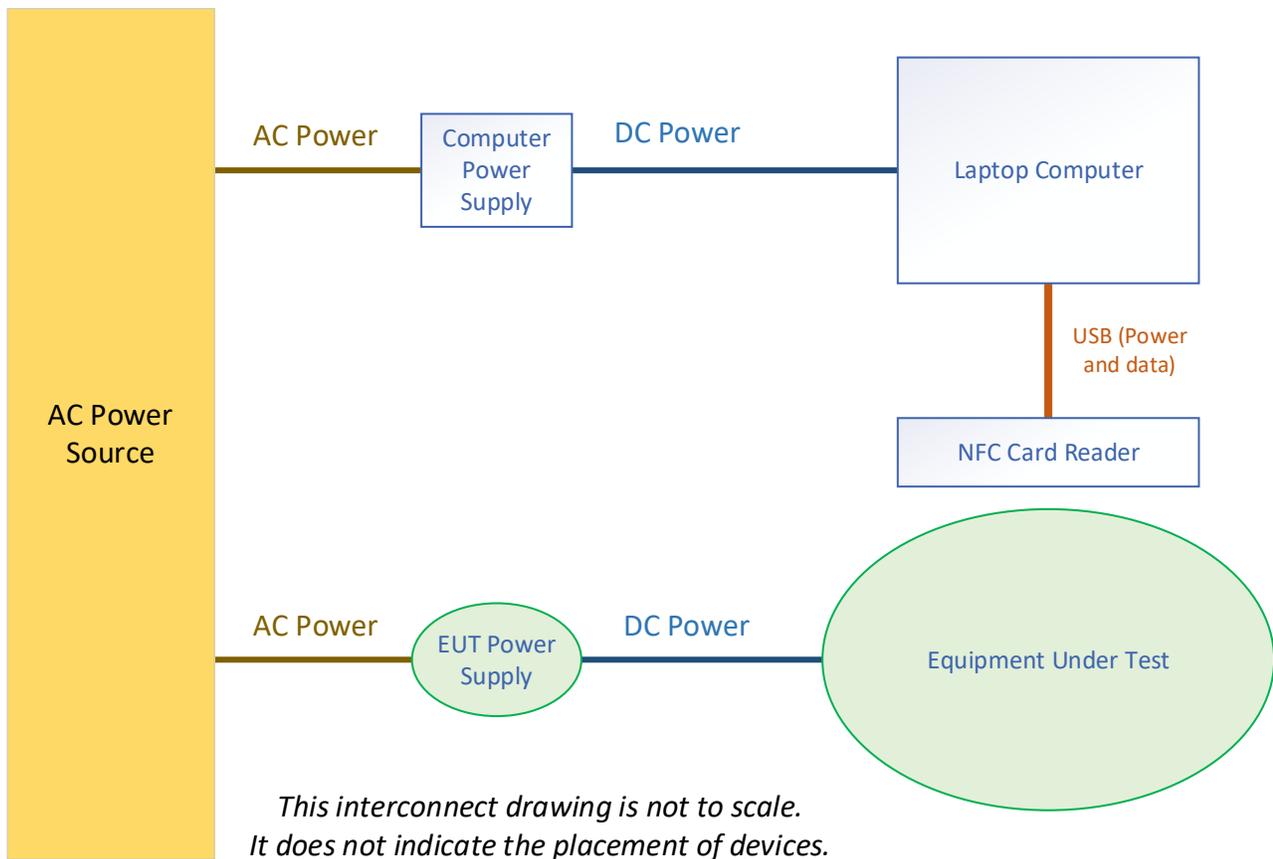


Figure 2: Block diagram of equipment arrangement A5

Arrangement 6: A6 (NFCu) The test sample is placed near an NFC Card Reader. The NFC Card Reader is connected to a laptop computer. The test sample is powered by its own batteries rather than an external power source. The test sample is NOT powered by, or connected to, the laptop computer that powers the NFC Card Reader.

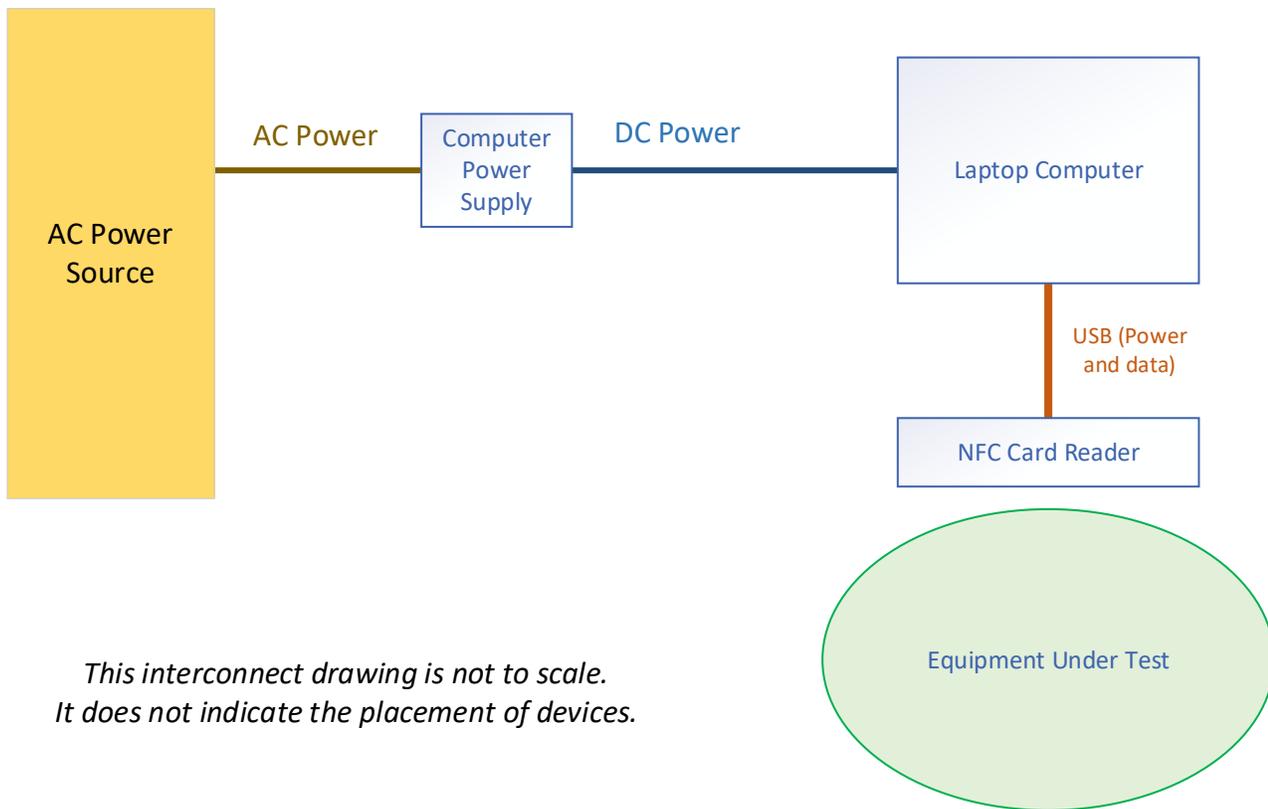


Figure 3: Block diagram of equipment arrangement A6

5.5 Associated Equipment (AE) used

Description	Manufacturer	Model	Serial Number
AC/DC Power Converter	Garmin	362-00118-00	None
Laptop Computer	Dell	Latitude 5410	5VSPFB3
Laptop Power Supply	Dell	HA65NM191	None

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

5.6 Cables used

Description	From	To	Length	EMC Treatment
USB	Power and/or Data source	EUT	54 cm	None

Table 3: List of cables that may have been used during test

6 Test Standards Applied

6.1. Accredited Standards

The following test or measurement standards were applied and are within the scope of the lab's accreditation. All results in this report that cite these standards are presented as Accredited results consistent with ISO/IEC 17025.

AS/NZS 4268: 2017
CFR 47, FCC Part 15.247
ANSI C63.10: 2013 and ANSI C63.10: 2020
RSS-GEN Issue 5 Amd 2
RSS-247 Issue 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 1470 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

$$(7.145 \text{ dBuV}) + (9.812 \text{ dB}) + (0.216 \text{ dB}) = 17.173 \text{ dBuV}$$

8.2 Radiated Emissions at 630 MHz

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

$$(2.25 \text{ dBuV}) + (27.80 \text{ dB/m}) + (2.89 \text{ dB}) = 32.94 \text{ dBuV/m}$$

8.3 Radiated Emissions at 2.7 GHz

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

$$(43.72 \text{ dBuV}) + (32.22 \text{ dB/m}) + (-36.09 \text{ dB}) = 39.85 \text{ dBuV/m}$$

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:	20.7 to 24.7 °C
Relative Humidity:	33.2% to 67.4% (non-condensing)
Barometric Pressure	97.2 to 98.9 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
Transmitter Bandwidth Tests - DTS
Test IDs TR03a
Project GCL-0385

Test Date(s) 25 May 2023
 Test Personnel David Arnett

Product Model A04724
 Serial Number tested 441085328

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

Radio Protocol Bluetooth Classic (Including Basic Rated, Extended Data Rate 2 and Extended Data Rate 3), Bluetooth Low Energy (BLE), ANT
 Radio Band 2480 to 2483.5 MHz

Pass/Fail Judgment: PASS

Test record created by: David Arnett
Date of this record: 31 May 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 TR03a.1: List of test equipment used

Test Software Used: Keysight PXE firmware A.33.03

Test Method

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

Test Setup

This block diagram shows the test equipment setup.

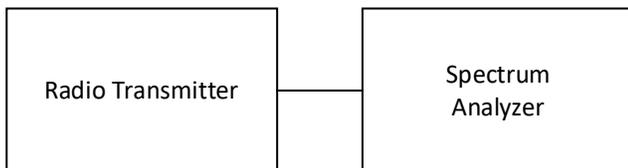


Figure TR03a.1: Test setup

Test Data

The data for each test is summarized below, followed by the spectral data for each case highlighted in yellow. For BLE operating at 2 Mbps, the lowest operating frequency was 2404 MHz, and the highest operating frequency was

2478 MHz. For all other radios reported here, the lowest operating frequency was 2402 MHz, and the highest operating frequency was 2480 MHz.

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

		2402 (04)	2440	2480 (78)
BT	BR	0.517	0.518	0.518
	EDR2	1.085	1.088	1.085
	EDR3	1.092	1.091	1.089
BLE	1 Mb	0.757	0.764	0.761
	2 Mb	1.080	1.085	1.084
ANT		0.516	0.519	0.518

Table TR03a.2: Summary of bandwidth data in MHz for Bluetooth, ANT and BLE modes

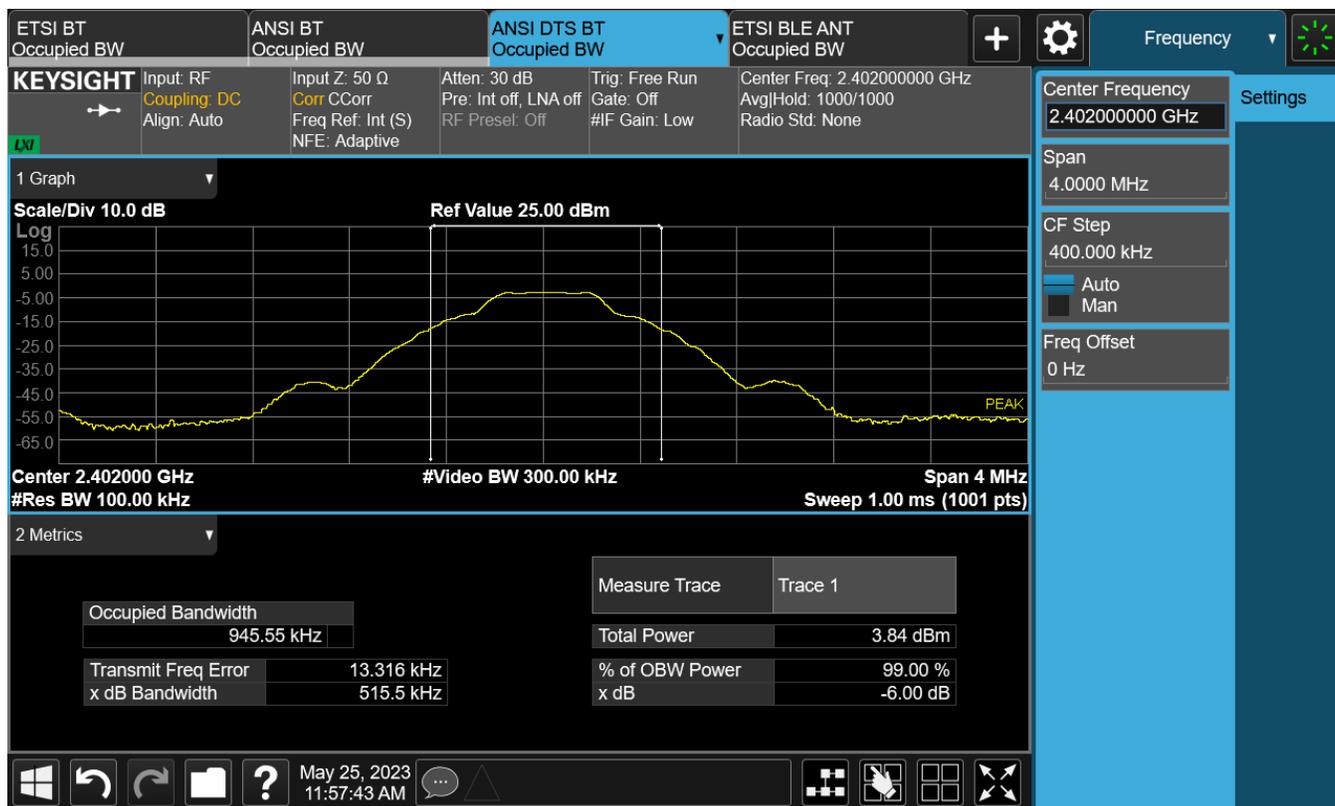


Figure TR03a.2: Bandwidth data for ANT at low channel (2402 MHz)



Figure TR03a.3: Bandwidth data for BLE 1 Mb at low channel (2402 MHz)



Figure TR03a.4: Bandwidth data for Bluetooth Basic Rate at low channel (2402 MHz)

This line is the end of the test record.

Test Record
Transmitter Bandwidth Tests - DTS
Test IDs TR03b
Project GCL-0385

Test Date(s) 25 May 2023
 Test Personnel David Arnett

Product Model A04724
 Serial Number tested 441085073

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

Radio Protocol IEEE 802.11b/g/n (WiFi)
 Radio Band 2400 to 2483.5 MHz

Pass/Fail Judgment: PASS

Test record created by: David Arnett
Date of this record: 7 Jul 2023

Version A was released 1 June 2023. Version B released 7 July 2023 corrects the frequency range.

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 TR03b.1: List of test equipment used

Test Software Used: Keysight PXE firmware A.33.03

Test Method

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

Test Setup

This block diagram shows the test equipment setup.

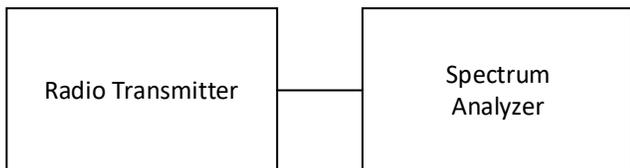


Figure TR03b.1: Test setup

Test Data

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

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

Channel	1	6	11	12	13
B1	11.16	11.16	12.09	11.17	12.11
B2	11.45	11.45	11.46	11.45	11.46
B5.5	12.08	12.07	12.09	12.08	12.09
B11	11.72	11.72	11.72	11.72	11.73
G06	16.51	16.50	16.49	16.48	16.49
G09	16.49	16.49	16.48	16.50	16.50
G12	16.49	16.53	16.52	16.53	16.52
G18	16.51	16.51	16.53	16.51	16.52
G24	16.55	16.51	16.51	16.54	16.55
G36	16.50	16.53	16.52	16.52	16.49
G48	16.52	16.54	16.50	16.52	16.50
G54	16.49	16.52	16.51	16.50	16.50
N0	17.76	17.75	17.78	17.76	17.74
N1	17.74	17.75	17.76	17.76	17.76
N2	17.77	17.77	17.76	17.71	17.77
N3	17.73	17.70	17.76	17.71	17.77
N4	17.74	17.77	17.77	17.75	17.75
N5	17.69	17.76	17.73	17.77	17.76
N6	17.73	17.74	17.73	17.75	17.74
N7	17.76	17.76	17.75	17.74	17.75

Table TR03b.2: Summary of bandwidth data in MHz for WiFi modes

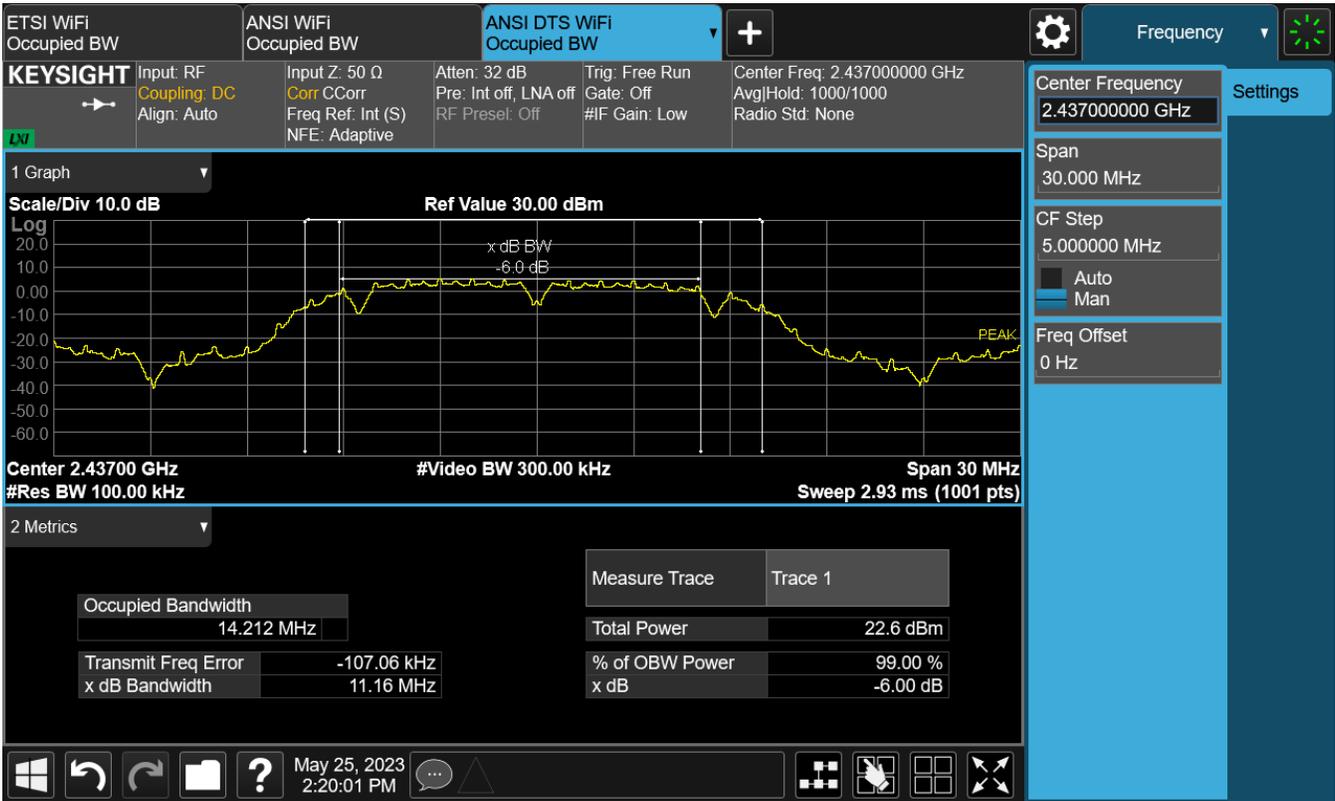


Figure TR03b.2: Bandwidth data for B1 modulation, on channel 1 (2412 MHz)



Figure TR03b.3: Bandwidth data for G9 modulation, on channel 11 (2462 MHz)

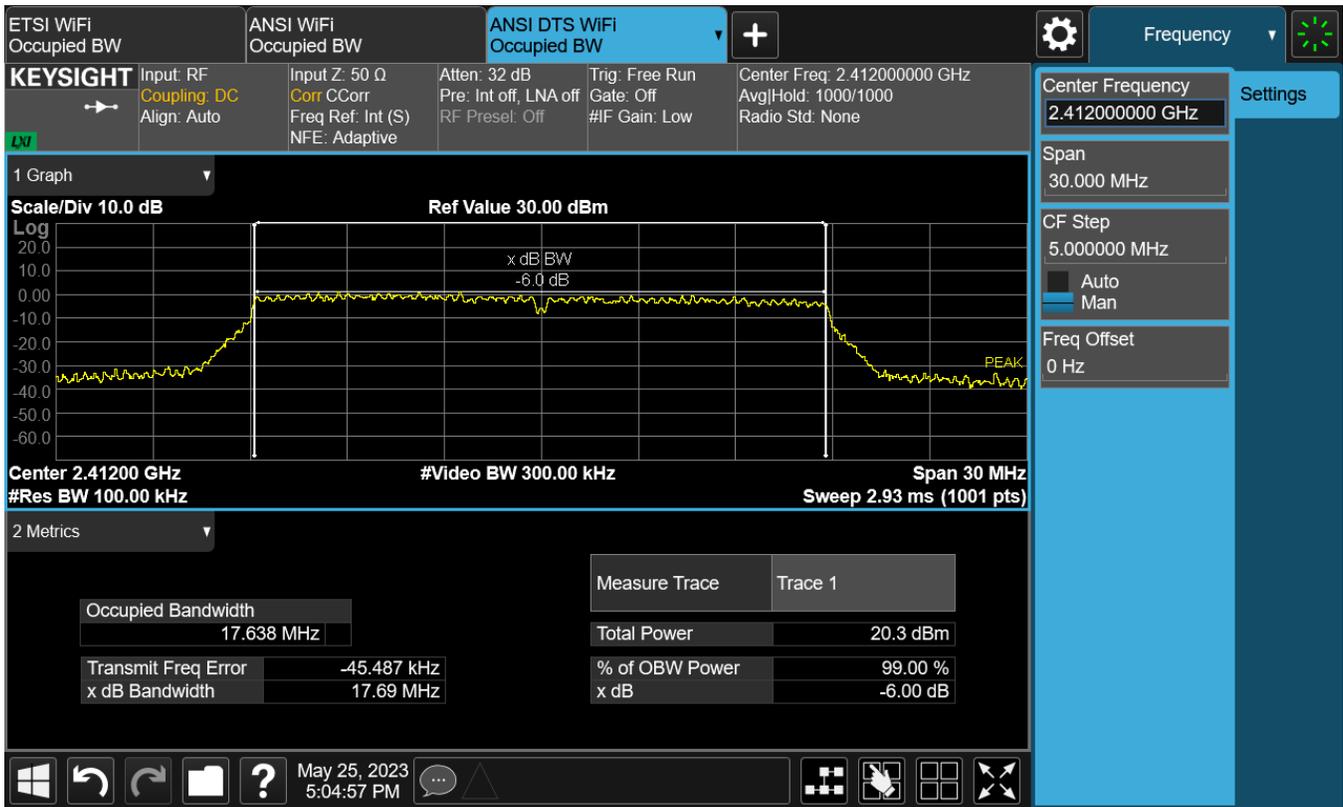


Figure TR03b.4: Bandwidth data for N MCS5 modulation, on channel 1 (2412 MHz)

This line is the end of the test record.

Test Record
Transmitter Bandwidth Tests - Other
Test IDs TR04a
Project GCL-0385

Test Date(s) 25 May 2023
 Test Personnel David Arnett

Product Model A04724
 Serial Number tested 441085073, 441085328

Test Standards: FCC Part 2.202, ANSI C63.10, TRC-43, RSS-GEN (as noted in Section 6 of the report).

Radio Protocol Bluetooth Classic (Including EDR2 and EDR3), Bluetooth Low Energy (BLE), ANT, IEEE 802.11 b/g/n (WiFi)
 Radio Band 2480 to 2483.5 MHz

Pass/Fail Judgment: Reported

Test record created by: David Arnett
Date of this record: 1 Jun 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 TR04a.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 Bluetooth, BLE, and ANT radios reported here, the lowest operating frequency was 2402 MHz, and the highest operating frequency was 2480 MHz.

Test Setup

This block diagram shows the test equipment setup.

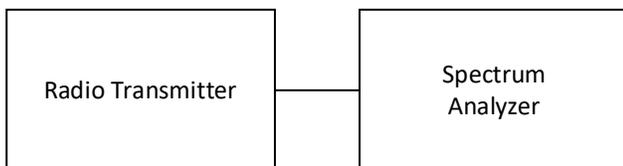


Figure TR04a.1: Test setup

Occupied Bandwidth, 99% Test Method

During this test the transmitter output is fed directly, or through RF attenuators, to the spectrum analyzer. The analyzer has a built-in capability to identify the minimum bandwidth that contains a specified percentage of the total

power observed. The spectrum is scanned hundreds of times so that the varied effects of modulation are appropriately assessed. Since the focus is on the relative distribution of energy across a range of frequencies, the absolute amplitudes recorded during this test are not relevant and may not include cable losses or attenuation factors.

Occupied Bandwidth, 99% Test Data

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

		2402 (04)	2440	2480 (78)
BT	BR	0.950	0.943	0.924
	EDR2	1.293	1.277	1.278
	EDR3	1.286	1.300	1.247
BLE	1 Mb	1.062	1.069	1.066
	2 Mb	2.060	2.062	2.062
ANT		0.904	0.962	0.888

Table TR04a.2: Summary of 99% Occupied Bandwidth Data for Bluetooth, ANT and BLE modes

	1	6	11	12	13
B1	14.10	14.31	14.02	14.02	13.92
B2	14.02	14.26	14.02	14.01	13.92
B5.5	13.83	13.90	13.84	13.84	13.83
B11	13.87	13.99	13.87	13.87	13.84
G06	17.28	18.03	17.24	17.24	17.11
G09	17.23	17.98	17.21	17.20	17.10
G12	17.05	17.41	17.02	16.99	16.94
G18	17.02	17.37	17.04	17.01	16.98
G24	16.99	17.30	16.96	16.95	16.91
G36	16.95	17.30	16.99	16.95	16.86
G48	16.96	17.36	16.96	16.97	16.88
G54	17.00	17.34	16.97	16.96	16.87
N0	17.94	18.13	17.90	17.92	17.90
N1	17.93	18.16	17.92	17.91	17.88
N2	17.93	18.17	17.96	17.93	17.88
N3	17.94	18.22	17.93	17.94	17.88
N4	17.96	18.29	17.94	17.94	17.89
N5	17.93	18.18	17.92	17.94	17.89
N6	18.04	18.57	18.06	18.05	17.97
N7	17.94	18.16	17.93	17.93	17.88

Table TR04a.3: Summary of 99% Occupied Bandwidth Data for IEEE 802.11 WiFi modes



Figure TR04a.1: Occupied bandwidth data for ANTI at mid channel (2440 MHz)



Figure TR04a.2: Occupied bandwidth data for BLE 2 Mbps at mid channel (2440 MHz)



Figure TR04a.3: Occupied bandwidth data for Bluetooth EDR3 at mid channel (2440 MHz)



Figure TR04a.4: Occupied bandwidth data for 802.11b 1 Mbps at channel 6



Figure TR04a.5: Occupied bandwidth data for 802.11g 6 Mbps at channel 6

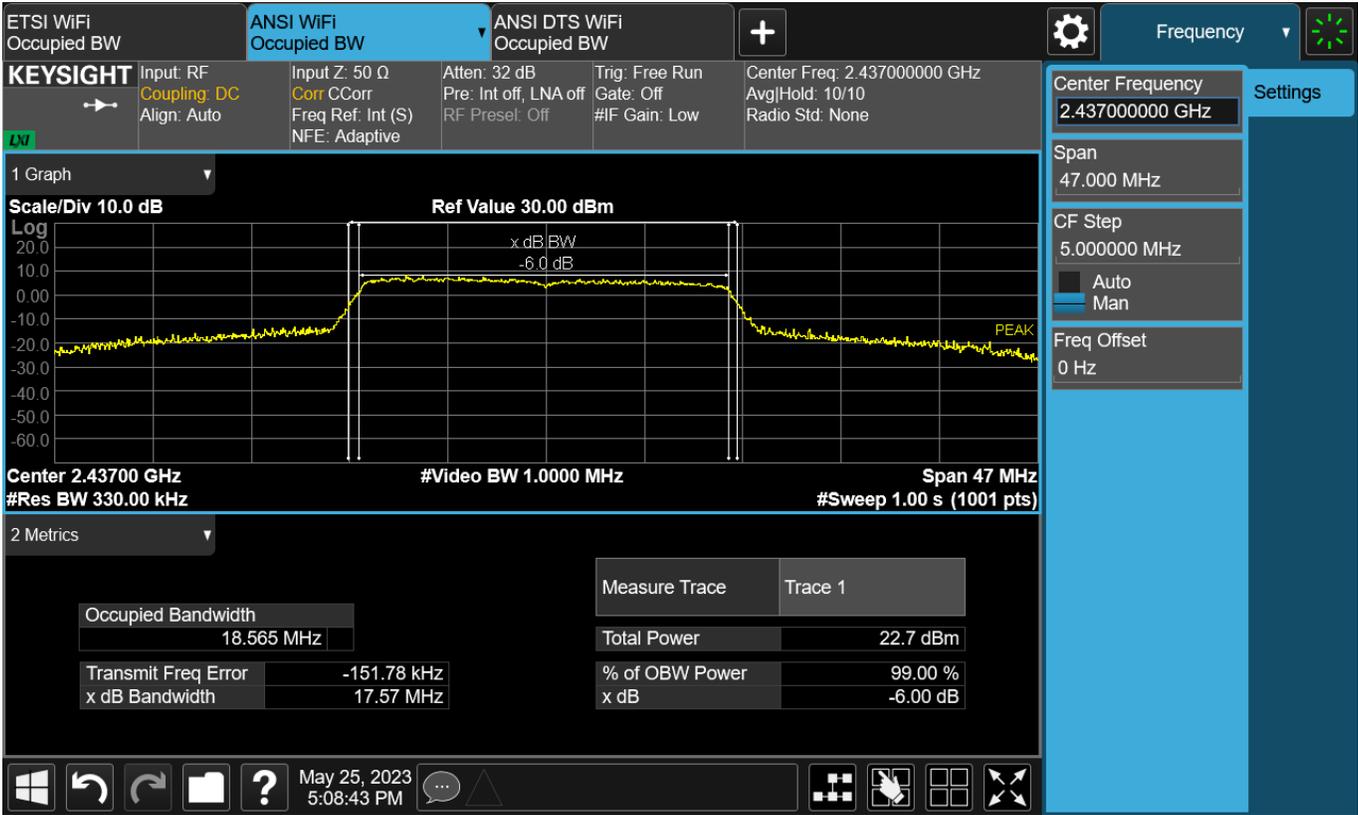


Figure TR04a.6: Occupied bandwidth data for 802.11n MCS6 at channel 6

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:

$$B_N = 2R / \text{Log}_2(S)$$

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 TR04a.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 TR04a.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 TR04a.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
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 TR04a.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 MCS7 would 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, N_s 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	N _s (MHz)	K	BN (MHz)
802.11g	0.3125	53	16.6
802.11n	0.3125	57	17.8

Table TR04a.105: Necessary Bandwidth for IEEE 802.11 g and n 20 MHz Radio Protocols (TRC-43)

This line is the end of the test record.

Test Record
Transmitter Power
Test IDs TR01a
Project GCL0385

Test Date(s) 12 May 2023
 Test Personnel David Arnett

Product Model A04724
 Serial Number tested 441085073

Operating Mode M1 (BLE Tx), M3 (ANT Tx), M10 (BT Tx)
 Arrangement A3 (Udata)
 Input Power 5Vdc

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 -0.37 dBi, as reported by the client
 Radio Protocol Bluetooth, Bluetooth Low Energy, ANT

Pass/Fail Judgment: PASS

Test record created by: David Arnett
Date of this record: 24 May 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

Table TR01a.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
 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 Data

Each measurement is made conducted from the antenna port with the transmitter on a specified channel and in a selected transmission protocol.

Where standards cited here apply different analytical test methods for the same fundamental data or different limits, the results for both methods are provided and the more-strict limit may be applied. In this case, the ANSI method finds the highest value (numerical peak) and applies the 30 dBm limit from the US and Canadian standards. By contrast, the ETSI method reports the highest numerical average observed during any transmission burst and applies a 20 dBm EIRP limit. All values met the respective limits with more than 10 dB of margin.

The results are shown below. 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)	Lowest	2420	2440	2460	Highest
Bluetooth	Basic	8.80	8.94	9.07	9.58	9.58
Bluetooth	EDR2	4.09	4.49	4.31	4.79	5.53
Bluetooth	EDR3	4.03	4.47	4.28	4.76	5.45
BT Low Energy	1 Mbps	-2.01	-2.02	-1.94	-1.92	-1.94
BT Low Energy	2 Mbps	-2.01	-2.02	-1.95	-1.92	-1.93
ANT	----	-1.10	-1.11	-1.14	-1.00	-1.00

Table TR01a.2: Transmit Power Summary in dBm with ANSI C63.10 analytical methods

Frequency	(MHz)	Lowest	2420	2440	2460	Highest
Bluetooth	Basic	8.39	8.53	8.66	9.18	9.18
Bluetooth	EDR2	3.62	4.01	3.84	4.32	5.06
Bluetooth	EDR3	3.55	3.99	3.81	4.30	4.95
BT Low Energy	1 Mbps	-2.79	-2.80	-2.73	-2.70	-2.73
BT Low Energy	2 Mbps	-3.02	-3.04	-2.96	-2.93	-2.95
ANT	----	-1.48	-1.48	-1.52	-1.37	-1.37

Table TR01a.3: Transmit Power Summary in dBm EIRP with ETSI analytical methods

Additional Transmit Power Data Analysis

The technical requirements for safety to RF exposure also look at transmitter power. Since data from this report may be compared with data from RF exposure reports, this lab has performed a further analysis of the same raw data for power over time used above. This analysis applies standards such as FCC Part 2.1091, FCC Part 2.1093, RSS-102, ANSI C95.3, EN/IEC 62311, or EN 62479.

These data analyses look at average power over time in linear milliwatt units. These data are averaged over a time period no longer than 1 second.

Frequency	(MHz)	Lowest	2420	2440	2460	Highest
Bluetooth	Basic	7.52	7.77	8.00	9.02	9.02
Bluetooth	EDR2	2.51	2.74	2.63	2.95	3.49
Bluetooth	EDR3	2.47	2.73	2.62	2.93	3.41
BT Low Energy	1 Mbps	0.26	0.26	0.26	0.26	0.26
BT Low Energy	2 Mbps	0.14	0.14	0.14	0.14	0.14
ANT	----	0.78	0.77	0.77	0.79	0.79

Table TR01a.4: Additional RF exposure power summary, with units of milliwatt

Setup Diagram

The following block diagrams show how the EUT and test equipment is arranged for test. The client provided a short length of cable to bring the signals out to a connector. This cable was found to have 0.78 dB of loss in this frequency range. This factor was taken into account during the data analysis.

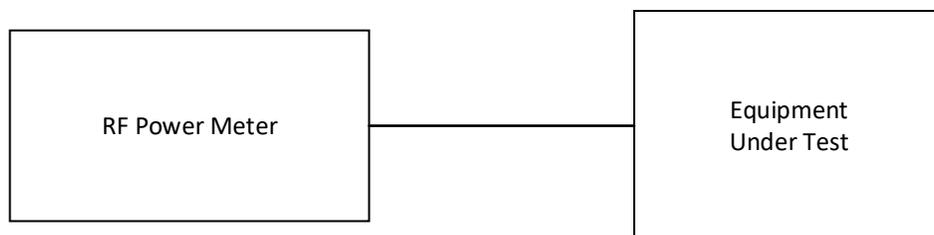


Figure TR01a.1: Test equipment setup

This line is the end of the test record.

Test Record
Transmitter Power
Test IDs TR01b
Project GCL0385

Test Date(s) 12, 23 May 2023
 Test Personnel David Arnett

Product Model A04724
 Serial Number tested 441085073

Operating Mode M8 (WiFi Tx)
 Arrangement A3 (Udata)
 Input Power 5Vdc

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

FCC Part 2.1091, FCC Part 2.1093, RSS-102, ANSI C95.3

Antenna Gain -0.37 dBi, as reported by the client
 Radio Protocol IEEE 802.11b/g/n

Pass/Fail Judgment: PASS

Test record created by: David Arnett
Date of this record: 24 May 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

Table TR01b.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.

ANSI C63.10: 11.9.1.3

Transmit Power Data

Each measurement is made conducted from the antenna port with the transmitter on a specified channel and in a selected transmission protocol. Where standards cited here apply harmonized test methods and different limits, the more strict limit has applied.

The ANSI method finds the highest value (numerical peak) and applies the 30 dBm limit from the US and Canadian standards. All values met the limit with better than 10 dB of margin.

Data shown here for channels 1 through 11 are from the 12 May data set, measured while the test sample used firmware version 2.14. In 2.14, channels 11, 12, and 13 had the same power setting. Data shown here for channels 12 and 13 were collected on 23 May while the test sample used firmware version 2.15. As stated in the main test report, the change in firmware only lowered the transmit power on channel 13. Channel 12 power was then greater than channel 13 power. Lab staff felt it helpful to include channel 12 power results in the test sequence for a complete view of transmitter operations beyond the typical Channel 1 – 11 range used in North America.

The results are shown below. Yellow highlighted cells indicate the highest power value for each radio protocol. An NT entry in a grey cell indicates a combination of data rate and transmit channel that were not tested.

Mode	Speed	1	2	3	4	5	6	7	8	9	10	11	12	13
B	1	16.80	18.92	19.11	19.14	19.67	18.59	19.62	18.71	18.81	18.82	16.50	16.84	13.20
B	2	17.01	NT	NT	NT	NT	19.00	NT	NT	NT	NT	16.73	16.91	13.39
B	5.5	17.28	NT	NT	NT	NT	19.33	NT	NT	NT	NT	16.91	17.03	13.43
B	11	17.24	19.30	19.30	19.21	19.14	19.14	19.11	19.07	19.10	19.00	16.79	16.94	13.37
G	6	14.85	17.64	17.58	17.52	17.48	17.49	17.46	17.39	17.33	17.29	14.43	14.59	10.41
G	9	14.87	NT	NT	NT	NT	17.45	NT	NT	NT	NT	14.43	14.59	10.37
G	12	14.86	NT	NT	NT	NT	17.48	NT	NT	NT	NT	14.48	14.63	10.38
G	18	14.92	NT	NT	NT	NT	17.49	NT	NT	NT	NT	14.54	14.59	10.36
G	24	14.96	NT	NT	NT	NT	17.54	NT	NT	NT	NT	14.49	14.59	10.41
G	36	14.89	NT	NT	NT	NT	17.50	NT	NT	NT	NT	14.53	14.60	10.39
G	48	14.88	NT	NT	NT	NT	17.48	NT	NT	NT	NT	14.49	14.59	10.38
G	54	14.91	17.63	17.58	17.52	17.46	17.45	17.40	17.37	17.33	17.31	14.44	14.59	10.40
N	MCS0	14.78	17.55	17.50	17.49	17.43	17.37	17.35	17.34	17.27	17.24	14.38	14.52	10.32
N	MCS1	14.82	NT	NT	NT	NT	17.41	NT	NT	NT	NT	14.42	14.55	10.36
N	MCS2	14.70	NT	NT	NT	NT	17.36	NT	NT	NT	NT	14.34	14.47	10.25
N	MCS3	14.75	NT	NT	NT	NT	17.39	NT	NT	NT	NT	14.41	14.50	10.29
N	MCS4	14.73	NT	NT	NT	NT	17.34	NT	NT	NT	NT	14.28	14.45	10.23
N	MCS5	14.75	NT	NT	NT	NT	17.39	NT	NT	NT	NT	14.37	14.50	10.28
N	MCS6	14.71	NT	NT	NT	NT	17.37	NT	NT	NT	NT	14.31	14.44	10.24
N	MCS7	14.77	17.51	17.48	17.49	17.45	17.41	17.34	17.33	17.27	17.25	14.39	14.48	10.27

Table TR01b.2: Transmit Power Summary, with units of dBm

Additional Transmit Power Data Analysis

The technical requirements for safety to RF exposure also look at transmitter power. Since data from this report may be compared with data from RF exposure reports, this lab has performed a further analysis of the same raw data for power over time used above. This analysis applies standards such as FCC Part 2.1091, FCC Part 2.1093, RSS-102, ANSI C95.3, EN/IEC 62311, or EN 62479.

These data analyses look at average power over time in linear milliwatt units. These data are averaged over a time period no longer than 1 second.

Mode	Speed	1	2	3	4	5	6	7	8	9	10	11	12	13
B	1	47.30	77.17	78.93	78.96	81.00	72.04	79.95	73.30	74.45	74.48	44.11	47.56	20.48
B	2	49.38	NT	NT	NT	NT	78.45	NT	NT	NT	NT	46.15	48.31	21.37
B	5.5	52.46	NT	NT	NT	NT	84.40	NT	NT	NT	NT	48.17	49.76	21.61
B	11	52.14	84.13	84.15	82.41	81.02	80.91	80.36	79.67	79.89	78.49	46.94	48.70	21.31
G	6	29.69	56.34	55.75	54.94	54.43	54.52	53.95	53.42	52.69	52.25	26.93	28.12	10.69
G	9	29.75	NT	NT	NT	NT	54.27	NT	NT	NT	NT	27.02	27.98	10.61
G	12	29.82	NT	NT	NT	NT	54.49	NT	NT	NT	NT	27.18	28.08	10.59
G	18	30.16	NT	NT	NT	NT	54.86	NT	NT	NT	NT	27.59	27.89	10.55
G	24	29.99	NT	NT	NT	NT	54.55	NT	NT	NT	NT	27.07	27.63	10.47
G	36	29.54	NT	NT	NT	NT	54.01	NT	NT	NT	NT	27.16	27.71	10.45
G	48	29.52	NT	NT	NT	NT	53.95	NT	NT	NT	NT	26.92	27.54	10.41
G	54	29.46	55.61	55.09	54.39	53.84	53.55	53.08	52.52	52.11	51.44	26.57	27.54	10.40
N	MCS0	28.96	55.04	54.43	54.05	53.38	52.89	52.56	52.18	51.66	51.14	26.35	27.26	10.35
N	MCS1	28.98	NT	NT	NT	NT	53.02	NT	NT	NT	NT	26.37	27.31	10.36
N	MCS2	28.67	NT	NT	NT	NT	53.04	NT	NT	NT	NT	26.34	27.21	10.27
N	MCS3	28.72	NT	NT	NT	NT	53.01	NT	NT	NT	NT	26.35	27.17	10.26
N	MCS4	28.88	NT	NT	NT	NT	52.86	NT	NT	NT	NT	26.13	27.14	10.23
N	MCS5	28.54	NT	NT	NT	NT	52.73	NT	NT	NT	NT	26.10	26.89	10.21
N	MCS6	28.85	NT	NT	NT	NT	53.18	NT	NT	NT	NT	26.26	27.05	10.20
N	MCS7	28.90	54.58	54.30	54.08	53.54	53.02	52.48	52.20	51.62	51.11	26.31	27.05	10.16

Table TR01b.3: Additional RF exposure power summary, with units of milliwatt

Setup Diagram

The following block diagrams show how the EUT and test equipment is arranged for test. The client provided a short length of cable to bring the signals out to a connector. This cable was found to have 0.78 dB of loss in this frequency range. This factor was taken into account during the data analysis.

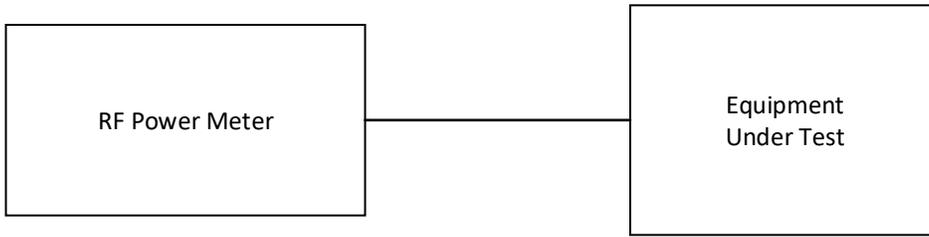


Figure TRxx.1: Test equipment setup

This line is the end of the test record.

Test Record
Conducted Spurious Emissions
Test IDs TR18, TR20 and TR22
Project GCL-0385

Test Date(s) 9 Jun 2023
 Test Personnel Majid Farah

Product Model A04724
 Serial Number tested 441085073
 Operating Mode M1 (BLE Tx), M3 (ANT Tx) and M10 (BT Tx)
 Arrangement A2 (Upwr)
 Input Power 5 Vdc

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

Pass/Fail Judgment: PASS

Test record created by: Majid Farah
Date of this test record: 14 Jun 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 TR18.1: 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.

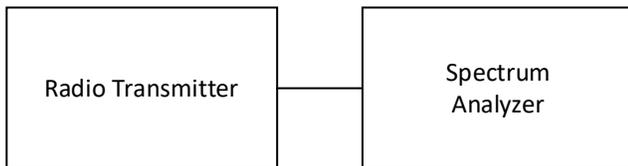


Figure TR18.1: Test setup

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 than 20 is a passing result. The minimum margin from the peak level for each mode are highlighted in yellow.

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

	Frequency (MHz)		
	2402	2440	2480
Bluetooth BR	54.53	54.97	55.35
BLE 1 Mbps	43.71	43.88	43.85
ANT	39.99	41.86	43.72

Table TR18.2: Results Summary

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

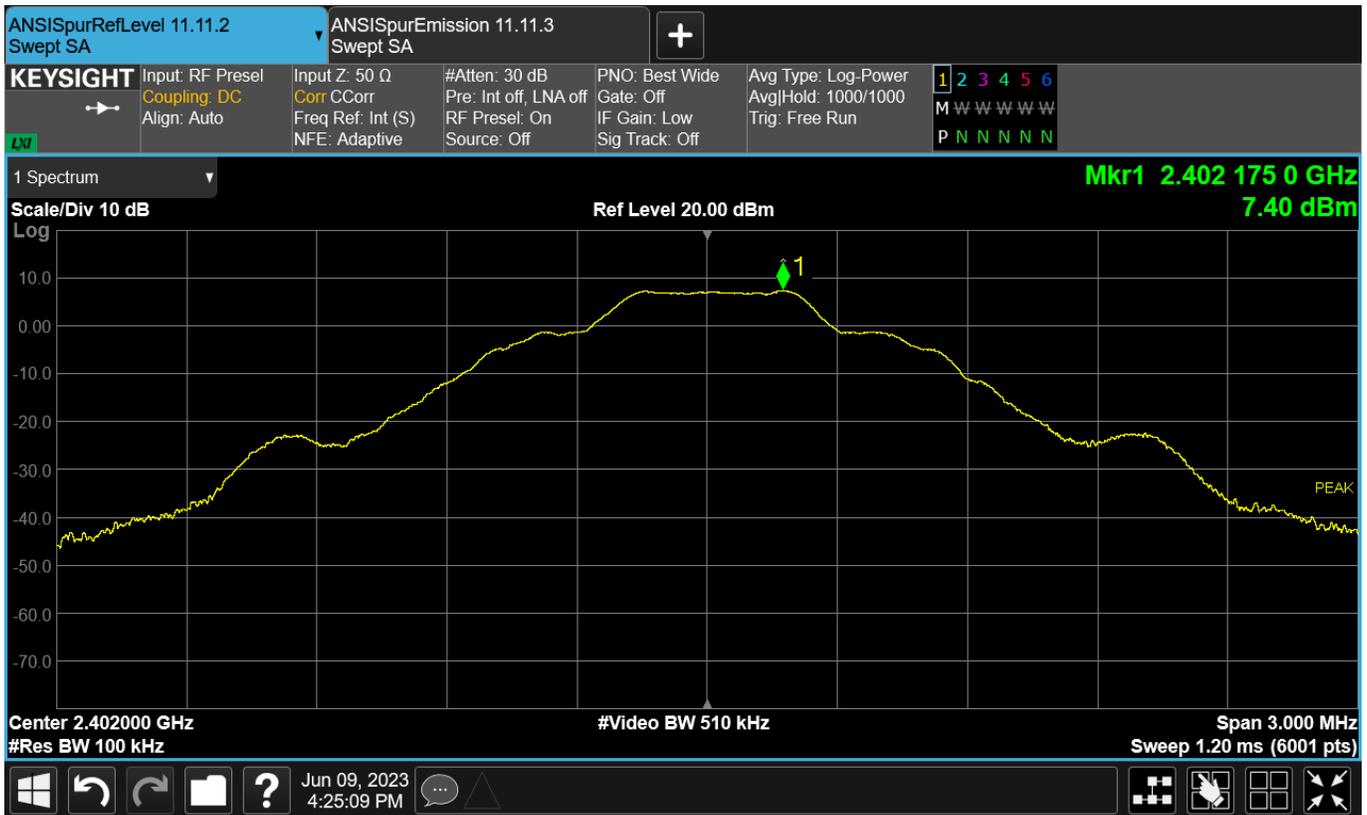


Figure TR18.2: Reference level measurement for Bluetooth BR at 2402 MHz

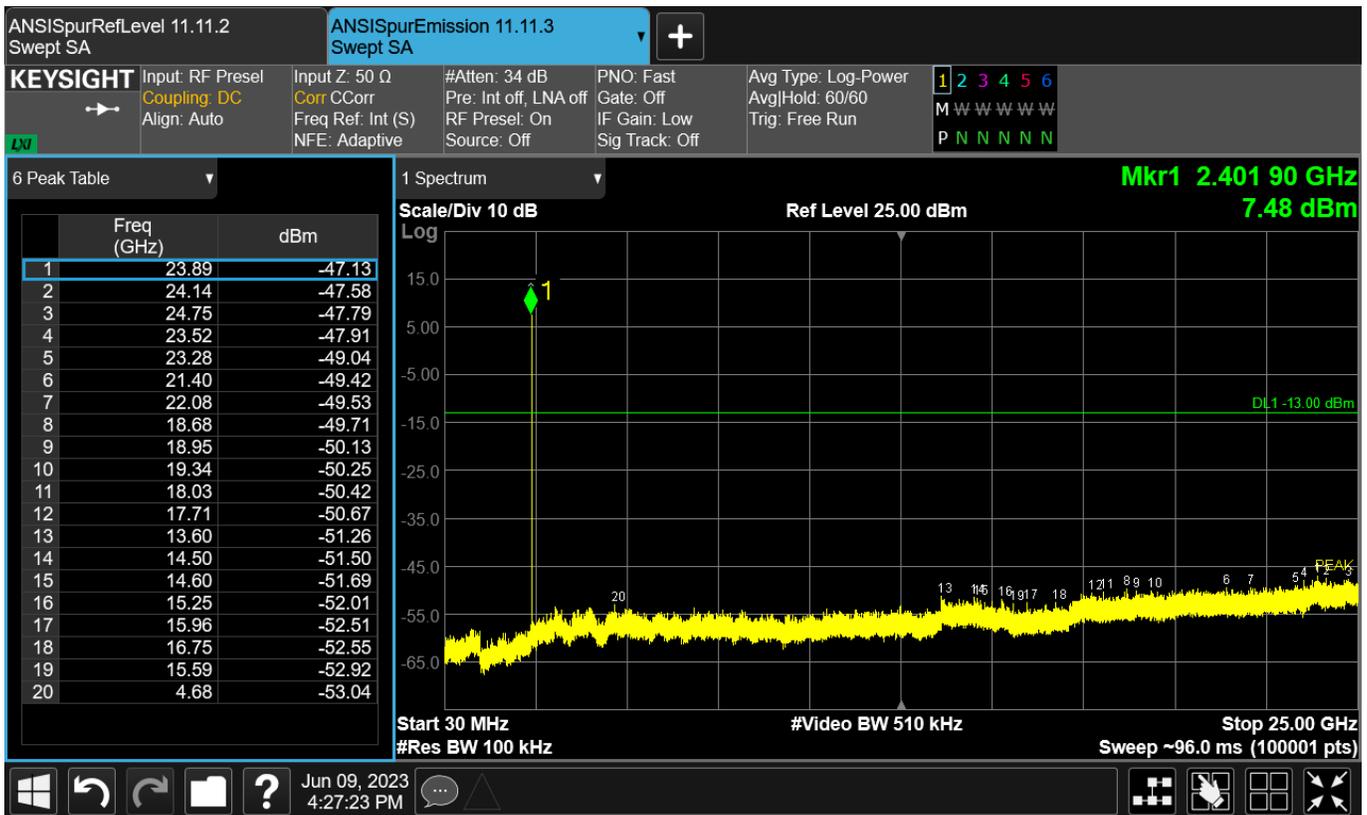


Figure TR18.3: Spectral data for Bluetooth BR at 2402 MHz

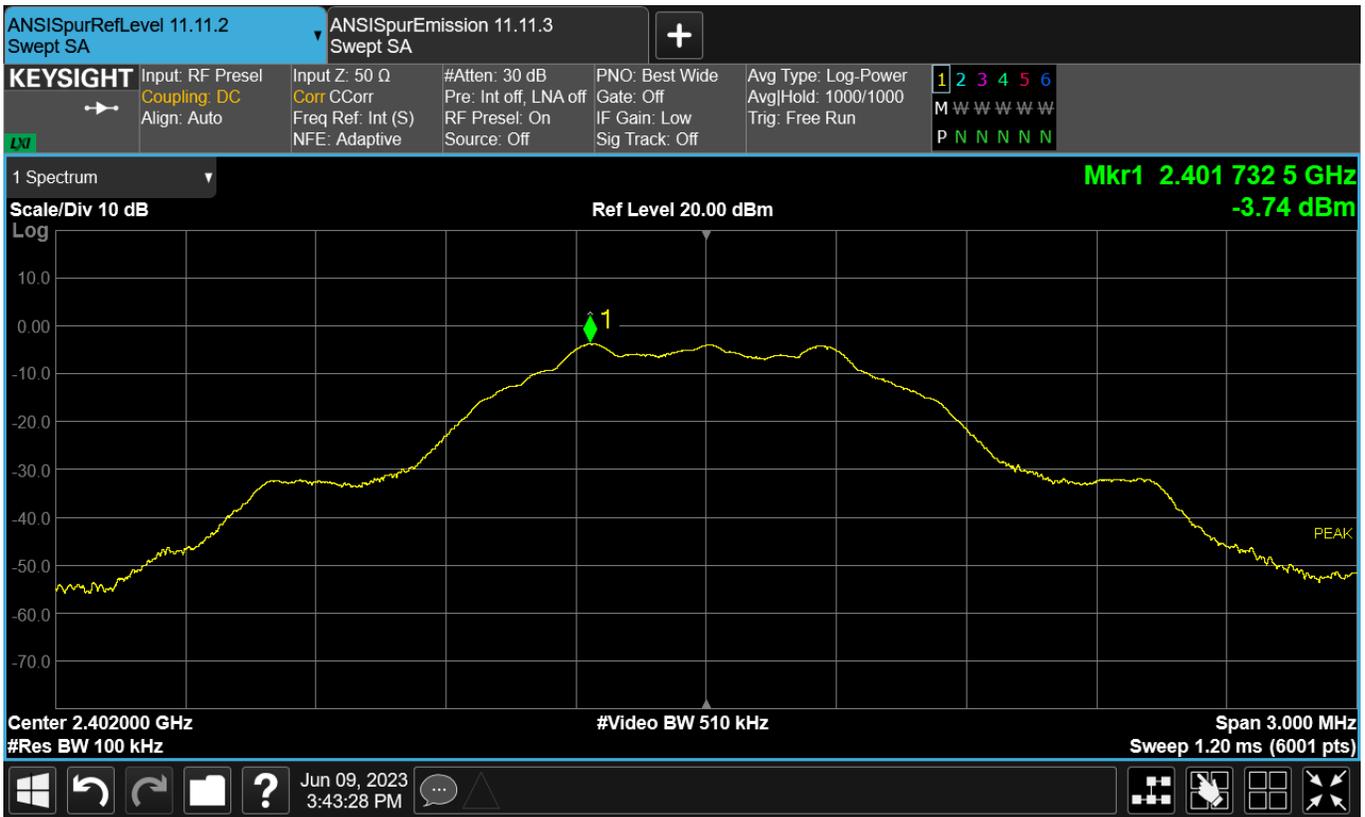


Figure TR18.4: Reference level measurement for Bluetooth BLE 1 Mbps at 2402 MHz

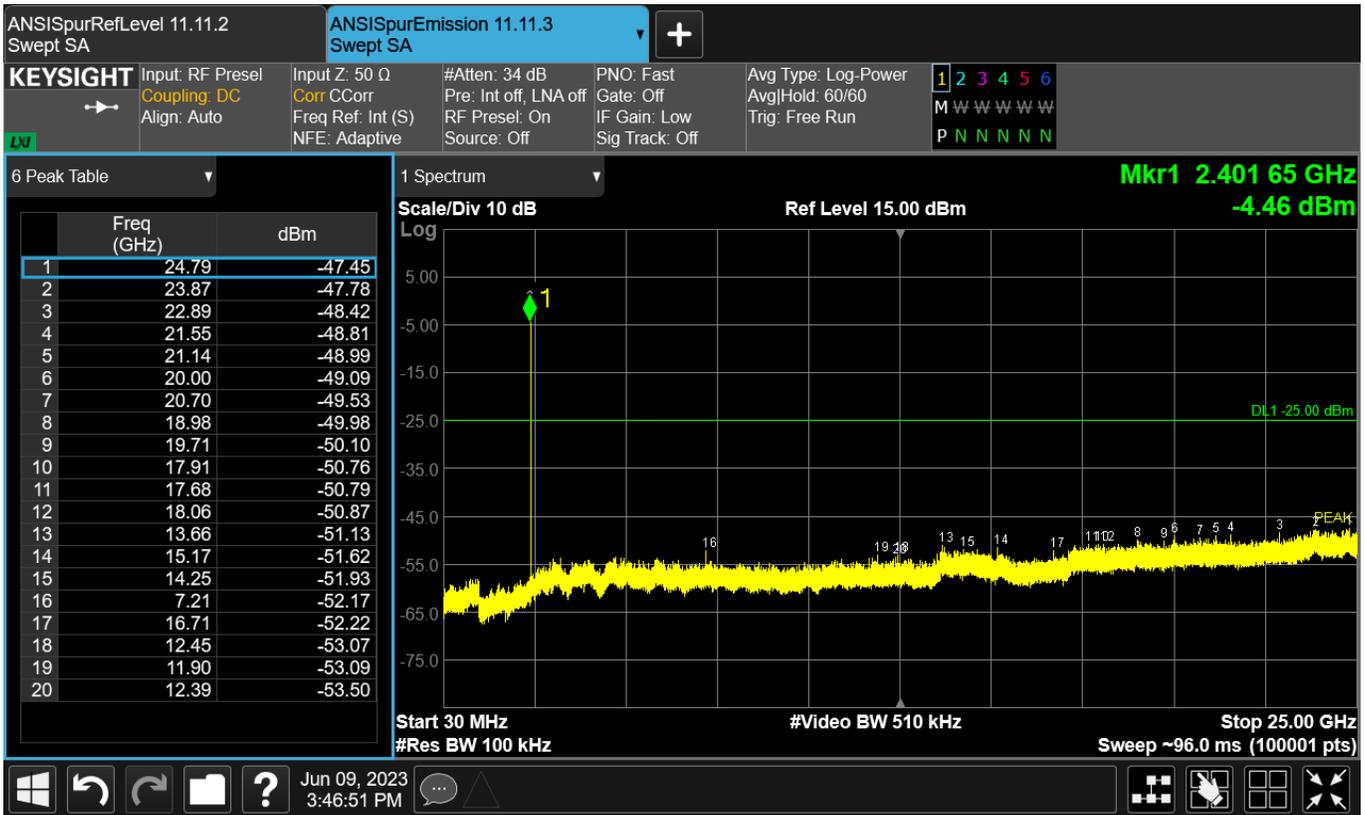


Figure TR18.5 Spectral data for Bluetooth BLE 1 Mbps at 2402 MHz

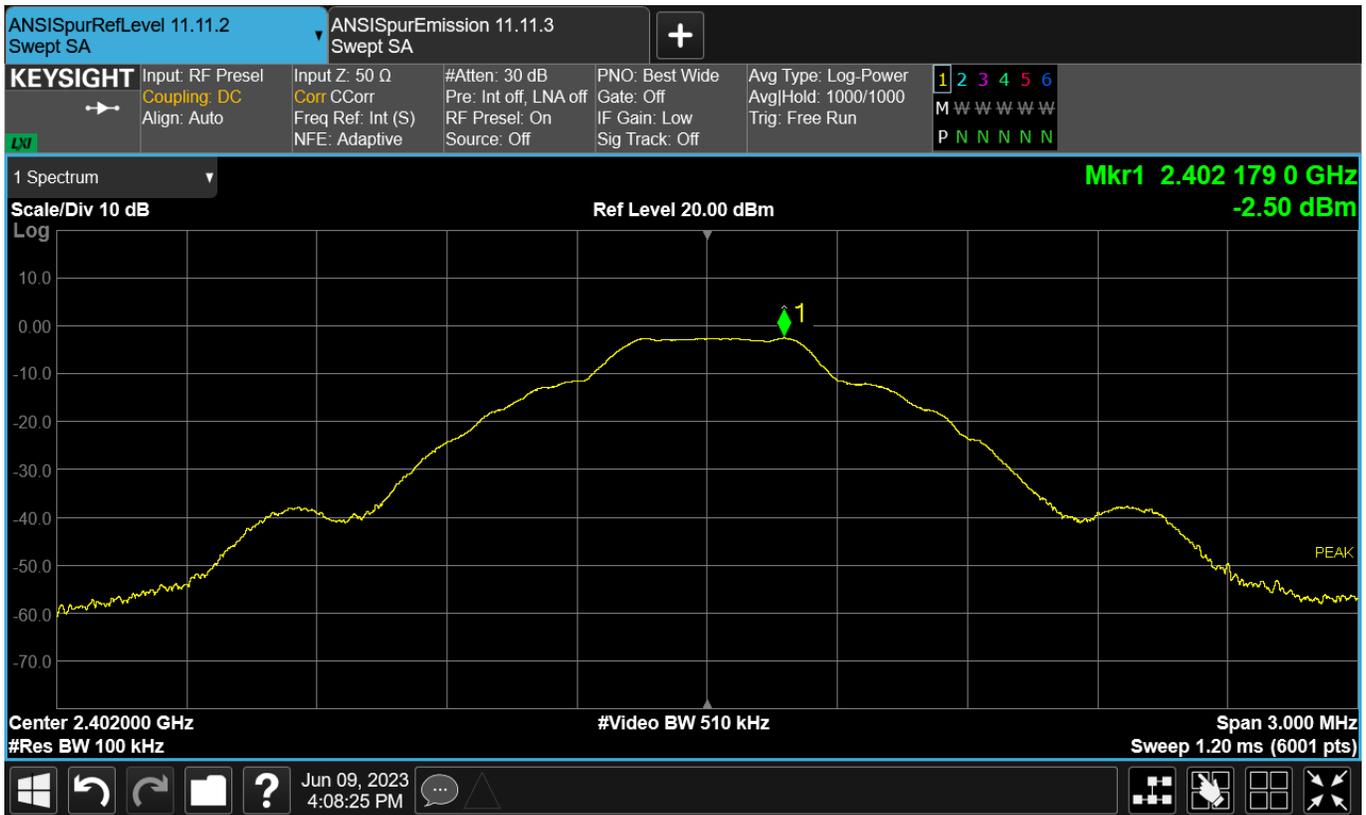


Figure TR18.6: Reference level measurement for ANT at 2402 MHz

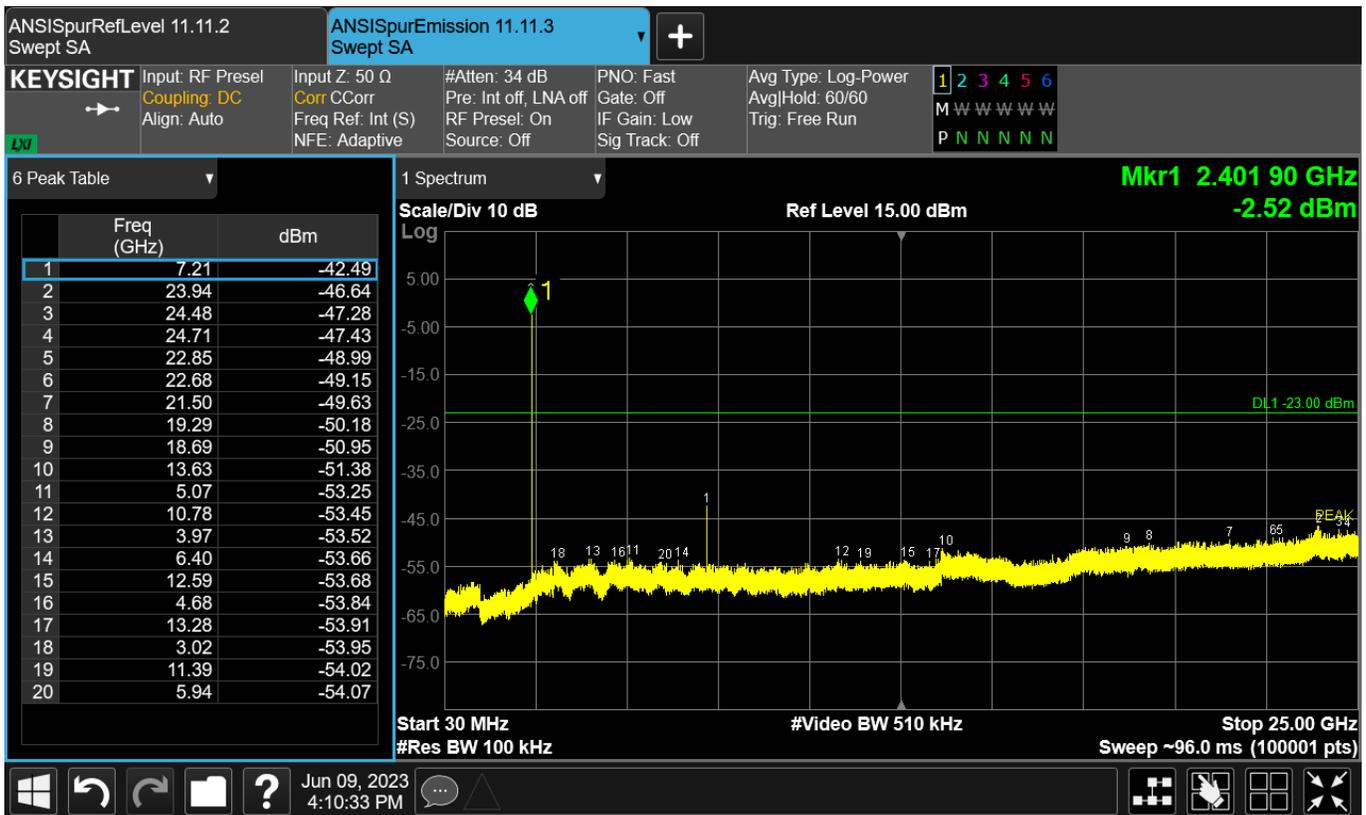


Figure TR18.7 Spectral data for ANT at 2402 MHz

This line is the end of the test record.

Test Record
Conducted Spurious Emissions
Test IDs TR24, TR26 and TR28
Project GCL-0385

Test Date(s) 9 Jun 2023
 Test Personnel Majid Farah

Product Model A04724
 Serial Number tested 441085073

Operating Mode M8 (WiFi Tx)
 Arrangement A2 (Upwr)
 Input Power 5 Vdc

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

Pass/Fail Judgment: PASS

Test record created by: Majid Farah
Date of this test record: 14 Jun 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 TR24.1: 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.

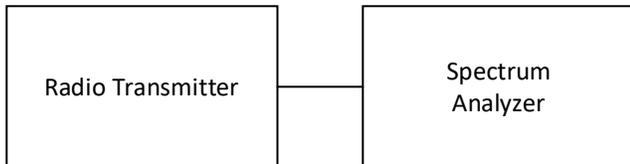


Figure TR24.1: Test setup

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 than 20 is a passing result. The minimum margin from the peak level for each mode are highlighted in yellow.

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

Mode	Data rate (Mbps)	Channel No.				
		1	6	11	12	13
B	1	39.77	52.67	48.82	49.54	42.90
G	6	46.03	49.10	45.50	45.25	41.30
N	MCS0	46.97	49.73	45.18	46.65	42.64

Table TR24.2: Results Summary

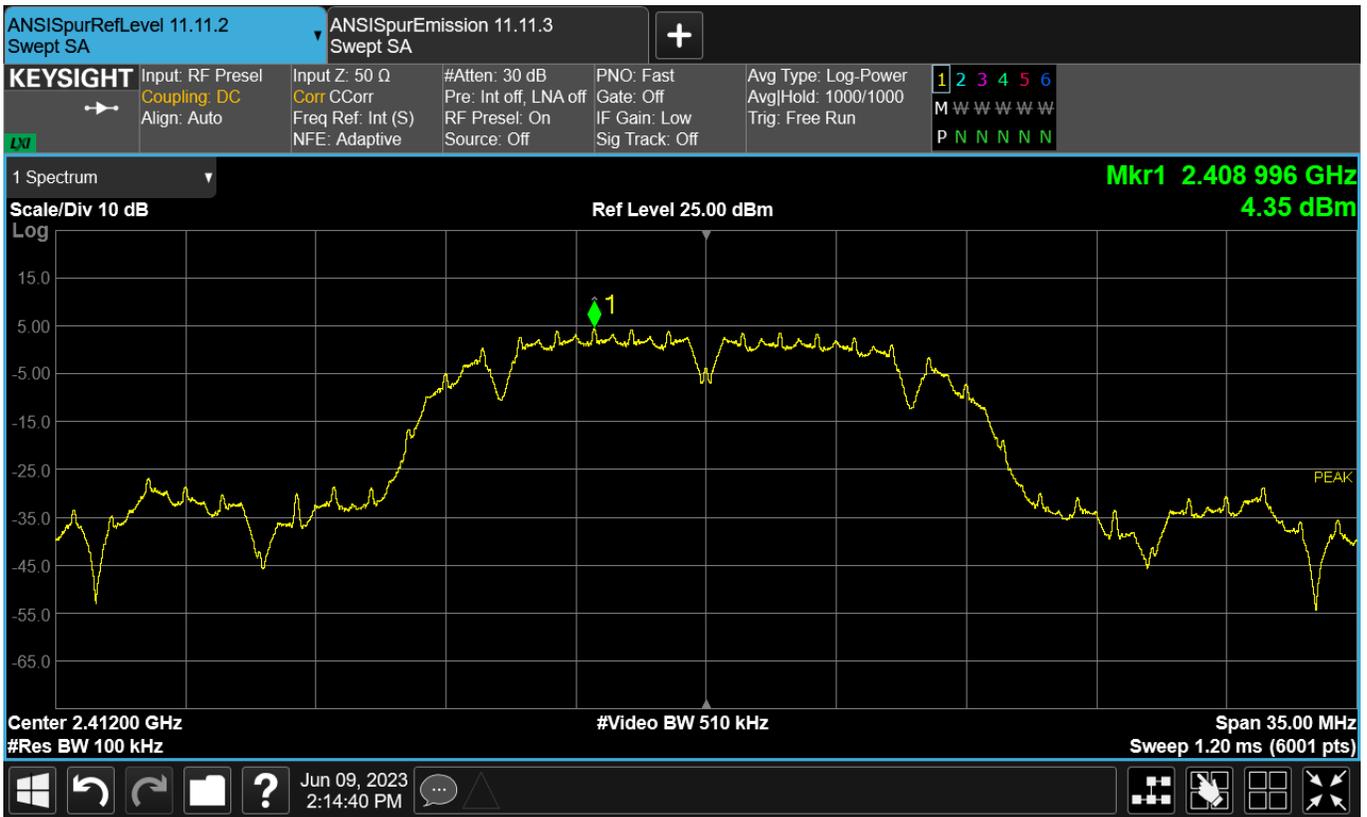


Figure TR25.2: Reference level measurement for IEEE 802.11 b 1 Mbps on Ch.1

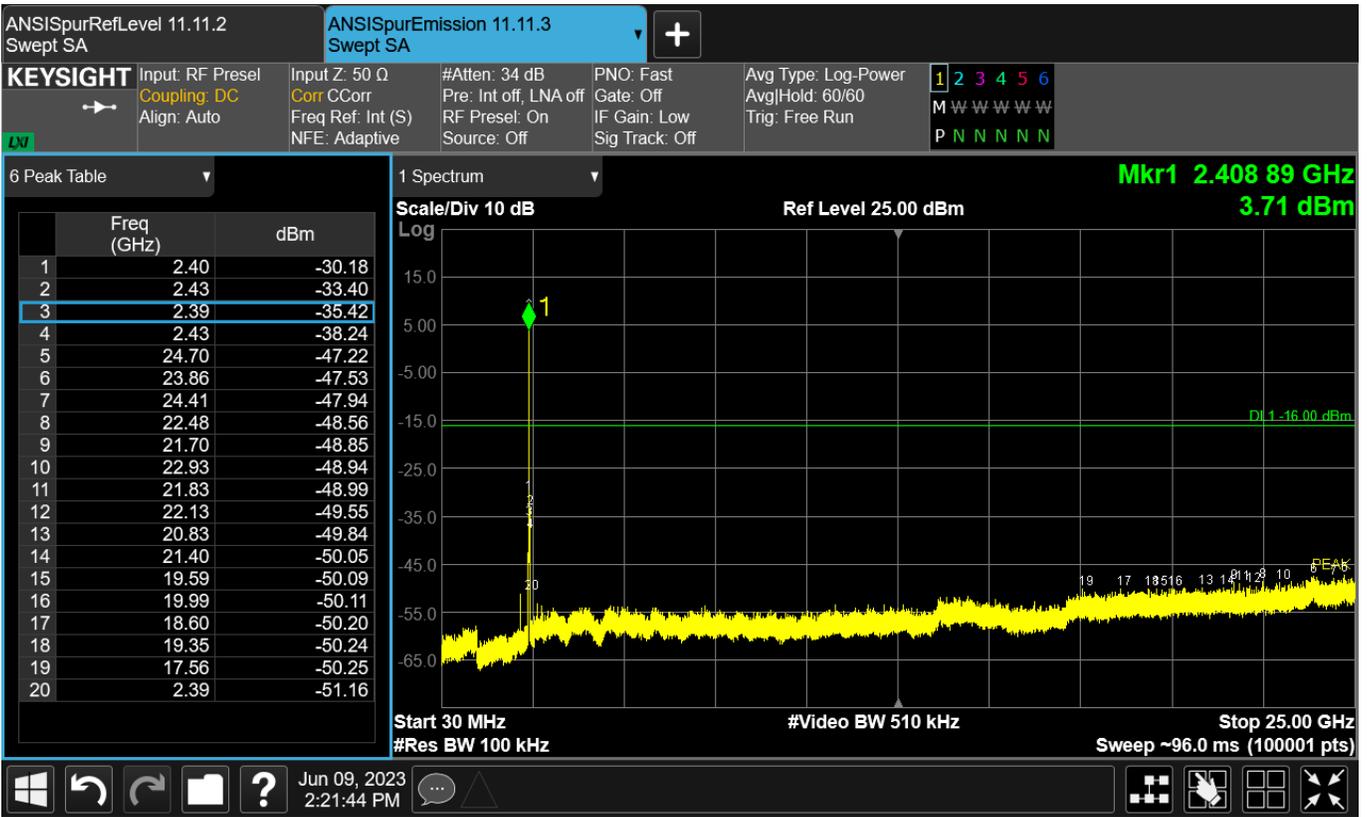


Figure TR25.3: Spectral data for IEEE 802.11 b 1 Mbps on Ch.1



Figure TR25.4: Reference level measurement for IEEE 802.11 g 6 Mbps on Ch.13

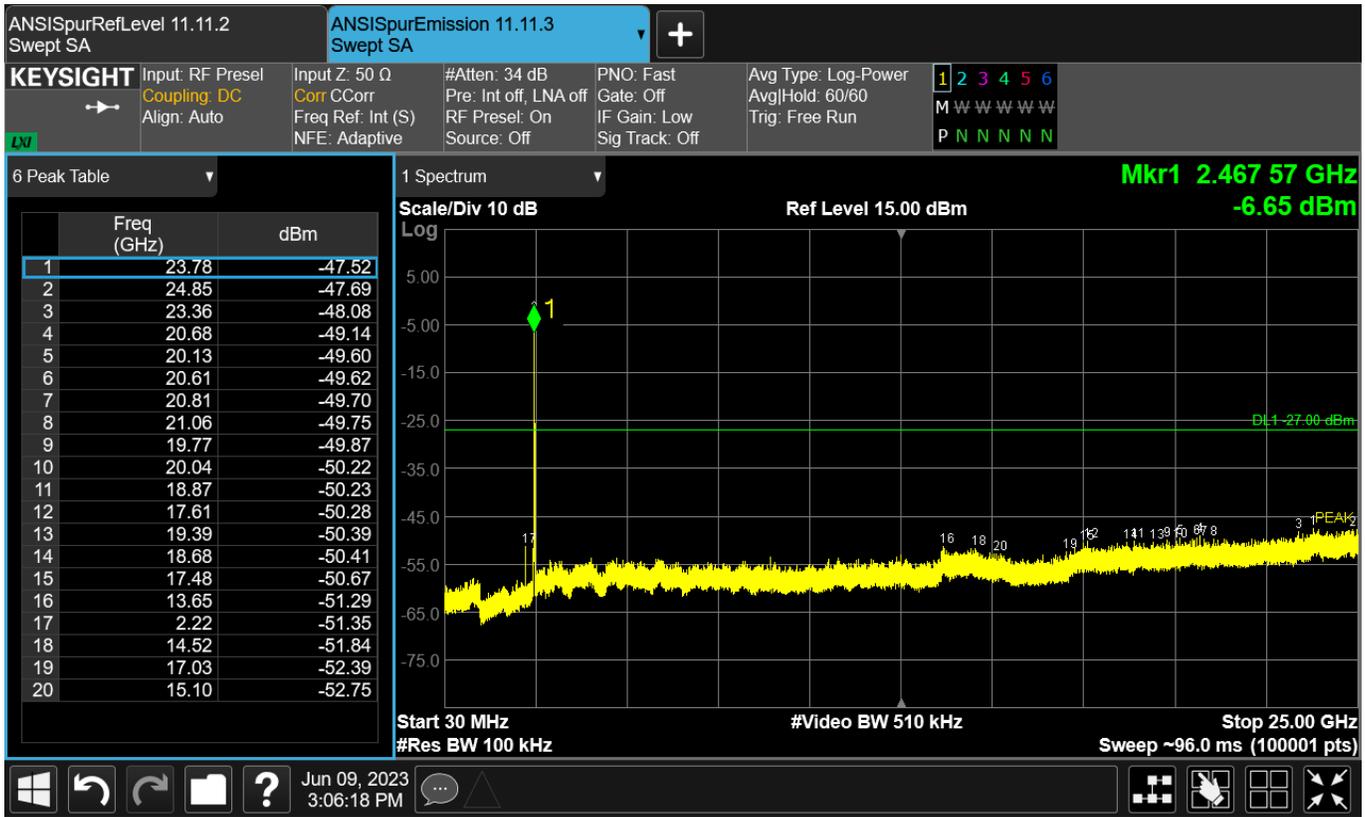


Figure TR25.5 Spectral data for IEEE 802.11 g 6 Mbps on Ch.13

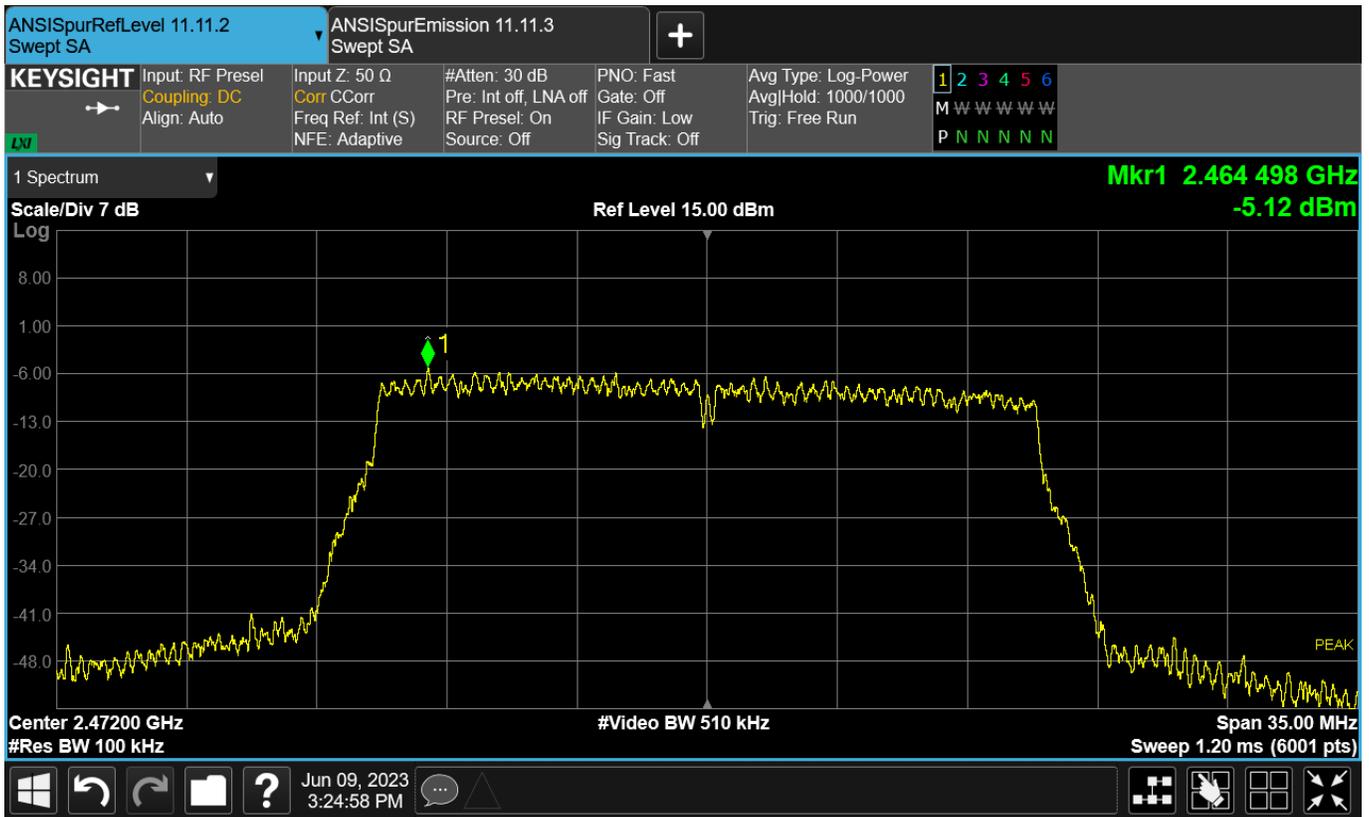


Figure TR25.6: Reference level measurement for IEEE 802.11 n MCS0 on Ch.13

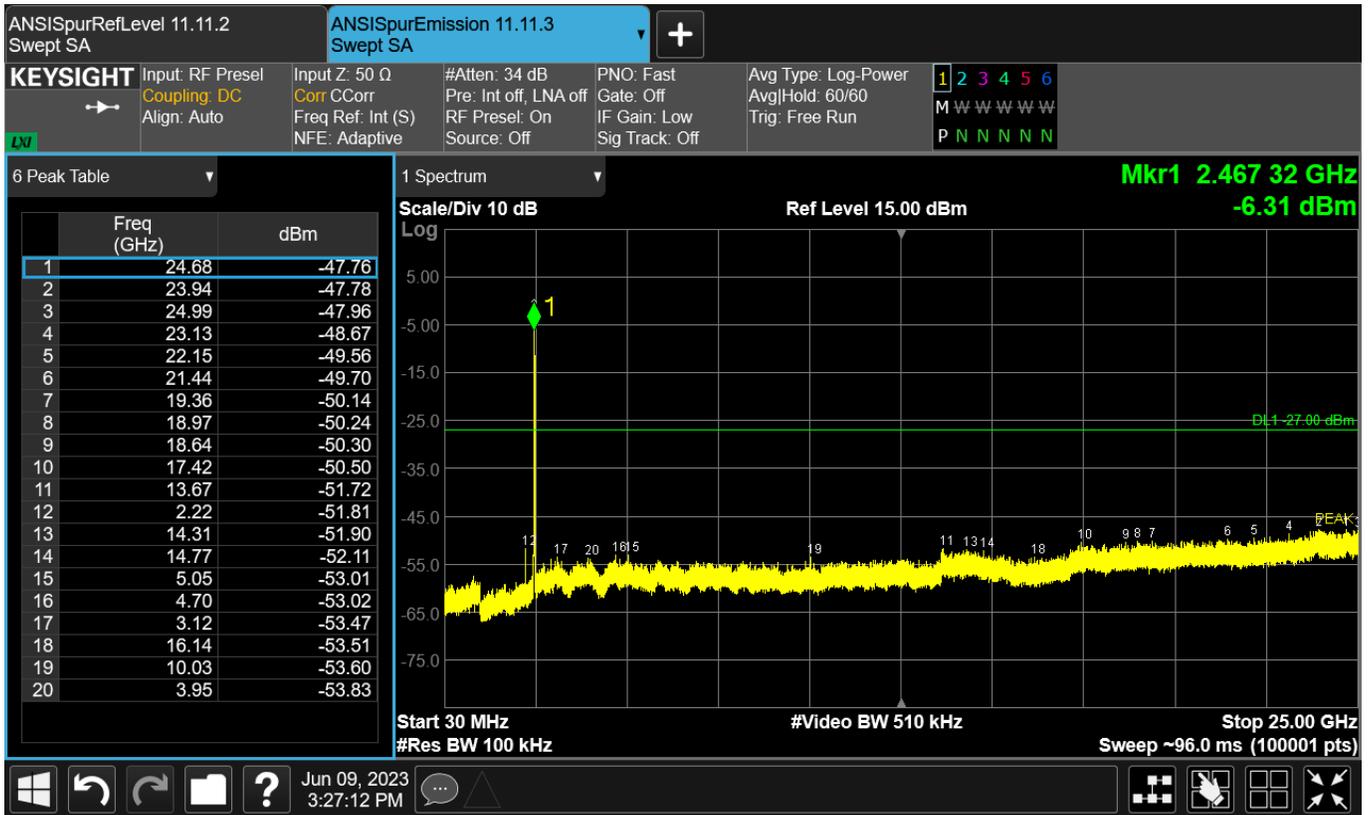


Figure TR25.7 Spectral data for IEEE 802.11 n MCS0 on Ch.13

This line is the end of the test record.

Test Record
Radiated Emission Test RE01
Project GCL0385

Test Date(s) 11-12,15-16, 23 May 2023
 Test Personnel Jim Solum

Product Model A04724
 Serial Number tested 441084880

Operating Mode M8 (WiFi Tx)
 Arrangement A2 (Upwr)
 Input Power 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: Jim Solum
Date of this record: 31 May 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 RE01.1: Test Equipment Used

Software Used

Keysight PXE N9048B Firmware version A.32.06
 RE Signal Maximization Tool v2021Feb25.xlsx
 WiFi FCC Restricted Band 2p4GHz Template v2.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. The turntable angle, antenna height, and antenna polarization were explored to find the worst-case settings for each of the restricted band ranges. 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 the strongest emissions observed relative to the test limit, along with other data points of interest. Where a data point is highlighted in 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.

Channel & Modulation	Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Polarity
B1 Mode Peak	2390	54	74	39.416	69.486	14.584	4.514	162	1500	HORZ
B1 Mode Average	2389.8	54	74	39.801	69.389	14.199	4.611	162	1500	HORZ
G9 Mode Peak	2389	54	74	44.56	71.285	9.44	2.715	162	1500	HORZ
G9 Mode Average	2390	54	74	45.671	72.04	8.329	1.96	162	1500	HORZ
N6 Mode Peak	2390	54	74	46.627	72.247	7.373	1.753	162	1500	HORZ
N6 Mode Average	2390	54	74	46.626	72.842	7.374	1.158	162	1500	HORZ

Table RE01.2: Emission summary FCC restricted band from 2200 to 2390 MHz (Ch01)

Channel & Modulation	Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Polarity
B2 Mode Peak	2390	54	74	39.861	67.508	14.139	6.492	162	1500	HORZ
B2 Mode Average	2390	54	74	39.844	67.549	14.156	6.451	162	1500	HORZ
G9 Mode Peak	2388.5	54	74	49.064	69.872	4.936	4.128	162	1500	HORZ
G9 Mode Average	2390	54	74	50.624	71.912	3.376	2.088	162	1500	HORZ
N0 Mode Peak	2390	54	74	51.463	72.625	2.537	1.375	162	1500	HORZ
N0 Mode Average	2390	54	74	51.459	71.123	2.541	2.877	162	1500	HORZ

Table RE01.3: Emission summary FCC restricted band from 2200 to 2390 MHz (Ch02)

Channel & Modulation	Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Polarity
B11 Mode Peak	2484.5	54	74	34.408	63.212	19.592	10.788	-135	1500	HORZ
B11 Mode Average	2483.5	54	74	34.952	63.597	19.048	10.403	-135	1500	HORZ
G24 Mode Peak	2484	54	74	48.341	66.685	5.659	7.315	-135	1500	HORZ
G24 Mode Average	2483.5	54	74	48.678	66.877	5.322	7.123	-135	1500	HORZ
N0 Mode Peak	2483.5	54	74	50.421	69.5	3.579	4.5	-135	1500	HORZ
N0 Mode Average	2483.5	54	74	50.376	69.263	3.624	4.737	-135	1500	HORZ

Table RE01.4: Emission summary FCC restricted band from 2483.5 to 2500 MHz (Ch10)

Channel & Modulation	Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Polarity
B11 Mode Peak	2484	54	74	34.75	68.741	19.25	5.259	-135	1500	HORZ
B11 Mode Average	2484	54	74	34.746	64.675	19.254	9.325	-135	1500	HORZ
G18 Mode Peak	2483.5	54	74	46.912	69.207	7.088	4.793	-135	1500	HORZ
G18 Mode Average	2483.5	54	74	46.884	69.085	7.116	4.915	-135	1500	HORZ
N6 Mode Peak	2483.5	54	74	46.513	68.647	7.487	5.353	-135	1500	HORZ
N6 Mode Average	2483.5	54	74	46.514	70.554	7.486	3.446	-135	1500	HORZ

Table RE01.5: Emission summary FCC restricted band from 2483.5 to 2500 MHz (Ch11)

Channel & Modulation	Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Polarity
B11 Mode Peak	2484.3	54	74	48.737	68.847	5.263	5.153	-135	1500	HORZ
B11 Mode Average	2483.5	54	74	50.323	69.392	3.677	4.608	-135	1500	HORZ
G9 Mode Peak	2483.8	54	74	49.499	72.124	4.501	1.876	-135	1500	HORZ
G9 Mode Average	2483.5	54	74	49.689	72.69	4.311	1.31	-135	1500	HORZ
N6 Mode Peak	2484.5	54	74	49.355	72.571	4.645	1.429	-135	1500	HORZ
N6 Mode Average	2483.5	54	74	50.049	73.692	3.951	0.308	-135	1500	HORZ

Table RE01.6: Emission summary FCC restricted band from 2483.5 to 2500 MHz (Ch12)

Channel & Modulation	Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Polarity
B5.5 Mode Peak	2484.8	54	74	43.289	69.274	10.711	4.726	-136	1566	HOR
B5.5 Mode Average	2484.3	54	74	43.624	69.504	10.376	4.496	-136	1566	HOR
G9 Mode Peak	2483.5	54	74	43.89	70.247	10.11	3.753	-136	1566	HOR
G9 Mode Average	2483.5	54	74	43.888	70.75	10.112	3.25	-136	1566	HOR
N4 Mode Peak	2484	54	74	43.757	70.57	10.243	3.43	-136	1566	HOR
N4 Mode Average	2483.5	54	74	44.602	71.334	9.398	2.666	-136	1566	HOR

Table RE01.7: Emission summary FCC restricted band from 2483.5 to 2500 MHz (Ch13)

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

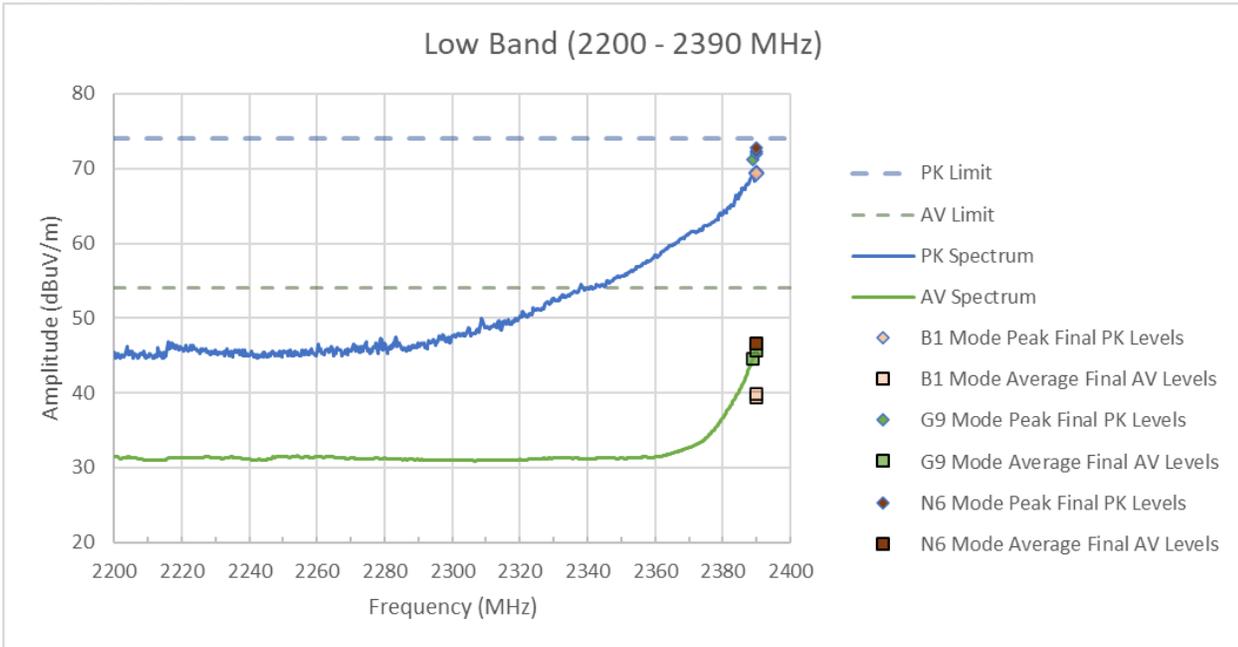


Figure RE01.1: Spectral data FCC restricted band from 2200 to 2390 MHz (Ch01)

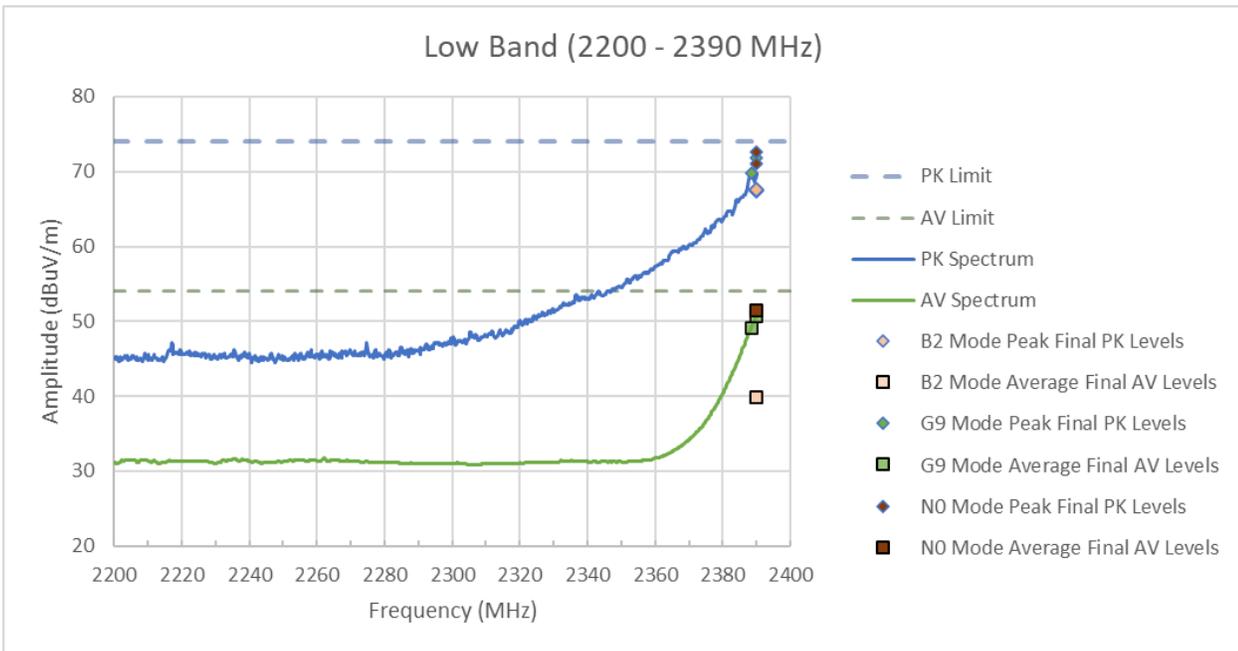


Figure RE01.2: Spectral data FCC restricted band from 2200 to 2390 MHz (Ch02)

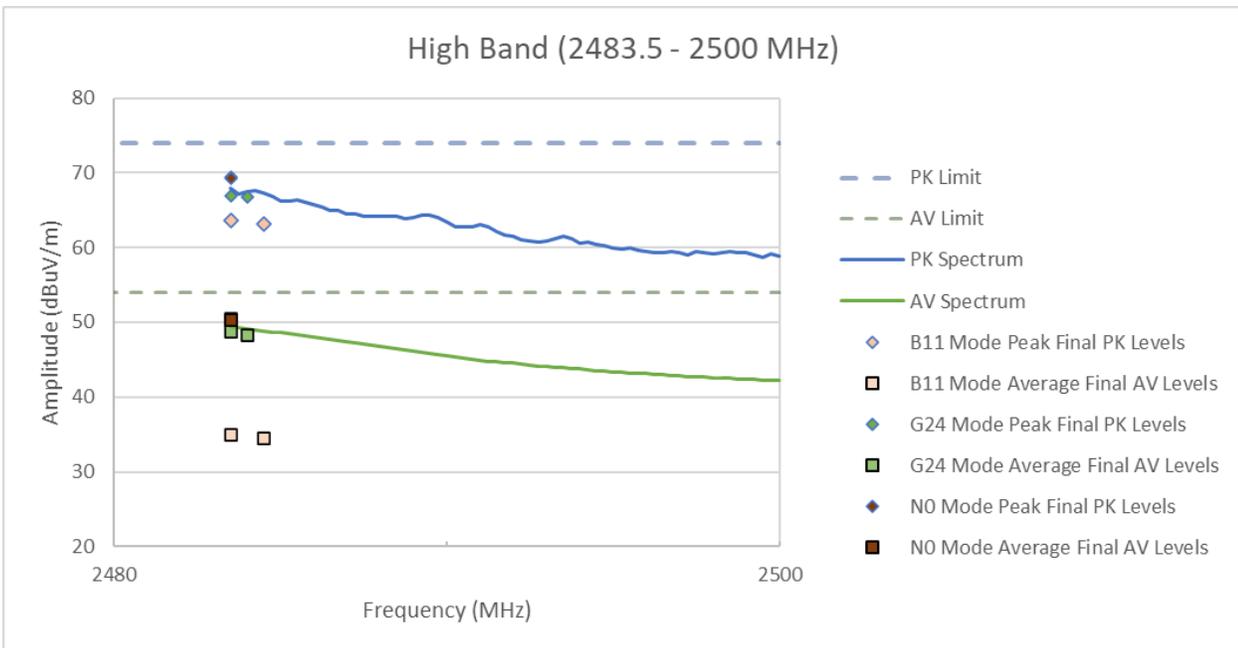


Figure RE01.3: Spectral data FCC restricted band from 2483.5 to 2500 MHz (Ch10)

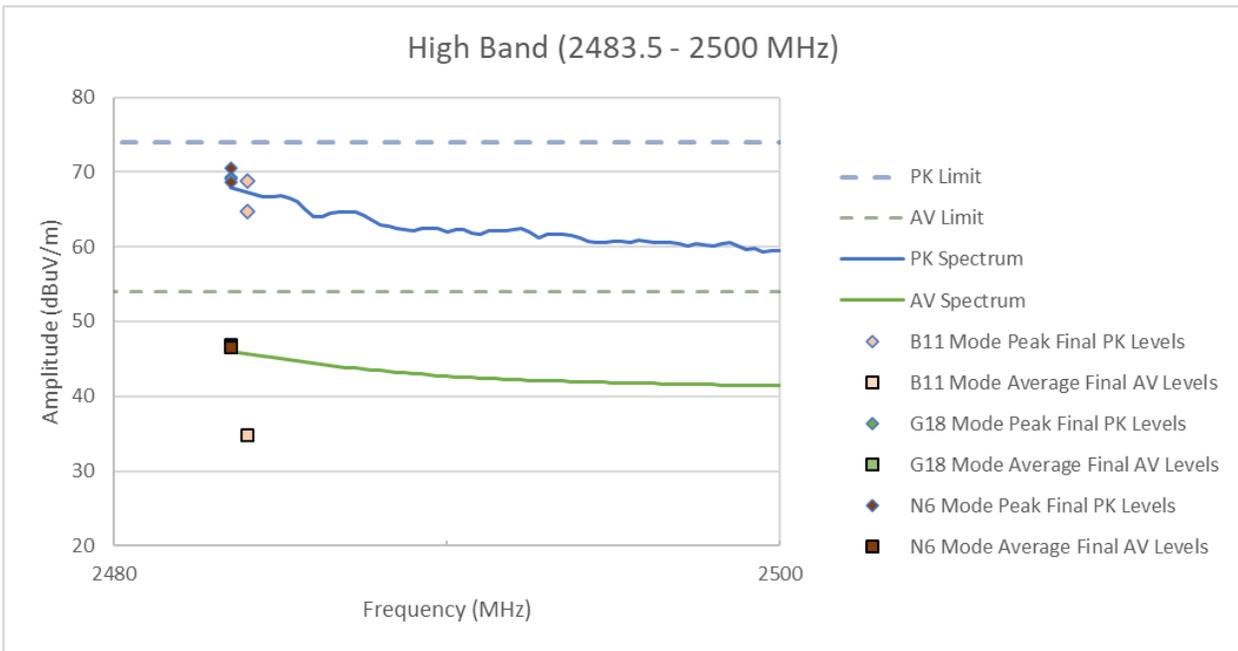


Figure RE01.4: Spectral data FCC restricted band from 2483.5 to 2500 MHz (Ch11)

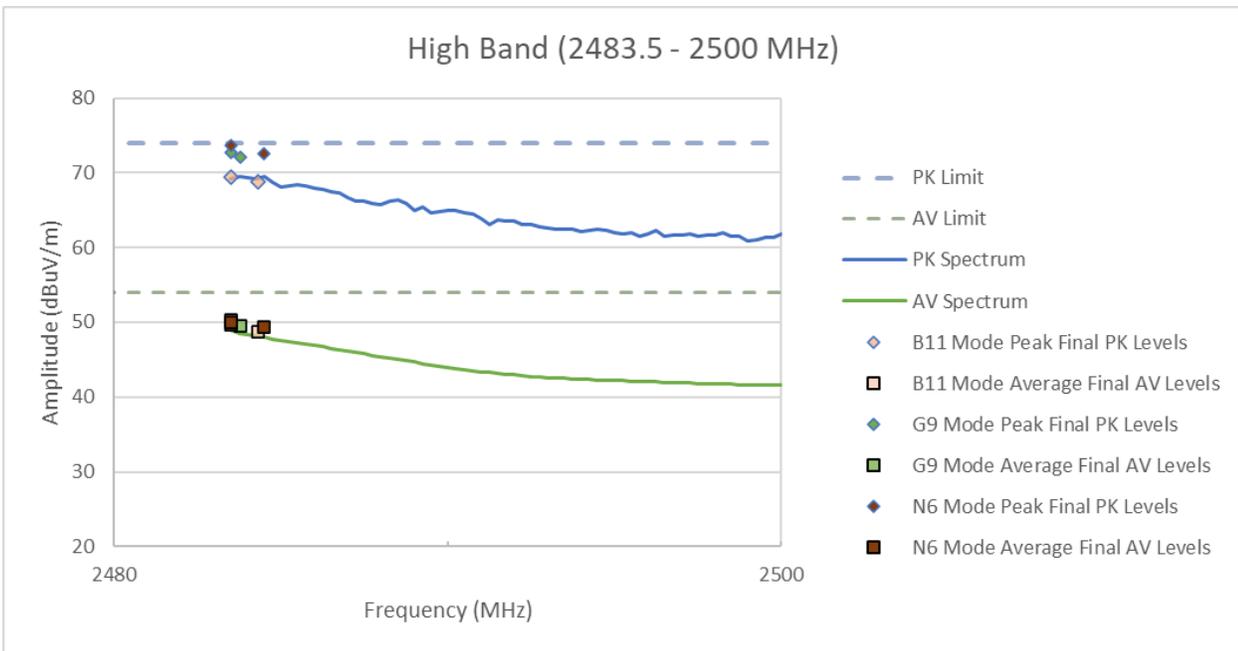


Figure RE01.5: Spectral data FCC restricted band from 2483.5 to 2500 MHz (Ch12)

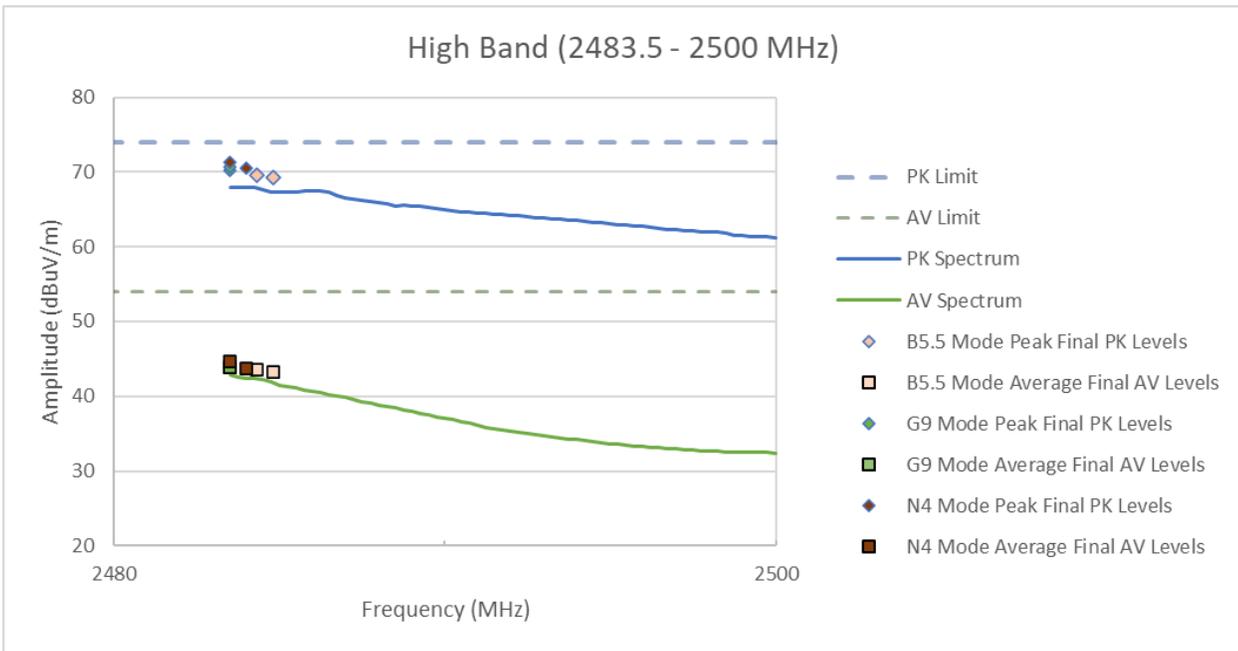


Figure RE01.6: Spectral data FCC restricted band from 2483.5 to 2500 MHz (Ch13)

Setup Photographs

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

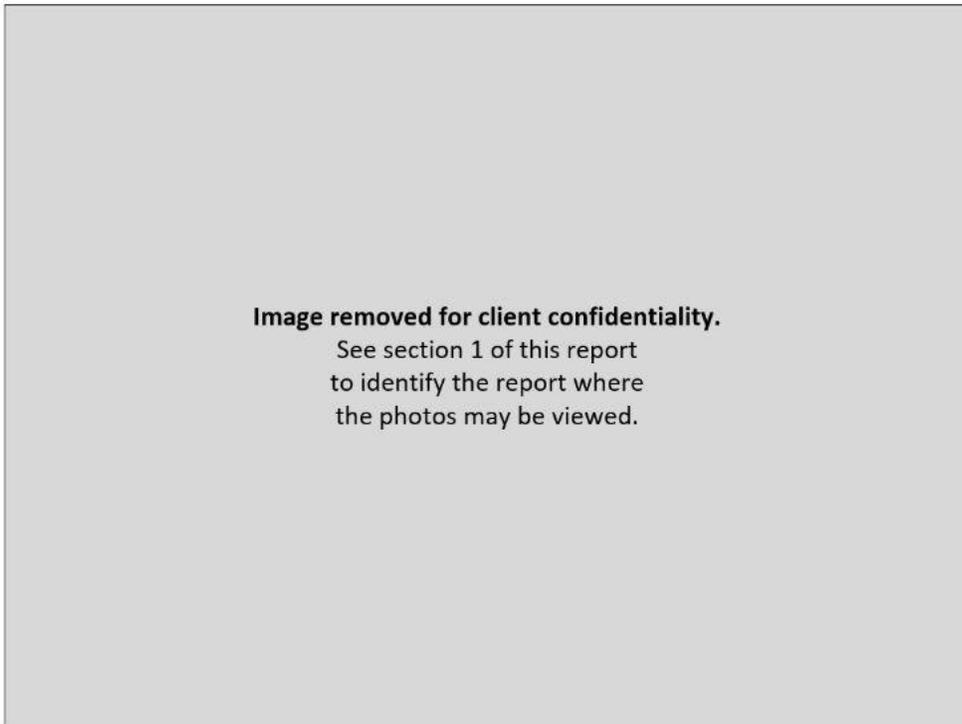


Figure RE01.7: EUT test setup, front view (Y orientation)



Figure RE01.8: EUT test setup, reverse view (Y orientation)

This line is the end of the test record.

Test Record
Radiated Emission Test RE04
Project GCL0385

Test Date(s) 19 May 2023
 Test Personnel Jim Solum

Product Model A04724
 Serial Number tested 441084880

Operating Mode M1 (BLE Tx)
 Arrangement A2 (Upwr)
 Input Power 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: Jim Solum
Date of this record: 26 May 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 RE04.1: 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. The turntable angle, antenna height, and antenna polarization were explored to find the worst-case settings for each of the restricted band ranges. 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 2402 MHz for the 1 Mbps data rate, and 2404 MHz for the 2 Mbps data rate. Measurements in the

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

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

The tables show the selected final measurement data between the FCC restricted bands. It includes the strongest emissions observed relative to the test limit, along with other data points of interest. Where a data point is highlighted in 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)	---
2222.5	54	74	31.969	46.342	22.031	27.658	158	1500	HORZ
2390	54	74	32.684	46.391	21.316	27.609	158	1500	HORZ

Table RE04.2: Emission summary FCC restricted band from 2200 to 2390 MHz (1 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)	---
2484	54	74	33.58	47.687	20.42	26.313	-135	1580	HORZ
2483.5	54	74	33.692	48.628	20.308	25.372	-135	1580	HORZ

Table RE04.3: Emission summary FCC restricted band from 2483.5 to 2500 MHz (1Mbps)

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)	---
2223.8	54	74	32.004	46.212	21.996	27.788	158	1500	HORZ
2390	54	74	32.674	46.585	21.326	27.415	158	1500	HORZ

Table RE04.4: Emission summary FCC restricted band from 2200 to 2390 MHz (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)	---
2496	54	74	33.076	46.947	20.924	27.053	-135	1580	HORZ
2483.5	54	74	33.533	47.199	20.467	26.801	-135	1580	HORZ

Table RE04.5: Emission summary FCC restricted band from 2483.5 to 2500 MHz (2 Mbps)

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

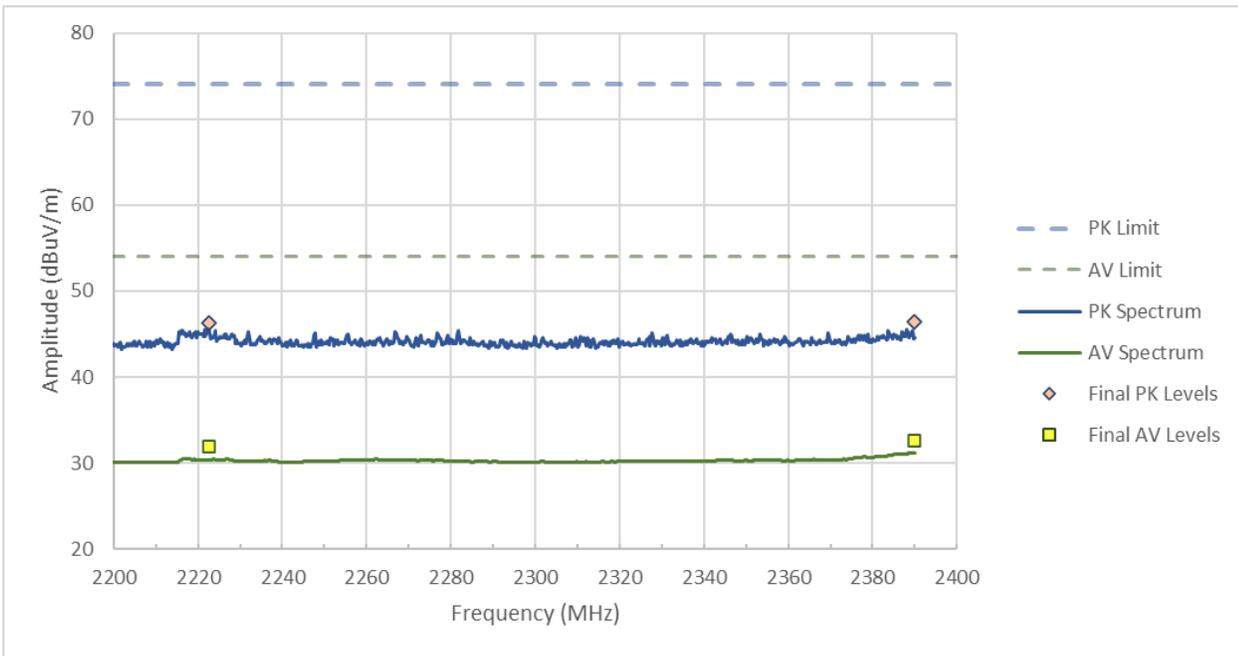


Figure RE04.1: Spectral data FCC restricted band from 2200 to 2390 MHz (1Mbps)

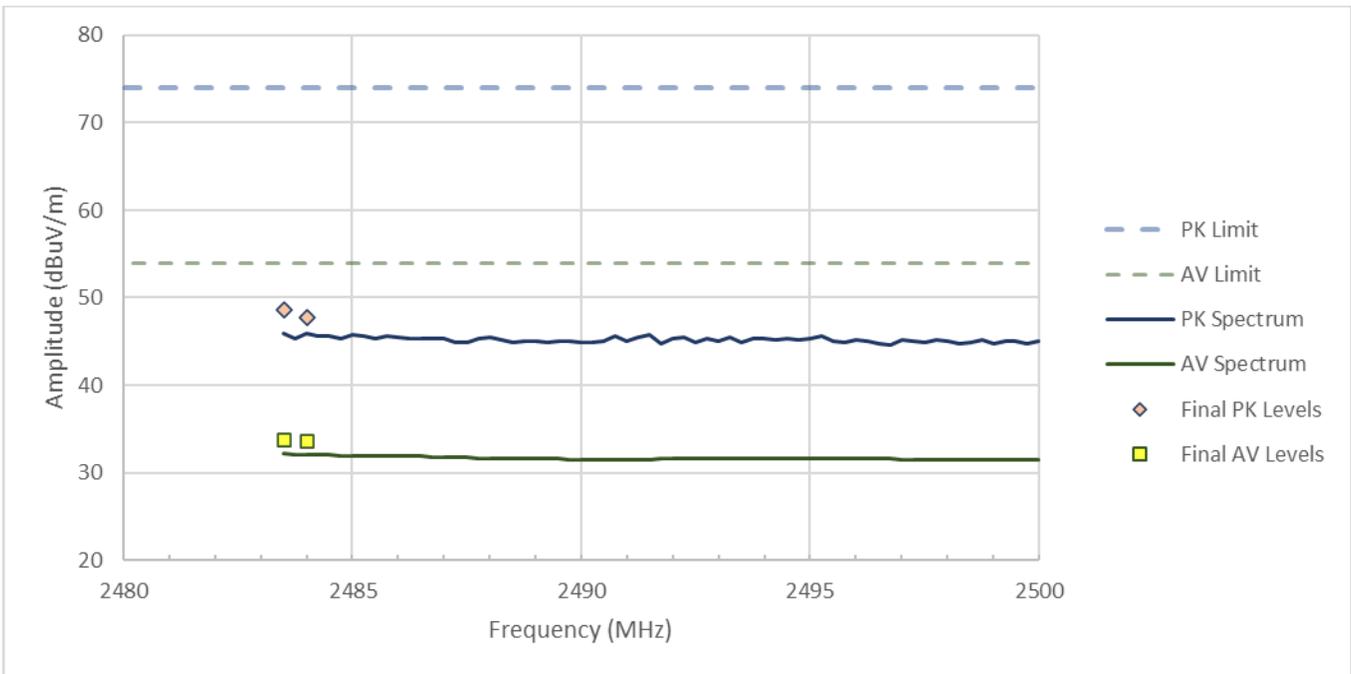


Figure RE04.2: Spectral data FCC restricted band from 2483.5 to 2500 MHz (1 Mbps)

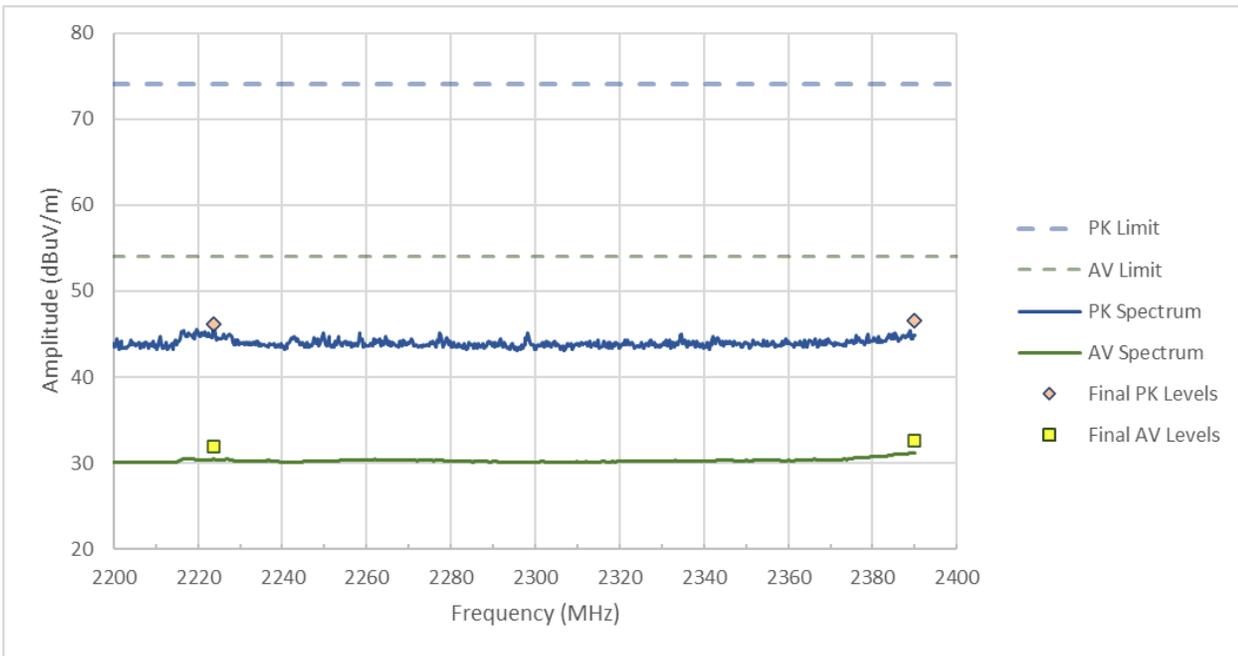


Figure RE04.3: Spectral data FCC restricted band from 2200 to 2390 MHz (2 Mbps)

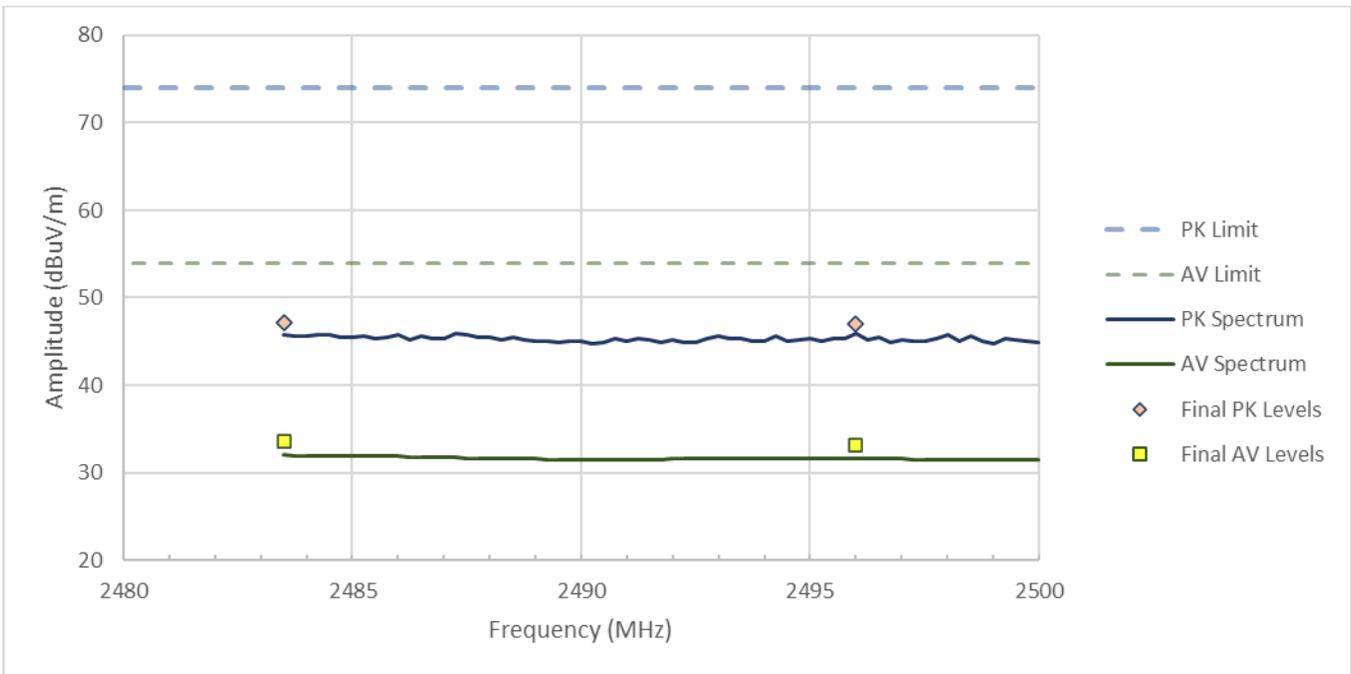


Figure RE04.4: Spectral data FCC restricted band from 2483.5 to 2500 MHz (2 Mbps)

Setup Photographs

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

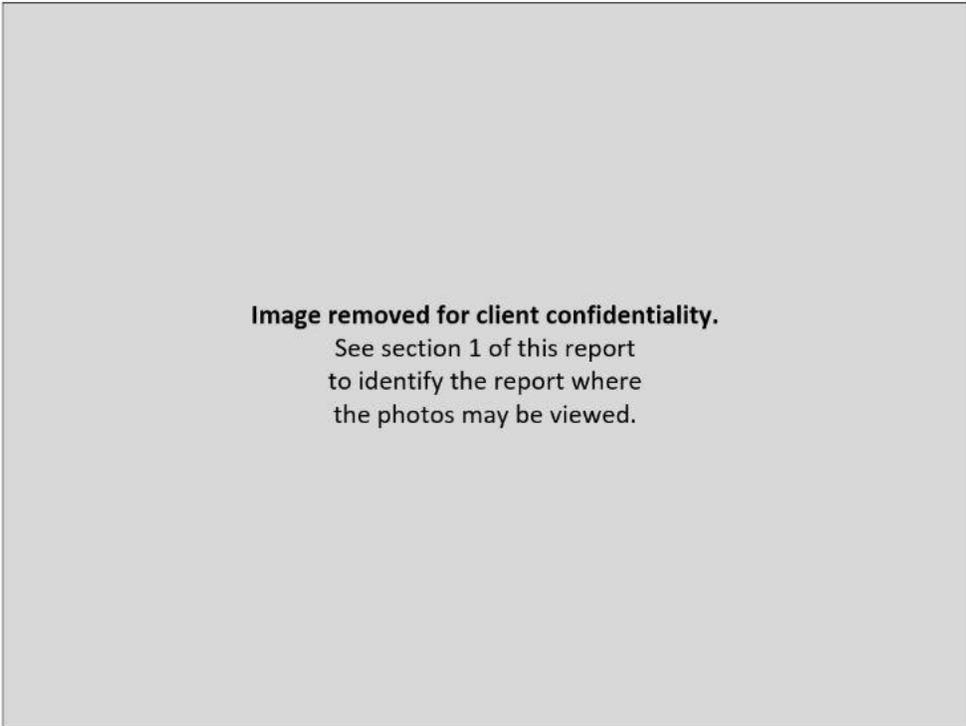


Figure RE04.5: EUT test setup, front view (Y orientation)



Figure RE04.6: EUT test setup, reverse view (Y orientation)

This line is the end of the test record.

Test Record
Radiated Emission Test RE06
Project GCL0385

Test Date(s) 19 May 2023
 Test Personnel Jim Solum

Product Model A04724
 Serial Number tested 441084880

Operating Mode M10 (BT Tx)
 Arrangement A2 (Upwr)
 Input Power 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: Jim Solum
Date of this record: 30 May 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 RE06.1: 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. The turntable angle, antenna height, and antenna polarization were explored to find the worst-case settings for each of the restricted band ranges. 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 2402 MHz. Measurements in the upper band were made while the transmitter was tuned to its highest frequency of 2480 MHz.

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

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

Frequency	Avg Limit	Pk Limit	Avg Level	Pk Level	Av Margin	Pk Margin	Azimuth	Height	Polarity
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	---
2218.3	54	74	32.041	46.123	21.959	27.877	158	1500	HORZ
2390	54	74	33.167	46.4	20.833	27.6	158	1500	HORZ

Table RE06.2: Emission summary FCC restricted band from 2200 to 2390 MHz (Basic Rate)

Frequency	Avg Limit	Pk Limit	Avg Level	Pk Level	Av Margin	Pk Margin	Azimuth	Height	Polarity
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	---
2483.8	54	74	36.574	50.087	17.426	23.913	-135	1580	HORZ
2483.5	54	74	36.842	50.423	17.158	23.577	-135	1580	HORZ

Table RE06.3: Emission summary FCC restricted band from 2483.5 to 2500 MHz (Basic Rate)

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)	---
2217	54	74	32.105	46.458	21.895	27.542	158	1500	HORZ
2258	54	74	32.744	45.886	21.256	28.114	158	1500	HORZ

Table RE06.4: Emission summary FCC restricted band from 2200 to 2390 MHz (EDR2)

Frequency	Avg Limit	Pk Limit	Avg Level	Pk Level	Av Margin	Pk Margin	Azimuth	Height	Polarity
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	---
2483.5	54	74	38.711	63.195	15.289	10.805	-135	1580	HORZ
2483.5	54	74	38.717	63.49	15.283	10.51	-135	1580	HORZ

Table RE06.5: Emission summary FCC restricted band from 2483.5 to 2500 MHz (EDR2)

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)	---
2222	54	74	32.093	46.713	21.907	27.287	158	1500	HORZ
2258	54	74	32.75	46.471	21.25	27.529	158	1500	HORZ

Table RE06.6: Emission summary FCC restricted band from 2200 to 2390 MHz (EDR3)

Frequency	Avg Limit	Pk Limit	Avg Level	Pk Level	Av Margin	Pk Margin	Azimuth	Height	Polarity
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	---
2483.5	54	74	37.92	64.844	16.08	9.156	-135	1580	HORZ
2483.5	54	74	37.926	65	16.074	9	-135	1580	HORZ

Table RE06.7: Emission summary FCC restricted band from 2483.5 to 2500 MHz (EDR3)

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

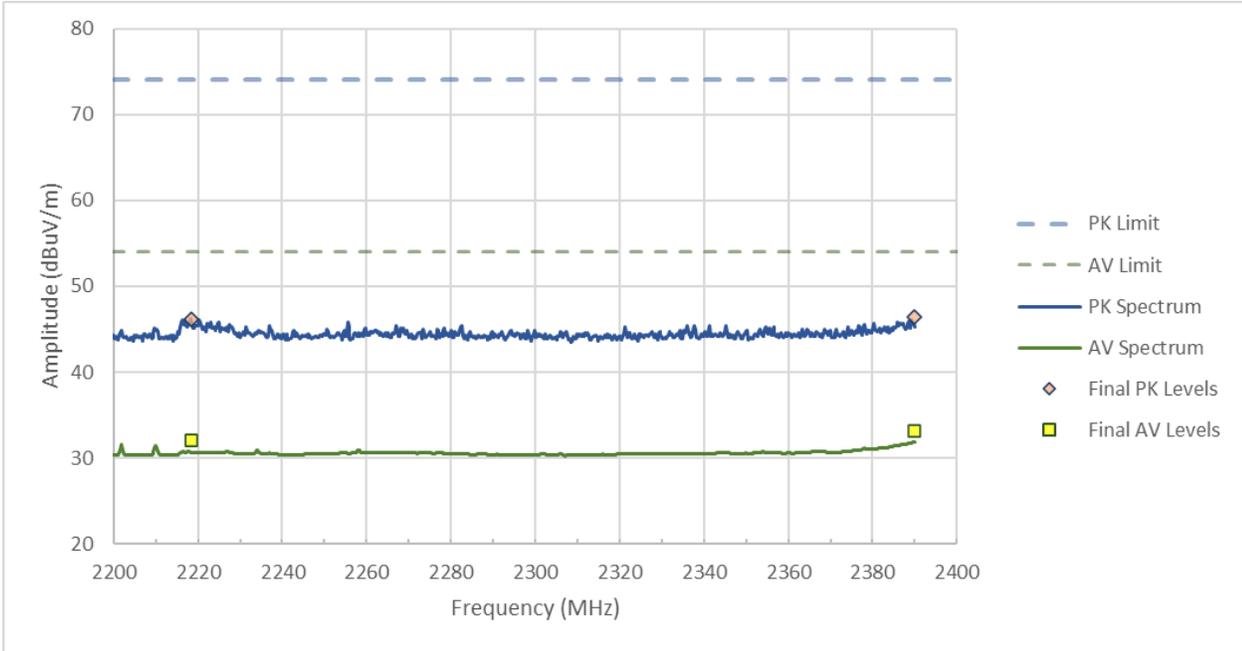


Figure RE06.1: Spectral data FCC restricted band from 2200 to 2390 MHz (Basic Rate)

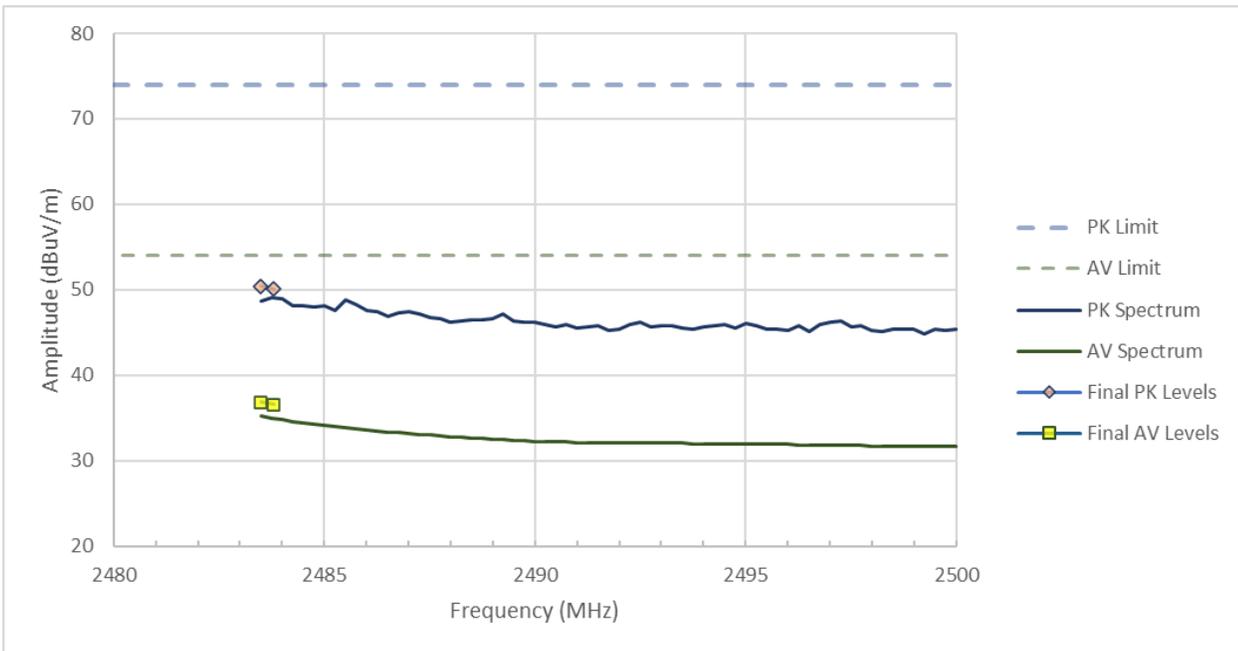


Figure RE06.2: Spectral data FCC restricted band from 2483.5 to 2500 MHz (Basic Rate)

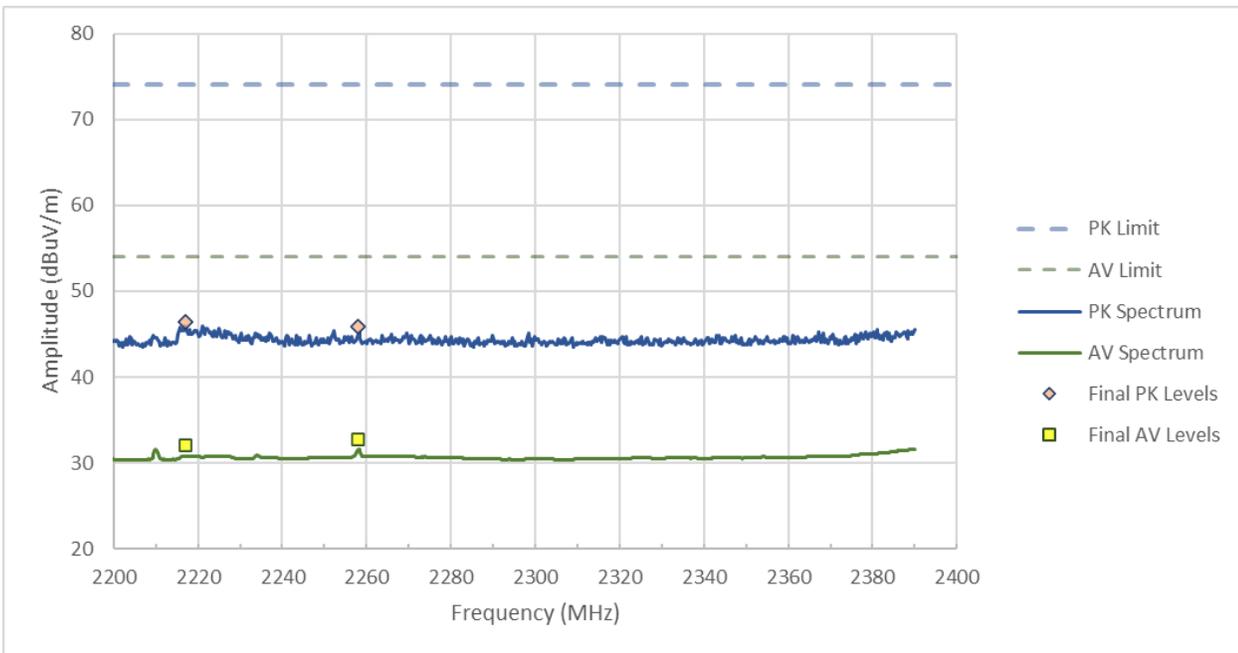


Figure RE06.3: Spectral data FCC restricted band from 2200 to 2390 MHz (EDR2)

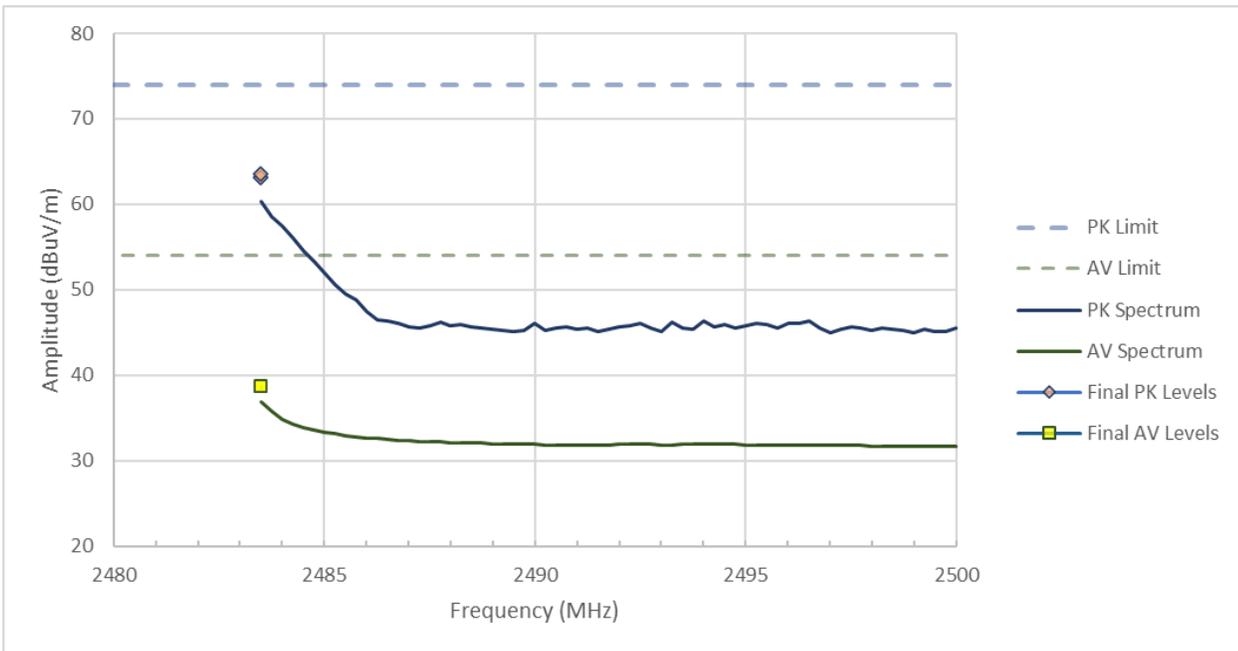


Figure RE06.4: Spectral data FCC restricted band from 2483.5 to 2500 MHz (EDR2)

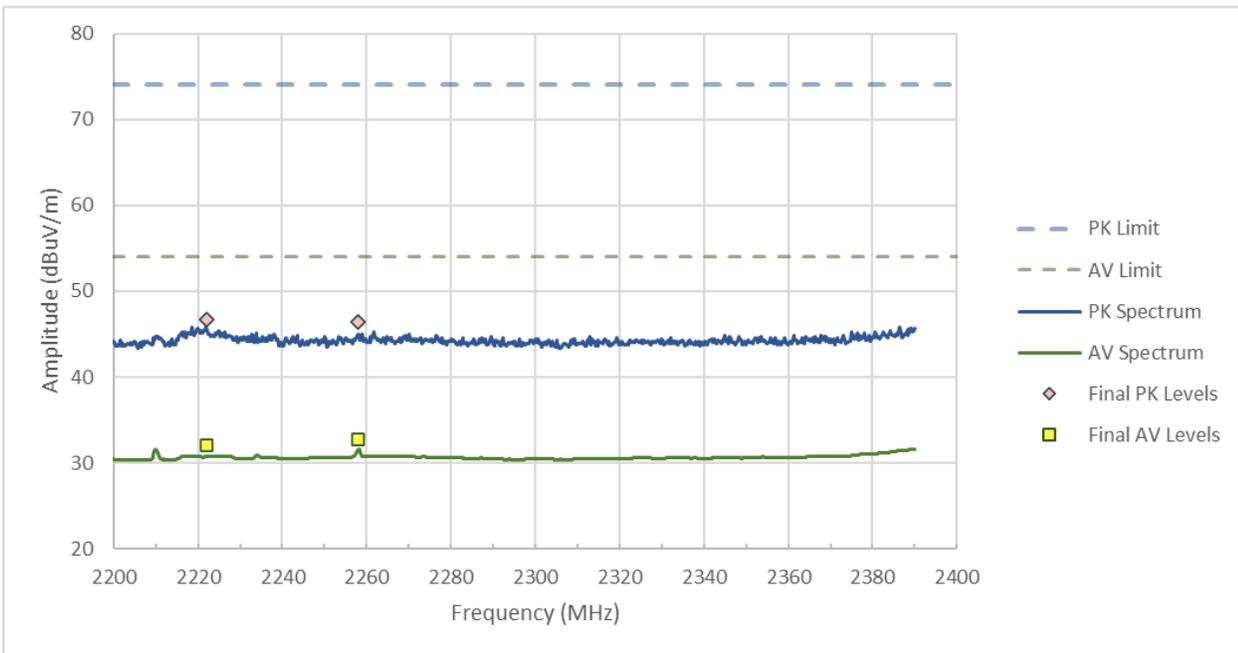


Figure RE06.5: Spectral data FCC restricted band from 2200 to 2390 MHz (EDR3)

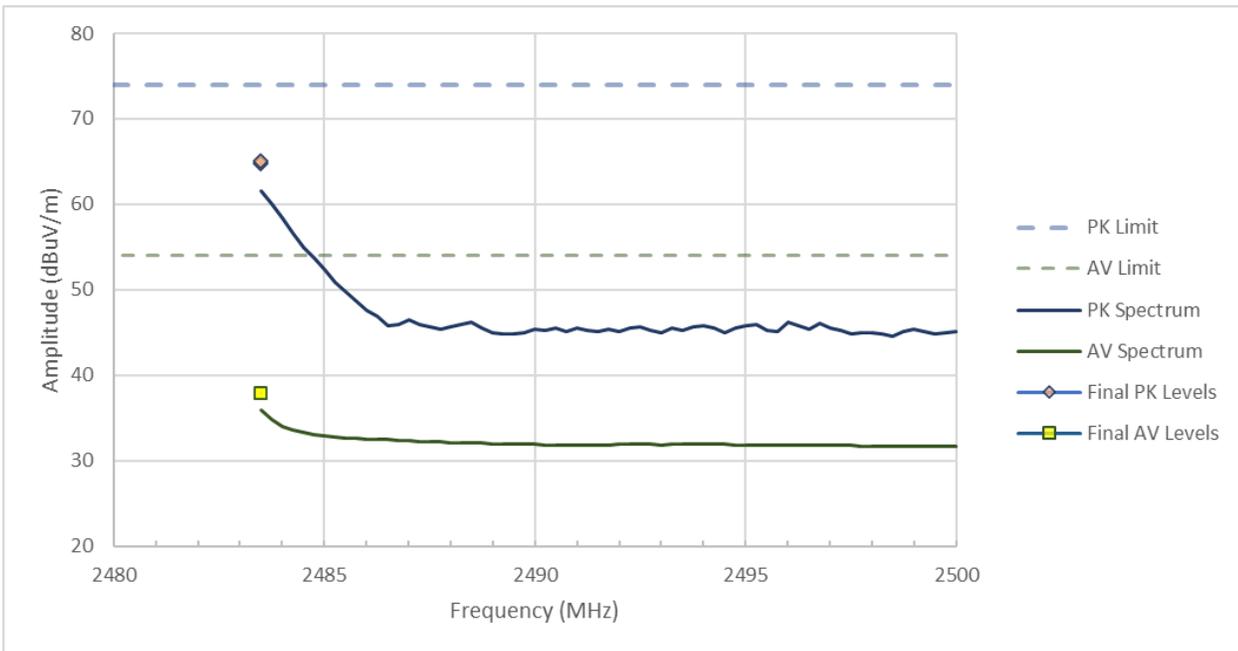


Figure RE06.6: Spectral data FCC restricted band from 2483.5 to 2500 MHz (EDR3)

Setup Photographs

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



Figure RE06.7: EUT test setup, front view (Y orientation)



Figure RE06.8: EUT test setup, reverse view (Y orientation)

This line is the end of the test record.

Test Record
Radiated Emission Test RE09
Project GCL0385

Test Date(s) 19 May 2023
 Test Personnel Jim Solum

Product Model A04724
 Serial Number tested 441084880

Operating Mode M3 (ANT Tx)
 Arrangement A2 (Upwr)
 Input Power 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: Jim Solum
Date of this record: 25 May 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 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 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. The turntable angle, antenna height, and antenna polarization were explored to find the worst-case settings for each of the restricted band ranges. 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 2402 MHz. Measurements in the upper band were made while the transmitter was tuned to its highest frequency of 2480 MHz.

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

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

Frequency	Avg Limit	Pk Limit	Avg Level	Pk Level	Av Margin	Pk Margin	Azimuth	Height	Polarity
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	---
2217.8	54	74	32.061	46.391	21.939	27.609	158	1500	HORZ
2390	54	74	32.809	46.857	21.191	27.143	158	1500	HORZ

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
(MHz)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dBuV/m)	(dB)	(dB)	(degree)	(mm)	---
2495.3	54	74	33.122	46.576	20.878	27.424	-135	1580	HORZ
2483.5	54	74	34.119	47.624	19.881	26.376	-135	1580	HORZ

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.

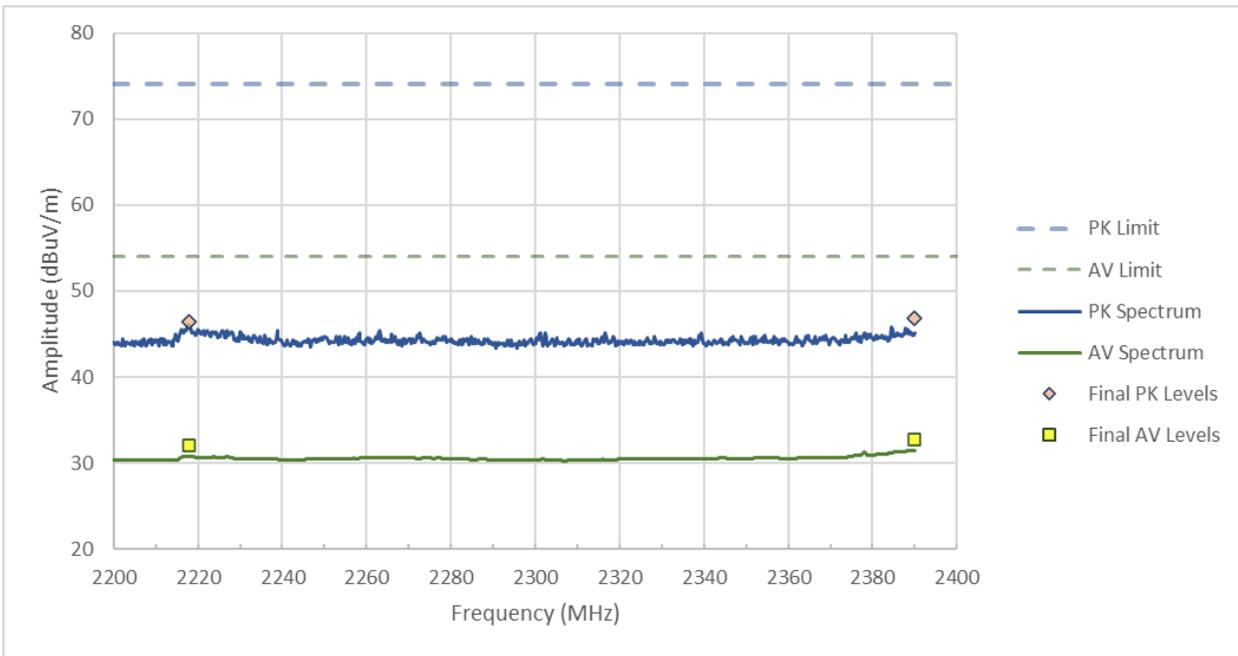


Figure RE09.1: FCC restricted band spectral data from 2200 to 2390 MHz

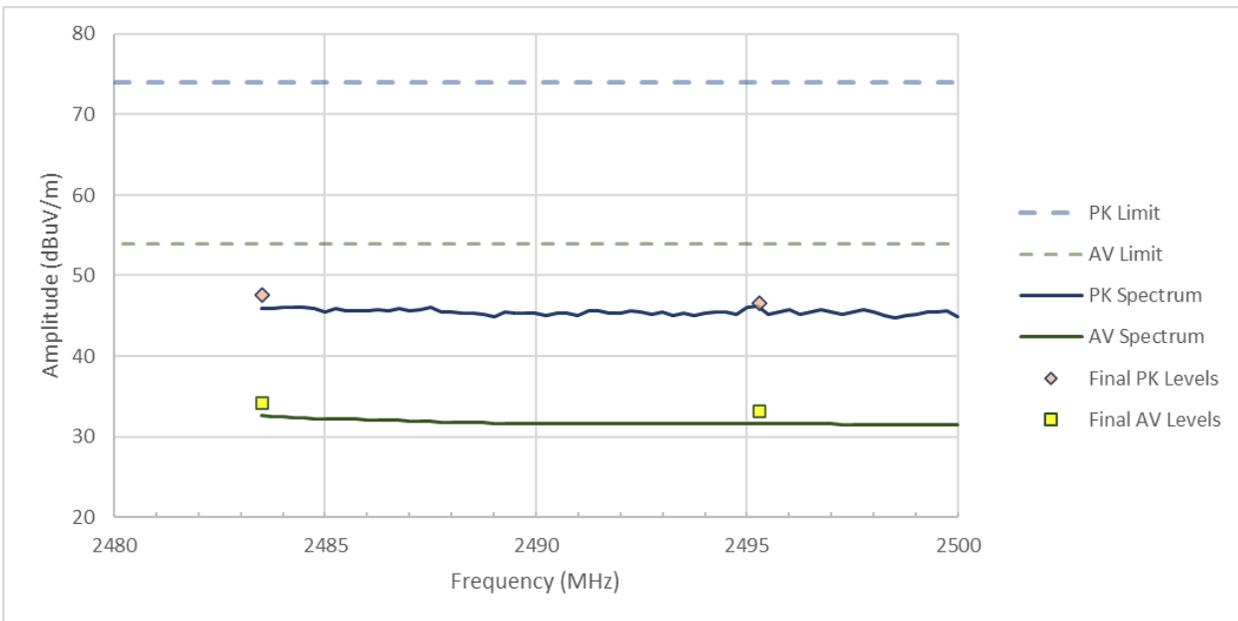


Figure RE09.2: FCC restricted band spectral data from 2483.5 to 2500 MHz

Setup Photographs

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



Figure RE09.3: EUT test setup, front view (Y orientation)



Figure RE09.4: EUT test setup, reverse view (Y orientation)

This line is the end of the test record.

Test Record
Transmitter Power Spectral Density
Test IDs TR06, TR08, TR10
Project GCL-0385

Test Date(s) 26 May 2023
 Test Personnel David Arnett

Product Model A04724
 Serial Number tested 441085073

Test Standards: FCC Part 15, ANSI C63.10, AS/NZS 4268, RSS-GEN, RSS-247 (as noted in Section 6 of the report).

Antenna Gain -0.37 dBi, as reported by the client
 Radio Protocol IEEE 802.11b/g/n (WiFi)

Pass/Fail Judgment: PASS

Test record created by: David Arnett
Date of this record: 13 July 2023

Version A was created on 2 June 2023. Version B was created on 13 July 2023 to remove an unneeded reference to RSS-210.

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 TR06.1: 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.

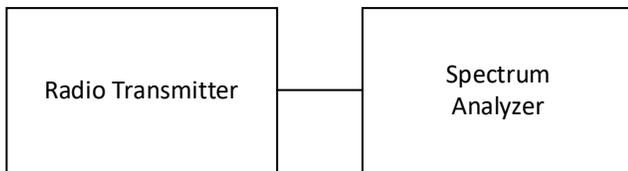


Figure TR06.1: Test setup

Test Data

The standards require measuring Power Spectral Density on the low, mid, and high channels. PSD is primarily affected by the process of modulation and the total power. Since it was known from previous testing that the mid channel has higher power than the edge channels, PSD was measured at the mid channel, channel 6, for all modulations. PSD for channels 1, 11, and 13 were then added for the modulation in each group (B, G, N) with the highest channel 6 PSD. Other channel and modulation combinations were not tested (NT in the summary table).

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 30 kHz resolution bandwidth.

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

	1	6	11	13
B1	NT	-0.73	NT	NT
B2	NT	0.74	NT	NT
B5.5	NT	1.27	NT	NT
B11	0.27	1.74	-0.03	-4.03
G06	NT	0.13	NT	NT
G09	NT	-0.44	NT	NT
G12	NT	0.33	NT	NT
G18	NT	-0.34	NT	NT
G24	NT	-0.22	NT	NT
G36	NT	0.11	NT	NT
G48	-2.28	0.89	-2.83	-7.28
G54	NT	-0.74	NT	NT
N0	NT	-0.5	NT	NT
N1	-2.32	-0.2	-3.45	-7.47
N2	NT	-1.37	NT	NT
N3	NT	-0.9	NT	NT
N4	NT	-0.85	NT	NT
N5	NT	-1.06	NT	NT
N6	NT	-1.06	NT	NT
N7	NT	-0.82	NT	NT

Table TR06.2: Summary of results



Figure TR06.3: Test data for B11 modulation, channel 6

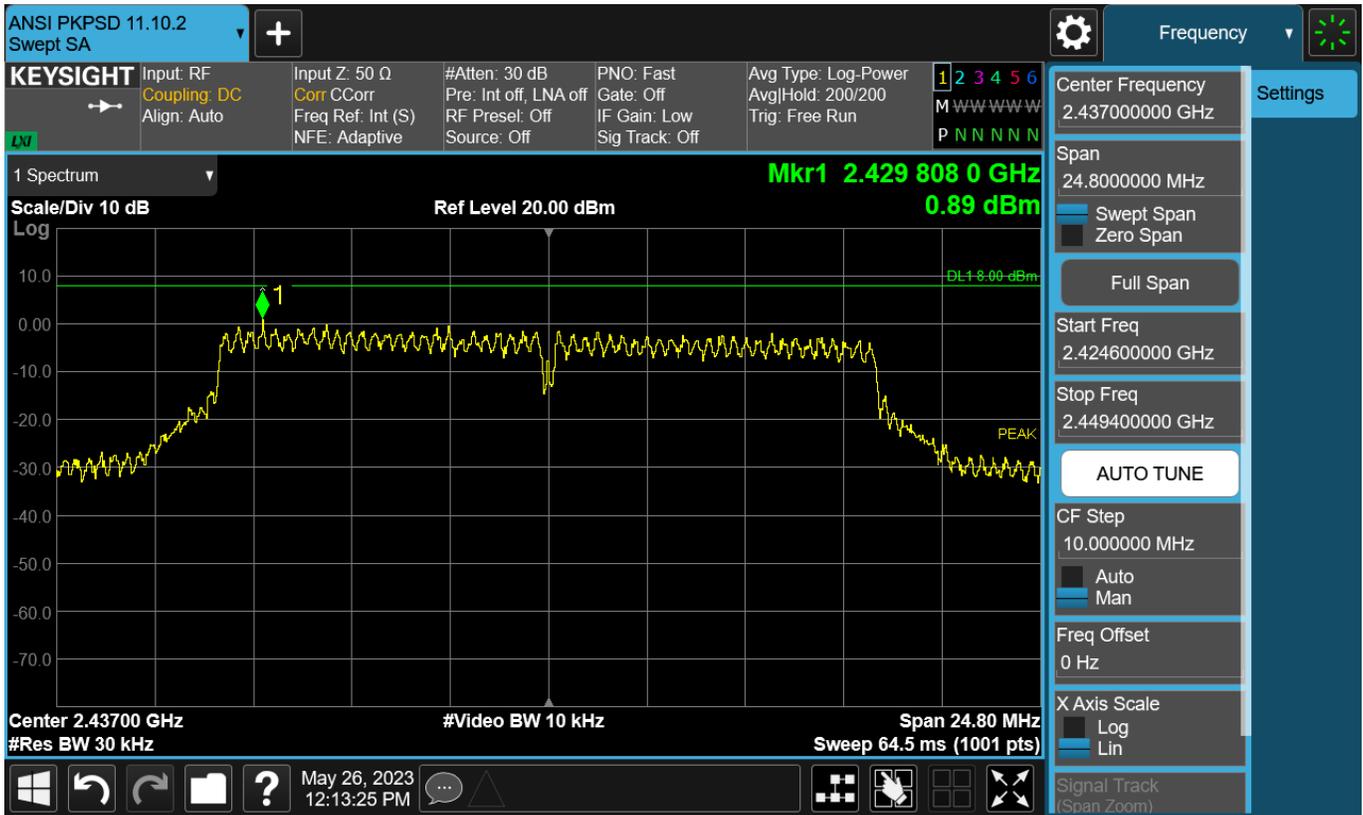


Figure TR06.4: Test data for G48 modulation, channel 6

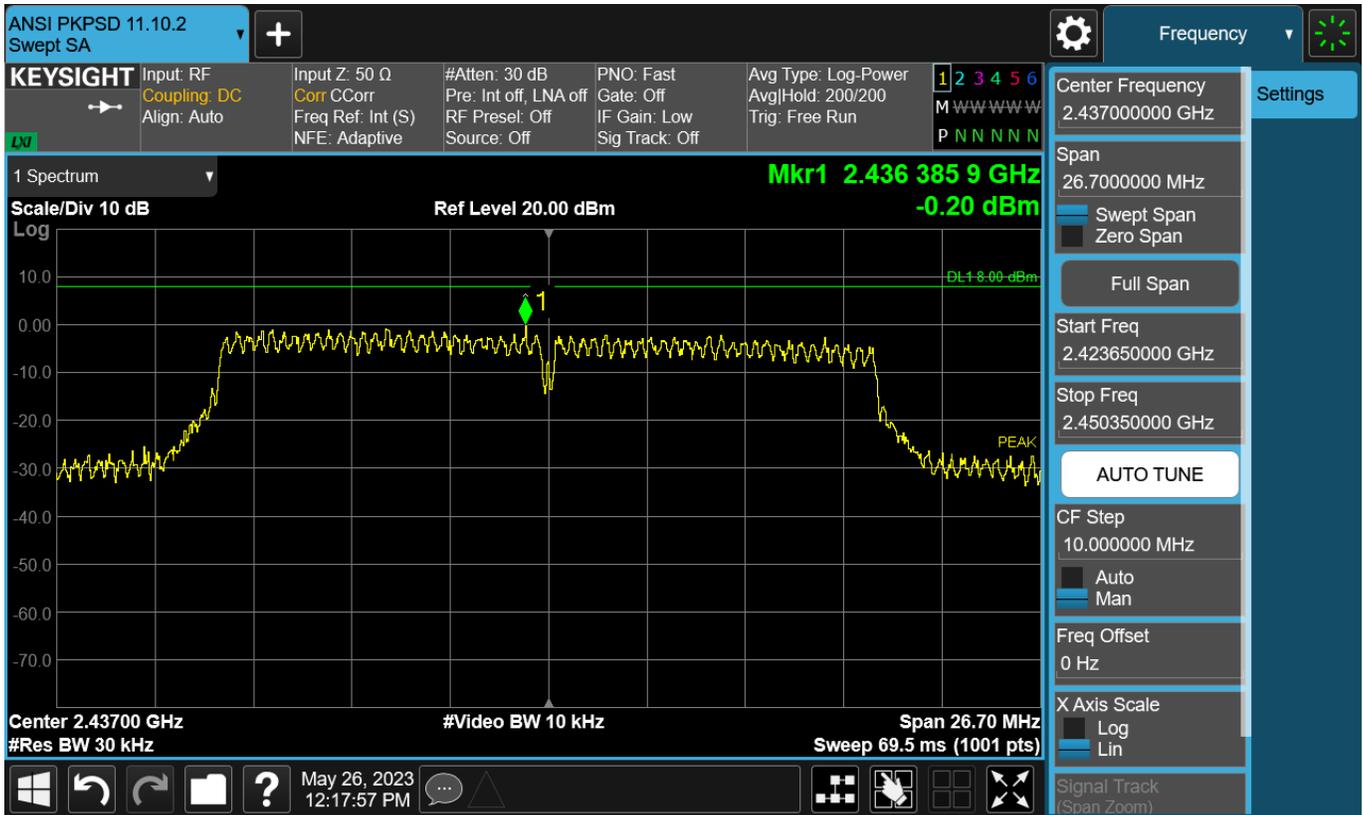


Figure TR06.5: Test data for N MSC1 modulation, channel 6

This line is the end of the test record.

Test Record
Transmitter Power Spectral Density
Test IDs TR12, TR14, TR16
Project GCL-0385

Test Date(s) 26 May 2023
 Test Personnel David Arnett

Product Model A04724
 Serial Number tested 441085073

Test Standards: FCC Part 15, ANSI C63.10, AS/NZS 4268, RSS-GEN, RSS-247 (as noted in Section 6 of the report).

Antenna Gain -0.37 dBi, as reported by the client
 Radio Protocol Bluetooth Classic (Including EDR2 and EDR3), Bluetooth Low Energy (BLE), ANT

Pass/Fail Judgment: PASS

Test record created by: David Arnett
Date of this record: 13 July 2023

Version A was created on 2 June 2023. Version B was created on 13 July 2023 to remove an unneeded reference to RSS-210.

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 TR12.1: 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.

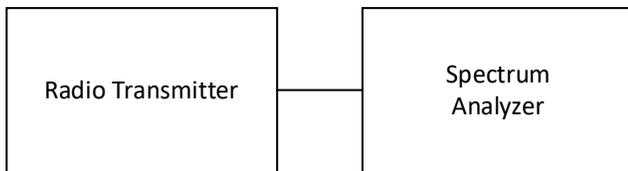


Figure TR12.1: Test setup

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 30 kHz resolution bandwidth.

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

		2402 (04)	2440	2480 (78)
BT	BR	4.44	4.82	5.55
	EDR2	-3.2	-3.7	-2.03
	EDR3	-2.28	-2.98	-1.53
BLE	1 Mb	-9.39	-9.45	-9.36
	2 Mb	-12.18	-12.38	-12.28
ANT		-4.97	-5.09	-4.87

Table TR12.2: Summary of results

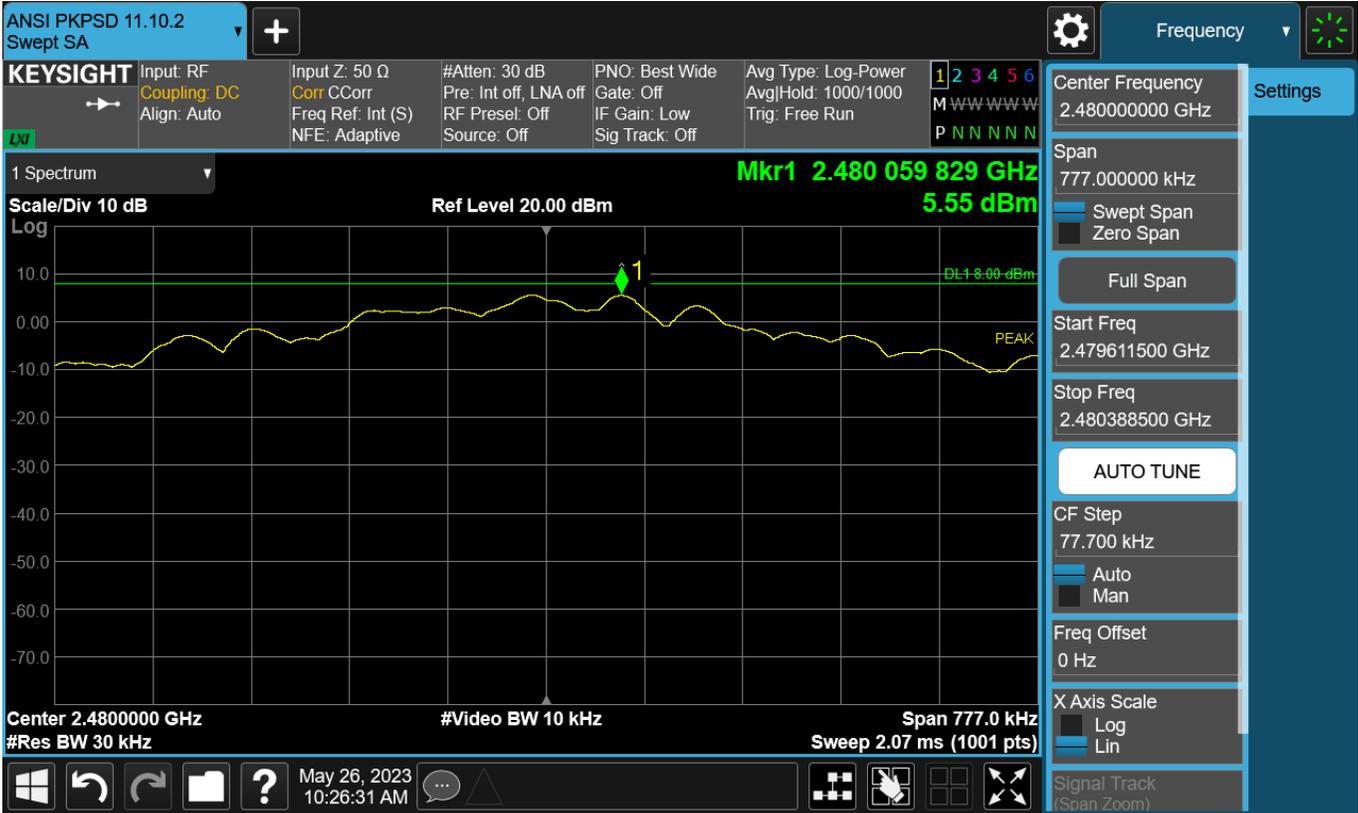


Figure TR12.2: Test data for Bluetooth Basic Rate, 2480 MHz



Figure TR12.3: Test data for Bluetooth Extended Data Rate 2, 2480 MHz



Figure TR12.4: Test data for Bluetooth Extended Data Rate 3, 2480 MHz



Figure TR12.5: Test data for BLE at 1 Mb/s, 2480 MHz

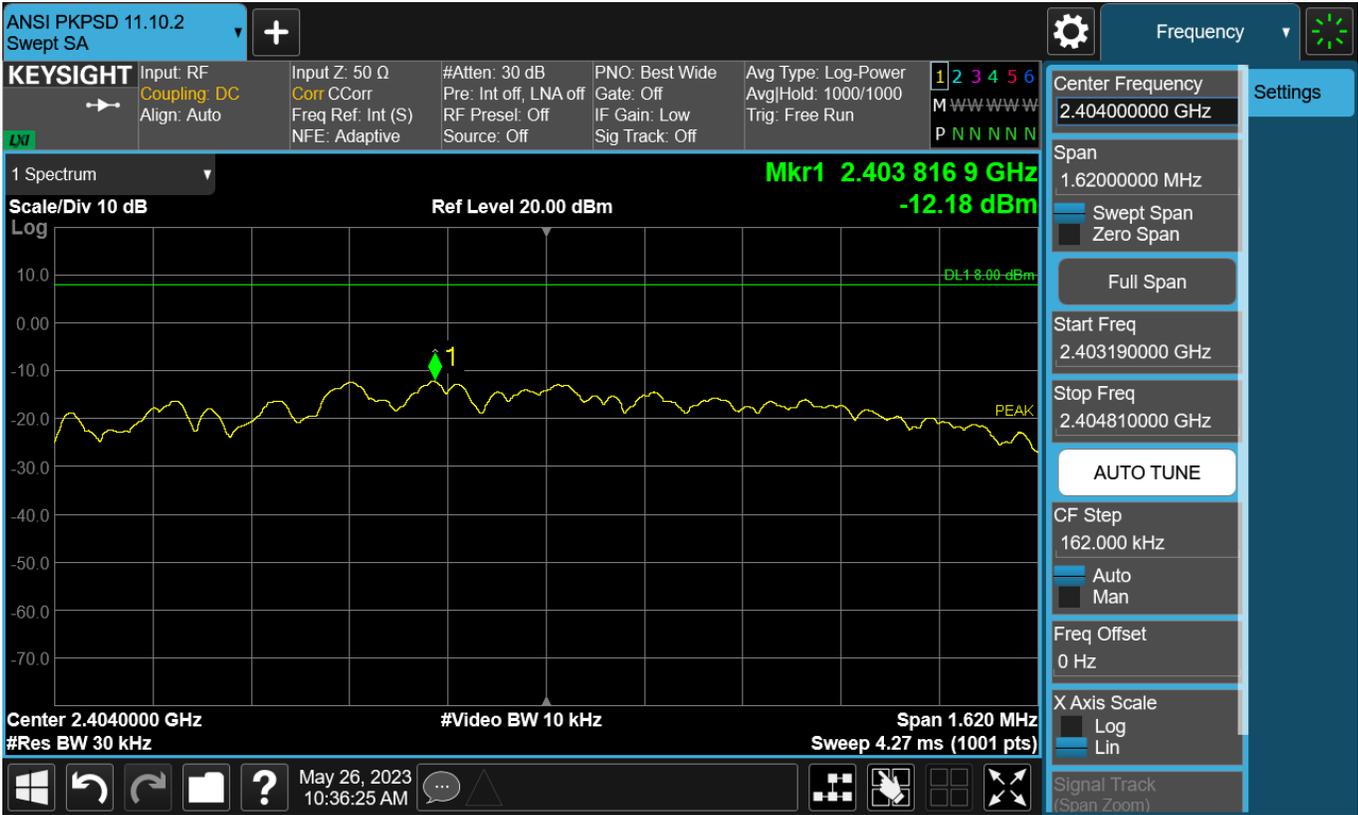


Figure TR12.6: Test data for BLE at 2 Mb/s, 2404 MHz

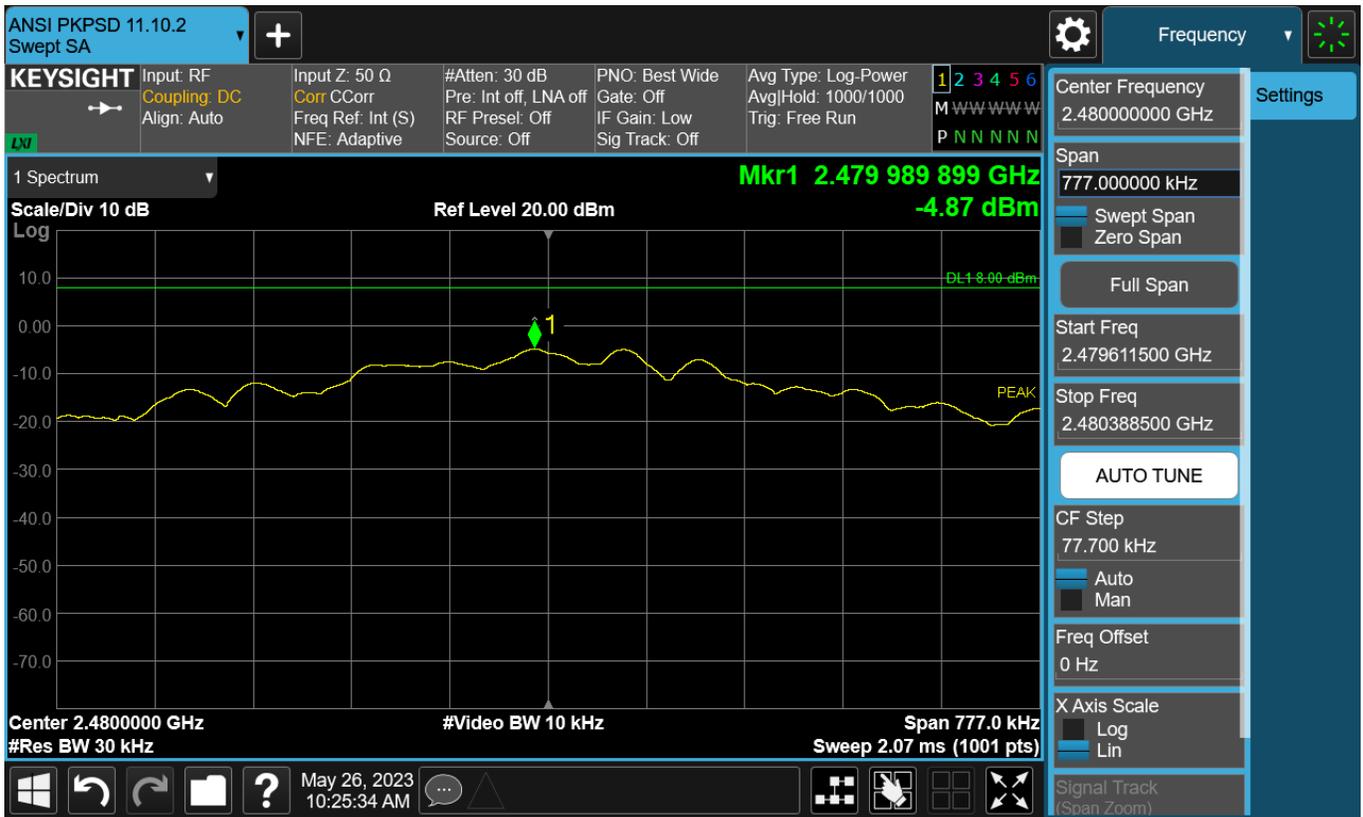


Figure TR12.7: Test data for ANT, 2480 MHz

This line is the end of the test record.

Test Record
Transmitter Frequency Stability
Test IDs TR38
Project GCL-0385

Test Date(s) 7 and 8 Jun 2023
 Test Personnel Majid Farah
 Product Model A04724
 Serial Number tested 441085073

Operating Mode M8 (WifiT)
 Arrangement A2 (Upwr)
 Nominal Input Power 5 Vdc

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

Radio Protocol WiFi (IEEE 802.11 b/g/n)

Pass/Fail Judgment: PASS

Test record created by: Majid Farah
Date this record: 13 Jul 2023

Version A was created on 13 Jun 2023. Version B was created on 13 July 2023 to remove an unneeded reference to RSS-210.

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 TR38.1: 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.

The EUT has a minimum transmission center frequency at 2412 MHz (channel 1) and a maximum at 2472 MHz (channel 13). The temperature stability of the transmissions was observed for channel 1, 11 and 13 of n MCS6 modulations were selected as the worst case to investigate due to their high occupied bandwidth.

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 (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.

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 WiFi 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 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	Ch. 1	Ch. 11	Ch. 13
WiFi	°C	Vdc	dBc	dBc	dBc
N MCS6	50	5	26.4	37.3	33.1
N MCS6	40	5	27.1	34.8	28.3
N MCS6	30	5	27.1	35.8	31.8
N MCS6	20	5	26.5	35.0	34.5
N MCS6	10	5	24.2	31.0	28.9
N MCS6	0	5	24.4	34.2	35.5
N MCS6	-10	5	26.5	32.3	29.0
N MCS6	-20	5	26.0	33.6	29.0

Table TR38.2 Difference between peak and band edge levels for IEEE 802.11 n MCS6 transmissions during temperature variations

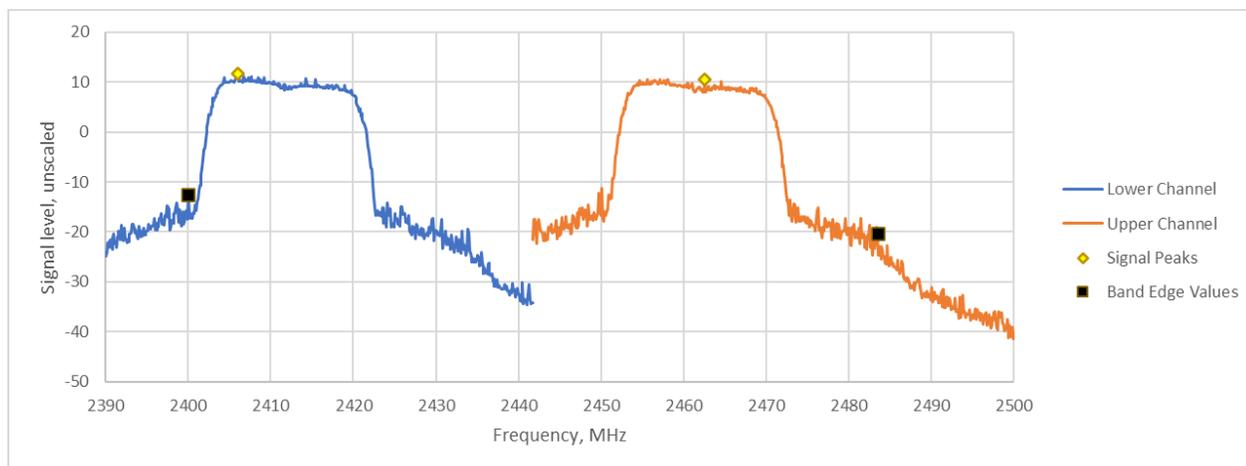


Figure TR38.1: Spectral data for IEEE 802.11 n MCS6 at 10 °C which represent Ch1 and Ch11

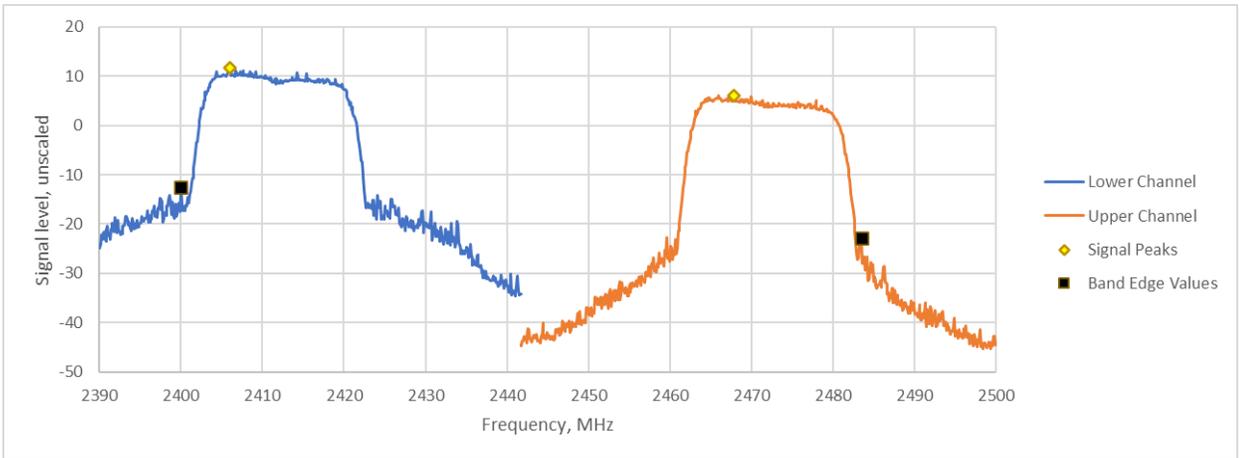


Figure TR38.2: Spectral data for IEEE 802.11 n MCS6 at 10 °C which represent Ch1 and Ch13

Tx Mode	Temp	Volts	Ch. 1	Ch. 11	Ch. 13
WiFi	°C	Vdc	dBc	dBc	dBc
N MCS6	20	4.25	26.3	34.8	38.1
N MCS6	20	5	26.5	35.0	34.5
N MCS6	20	5.75	25.9	35.0	37.1

Table TR38.3 Difference between peak and band edge levels for IEEE 802.11 n MCS6 transmissions at 20 °C during voltage variations

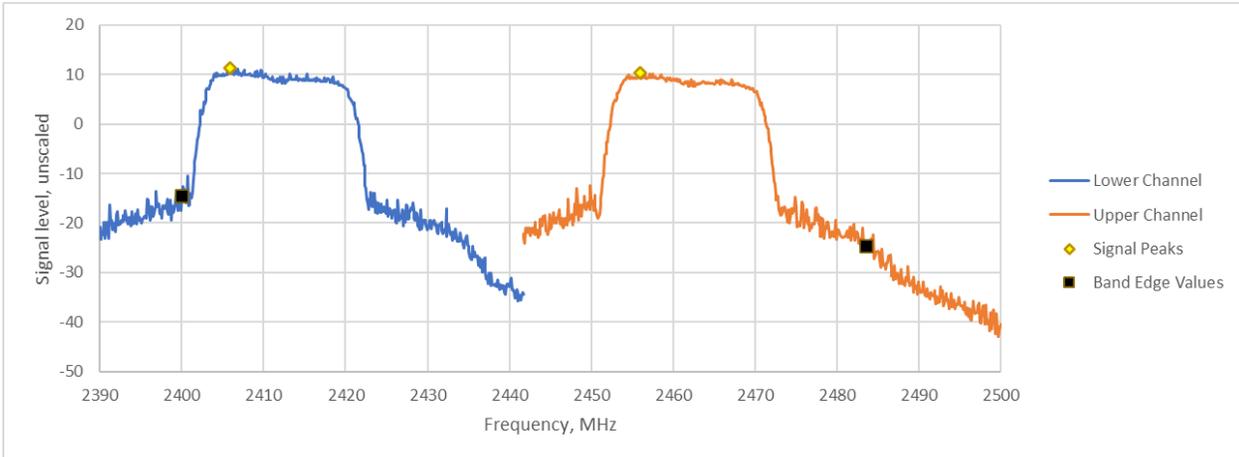


Figure TR38.3: Spectral data for IEEE 802.11 n MCS6 Mbps at 20 °C and 5.75 Vdc which represent Ch1 and Ch11

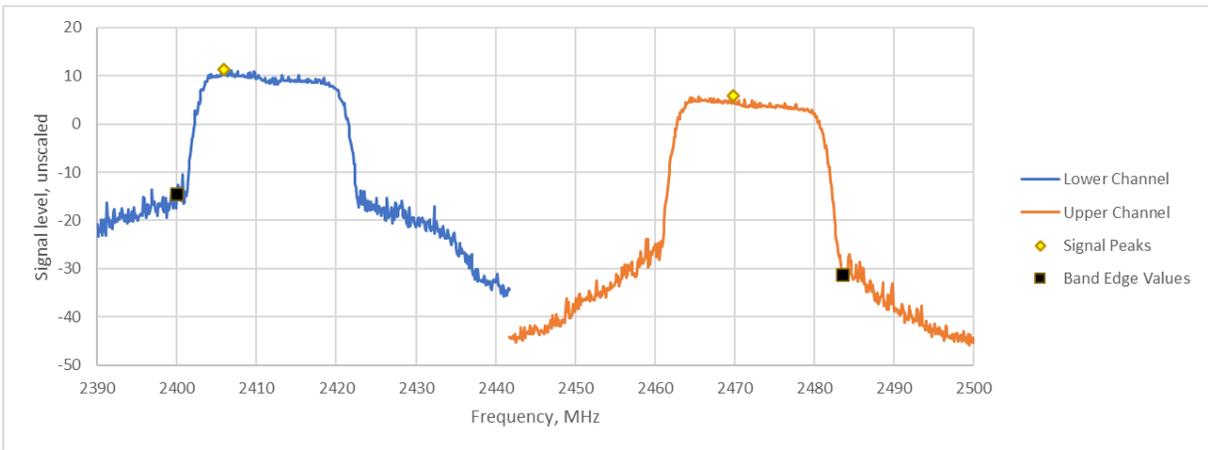


Figure TR38.4: Spectral data for IEEE 802.11 n MCS6 Mbps at 20 °C and 5.75 Vdc which represent Ch1 and Ch13

Setup Block Diagram

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

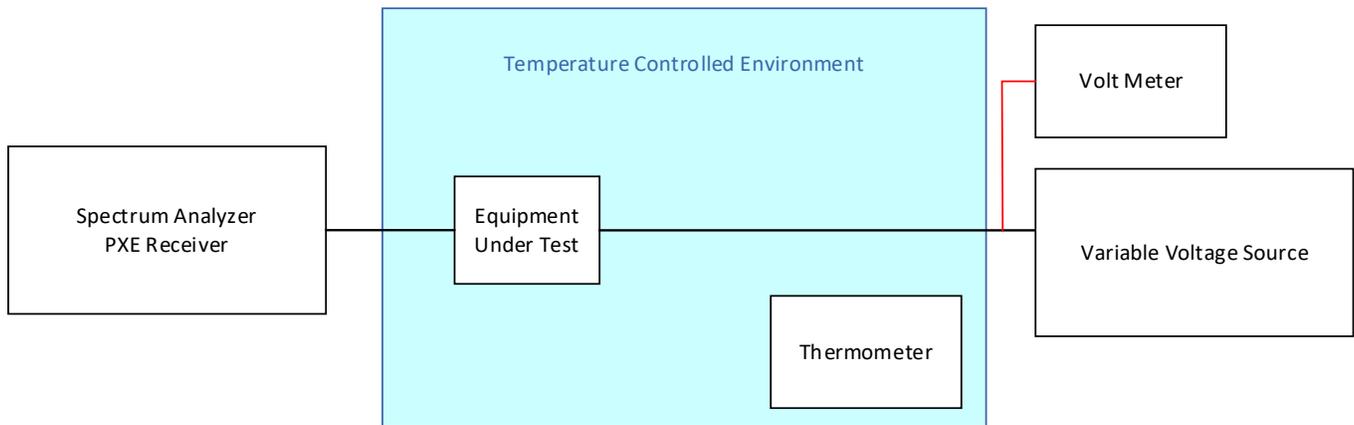


Figure TR38.5: Schematic drawing of the test equipment setup for WiFi (IEEE 802.11 b/g/n)

This line is the end of the test record.

Test Record
Transmitter Frequency Stability
Test IDs TR39 and TR40
Project GCL-0385

Test Date(s) 7 and 8 Jun 2023
 Test Personnel Majid Farah
 Product Model A04724
 Serial Number tested 441085073

Operating Mode M1 (BleT) and M10 (BtcT)
 Arrangement A2 (Upwr)
 Nominal Input Power 5 Vdc

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

Radio Protocol Bluetooth (BR, EDR2 and EDR3), BLE (Bluetooth Low Energy), ANT

Pass/Fail Judgment: PASS

Test record created by: Majid Farah
Date this record: 13 Jul 2023

Version A was created on 13 Jun 2023. Version B was created on 13 July 2023 to remove an unneeded reference to RSS-210.

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 TR39.1: 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, BLE and ANT use channel plans with a minimum transmission center frequency at 2402 MHz and a maximum at 2480 MHz. Bluetooth EDR3 and BLE1 were selected as the worst case among radios to investigate, due to its higher occupied bandwidth. Additional information regarding Bluetooth, BLE and ANT technologies is provided in the following table.

	First Channel	Last Channel	Channel spacing	Data rate
	MHz	MHz	MHz	Mb/s
Bluetooth BR	2402	2480	1	1
Bluetooth EDR2	2402	2480	1	2
Bluetooth EDR3	2402	2480	1	3
BLE1	2402	2480	2	1
BLE2	2404	2478	2	2
ANT	2402	2402	1	60 Kb/s

Table TR39.2 Bluetooth, 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 (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.

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 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
BT EDR3	50	5	23.4	37.6
BT EDR3	40	5	22.9	36.8
BT EDR3	30	5	22.1	37.3
BT EDR3	20	5	24.8	37.0
BT EDR3	10	5	26.0	36.3
BT EDR3	0	5	23.7	37.1
BT EDR3	-10	5	22.7	36.7
BT EDR3	-20	5	23.0	37.9

Table TR39.3 Difference between peak and band edge levels for Bluetooth EDR3 transmissions during temperature variations

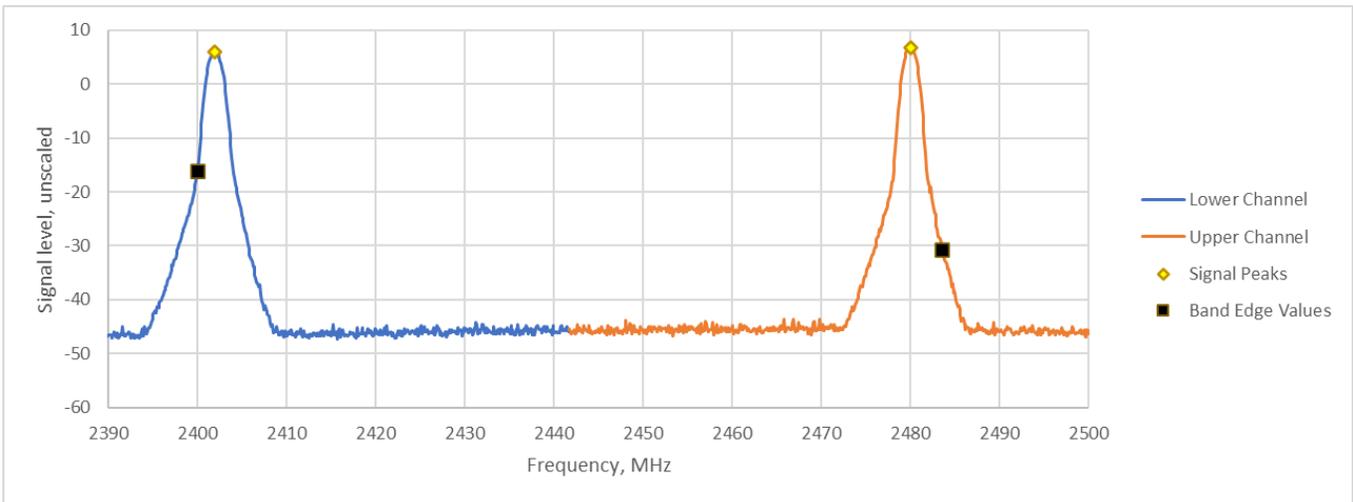


Figure TR39.1: Spectral data for Bluetooth EDR3 at 30 °C

Tx Mode	Temp	Volts	Low Ch.	High Ch.
Bluetooth	°C	Vdc	dBc	dBc
BT EDR3	20	4.25	24.3	37.4
BT EDR3	20	5	24.8	37.0
BT EDR3	20	5.75	25.7	36.9

Table TR39.4 Difference between peak and band edge levels for Bluetooth EDR3 transmissions at 20 °C during voltage variations

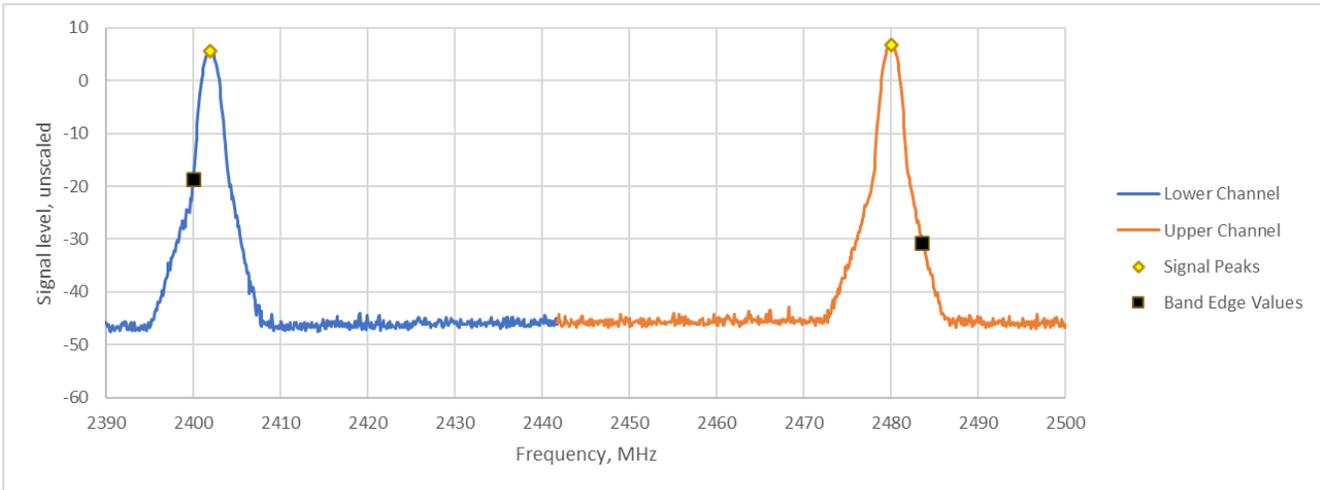


Figure TR39.2: Spectral data for Bluetooth EDR3 at 20 °C and 4.25 Vdc

Tx Mode	Temp	Volts	Low Ch.	High Ch.
Bluetooth	°C	Vdc	dBc	dBc
BLE 1 Mbps	50	5	29.9	42.3
BLE 1 Mbps	40	5	30.9	41.5
BLE 1 Mbps	30	5	30.3	41.6
BLE 1 Mbps	20	5	30.8	42.1
BLE 1 Mbps	10	5	30.7	43.0
BLE 1 Mbps	0	5	30.6	42.4
BLE 1 Mbps	-10	5	30.2	43.5
BLE 1 Mbps	-20	5	30.4	42.3

Table TR39.5 Difference between peak and band edge levels for BLE 1 Mbps transmissions during temperature variations

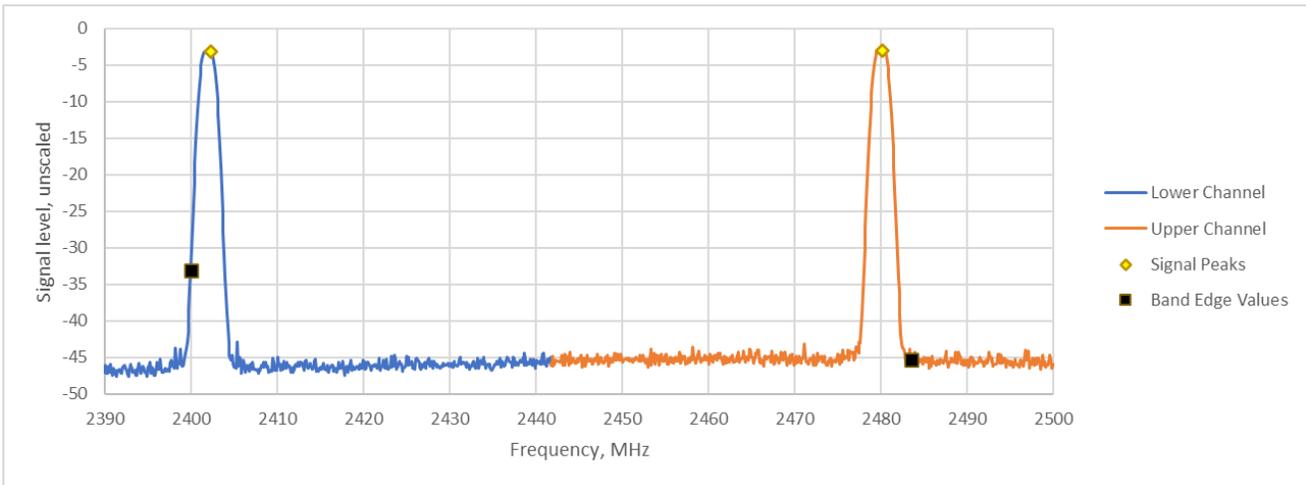


Figure TR39.3: Spectral data for BLE 1 Mbps at 50 °C

Tx Mode	Temp	Volts	Low Ch.	High Ch.
Bluetooth	°C	Vdc	dBc	dBc
BLE 1 Mbps	20	4.25	30.2	42.4
BLE 1 Mbps	20	5	30.8	42.1
BLE 1 Mbps	20	5.75	30.8	42.4

Table TR39.6 Difference between peak and band edge levels for BLE 1 Mbps transmissions at 20 °C during voltage variations

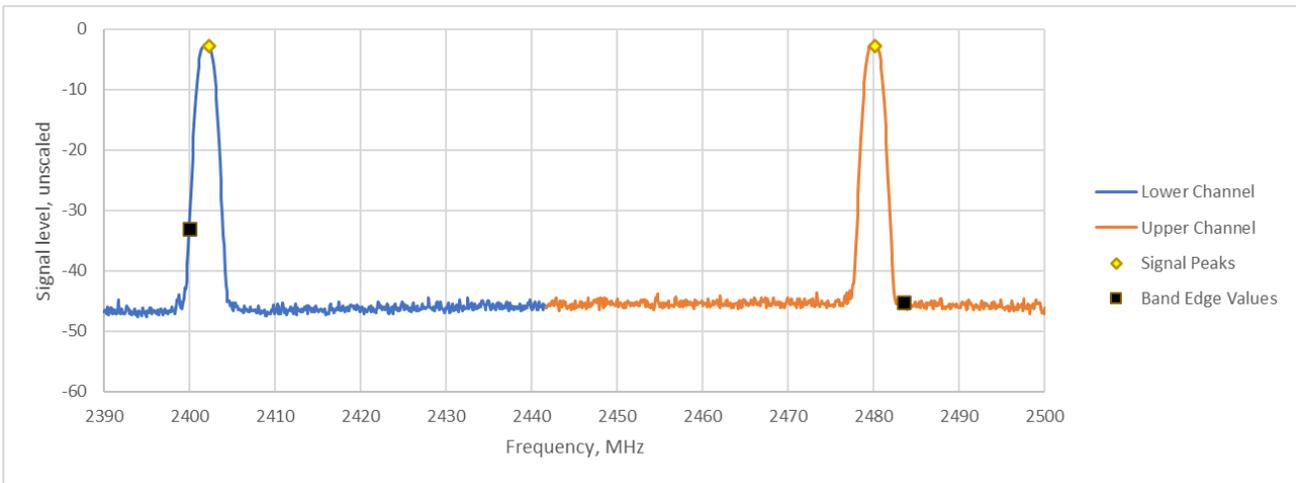


Figure TR39.4: Spectral data for BLE 1 Mbps at 20 °C and 4.25 Vdc

Setup Block Diagram

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

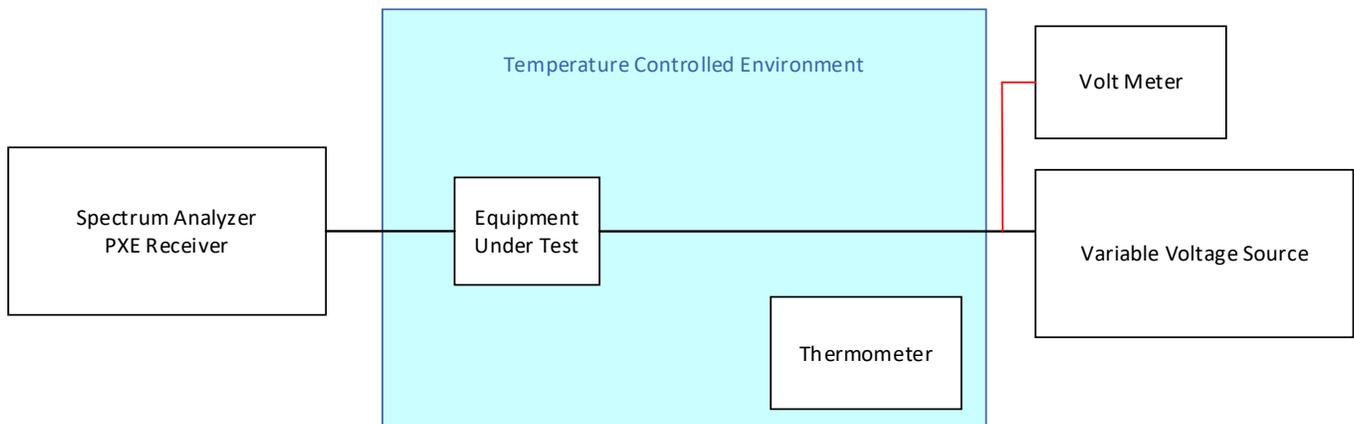


Figure TR39.5: Schematic drawing of the test equipment setup for Bluetooth, BLE and ANT

This line is the end of the test record.

Test Record
Conducted Emissions Mains Test CE01
Project GCL0385

Test Date(s) 06 Jun 2023
 Test Personnel David Kerr

Product Model A04724
 Serial Number tested 441084880

Operating Mode M8 (WifiT)
 Arrangement A2 (Upwr)
 Input Power 115 Vac 60 Hz

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

Frequency Range: 150 kHz to 30 MHz
Pass/Fail Judgment: PASS

Test record created by: Ryan Townsend
Date of this record: 15 Jun 2023
 Original record, Version A.

Table CE01.1: 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
DMM Multimeter	FLUKE	79 III	71740743	18-Apr-2022	1-Apr-2023
Power Source	Elgar	1001B-167	1618	Calibration	Not Required
LISN multiline; 20A 50uH	Com-Power	LIN-120C	20160005	22-Aug-2022	15-Aug-2023

Software Used

Keysight PXE software A.32.06
 CE Mains 150k to 30M Data Analysis.xlsx

Test Data

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

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

Frequency	QP Limit	AV Limit	L1 QP	L2 QP	L1 AV	L2 AV	QP Margin	AV Margin
(kHz)	(dBuV)	(dBuV)	(dBuV)	(dBuV)	(dBuV)	(dBuV)	(dB)	(dB)
150	66.00	56.00	47.30	55.34	25.81	27.78	10.66	28.22
175	64.73	54.73	52.41	55.07	28.81	29.23	9.66	25.50
200	63.63	53.63	44.52	48.89	30.45	29.70	14.75	23.18
200	63.63	53.63	46.95	46.87	30.61	29.82	16.68	23.02
224	62.66	52.66	45.23	43.70	26.72	25.49	17.43	25.94
299	60.28	50.28	39.08	42.70	25.24	23.64	17.58	25.04
323	59.62	49.62	41.03	40.97	26.96	23.77	18.59	22.66
353	58.90	48.9	38.77	36.44	25.03	24.3	20.13	23.87
713	56.00	46.00	31.15	30.68	26.45	26.39	24.85	19.55
1424	56.00	46.00	27.49	27.33	23.11	22.63	28.51	22.89

Table CE01.2: Emission summary

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

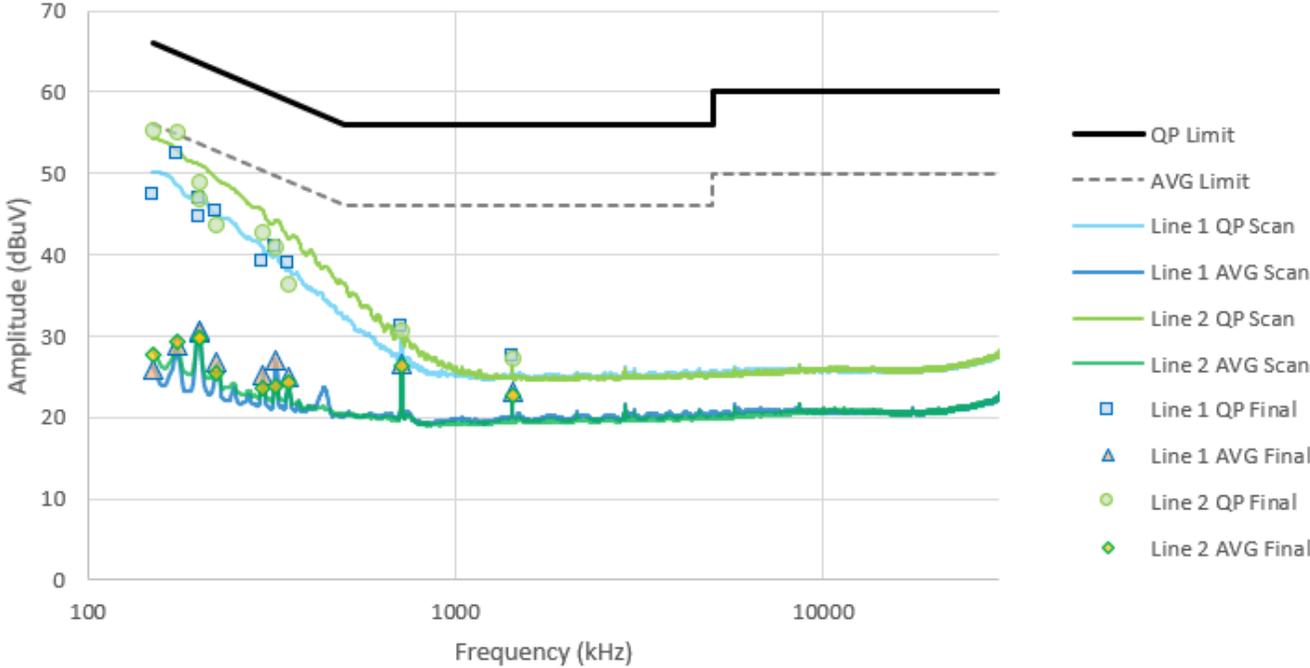


Figure CE01.1: Spectral data

Setup Photographs

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

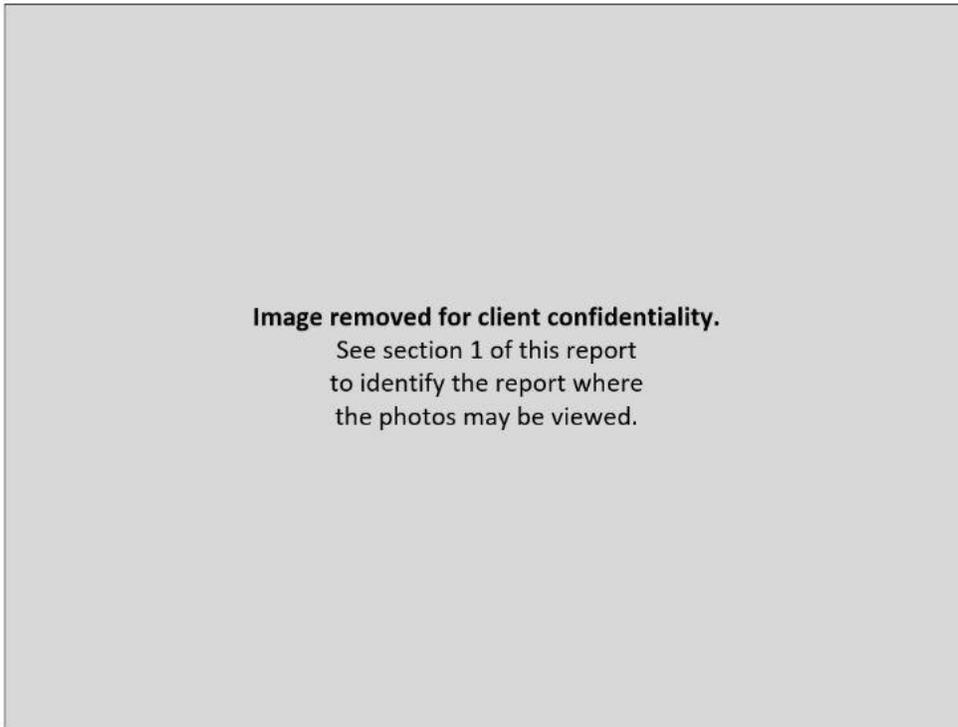


Figure CE01.2: EUT test setup

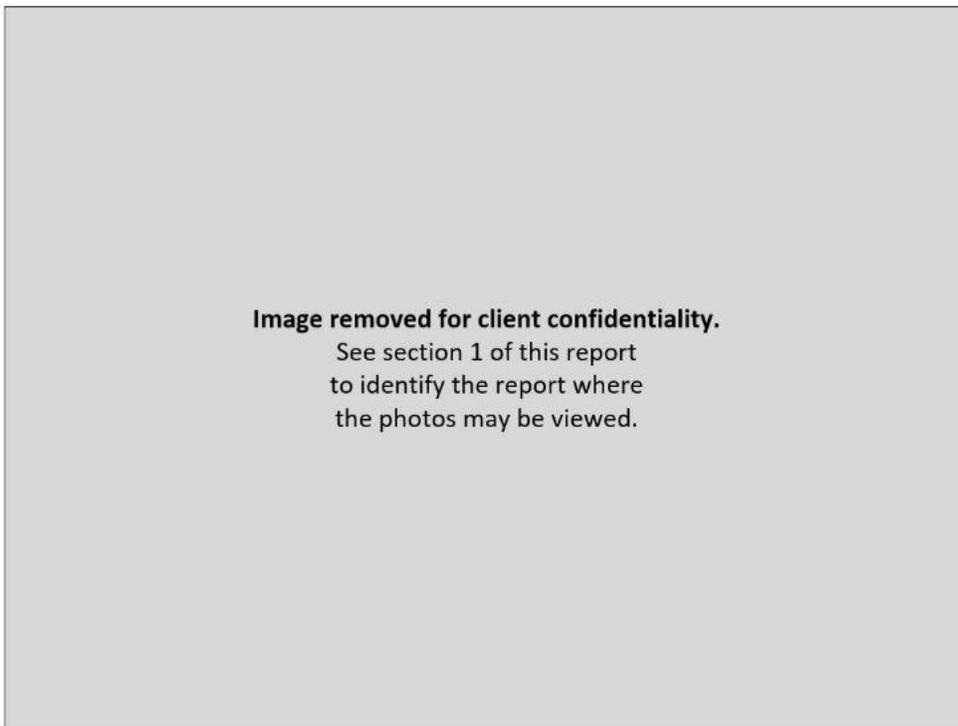


Figure CE01.3: EUT test setup cont.

This line is the end of the test record.

Test Record
Radiated Emission Test RE13
Project GCL0385

Test Date(s) 01 Jun 2023
 Test Personnel David Kerr

Product Model A04724
 Serial Number tested 441084880

Operating Mode M8 (WifiT)
 Arrangement A2 (Upwr)
 Input Power 5 Vdc
 Test Standards: FCC Part 15, ANSI C63.10 (as noted in Section 6 of the report).

Frequency Range: 30 MHz to 1000 MHz
Pass/Fail Judgment: PASS

Test record created by: Ryan Townsend
Date of this record: 13 Jun 2023

Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE Receiver 26 GHz	Keysight	N9048B	MY59290135	21-Sep-2022	15-Sep-2023
FSOATS 3m, above 1 GHz	Frankonia	SAC3	F199004	16-Nov-2022	16-Nov-2025
Tape measure, 1" x 33'	Lufkin	PHV1410CM	10720	16-Jan-2023	15-Jan-2026
Antenna, Bicon, 30 - 300 MHz	Schwarzbeck	VHBB9124	01434	2-Sep-2021	1-Sep-2023

Table RE13.1: Test Equipment Used

Software Used:

Keysight PXE software A.32.06
 RE Signal Maximization Tool v2021Feb25.xlsx
 RE 30M to 1G Data AnalysisV1 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 tables show 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 in 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.

Frequency (MHz)	Limit (dBuV/m)	Measured (dBuV/m)	Margin (dB)	Azimuth (degree)	Height (mm)	Antenna Polarity
30.000	40.00	27.50	12.50	160.00	3979.00	HORZ
187.470	43.50	21.20	22.30	59.00	2524.00	HORZ
469.710	46.00	25.70	20.30	-147.00	1497.00	VERT
549.990	46.00	28.20	17.80	-127.00	1137.00	VERT
580.020	46.00	27.20	18.80	35.00	1677.00	VERT
945.270	46.00	32.60	13.40	-3.00	3495.00	HORZ

Table RE13.2: Emission summary (B5.5 CH 1)

Frequency (MHz)	Limit (dBuV/m)	Measured (dBuV/m)	Margin (dB)	Azimuth (degree)	Height (mm)	Antenna Polarity
160.560	43.50	19.70	23.80	151.00	3858.00	VERT
188.430	43.50	23.50	20.00	-130.00	1742.00	HORZ
399.990	46.00	24.40	21.60	-180.00	3883.00	HORZ
589.980	46.00	26.90	19.10	-197.00	4000.00	VERT
809.910	46.00	31.20	14.80	-188.00	1497.00	HORZ
937.320	46.00	32.40	13.60	-42.00	1140.00	HORZ

Table RE13.3: Emission summary (B5.5 CH 6)

Frequency (MHz)	Limit (dBuV/m)	Measured (dBuV/m)	Margin (dB)	Azimuth (degree)	Height (mm)	Antenna Polarity
160.530	43.50	19.60	23.90	-28.00	4000.00	VERT
187.620	43.50	23.50	20.00	-107.00	1853.00	HORZ
541.800	46.00	28.30	17.70	-123.00	3399.00	HORZ
580.020	46.00	27.30	18.70	-200.00	1813.00	VERT
804.090	46.00	32.00	14.00	-124.00	3439.00	HORZ
945.210	46.00	33.20	12.80	-63.00	1397.00	VERT

Table RE13.4: Emission summary (B5.5 CH 11)

Frequency (MHz)	Limit (dBuV/m)	Measured (dBuV/m)	Margin (dB)	Azimuth (degree)	Height (mm)	Antenna Polarity
151.830	43.50	20.60	22.90	111.00	1987.00	HORZ
202.710	43.50	22.20	21.30	-114.00	1087.00	HORZ
399.990	46.00	24.30	21.70	-150.00	2639.00	HORZ
541.590	46.00	27.80	18.20	-142.00	2086.00	HORZ
806.550	46.00	30.50	15.50	-114.00	1611.00	HORZ
944.820	46.00	33.00	13.00	159.00	2040.00	HORZ

Table RE13.5: Emission summary (B5.5 CH 13)

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

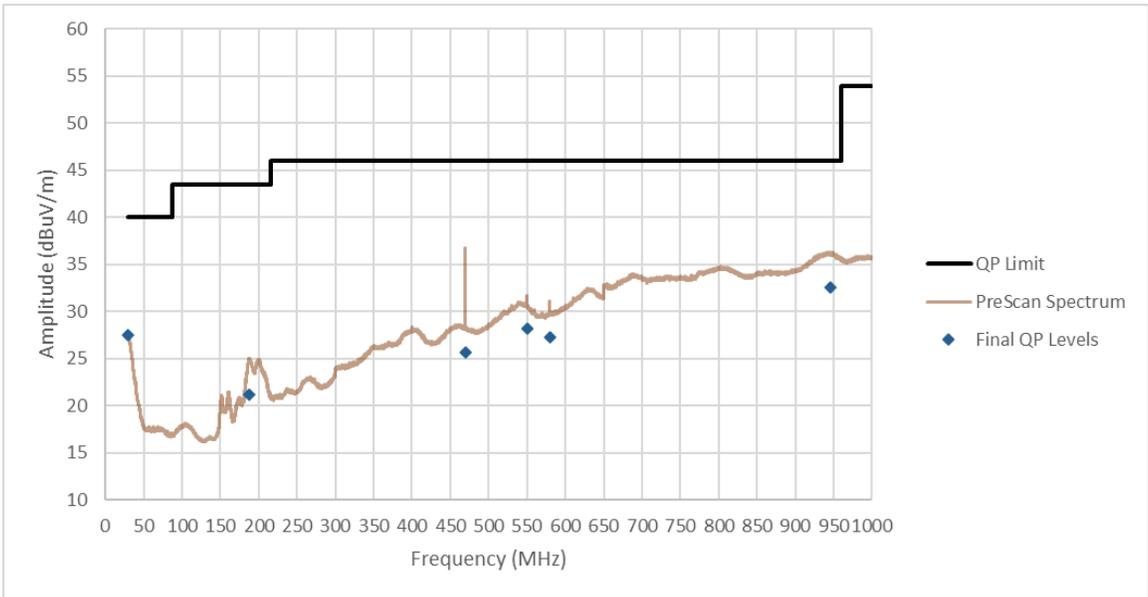


Figure RE13.1: Spectral data (B5.5 CH1)

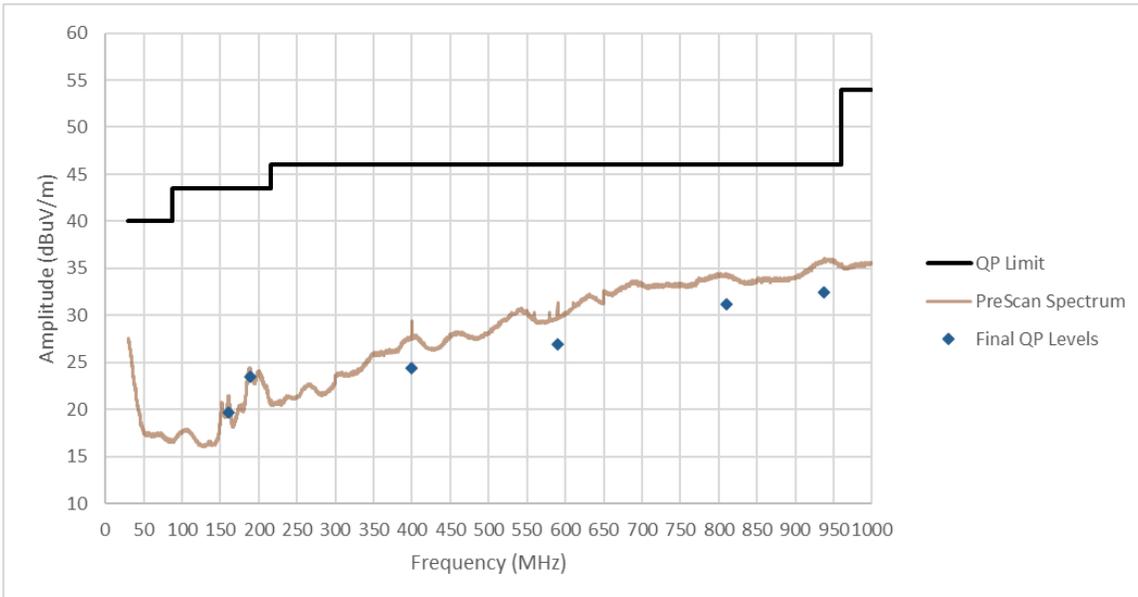


Figure RE13.2: Spectral data (B5.5 CH6)

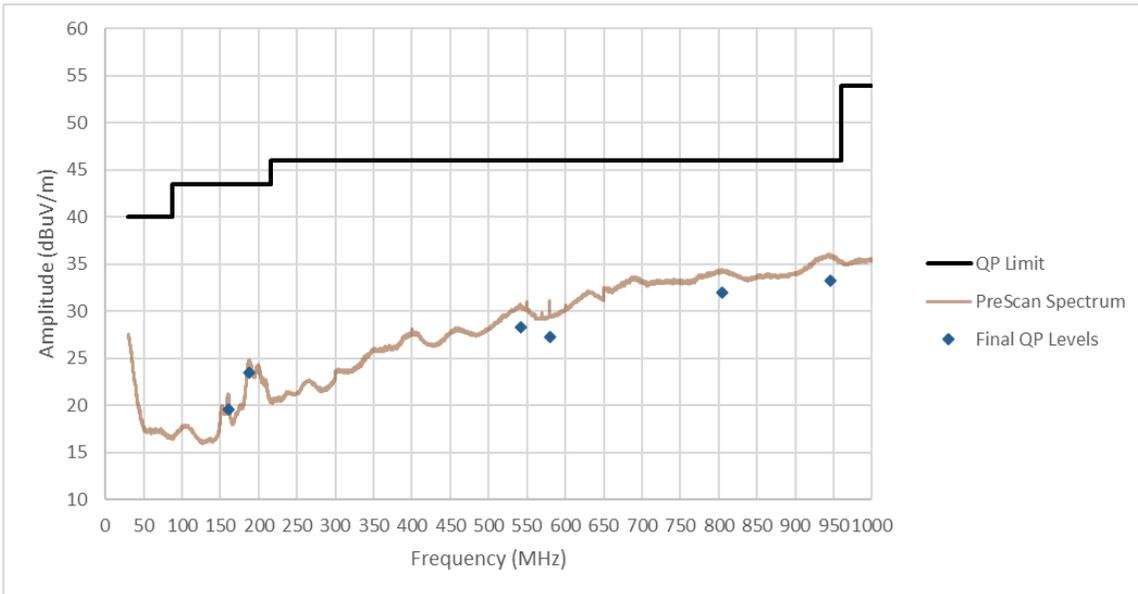


Figure RE13.3: Spectral data (B5.5 CH11)

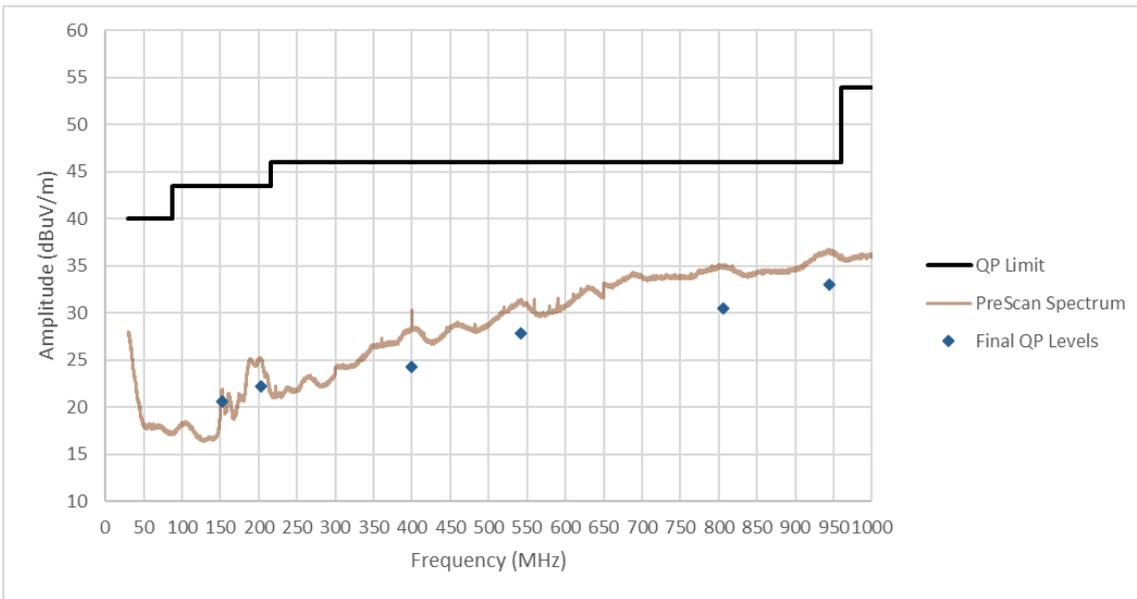


Figure RE13.4: Spectral data (B5.5 CH13)

Setup Photographs

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



Figure RE13.5: EUT test setup, front view

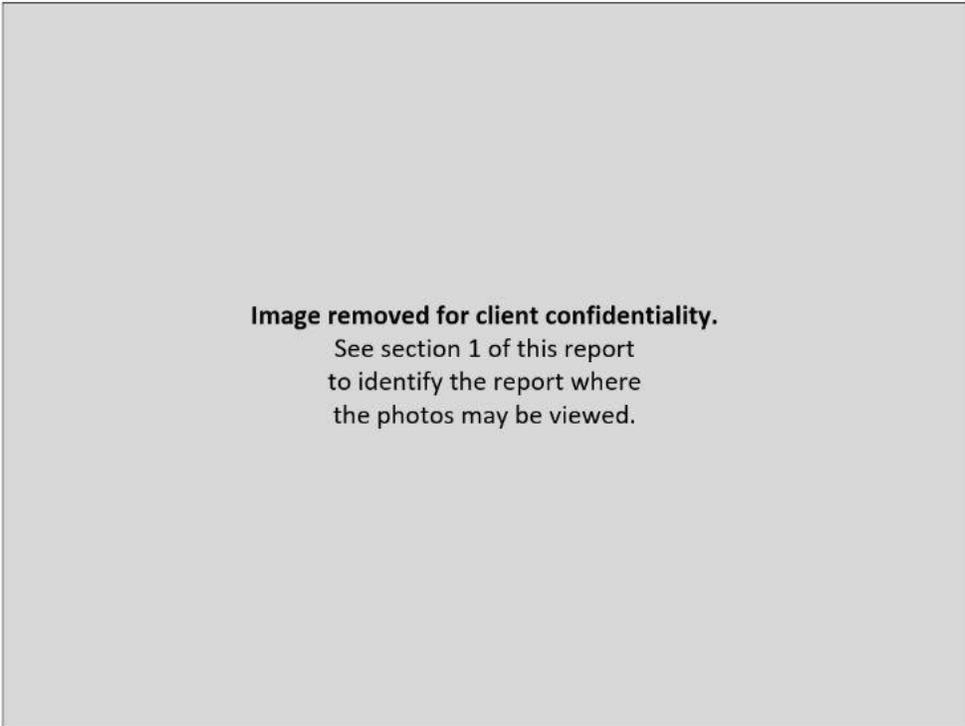


Figure RE13.6: EUT test setup, reverse view

This line is the end of the test record.

Test Record
Radiated Emission Test RE10
Project GCL385

Test Date(s) 25 May 2023
 Test Personnel David Kerr

Product Model A04724
 Serial Number tested 441084880

Operating Mode M8 (WiFi Tx)
 Arrangement A2 (Upwr)
 Input Power 5 Vdc

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

Frequency Range: 1 GHz to 2 GHz
Pass/Fail Judgment: PASS

Test record created by: Jim Solum
Date of this record: 13 Jun 2023

Original record, Version A.

Test Equipment

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
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10721	15-Aug-2022	15-Aug-2023

Table RE10.1: Test Equipment Used

Software Used:

Keysight PXE software A.32.06
 RE Signal Maximization Tool v2021Feb25.xlsx
 RE 1G to 18G Data AnalysisV1 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 tables show the selected final measurement data between 1 GHz and 2 GHz. It includes at least the six strongest emissions observed relative to the test limit, along with other data points of interest. Where a data point is highlighted in 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.

Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Polarity ---
1928.000	50.0	70.0	31.2	44.7	18.8	25.3	0	1000	*
1995.500	50.0	70.0	31.9	45.7	18.1	24.3	0	1000	*
2018.500	50.0	70.0	32.0	45.4	18.0	24.6	0	1000	*
2170.750	50.0	70.0	37.8	47.9	12.2	22.1	174	1751	HORZ
2176.000	50.0	70.0	33.2	46.8	16.8	23.2	-181	2242	HORZ
2200.000	50.0	70.0	32.0	45.6	18.0	24.4	0	1000	*

Table RE10.2: Emission summary (B5.5 CH 1)

Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Polarity ---
1980.750	50.0	70.0	31.8	45.6	18.2	24.4	149	3030	VERT
2049.750	50.0	70.0	31.8	45.1	18.2	24.9	-147	2288	VERT
2057.750	50.0	70.0	31.8	45.4	18.2	24.6	-106	2394	VERT
2083.500	50.0	70.0	31.6	45.3	18.4	24.7	-80	3839	HORZ
2193.500	50.0	70.0	31.6	45.4	18.4	24.6	88	3899	VERT
2198.000	50.0	70.0	31.7	45.7	18.3	24.3	-109	3883	HORZ

Table RE10.3: Emission summary (B5.5 CH 6)

Frequency (MHz)	Avg Limit (dBuV/m)	Pk Limit (dBuV/m)	Avg Level (dBuV/m)	Pk Level (dBuV/m)	Av Margin (dB)	Pk Margin (dB)	Azimuth (degree)	Height (mm)	Polarity ---
2002.750	54.0	74.0	32.2	46.1	21.8	27.9	80	3291	HORZ
2008.500	54.0	74.0	32.3	45.7	21.7	28.3	0	3291	*
2019.500	54.0	74.0	32.3	46.1	21.7	27.9	0	3291	*
2057.000	54.0	74.0	32.1	46.0	21.9	28.0	0	3291	*
2066.250	54.0	74.0	32.0	45.7	22.0	28.3	0	3291	*
2158.000	54.0	74.0	31.9	45.1	22.1	28.9	0	3291	*

Table RE10.4: Emission summary (B5.5 CH 11)

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)	---
1968.500	54.0	74.0	32.0	45.8	22.0	28.2	21	3530	*
1973.000	54.0	74.0	31.9	45.7	22.1	28.3	21	3530	*
2016.750	54.0	74.0	32.2	45.9	21.8	28.1	21	3530	*
2156.000	54.0	74.0	31.8	45.7	22.2	28.3	21	3530	*
2164.500	54.0	74.0	31.7	45.1	22.3	28.9	21	3530	HORZ
2175.000	54.0	74.0	31.8	45.4	22.2	28.6	21	3530	*

Table RE10.5: Emission summary (B5.5 CH 13)

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

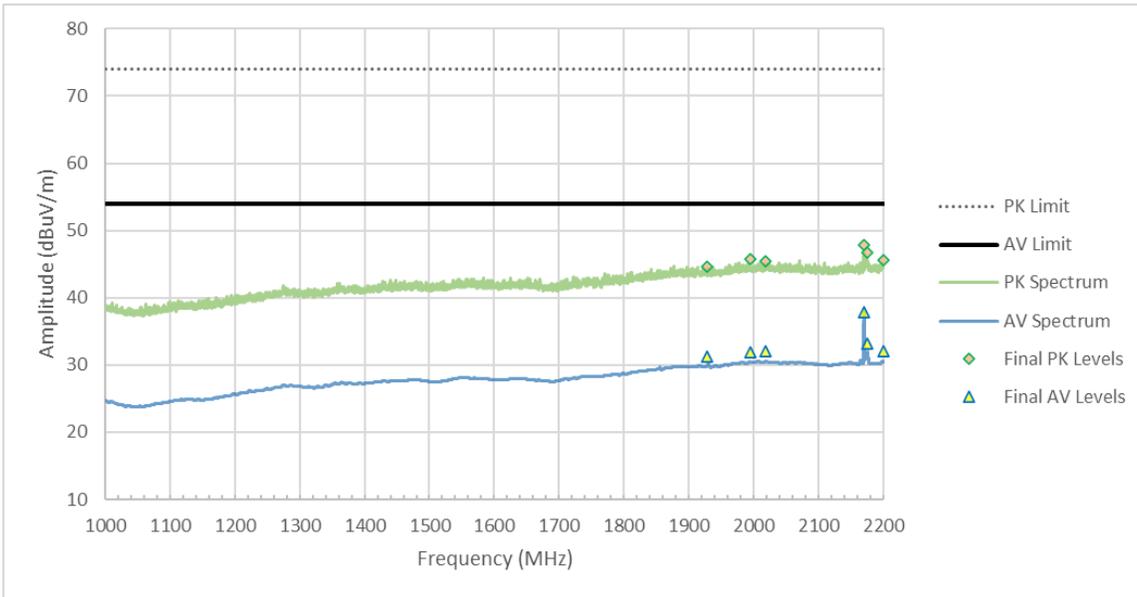


Figure RE10.1: Spectral data (B5.5 CH 1)

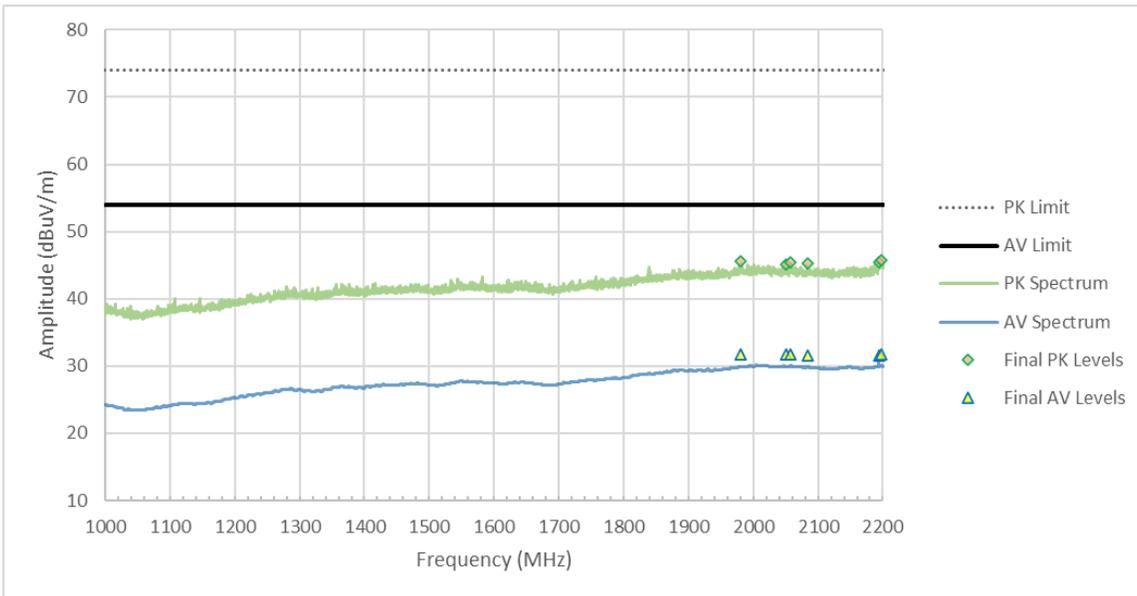


Figure RE10.2: Spectral data (B5.5 CH 6)

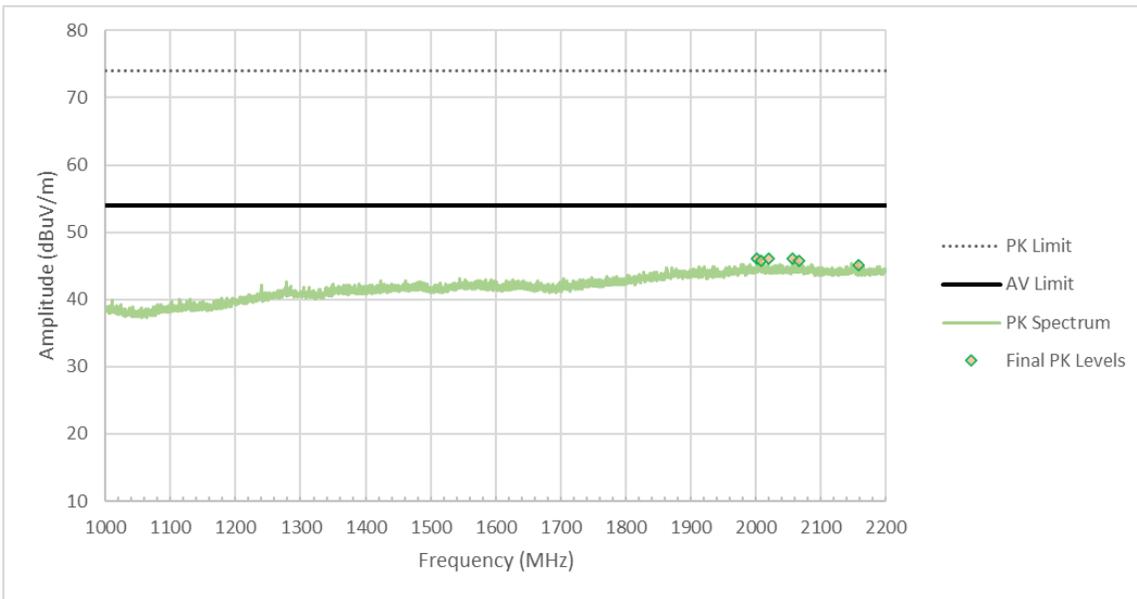


Figure RE10.3: Spectral data (B5.5 CH 11)

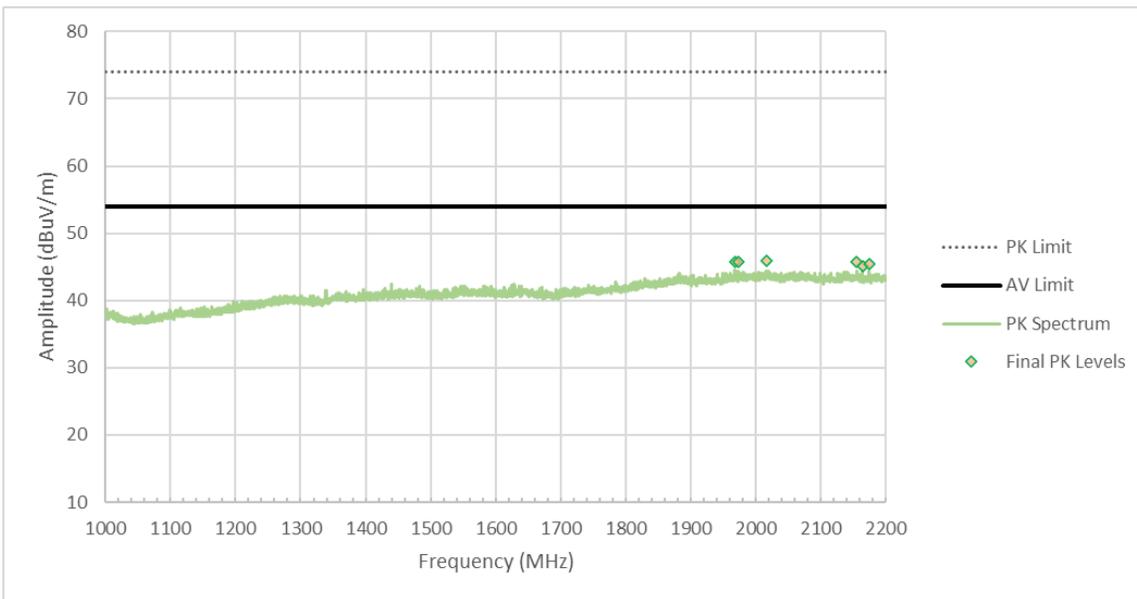


Figure RE10.4: Spectral data (B5.5 CH 13)

Setup Photographs

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



Figure RE10.5: EUT test setup, front view



Figure RE10.6: EUT test setup, reverse view

This line is the end of the test record.

Concluding Notes

This report stands as an integrated record of the tests performed and must be copied or distributed in its complete form. The reproduction of selected pages or sections separate from the complete report would require specific approval from the manager of the Garmin Compliance Lab.

This is the final page of the report.