Test Report 2022-034

Version C
Issued 27 Mar 2023

Project GCL-0305
Model Identifier A04600
Primary Test Standard
FCC part 15.225
RSS-210 Issue 10
ICES-003 Issue 7

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

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

ACCREDITED
CERTIFICATE #6162.01

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

1. Summary

The equipment or product described in section 5 of this report was tested at the Garmin Compliance Lab according to standards listed in section 6. The results are as follows.

Parameter	Description	Key Performance Values	Result	Data starts at page
Radiated emissions	Radio emissions that this device may generate via its strictures and connected cables that are not necessary for its operation and that may affect other radio communication	25.1 dB of margin to the Class B limit.	PASS	9
Transmitter spurious emissions	Emissions beyond the intended radio band while transmitting must be suppressed according to a limit that varies with frequency.	The amplitude margin was 6 dB or greater.	PASS with caveat	21
Frequency stability under extreme Conditions	The ability for the radio to accurately maintain carrier frequency stable with changes in temperature and supply voltage. [FCC 15.225 (e) and RSS-Gen at 6.11]	The Carrier frequency was stable within 0.01% of the target frequency.	PASS with caveat	25
Other Bandwidths	Bandwidth values are presented for 99% Occupied Bandwidth and Necessary Bandwidth	There are requirements to report these numbers, but they do not have performance limits.	Reported	27

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 2022-40. That report is treated as a part of this document by way of this reference.

2. Test Background

The testing reported here was performed at the Garmin Compliance Lab, an organization within Garmin International, located at 1200 E 151st St, Olathe Kansas, USA. The contact telephone number is +1.913.397.8200.

The testing was performed on behalf of the Garmin design group, a separate organization located at 1200 E 151st St, Olathe Kansas, USA. Witnesses from the business group included: None.

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

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

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

3. Report History and Approval

This report was written by Majid Farah and initially issued on 03 Feb 2023 as Version A.
Version B released on 1 Mar 2023 provides regulatory identifiers on the cover page, and removed some data regarding radios that are not within the subject of this report. It also provides additional bandwidth data.
Version C issued 27 Mar 2023 transferred additional sensitive materials to GCL Test Report 2023-040.

Report Technical Review: ______________________

David Arnett
Technical Lead EMC Engineer

Report Approval: ______________________

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

4. Test Sample Modifications and Special Conditions

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

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

5. Description of the Equipment Tested

5.1 Unique Identification

Product Model	A04600
Serial Numbers Tested	3431708344, 3431708548, 3431708479, 3431708421, 3431708497

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

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

5.2 Key Parameters

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

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

5.3 Operating modes

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

Mode 2: M2 (NFC-L). EUT linked to NFC reader pad and transmit data
Mode 5: M5 (BLE Tx). EUT in test mode-BLE Tx always On
Mode 8: M8 (ANT Tx). EUT in test mode- ANT Tx always On

5.4 EUT Arrangement

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

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

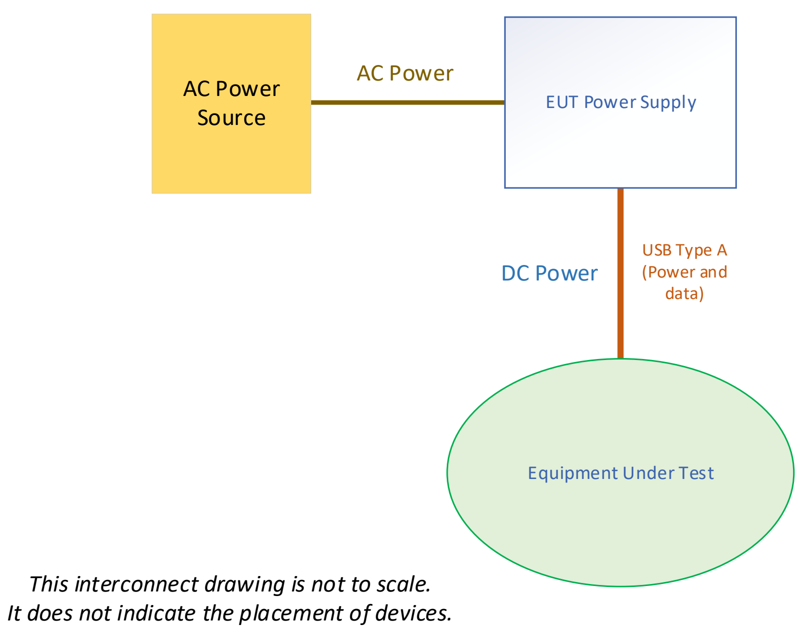

Figure 1: Block diagram of equipment arrangement A1

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

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

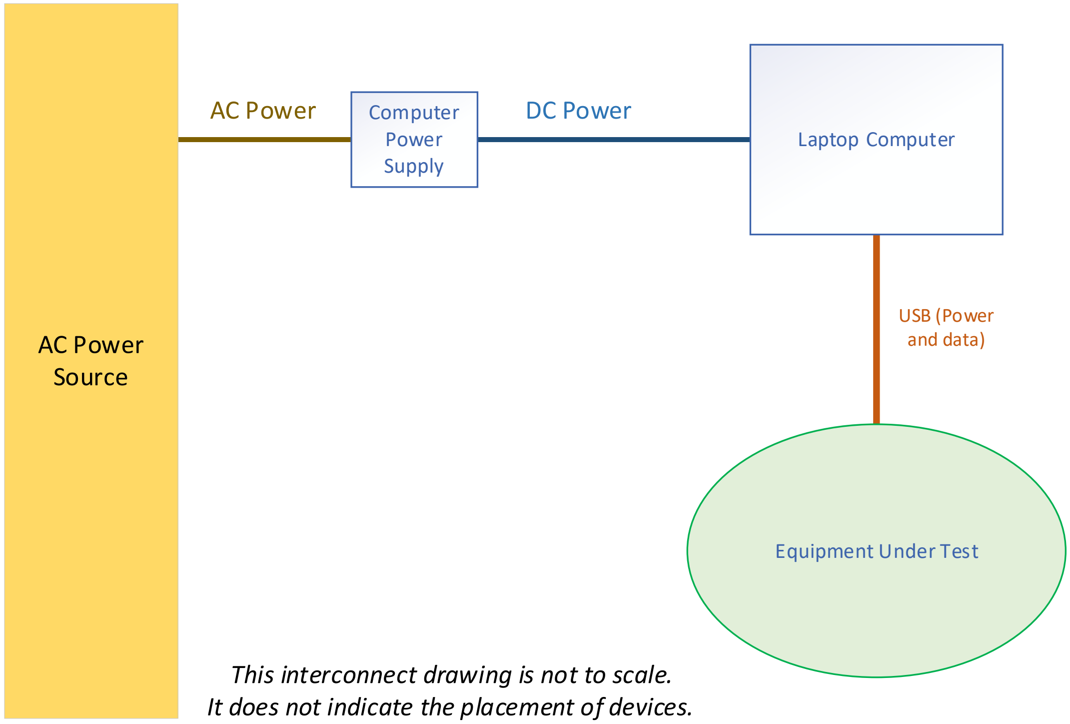

Figure 2: Block diagram of equipment arrangement A3

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

5.5 Associated Equipment (AE) used

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

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

5.6 Cables used

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

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

5.7 Additional EUT Information Provided by the Requestor

None

6 Test Standards Applied

6.1. Accredited Standards

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

FCC Part 15.225
ANSI C63.4: 2014
ANSI C63.10: 2013
ICES-003 Issue 7: 2020
RSS-GEN Issue 5 Amd 2
RSS-210 Issue 10 Amd 1
CISPR 32

6.2. Non-accredited Standards

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

(None)

6.3 Variances

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

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

6.4 Laboratory Accreditation

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

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

7 Measurement Instrumentation Uncertainty

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

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

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

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

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

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

8 Selected Example Calculations

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

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

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

8.1 AC Mains conducted emissions at 22 MHz
(Raw measurement) + (AMN factor) + (transmission loss) = Result

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

8.2 Radiated Emissions at 630 MHz
(Raw measurement) + (Antenna factor) + (transmission loss) = Result

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

8.3 Radiated Emissions at 2.7 GHz
(Raw measurement) + (Antenna factor) + (transmission loss) = Result

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

9 Environmental Conditions During Test

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

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

ANNEX

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

Test Record
Radiated Emission Test RE12
Project GCL0305

Test Date(s)	15 Dec 2022
Test Personnel	David Kerr assisted by Jim Solum
Product Model	A04600
Serial Number tested	3431708344
Operating Mode	M2 (NFC-L) Type A
Arrangement	A2 (NFC)
Input Power	USB 5 Vdc
Test Standards:	FCC Part 15, CISPR 32, ANSI C63.10 (as noted in Section 6 of the report).
Frequency Range:	150K to 30MHz
Pass/Fail Judgment:	**PASS**
Test record created by:	**David Kerr**
Date of this record:	**27 Dec 2022**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10720	3-Jan-2020	7-Jan-2023
PXE Receiver	Keysight	N9048B	MY59290135	21-Sep-2022	15-Sep-2023
SAC 3m, below 1 GHz	Frankonia	SAC3	F199004	25-Oct-2021	25-Oct-2024
Loop antenna, amplified	Schwarzbeck	FMZB 1519B	174	18-Jul-2022	15-Jul-2023
Barometer	Traceable	6453	221702700	3-Aug-2022	1-Aug-2024

Table RE12.1: Test Equipment Used

Software Used
PXE Firmware version A32.06
RE 150k to 30M Signal Maximization Tool V1 2021Mar17.xlsx
RE 150k to 30M XYZ_orientations_ TemplateV6.xlsm
GCL RE NFC 150k to 30M Data Analysis Template V1 2023Jan17.xlsx

Test Data

The radiated emission test process began with a preliminary scan at multiple turntable angles, and three antenna polarizations typically described as X, Y, and Z. Subsequent testing was done using the antenna polarization(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, 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. The designation of the X, Y, and Z antenna polarizations are reported by use of photographs.

The tables show the selected final measurement data between 150 kHz and 30 MHz. It includes at least the six strongest emissions observed relative to the test limit, along with other data points of interest. Where a data point is highlighted is yellow, this is an aid to indicate the data point(s) with the least margin to the test limit. The dbuA/m limits and measured dBuA/m values in the chart below are obtained from the dBuV/m limits and measured dBuV/m measured values. The two values differ by 51.52 dB based on the 377 Ohm characteristic impedance of free space. A positive margin value indicates that the emission was below the test limit. The test limits are for FCC & RSS-210 / ETSI 300 330 at 3m.

Frequency (MHz)	Limit (dBuV/m)	Limit (dBuA/m)	Measured (dBuV/m)	Measured (dBuA/m)	Margin (dB)	Azimuth (degree)	Height (mm)	Antenna Orientation
0.746	N/A	N/A	49.0	-2.5	N/A	-75	1500	Z
1.493	N/A	N/A	40.4	-11.1	N/A	-86	1500	Z
2.321	N/A	N/A	28.9	-22.6	N/A	-73	1500	Z
2.328	N/A	N/A	30.1	-21.4	N/A	-136	1500	X
2.983	N/A	N/A	35.5	-16.0	N/A	-104	1500	Z
13.560	104.0	52.5	62.5	11.0	41.5	-9	1500	X

Table RE12.2: Emission summary Emission summary (FCC / Canada)

Frequency (MHz)	Limit (dBuA/m)	Measured (dBuA/m)	Margin (dB)	Azimuth (degree)	Height (mm)	Antenna Orientation
0.746	26.2	-2.5	28.7	-75	1500	Z
1.493	25.7	-11.1	36.8	-86	1500	Z
2.321	25.2	-22.6	47.8	-73	1500	Z
2.328	25.2	-21.4	46.6	-136	1500	X
2.983	24.8	-16.0	40.8	-104	1500	Z
13.560	83.1	11.0	72.1	-9	1500	X

Table RE012.3: Emission summary (ETSI 300 330)

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

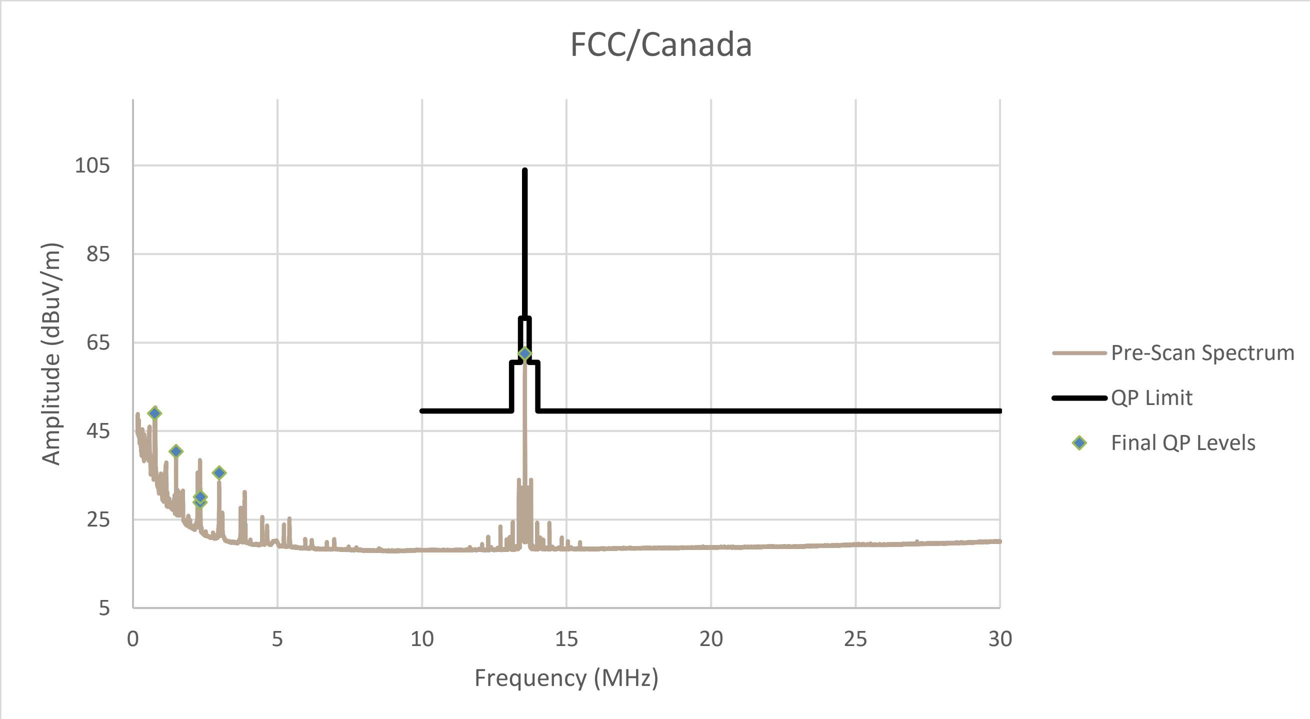

Figure RE12.1: Spectral data (FCC/Canada)

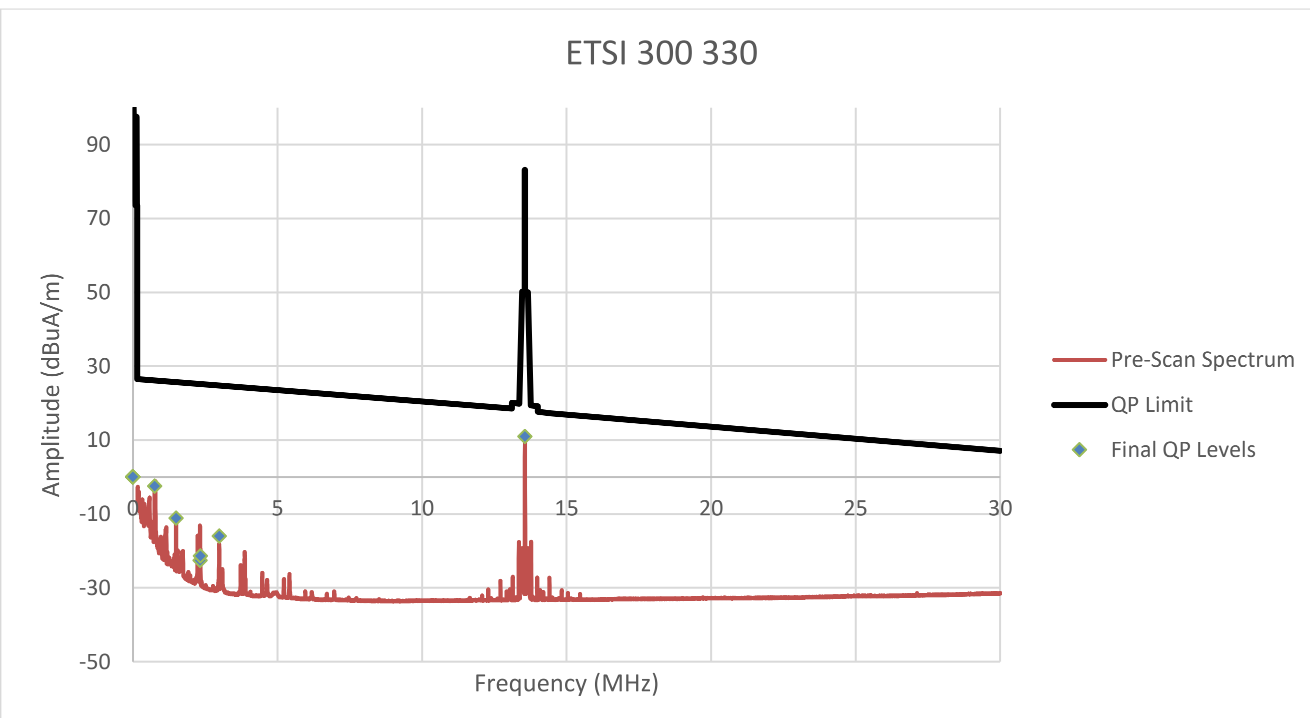

Figure RE12.2: (ETSI 300 330)

Setup Photographs

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

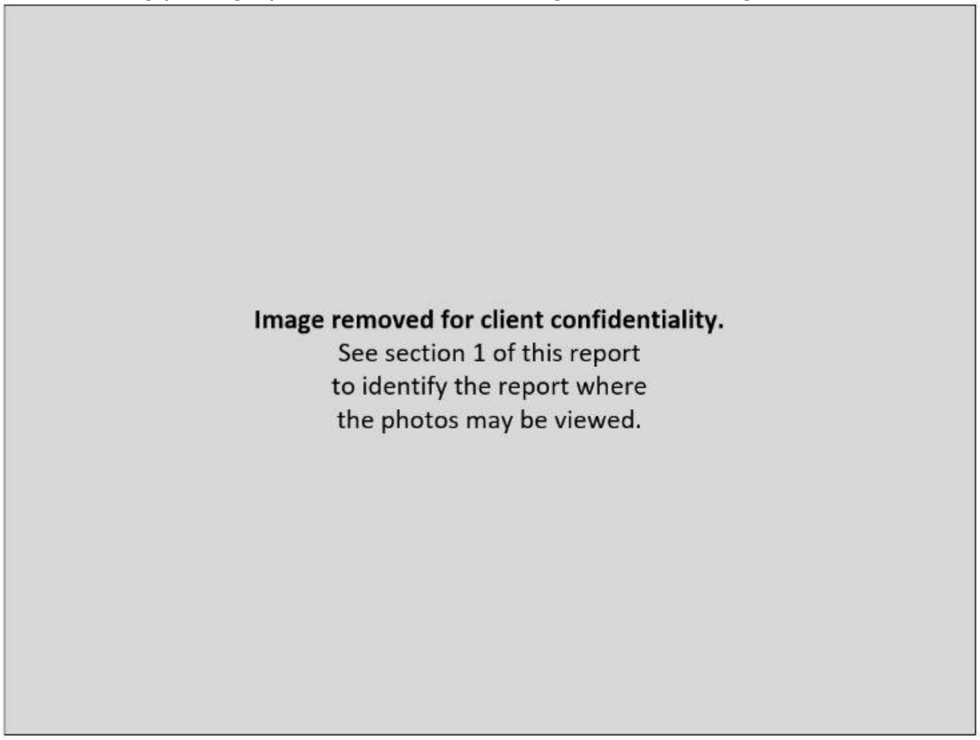

Figure RE012.3: EUT test setup (EUT Rear View, Antenna X Orientation)

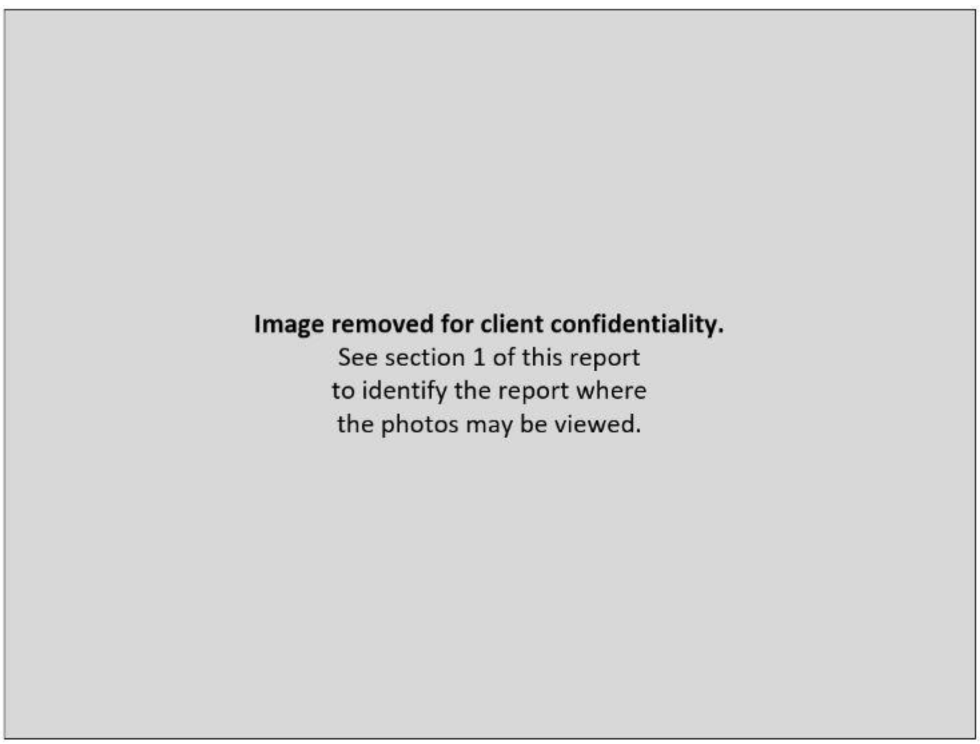

Figure RE012.4: EUT test setup (EUT Front View, Antenna X Orientation)

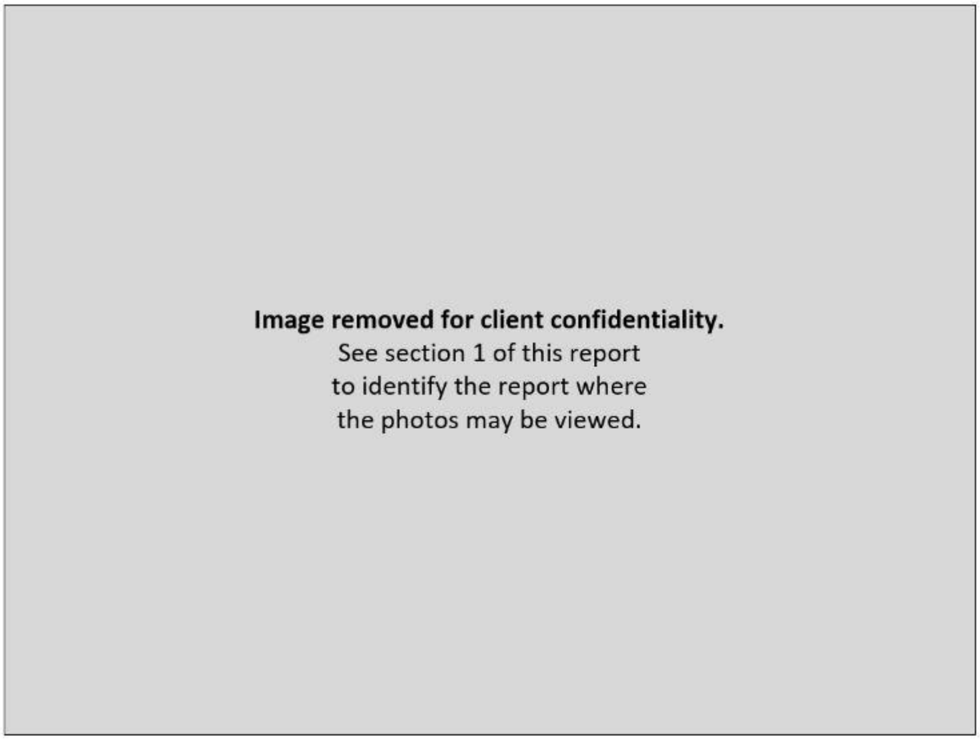

Figure RE012.5: EUT test setup (EUT Rear View, Antenna Y Orientation)

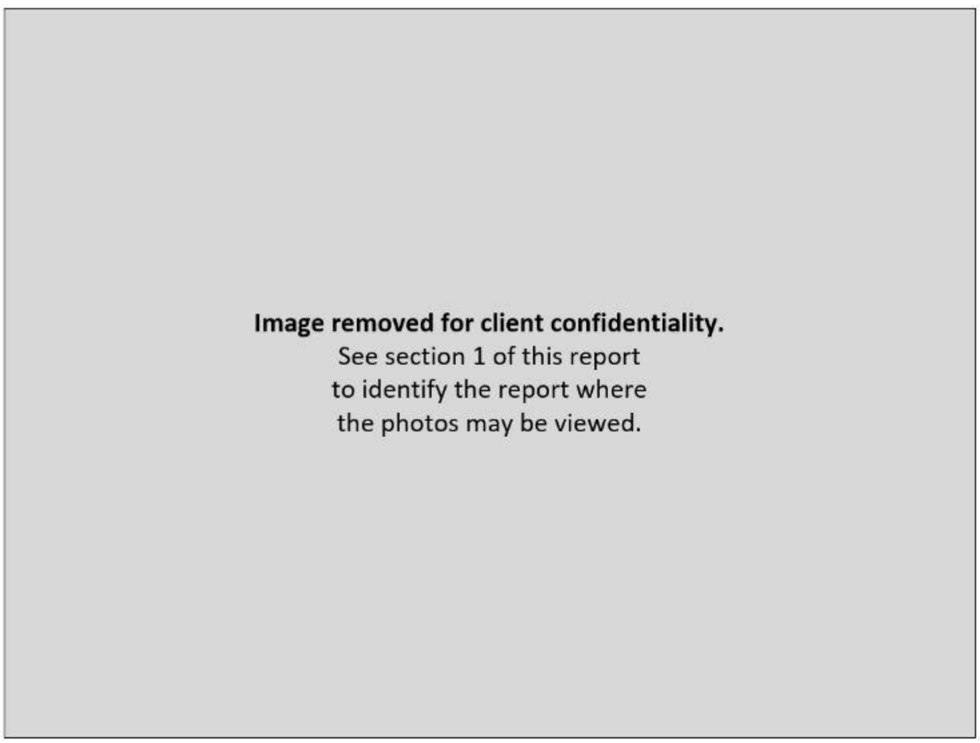

Figure RE012.6: EUT test setup (EUT Front View, Antenna Y Orientation)

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

Figure RE012.7: EUT test setup (EUT Rear View, Antenna Z Orientation)

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

Figure RE012.8: EUT test setup (EUT Front View, Antenna Z Orientation)

This line is the end of the test record.

Test Record
Radiated Emission Test RE13
Project GCL0305

Test Date(s)	15 Dec 2022
Test Personnel	David Kerr assisted by Jim Solum
Product Model	A04600
Serial Number tested	3431708344
Operating Mode	M2 (NFC-L) Type B
Arrangement	A2 (NFC)
Input Power	USB 5 Vdc
Test Standards:	FCC Part 15, ANSI C63.10, ETSI 300 330, RSS-210, RSS-GEN (as noted in Section 6 of the report).
Frequency Range:	150 kHz to 30 MHz
Pass/Fail Judgment:	**PASS**
Test record created by:	Jim Solum, David Kerr
Date of this record:	19 Jan 2023

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
Barometer	Traceable	6453	221702700	3-Aug-2022	1-Aug-2024
Loop antenna, amplified	Schwarzbeck	FMZB 1519B	00174	18-Jul-2022	15-Jul-2023
PXE Receiver	Keysight	N9048B	MY59290135	21-Sep-2022	15-Sep-2023
SAC 3m, below 1 GHz	Frankonia	SAC3	F199004	25-Oct-2021	25-Oct-2024
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10721	15-Aug-2022	15-Aug-2023

Table RE13.1: Test Equipment Used

Software Used

PXE Firmware version A.32.06
GCL RE 150k to 30M Signal Maximization Tool V1 2021Mar17.xlsx
GCL RE 150k to 30M XYZ_orientations_ TemplateV6.xlsm
GCL RE NFC 150k to 30M Data Analysis Template V1 2023Jan17.xlsx

Test Data

The radiated emission test process began with a preliminary scan at multiple turntable angles, and three antenna polarizations typically described as X, Y, and Z. Subsequent testing was done using the antenna polarization(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, 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. The designation of the X, Y, and Z antenna polarizations are reported by use of photographs.

The tables show the selected final measurement data between 150 kHz and 30 MHz. It includes at least the six strongest emissions observed relative to the test limit, along with other data points of interest. Where a data point is highlighted is yellow, this is an aid to indicate the data point(s) with the least margin to the test limit. The dbuA/m limits and measured dBuA/m values in the chart below are obtained from the dBuV/m limits and measured dBuV/m measured values. The two values differ by 51.52 dB based on the 377 Ohm characteristic impedance of free space. A positive margin value indicates that the emission was below the test limit. The test limits are for FCC & RSS-210 / ETSI 300 330 at 3m.

Frequency (MHz)	Limit (dBuV/m)	Limit (dBuA/m)	Measured (dBuV/m)	Measured (dBuA/m)	Margin (dB)	Azimuth (degree)	Height (mm)	Antenna Orientation
0.746	N/A	N/A	51.0	-0.5	N/A	-156	1500	X
1.493	N/A	N/A	44.3	-7.2	N/A	-129	1500	X
2.328	N/A	N/A	23.7	-27.8	N/A	-39	1500	Z
2.983	N/A	N/A	36.0	-15.5	N/A	-132	1500	X
13.560	104.0	52.5	62.8	11.3	41.2	-9	1500	X
14.408	49.5	-2.0	24.4	-27.1	25.1	-10	1500	X

Table RE013.2: Emission summary (FCC / Canada)

Frequency (MHz)	Limit (dBuA/m)	Measured (dBuA/m)	Margin (dB)	Azimuth (degree)	Height (mm)	Antenna Orientation
0.746	26.2	-0.5	26.7	-156	1500	X
1.493	25.7	-7.2	32.9	-129	1500	X
2.328	25.2	-27.8	53.0	-39	1500	Z
2.983	24.8	-15.5	40.3	-132	1500	X
13.560	83.1	11.3	71.8	-9	1500	X
14.408	17.3	-27.1	44.4	-10	1500	X

Table RE013.3: Emission summary (ETSI 300 330)

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

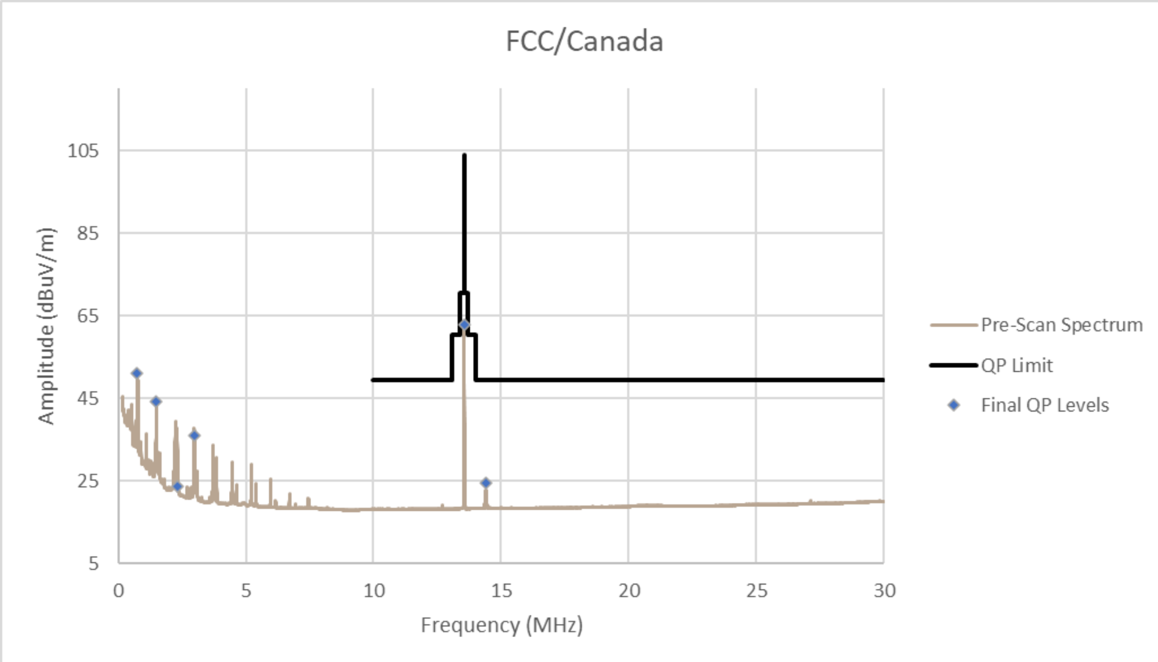

Figure RE013.1: Spectral data (FCC/Canada)

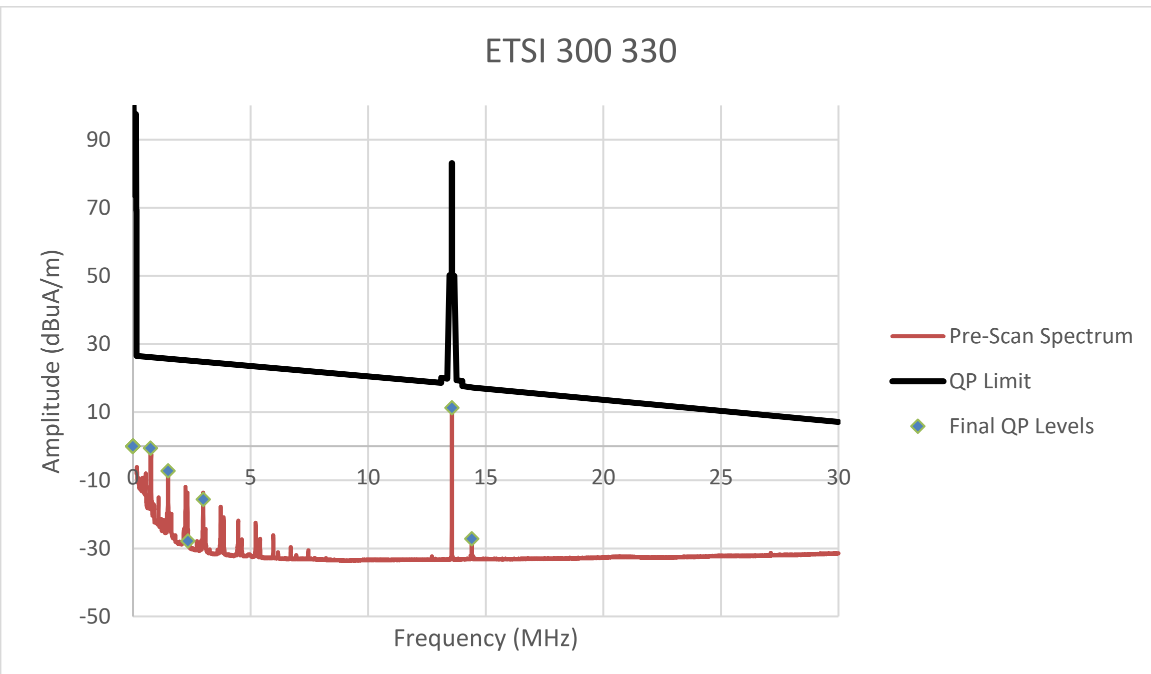

Figure RE013.2: Spectral data (ETSI 300 330)

Setup Photographs

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

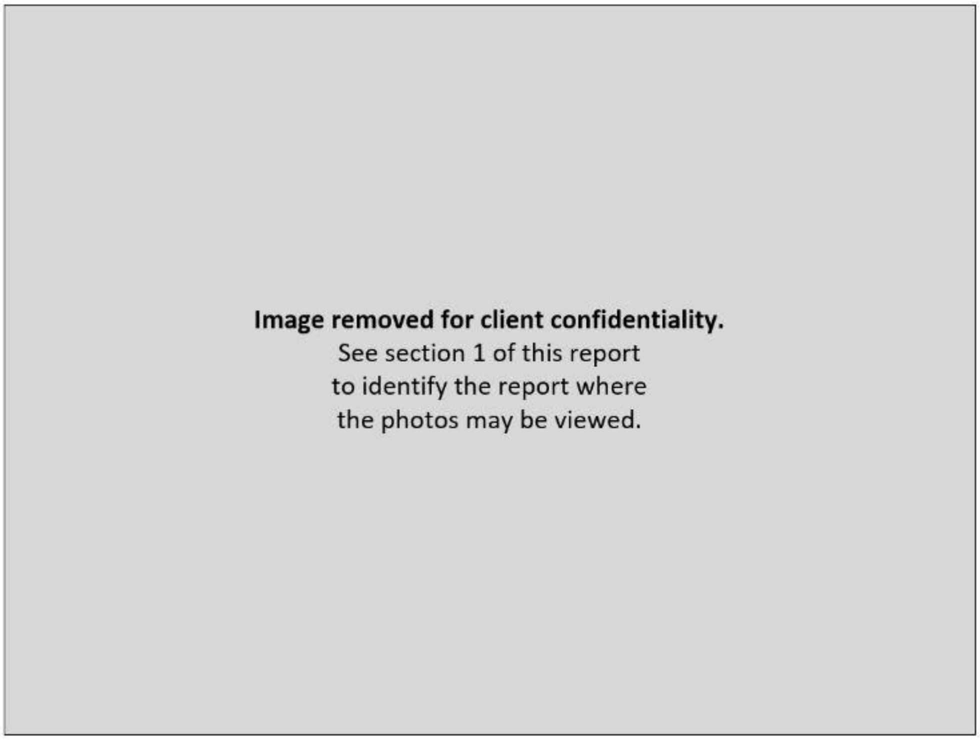

Figure RE013.3: EUT test setup (EUT Rear View, Antenna X Orientation)

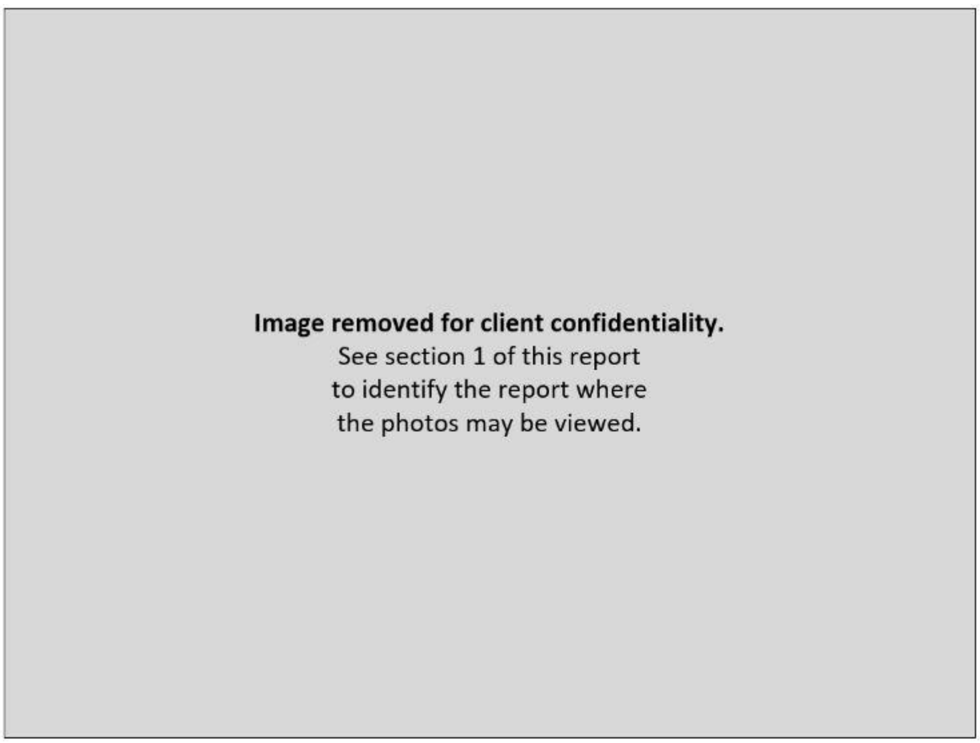

Figure RE013.4: EUT test setup (EUT Front View, Antenna X Orientation)

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

Figure RE013.5: EUT test setup (EUT Rear View, Antenna Y Orientation)

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

Figure RE013.6: EUT test setup (EUT Front View, Antenna Y Orientation)

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

Figure RE013.7: EUT test setup (EUT Rear View, Antenna Z Orientation)

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

Figure RE013.8: EUT test setup (EUT Front View, Antenna Z Orientation)

This line is the end of the test record.

Test Record

Radiated Emission Test RE03E
Project GCL0305

Test Date(s) 31 Jan – 1 Feb 2023
Test Personnel David Kerr assisted by Jim Solum

Product Model A04600
Serial Number tested 3431708344

Operating Mode M1 (NFC)
Arrangement A2 (NFC)
Input Power Internal battery power

Test Standards: FCC Part 15, ANSI C63.10, RSS-GEN, RSS-210 (as noted in Section 6 of the report).

Frequency Range: 30 MHz to 140 MHz
Pass/Fail Judgment: PASS

Test record created by: David Arnett
Date of this record:
Original record, Version A.

Test Equipment

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
Tape measure, 1" x 33'	Lufkin	PHV1410CMEN	10720	3-Jan-2020	7-Jan-2023
PXE Receiver	Keysight	N9048B	MY59290135	21-Sep-2022	15-Sep-2023
SAC 3m, below 1 GHz	Frankonia	SAC3	F199004	25-Oct-2021	25-Oct-2024
Antenna, Biconilog, 30M-6 GHz	ETS Lindgren	3142E	00233201	19-Jul-2022	15-Jul-2024

Table RE03E.1: Test Equipment Used

Software Used: Keysight PXE software A.32.06, RE Signal Maximization Tool v2021Feb25.xlsx

Test Data

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

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

The table shows the selected final measurement data between 30 MHz and 140 MHz, covering the 10th harmonic of the NFC radio. It includes at least the six strongest emissions observed relative to the test limit, along with other data points of interest. Where a data point is highlighted is yellow, this is an aid to indicate the data point(s) with the least margin to the test limit. A positive margin value indicates that the emission was below the test limit. The test limit is the Composite FCC Class B Limit at 3m.

Frequency (MHz)	Limit (dBuV/m)	Measured (dBuV/m)	Margin (dB)	Azimuth (degree)	Height (mm)	Antenna Polarity	Sample Orientation
30.000	40.0	34.0	6.0	-182	2465	VERT	Z
40.680	40.0	25.4	14.6	45	2667	VERT	Y
55.290	40.0	17.8	22.2	-128	1891	HORZ	Y
59.400	40.0	18.7	21.3	135	2847	VERT	Y
63.480	40.0	17.4	22.6	-83	2195	VERT	Y
67.590	40.0	17.8	22.2	-108	1624	VERT	Y
121.200	43.5	29.0	14.5	65	1751	HORZ	Z

Table RE03E.2: Emission summary

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

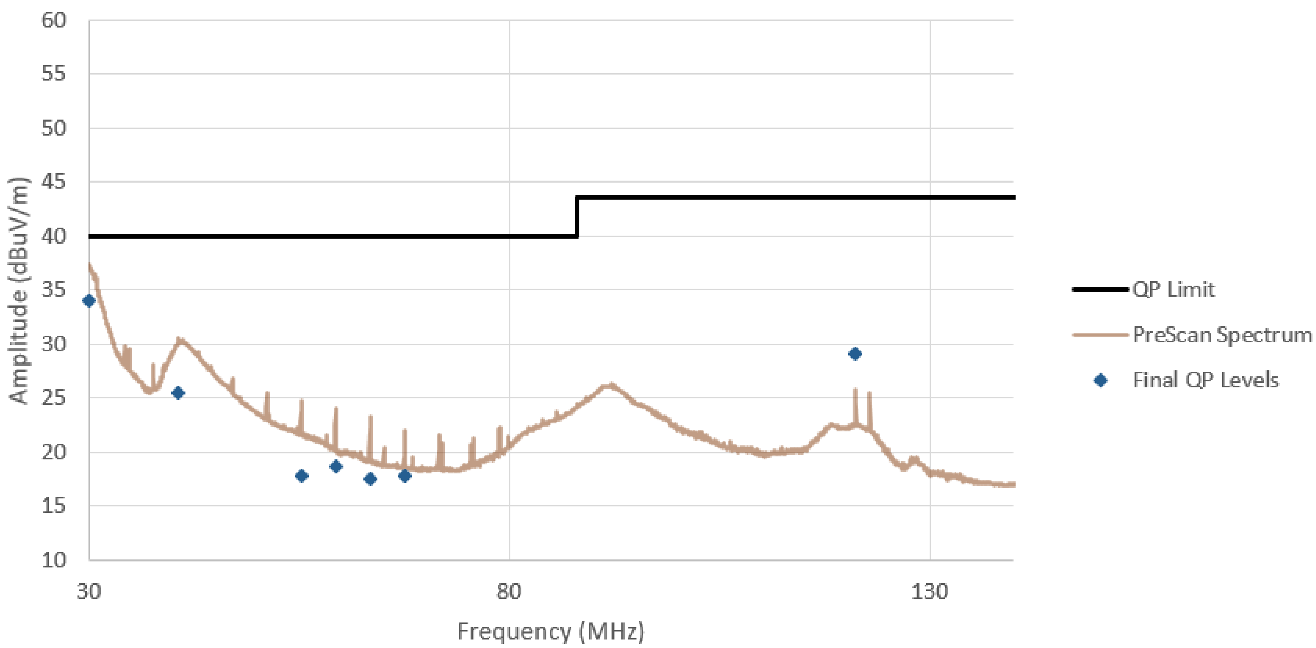

Figure RE03E.1: Spectral data

Setup Photographs

The following photographs show the EUT configured and arranged in the manner in which it was measured. The sample was strapped to the face of an NFC reader, and this pair of items placed in a green support vise for stable 3-axis mechanical positioning. The reader was attached by its ferrited USB cable to a laptop computer that enabled its NFC Reading activity.

Figure RE03E.4 shows the unit in the Y orientation. In the X orientation, the square green face of the support vise closest to the computer would have been on the table. The vise handle, pointing left in figure RE03E.3 farthest from the computer, would have been pointing up. In that X orientation, the operational face of the black NFC reader would have been parallel with the chamber floor. The Z orientation is mutually orthogonal to these two, so that the face of the green vise facing the camera in figure RE03E.4 would have been on the table.

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

Figure RE03E.2: EUT test setup, front view

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

Figure RE03E.3: EUT test setup, reverse view

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

Figure RE03E.4: EUT test setup detail, Y orientation

This line is the end of the test record.

Test Record
Transmitter Frequency Stability
Test IDs TR21
Project GCL-0305

Test Date(s)	12 - 13 Jan 2023
Test Personnel	Majid Farah and Jim Solum supervised by David Arnett
Product Model	A04600
Serial Number tested	3431708497 and 3431708344
Operating Mode	M2 (NFC-L)
Arrangement	A1 (PwrA)
Nominal Input Power	5 Vdc
Test Standards:	FCC part 15, RSS-GEN, RSS-210, ANSI C63.10 (as noted in Section 6 of the report)
Radio Protocol	NFC
Pass/Fail Judgment:	**PASS with caveat**
Test record created by:	**Majid Farah**
Date this record:	**19 Jan 2023**

Original record, Version A.

Test Equipment Used

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

Table TR21.1: Equipment used

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

Test Method

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

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

The sample uses NFC technology with a carrier at 13.56 GHz. For continuous transmission, the sample needs to be at a close distance with an NFC card Reader along entire test. The test sample was placed in a thermal chamber and connected to an appropriate dc power source. A near-field probe was placed near the sample then connected by a cable to the PXE analyzer. The analyzer was set up to detect radio signals from the test sample in a way to read carrier frequency with high resolution. The Standard indicated carrier frequency stability shall not exceed 0.01% of operation frequency.

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

Caveat

The NFC transceiver under test only operates when in the close vicinity of an NFC Reader. In this test, the client provided the ACR1252 manufactured by Advanced Card Systems as described in section 5.5 of the test report.

Emissions presented here show the combined signals from the NFC reader and the device under test. Signals for each were not distinguishable during test. Per the client, the device under test matches its transmitting frequency to correspond to that of the reader device. The data presented here, and the conclusions drawn, apply to the device under test and the NFC Reader when tested together as a system.

Test Data

The various standards require observation of the stability for transmission frequency and/or power at certain environmental extremes. The reference is performance on nominal input voltage and a temperature of 20 °C. Where the standards cited here apply different limits or conditions, the most stringent limits and conditions have been applied.

During NFC test mode, each measurement was made conducted from a near field probe located at a close distance to the sample and NFC reader. The sample needs to be attached to an NFC reader for continuous transmission.

Yellow highlight indicates the maximum and minimum measured carrier frequency. The maximum frequency measured was 13,559,949 Hz and the minimum was 13,559,792 Hz. The margin to high side of limit is 1407 Hz and margin for low side of the limit is 1148 Hz.

			NFC carrier frequency (HZ)			
Tx Mode	Temp	Volts	Time interval (minute)			
	˚C	Vdc	0	2	5	10
NFC	50	5	13,559,796	13,559,794	13,559,793	13,559,792
NFC	40	5	13,559,796	13,559,800	13,559,803	13,559,805
NFC	30	5	13,559,825	13,559,828	13,559,832	13,559,836
NFC	20	5	13,559,868	13,559,867	13,559,869	13,559,872
NFC	20	4.25	13,559,873	N/A	N/A	N/A
NFC	20	5.75	13,559,873	N/A	N/A	N/A
NFC	10	5	13,559,908	13,559,907	13,559,907	13,559,908
NFC	0	5	13,559,938	13,559,937	13,559,936	13,559,937
NFC	-10	5	13,559,946	13,559,948	13,559,949	13,559,949
NFC	-20	5	13,559,927	13,559,934	13,559,935	13,559,935

Table TR21.6 Carrier frequency measurement for NFC transmission during temperature and voltage variations

Setup Block Diagram

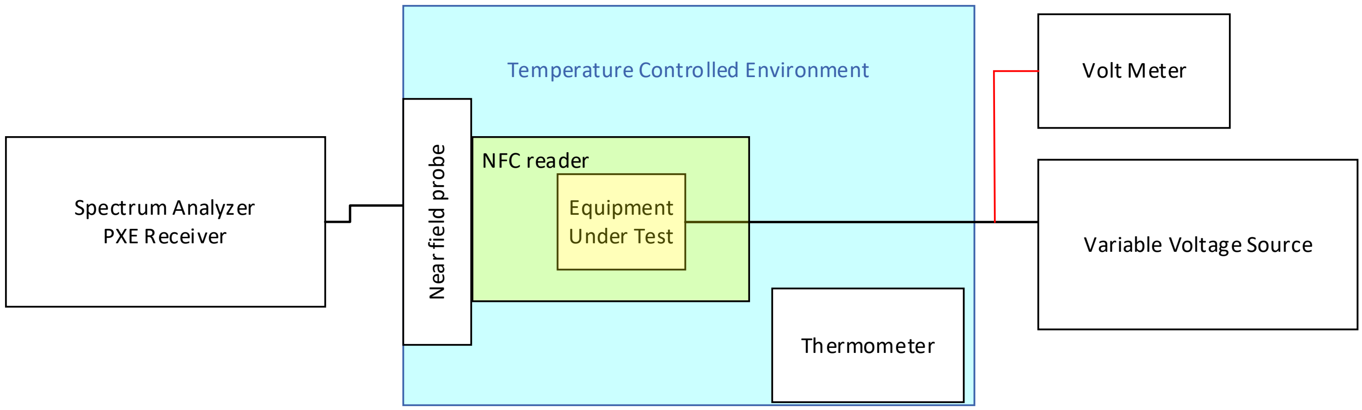

Figure TR21.6: Schematic drawing of the test equipment setup for NFC

This line is the end of the test record.

Test Record
Other Bandwidth Tests
Test IDs TR22
Project GCL-0305

Test Date(s)	27 Feb 2023
Test Personnel	David Arnett
Product Model	A04600
Serial Number tested	3431708344
Operating Mode	M2 (NFC-L)
Arrangement	A1 (PwrA)
Input Power	5V dc
Test Standards:	FCC Part 2.202, ANSI C63.10, TRC-43, RSS-GEN (as noted in Section 6 of the report).
Radio Protocol	NFC
Radio Band	13.56 MHz
Pass/Fail Judgment:	**Reported**
Test record created by:	**David Arnett**
Date of this record:	**28 Feb 2023**

Original record, Version A.

Test Equipment Used

Description	Make	Model #	Serial #	Last Cal/Ver	Next Due
PXE 44GHz	Keysight	N9048B	MY59500016	2-Feb-2022	10-Mar-2023

Table TR22.1

Test Software used: Keysight MXE System Code rev. A.33.03.

Background
There are regulatory requirements to present two additional types of bandwidth analyses: 99% Occupied Bandwidth and Necessary Bandwidth. There are no limits or functional requirements around these data, beyond a reporting requirement. The contents of this test record are for information, and do not affect compliance of the devices that are the subject of this report.

Test Setup

This block diagram shows the test equipment setup.

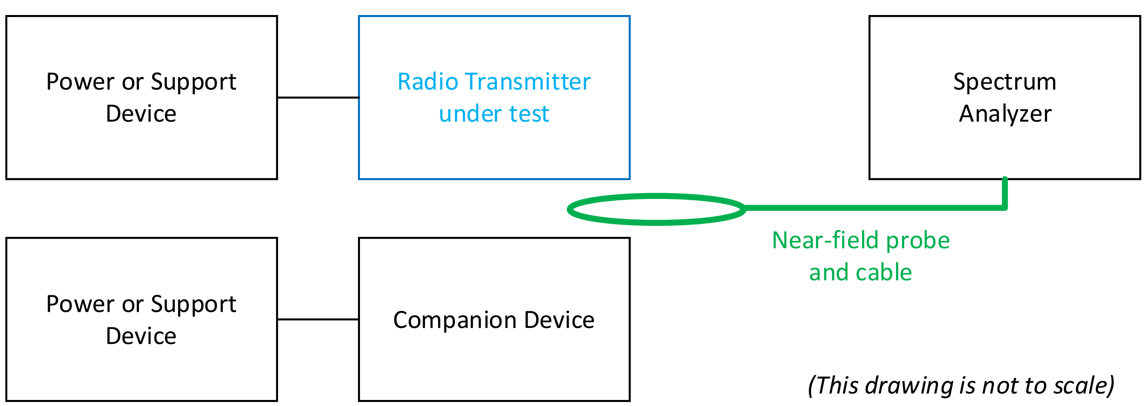

Figure TR22.1: Test setup

Caveat

The NFC transceiver under test only operates when in the close vicinity of an NFC Reader. In this test, the client provided the ACR1252 manufactured by Advanced Card Systems as described in section 5.5 of the test report.

Emissions presented here show the combined signals from the NFC reader and the device under test. Signals for each were not distinguishable during test. Per the client, the device under test matches its transmitting frequency to correspond to that of the reader device. The data presented here, and the conclusions drawn, apply to the device under test and the NFC Reader when tested together as a system.

Occupied Bandwidth, 99% Test Method

During this test the transmitter is coupled to a companion device. A link established and maintained. A near-field loop probe is placed between the device under test and the companion device. The probe output is fed directly 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. The analysis threshold for this test was the bandwidth containing 99% of the observed power using the ANSI C63.10 method. The measured bandwidth data are in bold font and have kHz as their units of measure.

NFC Type	99% OBW
----	kHz
A	4.949
B	3531

Table TR22.2: Summary of 99% Occupied Bandwidth Data, Type A and Type B NFC modes

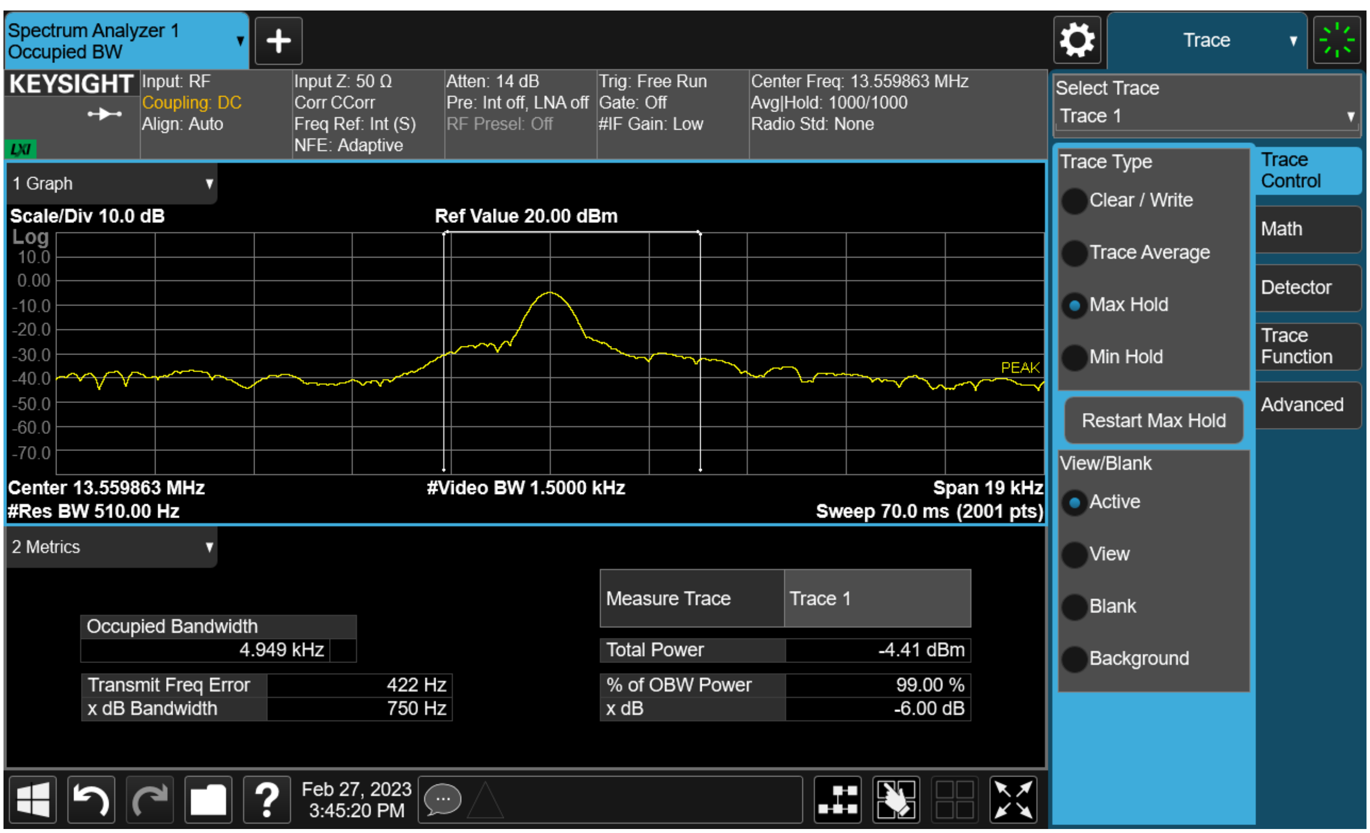

Figure TR22.1: Occupied bandwidth data for Type A NFC

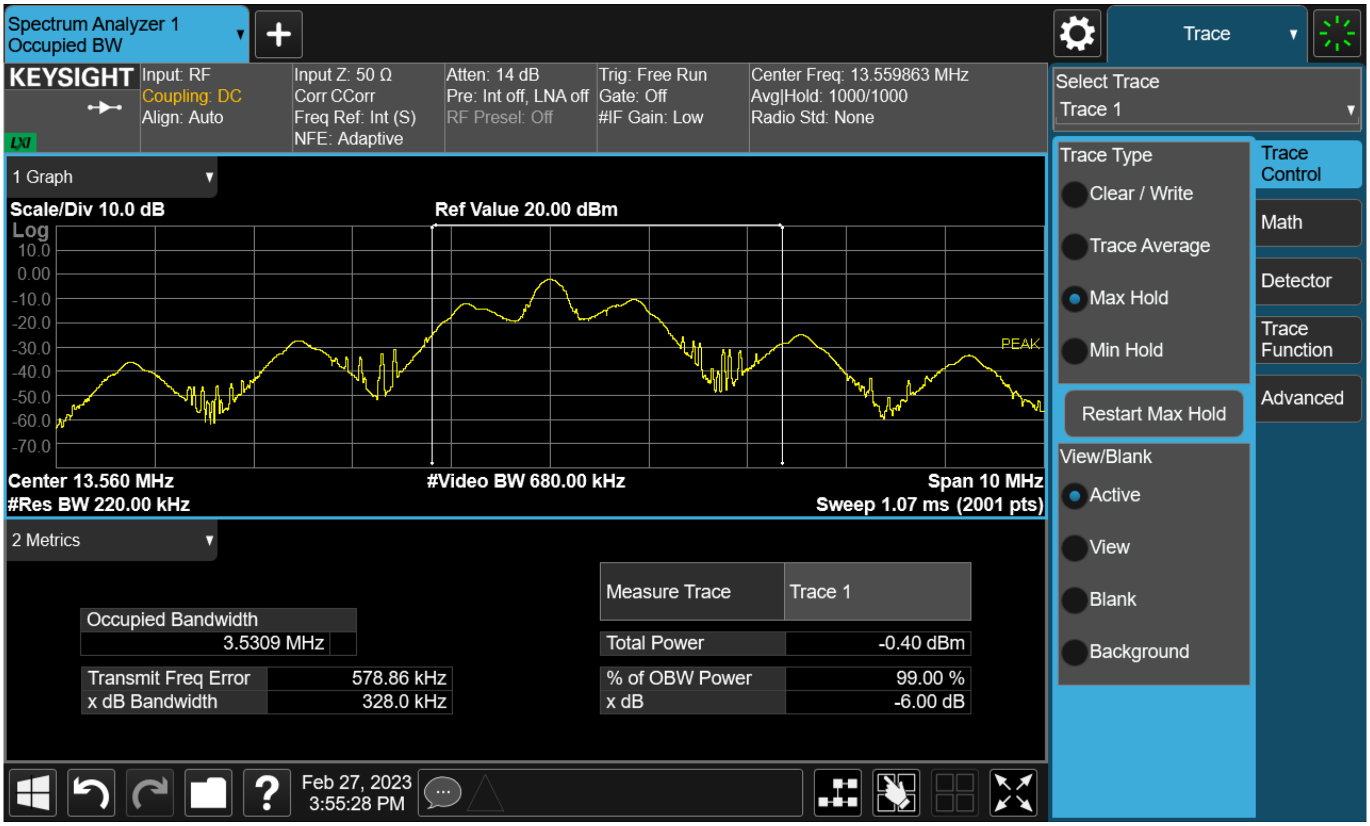

Figure TR22.2: Occupied bandwidth data for Type B NFC

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 approach for NFC is also different but is consistent between the US and Canadian standards. The tables below will show the analysis for most of the radios signals as a combined approach, then separately analyze the results for IEEE 802.11g and n systems. The tables below may include radio protocols that are not part of the product being evaluated.

The radio modulation schemes for Ant, for the various Bluetooth protocols, and for IEEE 802.11 b WiFi are a mix of Phase Shift Key (PSK) and Quadrature Amplitude Modulation (QAM) techniques. The Necessary Bandwidth calculations use the equations from 47CFR Part 2.202(g) table section 6. We have set the variable K=1, which leaves the equation for both PSK and QAM as:

$$B_N = 2R / Log_2(S)$$

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

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

Table TR22.101: 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 TR22.102: 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 TR22.103: Necessary Bandwidth for IEEE 802.11 b Radio Protocol (FCC and TRC-43)

Radio Type	Sub-type	R Mbps	K	S	LogBase2 of (S)	BN (MHz)
802.11 g	6	6	1	2	1	12
	9	9	1	2	1	18
	12	12	1	4	2	12
	18	18	1	4	2	18
	24	24	1	16	4	12
	36	36	1	16	4	18
	48	48	1	64	6	16
	54	54	1	64	6	18
802.11 n	MCS0	7.2	1	2	1	14.4
	MCS1	14.4	1	4	2	14.4
	MCS2	21.7	1	4	2	21.7
	MCS3	28.9	1	16	4	14.5
	MCS4	43.3	1	16	4	21.7
	MCS5	57.8	1	64	6	19.3
	MCS6	65	1	64	6	21.7
	MCS7	72.2	1	64	6	24.1

Table TR22.104: Necessary Bandwidth for IEEE 802.11 g and n 20 MHz Radio Protocols (FCC)

As a note, the bit rate for IEEE 802.11 n WiFi is calculated based on the IEEE standard's short guard interval of 400 nsec. If only the long guard interval of 800 nsec were implemented, the bit rate for MCS7would decrease to 65 Mbps for a Necessary Bandwidth of 21.7 MHz.

The TRC-43 method for OFDM signals simply multiplies the number of subcarriers, K, and the subcarrier spacing, N_S. In both cases, Ns is 312.5 kHz. The count of subcarriers includes nulls. So for example, 802.11 n uses 4 pilot subcarriers, 52 data subcarriers, and one null suppressed subcarrier in the middle for 57 total subcarrier channels.

$B_N = N_S * K$

Radio Type	Ns (MHz)	K	BN (MHz)
802.11g	0.3125	53	16.6
802.11n	0.3125	57	17.8

Table TR22.105: Necessary Bandwidth for IEEE 802.11 g and n 20 MHz Radio Protocols (TRC-43)

NFC is a 13.56 MHz communication protocol that uses telegraphy-style amplitude modulation of the carrier to transmit data. It uses Miller (Type A) or Manchester (Type B) encoding. In Miller coding, one symbol occurs in each bit time, whereas in Manchester coding two symbols are typically used for each data bit to improve synchronization. This aspect of the Manchester-encoded baud rate is quantified here using the variable C (for coding).

The standards cited define the Necessary Bandwidth, BN, for telegraphy amplitude modulation as:

$B_N = B * K$

where B is the Baud Rate and K is 3 for a non-fading channel. Since Manchester encoding doubles the underlying Baud rate, we will set C = 2 for Manchester encoding and C = 1 for Miller encoding. The formula then becomes:

$B_N = B * C * K$

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

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.