

RF Test Report

Project Number: 5028090**Offer Number: SUW-202302004095****Report Number: 5028090EMC01****Revision Level: 1****Client: UTEC, Inc.****Equipment Under Test: Refrigerated Shipping Container Controller****Product Name: Micro-Link 5 Controller****Model: MICROLINK5B****FCC ID: 2AK6N-MICROLINK5B****IC: 703A-MICROLINK5B****Applicable Standards: FCC Part 15 Subpart C, § 15.247****RSS-247, Issue 3, August 2023****RSS-GEN, Issue 5, February 2021, Amendment 2****ANSI C63.10:2013****Report issued on: 17 November 2023****Test Result: Compliant**

FOR THE SCOPE OF ACCREDITATION UNDER CERTIFICATE NUMBER: 3212.01

Report must not be used by the client to claim product certification, approval, or endorsement by A2LA, NIST, or any agency of the Federal Government.

Prepared by:


Daniel Alvarez, RF/EMC Sr. Staff Engineer

Reviewed by:


Martin Taylor, RF/EMC Project Engineer

Remarks: This document is issued by the Company subject to its General Conditions of Service printed overleaf, available on request or accessible at <http://www.sgs.com/en/Terms-and-Conditions.aspx>. And for electronic format documents, subject to Terms and Conditions for Electronic Documents at <http://www.sgs.com/en/Terms-and-Conditions/terms-e-document.aspx>.

Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents. This document cannot be reproduced except in full, without prior written approval of the Company. Any unauthorized alteration, forgery or falsification of the content or appearance of this document is unlawful, and offenders may be prosecuted to the fullest extent of the law. Unless otherwise stated the results shown in this test report refer only to the sample(s) tested and such sample(s) are retained for a maximum of 30 days only.

Table of Contents

1	SUMMARY OF TEST RESULTS	4
1.1	MODIFICATIONS REQUIRED FOR COMPLIANCE	4
2	GENERAL INFORMATION.....	5
2.1	CLIENT INFORMATION	5
2.2	TEST LABORATORY	5
2.3	GENERAL INFORMATION OF EUT	5
2.4	OPERATING MODES AND CONDITIONS	5
2.5	EUT CONNECTION BLOCK DIAGRAM – CONDUCTED MEASUREMENTS.....	6
2.6	EUT CONNECTION BLOCK DIAGRAM – RADIATED MEASUREMENTS	6
2.7	SYSTEM CONFIGURATIONS	6
2.8	CABLE LIST	6
3	OCCUPIED BANDWIDTH	7
3.1	TEST RESULT.....	7
3.2	TEST METHOD.....	7
3.3	TEST SITE	7
3.4	TEST EQUIPMENT	7
3.5	TEST DATA – 20dB BANDWIDTH / 99% BANDWIDTH.....	8
4	PEAK OUTPUT POWER	10
4.1	TEST RESULT.....	10
4.2	TEST METHOD.....	10
4.3	TEST SITE	10
4.4	TEST EQUIPMENT	10
4.5	TEST DATA.....	10
5	CONDUCTED SPURIOUS EMISSIONS / BAND EDGE.....	12
5.1	TEST RESULT.....	12
5.2	TEST METHOD.....	12
5.3	TEST SITE	12
5.4	TEST EQUIPMENT	12
5.5	TEST DATA - BAND EDGE - CONDUCTED SPURIOUS EMISSIONS	13
6	FIELD STRENGTH OF SPURIOUS RADIATION	17
6.1	TEST RESULT.....	17
6.2	TEST METHOD.....	17
6.3	TEST SITE	17
6.4	TEST EQUIPMENT	18
6.5	TEST DATA.....	19
7	RADIATED EMISSIONS AT BAND EDGE / RESTRICTED BANDS	24
7.1	TEST RESULT.....	24
7.2	TEST METHOD.....	24
7.3	TEST SITE	24
7.4	TEST EQUIPMENT	24
7.5	TEST DATA – RESTRICTED BAND EDGE	25
8	PSEUDO-RANDOM HOP SEQUENCE.....	28
8.1	TEST RESULT.....	28
8.2	TEST METHOD.....	28
9	CHANNEL SEPARATION	29
9.1	TEST RESULT.....	29

9.2	TEST METHOD.....	29
9.3	TEST SITE	29
9.4	TEST EQUIPMENT	29
9.5	TEST DATA.....	29
10	NUMBER OF HOPPING CHANNELS	31
10.1	TEST RESULT.....	31
10.2	TEST METHOD.....	31
10.3	TEST SITE	31
10.4	TEST EQUIPMENT	31
10.5	TEST DATA.....	31
11	DWELL TIME	33
11.1	TEST RESULT.....	33
11.2	TEST METHOD.....	33
11.3	TEST SITE	33
11.4	TEST EQUIPMENT	33
11.5	TEST DATA.....	33
12	AC POWERLINE CONDUCTED EMISSIONS.....	35
12.1	TEST RESULT.....	35
12.2	TEST METHOD.....	35
12.3	TEST SITE	35
12.4	TEST EQUIPMENT	35
12.5	TEST DATA.....	36
13	MEASUREMENT UNCERTAINTY.....	38
14	REVISION HISTORY	39

1 Summary of Test Results

Test Description	Test Specification		Test Result
Occupied Bandwidth	15.247(a)(1)	RSS-247 5.1(a) RSS-GEN 6.7	Compliant
Peak Output Power	15.247(a)(1), (b)(1)	RSS-247 5.4(b), 5.1(b)	Compliant
Conducted Spurious Emissions / Band Edge	15.247(d)	RSS-247 5.5	Compliant
Field Strength of Spurious Radiation	15.247(d), 15.35(b) 15.205, 15.209	RSS-247 5.5 RSS-GEN 8.9, 8.10	Compliant
Radiated Emissions at Band Edge / Restricted Bands	15.205, 15.209	RSS-GEN 8.9, 8.10	Compliant
Pseudo-Random Hop Sequence	15.247(a)(1)	RSS-247 5.1(a)	Compliant
Channel Separation	15.247(a)(1)	RSS-247 5.1(b)	Compliant
Number of Hopping Channels	15.247(a)(1)(iii)	RSS-247 5.1(d)	Compliant
Dwell Time	15.247(a)(1)(iii)	RSS-247 5.1(d)	Compliant
AC Powerline Conducted Emissions	15.207	RSS-GEN 8.8	Compliant
Antenna Requirement	15.203	RSS-GEN 6.8	Compliant ⁽¹⁾

(1) The device uses a PCB trace PIFA antenna which cannot be replaced by the end user.

1.1 Modifications Required for Compliance

None

2 General Information

2.1 Client Information

Company Name: UTEC, Inc.
Address: 111 E. Wayne St., Suite 800
City, State, Zip, Country: Fort Wayne, Indiana 46802, USA

2.2 Test Laboratory

Name: SGS North America, Inc.
Address: 620 Old Peachtree Road NW, Suite 100
City, State, Zip, Country: Suwanee, GA 30024, USA

Accrediting Body: A2LA
Type of lab: Testing Laboratory
Certificate Number: 3212.01
CAB ID: US0186

2.3 General Information of EUT

Equipment Under Test: Refrigerated Shipping Container Controller

Product Name: Micro-Link 5 Controller

Model: MICROLINK5B

Serial Numbers: 4120W008381 (Conducted Sample)
3821W039479 (Radiated Sample)

FCC ID: 2AK6N-MICROLINK5B

IC: 703A-MICROLINK5B

Frequency Range: 2402 – 2480 MHz

Data Modes: Bluetooth Classic – GFSK, $\pi/4$ -DQPSK, 8DPSK

Antenna: PCB Trace PIFA (4.54dBi gain)

Rated Voltage: 5V_{DC} to Micro Board USB port or
Dual phase 18V_{AC} to IO Board

Test Voltage: 5V_{DC} to Micro Board USB port (for Conducted Measurements)
Dual phase 18V_{AC} to IO Board (for Radiated Measurements)

Sample Received Date: 03 February 2023

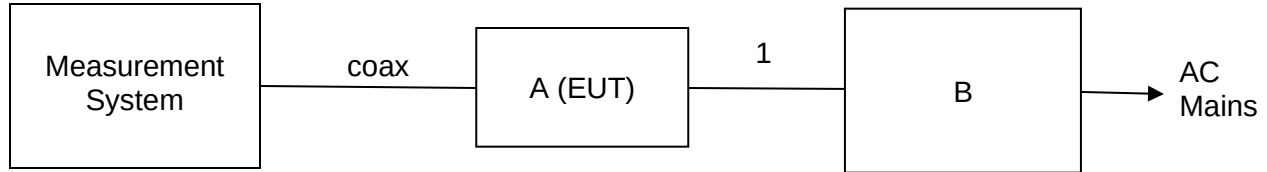
Dates of testing: 15 March to 17 April 2023

2.4 Operating Modes and Conditions

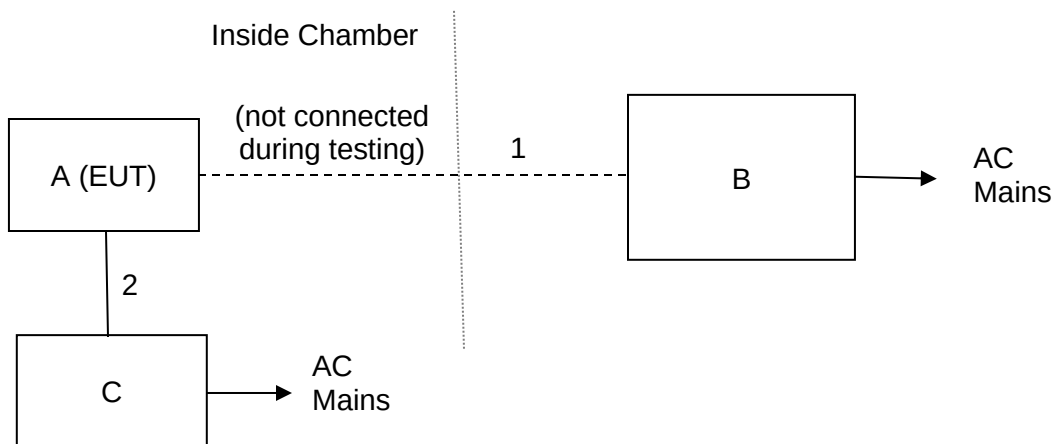
The EUT was running test mode firmware with TI tools which allowed the following:

- 1) selecting low, middle and high BLE channels;
- 2) selecting the modulation scheme as used in normal operation, but with 100% duty cycle;
- 3) setting the power level. [The maximum power setting of 7 was used for all tests.]

2.5 EUT Connection Block Diagram – Conducted Measurements



2.6 EUT Connection Block Diagram – Radiated Measurements



2.7 System Configurations

Device Reference	Manufacturer	Description	Model Number	Serial Number
A	UTEC, Inc.	Micro-Link 5 Controller (EUT)	MICROLINK5B	4120W008381 3821W039479
B	Lenovo	Laptop Computer	T420	R8-X9XFV
C	UTEC, Inc.	Transformer Box	(none)	(none)

2.8 Cable List

Cable reference	Port Name	Start	End	Cable Length (m)	Ferrite installed?	Shielded?
1	USB	EUT	Laptop Computer	1.0	N	N
2	AC Power (5-wire harness)	EUT	Transformer Box	0.7	N	N

3 Occupied Bandwidth

3.1 Test Result

Test Description	Basic Standards	Test Result
99% Bandwidth 20dB Bandwidth	ANSI C63.10:2013 15.247(a)(1) RSS-247 5.1(a) RSS-GEN 6.7	Compliant

3.2 Test Method

Occupied bandwidth measurements were taken using the methods defined in ANSI C63.10, Clause 6.9. Measurements were recorded using the 99% OBW function of the measurement receiver.

3.3 Test Site

SGS EMC Laboratory, Suwanee, GA

Environmental Conditions

Temperature: 19.17 °C

Relative Humidity: 52.1 %

Atmospheric Pressure: 98.2 kPa

3.4 Test Equipment

Test End Date: 15-Mar-2023

Tester: DA

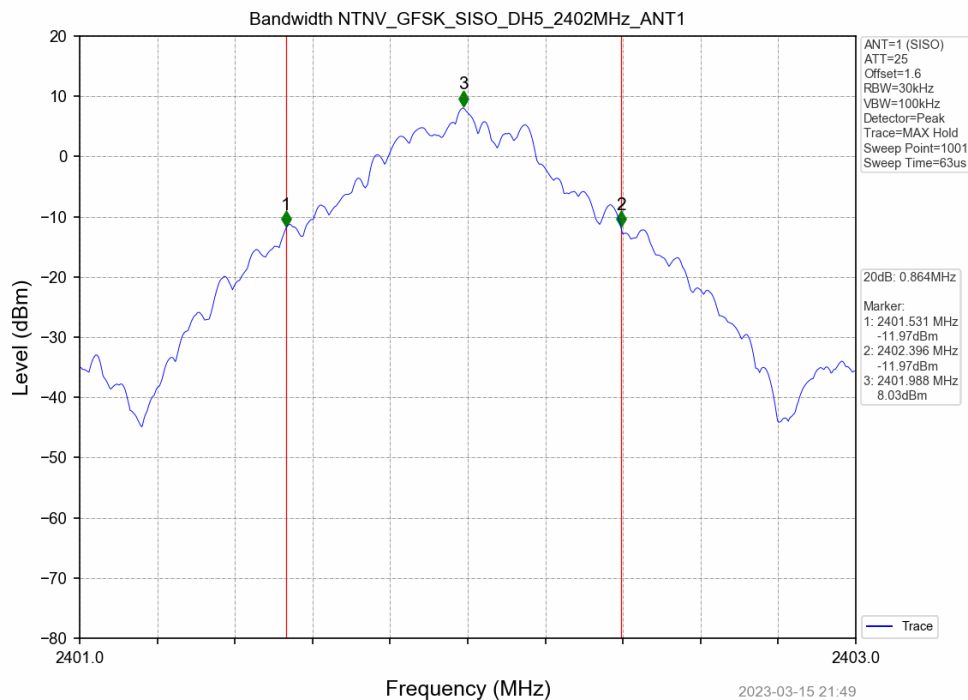
Equipment	Model	Manufacturer	Asset	Cal Date	Cal Due Date
SIGNAL ANALYZER (TS8997)	FSV30	ROHDE & SCHWARZ	B085749	7-Dec-2022	7-Dec-2023
RF CABLE SMA TO SMA, 0.01-40GHZ	084-0505-059	TELEDYNE STORM MICROWAVE	20108	13-Mar-2023	13-Mar-2024

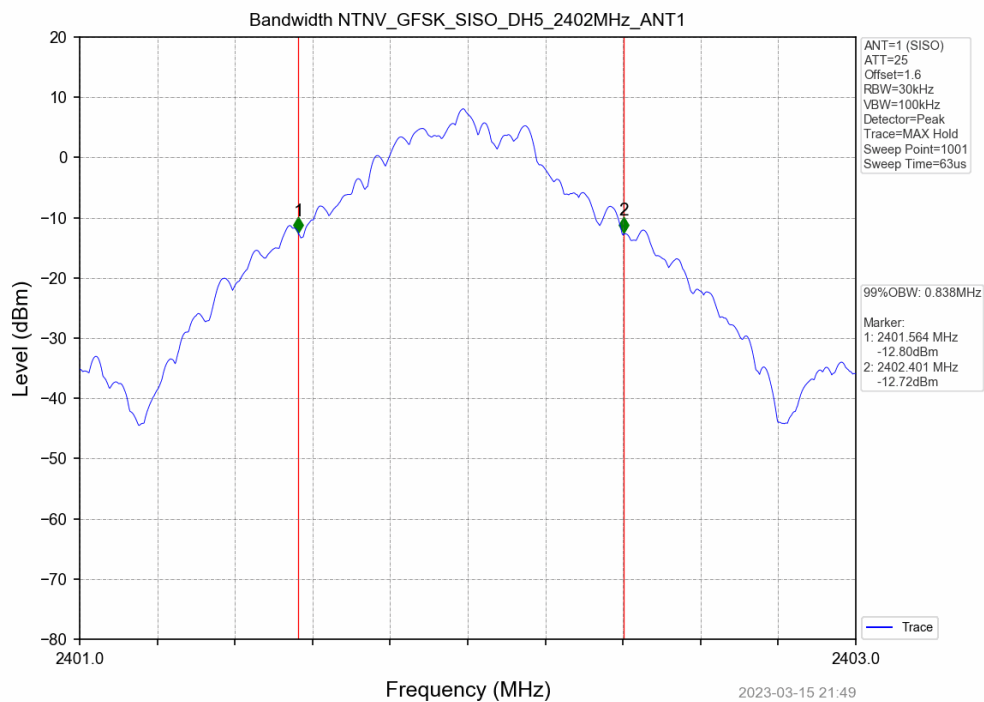
3.5 Test Data – 20dB Bandwidth / 99% Bandwidth

Test Mode	Frequency (MHz)	TX Type	ANT No.	20dB Bandwidth	Verdict
				Test Result (MHz)	
GFSK	2402	SISO	1	0.864	PASS
	2441	SISO	1	0.866	PASS
	2480	SISO	1	0.864	PASS
Pi/4DQPSK	2402	SISO	1	1.278	PASS
	2441	SISO	1	1.278	PASS
	2480	SISO	1	1.278	PASS
8DPSK	2402	SISO	1	1.281	PASS
	2441	SISO	1	1.281	PASS
	2480	SISO	1	1.280	PASS

Test Mode	Frequency (MHz)	TX Type	ANT No.	99% Occupied Bandwidth	
				Test Result (MHz)	
GFSK	2402	SISO	1	0.838	Only for Report Use
	2441	SISO	1	0.838	Only for Report Use
	2480	SISO	1	0.837	Only for Report Use
Pi/4DQPSK	2402	SISO	1	1.181	Only for Report Use
	2441	SISO	1	1.179	Only for Report Use
	2480	SISO	1	1.178	Only for Report Use
8DPSK	2402	SISO	1	1.179	Only for Report Use
	2441	SISO	1	1.178	Only for Report Use
	2480	SISO	1	1.177	Only for Report Use

Representative Plot





4 Peak Output Power

4.1 Test Result

Test Description	Test Specification	Test Result
Peak Output Power	ANSI C63.10:2013 15.247(a)(1), (b)(1) RSS-247 5.4(b), 5.1(b)	Compliant

4.2 Test Method

Output power measurements were taken using the methods defined in ANSI C63.10, Clause 7.8.5.

Limit

§15.247(b)(1): For frequency hopping systems operating in the 2400–2483.5 MHz band employing at least 75 non-overlapping hopping channels...: 1 watt (30 dBm).

§15.247(a)(1): Frequency hopping systems operating in the 2400-2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW (21 dBm).

4.3 Test Site

SGS EMC Laboratory, Suwanee, GA

Environmental Conditions

Temperature: 19.17 °C

Relative Humidity: 52.1 %

Atmospheric Pressure: 98.2 kPa

4.4 Test Equipment

Test End Date: 15-Mar-2023

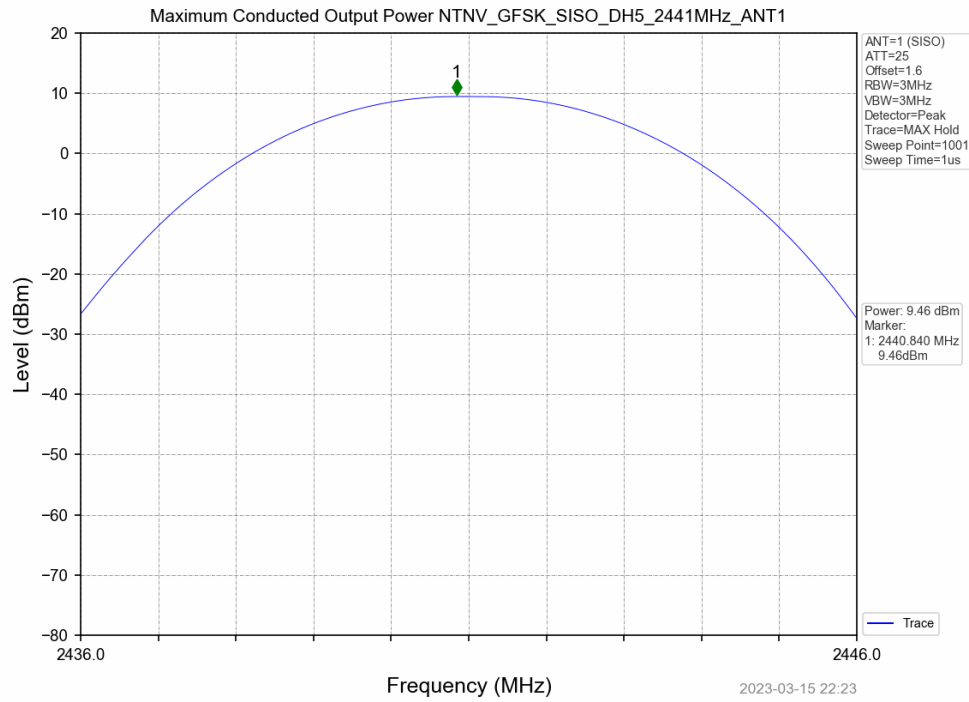
Tester: DA

Equipment	Model	Manufacturer	Asset	Cal Date	Cal Due Date
SIGNAL ANALYZER (TS8997)	FSV30	ROHDE & SCHWARZ	B085749	7-Dec-2022	7-Dec-2023
RF CABLE SMA TO SMA, 0.01-40GHZ	084-0505-059	TELEDYNE STORM MICROWAVE	20108	13-Mar-2023	13-Mar-2024

4.5 Test Data

Test Mode	Frequency (MHz)	Tx Type	Measured Peak Output Power (dBm)	Limits (dBm)	Verdict
			Ant 1		
GFSK	2402	SISO	8.67	30	PASS
	2441	SISO	9.46	30	PASS
	2480	SISO	9.51	30	PASS
Pi/4DQPSK	2402	SISO	6.02	21	PASS
	2441	SISO	6.64	21	PASS
	2480	SISO	6.86	21	PASS
8DPSK	2402	SISO	6.28	21	PASS
	2441	SISO	7.21	21	PASS
	2480	SISO	7.30	21	PASS

Representative Plot



5 Conducted Spurious Emissions / Band Edge

5.1 Test Result

Test Description	Test Specification	Test Result
Conducted Spurious and Band Edge Emissions	ANSI C63.10:2013 15.247(d) RSS-247 5.5	Compliant

5.2 Test Method

Conducted spurious emissions measurements were taken using the methods defined in ANSI C63.10, Clauses 5.5, 5.6, & 6.7. Authorized band edge measurements were recorded using the methods in clause 6.10.4. Basic Rate, EDR-2, & EDR-3 with a DH1, DH3, & DH5 packet types were used for spurious measurements. Band edge measurements were also recorded using each modulation (Basic Rate, EDR-2, and EDR-3).

The limit is 20 dB below the measured peak power.

5.3 Test Site

SGS EMC Laboratory, Suwanee, GA

Environmental Conditions

Temperature: 19.17 °C

Relative Humidity: 52.1 %

Atmospheric Pressure: 98.2 kPa

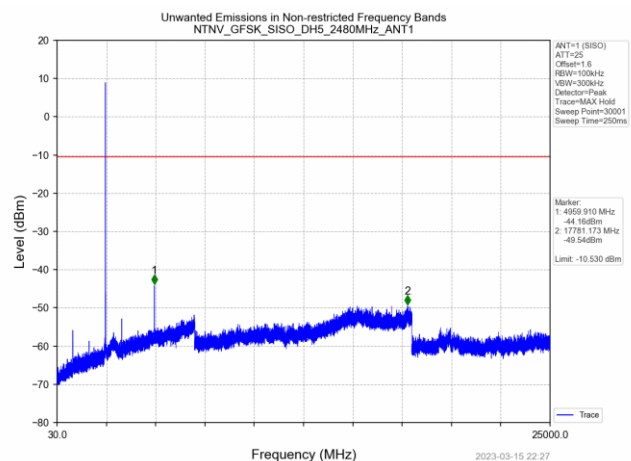
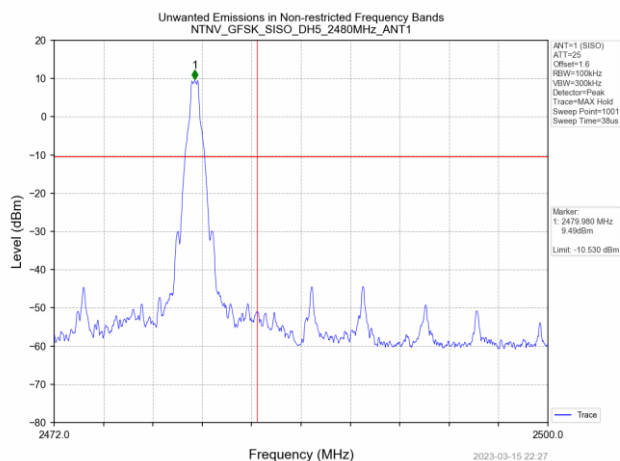
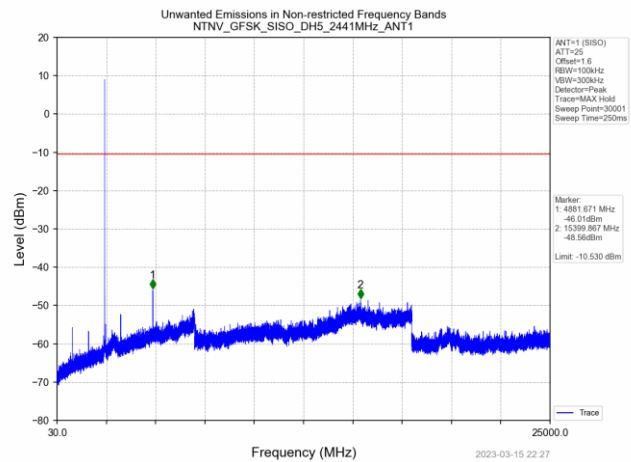
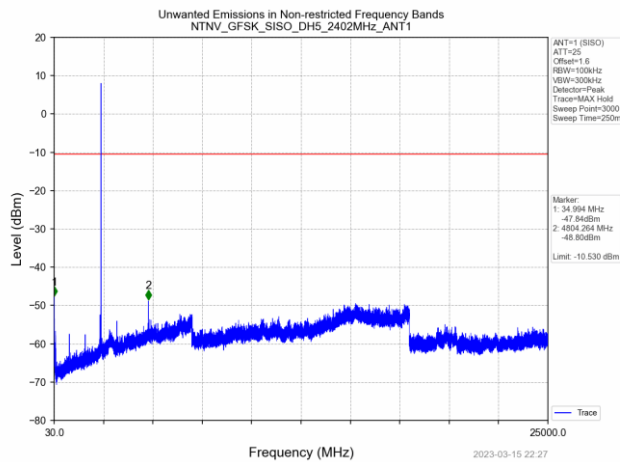
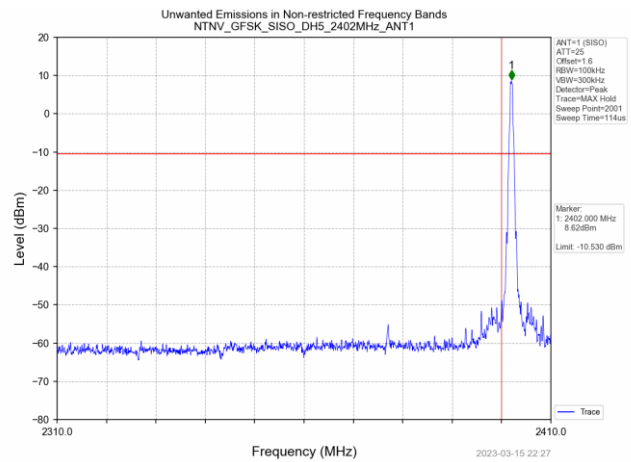
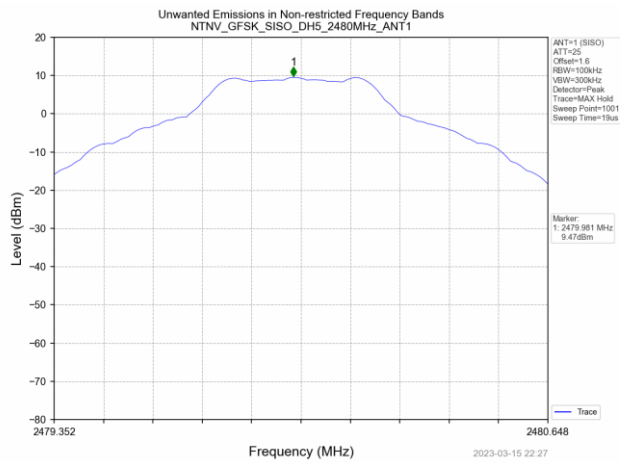
5.4 Test Equipment

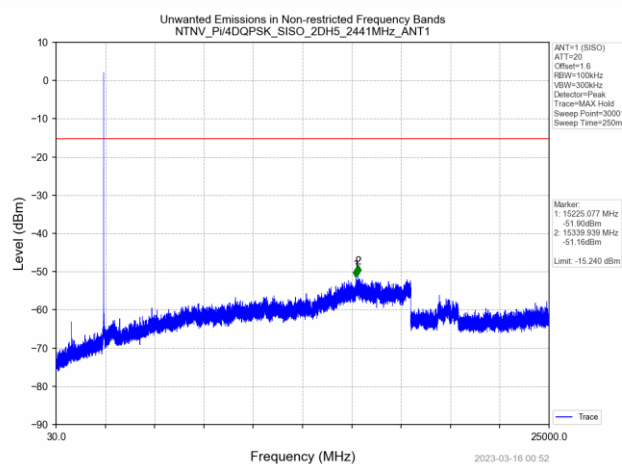
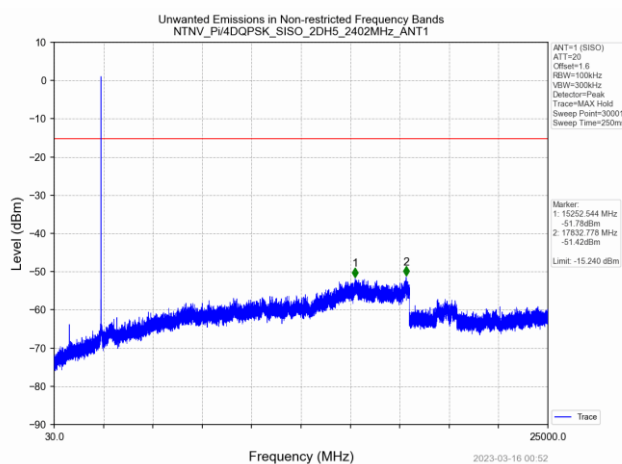
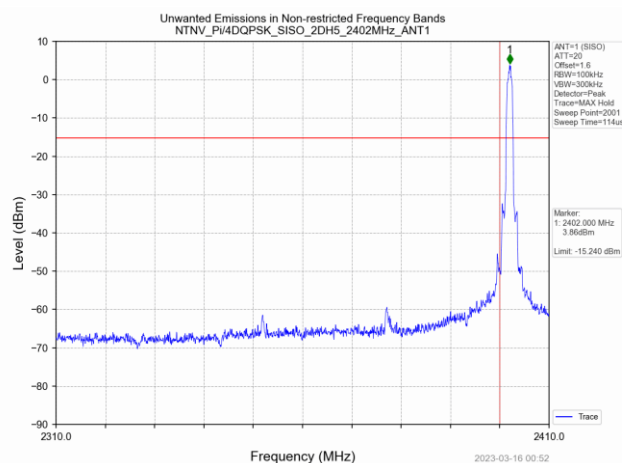
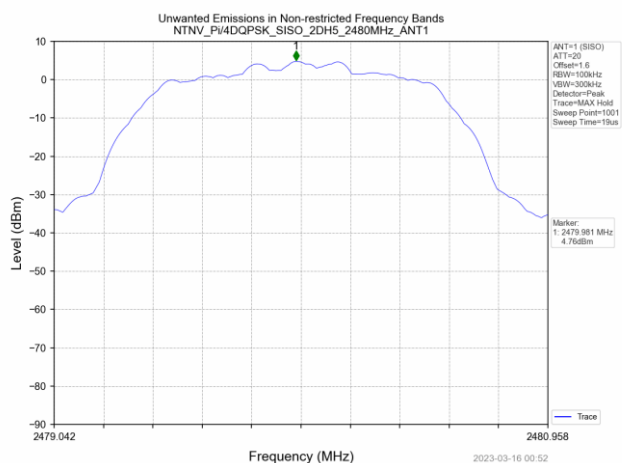
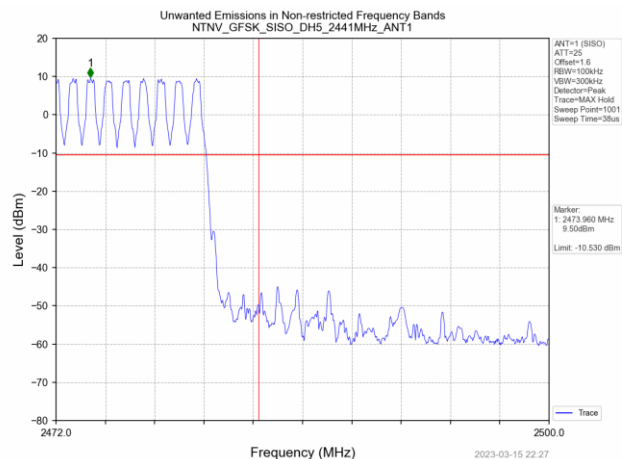
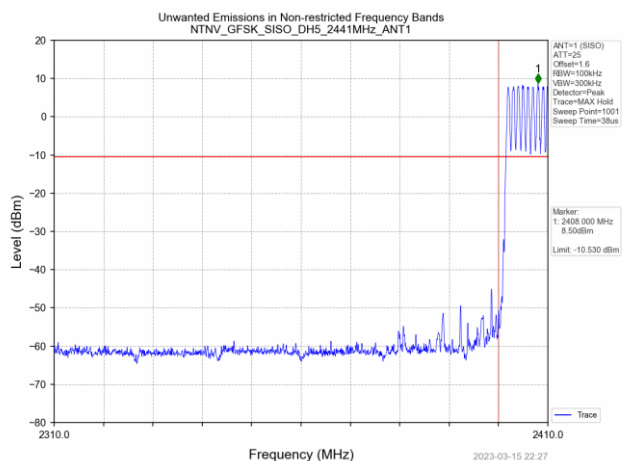
Test End Date: 15-Mar-2023

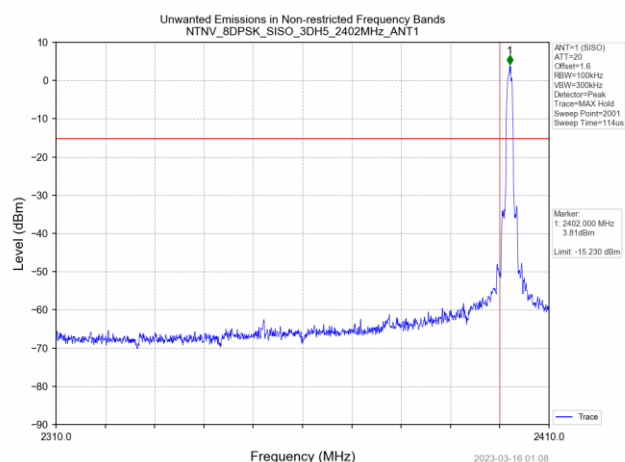
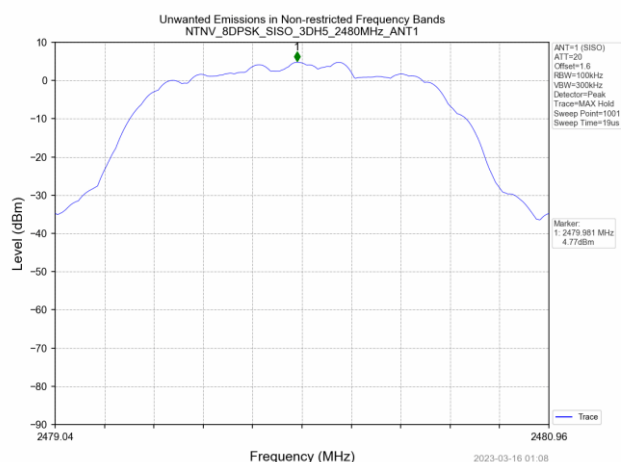
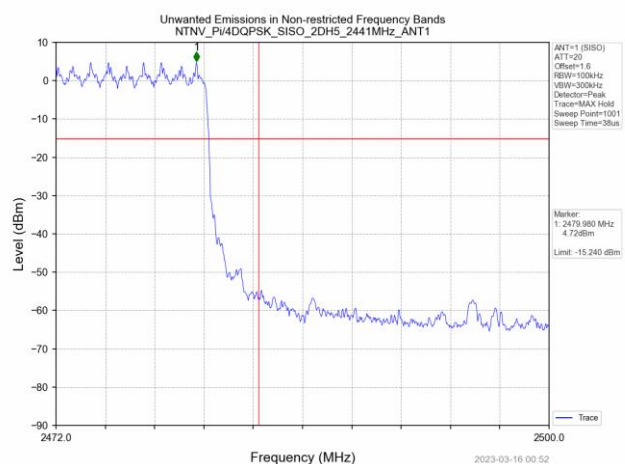
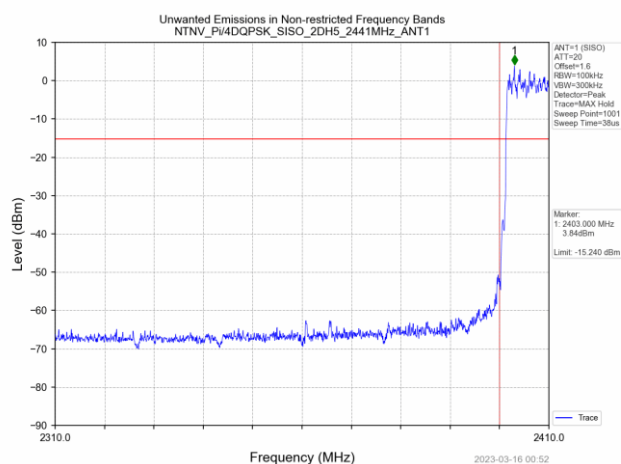
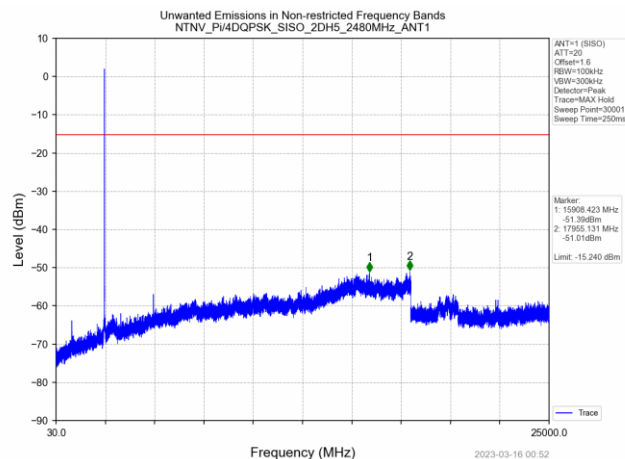
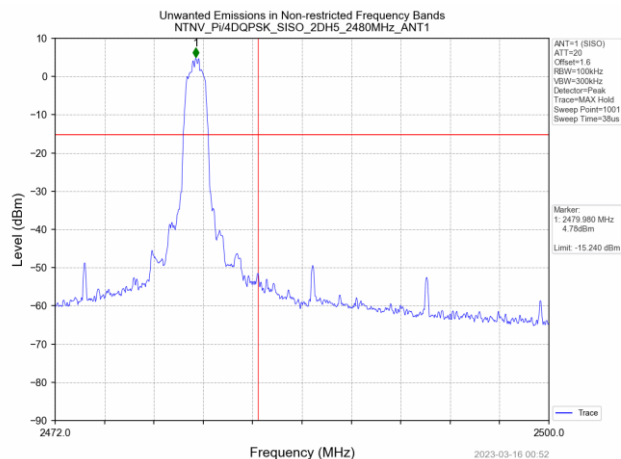
Tester: DA

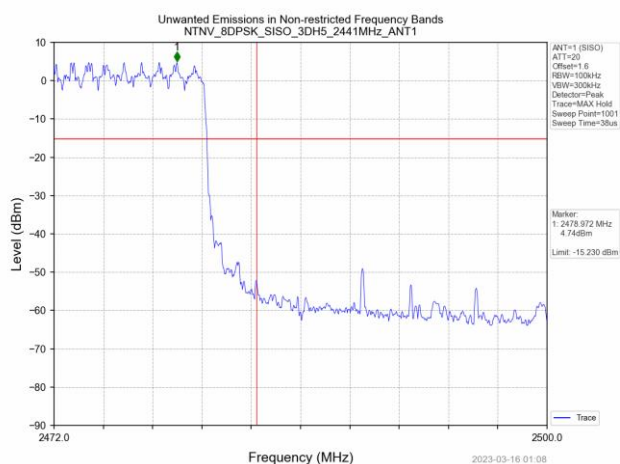
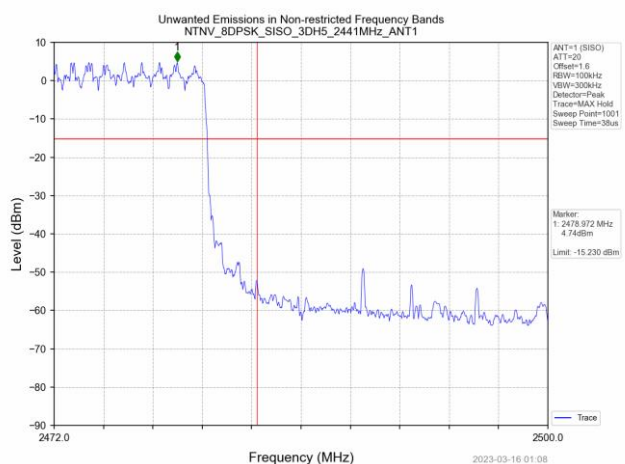
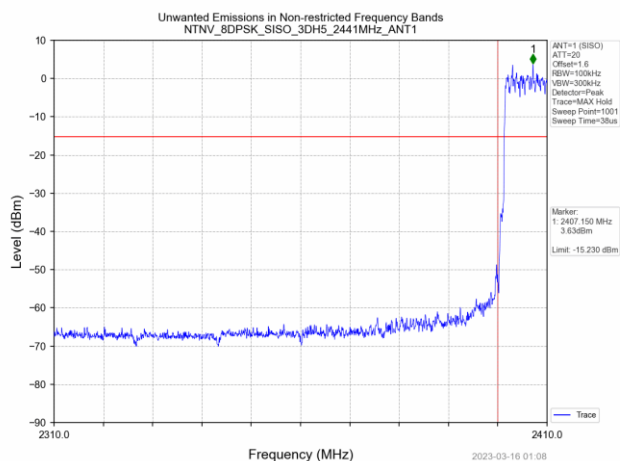
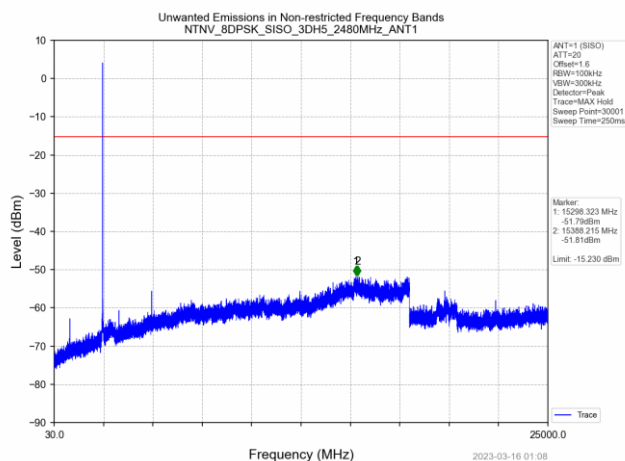
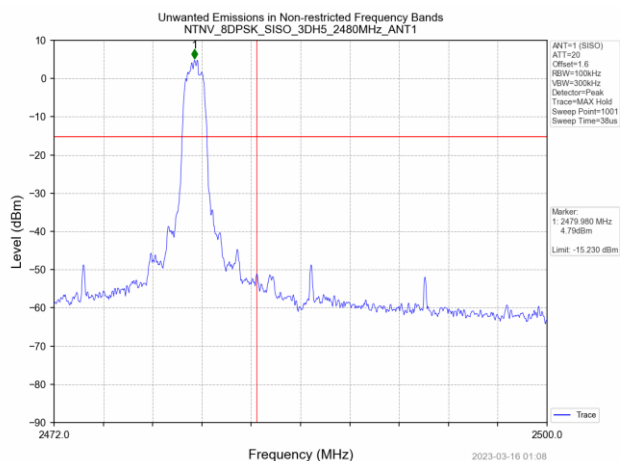
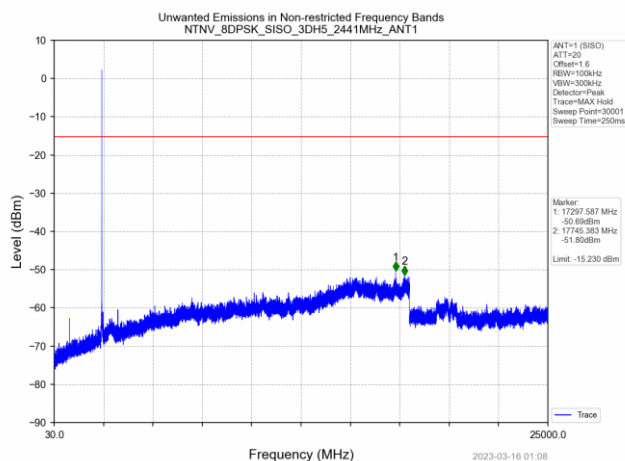
Equipment	Model	Manufacturer	Asset	Cal Date	Cal Due Date
SIGNAL ANALYZER (TS8997)	FSV30	ROHDE & SCHWARZ	B085749	7-Dec-2022	7-Dec-2023
RF CABLE SMA TO SMA, 0.01-40GHZ	084-0505-059	TELEDYNE STORM MICROWAVE	20108	13-Mar-2023	13-Mar-2024

5.5 Test Data - Band Edge - Conducted Spurious Emissions









6 Field Strength of Spurious Radiation

6.1 Test Result

Test Description	Test Specification		Test Result
Radiated Spurious Emissions	15.247(d), 15.35(b) 15.205, 15.209	RSS-247 5.5 RSS-GEN 8.9, 8.10	Compliant

6.2 Test Method

The measurement methods defined in ANSI C63.10: 2013 were used.

Lowest, middle, and highest channels were investigated – the device was commanded to continuously transmit on low, middle, and high channels.

Test distance:

- 9k to 30 MHz – Near field prescan to determine if there were any emissions
- 30 to 1000 MHz - The EUT to measurement antenna distance was 3 meters
- 1 to 18 GHz - The EUT to measurement antenna distance was 3 meters
- 18 to 26 GHz - The EUT to measurement antenna distance was 3 meters

Limits within restricted bands of operation:

Frequency	Limits ⁽¹⁾		Peak Limits dBuV/m
	Microvolts/m	dBuV/m	
30 - 88 MHz	100	40 ⁽²⁾	--
88 - 216 MHz	150	43.5 ⁽²⁾	--
216 - 960 MHz	200	46 ⁽²⁾	--
960 - 1000 MHz	500	54 ⁽²⁾	--
1 - 40 GHz	500	54 ⁽³⁾	74

(1) These limits are applicable to emissions outside of the intentional transmit frequency band.

(2) Quasi-peak limit

(3) Average limit

6.3 Test Site

SGS EMC Laboratory, Suwanee, GA

Environmental Conditions	30-1000MHz	1-18GHz
Temperature:	25.3 °C	22.8 °C
Relative Humidity:	44.9 %	37.9 %
Atmospheric Pressure:	98.05 kPa	97.85 kPa

6.4 Test Equipment

30-1000 MHz

Test End Date: 5-Apr-2023

Tester: ZH

Equipment	Model	Manufacturer	Asset	Cal Date	Cal Due Date
ANTENNA, BILOG	JB6	SUNOL	B079689	26-May-2022	26-May-2024
N to N RF Cable	TR-48-25P	Echelon	23007	31-Mar-2023	31-Mar-2024
RF CABLE NM TO NM, 0.01-12GHZ	90-078-079	TELEDYNE STORM MICROWAVE	20115	15-Mar-2023	15-Mar-2024
RF CABLE NM TO NM, 0.01-18GHZ	90-195-079	TELEDYNE STORM MICROWAVE	20123	9-Feb-2023	9-Feb-2024
RF CABLE RIGHT ANGLE NM TO NM, 0.01-18GHZ	90-076-020	TELEDYNE STORM MICROWAVE	20131	13-Mar-2023	13-Mar-2024
LOW NOISE AMPLIFIER	ZKL-2+	MINI-CIRCUITS	B079817	25-Aug-2022	25-Aug-2023
EMI TEST RECEIVER	ESW44	ROHDE & SCHWARZ	22027	13-Sep-2022	13-Sep-2023

Above 1GHz

Test End Date: 6-Apr-2023

Tester: EW

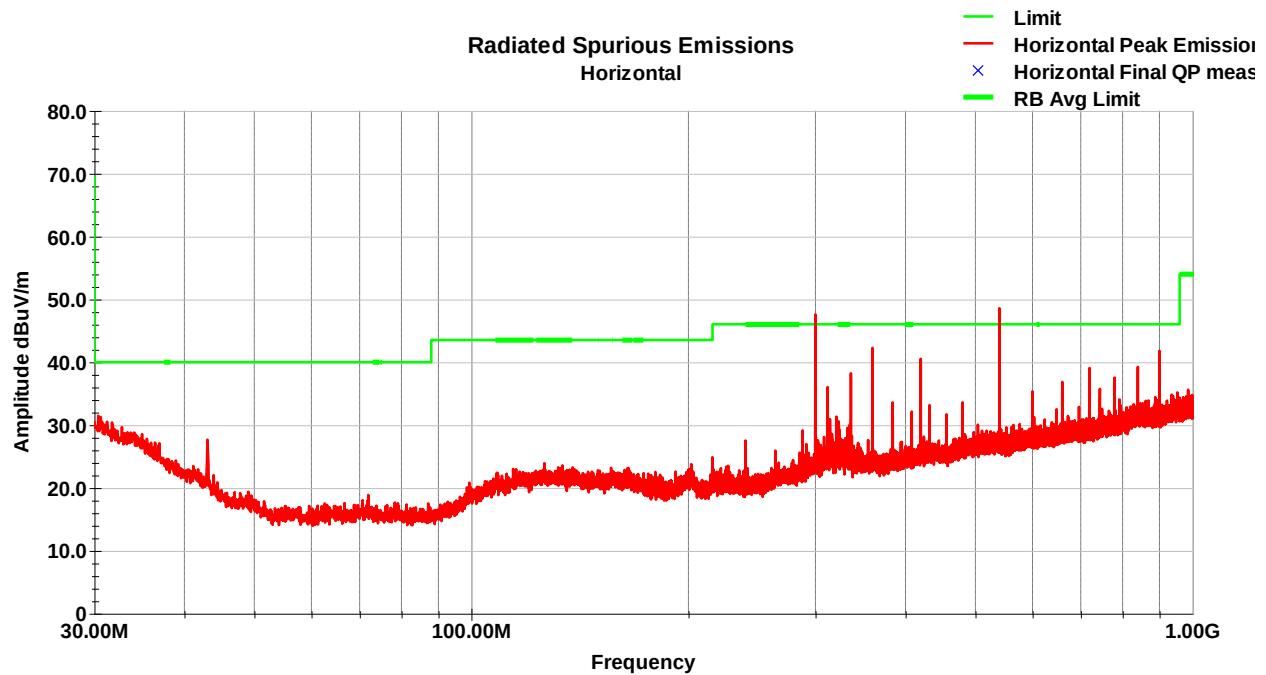
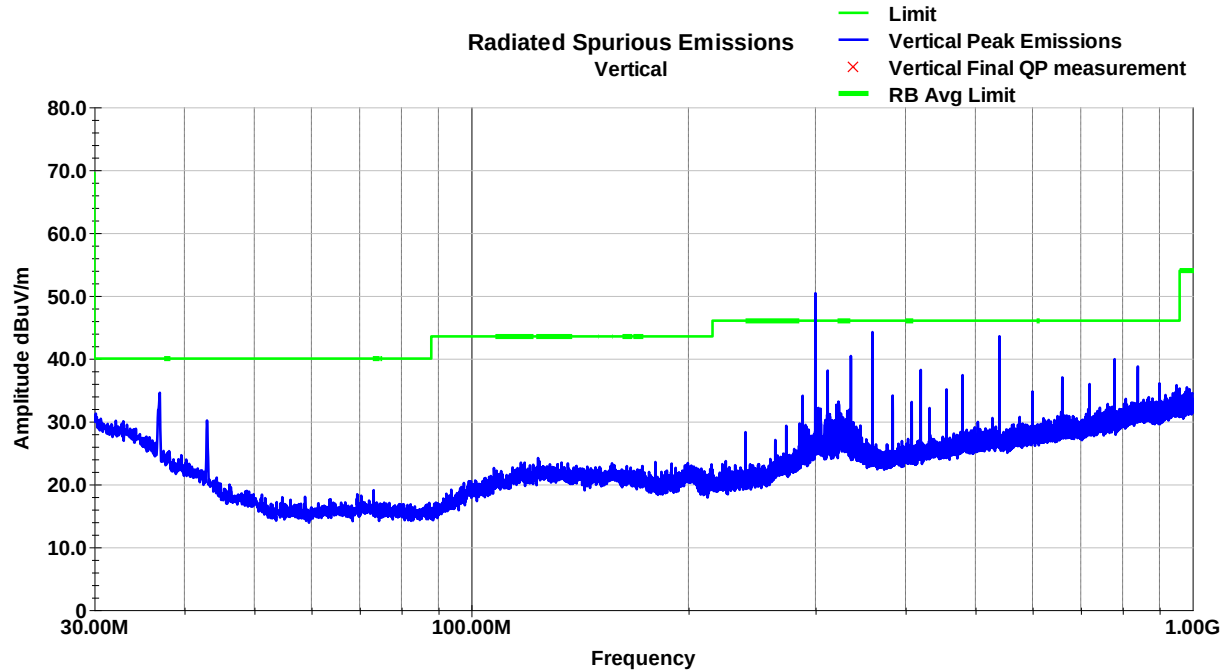
Equipment	Model	Manufacturer	Asset	Cal Date	Cal Due Date
ANTENNA, DRG HORN (MEDIUM)	3117	ETS LINDGREN	B079691	15-Aug-2022	15-Aug-2024
RF CABLE NM TO NF, 0.01-18GHZ	TR-48-25P	TELEDYNE STORM MICROWAVE	20118	13-Mar-2023	13-Mar-2024
RF CABLE, NM TO NM.	90-195-157	TELEDYNE STORM MICROWAVE	21019	14-Mar-2023	14-Mar-2024
RF CABLE RIGHT ANGLE NM TO NM, 0.01-	90-076-020	TELEDYNE STORM MICROWAVE	20132	13-Mar-2023	13-Mar-2024
LOW NOISE AMPLIFIER	TS-PR18	ROHDE & SCHWARZ	B094463	13-Jul-2022	13-Jul-2023
EMI TEST RECEIVER	ESW44	ROHDE & SCHWARZ	22032	24-Nov-2022	24-Nov-2023
FILTER, HIGH PASS, >2800MHZ	HPM50111	MICRO-TRONICS	22017	16-Jun-2022	16-Jun-2023

6.5 Test Data

No emissions were detected in the 9kHz to 30MHz frequency range.

6.5.1 30-1000 MHz

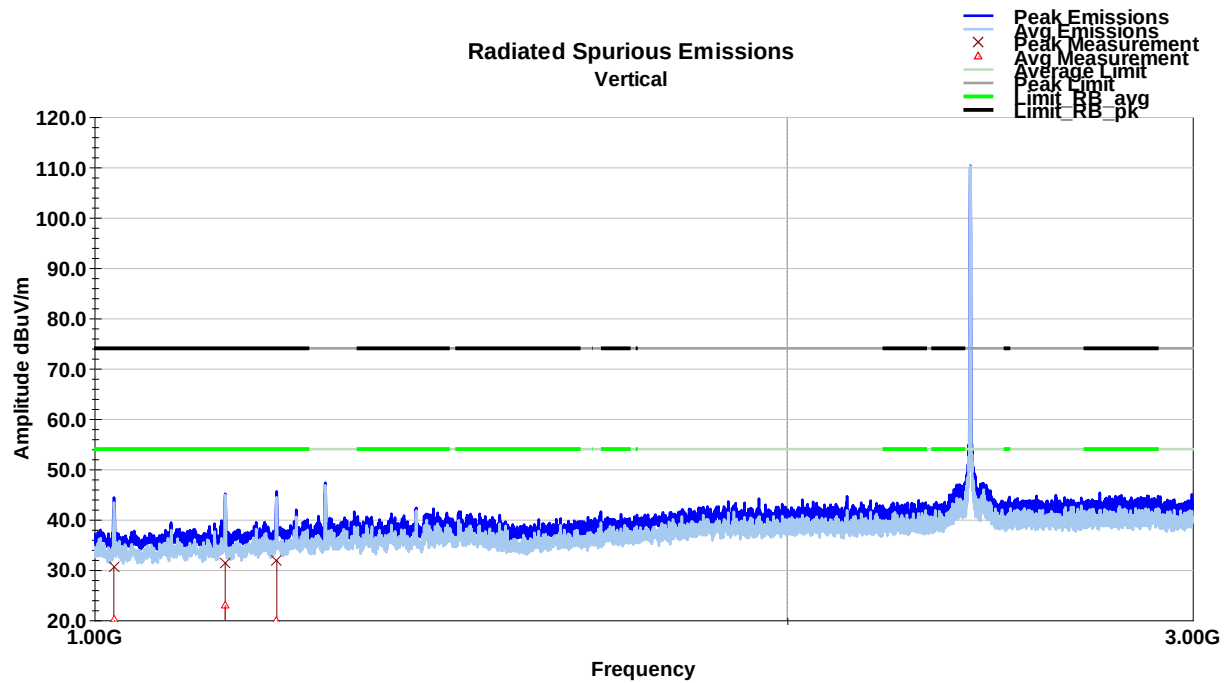
There was little deviation based on axis or channel in the 30-1000MHz range (worst case shown).



All emissions above were either not in restricted bands or were verified to be non-radio emissions.

6.5.2 1-3 GHz

All channels had similar plots (worst case shown).

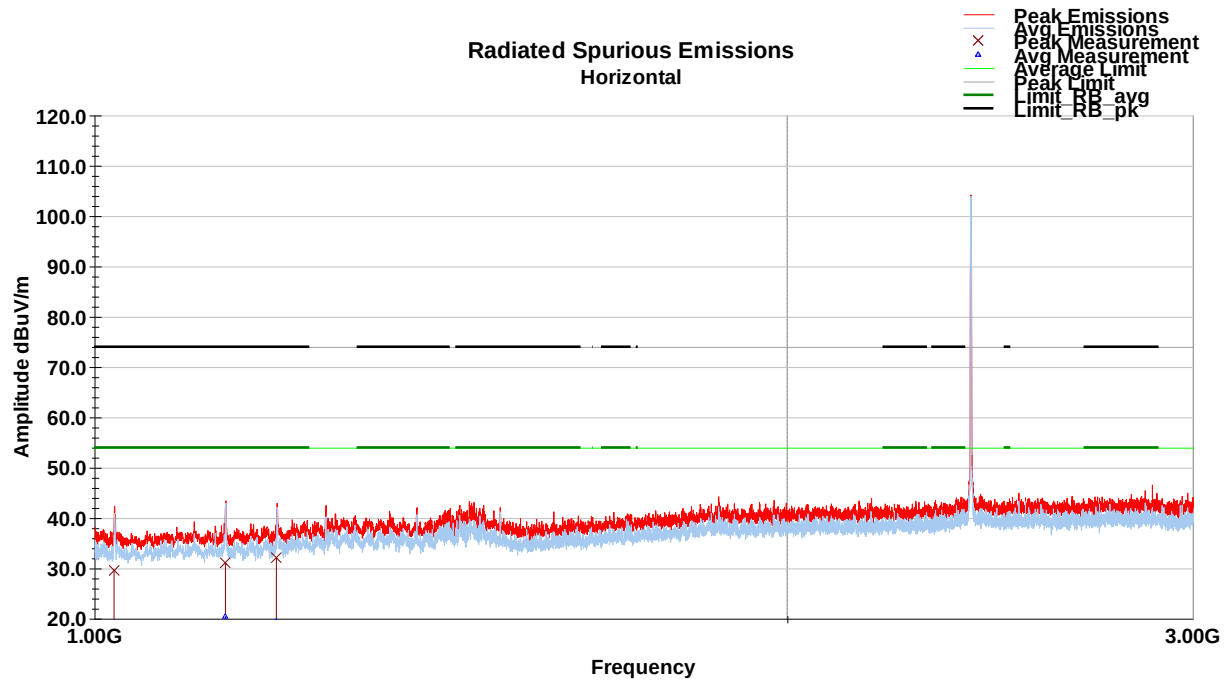


Average

Frequency MHz	Raw Avg dBuV	Polarity (V/H)	Azimuth (degrees)	Height (cm)	AF (dB/m)	Loss (dB)	Amp (dB)	Final Avg dBuV/m	Limit (dBuV/m)	Margin (dB)
1019.76	24.9	V	0.0	249.0	27.2	1.5	33.6	20.1	54.0	-33.9
1139.92	27.3	V	234.0	247.0	27.6	1.5	33.6	22.9	54.0	-31.1
1200.36	23.4	V	276.0	105.0	28.5	1.7	33.5	19.9	54.0	-34.0
Final Avg = Raw Avg + AF + Loss - Amp										
Margin = Final Avg - Limit										

Peak

Frequency MHz	Raw Pk dBuV	Polarity (V/H)	Azimuth (degrees)	Height (cm)	AF (dB/m)	Loss (dB)	Amp (dB)	Final Pk dBuV/m	Limit dBuV/m	Margin dB
1019.76	35.3	V	0.0	249.0	27.2	1.5	33.6	30.5	74.0	-43.5
1139.92	35.8	V	234.0	247.0	27.6	1.5	33.6	31.4	74.0	-42.6
1200.36	35.3	V	276.0	105.0	28.5	1.7	33.5	31.9	74.0	-42.1
Final Pk = Raw Pk + AF + Loss - Amp										
Margin = Final Pk - Limit										



Average

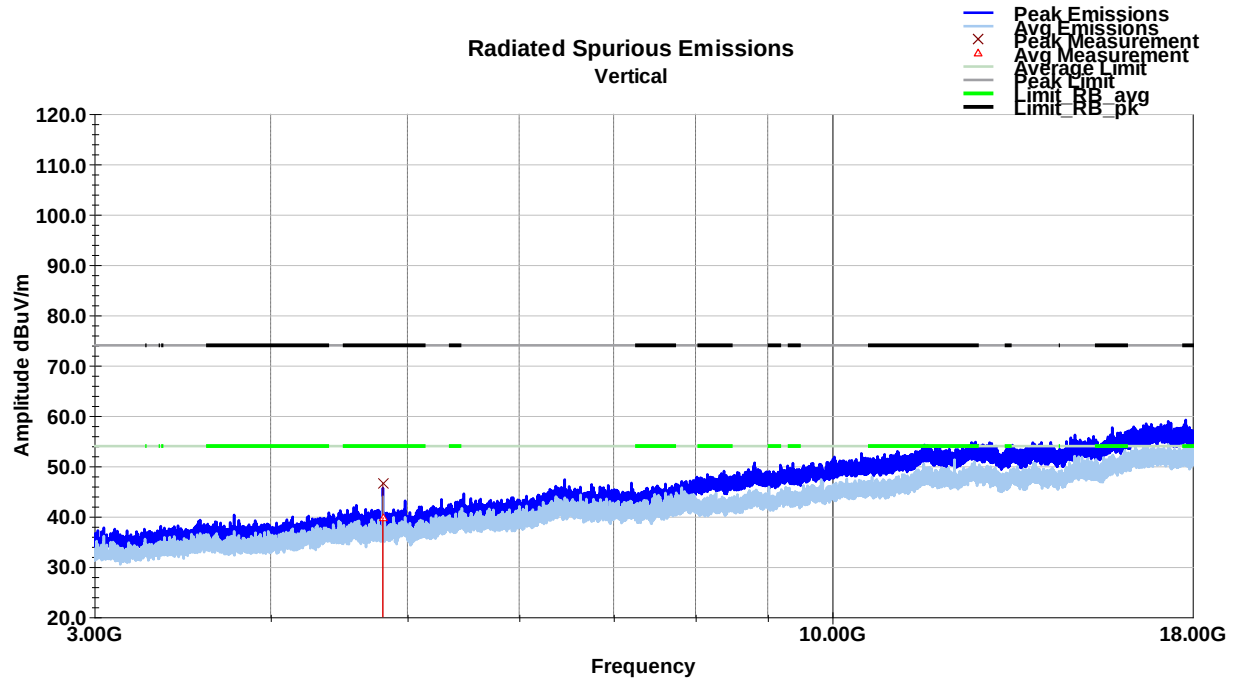
Frequency MHz	Raw Avg dBuV	Polarity (V/H)	Azimuth (degrees)	Height (cm)	AF (dB/m)	Loss (dB)	Amp (dB)	Avg Value dBuV/m	Limit (dBuV/m)	Margin (dB)
1019.90	22.3	H	12.0	109.0	27.2	1.5	33.6	17.4	54.0	-36.5
1140.08	24.9	H	286.0	218.0	27.6	1.5	33.6	20.5	54.0	-33.5
1199.76	22.8	H	257.0	210.0	28.5	1.7	33.6	19.4	54.0	-34.6
Final Avg = Raw Avg + AF + Loss - Amp										
Margin = Final Avg - Limit										

Peak

Frequency MHz	Raw Pk dBuV	Polarity (V/H)	Azimuth (degrees)	Height (cm)	AF (dB/m)	Loss (dB)	Amp (dB)	Final Pk dBuV/m	Limit dBuV/m	Margin dB
1019.90	34.5	H	12.0	109.0	27.2	1.5	33.6	29.7	74.0	-44.3
1140.08	35.4	H	286.0	218.0	27.6	1.5	33.6	31.0	74.0	-43.0
1199.76	35.5	H	257.0	210.0	28.5	1.7	33.6	32.1	74.0	-41.9
Final Pk = Raw Pk + AF + Loss - Amp										
Margin = Final Pk - Limit										

6.5.3 3-18 GHz

All channels had similar plots (worst case shown).

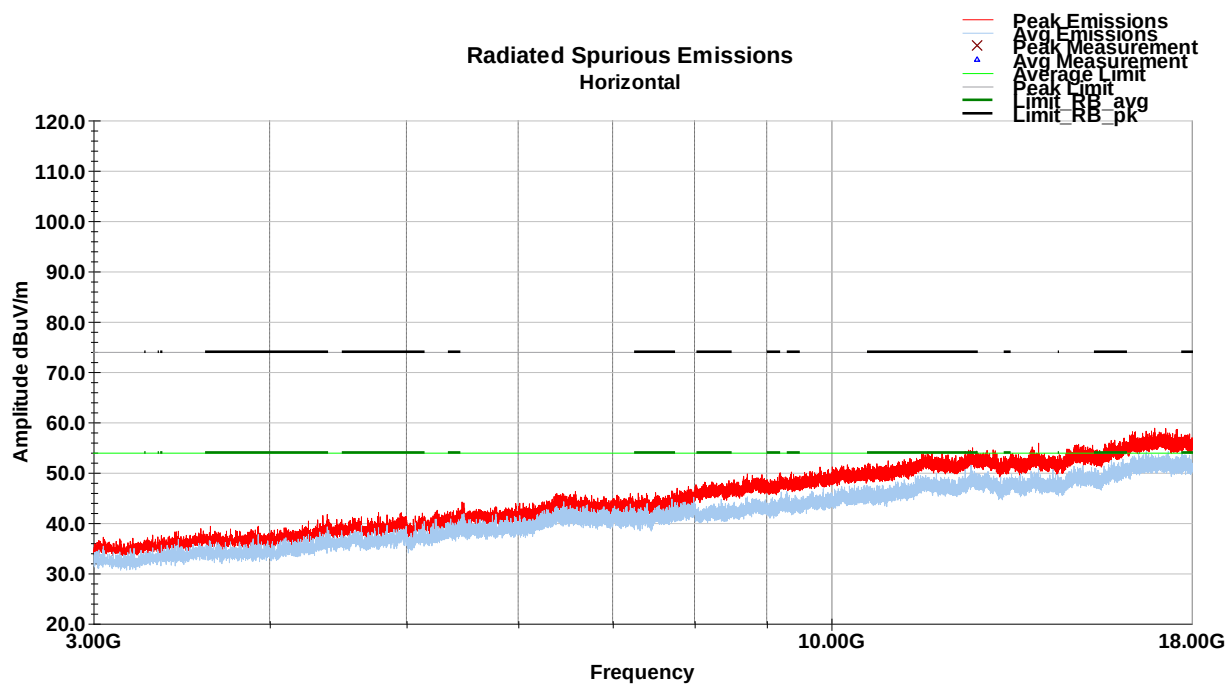


Average

Frequency MHz	Raw Avg dBuV	Polarity (V/H)	Azimuth (degrees)	Height (cm)	AF (dB/m)	Loss (dB)	Amp (dB)	Final Avg dBuV/m	Limit (dBuV/m)	Margin (dB)
4803.56	35.8	V	349.0	240.0	33.9	3.9	33.7	39.8	54.0	-14.2
Final Avg = Raw Avg + AF + Loss - Amp										
Margin = Final Avg - Limit										

Peak

Frequency MHz	Raw Pk dBuV	Polarity (V/H)	Azimuth (degrees)	Height (cm)	AF (dB/m)	Loss (dB)	Amp (dB)	Final Pk dBuV/m	Limit dBuV/m	Margin dB
4803.56	42.7	V	349.0	240.0	33.9	3.9	33.7	46.7	74.0	-27.3
Final Pk = Raw Pk + AF + Loss - Amp										
Margin = Final Pk - Limit										



There were no emissions in the 18-26GHz frequency range.

7 Radiated Emissions at Band Edge / Restricted Bands

7.1 Test Result

Test Description	Test Specification	Test Result
Radiated Emissions at Band Edge / Restricted Bands	ANSI C63.10:2013 15.205, 15.209 RSS-GEN 8.9, 8.10	Compliant

7.2 Test Method

Field strength measurements were performed at the restricted band edges of 2390MHz and 2483.5MHz for each modulation. Measurements were made using the conducted method following the procedures in ANSI C63.10 section 6.10.5 (see footnote 57 for conducted testing provision).

Offset Calculations:

Offset calculations so that conducted measurements on the spectrum analyzer in dBμV represent field strength measurements in dBμV/m.

$$\text{Offset} = -20\log(D) + 104.8 - 107 + \text{CL} + \text{DC} + \text{AG}$$

$$\text{Offset}_{3m} = -11.7 + \text{CL} + \text{DC} + \text{AG}$$

D = 3m

Distance

CL = 1.6 dB

Cable Loss (This value was accounted for in measurements)

DC = 4.9 dB (32.2%)

Duty Cycle Correction Factor (DCCF) (Basic Rate, EDR-2, and EDR-3)
(Worst case duty cycle from all data rates used to calculate the DCCF.)

AG = 4.54 dB

Antenna Gain

$$\text{Offset} = -0.66 \text{ dB} - \text{CL} (1.6) = -2.3 \text{ dB (rounded)}$$

7.3 Test Site

SGS EMC Laboratory, Suwanee, GA

Environmental Conditions

Temperature: 22.4 °C

Relative Humidity: 43.2 %

Atmospheric Pressure: 98.2 kPa

7.4 Test Equipment

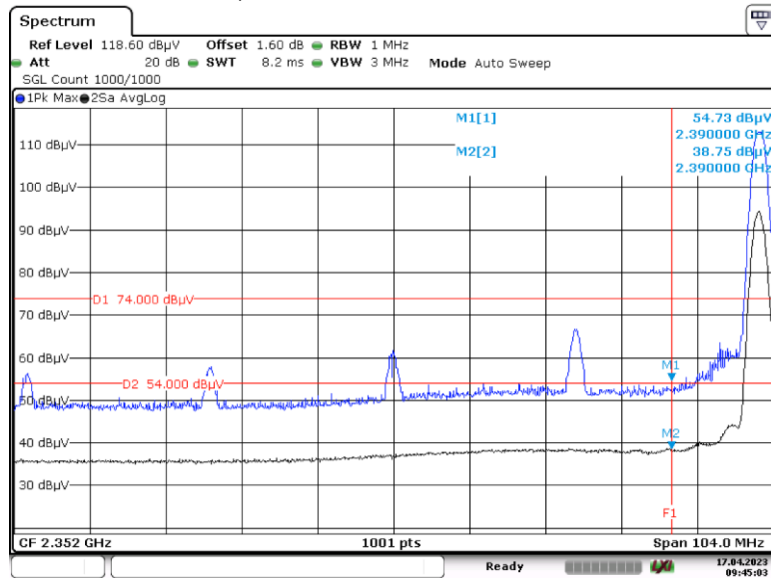
Test End Date: 17-Apr-2023

Tester: DA

Equipment	Model	Manufacturer	Asset	Cal Date	Cal Due Date
SIGNAL ANALYZER (TS8997)	FSV30	ROHDE & SCHWARZ	B085749	7-Dec-2022	7-Dec-2023
RF CABLE SMA TO SMA, 0.01-40GHZ	084-0505-059	TELEDYNE STORM MICROWAVE	20108	13-Mar-2023	13-Mar-2024
TSTPASS SWITCHBOX	SB2	TSTPASS	23009	CNR	CNR

7.5 Test Data – Restricted Band Edge

Basic Rate - DH5, Ch0



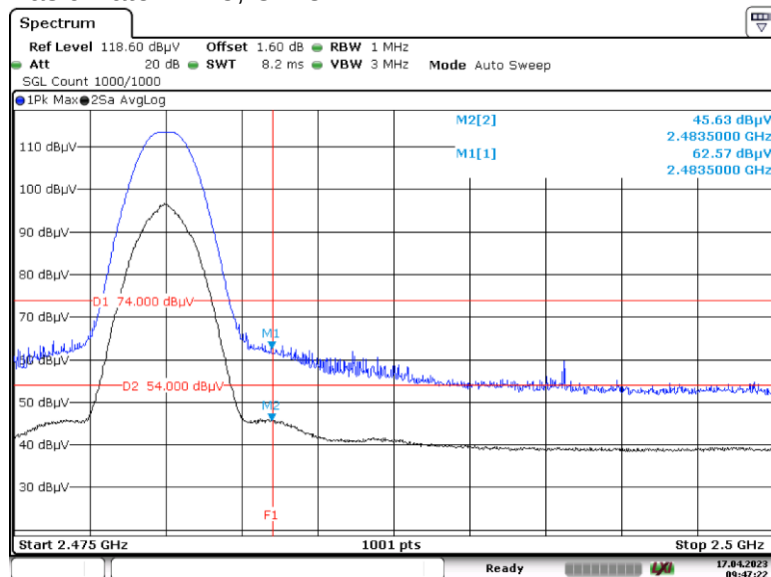
Date: 17.APR.2023 09:45:04

Frequency (MHz)	Peak (dBμV)	Distance Factor	DOCF (dB)	Antenna Gain (dBi)	Cable Loss (dB)	Offset 3m (dB)	Value (dBμV/m)	Limit (dBμV/m)	Margin (dB)
2352.00	62.0	-11.7	4.9	4.5	1.6	-2.3	59.7	74.0	-14.3
2377.00	67.0	-11.7	4.9	4.5	1.6	-2.3	64.7	74.0	-9.3

Offset_{3m} = -2.3 dB = -11.7 + 4.9 + 4.54 (Cable Loss is accounted for in plot)

Value = Peak + Offset_{3m}

Basic Rate - DH5, Ch78



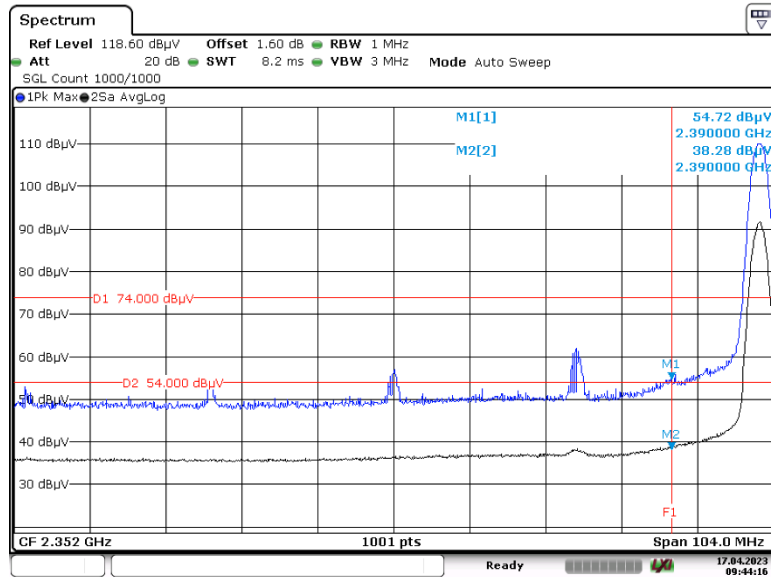
Date: 17.APR.2023 09:47:23

Frequency (MHz)	Peak (dBμV)	Distance Factor	DOCF (dB)	Antenna Gain (dBi)	Cable Loss (dB)	Offset 3m (dB)	Value (dBμV/m)	Limit (dBμV/m)	Margin (dB)
2491.00	62.6	-11.7	4.9	4.5	1.6	-2.3	60.3	74.0	-13.7

Offset_{3m} = -2.3 dB = -11.7 + 4.9 + 4.54 (Cable Loss is accounted for in plot)

Value = Peak + Offset_{3m}

EDR-2 - DH5, Ch0



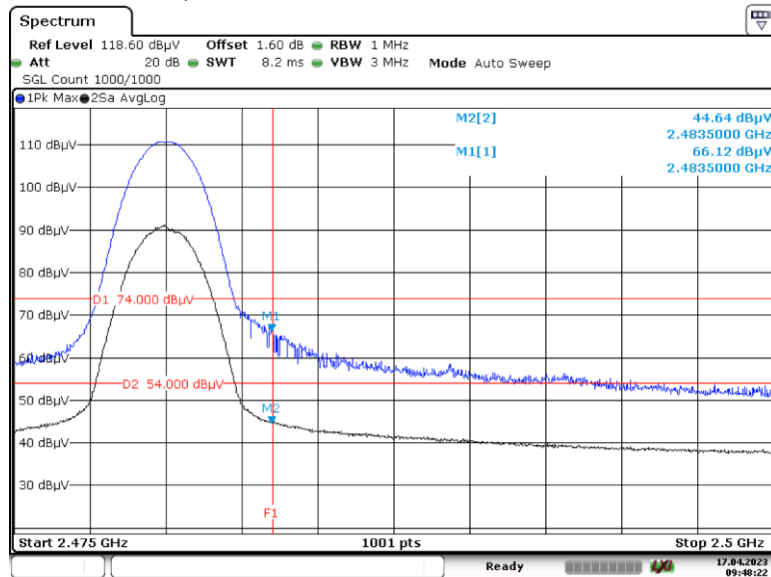
Date: 17.APR.2023 09:44:17

Frequency MHz	Peak (dBμV)	Distance Factor	DCCF (dB)	Antenna Gain (dBi)	Cable Loss (dB)	Offset 3m (dB)	Value (dBμV/m)	Limit (dBμV/m)	Margin (dB)
2352.00	56.0	-11.7	4.9	4.5	1.6	-2.3	53.7	74.0	-20.3
2377.00	62.0	-11.7	4.9	4.5	1.6	-2.3	59.7	74.0	-14.3

Offset_{3m} = -2.3 dB = -11.7 + 4.9 + 4.54 (Cable Loss is accounted for in plot)

Value = Peak + Offset_{3m}

EDR-2 - DH5, Ch78



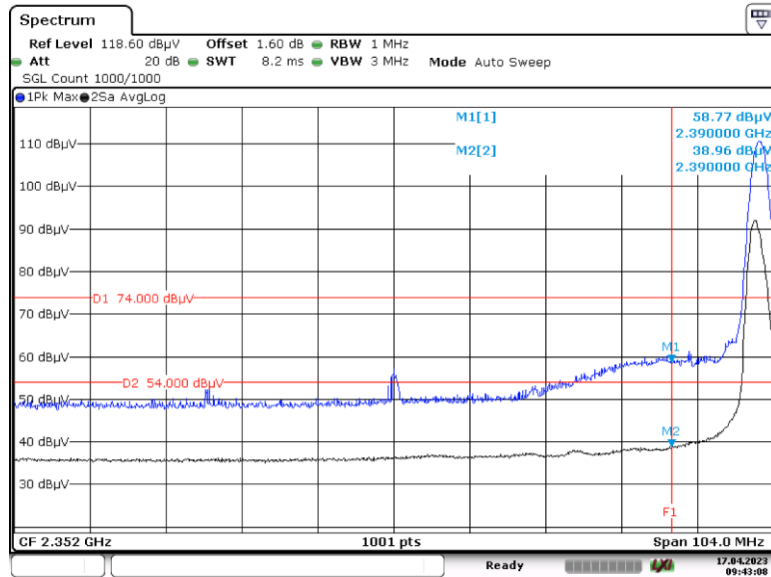
Date: 17.APR.2023 09:48:23

Frequency MHz	Peak (dBμV)	Distance Factor	DCCF (dB)	Antenna Gain (dBi)	Cable Loss (dB)	Offset 3m (dB)	Value (dBμV/m)	Limit (dBμV/m)	Margin (dB)
2483.50	66.1	-11.7	4.9	4.5	1.6	-2.3	63.8	74.0	-10.2

Offset_{3m} = -2.3 dB = -11.7 + 4.9 + 4.54 (Cable Loss is accounted for in plot)

Value = Peak + Offset_{3m}

EDR-3 - DH5, Ch0



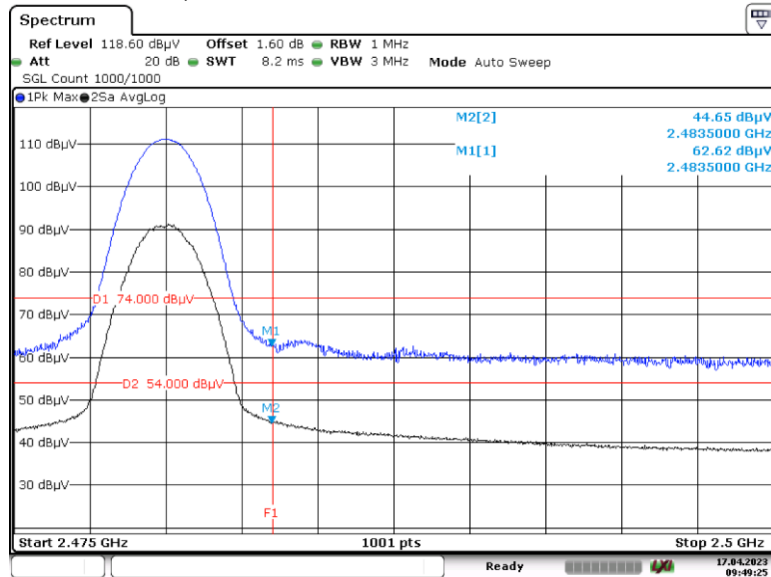
Date: 17.APR.2023 09:43:09

Frequency MHz	Peak (dBμV)	Distance Factor	DCCF (dB)	Antenna Gain (dBi)	Cable Loss (dB)	Offset 3m (dB)	Value (dBμV/m)	Limit (dBμV/m)	Margin (dB)
2352.00	55.0	-11.7	4.9	4.5	1.6	-2.3	52.7	74.0	-21.3
2390.00	58.8	-11.7	4.9	4.5	1.6	-2.3	56.5	74.0	-17.5

Offset_{3m} = -2.3 dB = -11.7 + 4.9 + 4.54 (Cable Loss is accounted for in plot)

Value = Peak + Offset_{3m}

EDR-3 - DH5, Ch78



Date: 17.APR.2023 09:49:25

Frequency MHz	Peak (dBμV)	Distance Factor	DCCF (dB)	Antenna Gain (dBi)	Cable Loss (dB)	Offset 3m (dB)	Value (dBμV/m)	Limit (dBμV/m)	Margin (dB)
2484.00	63.0	-11.7	4.9	4.5	1.6	-2.3	60.7	74.0	-13.3

Offset_{3m} = -2.3 dB = -11.7 + 4.9 + 4.54 (Cable Loss is accounted for in plot)

Value = Peak + Offset_{3m}

8 Pseudo-Random Hop Sequence

8.1 Test Result

Test Description	Test Specification	Test Result
Pseudo-Random Hop Sequence	ANSI C63.10:2013 15.247(a)(1) RSS-247 5.1(a)	Compliant ⁽¹⁾

Note (1): The theory of operation states that the device is Bluetooth and operates using a pseudo-random hopping technique.

8.2 Test Method

Compliance is demonstrated by Manufacturer's declaration or is stated in the Theory of Operation.

Requirement

The hopset shall be such that the near-term distribution of frequencies appears random, with sequential hops randomly distributed in both direction and magnitude of change in the hopset, while the long-term distribution appears evenly distributed.

9 Channel Separation

9.1 Test Result

Test Description	Test Specification	Test Result
Channel Separation	ANSI C63.10:2013 15.247(a)(1) RSS-247 5.1(b)	Compliant

9.2 Test Method

Measurements were taken using the methods defined in ANSI C63.10, Clause 7.8.2. The test data was measured using a spectrum analyzer with Peak detector (max hold) and a resolution bandwidth of 100 kHz. The trace was allowed to stabilize until all channels were displayed.

Requirement

Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the band 2400-2483.5 MHz may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the -20 dB bandwidth of the hopping channel, whichever is greater, provided that the systems operate with an output power no greater than 0.125 W.

9.3 Test Site

SGS EMC Laboratory, Suwanee, GA

Environmental Conditions

Temperature: 19.17 °C

Relative Humidity: 52.1 %

Atmospheric Pressure: 98.2 kPa

9.4 Test Equipment

Test End Date: 15-Mar-2023

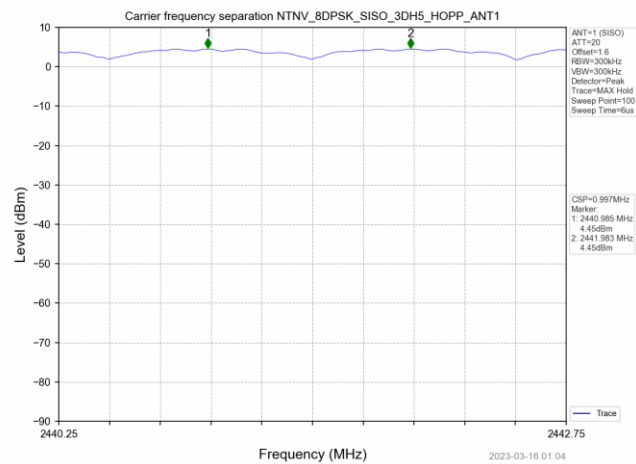
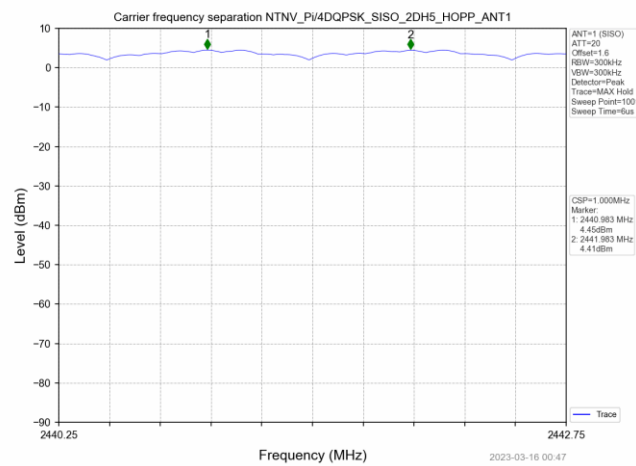
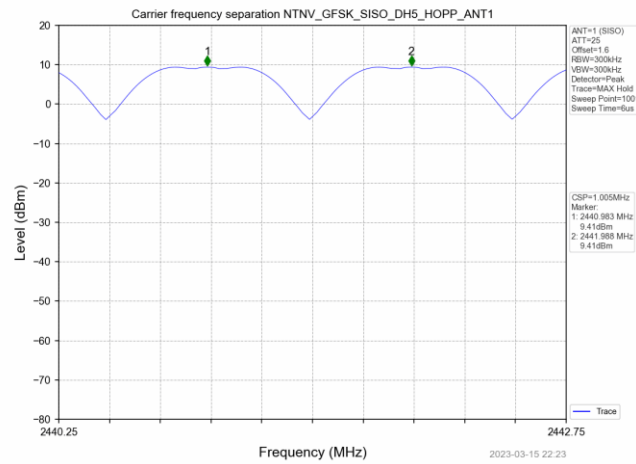
Tester: DA

Equipment	Model	Manufacturer	Asset	Cal Date	Cal Due Date
SIGNAL ANALYZER (TS8997)	FSV30	ROHDE & SCHWARZ	B085749	7-Dec-2022	7-Dec-2023
RF CABLE SMA TO SMA, 0.01-40GHZ	084-0505-059	TELEDYNE STORM MICROWAVE	20108	13-Mar-2023	13-Mar-2024

9.5 Test Data

Test Mode	TX Type	ANT No.	Channel Separation (MHz)	20dB Bandwidth (MHz)	Limits (MHz)	Verdict
GFSK	SISO	1	1.005	0.866	≥0.866	PASS
Pi/4DQPSK	SISO	1	1.000	1.278	≥0.852	PASS
8DPSK	SISO	1	0.997	1.281	≥0.854	PASS

Sample Plot



10 Number of Hopping Channels

10.1 Test Result

Test Description	Test Specification	Test Result
Number of Hopping Channels	ANSI C63.10:2013 15.247(a)(1)(iii) RSS-247 5.1(d)	Compliant

10.2 Test Method

Measurements were taken using the methods defined in ANSI C63.10, Clause 7.8.3. The test data was measured using a spectrum analyzer with Peak detector (max hold) and a resolution bandwidth of 30 kHz. The trace was allowed to stabilize until all channels were displayed.

Requirement

Frequency hopping systems operating in the band 2400-2483.5 MHz shall use at least 15 hopping channels.

10.3 Test Site

SGS EMC Laboratory, Suwanee, GA

Environmental Conditions

Temperature: 19.17 °C

Relative Humidity: 52.1 %

Atmospheric Pressure: 98.2 kPa

10.4 Test Equipment

Test End Date: 15-Mar-2023

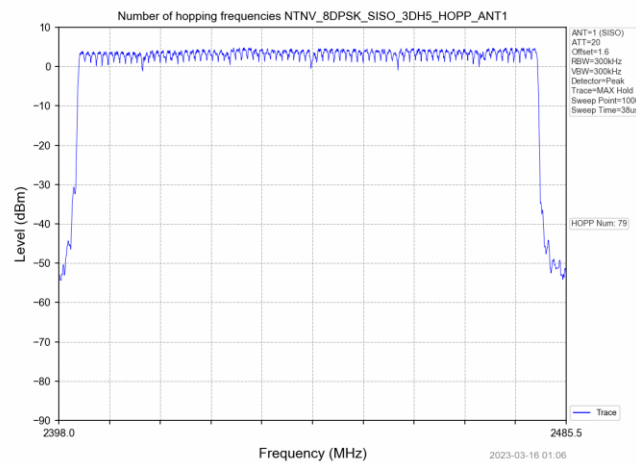
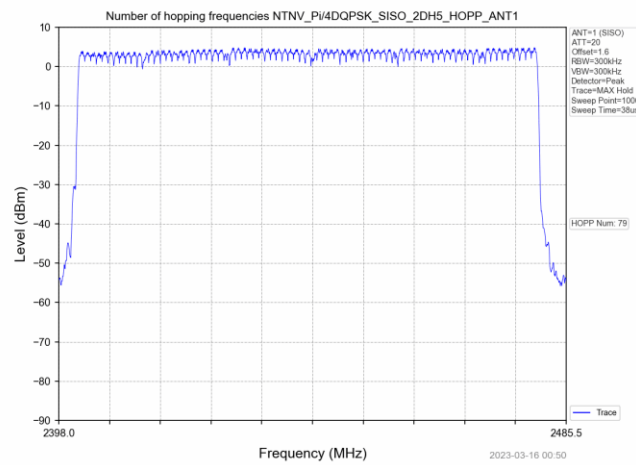
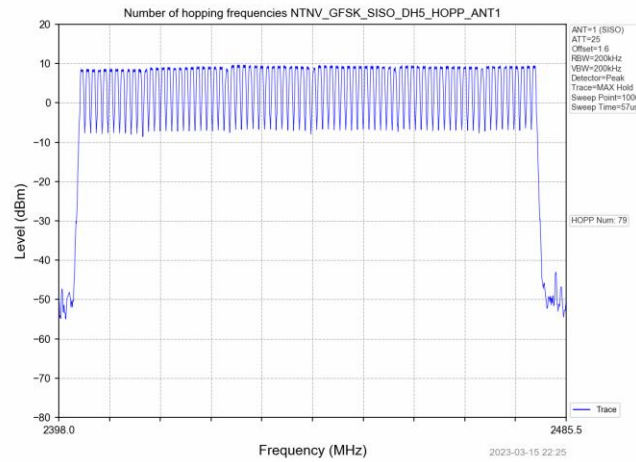
Tester: DA

Equipment	Model	Manufacturer	Asset	Cal Date	Cal Due Date
SIGNAL ANALYZER (TS8997)	FSV30	ROHDE & SCHWARZ	B085749	7-Dec-2022	7-Dec-2023
RF CABLE SMA TO SMA, 0.01-40GHZ	084-0505-059	TELEDYNE STORM MICROWAVE	20108	13-Mar-2023	13-Mar-2024

10.5 Test Data

Test Mode	TX Type	ANT No.	Num of Hopping Frequencies	Limits	Verdict
GFSK	SISO	1	79	≥15	PASS
Pi/4DQPSK	SISO	1	79	≥15	PASS
8DPSK	SISO	1	79	≥15	PASS

Sample Plot



11 Dwell Time

11.1 Test Result

Test Description	Test Specification	Test Result
Dwell Time	ANSI C63.10:2013 15.247(a)(1)(iii) RSS-247 5.1(d)	Compliant

11.2 Test Method

Measurements were taken using the methods defined in ANSI C63.10, Clause 7.8.4. For each packet type and data rate, the pulse width of the packet was measured, and the pulses were counted over the total observation period.

Requirement

The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds, multiplied by the number of hopping channels employed ($0.4 \times 79 = 31.6s$).

11.3 Test Site

SGS EMC Laboratory, Suwanee, GA

Environmental Conditions

Temperature: 19.17 °C

Relative Humidity: 52.1 %

Atmospheric Pressure: 98.2 kPa

11.4 Test Equipment

Test End Date: 15-Mar-2023

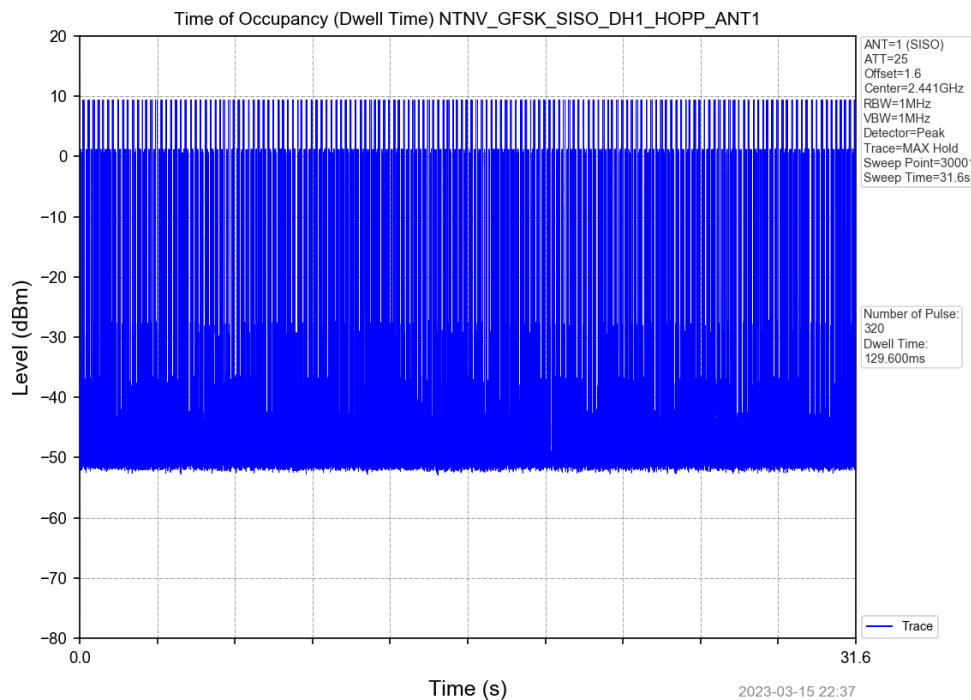
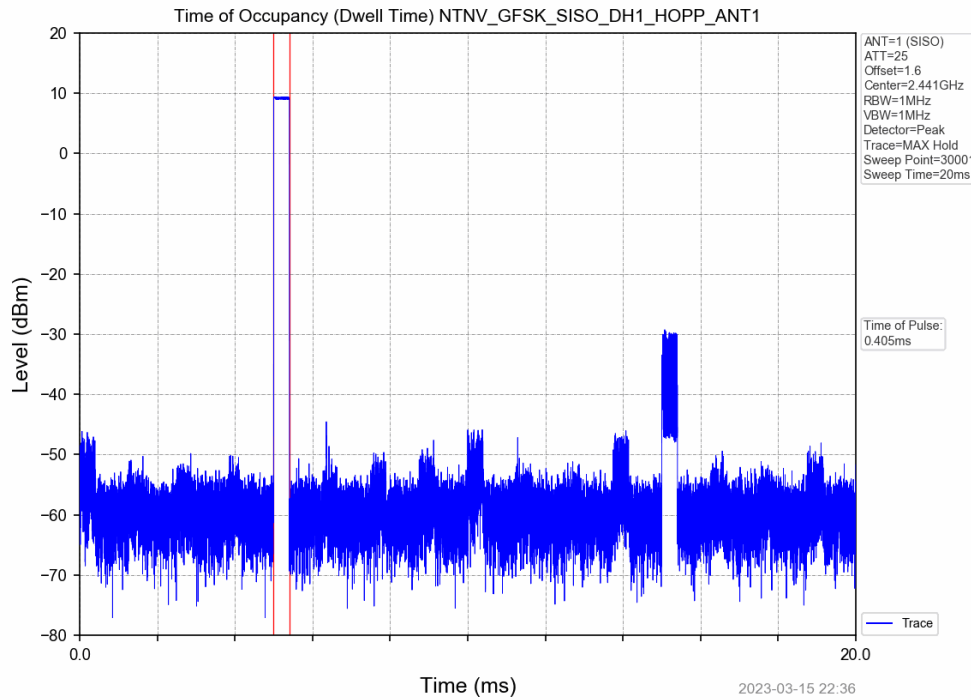
Tester: DA

Equipment	Model	Manufacturer	Asset	Cal Date	Cal Due Date
SIGNAL ANALYZER (TS8997)	FSV30	ROHDE & SCHWARZ	B085749	7-Dec-2022	7-Dec-2023
RF CABLE SMA TO SMA, 0.01-40GHZ	084-0505-059	TELEDYNE STORM MICROWAVE	20108	13-Mar-2023	13-Mar-2024

11.5 Test Data

Test Mode	Packet Type	TX Type	ANT No.	Duration of Single Pulse (ms)	Observation Period (s)	Num of Pulse in Observation Period	Dwell Time (ms)	Limits (ms)	Verdict
GFSK	DH1	SISO	1	0.405	31.6	320	129.600	≤400	PASS
	DH3	SISO	1	1.660	31.6	154	255.640	≤400	PASS
	DH5	SISO	1	2.908	31.6	105	305.340	≤400	PASS
Pi/4DQPSK	2DH1	SISO	1	0.409	31.6	320	130.880	≤400	PASS
	2DH3	SISO	1	1.661	31.6	156	259.116	≤400	PASS
	2DH5	SISO	1	2.909	31.6	108	314.172	≤400	PASS
8DPSK	3DH1	SISO	1	0.409	31.6	319	130.471	≤400	PASS
	3DH3	SISO	1	1.660	31.6	152	252.320	≤400	PASS
	3DH5	SISO	1	2.911	31.6	120	349.320	≤400	PASS

Sample Plot



12 AC Powerline Conducted Emissions

12.1 Test Result

Test Description	Test Specification		Test Result
AC Powerline Conducted Emissions	15.207	RSS-GEN 8.8	Compliant

12.2 Test Method

With the receiver's resolution bandwidth was set to 9 kHz, exploratory scans were performed over the measuring frequency range (0.15 MHz to 30 MHz) using a max hold mode incorporating a Peak detector and Average detector and using the TILE! software. The final test data was measured using a Quasi-Peak detector and Average detector and compared against the limits indicated in the table below.

Frequency Range	Limits (dBuV)
0.15 to 0.5 MHz	Avg 56 to 46 QP 66 to 56
0.5 to 5 MHz	Avg 46 Pk 56
5 to 30 MHz	Avg 50 Pk 60

12.3 Test Site

SGS EMC Laboratory, Suwanee, GA

Environmental Conditions:

Temperature: 22.7 °C

Relative Humidity: 38.8 %

Atmospheric Pressure 97.8 kPa

12.4 Test Equipment

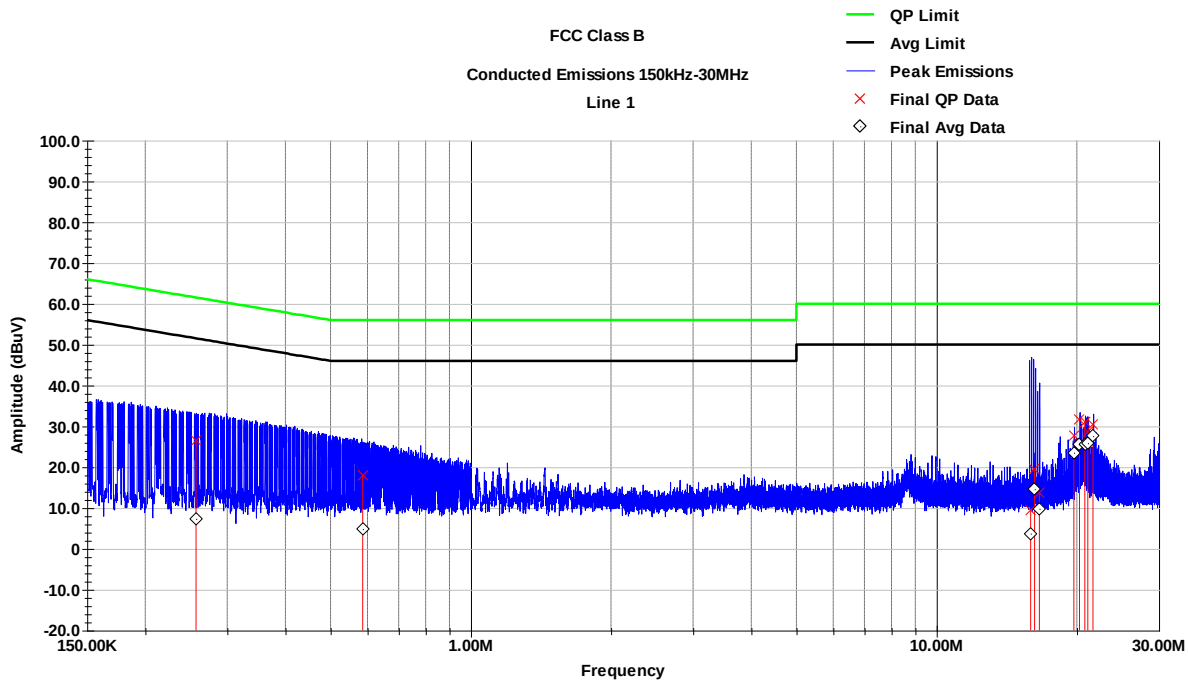
Test End Date: 13-Apr-2023

Tester: EW

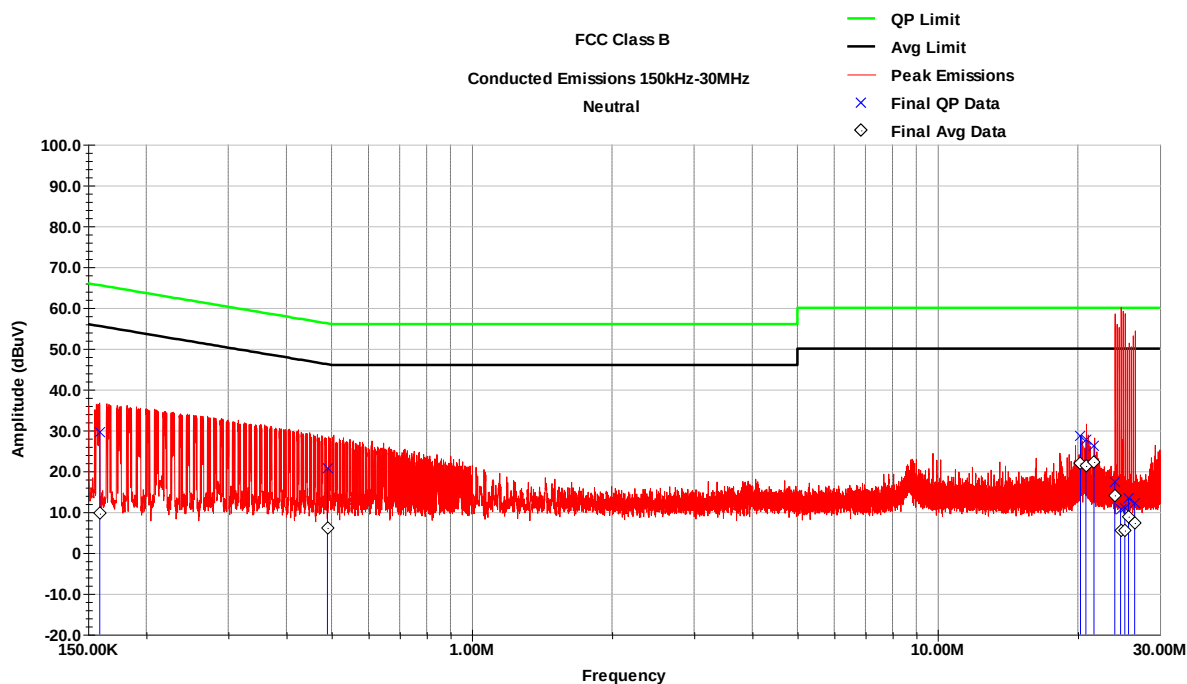
Equipment	Model	Manufacturer	Asset	Cal Date	Cal Due Date
LINE IMPEDANCE STABILIZATION NETWORK	NNB 51	TESEQ	B085882	15-Apr-2022	15-Apr-2023
RF CABLE	UC-N-MM-78	MAURY MICROWAVE	17017	25-Aug-2022	25-Aug-2023
EMI TEST RECEIVER	ESW44	ROHDE & SCHWARZ	22032	24-Nov-2022	24-Nov-2023

Software: Conducted Emissions 230206.til

12.5 Test Data



Frequency MHz	QP Value dBuV	QP Limit dBuV	QP Margin dB	Avg Value dBuV	Avg Limit dBuV	Avg Margin dB
0.257	26.5	61.5	-35.0	7.3	51.5	-44.2
0.586	17.9	56.0	-38.1	4.8	46.0	-41.2
15.918	9.5	60.0	-50.5	3.7	50.0	-46.3
16.230	19.5	60.0	-40.5	14.6	50.0	-35.4
16.616	13.6	60.0	-46.4	9.8	50.0	-40.2
19.708	27.7	60.0	-32.3	23.5	50.0	-26.5
20.257	31.7	60.0	-28.3	25.5	50.0	-24.5
20.808	31.1	60.0	-28.9	25.7	50.0	-24.3
21.113	28.5	60.0	-31.5	25.9	50.0	-24.1
21.663	30.6	60.0	-29.4	27.6	50.0	-22.4



Frequency MHz	QP Value dBuV	QP Limit dBuV	QP Margin dB	Avg Value dBuV	Avg Limit dBuV	Avg Margin dB
0.159	29.6	65.5	-35.9	9.6	55.5	-45.9
0.490	20.6	56.2	-35.6	6.1	46.2	-40.1
20.259	28.7	60.0	-31.3	21.9	50.0	-28.1
20.809	27.6	60.0	-32.4	21.3	50.0	-28.7
21.662	26.2	60.0	-33.8	22.2	50.0	-27.8
24.001	17.3	60.0	-42.7	14.1	50.0	-35.9
24.706	10.7	60.0	-49.3	5.4	50.0	-44.6
25.224	11.1	60.0	-48.9	5.5	50.0	-44.5
25.692	13.5	60.0	-46.5	8.9	50.0	-41.1
26.484	12.3	60.0	-47.7	7.3	50.0	-42.7

13 Measurement Uncertainty

The measurement uncertainty figures are be calculated in accordance with TR 100 028-1 [2] and correspond to an expansion factor (coverage factor) $k = 2$ (which provide confidence levels of 95,45 % in the case where the distributions characterizing the actual measurement uncertainties are normal (Gaussian)).

Parameter	Expanded Uncertainty for Normal k factor equal to 2	
	Required	Laboratory Actual
Radio Frequency	$\pm 1 \times 10^{-5}$	$\pm 9.8 \times 10^{-8}$
total RF power, conducted	± 1.5 dB	± 1.2 dB
RF power density, conducted	± 3 dB	± 0.7 dB
spurious emissions, conducted	± 3 dB	± 2.1 dB
all emissions, radiated	± 6 dB	± 4.8 dB
temperature	$\pm 1^{\circ}\text{C}$	$\pm 0.5^{\circ}\text{C}$
humidity	± 5 %	$\pm 3.5\%$
DC and low frequency voltages	± 3 %	$\pm 0.4\%$

14 Revision History

Revision Level	Description of changes	Revision Date
0	Initial release	31 May 2023
1	- Updated RSS-247 reference to latest issue on title page - Clarified antenna type in sections 1 & 2.3 - Corrected dates of testing in section 2.3 - Added notes on prescan testing <30MHz in sections 6.2 & 6.5 - Corrected ANSI C63.10 section reference in section 7.2	17 November 2023