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EMC Test Report

Prepared for: **Amusement Connect LLC**

Address: **7050 Universal Avenue**
Kansas City, MO 64120, USA

Product: **SmartMech**

FCC ID: **2BA2JGEN4**
IC ID: **30456-GEN4**

Test Report No: **R20220216-20-E4C**

Approved By:

Fox Lane,
EMC Test Engineer

DATE: **25 January 2024**

Total Pages: **20**

Revision Page

Rev. No.	Date	Description
0	31 August 2023	Issued by FLane Prepared by BWinter
A	5 January 2024	Added ISED Standards – FL
B	5 January 2024	Added FCC/IC IDs – FL
C	25 January 2024	Modified Page 1 and 5 -KV

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1 Summary of Test Results

The worst-case measurements were reported in this report. Summary of test results presented in this report correspond to the following section(s):

1.1 Emissions Test Results

The EUT was tested for compliance to:

US CFR Title 47 FCC Part 15.225
RSS-210 Issue 10

Table 1 – Emissions Test Results

Emissions Tests	Test Method and Limits	Result
Radiated Emissions	FCC Part 15.225 (a), (b), (c), (d) RSS-Gen, Issue 5, 6.5, 6.13 RSS-210 Issue 10 B.6	Complies
Bandedge	FCC Part 15.225 (b) (c) RSS-210 Issue 10 B.6	Complies
Frequency Error	FCC Part 15.225 (e) RSS-210 Issue 10 B.6 (b)	Complies
Conducted Emissions	FCC Part 15.207 RSS-Gen Issue 5, Section 8.8	Complies

2 EUT Description

2.1 Equipment under Test (EUT)

Table 2 – Equipment under Test (EUT)

EUT	SmartMech
FCC ID	2BA2JGEN4
IC ID	30456-GEN4
EUT Received	17 July 2023 (Conducted) 17 July 2023 (Radiated)
EUT Tested	18 July 2023- 22 August 2023
Serial No.	NCEE 011234 (Radiated Measurements) NCEE 011233 (Conducted Measurements)
Operating Band	13.56 MHz
Device Type	☐ GMSK ☐ GFSK ☐ BT BR ☐ BT EDR 2MB ☐ BT EDR 3MB ☐ 802.11x ☒ NFC
Power Supply / Voltage	12VDC Power Supply, (SN 00077 for conducted emissions)

2.2 Laboratory Description

All testing was performed at the following Facility:

The Nebraska Center for Excellence in Electronics (NCEE Labs)
4740 Discovery Drive
Lincoln, NE 68521

A2LA Certificate Number:	1953.01
FCC Accredited Test Site Designation No:	US1060
Industry Canada Test Site Registration No:	4294A-1
NCC CAB Identification No:	US0177

Environmental conditions varied slightly throughout the tests.

2.3 EUT Setup

The EUT was powered by 120 VAC / 60Hz power supply with 12 VDC Output for all tests.

Conducted Emissions used the 12VDC power supply with NCEE serial number 00077.

3 Test Results

3.1 Radiated Emissions, Band Width, Field Strength, and Band edge

Test:	FCC Part 15.225 (a), (b), (c), (d) RSS-210 Issue 10 B.6
Test Specifications:	Class A
Test Result:	Complies

3.1.1 Test Description

Radiated emissions measurements were made from 30MHz to 1GHz at a distance of 3m (Radiated Emissions) and 3m (Bandwidth, Field Strength and Band edges) inside a semi-anechoic chamber. The EUT was rotated 360°, the antenna height varied from 1-4 meters and both the vertical and horizontal antenna polarizations examined. For measurements below 30 MHz, the loop antenna was used to measure in all 3 axes. The results were compared against the limits. Measurements were made by first using a spectrum analyzer to acquire the signal spectrum; individual frequencies were then measured using a CISPR 16.1 compliant receiver with the following bandwidth setting:

30MHz – 1GHz: 120kHz IF bandwidth, 60kHz steps
150kHz – 30MHz: 9kHz RBW, 4.5 kHz steps

Intermodulation products were investigated by measuring spurious emissions with the 2.4 GHz radio running in parallel with the NFC radio. No intermodulation products were found above the limits.

3.1.2 Test Results

No radiated emissions measurements were found in excess of the limits. Test result data can be seen below.

3.1.3 Test Environment

Testing was performed at the NCEE Labs Lincoln facility in the 10m semi-anechoic chamber. Laboratory environmental conditions varied slightly throughout the test.

3.1.4 Test Setup

See Section 2.3 for further details.

3.1.5 Test Equipment Used

DESCRIPTION AND MANUFACTURER	MODEL NO.	SERIAL NO.	LAST CALIBRATION DATE	CALIBRATION DUE DATE
Keysight MXE Signal Analyzer (44GHz)**	N9038A	MY59050109	July 17, 2023	July 17, 2025
Keysight MXE Signal Analyzer (26.5GHz)**	N9038A	MY56400083	July 17, 2023	July 17, 2025
SunAR RF Motion	JB1	A082918-1	July 26, 2022	July 26, 2023
SunAR RF Motion	JB1	A091418	July 26, 2023	July 26, 2024
Com-Power Active Loop Antenna**	AI-130R	10160084	April 12, 2022	April 12, 2024
Com-Power LISN, Single Phase**	LI-220C	20070017	July 18, 2023	July 18, 2025
8447F POT H64 Preamplifier*	8447F POT H64	3113AD4667	March 21, 2022	March 21, 2024
Agilent 87405A Preamplifier	87405A	3207A01838	June 5, 2023	June 5, 2025
ETS – Lindgren- VSWR on 10m Chamber***	10m Semi-anechoic chamber-VSWR	4740 Discovery Drive	July 30, 2020	July 30, 2024
NCEE Labs-NSA on 10m Chamber*	10m Semi-anechoic chamber-NSA	NCEE-001	May 25, 2022	May 25, 2024
TDK Emissions Lab Software	V11.25	700307	NA	NA
RF Cable (preamplifier to antenna)*	MFR-57500	90-195-040	August 22, 2022	August 22, 2024
RF Cable (antenna to 10m chamber bulkhead)*	FSCM 64639	01E3872	June 5, 2023	June 5, 2025
RF Cable (10m chamber bulkhead to control room bulkhead)*	FSCM 64639	01E3874	June 5, 2023	June 5, 2025
RF Cable (control room bulkhead to test receiver)*	FSCM 64639	01F1206	June 5, 2023	June 5, 2025
N connector bulkhead (10m chamber)*	PE9128	NCEEBH1	June 5, 2023	June 5, 2025
N connector bulkhead (control room)*	PE9128	NCEEBH2	June 5, 2023	June 5, 2025

*Internal Characterization
**Two Year Calibration Cycle
***Four Year Calibration Cycle

3.1.6 Test Pictures and/or Figures

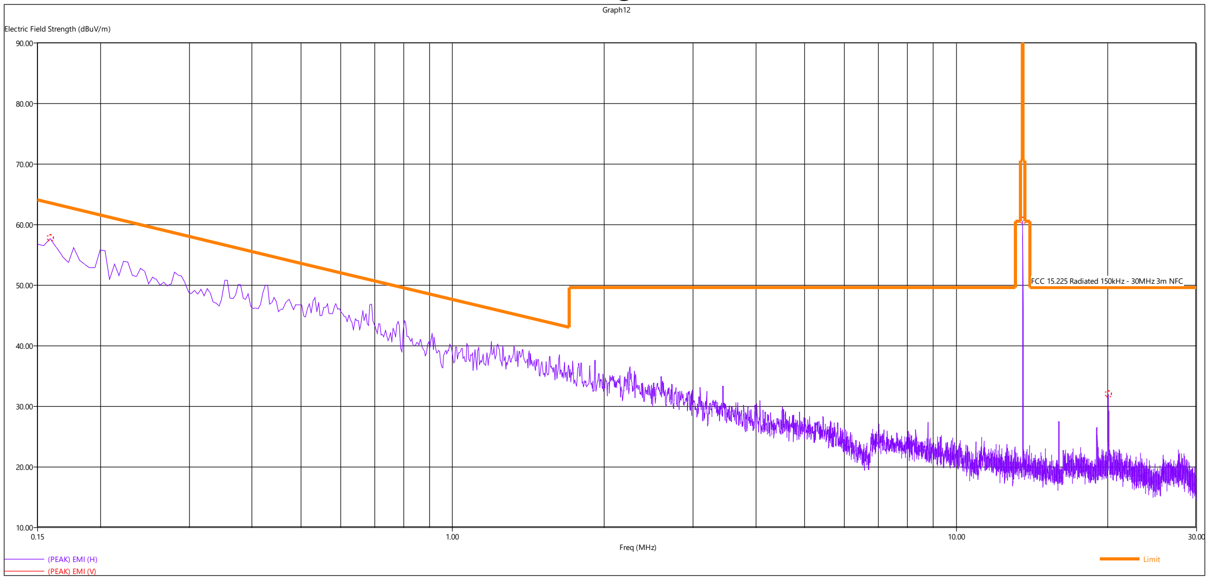

Figure 1 – NFC Radiated Emissions Plot, 150kHz – 30MHz

Peak Measurements, 150kHz – 30MHz			
Freq (MHz)	**(PEAK) EMI (H) (dBuV/m)**	**Limit (dBuV/m)**	**(PEAK) Margin (H) (dB)**
0.16	**57.69**	**63.58**	**5.89**
13.56	60.66	104.00	43.34
20.05	32.00	49.54	17.54

The EUT was maximized in all 3 orthogonal axes. The worst-case is shown in the plot and table above.

NFC Field Strength			
Field Strength (dBµV/m)	**Limit (dBµV/m)***	**Margin**	**Result**
60.66	104.00	43.34	Pass

*Limit extrapolated to 3m test distance.

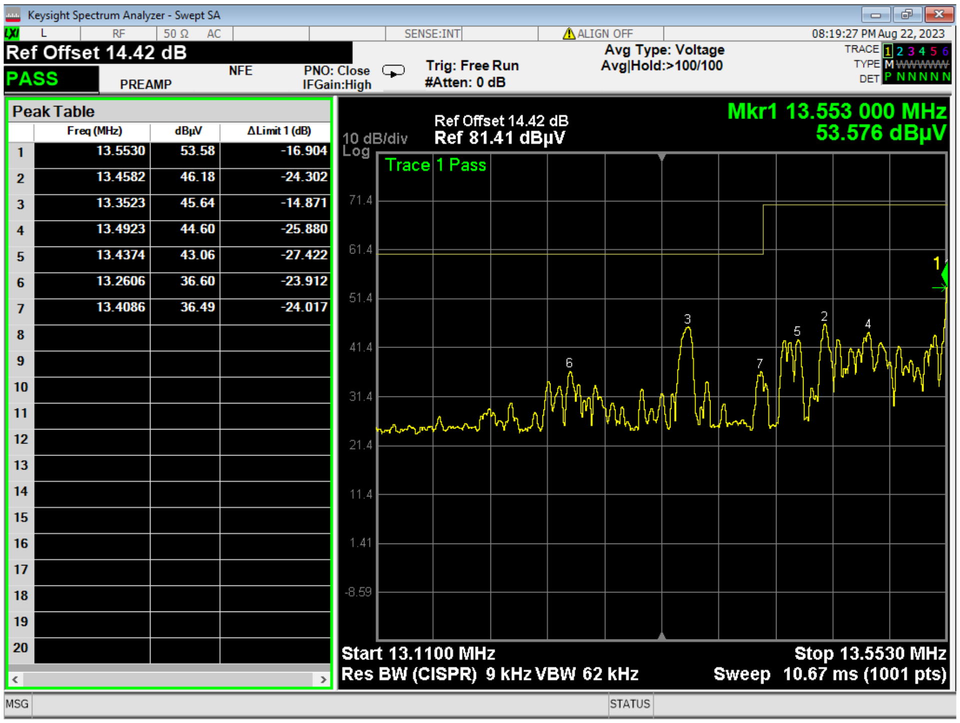

Figure 2 – Lower Band Edge

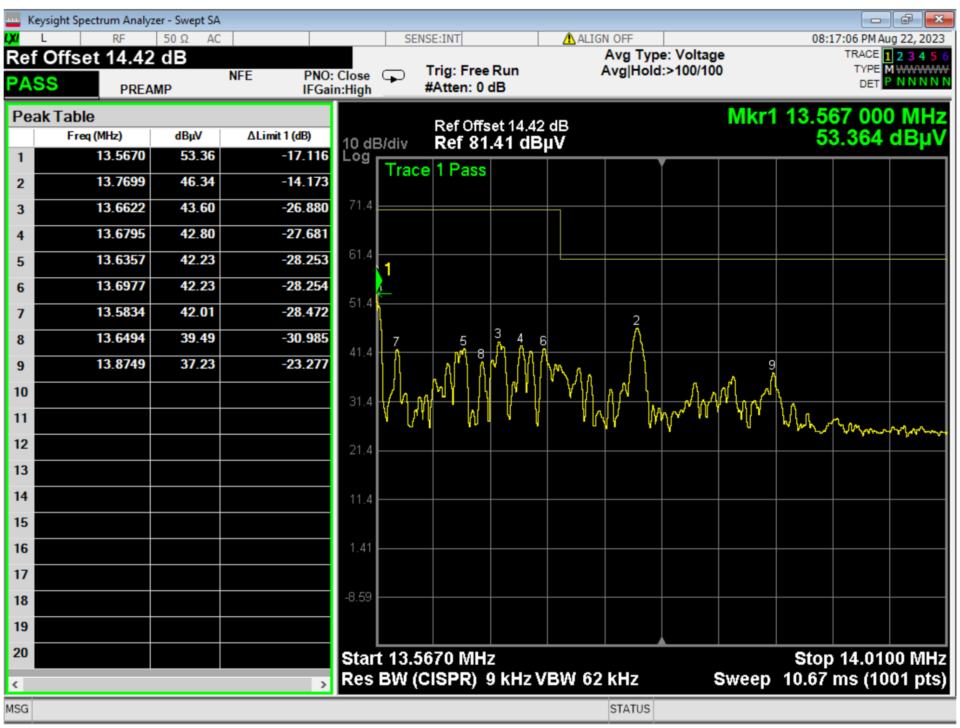

Figure 3 – Upper Bandedge

Band Edge Measurements				
Band edge /Measurement Frequency (MHz)	**Corrected band level dBμV/m @ 3m**	**Limit* dBμV**	**Margin**	**Result**
13.3523	45.64	60.51	14.87	Pass
13.7699	46.34	60.51	14.17	Pass

*Limit extrapolated to 3m test distance

The EUT was maximized in all 3 orthogonal axes. The worst case is shown in the plot above.

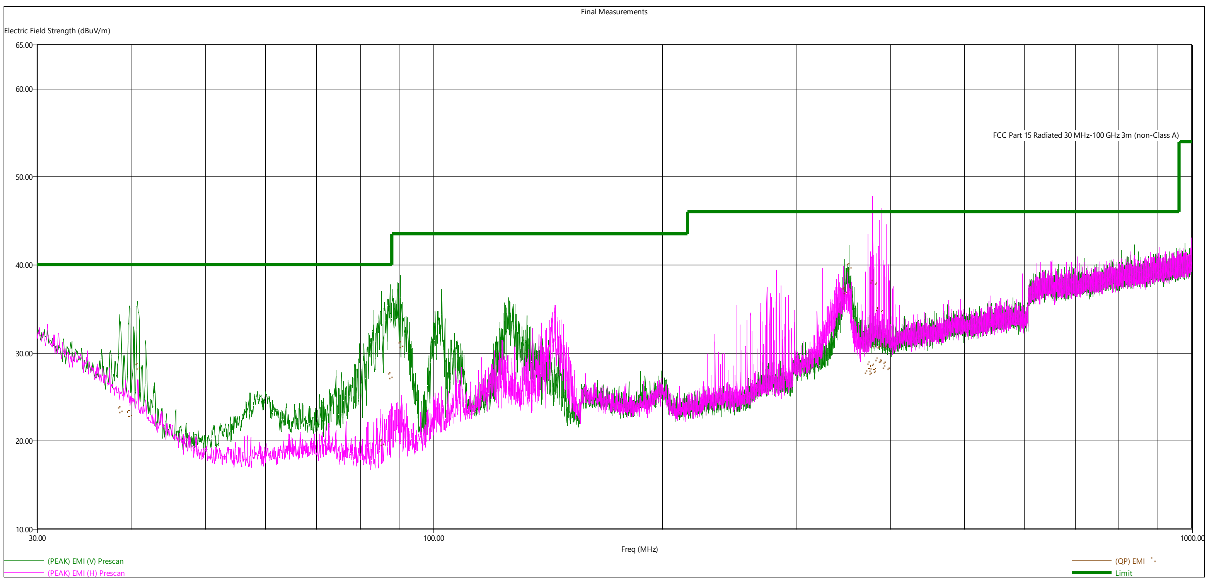

Figure 4 – NFC Radiated Emissions Plot, 30MHz – 1GHz

Quasi-Peak Measurements, 30MHz – 1GHz						
Frequency	**Level**	**Limit**	**Margin**	**Height**	**Angle**	**Pol**
MHz	**dBµV/m**	**dBµV/m**	**dB**	**cm.**	**deg.**	
373.370160	27.71	46.02	18.31	219.94	88.75	H
376.086000	28.66	46.02	17.36	253.25	282.75	H
377.251200	28.28	46.02	17.74	243.40	343.25	H
378.686400	27.88	46.02	18.14	289.91	254.00	H
379.661040	37.93	46.02	8.09	224.23	317.00	H
382.682160	30.70	46.02	15.32	232.65	290.00	H
385.358160	29.13	46.02	16.89	322.50	165.75	H
386.774400	34.82	46.02	11.20	116.77	112.00	H
389.457840	28.89	46.02	17.13	259.58	278.75	H
390.660480	30.74	46.02	15.28	105.85	313.50	H
394.771440	28.29	46.02	17.73	319.46	159.25	H
38.573760	23.50	40.00	16.50	216.17	102.00	V
39.557760	23.00	40.00	17.00	104.23	134.75	V
40.693920	28.44	40.00	11.56	107.88	133.75	V
85.041120	19.77	40.00	20.23	106.86	140.50	V
87.337920	27.34	40.00	12.66	247.58	132.50	V
90.231120	30.83	43.52	12.69	250.74	133.25	V
348.064080	37.02	46.02	9.00	129.13	69.25	V
352.564320	39.79	46.02	6.23	130.26	270.00	V

The EUT was maximized in all 3 orthogonal axes. The worst-case is shown in the plot and table above.

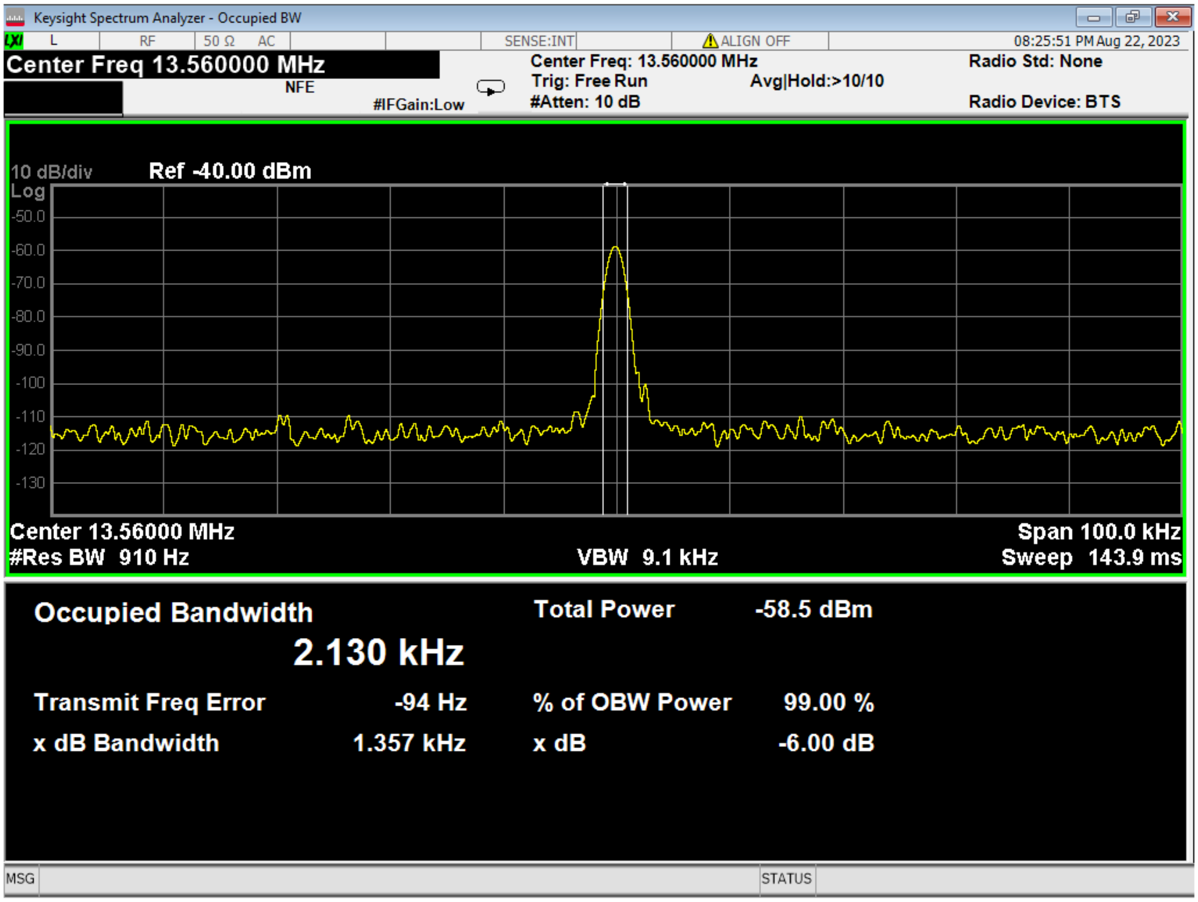

Figure 5 – NFC Occupied Bandwidth

3.2 Frequency Error

Test:	FCC Part 15.225 (e) RSS-210 Issue 10 B.6 (b)
Test Result:	Complies

3.2.1 Test Description

Frequency error was determined using the built-in frequency error function of the spectrum analyzer. The analyzer finds the occupied bandwidth, calculates the center of the given band then returns the deviation with respect to the given transmit frequency. The temperature was varied from -20°C to 50°C. The voltage was varied from 10.2V to 13.8V at 20C.
Limit: 100 PPM

3.2.2 Test Results

No results were found to be in excess of the limits. A table of the results can be seen below.

3.2.3 Test Environment

Testing was performed at the NCEE Labs Lincoln facility.

3.2.4 Test Setup

The device was tested at 10.2V and 13.8V for worst case voltage for frequency error.
See Section 2.3 for further details.

3.2.5 Test Equipment Used

See section 2.4 for the equipment list.

3.2.6 Test results

Smart Mech	
Temperature (°C)	Channel (Hz) 13.56000 Nom.
-20°C	49
-10°C	53
0°C	38
10°C	2
20°C	-42
30°C	-90
40°C	-137
55°C	-164

Smart Mech		Nominal Battery Voltage: 12VDC
Voltage (VDC)	Temperature	Frequency Error (Hz)
10.2	20°C	-44
12.0	20°C	-42
13.8	20°C	-45

Limit: 100 PPM = 0.01% = 0.01 x 13.56 kHz = 1356 Hz
Values shown in Hz.
Uncertainty = ±200 Hz

3.3 Conducted AC Mains Emissions

Test Method: ANSI C63.10-2013, Section(s) 6.2

Limits for conducted emissions measurements:

FREQUENCY OF EMISSION (MHz)	CONDUCTED LIMIT (dBµV)	
	Quasi-peak	Average
0.15-0.5	66 to 56	56 to 46
0.5-5	56	46
5-30	60	50

Notes:
1. The lower limit shall apply at the transition frequencies.
2. The limit decreases in line with the logarithm of the frequency in the range of 0.15 to 0.50 MHz
3. All emanations from a class A/B digital device or system, including any network of conductors and apparatus connected thereto, shall not exceed the level of field strengths specified above.

Test Procedures:

a. The EUT was placed 0.8m above a ground reference plane and 0.4 meters from the conducting wall of a shielded room with EUT being connected to the power mains through a line impedance stabilization network (LISN). The LISN provides 50 ohm/ 50uH of coupling impedance for the measuring instrument.
b. Both lines of the power mains connected to the EUT were checked for maximum conducted interference as well as the ground.
c. The frequency range from 150 kHz to 30 MHz was searched. Emission levels over 10dB under the prescribed limits are not reported.
d. Results were compared to the FCC 15.207 limits.

Deviation from the test standard:
No deviation

EUT operating conditions:
Details can be found in section 2.1 of this report. NCEE SN 00077 12VDC power supply was used for AC Conducted Emissions instead of the generic 12VDC power supply that came with the EUT.
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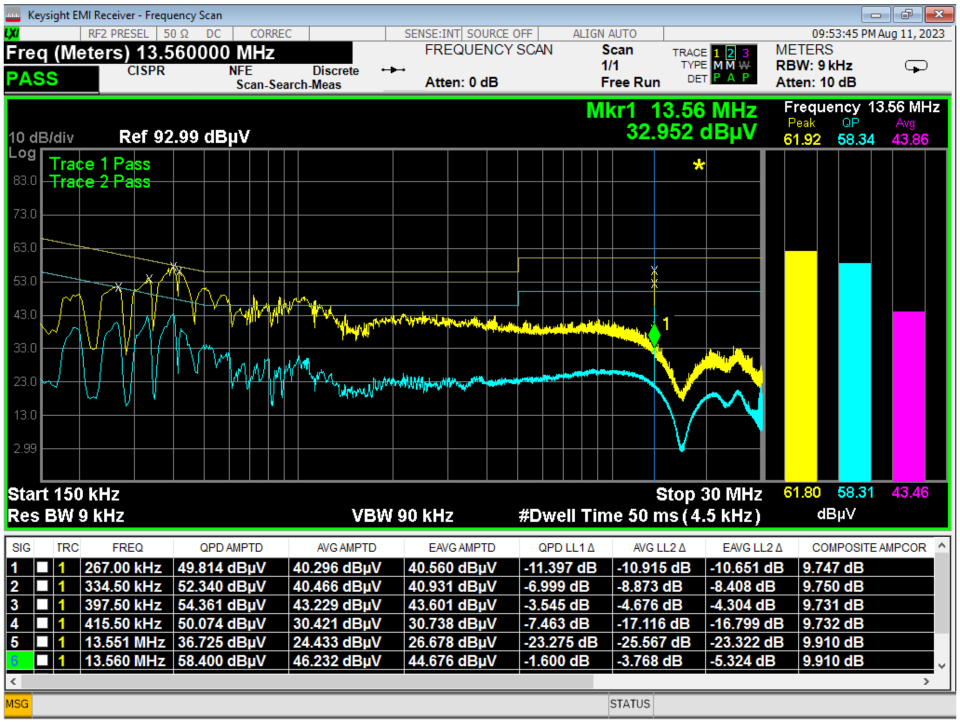
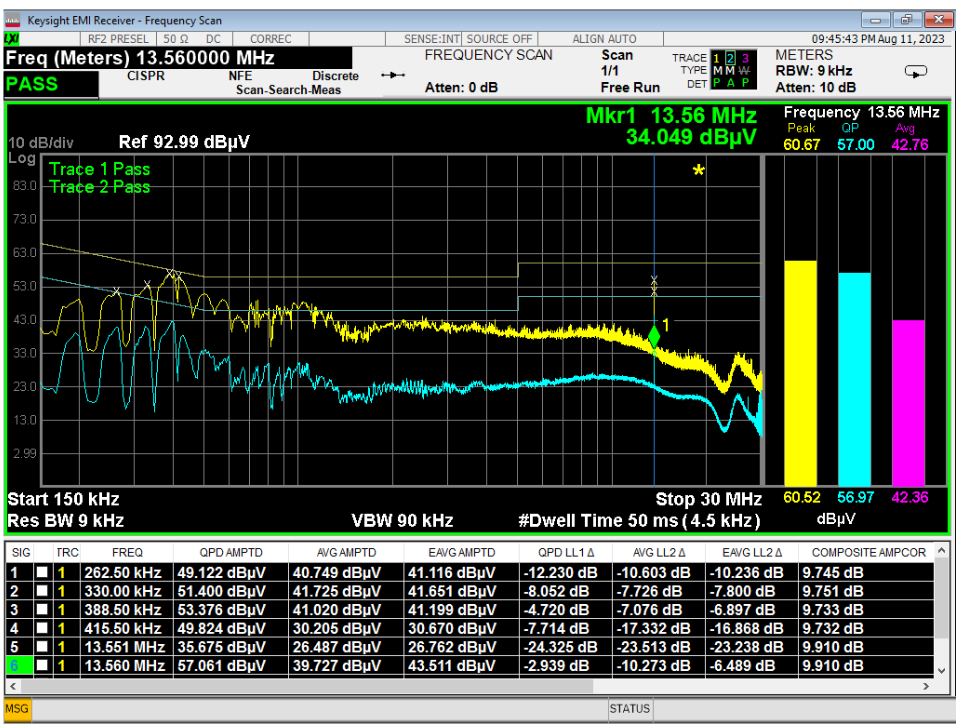
Test Results:



SIG	TRC	FREQ	QPD AMPTD	AVG AMPTD	EAVG AMPTD	QPD LL1 Δ	AVG LL2 Δ	EAVG LL2 Δ	COMPOSITE AMPCOR
1	1	267.00 kHz	49.814 dBµV	40.296 dBµV	40.560 dBµV	-11.397 dB	-10.915 dB	-10.651 dB	9.747 dB
2	1	334.50 kHz	52.340 dBµV	40.466 dBµV	40.931 dBµV	-6.999 dB	-8.873 dB	-8.408 dB	9.750 dB
3	1	397.50 kHz	54.361 dBµV	43.229 dBµV	43.601 dBµV	-3.545 dB	-4.676 dB	-4.304 dB	9.731 dB
4	1	415.50 kHz	50.074 dBµV	30.421 dBµV	30.738 dBµV	-7.463 dB	-17.116 dB	-16.799 dB	9.732 dB
5	1	13.551 MHz	36.725 dBµV	24.433 dBµV	26.678 dBµV	-23.275 dB	-25.567 dB	-23.322 dB	9.910 dB
6	1	13.560 MHz	58.400 dBµV	46.232 dBµV	44.676 dBµV	-1.600 dB	-3.768 dB	-5.324 dB	9.910 dB

Figure 6 – Conducted Emissions Plot, Line, NFC, 12% RFID duty cycle, SN 00077 power supply



SIG	TRC	FREQ	QPD AMPTD	AVG AMPTD	EAVG AMPTD	QPD LL1 Δ	AVG LL2 Δ	EAVG LL2 Δ	COMPOSITE AMPCOR
1	1	262.50 kHz	49.122 dBµV	40.749 dBµV	41.116 dBµV	-12.230 dB	-10.603 dB	-10.236 dB	9.745 dB
2	1	330.00 kHz	51.400 dBµV	41.725 dBµV	41.651 dBµV	-8.052 dB	-7.726 dB	-7.800 dB	9.751 dB
3	1	388.50 kHz	53.376 dBµV	41.020 dBµV	41.199 dBµV	-4.720 dB	-7.076 dB	-6.897 dB	9.733 dB
4	1	415.50 kHz	49.824 dBµV	30.205 dBµV	30.670 dBµV	-7.714 dB	-17.332 dB	-16.868 dB	9.732 dB
5	1	13.551 MHz	35.675 dBµV	26.487 dBµV	26.762 dBµV	-24.325 dB	-23.513 dB	-23.238 dB	9.910 dB
6	1	13.560 MHz	57.061 dBµV	39.727 dBµV	43.511 dBµV	-2.939 dB	-10.273 dB	-6.489 dB	9.910 dB

Figure 7 – Conducted Emissions Plot, Neutral, NFC, 12% RFID duty cycle, SN 00077 power supply

APPENDIX A: SAMPLE CALCULATION

Field Strength Calculation

The field strength is calculated by adding the Antenna Factor and Cable Factor, and subtracting the Amplifier Gain (if any) from the measured reading. The basic equation with a sample calculation is as follows:

FS = RA + AF – (-CF + AG) + AV

where FS = Field Strength
RA = Receiver Amplitude
AF = Antenna Factor
CF = Cable Attenuation Factor
AG = Amplifier Gain
AV = Averaging Factor (if applicable)

Assume a receiver reading of 55 dBμV is obtained. The Antenna Factor of 12 and a Cable Factor of 1.1 is added. The Amplifier Gain of 20 dB is subtracted, giving a field strength of 48.1 dBμV/m.

FS = 55 + 12 – (-1.1 + 20) + 0 = 48.1 dBμV/m

The 48.1 dBμV/m value can be mathematically converted to its corresponding level in μV/m.
Level in μV/m = Common Antilogarithm [(48.1 dBμV/m)/20]= 254.1 μV/m
AV is calculated by taking the 20*log(T_{on}/100) where T_{on} is the maximum transmission time in any 100ms window.

EIRP Calculations

In cases where direct antenna port measurement is not possible or would be inaccurate, output power is measured in EIRP. The maximum field strength is measured at a specified distance and the EIRP is calculated using the following equation;

EIRP (Watts) = [Field Strength (V/m) x antenna distance (m)]^2 / 30
Power (watts) = 10^[Power (dBm)/10] / 1000
Voltage (dBμV) = Power (dBm) + 107 (for 50Ω measurement systems)
Field Strength (V/m) = 10^[Field Strength (dBμV/m) / 20] / 10^6
Gain = 1 (numeric gain for isotropic radiator)
Conversion from 3m field strength to EIRP (d=3):

EIRP = [FS(V/m) x d^2]/30 = FS [0.3]   for d = 3

EIRP(dBm) = FS(dBμV/m) – 10(log 10^9)+ 10log[0.3] = FS(dBμV/m) - 95.23

10log(10^9) is the conversion from micro to milli.

APPENDIX B – MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been for tests performed in this test report:

Test	Frequency Range	Uncertainty Value (dB)
Radiated Emissions, 3m	30MHz - 1GHz	±4.31
Radiated Emissions, 3m	1GHz - 18GHz	±5.08
Emissions limits, conducted	30MHz – 18GHz	±3.03

Expanded uncertainty values are calculated to a confidence level of 95%.

REPORT END