Test Report # 319122 A

Equipment Under Test:	HC1
Test Date(s):	7/30/2019 – 8/1/2019
Prepared for:	ATTN: Basman Dahleh Guardhat 1520 Woodward Ave 3rd floor Detroit, MI 48226

Report Issued by: Shane Dock, EMC Engineer

Signature:

Date: 11/25/2019

Report Reviewed by: Laura Zehnder, Certification Engineer

Signature:

Date: 9/4/2019

Report Constructed by: Shane Dock, EMC Engineer

Signature:

Date: 8/13/2019

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Laird Technologies Test Services in Review

The Laird Technologies, Inc. laboratory located at W66 N220 Commerce Court Cedarburg, Wisconsin, 53012 USA is recognized through the following organizations:

TESTING CERT #1255.01

A2LA – American Association for Laboratory Accreditation

Accreditation based on ISO/IEC 17025:2017 with Electrical (EMC) Scope

A2LA Certificate Number: 1255.01

Scope of accreditation includes all test methods listed herein unless otherwise noted

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Federal Communications Commission (FCC) – USA

Accredited Test Firm Registration Number: 953492

Recognition of two 3 meter Semi-Anechoic Chambers

Government of Canada

Innovation, Science and Economic Development Canada

Accredited U.S. Identification Number: US0218

Recognition of two 3 meter Semi-Anechoic Chambers

1 Test Report Summary

During **7/30/2019 – 8/1/2019** the Equipment Under Test (EUT), **HC1**, as provided by **Guardhat** was tested to the following requirements:

FCC Part 15.225

Requirements	Description	Method	Compliant
FCC Part 15.225 a-d RSS-210	Radiated Emissions	ANSI C63.10	Yes
FCC Part 15.225 e RSS-210	Frequency Tolerance of the Carrier Signal	ANSI C63.10	Yes
FCC: 2.1049 IC: RSS-GEN 6.6	Occupied Bandwidth	ANSI C63.10	Reported

Notice:

The results relate only to the item tested as configured and described in this report. Any additional configurations, modes of operation, or modifications made to the equipment under test after the specified test date(s) are at the decision of the client and may not apply to the data seen in this test report.

The decision rule for Pass / Fail assessment to the specification or standard listed in this test report has been agreed upon by the client and laboratory to be as follows:

Measurement Type	Rule
Emissions – Amplitude	1 dB below specified limit
Emissions – Frequency	1% less than the specification
Immunity	Tested at specified level

2 CLIENT INFORMATION

Company Name	Guardhat
Contact Person	Basman Dahleh
Address	1520 Woodward Ave 3rd floor Detroit, MI 48226

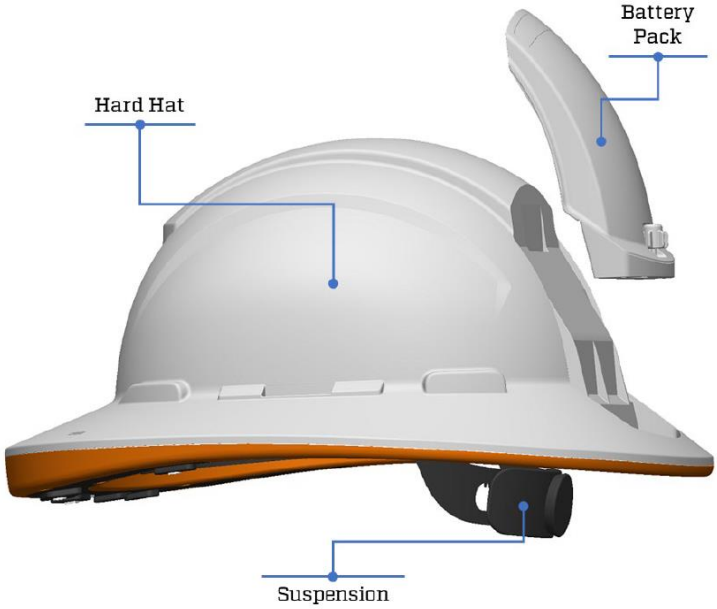
2.1 Equipment Under Test (EUT) Information

The following information has been supplied by the client

Product Name	HC1
Model Number	HC1
Serial Number	P240
FCC/IC ID	FCC ID: 2AR6OHC1000 IC ID: 24751-HC1000

2.2 Product Description

The HC1 Hardhat is a battery-operated smart hardhat as shown in the figure below.



The HC1 is intended for use in outdoor or indoor environments with data connectivity to a Guardhat IoT data platform for user management, device management, and message management. The data

connectivity is automatically selected based on availability, wifi or LTE in order of preference. The user can authenticate for services via the NFC reader located near the front of the brim. The unit can also connect to other devices via a BT/BLE interface. For location finding the device can utilize the embedded position board for precise requirements (UWB and/or 2.4GHz) or GPS for general use. The antennas are all affixed to the hat or pc boards and all cabled antennas use connectors that are affixed, with permanent epoxy, to their respective receptacles without an opportunity for removal or replacement by the user.

2.3 Modifications Incorporated for Compliance

None noted at time of test

2.4 Deviations and Exclusions from Test Specifications

None noted at time of test

2.5 Additional Information

EUT features an NFC radio at 13.56 MHz manufactured by NXP (Part Number PN7150B0HN/ C11002Y) with a FxR.80.52 antenna. EUT tested in a modulated Tx mode for radiated emissions testing and in an unmodulated mode for frequency stability.

2.6 Simultaneous Transmission Cases

The EUT was also tested for simultaneous transmission (not included in this report. Multiple configurations were tested to facilitate each combination of radios that could be on and transmitting as provided by the manufacturer.

3 REFERENCES

Publication	Edition	Date	AMD1
FCC Part 2 & 15	-	2019	-
ANSI C63.10	-	2013	-
RSS-210	9	2016	2017
RSS-GEN	5	2018	-

4 Uncertainty Summary

Using the guidance of the following publications the calculated measurement uncertainty represents an expanded uncertainty expressed at approximately the 95 % confidence level, using a coverage factor of k = 2.

References	Version / Date
CISPR 16-4-1	Ed. 2 (2009-02)
CISPR 16-4-2	Ed. 2 (2011-06)
CISPR 32	Ed. 1 (2012-01)
ANSI C63.23	2012
A2LA P103	February 4, 2016
A2LA P103c	August 10, 2015
ETSI TR 100-028	V1.3.1 (2001-03)

Measurement Type	Configuration	Uncertainty ±
Radiated Emissions	Biconical Antenna	5.0 dB
Radiated Emissions	Log Periodic Antenna	5.3 dB
Radiated Emissions	Horn Antenna	4.7 dB
AC Line Conducted Emissions	Artificial Mains Network	3.4 dB
Telecom Conducted Emissions	Asymmetric Artificial Network	4.9 dB
Disturbance Power Emissions	Absorbing Clamp	4.1 dB
Radiated Immunity	3 Volts/meter	2.2 dB
Conducted Immunity	CDN/EM/BCI	2.4/3.5/3.4 dB
EFT Burst/Surge	Peak pulse voltage	164 volts
ESD Immunity	15 kV level	1377 Volts

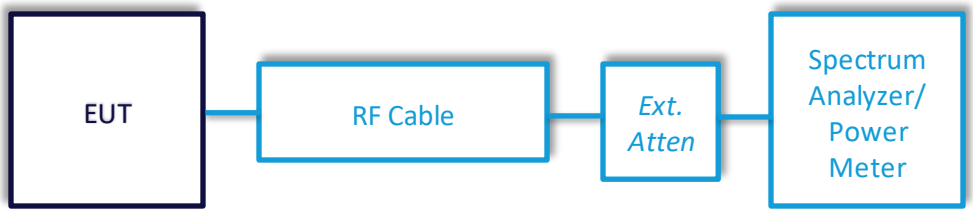
Parameter	ETSI U.C. ±	U.C. ±
Radio Frequency, from F0	$1x10^{-7}$	$0.55x10^{-7}$
Occupied Channel Bandwidth	5 %	2 %
RF conducted Power (Power Meter)	1.5 dB	1.2 dB
RF conducted emissions (Spectrum Analyzer)	3.0 dB	1.7 dB
All emissions, radiated	6.0 dB	5.3 dB
Temperature	1° C	0.65° C
Humidity	5 %	2.9 %
Supply voltages	3 %	1 %

5 Test Data

5.1 Antenna Port Conducted Emissions

Description of Measurement	The direct measurement of emissions at the antenna port of the EUT is achieved by use of a RF connection to a spectrum analyzer or power meter. The cable and attenuator factors are loaded into the analyzer or power meter allowing for direct measurement readings without the need for further corrections.
Example Calculations	Measurement (dBm) + Cable factor (dB) + External Attenuator (dB) = Corrected Reading (dBm) Margin (dB) = Limit (dBm) – Corrected Reading (dBm)

Block Diagram



5.1.1 Frequency Tolerance Test

Operator	Jon Dilley	**QA**	Shane Dock
Temperature	23.3 degrees C	**R.H. %**	43.2% RH
Test Date	8/1/19	**Location**	Temperature Chamber
Requirement	FCC 15.225 e	**Method**	ANSI C63.10

Limits:

Frequency Tolerance
0.01% of operating frequency

Test Parameters

Frequency	13.56 MHz	**Setup**	EUT Placed in a temperature chamber and monitored with a loop antenna.
RBW	1 MHz	**VBW**	3 MHz
Detector(s)	Peak Detector	**Settings**	EUT Tested at -20, 20 and 50 degrees Celsius. 20 degrees Celsius test run at 3.4, 4.0, and 4.6 VDC.

Instrumentation

Laird

Date : 29-Jul-2019 Test : NFC Tx Job : C-3227

PE : Shane Dock Customer : Guardhat Quote : 319122

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	EE 960088	Analyzer - EMI Receiver	Agilent	N9038A	MY51210138	4/23/2019	4/23/2020	Active Calibration
2	AA 960006	Antenna - Active Loop	EMCO	6502	9205-2753	8/28/2017	8/28/2019	Active Calibration

EUT Parameters

Input Power	4 VDC (3.4 and 4.6 VDC also tested at 20 degrees Celsius	**Mode**	Unmodulated Tx
Frequency	13.56 MHz		

Data Table

Temperature (Celsius)	Voltage	Frequency (Hz)
-20	4.0	13560640
50	4.0	13560245
20	4.0	13560910
20	3.4	13560400
20	4.6	13560700

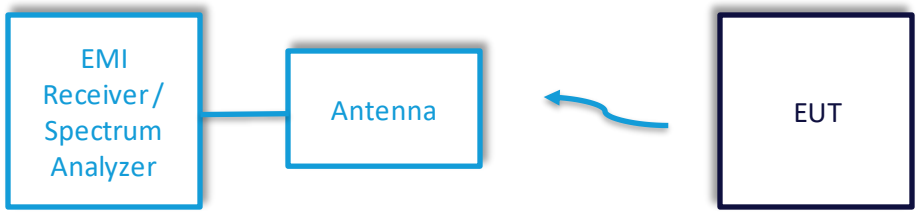
Maximum Tolerance = 13560000 Hz * 0.01% = 1356 Hz

Maximum Deviation from 13.56 MHz = 910 Hz, therefore the EUT passes the Frequency Tolerance test.

5.2 Radiated Emissions

Description of Measurement	The frequency spectrum is investigated for intentional and / or unintentional signals emanating from the EUT by use of a standardized test site and measurement antenna. The antenna, cable, pre-amp, and other necessary measurement system correction factors are loaded onto the EMI receiver / spectrum analyzer when the measurements are performed allowing the data to be gathered and reported as corrected values. The maximum emissions from the EUT are determined by turn-table azimuth rotation (360°) and scanning of the measurement antenna. Maximized levels are noted at degree values of azimuth, measurement antenna height, and measurement antenna polarity.
Example Calculations	Measurement (dBµV) + Cable factor (dB) + Other (dB) + Antenna Factor (dB/m) = Corrected Reading (dBµV/m) Margin (dB) = Limit (dBµV/m) - Corrected Reading (dBµV/m) Example at 4000 MHz: Reading = 40 dBµV + 3.4 dB + 0.9 dB + 6.5 dB/m = 50.8 dBµV/m Average Limit = 20 log (500) = 54 dBµV/m Margin = 54 dBµV/m - 50.8 dBµV/m = 3.2 dB

Block Diagram



5.2.1 Radiated Emissions

Operator	Jon Dilley; Braden Smith	**QA**	Laura Zehnder; Shane Dock
Temperature	23.6 degrees C	**R.H. %**	43.20%
Test Date	7/30/2019-9/10/2019	**Location**	Chamber 3
Requirement	FCC 15.225 a-d FCC Part 2.1049	**Method**	ANSI C63.10 RSS-GEN 6.6

Limits:

(a) The field strength of any emissions within the band 13.553-13.567 MHz shall not exceed 15,848 microvolts/meter at 30 meters.

(b) Within the bands 13.410-13.553 MHz and 13.567-13.710 MHz, the field strength of any emissions shall not exceed 334 microvolts/meter at 30 meters.

(c) Within the bands 13.110-13.410 MHz and 13.710-14.010 MHz the field strength of any emissions shall not exceed 106 microvolts/meter at 30 meters.

(d) The field strength of any emissions appearing outside of the 13.110-14.010 MHz band shall not exceed the general radiated emission limits in §15.209.

Frequency (MHz)	Field strength (microvolts/meter)	Measurement distance (meters)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	30
30-88	100**	3
88-216	150**	3
216-960	200**	3
Above 960	500	3

Test Parameters

Frequency	150 kHz-30 MHz; 30 -1000 MHz	**Distance**	3m
Detector(s)	Avg (150-490 kHz), QP (490kHz-1000MHz)	**Table height**	80cm
RBW	9 kHz; 120 kHz	**VBW**	90 kHz; 1.2 MHz
Notes	EUT tested in modulated Tx Mode. Emissions from 200-1000 MHz are not a function of the Tx. Occupied bandwidth measurements are reported, with no limit.		

Instrumentation

Date : 29-Jul-2019 Test : NFC Tx Job : C-3227

PE : Shane Dock Customer : Guardhat Quote : 319122

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	EE 960088	Analyzer - EMI Receiver	Agilent	N9038A	MY51210138	4/23/2019	4/23/2020	Active Calibration
2	AA 960006	Antenna - Active Loop	EMCO	6502	9205-2753	8/28/2017	8/28/2019	Active Calibration
3	AA 960150	Antenna - Biconical	ETS Lindgren	3110B	0003-3346	4/20/2018	4/20/2020	Active Calibration
4	AA 960195	Antenna - Log Periodic	A.H. Systems, Inc	SAS-512-2	557	1/30/2018	1/30/2020	Active Calibration

EUT Parameters

Input Power	4 VDC (Power supply under turn table)	**Mode**	NFC Modulated Tx

Test Data Extrapolation

Three equations from ANSI C63.10 were used to extrapolate data to the limit distance per Sections 6.4.4.1 and 6.4.4.2. The limit distance is 30m below 30 MHz, while the measured distance is 3m.

$D_{nearfield} = 47.77 / f(MHz)$

At $f(MHz) = 15.92$, $D_{nearfield} = 3m$.

When $f(MHz) > 15.92$,

$FS_{limit} = FS_{max} - 20*\log (D_{lim}/D_{measured})$

When $f(MHz) < 15.92$,

$FS_{limit} = FS_{max} - 40*\log (D_{nearfield}/D_{measured}) - 20*\log (D_{limit}/D_{nearfield})$

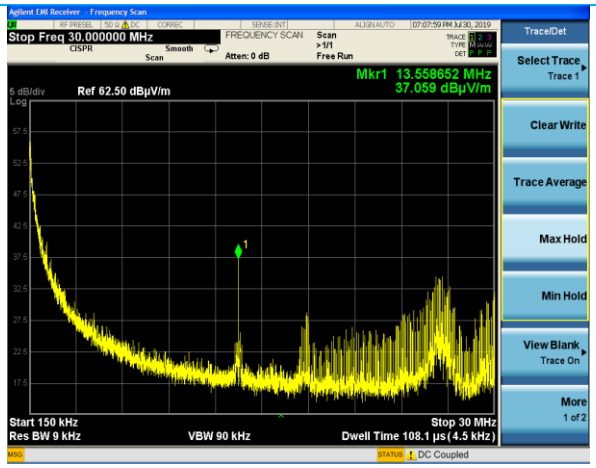
Table

Frequency (MHz)	Antenna Polarity	EUT Orientation	Height (cm)	Azimuth (degree)	Quasi-Peak Reading (dBµV/m)	Quasi-Peak Reading @ 30m (dBµV/m)	Quasi-Peak Limit @ 30m (dBµV/m)	Quasi-Peak Margin (dB)
13.560	Horizontal	Flat	100	345	40.0	18.6	84.0	65.4
29.982	Horizontal	Flat	100	0	28.1	8.1	29.5	21.4
9.959	Horizontal	Flat	100	0	23.0	-1.1	29.5	30.6
17.928	Horizontal	Flat	100	190	28.5	8.5	29.5	21.0
13.560	Horizontal	Side	100	103	40.3	18.9	84.0	65.1
17.930	Horizontal	Side	100	250	30.9	10.9	29.5	18.6
13.560	Horizontal	Vertical	100	195	34.1	12.7	84.0	71.3
26.434	Skew	Vertical	100	230	33.4	13.4	29.5	16.1
13.560	Skew	Vertical	100	308	36.1	14.7	84.0	69.3
13.560	Skew	Side	100	192	42.8	21.4	84.0	62.6
13.560	Skew	Flat	100	66	41.6	20.2	84.0	63.8
17.935	Vertical	Flat	100	175	34.4	14.4	29.5	15.1
13.560	Vertical	Flat	100	47	30.5	9.1	84.0	74.9
29.895	Vertical	Flat	100	149	41.1	21.1	29.5	8.4
13.560	Vertical	Side	100	146	31.5	10.1	84.0	73.9
29.991	Vertical	Vertical	100	99	39.2	19.2	29.5	10.3
13.560	Vertical	Vertical	100	263	29.4	8.0	84.0	76.0
13.560	Skew	Side	100	192	42.6	21.2	84.0	62.8
27.120	Skew	Side	100	153	33.4	13.4	29.5	16.1
27.120	Horizontal	Side	100	103	23.9	3.9	29.5	25.6
27.120	Horizontal	Vertical	100	97	25.1	5.1	29.5	24.4
27.120	Skew	Vertical	100	211	34.1	14.1	29.5	15.5
27.120	Skew	Flat	100	178	31.3	11.3	29.5	18.3
27.120	Horizontal	Flat	100	88	22.4	2.4	29.5	27.2
27.120	Vertical	Flat	100	279	19.7	-0.3	29.5	29.8
27.120	Vertical	Vertical	100	242	20.0	0.0	29.5	29.5
27.120	Vertical	Side	100	317	19.0	-1.0	29.5	30.5

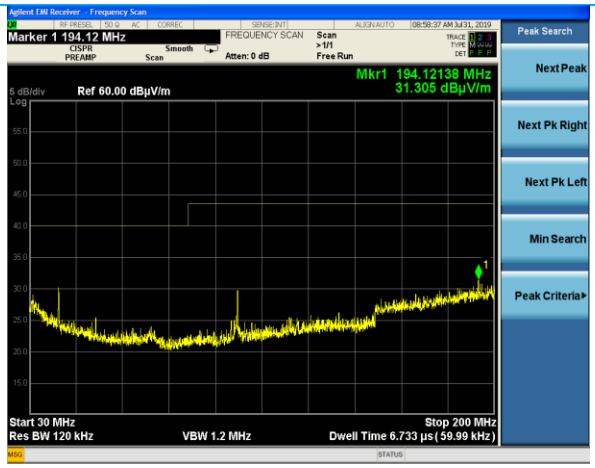
Frequency (MHz)	Antenna Polarity	EUT Orient	Height (cm)	Azimuth (degree)	Quasi-Peak Reading (dBµV/m)	Quasi-Peak Limit (dBµV/m)	Quasi-Peak Margin (dB)
40.710	Vertical	Side	100	100	27.4	40.0	12.6
40.710	Horizontal	Side	260	90	20.6	40.0	19.4
40.710	Horizontal	Vertical	240	0	19.9	40.0	20.1
40.710	Vertical	Vertical	100	55	27.9	40.0	12.1
40.710	Vertical	Flat	100	255	26.5	40.0	13.5
40.710	Horizontal	Flat	325	275	20.3	40.0	19.7
54.270	Vertical	Side	100	0	21.6	40.0	18.4
54.270	Horizontal	Side	340	340	18.3	40.0	21.8

54.270	Horizontal	Vertical	325	250	18.4	40.0	21.6
54.270	Vertical	Vertical	100	0	22.4	40.0	17.6
54.270	Vertical	Flat	100	55	21.2	40.0	18.8
54.270	Horizontal	Flat	355	255	18.7	40.0	21.3
67.830	Vertical	Side	100	0	21.0	40.0	19.0
67.830	Horizontal	Side	235	235	18.1	40.0	21.9
67.830	Horizontal	Vertical	180	240	18.1	40.0	21.9
67.830	Vertical	Vertical	110	0	21.6	40.0	18.4
67.830	Vertical	Flat	100	60	19.9	40.0	20.1
67.830	Horizontal	Flat	370	240	18.1	40.0	21.9

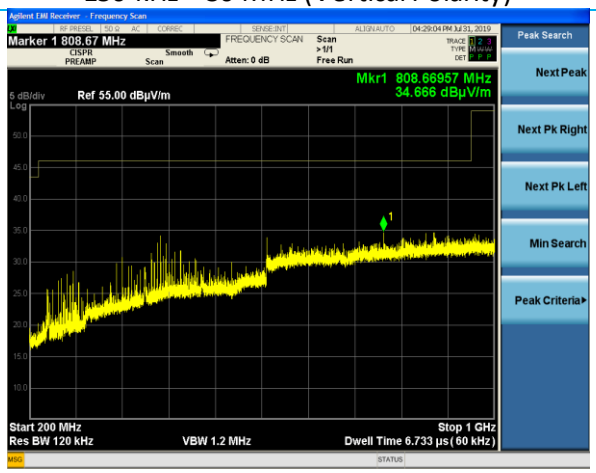
Plots



150 kHz – 30 MHz (Vertical Polarity)



30-200 MHz (Vertical Polarity)



200-1000 MHz (Vertical Polarity)

Occupied Bandwidth

6 REVISION HISTORY

Version	Date	Notes	Person
V0	8/13/19	First Draft	Shane Dock
V1	9/3/19	Second Draft	Shane Dock
V2	10/29/19	Final Draft	Shane Dock
V3	11/26/19	Updates per TCB response	Shane Dock

END OF REPORT