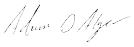
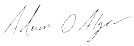
Test Report # 318246 B

Equipment Under Test:	IoT LoRa Module
Test Date(s):	May 25th, 2019 to August 18th, 2020
Prepared for:	Georgia Pacific Attn: Kim Cannon 1915 Marathon Avenue Neenah, WI 54956

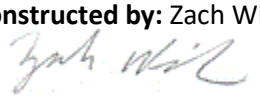
Report Issued by: Adam Alger, Quality Manager

Signature:  Date: 9/24/2020

Report Reviewed by: Adam Alger, Quality Manager

Signature:  Date: 8/20/2020

Report Constructed by: Zach Wilson, EMC Engineer

Signature:  Date: 7/16/2019

CONTENTS

Laird Connectivity Test Services in Review

The Laird Connectivity, 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

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 **May 25th, 2019 to August 18th, 2020** the Equipment Under Test (EUT), **IoT LoRa Module**, as provided by **Georgia Pacific** was tested to the following requirements of the **Federal Communications Commission** and **Innovation, Science and Economic Development Canada** :

DTS (Digital Transmission System)

Requirement	Description	Specification	Method	Result
FCC: 15.247 (a)(2) IC: RSS-247 5.2 (a)	Digital Modulation System 6 dB bandwidth	500 kHz	ANSI C63.10	Pass
FCC: 2.1049 IC: RSS-GEN 6.7	Occupied Bandwidth	Reported	ANSI C63.10	Reported
FCC: 15.247 (b)(3) IC: RSS-247 5.4 (d)	Maximum Conducted Output Power	30 dBm	ANSI C63.10	Pass
FCC: 15.247 (e) IC: RSS-247 5.2 (b)	Digital Modulation System Power Spectral Density	8 dBm / 3 kHz	ANSI C63.10	Pass
FCC: 15.247 (d) IC: RSS-247 5.5	RF Spurious Emissions at the Transmitter Antenna Terminal	20 dBc	ANSI C63.10	Pass
FCC: 15.247 (d) IC: RSS-GEN 8.10	Spurious Radiated Emissions in Restricted Bands	FCC 15.209 RSS-GEN 8.9	ANSI C63.10	Pass
FCC: 2.1055 (d) IC: RSS-GEN 6.11	Frequency Stability	Reported	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	Georgia Pacific
Contact Person	Kim Cannon
Address	1915 Marathon Avenue Neenah, WI 54956

2.1 Equipment Under Test (EUT) Information

The following information has been supplied by the client

Product Name	IoT LoRa Module
Model Number	A-101129
Serial Number	Engineering Sample
LoRa Radio FCC ID	2AALY-529GP
LoRa Radio IC ID	21620-529GP

2.2 Product Description

The EUT contains a LoRa radio with the below channel plan, data rates, and nominal bandwidths.

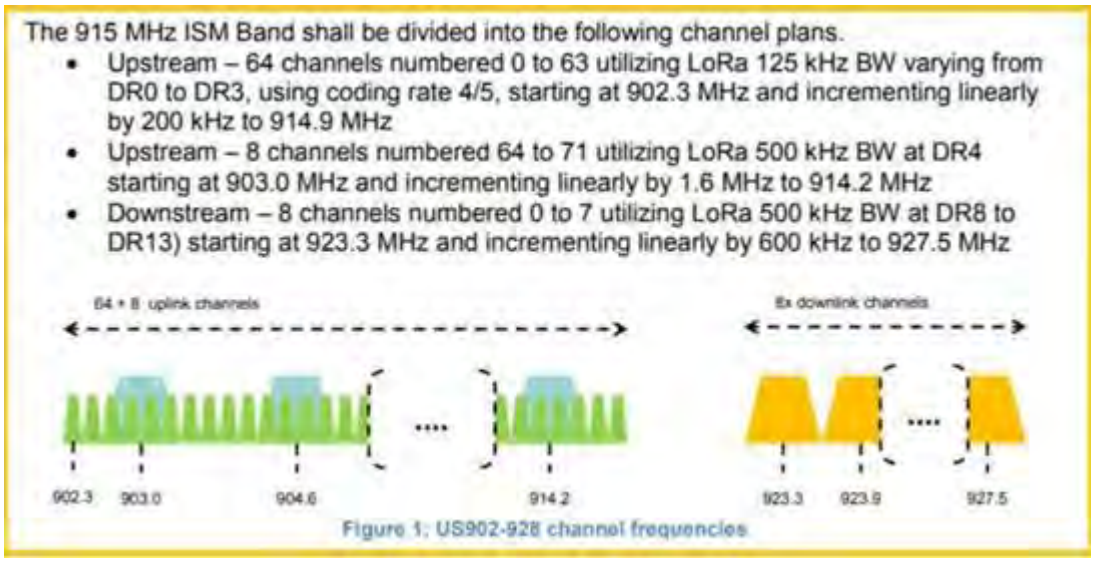


Figure 1: US902-928 channel frequencies

The EUT also contains the pre-certified Laird BL654 BLE radio utilizing an internal PCB F-type antenna with a maximum gain of -1.0 dBi.

There are two PCB versions of the EUT. The Laird Rev_B contains a Johanson 0900AT43A0070 chip antenna, peak gain -0.5 dBi. The Laird Rev_B1 has the PCB configured for a SMA connector and is fitted with the Molex 206764 Flexible Dipole Antenna, peak gain of 1.3 dBi.

Both versions of the EUT were tested.

The EUT input voltage was 3.3 VDC provided by a lab power supply. The EUT can also be powered by removable batteries.

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 Radio Programming Information

EUT programmed using Tera Term v4.99. The radio manufacturer provided the commands to put the radio into the correct test modes. The firmware version was PRT-0000000174. The tested channels were, 903 MHz (Low), 907.8 MHz (Mid), and 914.2 MHz (High). The EUT voltage was 3.3 VDC.

2.6 Radio Power Information

The end user will have the capability of changing the power levels of the Laird Rev_B. The minimum power setting is -17 . The maximum power setting is 18. The EUT was tested at both power levels.

The Laird Rev_B1 was tested at power setting 12 only which will be considered maximum power for that board variant.

3 REFERENCES

Publication	Edition	Date
CFR Title 47	-	2020
ANSI C63.10	-	2013
RSS 247	2	2017
RSS GEN	5	2019

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

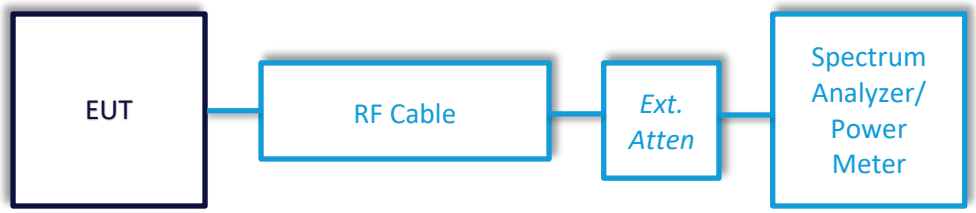
Parameter	ETSI U.C. ±	U.C. ±
Radio Frequency, from F0	$1x10^{-7}$	$0.55x10^{-7}$
Occupied Channel Bandwidth	5 %	2 %
RF conducted Power (Power Meter)	1.5 dB	1.2 dB
RF conducted emissions (Spectrum Analyzer)	3.0 dB	1.7 dB
All emissions, radiated	6.0 dB	5.3 dB
Temperature	1° C	0.65° C
Humidity	5 %	2.9 %
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 DTS and 99% Bandwidth

Operator	Zach Wilson	**QA**	Jeysson Gonzalez
Temperature	21.0°C, 22.4°C	**R.H. %**	44.1, 47.3
Test Date	6/3/2019, 7/15/2019, 8/19/2020	**Location**	Conducted Radio Bench
Requirement	FCC 15.247, FCC 2.1049, RSS-247, RSS-GEN	**Method**	ANSI C63.10 11.8 Option 2 and 6.9.3

Limits:

The minimum 6 dB bandwidth shall be 500 kHz.

Test Parameters

Frequency	903.0, 907.8, 914.2 MHz		
RBW	DTS: 100 kHz 99%: 10 kHz	**VBW**	DTS: 300 kHz 99%: 30 kHz
Detector(s)	Max hold with peak detector.	**Span**	DTS: 1 MHz 99%: 1.5 MHz

Instrumentation

Laird

Date: 3-Jun-2019 Test: Conducted Radio Job: C-3164

PE: Zach Wilson Customer: Georgia Pacific Quote: 318246

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	AA 960172	Cable	A.H. Systems, Inc	SAC-26G-1	387	12/9/2018	12/9/2020	Active Verification
2	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	7/14/2018	7/14/2021	Active Calibration

Laird

Date: 18-Aug-2020 Test: Conducted Radio Job: C-3164

PE: Zach Wilson Customer: Georgia Pacific Quote: 318246

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	AA 960173	Cable	A.H. Systems, Inc	SAC-26G-1	388	12/9/2018	12/9/2020	Active Verification
2	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	7/14/2018	7/14/2021	Active Calibration

EUT Parameters

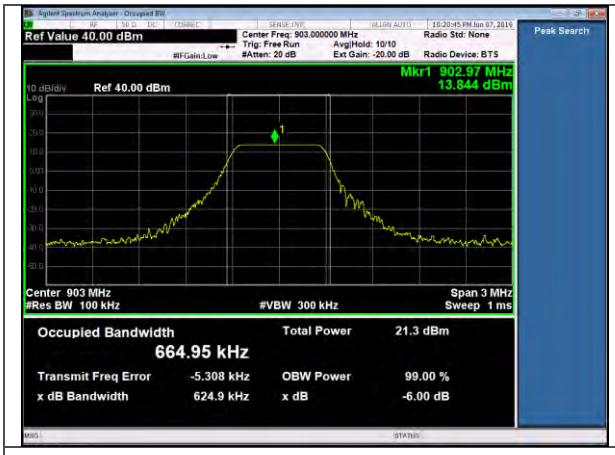
Input Power	3.3 VDC	**Mode**	Single Channel DTS
Frequency	903.0 (Low), 907.8 (Mid), 914.2 (High) MHz	**Data Rates**	DR4, DR13
Power Settings	Laird Rev_B: 18 Minimum: -17 dBm		

Data Tables

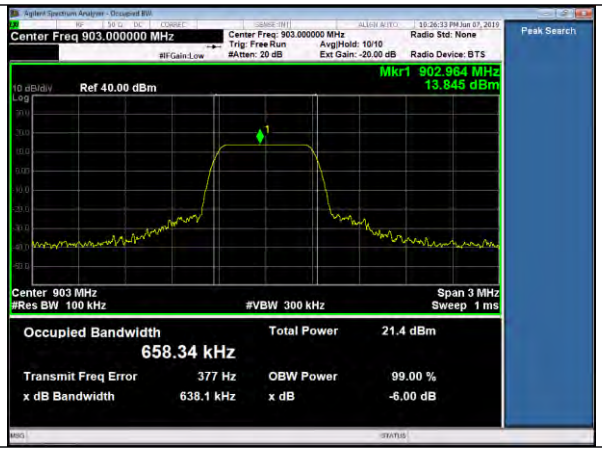
DTS OBW - Laird Rev_B							
Frequency (MHz)	Data Rate	Power Setting	Fundamental BW (kHz)	DTS BW (kHz)	DTS Limit (>500 kHz)	Margin (kHz)	99% OBW (kHz)
903.0	DR4	18.0	500.0	624.9	500.0	124.9	665.0
903.0	DR13	18.0	500.0	638.1	500.0	138.1	658.3
907.8	DR4	18.0	500.0	639.7	500.0	139.7	658.8
907.8	DR13	18.0	500.0	630.1	500.0	130.1	647.1
914.2	DR4	18.0	500.0	630.7	500.0	130.7	658.6
914.2	DR13	18.0	500.0	620.2	500.0	120.2	666.5

DTS OBW - Laird Rev_B1							
Frequency (MHz)	Data Rate	Power Setting	Fundamental BW (kHz)	DTS BW (kHz)	DTS Limit (>500 kHz)	Margin (kHz)	99% OBW (kHz)
903.0	DR4	12.0	500.0	624.8	500.0	124.8	676.4
903.0	DR13	12.0	500.0	614.7	500.0	114.7	658.3
907.8	DR4	12.0	500.0	625.7	500.0	125.7	658.8
907.8	DR13	12.0	500.0	612.6	500.0	112.6	647.1
914.2	DR4	12.0	500.0	631.1	500.0	131.1	658.6
914.2	DR13	12.0	500.0	617.1	500.0	117.1	666.5

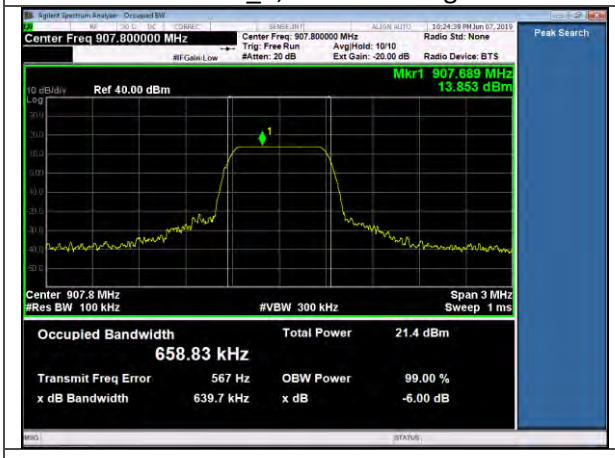
Plots



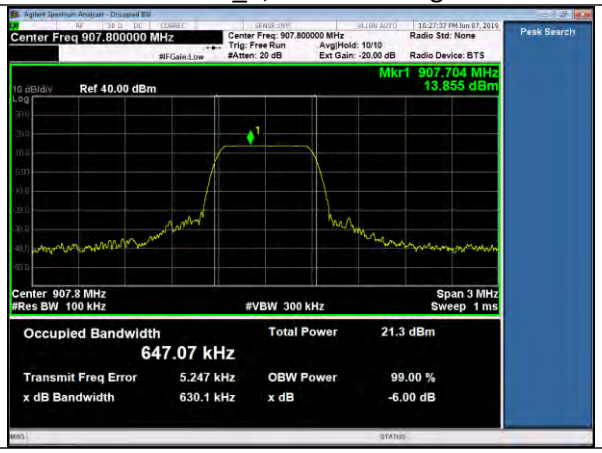
DTS BW, DR4 Low Channel
Laird Rev_B, Power Setting 18



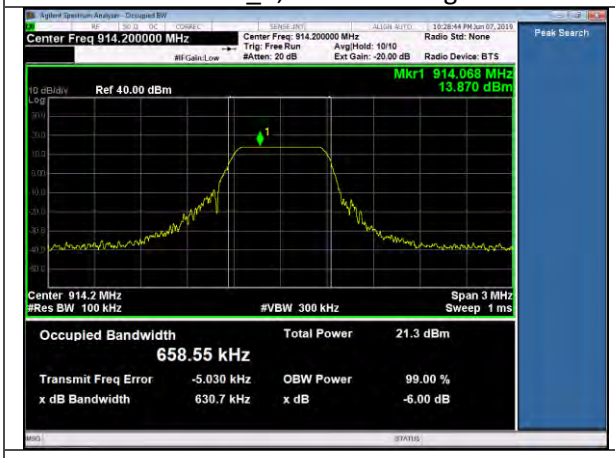
DTS BW, DR13 Low Channel
Laird Rev_B, Power Setting 18



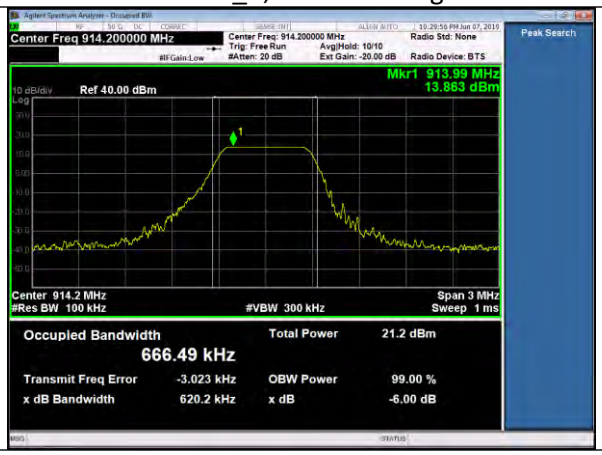
DTS BW, DR4 Mid Channel
Laird Rev_B, Power Setting 18



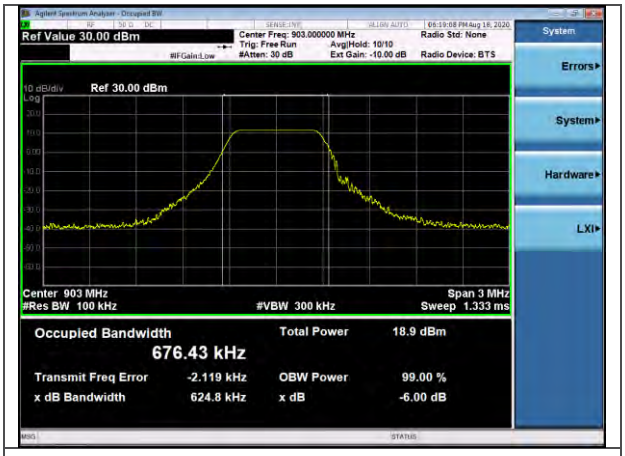
DTS BW, DR13 Mid Channel
Laird Rev_B, Power Setting 18



DTS BW, DR4 High Channel
Laird Rev_B, Power Setting 18



DTS BW, DR13 High Channel
Laird Rev_B, Power Setting 18



DTS BW, DR 4 Low Channel
Laird Rev_B1, Power Setting 12

5.1.2 Power Spectral Density

Operator	Zach Wilson	**QA**	Jeysson Gonzalez
Temperature	21.0°C, 22.4°C	**R.H. %**	44.1, 47.3
Test Date	6/3/2019, 7/15/2019, 8/19/2020	**Location**	Conducted Radio Bench
Requirement	FCC 15.247, RSS-247	**Method**	ANSI C63.10 11.10.2, Option 2

Limits:

The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

Test Parameters

Frequency	903.0, 907.8, 914.2 MHz		
RBW	3 kHz	**VBW**	10 kHz
Detector(s)	Max hold with peak detector.	**Span**	1 MHz

Instrumentation

Laird

Date : 3-Jun-2019 Test : Conducted Radio Job : C-3164

PE : Zach Wilson Customer : Georgia Pacific Quote : 318246

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	AA 960172	Cable	A.H. Systems, Inc	SAC-26G-1	387	12/9/2018	12/9/2020	Active Verification
2	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	7/14/2018	7/14/2021	Active Calibration

Laird

Date : 18-Aug-2020 Test : Conducted Radio Job : C-3164

PE : Zach Wilson Customer : Georgia Pacific Quote : 318246

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	AA 960173	Cable	A.H. Systems, Inc	SAC-26G-1	388	12/9/2018	12/9/2020	Active Verification
2	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	7/14/2018	7/14/2021	Active Calibration

EUT Parameters

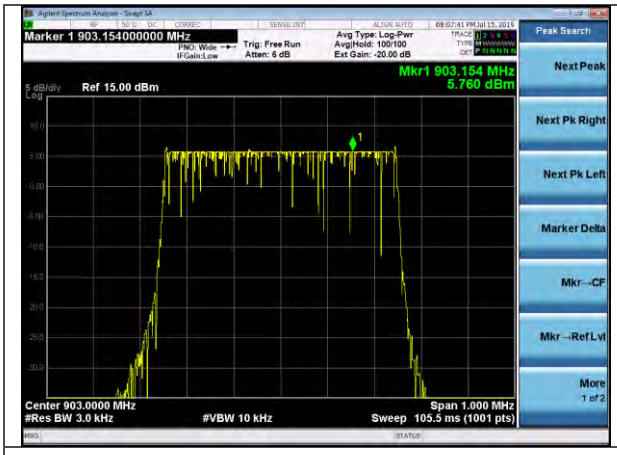
Input Power	3.3 VDC	**Mode**	Single Channel DTS
Frequency	903.0 (Low), 907.8 (Mid), 914.2 (High) MHz	**Data Rates**	DR4, DR13
Power Settings	Laird Rev_B: 18 Laird Rev_B1: 12		

Data

PSD - Laird Rev_B						
Frequency (MHz)	Data Rate	Power Setting	Fundamental BW (kHz)	Peak Power Spectral Density (dBm/3kHz)	PSD Limit (dBm/3kHz)	Margin (dBm)
903.0	DR4	18.0	500.0	5.8	8.0	2.2
903.0	DR13	18.0	500.0	5.7	8.0	2.3
907.8	DR4	18.0	500.0	5.8	8.0	2.2
907.8	DR13	18.0	500.0	5.7	8.0	2.3
914.2	DR4	18.0	500.0	5.8	8.0	2.2
914.2	DR13	18.0	500.0	5.7	8.0	2.3

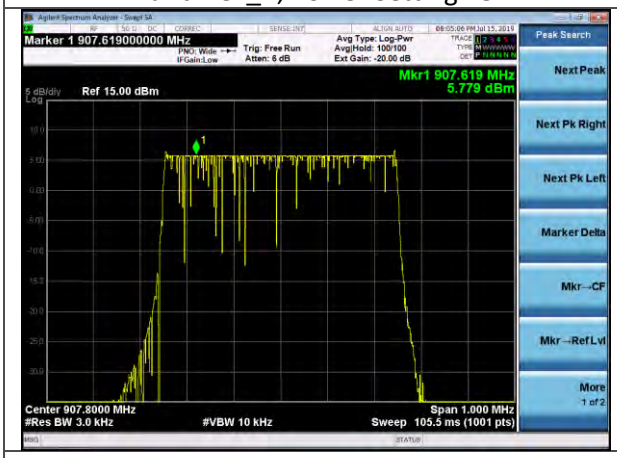
PSD - Laird Rev_B1						
Frequency (MHz)	Data Rate	Power Setting	Fundamental BW (kHz)	Peak Power Spectral Density (dBm/3kHz)	PSD Limit (dBm/3kHz)	Margin (dBm)
903.0	DR4	12.0	500.0	2.3	8.0	5.7
903.0	DR13	12.0	500.0	-1.6	8.0	9.6
907.8	DR4	12.0	500.0	0.7	8.0	7.3
907.8	DR13	12.0	500.0	-1.6	8.0	9.6
914.2	DR4	12.0	500.0	1.6	8.0	6.4
914.2	DR13	12.0	500.0	1.1	8.0	6.9

Plots



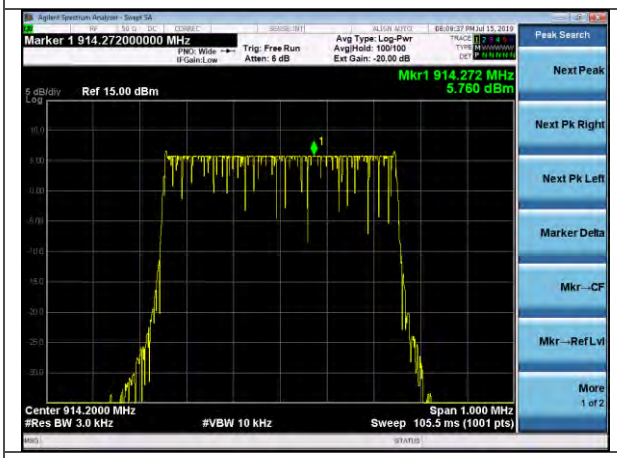
PSD, DR4 Low Channel
Laird Rev_B, Power Setting 18

PSD, DR13 Low Channel
Laird Rev_B, Power Setting 18



PSD, DR4 Mid Channel, Max Power

PSD, DR13 Mid Channel
Laird Rev_B, Power Setting 18



PSD, DR4 High Channel, Max Power

PSD, DR13 High Channel
Laird Rev_B, Power Setting 18

5.1.3 Transmitter Output Power

Operator	Zach Wilson	**QA**	Jeysson Gonzalez
Temperature	21.0°C, 22.4°C	**R.H. %**	44.1, 47.3
Test Date	6/3/2019, 7/15/2019, 8/19/2020	**Location**	Conducted Radio Bench
Requirement	FCC 15.247, RSS-247	**Method**	ANSI C63.10 11.9.1.1

Limits:

For DTSs employing digital modulation techniques operating in the bands 902-928 MHz and 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1 W. The e.i.r.p. shall not exceed 4 W

Test Parameters

Frequency	903.0, 907.8, 914.2 MHz		
RBW	1 MHz	**VBW**	3 MHz
Detector(s)	Max hold with peak detector.	**Span**	3 MHz

Instrumentation

Laird

Date : 3-Jun-2019 Test : Conducted Radio Job : C-3164

PE : Zach Wilson Customer : Georgia Pacific Quote : 318246

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	AA 960172	Cable	A.H. Systems, Inc	SAC-26G-1	387	12/9/2018	12/9/2020	Active Verification
2	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	7/14/2018	7/14/2021	Active Calibration

Laird

Date : 18-Aug-2020 Test : Conducted Radio Job : C-3164

PE : Zach Wilson Customer : Georgia Pacific Quote : 318246

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	AA 960173	Cable	A.H. Systems, Inc	SAC-26G-1	388	12/9/2018	12/9/2020	Active Verification
2	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	7/14/2018	7/14/2021	Active Calibration

EUT Parameters

Input Power	3.3 VDC	**Mode**	Single Channel DTS
Frequency	903.0 (Low), 907.8 (Mid), 914.2 (High) MHz	**Data Rates**	DR4, DR13
Power Settings	Laird Rev_B: 18, -17 Laird Rev_B1: 12		

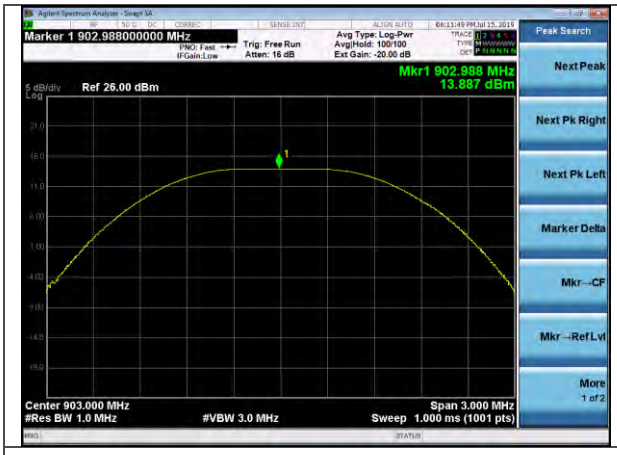
Data

Peak Output Power - Laird Rev_B						
Frequency (MHz)	Data Rate	Power Setting	Fundamental BW (kHz)	Peak Output Power (dBm)	Peak Output Power Limit (dBm)	Margin (dB)
903.0	DR4	18.0	500	13.9	30.0	16.1
907.8	DR4	18.0	500	13.9	30.0	16.1
914.2	DR4	18.0	500	13.9	30.0	16.1
903.0	DR13	18.0	500	13.9	30.0	16.1
907.8	DR13	18.0	500	13.9	30.0	16.1
914.2	DR13	18.0	500	13.9	30.0	16.1

Peak Output Power - Laird Rev_B						
Frequency (MHz)	**Data Rate**	**Power Setting**	**Fundamental BW (kHz)**	**Peak Output Power (dBm)**	**Peak Output Power Limit (dBm)**	**Margin (dBm)**
903.0	DR4	-17.0	500.0	-16.6	30.0	46.6
903.0	DR13	-17.0	500.0	-16.6	30.0	46.6
907.8	DR4	-17.0	500.0	-16.7	30.0	46.7
907.8	DR13	-17.0	500.0	-16.6	30.0	46.6
914.2	DR4	-17.0	500.0	-16.7	30.0	46.7
914.2	DR13	-17.0	500.0	-16.6	30.0	46.6

Peak Output Power - Laird Rev_B1						
Frequency (MHz)	**Data Rate**	**Power Setting**	**Fundamental BW (kHz)**	**Peak Output Power (dBm)**	**Peak Output Power Limit (dBm)**	**Margin (dBm)**
903.0	DR4	12.0	500.0	11.4	30.0	18.6
903.0	DR13	12.0	500.0	11.4	30.0	18.6
907.8	DR4	12.0	500.0	11.4	30.0	18.6
907.8	DR13	12.0	500.0	11.4	30.0	18.6
914.2	DR4	12.0	500.0	11.4	30.0	18.6
914.2	DR13	12.0	500.0	11.4	30.0	18.6

Plots

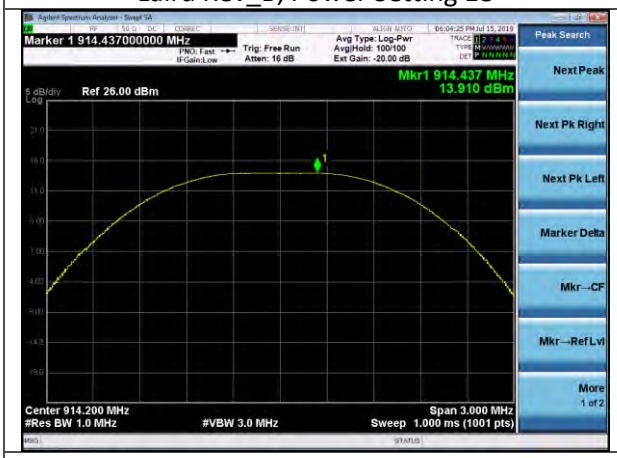


Pout, DR4 Low Channel
Laird Rev_B, Power Setting 18

Pout, DR 4 Low Channel
Laird Rev_B, Power Setting -17

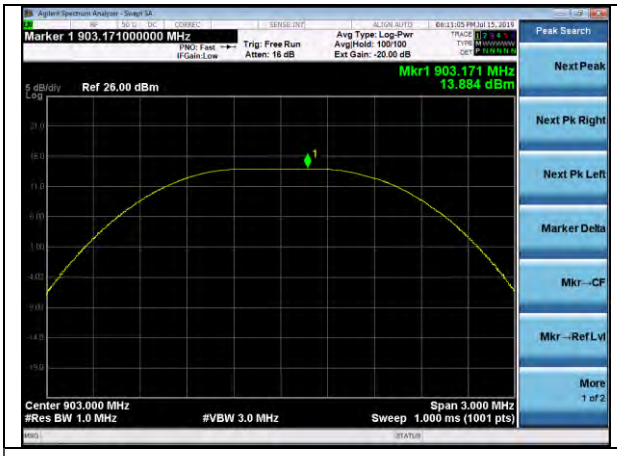
Pout, DR4 Mid Channel
Laird Rev_B, Power Setting 18

Pout, DR4 Mid Channel
Laird Rev_B, Power Setting -17



Pout, DR4 High Channel
Laird Rev_B, Power Setting 18

Pout, DR4 High Channel
Laird Rev_B, Power Setting -17

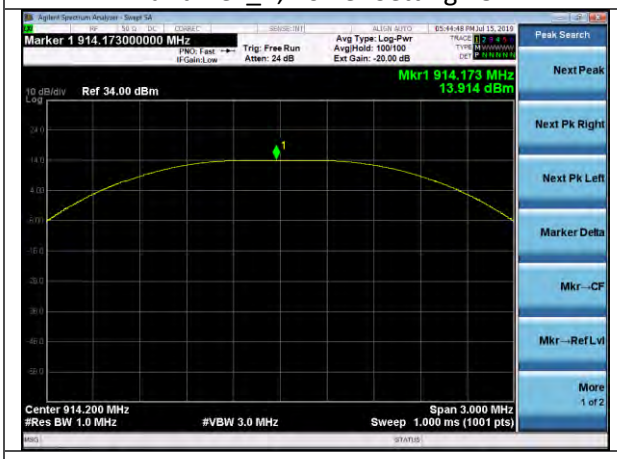


Pout, DR13 Low Channel
Laird Rev_B, Power Setting 18

Pout, DR13 Low Channel
Laird Rev_B, Power Setting -17

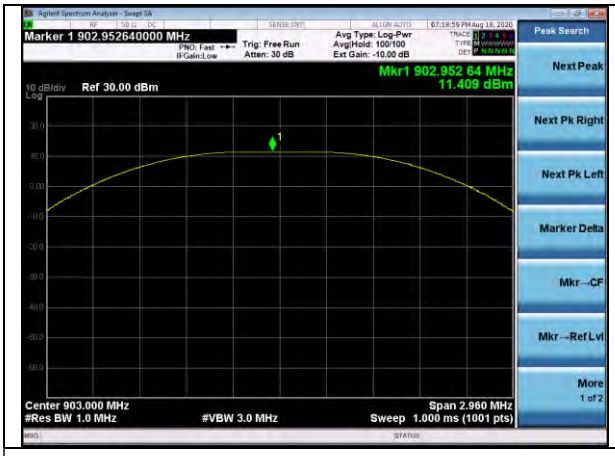
Pout, DR13 Mid Channel
Laird Rev_B, Power Setting 18

Pout, DR13 Mid Channel
Laird Rev_B, Power Setting -17

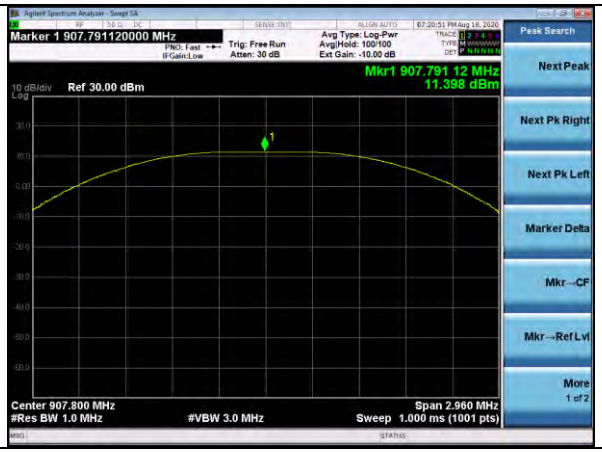


Pout, DR13 High Channel
Laird Rev_B, Power Setting 18

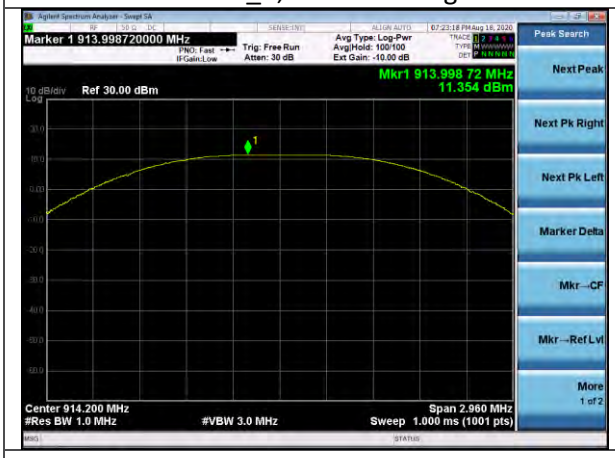
Pout, DR13 High Channel
Laird Rev_B, Power Setting -17



Pout, DR13 Low Channel
Laird Rev_B, Power Setting 12

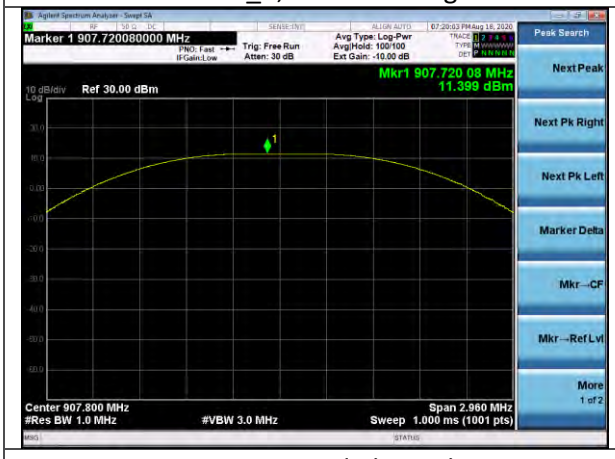


Pout, DR13 Mid Channel
Laird Rev_B, Power Setting 12

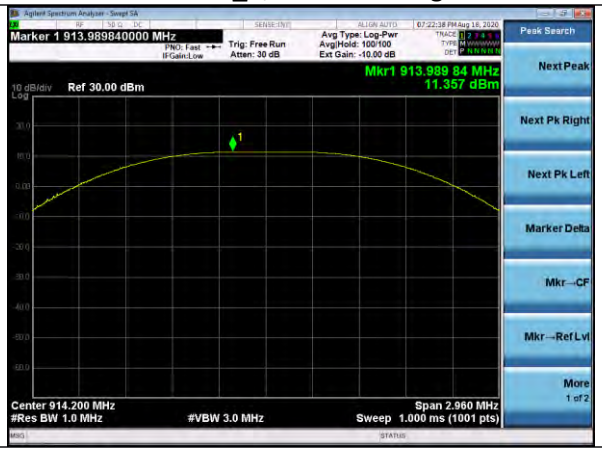


Pout, DR13 High Channel
Laird Rev_B, Power Setting 12

Pout, DR4 Low Channel
Laird Rev_B, Power Setting 12



Pout, DR4 Mid Channel
Laird Rev_B, Power Setting 12



Pout, DR4 High Channel
Laird Rev_B, Power Setting -12

5.1.4 Conducted RF Spurious Emissions

Operator	Zach Wilson	**QA**	Jeysson Gonzalez
Temperature	21.0°C, 22.4°C	**R.H. %**	44.1, 47.3
Test Date	6/3/2019, 7/15/2019, 8/19/2020	**Location**	Conducted Radio Bench
Requirement	FCC 15.247, RSS-247	**Method**	ANSI C63.10 11.12 and 11.13

Limits:

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits

Laird Rev_B Power Setting 18 Limit: 4.1 dBm reference level. Limit set to -15.9 dBm

Laird Rev_B Power Setting -17 Limit: -21.4 dBm highest peak output power. Limit set to -41.4 dBm

Laird Rev_B1 Power Setting 12 Limit: 11.4 dBm highest peak output power. Limit set to -8.6 dBm

Test Parameters

Frequency	903.0, 907.8, 914.2 MHz		
RBW	1 MHz	**VBW**	3 MHz
Detector(s)	Max hold with peak detector.	**Span**	3 MHz
Example Calculations	Limit (dBm) = Reference Level (dBm) – 20 (dB)		

Instrumentation

Laird

Date: 3-Jun-2019 Test: Conducted Radio Job: C-3164

PE: Zach Wilson Customer: Georgia Pacific Quote: 318246

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	AA 960172	Cable	A.H. Systems, Inc	SAC-26G-1	387	12/9/2018	12/9/2020	Active Verification
2	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	7/14/2018	7/14/2021	Active Calibration

Laird

Date: 18-Aug-2020 Test: Conducted Radio Job: C-3164

PE: Zach Wilson Customer: Georgia Pacific Quote: 318246

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	AA 960173	Cable	A.H. Systems, Inc	SAC-26G-1	388	12/9/2018	12/9/2020	Active Verification
2	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	7/14/2018	7/14/2021	Active Calibration

EUT Parameters

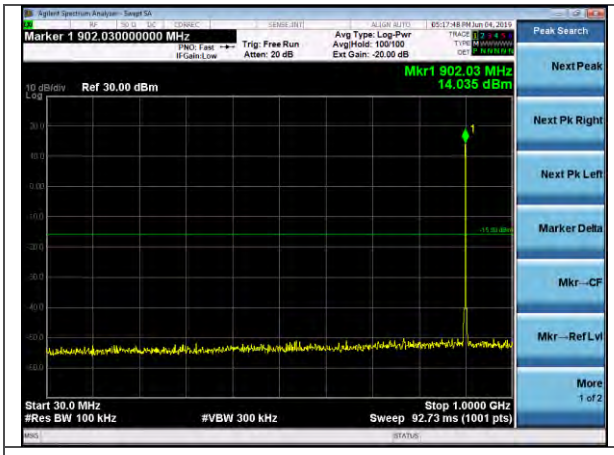
Input Power	3.3 VDC	**Mode**	Single Channel DTS
Frequency	903.0 (Low), 907.8 (Mid), 914.2 (High) MHz	**Data Rates**	DR4, DR13
Power Settings	Laird Rev_B: 18, -17 Laird Rev_B1: 12		

Data

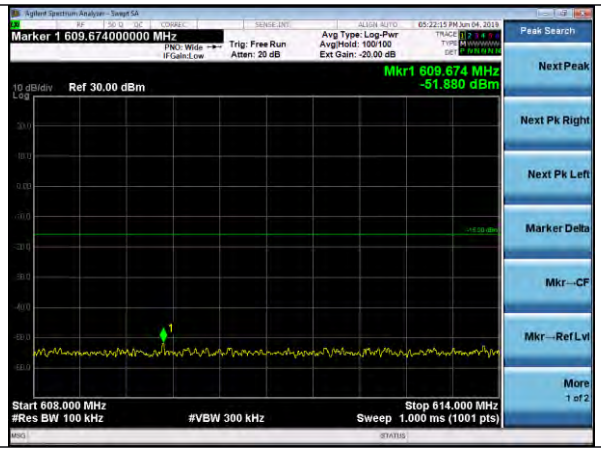
Conducted Spurious Emissions - Laird Rev_B						
Frequency (MHz)	**Fundamental Frequency (MHz)**	**Data Rate**	**Power Setting (dBm)**	**Peak Reading (dBm)**	**Peak Limit (dBm)**	**Peak Margin (dB)**
609.9	903.0	DR4	-17.0	-66.2	-41.4	24.8
612.7	903.0	DR13	-17.0	-66.4	-41.4	25.0
1043.2	914.2	DR13	-17.0	-64.9	-41.4	23.5
1046.5	914.2	DR4	-17.0	-64.3	-41.4	22.9
3655.0	914.2	DR4	-17.0	-59.2	-41.4	17.8
3799.0	903.0	DR4	-17.0	-59.6	-41.4	18.2
609.7	914.2	DR13	18.0	-51.9	-15.9	36.0
613.2	903.0	DR4	18.0	-52.2	-15.9	36.3
985.4	914.2	DR13	18.0	-50.4	-15.9	34.5
995.4	903.0	DR4	18.0	-51.7	-15.9	35.8
1224.4	914.2	DR13	18.0	-50.3	-15.9	34.4
1225.8	903.0	DR4	18.0	-50.3	-15.9	34.4
2746.0	914.2	DR13	18.0	-42.1	-15.9	26.2
3772.0	903.0	DR4	18.0	-44.0	-15.9	28.1
22576.0	914.2	DR13	18.0	-39.9	-15.9	24.0
24016.0	903.0	DR4	18.0	-39.4	-15.9	23.5

Conducted Spurious Emission - Laird Rev_B1						
Frequency (MHz)	**Fundamental Frequency (MHz)**	**Data Rate**	**Power Setting (dBm)**	**Peak Reading (dBm)**	**Peak Limit (dBm)**	**Peak Margin (dB)**
967.4	914.2	DR13	12.0	-51.8	-8.6	43.2
328.2	903.0	DR4	12.0	-51.1	-8.6	42.5
610.1	914.2	DR13	12.0	-52.9	-8.6	44.3
1232.8	914.2	DR13	12.0	-52.0	-8.6	43.4
23754.3	903.0	DR4	12.0	-44.4	-8.6	35.8

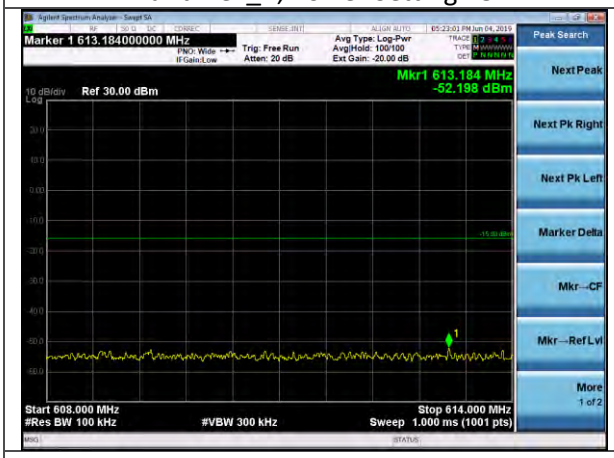
Plots



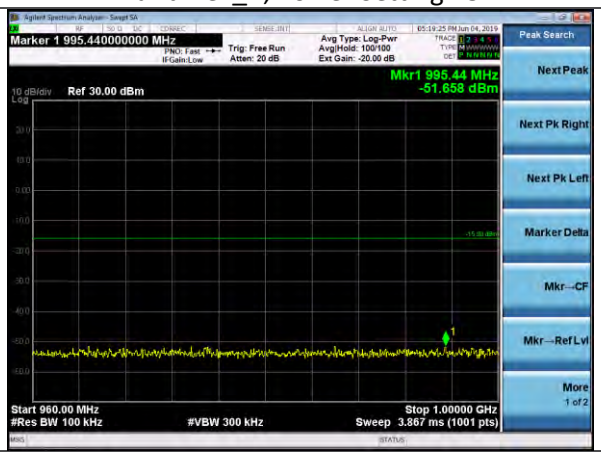
30-1000 MHz, DR4 Low Channel
Laird Rev_B, Power Setting 18



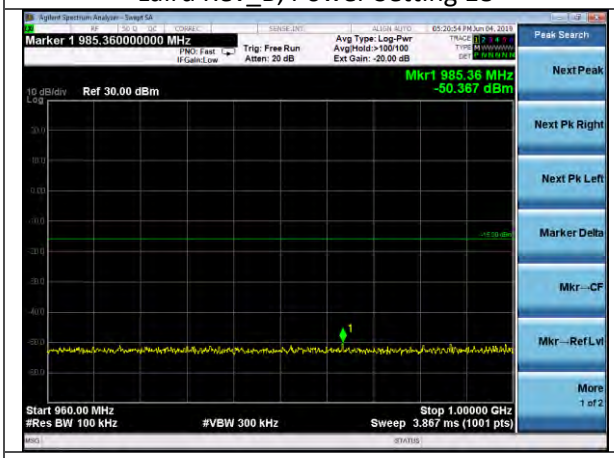
608-614 MHz, DR13 High Channel
Laird Rev_B, Power Setting 18



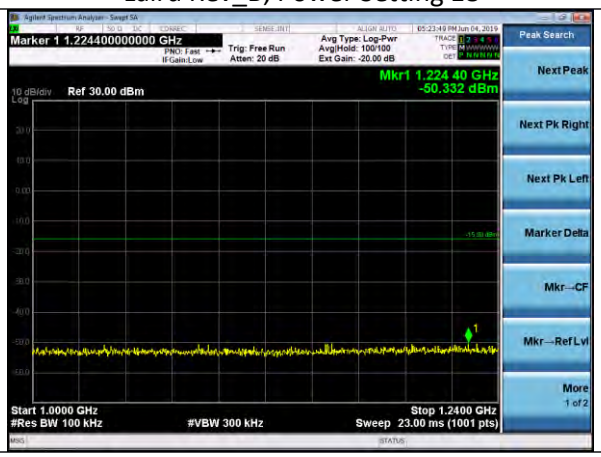
608-614 MHz, DR4 Low Channel
Laird Rev_B, Power Setting 18



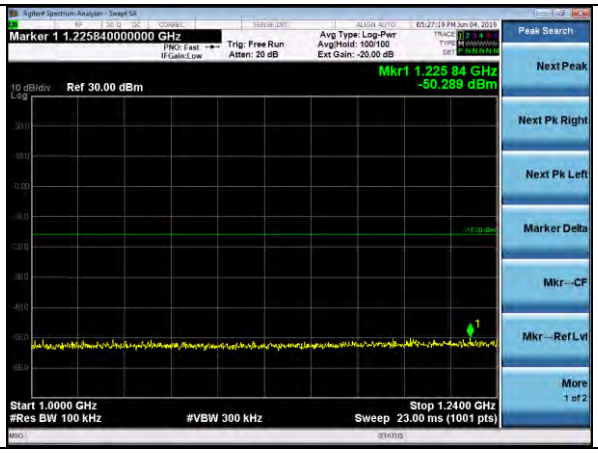
960-1000 MHz, DR4 Low Channel
Laird Rev_B, Power Setting 18



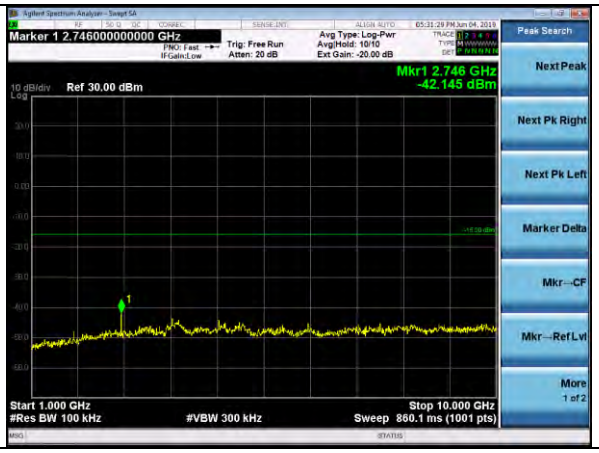
960-1000 MHz, DR13 High Channel
Laird Rev_B, Power Setting 18



1000-1240 MHz, DR13 High Channel
Laird Rev_B, Power Setting 18



1000-1240 MHz, DR4 Low Channel
Laird Rev_B, Power Setting 18

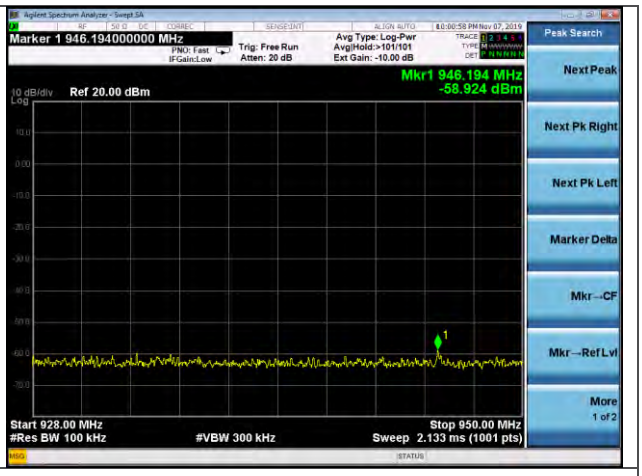


1-10 GHz, DR13 High Channel
Laird Rev_B, Power Setting 18

1-25 GHz, DR13 High Channel
Laird Rev_B, Power Setting 18

1-10 GHz, DR4 Low Channel
Laird Rev_B, Power Setting 18

1-25 GHz, DR4 Low Channel
Laird Rev_B, Power Setting 18

	
875-902 MHz, DR4 Low Channel Laird Rev_B, Power Setting 18	928-950 MHz, DR4 High Channel Laird Rev_B, Power Setting 18

5.1.5 Frequency Stability

Operator	Zach Wilson	**QA**	Jeysson Gonzalez
Temperature	21.0°C	**R.H. %**	44.1%
Test Date	6/3/2019	**Location**	Conducted Radio Bench
Requirement	FCC 2.1055, RSS GEN	**Method**	ANSI C63.10 6.8

Test Parameters

Frequency	903.0, 914.2 MHz		
RBW	300 kHz	**VBW**	1 MHz
Detector(s)	Max hold with peak detector.	**Span**	0 Hz
Notes	Both Maximum and Minimum power settings tested. Plots and data only for maximum power as minimum power readings were similar.		
Temperatures Tested	Nominal: 20°C Low: -20°C High: 50°C		

Instrumentation

Laird

Date : 26-Nov-2019 Test : Frequency Stability Job : C-3164

PE : Zach Wilson Customer : Georgia Pacific Quote : 318246

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	CC 000210C	Chamber - Enviromental	Thermotron	S-8C	28133	10/26/2018	10/16/2020	Active Verification
2	AA 960172	Cable	A.H. Systems, Inc	SAC-26G-1	387	6/4/2018	6/4/2020	Active Verification
3	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	4/24/2019	4/24/2020	Active Calibration

EUT Parameters

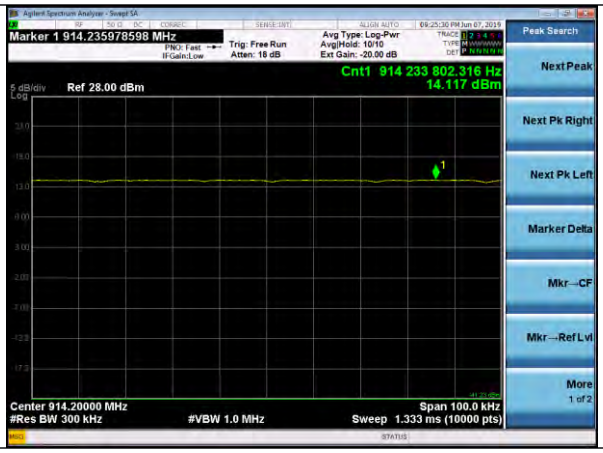
Input Power	2.6 VDC, 3.3 VDC, 3.8 VDC	**Mode**	Single Channel DTS
Frequency	903.0 (Low), 914.2 (High) MHz	**Data Rates**	DR4
Power Settings	Laird Rev_B: 18		

Data

Frequency Stability						
Temperature (°C)	Input Power (VDC)	Channel	Data Rate	Power Setting (dBm)	Frequency Reading (Hz)	Frequency Deviation (Hz)
20	2.6	Low	DR4	18	903067947	446
20	3.0	Low	DR4	18	903068393	0
20	3.8	Low	DR4	18	903026342	42051
20	2.6	High	DR4	18	914214525	19277
20	3.0	High	DR4	18	914233802	0
20	3.8	High	DR4	18	914217330	16472
-20	3.0	Low	DR4	18	903141790	73397
-20	3.0	High	DR4	18	914398840	165038
50	3.0	Low	DR4	18	903011846	56547
50	3.0	High	DR4	18	914931158	697356

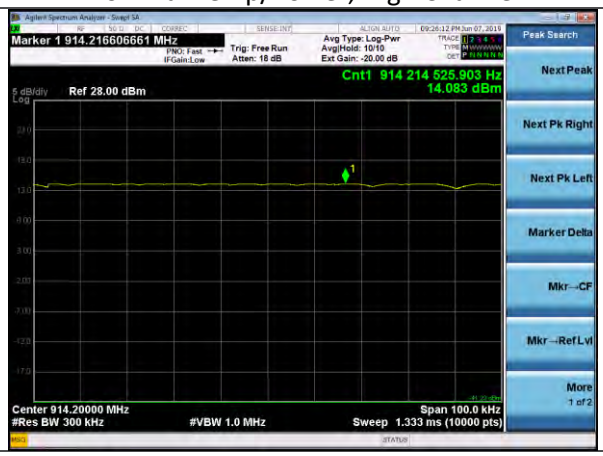
Plots

Nominal Temp/Power, Low Channel



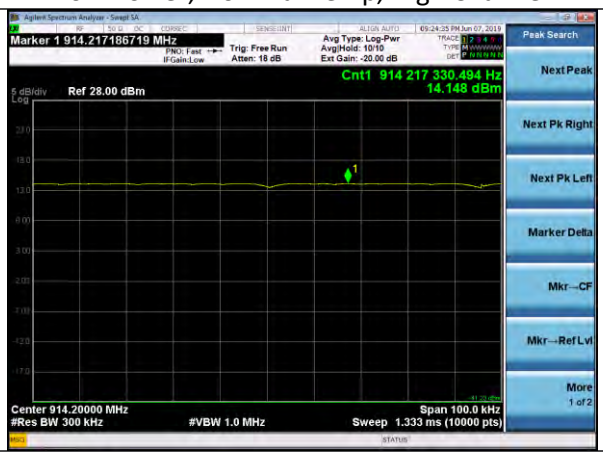
Nominal Temp/Power, High Channel

Low Power, Nominal Temp, Low Channel



Low Power, Nominal Temp, High Channel

High Power, Nominal Temp, Low Channel



High Power, Nominal Temp, High Channel

Nominal Power, Low Temp, Low Channel

Nominal Power, Low Temp, High Channel

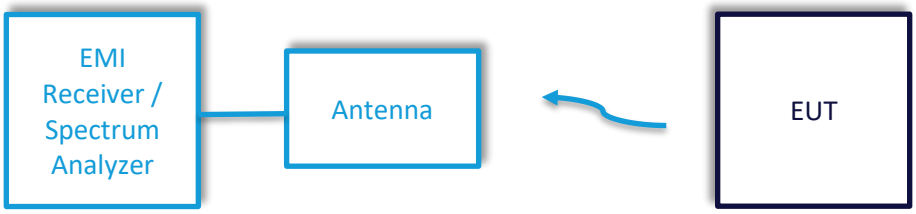
Nominal Power, High Temp, Low Channel

Nominal Power, High Temp, High Channel

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 30-1240 MHz

Operator	Braden Smith, Anthony Smith, Jon Dilley	**QA**	Zach Wilson, Jeysson Gonzalez, Shane Dock
Temperature	23.3°C, 25.1°C, 24.3°C	**R.H. %**	48.2%, 42.2%, 44.0%
Test Date	5/23-5/30/2019, 7/31/2020	**Location**	Chamber 3
Requirement	FCC 15.209	**Method**	ANSI C63.10

Limits: Spurious Emissions

Frequency (MHz)	Quasi Peak Limit (dBµV/m)	Peak Limit (dBµV/m)	Quasi Peak Limit (dBµV/m)
30-88	40	-	-
88-216	43.5	-	-
216-960	46	-	-
960-1000	54	-	-
1000-10000	-	74	54

Test Parameters

Frequency	30-10000 MHz	**Distance**	3m
Detector(s)	Max peak hold for plots. Quasi peak detector for measurements under 1 GHz. Average measurements taken at 30 Hz VBW.	**Table height**	Below 1 GHz: 80cm Above 1 GHz: 150cm
RBW	Below 1 GHz: 120 kHz Above 1 GHz: 1 MHz	**VBW**	Below 1 GHz: 1.2 MHz Above 1 GHz: 3 MHz Peak, 30 Hz Average obtained from fundamental duty cycle.
Notes	Plots shown are of power setting 18. Power settings 12, -17 tested but emissions seen were equal or lower than power setting 18 emissions.	**Orientations**	Side, Flat, Vertical. Side had worst case emissions and is shown in the plots.

EUT Parameters

Input Power	3VDC (Two D Batteries)	**Mode**	LoRa Tx
Data Rate	DR13, DR4	**EUT BW**	500 kHz channel BW
Power Settings	Laird Rev_B: 18, -17 Laird Rev_B1: 12		

Instrumentation

Date : 23-May-2019 Test : Radiated Emissions Job : C-3164

PE : Zach Wilson Customer : Georgia Pacific Quote : 318246

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	EE 960085	Analyzer - EMI Receiver	Agilent	N9038A	MY51210148	7/13/2018	7/13/2021	Active Calibration
2	AA 960007	Antenna - Double Ridge Horn	EMCO	3115	9311-4138	10/7/2018	10/7/2020	Active Calibration
3	AA 960195	Antenna - Log Periodic	A.H. Systems, Inc	SAS-512-2	557	7/24/2018	7/24/2021	Active Calibration
4	AA 960150	Antenna - Biconical	ETS Lindgren	3110B	0003-3346	10/9/2018	10/9/2020	Active Calibration
5	EE 960088	Analyzer - EMI Receiver	Agilent	N9038A	MY51210138	7/14/2018	7/14/2021	Active Calibration
6	EE 960087	Analyzer - Spectrum	Agilent	N9010A	MY53400296	7/14/2018	7/14/2021	Active Calibration
7	EE 960160	Antenna - Low Noise Amplifier	Mini-Circuits	ZVA-213X-S+	977711030	10/7/2018	10/7/2020	Active Calibration

Date : 29-Jul-2020 Test : Radiated Emissions - Harmonics Job : C-3164

PE : Zach Wilson Customer : Georgia Pacific Quote : 318246

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	AA 960081	Antenna - Double Ridge Horn	EMCO	3115	6907	10/18/2019	10/18/2020	Active Calibration
2	EE 960096	Antenna - Low Noise Amplifier	Mini-Circuits	ZVA-213X-S+	40201429	10/18/2019	10/18/2020	Active Calibration
3	EE 960203	Analyzer - EMI Receiver	Keysight	N9038A	MY56400072	7/14/2020	7/14/2021	Active Calibration
4	AA 960155	Filter - High Pass Filter 900 MHz	KWM	HPF-L-14185	7272-03	7/16/2020	7/16/2021	Active Calibration
5	LSC-300	Cable	Chamber 3 Emiss	-	-	12/9/2019	12/9/2020	Active Verification

Data Tables

Spurious Below 1 GHz, Laird Rev_B							
Frequency (MHz)	Antenna Polarity	Height (cm)	Azimuth (deg)	Data Rate	Quasi-Peak Reading (dBuV/m)	QP Limit (dBuV/m)	QP Margin (dB)
180.3	Vertical	210	0	DR4	26.8	43.5	16.7
180.3	Vertical	100	0	DR13	28.6	43.5	14.9
180.3	Vertical	100	0	DR13	28.0	43.5	15.5
199.9	Horizontal	100	0	DR4	24.8	43.5	18.7

Band Edges Below 1 GHz, Laird Rev_B							
Frequency (MHz)	Antenna Polarity	Height (cm)	Azimuth (deg)	Data Rate	Quasi-Peak Reading (dBuV/m)	QP Limit (dBuV/m)	QP Margin (dB)
609.2	Horizontal	150	174	DR4	35.5	46.0	10.5
612.2	Horizontal	150	174	DR13	35.6	46.0	10.4
612.6	Horizontal	155	174	DR13	25.5	46.0	20.5
881.3	Horizontal	100	150	DR4	29.9	46.0	16.1
882.6	Horizontal	100	150	DR13	30.3	46.0	15.7
968.4	Horizontal	155	174	DR13	28.1	54.0	25.9

Band Edges Below 1 GHz, Laird Rev_B1							
Frequency (MHz)	Antenna Polarity	Height (cm)	Azimuth (deg)	Data Rate	Quasi-Peak Reading (dBuV/m)	QP Limit (dBuV/m)	QP Margin (dB)
609.0	Horizontal	155	174	DR13	26.7	46.0	19.3
612.8	Horizontal	150	174	DR4	34.6	46.0	11.4
613.9	Horizontal	150	174	DR13	35.7	46.0	10.3
879.9	Horizontal	100	150	DR4	30.1	46.0	15.9
881.4	Horizontal	155	174	DR13	29.9	46.0	16.1
898.8	Horizontal	100	150	DR13	30.1	46.0	15.9

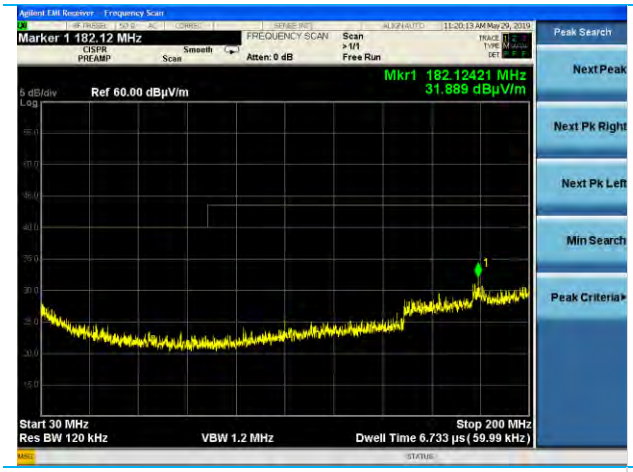
DR4 Above 1 GHz

Frequency (GHz)	EUT Orientation	Antenna Polarity	Height (cm)	Azimuth (degree)	Average Reading (dBµV/m)	Average Limit (dBµV/m)	Average Margin (dB)	Peak Reading (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	Note
1806.0	Vertical	V	195	304	34.3	54.0	19.7	41.3	74.0	32.7	Tx 903, 30Hz VBW
5418.0	Vertical	V	100	185	32.0	54.0	22.0	45.7	74.0	28.3	Tx 903, 30Hz VBW
5418.2	Vertical	H	220	101	34.4	54.0	19.6	46.6	74.0	27.4	Tx 903, 30Hz VBW
1806.0	Vertical	H	230	0	32.5	54.0	21.5	40.3	74.0	33.7	Tx 903, 30Hz VBW
5418.1	Side	V	200	149	34.6	54.0	19.4	46.5	74.0	27.5	Tx 903, 30Hz VBW
1806.0	Side	V	150	99	34.5	54.0	19.5	41.5	74.0	32.5	Tx 903, 30Hz VBW
5418.0	Side	H	150	229	33.0	54.0	21.0	46.1	74.0	27.9	Tx 903, 30Hz VBW
1806.0	Flat	V	280	267	36.0	54.0	18.0	41.7	74.0	32.3	Tx 903, 30Hz VBW
5418.2	Flat	V	100	48	34.5	54.0	19.5	46.7	74.0	27.3	Tx 903, 30Hz VBW
1806.0	Flat	H	150	288	46.2	54.0	7.8	49.1	74.0	24.9	Tx 903, 30Hz VBW
5418.3	Flat	H	100	241	35.1	54.0	18.9	50.3	74.0	23.7	Tx 903, 30Hz VBW
1815.6	Flat	H	150	288	43.3	54.0	10.7	46.8	74.0	27.2	Tx 907.8, 30Hz VBW
5446.5	Flat	H	100	241	37.8	54.0	16.2	49.6	74.0	24.4	Tx 907.8, 30Hz VBW
1830.0	Flat	H	150	288	36.1	54.0	17.9	41.8	74.0	32.2	Tx 915, 30Hz VBW
5490.2	Flat	H	100	241	37.9	54.0	16.1	49.0	74.0	25.0	Tx 915, 30Hz VBW

DR13 Above 1 GHz

Frequency (GHz)	EUT Orientation	Antenna Polarity	Height (cm)	Azimuth (degree)	Average Reading (dBµV/m)	Average Limit (dBµV/m)	Average Margin (dB)	Peak Reading (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	Note
1806.000	Flat	H	150	288	46.1	54.0	7.9	49.0	74.0	25.0	Tx 903, 30Hz VBW
5418.300	Flat	H	100	241	35.2	54.0	18.8	47.6	74.0	26.4	Tx 903, 30Hz VBW
5446.770	Flat	H	100	241	37.2	54.0	16.8	51.5	74.0	22.5	Tx 907.8, 30Hz VBW
1815.620	Flat	H	150	288	43.3	54.0	10.7	46.7	74.0	27.3	Tx 907.8, 30Hz VBW
1829.990	Flat	H	150	288	36.2	54.0	17.8	42.0	74.0	32.0	Tx 915, 30Hz VBW
5490.000	Flat	H	100	241	38.6	54.0	15.4	50.2	74.0	23.8	Tx 915, 30Hz VBW

Plots

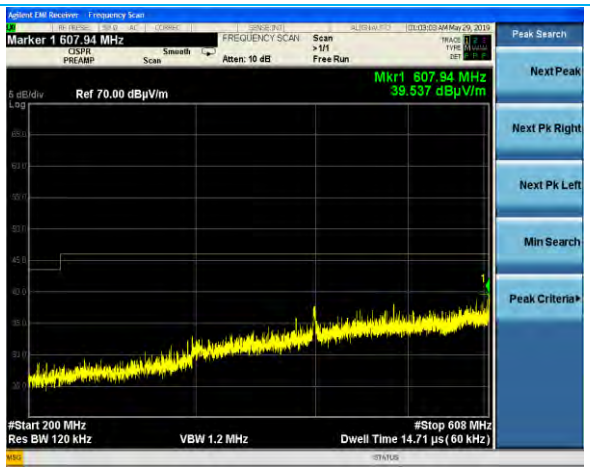


30-200MHz, Horizontal Antenna, Lo Ch, 500k, DR4

30-200MHz, Vertical Antenna, Lo Ch, 500k, DR4

30-200MHz, Horizontal Antenna, High Ch, 500k, DR4

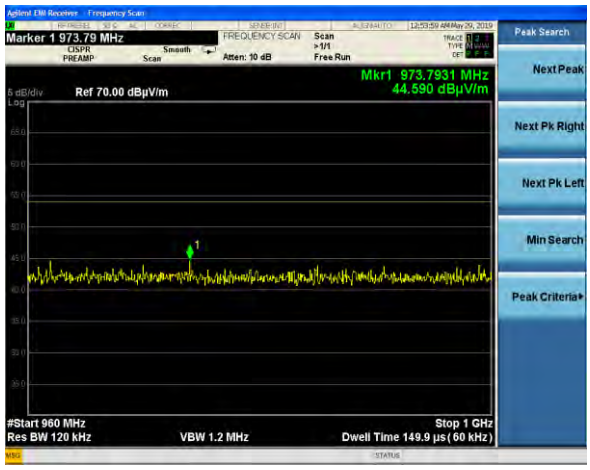
30-200MHz, Vertical Antenna, High Ch, 500k, DR4



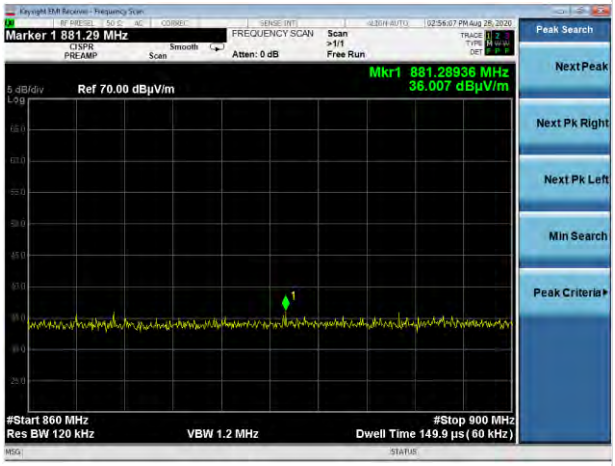
200-608 MHz, Horizontal Antenna, Low Ch, 500kHz, DR13

608-614 MHz, Horizontal Antenna, Low Channel, 500kHz, DR13

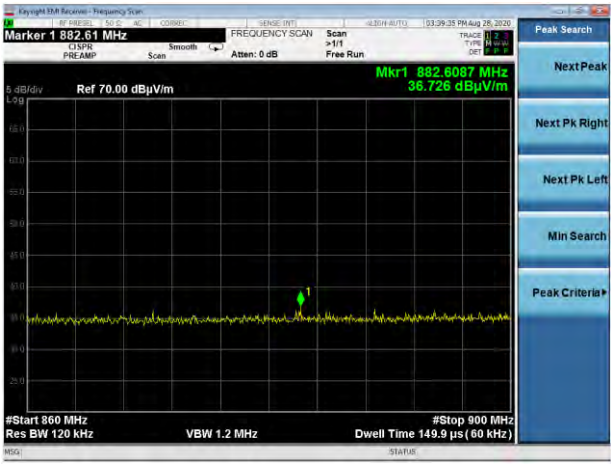
608-614 MHz, Horizontal Antenna, Low Channel, 500kHz, DR4



960-1000 MHz, Horizontal Antenna, High Channel, 500 kHz, DR4

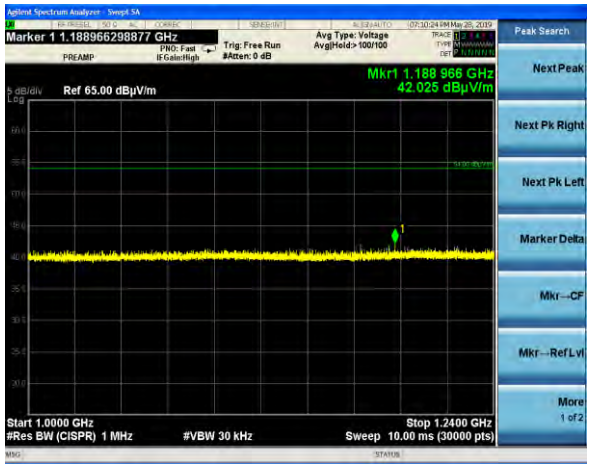


860-900 MHz, Horizontal Antenna DR4 Low Channel, EUT Flat

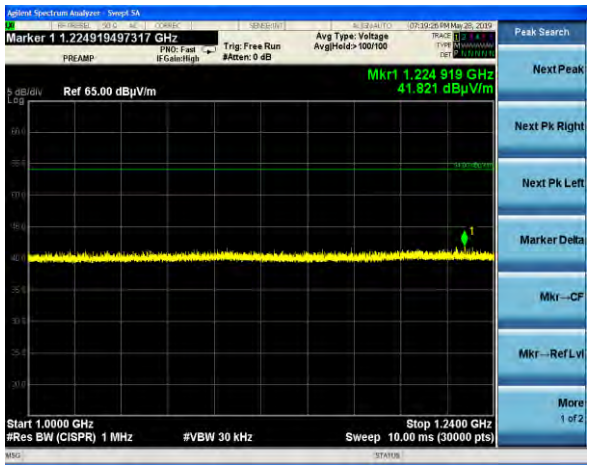


860-900 MHz, Horizontal Antenna DR13 Low Channel, EUT Flat

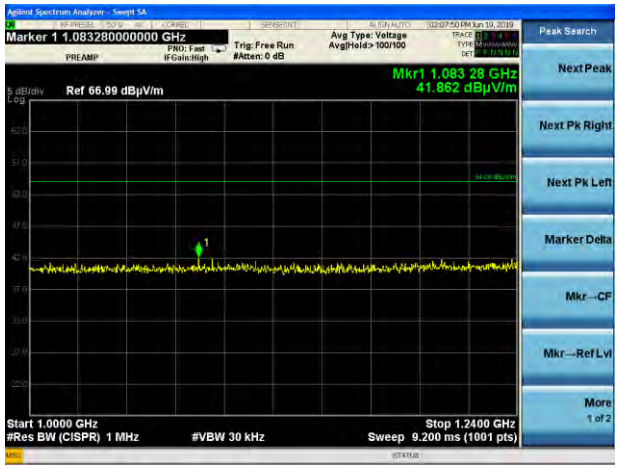
960-1000 MHz, Horizontal Antenna, High Channel, 500 kHz, DR13



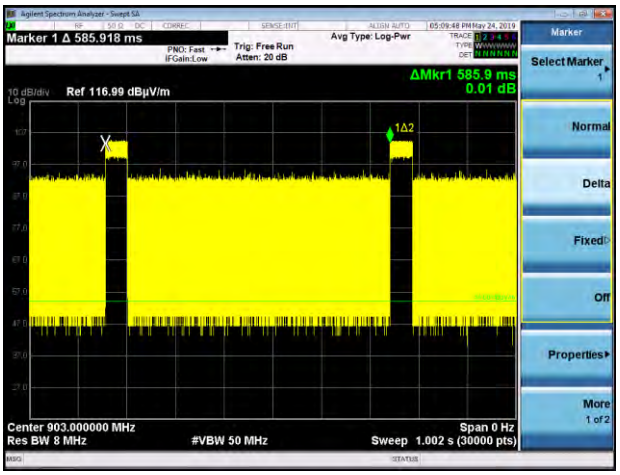
1000-1240 MHz, Horizontal Antenna, High Channel, 500 kHz, DR 13, Reduced VBW



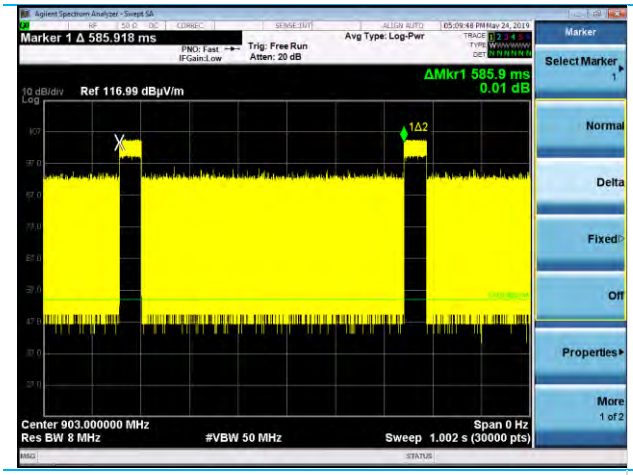
1000-1240 MHz, Vertical Antenna, High Channel, 500 kHz, DR 13, Reduced VBW



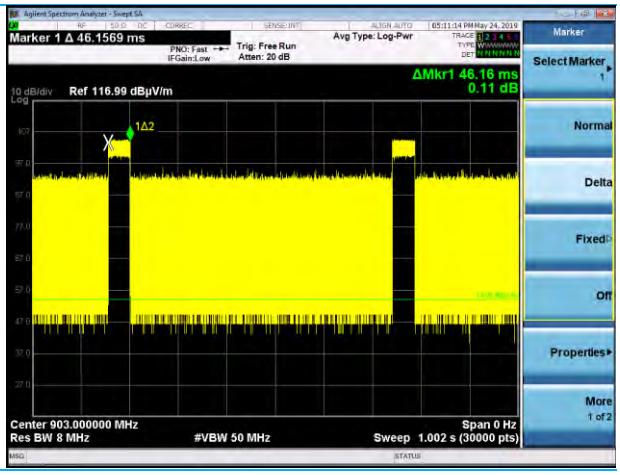
1000-1240 MHz, Vertical Antenna, High Channel, 500 kHz, DR4, Reduced VBW



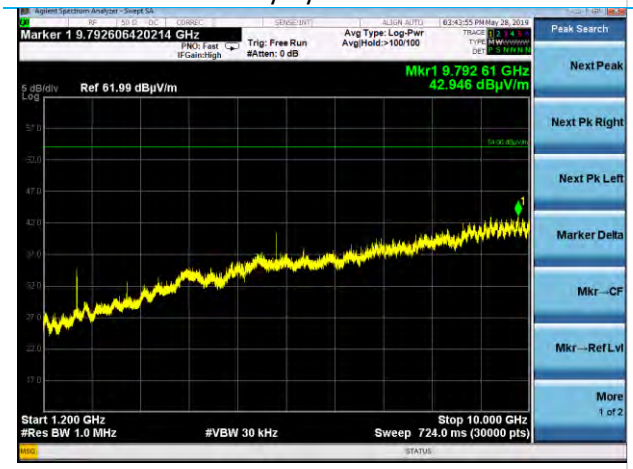
DR4 Duty Cycle



Duty Cycle DR3



Duty Cycle DR3

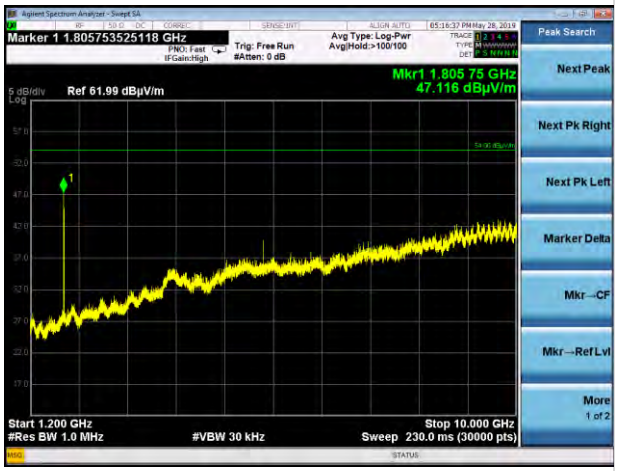


1.2-10 GHz, Horizontal Antenna, Low Ch, 500k, DR4, EUT Vertical

1.2-10 GHz, Vertical Antenna, Low Ch, 500k, DR4, EUT Vertical

1.2-10 GHz, Horizontal Antenna, Low Ch, 500k, DR4, EUT Side

1.2-10 GHz, Vertical Antenna, Low Ch, 500k, DR4, EUT Side



1.2-10 GHz, Horizontal Antenna, Low Ch, 500k, DR4, EUT Flat

1.2-10 GHz, Vertical Antenna, Low Ch, 500k, DR4, EUT Flat

1.2-10 GHz, Horizontal Antenna, Low Ch, 500k, DR13, EUT Flat

1.2-10 GHz, Vertical Antenna, Low Ch, 500k, DR13, EUT Flat

6 REVISION HISTORY

Version	Date	Notes	Person
v0.1	8-9-2019	Initial Draft	Zach Wilson
v0.2	11-26-2019	Revised draft	Zach Wilson
v1.0	11-26-2019	Revised per internal review	Zach Wilson
v2.0	8-19-2020	Added Laird Rev_B1	Zach Wilson
v2.1	8-20-2020	Revised per internal review	Zach Wilson
V2.4	9-18-2020	Address TCB comment for illegible equipment lists on page 14,17,22 during pdf process	Adam Alger
V2.5	9-22-2020	Address TCB comment for typo in DTS BW table page 11 and removed erroneous low channel copied plots on page 12-13	Adam Alger
V2.6	9-24-2020	Address TCB comment for 99% BW on page 11 Rev_B1 low channel DR4 to match plot	Adam Alger

END OF REPORT