

Test Report # 317399 A

Equipment Under Test:	USB Wireless Adapter
Test Date(s):	12/19/17 – 1/15/18
Prepared for:	ATTN: Michael Caruthers Caterpillar Inc. 100 North East Adams Street Peoria, IL 61629

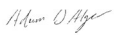
Report Issued by: Shane Dock, EMC Engineer

Signature:



Date: 7/12/2018

Report Reviewed by: Adam Alger, Quality Manager

Signature: 

Date: 04/25/2018

Report Constructed by: Shane Dock, EMC Engineer

Signature:



Date: 4/25/2018

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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:



A2LA – American Association for Laboratory Accreditation

Accreditation based on ISO/IEC 17025: 2005 with Electrical (EMC) Scope

A2LA Certificate Number: 1255.01

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



Federal Communications Commission (FCC) – USA

Accredited recognition of two 3 meter Semi-Anechoic Chambers

Accredited Test Firm Registration Number: 953492



Innovation, Science and Economic Development Canada

ISED Site listing of two 3 meter Semi-Anechoic Chambers based on RSS-GEN – Issue 4

File Number: IC 3088A-2

File Number: IC 3088A-3

Company: Caterpillar Inc	Page 3 of 31	Name: USB Wireless Adapter
Report: 317399 A		Model: See Section 2
Job: C-2894		Serial: See Section 2

1 TEST REPORT SUMMARY

During **12/19/17 – 1/15/18** the Equipment Under Test (EUT), **PQMWIFIBT**, as provided by **Caterpillar Inc.** was tested to the following requirements:

Requirement	Description	Specification	Method	Result
FCC: 15.247 (a)(2) IC: RSS-247 5.2 (a)	Digital Modulation System 6 dB bandwidth	500 kHz	KDB 558074	Pass
FCC: 2.1049 IC: RSS-GEN 6.6	Occupied Bandwidth	Reported	KDB 558074	Pass
FCC: 15.247 (b)(3) IC: RSS-247 5.4 (d)	Maximum Conducted Output Power	30 dBm	KDB 558074	Pass
FCC: 15.247 (e) IC: RSS-247 5.2 (b)	Digital Modulation System Power Spectral Density	8 dBm / 3 kHz	KDB 558074	Pass
FCC: 15.247 (d) IC: RSS-247 5.5	RF Spurious Emissions at the Transmitter Antenna Terminal	20 dBc	KDB 558074	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	Pass
FCC: 15.207 IC: RSS-GEN 8.8	AC Power Line Conducted Emissions	0.150-30 MHz	ANSI C63.10	N/A

Notice:

The results relate only to the item tested and described in this report. Any modifications made to the equipment under test after the specified test date(s) may invalidate the data herein.

If the resulting measurement margin is seen to be within the uncertainty value, as listed in this report, the possibility exists that this unit may not meet the required limit specification if subsequently tested.

2 CLIENT INFORMATION

Company Name	Caterpillar Inc.
Contact Person	Michael Caruthers
Address	Caterpillar Inc. 100 North East Adams Street Peoria, IL 61629

2.1 Equipment Under Test (EUT) Information

The following information has been supplied by the client

Product Name	USB Wireless Adapter
Model Number	WIFIBT
Serial Number	Radiated Emission Units: LK0X001Q12, LK0X001G12 Conducted RF Unit: LK0X001712
FCC / IC ID	FCC ID: PQMWIFIBT IC ID: 4071A-WIFIBT

2.2 Product Description

The USB Wireless Adapter is a mobile device mounted on a vehicle/machine in order to provide Wi-Fi and Bluetooth Low Energy local connectivity. The Wi-Fi connectivity is to enable local basic diagnostic and service functionality allowing connection to the asset to monitor the health of the machine. The Bluetooth Low Energy connectivity is used for other sensing and detection. The Adapter connects to the existing Caterpillar network manager via a USB 2.0 interface. All processing capability resides on the network manager.

2.3 Modifications Incorporated for Compliance

Cable implemented to separate module from host board units.

2.4 Deviations and Exclusions from Test Specifications

None noted at time of test

2.5 Additional Information

EUT programmed via ethernet connection to host board, which is connected to the unit via USB cable. Unit is programmed with the Caterpillar_USB_Adapter_Compliance_App_1749 program. Module is provided with 5V dc power from the host board.

Company: Caterpillar Inc	Page 5 of 31	Name: USB Wireless Adapter
Report: 317399 A		Model: See Section 2
Job: C-2894		Serial: See Section 2

2.6 BLE Information

Unit tested at output power settings of 9 and -18, as the unit has a variable output power. The unit was tested at 2402 MHz, 2440 MHz, and 2480 MHz.

3 REFERENCES

Publication	Edition	Date
CFR 47 Part 15	-	2017
ANSI C63.10	-	2013
RSS-247	2	2017
RSS GEN	4	2014
KDB 558074	4	2017

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 $\pm$
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

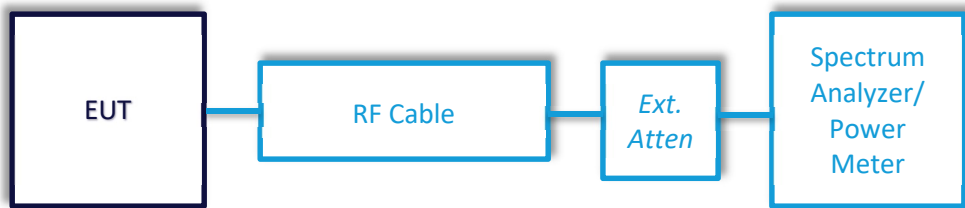
Parameter	ETSI U.C. $\pm$	U.C. $\pm$
Radio Frequency, from F0	1×10^{-7}	0.55×10^{-7}
Occupied Channel Bandwidth	5 %	2 %
RF conducted Power (Power Meter)	1.5 dB	1.2 dB
RF conducted emissions (Spectrum Analyzer)	3.0 dB	1.7 dB
All emissions, radiated	6.0 dB	5.3 dB
Temperature	1° C	0.65° C
Humidity	5 %	2.9 %
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 Antenna Port Conducted Emissions – DTS/99% Bandwidth

Operator	Shane Dock
Test Date	12/27/17
Location	Conducted RF Area
Temp. / R.H.	70 degrees Fahrenheit/23% RH
Requirement	FCC 15.247 (a)(2) IC: RSS-247 5.2 (a)
Method	KDB 558074 Section 8.2 ANSI C63.10 Section 6.9.2

Limits:

Minimum 6 dB BW (MHz)
0.5

Test Parameters

Frequency	2402-2480 MHz
EUT	Unit Tested on Low, Mid, and High Channel

Instrumentation



Date : 28-Dec-2017

Test : Conducted RF Measurements

Job : C-2894

PE : Shane Dock

Customer : Caterpillar

Quote : 317399

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	AA 960143	Cable	Gore	EKD01D01048.0	5546519	11/15/2017	11/15/2018	Active Verification
2	EE 960085	Analyzer - EMI Receiver	Agilent	N9038A	MY 51210148	5/12/2017	5/12/2018	Active Calibration

Table

Channel	Low	Mid	High
6 db BW (kHz)	686.1	683.7	682.7
99% BW (kHz)	1032.8	1032.3	1033.5

Worst Case Margin = Closest Measurement – Limit = 682.7 kHz – 500kHz = 182.7 kHz

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Plots



5.1.2 Antenna Port Conducted Emissions – Conducted Output Power

Operator	Shane Dock
Test Date	1/10/18, 1/15/18
Location	Conducted RF Area
Temp. / R.H.	70 degrees F/34%
Requirement	FCC: 15.247 (b)(3) IC: RSS-247 5.4 (d)
Method	KDB 558074 Section 9.1.1

Limits: (Measured as Average)

Maximum Conducted Output Power (dBm)	Maximum Conducted Output Power (watts)
30	1

Test Parameters

Frequency	2402-2480 MHz
Settings	Low, Mid, and High Channels Measured
Settings	Unit measured at full power and minimum power

Table

Max Power (dBm)

Channel	Low	Mid	High
Output Power (dBm)	8.781	8.608	8.506

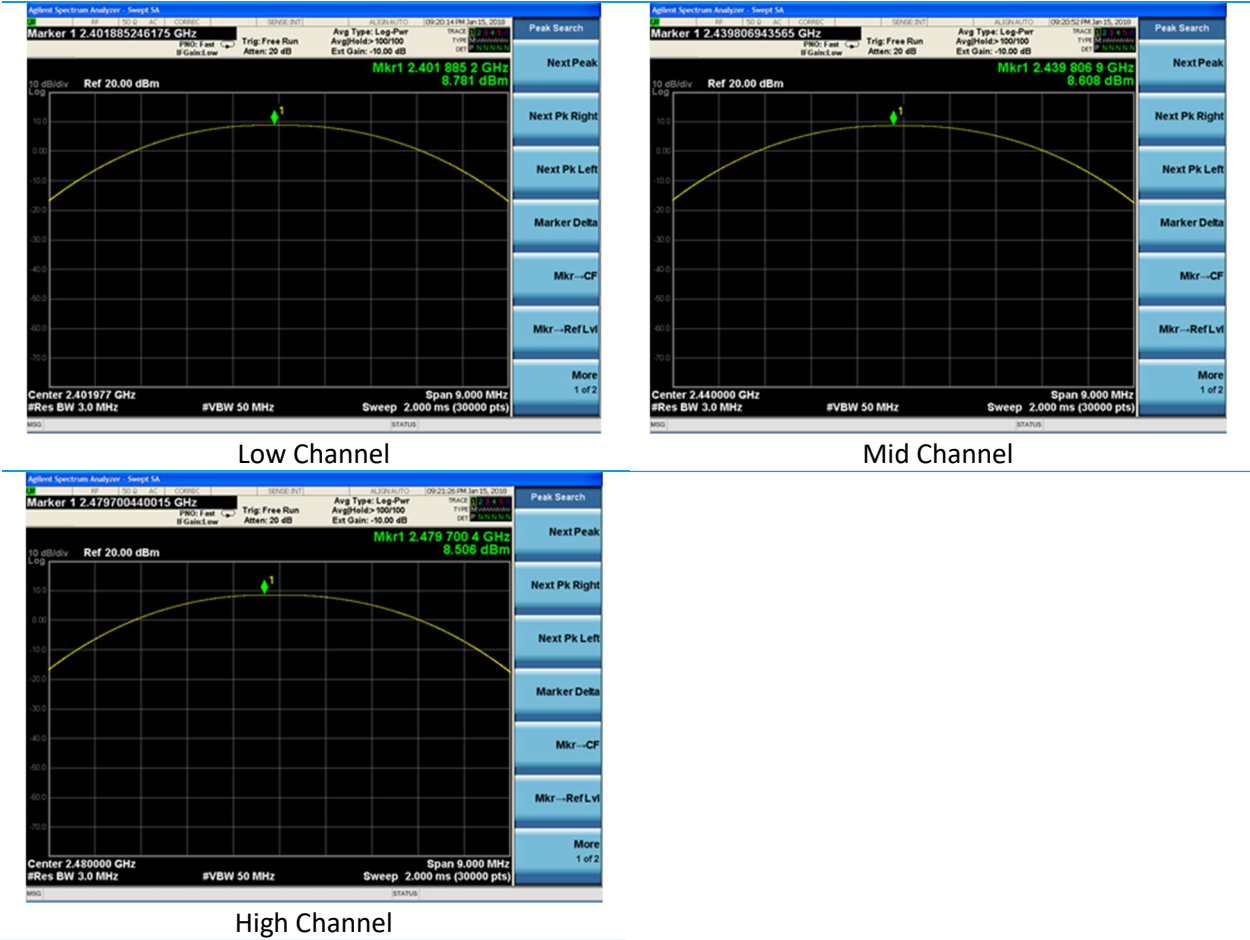
Min Power (dBm)

Channel	Low	Mid	High
Output Power (dBm)	-17.852	-17.910	-17.957

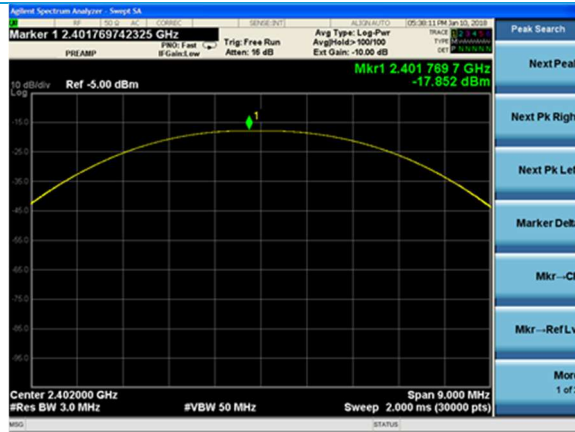
Worst Case Margin = Limit - Closest Measurement = 30.0 dBm – 8.781 dBm = 21.219 dB

Plots

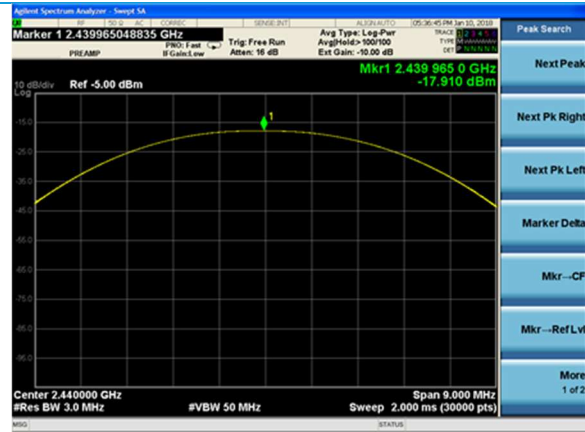
Maximum Power



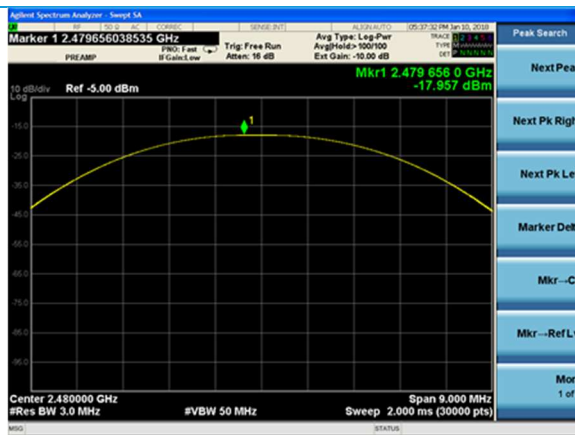
Minimum Power



Low Channel



Mid Channel



High Channel

5.1.3 Antenna Port Conducted Emissions – Power Spectral Density

Operator	Shane Dock
Test Date	1/10/18, 1/15/18
Location	Conducted RF Area
Temp. / R.H.	70 degrees F/34%
Requirement	FCC: 15.247 (e) IC: RSS-247 5.2 (b)
Method	KDB 558074 Section 10.2

Limits:

Power Spectral Density (dBm/ 3 kHz)
8

Test Parameters

Frequency	2402-2480 MHz
Settings	Low, Mid, and High Channels Measured
Settings	Unit measured at full power and minimum power

Table

Maximum Power

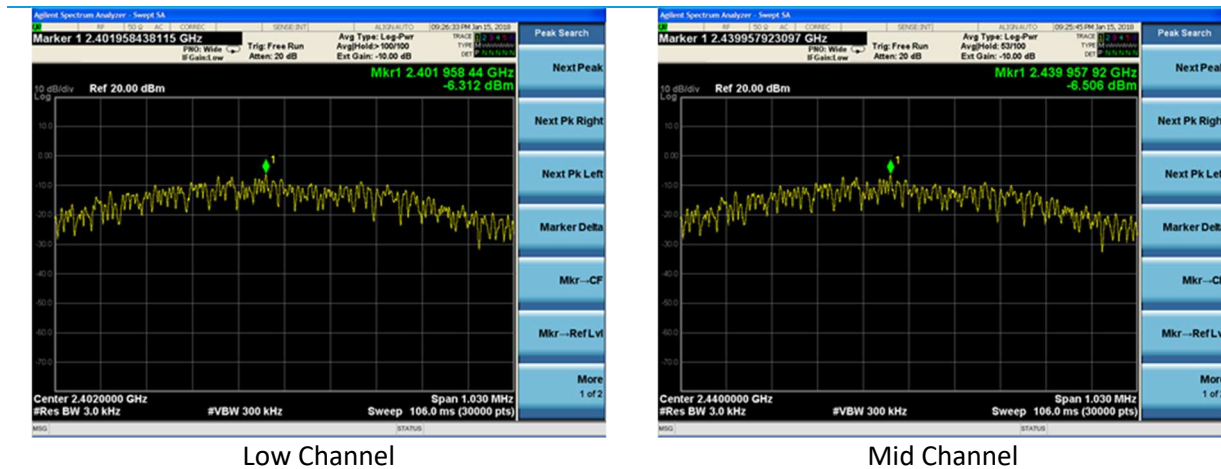
Channel (dBm)	Low	Mid	High
PSD (dBm)	-6.312	-6.506	-6.586

Minimum Power

Channel (dBm)	Low	Mid	High
PSD (dBm)	-18.379	-18.478	-18.507

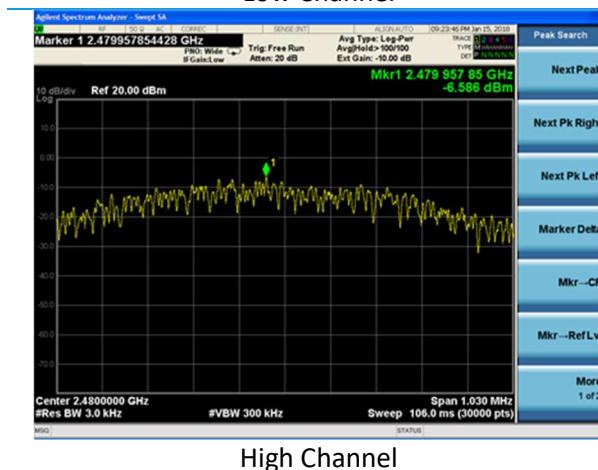
Worst Case Margin = Limit - Closest Measurement = 8 dBm – (-6.312) dBm = 14.312 dB

Maximum Power



Low Channel

Mid Channel



High Channel

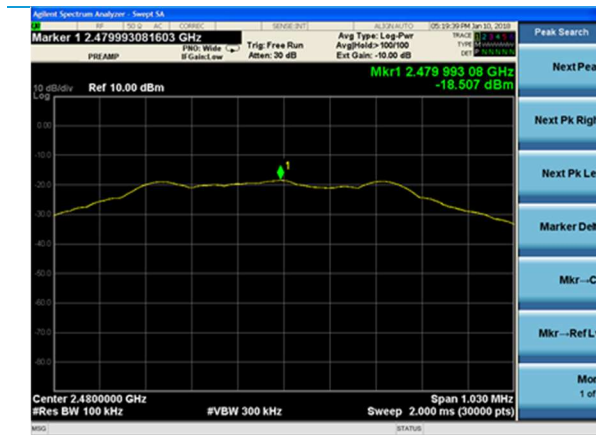
Minimum Power



Low Channel



Mid Channel



High Channel

5.1.4 Antenna Port Conducted Emissions – Tx Conducted Spurious

Operator	Shane Dock
Test Date	1/10/18, 1/15/18
Location	Conducted RF Area
Temp. / R.H.	70 degrees F/34%
Requirement	FCC: 15.247 (d) IC: RSS-247 5.5
Method	KDB 558074 Section 11

Limits:

Spurious Emissions Limit (dBc from Reference Point)
20

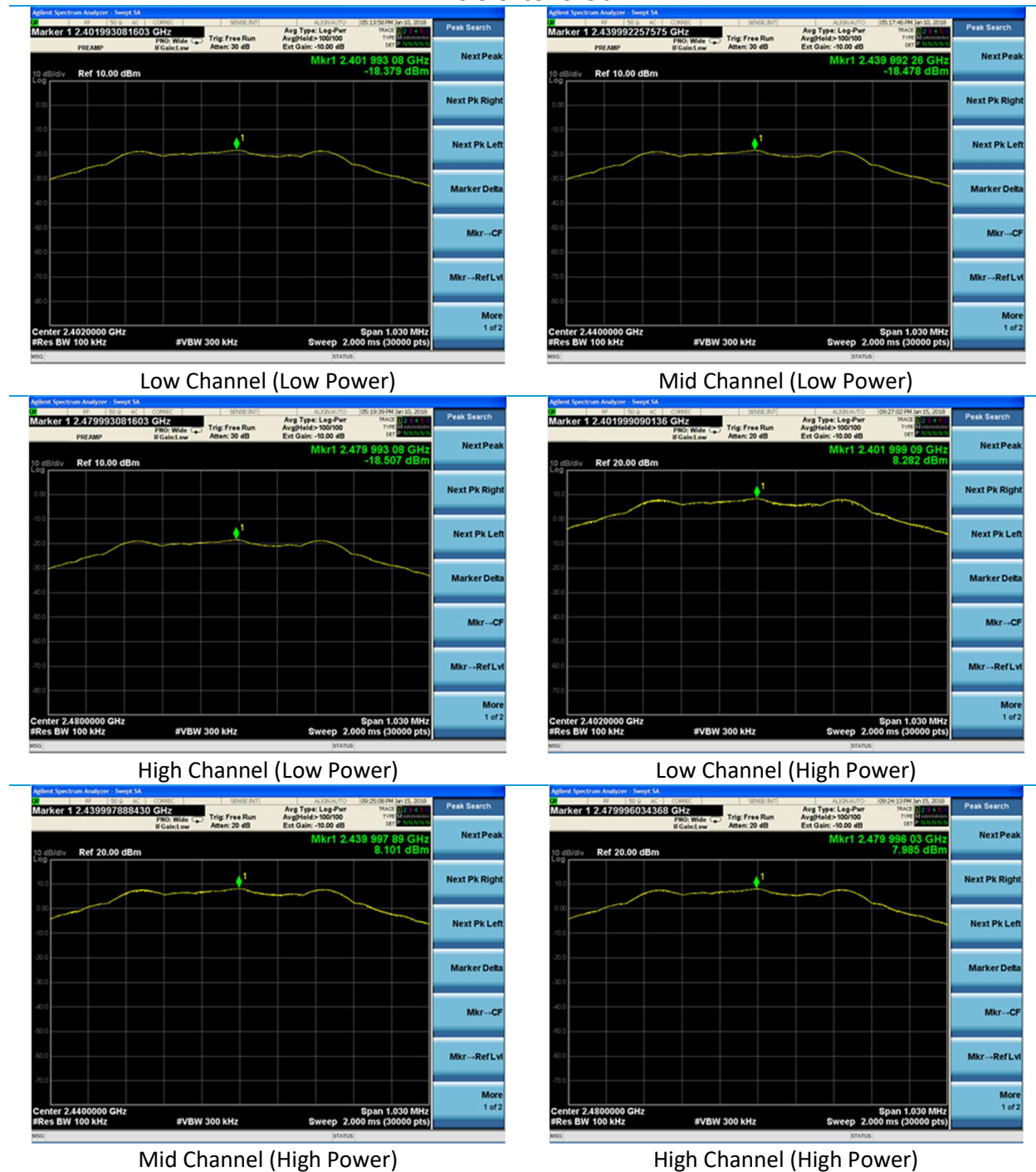
Test Parameters

Frequency	30-25000 MHz
Settings	100k RBW/ 300k RBW
EUT	Low, Mid, High Checked at Max and Min Power

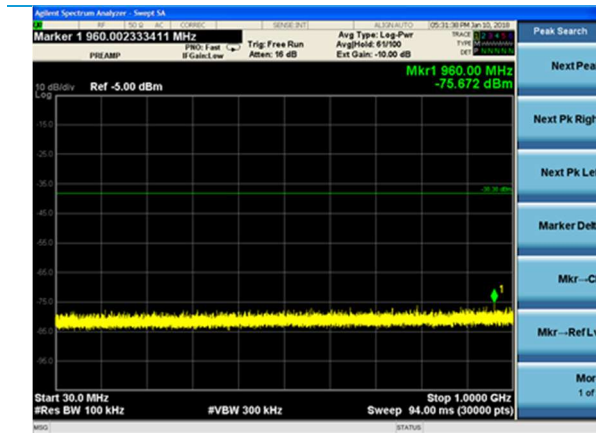
Worst Case Margin = Limit - Closest Measurement = (7.985 dBm – 20 dB) – (-41.634 dBm) = -12.015 dBm – (-41.634 dBm) = 29.619 dB

Plots

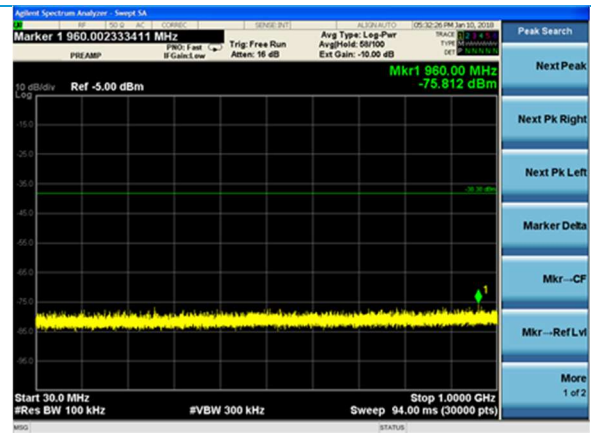
Reference Levels



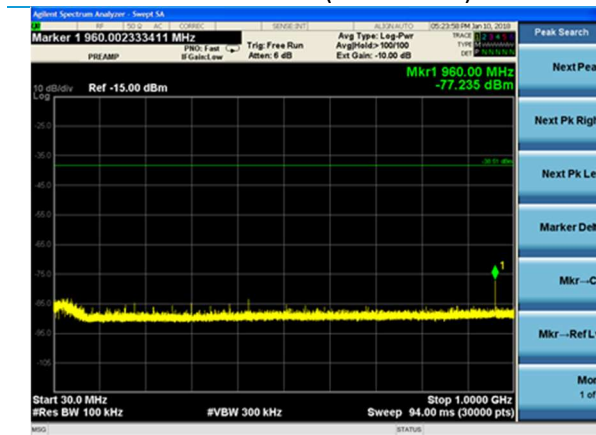
30-1000 MHz



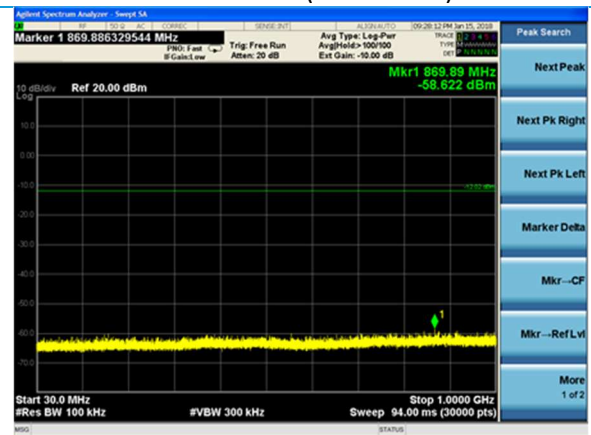
Low Channel (Low Power)



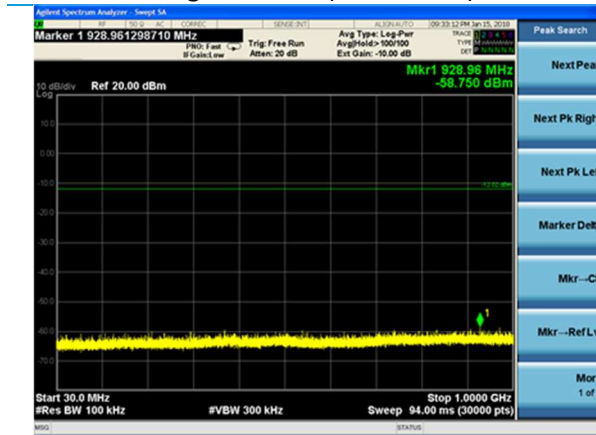
Mid Channel (Low Power)



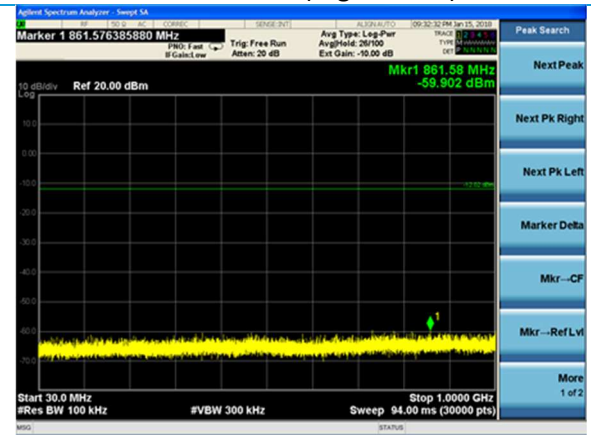
High Channel (Low Power)



Low Channel (High Power)

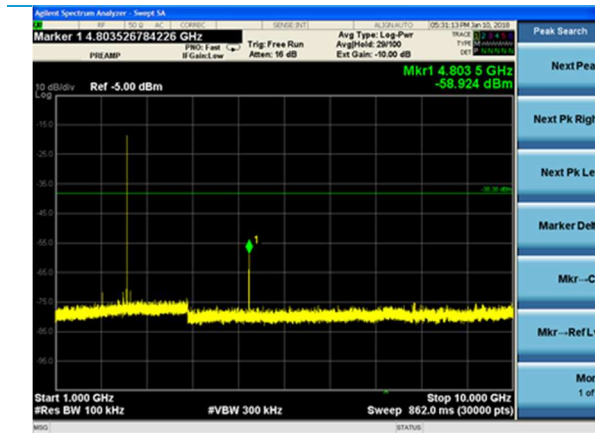


Mid Channel (High Power)

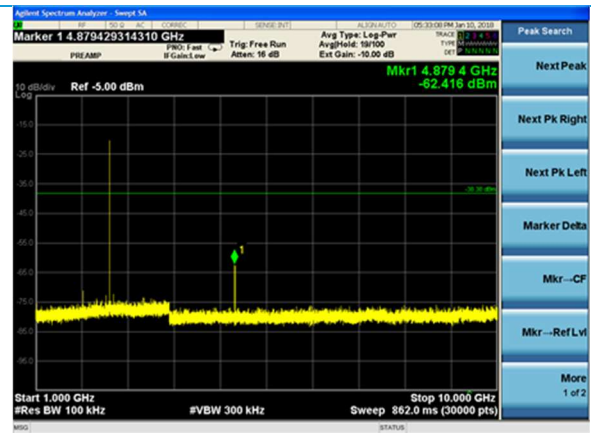


High Channel (High Power)

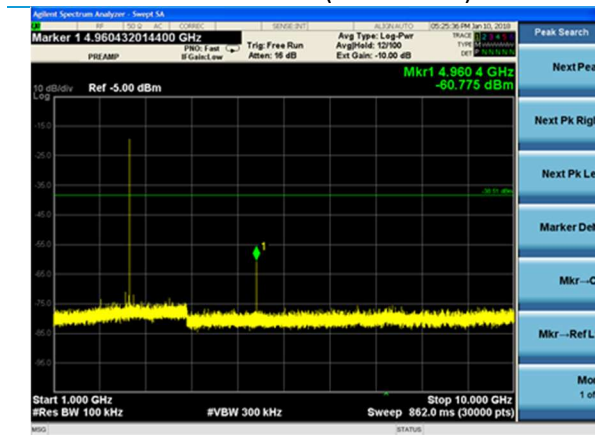
1000-10000 MHz



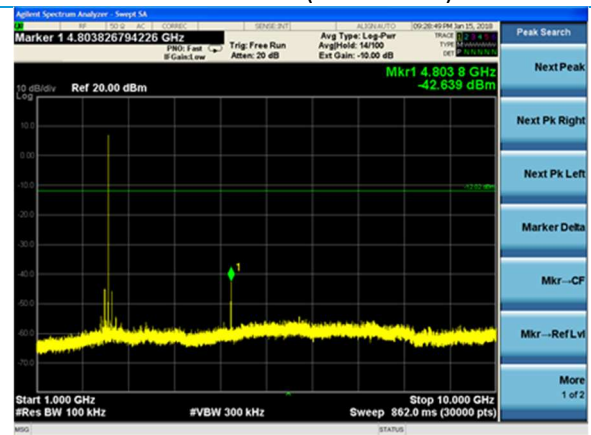
Low Channel (Low Power)



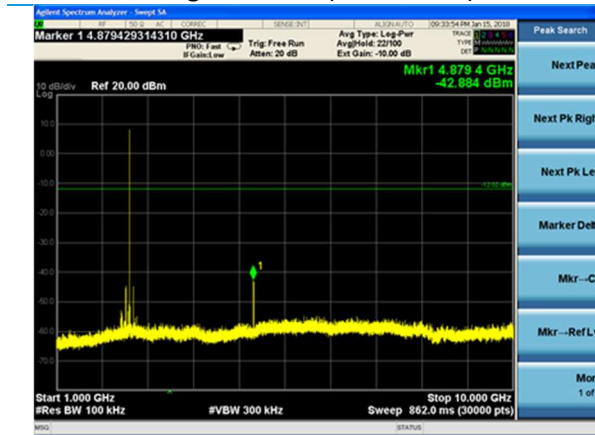
Mid Channel (Low Power)



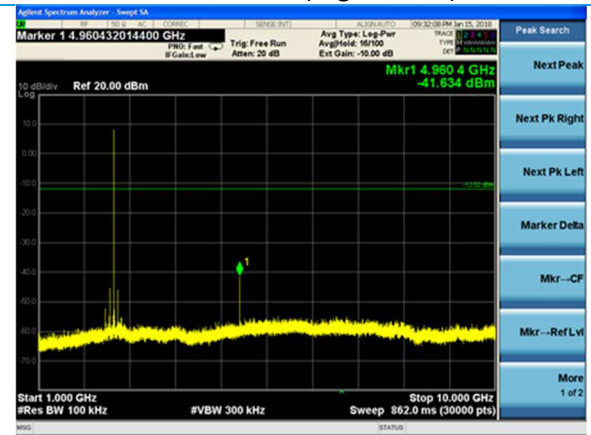
High Channel (Low Power)



Low Channel (High Power)

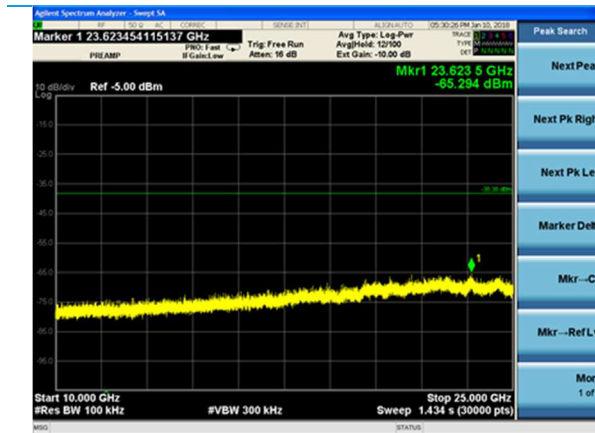


Mid Channel (High Power)

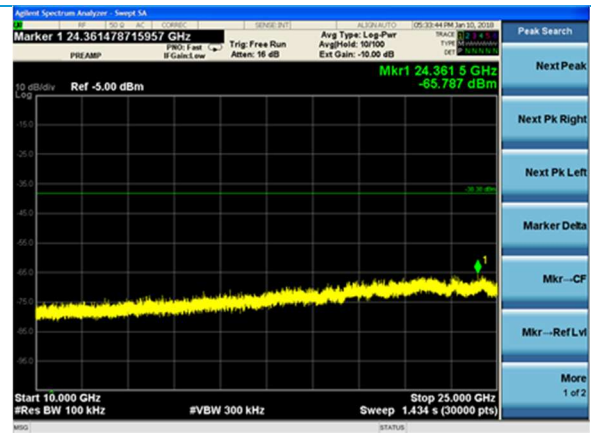


High Channel (High Power)

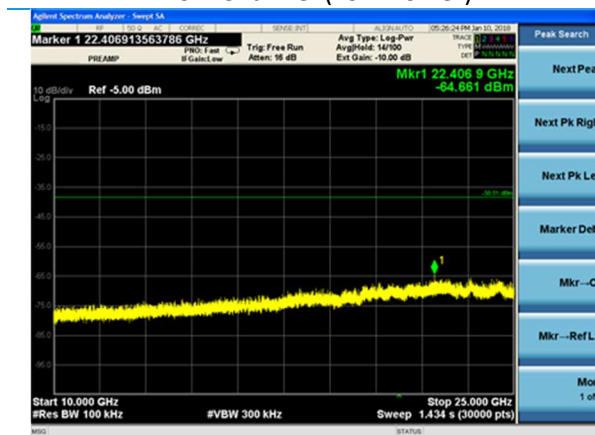
10000-25000 MHz



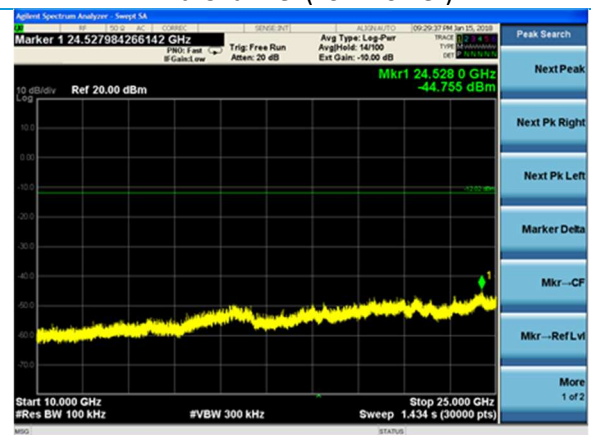
VLBW Channel (Low Power)



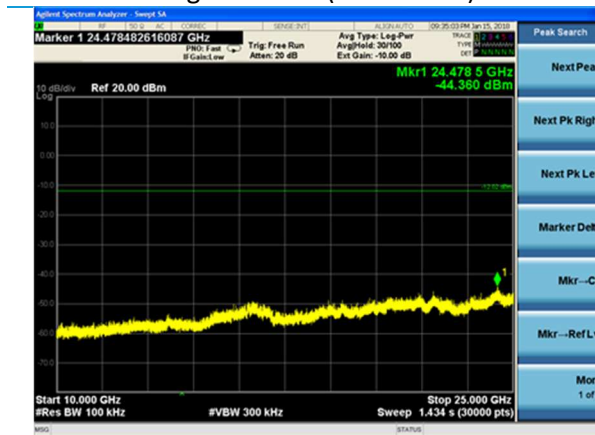
Mid Channel (Low Power)



High Channel (Low Power)



Low Channel (High Power)

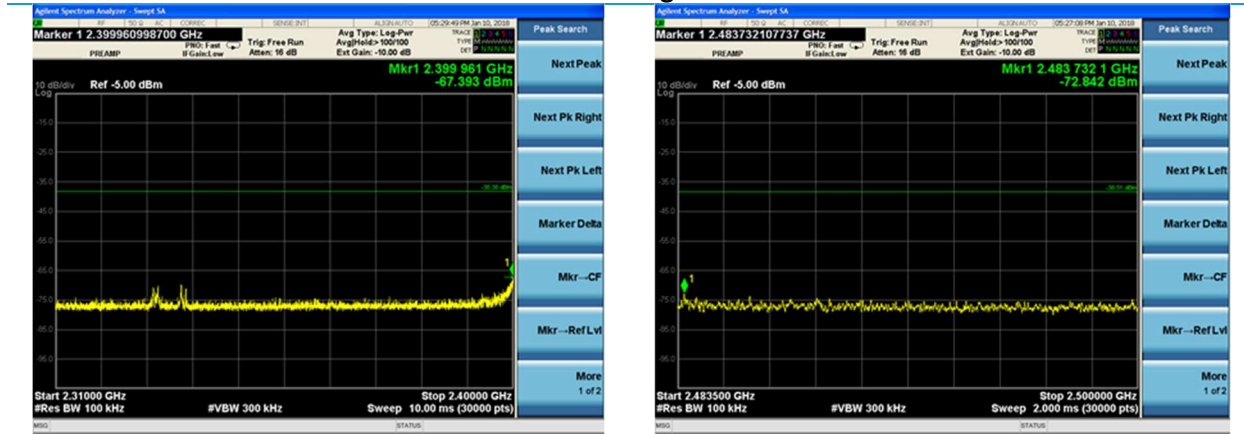


Mid Channel (High Power)



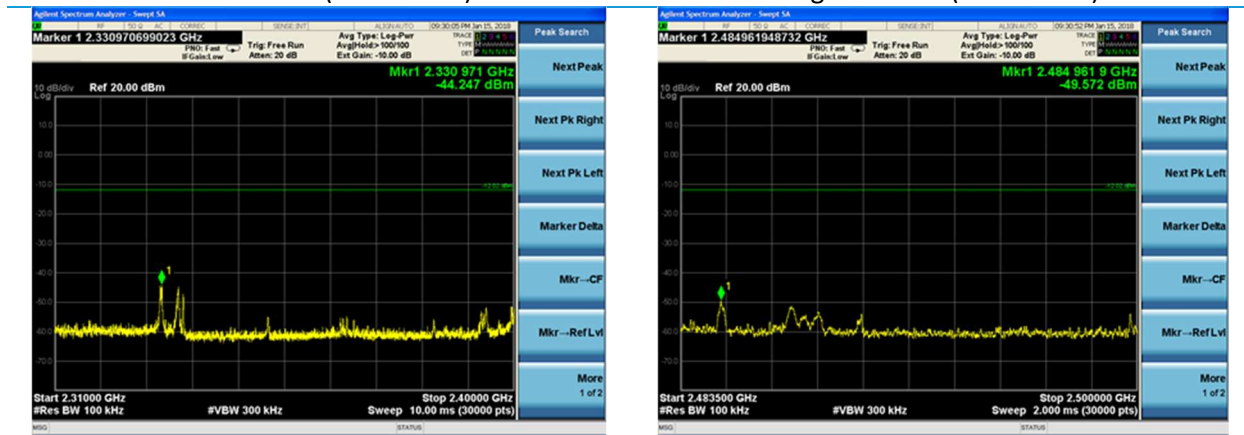
High Channel (High Power)

Band Edges



Low Channel (Low Power)

High Channel (Low Power)



Low Channel (High Power)

High Channel (High Power)

5.1.5 Antenna Port Conducted Emissions – Frequency Stability

Operator	Shane Dock
Test Date	1/10/18
Location	Conducted RF Area
Temp. / R.H.	70 degrees F/34%
Requirement	FCC: 2.1055 (d) IC: RSS-GEN 6.11
Method	ANSI C63.10 Section 6.8

Test Parameters

Frequency	2402-2480 MHz
Settings	Voltage range of 4.5-5.5 VDC

Table

Channel	4.50 VDC Frequency (Hz)	5.00 VDC Frequency (Hz)	5.50 VDC Frequency (Hz)	Deviation (Hz)
Low	2401995725	2401996092	2401994241	1851
Mid	2439992125	2439992058	2439994341	2283
High	2479994391	2479991875	2479992841	2516

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	Shane Dock
Test Date	12/19/17 – 1/8/18
Location	Chamber 5
Temp. / R.H.	71 degrees F/33%RH
Requirement	FCC: 15.247 (d) IC: RSS-GEN 8.10
Method	ANSI C63.10 Sections 6.3, 6.5, 6.6

Limits at 3m:

	30-88 MHz	88-216 MHz	216 – 960 MHz	960+ MHz
Field Strength ($\mu\text{V}/\text{m}$)	100	150	200	500
Field Strength ($\text{dB}\mu\text{V}/\text{m}$)	40.0	43.5	46.0	54.0

Test Parameters

Frequency	30-25000
Distance	3 meters
Settings	Unit tested at low, mid, and high channels. Unit has a 0.3685 ms “on” time.
Settings	RBW = 120kHz, VBW = 1.2 MHz (<1 GHz) RBW = 1 MHz, VBW = 3 MHz (>1 GHz) , 3 kHz for average measurements
EUT	Unit tested and measured in three orientations.
Notes	Measurements taken in restricted bands. For measurements above 1 GHz, antenna used with a tilt gear to keep EUT within the cone of radiation. Absorbers were also added to the floor of the chamber while measuring emissions above 1 GHz. Emissions below 1 GHz are not a function of the EUT. RVBW = Reduced Video Bandwidth
Example Calculation	Limit ($\text{dB}\mu\text{V}$) = $20 * \text{Log}[\text{Limit } (\mu\text{V})]$ $40 = 20 * \text{log}(100)$ Raw Data + Antenna Factor + Cable Factor = Reported Data $19.77 \text{ dB}\mu\text{V} + 12.50 \text{ dB/m} + 0.93 \text{ dB} = 33.20 \text{ dB}\mu\text{V/m}$

Instrumentation



Date : 28-Dec-2017

Test : Radiated Emissions

Job : C-2894

PE : Shane Dock

Customer : Caterpillar

Quote : 317399

No.	Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due Date	Equipment Status
1	EE 960088	Analyzer - EMI Receiver	Agilent	N9038A	MY51210138	3/2/2017	3/2/2018	Active Calibration
2	AA 960150	Antenna - Biconical	ETS Lindgren	3110B	0003-3346	3/3/2017	3/3/2018	Active Calibration
3	AA 960078	Antenna - Log Periodic	EMCO	93146	9701-4855	4/17/2017	4/17/2018	Active Calibration
4	AA 960007	Antenna - Double Ridge Horn	EMCO	3115	9311-4138	8/30/2017	8/30/2018	Active Calibration
5	AA 960153	Filter - High Pass 2.4 GHz	KWM	HPF-L-14186	7272-04	5/2/2017	5/2/2018	Active Calibration
6	EE 960160	Antenna - Low Noise Amplifier	Mini-Circuits	ZVA-213X-S+	977711030	8/30/2017	8/30/2018	Active Calibration
7	AA 960174	Antenna - Small Horn	ETS Lindgren	3116C-PA	00206880	5/1/2017	5/1/2018	Active Calibration

Table

Frequency (MHz)	Height (cm)	Azimuth (degree)	Peak Reading (dBμV/m)	Average Reading (dBμV/m)	Peak Limit (dBμV/m)	Average Limit (dBμV/m)	Peak Margin (dB)	Average Margin (dB)	Antenna Polarity	EUT orientation
4960.00	181.09	209.50	50.26	45.75	74.0	54.0	23.7	8.3	H	F
4880.00	172.23	208.25	52.68	49.07	74.0	54.0	21.3	4.9	H	F
4804.00	174.52	210.25	53.68	50.37	74.0	54.0	20.3	3.6	H	F

Table – Band Edge Measurements

Frequency (MHz)	Peak Measurement (dBuV/m)	Peak Limit (dBuV/m)	Peak Margin (dB)
2333.7	54.3	74.0	19.7
2484.6	54.0	74.0	20.0

Frequency (MHz)	Average Measurement (dBuV/m)	Average Limit (dBuV/m)	Average Margin (dB)
2333.9	42.1	54.0	11.9
2487.5	41.0	54.0	13.0

Table (Under 1 GHz)

Frequency (MHz)	Height (cm)	Azimuth (degree)	Quasi Peak Reading (dBμV/m)	Quasi Peak Limit (dBμV/m)	Quasi Peak Margin (dB)	Antenna Polarity	EUT orientation
178.13	185.28	261.00	30.14	43.5	13.4	H	V
85.33	100.00	339.50	34.14	40.0	5.9	V	V
238.15	185.40	94.00	43.00	46.0	3.0	H	V
238.15	181.38	0.00	40.46	46.0	5.5	V	V

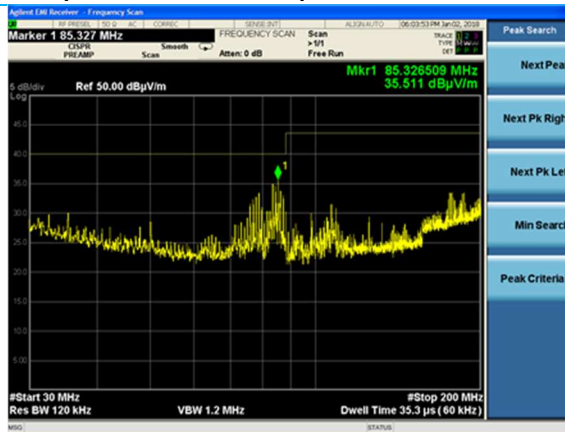
Orientations

V – Vertical

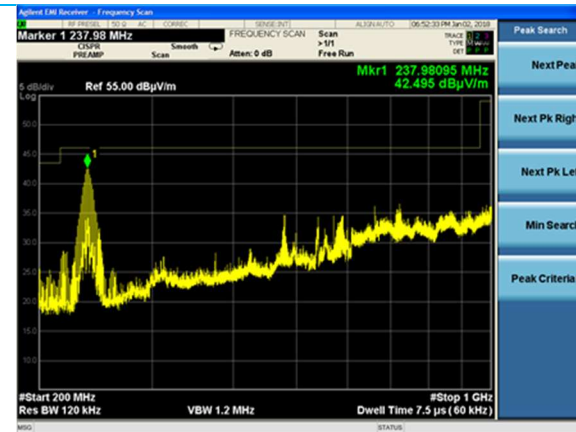
H – Horizontal

F – Flat

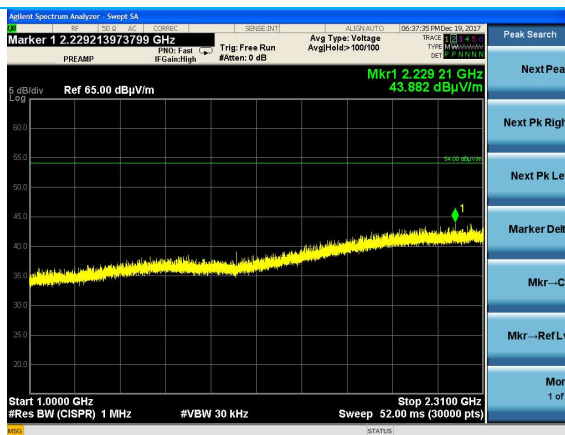
Plots (Worst-Case Shown)



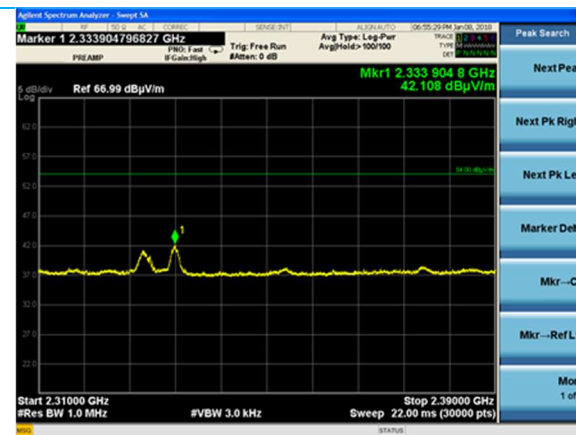
30-200 MHz



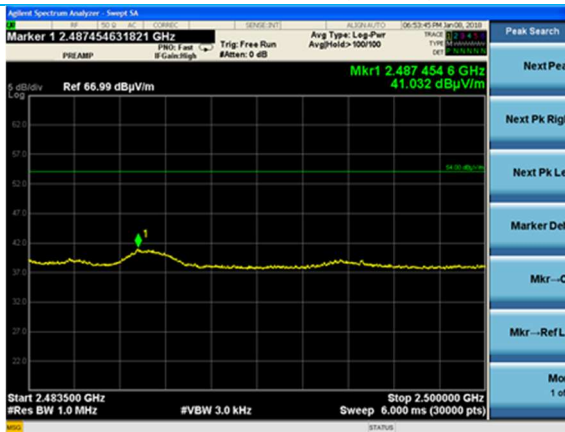
200-1000 MHz



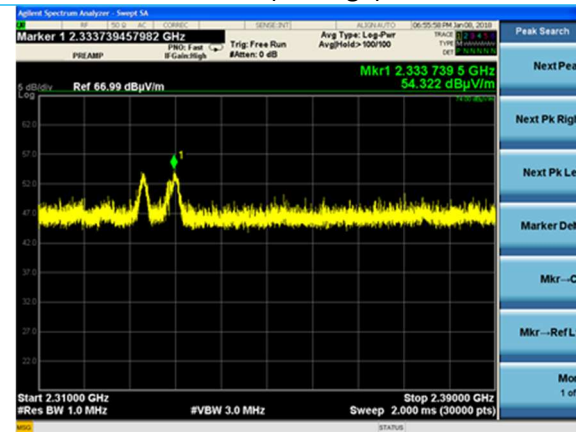
1000-2310 MHz (RVBW)



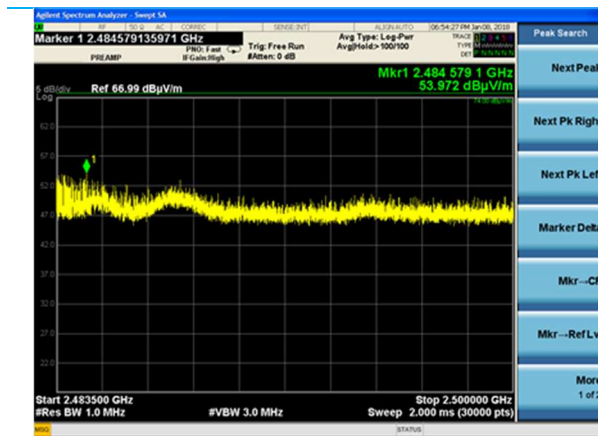
LBE (Average)



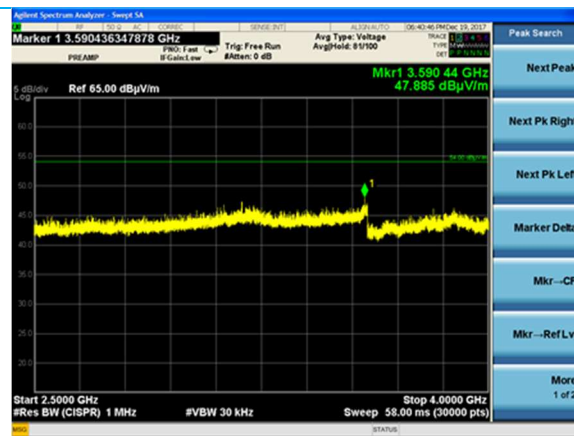
UBE (Average)



LBE (Peak)



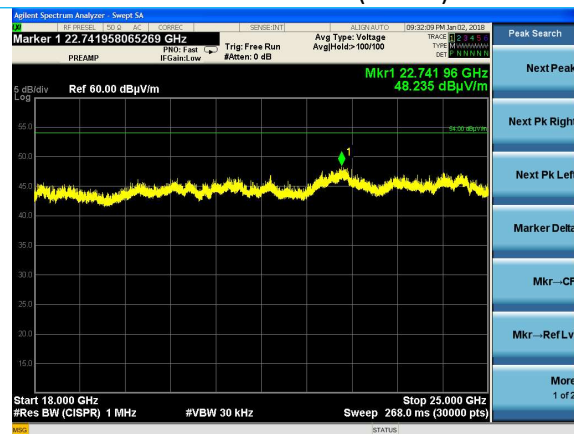
UBE (Peak)



2500 – 4000 MHz (RVBW)



4-18 GHz (RVBW)



18-25 GHz (RVBW)

6 REVISION HISTORY

Version	Date	Notes	Person
V0	1/18/18	Rough Draft	Shane Dock
V1	4/3/18	Updated Draft	Shane Dock
V2	4/20/18	Further Updates	Shane Dock
V3	4/25/18	Final Draft	Shane Dock
V4	7/9/18	Further Revisions	Shane Dock

END OF REPORT