MET Laboratories, Inc. *Safety Certification - EMI - Telecom Environmental Simulation*

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13301 MCCALLEN PASS ● AUSTIN, TX 78753 ● PHONE (512) 287-2500 ● FAX (512) 287-2513

March 14, 2018

Caterpillar Inc.
100 NE Adams St.
Peoria, IL 61629

Dear David Mitchell,

Enclosed is the EMC Wireless test report for compliance testing of the Caterpillar Inc., PL671, tested to the requirements of Title 47 of the Code of Federal Regulations (CFR), Part 95 Subpart L for Land Mobile Radio Services.

Thank you for using the services of MET Laboratories, Inc. If you have any questions regarding these results or if MET can be of further service to you, please feel free to contact me.

Sincerely yours,
MET LABORATORIES, INC.

Joel Huna
Documentation Department

Reference: (\Caterpillar Inc.\EMC95659-FCC95L Rev. 2)

ACCREDITED
TESTING CERT #0591.01

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Electromagnetic Compatibility Criteria
Test Report

For the

Caterpillar Inc.
PL671

Tested under

The FCC Verification Rules
Contained in Title 47 of the CFR, Part 95, Subpart L
for Private Land Mobile Radio Services

MET Report: EMC95659-FCC95L Rev. 2

March 14, 2018

Prepared For:
Caterpillar Inc.
100 NE Adams St.
Peoria, IL 61629

Prepared By:
MET Laboratories, Inc.
914 West Patapsco Avenue, Baltimore, MD 21230

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for Private Land Mobile Radio Services

MET Report: EMC95659-FCC95L Rev. 2

Donald Salguero, Project Engineer
Electromagnetic Compatibility Lab

Joel Huna
Documentation Department

Engineering Statement: The measurements shown in this report were made in accordance with the procedures indicated, and the emissions from this equipment were found to be within the limits applicable. I assume full responsibility for the accuracy and completeness of these measurements, and for the qualifications of all persons taking them. It is further stated that upon the basis of the measurements made, the equipment tested is capable of operation in accordance with the requirements of Part 95, Subpart L of the FCC Rules under normal use and maintenance.

John Mason,
Director, Electromagnetic Compatibility Lab

Report Status Sheet

Revision	Report Date	Reason for Revision
0	January 26, 2018	Initial issue.
1	March 1, 2018	FCC ID Update.
2	March 14, 2018	Updated Customer Name and TCB Corrections.

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List of Terms and Abbreviations

AC	**A**lternating **C**urrent
ACF	**A**ntenna **C**orrection **F**actor
Cal	**Cal**ibration
d	**M**easurement **D**istance
dB	**D**eci**b**els
dBµA	**D**eci**b**els above one **micro**amp
dBµV	**D**eci**b**els above one **micro**volt
dBµA/m	**D**eci**b**els above one **micro**amp **per m**eter
dBµV/m	**D**eci**b**els above one **micro**volt **per m**eter
DC	**D**irect **C**urrent
E	**E**lectric Field
DSL	**D**igital **S**ubscriber **L**ine
ESD	**E**lectro**s**tatic **D**ischarge
EUT	**E**quipment **U**nder **T**est
f	**F**requency
FCC	**F**ederal **C**ommunications **C**ommission
GRP	**G**round **R**eference **P**lane
H	Magnetic Field
HCP	**H**orizontal **C**oupling **P**lane
Hz	**H**er**z**
IEC	**I**nternational **E**lectrotechnical **C**ommission
kHz	**k**ilo**h**er**z**
kPa	**k**ilo**pa**scal
kV	**k**ilo**v**olt
LISN	**L**ine **I**mpedance **S**tabilization **N**etwork
MHz	**M**ega**h**ertz
µH	**microh**enry
µ	**microf**arad
µs	**micros**econds
NEBS	**N**etwork **E**quipment-**B**uilding **S**ystem
PRF	**P**ulse **R**epetition **F**requency
RF	**R**adio **F**requency
RMS	**R**oot-**M**ean-**S**quare
TWT	**T**raveling **W**ave **T**ube
V/m	**V**olts **per m**eter
VCP	**V**ertical **C**oupling **P**lane

Executive Summary

1. Testing Summary

These tests were conducted on a sample of the equipment for the purpose of demonstrating compliance with Part 95, Subpart L. All tests were conducted using measurement procedure ANSI TIA/EIA-603-A-2004.

Title 47 of the CFR, Part 95, Subpart L, and FCC 04-265 Reference and Test Description	Compliance / Comments
2.1046; 95.3167; 95.3189; 90.377 Peak Power Output	Compliant
2.1046; 95.3189 Transmit Spectrum Mask	Compliant
2.1049; 95.3163 Occupied Bandwidth (Emission Mask)	Compliant
2.1051; Spurious Emissions at Antenna Terminals	Compliant
2.1053; Radiated Spurious Emissions	Compliant
2.1055(a) (1); 90.213 Frequency Stability	Compliant
90.214 RF Exposure	Compliant

Equipment Configuration

2. Equipment Configuration

2.1. Overview

MET Laboratories, Inc. was contracted by Caterpillar Inc. to perform testing on the PL671 under purchase order number PO9516.

This document describes the test setups, test methods, required test equipment, and the test limit criteria used to perform compliance testing of the Caterpillar Inc., PL671.

An EMC evaluation to determine compliance of the PL671 with the requirements of Part 95, Subpart L, was conducted. (All references are to the most current version of Title 47 of the Code of Federal Regulations in effect). In accordance with §2.1033, the following data is presented in support of the Certification of the PL671. Caterpillar Inc. should retain a copy of this document and it should be kept on file for at least five years after the manufacturing of the EUT has been **permanently** discontinued. The results obtained relate only to the item(s) tested.

Model(s) Tested:	PL671	
Model(s) Covered:	PL671	
EUT Specifications:	Primary Power Source: 9 – 32 VDC	
	FCC ID: PQMPL671	
	Type of Modulations:	BPSK, QPSK, 16QAM, 64QAM
	Max Peak and Output Power:	20.15dBm @ 5890MHz
	Equipment Code:	TNB
	EUT Frequency Ranges:	5850 to 5925 MHz
Analysis:	The results obtained relate only to the item(s) tested.	
Environmental Test Conditions:	Temperature (15-35º C):	
	Relative Humidity (30-60%):	
	Barometric Pressure (860-1060 mbar):	
Evaluated by:	Donald Salguero	
Report Date(s):	March 14, 2018	

2.2. Test Site

All testing was performed at MET Laboratories, Inc., 914 West Patapsco Avenue, Baltimore, MD 21230. All equipment used in making physical determinations is accurate and bears recent traceability to the National Institute of Standards and Technology.

Radiated Emissions measurements were performed in a semi-anechoic chamber (equivalent to an Open Area Test Site). In accordance with §2.948(a)(3), a complete site description is contained at MET Laboratories.

2.3. Measurement Uncertainty

Test Method	Typical Expanded Uncertainty	K	Confidence Level
RF Frequencies	±4.52 Hz	2	95%
RF Power Conducted Emissions	±2.32 dB	2	95%
RF Power Conducted Spurious Emissions	±2.25 dB	2	95%
RF Power Radiated Emissions	±3.01 dB	2	95%

Table 1. Measurement Uncertainty

2.4. Description of Test Sample

The Caterpillar Inc. PL671, Equipment Under Test (EUT), is a dedicated short range communication (DSRC) device. Units are mounted on heavy machinery on both sides of the vehicle to minimize blind spots. It is intended to provide proximity information vehicle to vehicle. A dedicated radio module in the EUT is used to do provide this link. EUT can also communicate to a stationary device or device on a smaller vehicle by Wi-Fi or BT. A GNSS module inside the EUT provides positioning information to the EUT. The two EUTs communicate with each other and the vehicle using Ethernet. An audio module in the EUT can send audible warnings in case of collision possibilities.

2.5. Equipment Configuration

The EUT was set up as outlined in Figure 1 and Figure 2. All cards, racks, etc., incorporated as part of the EUT is included in the following list.

Ref. ID	Slot #	Name / Description	Model Number	Serial Number	Rev. #
EUT	N/A	DSRC Radio	PL671		A

Table 2. Equipment Configuration

2.6. Support Equipment

Caterpillar Inc. supplied support equipment necessary for the operation and testing of the PL671. All support equipment supplied is listed in the following Support Equipment List.

Ref. ID	Name / Description	Manufacturer	Model Number	* Customer Supplied Calibration Data
PS	Power Supply	BK Precision	1697 or Equiv.	N/A
KB	Standard PC Keyboard	Dell	Any	N/A
PC	Computer	Dell	VOSTRO or Equiv.	N/A
MON	Monitor	Dell	Any	N/A
ENET SW	Ethernet Switch 10/100/1000	Linksys	EG005 or equiv.	N/A
The 'Customer Supplied Calibration Data' column will be marked as either not applicable, not available, or will contain the calibration date supplied by the customer.				

Table 3. Support Equipment

2.7. Ports and Cabling Information

Ref. ID	Port Name on EUT	Cable Description	Qty.	Length (m)	Max Length	Shielded (Y/N)	Termination Point
1	Data Cable	RJ45 CAT 5 or 6 on Quake Cable	2	TBD		No	12 PIN Conn.
2	Power Supply Leads	On Quake Conn. Red, Black, and Yellow		TBD		No	9-32V

Table 4. Ports and Cabling Information

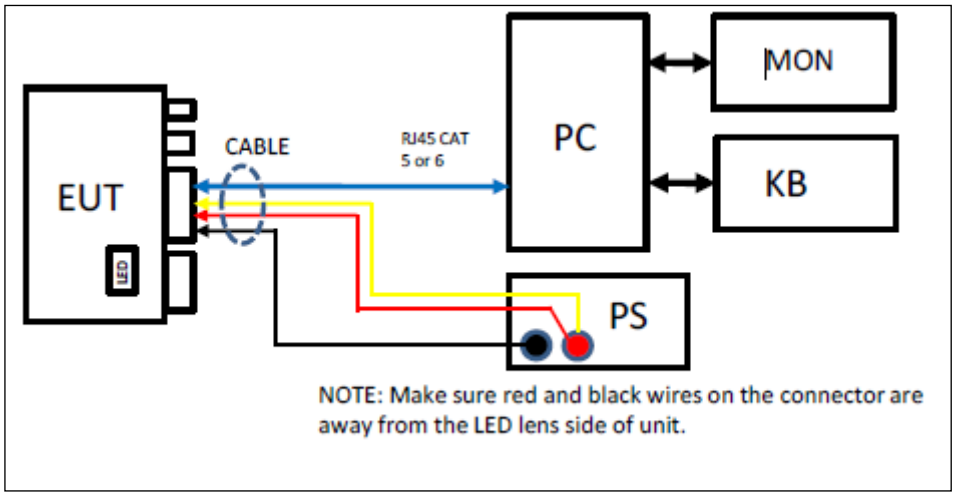
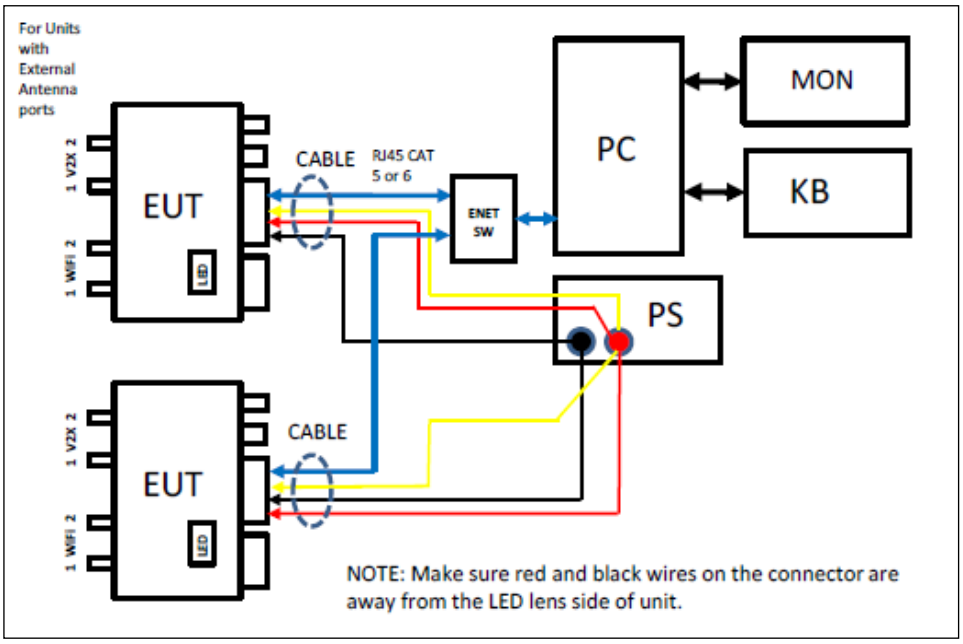


Figure 1. Block Diagram of Test Configuration 1.1



Note: EUT modified with antenna terminal only for test purposes. Otherwise, EUT will have permanent antenna.

Figure 2. Block Diagram of Test Configuration 1.2

2.8. Mode of Operation

Mode 1: The DSRC module in the EUT is put in a continuous transmit mode using the test script. It will broadcast at full power till turned off.
Mode 2: The Wi-Fi module in the EUT is put into continuous transmit mode using the test script. It will broadcast at full power till turned off.
Mode 3: The GNSS module in the EUT is activated using the test script and sends out NMEA data to the CPU. It will receive and send data till turned off. The EUT must be connected to an active antenna and have a clear sky view
Mode 4: The Ethernet is used to set up the test modes. The Ethernet is set to full duplex and set to communicate with the computer in a continuous mode.

2.9. Method of Monitoring EUT Operation

Mode 1: The DSRC is activated for the test menu using “d”. It will down load firmware to the DSRC module. A secondary menu will appear. Select “b” (TX with no GPS). Current will increase and a rolling script will appear in the terminal window continuously. Please refer to Quake document 1153-3011 for instructions.
Mode 2: The Wi-Fi is activated by opening another terminal. Use the test script to select “w”. Select TX mode. A continuous script will scroll in the terminal as the module transmits.
Mode 3: Open another terminal and select “g” to activate the GNSS module. The NMEA data stream from the module will scroll continuously.
Mode 4: Open another terminal and set up a ping on the ENET. Continuous acknowledgement will be sent.

2.10. Modifications

2.10.1. Modifications to EUT

No modifications were made to the EUT.

2.10.2. Modifications to Test Standard

No modifications were made to the test standard.

2.11. Disposition of EUT

The test sample including all support equipment submitted to the Electro-Magnetic Compatibility Lab for testing was returned to Caterpillar Inc. upon completion of testing.

III. Electromagnetic Compatibility Criteria for Intentional Radiators

3. Electromagnetic Compatibility RF Power Output Requirements

3.1. RF Power Output

Test Requirement(s): **§2.1046 and §90.377**

5850 – 5925 MHz			
Channel No.	**Frequency Range (MHz)**	**Max. EIRP (dBm)**	**Channel Use**
170	5850 - 5855	33	Reserved
172	5855 – 5865	33	Service Channel
174	5865 - 5875	33	Service Channel
175	5865 - 5885	23	Service Channel
176	5875 - 5885	33	Service Channel
178	5885 - 5895	33/44.8	Control Channel
180	5895 - 5905	23	Service Channel
181	5895 - 5915	23	Service Channel
182	5905 – 5915	23	Service Channel
184	5915 - 5925	33/40	Service Channel

Note:
1. Public Safety RSU installation transmissions in Channel 178 shall not exceed 28.8 dBm antenna input power and 44.8 dBm EIRP. Private RSU installation transmissions in Channel 178 shall not exceed 28.8 dBm antenna input power and 33 dBm EIRP.
2. Public Safety RSU and OBU operations in Channel 184 shall not exceed 28.8 dBm antenna input power and 40 dBm EIRP. Private RSU operations in Channel 184 shall not exceed 28.8 dBm antenna input power and 33 dBm EIRP.

§95.367 Transmitting power.
For transmission of emergency messages, where operators of Personal Radio Services stations have the ability to select transmitting power levels, the highest transmitting power available may be used. In all other circumstances, the minimum amount of transmitting power necessary to carry out the desired communications must be used.

§95.3167 OBU transmit power limit.
The maximum output power for portable On-Board Unit transmitter types is 1.0 mW. For purposes of this paragraph, a portable is a transmitting device designed to be used so that the radiating structure(s) of the device is/are within 20 centimeters of the body of the user.

Test Procedures: As required by 47 CFR 2.1046, *RF power output measurements* were made at the RF output terminals using a Spectrum Analyzer. Procedure 5.2.4.4.3 from ANSI C63.26-2015 was used to perform the measurements.

A laptop was connected to EUT to control the RF power output and frequency channel. The EUT was connected to a Spectrum Analyzer via an attenuator to measure the Peak power. The EUT power was adjusted enough to produce maximum output power as specified in the owner's manual. The output power was then recorded with as an average reading. Measurements were made at the low, mid and high channels.

Test Results: Equipment is compliant with 47CFR 2.1046 and 90.377. Since EUT is not a portable device (within 20cm of user's body) portable limits are not applicable.

All RF Power output measurements were direct connection to RF output Terminal of EUT from a Spectrum Analyzer.

Test Engineer(s): Arsalan Hasan

Test Date(s): November 8, 2017

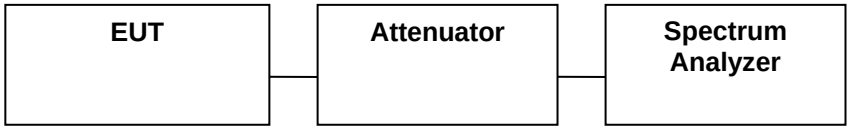
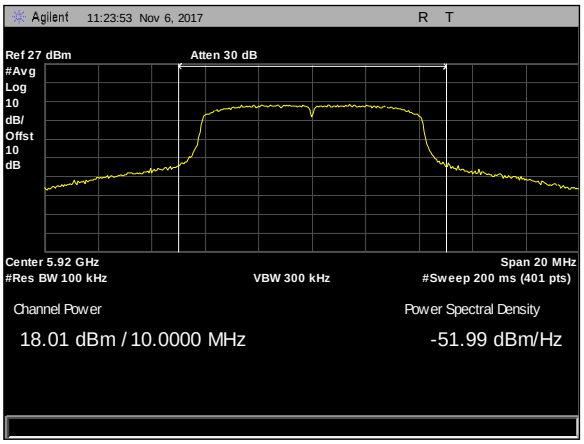


Figure 3. RF Power Output Test Setup

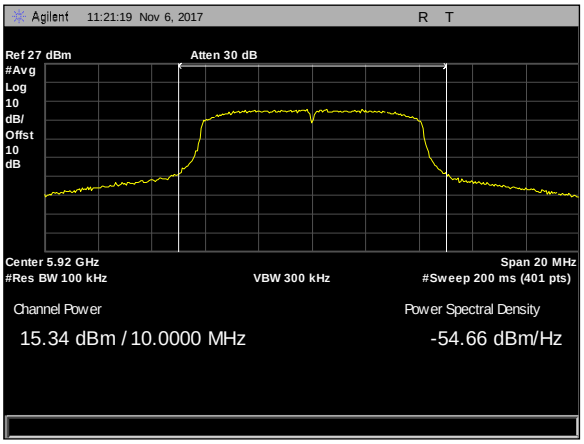
Frequency	ANT1	ANT2	Sum	Antenna Gain	EIRP	Limit	Margin
5860	17.48	14.81	19.35733	4.5	23.85733	33	-9.14267
5890	18.22	15.7	20.15057	4.5	24.65057	33	-8.34943
5920	18.01	15.34	19.88733	4.5	24.38733	33	-8.61267

Table 5. RF Output Power, Test Results

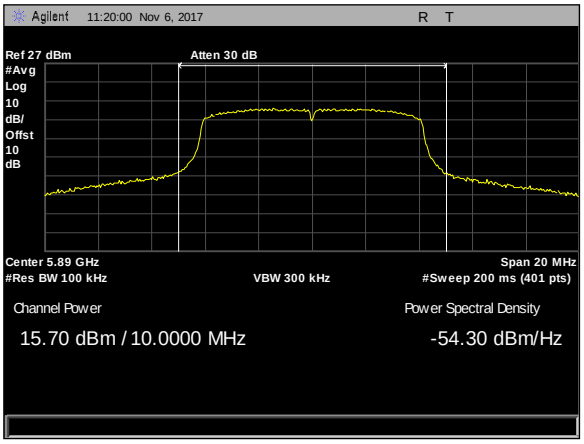
RF Power Output



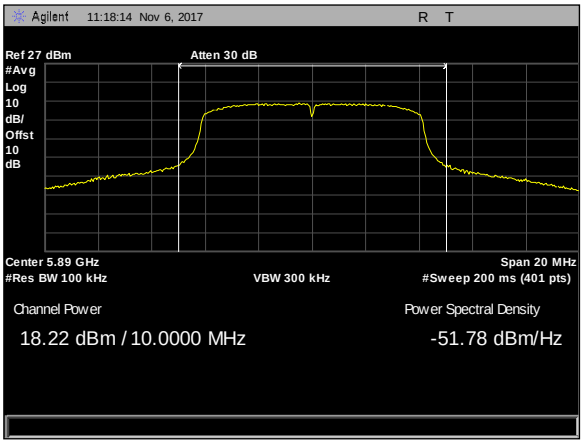
Plot 1. Maximum Transmitter Power, high channel, 5920M, ANT1



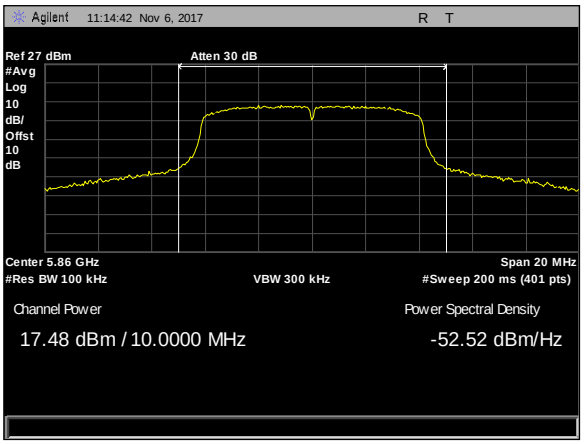
Plot 2. Maximum Transmitter Power, high channel, 5920M, ANT2



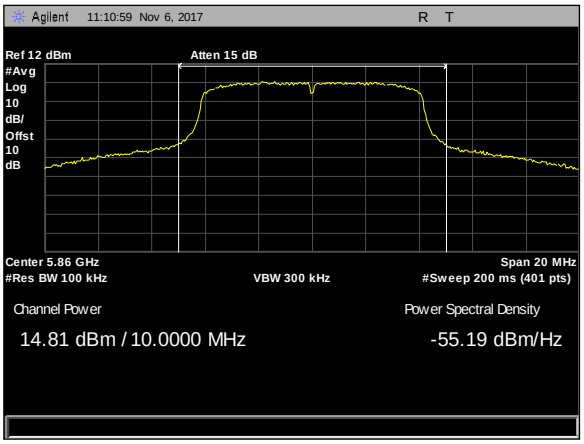
Plot 3. Maximum Transmitter Power, mid channel, 5890M, ANT2



Plot 4. Maximum Transmitter Power, mid channel, 5890M, ANT1



Plot 5. Maximum Transmitter Power, low channel, 5860M, ANT1



Plot 6. Maximum Transmitter Power, low channel, 5860M, ANT2

3.2. Transmit Spectrum Mask

Test Requirement(s): **§95.3189**

On-Board Unit transmitter types operating in the 5850-5925 MHz band must be designed to comply with the technical standard ASTM E2213-03, Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems—5 GHz Band Dedicated Short-range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications published 2003 (ASTM E2213-03).

RSU class	Max. output power (dBm)[1]	Communications zone (meters)
A	0	15
B	10	100
C	20	400
D	28.8	1000

Table 6. RSU Classes

NOTE—Reduction in Power Spectral Density, dBr.

Class	± 4.5-MHz Offset	± 5.0-MHz Offset	± 5.5-MHz Offset	± 10-MHz Offset	± 15-MHz Offset
Class A	0	-10	-20	-28	-40
Class B	0	-16	-20	-28	-40
Class C	0	-26	-32	-40	-50
Class D	0	-35	-45	-55	-65

[A] From IEEE 802.11a. Copyright 1999 IEEE. All rights reserved.

Table 7. Transmit Spectrum Mask Limits

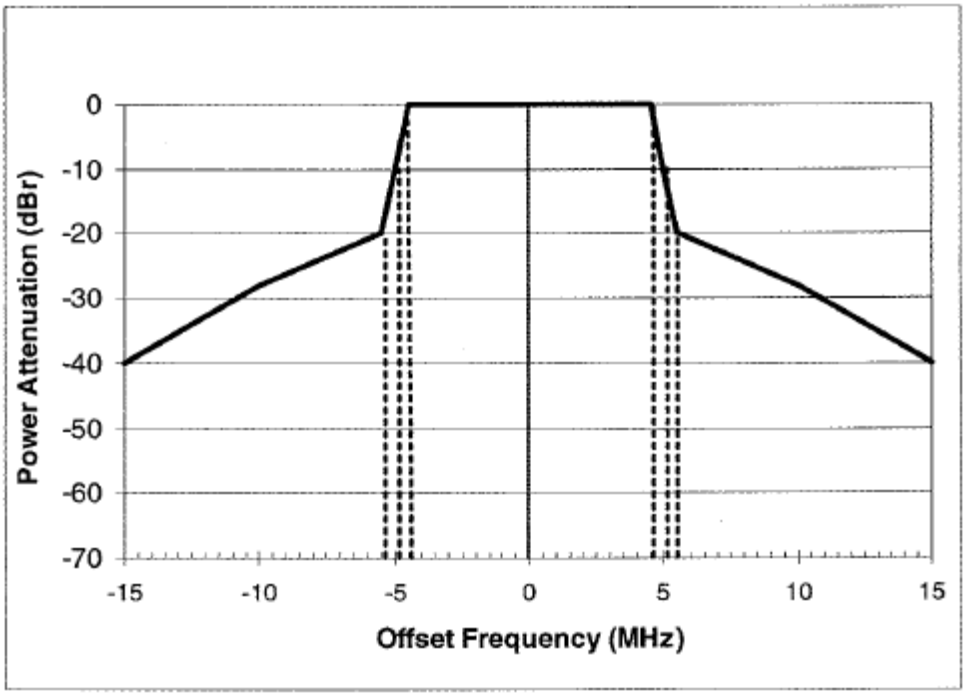


Figure 4. Class A Transmit Spectrum Mask

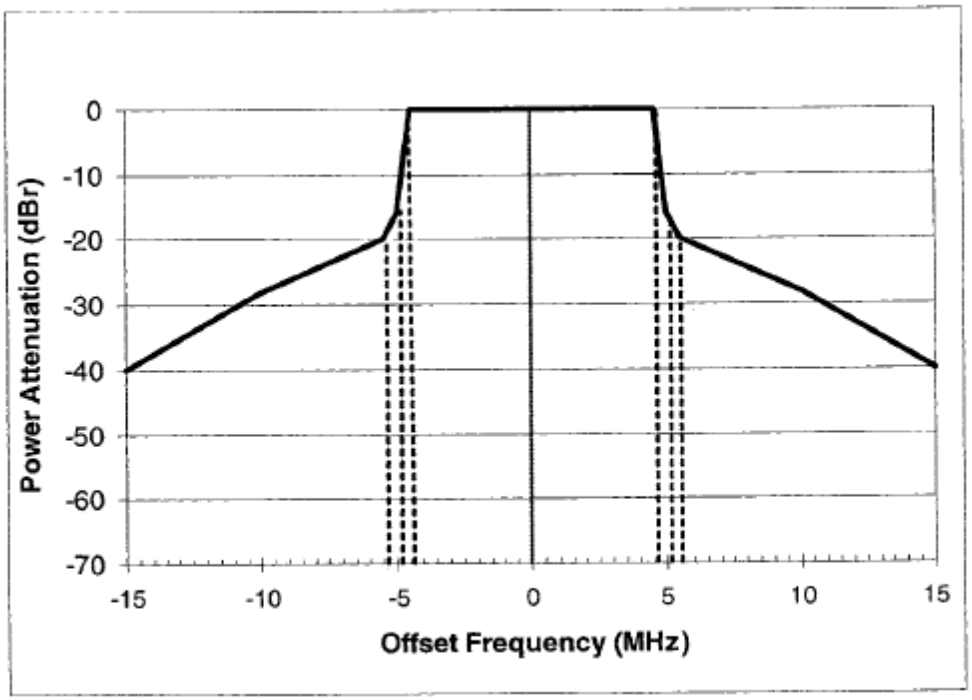


Figure 5. Class B Transmit Spectrum Mask

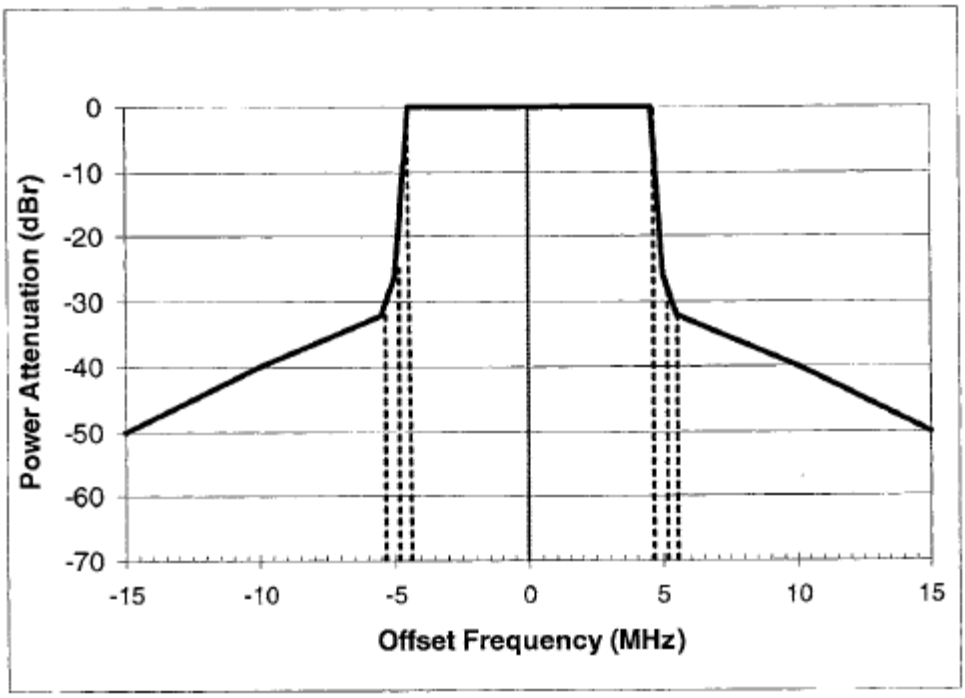


Figure 6. Class C Transmit Spectrum Mask

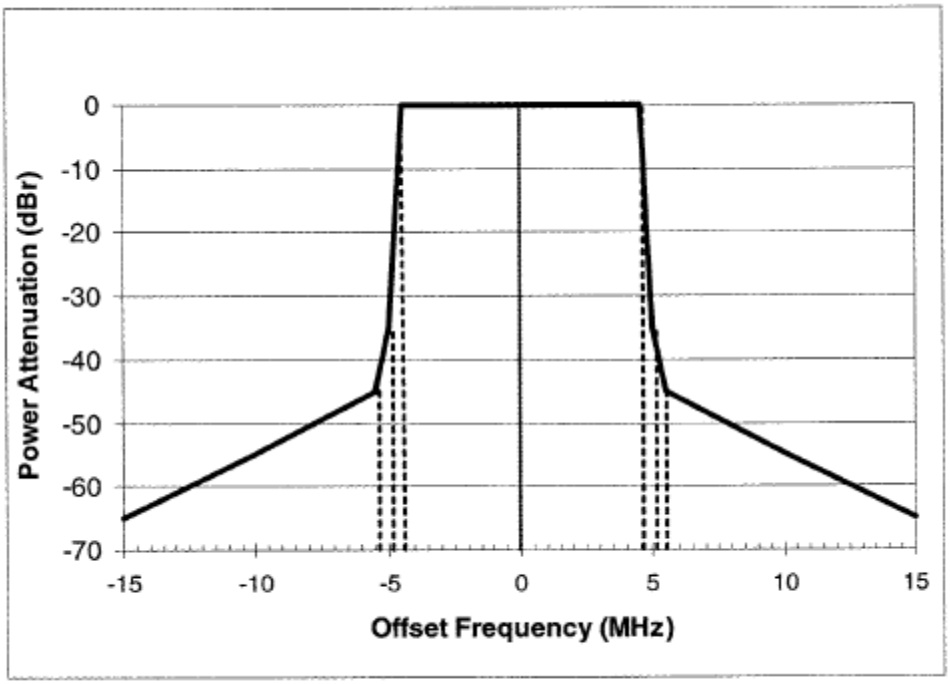


Figure 7. Class D Transmit Spectrum Mask

Test Procedures: RBW= 100 kHz and VBW= 30 KHz were used to make transmit spectral density measurments.

A laptop was connected to EUT to control the RF power output and frequency channel. The EUT was connected to a Spectrum Analyzer in order to measure the power level. The EUT power was adjusted at the maximum output power level. The max hold key from the Spectrum Analyzer was activated capturing the modulated envelope of the EUT. The Peak Power Spectral Density was then recorded. Measurements were made at the low, mid and high channels.

Test Results: Equipment is compliant with 47 CFR 2.1046 and 95.3189 with FCC 04-265. The equipment meets the Class C criteria; therefore the emission mask was tested against class C limits
The EUT does not exceed the Transmit Spectrum Mask limit.

The following pages show measurements of Transmit Spectrum Mask plots:

Test Engineer(s): Arsalan Hasan

Test Date(s): November 8, 2017

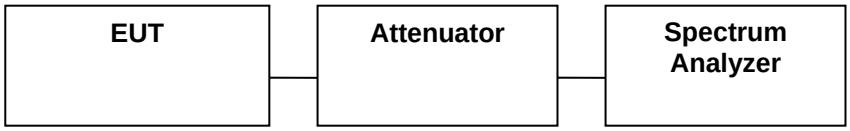
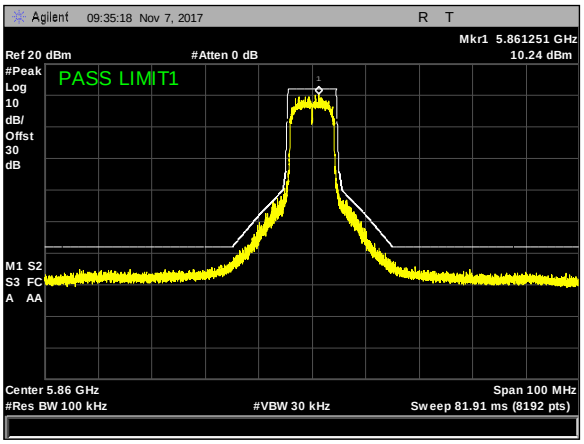
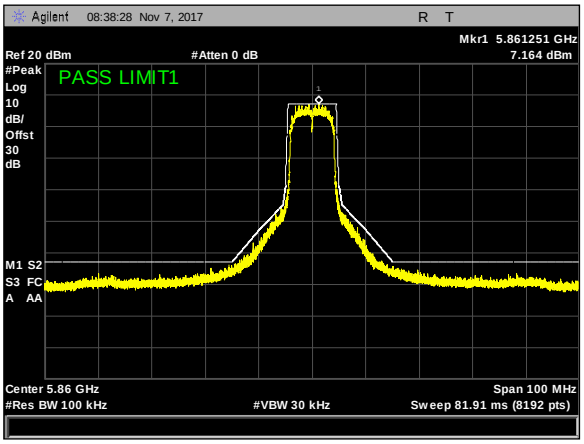


Figure 8. Transmit Spectrum Mask Test Setup

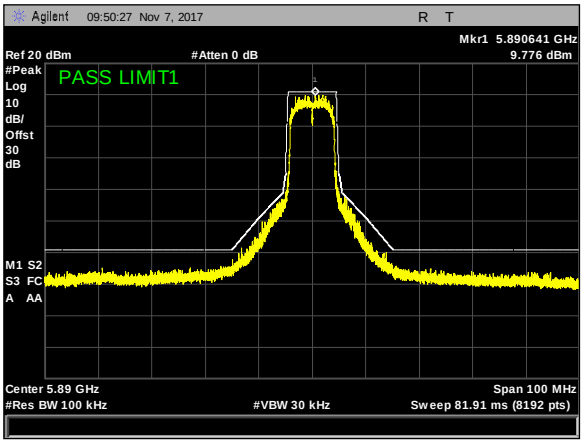
Transmit Spectrum Mask



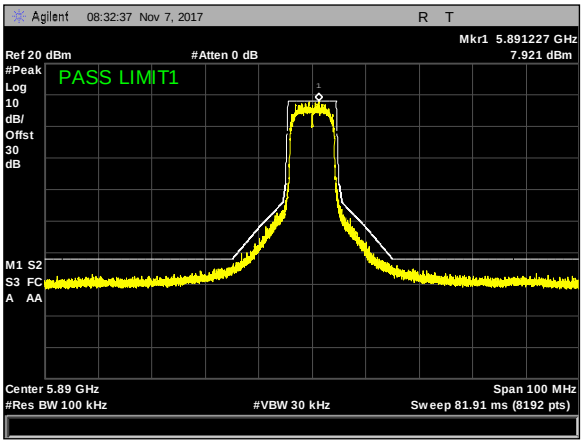
Plot 7. Transmit Spectrum Mask, Class C, 5860, ANT1



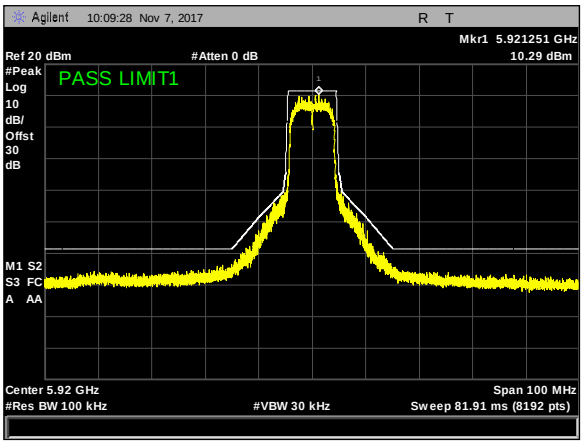
Plot 8. Transmit Spectrum Mask, Class C, 5860, ANT2



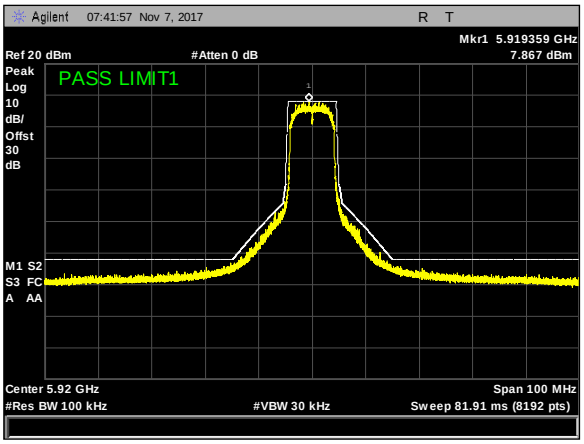
Plot 9. Transmit Spectrum Mask, Class C, 5890, ANT1



Plot 10. Transmit Spectrum Mask, Class C, 5890, ANT2



Plot 11. Transmit Spectrum Mask, Class C, 5920, ANT1



Plot 12. Transmit Spectrum Mask, Class C, 5920, ANT2

4. Electromagnetic Compatibility Occupied Bandwidth Requirements

4.1. Occupied Bandwidth (Emission Mask)

Test Requirement(s): **§2.1049 and §95.3163**

Channel No.	Channel use	Frequency range (MHz)
170	Reserved	5850-5855
172	Service	5855-5865
174	Service	5865-5875
175	Service	5865-5885
176	Service	5875-5885
178	Control	5885-5895
180	Service	5895-5905
181	Service	5895-5915
182	Service	5905-5915
184	Service	5915-5925

Table 8. Channels allotted for use by On-Board Units (OBUs)

(a) Channels 174 and 176 may be combined to create a 20 MHz bandwidth channel designated as Channel 175.

(b) Channels 180 and 182 may be combined to create a 20 MHz bandwidth channel designated as Channel 181.

The 99% Occupied bandwidth is the frequency bandwidth of the signal power at the 99% channel power of occupied bandwidth when resolution bandwidth should be approximately 1% to 5% of the occupied bandwidth (OBW). These measurements shall also be performed at normal test conditions.

Test Procedures: As required by 47 CFR 2.1049, *occupied bandwidth measurements* were made at the RF output terminals using a Spectrum Analyzer. The procedures of ANSI C63.26 - 2015 Section 5.4.3 and 5.4.4 were used

A laptop was connected to EUT to control the RF power output and frequency channel. The EUT was connected to a Spectrum Analyzer via attenuator. The measured highest Average Power was set relative to zero dB reference. The RBW of the Spectrum Analyzer was set to at least 1% of the channel bandwidth. The EUT power was adjusted at the maximum output power level. Measurements were carried out at the low, mid and high channels of the TX band.

Test Results: Equipment is compliant with Section 2.1049 and 90.3163

Test Engineer(s): Arsalan Hasan

Test Date(s): November 8, 2017

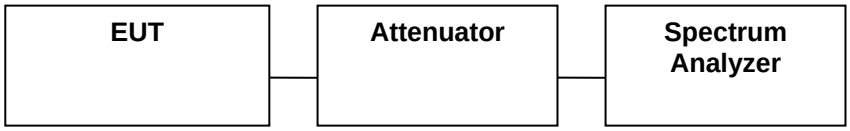
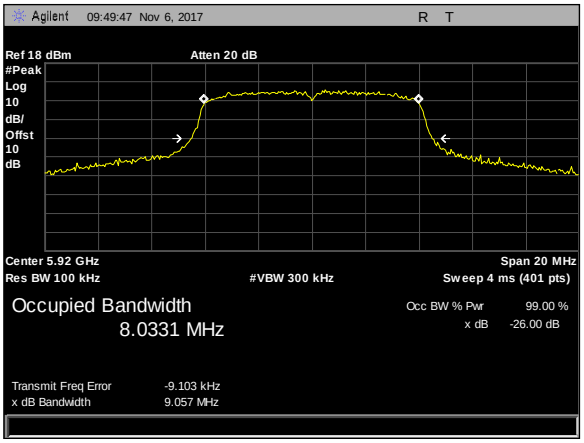
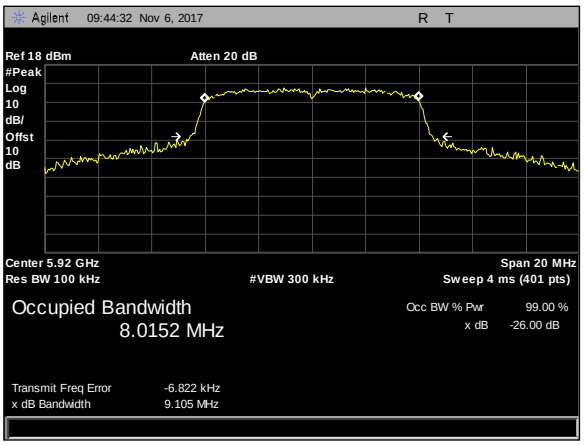


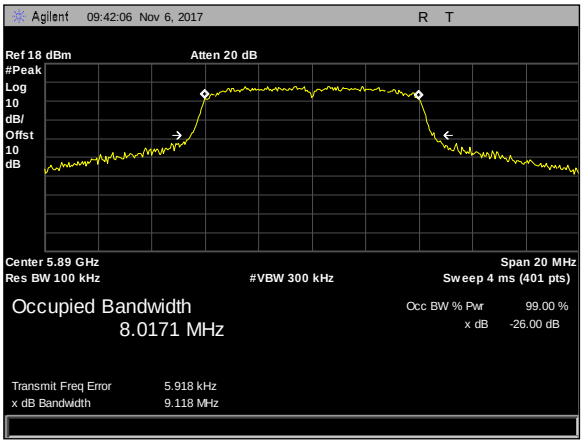
Figure 9. Occupied Bandwidth Test Setup



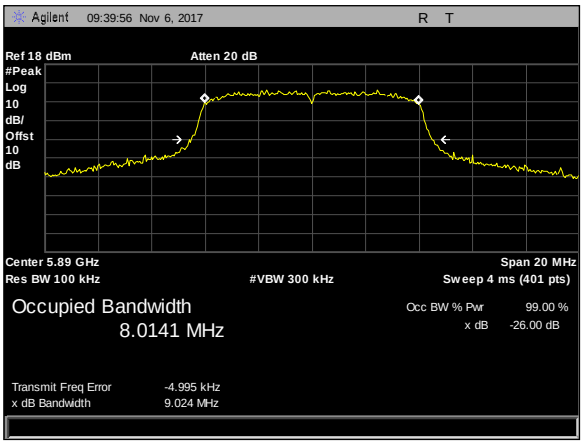
Plot 13. Emissions Bandwidth, 26dB BW, high channel, 5920M, ANT2



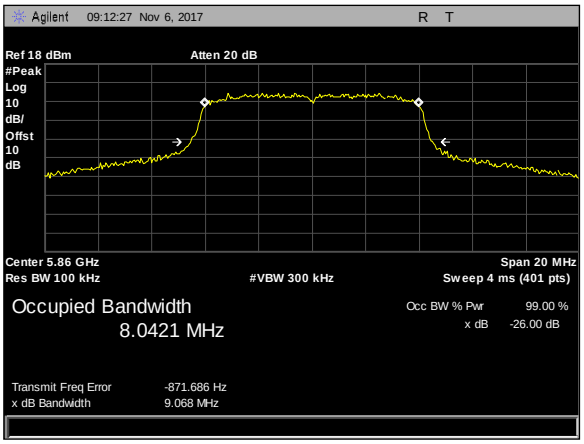
Plot 14. Emissions Bandwidth, 26dB BW, high channel, 5920M, ANT1



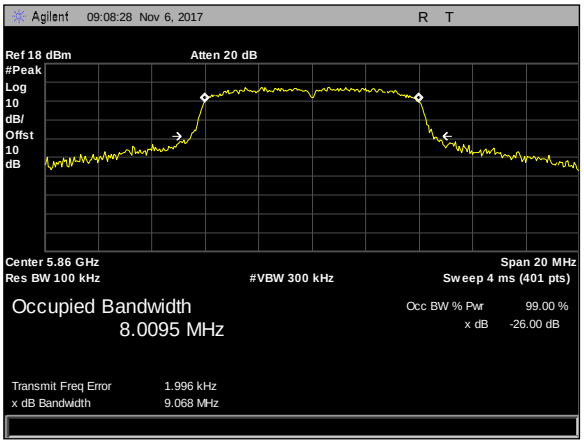
Plot 15. Emissions Bandwidth, 26dB BW, mid channel, 5890M, ANT1



Plot 16. Emissions Bandwidth, 26dB BW, mid channel, 5890M, ANT2



Plot 17. Emissions Bandwidth, 26dB BW, low channel, 5860M, ANT2



Plot 18. Emissions Bandwidth, 26dB BW, low channel, 5860M, ANT1

5. Electromagnetic Compatibility Spurious Emissions at Antenna Terminal Requirements

5.1. Spurious Emissions at Antenna Terminals

Test Requirement(s): **§2.1051 and §90.210(L) with FCC 04-265**

The power of any emission outside a license's frequency band(s) of operation shall be attenuated below the transmitter power (P) within the licensed band(s) of operation, measured in watts, by at least [55 + 10 log (P)] (-25dBm).

Test Procedures: As required by 47 CFR 2.1051, *spurious emissions at antenna terminal measurements* were made at the RF output terminals using a Spectrum Analyzer. Testing procedures were taken from ANSI/TIA-603-D-2010, clause 3.2.13.

A laptop was connected to EUT to control the RF power output and frequency channel. The EUT was connected to a Spectrum Analyzer and a Power Meter to monitor the output power level. The Spectrum Analyzer was set to sweep 30 MHz and up to 10th harmonic of the fundamental or 40GHz whichever is the lesser. Measurements were made at the low, mid and high channels.

The Conducted Spurious Emissions *Limit* is obtained by the following plots. Note: only noise floor was measurable above 26GHz.

Test Results: Equipment is compliant with Section 2.1051 and 90.210(M) with FCC 04-265.

Test Engineer(s): Donald Salguero

Test Date(s): November 9, 2017

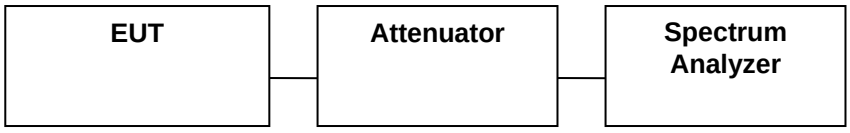
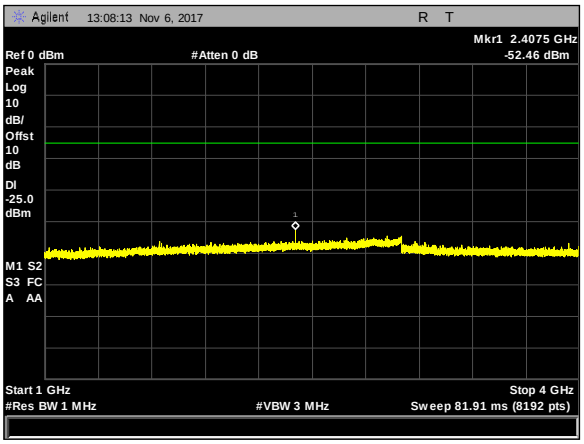
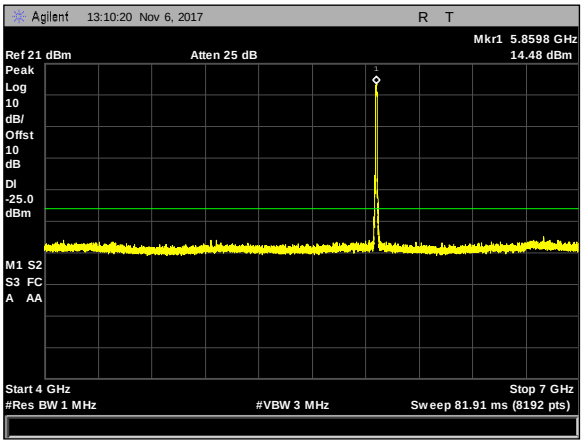


Figure 10. Spurious Emissions at Antenna Terminals Test Setup

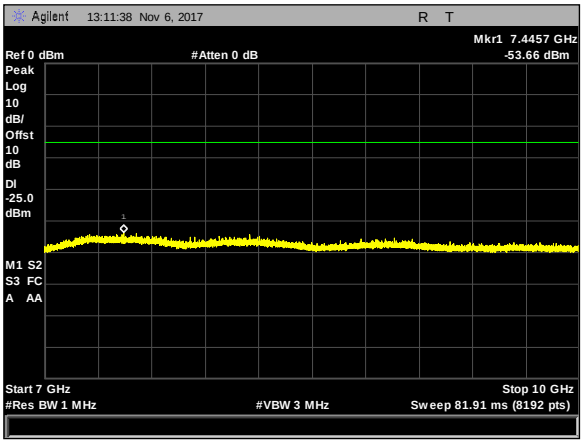
Conducted Spurious Emissions, 5860 MHz



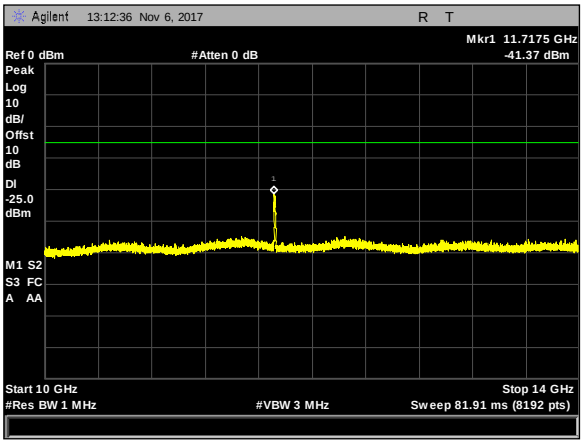
Plot 19. Transmitter Conducted Unwanted Emissions, ANT1, 5860M, 1-4GHz



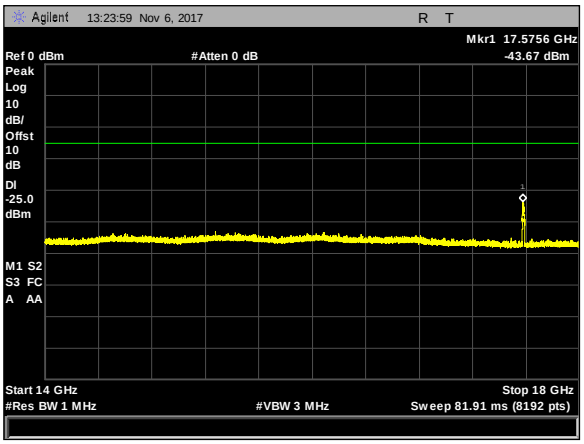
Plot 20. Transmitter Conducted Unwanted Emissions, ANT1, 5860M, 4-7GHz



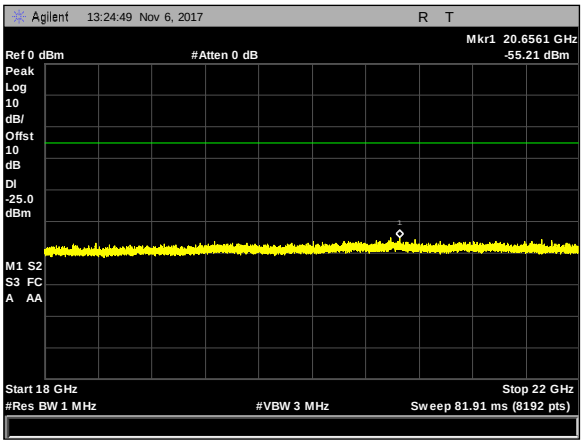
Plot 21. Transmitter Conducted Unwanted Emissions, ANT1, 5860M, 7-10GHz



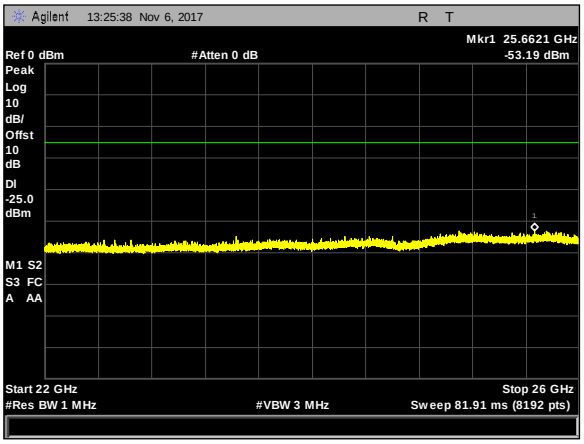
Plot 22. Transmitter Conducted Unwanted Emissions, ANT1, 5860M, 10-14GHz



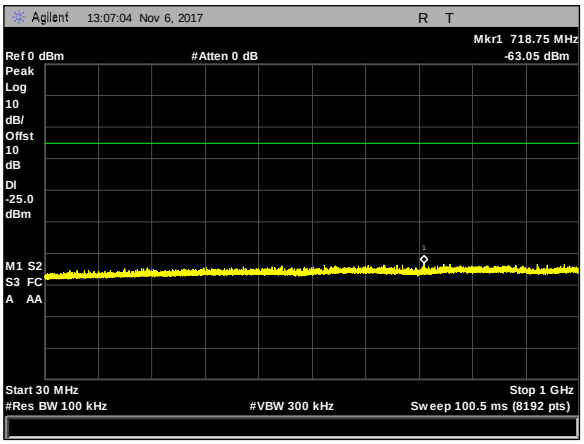
Plot 23. Transmitter Conducted Unwanted Emissions, ANT1, 5860M, 14-18GHz



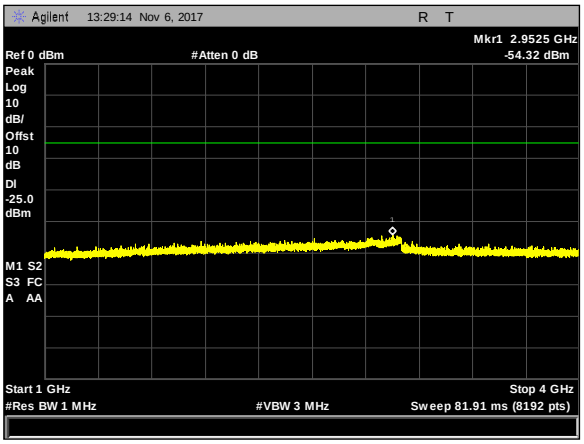
Plot 24. Transmitter Conducted Unwanted Emissions, ANT1, 5860M, 18-22GHz



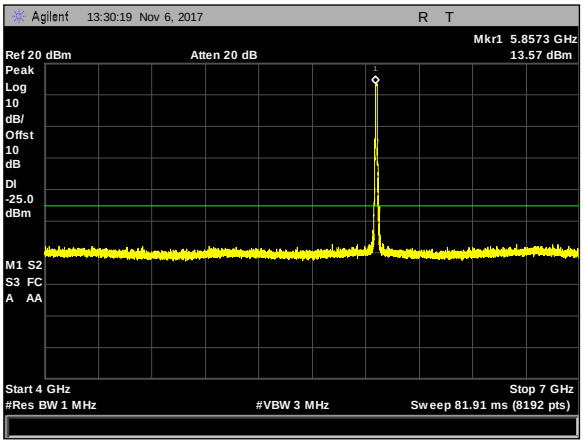
Plot 25. Transmitter Conducted Unwanted Emissions, ANT1, 5860M, 22-26GHz



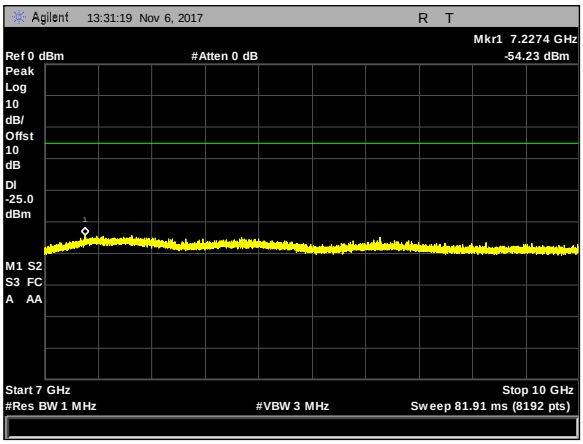
Plot 26. Transmitter Conducted Unwanted Emissions, ANT1, 5860M, 30-1000MHz



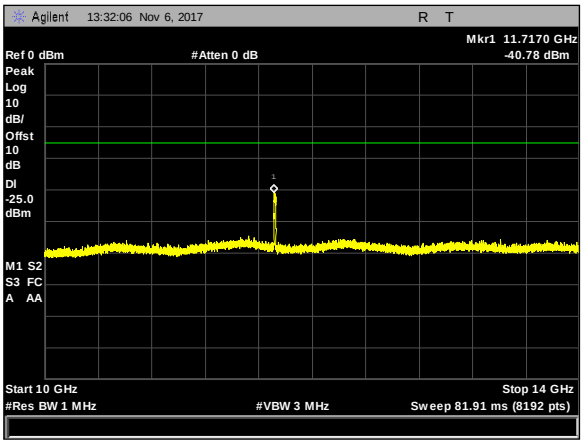
Plot 27. Transmitter Conducted Unwanted Emissions, ANT2, 5860M, 1-4GHz



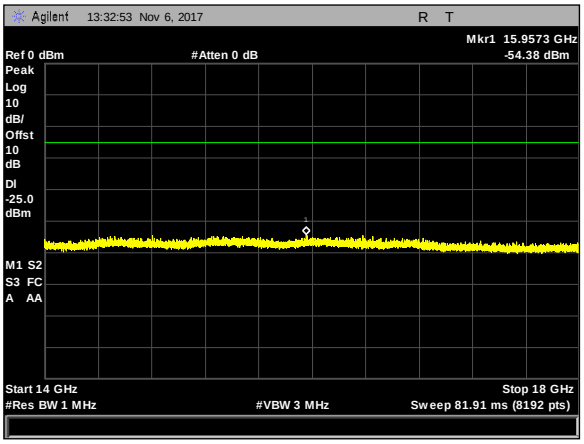
Plot 28. Transmitter Conducted Unwanted Emissions, ANT2, 5860M, 4-7GHz



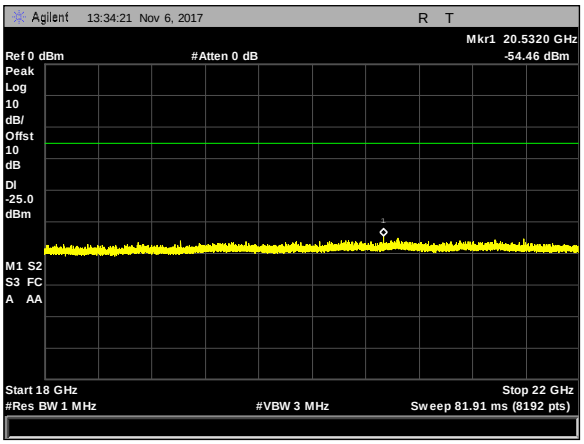
Plot 29. Transmitter Conducted Unwanted Emissions, ANT2, 5860M, 7-10GHz



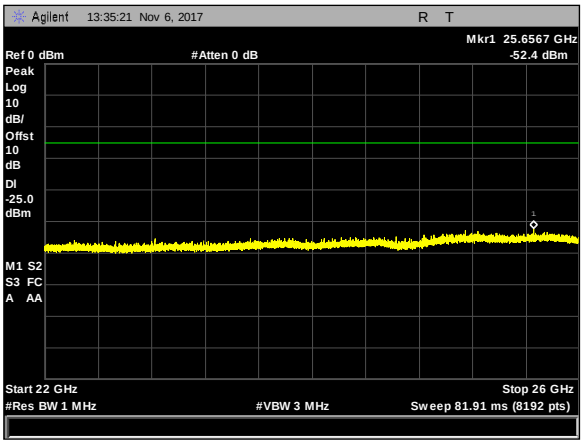
Plot 30. Transmitter Conducted Unwanted Emissions, ANT2, 5860M, 10-14GHz



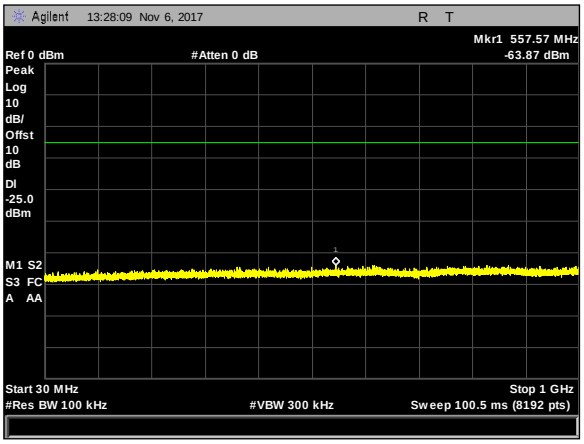
Plot 31. Transmitter Conducted Unwanted Emissions, ANT2, 5860M, 14-18GHz



Plot 32. Transmitter Conducted Unwanted Emissions, ANT2, 5860M, 18-22GHz

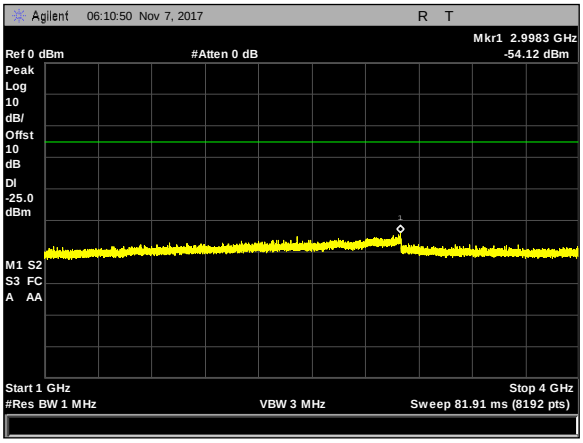


Plot 33. Transmitter Conducted Unwanted Emissions, ANT2, 5860M, 22-26GHz

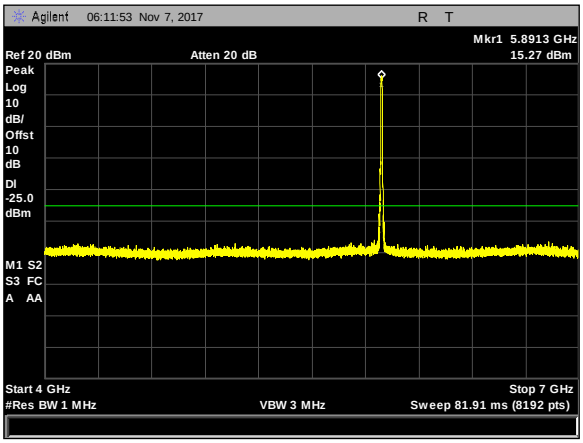


Plot 34. Transmitter Conducted Unwanted Emissions, ANT2, 5860M, 30-1000MHz

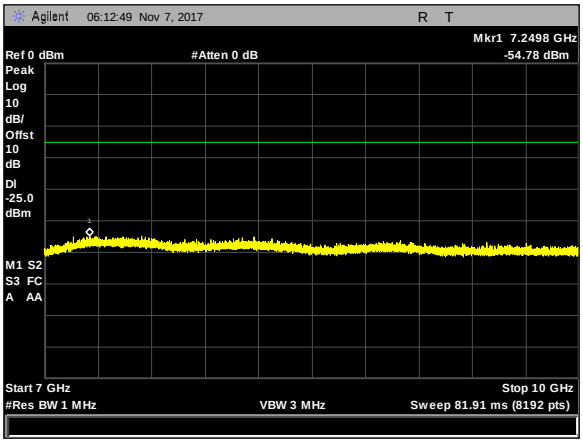
Conducted Spurious Emissions, 5890 MHz



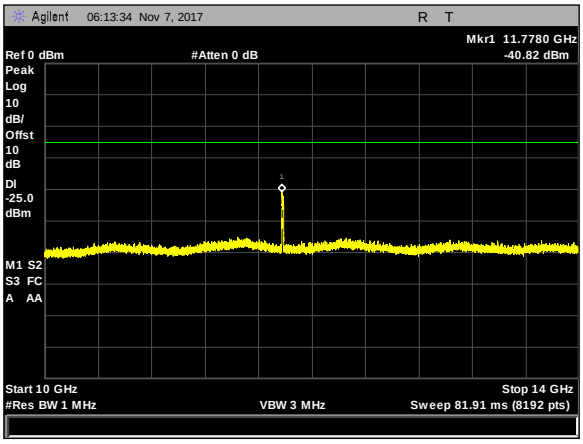
Plot 35. Transmitter Conducted Unwanted Emissions, ANT1, 5890M, 1-4GHz



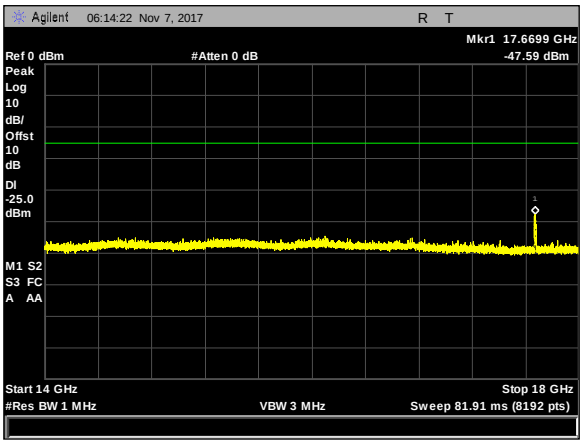
Plot 36. Transmitter Conducted Unwanted Emissions, ANT1, 5890M, 4-7GHz



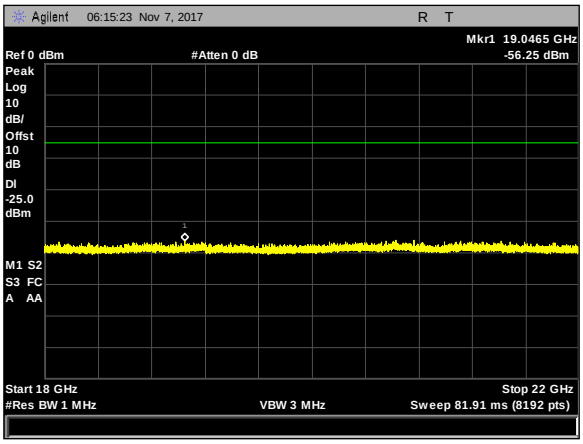
Plot 37. Transmitter Conducted Unwanted Emissions, ANT1, 5890M, 7-10GHz



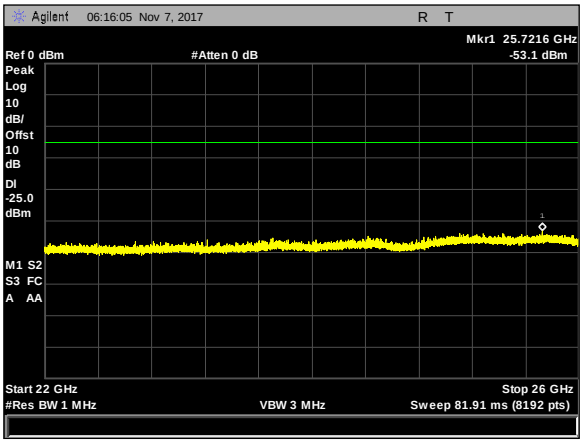
Plot 38. Transmitter Conducted Unwanted Emissions, ANT1, 5890M, 10-14GHz



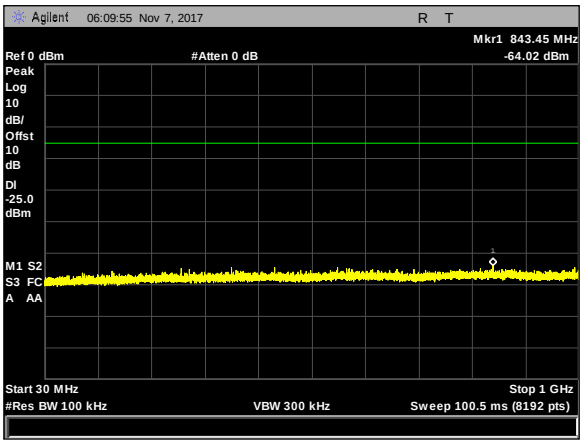
Plot 39. Transmitter Conducted Unwanted Emissions, ANT1, 5890M, 14-18GHz



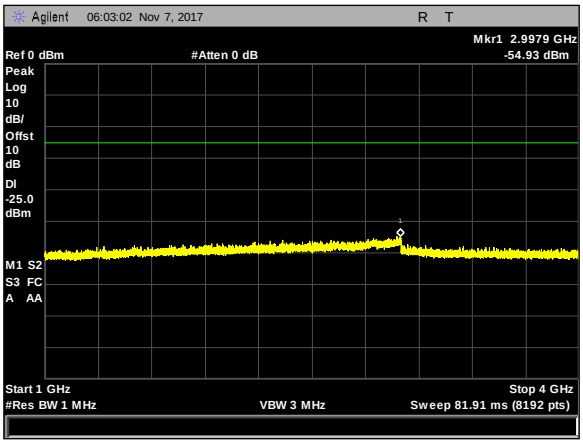
Plot 40. Transmitter Conducted Unwanted Emissions, ANT1, 5890M, 18-22GHz



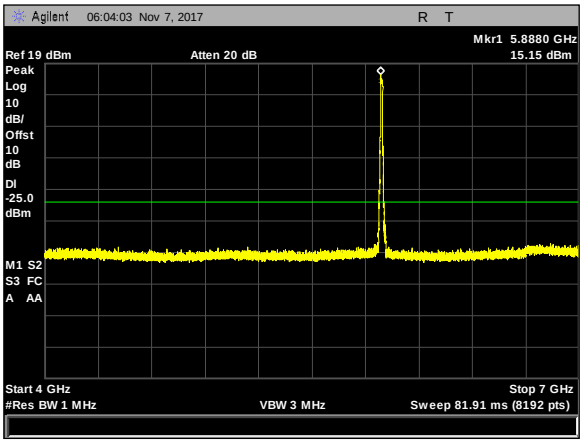
Plot 41. Transmitter Conducted Unwanted Emissions, ANT1, 5890M, 22-26GHz



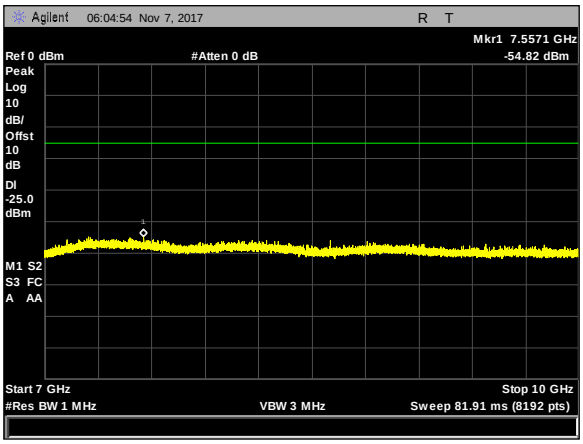
Plot 42. Transmitter Conducted Unwanted Emissions, ANT1, 5890M, 30-1000MHz



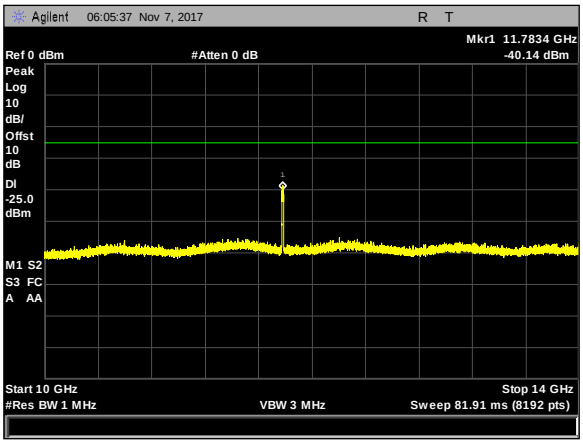
Plot 43. Transmitter Conducted Unwanted Emissions, ANT2, 5890M, 1-4GHz



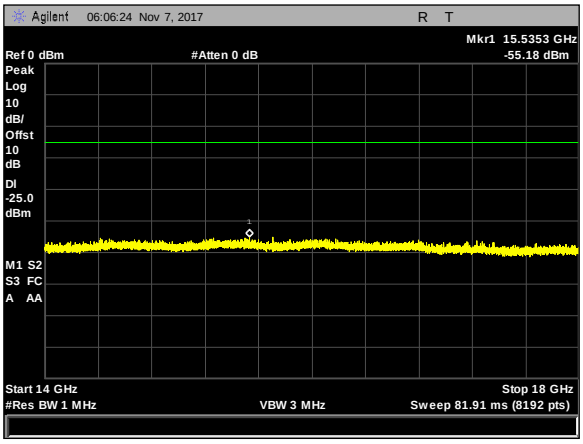
Plot 44. Transmitter Conducted Unwanted Emissions, ANT2, 5890M, 4-7GHz



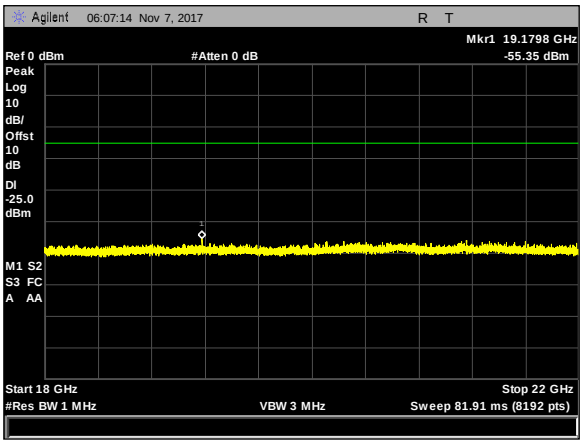
Plot 45. Transmitter Conducted Unwanted Emissions, ANT2, 5890M, 7-10GHz



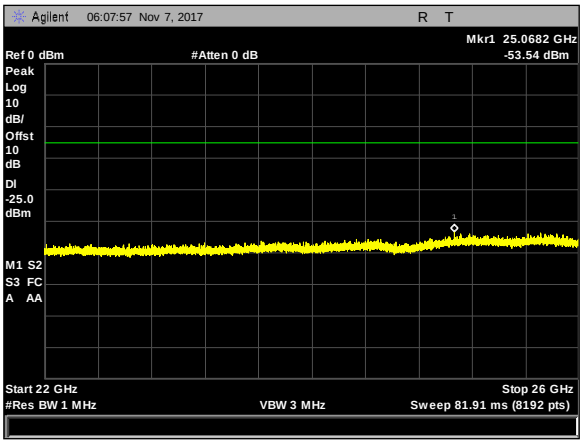
Plot 46. Transmitter Conducted Unwanted Emissions, ANT2, 5890M, 10-14GHz



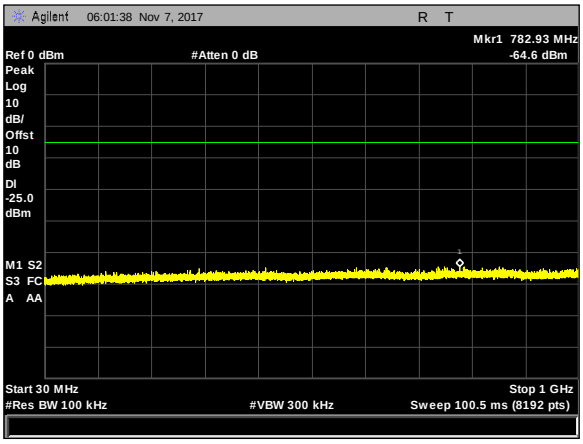
Plot 47. Transmitter Conducted Unwanted Emissions, ANT2, 5890M, 14-18GHz



Plot 48. Transmitter Conducted Unwanted Emissions, ANT2, 5890M, 18-22GHz

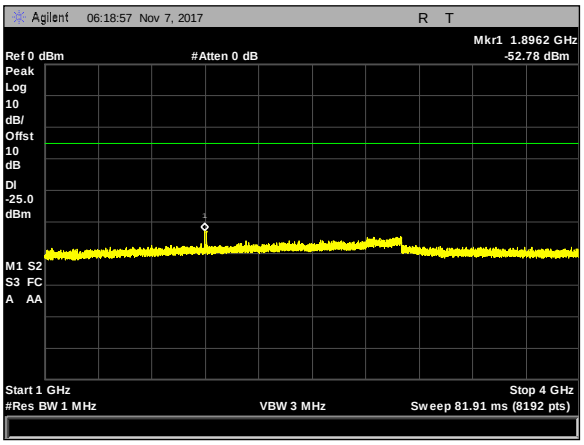


Plot 49. Transmitter Conducted Unwanted Emissions, ANT2, 5890M, 22-26GHz

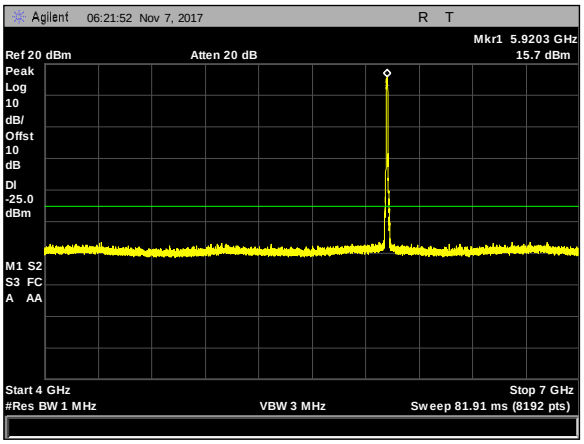


Plot 50. Transmitter Conducted Unwanted Emissions, ANT2, 5890M, 30-1000MHz

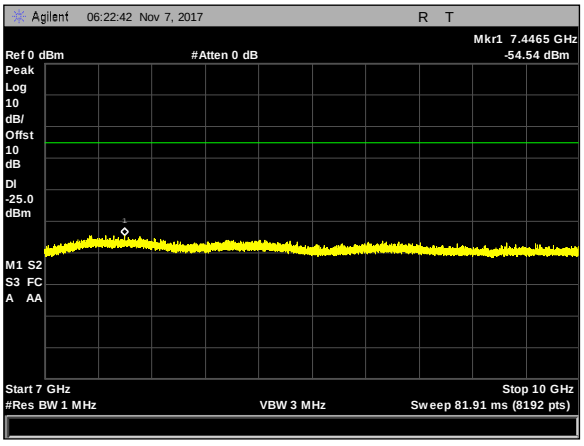
Conducted Spurious Emissions, 5920 MHz



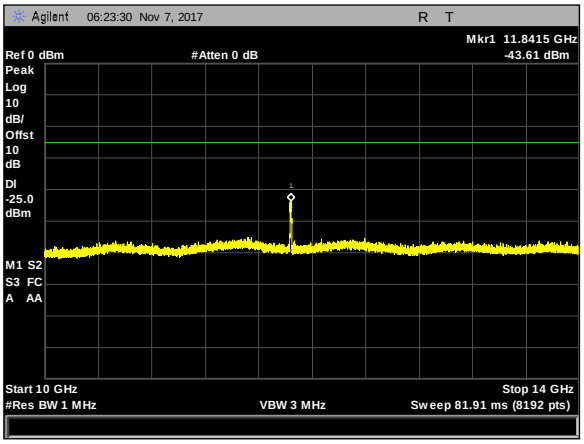
Plot 51. Transmitter Conducted Unwanted Emissions, ANT1, 5920M, 1-4GHz



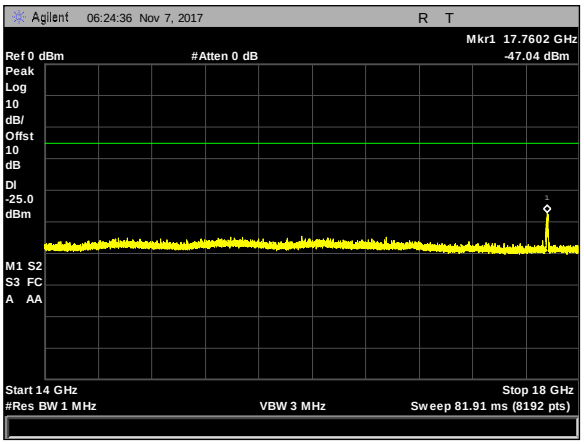
Plot 52. Transmitter Conducted Unwanted Emissions, ANT1, 5920M, 4-7GHz



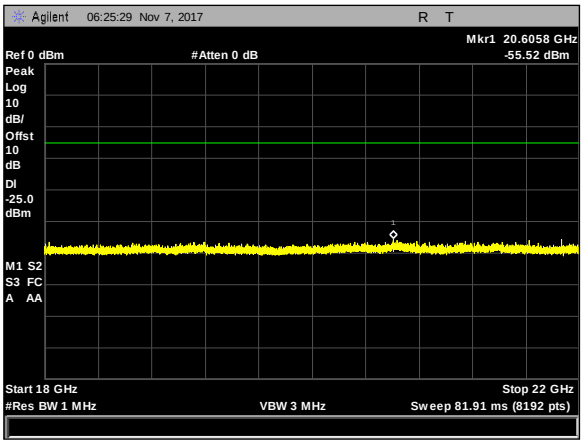
Plot 53. Transmitter Conducted Unwanted Emissions, ANT1, 5920M, 7-10GHz



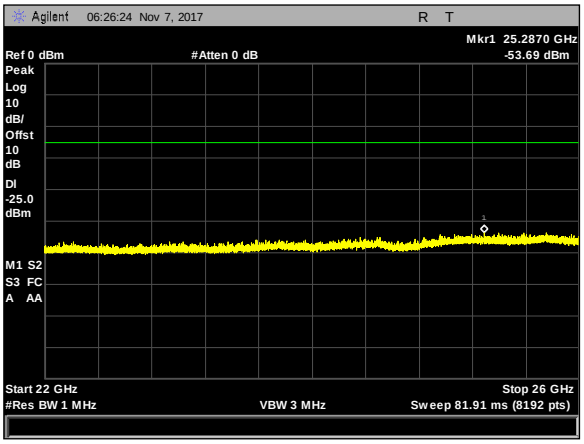
Plot 54. Transmitter Conducted Unwanted Emissions, ANT1, 5920M, 10-14GHz



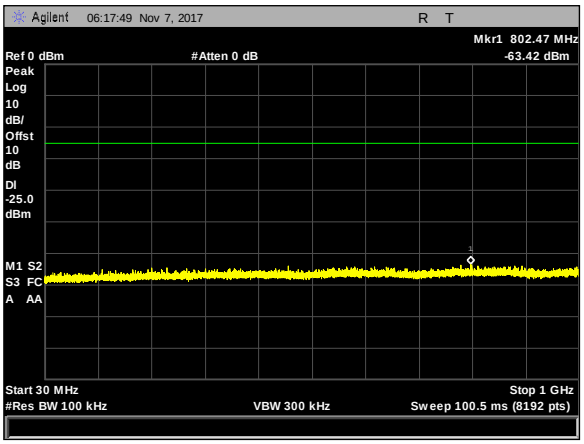
Plot 55. Transmitter Conducted Unwanted Emissions, ANT1, 5920M, 14-18GHz



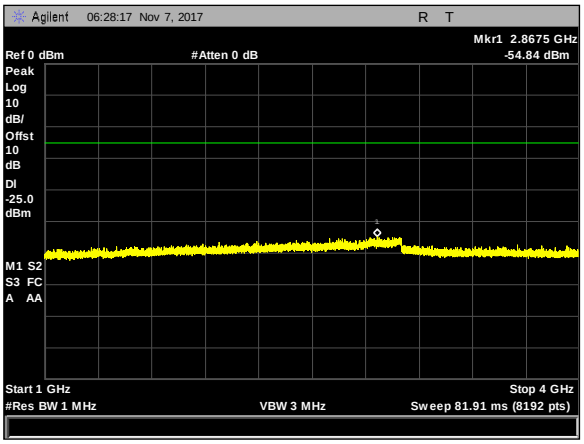
Plot 56. Transmitter Conducted Unwanted Emissions, ANT1, 5920M, 18-22GHz



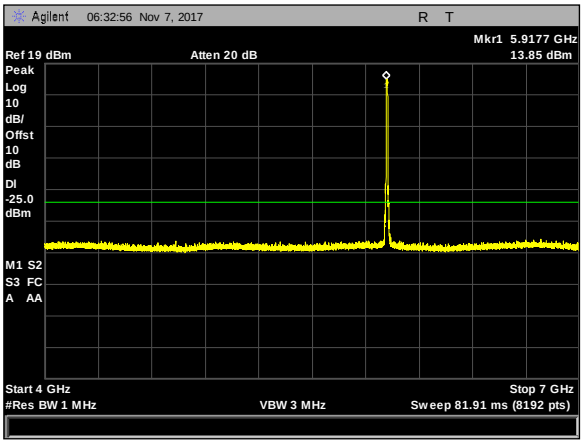
Plot 57. Transmitter Conducted Unwanted Emissions, ANT1, 5920M, 22-26GHz



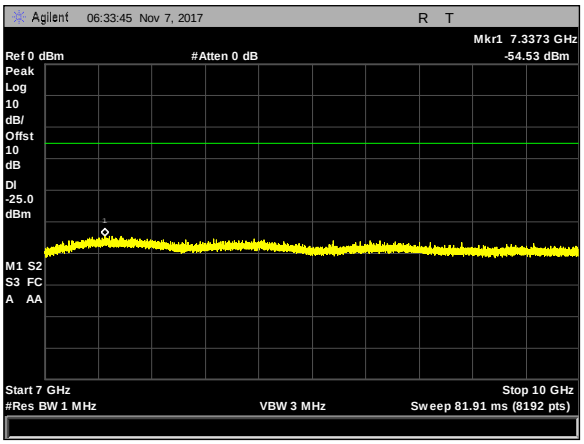
Plot 58. Transmitter Conducted Unwanted Emissions, ANT1, 5920M, 30-1000MHz



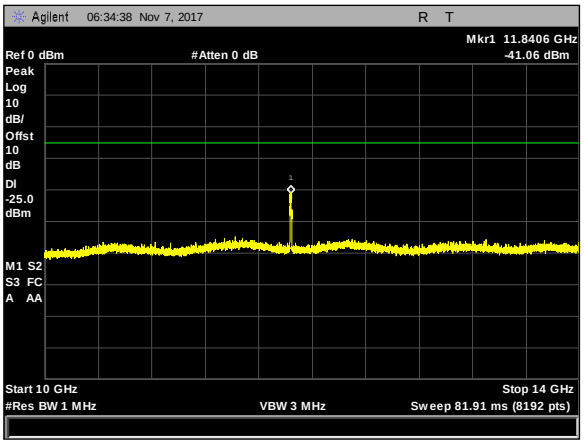
Plot 59. Transmitter Conducted Unwanted Emissions, ANT2, 5920M, 1-4GHz



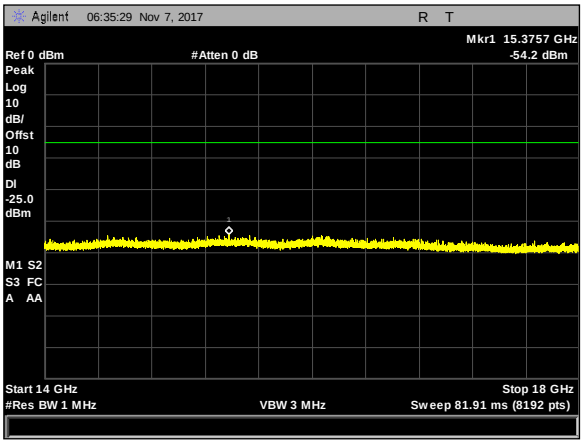
Plot 60. Transmitter Conducted Unwanted Emissions, ANT2, 5920M, 4-7GHz



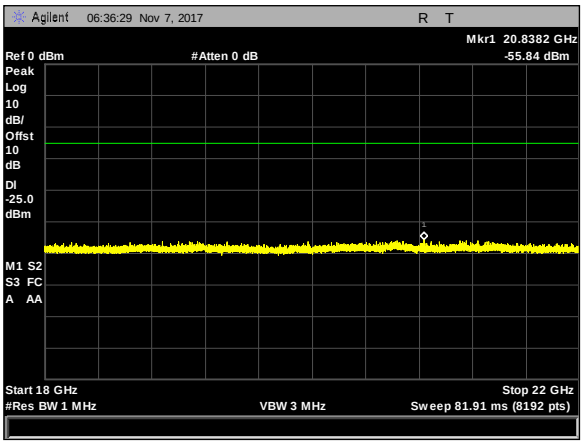
Plot 61. Transmitter Conducted Unwanted Emissions, ANT2, 5920M, 7-10GHz



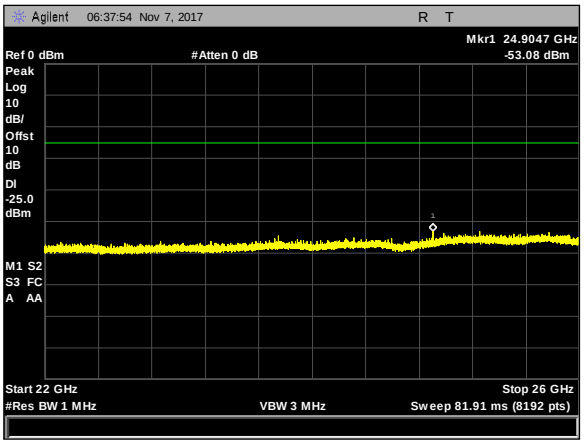
Plot 62. Transmitter Conducted Unwanted Emissions, ANT2, 5920M, 10-14GHz



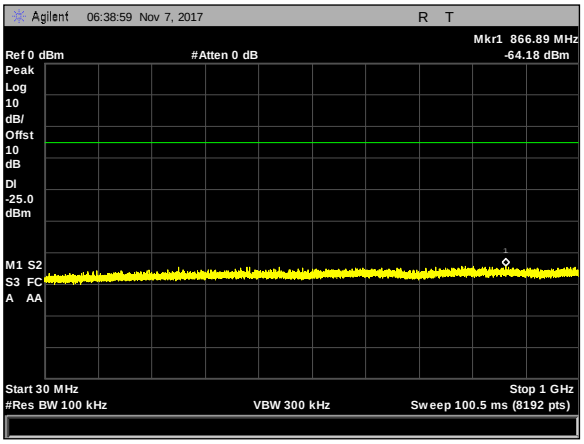
Plot 63. Transmitter Conducted Unwanted Emissions, ANT2, 5920M, 14-18GHz



Plot 64. Transmitter Conducted Unwanted Emissions, ANT2, 5920M, 18-22GHz



Plot 65. Transmitter Conducted Unwanted Emissions, ANT2, 5920M, 22-26GHz



Plot 66. Transmitter Conducted Unwanted Emissions, ANT2, 5920M, 30-1000MHz

Electromagnetic Compatibility Radiated Emissions Requirements

5.2. Radiated Emissions

Test Requirement(s): **§2.1053 and §90.210**

Requirements were taken from ASTM E2213-03 Clause 8.9.2.

Test Procedures: As required by 47 CFR 2.1053, *field strength of radiated spurious measurements* were made in accordance with the procedures of TIA/EIA-603-A-2001 "Land Mobile FM or PM Communications Equipment Measurement and Performance Standards". Test procedures were taken from ANSI/TIA-603-D-2010. Clause 3.2.12.

Radiated emission measurements were performed inside a 10 meter semi-anechoic chamber. The EUT was set at a distance of 3m from the receiving antenna. The EUT's RF ports were terminated to 50ohm load. The EUT was set to transmit at the low, mid and high channels of the transmitter frequency range at its maximum power level. The EUT was rotated about 360^0 and the receiving antenna scanned from 1-4m in order to capture the maximum emission. A calibrated antenna source was positioned in place of the EUT and the previously recorded signal was duplicated. The maximum EIRP of the emission was calculated by adding the forward power to the calibrated source plus its appropriate gain value. These steps were carried out with the receiving antenna in both vertical and horizontal polarization. Harmonic emissions up to the 10^{th} or 40GHz, which ever was the lesser, were investigated.

No peaks were found above 18 GHz.

Note: Signal substitution was not performed due to the fact that only noise floor was detected from 30 MHz – 40 GHz.

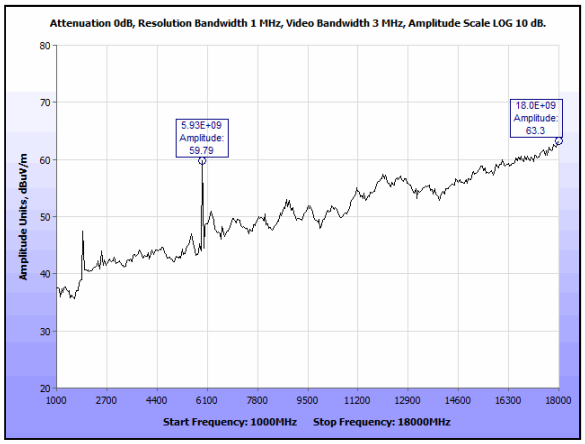
Note: only noise floor was measurable above 18GHz.

Test Results: Limit for emissions above 1GHz is 70.2 dBµV/m. Equipment is compliant with Section 2.1053 and 90.210.

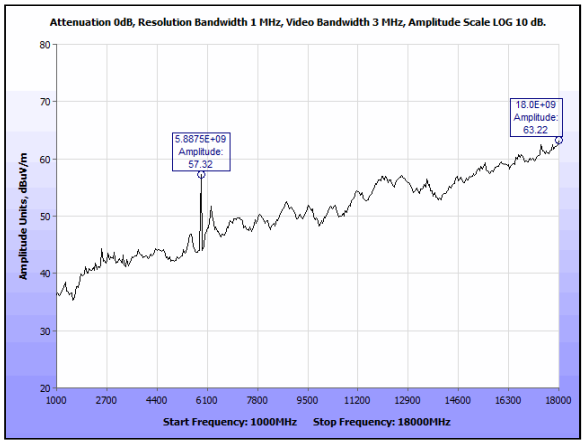
Test Engineer(s): Arsalan Hasan

Test Date(s): November 8, 2017

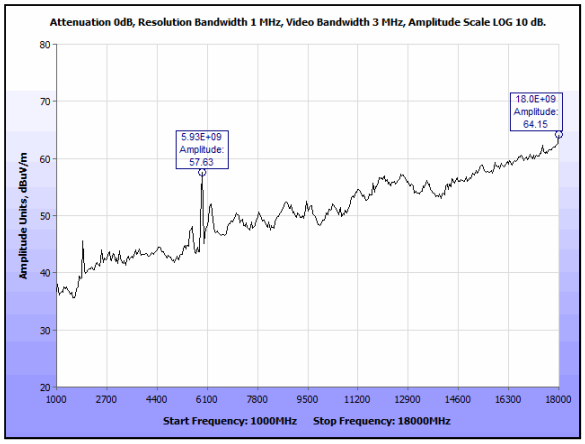
Radiated Spurious Emissions



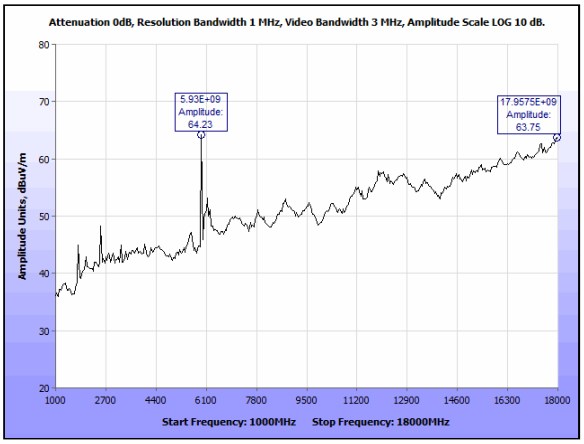
Plot 67. Transmitter Radiated Unwanted Emissions, Ant1, high channel, 1-18GHz, shielded unit



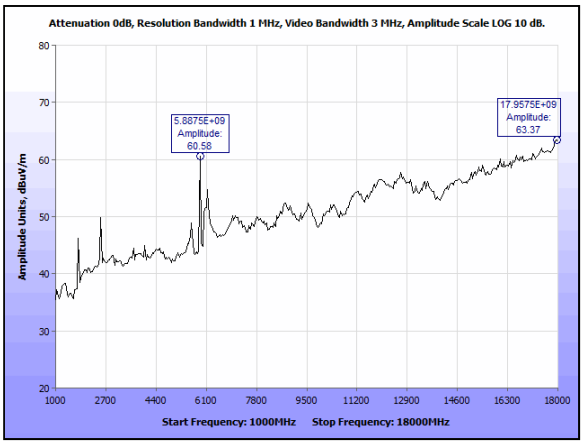
Plot 68. Transmitter Radiated Unwanted Emissions, Ant1, low channel, 1-18GHz, shielded unit



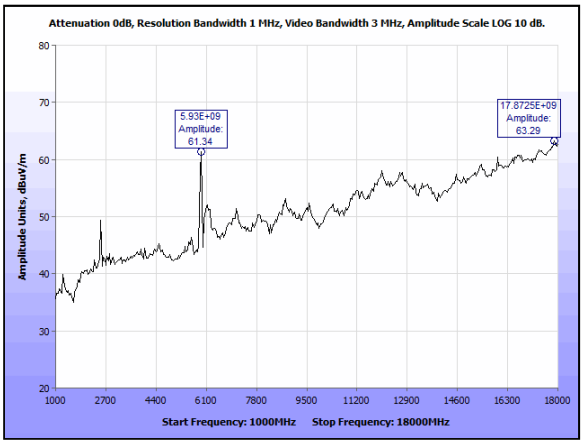
Plot 69. Transmitter Radiated Unwanted Emissions, Ant1, mid channel, 1-18GHz, shielded unit



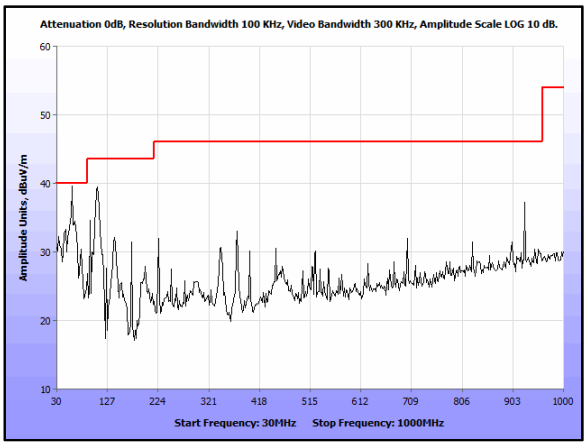
Plot 70. Transmitter Radiated Unwanted Emissions, MIMO2x2, high channel, 1-18GHz



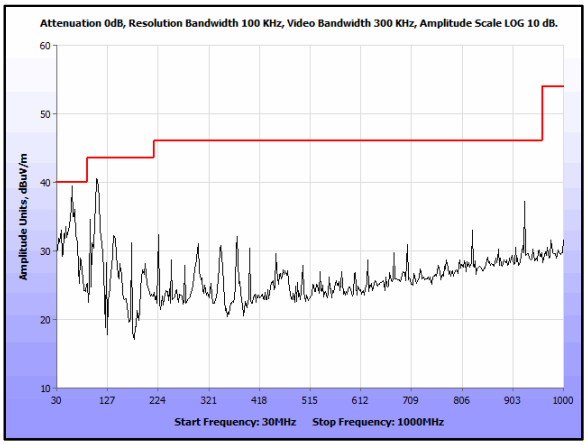
Plot 71. Transmitter Radiated Unwanted Emissions, MIMO2x2, low channel, 1-18GHz



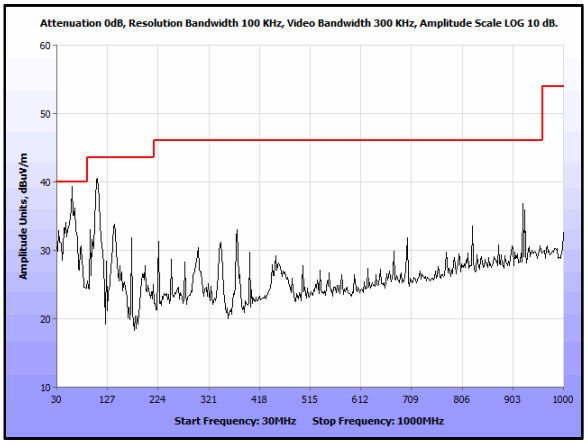
Plot 72. Transmitter Radiated Unwanted Emissions, MIMO2x2, mid channel, 1-18GHz



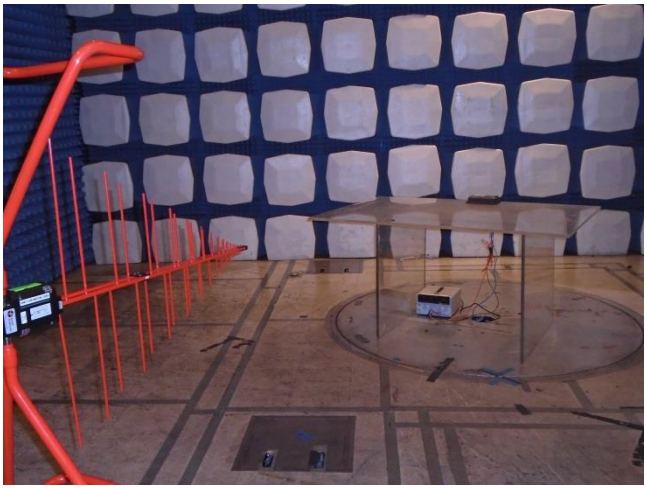
Plot 73. Transmitter Radiated Unwanted Emissions, MIMO2x2, low channel, 30MHz - 1GHz



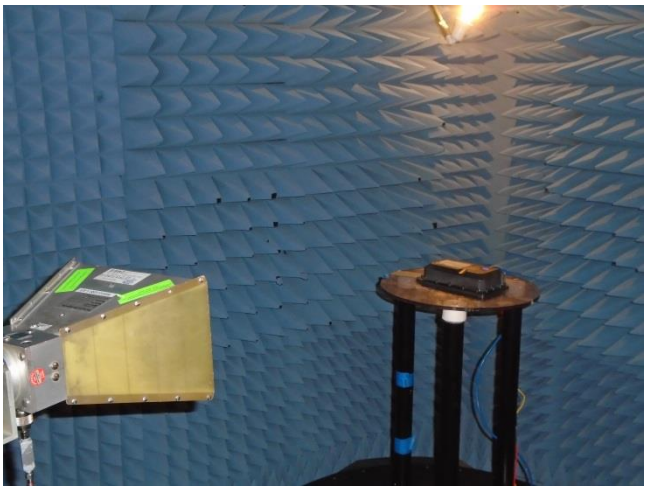
Plot 74. Transmitter Radiated Unwanted Emissions, MIMO2x2, mid channel, 30MHz - 1GHz



Plot 75. Transmitter Radiated Unwanted Emissions, MIMO2x2, high channel, 30MHz - 1GHz



Photograph 1. Radiated Spurious Emissions, Test Setup, 30 MHz – 1 GHz



Photograph 2. Radiated Spurious Emissions, Test Setup, Above 1 GHz

6. Electromagnetic Compatibility Frequency Stability Requirements

6.1. Frequency Stability

Test Requirement(s): **§2.1055 and §90.213**

Test limits shall be set to -30 to +50º C, voltage variation to +, -15%, and ±10 PPM.

Test Procedures: As required by 47 CFR 2.1055, *Frequency Stability measurements* were made at the RF output terminals using a Directional Coupler through a Spectrum Analyzer and Power Meter. Test procedures were taken from ANSI/TIA 603-D: 2010 clause 3.2.2.

The EUT was placed in the Environmental Chamber and support equipments are outside the chamber on a table. The EUT was set to transmit a CW signal corresponding to the low, mid and high Channels for 10MHz Bandwidths. The frequency counter option on the Spectrum Analyzer was used to measure frequency deviations. The frequency drift was investigated for every 10^{C} increment until the unit is stabilized then recorded the reading in tabular format with the temperature range of -30 to 50^{C}.

Voltage supplied to EUT is 120 VAC reference temperature was done at 20 ^{C}. The voltage was varied by ± 15 % of nominal.

Test Results: Equipment is compliant with Section 2.1055 and 90.213.

Test Engineer(s): Donald Salguero

Test Date(s): November 9, 2017

Temperature (°C)	DC Voltage (V)	Frequency Low (MHz)	Frequency High (MHz)	Center Frequency (MHz)	Deviation (ppm)	Limit (ppm)	Margin (ppm)
-30	12	5855.475	5864.550	5860.013	2.218	10	-7.782
-20		5855.475	5864.450	5859.963	6.314	10	-3.686
-10		5855.425	5864.538	5859.981	3.242	10	-6.758
0		5855.463	5864.538	5860.000	0	10	-10
10		5855.350	5864.538	5859.944	9.556	10	-0.444
20		5855.463	5864.575	5860.019	3.242	10	-6.758
30		5855.500	5864.475	5859.988	2.048	10	-7.952
40		5855.406	5864.519	5859.963	6.314	10	-3.686
50		5855.463	5864.538	5860.001	0.171	10	-9.829

Table 9. Frequency Stability, ANT1, Test Results 1

Temperature (°C)	DC Voltage (V)	Frequency Low (MHz)	Frequency High (MHz)	Center Frequency (MHz)	Deviation (ppm)	Limit (ppm)	Margin (ppm)
20	10.2	5855.425	5864.538	5859.981	3.242	10	-6.758
	12	5855.463	5864.575	5860.019	3.242	10	-6.758
	13.8	5855.500	5864.463	5859.981	3.242	10	-6.758

Table 10. Frequency Stability, ANT1 Test Results 2

Temperature (°C)	DC Voltage (V)	Frequency Low (MHz)	Frequency High (MHz)	Center Frequency (MHz)	Deviation (ppm)	Limit (ppm)	Margin (ppm)
-30	12	5855.463	5864.463	5859.963	6.314	10	-3.686
-20		5855.538	5864.482	5860.010	1.706	10	-8.294
-10		5855.463	5864.519	5859.991	1.536	10	-8.464
0		5855.444	5864.482	5859.963	6.314	10	-3.686
10		5855.556	5864.481	5860.019	3.242	10	-6.758
20		5855.463	5864.463	5859.963	6.314	10	-3.686
30		5855.444	5864.482	5859.963	6.314	10	-3.686
40		5855.463	5864.538	5860.001	0.171	10	-9.829
50		5855.519	5864.463	5859.991	1.536	10	-8.464

Table 11. Frequency Stability, ANT2 Test Results 1

Temperature (°C)	DC Voltage (V)	Frequency Low (MHz)	Frequency High (MHz)	Center Frequency (MHz)	Deviation (ppm)	Limit (ppm)	Margin (ppm)
20	10.2	5855.463	5864.482	5859.973	4.608	10	-5.392
	12	5855.463	5864.463	5859.963	6.314	10	-3.686
	13.8	5855.500	5864.463	5859.982	3.072	10	-6.928

Table 12. Frequency Stability, ANT1 Test Results 2

7. RF Exposure Requirements

RF Exposure Requirements: **§1.1307(b)(1) and §1.1307(b)(2):** Systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy levels in excess of the Commission's guidelines.

RF Radiation Exposure Limit: **§1.1310:** As specified in this section, the Maximum Permissible Exposure (MPE) Limit shall be used to evaluate the environmental impact of human exposure to radiofrequency (RF) radiation as specified in Sec. 1.1307(b), except in the case of portable devices which shall be evaluated according to the provisions of Sec. 2.1093 of this chapter.

FCC									
Frequency (MHz)	**Con. Pwr. (dBm)**	**Con. Pwr. (mW)**	**Ant. Gain (dBi)**	**Ant. Gain numeric**	**Pwr. Density (mW/cm^2)**	**Limit (mW/cm^2)**	**Margin**	**Distance (cm)**	**Result**
5890	20.15	103.514	4.5	2.818	0.05804	1	0.94196	20	Pass

8. Test Equipment

Calibrated test equipment utilized during testing was maintained in a current state of calibration per the requirements of ISO/IEC 17025:2005.

MET Asset #	Equipment	Manufacturer	Model	Last Cal Date	Cal Due Date
1T4771	PSA Spectrum Analyzer	Agilent Technologies	E4446A	8/10/2016	2/10/2018
1T4409	EMI Receiver	Rohde & Schwarz	ESIB7	12/7/2016	12/7/2018
1T4612	Spectrum Analyzer	Agilent Technologies	E4407B	3/30/2017	9/30/2018
1T2665	Antenna; Horn	EMCO	3115	6/22/2017	12/22/2018
1T4753	Antenna - Bilog	Sunol Sciences	JB6	10/24/2016	4/24/2018
1T4505	Temperature Chamber	Test Equity	115	2/11/2017	2/11/2018
1T4442	Pre-amplifier, Microwave	Miteq	AFS42-01001800-30-10P	Func Verify	

Note: Functionally tested equipment is verified using calibrated instrumentation at the time of testing.

Certification & User's Manual Information

9. Certification Label & User's Manual Information

9.1. Certification Information

The following is extracted from Title 47 of the Code of Federal Regulations, Part 2, Subpart I — Marketing of Radio frequency devices:

§ 2.801 Radio-frequency device defined.

As used in this part, a radio-frequency device is any device which in its operation is capable of Emitting radio-frequency energy by radiation, conduction, or other means. Radio- frequency devices include, but are not limited to:

(a) The various types of radio communication transmitting devices described throughout this chapter.

(b) The incidental, unintentional and intentional radiators defined in Part 15 of this chapter.

(c) The industrial, scientific, and medical equipment described in Part 18 of this chapter.

(d) Any part or component thereof which in use emits radio-frequency energy by radiation, conduction, or other means.

§ 2.803 Marketing of radio frequency devices prior to equipment authorization.

(a) Except as provided elsewhere in this chapter, no person shall sell or lease, or offer for sale or lease (including advertising for sale or lease), or import, ship or distribute for the purpose of selling or leasing or offering for sale or lease, any radio frequency device unless:

(1) In the case of a device subject to certification, such device has been authorized by the Commission in accordance with the rules in this chapter and is properly identified and labeled as required by §2.925 and other relevant sections in this chapter; or

(2) In the case of a device that is not required to have a grant of equipment authorization issued by the Commission, but which must comply with the specified technical standards prior to use, such device also complies with all applicable administrative (including verification of the equipment or authorization under a Declaration of Conformity, where required), technical, labeling and identification requirements specified in this chapter.

(d) Notwithstanding the provisions of paragraph (a) of this section, the offer for sale solely to business, commercial, industrial, scientific or medical users (but not an offer for sale to other parties or to end users located in a residential environment) of a radio frequency device that is in the conceptual, developmental, design or pre-production stage is permitted prior to equipment authorization or, for devices not subject to the equipment authorization requirements, prior to a determination of compliance with the applicable technical requirements *provided* that the prospective buyer is advised in writing at the time of the offer for sale that the equipment is subject to the FCC rules and that the equipment will comply with the appropriate rules before delivery to the buyer or to centers of distribution.

(e)(1) Notwithstanding the provisions of paragraph (a) of this section, prior to equipment authorization or determination of compliance with the applicable technical requirements any radio frequency device may be operated, but not marketed, for the following purposes and under the following conditions:

(i) Compliance testing;

(ii) Demonstrations at a trade show provided the notice contained in paragraph (c) of this section is displayed in a conspicuous location on, or immediately adjacent to, the device;

(iii) Demonstrations at an exhibition conducted at a business, commercial, industrial, scientific or medical location, but excluding locations in a residential environment, provided the notice contained in paragraphs (c) or (d) of this section, as appropriate, is displayed in a conspicuous location on, or immediately adjacent to, the device;

(iv) Evaluation of product performance and determination of customer acceptability, provided such operation takes place at the manufacturer's facilities during developmental, design or pre-production states; or

(v) Evaluation of product performance and determination of customer acceptability where customer acceptability of a radio frequency device cannot be determined at the manufacturer's facilities because of size or unique capability of the device, provided the device is operated at a business, commercial, industrial, scientific or medical user's site, but not at a residential site, during the development, design or pre-production stages.

(e)(2) For the purpose of paragraphs (e)(1)(iv) and (e)(1)(v) of this section, the term *manufacturer's facilities* includes the facilities of the party responsible for compliance with the regulations and the manufacturer's premises, as well as the facilities of other entities working under the authorization of the responsible party in connection with the development and manufacture, but not the marketing, of the equipment.

(f) For radio frequency devices subject to verification and sold solely to business, commercial, industrial, scientific and medical users (excluding products sold to other parties or for operation in a residential environment), parties responsible for verification of the devices shall have the option of ensuring compliance with the applicable technical specifications of this chapter at each end user's location after installation, provided that the purchase or lease agreement includes a provision that such a determination of compliance be made and is the responsibility of the party responsible for verification of the equipment.

The following is extracted from Title 47 of the Code of Federal Regulations, Part 2, Subpart Y — Equipment Authorization Procedures:

§ 2.901 Basis and Purpose

(a) In order to carry out its responsibilities under the Communications Act and the various treaties and international regulations, and in order to promote efficient use of the radio spectrum, the Commission has developed technical standards for radio frequency equipment and parts or components thereof. The technical standards applicable to individual types of equipment are found in that part of the rules governing the service wherein the equipment is to be operated.[1] *In addition to the technical standards provided, the rules governing the service may require that such equipment be verified by the manufacturer or importer*, be authorized under a Declaration of Conformity, or receive an equipment authorization from the Commission by one of the following procedures: certification or registration.

(b) The following sections describe the verification procedure, the procedure for a Declaration of Conformity, and the procedures to be followed in obtaining certification from the Commission and the conditions attendant to such a grant, whichever is applicable.

§ 2.902 Certification.

(a) Certification is an equipment authorization issued by the Commission, based on representation and test data submitted by the applicant.

(b) Certification attaches to all units subsequently marketed by the grantee which are identical (see Section 2.908) to the sample tested except for permissive changes or other variations authorized by the Commission pursuant to Section 2.1043.

[1] In this case, the equipment is subject to the rules of Part 15. More specifically, the equipment falls under Subpart B (of Part 15), which deals with unintentional radiators.

§ 2.948 Description of measurement facilities.

(a) Each party making measurements of equipment that is subject to an equipment authorization under Part 15 or Part 18 of this chapter, regardless of whether the measurements are filed with the Commission or kept on file by the party responsible for compliance of equipment marketed within the U.S. or its possessions, shall compile a description of the measurement facilities employed.

(1) If the measured equipment is subject to the verification procedure, the description of the measurement facilities shall be retained by the party responsible for verification of the equipment.

(i) If the equipment is verified through measurements performed by an independent laboratory, it is acceptable for the party responsible for verification of the equipment to rely upon the description of the measurement facilities retained by or placed on file with the Commission by that laboratory. In this situation, the party responsible for the verification of the equipment is not required to retain a duplicate copy of the description of the measurement facilities.

(ii) If the equipment is verified based on measurements performed at the installation site of the equipment, no specific site calibration data is required. It is acceptable to retain the description of the measurement facilities at the site at which the measurements were performed.

(2) If the equipment is to be authorized by the Commission under the certification procedure, the description of the measurement facilities shall be filed with the Commission's Laboratory in Columbia, Maryland. The data describing the measurement facilities need only be filed once but must be updated as changes are made to the measurement facilities or as otherwise described in this section. At least every three years, the organization responsible for filing the data with the Commission shall certify that the data on file is current.

9.2. Label and User's Manual Information

The following is extracted from Title 47 of the Code of Federal Regulations, Part 15, Subpart A — General:

§ 15.19 Labeling requirements.

(a) In addition to the requirements in Part 2 of this chapter, a device subject to certification or verification shall be labeled as follows:

(1) Receivers associated with the operation of a licensed radio service, e.g., FM broadcast under Part 73 of this chapter, land mobile operation under Part 90, etc., shall bear the following statement in a conspicuous location on the device:

This device complies with Part 15 of the FCC Rules. Operation is subject to the condition that this device does not cause harmful interference.

(2) A stand-alone cable input selector switch, shall bear the following statement in a conspicuous location on the device:

This device is verified to comply with Part 15 of the FCC Rules for use with cable television service.

(3) All other devices shall bear the following statement in a conspicuous location on the device:

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

(4) Where a device is constructed in two or more sections connected by wires and marketed together, the statement specified under paragraph (a) of this section is required to be affixed only to the main control unit.

(5) When the device is so small or for such use that it is not practicable to place the statement specified under paragraph (a) of this section on it, the information required by this paragraph shall be placed in a prominent location in the instruction manual or pamphlet supplied to the user or, alternatively, shall be placed on the container in which the device is marketed. However, the FCC identifier or the unique identifier, as appropriate, must be displayed on the device.

§ 15.21 Information to user.

The users manual or instruction manual for an intentional or unintentional radiator shall caution the user that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

The following is extracted from Title 47 of the Code of Federal Regulations, Part 15, Subpart B — Unintentional Radiators:

§ 15.105 Information to the user.

(a) For a Class B digital device or peripheral, the instructions furnished the user shall include the following or similar statement, placed in a prominent location in the text of the manual:

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a residential environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

– Reorient or relocate the receiving antenna.
– Increase the separation between the equipment and receiver.
– Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
– Consult the dealer or an experienced radio/TV technician for help.

End of Report

