HEADQUARTERS: 914 WEST PATAPSCO AVENUE • BALTIMORE, MARYLAND 21230 • PHONE (410) 354-3300 • FAX (410) 354-3313

March 16, 2021

Thales Communications, Inc.
22605 Gateway Center Drive
Clarksburg, MD 20871

Dear Robert Peterson,

Enclosed is the EMC Wireless test report for compliance testing of the Thales Communications, Inc., ESP32-WROOM-32U as tested to the requirements of Title 47 of the CFR, Ch. 1 (10-1-06 ed.), Part 15 Subpart C for Intentional Radiators.

Thank you for using the services of Eurofins E&E North America. If you have any questions regarding these results or if we can be of further service to you, please feel free to contact me.

Sincerely yours,
EUROFINS E&E NORTH AMERICA

Michelle Tawmging

Michelle Tawmging
Documentation Department

Reference: (\Thales Communications, Inc.\WIR107948-FCC247 Rev. 6)

Electromagnetic Compatibility Criteria
Test Report

for the

Thales Communications, Inc.
ESP32-WROOM-32U

Tested under
the FCC Certification Rules
contained in
15.247 Subpart C for Intentional Radiators

Report: WIR107948-FCC247 Rev. 6

February 5, 2021

Prepared For:

Thales Communications, Inc.
22605 Gateway Center Drive
Clarksburg, MD 20871

Prepared By:
Eurofins MET Labs, Inc.
914 West Patapsco Ave.,
Baltimore MD 21230

Electromagnetic Compatibility Criteria
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ESP32-WROOM-32U

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15.247 Subpart C for Intentional Radiators

Donald Salguero, Project Engineer
Electromagnetic Compatibility Lab

Michelle Tawmging
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 the FCC Rules Part 15.247 under normal use and maintenance.

Deepak Giri,
Manager, Electromagnetic Compatibility Lab

Report Status Sheet

Revision	Report Date	Reason for Revision
∅	July 15, 2020	Initial Issue.
1	August 6, 2020	Updated Figure 7 and Figure 8.
2	October 12, 2020	Updates per TCB comments. Output Power and MPE sections added
3	November 20, 2020	Updates per TCB comments.
4	February 5, 2021	Updated Test Sample Description
5	March 12, 2021	Updated per TCB comments.
6	March 16, 2021	TX Level Note Added

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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**ert**z**
IEC	**I**nternational **E**lectrotechnical **C**ommission
kHz	**k**ilo**h**ert**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	**micro**henry
µ	**micro**farad
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

A. Purpose of Test

An EMC evaluation was performed to determine compliance of the Thales Communications, Inc. ESP32-WROOM-32U, with the requirements of Part 15, §15.247. 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 ESP32-WROOM-32U. Thales Communications, Inc. should retain a copy of this document which should be kept on file for at least two years after the manufacturing of the ESP32-WROOM-32U, has been **permanently** discontinued.

B. Executive Summary

The following tests were conducted on a sample of the equipment for the purpose of demonstrating compliance with Part 15, §15.247, in accordance with Thales Communications, Inc., purchase order number RCI-717669-SV. All tests were conducted using measurement procedure ANSI C63.10-2013.

FCC Reference 47 CFR Part 15.247:2005	Description	Compliance
Title 47 of the CFR, Part 15 §15.203	Antenna Requirement	Compliant
Title 47 of the CFR, Part 15 §15.207(a)	Conducted Emission Limits	Not Tested
Title 47 of the CFR, Part 15 §15.247(a)(2)	6dB Occupied Bandwidth	Not Tested
Title 47 of the CFR, Part 15 §15.247(b)	Peak Power Output	Compliant
Title 47 of the CFR, Part 15 §15.247(c)	Spurious Emissions in Non-restricted Bands	Not Tested
Title 47 of the CFR, Part 15 §15.247(d); §15.209; §15.205	Radiated Spurious Emissions Requirements	Compliant
Title 47 of the CFR, Part 15; §15.247(e)	Peak Power Spectral Density	Not Tested
Title 47 of the CFR, Part 15 §15.247(i)	Maximum Permissible Exposure (MPE)	Compliant

Figure 1: Executive Summary of EMC Part 15.247 ComplianceTesting

Equipment Configuration

A. Overview

Eurofins MET Labs, Inc. was contracted by Thales Communications, Inc. to perform testing on the ESP32-WROOM-32U, under Thales Communications, Inc.'s purchase order number RCI-717669-SV.

This document describes the test setups, test methods, required test equipment, and the test limit criteria used to perform compliance testing of the Thales Communications, Inc., ESP32-WROOM-32U.

The results obtained relate only to the item(s) tested.

Model(s) Tested:	ESP32-WROOM-32U	
Model(s) Covered:	ESP32-WROOM-32U	
EUT Specifications:	Primary Power: 3~3.6VDC	
	FCC ID: OKCWROOM32U	
	Type of Modulations:	OFDM and DSSS
	Equipment Code:	DTS
	Maximun RF Output Power:	15.9 dBm; 0.039W
	EUT Frequency Ranges:	2412 – 2462 MHz 2422 – 2452 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 16, 2021	

Figure 2: EUT Summary Table

B. References

CFR 47, Part 15, Subpart C	Federal Communication Commission, Code of Federal Regulations, Title 47, Part 15: General Rules and Regulations, Allocation, Assignment, and Use of Radio Frequencies
ANSI C63.4:2014	Methods and Measurements of Radio-Noise Emissions from Low-Voltage Electrical And Electronic Equipment in the Range of 9 kHz to 40 GHz
ISO/IEC 17025:2017	General Requirements for the Competence of Testing and Calibration Laboratories
ANSI C63.10-2013	American National Standard for Testing Unlicensed Wireless Devices
KDB 558074 v04	Guidance For Performing Compliance Measurements On Digital Transmission Systems (DTS) Operating Under Section 15.247

Figure 3: References

C. Test Site

All testing was performed at Eurofins MET Labs, Inc., 914 West Patapsco Ave., 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 3 meter 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.

Eurofins MET Laboratories Inc. (Eurofins E&E North America) is part of the Eurofins Electrical & Electronics (E&E) global compliance network.

D. 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%

Figure 4: Uncertainty Calculations Summary

E. Description of Test Sample

ESP32-WROOM-32U are powerful, generic Wi-Fi+BT+BLE MCU modules that target a wide variety of applications. Comes with an U.FL connector which allows for external antennas to be connected to the module. Capable of 802.11 b/g/n(HT20/HT40) protocols.

Figure 5: Block Diagram of Test Configuration, Wi-Fi Module

F. Equipment Configuration

The EUT was set up as outlined in Figure 5 and Figure 6. All cards, racks, etc., incorporated as part of the EUT is included in the following list.

Ref. ID	Slot #	Name/Description	Model Number	Part Number	Serial Number	Rev. #
A		Certus Terminal	MF350BV or VF350BM	4102947-502 (Land) or 4102947-501 (Maritime)	SN 10200	Rev. A
B		Certus Land Antenna	Land HGA2	1600899-1	SN 901585	Rev. B
C		Certus Maritime Antenna	Maritime HGA2	1600901-1	SN 803005	Rev. B
D		Wi-Fi Antenna	LS Research 001-0001	85728-001	N/A	
E		AC/DC Power Supply	Meanwell GST160A12-TDSI	84670-001	TBD	A

Figure 6: Equipment Configuration

G. Support Equipment

Support equipment necessary for the operation and testing of the EUT is included in the following list.

Ref. ID	Name/Description	Manufacturer	Model Number	Customer Supplied Calibration Data
F	Notebook Computer (outside chamber)	Dell	Lattitude E7470	

Figure 7: Support Equipment

H. Ports and Cabling Information

Ref. ID	Port Name on EUT	Cable Description or reason for no cable	Qty	Length as tested (m)	Max Length (m)	Shielded? (Y/N)	Termination Box ID & Port Name
1	Antenna Cable	TWS-240 Coaxial Cable for Land (855021-010)	1	10ft. (2)	100 ft. (30.5)	Yes	Land HGA2, Ant
2	Antenna Cable	LMR-300 Coaxial Cable for Maritime (855023-082)	1	25m	50m	Yes	Maritime HGA2, Ant
3	AC input to AC/DC Power Supply	Cable AC Power USA Plug Type B	1	~7 ft.	Not specified	No	AC Input to Power Supply
6	WAN	Terra Grand 14' plus Shielded Ethernet Cable	1	14'+	Not Specified	Yes	WAN Port, J7

Figure 8: Ports and Cabling Information

I. Mode of Operation

Operating mode is a Wi-Fi test mode provided by the Wi-Fi module vendor. Regular Wi-Fi operation can also be tested if necessary (portable iPhone or Android local Wi-Fi communication with Terminal).

Note: TX LEVEL is built-in set parameters and cannnot be changed and selected

J. Method of Monitoring EUT Operation

Monitor Wi-Fi emissions of new Wi-Fi module and other Terminal emissions but not the satellite transmit waveform emissions (already completed FCC testing for this).

K. Modifications

a) Modifications to EUT

No modifications were made to the EUT.

b) Modifications to Test Standard

No modifications were made to the test standard.

L. Disposition of EUT

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

Electromagnetic Compatibility Criteria for Intentional Radiators

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.203 Antenna Requirement

Test Requirement: **§ 15.203:** An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited.

The structure and application of the EUT were analyzed to determine compliance with Section 15.203 of the Rules. Section 15.203 states that the subject device must meet at least one of the following criteria:

a.) Antenna must be permanently attached to the unit.

b.) Antenna must use a unique type of connector to attach to the EUT.

c.) Unit must be professionally installed. Installer shall be responsible for verifying that the correct antenna is employed with the unit.

Results: The EUT as tested is **compliant** the criteria of §15.203. EUT uses a unique connector.

Test Engineer: Donald Salguero

Test Date: June 30, 2020

Name/Description	Model Number	Part Number	Gain
Wi-Fi Antenna - Dipole	LS Research 001-0001	85728-001	2dBi

Figure 9: Antenna List

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.247(b) Conducted Power Output

Test Requirements: **§15.247(b):** The maximum peak output power of the intentional radiator shall not exceed the following:

§15.247(b)(3): For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands: 1 Watt. As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted output power. Maximum Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.

§15.247(c)(4): The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

Test Procedure: **Per original conducted measurements,** The EUT was connected to a spectrum analyzer with known loss. Measurements were taken with the EUT set to transmit continuously on its low, mid, and high channels for all its bandwidths at maximum power. Power was measured according to measurement method AVGSA-2, as described in ANSI C63.10-2013, section 11.9.2.2.4.

Results: The EUT was compliant with the Conducted Power Output limits of **§15.247(b)**. EIRP results were reassessed with regards to the new 2dBi dipole antenna.

Engineer(s): Donald Salguero

Date(s): October 7, 2020

Mode	Center Frequency (MHz)	Average Conducted Output Power (dBm)	Limit (dBm)	Antenna Gain (dBi)	EIRP (dBm)	EIRP Limit (dBm)	Conclusion
802.11b	2412	15.72	30	2	17.72	36	Pass
	2437	15.59	30	2	17.59	36	Pass
	2462	15.68	30	2	17.68	36	Pass
802.11g	2412	15.9	30	2	17.9	36	Pass
	2437	15.81	30	2	17.81	36	Pass
	2462	15.71	30	2	17.71	36	Pass
802.11n HT20	2412	15.81	30	2	17.81	36	Pass
	2437	15.48	30	2	17.48	36	Pass
	2462	15.66	30	2	17.66	36	Pass
802.11n HT40	2422	15.9	30	2	17.9	36	Pass
	2437	15.61	30	2	17.61	36	Pass
	2452	15.71	30	2	17.71	36	Pass

Figure 10: Conducted Power and EIRP Results

Electromagnetic Compatibility Criteria for Intentional Radiators
§ 15.209 Radiated Spurious Emissions Requirements and Band Edge

Test Requirements: **§15.247(d); §15.205:** Emissions outside the frequency band.

§15.205(a): Except as shown in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.090–0.110----------	16.42–16.423	399.9–410	4.5–5.15
[1] 0.495–0.505----------	16.69475–16.69525	608–614	5.35–5.46
2.1735–2.1905----------	16.80425–16.80475	960–1240	7.25–7.75
4.125–4.128----------	25.5–25.67	1300–1427	8.025–8.5
4.17725–4.17775----------	37.5–38.25	1435–1626.5	9.0–9.2
4.20725–4.20775----------	73–74.6	1645.5–1646.5	9.3–9.5
6.215–6.218----------	74.8–75.2	1660–1710	10.6–12.7
6.26775–6.26825----------	108–121.94	1718.8–1722.2	13.25–13.4
6.31175–6.31225----------	123–138	2200–2300	14.47–14.5
8.291–8.294----------	149.9–150.05	2310–2390	15.35–16.2
8.362–8.366----------	156.52475–156.52525	2483.5–2500	17.7–21.4
8.37625–8.38675----------	156.7–156.9	2655–2900	22.01–23.12
8.41425–8.41475----------	162.0125–167.17	3260–3267	23.6–24.0
12.29–12.293----------	167.72–173.2	3332–3339	31.2–31.8
12.51975–12.52025----------	240–285	3345.8–3358 36.	43–36.5
12.57675–12.57725----------	322–335.4	3600–4400	([2])

Figure 11: Restricted Bands of Operation

[1] Until February 1, 1999, this restricted band shall be 0.490 – 0.510 MHz.
[2] Above 38.6

Test Requirement(s): **§ 15.209 (a):** Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in Figure 12:

Frequency (MHz)	§ 15.209(a),Radiated Emission Limits (dBµV) @ 3m
30 - 88	40.00
88 - 216	43.50
216 - 960	46.00
Above 960	54.00

Figure 12: Radiated Emissions Limits Calculated from FCC Part 15, § 15.209 (a)

Test Procedures: The transmitter was turned on. Measurements were performed of the low, mid and high Channels. The EUT was rotated orthogonally through all three axes. Plots shown are corrected for both antenna correction factor and distance and compared to a 3 m limit line. Only noise floor was measured above 18 GHz.

Test Results: The EUT was **compliant** with the Radiated Spurious Emission limits of **§ 15.247(d) and § 15.209**. Measured emissions were below applicable limits.

Test Engineer: Donald Salguero

Test Date: June 24 and June 26, 2020

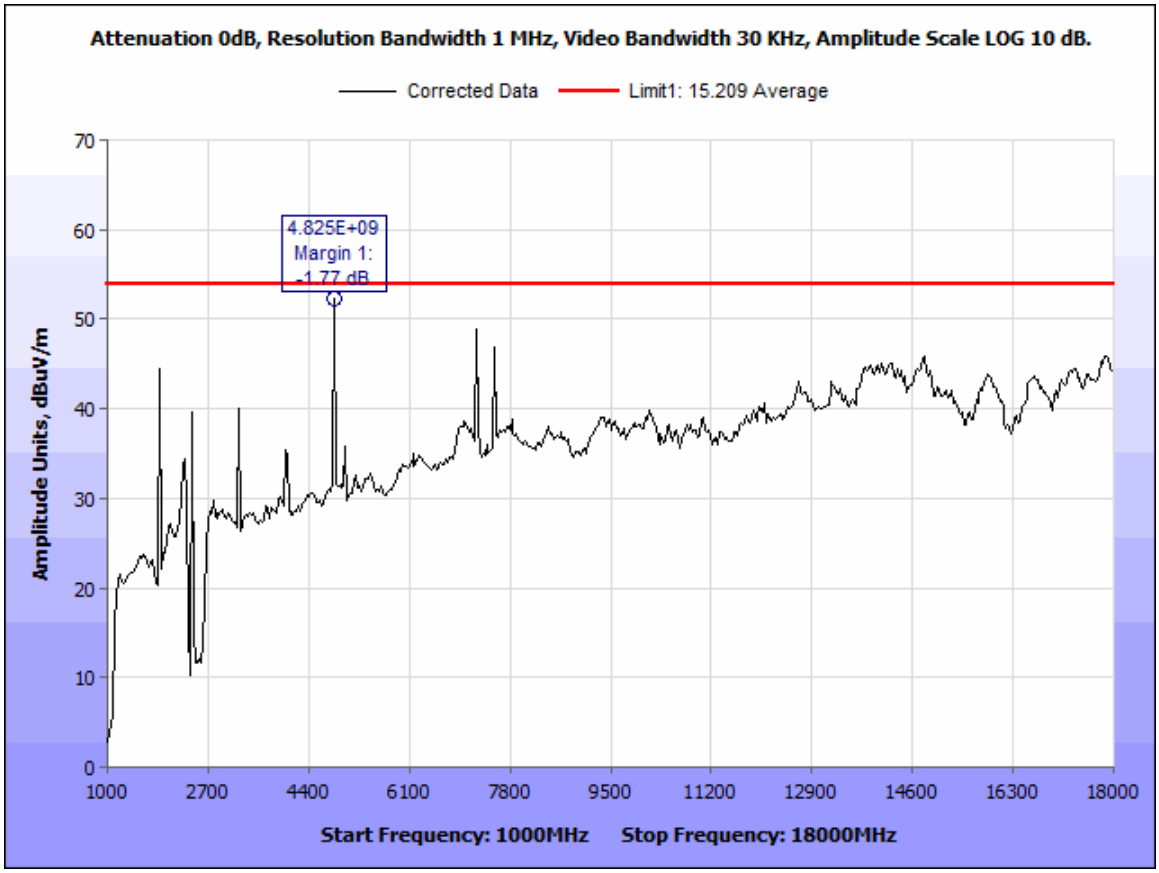

Figure 13: Radiated Spurious Emissions, 802.11b - Average Radiated Spurious Emissions - 2412MHz - 1-18GHz

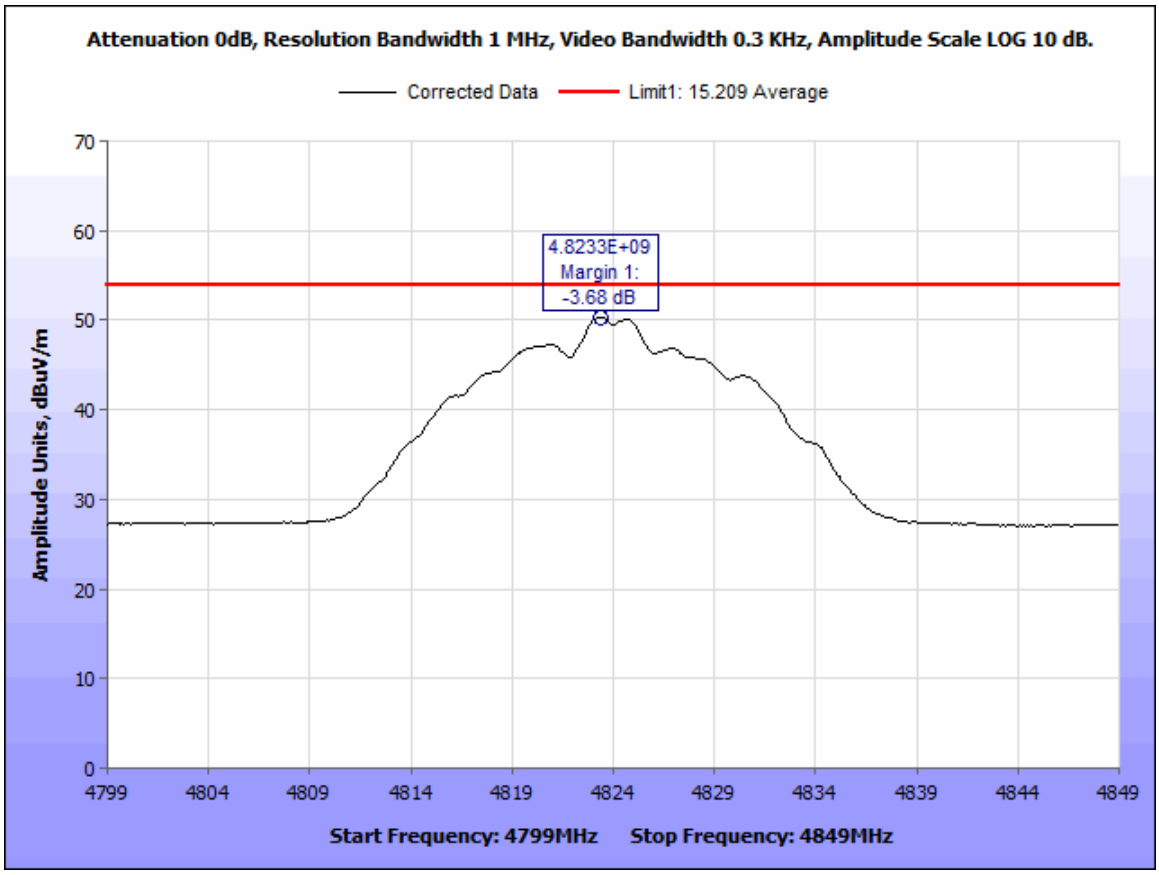

Figure 14: Radiated Spurious Emissions, 802.11b - Average Radiated Spurious Emissions - 2412MHz - 2xHarmonic

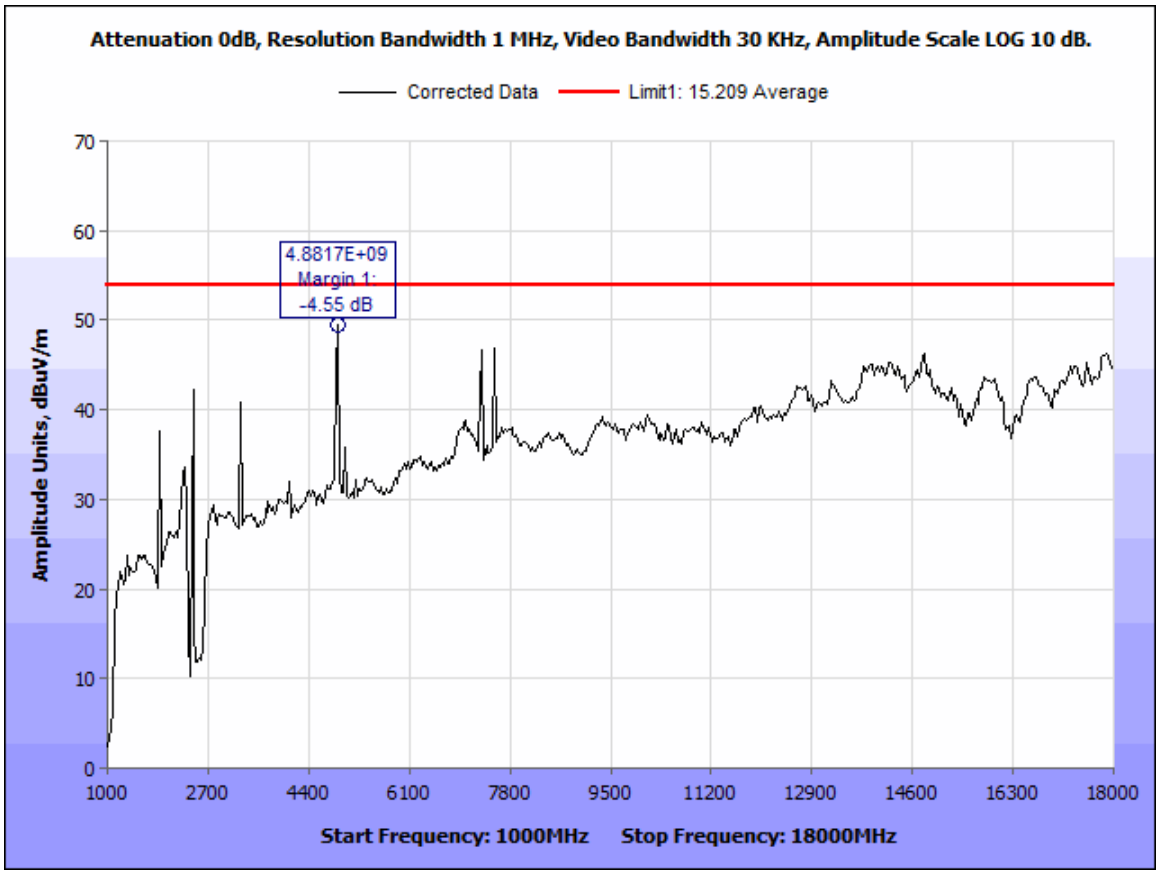

Figure 15: Radiated Spurious Emissions, 802.11b - Average Radiated Spurious Emissions - 2437MHz - 1-18GHz

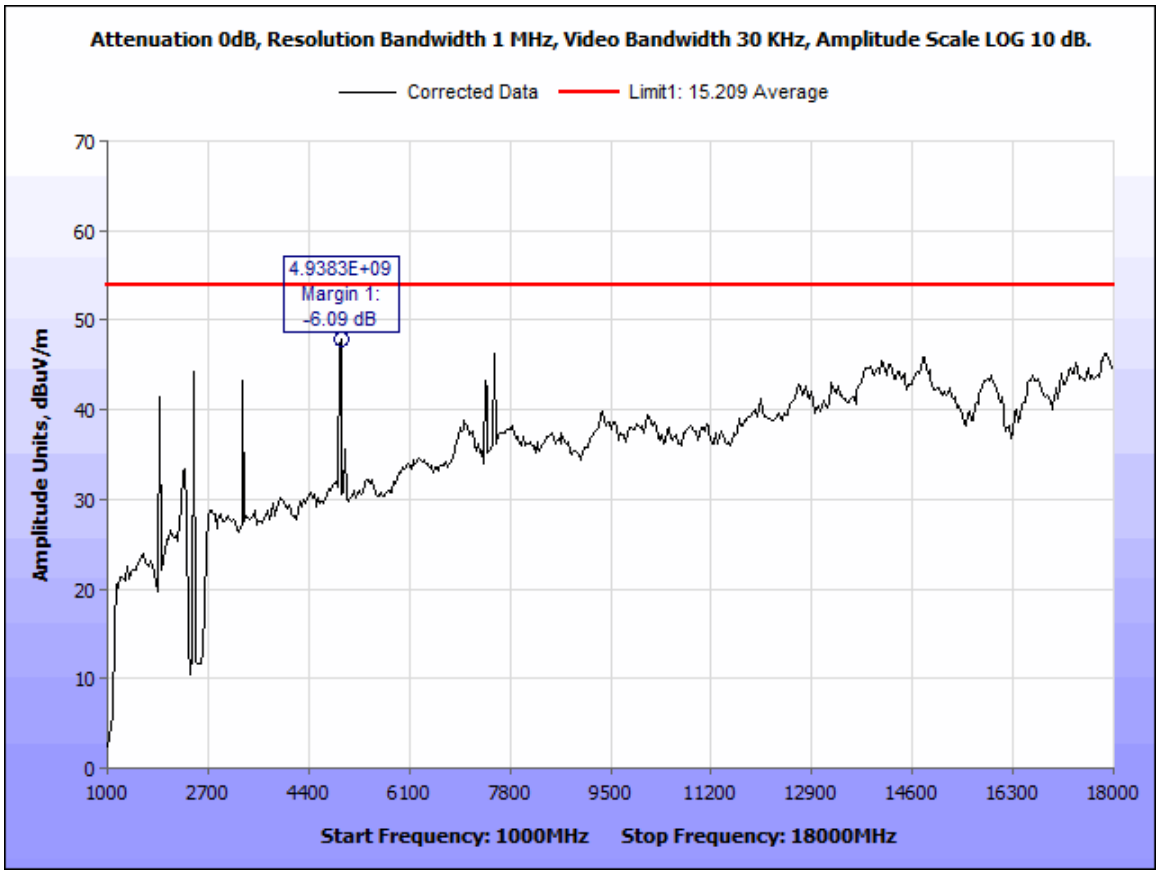

Figure 16: Radiated Spurious Emissions, 802.11b - Average Radiated Spurious Emissions - 2462MHz - 1-18GHz

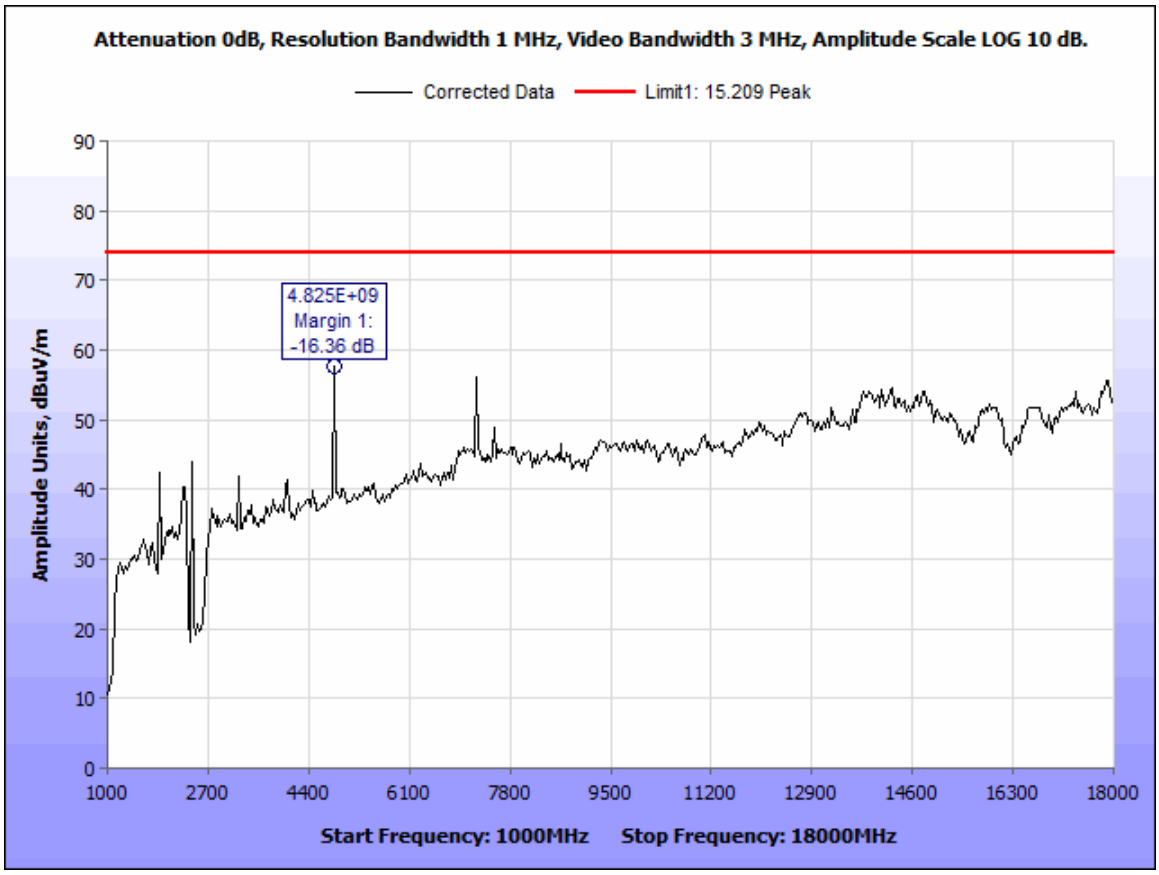

Figure 17: Radiated Spurious Emissions, 802.11b - Peak Radiated Spurious Emissions - 2412MHz - 1-18GHz

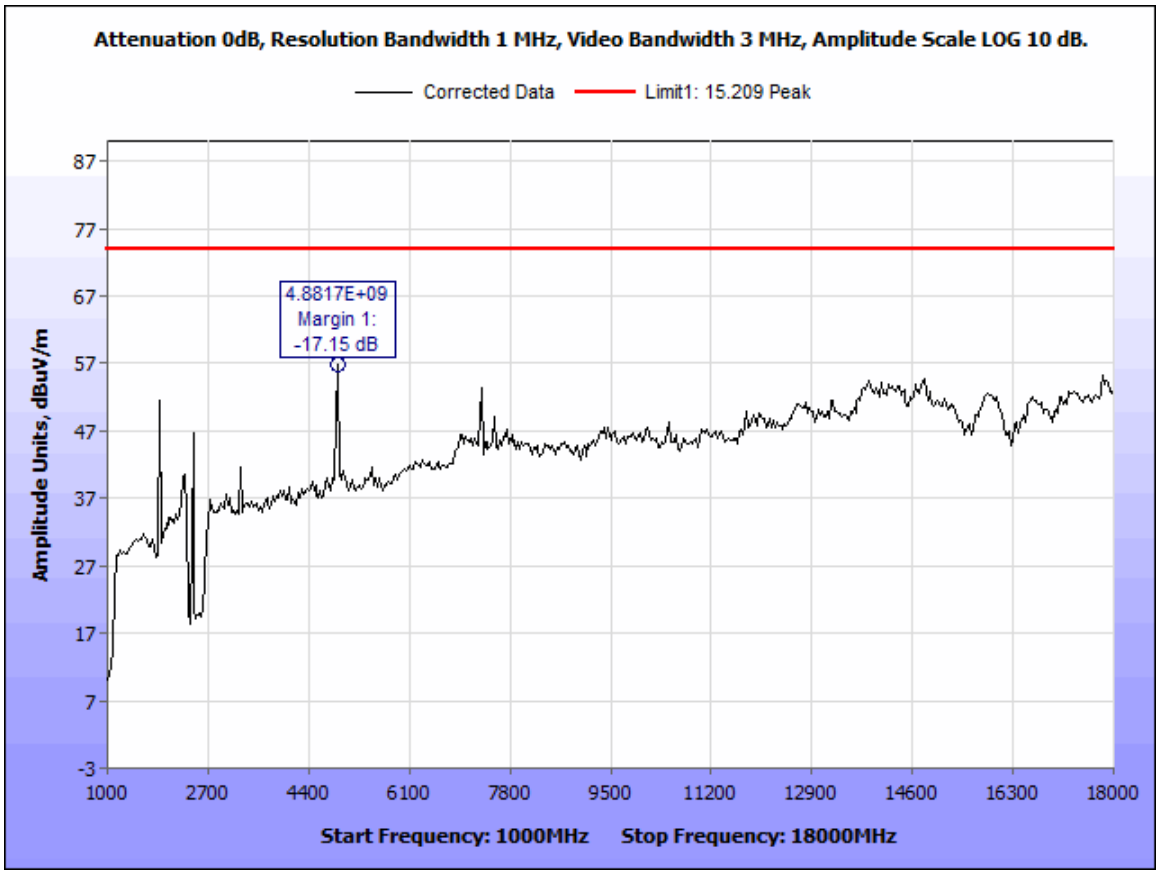

Figure 18: Radiated Spurious Emissions, 802.11b - Peak Radiated Spurious Emissions - 2437MHz - 1-18GHz

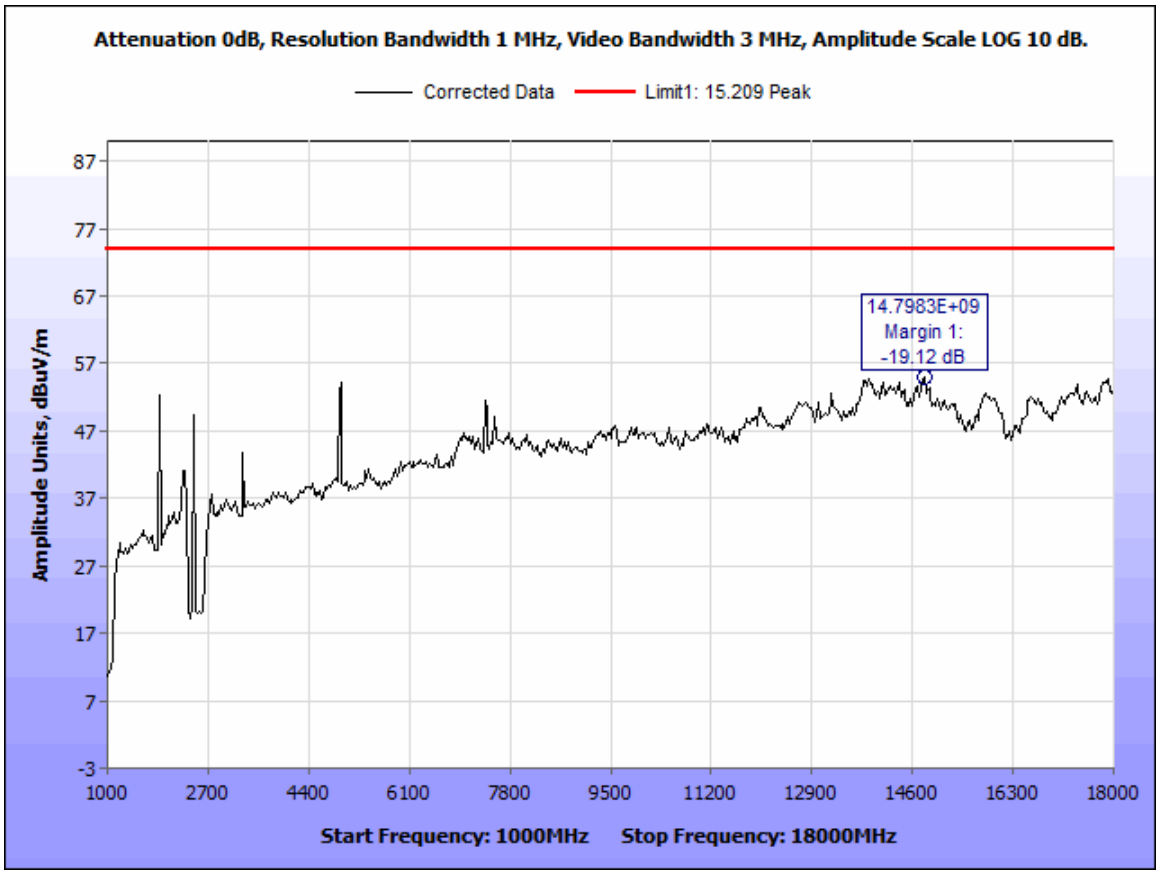

Figure 19: Radiated Spurious Emissions, 802.11b - Peak Radiated Spurious Emissions - 2462MHz - 1-18GHz

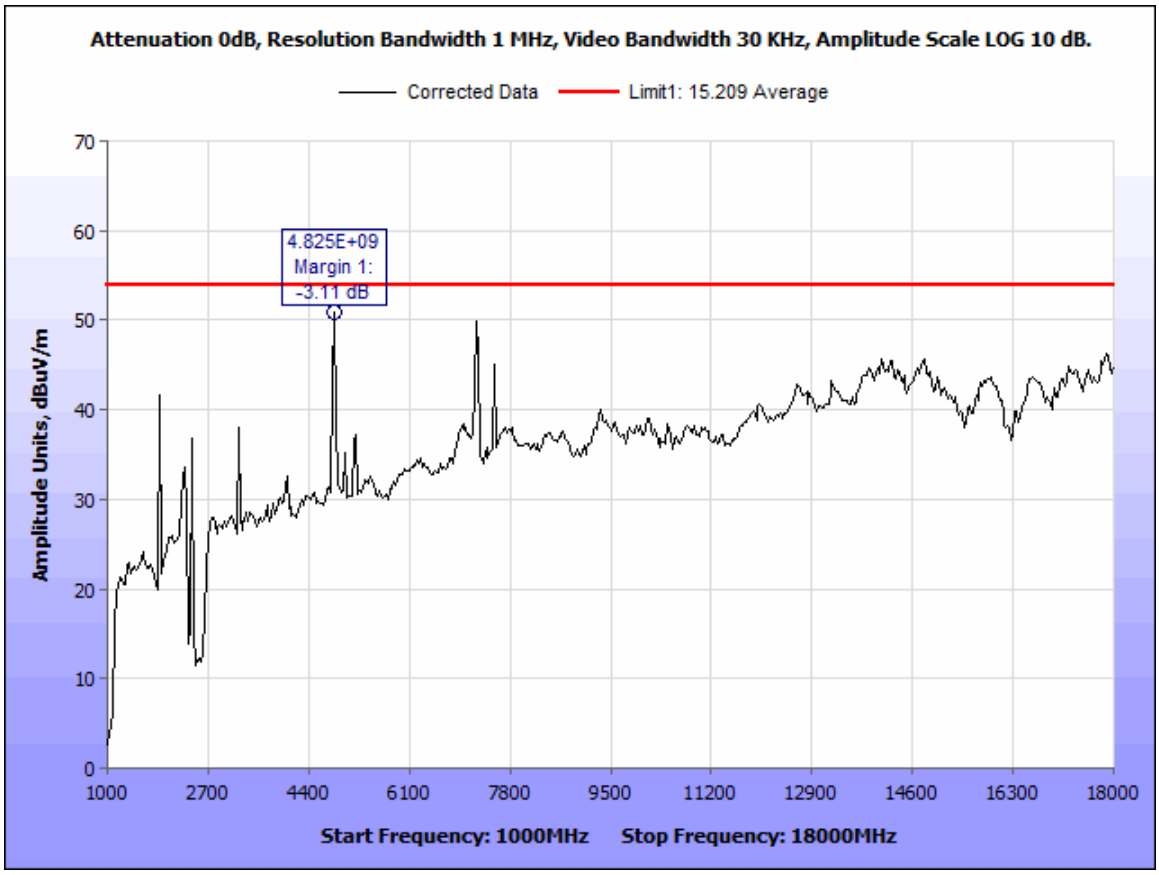

Figure 20: Radiated Spurious Emissions, 802.11g - Average Radiated Spurious Emissions - 2412MHz - 1-18GHz

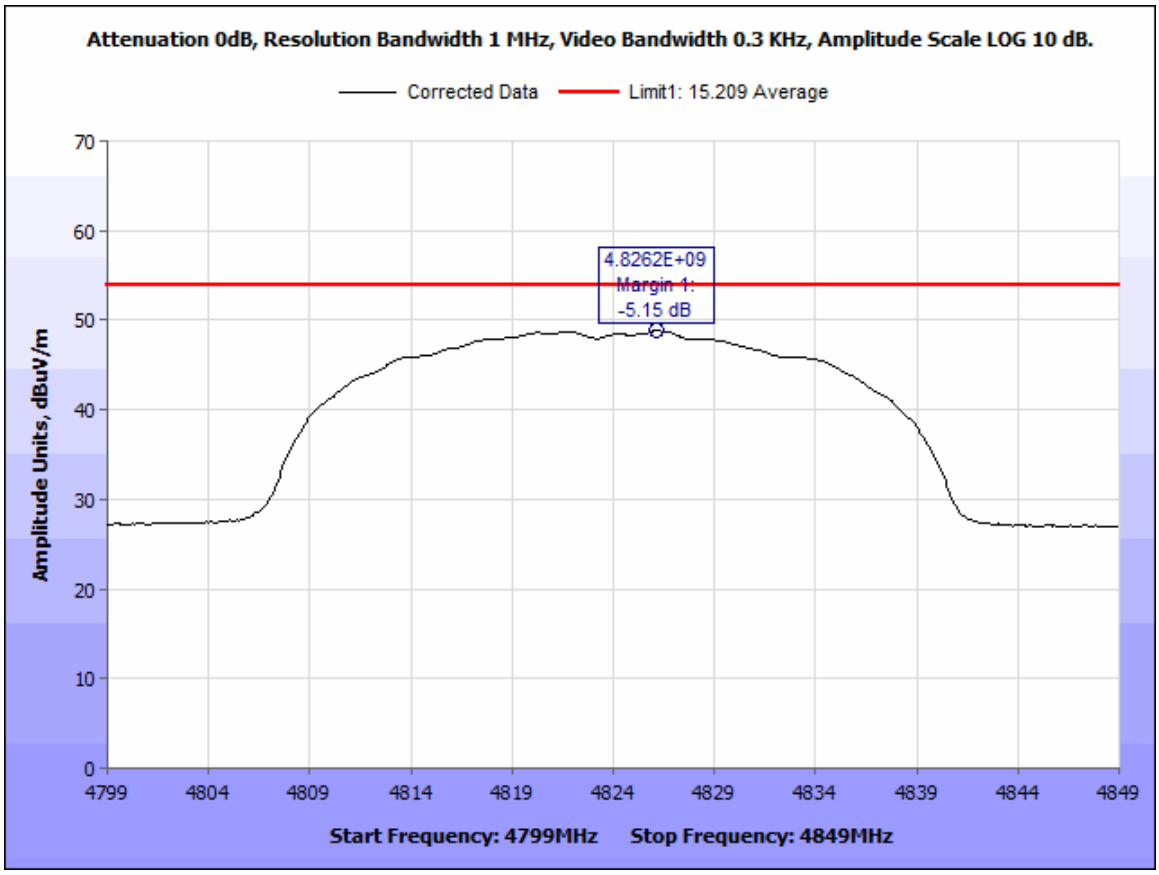

Figure 21: Radiated Spurious Emissions, 802.11g - Average Radiated Spurious Emissions - 2412MHz - 2xHarmonic.

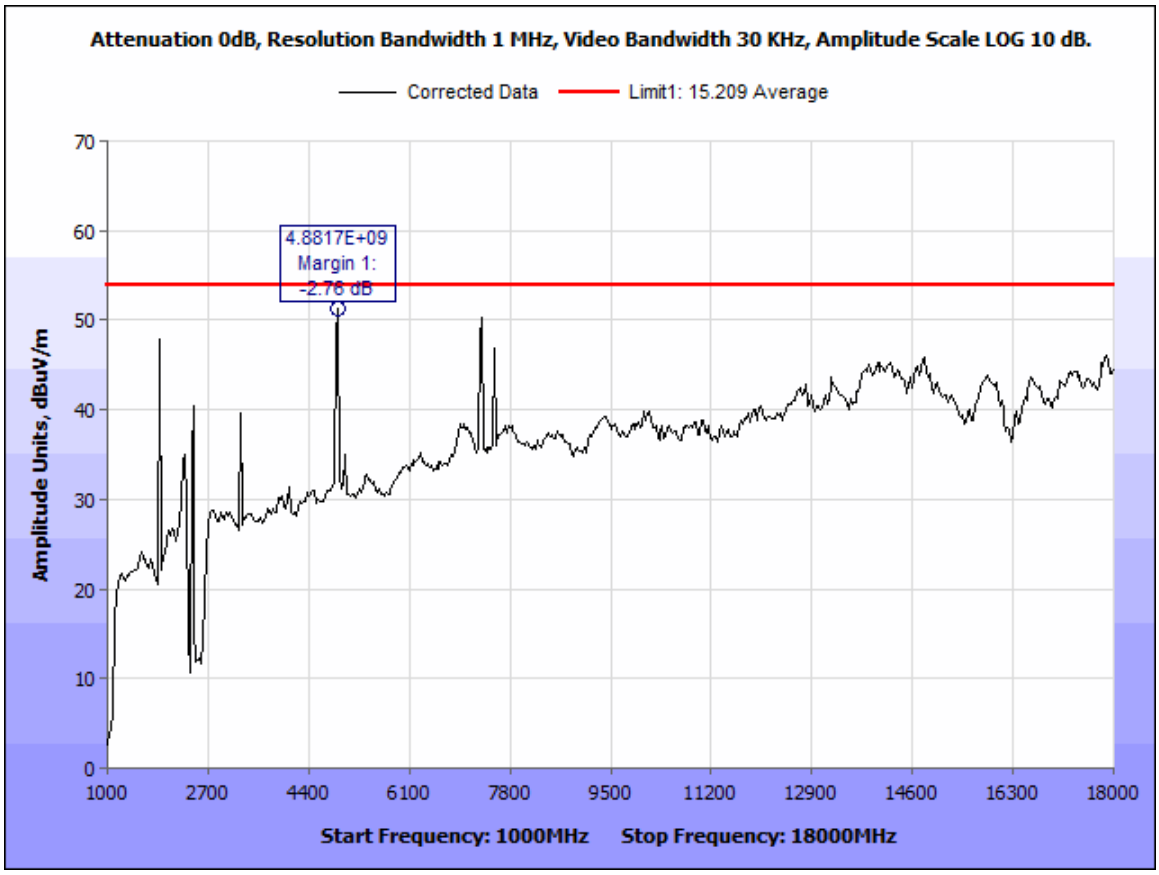

Figure 22: Radiated Spurious Emissions, 802.11g - Average Radiated Spurious Emissions - 2437MHz - 1-18GHz

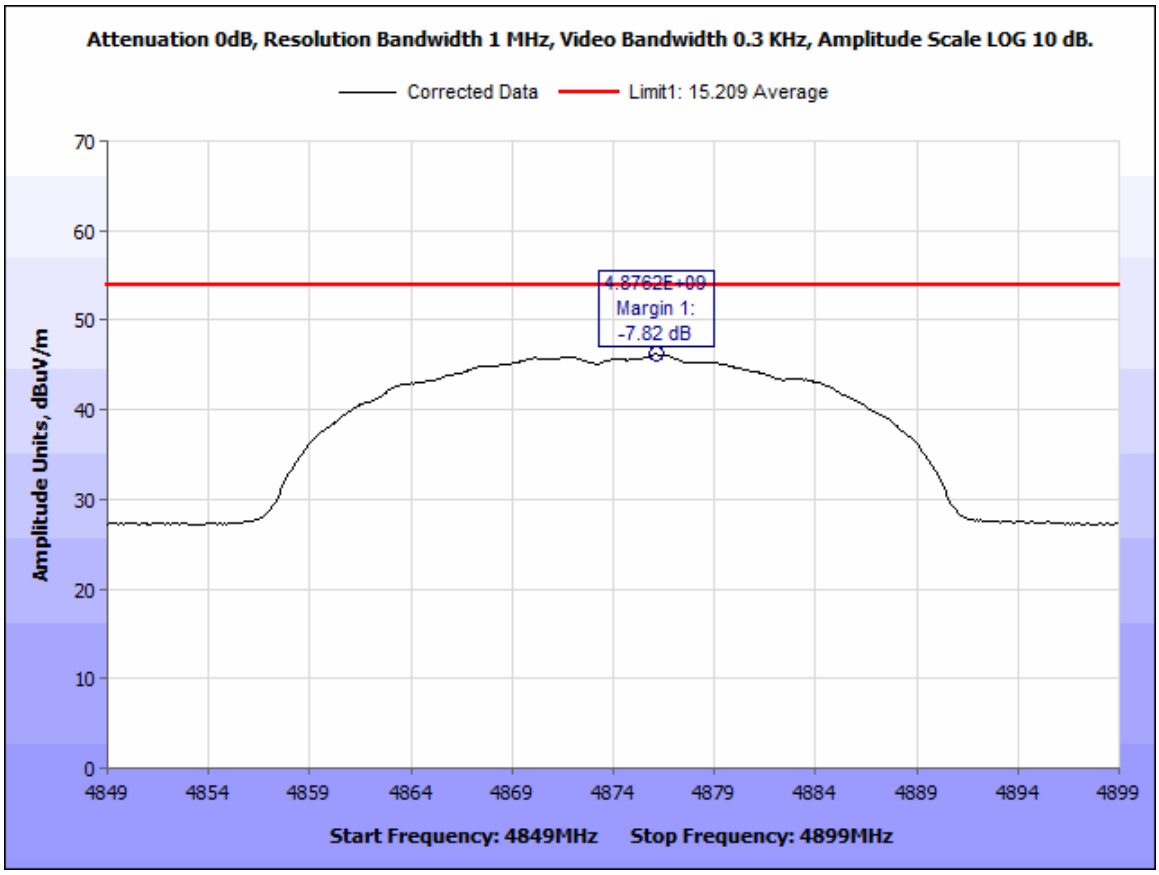

Figure 23: Radiated Spurious Emissions, 802.11g - Average Radiated Spurious Emissions - 2437MHz - 2xHarmonic.

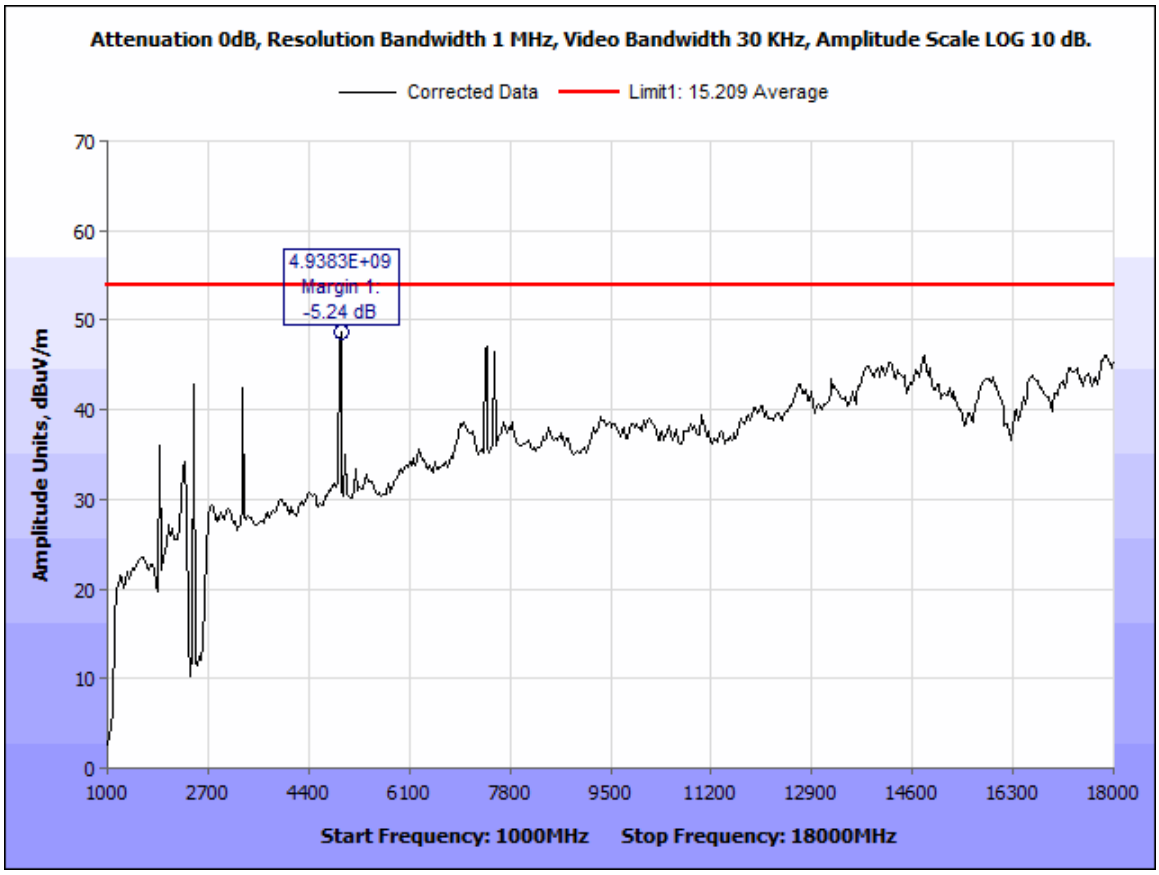

Figure 24: Radiated Spurious Emissions, 802.11g - Average Radiated Spurious Emissions - 2462MHz - 1-18GHz

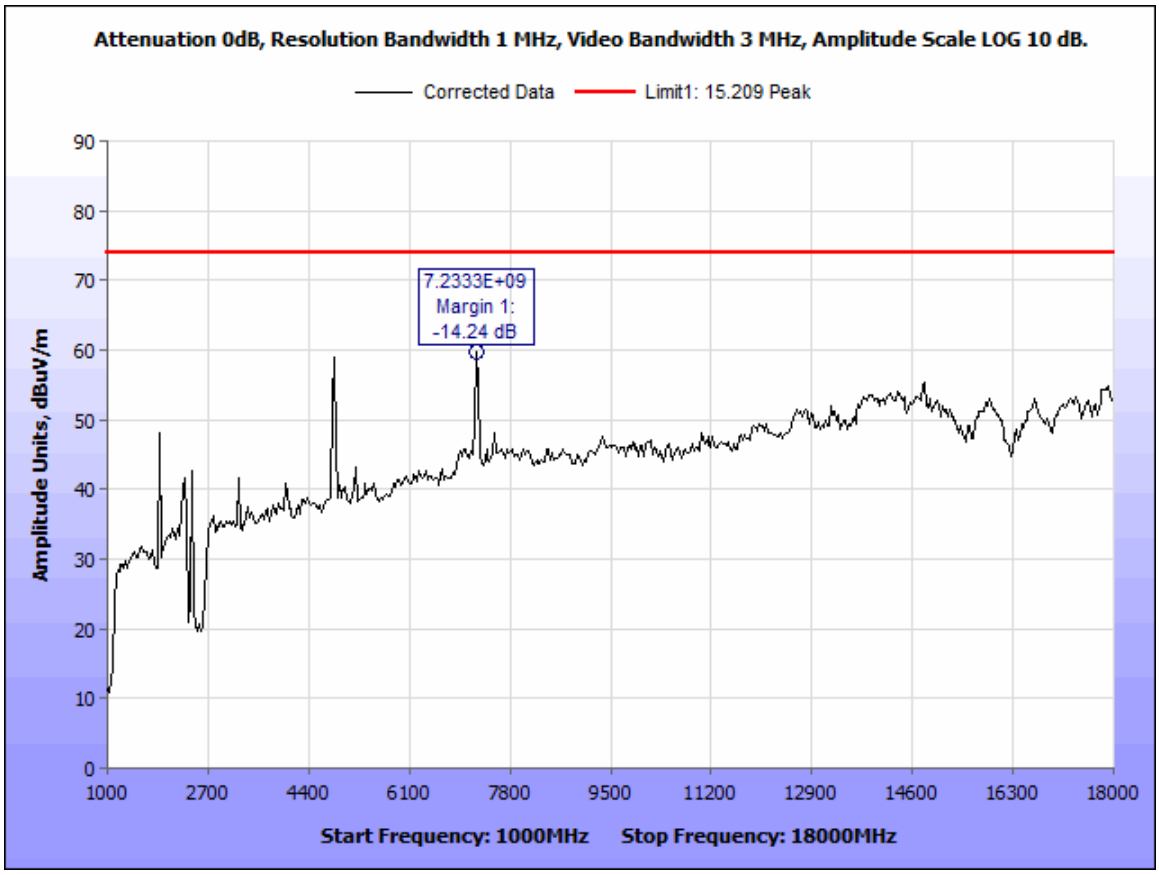

Figure 25: Radiated Spurious Emissions, 802.11g - Peak Radiated Spurious Emissions - 2412MHz - 1-18GHz

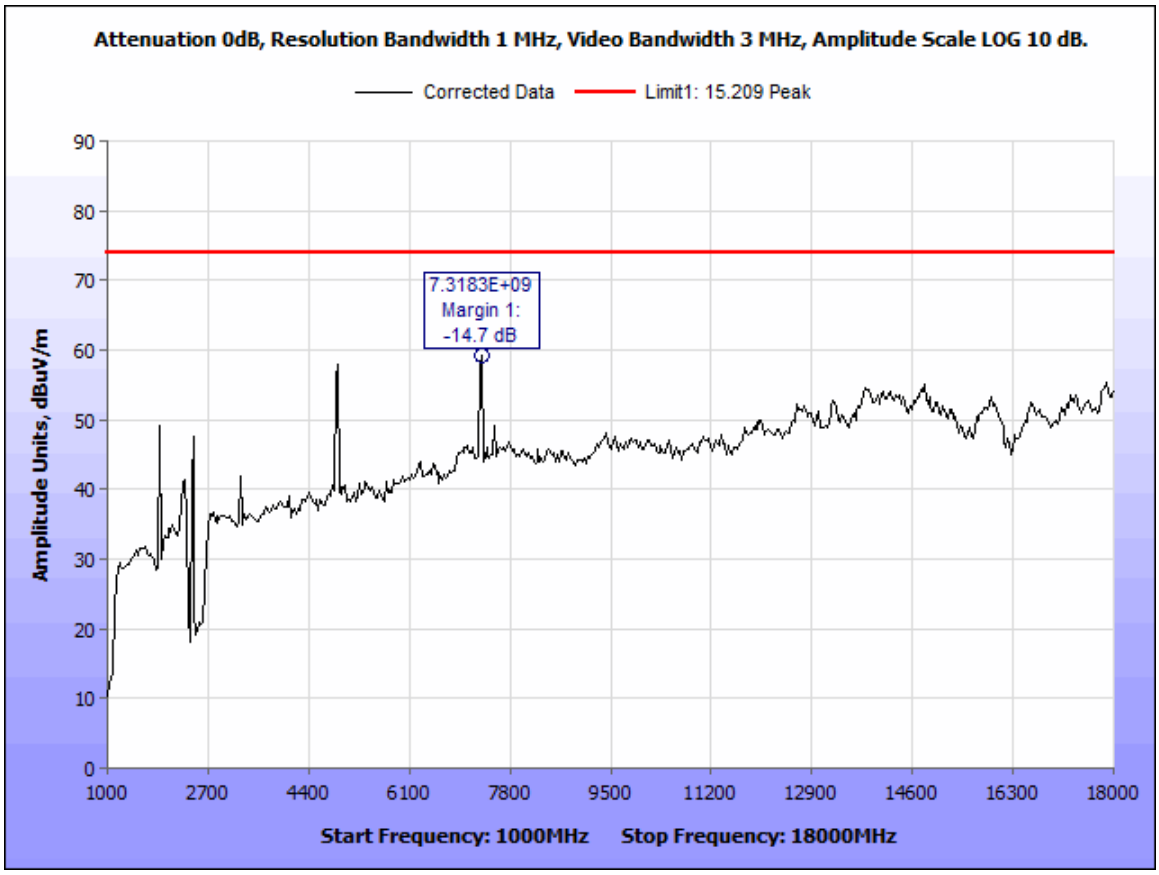

Figure 26: Radiated Spurious Emissions, 802.11g - Peak Radiated Spurious Emissions - 2437MHz - 1-18GHz

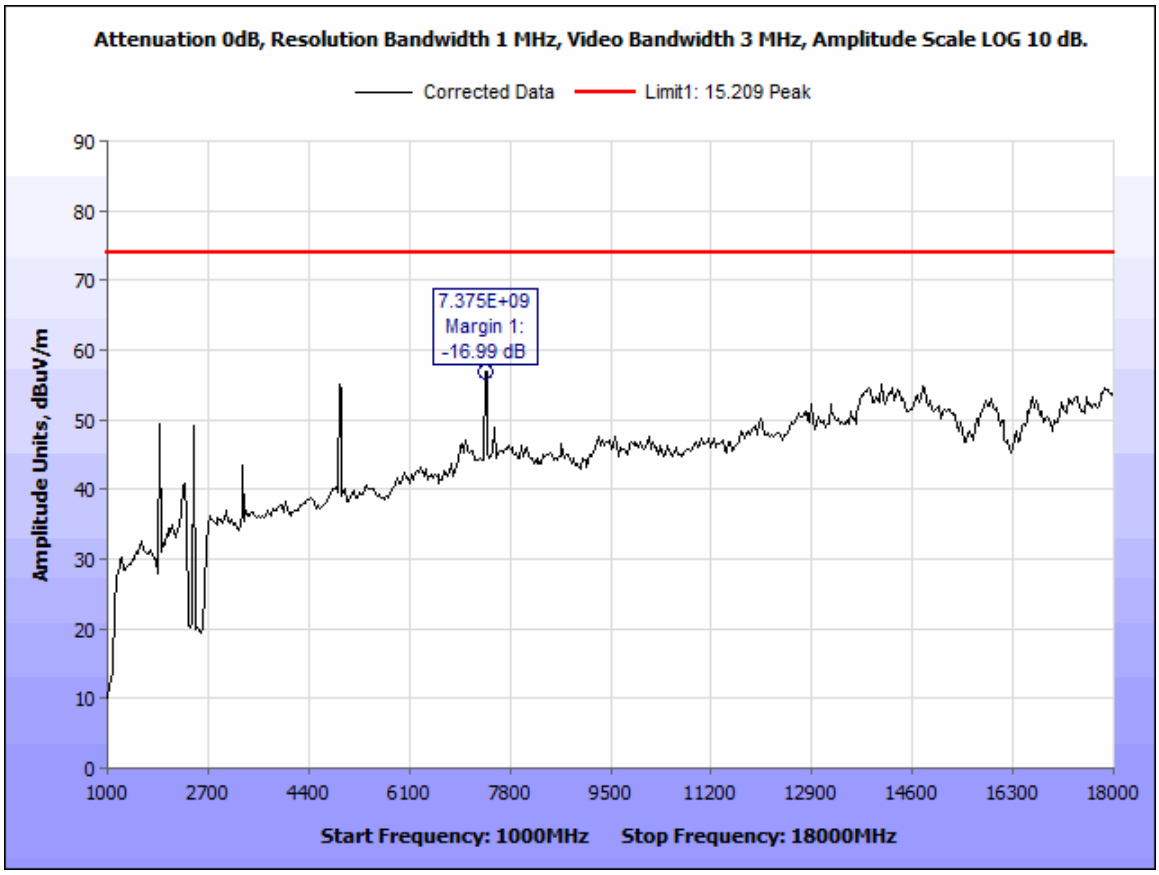

Figure 27: Radiated Spurious Emissions, 802.11g - Peak Radiated Spurious Emissions - 2462MHz - 1-18GHz

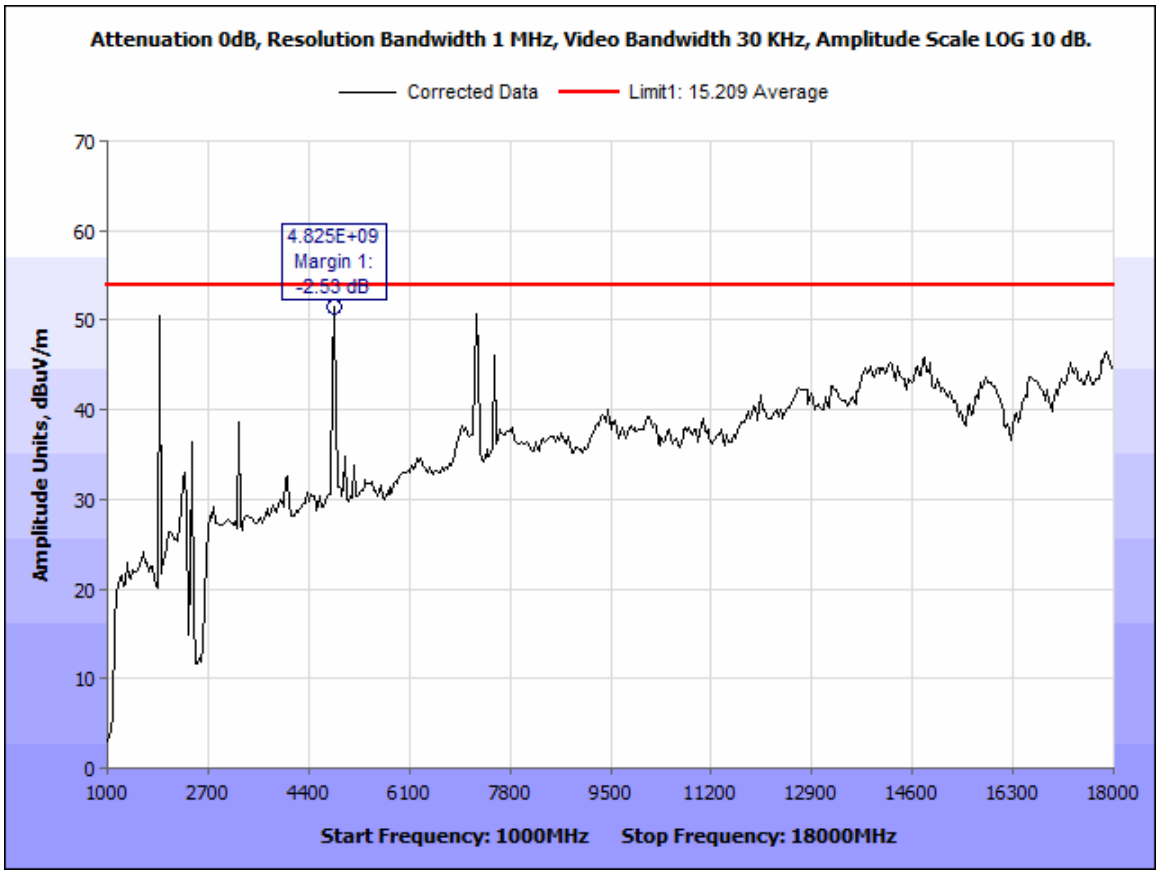

Figure 28: Radiated Spurious Emissions, 802.11n20 - Average Radiated Spurious Emissions - 2412MHz - 1-18GHz

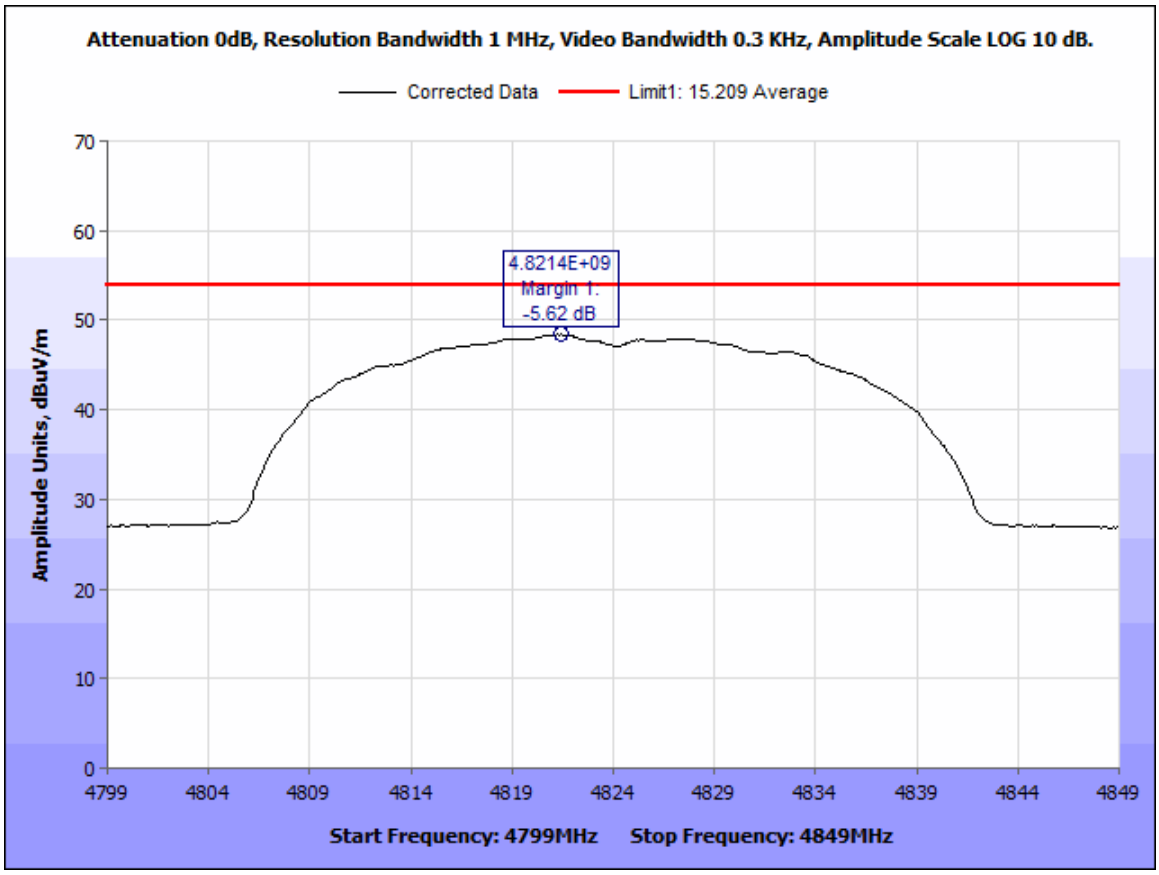

Figure 29: Radiated Spurious Emissions, 802.11n20 - Average Radiated Spurious Emissions - 2412MHz - 2xHarmonic.

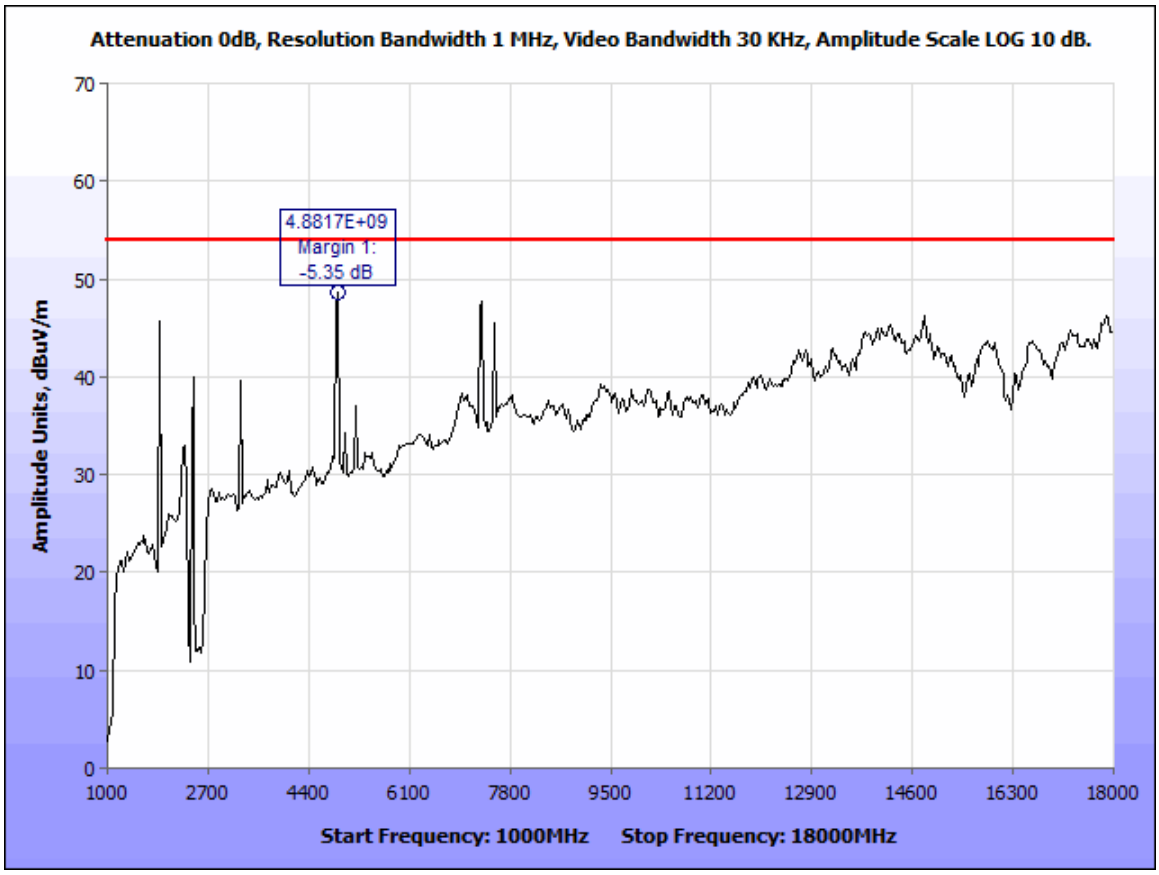

Figure 30: Radiated Spurious Emissions, 802.11n20 - Average Radiated Spurious Emissions - 2437MHz - 1-18GHz

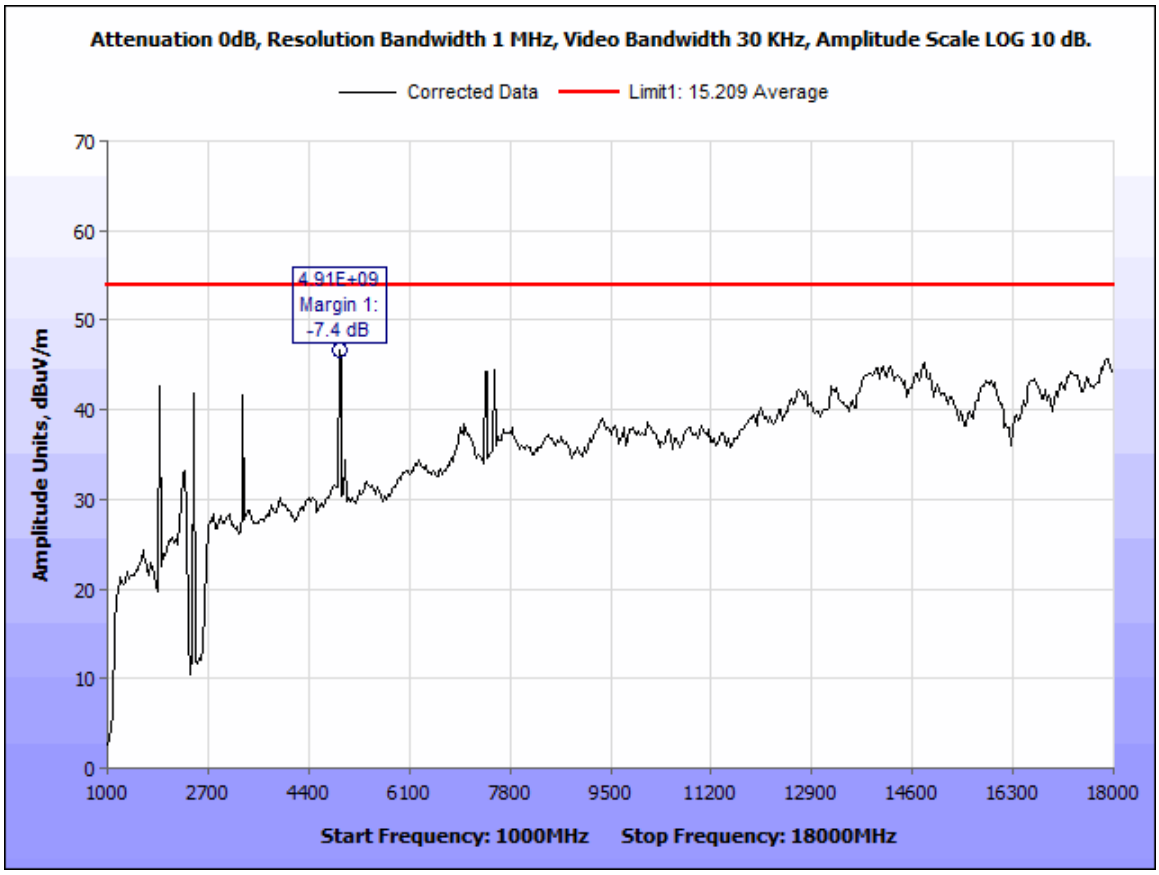

Figure 31: Radiated Spurious Emissions, 802.11n20 - Average Radiated Spurious Emissions - 2462MHz - 1-18GHz

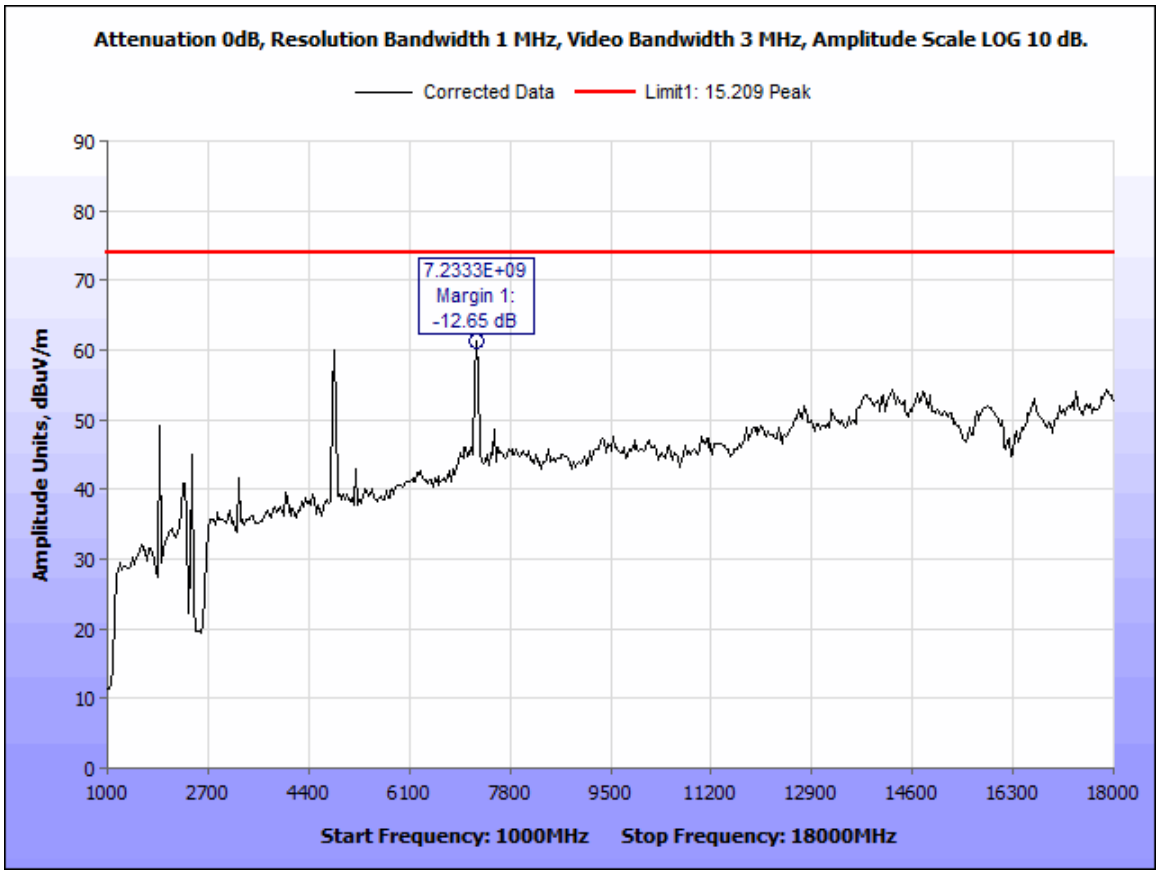

Figure 32: Radiated Spurious Emissions, 802.11n20 - Peak Radiated Spurious Emissions - 2412MHz - 1-18GHz

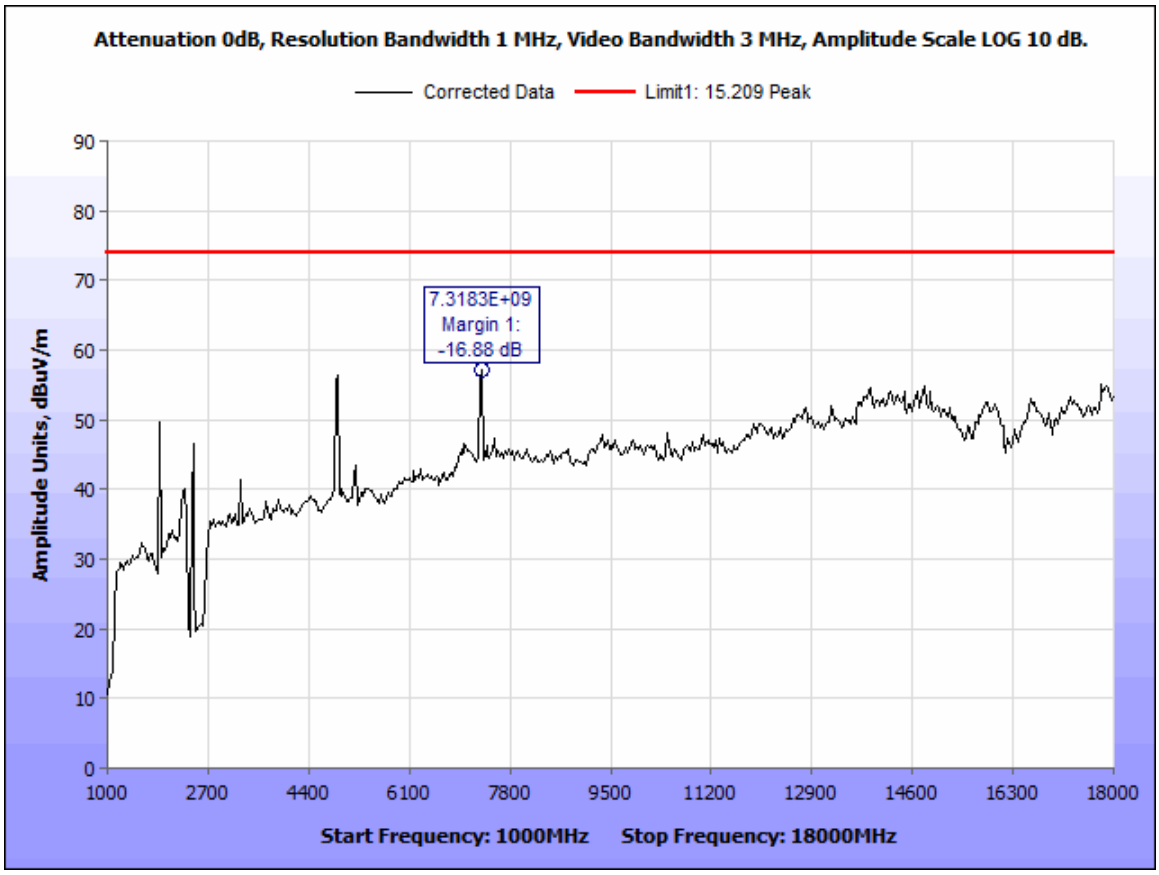

Figure 33: Radiated Spurious Emissions, 802.11n20 - Peak Radiated Spurious Emissions - 2437MHz - 1-18GHz

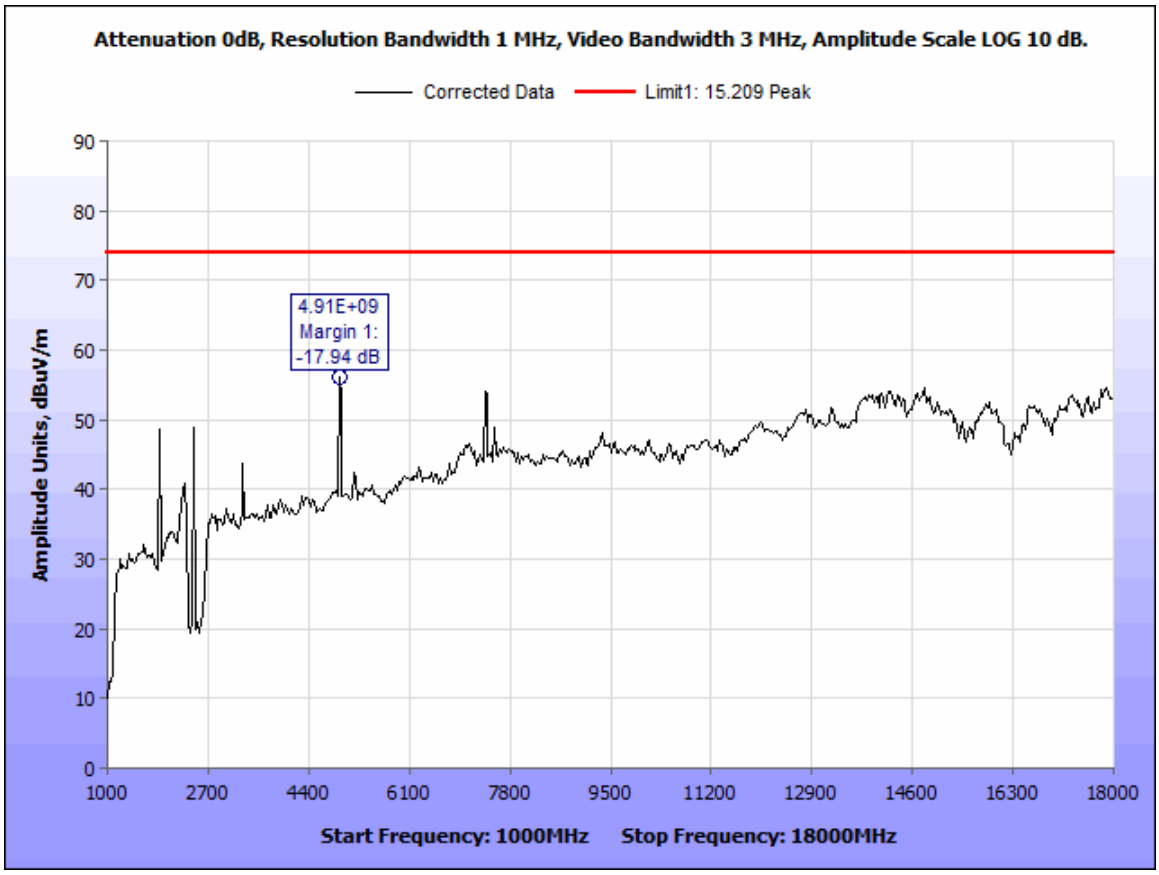

Figure 34: Radiated Spurious Emissions, 802.11n20 - Peak Radiated Spurious Emissions - 2462MHz - 1-18GHz

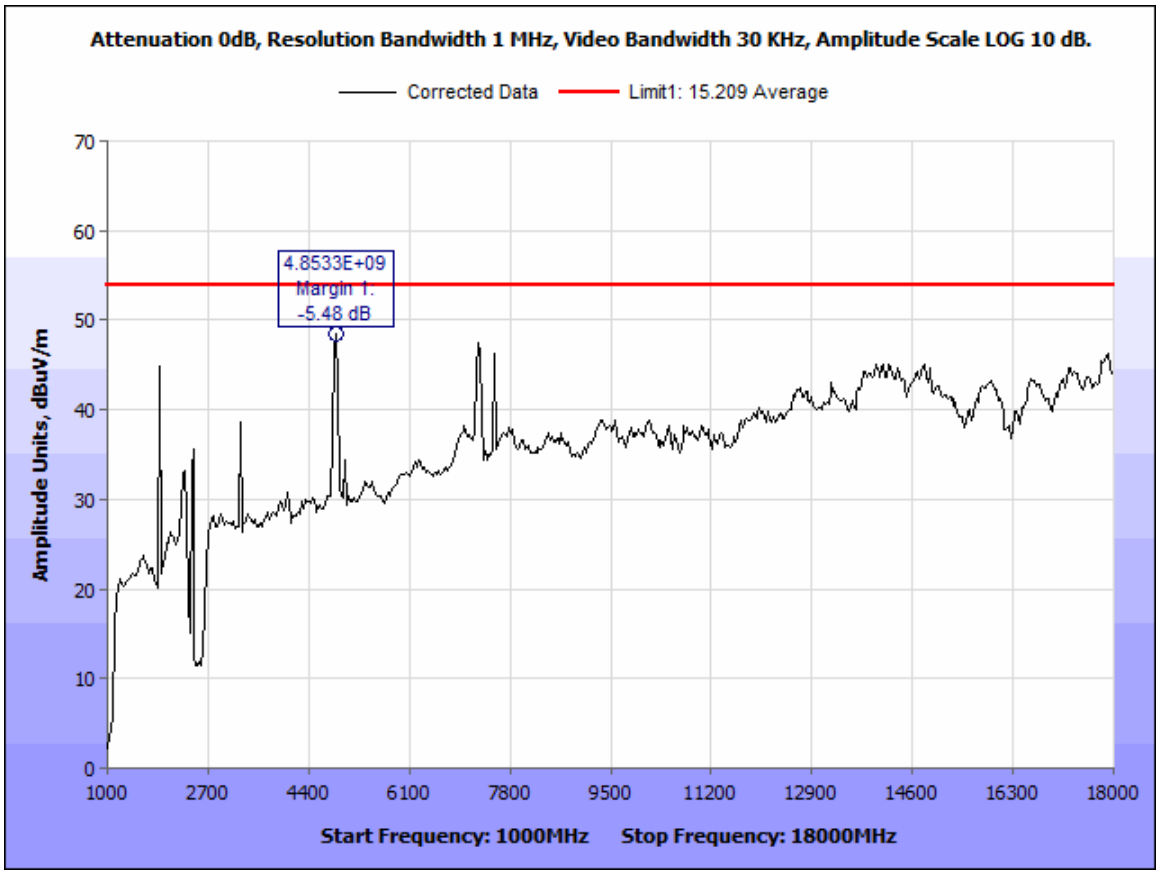

Figure 35: Radiated Spurious Emissions, 802.11n40 - Average Radiated Spurious Emissions - 2422MHz - 1-18GHz

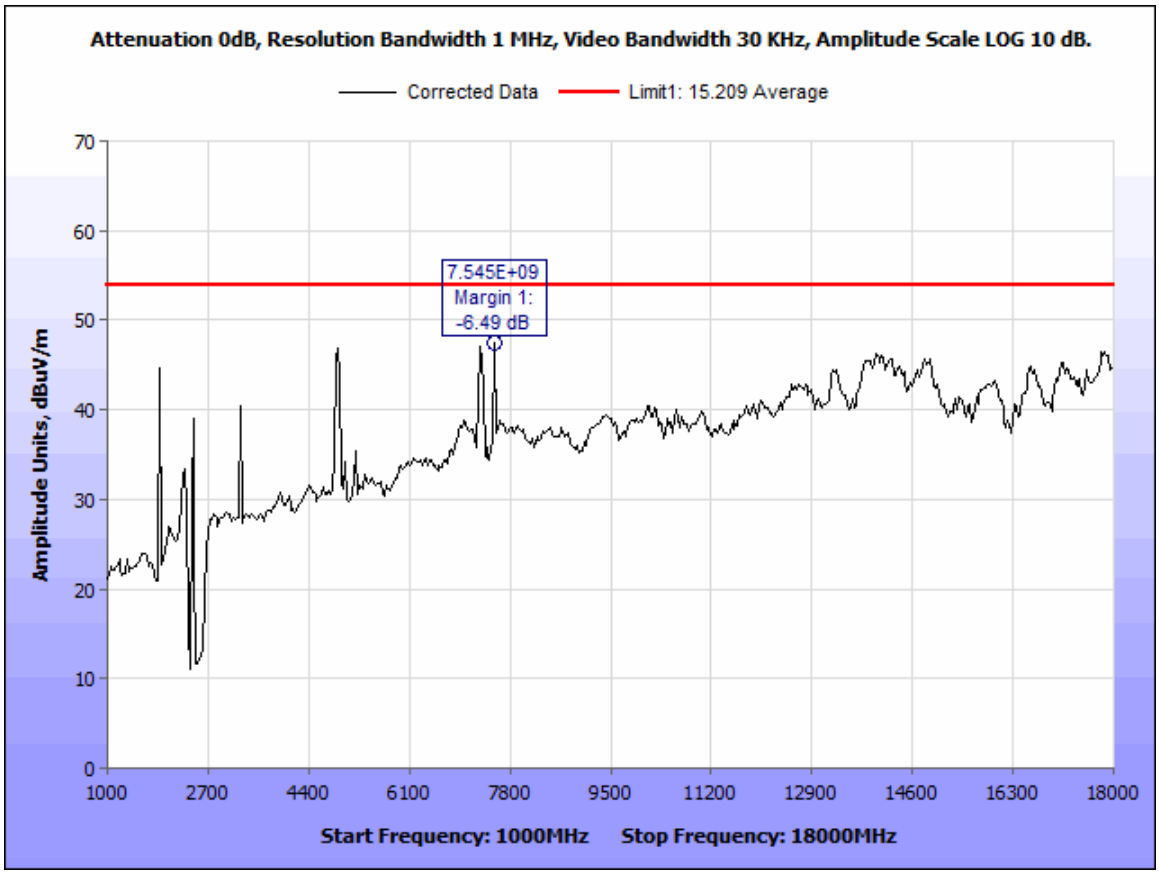

Figure 36: Radiated Spurious Emissions, 802.11n40 - Average Radiated Spurious Emissions - 2437MHz - 1-18GHz

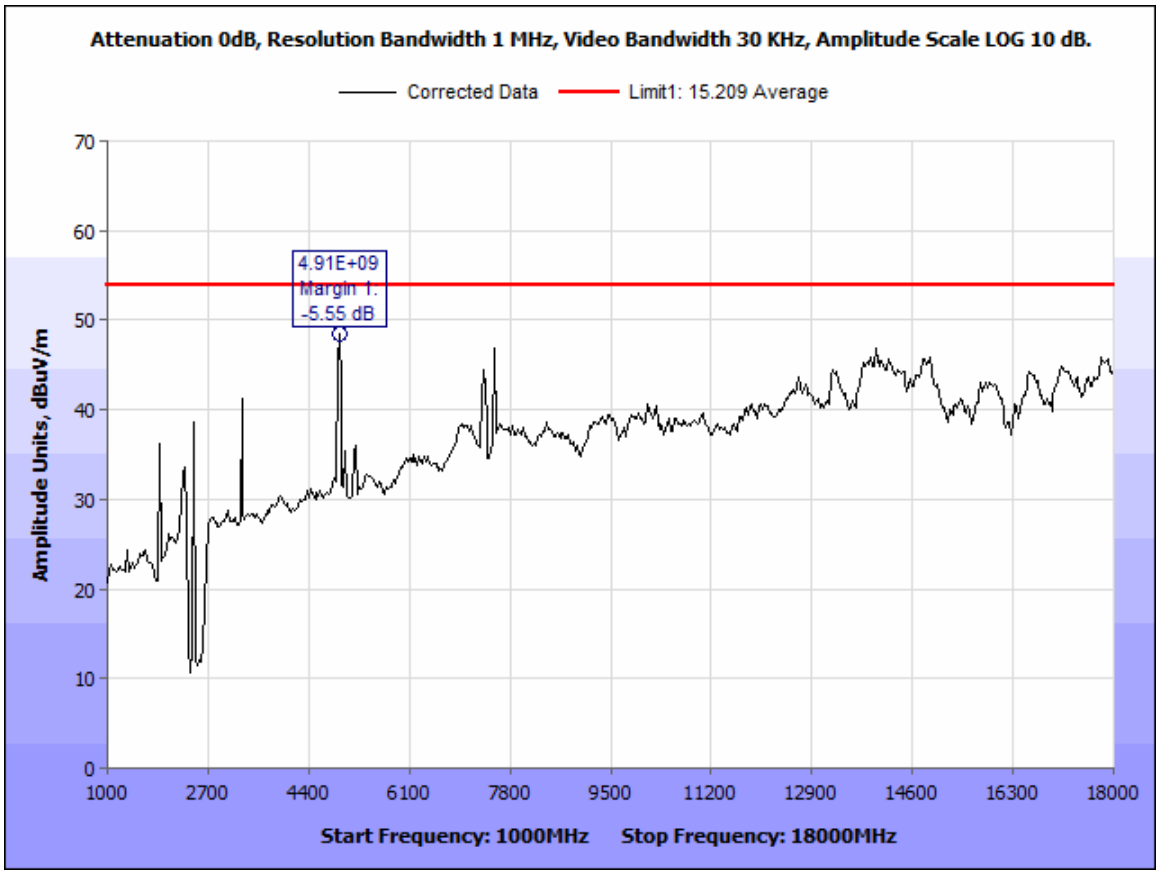

Figure 37: Radiated Spurious Emissions, 802.11n40 - Average Radiated Spurious Emissions - 2452MHz - 1-18GHz

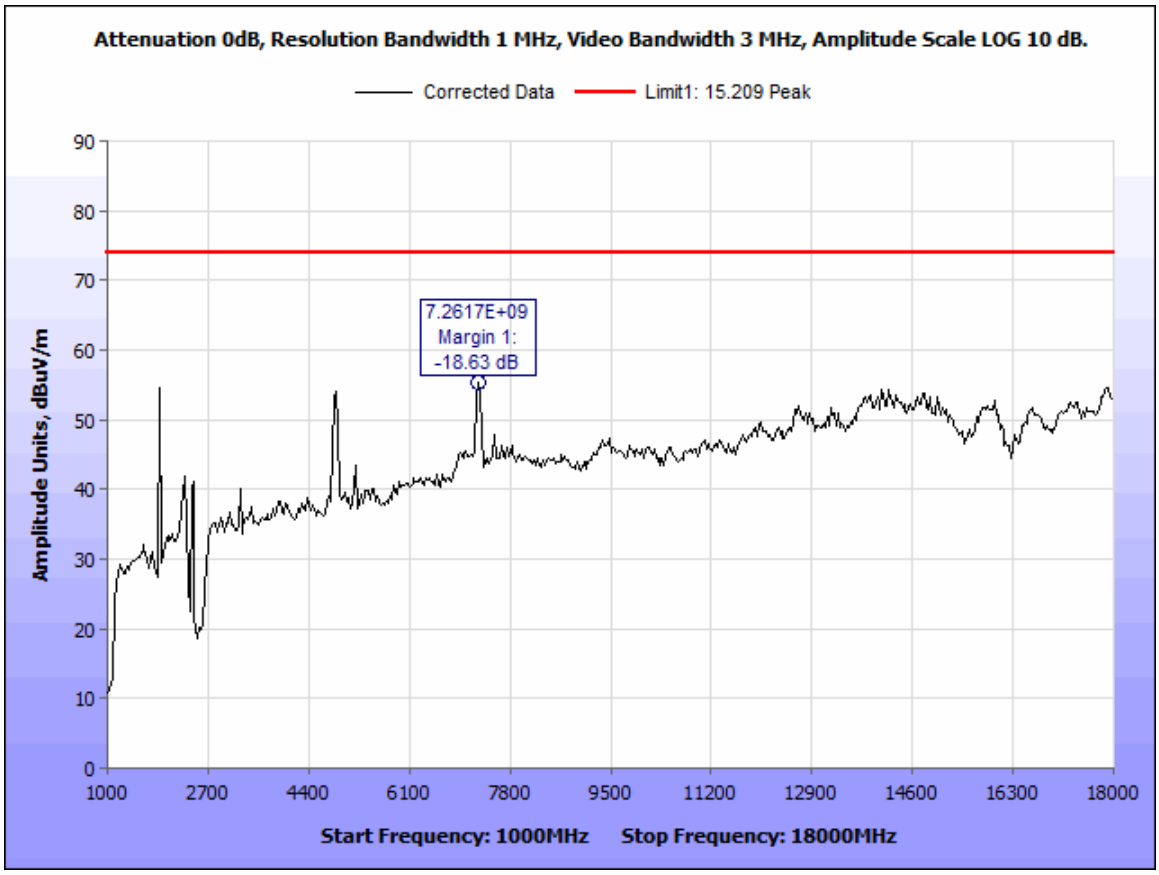

Figure 38: Radiated Spurious Emissions, 802.11n40 - Peak Radiated Spurious Emissions - 2422MHz - 1-18GHz

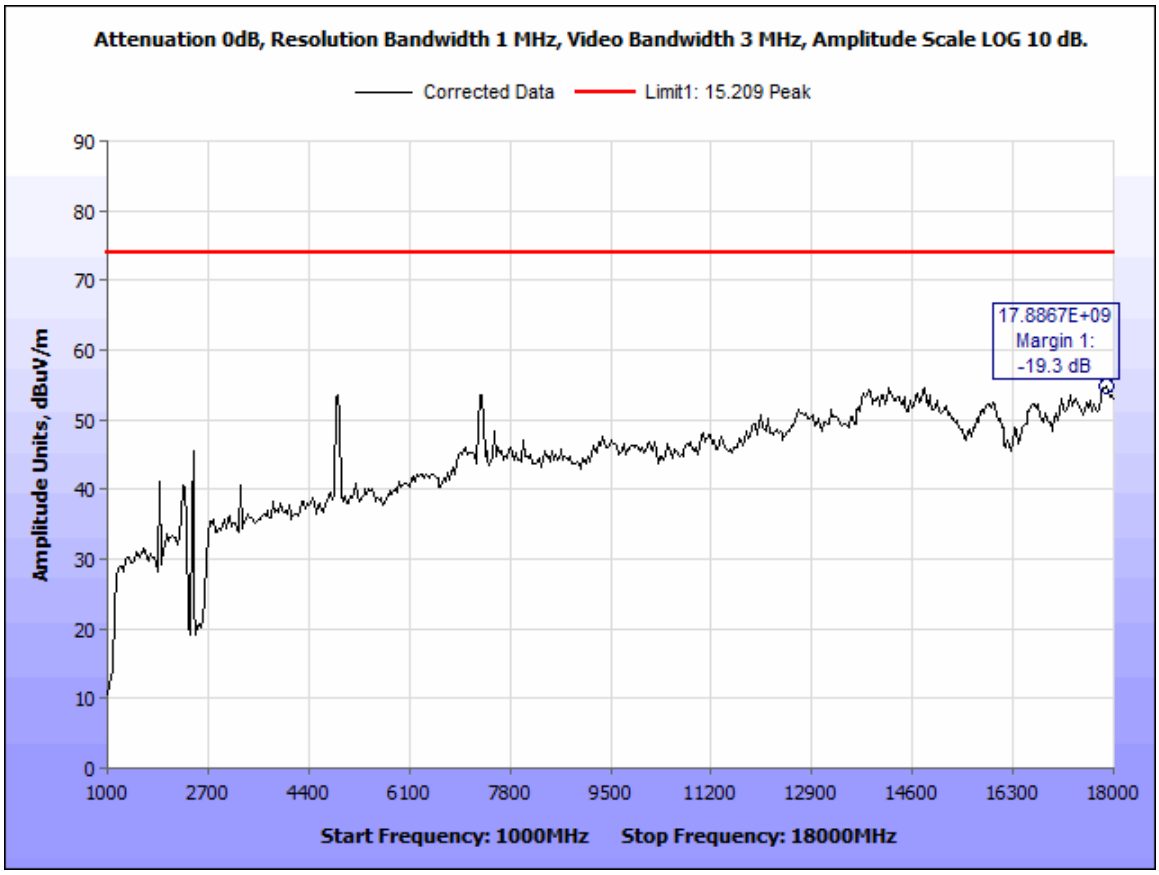

Figure 39: Radiated Spurious Emissions, 802.11n40 - Peak Radiated Spurious Emissions - 2437MHz - 1-18GHz

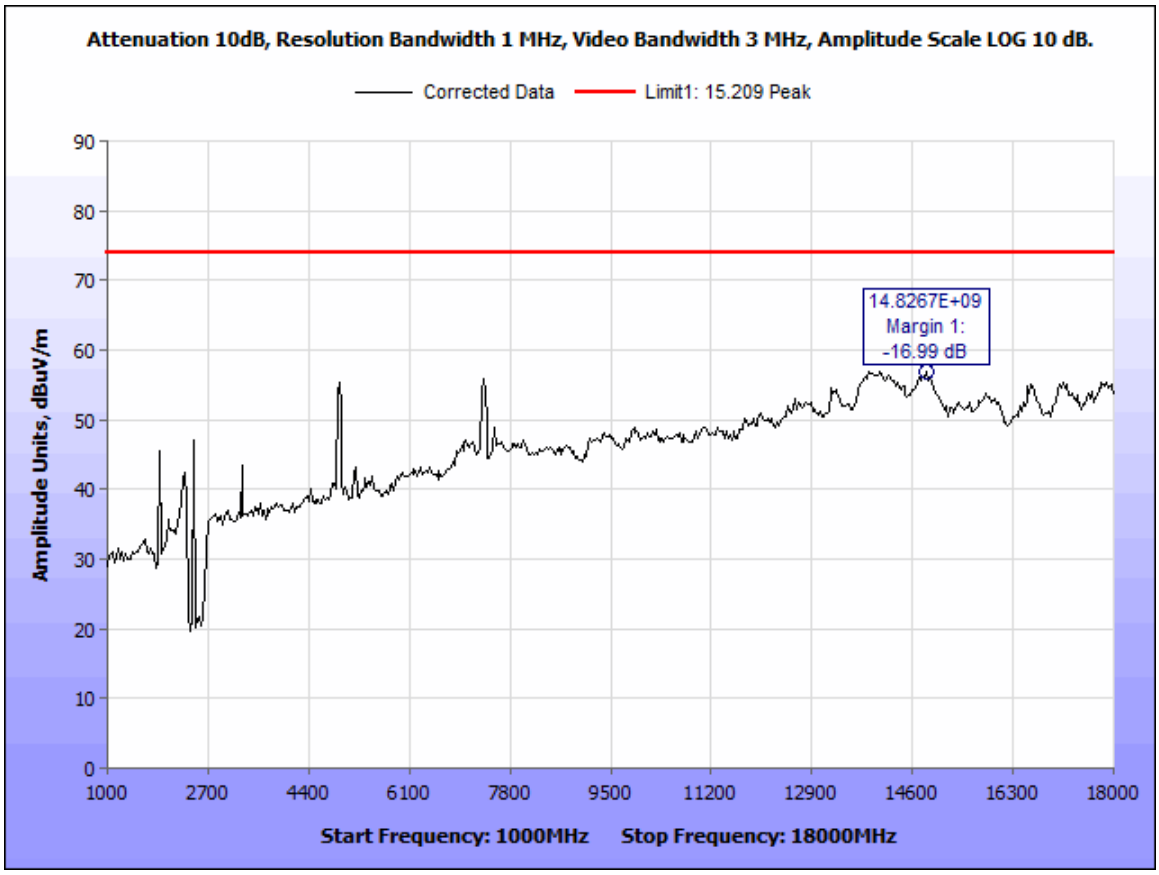

Figure 40: Radiated Spurious Emissions, 802.11n40 - Peak Radiated Spurious Emissions - 2452MHz - 1-18GHz

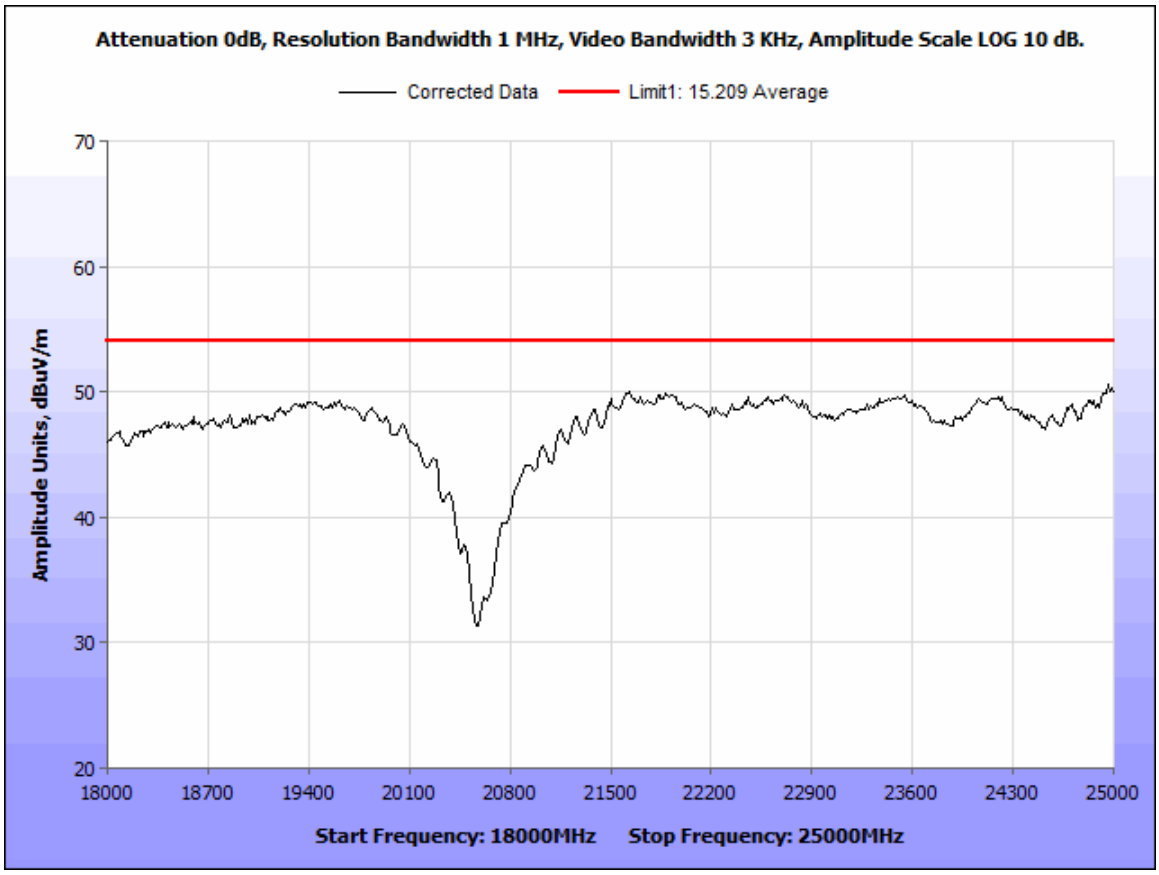

Figure 41: Radiated Spurious Emissions, Average - Worst Case - 18-25GHz

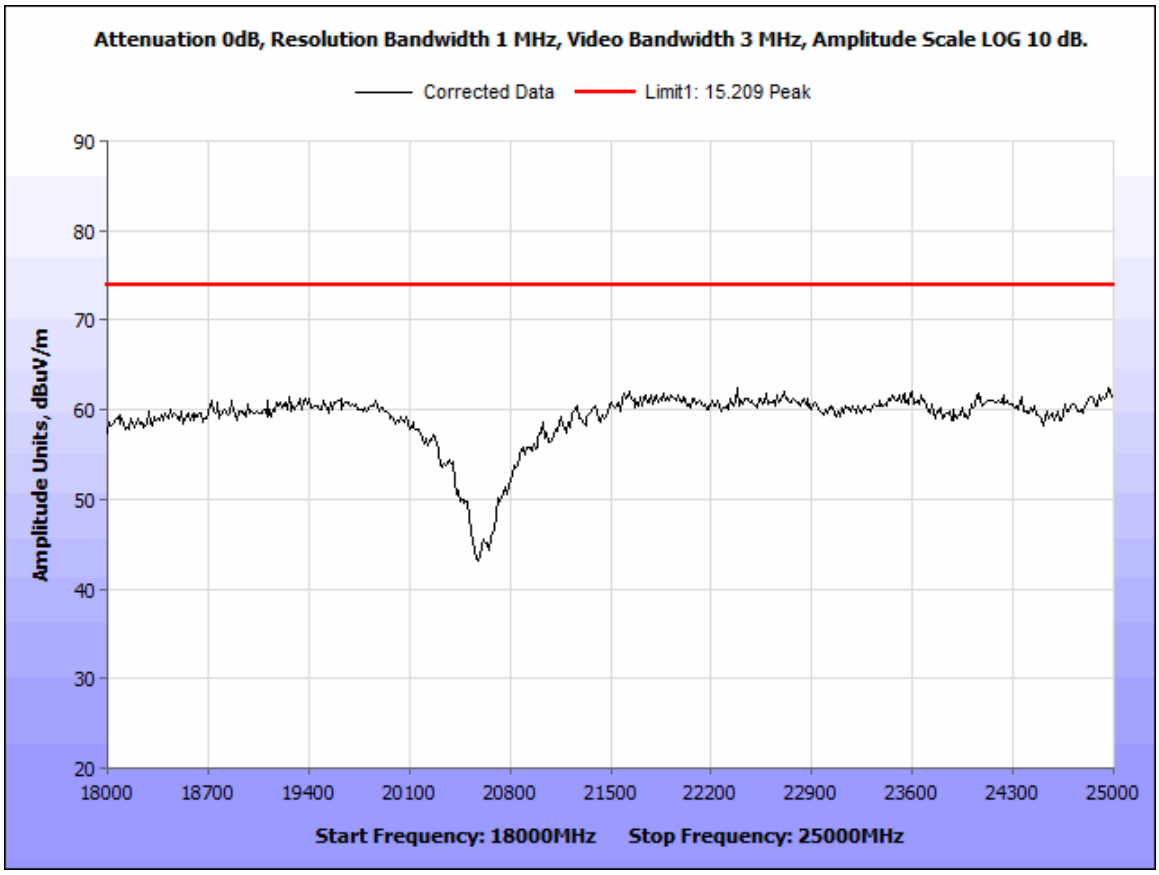

Figure 42: Radiated Spurious Emissions, Peak - Worst Case - 18-25GHz

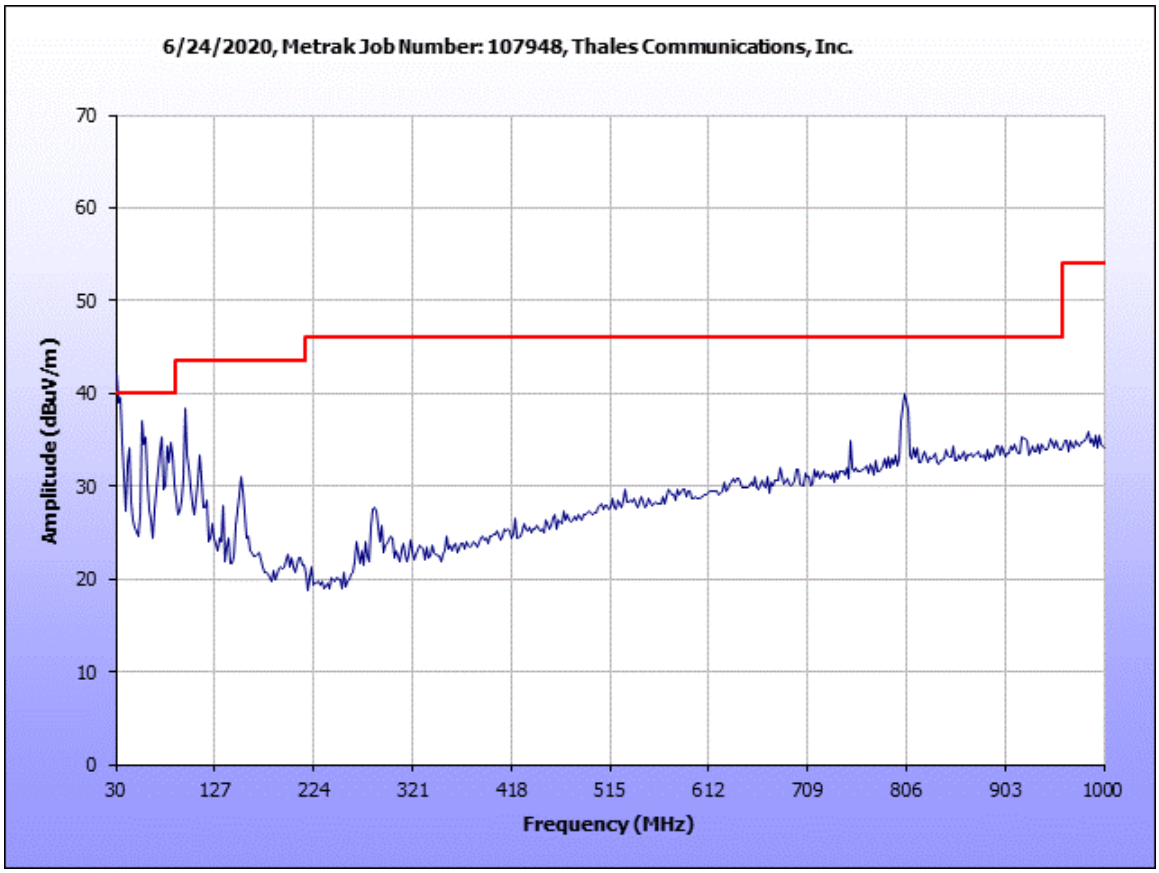

Figure 43: Radiated Spurious Emissions - Worst Case – 30-1000MHz

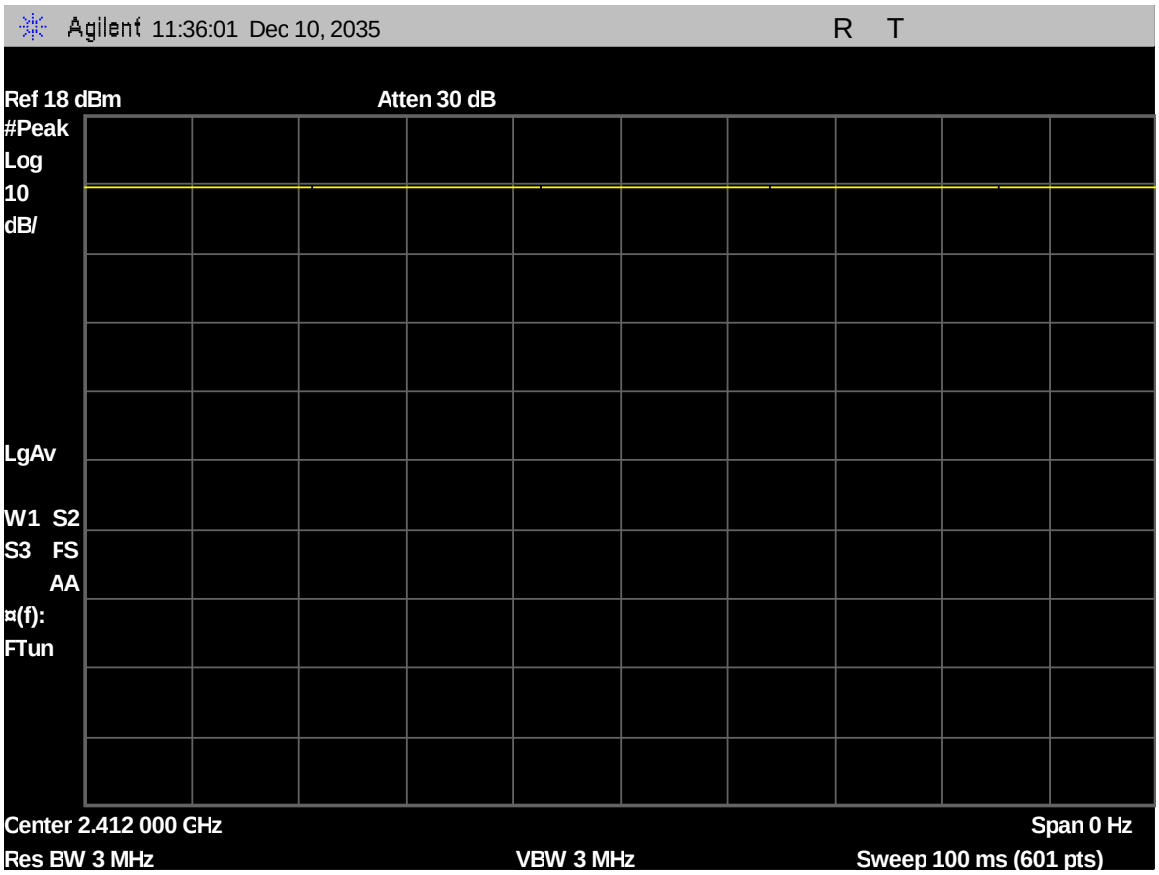

Figure 44: Radiated Spurious Emissions, DC - 802.11b

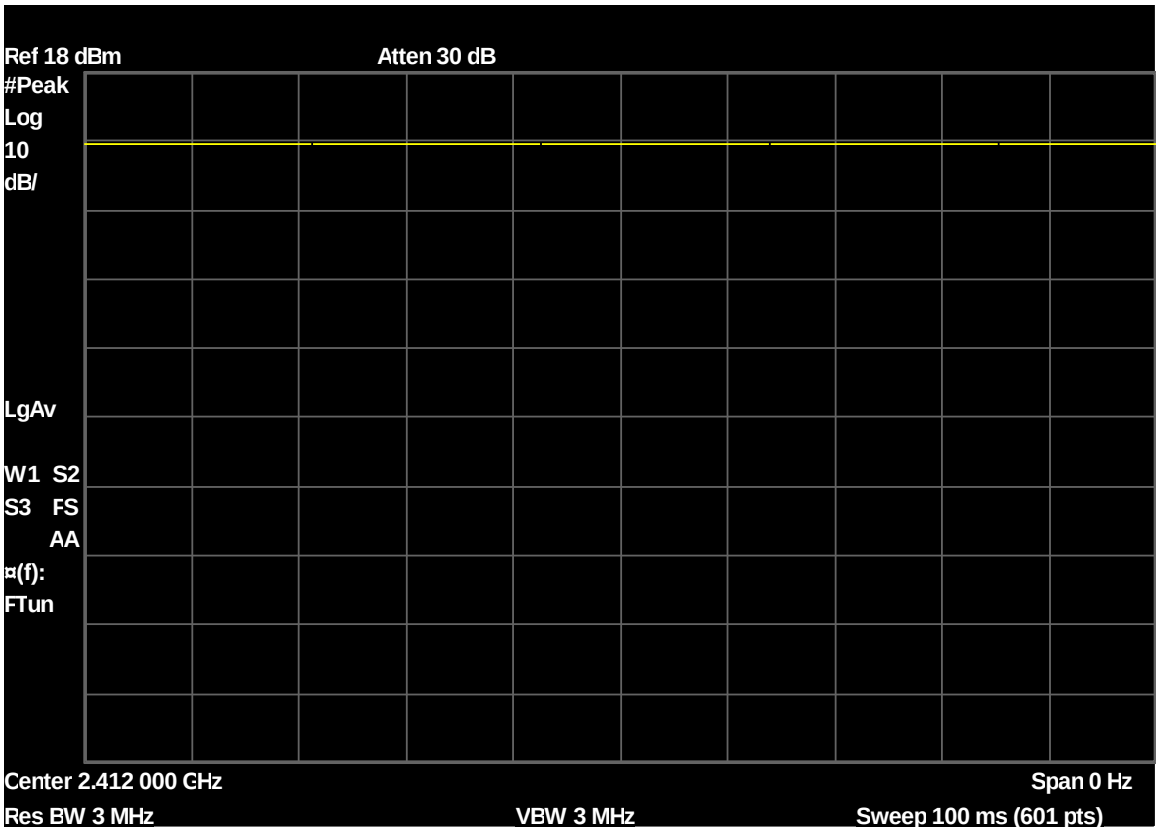

Figure 45: Radiated Spurious Emissions, DC - 802.11g

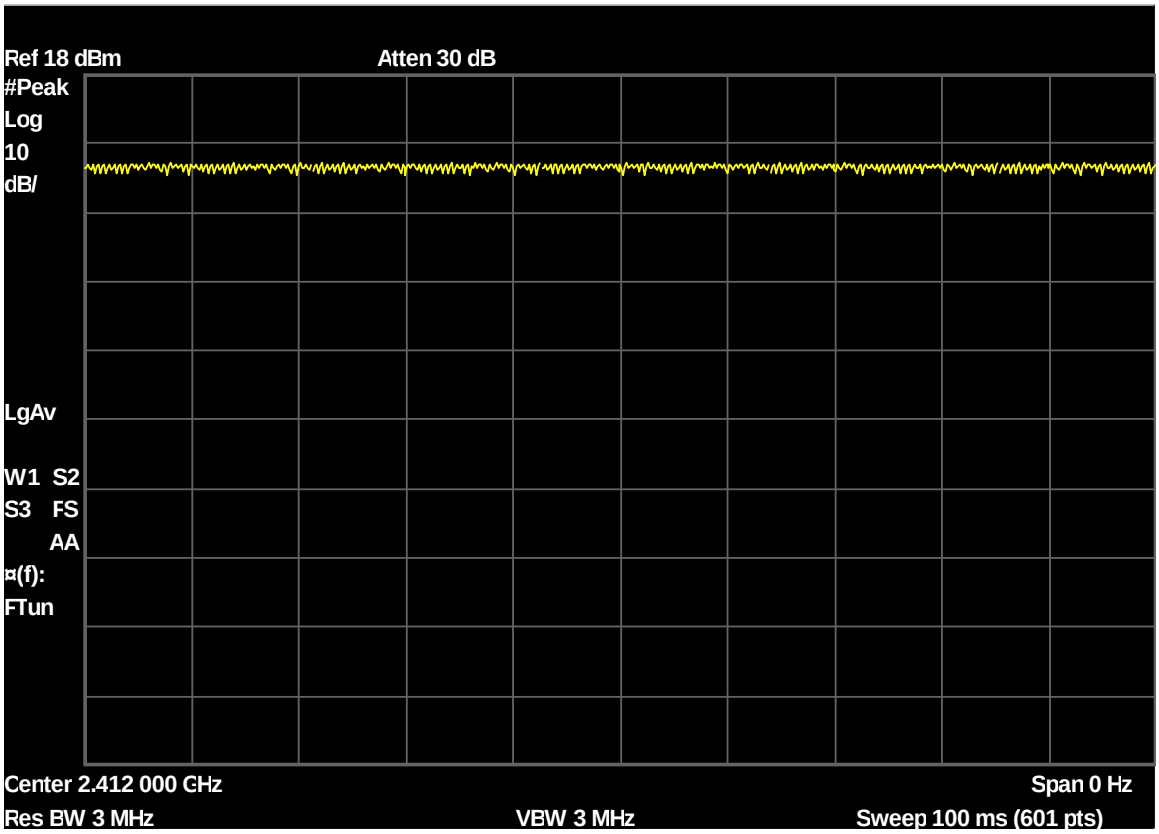

Figure 46: Radiated Spurious Emissions, DC - 802.11n20

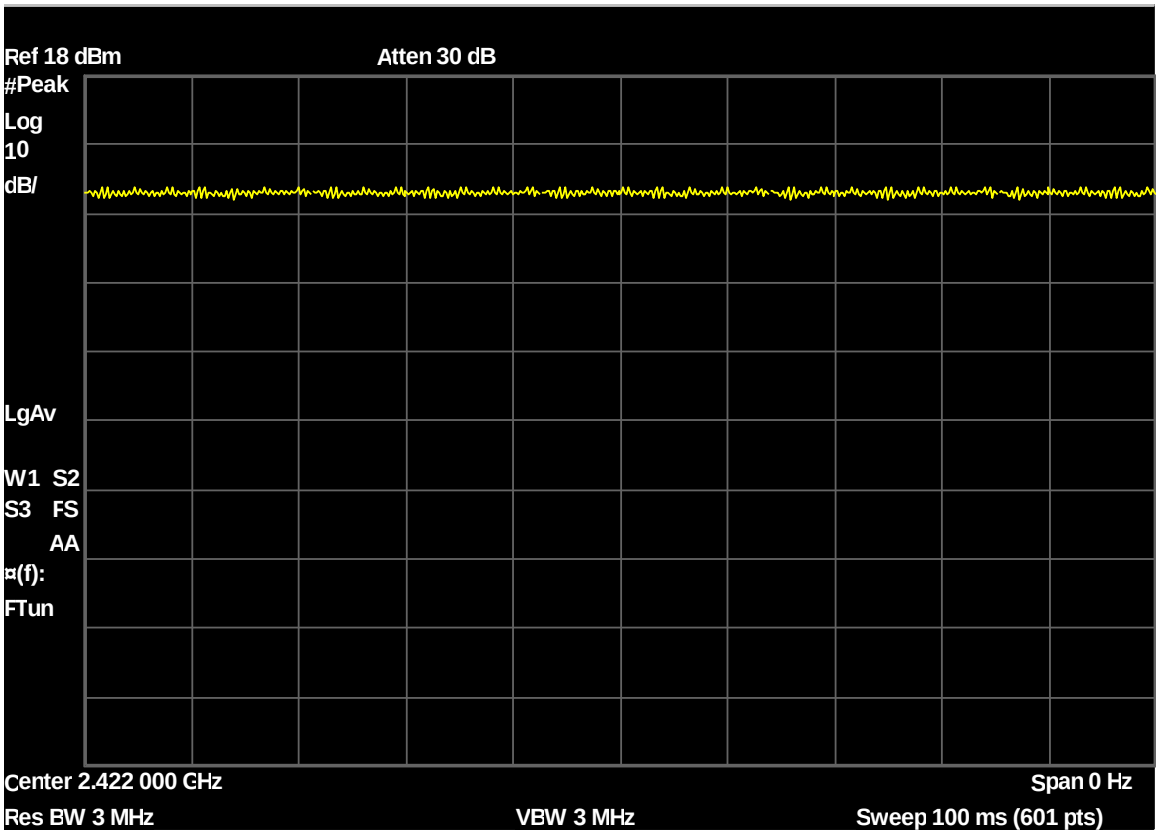

Figure 47: Radiated Spurious Emissions, DC - 802.11n40

Radiated Band Edge Measurements

Test Procedures: The transmitter was turned on. Measurements were performed of the low and high Channels. The EUT was rotated orthogonally through all three axes. Plots shown are corrected for both antenna correction factor and distance and compared to a 3 m limit line.

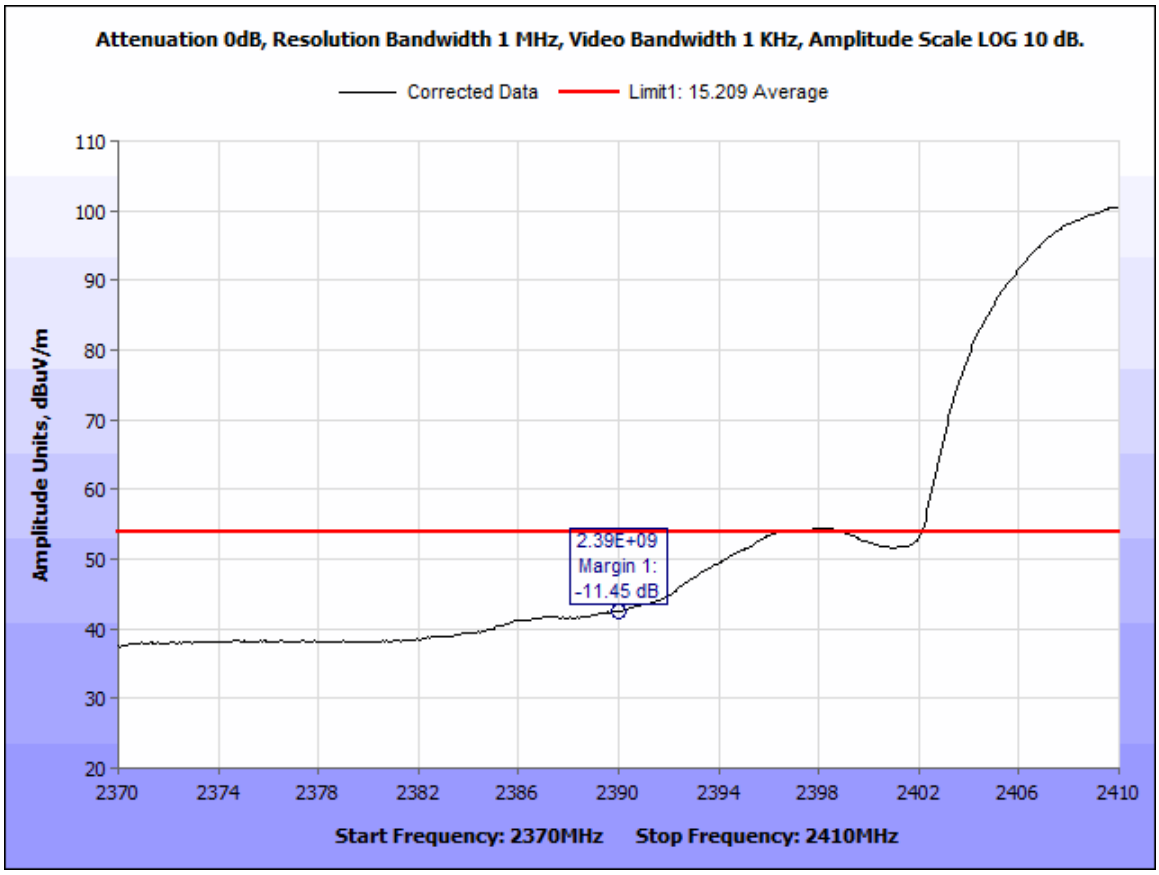

Figure 48: Radiated Spurious Emissions, 802.11b - Average Radiated Band Edge - 2390MHz - CF 2412 MHz

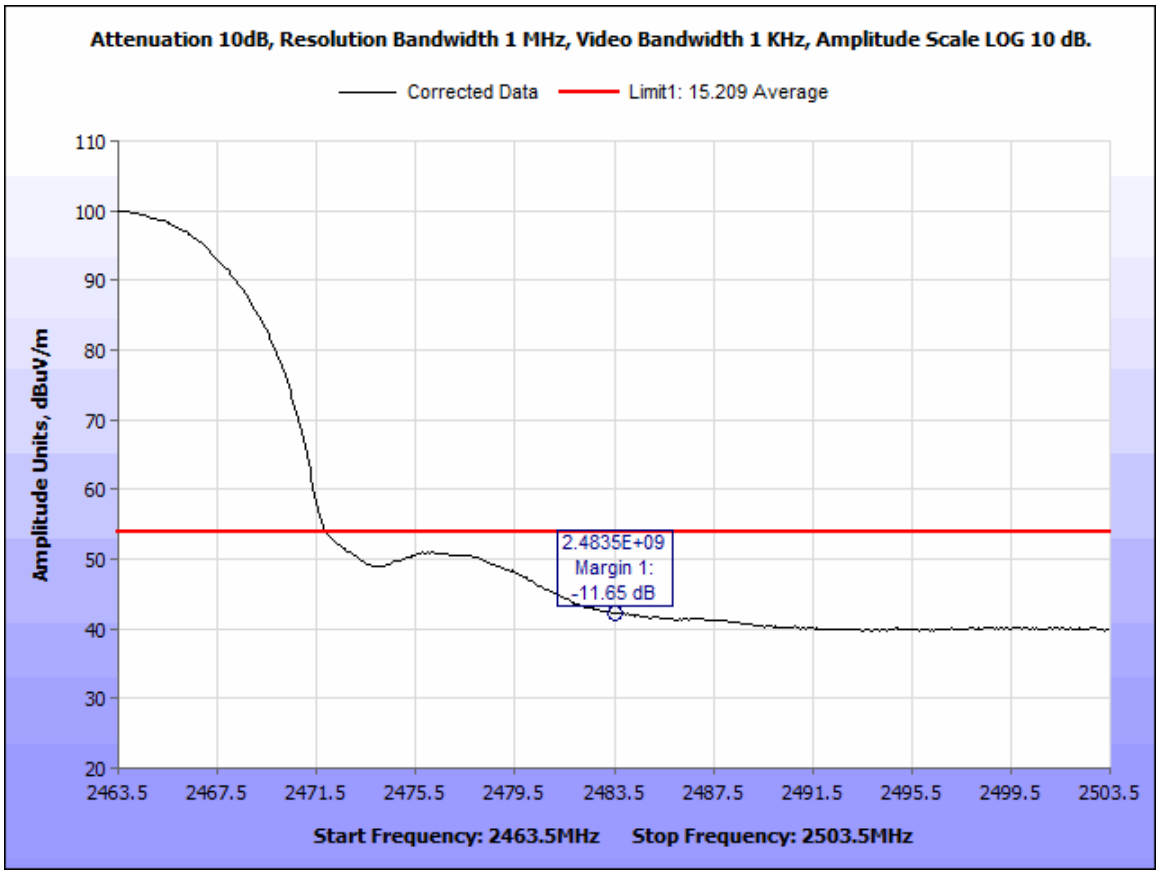

Figure 49: Radiated Spurious Emissions, 802.11b - Average Radiated Band Edge - 2483.5MHz - CF 2462 MHz

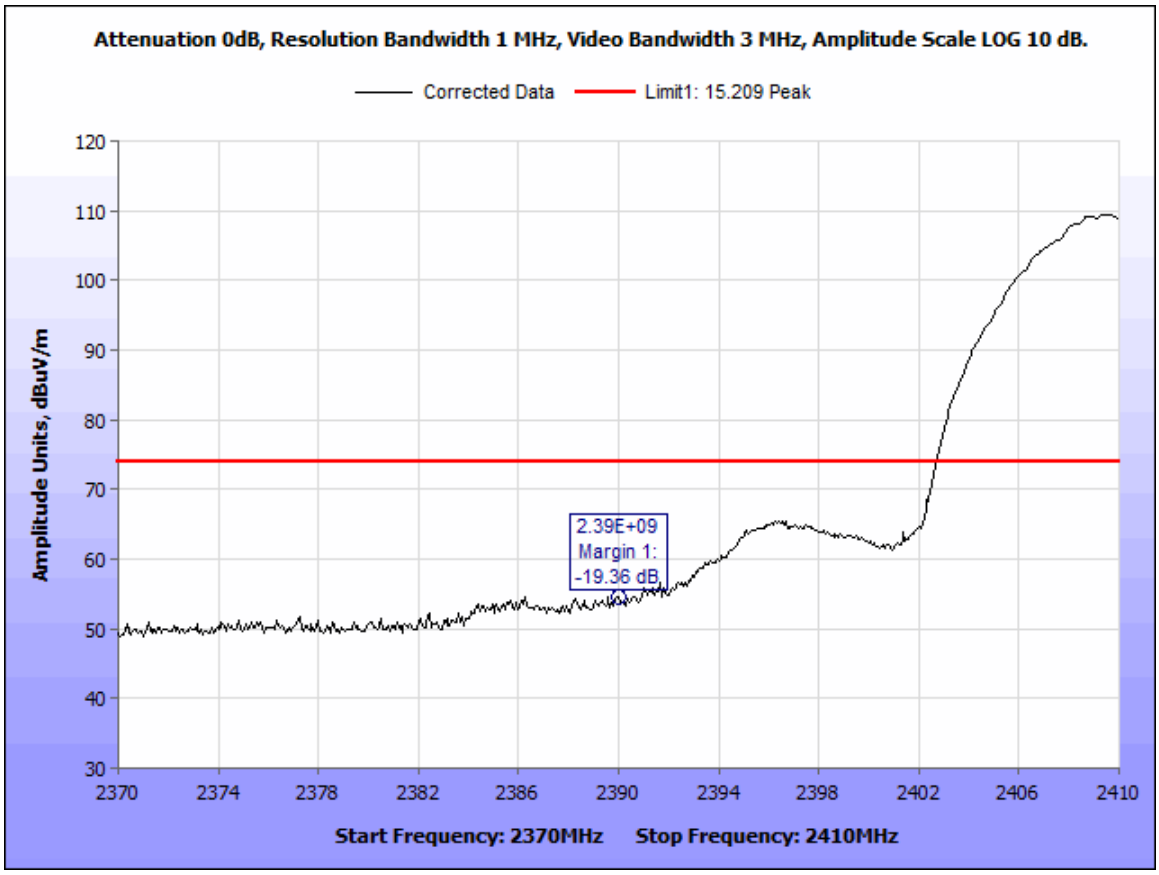

Figure 50: Radiated Spurious Emissions, 802.11b - Peak Radiated Band Edge - 2390MHz - CF 2412 MHz

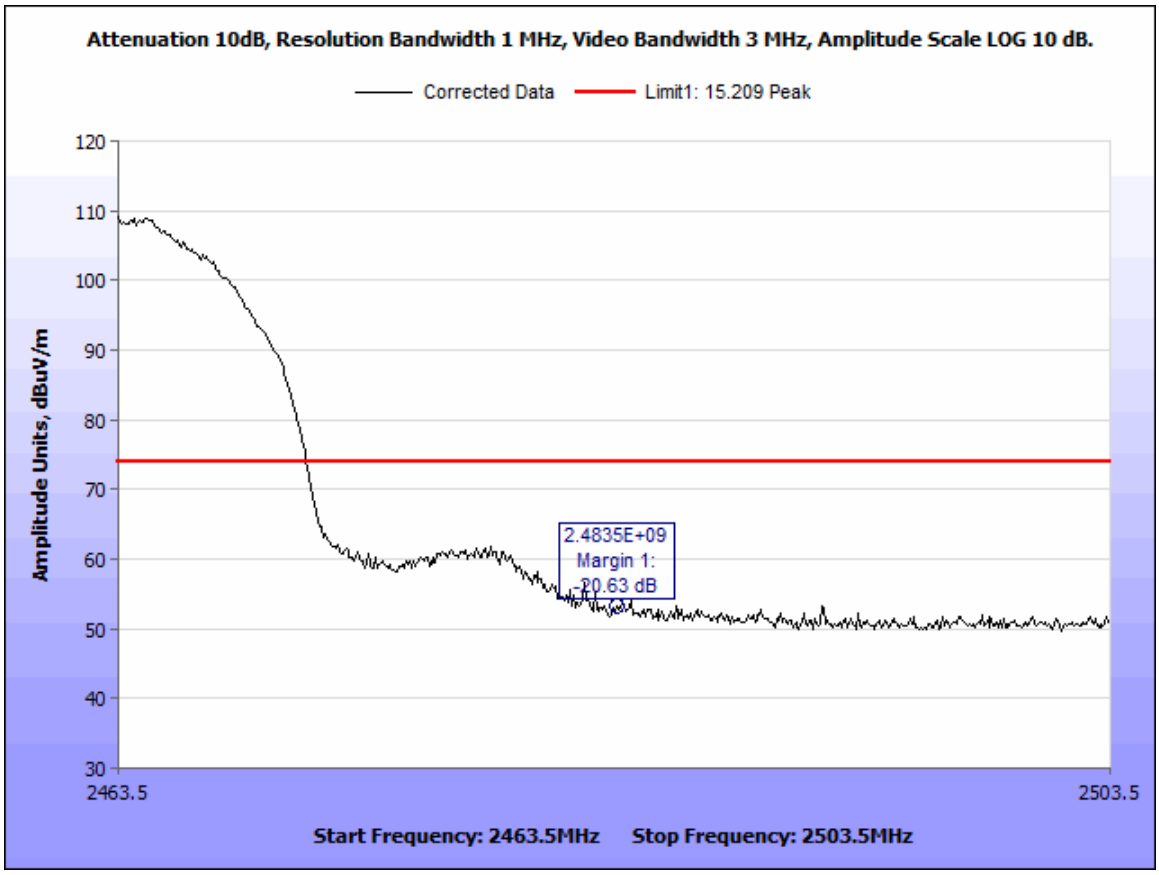

Figure 51: Radiated Spurious Emissions, 802.11b - Peak Radiated Band Edge - 2483.5MHz - CF 2462 MHz

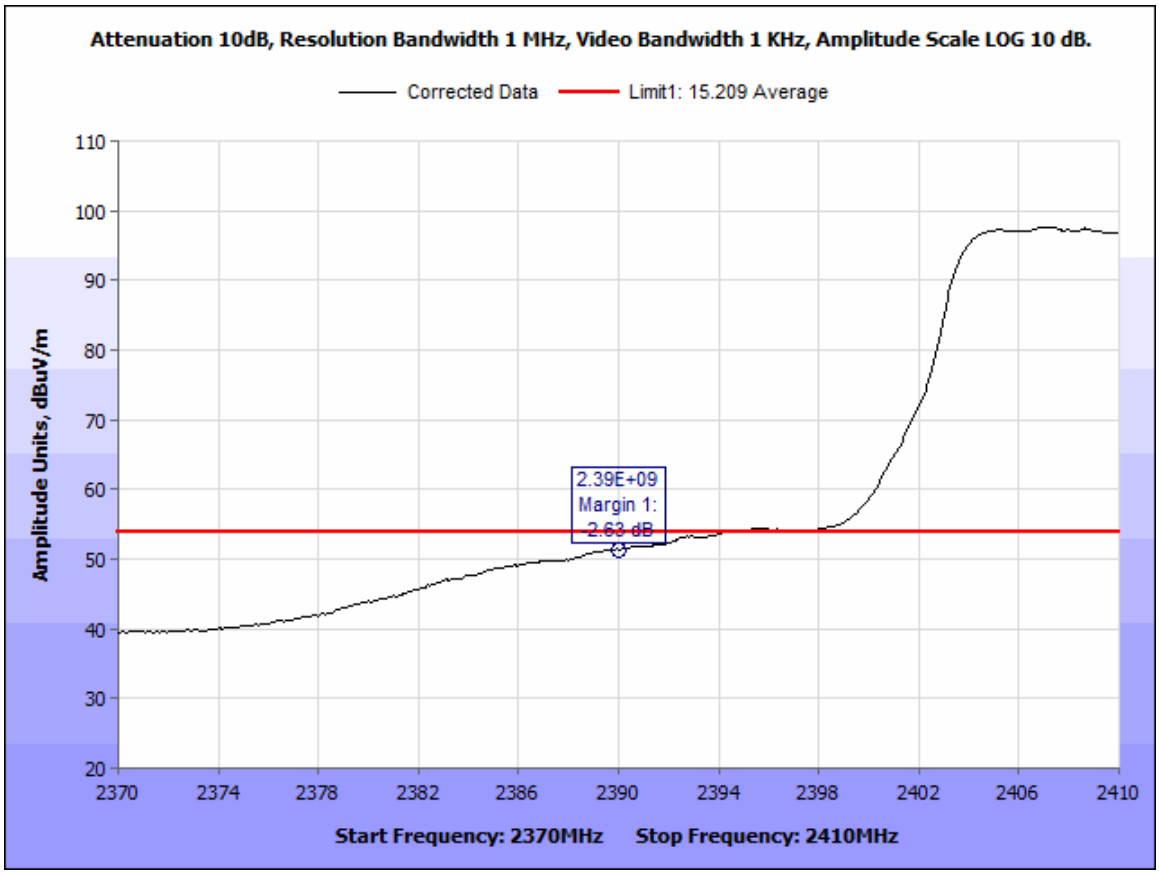

Figure 52: Radiated Spurious Emissions, 802.11g - Average Radiated Band Edge - 2390MHz - CF 2412 MHz

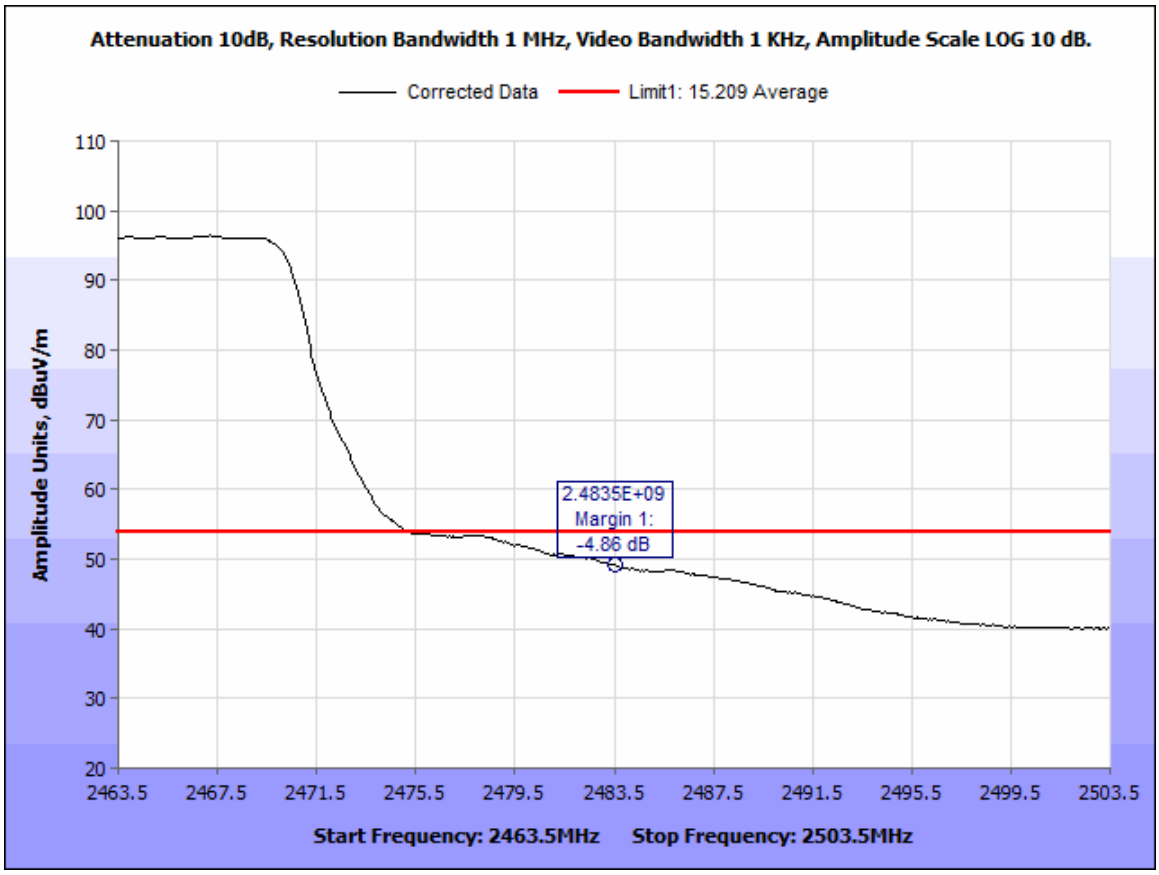

Figure 53: Radiated Spurious Emissions, 802.11g - Average Radiated Band Edge - 2483.5MHz - CF 2462 MHz

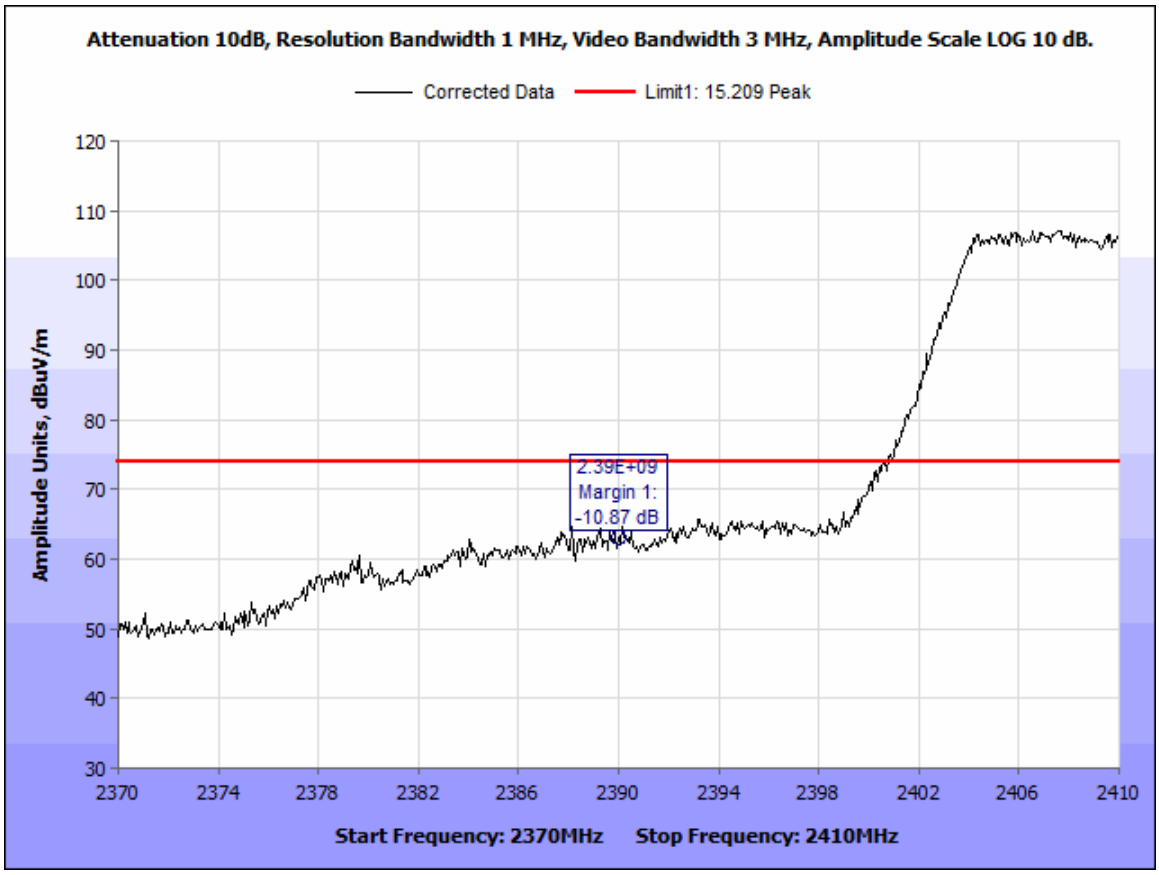

Figure 54: Radiated Spurious Emissions, 802.11g - Peak Radiated Band Edge - 2390MHz - CF 2412 MHz

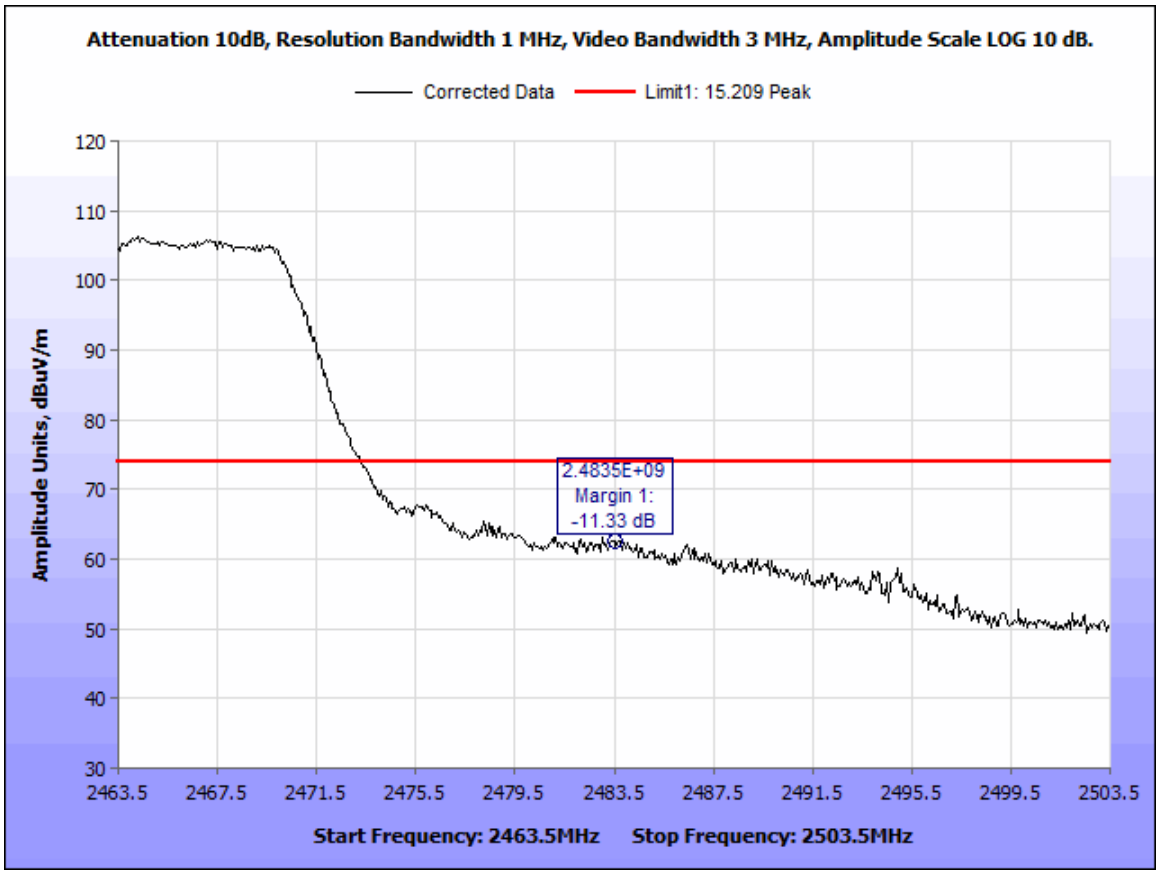

Figure 55: Radiated Spurious Emissions, 802.11g - Peak Radiated Band Edge - 2483.5MHz - CF 2462 MHz

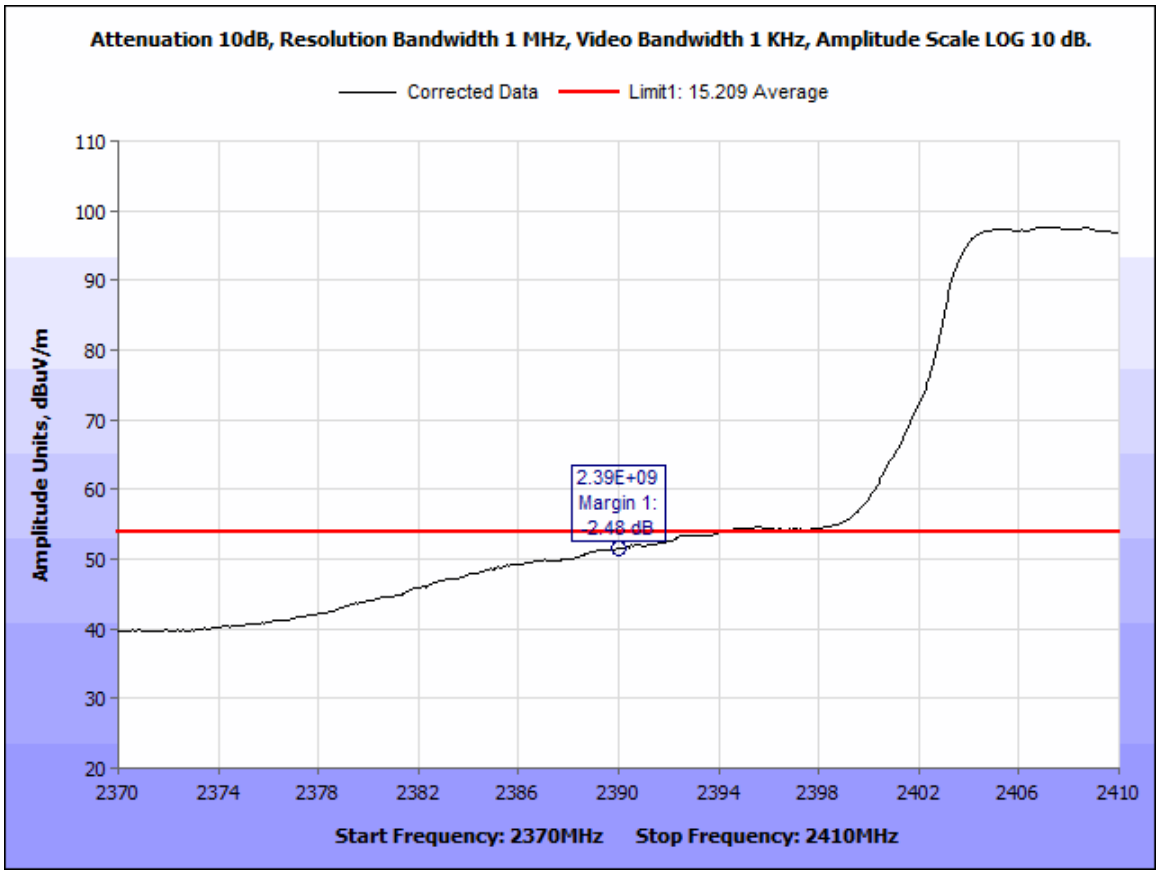

Figure 56: Radiated Spurious Emissions, 802.11n20 - Average Radiated Band Edge - 2390MHz - CF 2412 MHz

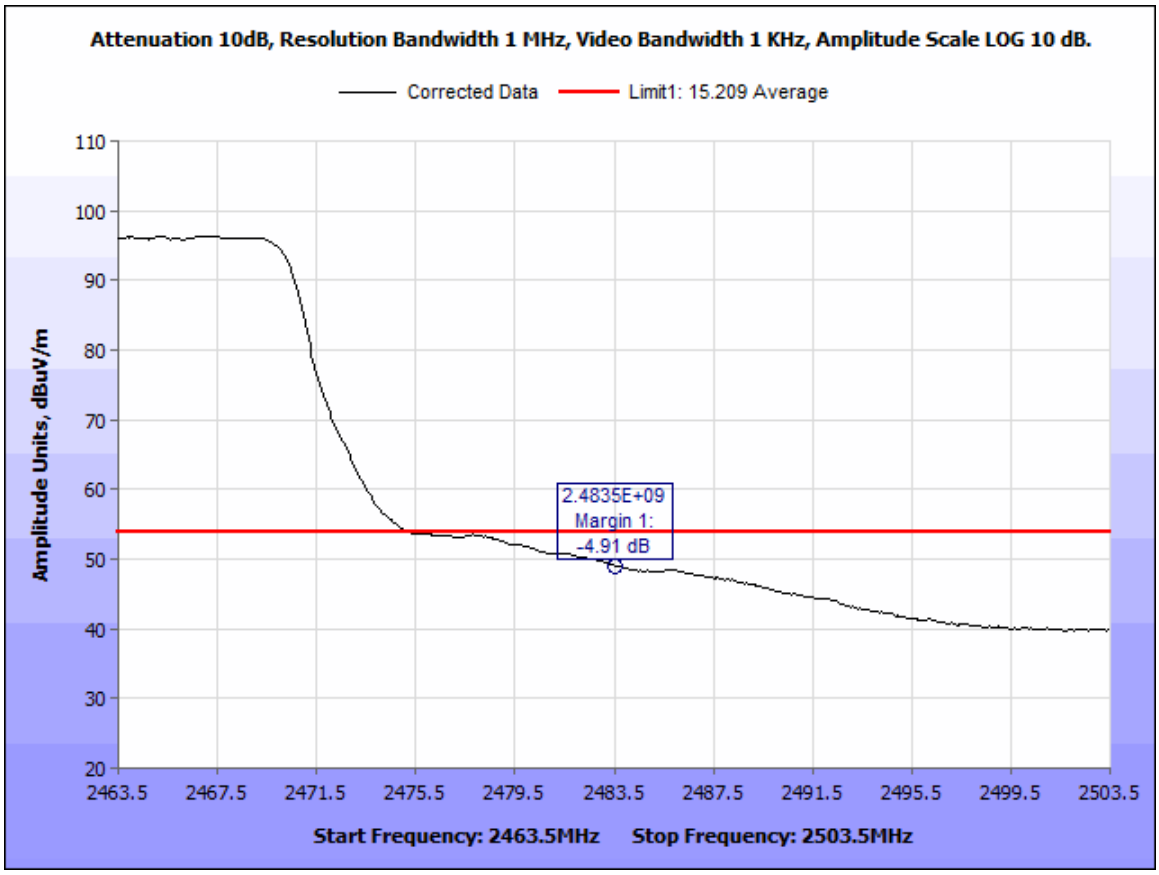

Figure 57: Radiated Spurious Emissions, 802.11n20 - Average Radiated Band Edge - 2483.5MHz - CF 2462 MHz

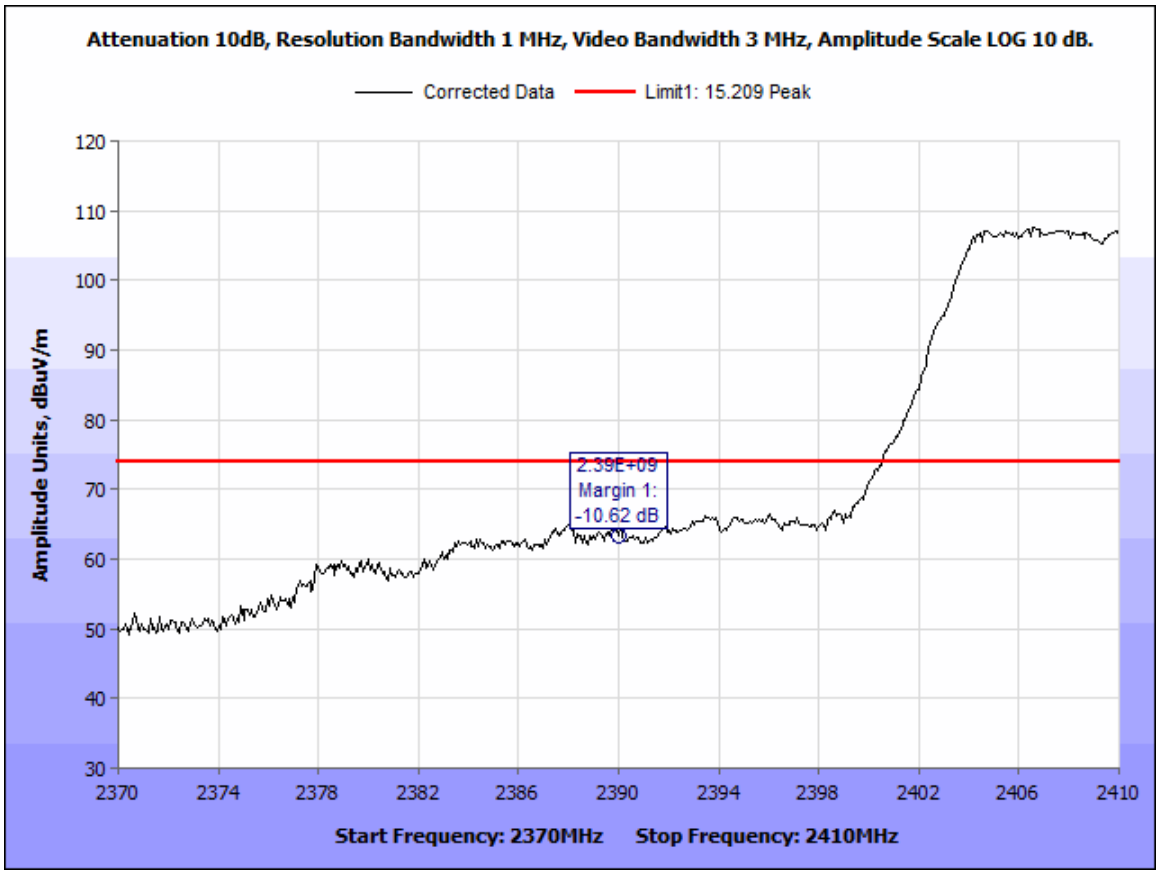

Figure 58: Radiated Spurious Emissions, 802.11n20 - Peak Radiated Band Edge - 2390MHz - CF 2412 MHz

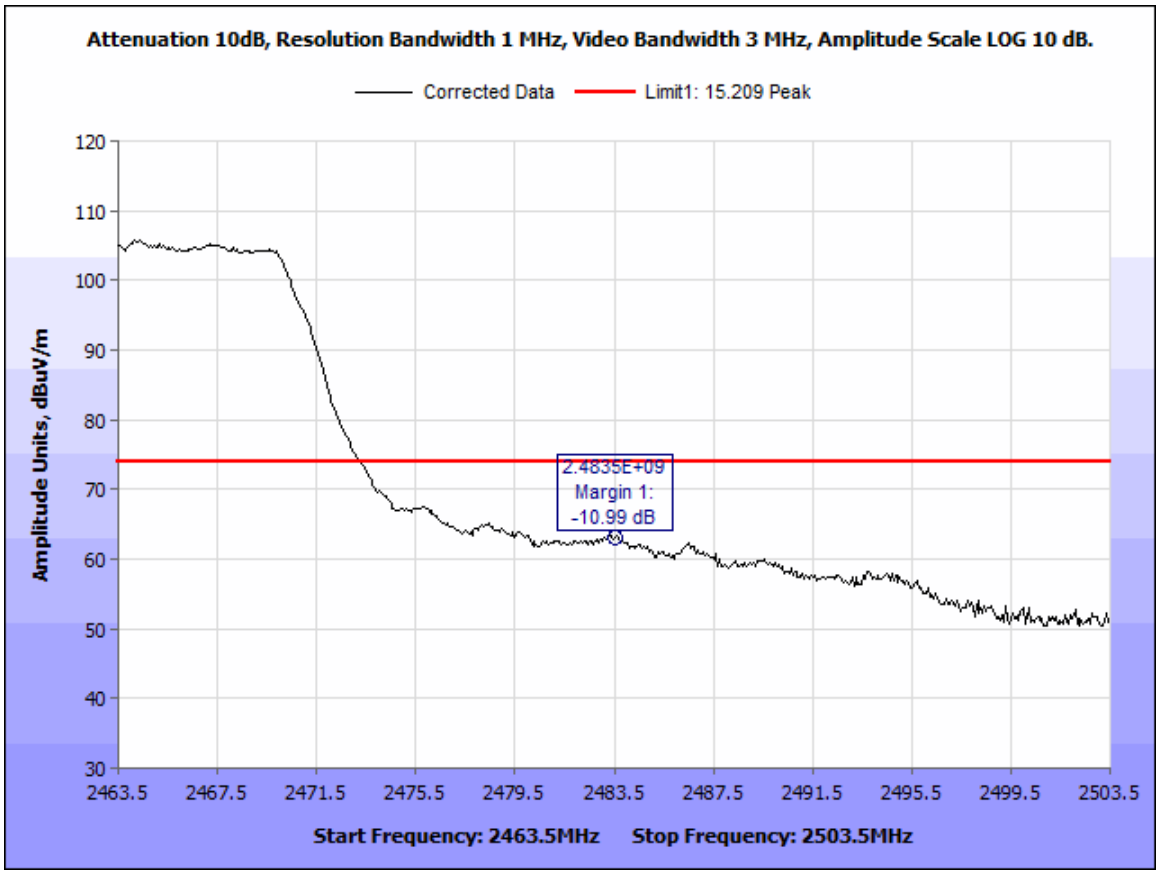

Figure 59: Radiated Spurious Emissions, 802.11n20 - Peak Radiated Band Edge - 2483.5MHz - CF 2462 MHz

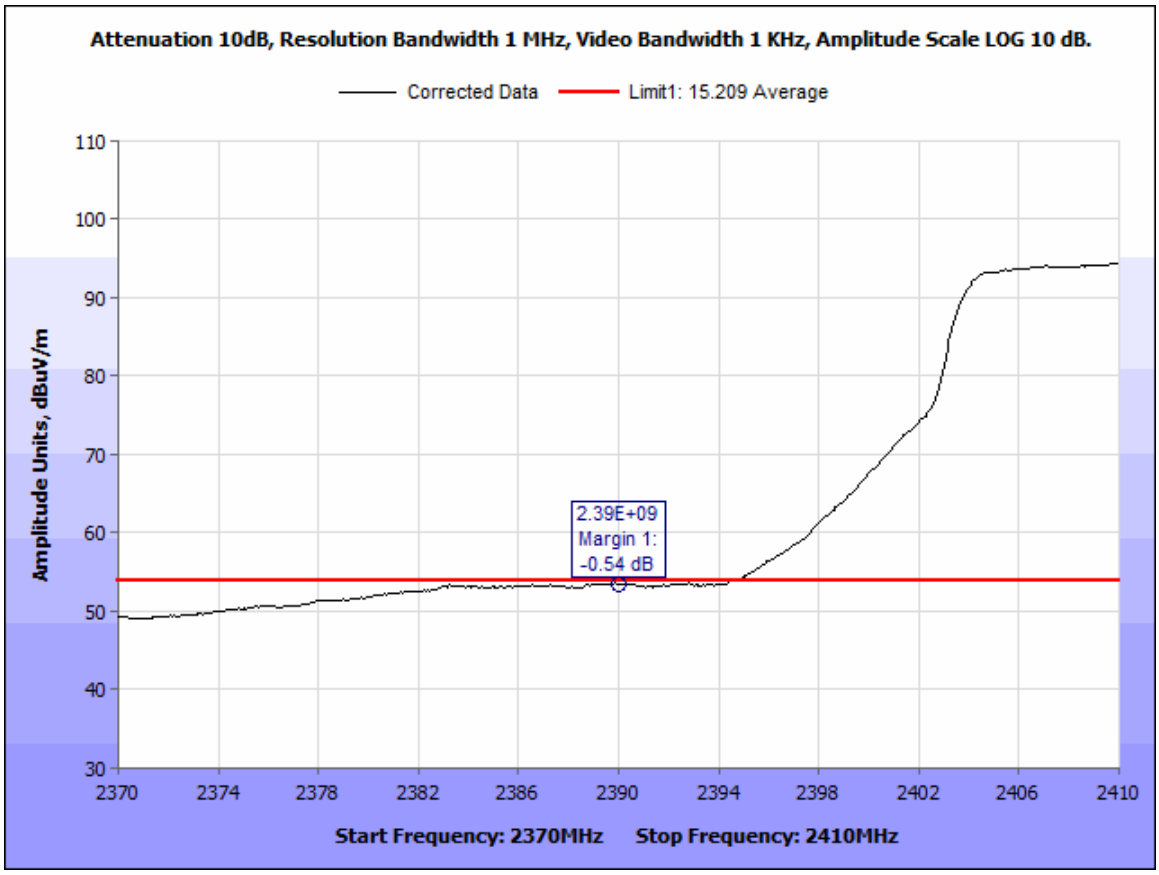

Figure 60: Radiated Spurious Emissions, 802.11n40 - Average Radiated Band Edge - 2390MHz - CF 2422 MHz

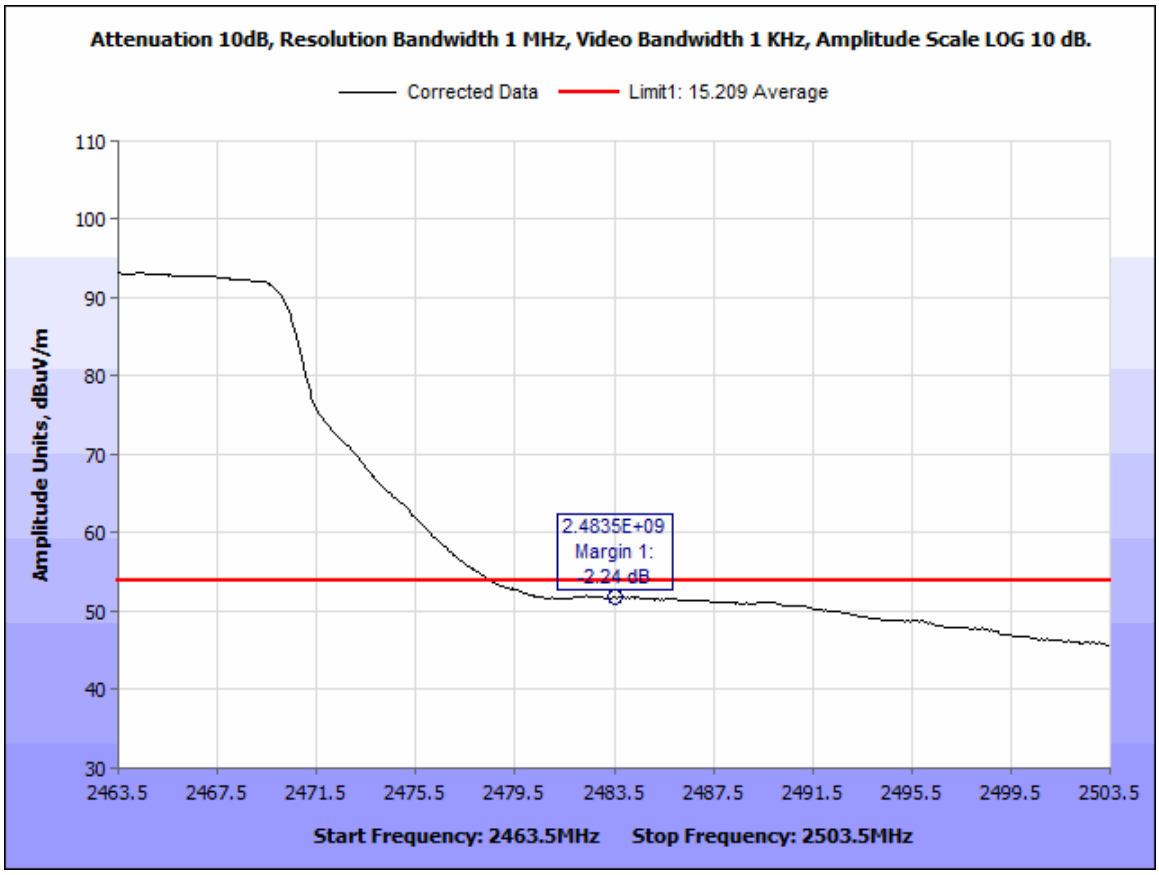

Figure 61: Radiated Spurious Emissions, 802.11n40 - Average Radiated Band Edge - 2483.5MHz - CF 2452 MHz

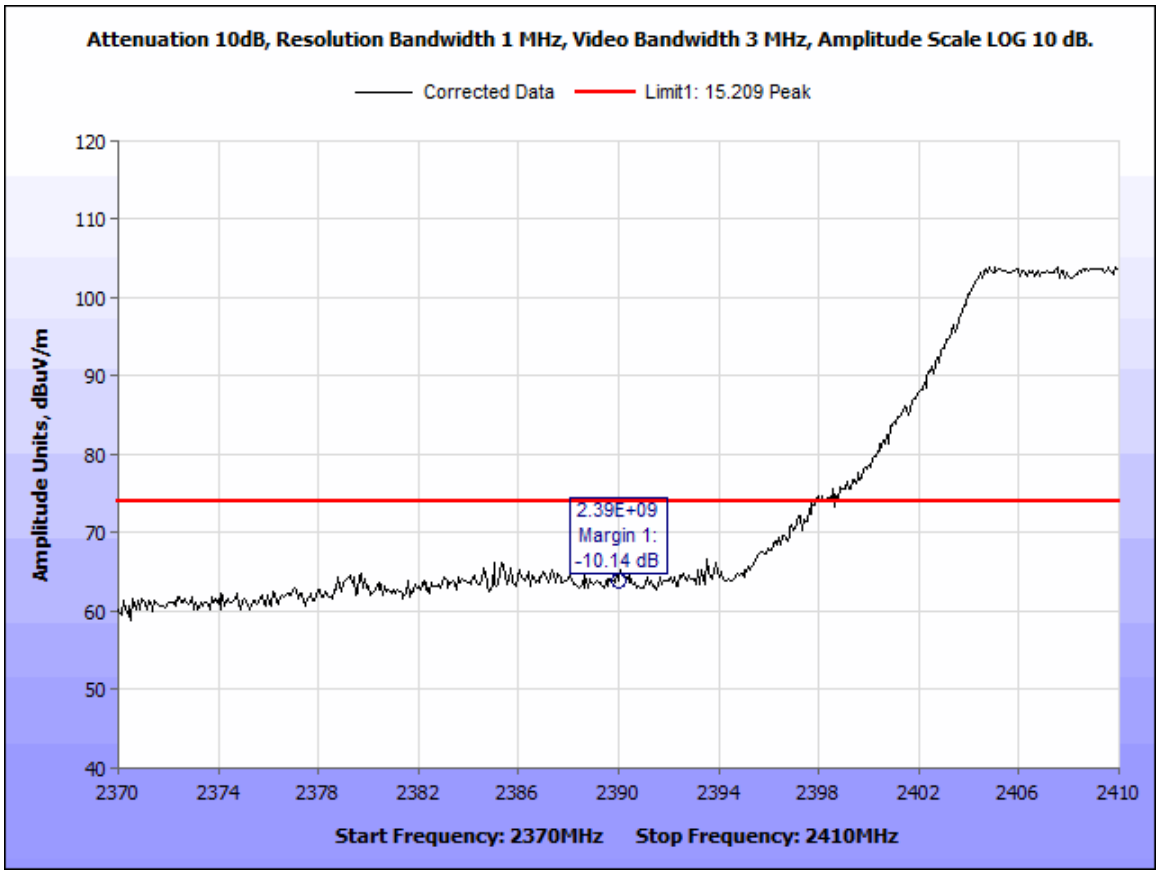

Figure 62: Radiated Spurious Emissions, 802.11n40 - Peak Radiated Band Edge - 2390MHz - CF 2422 MHz

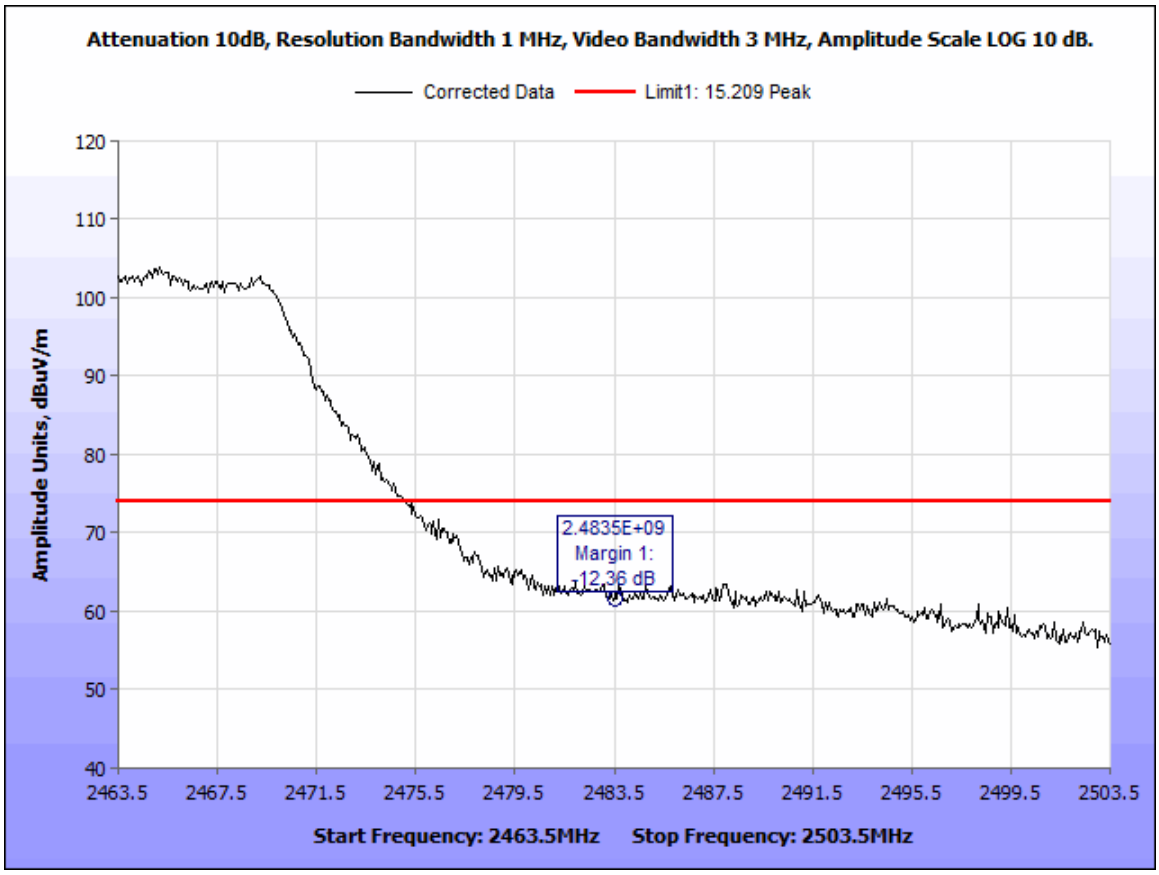

Figure 63: Radiated Spurious Emissions, 802.11n40 - Peak Radiated Band Edge - 2483.5MHz - CF 2452 MHz

Radiated Emissions Test Setup

Figure 64: Radiated Spurious Emissions, 1-18 GHz, Test Setup

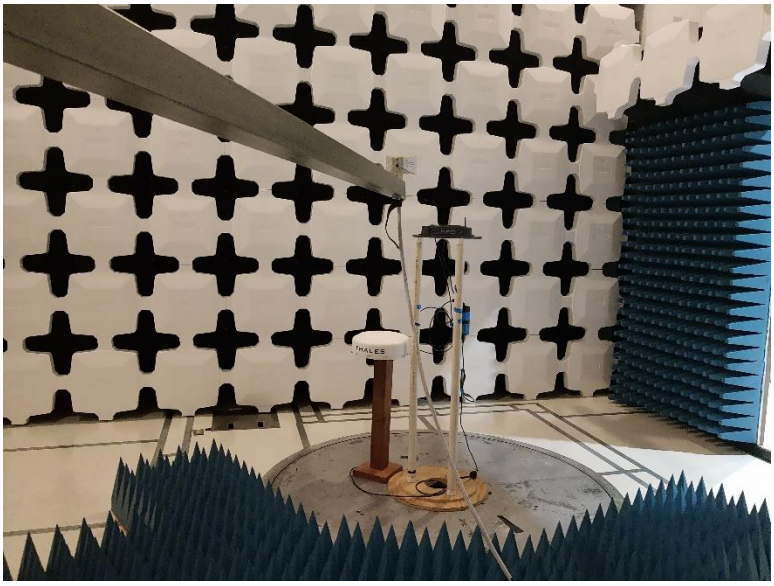

Figure 65: Radiated Spurious Emissions, 18-25 GHz, Test Setup

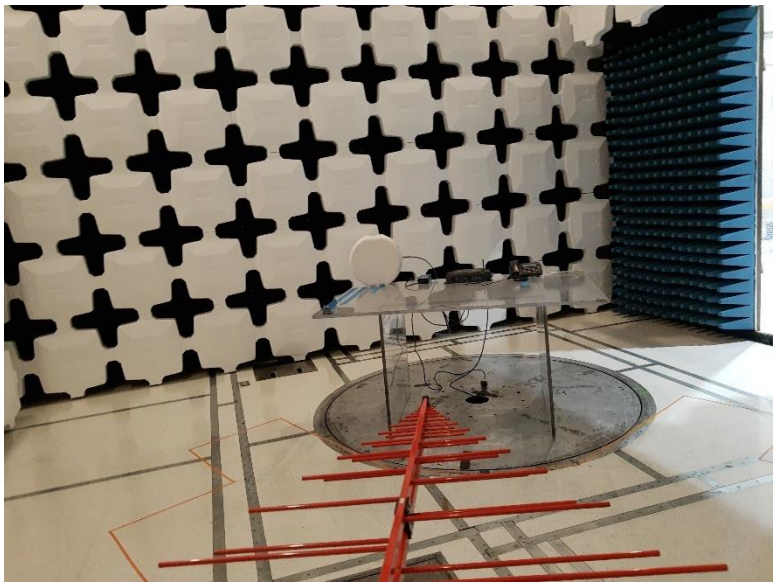

Figure 66: Radiated Spurious Emissions, 30-1000 MHz, Test Setup

Electromagnetic Compatibility Criteria for Intentional Radiators

§ 15.247(i) Maximum Permissible Exposure

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.

Test Results:

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**
2412	17.0	50.119	2	1.585	0.0158	1	0.9842	20	Pass

Conducted power accounts for a 1dB tune-up tolerance.

The safe distance where Power Density is less than the MPE Limit listed above was found to be _20_ cm.

Test Equipment

Test Equipment

Calibrated test equipment utilized during testing was maintained in a current state of calibration per the requirements of ISO/IEC 17025:2017.

ASSET	EQUIPMENT	MANUFACTURER	MODEL	CAL DATE	CAL DUE
1T4409	EMI RECEIVER	ROHDE & SCHWARZ	ESIB7	1/4/2019	1/4/2021
1T4771	PSA SPECTRUM ANALYZER	AGILENT TECHNOLOGIES	E4446A	2/26/2020	8/26/2021
1T4300B	SEMI-ANECHOIC 3M CHAMBER SVSWR	EMC TEST SYSTEMS	NONE	6/30/2019	12/30/2020
1T4300	SEMI-ANECHOIC CHAMBER (NSA)	EMC TEST SYSTEMS	NONE	6/30/2019	6/30/2020
1T4751	ANTENNA - BILOG	SUNOL SCIENCES	JB6	5/2/2019	11/2/2020
1T4576	ANTENNA, ACTIVE HORN	COM-POWER	AHA-118	5/8/2019	11/8/2020
1T4414	MICROWAVE PRE-AMPLIFIER	A.H. SYSTEMS, INC.	PAM-0118	FUNC VERIFY	FUNC VERIFY
1T4745	ANTENNA, HORN	ETS-LINDGREN	3116	11/27/2018	7/27/2020
1T4752	PRE-AMPLIFIER	MITEQ	JS44-18004000-35-8P	FUNC VERIFY	FUNC VERIFY

Figure 67: Test Equipment List

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

Certification & User's Manual Information

Certification & User's Manual Information

M. 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 proviso that such a determination of compliance be made and is the responsibility of the party responsible for verification of the equipment.

Certification & User's Manual Information

The following is extracted from Title 47 of the Code of Federal Regulations, Part 2, Subpart J — 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.

§ 2.907 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.

Certification & User's Manual Information

§ 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.

Certification & User's Manual Information

1. 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 user's 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.

Verification & User's Manual Information

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 A 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 A 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 commercial 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. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at own expense.

(b) 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