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Report On

Application for Grant of Equipment Authorization of the
Oculus VR, LLC
Touch Wireless Tracking Input Device

FCC Part 15 Subpart C §15.247 (FHSS)
IC RSS-247 Issue 1 May 2015
IC RSS-Gen Issue 4, November 2014

Report No. SD72112194-0616A **September 2016**

REPORT ON	Radio Testing of the Oculus VR, LLC Wireless Tracking Input Device
TEST REPORT NUMBER	SD72112194-0616A
PREPARED FOR	Oculus VR, LLC 1 Hacker Way Menlo Park, CA 94025
CONTACT PERSON	Pelagio Payumo Consumer Product Health & Safety Manager (408) 564-9962 pelagio.payumo@oculus.com
PREPARED BY	Ferdinand S. Custodio **Name** Authorized Signatory Title: EMC/Senior Wireless Test Engineer
APPROVED BY	Juan Manuel Gonzalez Name Authorized Signatory Title: EMC SL Manager West Region
DATED	September 21, 2016

TÜV SÜD AMERICA INC 10040 Mesa Rim Road San Diego, CA 92121-2912 Phone: 858 678 1400 FAX: 858 546 0364

Revision History

SD72112194-0616A Oculus VR, LLC Touch Wireless Tracking Input Device					
DATE	OLD REVISION	NEW REVISION	REASON	PAGES AFFECTED	APPROVED BY
09/21/2016	Initial Release				Juan Manuel Gonzalez

CONTENTS

TÜV SÜD AMERICA INC 10040 Mesa Rim Road San Diego, CA 92121-2912 Phone: 858 678 1400 FAX: 858 546 0364

SECTION 1

REPORT SUMMARY

Radio Testing of the
Oculus VR, LLC
Wireless Tracking Input Device

1.1 INTRODUCTION

The information contained in this report is intended to show verification of the Oculus VR, LLC Touch Wireless Tracking Input Device to the requirements of FCC Part 15 Subpart C §15.247 and IC RSS-247 Issue 1 May 2015.

Objective	To perform Radio Testing to determine the Equipment Under Test's (EUT's) compliance with the Test Specification, for the series of tests carried out.
Manufacturer	Oculus VR, LLC
Model Number(s)	TO-R and TO-L
FCC ID Number	2AGOZTO-R and 2AGOZTO-L
IC Number	20849-TOR and 20849-TOL
Serial Number(s)	WMTCL5371001XV and WMTCR5371003UH (Engineering Samples)
Number of Samples Tested	2
Test Specification/Issue/Date	• FCC Part 15 Subpart C §15.247 (October 1, 2015). • IC RSS-247 Issue 1 May 2015 Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices. • IC RSS-Gen Issue 4, November 2014 - General Requirements for Compliance of Radio Apparatus (Issue 4, November 2014). • ANSI C63.10-2013. American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
Start of Test	September 12, 2016
Finish of Test	September 21, 2016
Name of Engineer(s)	Ferdinand Custodio
Related Document(s)	• General instructions provided by the client was hardcopy. • SD72112194-1215A Facebook Oculus HM-A FCC IC Part 15.247 RSS247 Test Report.docx • Supporting documents for EUT certification are separate exhibits.

1.2 BRIEF SUMMARY OF RESULTS

A brief summary of the tests carried out in accordance with FCC Part 15 Subpart C §15.247 with cross-reference to the corresponding IC RSS standard is shown below.

Section	§15.247 Spec Clause	RSS	Test Description	Result
-	§15.207 (a)	RSS-Gen 8.8	Conducted Emissions	N/A
2.1	§15.247(a)(1)	RSS-247 5.1 (2)	Carrier Frequency Separation	Compliant*
2.2	§15.247(a)(1)(iii)	RSS-247 5.1 (4)	Number of Hopping Frequencies	Compliant*
2.3	§15.247(a)(1)(iii)	RSS-247 5.1 (4)	Time of Occupancy (Dwell Time)	Compliant*
2.4	§15.215(c)	RSS-247 5.1 (1)	20 dB Bandwidth	Compliant*
2.5		RSS-Gen 6.6	99% Emission Bandwidth	Compliant*
2.6	§15.247(b)(1)	RSS-247 5.4 (2)	Peak Output Power	Compliant
2.7	§15.247(d)	RSS-247 5.5	Band-edge Compliance of RF Conducted Emissions	Compliant
2.8			Spurious RF Conducted Emissions	Compliant
2.9	ANSI C63.10-2013 Clause 11.12.2.1	RSS-Gen 8.9 and 8.10	Cabinet/Case Radiated Emissions	Compliant

N/A - *Not applicable. EUT is a battery operated device.*

Compliant* - *Test results from SD72112194-1215A Facebook Oculus HM-A FCC IC Part 15.247 RSS247 Test Report.docx applies. Antenna conducted port verifications were performed on the Headset Master (HMD) that has the same RF chip and identical modulation scheme as the EUT*

1.1 PRODUCT INFORMATION

1.1.1 Technical Description

The Equipment Under Test (EUT) was an Oculus VR, LLC Touch Wireless Tracking Input Device as shown in the photograph below. The EUT are motion controllers for the Oculus Rift Virtual Reality Headset System. The EUT features traditional gamepad buttons, capacitive-sensitive control surfaces, proximity-sensitive control surfaces, triggers and thumb sticks.

Equipment Under Test

1.1.2 EUT General Description

EUT Description	Wireless Tracking Input Device
Model Name	Touch
Model Number(s)	TO-R and TO-L
Rated Voltage	AA Battery (LR6 1.5V)
Mode Verified	Proprietary 2.4GHz FHSS in the ISM Band
Capability	Proprietary 2.4GHz FHSS in the ISM Band
Modulation	GFSK
Primary Unit (EUT)	☐ Production
	☐ Pre-Production
	☒ Engineering
Antenna Type	2.4GHz Ceramic Chip antenna
Antenna Manufacturer	PSA Walsin Technology Corporation
Antenna Model Number	RFANT3216120A5T Series
Antenna Dimensions	3.2mm x 1.6mm x 1.2mm
Antenna Gain	2.12dBi

1.1.3 Maximum Conducted Output Power

Model	Mode	Frequency Range (MHz)	AverageOutput Power (dBm))	Peak Output Power (dBm)	Peak Output Power (mW)
TO-L	FHSS	2404-2478	1.76	4.72	2.96
TO-R	FHSS	2404-2478	1.50	4.59	2.89

1.2 EUT TEST CONFIGURATION

1.2.1 Test Configuration Description

Test Configuration	Description
A	Antenna Conducted Port Single Carrier Test Mode. Actual verifications were performed on the Headset Master (HMD) that has the same RF chip; identical modulation scheme and identical radio transmit power as the EUT (Headset Master has a temporary antenna connector for conducted RF testing). The term "EUT" referred in this test report therefore applies to both the Headset Master (Conducted) and the Wireless Tracking Input Device. Manufacturer provided a Command Prompt ".exe" and batch files forcing the EUT to single carrier test mode (modulated).
B	Antenna Conducted Port Single Carrier Test Mode. A conducted sample was provided by the manufacturer with temporary antenna connector (SMA). Manufacturer provided a Command Prompt ".exe" and batch files forcing the EUT to single carrier test mode (modulated).
C	Case/cabinet radiated emission test configuration. Antenna port terminated with 50Ω load.

1.2.2 EUT Exercise Software

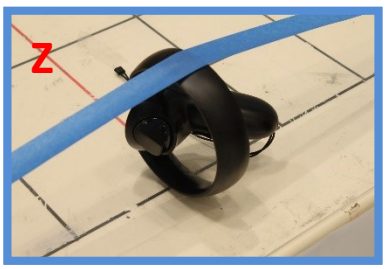
Command Prompt window on the host PC (support laptop) to program as per Test Configuration above.

1.2.3 Support Equipment and I/O cables

Manufacturer	Equipment/Cable	Description
Lenovo	Support Laptop (T410S)	P/N 0A31972 S/N R9-92MH0 10/11
LiteOn Technology Corporation	AC Adapter for Support Laptop	Model 42T4430 S/N 11S42T4430Z1ZGWE27AA9X REV G
Oculus	Support Headset Master	Build Name: EVT1-Main-04 S/N WMHE100T2000C8

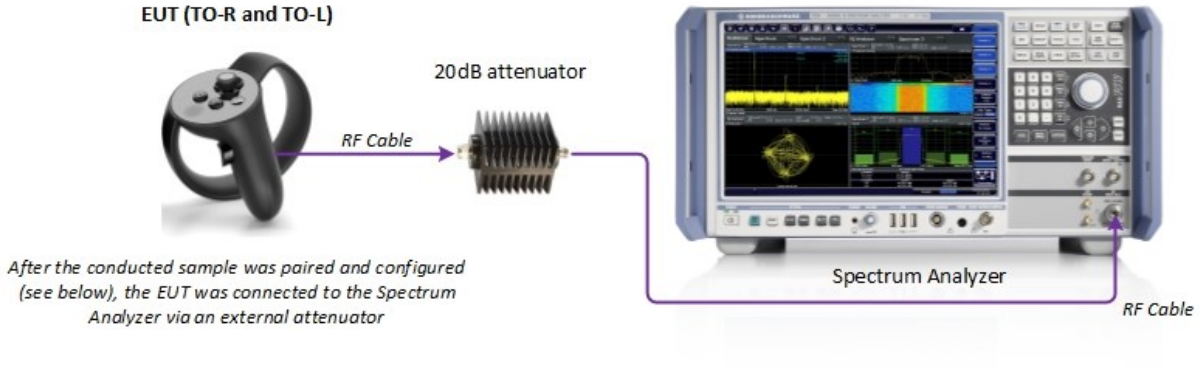
1.2.4 Worst Case Configuration

The EUT has only one modulation scheme. Being a mobile device, the EUT was verified on all axes. Only the worst axis ("X") presented in this test report for radiated measurements. Worst case Channel based from power measurements is Low channel for TO-R and Middle channel for TO-L.



1.2.5 Simplified Test Configuration Diagram

Antenna Conducted Port Verification



After the conducted sample was paired and configured (see below), the EUT was connected to the Spectrum Analyzer via an external attenuator

Radiated Emissions Test Configuration

The EUT is paired and configured wirelessly using a compatible Headset Master (HM-A). Once the EUT is configured, the unit was verified in a stand-alone configuration (see below).

Radiated Emissions Test Setup

1.3 DEVIATIONS FROM THE STANDARD

No deviations from the applicable test standards or test plan were made during testing.

1.4 MODIFICATION RECORD

Description of Modification	Modification Fitted By	Date Modification Fitted
Serial Number WMTCL5371001XV and WMTCR5371003UH		
N/A		

The table above details modifications made to the EUT during the test programme. The modifications incorporated during each test (if relevant) are recorded on the appropriate test pages.

1.5 TEST METHODOLOGY

All measurements contained in this report were conducted with ANSI C63.10-2013. American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices.

For conducted and radiated emissions the equipment under test (EUT) was configured to measure its highest possible emission level. This level was based on the maximized cable configuration from exploratory testing per ANSI C63.10-2013. The test modes were adapted according to the Operating Instructions provided by the manufacturer/client.

1.6 TEST FACILITY LOCATION

1.6.1 TÜV SÜD America Inc. (Mira Mesa)

10040 Mesa Rim Road, San Diego, CA 92121-2912 (32.901268,-117.177681). Phone: 858 678 1400 Fax: 858 546 0364.

1.6.2 TÜV SÜD America Inc. (Rancho Bernardo)

16936 Via Del Campo, San Diego, CA 92127-1708 (33.018644,-117.092409). Phone: 858 678-1400 Fax: 858 546 0364.

1.7 TEST FACILITY REGISTRATION

1.7.1 FCC – Registration No.: US1146

TUV SUD America Inc. (San Diego), is an accredited test facility with the site description report on file and has met all the requirements specified in §2.948 of the FCC rules. The acceptance letter from the FCC is maintained in our files and the Registration is US1146.

1.7.1 Innovation, Science and Economic Development Canada Registration No.: 3067A

The 10m Semi-anechoic chamber of TUV SUD America Inc. (San Diego) has been registered by Certification and Engineering Bureau of Innovation, Science and Economic Development Canada for radio equipment testing with Registration No. 3067A.

TÜV SÜD AMERICA INC 10040 Mesa Rim Road San Diego, CA 92121-2912 Phone: 858 678 1400 FAX: 858 546 0364

SECTION 2

TEST DETAILS

Radio Testing of the
Oculus VR, LLC
Wireless Tracking Input Device

2.1 CARRIER FREQUENCY SEPARATION

2.1.1 Specification Reference

Part 15 Subpart C §15.247(a)(1) and RSS-247 5.1 (2)

2.1.2 Standard Applicable

(1) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400–2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

2.1.3 Equipment Under Test and Modification State

Test Configuration A (Please refer to SD72112194-1215A Facebook Oculus HM-A FCC IC Part 15.247 RSS247 Test Report for the actual S/N of HM-A used)

2.1.4 Date of Test/Initial of test personnel who performed the test

October 08, 2015/FSC

2.1.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.1.6 Environmental Conditions

Test performed at TÜV SÜD America Inc. Rancho Bernardo facility.

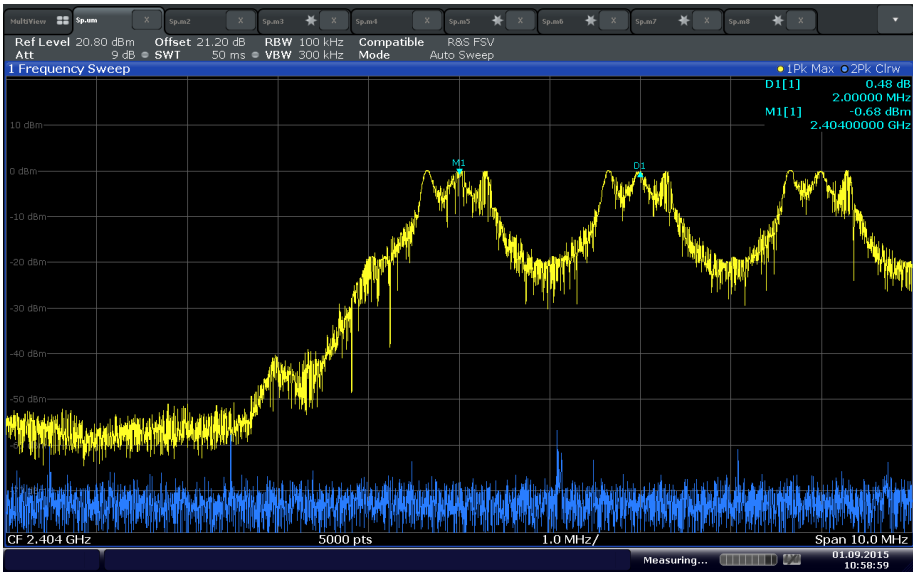
Ambient Temperature	24.8 °C
Relative Humidity	57.1 %
ATM Pressure	99.1 kPa

2.1.7 Additional Observations

- Hopping function enabled.
- Span is wide enough to capture the peaks of two adjacent channels.
- RBW is 1% of the span.
- VBW is 3x RBW
- Sweep is auto

- Detector is peak.
- Trace is max hold.
- An offset of 21.2dB was added to compensate for the external attenuator and cable used.
- Marker-delta function is used between the peaks of the adjacent channels.
- Limit used is >490 kHz (2/3 of worst case 20dB BW).

2.1.8 Test Results



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Observed carrier frequency separation between Channel 4 and Channel 6 = 2 MHz (**Complies**. Greater than 490 kHz, this is 2/3 of 0.7352 MHz 20 dB BW)

2.2 NUMBER OF HOPPING FREQUENCIES

2.2.1 Specification Reference

Part 15 Subpart C §15.247(a)(1)(iii) and RSS-247 5.1 (4)

2.2.2 Standard Applicable

(iii) Frequency hopping systems in the 2400–2483.5 MHz band shall use at least 15 channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

2.2.3 Equipment Under Test and Modification State

Test Configuration A (Please refer to SD72112194-1215A Facebook Oculus HM-A FCC IC Part 15.247 RSS247 Test Report for the actual S/N of HM-A used)

2.2.4 Date of Test/Initial of test personnel who performed the test

October 08, 2015/FSC

2.2.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.2.6 Environmental Conditions

Test performed at TÜV SÜD America Inc. Rancho Bernardo facility.

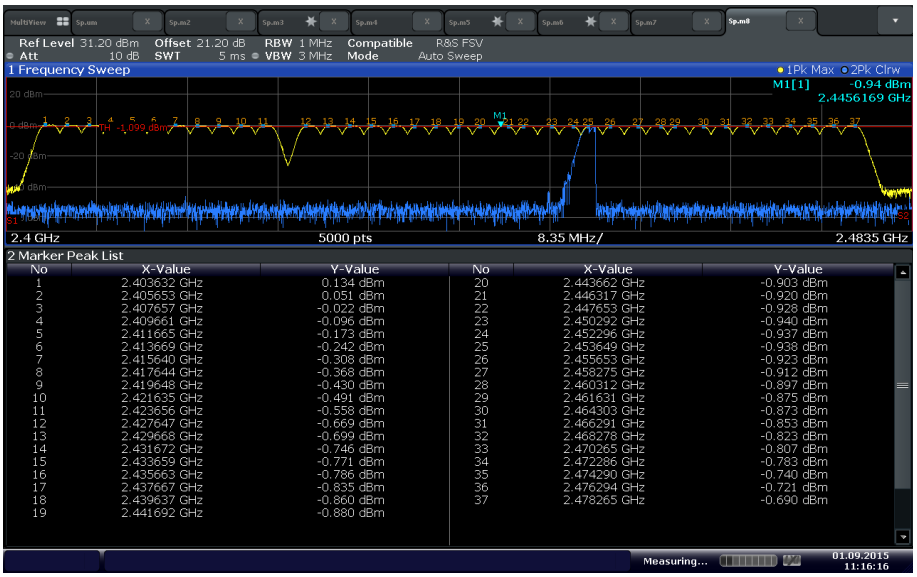
Ambient Temperature	24.8 °C
Relative Humidity	57.1 %
ATM Pressure	99.1 kPa

2.2.7 Additional Observations

- Hopping function enabled.
- Span was set to the entire Frequency Band.
- RBW is >1% of the span.
- VBW is 3x RBW
- Sweep is auto
- Trace was set to Max Hold.
- Marker Peak List function of the spectrum analyzer was used for this test.

2.2.8 Test Results

Observed Number of Hopping Frequencies is = **37 (Complies)**



2.4 GHz Frequency Band showing 37 channels where the EUT hops

2.3 TIME OF OCCUPANCY (DWELL TIME)

2.3.1 Specification Reference

Part 15 Subpart C §15.247(a)(1)(iii) and RSS-247 5.1 (4)

2.3.2 Standard Applicable

(iii) Frequency hopping systems in the 2400–2483.5 MHz band shall use at least 15 channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

2.3.3 Equipment Under Test and Modification State

Test Configuration A (Please refer to SD72112194-1215A Facebook Oculus HM-A FCC IC Part 15.247 RSS247 Test Report for the actual S/N of HM-A used)

2.3.4 Date of Test/Initial of test personnel who performed the test

October 08, 2015/FSC

2.3.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.3.6 Environmental Conditions

Test performed at TÜV SÜD America Inc. Rancho Bernardo facility.

Ambient Temperature	24.8 °C
Relative Humidity	57.1 %
ATM Pressure	99.1 kPa

2.3.7 Additional Observations

- Hopping function enabled.
- Span = zero span, centered on a hopping channel.
- RBW is 1MHz.
- VBW is 3x RBW
- Detector is peak.
- A single pulse is first measured. This measurement is then used to compute the average time of occupancy in the required period (no. of channels x 0.4 second).
- Marker Peak List function of the spectrum analyzer was used to determine the number of pulses within 3.16 seconds.
- Threshold set to -10 dBm in order to capture actual transmission within the channel being investigated (adjacent channel transmissions are rejected).

2.3.8 Test Results

Modulation	Measured time of occupancy	Requirement
GFSK	4.28 ms	<400 ms

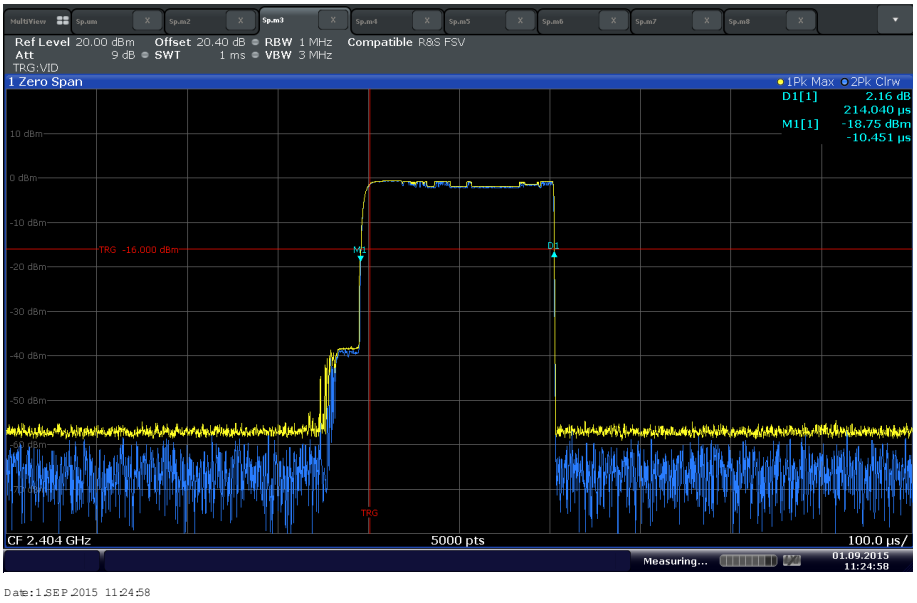
2.3.9 Sample Computation

Width of single pulse = 0.000214 second
Observed occurrence = 20 pulses/1.48 seconds
Required period = 37 channels x 0.4 second
= 14.8 seconds

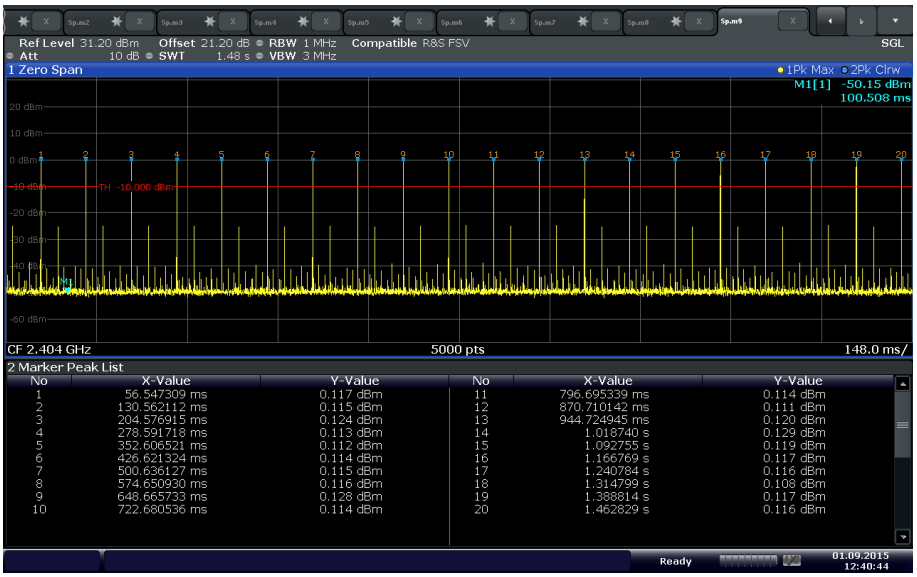
Average time of occupancy = Pulse width x #pulses in 1.48 seconds x 10
= 0.000214 second x 20 x 10
= 0.0428 second

Compliance = **Complies**. 0.0428 second < 0.4 second

2.3.10 Test Results Plots



GFSK width of single pulse (0.214 ms)



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20 pulses/1.48 seconds

2.4 20 dB BANDWIDTH

2.4.1 Specification Reference

Part 15 Subpart C §15.215(c) and RSS-247 5.1 (1)

2.4.2 Standard Applicable

(c) Intentional radiators operating under the alternative provisions to the general emission limits, as contained in §§15.217 through 15.257 and in Subpart E of this part, must be designed to ensure that the 20 dB bandwidth of the emission, or whatever bandwidth may otherwise be specified in the specific rule section under which the equipment operates, is contained within the frequency band designated in the rule section under which the equipment is operated. The requirement to contain the designated bandwidth of the emission within the specified frequency band includes the effects from frequency sweeping, frequency hopping and other modulation techniques that may be employed as well as the frequency stability of the transmitter over expected variations in temperature and supply voltage. If a frequency stability is not specified in the regulations, it is recommended that the fundamental emission be kept within at least the central 80% of the permitted band in order to minimize the possibility of out-of-band operation.

2.4.3 Equipment Under Test and Modification State

Test Configuration A (Please refer to SD72112194-1215A Facebook Oculus HM-A FCC IC Part 15.247 RSS247 Test Report for the actual S/N of HM-A used)

2.4.4 Date of Test/Initial of test personnel who performed the test

October 08, 2015/FSC

2.4.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.4.6 Environmental Conditions

Test performed at TÜV SÜD America Inc. Rancho Bernardo facility.

Ambient Temperature	24.8 °C
Relative Humidity	57.1 %
ATM Pressure	99.1 kPa

2.4.7 Additional Observations

- This is a conducted test.
- An offset of 21.2dB was added to compensate for the external attenuator and cable used.
- Span is approximately 2 to 3 times the expected 20dB bandwidth.
- RBW is ≥ 1% of the expected 20dB bandwidth while VBW is ≥ RBW.
- Sweep is auto.
- Detector is peak.
- Max hold function activated.
- "n dB down" marker function (20dB) of the spectrum analyzer was used for this test.

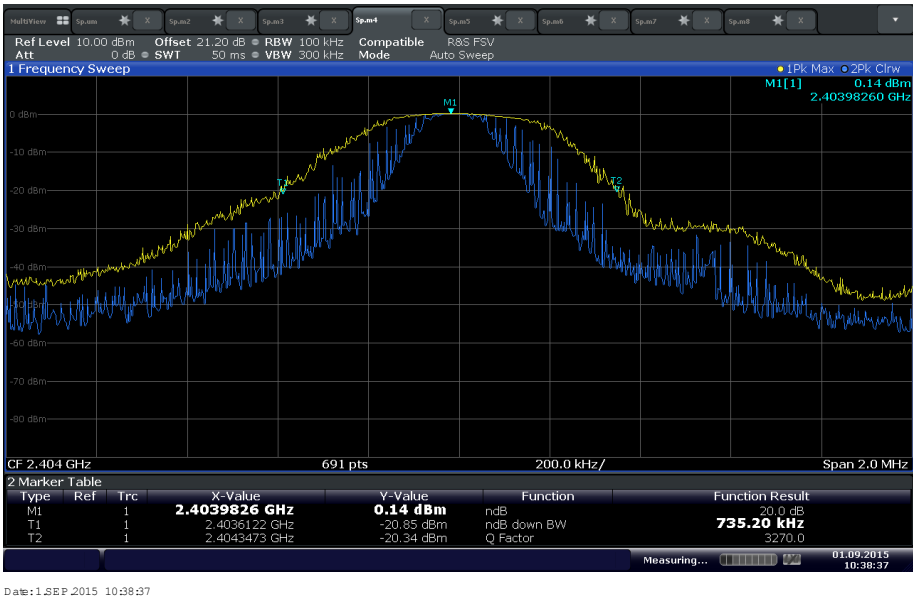
2.4.8 Test Results

Modulation	Channel	Frequency (MHz)	Measured 20dB Bandwidth (MHz)
GFSK	4	2404	0.7352
	40	2440	0.7120
	78	2478	0.7265

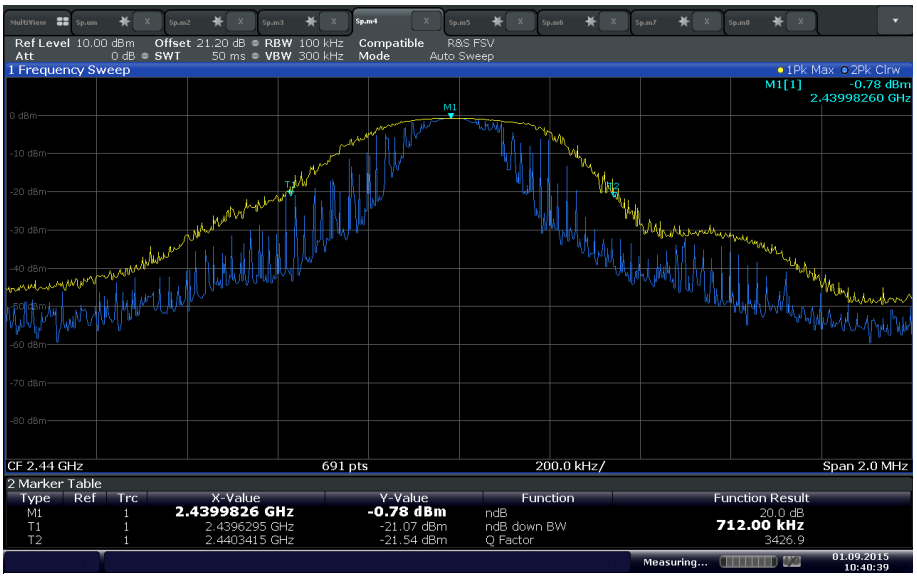
Using worst case 20 dB BW:

2404 MHz – (0.7352/2) = 2403.6324 MHz (within the frequency band - **Compliant**)
2478 MHz + (0.7352/2) = 2478.3675 MHz (within the frequency band - **Compliant**)

2.4.9 Test Results Plots



Low Channel (2404 MHz)



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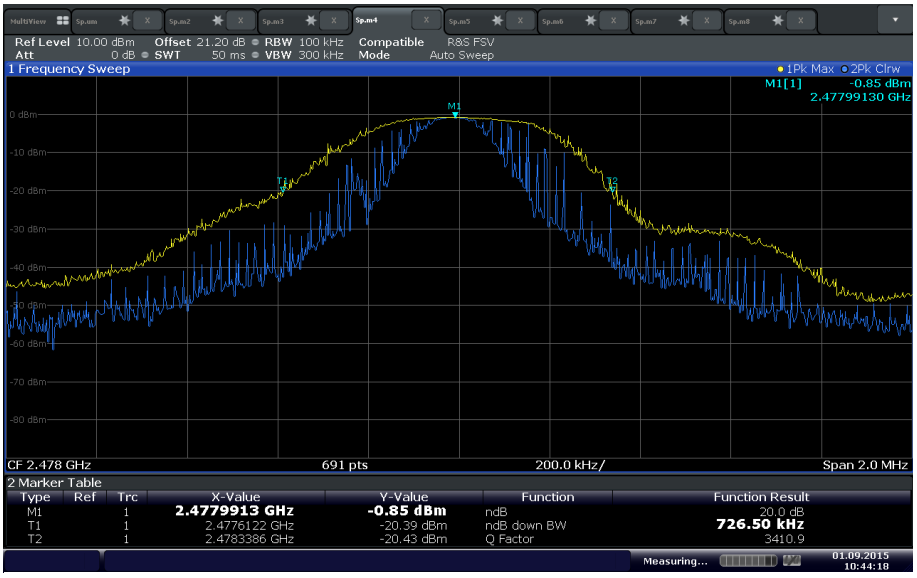
Mid Channel (2440 MHz)



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High Channel (2478 MHz)

2.5 99% EMISSION BANDWIDTH

2.5.1 Specification Reference

RSS-Gen Clause 6.6

2.5.2 Standard Applicable

The emission bandwidth (x dB) is defined as the frequency range between two points, one above and one below the carrier frequency, at which the spectral density of the emission is attenuated x dB below the maximum in-band spectral density of the modulated signal. Spectral density (power per unit bandwidth) is to be measured with a detector of resolution bandwidth in the range of 1% to 5% of the anticipated emission bandwidth, and a video bandwidth at least 3x the resolution bandwidth.
When the occupied bandwidth limit is not stated in the applicable RSS or reference measurement method, the transmitted signal bandwidth shall be reported as the 99% emission bandwidth, as calculated or measured.

- The transmitter shall be operated at its maximum carrier power measured under normal test conditions.
- • The span of the analyzer shall be set to capture all products of the modulation process, including the emission skirts.
- • The resolution bandwidth (RBW) shall be in the range of 1% to 5% of the occupied bandwidth (OBW) and video bandwidth (VBW) shall be approximately 3x RBW.

Note: Video averaging is not permitted.
A peak, or peak hold, may be used in place of the sampling detector as this may produce a wider bandwidth than the actual bandwidth (worst-case measurement). Use of a peak hold may be necessary to determine the occupied bandwidth if the device is not transmitting continuously.
The trace data points are recovered and are directly summed in linear power level terms. The recovered amplitude data points, beginning at the lowest frequency, are placed in a running sum until 0.5% of the total is reached and that frequency recorded. The process is repeated for the highest frequency data points (starting at the highest frequency, at the right side of the span, and going down in frequency). This frequency is then recorded.
The difference between the two recorded frequencies is the 99% occupied bandwidth.

2.5.3 Equipment Under Test and Modification State

Test Configuration A (Please refer to SD72112194-1215A Facebook Oculus HM-A FCC IC Part 15.247 RSS247 Test Report for the actual S/N of HM-A used)

2.5.4 Date of Test/Initial of test personnel who performed the test

October 08, 2015/FSC

2.5.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.5.6 Environmental Conditions

Test performed at TÜV SÜD America Inc. Rancho Bernardo facility.

Ambient Temperature	24.8 °C
Relative Humidity	57.1 %
ATM Pressure	99.1 kPa

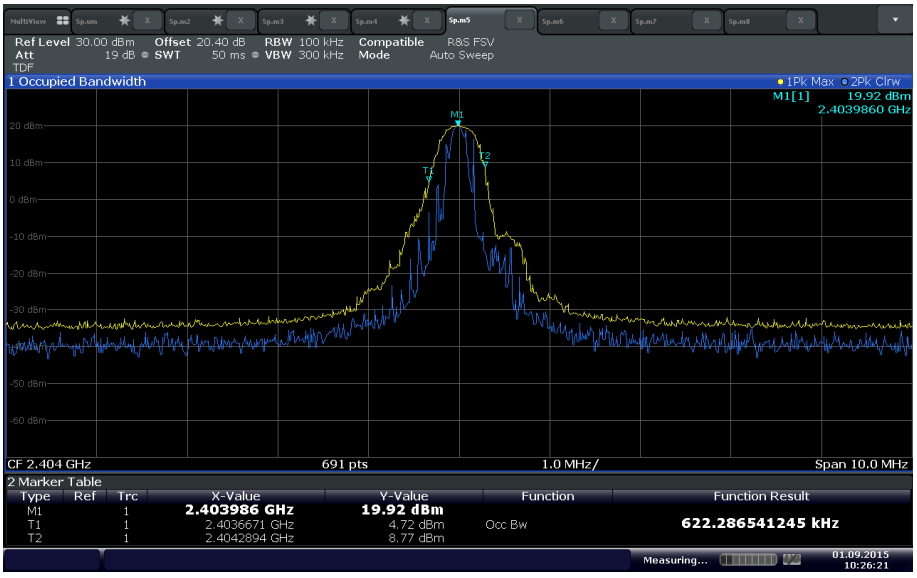
2.5.7 Additional Observations

- This is a conducted test.
- A TDF factor was used to compensate for the external attenuator and cable used within the frequency band.
- Span is wide enough to capture the channel transmission.
- RBW is 1% of the span.
- VBW is 3X RBW.
- Sweep is auto.
- Detector is peak.
- The % Power Bandwidth setting in the spectrum analyzer was set to 99% (default).
- The OBW power measurement function of the spectrum analyzer was used for this test.

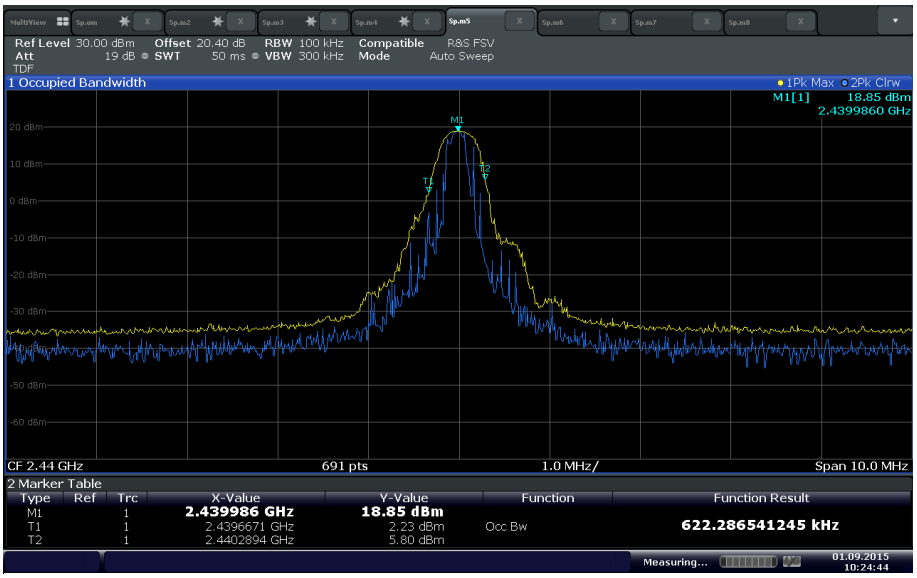
2.5.8 Test Results (For reporting purposes only)

Modulation	Channel	Frequency (MHz)	Measured 20dB Bandwidth (MHz)
GFSK	4	2404	0.622
	40	2440	0.622
	78	2478	0.637

2.5.9 Test Results Plots



Low Channel (2404 MHz)



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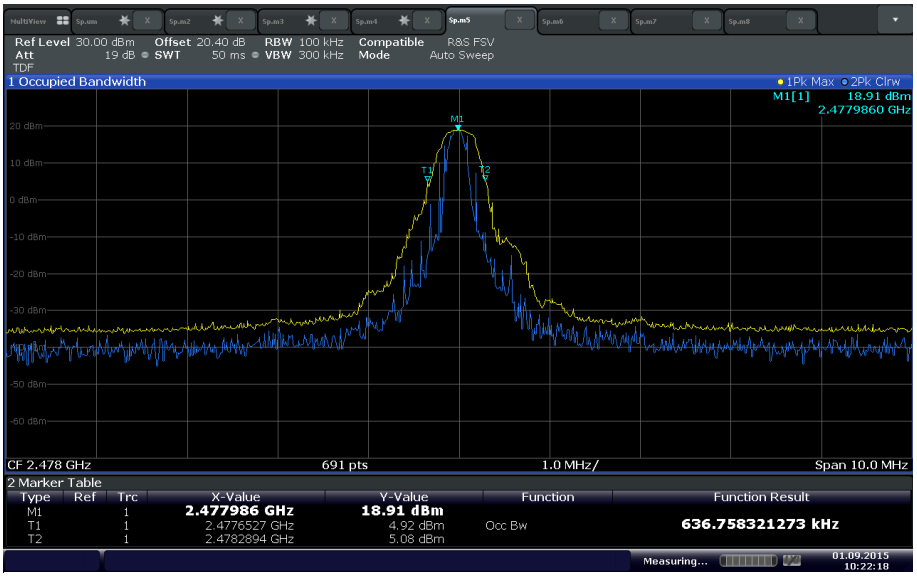
Mid Channel (2440 MHz)



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High Channel (2478 MHz)

2.6 PEAK OUTPUT POWER

2.6.1 Specification Reference

Part 15 Subpart C §15.247(b)(1) and RSS-247 5.4 (2)

2.6.2 Standard Applicable

(1) For frequency hopping systems operating in the 2400–2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725–5850 MHz band: 1 watt. For all other frequency hopping systems in the 2400–2483.5 MHz band: 0.125 watts.

For FHSs operating in the band 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1.0 W and the e.i.r.p. shall not exceed 4 W if the hopset uses 75 or more hopping channels; the maximum peak conducted output power shall not exceed 0.125 W and the e.i.r.p. shall not exceed 0.5 W if the hopset uses less than 75 hopping channels (see Section 5.4(5) for exceptions).

2.6.3 Equipment Under Test and Modification State

WMTCL5371001XV and WMTCR5371003UH / Test Configuration B

2.6.4 Date of Test/Initial of test personnel who performed the test

September 20, 2016/FSC

2.6.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.6.6 Environmental Conditions

Test performed at TÜV SÜD America Inc. Rancho Bernardo facility.

Ambient Temperature	26.3 °C
Relative Humidity	49.6 %
ATM Pressure	99.0 kPa

2.6.7 Additional Observations

- This is a conducted test using a Peak Power Meter.
- An offset of 20.6dB was added to compensate for the external attenuator and cable used.
- Both EUT were verified while in single carrier test mode.
- Average was also measured for RF exposure calculation purposes only.

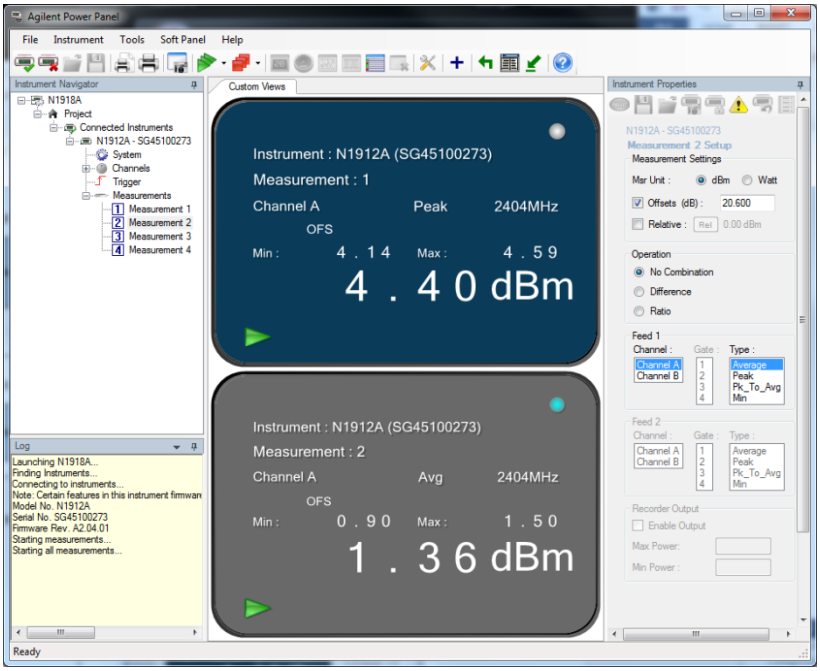
2.6.8 Test Results (Conducted)

Model	Channel	Frequency (MHz)	Measured Average Output Power (dBm)	Measured Peak Output Power (dBm)	Measured Peak Output Power (mW)	Limit (mW)
TO-L	4	2404	1.76	4.68	2.94	125.0
	40	2440	1.59	4.72	2.96	125.0
	78	2478	1.68	4.63	2.90	125.0
TO-R	4	2404	1.50	4.59	2.89	125.0
	40	2440	1.47	4.49	2.81	125.0
	78	2478	1.07	4.37	2.74	125.0

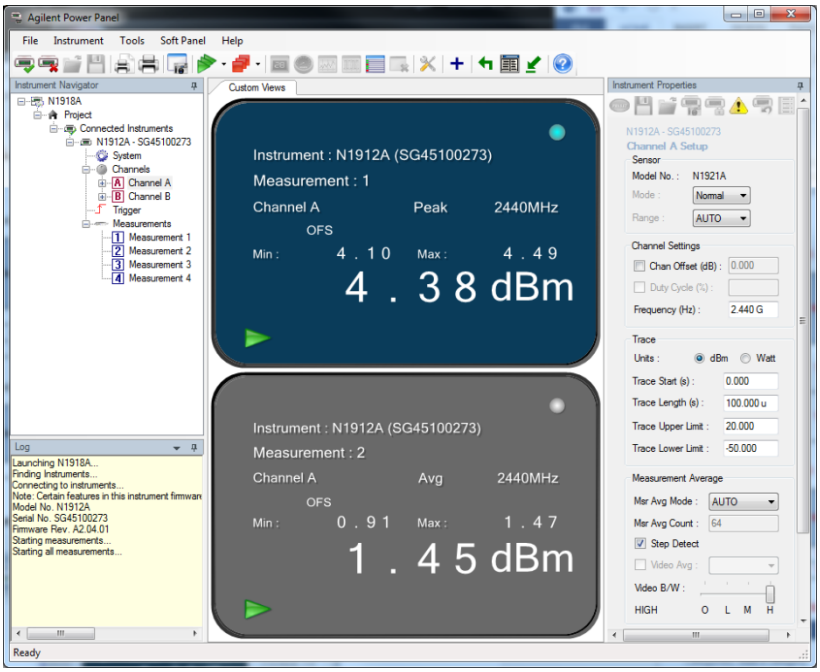
2.6.9 Test Results (*De Facto* EIRP Limit)

Model	Channel	Frequency (MHz)	Measured Peak Output Power (dBm))	Antenna Gain (dBi)	Calculated Peak Output Power EIRP (dBm))	Limit (dBm))
TO-L	40	2440	4.72	2.12	6.84	27
TO-R	4	2404	4.59	2.12	6.71	27

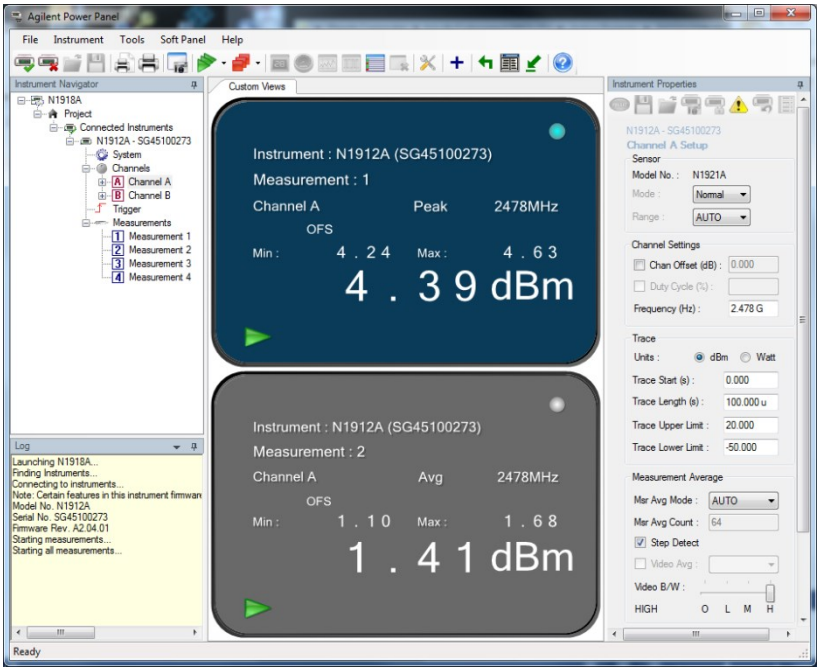
2.6.10 Sample Test Display



TO-R Low channel (Channel 4 2404 MHz)



TO-R Mid channel (Channel 40 2440 MHz)



TO-L High channel (Channel 78 2478 MHz)

2.7 BAND-EDGE COMPLIANCE OF RF CONDUCTED EMISSIONS

2.7.1 Specification Reference

Part 15 Subpart C §15.247(d) and RSS-247 5.5

2.7.2 Standard Applicable

(d) In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

2.7.3 Equipment Under Test and Modification State

WMTCL5371001XV and WMTCR5371003UH / Test Configuration B

2.7.4 Date of Test/Initial of test personnel who performed the test

September 21, 2016/FSC

2.7.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.7.6 Environmental Conditions

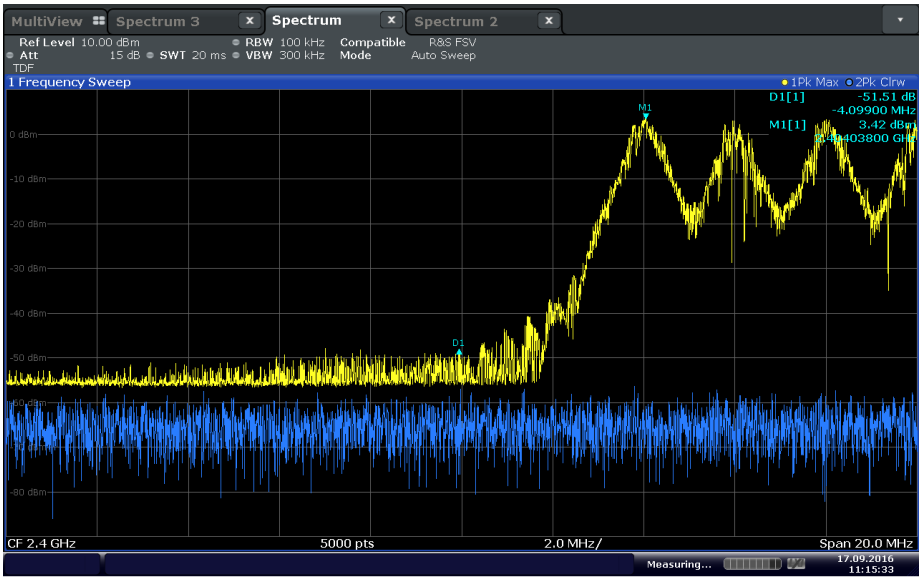
Test performed at TÜV SÜD America Inc. Rancho Bernardo facility.

Ambient Temperature	26.1 °C
Relative Humidity	55.3 %
ATM Pressure	98.8 kPa

2.7.7 Additional Observations

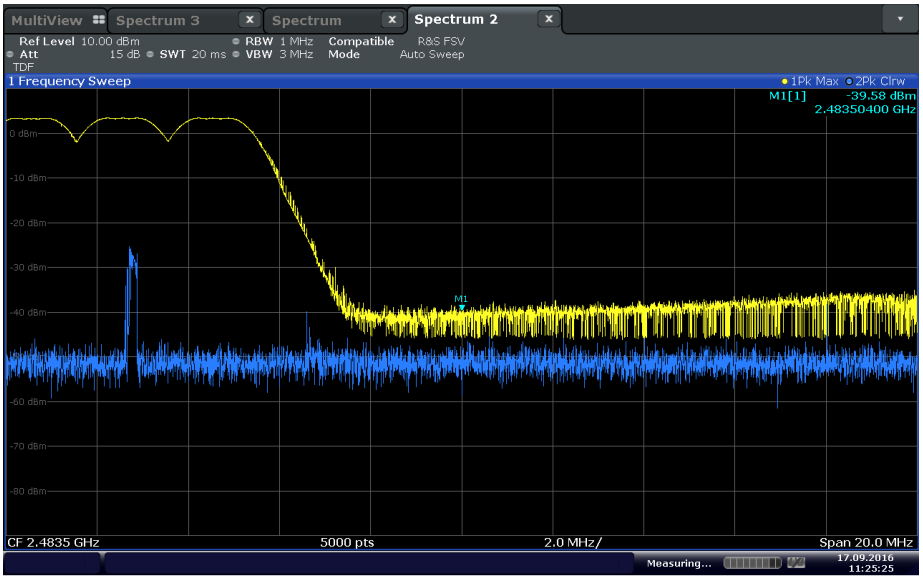
- This is a conducted test.
- A TDF factor was used to compensate for the external attenuator, connector and cable used within the frequency band.
- Span is wide enough to capture the peak level of the emission operating on the channel closest to the band edge.
- RBW is 100 kHz for 2.4GHz and 1MHz for 2.4835GHz, VBW is ≥ RBW.
- Test methodology is per Clause 6.10 and 11.13 of ANSI C63.10-2013
- Both Hopping and Non-Hopping mode verified.

2.7.8 Test Results



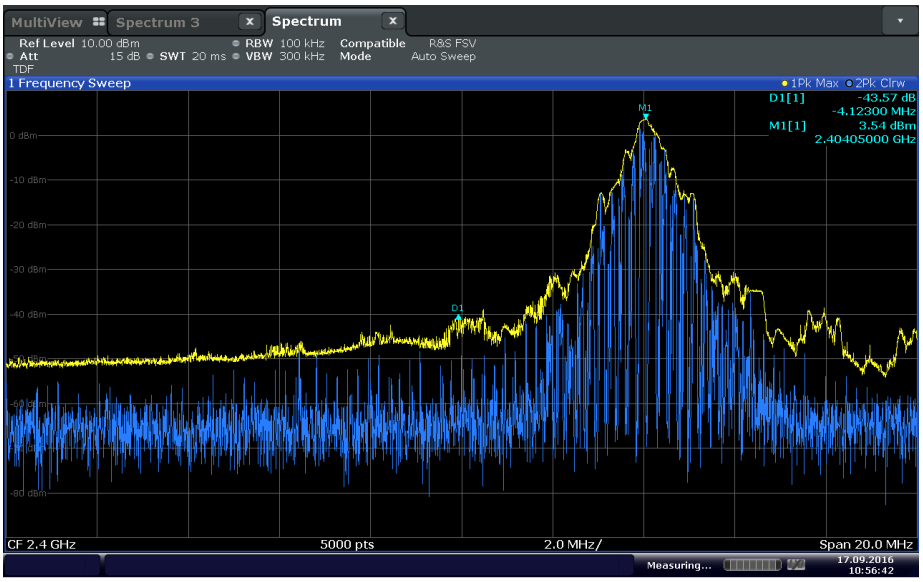
11:15:34 17.09.2016

TO-L Hopping lower band edge



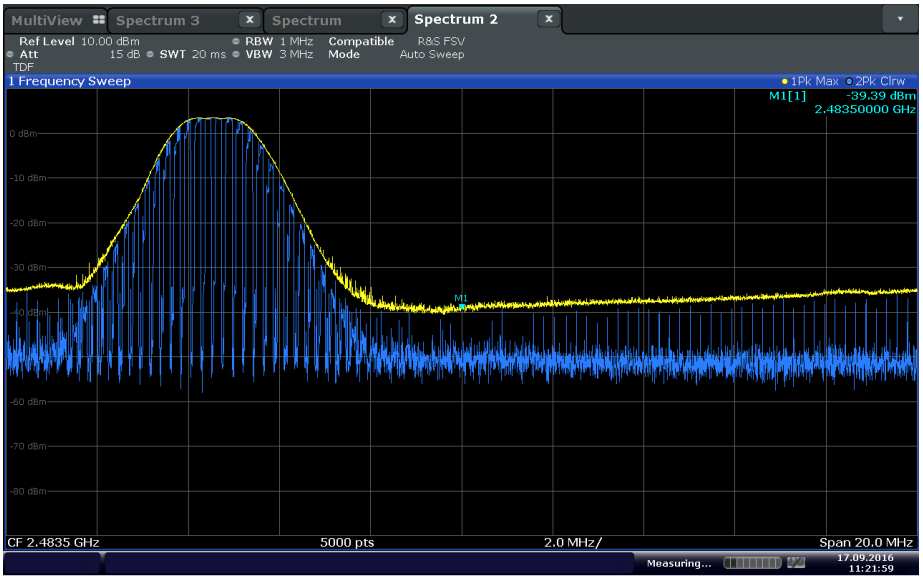
11:25:25 17.09.2016

TO-L Hopping upper band edge



10:56:43 17.09.2016

TO-L Non-hopping lower band edge



11:22:00 17.09.2016

TO-L Non-hopping upper band edge (Peak)

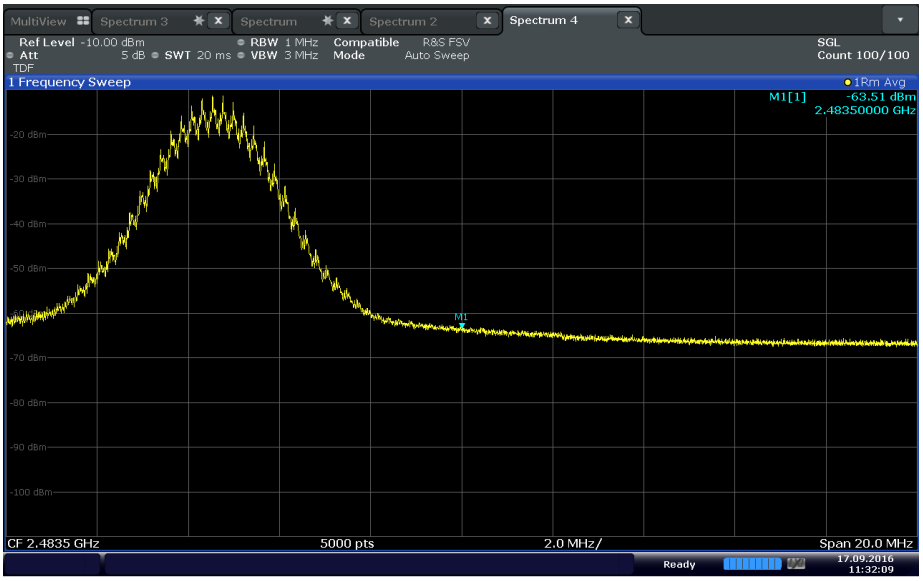
Conducted peak measurements in restricted bands calculation:

Measured Peak = -39.39dBm, since antenna gain is 2.12 dBi then EIRP is -37.27 dBm. Electric field strength in dBµV/m is then calculated using the formula:

$$E = EIRP - 20\log D + 104.8$$

Where:	E	= electric field strength in dBµV/m
	EIRP	= equivalent isotropic radiated power in dBm
	D	= specific measurement distance in meters

E is therefore =(-39.39 + 2.12 dbi) dBm – (20log 3 meters) + 104.8
= 57.99 dBµV/m @ 3 meters (complies with 74 dBµV/m Peak limits)



11:32:09 17.09.2016

TO-L Non-hopping upper band edge (Average)

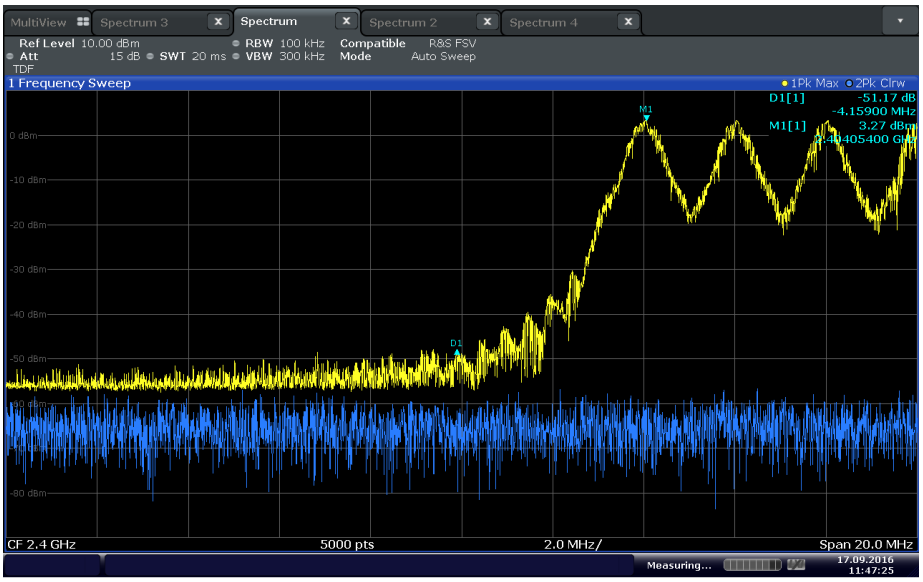
Conducted average measurements in restricted band calculation (trace averaging across ON and OFF times of the EUT transmissions followed by duty cycle correction):

Trace averaging result = -63.51dBm, since antenna gain is 2.12 dBi then EIRP is -37.27 dBm. Electric field strength in dBµV/m is then calculated using the formula:

$$E = EIRP - 20\log D + 104.8 + 10\log(1/D)$$

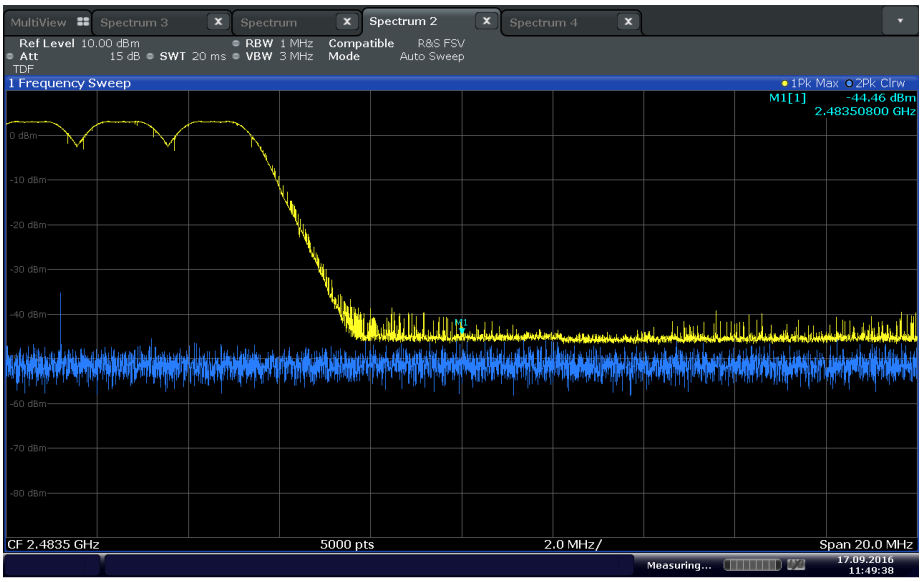
Where:	E	= electric field strength in dBµV/m
	EIRP	= equivalent isotropic radiated power in dBm
	D	= specific measurement distance in meters
	D	= Duty Cycle (see Section 2.7.9 for details)

E is therefore =(-63.51 + 2.12 dbi) dBm – (20log 3 meters) + 104.8 + (10log(1/0.6291))
= 35.88 dBµV/m @ 3 meters (complies with 54 dBµV/m Average limits)



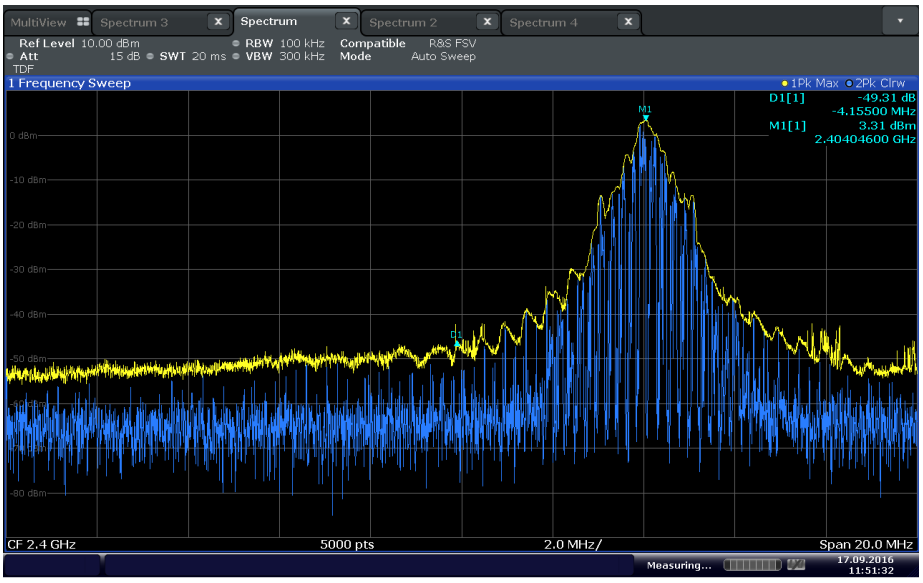
11:47:25 17.09.2016

TO-R Hopping lower band edge



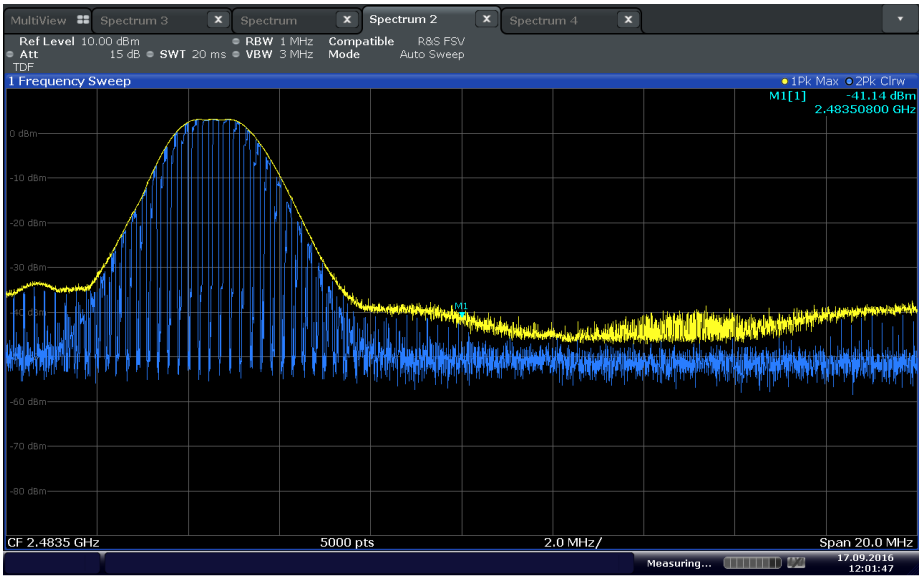
11:49:39 17.09.2016

TO-R Hopping upper band edge



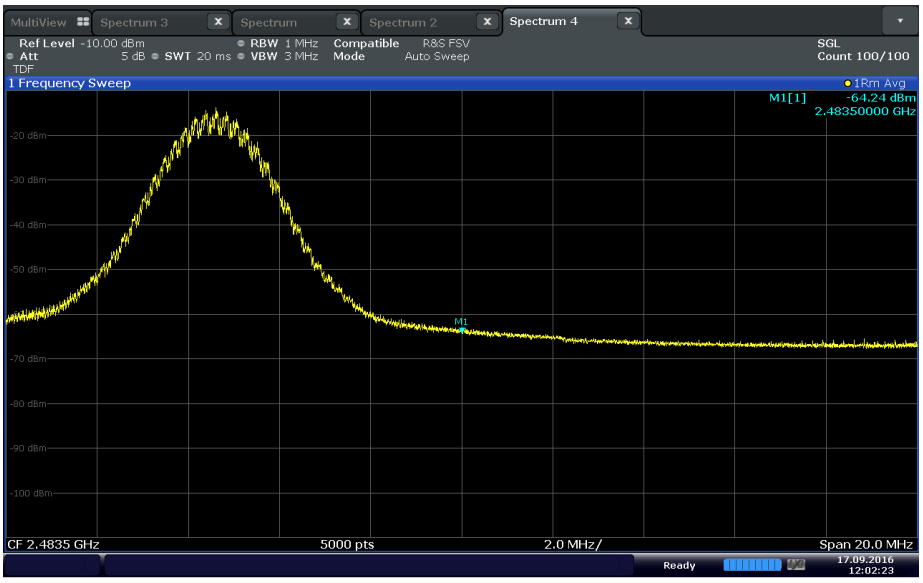
11:51:32 17.09.2016

TO-R Non-hopping lower band edge



12:01:48 17.09.2016

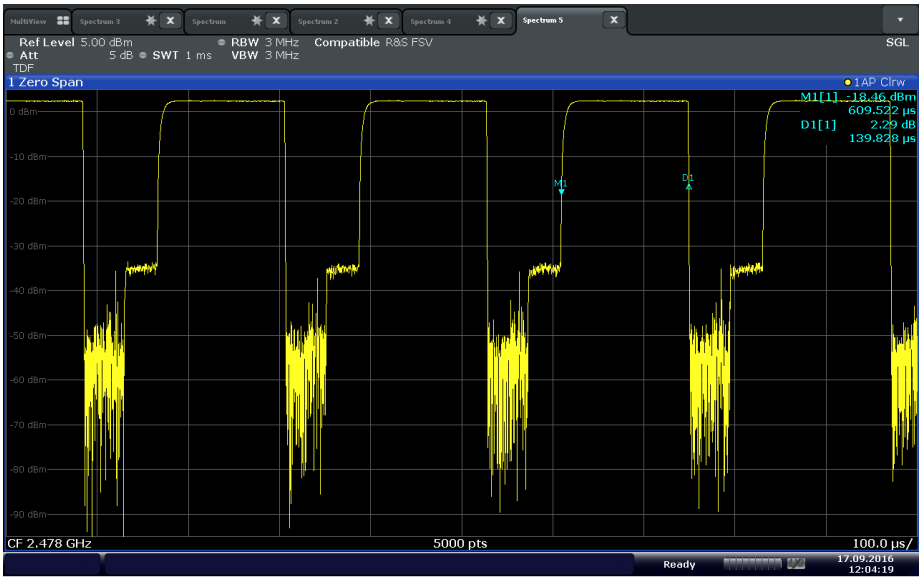
TO-R Non-hopping upper band edge (Peak)



12:02:23 17.09.2016

TO-R Non-hopping upper band edge (Average)

2.7.9 Duty Cycle Calculation



12:04:20 17.09.2016

12:05:45 17.09.2016

Duty Cycle (D) = 0.1398 ms (9 TX in 2 ms period) / 2 ms
= 1.2582 ms / 2 ms
= 0.6291

TÜV SÜD AMERICA INC 10040 Mesa Rim Road San Diego, CA 92121-2912 Phone: 858 678 1400 FAX: 858 546 0364

2.8 SPURIOUS RF CONDUCTED EMISSIONS

2.8.1 Specification Reference

Part 15 Subpart C §15.247(d) and RSS-247 5.5

2.8.2 Standard Applicable

(d) In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

2.8.3 Equipment Under Test and Modification State

WMTCL5371001XV and WMTCR5371003UH / Test Configuration B

2.8.4 Date of Test/Initial of test personnel who performed the test

September 21, 2016/FSC

2.8.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.8.6 Environmental Conditions

Test performed at TÜV SÜD America Inc. Rancho Bernardo facility.

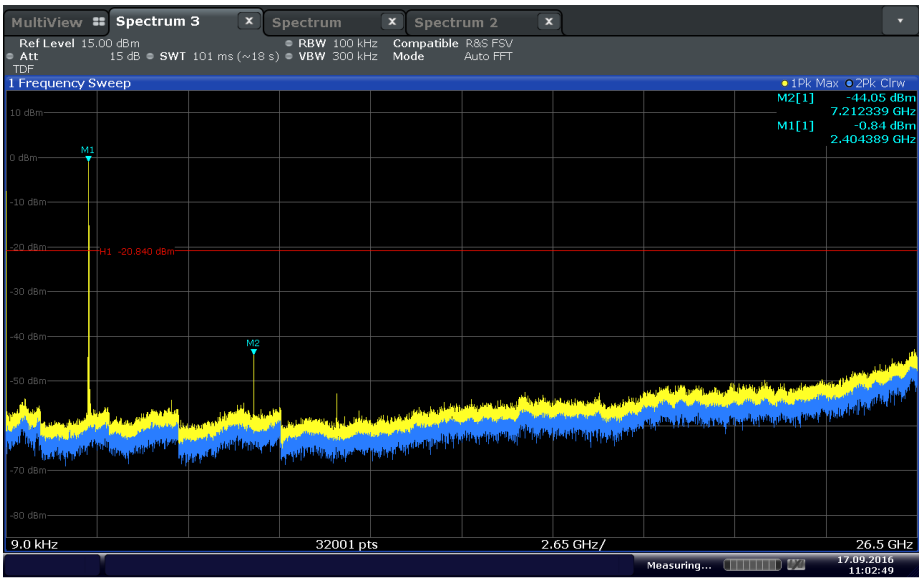
Ambient Temperature	26.1 °C
Relative Humidity	55.3 %
ATM Pressure	98.8 kPa

2.8.7 Additional Observations

- This is a conducted test.
- A TDF factor was used to compensate for the external attenuator, connector and cable used within the frequency band.
- Span is from 9 kHz up to 26.5GHz (to cover 10th harmonic of the High Channel).
- Sweep point setting of the spectrum analyzer is set to maximum (32001).
- RBW is 100 kHz, VBW is ≥ RBW.
- Sweep is auto, detector is peak.

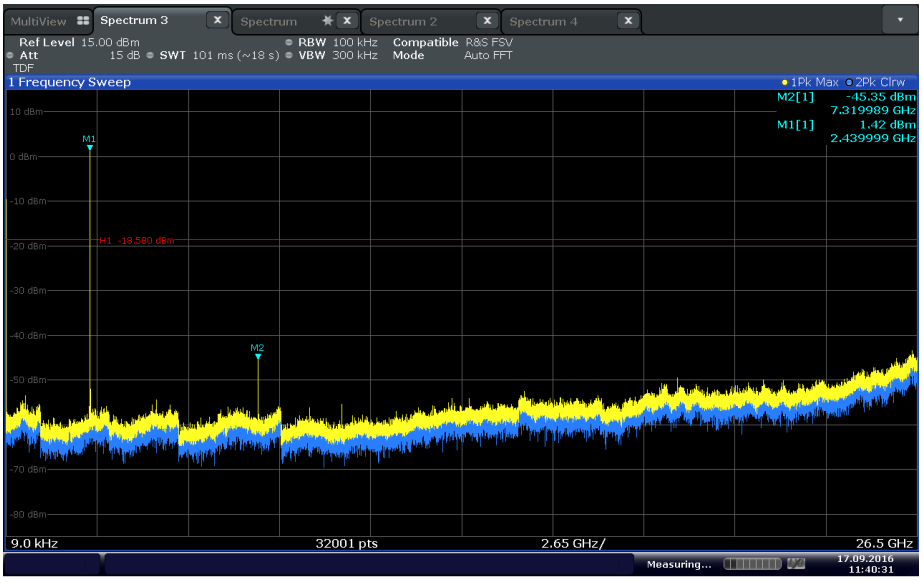
- Trace is max hold.
- Trace allowed to stabilize. Maximum spurious emission compared to limit.
- Limit is 20dBc.

2.8.8 Test Results Plots



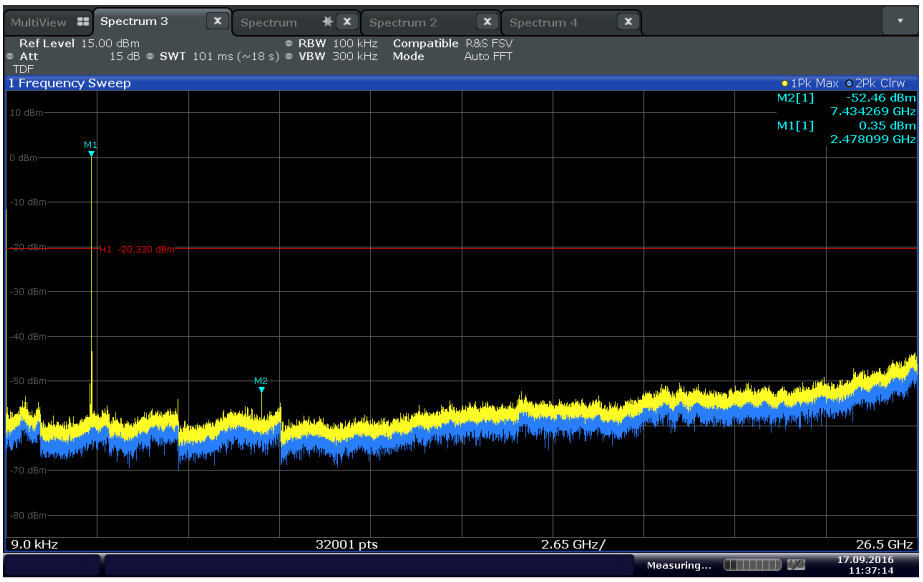
11:02:50 17.09.2016

TO-L Low Channel (2404 MHz)



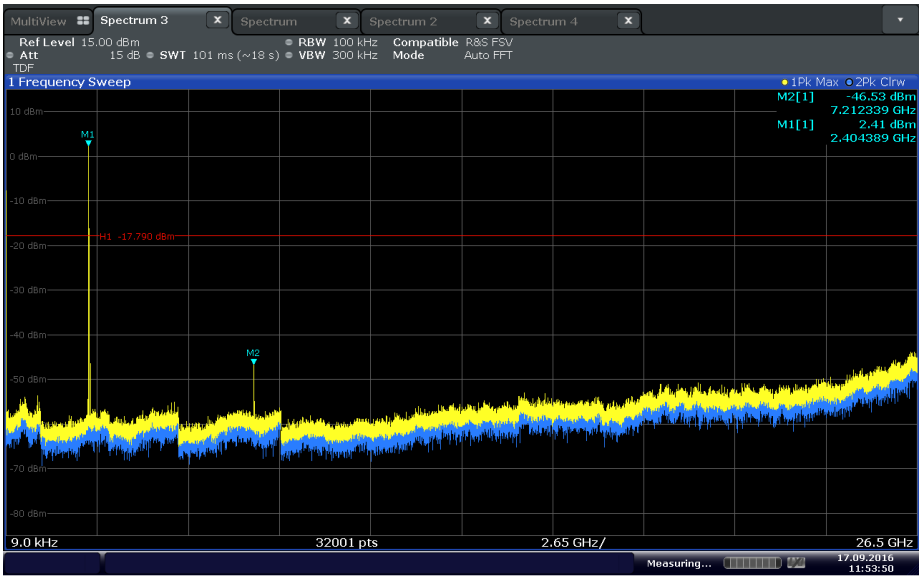
11:40:31 17.09.2016

TO-L Mid Channel (2440 MHz)



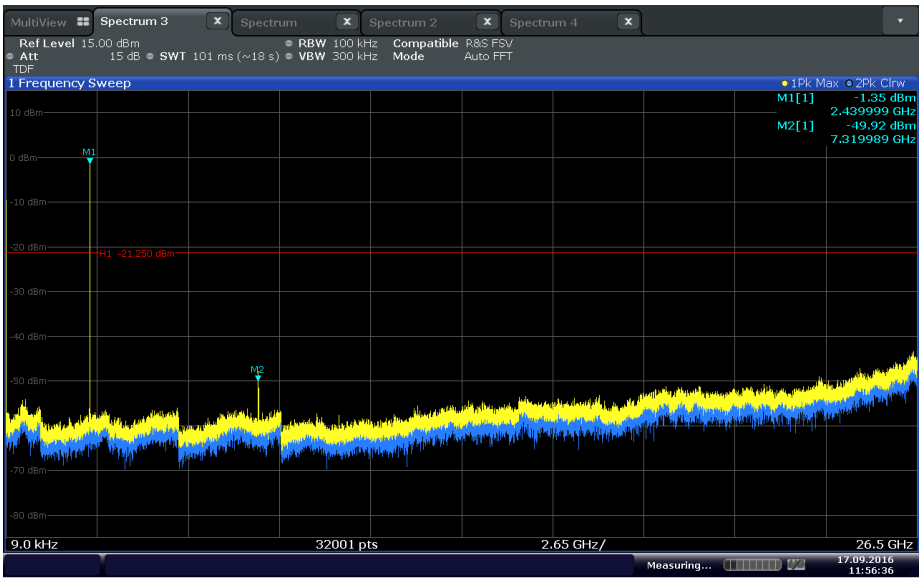
11:37:14 17.09.2016

TO-L High Channel (2478 MHz)



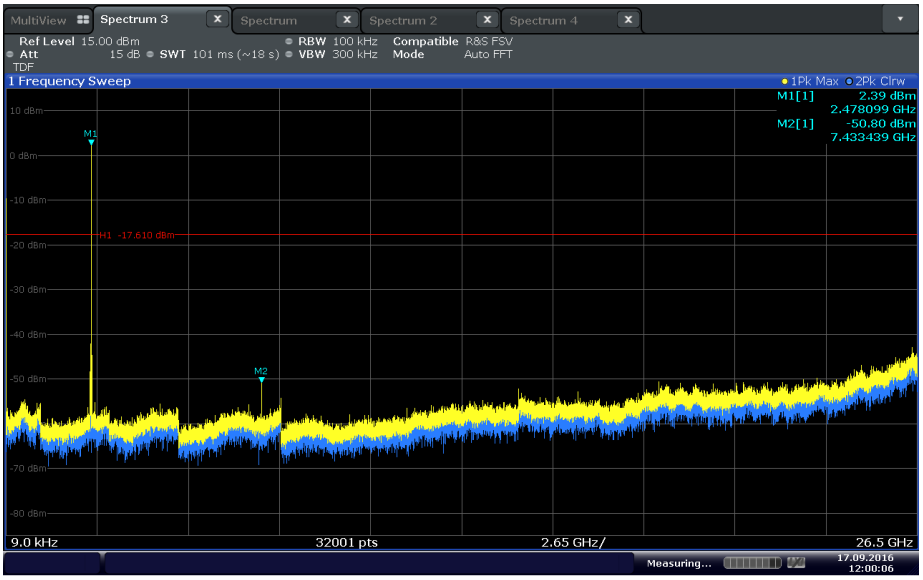
11:53:50 17.09.2016

TO-R Low Channel (2404 MHz)



11:56:37 17.09.2016

TO-R Mid Channel (2440 MHz)



12:00:06 17.09.2016

TO-R High Channel (2478 MHz)

2.9 CABINET/CASE RADIATED EMISSIONS

2.9.1 Specification Reference

ANSI C63.10-2013 Clause 11.12.2.1 and RSS-Gen 8.9 / 8.10

2.9.2 Standard Applicable

Antenna-port conducted measurements may also be used as an alternative to radiated measurements for determining compliance in the restricted frequency bands requirements. If conducted measurements are performed, then proper impedance matching must be ensured and an additional radiated test for cabinet/case emissions is required.

2.9.3 Equipment Under Test and Modification State

Serial No: WMTCL5371001XV and WMTCR5371003UH /Test Configuration C

2.9.4 Date of Test/Initial of test personnel who performed the test

September 12, 2015/FSC

2.9.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.9.6 Environmental Conditions

Test performed at TÜV SÜD America Inc. Rancho Bernardo facility

Ambient Temperature	24.6 °C
Relative Humidity	48.2 %
ATM Pressure	98.7 kPa

2.9.7 Additional Observations

- This is a radiated test. The spectrum was searched from 30MHz to the 10th harmonic.
- There are no emissions found that do not comply to the restricted bands defined in FCC Part 15 Subpart C, 15.205 or Part 15.247(d).
- Only noise floor measurements observed above 18GHz.
- Both models verified, results shows identical results. Plots presented is from TO-L since it was considered worst case model between the two in terms of measured maximum conducted power.
- Measurement was done using EMC32 automated software. Reported level is the actual level with all the correction factors factored in. Correction Factor column is for informational purposes only. See Section 2.9.8 for sample computation.

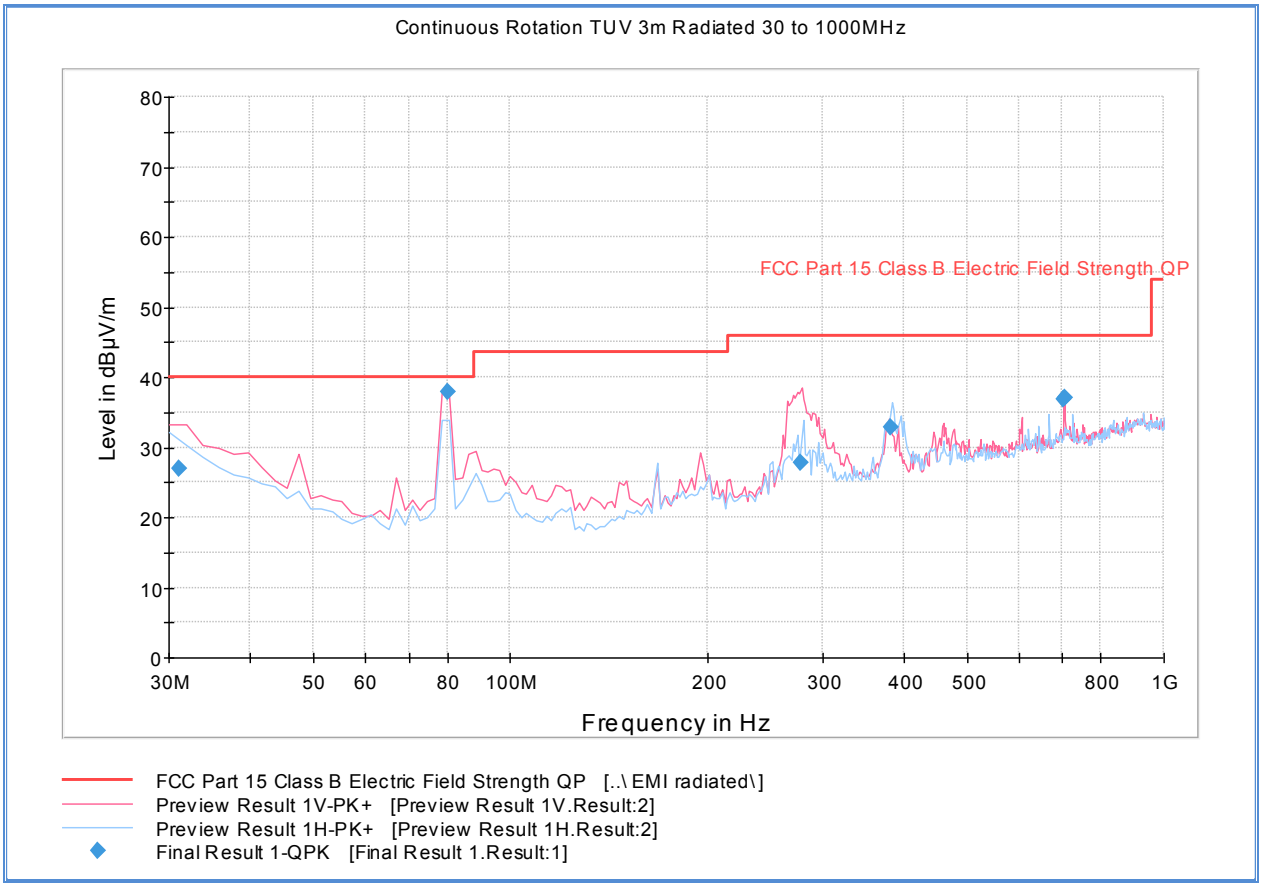
2.9.8 Sample Computation (Radiated Emission)

Measuring equipment raw measurement (dbµV) @ 30 MHz			24.4
Correction Factor (dB)	Asset# 1066 (cable)	0.3	-12.6
	Asset# 1172 (cable)	0.3	
	Asset# 1016 (preamplifier)	-30.7	
	Asset# 1175(cable)	0.3	
	Asset# 1002 (antenna)	17.2	
Reported QuasiPeak Final Measurement (dbµV/m) @ 30MHz			**11.8**

2.9.9 Test Results

See attached plots.

2.9.10 Test Results Below 1GHz (Worst Case Channel)

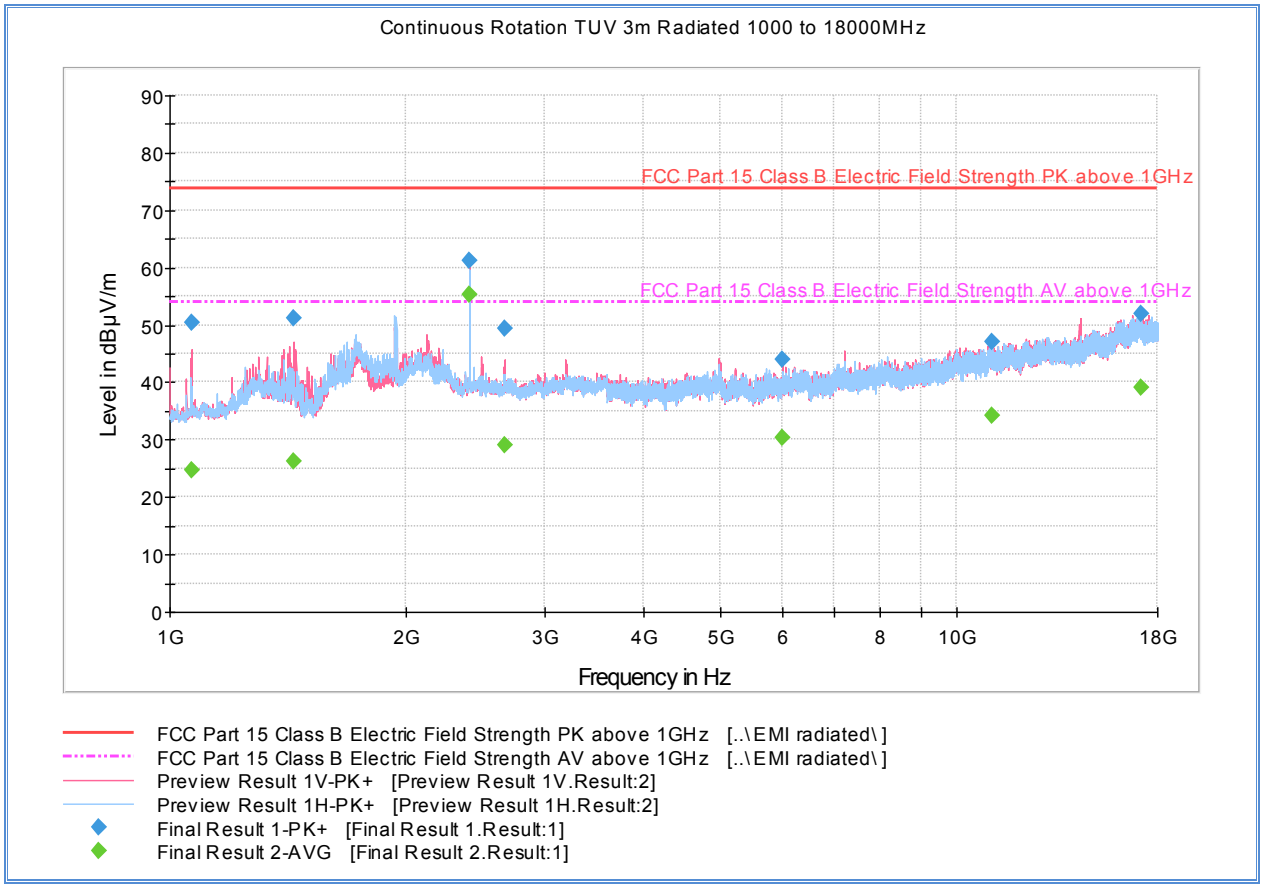


Quasi Peak Data

Frequency (MHz)	QuasiPeak (dBµV/m)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Polarization	Azimuth (deg)	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
31.080000	27.0	1000.0	120.000	105.0	V	120.0	-6.4	13.0	40.0
79.997194	37.9	1000.0	120.000	145.0	V	54.0	-16.6	2.1	40.0
278.577635	27.7	1000.0	120.000	127.0	V	64.0	-7.8	18.3	46.0
381.307575	32.9	1000.0	120.000	105.0	H	4.0	-4.6	13.1	46.0
701.945170	36.9	1000.0	120.000	150.0	V	46.0	2.9	9.1	46.0
704.769058	37.0	1000.0	120.000	150.0	V	39.0	3.0	9.0	46.0

Test Notes: Only worst case channel presented for spurious emissions below 1GHz.

2.9.11 Test Results Above 1GHz Low Channel



Peak Data

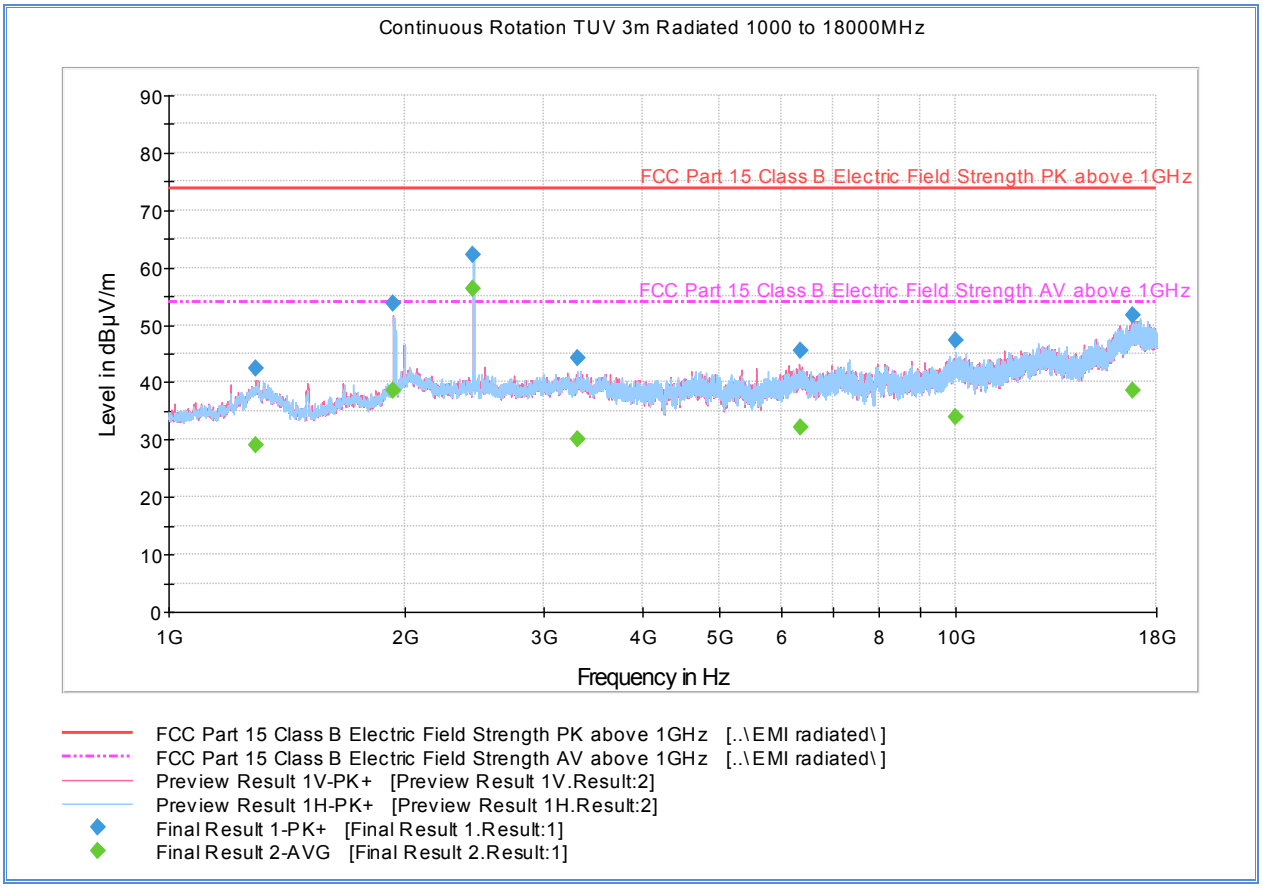
Frequency (MHz)	MaxPeak (dBµV/m)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Polarization	Azimuth (deg)	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
1064.800000	50.5	1000.0	1000.000	101.7	V	141.0	-7.5	23.4	73.9
1437.466667	51.2	1000.0	1000.000	203.5	V	109.0	-5.6	22.7	73.9
2403.833333	61.2	1000.0	1000.000	116.7	V	5.0	-1.1	Fundamental	
2665.433333	49.4	1000.0	1000.000	214.4	V	294.0	-0.8	24.5	73.9
5998.700000	44.0	1000.0	1000.000	343.1	V	141.0	5.0	29.9	73.9
11114.800000	47.1	1000.0	1000.000	365.1	H	226.0	12.9	26.8	73.9
17138.100000	52.1	1000.0	1000.000	348.2	H	174.0	19.7	21.8	73.9

Average Data

Frequency (MHz)	Average (dBµV/m)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Polarization	Azimuth (deg)	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
1064.800000	24.8	1000.0	1000.000	101.7	V	141.0	-7.5	29.1	53.9
1437.466667	26.2	1000.0	1000.000	203.5	V	109.0	-5.6	27.7	53.9
2403.833333	55.4	1000.0	1000.000	116.7	V	5.0	-1.1	Fundamental	
2665.433333	29.1	1000.0	1000.000	214.4	V	294.0	-0.8	24.8	53.9
5998.700000	30.5	1000.0	1000.000	343.1	V	141.0	5.0	23.4	53.9
11114.800000	34.2	1000.0	1000.000	365.1	H	226.0	12.9	19.7	53.9
17138.100000	39.2	1000.0	1000.000	348.2	H	174.0	19.7	14.7	53.9

Test Notes: Antenna port terminated with 50Ω load.

2.9.12 Test Results Above 1GHz Mid Channel



Peak Data

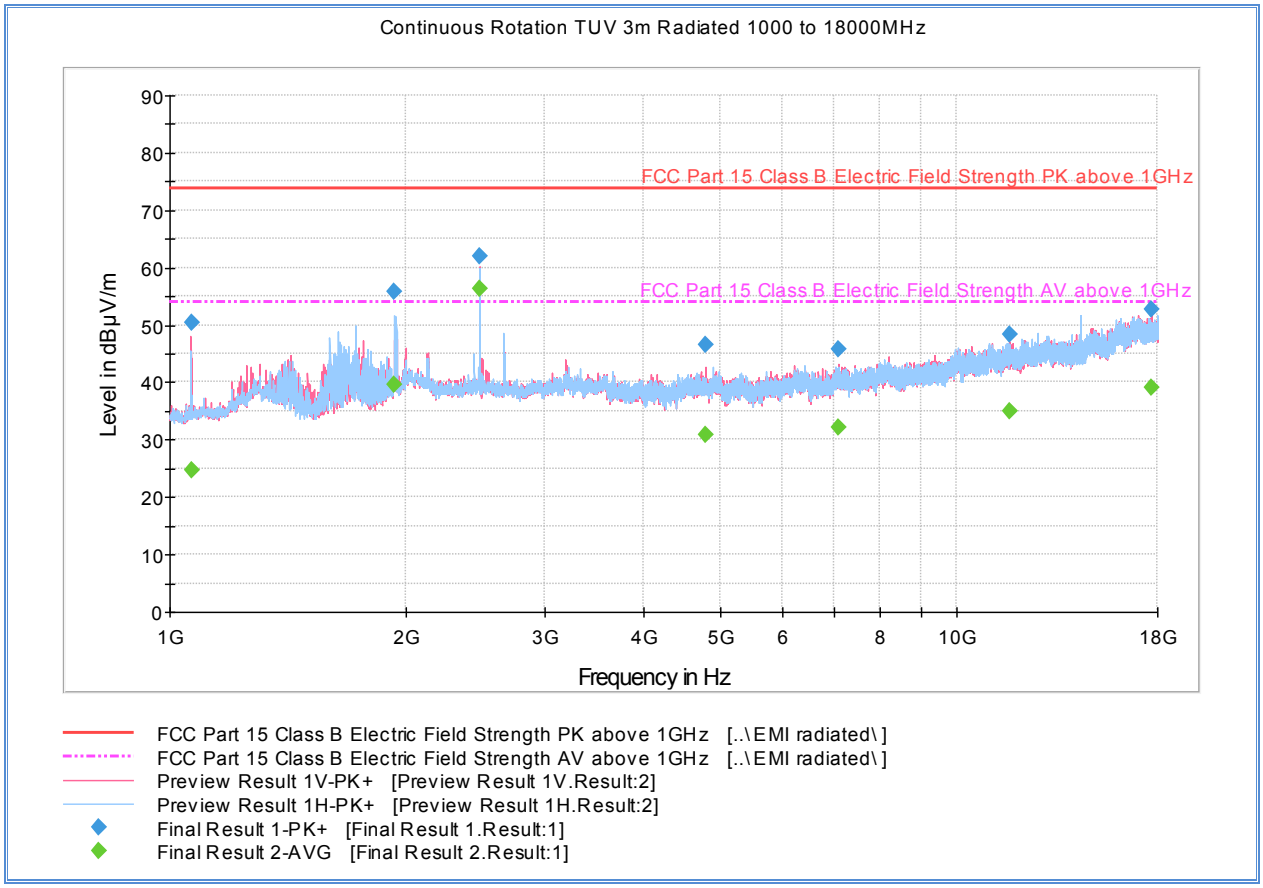
Frequency (MHz)	MaxPeak (dBµV/m)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Polarization	Azimuth (deg)	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
1291.266667	42.4	1000.0	1000.000	402.8	V	127.0	-4.7	31.5	73.9
1932.400000	53.8	1000.0	1000.000	286.2	V	307.0	-0.7	20.1	73.9
2440.300000	62.2	1000.0	1000.000	103.7	H	159.0	-1.0	Fundamental	
3309.966667	44.1	1000.0	1000.000	246.3	H	276.0	0.8	29.8	73.9
6341.066667	45.6	1000.0	1000.000	276.3	V	10.0	5.9	28.3	73.9
9999.766667	47.3	1000.0	1000.000	301.2	H	54.0	10.8	26.6	73.9
16777.500000	51.6	1000.0	1000.000	365.1	H	94.0	20.0	22.3	73.9

Average Data

Frequency (MHz)	Average (dBµV/m)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Polarization	Azimuth (deg)	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
1291.266667	29.2	1000.0	1000.000	402.8	V	127.0	-4.7	24.7	53.9
1932.400000	38.7	1000.0	1000.000	286.2	V	307.0	-0.7	15.2	53.9
2440.300000	56.4	1000.0	1000.000	103.7	H	159.0	-1.0	Fundamental	
3309.966667	30.2	1000.0	1000.000	246.3	H	276.0	0.8	23.7	53.9
6341.066667	32.3	1000.0	1000.000	276.3	V	10.0	5.9	21.6	53.9
9999.766667	33.9	1000.0	1000.000	301.2	H	54.0	10.8	20.0	53.9
16777.500000	38.5	1000.0	1000.000	365.1	H	94.0	20.0	15.4	53.9

Test Notes: Antenna port terminated with 50Ω load.

2.9.13 Test Results Above 1GHz High Channel



Peak Data

Frequency (MHz)	MaxPeak (dBµV/m)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Polarization	Azimuth (deg)	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
1065.200000	50.4	1000.0	1000.000	178.6	V	137.0	-7.5	23.5	73.9
1932.566667	55.7	1000.0	1000.000	383.0	H	-7.0	-0.7	18.2	73.9
2477.833333	62.1	1000.0	1000.000	151.6	V	258.0	-0.8	Fundamental	
4793.633333	46.4	1000.0	1000.000	399.0	V	96.0	3.2	27.5	73.9
7091.333333	45.7	1000.0	1000.000	155.6	V	208.0	7.0	28.2	73.9
11700.800000	48.3	1000.0	1000.000	300.6	V	262.0	13.8	25.6	73.9
17683.233333	52.6	1000.0	1000.000	371.1	V	309.0	20.2	21.3	73.9

Average Data

Frequency (MHz)	Average (dBµV/m)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Polarization	Azimuth (deg)	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
1065.200000	24.8	1000.0	1000.000	178.6	V	137.0	-7.5	29.1	53.9
1932.566667	39.6	1000.0	1000.000	383.0	H	-7.0	-0.7	14.3	53.9
2477.833333	56.4	1000.0	1000.000	151.6	V	258.0	-0.8	Fundamental	
4793.633333	30.8	1000.0	1000.000	399.0	V	96.0	3.2	23.1	53.9
7091.333333	32.1	1000.0	1000.000	155.6	V	208.0	7.0	21.8	53.9
11700.800000	35.0	1000.0	1000.000	300.6	V	262.0	13.8	18.9	53.9
17683.233333	39.1	1000.0	1000.000	371.1	V	309.0	20.2	14.8	53.9

Test Notes: Antenna port terminated with 50Ω load.

SECTION 3

TEST EQUIPMENT USED

3.1 TEST EQUIPMENT USED

List of absolute measuring and other principal items of test equipment.

ID Number (SDGE/SDRB)	Test Equipment	Type	Serial Number	Manufacturer	Cal Date	Cal Due Date
Antenna Conducted Port Setup						
7604	P-Series Power Meter	N1912A	SG45100273	Agilent	07/27/16	07/27/17
7605	50MHz-18GHz Wideband Power Sensor	N1921A	MY51100054	Agilent	04/18/16	04/18/17
7582	Signal/Spectrum Analyzer	FSW26	101614	Rhode & Schwarz	10/05/15	10/05/16
7608	Vector Signal Generator	SMBV100A	259021	Rhode & Schwarz	09/02/16	09/02/16
8825	20dB Attenuator	46-20-34	BK5773	Weinschel Corp.	Verified by 7582 and 7608	
Radiated Test Setup						
7611	Signal/Spectrum Analyzer	FSW26	102017	Rhode & Schwarz	02/01/16	02/01/17
7608	Vector Signal Generator	SMBV100A	259021	Rhode & Schwarz	07/29/15	07/29/16
1002	Bilog Antenna	3142C	00058717	ETS-Lindgren	11/06/15	11/06/17
1040	EMI Test Receiver	ESIB40	100292	Rhode & Schwarz	09/29/15	09/29/16
1016	Pre-amplifier	PAM-0202	187	PAM	12/15/15	12/15/16
1051	Double-ridged waveguide horn antenna	3115	9408-4329	EMCO	03/21/16	03/21/17
1049	EMI Test Receiver	ESU	100133	Rhode & Schwarz	03/17/16	03/17/17
8628	Pre-amplifier	QLJ 01182835-JO	8986002	QuinStar Technologies Inc.	01/11/16	01/11/17
1150	Horn antenna	3160-09	012054-004	ETS	07/16/15	07/16/17
1151	Pre-amplifier	TS-PR26	100026	Rhode & Schwarz	Verified by 7608 and 7611	
1153	High-frequency cable	SucoFlex 100 SX	N/A	Suhner	Verified by 7608 and 7611	
8543	High-frequency cable	Micropore 19057793	N/A	United Microwave Products	Verified by 7608 and 7611	
6815	2.4GHz Band Notch Filter	BRM50702	008	Micro-Tronics	Verified by 7608 and 7611	
Miscellaneous						
6792	Multimeter	3478A	2911A70964	Hewlett Packard	08/29/16	08/29/17
7560	Barometer/Temperature/Humidity Transmitter	iBTHX-W	1240476	Omega	10/19/15	10/19/16
	Test Software	EMC32	V8.53	Rhode & Schwarz	N/A	

3.2 MEASUREMENT UNCERTAINTY

For a 95% confidence level, the measurement uncertainties for defined systems are:

3.2.1 Radiated Measurements (Below 1GHz)

	Contribution	Probability Distribution Type	Probability Distribution x_i	Standard Uncertainty $u(x_i)$	$[u(x_i)]^2$
1	Receiver/Spectrum Analyzer	Rectangular	0.45	0.26	0.07
2	Cables	Rectangular	0.50	0.29	0.08
3	Preamp	Rectangular	0.50	0.29	0.08
4	Antenna	Rectangular	0.75	0.43	0.19
5	Site	Rectangular	2.70	1.56	2.43
6	EUT Setup	Rectangular	1.00	0.58	0.33
				Combined Uncertainty (u_c):	1.78
				Coverage Factor (k):	2
				Expanded Uncertainty:	3.57

3.2.2 Radiated Emission Measurements (Above 1GHz)

	Contribution	Probability Distribution Type	Probability Distribution x_i	Standard Uncertainty $u(x_i)$	$[u(x_i)]^2$
1	Receiver/Spectrum Analyzer	Rectangular	0.57	0.33	0.11
2	Cables	Rectangular	0.70	0.40	0.16
3	Preamp	Rectangular	0.50	0.29	0.08
4	Antenna	Rectangular	0.37	0.21	0.05
5	Site	Rectangular	2.70	1.56	2.43
6	EUT Setup	Rectangular	1.00	0.58	0.33
				Combined Uncertainty (u_c):	1.78
				Coverage Factor (k):	2
				Expanded Uncertainty:	3.56

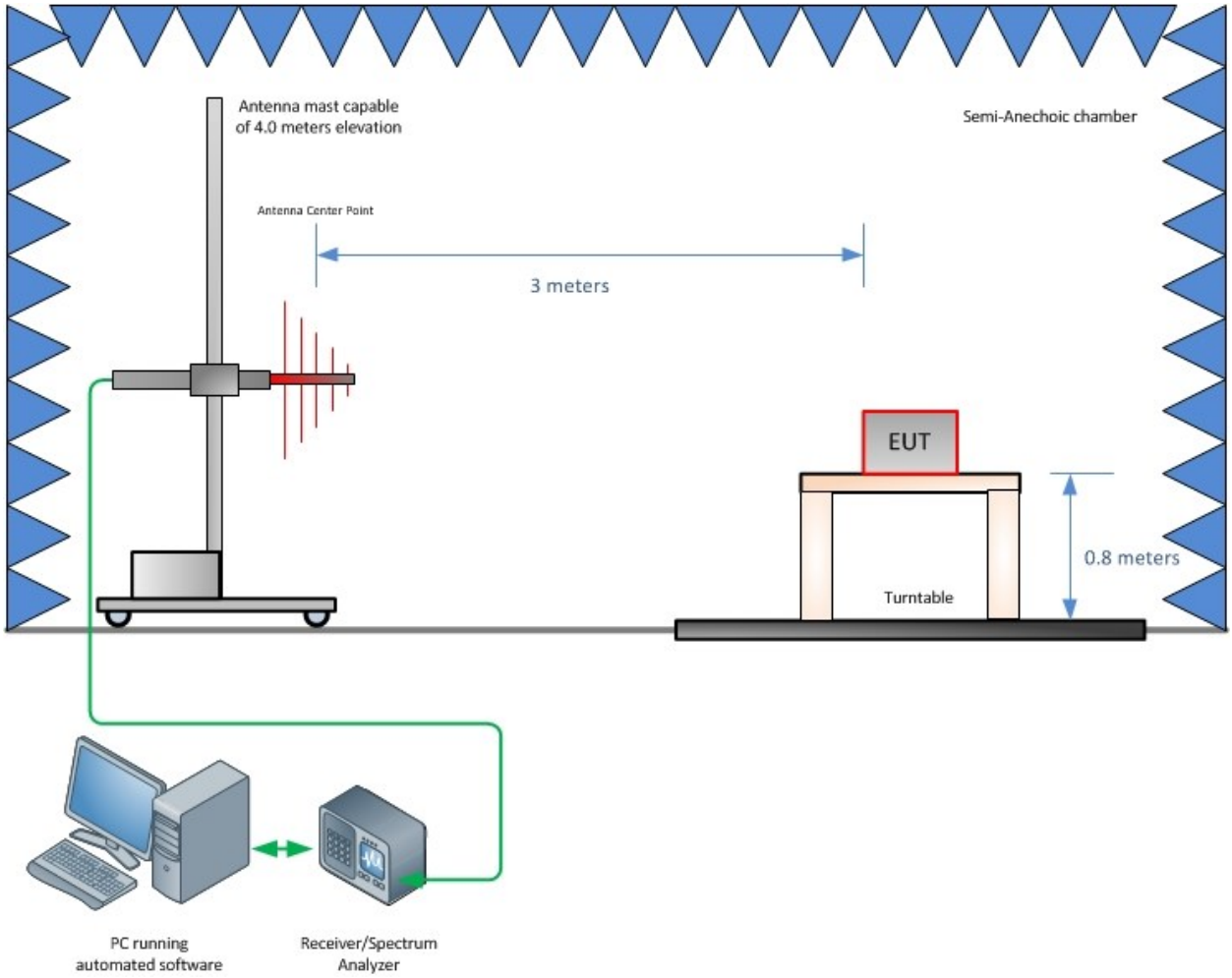
3.2.3 Conducted Antenna Port Measurement

	Contribution	Probability Distribution Type	Probability Distribution x_i	Standard Uncertainty $u(x_i)$	$[u(x_i)]^2$
1	Receiver/Spectrum Analyzer	Rectangular	0.57	0.33	0.11
2	Cables	Rectangular	0.50	0.29	0.08
3	EUT Setup	Rectangular	1.00	0.58	0.33
				Combined Uncertainty (u_c):	0.72
				Coverage Factor (k):	2
				Expanded Uncertainty:	1.45

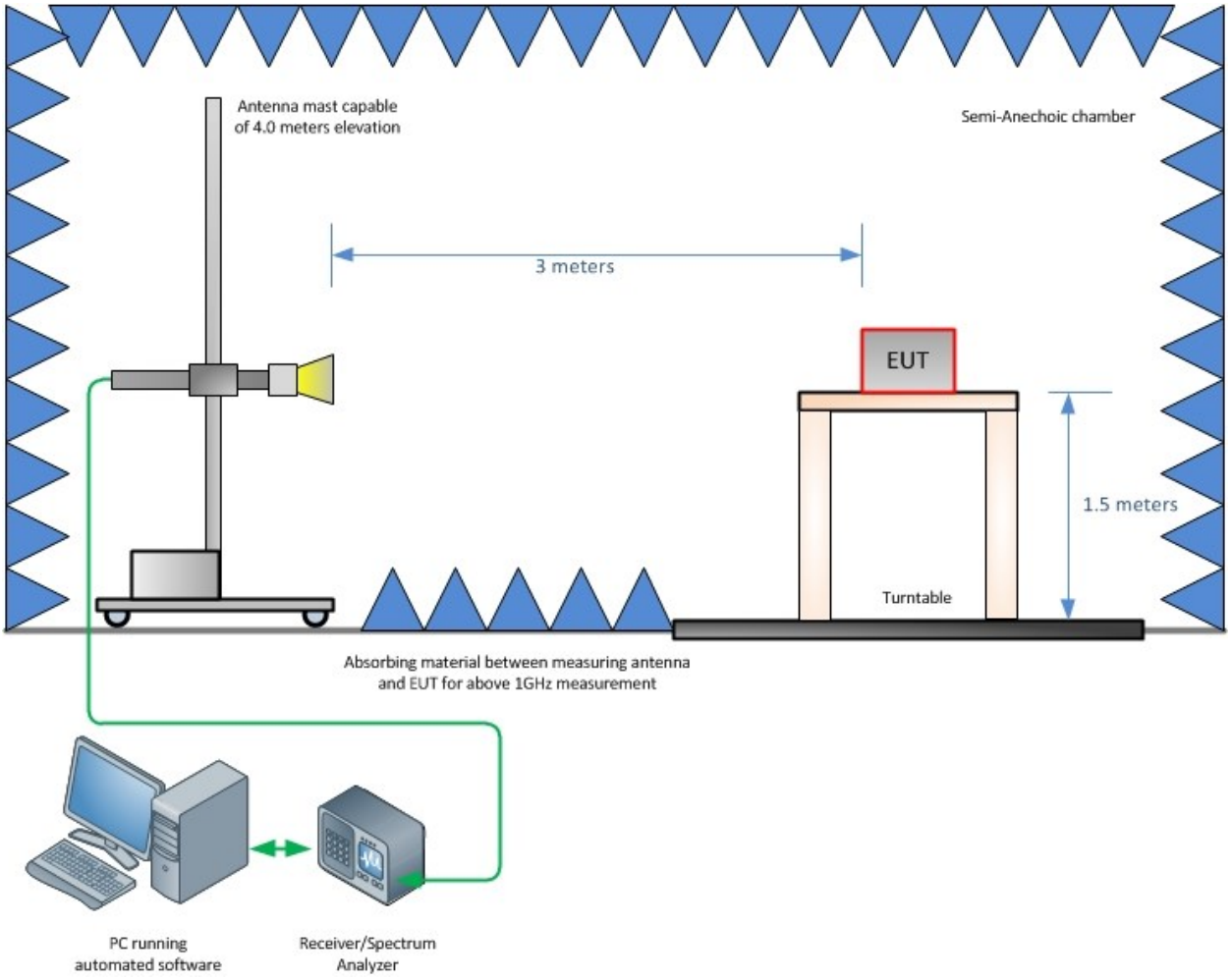
SECTION 4

DIAGRAM OF TEST SETUP

4.1 TEST SETUP DIAGRAM



Radiated Emission Test Setup (Below 1GHz)



Radiated Emission Test Setup (Above 1GHz)

SECTION 5

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5.1 ACCREDITATION, DISCLAIMERS AND COPYRIGHT

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TÜV SÜD AMERICA INC 10040 Mesa Rim Road San Diego, CA 92121-2912 Phone: 858 678 1400 FAX: 858 546 0364