FCC 47 CFR PART 15 SUBPART C
ISED RSS-247 ISSUE 2
ISED RSS-GEN ISSUE 4

TEST REPORT

FOR

GEN3 SPRINKLER CONTROLLER

MODEL NUMBER: 16ZULW-C

FCC ID: 2AOTB-ZULWC
IC: 23555-ZULWC

REPORT NUMBER: 11988952 - E3V2

ISSUE DATE: APRIL 3, 2018

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NVLAP LAB CODE 200065-0

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V1	03/12/18	Initial Issue	--
V2	04/03/18	Updated Sections 8.4, 9,	

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1. ATTESTATION OF TEST RESULTS

COMPANY NAME: RACHIO, INC.
1321 15 ST
DENVER, CO 80202, U.S.A.

EUT DESCRIPTION: GEN3 SPRINKLER CONTROLLER

MODEL: 16ZULW-C

SERIAL NUMBER: 1109141171

DATE TESTED: October 24, 2017 to March 09, 2018

APPLICABLE STANDARDS	
STANDARD	**TEST RESULTS**
CFR 47 Part 15 Subpart C	Complies
ISED RSS-247 Issue 2	Complies
ISED RSS-GEN Issue 4	Complies

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. All indications of Pass/Fail in this report are opinions expressed by UL Verification Services Inc. based on interpretations and/or observations of test results. Measurement Uncertainties were not taken into account and are published for informational purposes only. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

Note: The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. This document may not be altered or revised in any way unless done so by UL Verification Services Inc. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Verification Services Inc. will constitute fraud and shall nullify the document. This report must not be used by the client to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the U.S. Government.

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Prepared By:

JOHN LY
EMC TECHNICIAN
UL Verification Services Inc.

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2. TEST METHODOLOGY

The tests documented in this report were performed in accordance with FCC CFR 47 Part 2, FCC CFR 47 Part 15, ANSI C63.10-2013, RSS-GEN Issue 4, RSS-247 Issue 2.

3. FACILITIES AND ACCREDITATION

The test sites and measurement facilities used to collect data are located at 47173 Benicia Street, Fremont, California, USA. Line conducted emissions are measured only at the 47173 address. The following table identifies which facilities were utilized for radiated emission measurements documented in this report. Specific facilities are also identified in the test results sections.

47173 Benicia Street	47266 Benicia Street
☐ Chamber A	☐ Chamber D
☒ Chamber B	☐ Chamber E
☐ Chamber C	☐ Chamber F
	☐ Chamber G
	☐ Chamber H

The above test sites and facilities are covered under FCC Test Firm Registration # 208313. Chambers A through C are covered under Industry Canada company address code 2324B with site numbers 2324B -1 through 2324B-3, respectively. Chambers D through H are covered under Industry Canada company address code 22541 with site numbers 22541 -1 through 22541-5, respectively.

UL Verification Services Inc. is accredited by NVLAP, Laboratory Code 200065-0. The full scope of accreditation can be viewed at http://ts.nist.gov/standards/scopes/2000650.htm.

4. CALIBRATION AND UNCERTAINTY

4.1. MEASURING INSTRUMENT CALIBRATION

The measuring equipment utilized to perform the tests documented in this report has been calibrated in accordance with the manufacturer's recommendations, and is traceable to recognized national standards.

4.2. SAMPLE CALCULATION

Where relevant, the following sample calculation is provided:

Field Strength (dBuV/m) = Measured Voltage (dBuV) + Antenna Factor (dB/m) + Cable Loss (dB) – Preamp Gain (dB)

36.5 dBuV + 18.7 dB/m + 0.6 dB – 26.9 dB = 28.9 dBuV/m

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4.3. MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been estimated for tests performed on the apparatus:

PARAMETER	UNCERTAINTY
Conducted Disturbance, 9KHz to 0.15 MHz	3.84 dB
Conducted Disturbance, 0.15 to 30 MHz	3.65 dB
Radiated Disturbance, 9KHz to 30 MHz	3.15 dB
Radiated Disturbance, 30 to 1000 MHz	5.36 dB
Radiated Disturbance,1000 to 18000 MHz	4.32 dB
Radiated Disturbance,18000 to 26000 MHz	4.45 dB
Radiated Disturbance,26000 to 40000 MHz	5.24 dB
Occupied Channel Bandwidth	± 0.39 dB

Uncertainty figures are valid to a confidence level of 95%.

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5. EQUIPMENT UNDER TEST

5.1. DESCRIPTION OF EUT

The EUT is a GEN3 SPRINKLER CONTROLLER.

5.2. DESCRIPTION OF DIFFERENCES BETWEEN 16 ZONE AND 8 ZONE DEVICES

The 8 zone device uses the same circuit board as the 16 zone with some small population differences. The 8 zone has 8 fewer triacs (analog switches) populated as well as supporting resistors/capacitors around the triacs. There are also jumpers populated differently to route connections to different poles on the connector. None of these parts are related to the RF circuitry, power supply or any high frequency operation.

A spot test was performed on harmonics and spurious for the 8 zone unit, the results showed that the levels of harmonics and spurious were not higher than the original ones by more than 3 dB, therefore, this qualifies for C1PC for the 8 zone unit.

5.3. MAXIMUM OUTPUT POWER

The transmitter has a maximum conducted average output power as follows:

Frequency Range (MHz)	Average Output Power (dBm)	Peak Output Power (mW)
903.8 - 922.2	17.23	52.84

5.4. DESCIPTION OF CHANGE

Based on the manufacturer's declaration, the reason for the additional testing as covered by this report is the co-location of an additional radio (LoRa 915 MHz radio) on their device that is not covered under the Murata WiFi module's certification.

5.5. DESCRIPTION OF AVAILABLE ANTENNAS

The antenna that is used by LoRa 915 MHz radio is the following
Antenna Type: SMD chip antenna
Antenna Gain: -0.5dBi

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5.6. SOFTWARE AND FIRMWARE

The firmware installed in the EUT during testing was SONY, s_atp_1_00139_B_10_5.
The test utility software used during testing was Tera Term Ver 4.79.

5.7. WORST-CASE CONFIGURATION AND MODE

Radiated emission below 1 GHz and power line conducted emission were performed with the EUT set to transmit at the channel with highest output power as worst-case scenario.

The fundamental of the EUT was investigated in three orthogonal orientations X,Y, & Z, it was determined that Y orientation was worst-case orientation; therefore, all final radiated testing was performed with the EUT in Y orientation.

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5.8. DESCRIPTION OF TEST SETUP

SUPPORT EQUIPMENT

Support Equipment List			
Description	**Manufacturer**	**Model**	**Serial Number**
AC Adapter	Rachio	ILA48-24 1000	N/A

I/O CABLES

I/O Cable List						
Cable No	**Port**	**# of identical ports**	**Connector Type**	**Cable Type**	**Cable Length (m)**	**Remarks**
1	AC	1	2-Prong	Unshielded	1.5	

TEST SETUP

The EUT is a standalone device. Test software exercised the radio card.

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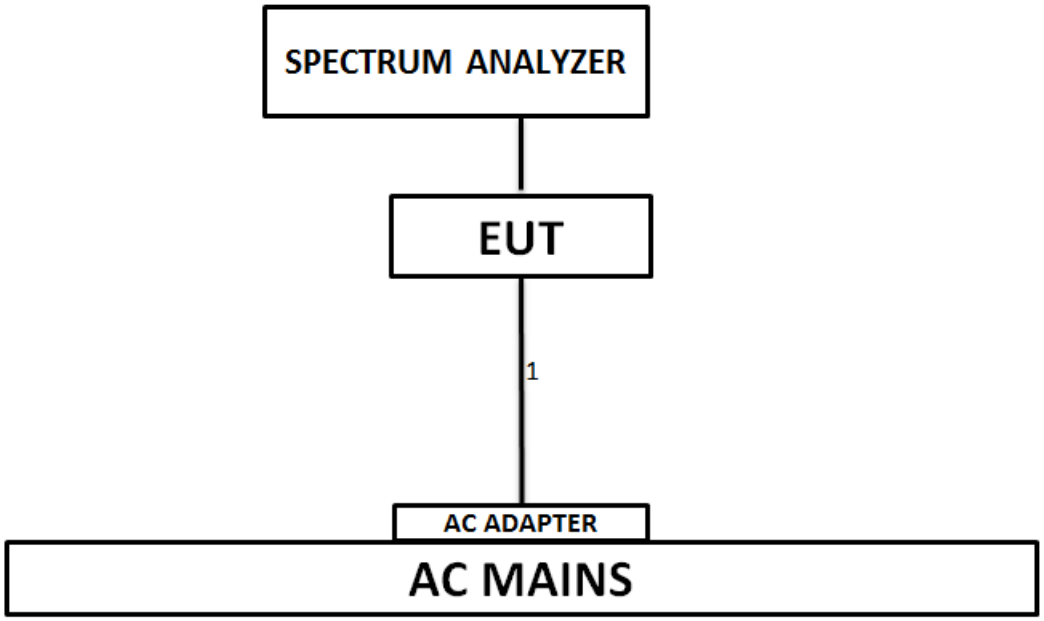
SETUP DIAGRAM FOR TESTS

CONDUCTED



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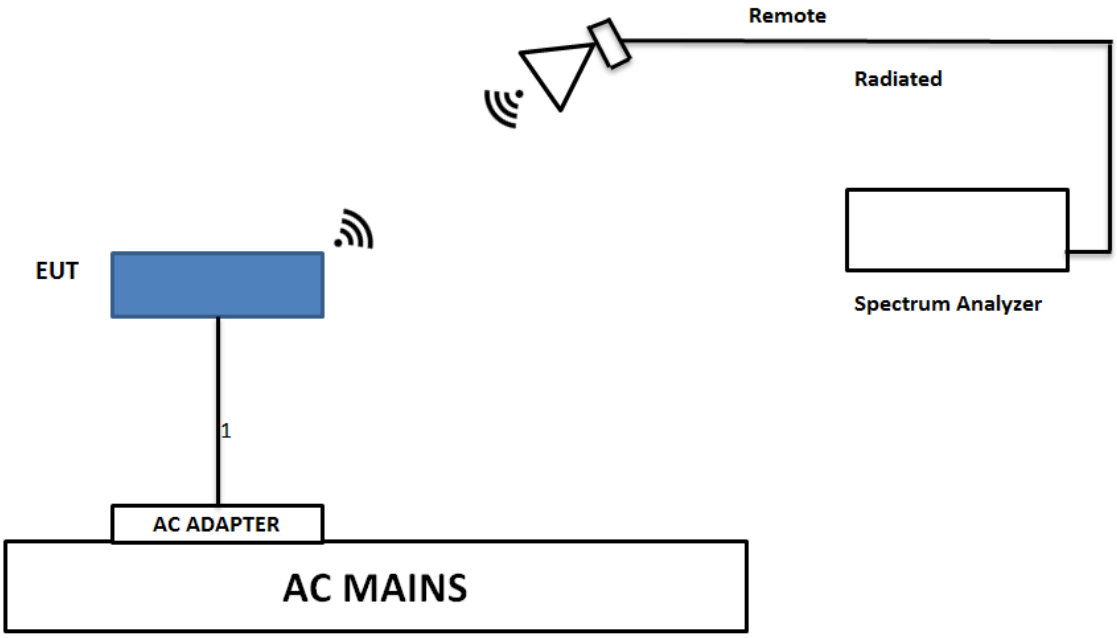
RADIATED



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6. TEST AND MEASUREMENT EQUIPMENT

The following test and measurement equipment was utilized for the tests documented in this report:

Test Equipment List				
Description	**Manufacturer**	**Model**	**T Number**	**Cal Due**
Amplifier, 1-18GHz	Miteq	AFS42-00101800-25-S-42	493	06/23/18
Filter, HPF 6 HPF	Micro-Tronics	HPS17542	483	06/24/18
Filter, HPF 3GHz	Micro-Tronics	HPM17543	485	06/24/18
Switch Driver	Keysight	11713A	457	N/A
Filter, LPF 5GHz	Micro-Tronics	LPS17541	482	06/24/18
Antenna, Horn 1-18GHz	ETS Lindgren	3117	346	03/28/18
Antenna, Horn 26.5 - 40GHz	ARA	MWH-2640	90	08/25/18
Amplifier, 26 - 40GHz	Miteq	NSP 4000 SP2	88	04/29/18
Antenna, Active Loop 9KHz to 30MHz	Emco	6502	35	03/09/19
Controller	Sunol Sciences	SC110V	1290	N/A
Antenna, Broadband Hybrid, 30MHz to 2000MHz	Sunol Sciences	JB1	899	06/15/18
Amplifier, 26 - 40GHz	Miteq	NSP 4000 SP2	T88	04/29/18
Amplifier, 10KHz to 1GHz, 32dB	Keysight	8447D	10	02/15/19
Amplifier, 1 to 8 GHz, 35dB	Miteq	AMF-4D-01000800-30-29P	1156	06/24/18
Spectrum Analyzer, PSA, 3Hz to 44GHz	Keysight	E4446A	T146	07/18/18
Spectrum Analyzer, PXA 3Hz to 44GHz	Keysight	N9030A	907	01/23/19

Test Software List			
Description	**Manufacturer**	**Model**	**Test Software**
Radiated Software	UL	UL EMC	Ver 9.5, Dec 01, 2016
Antenna Port Software	UL	UL RF	Ver 9.1, January 25, 2018

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7. MEASUREMENT METHODS

On Time and Duty Cycle: KDB 558074 D01 v04, Section 6.

6 dB BW: KDB 558074 D01 v04, Section 8.1.

99% BW: ANSI C63.10-2013, Section 6.9.3.

Output Power: KDB 558074 D01 v04, Section 9.2.3.1.

Power Spectral Density: KDB 558074 D01 v04, Section 10.3.

Out-of-band emissions in non-restricted bands: KDB 558074 D01 v04, Section 11.1 (b).

Out-of-band emissions in restricted bands: KDB 558074 D01 v04, Section 12.1.

Band-edge: KDB 558074 D01 v04, Section 12.1.
.

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8. ANTENNA PORT TEST RESULTS

8.1. ON TIME AND DUTY CYCLE

LIMITS

None; for reporting purposes only.

PROCEDURE

KDB 558074 Zero-Span Spectrum Analyzer Method.

ON TIME AND DUTY CYCLE RESULTS

Mode	ON Time B (msec)	Period (msec)	Duty Cycle x (linear)	Duty Cycle (%)	Duty Cycle Correction Factor (dB)	1/B Minimum VBW (kHz)
915MHz	0.499	0.499	1.000	100.00%	0.00	0.010

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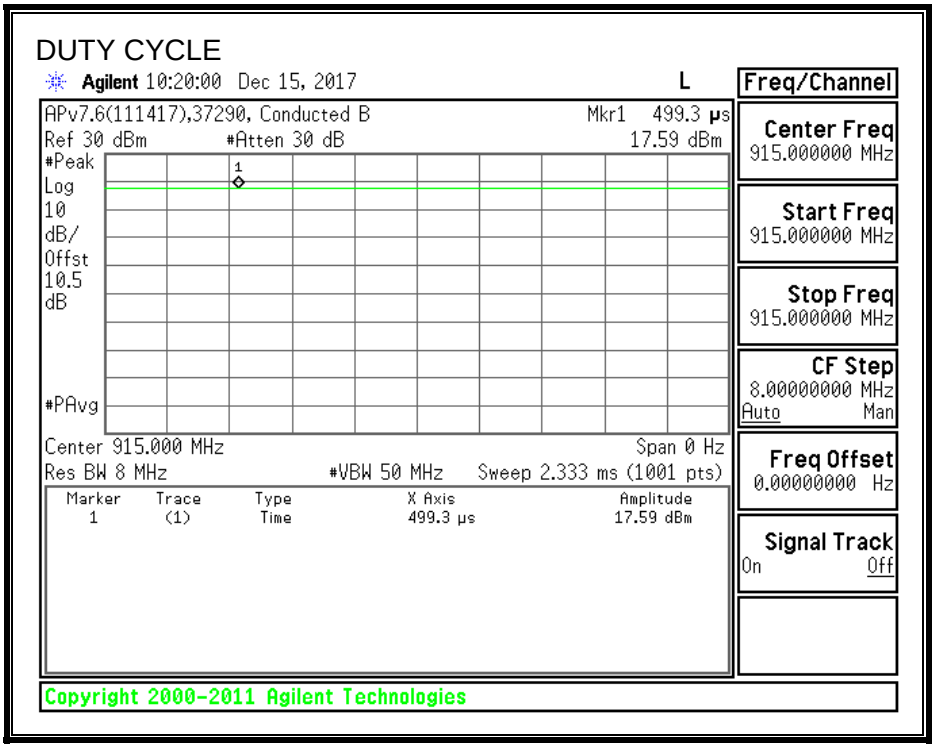
DUTY CYCLE PLOTS



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8.2. 6 dB BANDWIDTH

LIMITS

FCC §15.247 (a) (2)

ISED RSS-247 Clause 5.2 (a)

The minimum 6 dB bandwidth shall be at least 500 kHz.

RESULTS

Channel	Frequency (MHz)	6 dB Bandwidth (MHz)	Minimum Limit (MHz)
Low	903.8	0.771	0.5
Mid	915.0	0.759	0.5
High	922.2	0.777	0.5

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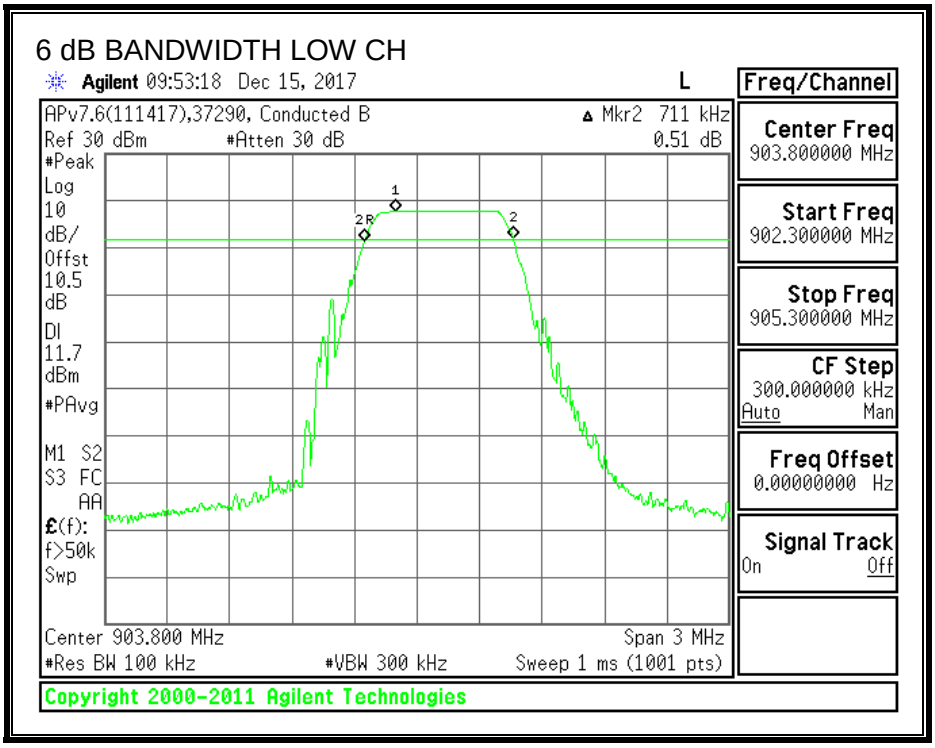
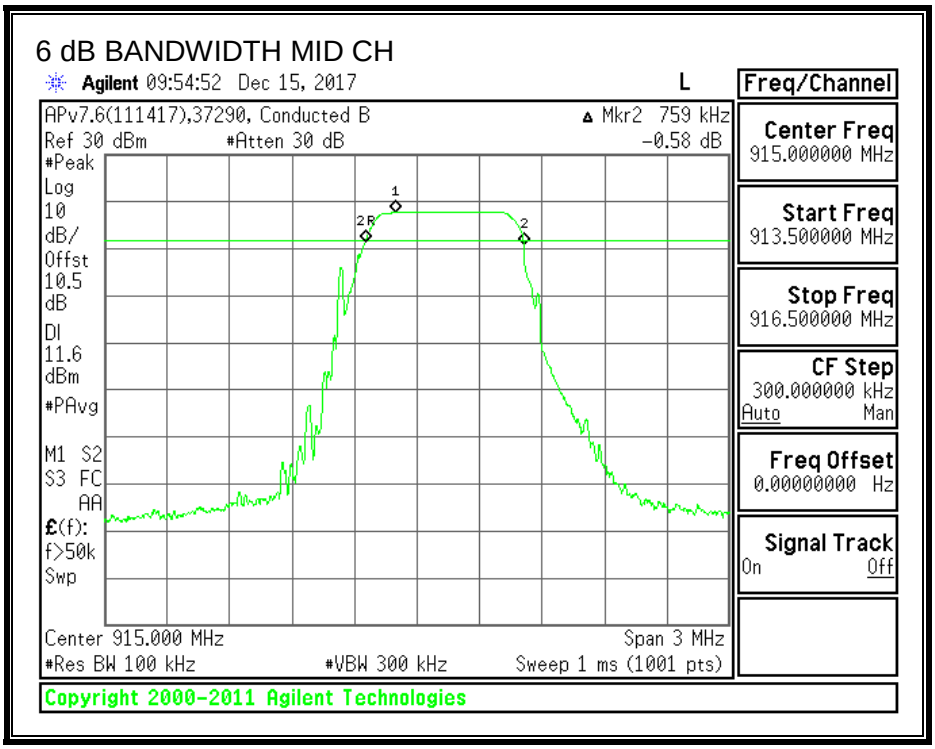
6 dB BANDWIDTH





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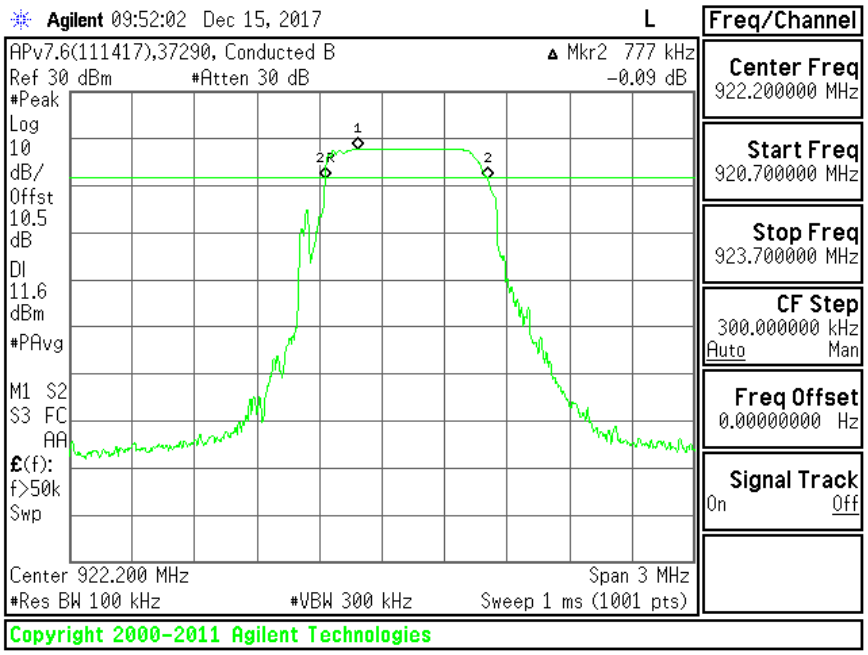
6 dB BANDWIDTH HIGH CH



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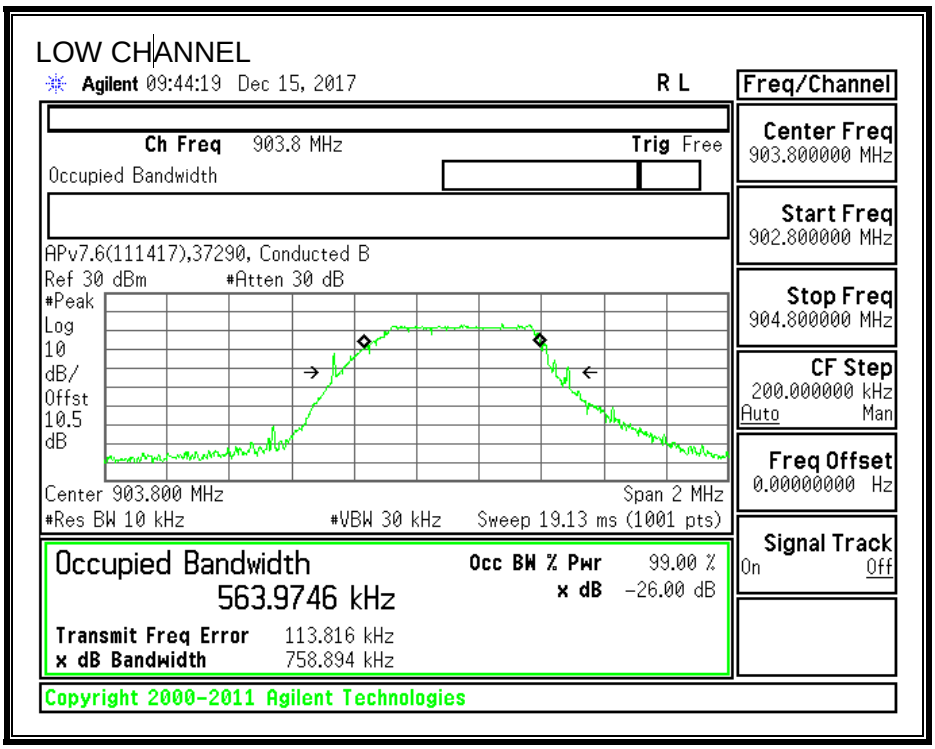
8.3. 99% BANDWIDTH

LIMITS

None; for reporting purposes only.

RESULTS

Channel	Frequency (MHz)	99% Bandwidth (MHz)
Low	903.8	0.5640
Mid	915.0	0.5786
High	922.2	0.5589



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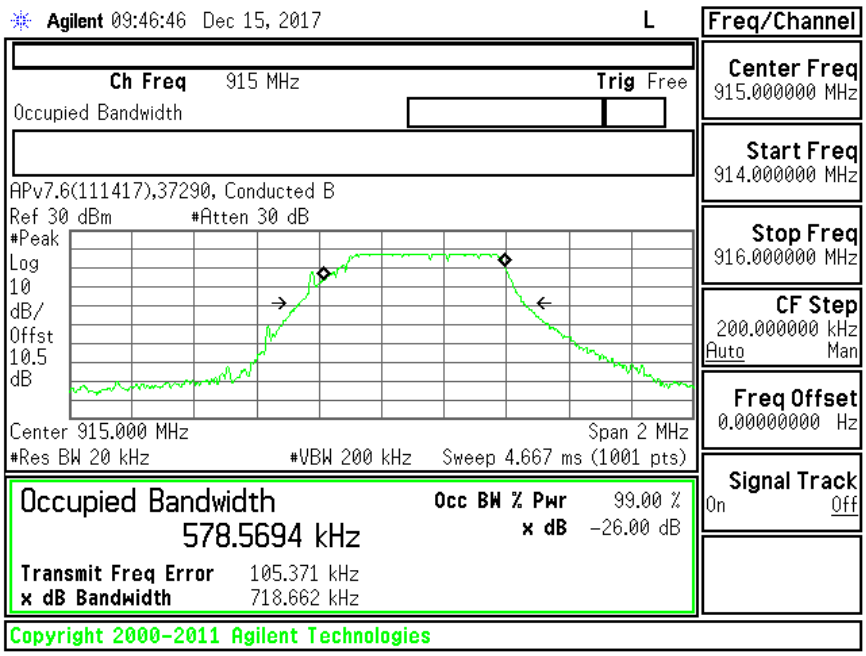
MID CHANNEL



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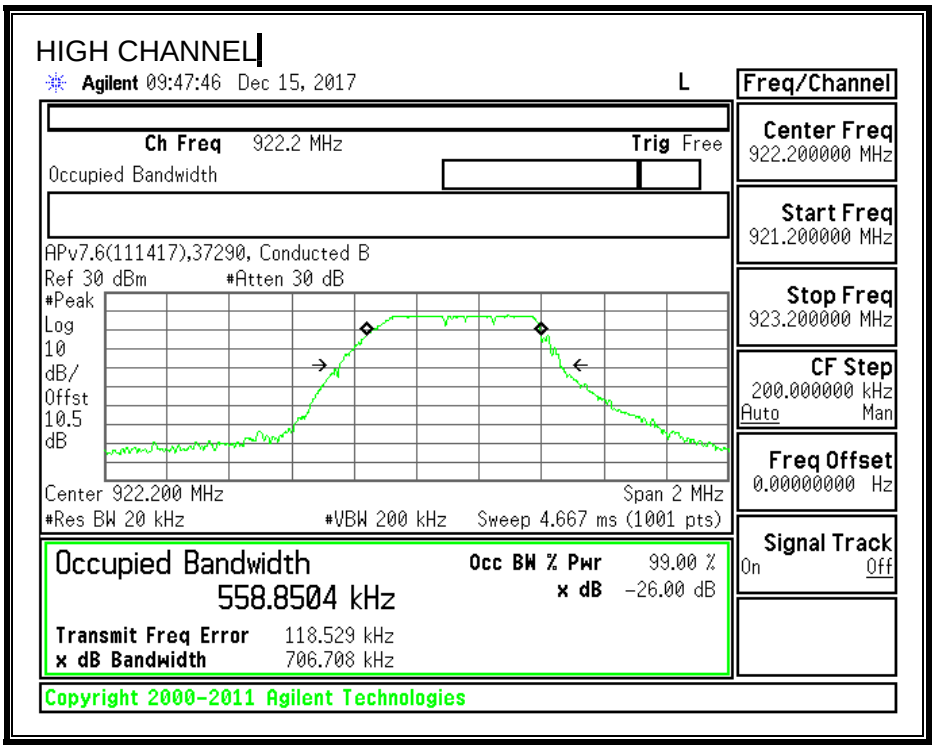

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8.4. AVERAGE OUTPUT POWER

LIMITS

FCC §15.247

ISED RSS-247 Clauses 5.4 (d)

For systems using digital modulation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands: 1 Watt, based on the use of antennas with directional gains that do not exceed 6 dBi. If transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

DIRECTIONAL ANTENNA GAIN

There is only one transmitter output therefore the directional gain is equal to the antenna gain.

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RESULTS

Limits

Channel	Frequency (MHz)	Directional Gain (dBi)	FCC Power Limit (dBm)	IC Power Limit (dBm)	IC EIRP Limit (dBm)	Max Power (dBm)
Low	903.8	-0.50	30.00	30	36	30.00
Mid	915	-0.50	30.00	30	36	30.00
High	922.2	-0.50	30.00	30	36	30.00

Duty Cycle CF (dB)	0.00	**Included in Calculations of Corr'd Power**

Results

Channel	Frequency (MHz)	Chain 0 Meas Average Power (dBm)	Total Corr'd Average Power (dBm)	Power Limit (dBm)	Margin (dB)
Low	903.8	17.23	17.23	30.00	-12.77
Mid	915	17.19	17.19	30.00	-12.81
High	922.2	17.17	17.17	30.00	-12.83

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8.5. POWER SPECTRAL DENSITY

LIMITS

FCC §15.247

ISED RSS-247 Clause 5.2 (b)

RESULTS

Duty Cycle CF (dB)	0.00	Included in Calculations of Corr'd PSD

PSD Results

Channel	Frequency (MHz)	Chain 0 Meas (dBm)	Total Corr'd PSD (dBm)	Limit (dBm)	Margin (dB)
Low	903.8	-2.66	-2.66	8.0	-10.7
Mid	915.0	-2.90	-2.90	8.0	-10.9
High	922.2	-2.74	-2.74	8.0	-10.7

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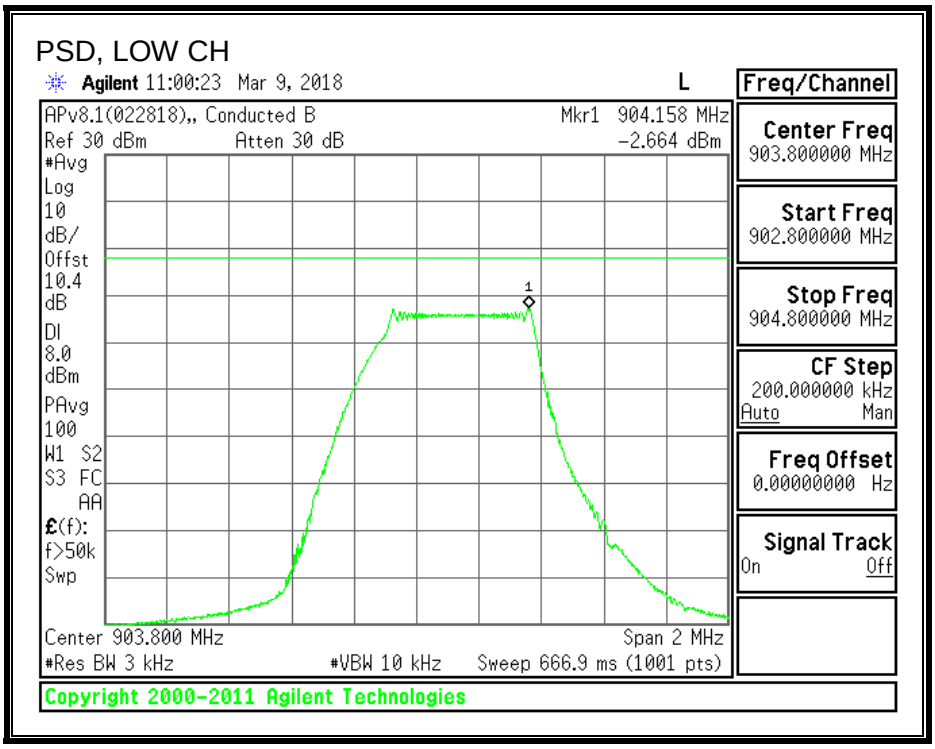
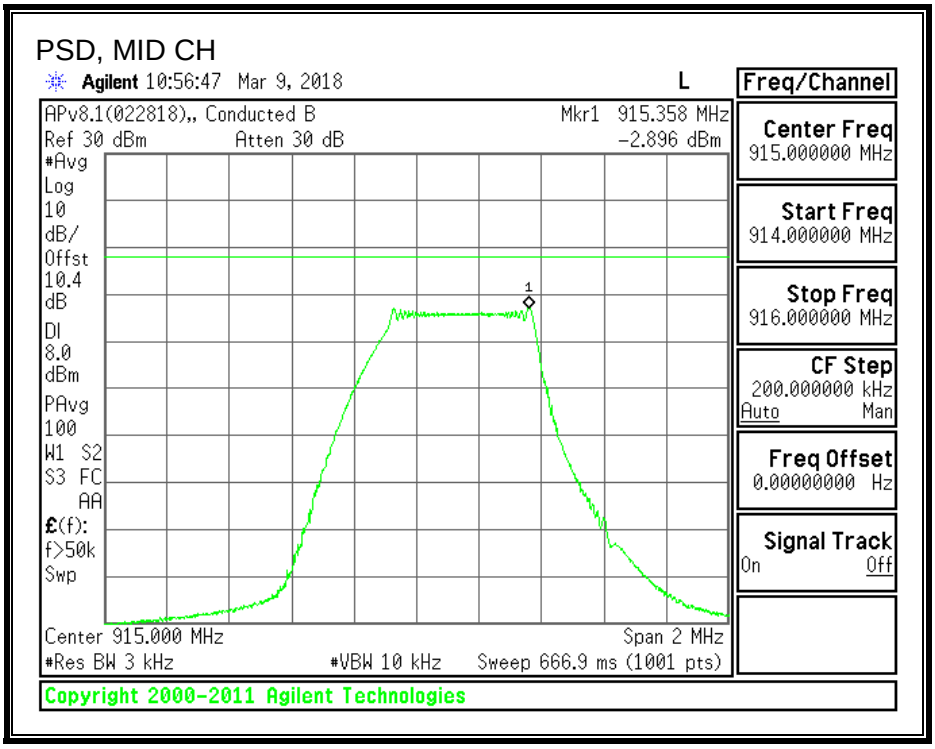
PSD, Chain 0





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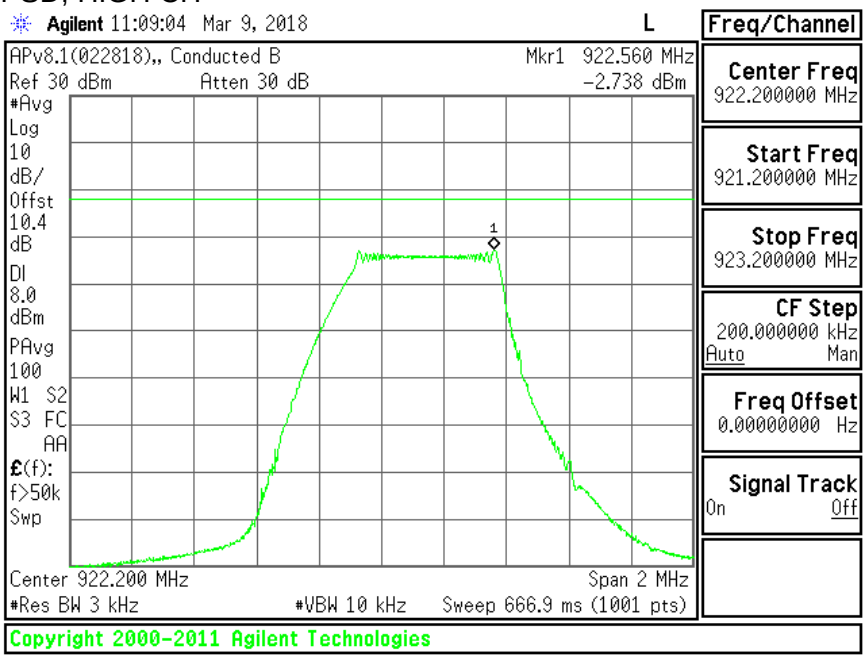
PSD, HIGH CH



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8.6. OUT-OF-BAND EMISSIONS

LIMITS

FCC §15.247 (d)

ISED RSS-247 Clause 5.5

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.

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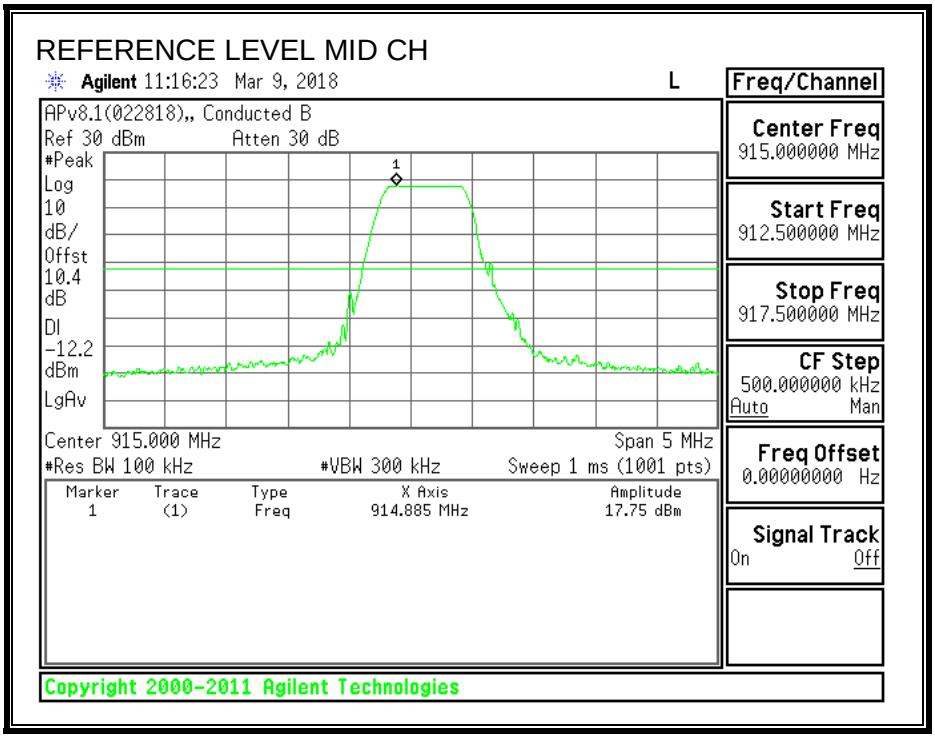
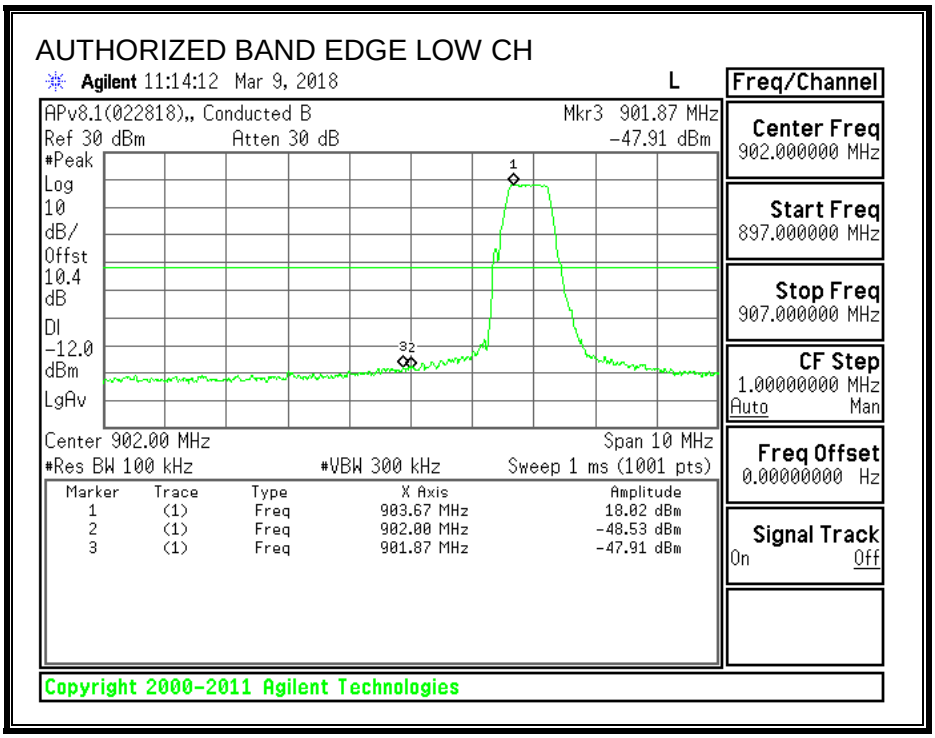
IN-BAND REFERENCE LEVEL



LOW CHANNEL BANDEDGE



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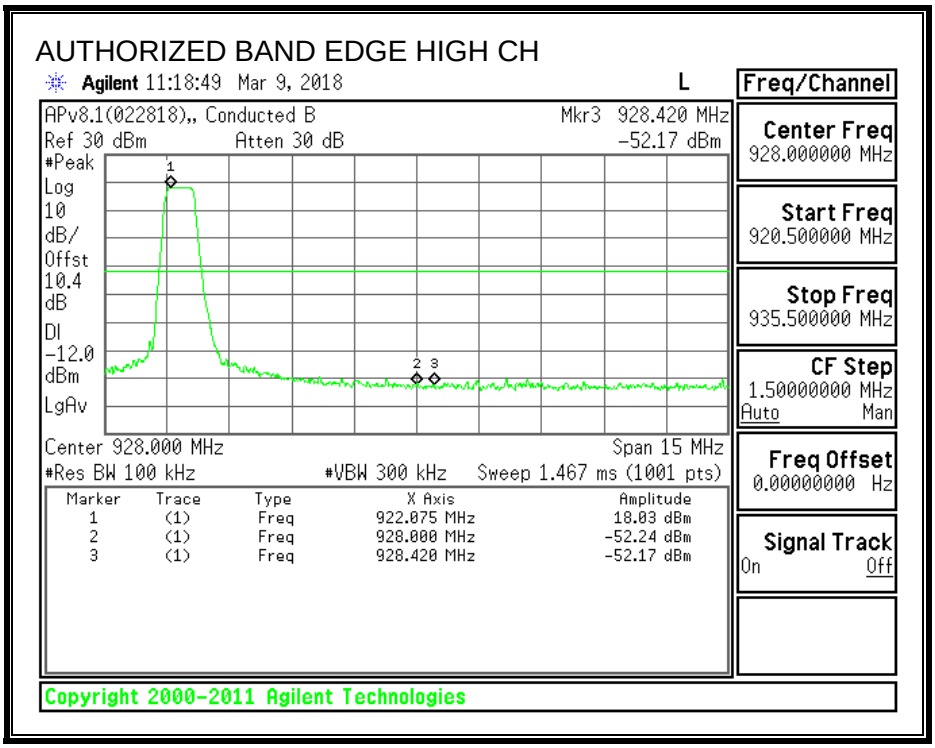
HIGH CHANNEL BANDEDGE



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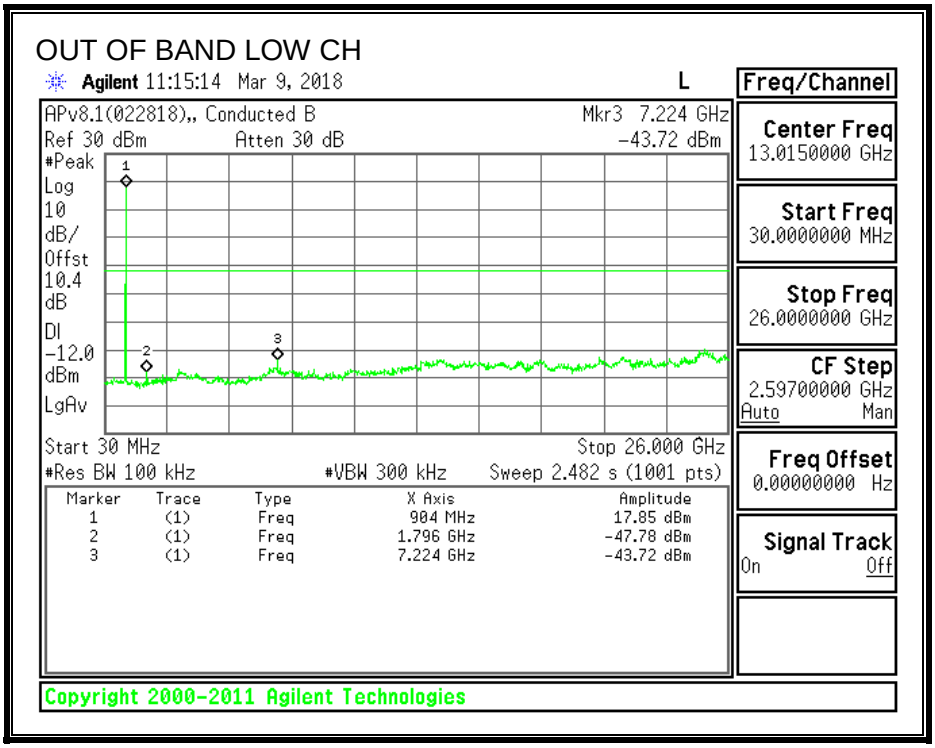
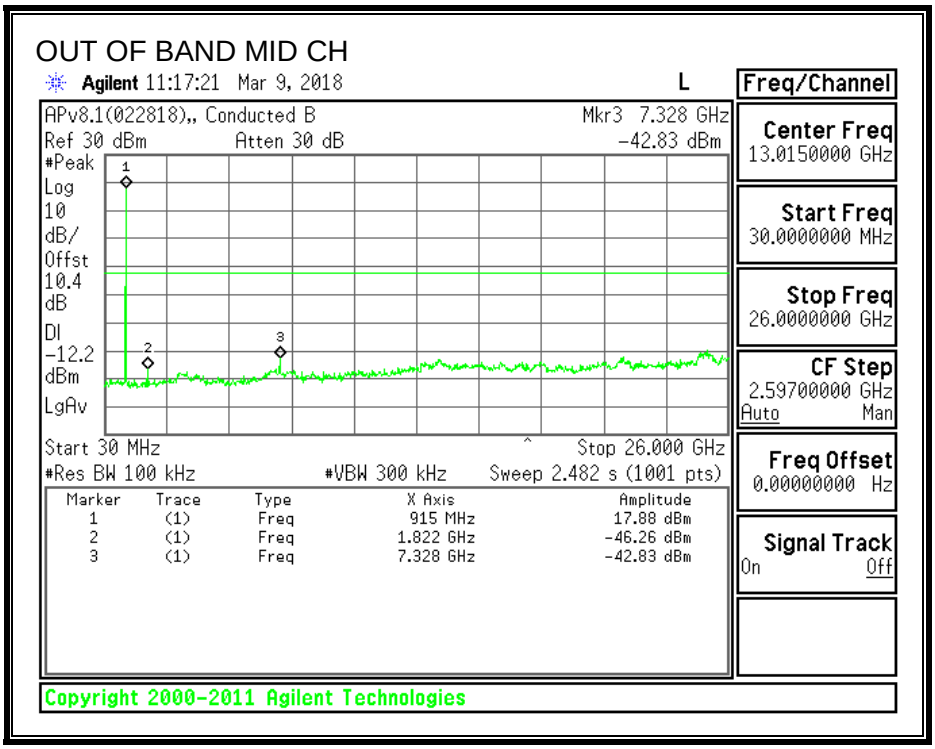
OUT-OF-BAND EMISSIONS





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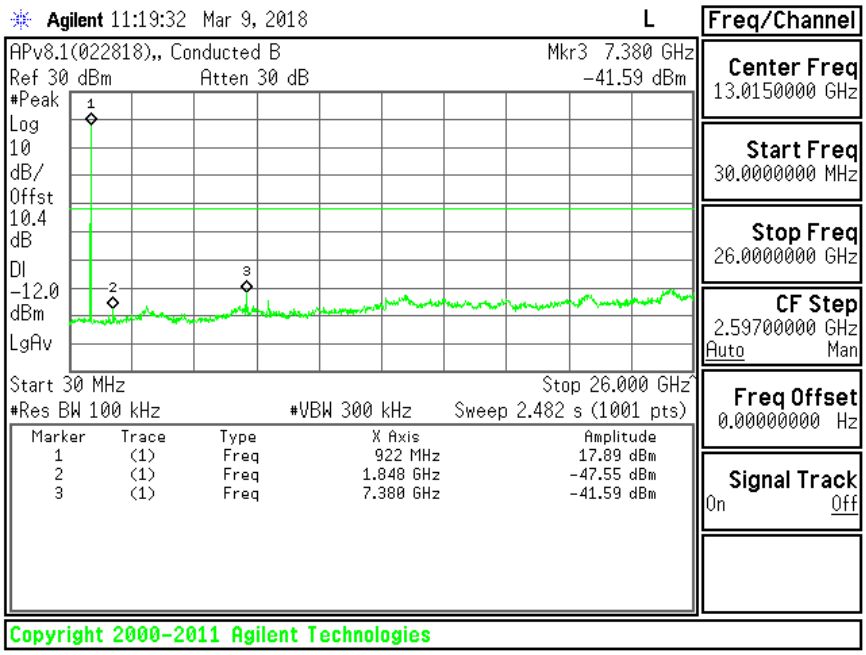
OUT OF BAND HIGH CH



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9. RADIATED TEST RESULTS

LIMITS

FCC 15.247

IC RSS-210
IC RSS-GEN Clause 8.9 (Transmitter)
IC RSS-GEN Clause 7 (Receiver)

Operation within the bands 902–928 MHz, 2400–2483.5 MHz, 5725–5875 MHZ, and 24.0–24.25 GHz.
(a) Except as provided in paragraph (b) of this section, the field strength of emissions from intentional radiators operated within these frequency bands shall comply with the following:

Fundamental frequency	Field strength of fundamental (millivolts/meter)	Field strength of harmonics (microvolts/meter)
902–928 MHz	50	500
2400–2483.5 MHz	50	500
5725–5875 MHz	50	500
24.0–24.25 GHz	250	2500

(d) Emissions radiated outside of the specified frequency bands, except for harmonics, shall be attenuated by at least 50 dB below the level of the fundamental or to the general radiated emission limits in § 15.209, whichever is the lesser attenuation.

Frequency (MHz)	Field strength (microvolts/meter)	Measurement distance (meters)
0.009–0.490	2400/F(kHz)	300
0.490–1.705	24000/F(kHz)	30
1.705–30.0	30	30
30–88	100 **	3
88–216	150 **	3
216–960	200 **	3
Above 960	500	3

** Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this section shall not be located in the frequency bands 54–72 MHz, 76–88 MHz, 174–216 MHz or 470–806 MHz. However, operation within these frequency bands is permitted under other sections of this part, e.g., §§15.231 and 15.241.

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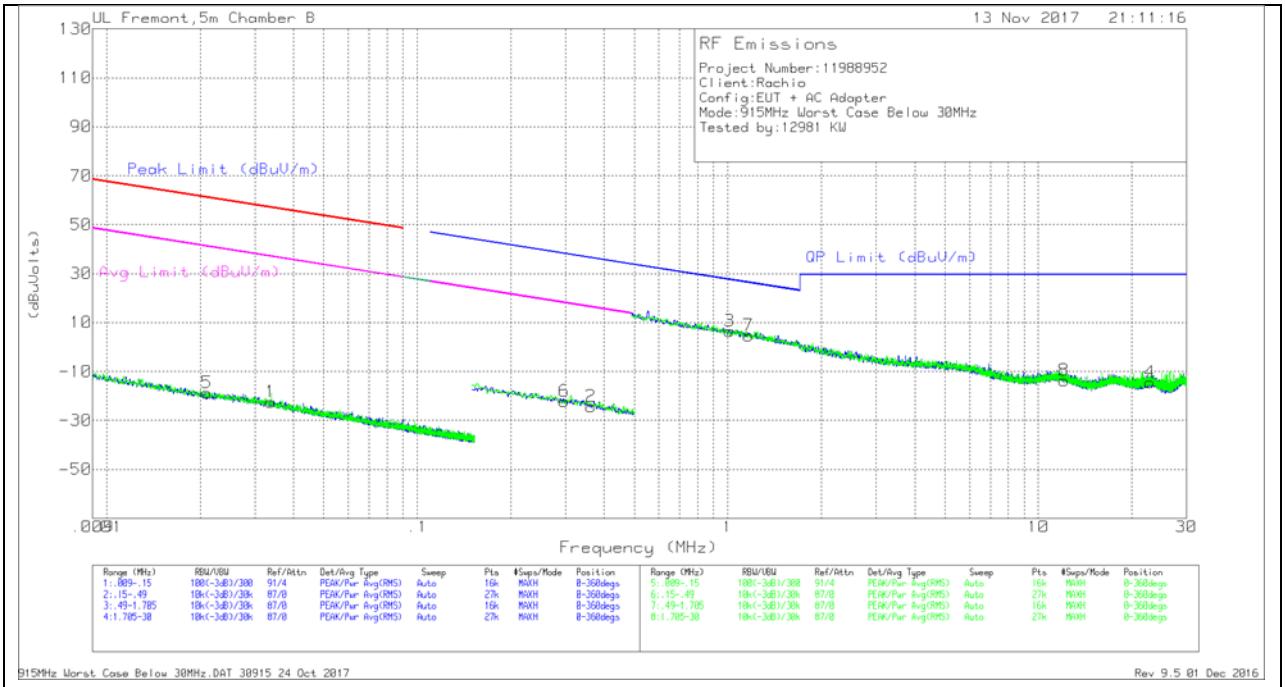
RESULTS

9.1. TRANSMITTER RADIATED EMISISONS 9 kHz TO 30 MHz



NOTE: KDB 937606 OATS and Chamber Correlation Justification

- Based on FCC 15.31 (f) (2): measurements may be performed at a distance closer than that specified in the regulations; however, an attempt should be made to avoid making measurements in the near field.
- OATs and chamber correlation testing had been performed and chamber measured test result is the worst case test result.

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Trace Markers

Marker	Frequency (MHz)	Meter Reading (dBuV)	Det	Loop Antenna (dB/m)	Cbl (dB)	Dist Corr 300m	Corrected Reading (dBuVolts)	Peak Limit (dBuV/m)	Margin (dB)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	Margin (dB)	Avg Limit (dBuV/m)	Margin (dB)	Azimuth (Degs)
5	.02108	44.97	Pk	14.8	1.4	-80	-18.83	61.11	-79.94	41.11	-59.94	-	-	-	-	0-360
1	.0338	40.76	Pk	15.3	1.4	-80	-22.54	57.01	-79.55	37.01	-59.55	-	-	-	-	0-360
6	.2975	42.42	Pk	13.8	1.5	-80	-22.28	-	-	-	-	38.14	-60.42	18.14	-40.42	0-360
2	.36256	40.3	Pk	13.8	1.5	-80	-24.4	-	-	-	-	36.42	-60.82	16.42	-40.82	0-360

Pk - Peak detector

Marker	Frequency (MHz)	Meter Reading (dBuV)	Det	Loop Antenna (dB/m)	Cbl (dB)	Dist Corr (dB) 40Log	Corrected Reading (dBuVolts)	QP Limit (dBuV/m)	Margin (dB)	Azimuth (Degs)
3	1.01273	30.68	Pk	14.3	1.5	-40	6.48	27.51	-21.03	0-360
7	1.16568	28.92	Pk	14.3	1.5	-40	4.72	26.29	-21.57	0-360
8	12.09435	9.99	Pk	14.7	1.6	-40	-13.71	29.5	-43.21	0-360
4	22.87827	10.03	Pk	13.8	1.7	-40	-14.47	29.5	-43.97	0-360

Pk - Peak detector

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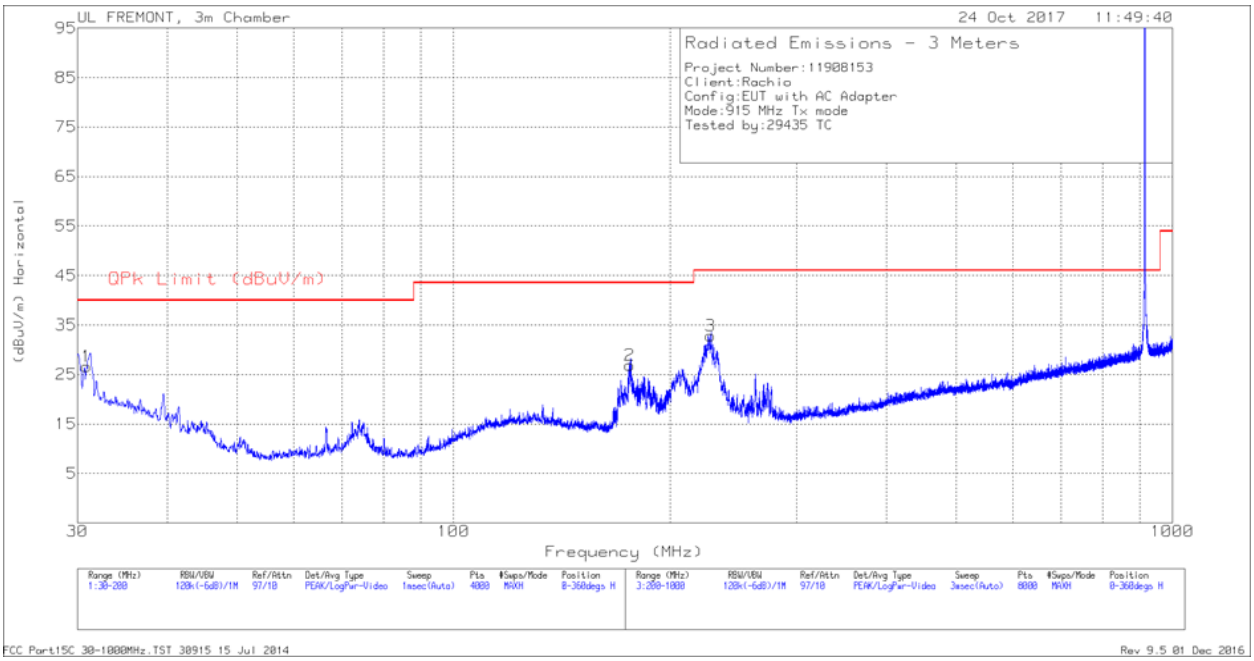
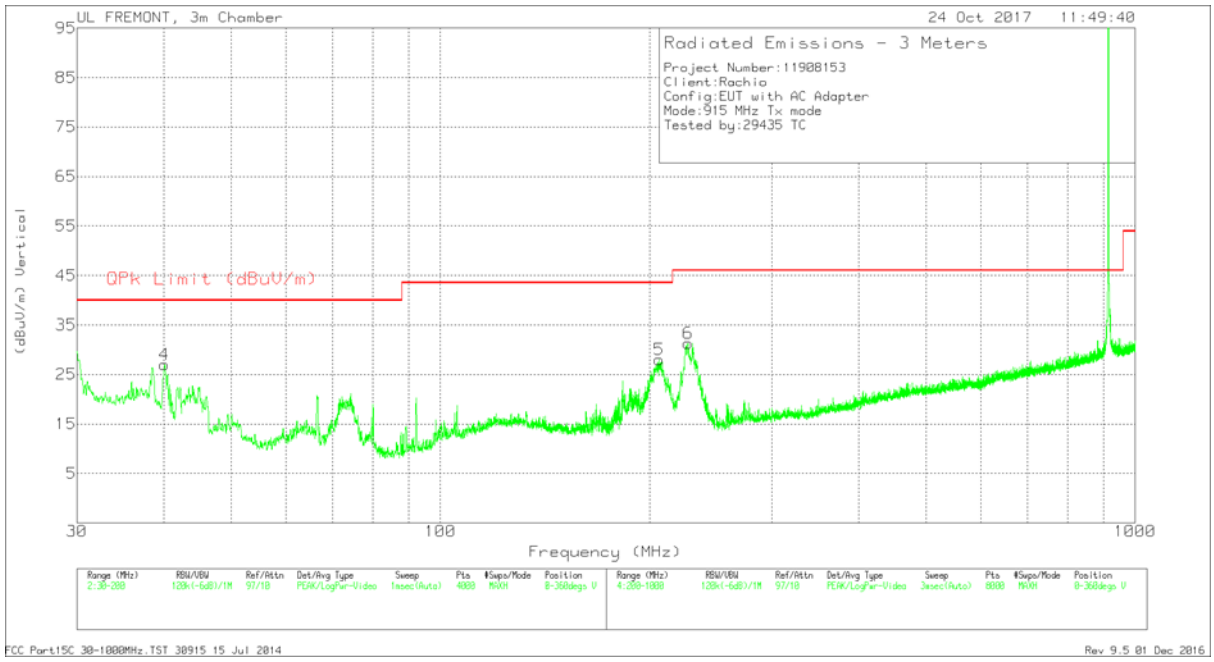
9.2. TRANSMITTER RADIATED EMISSIONS 30 TO 1000 MHz



HORIZONTAL



VERTICAL

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Data

Trace Markers

Marker	Frequency (MHz)	Meter Reading (dBuV)	Det	AF T408 (dB/m)	Amp/Cbl (dB/m)	Corrected Reading (dBuV/m)	QPk Limit (dBuV/m)	Margin (dB)	Azimuth (Degs)	Height (cm)	Polarity
1	30.8927	33.06	Pk	24.6	-31.1	26.56	40	-13.44	0-360	100	H
4	40.1176	40.09	Pk	17.8	-30.9	26.99	40	-13.01	0-360	100	V
2	175.8127	41	Pk	15.5	-29.6	26.9	43.52	-16.62	0-360	100	H
5	206.5008	42.34	Pk	15.1	-29.4	28.04	43.52	-15.48	0-360	100	V
6	227.1035	45.79	Pk	14.8	-29.3	31.29	46.02	-14.73	0-360	200	V
3	227.8036	47.23	Pk	14.9	-29.3	32.83	46.02	-13.19	0-360	100	H

Pk - Peak detector

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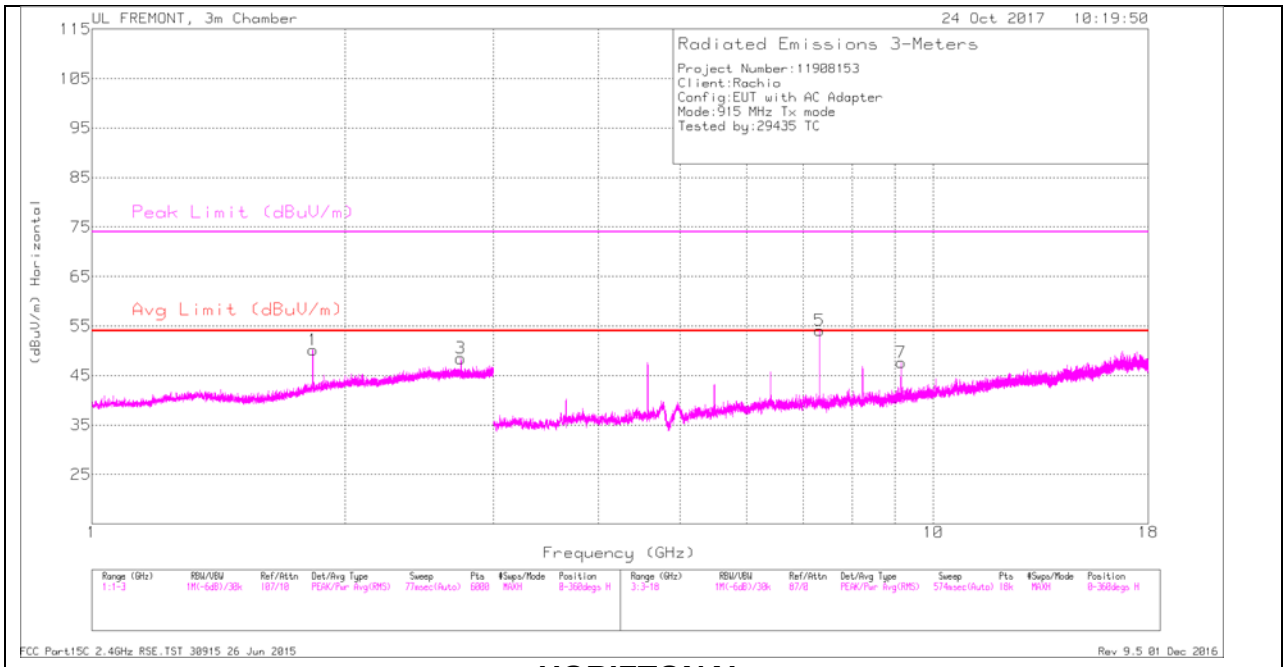
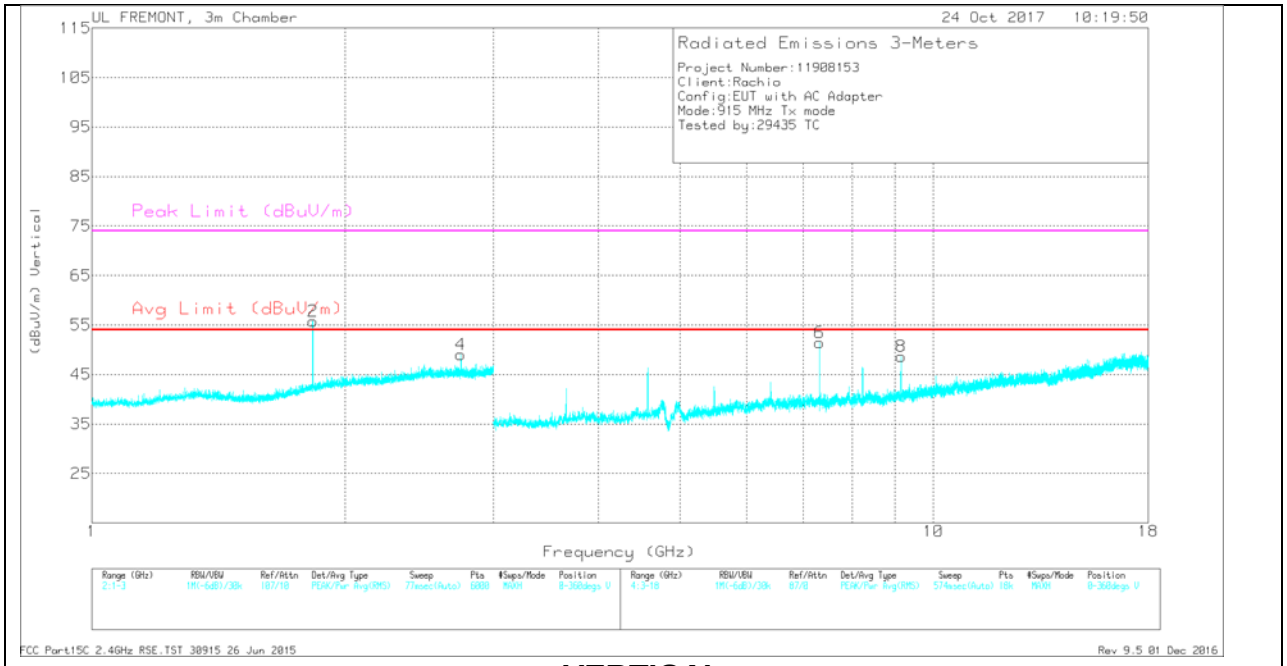
9.3. TRANSMITTER RADIATED EMISSIONS 1 TO 18 GHz

HARMONICS AND SPURIOUS EMISSIONS (915 MHz)



HORIZTONAL



VERTICAL

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DATA

Trace Markers

Marker	Frequency (GHz)	Meter Reading (dBuV)	Det	AF T712 (dB/m)	Amp/Cbl/Fltr/Pad (dB)	Corrected Reading (dBuV/m)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)	Azimuth (Degs)	Height (cm)	Polarity
1	1.83	41.79	Pk	30.4	-22	50.19	-	-	-	-	0-360	200	H
2	1.83	47.41	Pk	30.4	-22	55.81	-	-	-	-	0-360	200	V
3	2.745	37.16	Pk	32.4	-21.1	48.46	-	-	74	-25.54	0-360	200	H
4	2.745	37.78	Pk	32.4	-21.1	49.08	-	-	74	-24.92	0-360	100	V
6	7.321	42.92	Pk	35.5	-27	51.42	-	-	74	-22.58	0-360	200	V
5	7.322	45.65	Pk	35.5	-27	54.15	-	-	74	-19.85	0-360	200	H
8	9.149	36.03	Pk	36.1	-23.5	48.63	-	-	74	-25.37	0-360	200	V
7	9.151	35.13	Pk	36.1	-23.6	47.63	-	-	74	-26.37	0-360	100	H

Pk - Peak detector

Radiated Emissions

Frequency (GHz)	Meter Reading (dBuV)	Det	AF T712 (dB/m)	Amp/Cbl/Fltr/Pad (dB)	Corrected Reading (dBuV/m)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)	Azimuth (Degs)	Height (cm)	Polarity
1.83	48.03	PK2	30.4	-22	56.43	-	-	-	-	193	381	H
1.83	42.4	MAv1	30.4	-22	50.8	-	-	-	-	193	381	H
1.83	49.24	PK2	30.4	-22	57.64	-	-	-	-	155	260	V
1.83	44.42	MAv1	30.4	-22	52.82	-	-	-	-	155	260	V
2.744	43	PK2	32.4	-21.1	54.3	-	-	74	-19.7	215	234	H
2.745	32.2	MAv1	32.4	-21.1	43.5	54	-10.5	-	-	215	234	H
2.745	43.37	PK2	32.4	-21.1	54.67	-	-	74	-19.33	126	111	V
2.745	32.99	MAv1	32.4	-21.1	44.29	54	-9.71	-	-	126	111	V
7.32	39.14	MAv1	35.5	-27	47.64	54	-6.36	-	-	135	240	V
7.321	47.44	PK2	35.5	-27	55.94	-	-	74	-18.06	87	215	H
7.321	38.88	MAv1	35.5	-27	47.38	54	-6.62	-	-	87	215	H
7.321	47.7	PK2	35.5	-27	56.2	-	-	74	-17.8	135	240	V
9.15	41.47	PK2	36.1	-23.6	53.97	-	-	74	-20.03	189	394	H
9.15	29.99	MAv1	36.1	-23.6	42.49	54	-11.51	-	-	189	394	H
9.15	41	PK2	36.1	-23.6	53.5	-	-	74	-20.5	128	376	V
9.15	30.72	MAv1	36.1	-23.6	43.22	54	-10.78	-	-	128	376	V

PK2 - KDB558074 Method: Maximum Peak
MAv1 - KDB558074 Option 1 Maximum RMS Average

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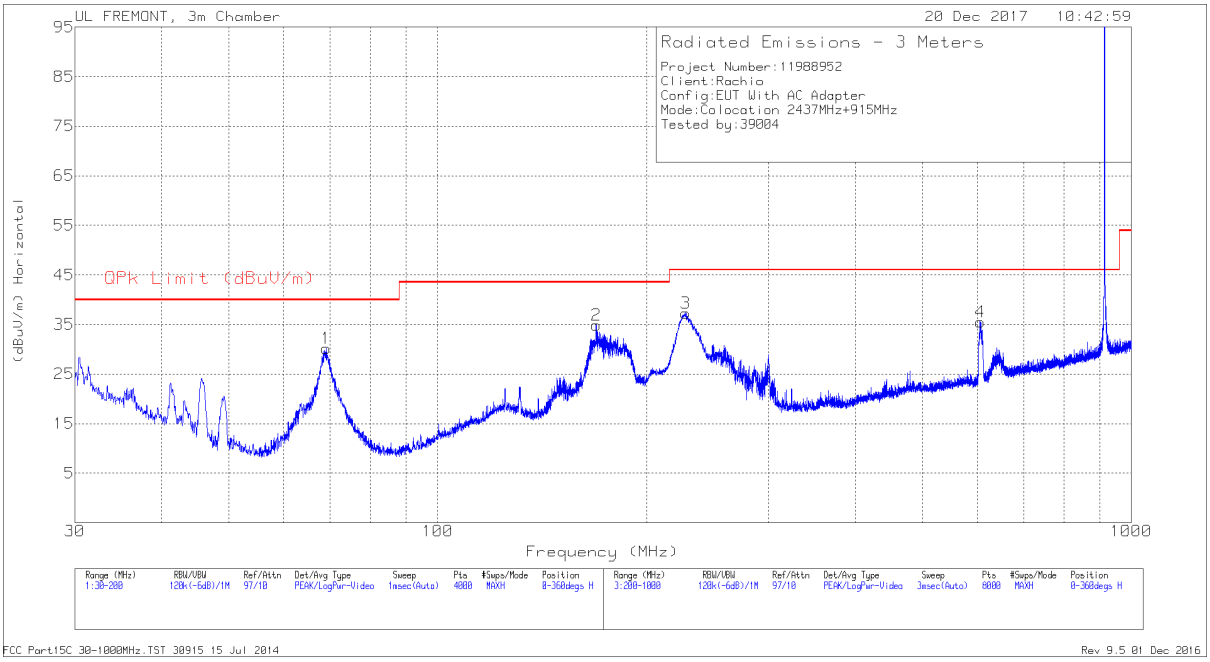
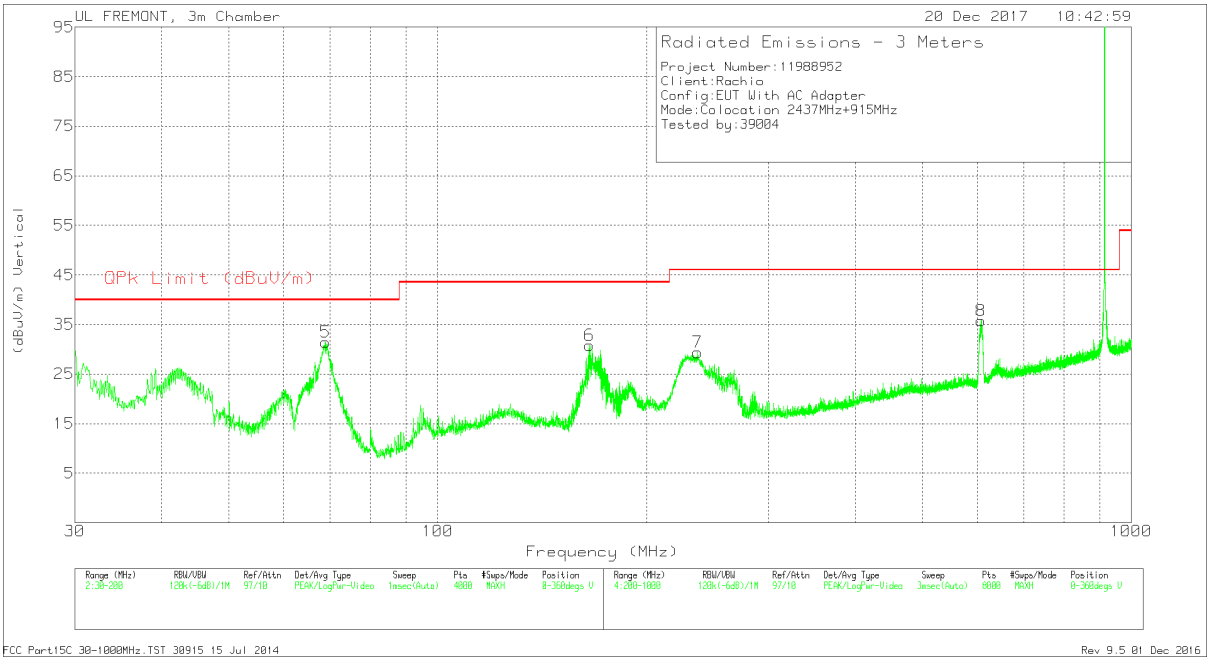
9.4. CO-LOCATION TEST RESULTS (900MHz + DTS 2.4GHz)

9.4.1. TX SPURIOUS EMISSIONS TEST 30MHz – 1000MHz

900MHz + DTS 2.4GHz





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Trace Markers

Marker	Frequency (MHz)	Meter Reading (dBuV)	Det	AF T243 (dB/m)	Amp/Cbl (dB/m)	Corrected Reading (dBuV/m)	QPk Limit (dBuV/m)	Margin (dB)	Azimuth (Degs)	Height (cm)	Polarity
5	68.8976	49.95	Pk	12.1	-30.6	31.45	40	-8.55	0-360	100	V
1	69.1101	48.63	Pk	12.1	-30.6	30.13	40	-9.87	0-360	300	H
6	165.5676	44.69	Pk	15.9	-29.8	30.79	43.52	-12.73	0-360	100	V
2	169.4786	48.91	Pk	15.7	-29.7	34.91	43.52	-8.61	0-360	100	H
3	227.9036	51.53	Pk	15	-29.3	37.23	46.02	-8.79	0-360	100	H
7	237.0048	42.85	Pk	15.6	-29.1	29.35	46.02	-16.67	0-360	100	V
4	605.9528	40.21	Pk	22.7	-27.4	35.51	46.02	-10.51	0-360	200	H
8	606.8529	40.5	Pk	22.7	-27.4	35.8	46.02	-10.22	0-360	100	V

Pk - Peak detector

FCC Part15C 30-1000MHz.TST 30915 15 Jul 2014
Rev 9.5 01 Dec 2016

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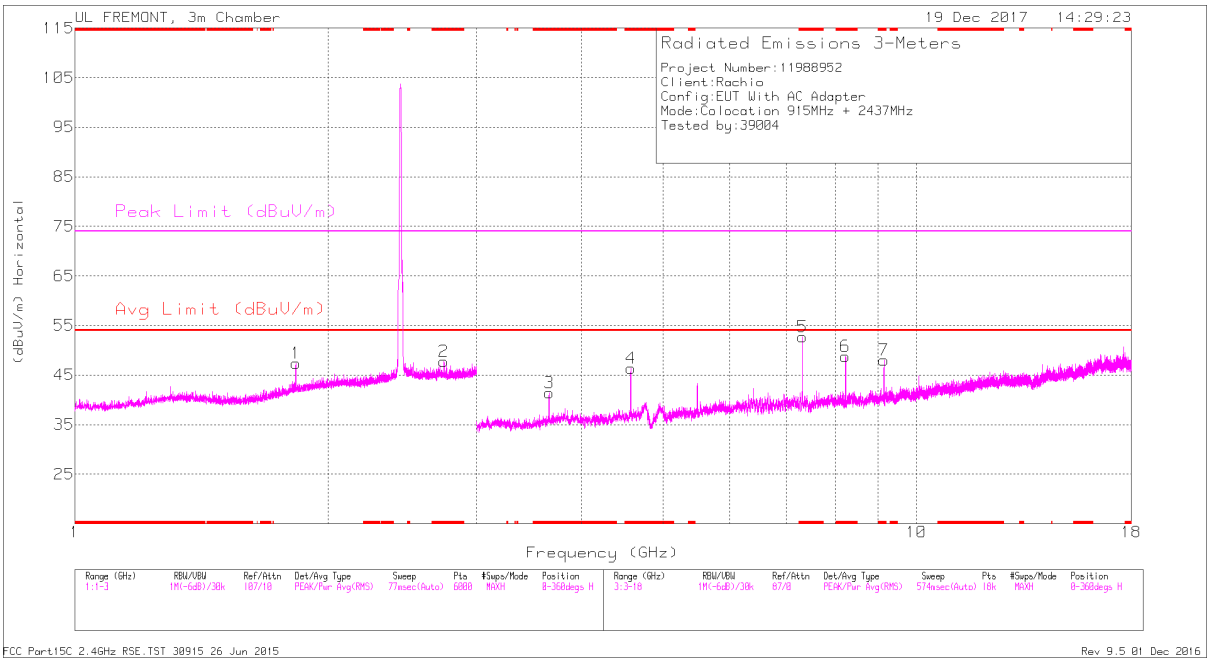
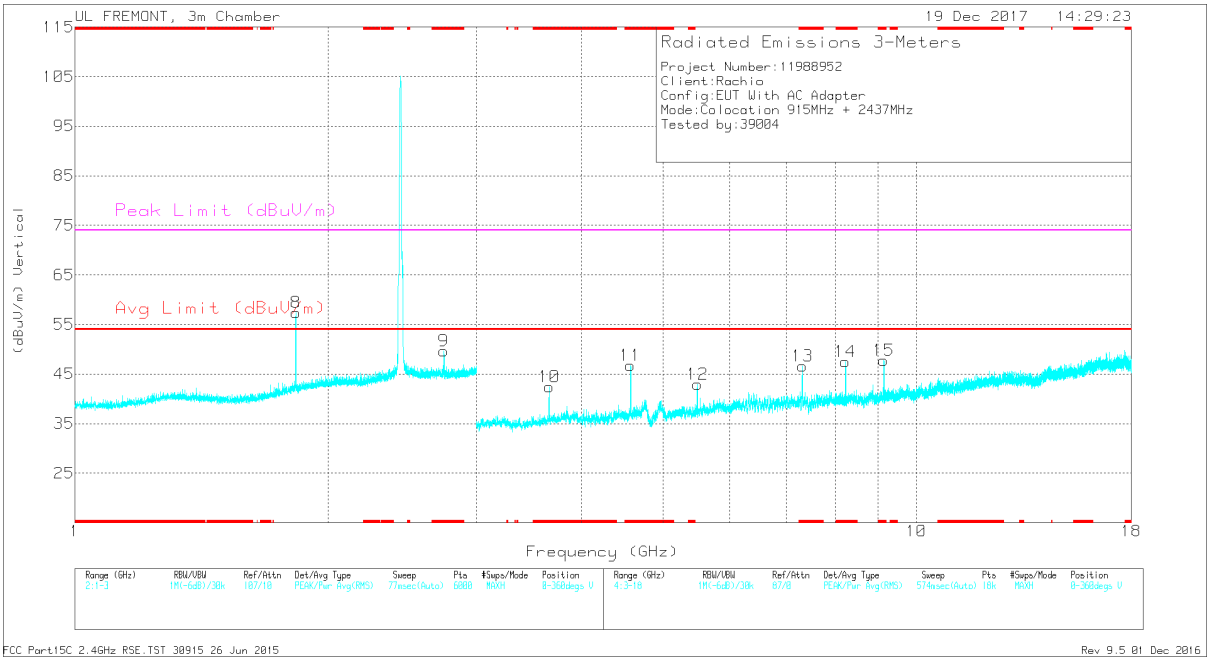
9.4.2. TX SPURIOUS EMISSIONS TEST 1GHz – 18GHz

900MHz + DTS 2.4GHz





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Trace Markers

Marker	Frequency (GHz)	Meter Reading (dBuV)	Det	AF T712 (dB/m)	Amp/Cbl/Fltr/Pad (dB)	Corrected Reading (dBuV/m)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)	Azimuth (Degs)	Height (cm)	Polarity
2	* 2.745	36.49	Pk	32.4	-21.1	47.79	-	-	74	-26.21	0-360	100	H
9	* 2.745	38.35	Pk	32.4	-21.1	49.65	-	-	74	-24.35	0-360	100	V
3	* 3.659	38.04	Pk	33.2	-29.8	41.44	-	-	74	-32.56	0-360	100	H
4	* 4.576	41.12	Pk	34	-28.8	46.32	-	-	74	-27.68	0-360	200	H
5	* 7.321	44.2	Pk	35.5	-27	52.7	-	-	74	-21.3	0-360	200	H
6	* 8.236	38.73	Pk	35.8	-25.7	48.83	-	-	74	-25.17	0-360	200	H
7	* 9.148	35.45	Pk	36.1	-23.5	48.05	-	-	74	-25.95	0-360	200	H
10	* 3.659	39.01	Pk	33.2	-29.8	42.41	-	-	74	-31.59	0-360	200	V
11	* 4.574	41.54	Pk	34	-28.8	46.74	-	-	74	-27.26	0-360	200	V
13	* 7.321	38.11	Pk	35.5	-27	46.61	-	-	74	-27.39	0-360	100	V
14	* 8.234	37.36	Pk	35.8	-25.7	47.46	-	-	74	-26.54	0-360	200	V
15	* 9.147	35.1	Pk	36.1	-23.4	47.8	-	-	74	-26.2	0-360	200	V
1	1.83	38.99	Pk	30.4	-22	47.39	-	-	-	-	0-360	200	H
8	1.83	48.98	Pk	30.4	-22	57.38	-	-	-	-	0-360	100	V
12	5.49	35.27	Pk	34.5	-26.8	42.97	-	-	-	-	0-360	200	V

* - indicates frequency in CFR47 Pt 15 / IC RSS-Restricted Band
Pk - Peak detector

Radiated Emissions

Marker	Frequency (GHz)	Meter Reading (dBuV)	Det	AF T712 (dB/m)	Amp/Cbl/Fltr/Pad (dB)	Corrected Reading (dBuV/m)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)	Azimuth (Degs)	Height (cm)	Polarity
2	* 2.745	41.42	PK2	32.4	-21.1	52.72	-	-	74	-21.28	310	115	H
	* 2.745	29.68	MAv1	32.4	-21.1	40.98	54	-13.02	-	-	310	115	H
9	* 2.745	41.9	PK2	32.4	-21.1	53.2	-	-	74	-20.8	287	152	V
	* 2.745	30.55	MAv1	32.4	-21.1	41.85	54	-12.15	-	-	287	152	V
3	* 3.659	40.34	PK2	33.2	-29.8	43.74	-	-	74	-30.26	287	100	H
	* 3.659	28.97	MAv1	33.2	-29.8	32.37	54	-21.63	-	-	287	100	H
4	* 4.576	39.55	PK2	34	-28.8	44.75	-	-	74	-29.25	300	235	H
	* 4.575	28.5	MAv1	34	-28.8	33.7	54	-20.3	-	-	300	235	H
5	* 7.32	44.63	PK2	35.5	-27	53.13	-	-	74	-20.87	250	171	H
	* 7.32	35.81	MAv1	35.5	-27	44.31	54	-9.69	-	-	250	171	H
6	* 8.235	40.96	PK2	35.8	-25.7	51.06	-	-	74	-22.94	231	215	H
	* 8.234	30.01	MAv1	35.8	-25.7	40.11	54	-13.89	-	-	231	215	H
7	* 9.149	35.04	PK2	36.1	-23.6	47.54	-	-	74	-26.46	210	182	H
	* 9.148	23.61	MAv1	36.1	-23.5	36.21	54	-17.79	-	-	210	182	H
10	* 3.661	42.23	PK2	33.3	-29.8	45.73	-	-	74	-28.27	186	182	V
	* 3.66	32.63	MAv1	33.2	-29.8	36.03	54	-17.97	-	-	186	182	V
11	* 4.575	40.96	PK2	34	-28.8	46.16	-	-	74	-27.84	166	225	V
	* 4.575	30.82	MAv1	34	-28.8	36.02	54	-17.98	-	-	166	225	V
13	* 7.32	41.39	PK2	35.5	-27	49.89	-	-	74	-24.11	149	136	V
	* 7.321	30.91	MAv1	35.5	-27	39.41	54	-14.59	-	-	149	136	V
14	* 8.236	41.8	PK2	35.8	-25.7	51.9	-	-	74	-22.1	176	232	V
	* 8.236	32.07	MAv1	35.8	-25.7	42.17	54	-11.83	-	-	176	232	V
15	* 9.148	34.61	PK2	36.1	-23.5	47.21	-	-	74	-26.79	200	178	V
	* 9.148	23.04	MAv1	36.1	-23.5	35.64	54	-18.36	-	-	200	178	V
1	1.828	41.29	PK2	30.3	-22	49.59	-	-	-	-	130	205	H
8	1.83	48.97	PK2	30.4	-22	57.37	-	-	-	-	159	115	V
12	5.491	39.15	PK2	34.5	-26.7	46.95	-	-	-	-	154	244	V

* - indicates frequency in CFR47 Pt 15 / IC RSS-Restricted Band
PK2 - KDB558074 Method: Maximum Peak
MAv1 - KDB558074 Option 1 Maximum RMS Average
FCC Part15C 2.4GHz RSE.TST 30915 26 Jun 2015
Rev 9.5 01 Dec 2016

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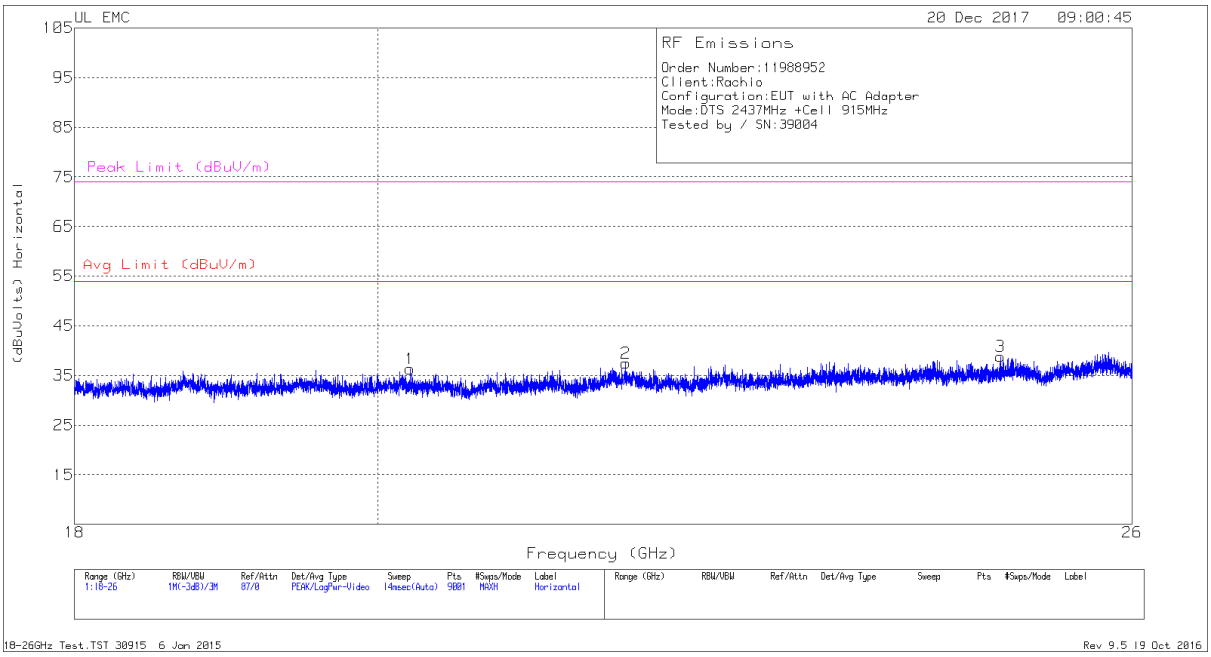
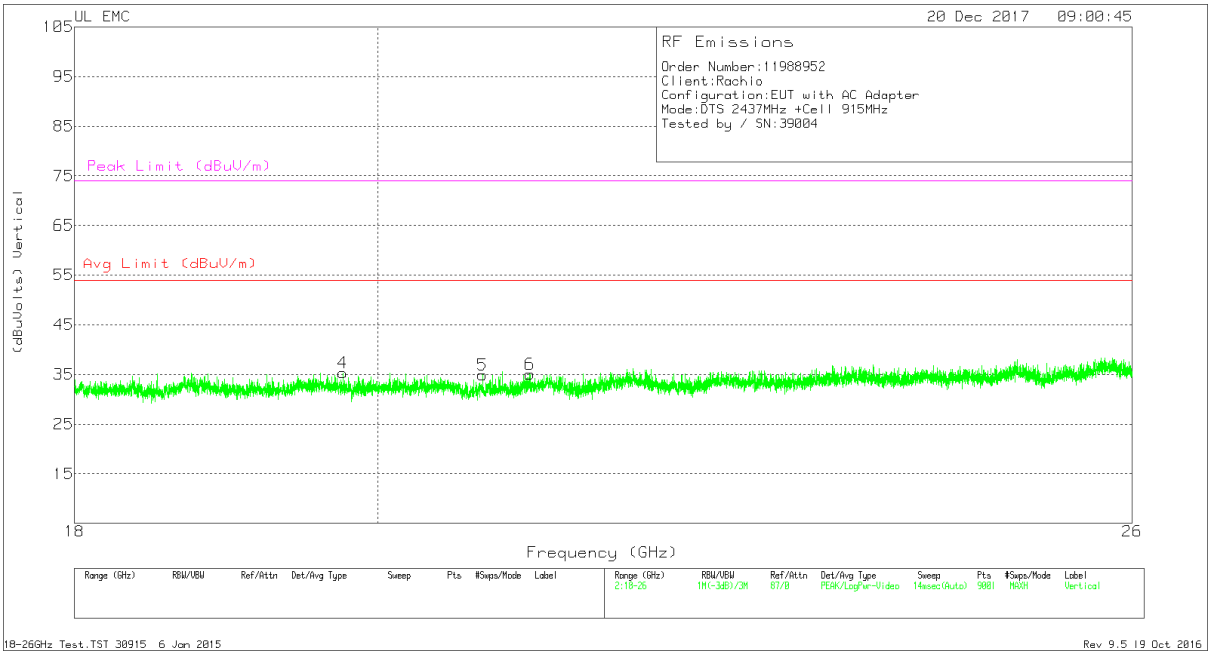
9.4.3. TX SPURIOUS EMISSIONS TEST 18GHz – 26GHz

900MHz + DTS 2.4GHz





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Trace Markers

Mrkr	Frequency (GHz)	Meter Reading (dBuV)	Det	T89 AF (dB/m)	Amp/Cbl (dB)	Dist Corr (dB)	Corrected Reading (dBuVolts)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)
1	20.227	38.61	Pk	32.6	-25.4	-9.5	36.31	54	-17.69	74	-37.69
2	21.801	38.18	Pk	33.3	-24.5	-9.5	37.48	54	-16.52	74	-36.52
3	24.836	38.72	Pk	33.9	-24.3	-9.5	38.82	54	-15.18	74	-35.18
4	19.76	37.19	Pk	32.5	-24.9	-9.5	35.29	54	-18.71	74	-38.71
5	20.744	36.82	Pk	32.8	-25.2	-9.5	34.92	54	-19.08	74	-39.08
6	21.087	37.08	Pk	32.7	-25.2	-9.5	35.08	54	-18.92	74	-38.92

Pk - Peak detector
18-26GHz Test.TST 30915 6 Jan 2015
Rev 9.5 19 Oct 2016

UL VERIFICATION SERVICES INC. FORM NO: CCSUP4701J
47173 BENICIA STREET, FREMONT, CA 94538, USA TEL: (510) 771-1000 FAX: (510) 661-0888
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Trace Markers

Marker	Frequency (GHz)	Meter Reading (dBuV)	Det	T90 AF (dB/m)	Amp/Cbl (dB)	Dist Corr (dB)	Corrected Reading (dBuVolts)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)
1	26.647	46.03	Pk	35.4	-30.8	-9.5	41.13	54	-12.87	74	-32.87
2	28.203	43.21	Pk	35.9	-31.7	-9.5	37.91	54	-16.09	74	-36.09
3	31.566	42.08	Pk	36.3	-33	-9.5	35.88	54	-18.12	74	-38.12
4	26.954	45.21	Pk	35.5	-31.2	-9.5	40.01	54	-13.99	74	-33.99
5	27.739	43.86	Pk	35.8	-31.4	-9.5	38.76	54	-15.24	74	-35.24
6	34.898	43.51	Pk	37.2	-33.2	-9.5	38.01	54	-15.99	74	-35.99

Pk - Peak detector

26-40GHz Test.TST 30915 6 Jan 2015
Rev 9.5 19 Oct 2016

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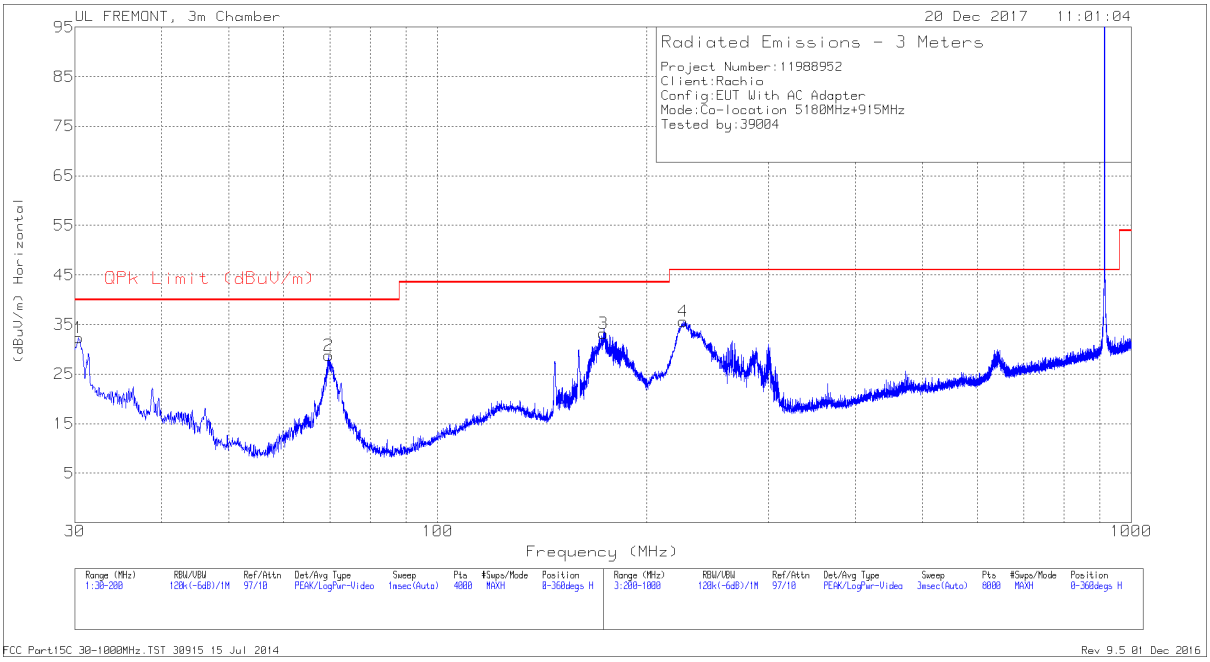
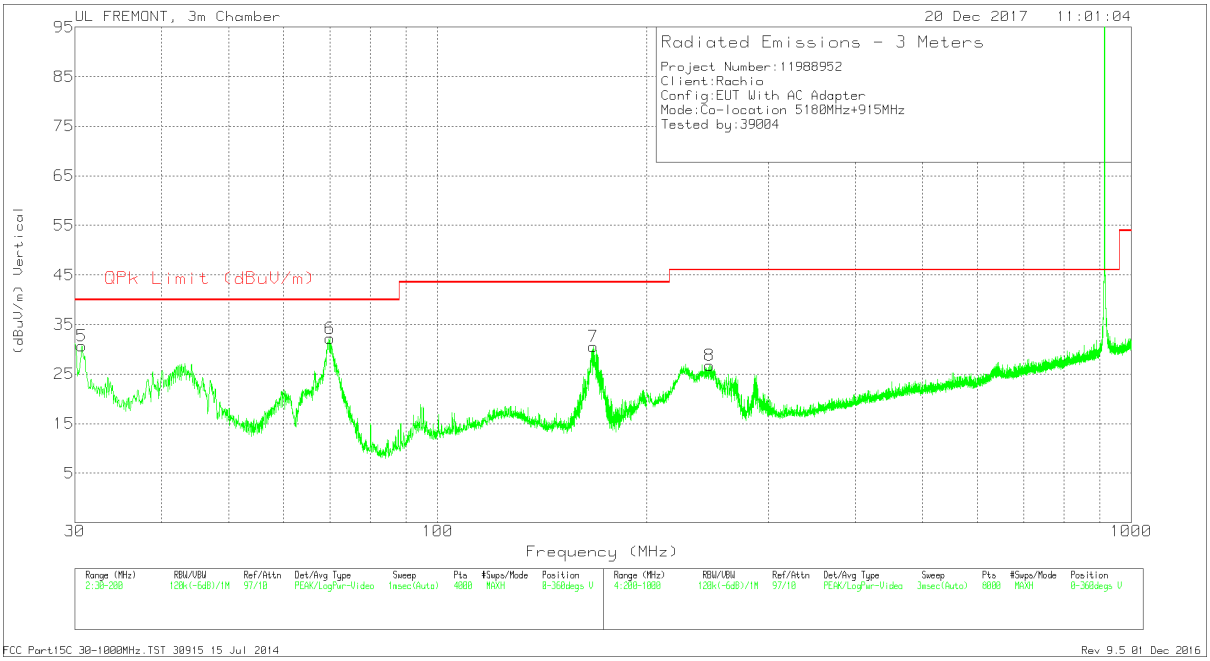
9.5. CO-LOCATION TEST RESULTS (900MHz + UNII 5GHz)

9.5.1. TX SPURIOUS EMISSIONS TEST 30MHz – 1000MHz

900MHz + UNII 5GHz





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Trace Markers

Marker	Frequency (MHz)	Meter Reading (dBuV)	Det	AF T243 (dB/m)	Amp/Cbl (dB/m)	Corrected Reading (dBuV/m)	QPk Limit (dBuV/m)	Margin (dB)	Azimuth (Degs)	Height (cm)	Polarity
1	30.3401	38.1	Pk	25.3	-31.1	32.3	40	-7.7	0-360	100	H
5	30.6802	36.75	Pk	25	-31.1	30.65	40	-9.35	0-360	100	V
2	69.6203	47.33	Pk	12.1	-30.6	28.83	40	-11.17	0-360	300	H
6	69.9178	50.67	Pk	12.1	-30.6	32.17	40	-7.83	0-360	100	V
7	167.6506	44.5	Pk	15.8	-29.7	30.6	43.52	-12.92	0-360	100	V
3	173.3471	47.32	Pk	15.5	-29.6	33.22	43.52	-10.3	0-360	100	H
4	225.9034	50.04	Pk	14.9	-29.3	35.64	46.02	-10.38	0-360	100	H
8	246.8061	40.1	Pk	15.7	-29.1	26.7	46.02	-19.32	0-360	100	V

Pk - Peak detector

FCC Part15C 30-1000MHz.TST 30915 15 Jul 2014
Rev 9.5 01 Dec 2016

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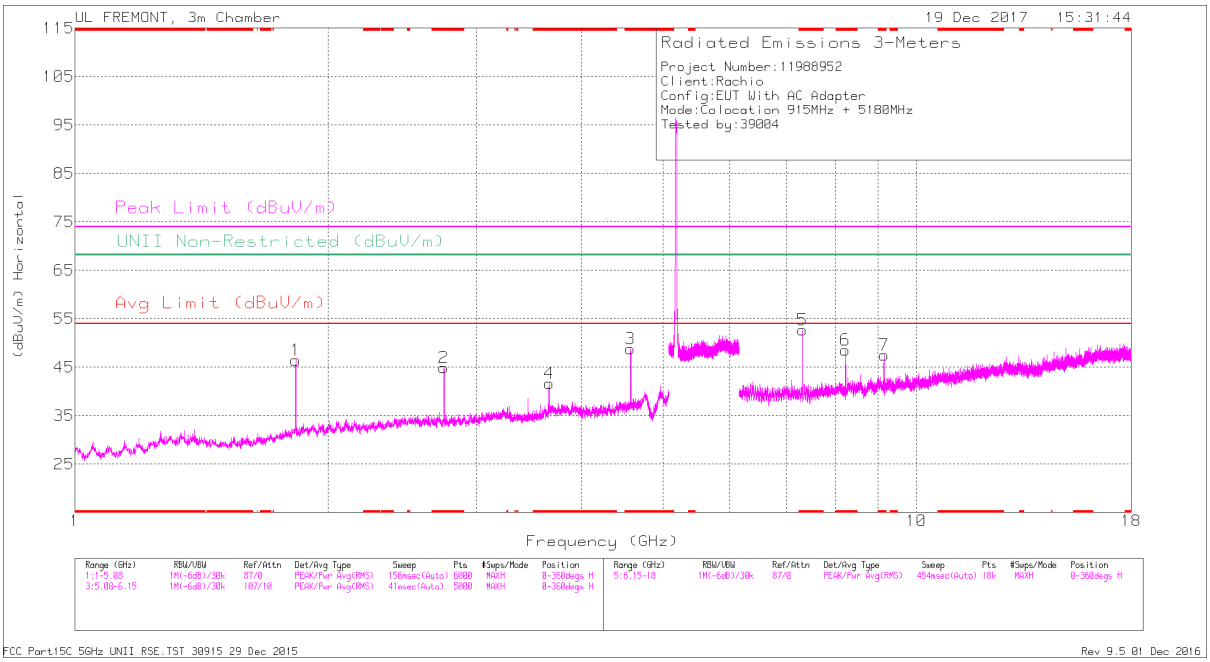
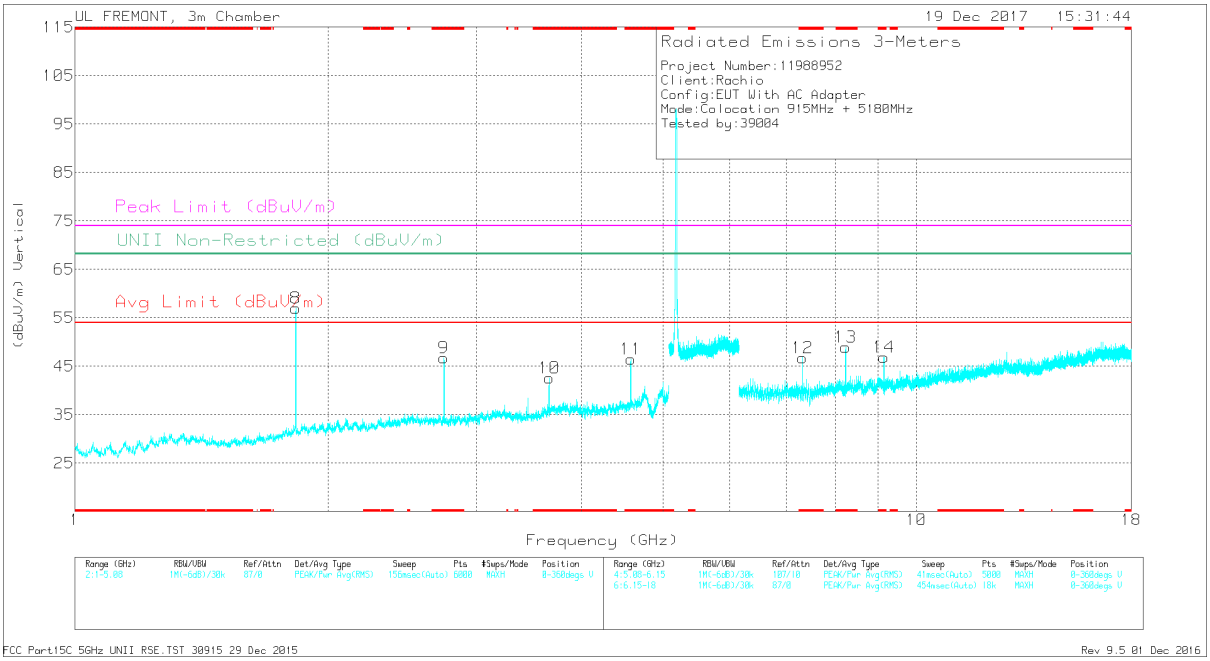
9.5.2. TX SPURIOUS EMISSIONS TEST 1GHz – 18GHz

900MHz + UNII 5GHz





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Trace Markers

Marker	Frequency (GHz)	Meter Reading (dBuV)	Det	AF T712 (dB/m)	Amp/Cbl/Fltr/Pad (dB)	Corrected Reading (dBuV/m)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)	UNII Non-Restricted (dBuV/m)	PK Margin (dB)	Azimuth (Degs)	Height (cm)	Polarity
2	* 2.745	43.11	Pk	32.4	-30.6	44.91	-	-	74	-29.09	-	-	0-360	200	H
3	* 4.575	43.56	Pk	34	-28.7	48.86	-	-	74	-25.14	-	-	0-360	200	H
4	* 3.659	38.13	Pk	33.2	-29.6	41.73	-	-	74	-32.27	-	-	0-360	100	H
9	* 2.744	44.88	Pk	32.4	-30.6	46.68	-	-	74	-27.32	-	-	0-360	100	V
10	* 3.66	39.04	Pk	33.2	-29.6	42.64	-	-	74	-31.36	-	-	0-360	100	V
11	* 4.575	41.14	Pk	34	-28.7	46.44	-	-	74	-27.56	-	-	0-360	200	V
5	* 7.319	42.98	Pk	35.5	-25.8	52.68	-	-	74	-21.32	-	-	0-360	200	H
6	* 8.233	38.13	Pk	35.8	-25.4	48.53	-	-	74	-25.47	-	-	0-360	200	H
7	* 9.149	34.73	Pk	36.1	-23.3	47.53	-	-	74	-26.47	-	-	0-360	200	H
12	* 7.318	37.03	Pk	35.5	-25.8	46.73	-	-	74	-27.27	-	-	0-360	200	V
13	* 8.237	38.49	Pk	35.8	-25.3	48.99	-	-	74	-25.01	-	-	0-360	200	V
14	* 9.148	34.02	Pk	36.1	-23.2	46.92	-	-	74	-27.08	-	-	0-360	200	V
1	1.83	46.92	Pk	30.4	-30.9	46.42	-	-	-	-	68.2	-21.78	0-360	200	H
8	1.83	57.46	Pk	30.4	-30.9	56.96	-	-	-	-	68.2	-11.24	0-360	100	V

* - indicates frequency in CFR47 Pt 15 / IC RSS-Restricted Band
Pk - Peak detector

Radiated Emissions

Marker	Frequency (GHz)	Meter Reading (dBuV)	Det	AF T712 (dB/m)	Amp/Cbl/Fltr/Pad (dB)	Corrected Reading (dBuV/m)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)	UNII Non-Restricted (dBuV/m)	PK Margin (dB)	Azimuth (Degs)	Height (cm)	Polarity
2	* 2.746	41.54	PK-U	32.4	-30.6	43.34	-	-	74	-30.66	-	-	289	250	H
	* 2.745	31.27	ADR	32.4	-30.6	33.07	54	-20.93	-	-	-	-	289	250	H
3	* 4.576	43.08	PK-U	34	-28.7	48.38	-	-	74	-25.62	-	-	265	190	H
	* 4.575	33.5	ADR	34	-28.7	38.8	54	-15.2	-	-	-	-	265	190	H
4	* 3.659	40.79	PK-U	33.2	-29.6	44.39	-	-	74	-29.61	-	-	251	115	H
	* 3.66	30.01	ADR	33.2	-29.6	33.61	54	-20.39	-	-	-	-	251	115	H
9	* 2.744	39.8	PK-U	32.4	-30.6	41.6	-	-	74	-32.4	-	-	233	162	V
	* 2.745	28.82	ADR	32.4	-30.6	30.62	54	-23.38	-	-	-	-	233	162	V
10	* 3.659	42.81	PK-U	33.2	-29.6	46.41	-	-	74	-27.59	-	-	210	144	V
	* 3.66	32.68	ADR	33.2	-29.6	36.28	54	-17.72	-	-	-	-	210	144	V
11	* 4.576	40.91	PK-U	34	-28.7	46.21	-	-	74	-27.79	-	-	245	230	V
	* 4.575	30.47	ADR	34	-28.7	35.77	54	-18.23	-	-	-	-	245	230	V
5	* 7.32	39.34	PK-U	35.5	-25.8	49.04	-	-	74	-24.96	-	-	221	172	H
	* 7.318	28.6	ADR	35.5	-25.8	38.3	54	-15.7	-	-	-	-	221	172	H
6	* 8.234	41.33	PK-U	35.8	-25.4	51.73	-	-	74	-22.27	-	-	178	156	H
	* 8.234	30.77	ADR	35.8	-25.4	41.17	54	-12.83	-	-	-	-	178	156	H
7	* 9.149	37.23	PK-U	36.1	-23.3	50.03	-	-	74	-23.97	-	-	183	196	H
	* 9.149	25.19	ADR	36.1	-23.2	38.09	54	-15.91	-	-	-	-	183	196	H
12	* 7.319	37.38	PK-U	35.5	-25.8	47.08	-	-	74	-26.92	-	-	219	221	V
	* 7.316	25.66	ADR	35.5	-25.7	35.46	54	-18.54	-	-	-	-	219	221	V
13	* 8.235	39.27	PK-U	35.8	-25.3	49.77	-	-	74	-24.23	-	-	192	177	V
	* 8.236	27.38	ADR	35.8	-25.3	37.88	54	-16.12	-	-	-	-	192	177	V
14	* 9.149	37.94	PK-U	36.1	-23.3	50.74	-	-	74	-23.26	-	-	165	205	V
	* 9.148	26.01	ADR	36.1	-23.2	38.91	54	-15.09	-	-	-	-	165	205	V
1	1.83	47.81	PK-U	30.4	-30.9	47.31	-	-	-	-	68.2	-20.89	149	200	H
8	1.83	56.87	PK-U	30.4	-30.9	56.37	-	-	-	-	68.2	-11.83	149	124	V

* - indicates frequency in CFR47 Pt 15 / IC RSS-Restricted Band
PK-U - U-NII: Maximum Peak
ADR - U-NII AD primary method, RMS average
FCC Part15C 5GHz UNII RSE.TST 30915 29 Dec 2015
Rev 9.5 01 Dec 2016

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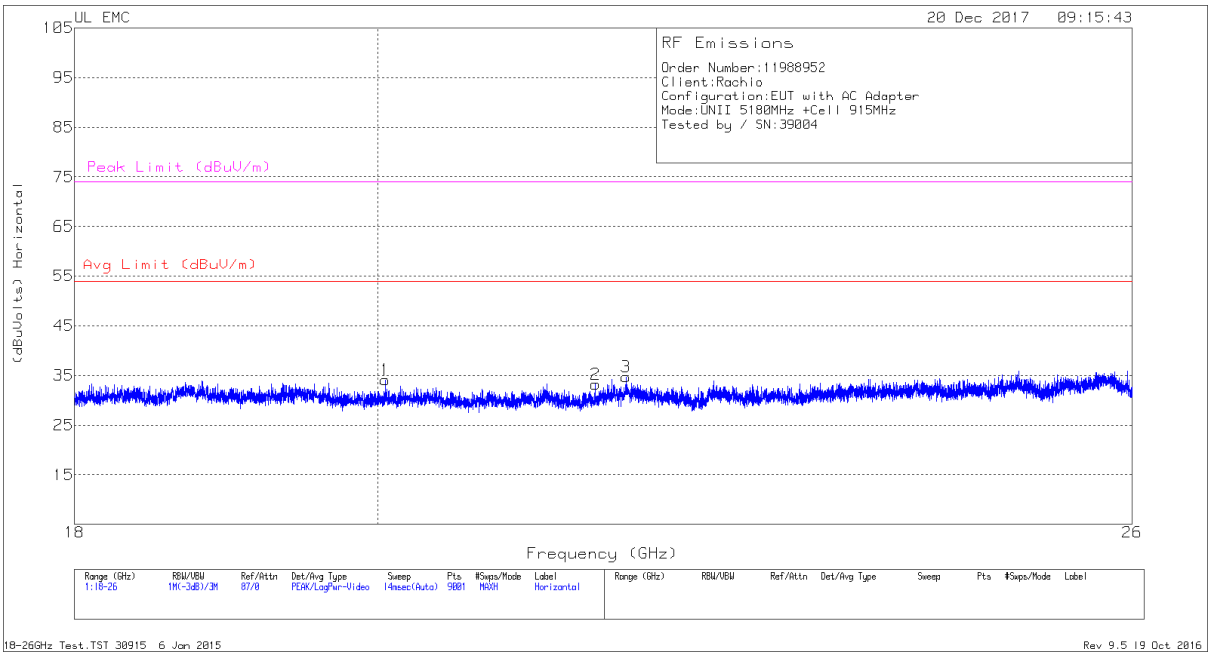
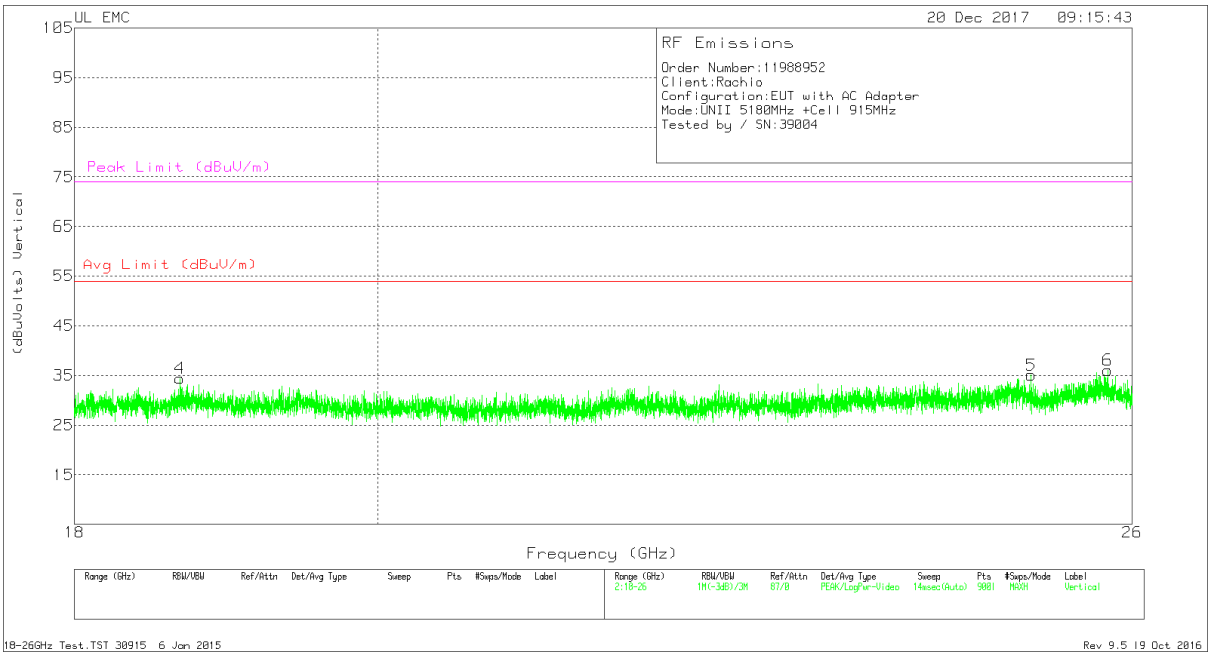
9.5.3. TX SPURIOUS EMISSIONS TEST 18GHz –26GHz

900MHz + UNII 5GHz





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Trace Markers

Marker	Frequency (GHz)	Meter Reading (dBuV)	Det	T89 AF (dB/m)	Amp/Cbl (dB)	Dist Corr (dB)	Corrected Reading (dBuVolts)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)
1	20.054	35.7	Pk	32.9	-25	-9.5	34.1	54	-19.9	74	-39.9
2	21.573	34.83	Pk	33.1	-25.2	-9.5	33.23	54	-20.77	74	-40.77
3	21.803	35.4	Pk	33.3	-24.5	-9.5	34.7	54	-19.3	74	-39.3
4	18.672	36.1	Pk	32.5	-24.7	-9.5	34.4	54	-19.6	74	-39.6
5	25.101	35.19	Pk	33.9	-24.5	-9.5	35.09	54	-18.91	74	-38.91
6	25.78	36.14	Pk	34.1	-24.7	-9.5	36.04	54	-17.96	74	-37.96

Pk - Peak detector
18-26GHz Test.TST 30915 6 Jan 2015
Rev 9.5 19 Oct 2016

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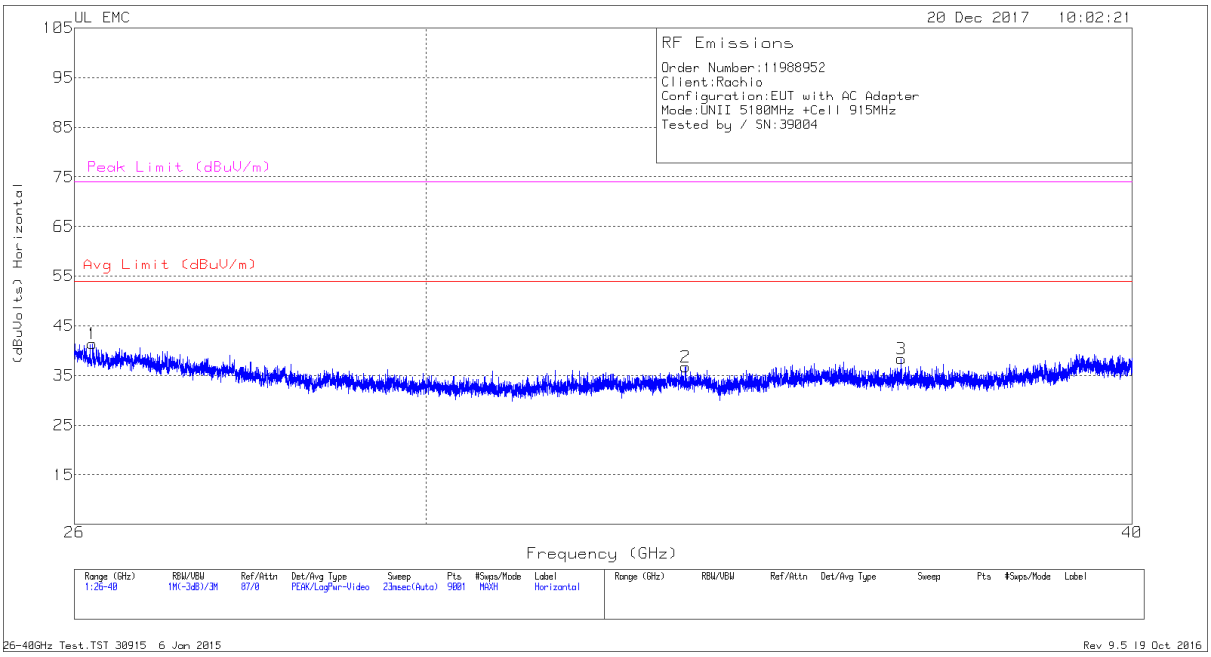
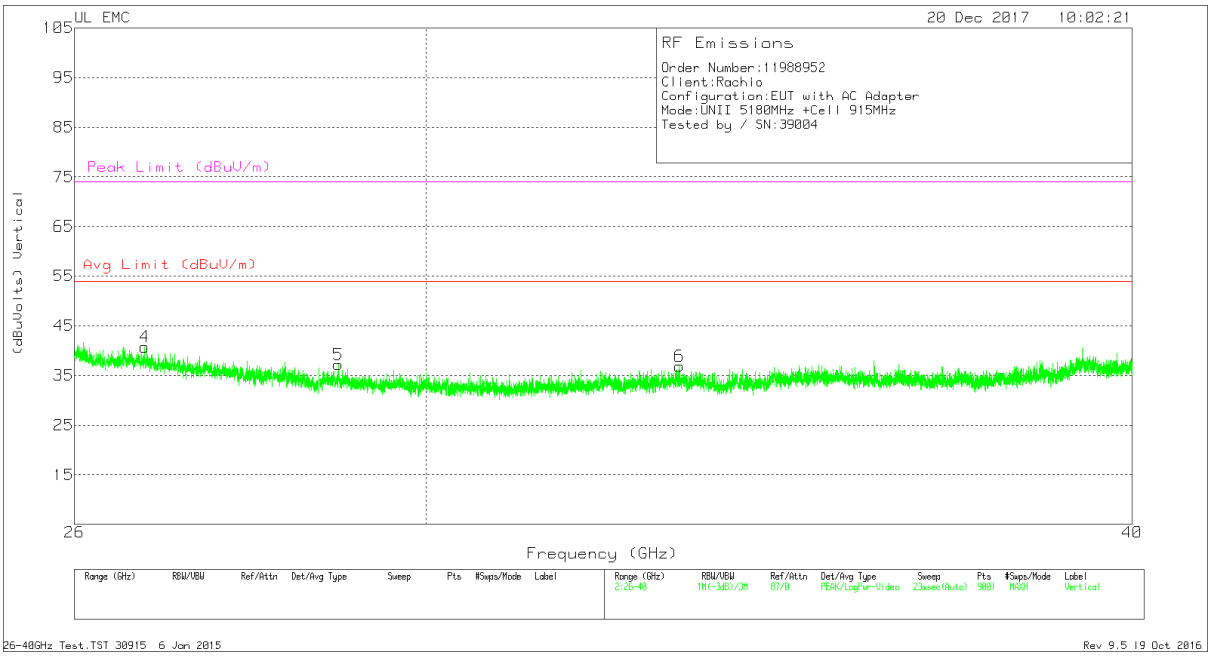
9.5.4. TX SPURIOUS EMISSIONS TEST 26GHz – 40GHz

900MHz + UNII 5GHz





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Trace Markers

Mrkr	Frequency (GHz)	Meter Reading (dBuV)	Det	T90 AF (dB/m)	Amp/Cbl (dB)	Dist Corr (dB)	Corrected Reading (dBuVolts)	Avg Limit (dBuV/m)	Margin (dB)	Peak Limit (dBuV/m)	PK Margin (dB)
1	26.19	46.08	Pk	35.6	-30.8	-9.5	41.38	54	-12.62	74	-32.62
2	33.345	41.93	Pk	37	-32.7	-9.5	36.73	54	-17.27	74	-37.27
3	36.408	43.63	Pk	37.2	-33	-9.5	38.33	54	-15.67	74	-35.67
4	26.753	45.73	Pk	35.3	-30.8	-9.5	40.73	54	-13.27	74	-33.27
5	28.948	42.68	Pk	35.9	-31.9	-9.5	37.18	54	-16.82	74	-36.82
6	33.261	42.31	Pk	36.9	-32.8	-9.5	36.91	54	-17.09	74	-37.09

Pk - Peak detector
26-40GHz Test.TST 30915 6 Jan 2015
Rev 9.5 19 Oct 2016

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10. AC POWER LINE CONDUCTED EMISSIONS

LIMITS

FCC §15.207 (a)

RSS-Gen 8.8

Frequency of Emission (MHz)	Conducted Limit (dBuV)	
	Quasi-peak	Average
0.15-0.5	66 to 56 *	56 to 46 *
0.5-5	56	46
5-30	60	50

* Decreases with the logarithm of the frequency.

RESULTS

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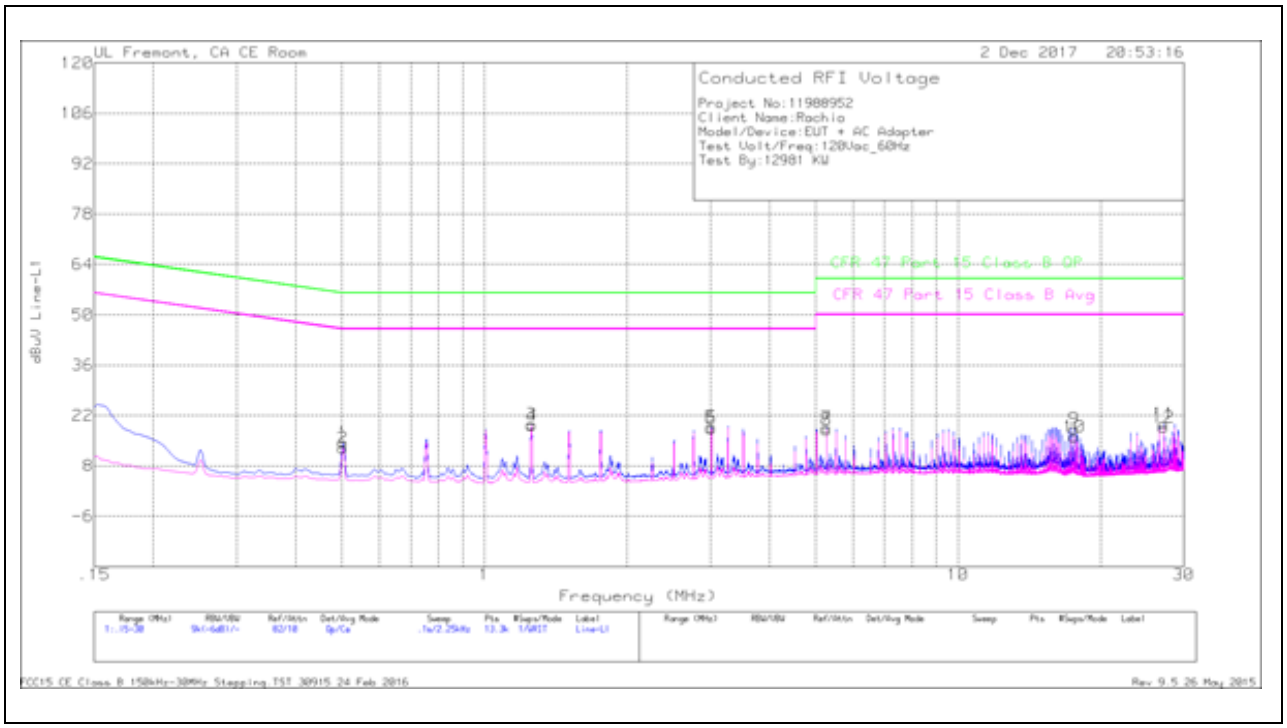
LINE 1 RESULTS



Trace Markers

Range 1: Line-L1 .15 - 30MHz											
Marker	Frequency (MHz)	Meter Reading (dBuV)	Det	LISN L1	LC Cables C1&C3	Limiter (dB)	Corrected Reading dBuV	CFR 47 Part 15 Class B QP	QP Margin (dB)	CFR 47 Part 15 Class B Avg	Av(CISPR) Margin (dB)
1	.50325	4.44	Qp	0	0	10.1	14.54	56	-41.46	-	-
2	.50325	2.88	Ca	0	0	10.1	12.98	-	-	46	-33.02
3	1.257	9.3	Qp	0	.1	10.1	19.5	56	-36.5	-	-
4	1.257	8.98	Ca	0	.1	10.1	19.18	-	-	46	-26.82
5	3.0165	8.75	Qp	0	.1	10.1	18.95	56	-37.05	-	-
6	3.0165	8.25	Ca	0	.1	10.1	18.45	-	-	46	-27.55
7	5.28	8.42	Qp	0	.1	10.2	18.72	60	-41.28	-	-
8	5.28	7.8	Ca	0	.1	10.2	18.1	-	-	50	-31.9
9	17.601	7.74	Qp	0	.3	10.3	18.34	60	-41.66	-	-
10	17.601	5.46	Ca	0	.3	10.3	16.06	-	-	50	-33.94
11	27.16125	8.75	Qp	.1	.4	10.5	19.75	60	-40.25	-	-
12	27.1635	7.68	Ca	.1	.4	10.5	18.68	-	-	50	-31.32

Qp - Quasi-Peak detector
Ca - CISPR average detection

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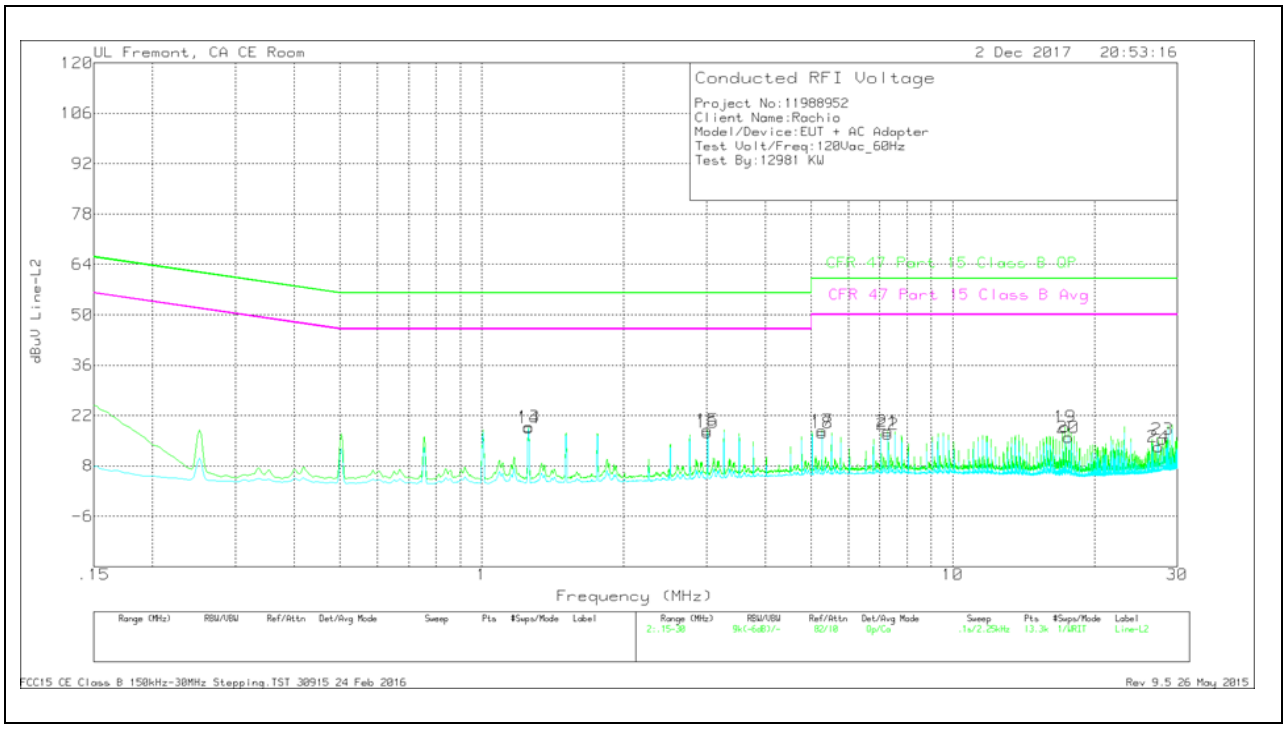
LINE 2 RESULTS



Trace Markers

Range 2: Line-L2 .15 - 30MHz											
Marker	Frequency (MHz)	Meter Reading (dBuV)	Det	LISN L2	LC Cables C2&C3	Limiter (dB)	Corrected Reading dBuV	CFR 47 Part 15 Class B QP	QP Margin (dB)	CFR 47 Part 15 Class B Avg	Av(CISPR) Margin (dB)
13	1.257	8.68	Qp	0	.1	10.1	18.88	56	-37.12	-	-
14	1.257	8.34	Ca	0	.1	10.1	18.54	-	-	46	-27.46
15	3.0165	7.79	Qp	0	.1	10.1	17.99	56	-38.01	-	-
16	3.0165	7.19	Ca	0	.1	10.1	17.39	-	-	46	-28.61
17	5.28	7.58	Qp	0	.1	10.2	17.88	60	-42.12	-	-
18	5.28	6.86	Ca	0	.1	10.2	17.16	-	-	50	-32.84
19	17.34675	8.33	Qp	0	.3	10.3	18.93	60	-41.07	-	-
20	17.5965	5.38	Ca	0	.3	10.3	15.98	-	-	50	-34.02
21	7.28925	7.24	Qp	0	.2	10.2	17.64	60	-42.36	-	-
22	7.28925	6.35	Ca	0	.2	10.2	16.75	-	-	50	-33.25
23	27.897	4.42	Qp	.1	.4	10.5	15.42	60	-44.58	-	-
24	27.34575	2.38	Ca	.1	.4	10.5	13.38	-	-	50	-36.62

Qp - Quasi-Peak detector
Ca - CISPR average detection

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