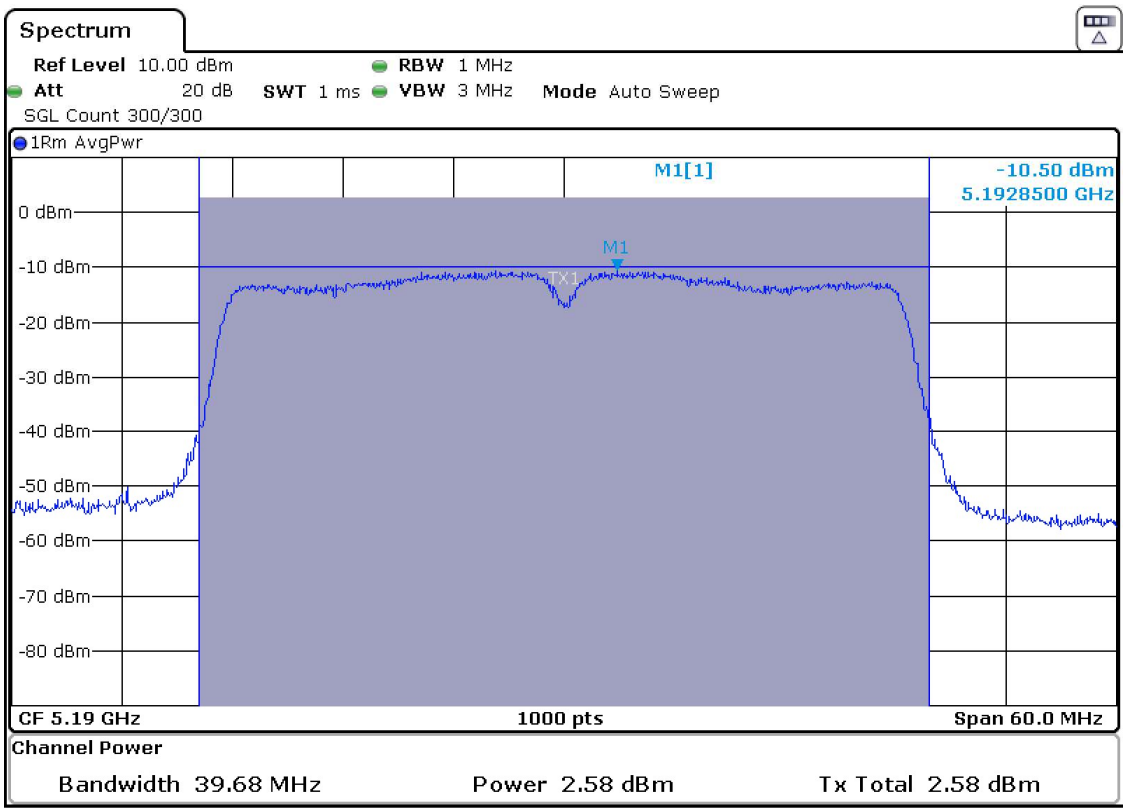
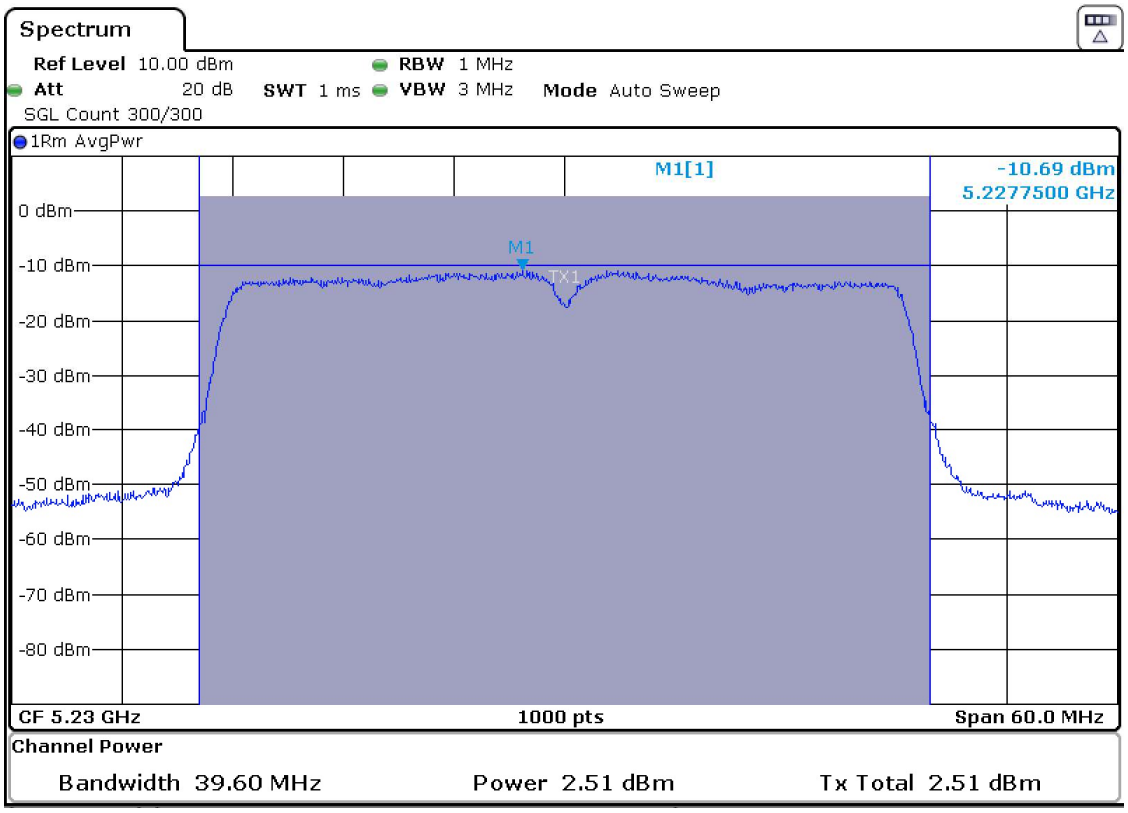
Mode 802.11 n40 (HT40)

- Low Channel 38:

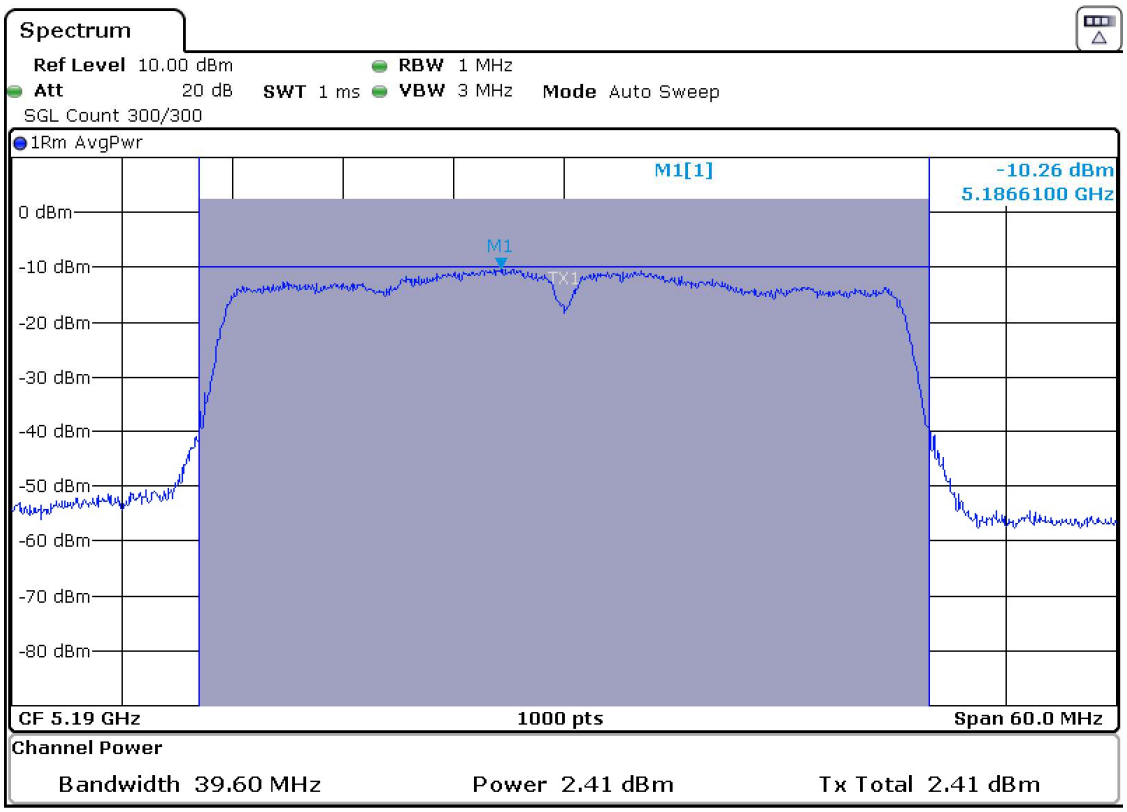


- High Channel 46:

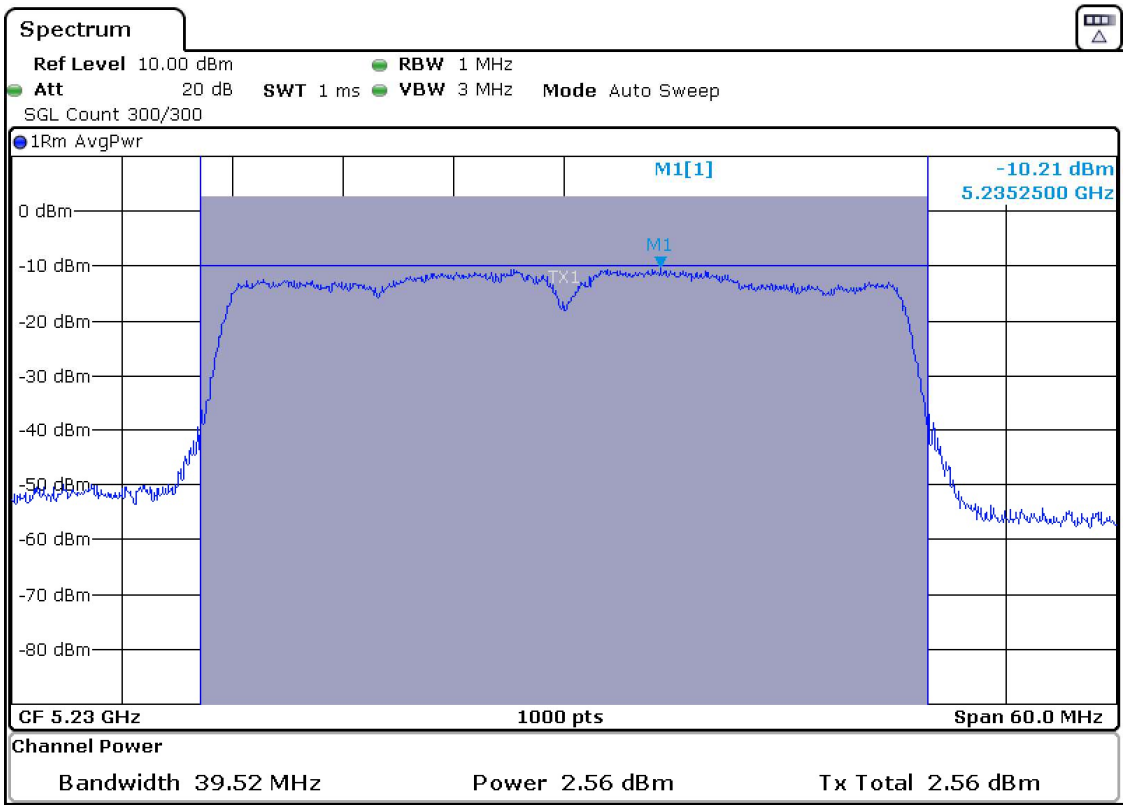


Mode 802.11 ac40 (VHT40)

- Low Channel 38:

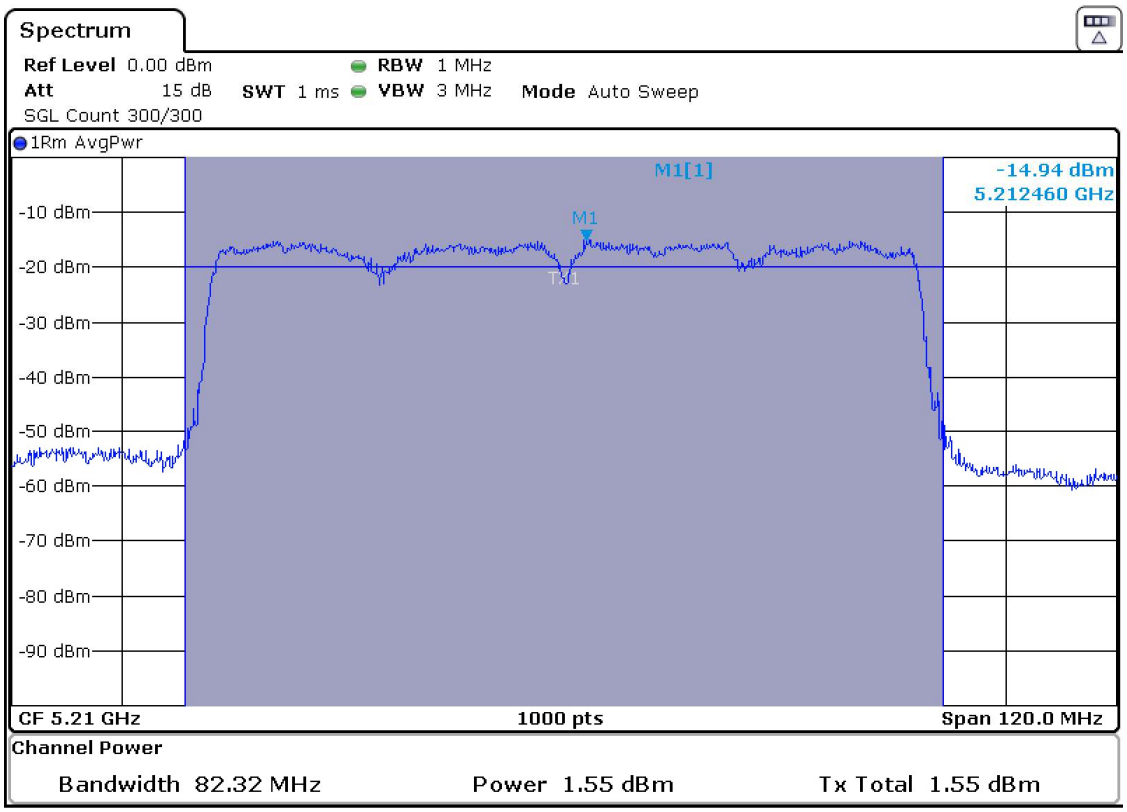


- High Channel 46:



Mode 802.11 ac80 (VHT80)

- Single Channel 42:



FCC 15.407 (a)(1)(ii) Density / RSS-247 Clause 6.2.1.1 Transmitter Maximum Power Spectral

SPECIFICATION:

FCC 15.407: The maximum power spectral density shall not exceed 17 dBm in any 1 megahertz band. If transmitting antennas of directional gain greater than 6 dBi are used, the maximum power spectral density shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

RSS-247: The e.i.r.p. spectral density shall not exceed 10dBm in any 1.0 MHz band.

RESULTS:

The maximum power spectral density (PSD) was measured using the method according to point F) referencing E.2.b) (Method SA-1) and E.2.b) (Method SA-2) of Guidance 789033 D02 General UNII Test Procedures New Rules v02r01.

For all modes of operation, the antenna gain is < 6 dBi.

The PSD test uses the same setup than the transmitter maximum conducted output power test. The result of the Peak PSD was measured by colocation a maker on the peak of the signal and the results are in the tables below.

For all modes of operation, the antenna gain is < 6 dBi.

Maximum Declared Antenna Gain: -5.4 dBi

Mode 802.11 a20

	Low Channel 36 (5180 MHz)	Middle Channel 40 (5200 MHz)	High Channel 48 (5240 MHz)
Maximum PSD (dBm/MHz)	-3.46	-3.93	-3.93
Maximum EIRP PSD (dBm/MHz)	-4.065495029	-4.535495029	-4.535495029
Duty Cycle Correction Factor (dB)	4.794504971		
Maximum PSD Corrected (dBm/MHz)	1.334504971	0.864504971	0.864504971
Measurement uncertainty (dB)	<±1.20		

Mode 802.11 n20 (HT20)

	Low Channel 36 (5180 MHz)	Middle Channel 40 (5200 MHz)	High Channel 48 (5240 MHz)
Maximum PSD (dBm/MHz)	-4.83	-5.14	-5
Maximum EIRP PSD (dBm/MHz)	-5.176157927	-5.486157927	-5.346157927
Duty Cycle Correction Factor (dB)	5.053842073		
Maximum PSD Corrected (dBm/MHz)	0.223842073	-0.086157927	0.053842073
Measurement uncertainty (dB)	<±1.20		

Mode 802.11 ac20 (VHT20)

	Low Channel 36 (5180 MHz)	Middle Channel 40 (5200 MHz)	High Channel 48 (5240 MHz)
Maximum PSD (dBm/MHz)	-5.95	-6.3	-6.05
Maximum EIRP PSD (dBm/MHz)	-0.496941196	-0.846941196	-0.596941196
Duty Cycle Correction Factor (dB)	5.453058804		
Maximum PSD Corrected (dBm/MHz)	-0.496941196	-0.846941196	-0.596941196
Measurement uncertainty (dB)	<±1.20		

Mode 802.11 n40 (HT40)

	Low Channel 38 (5190 MHz)	High Channel 46 (5230 MHz)
Maximum PSD (dBm/MHz)	-10.5	-10.69
Maximum EIRP PSD (dBm/MHz)	-3.646028029	-3.836028029
Duty Cycle Correction Factor (dB)	6.853971971	
Maximum PSD Corrected (dBm/MHz)	-3.646028029	-3.836028029
Measurement uncertainty (dB)	<±1.20	

Mode 802.11 ac40 (VHT40)

	Low Channel 38 (5190 MHz)	High Channel 46 (5230 MHz)
Maximum PSD (dBm/MHz)	-10.26	-10.21
Maximum EIRP PSD (dBm/MHz)	-2.961396236	-2.911396236
Duty Cycle Correction Factor (dB)	7.298603764	
Maximum PSD Corrected (dBm/MHz)	-2.961396236	-2.911396236
Measurement uncertainty (dB)	<±1.20	

Mode 802.11 ac80 (VHT80)

	Low Channel 42 (5210 MHz)
Maximum PSD (dBm/MHz)	-14.94
Maximum EIRP PSD (dBm/MHz)	-6.132153308
Duty Cycle Correction Factor (dB)	8.807846692
Maximum PSD Corrected (dBm/MHz)	-6.132153308
Measurement uncertainty (dB)	<±1.20

Verdict: PASS

FCC 15.407 (b)(1)(6) / RSS-247 6.2.1.2 Transmitter Out of Band Radiated Emissions

SPECIFICATION:

For transmitters operating in the 5.15–5.25 GHz band: all emissions outside of the 5.15–5.35 GHz band shall not exceed an EIRP of –27 dBm/MHz (68.23 dBµV/m at 3 m distance).

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)):

Frequency Range (MHz)	Field strength (µV/m)	Field strength (dBµV/m)	Measurement distance (m)
0.009-0.490	2400/F(kHz)	-	300
0.490-1.705	24000/F(kHz)	-	300
1.705 - 30.0	30	-	30
30 - 88	100	40	3
88 - 216	150	43.5	3
216 - 960	200	46	3
960 - 40000	500	54	3

The emission limits shown in the above table are based on measurements employing CISPR quasi-peak detector except for the frequency bands 9-90 kHz, 110-490 kHz and above 1000 MHz. Radiated emission limits in these three bands are based on measurements employing an average detector.

For average radiated emission measurements above 1000 MHz, there is also a limit corresponding to 20 dB above the indicated values in the table is specified when measuring with peak detector function.

RESULTS:

The situation and orientation was varied to find the maximum radiated emission. It was also rotated 360º and the antenna height was varied from 1 to 4 meters to find the maximum radiated emission.

Measurements were made in both horizontal and vertical planes of polarization.

All tests were performed in a semi-anechoic chamber at a distance of 1m for the frequency range 1 GHz-40 GHz and a distance of 3m for frequency range 30MHz-1GHz.

The field strength is calculated by adding correction factor to the measured level from the spectrum analyzer. This correction factor includes antenna factor, cable loss and pre-amplifiers gain.

Frequency range 30 MHz - 1 GHz

The spurious emissions below 1 GHz do not depend on either the operating channel or the modulation mode selected in the EUT.

Spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (MHz)	Emission Level (dBµV/m)	Limit (dBµV/m)	Polarization	Detector	Measurement Uncertainty (dB)
250.012	27.4	46	V	Peak	<±3.70

Frequency range 1 - 40 GHz

The results in the next tables show the maximum measured levels in the 1-40 GHz frequency range.

The Low, Middle and High Channels were measured for out-of-band emissions for the worst mode.

Spurious frequencies with peak levels above the average limit (54 dBµV/m at 3 m) are measured with an average detector for checking compliance with the average limit.

- **Mode 802.11 a20** (worst case)

- Low Channel. Spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Emission Level (dBµV/m)	Limit (dBµV/m)	Polarization	Detector	Measurement Uncertainty (dB)
10.35858	59.3	68.23	V	Peak	<±3.70
	50.51	54		Average	<±3.70

- Middle Channel. Spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Emission Level (dBµV/m)	Limit (dBµV/m)	Polarization	Detector	Measurement Uncertainty (dB)
10.40933	59.33	68.23	V	Peak	<±3.70
	49.98	54		Peak	<±3.70

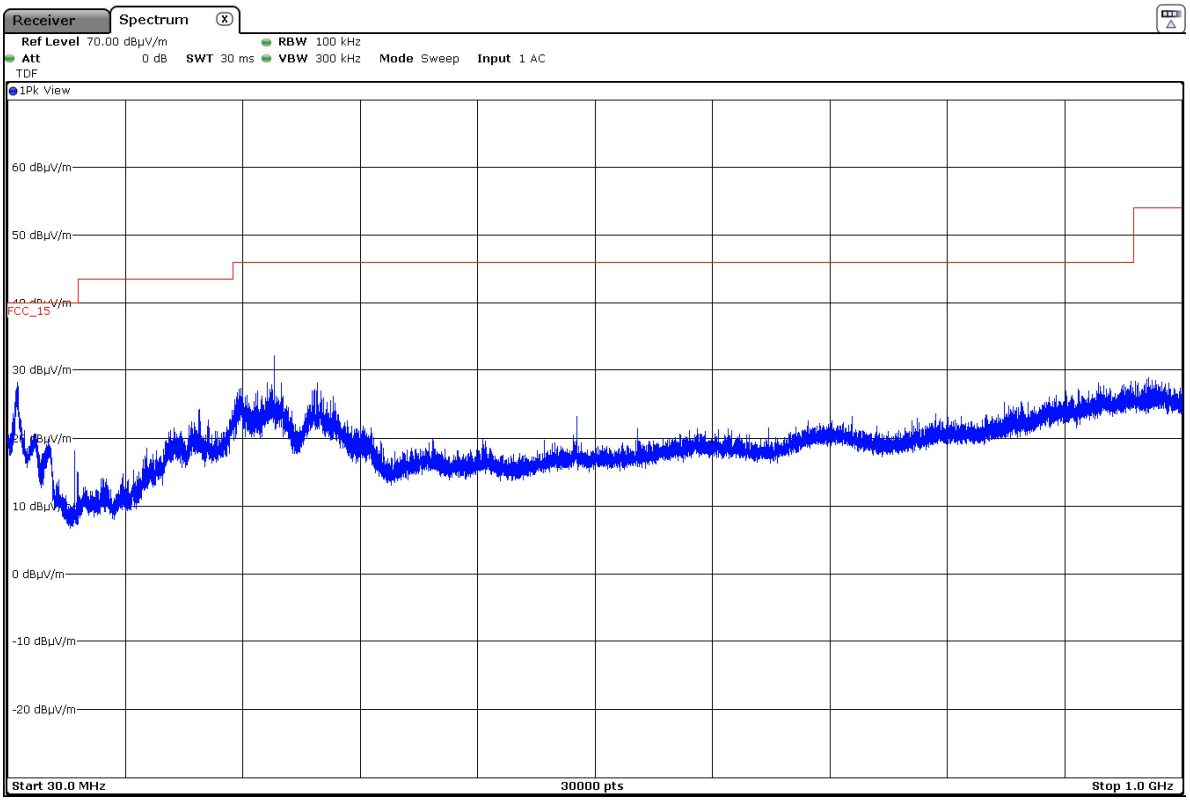
- High Channel. Spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Emission Level (dBµV/m)	Limit (dBµV/m)	Polarization	Detector	Measurement Uncertainty (dB)
10.48003	59.64	68.23	V	Peak	<±3.70
	49.99	54		Peak	<±3.70

Verdict: PASS

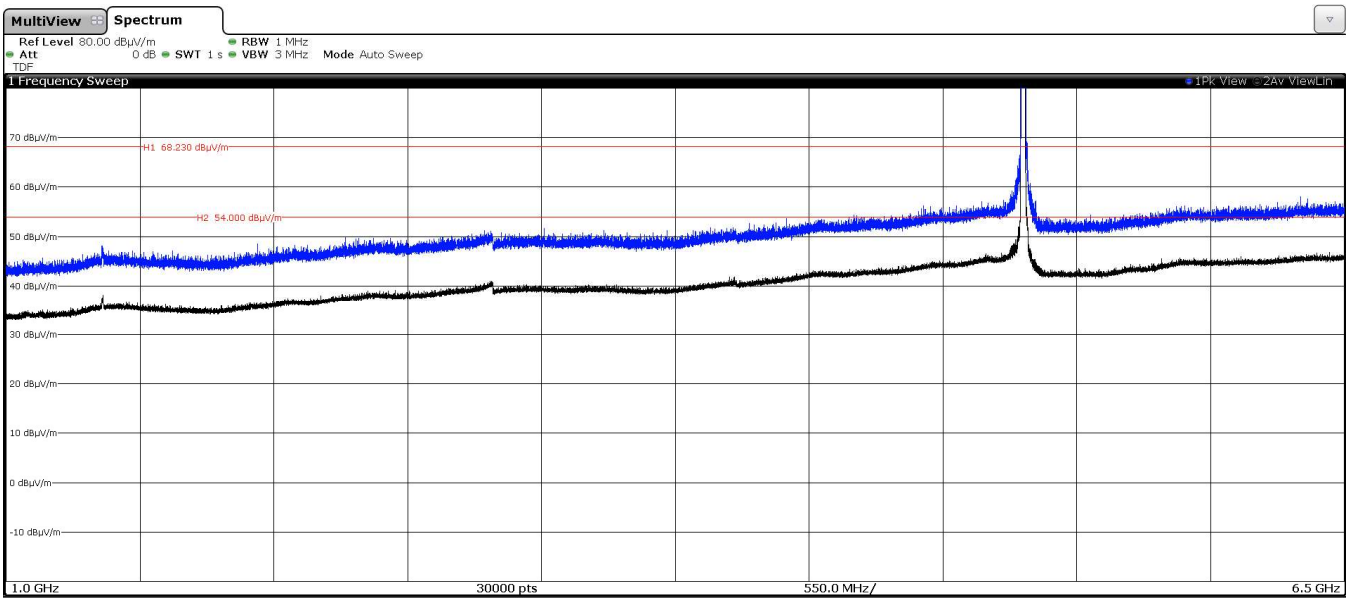
FREQUENCY RANGE 30 MHz - 1 GHz

This plot is valid for the Low, Middle and High Channels and all the modulation modes.

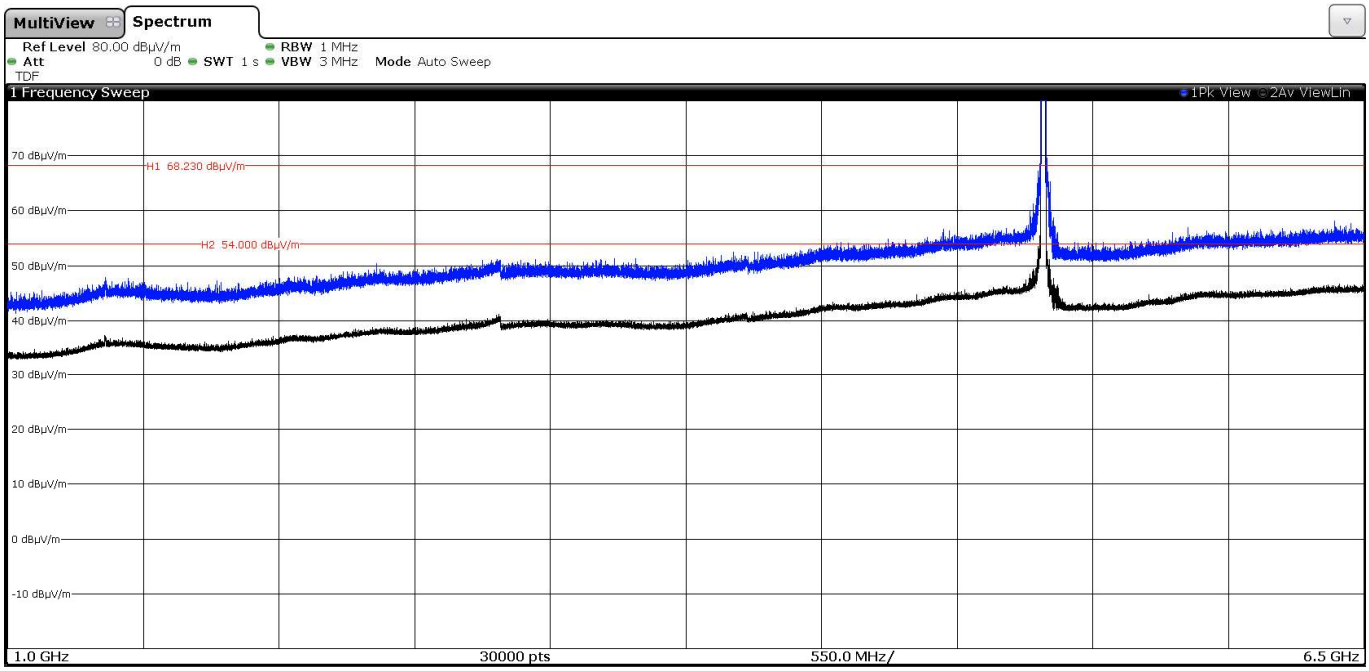


FREQUENCY RANGE 1 – 6.5 GHz (worst mode)

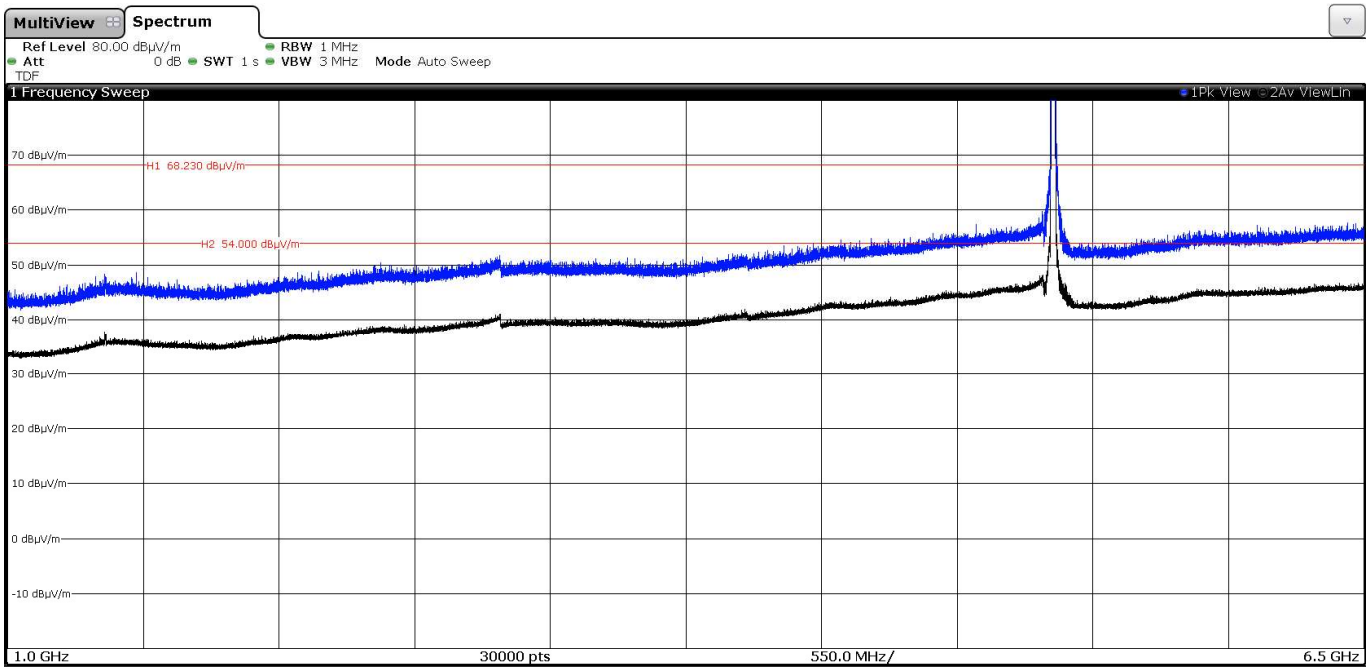
- Low Channel:



- Middle Channel:

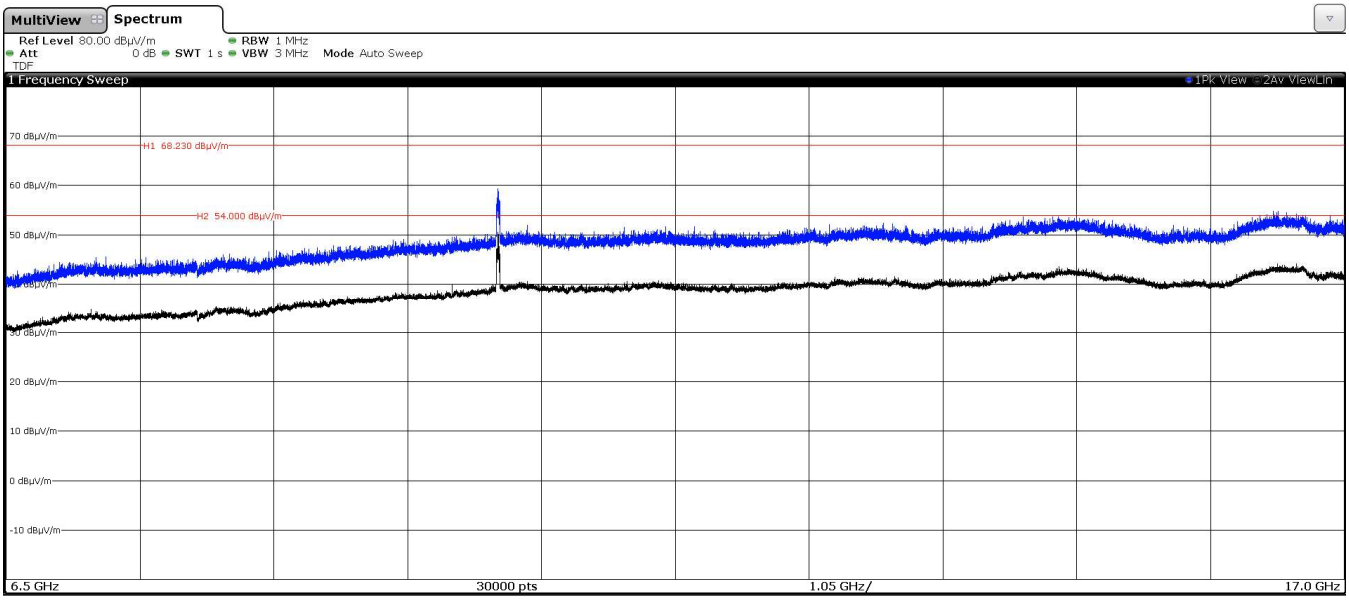


- High Channel:

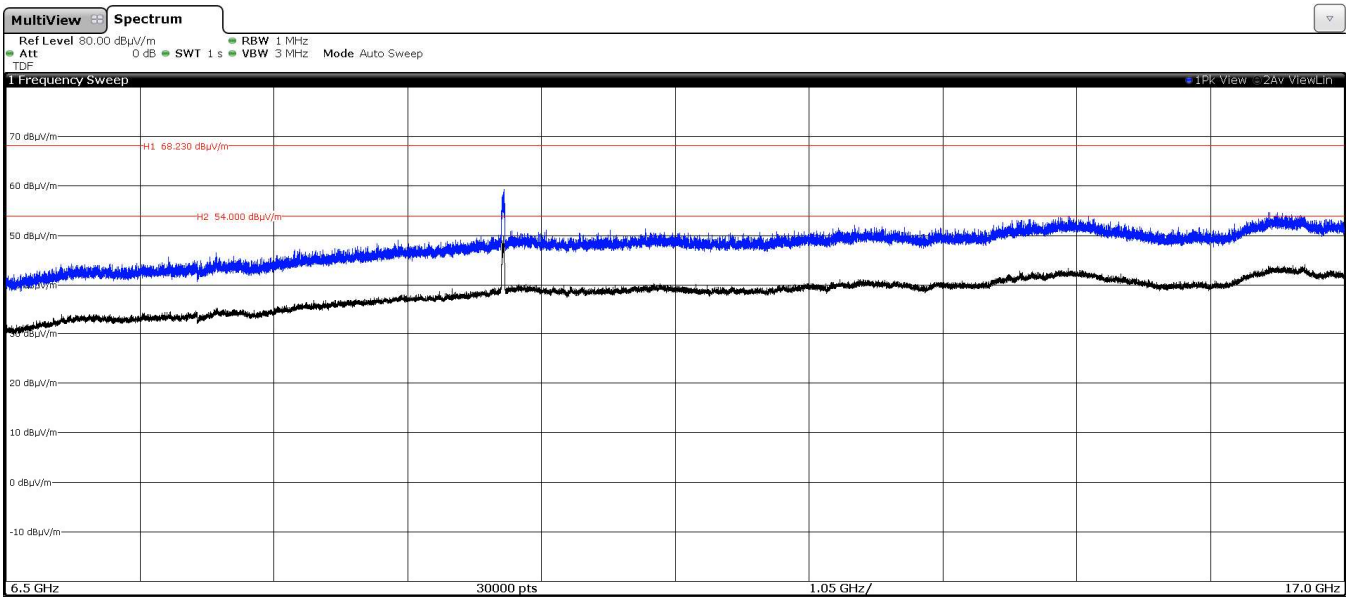


FREQUENCY RANGE 6.5 - 17 GHz. (worst mode)

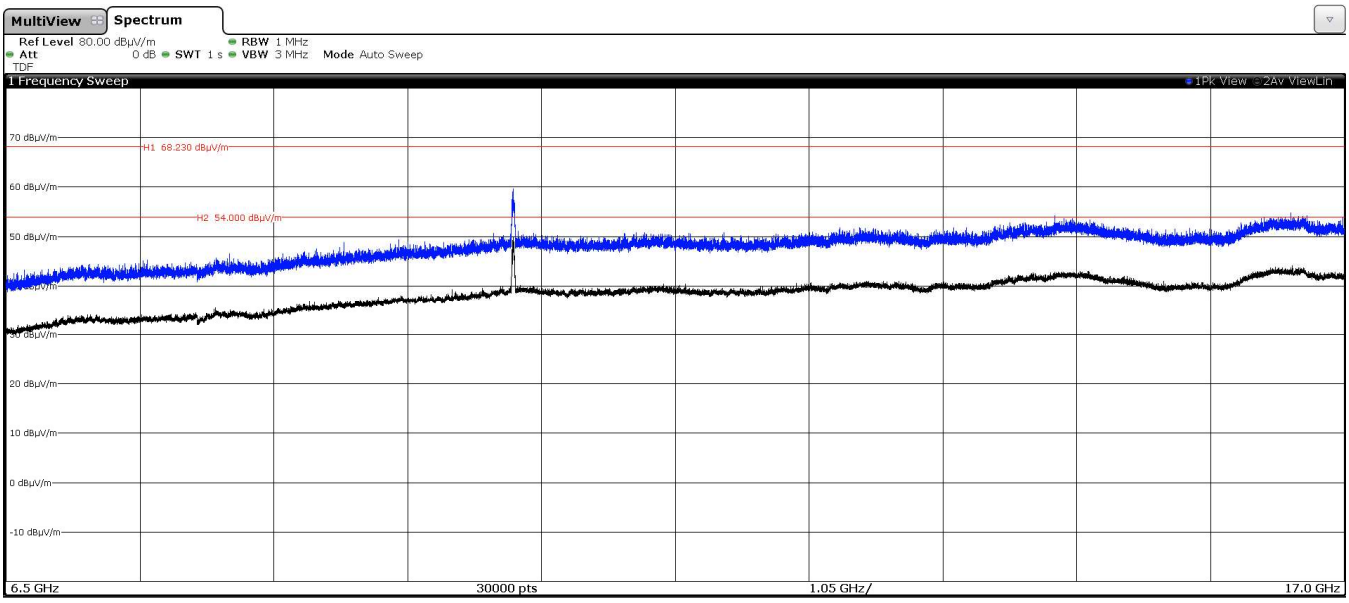
- Low Channel:



- Middle Channel:

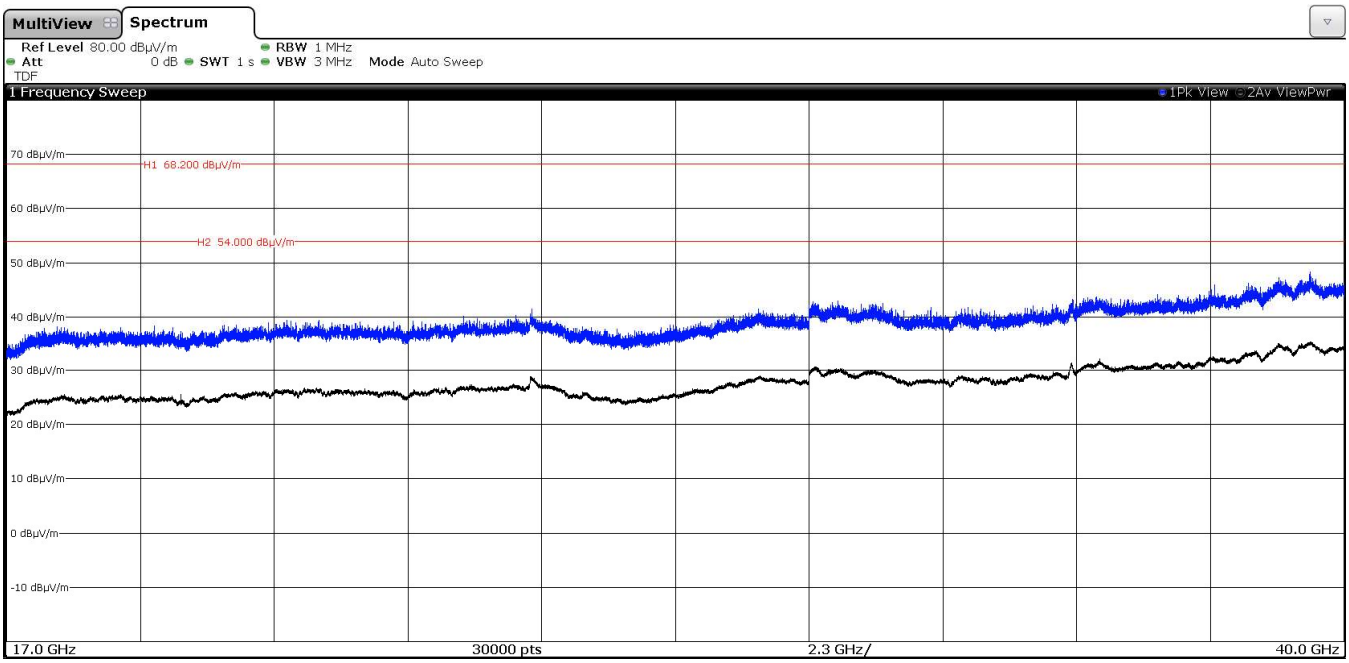


- High Channel:



FREQUENCY RANGE 17 - 40 GHz

This plot is valid for the Low, Middle and High Channels and all the modulation modes.



FCC 15.407 (b)(1) / RSS-247 6.2.1.2. Transmitter Band Edge Radiated Emissions

SPECIFICATION:

For transmitters operating in the 5.15–5.25 GHz band: all emissions outside of the 5.15–5.35 GHz band shall not exceed an EIRP of –27 dBm/MHz (68.20 dBµV/m at 3 m distance).

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)):

Frequency Range (MHz)	Field strength (µV/m)	Field strength (dBµV/m)	Measurement distance (m)
0.009-0.490	2400/F(kHz)	-	300
0.490-1.705	24000/F(kHz)	-	300
1.705 - 30.0	30	-	30
30 - 88	100	40	3
88 - 216	150	43.5	3
216 - 960	200	46	3
960 - 40000	500	54	3

The emission limits shown in the above table are based on measurements employing CISPR quasi-peak detector except for the frequency bands 9-90 kHz, 110-490 kHz and above 1000 MHz. Radiated emission limits in these three bands are based on measurements employing an average detector.

For average radiated emission measurements above 1000 MHz, there is also a limit corresponding to 20 dB above the indicated values in the table is specified when measuring with peak detector function.

RESULTS:

The field strength is calculated by adding correction factor to the measured level from the spectrum analyzer. This correction factor includes antenna factor, cable loss and pre-amplifiers gain.

All emissions outside of the 5.15-5.35GHz band shall not exceed an EIRP of -27dBm/MHz. There are restricted bands of operation below band edge at 4.5-5.15 GHz also above the upper band edge at 5.35-5.46GHz therefore the provision of FCC Part 15.205 apply.

Field strength measurements using peak and average detector performed in the restricted bands below 5.15GHz and above 5.35 GHz.

Test performed on the following worst cases modes in all relevant tests channels:

- 802.11a20: 6 Mbits
- 802.11n HT20: MCS0
- 802.11n HT40: MCS0
- 802.11ac VHT20: MCS0
- 802.11ac VHT40: MCS0
- 802.11ac VHT80: MCS0

Mode 802.11 a20

- Lower Band Edge Channel 36 (5180 MHz): Inside band 4.50-5.15 GHz.

Radiated spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Emission Level (dBµV/m)	Limit (dBµV/m)	Polarization	Detector	Measurement Uncertainty (dB)
5.14859	65.06	74	V	Peak	<±3.70
5.14968	48.96	54		Average	<±3.70

- Upper Band Edge Channel 48 (5240 MHz): Inside band 5.35-5.46 GHz.

No radiated spurious frequencies detected at less than 20 dB below the limit.

Mode 802.11 n20 (HT20)

- Lower Band Edge Channel 36 (5180 MHz): Inside band 4.50-5.15 GHz.

Radiated spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Emission Level (dBµV/m)	Limit (dBµV/m)	Polarization	Detector	Measurement Uncertainty (dB)
5.14478	63.57	74	H	Peak	<±3.70
5.14946	47.28	54		Average	<±3.70

- Upper Band Edge Channel 48 (5240 MHz): Inside band 5.35-5.46 GHz.

No radiated spurious frequencies detected at less than 20 dB below the limit.

Mode 802.11 ac20 (HT20)

- Lower Band Edge Channel 36 (5180 MHz): Inside band 4.50-5.15 GHz.

Radiated spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Emission Level (dBµV/m)	Limit (dBµV/m)	Polarization	Detector	Measurement Uncertainty (dB)
5.14773	61.44	74	H	Peak	<±3.70
5.14968	46.72	54		Average	<±3.70

- Upper Band Edge Channel 48 (5240 MHz): Inside band 5.35-5.46 GHz.

No radiated spurious frequencies detected at less than 20 dB below the limit.

Mode 802.11 n40 (HT40)

- Lower Band Edge Channel 38 (5190 MHz): Inside band 4.50-5.15 GHz.

Radiated spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Emission Level (dBµV/m)	Limit (dBµV/m)	Polarization	Detector	Measurement Uncertainty (dB)
5.14664	59.24	74	H	Peak	<±3.70
5.14946	46.14	54		Average	<±3.70

- Upper Band Edge Channel 46 (5230 MHz): Inside band 5.35-5.46 GHz.

No radiated spurious frequencies detected at less than 20 dB below the limit.

Mode 802.11 ac40 (VHT40)

- Lower Band Edge Channel 38 (5190 MHz): Inside band 4.50-5.15 GHz.

Radiated spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Emission Level (dBµV/m)	Limit (dBµV/m)	Polarization	Detector	Measurement Uncertainty (dB)
5.13299	59.83	74	H	Peak	<±3.70
5.14751	46.38	54		Average	<±3.70

- Upper Band Edge Channel 46 (5230 MHz): Inside band 5.35-5.46 GHz.

No radiated spurious frequencies detected at less than 20 dB below the limit.

Mode 802.11 ac80 (VHT80)

- Single Channel 42 (5240 MHz): Inside band 4.50-5.15 GHz and 5.35-5.46 GHz.

Radiated spurious frequencies detected at less than 20 dB below the limit:

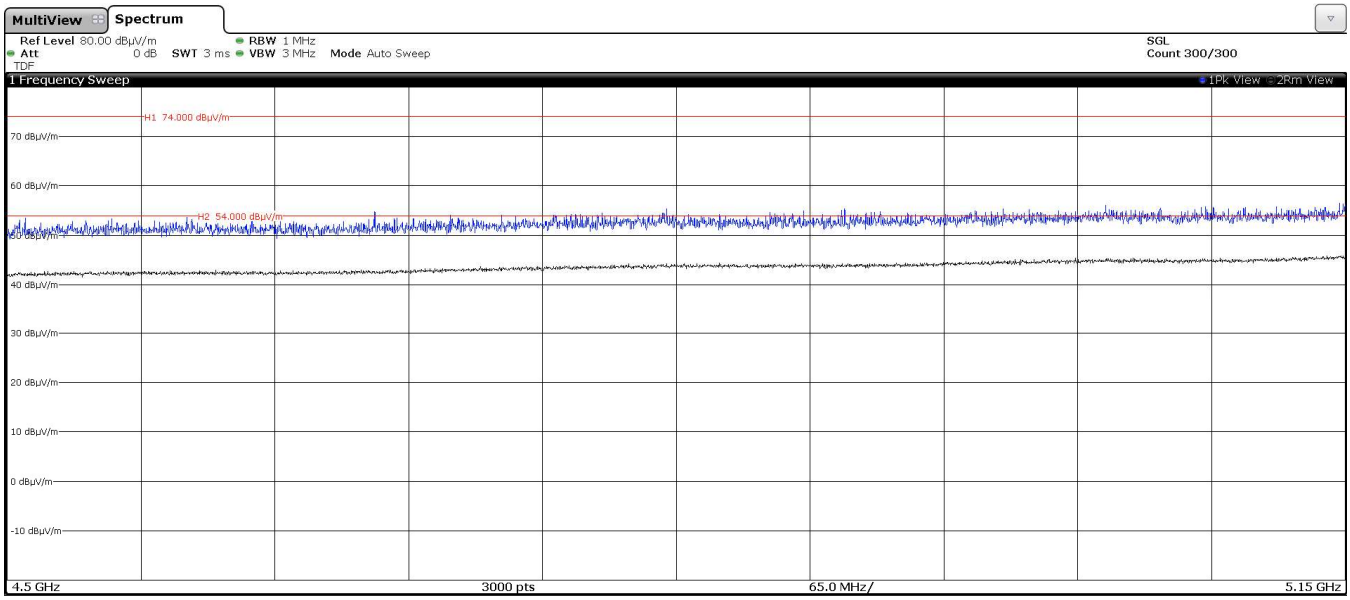
Spurious frequency (GHz)	Emission Level (dBµV/m)	Limit (dBµV/m)	Polarization	Detector	Measurement Uncertainty (dB)
5.14621	59.35	74	H	Peak	<±3.70
5.14101	46.25	54		Average	<±3.70

Verdict: PASS

- **Mode 802.11 a20**

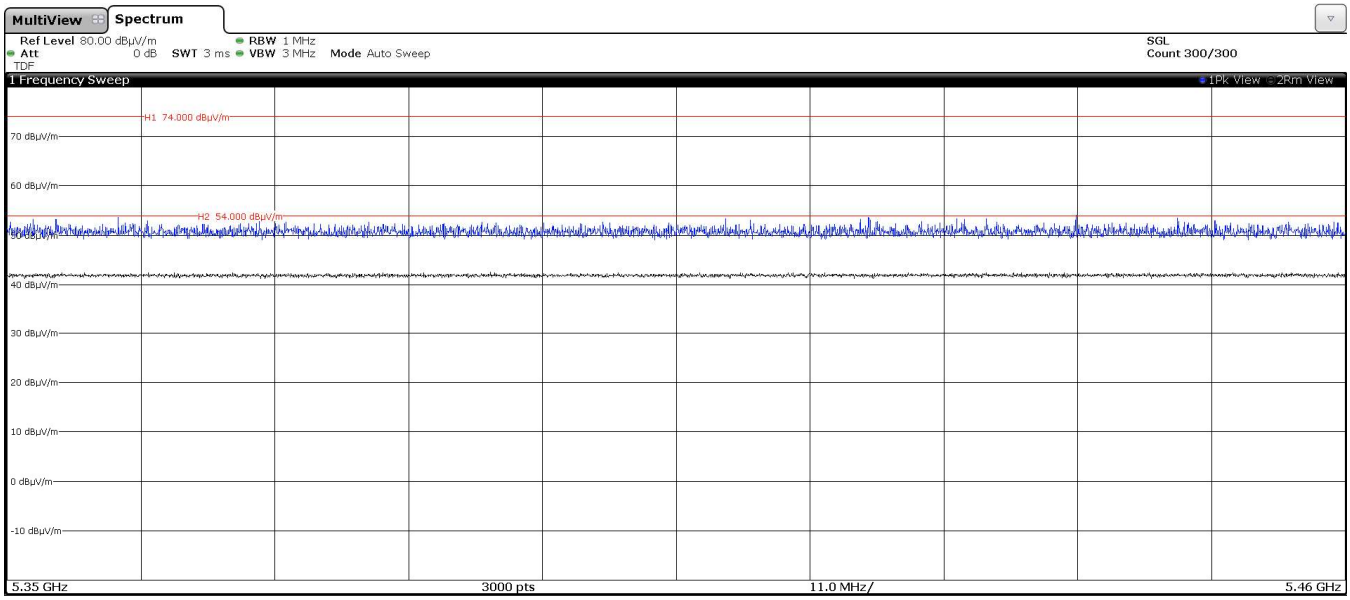
Radiated spurious emissions at band-edges and inside adjacent band 4.50 - 5.15 GHz

- Lower Band Edge Channel 36 (4500 to 5150 MHz)



Radiated spurious emissions at band-edges and inside adjacent band 5.35 - 5.46 GHz

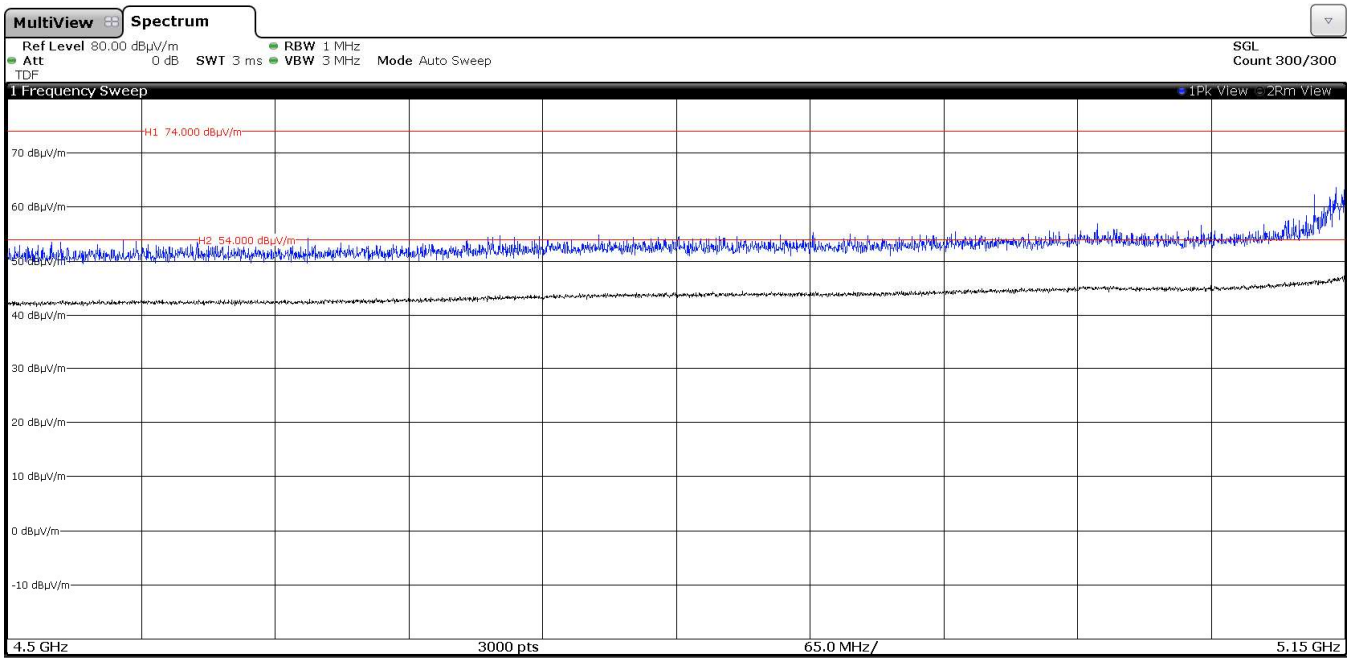
- Upper Band Edge Channel 48 (5350 to 5460 MHz)



- **Mode 802.11 n20 (HT20)**

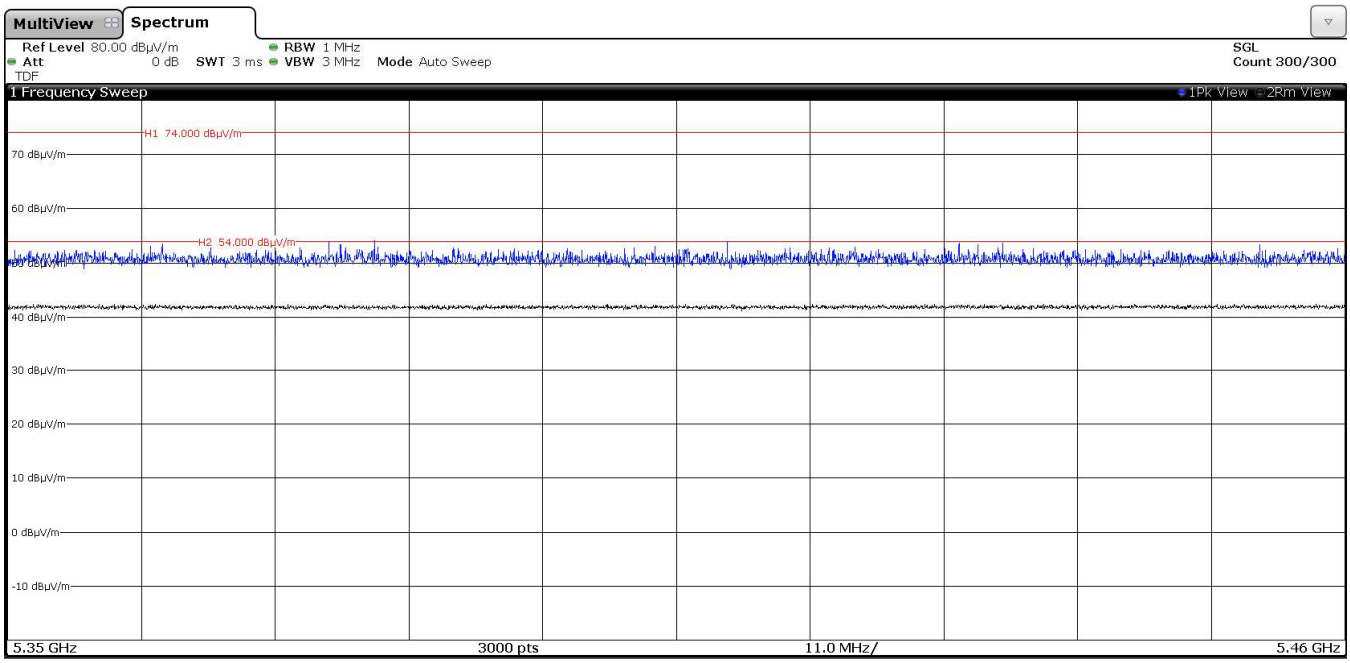
Radiated spurious emissions at band-edges and inside adjacent band 4.50 - 5.15 GHz

- Lower Band Edge Channel 36 (4500 to 5150 MHz)



Radiated spurious emissions at band-edges and inside adjacent band 5.35 - 5.46 GHz

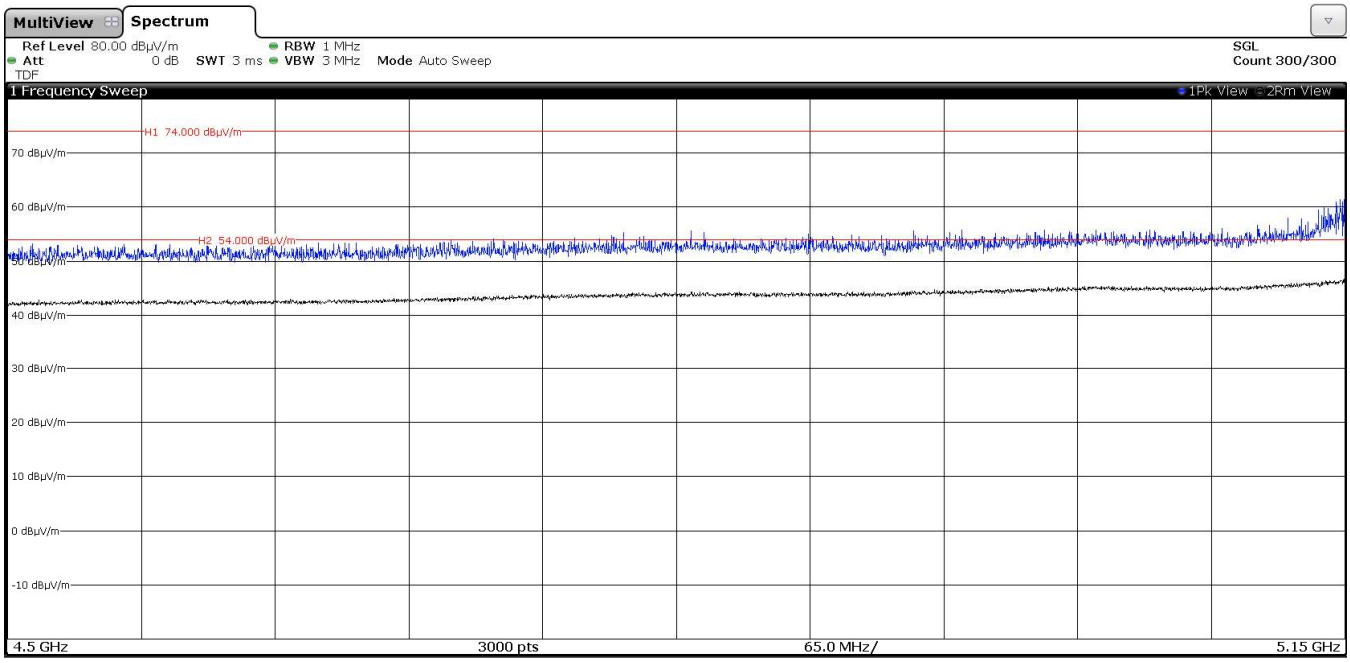
- Upper Band Edge Channel 48 (5350 to 5460 MHz)



- **Mode 802.11 ac20 (VHT20)**

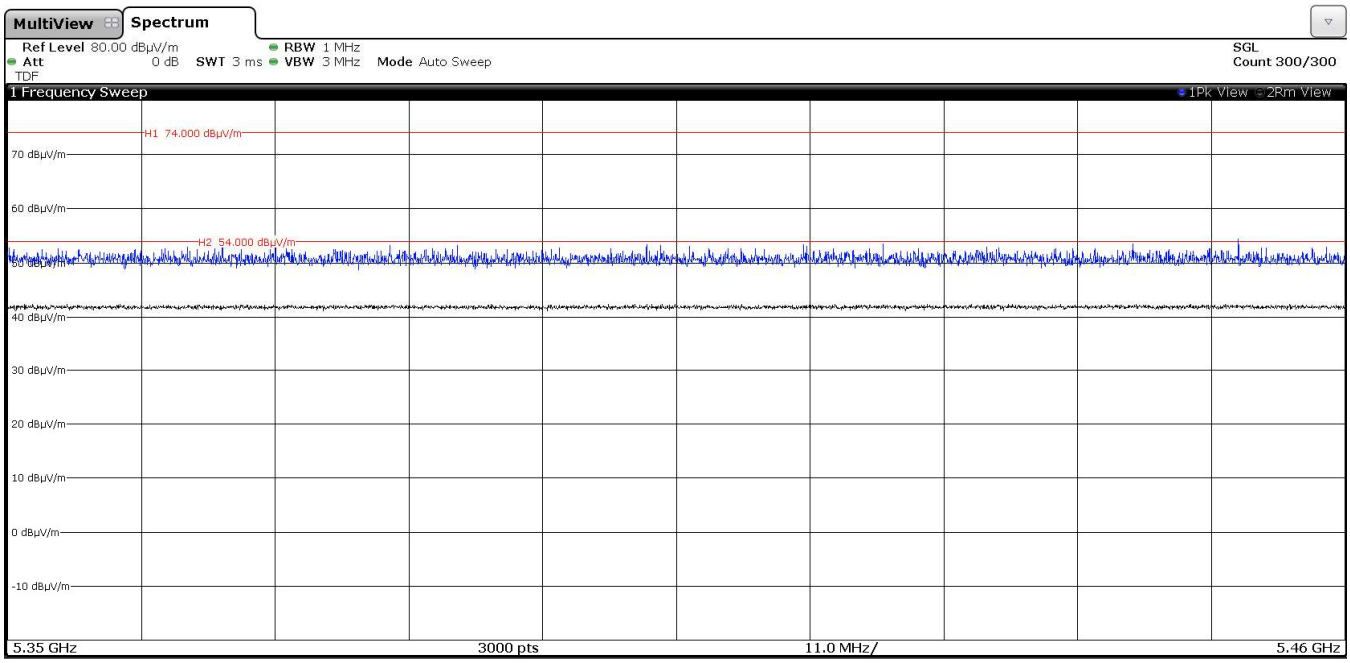
Radiated spurious emissions at band-edges and inside adjacent band 4.50 - 5.15 GHz

- Lower Band Edge Channel 36 (4500 to 5150 MHz)



Radiated spurious emissions at band-edges and inside adjacent band 5.35 - 5.46 GHz

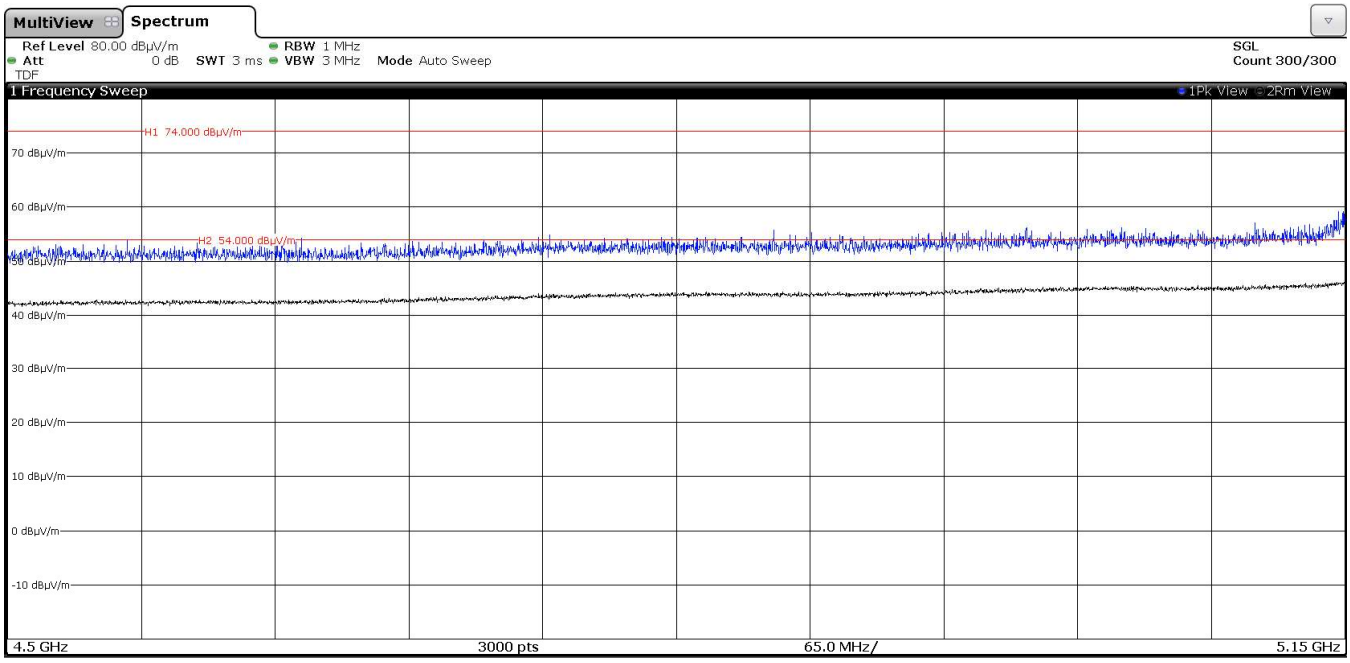
- Upper Band Edge Channel 48 (5350 to 5460 MHz)



- **Mode 802.11 n40 (HT40)**

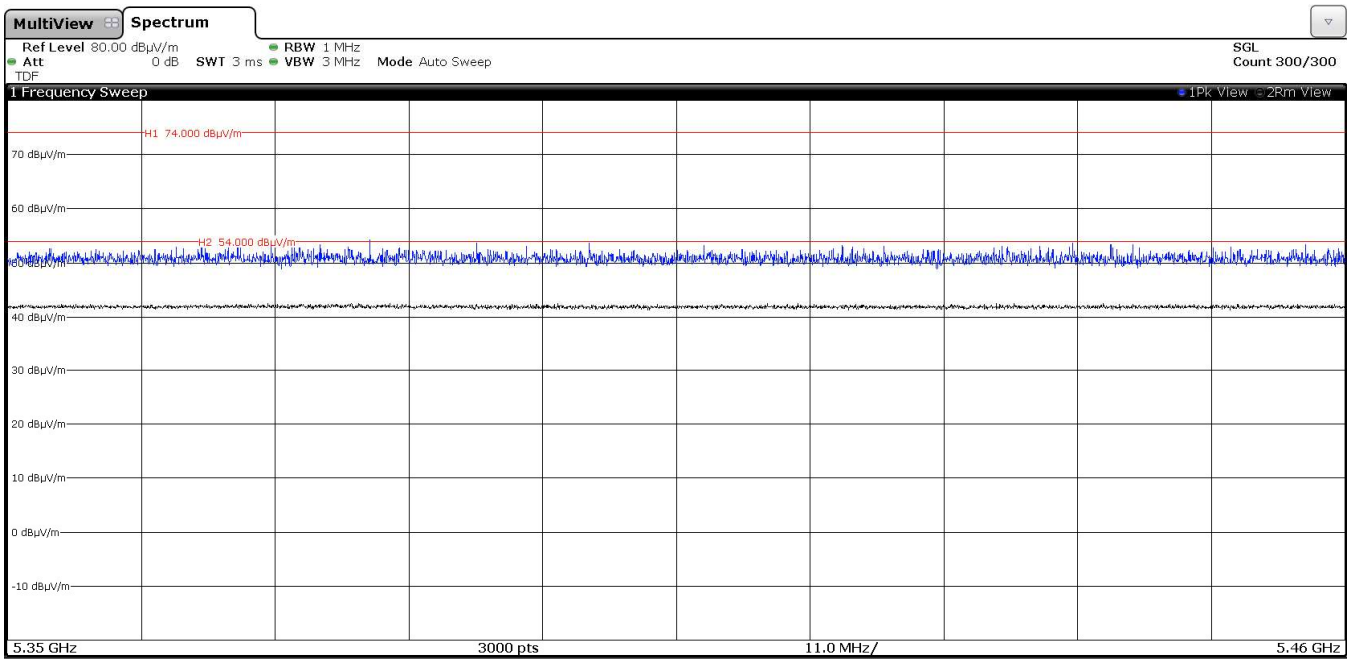
Radiated spurious emissions at band-edges and inside adjacent band 4.50 - 5.15 GHz

- Lower Band Edge Channel 38 (4500 to 5150 MHz)



Radiated spurious emissions at band-edges and inside adjacent band 5.35 - 5.46 GHz

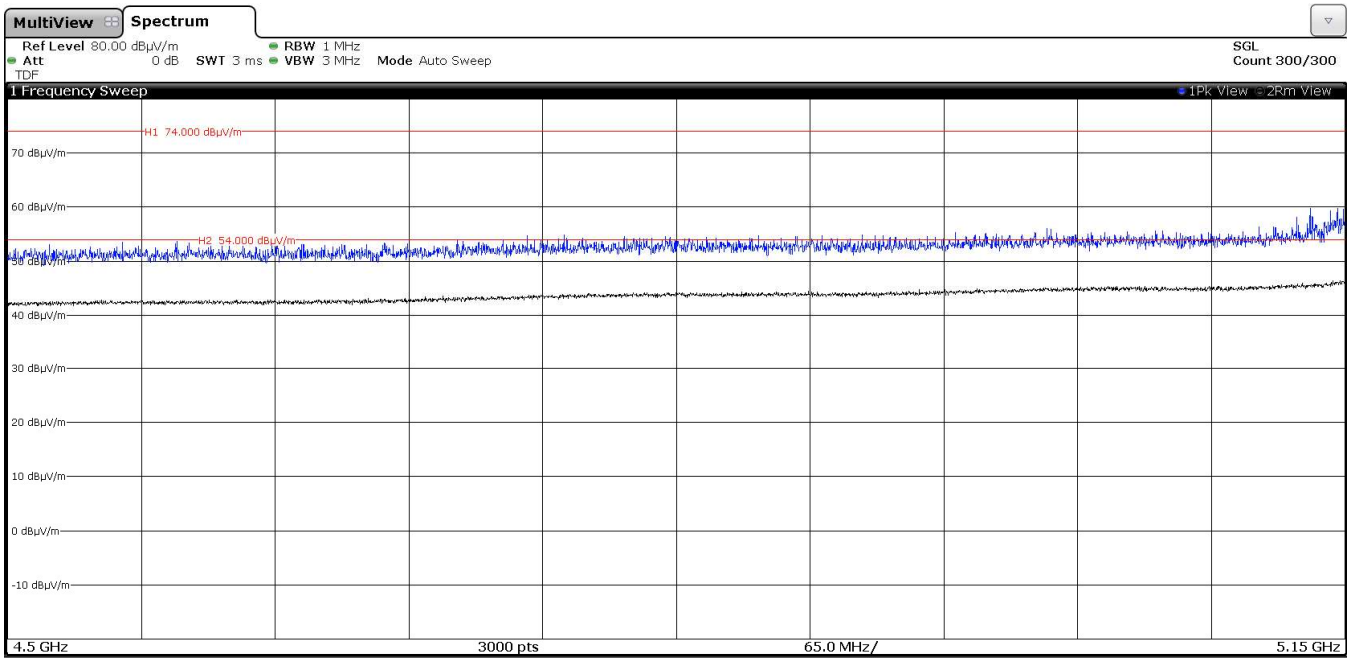
- Upper Band Edge Channel 46 (5350 to 5460 MHz)



- **Mode 802.11 ac40 (VHT40)**

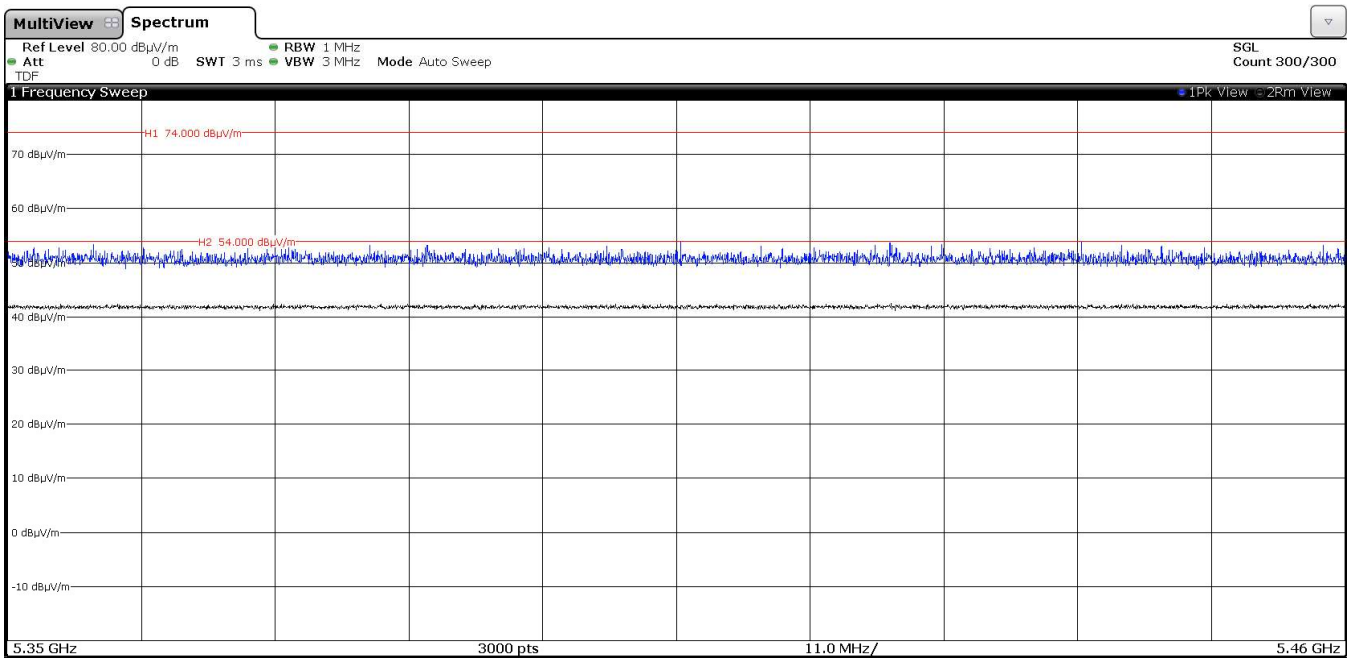
Radiated spurious emissions at band-edges and inside adjacent band 4.50 - 5.15 GHz

- Lower Band Edge Channel 38 (4500 to 5150 MHz)



Radiated spurious emissions at band-edges and inside adjacent band 5.35 - 5.46 GHz

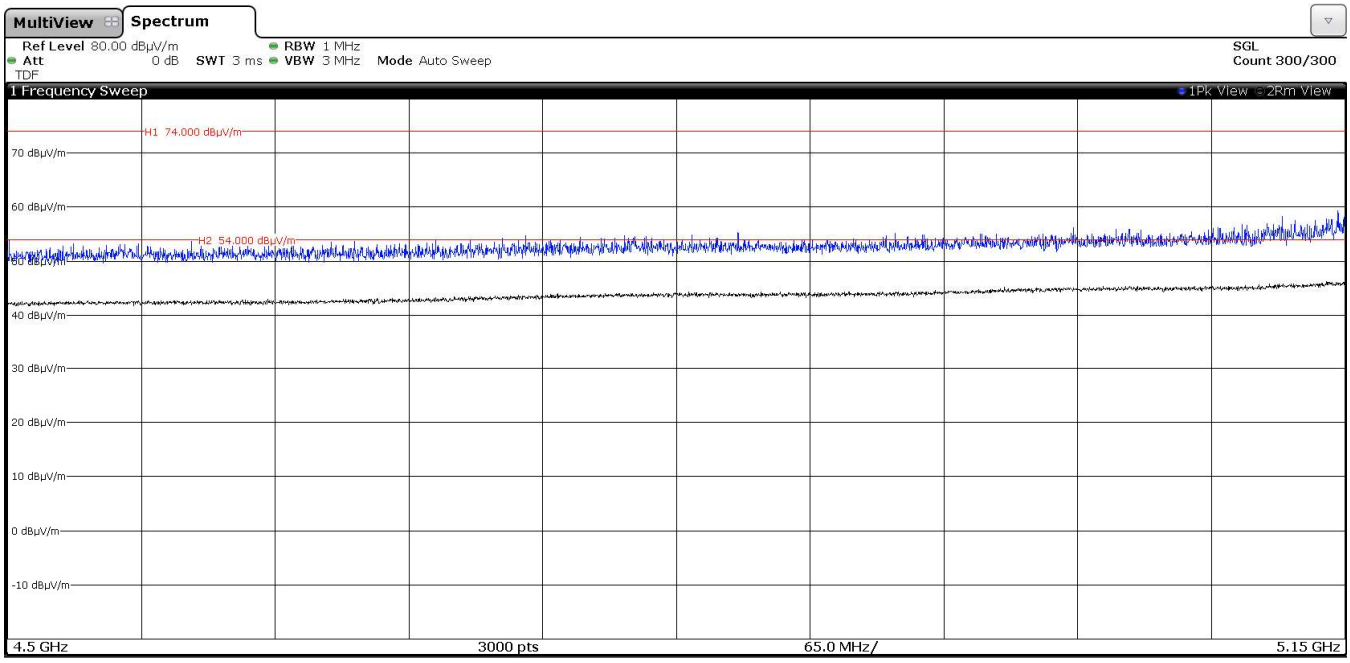
- Upper Band Edge Channel 46 (5350 to 5460 MHz)



- **Mode 802.11 ac80 (VHT80)**

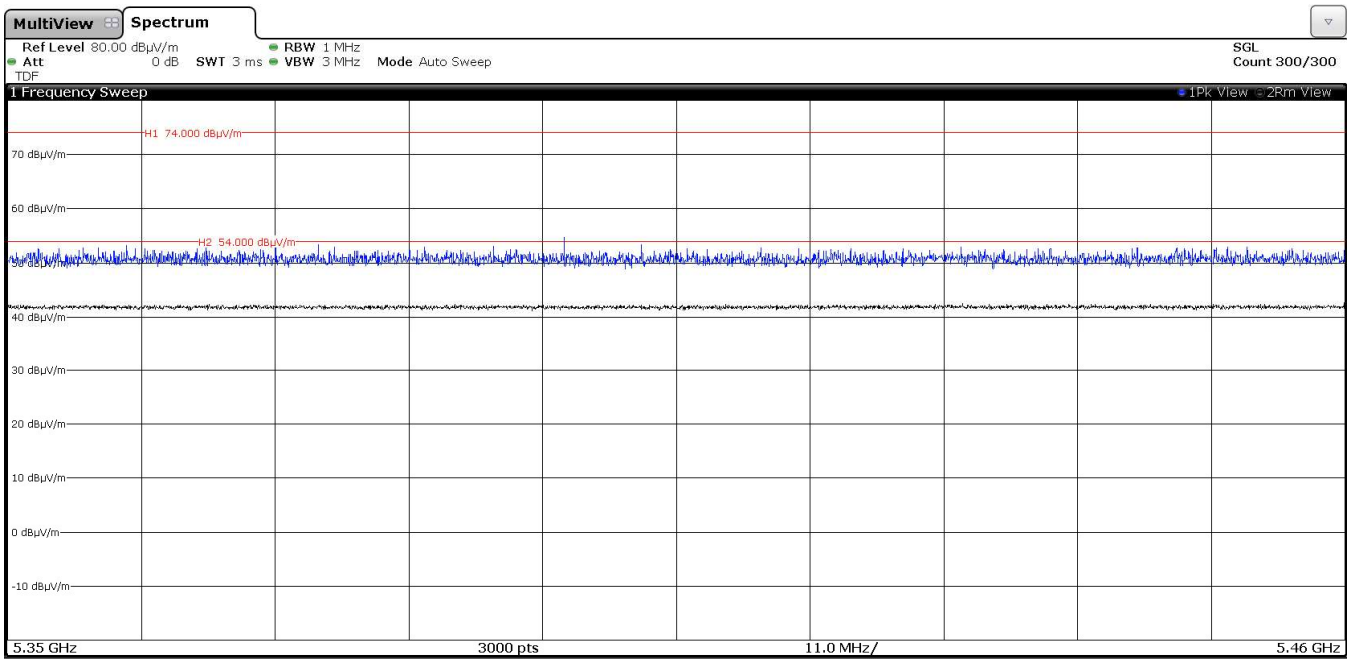
Radiated spurious emissions at band-edges and inside adjacent band 4.50 - 5.15 GHz

- Lower Band Edge Channel 42 (4500 to 5150 MHz)



Radiated spurious emissions at band-edges and inside adjacent band 5.35 - 5.46 GHz

- Upper Band Edge Channel 42 (5350 to 5460 MHz)



Appendix C: Tests results for the U-NII-3 Band 5.725 – 5.85 GHz

INDEX

TEST CONDITIONS 88
FCC 15.407 (e) / RSS-247 6.2.4.1. 6 dB Bandwidth 92
FCC 15.407 (a)(3) / RSS-247 6.2.4.1. Transmitter Maximum Conducted Output Power 102
FCC 15.407 (a)(3) / RSS-247 6.2.4.1. Transmitter Maximum Power Spectral Density 112
FCC 15.407 (b)(4) / RSS-247 6.2.4.2. Undesirable Radiated Emissions (Transmitter) 1 to 40 GHz 115

TEST CONDITIONS

POWER SUPPLY (V):

V nonimal:	12 Vdc.
Type of Power Supply:	External power supply (Car Battery).
Type of Antenna:	External antenna.
Maximum Declared Antenna Gain:	-5.4 dBi (antenna gain plus antenna cable loss).

Technology Tested:	WLAN (IEEE 802.11 a/n/ac): U-NII-3 band	
Modes:	802.11a: 6, 9, 12, 18, 24, 36, 48 & 54 Mbps	
	802.11n HT20: MCS0 to MCS7	
	802.11n HT40: MCS0 to MCS7	
	802.11ac VHT20: MCS0 to MCS8	
	802.11ac VHT40: MCS0 to MCS9	
	802.11ac VHT80: MCS0 to MCS9	
Setting of cores / ports:	One port.	
Beamforming:	No	
Frequency Range:	5725 MHz to 5850 MHz	
Channel Spacing:	20 MHz	
Transmit Channels	Channel	Channel Frequency (MHz)
	Lowest: 149	5745
	Middle: 157	5785
	Highest: 165	5825
Channel Spacing:	40 MHz	
Transmit Channels	Channel	Channel Frequency (MHz)
	Lowest: 151	5755
	Highest: 159	5795
Channel Spacing:	80 MHz	
Transmit Channels	Middle: 155	5775

The test set-up was made in accordance to the general provisions of ANSI C63.10: 2013 and FCC KDB 789033 D02 General UNII Test Procedures New Rules v02r01 dated 12/14/2017 and FCC KBD 662911 D01 Multiple Transmitter Output v02r01 dated 10/31/2013.

The EUT was tested in the following operating mode:

- Continuously transmitting with a modulated carrier at maximum power in all required channels using the supported data rates/modulations types.

The field strength at the band edges was evaluated for each mode individually on the lowest and highest channels at the rated power for the channel under test.

For all modes, the EUT was configured in test mode using a software application. The application was used to enable a continuous transmission and to select the test channels as required. The client supplied scripts to configure the EUT. The customer supplied a document containing the setup instructions.

The worst cases for testing were identified for output power and spurious levels at the band edges which were selected based on preliminary testing that correspond to next data rates:

- 802.11a20: 6 Mbits
- 802.11n HT20: MCS0
- 802.11n HT40: MCS0
- 802.11ac VHT20: MCS0
- 802.11ac VHT40: MCS0
- 802.11ac VHT80: MCS0

WIFI FCC:

tx_test.sh -a wlan0 stop

a20 - Core0

tx_test.sh -a wlan0 149 0 -d x -r 6 20 –c US

tx_test.sh -a wlan0 157 0 -d x -r 6 20 -c US

tx_test.sh -a wlan0 165 0 -d x -r 6 20 -c US

n20 - Core0

tx_test.sh -a wlan0 149 0 -d x -h 0 20 -c US

tx_test.sh -a wlan0 157 0 -d x -h 0 20 -c US

tx_test.sh -a wlan0 165 0 -d x -h 0 20 -c US

ac20 - Core0

tx_test.sh -a wlan0 149 0 -d x -v 0 20 -c US

tx_test.sh -a wlan0 157 0 -d x -v 0 20 -c US

tx_test.sh -a wlan0 165 0 -d x -v 0 20 -c US

n40 - Core0

tx_test.sh -a wlan0 153 0 -d x -h 0 40 -c US

tx_test.sh -a wlan0 161 0 -d x -h 0 40 -c US

ac40 - Core0

tx_test.sh -a wlan0 153 0 -d x -v 0 40 -c US

tx_test.sh -a wlan0 161 0 -d x -v 0 40 -c US

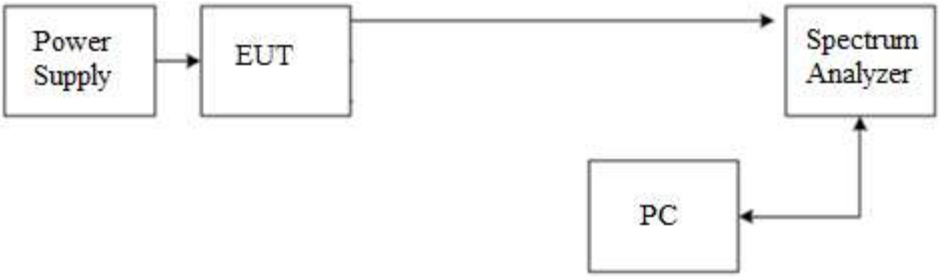
ac80 - Core0

tx_test.sh -a wlan0 161 0 -d x -v 0 80 -c US

CONDUCTED MEASUREMENTS

The equipment under test was set up in a shielded room and connected to the spectrum analyzer using a low loss RF cable. The reading in the spectrum analyzer is corrected taking into account the internal and external RF cable loss.

For all modes:



The DC supply voltage is applied using an external power supply.

RADIATED MEASUREMENTS

All radiated tests were performed in a semi-anechoic chamber. The measurement antenna is situated at a distance of 1 m for the frequency range 1 GHz-40 GHz (1 GHz-18 GHz Double ridge horn antenna and 18 GHz-40 GHz horn antenna).

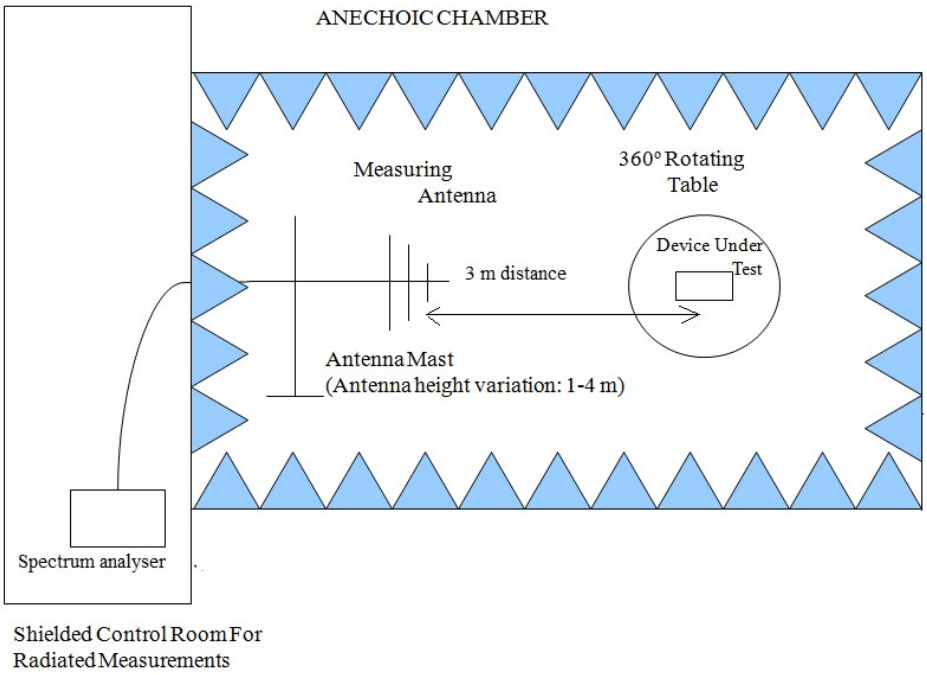
For radiated emissions in the range 1 GHz-40 GHz that is performed at a distance closer than the specified distance, an inverse proportionality factor of 20 dB per decade is used to normalize the measured data for determining compliance.

The EUT was placed at a height of 80 cm above the reference ground plane in the center of the chamber turntable to perform the measurements below 1GHz and the EUT was placed at a height of 1.5 meters above the test chamber floor in the center of the chamber turntable to perform the measurements above 1GHz. It was also rotated 360º and the antenna height was varied from 1 to 4 meters to find the maximum radiated emission.

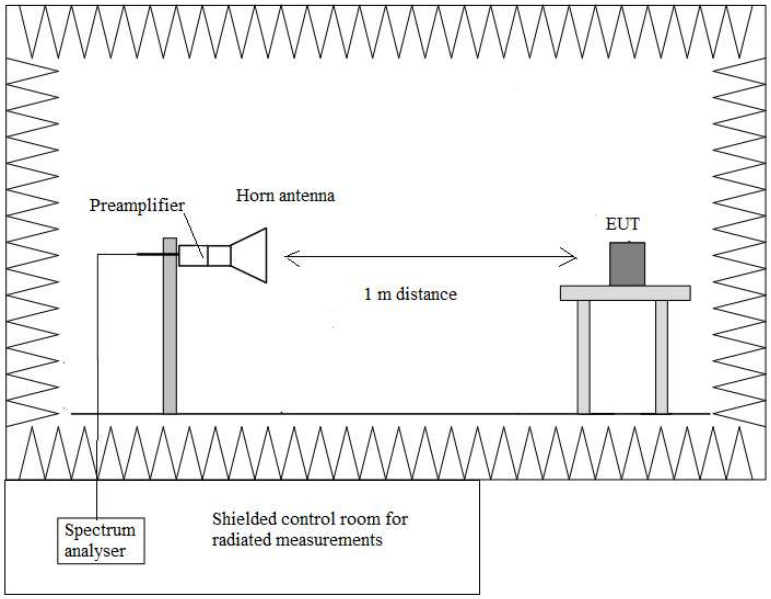
Measurements were made in both horizontal and vertical planes of polarization.

The final measured value, for the given emission, in the tables below incorporates the calibrated antenna factor and cable loss.

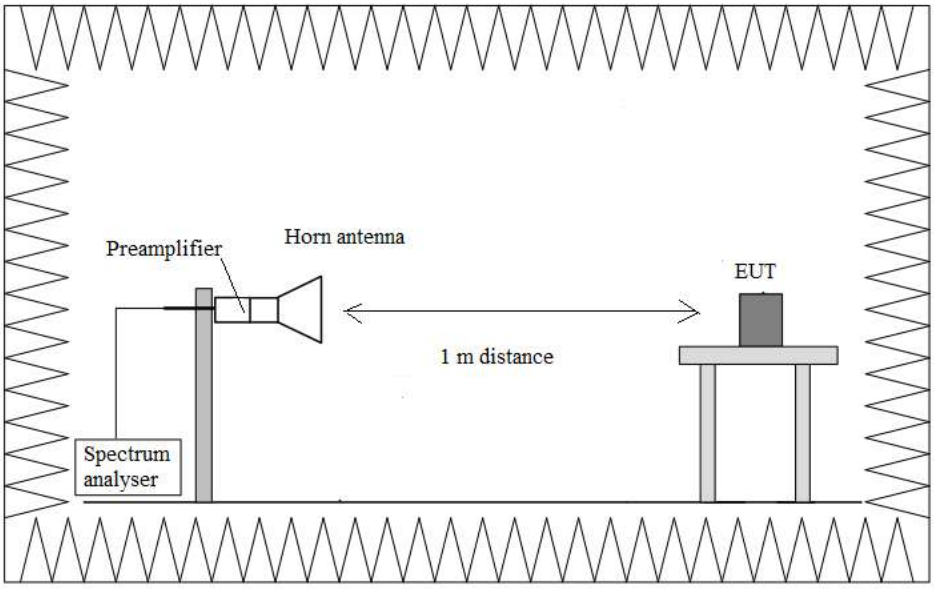
Radiated measurements setup f < 1 GHz



Radiated measurements setup f > 1 GHz up to 18 GHz.



Radiated measurements setup f > 18 GHz up to 40 GHz.



FCC 15.407 (e) / RSS-247 6.2.4.1. 6 dB Bandwidth

SPECIFICATION:

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

RESULTS:

The following modes and data rates were selected based on preliminary testing that identified those corresponding to the worst cases:

- 802.11a20: 6 Mbits
- 802.11n HT20: MCS0
- 802.11n HT40: MCS0
- 802.11ac VHT20: MCS0
- 802.11ac VHT40: MCS0
- 802.11ac VHT80: MCS0

Mode 802.11 a20

	Low Channel 149 (5745 MHz)	Middle Channel 157 (5785 MHz)	High Channel 165 (5825 MHz)
6 dB Bandwidth (MHz)	16.44	16.36	16.48
Measurement uncertainty (kHz)	<±23.02		

Mode 802.11 n20 (HT20)

	Low Channel 149 (5745 MHz)	Middle Channel 157 (5785 MHz)	High Channel 165 (5825 MHz)
6 dB Bandwidth (MHz)	17.84	17.80	17.84
Measurement uncertainty (kHz)	<±23.02		

Mode 802.11 ac20 (VHT20)

	Low Channel 149 (5745 MHz)	Middle Channel 157 (5785 MHz)	High Channel 165 (5825 MHz)
6 dB Bandwidth (MHz)	17.80	17.80	17.80
Measurement uncertainty (kHz)	<±23.02		

Mode 802.11 n40 (HT40)

	Low Channel 151 (5755 MHz)	High Channel 159 (5795 MHz)
6 dB Bandwidth (MHz)	36.52	36.51
Measurement uncertainty (kHz)	<±53.05	

Mode 802.11 ac40 (VHT40)

	Low Channel 151 (5755 MHz)	High Channel 159 (5795 MHz)
6 dB Bandwidth (MHz)	36.50	36.56
Measurement uncertainty (kHz)	<±53.05	

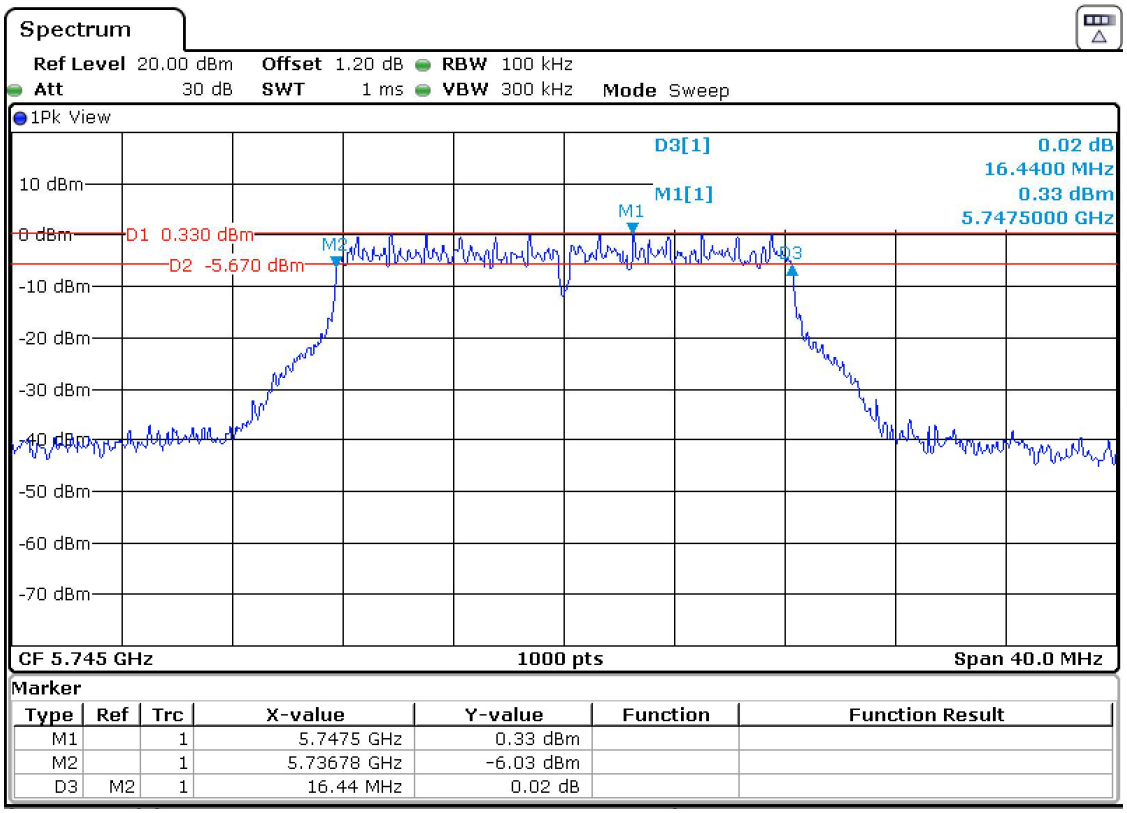
Mode 802.11 ac80 (VHT80)

	Single Channel 155 (5775 MHz)
6 dB bandwidth (MHz)	76.16
Measurement uncertainty (kHz)	<±103.10

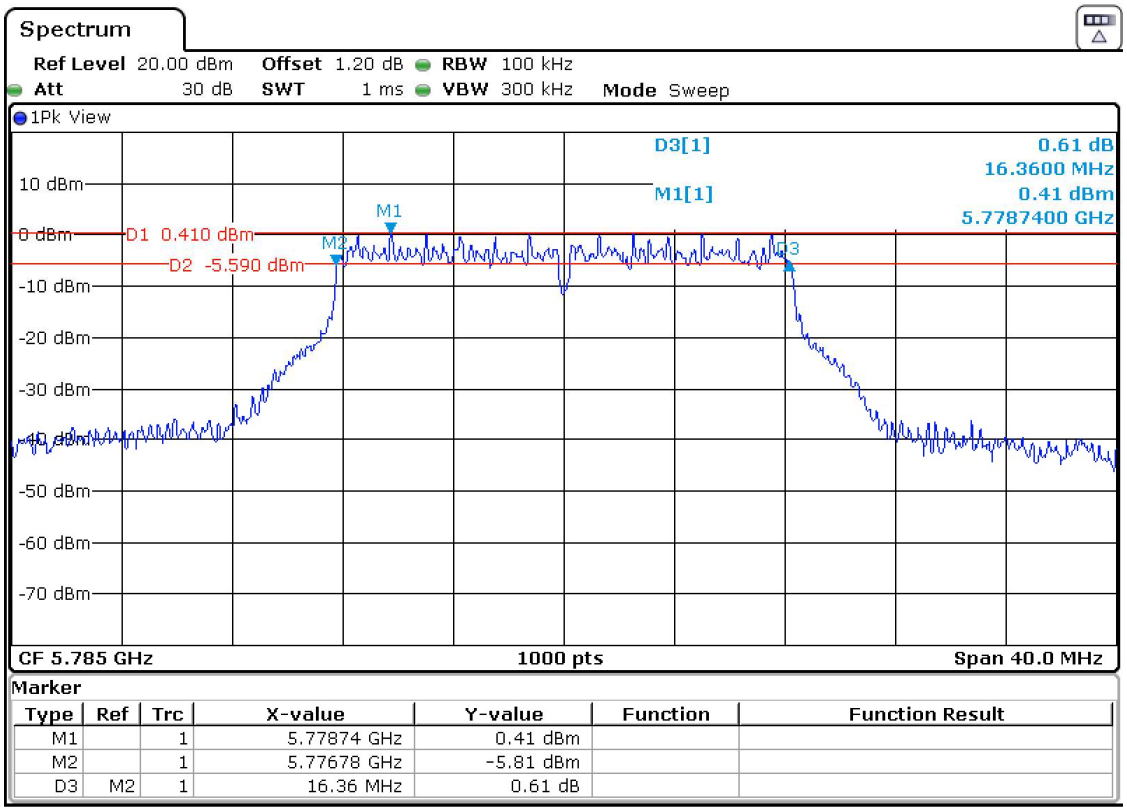
Verdict: PASS

Mode 802.11 a20

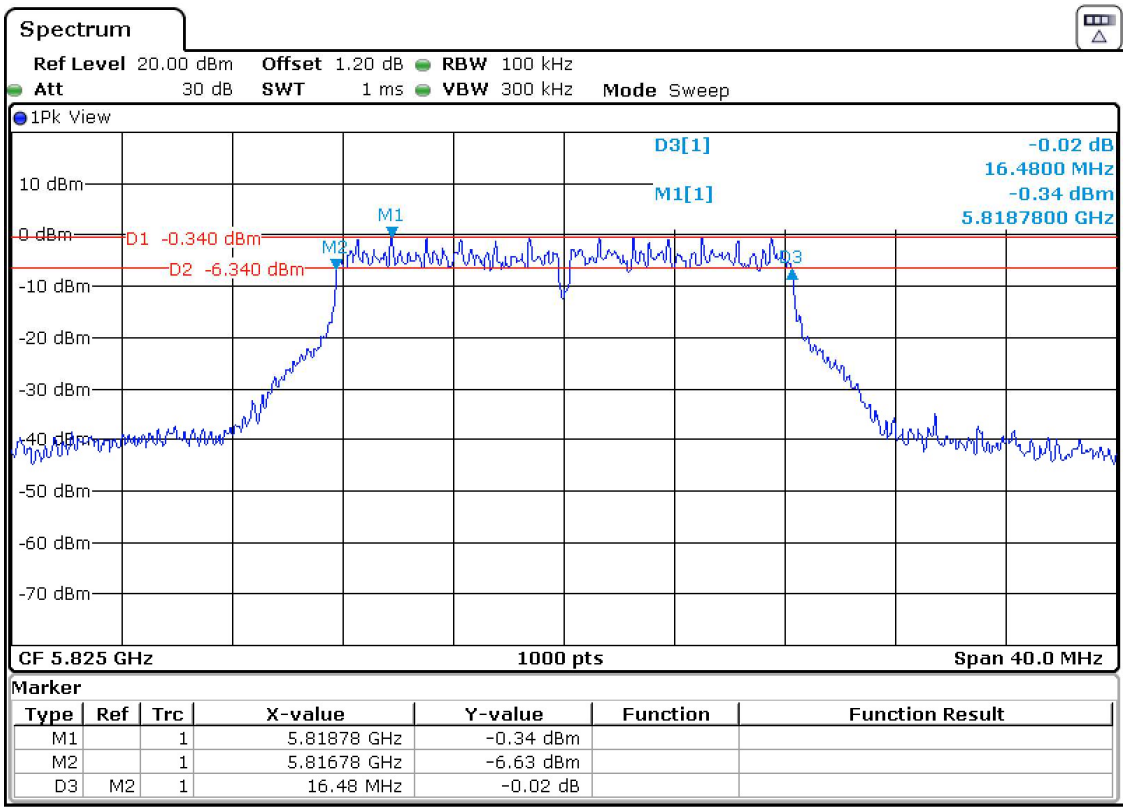
- Low Channel 149:

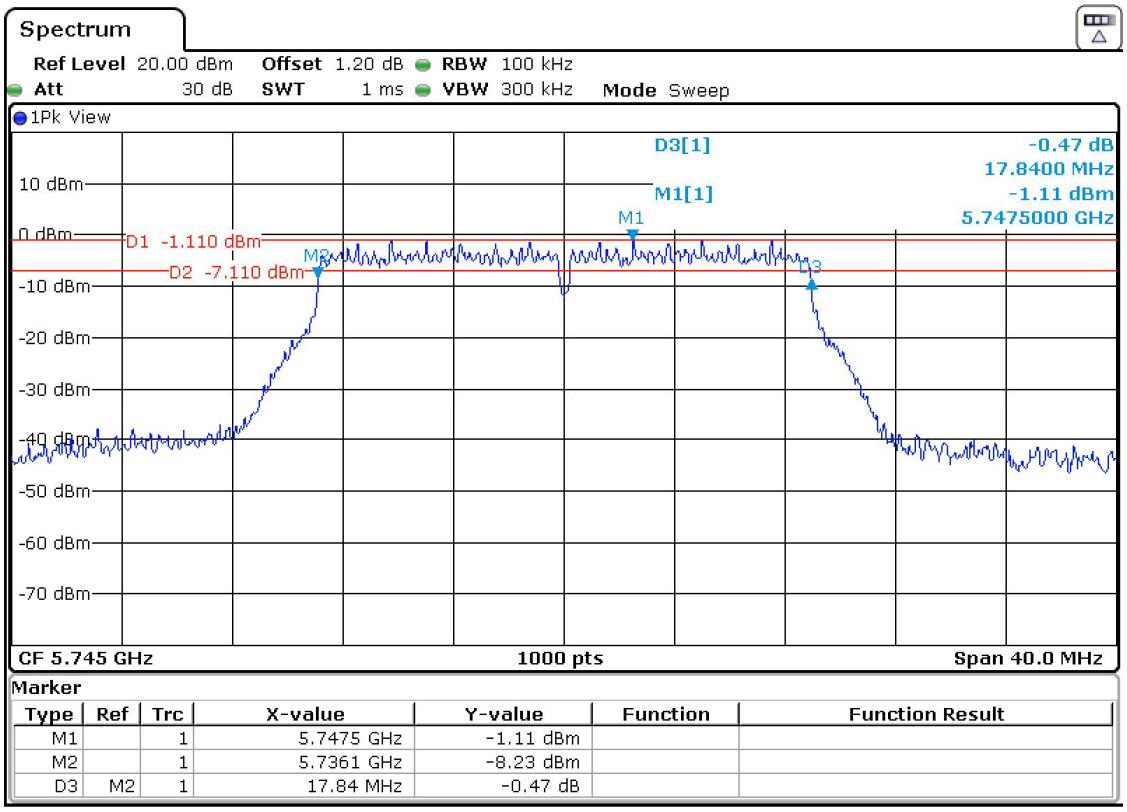


- Middle Channel 157:



- High Channel 165:



Mode 802.11 n20 (HT20)

- Low Channel 149: