

Appendix B: Test results. 802.11 bgn20 1x1.

INDEX

TEST CONDITIONS	83
Occupied Bandwidth	85
FCC Section 15.247 Subclause (a) (2) / RSS-247 Clause 5.2 (a) 6 dB Bandwidth.....	91
FCC Section 15.247 Subclause (b) / RSS-247 Clause 5.4 (d) Maximum output power and antenna gain	97
FCC Section 15.247 Subclause (d) / RSS-247 Clause 5.5. Emission limitations conducted (Transmitter).....	102
FCC Section 15.247 Subclause (e) / RSS-247 5.2. (b) Power spectral density	111
FCC Section 15.247 Subclause (d) / RSS-247 Clause 5.5. Emission limitations radiated (Transmitter)	117

TEST CONDITIONS

POWER SUPPLY (V):

V nominal: 12 Vdc
 Type of Power Supply: External power supply (car battery).
 Type of Antenna: Internal (printed).
 Maximum Declared Antenna Gain: -0.99 dBi.

TEST FREQUENCIES:

Low Channel: 2412 MHz
 Middle Channel: 2437 MHz
 High Channel: 2462 MHz

The sample was used to configure the EUT to continuously transmit at a specified output power in all channels with different modes and modulation schemes.

WiFi 2.4 GHz	
	SiSo
802.11b	31.75
802.11g	31.75
802.11n20	31.75

CONDUCTED MEASUREMENTS

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



RADIATED MEASUREMENTS

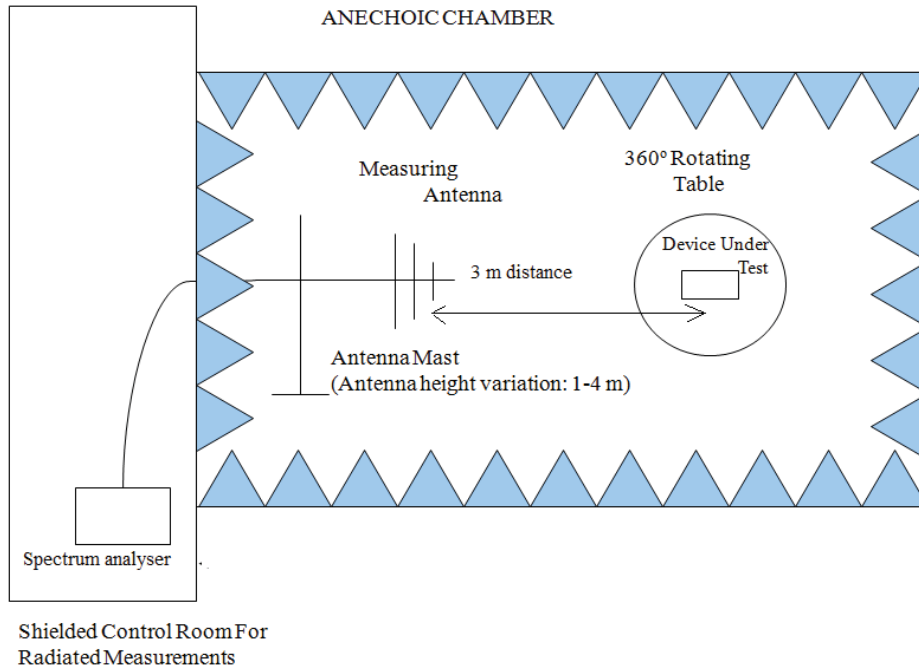
All radiated tests were performed in a semi-anechoic chamber. The measurement antenna (Bilog antenna for the range between 30 MHz to 1000 MHz) is situated at a distance of 3 m and at a distance of 1m for the frequency range 1 GHz-26 GHz (1 GHz-18 GHz Double ridge horn antenna and 18 GHz-40 GHz horn antenna).

For radiated emissions in the range 1 GHz-26 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.

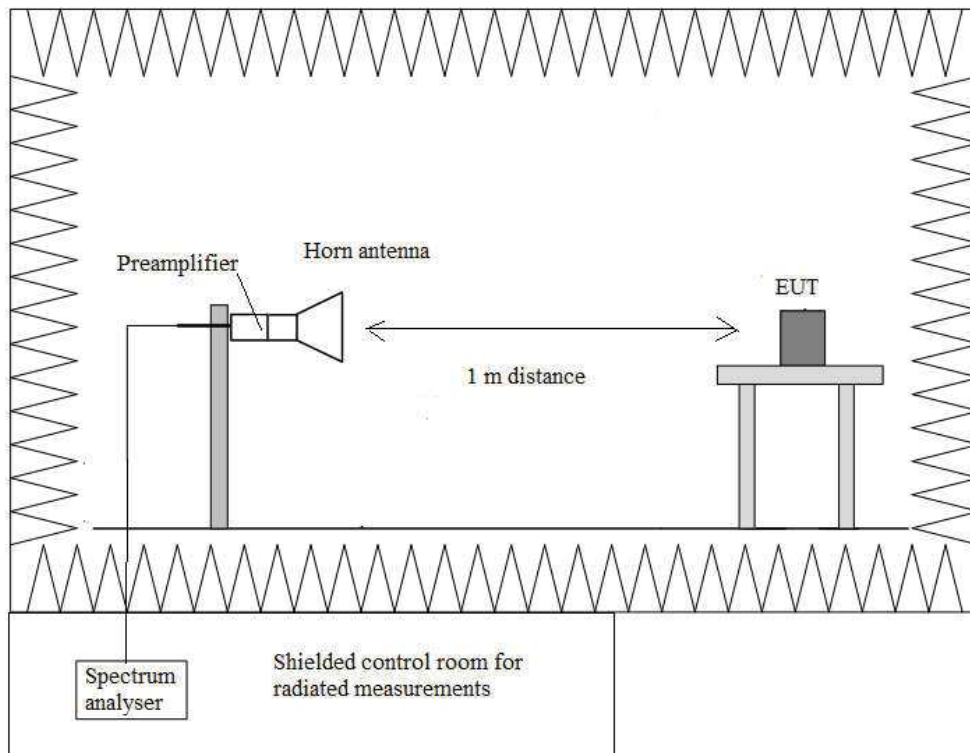
The equipment under test was set up on a non-conductive platform above the ground plane and the situation and orientation was varied to find the maximum radiated emission. It was also rotated 360° and the antenna height (Bilog antenna and Double ridge horn antenna) was varied from 1 to 4 meters to find the maximum radiated emission.

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

Radiated measurements setup from 30 MHz to 1 GHz:



Radiated measurements setup $f > 1$ GHz:



Occupied Bandwidth

RESULTS:

- **Mode 802.11 b**

	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
99% bandwidth (MHz)	13.239	13.308	13.329
-26 dBc bandwith (MHz)	17.159	17.189	17.190
Measurement uncertainty (kHz)	<± 4.50		

- **Mode 802.11 g**

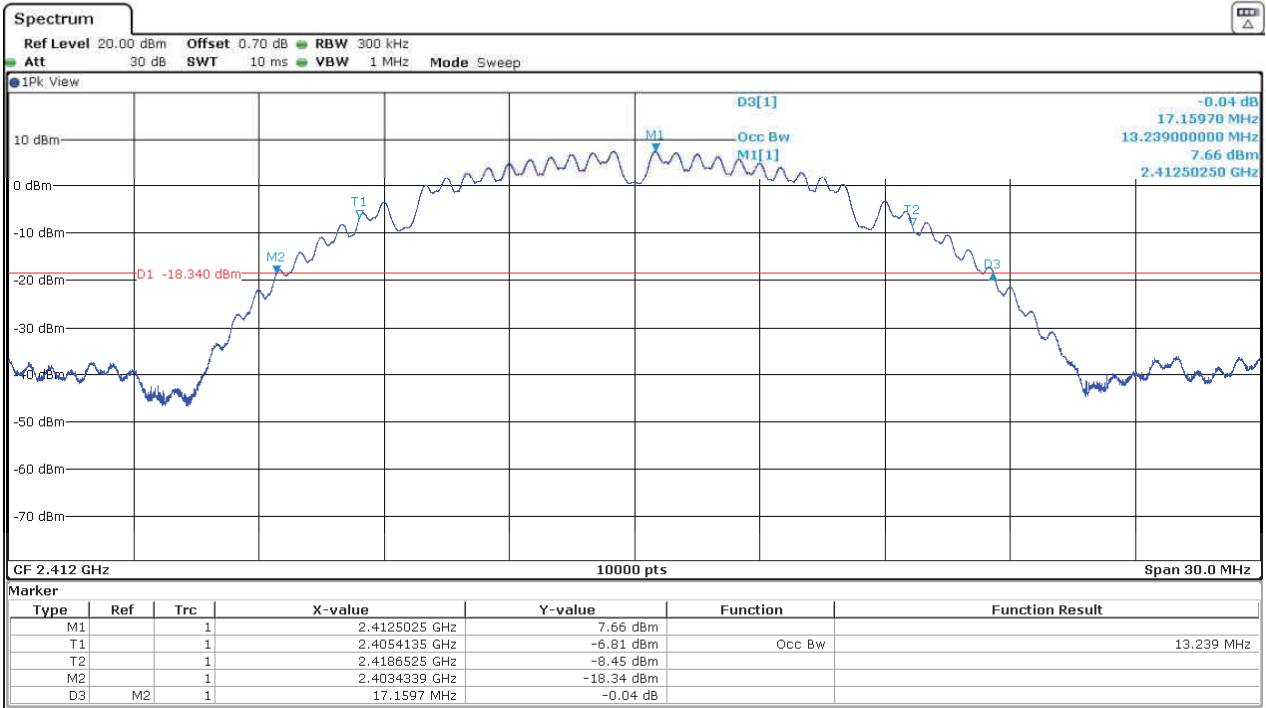
	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
99% bandwidth (MHz)	18.665	18.535	18.655
-26 dBc bandwith (MHz)	25.474	24.218	24.611
Measurement uncertainty (kHz)	<± 5.50		

- **Mode 802.11 n20**

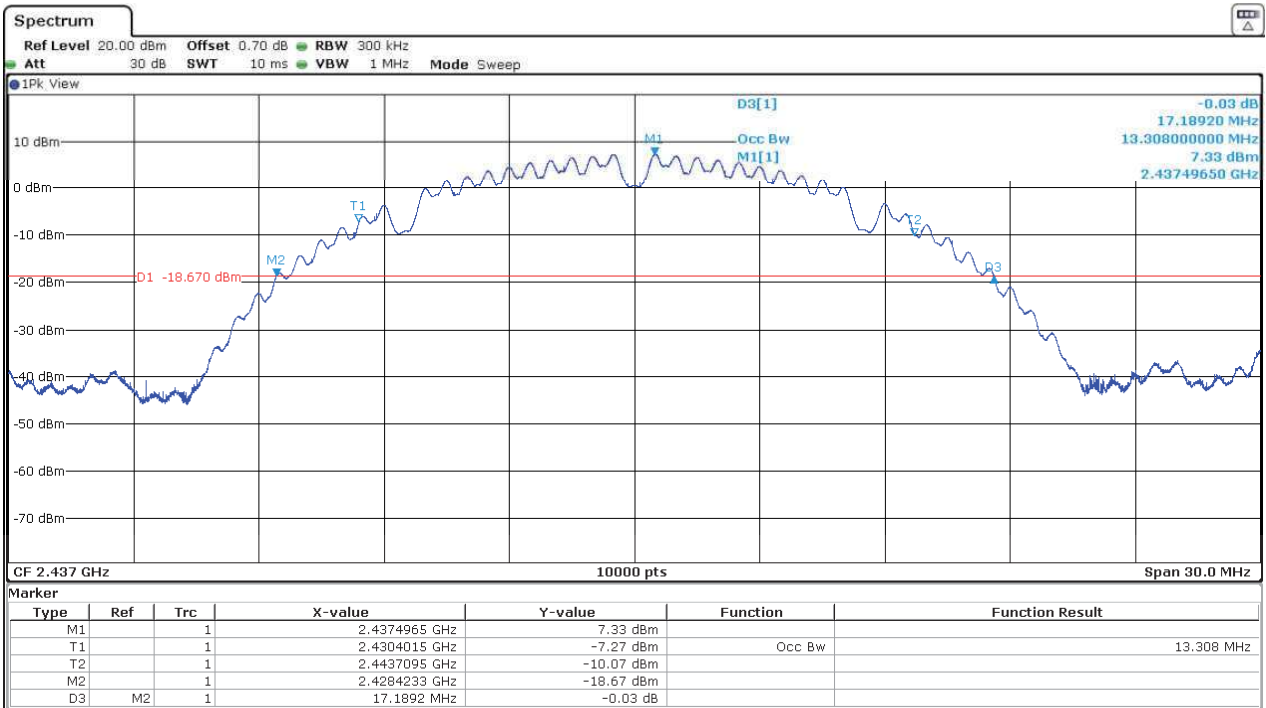
	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
99% bandwidth (MHz)	19.140	18.930	18.985
-26 dBc bandwith (MHz)	24.673	23.166	23.014
Measurement uncertainty (kHz)	<± 5.50		

- **Mode 802.11 b – Occupied Bandwidth**

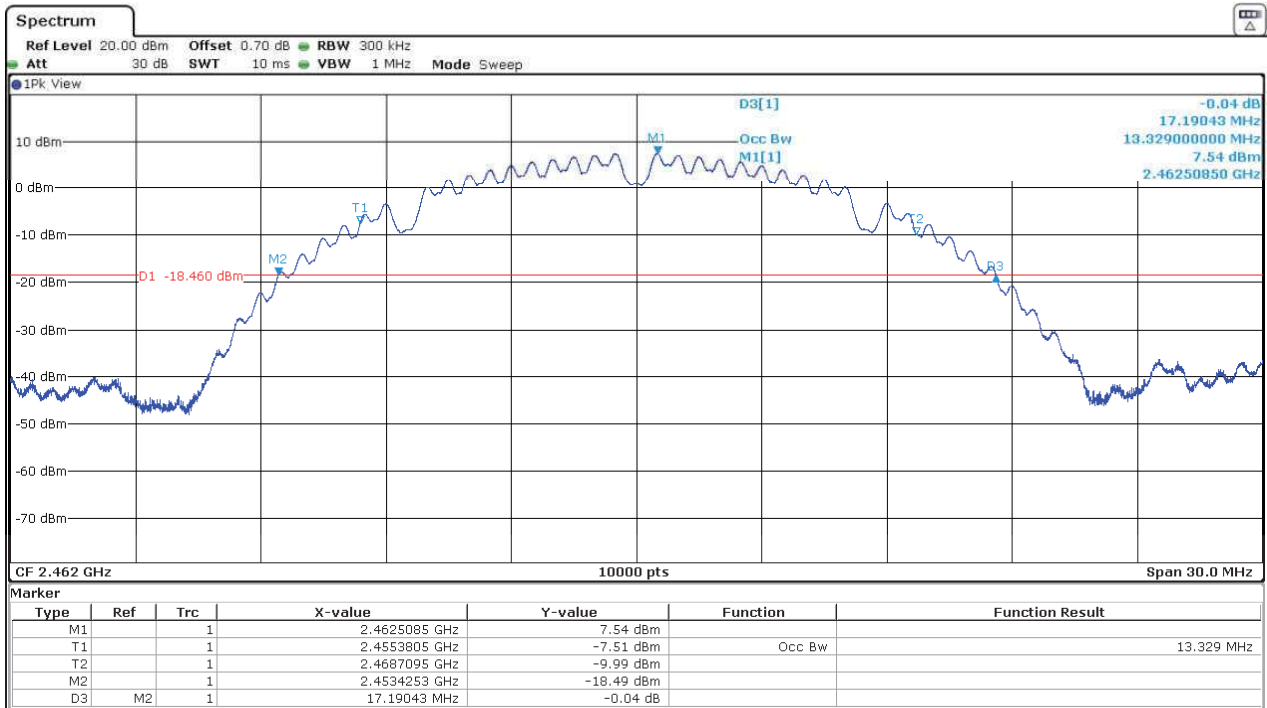
- Low Channel:



- Middle Channel:

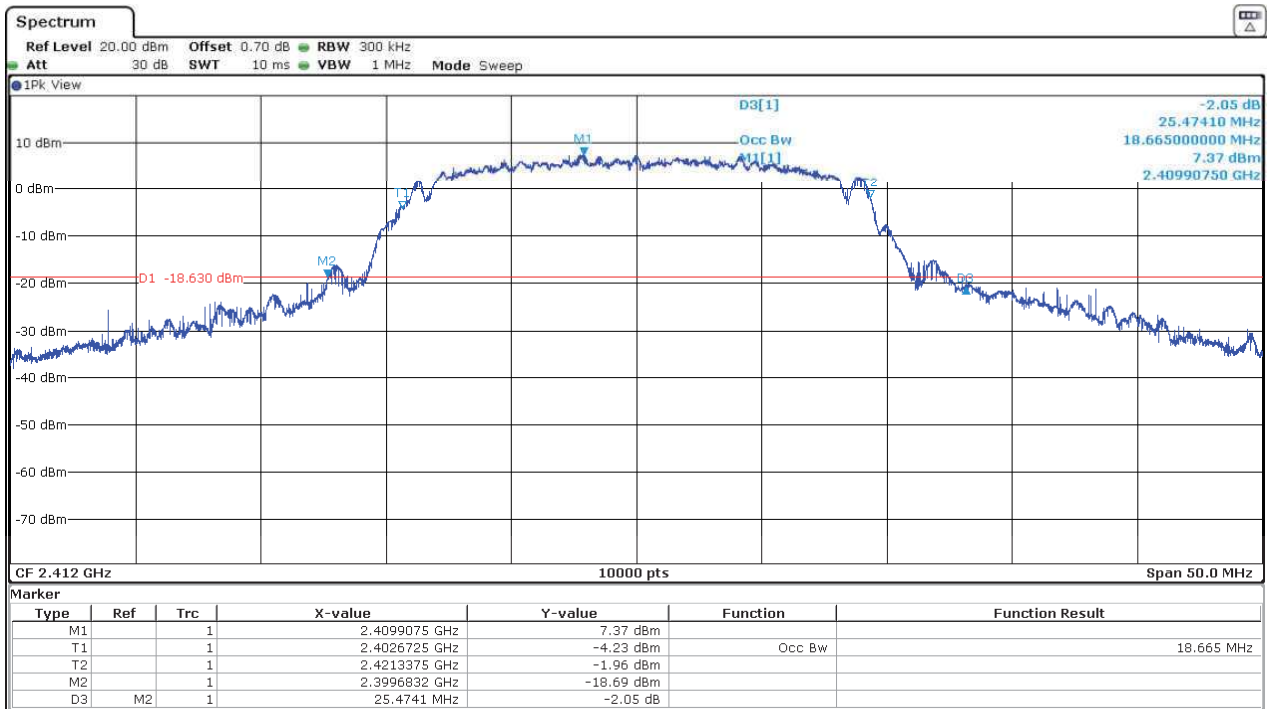


- High Channel:

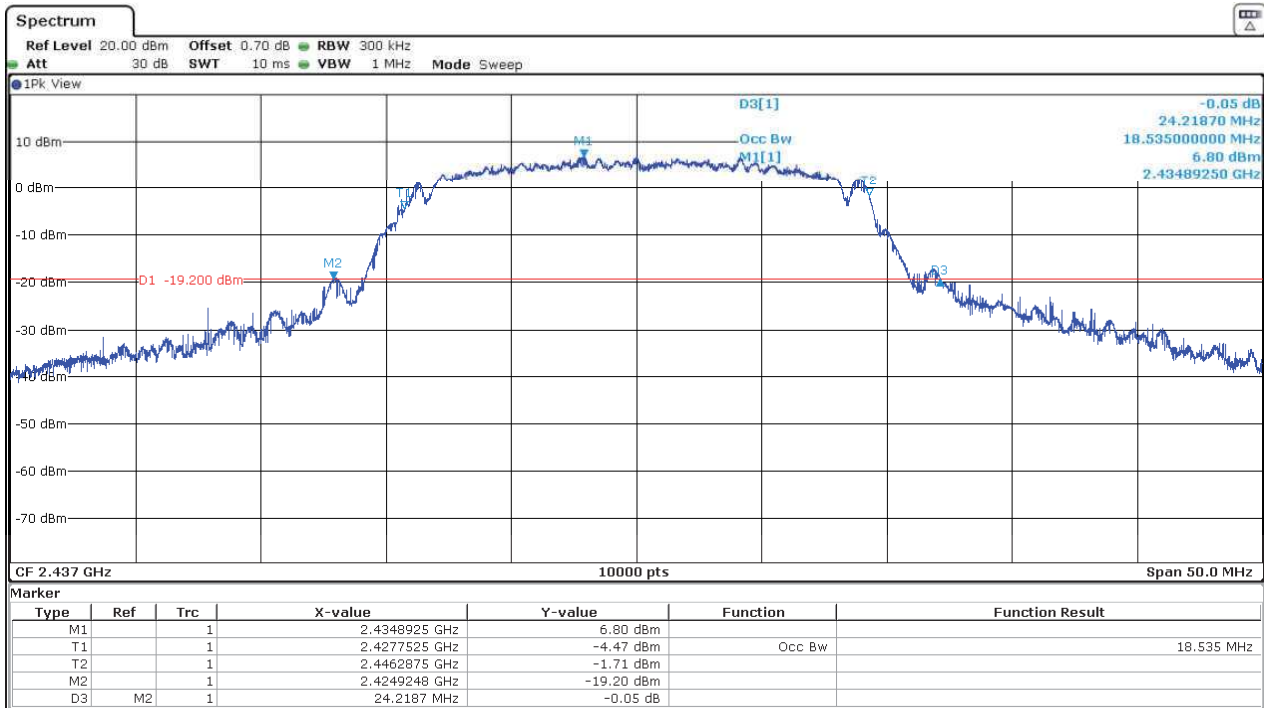


- Mode 802.11 g – Occupied Bandwidth

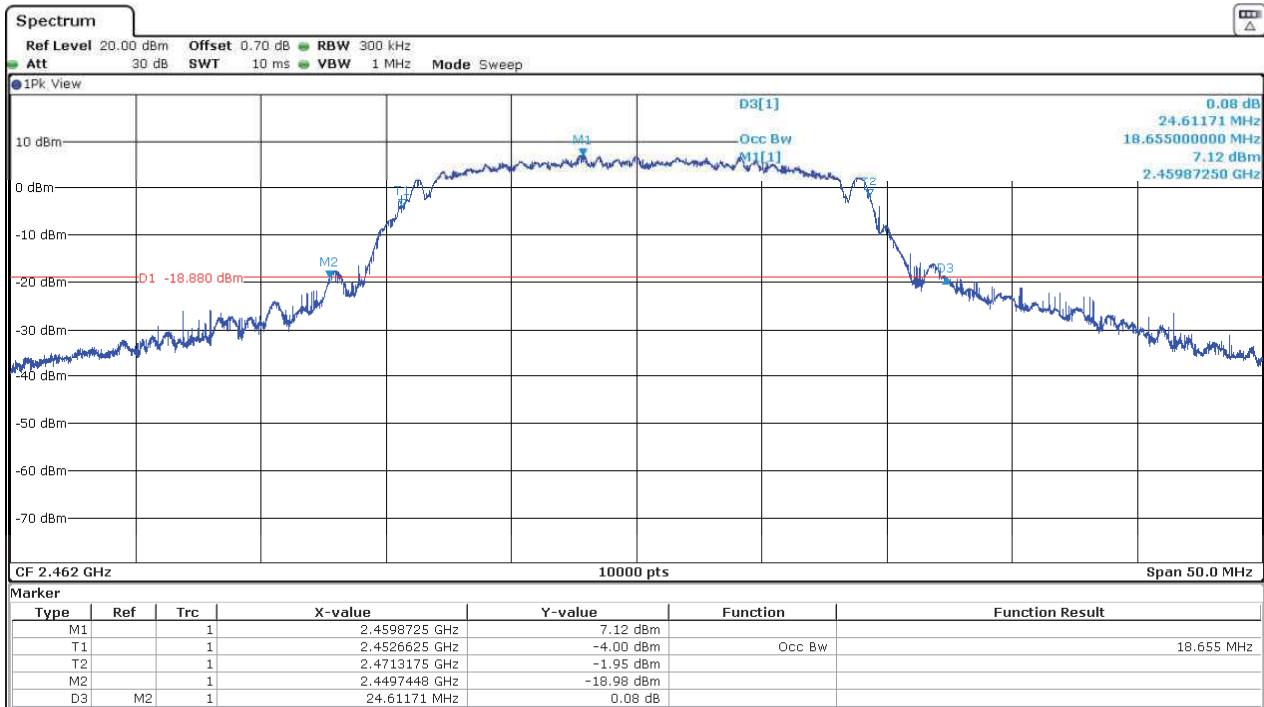
- Low Channel:



- Middle Channel:

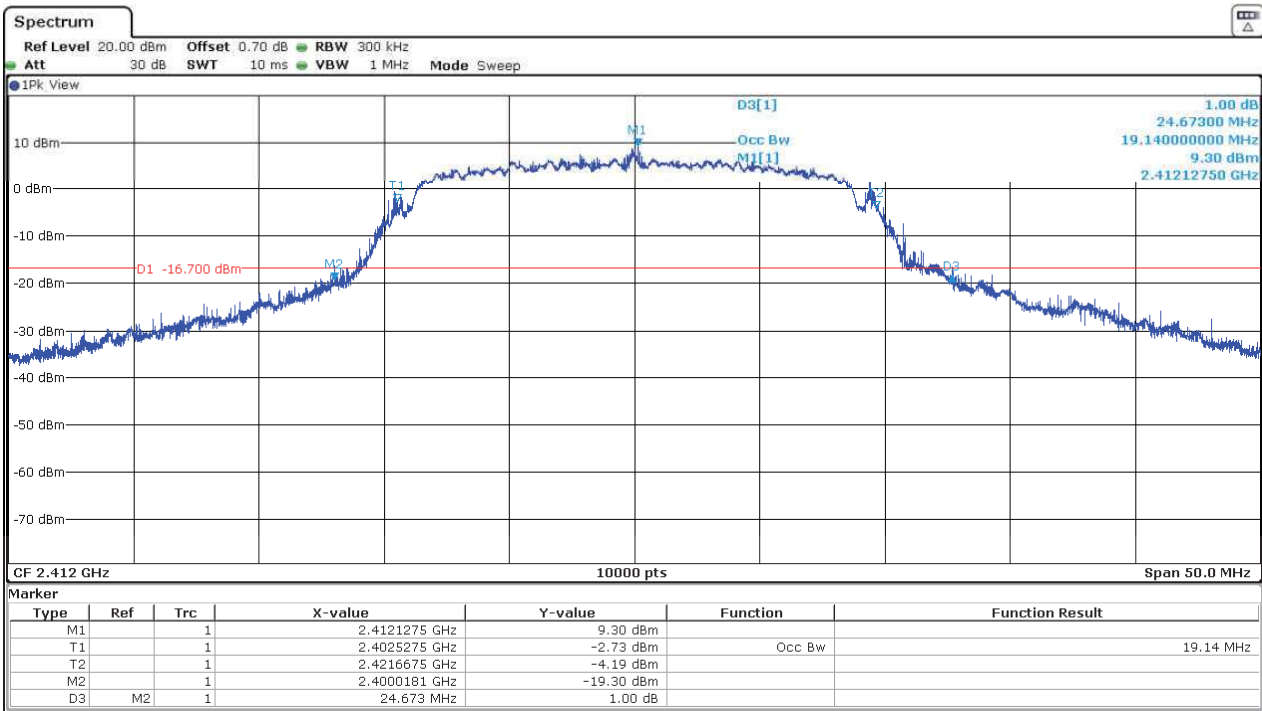


- High Channel:

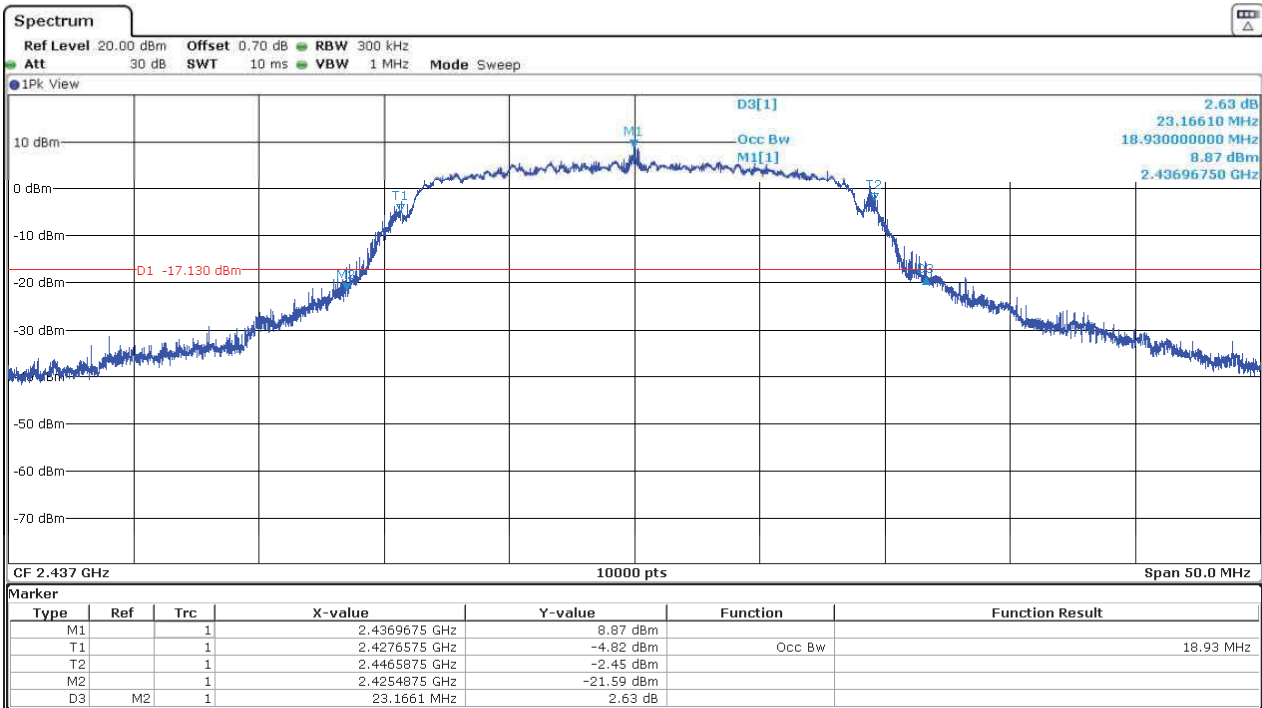


- **Mode 802.11 n20 – Occupied Bandwidth**

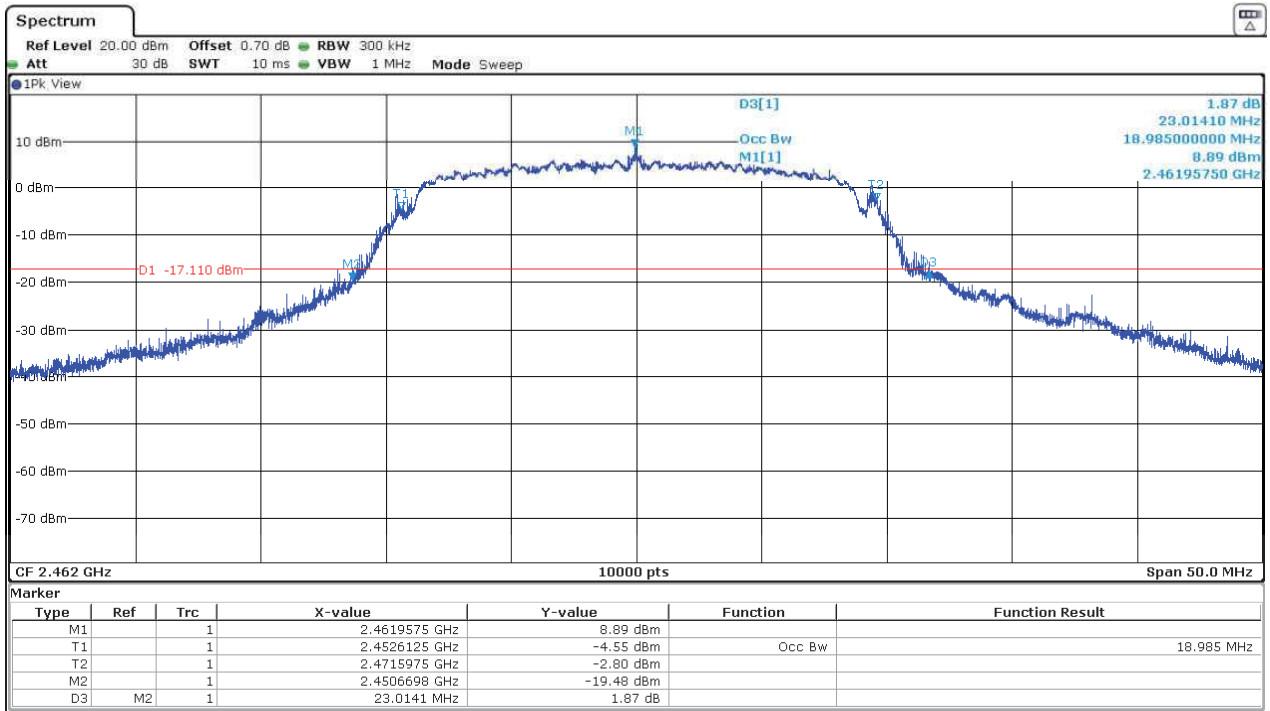
- Low Channel:



- Middle Channel:



- High Channel:



FCC Section 15.247 Subclause (a) (2) / RSS-247 Clause 5.2 (a) 6 dB Bandwidth.

SPECIFICATION:

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

RESULTS:

- **Mode 802.11 b**

	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
6 dB Spectrum Bandwidth (MHz)	8.081	8.083	8.081
Measurement uncertainty (kHz)	<±3.50		

- **Mode 802.11 g**

	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
6 dB Spectrum Bandwidth (MHz)	15.133	15.123	15.127
Measurement uncertainty (kHz)	<±3.50		

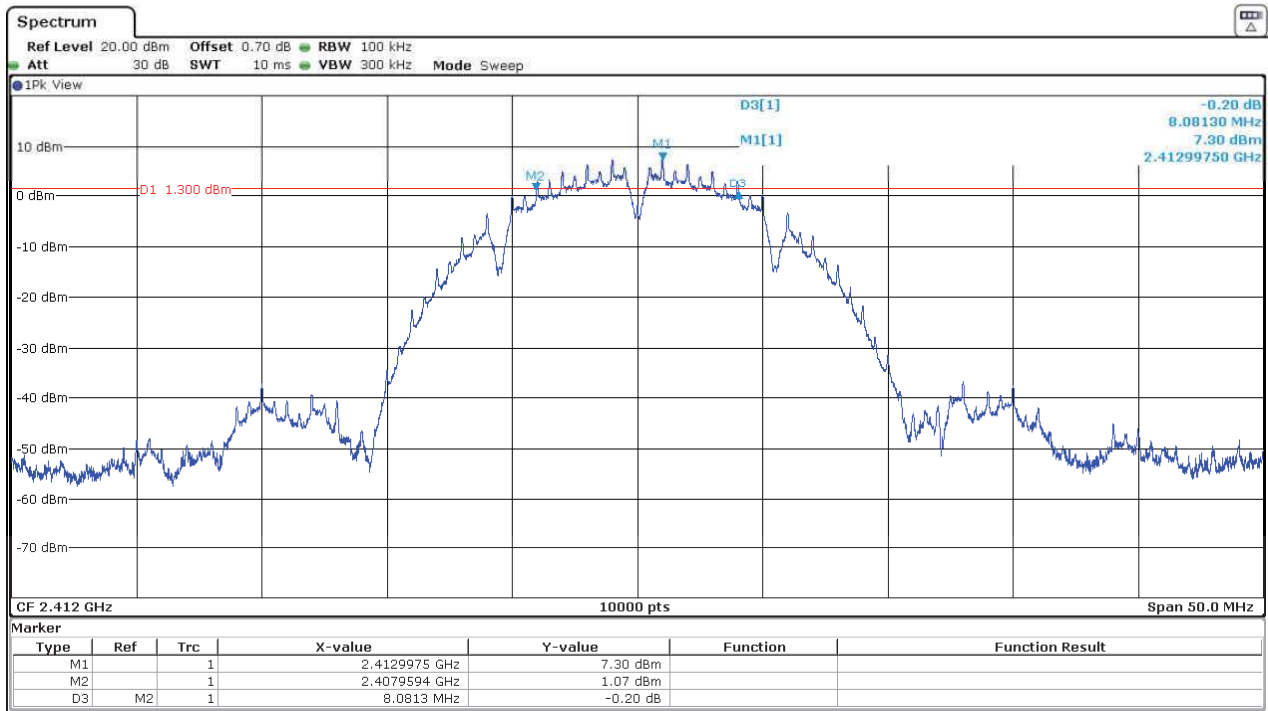
- **Mode 802.11 n20**

	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
6 dB Spectrum Bandwidth (MHz)	15.133	15.131	15.128
Measurement uncertainty (kHz)	<±3.50		

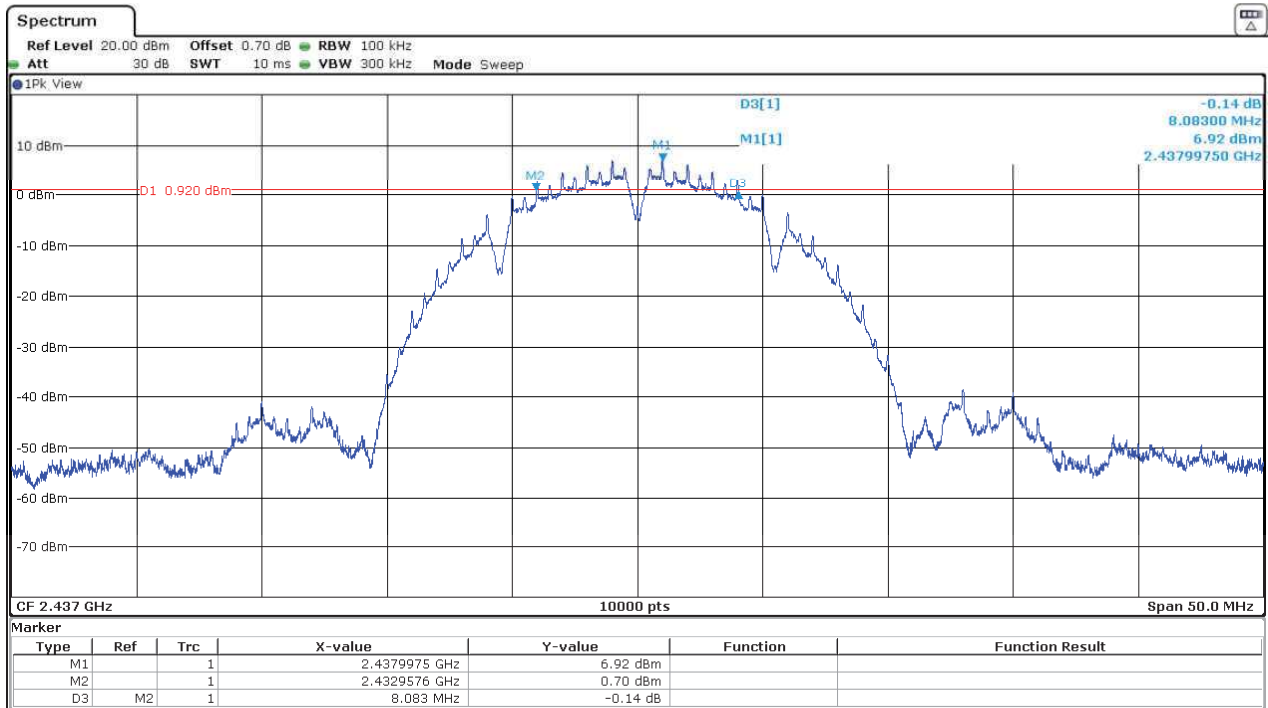
Verdict: PASS

- **Mode 802.11 b – 6 dB Bandwidth**

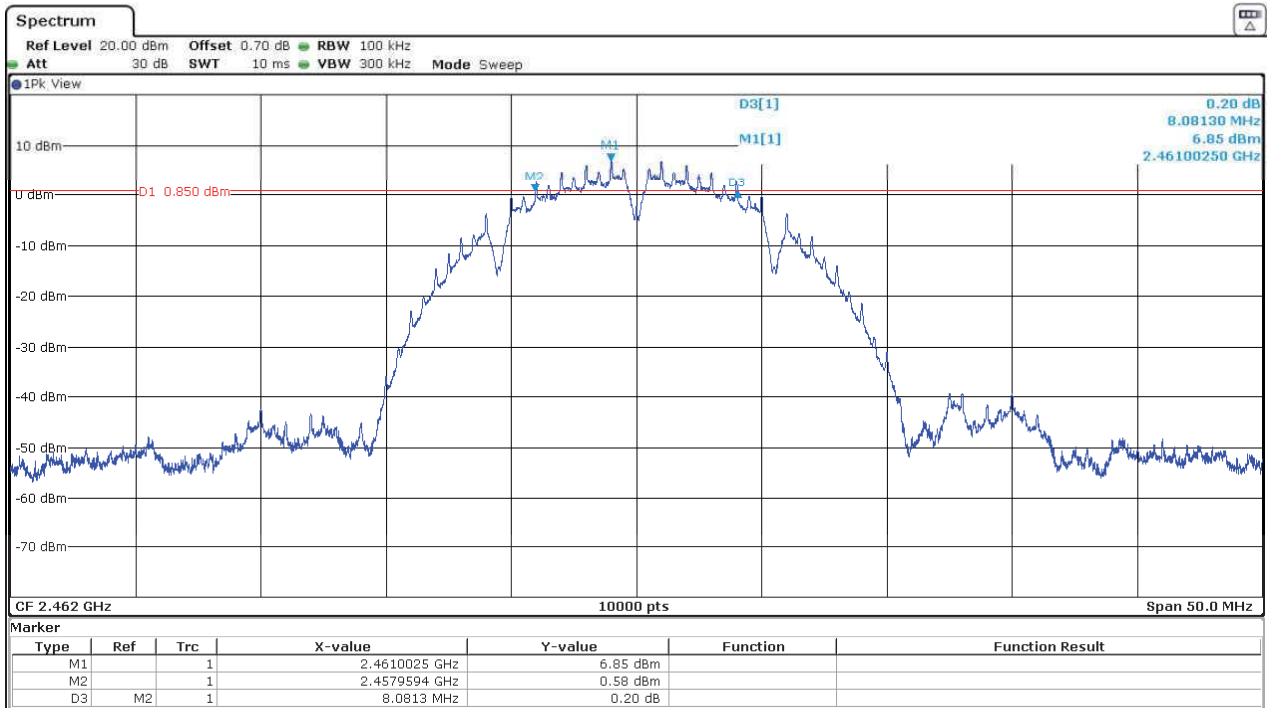
- Low Channel:



- Middle Channel:

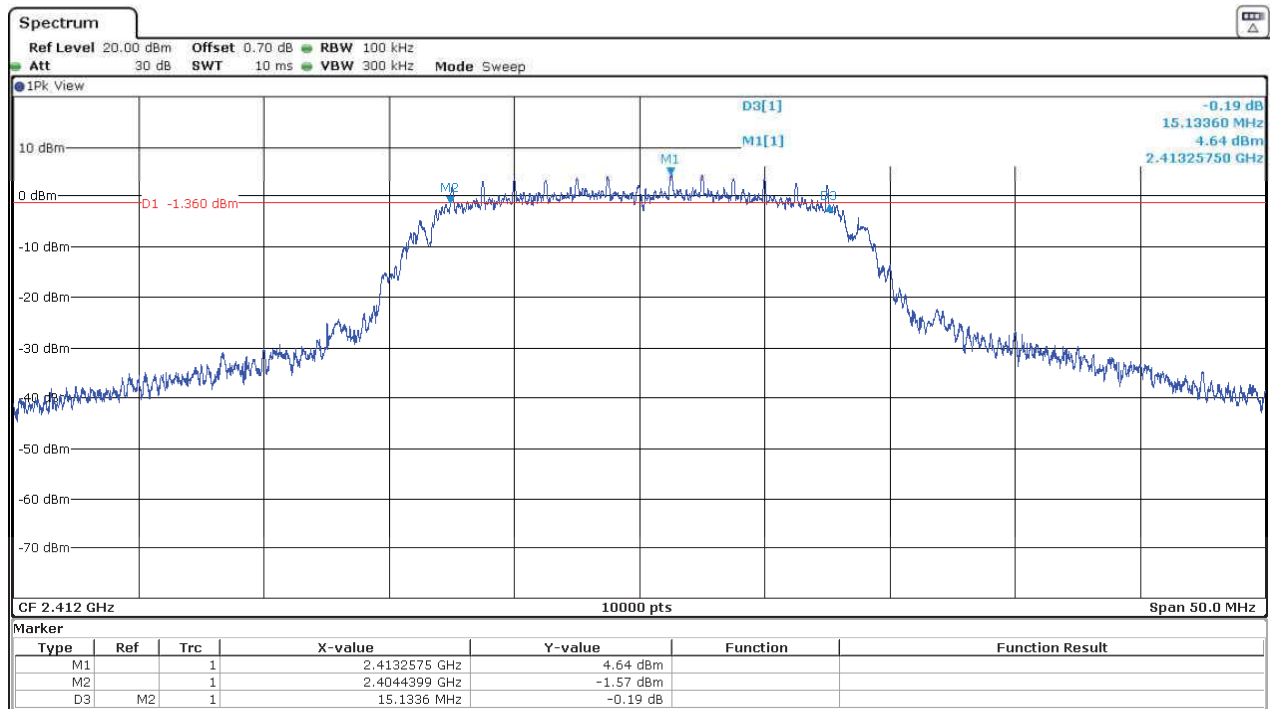


- High Channel:

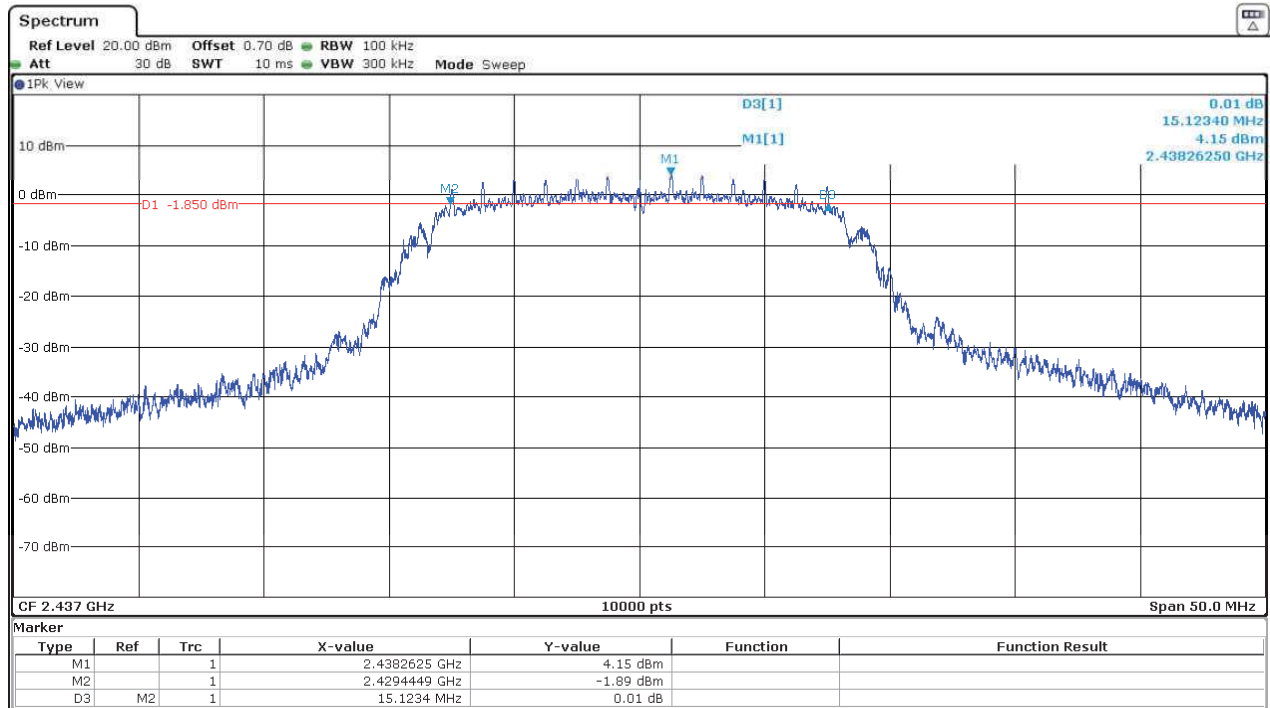


- Mode 802.11 g – 6 dB Bandwidth

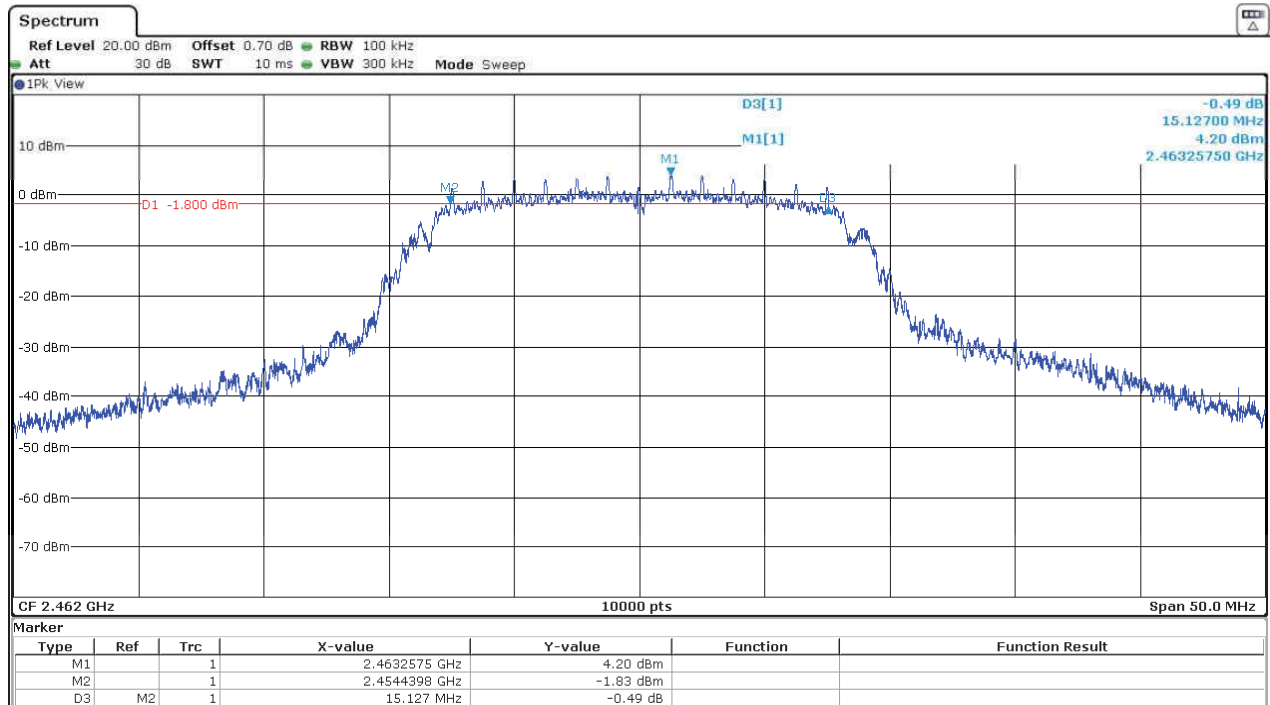
- Low Channel:



- Middle Channel:

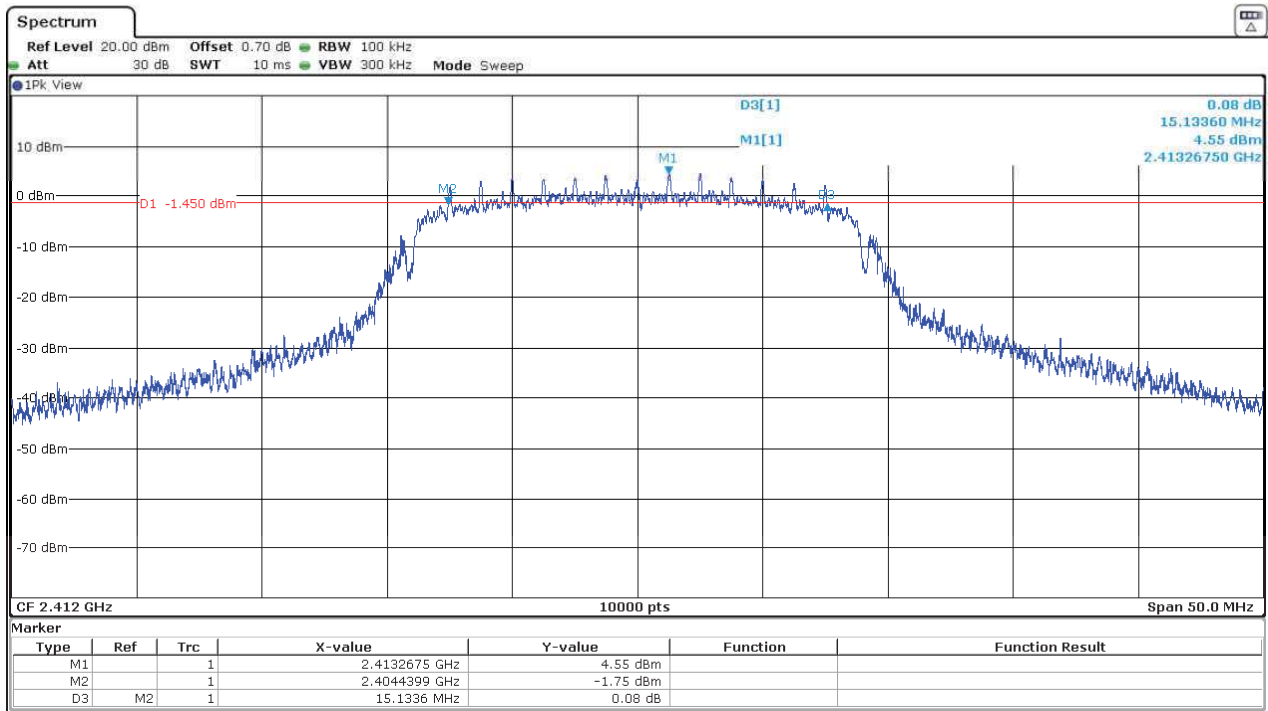


- High Channel:

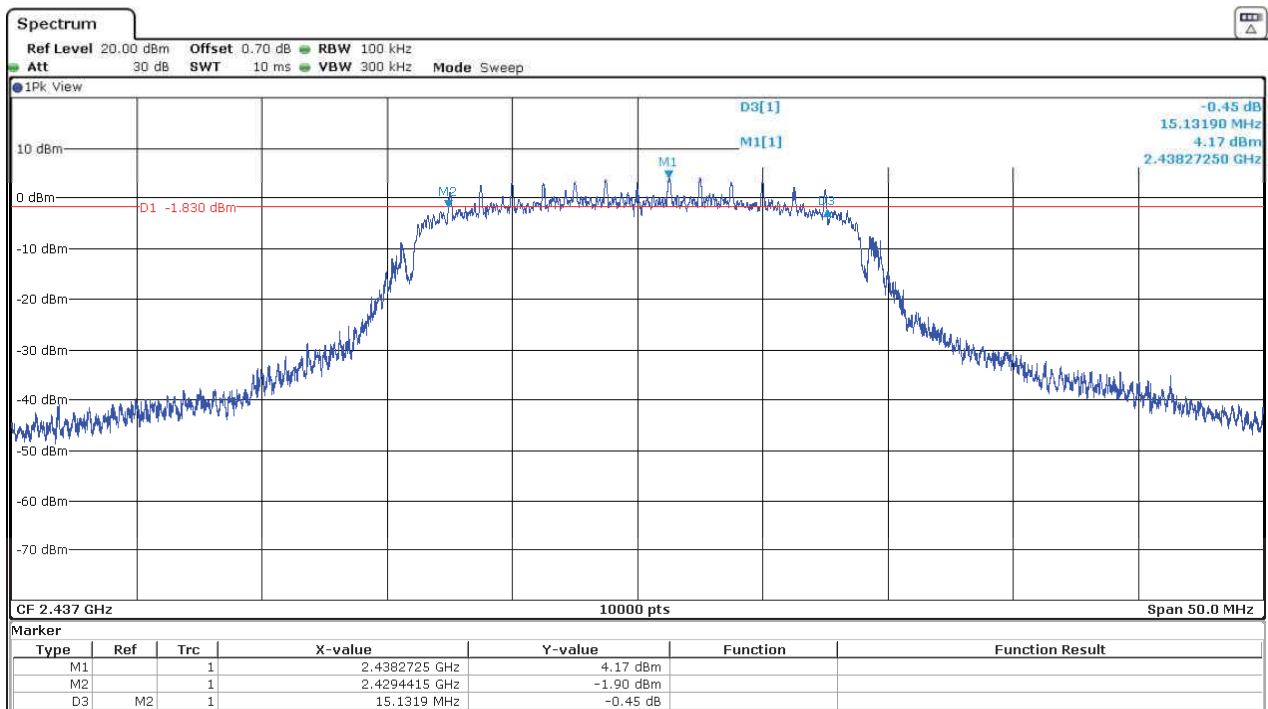


- **Mode 802.11 n20 – 6 dB Bandwidth**

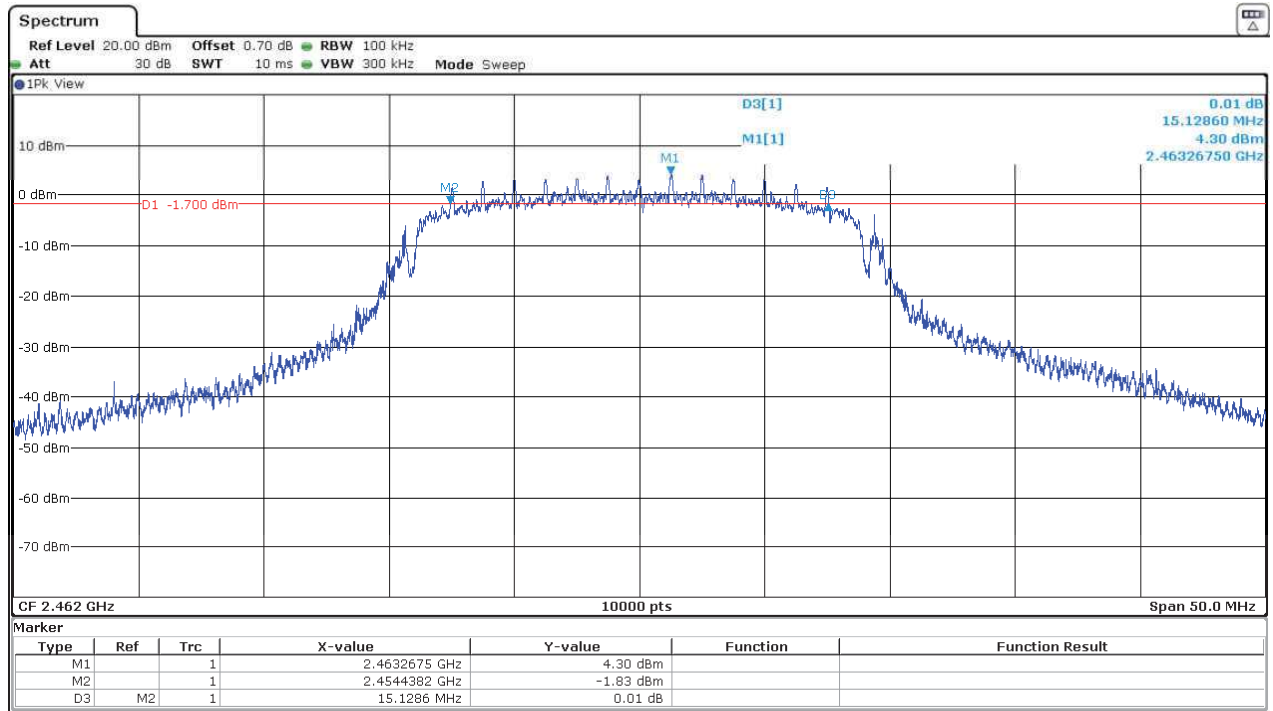
- Low Channel:



- Middle Channel:



- High Channel:



FCC Section 15.247 Subclause (b) / RSS-247 Clause 5.4 (d) Maximum output power and antenna gain

SPECIFICATION:

For systems using digital modulation in the 2400-2483.5 MHz band: 1 watt (30 dBm).
 The e.i.r.p. shall not exceed 4 W (36 dBm) (Canada).

RESULTS:

For b and n20 modes, the maximum conducted output power was measured using the method according to point 11.9.2.2.2 "Method AVGSA-1" of ANSI C.63.10-2013.

For g mode, the maximum conducted output power was measured using the method according to point 11.9.1.3 "Method PKPM1" of ANSI C.63.10-2013.

The EIRP power (dBm) is calculated by adding the declared maximum antenna gain to the measured conducted power.

Maximum Declared Antenna Gain: -0.99 dBi

The maximum directional gain of the antenna is less than 6 dBi and therefore the maximum output power is not required to be reduced from the stated values.

Mode 802.11 b

	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
Maximum Average Conducted Power (dBm)	15.14	14.75	14.52
Maximum EIRP Power (dBm)	14.15	13.76	13.53
Measurement uncertainty (dB)	<±0.33		

Mode 802.11 g

	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
Maximum Peak Conducted Power (dBm)	21.83	21.81	21.90
Maximum EIRP Power (dBm)	20.84	20.82	20.91
Measurement uncertainty (dB)	<±0.33		

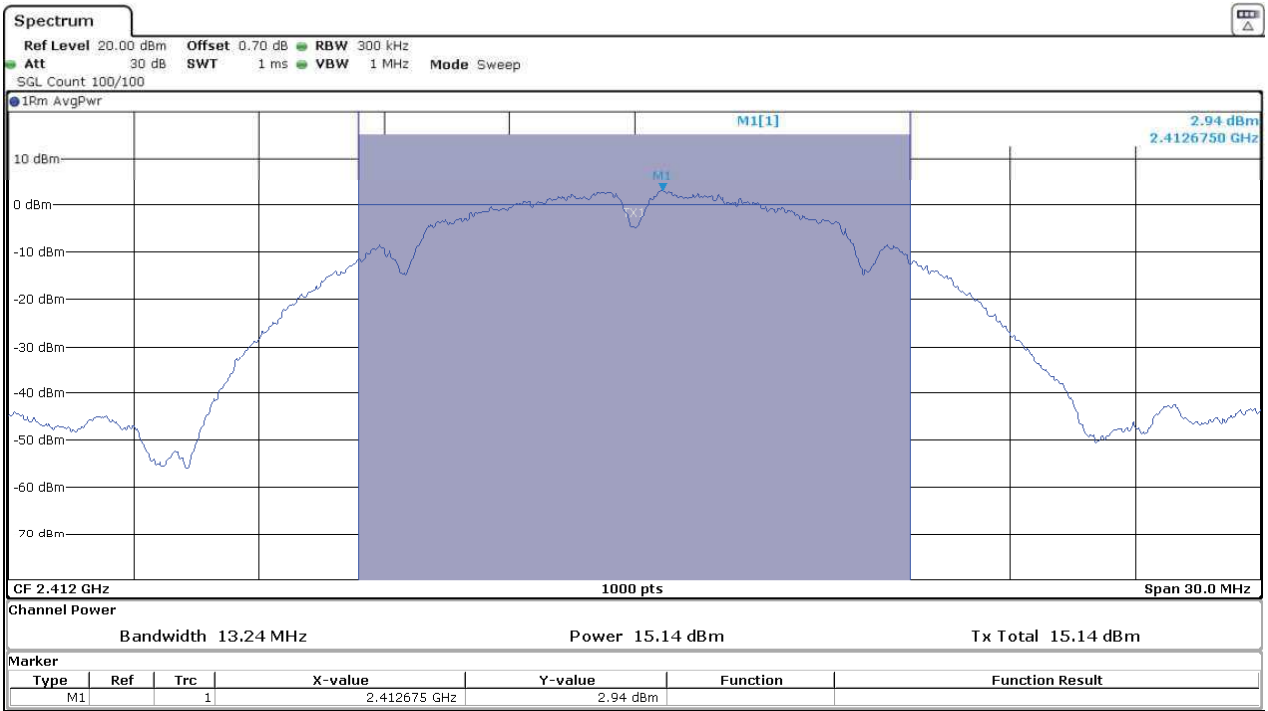
Mode 802.11 n20

	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
Maximum Average Conducted Power (dBm)	14.80	14.36	14.35
Maximum EIRP Power (dBm)	13.81	13.37	13.36
Measurement uncertainty (dB)	<±0.33		

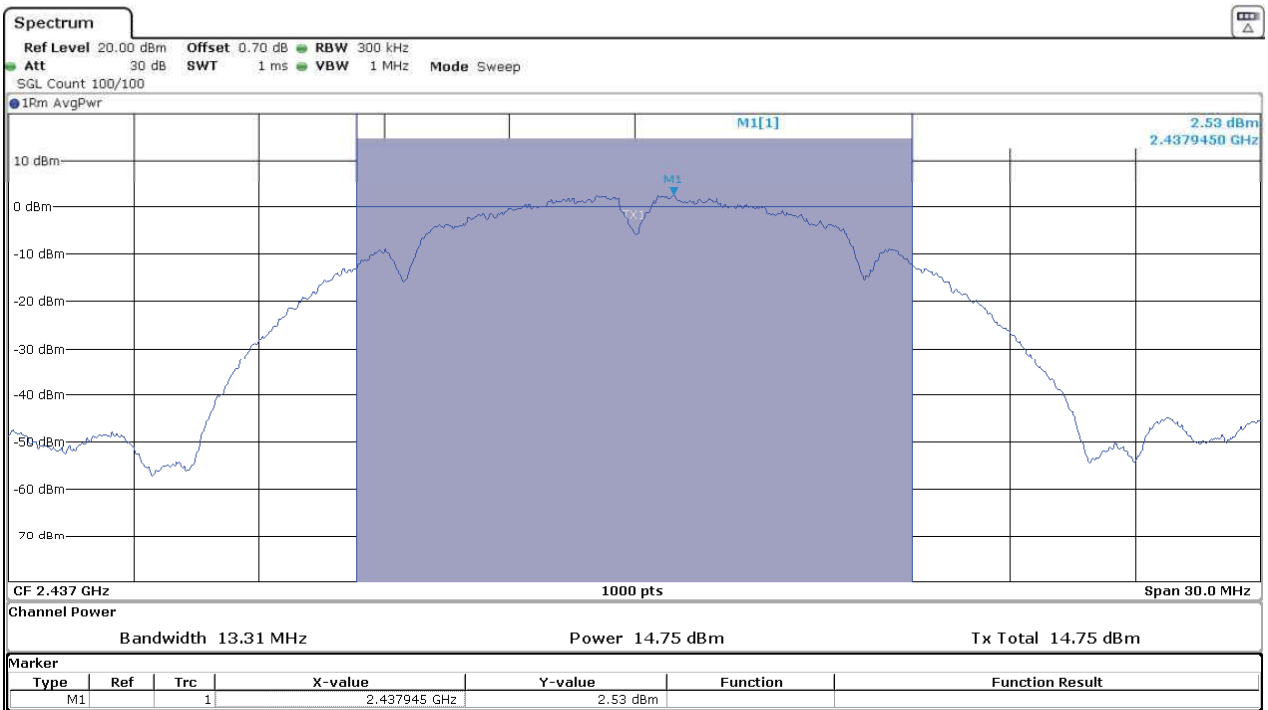
Verdict: PASS

Mode 802.11 b

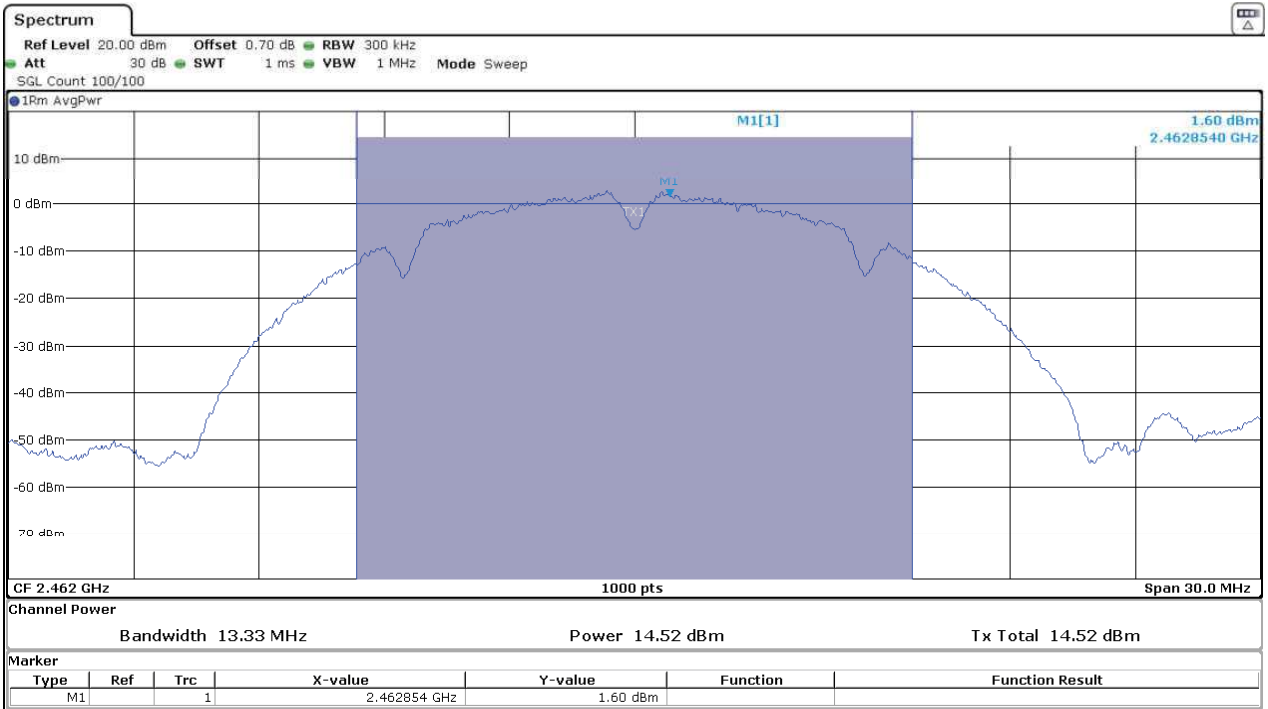
Low Channel:



Middle Channel:

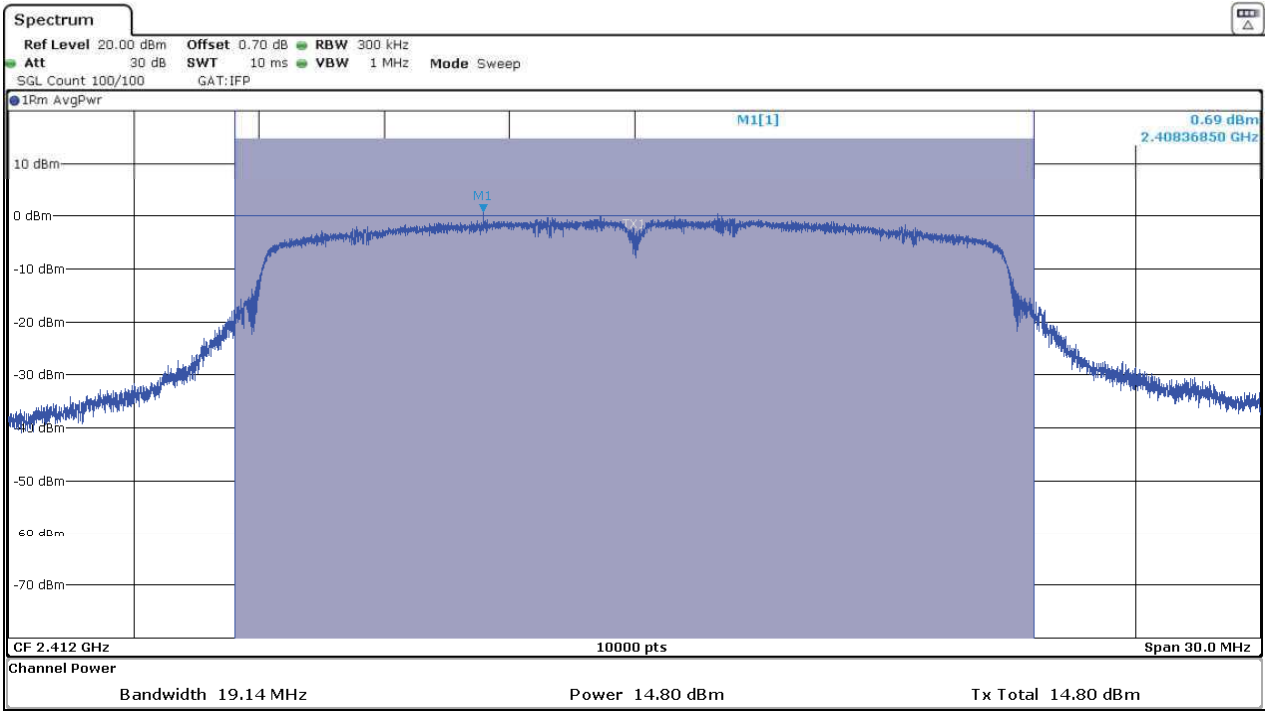


High Channel:

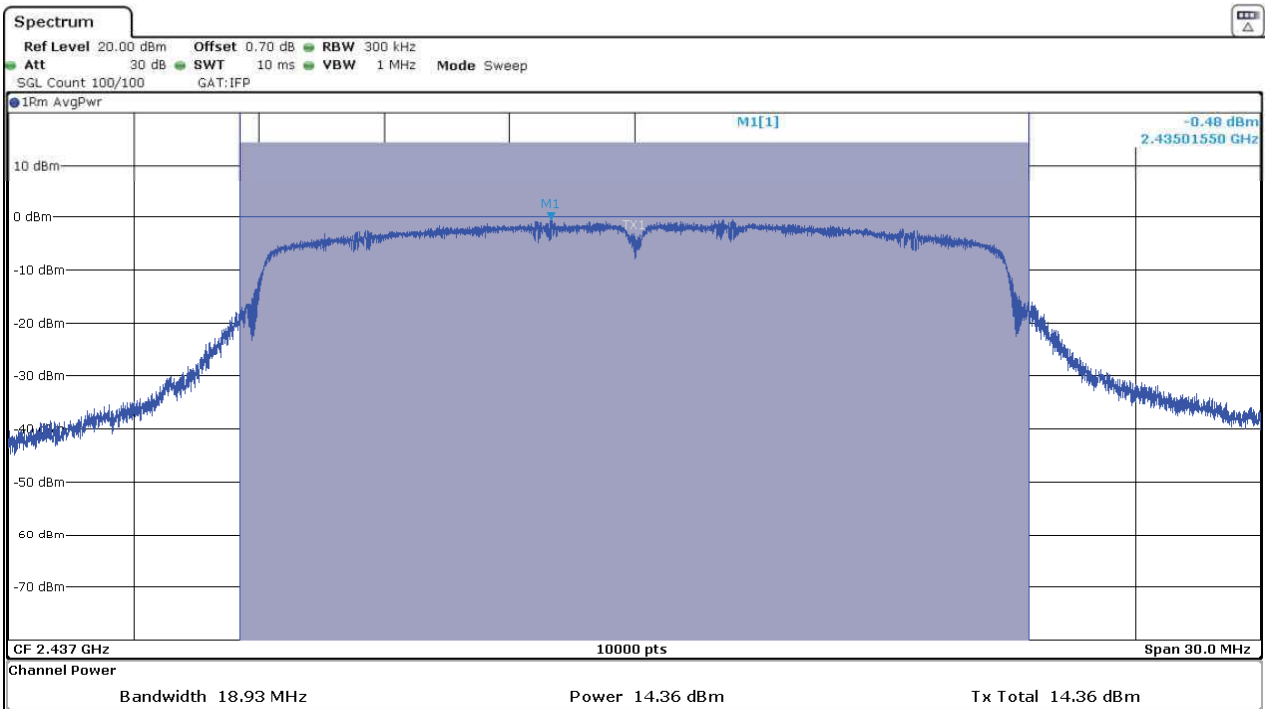


Mode 802.11 n20

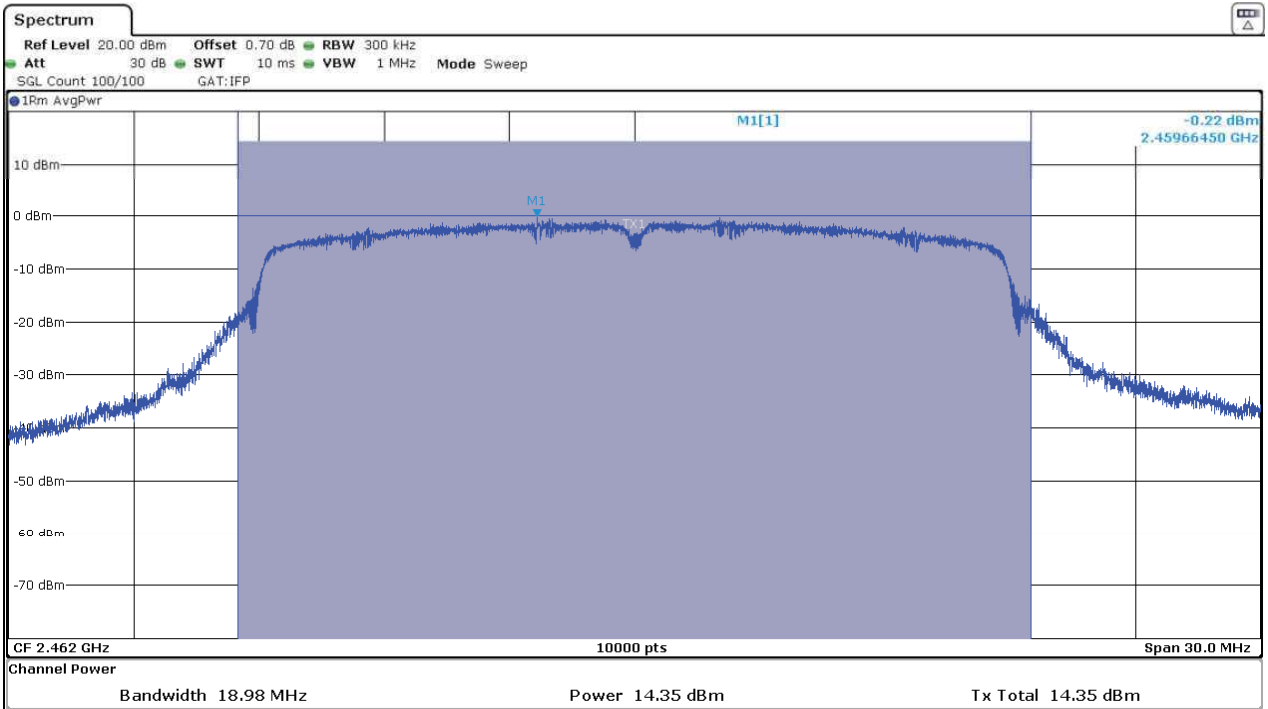
Low Channel:



Middle Channel:



High Channel:



FCC Section 15.247 Subclause (d) / RSS-247 Clause 5.5. Emission limitations conducted (Transmitter)

SPECIFICATION:

In any 100 kHz bandwidths outside the frequency band in which the intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at less 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, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.

RESULTS:

- **Mode 802.11 b**

	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
Reference Level Measurement (dBm)	7.02	6.61	6.49
Measurement uncertainty (dB)	<±1.56		

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

- **Mode 802.11 g**

	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
Reference Level Measurement (dBm)	4.11	3.66	3.69
Measurement uncertainty (dB)	<±1.56		

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

- **Mode 802.11 n20**

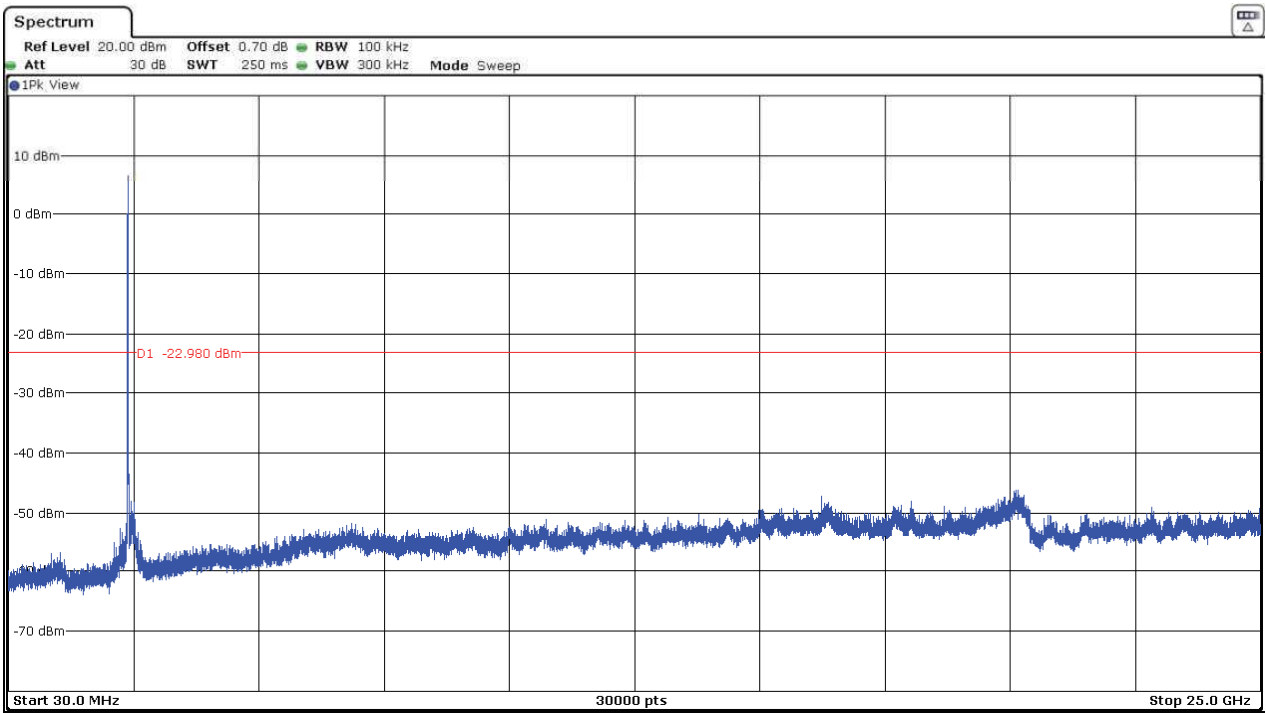
	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
Reference Level Measurement (dBm)	4.33	3.75	3.72
Measurement uncertainty (dB)	<±1.56		

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

Verdict: PASS

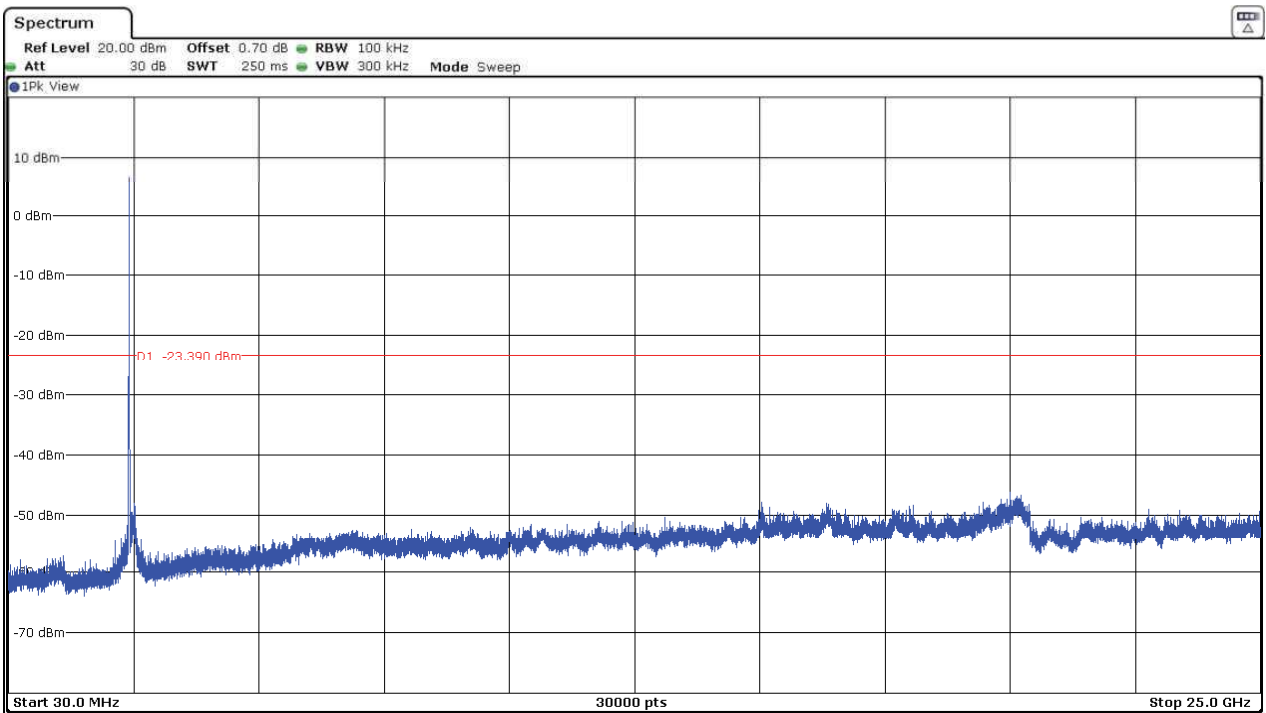
- **Mode 802.11 b – Emission limitations conducted**

- Low Channel:



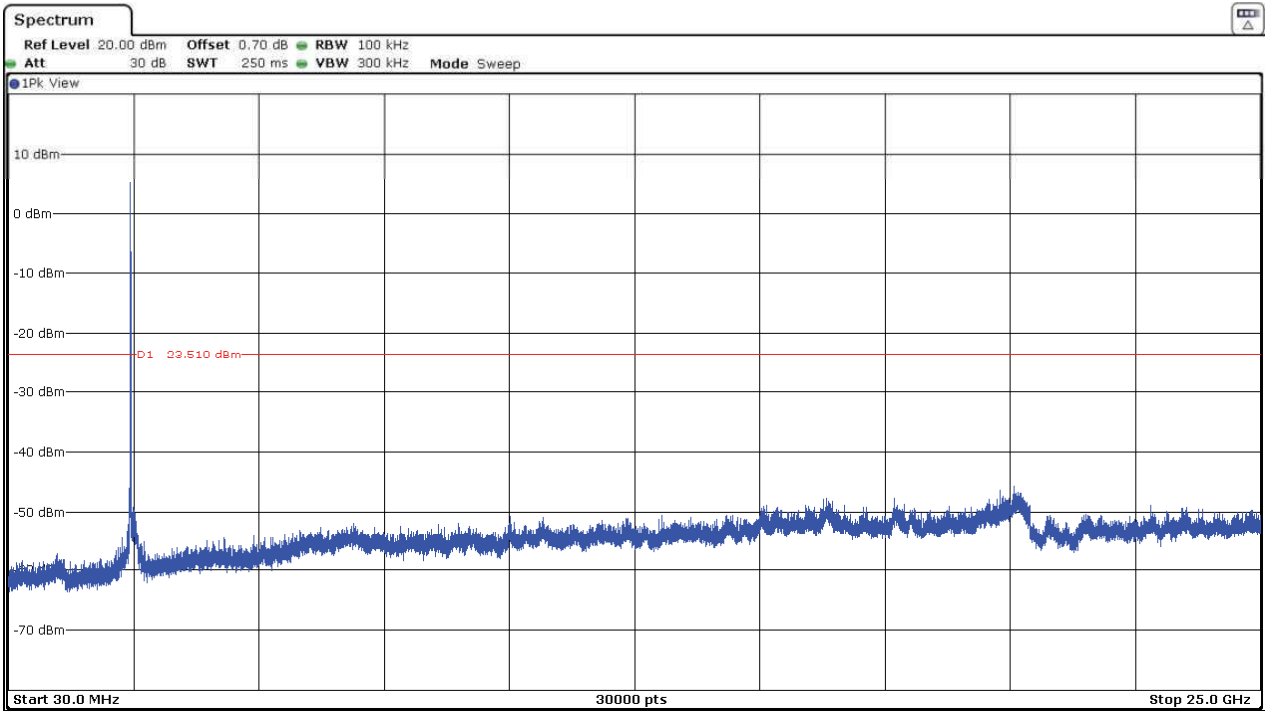
The peak shown in the plot above the limit is the carrier frequency.

- Middle Channel:



The peak shown in the plot above the limit is the carrier frequency.

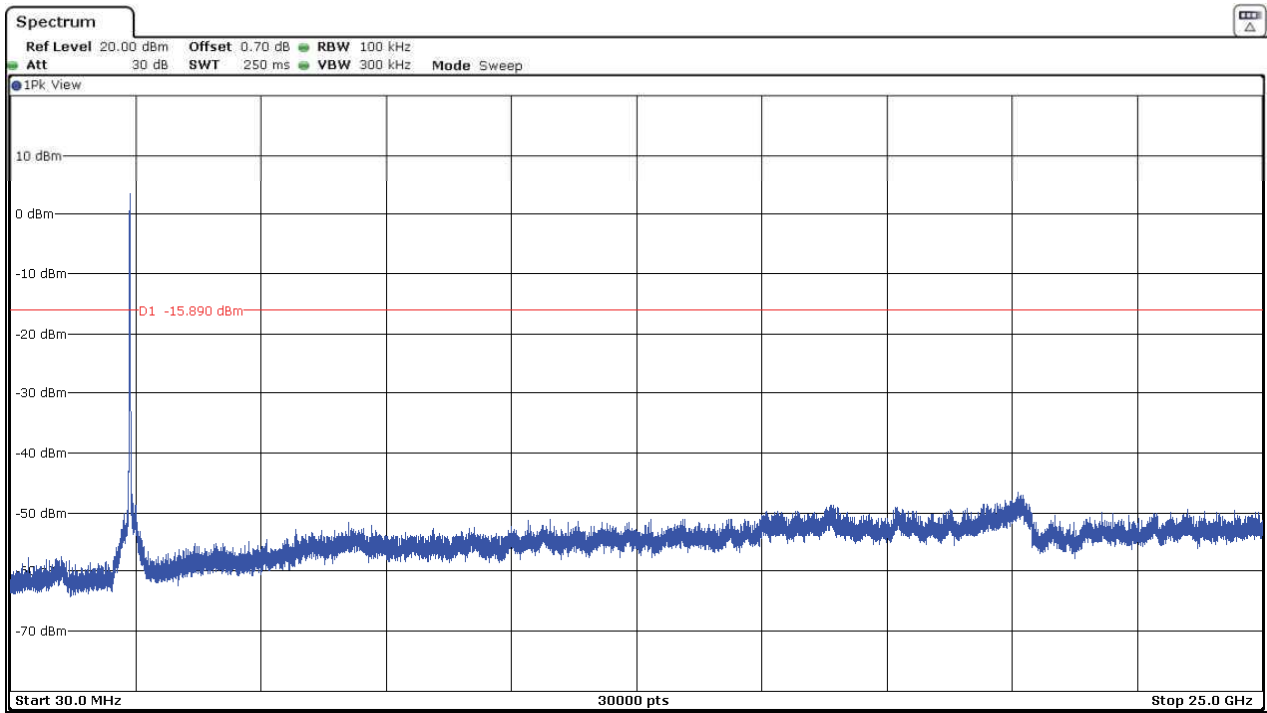
- High Channel:



The peak shown in the plot above the limit is the carrier frequency.

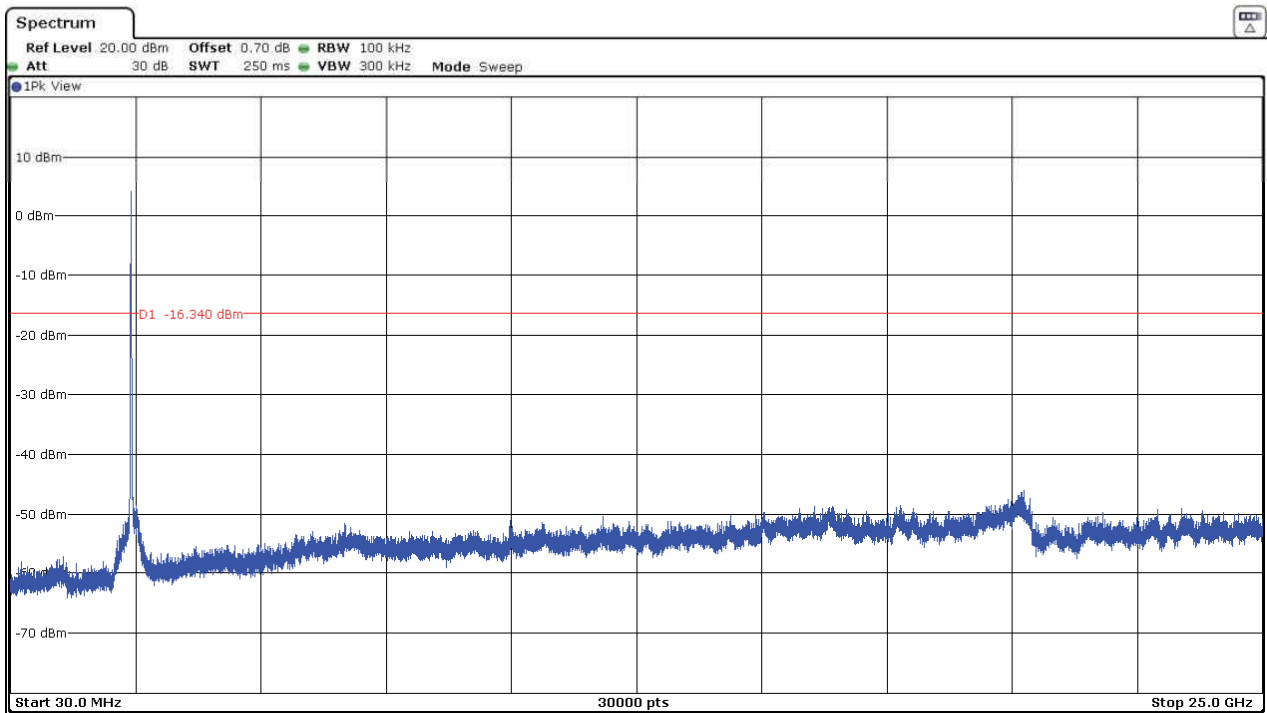
- **Mode 802.11 g – Emission limitations conducted**

- Low Channel:



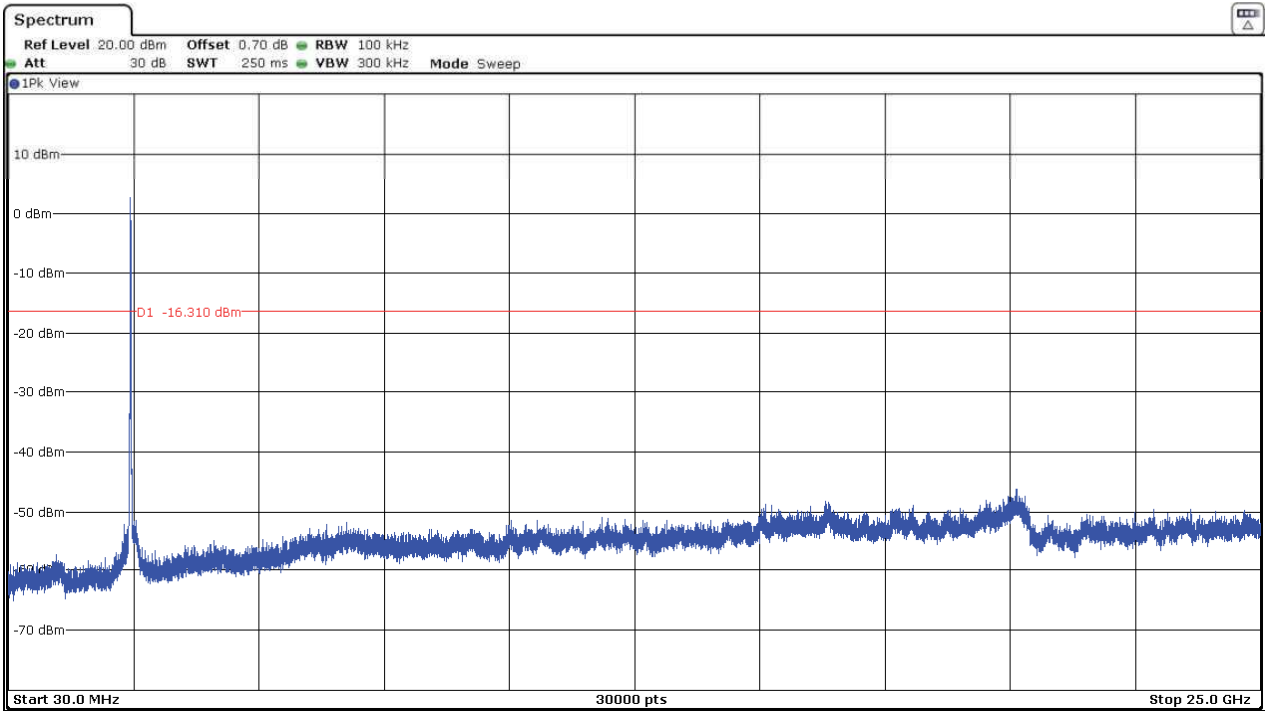
The peak shown in the plot above the limit is the carrier frequency.

- Middle Channel:



The peak shown in the plot above the limit is the carrier frequency.

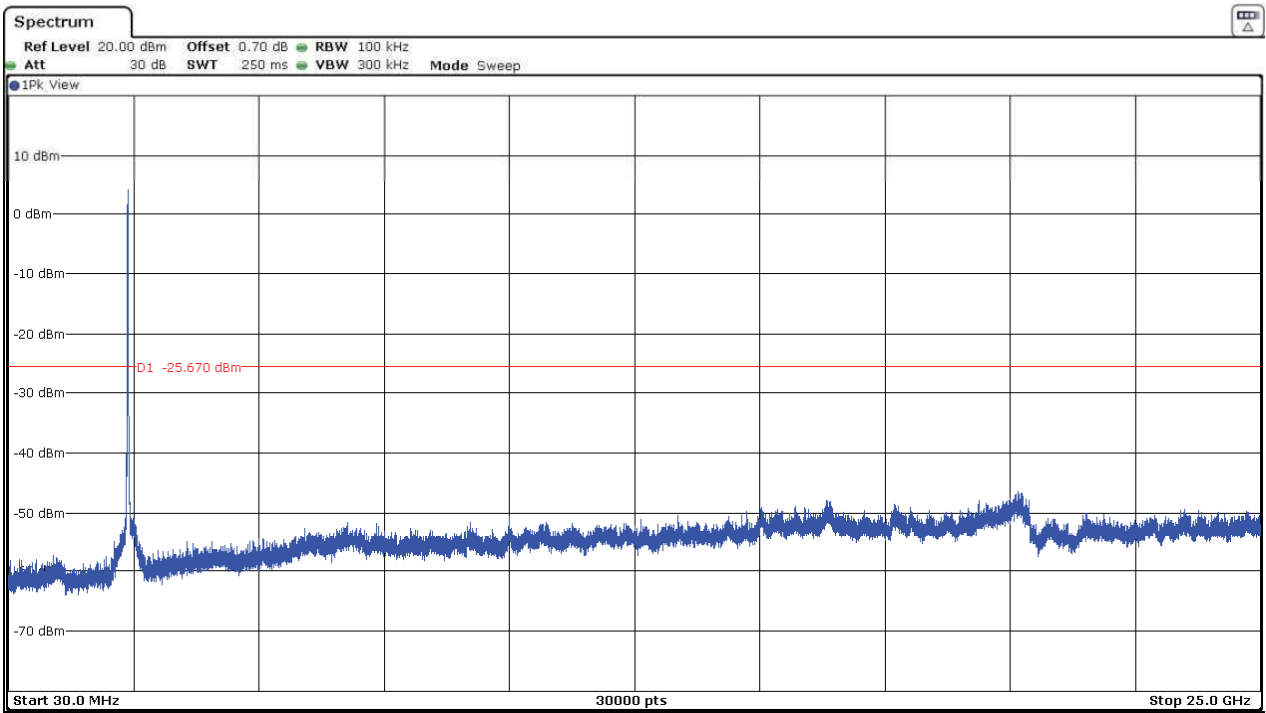
- High Channel:



The peak shown in the plot above the limit is the carrier frequency.

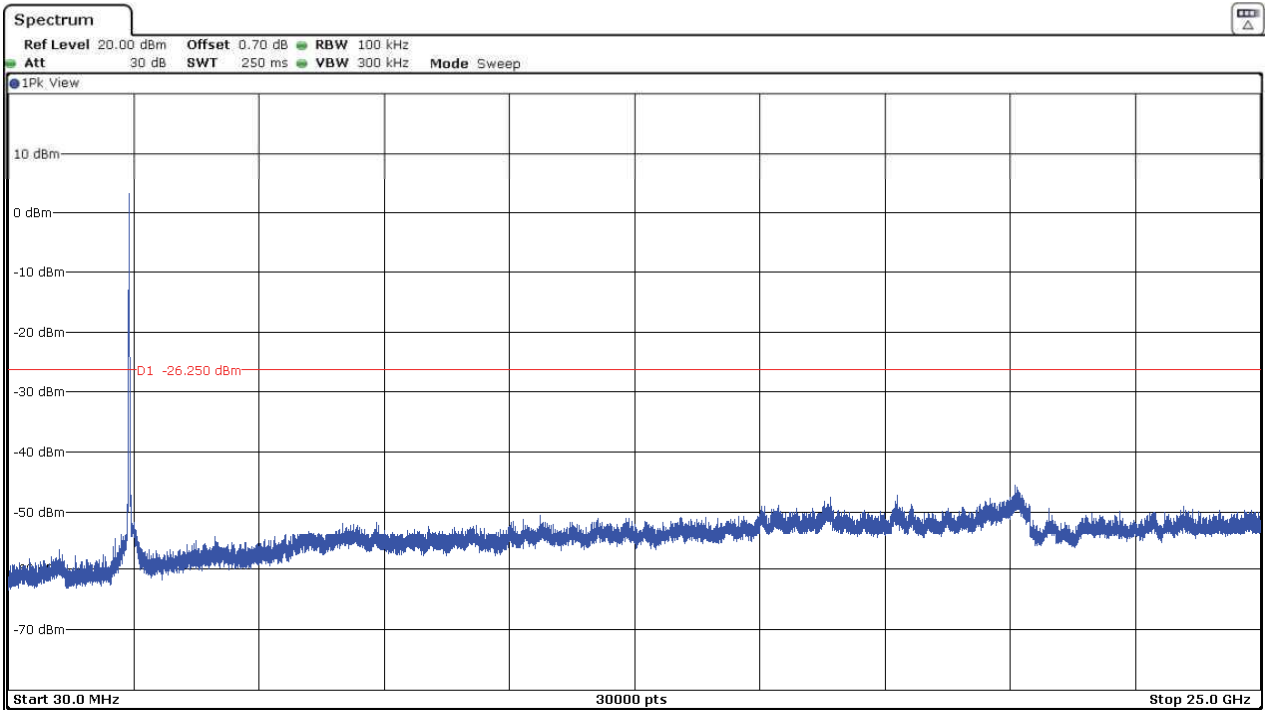
- **Mode 802.11 n20 – Emission limitations conducted**

- Low Channel:



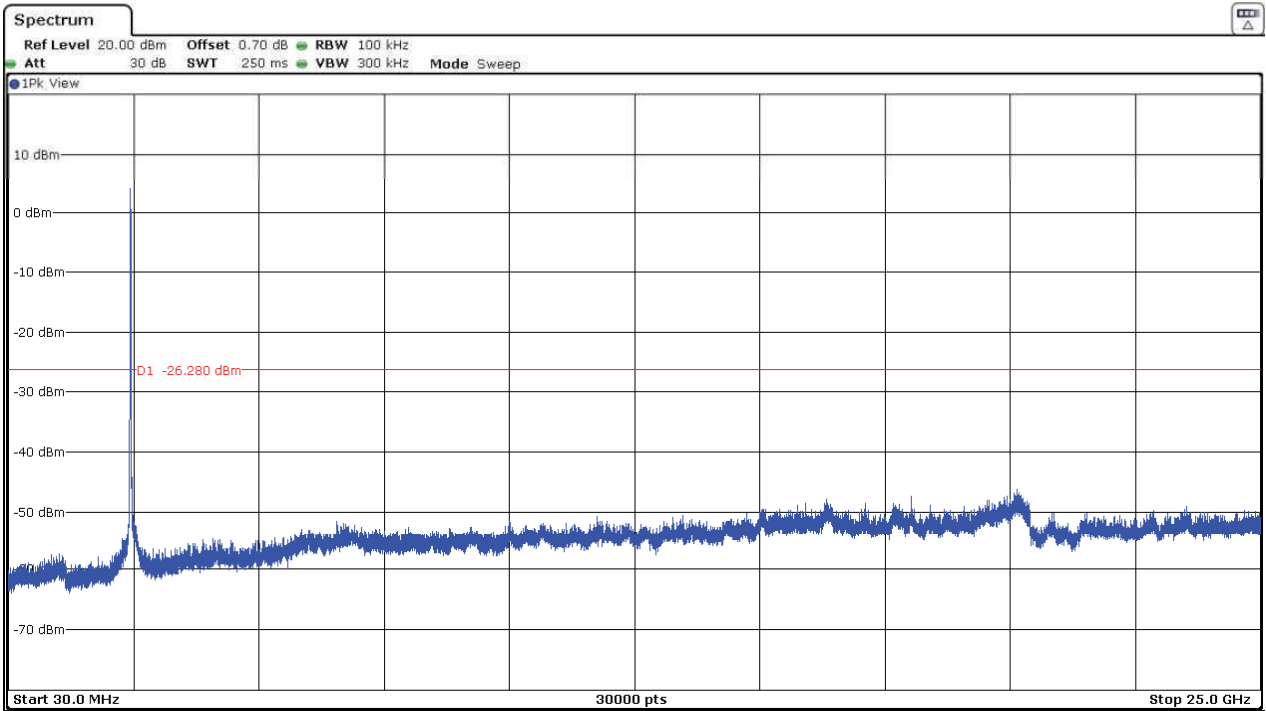
The peak shown in the plot above the limit is the carrier frequency.

- Middle Channel:



The peak shown in the plot above the limit is the carrier frequency.

- High Channel:



The peak shown in the plot above the limit is the carrier frequency.

FCC Section 15.247 Subclause (d) / RSS-247 Clause 5.5. Band-edge emissions compliance (Transmitter)

SPECIFICATION:

In any 100 kHz bandwidth outside the frequency band in which the 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. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, the attenuation required shall be 30 dB instead of 20 dB.

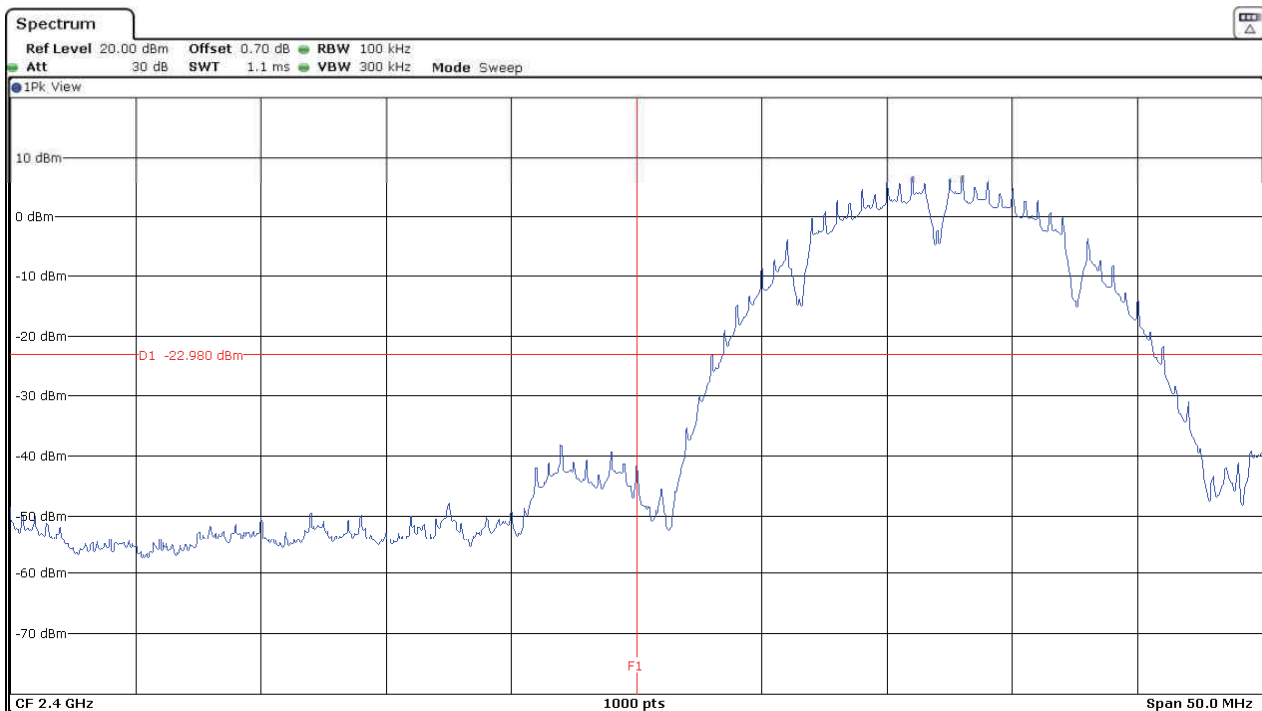
RESULTS:

Radiated measurements were used to show compliance with the limits in the restricted bands 2.31-2.39 GHz and 2.4835-2.5 GHz.

Measurement uncertainty (dB)	<±1.56
------------------------------	--------

- **Mode 802.11 b – Band-edge emissions compliance**

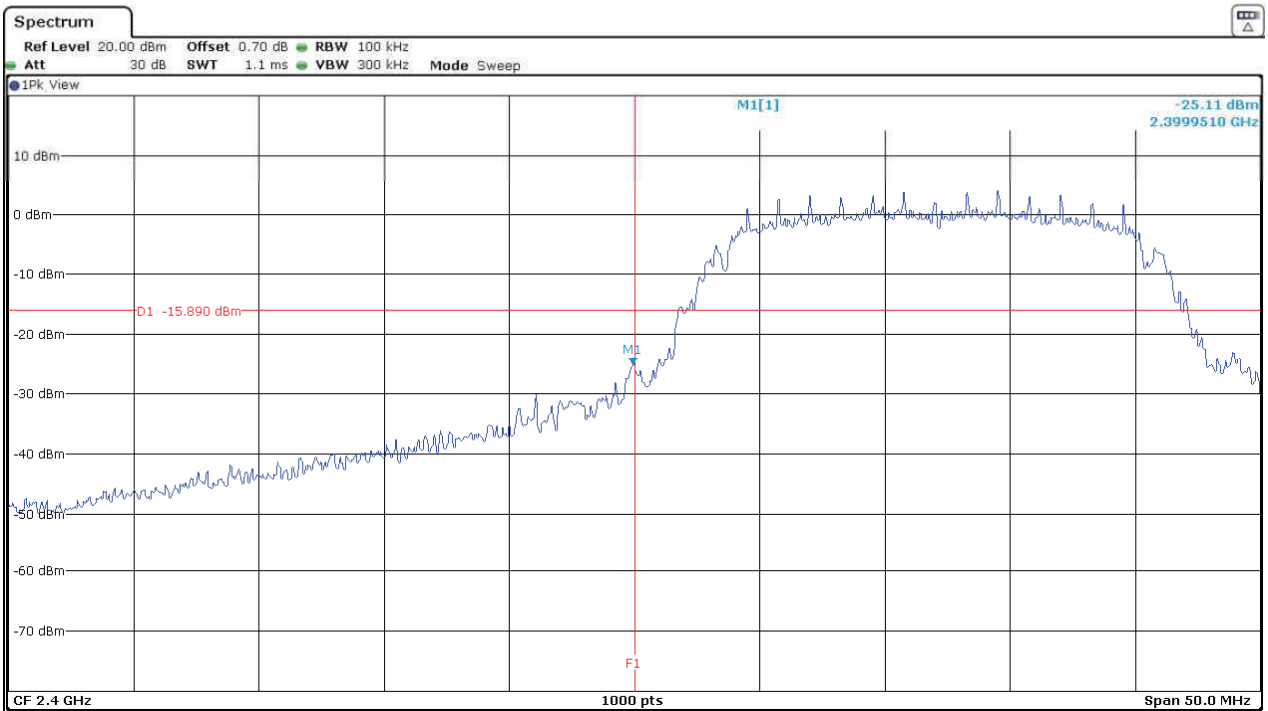
- Low Channel:



Verdict: PASS

- **Mode 802.11 g – Band-edge emissions compliance**

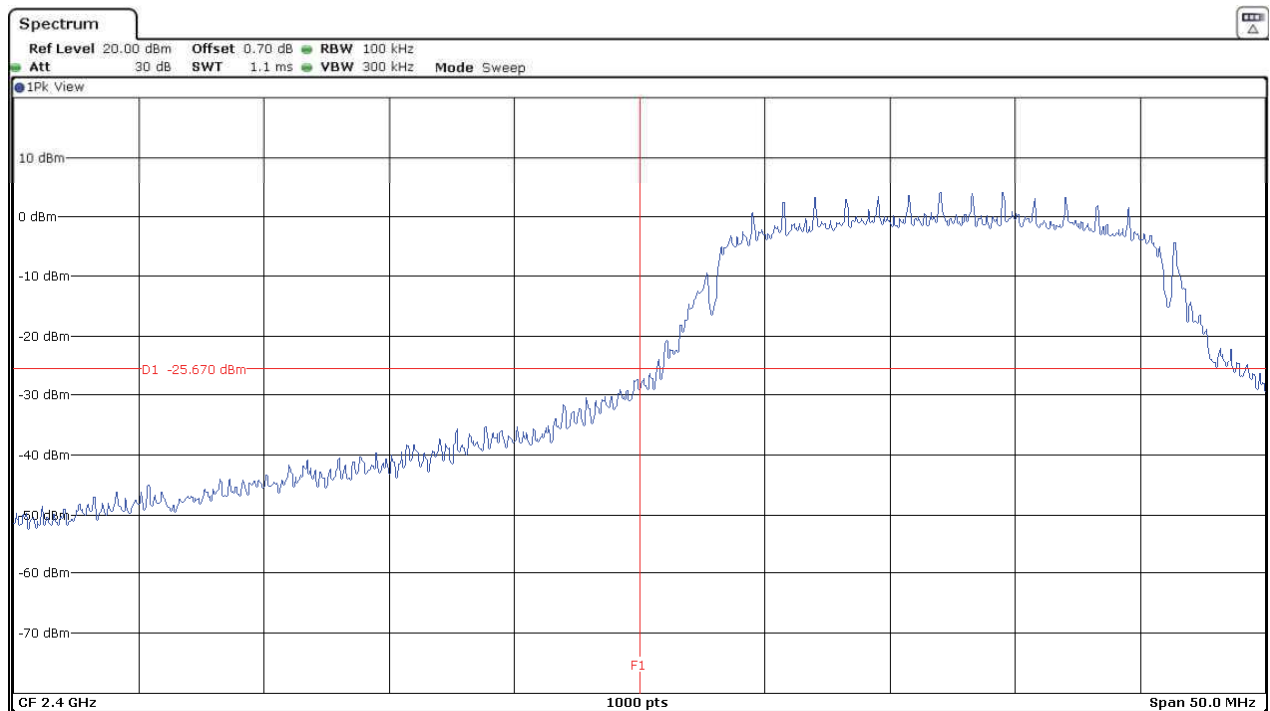
- Low Channel:



Verdict: PASS

- **Mode 802.11 n20 – Band-edge emissions compliance**

- Low Channel:



Verdict: PASS

FCC Section 15.247 Subclause (e) / RSS-247 5.2. (b) Power spectral density

SPECIFICATION:

For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

RESULTS:

For b and n20 modes, the maximum power spectral density level in the fundamental emission was measured using the method according to point 11.10.3." Method AVGPSD-1" of ANSI C.63.10-2013.

For g mode, the maximum power spectral density level in the fundamental emission was measured using the method according to point 11.10.2 "Method PKPSD" of ANSI C.63.10-2013.

- **Mode 802.11 b**

	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
Average Power Spectral Density (dBm/100KHz)	-2.46	-1.99	-1.67
Measurement uncertainty (dB)	<±0.78		

- **Mode 802.11 g**

	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
Peak Power Spectral Density (dBm/100KHz)	3.13	3.37	3.34
Measurement uncertainty (dB)	<±0.78		

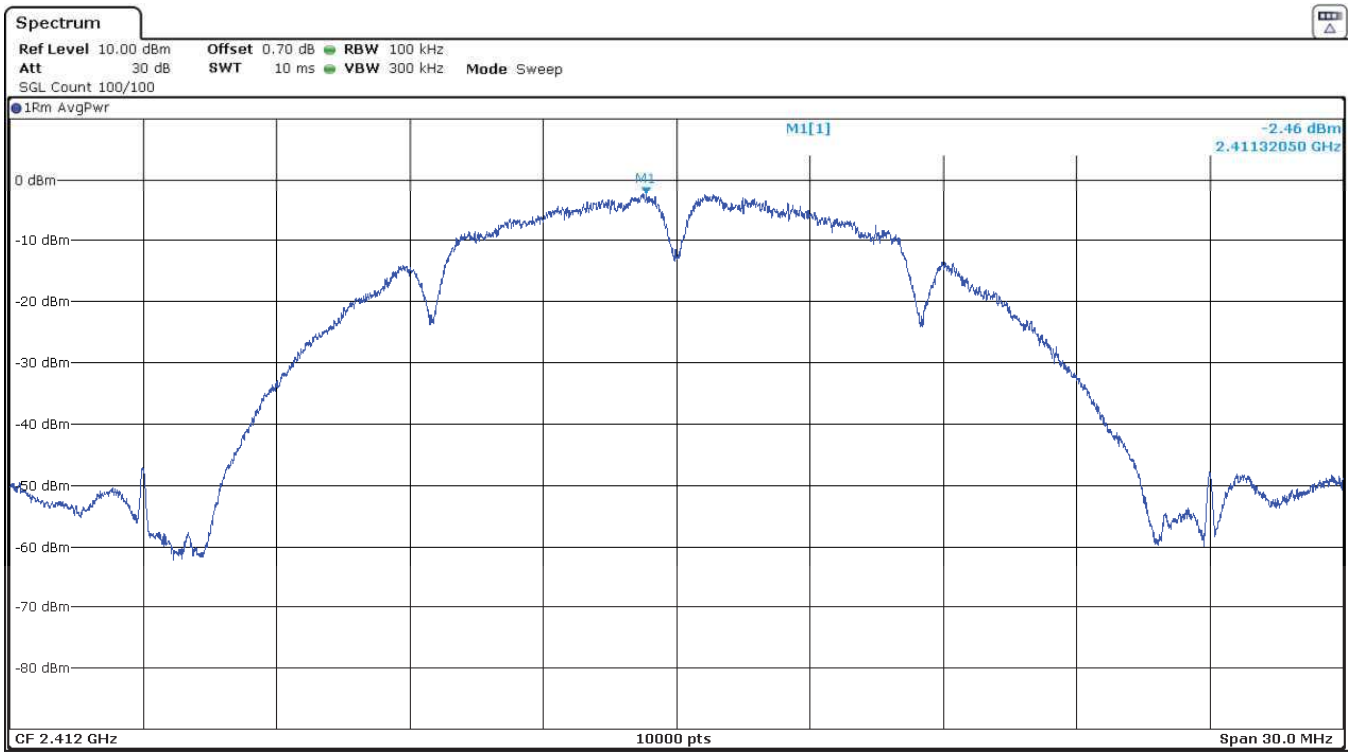
- **Mode 802.11 n20**

	Low Channel 2412 MHz	Middle Channel 2437 MHz	High Channel 2462 MHz
Average Power Spectral Density (dBm/100KHz)	-4.98	-5.8	-5.59
Measurement uncertainty (dB)	<±0.78		

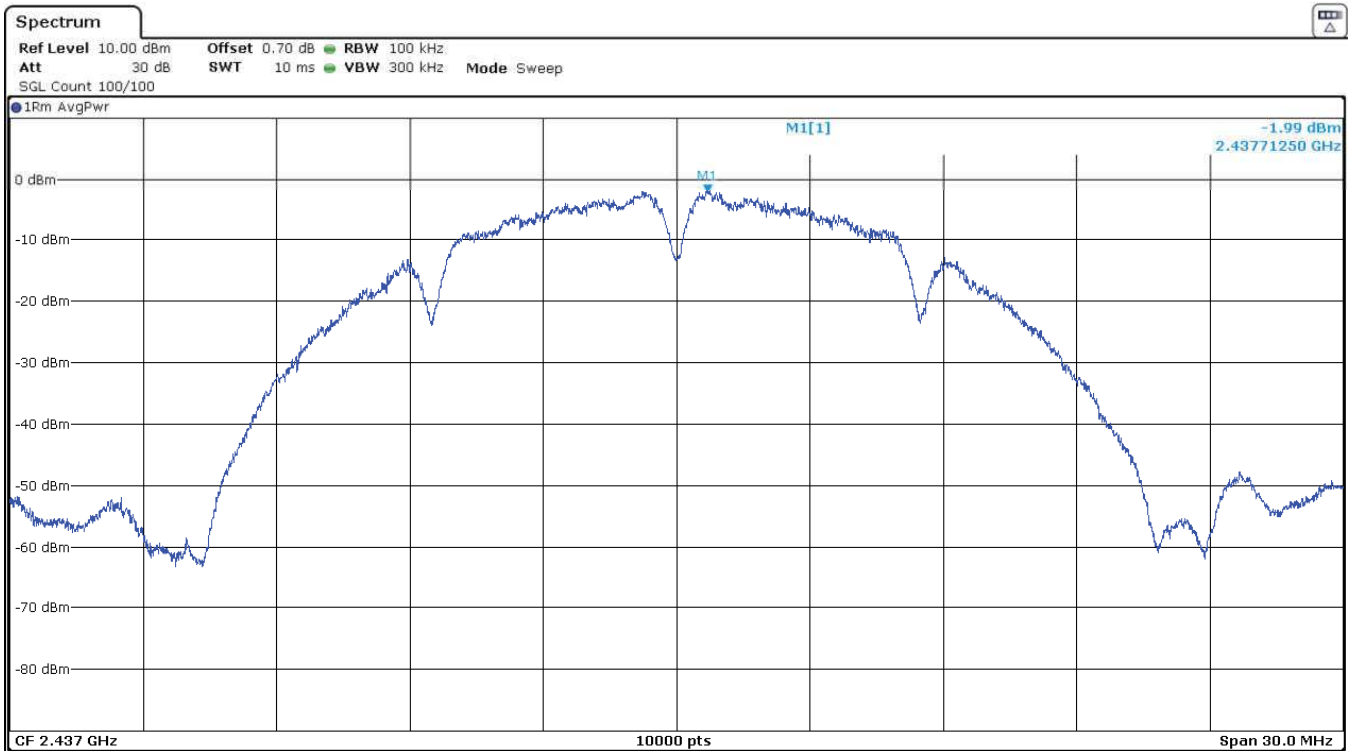
Verdict: PASS

- **Mode 802.11 b – Power Spectral Density**

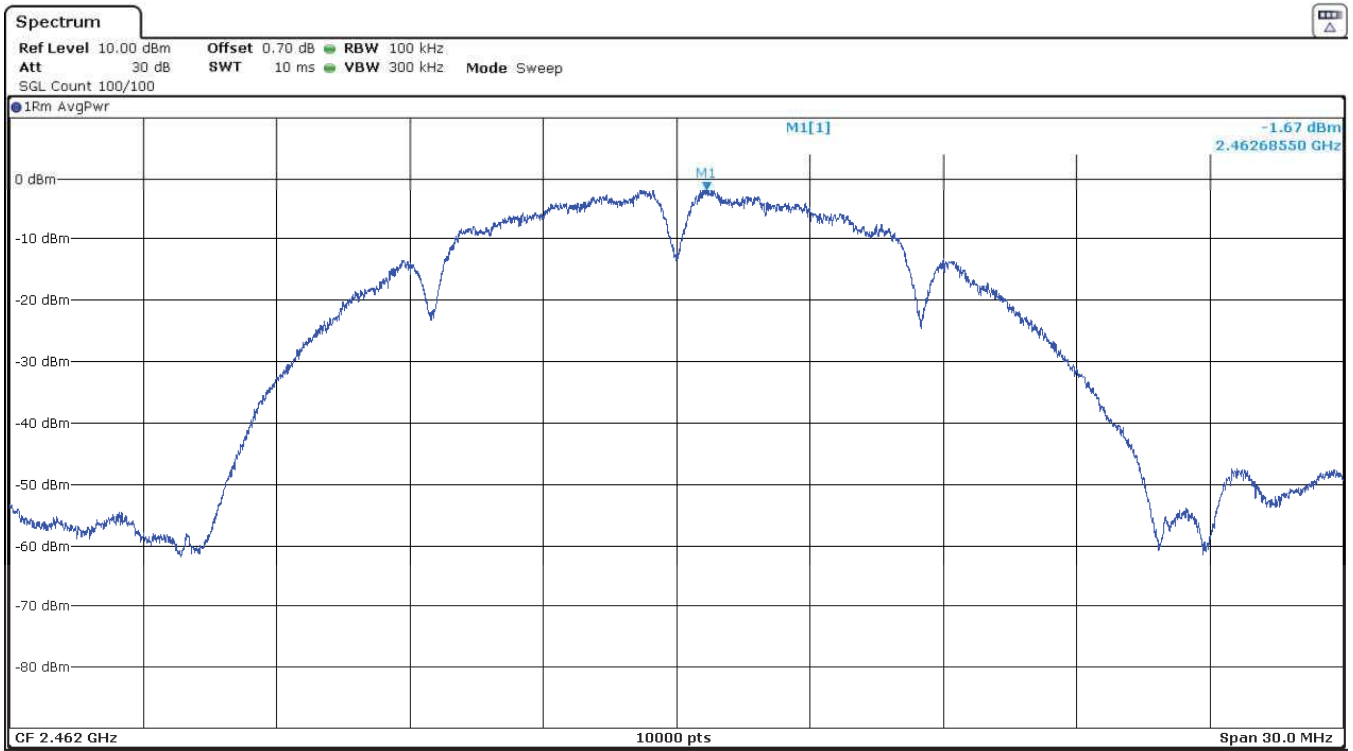
- Low Channel:



- Middle Channel:

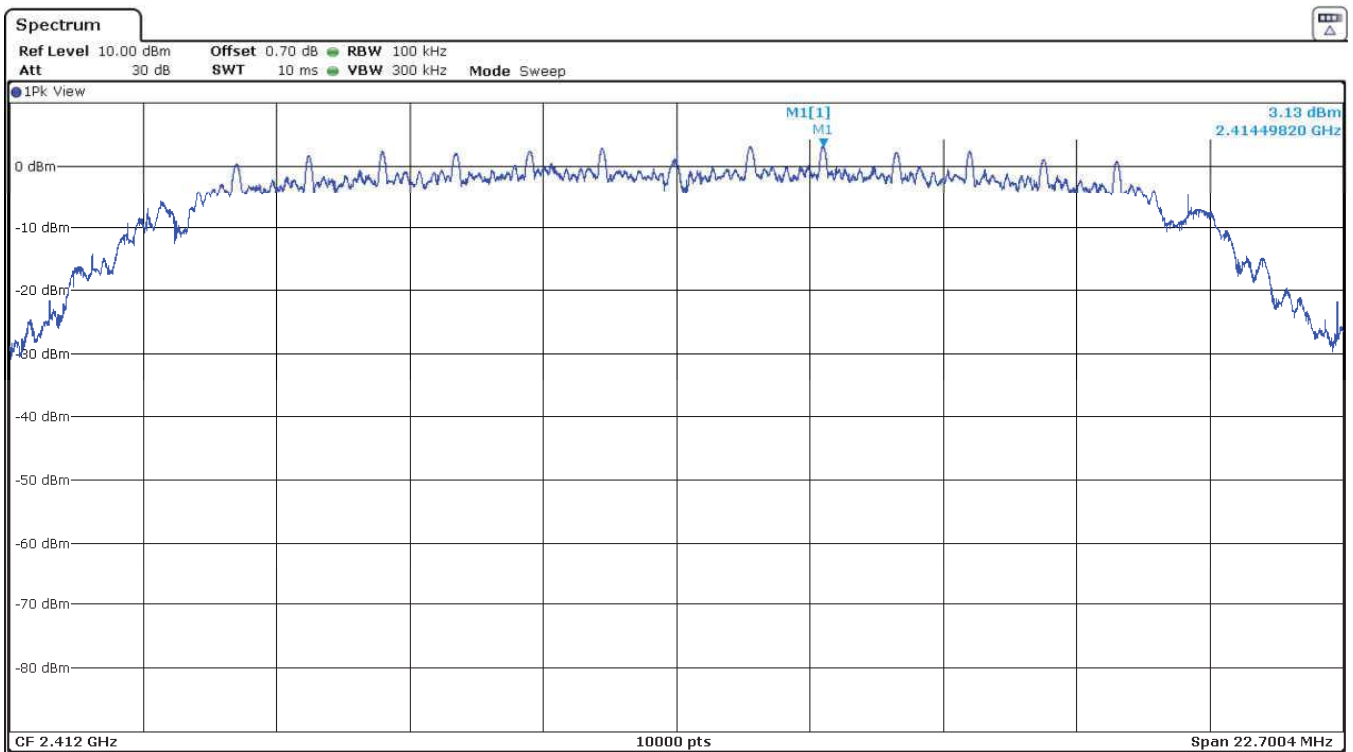


- High Channel:

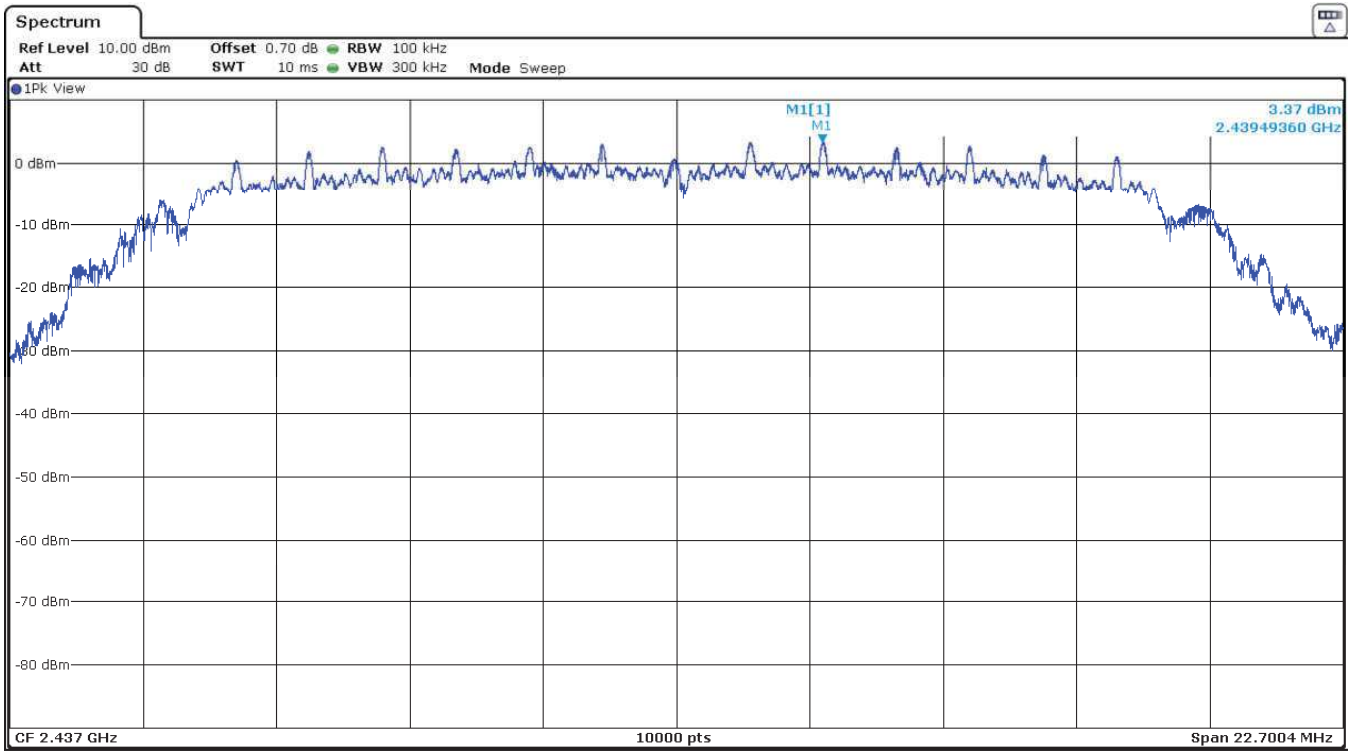


- Mode 802.11 g – Power Spectral Density

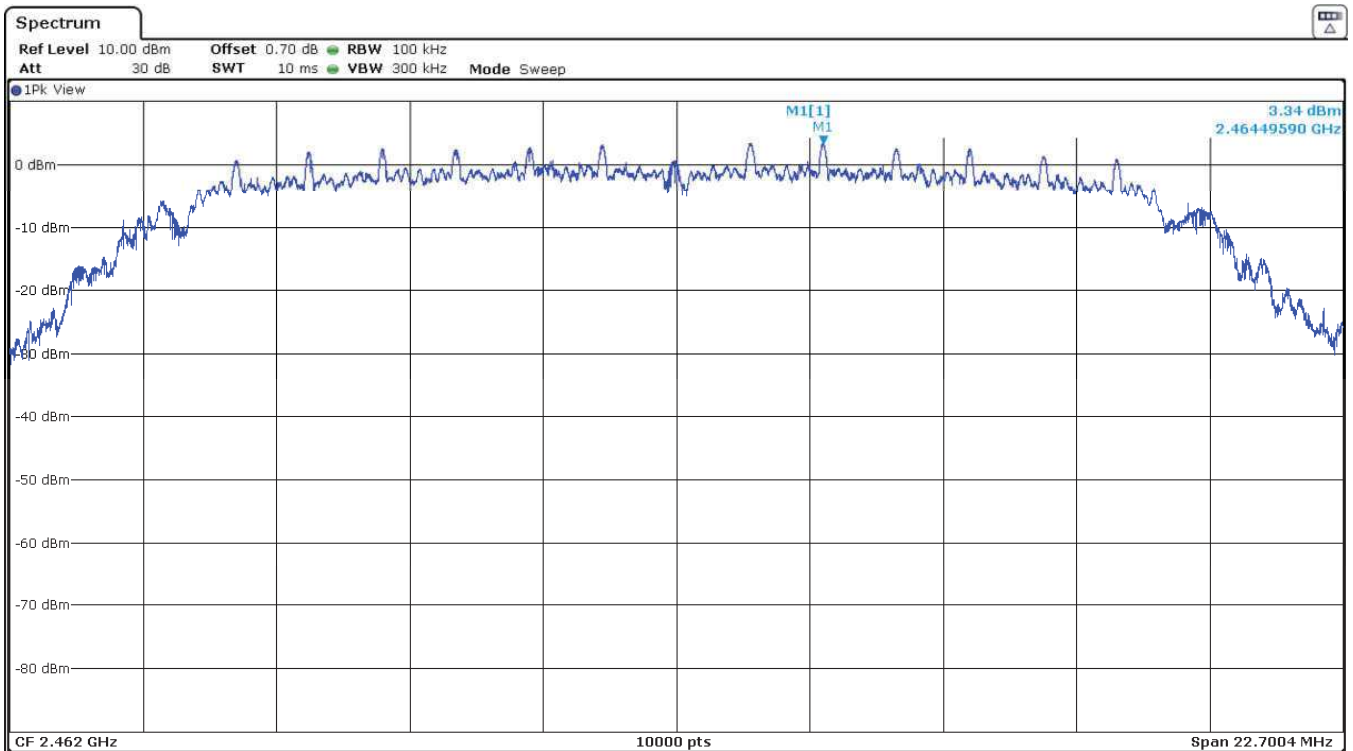
- Low Channel:



- Middle Channel:

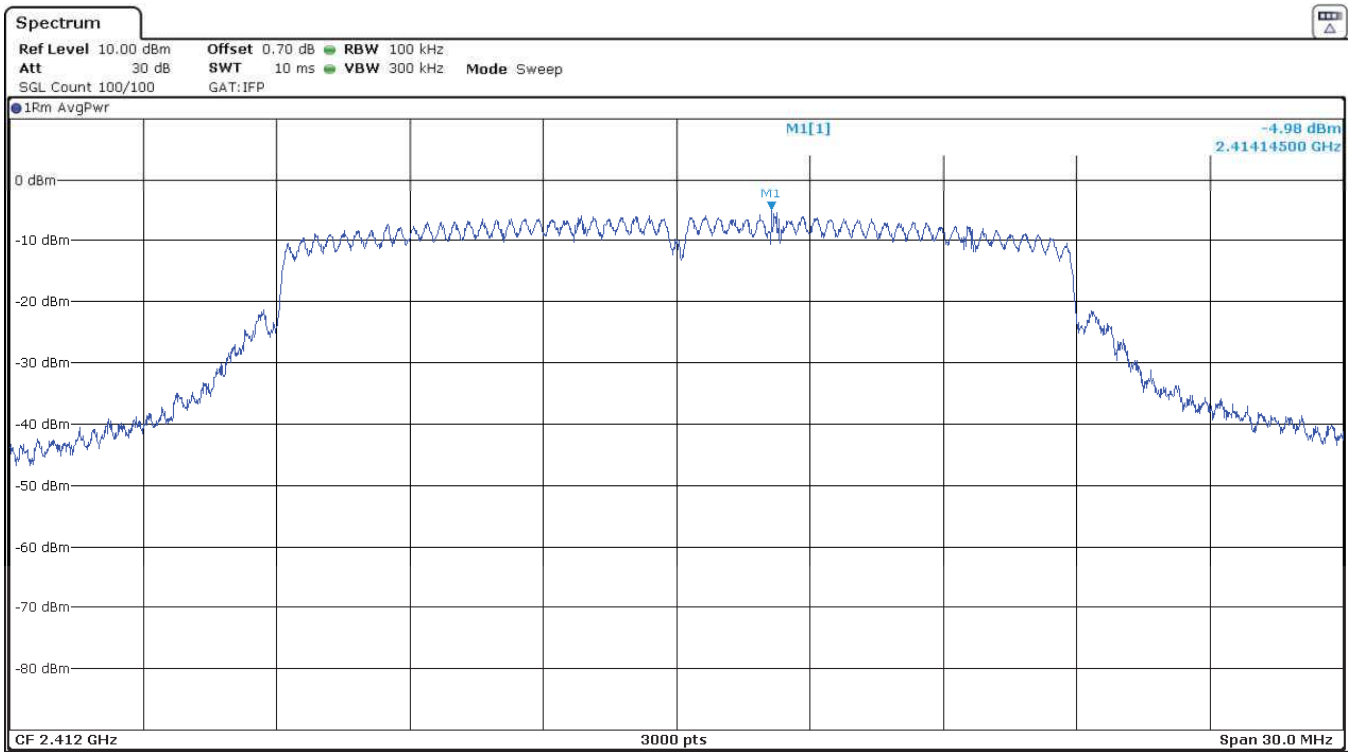


- High Channel:

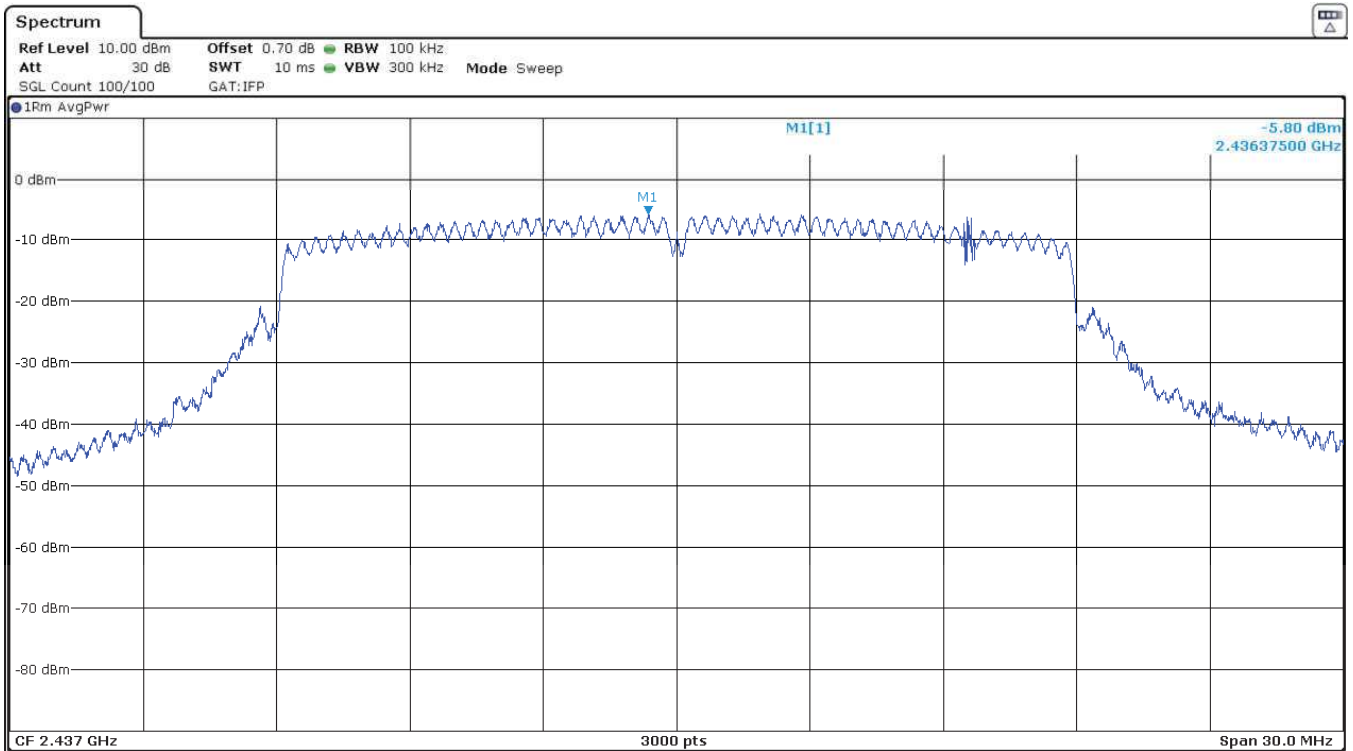


- **Mode 802.11 n20 – Power Spectral Density**

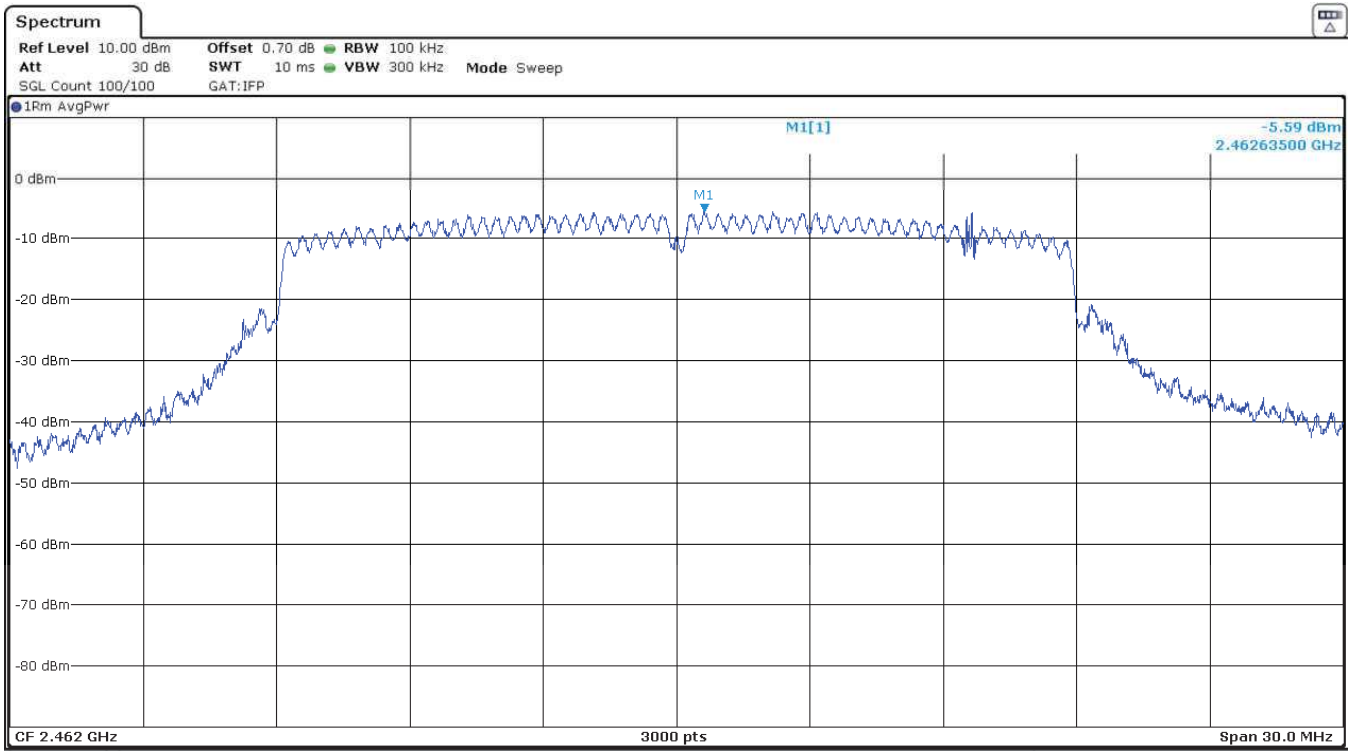
- Low Channel:



- Middle Channel:



- High Channel:



FCC Section 15.247 Subclause (d) / RSS-247 Clause 5.5. Emission limitations radiated (Transmitter)

SPECIFICATION:

Radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 15.205(c)/RSS-Gen):

Frequency Range (MHz)	Field strength ($\mu\text{V/m}$)	Field strength ($\text{dB}\mu\text{V/m}$)	Measurement distance (m)
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	40	3
88 - 216	150	43.5	3
216 - 960	200	46	3
960 - 10000	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 360° 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 3 m for the frequency range 30 MHz-1000 MHz and at distance of 1m for the frequency range 1 GHz-26 GHz.

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.

RADIATED:

Frequency range 30 MHz - 1 GHz:

The spurious frequencies do not depend neither on the operating channel nor the modulation mode.

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

Spurious frequency (MHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
41.365	Quasi peak	31.3	V	< \pm 2.07
192.006	Quasi peak	27.9	V	< \pm 2.07
264.013	Quasi peak	39.1	V	< \pm 2.07
271.999	Quasi peak	36.1	H	< \pm 2.07
336.019	Quasi peak	39.2	V	< \pm 2.07
352.024	Quasi peak	32.8	H	< \pm 2.07
392.020	Quasi peak	42.4	H	< \pm 2.07
512.009	Quasi peak	35.2	H	< \pm 2.07
519.996	Quasi peak	35.7	V	< \pm 2.07

• **Mode 802.11 b**

Frequency range 1 - 26 GHz:

The results in the next tables show the maximum measured levels in the 1-25 GHz range including the restricted bands 2.31-2.39 GHz and 2.4835-2.5 GHz.

Spurious signals with peak levels above the average limit (54 dB μ V/m at 3 m) are measured with average detector for checking compliance with the average limit.

- LOW CHANNEL. Spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
2.38927	Peak	53.21	V	< \pm 4.88
3.25270	Peak	43.85	V	< \pm 4.88
3.46410	Peak	44.62	H	< \pm 4.88
4.82397	Peak	45.20	V	< \pm 4.88
7.23757	Peak	46.91	H	< \pm 4.88

- MIDDLE CHANNEL. Spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
3.14863	Peak	45.24	V	< \pm 4.88
3.44450	Peak	43.92	H	< \pm 4.88
4.87390	Peak	45.03	H	< \pm 4.88
7.31083	Peak	48.07	V	< \pm 4.88

- HIGH CHANNEL. Spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (MHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
3.31383	Peak	44.49	H	< \pm 4.88
4.92383	Peak	43.90	H	< \pm 4.88
7.38503	Peak	47.22	V	< \pm 4.88

Verdict: PASS

OFDM modes:

For spurious emissions in the range 30 MHz - 26 GHz (except field strength at the band edges that was performed for all modes) a preliminary scan was performed to determine the worst case mode. Herein the results for the worst case mode: 802.11n20.

Spurious emissions in the Restricted Band (2.31-2.39GHz) and Restricted Band (2.4835-2.5GHz) are measured for all modes.

• **Mode 802.11 n20 (OFDM worst case for spurious emissions)**

Frequency range 1 - 26 GHz:

The results in the next tables show the maximum measured levels in the 1-25 GHz range including the restricted bands 2.31-2.39 GHz and 2.4835-2.5 GHz.

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

- LOW CHANNEL. Spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Detector	Emission Level (dBµV/m)	Polarization	Measurement Uncertainty (dB)
2.38986	Peak	68.54	V	<± 4.88
	Average	52.06		<± 4.88
3.26857	Peak	43.13	H	<± 4.88
4.82350	Peak	45.77	V	<± 4.88
7.24030	Peak	50.63	V	<± 4.88

- MIDDLE CHANNEL. Spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Detector	Emission Level (dBµV/m)	Polarization	Measurement Uncertainty (dB)
3.33577	Peak	44.88	H	<± 4.88
4.86737	Peak	43.87	H	<± 4.88
7.30990	Peak	52.10	H	<± 4.88

- HIGH CHANNEL. Spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Detector	Emission Level (dB μ V/m)	Polarization	Measurement Uncertainty (dB)
1.94710	Peak	50.92	V	< \pm 4.88
2.48361	Peak	69.90	V	< \pm 4.88
	Average	53.96		< \pm 4.88
3.36143	Peak	44.33	H	< \pm 4.88
4.92383	Peak	44.20	V	< \pm 4.88
7.38783	Peak	51.49	V	< \pm 4.88
9.84810	Peak	48.33	V	< \pm 4.88

Verdict: PASS

• **Mode 802.11 g**

The results in the next tables show the maximum measured levels in the restricted bands 2.31-2.39 GHz and 2.4835-2.5 GHz.

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

- LOW CHANNEL. Spurious frequencies detected at less than 20 dB below the limit:

Spurious frequency (GHz)	Detector	Emission Level (dBµV/m)	Polarization	Measurement Uncertainty (dB)
2.38992	Peak	67.97	V	<± 4.88
	Average	52.26		<± 4.88

- HIGH CHANNEL. Spurious frequencies detected at less than 20 dB below the limit:

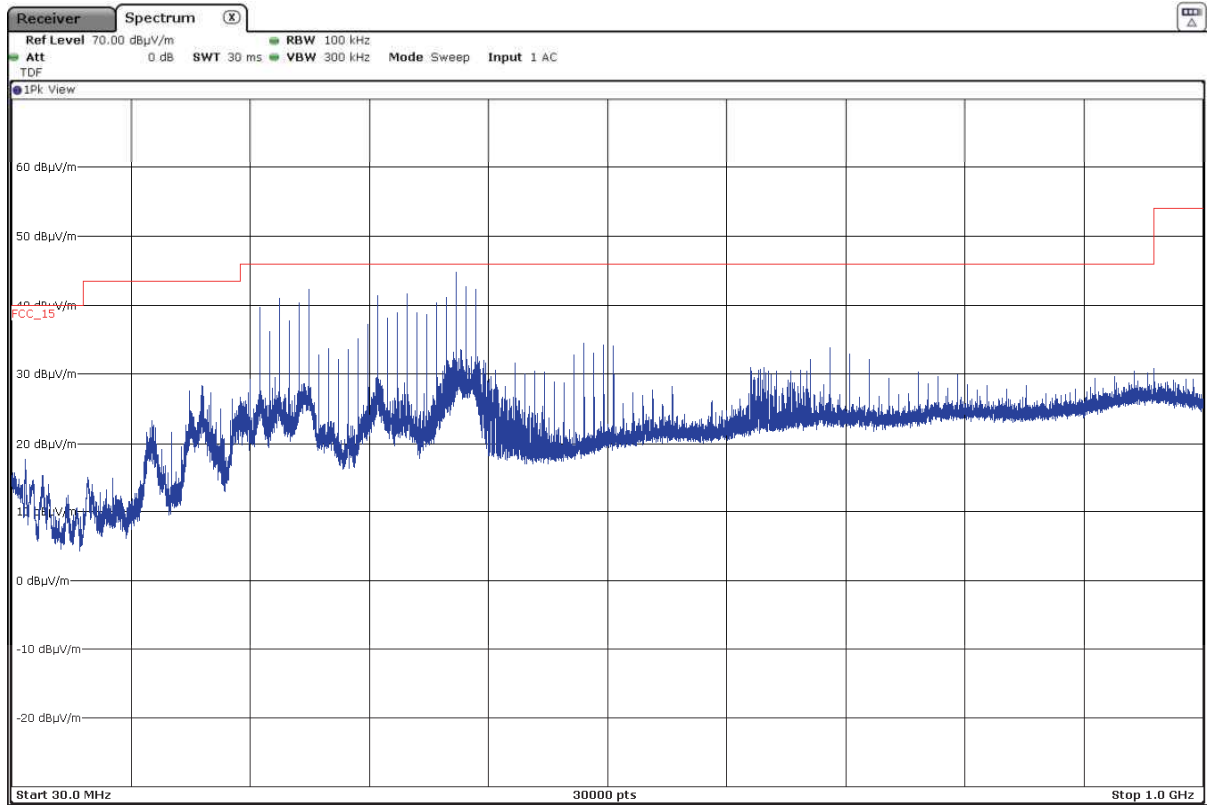
Spurious frequency (GHz)	Detector	Emission Level (dBµV/m)	Polarization	Measurement Uncertainty (dB)
2.48449	Peak	71.65	V	<± 4.88
	Average	52.54		<± 4.88

Verdict: PASS

FREQUENCY RANGE 30 MHz - 1 GHz:

The spurious frequencies detected do not depend neither on the operating channel nor the modulation mode.

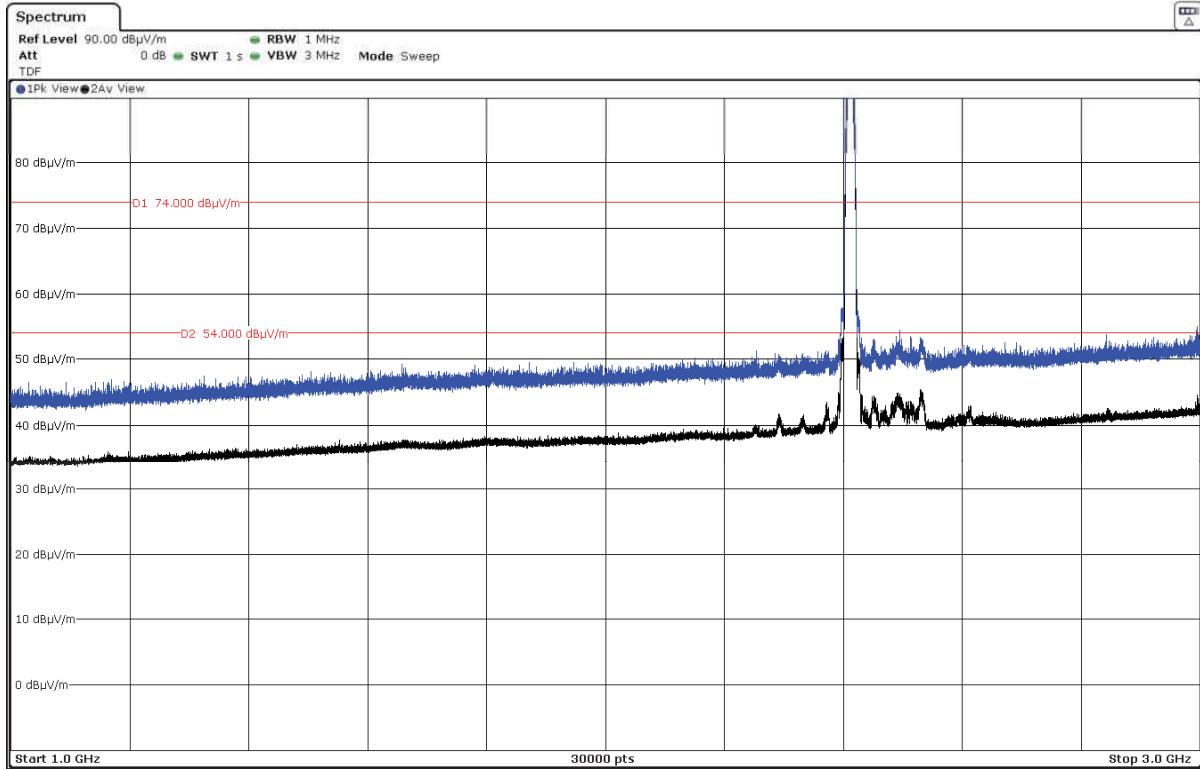
This plot is valid for the Low, Middle and High Channels.



- **Mode 802.11 b**

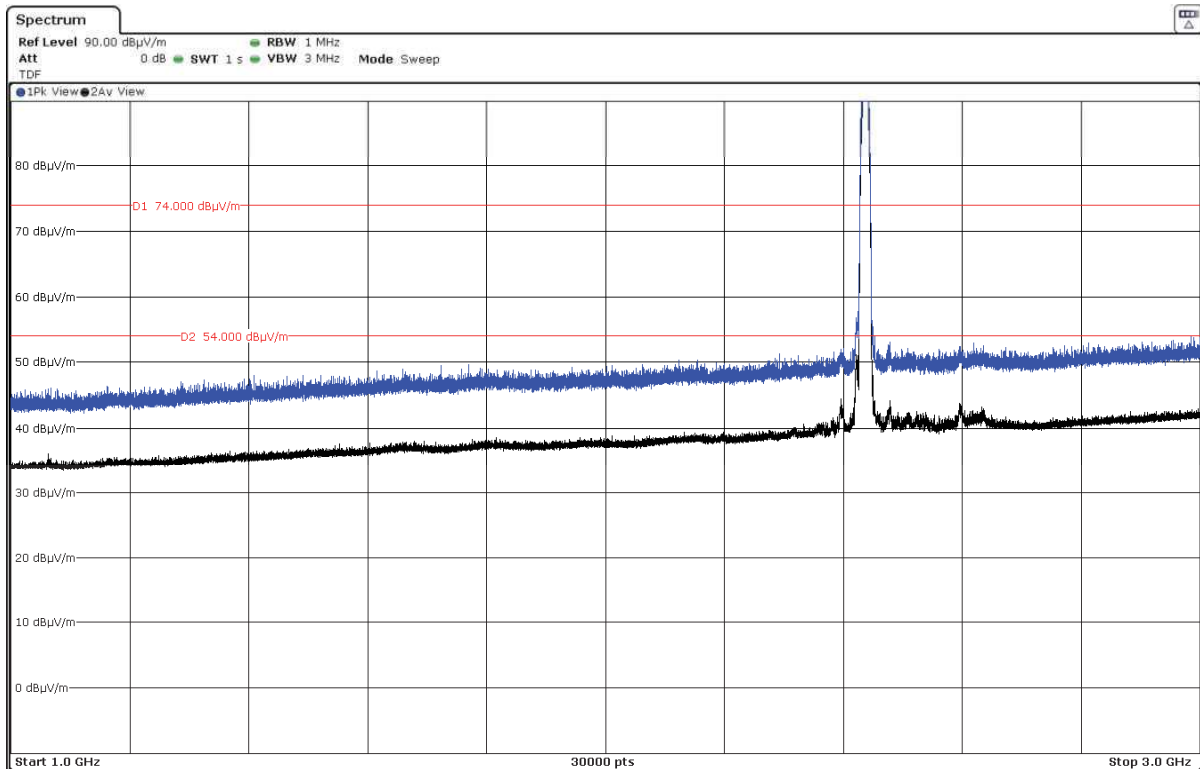
FREQUENCY RANGE 1 - 3 GHz:

- Low Channel:



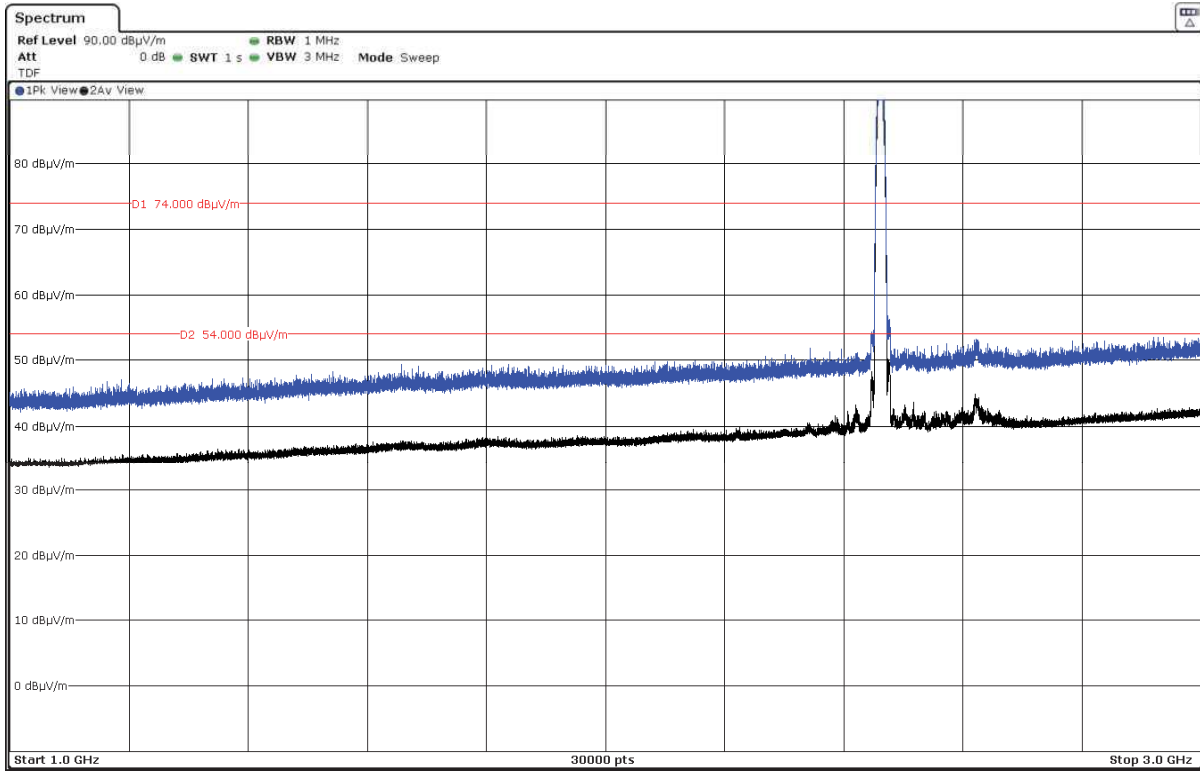
The peak above the limit is the carrier frequency.

- Middle Channel:



The peak above the limit is the carrier frequency.

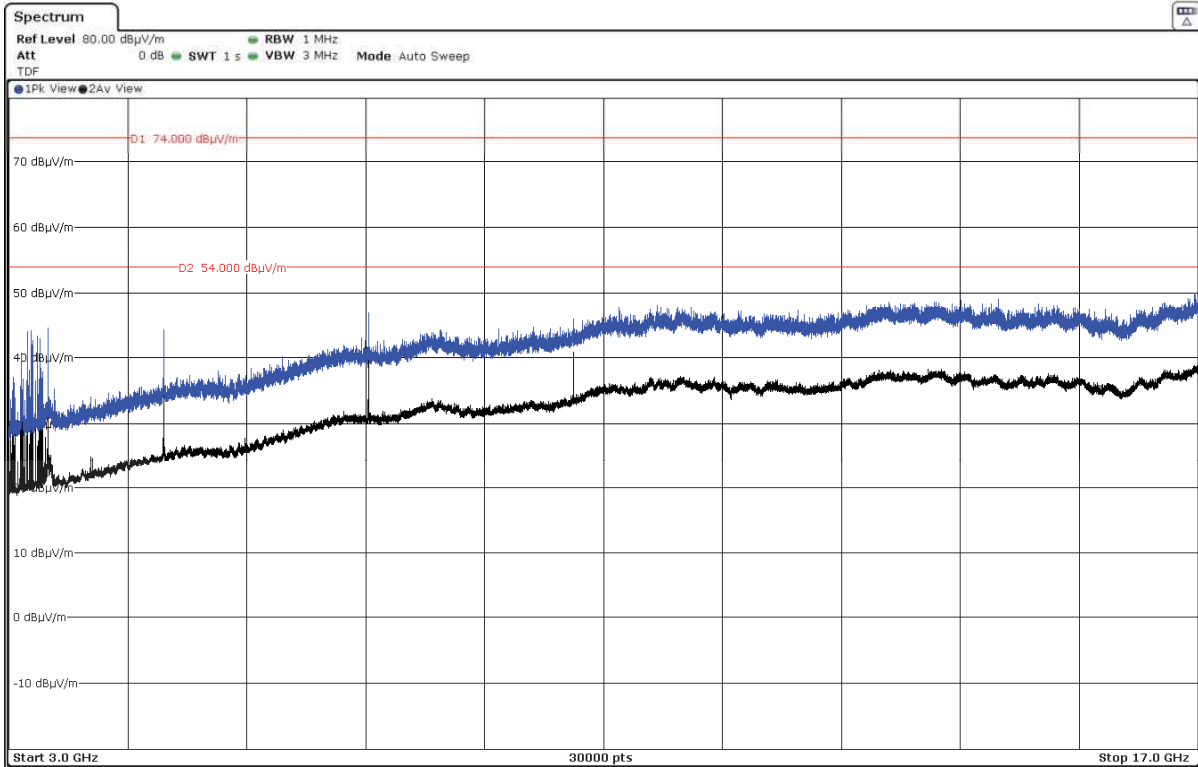
- High Channel:



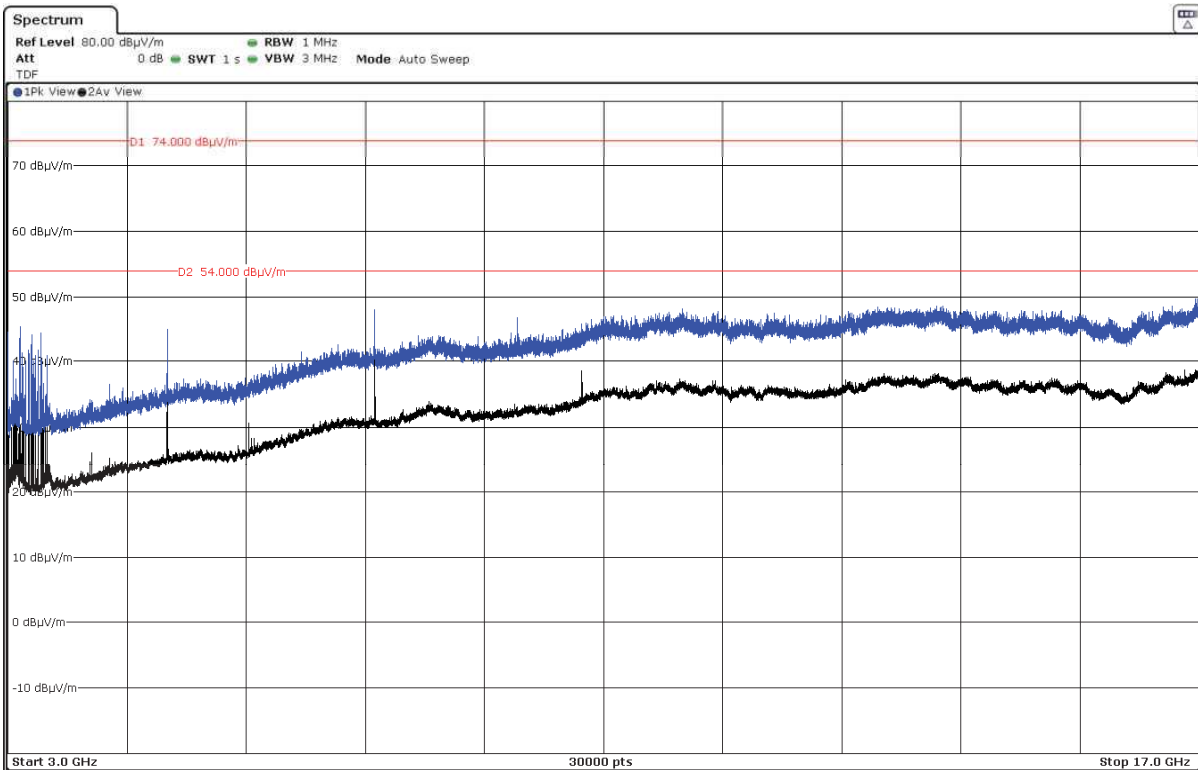
The peak above the limit is the carrier frequency.

FREQUENCY RANGE 3 - 17 GHz:

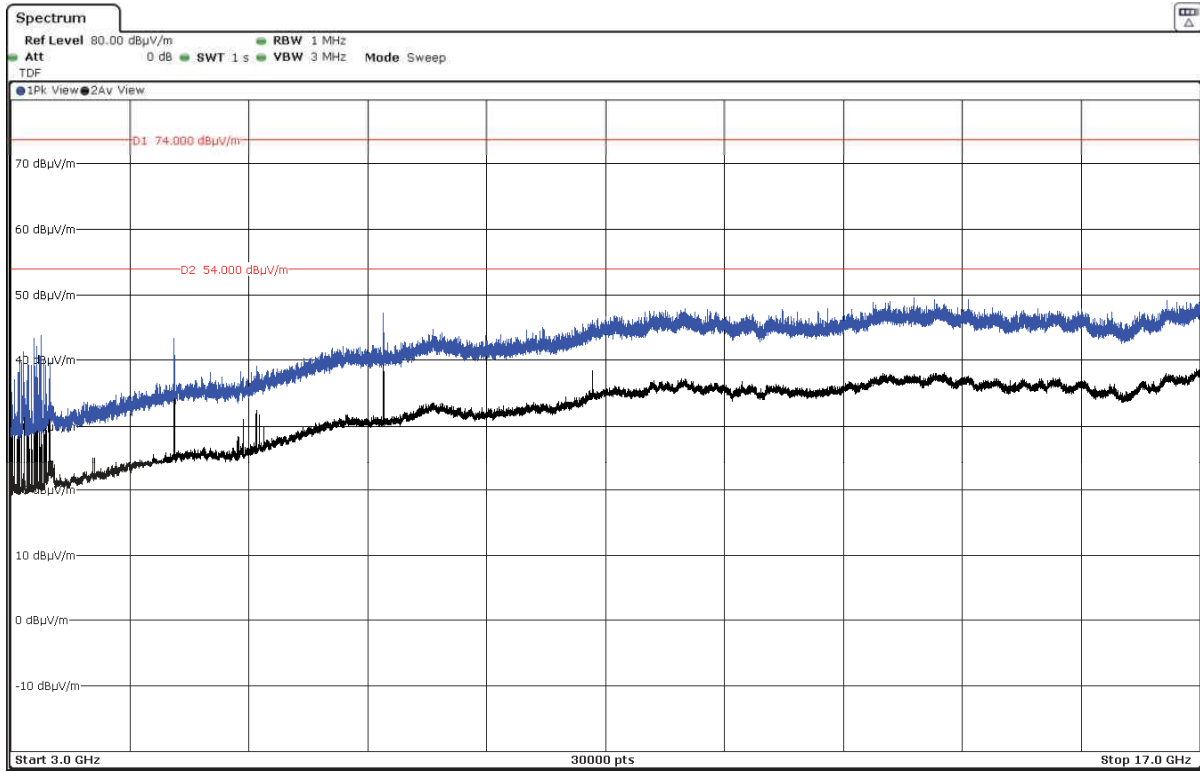
- Low Channel:



- Middle Channel:

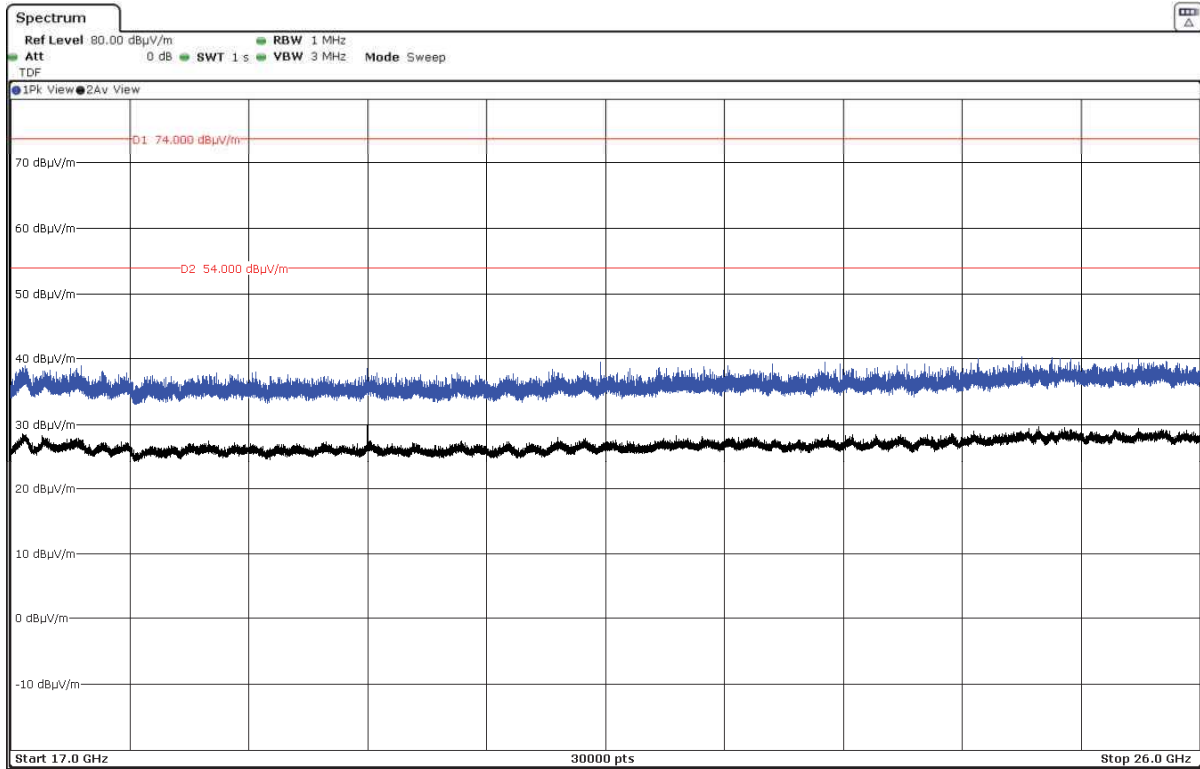


- High Channel:



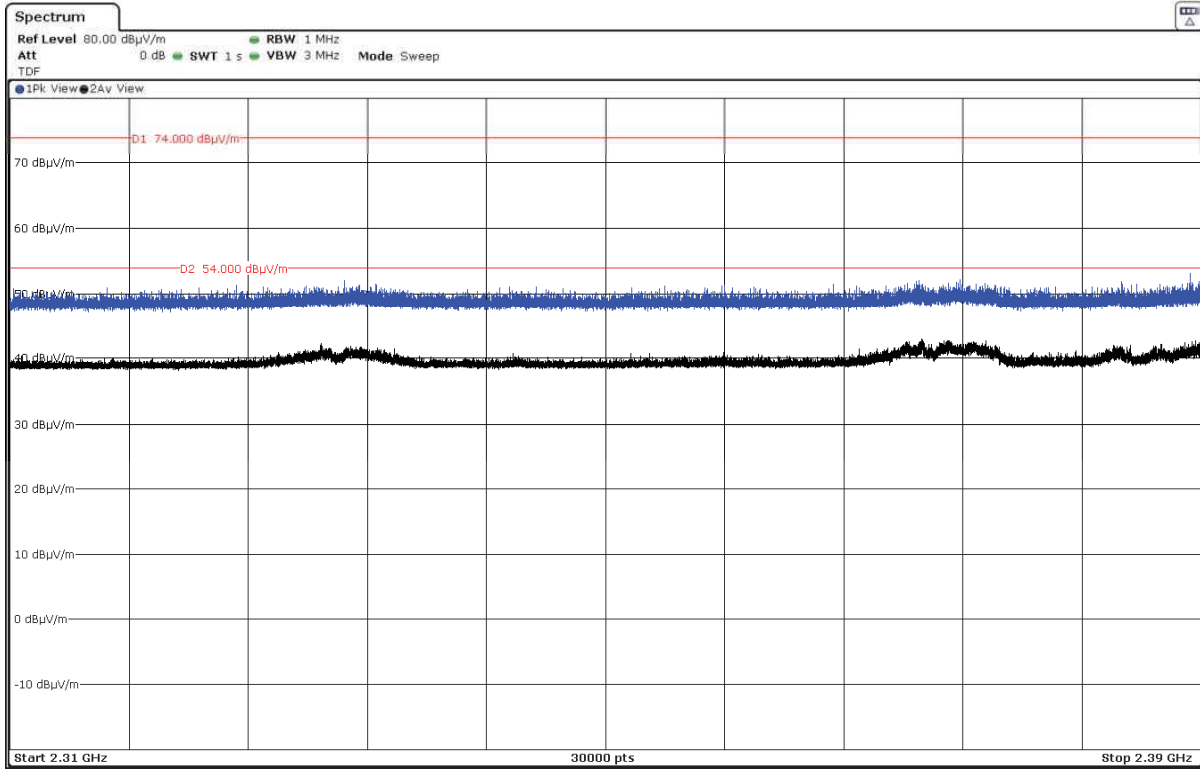
FREQUENCY RANGE 17 - 26 GHz:

The spurious frequencies detected do not depend on the operating channel.



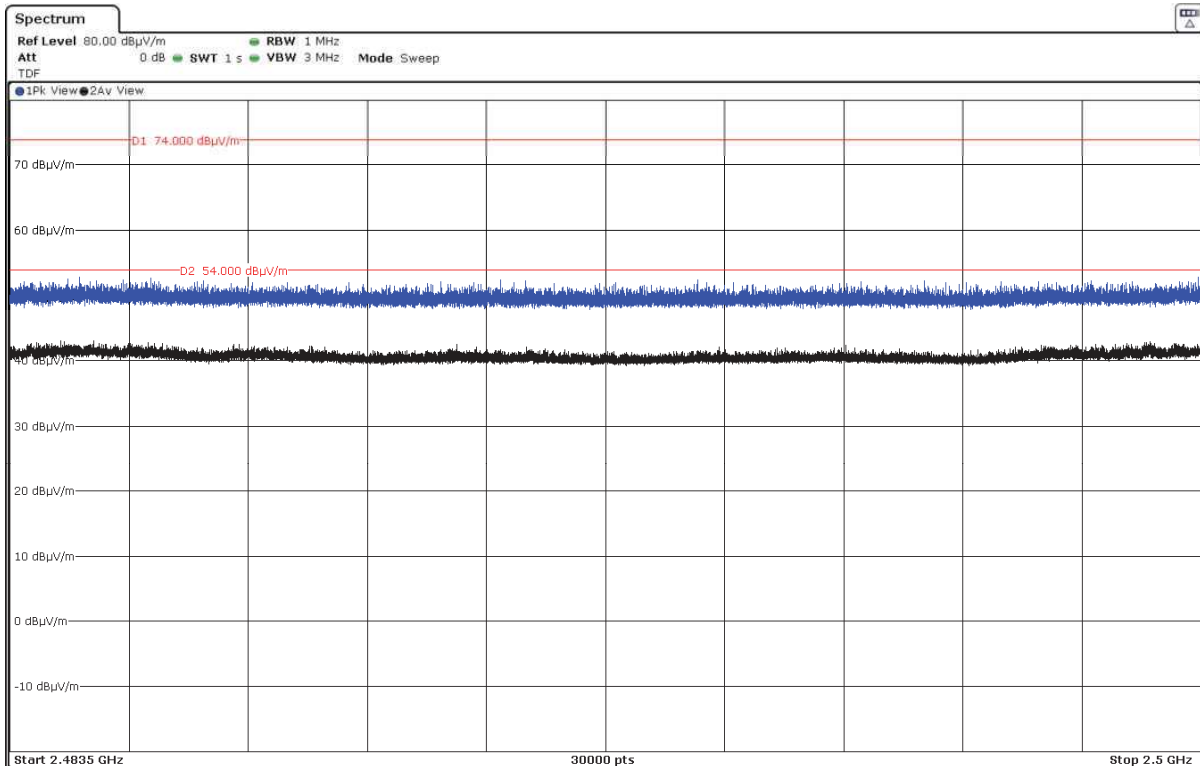
FREQUENCY RANGE 2.31-2.39 GHz:

- Low Channel. CH 1:



FREQUENCY RANGE 2.4835-2.5 GHz:

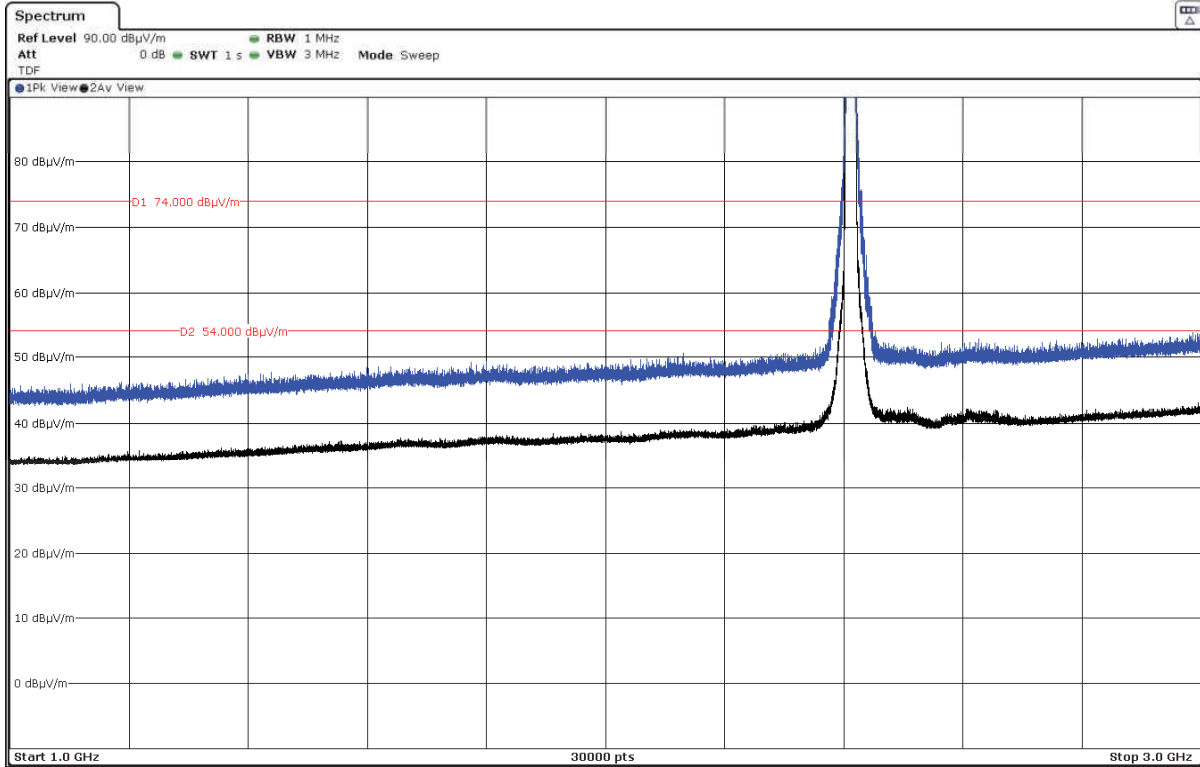
- High Channel. CH 11:



- Mode 802.11 n20 (OFDM worst case for spurious emissions)

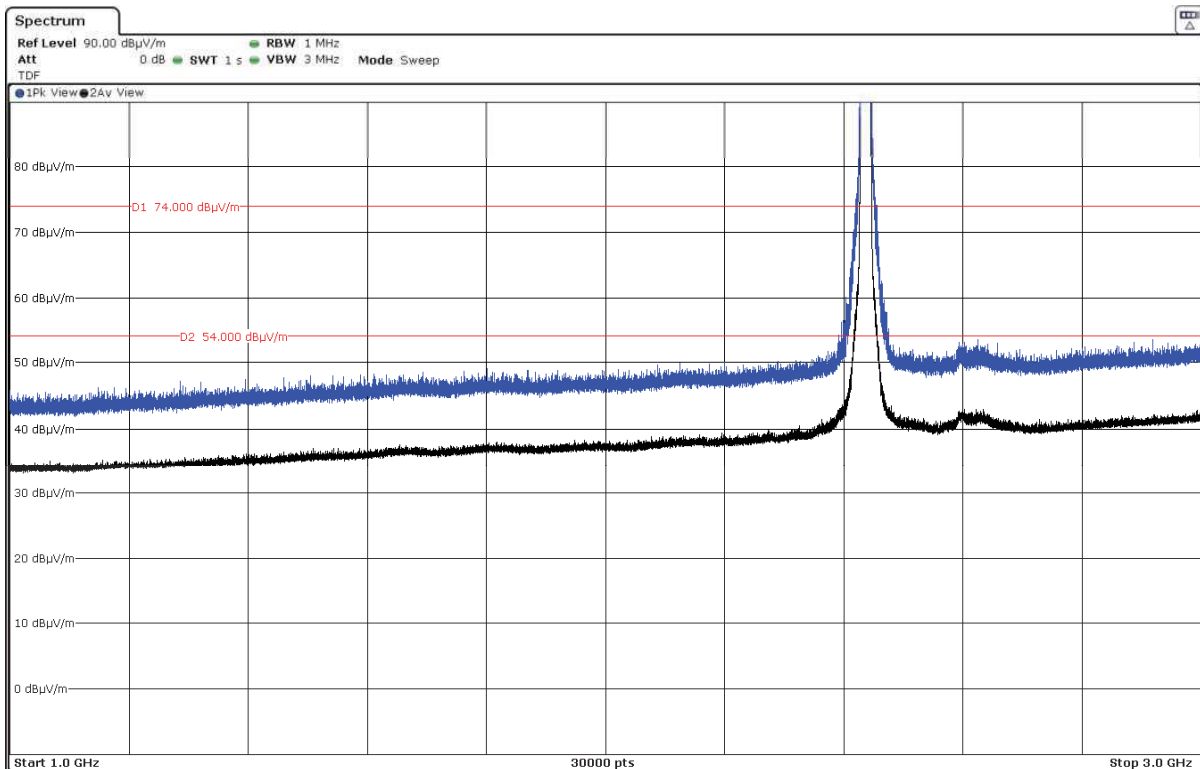
FREQUENCY RANGE 1 - 3 GHz:

- Low Channel:



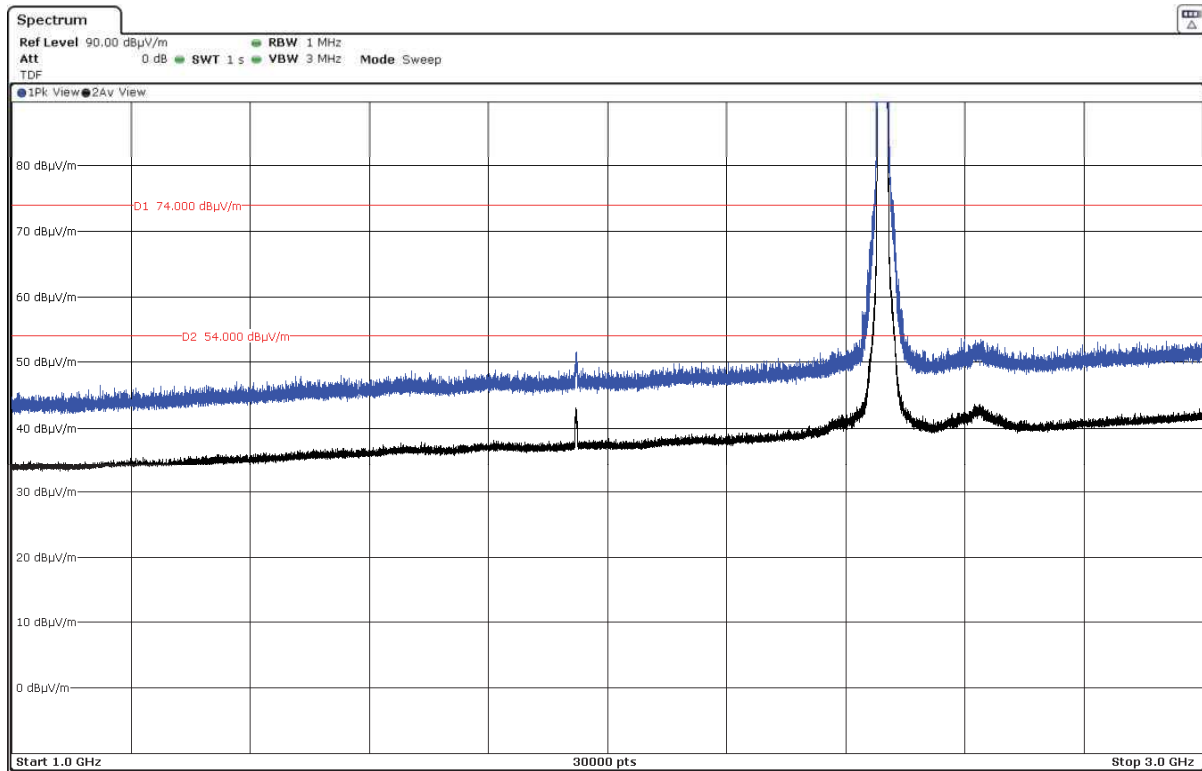
The peak above the limit is the carrier frequency.

- Middle Channel:



The peak above the limit is the carrier frequency.

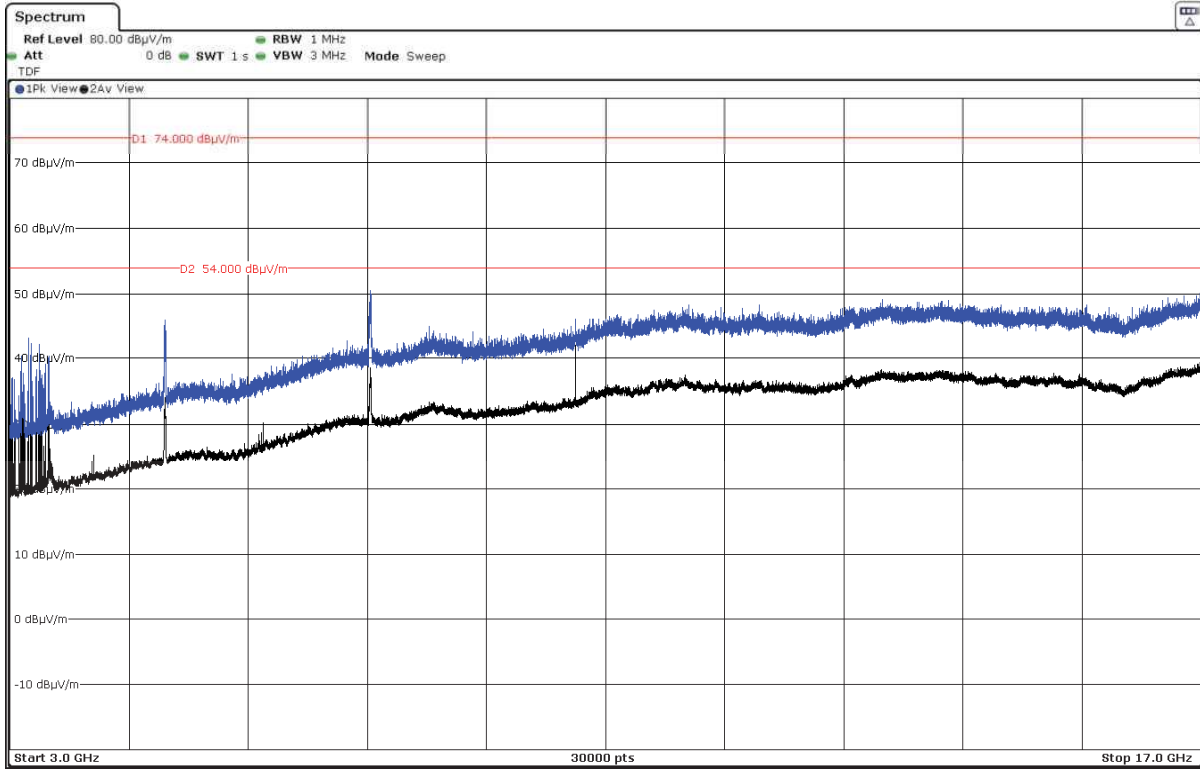
- High Channel:



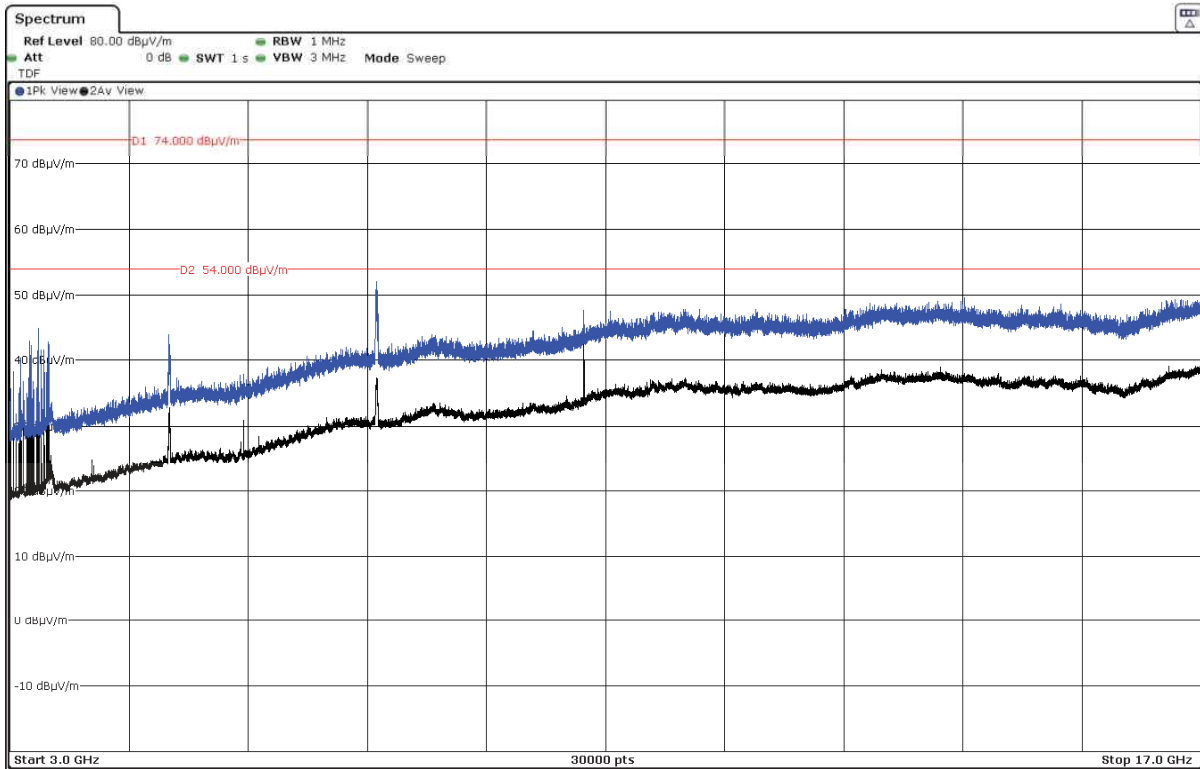
The peak above the limit is the carrier frequency.

FREQUENCY RANGE 3 - 17 GHz:

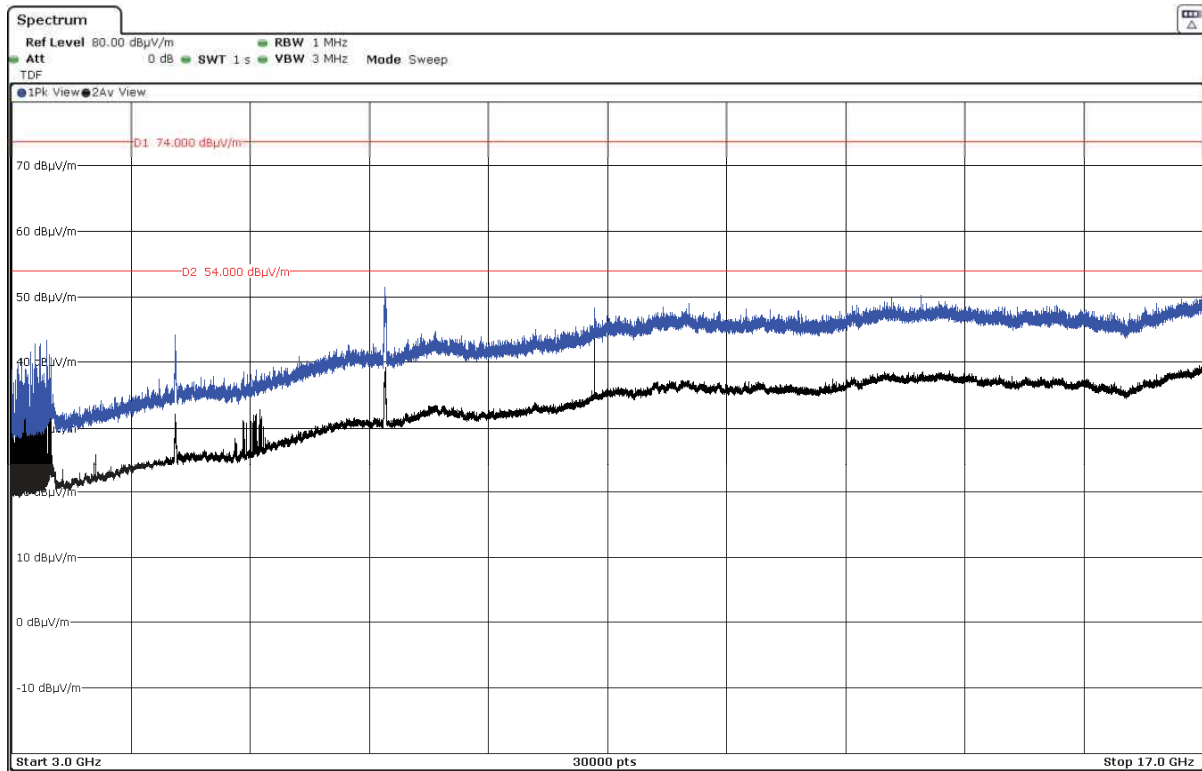
- Low Channel:



- Middle Channel:

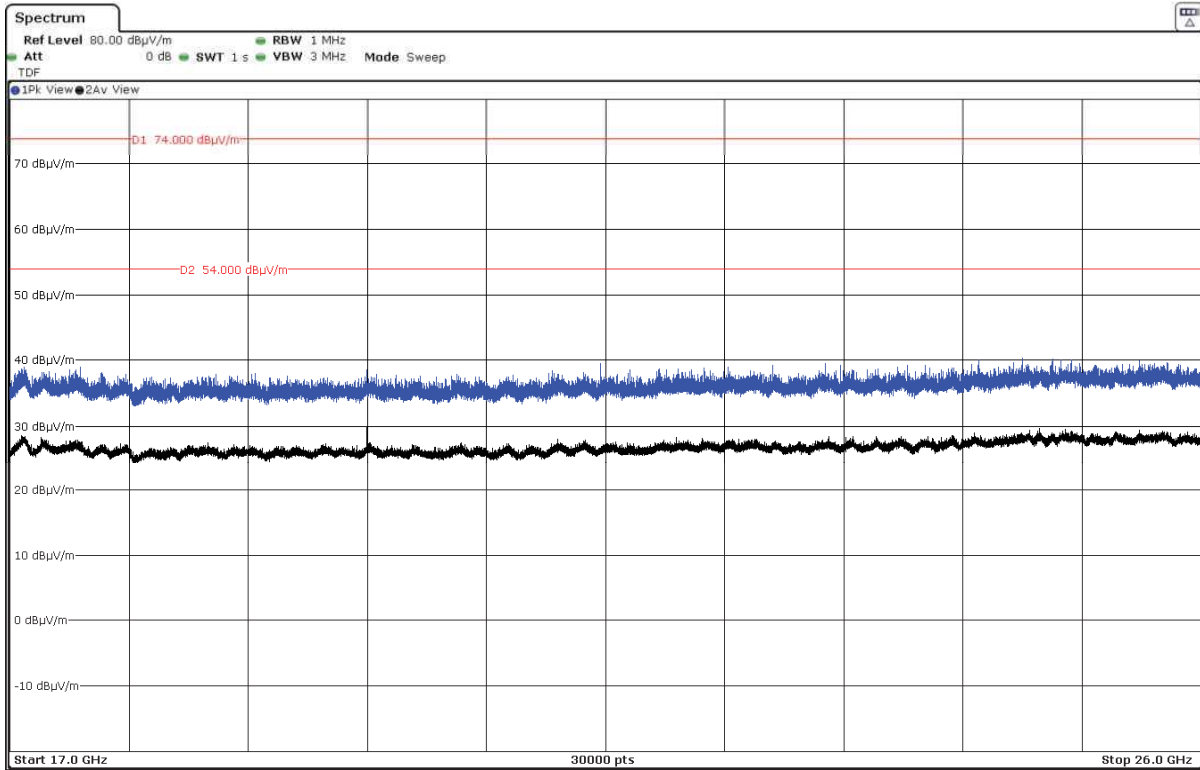


- High Channel:



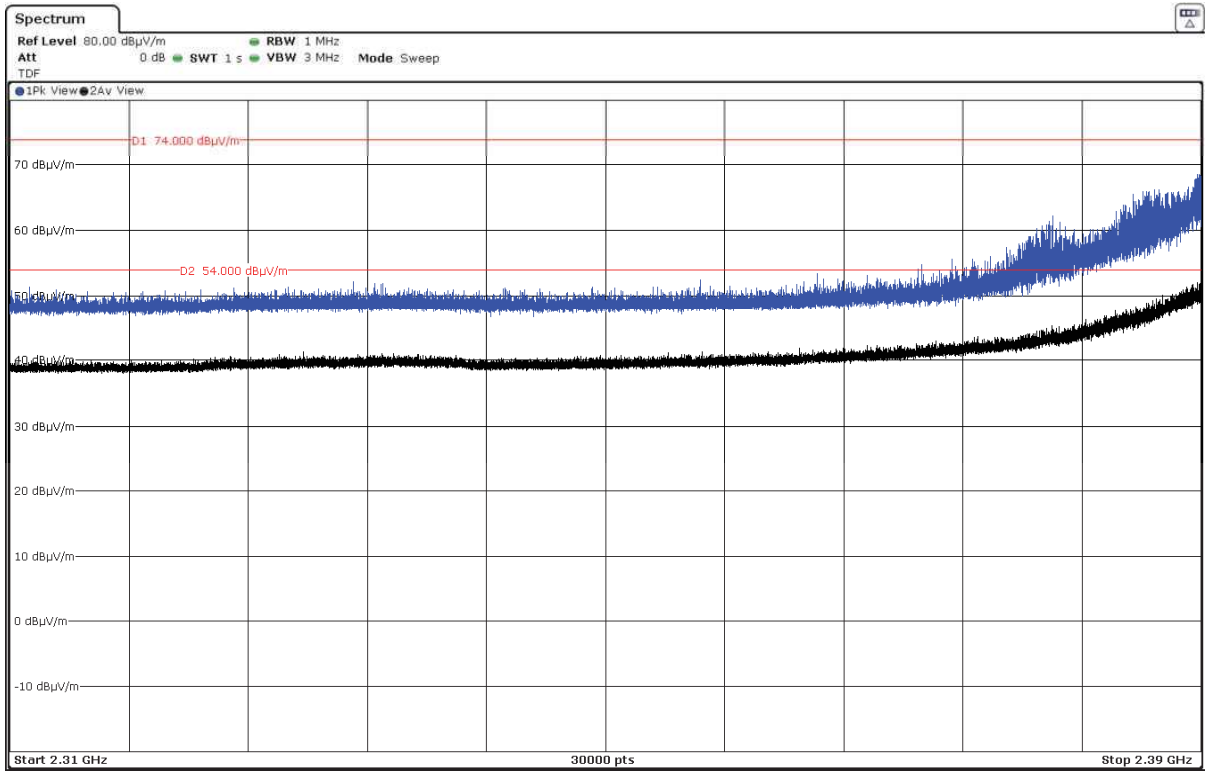
FREQUENCY RANGE 17 - 26 GHz:

The spurious frequencies detected do not depend on the operating channel.



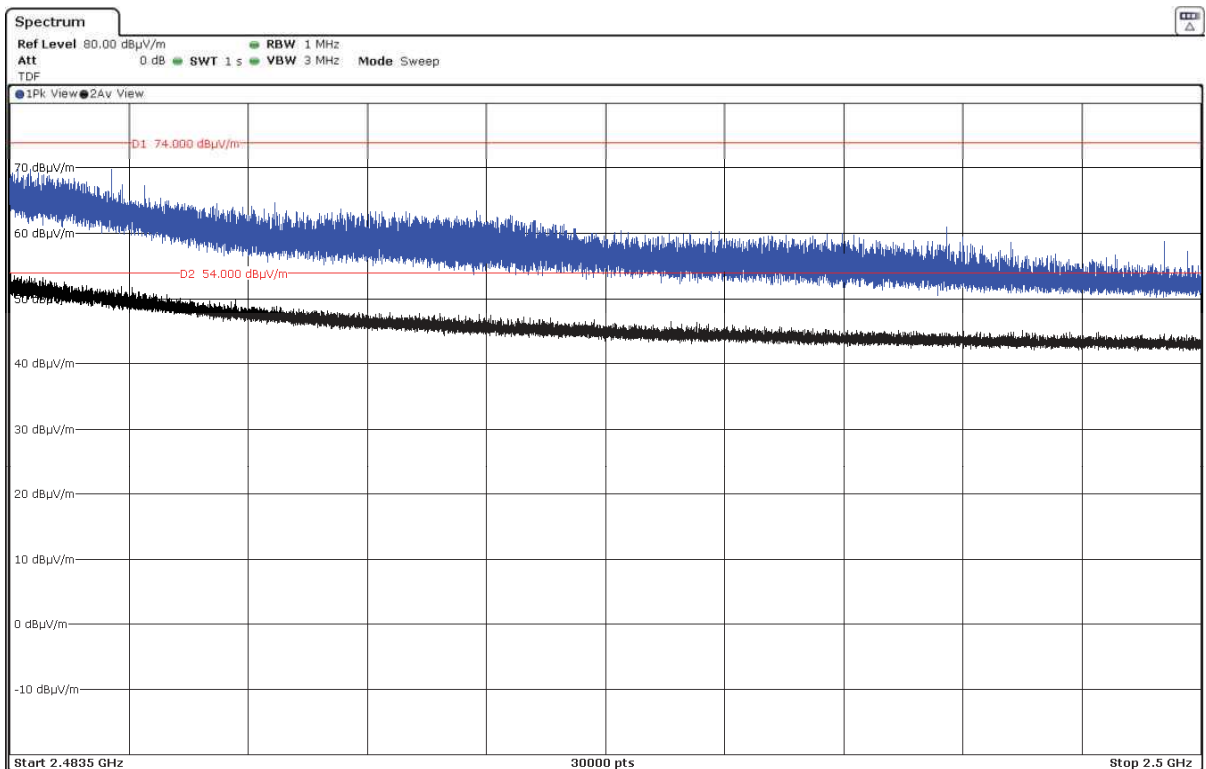
FREQUENCY RANGE 2.31-2.39 GHz:

- Low Channel. CH 1:



FREQUENCY RANGE 2.4835-2.5 GHz:

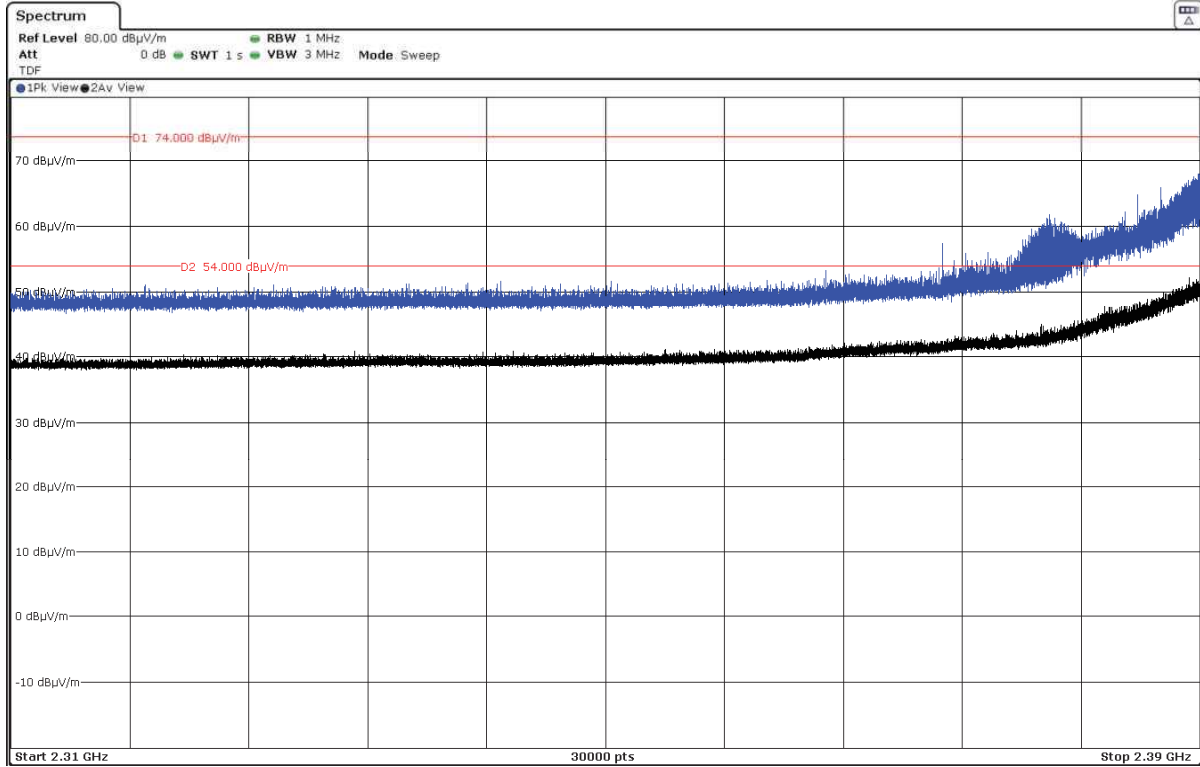
- High Channel. CH 11:



- **Mode 802.11 g**

FREQUENCY RANGE 2.31-2.39 GHz:

- Low Channel. CH 1:



FREQUENCY RANGE 2.4835-2.5 GHz:

- High Channel. CH 11:

