

5.4. Power Spectral Density

Ambient condition

Temperature	Relative humidity	Pressure
23°C ~25°C	45%~50%	101.5kPa

Method of Measurement

During the process of the testing, The EUT was connected to Spectrum Analyzer with a known loss.

The EUT is max power transmission with proper modulation.

Method AVGPSD-1 was used for this test.

- Set instrument center frequency to DTS channel center frequency
- Set span to at least 1.5 times the OBW
- Set RBW to: $3\text{kHz} \leq \text{RBW} \leq 100\text{kHz}$
- Set VBW $\geq [3 \times \text{RBW}]$
- Detector=power averaging(rms) or sample detector(when rms not available)
- Ensure that the number of measurement points in the sweep $2[2 \times \text{span}/\text{RBWT}]$
- Sweep time auto couple
- Employ trace averaging(rms) mode over a minimum of 100 traces
- Use the peak marker function to determine the maximum amplitude level.
- If the measured value exceeds requirement, then reduce RBW (but no less than 3 kHz) and repeat(note that this may require zooming in on the emission of interest and reducing the span to meet the minimum measurement point requirement as the RBW is reduced)

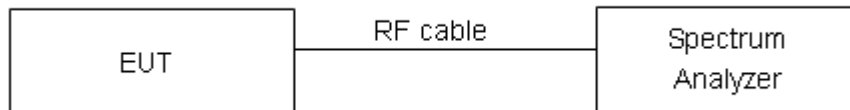
Method AVGPSD-2 was used for this test.

- Measure the duty cycle(D)of the transmitter output signal as described in 11.6
- Set instrument center frequency to DTS channel center frequency
- Set span to at least 1.5 times the OBW
- Set RBW to: $3\text{kHz} \leq \text{RBW} \leq 100\text{Kh}$
- Set VBW $\geq [3 \times \text{RBW}]$
- Detector= power averaging(rms) or sample detector (when rms not available)
- Ensure that the number of measurement points in the sweep $2[2 \times \text{span}/\text{RBW}]$
- Sweep time =auto couple
- Do not use sweep triggering; allow sweep to "free run"
- Employ trace averaging(rms) mode over a minimum of 100 traces
- Use the peak marker function to determine the maximum amplitude level
- Add $[10 \log(1/ D)]$, where D is the duty cycle measured in step a), to the measured PSD to

compute the average PSD during the actual transmission time

m) If measured value exceeds requirement specified by regulatory agency then reduce RBW (but no less than 3 kHz) and repeat (note that this may require zooming in on the emission of interest and reducing the span to meet the minimum measurement point requirement as the RBW is reduced)

Test setup



Limits

Rule Part 15.247(e) specifies that "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. "

Limits	$\leq 8 \text{ dBm} / 3\text{kHz}$
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Measurement Uncertainty

The assessed measurement uncertainty to ensure 95% confidence level for the normal distribution is with the coverage factor $k = 2$, $U = 0.75\text{dB}$.

**Test Results:**

Test Mode	Channel Number	Read Value (dBm / 3kHz)	Power Spectral Density (dBm / 3kHz)	Limit (dBm / 3kHz)	Conclusion
802.11b	2412/CH 1	-13.41	-13.41	8	PASS
	2437/CH 6	-14.21	-14.21	8	PASS
	2462/CH11	-13.54	-13.54	8	PASS
802.11g	2412/CH 1	-19.29	-19.29	8	PASS
	2417/CH 2	-17.86	-17.86	8	PASS
	2422/CH 3	-15.53	-15.53	8	PASS
	2427/CH 4	-15.66	-15.66	8	PASS
	2437/CH 6	-15.31	-15.31	8	PASS
	2447/CH 8	-15.25	-15.25	8	PASS
	2452/CH 9	-15.76	-15.76	8	PASS
	2457/CH 10	-18.14	-18.14	8	PASS
	2462/CH 11	-19.50	-19.50	8	PASS
802.11n HT20	2412/CH 1	-19.97	-19.97	8	PASS
	2417/CH 2	-18.34	-18.34	8	PASS
	2422/CH 3	-15.86	-15.86	8	PASS
	2427/CH 4	-15.96	-15.96	8	PASS
	2437/CH 6	-15.54	-15.54	8	PASS
	2447/CH 8	-16.42	-16.42	8	PASS
	2452/CH 9	-16.67	-16.67	8	PASS
	2457/CH 10	-17.79	-17.79	8	PASS
	2462/CH 11	-19.64	-19.64	8	PASS
802.11n HT40	2422/CH 3	-27.06	-26.82	8	PASS
	2427/CH 4	-26.43	-26.19	8	PASS
	2432/CH 5	-26.35	-26.11	8	PASS
	2437/CH 6	-24.45	-24.21	8	PASS
	2442/CH 7	-25.14	-24.90	8	PASS
	2447/CH 8	-26.03	-25.79	8	PASS
	2452/CH 9	-25.84	-25.60	8	PASS
Bluetooth (Low Energy)	2402/CH 0	-15.36	-14.70	8	PASS
	2440/CH 19	-15.98	-15.32	8	PASS
	2480/CH 39	-15.00	-14.34	8	PASS

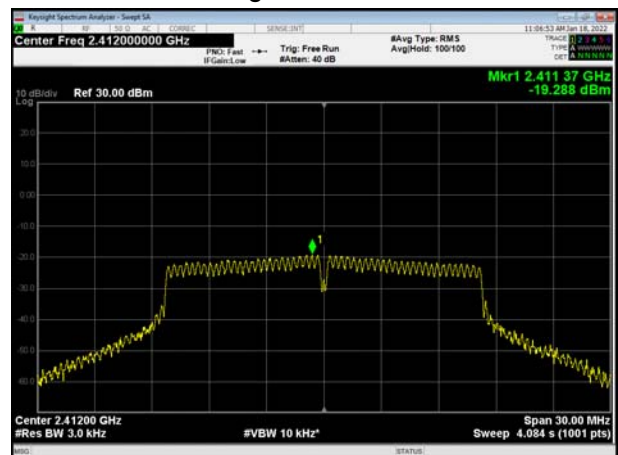
Note: Power Spectral Density =Read Value+Duty cycle correction factor



802.11b, Channel No.: 1



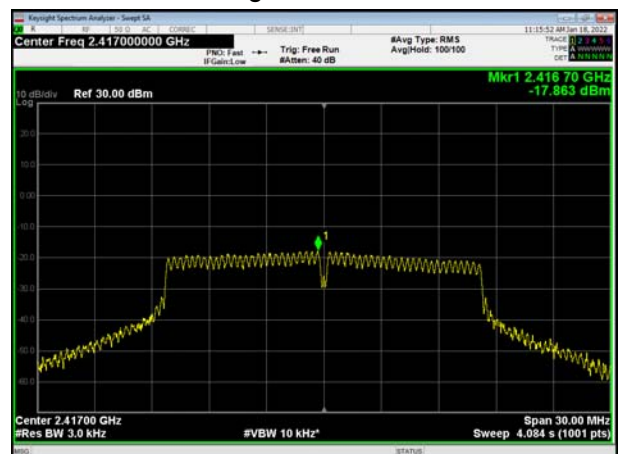
802.11g, Channel No.: 1



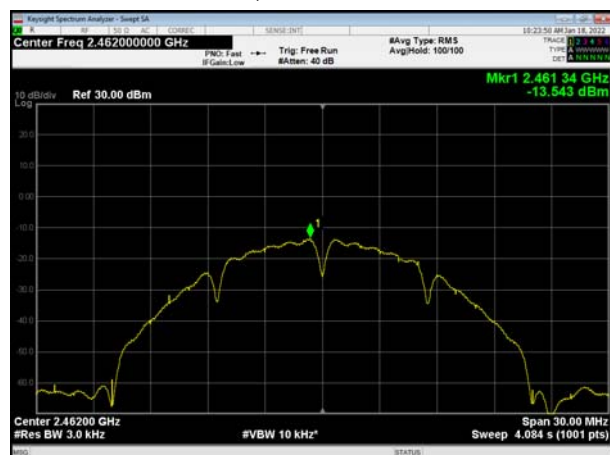
802.11b, Channel No.: 6



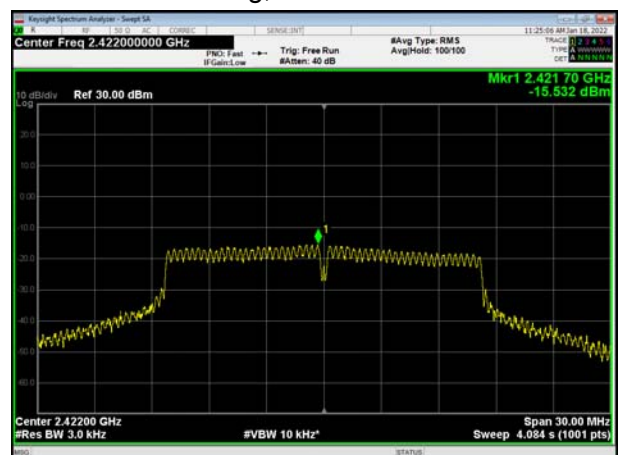
802.11g, Channel No.: 2



802.11b, Channel No.: 11



802.11g, Channel No.: 3





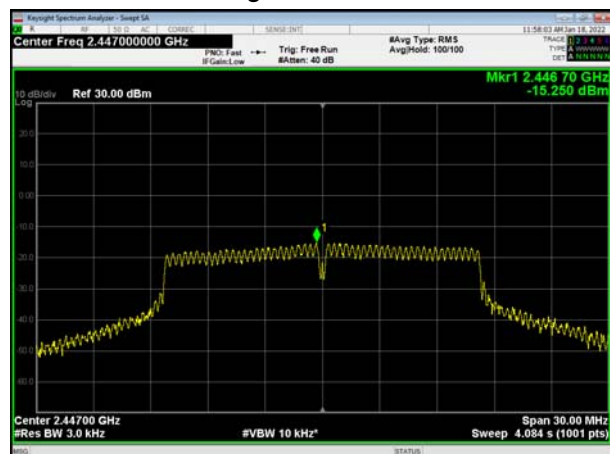
802.11g, Channel No.: 4



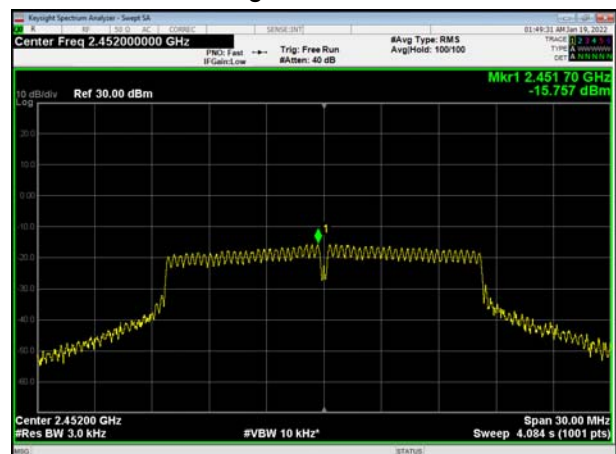
802.11g, Channel No.: 6



802.11g, Channel No.: 8



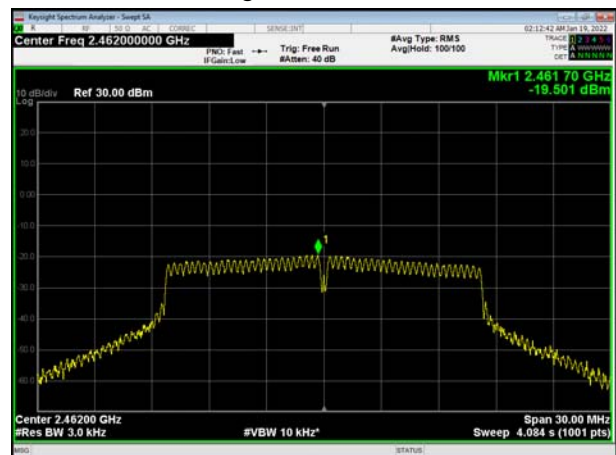
802.11g, Channel No.: 9



802.11g, Channel No.: 10

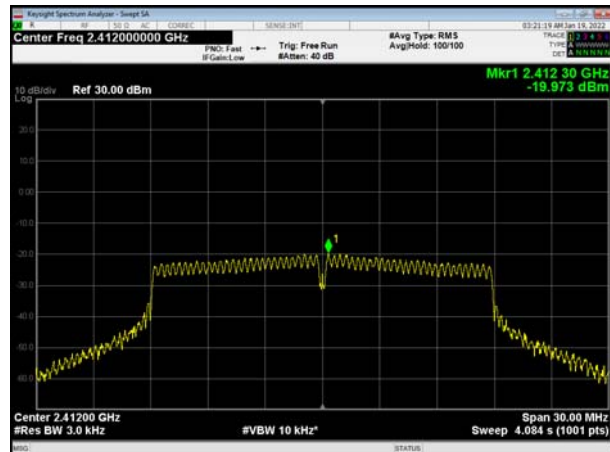


802.11g, Channel No.: 11





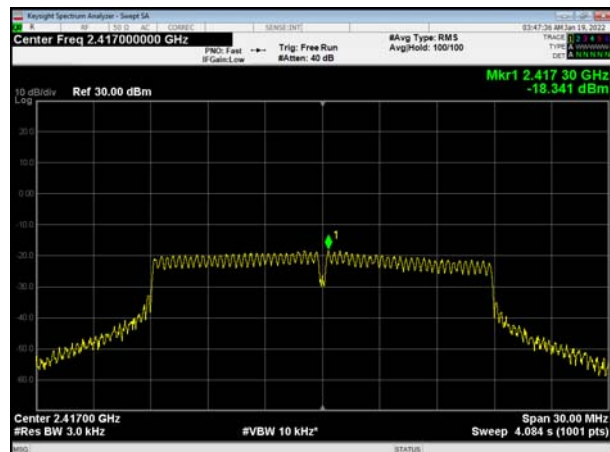
802.11n(HT20), Channel No. 1



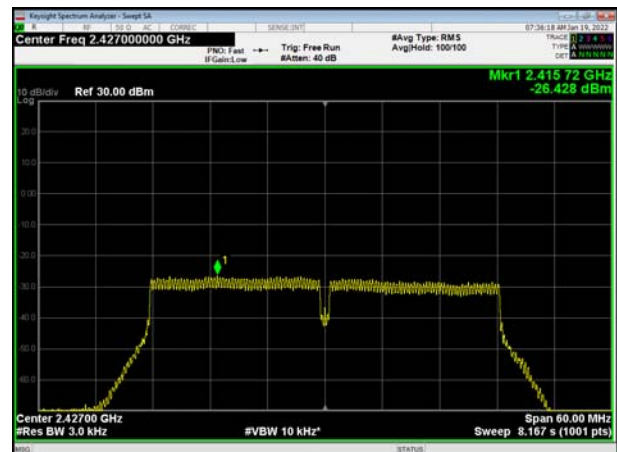
802.11n(HT40), Channel No. 3



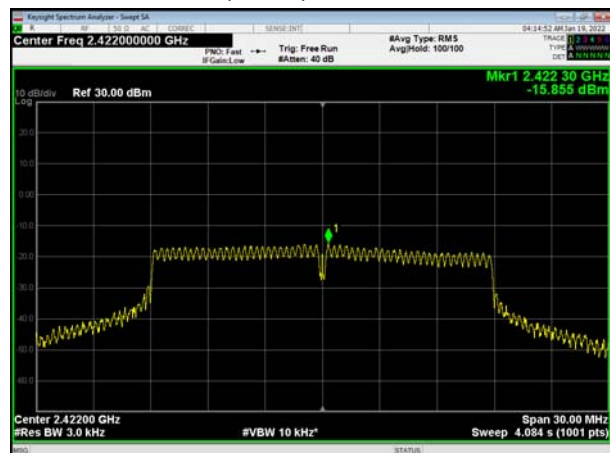
802.11n(HT20), Channel No. 2



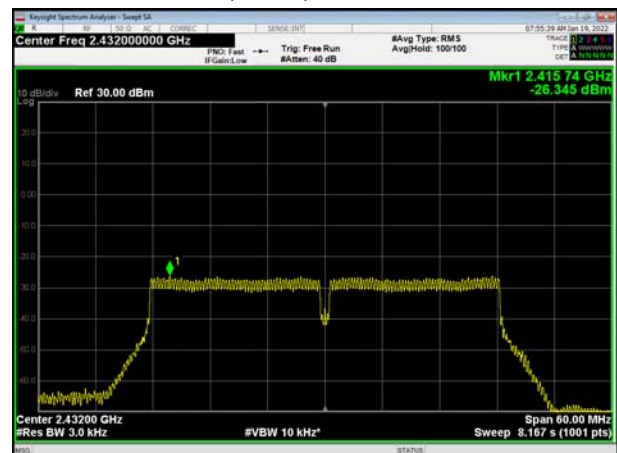
802.11n(HT40), Channel No. 4



802.11n(HT20), Channel No. 3



802.11n(HT40), Channel No. 5

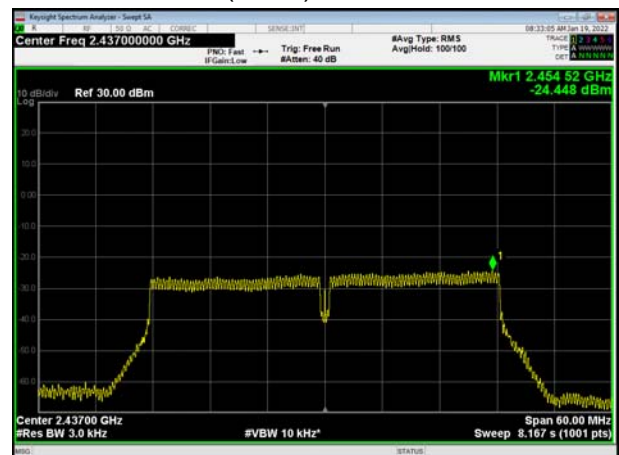




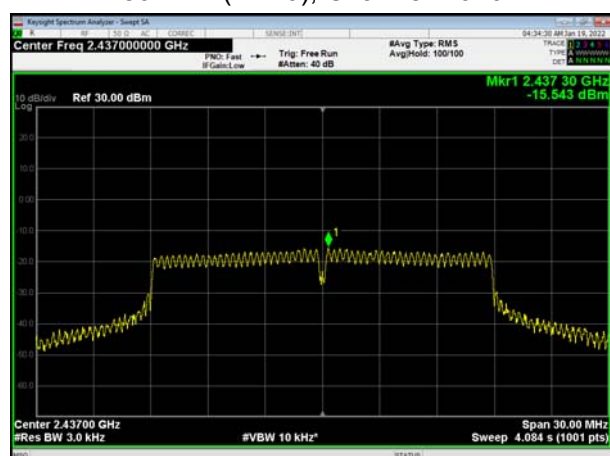
802.11n(HT20), Channel No. 4



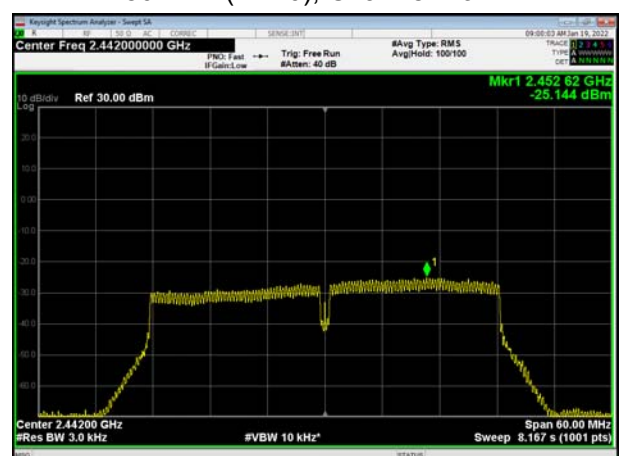
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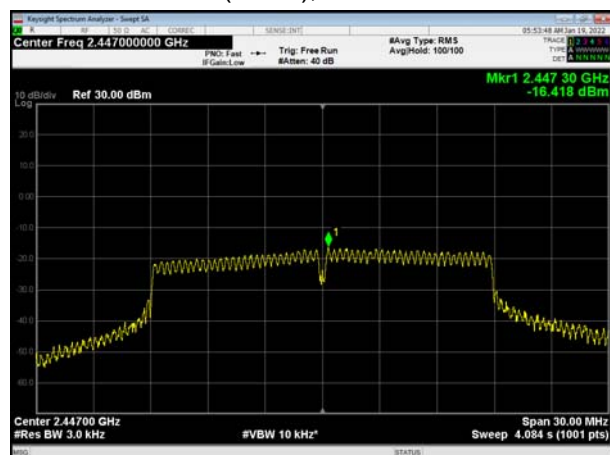
802.11n(HT20), Channel No. 6



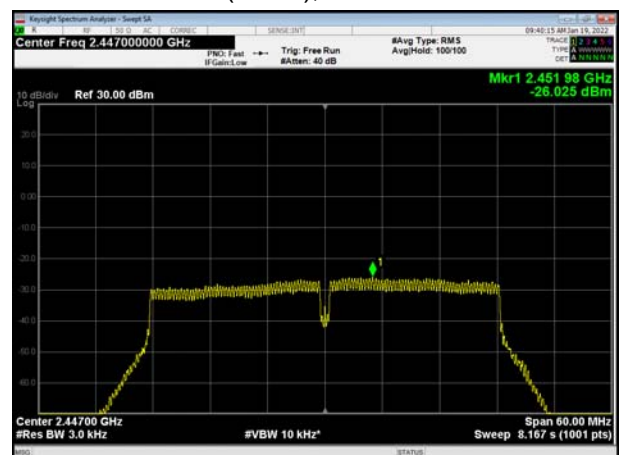
802.11n(HT40), Channel No. 7



802.11n(HT20), Channel No. 8



802.11n(HT40), Channel No. 8





802.11n(HT20), Channel No. 9



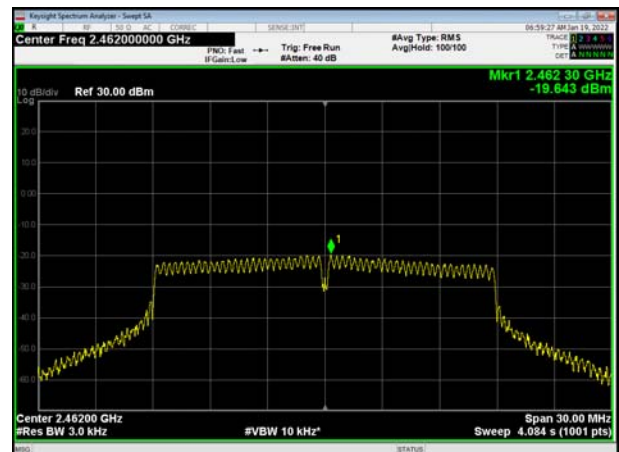
802.11n(HT40), Channel No. 9



802.11n(HT20), Channel No. 10



802.11n(HT20), Channel No. 11

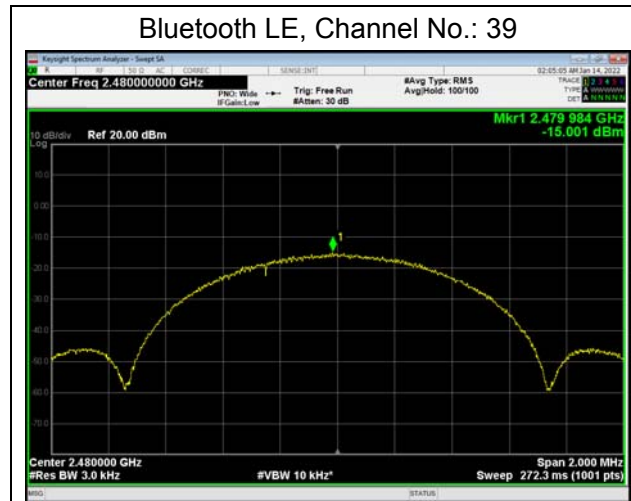


Bluetooth LE, Channel No.: 0



Bluetooth LE, Channel No.: 19





5.5. Spurious RF Conducted Emissions

Ambient condition

Temperature	Relative humidity	Pressure
23°C ~25°C	45%~50%	101.5kPa

Method of Measurement

The EUT was connected to the spectrum analyzer with a known loss. The spectrum analyzer scans from 30MHz to the 10th harmonic of the carrier. The peak detector is used. Set RBW to 100 kHz and VBW to 300 kHz, Sweep is set to ATUO.

The test is in transmitting mode.

Test setup



Limits

Rule Part 15.247(d) pacifies that “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. ”

Antenna 1

Test Mode	Carrier frequency (MHz)	Reference value (dBm)	Limit
802.11b	2412/CH 1	10.56	-19.44
	2437/CH 6	9.96	-20.04
	2462/CH11	10.41	-19.59
802.11g	2412/CH 1	5.66	-24.34
	2417/CH 2	6.46	-23.54
	2422/CH 3	7.50	-22.50
	2427/CH 4	9.13	-20.87
	2437/CH 6	8.43	-21.57
	2447/CH 8	9.29	-20.71
	2452/CH 9	7.93	-22.07
	2457/CH 10	3.82	-26.18

	2462/CH 11	2.40	-27.60
802.11n HT20	2412/CH 1	5.44	-24.56
	2417/CH 2	5.78	-24.22
	2422/CH 3	8.24	-21.76
	2427/CH 4	8.15	-21.85
	2437/CH 6	8.50	-21.50
	2447/CH 8	7.75	-22.25
	2452/CH 9	9.86	-20.14
	2457/CH 10	7.49	-22.51
	2462/CH 11	5.19	-24.81
802.11n HT40	2422/CH 3	-2.97	-32.97
	2427/CH 4	-1.97	-31.97
	2432/CH 5	-1.50	-31.50
	2437/CH 6	0.28	-29.72
	2442/CH 7	-0.54	-30.54
	2447/CH 8	-1.30	-31.30
	2452/CH 9	-1.22	-31.22
Bluetooth (Low Energy)	2402/CH 0	6.31	-23.69
	2440/CH 19	6.00	-24.00
	2480/CH 39	6.90	-23.10

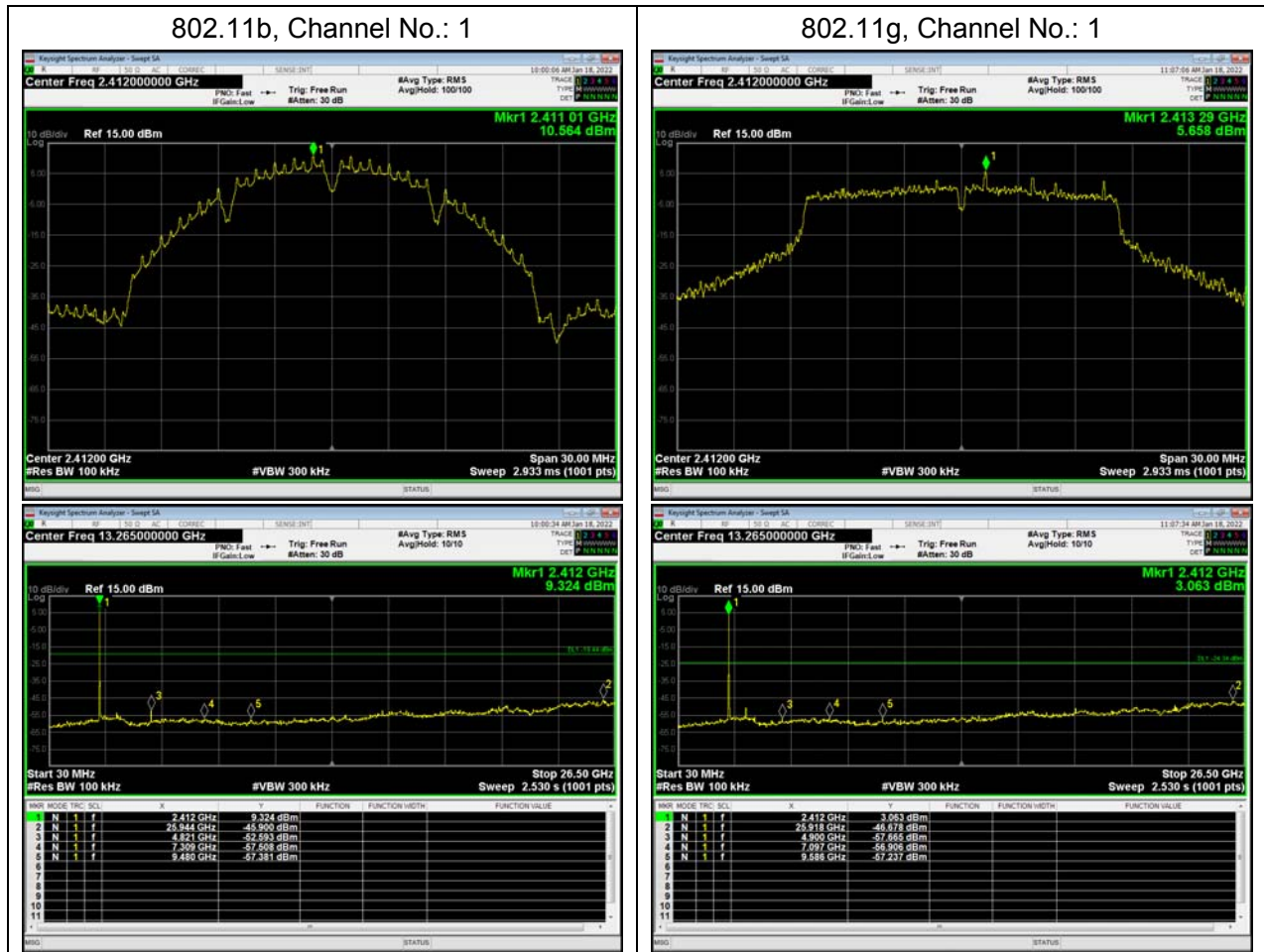
Measurement Uncertainty

The assessed measurement uncertainty to ensure 95% confidence level for the normal distribution is with the coverage factor $k = 1.96$.

Frequency	Uncertainty
100kHz-2GHz	0.684 dB
2GHz-26GHz	1.407 dB



Test Results:





802.11b, Channel No.: 6

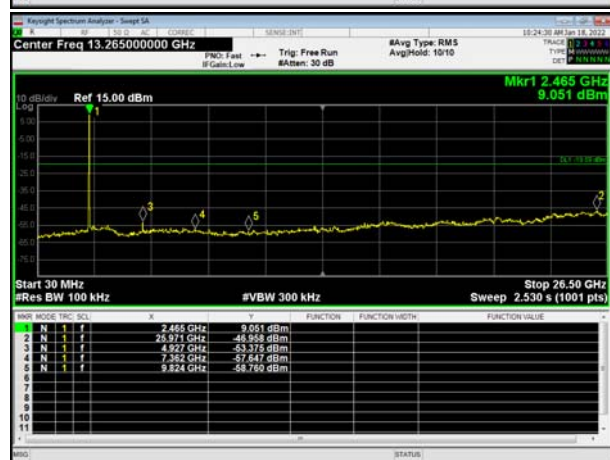


802.11g, Channel No.: 2

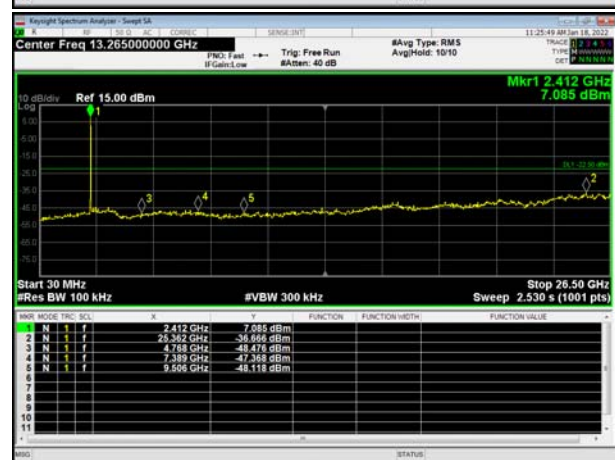




802.11b, Channel No.: 11



802.11g, Channel No.: 3





802.11g, Channel No.: 4

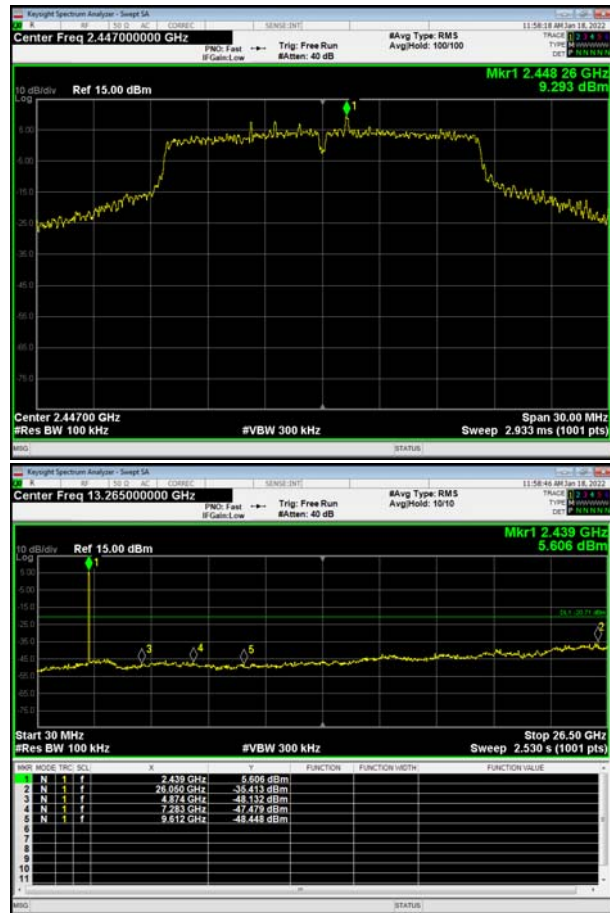


802.11g, Channel No.: 6

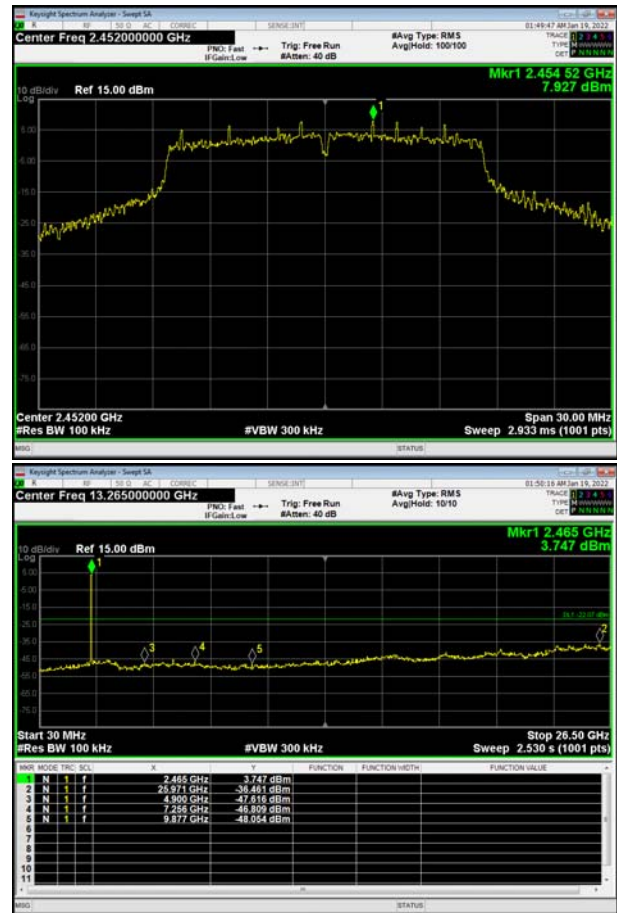




802.11g, Channel No.: 8

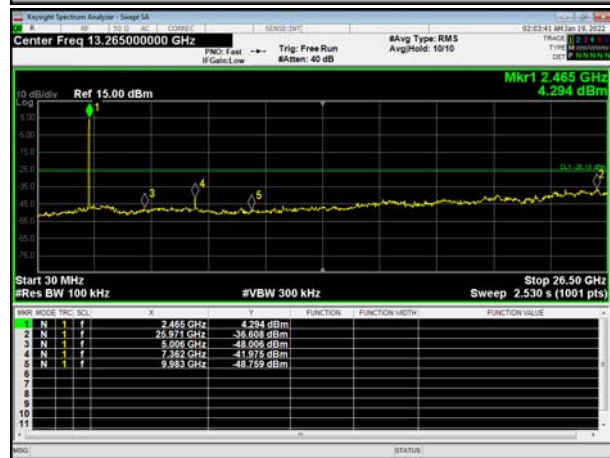


802.11g, Channel No.: 9

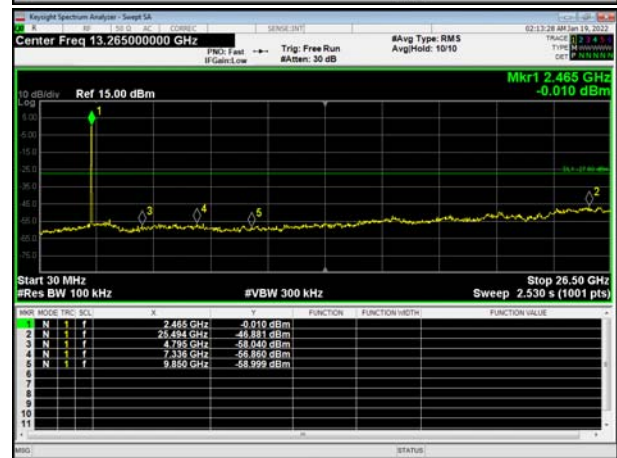




802.11g, Channel No.: 10



802.11g, Channel No.: 11

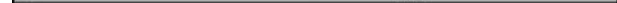




802.11n(HT20), Channel No. 1



802.11n(HT40), Channel No. 3





802.11n(HT20), Channel No. 2

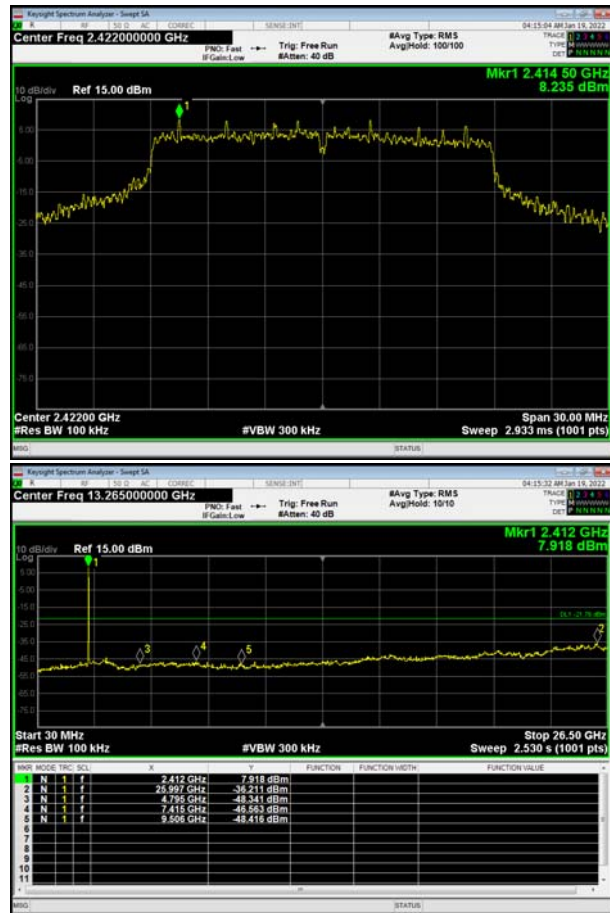


802.11n(HT40), Channel No. 4

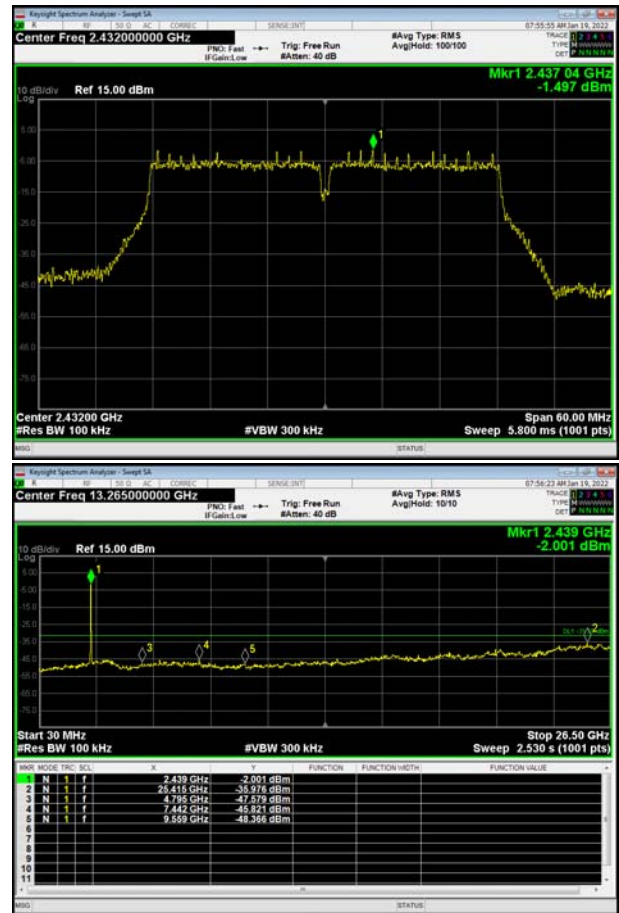




802.11n(HT20), Channel No. 3

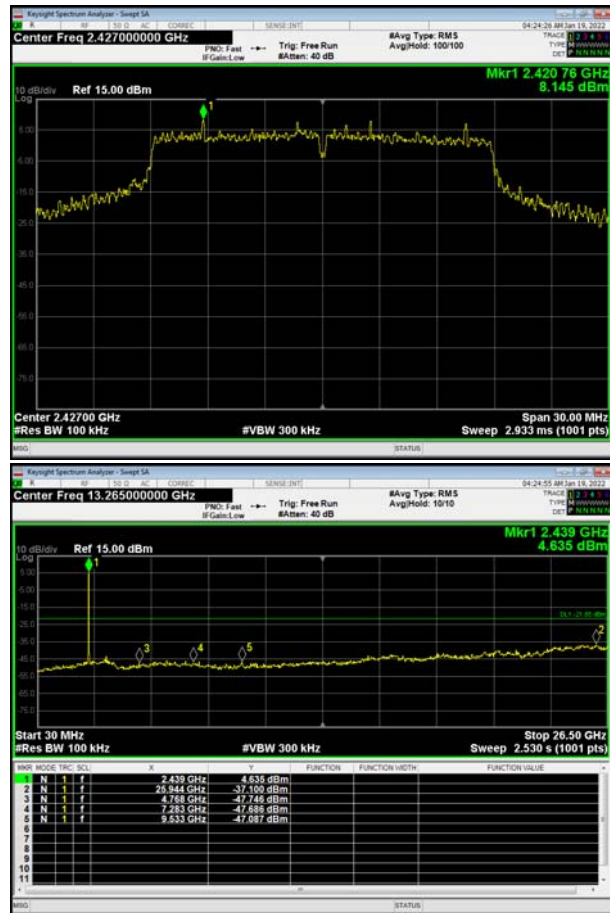


802.11n(HT40), Channel No. 5

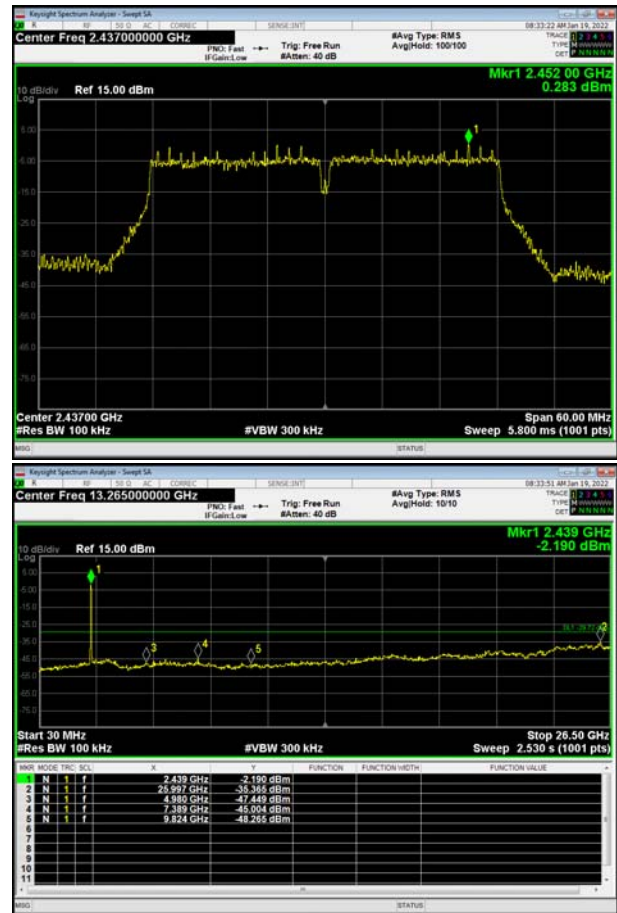




802.11n(HT20), Channel No. 4

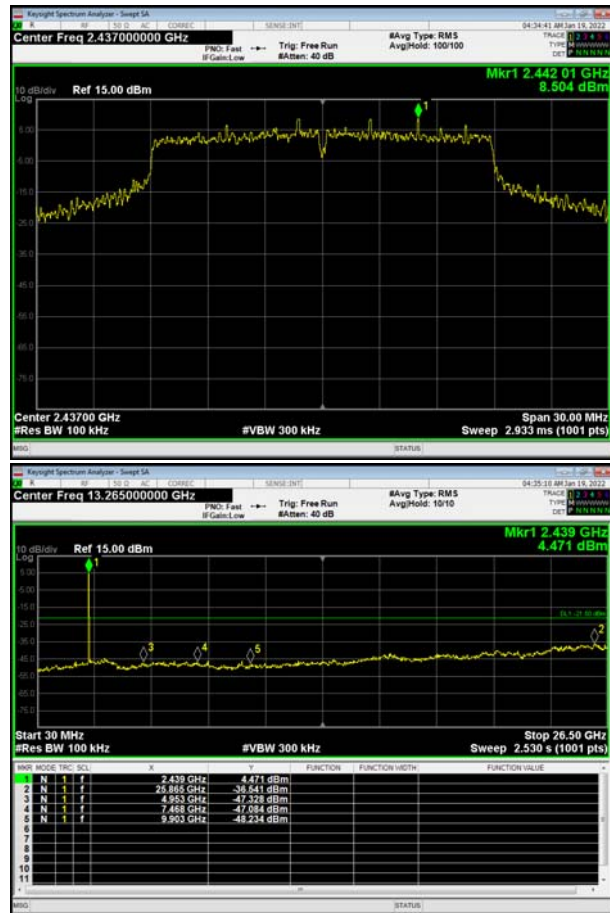


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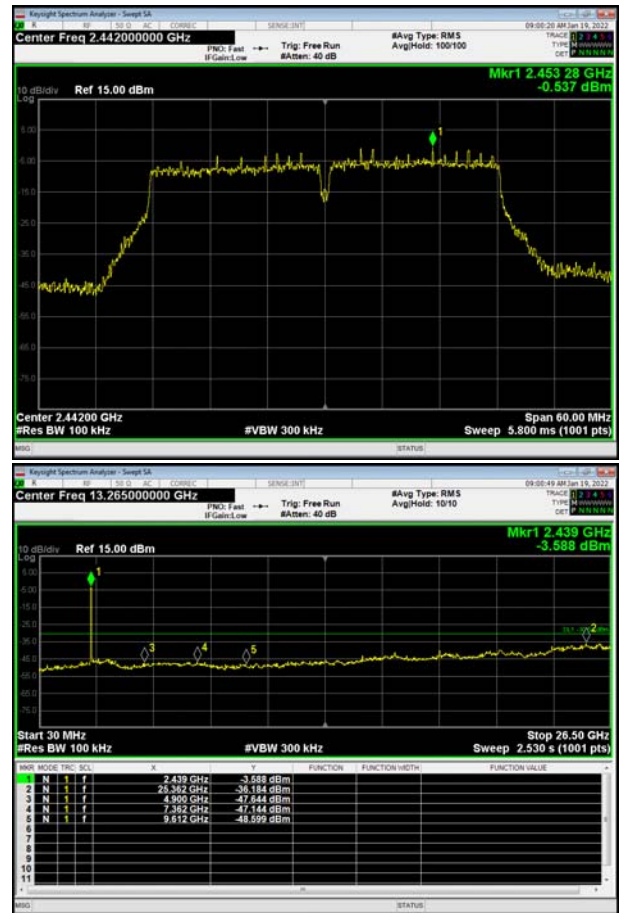




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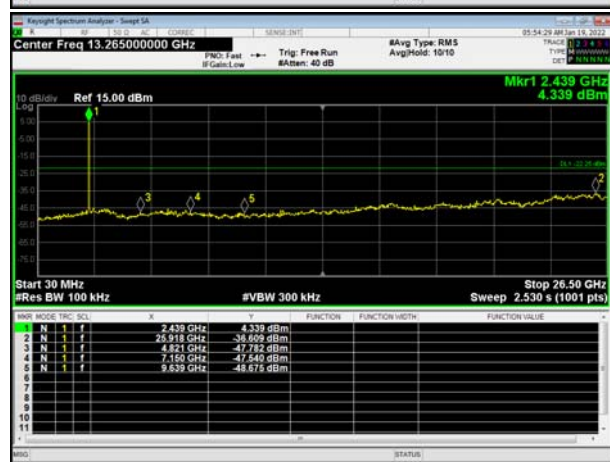


802.11n(HT40), Channel No. 7

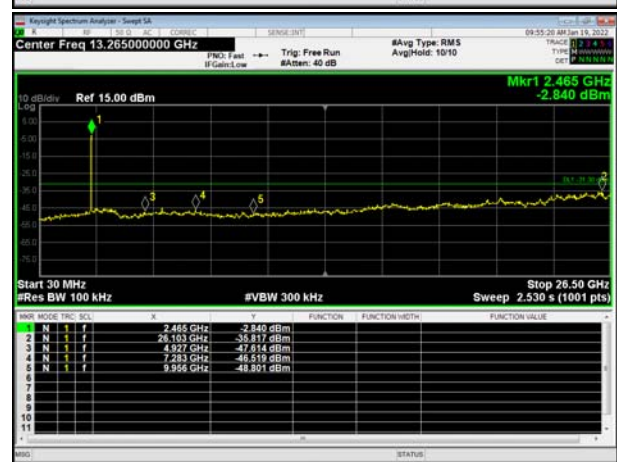




802.11n(HT20), Channel No. 8

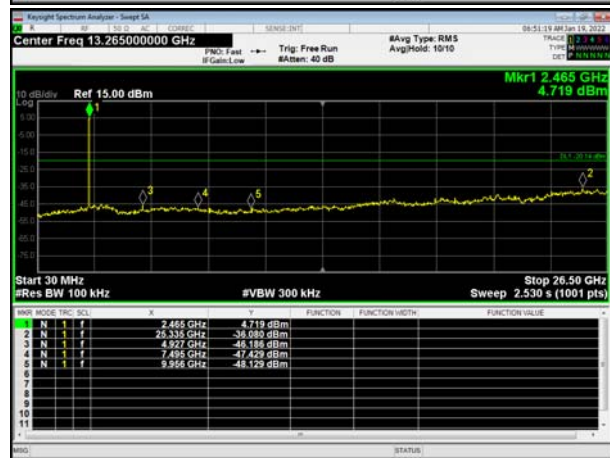


802.11n(HT40), Channel No. 8

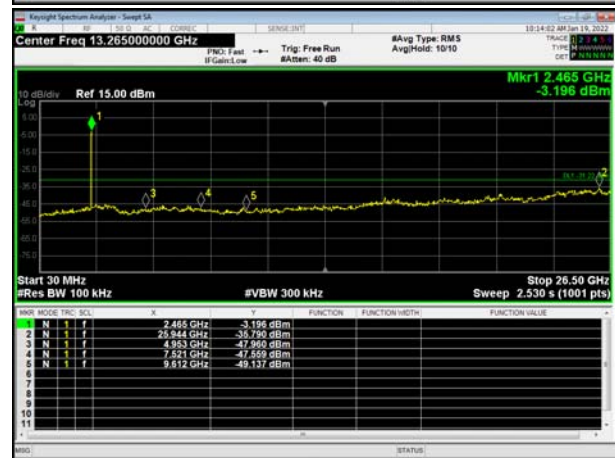




802.11n(HT20), Channel No. 9

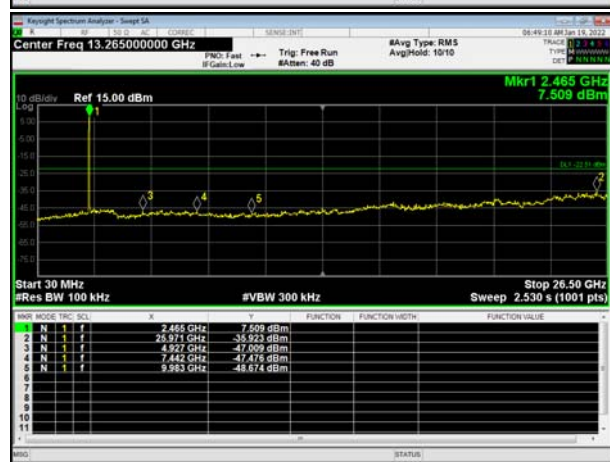


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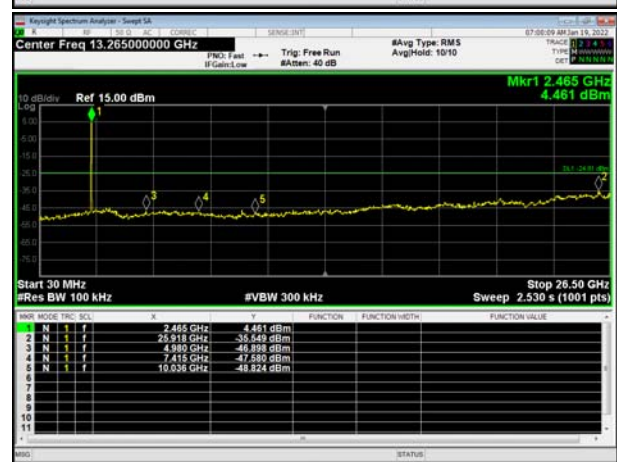




802.11n(HT20), Channel No. 10

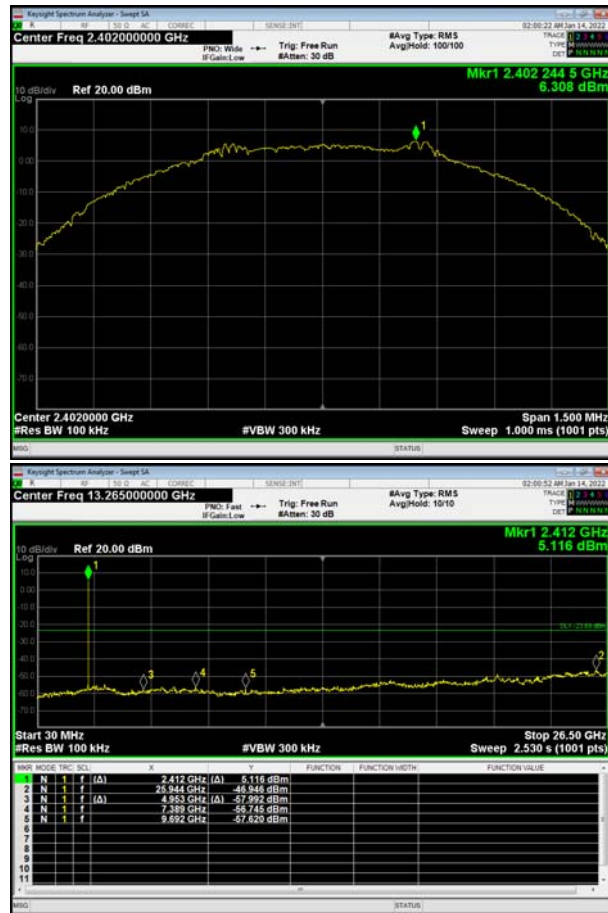


802.11n(HT20), Channel No. 11

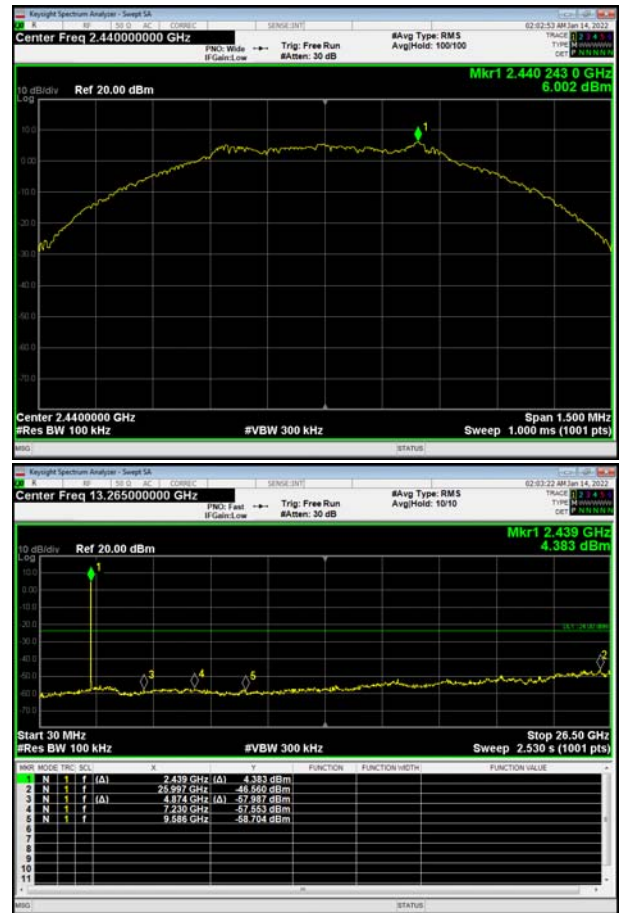




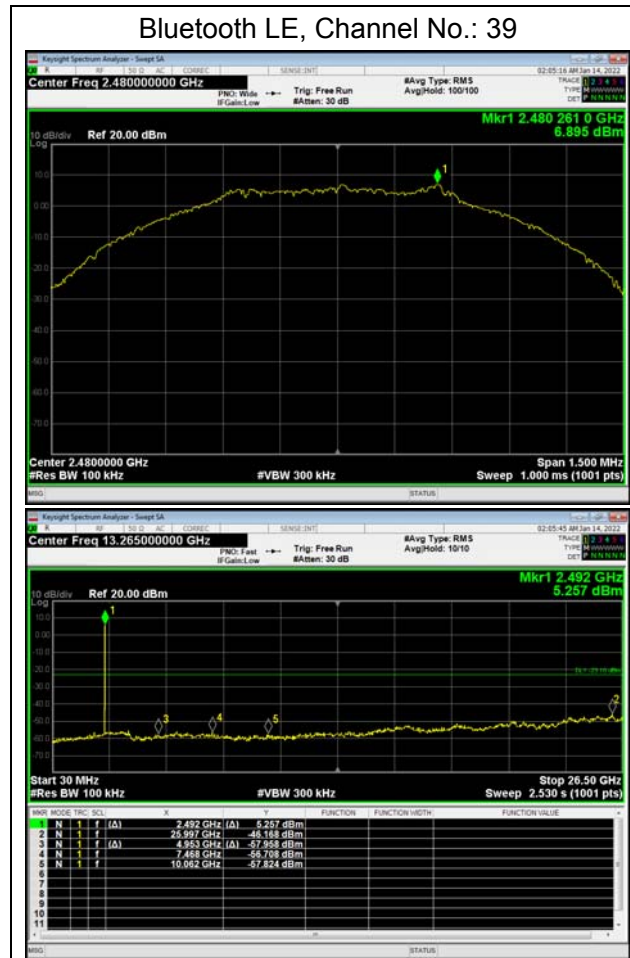
Bluetooth LE, Channel No.: 0



Bluetooth LE, Channel No.: 19



Bluetooth LE, Channel No.: 39



5.6. Unwanted Emission

Ambient condition

Temperature	Relative humidity	Pressure
23°C ~25°C	45%~50%	102.5kPa

Method of Measurement

The test set-up was made in accordance to the general provisions of ANSI C63.10.

The Equipment Under Test (EUT) was set up on a non-conductive table in the semi-anechoic chamber. The test was performed at the distance of 3 m between the EUT and the receiving antenna.

The turntable shall be rotated from 0 to 360 degrees for detecting the maximum of radiated spurious signal level. The measurements shall be repeated with orthogonal polarization of the test antenna. The data of cable loss and antenna factor has been calibrated in full testing frequency range before the testing. Sweep the Restricted Band and the emissions less than 20 dB below the permissible value are reported.

The radiated emissions measurements were made in a typical installation configuration.

Sweep the whole frequency band through the range from 9 kHz to the 10th harmonic of the carrier, and the emissions less than 20 dB below the permissible value are reported.

This method refer to ANSI C63.10.

The procedure for peak unwanted emissions measurements above 1000 MHz is as follows:

Set the spectrum analyzer in the following:

9kHz~150 kHz

RBW=200Hz, VBW=1kHz/ Sweep=AUTO

150 kHz~30MHz

RBW=9KHz, VBW=30KHz,/ Sweep=AUTO

Below 1GHz

RBW=100kHz / VBW=300kHz / Sweep=AUTO

a) Peak emission levels are measured by setting the instrument as follows:

Above 1GHz

PEAK: RBW=1MHz VBW=3MHz/ Sweep=AUTO

b) Average emission levels are measured by setting the instrument as follows:

Above 1GHz

AVERAGE: RBW=1MHz / VBW=3MHz / Sweep=AUTO

c) Detector: The measurements employing a 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.

d) Averaging type = power (i.e., rms) (As an alternative, the detector and averaging type may be set for linear voltage averaging. Some instruments require linear display mode to use linear voltage



averaging. Log or dB averaging shall not be used.)

e) Sweep time = auto.

f) Perform a trace average of at least 100 traces if the transmission is continuous. If the transmission is not continuous, then the number of traces shall be increased by a factor of $1 / D$, where D is the duty cycle. For example, with 50% duty cycle, at least 200 traces shall be averaged. (If a specific emission is demonstrated to be continuous—i.e., 100% duty cycle—then rather than turning ON and OFF with the transmit cycle, at least 100 traces shall be averaged.)

g) If tests are performed with the EUT transmitting at a duty cycle less than 98%, then a correction factor shall be added to the measurement results prior to comparing with the emission limit, to compute the emission level that would have been measured had the test been performed at 100% duty cycle. The correction factor is computed as follows:

1) If power averaging (rms) mode was used in the preceding step e), then the correction factor is $[10 \log (1 / D)]$, where D is the duty cycle. For example, if the transmit duty cycle was 50%, then 3 dB shall be added to the measured emission levels.

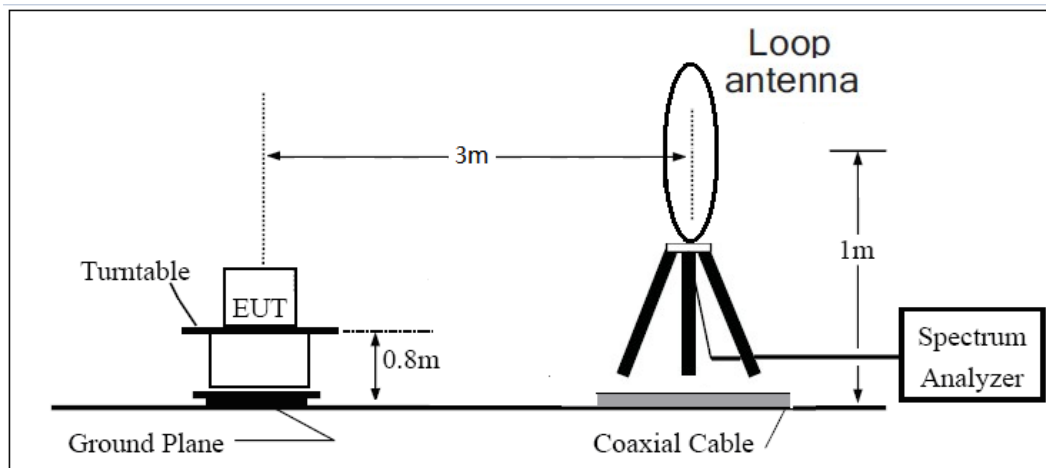
2) If linear voltage averaging mode was used in the preceding step e), then the correction factor is $[20 \log (1 / D)]$, where D is the duty cycle. For example, if the transmit duty cycle was 50%, then 6 dB shall be added to the measured emission levels.

3) If a specific emission is demonstrated to be continuous (100% duty cycle) rather than turning ON and OFF with the transmit cycle, then no duty cycle correction is required for that emission.

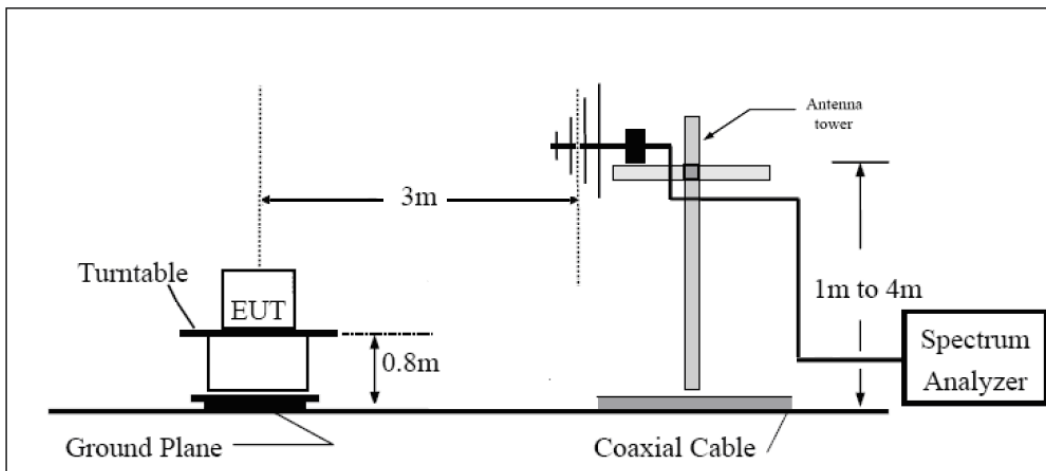
The test is in transmitting mode.

Test setup

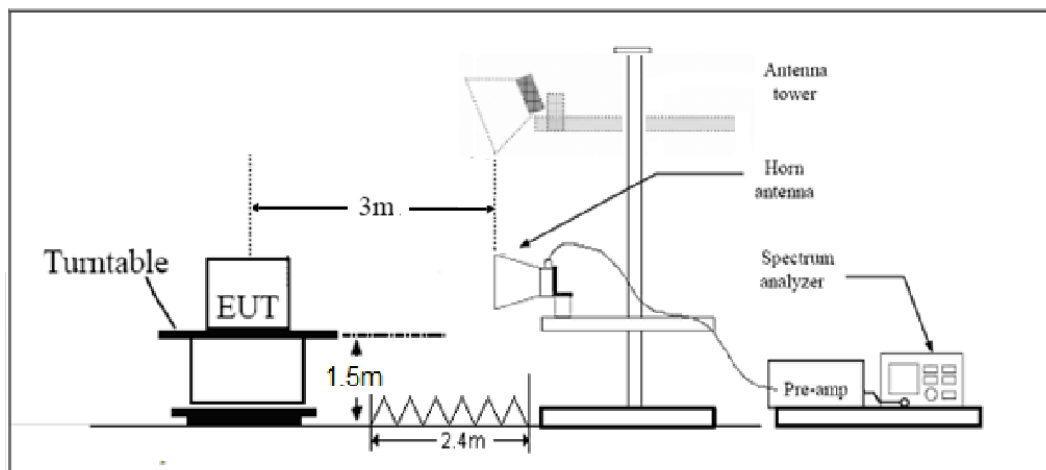
9KHz ~ 30MHz



30MHz ~ 1GHz



Above 1GHz



Note: Area side:2.4mX3.6m

Limits

Rule Part 15.247(d) specifies that “In addition, radiated emissions which fall in the restricted bands, as defined in § 15.205(a), must also comply with the radiated emission limits specified in § 15.209(a) (see § 15.205(c)).”

Limit in restricted band

Frequency of emission (MHz)	Field strength(uV/m)	Field strength(dBuV/m)
0.009–0.490	2400/F(kHz)	/
0.490–1.705	24000/F(kHz)	/
1.705–30.0	30	/
30-88	100	40
88-216	150	43.5
216-960	200	46
Above960	500	54

§15.35(b)

There is also a limit on the radio frequency emissions, as measured using instrumentation with a peak detector function, corresponding to 20 dB above the maximum permitted average limit.

Peak Limit=74 dBuV/m

Average Limit=54 dBuV/m

Spurious Radiated Emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.090-0.110	16.42-16.423	399.9-410	4.5-5.15
¹ 0.495-0.505	16.69475-16.69525	608-614	5.35-5.46
2.1735-2.1905	16.80425-16.80475	960-1240	7.25-7.75
4.125-4.128	25.5-25.67	1300-1427	8.025-8.5
4.17725-4.17775	37.5-38.25	1435-1626.5	9.0-9.2
4.20725-4.20775	73-74.6	1645.5-1646.5	9.3-9.5
6.215-6.218	74.8-75.2	1660-1710	10.6-12.7
6.26775-6.26825	108-121.94	1718.8-1722.2	13.25-13.4
6.31175-6.31225	123-138	2200-2300	14.47-14.5
8.291-8.294	149.9-150.05	2310-2390	15.35-16.2
8.362-8.366	156.52475-156.52525	2483.5-2500	17.7-21.4
8.37625-8.38675	156.7-156.9	2690-2900	22.01-23.12
8.41425-8.41475	162.0125-167.17	3260-3267	23.6-24.0
12.29-12.293	167.72-173.2	3332-3339	31.2-31.8
12.51975-12.52025	240-285	3345.8-3358	36.43-36.5
12.57675-12.57725	322-335.4	3600-4400	(²)
13.36-13.41			

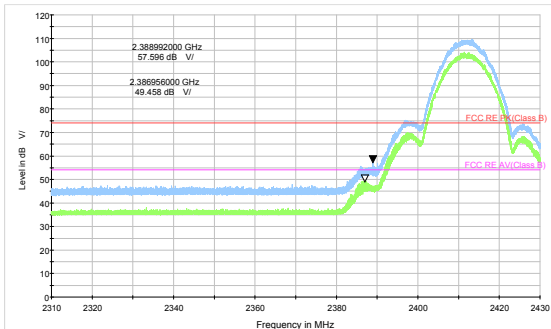
Measurement Uncertainty

The assessed measurement uncertainty to ensure 95% confidence level for the normal distribution is with the coverage factor $k = 1.96$.

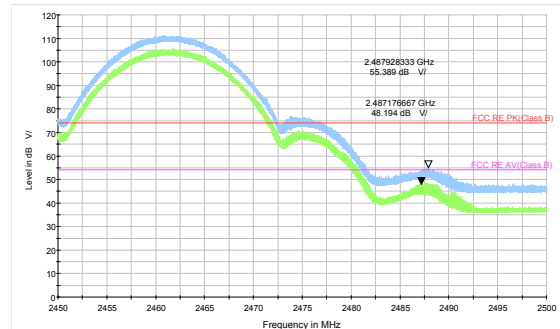
Frequency	Uncertainty
9KHz-30MHz	3.55 dB
30MHz-200MHz	4.17 dB
200MHz-1GHz	4.84 dB
1-18GHz	4.35 dB
18-26.5GHz	5.90 dB
26.5GHz~40GHz	5.92 dB

**Test Results:**

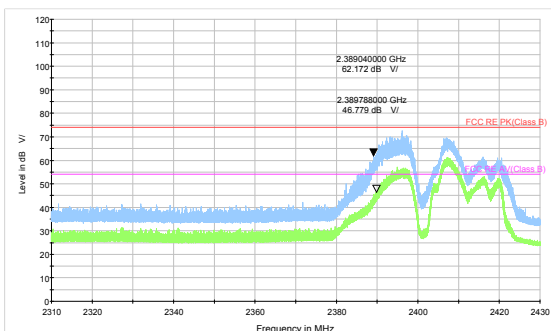
A font (dB μ V/m) in the test plot = (dB μ V/m)



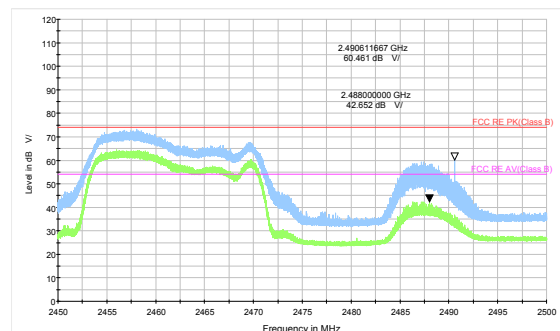
802.11b-Channel 1 Peak+ Average



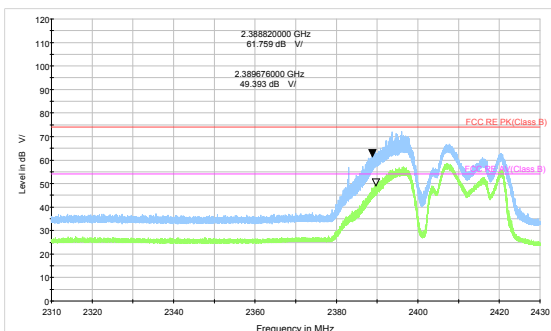
802.11b-Channel 11 Peak+ Average



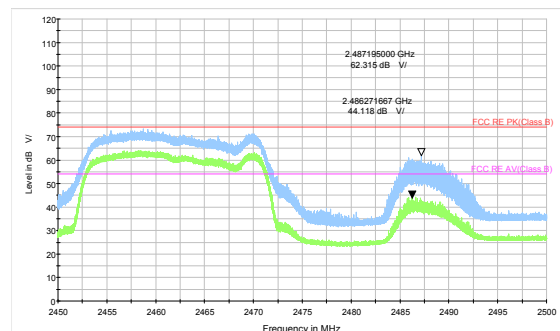
802.11g-Channel 1 Peak+ Average



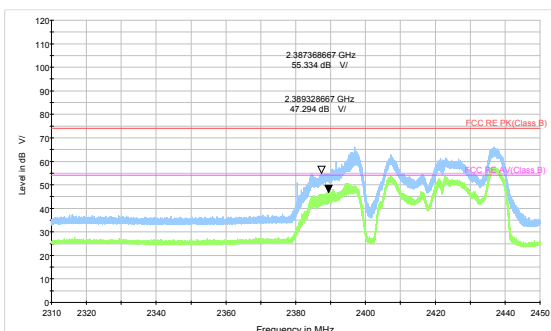
802.11g-Channel 11 Peak+ Average



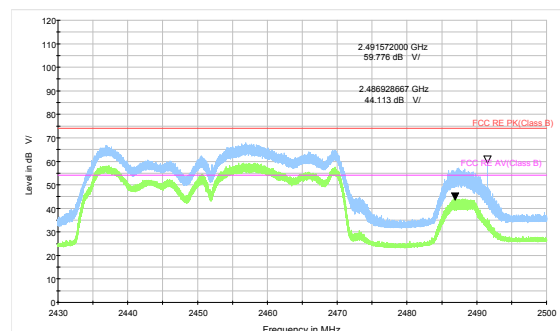
802.11n HT20 -Channel 1 Peak+ Average



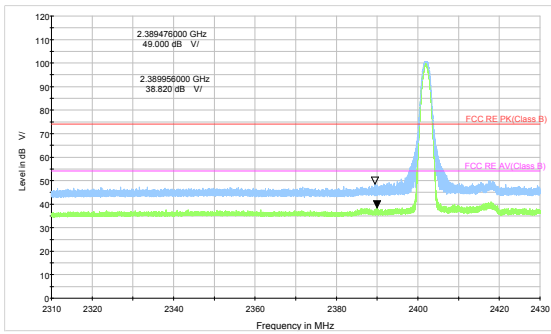
802.11n HT20 -Channel 11 Peak+ Average



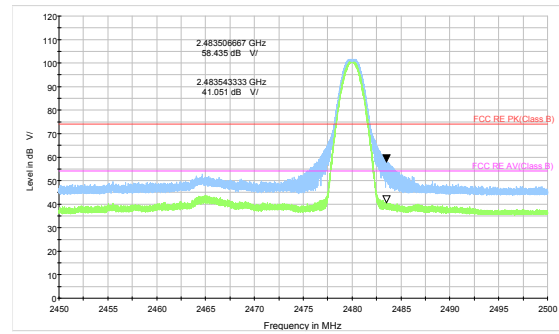
802.11n HT40 -Channel 3 Peak+ Average



802.11n HT40 -Channel 9 Peak+ Average



Bluetooth LE Channel 0 Peak+Average



Bluetooth LE Channel 39 Peak+Average

Result of RE

Test result

Sweep the whole frequency band through the range from 9kHz to the 10th harmonic of the carrier, the Emissions in the frequency band 9kHz-30MHz and 18GHz-26.5GHz are more than 20dB below the limit are not reported.

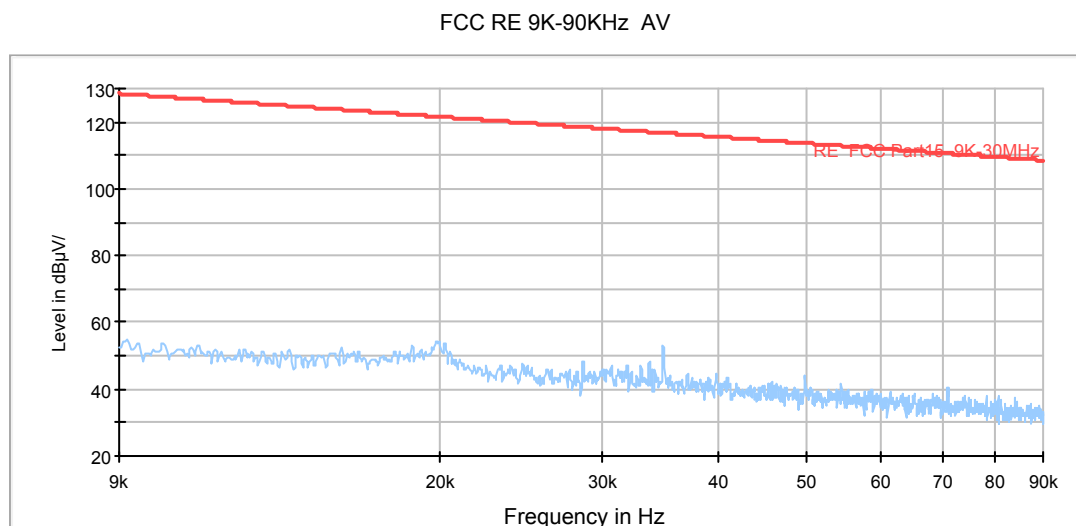
The following graphs display the maximum values of horizontal and vertical by software.
For above 1GHz, Blue trace uses the peak detection, Green trace uses the average detection.

During the test, the Radiates Emission from 30MHz to 1GHz was performed in all modes with all channels, 802.11g CH6 and Bluetooth LE-Channel 0 are selected as the worst condition. The test data of the worst-case condition was recorded in this report.

A font (Level in dBμV/) in the test plot =(level in dB μ V/m)

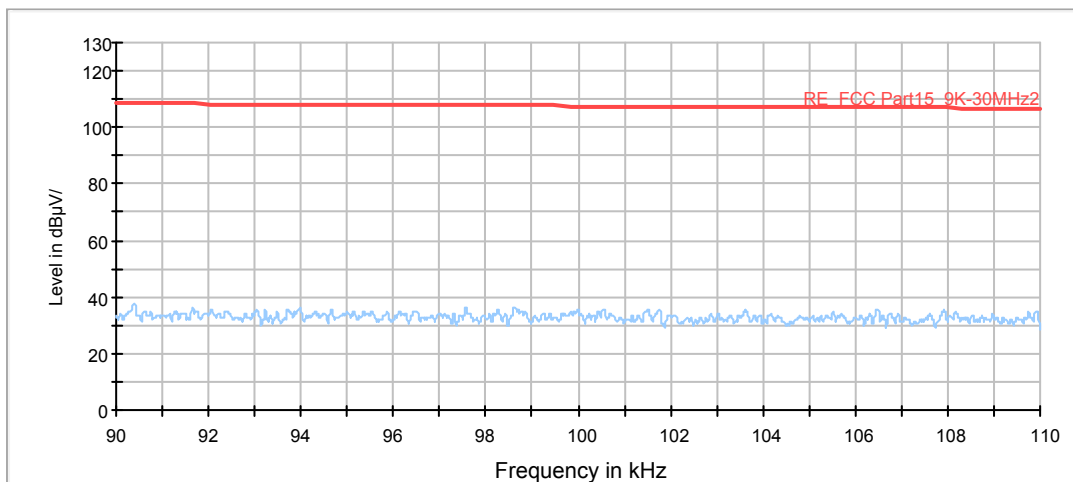
A font (dB V/) in the test plot =(dB μ V/m)

Continuous TX mode:



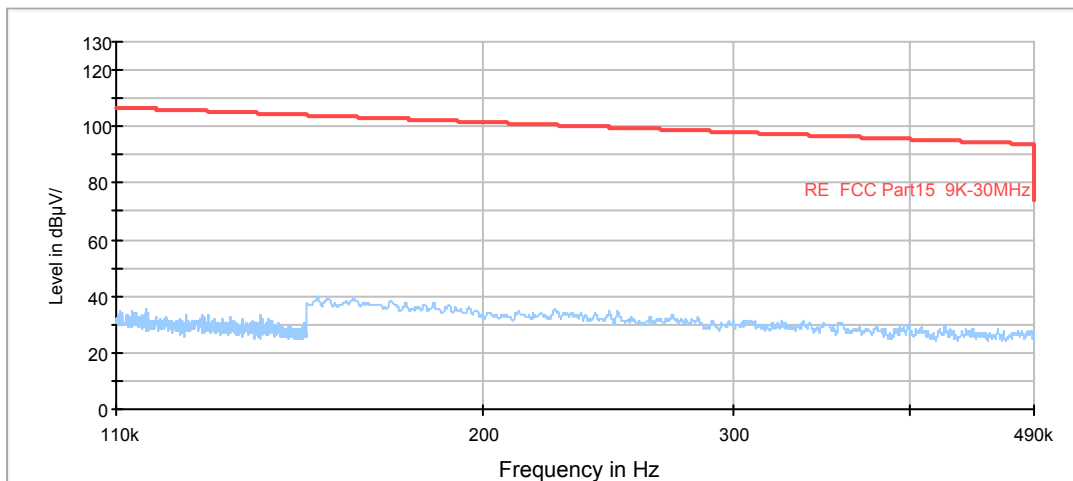
Radiates Emission from 9KHz to 90KHz

FCC RE 90K-110KHz QP



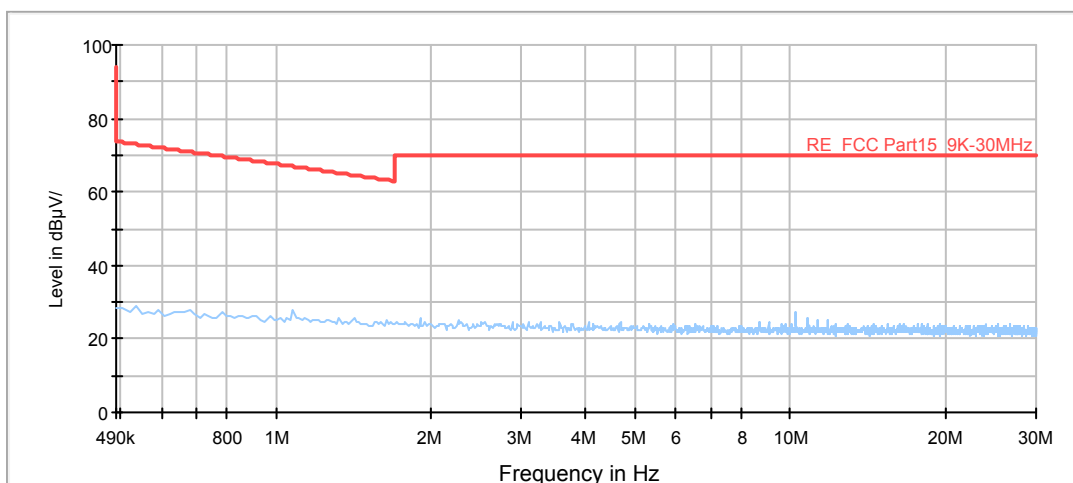
Radiates Emission from 90KHz to 110KHz

FCC RE 110K-490KHz AV



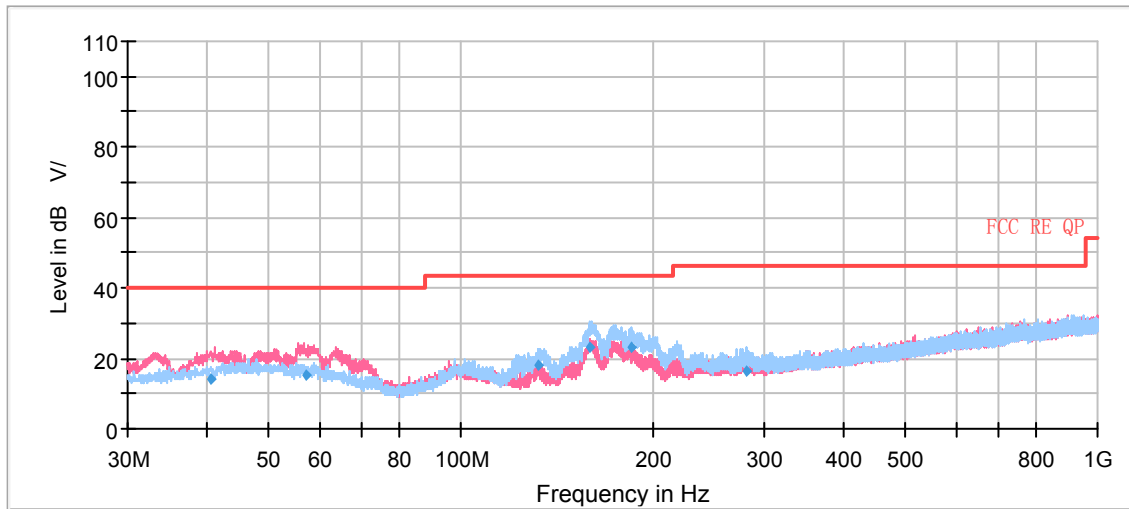
Radiates Emission from 110KHz to 490KHz

FCC RE 490K-30MHz QP



Radiates Emission from 490KHz to 30MHz

Wi-Fi 2.4G:



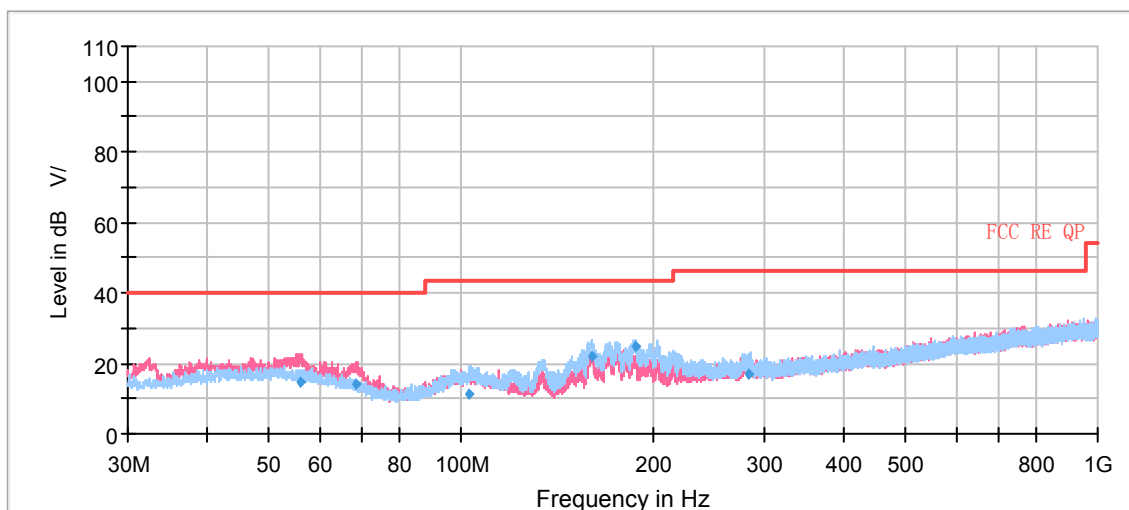
Radiates Emission from 30MHz to 1GHz

Frequency (MHz)	Quasi-Peak (dBuV/m)	Height (cm)	Polarization	Azimuth (deg)	Correct Factor (dB)	Margin (dB)	Limit (dBuV/m)
40.635000	14.33	100.0	V	13.0	20	25.67	40.00
57.082667	15.49	110.0	V	0.0	20	24.51	40.00
132.801333	18.06	225.0	H	85.0	15	25.44	43.50
159.879667	23.26	175.0	H	237.0	15	20.24	43.50
185.311333	23.08	175.0	H	83.0	17	20.42	43.50
281.631667	16.19	110.0	H	64.0	20	29.81	46.00

Remark: 1. Correction Factor = Antenna factor+ Insertion loss(cable loss+amplifier gain)

2. Margin = Limit – Quasi-Peak

Bluetooth LE:



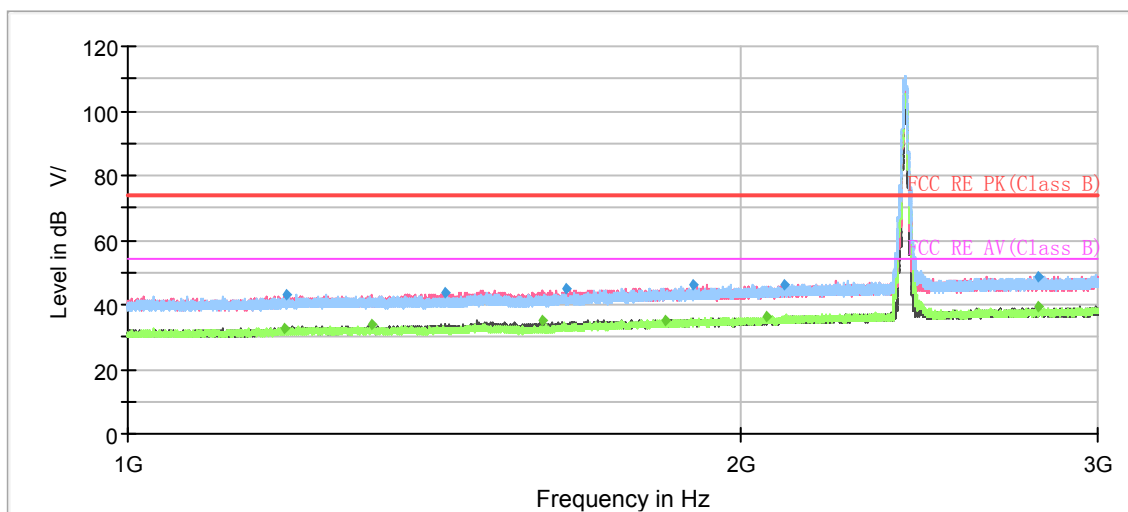
Radiates Emission from 30MHz to 1GHz

Frequency (MHz)	Quasi-Peak (dBuV/m)	Height (cm)	Polarization	Azimuth (deg)	Correct Factor (dB)	Margin (dB)	Limit (dBuV/m)
55.874333	14.75	100.0	V	88.0	20	25.25	40.00
68.531000	13.94	100.0	V	21.0	17	26.06	40.00
103.287000	11.54	210.0	H	244.0	19	31.96	43.50
160.832667	22.27	184.0	H	76.0	15	21.23	43.50
187.704000	24.86	175.0	H	76.0	17	18.64	43.50
283.764667	17.12	100.0	H	60.0	20	28.88	46.00

Remark: 1. Correction Factor = Antenna factor+ Insertion loss(cable loss+amplifier gain)

2. Margin = Limit – Quasi-Peak

802.11b CH1

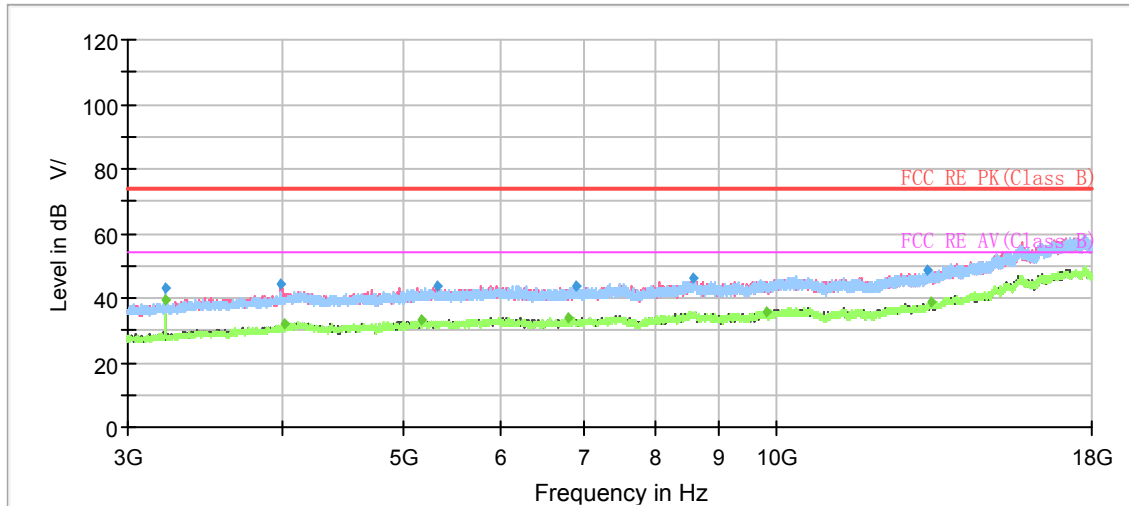


Note: The signal beyond the limit is carrier.

Radiates Emission from 1GHz to 3GHz

Frequency (MHz)	MaxPeak (dB μ V/m)	Average (dB μ V/m)	Limit (dB μ V/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1193.133333	---	32.86	54.00	21.14	200.0	H	0.0	-8
1196.066667	43.15	---	74.00	30.85	100.0	V	185.0	-8
1317.733333	---	33.75	54.00	20.25	200.0	H	104.0	-7
1432.333333	43.57	---	74.00	30.43	100.0	V	266.0	-6
1600.066667	---	35.08	54.00	18.92	100.0	V	185.0	-5
1641.666667	44.77	---	74.00	29.23	100.0	V	2.0	-5
1839.133333	---	35.33	54.00	18.67	100.0	V	38.0	-4
1897.533333	46.11	---	74.00	27.89	100.0	V	68.0	-4
2060.600000	---	36.30	54.00	17.70	100.0	H	119.0	-3
2105.333333	45.95	---	74.00	28.05	200.0	V	268.0	-2
2802.333333	---	39.60	54.00	14.40	200.0	H	82.0	1
2803.333333	48.82	---	74.00	25.18	200.0	H	0.0	1

Remark: 1. Correction Factor = Antenna factor+ Insertion loss (cable loss + amplifier gain)



Radiates Emission from 3GHz to 18GHz

Frequency (MHz)	MaxPeak (dB μ V/m)	Average (dB μ V/m)	Limit (dB μ V/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
3216.000000	---	39.51	54.00	14.49	100.0	H	309.0	-8
3216.000000	42.95	---	74.00	31.05	200.0	H	307.0	-8
3985.000000	44.01	---	74.00	29.99	200.0	V	251.0	-4
4020.500000	---	32.11	54.00	21.89	200.0	V	344.0	-4
5179.500000	---	33.21	54.00	20.79	200.0	H	323.0	-1
5327.000000	43.42	---	74.00	30.58	200.0	H	220.0	-1
6801.000000	---	34.00	54.00	20.00	200.0	H	189.0	0
6913.500000	43.94	---	74.00	30.06	200.0	H	58.0	1
8583.000000	46.12	---	74.00	27.88	100.0	V	208.0	4
9848.000000	---	35.95	54.00	18.05	200.0	V	171.0	4
13254.000000	48.73	---	74.00	25.27	200.0	V	227.0	9
13348.500000	---	38.91	54.00	15.09	200.0	H	58.0	9

Remark: 1. Correction Factor = Antenna factor+ Insertion loss (cable loss + amplifier gain)