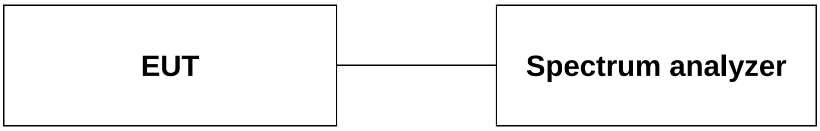
8. 20 ㏈ bandwidth measurement & 99 % bandwidth measurement

8.1. Test setup



8.2. Limit

Not applicable

8.3. Test procedure

1. The 20 ㏈ band width was measured with a spectrum analyzer connected to RF antenna connector (conducted measurement) while EUT was operating in transmit mode at the appropriate center frequency. The analyzer center frequency was set to the EUT carrier frequency, using the analyzer. Display Line and Marker Delta functions, the 20 ㏈ band width of the emission was determined.
2. The bandwidth of the fundamental frequency was measured with the spectrum analyzer using RBW ≥ 10 ㎑, VBW ≥ 10 ㎑, Span = 5 ㎒.

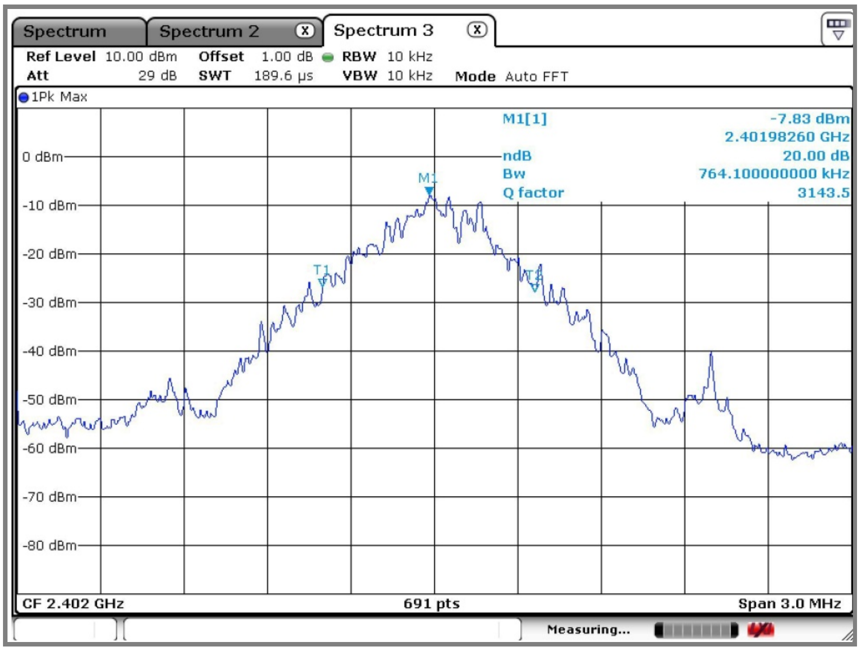
8.4. Test results

Ambient temperature: 22 ℃
Relative humidity: 55 % R.H.

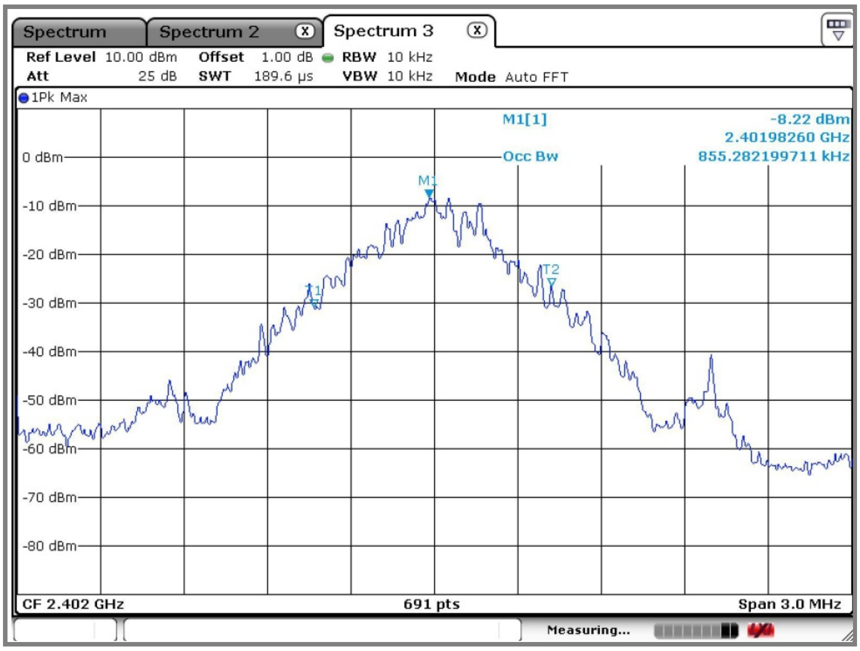
Operation mode	Frequency(㎒)	20 ㏈ bandwidth(㎒)	99 % bandwidth(㎒)
BDR mode	2 402	0.764	0.855
	2 441	0.760	0.851
	2 480	0.764	0.855
EDR mode	2 402	1.216	1.190
	2 441	1.242	1.172
	2 480	1.263	1.177

Operation mode: BDR mode

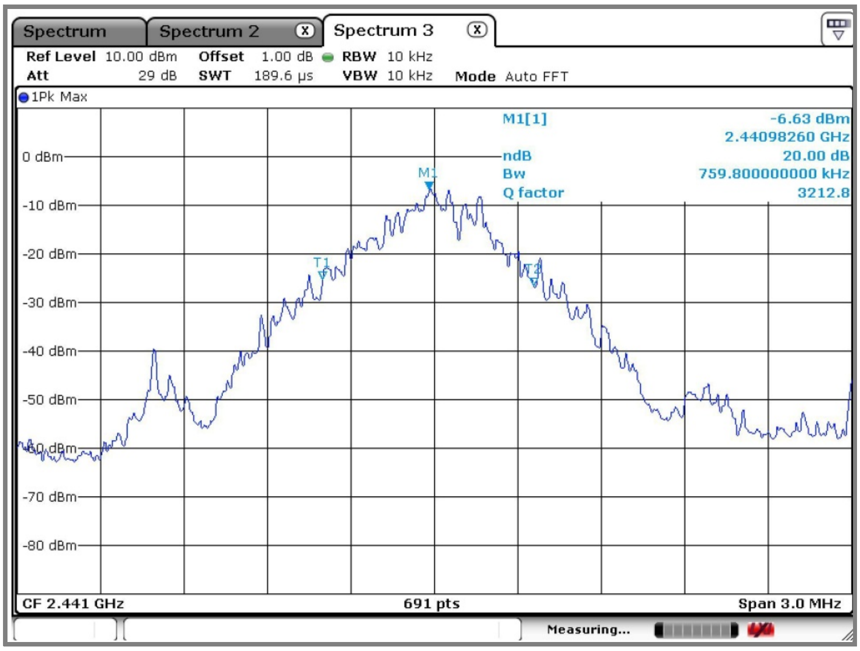
A. Low channel (2 402 ㎒) – 20 ㏈ bandwidth



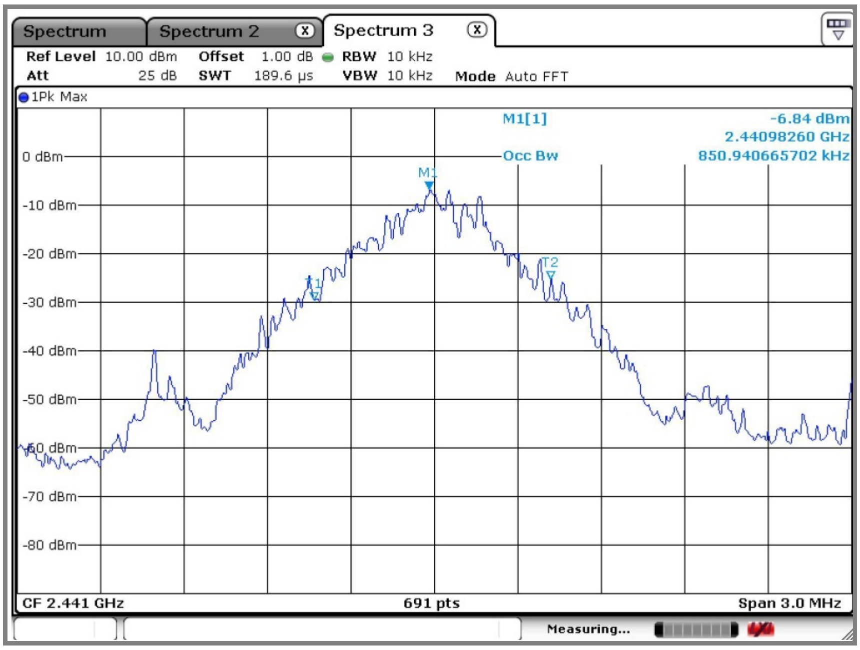
A. Low channel (2 402 ㎒) – 99 % bandwidth



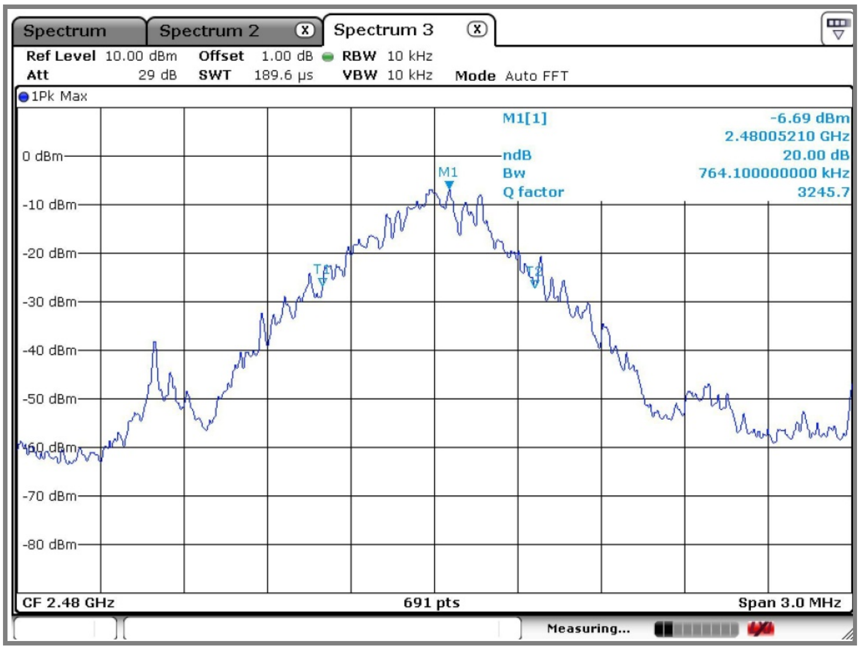
B. Middle channel (2 441 ㎒) – 20 ㏈ bandwidth



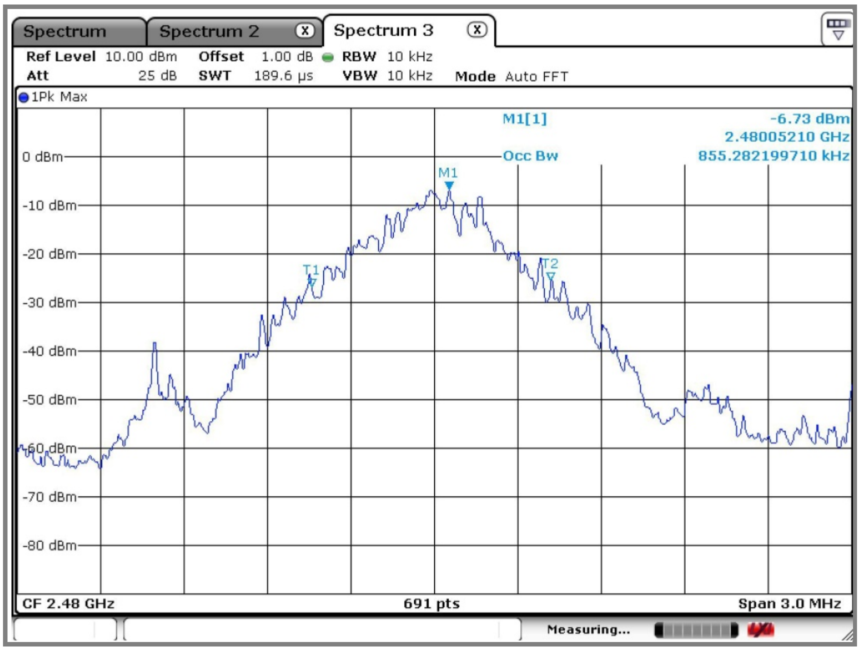
B. Middle channel (2 441 ㎒) – 99 % bandwidth



C. High channel (2 480 ㎒) – 20 ㏈ bandwidth

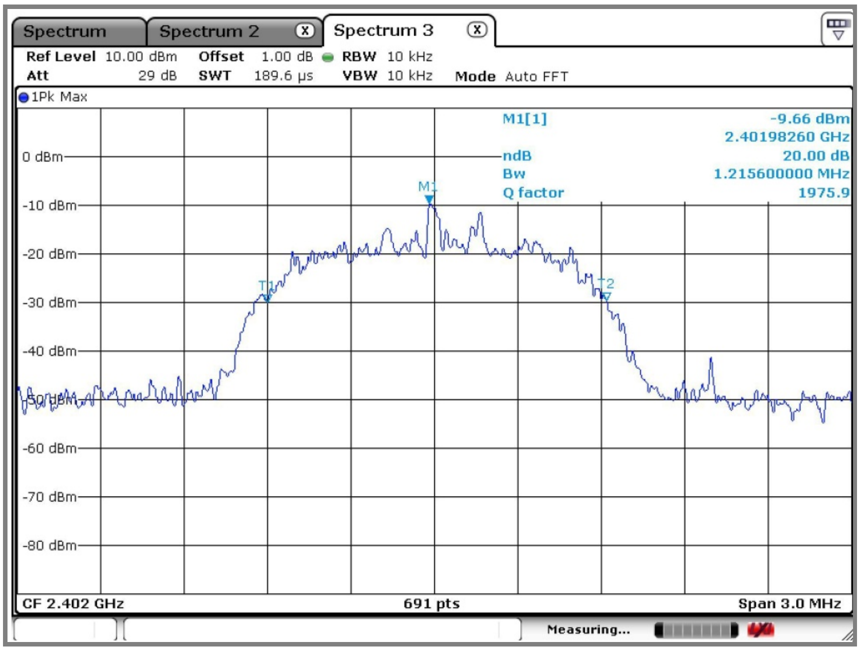


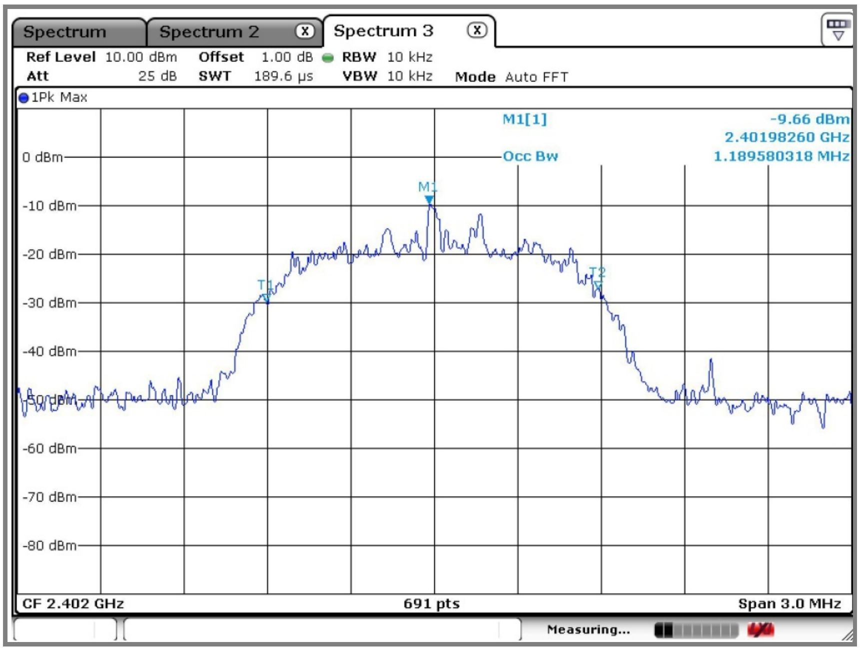
C. High channel (2 480 ㎒) – 99 % bandwidth



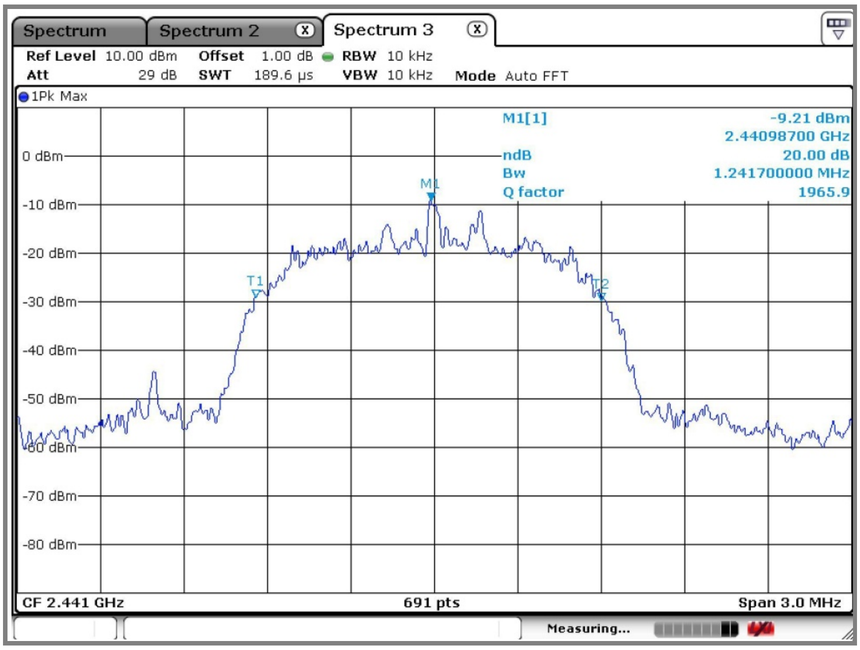
Operation mode: EDR mode

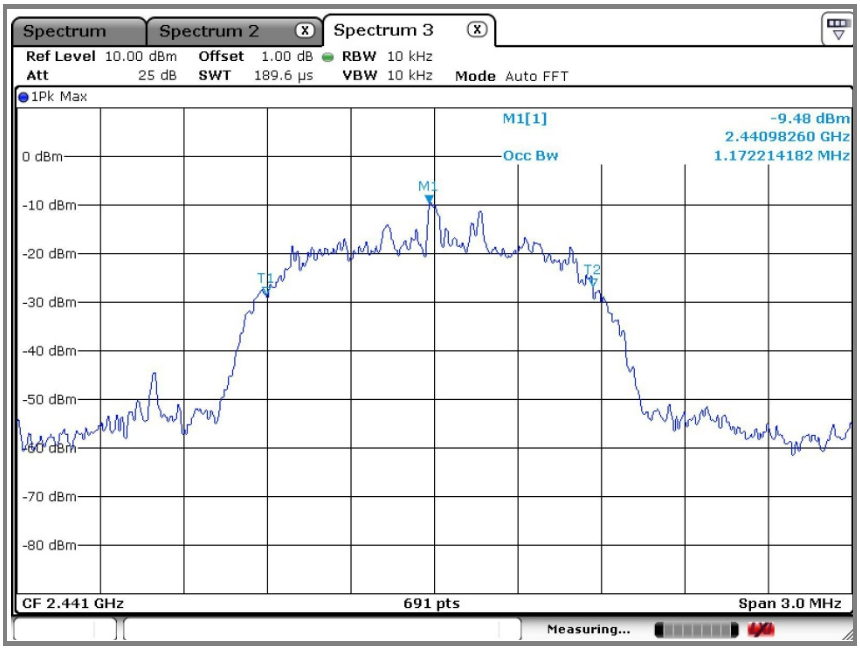
A. Low channel (2 402 ㎒)– 20 ㏈ bandwidth & 99 % bandwidth



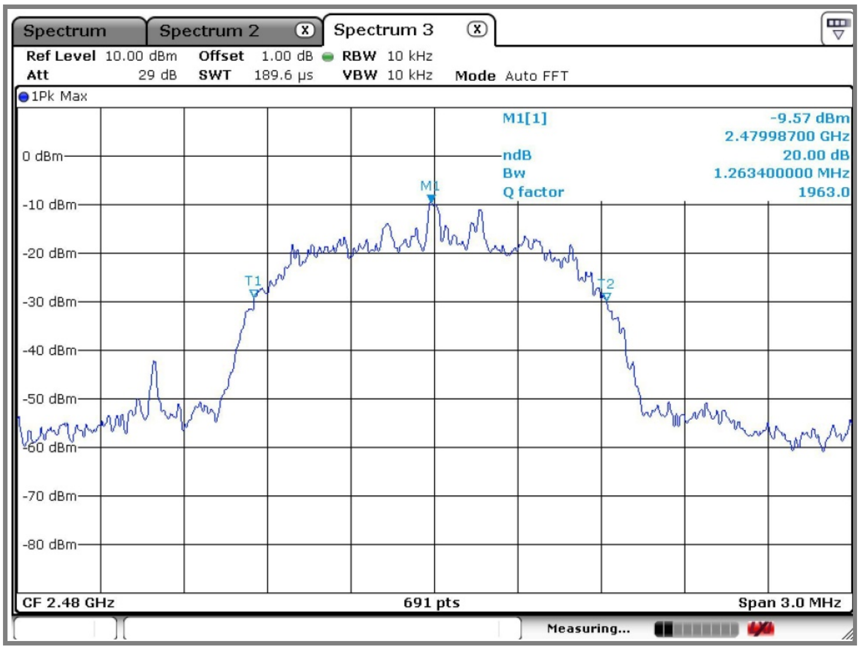


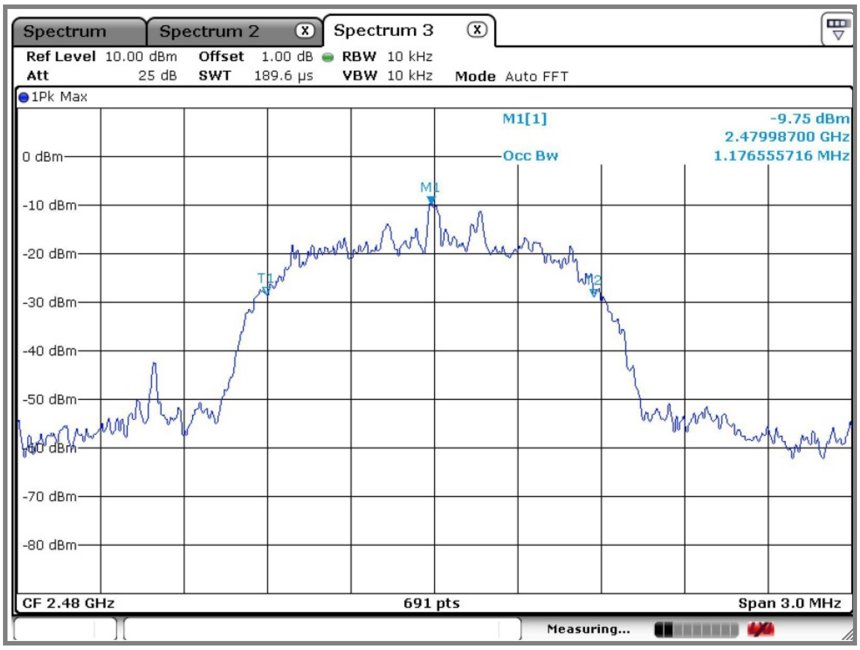
B. Middle channel (2 441 ㎒)– 20 ㏈ bandwidth & 99 % bandwidth





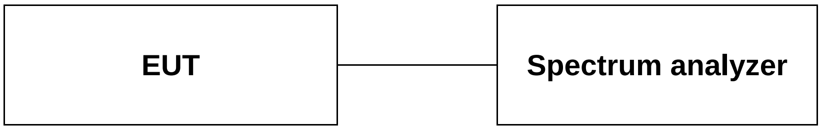
C. High channel (2 480 ㎒)– 20 ㏈ bandwidth & 99 % bandwidth





9. Maximum peak output power measurement

9.1. Test setup.



9.2. Limit

The maximum peak output power of the intentional radiator shall not exceed the following:

1. §15.247(a)(1), Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 ㎑ or the 20 ㏈ bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 ㎽
2. §15.247(b)(1), For frequency hopping systems operating in the 2 400 – 2 483.5 ㎒ employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5 725 – 5 805 ㎒ band: 1 Watt.

9.3. Test procedure

1. The RF power output was measured with a Spectrum analyzer connected to the RF Antenna connector(conducted measurement) while EUT was operating in transmit mode at the appropriate center frequency, A spectrum analyzer was used to record the shape of the transmit signal.
2. The bandwidth of the fundamental frequency was measured with the spectrum analyzer using;
   Span = approximately 5 times the 20 ㏈ bandwidth, centered on a hopping channel
   RBW ≥ 20 ㏈ BW, VBW ≥ RBW, Sweep = auto, Detector function = peak, Trace = max hold

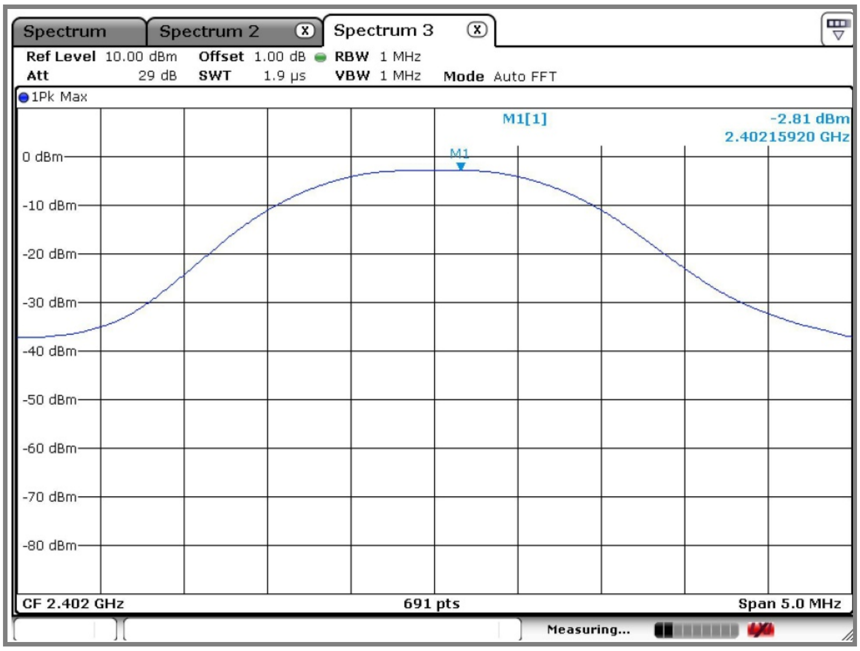
9.4. Test results

Ambient temperature: 22 ℃
Relative humidity: 55 % R.H.

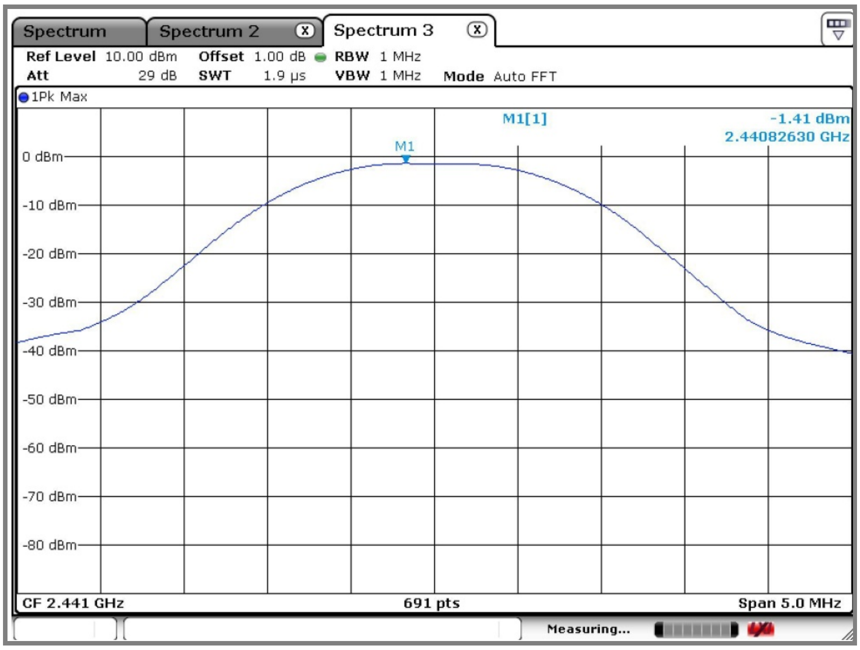
Operation mode	Frequency(㎒)	Peak output power(㏈m)	Limit(㏈m)
BDR mode	2 402	-2.81	30
	2 441	-1.41	30
	2 480	-1.05	30
EDR mode	2 402	-3.87	30
	2 441	-2.82	30
	2 480	-2.53	30

Operation mode: BDR mode

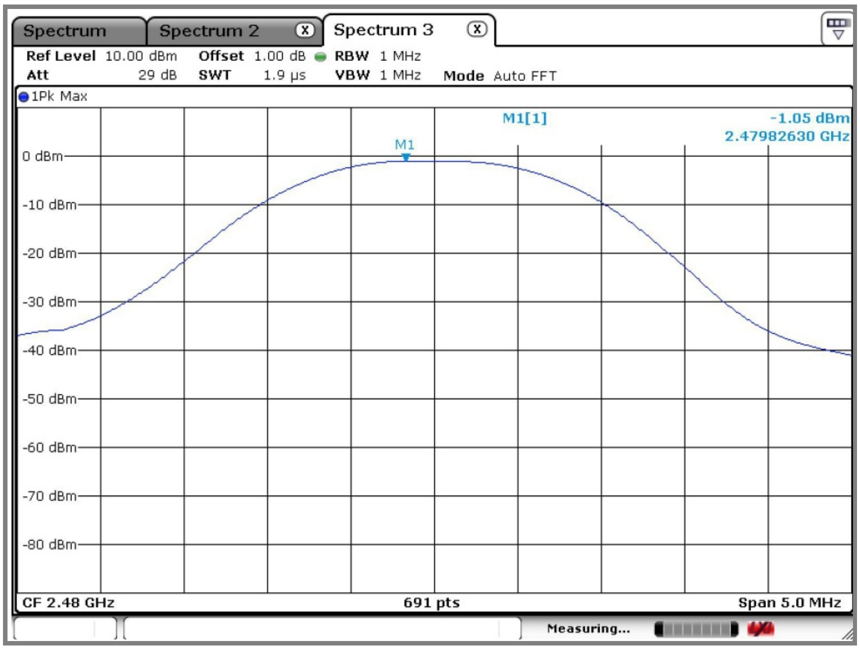
A. Low channel (2 402 ㎒)



B. Middle channel (2 441 ㎒)

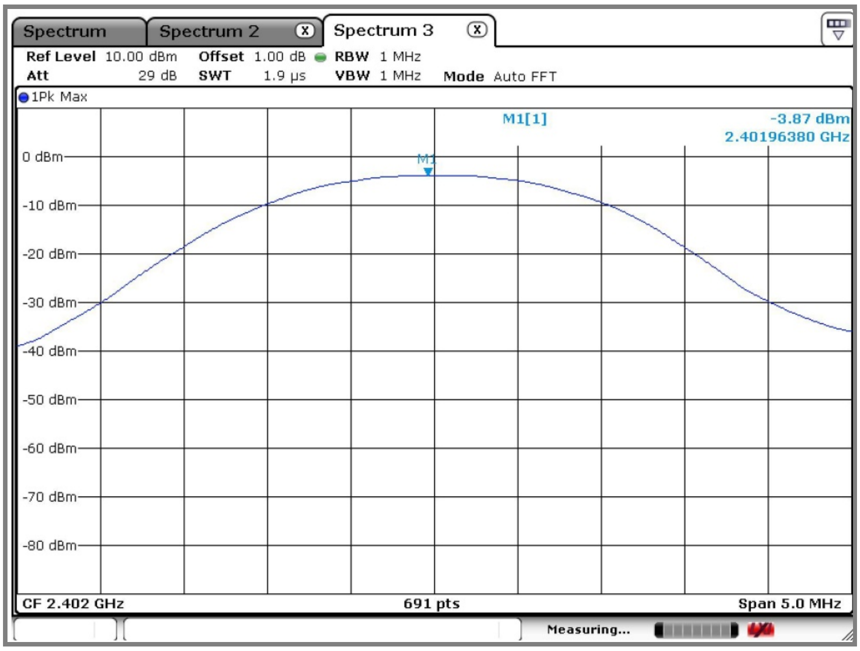


C. High channel (2 480 ㎒)

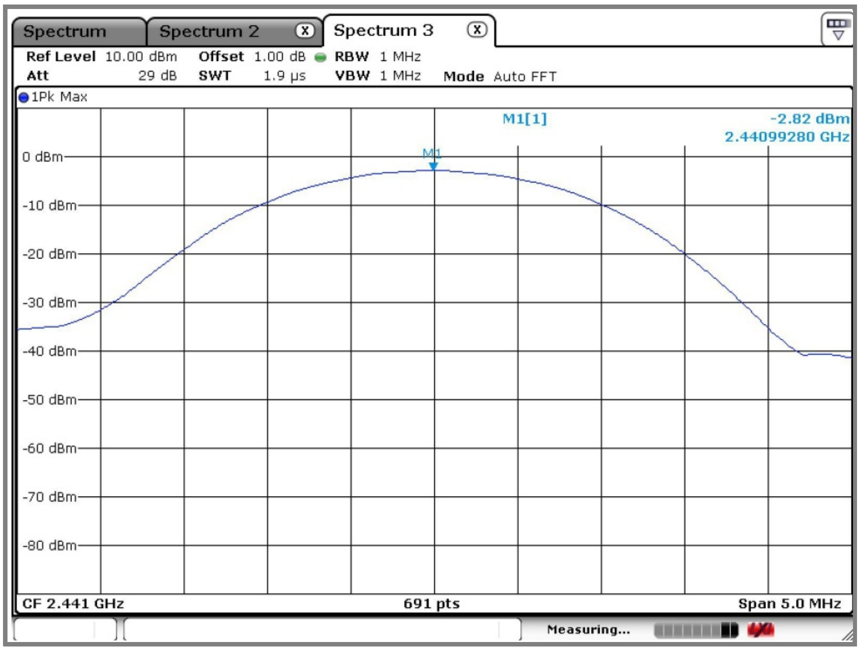


Operation mode: EDR mode

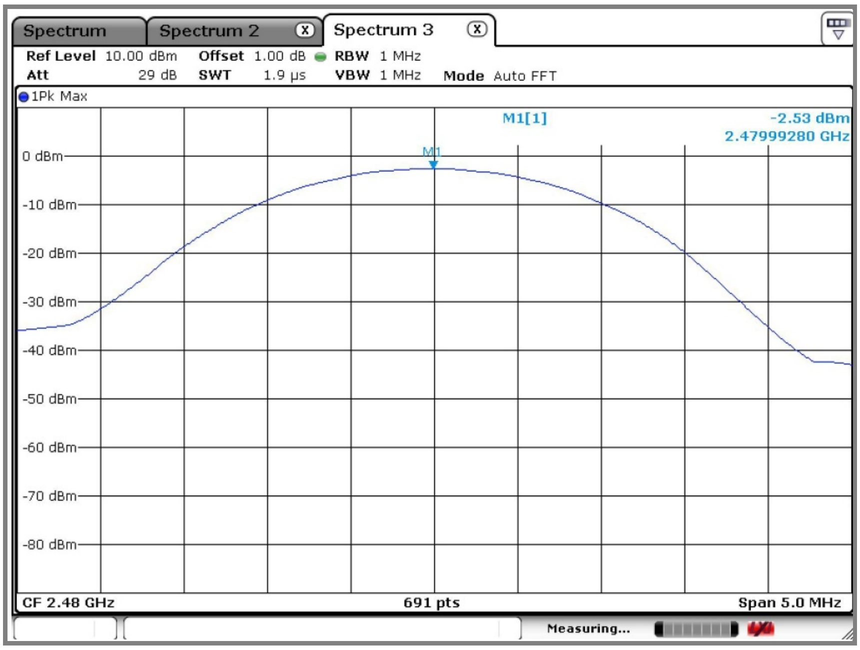
A. Low channel (2 402 ㎒)



B. Middle channel (2 441 ㎒)



C. High channel (2 480 ㎒)



10. Hopping channel separation

10.1. Test setup

EUT	—	Spectrum analyzer

10.2. Limit

§15.247(a)(1) Frequency hopping system operating in 2 400 – 2 483.5 ㎒. Band may have hopping channel carrier frequencies that are separated by 25 ㎑ or two-third of 20 ㏈ bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 ㎽.

10.3. Test procedure

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Position the EUT as shown in test setup without connection to measurement instrument. Turn on the EUT and connect it to measurement instrument. Then set it to any one convenient frequency within its operating range.
3. By using the max hold function record the separation of adjacent channels.
4. Measure the frequency difference of these two adjacent channels by spectrum analyzer mark function. And then plot the result on spectrum analyzer screen.
5. Repeat above procedures until all frequencies measured were complete.
6. Set center frequency of spectrum analyzer = middle of hopping channel.
7. Set the spectrum analyzer as RBW = 100 ㎑, VBW = 100 ㎑, Span = 5 ㎒ and Sweep = auto.

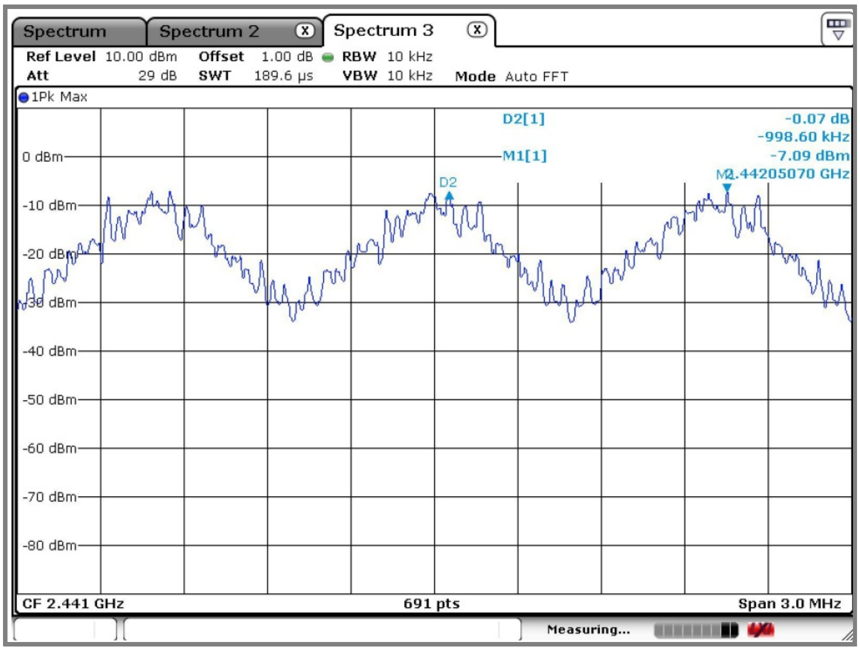
10.4. Test results

Ambient temperature: 22 ℃
Relative humidity: 55 % R.H.

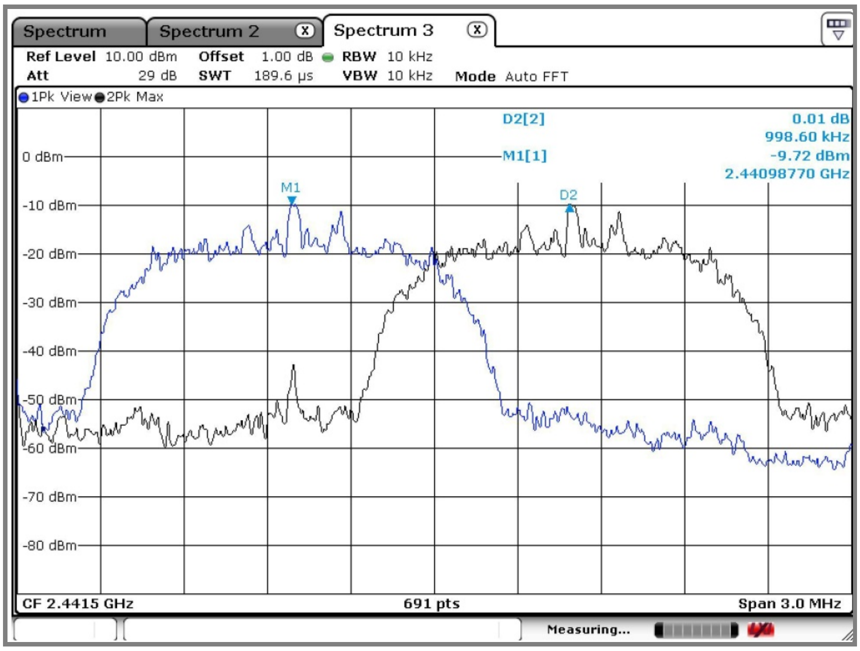
Operation mode	Frequency (㎒)	Adjacent hopping Channel separation (㎑)	Two-third of 20 ㏈ bandwidth (㎑)	Minimum bandwidth (㎑)
BDR mode	2 441	998.6	509.4	25
EDR mode	2 441	998.6	842.0	25

※ Remark:
20 ㏈ bandwidth measurement, the measured channel separation should be greater than two-third of 20 ㏈ bandwidth or Minimum bandwidth.

Operation mode : BDR mode

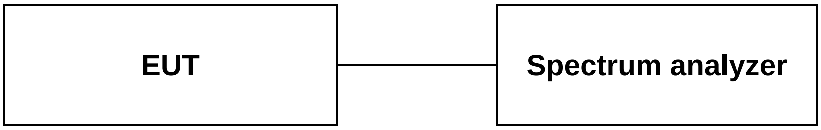


Operation mode: EDR mode



11. Number of hopping frequency

11.1. Test setup



11.2. Limit

§15.247(a)(1)(iii) For frequency hopping system operating in the 2 400 - 2 483.5 ㎒ bands shall use at least 15 hopping frequencies.

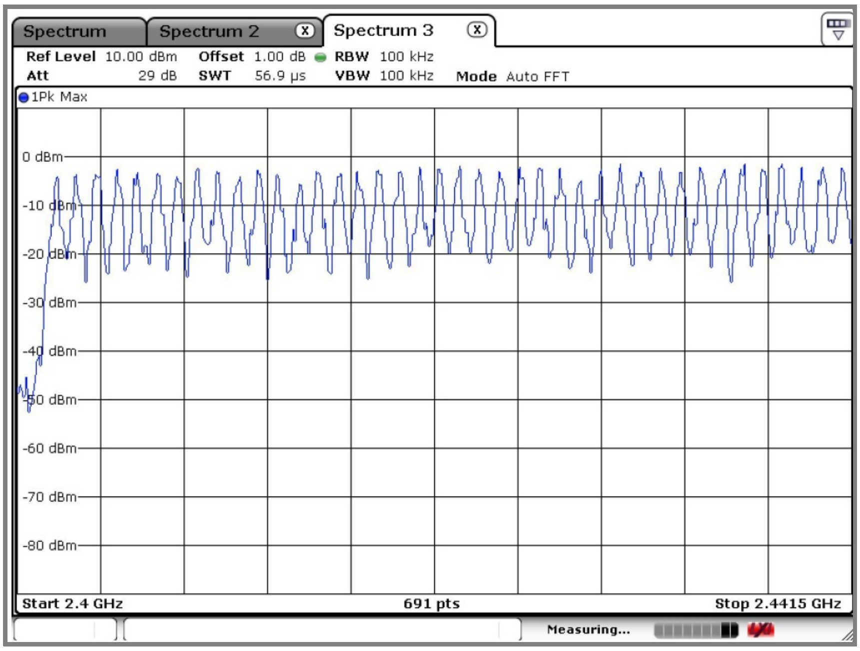
11.3. Test procedure

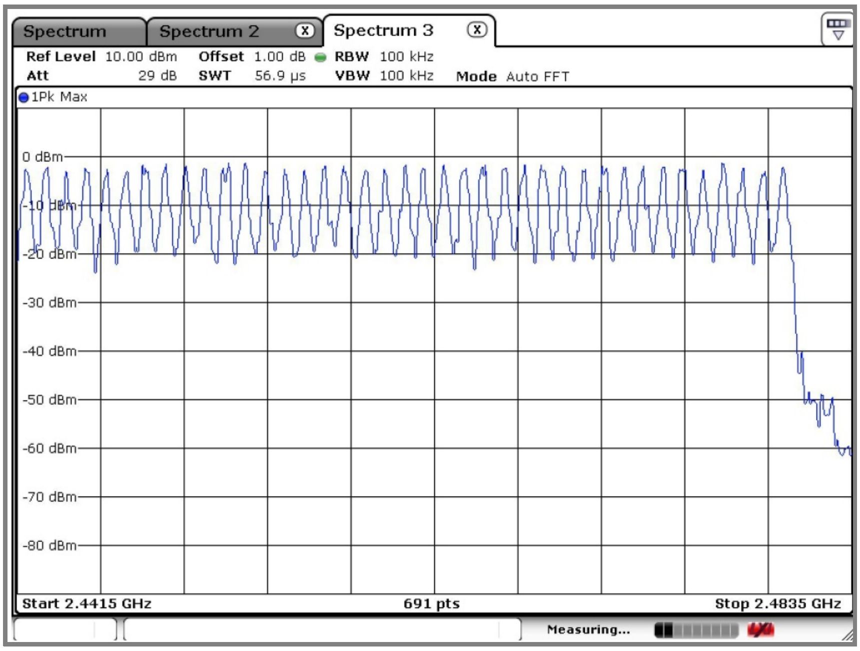
1. Place the EUT on the table and set it in transmitting mode.
2. Remove the antenna from the EUT and then connect a low loss RF cable from the antenna the port to the Spectrum analyzer
3. Set spectrum analyzer Start = 2 400 ㎒, Stop = 2 441.5 ㎒, Sweep = auto and Start = 2 441.5 ㎒, Stop = 2 483.5 ㎒, Sweep = auto.
4. Set the spectrum analyzer as RBW, VBW = 300 ㎑.
5. Max hold, view and count how many channel in the band.

11.4. Test results

Ambient temperature: 22 ℃
Relative humidity: 55 % R.H.

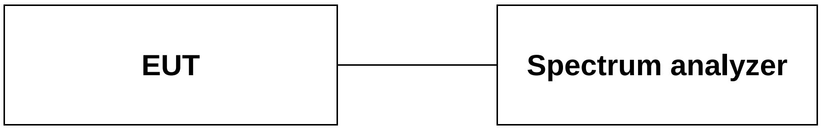
Number of Hopping Frequency	Limit
79	≥ 15


Spectrum
Spectrum 2
Spectrum 3
Ref Level 10.00 dBm Offset 1.00 dB RBW 100 kHz
Att 29 dB SWT 56.9 µs VBW 100 kHz Mode Auto FFT
1Pk Max
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
Start 2.4 GHz
691 pts
Stop 2.4415 GHz
Measuring...


Spectrum
Spectrum 2
Spectrum 3
Ref Level 10.00 dBm Offset 1.00 dB RBW 100 kHz
Att 29 dB SWT 56.9 µs VBW 100 kHz Mode Auto FFT
1Pk Max
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
Start 2.4415 GHz
691 pts
Stop 2.4835 GHz
Measuring...

12. Time of occupancy (Dwell time)

12.1. Test setup



12.2. Limit

§15.247(a)(1)(iii) For frequency hopping system operating in the 2 400 – 2 483.5 ㎒ band, the average time of occupancy on any frequency shall not be greater than 0.4 second within a 31.6 second period.

A period time = 0.4(s) * 79 = 31.6(s)

12.3. Test procedure

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Position the EUT as shown in test setup without connection to measurement instrument. Turn on the EUT and connect its antenna terminal to measurement instrument via a low loss cable.
3. Adjust the center frequency of spectrum analyzer on any frequency be measured and set spectrum analyzer to zero span mode. And then, set RBW and VBW of spectrum analyzer to proper value.
4. Measure the time duration of one transmission on the measured frequency. And then plot the result with time difference of this time duration.
5. Repeat above procedures until all frequencies measured were complete.
6. The Bluetooth has 6 type of payload, DH1, DH3, DH5. The hopping rate is 1 600 per second.

12.4. Test results

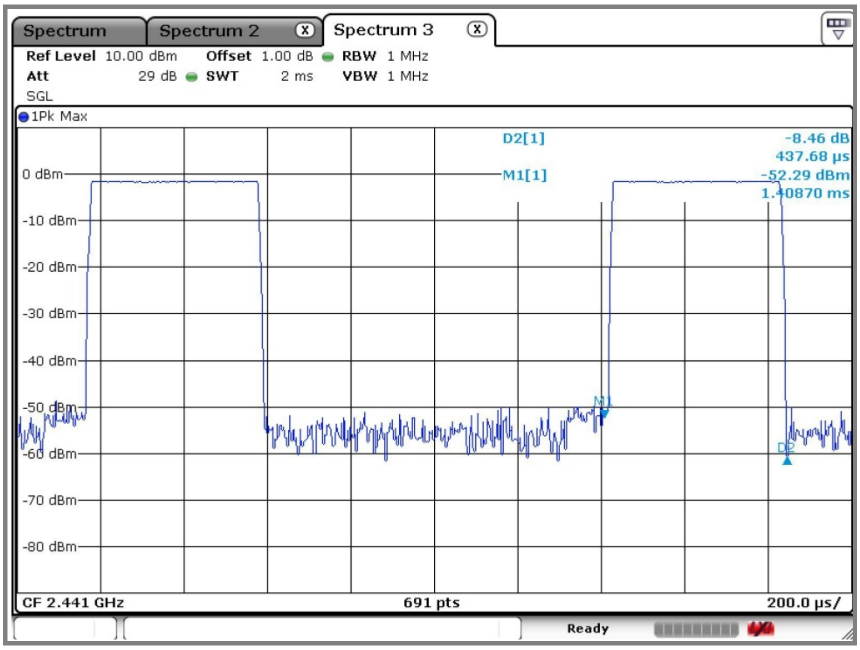
Ambient temperature: 22 ℃
Relative humidity: 55 % R.H.

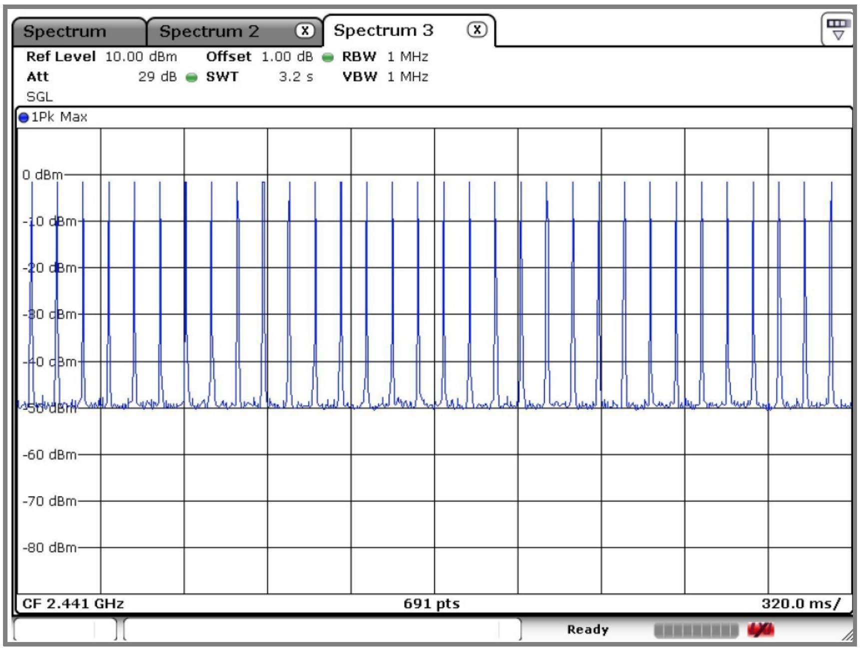
0.4 seconds within a 30 second period per any frequency

Mode	Number of transmission ina 31.6s (79Hopping*0.4)	Length of Transmission Time (msec)	Result (msec)	Limit (msec)
DH1	32(Times / 3.16sec) *10 = 320	0.438	140.16	400
DH3	16(Times / 3.16sec) *10= 160	1.790	286.40	400
DH5	11(Times / 3.16sec) *10= 110	3.029	333.19	400
3-DH5	11(Times / 3.16sec) *10= 110	2.957	325.27	400

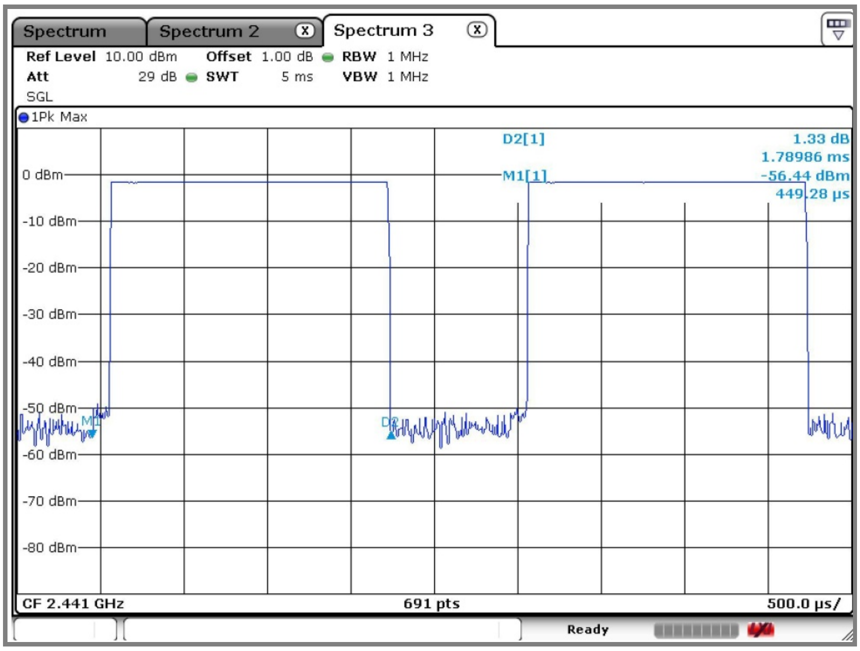
※ Remark:
dwell time = {(number of hopping per second / number of slot) x duration time per channel} x 0.4 ms

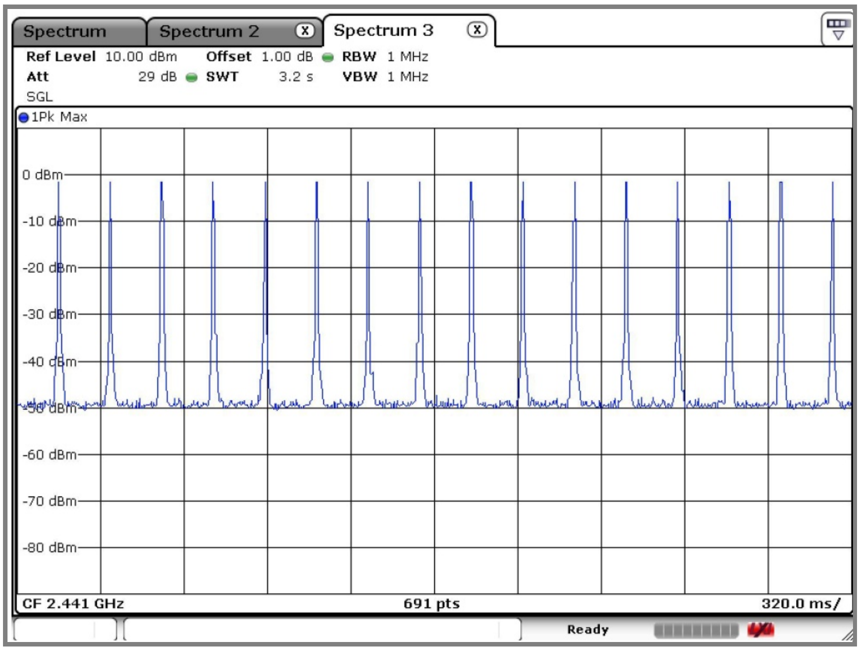
A. DH1


Spectrum
Spectrum 2
Spectrum 3
Ref Level 10.00 dBm Offset 1.00 dB RBW 1 MHz
Att 29 dB SWT 2 ms VBW 1 MHz
SGL
1Pk Max
D2[1] -8.46 dB
437.68 µs
M1[1] -52.29 dBm
1.40870 ms
CF 2.441 GHz
691 pts
200.0 µs/
Ready

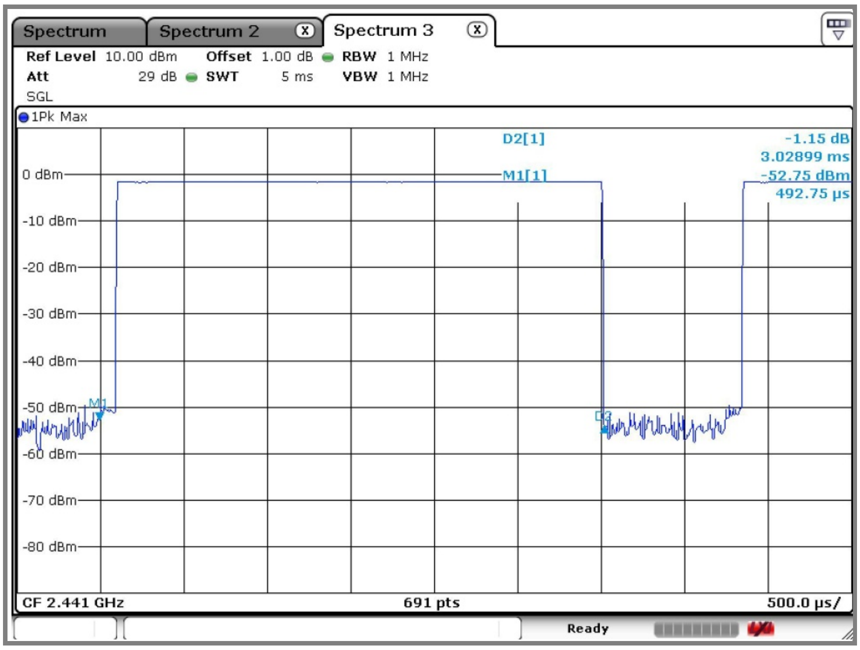

Spectrum
Spectrum 2
Spectrum 3
Ref Level 10.00 dBm Offset 1.00 dB RBW 1 MHz
Att 29 dB SWT 3.2 s VBW 1 MHz
SGL
1Pk Max
CF 2.441 GHz
691 pts
320.0 ms/
Ready

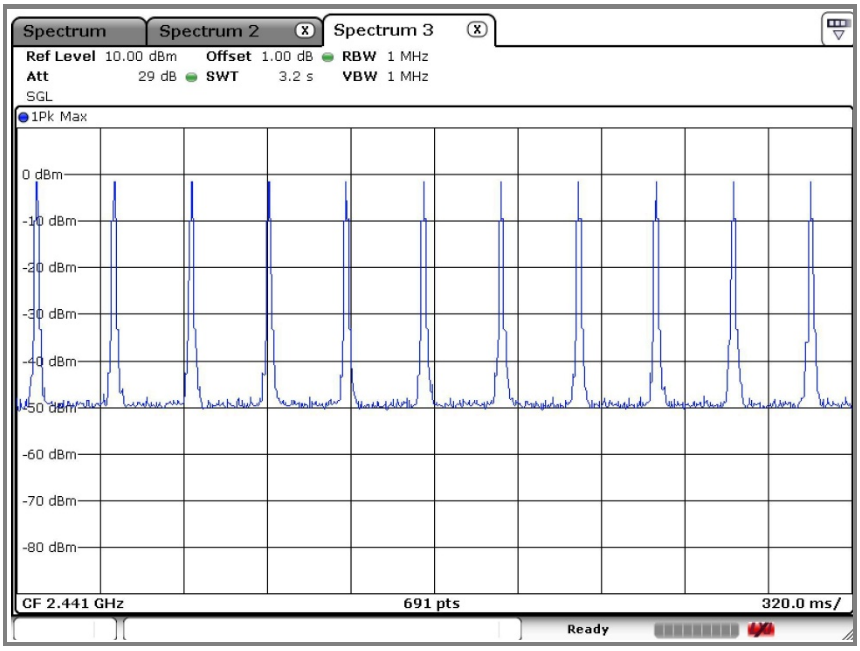
B. DH3


Spectrum
Spectrum 2
Spectrum 3
Ref Level 10.00 dBm Offset 1.00 dB RBW 1 MHz
Att 29 dB SWT 5 ms VBW 1 MHz
SGL
1Pk Max
D2[1] 1.33 dB
1.78986 ms
M1[1] -56.44 dBm
449.28 µs
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
CF 2.441 GHz
691 pts
500.0 µs/
Ready

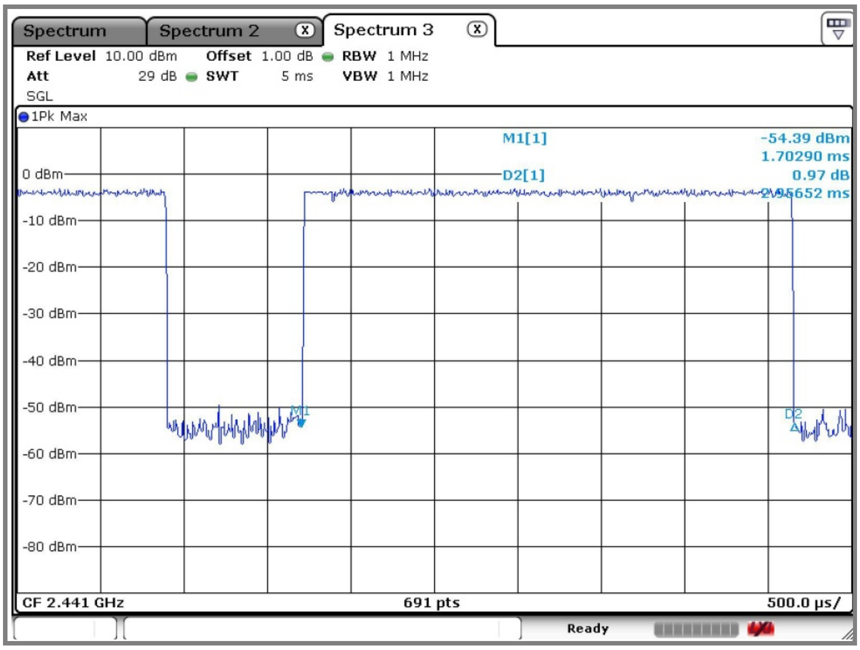

Spectrum
Spectrum 2
Spectrum 3
Ref Level 10.00 dBm Offset 1.00 dB RBW 1 MHz
Att 29 dB SWT 3.2 s VBW 1 MHz
SGL
1Pk Max
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
CF 2.441 GHz
691 pts
320.0 ms/
Ready

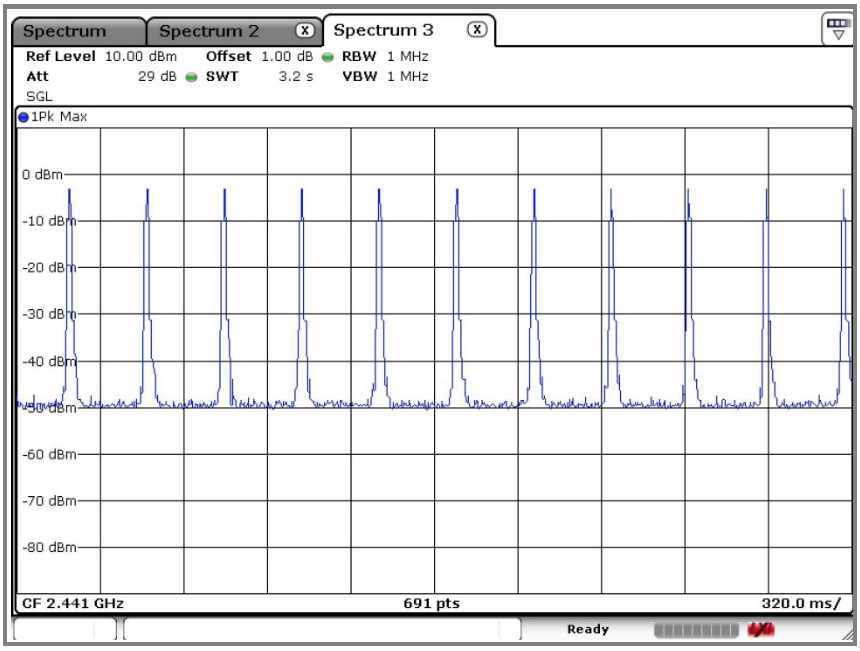
C. DH5


Spectrum
Spectrum 2
Spectrum 3
Ref Level 10.00 dBm Offset 1.00 dB RBW 1 MHz
Att 29 dB SWT 5 ms VBW 1 MHz
SGL
1Pk Max
D2[1] -1.15 dB
3.02899 ms
M1[1] -52.75 dBm
492.75 µs
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
CF 2.441 GHz
691 pts
500.0 µs/
Ready


Spectrum
Spectrum 2
Spectrum 3
Ref Level 10.00 dBm Offset 1.00 dB RBW 1 MHz
Att 29 dB SWT 3.2 s VBW 1 MHz
SGL
1Pk Max
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
CF 2.441 GHz
691 pts
320.0 ms/
Ready

D. 3-DH5


Spectrum
Spectrum 2
Spectrum 3
Ref Level 10.00 dBm
Offset 1.00 dB
RBW 1 MHz
Att 29 dB
SWT 5 ms
VBW 1 MHz
SGL
1Pk Max
M1[1]
-54.39 dBm
1.70290 ms
D2[1]
0.97 dB
2.95652 ms
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
CF 2.441 GHz
691 pts
500.0 µs/
Ready


Spectrum
Spectrum 2
Spectrum 3
Ref Level 10.00 dBm
Offset 1.00 dB
RBW 1 MHz
Att 29 dB
SWT 3.2 s
VBW 1 MHz
SGL
1Pk Max
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
CF 2.441 GHz
691 pts
320.0 ms/
Ready

13. Antenna requirement

13.1. Standard Applicable

For intentional device, according to FCC 47 CFR Section §15.203, an intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. And according to FCC 47 CFR Section §15.247 (b) if transmitting antennas of directional gain greater than 6 ㏈i are used.

13.2. Antenna Connected Construction

Antenna used in this product is FPCB type antenna,
Antenna gain is -2.49 ㏈i.

14. RF exposure evaluation

14.1. Environmental evaluation and exposure limit according to FCC CFR 47 part 1, 1.1307(b), 1.1310

According to §15.247(e)(i) and §1.1307(b)(1), systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy level in excess of the Commission's guidelines. According to KDB 447498 (2)(a)(i)

Limits for maximum permissible exposure (MPE)

Frequency range (㎒)	Electric field strength(V/m)	Magnetic field strength (A/m)	Power density (㎽/㎠)	Average time
(A) Limits for Occupational / Control exposures				
300 – 1 500	--	--	F/300	6
1 500 – 100 000	--	--	5	6
(B) Limits for General Population / Uncontrol Exposures				
300 – 1 500	--	--	F/1 500	6
1 500 – 100 000	--	--	1	30

RF exposure evaluation is required if the separation distance between the user and the device's radiating element is greater than 20 cm, except when the device operates as follows:

below 1.5 GHz and the maximum e.i.r.p. of the device is equal to or less than 2.5 W;

at or above 1.5 GHz and the maximum e.i.r.p. of the device is equal to or less than 5 W.

In these cases, the information contained in the RF exposure technical brief may be limited to information that demonstrates how the e.i.r.p. was derived.

14.2. Friis transmission formula : Pd=(Pout*G)\(4*pi*R2)

Where
Pd= Power density in ㎽/㎠
Pout=output power to antenna in ㎽
G= Numeric gain of the antenna relative to isotropic antenna
Pi=3.1416
R= distance between observation point and center of the radiator in cm
Pd the limit of MPE, 1 ㎽/㎠. If we know the maximum gain of the antenna and total power input to the antenna, through the calculation, we will know the distance where the MPE limit is reached.

14.2. Test result of RF exposure evaluation

Test Item : RF Exposure evaluation data
Test Mode : Normal operation

14.4. Output power into antenna & RF exposure evaluation distance

Antenna gain: **-2.49 dB i**

Operation mode : BDR mode

Frequency (㎒)	Output Peak power to antenna (dBm)	Antenna gain (dBi)	Antenna Gain (dBi) Numeric	Power density at 20 ㎝ (㎽/㎠)	e.i.r.p. (mW)	e.i.r.p. Limits (W)	Power density Limits (㎽/㎠)
2 402	-2.81	-2.49	0.56	0.0001	0.30	5	1
2 441	-1.41	-2.49	0.56	0.0001	0.41		
2 480	-1.05	-2.49	0.56	0.0001	0.44		

Operation mode : EDR mode

Frequency (㎒)	Output Peak power to antenna (dBm)	Antenna gain (dBi)	Antenna Gain (dBi) Numeric	Power density at 20 ㎝ (㎽/㎠)	e.i.r.p. (mW)	e.i.r.p. Limits (W)	Power density Limits (㎽/㎠)
2 402	-3.87	-2.49	0.56	0.0001	0.23	5	1
2 441	-2.82	-2.49	0.56	0.0001	0.29		
2 480	-2.53	-2.49	0.56	0.0001	0.31		

※ Remark

The power density P_d (5th column) at a distance of 20 ㎝ calculated from the friis transmission formula is far below the limit of 1 ㎽/㎠ .

15. Test setup photo of EUT

Photo of radiated spurious emission at below 30 ㎒

Photo of radiated spurious emission at 30 ㎒ ~ 1 000 ㎒

Photo of radiated spurious emission at above 1 000 ㎒

Photo of Conducted emission at below 30 ㎒