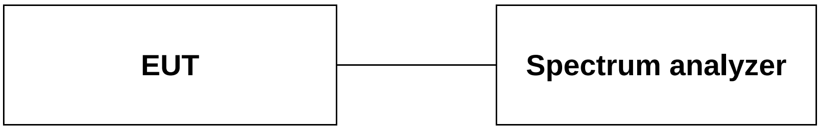
8. Hopping channel separation

8.1. Test setup



9.2. 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 ㎽.

9.3. 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.

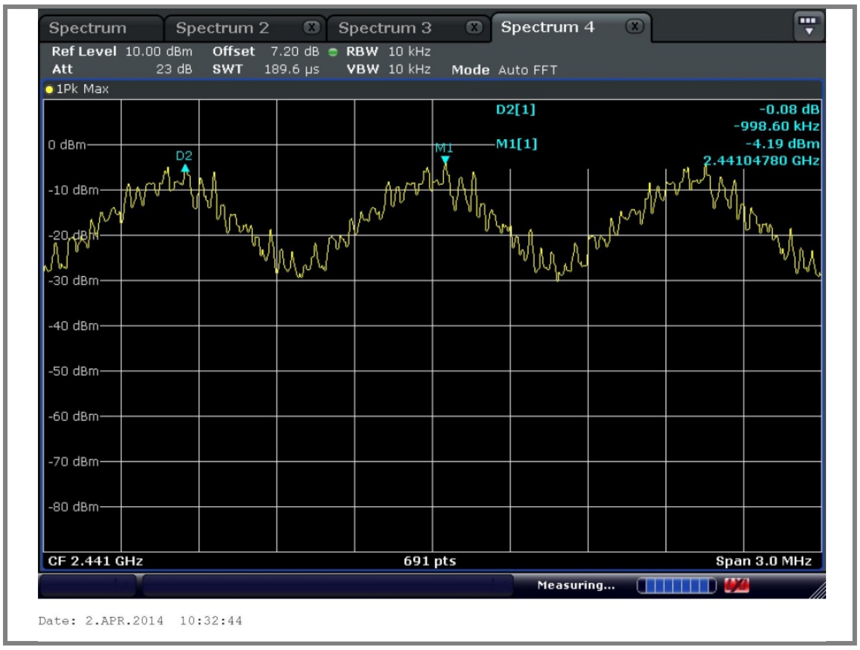
9.4. Test results

Ambient temperature: 23 ℃
Relative humidity: 51 % R.H.

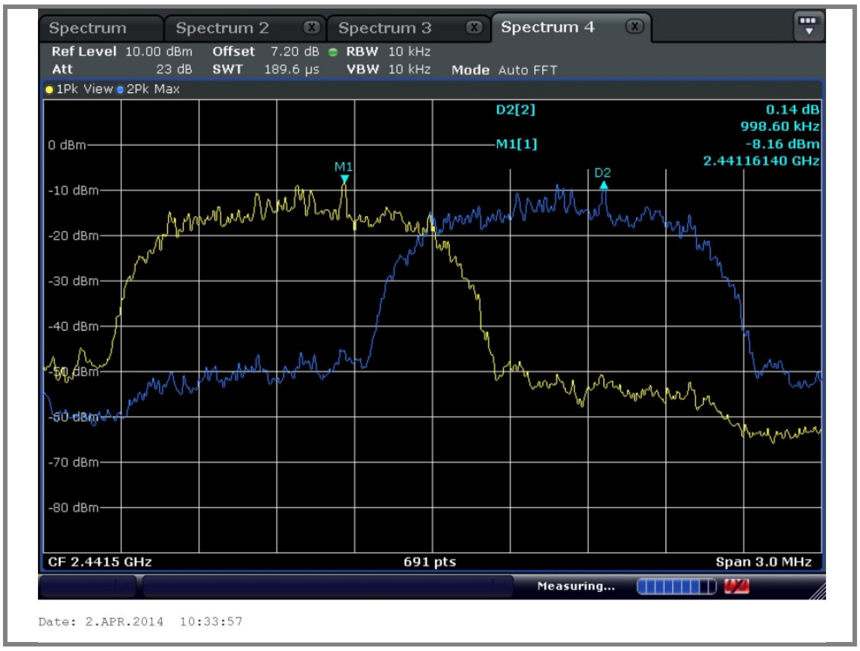
Operation mode	Frequency (㎒)	Adjacent hopping Channel separation (㎑)	Two-third of 20 ㏈ bandwidth (㎑)	Minimum bandwidth (㎑)
BASIC	2 441	998.6	509.1	25
EDR	2 441	998.6	846.5	25

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

Operation mode : BASIC

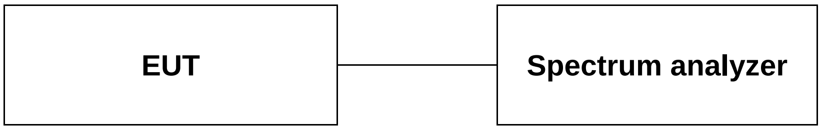


Operation mode: EDR



9. Number of hopping frequency

9.1. Test setup



10.2. 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.

10.3. Test procedure

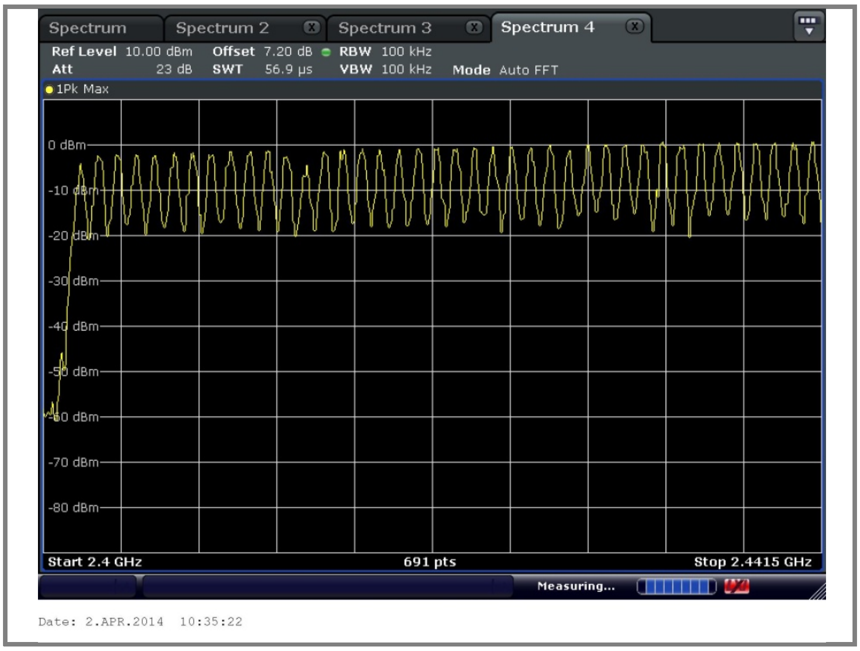
1. Place the EUT on the table and set it in transmitting mode.
2. Remove the antenna from the EUT and then connect a low loss RF cable from the antenna the port to the Spectrum analyzer
3. Set spectrum analyzer Start = 2 400 ㎒, Stop = 2 441.5 ㎒, Sweep = auto and Start = 2 441.5 ㎒, Stop = 2 483.5 ㎒, Sweep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

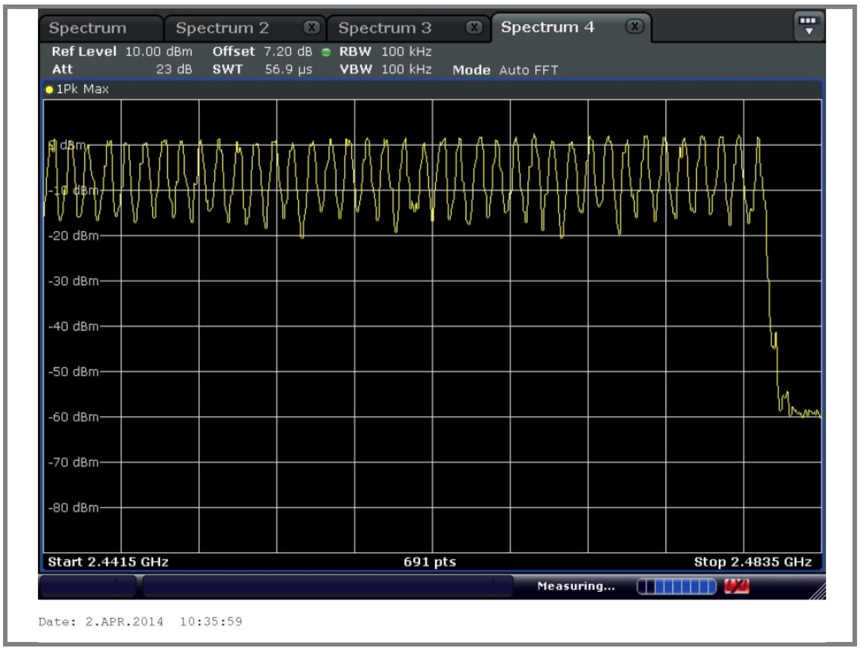
10.4. Test results

Ambient temperature: 23℃
Relative humidity: 51 % R.H.

Operation mode	Number of Hopping Frequency	Limit
BASIC	79	≥ 15

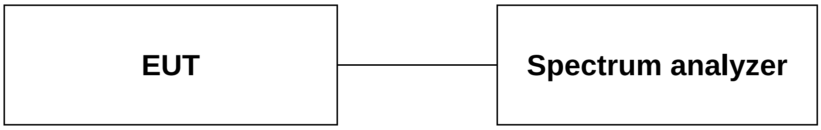
Operation mode: BASIC





10. Time of occupancy(Dwell time)

10.1. Test setup



11.2. 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)

11.3. 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.

11.4. Test results

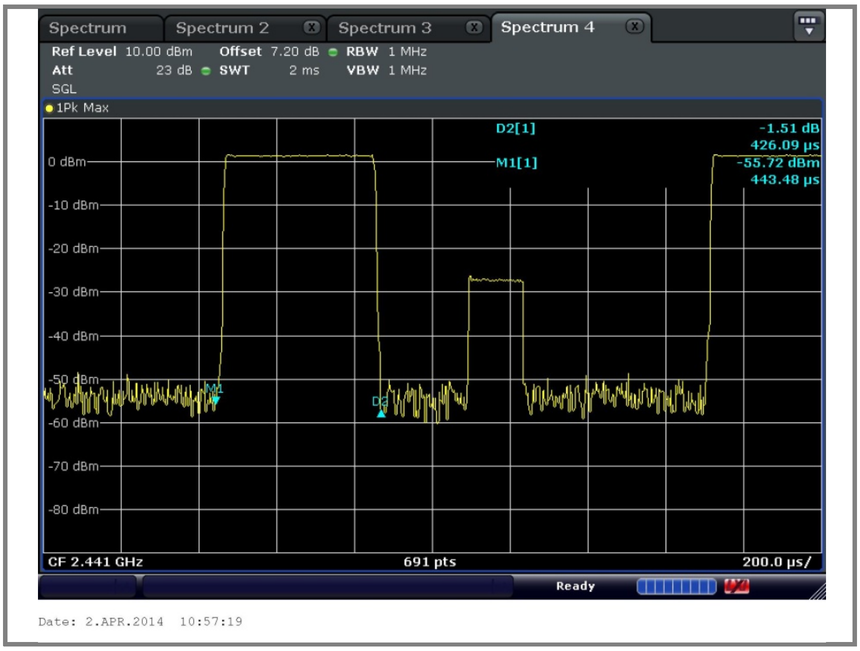
Ambient temperature: 23℃
Relative humidity: 51 % R.H.

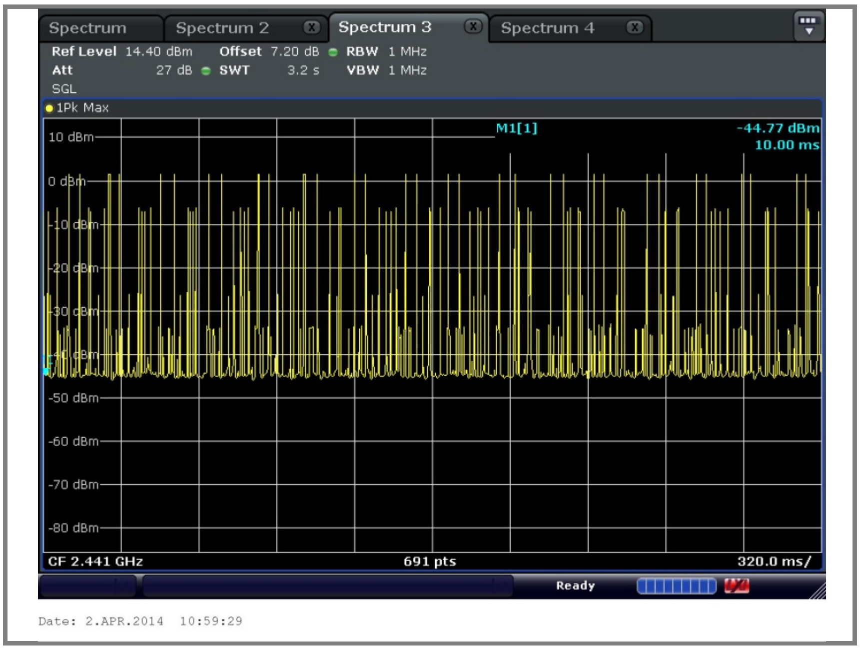
0.4 seconds within a 30 second period per any frequency

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	0.426	136.3	400
DH3	16(Times / 3.16sec) *10= 160	1.684	269.4	400
DH5	11(Times / 3.16sec) *10= 110	2.959	325.5	400
2-DH5	11(Times / 3.16sec) *10= 110	2.959	325.5	400
3-DH5	11(Times / 3.16sec) *10= 110	2.959	325.5	400

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

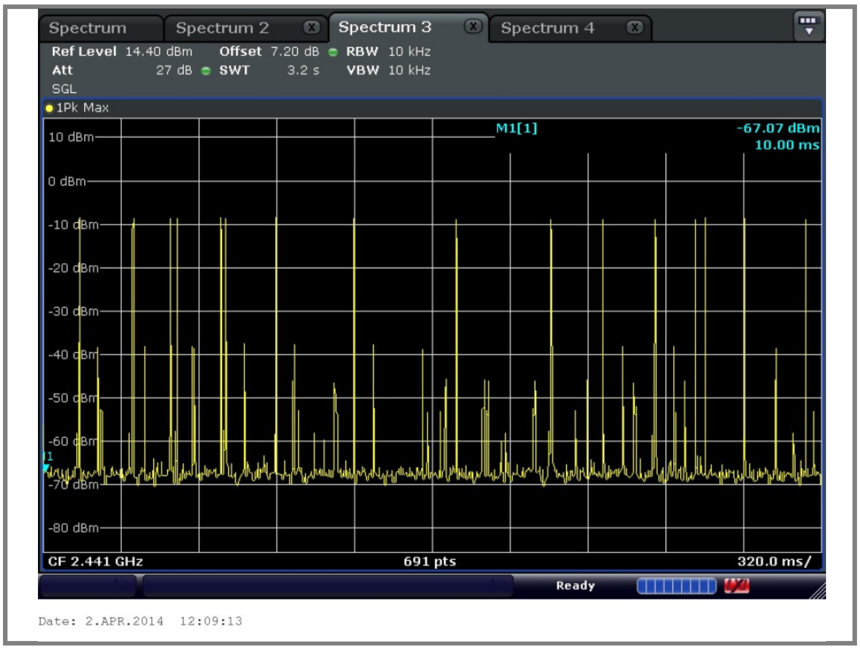
A. DH1


Spectrum
Spectrum 2
Spectrum 3
Spectrum 4
Ref Level 10.00 dBm
Offset 7.20 dB
RBW 1 MHz
Att 23 dB
SWT 2 ms
VBW 1 MHz
SGL
1Pk Max
D2[1]
-1.51 dB
426.09 µs
M1[1]
-55.72 dBm
443.48 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
200.0 µs/
Ready
Date: 2.APR.2014 10:57:19

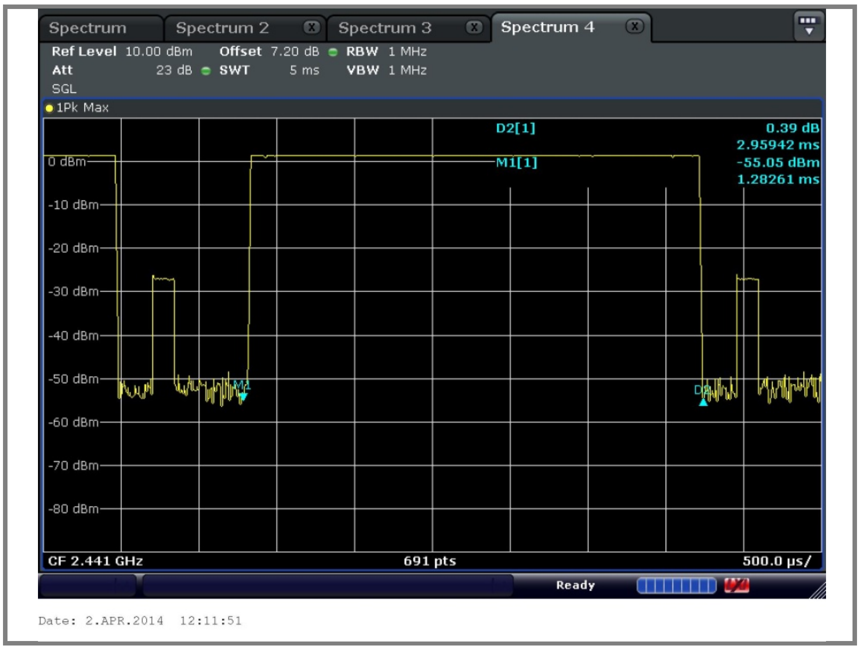

Spectrum
Spectrum 2
Spectrum 3
Spectrum 4
Ref Level 14.40 dBm
Offset 7.20 dB
RBW 1 MHz
Att 27 dB
SWT 3.2 s
VBW 1 MHz
SGL
1Pk Max
M1[1]
-44.77 dBm
10.00 ms
10 dBm
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
CF 2.441 GHz
691 pts
320.0 ms/
Ready
Date: 2.APR.2014 10:59:29

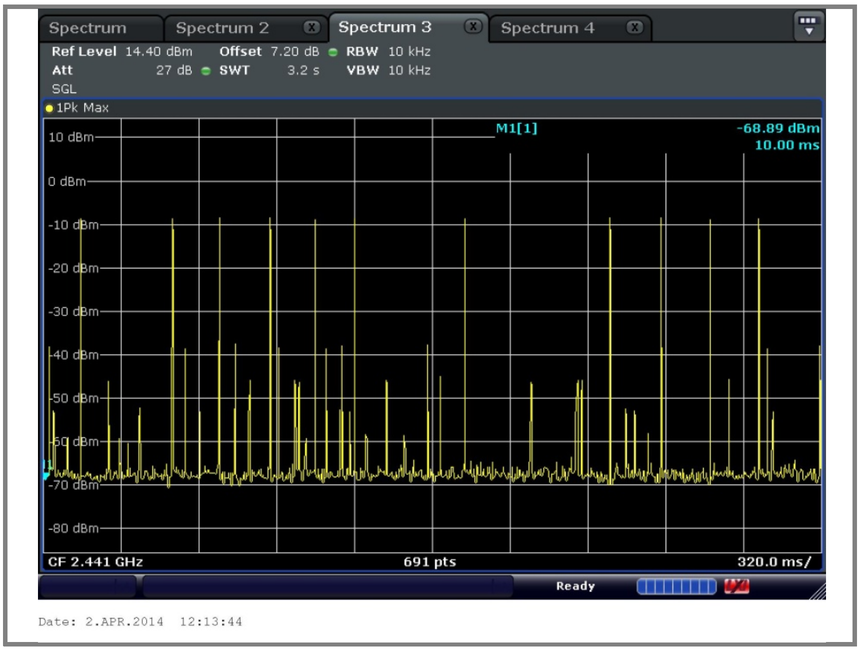
B. DH3


Spectrum
Spectrum 2
Spectrum 3
Spectrum 4
Ref Level 10.00 dBm
Offset 7.20 dB
RBW 1 MHz
Att 23 dB
SWT 2 ms
VBW 1 MHz
SGL
1Pk Max
M1[1]
-57.06 dBm
57.97 µs
D2[1]
0.59 dB
1.68406 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
200.0 µs/
Ready
Date: 2.APR.2014 12:11:14


Spectrum
Spectrum 2
Spectrum 3
Spectrum 4
Ref Level 14.40 dBm
Offset 7.20 dB
RBW 10 kHz
Att 27 dB
SWT 3.2 s
VBW 10 kHz
SGL
1Pk Max
M1[1]
-67.07 dBm
10.00 ms
10 dBm
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
Date: 2.APR.2014 12:09:13

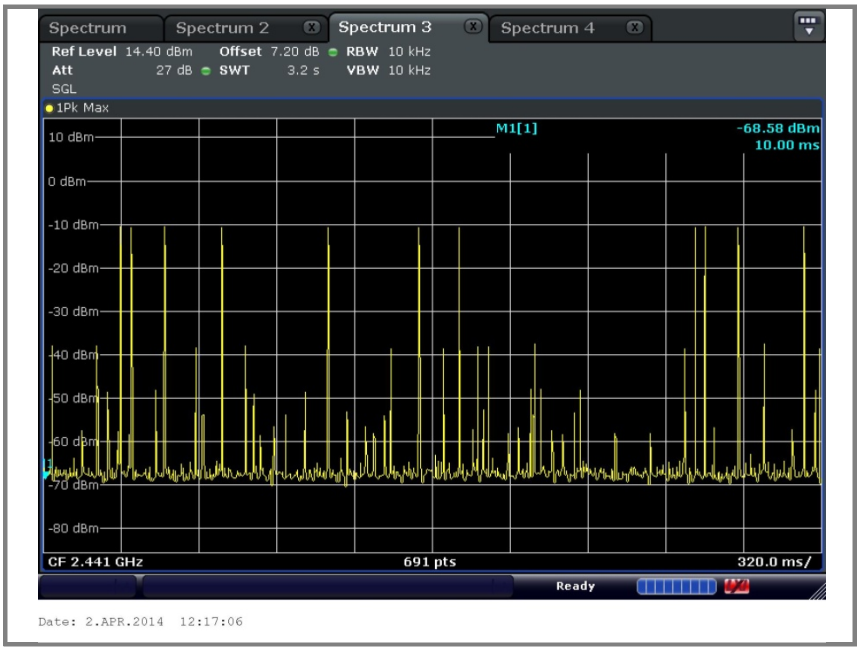
C. DH5


Spectrum
Spectrum 2
Spectrum 3
Spectrum 4
Ref Level 10.00 dBm
Offset 7.20 dB
RBW 1 MHz
Att 23 dB
SWT 5 ms
VBW 1 MHz
SGL
1Pk Max
D2[1]
0.39 dB
2.95942 ms
M1[1]
-55.05 dBm
1.28261 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
Date: 2.APR.2014 12:11:51


Spectrum
Spectrum 2
Spectrum 3
Spectrum 4
Ref Level 14.40 dBm
Offset 7.20 dB
RBW 10 kHz
Att 27 dB
SWT 3.2 s
VBW 10 kHz
SGL
1Pk Max
M1[1]
-68.89 dBm
10.00 ms
10 dBm
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
Date: 2.APR.2014 12:13:44

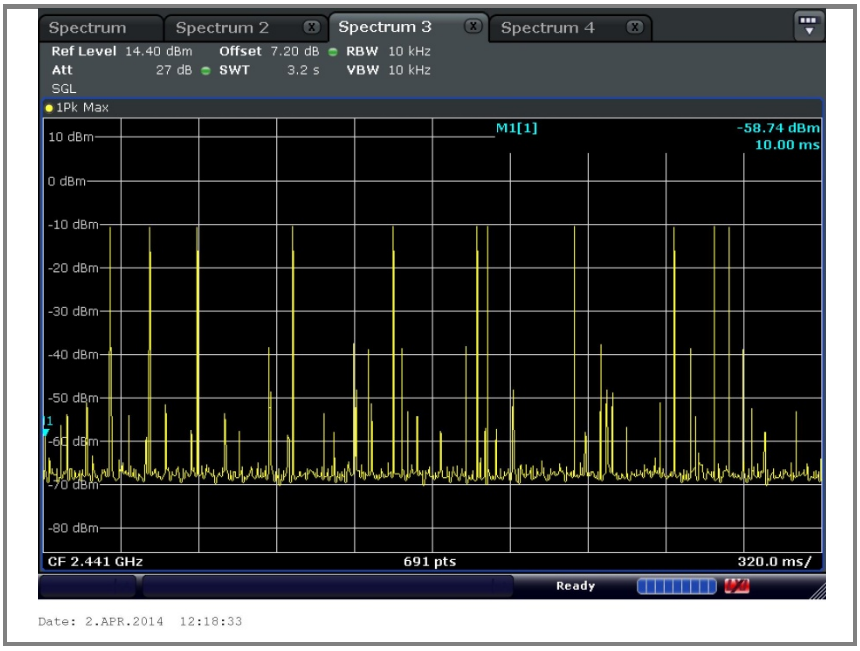
D. 2- DH5


Spectrum
Spectrum 2
Spectrum 3
Spectrum 4
Ref Level 10.00 dBm
Offset 7.20 dB
RBW 1 MHz
Att 23 dB
SWT 5 ms
VBW 1 MHz
SGL
1Pk Max
M1[1]
-53.31 dBm
1.32609 ms
D2[1]
-2.32 dB
2.95942 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
Date: 2.APR.2014 12:15:34


Spectrum
Spectrum 2
Spectrum 3
Spectrum 4
Ref Level 14.40 dBm
Offset 7.20 dB
RBW 10 kHz
Att 27 dB
SWT 3.2 s
VBW 10 kHz
SGL
1Pk Max
M1[1]
-68.58 dBm
10.00 ms
10 dBm
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
Date: 2.APR.2014 12:17:06

E. 3- DH5


Spectrum
Spectrum 2
Spectrum 3
Spectrum 4
Ref Level 10.00 dBm
Offset 7.20 dB
RBW 1 MHz
Att 23 dB
SWT 5 ms
VBW 1 MHz
SGL
1Pk Max
D2[1]
3.88 dB
2.95942 ms
M1[1]
-55.57 dBm
746.38 µs
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
M1
D2
CF 2.441 GHz
691 pts
500.0 µs/
Ready
Date: 2.APR.2014 12:17:33


Spectrum
Spectrum 2
Spectrum 3
Spectrum 4
Ref Level 14.40 dBm
Offset 7.20 dB
RBW 10 kHz
Att 27 dB
SWT 3.2 s
VBW 10 kHz
SGL
1Pk Max
M1[1]
-58.74 dBm
10.00 ms
10 dBm
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
Date: 2.APR.2014 12:18:33

11. Antenna requirement

12.1. 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, the power shall be reduced by the amount in ㏈ that the gain of the antenna exceeds 6 ㏈i.

12.2. Antenna Connected Construction

Antenna used in this product is Integral type (PCB pattern Antenna) gain of -1.72 ㏈ i.

12. RF exposure evaluation

13.1. 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

13.2. 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.

13.3. Test result of RF exposure evaluation

Test Item : RF Exposure evaluation data

Test Mode : Normal operation

13.4.Output power into antenna & RF exposure evaluation distance

Antenna gain: -1.72 dB i

Basic mode

Frequency (MHz)	Output Peak power to antenna (dBm)	Antenna gain (dBi)	Antenna Gain (dBi) Numeric	Power density at 20 cm (mW/cm²)	Power density Limits (mW/cm²)
2 402	-2.60	-1.72	0.67	0.000 1	1
2 441	1.60	-1.72	0.67	0.000 2	
2 480	3.08	-1.72	0.67	0.000 3	

EDR mode

Frequency (MHz)	Output Peak power to antenna (dBm)	Antenna gain (dBi)	Antenna Gain (dBi) Numeric	Power density at 20 cm (mW/cm²)	Power density Limits (mW/cm²)
2 402	-3.32	-1.72	0.67	0.000 1	1
2 441	0.89	-1.72	0.67	0.000 2	
2 480	2.30	-1.72	0.67	0.000 2	

※ **Remark**

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

13. 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 ㎒