

FCC Part 15 EMI TEST REPORT

of

E.U.T. : Radio Box
Model : 487-7442, 487-7440
FCC ID : PQMCRM01

for

APPLICANT : Caterpillar, Inc.
ADDRESS : 100, North East Adams Street, Peoria, Illinois,
61629, United States

Test Performed by

ELECTRONICS TESTING CENTER, TAIWAN

NO. 34. LIN 5, DINGFU VIL., LINKOU DIST.,
NEW TAIPEI CITY, TAIWAN, 24442, R.O.C.

Tel:(02)26023052 Fax:(02)26010910
<http://www.etc.org.tw> ; e-mail : emc@etc.org.tw

Report Number : 16-07-RBF-037

TEST REPORT CERTIFICATION

Applicant : Caterpillar, Inc.
 100, North East Adams Street, Peoria, Illinois, 61629, United States

Manufacture : Panasonic Taiwan Co.,Ltd
 579, Yuan Shan Road, Chung-Ho District, New Taipei City, Taiwan

Description of Device :

a) Type of EUT : Radio Box
 b) Trade Name : Caterpillar
 c) Model No. : 487-7442, 487-7440
 d) Power Supply : DC 24V

Regulation Applied : FCC Rules and Regulations Part 15 Subpart C

I HEREBY CERTIFY THAT: The data shown in this report were made in accordance with the procedures given in ANSI C63.10-2013, and the energy emitted by the device was founded to be within the limits applicable. I assume full responsibility for accuracy and completeness of these data.

Note: 1. The result of the testing report relate only to the item tested.
 2. The testing report shall not be reproduced expect in full, without the written approval of ETC.

Summary of Tests

Test	Results
Radiated Emission	Pass
Conducted Emission	N/A
Hopping Channel Separation	Pass
Number of Hopping frequencies used	Pass
Hopping Channel Bandwidth	Pass
Dwell Time of each frequency	Pass
Output Power Requirement	Pass
100 kHz Bandwidth of Frequency Band Edges Requirement	Pass
Out-of-Band Conducted Emission Requirement	Pass
Duty Cycle	N/A

Date Test Item Received : Jul. 22, 2016
Date Test Campaign Completed : Oct. 05, 2016
Date of Issue : Oct. 18, 2016

Test Engineer : Brian Huang
(Brian Huang , Engineer)

Approve & Authorized : S S Liou
S. S. Liou, Section Manager
EMC Dept. II of ELECTRONICS
TESTING CENTER, TAIWAN



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1 GENERAL INFORMATION

1.1 Product Description

- a) Type of EUT : Radio Box
- b) Trade Name : Caterpillar
- c) Model No. : 487-7442, 487-7440
- d) Power Supply : DC 24V
- e) Model Difference : Model 487-7442 and 487-7440 are the same circuit designation and the only difference is that 487-7442 has DAB function but 487-7440 has no DAB.

1.2 Test Methodology

Both conducted and radiated emissions were performed according to the procedures illustrated in ANSI C63.10-2013. Other required measurements were illustrated in separate sections of this test report for details.

Measurement Software

Software	Version	Note
e3	Version 6.100618b	Radiated Emission Test
e3	Version 6.100421	Conducted Emission Test

1.3 Test Facility

The open area test site and conducted measurement facility used to collect the radiated data is located on the roof top of Building at No.34, Lin 5, Dingfu Vil., Linkou Dist., New Taipei City, Taiwan 24442, R.O.C.

This site is FCC 2.948 listed and accepted in a letter dated Jan. 29, 2014.

Registration Number: 90589

2 PROVISIONS APPLICABLE

2.1 Definition

Unintentional radiator:

A device that intentionally generates and radio frequency energy for use within the device, or that sends radio frequency signals by conduction to associated equipment via connecting wiring, but which is not intended to emit RF energy by radiation or induction.

Class A Digital Device:

A digital device which is marketed for use in commercial or business environment; exclusive of a device which is market for use by the general public, or which is intended to be used in the home.

Class B Digital Device :

A digital device which is marketed for use in a residential environment notwithstanding use in a commercial, business of industrial environment. Example of such devices that are marketed for the general public.

Note : A manufacturer may also qualify a device intended to be marketed in a commercial, business, or industrial environment as a Class B digital device, and in fact is encouraged to do so, provided the device complies with the technical specifications for a Class B Digital Device. In the event that a particular type of device has been found to repeatedly cause harmful interference to radio communications, the Commission may classify such a digital device as a Class B Digital Device, Regardless of its intended use.

Intentional radiator:

A device that intentionally generates and emits radio frequency energy by radiation or induction.

2.2 Requirement for Compliance

(1) Conducted Emission Requirement

Except as shown in paragraphs (b) and (c) of this section, for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the band 150kHz to 30 MHz shall not exceed the limits in the following table, as measured using a 50μH/50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

Frequency MHz	Quasi Peak dB μV	Average dB μV
0.15 - 0.5	66-56*	56-46*
0.5 - 5.0	56	46
5.0 - 30.0	60	50

* Decreases with the logarithm of the frequency

For intentional device, according to §15.207(a) Line Conducted Emission Limits is same as above table.

(2) Radiated Emission Requirement

For unintentional device, according to §15.109(a), except for Class A digital devices, the field strength of radiated emissions from unintentional radiators at a distance of 3 meters shall not exceed the following values:

Frequency MHz	Distance Meters	Radiated dB μV/m	Radiated μV/m
30 - 88	3	40.0	100
88 - 216	3	43.5	150
216 - 960	3	46.0	200
Above 960	3	54.0	500

For intentional device, according to §15.209(a), the general requirement of field strength of radiated emissions from intentional radiators at a distance of 3 meters shall not exceed the above table.

(3) Antenna Requirement

For intentional device, according to §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.

(4) Hopping Channel Separation

According to 15.247(a)(1), frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400-2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW.

(5) Number of Hopping frequencies used

According to 15.247(a)(1)(iii), frequency hopping systems in the 2400–2483.5 MHz band shall use at least 15 channels.

(6) Hopping Channel Bandwidth

For frequency hopping system operating in the 2400–2483.5 MHz band, there is no requirement for the maximum 20dB bandwidth of the hopping channel. The measurement of the hopping channel bandwidth is for the reference of the hopping channel separation requirement.

(7) Dwell Time of each frequency

According to 15.247(a)(1)(iii), for frequency hopping system operating in the 2400-2483.5 band, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed.

(8) Output Power Requirement

According to 15.247(b)(1), for frequency hopping systems operating in the 2400–2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725–5850 MHz band: 1 watt. For all other frequency hopping systems in the 2400–2483.5 MHz band: 0.125 watts.

(9) 100 kHz Bandwidth of Frequency Band Edges Requirement

According to 15.247(d), 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. Attenuation below the general limits specified in §15.209(a) is not required.

(10) Out-of-Band Conducted Emission Requirement

According to 15.247(d), 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. Attenuation below the general limits specified in §15.209(a) is not required.

2.3 Restricted Bands of Operation

Only spurious 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
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	2655-2900	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	3360-4400	Above 38.6
13.36-13.41			

** : Until February 1, 1999, this restricted band shall be 0.490-0.510 MHz

2.4 Labeling Requirement

The device shall bear the following statement in a conspicuous location on the device :

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions : (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

2.5 User Information

The users manual or instruction manual for an intentional or unintentional radiator shall caution the user that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

For a Class B digital device or peripheral, the instructions furnished the user shall include the following or similar statement, placed in a prominent location in the text of the manual.

The Federal Communications Commission Radio Frequency Interference Statement includes the following paragraph.

This equipment has been tested and found to comply with the limits for a Class B Digital Device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation.

This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction may cause harmful interference to radio communication. However, there is no guarantee that interference will not occur in a particular installation.

If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio / TV technician for help.

3 SYSTEM TEST CONFIGURATION

3.1 Justification

For both radiated and conducted emissions below 1 GHz, the system was configured for testing in a typical fashion as a customer would normally use it. The peripherals other than EUT were connected in normally standing by situation. Measurement was performed under the condition that a computer program was exercised to simulate data communication of EUT, and the transmission rate was set to maximum allowed by EUT. Three highest emissions were verified with varying placement of the transmitting antenna connected to EUT (if applicable) to maximize the emission from EUT.

For conducted and radiated emissions, whichever RF channel is operated, the digital circuits' function identically. As the reason, measurement of emissions from digital circuits is performed with the highest, middle and the lowest channel by transmitting mode.

The following modes were investigated and the worst cases (mode 1 and 3) were chosen for final test.

1. Basic Rate (BR) 1 Mbps uses GFSK modulation
2. Enhanced Data Rate (EDR) 2Mbps uses pi/4-DQPSK modulation
3. Enhanced Data Rate (EDR) 3Mbps uses 8DPSK modulation

Model 487-7442 is the most complicated and has chosen for all tests.

3.2 Devices for Tested System

Device	Manufacture	Model / FCC ID.	Description
Radio Box *	Panasonic Taiwan Co.,Ltd	487-7440/ PQMCRM01	0.8m Unshielded Audio Cable
Speaker	----	----	1.2m Unshielded Speaker Cable
DC Power supply	GW	GPC-3030D	1.8m Unshielded AC Power Cord

Remark “*” means equipment under test.

4 RADIATED EMISSION MEASUREMENT

4.1 Applicable Standard

For unintentional radiator, the radiated emission shall comply with §15.109(a).

For intentional radiators, according to §15.247 (a), operation under this provision is limited to frequency hopping and direct sequence spread spectrum, and the out band emission shall be comply with §15.247 (d)

4.2 Measurement Procedure

1. Setup the configuration per figure 1 and 2 for frequencies measured below and above 1 GHz respectively.
2. For emission frequencies measured below 1 GHz, a pre-scan is performed in a shielded chamber to determine the accurate frequencies of higher emissions will be checked on a open test site. As the same purpose, for emission frequencies measured above 1 GHz, a pre-scan also be performed with a 1 meter measuring distance before final test.
3. For emission frequencies measured below and above 1 GHz, set the spectrum analyzer on a 100 kHz and 1 MHz resolution bandwidth respectively for each frequency measured in step 2.
4. The search antenna is to be raised and lowered over a range from 1 to 4 meters in horizontally polarized orientation. Position the highness when the highest value is indicated on spectrum analyzer, then change the orientation of EUT on test table over a range from 0 ° to 360 ° with a speed as slow as possible, and keep the azimuth that highest emission is indicated on the spectrum analyzer. Vary the antenna position again and record the highest value as a final reading. A RF test receiver is also used to confirm emissions measured.
5. Repeat step 4 until all frequencies need to be measured were complete.
6. Repeat step 5 with search antenna in vertical polarized orientations.
7. Check the three frequencies of highest emission with varying the placement of cables associated with EUT to obtain the worse case and record the result.

Figure 1 : Frequencies measured below 1 GHz configuration

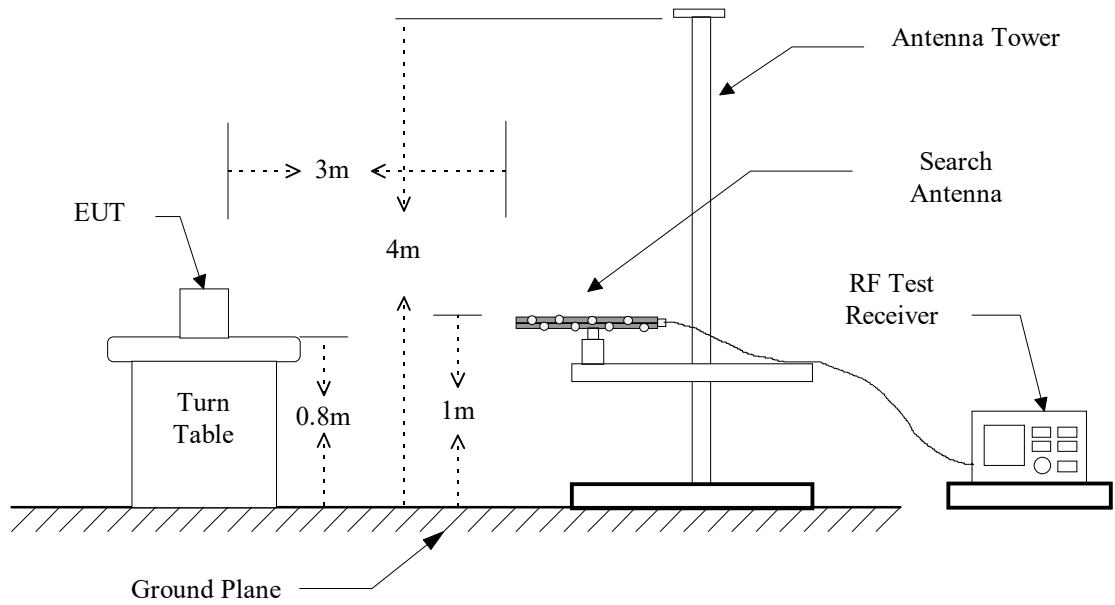
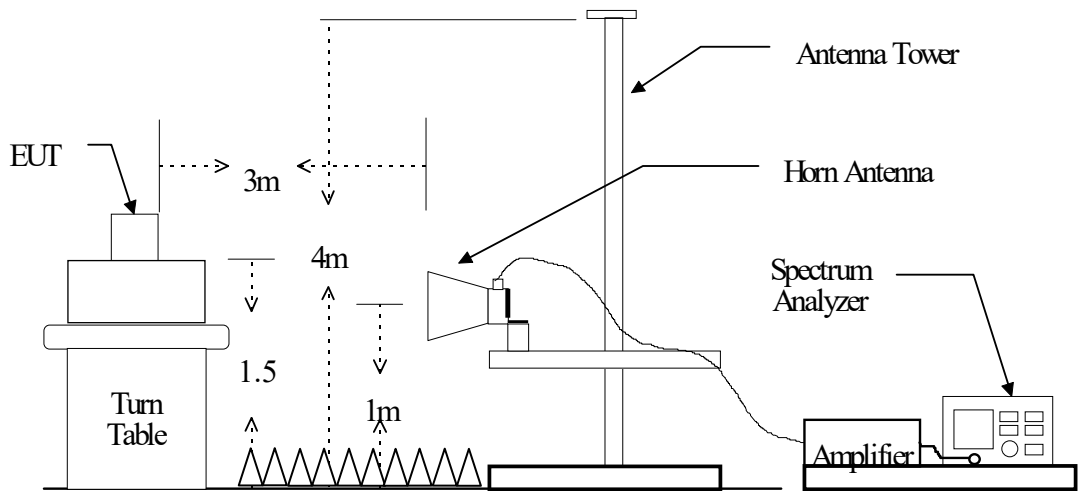


Figure 2 : Frequencies measured above 1 GHz configuration



4.3 Measuring Instrument

The following instrument are used for radiated emissions measurement:

Equipment	Manufacturer	Model No.	Calibration Date	Next Cal. Date
Test Receiver	Rohde & Schwarz	ESCI	2015/09/05	2016/09/04
Bi-Log Antenna	ETC	MCTD 2786	2016/07/15	2017/07/14
Log-periodic Antenna	EMCO	3146	2015/11/17	2016/11/16
Biconical Antenna	EMCO	3110	2015/11/17	2016/11/16
Horn Antenna	EMCO	3115	2015/10/08	2016/10/07
Horn Antenna	EMCO	3116	2015/10/12	2016/10/11
Horn Antenna	ETS	3160	2015/10/12	2016/10/11
Spectrum	R&S	FSP3	2015/12/21	2016/12/20
Amplifier	HP	8447D	2015/12/17	2016/12/16
EMI Test Receiver	Rohde & Schwarz	ESU 40	2015/10/07	2016/10/06
Attenuator	MINI-CIRCUITS	BW-S10W2+	2015/10/07	2016/10/06
Attenuator	MINI-CIRCUITS	BW-S20W2+	2015/10/07	2016/10/06
Attenuator	MINI-CIRCUITS	BW-S30W2+	2015/10/07	2016/10/06
Amplifier	HP	83051A	2016/07/18	2017/07/17

Measuring instrument setup in measured frequency band when specified detector function is used :

Frequency Band (MHz)	Instrument	Function	Resolution bandwidth	Video Bandwidth
30 to 1000	RF Test Receiver	Quasi-Peak	120 kHz	N/A
	Spectrum Analyzer	Peak	100 kHz	100 kHz
Above 1000	Spectrum Analyzer	Peak	1 MHz	1 MHz
	Spectrum Analyzer	Average	1 MHz	10 Hz or $\geq 1/T$ (Note 1)

Note 1:

VBW = 10 Hz, when the duty cycle is no less than 98%.

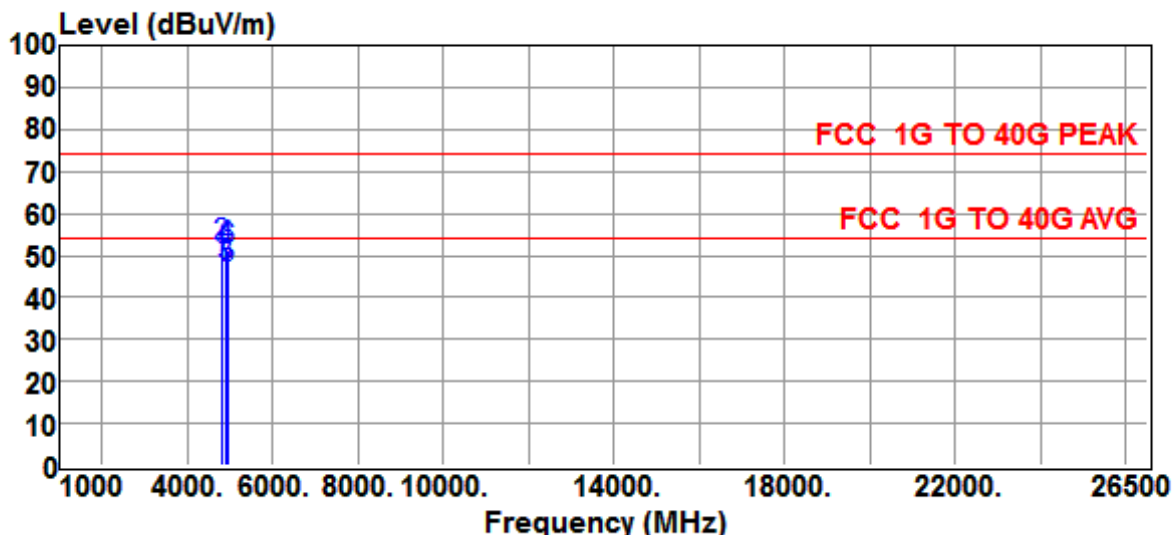
VBW $\geq 1/T$, when duty cycle is less than 98% where T is the minimum transmission duration over which the transmitter is on and is transmitting at its maximum power control level for the tested mode of operation.

4.4 Radiated Emission Data

4.4.1 Tx Portion

A. Bluetooth BR

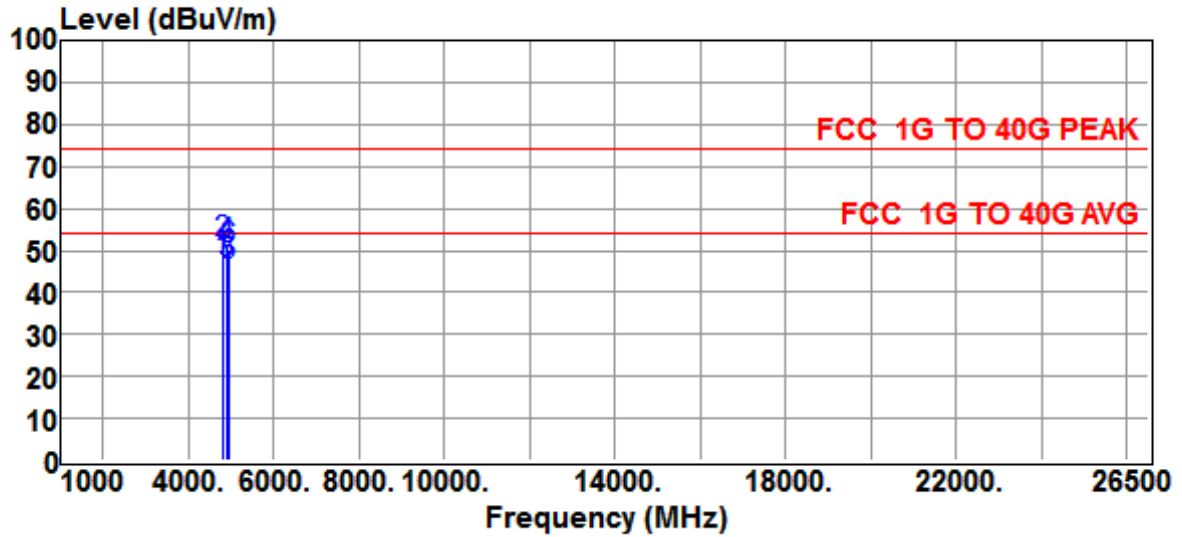
Test Date : Aug. 11, 2016 Temperature : 25 °C Humidity : 53 %



Site	:CHAMBER	Date	:2016-08-11
Limit	:FCC 1G TO 40G PEAK	Ant. Pol.	:HORIZONTAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:DC 24V	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:BR		

Freq MHz	Reading dB μ V	Correction Factor dB	Result dB μ V/m	Limits dB μ V/m	Over limit dB	Detector
4804.0000	47.2	1.1	48.3	54.0	-5.7	Average
4804.0000	51.2	1.1	52.3	74.0	-21.7	Peak
4882.0000	46.0	1.4	47.4	54.0	-6.6	Average
4882.0000	50.4	1.4	51.8	74.0	-22.2	Peak
4960.0000	45.4	1.6	47.0	54.0	-7.0	Average
4960.0000	49.7	1.6	51.3	74.0	-22.7	Peak

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss - Amplifier Gain (if any)
3. The margin value=Limit – Result



Site	:CHAMBER	Date	:2016-08-11
Limit	:FCC 1G TO 40G PEAK	Ant. Pol.	:VERTICAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:DC 24V	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:BR		

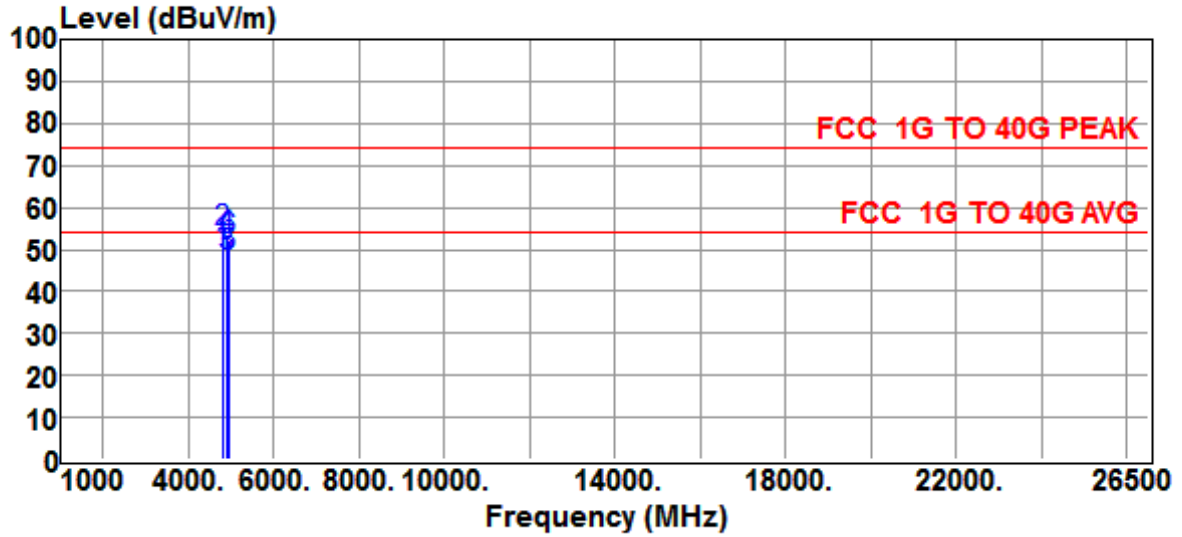
Freq MHz	Reading dBμV	Correction Factor dB	Result dBμV/m	Limits dBμV/m	Over limit dB	Detector
4804.0000	46.4	1.1	47.5	54.0	-6.5	Average
4804.0000	50.6	1.1	51.7	74.0	-22.3	Peak
4882.0000	45.4	1.4	46.8	54.0	-7.2	Average
4882.0000	49.7	1.4	51.1	74.0	-22.9	Peak
4960.0000	44.7	1.6	46.3	54.0	-7.7	Average
4960.0000	48.7	1.6	50.3	74.0	-23.7	Peak

Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss - Amplifier Gain (if any)
3. The margin value=Limit – Result

B. Bluetooth EDR

Test Date : Aug. 11, 2016 Temperature : 25 °C Humidity : 53 %

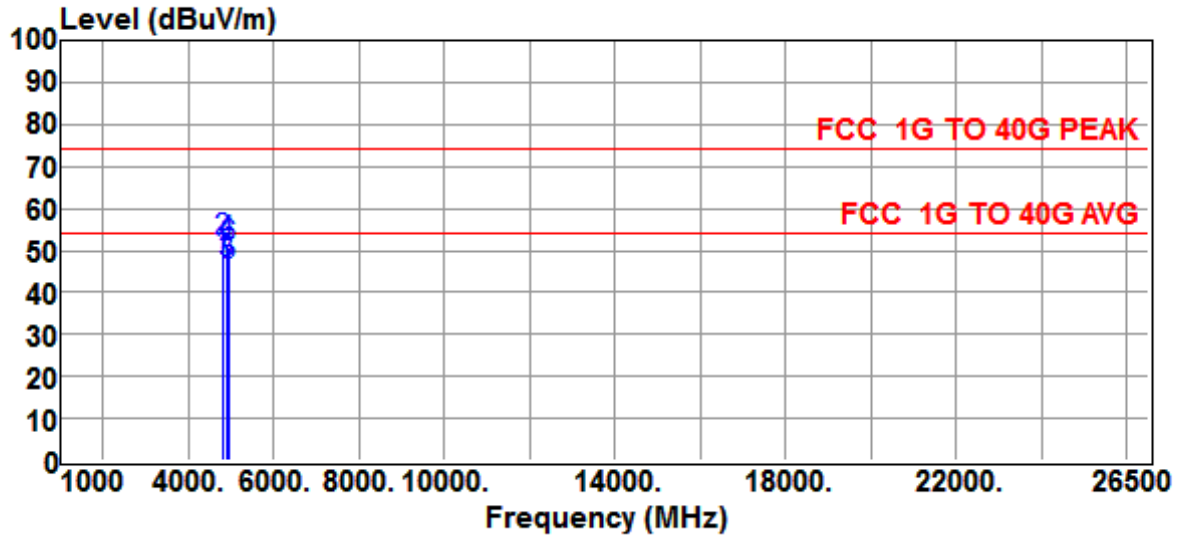


Site	:CHAMBER	Date	:2016-08-11
Limit	:FCC 1G TO 40G PEAK	Ant. Pol.	:HORIZONTAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:DC 24V	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:EDR		

Freq MHz	Reading dBμV	Correction Factor dB	Result dBμV/m	Limits dBμV/m	Over limit dB	Detector
4804.0000	48.2	1.1	49.3	54.0	-4.7	Average
4804.0000	52.8	1.1	53.9	74.0	-20.1	Peak
4882.0000	46.9	1.4	48.3	54.0	-5.7	Average
4882.0000	51.2	1.4	52.6	74.0	-21.4	Peak
4960.0000	46.7	1.6	48.3	54.0	-5.7	Average
4960.0000	50.6	1.6	52.2	74.0	-21.8	Peak

Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss - Amplifier Gain (if any)
3. The margin value=Limit – Result



Site	:CHAMBER	Date	:2016-08-11
Limit	:FCC 1G TO 40G PEAK	Ant. Pol.	:VERTICAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:DC 24V	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:EDR		

Freq MHz	Reading dB μ V	Correction Factor dB	Result dB μ V/m	Limits dB μ V/m	Over limit dB	Detector
4804.0000	47.2	1.1	48.3	54.0	-5.7	Average
4804.0000	51.0	1.1	52.1	74.0	-21.9	Peak
4882.0000	45.6	1.4	47.0	54.0	-7.0	Average
4882.0000	50.3	1.4	51.7	74.0	-22.3	Peak
4960.0000	45.0	1.6	46.6	54.0	-7.4	Average
4960.0000	49.3	1.6	50.9	74.0	-23.1	Peak

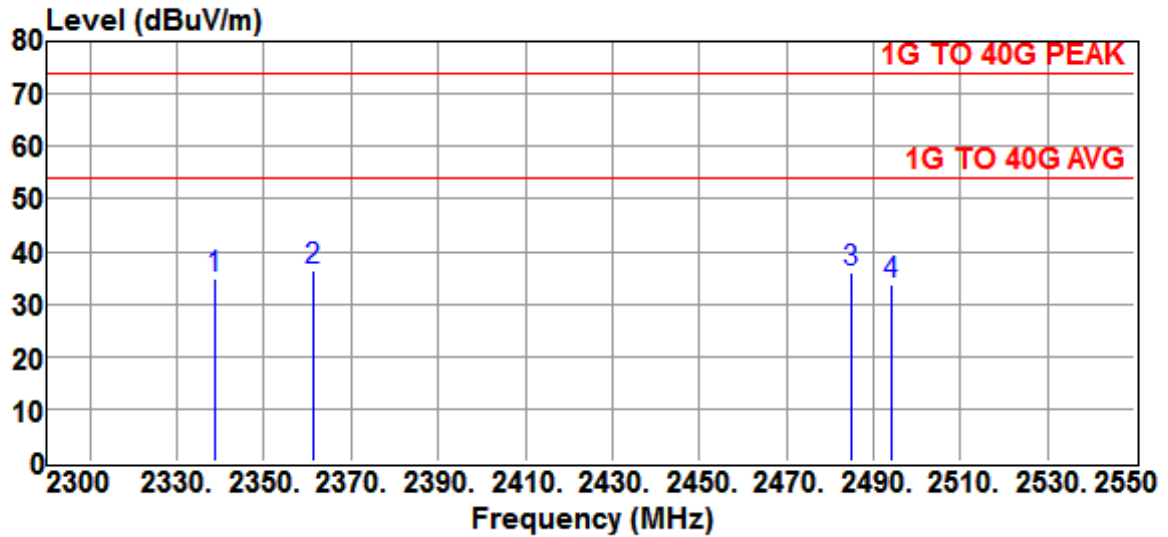
Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss - Amplifier Gain (if any)
3. The margin value=Limit - Result

4.4.2 Radiated Emissions in Restricted Bands

A. Bluetooth BR

Test Date : Aug. 11, 2016 Temperature : 25 °C Humidity : 53 %

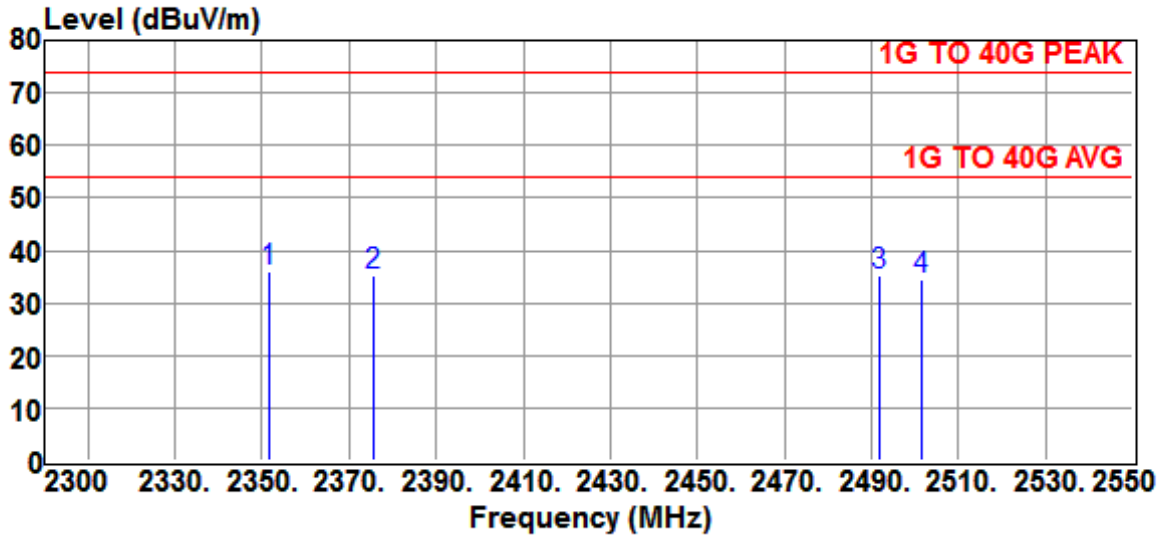


Site	:CHAMBER	Date	:2016-08-11
Limit	:1G TO 40G PEAK	Ant. Pol.	:HORIZONTAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:AC 110V60Hz	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:BR		

Freq MHz	Reading dBμV	Correction Factor dB	Result dBμV/m	Limits (AVG) dBμV/m	Over limit dB	Detector
2338.5000	44.0	-9.1	34.9	54.0	-19.1	Peak
2361.2500	45.4	-9.1	36.3	54.0	-17.7	Peak
2485.0000	45.0	-9.0	36.0	54.0	-18.0	Peak
2494.0000	42.8	-9.0	33.8	54.0	-20.2	Peak

Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss - Amplifier Gain (if any)
3. The margin value=Limit - Result
4. Peak measurements are compared to the average limit - as peak measurements are below the average limit, they also comply with the peak limit.



Site	:CHAMBER	Date	:2016-08-11
Limit	:1G TO 40G PEAK	Ant. Pol.	:VERTICAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:AC 110V60Hz	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:BR		

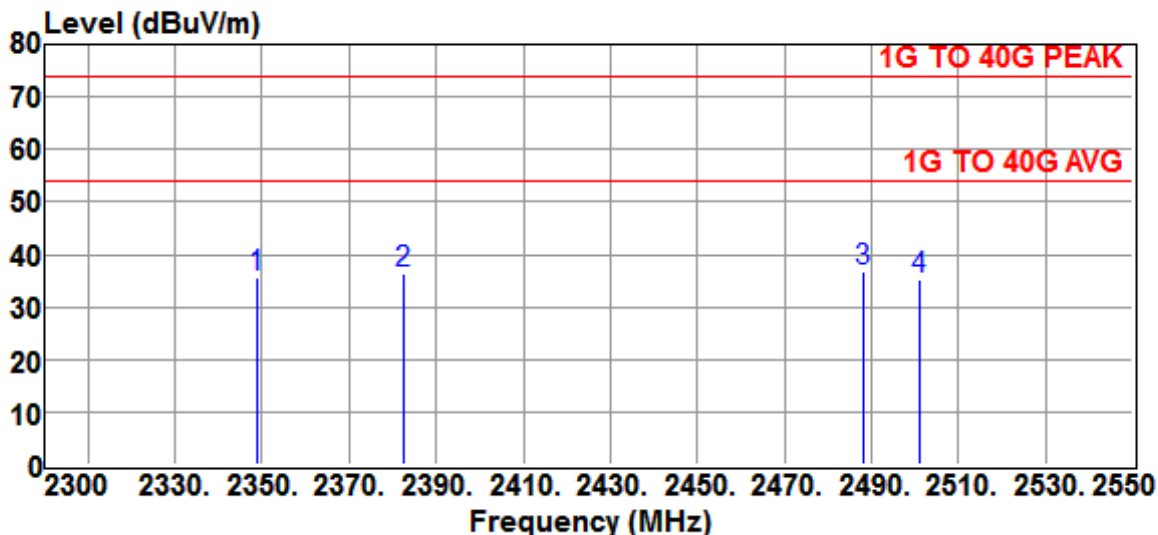
Freq MHz	Reading dBμV	Correction Factor dB	Result dBμV/m	Limits (AVG) dBμV/m	Over limit dB	Detector
2351.7500	45.0	-9.1	35.9	54.0	-18.1	Peak
2375.7500	44.3	-9.1	35.2	54.0	-18.8	Peak
2492.0000	44.2	-9.0	35.2	54.0	-18.8	Peak
2501.5000	43.3	-9.0	34.3	54.0	-19.7	Peak

Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss - Amplifier Gain (if any)
3. The margin value=Limit - Result
4. Peak measurements are compared to the average limit - as peak measurements are below the average limit, they also comply with the peak limit.

B. Bluetooth EDR

Test Date : Aug. 11, 2016 Temperature : 25 °C Humidity : 53 %

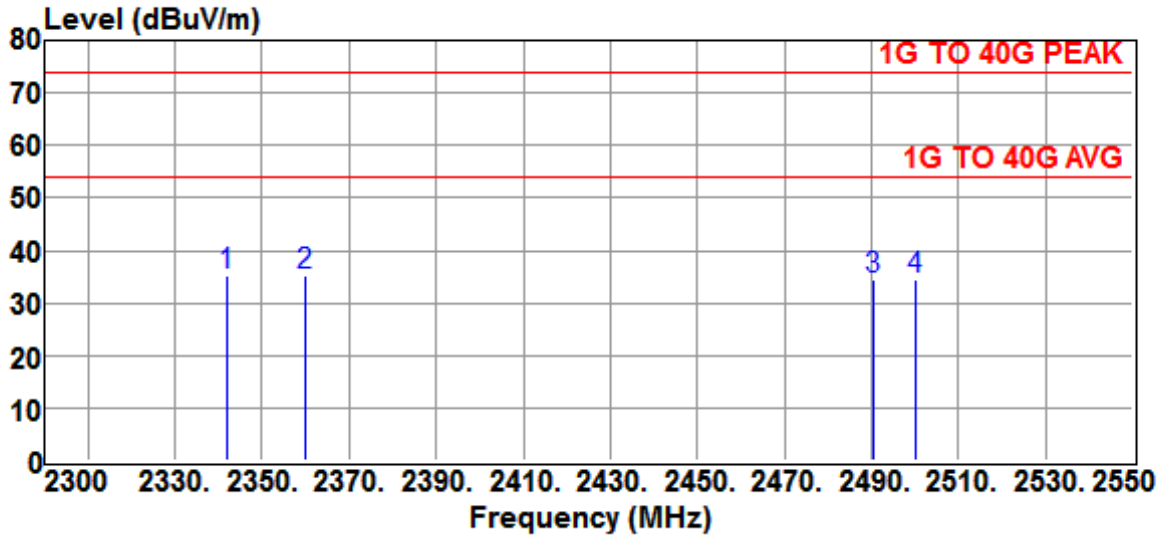


Site	:CHAMBER	Date	:2016-08-11
Limit	:1G TO 40G PEAK	Ant. Pol.	:HORIZONTAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:AC 110V60Hz	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:EDR		

Freq MHz	Reading dB μ V	Correction Factor dB	Result dB μ V/m	Limits (AVG) dB μ V/m	Over limit dB	Detector
2349.0000	44.8	-9.2	35.6	54.0	-18.4	Peak
2382.5000	45.6	-9.1	36.5	54.0	-17.5	Peak
2488.2500	45.7	-9.0	36.7	54.0	-17.3	Peak
2501.0000	44.2	-9.0	35.2	54.0	-18.8	Peak

Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss - Amplifier Gain (if any)
3. The margin value=Limit - Result
4. Peak measurements are compared to the average limit - as peak measurements are below the average limit, they also comply with the peak limit.



Site	:CHAMBER	Date	:2016-08-11
Limit	:1G TO 40G PEAK	Ant. Pol.	:VERTICAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:AC 110V60Hz	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:EDR		

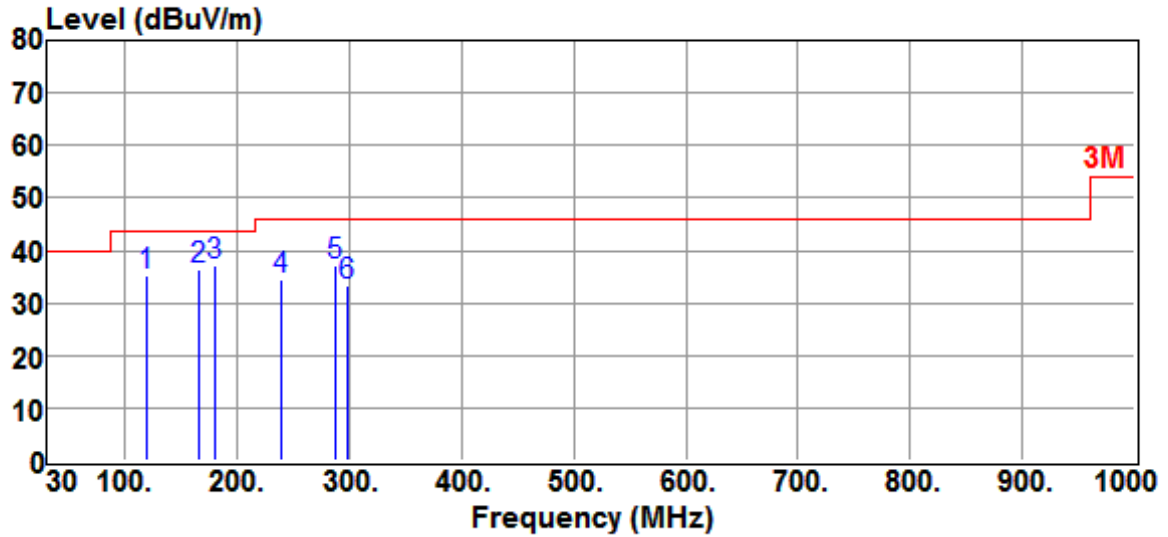
Freq MHz	Reading dBµV	Correction Factor dB	Result dBµV/m	Limits (AVG) dBµV/m	Over limit dB	Detector
2342.0000	44.5	-9.2	35.3	54.0	-18.7	Peak
2360.0000	44.2	-9.1	35.1	54.0	-18.9	Peak
2490.2500	43.6	-9.0	34.6	54.0	-19.4	Peak
2500.2500	43.3	-9.0	34.3	54.0	-19.7	Peak

Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss - Amplifier Gain (if any)
3. The margin value=Limit - Result
4. Peak measurements are compared to the average limit - as peak measurements are below the average limit, they also comply with the peak limit.

4.4.3 Other Emissions

a) Emission frequencies below 1 GHz

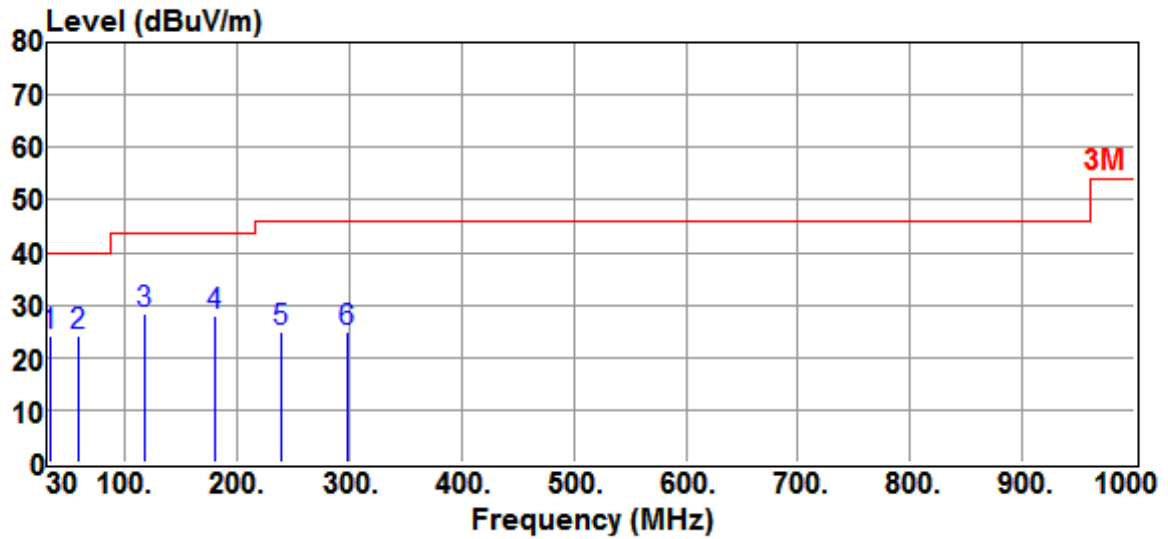


Site	:CHAMBER #2	Date	:2016-08-11
Limit	:3M	Ant. Pol.	:HORIZONTAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:DC 24V	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:BT MODE		

Freq MHz	Reading dBμV	Correction Factor dB	Result dBμV/m	Limits dBμV/m	Over limit dB	Detector
120.2100	49.5	-14.2	35.3	43.5	-8.2	QP
166.7700	50.4	-14.0	36.4	43.5	-7.1	QP
179.3800	52.2	-15.1	37.1	43.5	-6.4	QP
239.5200	47.4	-13.1	34.3	46.0	-11.7	QP
288.0200	47.0	-10.0	37.0	46.0	-9.0	QP
298.6900	43.1	-9.6	33.5	46.0	-12.5	QP

Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss
3. The margin value=Limit - Result

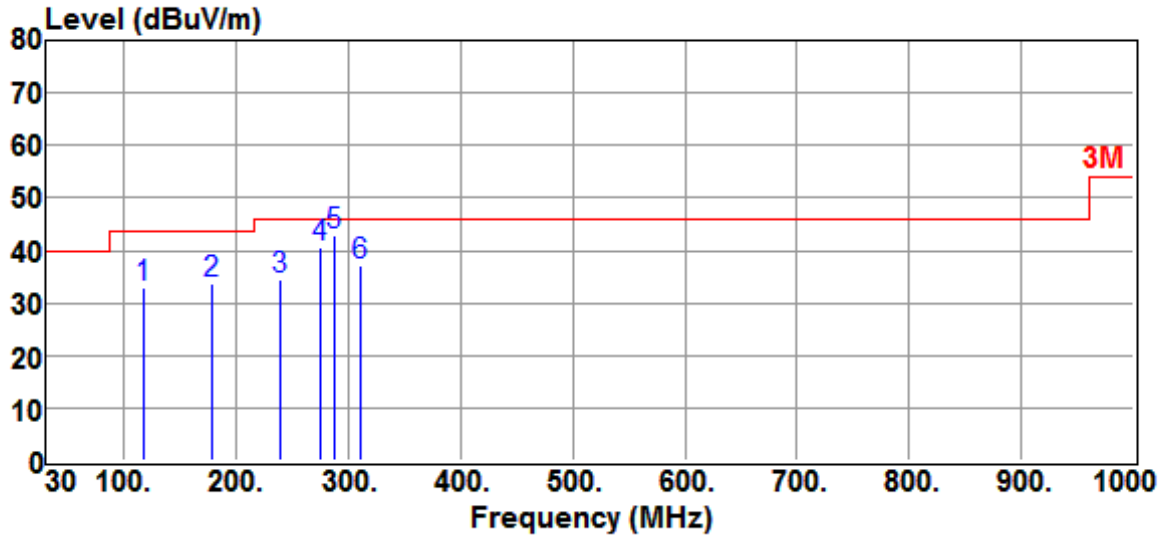


Site	:CHAMBER #2	Date	:2016-08-11
Limit	:3M	Ant. Pol.	:VERTICAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:DC 24V	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:BT MODE		

Freq MHz	Reading dBμV	Correction Factor dB	Result dBμV/m	Limits dBμV/m	Over limit dB	Detector
32.9100	33.2	-9.3	23.9	40.0	-16.1	QP
59.1000	42.7	-18.6	24.1	40.0	-15.9	QP
118.2700	42.7	-14.3	28.4	43.5	-15.1	QP
179.3800	43.0	-15.1	27.9	43.5	-15.6	QP
239.5200	37.9	-13.1	24.8	46.0	-21.2	QP
298.6900	34.4	-9.6	24.8	46.0	-21.2	QP

Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss
3. The margin value=Limit - Result

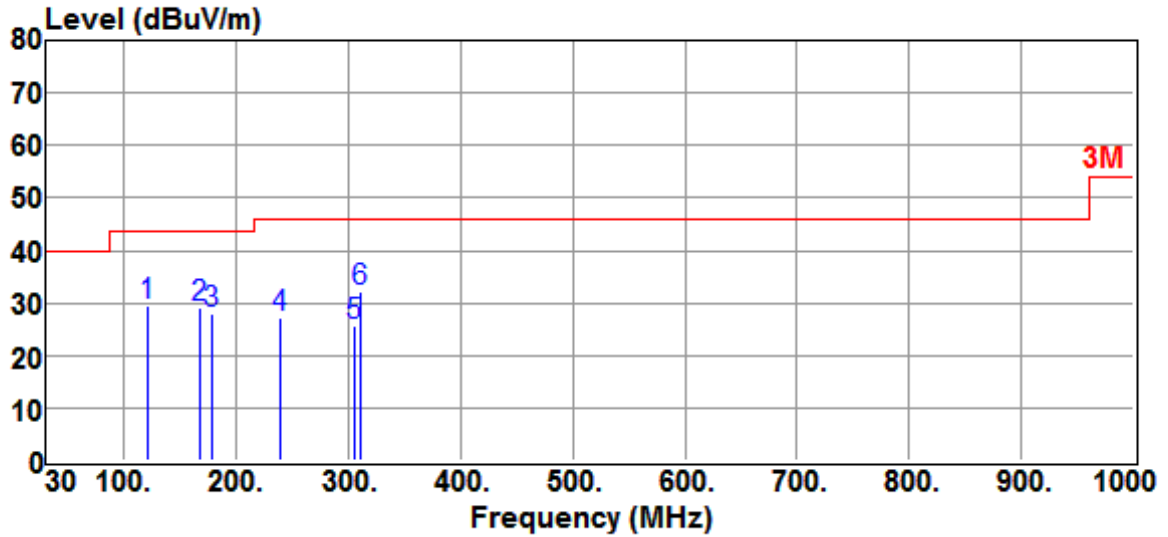


Site	:CHAMBER #2	Date	:2016-08-11
Limit	:3M	Ant. Pol.	:HORIZONTAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:DC 24V	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:FM MODE		

Freq MHz	Reading dBμV	Correction Factor dB	Result dBμV/m	Limits dBμV/m	Over limit dB	Detector
118.3100	47.3	-14.3	33.0	43.5	-10.5	QP
178.6600	48.6	-15.1	33.5	43.5	-10.0	QP
239.2010	47.4	-13.1	34.3	46.0	-11.7	QP
275.6600	51.0	-10.4	40.6	46.0	-5.4	QP
288.2600	53.0	-10.0	43.0	46.0	-3.0	QP
310.2300	46.2	-9.1	37.1	46.0	-8.9	QP

Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss
3. The margin value=Limit - Result

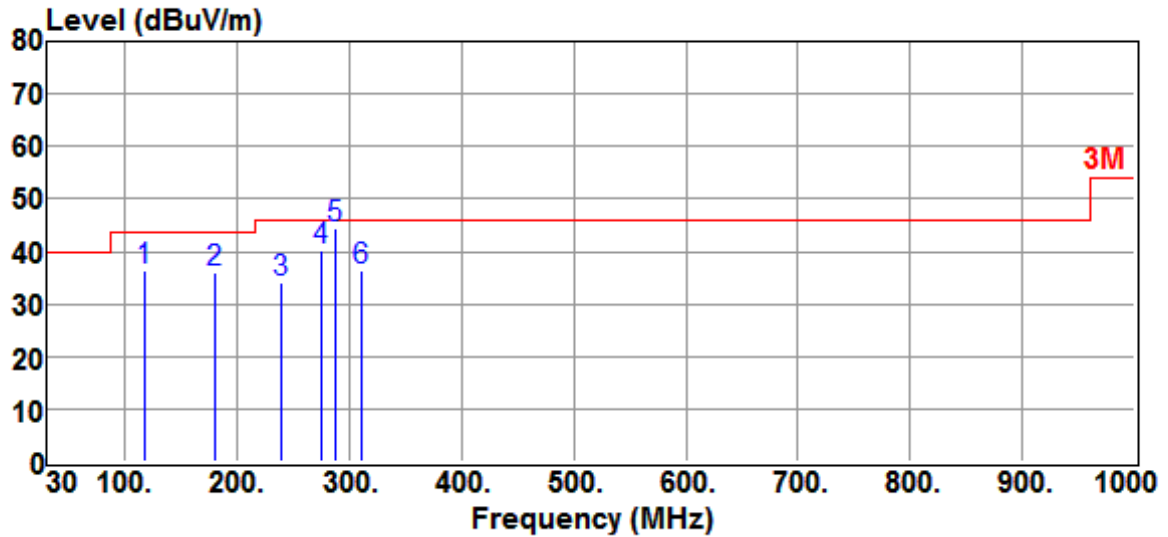


Site	:CHAMBER #2	Date	:2016-08-11
Limit	:3M	Ant. Pol.	:VERTICAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:DC 24V	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:FM MODE		

Freq MHz	Reading dBμV	Correction Factor dB	Result dBμV/m	Limits dBμV/m	Over limit dB	Detector
120.3250	43.8	-14.2	29.6	43.5	-13.9	QP
168.2200	43.2	-14.1	29.1	43.5	-14.4	QP
179.3600	43.2	-15.1	28.1	43.5	-15.4	QP
238.9200	40.3	-13.1	27.2	46.0	-18.8	QP
305.6900	34.9	-9.3	25.6	46.0	-20.4	QP
311.2400	41.4	-9.1	32.3	46.0	-13.7	QP

Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss
3. The margin value=Limit - Result

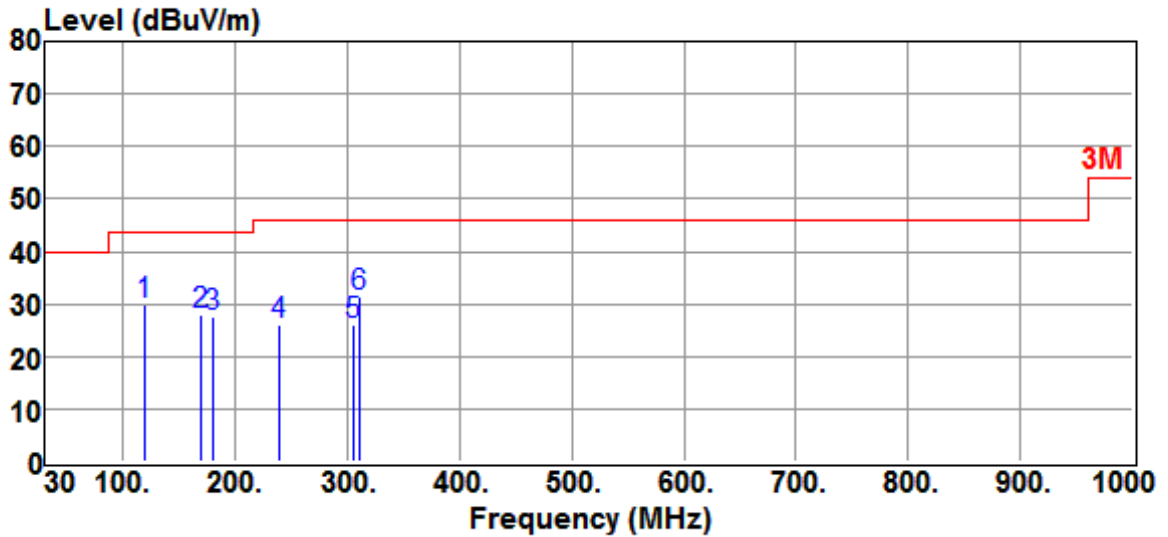


Site	:CHAMBER #2	Date	:2016-08-11
Limit	:3M	Ant. Pol.	:HORIZONTAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:DC 24V	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:USB IN		

Freq MHz	Reading dBμV	Correction Factor dB	Result dBμV/m	Limits dBμV/m	Over limit dB	Detector
118.2700	50.8	-14.3	36.5	43.5	-7.0	QP
179.3800	50.9	-15.1	35.8	43.5	-7.7	QP
239.5200	47.1	-13.1	34.0	46.0	-12.0	QP
275.4100	50.7	-10.5	40.2	46.0	-5.8	QP
288.0200	54.5	-10.0	44.5	46.0	-1.5	QP
311.3000	45.7	-9.1	36.6	46.0	-9.4	QP

Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss
3. The margin value=Limit - Result



Site	:CHAMBER #2	Date	:2016-08-11
Limit	:3M	Ant. Pol.	:VERTICAL
EUT	:Radio Box	Model	:487-7442
Power Rating	:DC 24V	Temp.	:25 °C
Engineer	:Brian Huang	Humi.	:53 %
Test Mode	:USB IN MODE		

Freq MHz	Reading dBµV	Correction Factor dB	Result dBµV/m	Limits dBµV/m	Over limit dB	Detector
120.2100	44.0	-14.2	29.8	43.5	-13.7	QP
168.7100	42.3	-14.2	28.1	43.5	-15.4	QP
179.3800	42.5	-15.1	27.4	43.5	-16.1	QP
239.5200	39.3	-13.1	26.2	46.0	-19.8	QP
305.4800	35.5	-9.3	26.2	46.0	-19.8	QP
311.3000	40.4	-9.1	31.3	46.0	-14.7	QP

Note :

1. Result = Reading + Corrected Factor
2. Corrected Factor = Antenna Factor + Cable Loss
3. The margin value=Limit - Result

b) Emission frequencies above 1 GHz

Radiated emission frequencies above 1 GHz to 26.5 GHz were too low to be measured with a pre-amplifier of 35 dB.

c) Emission frequencies below 30MHz (9kHz - 30MHz)

According to exploratory test no any obvious emission were detected from 9kHz to 30MHz. Although these tests were performed other than open area test site, adequate comparison measurements were confirmed against 30 m open are test site. Therefore sufficient tests were made to demonstrate that the alternative site produces results that correlate with the ones of tests made in an open field based on KDB 937606.

4.5 Field Strength Calculation

The field strength is calculated by adding the Antenna Factor, High Pass Filter Loss (if used) and Cable Loss, and subtracting the Amplifier Gain (if any) from the measured reading. The basic equation calculation is as follows:

$$\mathbf{Result = Reading + Corrected Factor}$$

where Corrected Factor

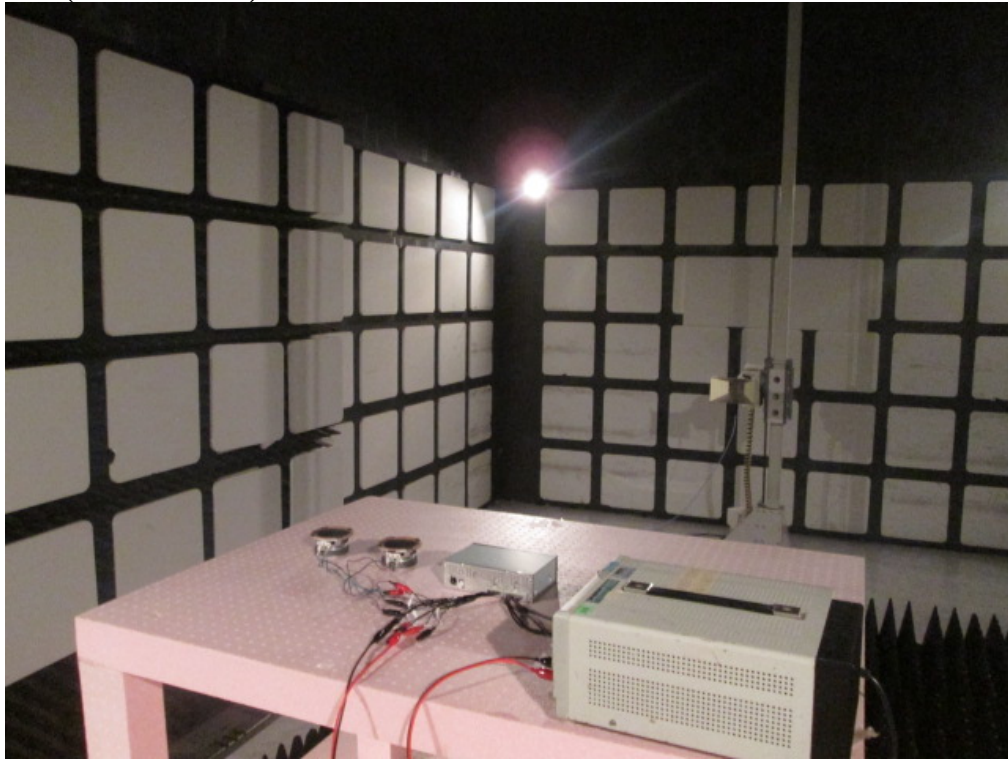
$$= \text{Antenna FACTOR} + \text{Cable Loss} + \text{High Pass Filter Loss} - \text{Amplifier Gain}$$

4.6 Photos of Radiation Measuring Setup

(Below 1GHz)



(Above 1GHz)



5 CONDUCTED EMISSION MEASUREMENT

5.1 Description

This EUT is excused from investigation of conducted emission, for it is powered by DC battery only. According to §15.207 (d), measurements to demonstrate compliance with the conducted limits are not required for devices which only employ battery power for operation and which do not operate from the AC power lines or contain provisions for operation while connected to the AC power lines.

6 ANTENNA REQUIREMENT

6.1 Standard Applicable

For intentional device, according to 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.

6.2 Antenna Construction

The antenna is connected to the main PCB and installed inside the housing, no consideration of replacement.

Please refer to the construction Photo for details.

7 HOPPING CHANNEL SEPARATION

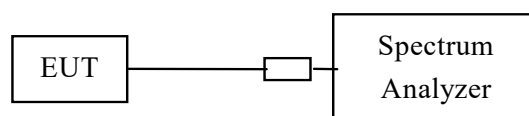
7.1 Standard Applicable

According to 15.247(a)(1), frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400-2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW.

7.2 Measurement 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 figure 4 without connection to measurement instrument. Turn on the EUT and connect it to measurement instrument. The EUT must have its hopping function enabled. Then set it to any one convenient frequency within its operating range.
3. Use the following spectrum analyzer settings:
 - Span = wide enough to capture the peaks of two adjacent channels
 - Resolution (or IF) Bandwidth (RBW) $\geq 1\%$ of the span
 - Video (or Average) Bandwidth (VBW) \geq RBW
 - Sweep = auto
 - Detector function = peak
 - Trace = max hold
4. Allow the trace to stabilize. Use the marker-delta function to determine the separation between the peaks of the adjacent channels. Plot the result on the screen of spectrum analyzer.
5. Repeat above procedures until all frequencies measured were complete.

Figure 4 : Measurement configuration.



7.3 Measurement Equipment

Equipment	Manufacturer	Model No.	Calibration Date	Next Cal. Date
Spectrum Analyzer	Rohde & Schwarz	FSP40	2016/10/03	2017/10/02
Attenuator	MINI-CIRCUITS	BW-S10W2+	2016/09/30	2017/09/29

7.4 Measurement Data

Test Date : Oct. 05, 2016 Temperature : 24 °C Humidity : 60 %

Mode: Bluetooth BR

- a) Channel Low : Adjacent Hopping Channel Separation is 1.008 MHz
- b) Channel Middle : Adjacent Hopping Channel Separation is 1.000 MHz
- c) Channel High : Adjacent Hopping Channel Separation is 1.000 MHz

Mode: Bluetooth EDR

- a) Channel Low : Adjacent Hopping Channel Separation is 1.002 MHz
- b) Channel Middle : Adjacent Hopping Channel Separation is 1.002 MHz
- c) Channel High : Adjacent Hopping Channel Separation is 1.002 MHz

Note : The expanded uncertainty: frequency $\times 1.65 \times 10^{-6}$ ($1 \text{ GHz} < f \leq 18 \text{ GHz}$).

Mode: Bluetooth BR

Channel Low



*RBW 30 kHz Delta 1 [T1]
VBW 100 kHz -0.23 dB
SWT 2.5 ms 1.008000000 MHz

Ref 21 dBm

Att 40 dB

1 PK
VIEW



Center 2.4025 GHz

200 kHz/

Span 2 MHz

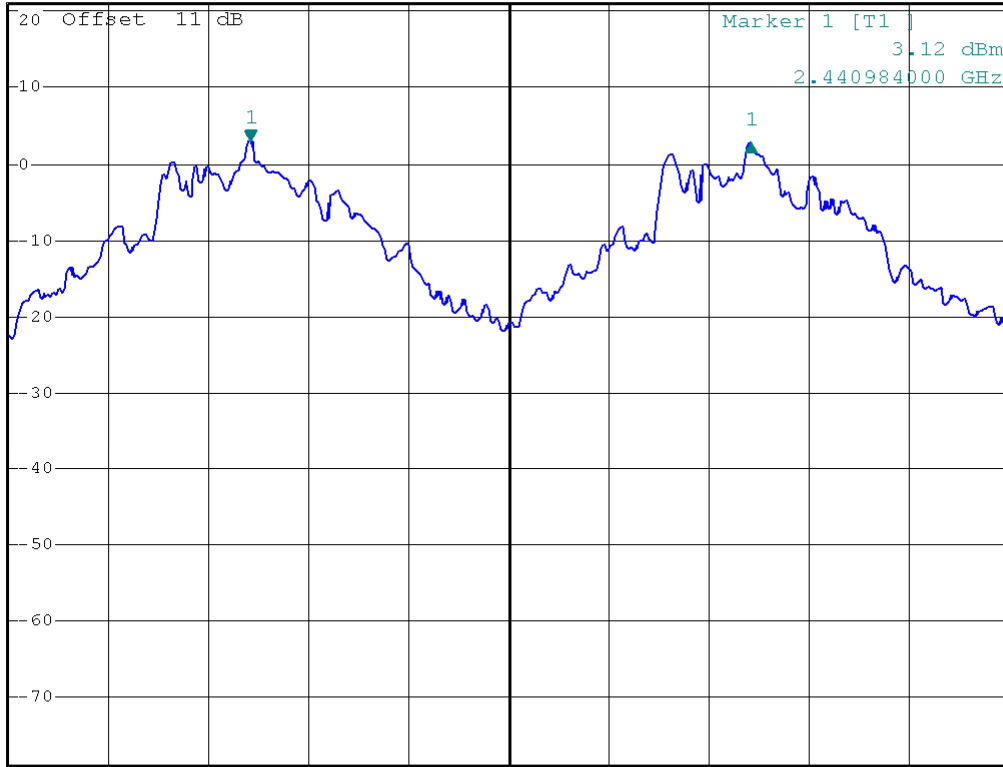
Channel Middle



*RBW 30 kHz Delta 1 [T1]
VBW 100 kHz -0.38
SWT 2.5 ms 1.000000000

Ref 21 dBm

Att 40 dB



Center 2.4415 GHz

200 kHz/

Span 2 MHz

Channel High



*RBW 30 kHz Delta 1 [T1]
VBW 100 kHz -0.42
SWT 2.5 ms 1.000000000

Ref 21 dBm

Att 40 dB

1 PK
MAXH



Center 2.4795 GHz

200 kHz/

Span 2 MHz

Mode: Bluetooth EDR

Channel Low



*RBW 30 kHz Delta 1 [T2]
VBW 100 kHz -1.22 dB
SWT 5 ms 1.002000000 MHz

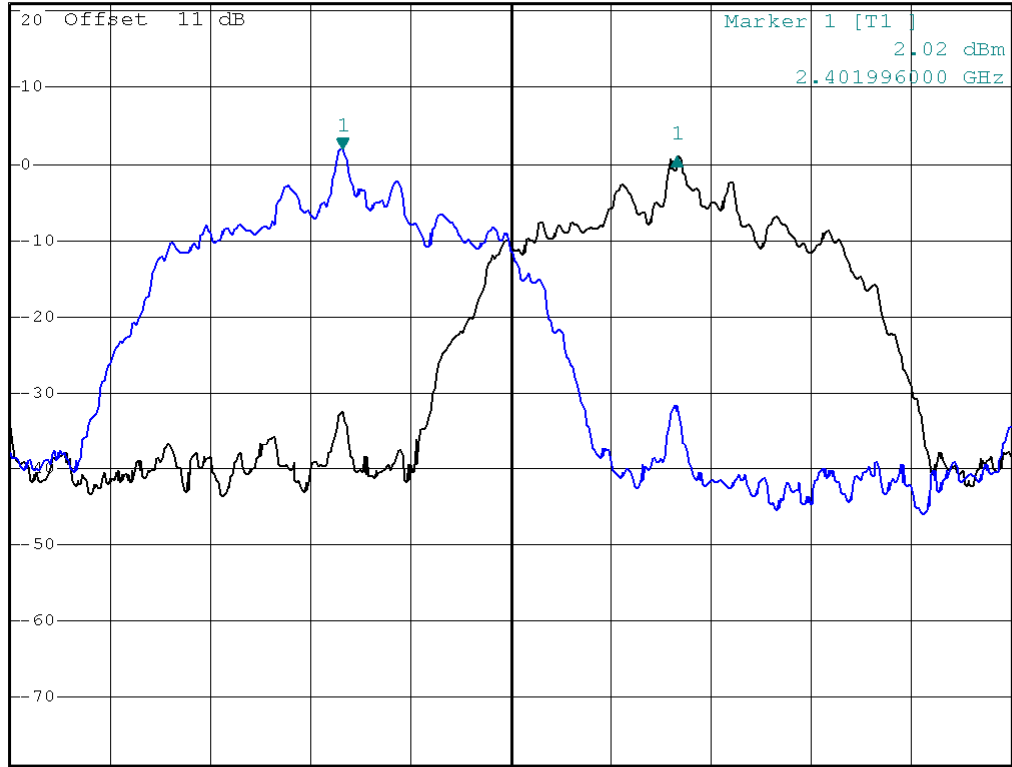
Ref 21 dBm

Att 40 dB

1.002000000 MHz

1 PK
VIEW

2 PK
VIEW

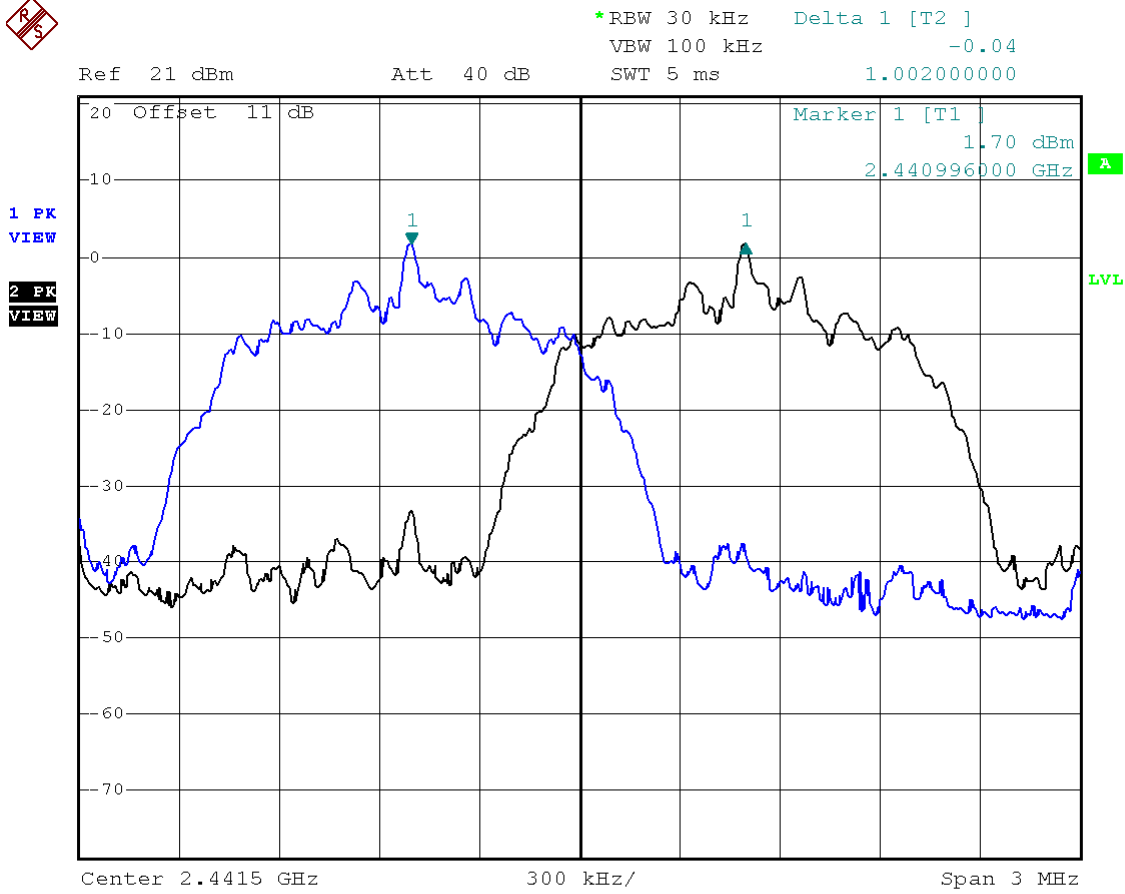


Center 2.4025 GHz

300 kHz/

Span 3 MHz

Channel Middle



Channel High

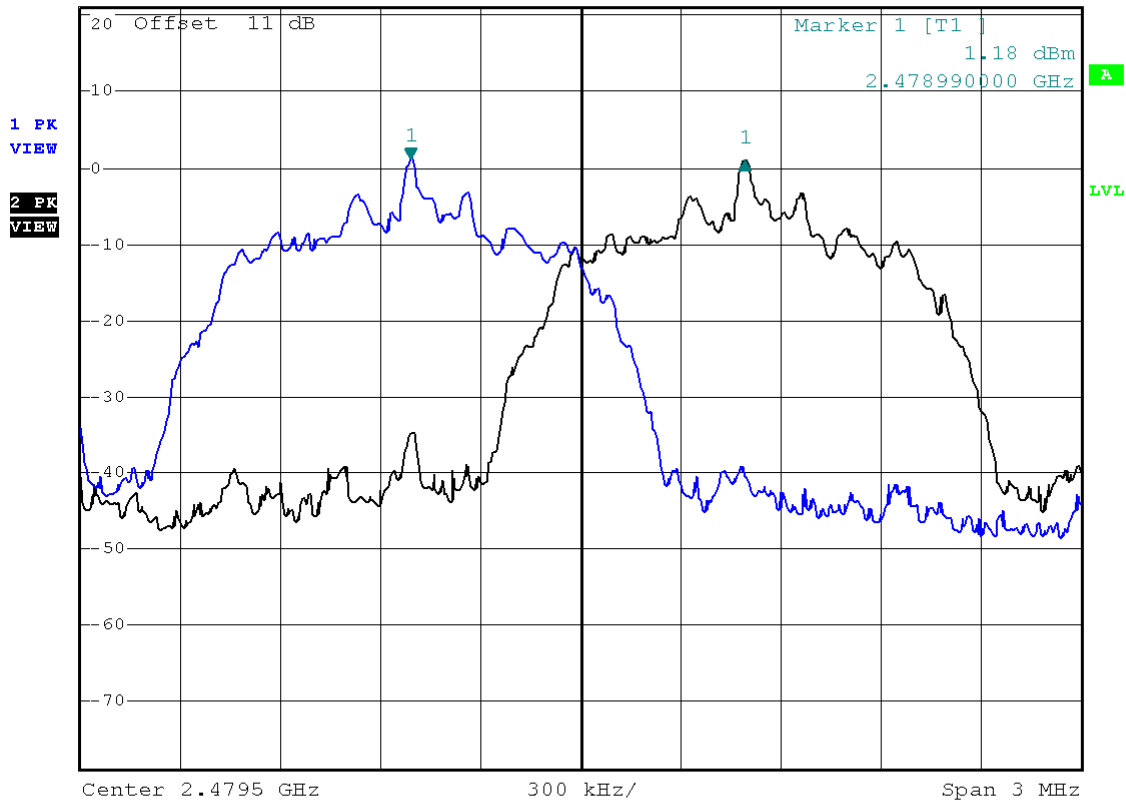


*RBW 30 kHz Delta 1 [T2]
VBW 100 kHz -0.22
SWT 5 ms 1.002000000

Ref 21 dBm

Att 40 dB

1.002000000



8 NUMBER OF HOPPING FREQUENCY USED

8.1 Standard Applicable

According to 15.247(a)(1)(iii), frequency hopping systems in the 2400–2483.5 MHz band shall use at least 15 channels.

8.2 Measurement 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 figure 4 without connection to measurement instrument. Turn on the EUT and connect it to measurement instrument. The EUT must have its hopping function enabled.
3. Use the following spectrum analyzer settings:
 - Span = the frequency band of operation
 - RBW \geq 1% of the span
 - VBW \geq RBW
 - Sweep = auto
 - Detector function = peak
 - Trace = max hold
4. Allow the trace to stabilize. Plot the result on the screen of spectrum analyzer.
5. Repeat above procedures until all frequencies measured were complete.

8.3 Measurement Equipment

Equipment	Manufacturer	Model No.	Calibration Date	Next Cal. Date
Spectrum Analyzer	Rohde & Schwarz	FSP40	2016/10/03	2017/10/02
Attenuator	MINI-CIRCUITS	BW-S10W2+	2016/09/30	2017/09/29

8.4 Measurement Data

Test Date : Oct. 05, 2016 Temperature : 24 °C Humidity : 60 %

There are 79 hopping frequencies used.

Justification on AFH mode:

Adaptive Frequency Hopping (AFH) means that a device can hop over a reduced set of frequencies. The frequencies hopped may be reduced in AFH mode but at least 15 channels will be used, normally AFH mode has 20 channels.

Note : The expanded uncertainty: frequency $\times 1.65 \times 10^{-6}$ ($1 \text{ GHz} < f \leq 18 \text{ GHz}$).

Mode: Bluetooth BR

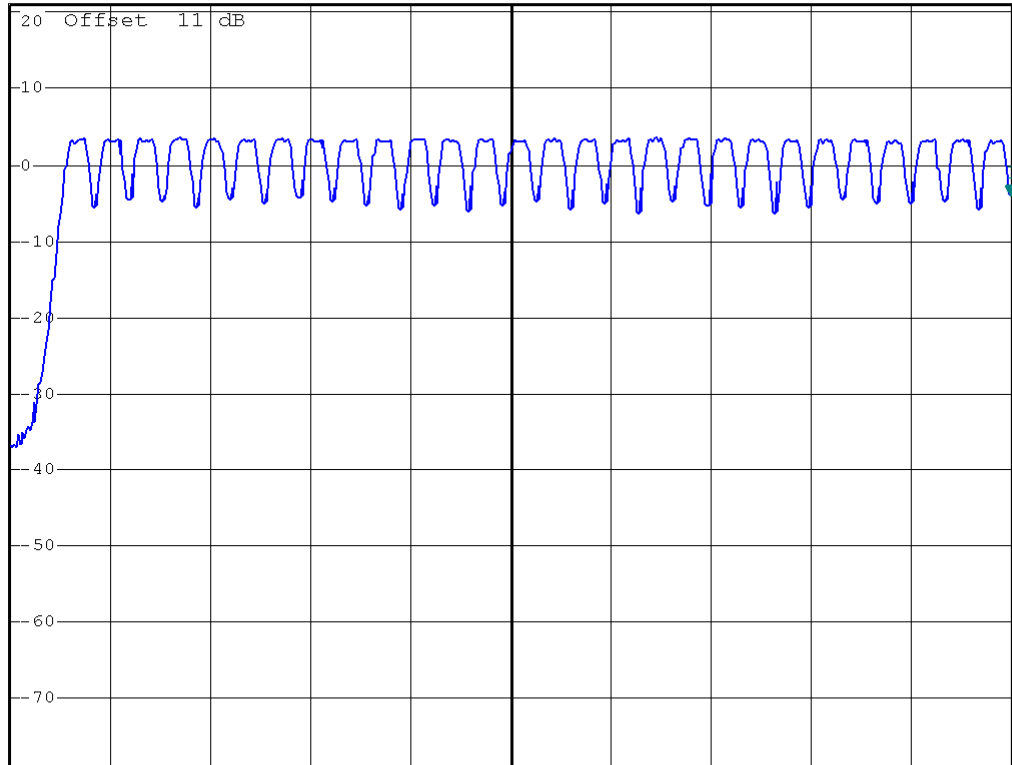


*RBW 300 kHz Marker 1 [T1]
VBW 1 MHz -4.19 dBm
SWT 2.5 ms 2.429500000 GHz

Ref 21 dBm

Att 40 dB

2.429500000 GHz



Start 2.4 GHz

2.95 MHz/

Stop 2.4295 GHz



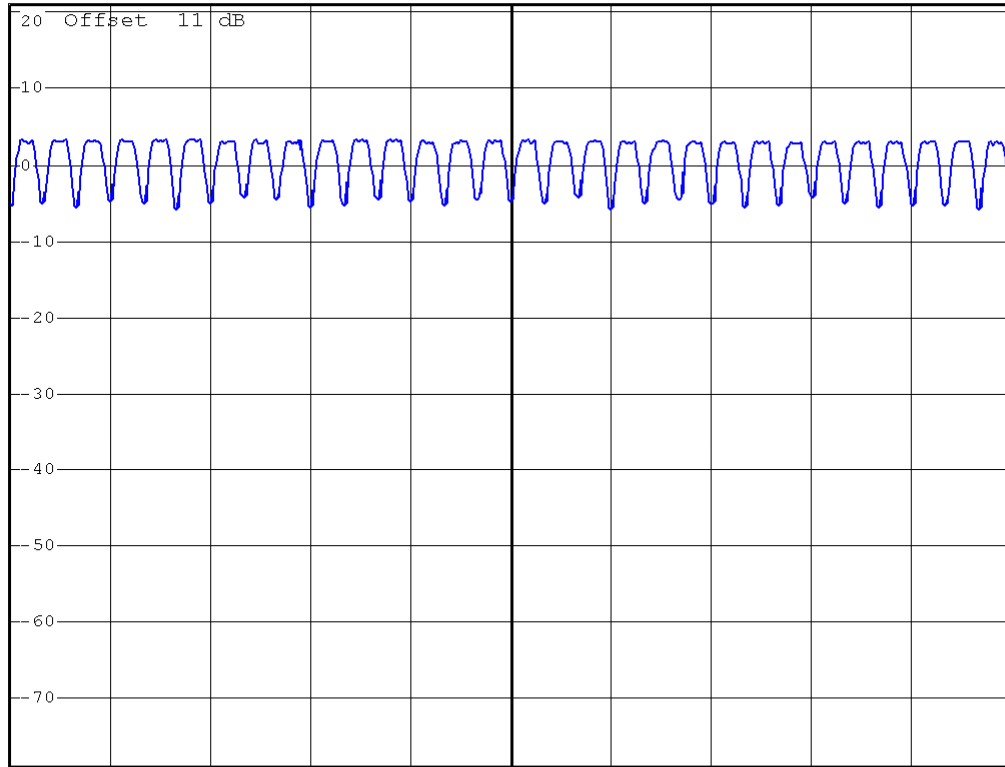
*RBW 300 kHz
VBW 1 MHz
SWT 2.5 ms

Ref 21 dBm

Att 40 dB

SWT 2.5 ms

1 PK
MAXH



Start 2.4295 GHz

3 MHz/

Stop 2.4595 GHz



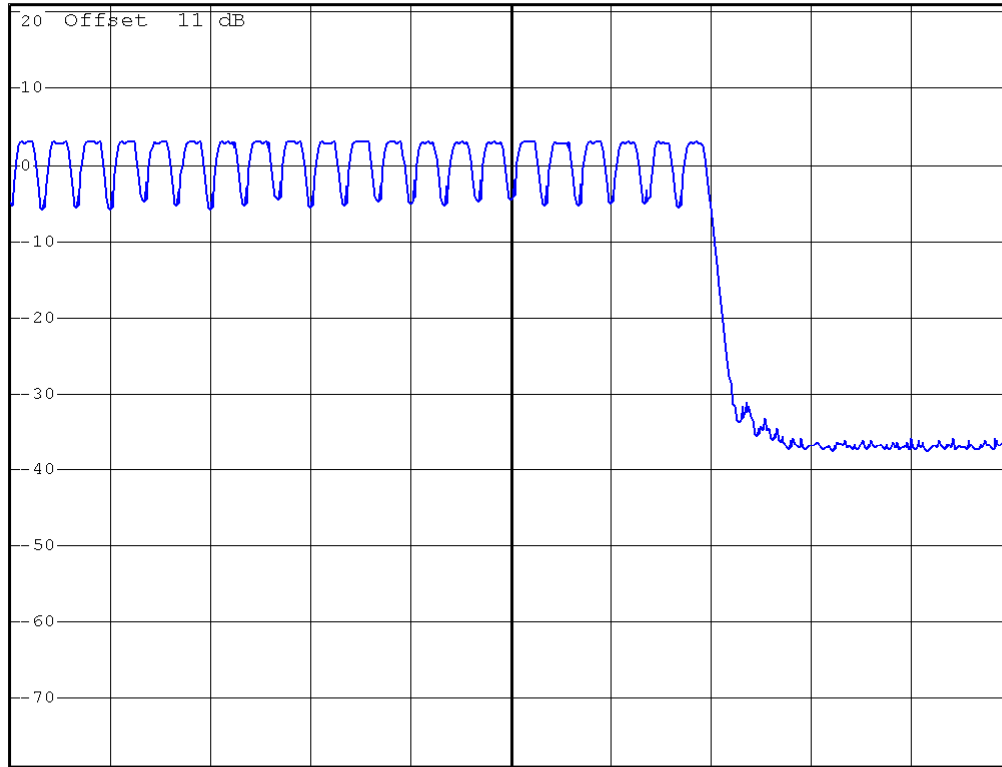
*RBW 300 kHz
VBW 1 MHz
SWT 2.5 ms

Ref 21 dBm

Att 40 dB

SWT 2.5 ms

1 PK
MAXH



A

LVL

Mode: Bluetooth EDR

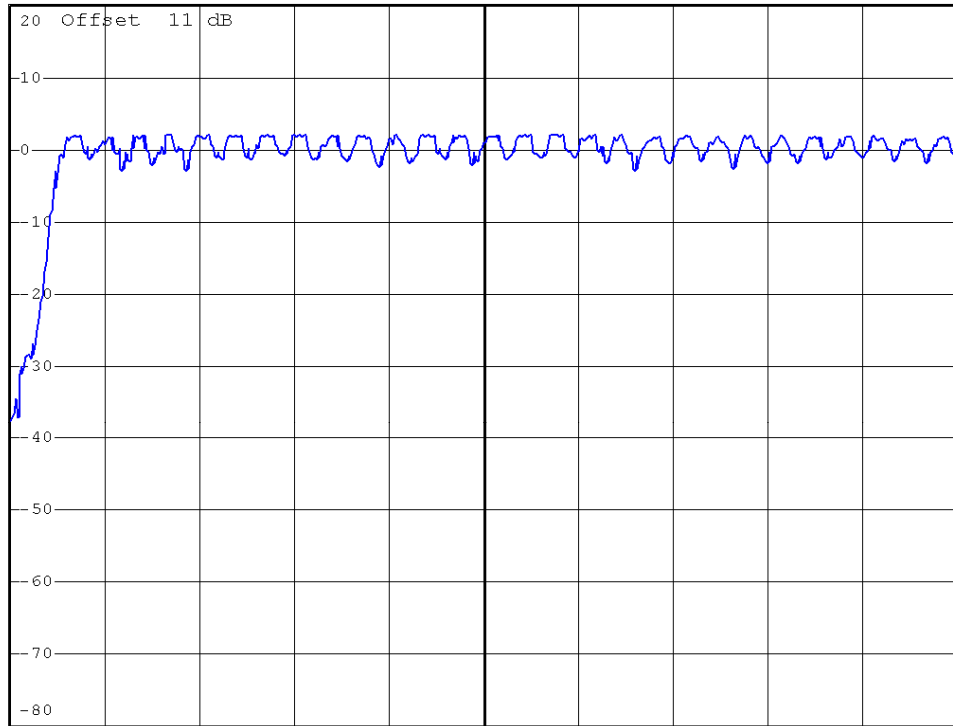


*RBW 300 kHz
VBW 1 MHz
SWT 2.5 ms

Ref 20 dBm

Att 40 dB

1 PK
VIEW



Start 2.4 GHz

2.95 MHz/

Stop 2.4295 GHz



*RBW 300 kHz

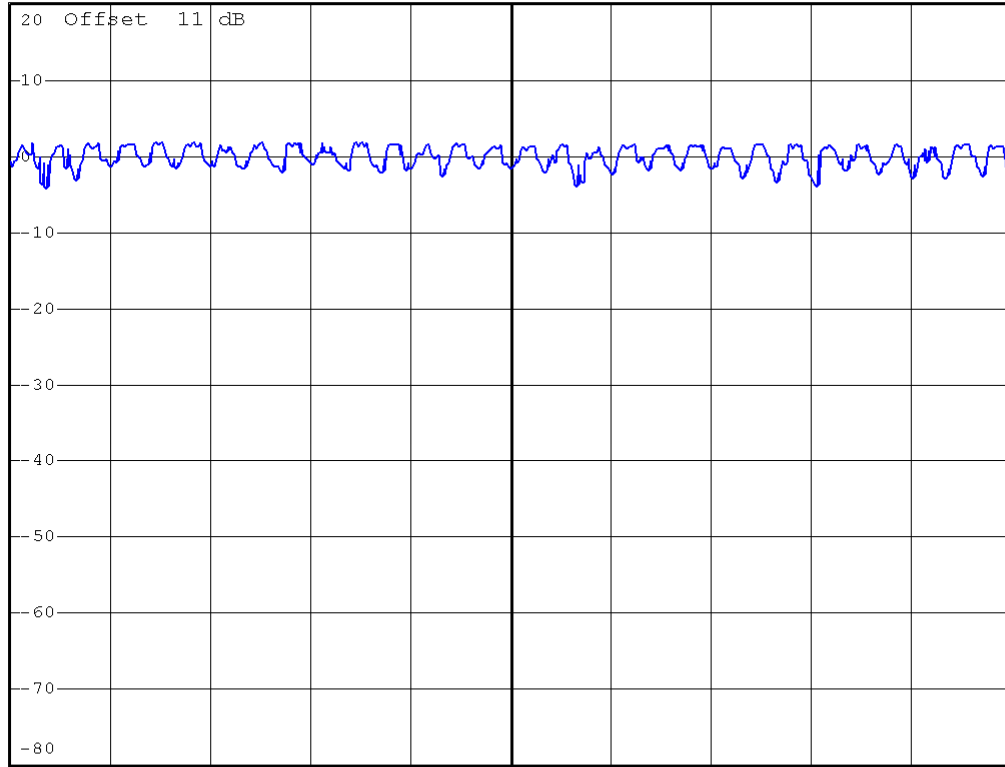
VBW 1 MHz

SWT 2.5 ms

Ref 20 dBm

Att 40 dB

1 PK
VIEW



Start 2.4295 GHz

3 MHz/

Stop 2.4595 GHz



*RBW 300 kHz

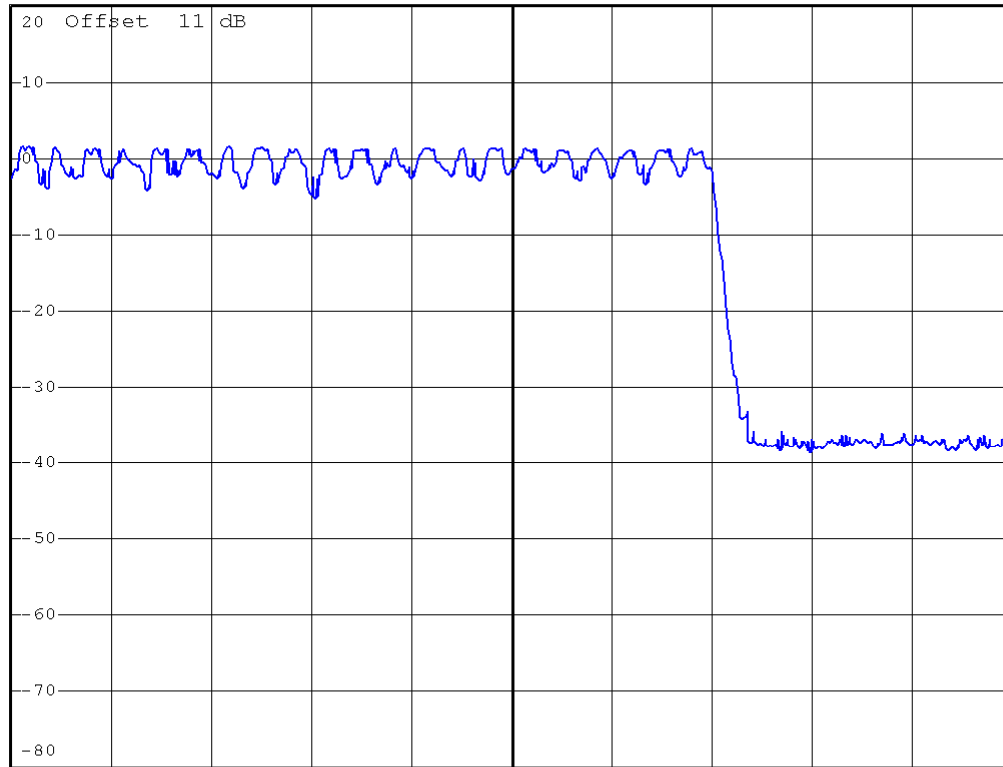
VBW 1 MHz

SWT 2.5 ms

Ref 20 dBm

Att 40 dB

1 PK
VIEW



Center 2.4745 GHz

3 MHz/

Span 30 MHz

9 CHANNEL BANDWIDTH

9.1 Standard Applicable

For frequency hopping system operating in the 2400–2483.5 MHz band, there is no requirement for the maximum 20dB bandwidth of the hopping channel. The measurement of the hopping channel bandwidth is for the reference of the hopping channel separation requirement.

9.2 Measurement 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 figure 4 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. Use the following spectrum analyzer settings:
 - Span = approximately 2 to 3 times the 20 dB bandwidth, centered on a hopping channel
 - RBW \geq 1% of the 20 dB bandwidth
 - VBW \geq RBW
 - Sweep = auto
 - Detector function = peak
 - Trace = max hold
4. Allow the trace to stabilize. Use the marker-to-peak function to set the marker to the peak of the emission. Use the marker-delta function to measure 20 dB down one side of the emission. Reset the marker-delta function, and move the marker to the other side of the emission, until it is (as close as possible to) even with the reference marker level. The marker-delta reading at this point is the 20 dB bandwidth of the emission. Plot the result on the screen of spectrum analyzer.
5. Repeat above procedures until all frequencies measured were complete.

9.3 Measurement Equipment

Equipment	Manufacturer	Model No.	Calibration Date	Next Cal. Date
Spectrum Analyzer	Rohde & Schwarz	FSP40	2016/10/03	2017/10/02
Attenuator	MINI-CIRCUITS	BW-S10W2+	2016/09/30	2017/09/29

9.4 Measurement Data

Test Date : Oct. 05, 2016 Temperature : 24 °C Humidity : 60 %

Mode: Bluetooth BR

- a) Channel Low : Channel Bandwidth is 0.796 MHz
- b) Channel Middle : Channel Bandwidth is 0.796 MHz
- c) Channel High : Channel Bandwidth is 0.808 MHz

Mode: Bluetooth EDR

- a) Channel Low : Channel Bandwidth is 1.200 MHz
- b) Channel Middle : Channel Bandwidth is 1.204 MHz
- c) Channel High : Channel Bandwidth is 1.204 MHz

Note : The expanded uncertainty: frequency $\times 1.65 \times 10^{-6}$ ($1 \text{ GHz} < f \leq 18 \text{ GHz}$).

Mode:Bluetooth BR

Channel Low

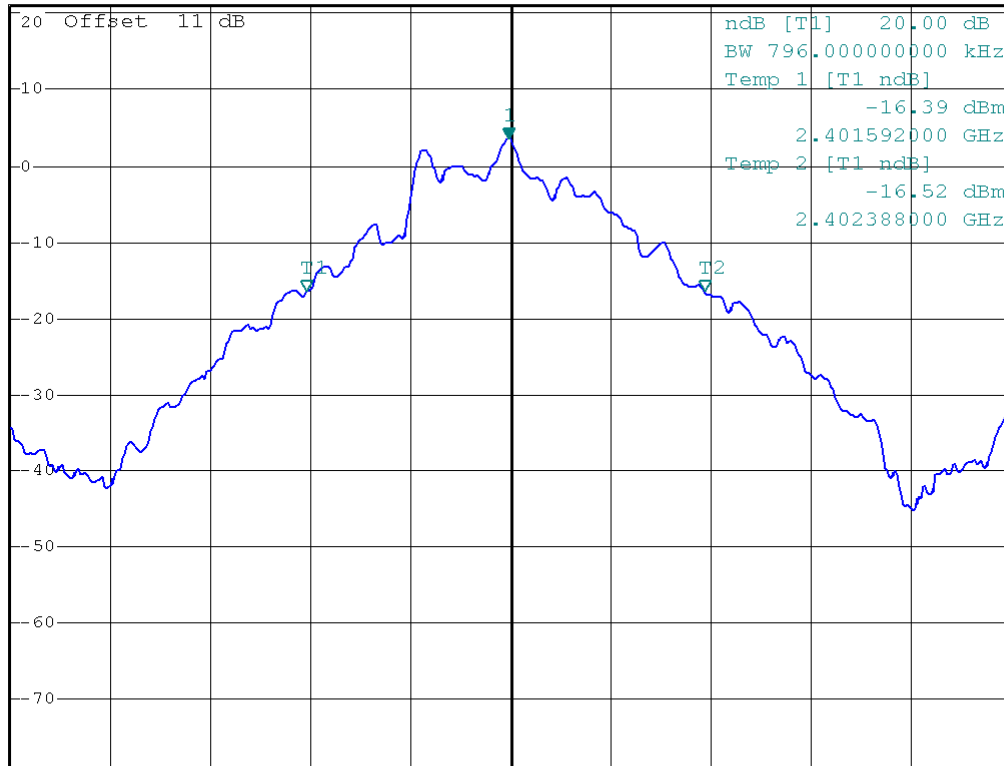


*RBW 30 kHz Marker 1 [T1]
VBW 100 kHz 3.59 dBm
SWT 2.5 ms 2.401996000 GHz

Ref 21 dBm

Att 40 dB

1 PK
VIEW



Center 2.402 GHz

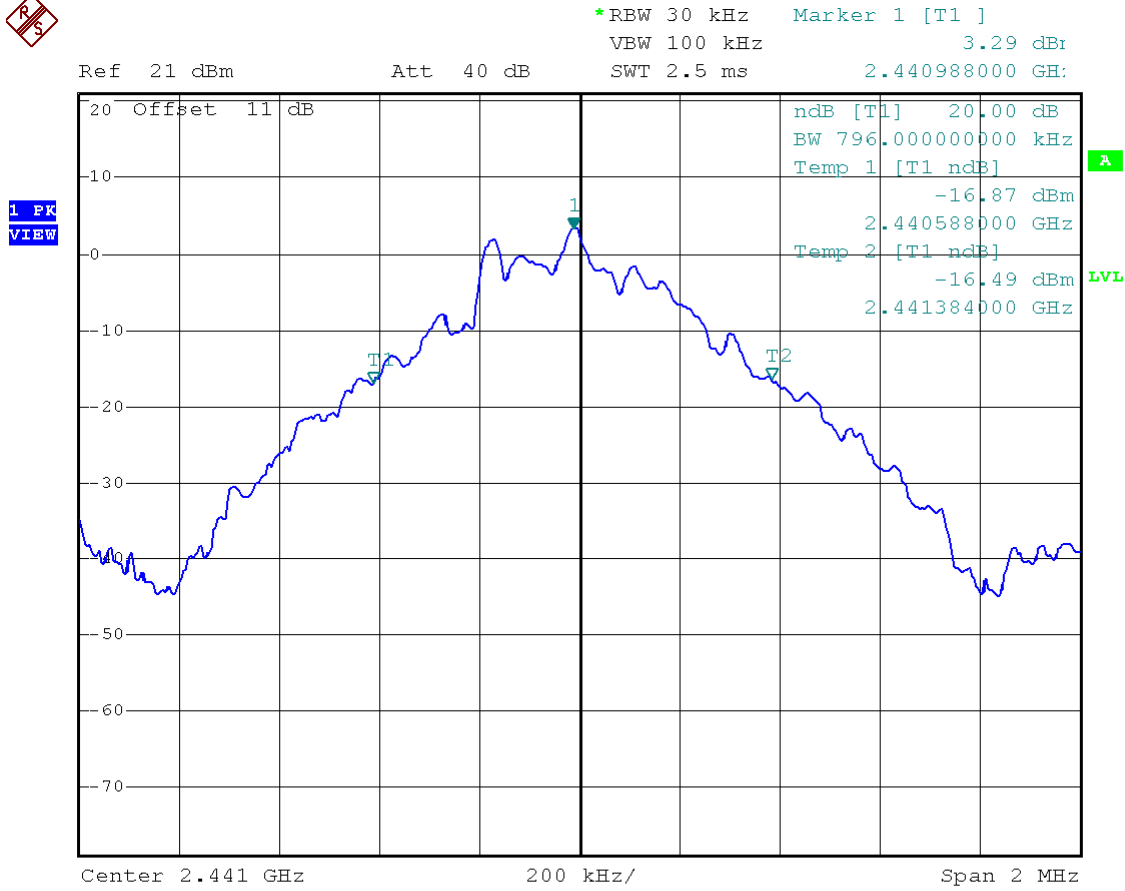
200 kHz/

Span 2 MHz

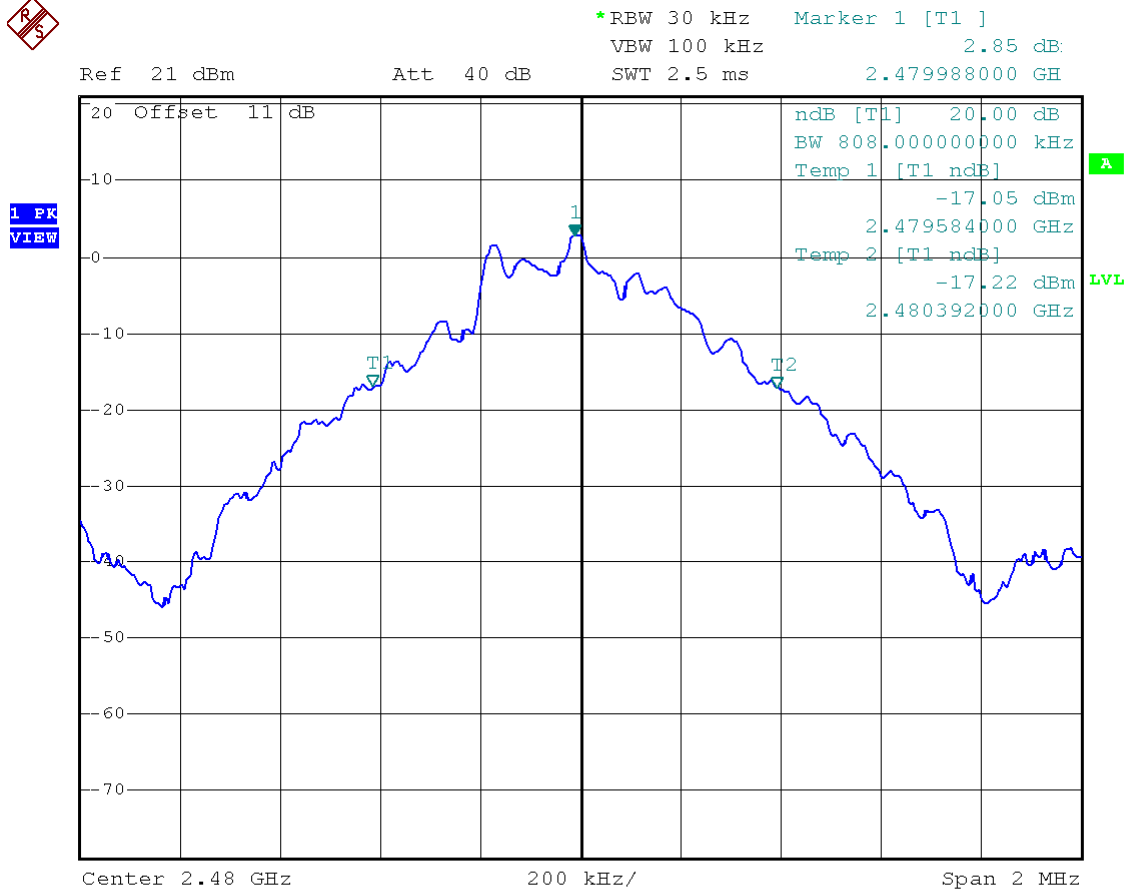
A

LVL

Channel Middle



Channel High



Mode: Bluetooth EDR

Channel Low

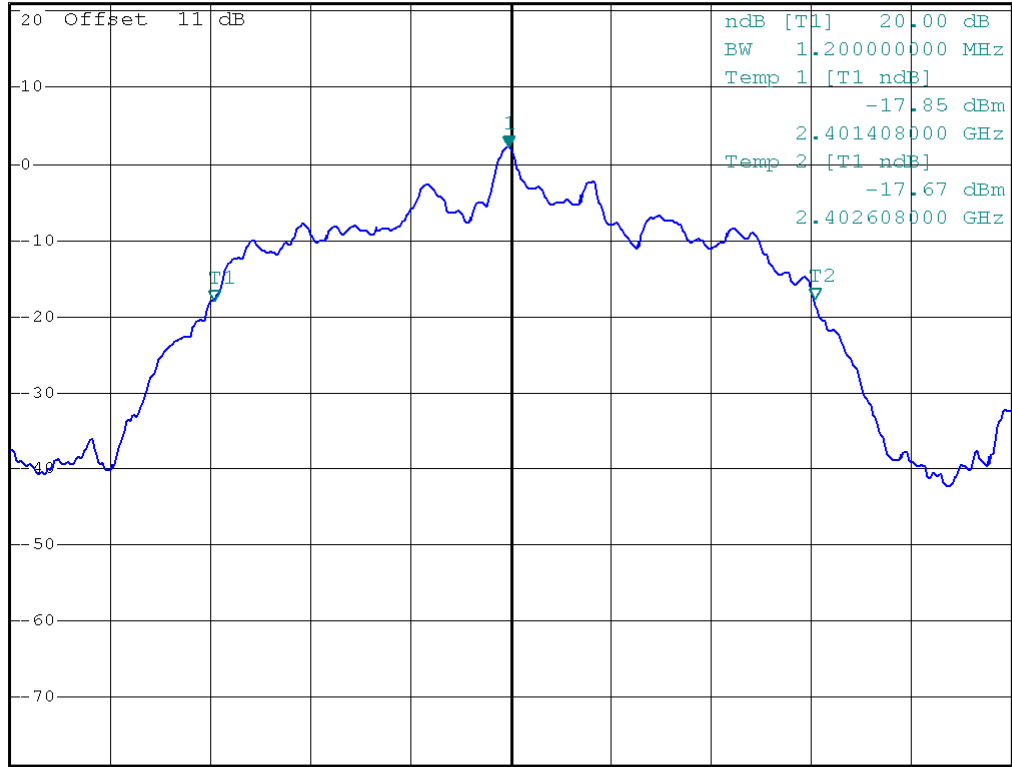


*RBW 30 kHz Marker 1 [T1]
VBW 100 kHz 2.25 dBm
SWT 2.5 ms 2.401996000 GHz

Ref 21 dBm

Att 40 dB

1 PK
VIEW



Center 2.402 GHz

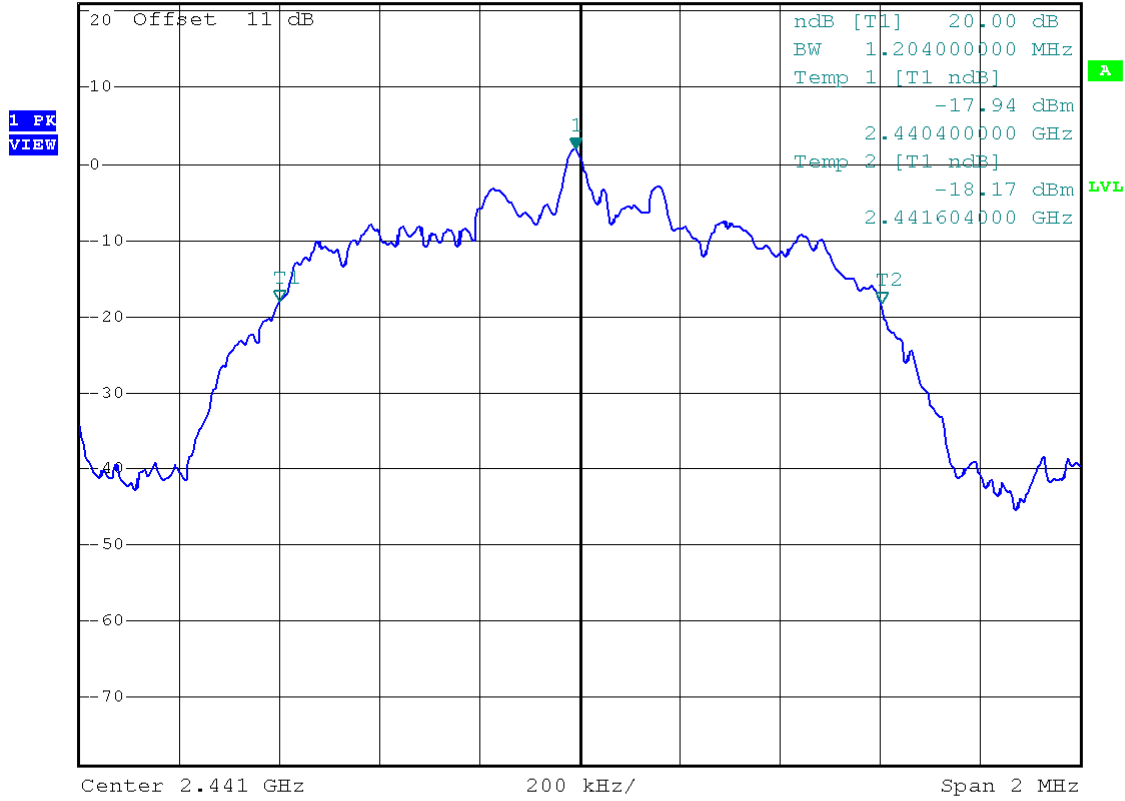
200 kHz/

Span 2 MHz

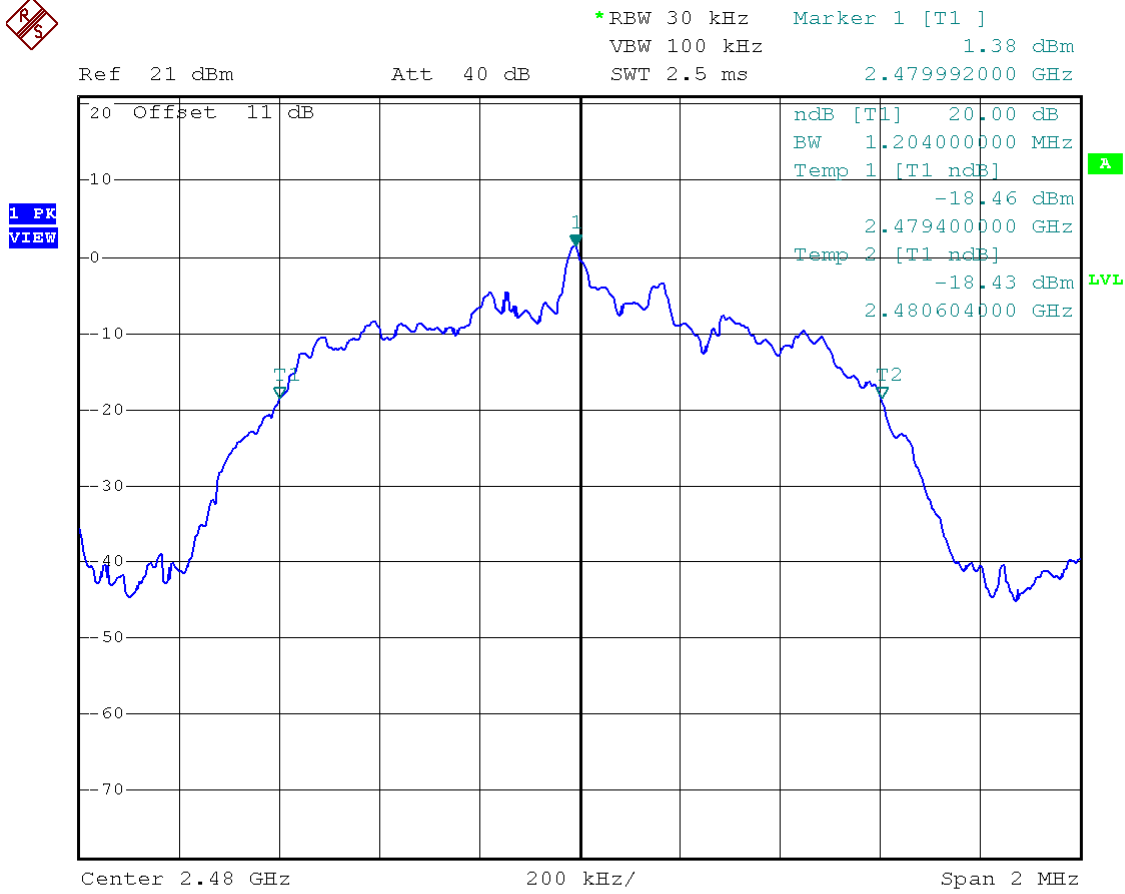
Channel Middle



*RBW 30 kHz Marker 1 [T1]
 VBW 100 kHz 1.87 dB
 Ref 21 dBm Att 40 dB SWT 2.5 ms 2.440992000 GHz:



Channel High



10 DWELL TIME ON EACH CHANNEL

10.1 Standard Applicable

According to 15.247(a)(1)(iii), for frequency hopping system operating in the 2400-2483.5 band, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed.

10.2 Measurement 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 figure 4 without connection to measurement instrument. Turn on the EUT and connect it to measurement instrument. The EUT must have its hopping function enabled.
3. Use the following spectrum analyzer settings:
 - Span = zero span, centered on a hopping channel
 - RBW = 1 MHz
 - VBW \geq RBW
 - Sweep = as necessary to capture the entire dwell time per hopping channel
 - Detector function = peak
 - Trace = max hold
4. Use the marker-delta function to determine the dwell time. Plot the result on the screen of spectrum analyzer.
5. Repeat above procedures until all frequencies measured were complete.

Justification on AFH mode:

Adaptive Frequency Hopping (AFH) means that a device can hop over a reduced set of frequencies. The frequencies hopped may be reduced in AFH mode but at least 15 channels will be used, normally AFH mode has 20 channels.

10.3 Measurement Equipment

Equipment	Manufacturer	Model No.	Calibration Date	Next Cal. Date
Spectrum Analyzer	Rohde & Schwarz	FSP40	2016/10/03	2017/10/02
Attenuator	MINI-CIRCUITS	BW-S10W2+	2016/09/30	2017/09/29

10.4 Measurement Data

Test Mode: Bluetooth BR

Test Date : Oct. 05, 2016 Temperature : 24 °C Humidity : 60 %

$$\text{Period} = 0.4(\text{seconds}) \times 79(\text{channels}) = 31.6 \text{ seconds}$$

A. DH1 Mode

The Bluetooth system hops at a rate of 1600 times per second. This means there are 1600 timeslots in one second. The DH1 data rate operates on a one-slot transmission and one-slot receiving basis. Thus there are $1600/(1+1) = 800$ transmissions per second. In one period for each particular channel there are $10.13 \times 31.6 = 320.1$ times of transmissions.

- a) Channel Low : the dwell time is 0.46 ms x 320.1 = 147.246 ms
- b) Channel Middle : the dwell time is 0.45 ms x 320.1 = 144.045 ms
- c) Channel High : the dwell time is 0.45 ms x 320.1 = 144.045 ms

The maximum time of occupancy for a particular channel is 147.246ms in any 31.6 second period, which is less than the 400ms allowed by the rules; therefore, it meets the requirements of this section.

B. DH3 Mode

The Bluetooth system hops at a rate of 1600 times per second. This means there are 1600 timeslots in one second. The DH3 data rate operates on a three-slot transmission and one-slot receiving basis. Thus there are $1600/(3+1) = 400$ transmissions per second. In one period for each particular channel there are $5.06 \times 31.6 = 159.9$ times of transmissions.

- a) Channel Low : the dwell time is 1.72 ms x 159.9 = 275.028 ms
- b) Channel Middle : the dwell time is 1.72 ms x 159.9 = 275.028 ms
- c) Channel High : the dwell time is 1.72 ms x 159.9 = 275.028 ms

The maximum time of occupancy for a particular channel is 281.424ms in any 31.6 second period, which is less than the 400 ms allowed by the rules; therefore, it meets the requirements of this section.

C. DH5 Mode

The Bluetooth system hops at a rate of 1600 times per second. This means there are 1600 timeslots in one second. The DH5 data rate operates on a five-slot transmission and one-slot receiving basis. Thus there are $1600/(5+1) = 266.7$ transmissions per second. In one period for each particular channel there are $3.38 \times 31.6 = 106.81$ times of transmissions.

- a) Channel Low : the dwell time is 3.04 ms x 106.81 = 324.7024 ms
- b) Channel Middle : the dwell time is 3.08 ms x 106.81 = 328.9748 ms
- c) Channel High : the dwell time is 3.04 ms x 106.81 = 324.7024 ms

The maximum time of occupancy for a particular channel is 326.838ms in any 31.6 second period, which is less than the 400 ms allowed by the rules; therefore, it meets the requirements of this section.

Note : The expanded uncertainty of dwell time on each channel tests is 2dB.

Test Mode:Bluetooth EDR

Test Date : Oct. 05, 2016 Temperature : 24 °C Humidity : 60 %

$$\text{Period} = 0.4(\text{seconds}) \times 79(\text{channels}) = 31.6 \text{ seconds}$$

A. DH1 Mode

The Bluetooth system hops at a rate of 1600 times per second. This means there are 1600 timeslots in one second. The DH1 data rate operates on a one-slot transmission and one-slot receiving basis. Thus there are $1600/(1+1) = 800$ transmissions per second. In one period for each particular channel there are $10.13 \times 31.6 = 320.1$ times of transmissions.

- a) Channel Low : the dwell time is $0.47 \text{ ms} \times 320.1 = 150.447 \text{ ms}$
- b) Channel Middle : the dwell time is $0.45 \text{ ms} \times 320.1 = 144.045 \text{ ms}$
- c) Channel High : the dwell time is $0.45 \text{ ms} \times 320.1 = 144.045 \text{ ms}$

The maximum time of occupancy for a particular channel is 147.246ms in any 31.6 second period, which is less than the 400ms allowed by the rules; therefore, it meets the requirements of this section.

B. DH3 Mode

The Bluetooth system hops at a rate of 1600 times per second. This means there are 1600 timeslots in one second. The DH3 data rate operates on a three-slot transmission and one-slot receiving basis. Thus there are $1600/(3+1) = 400$ transmissions per second. In one period for each particular channel there are $5.06 \times 31.6 = 159.9$ times of transmissions.

- a) Channel Low : the dwell time is $1.72 \text{ ms} \times 159.9 = 275.028 \text{ ms}$
- b) Channel Middle : the dwell time is $1.72 \text{ ms} \times 159.9 = 275.028 \text{ ms}$
- c) Channel High : the dwell time is $1.78 \text{ ms} \times 159.9 = 284.622 \text{ ms}$

The maximum time of occupancy for a particular channel is 287.820ms in any 31.6 second period, which is less than the 400 ms allowed by the rules; therefore, it meets the requirements of this section.

C. DH5 Mode

The Bluetooth system hops at a rate of 1600 times per second. This means there are 1600 timeslots in one second. The DH5 data rate operates on a five-slot transmission and one-slot receiving basis. Thus there are $1600/(5+1) = 266.7$ transmissions per second. In one period for each particular channel there are $3.38 \times 31.6 = 106.81$ times of transmissions.

- a) Channel Low : the dwell time is $2.98 \text{ ms} \times 106.81 = 318.294 \text{ ms}$
- b) Channel Middle : the dwell time is $2.98 \text{ ms} \times 106.81 = 318.294 \text{ ms}$
- c) Channel High : the dwell time is $2.98 \text{ ms} \times 106.81 = 318.294 \text{ ms}$

The maximum time of occupancy for a particular channel is 341.792ms in any 31.6 second period, which is less than the 400 ms allowed by the rules; therefore, it meets the requirements of this section.

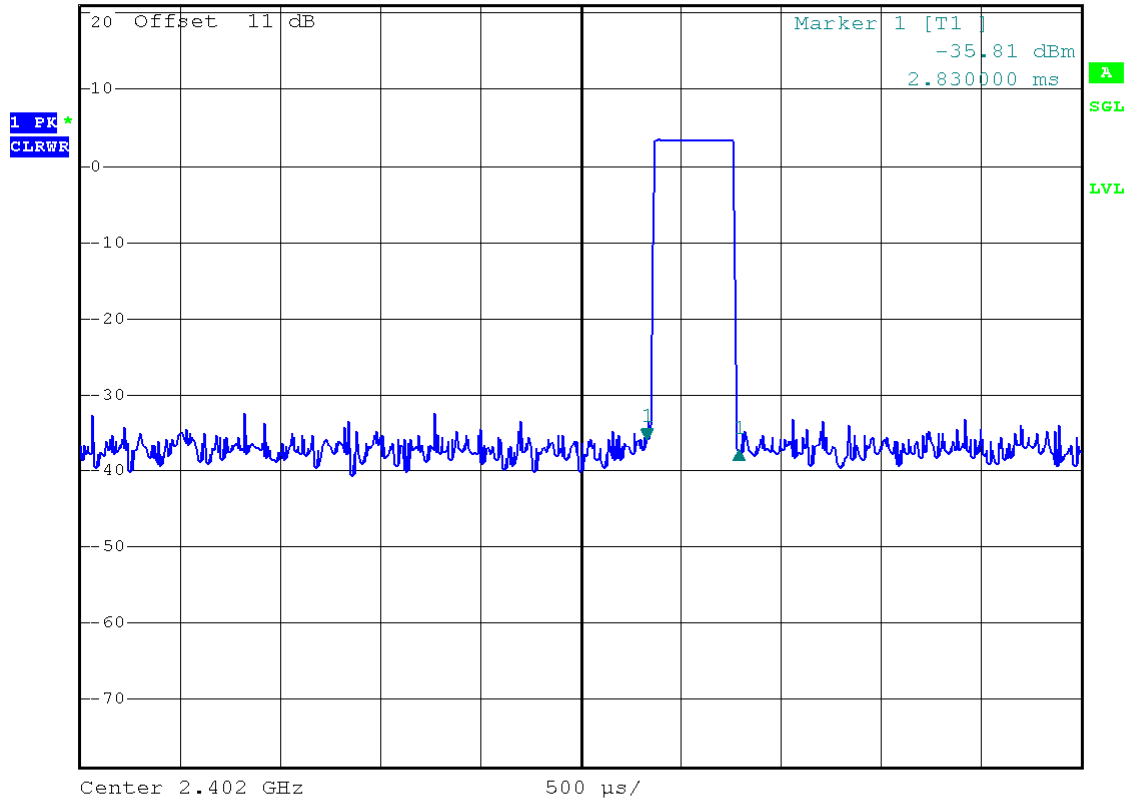
Note : The expanded uncertainty of dwell time on each channel tests is 2dB.

Mode: Bluetooth BR

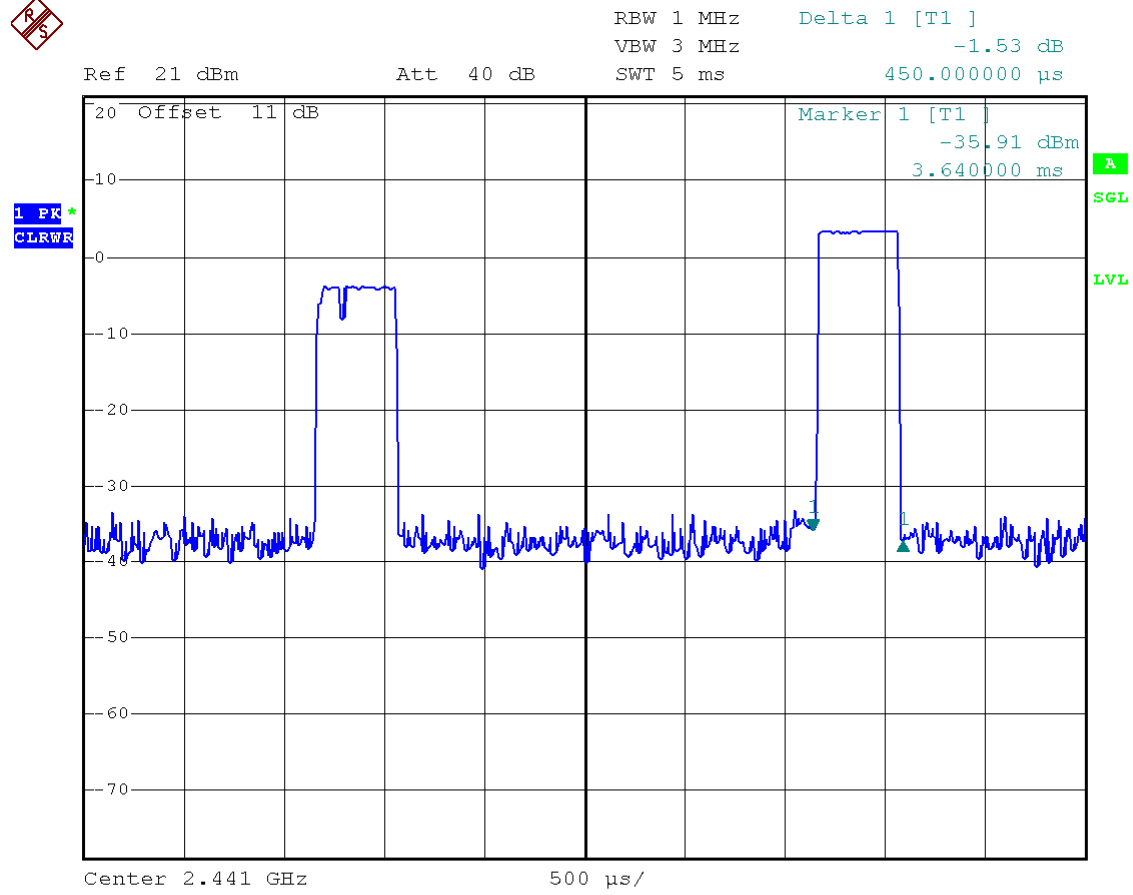
Channel Low; DHI



RBW 1 MHz Delta 1 [T1]
VBW 3 MHz -1.63 dB
SWT 5 ms 460.000000 μ s
Ref 21 dBm Att 40 dB



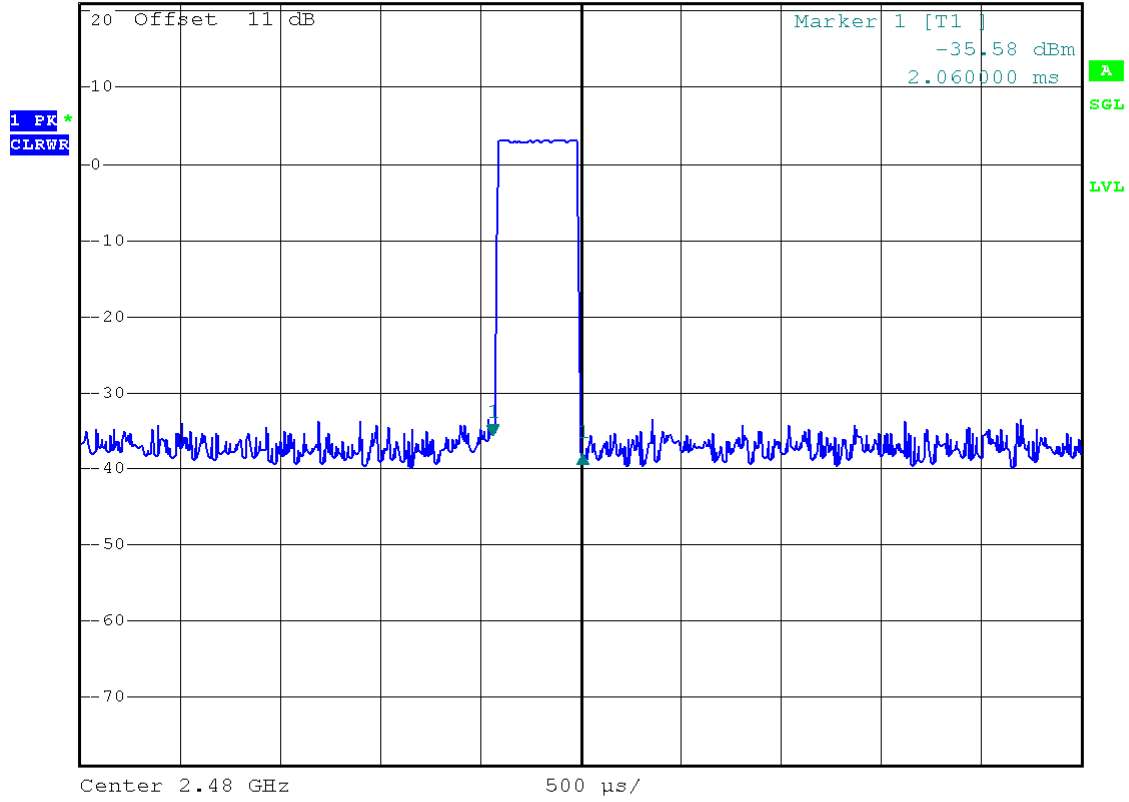
Channel Middle; DH1



Channel High; DH1



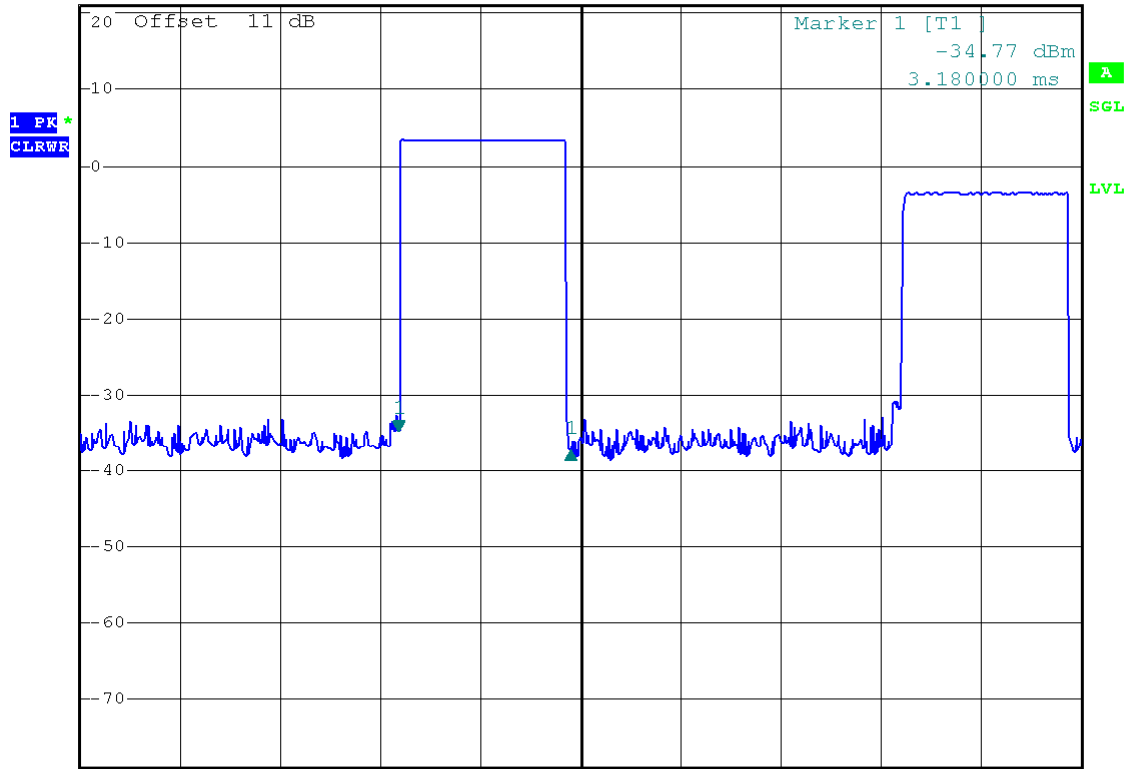
RBW 1 MHz Delta 1 [T1]
VBW 3 MHz -2.62 dB
Ref 21 dBm Att 40 dB SWT 5 ms 450.000000 μ s



Channel Low; DH3

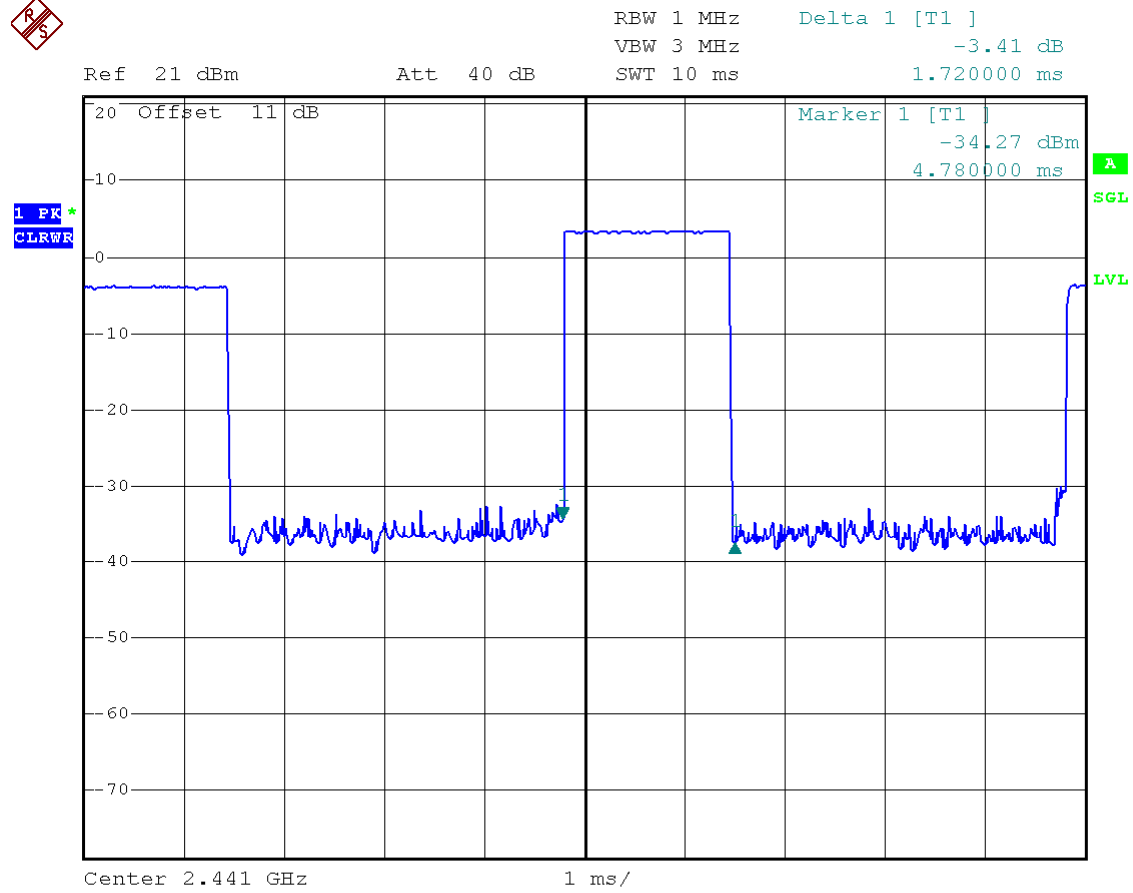


Ref 21 dBm Att 40 dB RBW 1 MHz Delta 1 [T1] -2.53 dB
SWT 10 ms 1.720000 ms



Center 2.402 GHz 1 ms/

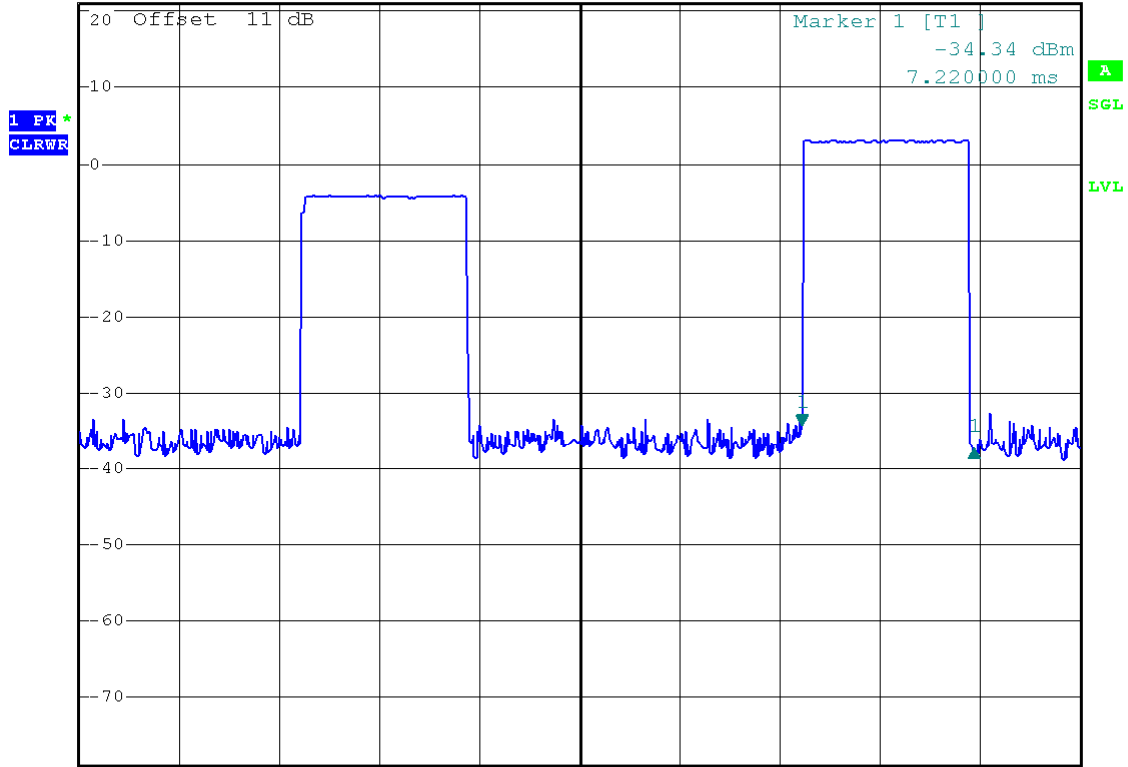
Channel Middle; DH3



Channel High; DH3



Ref 21 dBm Att 40 dB RBW 1 MHz Delta 1 [T1] -3.18 dB
VBW 3 MHz SWT 10 ms 1.720000 ms



Center 2.48 GHz 1 ms/

Channel Low; DH5

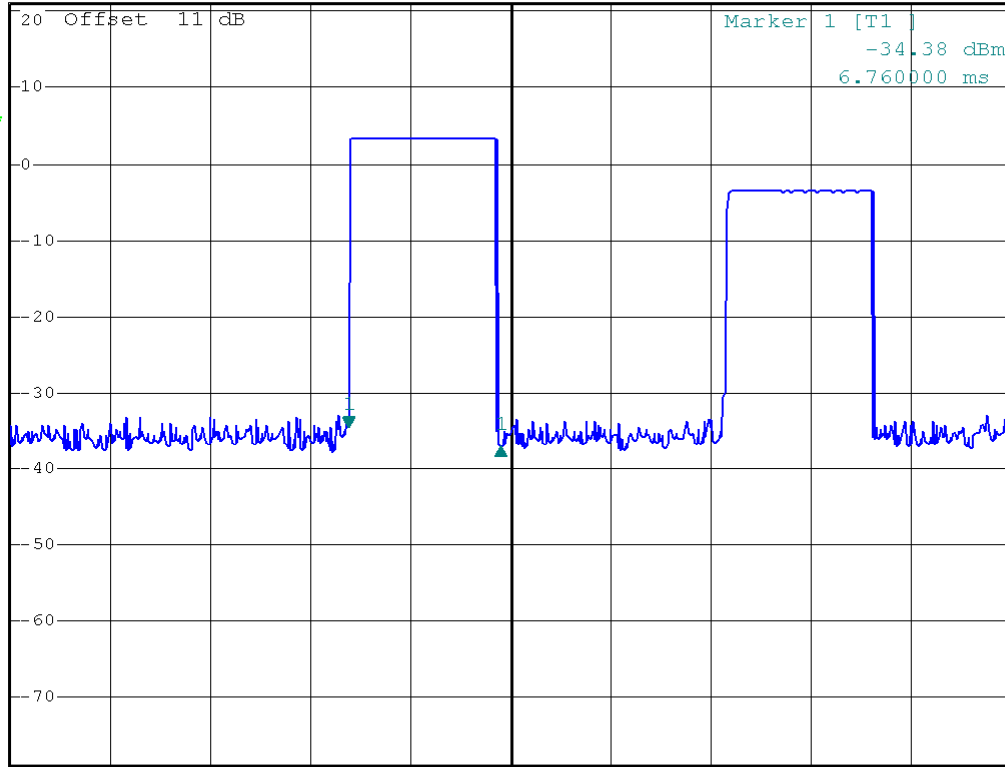


RBW 1 MHz Delta 1 [T1]
VBW 3 MHz -2.78 dB
SWT 20 ms 3.040000 ms

Ref 21 dBm

Att 40 dB

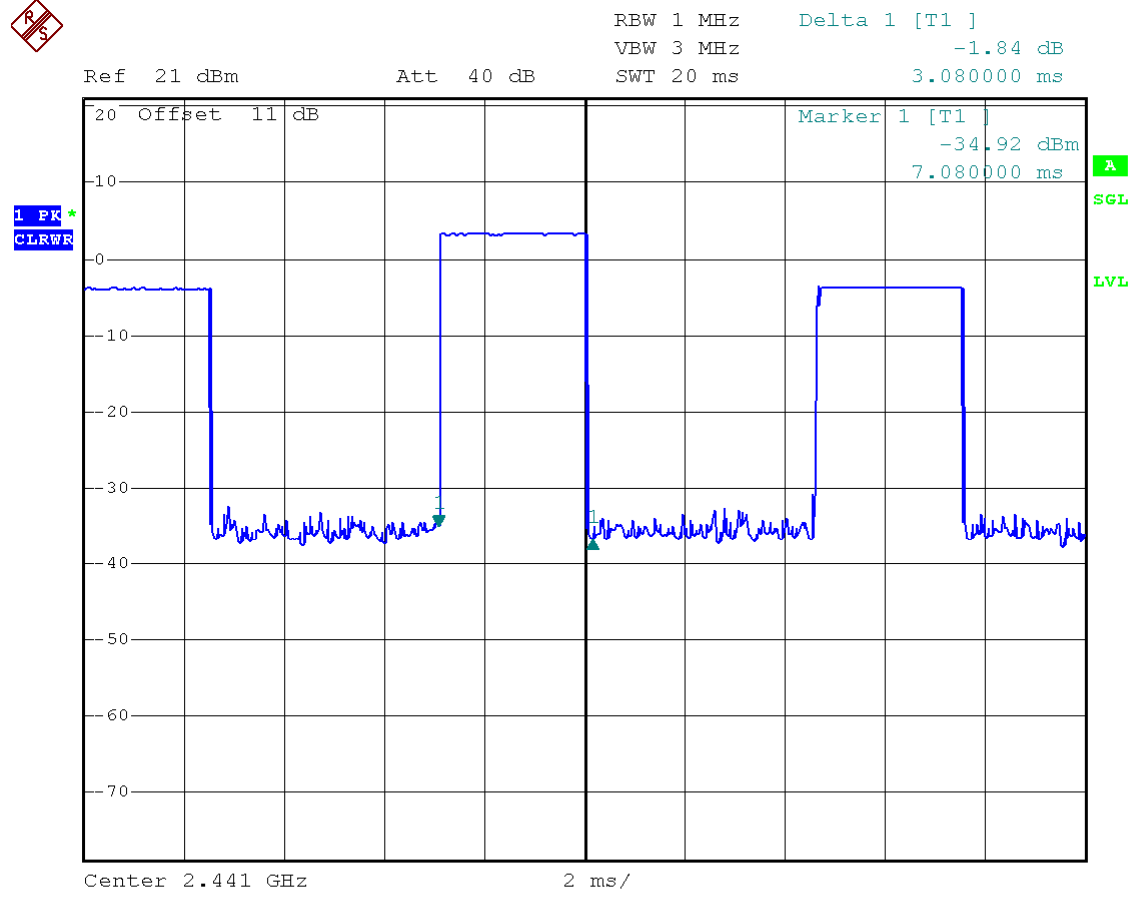
1 PK *
CLRWR



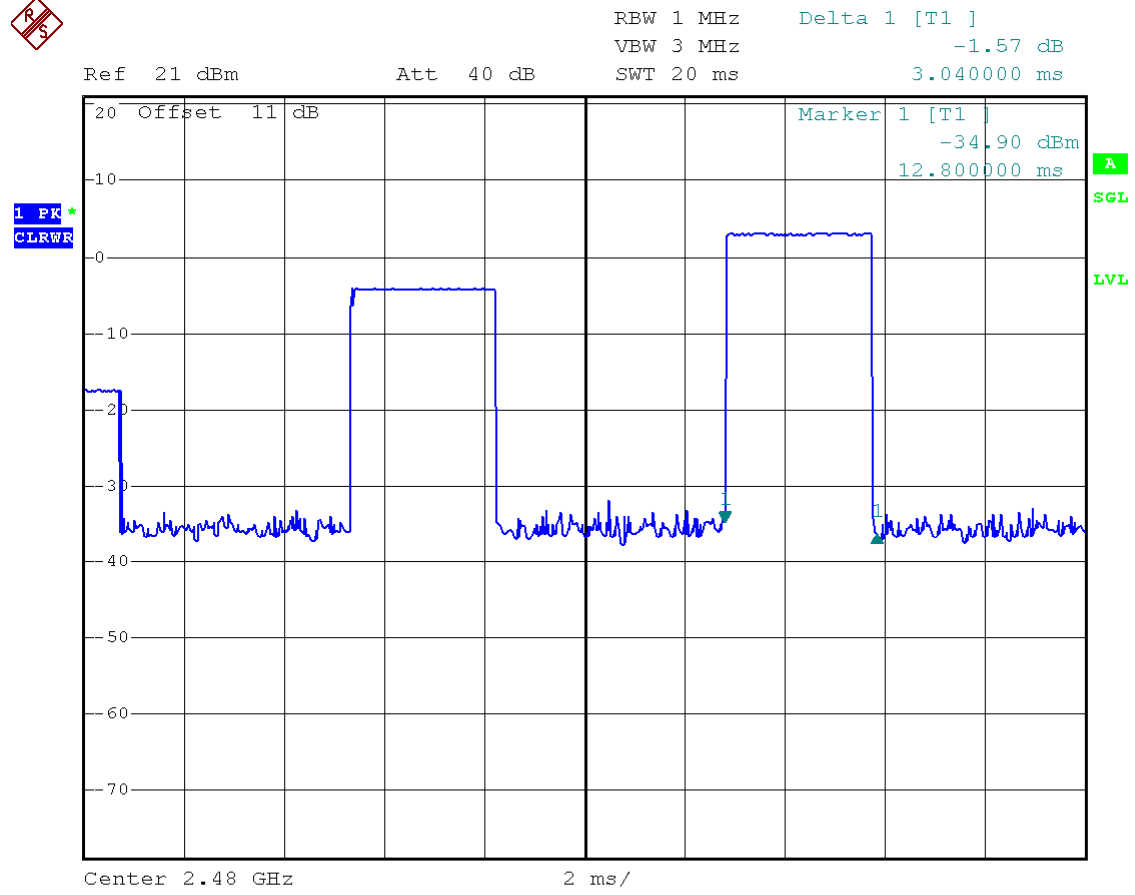
Center 2.402 GHz

2 ms/

Channel Middle; DH5



Channel High; DH5

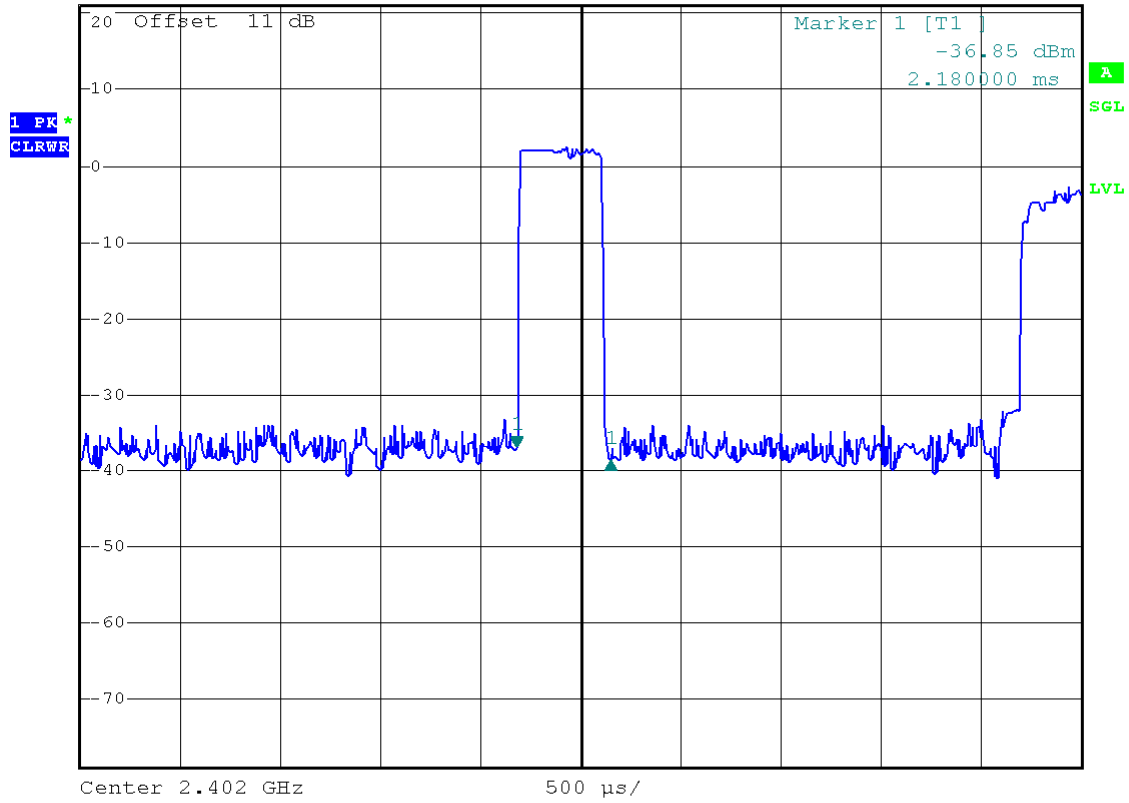


Mode: Bluetooth EDR

Channel Low; DHI



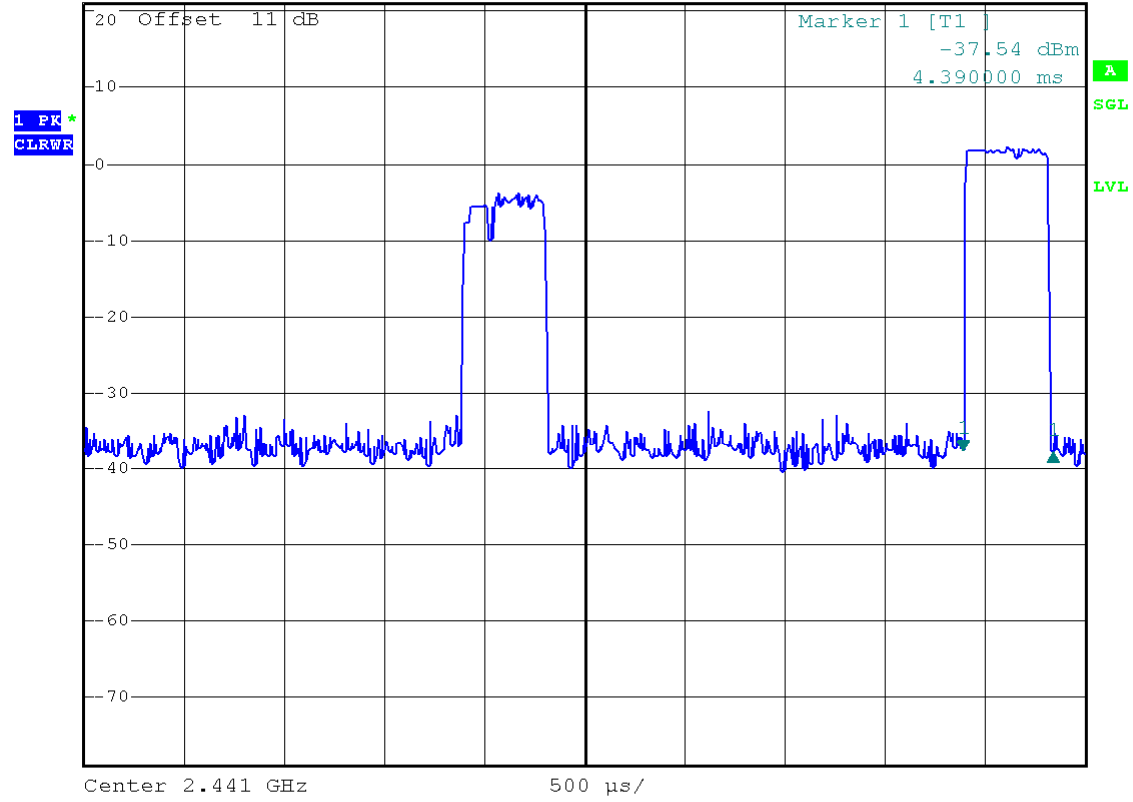
Ref 21 dBm Att 40 dB RBW 1 MHz Delta 1 [T1] -1.98 dB
SWT 5 ms 470.000000 μ s



Channel Middle; DH1



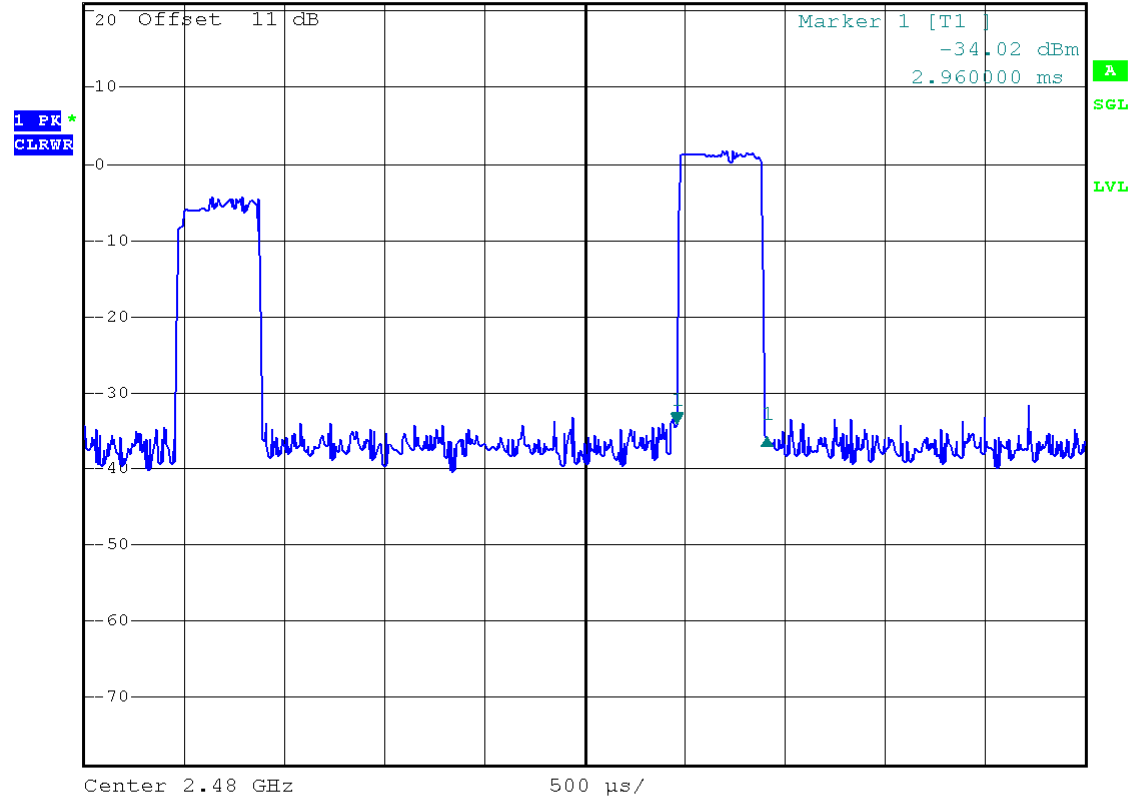
Ref 21 dBm Att 40 dB RBW 1 MHz Delta 1 [T1] -0.34 dB
SWT 5 ms 450.000000 μ s



Channel High; DH1



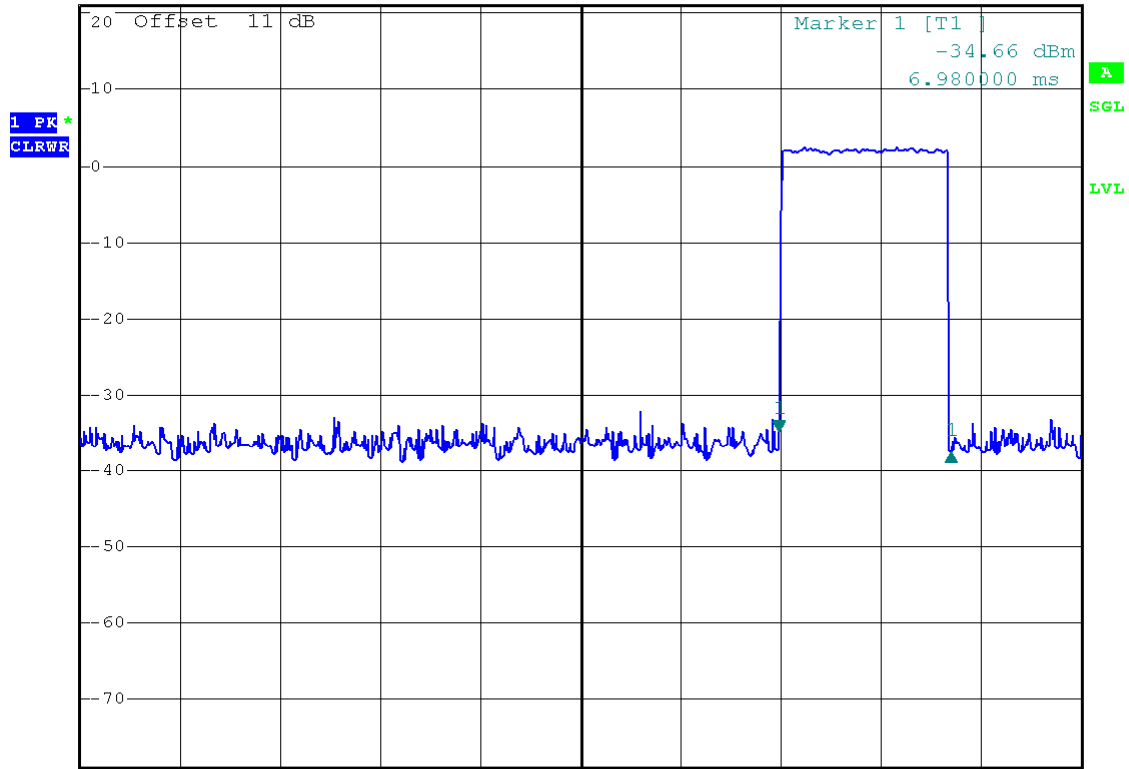
Ref 21 dBm Att 40 dB RBW 1 MHz Delta 1 [T1] -1.72 dB
SWT 5 ms 450.000000 μ s



Channel Low; DH3



Ref 21 dBm Att 40 dB RBW 1 MHz Delta 1 [T1] -3.10 dB
SWT 10 ms 1.720000 ms

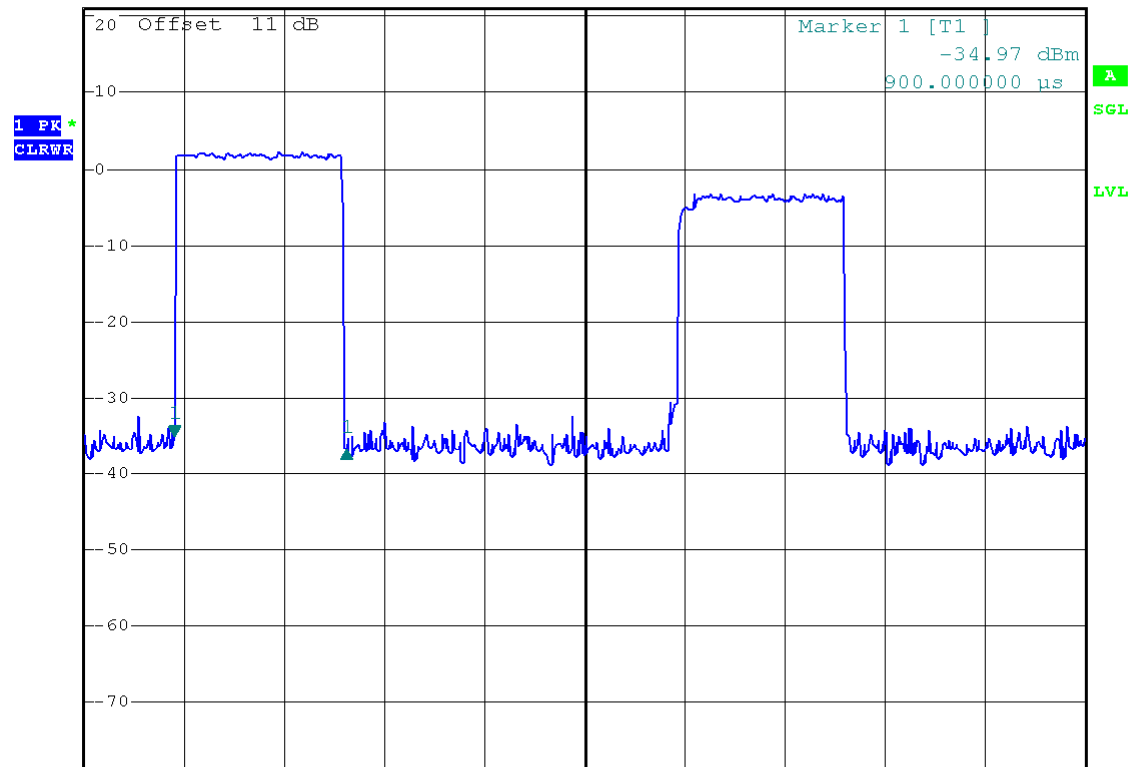


Center 2.402 GHz 1 ms/

Channel Middle; DH3



RBW 1 MHz Delta 1 [T1]
VBW 3 MHz -1.79 dB
Ref 21 dBm Att 40 dB SWT 10 ms 1.720000 ms

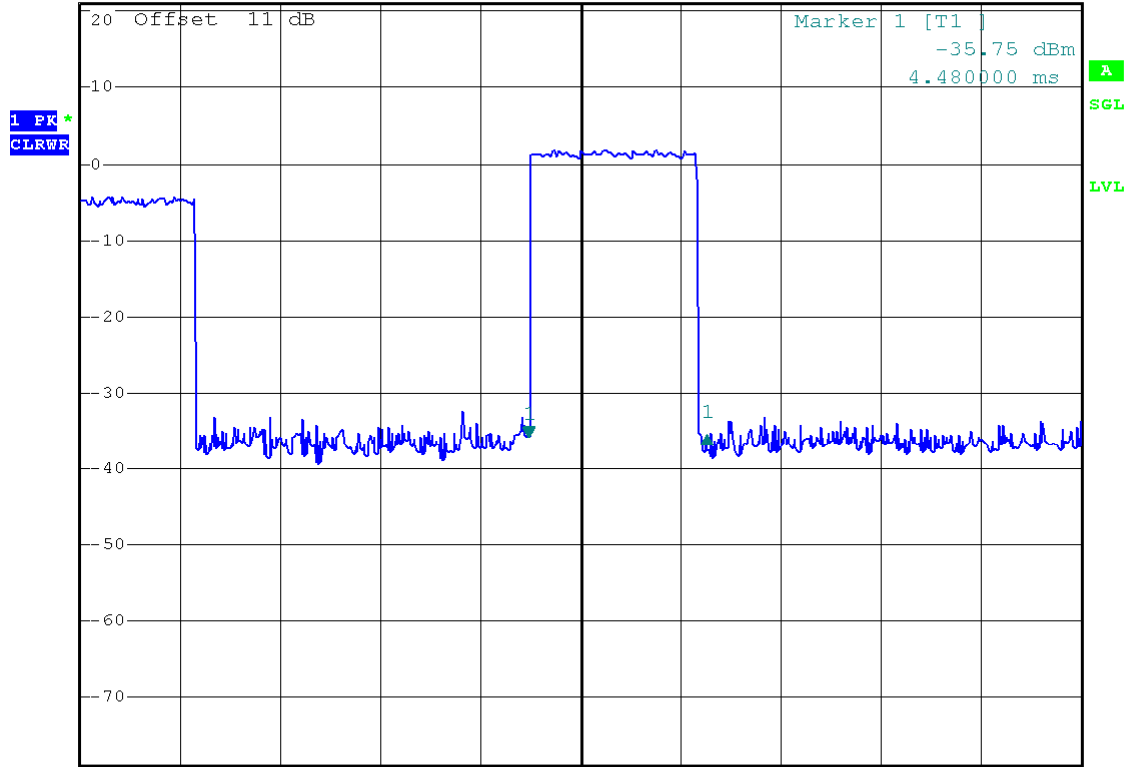


Center 2.441 GHz 1 ms/

Channel High; DH3



Ref 21 dBm Att 40 dB RBW 1 MHz Delta 1 [T1] 0.26 dB
SWT 10 ms 1.780000 ms

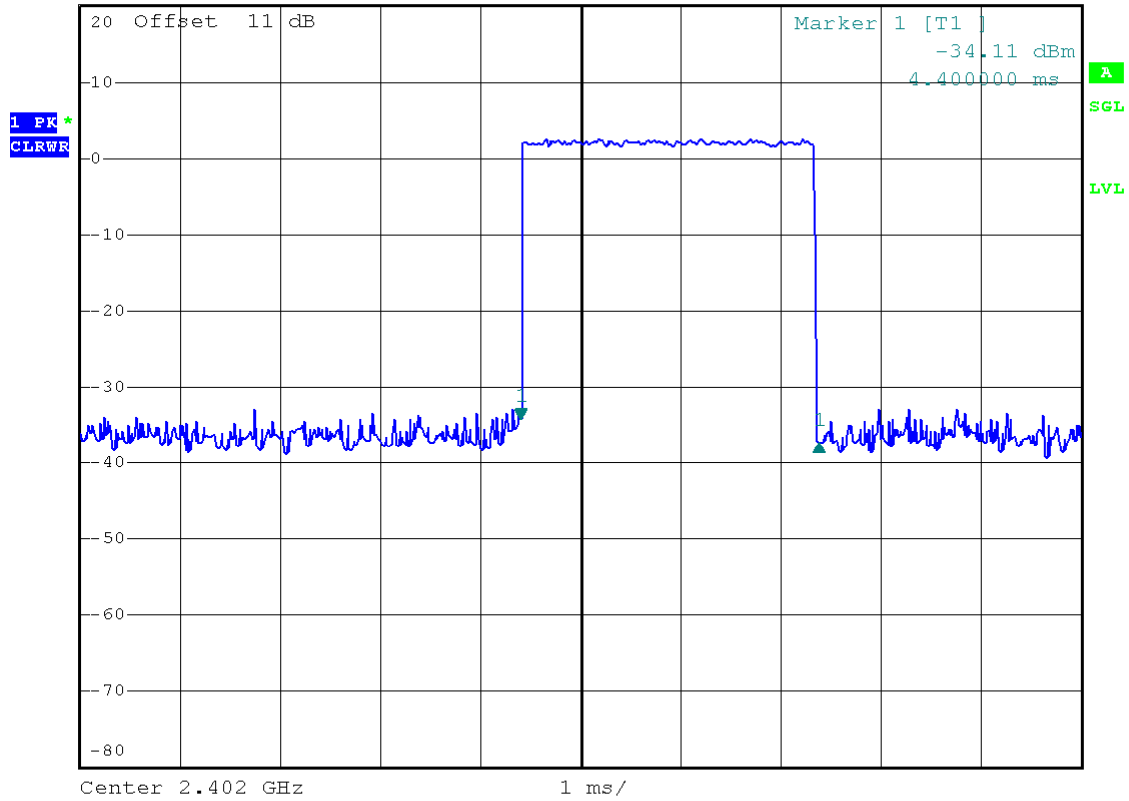


Center 2.48 GHz 1 ms/

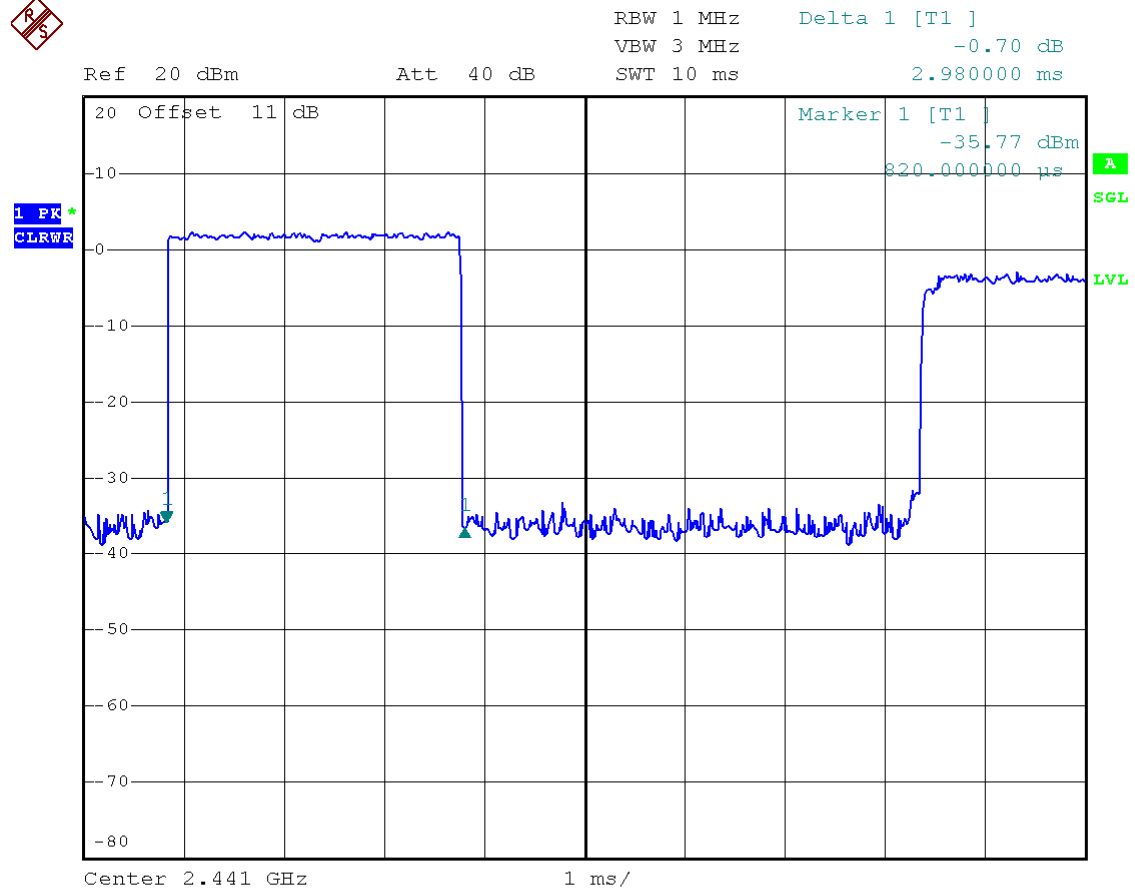
Channel Low; DH5



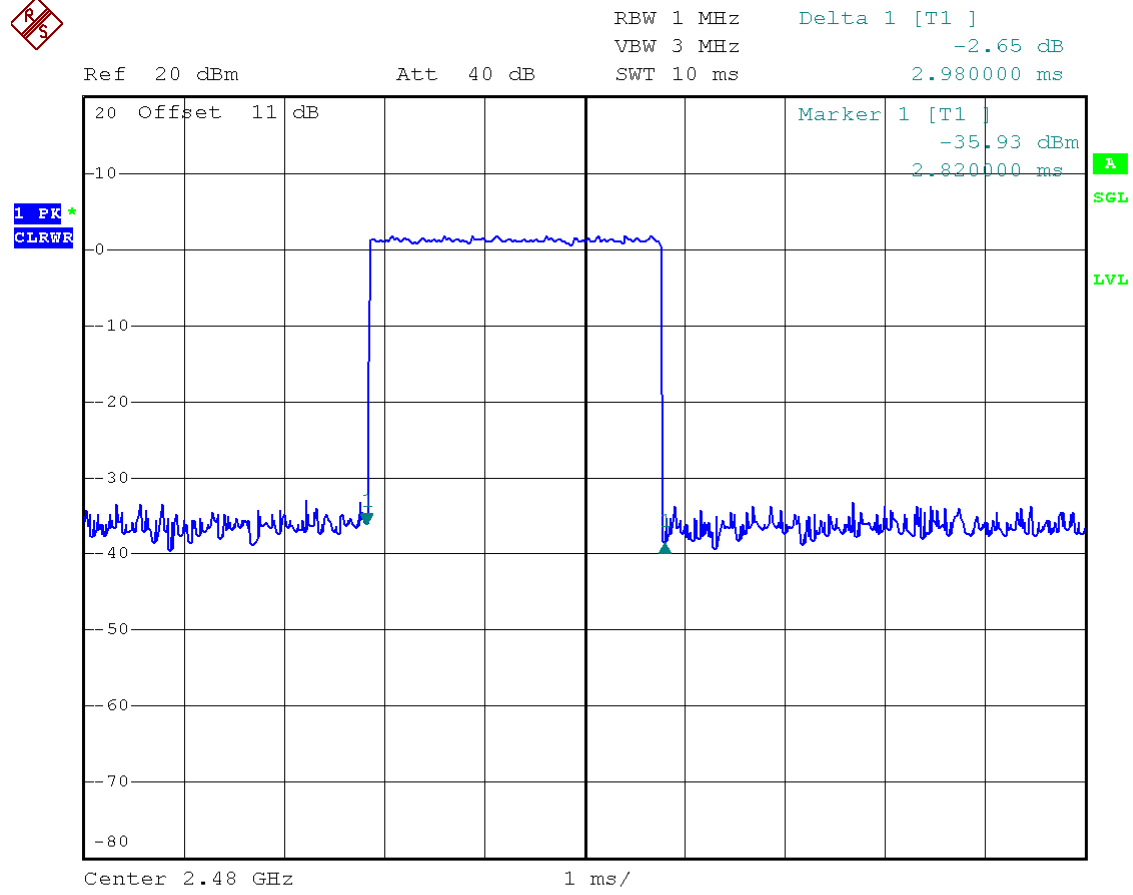
RBW 1 MHz Delta 1 [T1]
VBW 3 MHz -3.19 dB
SWT 10 ms 2.980000 ms
Ref 20 dBm Att 40 dB



Channel Middle; DH5



Channel High; DH5



11 OUTPUT POWER MEASUREMENT

11.1 Standard Applicable

According to 15.247(b)(1), for frequency hopping systems operating in the 2400–2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725–5850 MHz band: 1 watt. For all other frequency hopping systems in the 2400–2483.5 MHz band: 0.125 watts.

11.2 Measurement 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 figure 4 without connection to measurement instrument. Turn on the EUT and connect its antenna terminal to measurement instrument via a low loss cable. Then set it to any one measured frequency within its operating range and make sure the instrument is operated in its linear range.
3. Use the following spectrum analyzer settings:
 - Span = approximately 5 times the 20 dB bandwidth, centered on a hopping channel
 - RBW > the 20 dB bandwidth of the emission being measured
 - VBW \geq RBW
 - Sweep = auto
 - Detector function = peak
 - Trace = max hold
4. Allow the trace to stabilize. Use the marker-to-peak function to set the marker to the peak of the emission. The indicated level is the peak output power. Plot the result on the screen of spectrum analyzer.
5. Repeat above procedures until all frequencies measured were complete.

11.3 Measurement Equipment

Equipment	Manufacturer	Model No.	Calibration Date	Next Cal. Date
Spectrum Analyzer	Rohde & Schwarz	FSP40	2016/10/03	2017/10/02
Attenuator	MINI-CIRCUITS	BW-S10W2+	2016/09/30	2017/09/29

11.4 Measurement Data

Test Date : Oct. 05, 2016 Temperature : 24 °C Humidity : 60 %

Mode: Bluetooth BR

- a) Channel Low : Output Peak Power is 3.48 dBm or 2.228 mW ◦
- b) Channel Middle : Output Peak Power is 3.36 dBm or 2.168 mW ◦
- c) Channel High : Output Peak Power is 3.06 dBm or 2.023 mW ◦

Mode: Bluetooth EDR

- a) Channel Low : Output Peak Power is 3.04 dBm or 2.014 mW ◦
- b) Channel Middle : Output Peak Power is 2.73 dBm or 1.875 mW ◦
- c) Channel High : Output Peak Power is 2.31 dBm or 1.702 mW ◦

Justification on AFH mode:

Adaptive Frequency Hopping (AFH) means that a device can hop over a reduced set of frequencies. The frequencies hopped may be reduced in AFH mode but at least 15 channels will be used. Hence the output power limit is 125mW.

Note : The expanded uncertainty: 2dB.

Mode: Bluetooth BR

Channel Low

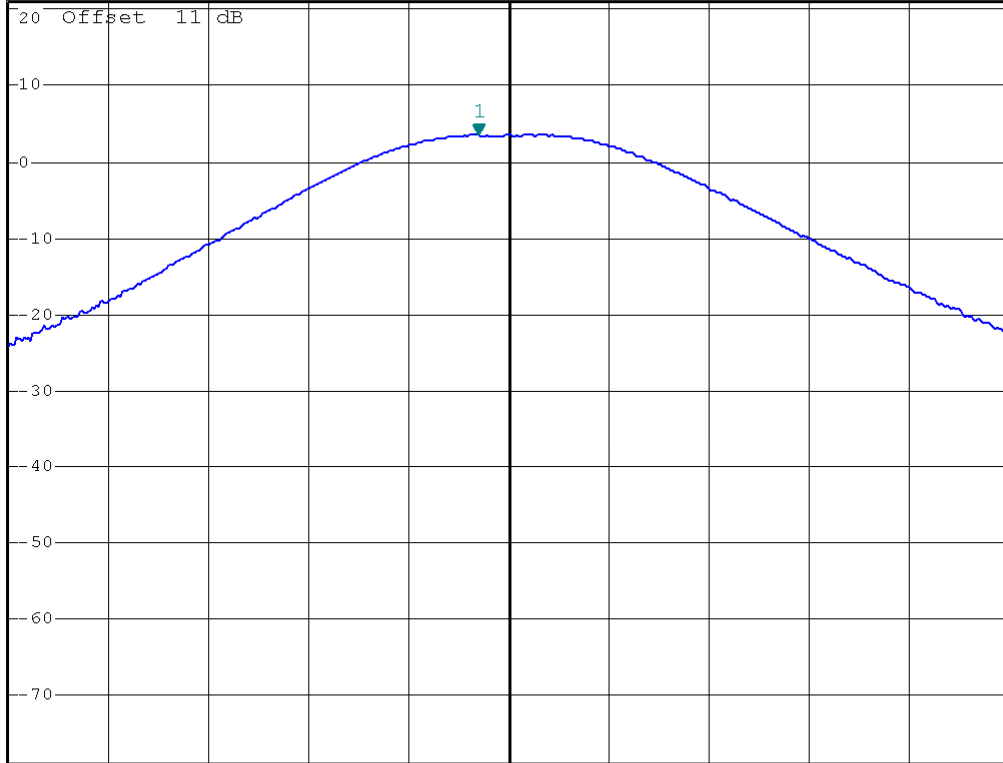


*RBW 1 MHz Marker 1 [T1]
VBW 3 MHz 3.48 dBm
SWT 2.5 ms 2.401850000 GHz

Ref 21 dBm

Att 40 dB

1 PK
VIEW



Channel Middle

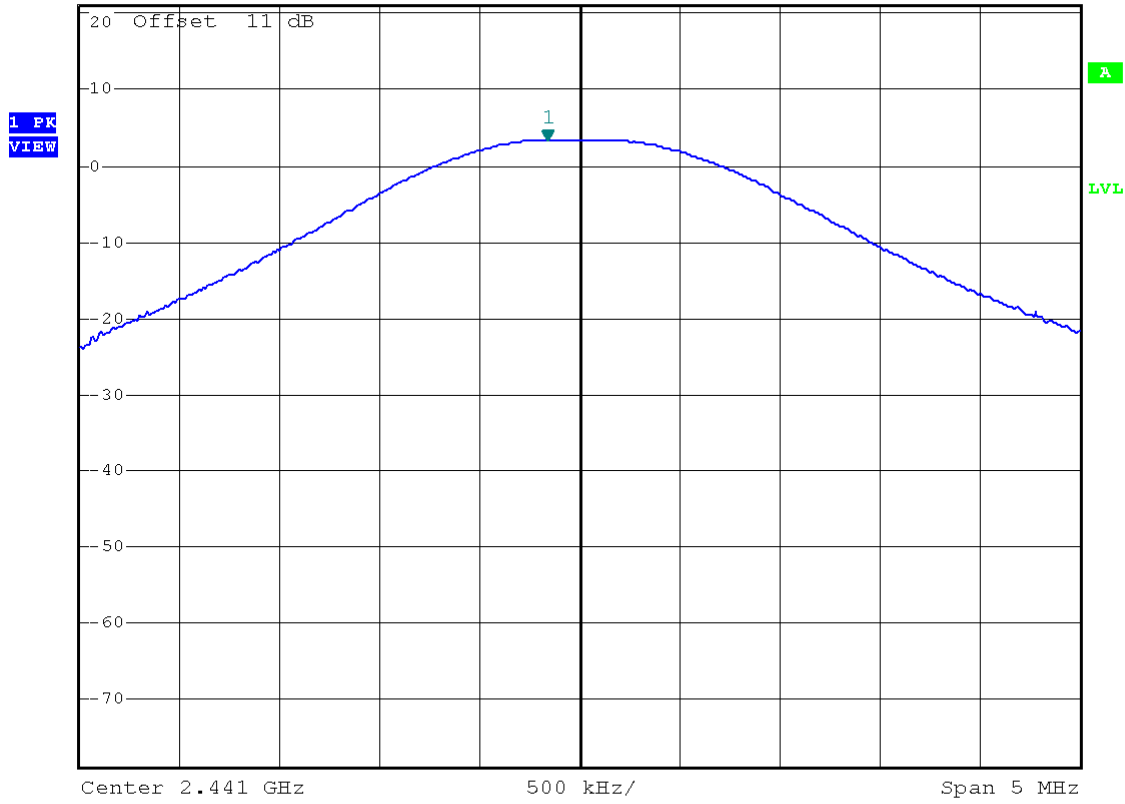


*RBW 1 MHz Marker 1 [T1]
VBW 3 MHz 3.36 dBm
SWT 2.5 ms 2.440840000 GHz

Ref 21 dBm

Att 40 dB

2.440840000 GHz



Channel High

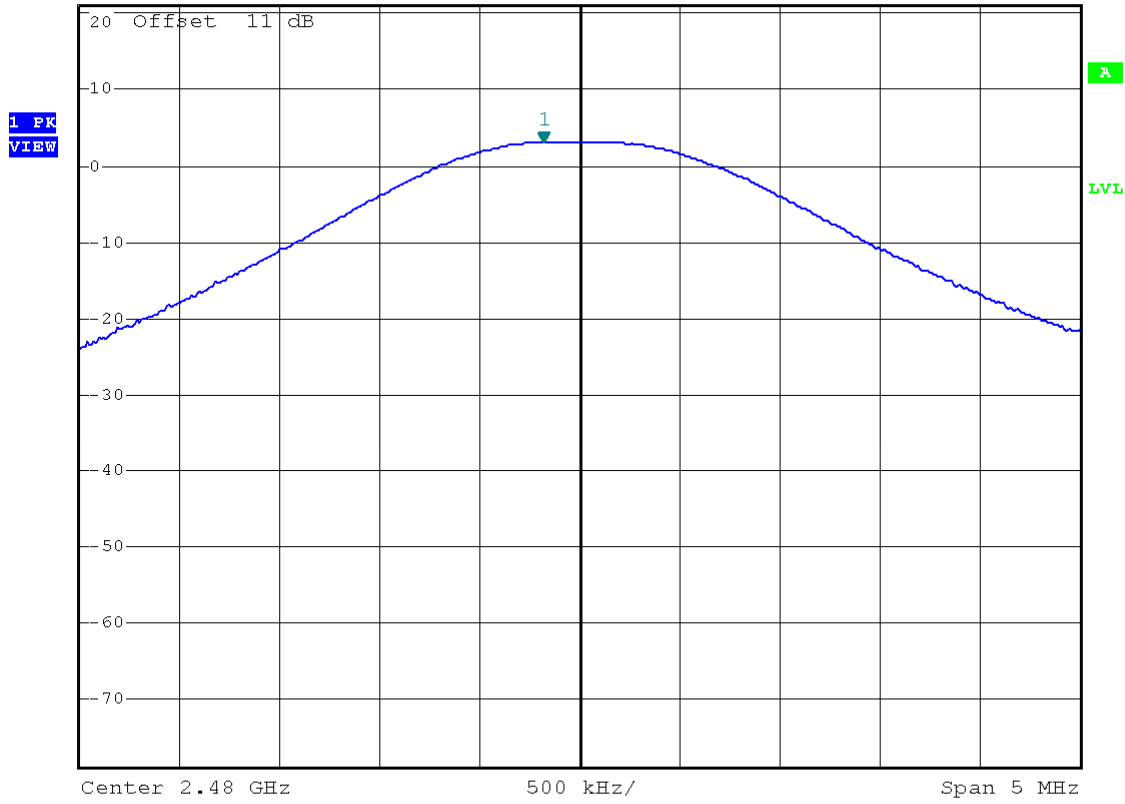


*RBW 1 MHz Marker 1 [T1]
VBW 3 MHz 3.06 dBm
SWT 2.5 ms 2.479820000 GHz

Ref 21 dBm

Att 40 dB

2.479820000 GHz



Mode: Bluetooth EDR

Channel Low

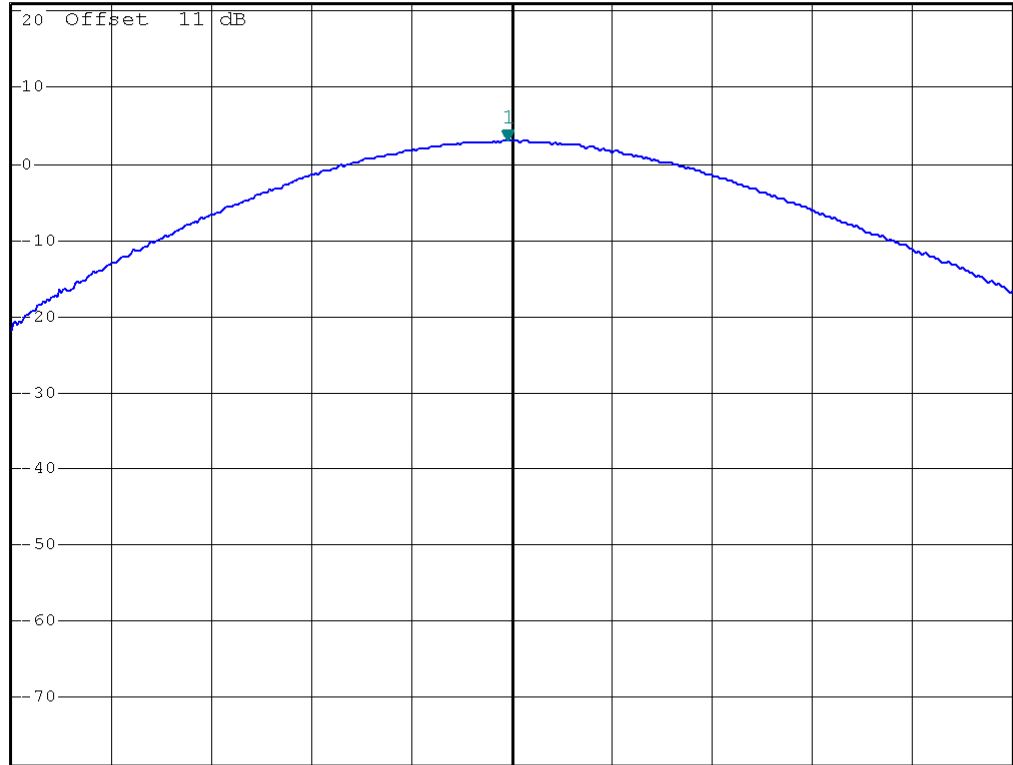


*RBW 3 MHz Marker 1 [T1]
VBW 10 MHz 3.04 dBm
SWT 2.5 ms 2.401960000 GHz

Ref 21 dBm

Att 40 dB

1 PK
VIEW



Center 2.402 GHz

1 MHz/

Span 10 MHz

Channel Middle

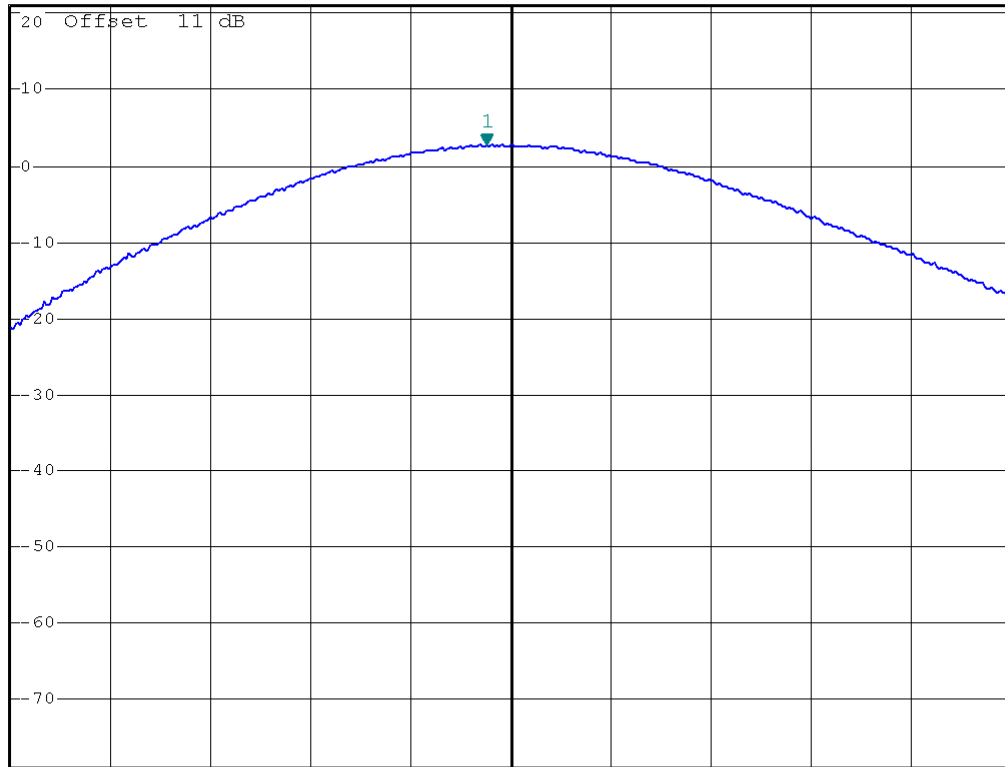


*RBW 3 MHz Marker 1 [T1]
VBW 10 MHz 2.73 dBm
SWT 2.5 ms 2.440760000 GHz

Ref 21 dBm

Att 40 dB

1 PK
VIEW



Center 2.441 GHz

1 MHz/

Span 10 MHz

Channel High

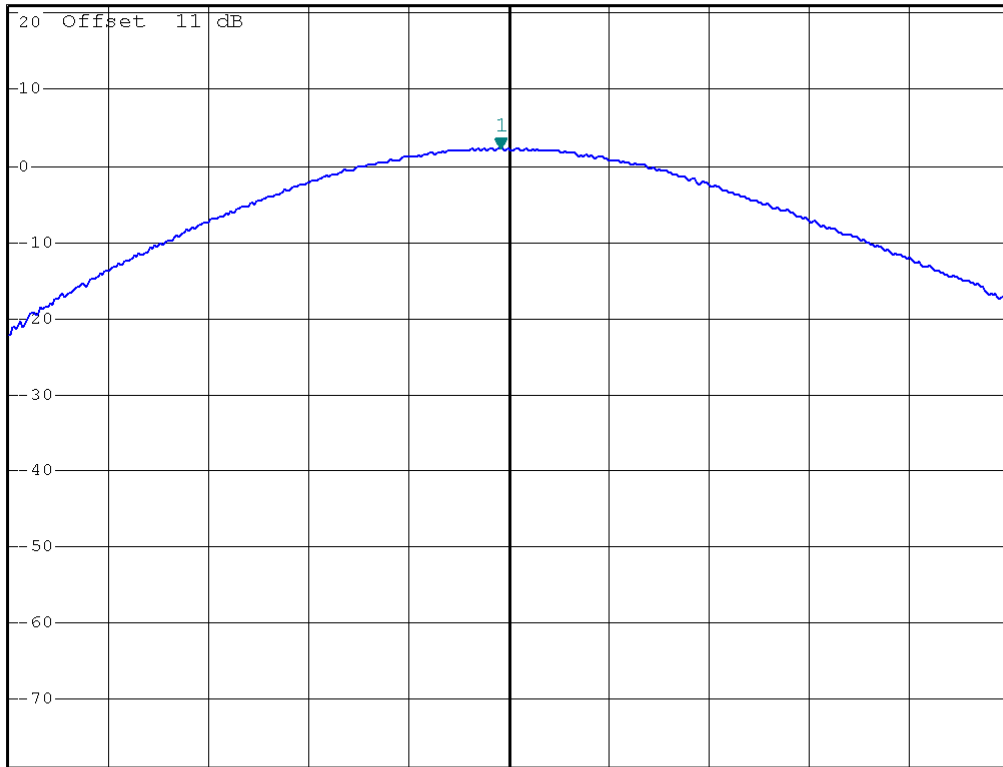


*RBW 3 MHz Marker 1 [T1]
VBW 10 MHz 2.31 dBm
SWT 2.5 ms 2.479920000 GHz

Ref 21 dBm

Att 40 dB

1 PK
VIEW



Center 2.48 GHz

1 MHz/

Span 10 MHz

12 100 kHz BANDWIDTH OF BAND EDGES MEASUREMENT

12.1 Standard Applicable

According to 15.247(d), 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. Attenuation below the general limits specified in §15.209(a) is not required.

12.2 Measurement 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 figure 4 without connection to measurement instrument. Turn on the EUT and connect its antenna terminal to measurement instrument via a low loss cable. Then set it to any one measured frequency within its operating range and make sure the instrument is operated in its linear range.
3. Use the following spectrum analyzer settings:
 - Span = wide enough to capture the peak level of the emission operating on the channel closest to the bandedge, as well as any modulation products which fall outside of the authorized band of operation
 - RBW \geq 1% of the span
 - VBW \geq RBW
 - Sweep = auto
 - Detector function = peak
 - Trace = max hold
4. Allow the trace to stabilize. Set the marker on the emission at the bandedge, or on the highest modulation product outside of the band, if this level is greater than that at the bandedge. Enable the marker-delta function, then use the marker-to-peak function to move the marker to the peak of the in-band emission. Plot the result on the screen of spectrum analyzer.
5. Repeat above procedures until all measured frequencies were complete.

12.3 Measurement Equipment

Equipment	Manufacturer	Model No.	Calibration Date	Next Cal. Date
Spectrum Analyzer	Rohde & Schwarz	FSP40	2016/10/03	2017/10/02
Attenuator	MINI-CIRCUITS	BW-S10W2+	2016/09/30	2017/09/29

12.4 Measurement Data

Test Date : Oct. 05, 2016 Temperature : 24 °C Humidity : 60 %

Mode: Bluetooth BR

- a) Lower Band Edge : All emissions in this 100kHz bandwidth are attenuated more than 20dB from the carrier.
- b) Upper Band Edge : All emissions in this 100kHz bandwidth are attenuated more than 20dB from the carrier.

Mode: Bluetooth EDR

- a) Lower Band Edge : All emissions in this 100kHz bandwidth are attenuated more than 20dB from the carrier.
- b) Upper Band Edge : All emissions in this 100kHz bandwidth are attenuated more than 20dB from the carrier.

Note : The expanded uncertainty: 2dB.

Mode: Bluetooth BR

Lower Band Edge (Hoppin off)

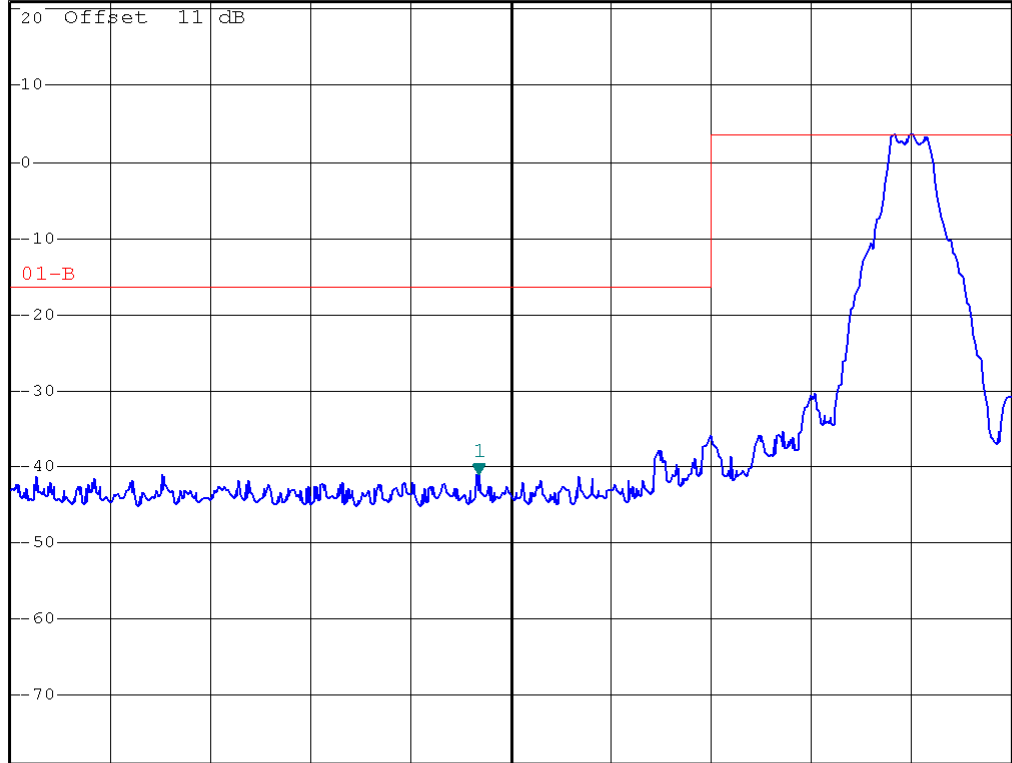


*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -41.00 dBm
SWT 2.5 ms 2.397680000 GHz

Ref 21 dBm

Att 40 dB

1 PK
VIEW



Start 2.393 GHz

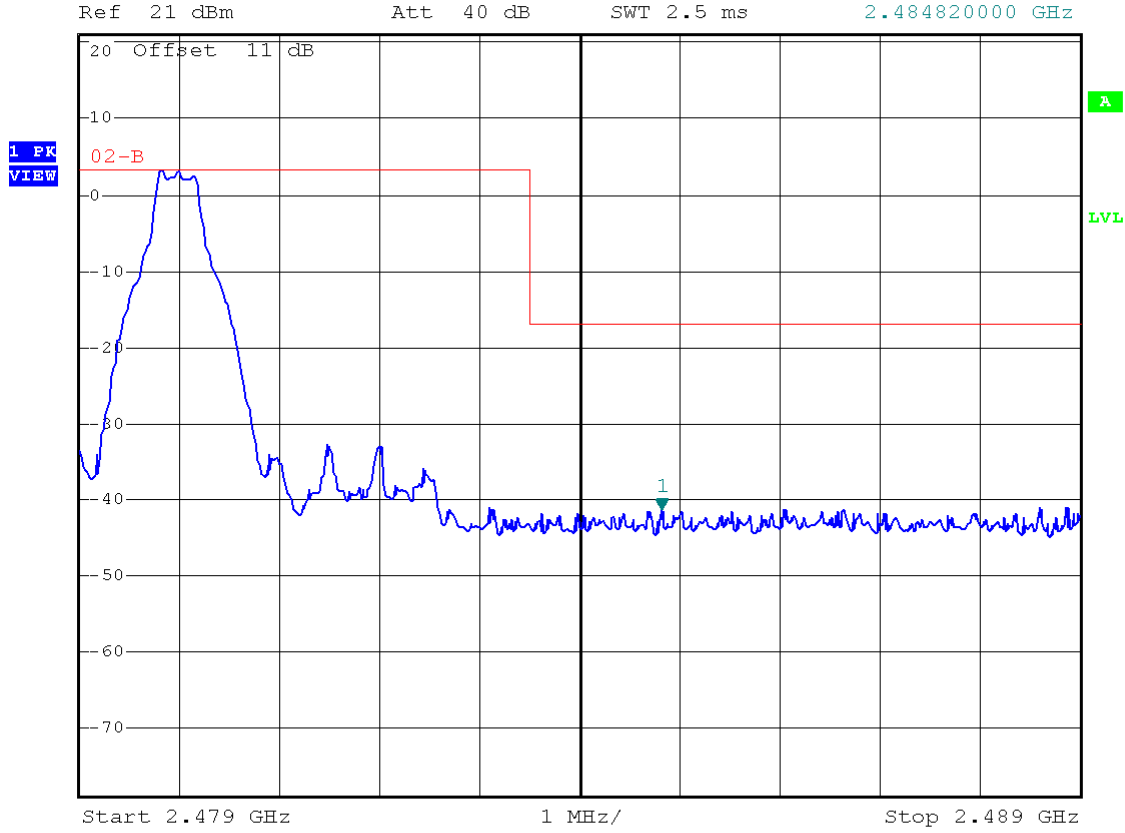
1 MHz/

Stop 2.403 GHz

Upper Band Edge (Hoppin off)



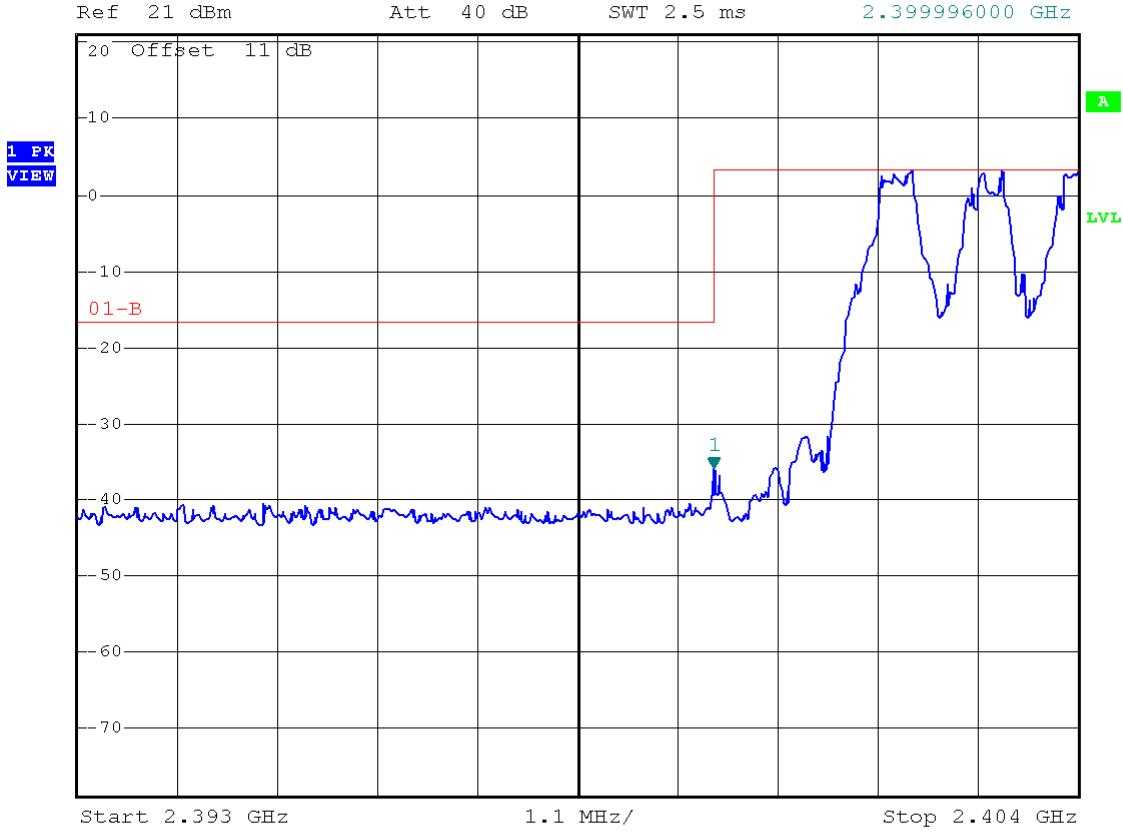
*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -41.23 dBm
SWT 2.5 ms 2.484820000 GHz



Lower Band Edge (Hoppin on)



*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -35.94 dBm
SWT 2.5 ms 2.399996000 GHz



Upper Band Edge (Hoppin on)

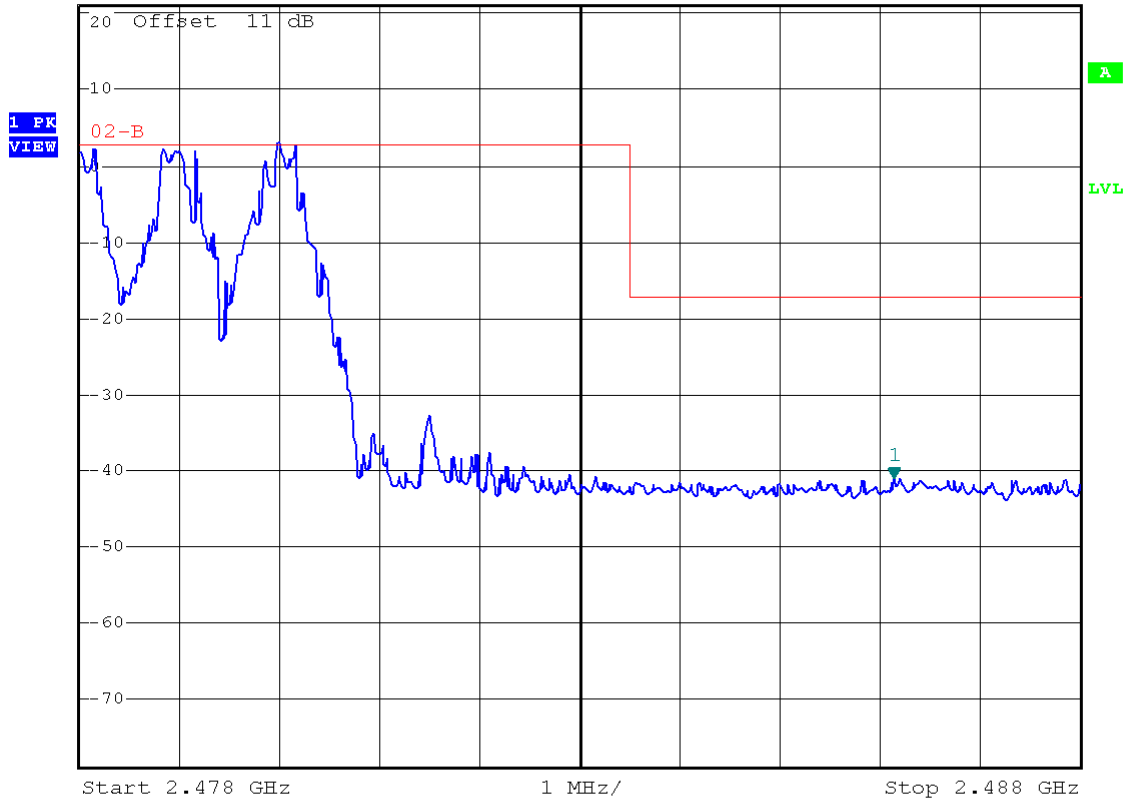


*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -41.15 dBm
SWT 2.5 ms 2.486140000 GHz

Ref 21 dBm

Att 40 dB

2.486140000 GHz



Mode: Bluetooth EDR

Lower Band Edge (Hoppin off)

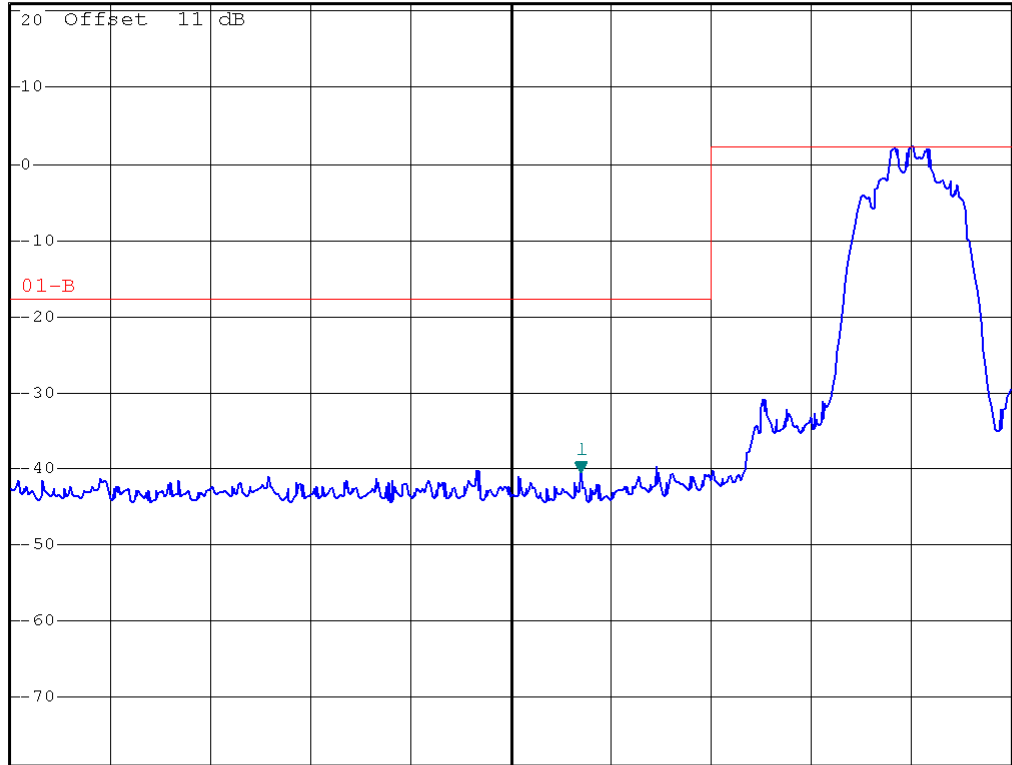


*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -40.58 dBm
SWT 2.5 ms 2.398700000 GHz

Ref 21 dBm

Att 40 dB

1 PK
VIEW



Upper Band Edge (Hoppin off)

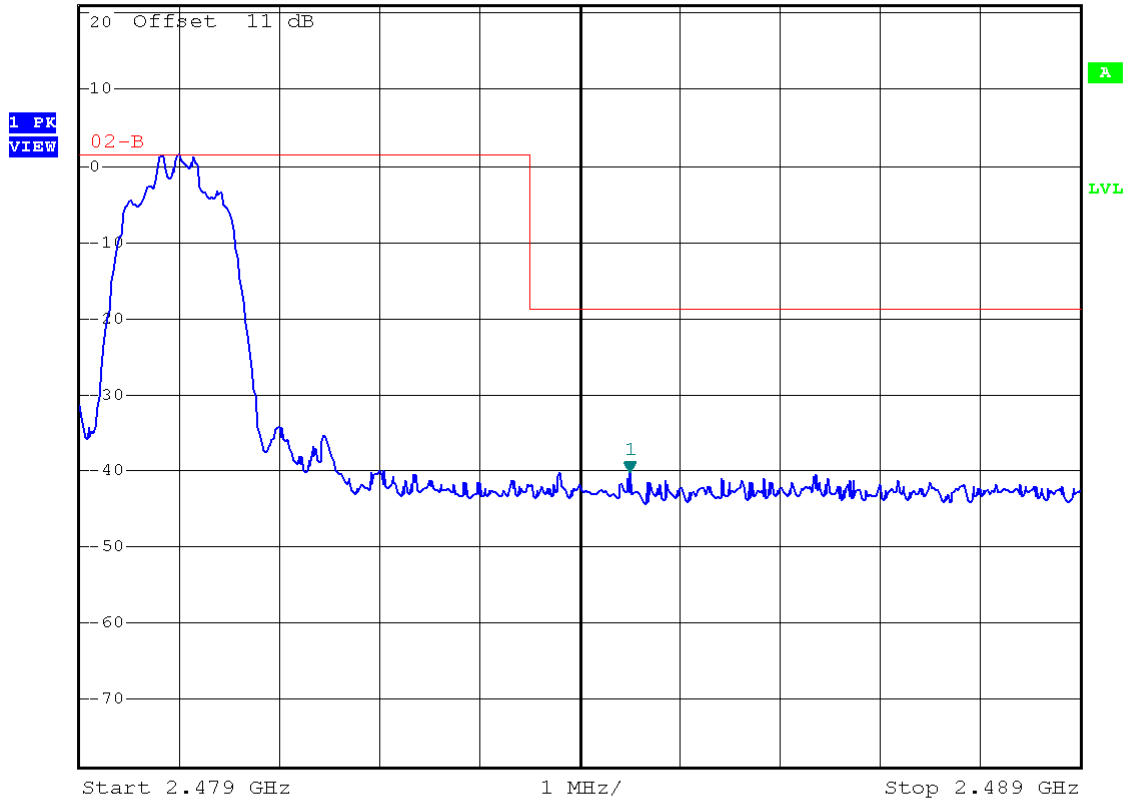


*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -40.30 dBm
SWT 2.5 ms 2.484500000 GHz

Ref 21 dBm

Att 40 dB

2.484500000 GHz



Lower Band Edge (Hoppin on)



*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -38.06 dBm
SWT 2.5 ms 2.399520000 GHz



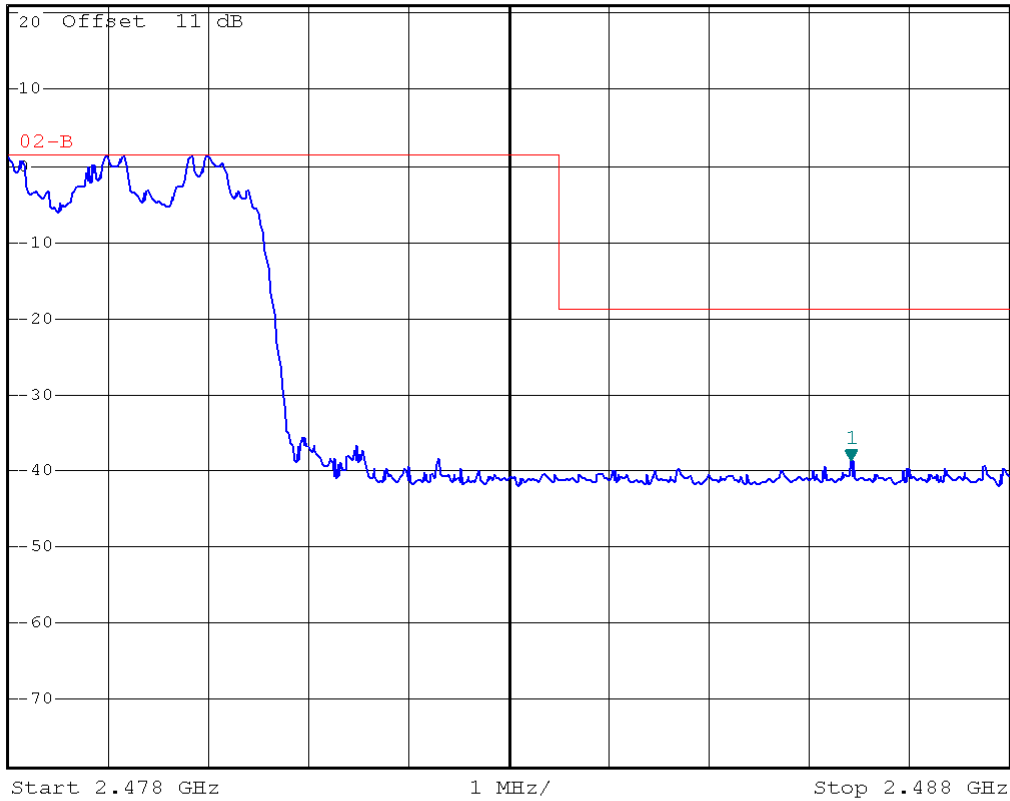
Upper Band Edge (Hoppin on)



*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -38.66 dBm
SWT 2.5 ms 2.486420000 GHz

Ref 21 dBm

Att 40 dB



13 CONDUCTED SPURIOUS EMISSION MEASUREMENT

13.1 Standard Applicable

According to 15.247(d), 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. Attenuation below the general limits specified in §15.209(a) is not required.

13.2 Measurement 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 figure 4 without connection to measurement instrument. Turn on the EUT and connect its antenna terminal to measurement instrument via a low loss cable. Then set it to any one measured frequency within its operating range and make sure the instrument is operated in its linear range.
3. Use the following spectrum analyzer settings:
 - Span = wide enough to capture the peak level of the in-band emission and all spurious emissions (e.g., harmonics) from the lowest frequency generated in the EUT up through the 10th harmonic. Typically, several plots are required to cover this entire span.
 - RBW = 100 kHz
 - VBW \geq RBW
 - Sweep = auto
 - Detector function = peak
 - Trace = max hold.
4. Allow the trace to stabilize. Set the marker on the peak of any spurious emission recorded. Plot the result on the screen of spectrum analyzer.
5. Repeat above procedures until all measured frequencies were complete.

13.3 Measurement Equipment

Equipment	Manufacturer	Model No.	Calibration Date	Next Cal. Date
Spectrum Analyzer	Rohde & Schwarz	FSP40	2016/10/03	2017/10/02
Attenuator	MINI-CIRCUITS	BW-S10W2+	2016/09/30	2017/09/29

13.4 Measurement Data

Test Date : Oct. 05, 2016 Temperature : 24 °C Humidity : 60 %

Mode: Bluetooth BR

Mode : Low Channel/ Mid Channel/ Hi Channel

- a) 1 GHz to 26.5 GHz frequency band: All emissions are attenuated more than 20dB from the carrier.

Mode: Bluetooth EDR

Mode : Low Channel/ Mid Channel/ Hi Channel

- a) 1 GHz to 26.5 GHz frequency band: All emissions are attenuated more than 20dB from the carrier.

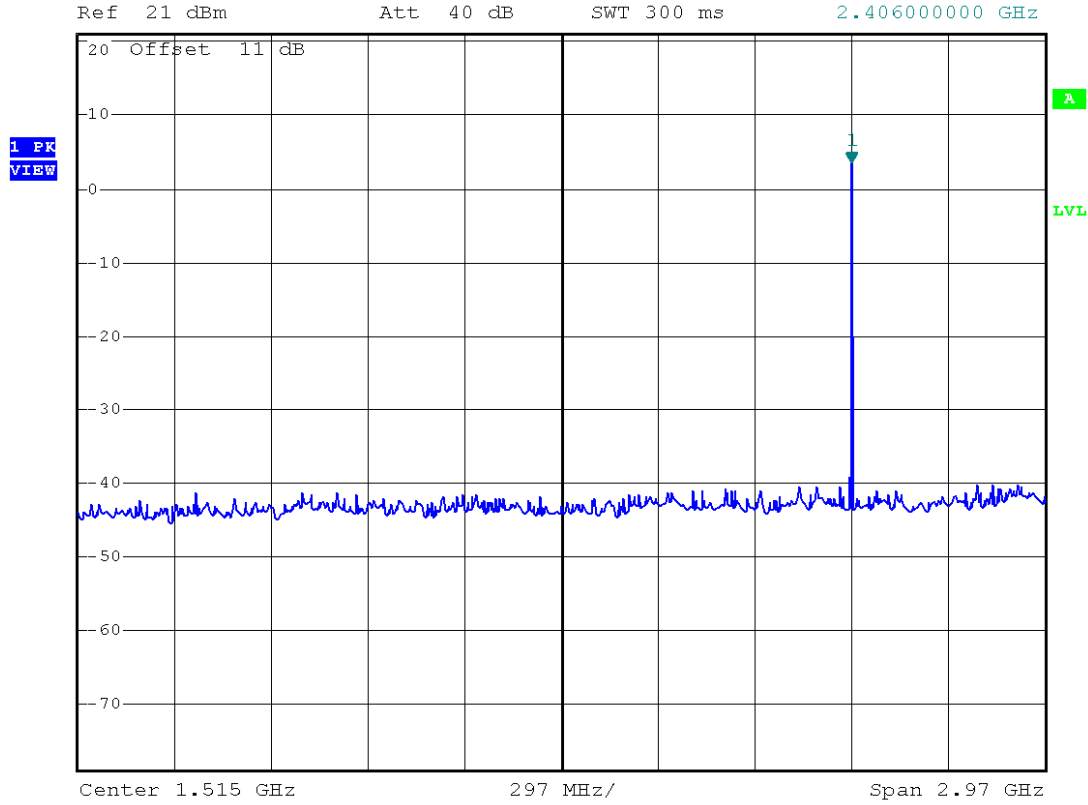
Note : The expanded uncertainty: 2dB.

Mode: Bluetooth BR

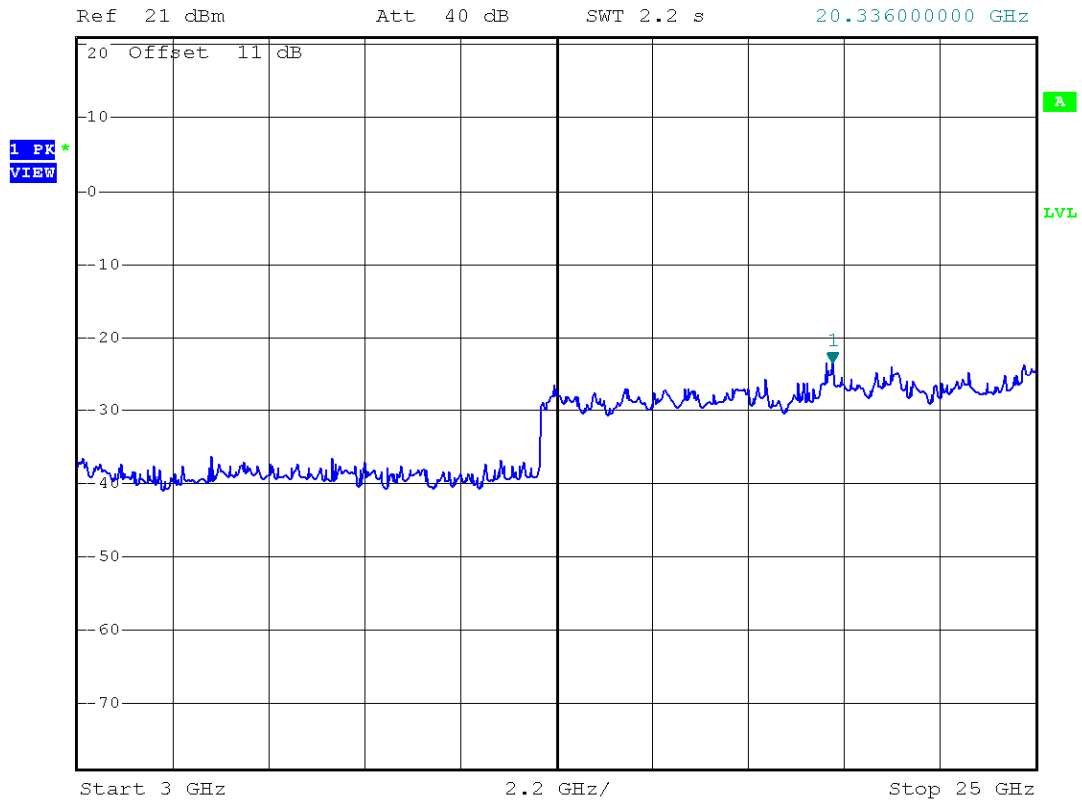
Mode : Low Channel



*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz 3.59 dBm
SWT 300 ms 2.406000000 GHz



*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -23.43 dBm
SWT 2.2 s 20.336000000 GHz

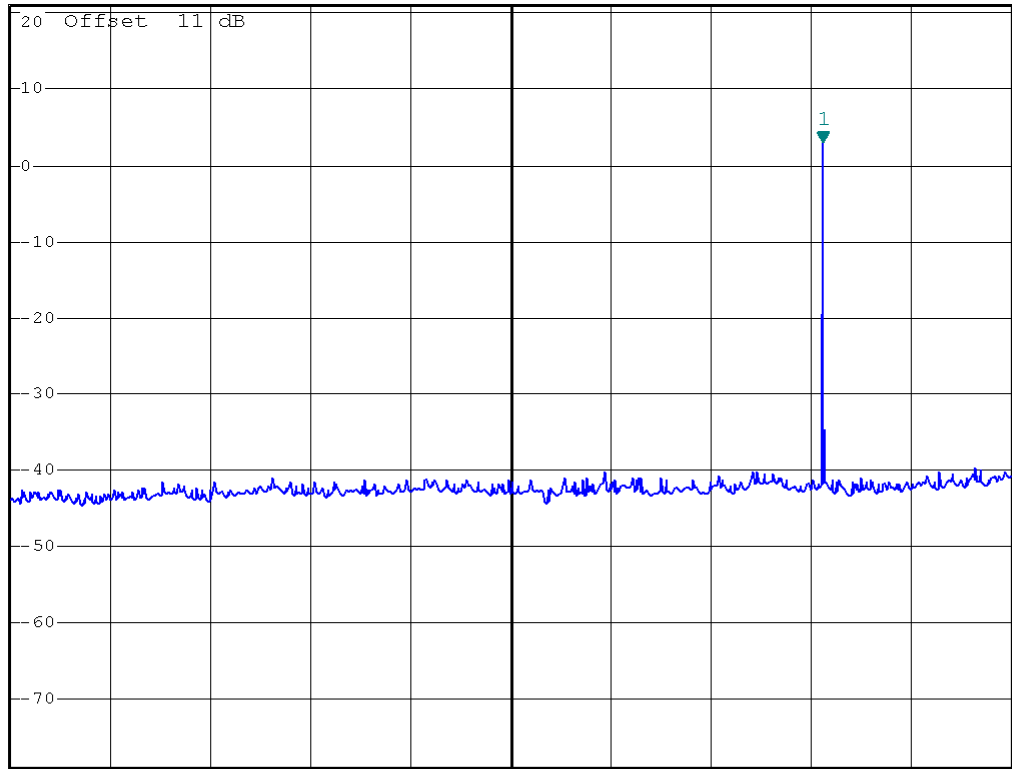


Mode : Mid Channel



Ref 21 dBm Att 40 dB SWT 300 ms 2.441640000 GHz
*RBW 100 kHz Marker 1 [T1] 3.09 dBm
VBW 300 kHz

1 PR
MAXH

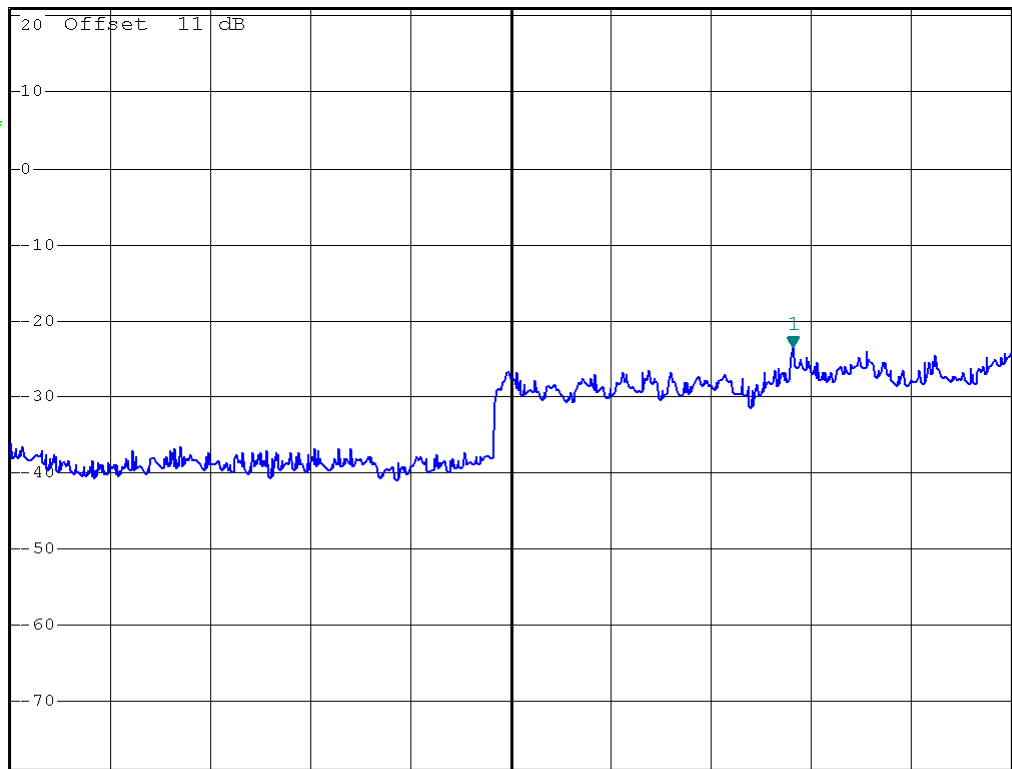


Start 30 MHz 297 MHz/ Stop 3 GHz



Ref 21 dBm Att 40 dB SWT 2.2 s 20.204000000 GHz
*RBW 100 kHz Marker 1 [T1] -23.61 dBm
VBW 300 kHz

1 PR *
VIEW



Start 3 GHz 2.2 GHz/ Stop 25 GHz

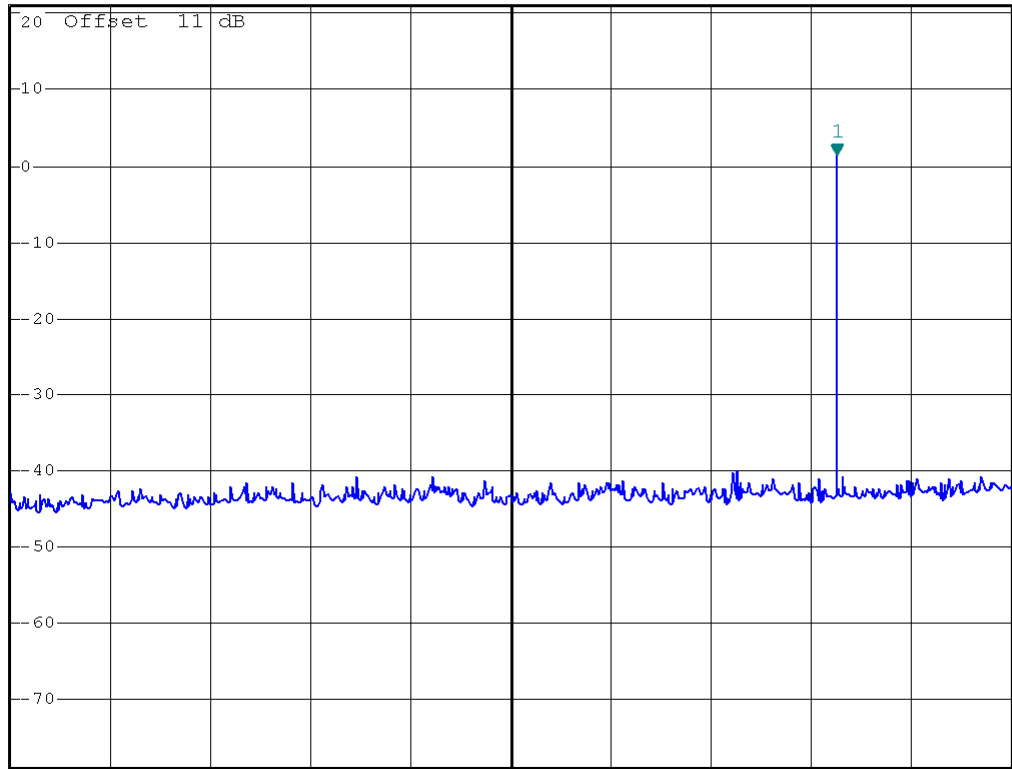
Mode : Hi Channel



*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz 1.42 dBm
SWT 300 ms 2.483220000 GHz

Ref 21 dBm Att 40 dB

1 PK
VIEW



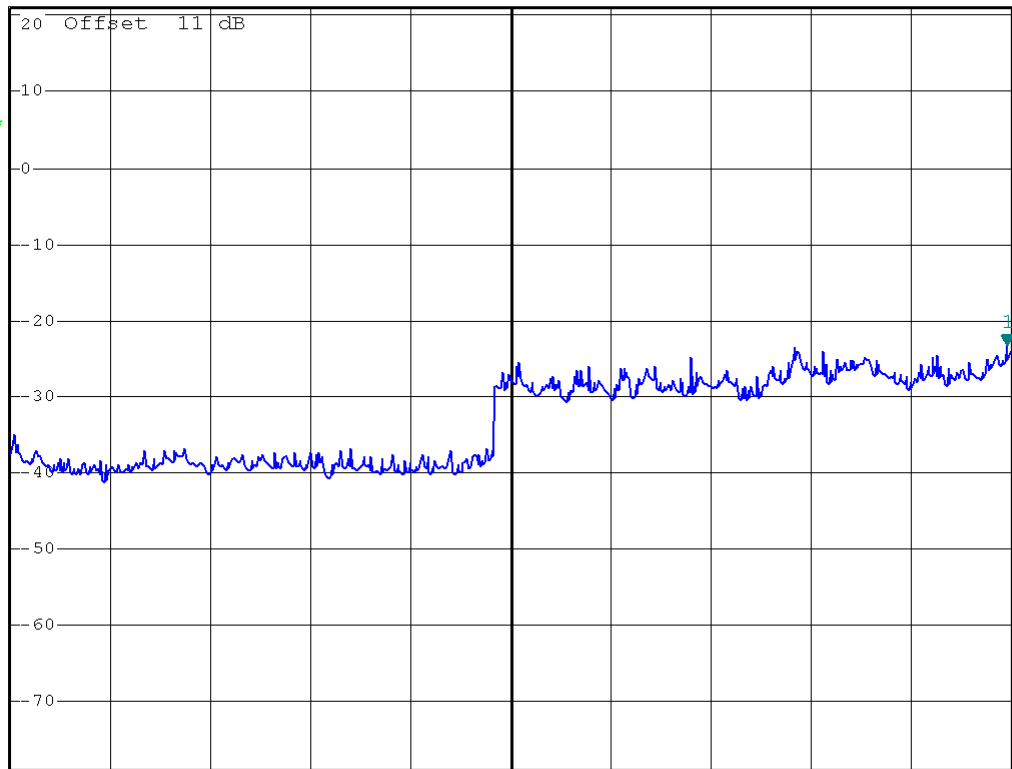
Start 30 MHz 297 MHz/ Stop 3 GHz



*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -23.25 dBm
SWT 2.2 s 24.912000000 GHz

Ref 21 dBm Att 40 dB

1 PK *
VIEW



Start 3 GHz 2.2 GHz/ Stop 25 GHz

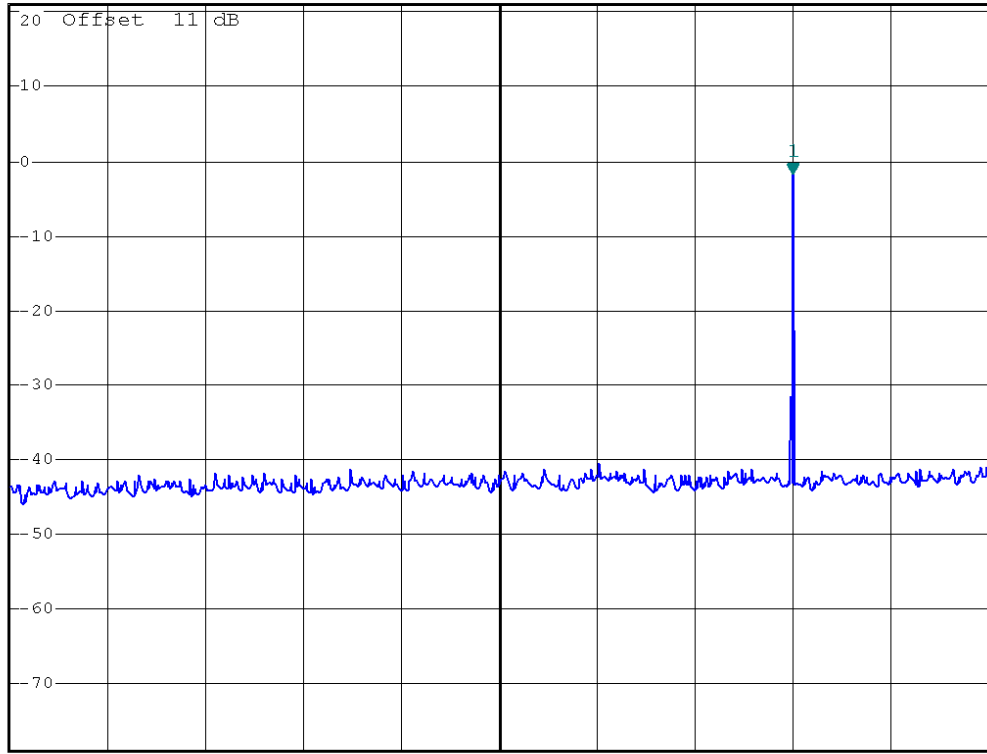
Mode: Bluetooth EDR

Mode : Low Channel



Ref 21 dBm Att 40 dB SWT 300 ms 2.406000000 GHz
*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -1.68 dBm

1 PK
VIEW

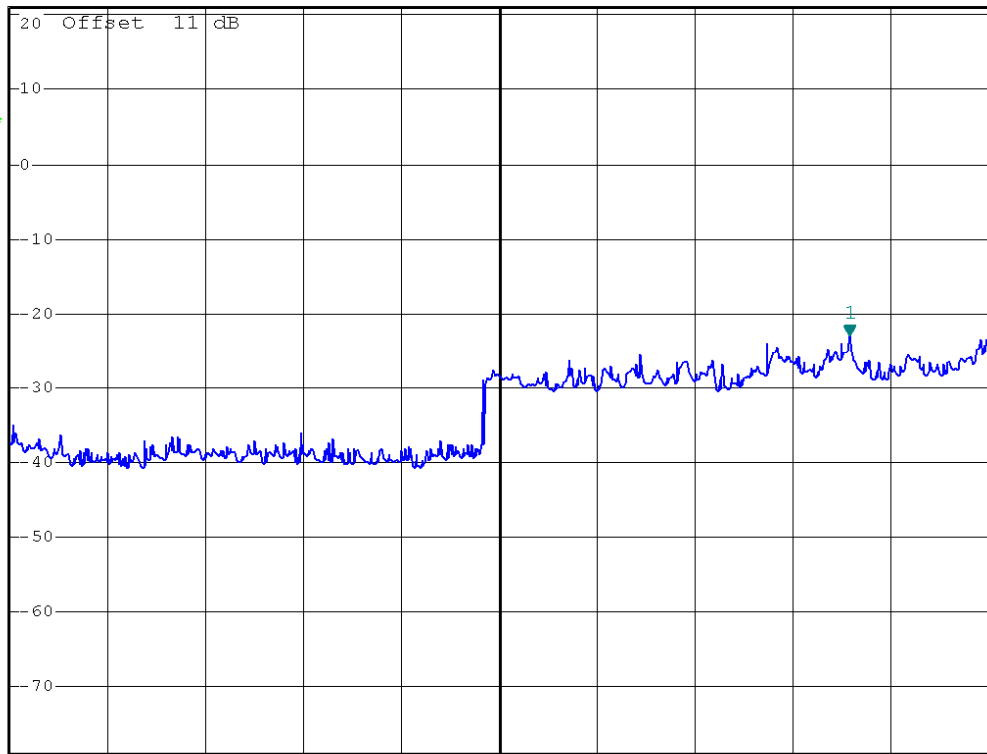


Start 30 MHz 297 MHz/ Stop 3 GHz



Ref 21 dBm Att 40 dB SWT 2.2 s 21.876000000 GHz
*RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -22.96 dBm

1 PK *
VIEW



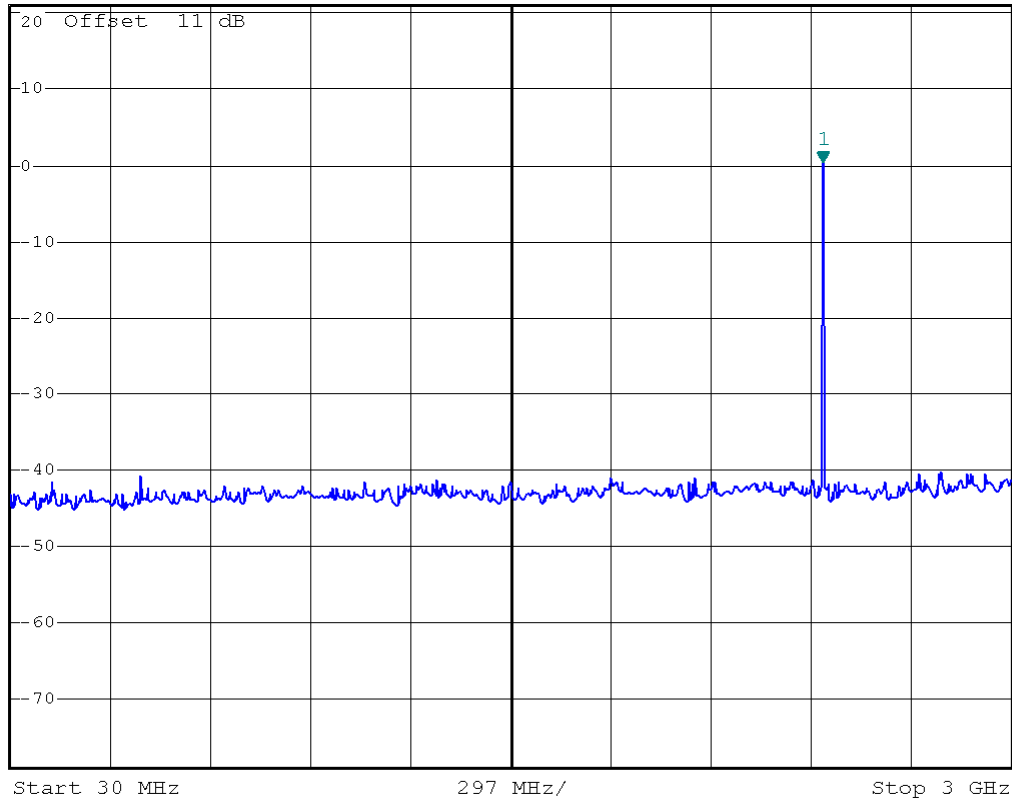
Start 3 GHz 2.2 GHz/ Stop 25 GHz

Mode : Mid Channel



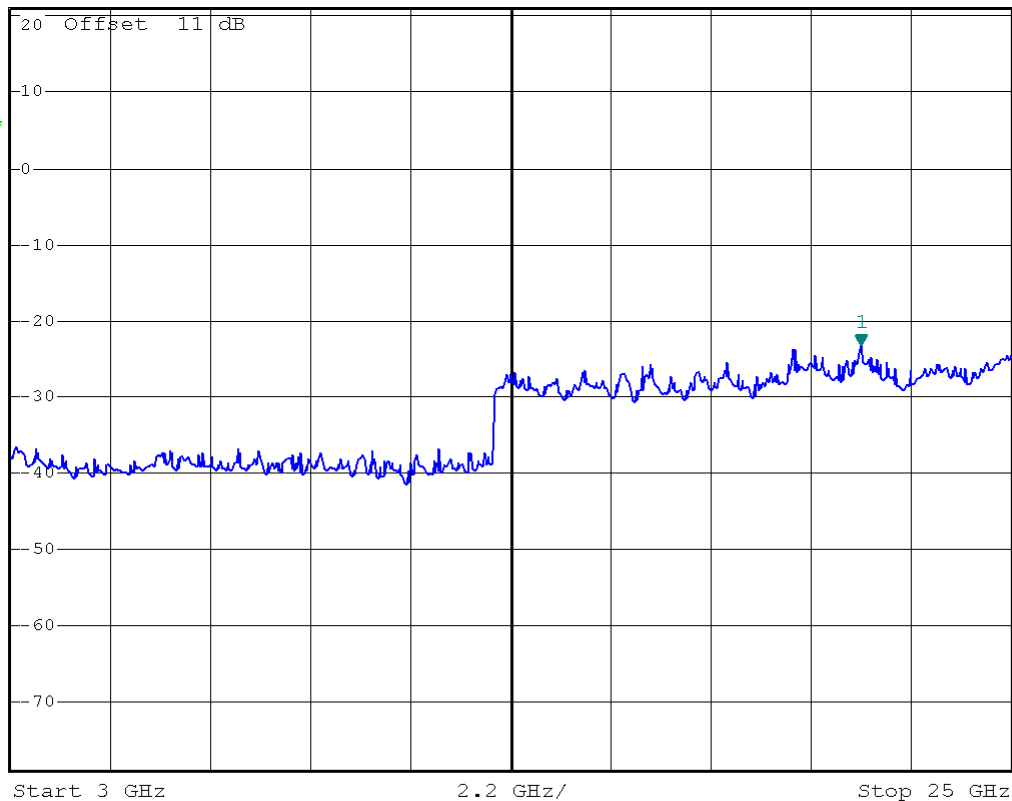
Ref 21 dBm Att 40 dB *RBW 100 kHz Marker 1 [T1]
VBW 300 kHz 0.45 dBm
SWT 300 ms 2.441640000 GHz

1 PR
VIEW

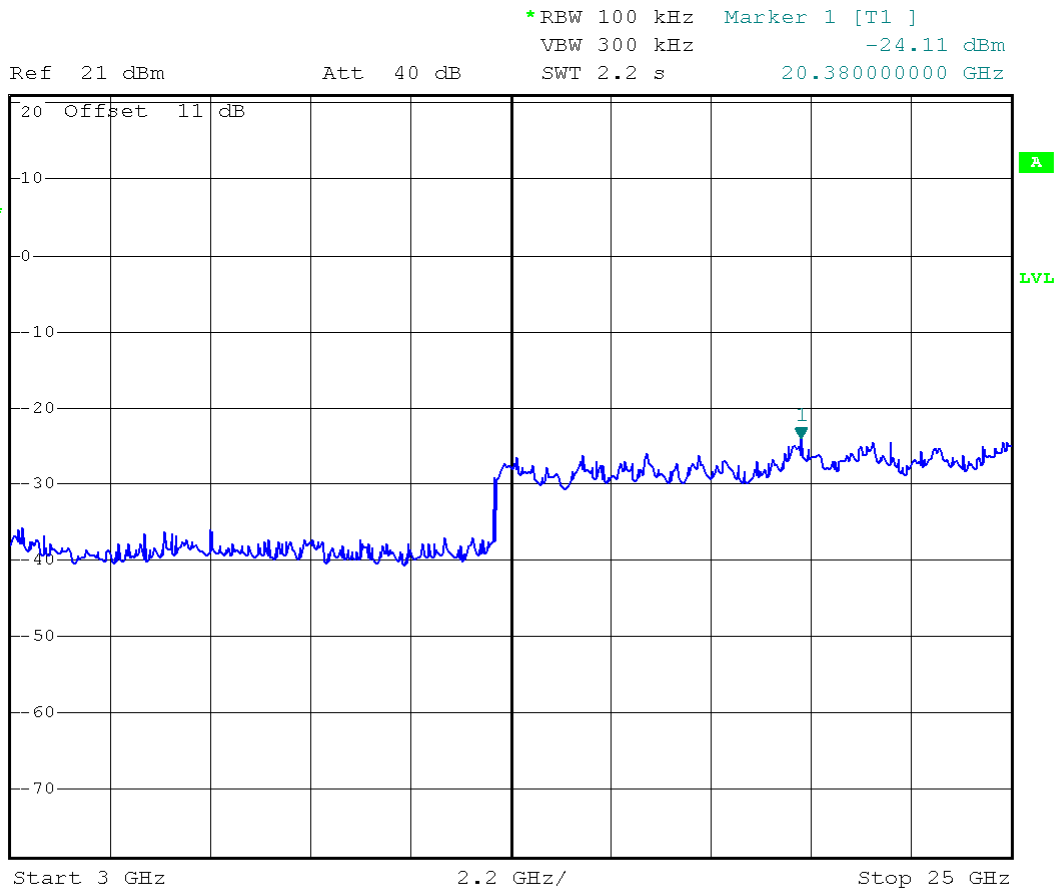
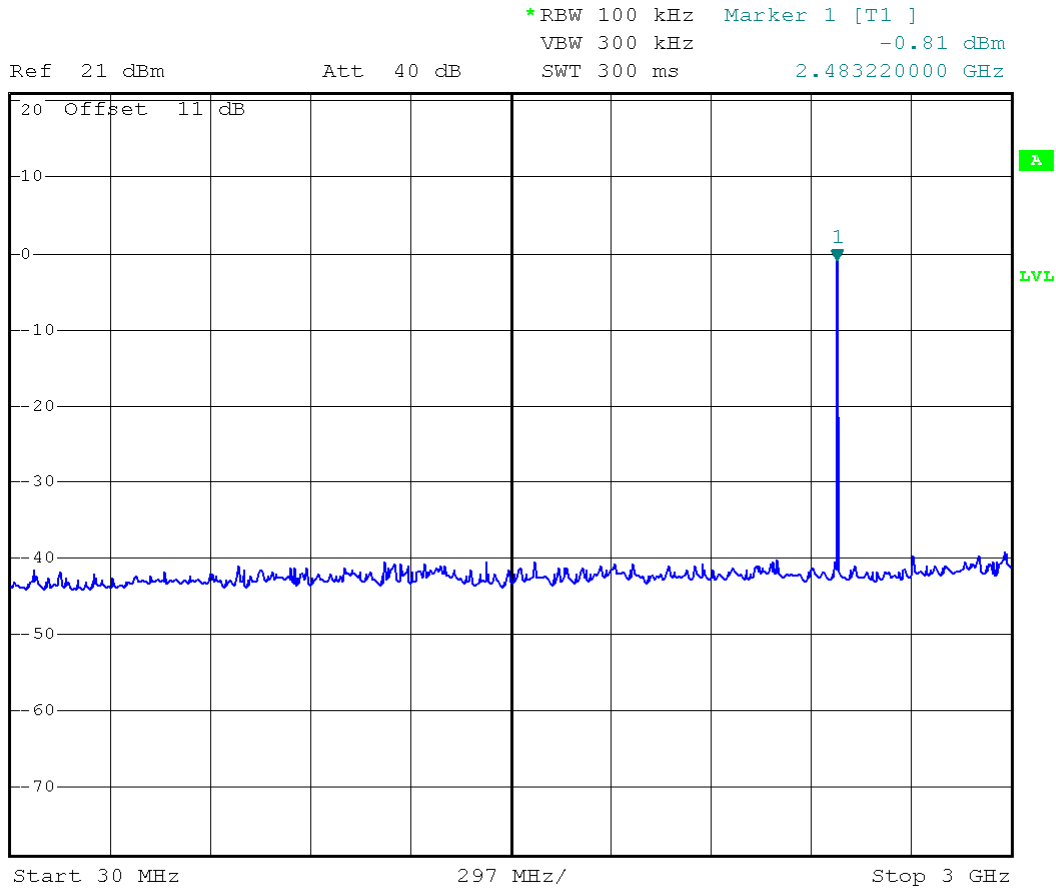


Ref 21 dBm Att 40 dB *RBW 100 kHz Marker 1 [T1]
VBW 300 kHz -23.27 dBm
SWT 2.2 s 21.700000000 GHz

1 PR *
VIEW



Mode : Hi Channel



14. DUTY CYCLE

14.1 Standard Applicable

None. Reference only.

14.2 Measurement Equipment

Equipment	Manufacturer	Model No.	Calibration Date	Next Cal. Date
Spectrum Analyzer	Rohde & Schwarz	FSP40	2016/10/03	2017/10/02
Attenuator	MINI-CIRCUITS	BW-S10W2+	2016/09/30	2017/09/29

14.3 Measurement Data

Test Date : Oct. 05, 2016 Temperature : 24 °C Humidity : 60 %

Duty Cycle Calculation

Mode	Period (ms)	Transmission duration (T) (ms)	Duty Cycle (%)	1/T (kHz)	VBW setting (kHz)
BR / DH5	3.76	3.08	81.9	0.324	1
EDR / DH5	3.88	3.20	82.4	0.312	1

Note:

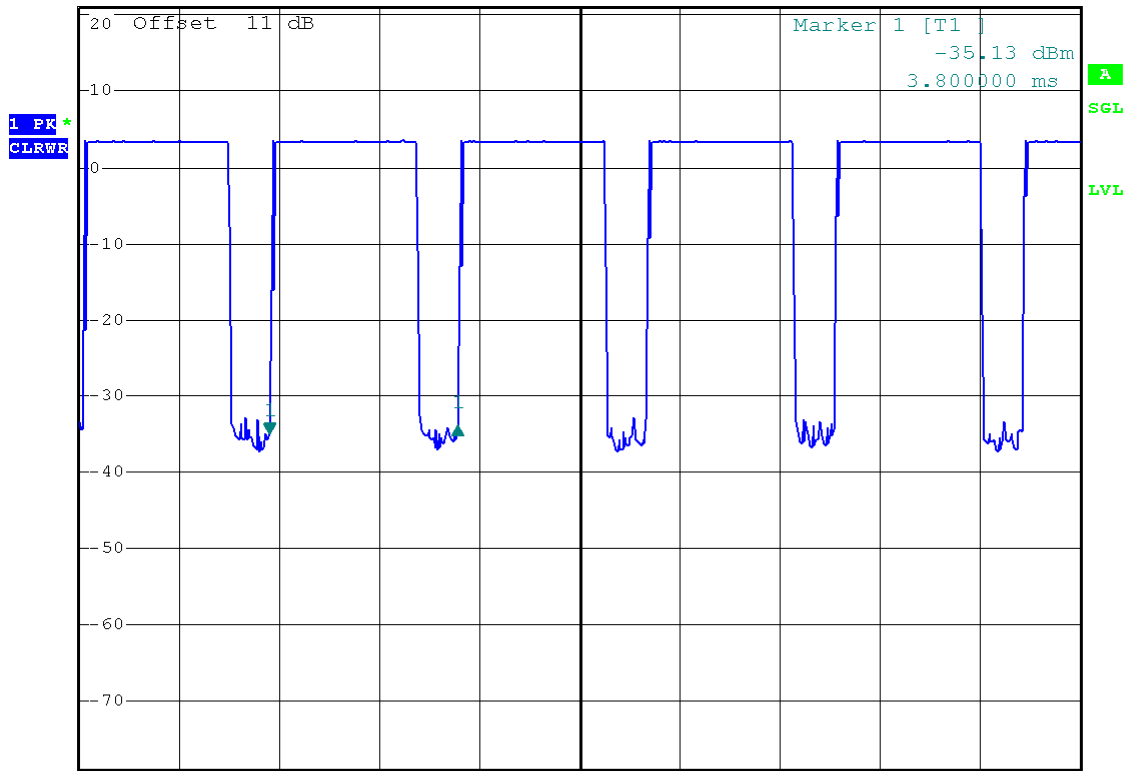
1. DH5 has the highest duty cycle worst case and is reported.
2. When the duty cycle is less than 98%, for the average measurement of the radiated emission test, the VBW setting is $>1/T$ where the T is the minimum transmission duration over which the transmitter is on and is transmitting at its maximum power control level for the tested mode of operation.

Refer to the following page for data plots.

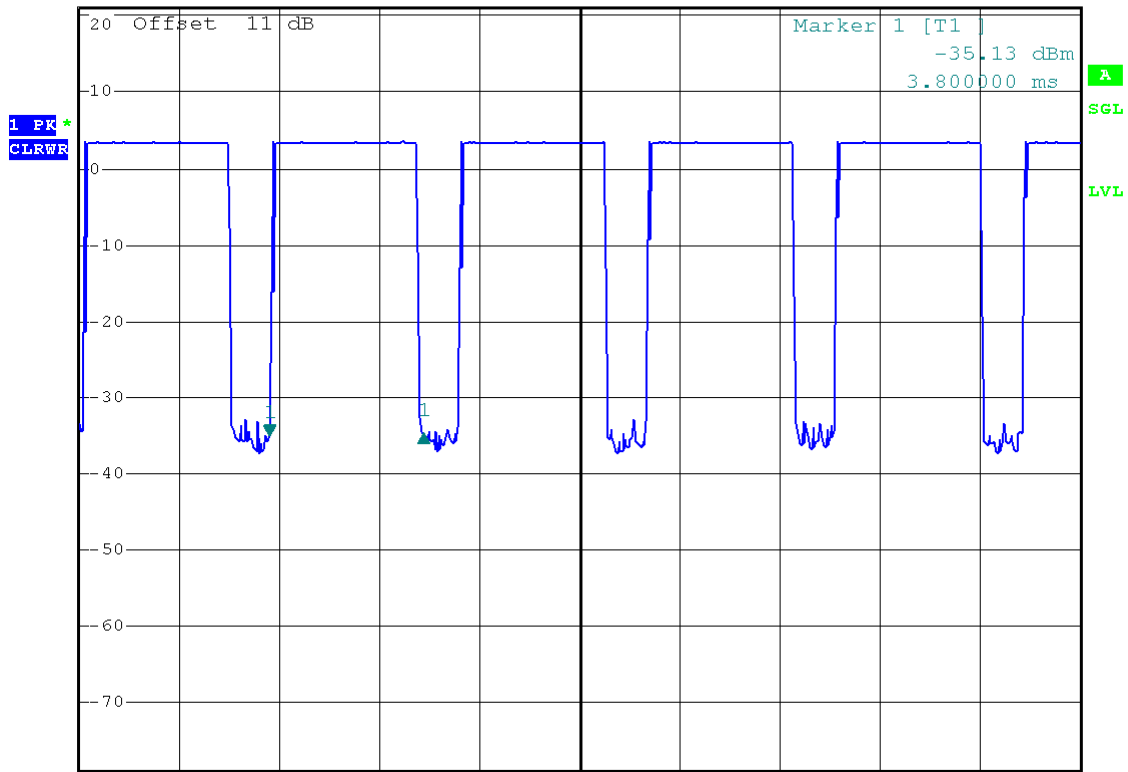
Mode: Bluetooth BR / Duty-DH5



RBW 1 MHz Delta 1 [T1]
VBW 3 MHz 1.12 dB
Ref 21 dBm Att 40 dB SWT 20 ms 3.760000 ms



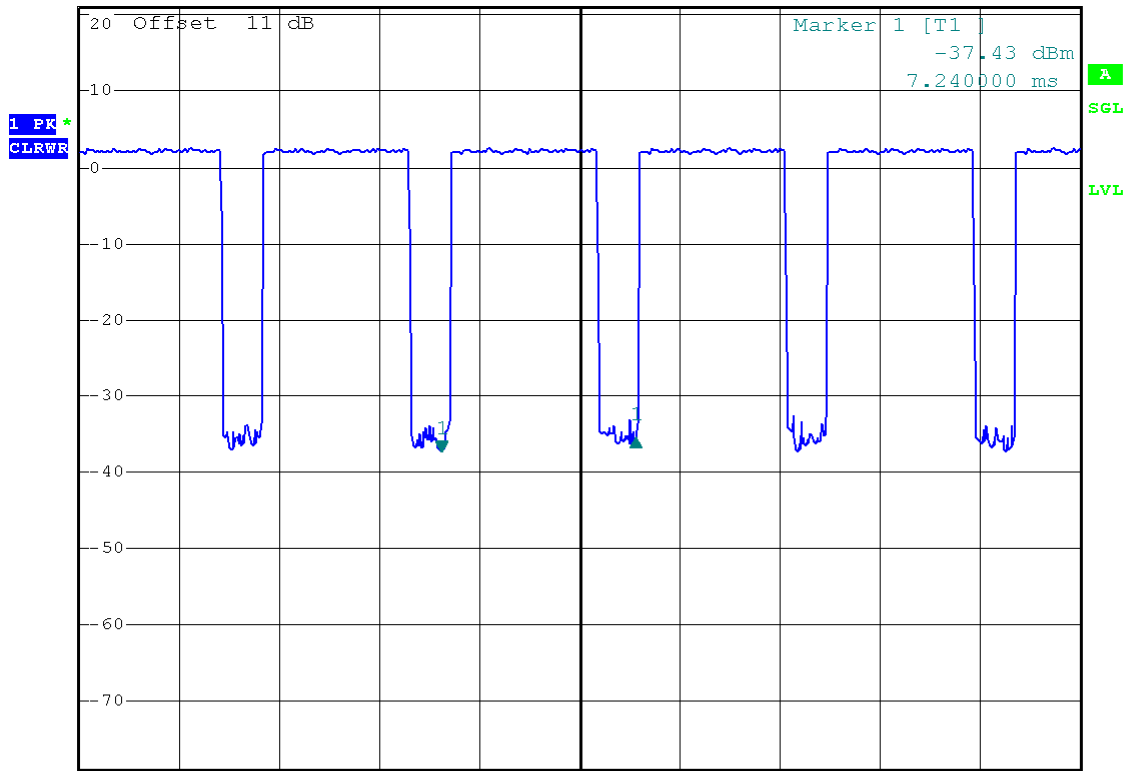
RBW 1 MHz Delta 1 [T1]
VBW 3 MHz 0.30 dB
Ref 21 dBm Att 40 dB SWT 20 ms 3.080000 ms



Mode: Bluetooth EDR / Duty-DH5



RBW 1 MHz Delta 1 [T1]
VBW 3 MHz 1.82 dB
Ref 21 dBm Att 40 dB SWT 20 ms 3.880000 ms



RBW 1 MHz Delta 1 [T1]
VBW 3 MHz 2.32 dB
Ref 21 dBm Att 40 dB SWT 20 ms 3.200000 ms

