TEST REPORT

of

FCC Part 15 Subpart C §15.247

FCC ID: ZNFHBSAL4

Equipment Under Test	:	LG STEREO Headset
Model Name	:	HBS-AL4
Variant Model Name	:	HBS-PAL4
Applicant	:	LG Electronics USA, Inc.
Manufacturer	:	GoerTek
Date of Receipt	:	2019.04.08
Date of Test(s)	:	2019.04.10 ~ 2019.06.10
Date of Issue	:	2019.06.10

In the configuration tested, the EUT complied with the standards specified above.

Tested By:	**Murphy Kim**	**Date:**	**2019.06.10**
Technical Manager:	**Jungmin Yang**	**Date:**	**2019.06.10**

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1. General Information

1.1. Testing Laboratory

SGS Korea Co., Ltd. (Gunpo Laboratory)
- 10-2, LS-ro 182beon-gil, Gunpo-si, Gyeonggi-do, Korea, 15807
- 4, LS-ro 182beon-gil, Gunpo-si, Gyeonggi-do, Korea, 15807
- Designation number: KR0150

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1.2. Details of Applicant

Applicant : LG Electronics USA, Inc.
Address : 1000 Sylvan Ave, Englewood Cliffs, New Jersey, United States 07632
Contact Person : Han, Kyung-Su
Phone No. : +1 201 266 2215

1.3. Details of Manufacturer

Company : GoerTek
Address : No.268 Dongfang Road, Hegh-Tech Industry Development District, Weifang, Shandong, P.R.C

1.4. Description of EUT

Kind of Product	LG STEREO Headset
Model Name	HBS-AL4
Variant Model Name	HBS-PAL4
Power Supply	DC 3.7 V
Frequency Range	2 402 ㎒ ~ 2 480 ㎒ (Bluetooth)
Modulation Technique	GFSK, π/4DQPSK, 8DPSK
Number of Channels	79 channels (Bluetooth)
Antenna Type	FPC antenna
Antenna Gain	1.80 ㏈i

1.5. Test Equipment List

Equipment	Manufacturer	Model	S/N	Cal. Date	Cal. Interval	Cal. Due
Signal Generator	R&S	SMR40	100272	Jun. 12, 2018	Annual	Jun. 12, 2019
Signal Generator	R&S	SMBV100A	255834	Jun. 15, 2018	Annual	Jun. 15, 2019
Spectrum Analyzer	R&S	FSV30	103210	Dec. 05, 2018	Annual	Dec. 05, 2019
Spectrum Analyzer	Agilent	N9020A	MY53421758	Sep. 21, 2018	Annual	Sep. 21, 2019
Bluetooth Tester	TESCOM	TC-3000C	3000C000296	Jun. 12, 2018	Annual	Jun. 12, 2019
Directional Coupler	KRYTAR	152613	122660	Jun. 14, 2018	Annual	Jun. 14, 2019
High Pass Filter	Wainwright Instrument GmbH	WHK3.0/18G-10SS	344	May 21, 2019	Annual	May 21, 2020
High Pass Filter	Wainwright Instrument GmbH	WHNX7.5/26.5G-6SS	15	Jun. 11, 2018	Annual	Jun. 11, 2019
Low Pass Filter	Mini-Circuits	NLP-1200+	V 8979400903-2	Feb. 19, 2019	Annual	Feb. 19, 2020
Power Sensor	R&S	NRP-Z81	100748	Jun. 12, 2018	Annual	Jun. 12, 2019
DC Power Supply	R&S	HMP2020	019258024	Nov. 06, 2018	Annual	Nov. 06, 2019
Preamplifier	H.P.	8447F	2944A03909	Aug. 07, 2018	Annual	Aug. 07, 2019
Preamplifier	Agilent	8449B	3008A01932	Feb. 22, 2019	Annual	Feb. 22, 2020
Preamplifier	MITEQ Inc.	JS44-18004000-35-8P	1546891	May 13, 2019	Annual	May 13, 2020
Loop Antenna	Schwarzbeck Mess-Elektronik	FMZB 1519	1519-039	Aug. 23, 2017	Biennial	Aug. 23, 2019
Bilog Antenna	Schwarzbeck Mess-Elektronik	VULB 9163	01126	Mar. 26, 2018	Biennial	Mar. 26, 2020
Horn Antenna	R&S	HF906	100326	Feb. 14, 2018	Biennial	Feb. 14, 2020
Horn Antenna	Schwarzbeck Mess-Elektronik	BBHA 9170	BBHA9170431	Sep. 10, 2018	Biennial	Sep. 10, 2020
Test Receiver	R&S	ESU26	100109	Jan. 31, 2019	Annual	Jan. 31, 2020
Turn Table	Innco systems GmbH	DS 1200 S	N/A	N.C.R.	N/A	N.C.R.
Controller	Innco systems GmbH	CONTROLLER CO3000-4P	CO3000/963/383 30516/L	N.C.R.	N/A	N.C.R.
Antenna Mast	Innco systems GmbH	MA4640-XP-ET	MA4640/536/383 30516/L	N.C.R.	N/A	N.C.R.
Anechoic Chamber	SY Corporation	L × W × H (9.6 m × 6.4 m × 6.6 m)	N/A	N.C.R.	N/A	N.C.R.
Coaxial Cable	SUCOFLEX	104 (3 m)	MY3258414	Jan. 04, 2019	Semi-annual	Jul. 04, 2019
Coaxial Cable	SUCOFLEX	104 (10 m)	MY3145814	Jan. 04, 2019	Semi-annual	Jul. 04, 2019
Coaxial Cable	Rosenberger	LA1-C006-1500	131014 01/20	Feb. 28, 2019	Semi-annual	Aug. 28, 2019
Coaxial Cable	Rosenberger	LA1-C006-1500	131014 05/20	Feb. 28, 2019	Semi-annual	Aug. 28, 2019
Coaxial Cable	Rosenberger	LA1-C006-1500	131014 10/20	Feb. 28, 2019	Semi-annual	Aug. 28, 2019

1.6. Declaration by the Manufacturer

- Adaptive Frequency Hopping is supported and use at least 20 channels.

1.7. Information about the FHSS characteristics:

1.7.1. Pseudorandom Frequency Hopping Sequence

The channel is represented by a pseudo-random hopping sequence hopping through the 79 RF channels. The hopping sequence is unique for the piconet and is determined by the Bluetooth device address of the master; the phase in the hopping sequence is determined by the Bluetooth clock of the master. The channel is divided into time slots where each slot corresponds to an RF hop frequency. Consecutive hops correspond to different RF hop frequencies. The nominal hop rate is 1 600 hops/s.

1.7.2. Equal Hopping Frequency Use

The channels of this system will be used equally over the long-term distribution of the hopsets.

1.7.3. Example of a 79 hopping sequence in data mode:

02, 05, 31, 24, 20, 10, 43, 36, 30, 23, 40, 06, 21, 50, 44, 09, 71, 78, 01, 13, 73, 07, 70, 72, 35, 62, 42, 11, 41, 08, 16, 29, 60, 15, 34, 61, 58, 04, 67, 12, 22, 53, 57, 18, 27, 76, 39, 32, 17, 77, 52, 33, 56, 46, 37, 47, 64, 49, 45, 38, 69, 14, 51, 26, 79, 19, 28, 65, 75, 54, 48, 03, 25, 66, 05, 16, 68, 74, 59, 63, 55

1.7.4. System Receiver Input Bandwidth

Each channel bandwidth is 1 ㎒.
The system receivers have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shift frequencies in synchronization with the transmitted signals.

1.7.5. Equipment Description

15.247(a)(1) that the Rx input bandwidths shift frequencies in synchronization with the transmitted signals.

15.247(g): In accordance with the Bluetooth Industry Standard, the system is designed to comply with all of the regulations in Section 15.247 when the transmitter is presented with a continuous data (or information) system.

15.247(h): In accordance with the Bluetooth Industry Standard, the system does not coordinate it channels selection/ hopping sequence with other frequency hopping systems for the express purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters.

1.8. Summary of Test Results

The EUT has been tested according to the following specifications:

APPLIED STANDARD: FCC Part15 Subpart C		
Section	**Test Item**	**Result**
15.205(a) 15.209 15.247(d)	Transmitter Radiated Spurious Emissions and Conducted Spurious Emission	Complied
15.247(a)(1)	20 dB Bandwidth	Complied
15.247(b)(1)	Maximum Peak Conducted Output Power	Complied
15.247(a)(1)	Carrier Frequency Separation	Complied
15.247(a)(1)(iii)	Number of Hopping Frequencies	Complied
15.247(a)(1)(iii)	Time of Occupancy (Dwell Time)	Complied
15.207	AC Power Line Conducted Emission	N/A[1)]

Note;

1) The AC power line test was not performed because the EUT does not operate while charging.

1.9. Test Procedure(s)

The measurement procedures described in the American National Standard of Procedure for Compliance Testing of unlicensed Wireless Devices (ANSI C63.10-2013) and the guidance provided in KDB 558074 D01 15.247 Meas Guidance v05r02 were used in the measurement of the DUT.

1.10. Sample Calculation

Where relevant, the following sample calculation is provided:

1.10.1. Conducted Test

Offset value (dB) = Directional coupler (dB) + Cable loss (dB)

1.10.2. Radiation Test

Field strength level (dB㎶/m) = Measured level (dB㎶) + Antenna factor (dB) + Cable loss (dB) - Amplifier gain (dB)

1.11. Measurement Uncertainty

Where relevant, the following measurement uncertainty levels have been estimated for tests performed on the apparatus:

Parameter	Uncertainty (㏈)
RF Output Power	±0.40 ㏈
Conducted Spurious Emission	±0.76 ㏈
Power Spectral Density	±0.41 ㏈
Occupied Bandwidth	±**9.66** ㎑
Radiated Emission, 9 ㎑ to 30 ㎒	±**3**.59 ㏈
Radiated Emission, below 1 ㎓	±5.88 ㏈
Radiated Emission, above 1 ㎓	±5.94 ㏈

Uncertainty figures are valid to a confidence level of 95 %.

1.12. Test Report Revision

Revision	Report Number	Date of Issue	Description
0	F690501/RF-RTL013931	2019.06.10	Initial

1.13. Information of Variant Models

Model Name	Description
HBS-AL4	-Basic model
HBS-PAL4	-Same to basic mode, but variant model name is made for marketing purpose

1.14. Descriptions of Test Mode

Preliminary tests were performed in different data rates and recorded the RF output power in the following table:

Operation Mode	Data Rate (Mbps)	Channel	Frequency (㎒)	RF Output Power (㏈ m)
GFSK	1	Low	2 402	4.53
		Middle	2 441	**4.68**
		High	2 480	4.36
π/4DQPSK	2	Low	2 402	4.40
		Middle	2 441	**4.61**
		High	2 480	4.25
8DPSK	3	Low	2 402	4.45
		Middle	2 441	**4.62**
		High	2 480	4.27

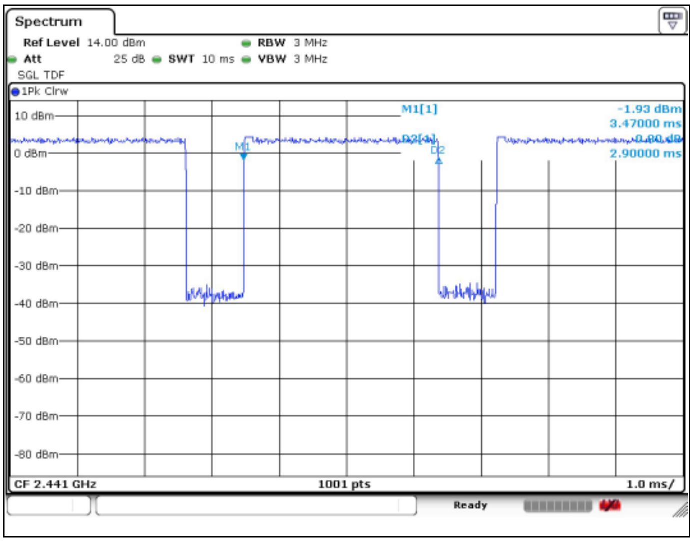
Note;

1. For transmitter radiated spurious emissions, conducted spurious emission, carrier frequency separation and number of hopping frequencies, GFSK / DH5 and 8DPSK / 3DH5 are tested as worst condition.
2. For 20 ㏈ bandwidth and maximum peak conducted output power, GFSK / DH5, π/4DQPSK / 2DH5 and 8DPSK / 3DH5 are tested as worst condition.
3. For Time of Occupancy, GFSK / DH1, DH3, DH5 and 8DPSK / 3DH1, 3DH3, 3DH5 are tested as worst condition.

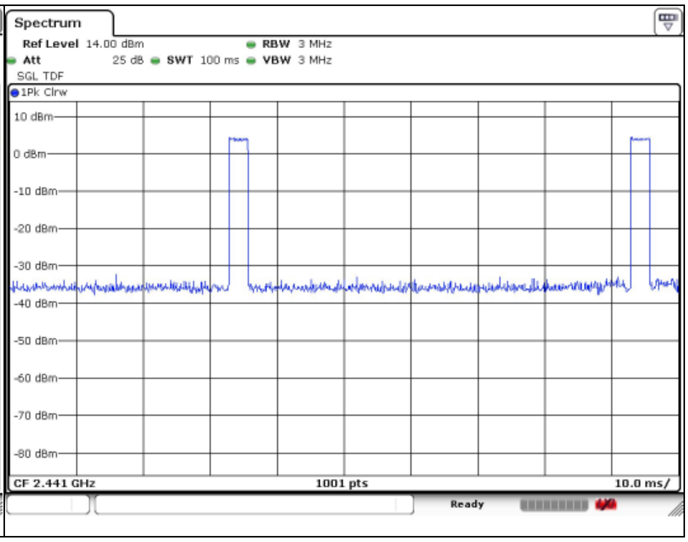
1.15. Duty Cycle Correction Factor of EUT

According to KDB 558074 D01 15.247 Meas Guidance v05r02, 9, as a “duty cycle correction factor”, pulse averaging with 20 log (worst case dwell time / 100 ㎳) has to be used for average result.

3DH5 on time (One Pulse) Plot on Channel 39



3DH5 on time (Count Pulses) Plot on Channel 39



In AFH mode, the minimum hopping frequencies are 20, to get the longest dwell time DH5 packet is observed;
the period to have 3DH5 packet completing one hopping sequence is 2.90 ㎳ x 20 channels = 58.00 ㎳

There cannot be 2 complete hopping sequences within 100 ㎳ period, considering the random hopping behavior, maximum 2 hops can be possibly observed within the period. [100 ㎳ / 58.00 ㎳] = 2 hops

Thus, the maximum possible ON time:

2.90 ㎳ x 2 = 5.80 ㎳

Worst case Duty Cycle Correction factor, which is derived from the maximum possible ON time:

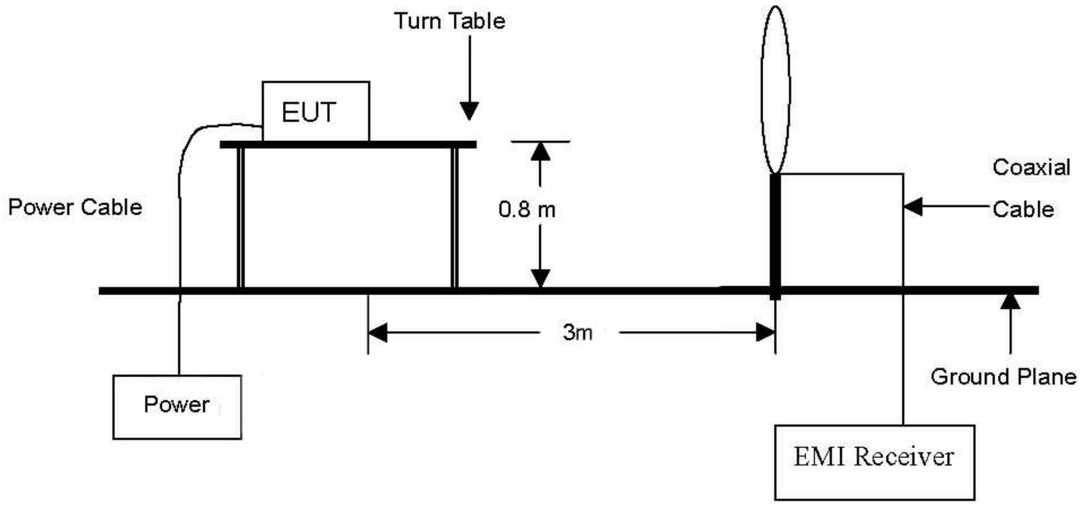
20 x log (5.80 ㎳ / 100 ㎳) = -24.73 ㏈

2. Transmitter Radiated Spurious Emissions and Conducted Spurious Emission

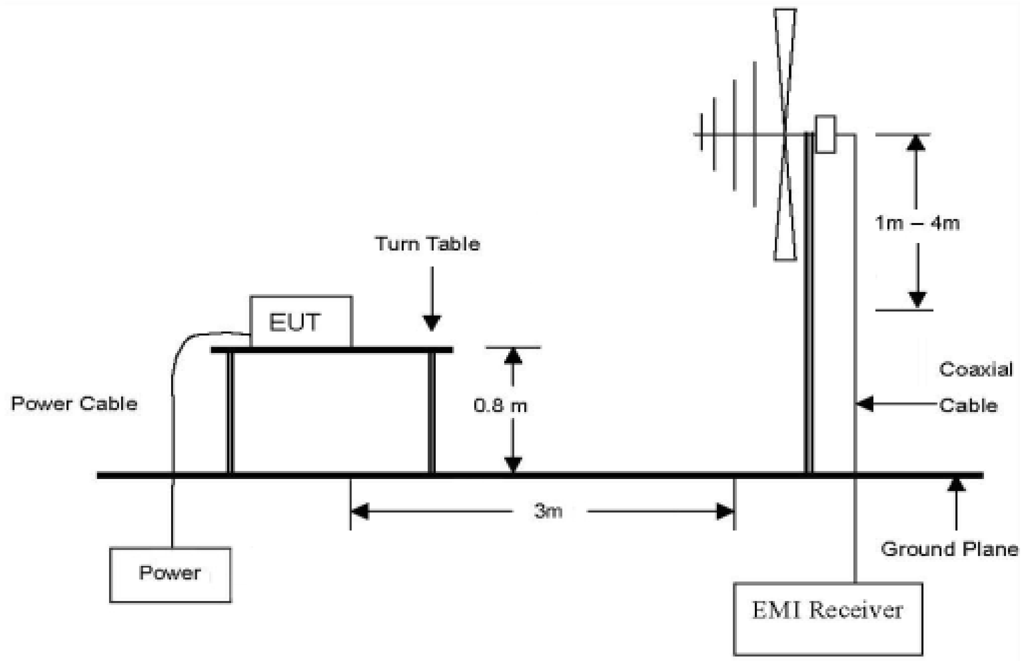
2.1. Test Setup

2.1.1. Transmitter Radiated Spurious Emissions

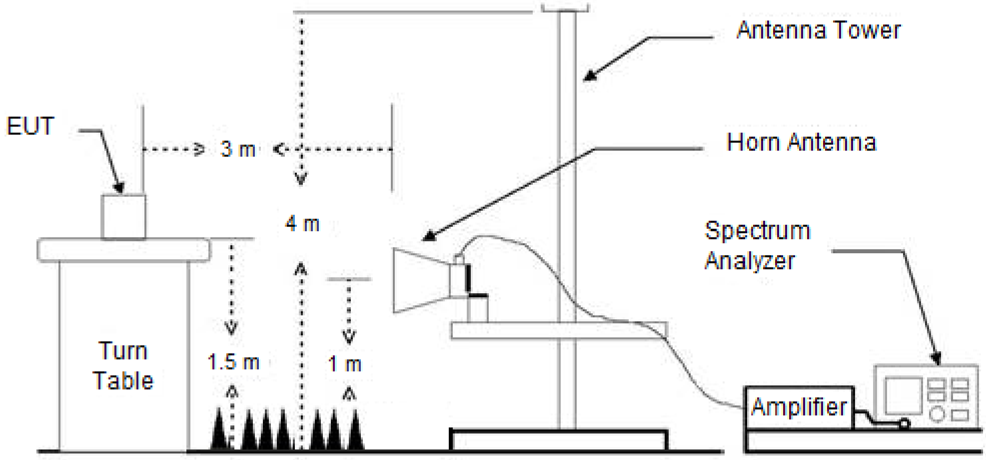
The diagram below shows the test setup that is utilized to make the measurements for emission from 9 ㎑ to 30 ㎒.



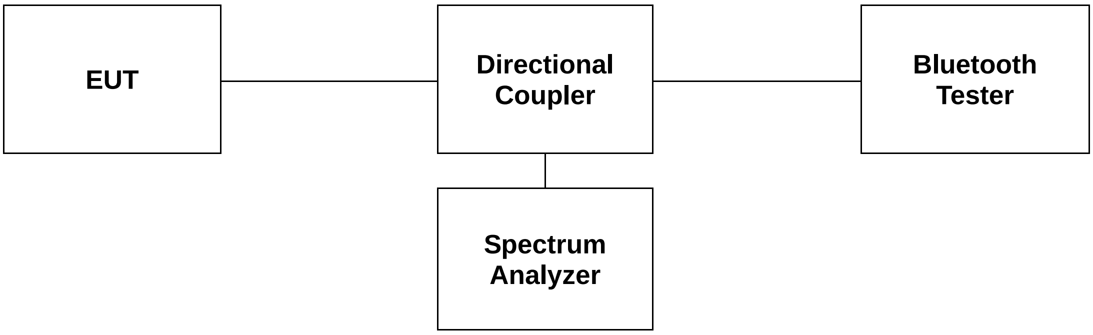
The diagram below shows the test setup that is utilized to make the measurements for emission from 30 ㎒ to 1 ㎓.



The diagram below shows the test setup that is utilized to make the measurements for emission. The spurious emissions were investigated form 1 ㎓ to the 10th harmonic of the highest fundamental frequency or 40 ㎓, whichever is lower.



2.1.2. Conducted Spurious Emissions



2.2. Limit

According to §15.247(d), in any 100 ㎑ 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 ㏈ below that in the 100 ㎑ 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 ㏈ instead of 20 ㏈. Attenuation below the general limits specified in section §15.209(a) is not required. In addition, radiated emission which fall in the restricted bands, as defined in section §15.205(a), must also comply with the radiated emission limits specified in section §15.209(a) (see §15.205(c)).

According to §15.209(a), except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

Frequency (㎒)	Field Strength (㎶/m)	Measurement Distance (Meters)
0.009-0.490	2 400/F(㎑)	300
0.490-1.705	24 000/F(㎑)	30
1.705-30.0	30	30
30-88	100**	3
88-216	150**	3
216-960	200**	3
Above 960	500	3

** Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this section shall not be located in the frequency bands 54-72 ㎒, 76-88 ㎒, 174-216 ㎒ or 470-806 ㎒. However, operation within these frequency bands is permitted under other sections of this part, e.g., §§15.231 and 15.241.

2.3. Test Procedures

Radiated emissions from the EUT were measured according to the dictates of ANSI C63.10-2013.

2.3.1. Test Procedures for emission below 30 ㎒

1. The EUT was placed on the top of a rotating table 0.8 meters above the ground at a 3 meter anechoic chamber test site. The table was rotated 360 degrees to determine the position of the highest radiation.
2. Then antenna is a loop antenna is fixed at one meter above the ground to determine the maximum value of the field strength. Both parallel and perpendicular of the antenna are set to make the measurement.
3. For each suspected emission, the EUT was arranged to its worst case and then the table was turned from 0 degrees to 360 degrees to find the maximum reading.
4. The test-receiver system was set to average or quasi peak detect function and Specified Bandwidth with Maximum Hold Mode.

2.3.2. Test Procedures for emission from above 30 ㎒

1. The EUT was placed on the top of a rotating table 0.8 meters above the ground at a 3 meter anechoic chamber test site below 1 ㎓ and 1.5 meter above the ground at a 3 meter anechoic chamber test site above 1 ㎓. The table was rotated 360 degrees to determine the position of the highest radiation.
2. During performing radiated emission below 1 ㎓, the EUT was set 3 meters away from the interference receiving antenna, which was mounted on the top of a variable-height antenna tower. During performing radiated emission above 1 ㎓, the EUT was set 3 meter away from the interference-receiving antenna.
3. The antenna is a bi-log antenna, a horn antenna and its height is varied from one meter to four meters above the ground to determine the maximum value of the field strength. Both horizontal and vertical polarizations of the antenna are set to make the measurement.
4. For each suspected emission, the EUT was arranged to its worst case and then the antenna was tuned to heights from 1 meter to 4 meters and the table was turned from 0 degrees to 360 degrees to find the maximum reading.
5. The test-receiver system was set to Peak Detect Function and Specified Bandwidth with Maximum Hold Mode.
6. If the emission level of the EUT in peak mode was 10 ㏈ lower than the limit specified, then testing could be stopped and the peak values of the EUT would be reported. Otherwise the emissions that did not have 10 ㏈ margin would be re-tested one by one using peak, quasi-peak or average method as specified and then reported in a data sheet.

Note;

1. The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 120 ㎑ for Peak detection (PK) and Quasi-peak detection (QP) at frequency below 1 ㎓.
2. For frequency above 1 ㎓, set spectrum analyzer detector to peak, and resolution bandwidth is 1 ㎒ and video bandwidth is 3 ㎒.
3. Definition of DUT Axis.
   Definition of the test orthogonal plan for EUT was described in the test setup photo.
   The test orthogonal plan of EUT is **Z – axis** during radiation test.

2.3.3. Test Procedures for Conducted Spurious Emissions

2.3.3.1. Band-edge Compliance of RF Conducted Emissions

The transmitter output was connected to the spectrum analyzer.
Span = wide enough to capture the peak level of the emission operating on the channel closest to the band edge, as well as any modulation products which fall outside of the authorized band of operation.
RBW ≥ 100 ㎑
VBW = 300 ㎑
Sweep = auto
Detector function = peak
Trace = max hold

2.3.3.2. Spurious RF Conducted Emissions

The transmitter output was connected to the spectrum analyzer.
RBW = 1 ㎒
VBW = 3 ㎒
Sweep = auto
Detector function = peak
Trace = max hold

2.3.3.3. TDF function

- For plots showing conducted spurious emissions from 9 ㎑ to 25 ㎓, all path loss of wide frequency range was investigated and compensated to spectrum analyzer as TDF function.
So, the reading values shown in plots were final result.

2.4. Test Results

Ambient temperature : (23 ± 1) ℃

Relative humidity : 47 % R.H.

2.4.1. Radiated Spurious Emission below 1 000 ㎒

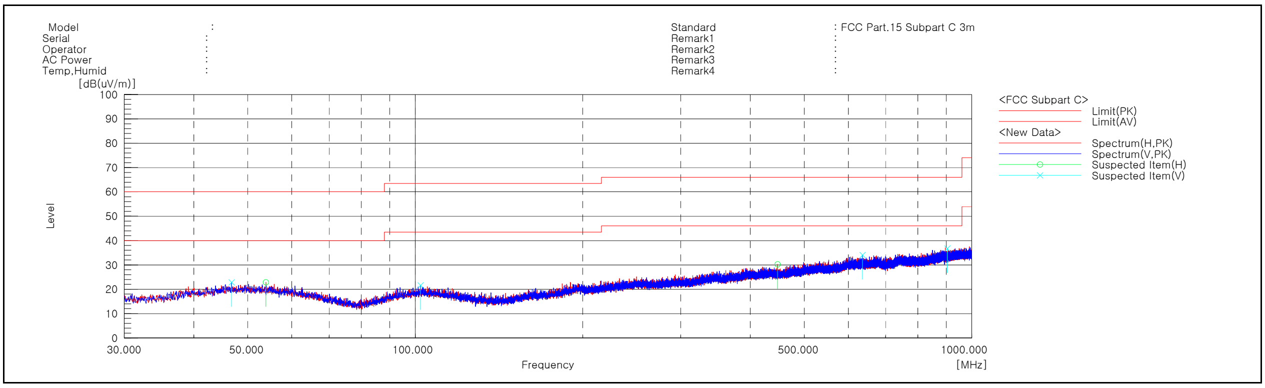
The frequency spectrum from 9 ㎑ to 1 000 ㎒ was investigated. All reading values are peak values.

Radiated Emissions			Ant.	Correction Factors		Total	Limit	
Frequency (㎒)	Reading (dB㎶)	Detect Mode	Pol.	AF (dB/m)	AMP + CL (dB)	Actual (dB㎶/m)	Limit (dB㎶/m)	Margin (dB)
46.77	29.50	Peak	V	20.60	-26.53	23.57	40.00	16.43
53.89	29.70	Peak	H	19.62	-26.37	22.95	40.00	17.05
447.67	31.20	Peak	H	22.00	-23.06	30.14	46.00	15.86
635.89	31.20	Peak	V	25.12	-22.00	34.32	46.00	11.68
903.65	30.80	Peak	V	28.17	-22.01	36.96	46.00	9.04

Remark;

1. Spurious emissions for all channels and modes were investigated and almost the same below 1 ㎓.
2. Reported spurious emissions are in **BDR / DH5 / Middle channel** as worst case among other modes.
3. Radiated spurious emission measurement as below.
   (Actual = Reading + AF + AMP + CL)
4. According to §15.31(o), emission levels are not report much lower than the limits by over 20 ㏈.

- Test plot



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2.4.2. Radiated Spurious Emission above 1 000 ㎒

The frequency spectrum above 1 000 ㎒ was investigated. All reading values are peak values.

Operating Mode: GFSK (1 Mbps)

A. Low Channel (2 402 ㎒)

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (㎒)	Reading (dB㎶)	Detect Mode	Pol.	AF (dB/m)	CL (dB)	DF (dB)	Actual (dB㎶/m)	Limit (dB㎶/m)	Margin (dB)
*2 310.00	25.74	Peak	V	28.54	10.56	-	64.84	74.00	9.16
*2 310.00	-	-	-	-	-	-24.73	40.11	54.00	13.89
*2 362.19	27.21	Peak	V	28.77	10.61	-	66.59	74.00	7.41
*2 362.19	-	-	-	-	-	-24.73	41.86	54.00	12.14
*2 390.00	24.97	Peak	V	28.94	10.65	-	64.56	74.00	9.44
*2 390.00	-	-	-	-	-	-24.73	39.83	54.00	14.17

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (㎒)	Reading (dB㎶)	Detect Mode	Pol.	AF (dB/m)	AMP+CL (dB)	DF (dB)	Actual (dB㎶/m)	Limit (dB㎶/m)	Margin (dB)
Above 1 000.00	Not detected	-	-	-	-	-	-	-	-

B. Middle Channel (2 441 ㎒)

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (㎒)	Reading (dB㎶)	Detect Mode	Pol.	AF (dB/m)	AMP+CL (dB)	DF (dB)	Actual (dB㎶/m)	Limit (dB㎶/m)	Margin (dB)
Above 1 000.00	Not detected	-	-	-	-	-	-	-	-

C. High Channel (2 480 ㎒)

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (㎒)	Reading (dB㎶)	Detect Mode	Pol.	AF (dB/m)	CL (dB)	DF (dB)	Actual (dB㎶/m)	Limit (dB㎶/m)	Margin (dB)
*2 483.50	27.21	Peak	V	29.17	10.74	-	67.12	74.00	6.88
*2 483.50	-	-	-	-	-	-24.73	42.39	54.00	11.61
*2 484.26	27.61	Peak	V	29.17	10.74	-	67.52	74.00	6.48
*2 484.26	-	-	-	-	-	-24.73	42.79	54.00	11.21
*2 500.00	26.42	Peak	V	29.20	10.75	-	66.37	74.00	7.63
*2 500.00	-	-	-	-	-	-24.73	41.64	54.00	12.36

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (㎒)	Reading (dB㎶)	Detect Mode	Pol.	AF (dB/m)	AMP+CL (dB)	DF (dB)	Actual (dB㎶/m)	Limit (dB㎶/m)	Margin (dB)
Above 1 000.00	Not detected	-	-	-	-	-	-	-	-

Operating Mode: 8DPSK (3 Mbps)

A. Low Channel (2 402 ㎒)

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (㎒)	Reading (dB㎶)	Detect Mode	Pol.	AF (dB/m)	CL (dB)	DF (dB)	Actual (dB㎶/m)	Limit (dB㎶/m)	Margin (dB)
*2 310.00	24.43	Peak	V	28.54	10.56	-	63.53	74.00	10.47
*2 310.00	-	-	-	-	-	-24.73	38.80	54.00	15.20
*2 369.16	26.93	Peak	V	28.81	10.62	-	66.36	74.00	7.64
*2 369.16	-	-	-	-	-	-24.73	41.63	54.00	12.37
*2 390.00	24.93	Peak	V	28.94	10.65	-	64.52	74.00	9.48
*2 390.00	-	-	-	-	-	-24.73	39.79	54.00	14.21

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (㎒)	Reading (dB㎶)	Detect Mode	Pol.	AF (dB/m)	AMP+CL (dB)	DF (dB)	Actual (dB㎶/m)	Limit (dB㎶/m)	Margin (dB)
Above 1 000.00	Not detected	-	-	-	-	-	-	-	-

B. Middle Channel (2 441 ㎒)

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (㎒)	Reading (dB㎶)	Detect Mode	Pol.	AF (dB/m)	AMP+CL (dB)	DF (dB)	Actual (dB㎶/m)	Limit (dB㎶/m)	Margin (dB)
Above 1 000.00	Not detected	-	-	-	-	-	-	-	-

C. High Channel (2 480 ㎒)

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (㎒)	Reading (dB㎶)	Detect Mode	Pol.	AF (dB/m)	CL (dB)	DF (dB)	Actual (dB㎶/m)	Limit (dB㎶/m)	Margin (dB)
*2 483.50	25.68	Peak	V	29.17	10.74	-	65.59	74.00	8.41
*2 483.50	-	-	-	-	-	-24.73	40.86	54.00	13.14
*2 498.05	27.85	Peak	V	29.20	10.75	-	67.80	74.00	6.20
*2 498.05	-	-	-	-	-	-24.73	43.07	54.00	10.93
*2 500.00	25.91	Peak	V	29.20	10.75	-	65.86	74.00	8.14
*2 500.00	-	-	-	-	-	-24.73	41.13	54.00	12.87

Radiated Emissions			Ant.	Correction Factors			Total	Limit	
Frequency (㎒)	Reading (dB㎶)	Detect Mode	Pol.	AF (dB/m)	AMP+CL (dB)	DF (dB)	Actual (dB㎶/m)	Limit (dB㎶/m)	Margin (dB)
Above 1 000.00	Not detected	-	-	-	-	-	-	-	-

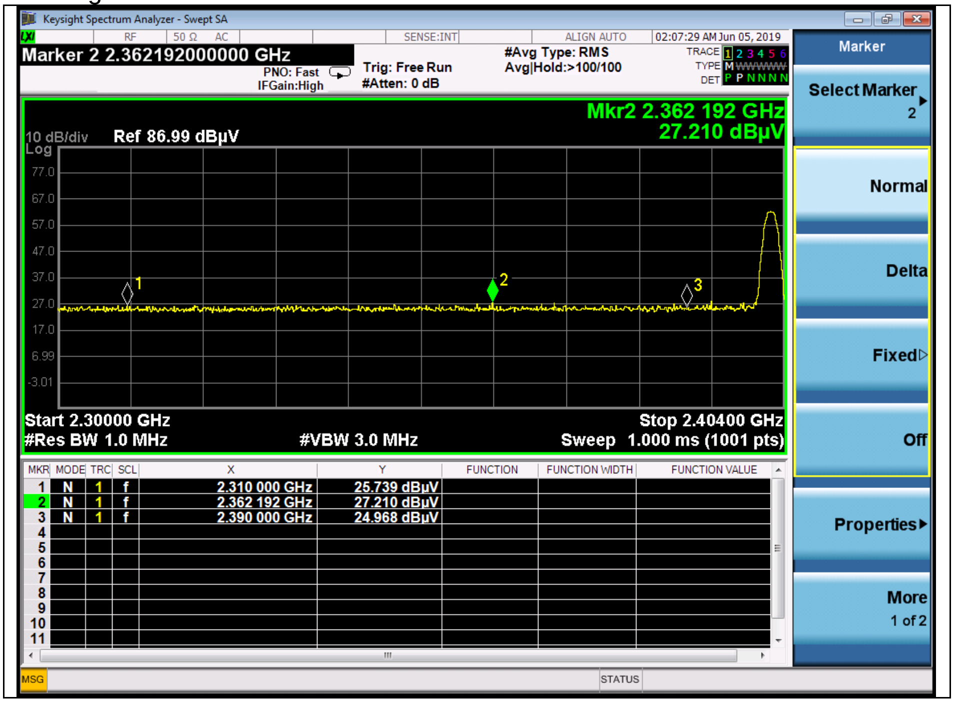
Remark;

1. "*" means the restricted band.
2. Measuring frequencies from 1 ㎓ to the 10th harmonic of highest fundamental frequency.
3. Radiated emissions measured in frequency above 1 000 ㎒ were made with an instrument using peak/average detector mode.
4. Actual = Reading + AF + CL + (DF) or Reading + AF + AMP + CL + (DF).
5. According to § 15.31(o), emission levels are not reported much lower than the limits by over 20 ㏈.
6. The maximized peak measured value complies with the average limit, to perform an average measurement is unnecessary.

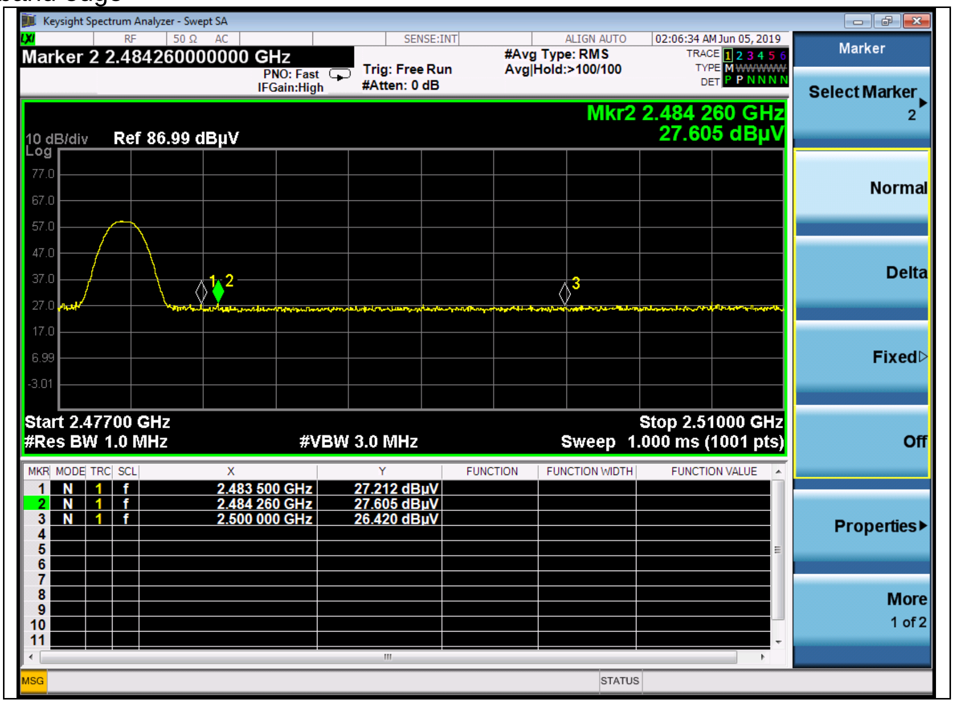
- Test plots

Operating Mode: GFSK (1 Mbps)

Low channel band edge

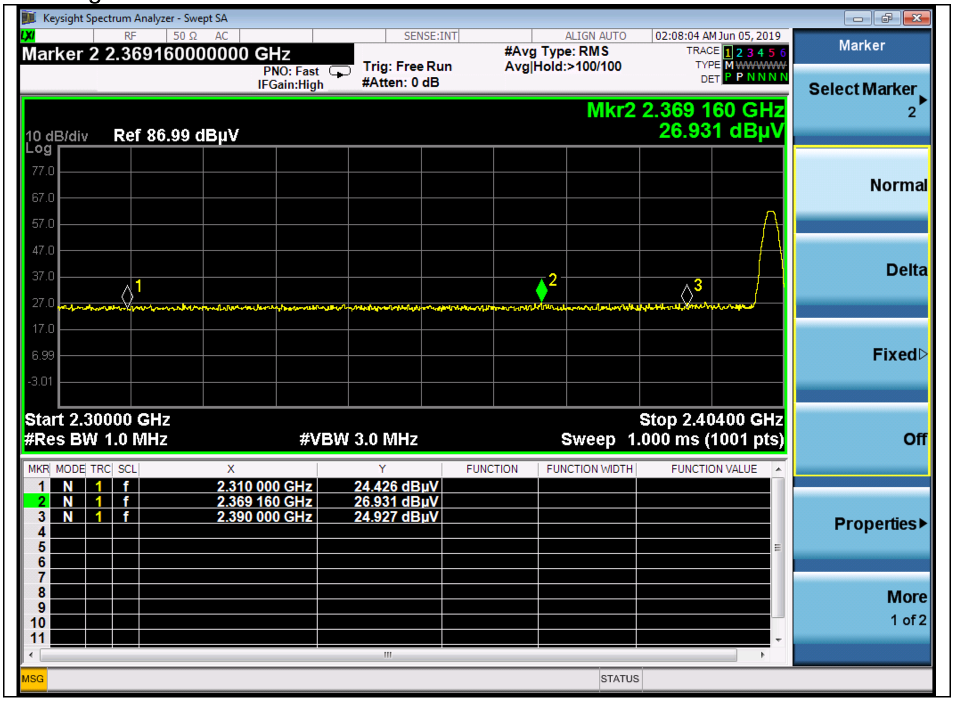


High channel band edge

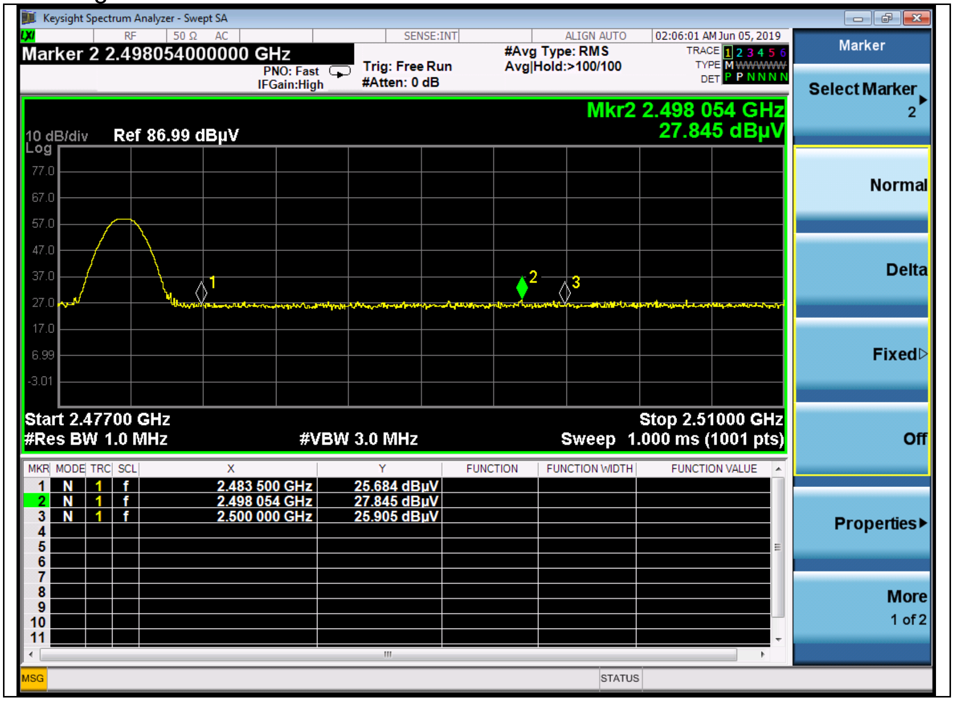


Operating Mode: 8DPSK (3 Mbps)

Low channel band edge



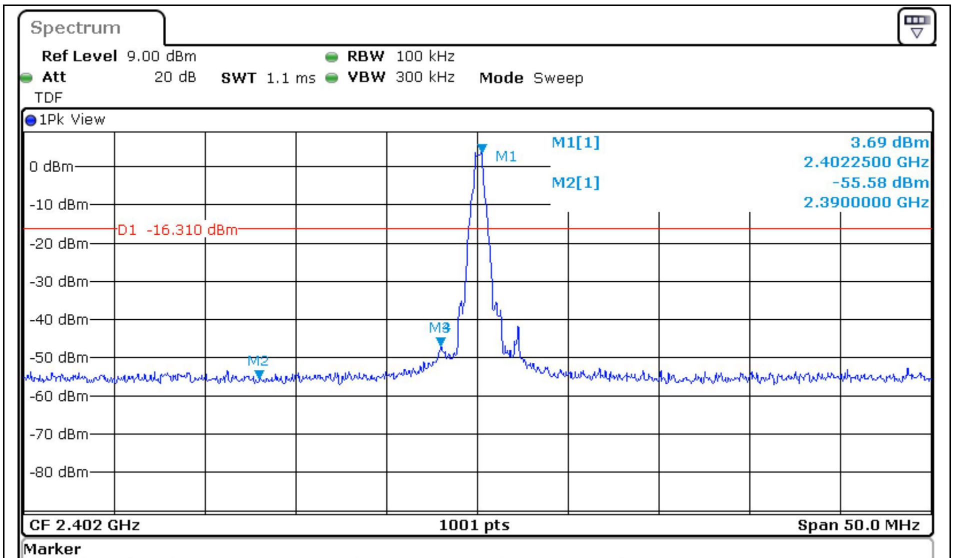
High channel band edge



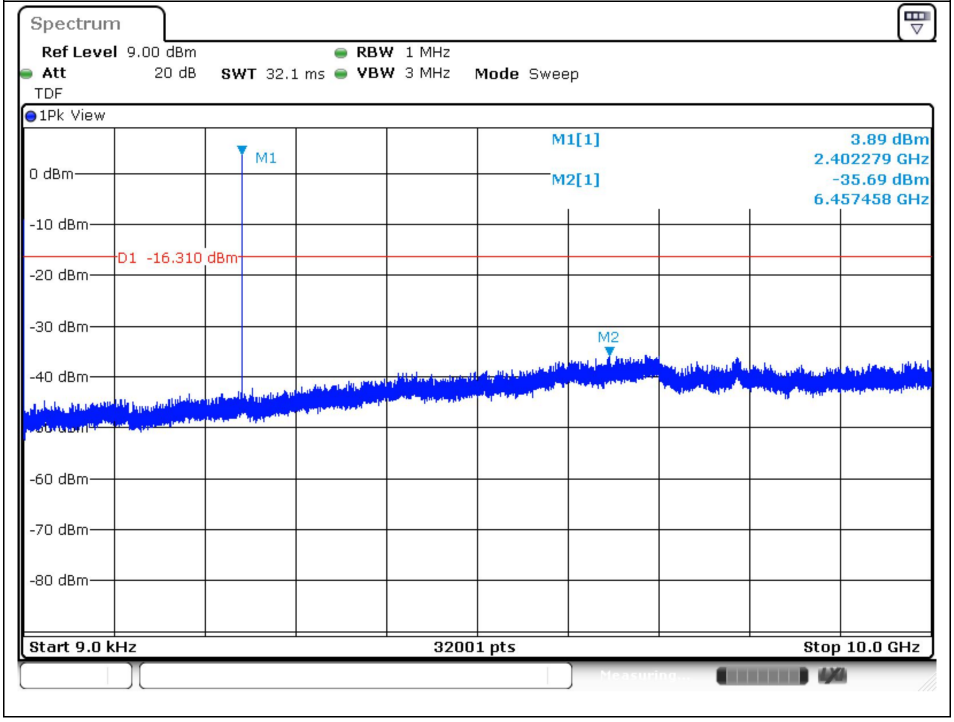
2.4.3. Spurious RF Conducted Emissions

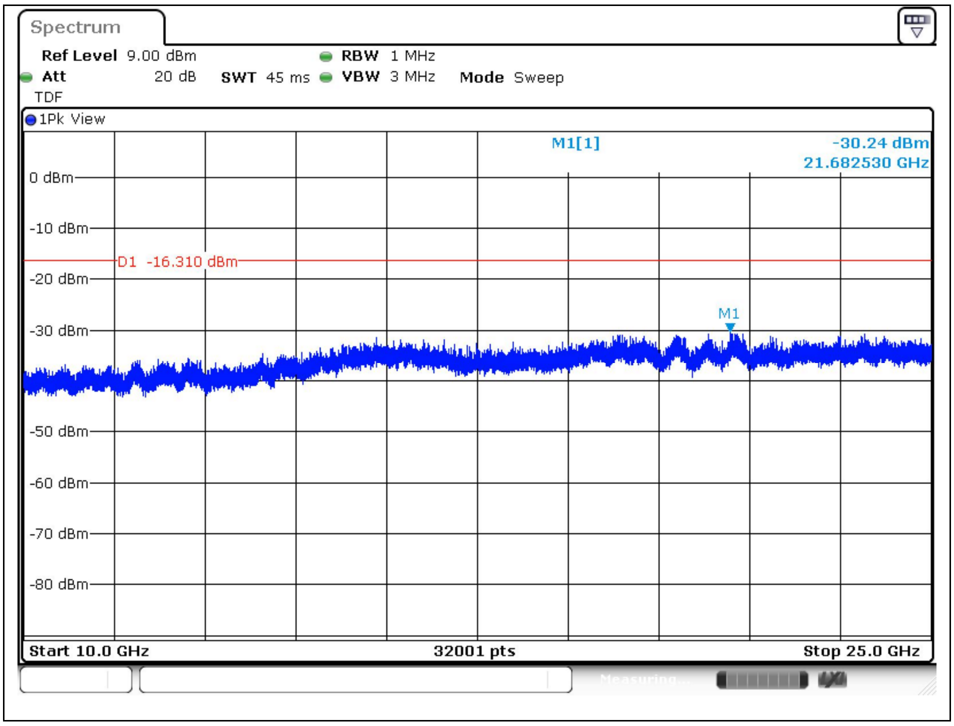
Operating Mode: GFSK (1 Mbps)

Low channel

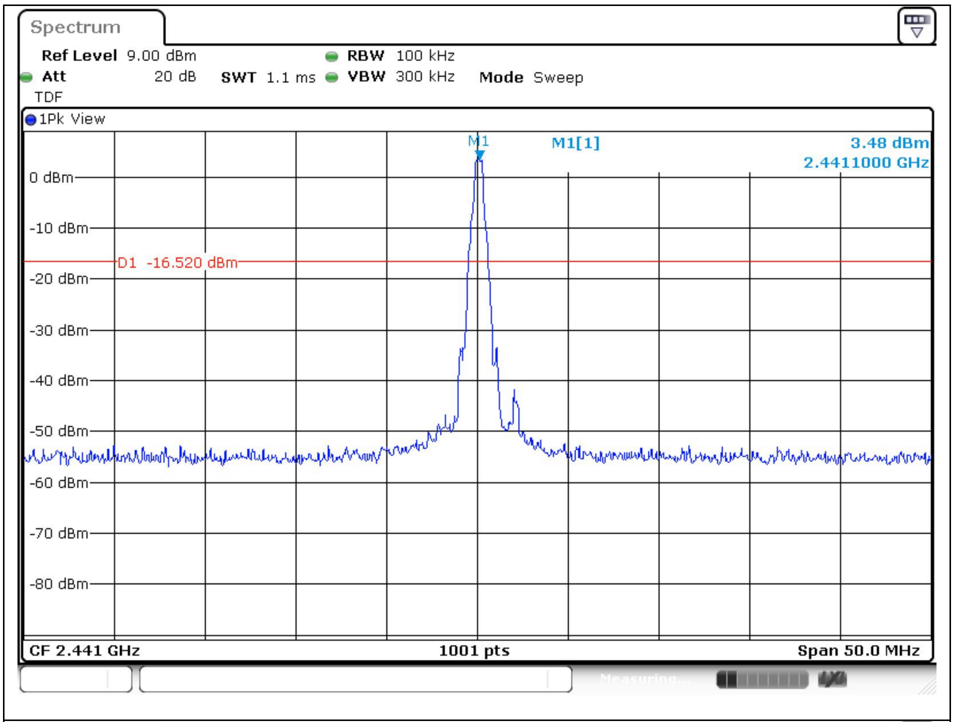


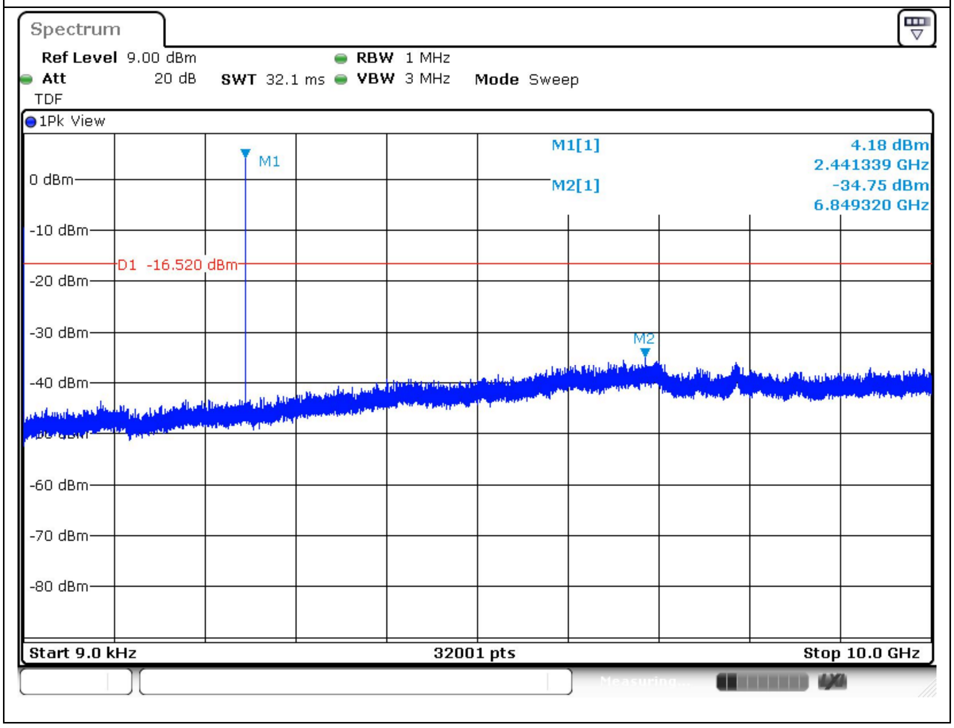
Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	2.40225 GHz	3.69 dBm		
M2		1	2.39 GHz	-55.58 dBm		
M3		1	2.399952 GHz	-46.75 dBm		
M4		1	2.4 GHz	-46.74 dBm		

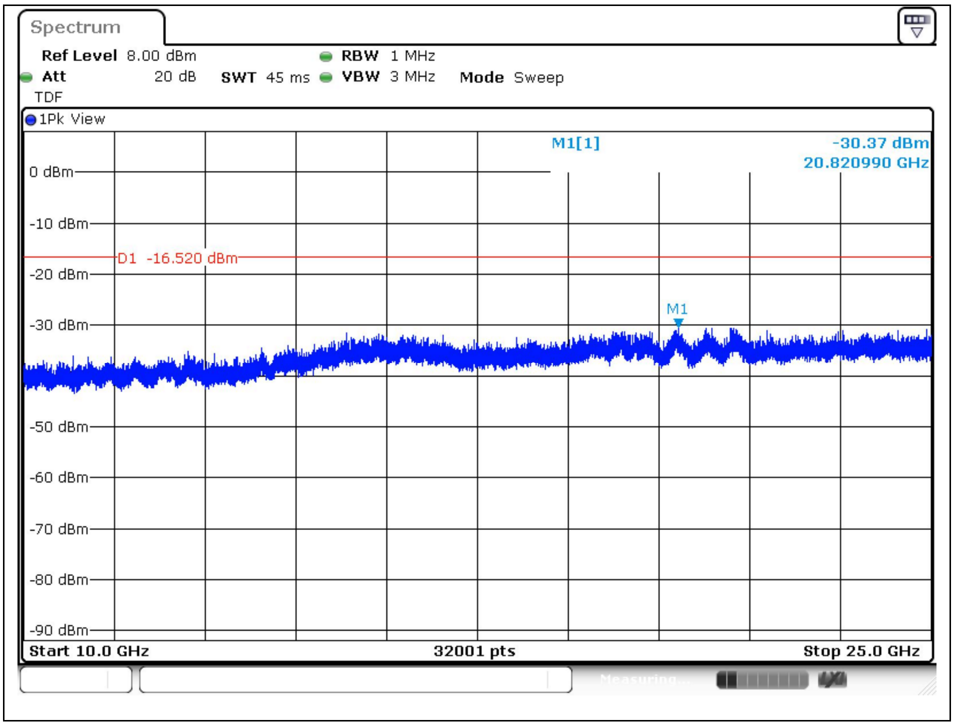



Spectrum
Ref Level 9.00 dBm
Att 20 dB
SWT 45 ms
RBW 1 MHz
VBW 3 MHz
Mode Sweep
TDF
1Pk View
M1[1]
-30.24 dBm
21.682530 GHz
0 dBm
-10 dBm
D1 -16.310 dBm
-20 dBm
-30 dBm
M1
-50 dBm
-60 dBm
-70 dBm
-80 dBm
Start 10.0 GHz
32001 pts
Stop 25.0 GHz

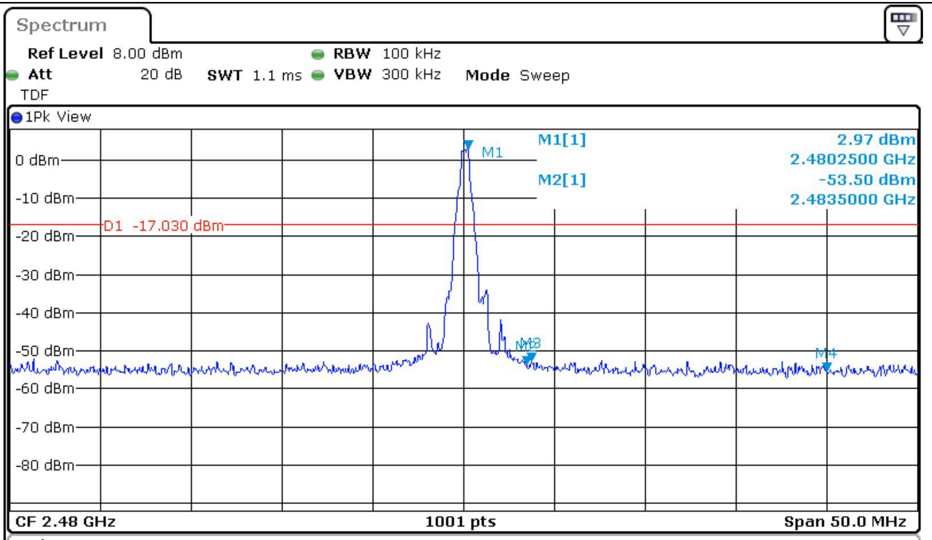
Middle channel





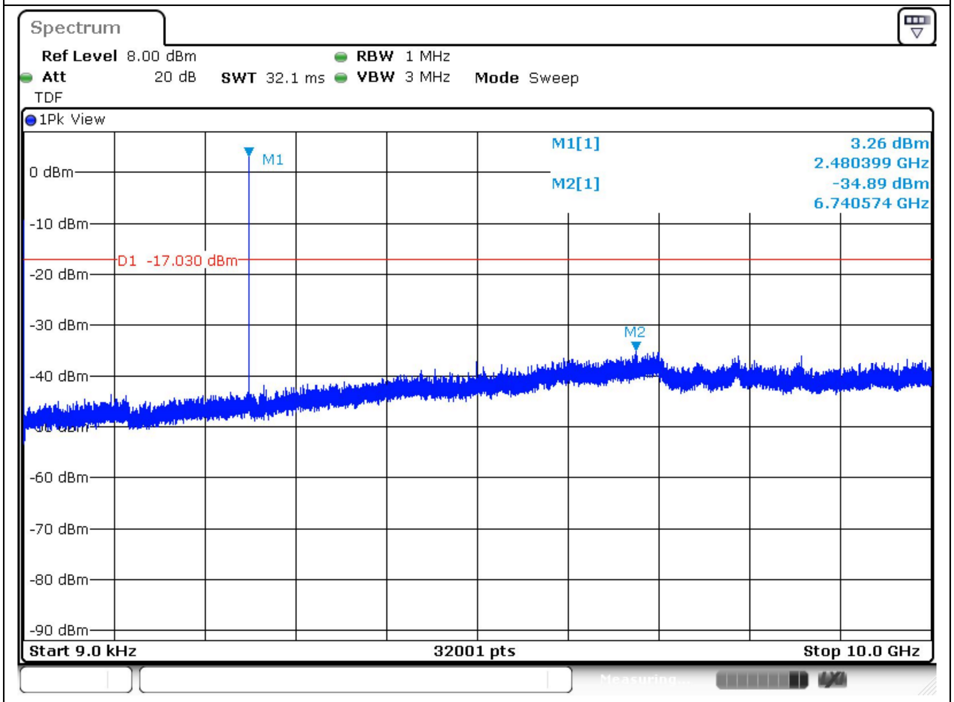

Spectrum
Ref Level 8.00 dBm
Att 20 dB
SWT 45 ms
RBW 1 MHz
VBW 3 MHz
Mode Sweep
TDF
1Pk View
M1[1]
-30.37 dBm
20.820990 GHz
0 dBm
-10 dBm
D1 -16.520 dBm
-20 dBm
-30 dBm
M1
-50 dBm
-60 dBm
-70 dBm
-80 dBm
-90 dBm
Start 10.0 GHz
32001 pts
Stop 25.0 GHz

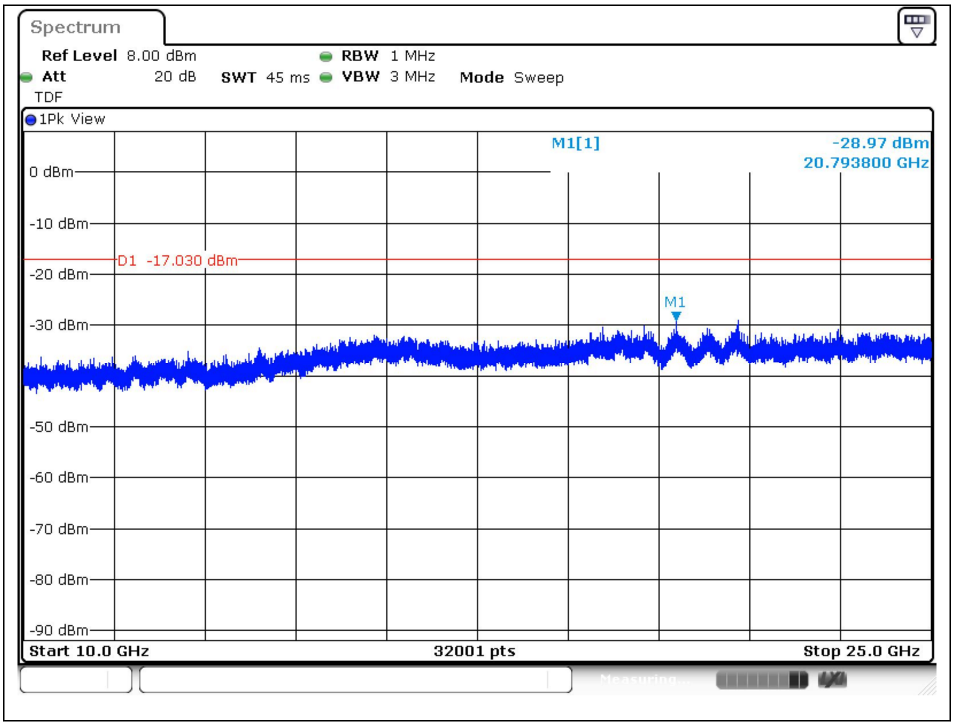
High channel



Marker

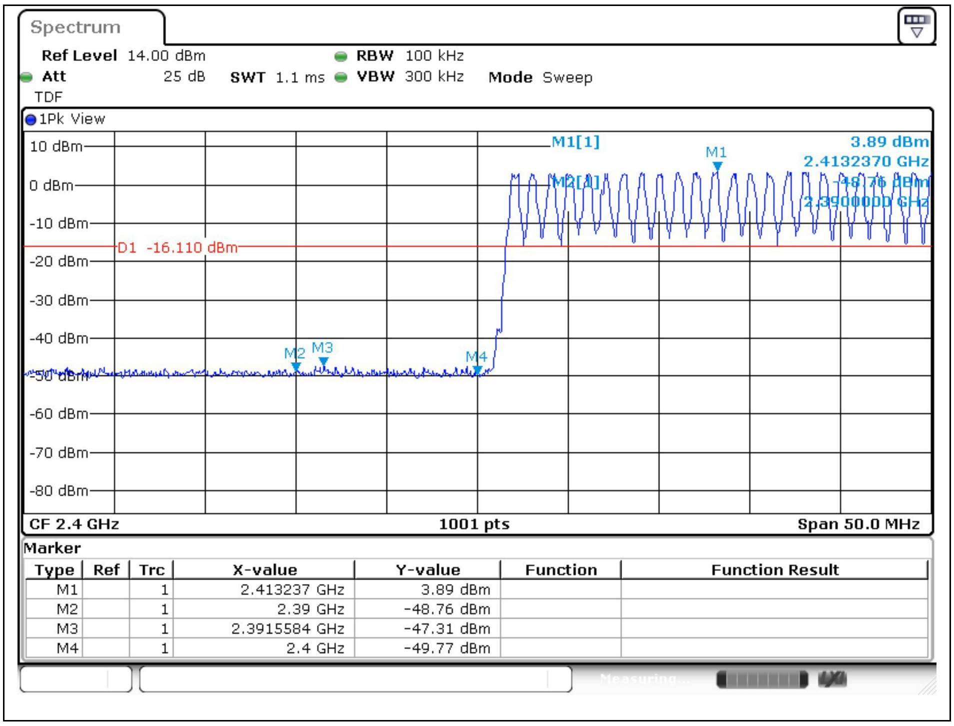
Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	2.48025 GHz	2.97 dBm		
M2		1	2.4835 GHz	-53.50 dBm		
M3		1	2.4837463 GHz	-52.76 dBm		
M4		1	2.5 GHz	-55.44 dBm		



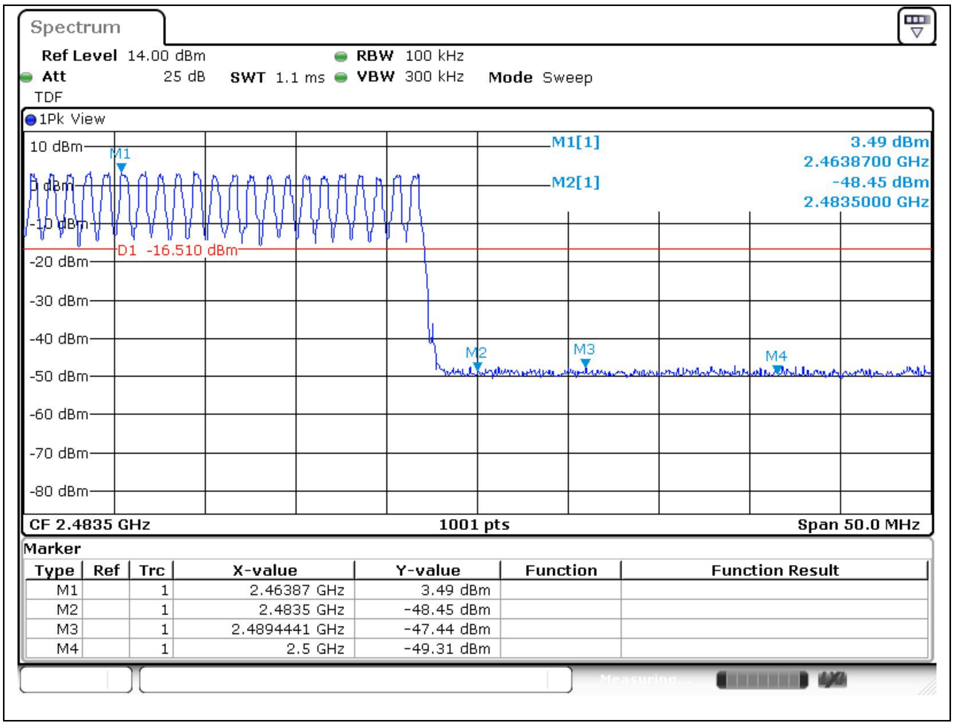

Spectrum
Ref Level 8.00 dBm
Att 20 dB
SWT 45 ms
RBW 1 MHz
VBW 3 MHz
Mode Sweep
TDF
1Pk View
M1[1]
-28.97 dBm
20.793800 GHz
0 dBm
-10 dBm
-20 dBm
-30 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
-90 dBm
D1 -17.030 dBm
M1
Start 10.0 GHz
32001 pts
Stop 25.0 GHz

Band edge compliance with hopping enabled

Low channel

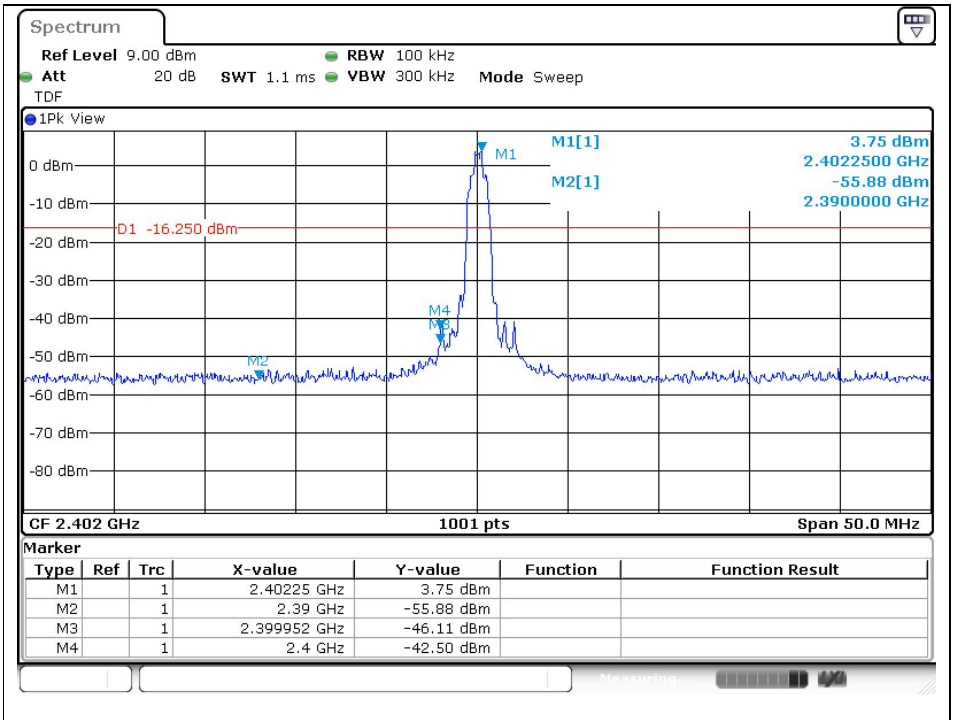


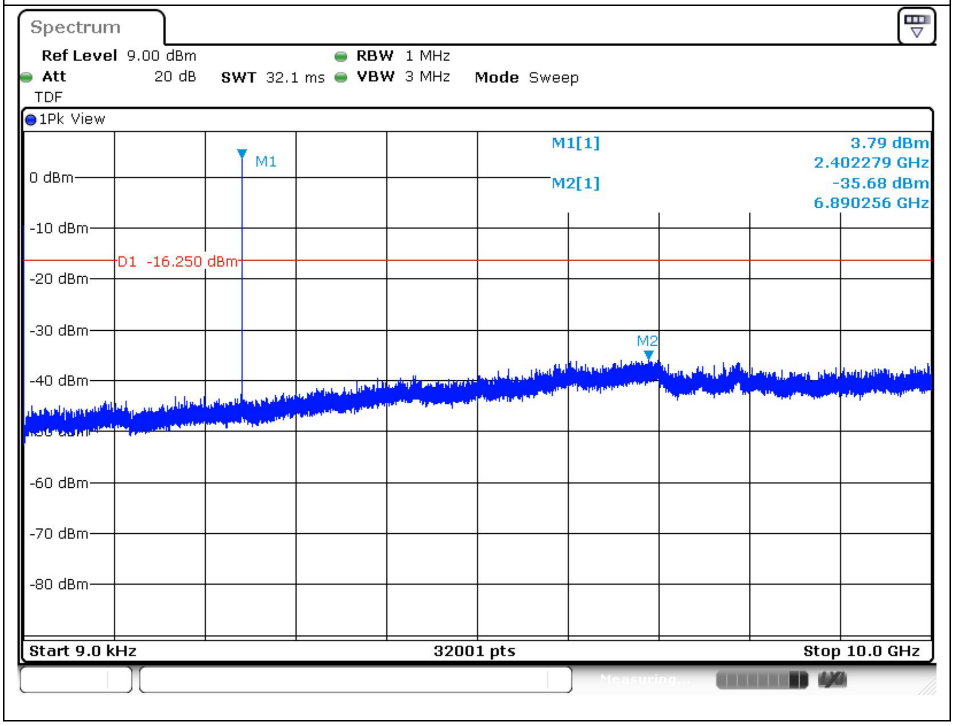
High channel

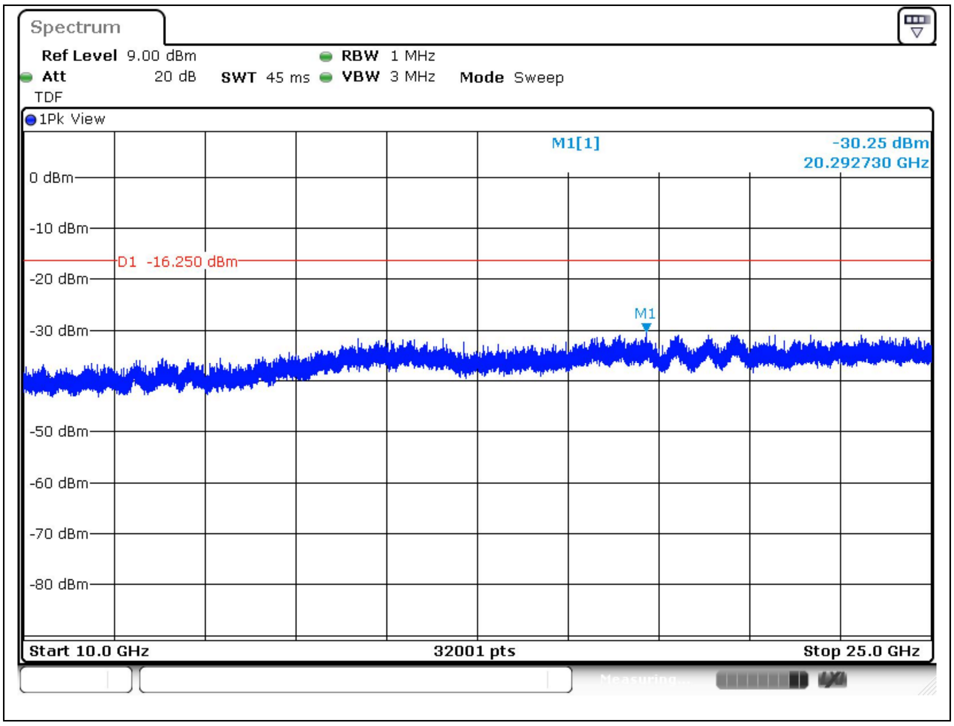


Operating Mode: 8DPSK (3 Mbps)

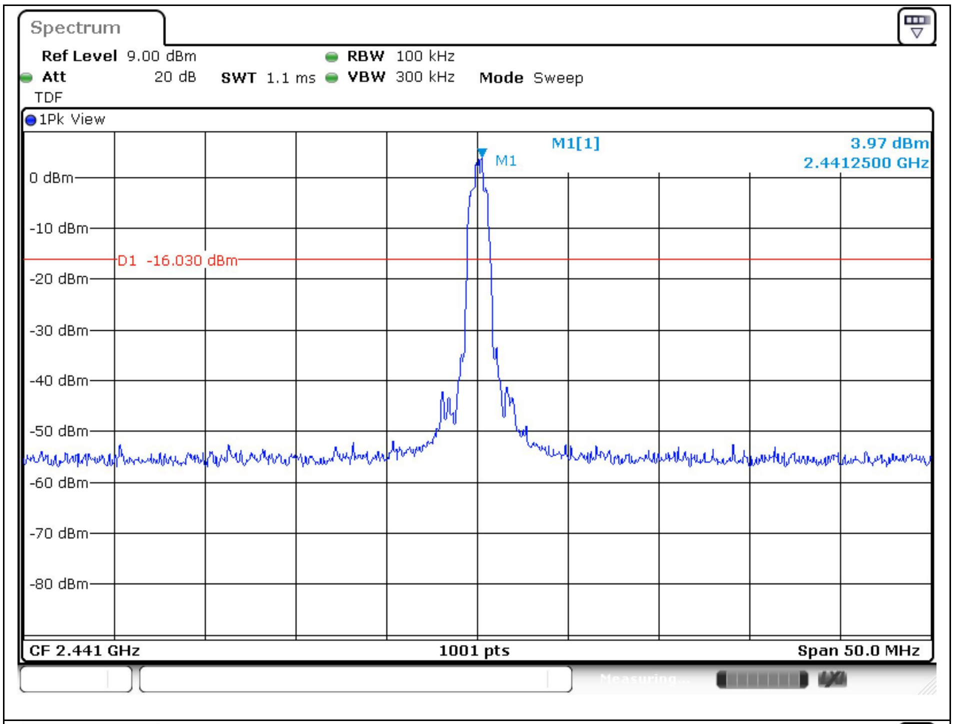
Low channel

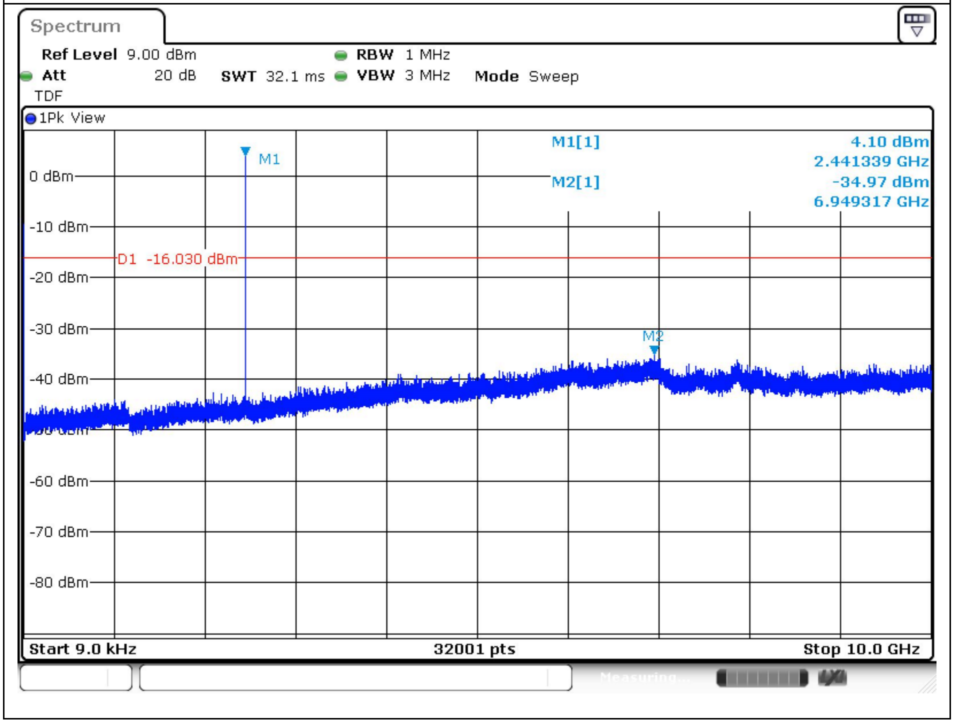


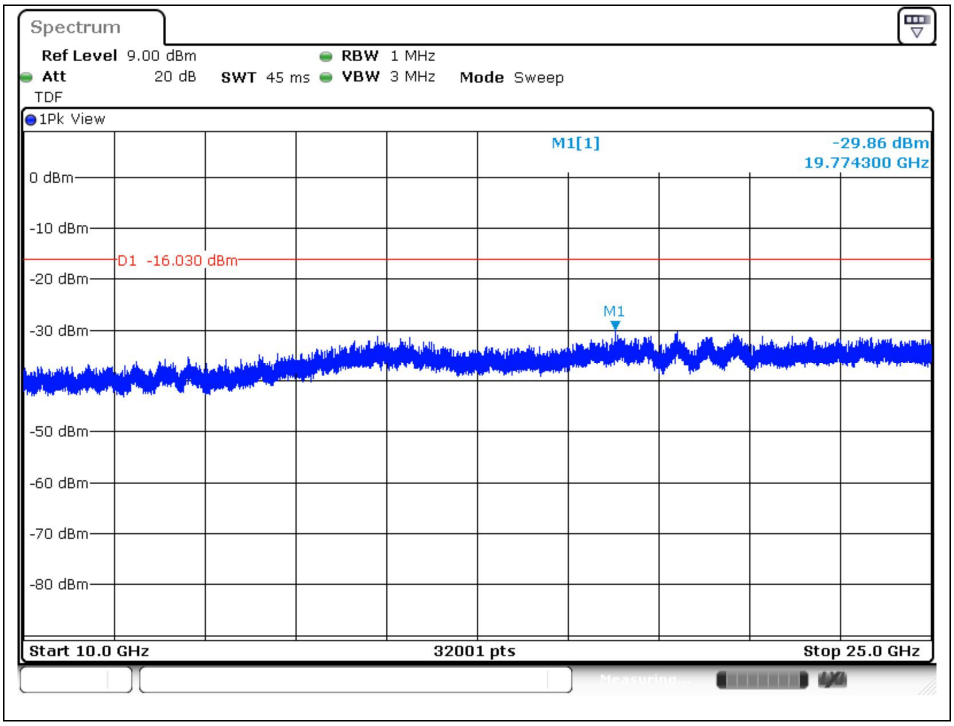



Spectrum
Ref Level 9.00 dBm
RBW 1 MHz
Att 20 dB
SWT 45 ms
VBW 3 MHz
Mode Sweep
TDF
1Pk View
M1[1]
-30.25 dBm
20.292730 GHz
0 dBm
-10 dBm
D1 -16.250 dBm
-20 dBm
-30 dBm
M1
-50 dBm
-60 dBm
-70 dBm
-80 dBm
Start 10.0 GHz
32001 pts
Stop 25.0 GHz

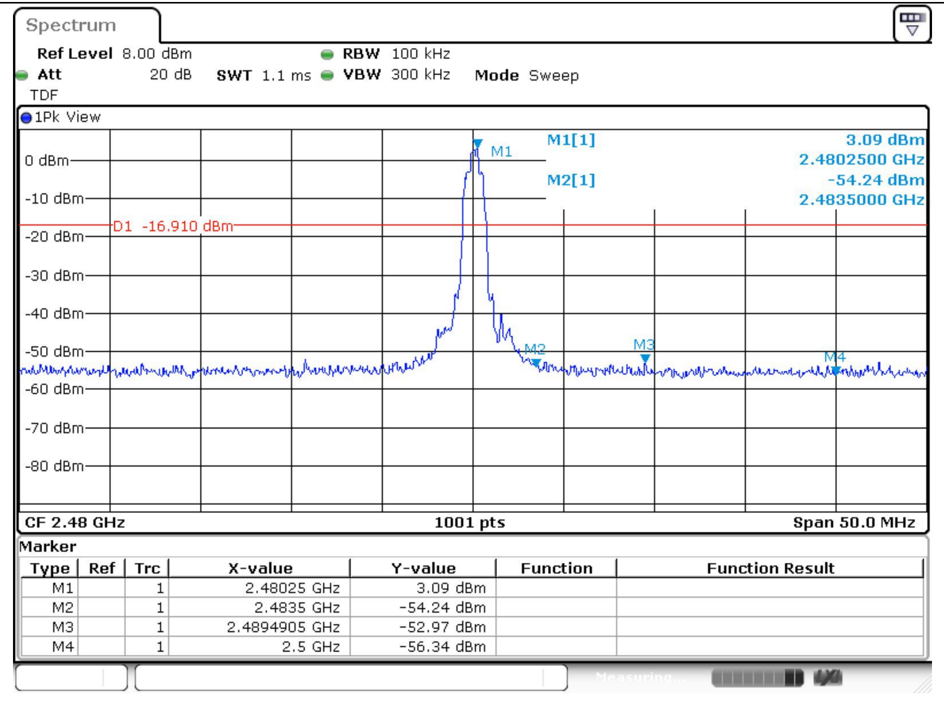
Middle channel

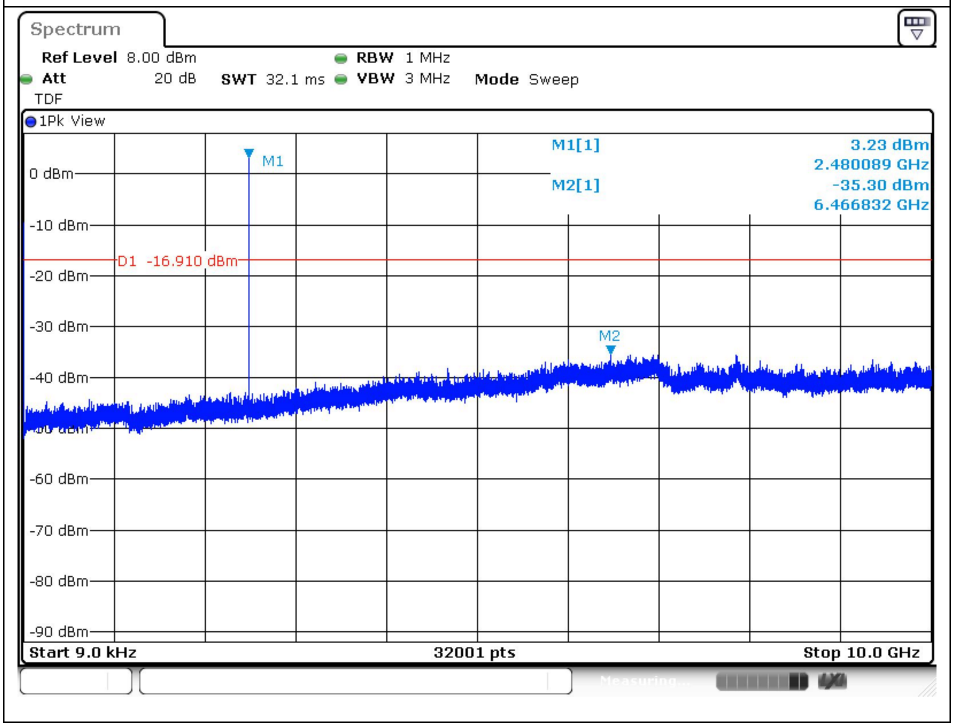


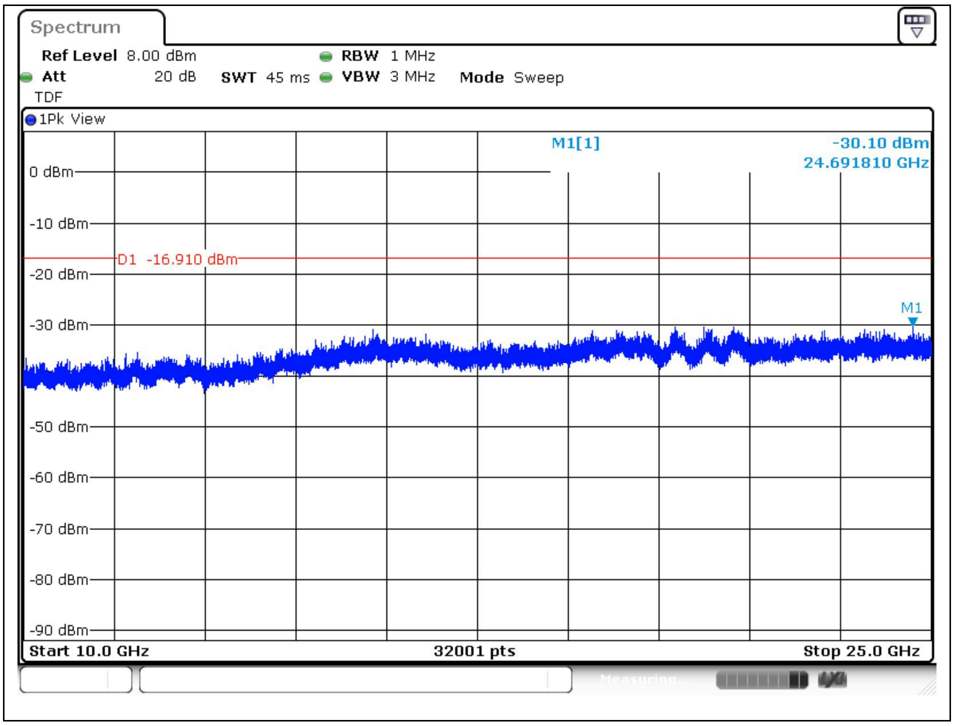



Spectrum
Ref Level 9.00 dBm
Att 20 dB
SWT 45 ms
RBW 1 MHz
VBW 3 MHz
Mode Sweep
TDF
1Pk View
M1[1]
-29.86 dBm
19.774300 GHz
0 dBm
-10 dBm
D1 -16.030 dBm
-20 dBm
-30 dBm
M1
-50 dBm
-60 dBm
-70 dBm
-80 dBm
Start 10.0 GHz
32001 pts
Stop 25.0 GHz

High channel

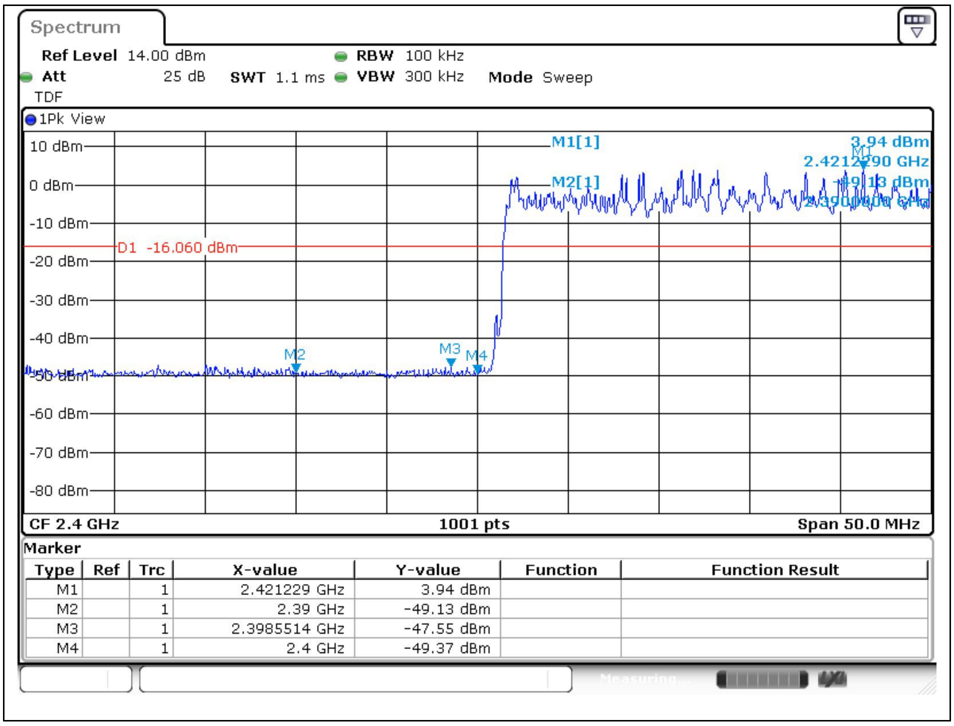




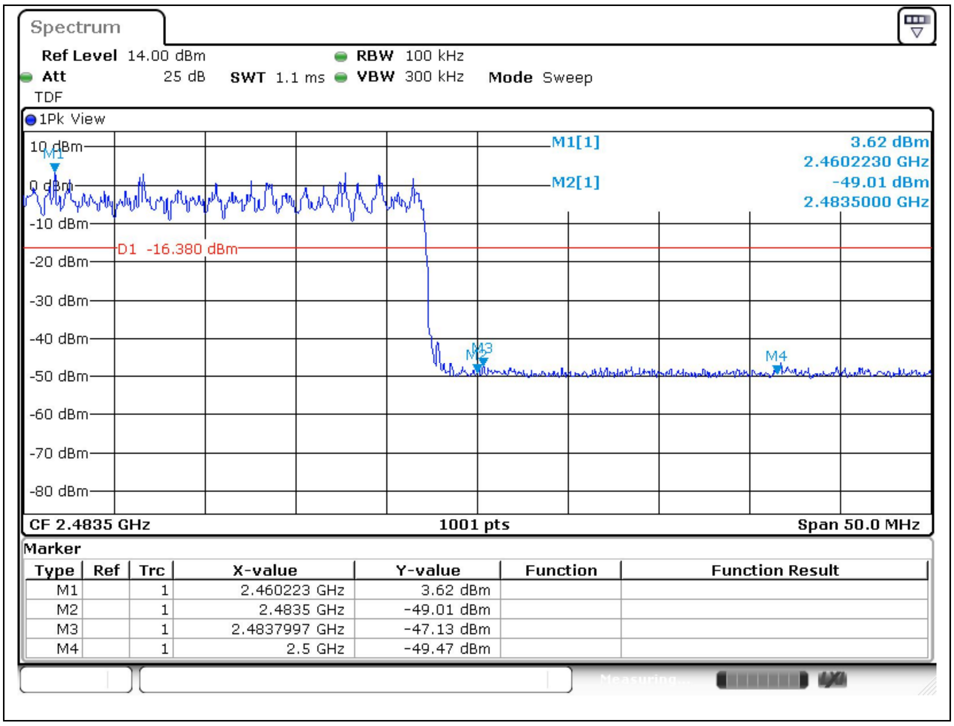

Spectrum
Ref Level 8.00 dBm
Att 20 dB
SWT 45 ms
RBW 1 MHz
VBW 3 MHz
Mode Sweep
TDF
1Pk View
M1[1]
-30.10 dBm
24.691810 GHz
0 dBm
-10 dBm
D1 -16.910 dBm
-20 dBm
-30 dBm
M1
-50 dBm
-60 dBm
-70 dBm
-80 dBm
-90 dBm
Start 10.0 GHz
32001 pts
Stop 25.0 GHz

Band edge compliance with hopping enabled

Low channel

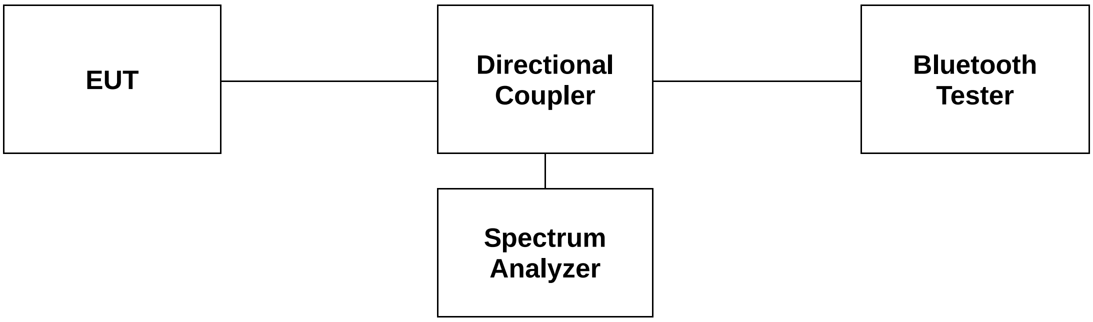


High channel



3. 20 ㏈ Bandwidth

3.1. Test Setup



3.2. Limit

Limit: Not Applicable

3.3. Test Procedure

The test follows ANSI C63.10-2013.

The 20 ㏈ bandwidth was measured with a spectrum analyzer connected to RF antenna connector (conducted measurement) while EUT was operating in transmit mode at the appropriate center frequency.

Use the following spectrum analyzer setting:

1. Span = approximately 2 to 5 times the 20 ㏈ bandwidth.
2. RBW ≥ 1 % to 5 % of the 20 ㏈ bandwidth.
3. VBW ≥ 3 x RBW
4. Sweep = auto
5. Detector = peak
6. Trace = max hold

The marker-to-peak function to set the mark to the peak of the emission. Use the marker-delta function to measure 20 ㏈ down one side of the emission. Reset the 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 20 ㏈ bandwidth of the emission.

3.4. Test Results

Ambient temperature : (23 ± 1) ℃

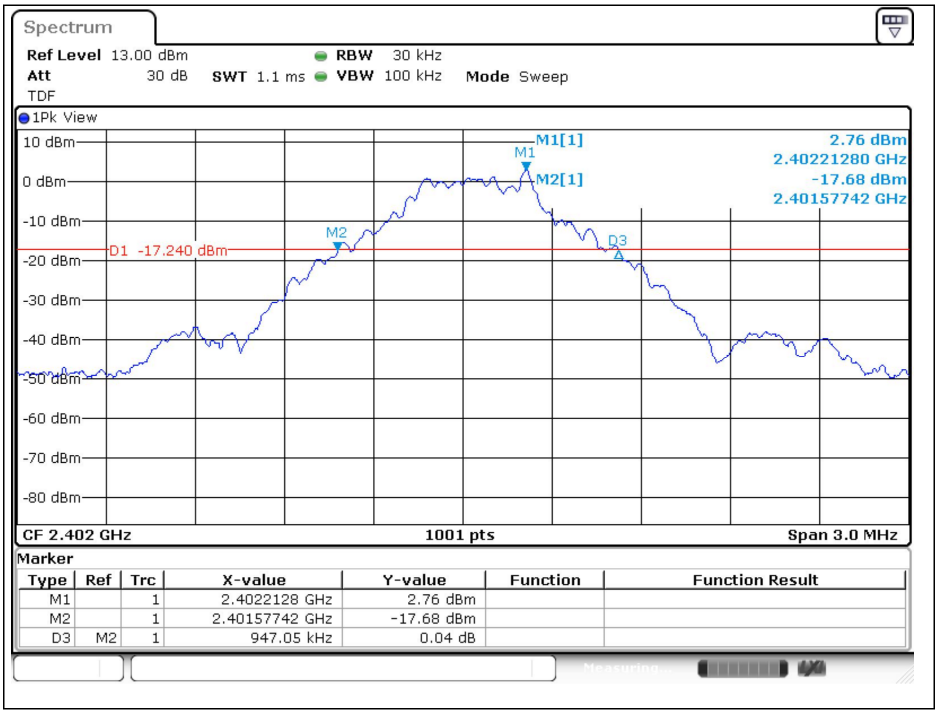
Relative humidity : 47 % R.H.

Operation Mode	Data Rate (Mbps)	Channel	Frequency (㎒)	20 ㏈ Bandwidth (㎒)
GFSK	1	Low	2 402	0.947
		Middle	2 441	0.962
		High	2 480	0.962
π/4DQPSK	2	Low	2 402	1.190
		Middle	2 441	1.208
		High	2 480	1.208
8DPSK	3	Low	2 402	1.259
		Middle	2 441	1.202
		High	2 480	1.199

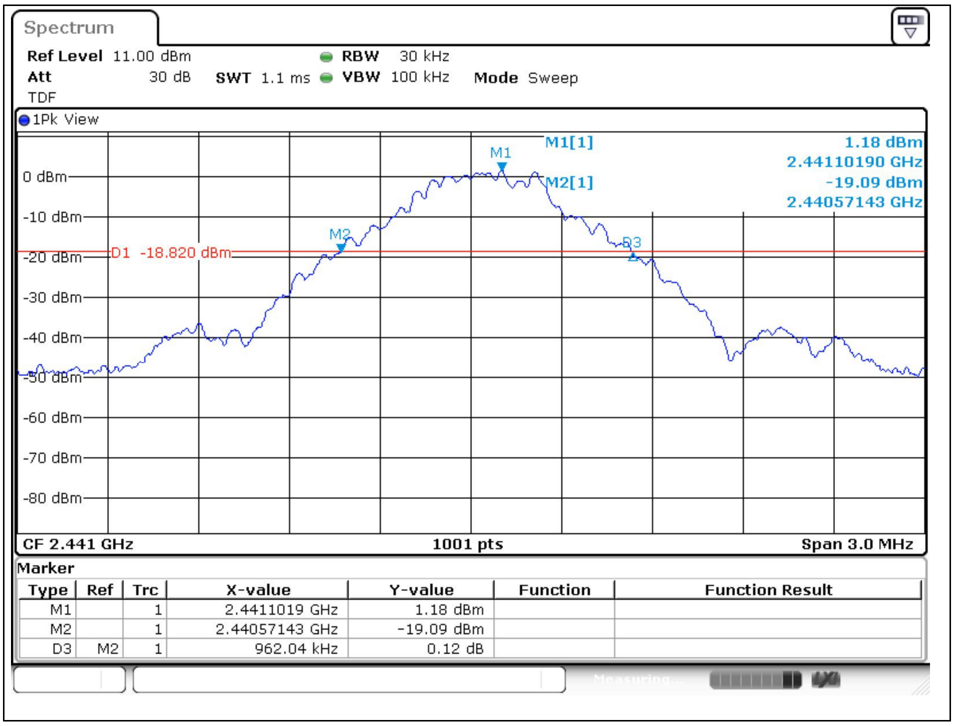
- Test plots

Operating Mode: GFSK

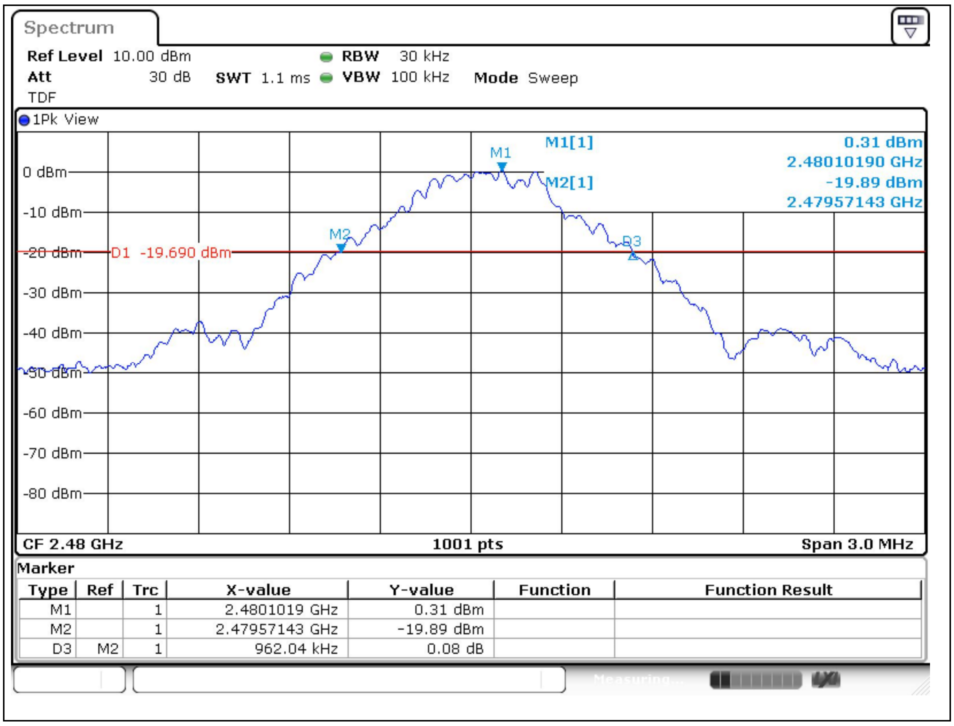
Low Channel



Middle Channel

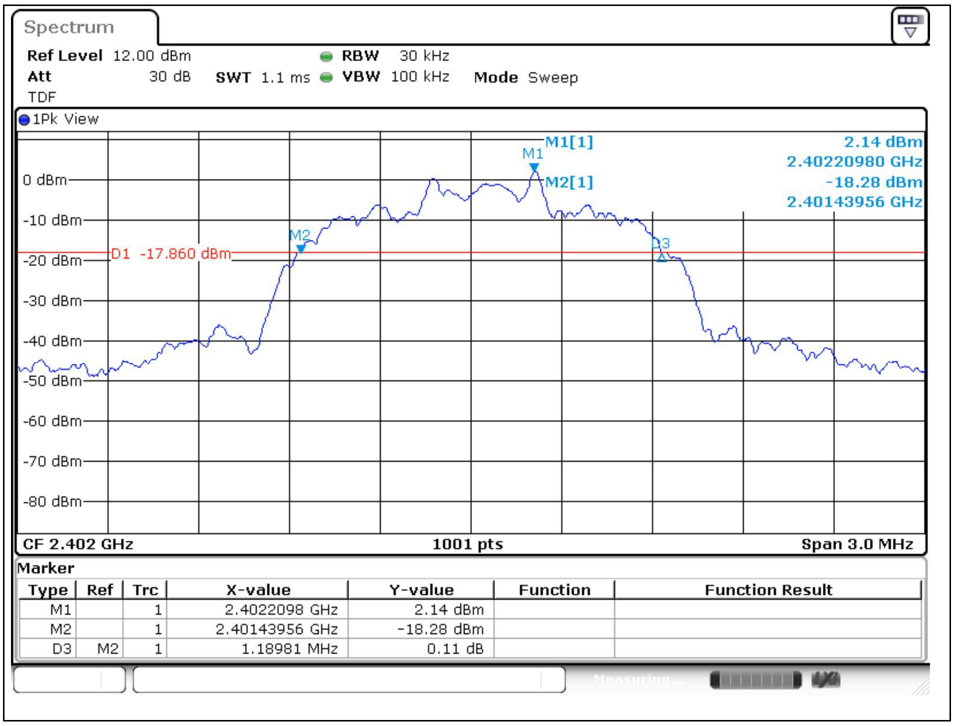


High Channel

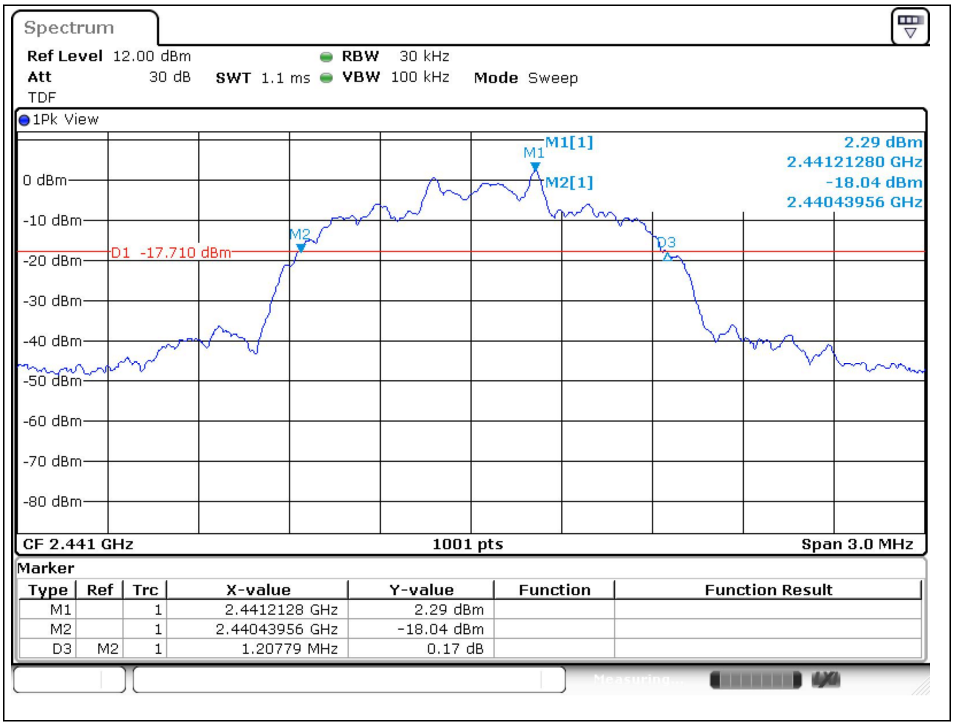


Operating Mode: π/4DQPSK

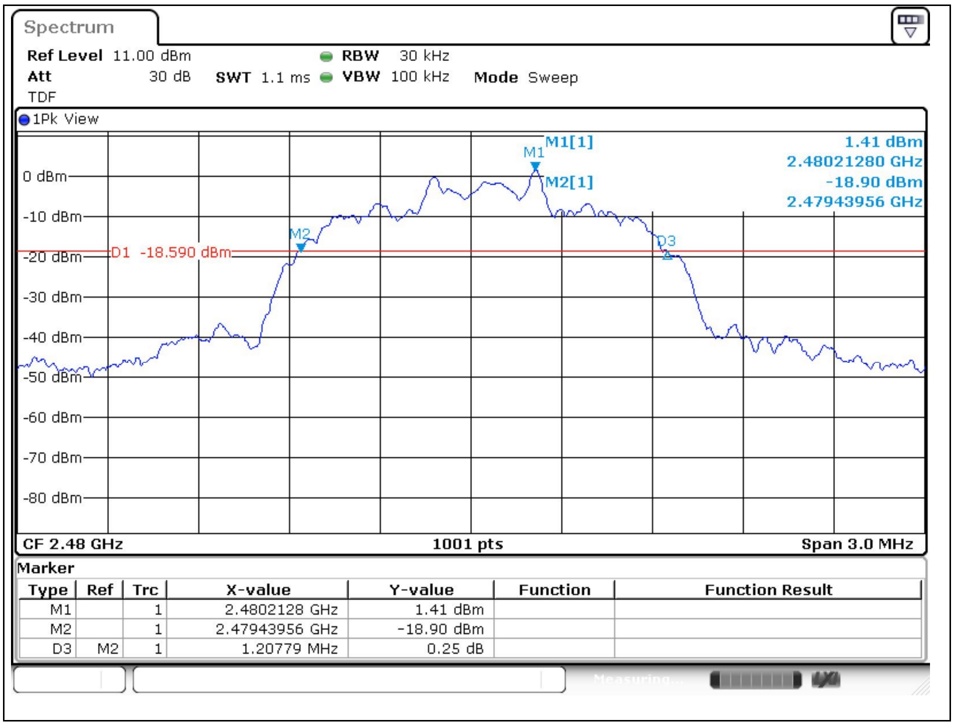
Low Channel



Middle Channel

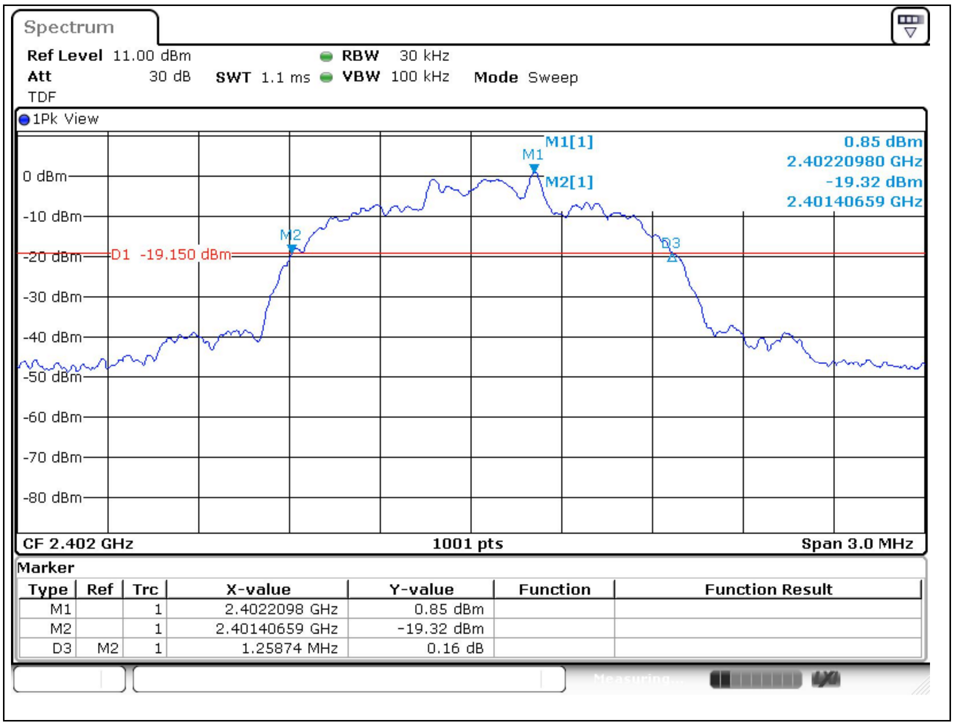


High Channel

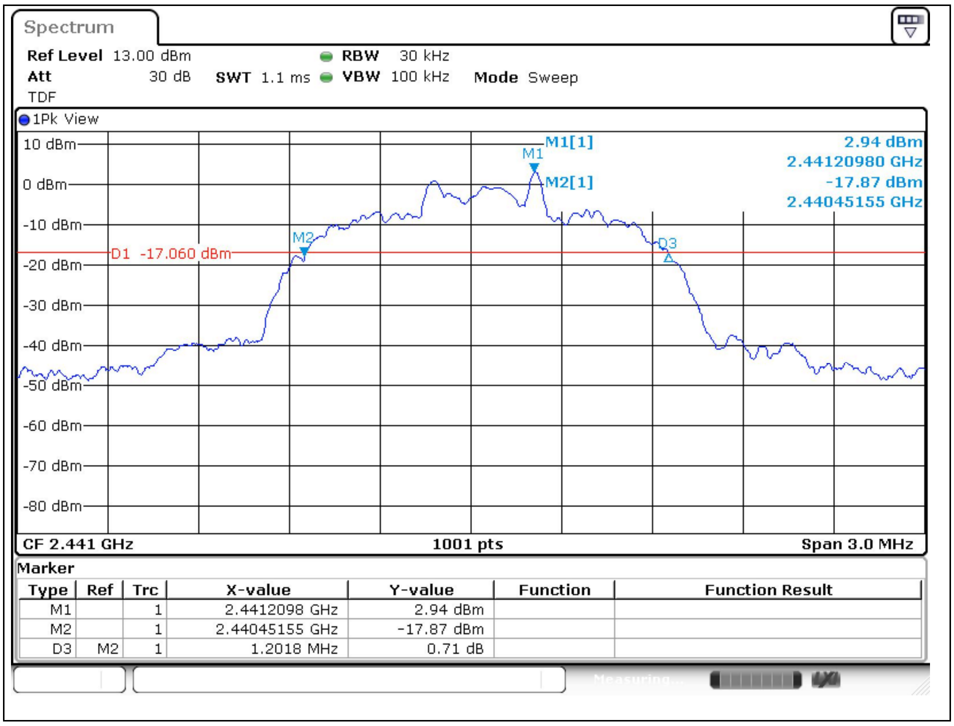


Operating Mode: 8DPSK

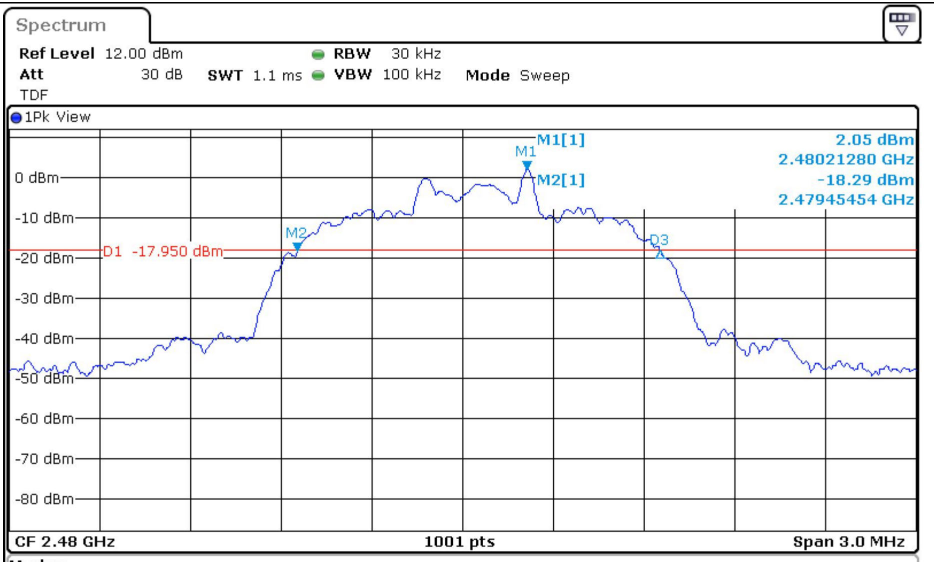
Low Channel



Middle Channel



High Channel

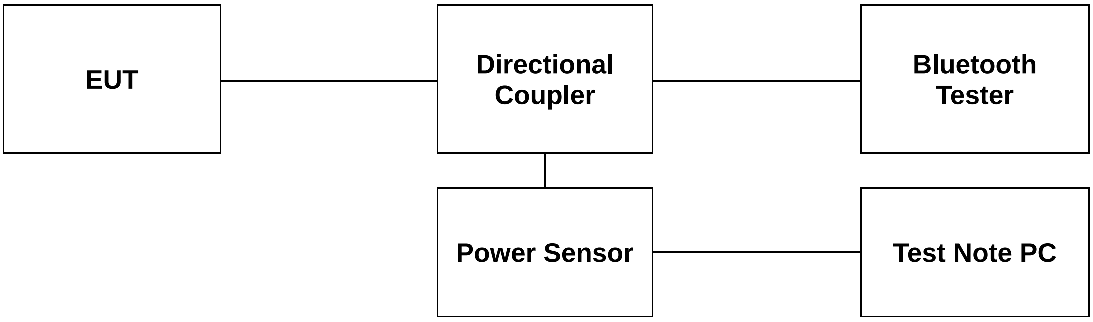


Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	2.4802128 GHz	2.05 dBm		
M2		1	2.47945455 GHz	-18.29 dBm		
D3	M2	1	1.1988 MHz	0.29 dB		

4. Maximum Peak Conducted Output Power

4.1. Test Setup



4.2. Limit

1. §15.247(a)(1), Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 ㎑ or the 20 ㏈ bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2 400-2 483.5 ㎒ band may have hopping channel carrier frequencies that are separated by 25 ㎑ or two-thirds of the 20 ㏈ bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 ㎽.
2. §15.247(b)(1), For frequency hopping systems operating in the 2 400-2 483.5 ㎒ band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5 725-5 850 ㎒ band: 1 watt. For all other frequency hopping systems in the 2 400-2 483.5 ㎒ band: 0.125 watts.

4.3. Test Procedure

The test follows ANSI C63.10-2013. Using the power sensor instead of a spectrum analyzer.

1. Place the EUT on the table and set it in the transmitting mode.
2. Remove the antenna from the EUT and then connect a low loss RF cable from the antenna port to the Power sensor.
3. Test program: (S/W name: R&S Power Viewer, Version: 3.2.0)
4. Measure peak power each channel.

4.4. Test Results

Ambient temperature : (23 ± 1) ℃

Relative humidity : 47 % R.H.

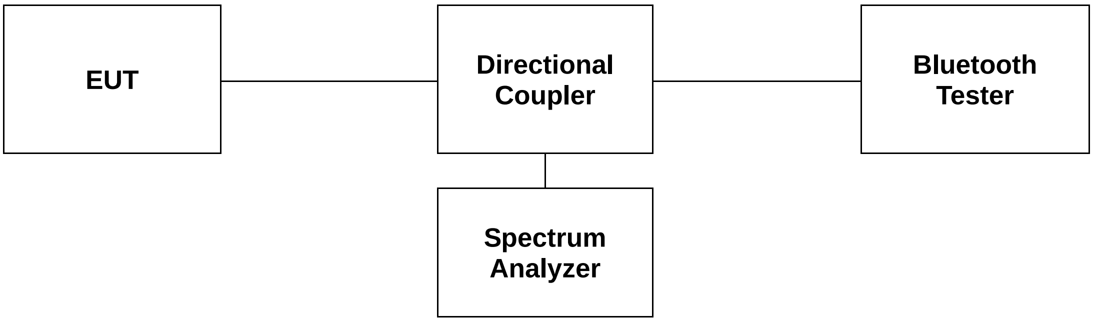
Operation Mode	Data Rate (Mbps)	Channel	Frequency (㎒)	Average Power Result (㏈ m)	Peak Power Result (㏈ m)	Limit (㏈ m)
GFSK	1	Low	2 402	4.11	4.53	30
		Middle	2 441	**4.32**	**4.68**	
		High	2 480	3.90	4.36	
π/4DQPSK	2	Low	2 402	1.06	4.40	20.97
		Middle	2 441	**1.31**	**4.61**	
		High	2 480	0.88	4.25	
8DPSK	3	Low	2 402	1.05	4.45	
		Middle	2 441	**1.26**	**4.62**	
		High	2 480	0.87	4.27	

Remark;

In the case of AFH, the limit for peak power is 0.125 W.
Directional coupler and cable offset compensate for test program (R&S Power Viewer) before measuring.

5. Carrier Frequency Separation

5.1. Test Setup



5.2. Limit

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

5.3. Test Procedure

The test follows ANSI C63.10-2013.

The device is operating in hopping mode between 79 channels and also supporting Adaptive Frequency Hopping with hopping between 20 channels. As compared with each operating mode, 79 channels are chosen as a representative for test.
Use the following spectrum analyzer settings:

1. Span: Wide enough to capture the peaks of two adjacent channels
2. RBW: Start with the RBW set to approximately 30% of the channel spacing; adjust as necessary to best identify the center of each individual channel.
3. VBW ≥ RBW
4. Sweep: Auto
5. Detector: Peak
6. Trace: Max hold
7. Allow the trace to stabilize.

Use the marker-delta function to determine the between the peaks of the adjacent channels.

5.4. Test Results

Ambient temperature : (23 ± 1) ℃
Relative humidity : 47 % R.H.

Operation Mode	Frequency (㎒)	Adjacent Hopping Channel Separation (㎑)	20 ㏈ Bandwidth (㎑)
GFSK	2 441	1 000	962

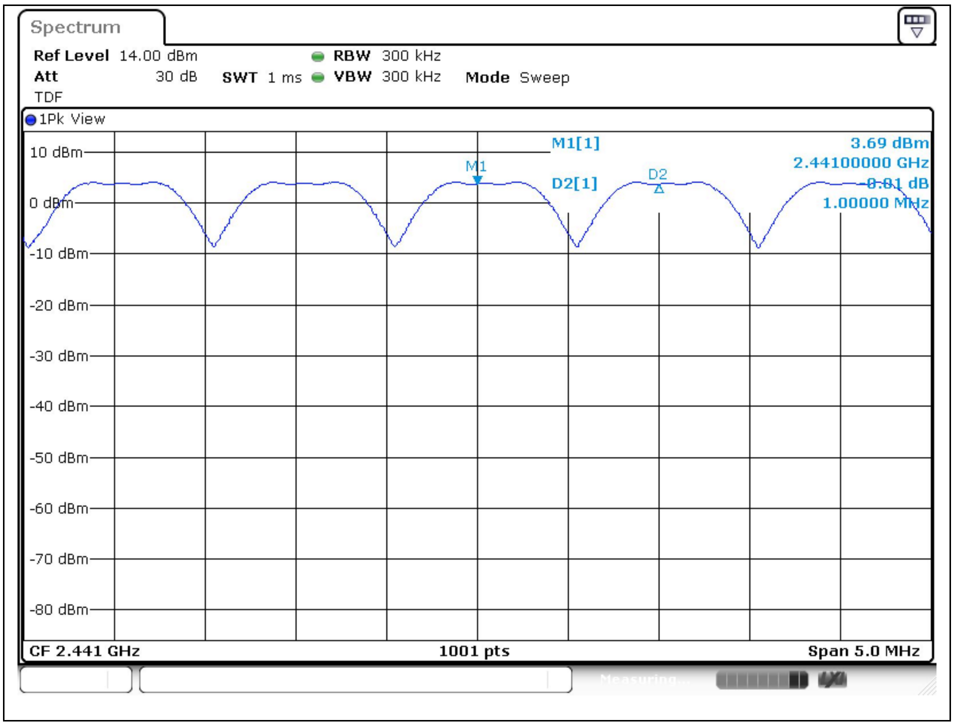
Operation Mode	Frequency (㎒)	Adjacent Hopping Channel Separation (㎑)	Two-third of 20 ㏈ Bandwidth (㎑)
8DPSK	2 441	1 000	801

Remark;

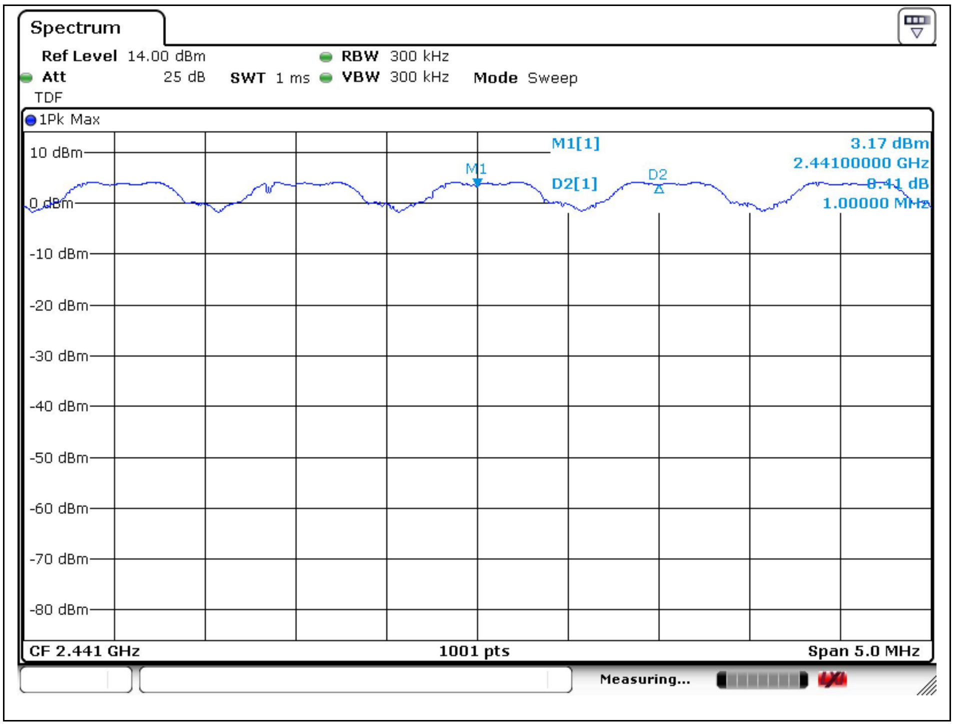
Measurement is made with EUT operating in hopping mode between 79 channels providing a worst case scenario as compared to AFH mode hopping between 20 channels.

- **Test plots**

Operating Mode: GFSK

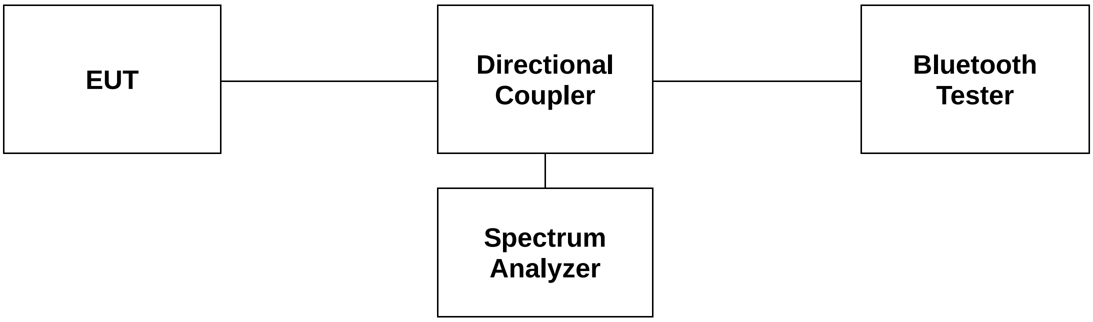


Operating Mode: 8DPSK



6. Number of Hopping Frequencies

6.1. Test Setup



6.2. Limit

§15.247(a)(1)(iii), Frequency hopping systems in the 2 400-2 483.5 ㎒ band shall use at least 15 channels. 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. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

6.3. Test Procedure

The test follows ANSI C63.10-2013.

The device supports Adaptive Frequency Hopping and will use a minimum of 20 channels of the 79 available channels.

The EUT shall have its hopping function enabled. Use the following spectrum analyzer settings:

1. Span: The frequency band of operation. Depending on the number of channels the device supports, it may be necessary to divide the frequency range of operation across multiple spans, to allow the individual channels to be clearly seen.
2. RBW: To identify clearly the individual channels, set the RBW to less than 30 % of the channel spacing or the 20 ㏈ bandwidth, whichever is smaller.
3. VBW ≥ RBW
4. Sweep: Auto
5. Detector function: Peak
6. Trace: Max hold
7. Allow the trace to stabilize.

6.4. Test Results

Ambient temperature : (23 ± 1) ℃
Relative humidity : 47 % R.H.

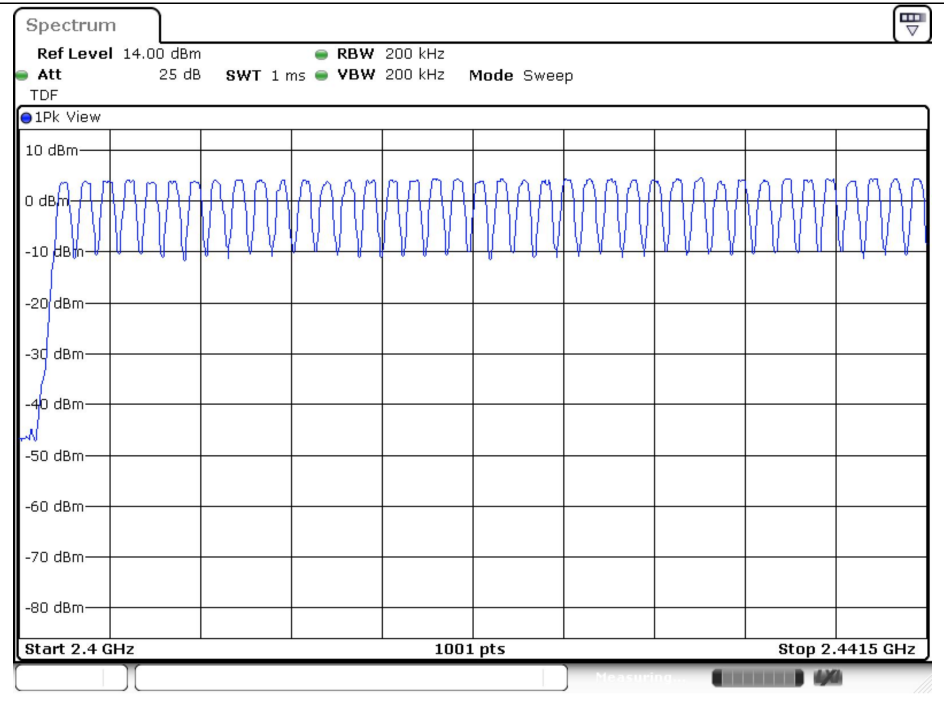
Operation Mode	Number of Hopping Frequency	Limit
GFSK	79	≥ 15
8DPSK	79	≥ 15

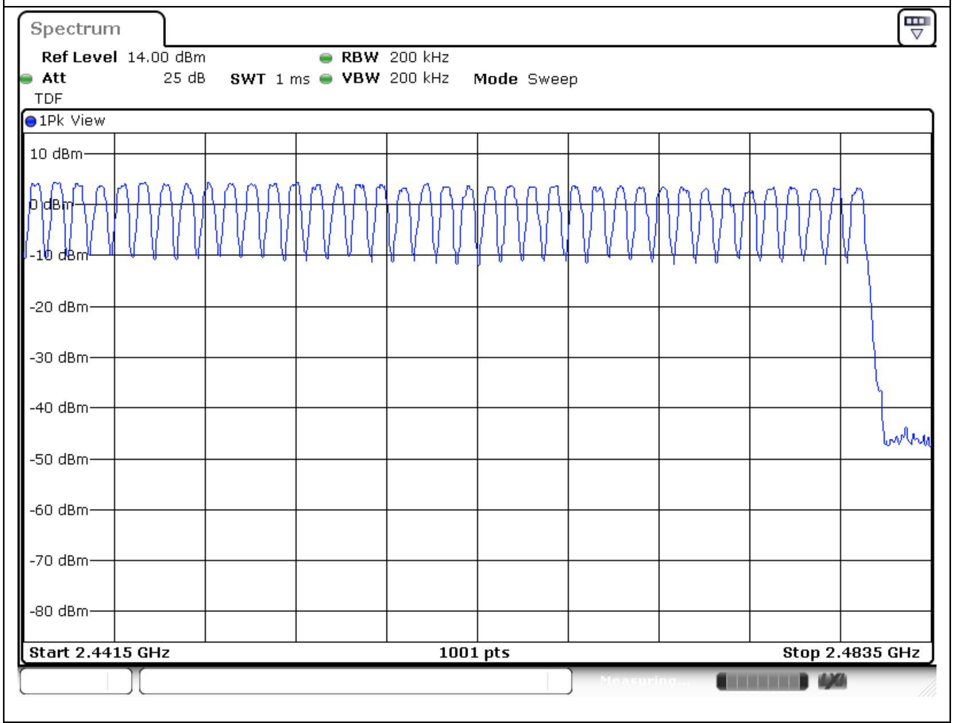
Remark;

Measurement is made with EUT operating in hopping mode between 79 channels providing a worst case scenario as compared to AFH mode hopping between 20 channels.

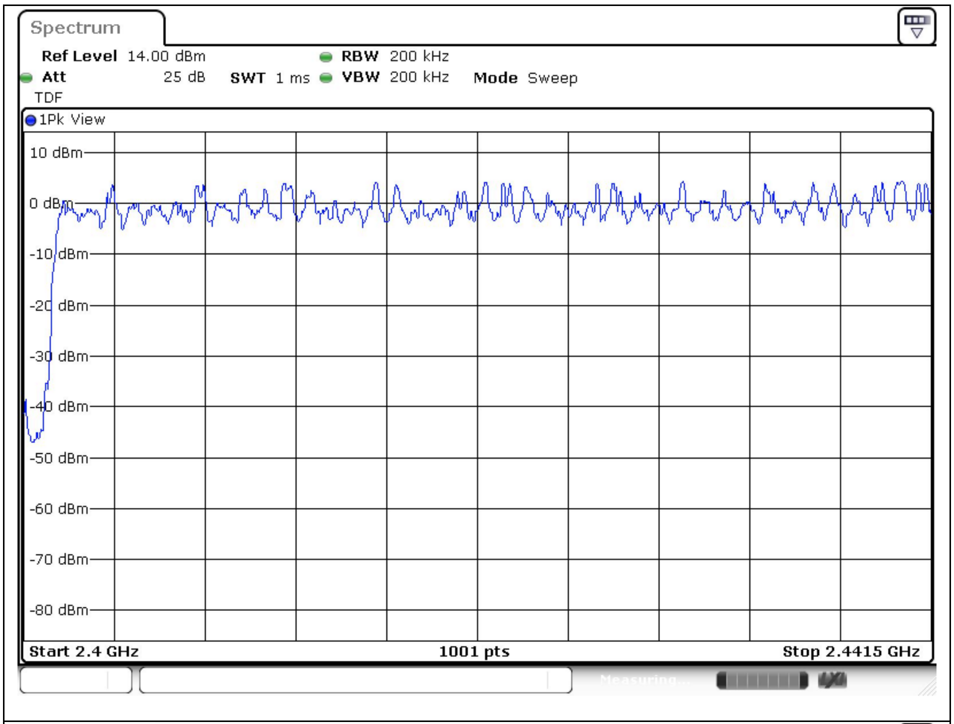
- **Test plots**

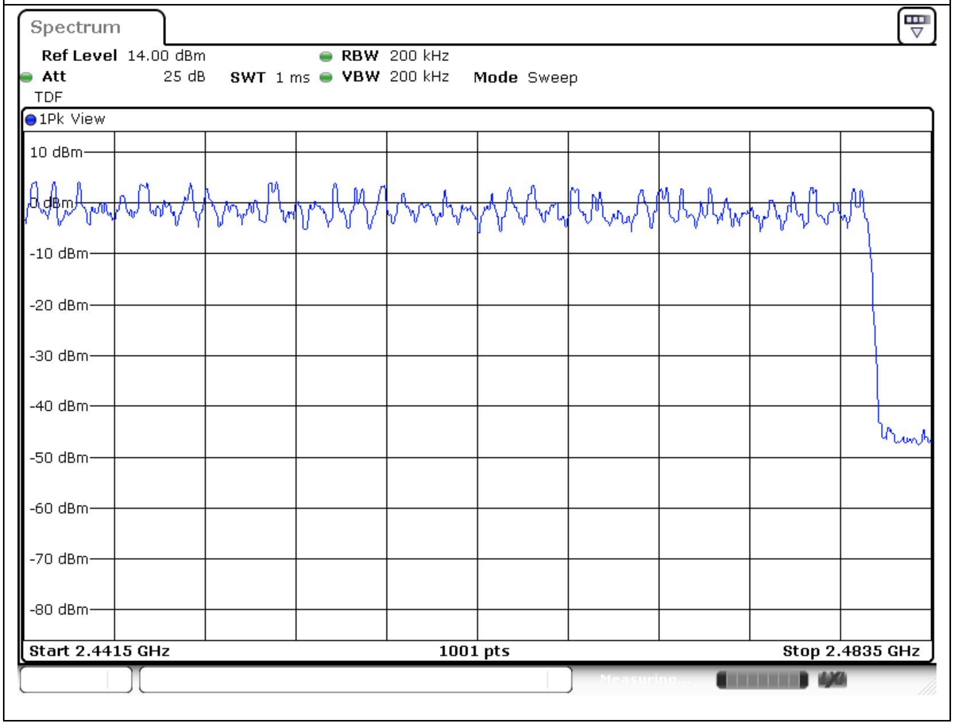
Operating Mode: GFSK





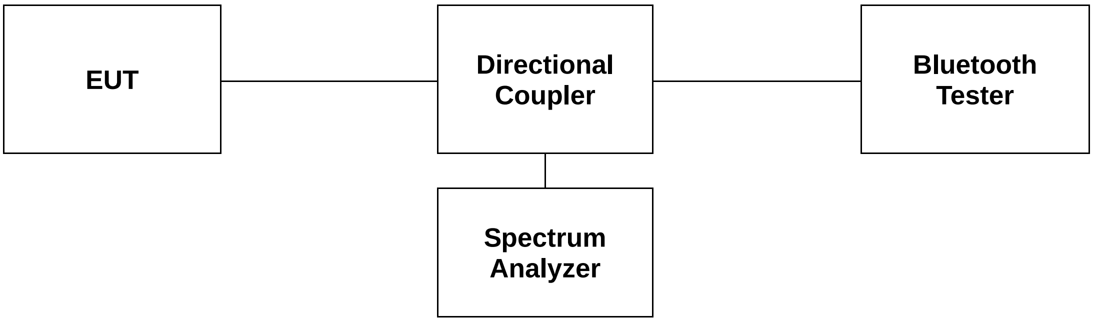
Operating Mode: 8DPSK





7. Time of Occupancy (Dwell Time)

7.1. Test Set up



7.2. Limit

§15.247(a)(1)(iii), Frequency hopping systems 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)

***Adaptive Frequency Hopping**

A period time = 0.4 (s) * 20 = 8 (s)

7.3. Test Procedure

All data rates and modes were investigated for this test. The full data for the worst case data rate are reported in this section. The test follows ANSI C63.10-2013.

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. Measure the time duration of one transmission on the measured frequency. And then plot the result with time difference of this time duration.
4. The Bluetooth has 3 type of payload, DH1, DH3, DH5 and 3DH1, 3DH3, 3DH5.The hopping rate is insisted of 1 600 per second.

The EUT must have its hopping function enabled. Use the following spectrum analyzer setting:

1. Span = Zero span, centered on a hopping channel.
2. RBW = 1 ㎒.
3. VBW ≥ RBW.
4. Sweep = As necessary to capture the entire dwell time per hopping channel.
5. Detector = Peak.
6. Trace = Max hold.

Use the marker-delta function to determine the dwell time. If this value varies with different modes of operation, then repeat this test for each variation.

7.4. Test Results

Ambient temperature : (23 ± 1) ℃
Relative humidity : 47 % R.H.

7.4.1. Packet Type: DH1, 3DH1

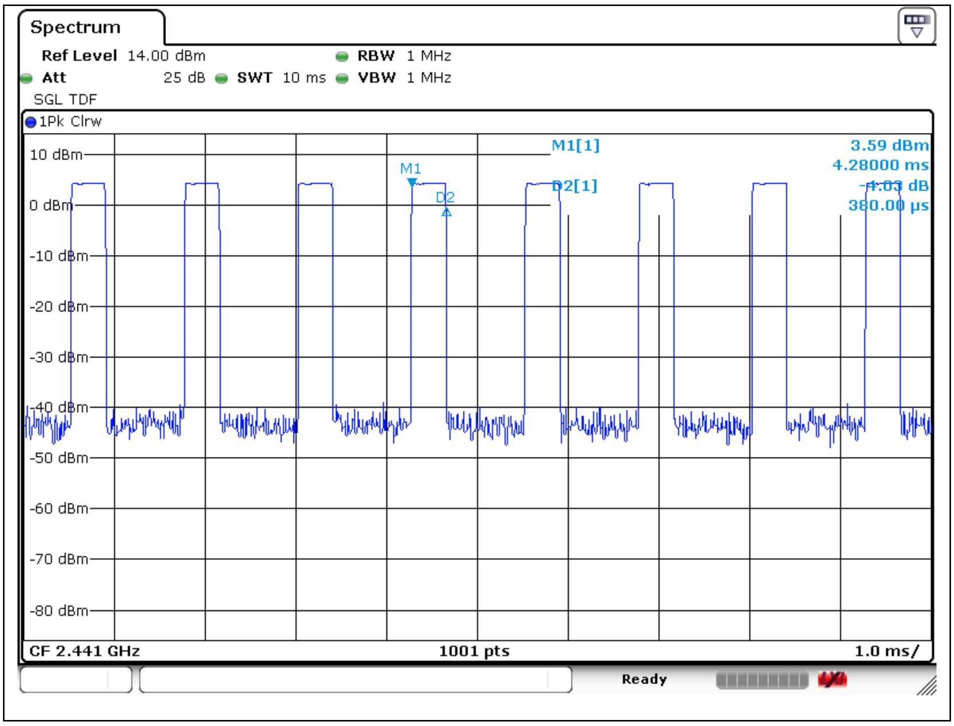
Operation Mode	Frequency (㎒)	Dwell Time (㎳)	Time of occupancy on the Tx Channel in 31.6 sec (㎳)	Limit for time of occupancy on the Tx Channel in 31.6 sec (㎳)
GFSK	2 441	0.38	121.60	400
8DPSK	2 441	0.39	124.80	400

Remark;

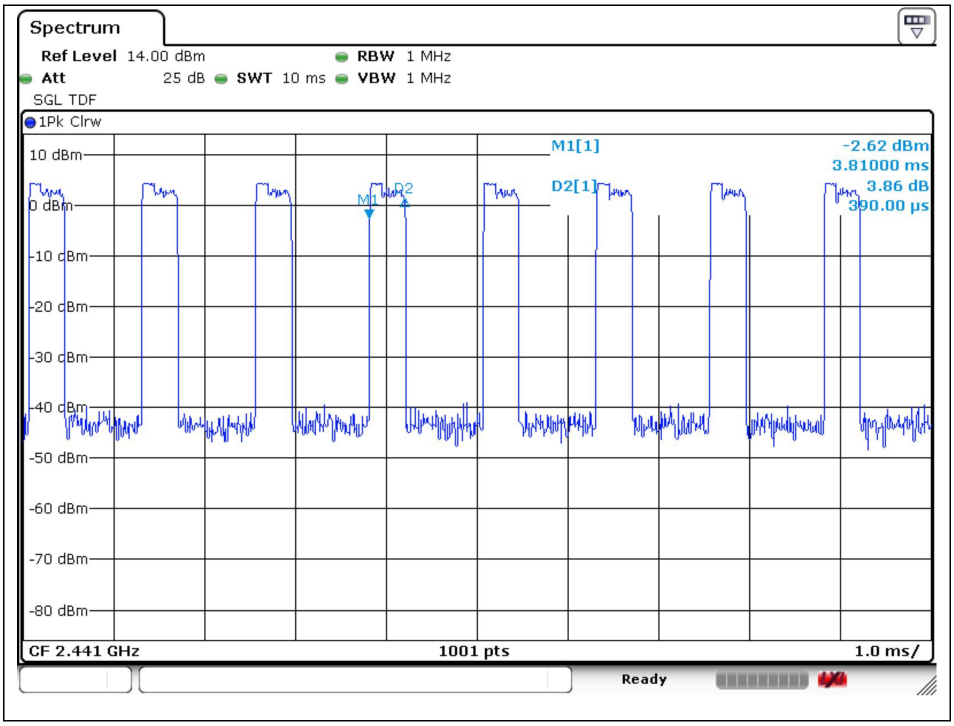
Time of occupancy on the TX channel in 31.6 sec
In case of GFSK: 0.38 × {(1 600 ÷ 2) / 79} × 31.6 = 121.60 ㎳
In case of 8DPSK: 0.39 × {(1 600 ÷ 2) / 79} × 31.6 = 124.80 ㎳

- Test plots

Operating Mode: GFSK



Operating Mode: 8DPSK



7.4.2. Packet Type: DH3, 3DH3

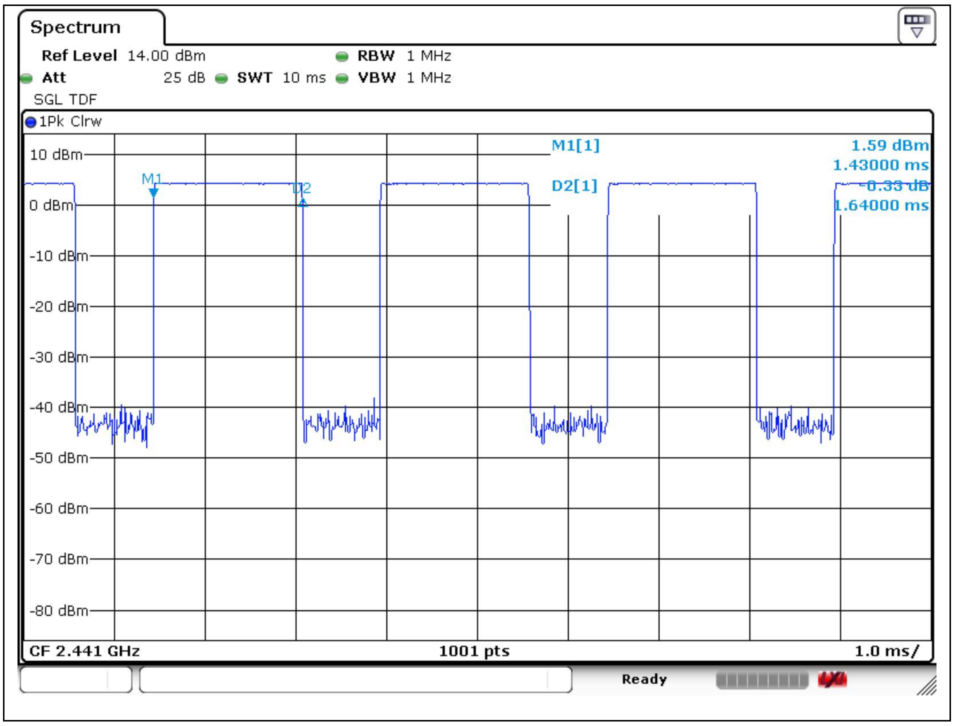
Operation Mode	Frequency (㎒)	Dwell Time (㎳)	Time of occupancy on the Tx Channel in 31.6 sec (㎳)	Limit for time of occupancy on the Tx Channel in 31.6 sec (㎳)
GFSK	2 441	1.64	262.40	400
8DPSK	2 441	1.64	262.40	400

Remark;

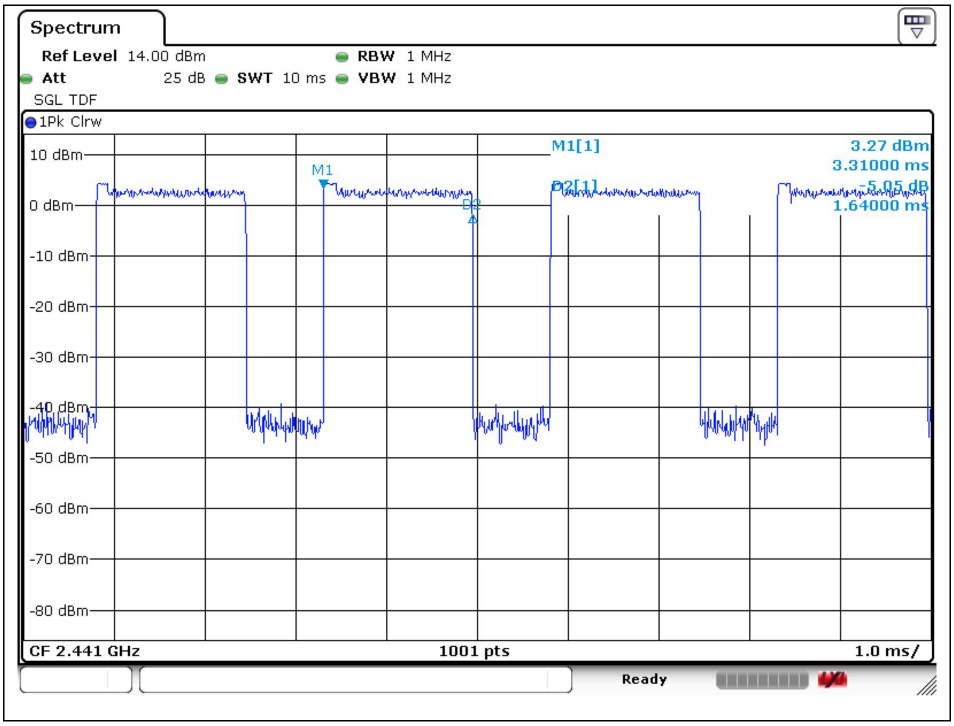
Time of occupancy on the TX channel in 31.6 sec
In case of GFSK and 8DPSK: 1.64 × {(1 600 ÷ 4) / 79} × 31.6 = 262.40 ㎳

- Test plots

Operating Mode: GFSK



Operating Mode: 8DPSK



7.4.3. Packet Type: DH5, 3DH5

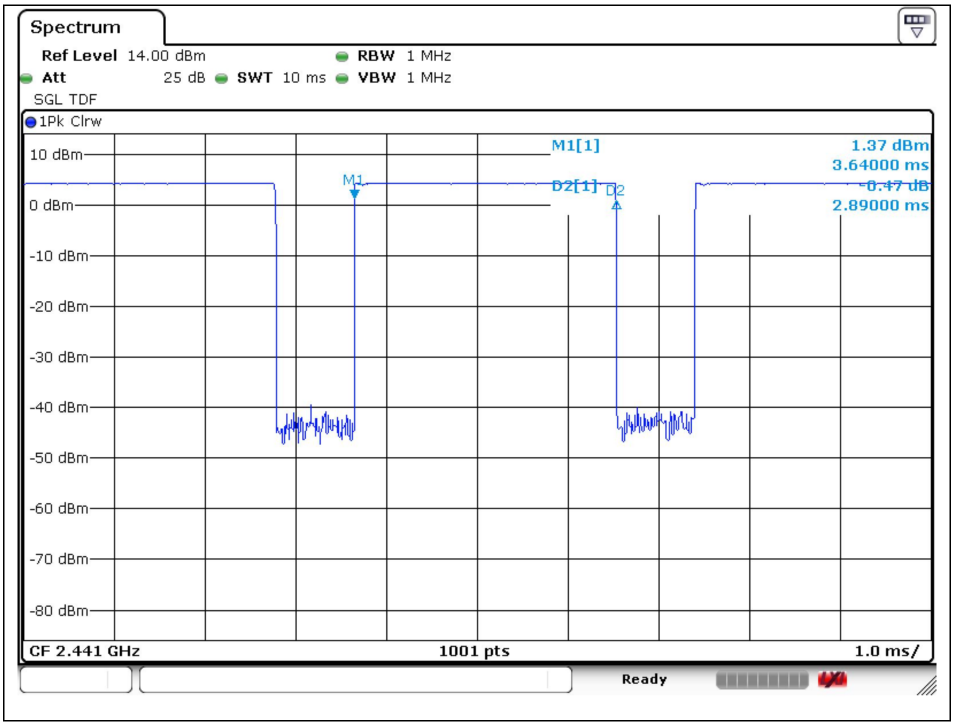
Operation Mode	Frequency (㎒)	Dwell Time (㎳)	Time of occupancy on the Tx Channel in 31.6 sec (㎳)	Limit for time of occupancy on the Tx Channel in 31.6 sec (㎳)
GFSK	2 441	2.89	308.27	400
8DPSK	2 441	2.90	309.33	400

Remark;

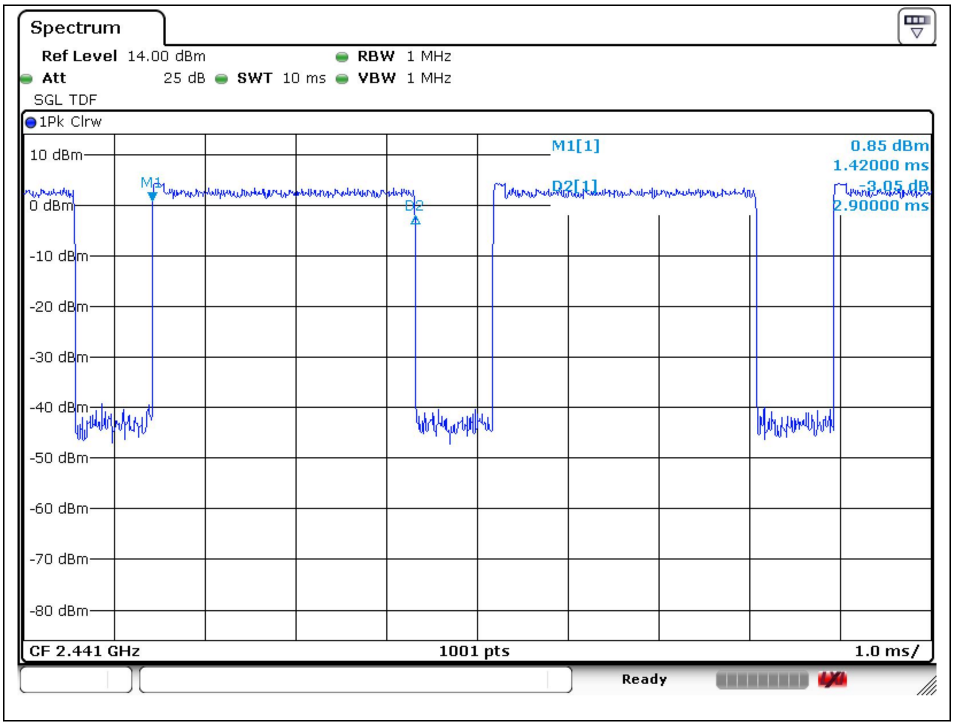
Time of occupancy on the TX channel in 31.6 sec
In case of GFSK: 2.89 × {(1 600 ÷ 6) / 79} × 31.6 = 308.27 ㎳
In case of 8DPSK: 2.90 × {(1 600 ÷ 6) / 79} × 31.6 = 309.33 ㎳

- Test plots

Operating Mode: GFSK



Operating Mode: 8DPSK



7.4.4. Packet Type: DH1, 3DH1 (Adaptive Frequency Hopping)

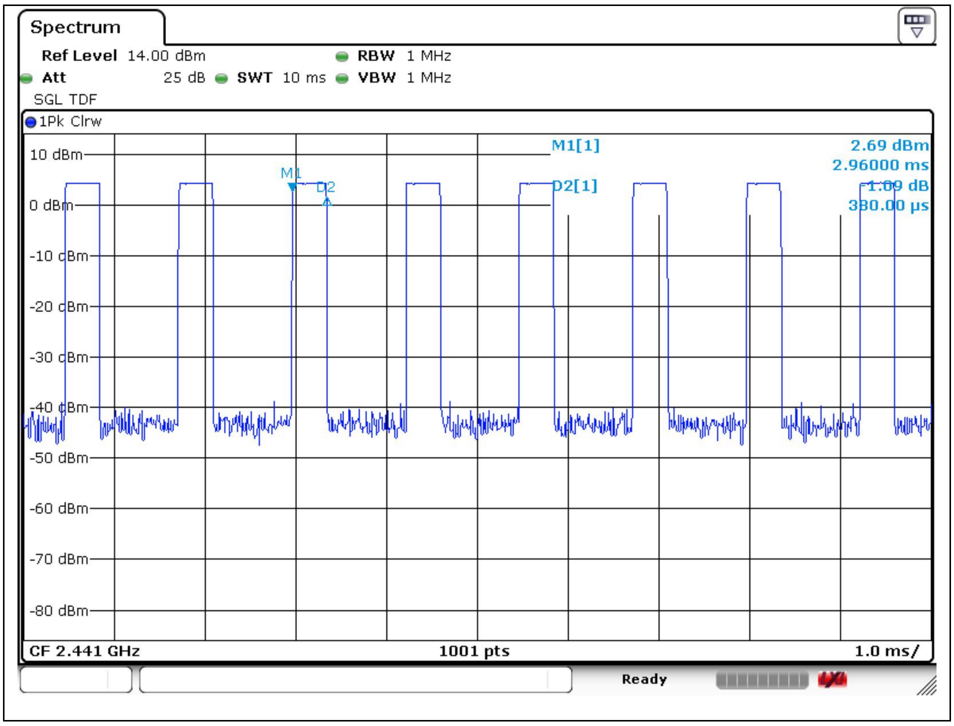
Operation Mode	Frequency (㎒)	Dwell Time (㎳)	Time of occupancy on the Tx Channel in 8 sec (㎳)	Limit for time of occupancy on the Tx Channel in 8 sec (㎳)
GFSK	2 441	0.38	60.80	400
8DPSK	2 441	0.38	60.80	400

Remark;

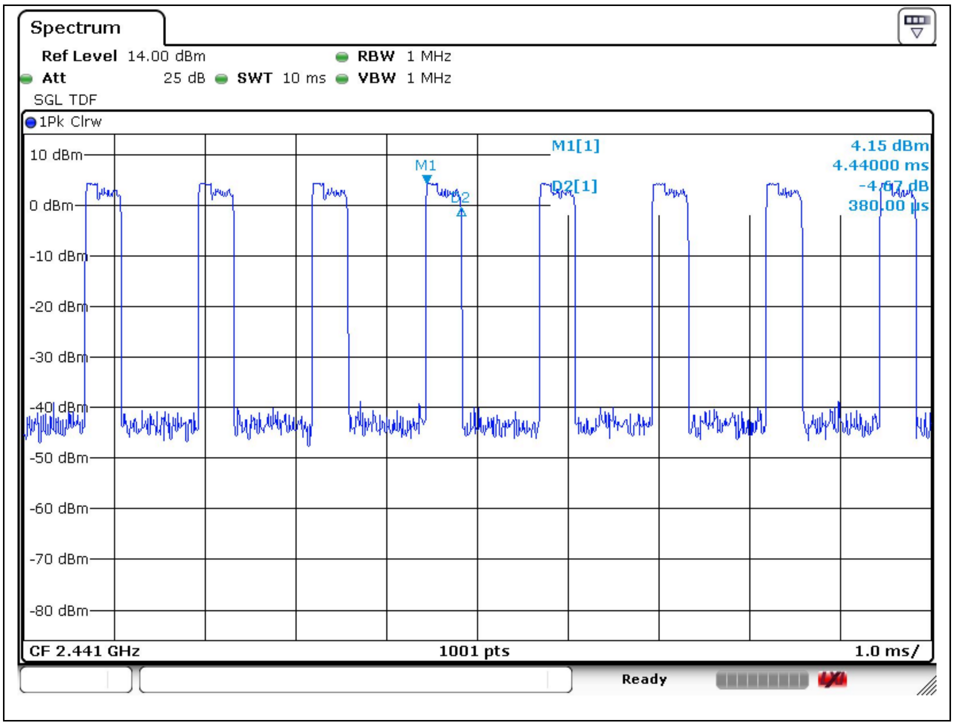
Time of occupancy on the TX channel in 8 sec
In case of GFSK and 8DPSK: 0.38 × {(800 ÷ 2) / 20} × 8 = 60.80 ㎳

- Test plots

Operating Mode: GFSK



Operating Mode: 8DPSK



7.4.5. Packet Type: DH3, 3DH3 (Adaptive Frequency Hopping)

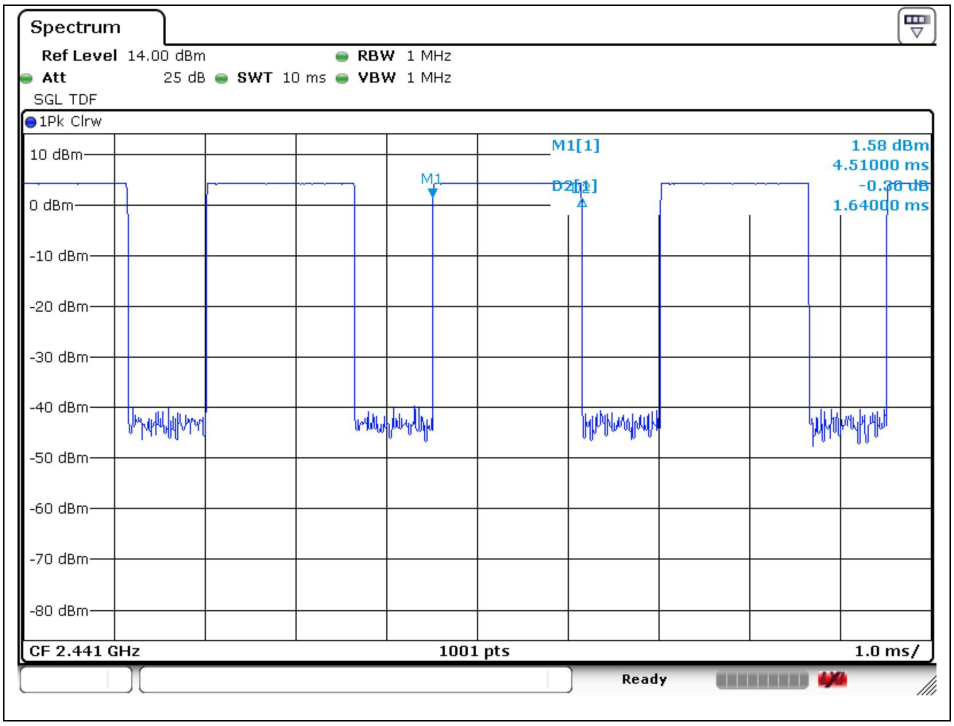
Operation Mode	Frequency (㎒)	Dwell Time (㎳)	Time of occupancy on the Tx Channel in 8 sec (㎳)	Limit for time of occupancy on the Tx Channel in 8 sec (㎳)
GFSK	2 441	1.64	131.20	400
8DPSK	2 441	1.64	131.20	400

Remark;

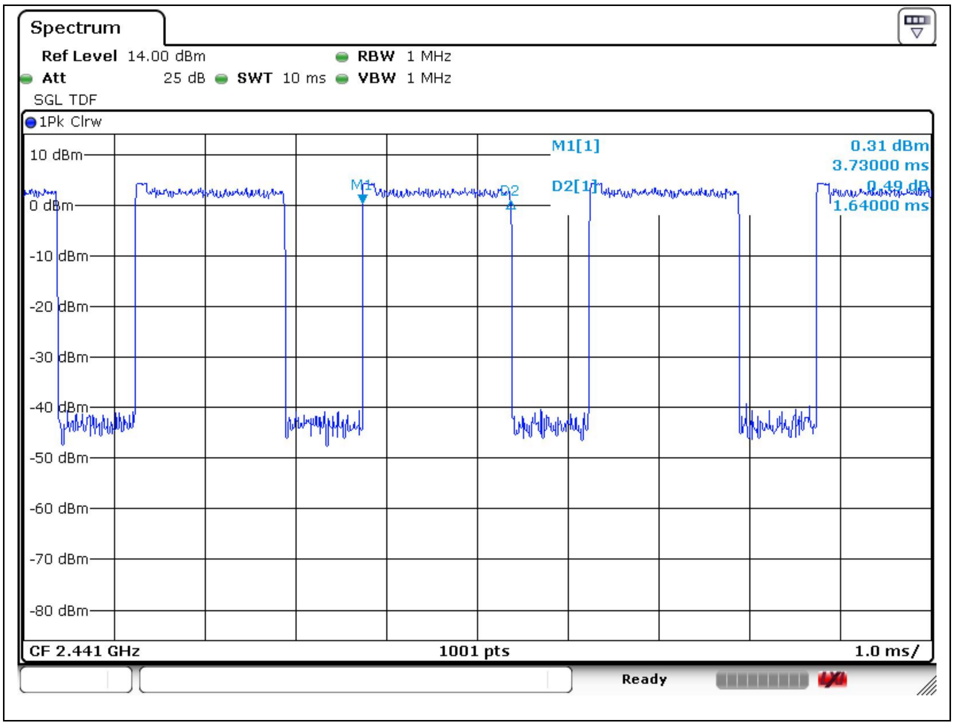
Time of occupancy on the TX channel in 8 sec
In case of GFSK and 8DPSK: 1.64 × {(800 ÷ 4) / 20} × 8 = 131.20 ㎳

- Test plots

Operating Mode: GFSK



Operating Mode: 8DPSK



7.4.6. Packet Type: DH5, 3DH5 (Adaptive Frequency Hopping)

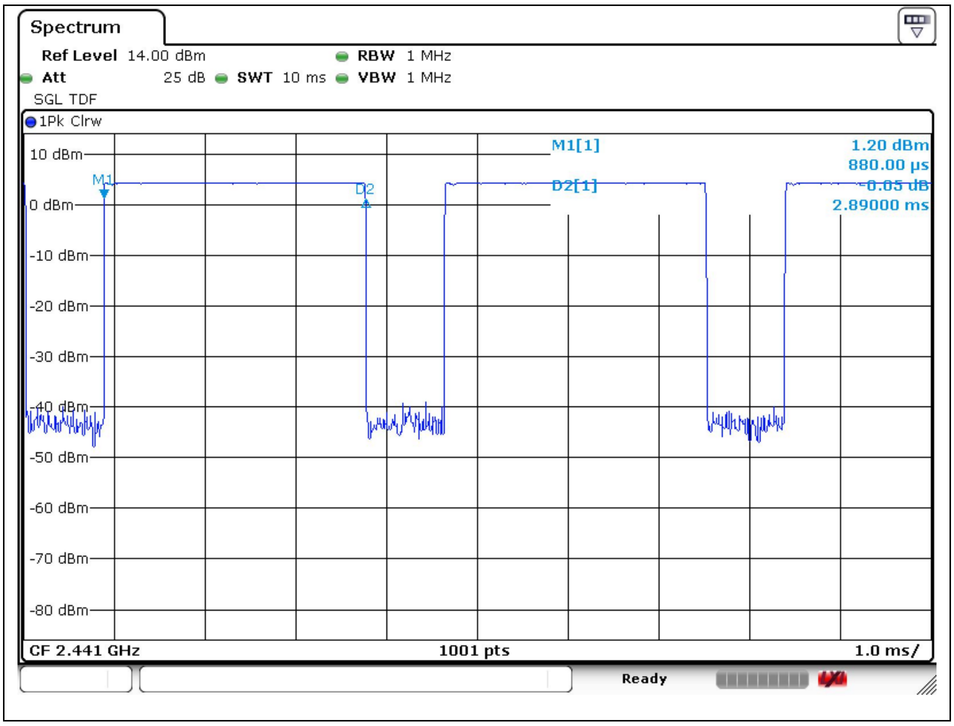
Operation Mode	Frequency (㎒)	Dwell Time (㎳)	Time of occupancy on the Tx Channel in 8 sec (㎳)	Limit for time of occupancy on the Tx Channel in 8 sec (㎳)
GFSK	2 441	2.89	154.13	400
8DPSK	2 441	2.90	154.67	400

Remark;

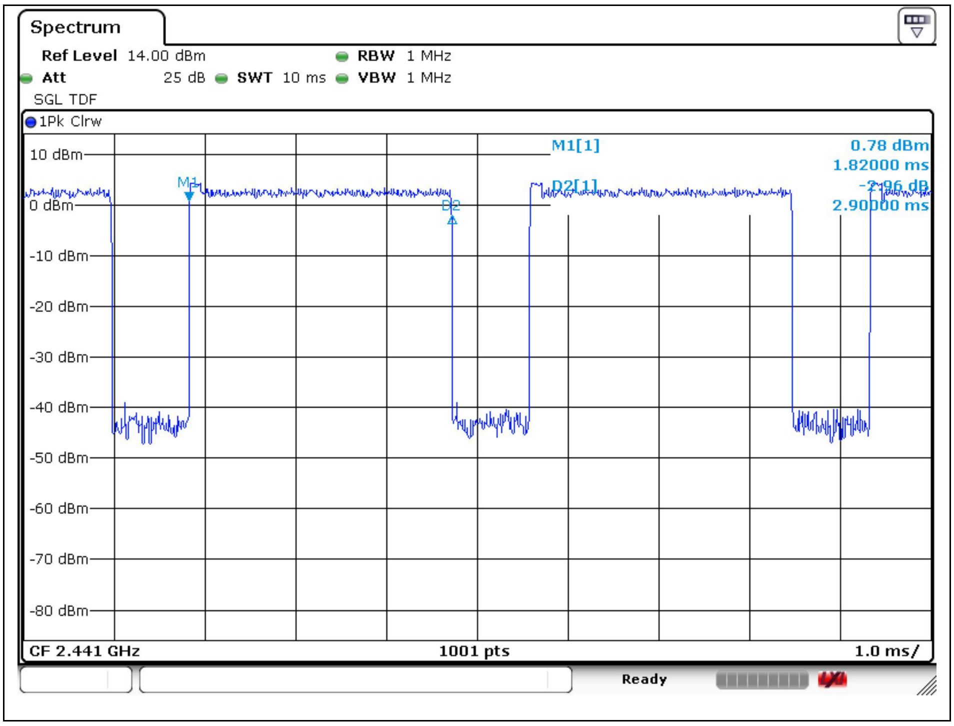
Time of occupancy on the TX channel in 8 sec
In case of GFSK: 2.89 × {(800 ÷ 6) / 20} × 8 = 154.13 ㎳
In case of 8DPSK: 2.90 × {(800 ÷ 6) / 20} × 8 = 154.67 ㎳

- Test plots

Operating Mode: GFSK



Operating Mode: 8DPSK



8. Antenna Requirement

8.1. 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.

8.2. Antenna Connected Construction

Antenna used in this product is FPC antenna with gain of 1.80 ㏈i

- End of the Test Report -