

# TEST REPORT

Of

FCC Part 15 Subpart C §15.247

FCC ID: TQ8-AM1B1DPAN

Equipment Under Test : DIGITAL CAR AUDIO SYSTEM  
Model Name : AM1B1DPAN(Alt.: AM1B0DPKN, AM110DMGG,  
AM110DMGE, AM111DMGL, AM110DMGN,  
AM110DPGN)  
Applicant : Hyundai MOBIS Co., Ltd.  
Manufacturer : Hyundai MOBIS Co., Ltd.  
Date of Test(s) : 2015.02.10 ~ 2015.02.23  
Date of Issue : 2015.03.13

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

Tested By:



Patrick Kang

Date:

2015.03.13

Approved By:



Hyunchoe You

Date:

2015.03.13

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## 1. General Information

### 1.1. Testing Laboratory

SGS Korea Co., Ltd. (Gunpo Laboratory)

- Wireless Div. 2FL, 10-2, LS-ro 182beon-gil, Gunpo-si, Gyeonggi-do, Korea, 435-837

All SGS services are rendered in accordance with the applicable SGS conditions of service available on request and accessible at <http://www.sgs.com/en/Terms-and-Conditions.aspx>.

Telephone : +82 31 688 0901

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### 1.2. Details of Applicant

Applicant : Hyundai MOBIS Co., Ltd.

Address : 203, Teheran-ro, Gangnam-gu, Seoul, 135-977, Korea

Contact Person : Choi, Seung-Hoon

Phone No. : +82 31 260 0098

### 1.3. Description of EUT

|                      |                                                                                   |
|----------------------|-----------------------------------------------------------------------------------|
| Kind of Product      | DIGITAL CAR AUDIO SYSTEM                                                          |
| Model Name           | AM1B1DPAN(Alt.: AM1B0DPKN, AM110DMGG, AM110DMGE, AM111DMGL, AM110DMGN, AM110DPGN) |
| Power Supply         | DC 14.4 V (Vehicle Battery)                                                       |
| Frequency Range      | 2 402 MHz ~ 2 480 MHz                                                             |
| Modulation Technique | GFSK, $\pi/4$ DQPSK, 8DPSK                                                        |
| Number of Channels   | 79 channels                                                                       |
| Antenna Type         | Internal Type                                                                     |
| Antenna Gain         | 3.5 dBi                                                                           |

### 1.4. Declaration by the manufacturer

- Adaptive Frequency Hopping is supported and use at least 20 channels
- Because EUT is only supplied by car DC power, AC power line emission test does not apply.

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**SGS Korea Co., Ltd. (Gunpo Laboratory)**

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RTT5041-20(2014.01.20)(2)

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A4(210 mm x 297 mm)

## 1.5. Information about the FHSS characteristics:

### 1.5.1. 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.

### 1.5.2. Equal Hopping Frequency Use

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

### 1.5.3. 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

### 1.5.4. System Receiver Input Bandwidth

Each channel bandwidth is 1 MHz.

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.

### 1.5.5. Equipment Description

15.247(a)(1) that the rx input bandwidths shift frequencies in synchronization with the transmitted

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 its 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.

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## 1.6. Test Equipment List

| Equipment                | Manufacturer               | Model                                | S/N           | Cal Date      | Cal Interval | Cal Due.      |
|--------------------------|----------------------------|--------------------------------------|---------------|---------------|--------------|---------------|
| Signal Generator         | R&S                        | SMR40                                | 100272        | Jul. 18, 2014 | Annual       | Jul. 18, 2015 |
| Signal Generator         | R&S                        | SMBV100A                             | 259067        | Jun. 25, 2014 | Annual       | Jun. 25, 2015 |
| Spectrum Analyzer        | Agilent                    | N9020A                               | MY53421758    | Nov. 04, 2014 | Annual       | Nov. 04, 2015 |
| Spectrum Analyzer        | R&S                        | FSV30                                | 103101        | Jul. 16, 2014 | Annual       | Jul. 16, 2015 |
| High Pass Filter         | Wainwright                 | WHK3.0/18G-10SS                      | 344           | Jun. 10, 2014 | Annual       | Jun. 10, 2015 |
| High Pass Filter         | Wainwright                 | WHNX7.5/26.5G-6SS                    | 15            | Jul. 02, 2014 | Annual       | Jul. 02, 2015 |
| Low Pass Filter          | Mini circuits              | NLP-1200+                            | V9500401023-2 | Jul. 01, 2014 | Annual       | Jul. 01, 2015 |
| Power Sensor             | R&S                        | NRP-Z81                              | 102910        | Dec. 29, 2014 | Annual       | Dec. 29, 2015 |
| Bluetooth Tester         | TESCOM                     | TC-3000C                             | 3000C000142   | Dec. 11, 2014 | Annual       | Dec. 11, 2015 |
| Directional Coupler      | KRYTAR                     | 152613                               | 162412        | Nov. 04, 2014 | Annual       | Nov. 04, 2015 |
| DC Power Supply          | Agilent                    | U8002A                               | MY50070064    | Mar. 27, 2014 | Annual       | Mar. 27, 2015 |
| Preamplifier             | H.P.                       | 8447F                                | 2944A03909    | Aug. 27, 2014 | Annual       | Aug. 27, 2015 |
| Preamplifier             | R&S                        | SCU 18                               | 10117         | Dec. 26, 2014 | Annual       | Dec. 26, 2015 |
| Preamplifier             | MITEQ Inc.                 | JS44-18004000-35-8P                  | 1546891       | Apr. 28, 2014 | Annual       | Apr. 28, 2015 |
| Test Receiver            | R&S                        | ESU26                                | 100109        | Mar. 04, 2014 | Annual       | Mar. 04, 2015 |
| Trilog Broadband Antenna | SCHWARZBECK MESSELEKTRONIK | VULB9163                             | 396           | Jun. 07, 2013 | Biennial     | Jun. 07, 2015 |
| Loop Antenna             | SCHWARZBECK MESSELEKTRONIK | FMZB 1519                            | 1519-039      | Jul. 09, 2013 | Biennial     | Jul. 09, 2015 |
| Horn Antenna             | R&S                        | HF906                                | 100326        | Dec. 10, 2013 | Biennial     | Dec. 10, 2015 |
| Horn Antenna             | SCHWARZBECK MESSELEKTRONIK | BBHA9170                             | BBHA9170223   | Sep. 01, 2014 | Biennial     | Sep. 01, 2016 |
| Antenna Master           | INN-CO                     | MM4000                               | N/A           | N.C.R.        | N/A          | N.C.R.        |
| Turn Table               | INN-CO                     | DS 1200S                             | N/A           | N.C.R.        | N/A          | N.C.R.        |
| Anechoic Chamber         | SY Corporation             | L × W × H<br>(9.6 m × 6.4 m × 6.4 m) | N/A           | N.C.R.        | N/A          | N.C.R.        |

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## 1.7. Summary of Test Results

The EUT has been tested according to the following specifications:

| APPLIED STANDARD:FCC Part15 subpart C |                                                                               |          |
|---------------------------------------|-------------------------------------------------------------------------------|----------|
| Section in FCC 15                     | Test Item                                                                     | Result   |
| 15.205(a)<br>15.209<br>15.247(d)      | Transmitter Radiated Spurious Emissions<br>and<br>Conducted Spurious Emission | Complied |
| 15.247(a)(1)                          | 20 dB Bandwidth                                                               | Complied |
| 15.247(b)(1)                          | Maximum Peak 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<br>(Dwell Time)                                             | Complied |

## 1.8. Sample calculation

Where relevant, the following sample calculation is provided:

### 1.8.1. Conducted test

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

### 1.8.2. Radiation test

Field strength level (dB $\mu$ V/m) = Measured level (dB $\mu$ V) + Antenna factor (dB) + Cable loss (dB) – amplifier gain (dB)

## 1.9. Test report revision

| Revision | Report number          | Date of Issue | Description                 |
|----------|------------------------|---------------|-----------------------------|
| 0        | F690501/RF-RTL008447   | 2015.02.24    | Initial                     |
| 1        | F690501/RF-RTL008447-1 | 2015.03.13    | Modified alternative models |

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## 1.10. Alternative models

| DM PE2 Audio B Type |           |                   | H/W      |         |               | S/W           |           |                                     |                   |    |
|---------------------|-----------|-------------------|----------|---------|---------------|---------------|-----------|-------------------------------------|-------------------|----|
|                     |           |                   | B/T type | KNOB    | NAND Capacity | Region        | Frequency | Freq. RANGE                         | Freq. SPACE       | VR |
| Basic Model         | AM1B1DPAN | R+CD+MP3+BT+VR+XM | 9552A2   | General | 1G            | North America | 9615A2    | 87.5 ~ 107.9 MHz<br>530 ~ 1 710 kHz | 200 kHz<br>10 kHz | O  |
| Alternative models  | AM1B0DPKN | R+CD+MP3+BT+VR+XM | 9552A1   | General | 1G            | Canada        | 9615A2    | 87.5 ~ 107.9 MHz<br>530 ~ 1 710 kHz | 200 kHz<br>10 kHz | O  |
|                     | AM110DMGG | R+CD+MP3+BT       | 9552A1   | Europe  | 1G            | General       | 9615A1    | 87.5 ~ 108.0 MHz<br>531 ~ 1 602 kHz | 100K kHz<br>9 kHz | X  |
|                     | AM110DMGE | R+CD+MP3+BT       | 9552A1   | Europe  | 1G            | General       | 9615A3    | 87.5 ~ 108.0 MHz<br>522 ~ 1 620 kHz | 50 kHz<br>9 kHz   | X  |
|                     | AM111DMGL | R+CD+MP3+BT       | 9552A1   | Europe  | 1G            | Colombia      | 9615A5    | 87.5 ~ 107.9 MHz<br>530 ~ 1 710 kHz | 100 kHz<br>10 kHz | X  |
|                     | AM110DMGN | R+CD+MP3+BT       | 9552A1   | Europe  | 1G            | General       | 9615A2    | 87.5 ~ 107.9 MHz<br>530 ~ 1 710 kHz | 200 kHz<br>10 kHz | X  |
|                     | AM110DPGN | R+CD+MP3+BT       | 9552A1   | Europe  | 1G            | Mexico        | 9615A2    | 87.5 ~ 107.9 MHz<br>530 ~ 1 710 kHz | 200 kHz<br>10 kHz | X  |

\*9552A1 : Not supporting bluetooth voice recognition

\*9553A2 : Supporting bluetooth voice recognition

\*VR : Voice Recognition

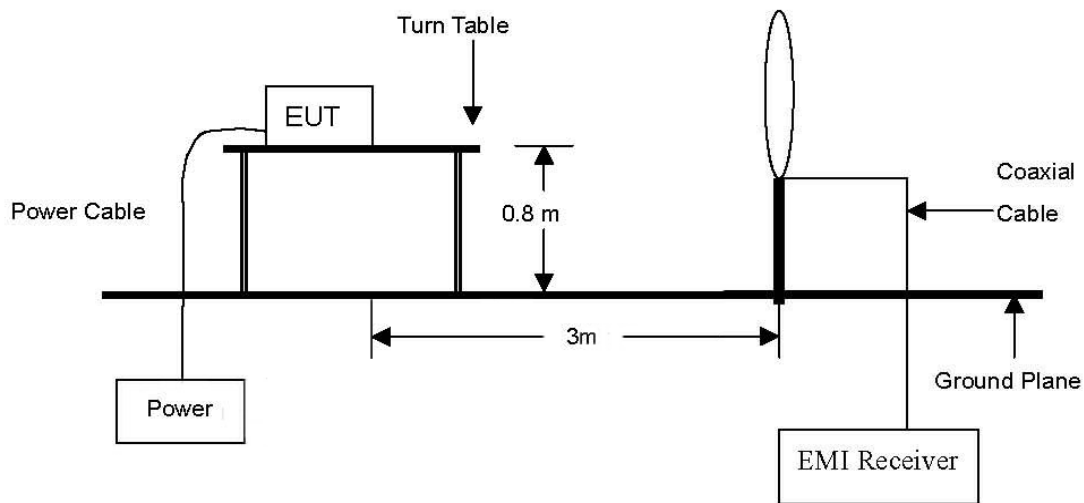
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## 2. Transmitter Radiated Spurious Emissions and Conducted Spurious Emission

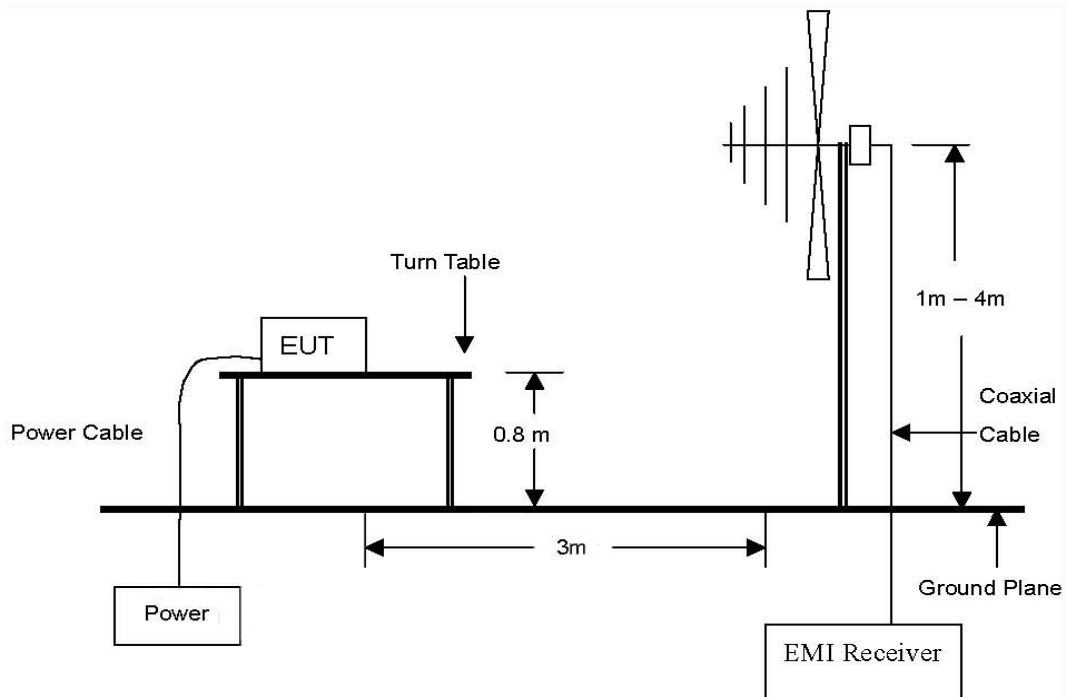
### 2.1. Test Setup

#### 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 kHz to 30 MHz Emissions.



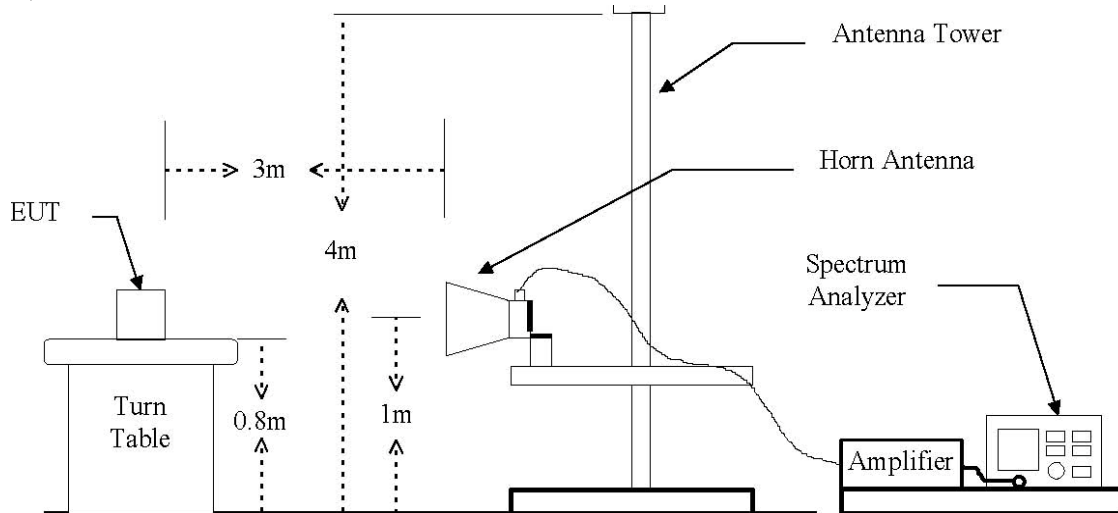
The diagram below shows the test setup that is utilized to make the measurements for emission from 30 MHz to 1 GHz Emissions.



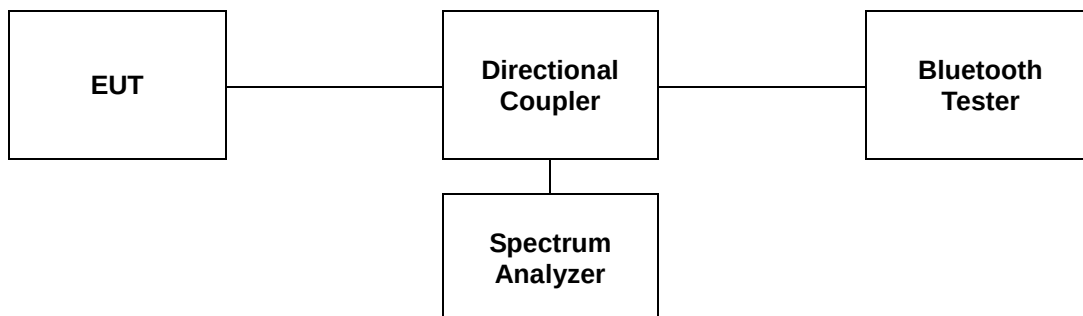
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The diagram below shows the test setup that is utilized to make the measurements for emission. The spurious emissions were investigated from 1 GHz to the 10th harmonic of the highest fundamental frequency or 40 GHz, whichever is lower.



## 2.1.2. Conducted Spurious Emissions



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## 2.2. Limit

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 section §15.209(a) is not required. In addition, radiated emission which in the restricted band, as define in section §15.205(a), must also comply the radiated emission limits specified in section §15.209(a) (see section §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<br>(MHz) | Distance<br>(Meters) | Field Strength<br>(dBμV/m)        | Field Strength<br>(μV/m) |
|--------------------|----------------------|-----------------------------------|--------------------------|
| 0.009 – 0.490      | 300                  | $20 \log (2\,400/F(\text{kHz}))$  | $2\,400/F(\text{kHz})$   |
| 0.490 – 1.705      | 30                   | $20 \log (24\,000/F(\text{kHz}))$ | $24\,000/F(\text{kHz})$  |
| 1.705 – 30.0       | 30                   | 29.54                             | 30                       |
| 30 - 88            | 3                    | 40.0                              | 100                      |
| 88 – 216           | 3                    | 43.5                              | 150                      |
| 216 – 960          | 3                    | 46.0                              | 200                      |
| Above 960          | 3                    | 54.0                              | 500                      |

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## 2.3. Test Procedures

Radiated emissions from the EUT were measured according to the dictates of DA000705, ANSI C63.4:2009

### 2.3.1. Test Procedures for emission below 30 MHz

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 MHz

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. During performing radiated emission below 1 GHz, 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 GHz, the EUT was set 3 meter away from the interference-receiving antenna.
3. The antenna is a Trilog Broadband 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 dB 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 dB margin would be re-tested one by one using peak, quasi-peak or average method as specified and then reported in a data sheet.

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#### NOTE;

All data rates and modes were investigated for radiated spurious emissions. Only the radiated emissions of the configuration that produced the worst case emissions are reported in this section.

1. The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 120 kHz for Peak detection (PK) and Quasi-peak detection (QP) at frequency below 1 GHz.
2. The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 1 MHz for Peak detection and frequency above 1 GHz.
3. The resolution bandwidth of test receiver/spectrum analyzer is 1 MHz and the video bandwidth is 1/T Hz for Average detection (AV) at frequency above 1 GHz.  
 $VBW = 360 \text{ Hz} \geq 1/T \text{ Hz}$ , Where T is the bluetooth pulse width in seconds( $T = 0.0029 \text{ s}$ ).  
Refer to the DH5, 3DH5 of time of occupancy (dwell time) test item.
4. When Average result is different from peak result over 20 dB (over-averaging), According to 15.35 (c), as a "duty cycle correction factor", pulse averaging with 20 log(duty cycle) has to be used.

### 2.3.2. Test Procedures for Conducted Spurious Emissions

#### 2.3.2.1. 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 bandedge, as well as any modulation products which fall outside of the authorized band of operation.

RBW  $\geq$  100 kHz

VBW  $\geq$  RBW

Sweep = auto

Detector function = peak

Trace = max hold

#### 2.3.2.2. Spurious RF Conducted Emissions

The transmitter output was connected to the spectrum analyzer.

RBW = 100 kHz

VBW  $\geq$  RBW

Sweep = auto

Detector function = peak

Trace = max hold

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## 2.4. Test Results

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

### 2.4.1. Spurious Radiated Emission

The frequency spectrum from 26 MHz to 1 000 MHz was investigated. All reading values are peak values.

| Radiated Emissions |                |             | Ant  | Correction Factors |               | Total           | FCC Limit      |             |
|--------------------|----------------|-------------|------|--------------------|---------------|-----------------|----------------|-------------|
| Frequency (MHz)    | Reading (dBμV) | Detect Mode | Pol. | AF (dB/m)          | AMP + CL (dB) | Actual (dBμV/m) | Limit (dBμV/m) | Margin (dB) |
| 31.09              | 43.74          | Peak        | V    | 12.71              | -27.05        | 29.40           | 40.00          | 10.60       |
| 100.61             | 39.90          | Peak        | V    | 12.27              | -26.27        | 25.90           | 43.50          | 17.60       |
| 113.91             | 38.95          | Peak        | H    | 12.75              | -26.20        | 25.50           | 43.50          | 18.00       |
| 188.80             | 41.01          | Peak        | V    | 10.13              | -25.44        | 25.70           | 43.50          | 17.80       |
| 320.03             | 43.17          | Peak        | H    | 14.57              | -24.64        | 33.10           | 46.00          | 12.90       |
| 370.03             | 44.60          | Peak        | H    | 16.13              | -24.83        | 35.90           | 46.00          | 10.10       |
| Above 400.00       | Not detected   | -           | -    | -                  | -             | -               | -              | -           |

Remark:

1. Spurious emissions for all channels and modes were investigated and almost the same below 1 GHz.
2. Reported spurious emissions are in **EDR / 3DH5 / low channel** as worst case among other modes.
3. Radiated spurious emission measurement as below  
(Actual = Reading + Antenna Factor + Amp + CL)
4. The device has a reference clock operating 26 MHz.

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## 2.4.2. Spurious Radiated Emission

The frequency spectrum above 1 000 MHz was investigated.

### Operating Mode: GFSK(1 Mbps)

#### A. Low Channel (2 402 MHz)

| Radiated Emissions |                      |             | Ant  | Correction Factors |         | Total                 | FCC Limit            |             |
|--------------------|----------------------|-------------|------|--------------------|---------|-----------------------|----------------------|-------------|
| Frequency (MHz)    | Reading (dB $\mu$ V) | Detect Mode | Pol. | AF (dB/m)          | CL (dB) | Actual (dB $\mu$ V/m) | Limit (dB $\mu$ V/m) | Margin (dB) |
| *2 310.00          | 24.11                | Peak        | V    | 27.77              | 6.48    | 58.36                 | 74.00                | 15.64       |
| *2 310.00          | 14.52                | Average     | V    | 27.77              | 6.48    | 48.77                 | 54.00                | 5.23        |
| *2 389.00          | 25.74                | Peak        | V    | 28.09              | 6.47    | 60.30                 | 74.00                | 13.70       |
| *2 389.00          | 14.88                | Average     | V    | 28.09              | 6.47    | 49.44                 | 54.00                | 4.56        |
| *2 390.00          | 24.24                | Peak        | V    | 28.08              | 6.47    | 58.79                 | 74.00                | 15.21       |
| *2 390.00          | 14.29                | Average     | V    | 28.08              | 6.47    | 48.84                 | 54.00                | 5.16        |

| Radiated Emissions |                      |             | Ant  | Correction Factors |               | Total                 | FCC Limit            |             |
|--------------------|----------------------|-------------|------|--------------------|---------------|-----------------------|----------------------|-------------|
| Frequency (MHz)    | Reading (dB $\mu$ V) | Detect Mode | Pol. | AF (dB/m)          | AMP + CL (dB) | Actual (dB $\mu$ V/m) | Limit (dB $\mu$ V/m) | Margin (dB) |
| *4 804.00          | 47.30                | Peak        | H    | 32.61              | -33.97        | 45.94                 | 74.00                | 28.06       |
| *4 804.00          | 43.68                | Average     | H    | 32.61              | -33.97        | 42.32                 | 54.00                | 11.68       |
| Above 4 900.00     | Not detected         | -           | -    | -                  | -             | -                     | -                    | -           |

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## B. Middle Channel (2 441 MHz)

| Radiated Emissions |                      |             | Ant  | Correction Factors |               | Total                 | FCC Limit            |             |
|--------------------|----------------------|-------------|------|--------------------|---------------|-----------------------|----------------------|-------------|
| Frequency (MHz)    | Reading (dB $\mu$ V) | Detect Mode | Pol. | AF (dB/m)          | AMP + CL (dB) | Actual (dB $\mu$ V/m) | Limit (dB $\mu$ V/m) | Margin (dB) |
| *4 882.01          | 50.10                | Peak        | H    | 33.01              | -33.72        | 49.39                 | 74.00                | 24.61       |
| *4 882.01          | 47.15                | Average     | H    | 33.01              | -33.72        | 46.44                 | 54.00                | 7.56        |
| Above 4 900.00     | Not detected         | -           | -    | -                  | -             | -                     | -                    | -           |

## C. High Channel (2 480 MHz)

| Radiated Emissions |                      |             | Ant  | Correction Factors |         | Total                 | FCC Limit            |             |
|--------------------|----------------------|-------------|------|--------------------|---------|-----------------------|----------------------|-------------|
| Frequency (MHz)    | Reading (dB $\mu$ V) | Detect Mode | Pol. | AF (dB/m)          | CL (dB) | Actual (dB $\mu$ V/m) | Limit (dB $\mu$ V/m) | Margin (dB) |
| *2 483.50          | 24.13                | Peak        | V    | 28.17              | 6.65    | 58.95                 | 74.00                | 15.05       |
| *2 483.50          | 15.22                | Average     | V    | 28.17              | 6.65    | 50.04                 | 54.00                | 3.96        |
| *2 499.20          | 25.68                | Peak        | V    | 28.30              | 6.87    | 60.85                 | 74.00                | 13.15       |
| *2 499.20          | 15.29                | Average     | V    | 28.30              | 6.87    | 50.46                 | 54.00                | 3.54        |
| *2 500.00          | 24.77                | Peak        | V    | 28.31              | 6.88    | 59.96                 | 74.00                | 14.04       |
| *2 500.00          | 15.20                | Average     | V    | 28.31              | 6.88    | 50.39                 | 54.00                | 3.61        |

| Radiated Emissions |                      |             | Ant  | Correction Factors |               | Total                 | FCC Limit            |             |
|--------------------|----------------------|-------------|------|--------------------|---------------|-----------------------|----------------------|-------------|
| Frequency (MHz)    | Reading (dB $\mu$ V) | Detect Mode | Pol. | AF (dB/m)          | AMP + CL (dB) | Actual (dB $\mu$ V/m) | Limit (dB $\mu$ V/m) | Margin (dB) |
| *4 959.94          | 46.50                | Peak        | H    | 33.16              | -33.55        | 46.11                 | 74.00                | 27.89       |
| *4 959.94          | 42.30                | Average     | H    | 33.16              | -33.55        | 41.91                 | 54.00                | 12.09       |
| Above 5 000.00     | Not detected         | -           | -    | -                  | -             | -                     | -                    | -           |

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**Operating Mode: 8DPSK(3 Mbps)**
**A. Low Channel (2 402 MHz)**

| Radiated Emissions |                      |             | Ant  | Correction Factors |         | Total                 | FCC Limit            |             |
|--------------------|----------------------|-------------|------|--------------------|---------|-----------------------|----------------------|-------------|
| Frequency (MHz)    | Reading (dB $\mu$ V) | Detect Mode | Pol. | AF (dB/m)          | CL (dB) | Actual (dB $\mu$ V/m) | Limit (dB $\mu$ V/m) | Margin (dB) |
| *2 310.00          | 24.60                | Peak        | V    | 27.77              | 6.48    | 58.85                 | 74.00                | 15.15       |
| *2 310.00          | 14.55                | Average     | V    | 27.77              | 6.48    | 48.80                 | 54.00                | 5.20        |
| *2 374.50          | 26.00                | Peak        | V    | 28.17              | 6.55    | 60.72                 | 74.00                | 13.28       |
| *2 374.50          | 14.80                | Average     | V    | 28.17              | 6.55    | 49.52                 | 54.00                | 4.48        |
| *2 390.00          | 24.20                | Peak        | V    | 28.08              | 6.47    | 58.75                 | 74.00                | 15.25       |
| *2 390.00          | 14.80                | Average     | V    | 28.08              | 6.47    | 49.35                 | 54.00                | 4.65        |

| Radiated Emissions |                      |             | Ant  | Correction Factors |               | Total                 | FCC Limit            |             |
|--------------------|----------------------|-------------|------|--------------------|---------------|-----------------------|----------------------|-------------|
| Frequency (MHz)    | Reading (dB $\mu$ V) | Detect Mode | Pol. | AF (dB/m)          | AMP + CL (dB) | Actual (dB $\mu$ V/m) | Limit (dB $\mu$ V/m) | Margin (dB) |
| *4 804.04          | 44.98                | Peak        | H    | 32.61              | -33.97        | 43.62                 | 74.00                | 30.38       |
| *4 804.04          | 37.19                | Average     | H    | 32.61              | -33.97        | 35.83                 | 54.00                | 18.17       |
| Above 4 900.00     | Not detected         | -           | -    | -                  | -             | -                     | -                    | -           |

**B. Middle Channel (2 441 MHz)**

| Radiated Emissions |                      |             | Ant  | Correction Factors |               | Total                 | FCC Limit            |             |
|--------------------|----------------------|-------------|------|--------------------|---------------|-----------------------|----------------------|-------------|
| Frequency (MHz)    | Reading (dB $\mu$ V) | Detect Mode | Pol. | AF (dB/m)          | AMP + CL (dB) | Actual (dB $\mu$ V/m) | Limit (dB $\mu$ V/m) | Margin (dB) |
| *4 881.92          | 46.68                | Peak        | H    | 33.01              | -33.72        | 45.97                 | 74.00                | 28.03       |
| *4 881.92          | 39.01                | Average     | H    | 33.01              | -33.72        | 38.30                 | 54.00                | 15.70       |
| Above 4 900.00     | Not detected         | -           | -    | -                  | -             | -                     | -                    | -           |

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## C. High Channel (2 480 MHz)

| Radiated Emissions |                |             | Ant  | Correction Factors |         | Total           | FCC Limit      |             |
|--------------------|----------------|-------------|------|--------------------|---------|-----------------|----------------|-------------|
| Frequency (MHz)    | Reading (dBμV) | Detect Mode | Pol. | AF (dB/m)          | CL (dB) | Actual (dBμV/m) | Limit (dBμV/m) | Margin (dB) |
| *2 483.50          | 24.55          | Peak        | V    | 28.17              | 6.65    | 59.37           | 74.00          | 14.63       |
| *2 483.50          | 15.07          | Average     | V    | 28.17              | 6.65    | 49.89           | 54.00          | 4.11        |
| *2 499.15          | 26.60          | Peak        | V    | 28.30              | 6.87    | 61.77           | 74.00          | 12.23       |
| *2 499.15          | 15.40          | Average     | V    | 28.30              | 6.87    | 50.57           | 54.00          | 3.43        |
| *2 500.00          | 24.88          | Peak        | V    | 28.31              | 6.88    | 60.07           | 74.00          | 13.93       |
| *2 500.00          | 15.40          | Average     | V    | 28.31              | 6.88    | 50.59           | 54.00          | 3.41        |

| Radiated Emissions |                |             | Ant  | Correction Factors |               | Total           | FCC Limit      |             |
|--------------------|----------------|-------------|------|--------------------|---------------|-----------------|----------------|-------------|
| Frequency (MHz)    | Reading (dBμV) | Detect Mode | Pol. | AF (dB/m)          | AMP + CL (dB) | Actual (dBμV/m) | Limit (dBμV/m) | Margin (dB) |
| *4 959.91          | 43.30          | Peak        | H    | 33.16              | -33.55        | 42.91           | 74.00          | 31.09       |
| *4 959.91          | 34.61          | Average     | H    | 33.16              | -33.55        | 34.22           | 54.00          | 19.78       |
| Above 5 000.00     | Not detected   | -           | -    | -                  | -             | -               | -              | -           |

## Remarks:

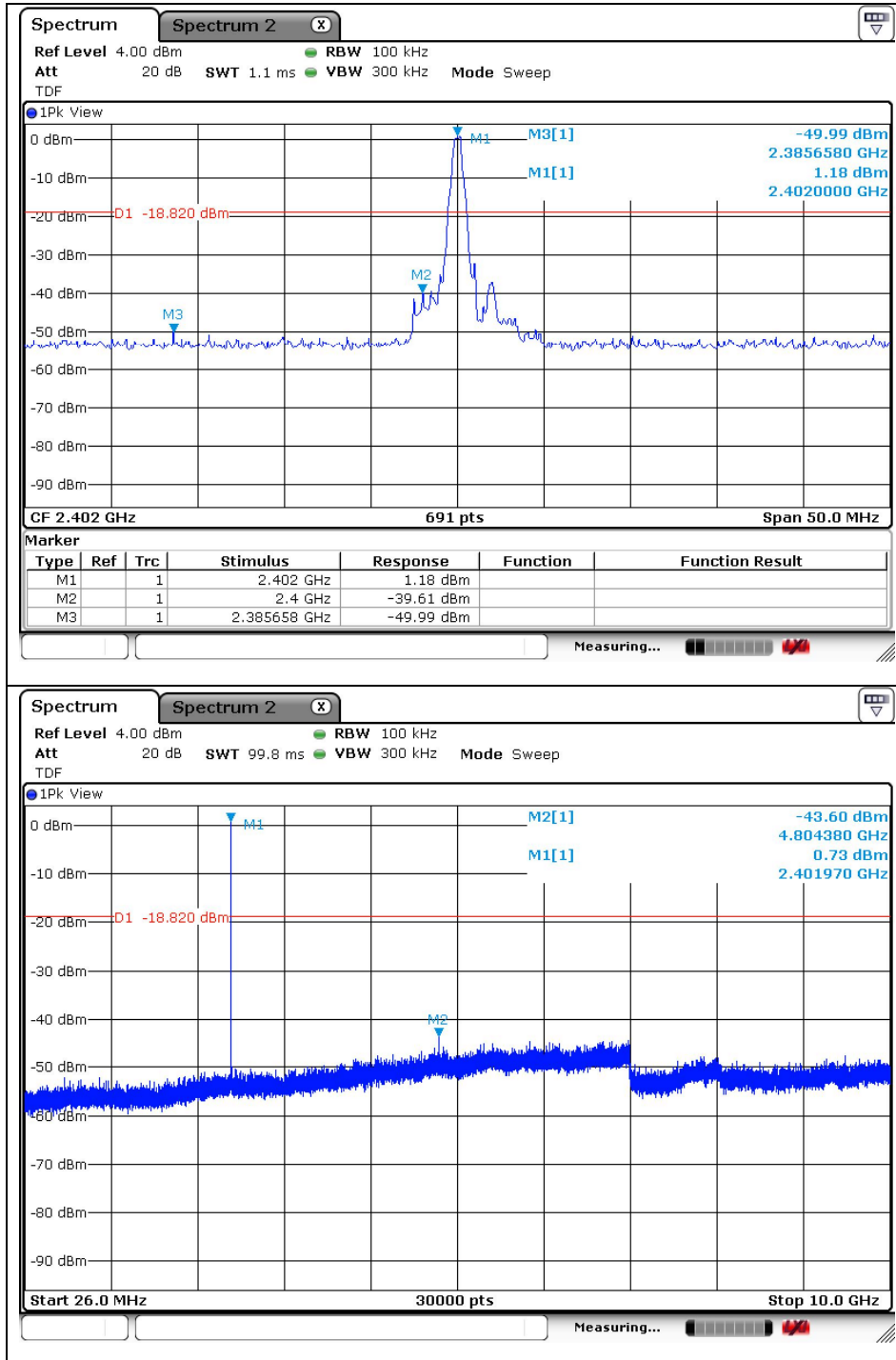
1. "\*" means the restricted band.
2. Measuring frequencies from 1 GHz to the 10<sup>th</sup> harmonic of highest fundamental frequency.
3. Radiated emissions measured in frequency above 1 000 MHz were made with an instrument using peak/average detector mode if frequency was in the restricted band.
4. Actual = Reading + AF + AMP + CL

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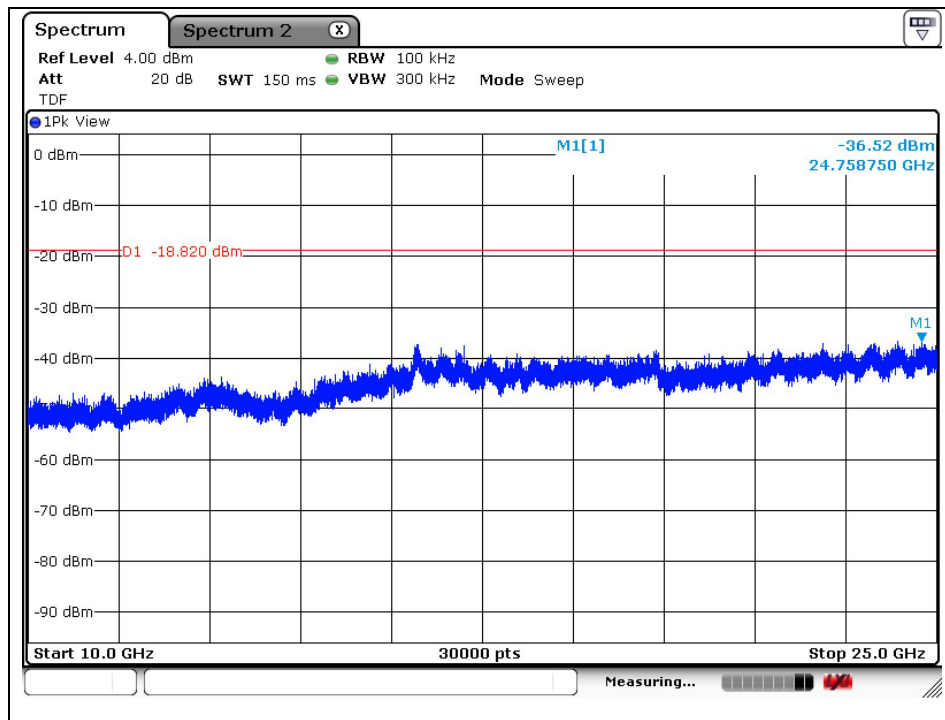
## 2.4.3. Spurious RF Conducted Emissions: Plot of Spurious RF Conducted Emission

Operating Mode: GFSK(1 Mbps)

Low Channel

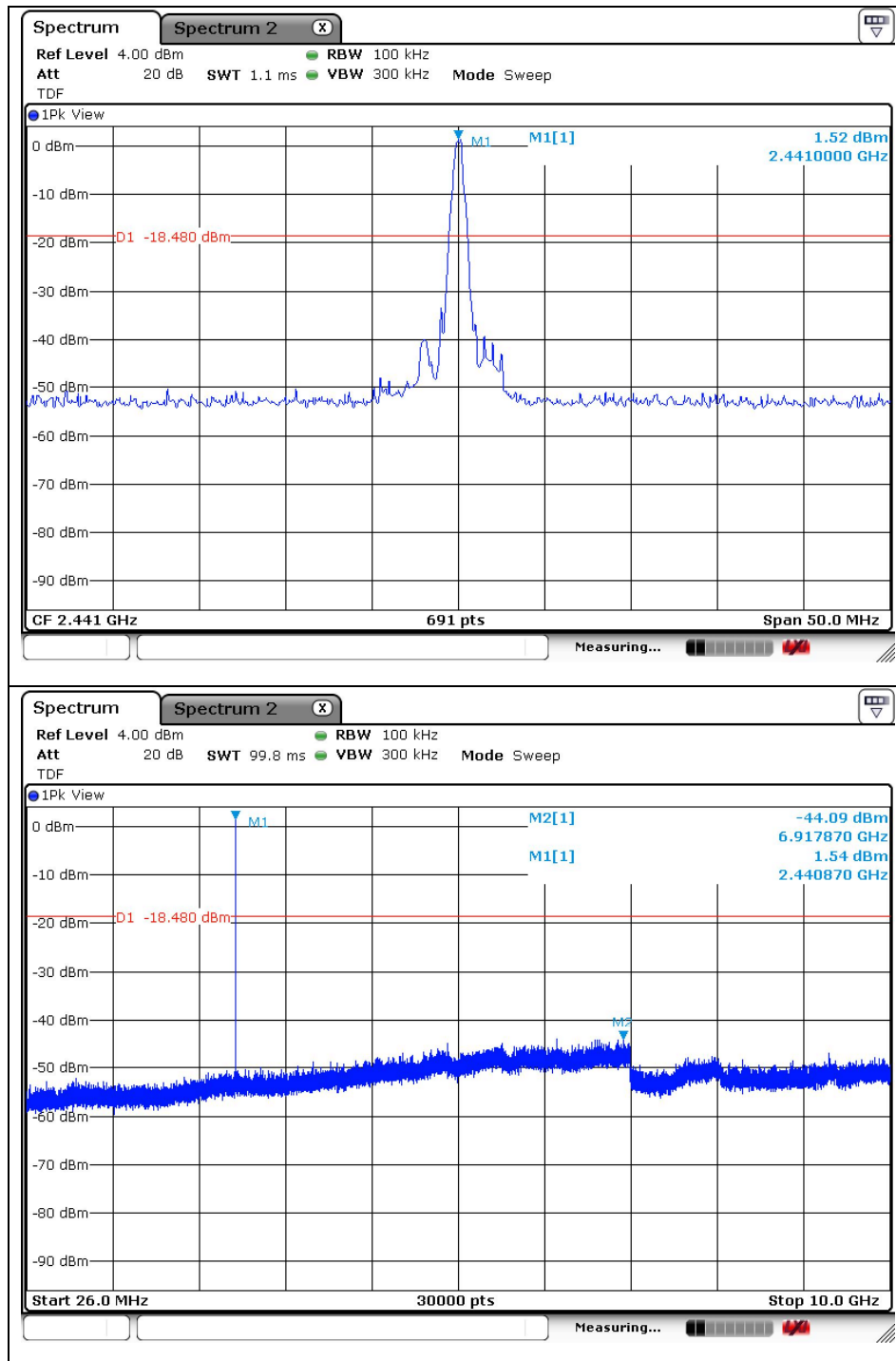


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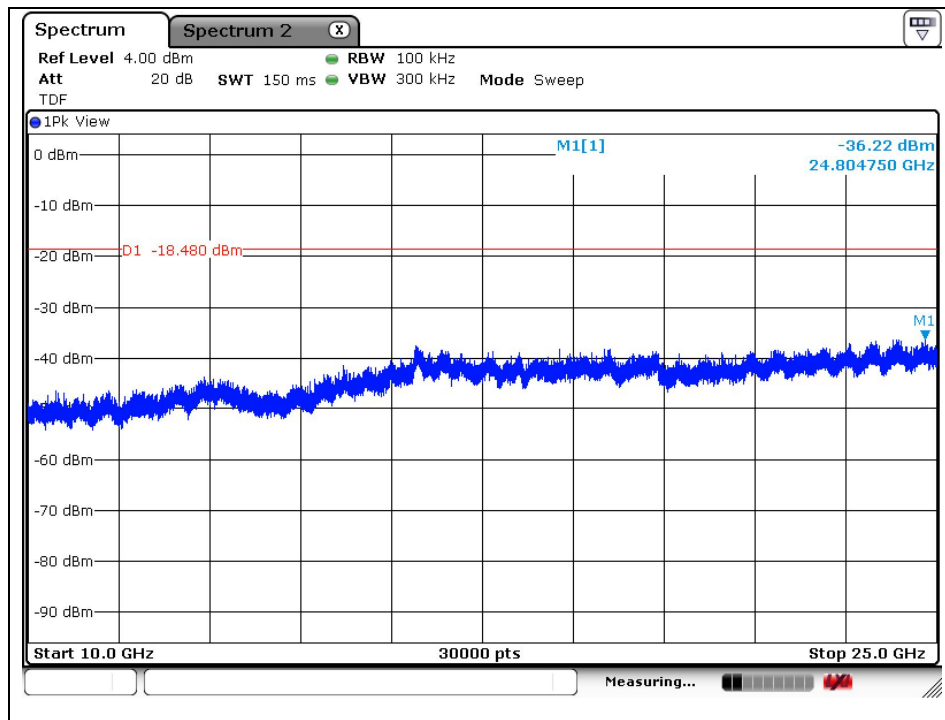


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## Middle Channel

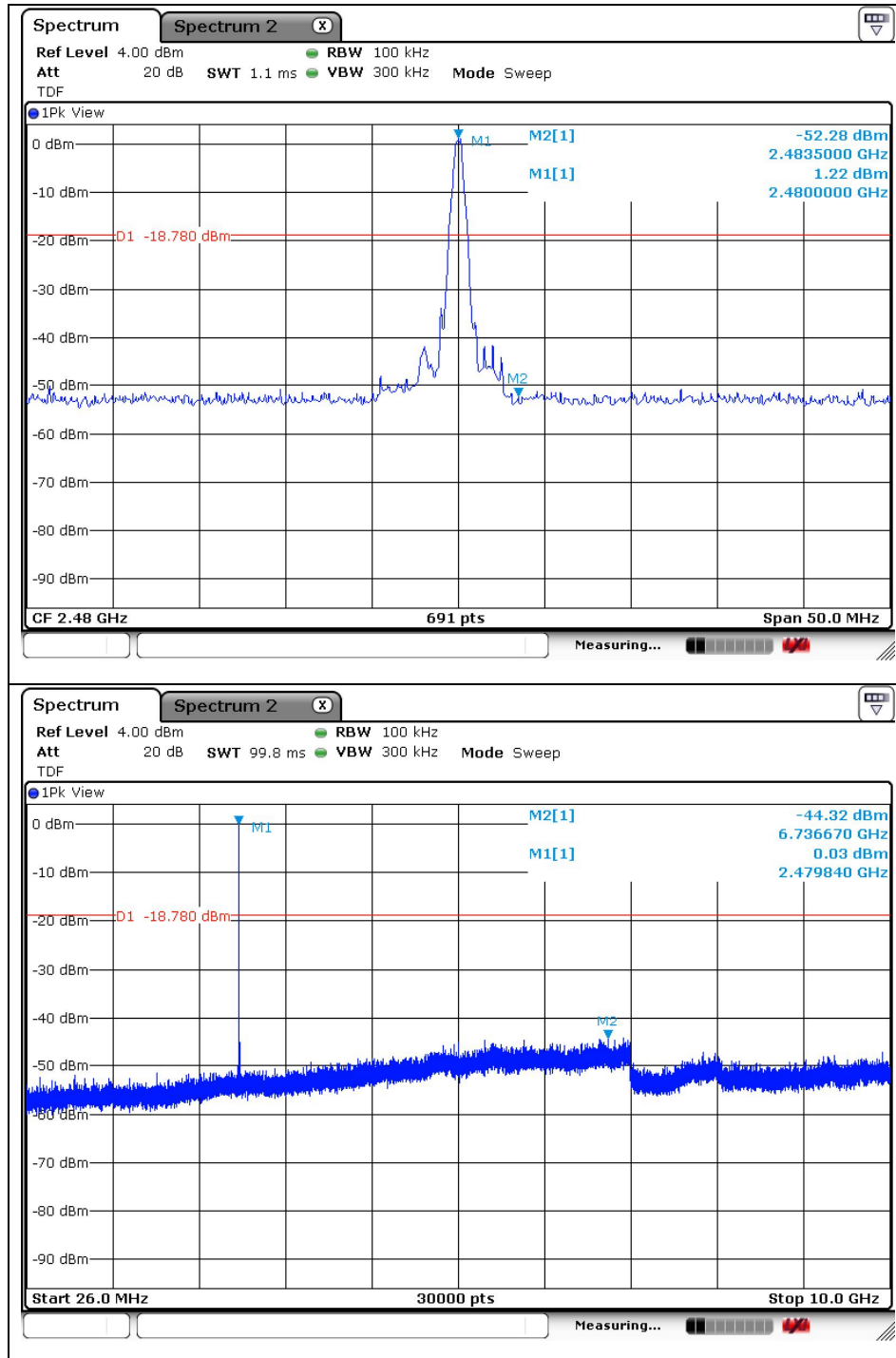


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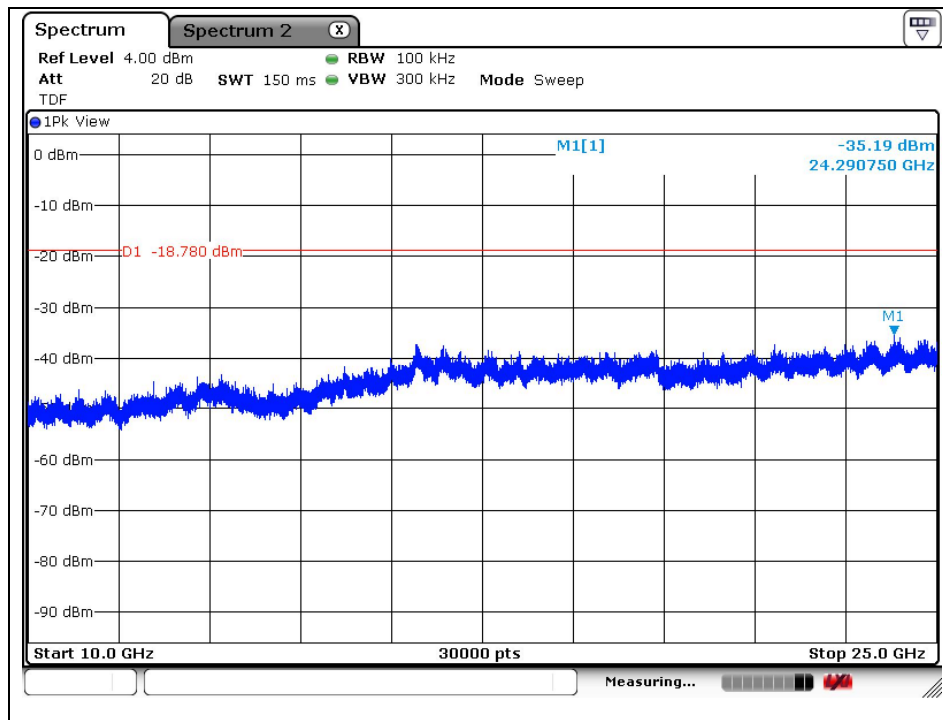


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## High Channel

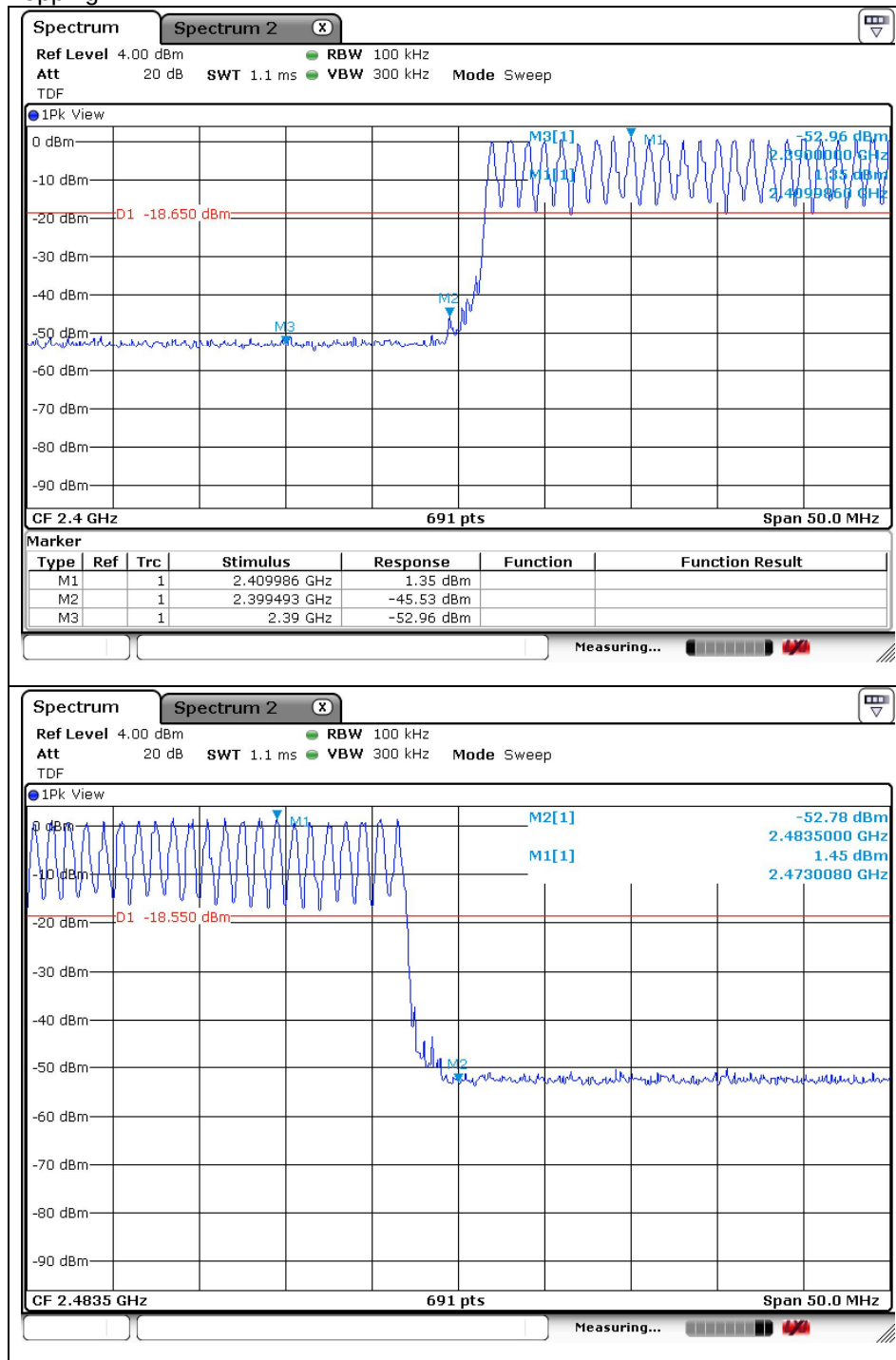


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## Band edge at Hopping

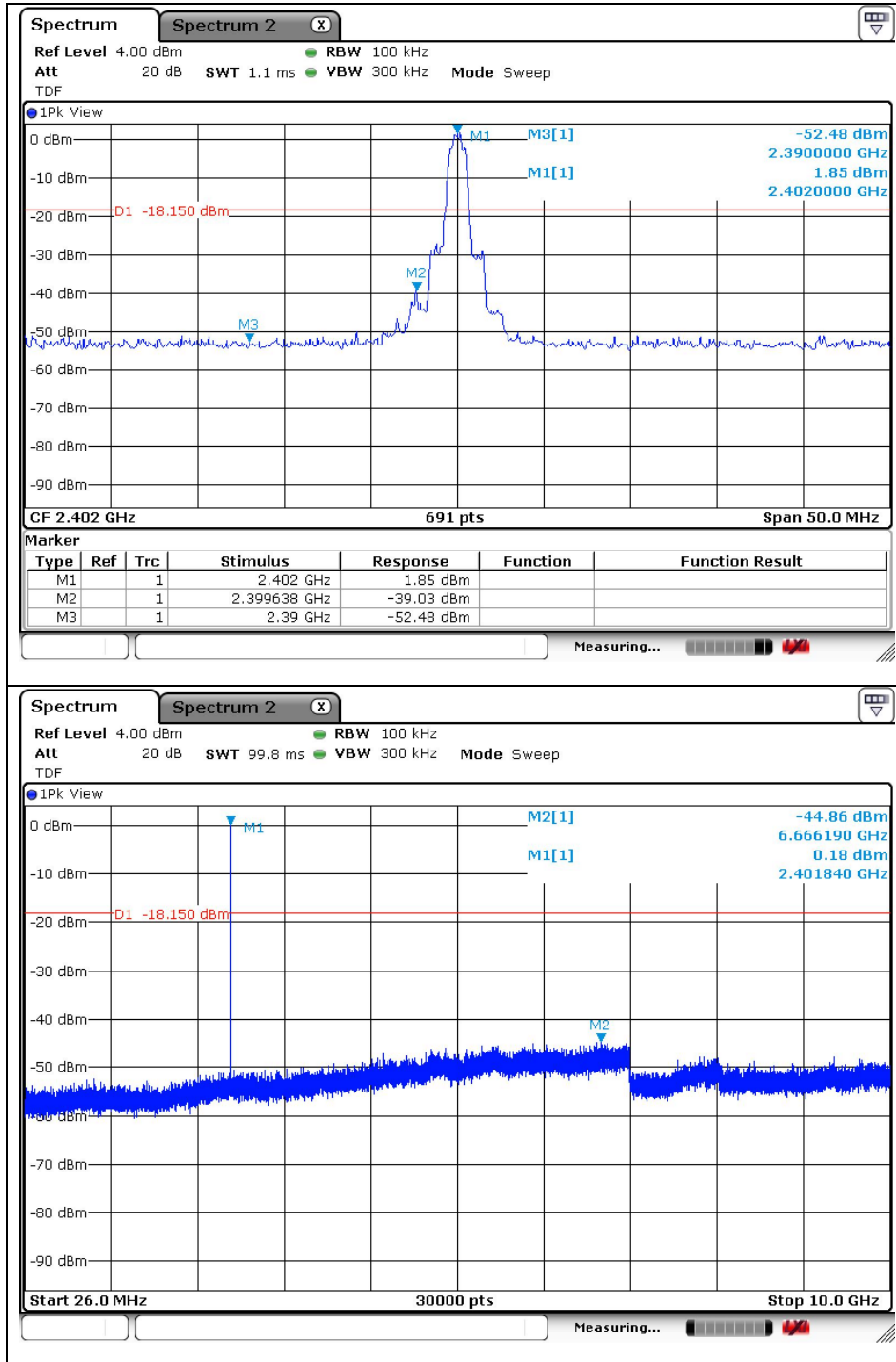


The results shown in this test report refer only to the sample(s) tested unless otherwise stated. This test report cannot be reproduced, except in full, without prior written permission of the Company.

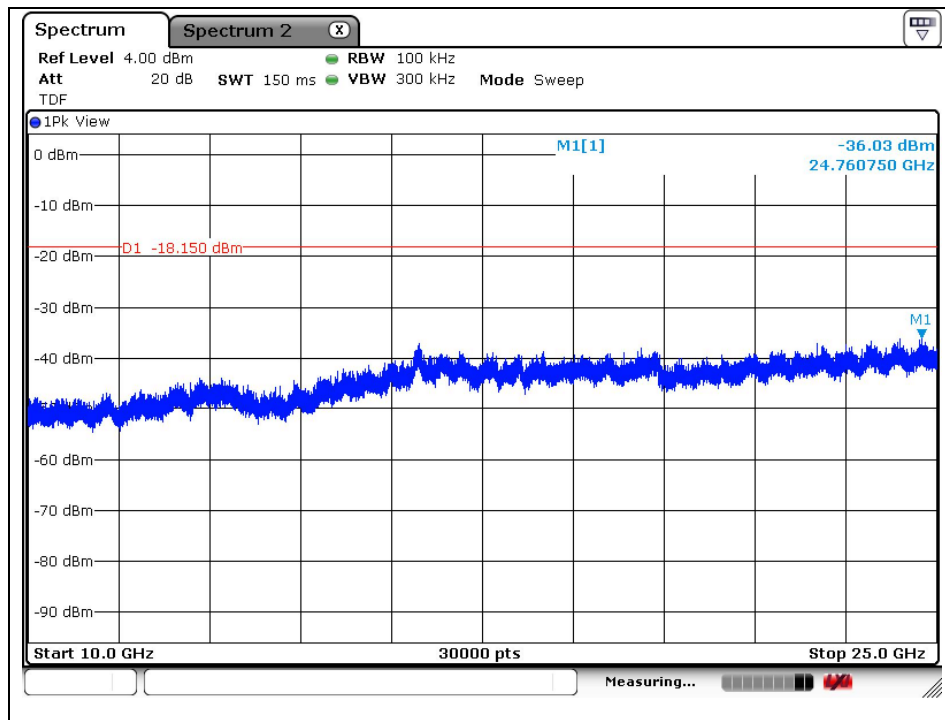


## Operating Mode : 8DPSK(3 Mbps)

Low Channel

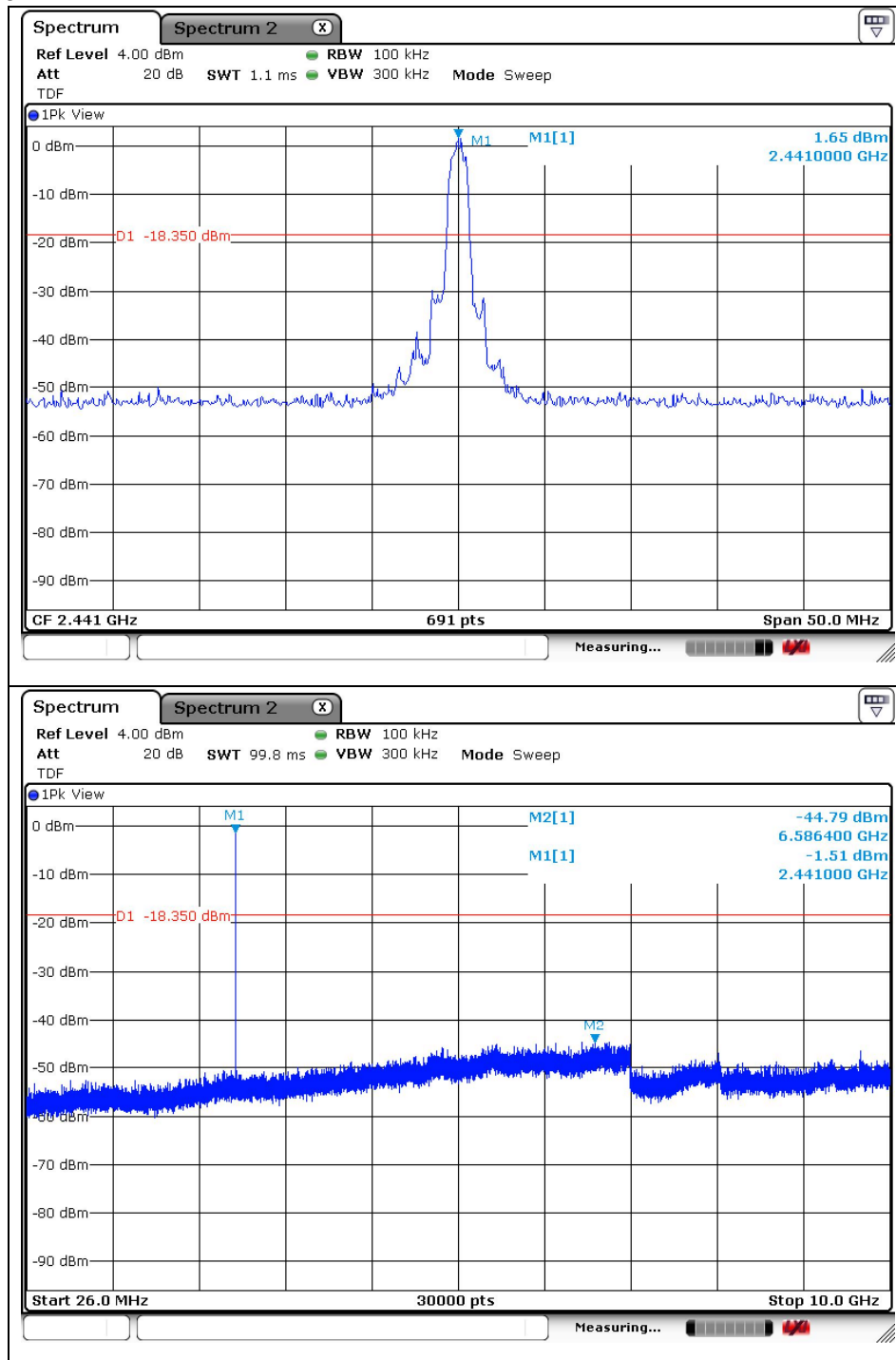


The results shown in this test report refer only to the sample(s) tested unless otherwise stated. This test report cannot be reproduced, except in full, without prior written permission of the Company.

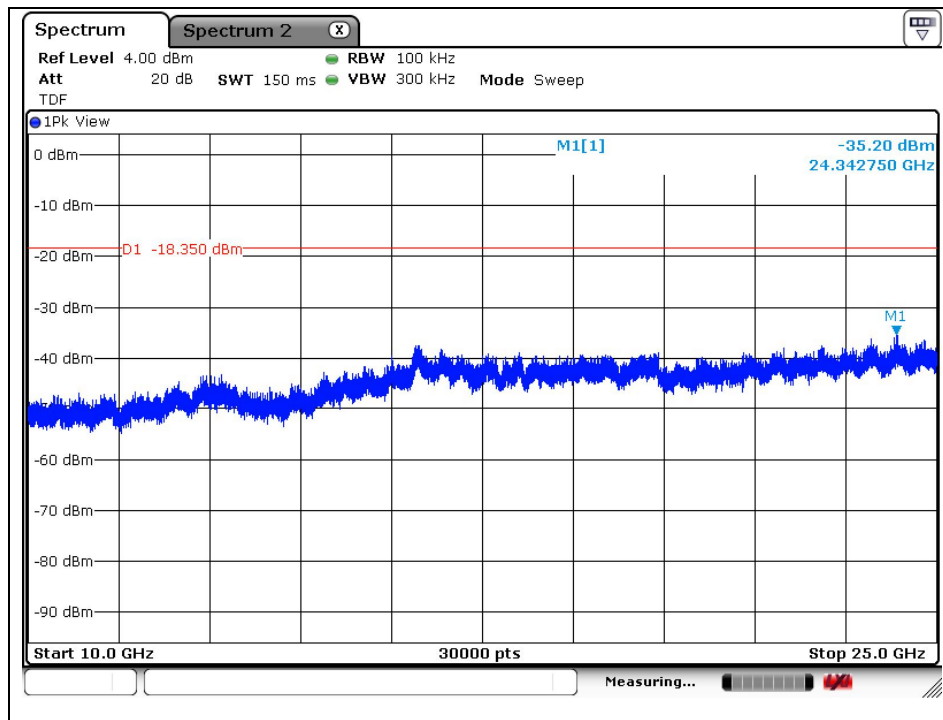


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## Middle Channel

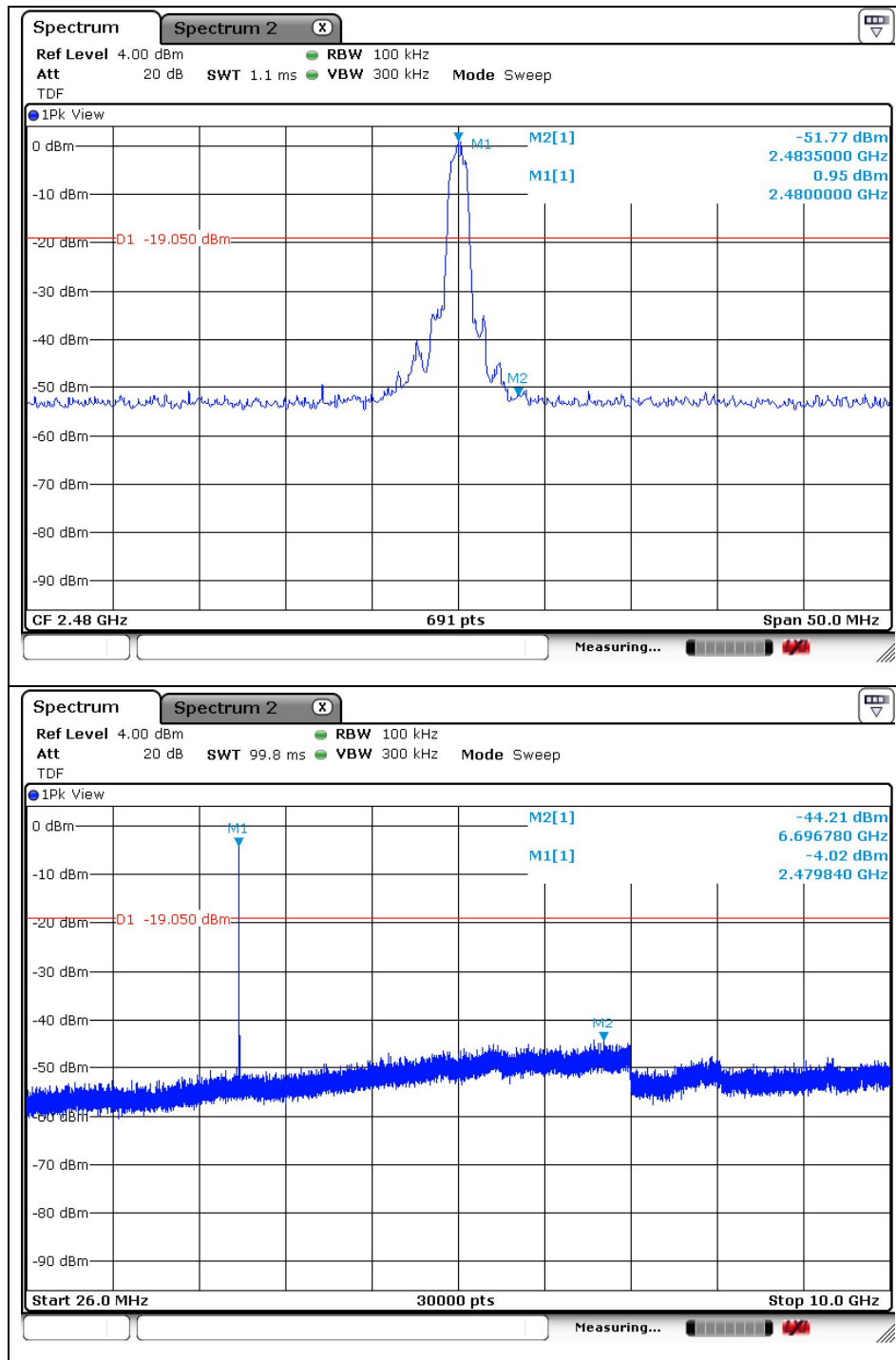


The results shown in this test report refer only to the sample(s) tested unless otherwise stated. This test report cannot be reproduced, except in full, without prior written permission of the Company.

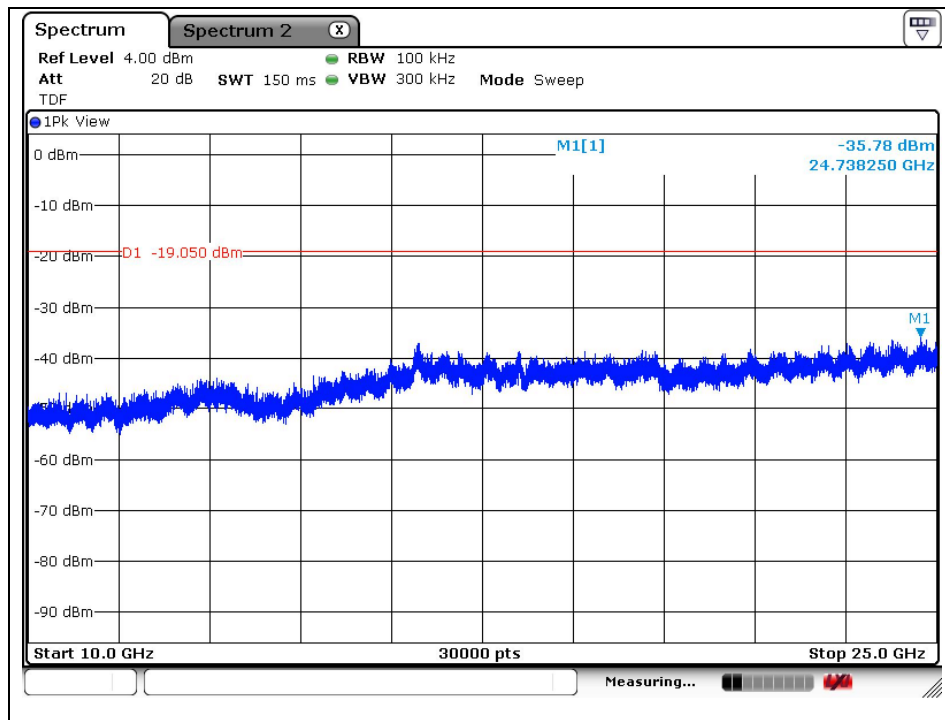


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## High Channel

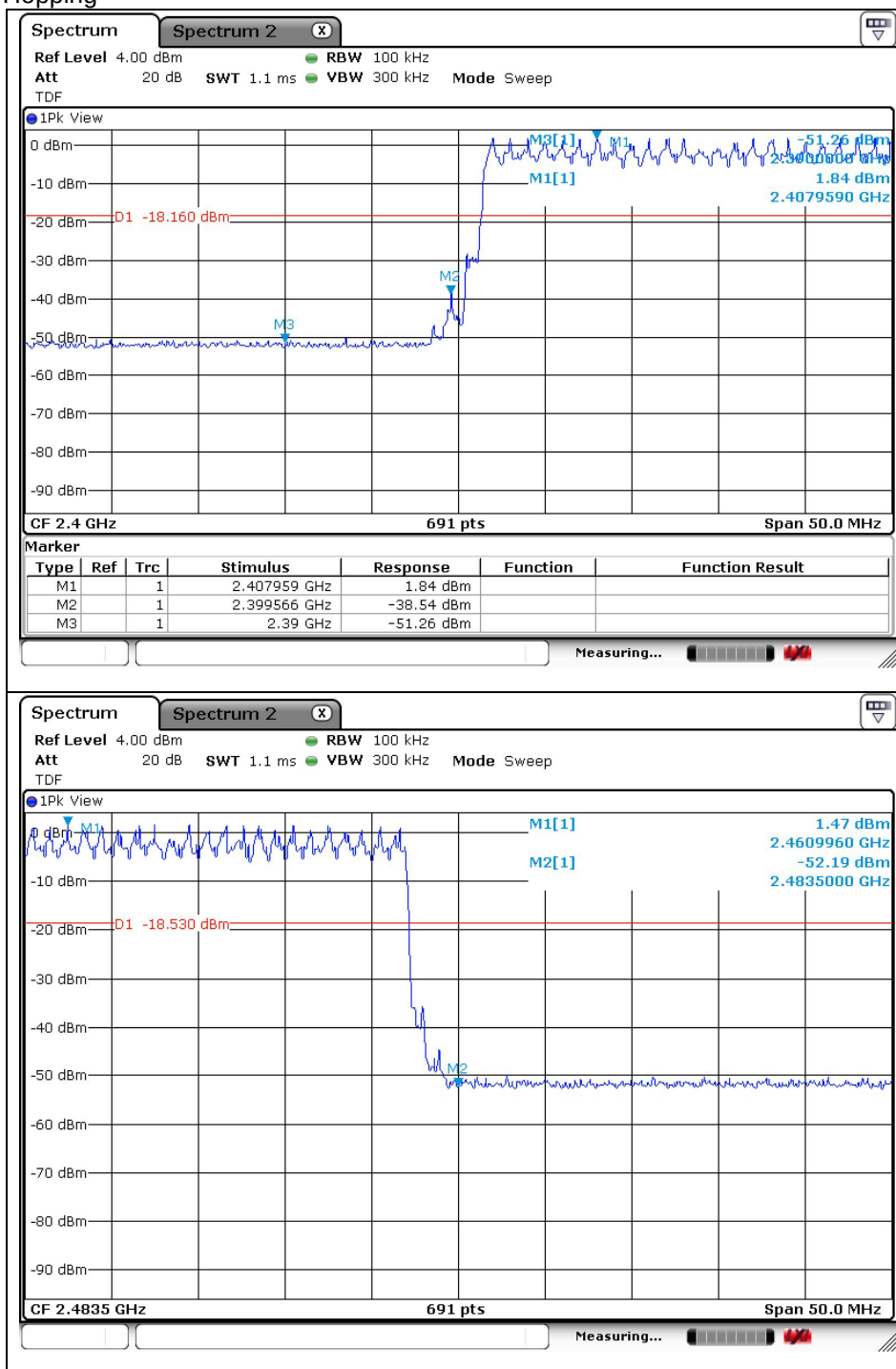


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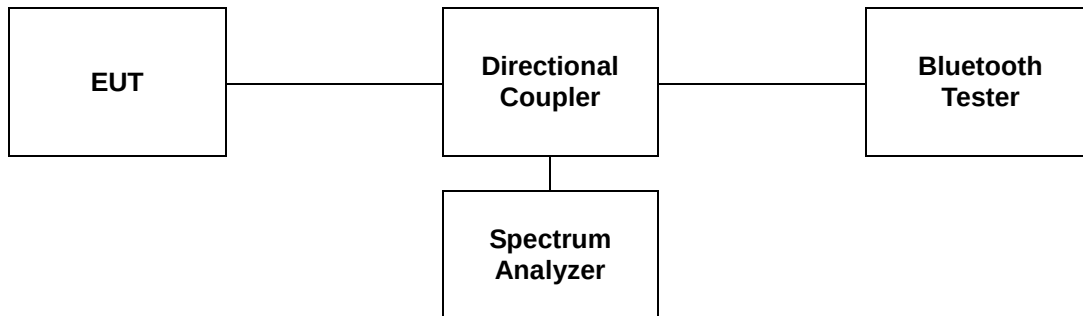
## Band edge at Hopping



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### 3. 20 dB Bandwidth

#### 3.1. Test Setup



#### 3.2. Limit

Limit: Not Applicable

#### 3.3. Test Procedure

##### 3.3.1. 20 dB Bandwidth

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 DA000705

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

Use the following spectrum analyzer setting :

Span = approximately 2 to 3 times the 20 dB bandwidth, centered on a hopping channel.

RBW = greater than 1 % of the 20 dB bandwidth

VBW = RBW

Sweep = auto

Detector = peak

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 dB 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 dB bandwidth of the emission.

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RTT5041-20(2014.01.20)(2)

Tel. +82 31 428 5700 / Fax. +82 31 427 2370

A4(210 mm x 297 mm)



### 3.4. Test Results

Ambient temperature : (23 ± 1) °C

Relative humidity : 47 % R.H.

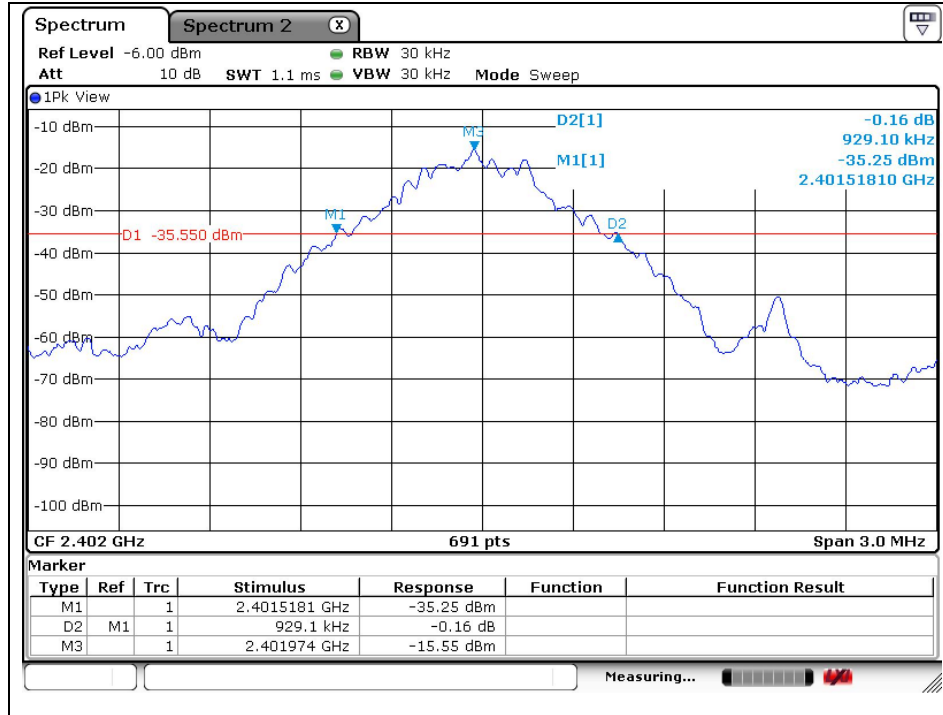
| Operation Mode | Data Rate | Channel | Channel Frequency (MHz) | 20 dB Bandwidth(MHz) |
|----------------|-----------|---------|-------------------------|----------------------|
| GFSK           | 1 Mbps    | Low     | 2 402                   | 0.93                 |
|                |           | Middle  | 2 441                   | 0.92                 |
|                |           | High    | 2 480                   | 0.93                 |
| π/4DQPSK       | 2 Mbps    | Low     | 2 402                   | 1.27                 |
|                |           | Middle  | 2 441                   | 1.24                 |
|                |           | High    | 2 480                   | 1.24                 |
| 8DPSK          | 3 Mbps    | Low     | 2 402                   | 1.27                 |
|                |           | Middle  | 2 441                   | 1.26                 |
|                |           | High    | 2 480                   | 1.26                 |

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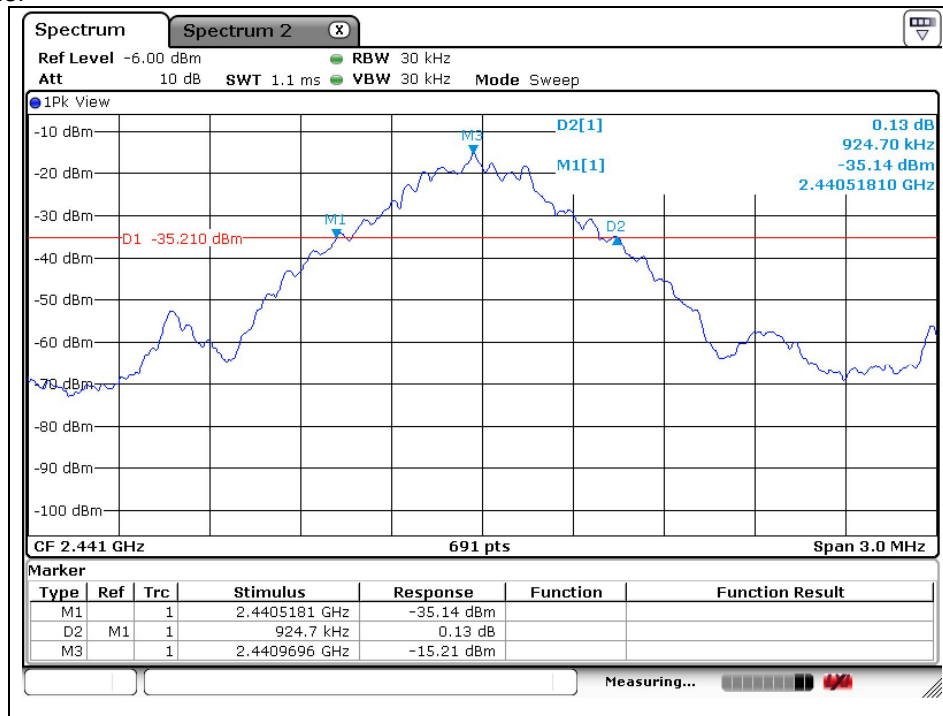
## 20 dB Bandwidth

### Operating Mode: GFSK

Low Channel

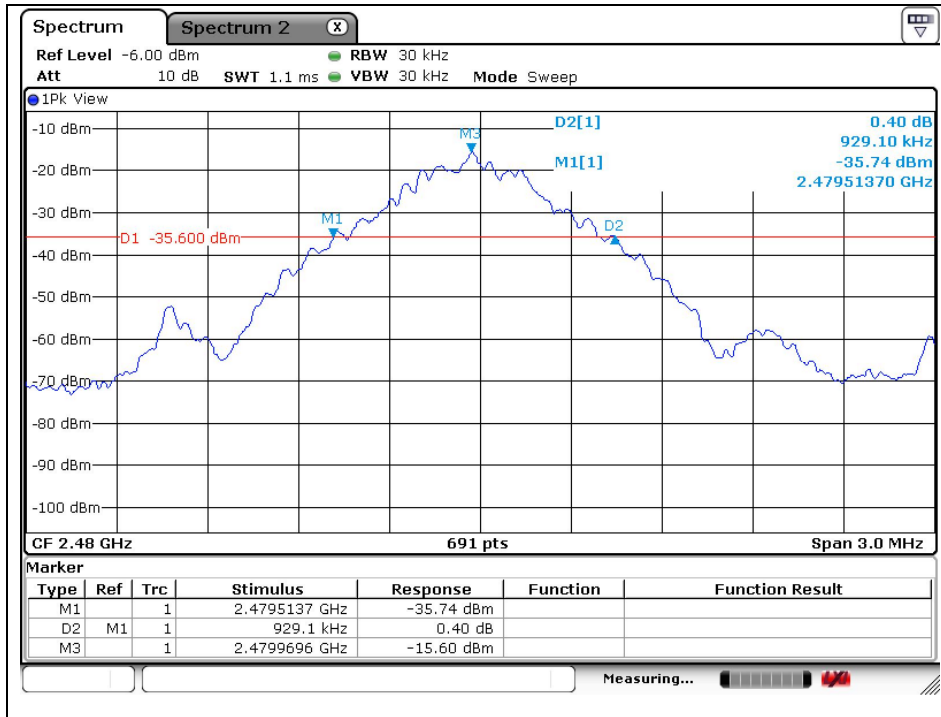


Middle Channel



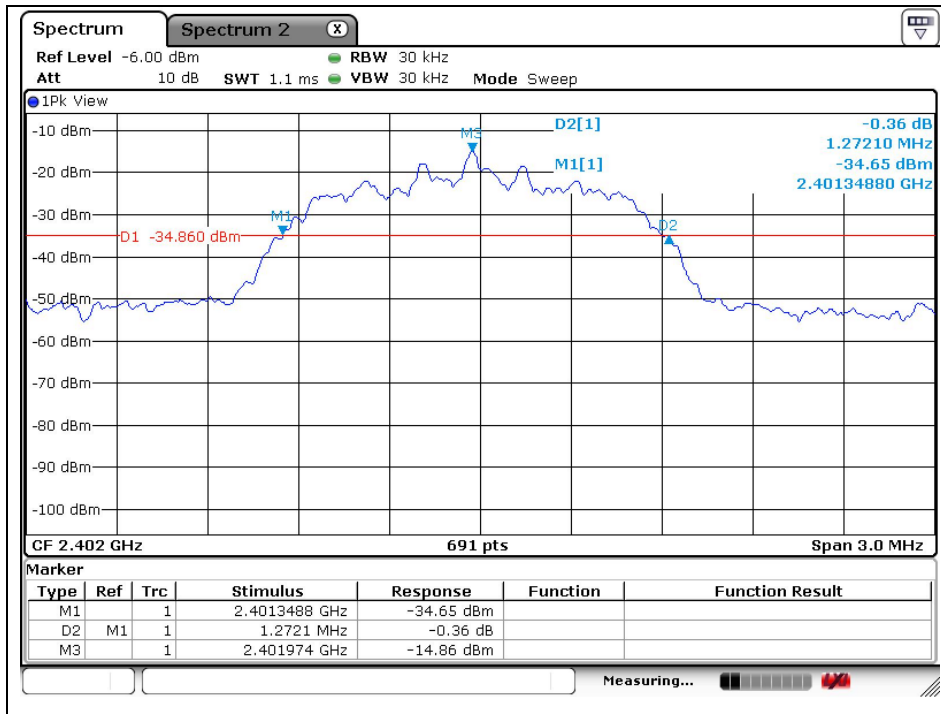
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## High Channel



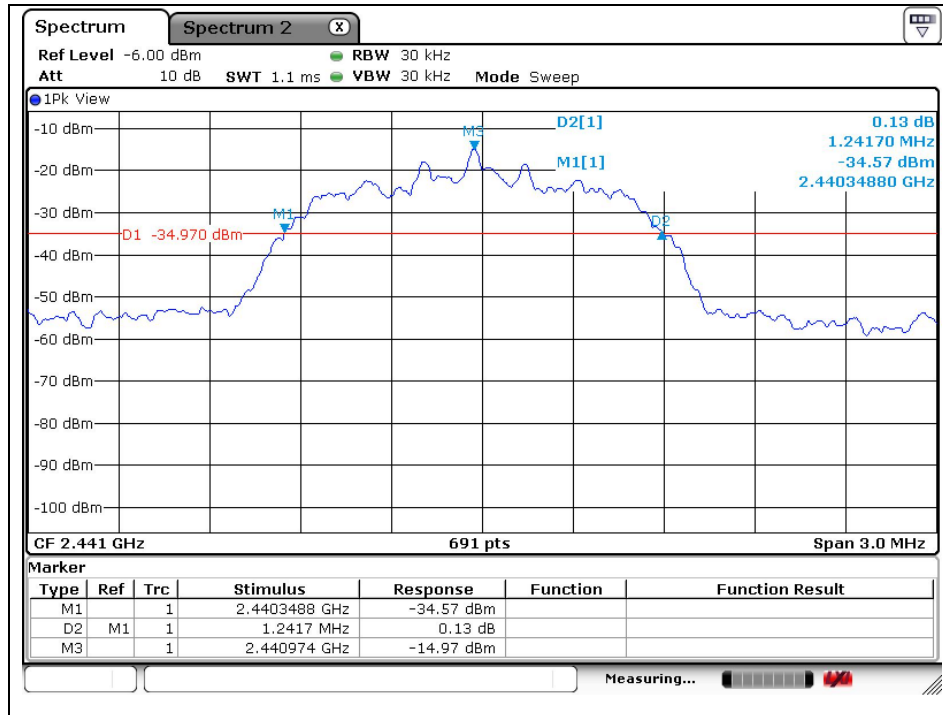
## Operating Mode: $\pi/4$ DQPSK

### Low Channel

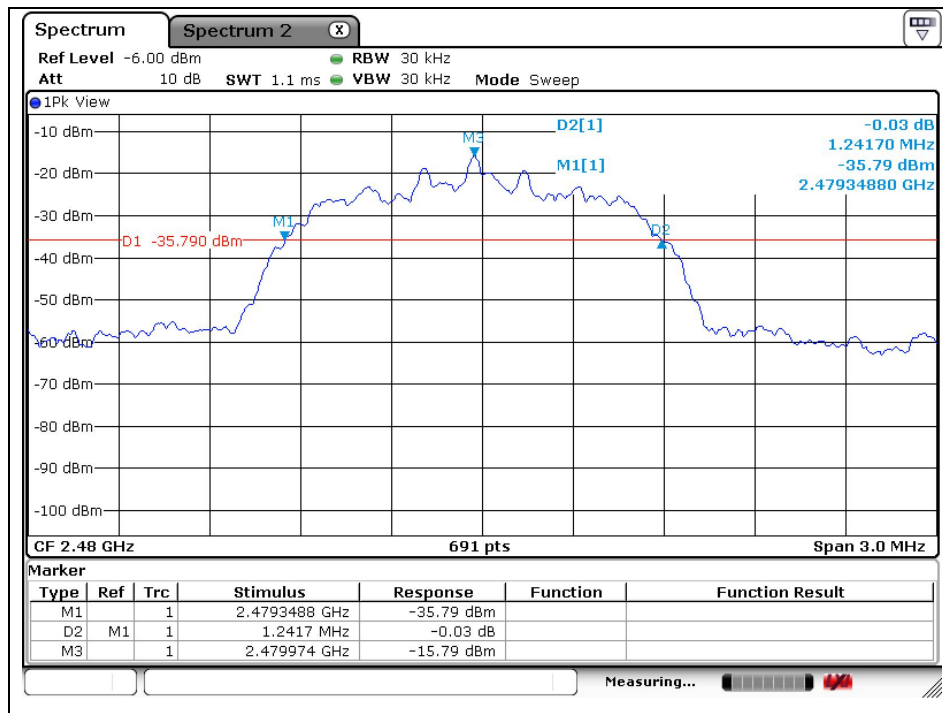


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## Middle Channel



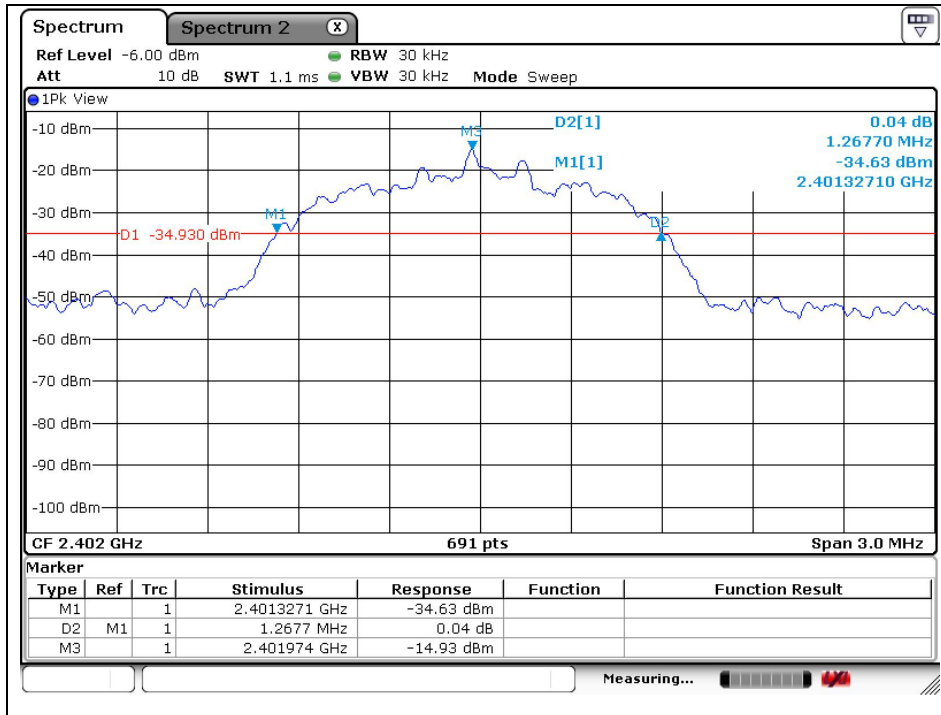
## High Channel



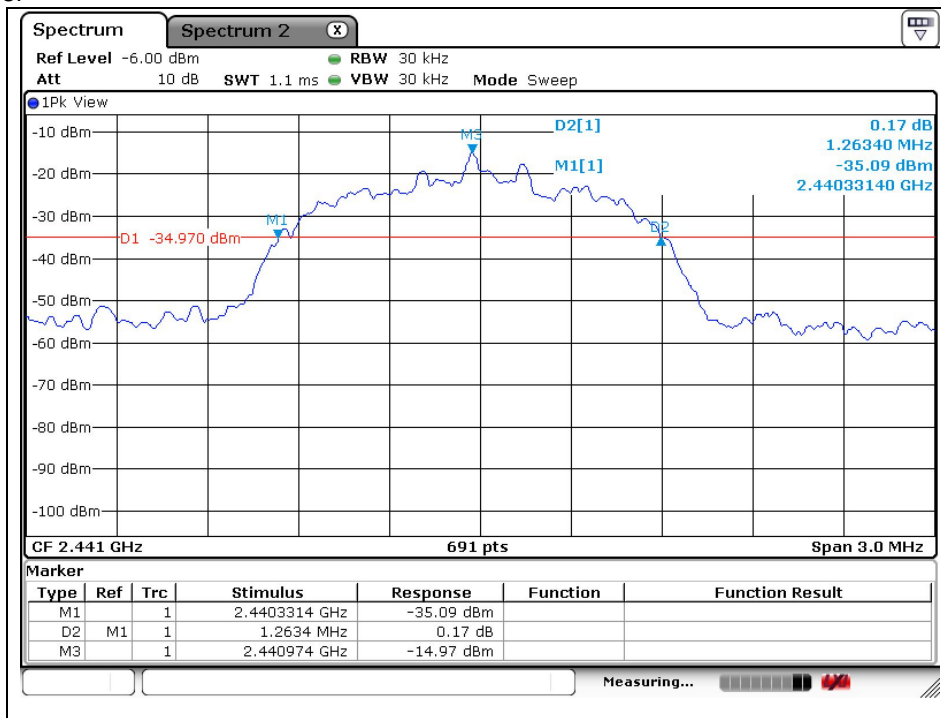
The results shown in this test report refer only to the sample(s) tested unless otherwise stated. This test report cannot be reproduced, except in full, without prior written permission of the Company.

## Operating Mode: 8DPSK

### Low Channel

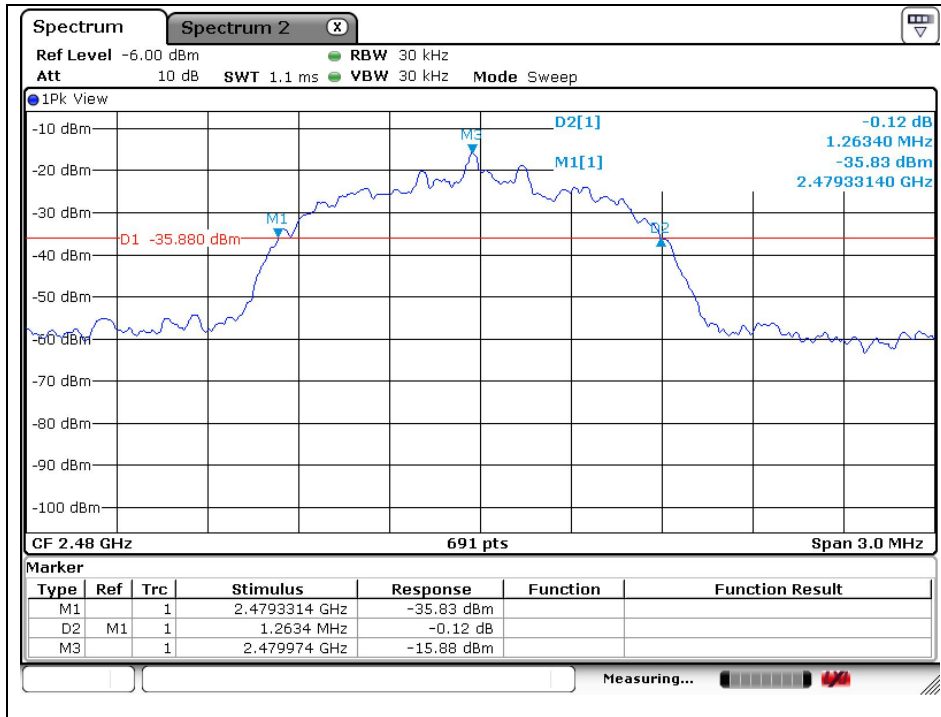


### Middle Channel



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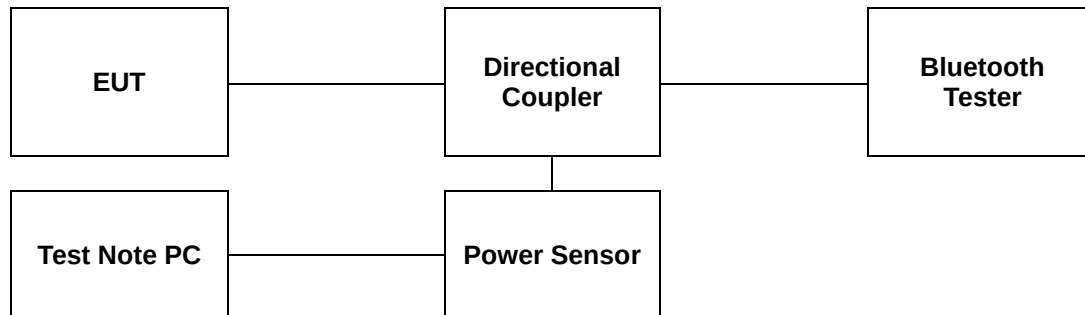
## High Channel



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## 4. Maximum Peak Output Power

### 4.1. Test Setup



### 4.2. Limit

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

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

### 4.3. Test Procedure

All data rates and modes were investigated for this test. The test follows DA000705. 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 for each channel.

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#### 4.4. Test Results

Ambient temperature : (23 ± 1) °C

Relative humidity : 47 % R.H.

| Operation Mode | Data Rate | Channel | Channel Frequency (MHz) | Attenuator + Cable offset (dB) | Peak Power Result (dB m) | Peak Power Limit (dB m) |
|----------------|-----------|---------|-------------------------|--------------------------------|--------------------------|-------------------------|
| GFSK           | 1 Mbps    | Low     | 2 402                   | 16.88                          | <u>2.62</u>              | 30.00                   |
|                |           | Middle  | 2 441                   | 16.73                          | 2.61                     | 30.00                   |
|                |           | High    | 2 480                   | 16.76                          | 2.33                     | 30.00                   |
| π/4DQPSK       | 2 Mbps    | Low     | 2 402                   | 16.88                          | <u>3.78</u>              | 20.97                   |
|                |           | Middle  | 2 441                   | 16.73                          | 3.51                     | 20.97                   |
|                |           | High    | 2 480                   | 16.76                          | 2.84                     | 20.97                   |
| 8DPSK          | 3 Mbps    | Low     | 2 402                   | 16.88                          | <u>3.84</u>              | 20.97                   |
|                |           | Middle  | 2 441                   | 16.73                          | 3.60                     | 20.97                   |
|                |           | High    | 2 480                   | 16.76                          | 2.92                     | 20.97                   |

Remark:

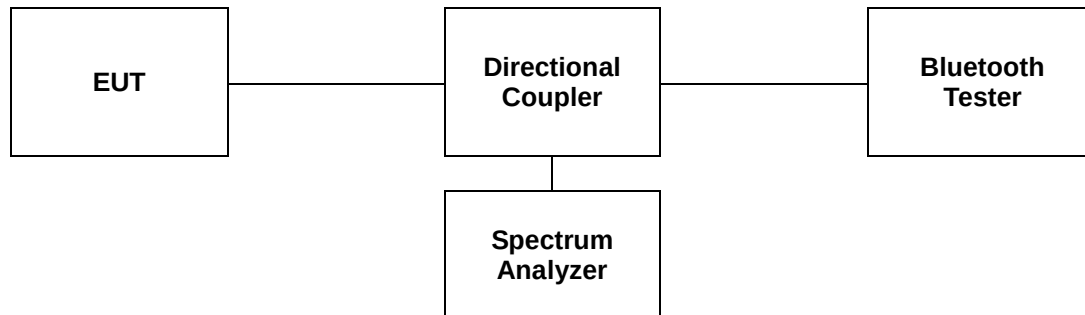
In the case of AFH, the limit for peak power is 0.125 W

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## 5. Carrier Frequency Separation

### 5.1. Test Setup



### 5.2. Limit

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

### 5.3. 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 DA000705.

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:

Span = wide enough to capture the peaks of two adjacent channels.

RBW  $\geq$  1 % of the span.

VBW  $\geq$  RBW

Sweep = auto

Detector = peak

Trace = max hold.

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

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## 5.4. Test Results

Ambient temperature : (23 ± 1) °C

Relative humidity : 47 % R.H.

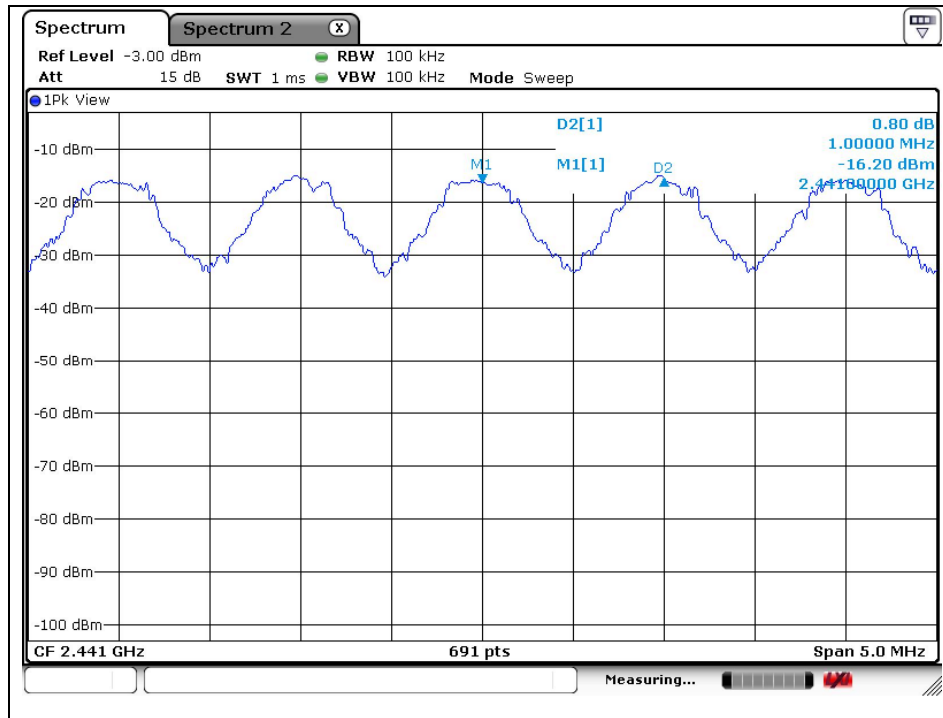
| Operation Mode | Channel (Middle) | Adjacent Hopping Channel Separation (kHz) | Two-third of 20 dB Bandwidth (kHz) | Minimum Bandwidth (kHz) |
|----------------|------------------|-------------------------------------------|------------------------------------|-------------------------|
| GFSK           | 2 441 MHz        | 1 000                                     | 613                                | 25                      |
| 8DPSK          | 2 441 MHz        | 1 000                                     | 840                                | 25                      |

Note;

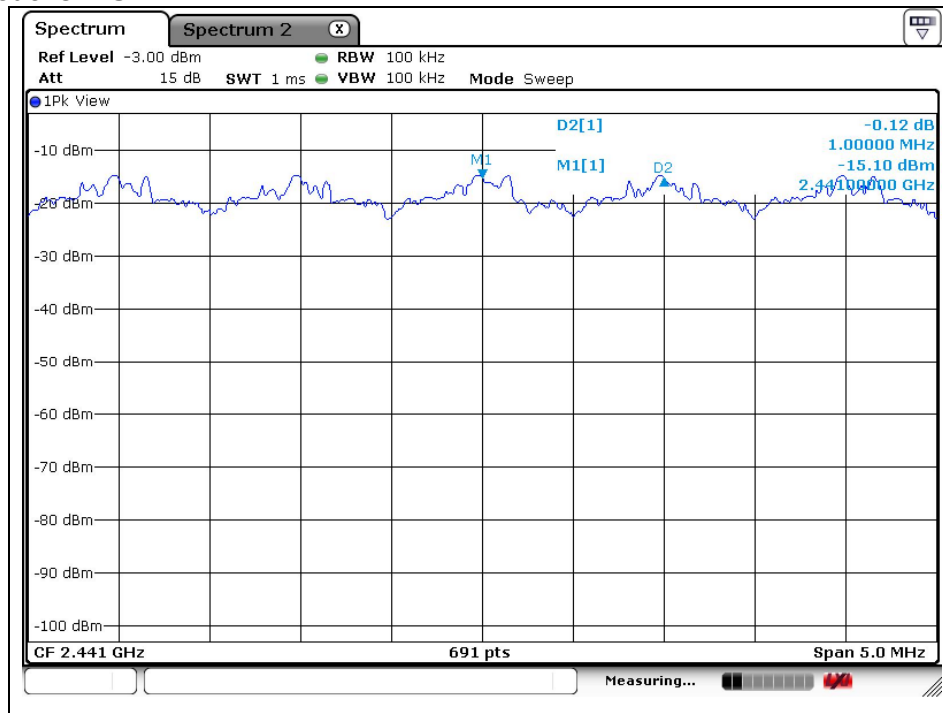
Measurement is made with EUT operating in hopping mode between 79 channels providing a worse case scenario as compared to AFH mode hopping between 20 channels.

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## Operating Mode: GFSK



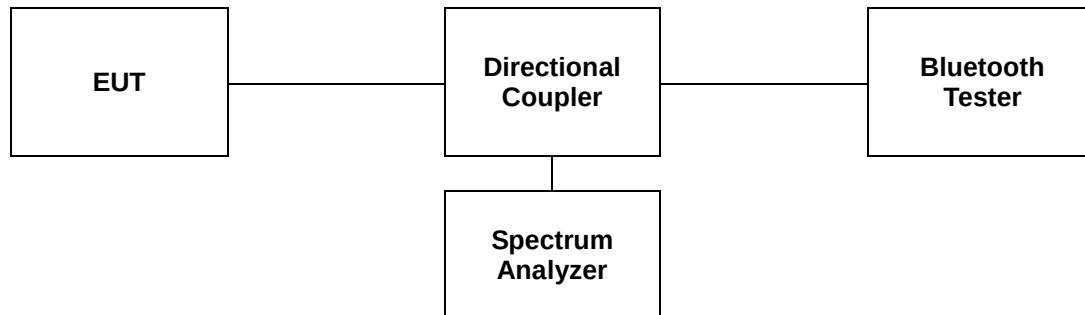
## Operating Mode: 8DPSK



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## 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 MHz 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

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 DA000705.

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

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

1. Remove the antenna from the EUT and then connect a low loss RF cable from the antenna the port to the Spectrum analyzer
3. Set spectrum analyzer Start = 2 400 MHz, Stop = 2 441.5 MHz, Sweep=sweep and Start = 2 441.5 MHz, Stop = 2 483.5 MHz, Sweep = sweep. Detector = peak.
4. Set the spectrum analyzer as RBW, VBW = 500 kHz.
5. Max hold, allow the trace to stabilize and count how many channel in the band.

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## 6.4. Test Results

Ambient temperature : (23 ± 1) °C

Relative humidity : 47 % R.H.

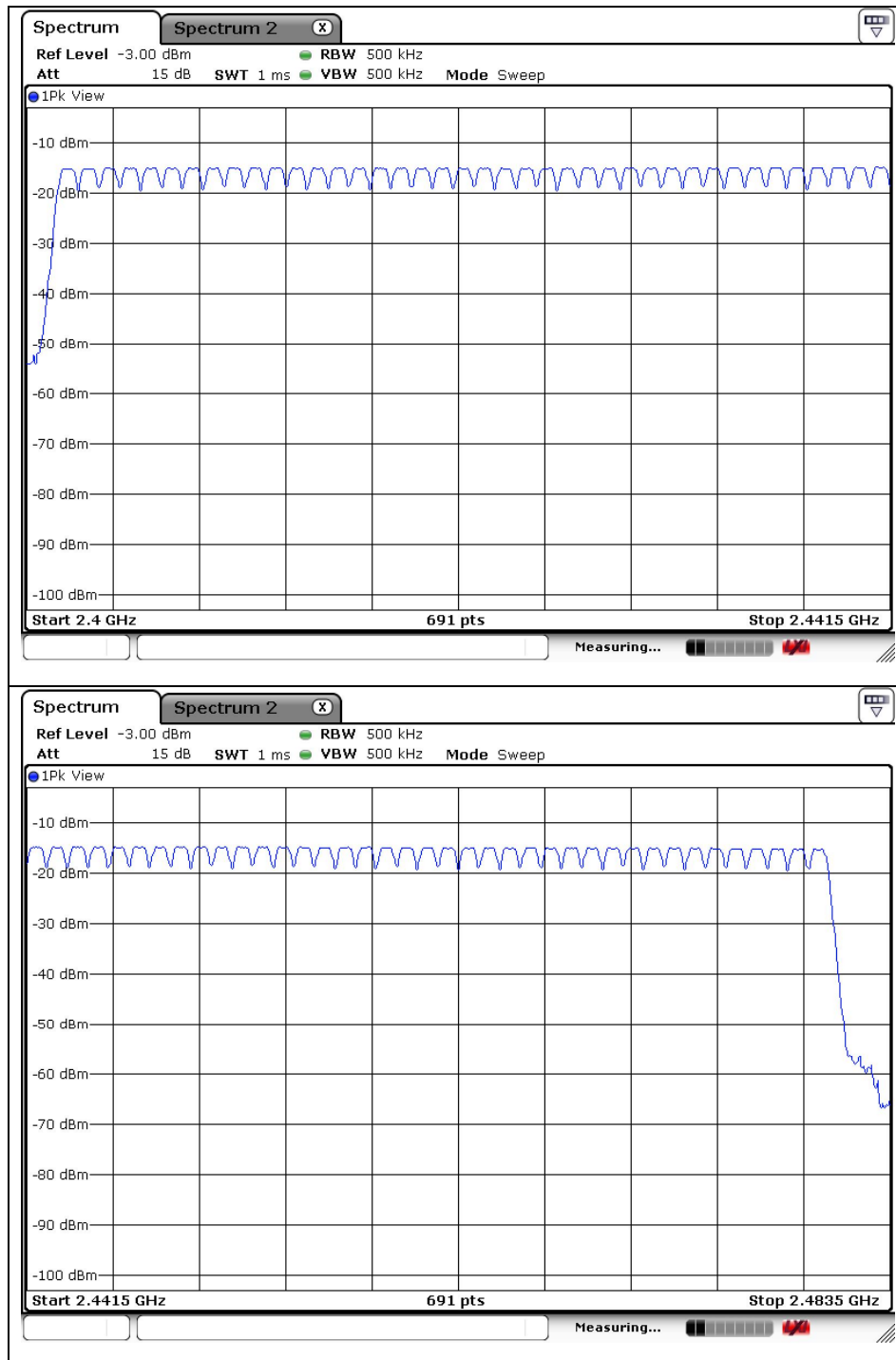
| Operation Mode | Number of Hopping Frequency | Limit |
|----------------|-----------------------------|-------|
| GFSK           | 79                          | ≥ 15  |
| 8DPSK          | 79                          | ≥ 15  |

**Remark:**

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

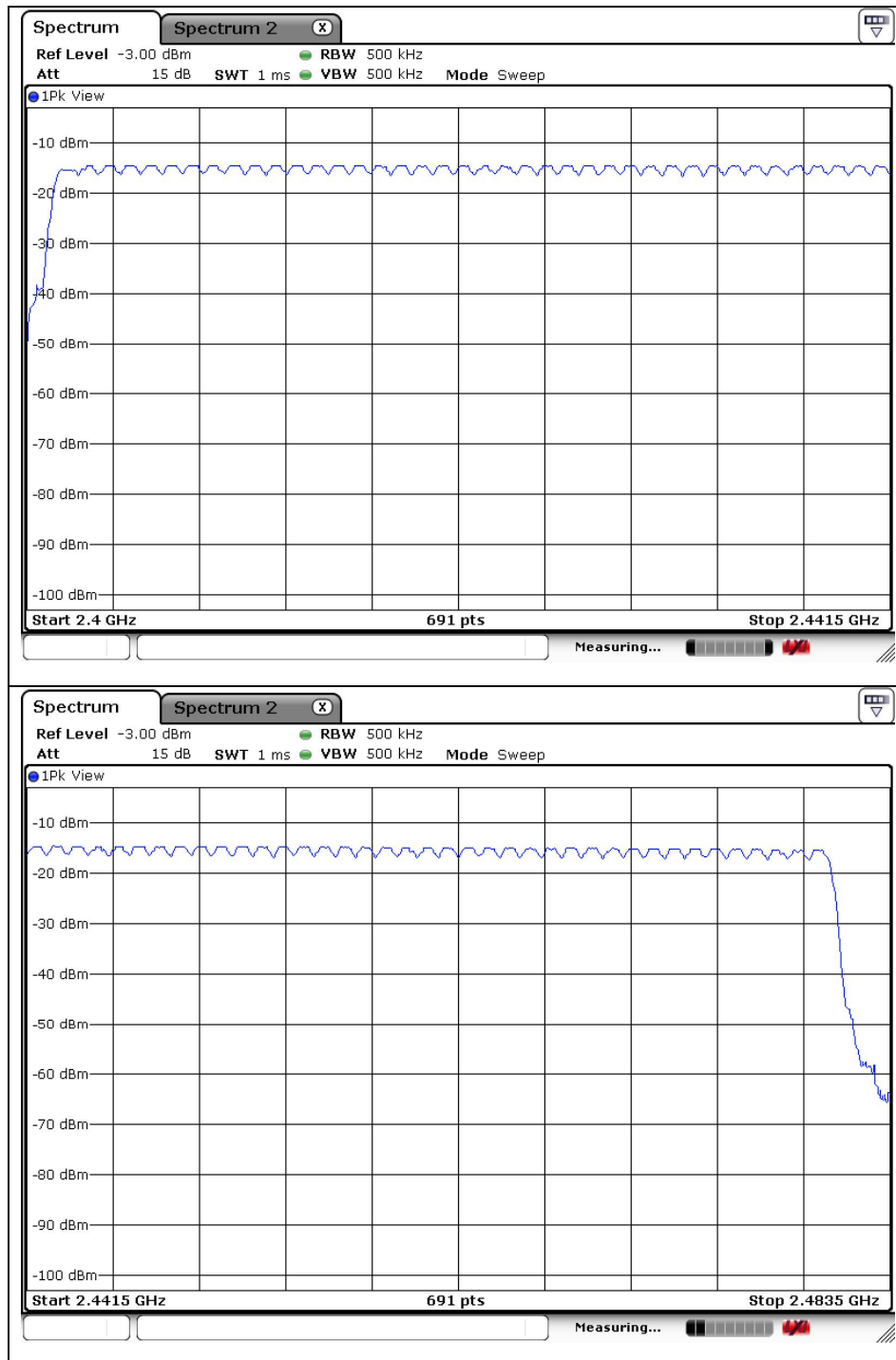
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## Operating Mode: GFSK



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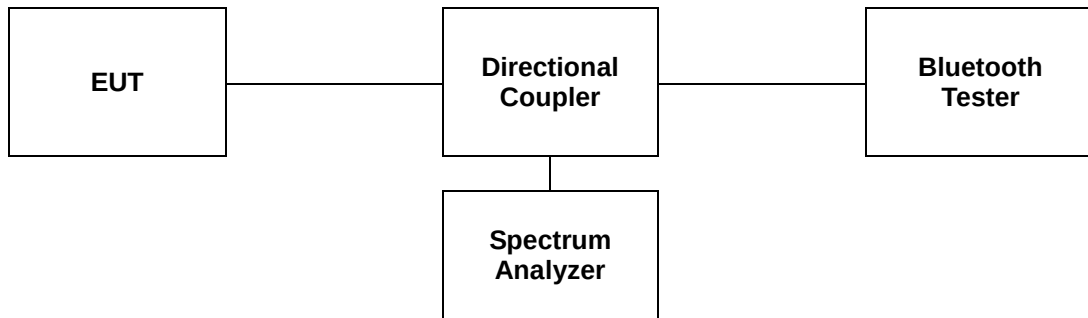
## Operating Mode : 8DPSK



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## 7. Time of Occupancy (Dwell Time)

### 7.1. Test Set up



### 7.2. Limit

§15.247(a)(1)(iii) For frequency hopping system operating in the 2 400 – 2 483.5 MHz 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)

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### 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 DA000705.

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 3-DH1, 3-DH3, 3-DH5. The hopping rate is insisted of 1 600 per second.

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

Span = zero span, centered on a hopping channel

RBW = 1 MHz

VBW = RBW

Sweep = as necessary to capture the entire dwell time per hopping channel

Detector = peak

Trace = max hold

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

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## 7.4. Test Results

Ambient temperature : (23 ± 1) °C

Relative humidity : 47 % R.H.

### 7.4.1. Packet Type: DH1, 3-DH1

| Operation Mode | Frequency | Dwell Time (ms) | Time of occupancy on the Tx Channel in 31.6 sec (ms) | Limit for time of occupancy on the Tx Channel in 31.6 sec (ms) |
|----------------|-----------|-----------------|------------------------------------------------------|----------------------------------------------------------------|
| GFSK           | 2 441 MHz | 0.40            | 128.00                                               | 400                                                            |
| 8DPSK          | 2 441 MHz | 0.41            | 131.20                                               | 400                                                            |

Note:

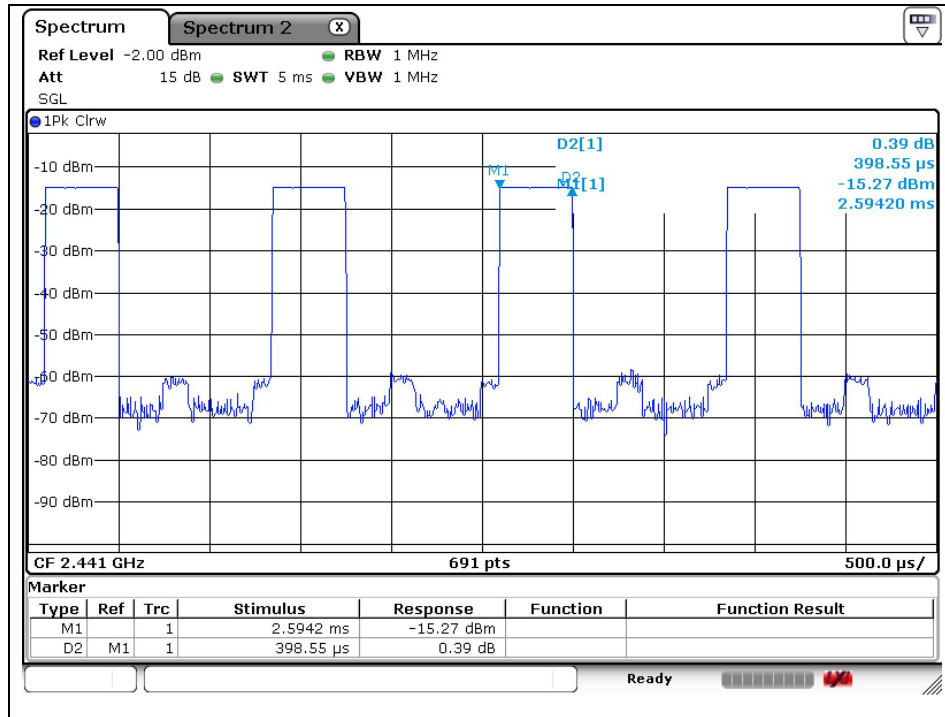
Time of occupancy on the TX channel in 31.6 sec

In case of GFSK,  $0.40 \times \{(1600 \div 2) / 79\} \times 31.6 = 128.00$  ms

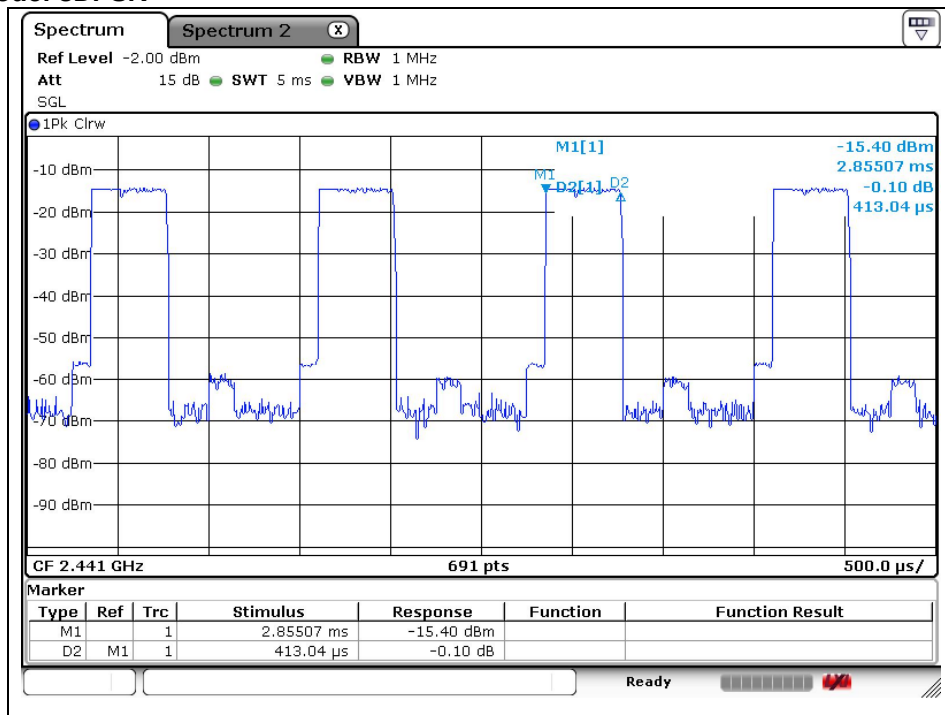
In case of 8DPSK,  $0.41 \times \{(1600 \div 2) / 79\} \times 31.6 = 131.20$  ms

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## Operating Mode: GFSK



## Operating Mode: 8DPSK



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#### 7.4.2. Packet Type: DH3, 3-DH3

| Operation Mode | Frequency | Dwell Time (ms) | Time of occupancy on the Tx Channel in 31.6 sec (ms) | Limit for time of occupancy on the Tx Channel in 31.6 sec (ms) |
|----------------|-----------|-----------------|------------------------------------------------------|----------------------------------------------------------------|
| GFSK           | 2 441 MHz | 1.65            | 264.00                                               | 400                                                            |
| 8DPSK          | 2 441 MHz | 1.67            | 267.20                                               | 400                                                            |

Note:

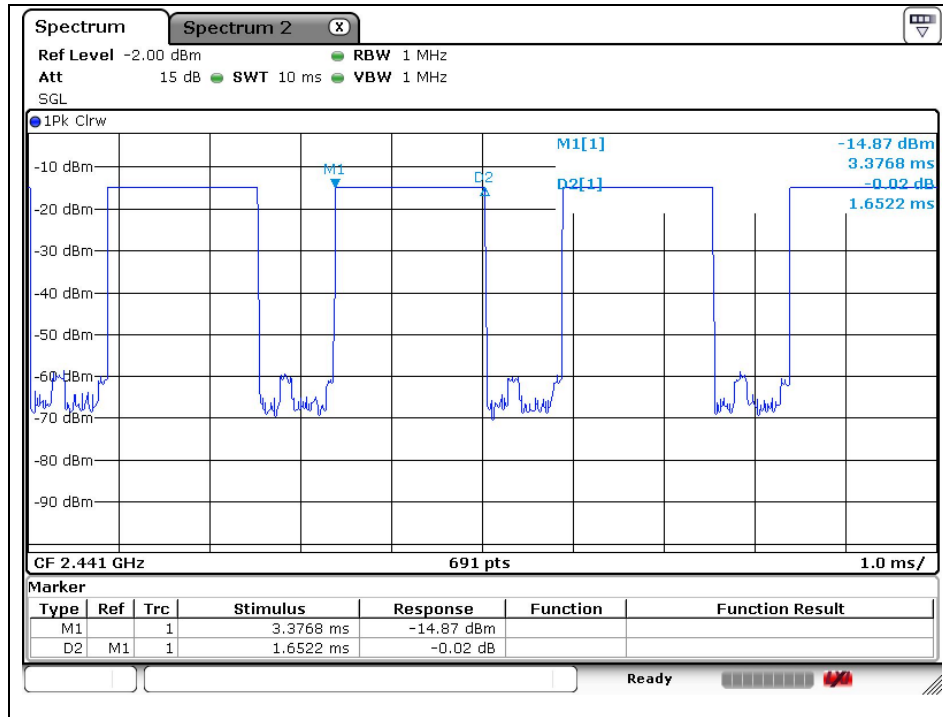
Time of occupancy on the TX channel in 31.6 sec

In case of GFSK,  $1.65 \times \{(1600 \div 4) / 79\} \times 31.6 = 264.00 \text{ ms}$

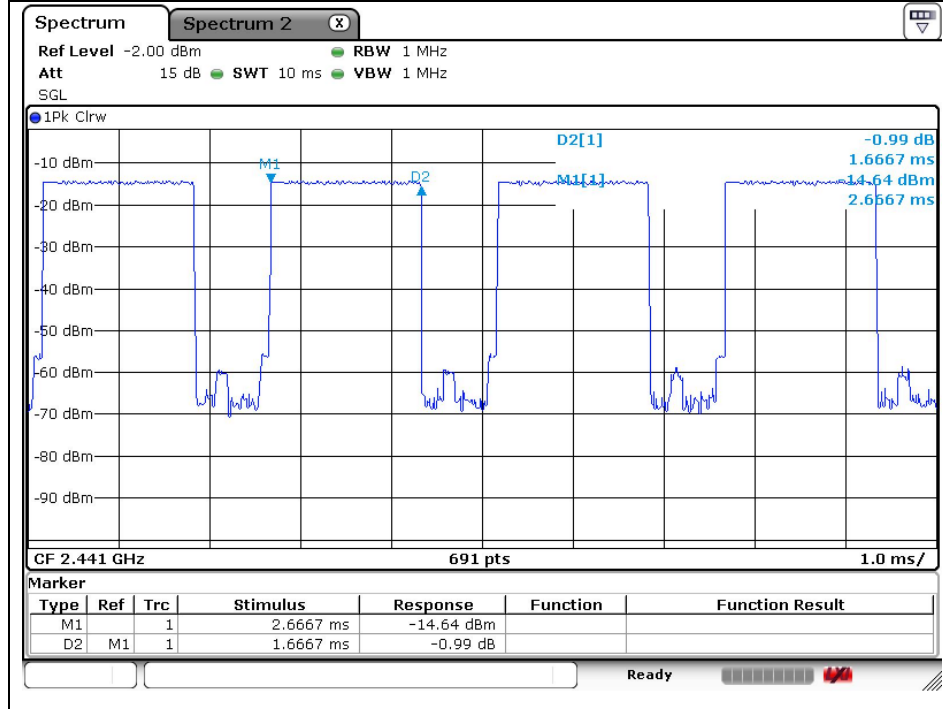
In case of 8DPSK,  $1.67 \times \{(1600 \div 4) / 79\} \times 31.6 = 267.20 \text{ ms}$

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## Operating Mode: GFSK



## Operating Mode: 8DPSK



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### 7.4.3. Packet Type: DH5, 3-DH5

| Operation Mode | Frequency | Dwell Time (ms) | Time of occupancy on the Tx Channel in 31.6 sec (ms) | Limit for time of occupancy on the Tx Channel in 31.6 sec (ms) |
|----------------|-----------|-----------------|------------------------------------------------------|----------------------------------------------------------------|
| GFSK           | 2 441 MHz | 2.90            | 309.33                                               | 400                                                            |
| 8DPSK          | 2 441 MHz | 2.91            | 310.40                                               | 400                                                            |

Note:

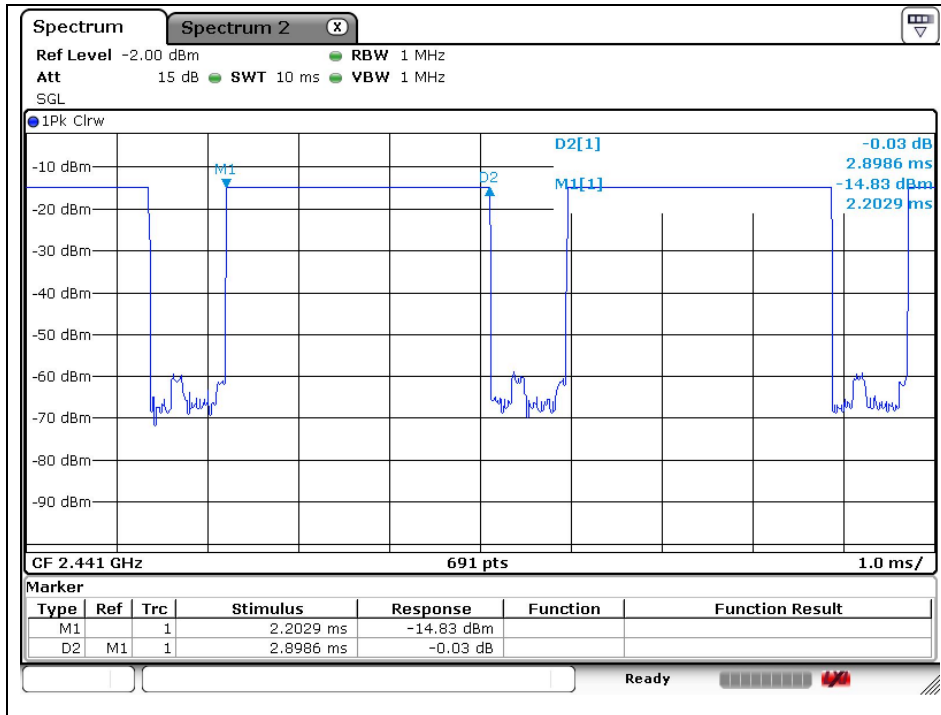
Time of occupancy on the TX channel in 31.6 sec

In case of GFSK,  $2.90 \times \{(1600 \div 6) / 79\} \times 31.6 = 309.33 \text{ ms}$

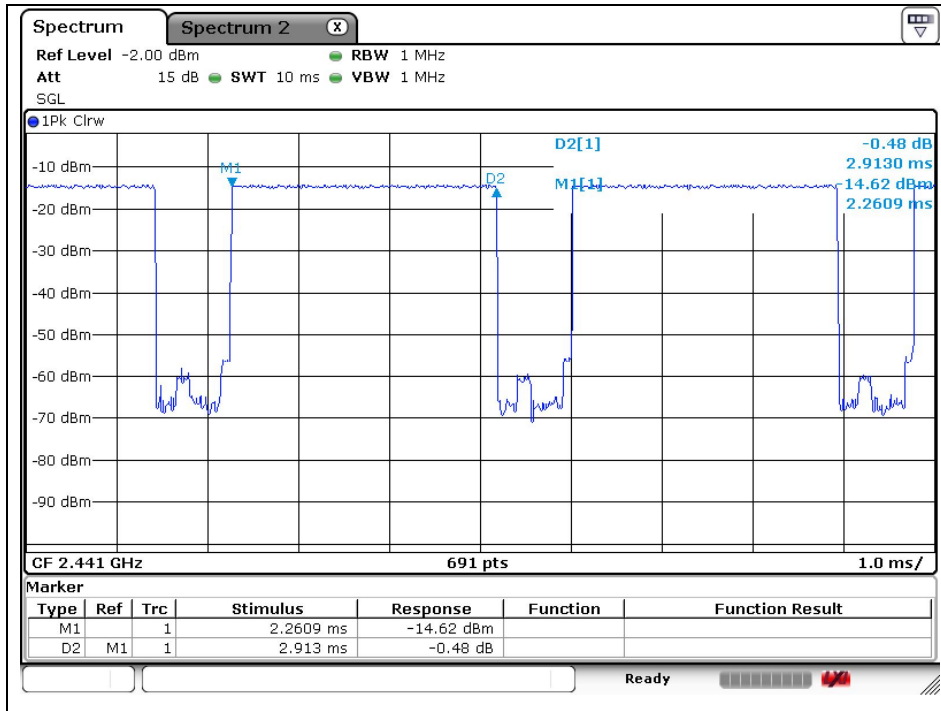
In case of 8DPSK,  $2.91 \times \{(1600 \div 6) / 79\} \times 31.6 = 310.40 \text{ ms}$

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## Operating Mode: GFSK



## Operating Mode: 8DPSK



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

| Operation Mode | Frequency | Dwell Time (ms) | Time of occupancy on the Tx Channel in 8 sec (ms) | Limit for time of occupancy on the Tx Channel in 8 sec (ms) |
|----------------|-----------|-----------------|---------------------------------------------------|-------------------------------------------------------------|
| GFSK           | 2 441 MHz | 0.40            | 64.00                                             | 400                                                         |
| 8DPSK          | 2 441 MHz | 0.41            | 65.60                                             | 400                                                         |

Note:

Time of occupancy on the TX channel in 8 sec

In case of GFSK,  $0.40 \times \{(800 \div 2) / 20\} \times 8 = 64.00$  ms

In case of 8DPSK,  $0.41 \times \{(800 \div 2) / 20\} \times 8 = 65.60$  ms

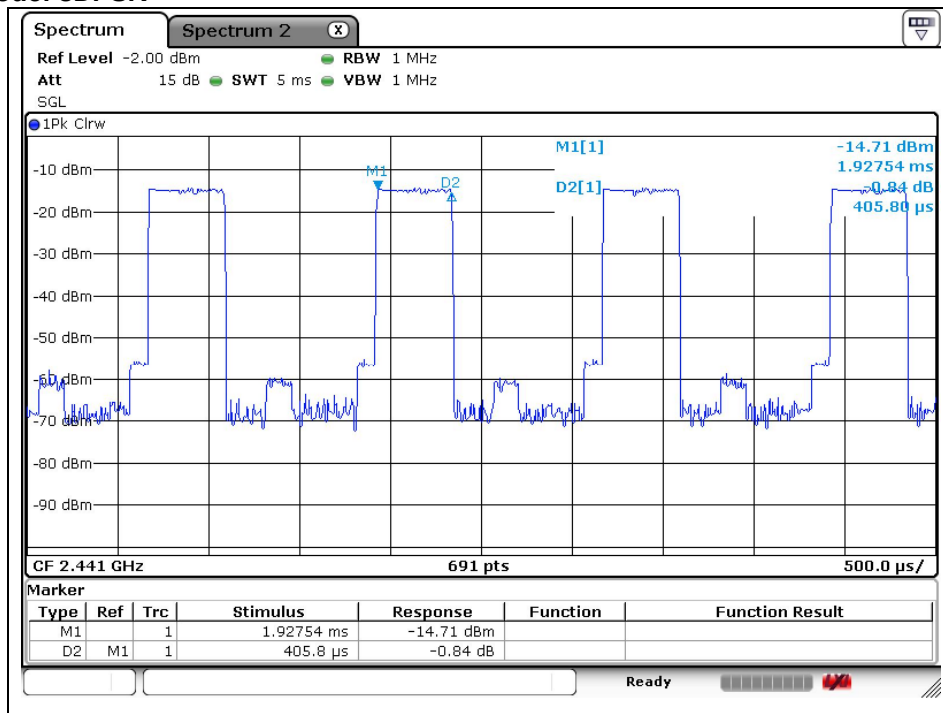
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## Operating Mode: GFSK



## Operating Mode: 8DPSK



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

| Operation Mode | Frequency | Dwell Time (ms) | Time of occupancy on the Tx Channel in 8 sec (ms) | Limit for time of occupancy on the Tx Channel in 8 sec (ms) |
|----------------|-----------|-----------------|---------------------------------------------------|-------------------------------------------------------------|
| GFSK           | 2 441 MHz | 1.65            | 132.00                                            | 400                                                         |
| 8DPSK          | 2 441 MHz | 1.65            | 132.00                                            | 400                                                         |

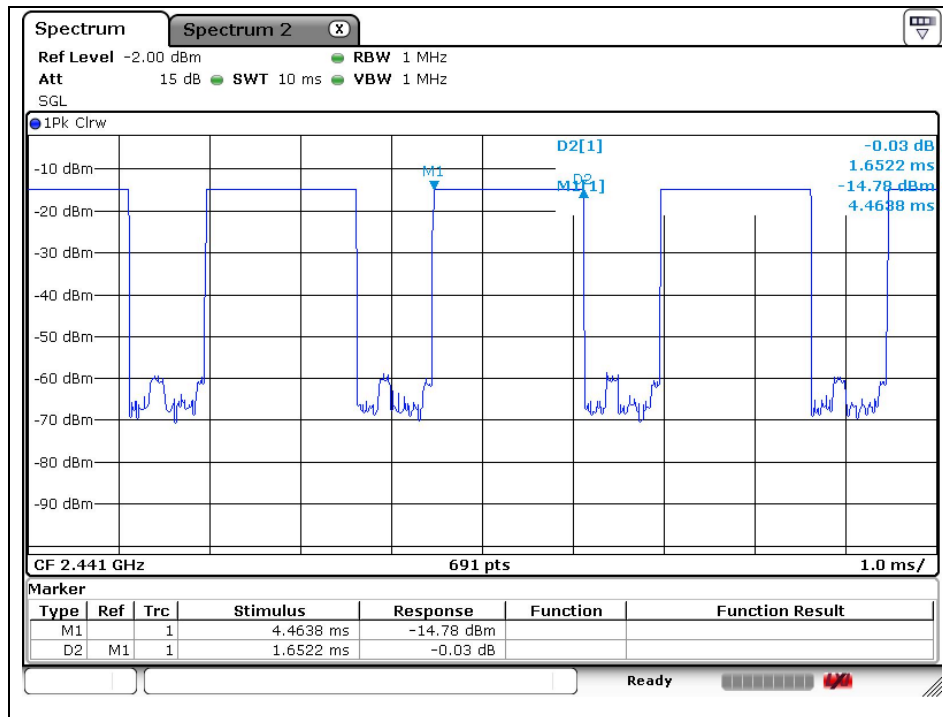
Note:

Time of occupancy on the TX channel in 8 sec

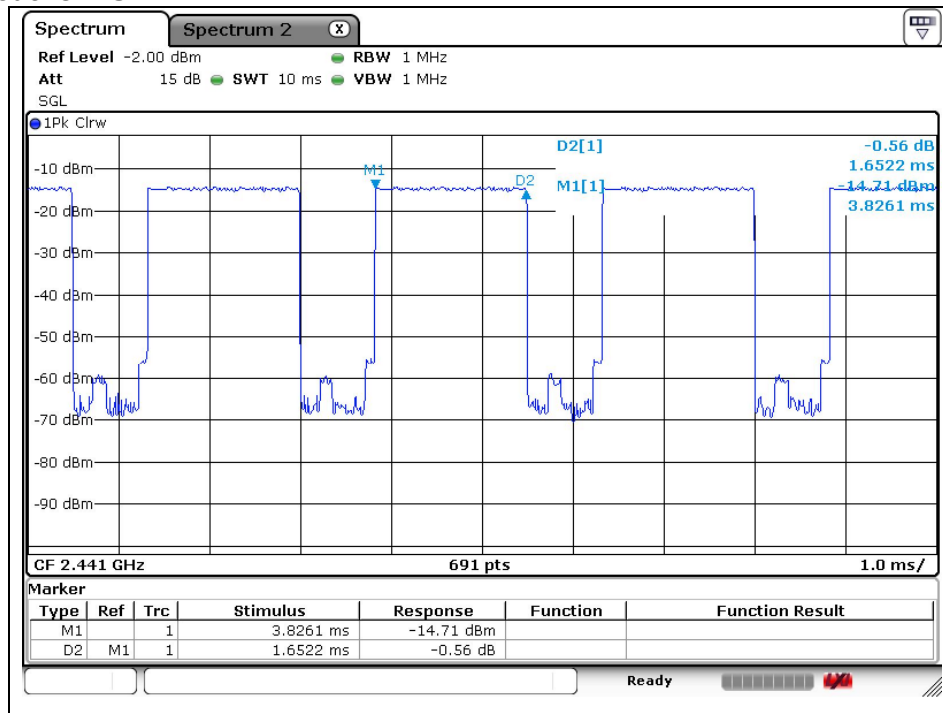
In case of GFSK and 8DPSK,  $1.65 \times \{(800 \div 4) / 20\} \times 8 = 132.00 \text{ ms}$

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## Operating Mode: GFSK



## Operating Mode: 8DPSK



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

| Operation Mode | Frequency | Dwell Time (ms) | Time of occupancy on the Tx Channel in 8 sec (ms) | Limit for time of occupancy on the Tx Channel in 8 sec (ms) |
|----------------|-----------|-----------------|---------------------------------------------------|-------------------------------------------------------------|
| GFSK           | 2 441 MHz | 2.90            | 154.67                                            | 400                                                         |
| 8DPSK          | 2 441 MHz | 2.91            | 155.20                                            | 400                                                         |

Note:

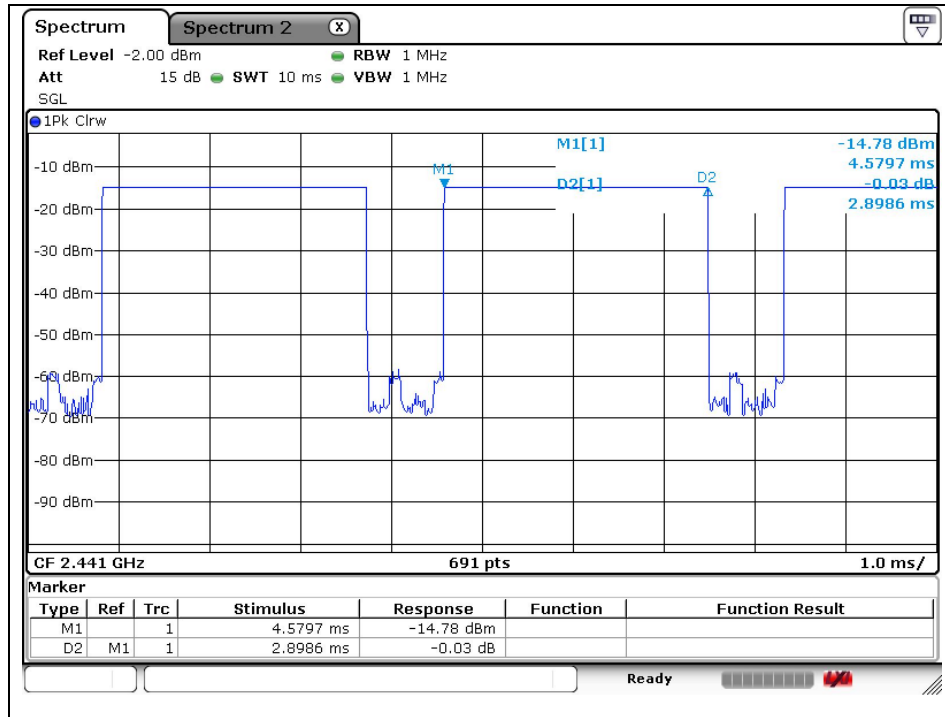
Time of occupancy on the TX channel in 8 sec

In case of GFSK,  $2.90 \times \{(800 \div 6) / 20\} \times 8 = 154.67 \text{ ms}$

In case of 8DPSK,  $2.91 \times \{(800 \div 6) / 20\} \times 8 = 155.20 \text{ ms}$

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## Operating Mode: GFSK



## Operating Mode: 8DPSK



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

### 8.2. Antenna Connected Construction

Antenna used in this product is Integral type with gain of 3.50 dB i.

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