Shenzhen CTL Testing Technology Co., Ltd.
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# TEST REPORT

## FCC PART 15.247

**Report Reference No.**: **CTL1609133506-WF-02**

| | | |
|---|---|---|
| Compiled by:<br>( position+printed name+signature) | Allen Wang<br>(File administrators) | Allen Wang |
| Tested by:<br>( position+printed name+signature) | Nice Nong<br>(Test Engineer) | Nice Nong |
| Approved by:<br>( position+printed name+signature) | Tracy Qi<br>(Manager) | Tracy Qi |

| | |
|---|---|
| **Product Name**: | RELESS RePad R606 |
| **Model/Type reference**: | R606 |
| **List Model(s)**: | N/A |
| **Trade Mark**: | RePad |
| **FCC ID**: | 2AFL3-R606 |
| **Applicant's name**: | **Hummingbird System Inc** |
| **Address of applicant**: | 2140 Peralta Blvd Suite 212D, Fremont, CA 94536 |
| **Test Firm**: | **Shenzhen CTL Testing Technology Co., Ltd.** |
| **Address of Test Firm**: | Floor 1-A, Baisha Technology Park, No.3011, Shahexi Road, Nanshan District, Shenzhen, China 518055 |
| **Test specification**: | |
| Standard: | **FCC Part 15.247:** Operation within the bands 902-928 MHz, 2400-2483.5 MHz and 5725-5850 MHz. |
| TRF Originator: | Shenzhen CTL Testing Technology Co., Ltd. |
| Master TRF: | Dated 2011-01 |
| **Date of Receipt**: | Nov. 03, 2016 |
| **Date of Test Date**: | Nov. 04, 2016–March 18, 2017 |
| **Data of Issue**: | March 18, 2017 |
| **Result**: | Pass |

# TEST REPORT

| Test Report No. : | CTL1610310501-WF-03 | March 18, 2017<br>Date of issue |
|---|---|---|

| | | |
|---|---|---|
| Equipment under Test | : | RELESS RePad R606 |
| Model /Type | : | R606 |
| Listed Models | : | N/A |
| **Applicant** | : | **Hummingbird System Inc** |
| Address | : | 2140 Peralta Blvd Suite 212D, Fremont, CA 94536 |
| **Manufacturer** | : | **Five Science and Technology Co.,LTD.** |
| Address | : | 12-13F, Block C2, Nanshan Zhiyuan, No. 1001 Xueyuan Road, Nanshan District, Shenzhen, China |

| Test result | Pass * |
|---|---|

*In the configuration tested, the EUT complied with the standards specified page 5.

The test report merely corresponds to the test sample.
It is not permitted to copy extracts of these test result without the written permission of the test laboratory.

# ** Modified History **

| Revisions | Description | Issued Data | Report No. | Remark |
|---|---|---|---|---|
| Version 1.0 | Initial Test Report Release | 2017-03-18 | CTL1610310501-WF-03 | Tracy Qi |
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# 1. SUMMARY

## 1.1. TEST STANDARDS

The tests were performed according to following standards:

FCC Rules Part 15.247: Frequency Hopping, Direct Spread Spectrum and Hybrid Systems that are in operation within the bands of 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz

ANSI C63.10: 2013: American National Standard for Testing Unlicensed Wireless Devices

ANSI C63.4: 2014: –American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40GHz Range of 9 kHz to 40GHz

KDB558074 D01 V03r03: Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247

## 1.2. Test Description

| **FCC PART 15.247** | | |
|---|---|---|
| FCC Part 15.207 | AC Power Conducted Emission | PASS |
| FCC Part 15.247(a)(1)(i) | 20dB Bandwidth | PASS |
| FCC Part 15.247(d) | Spurious RF Conducted Emission | PASS |
| FCC Part 15.247(b) | Maximum Peak Output Power | PASS |
| FCC Part 15.247(b) | Pseudorandom Frequency Hopping Sequence | PASS |
| FCC Part 15.247(a)(1)(iii) | Number of hopping frequency& Time of Occupancy | PASS |
| FCC Part 15.247(a)(1) | Frequency Separation | PASS |
| FCC Part 15.205/15.209 | Radiated Emissions | PASS |
| FCC Part 15.247(d) | Band Edge Compliance of RF Emission | PASS |
| FCC Part 15.203/15.247 (b) | Antenna Requirement | PASS |

## 1.3. Test Facility

### 1.3.1 Address of the test laboratory

Shenzhen CTL Testing Technology Co., Ltd.
Floor 1-A, Baisha Technology Park, No. 3011, Shahexi Road, Nanshan, Shenzhen 518055 China

There is one 3m semi-anechoic chamber and two line conducted labs for final test. The Test Sites meet the requirements in documents ANSI C63.4 and CISPR 22/EN 55022 requirements.

### 1.3.2 Laboratory accreditation

The test facility is recognized, certified, or accredited by the following organizations:

**IC Registration No.: 9618B**

The 3m alternate test site of Shenzhen CTL Testing Technology Co., Ltd. EMC Laboratory has been registered by Certification and Engineer Bureau of Industry Canada for the performance of with Registration No.: 9618B.

**FCC-Registration No.: 970318**

Shenzhen CTL Testing Technology Co., Ltd. EMC Laboratory has been registered and fully described in a report filed with the (FCC) Federal Communications Commission. The acceptance letter from the FCC is maintained in our files. Registration No.: 970318.

## 1.4. Statement of the measurement uncertainty

The data and results referenced in this document are true and accurate. The reader is cautioned that there may be errors within the calibration limits of the equipment and facilities. The measurement uncertainty was calculated for all measurements listed in this test report acc. to CISPR 16 - 4 “Specification for radio disturbance and immunity measuring apparatus and methods – Part 4: Uncertainty in EMC Measurements“ and is documented in the Shenzhen CTL Testing Technology Co., Ltd. quality system acc. to DIN EN ISO/IEC 17025. Furthermore, component and process variability of devices similar to that tested may result in additional deviation. The manufacturer has the sole responsibility of continued compliance of the device.

Hereafter the best measurement capability for CTL laboratory is reported:

| Test | Measurement Uncertainty | Notes |
|---|---|---|
| Transmitter power conducted | ±0.57 dB | (1) |
| Transmitter power Radiated | ±2.20 dB | (1) |
| Conducted spurious emission 9KHz-40 GHz | ±2.20 dB | (1) |
| Occupied Bandwidth | ±0.01ppm | (1) |
| Radiated Emission 30~1000MHz | ±4.10dB | (1) |
| Radiated Emission Above 1GHz | ±4.32dB | (1) |
| Conducted Disturbance0.15~30MHz | ±3.20dB | (1) |

(1) This uncertainty represents an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2.

# 2. GENERAL INFORMATION

## 2.1. Environmental conditions

During the measurement the environmental conditions were within the listed ranges:

| | |
|---|---|
| Normal Temperature: | 25°C |
| Relative Humidity: | 55 % |
| Air Pressure: | 101 kPa |

## 2.2. General Description of EUT

| | |
|---|---|
| Product Name: | RELESS RePad R606 |
| Model/Type reference: | R606 |
| Power supply: | DC 3.8V from battery |
| **Bluetooth:** | |
| Version: | Supported BT3.0 |
| Modulation: | GFSK, π/4DQPSK, 8DPSK |
| Operation frequency: | 2402MHz~2480MHz |
| Channel number: | 79 |
| Channel separation: | 1MHz |
| Antenna type: | FPC antenna |
| Antenna gain: | 0dBi |

Note: For more details, please refer to the user's manual of the EUT.

## 2.3. Description of Test Modes and Test Frequency

The Applicant provides communication tools software (AMFAN RF Test Tool) to control the EUT for staying in continuous transmitting (Duty Cycle more than 98%) and receiving mode for testing. There are 79 channels provided to the EUT and Channel 0/39/78 was selected to test.

**Operation Frequency:**

| Channel | Frequency (MHz) |
|---|---|
| 0 | 2402 |
| 1 | 2403 |
| ⋮ | ⋮ |
| 38 | 2440 |
| 39 | 2441 |
| 40 | 2442 |
| ⋮ | ⋮ |
| 77 | 2479 |
| 78 | 2480 |

Note: The line display in grey were the channel selected for testing

Preliminary tests were performed in each mode and packet length of BT, and found worst case as bellow, finally test were conducted at those mode and recorded in this report.

| Test Items | Worst case |
|---|---|
| Conducted Emissions | DH5 Middle channel |
| Radiated Emissions and Band Edge | DH5 |
| Maximum Conducted Output Power | DH5/2DH5/3DH5 |
| 20dB Bandwidth | DH5/2DH5/3DH5 |
| Frequency Separation | DH5/2DH5/3DH5 Middle channel |
| Number of hopping frequency | DH5/2DH5/3DH5 |
| Time of Occupancy (Dwell Time) | DH1/DH3/DH5 Middle channel<br>2DH1/2DH3/2DH5 Middle channel<br>3DH1/3DH3/3DH5 Middle channel |
| Out-of-band Emissions | DH5/2DH5/3DH5 |

## 2.4. Special Accessories

| No. | Equipment | Manufacturer | Model No. | Serial No. | Length | shielded/ unshielded | Notes |
|---|---|---|---|---|---|---|---|
| 1 | PC | ASUS | X555YA | QCWB335 | / | / | DOC |
| 2 | Power adapter | ASUS | Y481C | 8AW0829002095 | 1.00m | unshielded | DOC |

## 2.5. Equipment Used during the Test

| Test Equipment | Manufacturer | Model No. | Serial No. | Calibration Date | Calibration Due Date |
|---|---|---|---|---|---|
| LISN | R&S | ENV216 | 3560.6550.12 | 2016/06/02 | 2017/06/01 |
| LISN | R&S | ESH2-Z5 | 860014/010 | 2016/06/02 | 2017/06/01 |
| Bilog Antenna | Sunol Sciences Corp. | JB1 | A061713 | 2016/06/02 | 2017/06/01 |
| EMI Test Receiver | R&S | ESCI | 103710 | 2016/06/02 | 2017/06/01 |
| Spectrum Analyzer | Agilent | E4407B | MY41440676 | 2016/05/21 | 2017/05/20 |
| Spectrum Analyzer | Agilent | N9020A | US46220290 | 2016/01/17 | 2017/01/16 |
| Power Meter | Anritsu | ML2487B | 110553 | 2016/06/02 | 2017/06/01 |
| Power Sensor | Anritsu | MA2411B | 100345 | 2016/05/21 | 2017/05/20 |
| Controller | EM Electronics | Controller EM 1000 | N/A | 2016/05/21 | 2017/05/20 |
| Horn Antenna | Sunol Sciences Corp. | DRH-118 | A062013 | 2016/05/19 | 2017/05/18 |
| Horn Antenna | SCHWARZBACK | BBHA 9170 | BBHA9170184 | 2016/05/19 | 2017/05/18 |
| Active Loop Antenna | SCHWARZBECK | FMZB1519 | 1519-037 | 2016/05/19 | 2017/05/18 |
| Amplifier | Agilent | 8349B | 3008A02306 | 2016/05/19 | 2017/05/18 |
| Amplifier | Agilent | 8447D | 2944A10176 | 2016/05/19 | 2017/05/18 |
| Temperature/Humidity Meter | Gangxing | CTH-608 | 02 | 2016/05/20 | 2017/05/19 |
| High-Pass Filter | K&L | 9SH10-2700/ X12750-O/O | N/A | 2016/05/20 | 2017/05/19 |
| High-Pass Filter | K&L | 41H10-1375/ U12750-O/O | N/A | 2016/05/20 | 2017/05/19 |
| Coaxial Cables | HUBER+SUHNER | SUCOFLEX 104PEA-10M | 10m | 2016/06/02 | 2017/06/01 |
| Coaxial Cables | HUBER+SUHNER | SUCOFLEX 104PEA-3M | 3m | 2016/06/02 | 2017/06/01 |
| Coaxial Cables | HUBER+SUHNER | SUCOFLEX 104PEA-3M | 3m | 2016/06/02 | 2017/06/01 |
| RF Cable | Megalon | RF-A303 | N/A | 2016/06/02 | 2017/06/01 |
| EMC Test Software | Audix | E3 | N/A | N/A | N/A |
| EMC Test Software | R&S | ES-K1 | N/A | N/A | N/A |

The calibration interval was one year

## 2.6. Related Submittal(s) / Grant (s)

This submittal(s) (test report) is intended to comply with Section 15.247 of the FCC Part 15, Subpart C Rules.

## 2.7. Modifications

No modifications were implemented to meet testing criteria.

# 3. TEST CONDITIONS AND RESULTS

## 3.1. Conducted Emissions Test

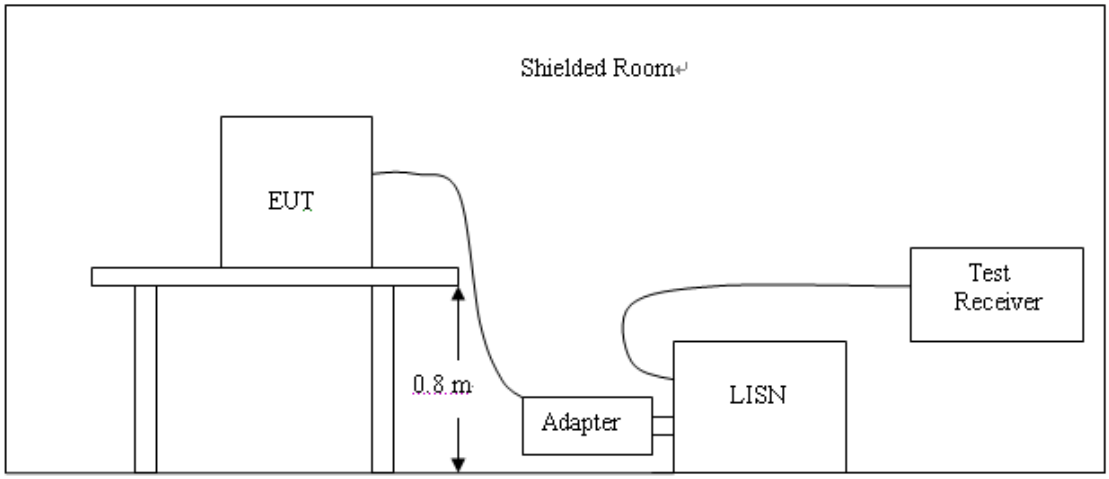
**LIMIT**

According to §15.207 (a): For an intentional radiator which is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz shall not exceed 250 microvolts (The limit decreases linearly with the logarithm of the frequency in the range 0.15 MHz to 0.50 MHz). The limits at specific frequency range are listed as follows:

| Frequency Range (MHz) | Limits (dBμV) | |
|---|---|---|
| | Quasi-peak | Average |
| 0.15 to 0.50 | 66 to 56 | 56 to 46 |
| 0.50 to 5 | 56 | 46 |
| 5 to 30 | 60 | 50 |

* Decreasing linearly with the logarithm of the frequency

**TEST CONFIGURATION**




**TEST PROCEDURE**

1. The equipment was set up as per the test configuration to simulate typical actual usage per the user's manual. The EUT is a tabletop system; a wooden table with a height of 0.8 meters is used and is placed on the ground plane as per ANSI C63.10:2013.
2. Support equipment, if needed, was placed as per ANSI C63.10:2013.
3. All I/O cables were positioned to simulate typical actual usage as per ANSI C63.10:2013.
4. The adapter received AC120V/60Hz power through a Line Impedance Stabilization Network (LISN) which supplied power source and was grounded to the ground plane.
5. All support equipment received AC power from a second LISN, if any.
6. The EUT test program was started. Emissions were measured on each current carrying line of the EUT using a spectrum Analyzer / Receiver connected to the LISN powering the EUT. The LISN has two monitoring points: Line 1 (Hot Side) and Line 2 (Neutral Side). Two scans were taken: one with Line 1 connected to Analyzer / Receiver and Line 2 connected to a 50 ohm load; the second scan had Line 1 connected to a 50 ohm load and Line 2 connected to the Analyzer / Receiver.
7. Analyzer / Receiver scanned from 150 KHz to 30MHz for emissions in each of the test modes.
8. During the above scans, the emissions were maximized by cable manipulation.

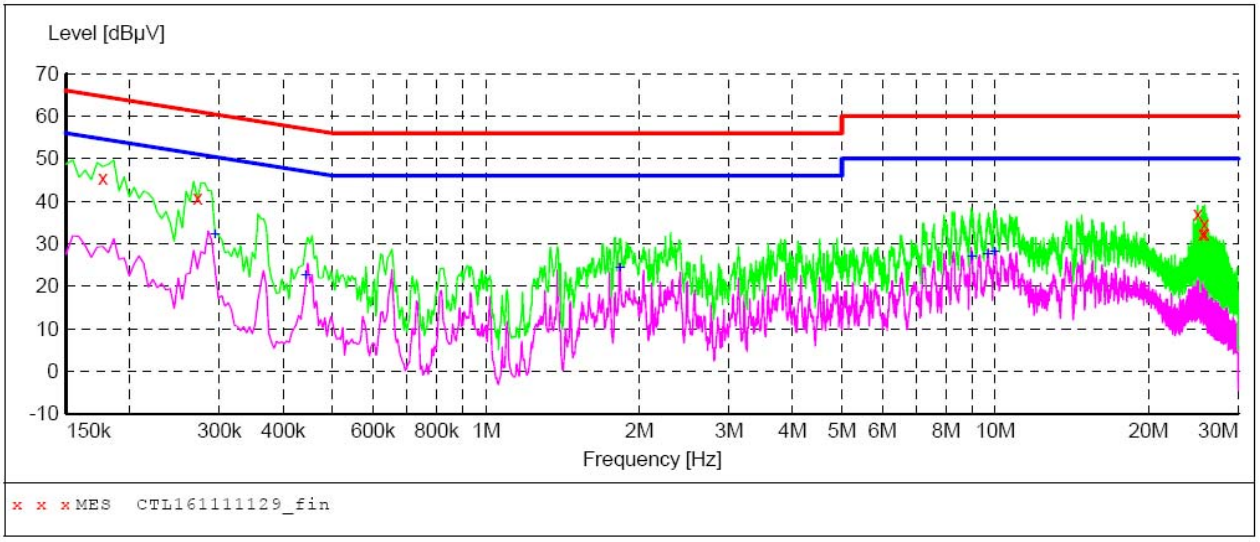
**TEST RESULTS**

*Remark:*

1. *We measured both at AC 120V/60Hz and AC 240V/50Hz, recorded worst case at AC 120V/60Hz.*
2. *We measured both at AC power adapter and PC charge modes, recorded worst case at AC power adapter charge mode;*
3. *Measured all modes and recorded worst case at GFSK modulation Middle Channel*

| Test Mode | BT - GFSK | Line: | L |
|---|---|---|---|

SCAN TABLE: "Voltage (9K-30M)FIN"
Short Description: 150K-30M Voltage




MEASUREMENT RESULT: "CTL161111129_fin"

11/11/2016 11:36AM

| Frequency MHz | Level dBµV | Transd dB | Limit dBµV | Margin dB | Detector | Line | PE |
|---|---|---|---|---|---|---|---|
| 0.177001 | 45.50 | 10.2 | 65 | 19.1 | QP | L1 | GND |
| 0.271501 | 40.90 | 10.2 | 61 | 20.2 | QP | L1 | GND |
| 24.967501 | 37.00 | 11.1 | 60 | 23.0 | QP | L1 | GND |
| 25.507501 | 32.30 | 11.1 | 60 | 27.7 | QP | L1 | GND |
| 25.692001 | 34.70 | 11.1 | 60 | 25.3 | QP | L1 | GND |
| 25.755001 | 32.30 | 11.1 | 60 | 27.7 | QP | L1 | GND |

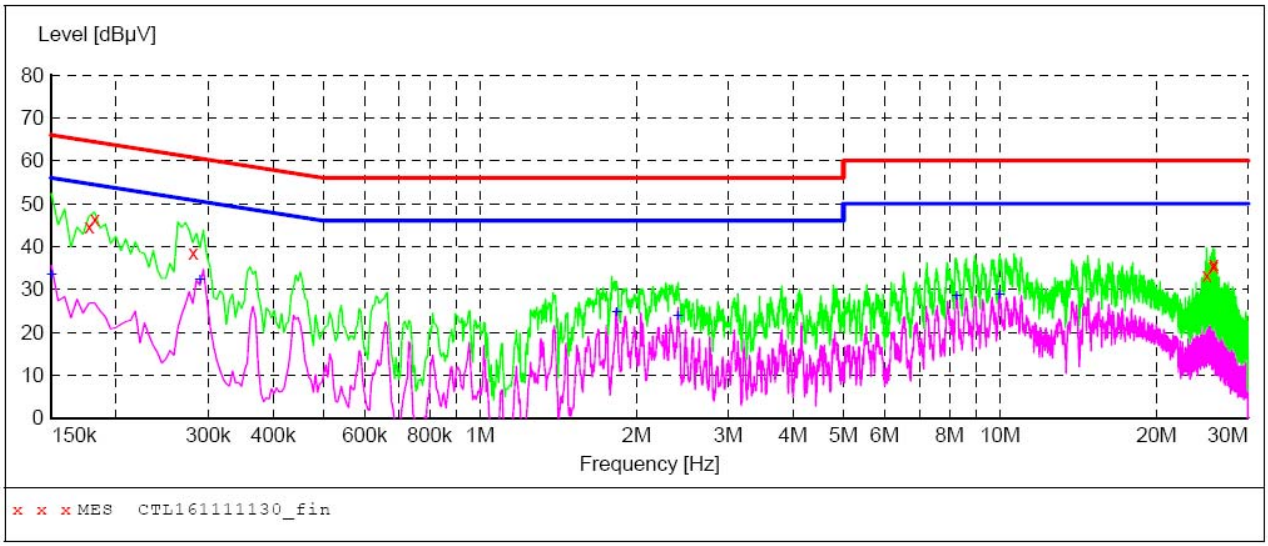
MEASUREMENT RESULT: "CTL161111129_fin2"

11/11/2016 11:36AM

| Frequency MHz | Level dBµV | Transd dB | Limit dBµV | Margin dB | Detector | Line | PE |
|---|---|---|---|---|---|---|---|
| 0.294001 | 32.00 | 10.2 | 50 | 18.4 | AV | L1 | GND |
| 0.442501 | 22.50 | 10.2 | 47 | 24.5 | AV | L1 | GND |
| 1.833001 | 24.20 | 10.3 | 46 | 21.8 | AV | L1 | GND |
| 9.001501 | 26.80 | 10.6 | 50 | 23.2 | AV | L1 | GND |
| 9.663001 | 27.40 | 10.6 | 50 | 22.6 | AV | L1 | GND |
| 9.964501 | 28.00 | 10.6 | 50 | 22.0 | AV | L1 | GND |

| Test Mode | BT - GFSK | Line: | N |
|---|---|---|---|

*SCAN TABLE: "Voltage (9K-30M)FIN"*
Short Description: 150K-30M Voltage




*MEASUREMENT RESULT: "CTL161111130_fin"*

11/11/2016 11:39AM

| Frequency MHz | Level dBµV | Transd dB | Limit dBµV | Margin dB | Detector | Line | PE |
|---|---|---|---|---|---|---|---|
| 0.177001 | 44.70 | 10.2 | 65 | 19.9 | QP | N | GND |
| 0.181501 | 46.40 | 10.2 | 64 | 18.0 | QP | N | GND |
| 0.280501 | 38.60 | 10.2 | 61 | 22.2 | QP | N | GND |
| 24.972001 | 33.30 | 11.1 | 60 | 26.7 | QP | N | GND |
| 25.692001 | 35.30 | 11.1 | 60 | 24.7 | QP | N | GND |
| 25.750501 | 35.90 | 11.1 | 60 | 24.1 | QP | N | GND |

*MEASUREMENT RESULT: "CTL161111130_fin2"*

11/11/2016 11:39AM

| Frequency MHz | Level dBµV | Transd dB | Limit dBµV | Margin dB | Detector | Line | PE |
|---|---|---|---|---|---|---|---|
| 0.150001 | 33.20 | 10.2 | 56 | 22.8 | AV | N | GND |
| 0.289501 | 32.10 | 10.2 | 51 | 18.4 | AV | N | GND |
| 1.833001 | 24.70 | 10.3 | 46 | 21.3 | AV | N | GND |
| 2.404501 | 23.80 | 10.4 | 46 | 22.2 | AV | N | GND |
| 8.254501 | 28.40 | 10.5 | 50 | 21.6 | AV | N | GND |
| 9.991501 | 28.70 | 10.6 | 50 | 21.3 | AV | N | GND |

## 3.2. Radiated Emissions

**LIMIT**

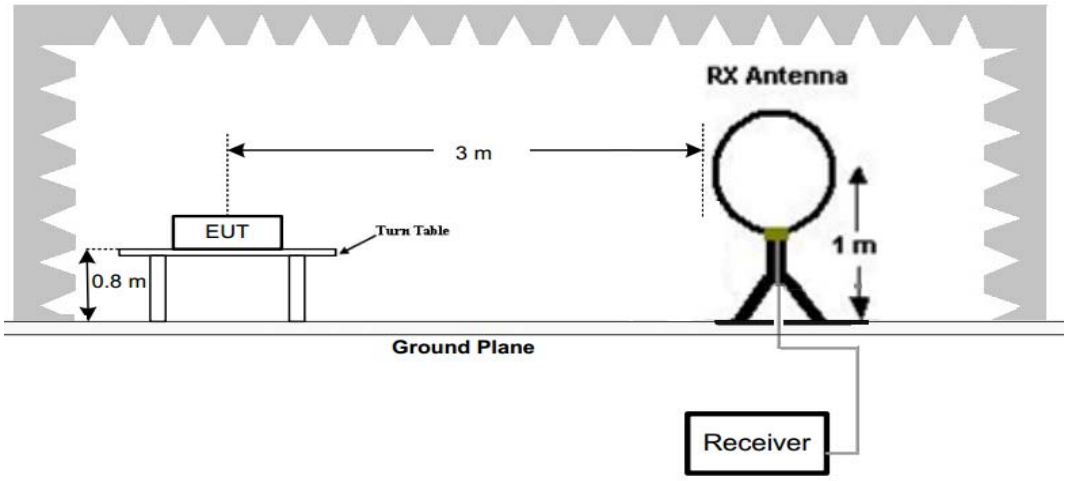
For intentional device, according to § 15.209(a), the general requirement of field strength of radiated emission out of authorized band shall not exceed the following table at a 3 meters measurement distance.
In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a)

Radiated emission limits

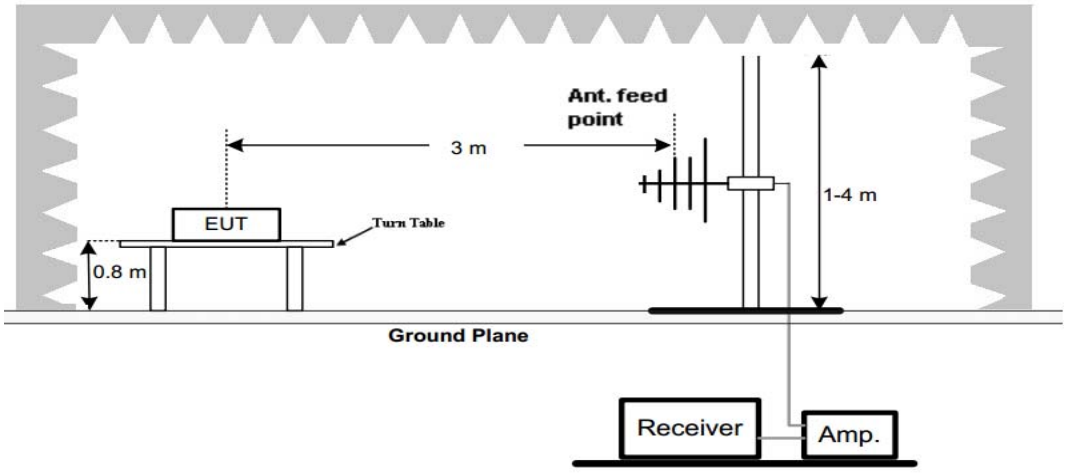
| Frequency (MHz) | Distance (Meters) | Radiated (dBμV/m) | Radiated (μV/m) |
|---|---|---|---|
| 0.009-0.49 | 3 | 20log(2400/F(KHz))+40log(300/3) | 2400/F(KHz) |
| 0.49-1.705 | 3 | 20log(24000/F(KHz))+ 40log(30/3) | 24000/F(KHz) |
| 1.705-30 | 3 | 20log(30)+ 40log(30/3) | 30 |
| 30-88 | 3 | 40.0 | 100 |
| 88-216 | 3 | 43.5 | 150 |
| 216-960 | 3 | 46.0 | 200 |
| Above 960 | 3 | 54.0 | 500 |

**TEST CONFIGURATION**

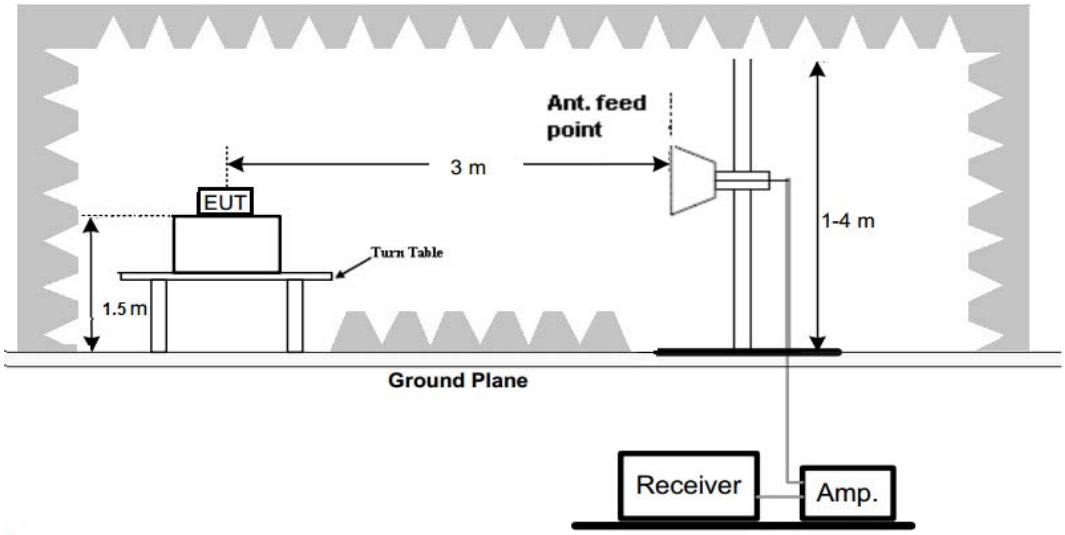
(A) Radiated Emission Test Set-Up, Frequency Below 30MHz




(B) Radiated Emission Test Set-Up, Frequency below 1000MHz



(C) Radiated Emission Test Set-Up, Frequency above 1000MHz




**TEST PROCEDURE**

a. The EUT was placed on a turn table which is 0.8m above ground plane for below 1GHz and 1.50m above ground plane for above 1GHz.
b. Maximum procedure was performed by raising the receiving antenna from 1m to 4m and rotating the turn table from 0℃ to 360℃ to acquire the highest emissions from EUT.
c. And also, each emission was to be maximized by changing the polarization of receiving antenna both horizontal and vertical.
d. Repeat above procedures until all frequency measurements have been completed.
e. The distance between test antenna and EUT as following table states:

| Test Frequency range | Test Antenna Type | Test Distance |
|---|---|---|
| 9KHz-30MHz | Active Loop Antenna | 3 |
| 30MHz-1GHz | Bilog Antenna | 3 |
| 1GHz-18GHz | Horn Antenna | 3 |
| 18GHz-25GHz | Horn Antenna | 1 |

f. Setting test receiver/spectrum as following table states:

| Test Frequency range | Test Receiver/Spectrum Setting | Detector |
|---|---|---|
| 9KHz-150KHz | RBW=200Hz/VBW=3KHz,Sweep time=Auto | QP/Average |
| 150KHz-30MHz | RBW=9KHz/VBW=100KHz,Sweep time=Auto | QP/Average |
| 30MHz-1GHz | RBW=120KHz/VBW=1000KHz,Sweep time=Auto | QP |
| 1GHz-40GHz | Peak Value: RBW=1MHz/VBW=3MHz, Sweep time=Auto | Peak |
| | Average Value: RBW=1MHz/VBW=330KHz, Sweep time=Auto | Peak |

More procure as follows;

**1) Sequence of testing 9 kHz to 30 MHz**

**Setup:**
--- The equipment was set up to simulate a typical usage like described in the user manual or described by manufacturer.
--- If the EUT is a tabletop system, a rotatable table with 0.8 m height is used.
--- If the EUT is a floor standing device, it is placed on the ground.
--- Auxiliary equipment and cables were positioned to simulate normal operation conditions.
--- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
--- The measurement distance is 3 meter.
--- The EUT was set into operation.

**Premeasurement:**
--- The turntable rotates from 0° to 315° using 45° steps.
--- The antenna height is 1.0 meter.
--- At each turntable position the analyzer sweeps with peak detection to find the maximum of all emissions

**Final measurement:**
--- Identified emissions during the premeasurement the software maximizes by rotating the turntable position (0° to 360°) and by rotating the elevation axes (0° to 360°).
--- The final measurement will be done in the position (turntable and elevation) causing the highest emissions with QP detector.
--- The final levels, frequency, measuring time, bandwidth, turntable position, correction factor, margin to the limit and limit will be recorded. Also a plot with the graph of the premeasurement and the limit will be stored.

**2) Sequence of testing 30 MHz to 1 GHz**

**Setup:**
--- The equipment was set up to simulate a typical usage like described in the user manual or described by manufacturer.
--- If the EUT is a tabletop system, a table with 0.8 m height is used, which is placed on the ground plane.
--- If the EUT is a floor standing device, it is placed on the ground plane with insulation between both.
--- Auxiliary equipment and cables were positioned to simulate normal operation conditions
--- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
--- The measurement distance is 3 meter.
--- The EUT was set into operation.

**Premeasurement:**
--- The turntable rotates from 0° to 315° using 45° steps.
--- The antenna is polarized vertical and horizontal.
--- The antenna height changes from 1 to 4 meter.
--- At each turntable position, antenna polarization and height the analyzer sweeps three times in peak to find the maximum of all emissions.

**Final measurement:**
--- The final measurement will be performed with minimum the six highest peaks.
--- According to the maximum antenna and turntable positions of premeasurement the software maximize the peaks by changing turntable position (± 45°) and antenna movement between 1 and 4 meter.
--- The final measurement will be done with QP detector with an EMI receiver.
--- The final levels, frequency, measuring time, bandwidth, antenna height, antenna polarization, turntable angle, correction factor, margin to the limit and limit will be recorded. Also a plot with the graph of the premeasurement with marked maximum final measurements and the limit will be stored.

**3) Sequence of testing 1 GHz to 18 GHz**

**Setup:**
--- The equipment was set up to simulate a typical usage like described in the user manual or described by manufacturer.
--- If the EUT is a tabletop system, a rotatable table with 1.5 m height is used.
--- If the EUT is a floor standing device, it is placed on the ground plane with insulation between both.
--- Auxiliary equipment and cables were positioned to simulate normal operation conditions
--- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
--- The measurement distance is 3 meter.
--- The EUT was set into operation.

**Premeasurement:**
--- The turntable rotates from 0° to 315° using 45° steps.
--- The antenna is polarized vertical and horizontal.
--- The antenna height scan range is 1 meter to 2.5 meter.
--- At each turntable position and antenna polarization the analyzer sweeps with peak detection to find the maximum of all emissions.

**Final measurement:**
--- The final measurement will be performed with minimum the six highest peaks.
--- According to the maximum antenna and turntable positions of premeasurement the software maximize the peaks by changing turntable position (± 45°) and antenna movement between 1 and 4 meter. This procedure is repeated for both antenna polarizations.
--- The final measurement will be done in the position (turntable, EUT-table and antenna polarization) causing the highest emissions with Peak and Average detector.
--- The final levels, frequency, measuring time, bandwidth, turntable position, EUT-table position, antenna polarization, correction factor, margin to the limit and limit will be recorded. Also a plot with the graph of the premeasurement with marked maximum final measurements and the limit will be stored.

**4) Sequence of testing above 18 GHz**

**Setup:**
--- The equipment was set up to simulate a typical usage like described in the user manual or described by manufacturer.
--- If the EUT is a tabletop system, a rotatable table with 1.5 m height is used.
--- If the EUT is a floor standing device, it is placed on the ground plane with insulation between both.
--- Auxiliary equipment and cables were positioned to simulate normal operation conditions
--- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
--- The measurement distance is 1 meter.
--- The EUT was set into operation.

**Premeasurement:**
--- The antenna is moved spherical over the EUT in different polarizations of the antenna.
Final measurement:
--- The final measurement will be performed at the position and antenna orientation for all detected emissions that were found during the premeasurements with Peak and Average detector.
--- The final levels, frequency, measuring time, bandwidth, correction factor, margin to the limit and limit will be recorded. Also a plot with the graph of the premeasurement and the limit will be stored.

**Field Strength Calculation**

The field strength is calculated by adding the Antenna Factor and Cable Factor and subtracting the Amplifier Gain and Duty Cycle Correction Factor (if any) from the measured reading. The basic equation with a sample calculation is as follows:

**FS = RA + AF + CL - AG**

| | |
|---|---|
| Where FS = Field Strength | CL = Cable Attenuation Factor (Cable Loss) |
| RA = Reading Amplitude | AG = Amplifier Gain |
| AF = Antenna Factor | |

For example

| Frequency (MHz) | FS (dBμV/m) | RA (dBμV/m) | AF (dB) | CL (dB) | AG (dB) | Transd (dB) |
|---|---|---|---|---|---|---|
| 300.00 | 40 | 58.1 | 12.2 | 1.6 | 31.90 | -18.1 |

Transd=AF +CL-AG

**TEST RESULTS**

*Remark:*
*1. All three channels (lowest/middle/highest), all modulation (GFSK, π/4 DQPSK, 8DPSK) and all data packet (DH1, DH3, DH5) were measured below 1GHz and recorded worst case at GFSK modulation DH5 data packet and low channel.*
*2. Radiated emission test from 9 KHz to 10th harmonic of fundamental was verified, and no emission found except system noise floor in 9 KHz to 30MHz and not recorded in this report.*
*3. "---" means not recorded as emission levels lower than limit.*
*4. Margin= Limit - Level*

***For 9 KHz to 30MHz***

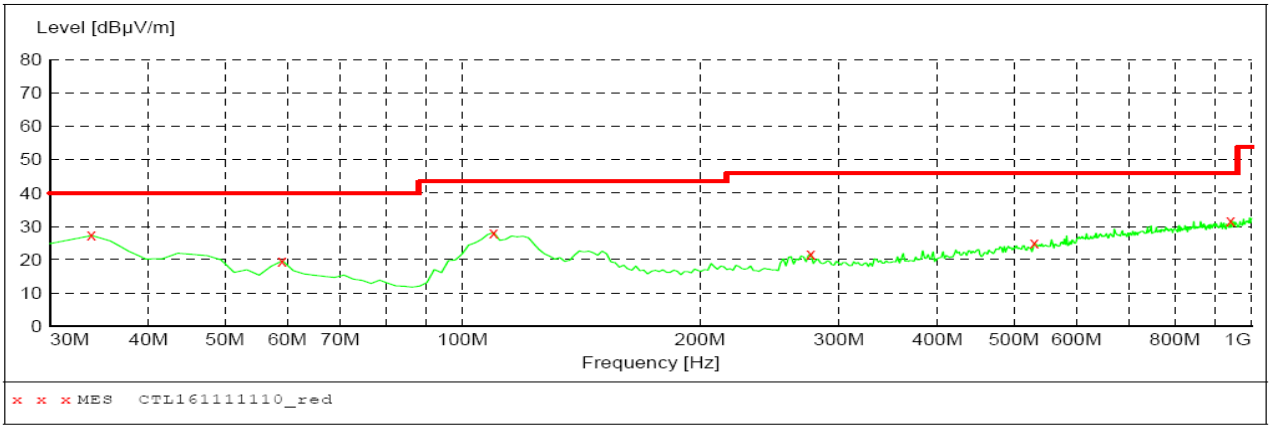
| Frequency (MHz) | Corrected Reading (dBμV/m)@3m | FCC Limit (dBμV/m) @3m | Margin (dB) | Detector | Result |
|---|---|---|---|---|---|
| --- | --- | --- | --- | --- | --- |
| | | | | | |

***For 30MHz-1GHz***

| Test mode: | BT - GFSK | Polarization: | Horizontal |
|---|---|---|---|

***SWEEP TABLE: "test (30M-1G)"***

| Short Description: | | | Field Strength | | |
|---|---|---|---|---|---|
| Start Frequency | Stop Frequency | Detector | Meas. Time | IF Bandw. | Transducer |
| 30.0 MHz | 1.0 GHz | MaxPeak | 300.0 ms | 120 kHz | JB1 |




***MEASUREMENT RESULT: "CTL161111110_red"***

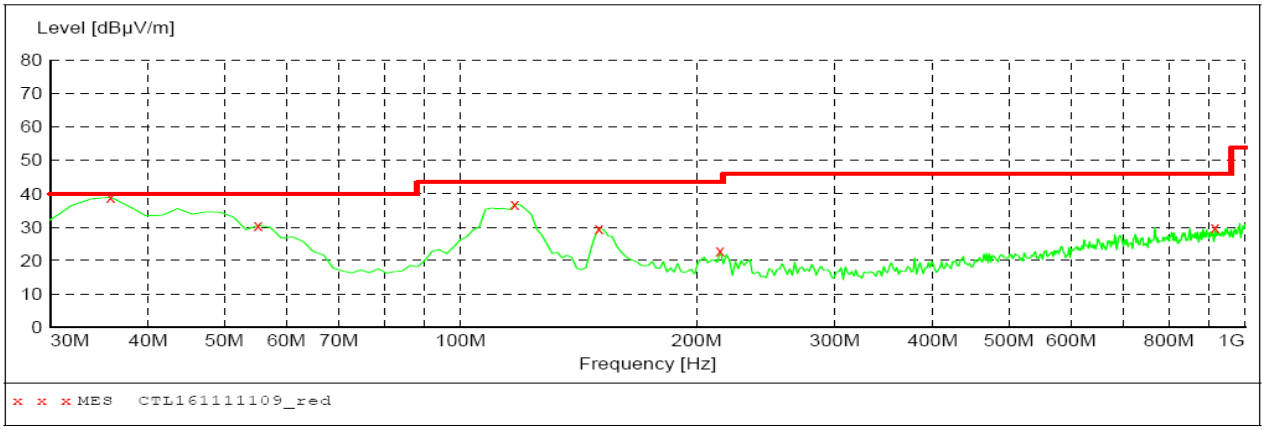
11/11/2016 9:53AM

| Frequency MHz | Level dBµV/m | Transd dB | Limit dBµV/m | Margin dB | Det. | Height cm | Azimuth deg | Polarization |
|---|---|---|---|---|---|---|---|---|
| 33.880000 | 27.30 | 17.7 | 40.0 | 12.7 | --- | 0.0 | 0.00 | HORIZONTAL |
| 59.100000 | 19.70 | 8.0 | 40.0 | 20.3 | --- | 0.0 | 0.00 | HORIZONTAL |
| 107.540000 | 28.10 | 13.3 | 43.5 | 15.4 | --- | 0.0 | 0.00 | HORIZONTAL |
| 276.380000 | 21.80 | 15.1 | 46.0 | 24.2 | --- | 0.0 | 0.00 | HORIZONTAL |
| 534.720000 | 24.90 | 20.4 | 46.0 | 21.1 | --- | 0.0 | 0.00 | HORIZONTAL |
| 940.800000 | 31.80 | 26.4 | 46.0 | 14.2 | --- | 0.0 | 0.00 | HORIZONTAL |

| Test mode: | BT - GFSK | Polarization: | Vertical |
|---|---|---|---|

***SWEEP TABLE: "test (30M-1G)"***

| Short Description: | | | Field Strength | | |
|---|---|---|---|---|---|
| Start Frequency | Stop Frequency | Detector | Meas. Time | IF Bandw. | Transducer |
| 30.0 MHz | 1.0 GHz | MaxPeak | 300.0 ms | 120 kHz | JB1 |




***MEASUREMENT RESULT: "CTL161111109_red"***

11/11/2016 9:55AM

| Frequency MHz | Level dBµV/m | Transd dB | Limit dBµV/m | Margin dB | Det. | Height cm | Azimuth deg | Polarization |
|---|---|---|---|---|---|---|---|---|
| 35.820000 | 39.00 | 16.2 | 40.0 | 1.0 | --- | 0.0 | 0.00 | VERTICAL |
| 55.220000 | 30.60 | 8.0 | 40.0 | 9.4 | --- | 0.0 | 0.00 | VERTICAL |
| 117.300000 | 36.80 | 14.7 | 43.5 | 6.7 | --- | 0.0 | 0.00 | VERTICAL |
| 150.280000 | 29.50 | 13.8 | 43.5 | 14.0 | --- | 0.0 | 0.00 | VERTICAL |
| 214.300000 | 22.80 | 14.0 | 43.5 | 20.7 | --- | 0.0 | 0.00 | VERTICAL |
| 916.580000 | 30.00 | 26.1 | 46.0 | 16.0 | --- | 0.0 | 0.00 | VERTICAL |

***For 1GHz to 25GHz***

***GFSK (above 1GHz)***

*Remark:*
*1. Measured all modes (GFSK, π/4 DQPSK, 8DPSK), recorded worst case at GFSK mode;*

| Frequency(MHz): | | | 2402 | | Polarity: | | | HORIZONTAL | |
|---|---|---|---|---|---|---|---|---|---|
| Frequency (MHz) | Emission Level (dBuV/m) | | Limit (dBuV/m) | Margin (dB) | Raw Value (dBuV) | Antenna Factor (dB/m) | Cable Factor (dB) | Pre-amplifier (dB) | Correction Factor (dB/m) |
| 4804.00 | 57.25 | PK | 74.00 | 16.75 | 52.74 | 33.49 | 6.91 | 35.89 | 4.51 |
| 4804.00 | 49.47 | AV | 54.00 | 4.53 | 44.96 | 33.49 | 6.91 | 35.89 | 4.51 |
| 5211.50 | 47.53 | PK | 74.00 | 26.47 | 40.14 | 34.55 | 7.15 | 34.31 | 7.39 |
| 5211.50 | -- | AV | 54.00 | -- | -- | -- | -- | -- | -- |
| 7206.00 | 50.15 | PK | 74.00 | 23.85 | 39.04 | 36.95 | 9.18 | 35.03 | 11.11 |
| 7206.00 | -- | AV | 54.00 | -- | -- | -- | -- | -- | -- |

| Frequency(MHz): | | | 2402 | | Polarity: | | | VERTICAL | |
|---|---|---|---|---|---|---|---|---|---|
| Frequency (MHz) | Emission Level (dBuV/m) | | Limit (dBuV/m) | Margin (dB) | Raw Value (dBuV) | Antenna Factor (dB/m) | Cable Factor (dB) | Pre-amplifier (dB) | Correction Factor (dB/m) |
| 4804.00 | 57.87 | PK | 74.00 | 16.13 | 53.36 | 33.49 | 6.91 | 35.89 | 4.51 |
| 4804.00 | 49.22 | AV | 54.00 | 4.78 | 44.71 | 33.49 | 6.91 | 35.89 | 4.51 |
| 5032.50 | 48.11 | PK | 74.00 | 25.89 | 41.21 | 34.09 | 7.05 | 34.24 | 6.90 |
| 5032.50 | -- | AV | 54.00 | -- | -- | -- | -- | -- | -- |
| 7206.00 | 50.69 | PK | 74.00 | 23.31 | 39.58 | 36.95 | 9.18 | 35.03 | 11.11 |
| 7206.00 | -- | AV | 54.00 | -- | -- | -- | -- | -- | -- |

| Frequency(MHz): | | | 2441 | | Polarity: | | | HORIZONTAL | |
|---|---|---|---|---|---|---|---|---|---|
| Frequency (MHz) | Emission Level (dBuV/m) | | Limit (dBuV/m) | Margin (dB) | Raw Value (dBuV) | Antenna Factor (dB/m) | Cable Factor (dB) | Pre-amplifier (dB) | Correction Factor (dB/m) |
| 4882.00 | 57.45 | PK | 74.00 | 16.55 | 52.80 | 33.60 | 6.95 | 35.90 | 4.65 |
| 4882.00 | 49.86 | AV | 54.00 | 4.14 | 45.21 | 33.60 | 6.95 | 35.90 | 4.65 |
| 5675.50 | 47.22 | PK | 74.00 | 26.78 | 39.50 | 34.79 | 7.41 | 34.47 | 7.72 |
| 5675.50 | -- | AV | 54.00 | -- | -- | -- | -- | -- | -- |
| 7323.00 | 49.15 | PK | 74.00 | 24.85 | 37.45 | 37.46 | 9.23 | 35.00 | 11.70 |
| 7323.00 | -- | AV | 54.00 | -- | -- | -- | -- | -- | -- |

| Frequency(MHz): | | | 2441 | | Polarity: | | | VERTICAL | |
|---|---|---|---|---|---|---|---|---|---|
| Frequency (MHz) | Emission Level (dBuV/m) | | Limit (dBuV/m) | Margin (dB) | Raw Value (dBuV) | Antenna Factor (dB/m) | Cable Factor (dB) | Pre-amplifier (dB) | Correction Factor (dB/m) |
| 4882.00 | 58.53 | PK | 74.00 | 15.47 | 53.88 | 33.60 | 6.95 | 35.90 | 4.65 |
| 4882.00 | 49.96 | AV | 54.00 | 4.04 | 45.31 | 33.60 | 6.95 | 35.90 | 4.65 |
| 5501.25 | 47.44 | PK | 74.00 | 26.56 | 39.79 | 34.75 | 7.31 | 34.41 | 7.65 |
| 5501.25 | -- | AV | 54.00 | -- | -- | -- | -- | -- | -- |
| 7323.00 | 49.35 | PK | 74.00 | 24.65 | 37.65 | 37.46 | 9.23 | 35.00 | 11.70 |
| 7323.00 | -- | AV | 54.00 | -- | -- | -- | -- | -- | -- |

| Frequency(MHz): | | | 2480 | | Polarity: | | | HORIZONTAL | |
|---|---|---|---|---|---|---|---|---|---|
| Frequency (MHz) | Emission Level (dBuV/m) | | Limit (dBuV/m) | Margin (dB) | Raw Value (dBuV) | Antenna Factor (dB/m) | Cable Factor (dB) | Pre-amplifier (dB) | Correction Factor (dB/m) |
| 4960.00 | 57.86 | PK | 74.00 | 16.14 | 52.94 | 33.84 | 7.00 | 35.92 | 4.92 |
| 4960.00 | 48.74 | AV | 54.00 | 5.26 | 43.82 | 33.84 | 7.00 | 35.92 | 4.92 |
| 5224.50 | 48.29 | PK | 74.00 | 25.71 | 40.88 | 34.56 | 7.15 | 34.31 | 7.41 |
| 5224.50 | -- | AV | 54.00 | -- | -- | -- | -- | -- | -- |
| 7440.00 | 49.11 | PK | 74.00 | 24.89 | 37.16 | 37.64 | 9.28 | 34.97 | 11.95 |
| 7440.00 | -- | AV | 54.00 | -- | -- | -- | -- | -- | -- |

| Frequency(MHz): | | | 2480 | | Polarity: | | | VERTICAL | |
|---|---|---|---|---|---|---|---|---|---|
| Frequency (MHz) | Emission Level (dBuV/m) | | Limit (dBuV/m) | Margin (dB) | Raw Value (dBuV) | Antenna Factor (dB/m) | Cable Factor (dB) | Pre-amplifier (dB) | Correction Factor (dB/m) |
| 4960.00 | 57.95 | PK | 74.00 | 16.05 | 53.03 | 33.84 | 7.00 | 35.92 | 4.92 |
| 4960.00 | 48.65 | AV | 54.00 | 5.35 | 43.73 | 33.84 | 7.00 | 35.92 | 4.92 |
| 5035.75 | 48.35 | PK | 74.00 | 25.65 | 41.44 | 34.11 | 7.05 | 34.24 | 6.91 |
| 5035.75 | -- | AV | 54.00 | -- | -- | -- | -- | -- | -- |
| 7440.00 | 50.11 | PK | 74.00 | 23.89 | 38.16 | 37.64 | 9.28 | 34.97 | 11.95 |
| 7440.00 | -- | AV | 54.00 | -- | -- | -- | -- | -- | -- |

*Remark:*
*1. Emission level (dBuV/m) =Raw Value (dBuV) +Correction Factor (dB/m)*
*2. Correction Factor (dB/m) = Antenna Factor (dB/m) +Cable Factor (dB)-Pre-amplifier Factor*
*3. Margin value = Limit value- Emission level.*
*4. -- Mean the PK detector measured value is below average limit.*
*5. The other emission levels were very low against the limit.*
*6. RBW=1MHz VBW=3MHz Peak detector is for Peak value; RBW=1MHz VBW=330KHz Peak detector is for Average value.*

## 3.3. Maximum Peak Output Power

**LIMITS**

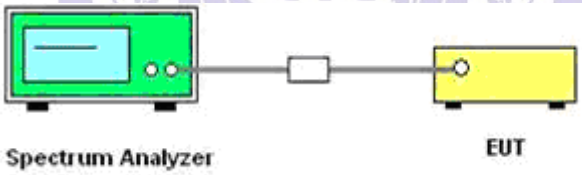
According to §15.247(b)(1), For frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725-5850 MHz band: 1watt. For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 watts.

**TEST PROCEDURE**

According to ANSI C63.10:2013 7.8.5 Output power test procedure for frequency-hopping spread-spectrum (FHSS) devices; this is an RF-conducted test to evaluate maximum peak output power. Use a direct connection between the antenna port of the unlicensed wireless device and the spectrum analyzer, through suitable attenuation. The hopping shall be disabled for this test:

a) Use the following spectrum analyzer settings:
1) Span: Approximately five times the 20 dB bandwidth, centered on a hopping channel.
2) RBW > 20 dB bandwidth of the emission being measured.
3) VBW ≥ RBW.
4) Sweep: Auto.
5) Detector function: Peak.
6) Trace: Max hold.
b) Allow trace to stabilize.
c) Use the marker-to-peak function to set the marker to the peak of the emission.
d) The indicated level is the peak output power, after any corrections for external attenuators and cables.

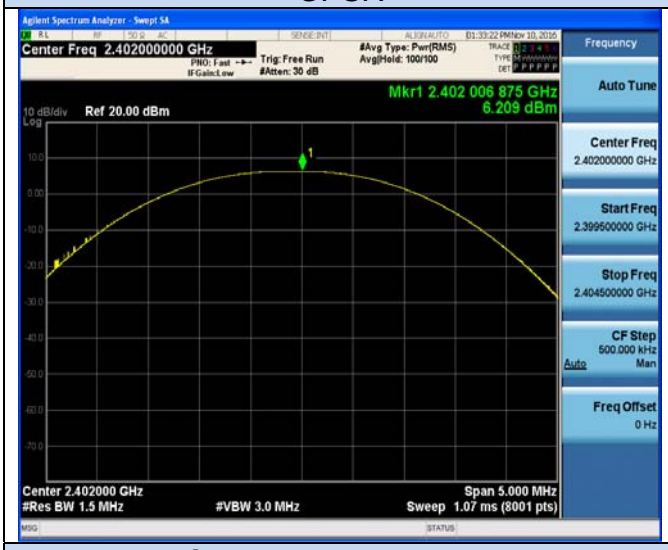
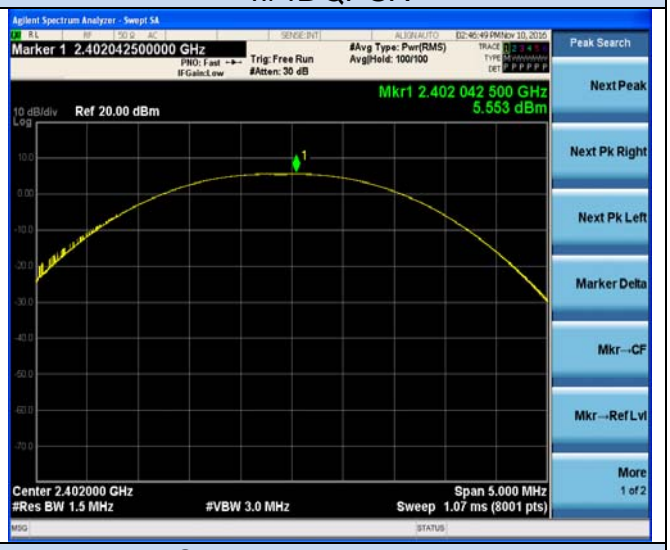
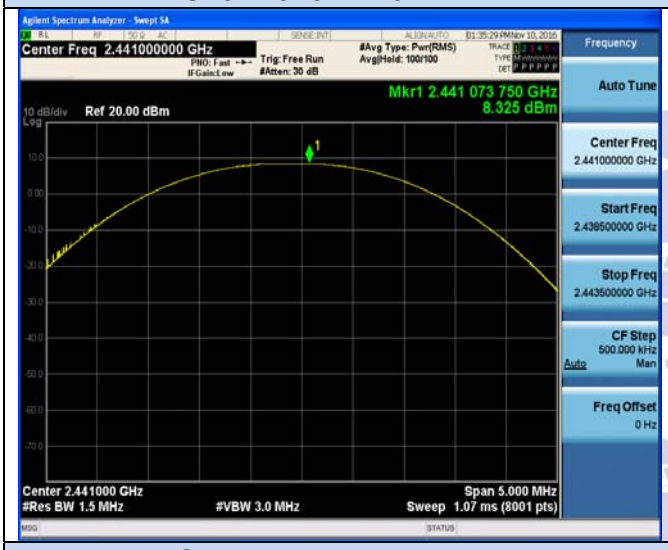
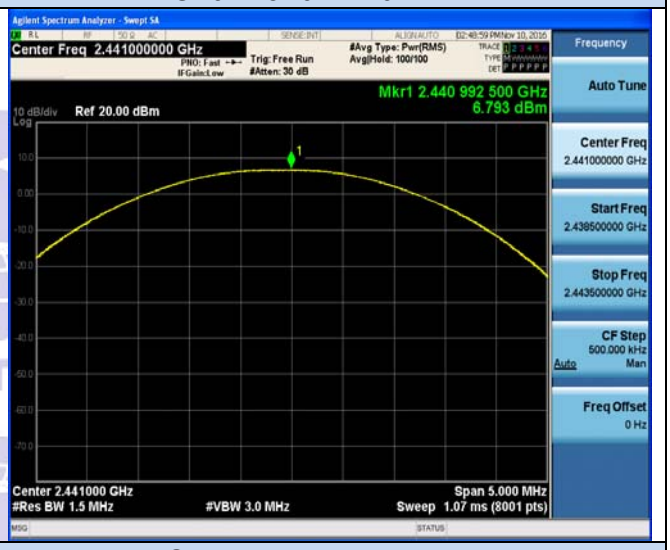
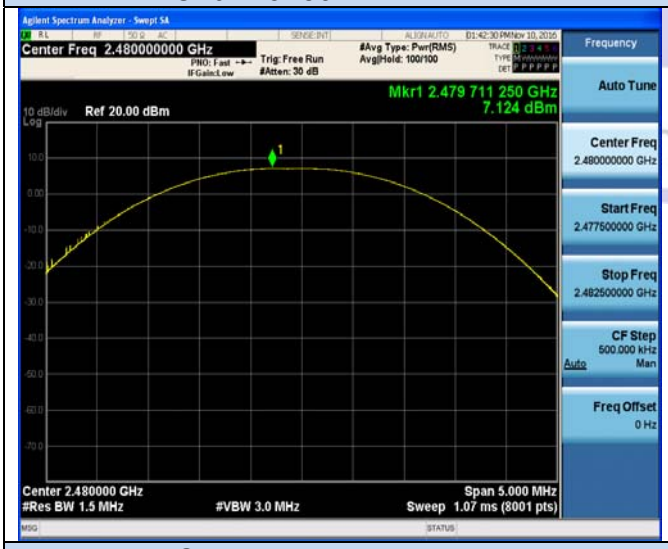
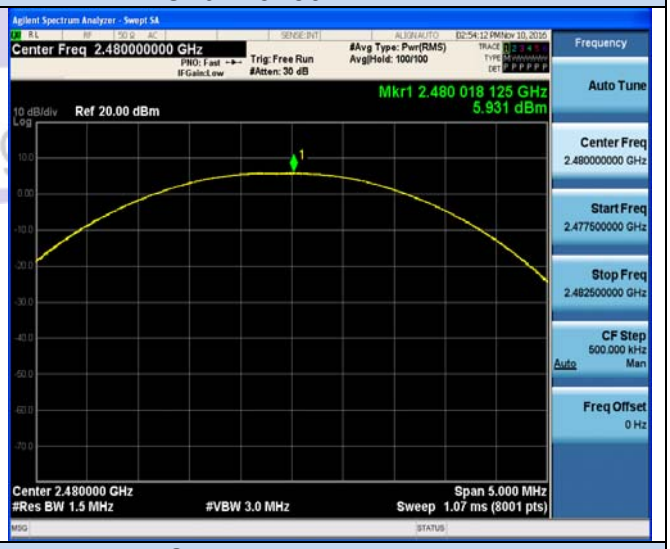
**TEST CONFIGURATION**

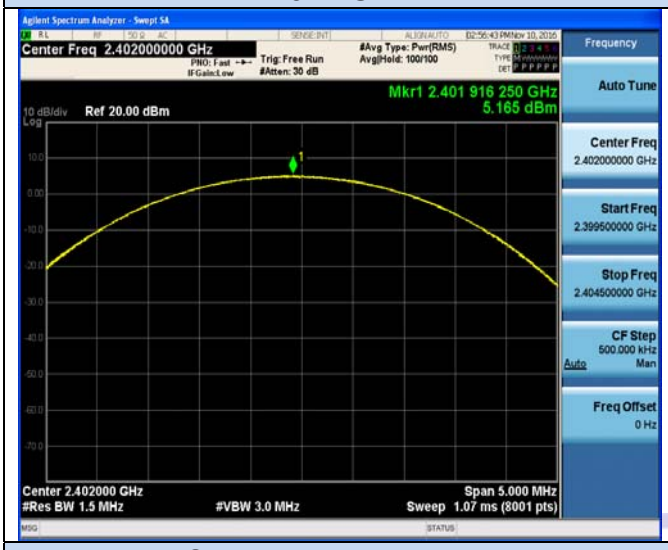
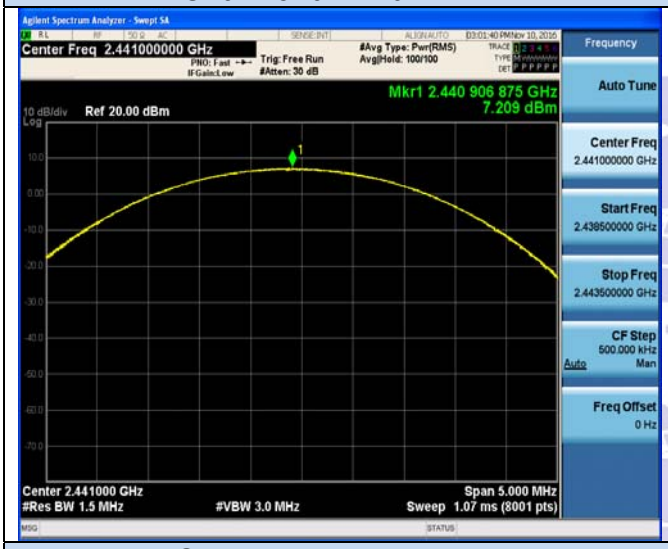
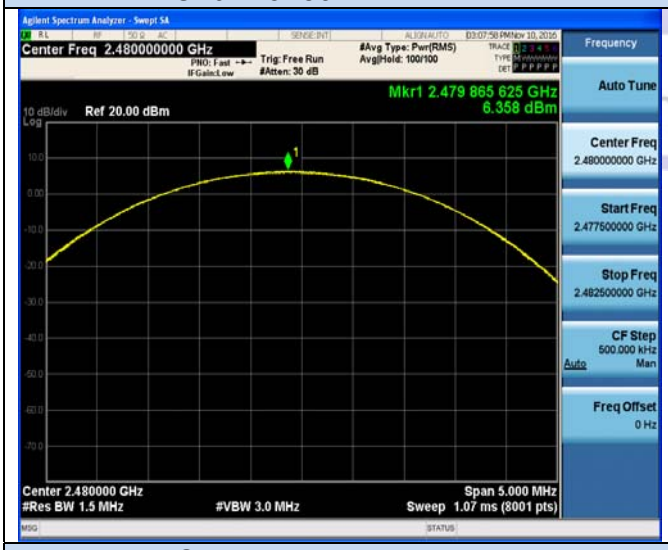



**TEST RESULTS**

| Test Mode | Channel | Frequency (MHz) | Measured Peak Power (dBm) | Limits (dBm) | Verdict |
|---|---|---|---|---|---|
| GFSK | 0 | 2402 | 6.209 | 30 | PASS |
| | 39 | 2441 | 8.325 | | |
| | 78 | 2480 | 7.124 | | |
| π/4DQPSK | 0 | 2402 | 5.553 | 21 | PASS |
| | 39 | 2441 | 6.793 | | |
| | 78 | 2480 | 5.931 | | |
| 8DPSK | 0 | 2402 | 5.165 | 21 | PASS |
| | 39 | 2441 | 7.209 | | |
| | 78 | 2480 | 6.358 | | |

*Remark:*
*1. Test results including cable loss;*
*2. Please refer to following plots;*
*3. Measured output power at difference Packet Type for each mode and recorded worst case for each mode.*
*4. Worst case data at DH5 for GFSK, π/4DQPSK, 8DPSK modulation type;*

| Maximum Peak Output Power | |
|---|---|
| GFSK | π/4DQPSK |
|  |  |
| Channel 0 / 2402 MHz | Channel 0 / 2402 MHz |
|  |  |
| Channel 39 / 2441 MHz | Channel 39 / 2441 MHz |
|  |  |
| Channel 78 / 2480 MHz | Channel 78 / 2480 MHz |

| Maximum Peak Output Power | |
|---|---|
| 8DPSK | |
|  | |
| Channel 0 / 2402 MHz | |
|  | |
| Channel 39 / 2441 MHz | |
|  | |
| Channel 78 / 2480 MHz | |

## 3.4. 20dB Bandwidth

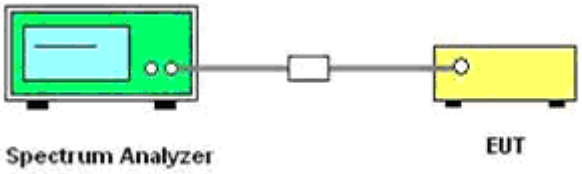
**LIMIT**

For frequency hopping systems operating in the 2400MHz-2483.5MHz no limit for 20dB bandwidth.

**TEST PROCEDURE**

The transmitter output was connected to the spectrum analyzer through an attenuator. The bandwidth of the fundamental frequency was measured by spectrum analyzer with RBW=30 KHz and VBW=100 KHz.
The 20dB bandwidth is defined as the total spectrum the power of which is higher than peak power minus 20dB.

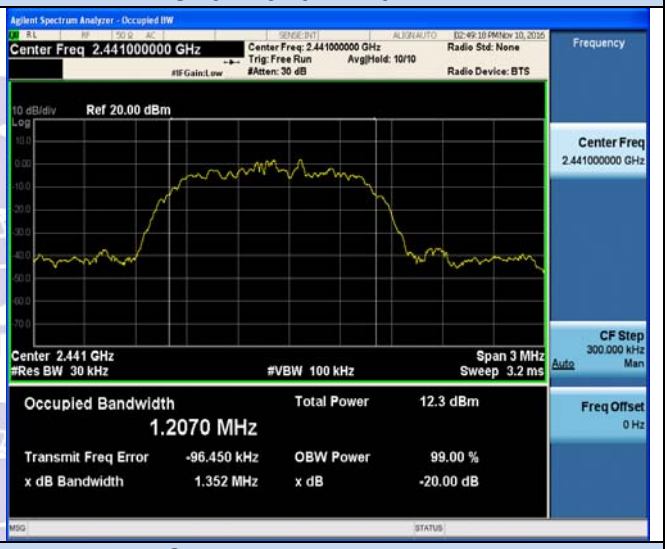
**TEST CONFIGURATION**




**TEST RESULTS**

| Channel | Frequency (MHz) | 20dB Bandwidth (KHz) | | | Limits (KHz) | Verdict |
|---|---|---|---|---|---|---|
| | | GFSK | π/4DQPSK | 8DPSK | | |
| 0 | 2402 | 942.90 | 1356.00 | 1313.00 | / | PASS |
| 39 | 2441 | 999.20 | 1352.00 | 1315.00 | / | PASS |
| 78 | 2480 | 1007.00 | 1353.00 | 1340.00 | / | PASS |

*Remark:*
*1. Test results including cable loss;*
*2. Please refer to following plots;*
*3. Measured at difference Packet Type for each mode and recorded worst case for each mode.*
*4. Worst case data at DH5 for GFSK, π/4DQPSK, 8DPSK modulation type;*

| 20dB Bandwidth | |
|---|---|
| GFSK | π/4DQPSK |
|  |  |
| Channel 0 / 2402 MHz | Channel 0 / 2402 MHz |
|  |  |
| Channel 39 / 2441 MHz | Channel 39 / 2441 MHz |
|  |  |
| Channel 78 / 2480 MHz | Channel 78 / 2480 MHz |

| 20dB Bandwidth | |
|---|---|
| 8DPSK | |
|  | |
| Channel 0 / 2402 MHz | |
|  | |
| Channel 39 / 2441 MHz | |
|  | |
| Channel 78 / 2480 MHz | |

## 3.5. Frequency Separation

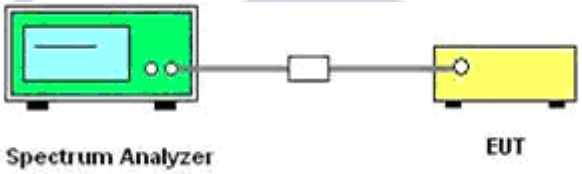
**LIMIT**

According to 15.247(a)(1),frequency hopping systems shall have hopping channel carrier frequencies separated by minimum of 25KHz or the 2/3*20dB bandwidth of the hopping channel, whichever is greater.

**TEST PROCEDURE**

The EUT shall have its hopping function enabled. Use the following spectrum analyser settings:
a) Span: Wide enough to capture the peaks of two adjacent channels.
b) RBW: Start with the RBW set to approximately 30% of the channel spacing; adjust as necessary to best identify the centre of each individual channel.
c) Video (or average) bandwidth (VBW) ≥ RBW.
d) Sweep: Auto.
e) Detector function: Peak.
f) Trace: Max hold.
g) Allow the trace to stabilize.

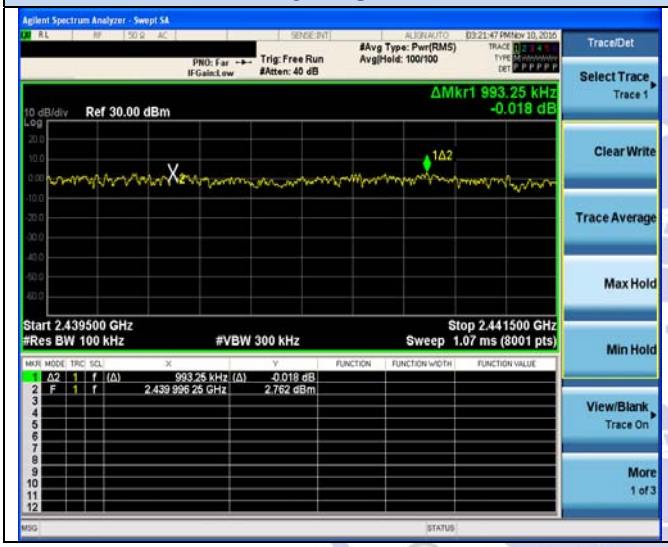
**TEST CONFIGURATION**




**TEST RESULTS**

| Test Mode | Channel | Frequency (MHz) | Frequency Separation (MHz) | Limits (MHz) | Verdict |
|---|---|---|---|---|---|
| GFSK | 38 | 2440 | 0.952 | 0.9249 | PASS |
| | 39 | 2441 | | | |
| π/4DQPSK | 38 | 2440 | 0.989 | 0.9013 | PASS |
| | 39 | 2441 | | | |
| 8DPSK | 38 | 2440 | 0.993 | 0.8954 | PASS |
| | 39 | 2441 | | | |

*Remark:*
*1. Test results including cable loss;*
*2. Please refer to following plots;*
*3. Measured at difference Packet Type for each mode and recorded worst case for each mode.*
*4. Measured all channels recorded middle channel;*
*5. Worst case data at DH5 for GFSK, π/4DQPSK, 8DPSK modulation type;*

| Frequency Separation | |
|---|---|
| GFSK | π/4DQPSK |
|  |  |
| 8DPSK | |
|  | |

## 3.6. Number of hopping frequency

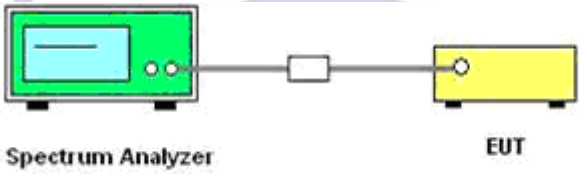
**LIMIT**

Frequency hopping systems in the 2400–2483.5 MHz band shall use at least 15 channels.

**TEST PROCEDURE**

The EUT shall have its hopping function enabled. Use the following spectrum analyzer settings:
a) 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.
b) RBW: To identify clearly the individual channels, set the RBW to less than 30% of the channel spacing or the 20 dB bandwidth;
c) VBW ≥ RBW.
d) Sweep: Auto.
e) Detector function: Peak.
f) Trace: Max hold.
g) Allow the trace to stabilize.

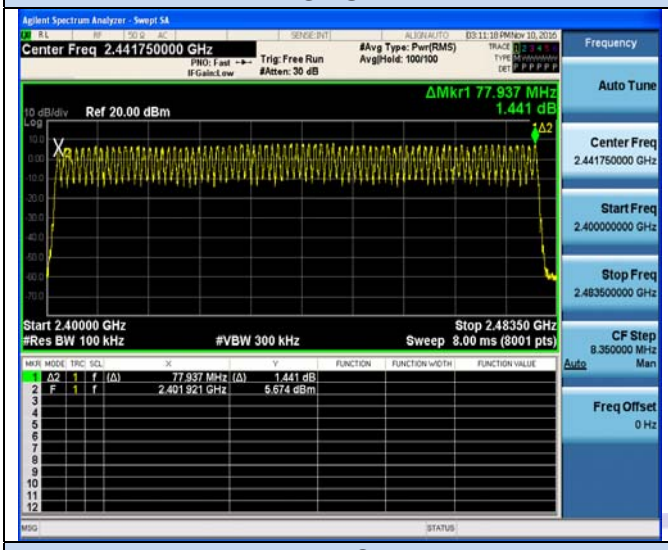
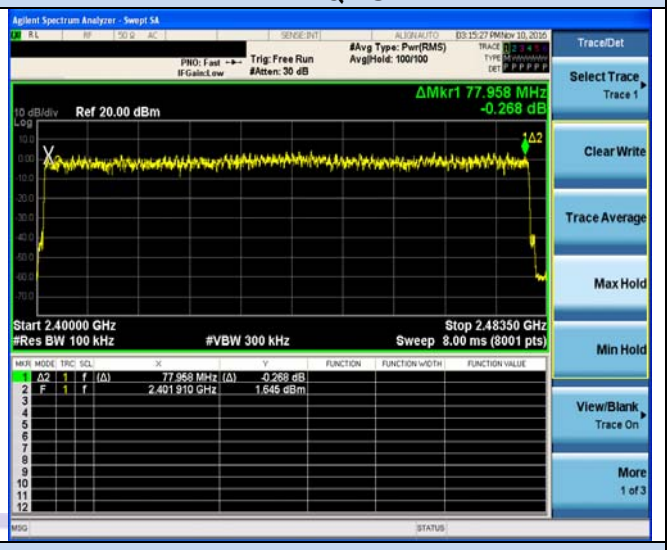
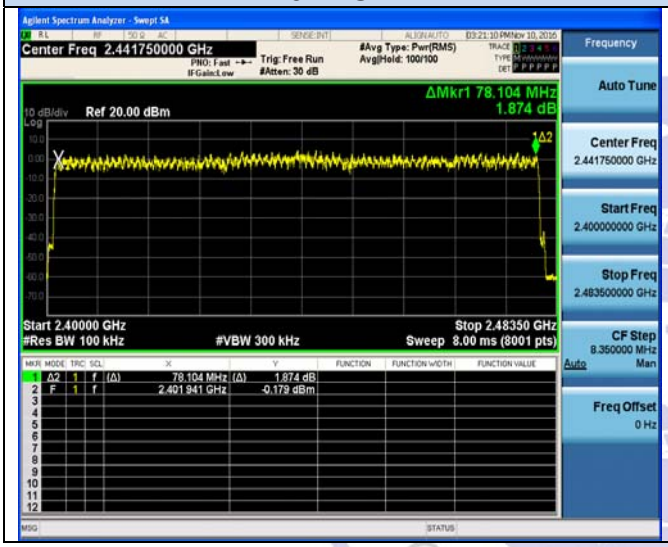
**TEST CONFIGURATION**




**TEST RESULTS**

| Test Mode | Channel | Frequency (MHz) | Numbers of Channel | Limits | Verdict |
|---|---|---|---|---|---|
| **GFSK** | Full (hopping) | 2402-2480 | 79 | 15 | PASS |
| **π/4DQPSK** | Full (hopping) | 2402-2480 | 79 | 15 | PASS |
| **8DPSK** | Full (hopping) | 2402-2480 | 79 | 15 | PASS |

*Remark:*
*1. Test results including cable loss;*
*2. Please refer to following plots;*
*3. Measured at difference Packet Type for each mode and recorded worst case for each mode.*
*4. Worst case data at DH5 for GFSK, π/4DQPSK, 8DPSK modulation type;*

| Frequency Separation | |
|---|---|
| GFSK | π/4DQPSK |
|  |  |
| 8DPSK | |
|  | |

## 3.7. Time of Occupancy (Dwell Time)

**LIMIT**

The average time of occupancy on any channel shall not be greater than 0.4 seconds within a pe-riod of 0.4 seconds multiplied by the number of hopping channels employed.

**TEST PROCEDURE**

The EUT shall have its hopping function enabled. Use the following spectrum analyzer settings:
a) Span: Zero span, centered on a hopping channel.
b) RBW shall be ≥ channel spacing and where possible RBW should be set >> 1 / T, where T is the expected dwell time per channel.
c) Sweep: As necessary to capture the entire dwell time per hopping channel; where possible use a video trigger and trigger delay so that the transmitted signal starts a little to the right of the start of the plot. The trigger level might need slight adjustment to prevent triggering when the system hops on an adjacent channel; a second plot might be needed with a longer sweep time to show two successive hops on a channel.
d) Detector function: Peak.
e) Trace: Max hold.

**TEST CONFIGURATION**

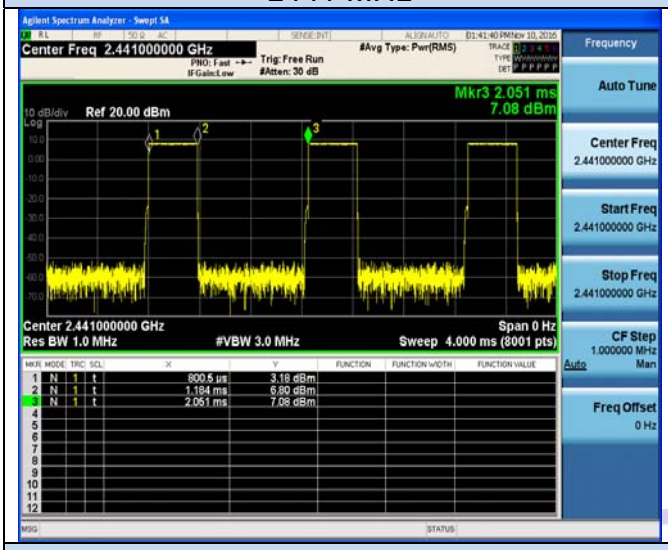
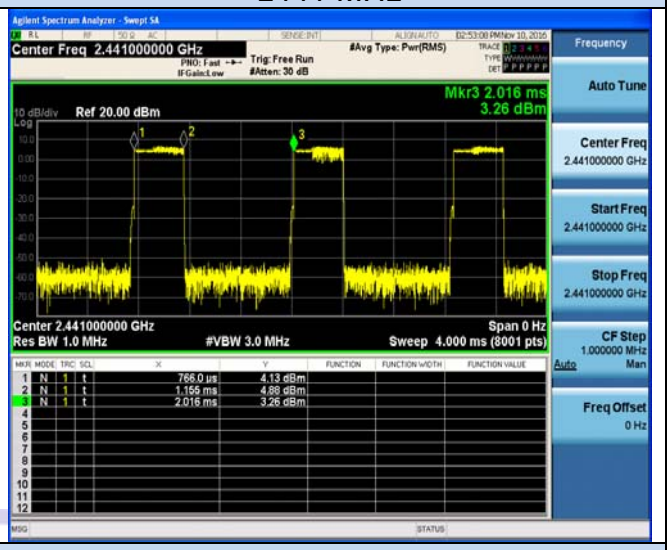
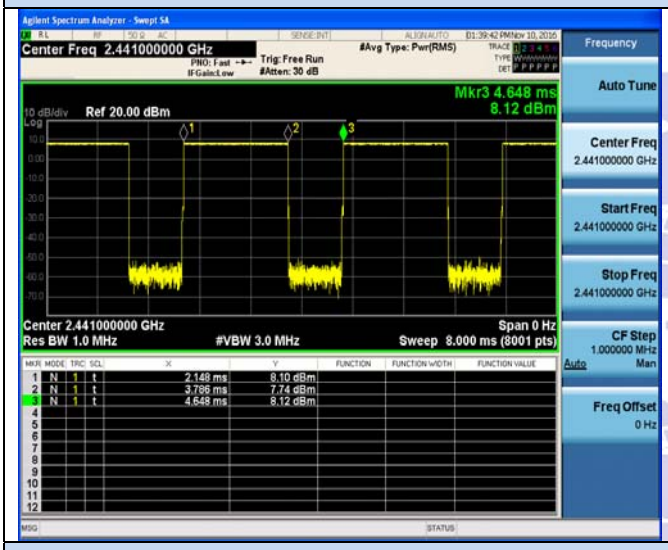
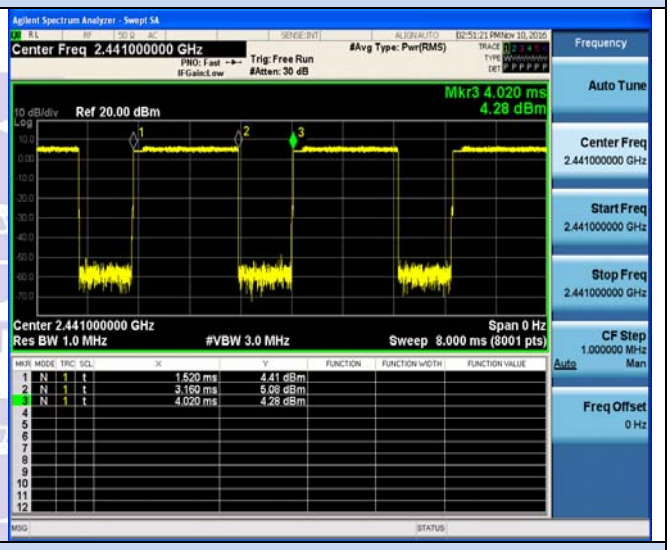
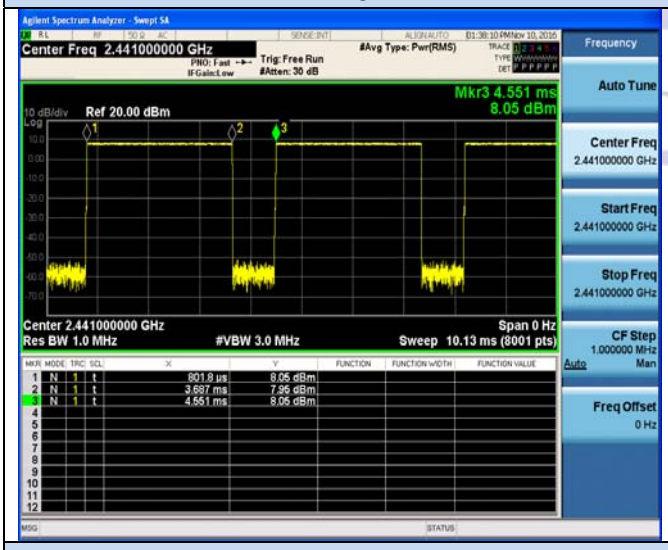
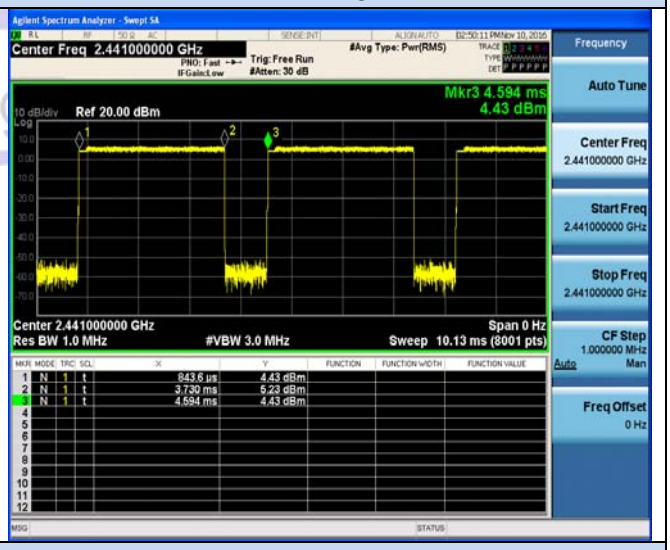

**TEST RESULTS**

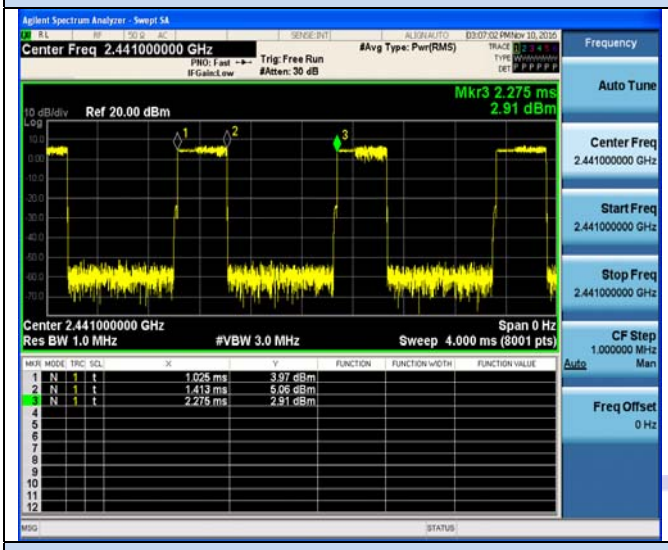
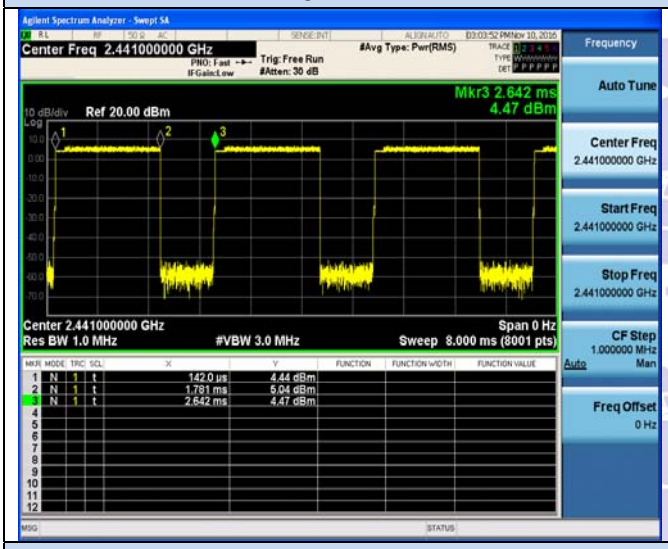
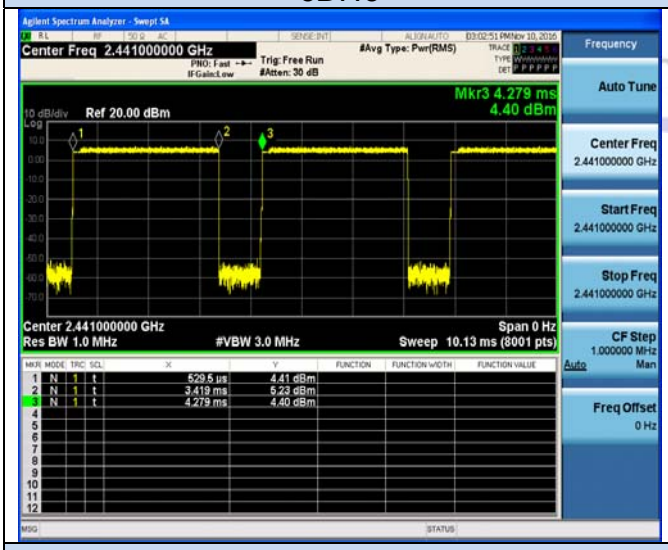
The Dwell Time=Burst Width*Total Hops. The detailed calculations are showed as follows:
The duration for dwell time calculation:0.4[s]*hopping number=0.4[s]*79[ch]=31.6[s*ch];
The burst width [ms/hop/ch], which is directly measured, refers to the duration on one channel hop.
The hops per second for all channels: The selected EUT Conf uses a slot type of 5-Tx&1-Rx and a hopping rate of 1600 [ch*hop/s] for all channels. So the final hopping rate for all channels is 1600/6=266.67 [ch*hop/s]
The hops per second on one channel: 266.67 [ch*hops/s]/79 [ch]=3.38 [hop/s];
The total hops for all channels within the dwell time calculation duration: 3.38 [hop/s]*31.6[s*ch]=106.67 [hop*ch];
The dwell time for all channels hopping: 106.67 [hop*ch]*Burst Width [ms/hop/ch].

| Mode | Frequency (MHz) | Burst Type | Pulse Width (ms) | Dwell Time (S) | Limit (S) | Verdict |
|---|---|---|---|---|---|---|
| GFSK | 2441 | DH1 | 0.384 | 0.123 | 0.4 | PASS |
| | | DH3 | 1.638 | 0.262 | 0.4 | PASS |
| | | DH5 | 2.885 | 0.308 | 0.4 | PASS |
| π/4DQPSK | 2441 | 2DH1 | 0.389 | 0.124 | 0.4 | PASS |
| | | 2DH3 | 1.640 | 0.262 | 0.4 | PASS |
| | | 2DH5 | 2.886 | 0.308 | 0.4 | PASS |
| 8DPSK | 2441 | 3DH1 | 0.388 | 0.124 | 0.4 | PASS |
| | | 3DH3 | 0.361 | 0.058 | 0.4 | PASS |
| | | 3DH5 | 2.890 | 0.308 | 0.4 | PASS |

*Remark:*
*1. Test results including cable loss;*
*2. Please refer to following plots;*
*3. Measured at difference Packet Type for each mode and recorded worst case for each mode.*
*4. Worst case data at DH5 for GFSK, π/4DQPSK, 8DPSK modulation type;*

*5. Dwell Time Calculate formula:*
*DH1: Dwell time=Pulse time (ms) × (1600 ÷ 2 ÷ 79) ×31.6 Second*
*DH3: Dwell time=Pulse time (ms) × (1600 ÷ 4 ÷ 79) ×31.6 Second*
*DH5: Dwell time=Pulse Time (ms) × (1600 ÷ 6 ÷ 79) ×31.6 Second*
*6. Measured at low, middle and high channel, recorded worst at middle channel;*

| Time Of Occupancy (Dwell Time) | |
|---|---|
| GFSK | π/4DQPSK |
| 2441 MHz | 2441 MHz |
|  |  |
| DH1 | 2DH1 |
|  |  |
| DH3 | 2DH3 |
|  |  |
| DH5 | 2DH5 |

| *Time Of Occupancy (Dwell Time)* | |
|---|---|
| *8DPSK* | |
| *2441 MHz* | |
|  | |
| *3DH1* | |
|  | |
| *3DH3* | |
|  | |
| *3DH5* | |

## 3.8. Spurious RF Conducted Emission

**LIMIT**

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 con-ducted or a radiated measurement, pro-vided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter com-plies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required.

**TEST PROCEDURE**

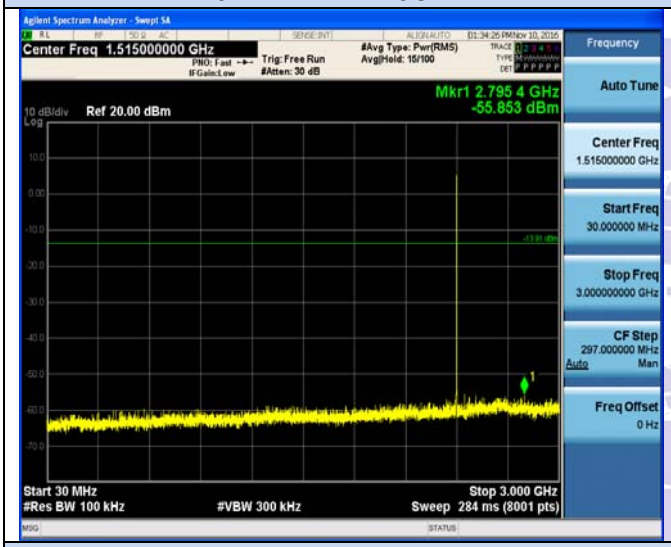
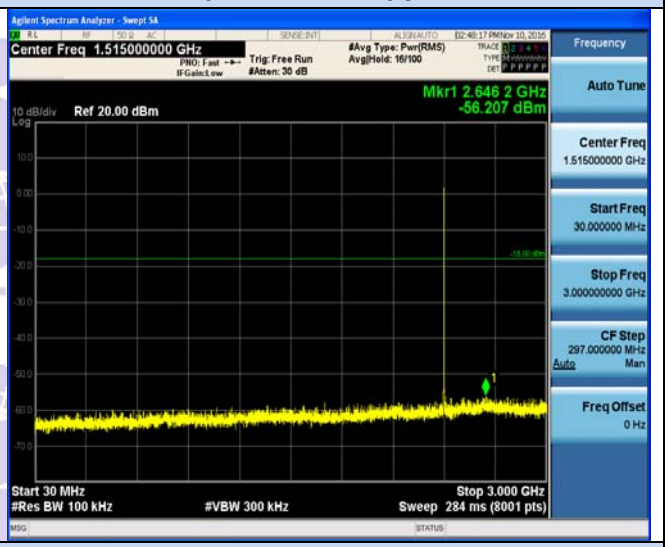
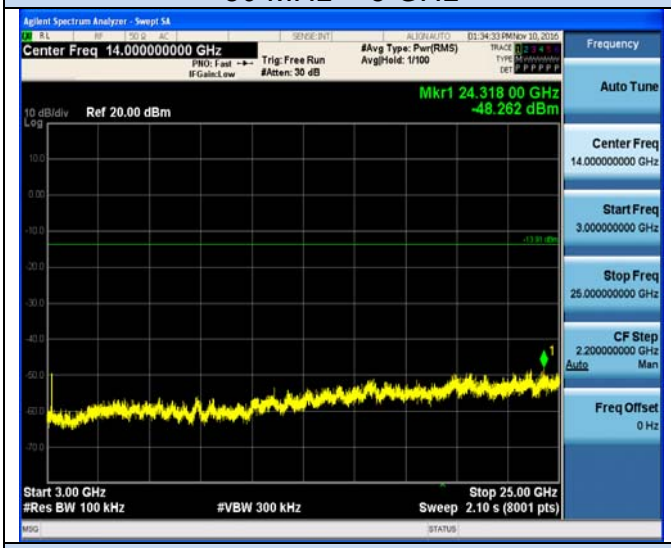
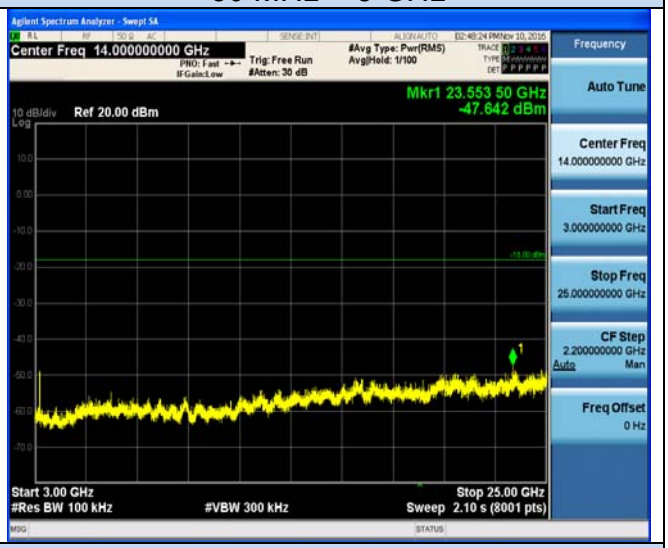
The Spurious RF conducted emissions compliance of RF radiated emission should be measured by following the guidance in ANSI C63.10-2013 with respect to maximizing the emission by rotating the EUT, measuring the emission while the EUT is situated in three orthogonal planes (if appropriate), adjusting the measurement antenna height and polarization etc. Set RBW=100 kHz and VBW= 300 KHz to measure the peak field strength, and measure frequency range from 9 KHz to 25GHz.

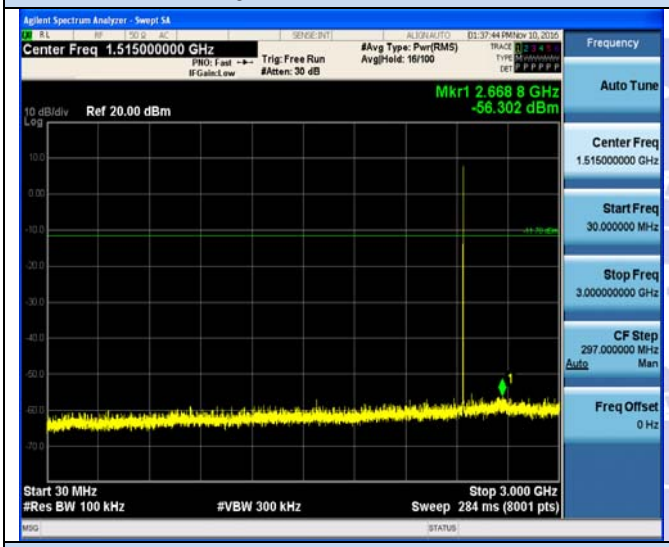
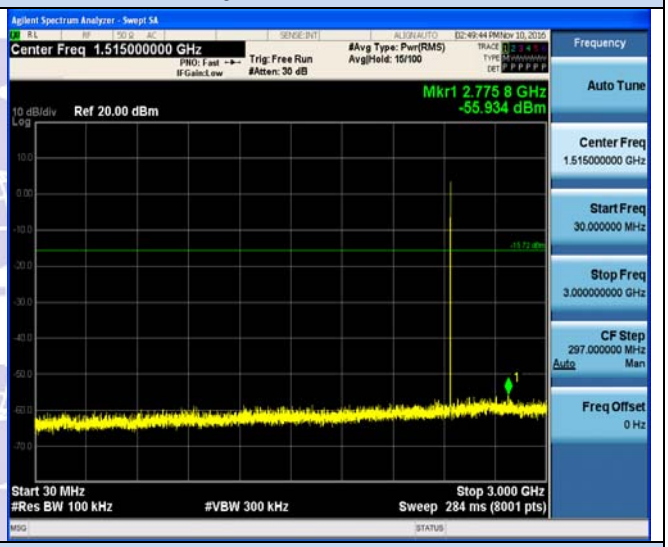
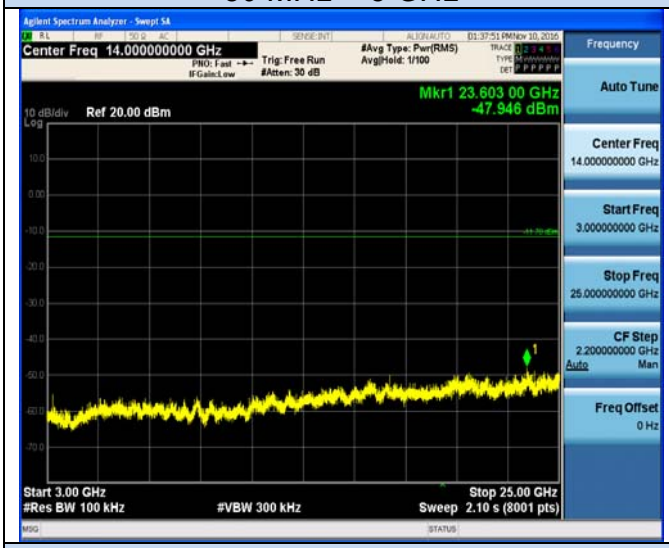
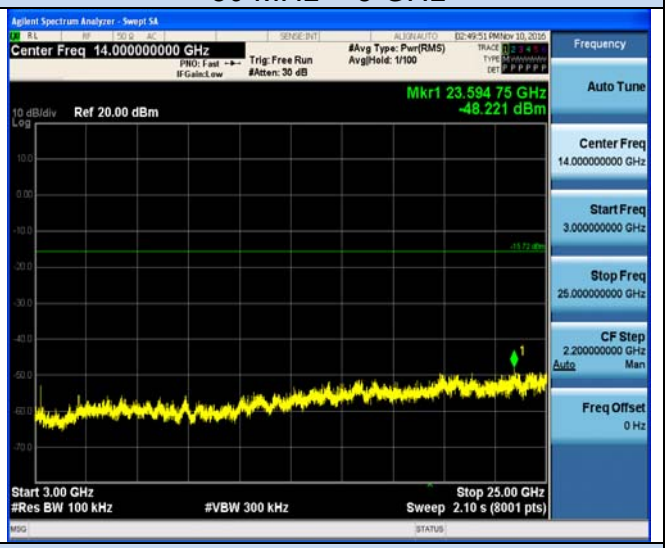
**TEST CONFIGURATION**

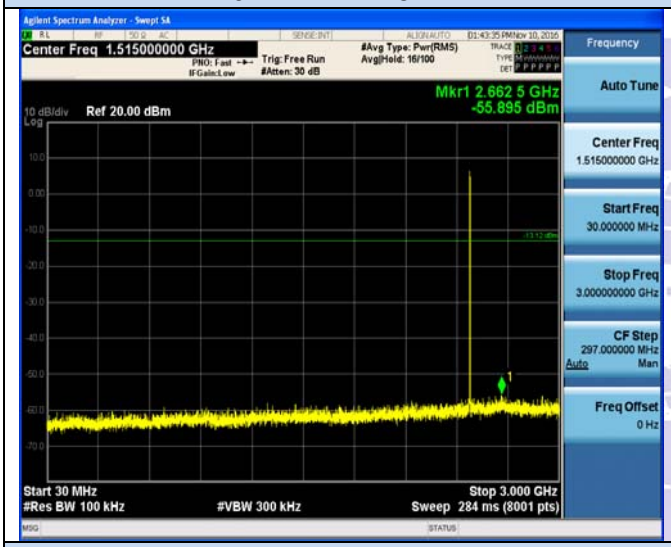
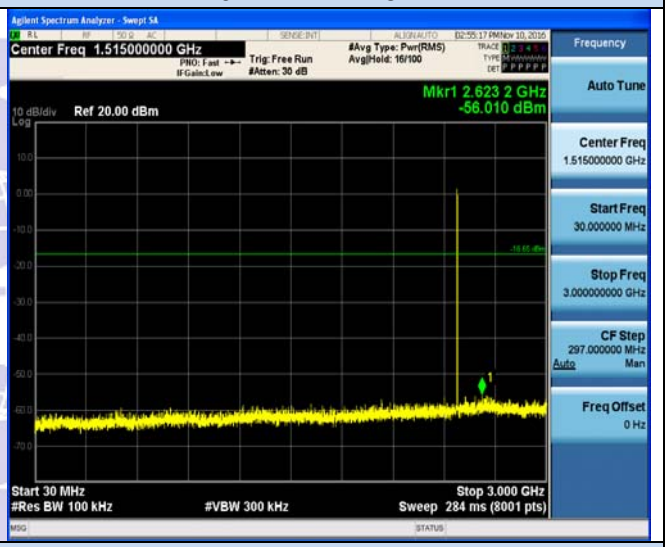
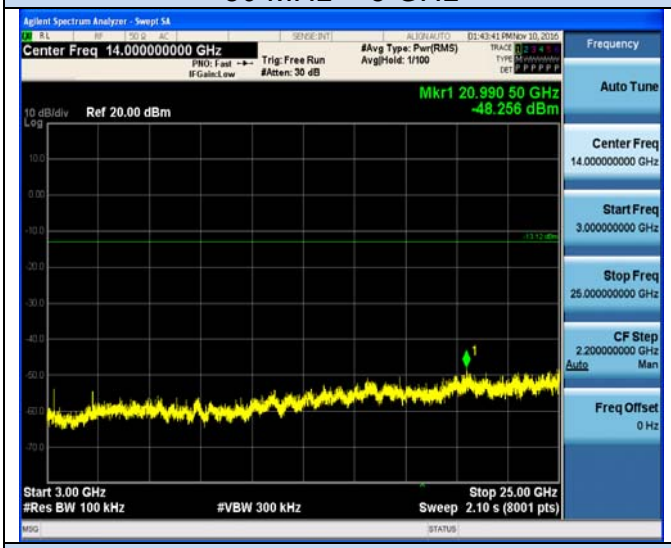
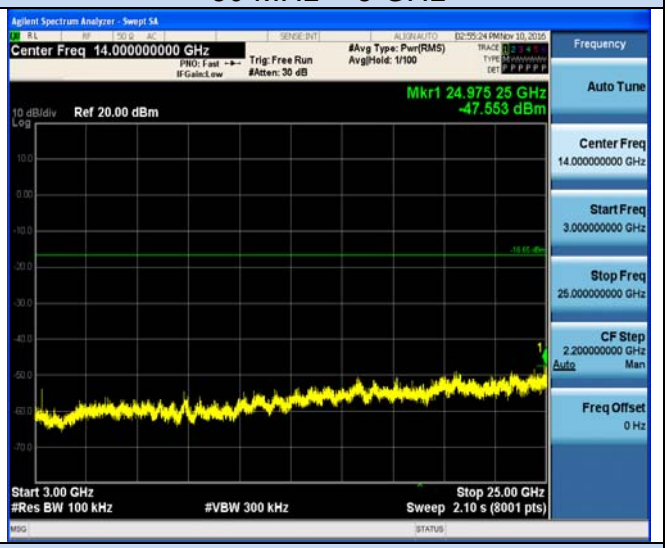

**TEST RESULTS**

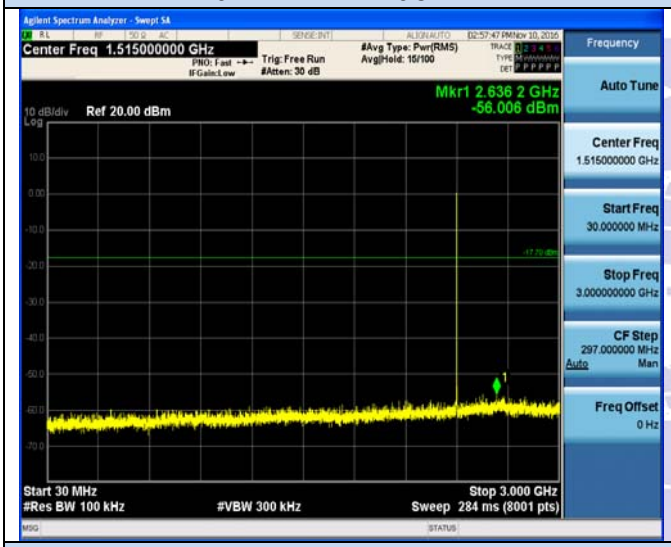
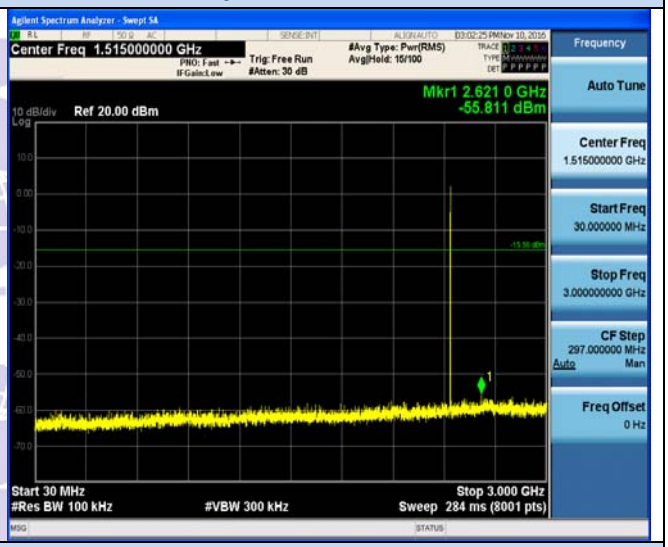
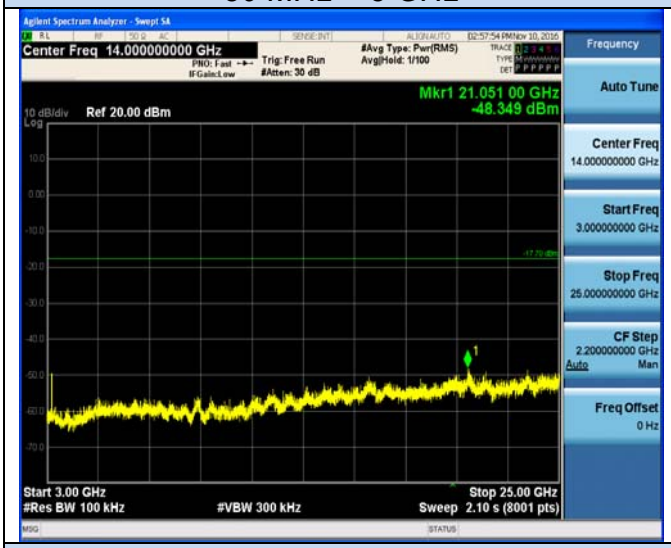
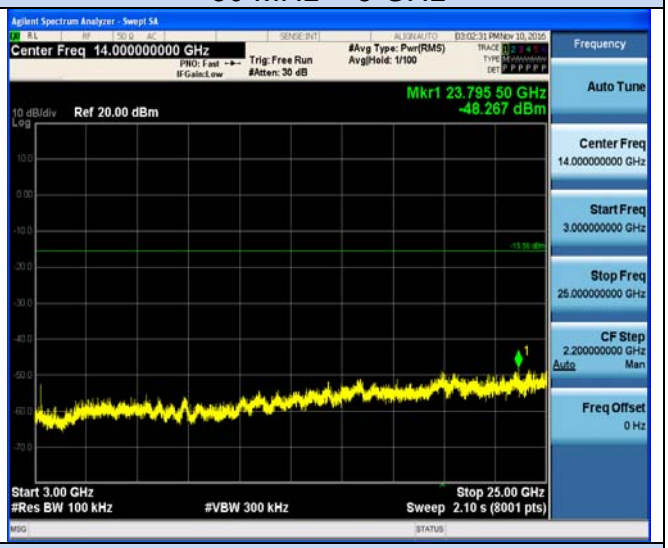
| Test Mode | Channel | Frequency (MHz) | Spurious RF Conducted Emission (dBc) | Limits (dBc) | Verdict |
|---|---|---|---|---|---|
| GFSK | 0 | 2402 | <-20dBc | -20 | PASS |
| | 39 | 2441 | <-20dBc | -20 | |
| | 78 | 2480 | <-20dBc | -20 | |
| π/4DQPSK | 0 | 2402 | <-20dBc | -20 | PASS |
| | 39 | 2441 | <-20dBc | -20 | |
| | 78 | 2480 | <-20dBc | -20 | |
| 8DPSK | 0 | 2402 | <-20dBc | -20 | PASS |
| | 39 | 2441 | <-20dBc | -20 | |
| | 78 | 2480 | <-20dBc | -20 | |

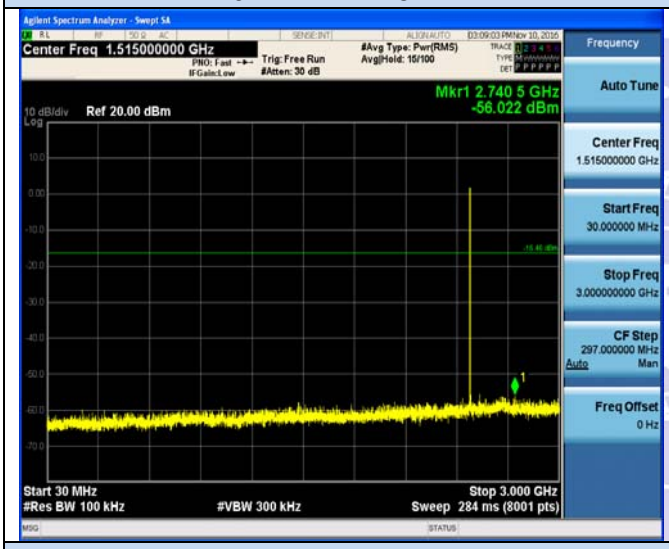
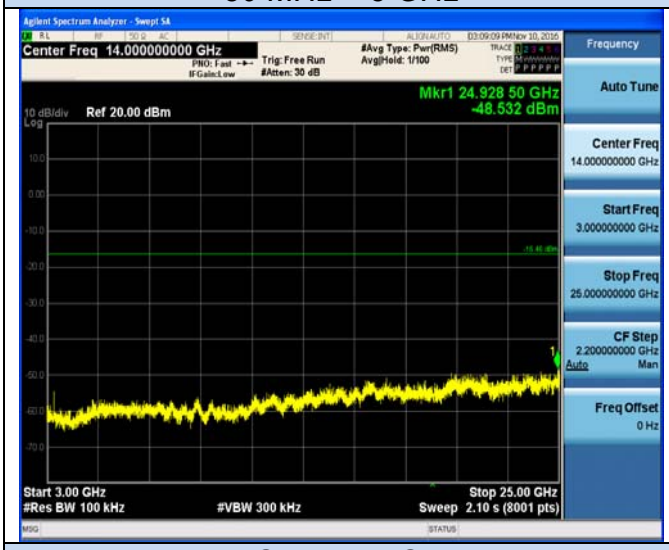
*Remark:*
*1. Test results including cable loss;*
*2. Please refer to following plots;*
*3. Measured at difference Packet Type for each mode and recorded worst case for each mode.*
*4. Worst case data at DH5 for GFSK, π/4DQPSK, 8DPSK modulation type;*
*5. Not recorded emission values from 9 KHz to 30 MHz as emission levels 20dB lower than emission limit;*

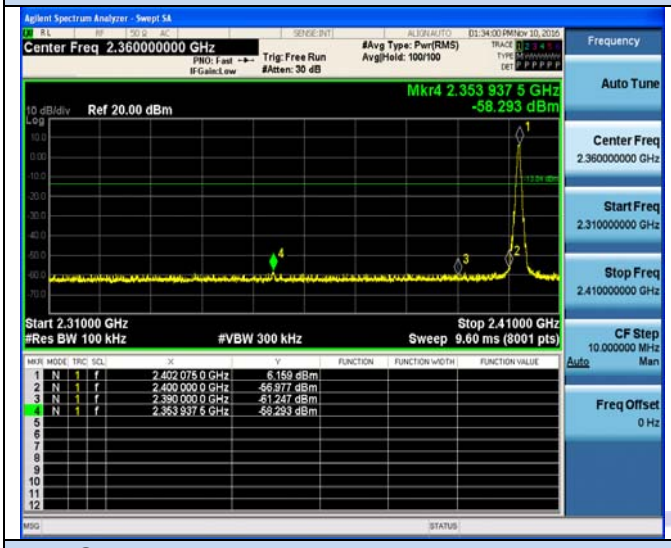
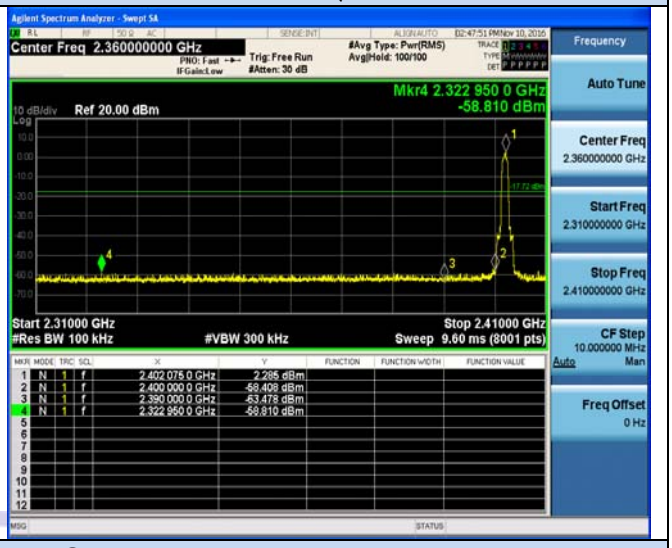
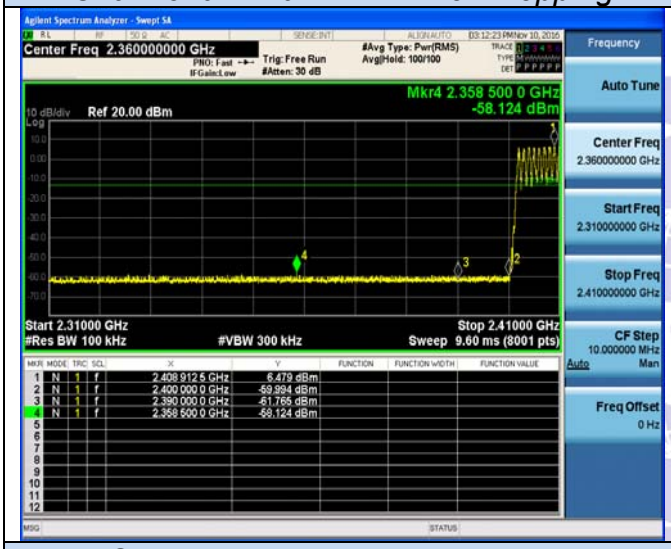
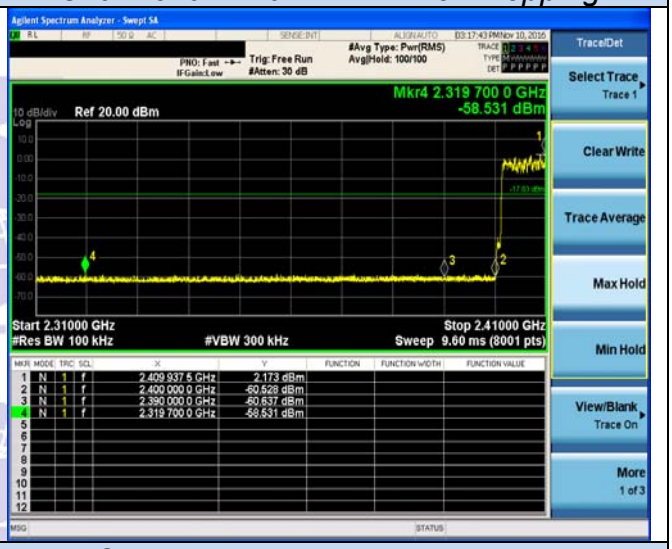
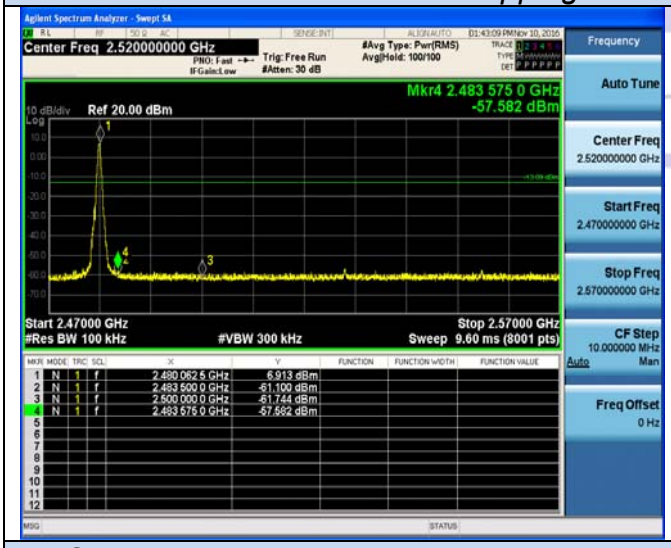
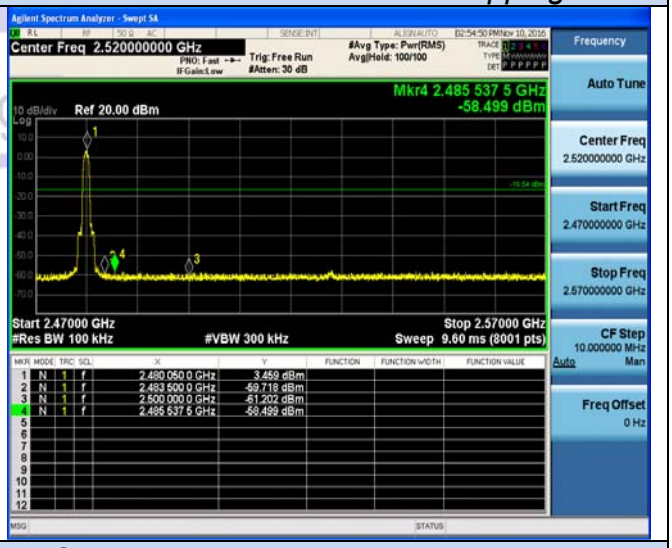
| RF Conducted Spurious Emissions | |
|---|---|
| GFSK | π/4DQPSK |
| Channel 0 / 2402 MHz | Channel 0 / 2402 MHz |
|  |  |
| 2401 MHz – 2403 MHz | 2401 MHz – 2403 MHz |
|  |  |
| 30 MHz – 3 GHz | 30 MHz – 3 GHz |
|  |  |
| 3 GHz – 25 GHz | 3 GHz – 25 GHz |

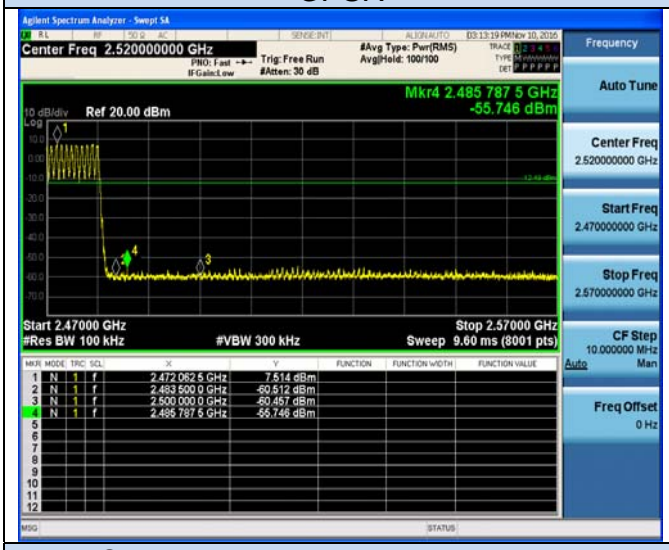
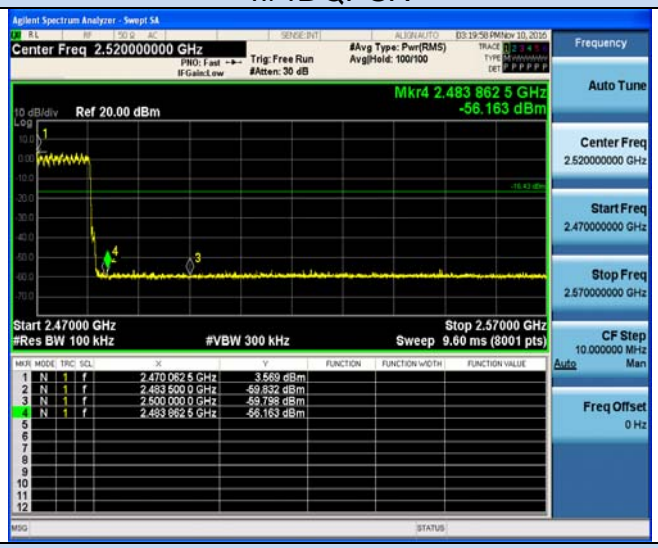
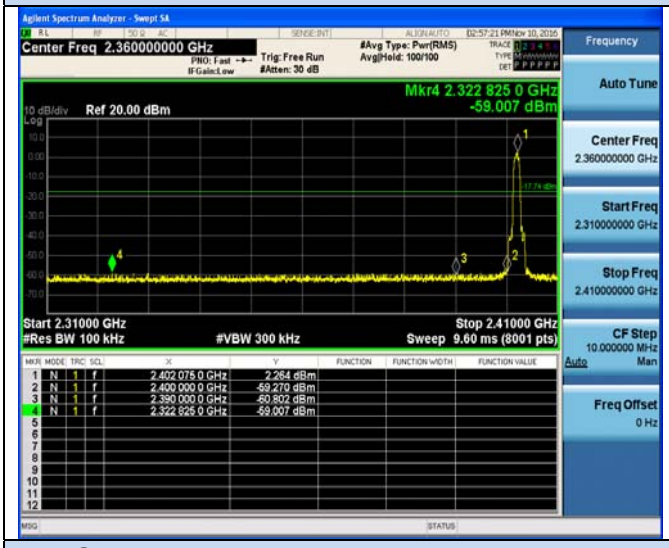
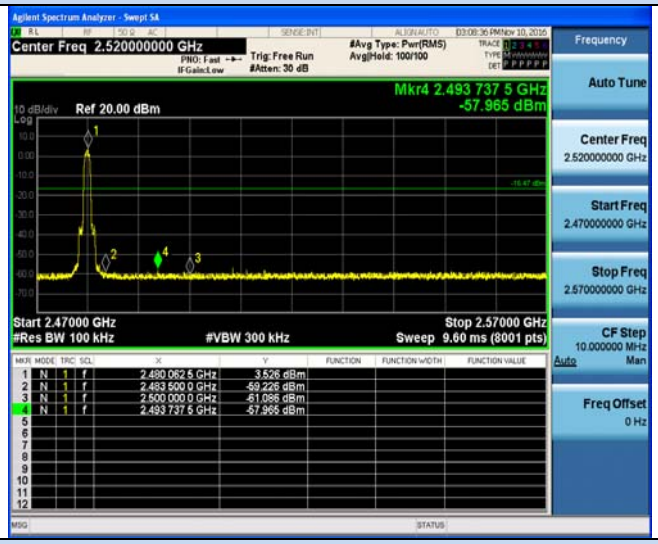
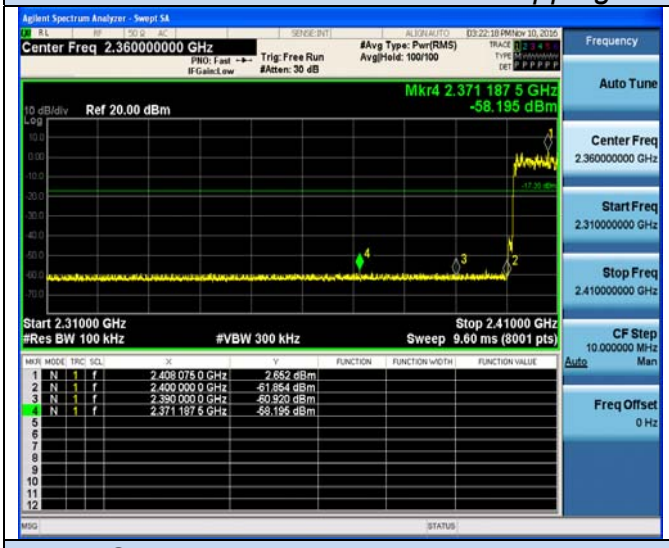
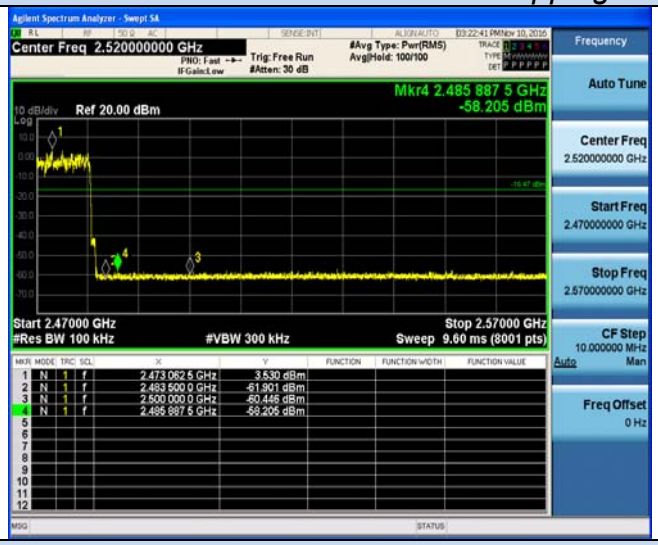
| RF Conducted Spurious Emissions | |
|---|---|
| GFSK | π/4DQPSK |
| Channel 39 / 2441 MHz | Channel 39 / 2441 MHz |
|  |  |
| 2440 MHz – 2442 MHz | 2440 MHz – 2442 MHz |
|  |  |
| 30 MHz – 3 GHz | 30 MHz – 3 GHz |
|  |  |
| 3 GHz – 25 GHz | 3 GHz – 25 GHz |

| RF Conducted Spurious Emissions | |
|---|---|
| GFSK | π/4DQPSK |
| Channel 78 / 2480 MHz | Channel 78 / 2480 MHz |
|  |  |
| 2479 MHz – 2482 MHz | 2479 MHz – 2482 MHz |
|  |  |
| 30 MHz – 3 GHz | 30 MHz – 3 GHz |
|  |  |
| 3 GHz – 25 GHz | 3 GHz – 25 GHz |

| RF Conducted Spurious Emissions | |
|---|---|
| 8DPSK | 8DPSK |
| Channel 0 / 2402 MHz | Channel 39 / 2441 MHz |
|  |  |
| 2401 MHz – 2403 MHz | 2440 MHz – 2442 MHz |
|  |  |
| 30 MHz – 3 GHz | 30 MHz – 3 GHz |
|  |  |
| 3 GHz – 25 GHz | 3 GHz – 25 GHz |

| RF Conducted Spurious Emissions | |
|---|---|
| 8DPSK | |
| Channel 78 / 2480 MHz | |
|  | |
| 2479 MHz – 2482 MHz | |
|  | |
| 30 MHz – 3 GHz | |
|  | |
| 3 GHz – 25 GHz | |

| Band-edge for RF conducted emissions | |
|---|---|
| GFSK | π/4DQPSK |
|  |  |
| Channel 0 / 2402 MHz – Non-Hopping | Channel 0 / 2402 MHz – Non-Hopping |
|  |  |
| Channel 0 / 2402 MHz – Hopping | Channel 0 / 2402 MHz – Hopping |
|  |  |
| Channel 78 / 2480 MHz – Non-Hopping | Channel 78 / 2480 MHz – Non-Hopping |

| *Band-edge for RF conducted emissions* | |
|---|---|
| *GFSK* | *π/4DQPSK* |
|  |  |
| *Channel 78 / 2480 MHz – Hopping* | *Channel 78 / 2480 MHz – Hopping* |
| *8DPSK* | *8DPSK* |
|  |  |
| *Channel 0 / 2402 MHz – Non-Hopping* | *Channel 78 / 2480 MHz – Non-Hopping* |
|  |  |
| *Channel 0 / 2402 MHz – Hopping* | *Channel 78 / 2480 MHz – Hopping* |

## 3.9. Bandedge Measurement for Radiated Emissions

**LIMIT**

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 con-ducted or a radiated measurement, pro-vided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter com-plies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required.

**TEST CONFIGURATION**


**TEST PROCEDURE**

According to KDB 412172 section 1.1 Field Strength Approach (linear terms):

$eirp = p_t \times g_t = (E \times d)^2/30$

Where:

$p_t$ = transmitter output power in watts,

$g_t$ = numeric gain of the transmitting antenna (unitless),

E = electric field strength in V/m,

d = measurement distance in meters (m).

$erp = eirp/1.64 = (E \times d)^2/(30 \times 1.64)$

Where all terms are as previously defined.

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Remove the antenna from the EUT and then connect to a low loss RF cable from the antenna port to an EMI test receiver, then turn on the EUT and make it operate in transmitting mode. Then set it to Low Channel and High Channel within its operating range, and make sure the instrument is operated in its linear range.
3. Set both RBW and VBW of spectrum analyzer to 100 kHz with a convenient frequency span including 100kHz bandwidth from band edge, for Radiated emissions restricted band RBW=1MHz, VBW=3MHz for peak detector and RBW=1MHz, VBW=1/B for Peak detector.
4. Measure the highest amplitude appearing on spectral display and set it as a reference level. Plot the graph with marking the highest point and edge frequency.
5. Repeat above procedures until all measured frequencies were complete.
6. Measure the conducted output power (in dBm) using the detector specified by the appropriate regulatory agency for guidance regarding measurement procedures for determining quasi-peak, peak, and average conducted output power, respectively).
7. Add the maximum transmit antenna gain (in dBi) to the measured output power level to determine the EIRP level (see 12.2.5 for guidance on determining the applicable antenna gain)
8. Add the appropriate maximum ground reflection factor to the EIRP level (6 dB for frequencies ≤ 30 MHz, 4.7 dB for frequencies between 30 MHz and 1000 MHz, inclusive and 0 dB for frequencies > 1000 MHz).
9. For devices with multiple antenna-ports, measure the power of each individual chain and sum the EIRP of all chains in linear terms (e.g., Watts, mW).
10. Compare the resultant electric field strength level to the applicable regulatory limit.
11. Perform radiated spurious emission test duress until all measured frequencies were complete.
12. Since the out-of-band characteristics of the EUT transmit antenna will often be unknown, the use of

a conservative antenna gain value is necessary. Thus, when determining the EIRP based on the measured conducted power, the upper bound on antenna gain for a device with a single RF output shall be selected as the maximum in-band gain of the antenna across all operating bands, or 2 dBi, whichever is greater. However, for devices that operate in multiple frequency bands while using the same transmit antenna, the highest gain of the antenna within the operating band nearest in frequency to the restricted band emission being measured may be used in lieu of the overall highest gain when the emission is at a frequency that is within 20 percent of the nearest band edge frequency, but in no case shall a value less than 2 dBi be used.

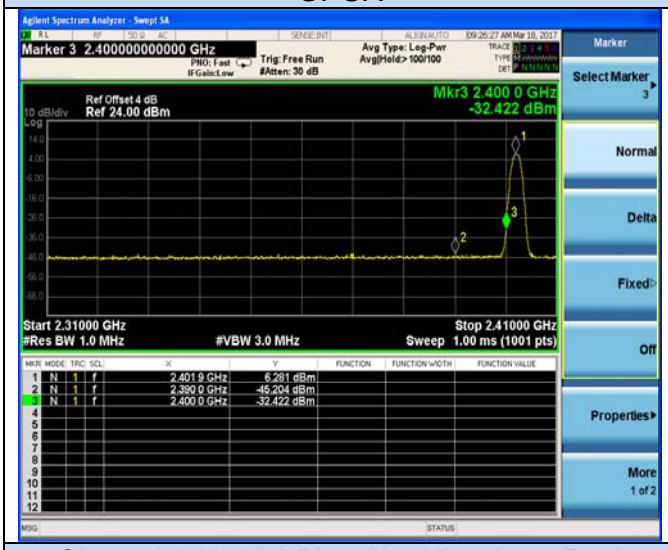
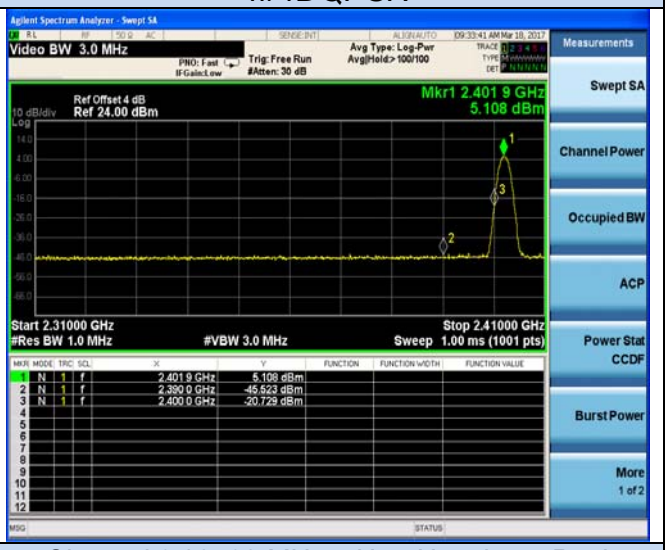
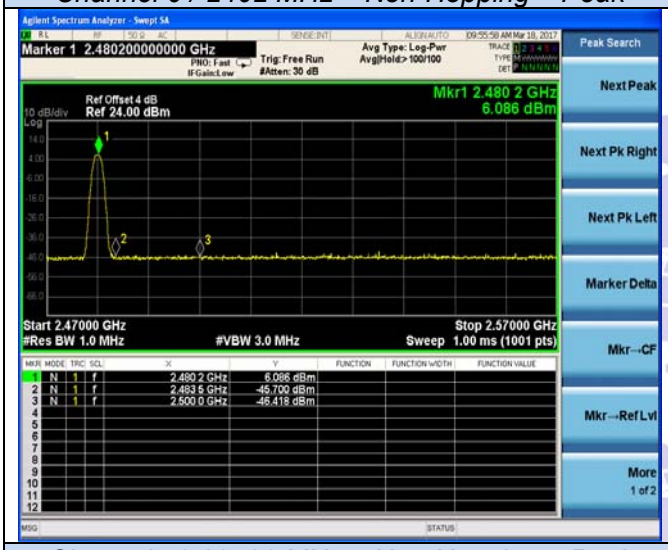
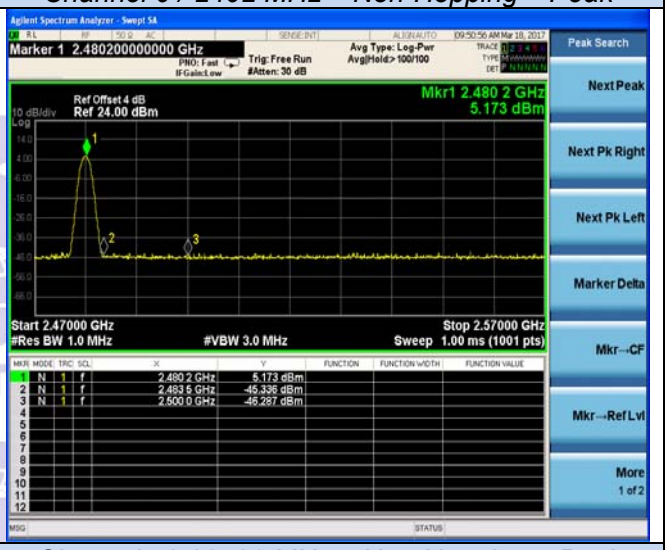
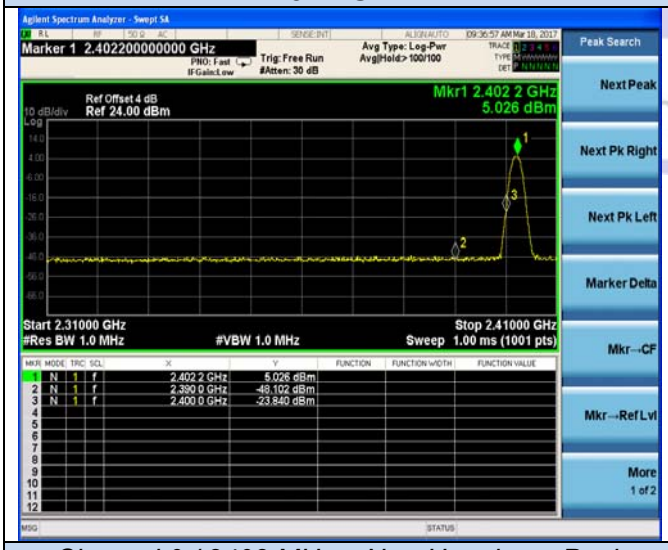
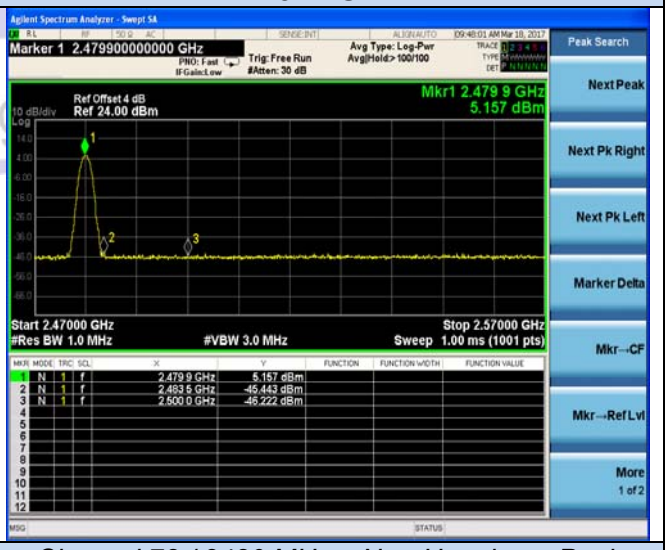
**TEST RESULTS**

| ***GFSK – Non-Hopping*** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Frequency (MHz) | Conducted Power (dBm) | Antenna Gain (dBi) | Ground Reflection Factor (dB) | Covert Radiated E Level At 3m (dBuV/m) | Detector | Limit (dBuV/m) | Verdict |
| 2390.000 | -45.204 | 0.000 | 0.000 | 52.054 | Peak | 74.00 | PASS |
| 2401.900 | 6.281 | 0.000 | 0.000 | 103.539 | Peak | --- | PASS |
| 2480.200 | 6.086 | 0.000 | 0.000 | 103.344 | Peak | --- | PASS |
| 2483.500 | -45.700 | 0.000 | 0.000 | 51.558 | Peak | 74.00 | PASS |
| 2500.000 | -46.418 | 0.000 | 0.000 | 50.840 | Peak | 74.00 | PASS |

| ***π/4DQPSK – Non-Hopping*** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Frequency (MHz) | Conducted Power (dBm) | Antenna Gain (dBi) | Ground Reflection Factor (dB) | Covert Radiated E Level At 3m (dBuV/m) | Detector | Limit (dBuV/m) | Verdict |
| 2390.000 | -45.523 | 0.000 | 0.000 | 51.735 | Peak | 74.00 | PASS |
| 2401.900 | 5.108 | 0.000 | 0.000 | 102.366 | Peak | --- | PASS |
| 2480.200 | 5.173 | 0.000 | 0.000 | 102.431 | Peak | --- | PASS |
| 2483.500 | -45.336 | 0.000 | 0.000 | 51.922 | Peak | 74.00 | PASS |
| 2500.000 | -46.287 | 0.000 | 0.000 | 50.971 | Peak | 74.00 | PASS |

| ***8DPSK – Non-Hopping*** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Frequency (MHz) | Conducted Power (dBm) | Antenna Gain (dBi) | Ground Reflection Factor (dB) | Covert Radiated E Level At 3m (dBuV/m) | Detector | Limit (dBuV/m) | Verdict |
| 2390.000 | -48.102 | 0.000 | 0.000 | 49.156 | Peak | 74.00 | PASS |
| 2402.200 | 5.026 | 0.000 | 0.000 | 102.284 | Peak | --- | PASS |
| 2479.900 | 5.157 | 0.000 | 0.000 | 102.415 | Peak | --- | PASS |
| 2483.500 | -45.433 | 0.000 | 0.000 | 51.825 | Peak | 74.00 | PASS |
| 2500.000 | -46.222 | 0.000 | 0.000 | 51.036 | Peak | 74.00 | PASS |

*Remark:*
*1. Measured at difference Packet Type for each mode and recorded worst case for each mode.*
*2. Worst case data at DH5 for GFSK, π/4DQPSK, 8DPSK modulation type;*
*3. Measured at Hopping and Non-Hopping mode, recorded worst at Non-Hopping mode.*
*4. The other emission levels were very low against the limit.*
*5. The average measurement was not performed when the peak measured data under the limit of average detection.*
*6. Detector AV is setting spectrum/receiver. RBW=1MHz/VBW=330 KHz/Sweep time=Auto/Detector=Peak;*
*7. "---"means that the fundamental frequency not for 15.209 limits requirement.*
*8. Please refer to following test plots;*

| *Band-edge measurements for radiated emissions* | |
|---|---|
| *GFSK* | *π/4DQPSK* |
|  |  |
| *Channel 0 / 2402 MHz – Non-Hopping – Peak* | *Channel 0 / 2402 MHz – Non-Hopping – Peak* |
|  |  |
| *Channel 78 / 2480 MHz – Non-Hopping – Peak* | *Channel 78 / 2480 MHz – Non-Hopping – Peak* |
| *8DPSK* | *8DPSK* |
|  |  |
| *Channel 0 / 2402 MHz – Non-Hopping – Peak* | *Channel 78 / 2480 MHz – Non-Hopping – Peak* |

## 3.10. Pseudorandom Frequency Hopping Sequence

**TEST APPLICABLE**

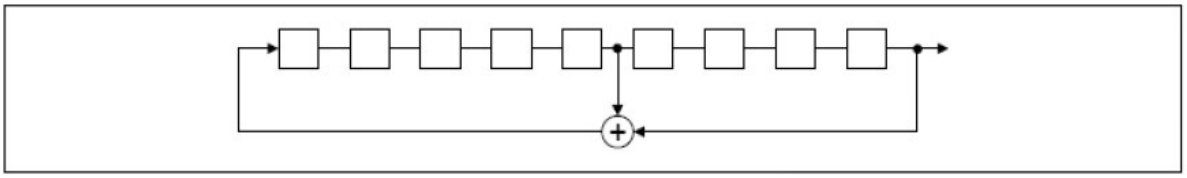
**For 47 CFR Part 15C sections 15.247 (a) (1) requirement:**

Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hop-ping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400–2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hop-ping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

**EUT Pseudorandom Frequency Hopping Sequence Requirement**

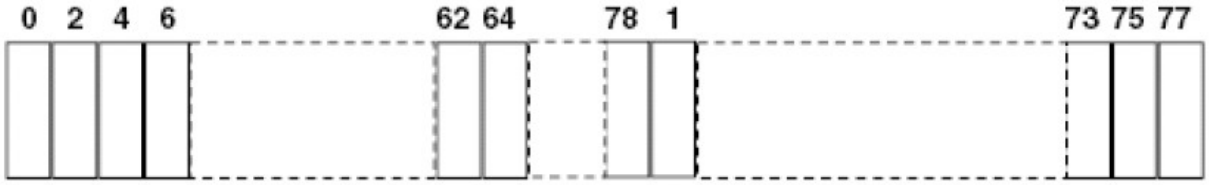
The pseudorandom frequency hopping sequence may be generated in a nice-stage shift register whose 5th and 9th stage outputs are added in a modulo-two addition stage. And the result is fed back to the input of the first stage. The sequence begins with the first one of 9 consecutive ones, for example: the shift register is initialized with nine ones.

- Number of shift register stages:9
- Length of pseudo-random sequence:29-1=511 bits
- Longest sequence of zeros:8(non-inverted signal)



*Linear Feedback Shift Register for Generation of the PRBS sequence*

An example of pseudorandom frequency hopping sequence as follows:




Each frequency used equally one the average by each transmitter.
The system receiver have input bandwidths that match the hopping channel bandwidths of their corresponding transmitter and shift frequencies in synchronization with the transmitted signals.

## 3.11. Antenna Requirement

**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. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator, the manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited.

**FCC CFR Title 47 Part 15 Subpart C Section 15.247(c) (1) (I):**

(i) Systems operating in the 2400-2483.5 MHz band that is used exclusively for fixed. Point-to-point operations may employ transmitting antennas with directional gain greater than 6dBi provided the maximum conducted output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6dBi.

**Antenna Connected Construction**

According to § 15.203, an intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device.

The directional gains of antenna used for transmitting is 0 dBi, and the antenna is an internal antenna connect to PCB board and no consideration of replacement. Please see EUT photo for details.
The WLAN and Bluetooth share same antenna.

**Measurement**

The antenna gain of the complete system is calculated by the difference of radiated power in EIRP and the conducted power of the module.
Conducted power refers ANSI C63.10:2013 Output power test procedure for frequency-hopping spread-spectrum (FHSS) devices.
Radiated power refers to ANSI C63.10:2013 Radiated emissions tests.

**Measurement parameters**

| Measurement parameter | |
|---|---|
| Detector: | Peak |
| Sweep Time: | Auto |
| Resolution bandwidth: | 1MHz |
| Video bandwidth: | 3MHz |
| Trace-Mode: | Max hold |

Note: The antenna gain of the complete system is calculated by the difference of radiated power in EIRP and the conducted power of the module. For normal Bluetooth devices, the GFSK mode is used.

**Limits**

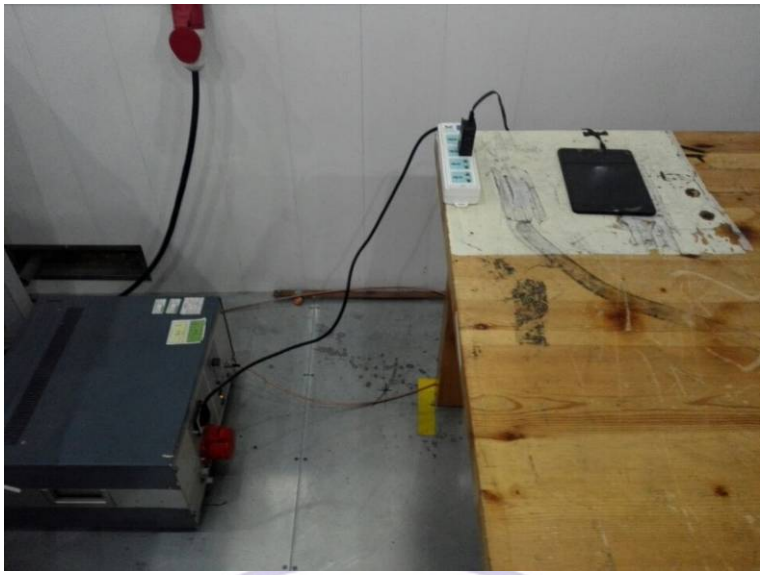
| FCC | ISED |
|---|---|
| Antenna Gain | |
| 6 dBi | |

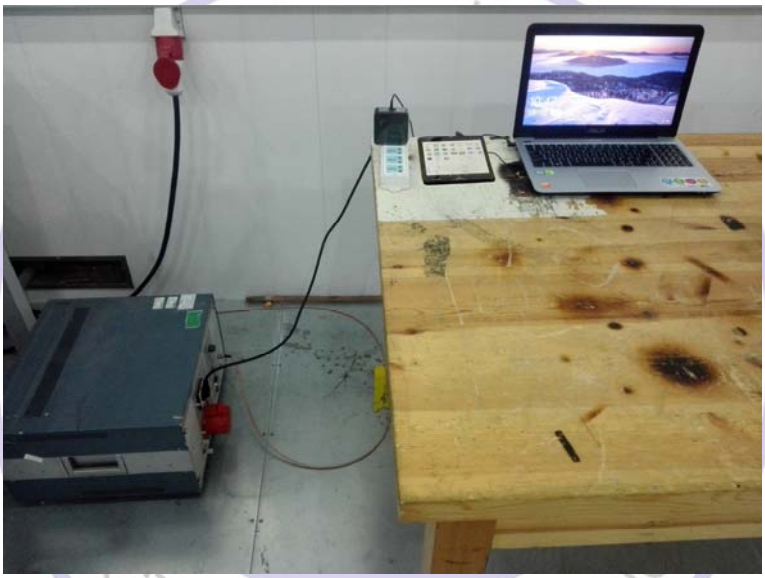
**Test Result:**

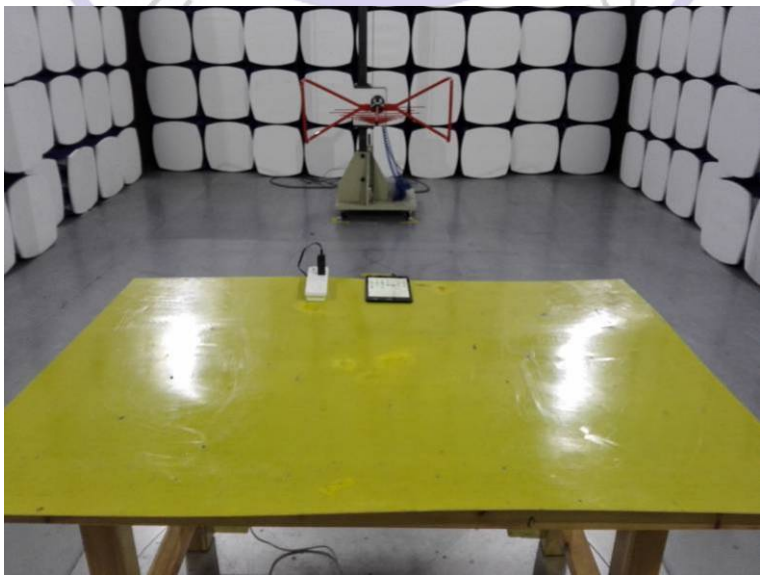
PASS

| $T_{nom}$ | $V_{nom}$ | lowest channel 2402 MHz | middle channel 2441 MHz | highest channel 2480 MHz |
|---|---|---|---|---|
| Conducted power [dBm] Measured with GFSK modulation | | 6.209 | 8.325 | 7.124 |
| Radiated power [dBm] Measured with GFSK modulation | | 4.715 | 7.623 | 4.636 |
| Gain [dBi] Calculated | | 4.715 | -0.702 | -2.488 |
| Measurement uncertainty | | | 0.57 dB (cond.) / 2.20 dB (rad.) | |

# 4. Test Setup Photos of the EUT







# 5. Photos of the EUT

Please reference to the test report No.: CTL1610310501-WF-01

********** End of Report **********