

**SK TECH CO., LTD.**

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# Certificate of Compliance

|                                                                                                                                     |                                                                                  |                                                                                                                                      |                   |
|-------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| Test Report No.:                                                                                                                    | SKTTRT-050104-001                                                                |                                                                                                                                      |                   |
| NVLAP CODE:                                                                                                                         | 200220-0                                                                         |                                                                                                                                      |                   |
| Applicant:                                                                                                                          | YOUNGBO ENGINEERING INC.                                                         |                                                                                                                                      |                   |
| Applicant Address:                                                                                                                  | Daeho B/D 7th 1462-7, Seocho3-dong, Seocho-gu, Seoul, Korea #137-070             |                                                                                                                                      |                   |
| Device Under Test:                                                                                                                  | Bluetooth Handsfree Carkit                                                       |                                                                                                                                      |                   |
| FCC ID:                                                                                                                             | SPXHKT100BDE                                                                     | Model No.:                                                                                                                           | HKT100BDE         |
| Receipt No.:                                                                                                                        | SKTEU04-0816                                                                     | Date of receipt:                                                                                                                     | December 17, 2004 |
| Date of Issue:                                                                                                                      | January 04, 2005                                                                 |                                                                                                                                      |                   |
| Location of Testing:                                                                                                                | SK TECH CO., LTD.<br>820-2, Wolmoon-Ri, Wabu-Up, Namyangju-Si, Kyunggi-Do, Korea |                                                                                                                                      |                   |
| Test Procedure:                                                                                                                     | ANSI C63.4                                                                       |                                                                                                                                      |                   |
| Test Specification:                                                                                                                 | 47CFR, Part 15 Rules                                                             |                                                                                                                                      |                   |
| Equipment Class:                                                                                                                    | DSS - Part 15 Spread Spectrum Transmitter                                        |                                                                                                                                      |                   |
| Test Result:                                                                                                                        | The above-mentioned device has been tested and passed.                           |                                                                                                                                      |                   |
| Tested & Reported by: Jong-Soo, Yoon                                                                                                |                                                                                  | Approved by: Jae-Kyung, Bae                                                                                                          |                   |
| <br>_____<br>Signature                      Date |                                                                                  | <br>_____<br>Signature                      Date |                   |
| Other Aspects:                                                                                                                      | -                                                                                |                                                                                                                                      |                   |
| Abbreviations:                                                                                                                      | · OK, Pass = passed · Fail = failed · N/A = not applicable                       |                                                                                                                                      |                   |

- This test report is not permitted to copy partly without our permission.
- This test result is dependent on only equipment to be used.
- This test result is based on a single evaluation of one sample of the above mentioned.
- This test report must not be used to claim product endorsement by NVLAP or any agency of the U.S Government.
- We certify that this test report has been based on the measurement standards that is traceable to the national or International standards.



NVLAP Lab. Code: 200220-0



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## **1. GENERAL**

These tests were performed using the test procedure outlined in ANSI C63.4, 2003 for intentional radiators, and in accordance with the limits set forth in FCC Part 15.247 for Spread Spectrum Transmitter. The EUT (Equipment Under Test) has been shown to be capable of compliance with the applicable technical standards.

We attest to the accuracy of data. All measurements reported herein were performed by SK Tech Co., Ltd. and were made under Chief Engineer's supervision.

We assume full responsibility for the completeness of these measurements and vouch for the qualifications of all persons taking them.

## **2. TEST SITE**

SK TECH Co., Ltd.

### **2.1 Location**

820-2, Wolmoon Ri, Wabu-Up, Namyangju-Si, Kyunggi-Do, Korea

This test site is in compliance with ISO/IEC 17025 for general requirements for the competence of testing and calibration laboratories.

This laboratory is accredited by NVLAP for NVLAP Lab. Code: 200220-0 and DATech for DAR-Registration No.: TTI-P-G155/97-10



## 2.2 List of Test and Measurement Instruments

| Description                            | Manufacturer    | Model #       | Serial #    |   |
|----------------------------------------|-----------------|---------------|-------------|---|
| Spectrum Analyzer                      | Agilent         | E4405B        | US40520856  | ☒ |
| EMC Spectrum Analyzer                  | Agilent         | E7405A        | US40240203  | ☒ |
| EMI Test Receiver                      | Rohde&Schwarz   | ESVS10        | 825120/013  | ☒ |
| EMI Test Receiver                      | Rohde&Schwarz   | ESVS10        | 834468/008  | ☒ |
| EMI Test Receiver                      | Rohde&Schwarz   | ESHS10        | 825120/013  |   |
| EMI Test Receiver                      | Rohde&Schwarz   | ESHS10        | 834468/008  |   |
| Artificial Mains Network               | Rohde&Schwarz   | ESH3-Z5       | 836679/018  |   |
| Pre-amplifier                          | HP              | 8447F         | 3113A05153  | ☒ |
| Pre-amplifier                          | HP              | 8349B         | 2644A03250  | ☒ |
| Power Meter                            | Agilent         | E4418B        | 3318A13916  |   |
| Power Sensor                           | HP              | 8485A         | 3318A13916  |   |
| VHF Precision Dipole Antenna (TX & RX) | Schwarzbeck     | VHAP          | 1014 & 1015 |   |
| UHF Precision Dipole Antenna (TX & RX) | Schwarzbeck     | UHAP          | 989 & 990   |   |
| Loop Antenna                           | Schwarzbeck     | HFH2-Z2       | 863048/019  |   |
| TRILOG Broadband Antenna               | Schwarzbeck     | VULB9160      | 3141        | ☒ |
| Biconical Antenna                      | Schwarzbeck     | VHA9103       | 2265        | ☒ |
| Log-Periodic Antenna                   | Schwarzbeck     | UHALP9107     | 1819        | ☒ |
| Horn Antenna                           | AH Systems      | SAS-200/571   | 304         | ☒ |
| Horn Antenna (TX & RX)                 | Electro Metrics | EM-6961       | 6297 & 6298 |   |
| Vector Signal Generator                | Agilent         | E4438C        | MY42080359  |   |
| Signal Generator                       | HP              | 8349B         | 2644A03250  |   |
| DC Power Supply                        | HP              | 6634A         | 2926A-01078 | ☒ |
| DC Power Supply                        | HP              | 6268B         | 2542A-07856 |   |
| Digital Multimeter                     | HP              | HP3458A       | 2328A14389  | ☒ |
| PCS Interface                          | HP              | 83236B        | 3711J00881  |   |
| CDMA Mobile Test Set                   | HP              | 8924C         | US35360253  |   |
| Hygro/Thermo Graph                     | SATO            | PC-5000TRH-II | -           | ☒ |
| Temperature/Humidity Chamber           | All Three       | ATH-50M       | 20030425    |   |

## 2.3 Test Date

Date of Application : December 17, 2004

Date of Test : December 30, 2004 ~ January 04, 2005

## 2.4 Test Environment

See each test item's description.



### 3. DESCRIPTION OF THE EQUIPMENT UNDER TEST

The product specification described herein was obtained from the product data sheet or user's manual.

#### 3.1 Rating and Physical Characteristics

|                           |                                                                                                       |
|---------------------------|-------------------------------------------------------------------------------------------------------|
| Type / Model No.          | Bluetooth Handsfree Carkit / HKT100BDE                                                                |
| Power source              | DC 12V/24V (Lead-acid battery on vehicles)                                                            |
| Local Oscillator or X-Tal | X-Tal: 7.3728 MHz, 18.432 MHz                                                                         |
| Transmit Frequency        | 2402 ~ 2480 MHz (1MHz, 79 channels)                                                                   |
| Antenna Type              | Integral SMD chip antenna (Model: AMAN903010U2P4, 50Ω, 3.59dBi)                                       |
| Type of Modulation        | FHSS (GFSK)                                                                                           |
| RF Output power           | < 4dBm                                                                                                |
| External Ports            | Remote Controller Input connector (10 Pin)<br>Power Input terminal (4 Pin)<br>Microphone Jack (2 Pin) |

#### 3.2 Equipment Modifications

According to § 2.1043(a), changes to the basic frequency determining and stabilizing circuitry (including clock or data rates), frequency multiplication stages, basic modulator circuit or maximum power or field strength ratings shall not be performed without application for and authorization of a new grant of certification. Variations in electrical or mechanical construction, other than these indicated items, are permitted provided the variations either do not affect the characteristics required to be reported to the Commission or the variations are made in compliance with the other provisions of this section.

The certificated equipment was changed in order to reduce audio noise. The main changes are as follows:

- PCB layout was changed; the crystal and RF module was rotated
- Many types of the components(R&C) were changed from 1608 into 1005 type as small size
- The minor upgrades for the schematics

#### 3.3 Submitted Documents

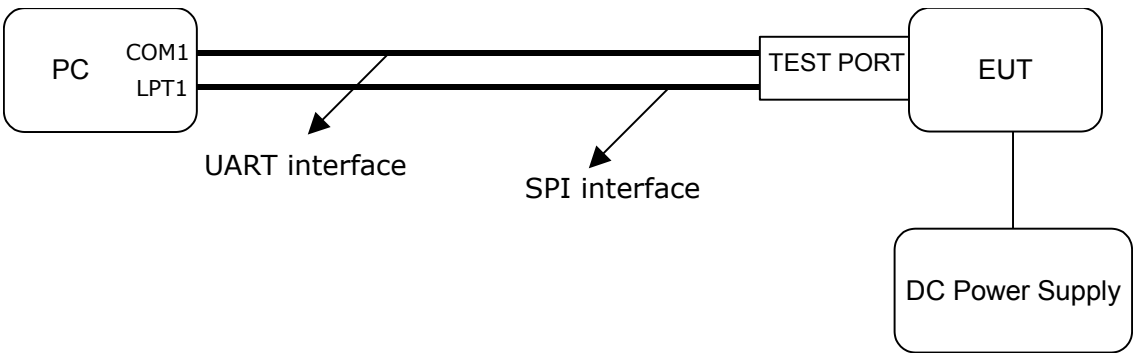
Block diagram / Schematic diagram / Antenna Specification / Part List / User manual



4. MEASUREMENT CONDITIONS

4.1 Description of test configuration

The measurements were taken in continuous transmitting mode, connecting the TEST PORT in the EUT to the PC for controlling the EUT via UART interface so that the operating frequency of the EUT could be changed with the frequency hopping turned off. The EUT was powered from the DC Power Supply, DC 13.2V.



4.2 List of Peripherals

| Equipment Type     | Manufacturer | Model | Cable Description              |
|--------------------|--------------|-------|--------------------------------|
| DC Power Supply    | H.P          | 6634A | 1.8m, Unshielded Power Line    |
| PC (Multinet / )** | LG IBM       | W8S   | 1.8m, Unshielded Power Line    |
| Serial Cable**     | Youngbo      | -     | 1.5m, Unshielded (COM1 ↔ UART) |
| Parallel Cable**   | Youngbo      | -     | 0.45m, Unshielded (LPT1 ↔ SPI) |

\*\* For control of RF module via UART interface in the EUT.

4.3 Uncertainty

| Measurement Item      | Combined Standard Uncertainty<br>U <sub>c</sub> | Expanded Uncertainty<br>U = KU <sub>c</sub> (K = 2) |
|-----------------------|-------------------------------------------------|-----------------------------------------------------|
| Conducted RF power    | ± 1.49 dB                                       | ± 2.98dB                                            |
| Radiated disturbance  | ± 2.37 dB                                       | ± 4.74dB                                            |
| Conducted disturbance | ± 1.47 dB                                       | ± 2.94dB                                            |



## 5. TEST AND MEASUREMENTS

### Summary of Test Results

| Requirement                                        | CFR 47 Section                             | Report Section | Test Result |
|----------------------------------------------------|--------------------------------------------|----------------|-------------|
| Antenna Requirement                                | 15.203, 15.247(b)(4)                       | 5.1            | PASS        |
| Maximum Peak Output Power                          | 15.247(b)(1), (4)                          | 5.2            | PASS        |
| Carrier Frequency Separation                       | 15.247(a)(1)                               | 5.3            | PASS        |
| 20dB Channel Bandwidth                             | 15.247(a)(1)                               | 5.4            | PASS        |
| Number of Hopping Channels                         | 15.247(a)(iii), 15.247(b)(1)               | 5.5            | PASS        |
| Time of Occupancy (Dwell Time)                     | 15.247(a)(iii)                             | 5.6            | PASS        |
| Spurious Emission, Band Edge, and Restricted bands | 15.247(d), 15.205(a), 15.209(a), 15.109(a) | 5.7            | PASS        |
| Peak Power Spectral Density                        | 15.247(e)                                  | 5.8            | PASS        |
| Conducted Emissions                                | 15.207(a), 15.107(a)                       | N/A*           | N/A*        |
| RF Exposure                                        | 15.247(i), 1.1307(b)(1)                    | 5.9            | PASS        |

*\* Not required, the EUT only employs battery power on the vehicles for operation.*

## 5.1 ANTENNA REQUIREMENT

### 5.1.1 Regulation

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 use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this Section. 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.

And according to §15.247(b)(4), the conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

### 5.1.2 Result:

**PASS**

The transmitter has an integral SMD chip antenna. The directional gain of the antenna is maximum 3.59 dBi.



## 5.2 MAXIMUM PEAK OUTPUT POWER

### 5.2.1 Regulation

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

According to §15.247(b)(4), the conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

### 5.2.2 Test Procedure

1. Check the calibration of the measuring instrument (spectrum analyzer) using either an internal calibrator or a known signal from an external generator.
2. Connect the antenna port of the EUT to RF input on the spectrum analyzer via a low loss cable.
3. Turn on the EUT and set it to any one measured frequency within its operating range by controlling it via UART interface and make sure the spectrum analyzer is operated in its linear range.
4. Set the spectrum analyzer to MAX HOLD mode with RBW = 3 MHz.
5. Measure the highest amplitude appearing on spectral display and record the level to calculate results.
6. Repeat above procedures until all frequencies measured were complete.

### 5.2.3 Test Results:

**PASS**

**Table 1: Measured values of the Maximum Peak Output Power (Conducted)**

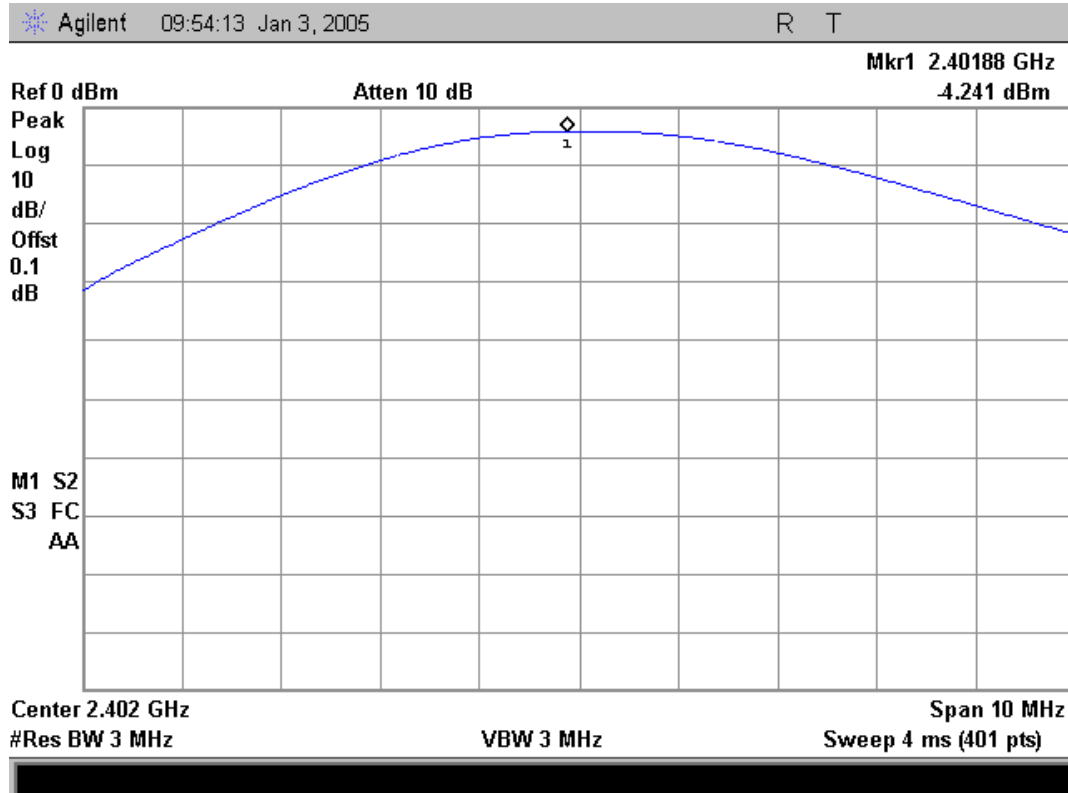
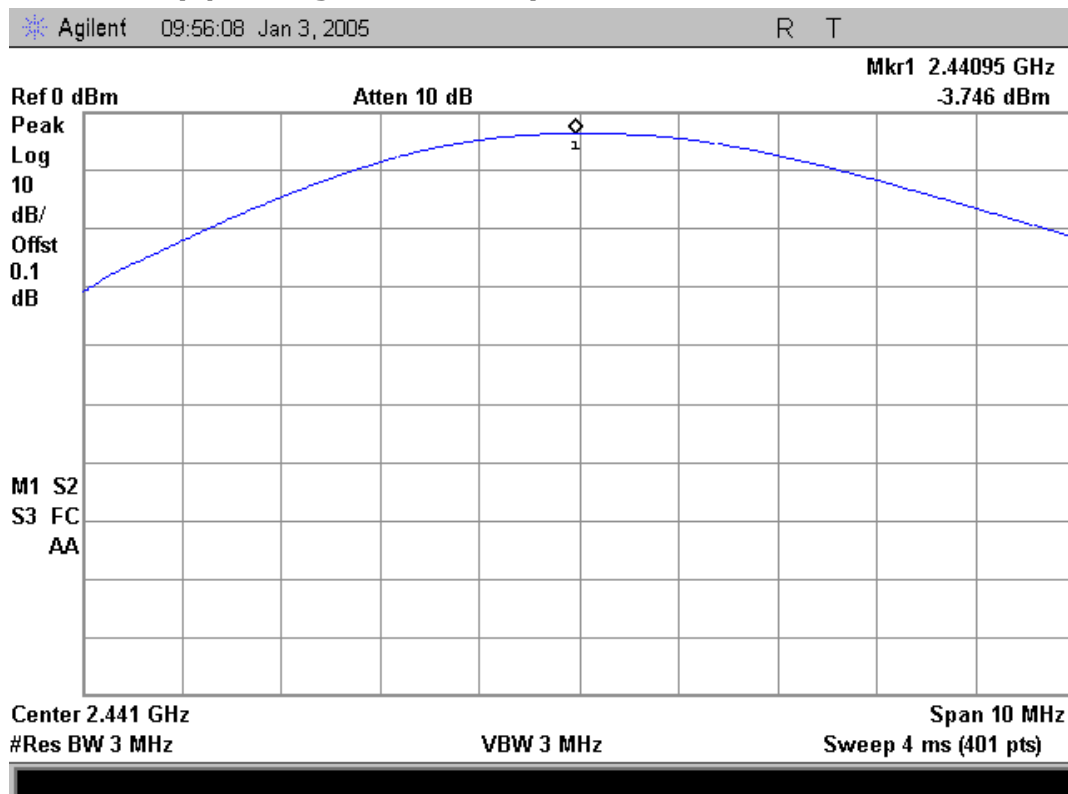
| Operating Frequency | Resolution Bandwidth | Cable Loss | Reading               | Limit        |
|---------------------|----------------------|------------|-----------------------|--------------|
| 2402 MHz            | 3 MHz                | 0.1 dB     | -4.241 dBm (0.377 mW) | 30 dBm (1 W) |
| 2441 MHz            | 3 MHz                | 0.1 dB     | -3.746 dBm (0.422 mW) | 30 dBm (1 W) |
| 2480 MHz            | 3 MHz                | 0.1 dB     | -3.119 dBm (0.488 mW) | 30 dBm (1 W) |

**Cable Loss was included in Reading as Offset.**

NOTE: Since the directional gain of the SMD chip antenna declared by manufacturer ( $G_{ANT} = 3.59$  dBi) does not exceed 6.0 dBi, there was no need to reduce the output power.

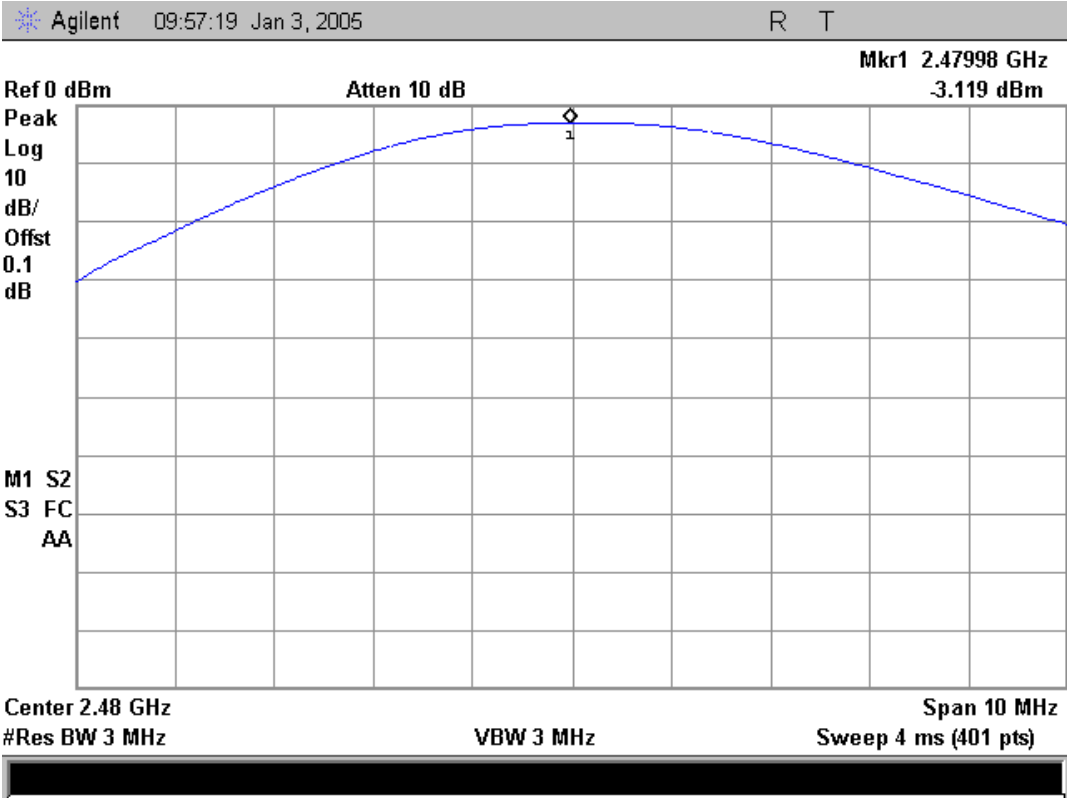
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**Figure 1. Plot of the Maximum Peak Output Power (Conducted)  
Lowest Channel (operating at 2402 MHz)****Middle Channel (operating at 2441 MHz)**



Highest Channel (operating at 2480 MHz)





## 5.3 CARRIER FREQUENCY SEPARATION

### 5.3.1 Regulation

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

### 5.3.2 Test Procedure

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Connect the antenna port of the EUT to RF input on the spectrum analyzer via a low loss cable.
3. Turn on the EUT and set it to any one measured frequency within its operating range by controlling it via UART interface, and then set the spectrum analyzer to MAX HOLD mode.
4. Measure the separation between the peaks of the adjacent channels using the marker-delta function.
5. Repeat above procedures until all frequencies measured were complete.

### 5.3.3 Test Results:

**PASS**

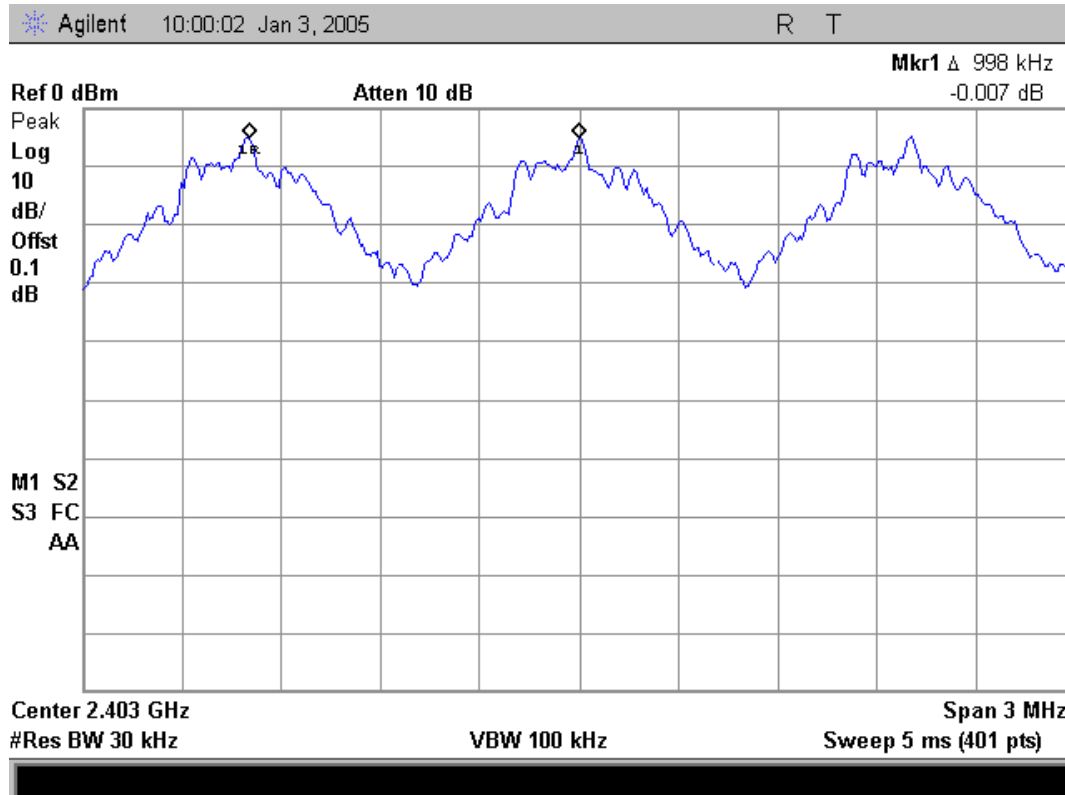
**Table 2: Measured values of the Carrier Frequency Separation (Conducted)**

| Operating frequency | Carrier frequency separation | Limit                       |
|---------------------|------------------------------|-----------------------------|
| 2402 MHz            | 998 kHz                      | ≥ 25 kHz or 20 dB bandwidth |
| 2441 MHz            | 998 kHz                      | ≥ 25 kHz or 20 dB bandwidth |
| 2480 MHz            | 998 kHz                      | ≥ 25 kHz or 20 dB bandwidth |

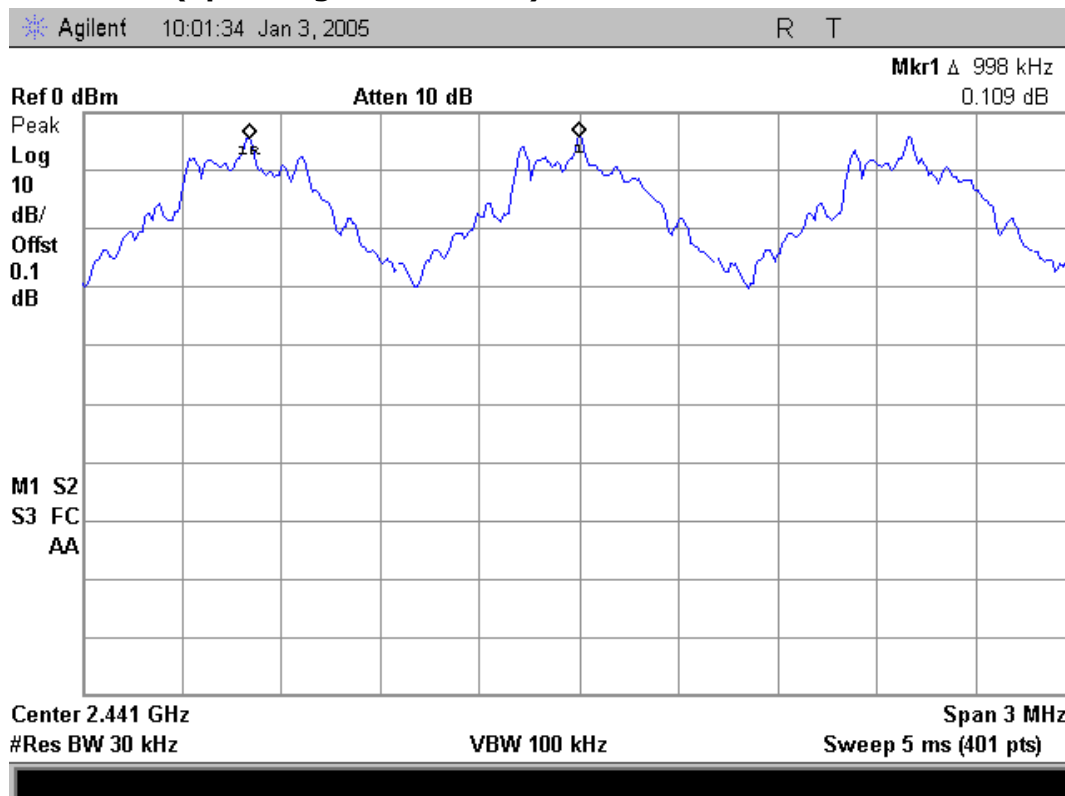
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**Figure 2. Plot of the Carrier Frequency Separation (Conducted)**  
**Lowest Channel (operating at 2402 MHz)**

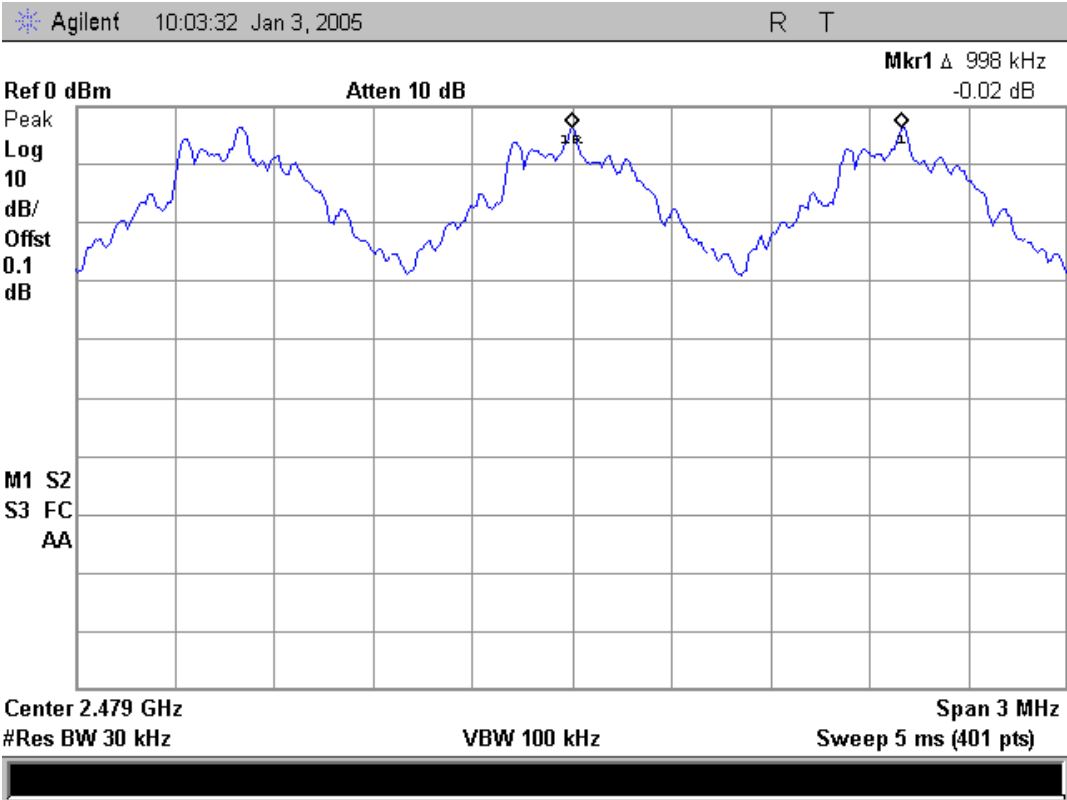


**Middle Channel (operating at 2441 MHz)**





Highest Channel (operating at 2480 MHz)





## 5.4 20dB CHANNEL BANDWIDTH

### 5.4.1 Regulation

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

### 5.4.2 Test Procedure

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Connect the antenna port of the EUT to RF input on the spectrum analyzer via a low loss cable.
3. Turn on the EUT and set it to any one measured frequency within its operating range by controlling it via UART interface and make sure the spectrum analyzer is operated in its linear range.
4. Set the spectrum analyzer to MAX HOLD mode and then set a reference level on it equal to the highest peak value.
5. Measure the frequency difference of two frequencies that were attenuated 20dB from the reference level. Record the frequency difference as the emission bandwidth.
6. Repeat above procedures until all frequencies measured were complete.

### 5.4.3 Test Results:

**PASS**

**Table 3: Measured values of the 20dB Channel Bandwidth (Conducted)**

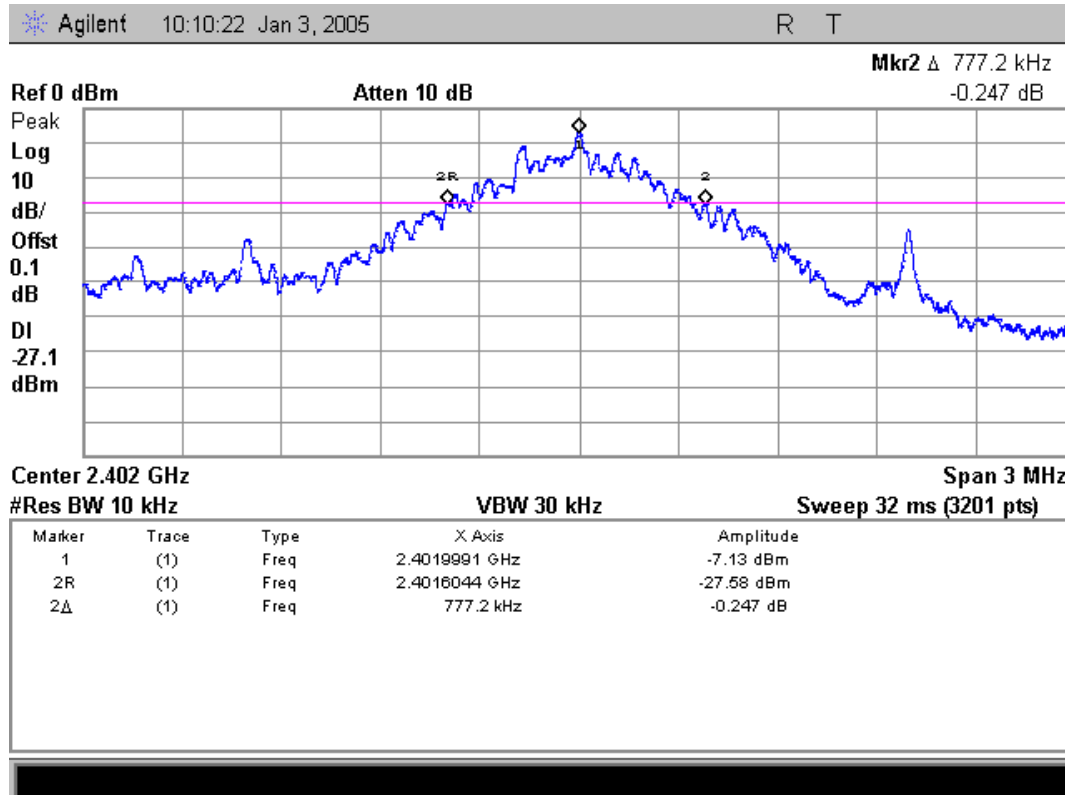
| Operating frequency | 20dB Channel bandwidth | Limit   |
|---------------------|------------------------|---------|
| 2402 MHz            | 777.2 kHz              | < 1 MHz |
| 2441 MHz            | 774.4 kHz              | < 1 MHz |
| 2480 MHz            | 776.3 kHz              | < 1 MHz |



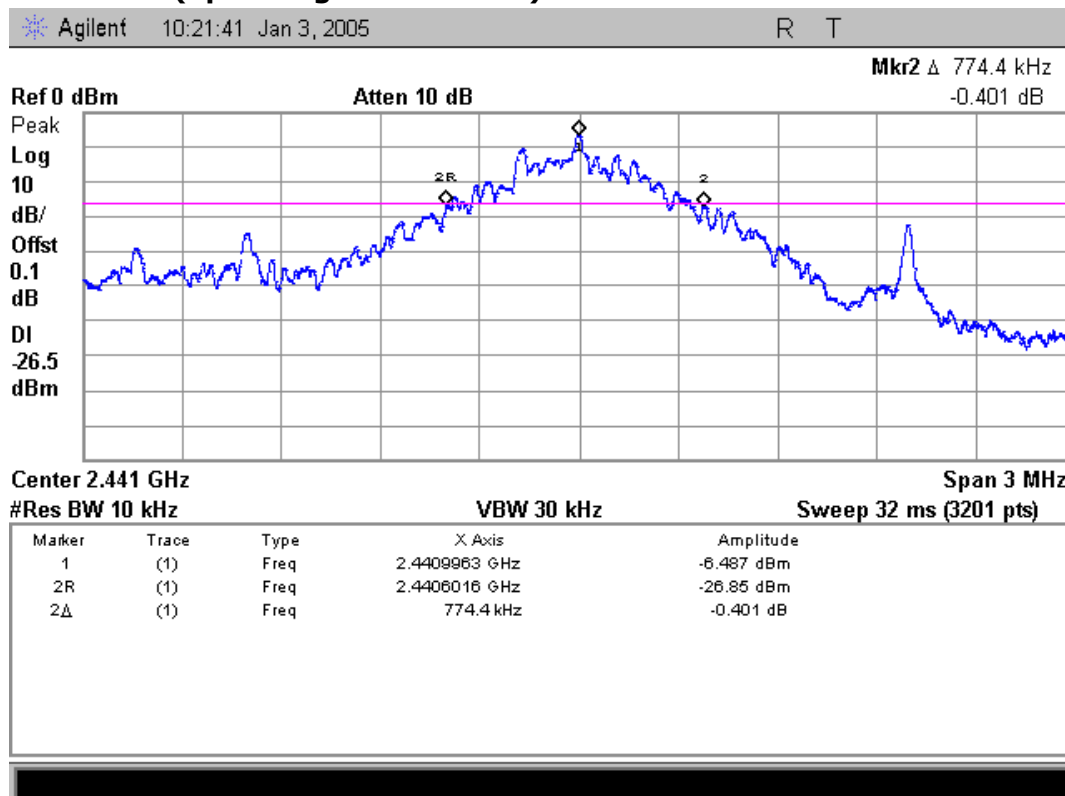
SK TECH CO., LTD.

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**Figure 3. Plot of the 20dB Channel Bandwidth (Conducted)**  
**Lowest Channel (operating at 2402 MHz)**

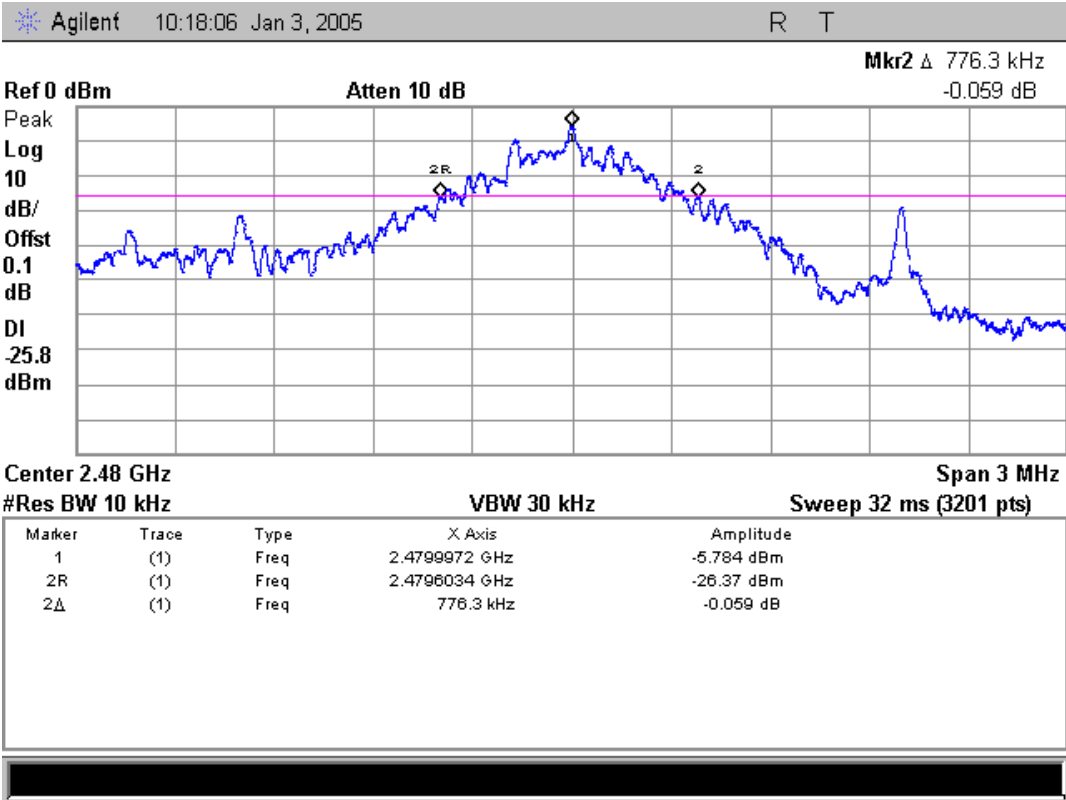


**Middle Channel (operating at 2441 MHz)**





Highest Channel (operating at 2480 MHz)





## 5.5 NUMBER OF HOPPING CHANNELS

### 5.5.1 Regulation

According to §15.247(a)(1)(iii), frequency hopping systems in the 2400-2483.5 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.

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

### 5.5.2 Test Procedure

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Connect the antenna port of the EUT to RF input on the spectrum analyzer via a low loss cable.
3. Turn on the EUT and set the hopping function enabled by controlling it via UART interface.
4. Set the spectrum analyzer MAX HOLD and record the number of hopping channels.

### 5.5.3 Test Results:

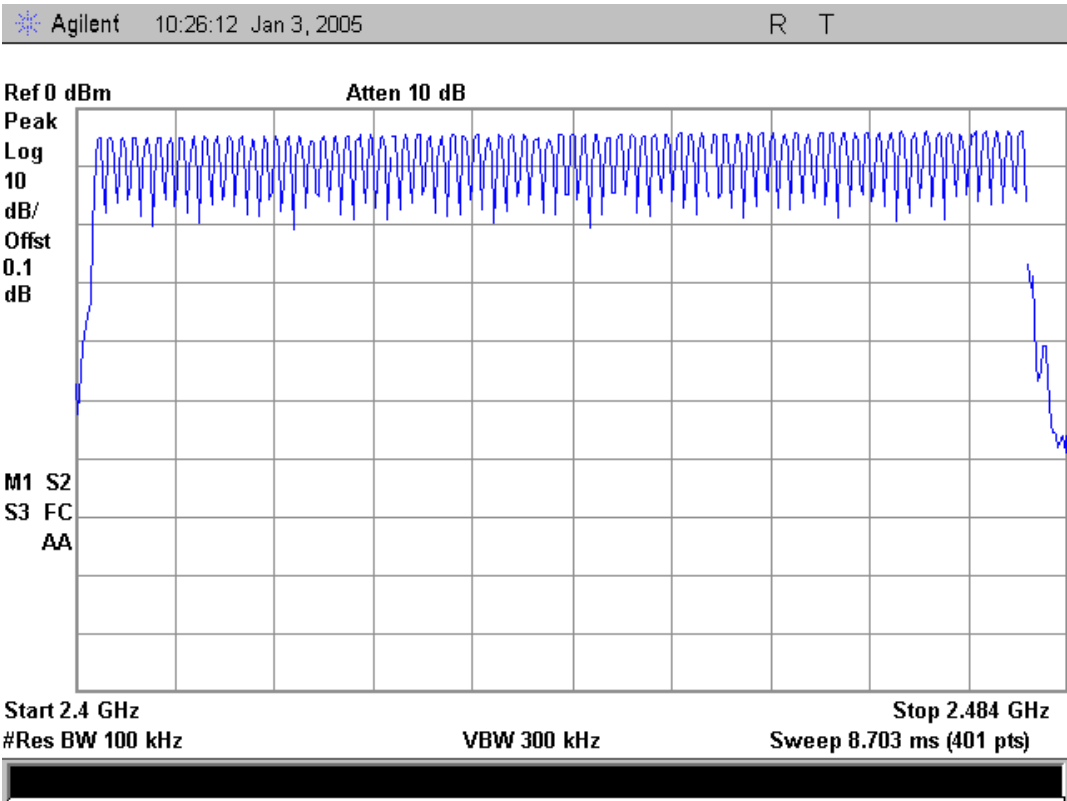
**PASS**

**Table 4: Measured values of the Number of Hopping Channels (Conducted)**

| Operating frequency | Number of hopping channels | Limit     |
|---------------------|----------------------------|-----------|
| 2402 - 2480 MHz     | 79                         | $\geq 15$ |



Figure 4. Plot of the Number of Hopping Channels (Conducted)





## 5.6 TIME OF OCCUPANCY (DWELL TIME)

### 5.6.1 Regulation

According to §15.247(a)(1)(iii), frequency hopping systems in the 2400-2483.5 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.

### 5.6.2 Test Procedure

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Connect the antenna port of the EUT to RF input on the spectrum analyzer via a low loss cable.
3. Turn on the EUT and set it to any one measured frequency within its operating range by controlling it via UART interface.
4. Set the spectrum analyzer to ZERO SAPN centered on the hopping channel with RBW = 1MHz, and then measure the dwell time using the marker-delta function.
6. Repeat above procedures until all frequencies measured were complete.
7. Repeat this test for different modes of operation (e.g., data rate, modulation format, etc.), if applicable.

### 5.6.3 Test Results:

**PASS**

**Table 5: Measured values of the Time of Occupancy (Conducted)**

| Operating frequency | Reading   | Hopping rate | Number of Channels | Actual         | Limit       |
|---------------------|-----------|--------------|--------------------|----------------|-------------|
| 2402 MHz            | 0.4238 ms | 800 hops/s   | 79                 | 0.1356 seconds | 0.4 seconds |
| 2441 MHz            | 0.4218 ms | 800 hops/s   | 79                 | 0.1350 seconds | 0.4 seconds |
| 2480 MHz            | 0.4225 ms | 800 hops/s   | 79                 | 0.1352 seconds | 0.4 seconds |

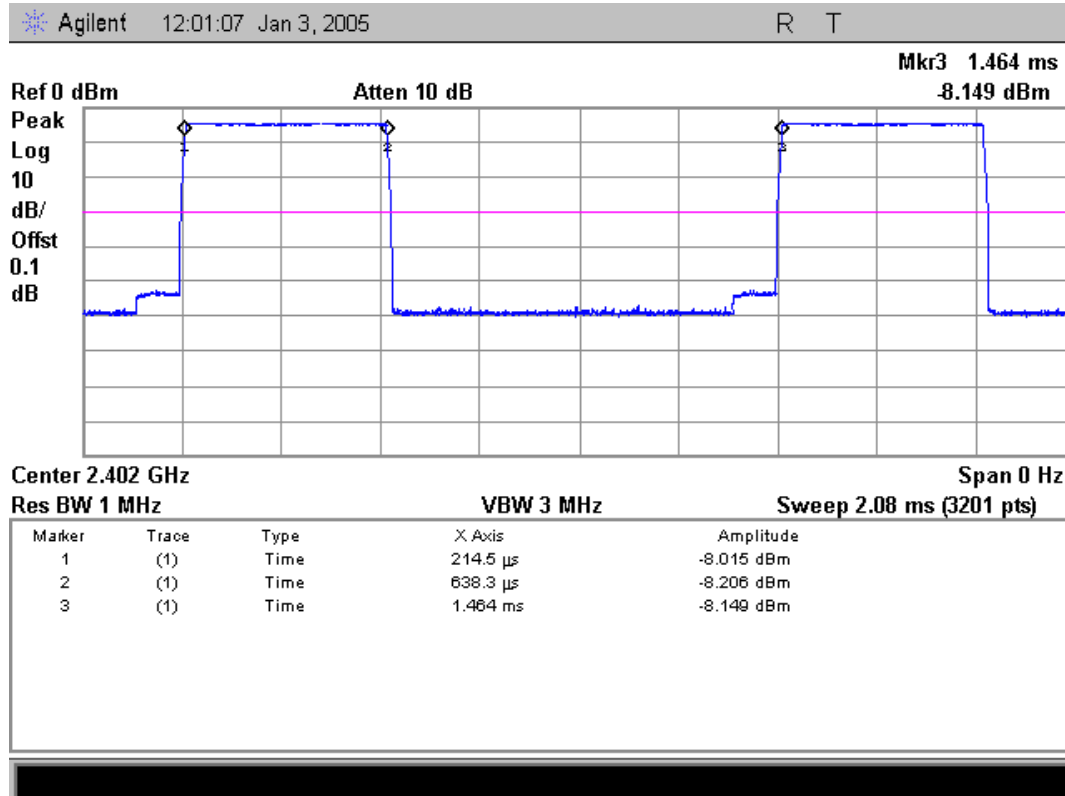
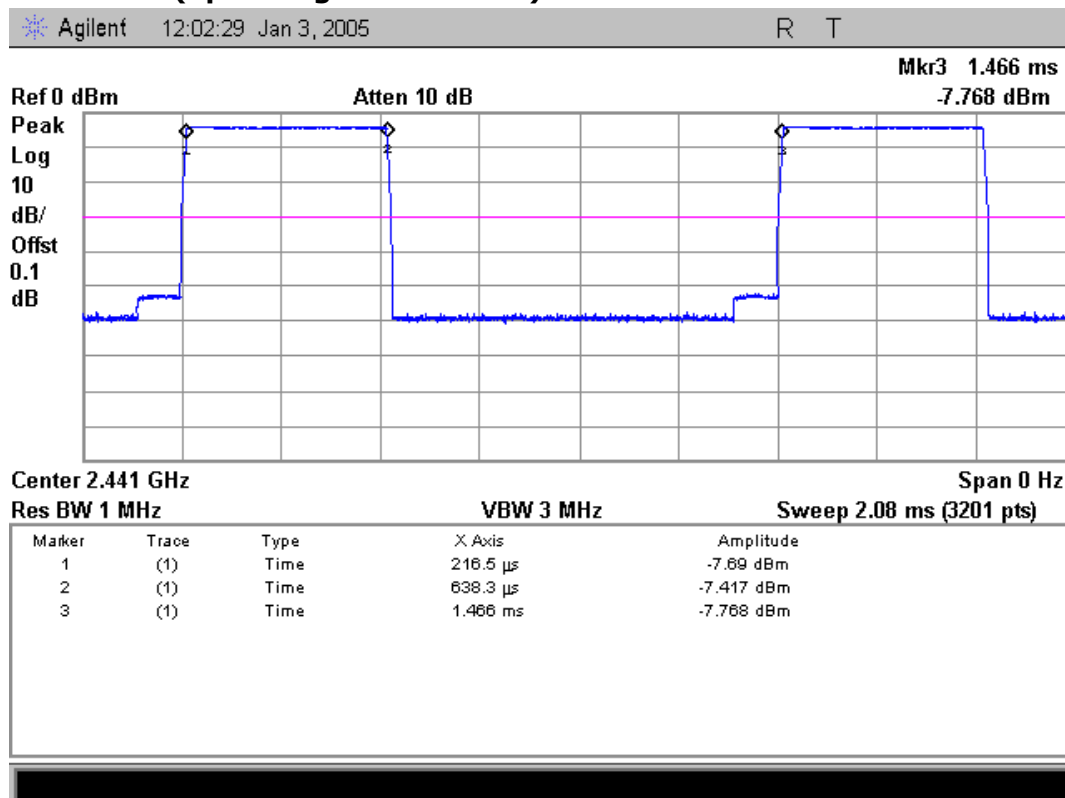
**Actual = Reading × (Hopping rate / Number of channels) × Test period**

**Test period = 0.4 [seconds / channel] × 79 [channel] = 31.6 [seconds]**

NOTE: The EUT makes worst case 1600 hops per second or 1 time slot has a length of 625μs with 79 channels. A DH1 Packet needs 1 time slot for transmitting and 1 time slot for receiving. Then the EUT makes worst case 800 hops per second with 79 channels.

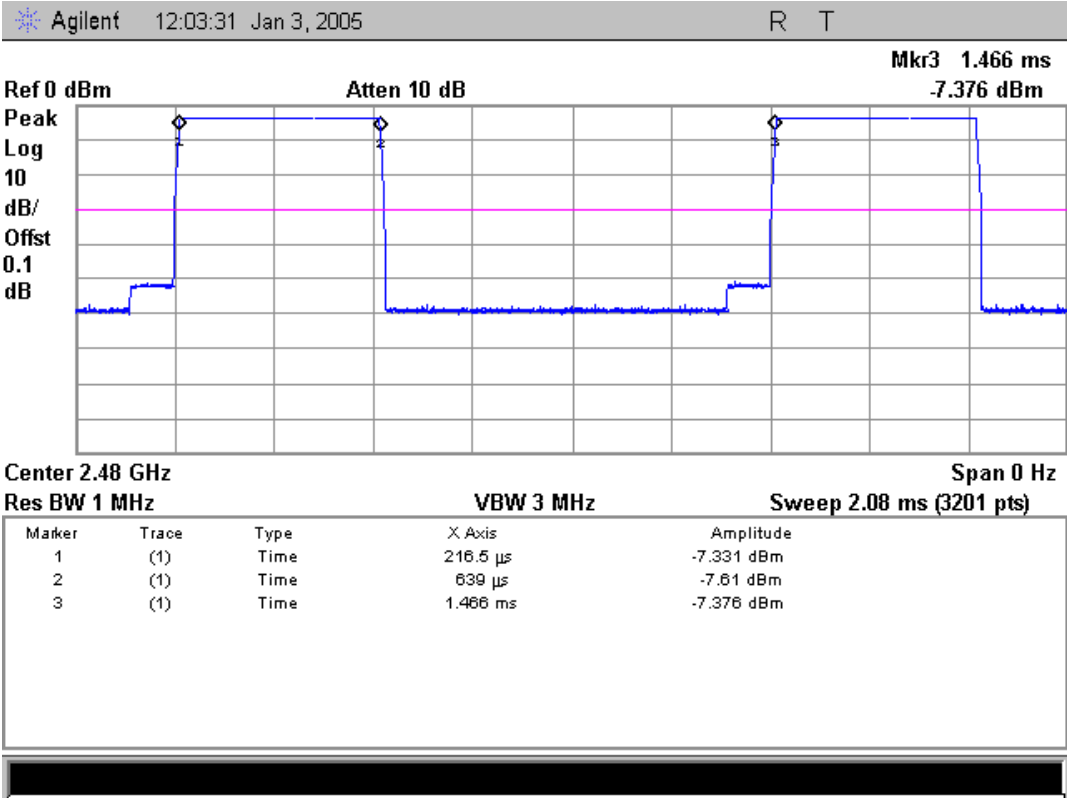

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**Figure 5. Plot of the Time of Occupancy (Conducted)**
**Lowest Channel (operating at 2402 MHz)**

**Middle Channel (operating at 2441 MHz)**




Highest Channel (operating at 2480 MHz)





## 5.7 SPURIOUS EMISSIONS, BAND EDGE, AND RESTRICTED BANDS

### 5.7.1 Regulation

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 emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 15.205(c)).

According to §15.209(a), for an intentional device, the general requirement of field strength of radiated emissions from intentional radiators at a distance of 3 meters shall not exceed the following values:

| Frequency (MHz) | Field strength ( $\mu\text{V}/\text{m}$ @ 3m) | Field strength ( $\text{dB}\mu\text{V}/\text{m}$ @ 3m) |
|-----------------|-----------------------------------------------|--------------------------------------------------------|
| 30–88           | 100                                           | 40.0                                                   |
| 88–216          | 150                                           | 43.5                                                   |
| 216–960         | 200                                           | 46.0                                                   |
| Above 960       | 500                                           | 54.0                                                   |

According to §15.109(a), for an unintentional device, except for Class A digital devices, the field strength of radiated emissions from unintentional radiators at a distance of 3 meters shall not exceed the above table.

\*\* The emission limits shown in the above table are based on measurement instrumentation employing a CISPR quasi-peak detector and above 1000 MHz are based on the average value of measured emissions.

### 5.7.2 Test Procedure

#### 1) Spurious RF Conducted Emissions:

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Connect the antenna port of the EUT to RF input on the spectrum analyzer via a low loss cable.
3. Turn on the EUT and set it to any one measured frequency within its operating range by controlling it via UART interface and make sure the spectrum analyzer is operated in its linear range.
4. Set the spectrum analyzer to MAX HOLD mode with RBW = 100kHz, VBW = 100kHz and wide SPAN enough to capture the peak level of the in-band emission and all spurious emissions from the lowest frequency generated in the EUT up through the 10th harmonic.



5. Set the marker on the peak of any spurious emission, and then measure the peak level of the emissions marked, using the spectrum analyzer with RBW = 100kHz, VBW = 100kHz, and SPAN = 100MHz.
6. Repeat above procedures until all frequencies measured were complete.

2) Spurious Radiated Emissions:

1. The preliminary radiated measurements were performed to determine the frequency producing the maximum emissions in an anechoic chamber at a distance of 3 meters.
2. The EUT was placed on the top of the 0.8-meter height, 1 × 1.5 meter non-metallic table. To find the maximum emission levels, the height of a measuring antenna was changed and the turntable was rotated 360°.
3. The antenna polarization was also changed from vertical to horizontal. The spectrum was scanned from 30 to 1000 MHz using the TRILOG broadband antenna, and from 1000 MHz to 18000 MHz using the horn antenna.
4. To obtain the final measurement data, the EUT was arranged on a turntable situated on a 4 × 4 meter at the Open Area Test Site. The EUT was tested at a distance 3 meters.
5. Each frequency found during preliminary measurements was re-examined and investigated. The test-receiver system was set up to average, peak, and quasi-peak detector function with specified bandwidth.
6. The presence of ambient signals was verified by turning the EUT off. In case an ambient signal was detected, the measurement bandwidth was reduced temporarily and verification was made that an additional adjacent peak did not exist. This ensures that the ambient signal does not hide any emissions from the EUT.



## 5.7.3 Test Results:

PASS

**Table 6: Measured values of the RF antenna port emissions (Conducted)**

| Frequency [MHz]                                | Reading [dBm] | Cable Loss [dB] | Actual [dBm] | Limit [dBm] | Margin [dB] |
|------------------------------------------------|---------------|-----------------|--------------|-------------|-------------|
| <b>Lowest Channel (operating at 2402 MHz)</b>  |               |                 |              |             |             |
| 2402.00                                        | -5.29         | 0.1             | -5.19        | -           | -           |
| 2400.00                                        | -47.10        | 0.1             | -47.00       | -25.19      | 21.81       |
| 2386.16                                        | -50.81        | 0.1             | -50.71       | -25.19      | 25.52       |
| 2399.50                                        | -46.90        | 0.1             | -46.80       | -25.19      | 21.61       |
| 4804.00                                        | -58.12        | 0.2             | -57.92       | -25.19      | 32.73       |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
| <b>Middle Channel (operating at 2441 MHz)</b>  |               |                 |              |             |             |
| 2441.00                                        | -4.98         | 0.1             | -4.88        | -           | -           |
| 4881.69                                        | -58.77        | 0.2             | -58.57       | -24.88      | 33.69       |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
| <b>Highest Channel (operating at 2480 MHz)</b> |               |                 |              |             |             |
| 2480.00                                        | -4.04         | 0.1             | -3.94        | -           | -           |
| 2483.50                                        | -57.75        | 0.1             | -57.65       | -23.94      | 33.71       |
| 2484.47                                        | -54.80        | 0.1             | -54.70       | -23.94      | 30.76       |
| 2496.00                                        | -56.42        | 0.1             | -56.32       | -23.94      | 32.38       |
| 4960.00                                        | -60.49        | 0.2             | -60.29       | -23.94      | 36.35       |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |
|                                                |               |                 |              |             |             |

**Actual = Reading + Cable Loss**

Remark "---" means the emission level was too low to be measured or in the noise floor.

NOTE: All the Reading values were taken using Spectrum Analyzer with RBW=100 kHz, VBW=100 kHz, and SPAN=100 MHz

**Table 7: Measured values of the Field strength of spurious emission (Radiated)**

| Frequency<br>[MHz]                                                  | Receiver<br>Bandwidth<br>[kHz] | Pol.<br>[V/H] | Antenna<br>Height<br>[m] | Table<br>Angle<br>[°] | Reading<br>[dB(μV)] | Amp<br>Gain<br>[dB] | AF / CL<br>[dB(1/m)] | Actual<br>[dB(μV/m)] | Limit<br>[dB(μV/m)] | Margin<br>[dB] |
|---------------------------------------------------------------------|--------------------------------|---------------|--------------------------|-----------------------|---------------------|---------------------|----------------------|----------------------|---------------------|----------------|
| <b>Quasi-peak data, emissions below 1000 MHz</b>                    |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
| 162.2                                                               | 120                            | H             | 1.9                      | 0                     | 38.48               | 27.5                | 15.3/2.1             | 28.38                | 43.5                | 15.12          |
| 176.9**                                                             | 120                            | H             | 1.9                      | 0                     | 40.42               | 27.4                | 15.7/2.1             | 30.82                | 43.5                | 12.68          |
| 191.7**                                                             | 120                            | H             | 1.9                      | 0                     | 37.87               | 27.0                | 15.9/2.4             | 29.17                | 43.5                | 14.33          |
| 331.8                                                               | 120                            | H             | 1.0                      | 27                    | 40.75               | 27.4                | 16.7/3.2             | 33.25                | 46.0                | 12.75          |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
| * Does not fall in the restricted bands specified in Section 15.205 |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
| <b>AVERAGE data, emissions above 1000 MHz</b>                       |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
| 2390.0                                                              | 1000                           | H             | 1.0                      | 75                    | 34.63               | 30.1                | 29.2/7.4             | 41.13                | 54.00               | 12.87          |
| 2386.2                                                              | 1000                           | H             | 1.0                      | 75                    | 34.50               | 30.1                | 29.2/7.4             | 41.00                | 54.00               | 13.00          |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
| 2483.5                                                              | 1000                           | H             | 1.1                      | 89                    | 37.05               | 30.1                | 29.2/7.4             | 43.55                | 54.00               | 10.45          |
| 2484.5                                                              | 1000                           | H             | 1.1                      | 89                    | 36.32               | 30.1                | 29.2/7.4             | 42.82                | 54.00               | 11.18          |
| 2496.0                                                              | 1000                           | H             | 1.1                      | 89                    | 36.08               | 30.1                | 29.2/7.4             | 42.58                | 54.00               | 11.42          |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
| <b>PEAK data, emissions above 1000 MHz</b>                          |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
| 2390.0                                                              | 1000                           | H             | 1.0                      | 75                    | 54.91               | 30.1                | 29.2/7.4             | 61.41                | 74.00               | 12.59          |
| 2386.2                                                              | 1000                           | H             | 1.0                      | 75                    | 54.95               | 30.1                | 29.2/7.4             | 61.45                | 74.00               | 12.55          |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
| 2483.5                                                              | 1000                           | H             | 1.1                      | 89                    | 55.19               | 30.1                | 29.2/7.4             | 61.69                | 74.00               | 12.31          |
| 2484.5                                                              | 1000                           | H             | 1.1                      | 89                    | 55.99               | 30.1                | 29.2/7.4             | 62.49                | 74.00               | 11.51          |
| 2496.0                                                              | 1000                           | H             | 1.1                      | 89                    | 55.89               | 30.1                | 29.2/7.4             | 62.39                | 74.00               | 11.61          |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |
|                                                                     |                                |               |                          |                       |                     |                     |                      |                      |                     |                |

**Margin (dB) = Limit – Actual****[Actual = Reading – Amp Gain + AF + CL]**

1. H = Horizontal, V = Vertical Polarization

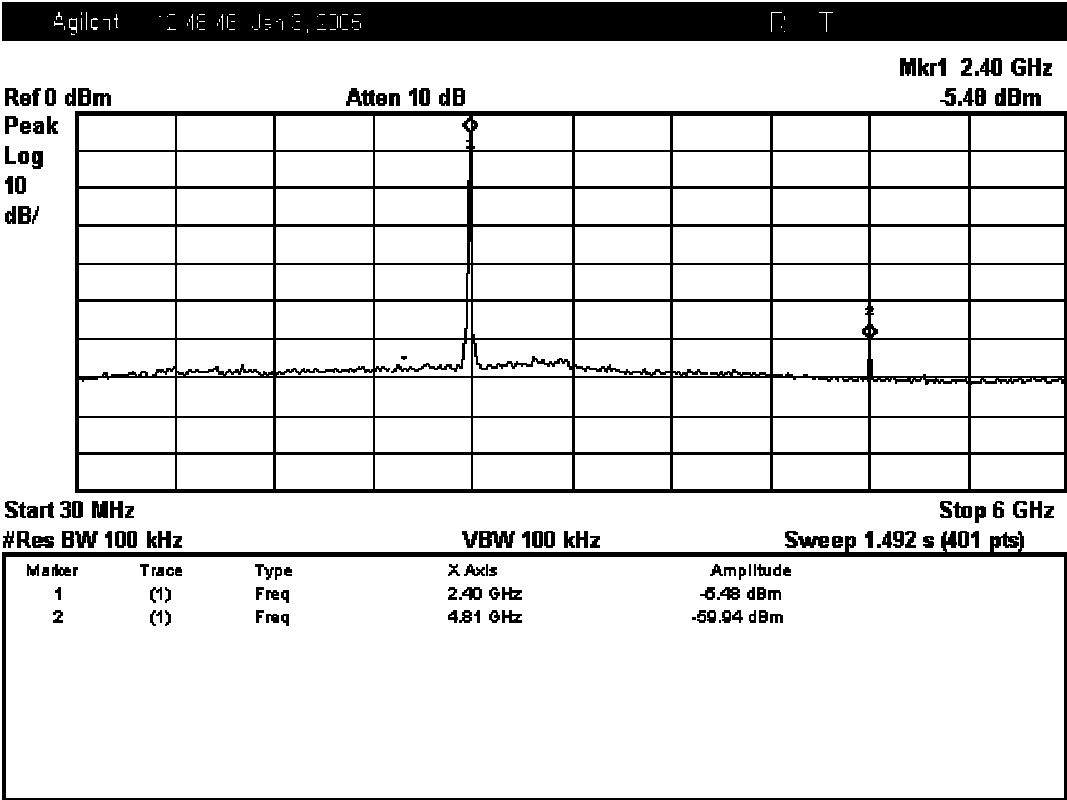
2. AF/CL = Antenna Factor and Cable Loss

NOTE: The spectrum was scanned from 30 MHz to 18 GHz. All emissions not reported were more than 20 dB below the specified limit or in the noise floor. The measured data in the above table include the spurious radiated emissions that do not fall in the restricted bands.

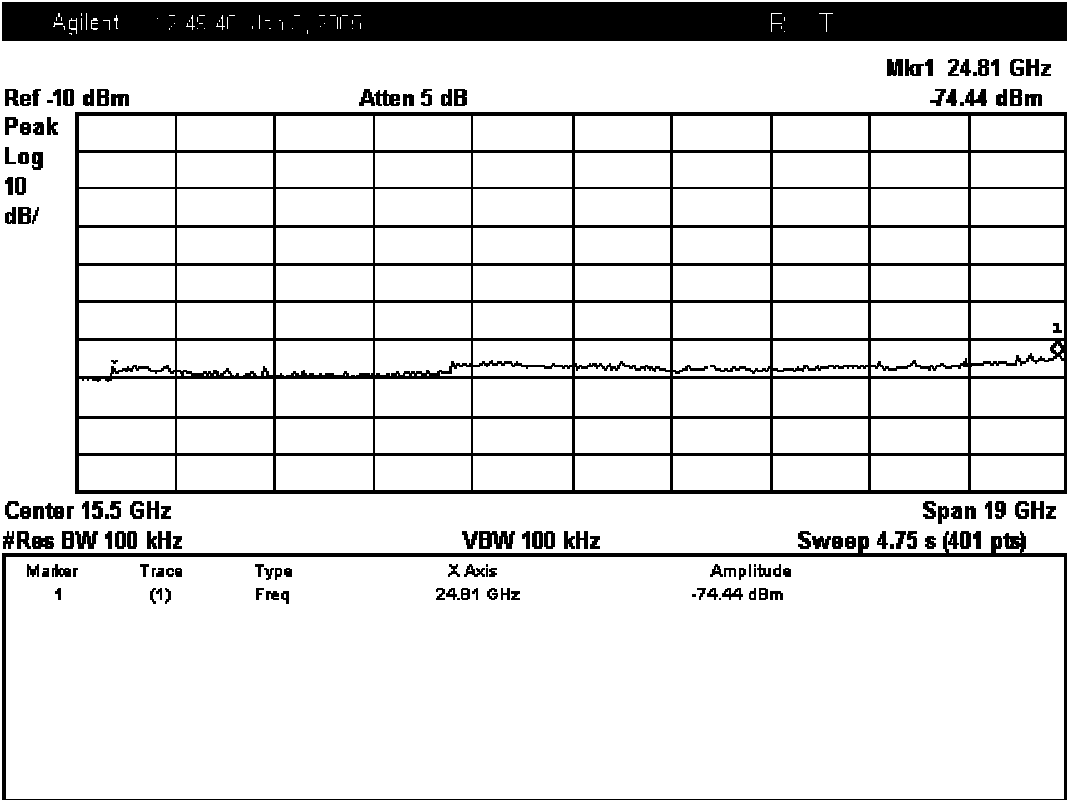


Figure 6. Plot of the RF antenna port emissions (Conducted)

Lowest Channel (operating at 2402 MHz): 30MHz ~ 6GHz

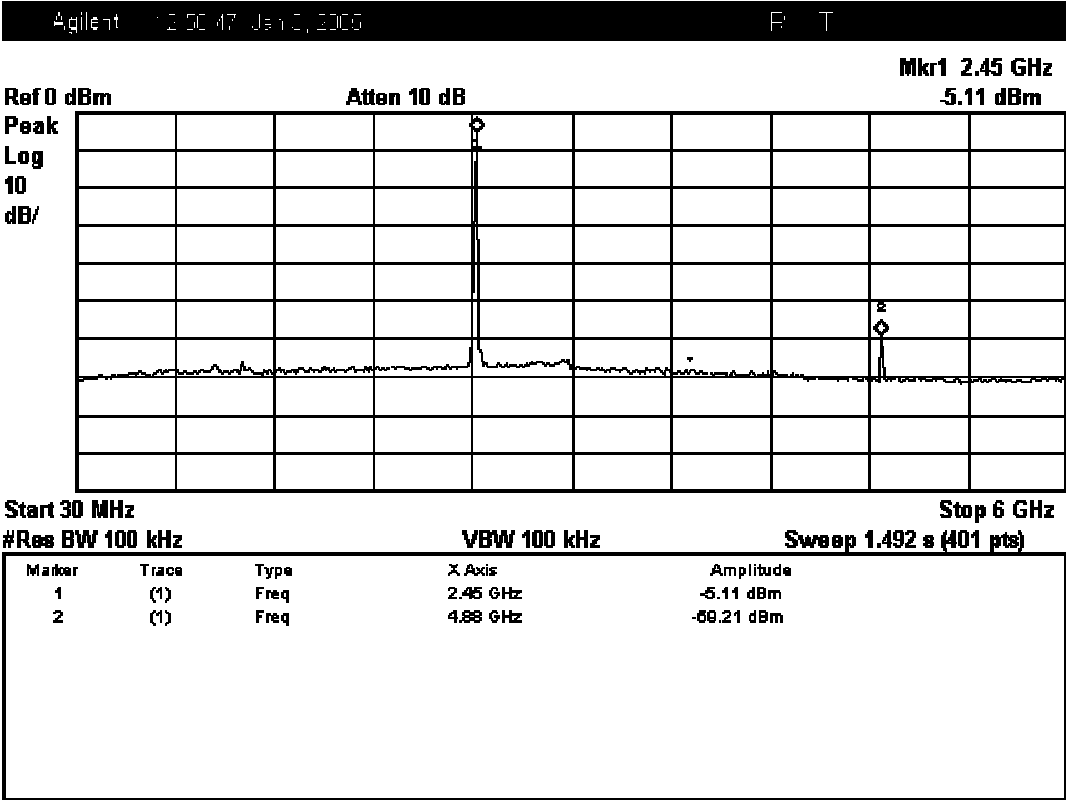


Lowest Channel (operating at 2402 MHz): 6GHz ~ 25GHz

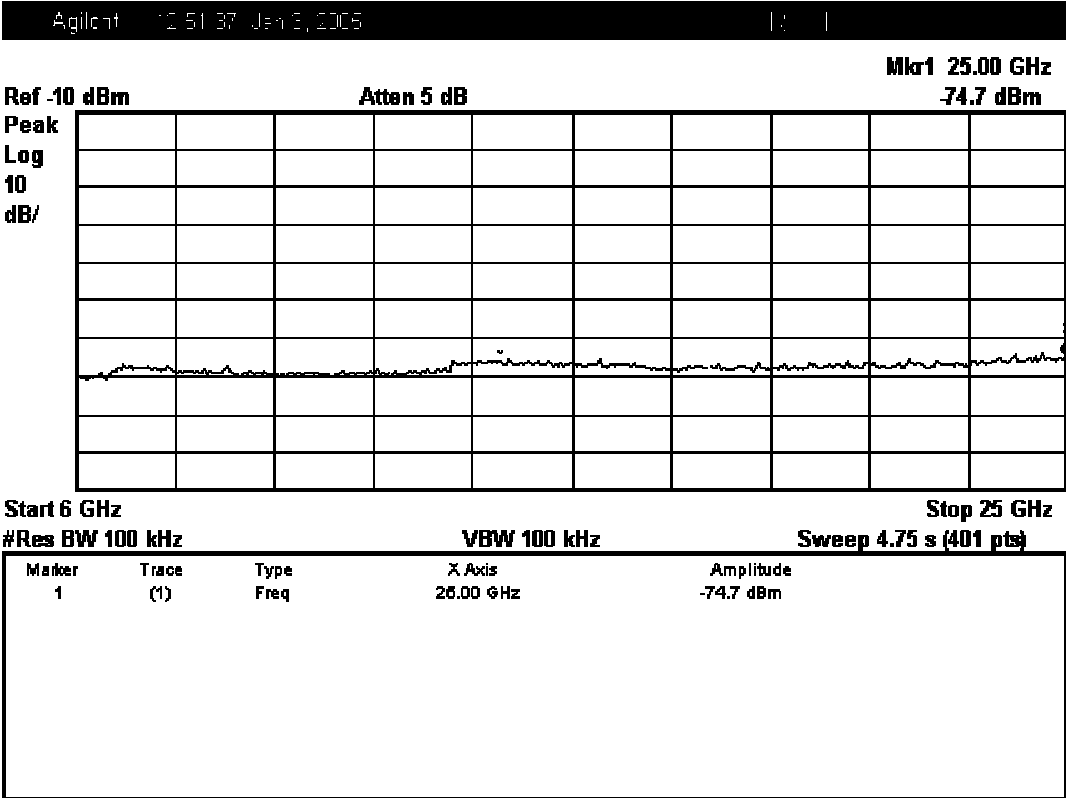




Middle Channel (operating at 2441 MHz): 30MHz ~ 6GHz

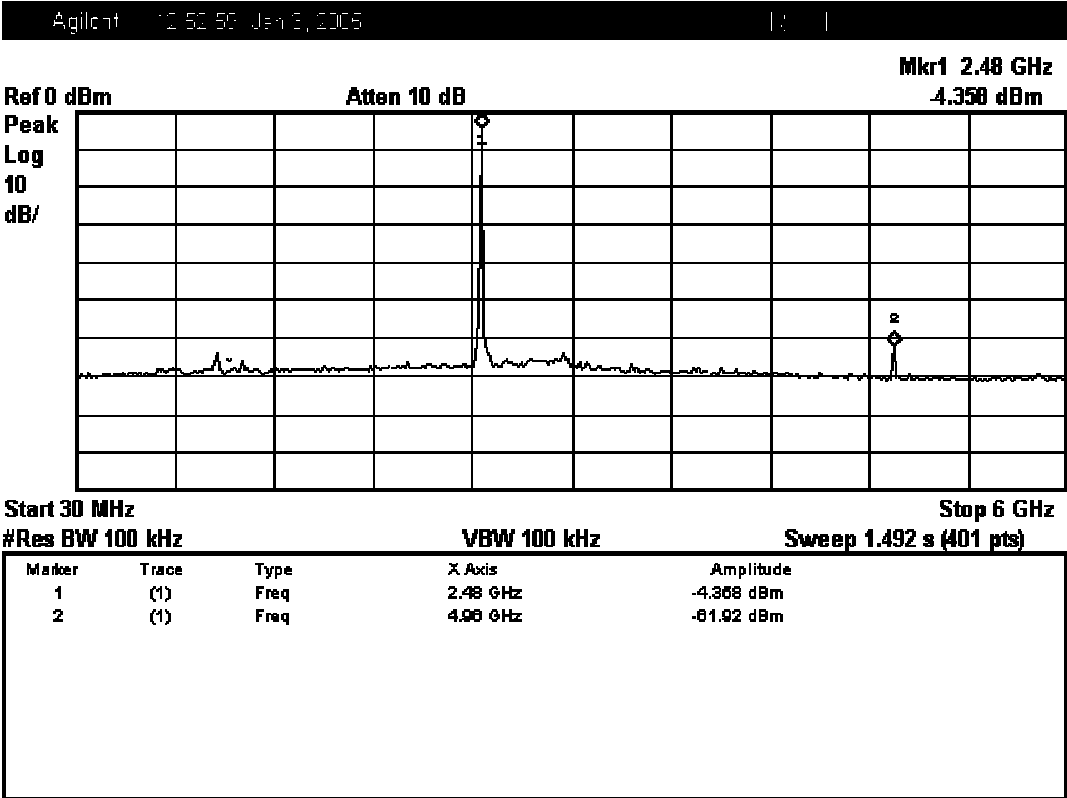


Middle Channel (operating at 2441 MHz): 6GHz ~ 25GHz





Highest Channel (operating at 2480 MHz): 30MHz ~ 6GHz



Highest Channel (operating at 2480 MHz): 6GHz ~ 25GHz

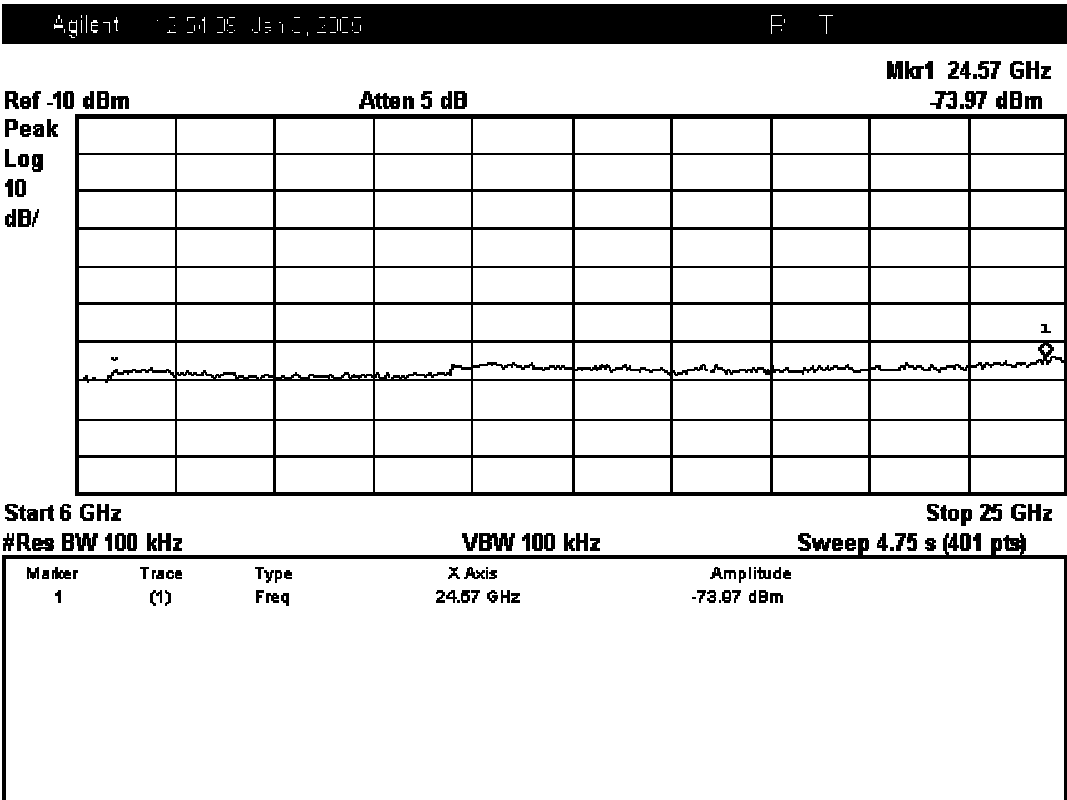
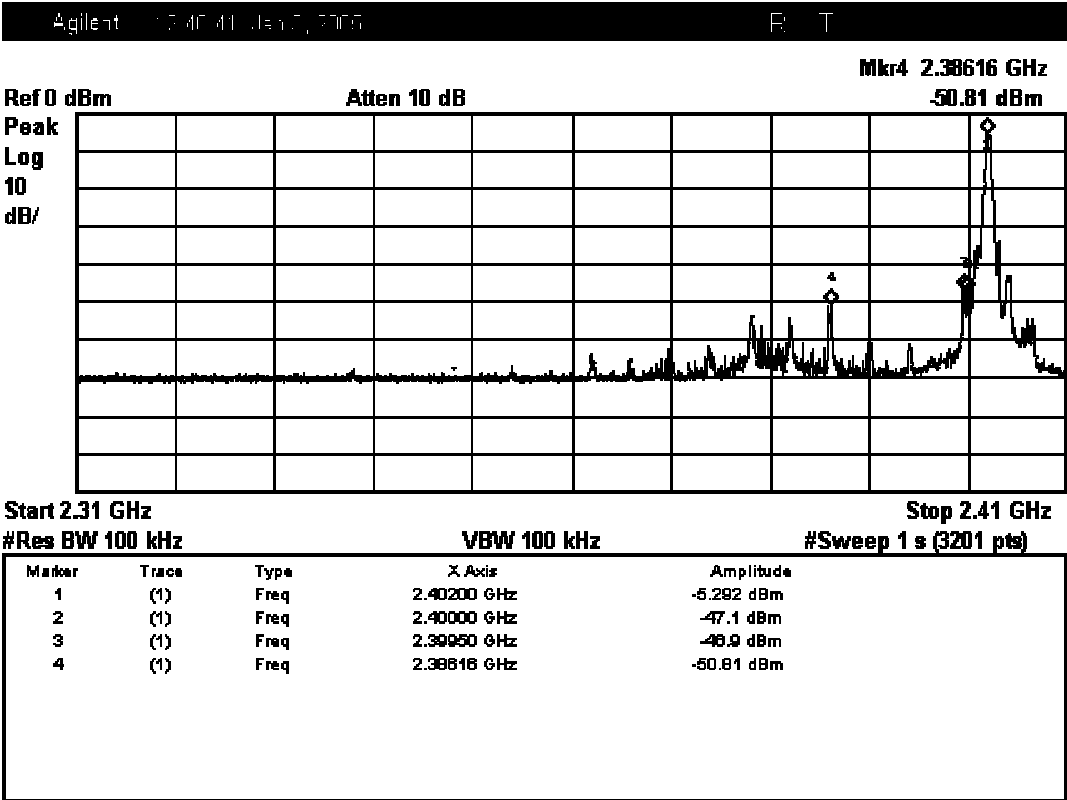




Figure 7. Plot of the Band Edge (Conducted)  
Lowest Channel (operating at 2402 MHz)



Highest Channel (operating at 2480 MHz)

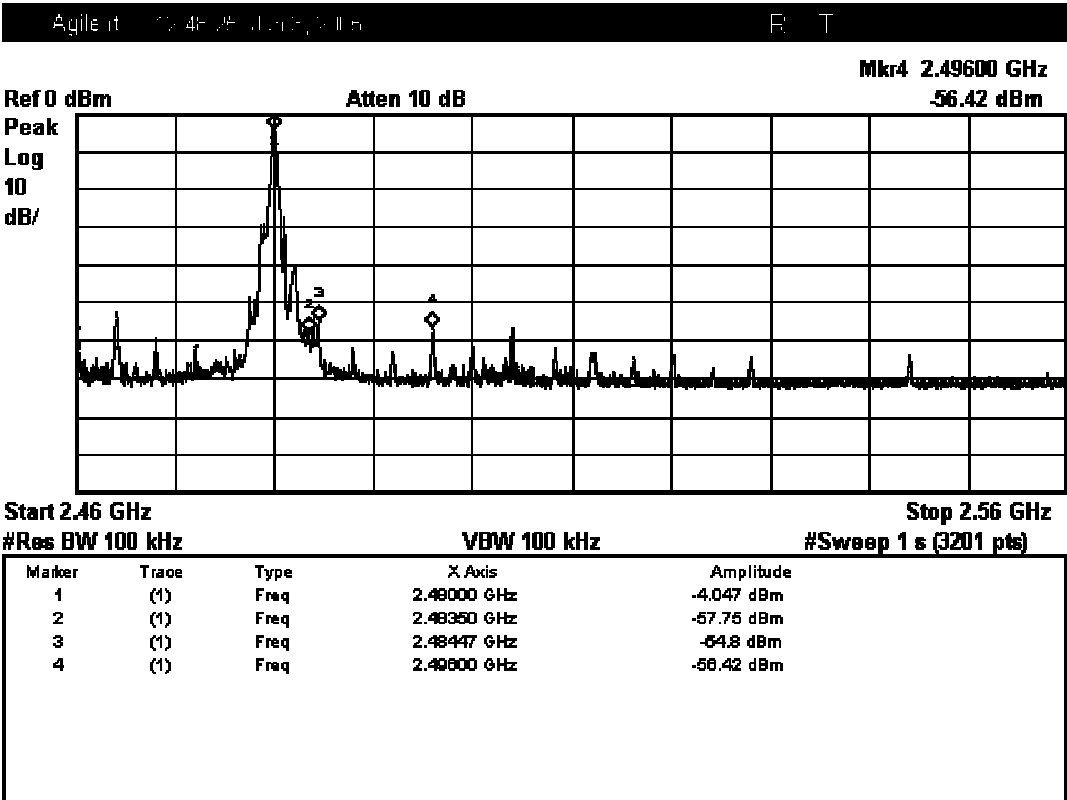
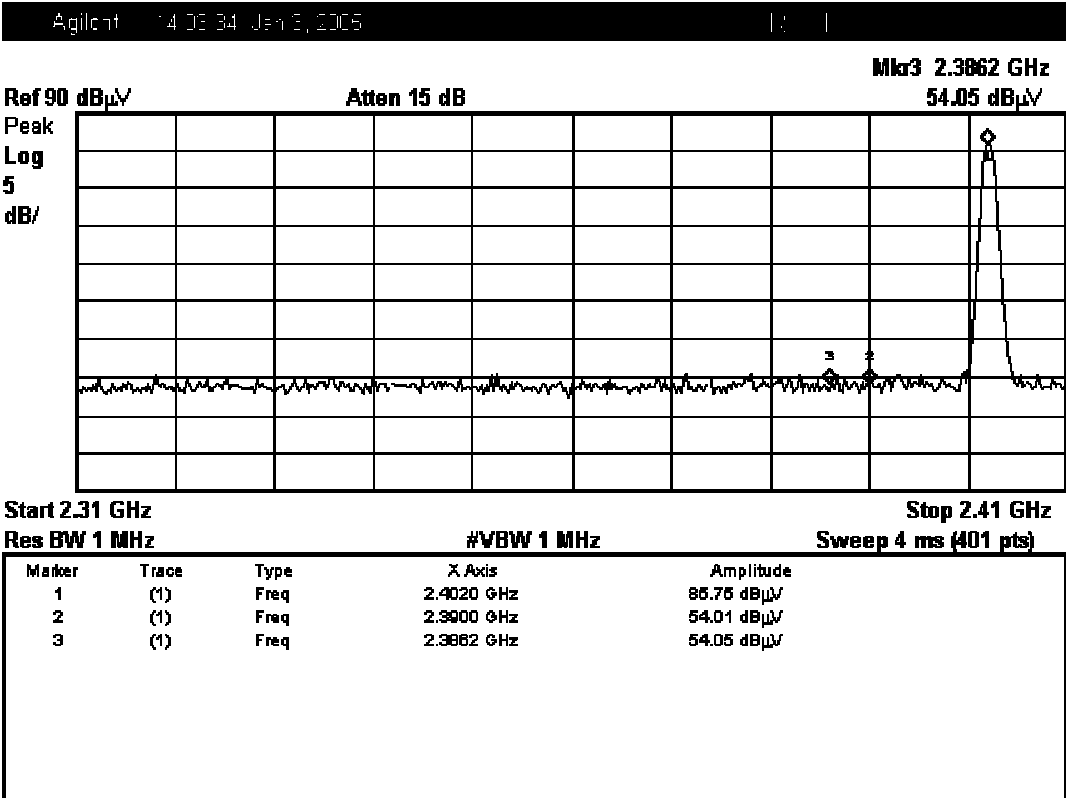


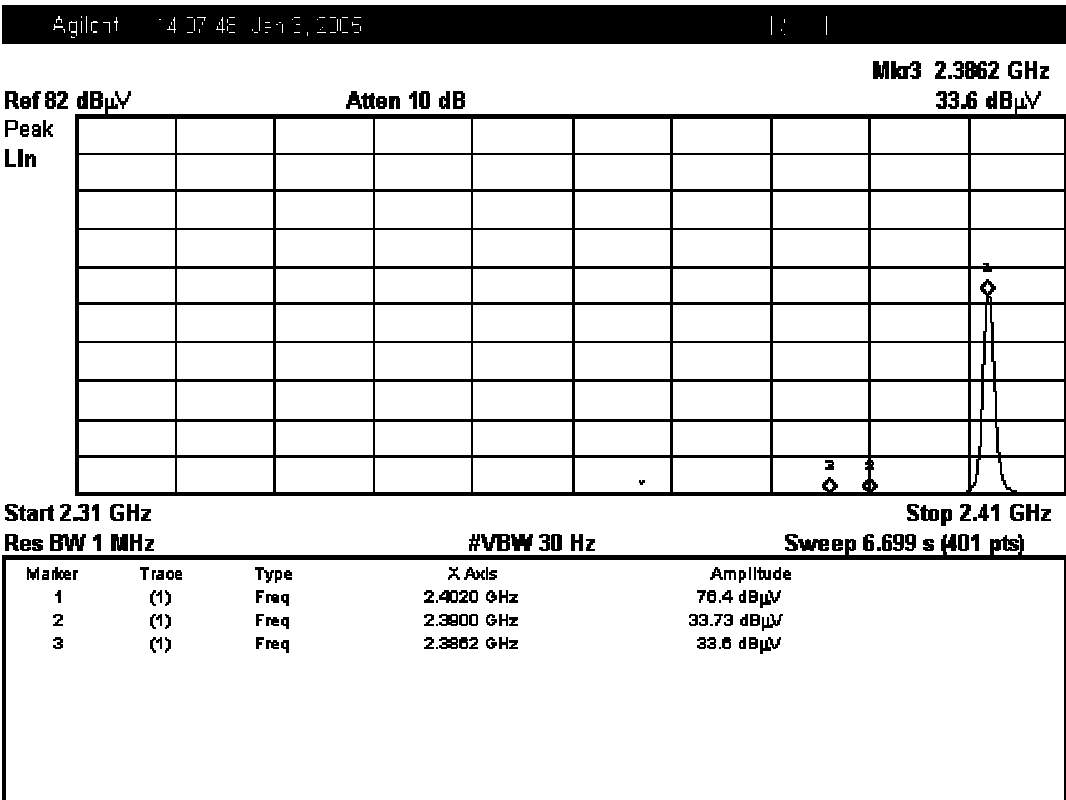


Figure 8. Plot of the Band Edge (Radiated)

Lowest Channel (operating at 2402 MHz): 2310 ~ 2390 MHz, PEAK

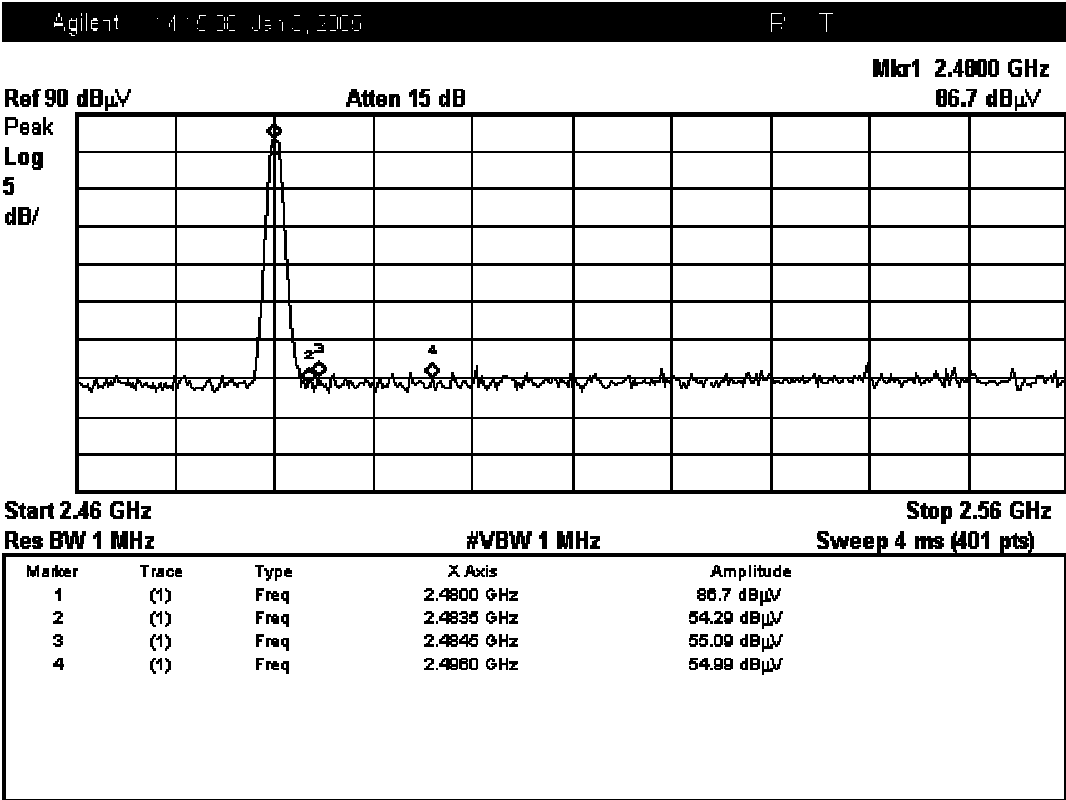


Lowest Channel (operating at 2402 MHz): 2310 ~ 2390 MHz, AVERAGE

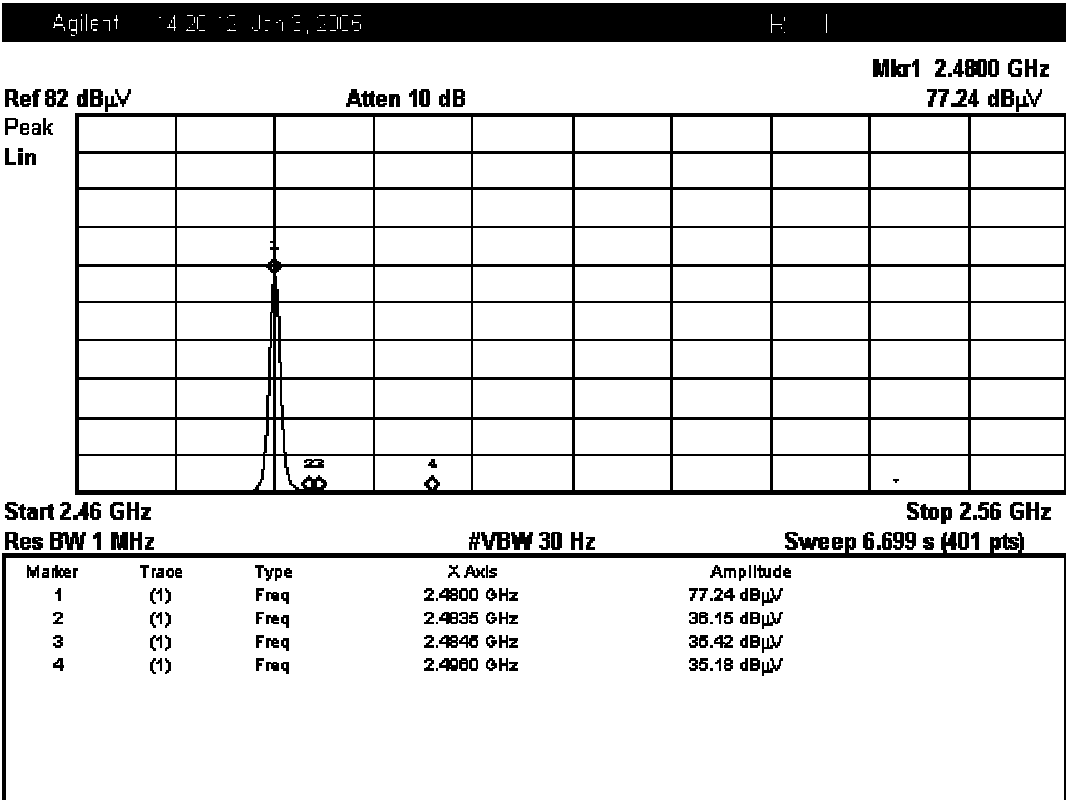




Highest Channel (operating at 2480 MHz): 2483.5 ~ 2500MHz, PEAK



Highest Channel (operating at 2480 MHz): 2483.5 ~ 2500MHz, AVERAGE





## 5.8 PEAK POWER SPECTRAL DENSITY

### 5.8.1 Regulation

According to §15.247(e), for digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.

### 5.8.2 Test Procedure

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Connect the antenna port of the EUT to RF input on the spectrum analyzer via a low loss cable.
3. Turn on the EUT and set it to any one measured frequency within its operating range by controlling it via UART interface and make sure the spectrum analyzer is operated in its linear range.
4. Set the spectrum analyzer to MAX HOLD mode with RBW = 3kHz.
5. Measure the highest amplitude appearing on spectral display and record the level to calculate results.
6. Repeat above procedures until all frequencies measured were complete.

### 5.8.3 Test Results:

**PASS**

**Table 8: Measured values of the Peak Power Spectral Density (Conducted)**

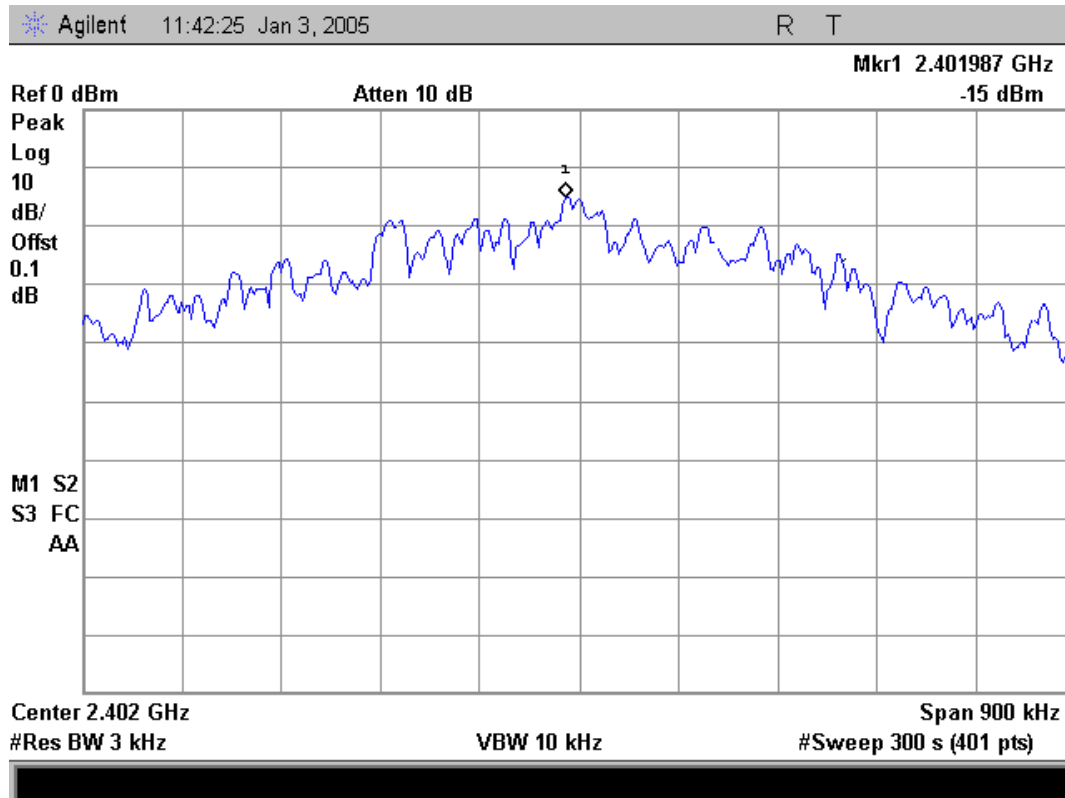
| Operating frequency | Cable Loss | Reading    | Limit   |
|---------------------|------------|------------|---------|
| 2402 MHz            | 0.1 dB     | -15.00 dBm | 8.0 dBm |
| 2441 MHz            | 0.1 dB     | -14.68 dBm | 8.0 dBm |
| 2480 MHz            | 0.1 dB     | -14.18 dBm | 8.0 dBm |

**Cable Loss was included in Reading as Offset.**

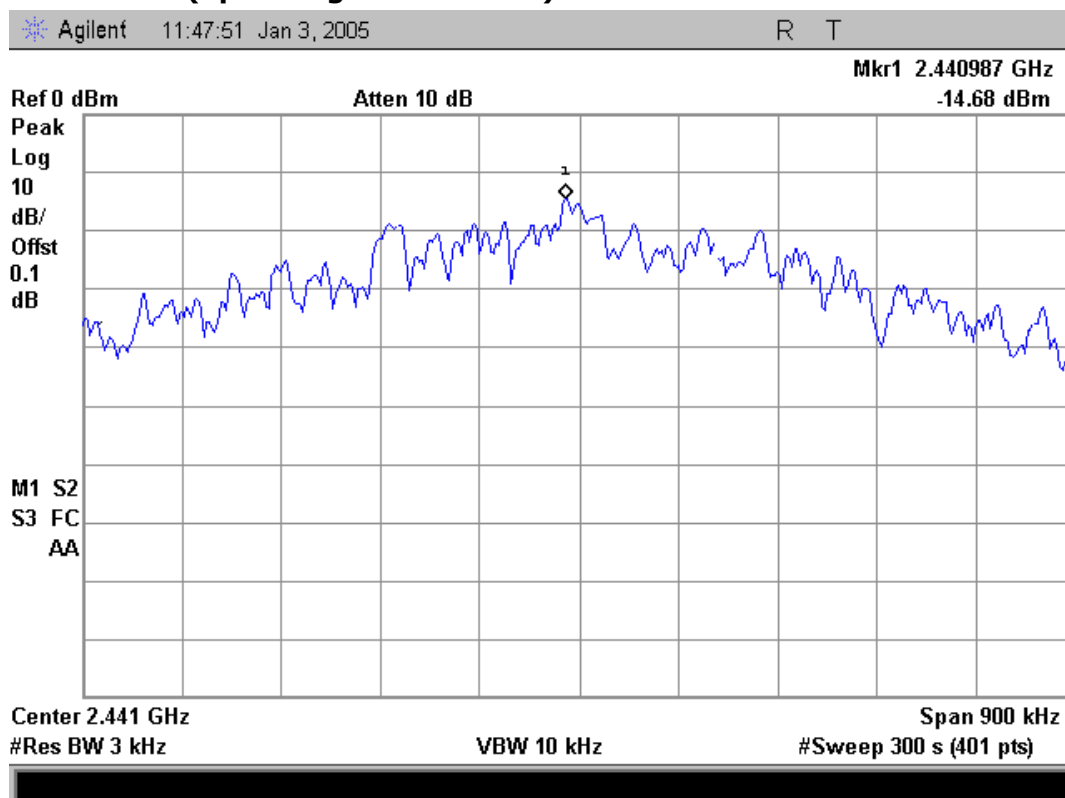
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**Figure 9. Plot of the Peak Power Spectral Density (Conducted)**  
**Lowest Channel (operating at 2402 MHz)**

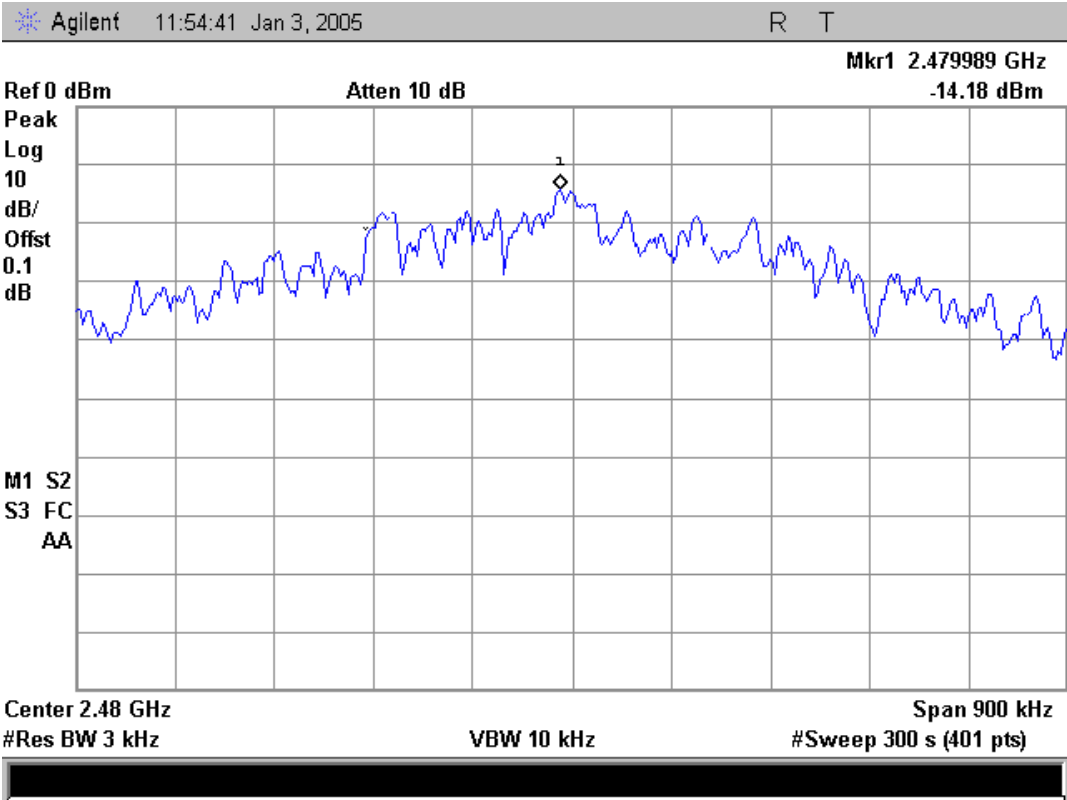


**Middle Channel (operating at 2441 MHz)**





Highest Channel (operating at 2480 MHz)





## 5.9 RF Exposure

### 5.9.1 Regulation

According to §15.247(i), systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy levels in excess of the Commission's guidelines. See § 1.1307(b)(1) of this Chapter.

Limits for Maximum Permissible Exposure: According to §1.1310 and §2.1093, RF exposure is calculated.

| Frequency Range                                     | Electric Field Strength [V/m] | Magnetic Field Strength [A/m] | Power Density [mW/cm <sup>2</sup> ] | Averaging Time [minute] |
|-----------------------------------------------------|-------------------------------|-------------------------------|-------------------------------------|-------------------------|
| Limits for General Population/Uncontrolled Exposure |                               |                               |                                     |                         |
| 0.3 ~ 1.34                                          | 614                           | 1.63                          | *(100)                              | 30                      |
| 1.34 ~ 30                                           | 824/f                         | 2.19/f                        | *(180/f <sup>2</sup> )              | 30                      |
| 30 ~ 300                                            | 27.5                          | 0.073                         | 0.2                                 | 30                      |
| 300 ~ 1500                                          | /                             | /                             | f/1500                              | 30                      |
| 1500 ~ 15000                                        | /                             | /                             | <u>1.0</u>                          | <u>30</u>               |

f = frequency in MHz,

\* = Plane-wave equivalent power density

### MPE (Maximum Permissible Exposure) Prediction

Predication of MPE limit at a given distance: Equation from page 18 of OET Bulletin 65, Edition 97-01

$$S = PG/4\pi R^2$$

S = power density [mW/cm<sup>2</sup>]

P = power input to antenna [mW]

$$\left(\Rightarrow R = \sqrt{PG/4\pi S}\right)$$

G = power gain of the antenna in the direction of interest relative to an isotropic radiator

R = distance to the center of radiation of the antenna [cm]

| EUT: Maximum peak output power = -3.119[dBm] (= 0.488 [mW]) & Antenna gain = 3.59[dBi] |                                                                                                                                  |
|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| 100mW, at 20cm from an antenna 6[dBi]                                                  | $S = PG/4\pi R^2 = 100 \times 3.98 / (4 \times \pi \times 400) = 0.0792 \text{ [mW/cm}^2\text{]} < 1.0 \text{ [mW/cm}^2\text{]}$ |
| 0.488mW, at 20cm from the antenna 3.59[dBi]                                            | $S = PG/4\pi R^2 = 0.0002 \text{ [mW/cm}^2\text{]} < 1.0 \text{ [mW/cm}^2\text{]}$                                               |
| 0.488mW, at 2.5cm from the antenna 3.59[dBi]                                           | $S = PG/4\pi R^2 = 0.0142 \text{ [mW/cm}^2\text{]} < 1.0 \text{ [mW/cm}^2\text{]}$                                               |
| 0.488mW, at 0.3cm from the antenna 3.59[dBi]                                           | $S = PG/4\pi R^2 = 0.9862 \text{ [mW/cm}^2\text{]} < 1.0 \text{ [mW/cm}^2\text{]}$                                               |

NOTE: The antenna used for the EUT is an integral SMD chip antenna. The calculated values of MPE for the EUT show that MPE is safe beyond 0.3 cm from the antenna.

### 5.9.2 RF Exposure Compliance Issue

The EUT is categorically excluded from routine environmental because it operates at very low power level. The equipment is deemed to comply with the SAR or MPE limits without testing due to this very low power level. The maximum RF EIRP power output from the EUT is less than 1.2mW. If the entire RF power was absorbed by 1 gram of tissue (not possible considering typical RF circuits), the SAR limit of 1.6mW/g would still not be exceed. Therefore no warning labels, no RF exposure warnings in the manual or other protection measures are required for the EUT.