# FCC/ISED - TEST REPORT

| | | | | |
|---|---|---|---|---|
| Report Number | : | **68.950.21.0001.01** | Date of Issue: | **2021-02-01** |
| Model | : | **HKTWS158, KOSS TWS250i** | | |
| Product Type | : | TRUE WIRELESS EARBUDS | | |
| Applicant | : | Koss Corporation | | |
| Address | : | 4129 N. Port Washington Avenue, Milwaukee, WI, 53212, United States Of America | | |
| Manufacturer | : | Koss Corporation | | |
| Address | : | 4129 N. Port Washington Avenue, Milwaukee, WI, 53212, United States Of America | | |
| Test Result | : | ■ **Positive** ☐ **Negative** | | |
| Total pages including Appendices | : | 63 | | |

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# 1 Table of Contents

# 2 Details about the Test Laboratory

**Details about the Test Laboratory**
Test Site 1

| | |
|---|---|
| Company name: | TÜV SÜD Certification and Testing (China) Co., Ltd. Shenzhen Branch<br>Building 12&13, Zhiheng Wisdomland Business Park,<br>Nantou Checkpoint Road 2, Nanshan District,<br>Shenzhen City, 518052,<br>P. R. China |
| FCC Designation Number: | CN5009 |
| FCC Registration No.: | 514049 |
| IC Registration Number: | 10320A |
| Telephone: | 86 755 8828 6998 |
| Fax: | 86 755 8828 5299 |

Report Version:

| Revision | Release Date | History/Memo. |
|---|---|---|
| N/A | 2021-02-01 | Initial Release |

# 3 Description of the Equipment Under Test

| | |
|---|---|
| Product: | TRUE WIRELESS EARBUDS |
| Model no.: | HKTWS158, KOSS TWS250i |
| FCC ID: | L76- TWS250I |
| IC: | 10021A- TWS250I |
| PMN: | HKTWS158, KOSS TWS250i |
| HVIN: | HKTWS158, KOSS TWS250i |
| Rating: | 3.7VDC, 50mAh (Supply by rechargeable battery) |
| RF Transmission Frequency: | 2402MHz-2480MHz |
| No. of Operated Channel: | 79 |
| Modulation: | GFSK, π/4-DQPSK, 8DPSK |
| Antenna Type: | Internal antenna |
| Antenna Gain: | 0.75dBi |
| Description of the EUT: | The Equipment Under Test (EUT) is a TRUE WIRELESS EARBUDS with Bluetooth BDR+EDR function.<br>The difference among all Models is only model name.<br>Unless otherwise specified the model HKTWS158 was chosen as the representative model to perform full tests, and model: KOSS TWS250i was deemed to fulfil relevant requirements without further testing.<br>The left earbud is identical with right earbud, so all the RF tests were applied on only one side. |

# 4 Summary of Test Standards

| Test Standards | |
|---|---|
| FCC Part 15 Subpart C 10-1-2019 Edition | PART 15 - RADIO FREQUENCY DEVICES<br>Subpart C - Intentional Radiators |
| RSS-Gen<br>Issue 5, Amendment 1, March 2019 | General Requirements for the Certification of Radio Apparatus |
| RSS-247 Issue 2 February 2017 | Digital Transmission Systems (DTSS), Frequency Hopping Systems (FHSS) and License-Exempt Local Area Network (LE-LAN) Devices |

All the test methods were according to Public Notice DA 00-705 -Frequency Hopper Spread Spectrum Test Procedure, KDB558074 D01 v05r02 and ANSI C63.10-2013.

# 5 Summary of Test Results

| Technical Requirements | | | | |
|---|---|---|---|---|
| **FCC Part 15 Subpart C/ RSS-247 Issue 2/RSS-Gen Issue 5** | | | | |
| Test Condition | | | Test Site | Test Result |
| §15.207 | RSS-GEN 8.8 | Conducted emission AC power port | -- | N/A |
| §15.247(b)(1) | RSS-247 Clause 5.4(b) | Conducted peak output power and e.i.r.p. | Site 1 | PASS |
| §15.247(e) | RSS-247 Clause 5.2(b) | Power spectral density | -- | N/A |
| §15.247(a)(2) | RSS-247 Clause 5.2(a) | 6dB bandwidth | -- | N/A |
| §15.247(a)(1) | RSS-247 Clause 5.1(a) & RSS-Gen 6.7 | 20dB bandwidth and 99% Occupied Bandwidth | Site 1 | PASS |
| §15.247(a)(1) | RSS-247 Clause 5.1(b) | Carrier frequency separation | Site 1 | PASS |
| §15.247(a)(1)(iii) | RSS-247 Clause 5.1(d) | Number of hopping frequencies | Site 1 | PASS |
| §15.247(a)(1)(iii) | RSS-247 Clause 5.1(d) | Dwell Time | Site 1 | PASS |
| §15.247(d) | RSS-247 Clause 5.5 | Spurious RF conducted emissions | Site 1 | PASS |
| §15.247(d) | RSS-247 Clause 5.5 | Band edge | Site 1 | PASS |
| §15.247(d) & §15.209 & §15.205 | RSS-247 Clause 5.5 & RSS-GEN 6.13 RSS-GEN 8.9 RSS-GEN 8.10 | Spurious radiated emissions for transmitter and receiver | Site 1 | PASS |
| §15.203 | RSS-GEN 6.8 | Antenna requirement | See note 2 | PASS |

Note 1: N/A=Not Applicable.
Note 2: The EUT uses an internal antenna, which gain is 0.75dBi. In accordance to §15.203 and RSS-GEN 6.8, it is considered sufficiently to comply with the provisions of this section.

# 6 General Remarks

**Remarks**

This submittal(s) (test report) is intended for FCC ID: L76- TWS250I, IC: 10021A- TWS250I, complies with Section 15.205, 15.209, 15.247 of the FCC Part 15, Subpart C and RSS-247 issue 2 and RSS-Gen issue 5 rules.

The Equipment Under Test (EUT) is a TRUE WIRELESS EARBUDS with Bluetooth BDR+EDR function.

**SUMMARY:**

All tests according to the regulations cited on page 6 were

■ - Performed

☐ - **Not** Performed

The Equipment Under Test

■ - **Fulfills** the general approval requirements.

☐ - **Does not** fulfill the general approval requirements.

| | |
|---|---|
| Sample Received Date: | 2021-01-10 |
| Testing Start Date: | 2021-01-10 |
| Testing End Date: | 2021-01-29 |

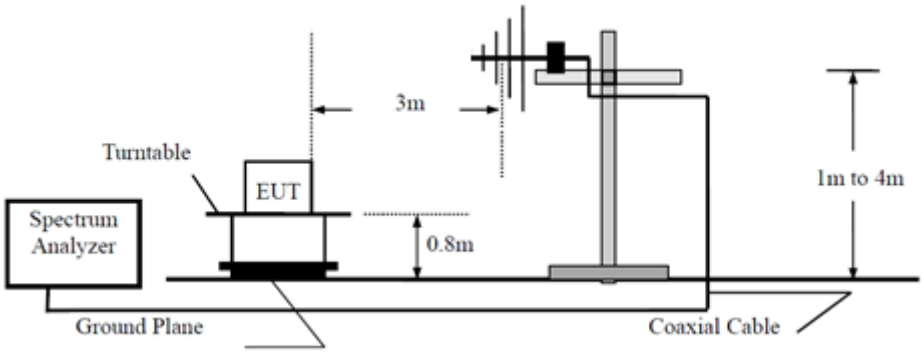
- TÜV SÜD Certification and Testing (China) Co., Ltd. Shenzhen Branch –

| Reviewed by: | Prepared by: | Tested by: |
|---|---|---|
| John Zhi | Joe Gu | Tree Zhan |
| Project Manager | Project Engineer | Test Engineer |

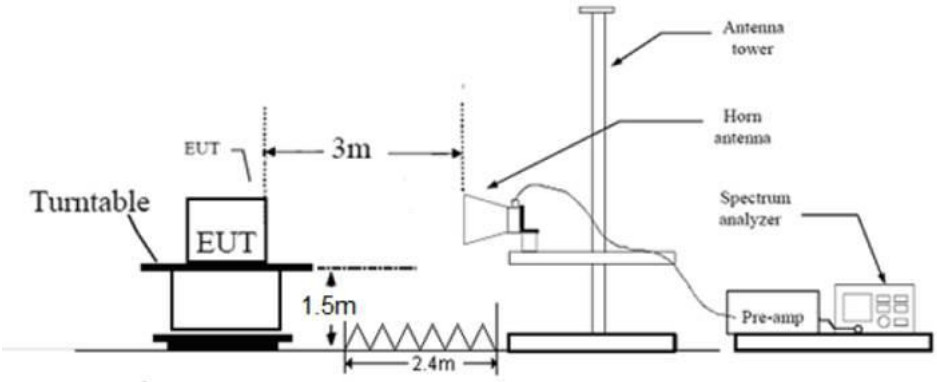
# 7 Test Setups

## 7.1 Radiated test setups

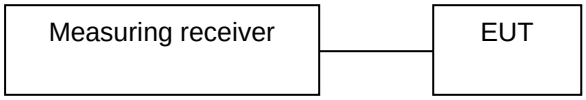
Below 1GHz




Above 1GHz




## 7.2 Conducted RF test setups



# 8 Systems test configuration

Auxiliary Equipment Used during Test:

| Name | Model | Manufacturer | S/N | Cal Due Date |
|---|---|---|---|---|
| Notebook | X220 | Lenovo | -- | -- |

The system was configured to hopping mode and non-hopping mode.

Hopping mode: typical working mode (normal hopping status)

Non-hopping mode: The system was configured to operate at a signal channel transmitting. The test software allows the configuration and operation at the worst-case duty and the highest transmit power.

# 9 Technical Requirement

## 9.1 Conducted peak output power and e.i.r.p.

**Test Method**

1. The EUT was placed on 0.8m height table, the RF output of EUT was connected to the test receiver by RF cable. The path loss was compensated to the results for each measurement.
2. Use the following spectrum analyzer settings:
   Span = approximately 5 times the 20dB bandwidth, centered on a hopping channel
   RBW > the 20dB bandwidth of the emission being measured, VBW≥RBW,
   Sweep = auto, Detector function = peak, Trace = max hold
3. Allow the trace to stabilize. Use the marker-to-peak function to set the marker to the peak of the emission. The indicated level is the peak output power

**Limits**

Conducted Peak Output Power:

| Frequency Range MHz | Limit W | Limit dBm |
|---|---|---|
| 2400-2483.5 | ≤1 | ≤30 |

For e.i.r.p.:

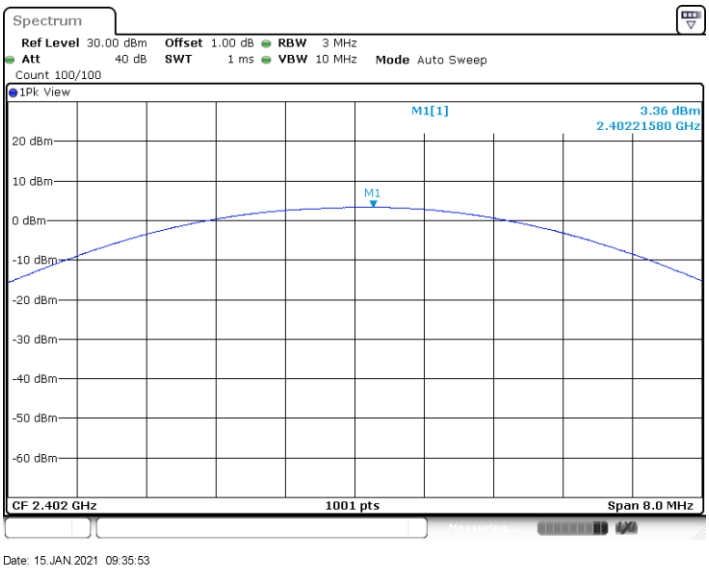
| Frequency Range MHz | Limit W | Limit dBm |
|---|---|---|
| 2400-2483.5 | ≤4 | ≤36 |

## Conducted peak output power

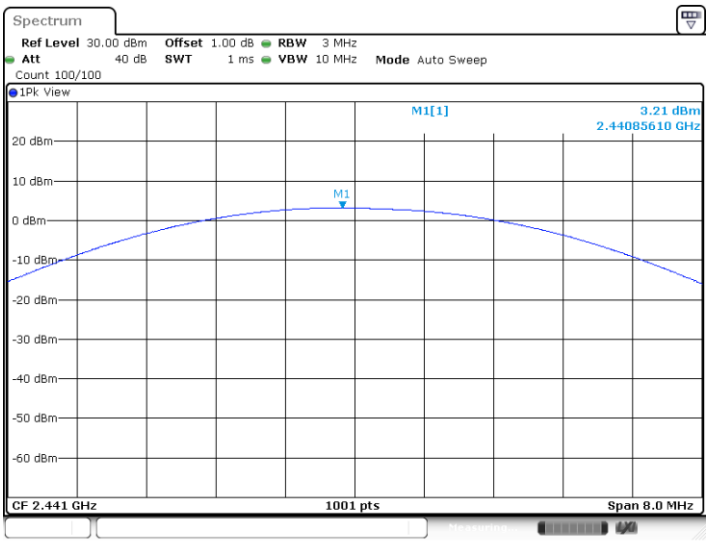
Bluetooth Mode GFSK modulation Test Result

| Frequency | Conducted Peak Output Power | Antenna Gain | EIRP | Result |
|---|---|---|---|---|
| MHz | dBm | dBi | dBm | |
| Low channel 2402MHz | 3.36 | 0.75 | 4.11 | Pass |
| Middle channel 2441MHz | 3.21 | 0.75 | 3.96 | Pass |
| High channel 2480MHz | 2.37 | 0.75 | 3.12 | Pass |

Low channel 2402MHz



Middle channel 2441MHz

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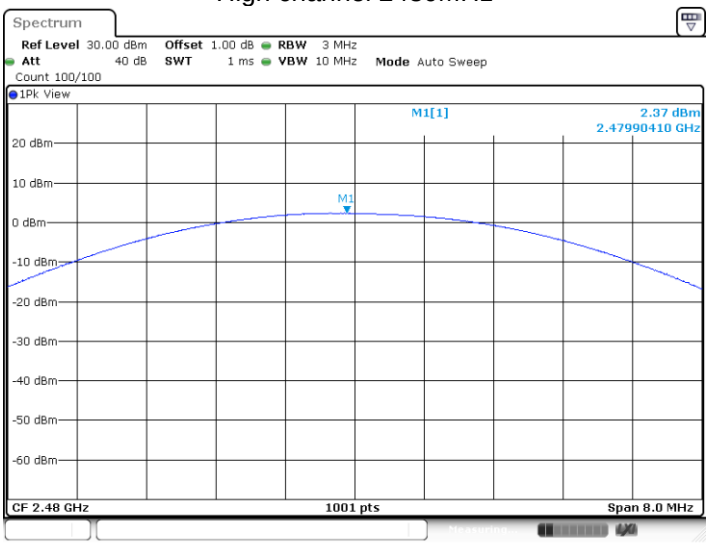
High channel 2480MHz

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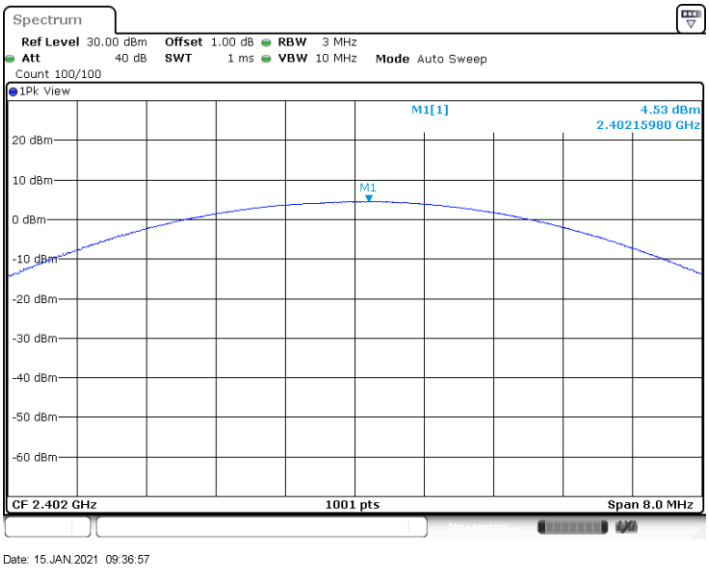
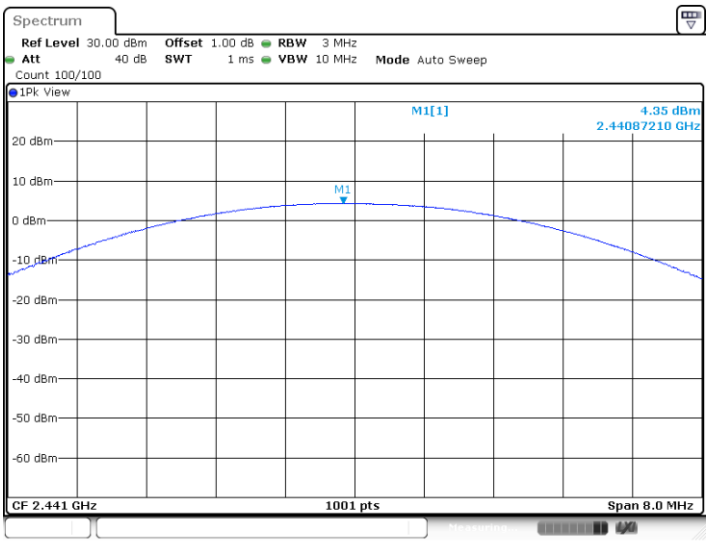
## Bluetooth Mode π/4-DQPSK modulation Test Result

| Frequency | Conducted Peak Output Power | Antenna Gain | EIRP | Result |
|---|---|---|---|---|
| MHz | dBm | dBi | dBm | |
| Low channel 2402MHz | 4.53 | 0.75 | 5.28 | Pass |
| Middle channel 2441MHz | 4.35 | 0.75 | 5.10 | Pass |
| High channel 2480MHz | 3.53 | 0.75 | 4.28 | Pass |

Low channel 2402MHz



Middle channel 2441MHz

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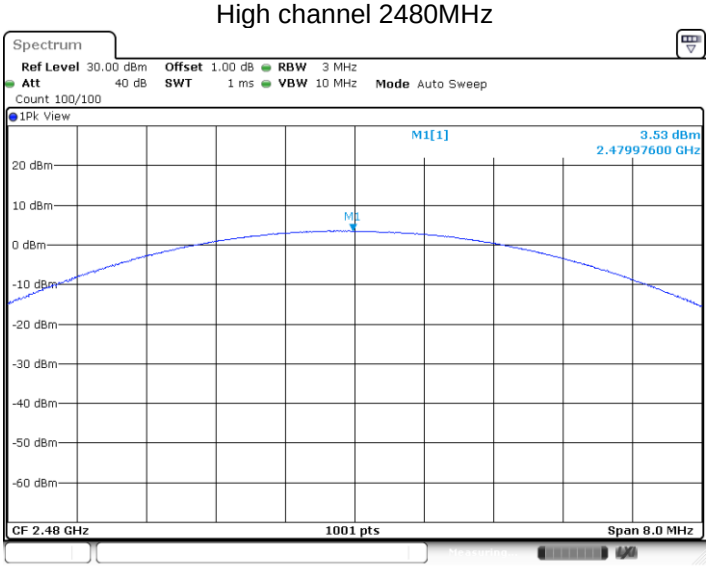
High channel 2480MHz

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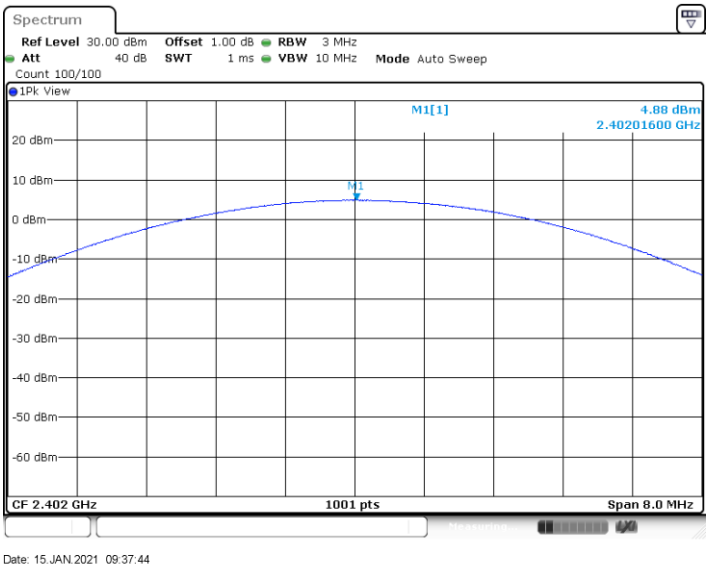
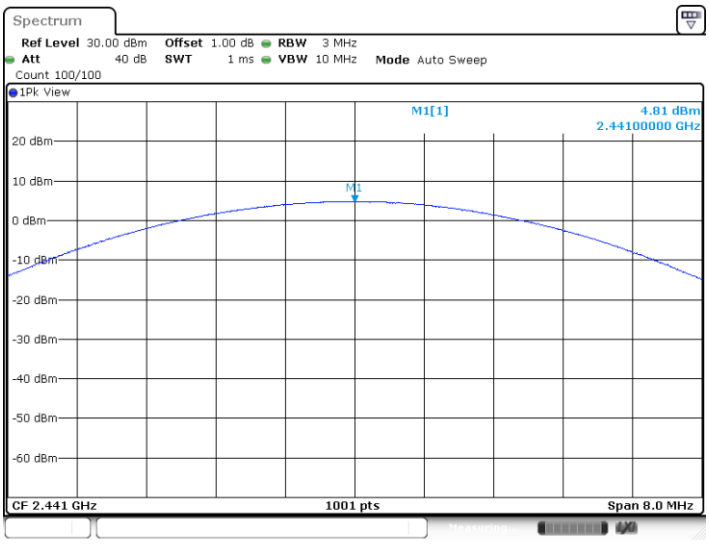
## Bluetooth Mode 8DPSK modulation Test Result

| Frequency | Conducted Peak Output Power | Antenna Gain | EIRP | Result |
|---|---|---|---|---|
| MHz | dBm | dBi | dBm | |
| Low channel 2402MHz | 4.88 | 0.75 | 5.63 | Pass |
| Middle channel 2441MHz | 4.81 | 0.75 | 5.56 | Pass |
| High channel 2480MHz | 3.98 | 0.75 | 4.73 | Pass |

Low channel 2402MHz



Middle channel 2441MHz

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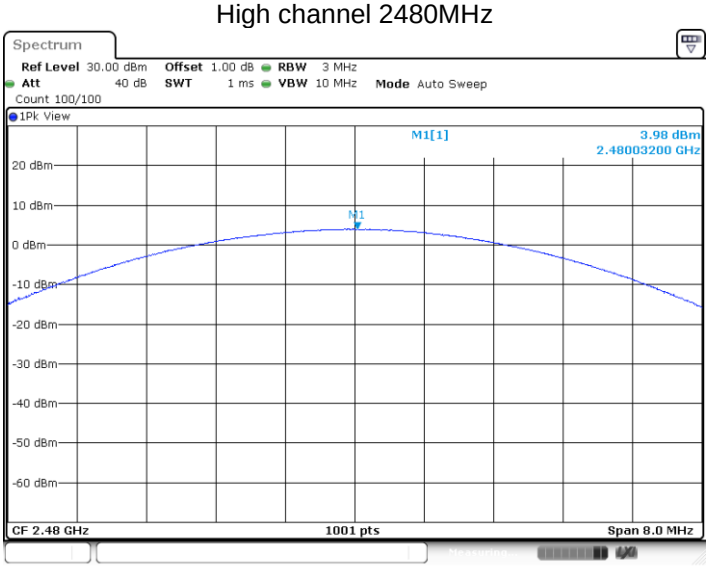
High channel 2480MHz

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## 9.2 20 dB bandwidth and 99% Occupied Bandwidth

**Test Method**

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Position the EUT without connection to measurement instrument. Turn on the EUT and connect it to measurement instrument. Then set it to any one convenient frequency within its operating range. Set a reference level on the measuring instrument equal to the highest peak value.
3. Measure the frequency difference of two frequencies that were attenuated 20 dB from the reference level. Record the frequency difference as the emission bandwidth.
4. Repeat above procedures until all frequencies measured were complete.

**Limit**

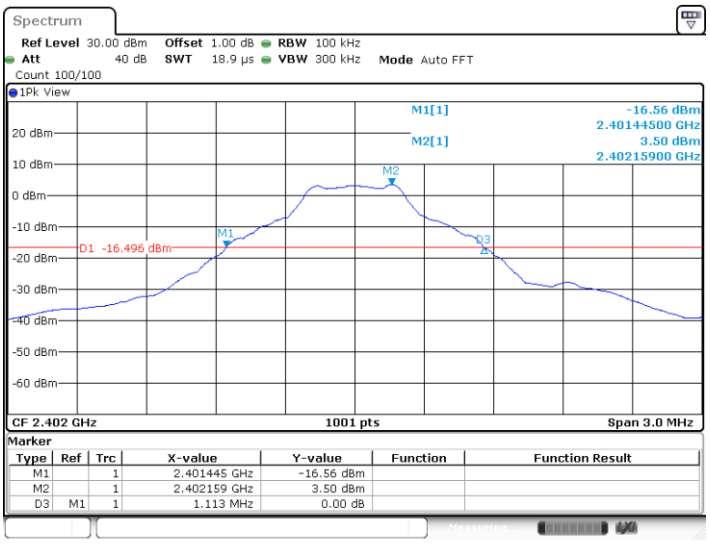
| Limit [kHz] |
|---|
| N/A |

## 20 dB bandwidth and 99% Occupied Bandwidth

Bluetooth Mode GFSK Modulation test result

| Frequency | 20 dB Bandwidth | 99% Bandwidth | Limit | Result |
|---|---|---|---|---|
| MHz | kHz | kHz | kHz | |
| 2402 | 1113 | 869 | -- | Pass |
| 2441 | 1119 | 866 | -- | Pass |
| 2480 | 1119 | 866 | -- | Pass |

Low channel 2402MHz

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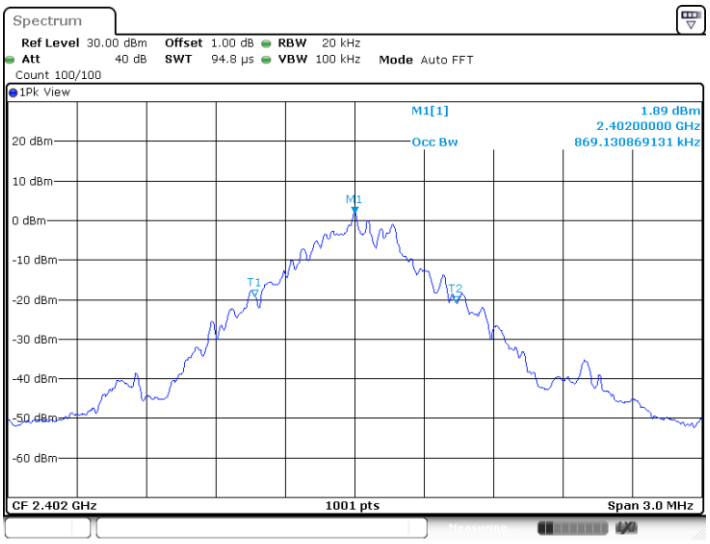


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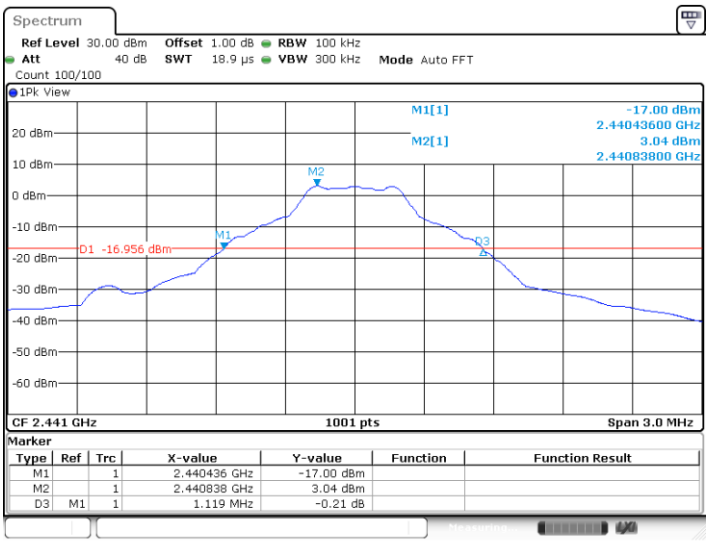
Middle channel 2441MHz

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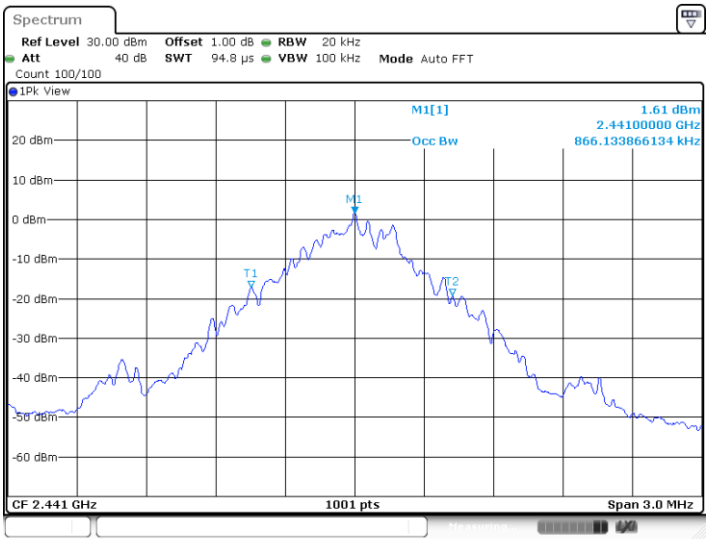


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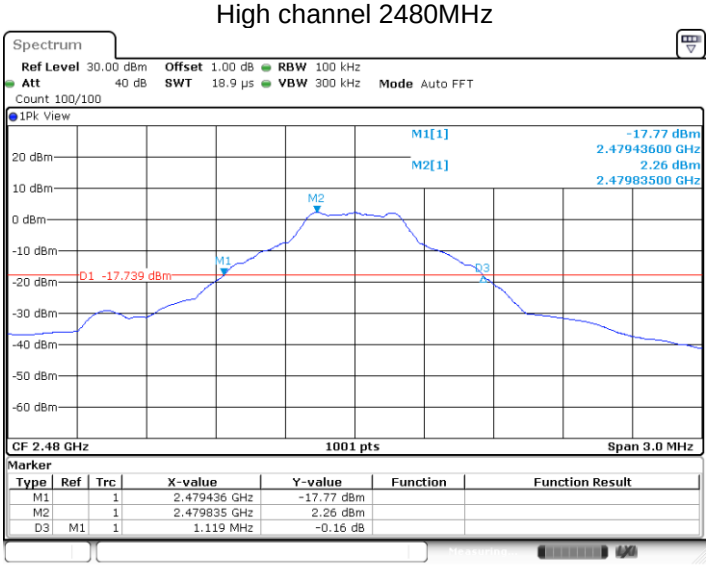
High channel 2480MHz

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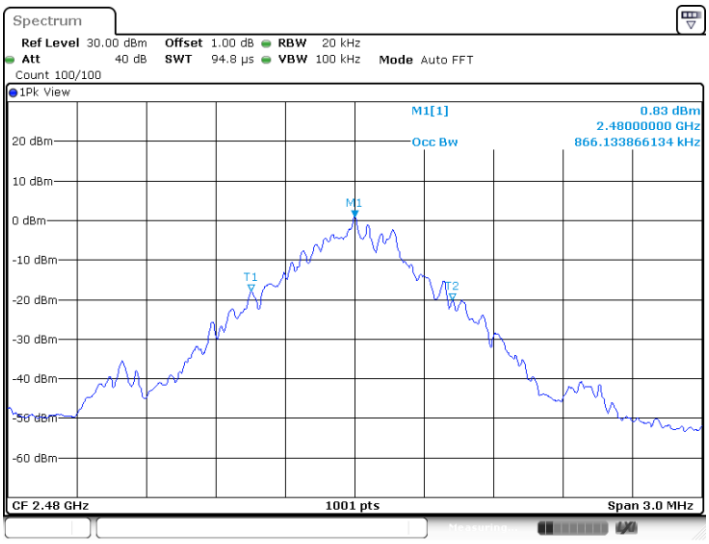


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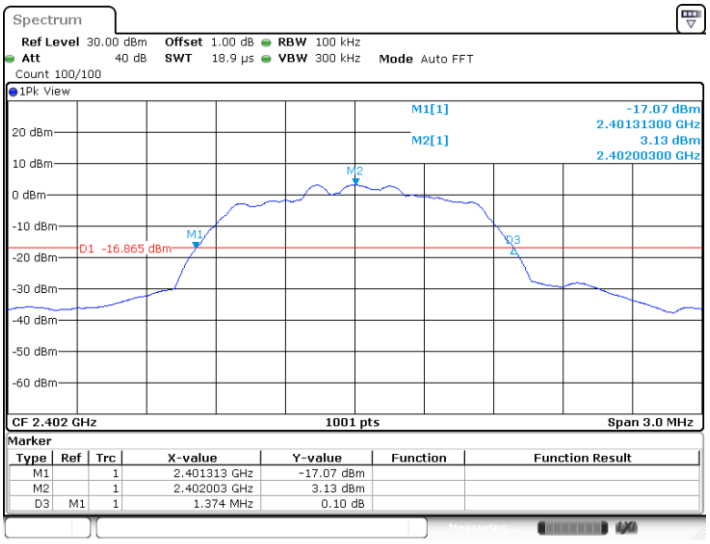
## 20 dB bandwidth and 99% Occupied Bandwidth

Bluetooth Mode π/4-DQPSK Modulation test result

| Frequency | 20 dB Bandwidth | 99% Bandwidth | Limit | Result |
|---|---|---|---|---|
| MHz | kHz | kHz | kHz | |
| 2402 | 1374 | 1169 | -- | Pass |
| 2441 | 1368 | 1166 | -- | Pass |
| 2480 | 1368 | 1166 | -- | Pass |

Low channel 2402MHz

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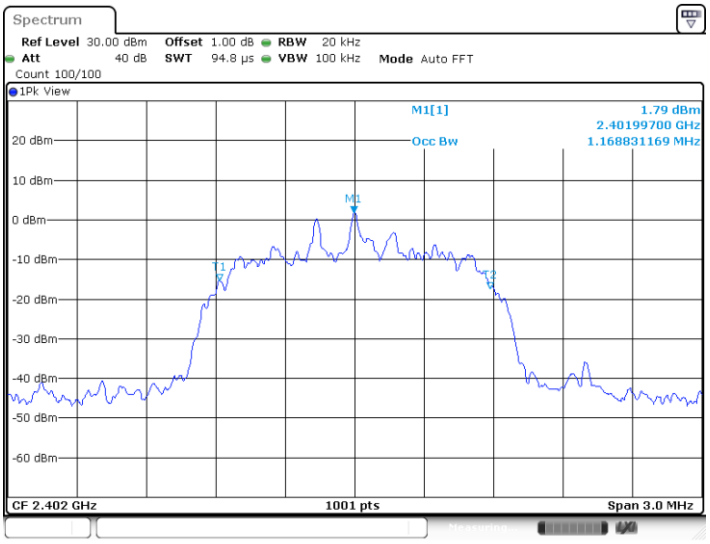


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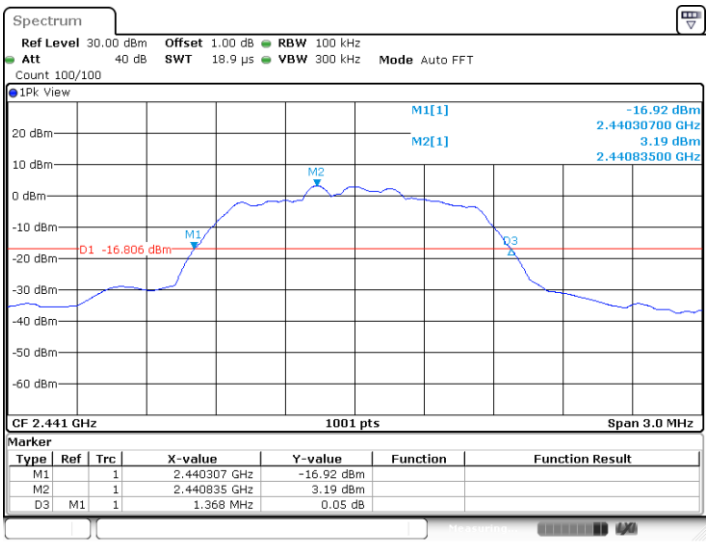
Middle channel 2441MHz

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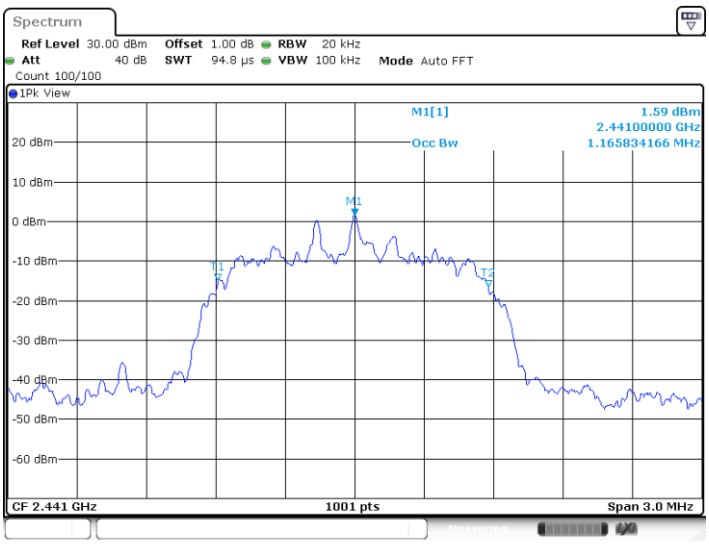


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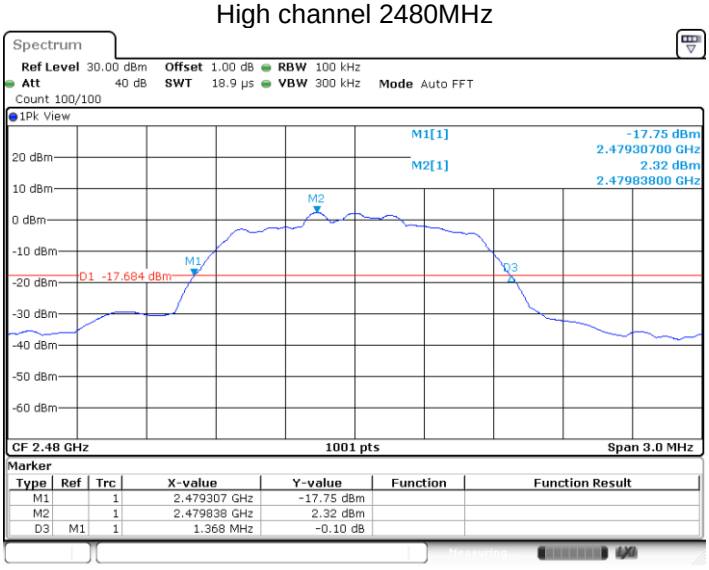
High channel 2480MHz

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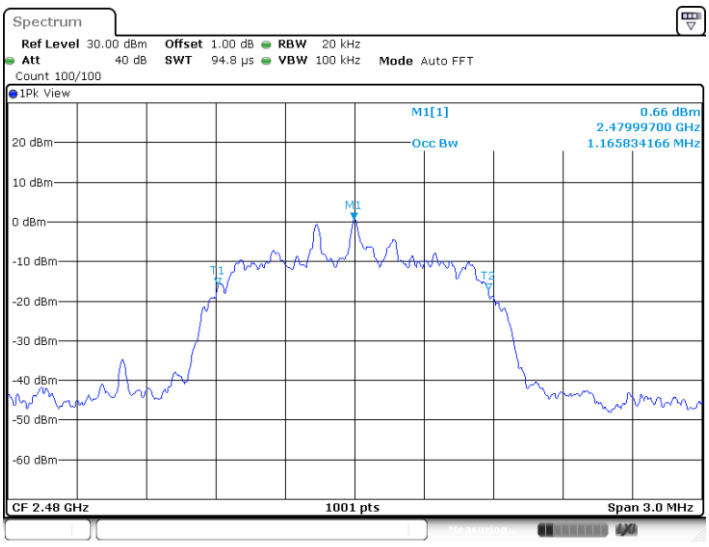


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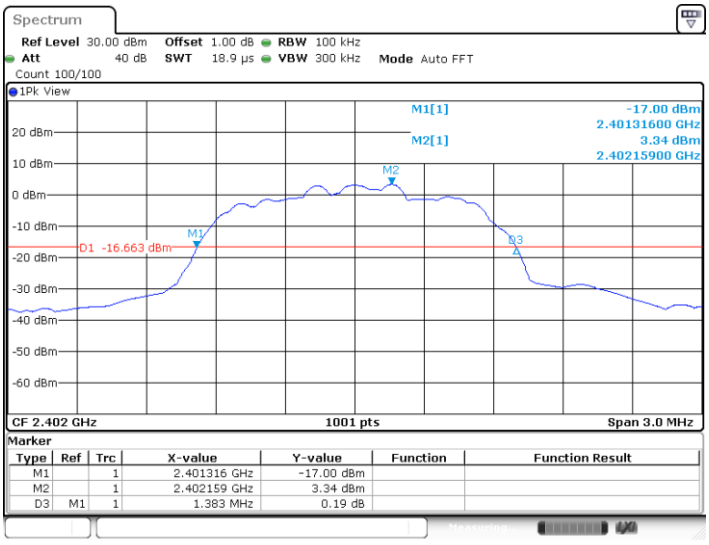
## 20 dB bandwidth and 99% Occupied Bandwidth

Bluetooth Mode 8DPSK Modulation test result

| Frequency MHz | 20 dB Bandwidth kHz | 99% Bandwidth kHz | Limit kHz | Result |
|---|---|---|---|---|
| 2402 | 1383 | 1169 | -- | Pass |
| 2441 | 1383 | 1172 | -- | Pass |
| 2480 | 1383 | 1172 | -- | Pass |

Low channel 2402MHz

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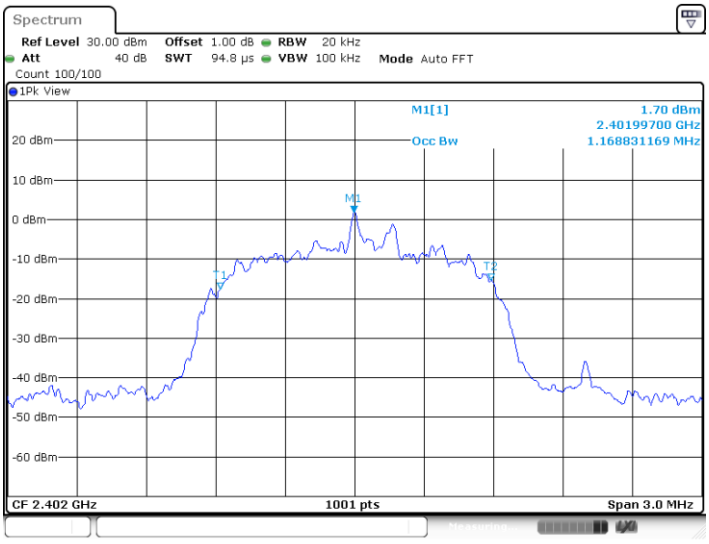


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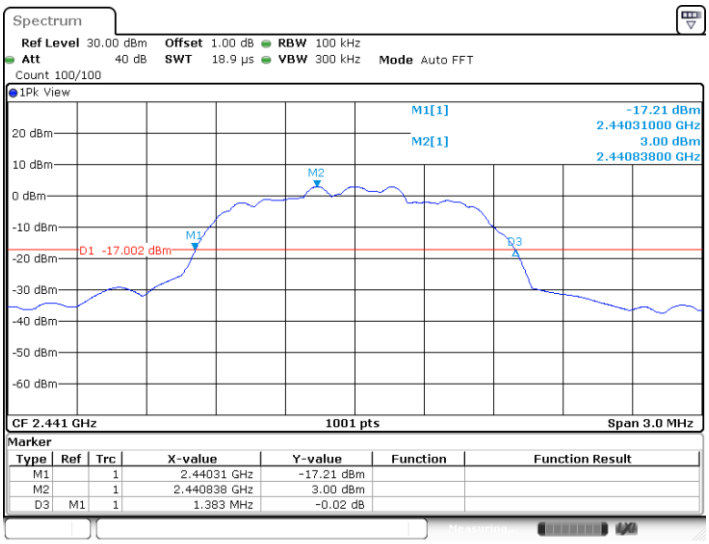
Middle channel 2441MHz

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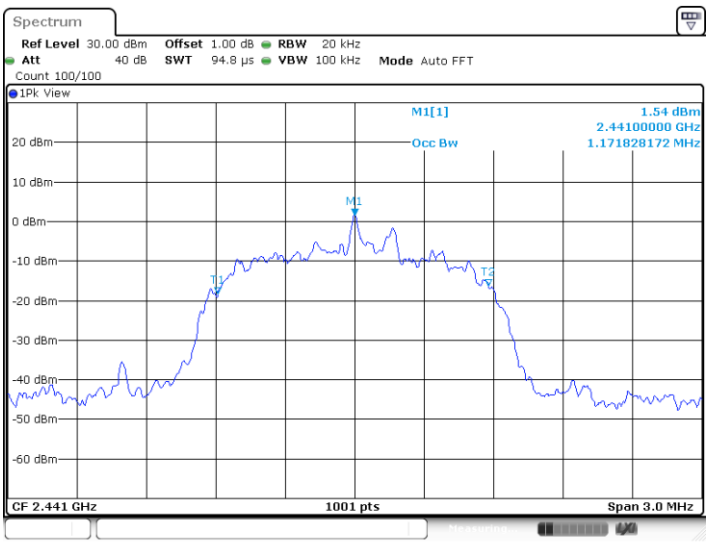


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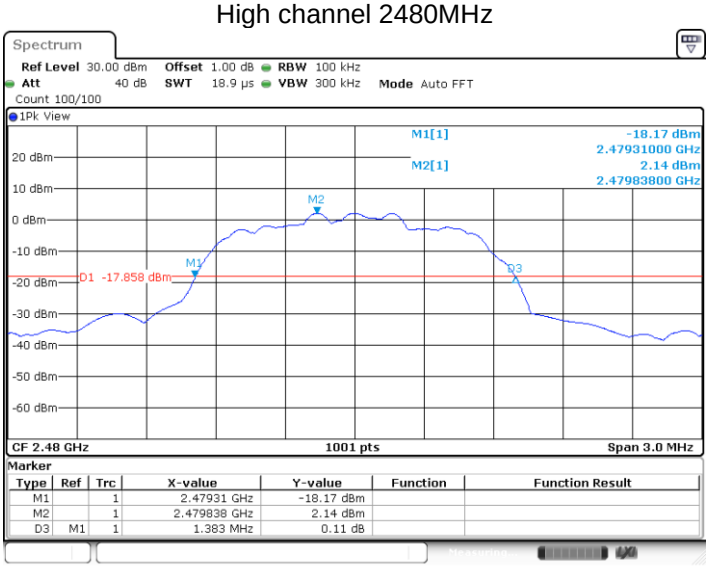
High channel 2480MHz

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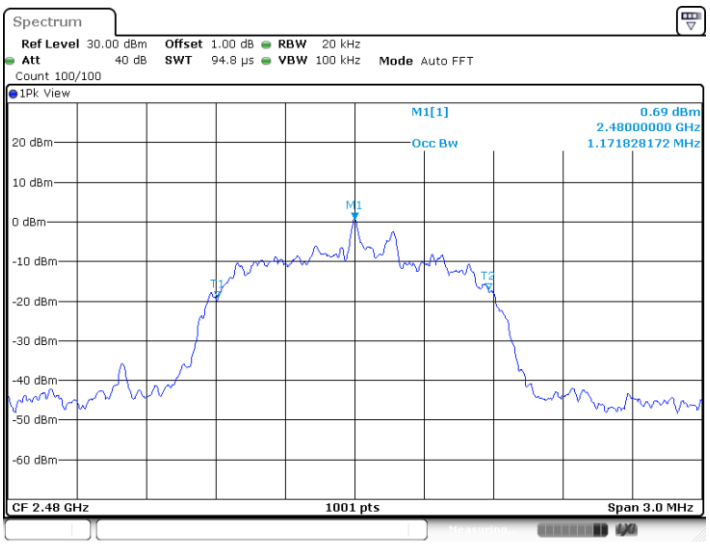


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## 9.3 Carrier Frequency Separation

**Test Method**

1. Use the following spectrum analyzer settings:
   Span = wide enough to capture the peaks of two adjacent channels, RBW ≥ 1% of the span, VBW) ≥RBW, Sweep = auto, Detector function = peak
2. By using the Max-Hold function record the separation of two adjacent channels.
3. Measure the frequency difference of these two adjacent channels by spectrum analyzer marker function.
4. Repeat above procedures until all frequencies measured were complete.

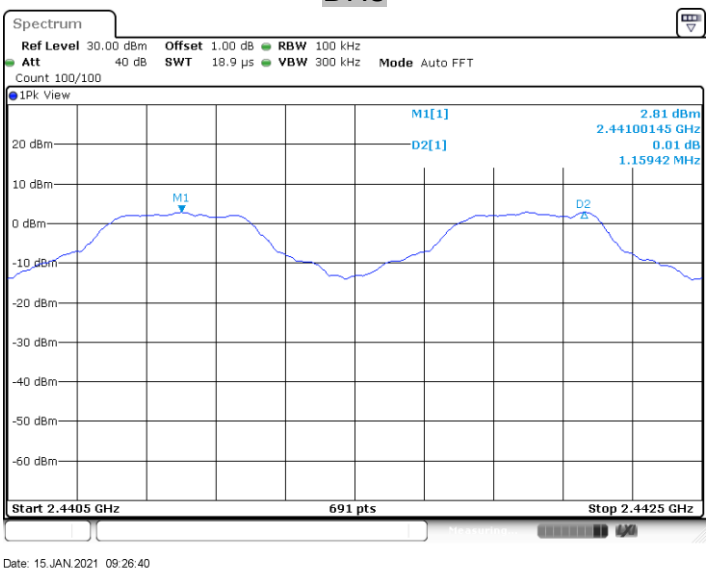
**Limit**

| Limit<br>kHz |
|---|
| ⩾25KHz or 2/3 of the 20 dB bandwidth which is greater |

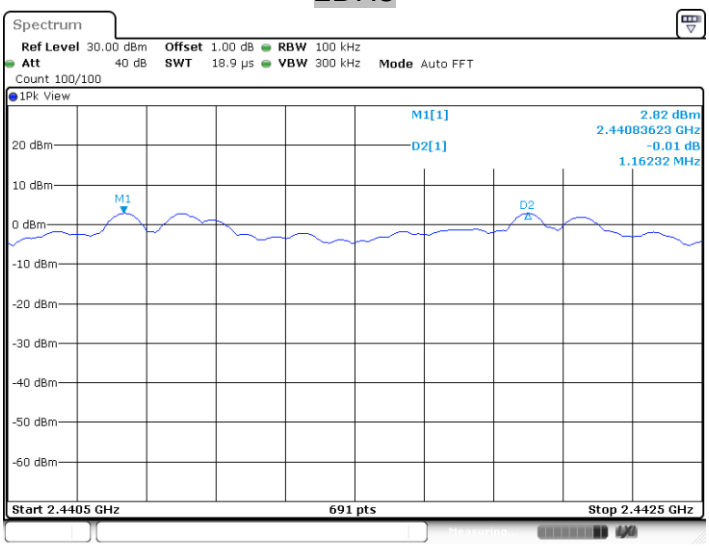
## Carrier Frequency Separation

| TestMode | Channel | Result[MHz] | Limit[MHz] | Verdict |
|---|---|---|---|---|
| DH5 | Hop | 1.159 | >=0.740 | PASS |
| 2DH5 | Hop | 1.162 | >=0.904 | PASS |
| 3DH5 | Hop | 1.159 | >=0.908 | PASS |

DH5

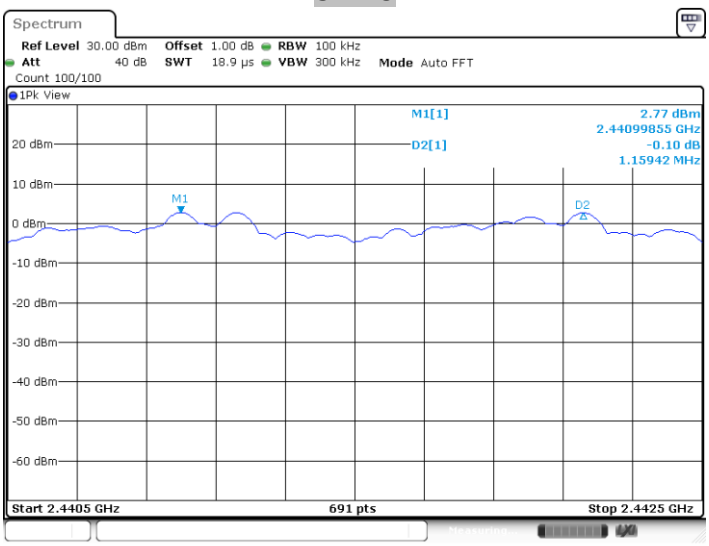


## 2DH5




Date: 15.JAN.2021 09:30:52

## 3DH5




Date: 15.JAN.2021 09:32:06

## 9.4 Number of hopping frequencies

**Test Method**

1. Use the following spectrum analyzer settings:
   Span = wide enough to capture the peaks of two adjacent channels, RBW ≥ 1% of the span, VBW) ≥RBW, Sweep = auto, Detector function = peak
2. Set the spectrum analyzer on Max-Hold Mode, and then keep the EUT in hopping mode.
3. Record all the signals from each channel until each one has been recorded.
4. Repeat above procedures until all frequencies measured were complete.

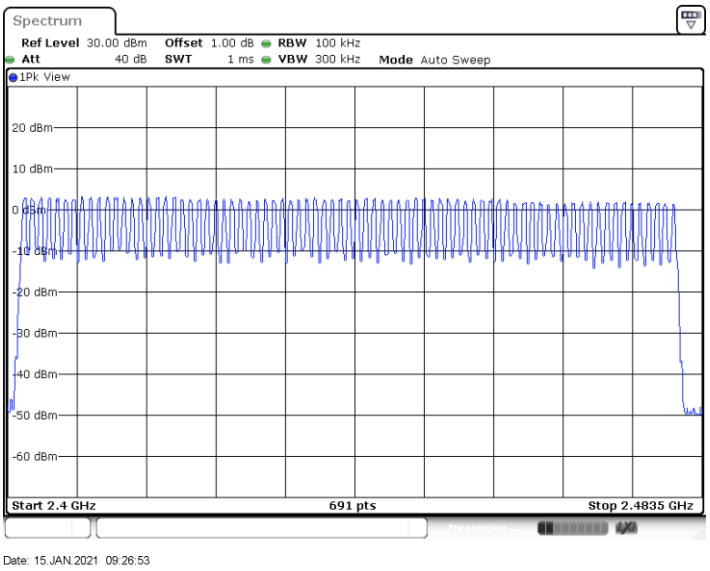
**Limit**

| Limit number |
|---|
| ⩾15 |

## Number of hopping frequencies

Test result: The measurement was performed with the typical configuration (normal hopping status), and the total hopping channels is constant for the all modulation mode according with the Bluetooth Core Specification. Here GFSK modulation mode was used to show compliance.

| Number of hopping frequencies | Result |
|---|---|
| 79 | Pass |



## 9.5 Dwell Time

**Test Method**

1. Connect EUT antenna terminal to the spectrum analyzer with a low loss cable. Equipment mode: Spectrum analyzer
2. RBW: 1MHz; VBW: 1MHz; SPAN: Zero Span
3. Adjust the center frequency of spectrum analyzer on any frequency be measured.
4. Measure the Dwell Time by spectrum analyzer Marker function.
5. Repeat above procedures until all frequencies measured were complete.

**Limit**

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

## Dwell Time

### Dwell time

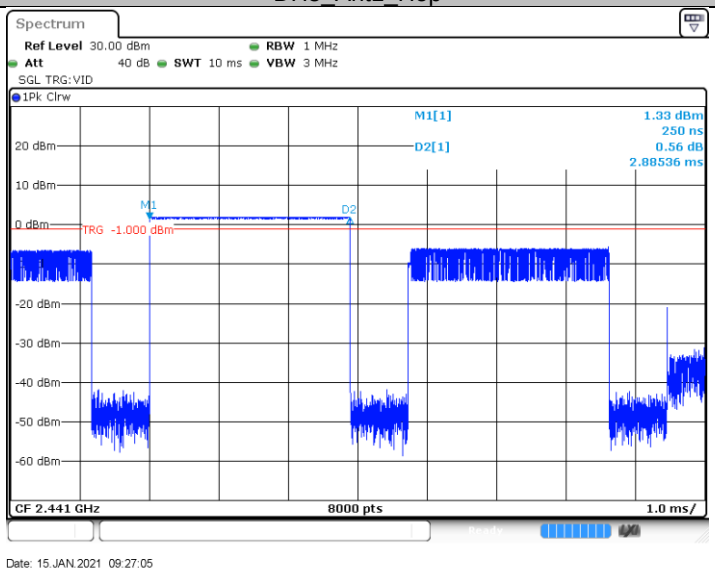
The maximum dwell time shall be 0.4 s.

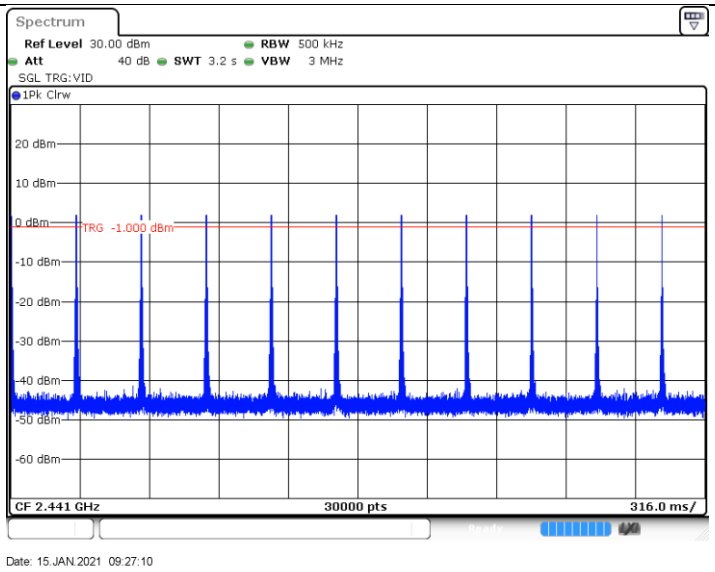
The Dwell Time = Burst Width * Total Hops. The detailed calculations are showed as follows:
The duration for dwell time calculation: 0.4 [s] * hopping number = 0.4 [s] * 79 [ch] = 31.6 [s*ch];

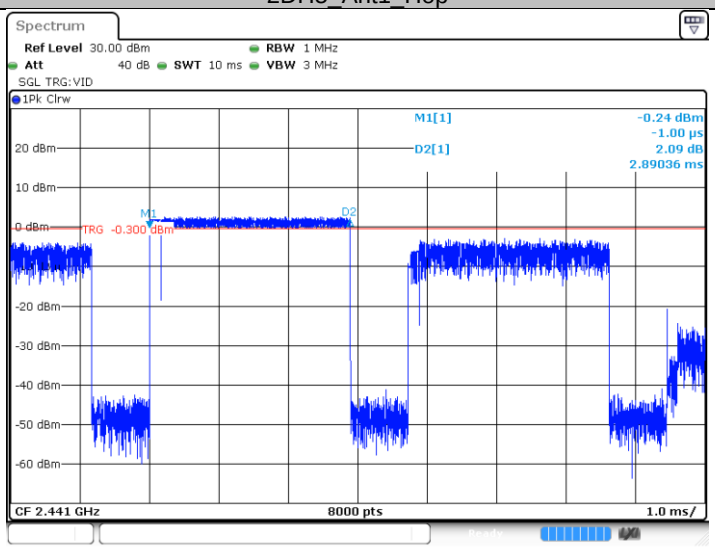
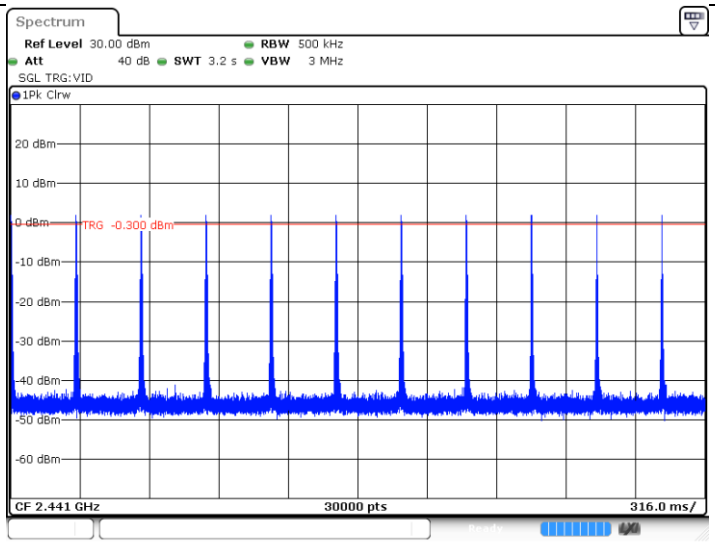
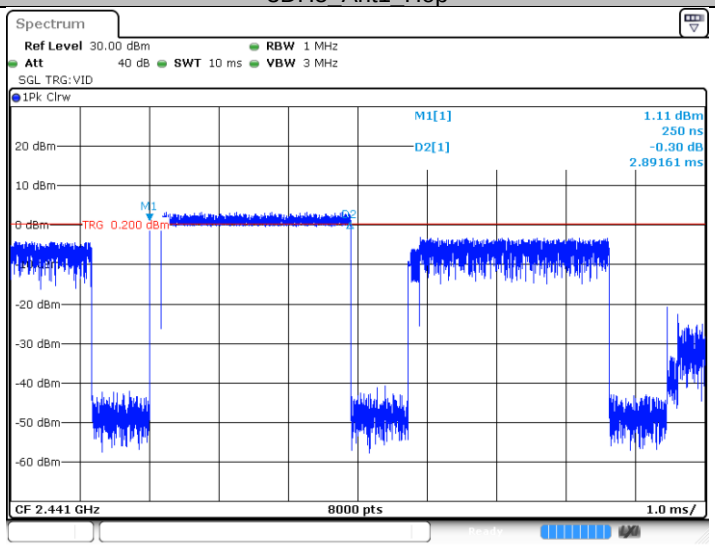
Test Result

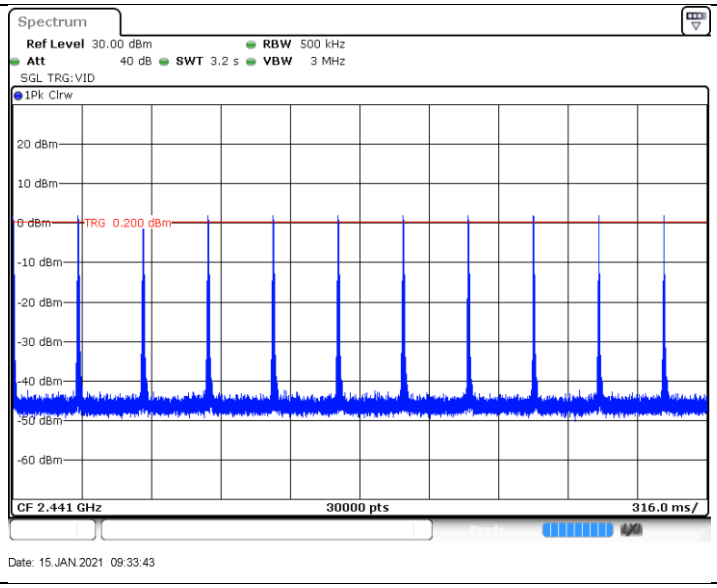
| TestMode | Channel | BurstWidth (ms) | TotalHops | Result(s) | Limit(s) | Verdict |
|---|---|---|---|---|---|---|
| DH5 | Hop | 2.89 | 110 | 0.317 | <=0.4 | PASS |
| 2DH5 | Hop | 2.89 | 110 | 0.318 | <=0.4 | PASS |
| 3DH5 | Hop | 2.89 | 110 | 0.318 | <=0.4 | PASS |

DH5_Ant1_Hop



| 2DH5_Ant1_Hop |
|---|
|  |
|  |
| 3DH5_Ant1_Hop |
|  |


Spectrum
Ref Level 30.00 dBm
RBW 500 kHz
Att 40 dB SWT 3.2 s VBW 3 MHz
SGL TRG:VID
1Pk Clrw
20 dBm
10 dBm
0 dBm
TRG 0.200 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
CF 2.441 GHz
30000 pts
316.0 ms/
Date: 15.JAN.2021 09:33:43

## 9.6 Spurious RF conducted emissions

**Test Method**

1. Use the following spectrum analyzer settings:
   Span = wide enough to capture the peak level of the in-band emission and all spurious emissions (e.g., harmonics) from the lowest frequency generated in the EUT up through the 10$^{th}$ harmonic. Typically, several plots are required to cover this entire span.
   RBW = 100 kHz, VBW≥RBW, Sweep = auto, Detector function = peak, Trace = max hold
2. Allow the trace to stabilize. Set the marker on the peak of any spurious emission recorded.
3. The level displayed must comply with the limit specified in this Section. Submit these plots.
4. Repeat above procedures until all frequencies measured were complete.

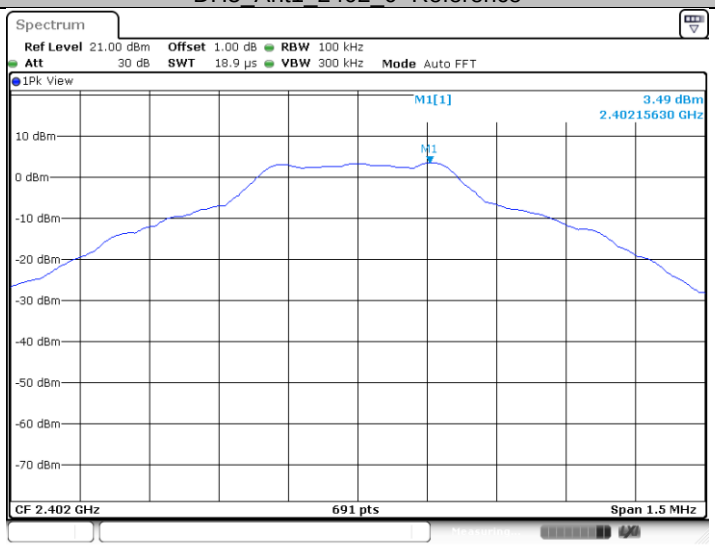
**Limit**

| Frequency Range MHz | Limit (dBc) |
|---|---|
| 30-25000 | -20 |

## Spurious RF conducted emissions

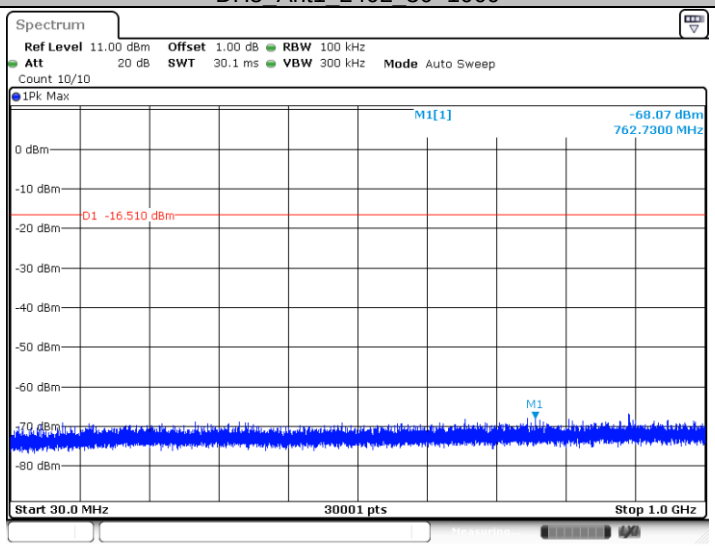
| TestMode | Antenna | Channel (MHz) | FreqRange(MHz) | RefLevel | Result(dBm) | Limit(dBm) | Verdict |
|---|---|---|---|---|---|---|---|
| DH5 | Ant1 | 2402 | Reference | 3.49(dBm) | 3.49 | --- | PASS |
| | | | 30~1000 | 30~1000(MHz) | -68.07 | <=-16.51 | PASS |
| | | | 1000~26500 | 1000~26500(MHz) | -30 | <=-16.51 | PASS |
| | | 2441 | Reference | 3.08(dBm) | 3.08 | --- | PASS |
| | | | 30~1000 | 30~1000(MHz) | -67.76 | <=-16.92 | PASS |
| | | | 1000~26500 | 1000~26500(MHz) | -32.76 | <=-16.92 | PASS |
| | | 2480 | Reference | 2.16(dBm) | 2.16 | --- | PASS |
| | | | 30~1000 | 30~1000(MHz) | -67.46 | <=-17.84 | PASS |
| | | | 1000~26500 | 1000~26500(MHz) | -36.71 | <=-17.84 | PASS |
| 2DH5 | Ant1 | 2402 | Reference | 3.15(dBm) | 3.15 | --- | PASS |
| | | | 30~1000 | 30~1000(MHz) | -67.55 | <=-16.85 | PASS |
| | | | 1000~26500 | 1000~26500(MHz) | -33.44 | <=-16.85 | PASS |
| | | 2441 | Reference | 3.20(dBm) | 3.20 | --- | PASS |
| | | | 30~1000 | 30~1000(MHz) | -67.62 | <=-16.8 | PASS |
| | | | 1000~26500 | 1000~26500(MHz) | -34.89 | <=-16.8 | PASS |
| | | 2480 | Reference | 2.22(dBm) | 2.22 | --- | PASS |
| | | | 30~1000 | 30~1000(MHz) | -67.1 | <=-17.78 | PASS |
| | | | 1000~26500 | 1000~26500(MHz) | -39.41 | <=-17.78 | PASS |
| 3DH5 | Ant1 | 2402 | Reference | 3.33(dBm) | 3.33 | --- | PASS |
| | | | 30~1000 | 30~1000(MHz) | -68.77 | <=-16.67 | PASS |
| | | | 1000~26500 | 1000~26500(MHz) | -32.23 | <=-16.67 | PASS |
| | | 2441 | Reference | 2.99(dBm) | 2.99 | --- | PASS |
| | | | 30~1000 | 30~1000(MHz) | -68.34 | <=-17.01 | PASS |
| | | | 1000~26500 | 1000~26500(MHz) | -36.73 | <=-17.01 | PASS |
| | | 2480 | Reference | 2.05(dBm) | 2.05 | --- | PASS |
| | | | 30~1000 | 30~1000(MHz) | -68.12 | <=-17.95 | PASS |
| | | | 1000~26500 | 1000~26500(MHz) | -40 | <=-17.95 | PASS |

DH5_Ant1_2402_0~Reference



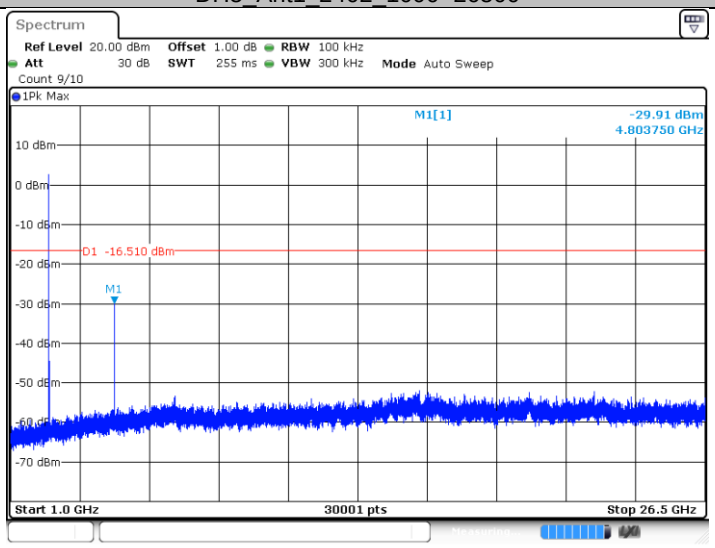

Date: 15.JAN.2021 09:10:39

DH5_Ant1_2402_30~1000



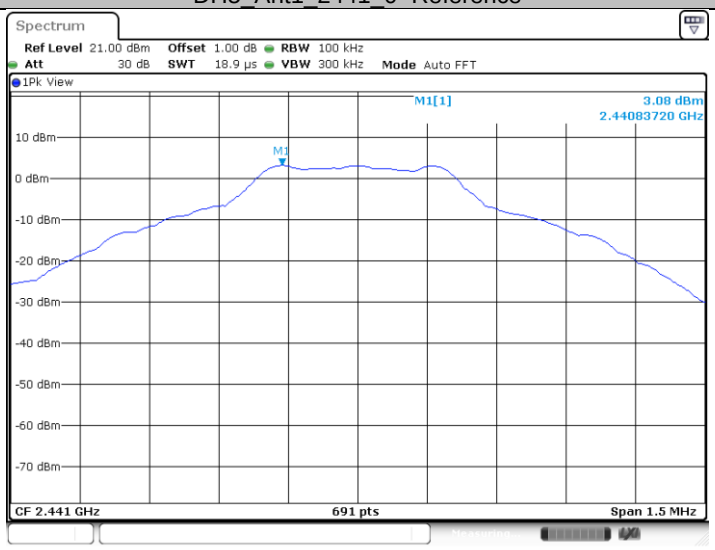

Date: 15.JAN.2021 09:10:45

DH5_Ant1_2402_1000~26500

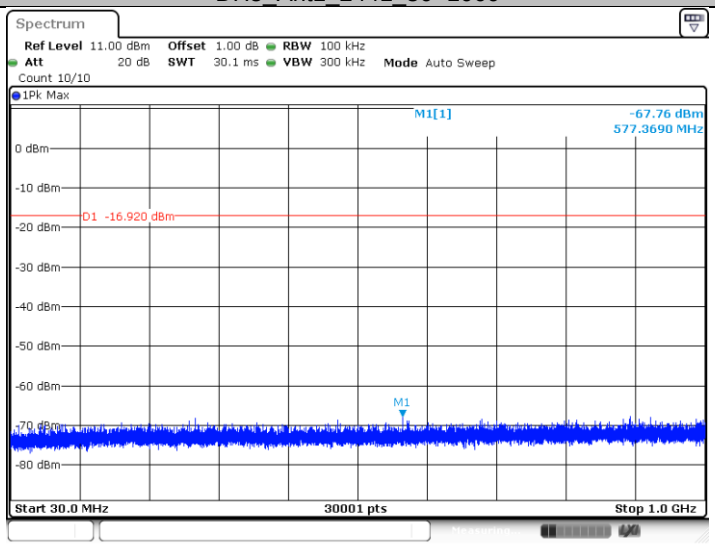



Date: 15.JAN.2021 09:10:53

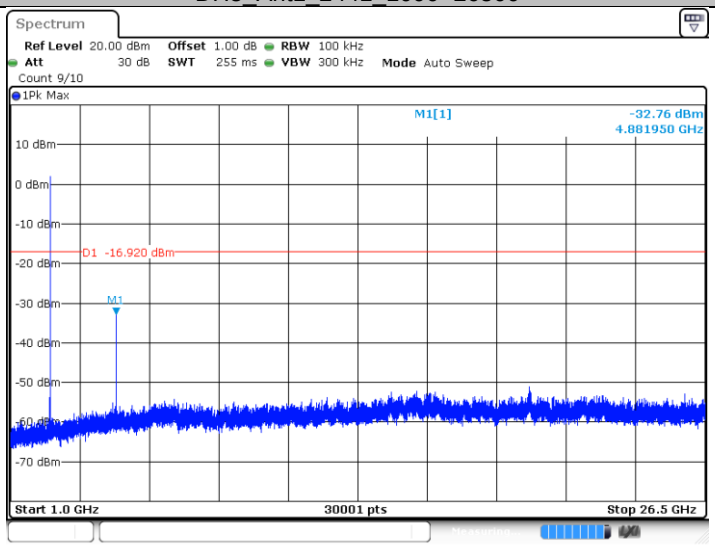
DH5_Ant1_2441_0~Reference



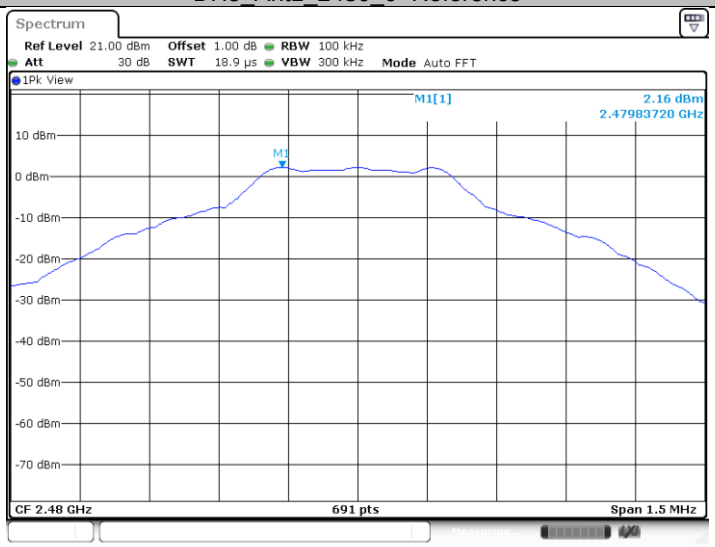

DH5_Ant1_2441_30~1000



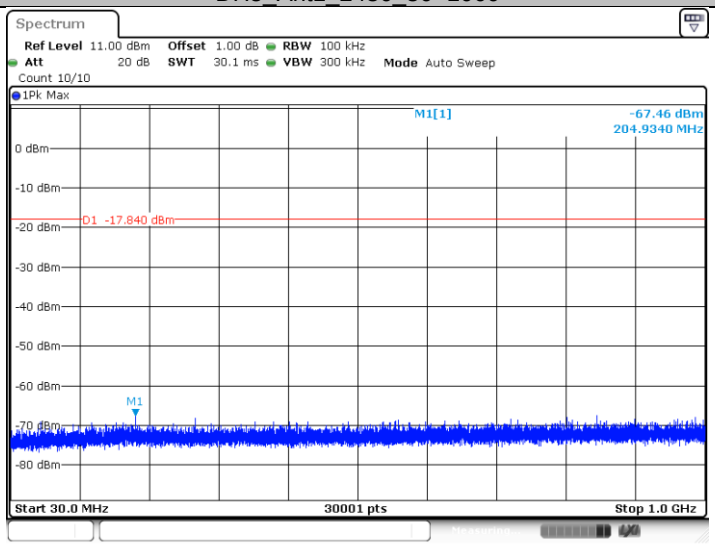

DH5_Ant1_2441_1000~26500



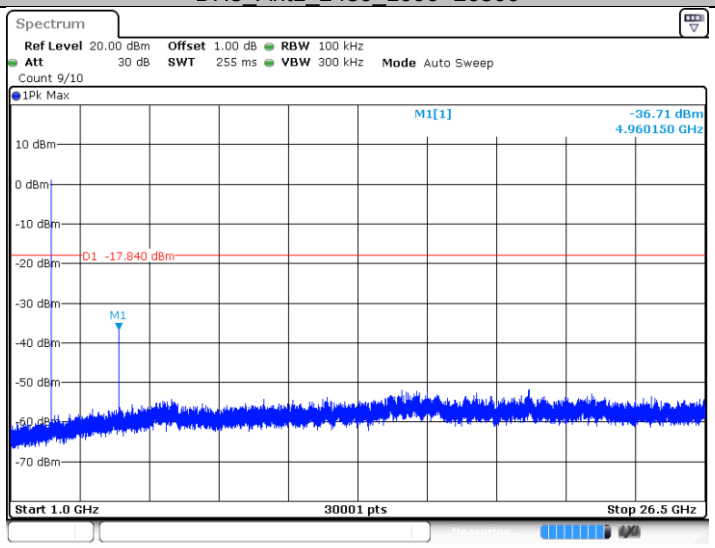
DH5_Ant1_2480_0~Reference



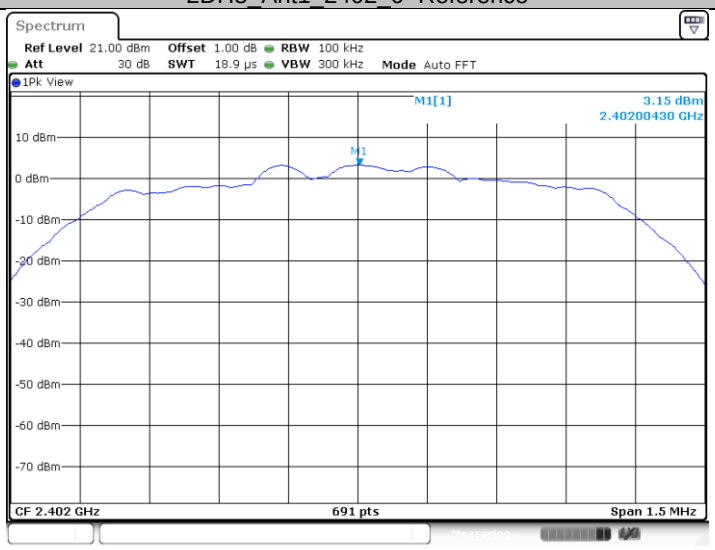

DH5_Ant1_2480_30~1000



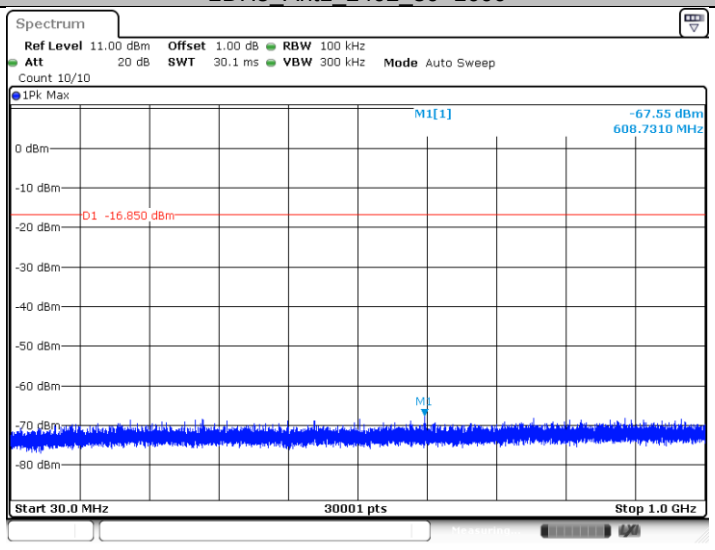

DH5_Ant1_2480_1000~26500



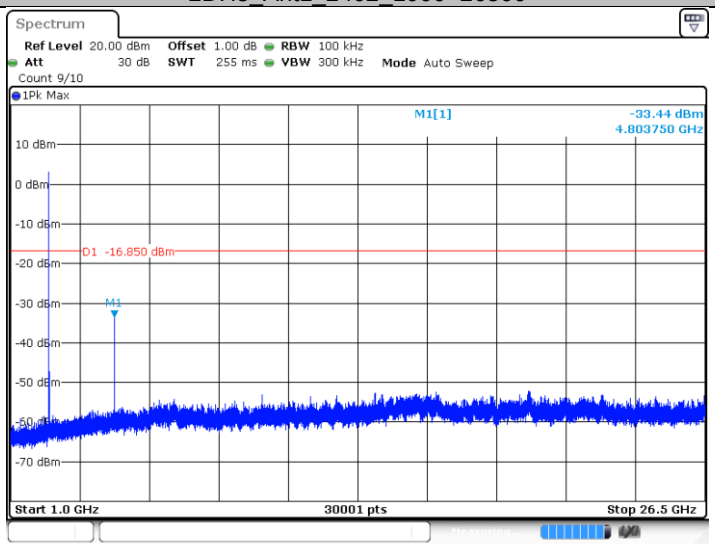
2DH5_Ant1_2402_0~Reference



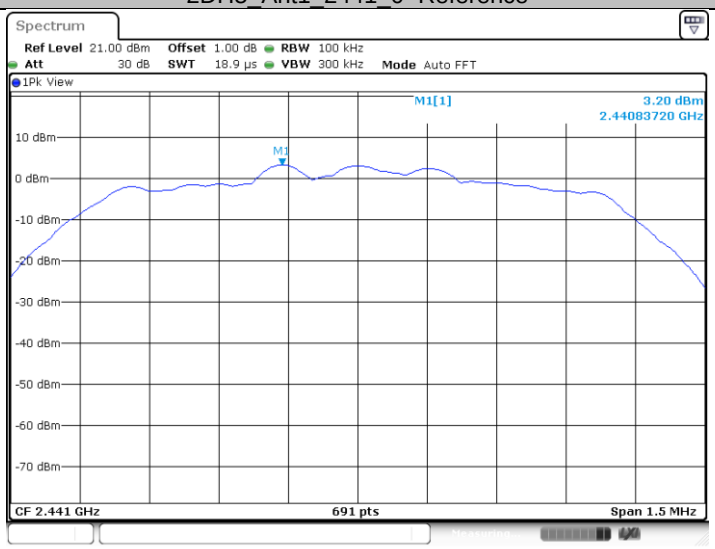

2DH5_Ant1_2402_30~1000



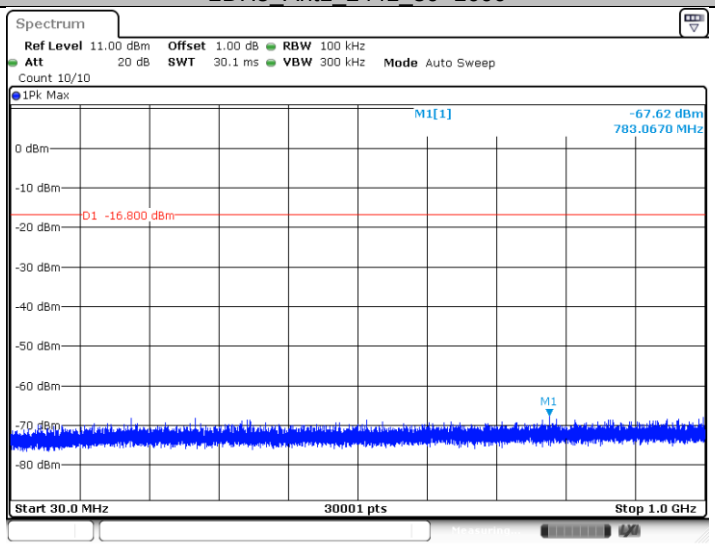

2DH5_Ant1_2402_1000~26500



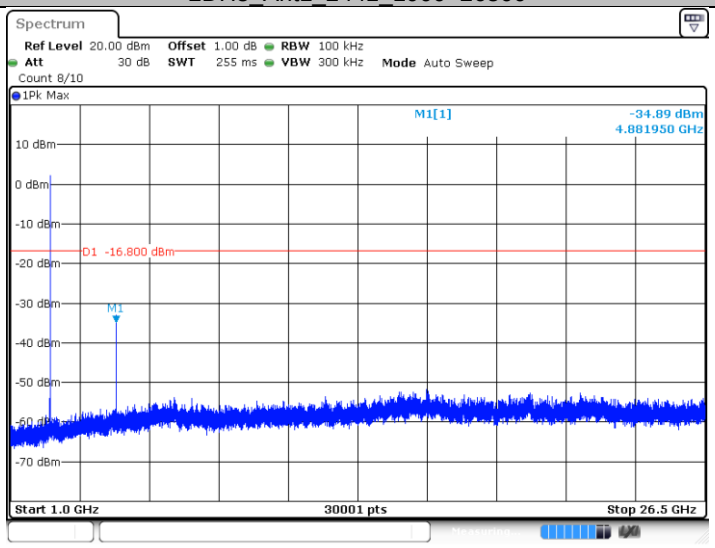
2DH5_Ant1_2441_0~Reference



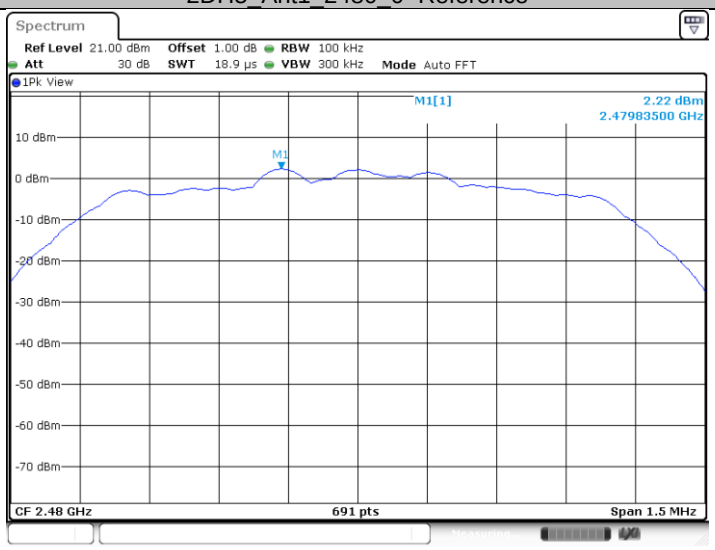

2DH5_Ant1_2441_30~1000



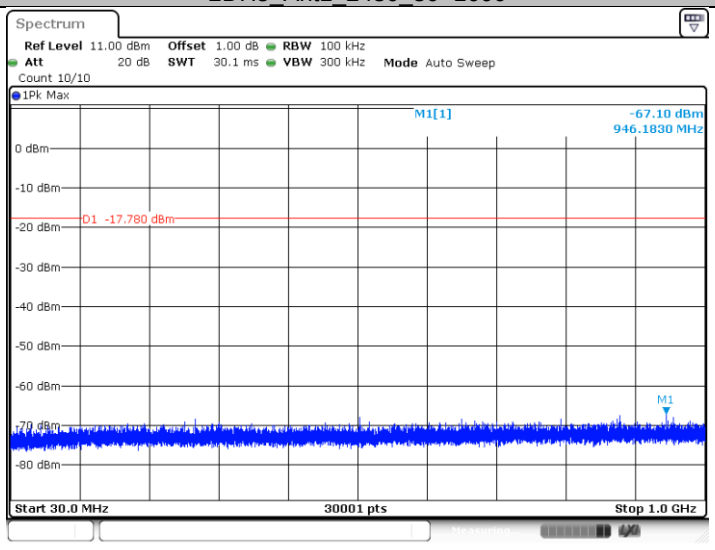

2DH5_Ant1_2441_1000~26500



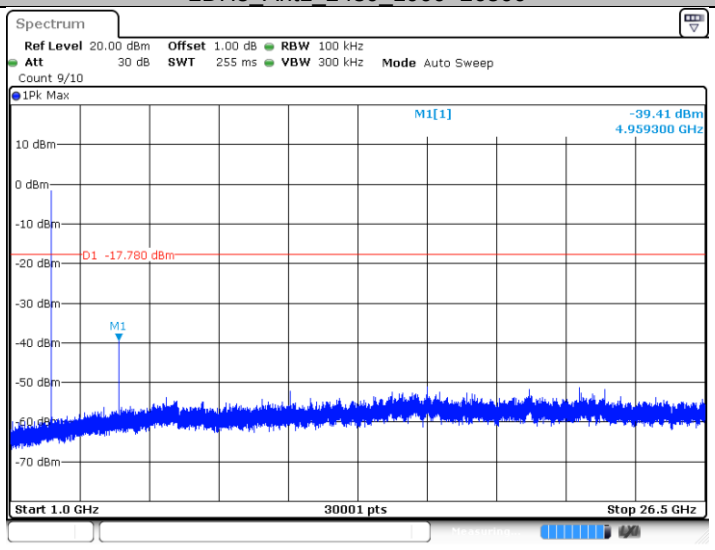
2DH5_Ant1_2480_0~Reference

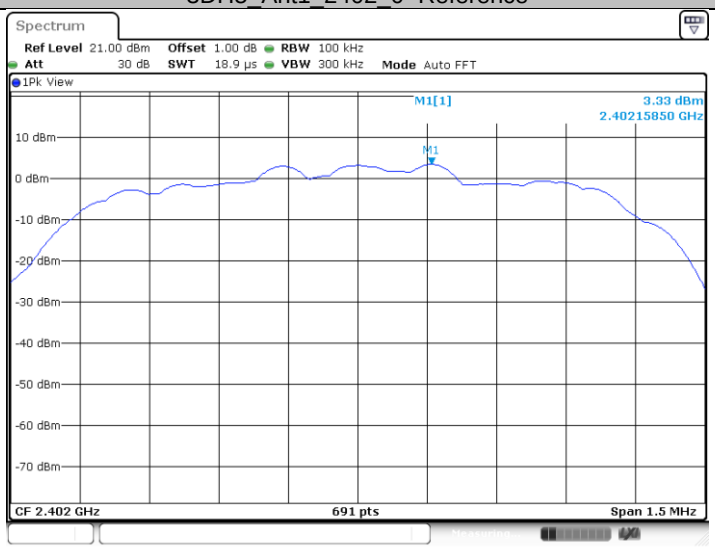
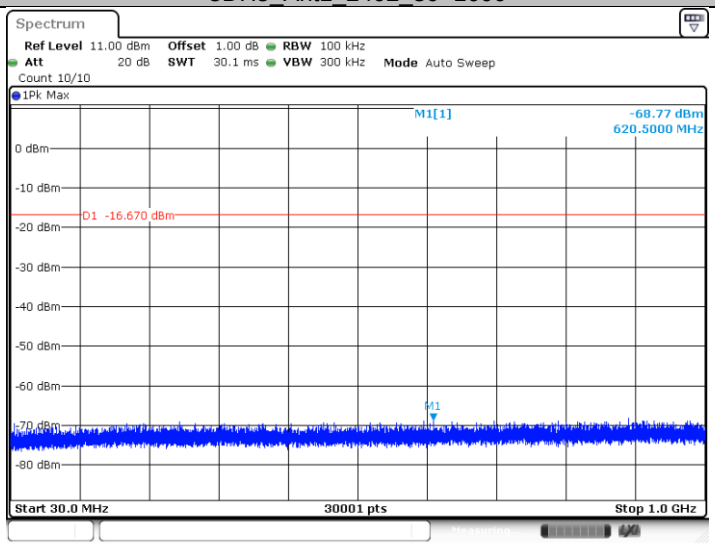
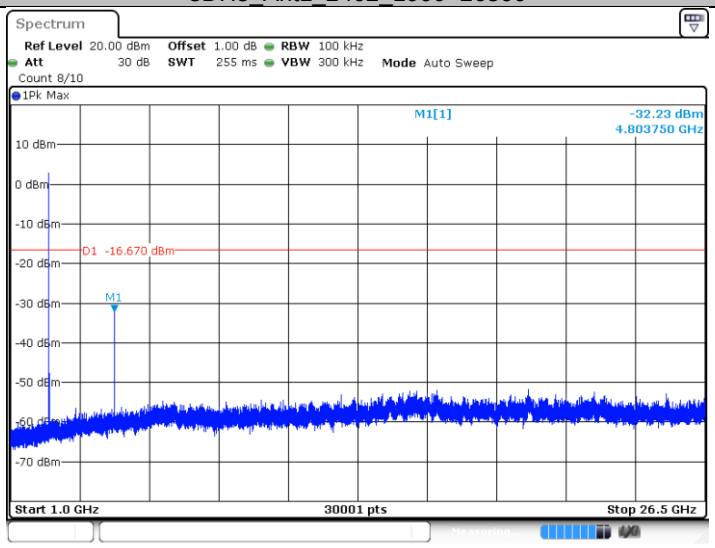


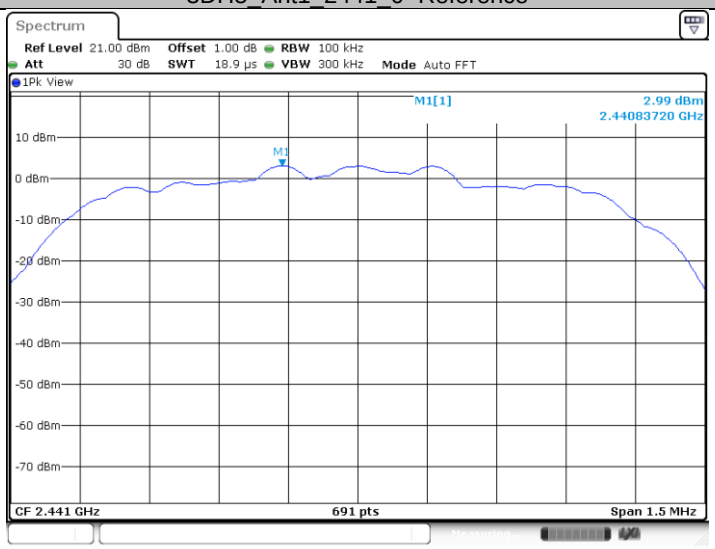
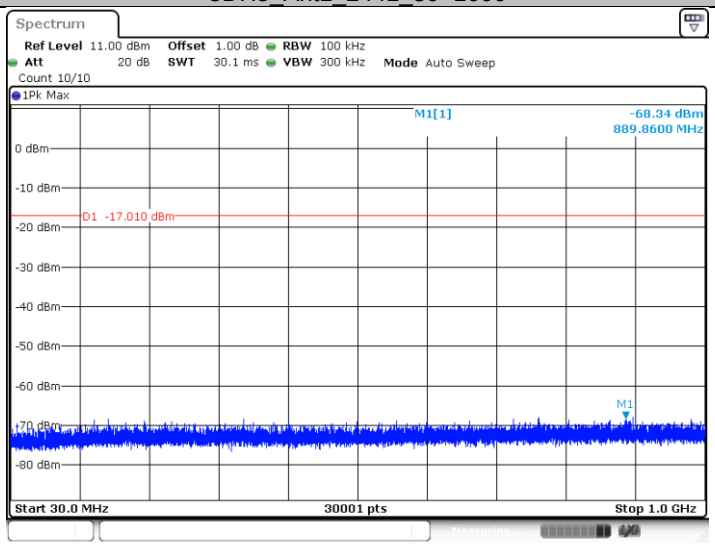
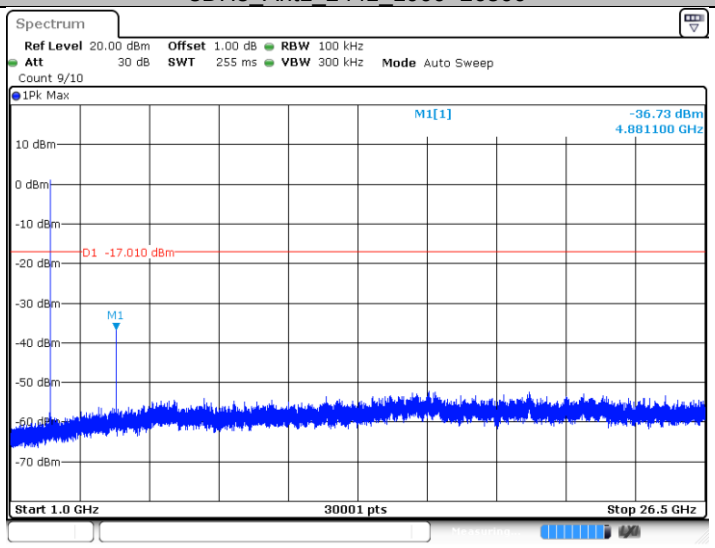

2DH5_Ant1_2480_30~1000



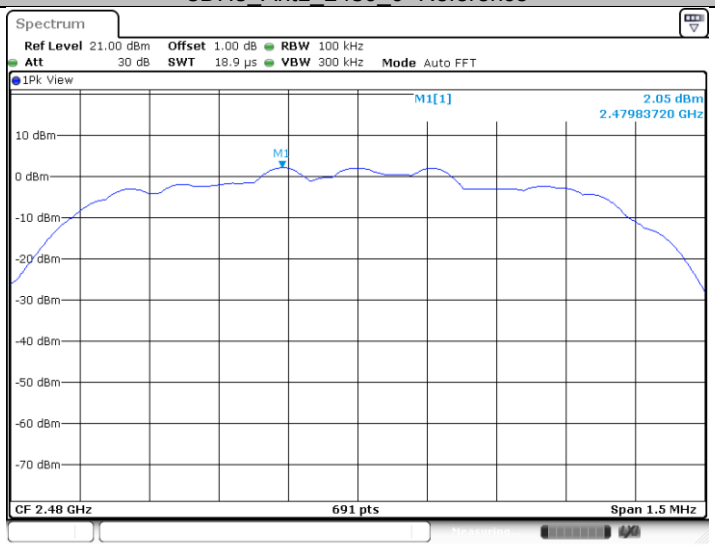

2DH5_Ant1_2480_1000~26500



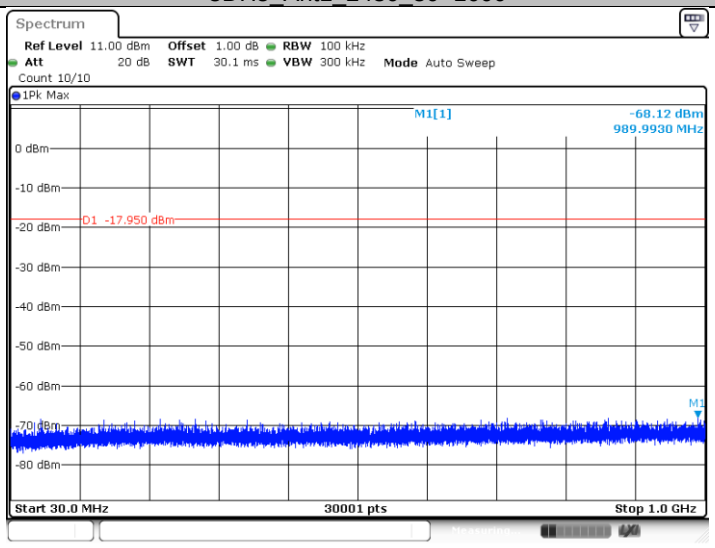
| 3DH5_Ant1_2402_0~Reference |
|---|
|  |
| 3DH5_Ant1_2402_30~1000 |
|  |
| 3DH5_Ant1_2402_1000~26500 |
|  |

| 3DH5_Ant1_2441_0~Reference |
|---|
|  |
| 3DH5_Ant1_2441_30~1000 |
|  |
| 3DH5_Ant1_2441_1000~26500 |
|  |

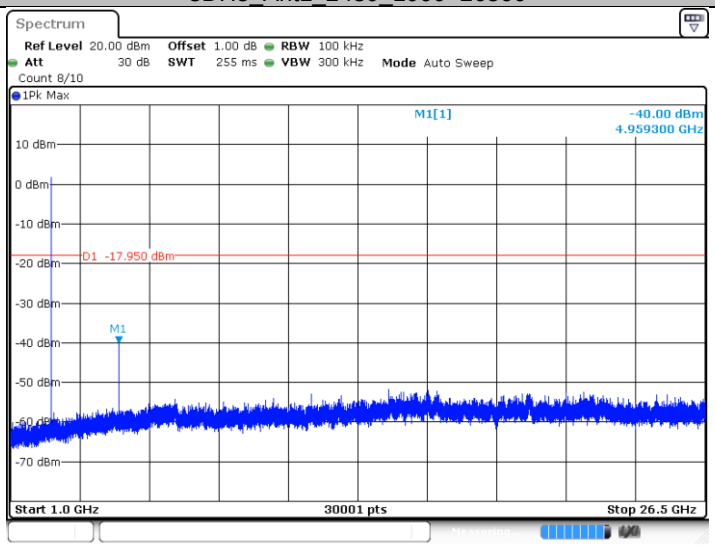
3DH5_Ant1_2480_0~Reference




3DH5_Ant1_2480_30~1000




3DH5_Ant1_2480_1000~26500



## 9.7 Band edge testing

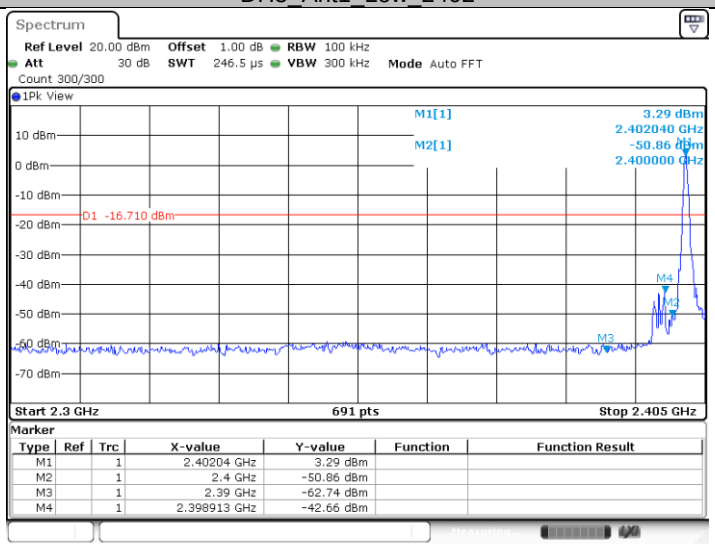
**Test Method**

1 Use the following spectrum analyzer settings:
Span = wide enough to capture the peak level of the in-band emission and all spurious
RBW = 100 kHz, VBW≥RBW, Sweep = auto, Detector function = peak, Trace = max hold
2 Allow the trace to stabilize, use the peak and delta measurement to record the result.
3 The level displayed must comply with the limit specified in this Section. .
4 Repeat the test at the hopping off and hopping on mode, submit all the plots.

**Limit:**

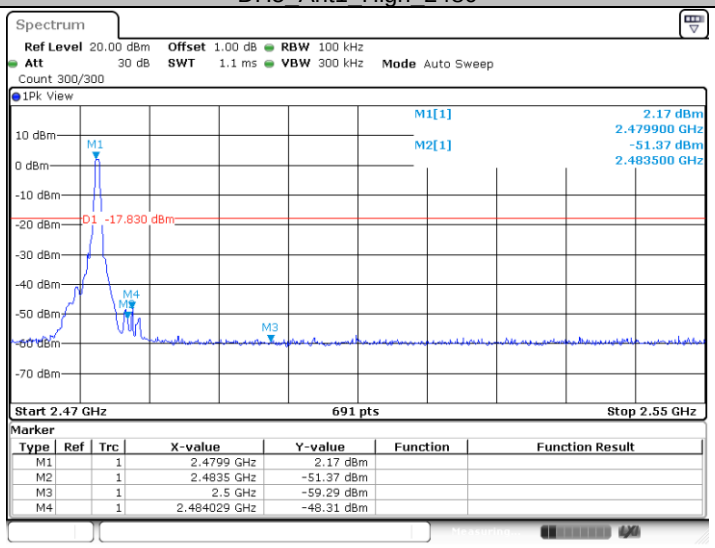
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits.

DH5_Ant1_Low_2402



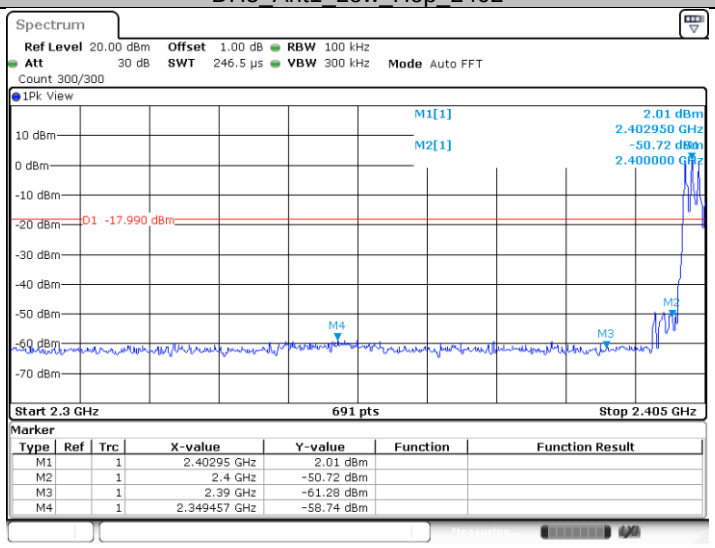

Date: 15.JAN.2021 09:10:33

DH5_Ant1_High_2480



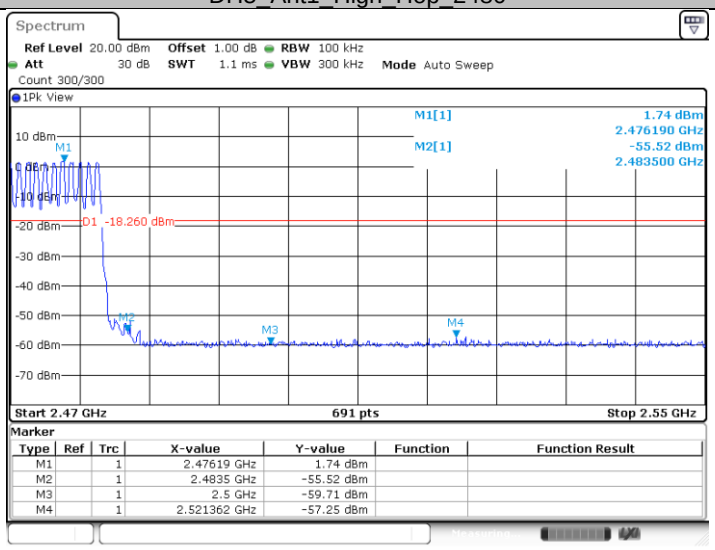

Date: 15.JAN.2021 09:13:49

DH5_Ant1_Low_Hop_2402




Date: 15.JAN.2021 09:26:22

DH5_Ant1_High_Hop_2480

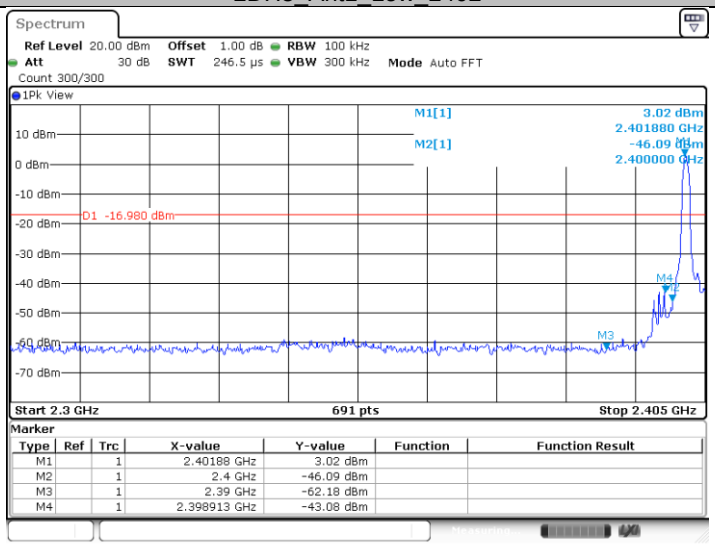



Marker

| Type | Ref | Trc | X-value | Y-value | Function | Function Result |
|---|---|---|---|---|---|---|
| M1 | | 1 | 2.47619 GHz | 1.74 dBm | | |
| M2 | | 1 | 2.4835 GHz | -55.52 dBm | | |
| M3 | | 1 | 2.5 GHz | -59.71 dBm | | |
| M4 | | 1 | 2.521362 GHz | -57.25 dBm | | |

Date: 15.JAN.2021 09:27:28

2DH5_Ant1_Low_2402

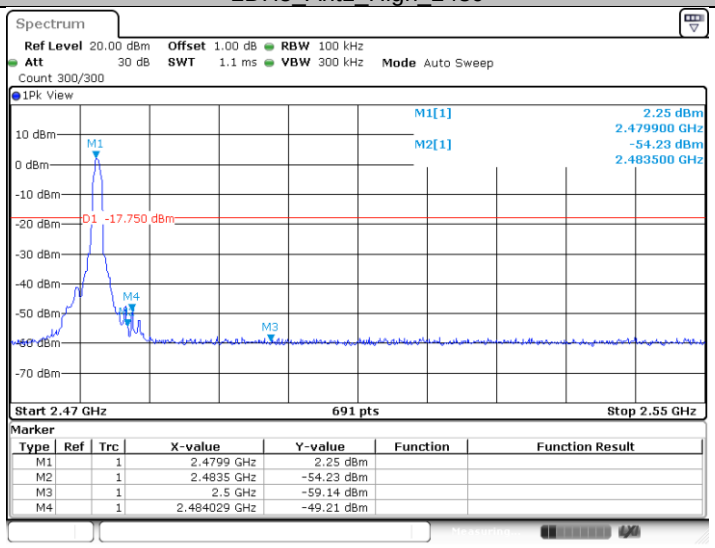



Marker

| Type | Ref | Trc | X-value | Y-value | Function | Function Result |
|---|---|---|---|---|---|---|
| M1 | | 1 | 2.40188 GHz | 3.02 dBm | | |
| M2 | | 1 | 2.4 GHz | -46.09 dBm | | |
| M3 | | 1 | 2.39 GHz | -62.18 dBm | | |
| M4 | | 1 | 2.398913 GHz | -43.08 dBm | | |

Date: 15.JAN.2021 09:16:11

2DH5_Ant1_High_2480

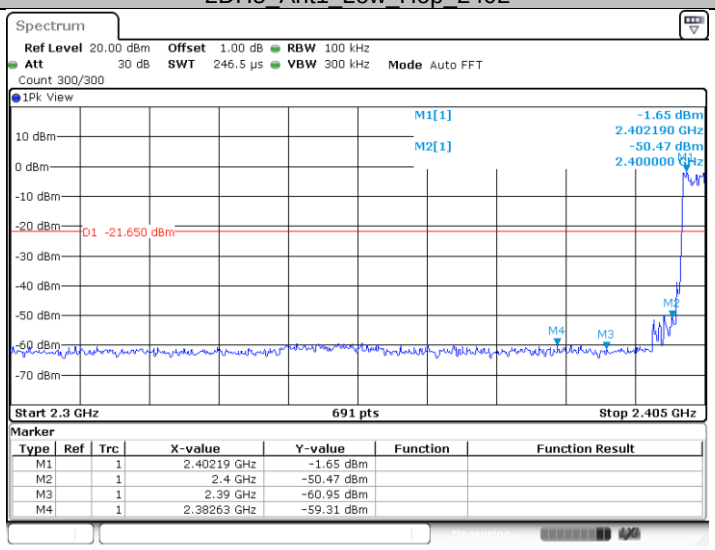



Marker

| Type | Ref | Trc | X-value | Y-value | Function | Function Result |
|---|---|---|---|---|---|---|
| M1 | | 1 | 2.4799 GHz | 2.25 dBm | | |
| M2 | | 1 | 2.4835 GHz | -54.23 dBm | | |
| M3 | | 1 | 2.5 GHz | -59.14 dBm | | |
| M4 | | 1 | 2.484029 GHz | -49.21 dBm | | |

Date: 15.JAN.2021 09:19:36

2DH5_Ant1_Low_Hop_2402

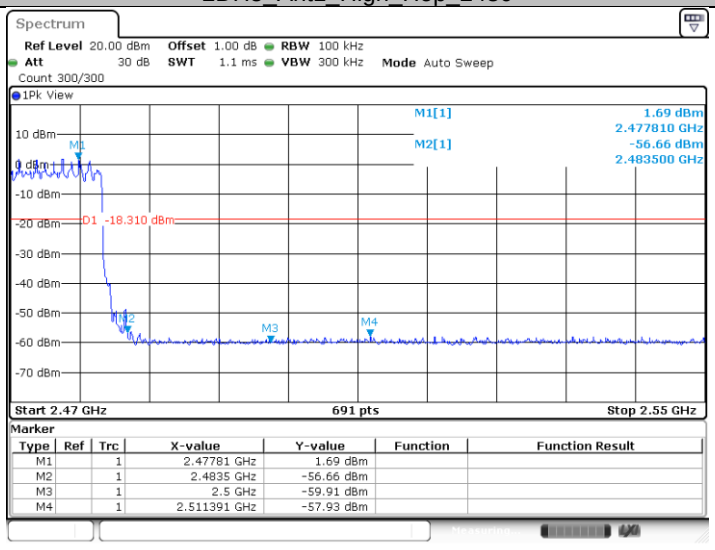



Marker

| Type | Ref | Trc | X-value | Y-value | Function | Function Result |
|---|---|---|---|---|---|---|
| M1 | | 1 | 2.40219 GHz | -1.65 dBm | | |
| M2 | | 1 | 2.4 GHz | -50.47 dBm | | |
| M3 | | 1 | 2.39 GHz | -60.95 dBm | | |
| M4 | | 1 | 2.38263 GHz | -59.31 dBm | | |

Date: 15.JAN.2021 09:28:08

2DH5_Ant1_High_Hop_2480

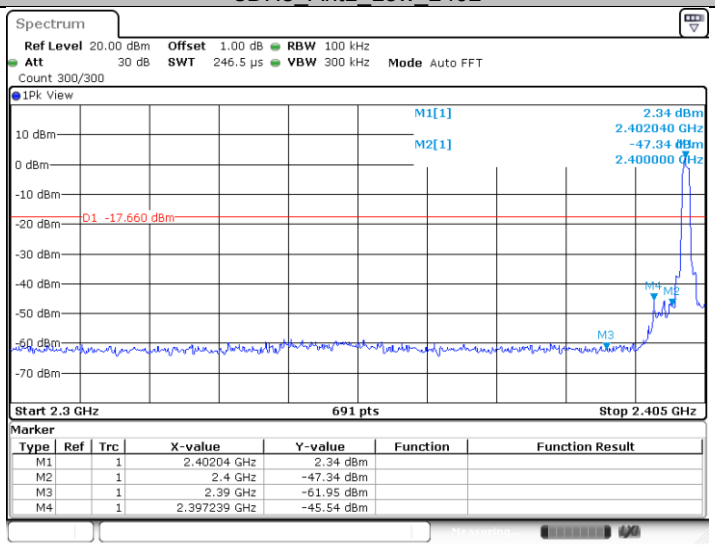



Marker

| Type | Ref | Trc | X-value | Y-value | Function | Function Result |
|---|---|---|---|---|---|---|
| M1 | | 1 | 2.47781 GHz | 1.69 dBm | | |
| M2 | | 1 | 2.4835 GHz | -56.66 dBm | | |
| M3 | | 1 | 2.5 GHz | -59.91 dBm | | |
| M4 | | 1 | 2.511391 GHz | -57.93 dBm | | |

Date: 15.JAN.2021 09:29:57

3DH5_Ant1_Low_2402

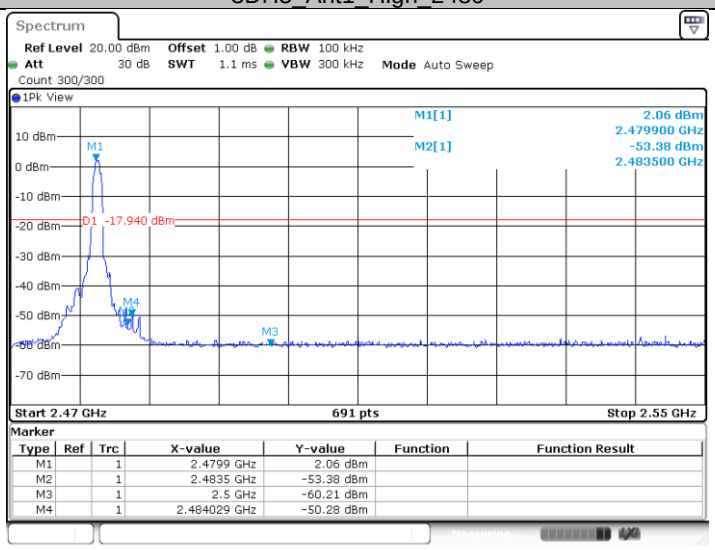



Marker

| Type | Ref | Trc | X-value | Y-value | Function | Function Result |
|---|---|---|---|---|---|---|
| M1 | | 1 | 2.40204 GHz | 2.34 dBm | | |
| M2 | | 1 | 2.4 GHz | -47.34 dBm | | |
| M3 | | 1 | 2.39 GHz | -61.95 dBm | | |
| M4 | | 1 | 2.397239 GHz | -45.54 dBm | | |

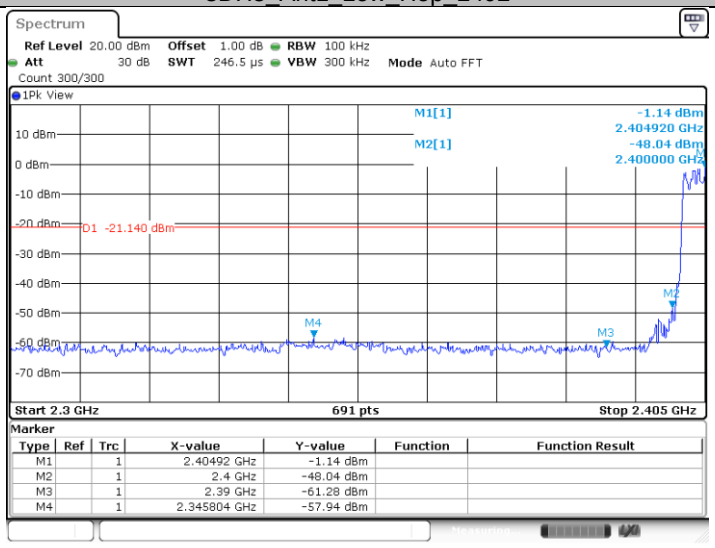
Date: 15.JAN.2021 09:21:40

3DH5_Ant1_High_2480



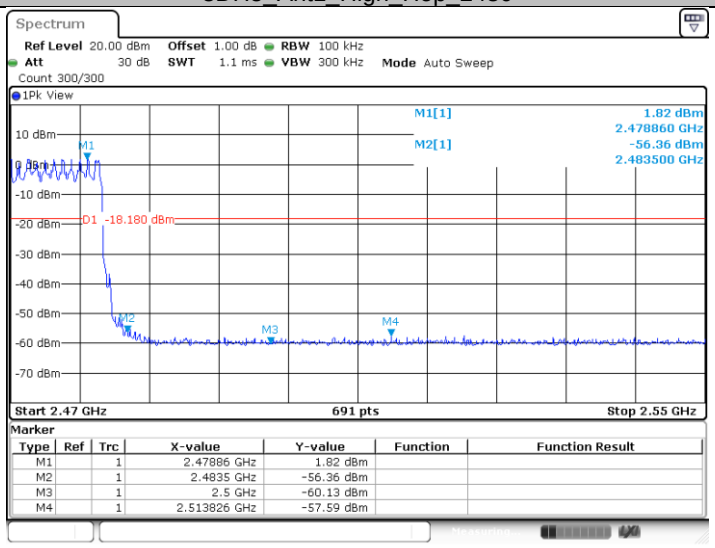

Date: 15.JAN.2021 09:25:37

3DH5_Ant1_Low_Hop_2402




Date: 15.JAN.2021 09:31:45

3DH5_Ant1_High_Hop_2480




Date: 15.JAN.2021 09:34:34

## 9.8 Spurious radiated emissions for transmitter

**Test Method**

1: The EUT was place on a turn table which is 1.5m above ground plane for above 1GHz and 0.8m above ground for below 1GHz at 3 meter chamber room for test. The table was rotated 360 degrees to determine the position of the highest radiation.

2: The EUT was set 3 meters away from the interference – receiving antenna, which was mounted on the top of a variable – height antenna tower.

3: The height of antenna is varied from one meter to four meters above the ground to determine the maximum value of the field strength. Both horizontal and vertical polarizations of the antenna are set to make the measurement.

4: For each suspected emission, the EUT was arranged to its worst case and then the antenna was tuned to heights from 1 meter to 4 meters and the rotatable table was turned from 0 degrees to 360 degrees to find the maximum reading.

5: Use the following spectrum analyzer settings According to C63.10:

For Below 1GHz

Use the following spectrum analyzer settings:

Span = wide enough to capture the peak level of the in-band emission and all spurious RBW = 100 KHz to 120KHz, VBW≥RBW for peak measurement, Sweep = auto, Detector function = peak, Trace = max hold.

For Peak unwanted emissions Above 1GHz:

Span = wide enough to capture the peak level of the in-band emission and all spurious RBW = 1MHz, VBW≥RBW for peak measurement ,Sweep = auto, Detector function = peak, Trace = max hold.

Procedures for average unwanted emissions measurements above 1000 MHz:

Span = wide enough to capture the peak level of the in-band emission and all spurious RBW = 1MHz, VBW=10Hz, Sweep = auto, Detector function = peak, Trace = max hold.

If the dwell time per channel of the hopping signal is less than 100 ms, then the reading obtained with the 10 Hz VBW may be further adjusted by a “duty cycle correction factor”, derived from 20log(dwell time/100 ms), in an effort to demonstrate compliance with the 15.209 limit.

If the emission is pulsed, modify the unit for continuous operation; use the settings shown above, then correct the reading by subtracting the peak-average correct factor, derived from the appropriate the duty cycle calculation.

The setting method can refer to DA00-705.

## Limit

The radio emission outside the operating frequency band 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. Radiated emissions which fall in the restricted bands, as defined in section15.205, must comply with the radiated emission limits specified in section 15.209.
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced 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 that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

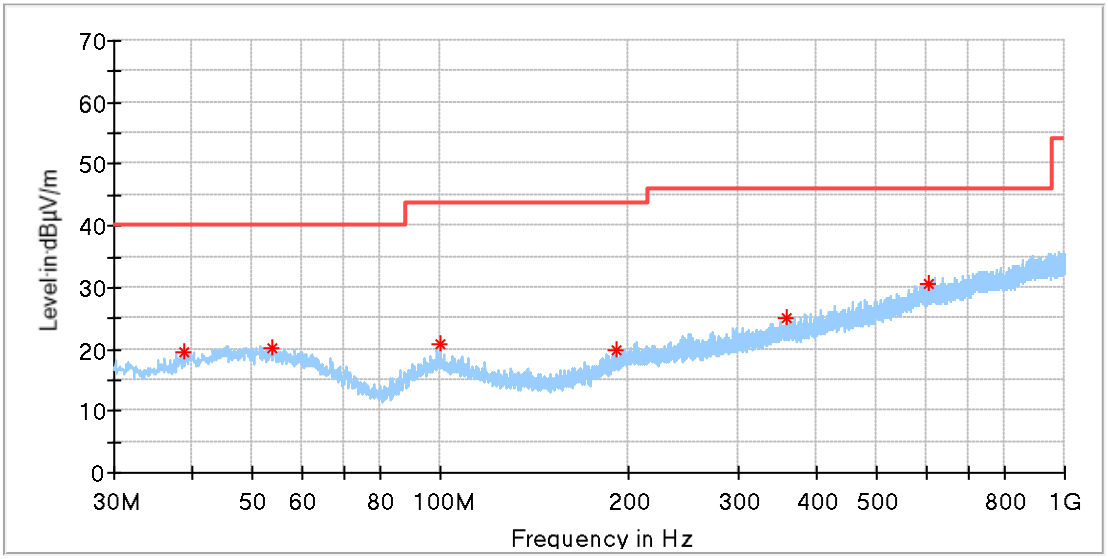
| Frequency MHz | Field Strength uV/m | Field Strength dBµV/m | Detector |
|---|---|---|---|
| 30-88 | 100 | 40 | QP |
| 88-216 | 150 | 43.5 | QP |
| 216-960 | 200 | 46 | QP |
| 960-1000 | 500 | 54 | QP |
| Above 1000 | 500 | 54 | AV |
| Above 1000 | 5000 | 74 | PK |

## Spurious radiated emissions for transmitter

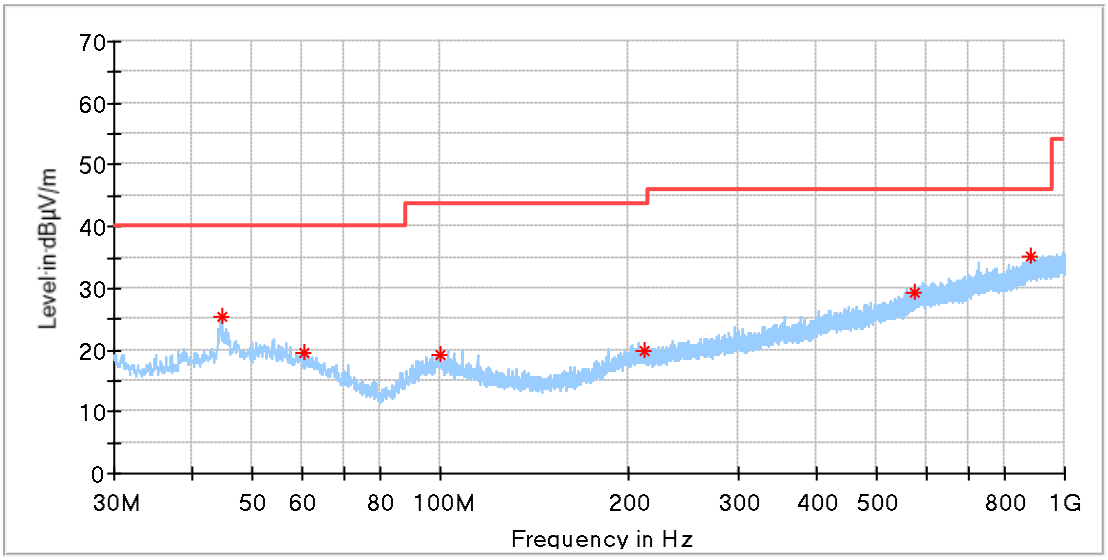
According to C63.10, if the peak (or quasi-peak) measured value complies with the average limit, it is unnecessary to perform an average measurement, so AV emission value did not show in below table if the peak value complies with average limit.
The only worse case (GFSK mode) test result is listed in the report.

### Transmitting spurious emission test result as below:

Below 1G:

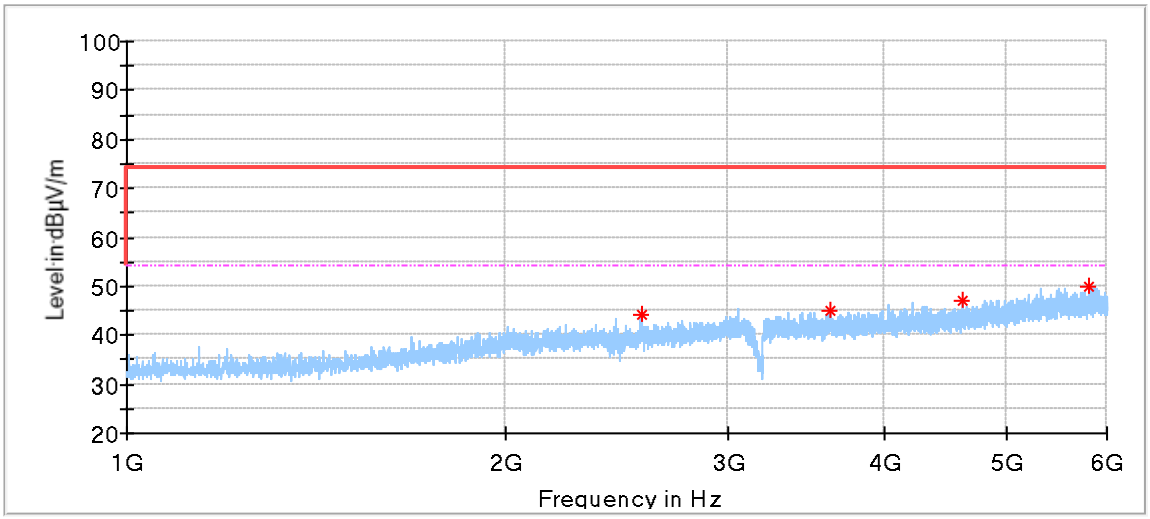



| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 38.851250 | 19.49 | 40.00 | 20.51 | 100.0 | H | 31.0 | 16.21 |
| 53.704375 | 20.12 | 40.00 | 19.88 | 200.0 | H | 192.0 | 17.68 |
| 100.021875 | 20.72 | 40.00 | 19.28 | 100.0 | H | 106.0 | 16.25 |
| 190.959375 | 19.86 | 40.00 | 20.14 | 200.0 | H | 130.0 | 15.61 |
| 358.951250 | 24.94 | 47.00 | 22.06 | 200.0 | H | 175.0 | 20.59 |
| 606.786250 | 30.67 | 47.00 | 16.33 | 200.0 | H | 9.0 | 25.69 |

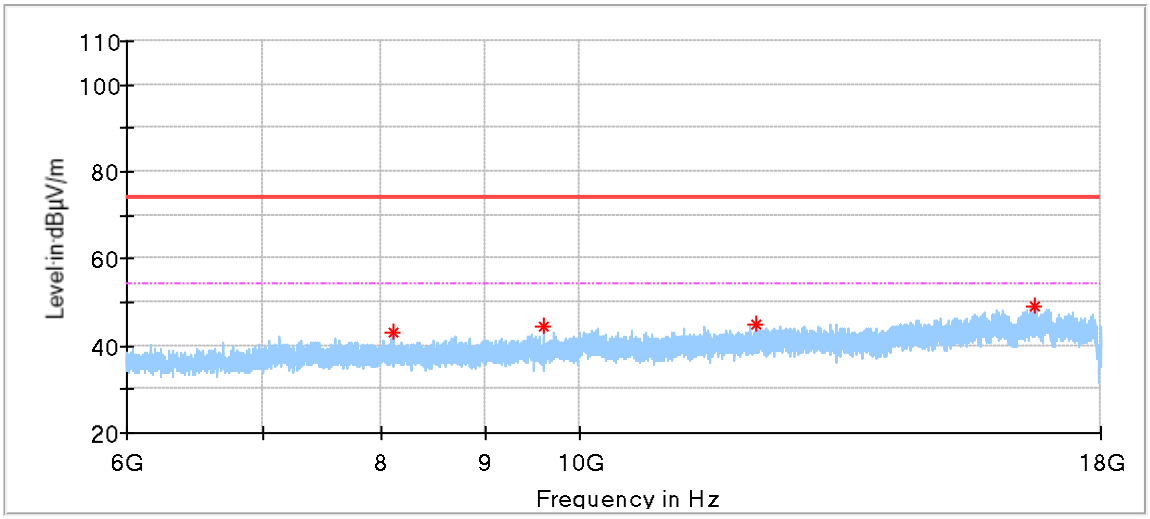



| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 44.792500 | 25.29 | 40.00 | 14.71 | 100.0 | V | 4.0 | 17.66 |
| 60.312500 | 19.63 | 40.00 | 20.37 | 200.0 | V | 146.0 | 16.76 |
| 100.082500 | 19.19 | 40.00 | 20.81 | 100.0 | V | 338.0 | 16.24 |
| 211.450625 | 19.95 | 40.00 | 20.05 | 100.0 | V | 293.0 | 16.60 |
| 576.776875 | 29.16 | 47.00 | 17.84 | 200.0 | V | 356.0 | 24.91 |
| 883.660625 | 35.25 | 47.00 | 11.75 | 200.0 | V | 3.0 | 29.25 |

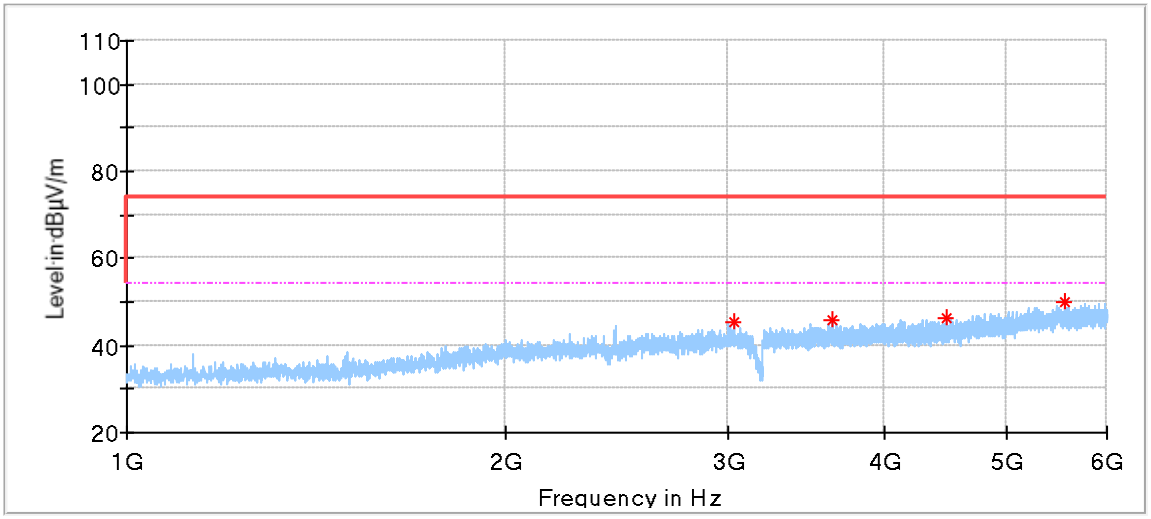
Low channel 2402MHz



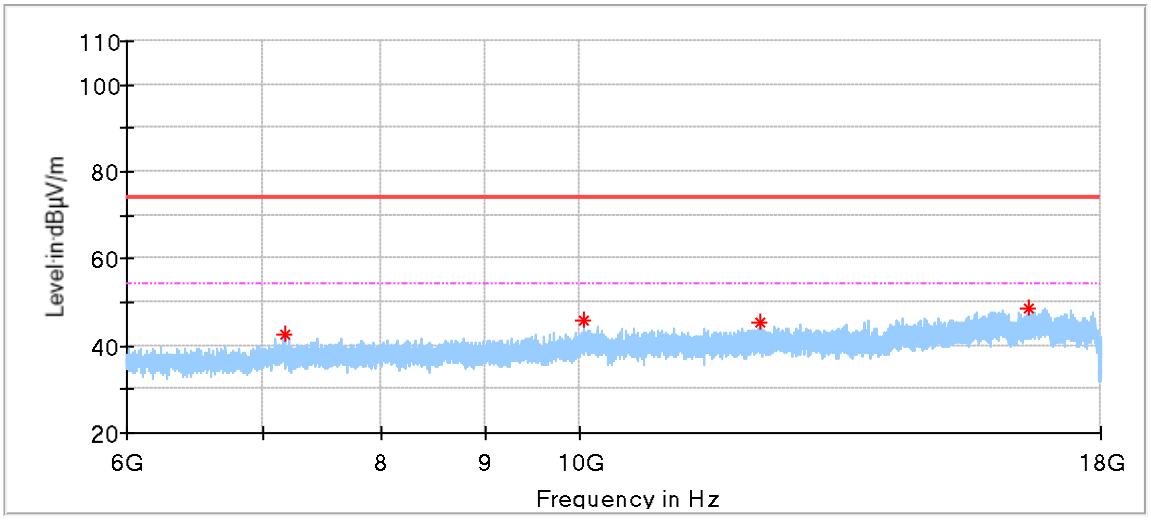

| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 2567.000000 | 44.32 | 74.00 | 29.68 | 100.0 | H | 121.0 | -2.71 |
| 3622.500000 | 45.22 | 74.00 | 28.78 | 100.0 | H | 0.0 | 0.07 |
| 4614.000000 | 47.06 | 74.00 | 26.94 | 100.0 | H | 317.0 | 2.54 |
| 5816.000000 | 49.80 | 74.00 | 24.20 | 100.0 | H | 350.0 | 5.16 |




| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 8104.000000 | 42.90 | 74.00 | 31.10 | 150.0 | H | 188.0 | 6.51 |
| 9612.000000 | 44.64 | 74.00 | 29.36 | 150.0 | H | 72.0 | 7.50 |
| 12195.000000 | 45.07 | 74.00 | 28.93 | 150.0 | H | 211.0 | 8.83 |
| 16710.000000 | 48.99 | 74.00 | 25.01 | 150.0 | H | 211.0 | 15.93 |

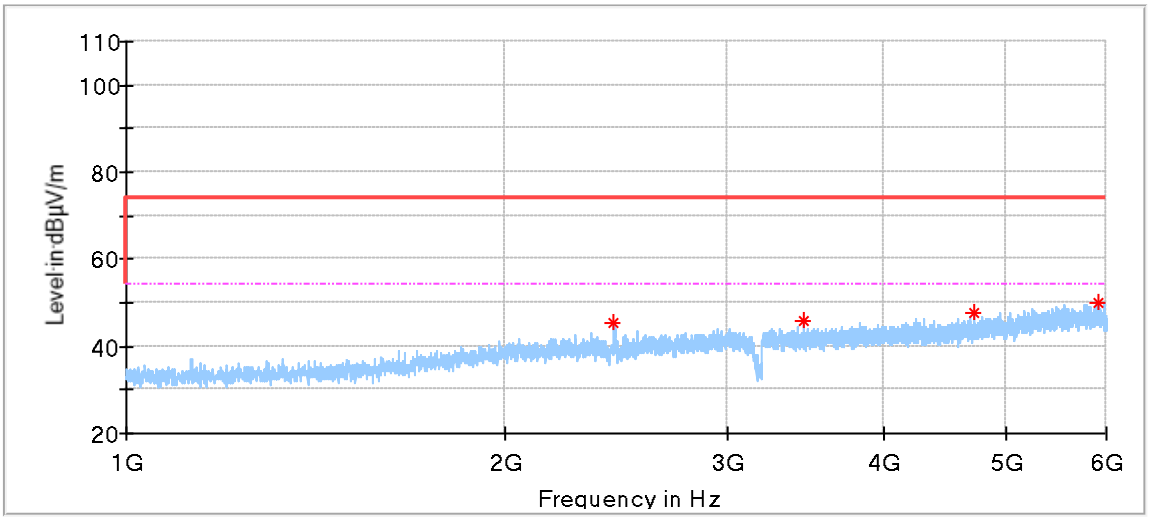



| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 3038.000000 | 45.17 | 74.00 | 28.83 | 150.0 | V | 213.0 | -1.28 |
| 3636.500000 | 45.94 | 74.00 | 28.06 | 150.0 | V | 9.0 | 0.04 |
| 4468.000000 | 46.35 | 74.00 | 27.65 | 150.0 | V | 352.0 | 2.33 |
| 5557.500000 | 49.82 | 74.00 | 24.18 | 150.0 | V | 54.0 | 4.41 |

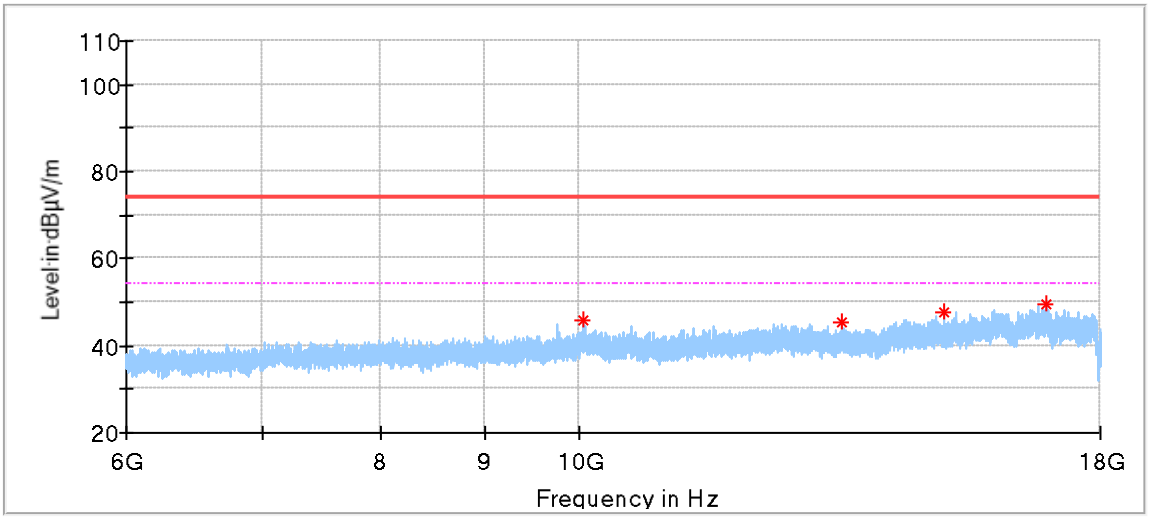



| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 7166.500000 | 42.39 | 74.00 | 31.61 | 150.0 | V | 125.0 | 4.91 |
| 10041.500000 | 45.75 | 74.00 | 28.25 | 150.0 | V | 197.0 | 9.12 |
| 12247.000000 | 45.42 | 74.00 | 28.58 | 150.0 | V | 0.0 | 9.00 |
| 16576.500000 | 48.78 | 74.00 | 25.22 | 150.0 | V | 11.0 | 15.72 |

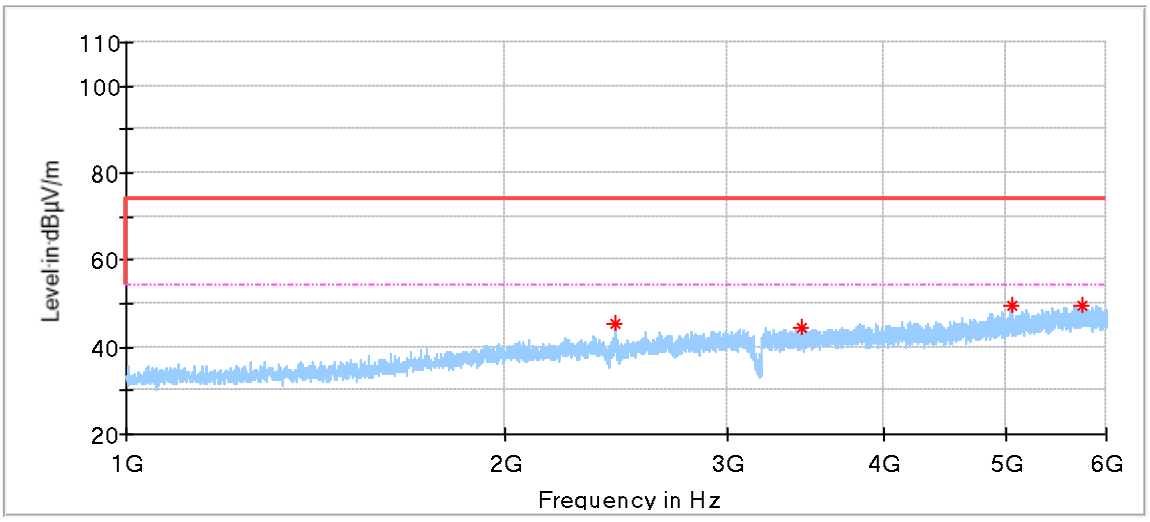
## Middle channel 2441MHz



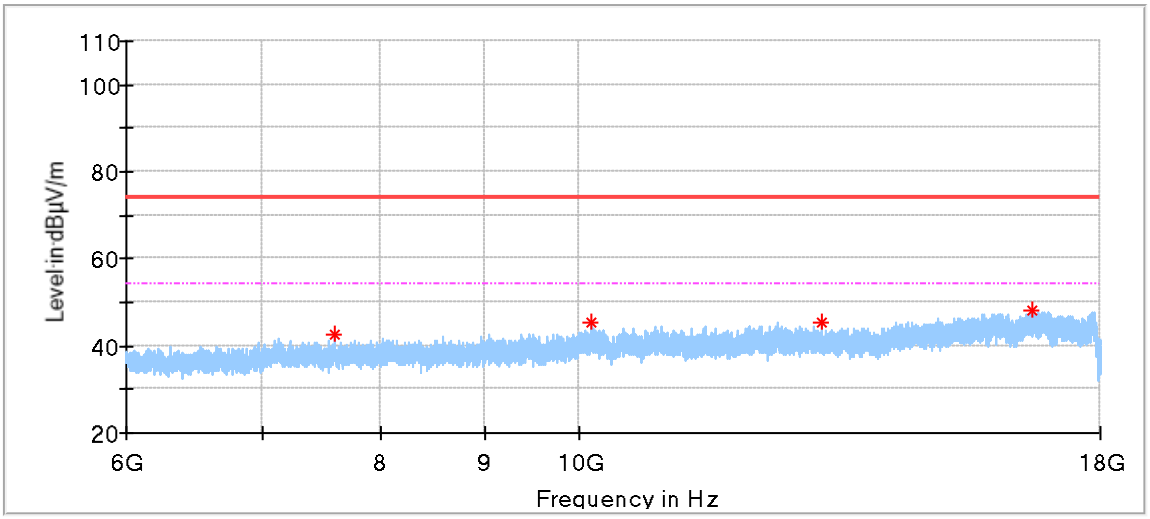

| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 2440.000000 | 45.52 | 74.00 | 28.48 | 100.0 | H | 164.0 | -3.09 |
| 3453.500000 | 45.84 | 74.00 | 28.16 | 100.0 | H | 345.0 | -0.49 |
| 4705.500000 | 47.57 | 74.00 | 26.43 | 100.0 | H | 0.0 | 2.59 |
| 5905.500000 | 50.07 | 74.00 | 23.93 | 100.0 | H | 117.0 | 5.51 |




| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 10048.500000 | 45.70 | 74.00 | 28.30 | 150.0 | H | 216.0 | 9.19 |
| 13433.000000 | 45.32 | 74.00 | 28.68 | 150.0 | H | 263.0 | 9.80 |
| 15075.000000 | 47.47 | 74.00 | 26.53 | 150.0 | H | 75.0 | 12.02 |
| 16936.000000 | 49.49 | 74.00 | 24.51 | 150.0 | H | 0.0 | 16.48 |

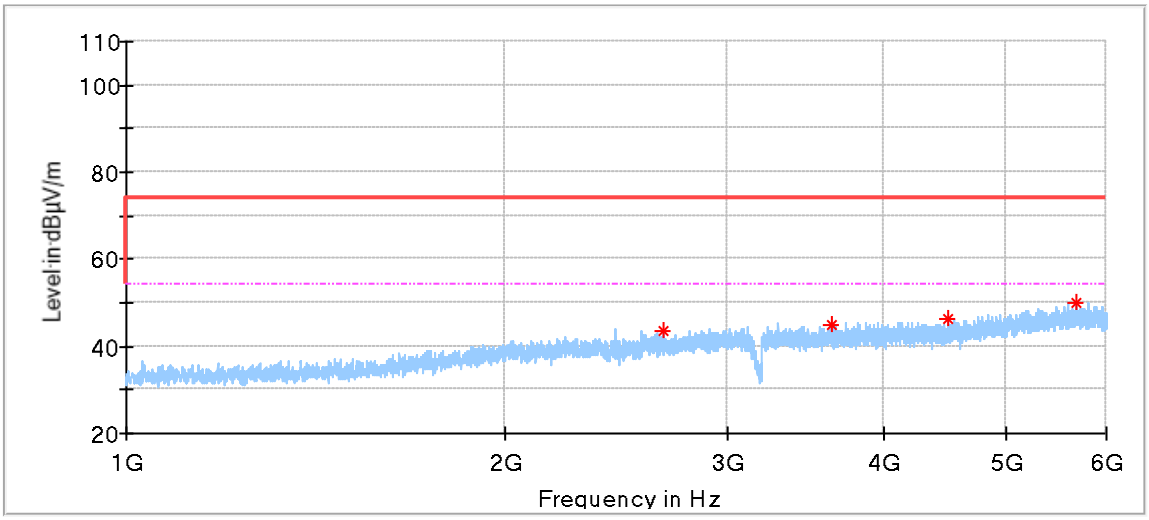



| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 2443.000000 | 45.19 | 74.00 | 28.81 | 150.0 | V | 85.0 | -3.08 |
| 3441.500000 | 44.62 | 74.00 | 29.38 | 150.0 | V | 117.0 | -0.49 |
| 5047.000000 | 49.41 | 74.00 | 24.59 | 150.0 | V | 226.0 | 3.02 |
| 5734.000000 | 49.68 | 74.00 | 24.32 | 150.0 | V | 65.0 | 5.00 |

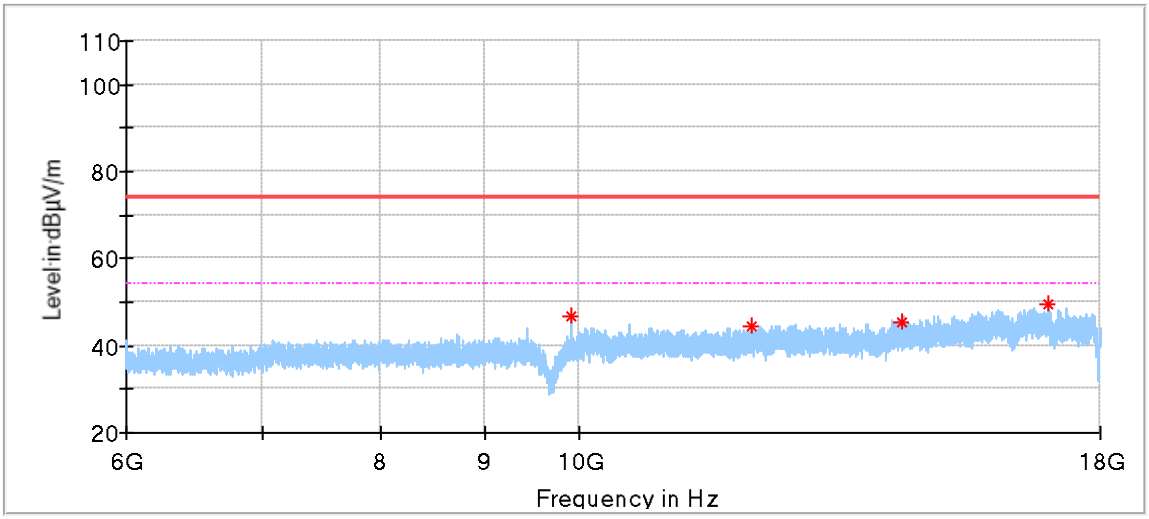



| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 7584.000000 | 42.60 | 74.00 | 31.40 | 150.0 | V | 347.0 | 5.49 |
| 10136.000000 | 45.26 | 74.00 | 28.74 | 150.0 | V | 0.0 | 9.11 |
| 13141.500000 | 45.35 | 74.00 | 28.65 | 150.0 | V | 347.0 | 9.22 |
| 16667.000000 | 48.08 | 74.00 | 25.92 | 150.0 | V | 163.0 | 15.86 |

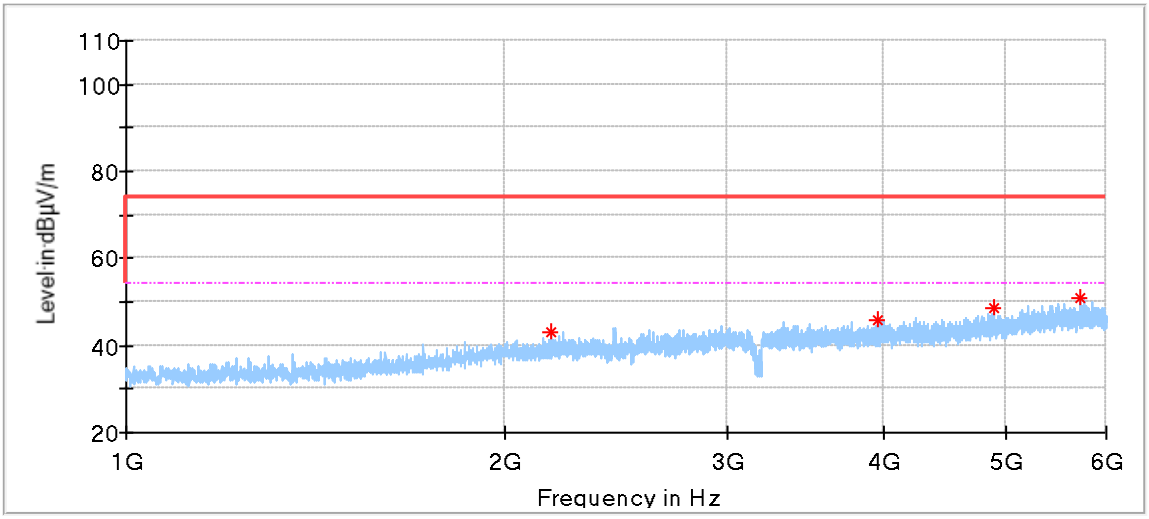
## High channel 2480MHz



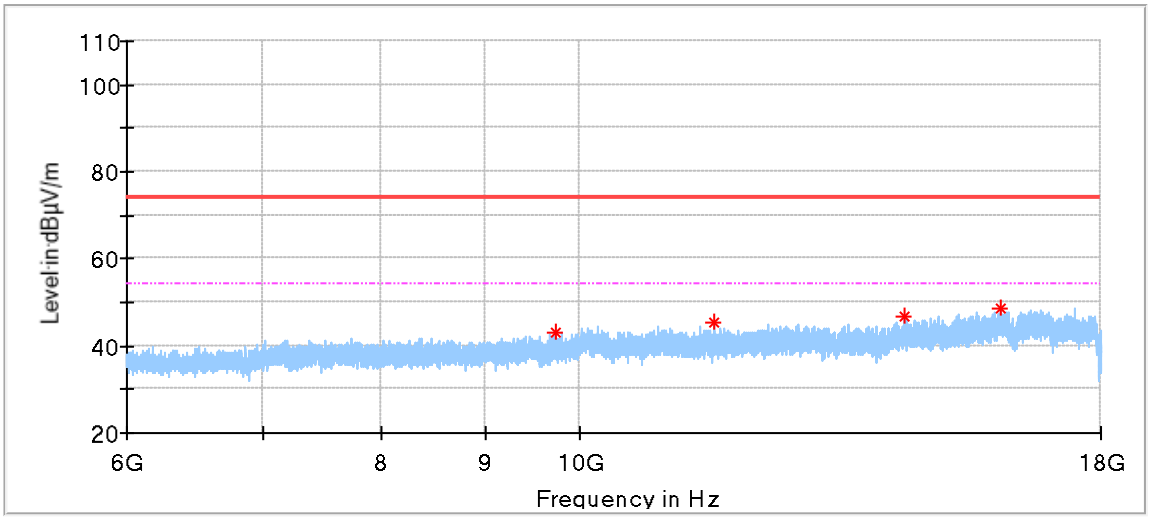

| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 2670.000000 | 43.77 | 74.00 | 30.23 | 150.0 | V | 101.0 | -2.40 |
| 3628.500000 | 45.15 | 74.00 | 28.85 | 150.0 | V | 218.0 | 0.06 |
| 4488.500000 | 46.19 | 74.00 | 27.81 | 150.0 | V | 326.0 | 2.32 |
| 5669.500000 | 50.20 | 74.00 | 23.80 | 150.0 | V | 302.0 | 4.69 |




| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 9916.500000 | 46.68 | 74.00 | 27.32 | 150.0 | H | 302.0 | 8.07 |
| 12160.000000 | 44.56 | 74.00 | 29.44 | 150.0 | H | 347.0 | 8.72 |
| 14374.500000 | 45.24 | 74.00 | 28.76 | 150.0 | H | 140.0 | 11.03 |
| 16968.500000 | 49.33 | 74.00 | 24.67 | 150.0 | H | 71.0 | 16.44 |




| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 2177.000000 | 43.21 | 74.00 | 30.79 | 100.0 | H | 194.0 | -3.77 |
| 3957.500000 | 45.82 | 74.00 | 28.18 | 100.0 | H | 23.0 | 1.28 |
| 4882.000000 | 48.62 | 74.00 | 25.38 | 100.0 | H | 331.0 | 2.85 |
| 5726.000000 | 50.76 | 74.00 | 23.24 | 100.0 | H | 299.0 | 4.95 |




| Frequency (MHz) | MaxPeak (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|---|---|---|---|---|---|---|---|
| 9726.000000 | 43.16 | 74.00 | 30.84 | 150.0 | V | 266.0 | 7.75 |
| 11644.500000 | 45.15 | 74.00 | 28.85 | 150.0 | V | 0.0 | 8.38 |
| 14435.000000 | 46.65 | 74.00 | 27.35 | 150.0 | V | 0.0 | 11.08 |
| 16077.500000 | 48.82 | 74.00 | 25.18 | 150.0 | V | 11.0 | 14.81 |

Remark:

(1) Data of measurement within frequency range18-26GHz are the noise floor or attenuated more than 20dB below the permissible limits or the field strength is too small to be measured, so test data does not present in this report,
(2) Level= Reading Level + Correction Factor
(3) Above 1GHz: Corrector factor = Antenna Factor + Cable Loss- Amplifier Gain
Below 1GHz: Corrector factor = Antenna Factor + Cable Loss
(The Reading Level is recorded by software which is not shown in the sheet)

# 10 Test Equipment List

Radiated Emission Test

| Description | Manufacturer | Model no. | Equipment ID | Serial no. | cal interval (year) | cal. due date |
|---|---|---|---|---|---|---|
| EMI Test Receiver | Rohde & Schwarz | ESR 26 | 68-4-74-14-002 | 101269 | 1 | 2021-6-29 |
| Trilog Super Broadband Test Antenna | Schwarzbeck | VULB 9162 | 68-4-80-19-003 | 284 | 1 | 2021-2-24 |
| Wave Guide Antenna | ETS | 3117 | 68-4-80-19-001 | 00218954 | 1 | 2021-6-15 |
| Pre-amplifier | Rohde & Schwarz | SCU 18F | 68-4-29-19-001 | 100745 | 1 | 2021-12-14 |
| Pre-amplifier | Rohde & Schwarz | SCU 08F2 | 68-4-29-19-004 | 08400018 | 1 | 2021-12-14 |
| Sideband Horn Antenna | Q-PAR | QWH-SL-18-40-K-SG | 68-4-80-14-008 | 12827 | 1 | 2021-8-5 |
| Pre-amplifier | Rohde & Schwarz | SCU 40A | 68-4-29-14-002 | 100432 | 1 | 2021-7-30 |
| 3m Semi-anechoic chamber | TDK | 9X6X6 | 68-4-90-19-006 | ---- | 3 | 2022-12-29 |
| Test software | Rohde & Schwarz | EMC32 | 68-4-90-19-006-A01 | Version10.35.02 | N/A | N/A |

RF Conducted Test

| Description | Manufacturer | Model no. | Equipment ID | Serial no. | cal interval (year) | cal. due date |
|---|---|---|---|---|---|---|
| Signal Analyzer | Rohde & Schwarz | FSV40 | 68-4-74-14-004 | 101030 | 1 | 2021-6-21 |

## 11 System Measurement Uncertainty

For a 95% confidence level, the measurement expanded uncertainties for defined systems, in accordance with the recommendations of ISO 17025 were:

| System Measurement Uncertainty | |
|---|---|
| Test Items | Extended Uncertainty |
| Radiated Spurious Emission 30MHz-1000MHz | Horizontal: 4.70dB;<br>Vertical: 4.67dB; |
| Radiated Spurious Emission 1000MHz-18000MHz | Horizontal: 4.65dB;<br>Vertical: 4.63dB; |
| Radiated Spurious Emission 18000MHz-40000MHz | Horizontal: 4.51dB;<br>Vertical: 4.50dB; |
| Conducted RF test with TS 8997 | RF Power Conducted: 1.31dB<br>Frequency test involved:<br>$0.6\times10^{-7}$ or 1% |

---THE END OF REPORT---