# FCC & ISED CERTIFICATION TEST REPORT

| | |
|---|---|
| **Project Number** | **: EA1912C-014** |
| **Test Report Number** | **: TR-W1912-002** |
| **Type of Equipment** | **: BLE Module** |
| **Model Name** | **: CRM-24B** |
| **FCC ID** | **: CCECRM-24B** |
| **ISED Canada ID** | **: 22254-CRM24B** |
| **Multiple Model Name** | **: N/A** |
| **Applicant** | **: COMMAX Co., Ltd.** |
| **Address** | **: 494 Dunchon-Daero, Jungwon-Gu, Seongnam-si, Gyeonggi-do, South Korea** |
| **Manufacturer** | **: COMMAX Co., Ltd.** |
| **Address** | **: 494 Dunchon-Daero, Jungwon-Gu, Seongnam-si, Gyeonggi-do, South Korea** |
| **Regulation** | **: FCC Part 15 Subpart C Section 15.247, ISED RSS-247 Issue2** |
| **Total page of Report** | **: 52 Pages** |
| **Date of Receipt** | **: 2019-11-12** |
| **Date of Issue** | **: 2019-12-05** |
| **Test Result** | **: PASS** |

This test report only contains the result of a single test of the sample supplied for the examination.

It is not a generally valid assessment of the features of the respective products of the mass-production.

Prepared by Song, In-young / Senior Engineer _____ (Signature) 2019-12-05 (Date)

Reviewed by Choi, Yeong-min / Technical Manager _____ (Signature) 2019-12-05 (Date)



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## Release Control Record

| Issue Report No. | Issued Date | Details/Revisions |
|---|---|---|
| TR-W1912-002 | 2019-12-05 | Initial Release |
| - | - | - |


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# 1. TEST SUMMARY

## 1.1 Regulations and results

The sample submitted for evaluation (Hereafter referred to as the EUT) has been tested in accordance with the following regulations or standards.

| FCC Reference Section | ISED Reference Section | Description | Result | | | |
|---|---|---|---|---|---|---|
| | | | P | F | N.T. | Note |
| 15.247(a)(2) | RSS-247 5.2 a) | 6 dB Bandwidth<br>Occupied Bandwidth | **P** | | | |
| 15.247(b)(3) | RSS-247 5.4 d) | Maximum peak output power | **P** | | | |
| 15.247(d) | RSS-247 5.5 | Band Edge<br>Conducted spurious emission | **P** | | | |
| 15.247(e) | RSS-247 5.2 b) | Power spectral density | **P** | | | |
| 15.205(a)<br>15.209(a) | RSS 247 5.5<br>RSS-GEN 8.9 | Radiated spurious emissions | **P** | | | |
| 15.207(a) | RSS GEN 8.8 | AC power line conducted emissions | **P** | | | |

**Remark:**

**P** means Passed **F** means Failed **N.T.** means Not Tested

## 1.2 Test Methodology

The tests mentioned in clause 1.1 in this test report were performed according to FCC CFR 47 Part 2, CFR 47 Part 15 and ANSI C63.10-2013, and RSS-Gen Issue 4.

KDB 558074 D01DTS Meas. Guidance v05r02: Measurement Procedure PK is used for power measurement.

## 1.3 Additions, deviations, exclusions from standards

No additions, deviations or exclusions have been made from standard.

## 1.4 Purpose of the test

The test was performed to determine whether the equipment under test fulfills the requirements of the regulation stated in FCC Part 15 Subpart C Section 15.247, RGG-Gen and RSS-247.

## 1.5 Test Facility

The measurement facilities are located at 135-60 Gyeongchung-daero, Gonjiam-eup, Gwangju-si, Gyeonggi-do 12813, Korea. Our test facilities are accredited as a Conformity Assessment Body (CAB) by the FCC and ISED Canada, designated by the RRA (National Radio Research Agency), and accredited by KOLAS (Korea Laboratory Accreditation Scheme) in Korea and approved by TUV Rheinland, TUV SÜD and Korean Register of Shipping according to the requirement of ISO/IEC 17025.

| Laboratory Qualification | Registration No. | Mark |
|---|---|---|
| FCC | KR0160 | |
| ISED Canada | 12721A | |
| RRA | KR0160 | |
| TUV Rheinland | UA 50314109-0002 | |
| TUV SÜD | CARAT 094465 0004 Rev.00 | |
| Korean Agency for Technology and Standards | KT733 | |
| KOREAN REGISTER OF SHIPPING | PCT40841-TL001 | |

Remark. This report is not related to KOLAS accreditation and relevant regulation.

## 2. EUT (Equipment Under Test) INFORMATION

### 2.1 General Description

The COMMAX Co., Ltd., Model CRM-24B (referred to as the EUT in this report) is a BLE Module. The EUT is a device for transferring Bluetooth low energy signal to a Bluetooth low energy Device through wireless communication. The product specification described herein was obtained from product data sheet or user's manual.

| | |
|---|---|
| Operating Frequency | 2 402 MHz ~ 2 480 MHz |
| Kind of Class | DTS – Digital Transmission System |
| Max. RF Output Power | 0.76 dBm |
| Modulation Types | GFSK |
| Number of Channels | 40 CH |
| Channel Bandwidth | 2 MHz |
| Generated or used Freq. in EUT | 32.768 kHz, 16 MHz |
| Type of Antenna | ■ Integrated Type □ Dedicated Type |
| Antenna Gain | 3.90 dBi |
| Operating Temperature | - 40 °C ~ + 85 °C |
| Normal Test Voltage | DC 3.3 V |
| Electrical Rating | DC 3.3 V |
| Test SW Version | Tera Term Version 4.91 |
| RF power setting in TEST SW | 04 |
| Software Version | 191114 |
| Hardware Version | 2.01 |

### 2.2 Additional Model

None

## 2.3 Available channel number and frequency

| Operating Mode: Bluetooth LE, 2 MHz Channel Spacing | | | | | |
|---|---|---|---|---|---|
| Channel | Frequency(MHz) | Channel | Frequency(MHz) | Channel | Frequency(MHz) |
| 0 | 2 402 | 14 | 2 430 | 28 | 2 458 |
| 1 | 2 404 | 15 | 2 432 | 29 | 2 460 |
| 2 | 2 406 | 16 | 2 434 | 30 | 2 462 |
| 3 | 2 408 | 17 | 2 436 | 31 | 2 464 |
| 4 | 2 410 | 18 | 2 438 | 32 | 2 466 |
| 5 | 2 412 | 19 | 2 440 | 33 | 2 468 |
| 6 | 2 414 | 20 | 2 442 | 34 | 2 470 |
| 7 | 2 416 | 21 | 2 444 | 35 | 2 472 |
| 8 | 2 418 | 22 | 2 446 | 36 | 2 474 |
| 9 | 2 420 | 23 | 2 448 | 37 | 2 476 |
| 10 | 2 422 | 24 | 2 450 | 38 | 2 478 |
| 11 | 2 424 | 25 | 2 452 | 39 | 2 480 |
| 12 | 2 426 | 26 | 2 454 | | |
| 13 | 2 428 | 27 | 2 456 | | |


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# 3. TEST CONDITION

## 3.1 Equipment Used During Test

The following peripheral devices and/or interface cables were connected during the measurement:

| Description | Model No. | Serial No. | Manufacturer. |
|---|---|---|---|
| BLE Module (EUT) | CRM-24B | N/A | COMMAX Co., Ltd. |
| Notebook PC | E5470 | ZU10190-15008 | DELL |
| Adapter for Notebook PC | LA65NM130 | N/A | DELL |

## 3.2 Mode of operation during the test

Software used to control the EUT for staying in continuous transmitting mode is programmed.

The used modulation type for the testing is GFSK.

## 3.3 Preliminary Testing for Worst case configuration

For finding worst case configuration and operating mode, preliminary testing was performed and radiated emission and conducted emission tests were performed with the EUT set to transmit and receive at the channel with the highest output power as worst case scenario. All spurious emission tests were performed in X, Y and Z axis direction. And the worst Z-axis (9 kHz ~ 30 MHz), Y-axis (30 MHz ~ 1 GHz, Above 1 GHz) test condition was recorded in this test report.

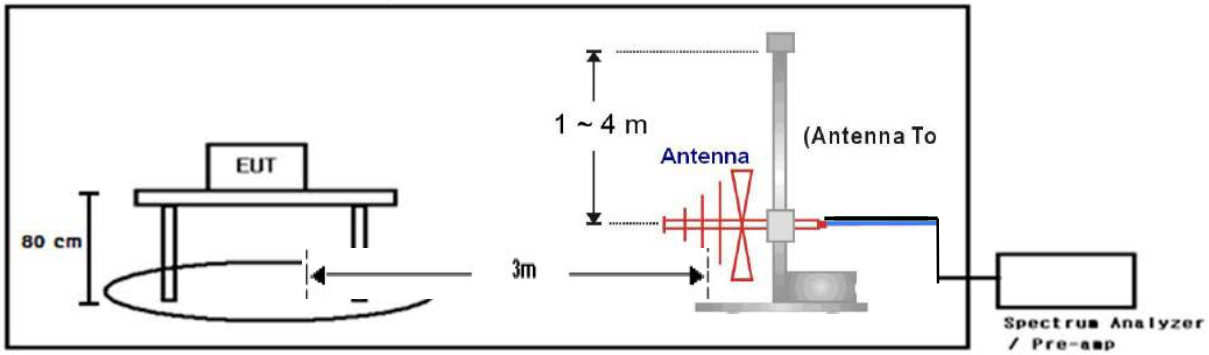
Based on preliminary testing following operating modes were selected for the final test as listed below.

### 3.3.1 Test Channel and Frequency

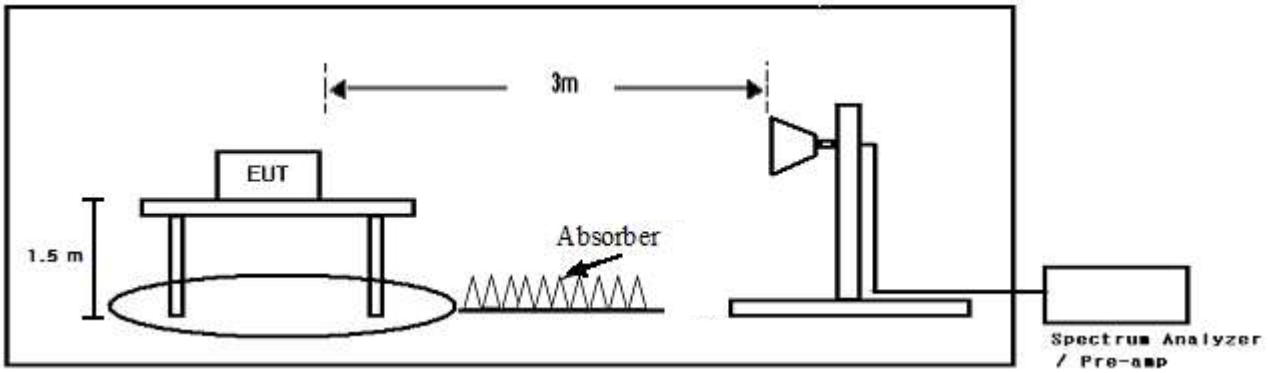
| Operating Mode | Test Channel | Frequency |
|---|---|---|
| Bluetooth Low Energy | Low Channel | 2 402 MHz |
| | Middle Channel | 2 440 MHz |
| | High Channel | 2 480 MHz |

## 3.4 Test Setup Drawing

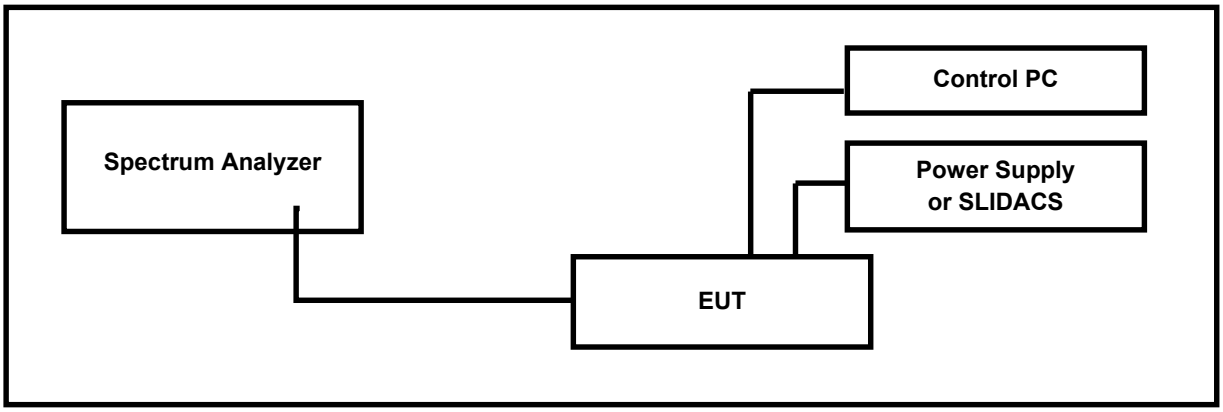
(Radiated Test below 1 GHz)




(Radiated Test above 1 GHz)




(Conducted Test)




## 3.5 EUT Modifications

- No EMC Relevant Modifications were performed by this test laboratory.



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## 4. ANTENNA REQUIREMENT

According to FCC CFR 47 Part 15 section 15.203, an intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provision of this section.

### 4.1 Antenna Description

| Frequency Band (GHz) | Antenna Type | Max Peak Gain (dBi) | Connector Type |
|---|---|---|---|
| 2.4 | PCB Pattern Antenna | 3.90 | - |

### 4.2 Conclusion

**The antenna connector type of the EUT is PCB Pattern Antenna, so the EUT met the requirement.**

# 5. TEST RESULT

## 5.1 6 dB Bandwidth

### 5.1.1 Limit

The minimum 6 dB bandwidth shall be at least 500 kHz acc to Section 15.247 (a) (2), and RSS-247 5.2 (a).

### 5.1.2 Method of Measurement

Reference to KDB 558074 D01 DTS Meas Guidance v05r02: 8.2

The transmitter output is connected to a spectrum analyzer with the RBW set to 100 kHz, VBW ≥ 3 X RBW, peak detector and max hold.

### 5.1.3 Test Data

| | | | |
|---|---|---|---|
| Date of Test | 2019-11-29 | Temperature | (22.5 ± 0.5) °C |
| | | Relative humidity | (41.1 ± 3.1) % R.H. |
| ***Test Result*** | ***PASS*** | Tested by | Do-heon Kim |
| Operating Mode: Bluetooth LE | | | |
| Channel | Frequency (MHz) | 6 dB Bandwidth (MHz) | Minimum Limit (MHz) |
| Low | 2 402 | 0.74 | 0.5 |
| Middle | 2 440 | 0.73 | |
| High | 2 480 | 0.74 | |


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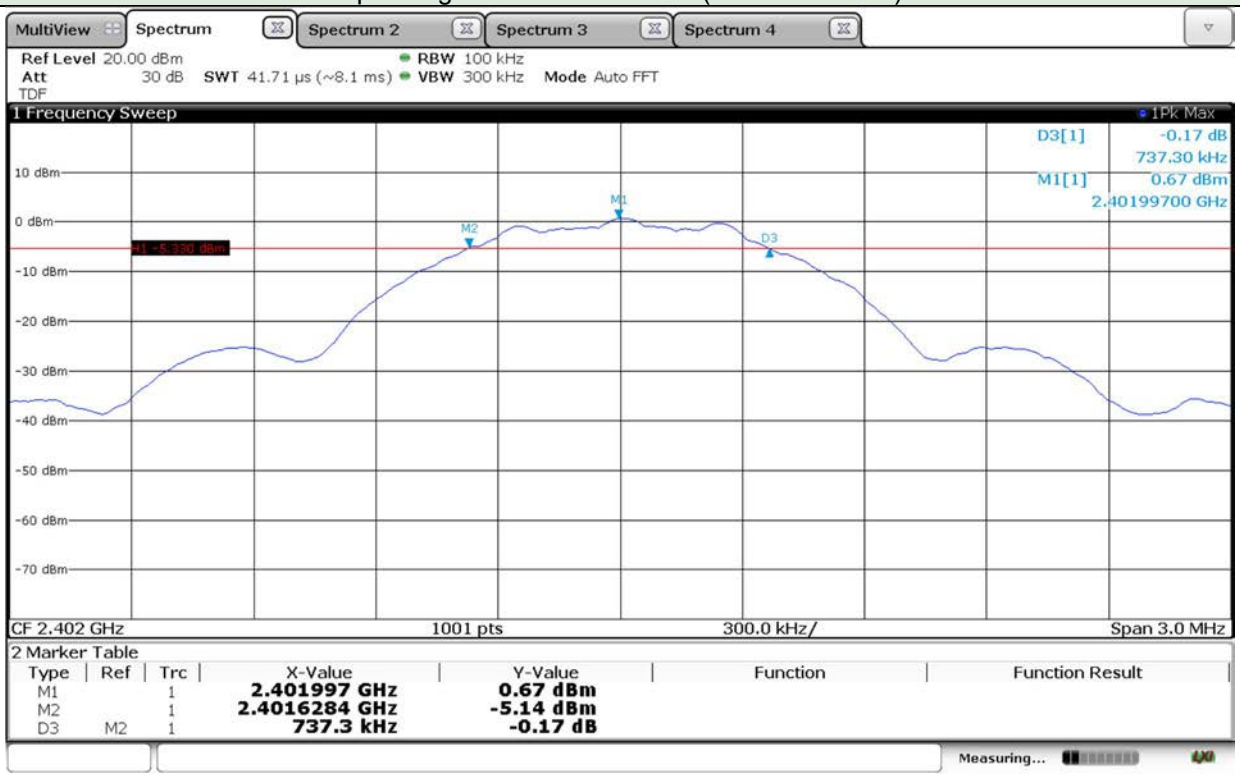
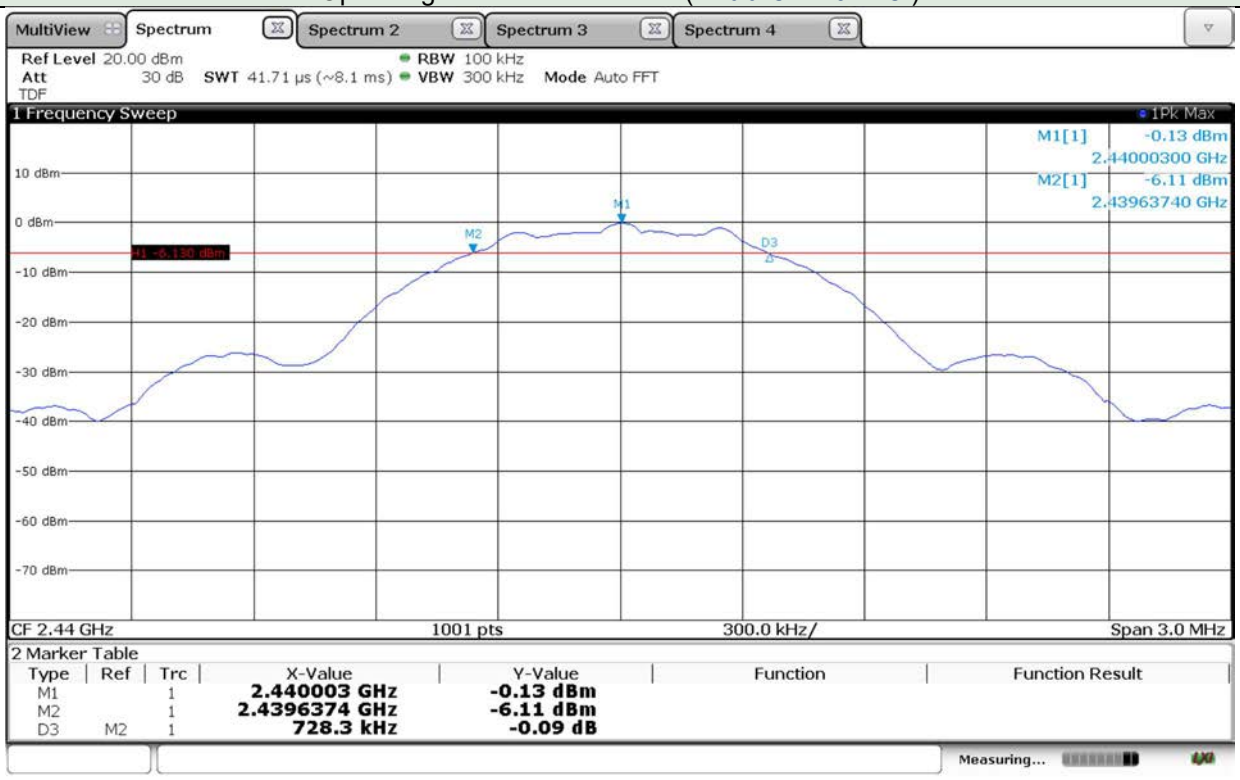
### 5.1.4 Test Plots

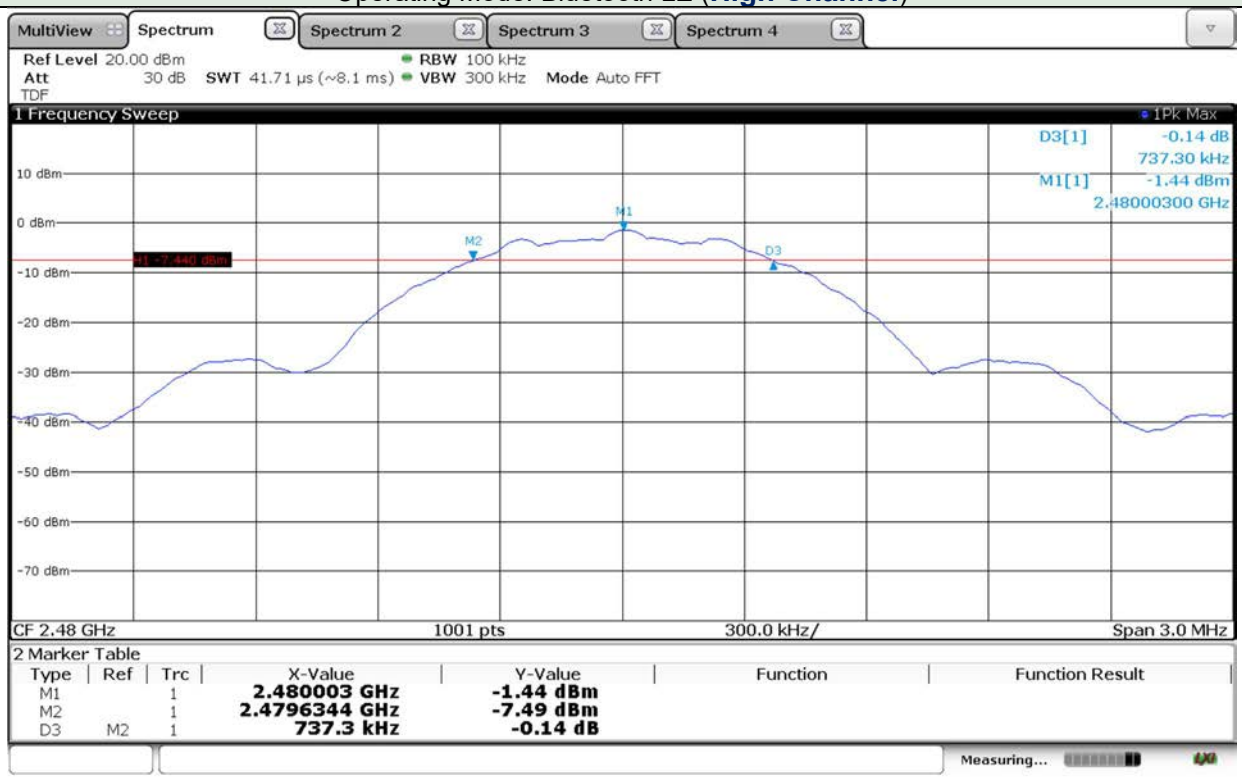
Operating Mode: Bluetooth LE (**Low Channel**)




Operating Mode: Bluetooth LE (**Middle Channel**)



Operating Mode: Bluetooth LE (**High Channel**)



## 5.2 99 % Bandwidth

### 5.2.1 Limit

Not applicable.

### 5.2.2 Method of Measurement

The transmitter output is connected to the spectrum analyzer. The RBW is set to 1 % to 5 % of the OBW.

The span is set to capture all products of the modulation process, including the emission skirts.

The VBW is set to 3 times the RBW. The sweep time is coupled and peak detection and max hold mode is used. The spectrum analyzer internal 99% bandwidth function is utilized.

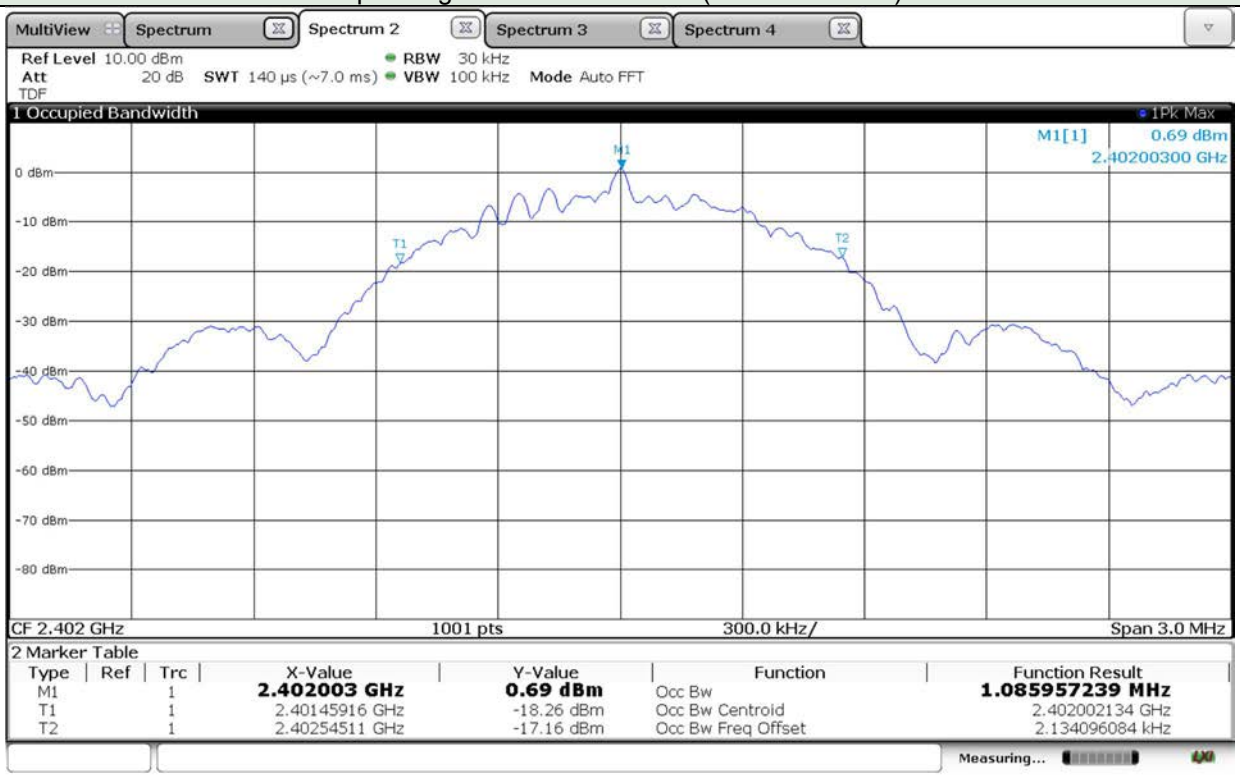
### 5.2.3 Test Data

| | | | |
|---|---|---|---|
| Date of Test | 2019-11-29 | Temperature | (22.5 ± 0.5) °C |
| | | Relative humidity | (41.1 ± 3.1) % R.H. |
| ***Test Result*** | ***PASS*** | Tested by | Do-heon Kim |

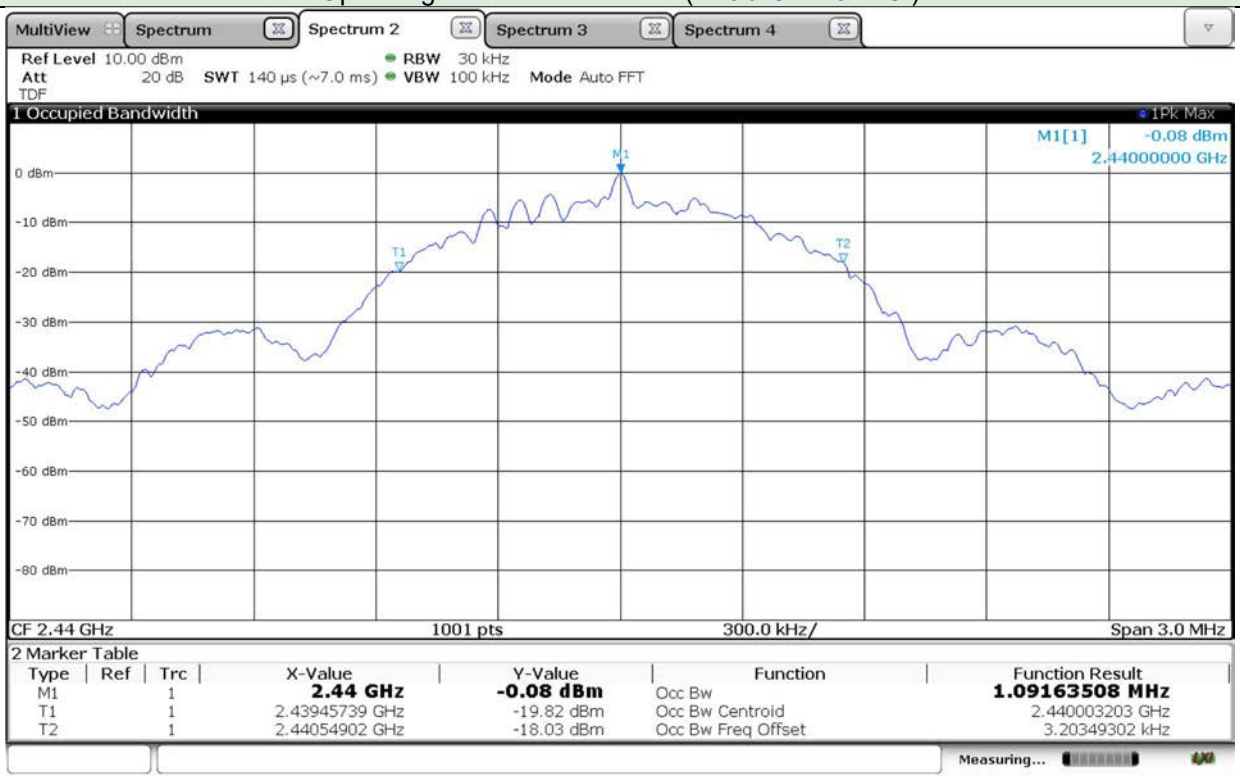
| Operational Mode: Bluetooth LE | | |
|---|---|---|
| Channel | Frequency (MHz) | 99 % Bandwidth (MHz) |
| Low | 2 402 | 1.09 |
| Middle | 2 440 | 1.09 |
| High | 2 480 | 1.11 |

### 5.2.4 Test Plots

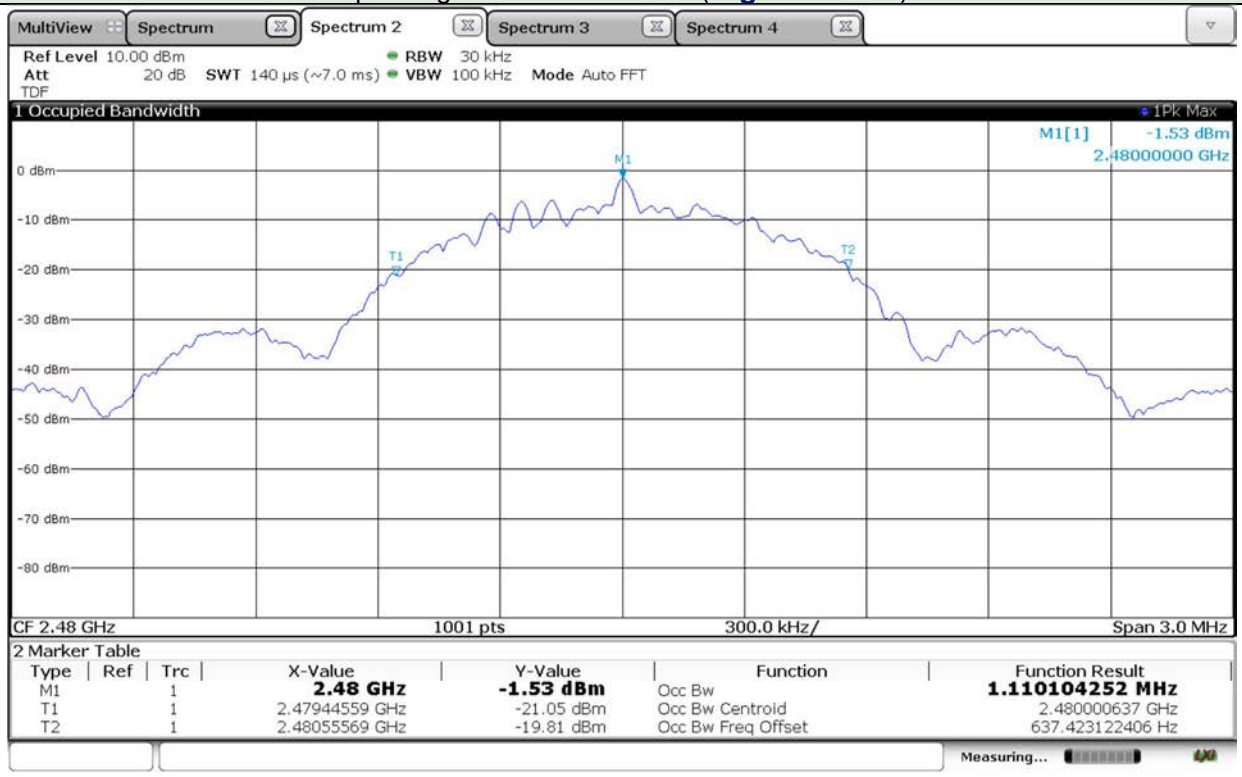
Operating Mode: Bluetooth LE (**Low Channel**)




Operating Mode: Bluetooth LE (**Middle Channel**)



Operating Mode: Bluetooth LE (**High Channel**)



## 5.3 Maximum Peak Output Power

### 5.3.1 Limit

Acc. To section 15.247 and RSS-247 5.4 d), For system using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands: 1 Watt, based on the use of antennas with directional gains that do not exceed 6 dBi. If transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

### 5.3.2 Method of Measurement

Reference to KDB 558074 D01 DTS Meas Guidance v05r02: 8.3.1.1 RBW ≥ DTS bandwidth

The cable assembly insertion loss was entered as an offset in the spectrum analyzer to allow for direct reading of power.

### 5.3.3 Test Data for Output Power

| | | | |
|---|---|---|---|
| Date of Test | 2019-11-29 | Temperature | (22.5 ± 0.5) °C |
| | | Relative humidity | (41.1 ± 3.1) % R.H. |
| ***Test Result*** | ***PASS*** | Tested by | Do-heon Kim |

| Operating Mode: Bluetooth LE | | | | |
|---|---|---|---|---|
| Channel | Frequency (MHz) | Measured Value (dBm) | Limit (dBm) | Margin (dB) |
| Low | 2 402 | 0.76 | 30 | 29.24 |
| Middle | 2 440 | 0.22 | | 29.78 |
| High | 2 480 | -1.25 | | 31.25 |

Remark. Margin = Limit – Measured Value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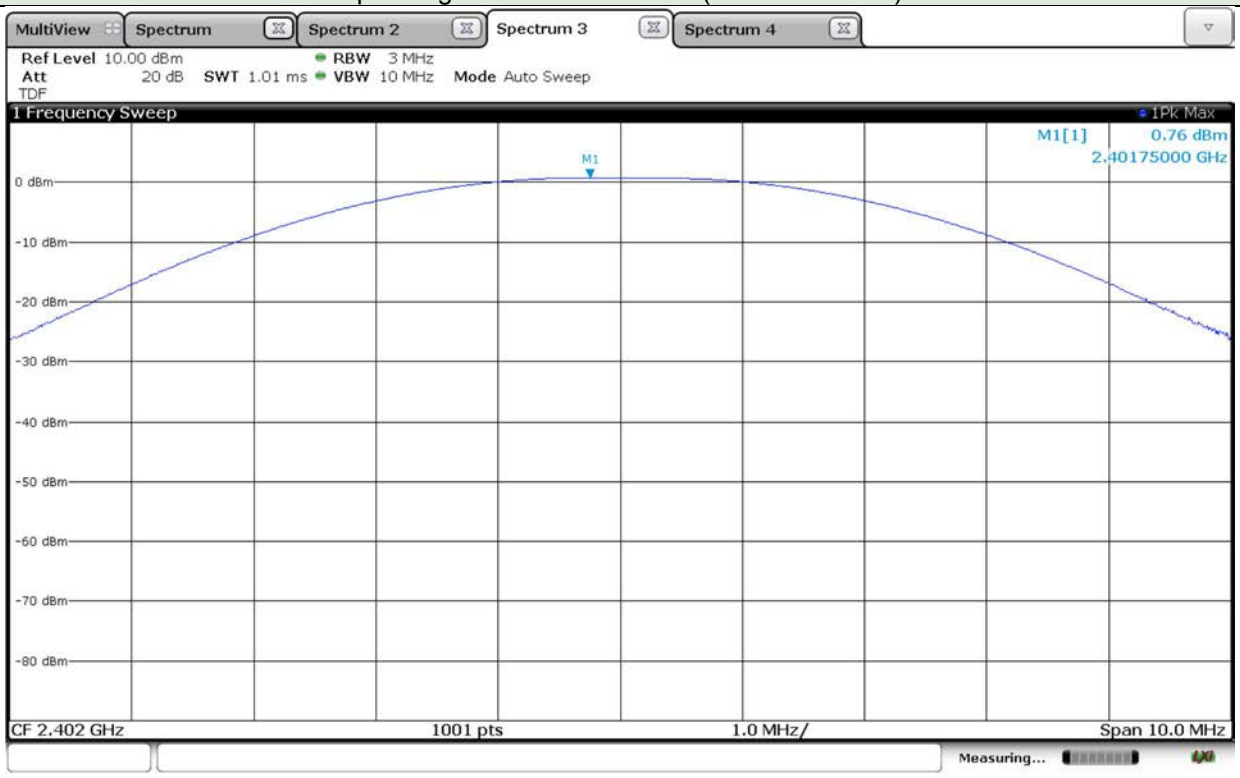
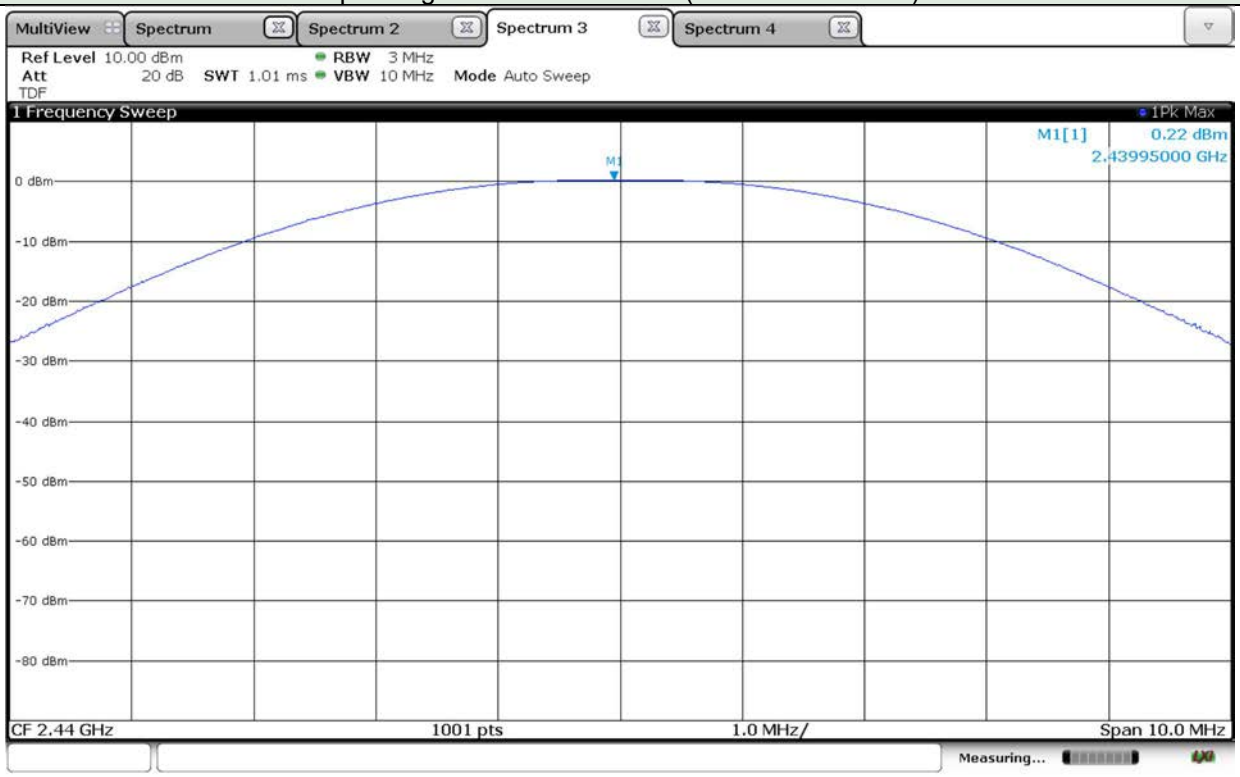
### 5.3.4 Test Plots

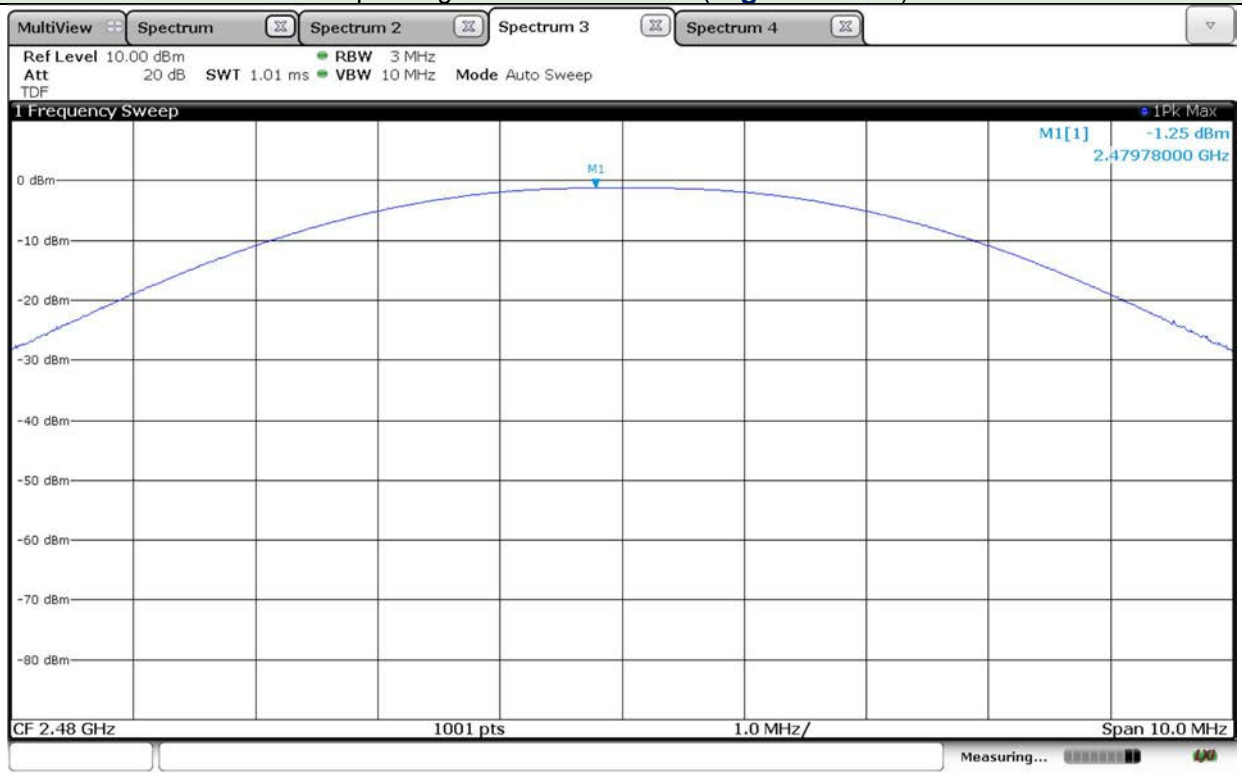
Operating Mode: Bluetooth LE (**Low Channel**)




Operating Mode: Bluetooth LE (**Middle Channel**)



Operating Mode: Bluetooth LE (**High Channel**)



## 5.4 Peak Power Spectral Density

### 5.4.1 Limit

Acc. To section 15.247 and RSS-247 5.2 b), the power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

### 5.4.2 Method of Measurement

Reference to KDB 558074 D01 DTS Meas Guidance v05r02: 8.4 Method PKPSD (peak PSD).

The transmitter output is connected to a spectrum analyzer with the RBW set from 3 kHz to 100 kHz, VBW ≥ 3 X RBW, peak detector and max hold.

### 5.4.3 Test Data

| | | | |
|---|---|---|---|
| Date of Test | 2019-11-29 | Temperature | (22.5 ± 0.5) °C |
| | | Relative humidity | (41.1 ± 3.1) % R.H. |
| ***Test Result*** | ***PASS*** | Tested by | Do-heon Kim |

| Operating Mode: Bluetooth LE | | | | |
|---|---|---|---|---|
| Channel | Frequency (MHz) | Measured Value (dBm) | Limit (dBm) | Margin (dB) |
| Low | 2 402 | -9.77 | 8 | 17.77 |
| Middle | 2 440 | -10.76 | | 18.76 |
| High | 2 480 | -12.44 | | 20.44 |

Remark. Margin = Limit – Measured Value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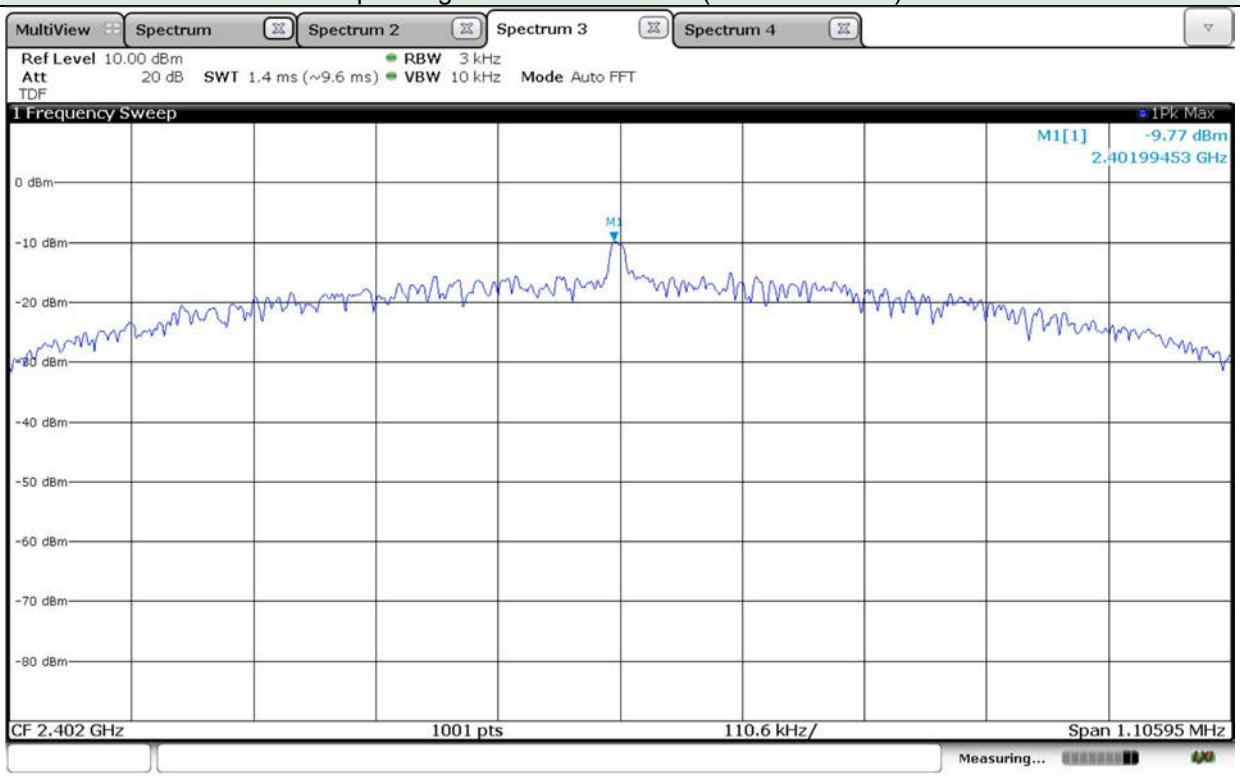
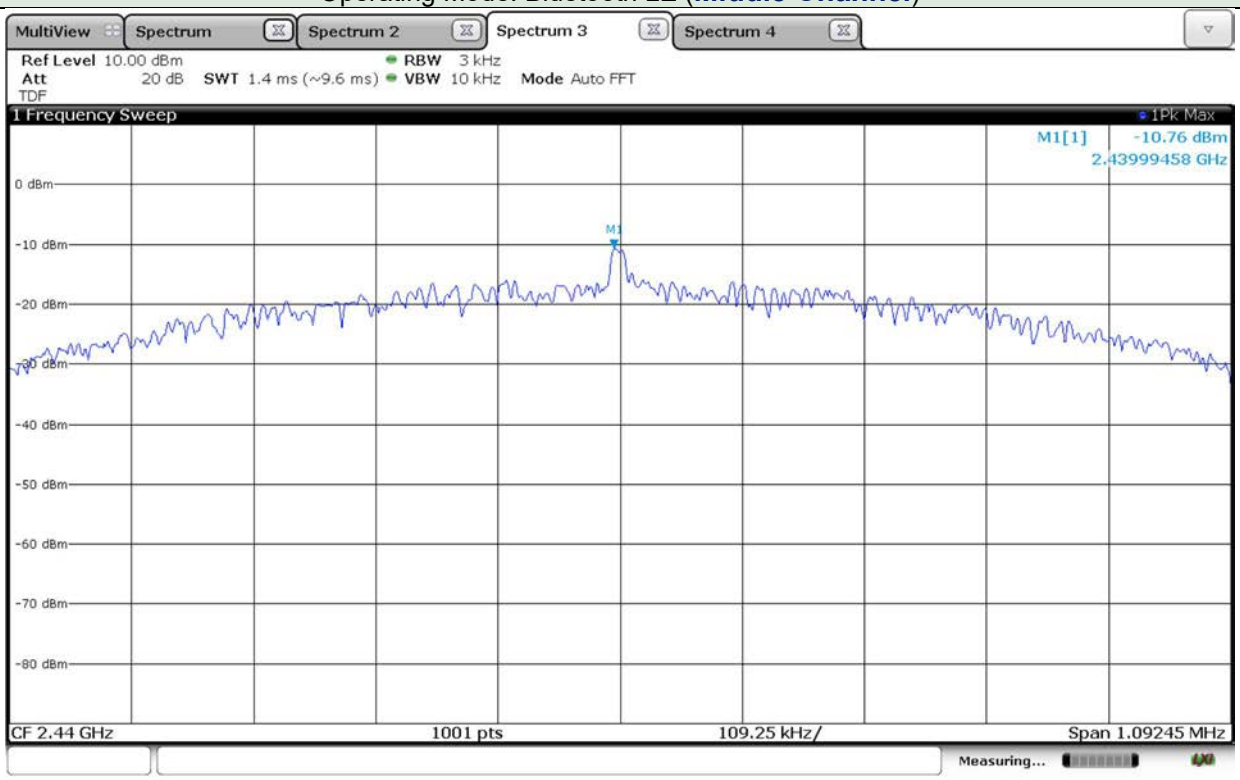
### 5.4.4 Test Plots

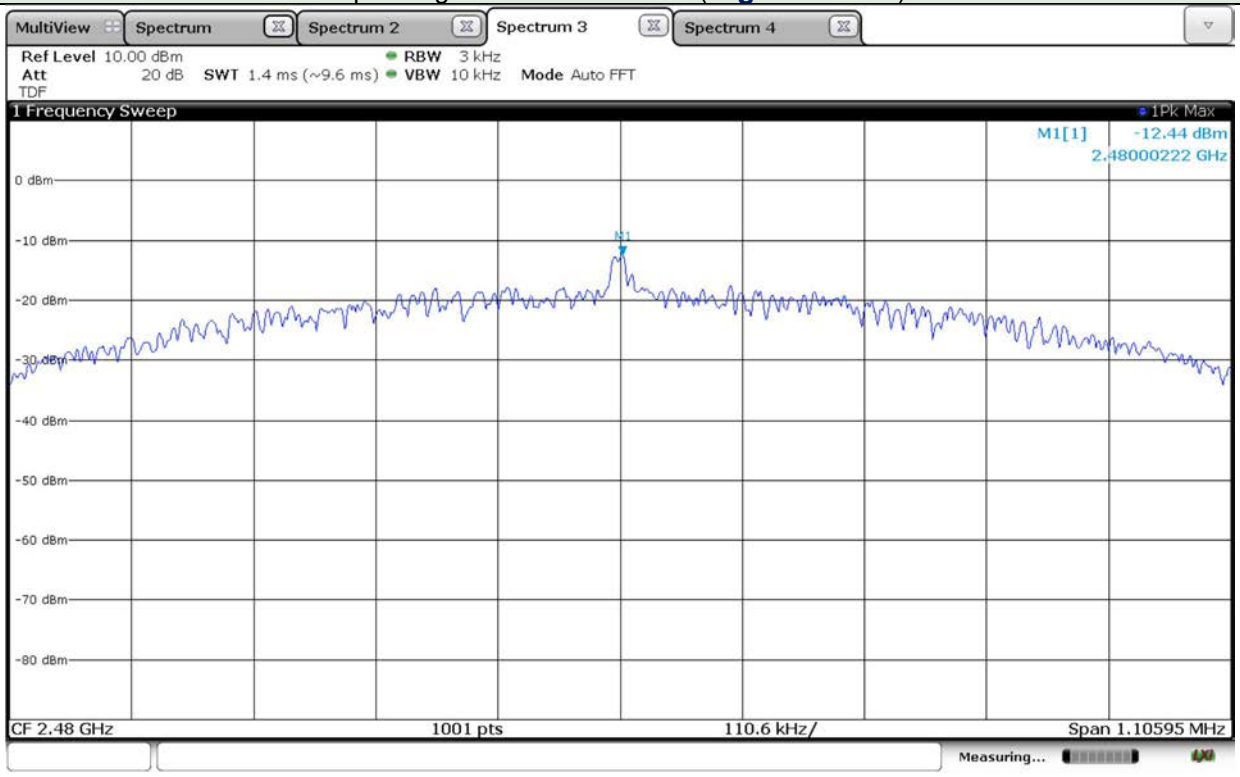
Operating Mode: Bluetooth LE (**Low Channel**)




Operating Mode: Bluetooth LE (**Middle Channel**)



Operating Mode: Bluetooth LE (**High Channel**)



## 5.5 Out of Band Emission

### 5.5.1 Limit

Acc. To section 15.247(d) and RSS-247 5.5, 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 15.209(a) is not required. In addition, radiated emission which in the restricted band, as define in section §15.205(a), must also comply the radiated emission limits specified in section §15.209(a) (see section §15.205(c))

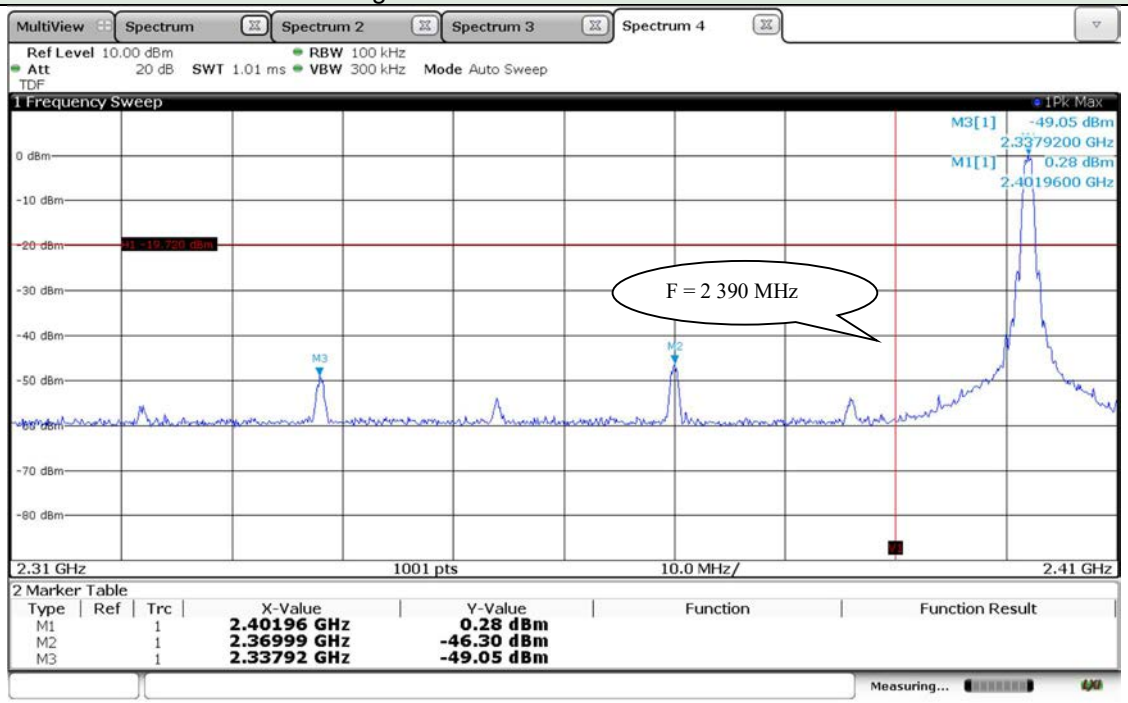
### 5.5.2 Method of Measurement

Reference to KDB 558074 D01 DTS Meas Guidance v05r02: 8.5 Emissions in non-restricted frequency bands. The transmitter output is connected to a spectrum analyzer with the RBW set to 100 kHz, VBW ≥ 3 X RBW, peak detector and max hold. Measurements utilizing these settings are made of the in-band reference level, band-edge (where measurements to the general radiated limits will not be made) and out-of-band emissions.

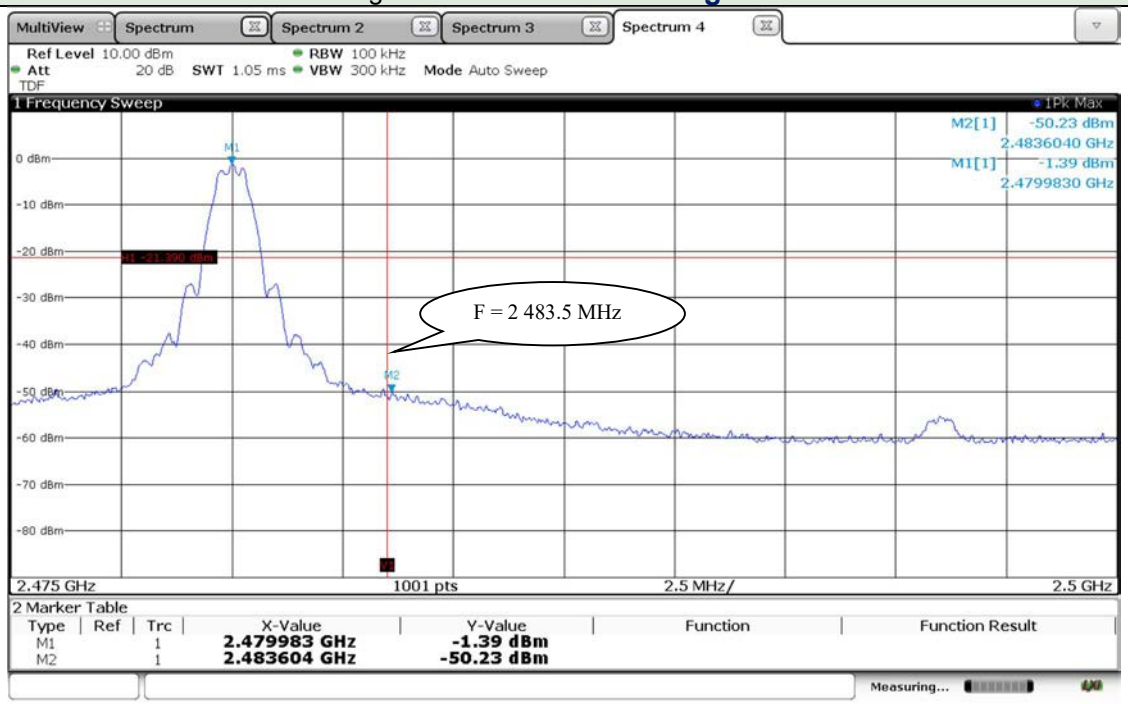
### 5.5.3 Test Data for Operating mode: Bluetooth LE

| | | | |
|---|---|---|---|
| Date of Test | 2019-11-29 | Temperature | (22.5 ± 0.5) °C |
| | | Relative humidity | (41.1 ± 3.1) % R.H. |
| ***Test Result*** | ***PASS*** | Tested by | Do-heon Kim |

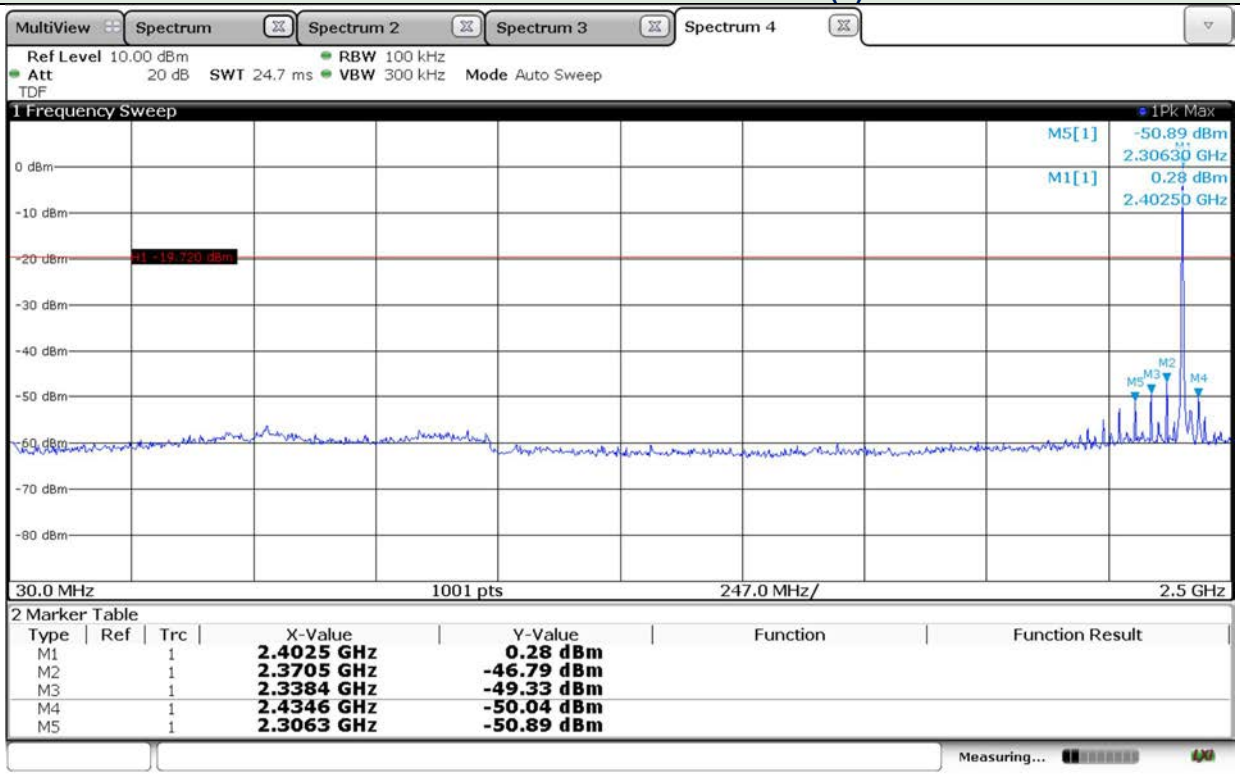
Band-edge and Restricted band – **Low channel**



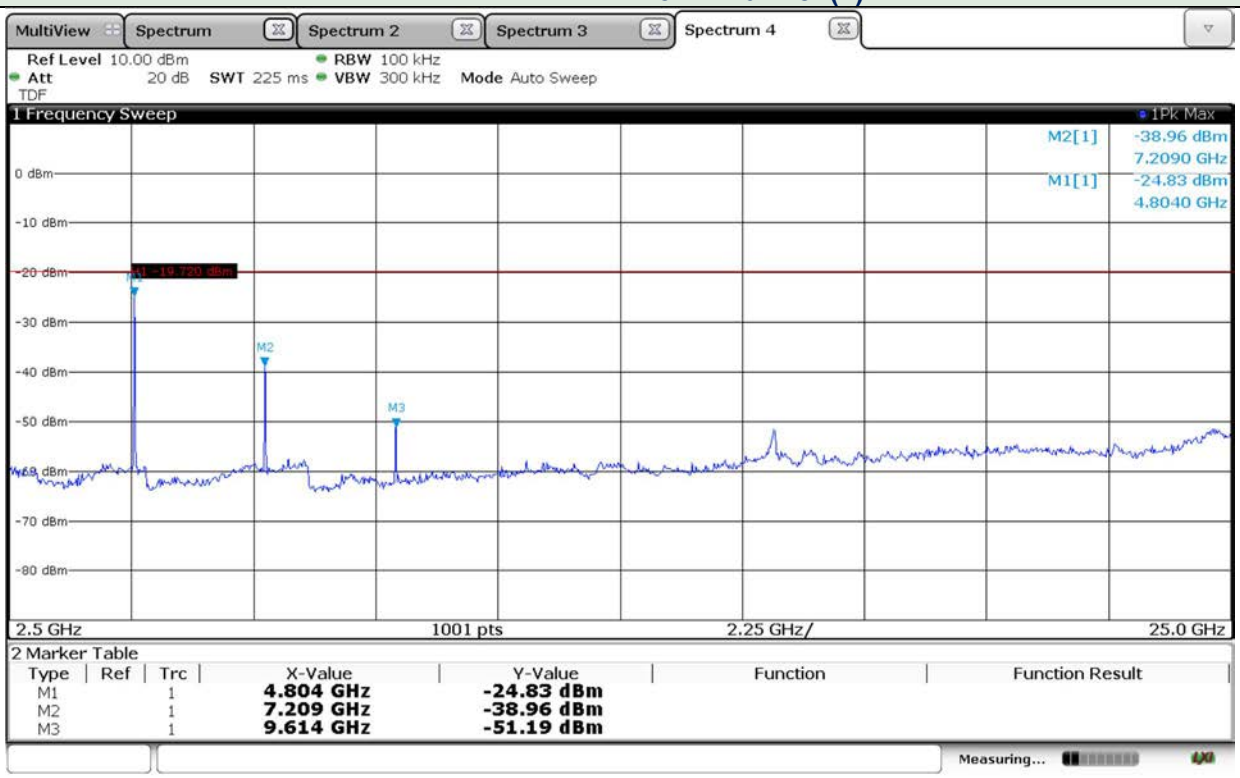

Band-edge and Restricted band – **High channel**



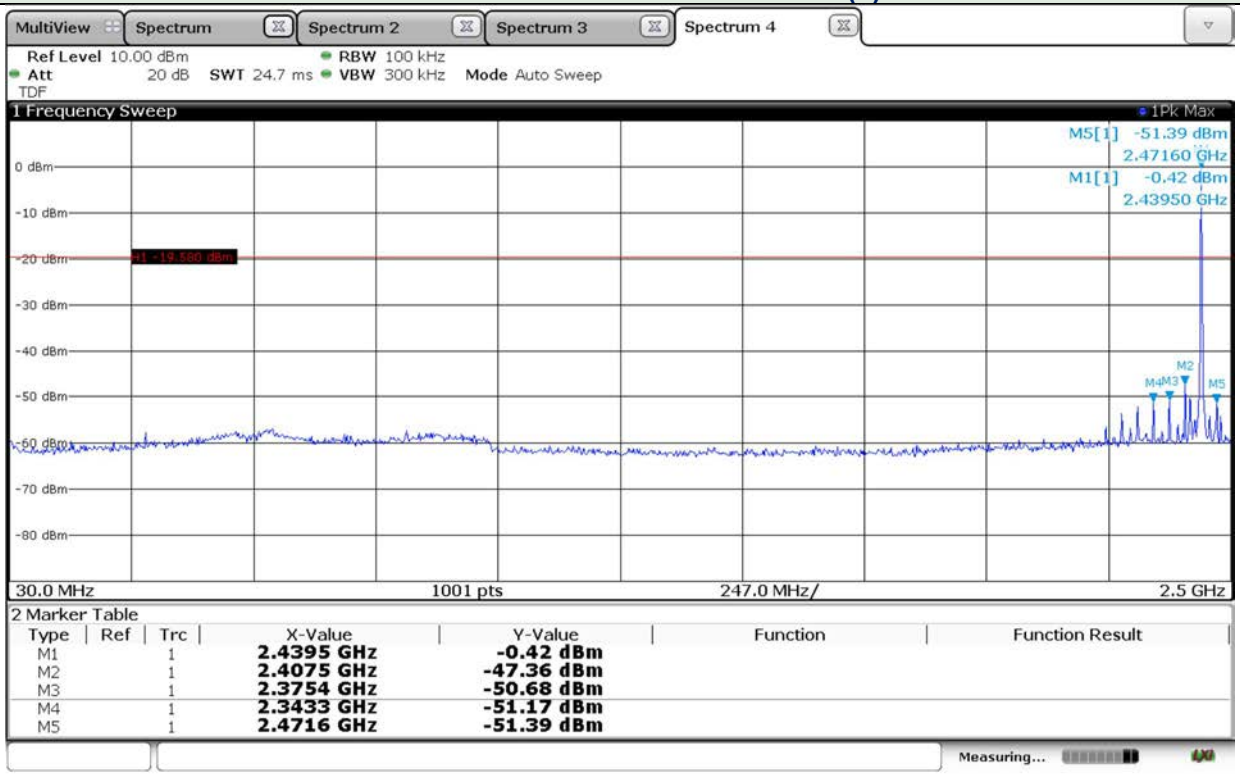
Non-restricted band – **Low Channel (1)**



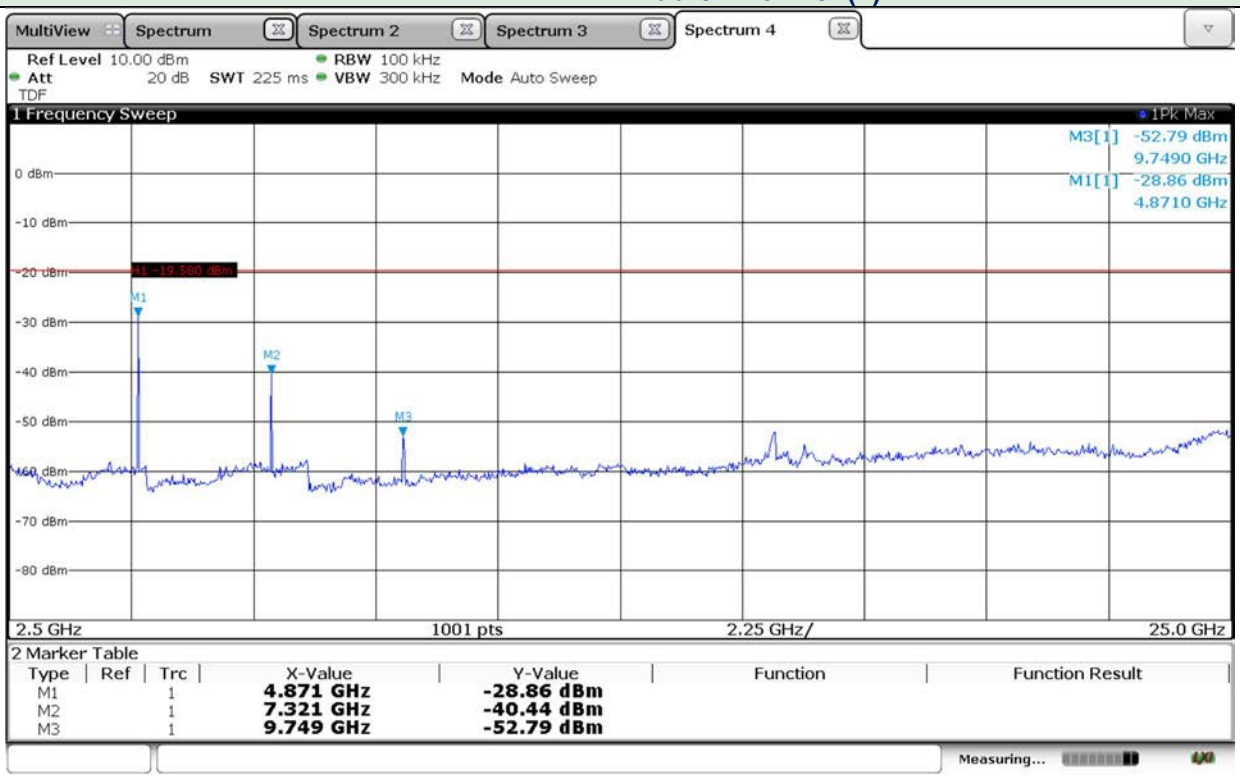

Non-restricted band – **Low Channel (2)**



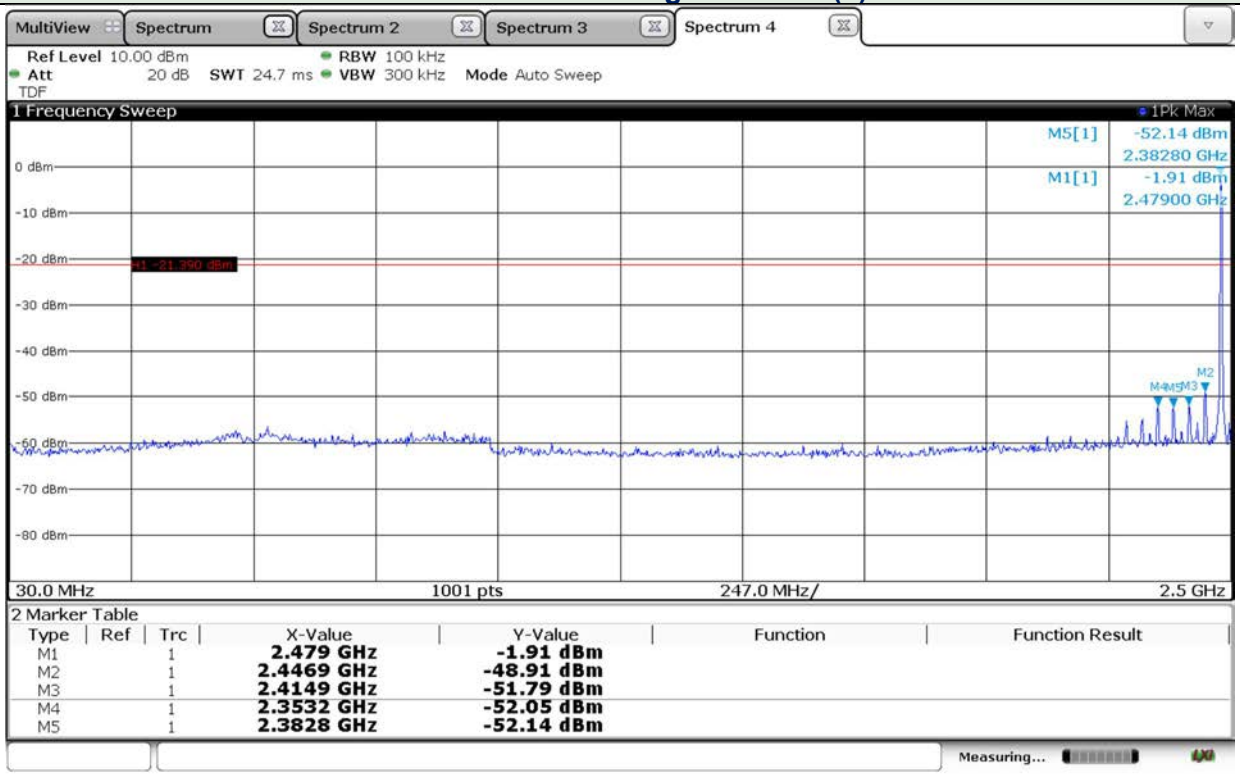
Non-restricted band – **Middle Channel (1)**



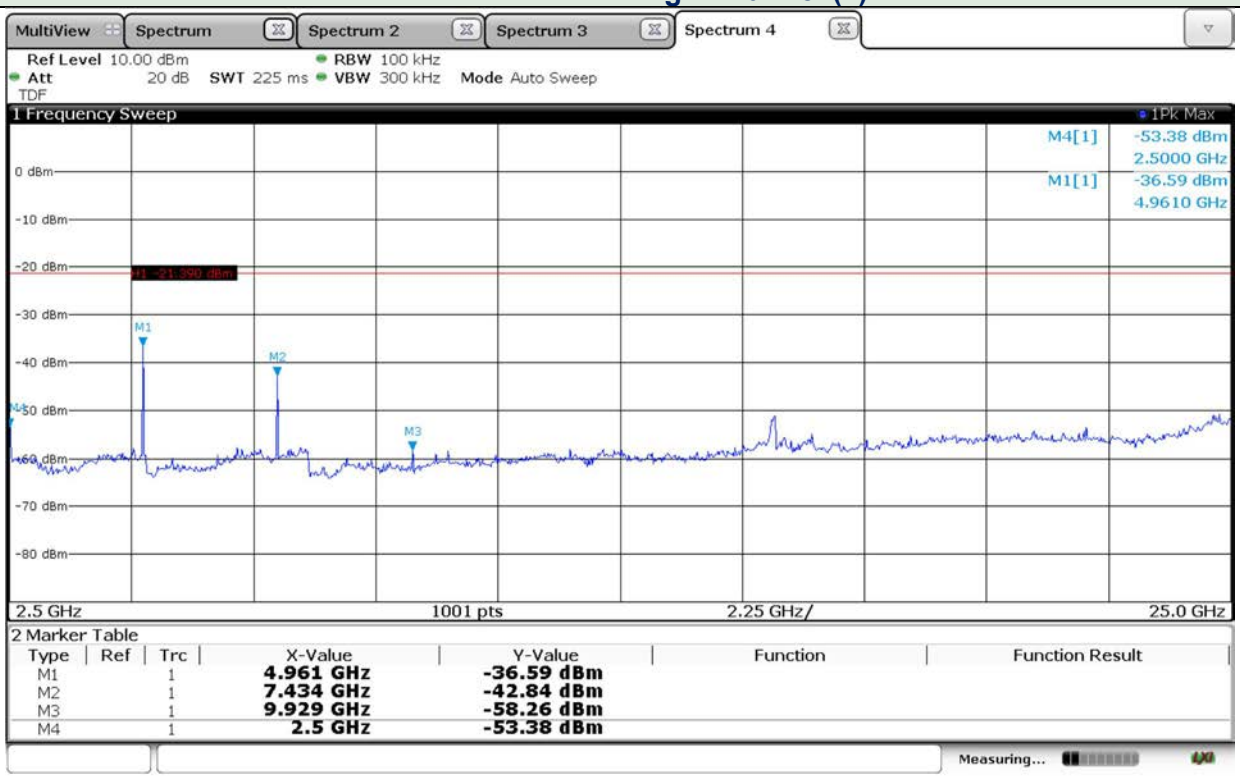

Non-restricted band – **Middle Channel (2)**



Non-restricted band – **High Channel (1)**




Non-restricted band – **High Channel (2)**



## 5.6 Radiated Emission

### 5.6.1 Limit

Acc. To section 15.205,15.209, RSS-GEN 8.9, following table shall be applied.

| Frequency Range (MHz) | Field Strength Limit (uV/m) at 3 m | Field Strength Limit (dBuV/m) at 3 m |
|---|---|---|
| 30 – 88 | 100 | 40 |
| 88 – 216 | 150 | 43.5 |
| 216 – 960 | 200 | 46 |
| Above 960 | 500 | 24 |

### 5.6.2 Method of Measurement

Reference to KDB 558074 D01 DTS Meas Guidance v05r02: 8.6 Radiated emission measurements.
The radiated emissions measurements were on 3 m, semi-anechoic chamber. The EUT and other support equipment were placed on a non-conductive table 80 cm for below 1 GHz and 1.5 m for above 1 GHz above the ground plane. The interconnecting cables from outside test site were inserted into ferrite clamps at the point where the cables reach the turntable.

The frequency spectrum from 30 MHz to 25 GHz was scanned and emission levels maximized at each frequency recorded. The system was rotated 360°, and the antenna was varied in height between 1.0 m and 4.0 m in order to determine the maximum emission levels. This procedure was performed for both horizontal and vertical polarization of the receiving antenna.

For measurement below 1 GHz, the resolution bandwidth is set to 100 kHz for peak detection measurements or 120 kHz for quasi-peak detection measurements. Peak detection is used unless otherwise noted as quasi-peak.

For peak emission measurements above 1 GHz the resolution bandwidth is set to 1 MHz; the video bandwidth is set to 3 MHz and for average measurement, resolution bandwidth is set to 1 MHz; and the video bandwidth is set to 10 Hz, when duty cycle is more than 98 %. If duty cycle is less than 98 %, the video bandwidth is set to ≥ 1/T, where T is the minimum transmission duration over which the transmitter is on and is transmitting at its maximum power control level for the tested mode of operation.

For measurements above 1 GHz the resolution bandwidth is set to 1 MHz; the video bandwidth is set to 3 MHz
The spectrum from 30 MHz to 25 GHz is investigated with the transmitter set to the lowest, middle, and highest channels in each applicable band.

### 5.6.3 Test Site Requirement for KDB 414788 D01

Acc. to KDB 414788 D01 Radiated Test Site v01, Semi Anechoic Chamber (SAC) shall be verified test results below 30 MHz with Open Area Test Site (OATS), so we compared test results between the measurements from our SAC and an OATS and found test results almost same, so we ***declare test result for below 30 MHz from our SAC is valid and met the requirement acc. to KDB 414788 D01 Radiated Test Site v01***.

### 5.6.4 Measurement Uncertainty

Measurement uncertainties were not taken into account and following uncertainty levels have been estimated for tests performed on the apparatus. The measurement uncertainties are given with at least 95 % confidence.

| Frequency Range | Uncertainty | Frequency Range | Uncertainty |
|---|---|---|---|
| 9 kHz ~ 30 MHz | ±2.6 dB | 30 MHz ~ 1 GHz | ±4.5 dB |
| 1 GHz ~ 18 GHz | ±5.0 dB | 18 GHz ~25 GHz | ±5.2 dB |

### 5.6.5 Sample Calculated Example

At 80 MHz Limit = 40.0 dBuV/m

Result (dBuV/m)

= Receiver Reading (dBuV) + Antenna Factor (dB/m) - Pre-amplifier Gain (dB) + Cable Loss (dB) = 30

Margin = Limit – Result = 40 – 30 = 10 so the EUT has 10.0 dB margin at 80 MHz

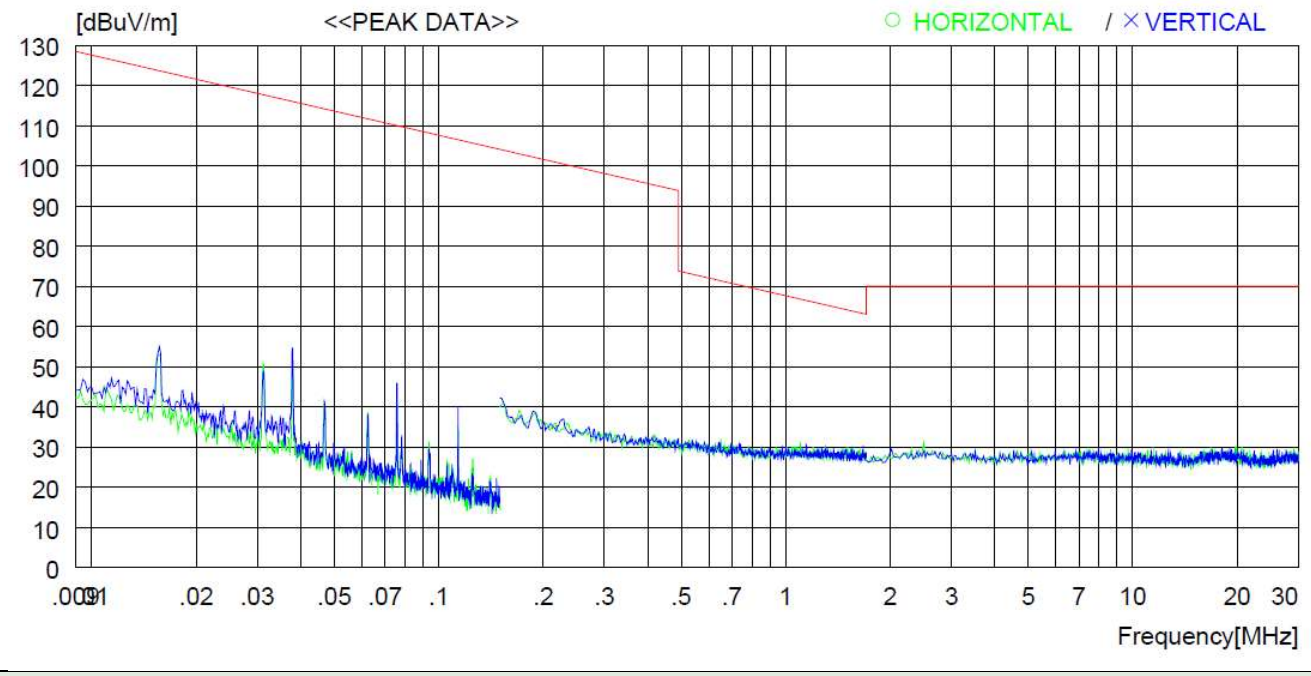
### 5.6.6 Test Data

| | | | |
|---|---|---|---|
| Date of Test | 2019-12-02 | Temperature | (22.1 ± 2.7) °C |
| | | Relative humidity | (40.9 ± 5.9) % R.H. |
| ***Measurement Frequency Range*** | | 9 kHz ~ 25 GHz | |
| ***Test Result*** | ***PASS*** | Tested By | Do-heon Kim |

| Frequency range | Detector Mode | Resolution BW | Video BW | Video Filtering | Measurement distance |
|---|---|---|---|---|---|
| Below 30 MHz | Peak or Q.P. | 9 kHz | 100 kHz | - | 3 m |
| 30 MHz ~ 1 000 MHz | Peak or Q.P. | 100 kHz | 300 kHz | - | 3 m |
| Above 1 GHz | Peak | 1 MHz | 3 MHz | | 3 m |
| | Average | 1 MHz | 3 MHz | | 3 m |

### 5.6.6.1 Test Data below 30 MHz

Graphical Test Data – Below 30 MHz




Tabulated Test Data – Low / Middle / High Channel

| Frequency (MHz) | Receiver Reading (dBuV) | Detector Mode | Pol. | Ant. Factor (dB/m) | Corr. Factor(dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Degree) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| * Spurious emissions that 20 dB below the limits didn't be recorded | | | | | | | | | | |
| | | | | | | | | | | |



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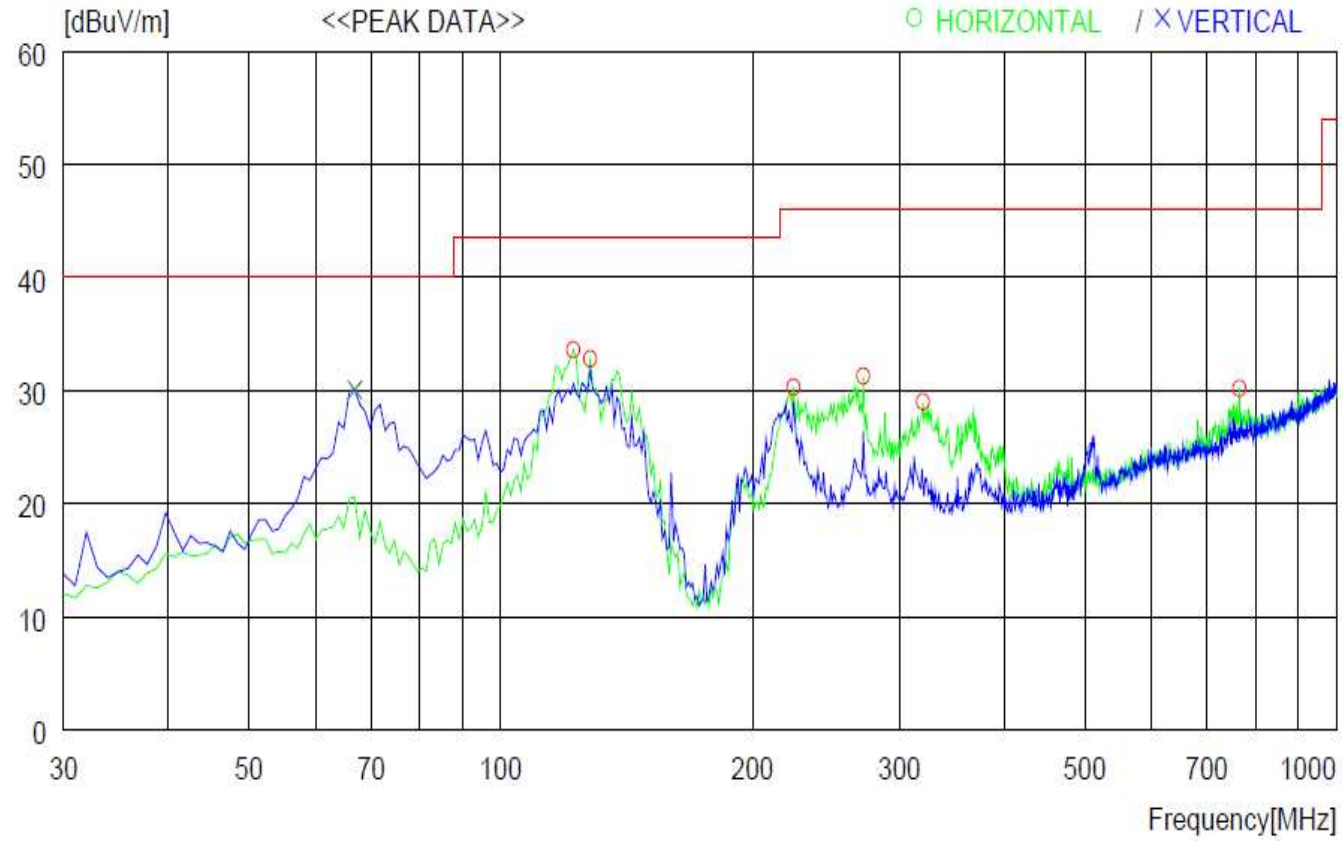
### 5.6.6.2 Test Data from 30 MHz to 1 GHz

Graphical Test Data – Below 1 GHz – **Low Channel (Peak)**




| No. | FREQ [MHz] | READING PEAK [dBuV] | ANT FACTOR [dB] | LOSS [dB] | GAIN [dB] | RESULT [dBuV/m] | LIMIT [dBuV/m] | MARGIN [dB] | ANTENNA [cm] | TABLE [DEG] |
|---|---|---|---|---|---|---|---|---|---|---|
| ----- Horizontal ------ | | | | | | | | | | |
| 1 | 122.150 | 48.5 | 9.5 | 8.2 | 32.6 | 33.6 | 43.5 | 9.9 | 200 | 295 |
| 2 | 127.970 | 48.3 | 8.9 | 8.2 | 32.6 | 32.8 | 43.5 | 10.7 | 200 | 0 |
| 3 | 224.000 | 42.1 | 11.8 | 9.0 | 32.6 | 30.3 | 46.0 | 15.7 | 100 | 275 |
| 4 | 271.530 | 41.7 | 12.8 | 9.4 | 32.6 | 31.3 | 46.0 | 14.7 | 100 | 252 |
| 5 | 320.030 | 38.1 | 13.7 | 9.8 | 32.6 | 29.0 | 46.0 | 17 | 100 | 359 |
| 6 | 765.253 | 30.3 | 20.6 | 12.1 | 32.8 | 30.2 | 46.0 | 15.8 | 100 | 119 |
| ----- Vertical ------ | | | | | | | | | | |
| 7 | 66.860 | 44.4 | 10.7 | 7.6 | 32.6 | 30.1 | 40.0 | 9.9 | 100 | 202 |



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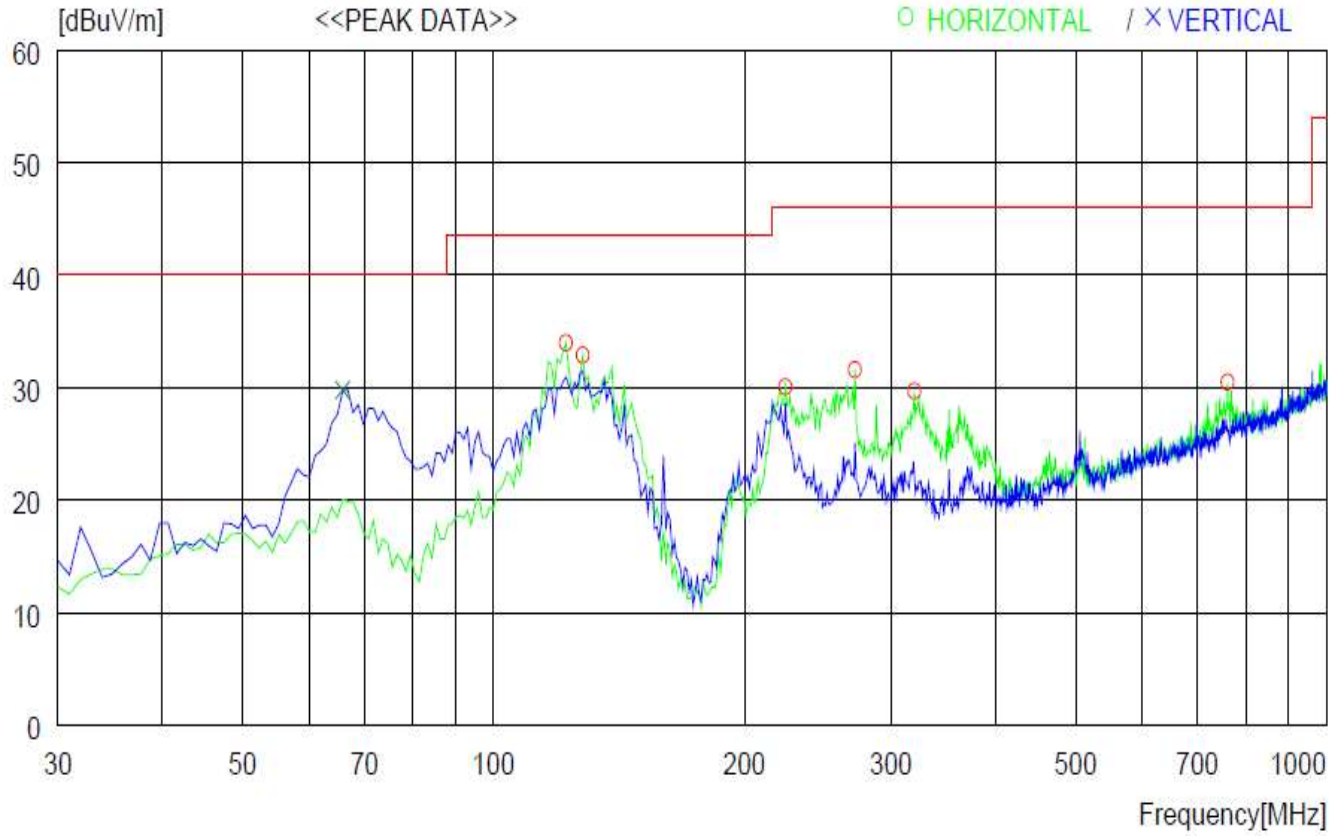
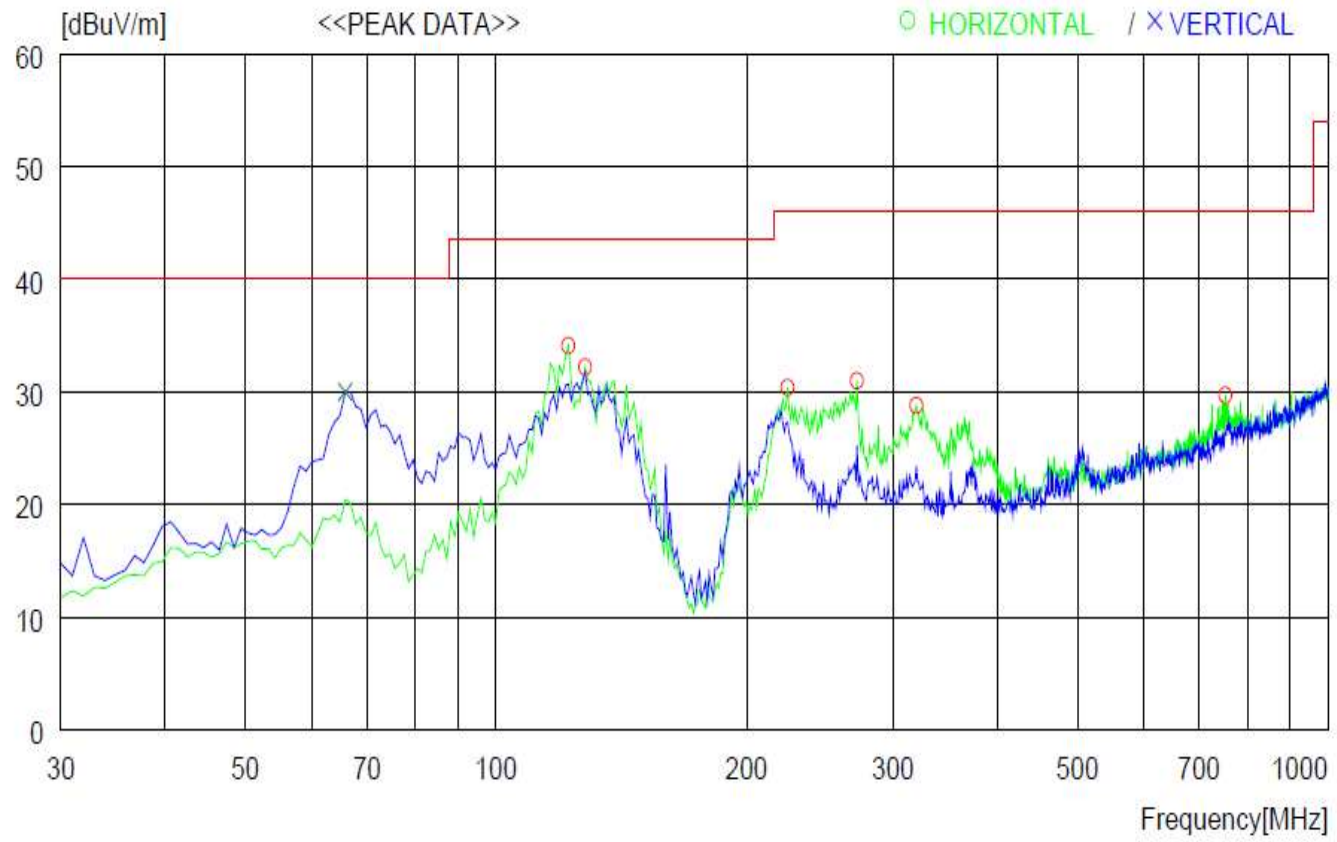
Graphical Test Data – Below 1 GHz – **Middle Channel (Peak)**




| No. | FREQ [MHz] | READING PEAK [dBuV] | ANT FACTOR [dB] | LOSS [dB] | GAIN [dB] | RESULT [dBuV/m] | LIMIT [dBuV/m] | MARGIN [dB] | ANTENNA [cm] | TABLE [DEG] |
|---|---|---|---|---|---|---|---|---|---|---|
| ----- Horizontal ------ | | | | | | | | | | |
| 1 | 122.150 | 48.9 | 9.5 | 8.2 | 32.6 | 34.0 | 43.5 | 9.5 | 200 | 0 |
| 2 | 127.970 | 48.4 | 8.9 | 8.2 | 32.6 | 32.9 | 43.5 | 10.6 | 200 | 279 |
| 3 | 224.000 | 41.9 | 11.8 | 9.0 | 32.6 | 30.1 | 46.0 | 15.9 | 100 | 299 |
| 4 | 271.530 | 42.0 | 12.8 | 9.4 | 32.6 | 31.6 | 46.0 | 14.4 | 100 | 262 |
| 5 | 320.030 | 38.8 | 13.7 | 9.8 | 32.6 | 29.7 | 46.0 | 16.3 | 100 | 269 |
| 6 | 760.403 | 30.6 | 20.6 | 12.1 | 32.8 | 30.5 | 46.0 | 15.5 | 100 | 112 |
| ----- Vertical ------ | | | | | | | | | | |
| 7 | 65.890 | 43.8 | 11.0 | 7.6 | 32.6 | 29.8 | 40.0 | 10.2 | 100 | 0 |

Note: “H” means Horizontal polarity, “V” means Vertical polarity.

Graphical Test Data – Below 1 GHz – **High Channel (Peak)**




| No. | FREQ [MHz] | READING PEAK [dBuV] | ANT FACTOR [dB] | LOSS [dB] | GAIN [dB] | RESULT [dBuV/m] | LIMIT [dBuV/m] | MARGIN [dB] | ANTENNA TABLE [cm] | [DEG] |
|---|---|---|---|---|---|---|---|---|---|---|
| ----- Horizontal ------ | | | | | | | | | | |
| 1 | 122.150 | 49.0 | 9.5 | 8.2 | 32.6 | 34.1 | 43.5 | 9.4 | 200 | 294 |
| 2 | 127.970 | 47.7 | 8.9 | 8.2 | 32.6 | 32.2 | 43.5 | 11.3 | 200 | 294 |
| 3 | 224.000 | 42.2 | 11.8 | 9.0 | 32.6 | 30.4 | 46.0 | 15.6 | 100 | 274 |
| 4 | 271.530 | 41.4 | 12.8 | 9.4 | 32.6 | 31.0 | 46.0 | 15 | 100 | 250 |
| 5 | 320.030 | 37.9 | 13.7 | 9.8 | 32.6 | 28.8 | 46.0 | 17.2 | 100 | 359 |
| 6 | 752.643 | 30.0 | 20.5 | 12.0 | 32.8 | 29.7 | 46.0 | 16.3 | 100 | 359 |
| ----- Vertical ------ | | | | | | | | | | |
| 7 | 65.890 | 44.0 | 11.0 | 7.6 | 32.6 | 30.0 | 40.0 | 10 | 100 | 0 |

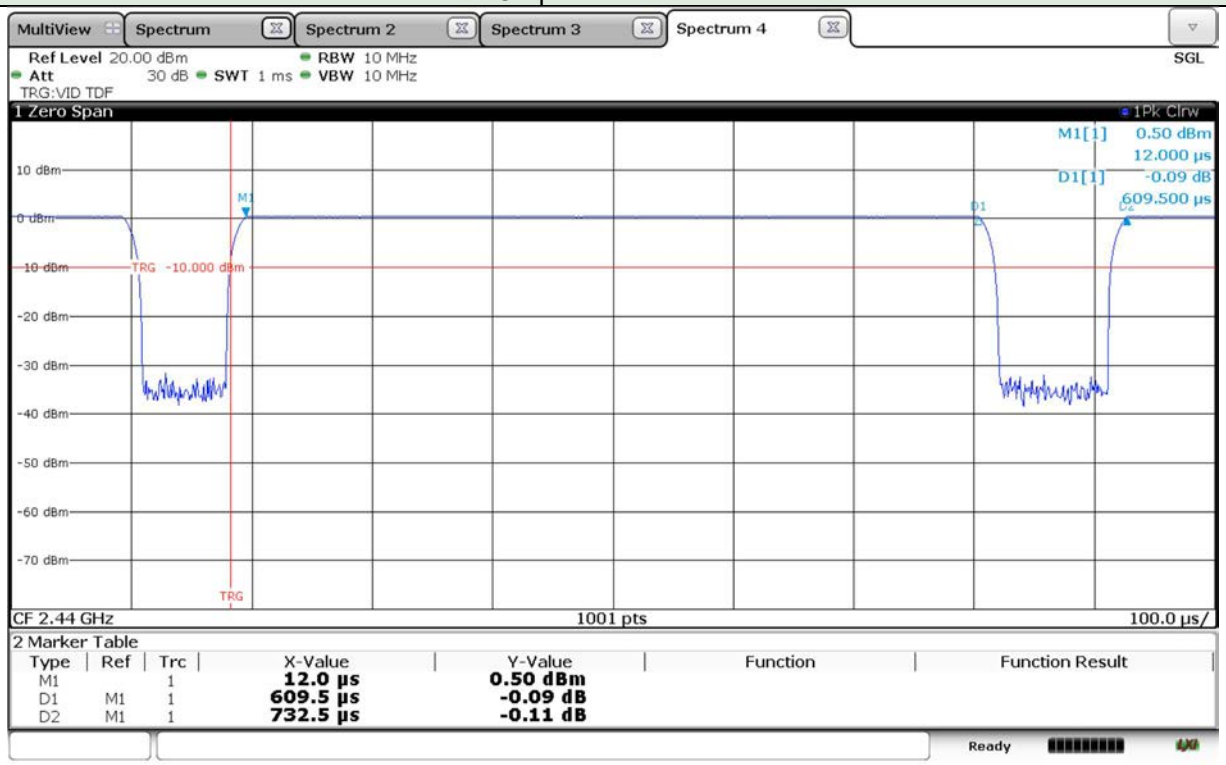
### 5.6.6.3 Test Data above 1 GHz

### 5.6.6.3.1 Duty Cycle

| | | | |
|---|---|---|---|
| Date of Test | 2019-12-02 | Temperature | (22.1 ± 2.7) °C |
| | | Relative humidity | (40.9 ± 5.9) % R.H. |
| Measurement Distance | 3 m | Tested By | Do-heon Kim |

| Detector Mode | Resolution BW | Video BW | Sweep Time |
|---|---|---|---|
| PEAK | 1 MHz | 3 MHz | Auto |
| AVERAGE | 1 MHz | 3 MHz | Auto |

Graphical Test Data



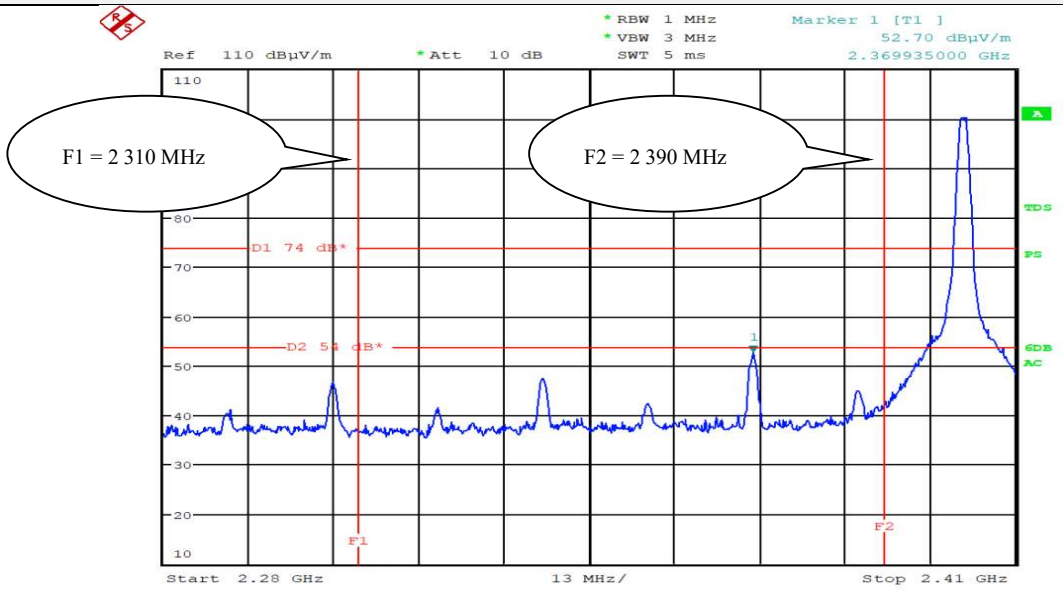

Tabulated Test Data

| Operating Mode | On Time (ms) | On + Off Time (ms) | Duty Cycle (%) | Duty Factor (dB) |
|---|---|---|---|---|
| Bluetooth LE | 609.5 | 732.5 | 83.21 | 0.80 |

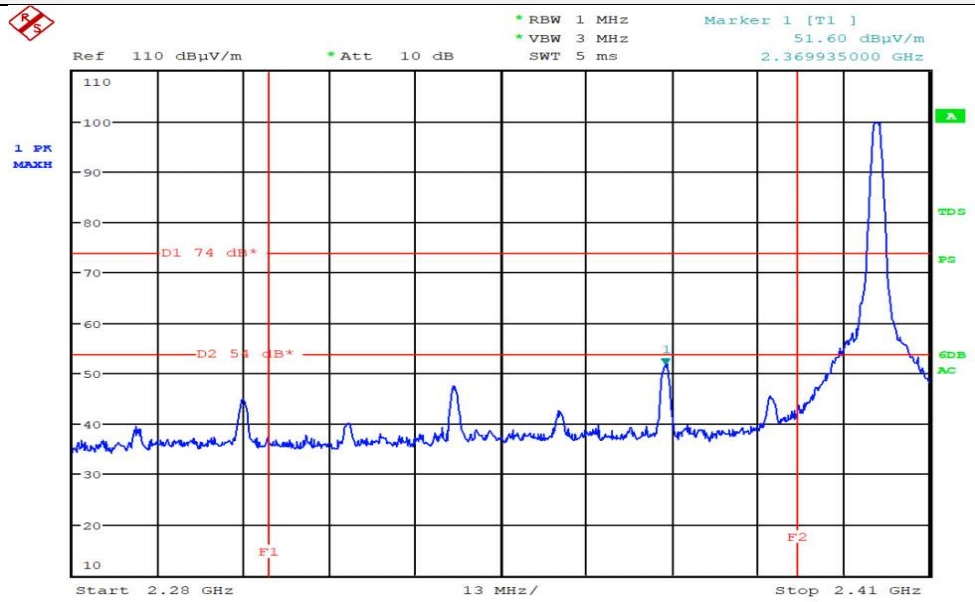
### 5.6.6.3.2 Test Data for Band edge (Restricted band)

Graphical Test Data – **Low Channel (Peak)**

Horizontal




Vertical




Tabulated Test Data – Low Channel

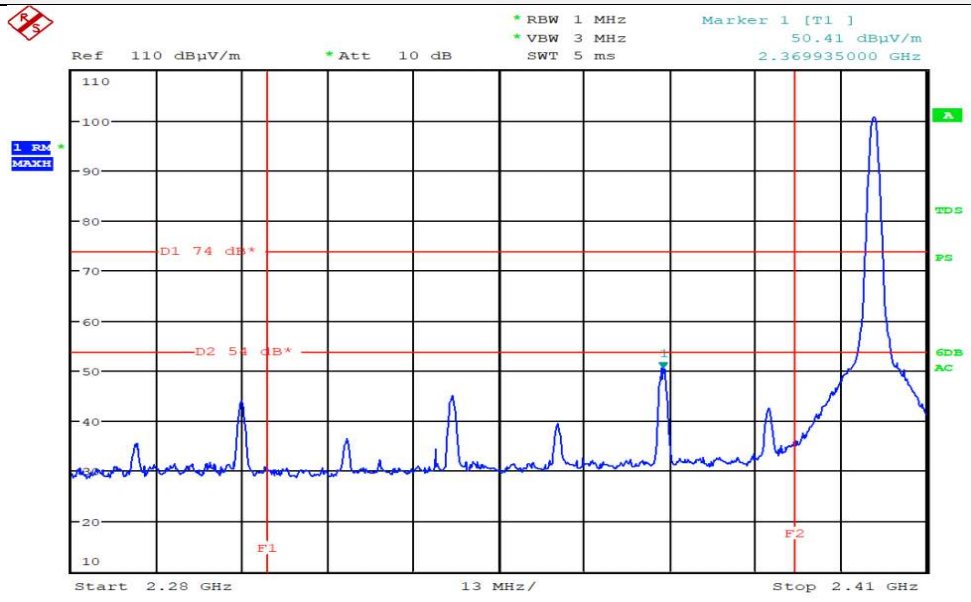
| Freq. (MHz) | Detector Mode | Pol. | Measured Value (dBuV/m) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|
| 2 369.9 | Peak | H | 52.70 | - | 52.70 | 74.00 | 21.30 | 130 | 250 |
| 2 369.9 | Peak | V | 51.60 | - | 51.60 | 74.00 | 22.40 | 140 | 10 |

**NOTE:** "H" means Horizontal polarity, "V" means Vertical polarity.

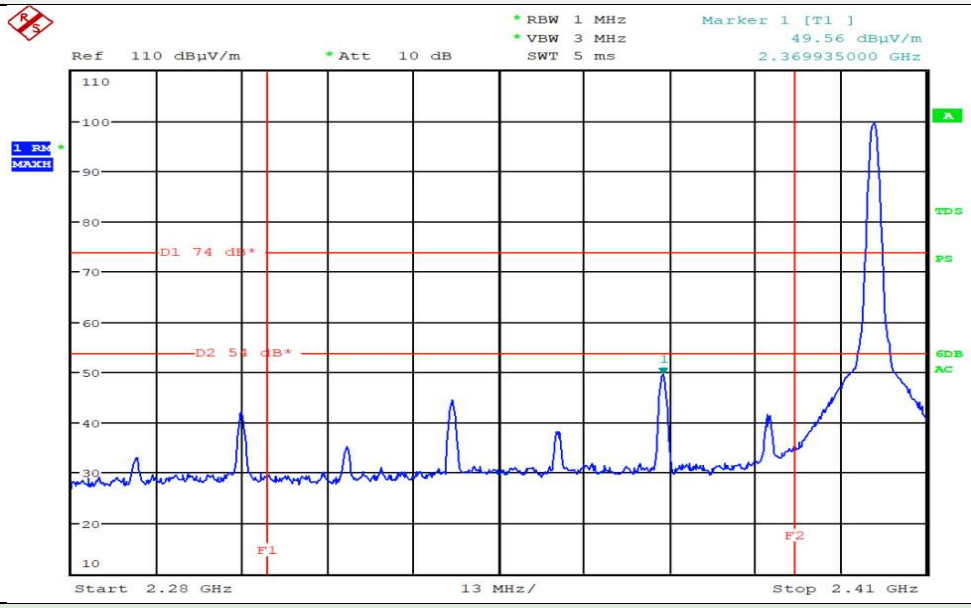
Measured Value = Receiver reading + Antenna Factor + Cable Loss - Pre-amplifier Gain

Graphical Test Data – **Low Channel (Average)**

Horizontal




Vertical




Tabulated Test Data – Low Channel

| Freq. (MHz) | Detector Mode | Pol. | Measured Value (dBuV/m) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|
| 2 369.9 | RMS | H | 50.41 | 0.80 | 51.21 | 54.00 | 2.79 | 130 | 250 |
| 2 369.9 | RMS | V | 49.56 | 0.80 | 50.36 | 54.00 | 3.64 | 140 | 10 |

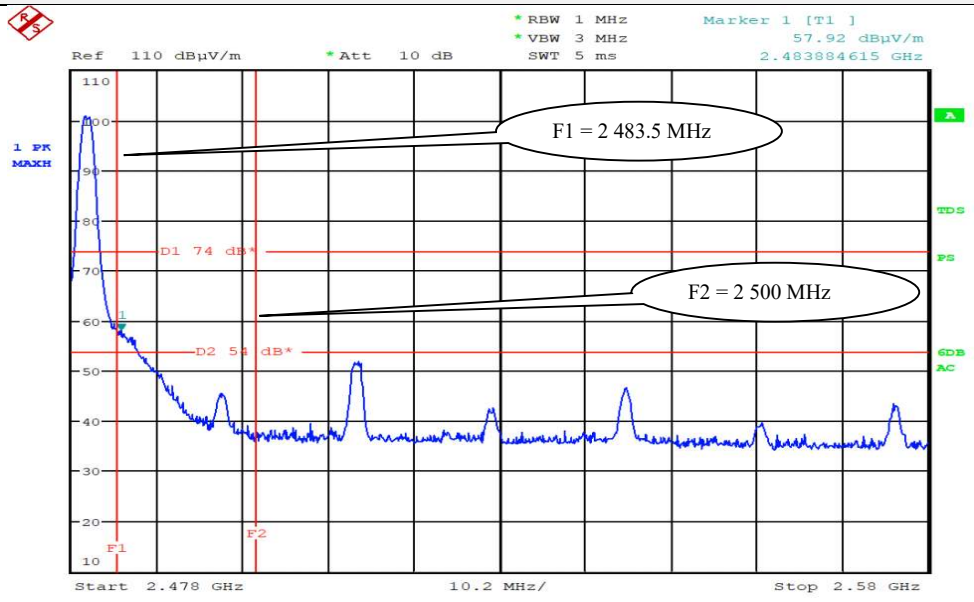
**NOTE:** "H" means Horizontal polarity, "V" means Vertical polarity.

Measured Value = Receiver reading + Antenna Factor + Cable Loss - Pre-amplifier Gain

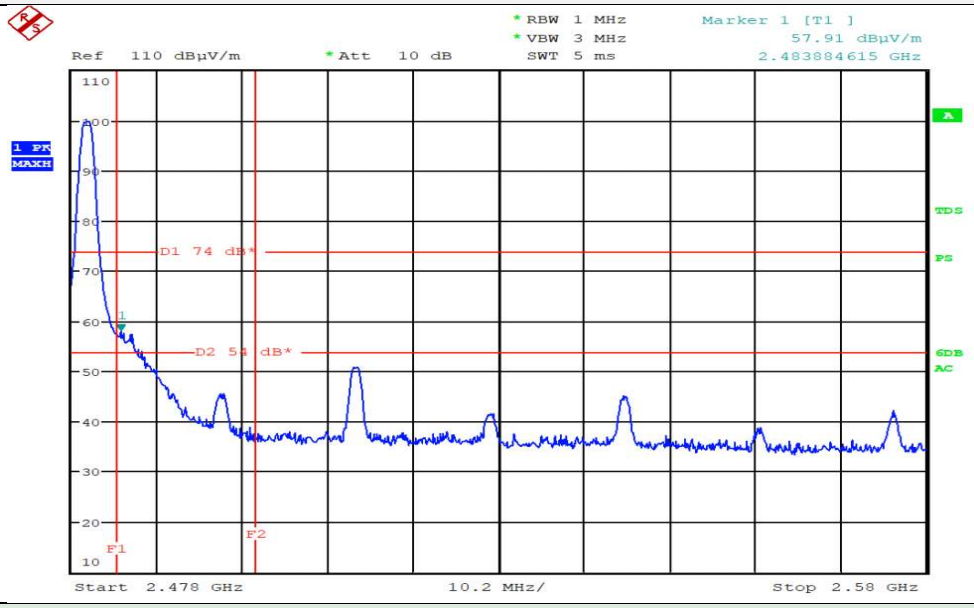
Result = Measured Value + Duty Factor

Graphical Test Data – **High Channel (Peak)**

Horizontal




Vertical



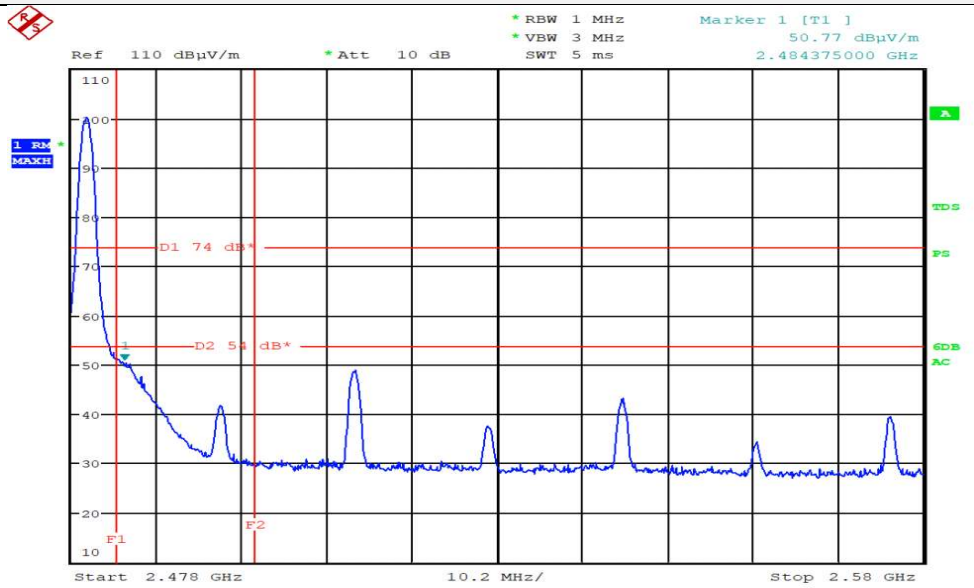

Tabulated Test Data – High Channel

| Freq. (MHz) | Detector Mode | Pol. | Measured Value (dBuV/m) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|
| 2 483.9 | Peak | H | 57.92 | - | 57.92 | 74.00 | 16.08 | 140 | 250 |
| 2 483.9 | Peak | V | 57.91 | - | 57.91 | 74.00 | 16.09 | 200 | 20 |

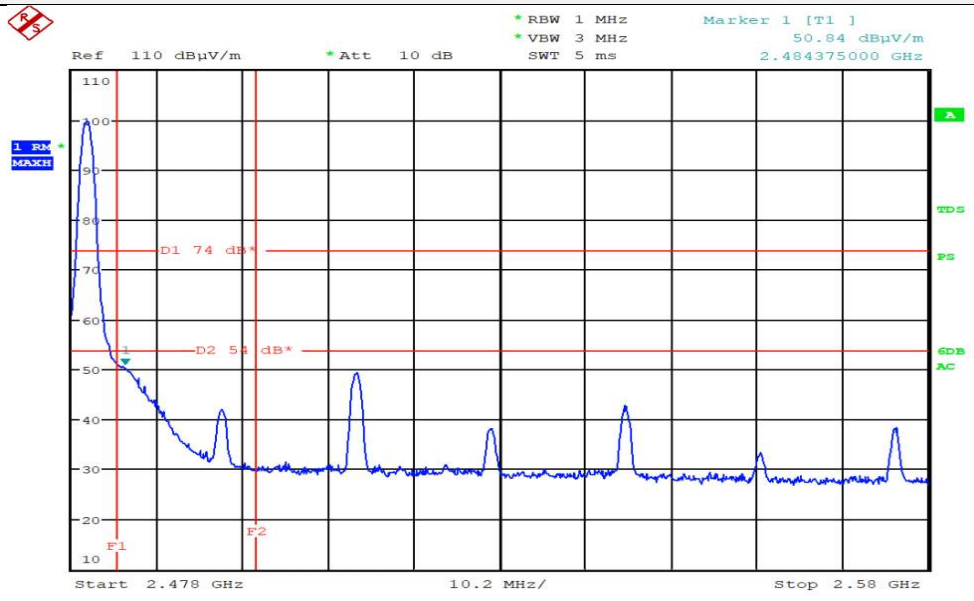
**NOTE:** "H" means Horizontal polarity, "V" means Vertical polarity.

Graphical Test Data – **High Channel (Average)**

Horizontal




Vertical




Tabulated Test Data – High Channel

| Freq. (MHz) | Detector Mode | Pol. | Measured Value (dBuV/m) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|
| 2 484.4 | RMS | H | 50.77 | 0.80 | 51.57 | 54.00 | 2.43 | 140 | 250 |
| 2 484.4 | RMS | V | 50.84 | 0.80 | 51.64 | 54.00 | 2.36 | 200 | 20 |

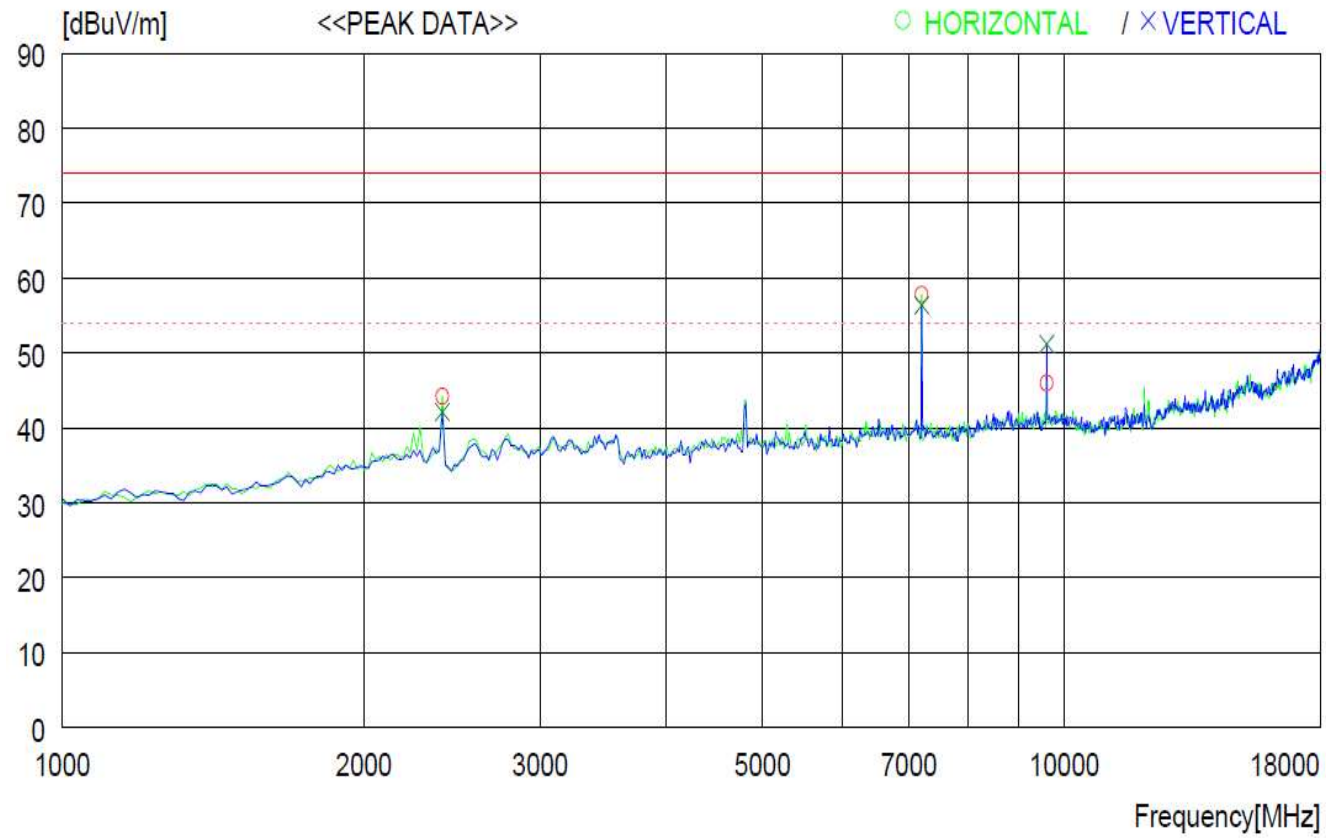
**NOTE:** "H" means Horizontal polarity, "V" means Vertical polarity.

Result = Measured Value + Duty Factor

### 5.6.6.4 Test Data for Harmonic & Spurious emission (1 GHz to 18 GHz)

### 5.6.6.4.1 Operating mode: Bluetooth LE

Graphical Test Data – **Low Channel (Peak)**




| Freq. (MHz) | Detector Mode | Pol. | Receiver Reading (dBuV) | Ant. Factor (dB/m) | Corr. Factor (dB) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tabulated Test Data – Low Channel | | | | | | | | | | | |
| 7 205.0 | Peak | H | 55.6 | 35.1 | 32.9 | - | 57.8 | 74.0 | 16.2 | 150 | 359 |
| * Spurious emissions that 20 dB below the limits didn't be recorded | | | | | | | | | | | |

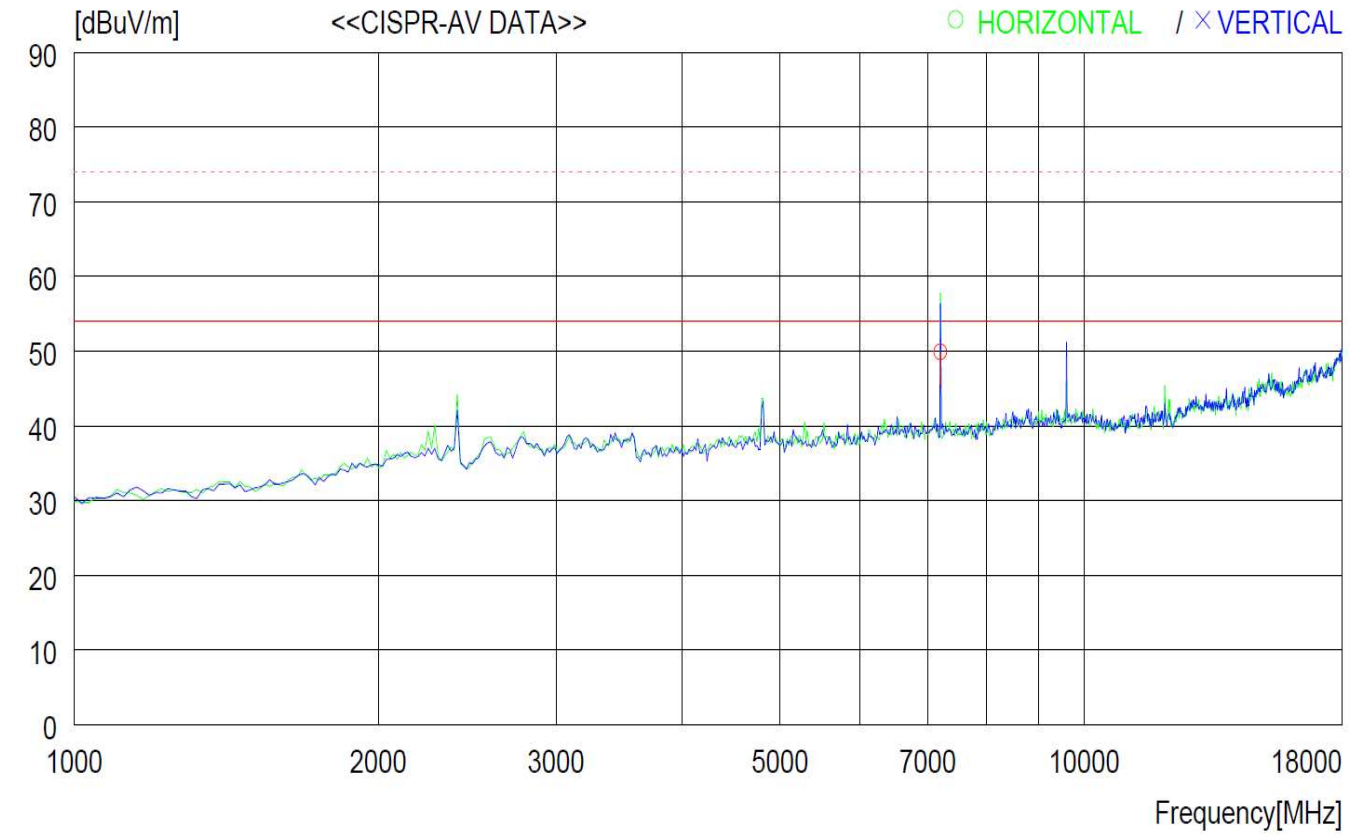
Note. "H" means Horizontal polarity, "V" means Vertical polarity.

Corr. Factor (dB) = Pre-amplifier gain - Cable Loss

Result = Receiver Reading + Antenna Factor - Corr. Factor + Duty factor

Margin = Limit – Result

Graphical Test Data – **Low Channel (Average)**




| Freq. (MHz) | Detector Mode | Pol. | Receiver Reading (dBuV) | Ant. Factor (dB/m) | Corr. Factor (dB) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tabulated Test Data – Low Channel | | | | | | | | | | | |
| 7 205.0 | Average | H | 47.7 | 35.1 | 32.9 | - | 49.9 | 54.0 | 4.1 | 150 | 359 |

Note. "H" means Horizontal polarity, "V" means Vertical polarity.

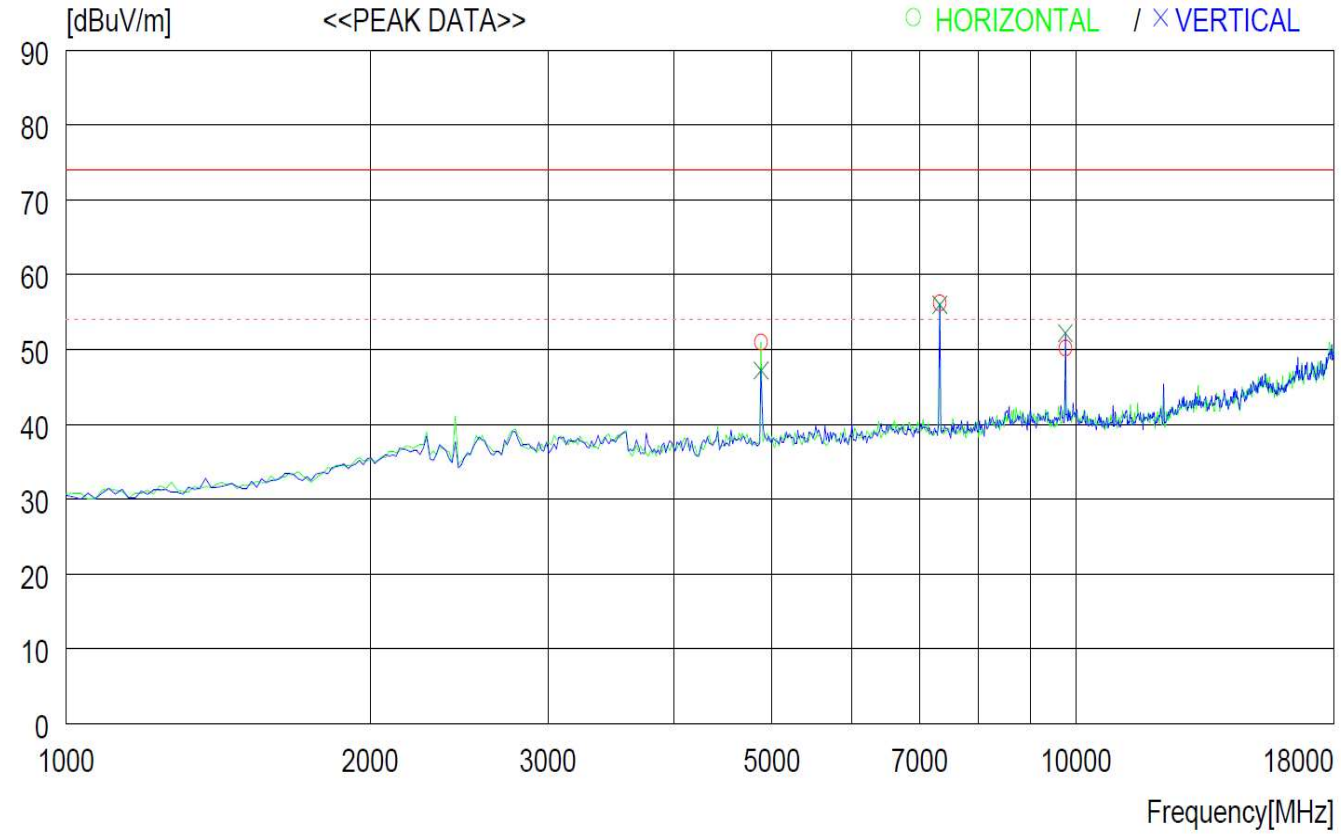
Corr. Factor (dB) = Pre-amplifier gain - Cable Loss

Result = Receiver Reading + Antenna Factor - Corr. Factor + Duty factor

Margin = Limit – Result

Non-restricted band emission is not added duty factor.

Graphical Test Data – **Middle Channel (Peak)**




| Freq. (MHz) | Detector Mode | Pol. | Receiver Reading (dBuV) | Ant. Factor (dB/m) | Corr. Factor (dB) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tabulated Test Data – Low Channel | | | | | | | | | | | |
| 7 324.0 | Peak | H | 53.9 | 35.2 | 32.9 | - | 56.2 | 74.0 | 17.8 | 150 | 186 |
| * Spurious emissions that 20 dB below the limits didn't be recorded | | | | | | | | | | | |

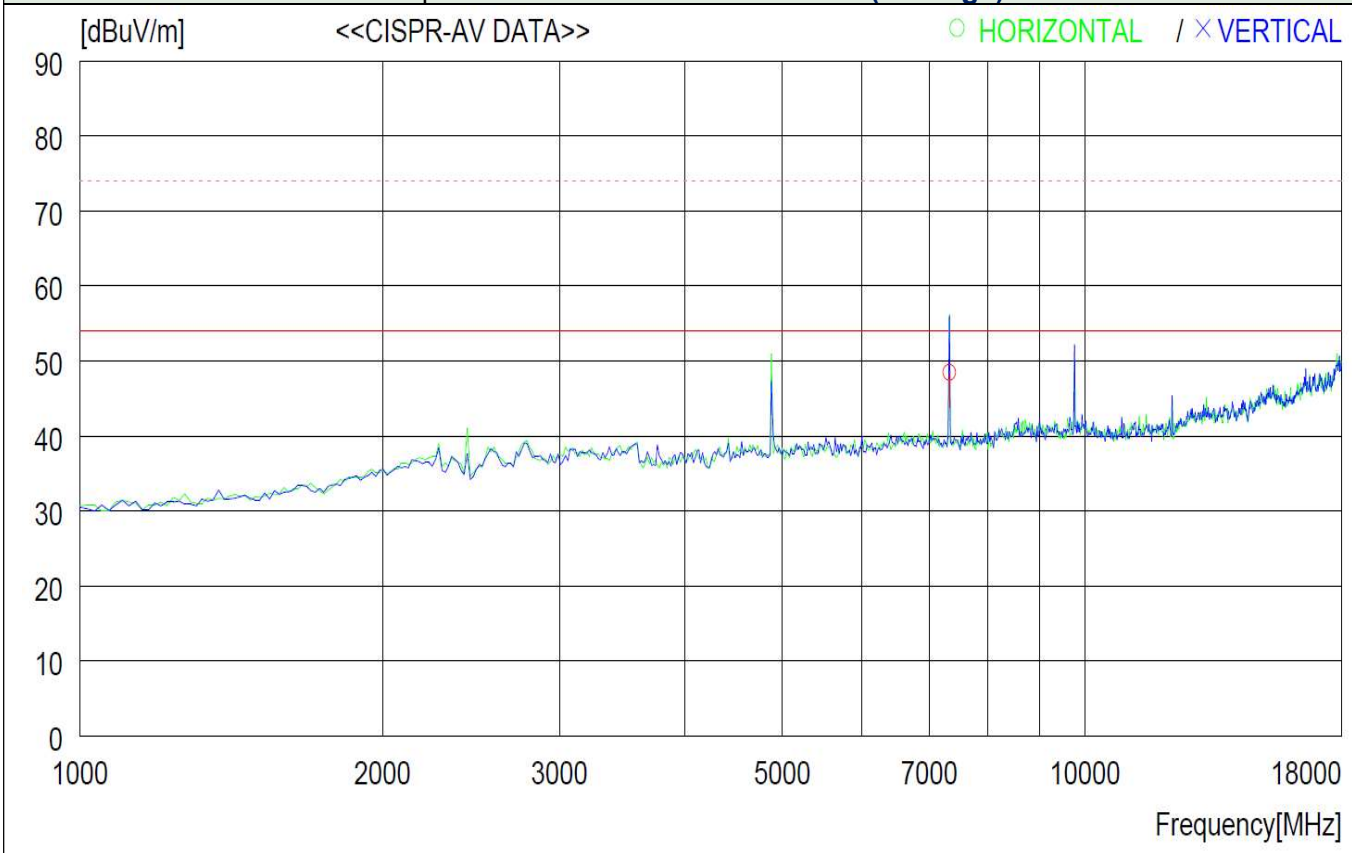
Note. "H" means Horizontal polarity, "V" means Vertical polarity.

Corr. Factor (dB) = Pre-amplifier gain - Cable Loss

Result = Receiver Reading + Antenna Factor - Corr. Factor + Duty factor

Margin = Limit – Result

Graphical Test Data – **Middle Channel (Average)**




| Freq. (MHz) | Detector Mode | Pol. | Receiver Reading (dBuV) | Ant. Factor (dB/m) | Corr. Factor (dB) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tabulated Test Data – Low Channel | | | | | | | | | | | |
| 7 324.0 | Average | H | 46.2 | 35.2 | 32.9 | - | 49.3 | 54.0 | 4.7 | 150 | 186 |

Note. "H" means Horizontal polarity, "V" means Vertical polarity.

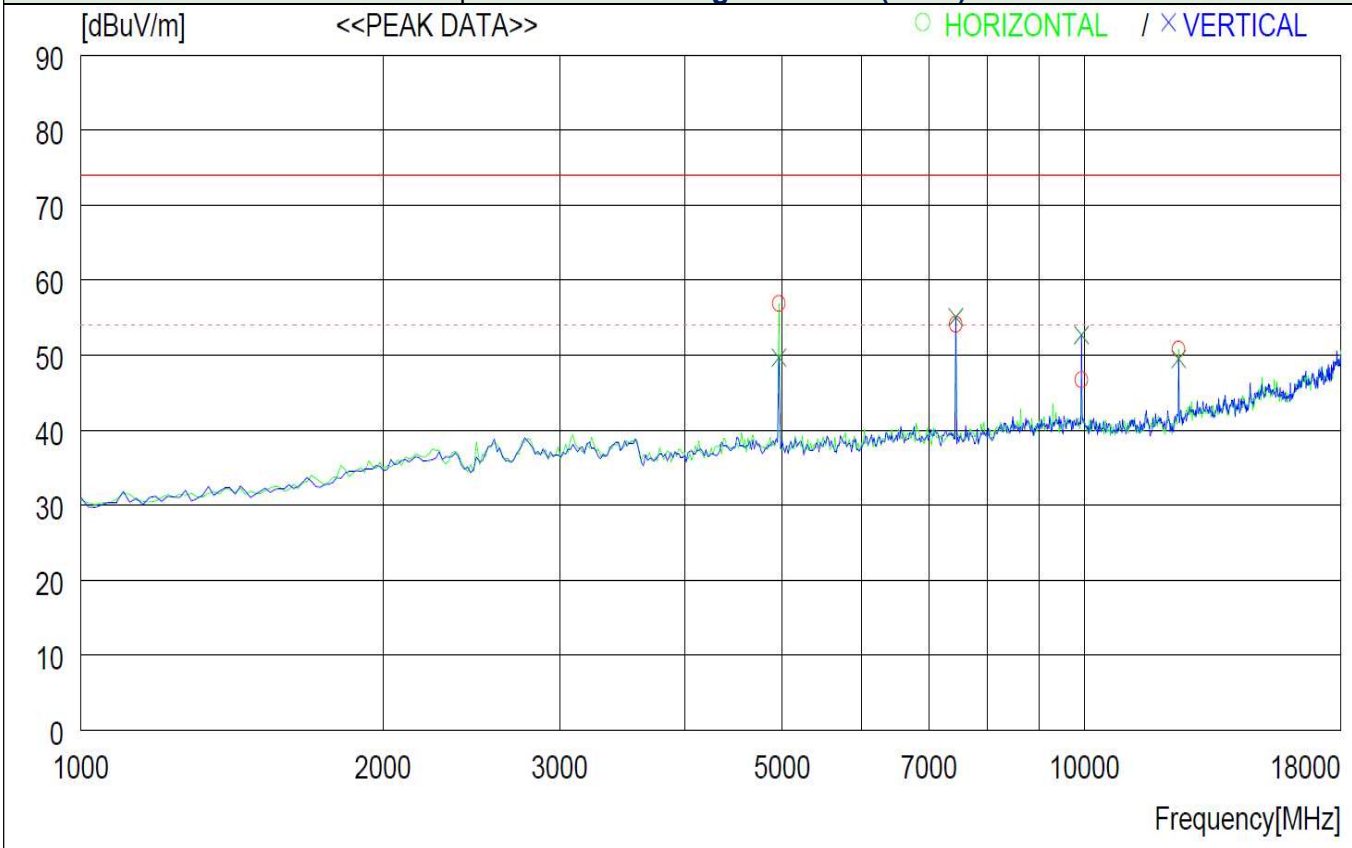
Corr. Factor (dB) = Pre-amplifier gain - Cable Loss

Result = Receiver Reading + Antenna Factor - Corr. Factor + Duty factor

Margin = Limit – Result

Non-restricted band emission is not added duty factor.

Graphical Test Data – **High Channel (Peak)**




| Freq. (MHz) | Detector Mode | Pol. | Receiver Reading (dBuV) | Ant. Factor (dB/m) | Corr. Factor (dB) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tabulated Test Data – Low Channel | | | | | | | | | | | |
| 4 961.0 | Peak | H | 57.2 | 33.8 | 34.1 | - | 56.9 | 74.0 | 17.1 | 150 | 193 |
| 7 443.0 | Peak | V | 52.7 | 35.3 | 32.9 | - | 55.1 | 74.0 | 18.9 | 150 | 359 |
| * Spurious emissions that 20 dB below the limits didn't be recorded | | | | | | | | | | | |

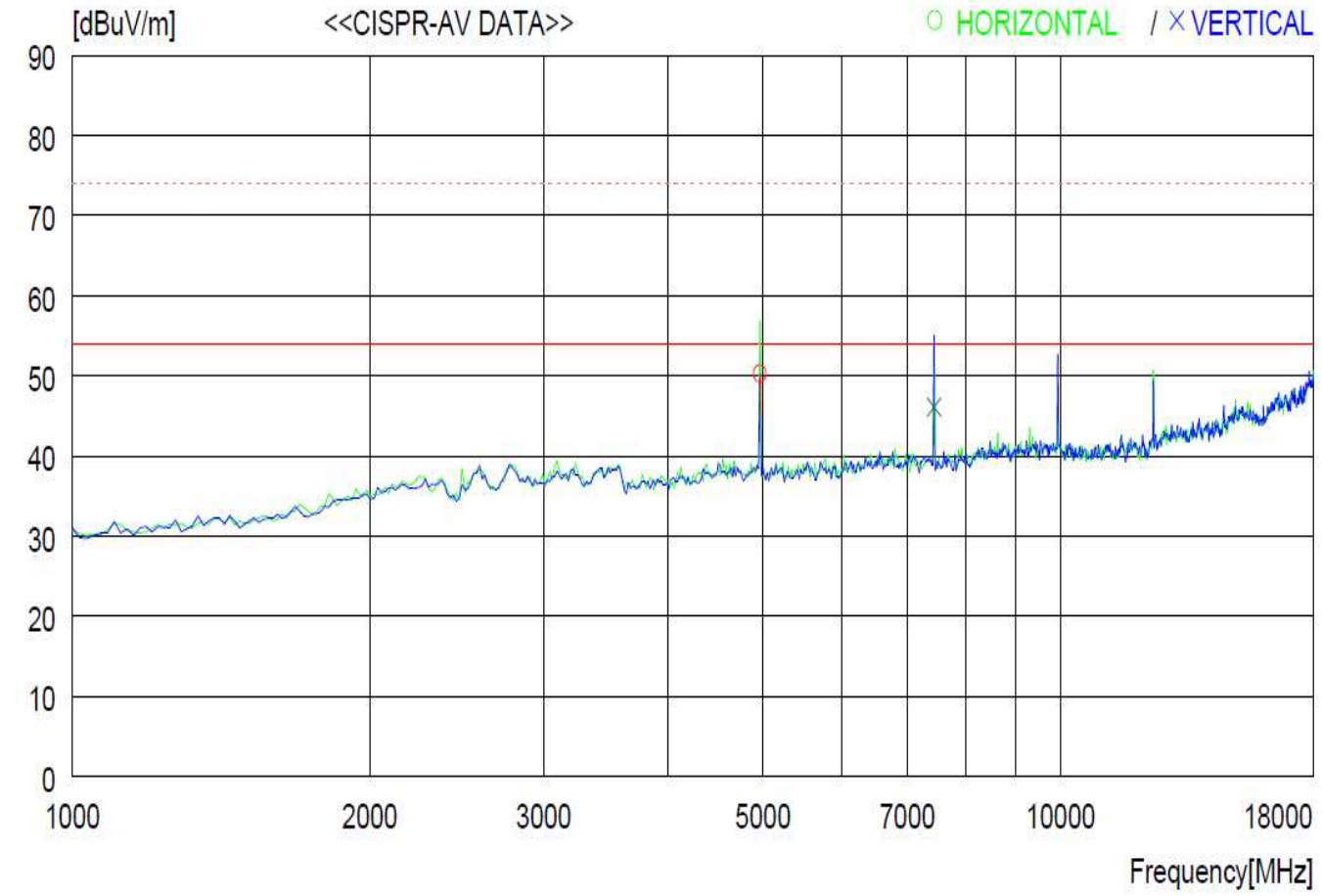
Note. "H" means Horizontal polarity, "V" means Vertical polarity.

Corr. Factor (dB) = Pre-amplifier gain - Cable Loss

Result = Receiver Reading + Antenna Factor - Corr. Factor + Duty factor

Margin = Limit – Result

Graphical Test Data – **High Channel (Average)**




| Freq. (MHz) | Detector Mode | Pol. | Receiver Reading (dBuV) | Ant. Factor (dB/m) | Corr. Factor (dB) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tabulated Test Data – Low Channel | | | | | | | | | | | |
| 4 961 | Average | H | 50.6 | 33.8 | 34.1 | - | 50.3 | 54.0 | 3.7 | 150 | 193 |
| 7 443 | Average | V | 43.7 | 35.3 | 32.9 | - | 46.1 | 54.0 | 7.9 | 150 | 359 |

Note. "H" means Horizontal polarity, "V" means Vertical polarity.

Corr. Factor (dB) = Pre-amplifier gain - Cable Loss

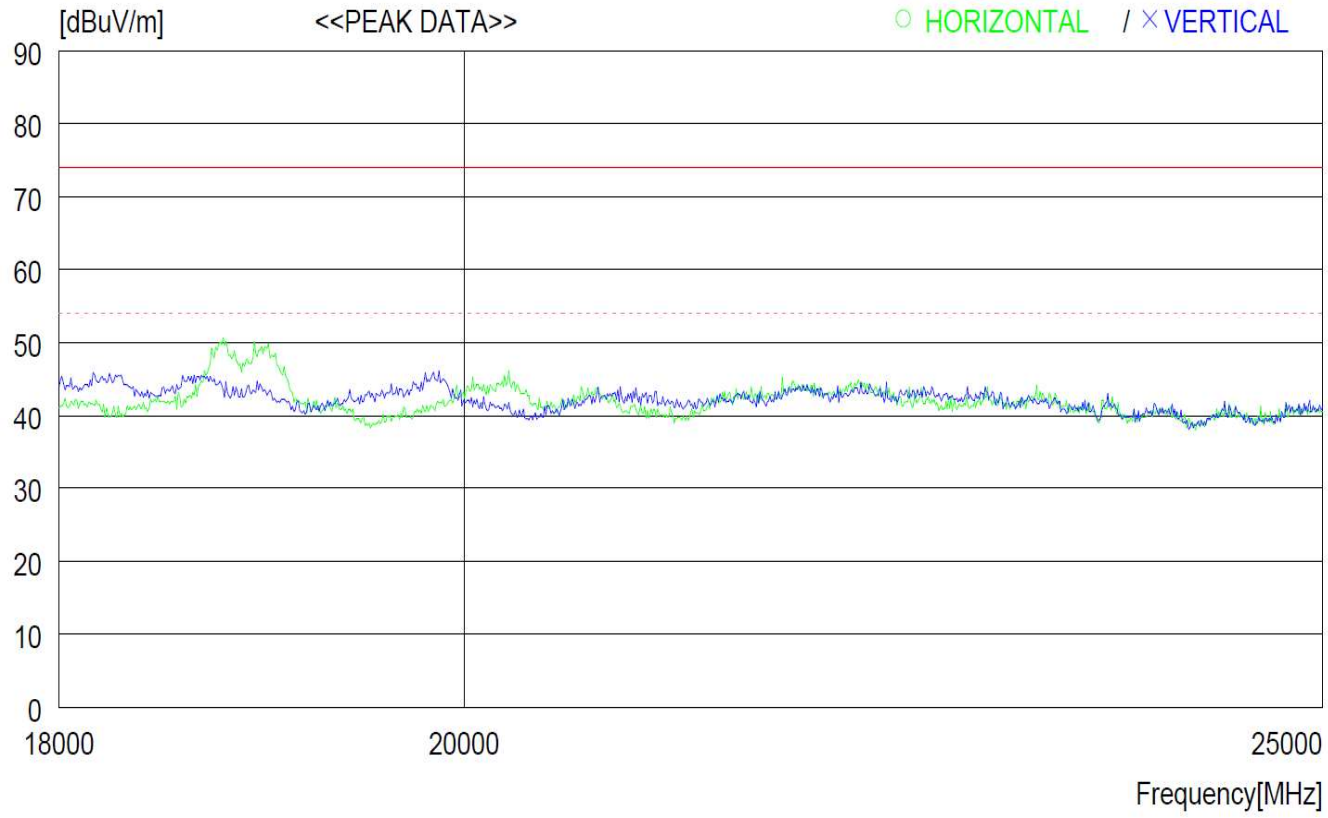
Result = Receiver Reading + Antenna Factor - Corr. Factor + Duty factor

Margin = Limit – Result

Non-restricted band emission is not added duty factor.

### 5.6.6.5 Test Data for Harmonic & Spurious emission (18 GHz to 25 GHz)

Graphical Test Data – **Low Channel (Peak)**




| Freq. (MHz) | Detector Mode | Pol. | Receiver Reading (dBuV) | Ant. Factor (dB/m) | Corr. Factor (dB) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Low / Middle / High Channel | | | | | | | | | | | |

* Spurious emissions that 20 dB below the limits didn't be recorded

**NOTE:** Peak results are met average limit, so average measurement was not performed.

Emission was scanned up to 25 GHz; No emissions were detected above the noise floor which was at least 20 dB below the specification limit

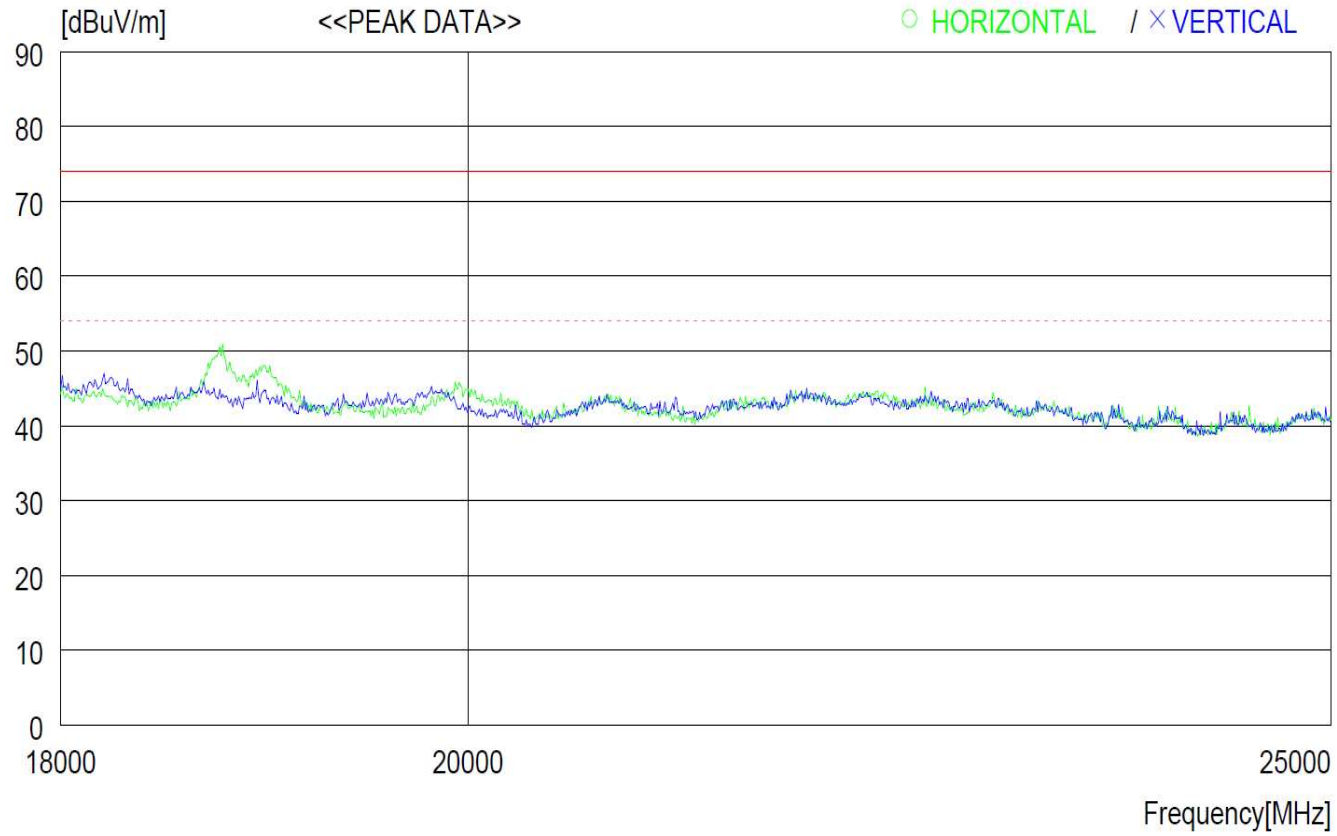
Note. "H" means Horizontal polarity, "V" means Vertical polarity.

Corr. Factor (dB) = Pre-amplifier gain - Cable Loss

Result = Receiver Reading + Antenna Factor - Corr. Factor + Duty factor

Margin = Limit – Result

Graphical Test Data – **Middle Channel (Peak)**




| Freq. (MHz) | Detector Mode | Pol. | Receiver Reading (dBuV) | Ant. Factor (dB/m) | Corr. Factor (dB) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|---|---|

Low / Middle / High Channel

* Spurious emissions that 20 dB below the limits didn't be recorded

**NOTE:** Peak results are met average limit, so average measurement was not performed.

Emission was scanned up to 25 GHz; No emissions were detected above the noise floor which was at least 20 dB below the specification limit

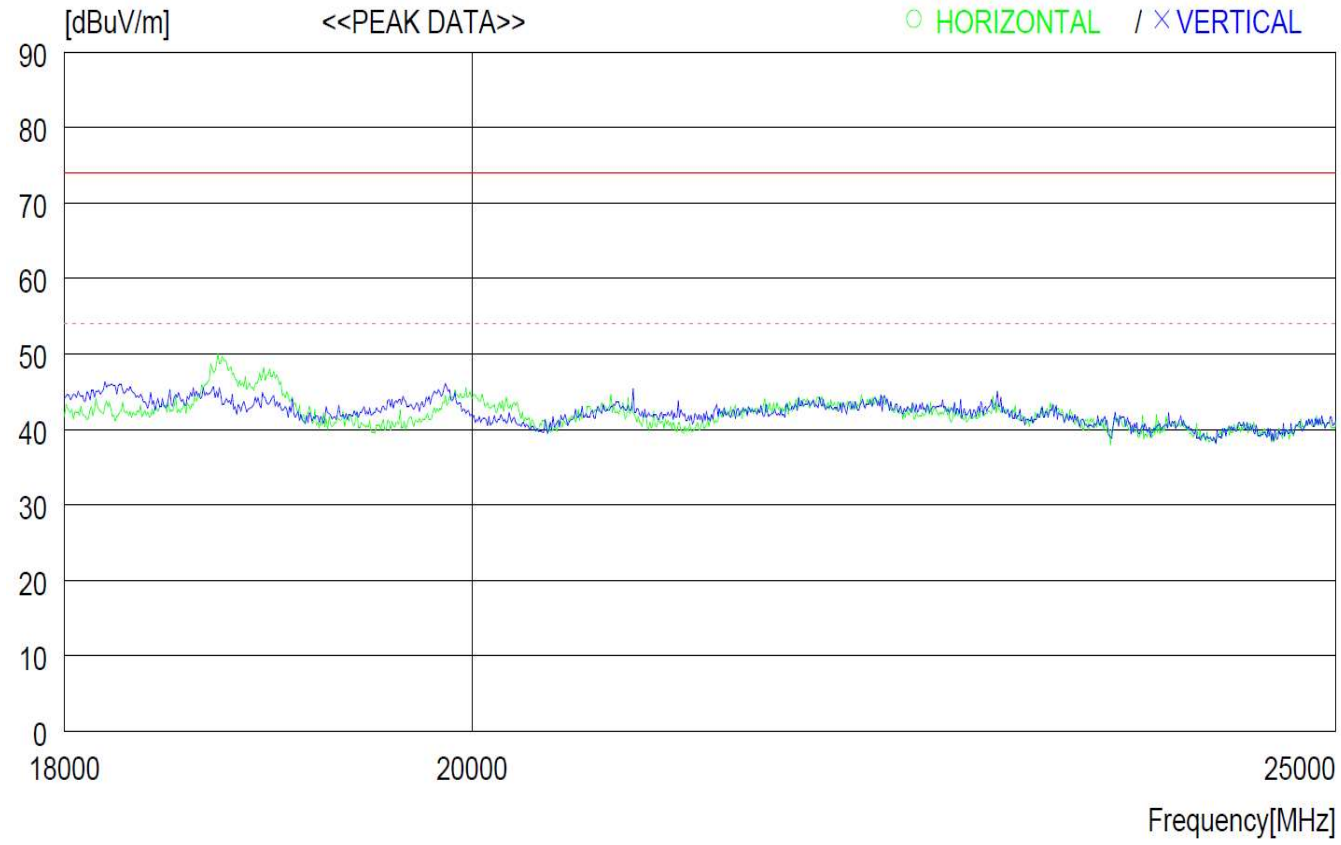
Note. "H" means Horizontal polarity, "V" means Vertical polarity.

Corr. Factor (dB) = Pre-amplifier gain - Cable Loss

Result = Receiver Reading + Antenna Factor - Corr. Factor + Duty factor

Margin = Limit – Result

Graphical Test Data – **High Channel (Peak)**




| Freq. (MHz) | Detector Mode | Pol. | Receiver Reading (dBuV) | Ant. Factor (dB/m) | Corr. Factor (dB) | Duty Factor (dB) | Result (dBuV/m) | Limit (dBuV/m) | Margin (dB) | Height (cm) | Azimuth (Deg) |
|---|---|---|---|---|---|---|---|---|---|---|---|

Low / Middle / High Channel

* Spurious emissions that 20 dB below the limits didn't be recorded

**NOTE:** Peak results are met average limit, so average measurement was not performed.

Emission was scanned up to 25 GHz; No emissions were detected above the noise floor which was at least 20 dB below the specification limit

Note. "H" means Horizontal polarity, "V" means Vertical polarity.

Corr. Factor (dB) = Pre-amplifier gain - Cable Loss

Result = Receiver Reading + Antenna Factor - Corr. Factor + Duty factor

Margin = Limit – Result

## 5.7 AC Power Line Conducted Emission

### 5.7.1 Limit

Acc. to section 15.207 (a), RSS-GEN 8.8 following table shall be applied.

| Frequency Range (MHz) | Quasi-Peak (dBuV) | Average (dBuV) |
|---|---|---|
| 0.15 - 0.5 | 66 to 56 | 56 to 46 |
| 0.5 - 5 | 56 | 46 |
| 5 -30 | 60 | 50 |

### 5.7.2 Method of Measurement

The EUT was placed on a wooden table, 0.8 m height above the horizontal ground plane and 40 cm from the vertical ground plane. Power was fed to the EUT through a 50 Ω / 50 μH + 5 Ω Artificial Mains Network (AMN). The ground plane was electrically bonded to the reference ground system and all power lines were filtered from ambient.

The receiver is set to a resolution bandwidth of 9 kHz. Peak detection is used unless otherwise noted as quasi-peak or average.

The test was performed for both Neutral and Hot lines.

### 5.7.3 Measurement Uncertainty

Measurement uncertainties were not taken into account and following uncertainty levels have been estimated for tests performed on the apparatus. The measurement uncertainties are given with at least 95 % confidence.

| Frequency Range | Uncertainty | Frequency Range | Uncertainty |
|---|---|---|---|
| 9 kHz ~ 150 kHz | ± 2.00 dB | 150 kHz ~ 30 MHz | ± 2.00 dB |

### 5.7.4 Sample Calculated Example

At 5.31 MHz QP Limit = 60.0 dBuV

Correction Factor (C. Factor) of LISN, Pulse Limiter and cable loss at 5.31 MHz = 9.7 dB

Q.P Reading from the Test receiver = 20.8 dBuV

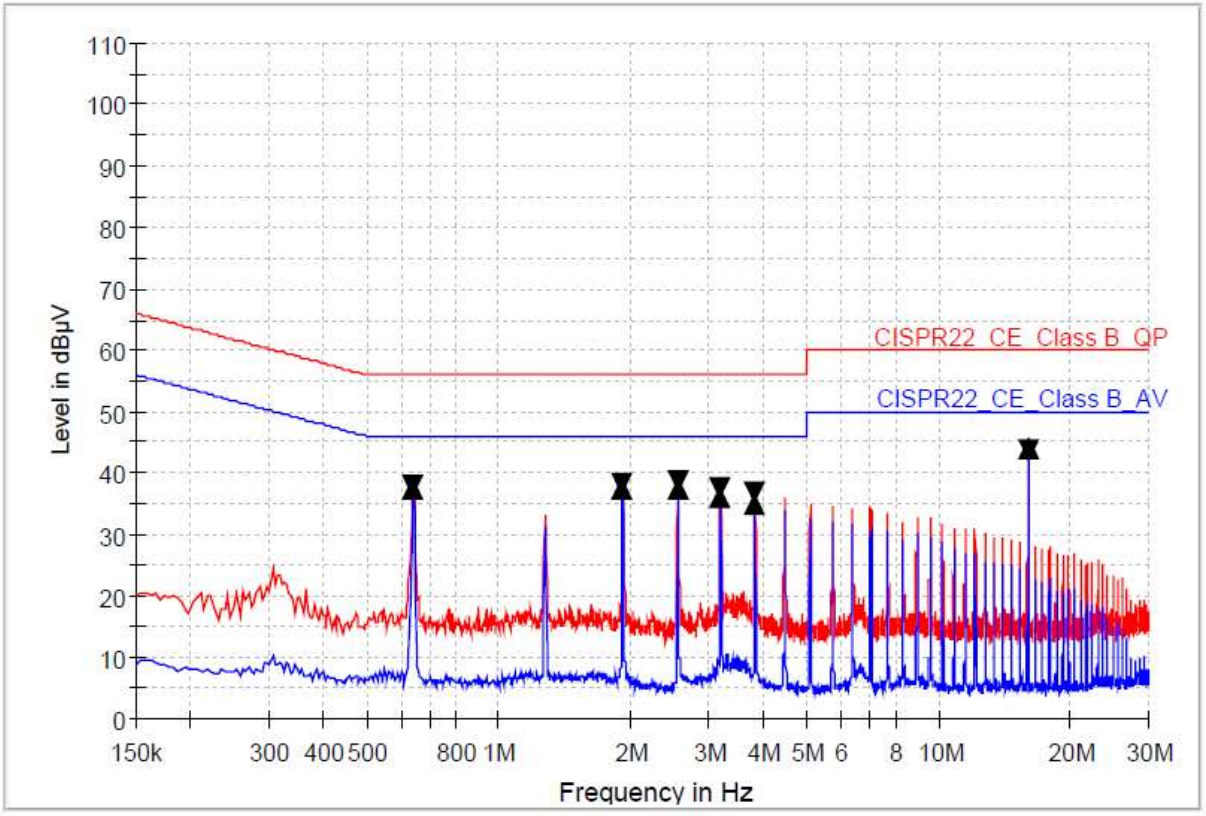
(Calculated value for system losses by software EMC32 manufactured by Rohde & Schwarz)

Therefore Q.P Margin = 60 - 20.8 = 39.2 so the EUT has 39.2 dB margin at 5.31 MHz

### 5.7.5 Worst Case Test Data

| | | | |
|---|---|---|---|
| Date of Test | 2019-11-29 | Temperature | 22.8 °C |
| | | Relative humidity | 40.9 % R.H. |
| ***Measurement Frequency Range*** | | 9 kHz ~ 30MHz | |
| ***Test Result*** | ***PASS*** | Tested By | Do-heon Kim |

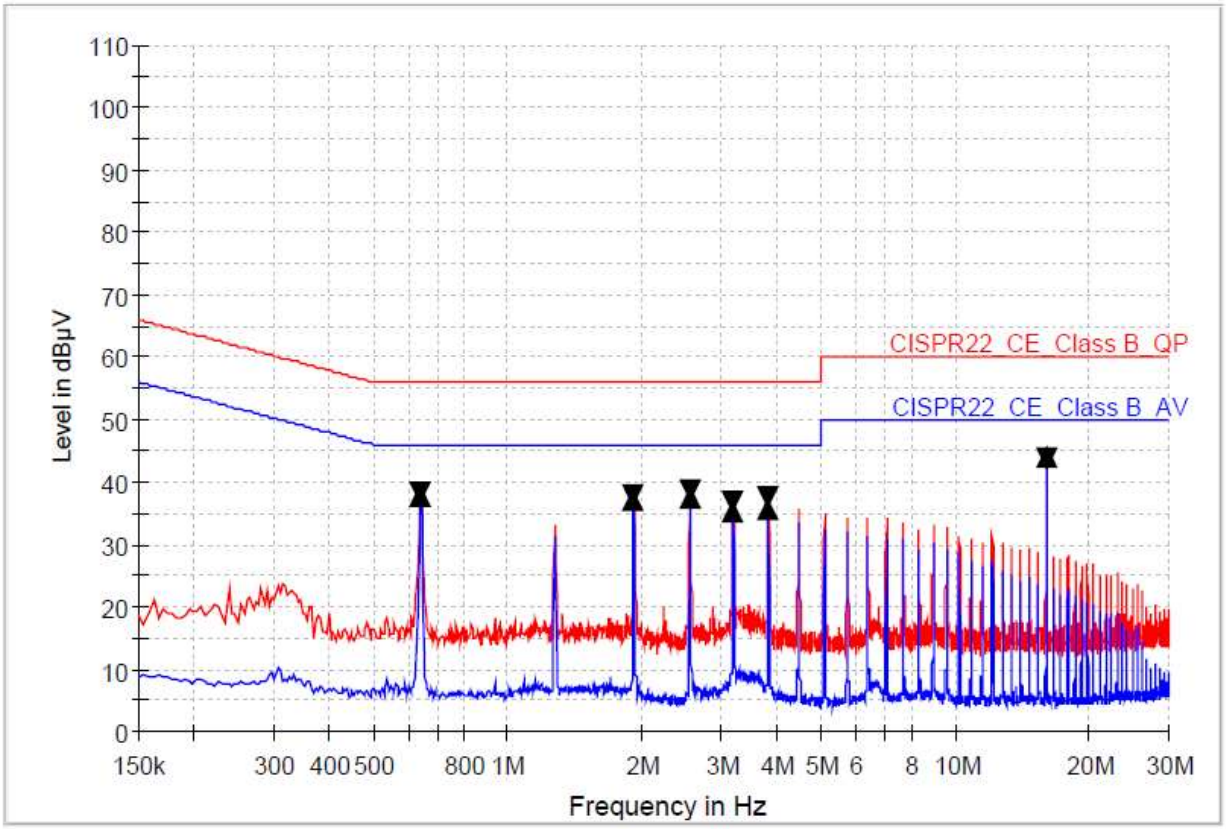
Hot Line




## Limit and Margin1

| Frequency (MHz) | QuasiPeak (dBµV) | CAverage (dBµV) | Bandwidth (kHz) | Line | Corr. (dB) | Margin - QPK (dB) | Limit - QPK (dBµV) | Margin - CAV (dB) | Limit - CAV (dBµV) |
|---|---|---|---|---|---|---|---|---|---|
| 0.638000 | 37.9 | 37.4 | 9.000 | L1 | 9.7 | 18.1 | 56.0 | 8.6 | 46.0 |
| 1.914000 | 38.1 | 37.4 | 9.000 | L1 | 9.8 | 17.9 | 56.0 | 8.6 | 46.0 |
| 2.554000 | 38.5 | 37.4 | 9.000 | L1 | 9.9 | 17.5 | 56.0 | 8.6 | 46.0 |
| 3.190000 | 37.6 | 36.2 | 9.000 | L1 | 10.0 | 18.4 | 56.0 | 9.8 | 46.0 |
| 3.826000 | 36.7 | 34.9 | 9.000 | L1 | 10.0 | 19.3 | 56.0 | 11.1 | 46.0 |
| 16.002000 | 43.7 | 44.0 | 9.000 | L1 | 10.3 | 16.3 | 60.0 | 6.0 | 50.0 |

Neutral Line




## Limit and Margin1

| Frequency (MHz) | QuasiPeak (dBµV) | CAverage (dBµV) | Bandwidth (kHz) | Line | Corr. (dB) | Margin - QPK (dB) | Limit - QPK (dBµV) | Margin - CAV (dB) | Limit - CAV (dBµV) |
|---|---|---|---|---|---|---|---|---|---|
| 0.638000 | 38.2 | 37.8 | 9.000 | N | 9.7 | 17.8 | 56.0 | 8.2 | 46.0 |
| 1.914000 | 37.8 | 37.1 | 9.000 | N | 9.8 | 18.2 | 56.0 | 8.9 | 46.0 |
| 2.554000 | 38.6 | 37.6 | 9.000 | N | 9.9 | 17.4 | 56.0 | 8.4 | 46.0 |
| 3.194000 | 36.9 | 35.2 | 9.000 | N | 10.0 | 19.1 | 56.0 | 10.8 | 46.0 |
| 3.830000 | 37.4 | 35.5 | 9.000 | N | 10.0 | 18.6 | 56.0 | 10.5 | 46.0 |
| 16.002000 | 43.7 | 44.0 | 9.000 | N | 10.3 | 16.3 | 60.0 | 6.0 | 50.0 |

## Appendix I – Test Instrumentation

| Description | Model No. | Serial No. | Manufacturer. | Due for Cal. Date | Cal. Interval |
|---|---|---|---|---|---|
| Signal & Spectrum Analyzer | FSW 43 | 100578 | Rohde & Schwarz | 2020-04-24 | 1 Y |
| Attenuator | 56-10 | 58769 | WEINSCHEL | 2020-01-22 | 1 Y |
| Test Receiver | ESU 26 | 100303 | Rohde & Schwarz | 2020-01-18 | 1 Y |
| Loop Antenna | HFH2-Z2 | 100341 | Rohde & Schwarz | 2021-04-22 | 2 Y |
| DC Power Supply | 6032A | SG41000637 | Agilent | 2020-03-29 | 1 Y |
| TRILOG Broadband Antenna | VULB9163 | 9163.799 | Schwarzbeck | 2021-11-12 | 2 Y |
| Horn Antenna | HF 907 | 102426 | Rohde & Schwarz | 2021-01-11 | 2 Y |
| Horn Antenna | BBHA 9170 | BBHA 9170 #783 | Schwarzbeck | 2020-11-26 | 2 Y |
| Notch Filter | BRM50702 | G318 | MICRO-TRONICS | 2020-11-07 | 1 Y |
| Attenuator | 6dB | 272.4110.50 | Rohde & Schwarz | 2020-01-18 | 1 Y |
| Pre-Amplifier | 310N | 344015 | Sonoma Instrument | 2020-01-18 | 1 Y |
| Pre-Amplifier | SCU 18D | 19006450 | Rohde & Schwarz | 2020-04-19 | 1 Y |
| Pre-Amplifier | CBL18265035 | 28706 | CERNEX | 2020-04-01 | 1 Y |
| Turn Table | DT3000-3t | 1310814 | INNCO SYSTEM | N/A | N/A |
| Antenna Master | MA4000-EP | 4600814 | INNCO SYSTEM | N/A | N/A |
| Antenna Master | MA4000-XP-ET | - | INNCO SYSTEM | N/A | N/A |
| Camera Controller | HDCon4102 | 6531445048 | PONTIS | N/A | N/A |
| CO3000 Controller | Co3000-4Port | CO3000/806/ 34130814/L | INNCO SYSTEM | N/A | N/A |
| CO3000 Controller | Co3000-4Port | CO3000/807/ 34130814/L | INNCO SYSTEM | N/A | N/A |
| EMI Test Receiver | ESCI 7 | 100722 | Rohde & Schwarz | 2020-01-18 | 1 Y |
| LISN | ENV216 | 100110 | Rohde & Schwarz | 2020-01-14 | 1 Y |

The measuring equipment utilized to perform the tests documented in this test report has been calibrated in accordance with manufacturer's recommendations, and is traceable to recognized national standards.