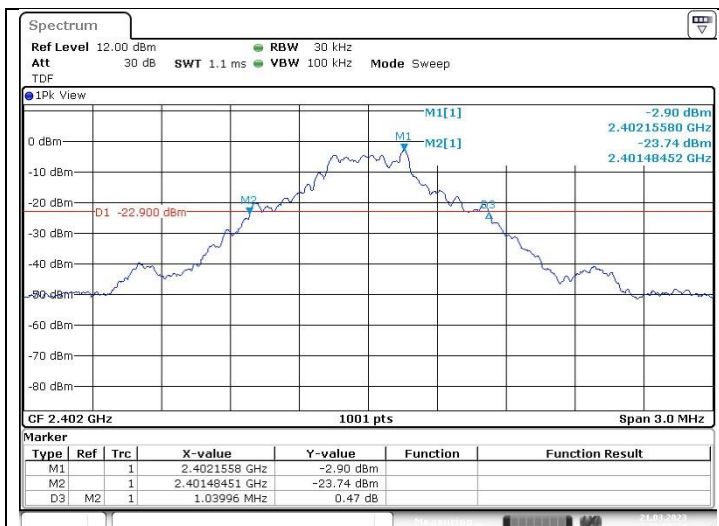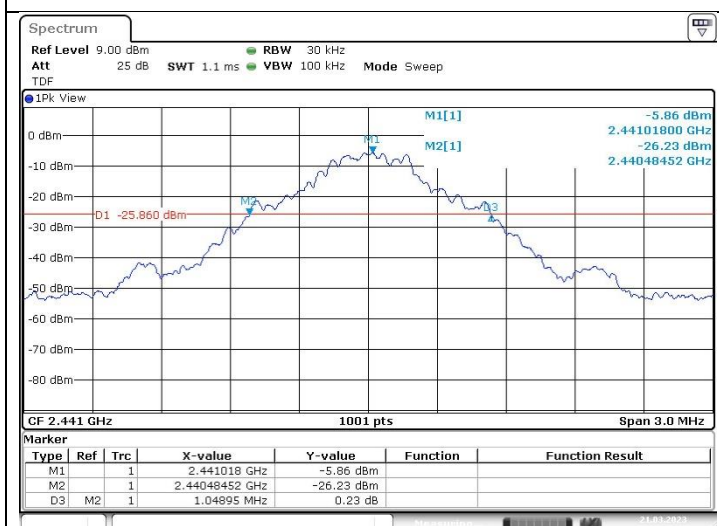**- Test plots**

**Operating Mode: GFSK**
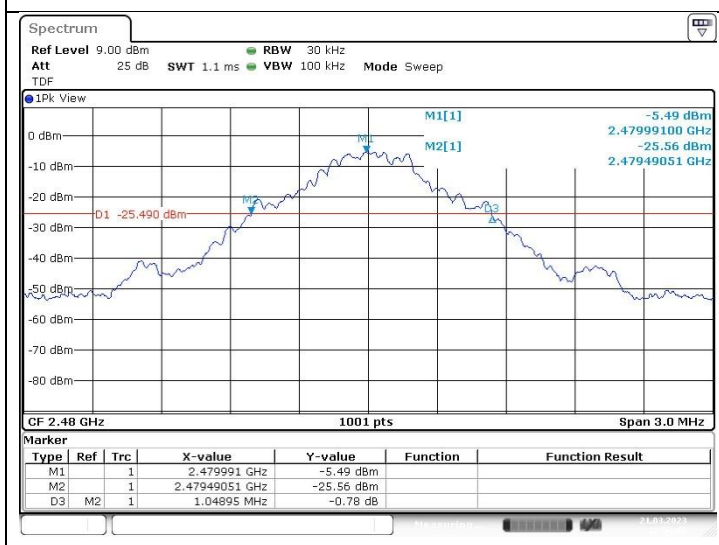
Low Channel



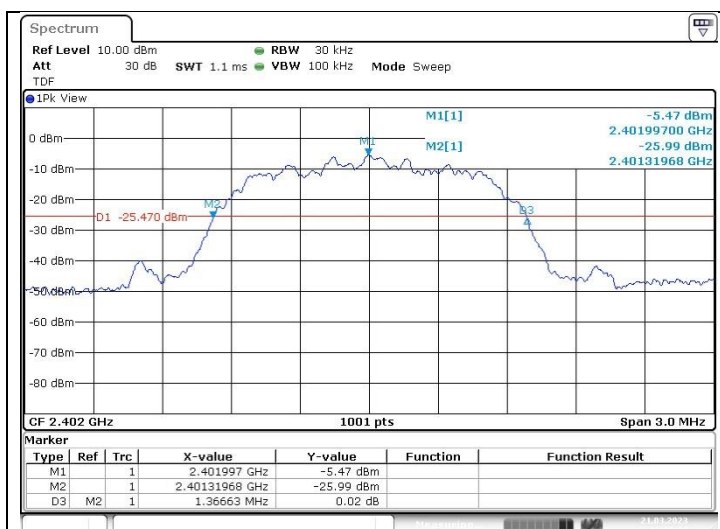Middle Channel



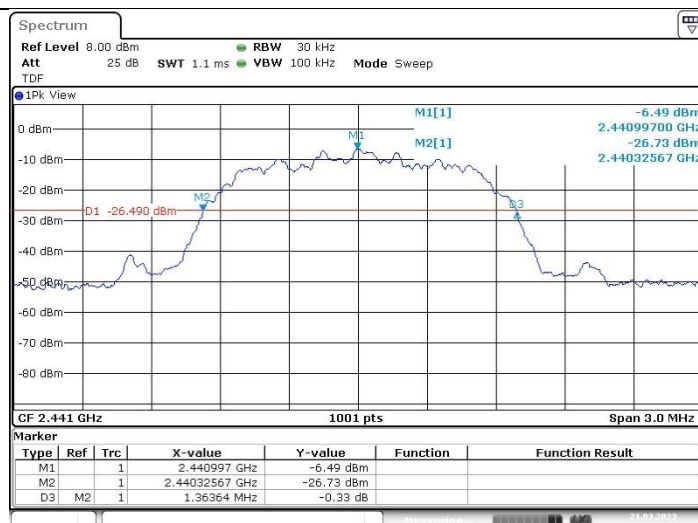High Channel

**Operating Mode: π/4DQPSK**

Low Channel



| Type | Ref | Trc | X-value | Y-value | Function | Function Result |
|---|---|---|---|---|---|---|
| M1 | | 1 | 2.401997 GHz | -5.47 dBm | | |
| M2 | | 1 | 2.40131968 GHz | -25.99 dBm | | |
| D3 | M2 | 1 | 1.36663 MHz | 0.02 dB | | |

Middle Channel



| Type | Ref | Trc | X-value | Y-value | Function | Function Result |
|---|---|---|---|---|---|---|
| M1 | | 1 | 2.440997 GHz | -6.49 dBm | | |
| M2 | | 1 | 2.44032567 GHz | -26.73 dBm | | |
| D3 | M2 | 1 | 1.36364 MHz | -0.33 dB | | |

High Channel



| Type | Ref | Trc | X-value | Y-value | Function | Function Result |
|---|---|---|---|---|---|---|
| M1 | | 1 | 2.480003 GHz | -5.45 dBm | | |
| M2 | | 1 | 2.47933167 GHz | -25.59 dBm | | |
| D3 | M2 | 1 | 1.36064 MHz | 0.14 dB | | |

**Operating Mode: 8DPSK**

Low Channel



| Type | Ref | Trc | X-value | Y-value | Function | Function Result |
|------|-----|-----|---------|---------|----------|-----------------|
| M1 | | 1 | 2.4021528 GHz | -3.27 dBm | | |
| M2 | | 1 | 2.40134965 GHz | -23.55 dBm | | |
| D3 | M2 | 1 | 1.31568 MHz | -0.27 dB | | |

Middle Channel



| Type | Ref | Trc | X-value | Y-value | Function | Function Result |
|------|-----|-----|---------|---------|----------|-----------------|
| M1 | | 1 | 2.441 GHz | -6.56 dBm | | |
| M2 | | 1 | 2.44032867 GHz | -26.92 dBm | | |
| D3 | M2 | 1 | 1.34865 MHz | -0.53 dB | | |

High Channel



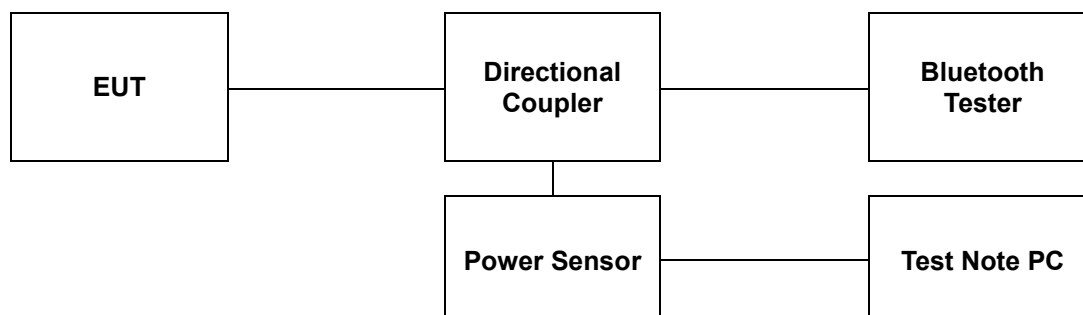| Type | Ref | Trc | X-value | Y-value | Function | Function Result |
|------|-----|-----|---------|---------|----------|-----------------|
| M1 | | 1 | 2.480006 GHz | -5.41 dBm | | |
| M2 | | 1 | 2.47933467 GHz | -25.51 dBm | | |
| D3 | M2 | 1 | 1.34566 MHz | -0.07 dB | | |

## 4. Maximum Peak Conducted Output Power

### 4.1. Test Setup



### 4.2. Limit

1. §15.247(a)(1), Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 ㎑ or the 20 ㏈ bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2 400-2 483.5 ㎒ band may have hopping channel carrier frequencies that are separated by 25 ㎑ or two-thirds of the 20 ㏈ bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 ㎽.
2. §15.247(b)(1), For frequency hopping systems operating in the 2 400-2 483.5 ㎒ band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5 725-5 850 ㎒ band: 1 watt. For all other frequency hopping systems in the 2 400-2 483.5 ㎒ band: 0.125 watts.

### 4.3. Test Procedure

The test follows ANSI C63.10-2013. Using the power sensor instead of a spectrum analyzer.

1. Place the EUT on the table and set it in the transmitting mode.
2. Remove the antenna from the EUT and then connect a low loss RF cable from the antenna port to the Power sensor.
3. Test program: (S/W name: R&S Power Viewer, Version: 3.2.0)
4. Measure each channel.

## 4.4. Test Results

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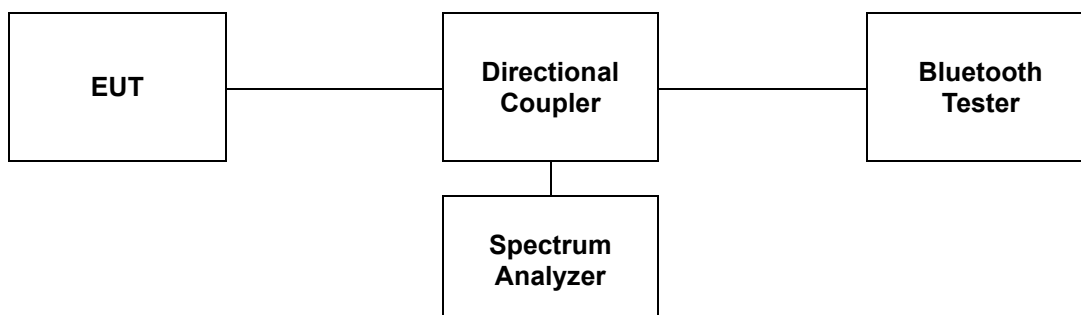Relative humidity       :    47      % R.H.

| Operation Mode | Data Rate (Mbps) | Channel | Frequency (㎒) | Average Power Result (dB m) | Peak Power Result (dB m) | Limit (dB m) |
|---|---|---|---|---|---|---|
| GFSK | 1 | Low | 2 402 | **-0.52** | **0.20** | |
| | | Middle | 2 441 | -2.82 | -1.80 | |
| | | High | 2 480 | -2.75 | -1.69 | |
| π/4DQPSK | 2 | Low | 2 402 | **-0.73** | **1.92** | 20.97 |
| | | Middle | 2 441 | -2.62 | 0.21 | |
| | | High | 2 480 | -1.84 | 0.84 | |
| 8DPSK | 3 | Low | 2 402 | **-0.76** | **1.96** | |
| | | Middle | 2 441 | -2.58 | 0.26 | |
| | | High | 2 480 | -1.84 | 0.83 | |

**Remark;**

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

# 5. Carrier Frequency Separation

## 5.1. Test Setup

```
┌──────────┐     ┌──────────────┐     ┌──────────────┐
│          │     │  Directional │     │   Bluetooth  │
│   EUT    │─────│   Coupler    │─────│    Tester    │
│          │     │              │     │              │
└──────────┘     └──────┬───────┘     └──────────────┘
                        │
                 ┌──────┴───────┐
                 │   Spectrum   │
                 │   Analyzer   │
                 │              │
                 └──────────────┘
```

## 5.2. Limit

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

## 5.3. Test Procedure

The test follows ANSI C63.10-2013.

The device is operating in hopping mode between 79 channels and also supporting Adaptive Frequency Hopping with hopping between 20 channels. As compared with each operating mode, 79 channels are chosen as a representative for test.

Use the following spectrum analyzer settings:

1. Span: Wide enough to capture the peaks of two adjacent channels
2. RBW: Start with the RBW set to approximately 30 % of the channel spacing; adjust as necessary to best identify the center of each individual channel.
3. VBW ≥ RBW
4. Sweep: Auto
5. Detector: Peak
6. Trace: Max hold
7. Allow the trace to stabilize.

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

## 5.4. Test Results

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

| Operation Mode | Frequency (㎒) | Adjacent Hopping Channel Separation (㎑) | Two-third of 20 dB Bandwidth (㎑) |
|---|---|---|---|
| GFSK | 2 441 | 1 000 | 699 |
| 8DPSK | 2 441 | 1 000 | 899 |

**Remark;**

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

**- Test plots**

| Operation Mode: GFSK | Operation Mode: 8DPSK |
|---|---|
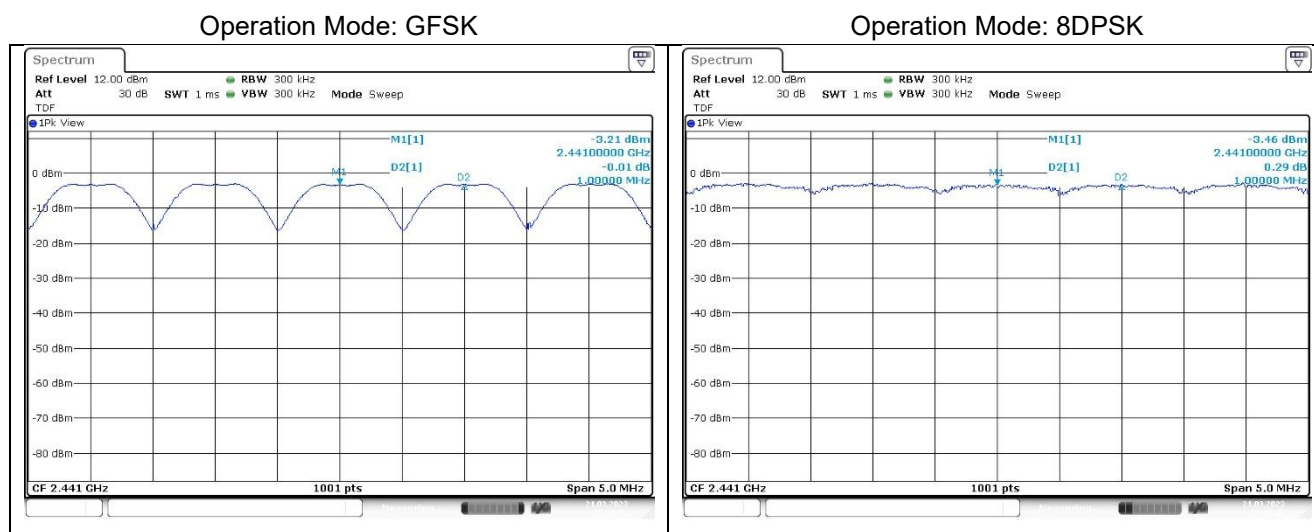
# 6. Number of Hopping Frequencies

## 6.1. Test Setup
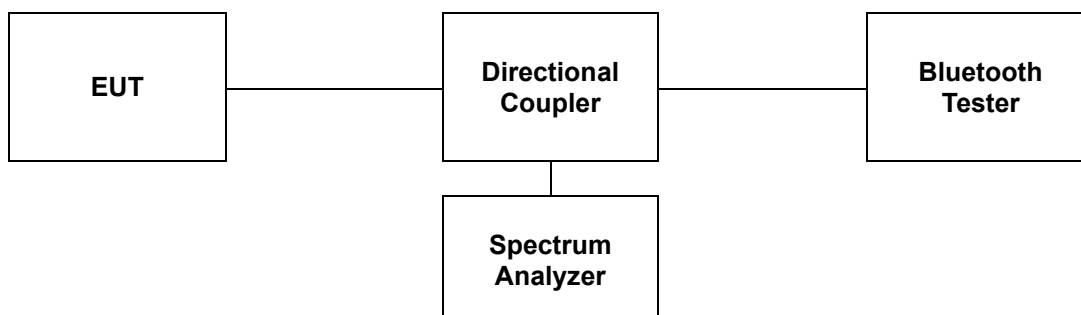


## 6.2. Limit

§15.247(a)(1)(iii), Frequency hopping systems in the 2 400-2 483.5 ㎒ band shall use at least 15 channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

## 6.3. Test Procedure

The test follows ANSI C63.10-2013.

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

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

1. Span: The frequency band of operation. Depending on the number of channels the device supports, it may be necessary to divide the frequency range of operation across multiple spans, to allow the individual channels to be clearly seen.
2. RBW: To identify clearly the individual channels, set the RBW to less than 30 % of the channel spacing or the 20 ㏈ bandwidth, whichever is smaller.
3. VBW ≥ RBW
4. Sweep: Auto
5. Detector function: Peak
6. Trace: Max hold
7. Allow the trace to stabilize.

## 6.4. Test Results

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

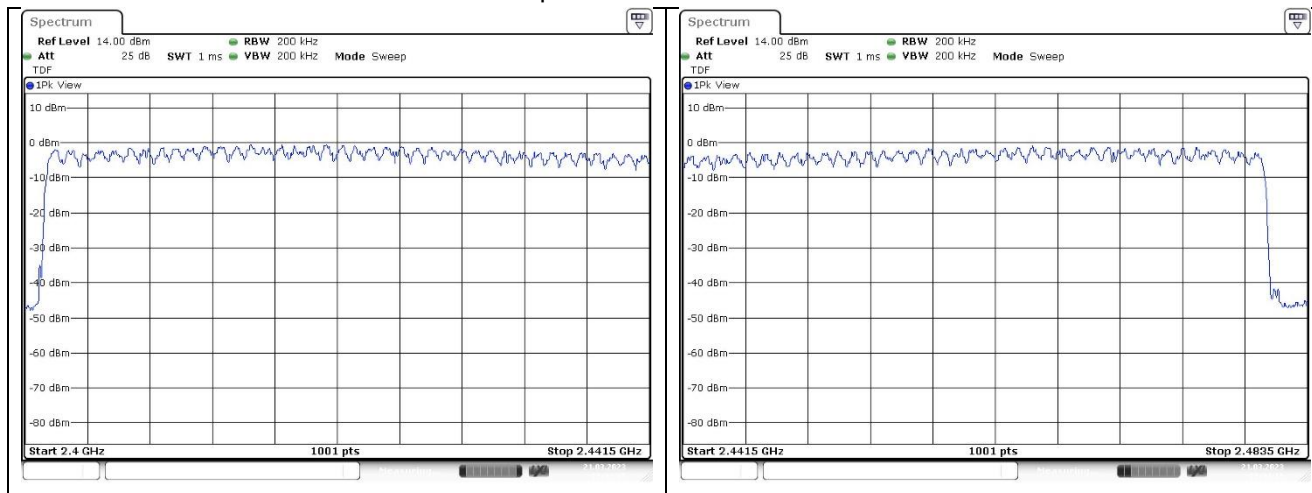| Operation Mode | Number of Hopping Frequency | Limit |
|:---:|:---:|:---:|
| GFSK | 79 | ≥ 15 |
| 8DPSK | 79 | ≥ 15 |

**Remark;**

Measurement is made with EUT operating in hopping mode between 79 channels providing a worst case scenario as compared to AFH mode hopping between 20 channels.
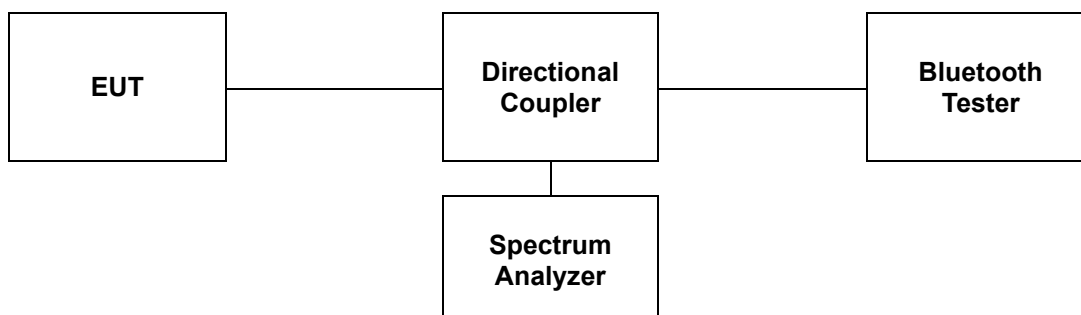
**- Test plots**

Operation Mode: GFSK



Operation Mode: 8DPSK

# 7. Time of Occupancy (Dwell Time)

## 7.1. Test Set up



## 7.2. Limit

§15.247(a)(1)(iii), Frequency hopping systems in the 2 400-2 483.5 ㎒ band, the average time of occupancy on any frequency shall not be greater than 0.4 second within a 31.6 second period.

A period time = 0.4 (s) * 79 = 31.6 (s)

**\*Adaptive Frequency Hopping**

A period time = 0.4 (s) * 20 = 8 (s)

## 7.3. Test Procedure

The test follows ANSI C63.10-2013.

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Position the EUT as shown in test setup without connection to measurement instrument. Turn on the EUT and connect its antenna terminal to measurement instrument via a low loss cable.
3. Measure the time duration of one transmission on the measured frequency. And then plot the result with time difference of this time duration.
4. The Bluetooth has 3 type of payload, DH1, DH3, DH5 and 3DH1, 3DH3, 3DH5.The hopping rate is insisted of 1 600 per second.

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

1. Span = Zero span, centered on a hopping channel.
2. RBW = 1 ㎒.
3. VBW ≥ RBW.
4. Sweep = As necessary to capture the entire dwell time per hopping channel.
5. Detector = Peak.
6. Trace = Max hold.

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

## 7.4. Test Results

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

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

| Operation Mode | Frequency (㎒) | Dwell Time (㎳) | Time of occupancy on the Tx Channel in 31.6 sec (㎳) | Limit for time of occupancy on the Tx Channel in 31.6 sec (㎳) |
|---|---|---|---|---|
| GFSK | 2 441 | 0.38 | 121.60 | 400 |
| 8DPSK | 2 441 | 0.39 | 124.80 | 400 |

**Remark;**

Time of occupancy on the TX channel in 31.6 sec
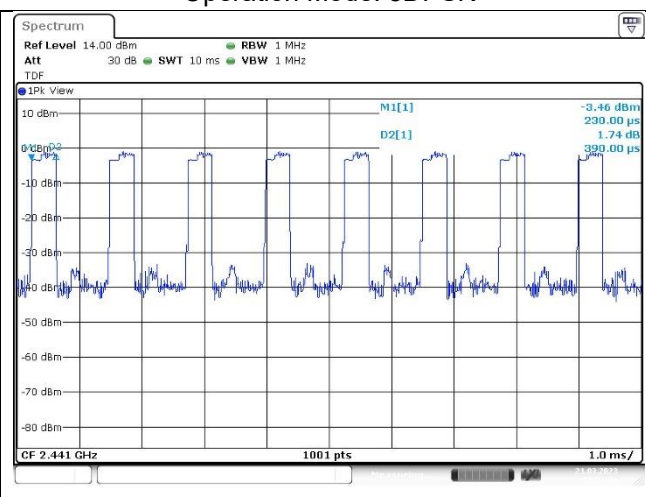In case of GFSK: 0.38 × {(1 600 ÷ 2) / 79} × 31.6 = 121.60 ㎳
In case of 8DPSK: 0.39 × {(1 600 ÷ 2) / 79} × 31.6 = 124.80 ㎳

**- Test plots**
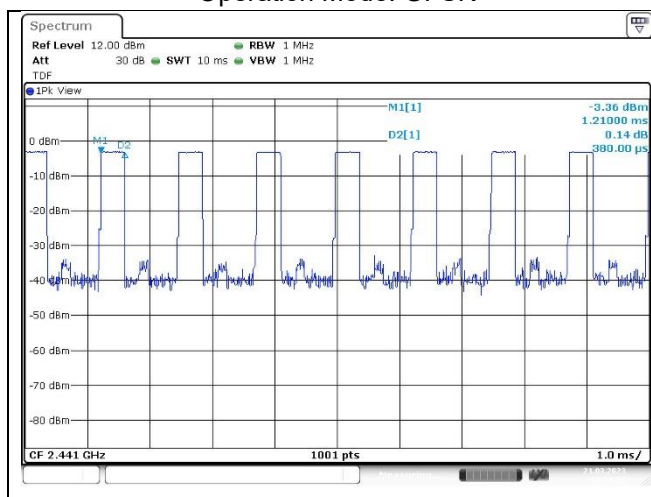
Operation Mode: GFSK                                   Operation Mode: 8DPSK
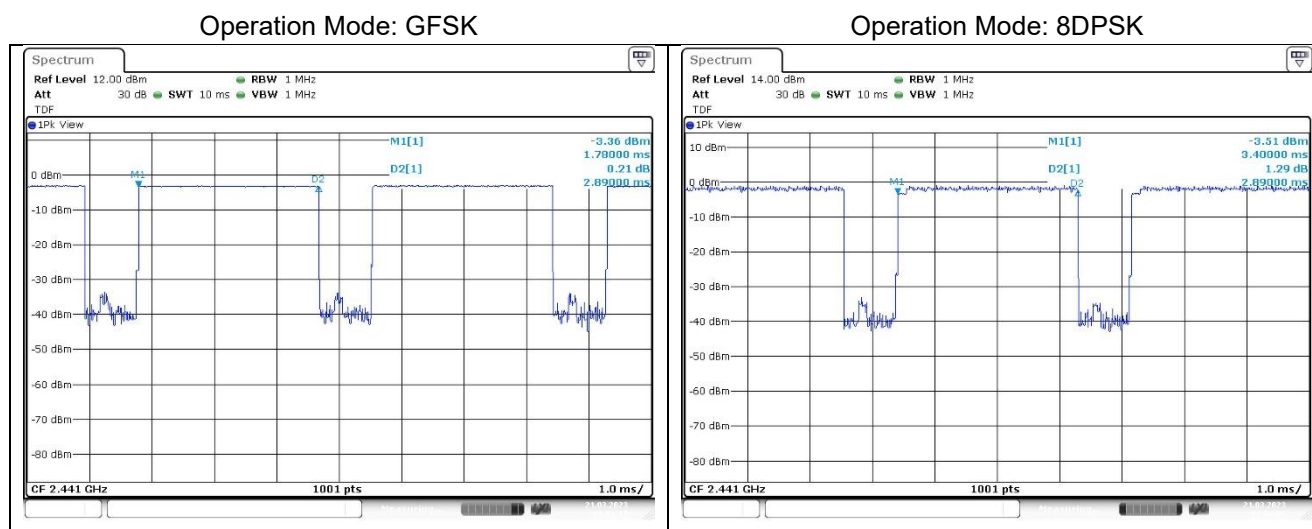
## 7.4.2. Packet Type: DH3, 3DH3

| Operation Mode | Frequency (㎒) | Dwell Time (㎳) | Time of occupancy on the Tx Channel in 31.6 sec (㎳) | Limit for time of occupancy on the Tx Channel in 31.6 sec (㎳) |
|---|---|---|---|---|
| GFSK | 2 441 | 1.64 | 262.40 | 400 |
| 8DPSK | 2 441 | 1.64 | 262.40 | 400 |

**Remark;**

Time of occupancy on the TX channel in 31.6 sec
In case of GFSK and 8DPSK: 1.64 × {(1 600 ÷ 4) / 79} × 31.6 = 262.40  ㎳

**- Test plots**

| Operation Mode: GFSK | Operation Mode: 8DPSK |
|---|---|
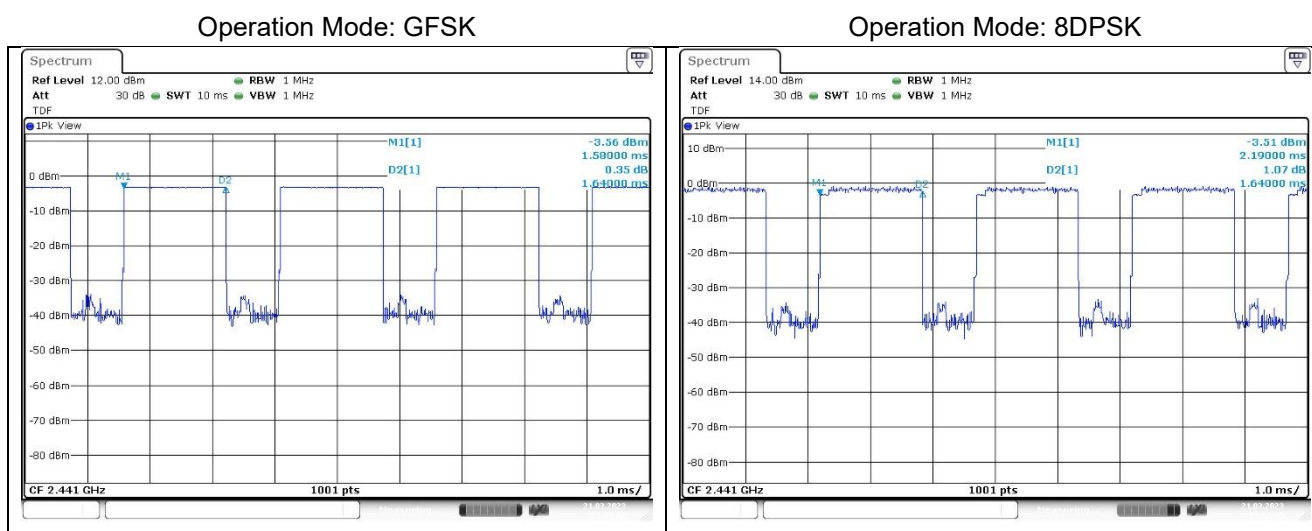
### 7.4.3. Packet Type: DH5, 3DH5

| Operation Mode | Frequency (㎒) | Dwell Time (㎳) | Time of occupancy on the Tx Channel in 31.6 sec (㎳) | Limit for time of occupancy on the Tx Channel in 31.6 sec (㎳) |
|---|---|---|---|---|
| GFSK | 2 441 | 2.89 | 308.27 | 400 |
| 8DPSK | 2 441 | 2.89 | 308.27 | 400 |

**Remark;**

Time of occupancy on the TX channel in 31.6 sec
In case of GFSK and 8DPSK: 2.89 × {(1 600 ÷ 6) / 79} × 31.6 = 308.27 ㎳

**- Test plots**

| Operation Mode: GFSK | Operation Mode: 8DPSK |
|---|---|

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

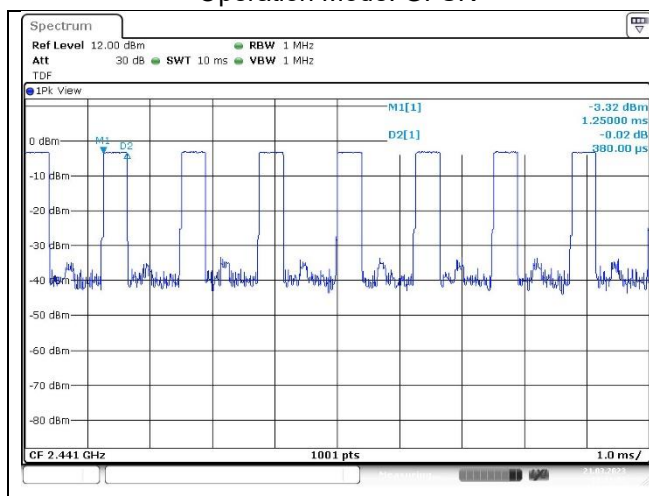| Operation Mode | Frequency (㎒) | Dwell Time (㎳) | Time of occupancy on the Tx Channel in 8 sec (㎳) | Limit for time of occupancy on the Tx Channel in 8 sec (㎳) |
|---|---|---|---|---|
| GFSK | 2 441 | 0.38 | 60.80 | 400 |
| 8DPSK | 2 441 | 0.39 | 62.40 | 400 |

**Remark;**

Time of occupancy on the TX channel in 8 sec
In case of GFSK: 0.38 × {(800 ÷ 2) / 20} × 8 = 60.80 ㎳
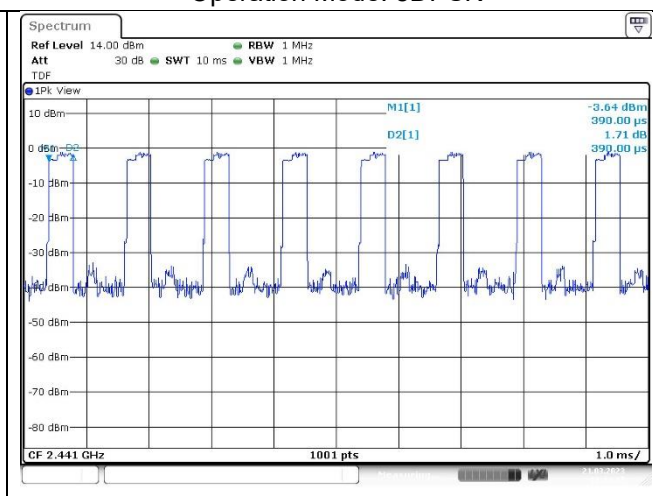In case of 8DPSK: 0.39 × {(800 ÷ 2) / 20} × 8 = 62.40 ㎳

**- Test plots**

Operation Mode: GFSK

Operation Mode: 8DPSK

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

| Operation Mode | Frequency (㎒) | Dwell Time (㎳) | Time of occupancy on the Tx Channel in 8 sec (㎳) | Limit for time of occupancy on the Tx Channel in 8 sec (㎳) |
|:---:|:---:|:---:|:---:|:---:|
| GFSK | 2 441 | 1.64 | 131.20 | 400 |
| 8DPSK | 2 441 | 1.64 | 131.20 | 400 |

**Remark;**

Time of occupancy on the TX channel in 8 sec
In case of GFSK and 8DPSK: 1.64 × {(800 ÷ 4) / 20} × 8 = 131.20 ㎳

**- Test plots**
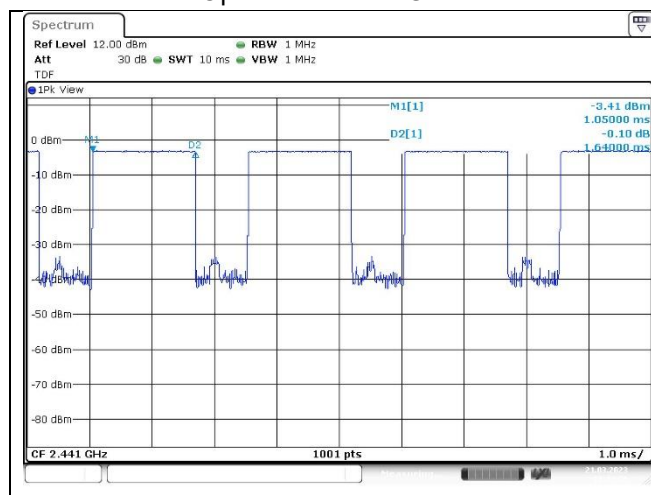
|  Operation Mode: GFSK  |  Operation Mode: 8DPSK  |
|:---:|:---:|
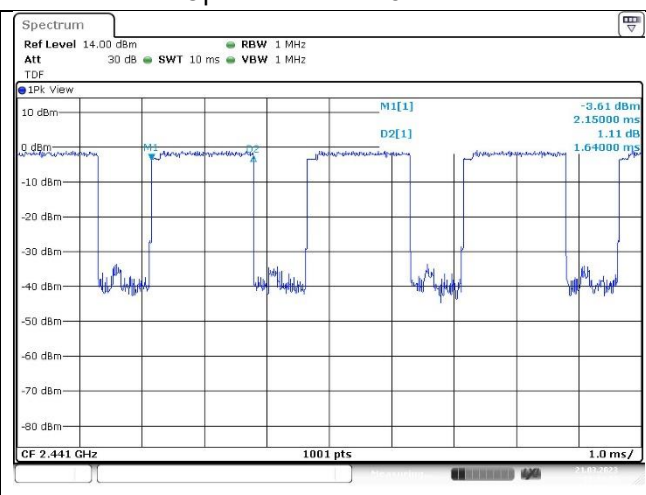
## 7.4.6. Packet Type: DH5, 3DH5 (Adaptive Frequency Hopping)

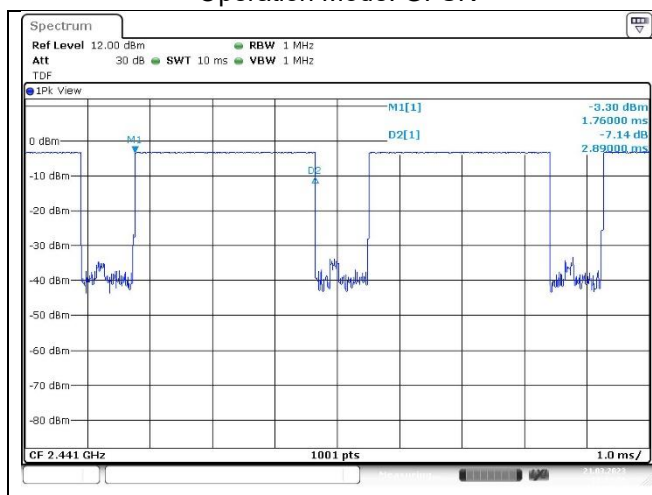| Operation Mode | Frequency (㎒) | Dwell Time (㎳) | Time of occupancy on the Tx Channel in 8 sec (㎳) | Limit for time of occupancy on the Tx Channel in 8 sec (㎳) |
|---|---|---|---|---|
| GFSK | 2 441 | 2.89 | 154.13 | 400 |
| 8DPSK | 2 441 | 2.89 | 154.13 | 400 |

**Remark;**

Time of occupancy on the TX channel in 8 sec
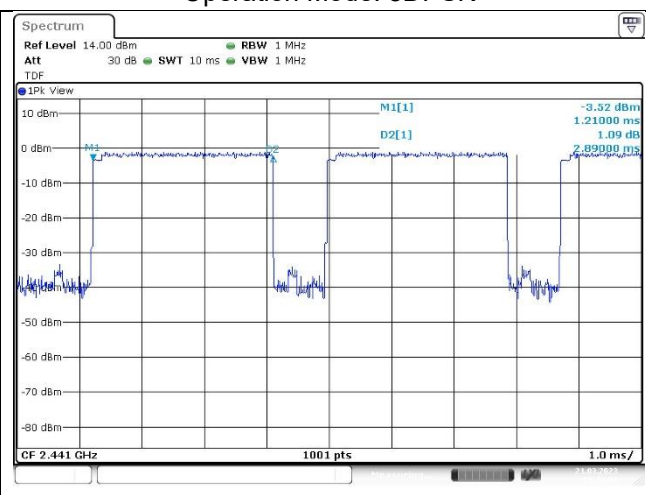In case of GFSK and 8DPSK: 2.89 × {(800 ÷ 6) / 20} × 8 = 154.13 ㎳
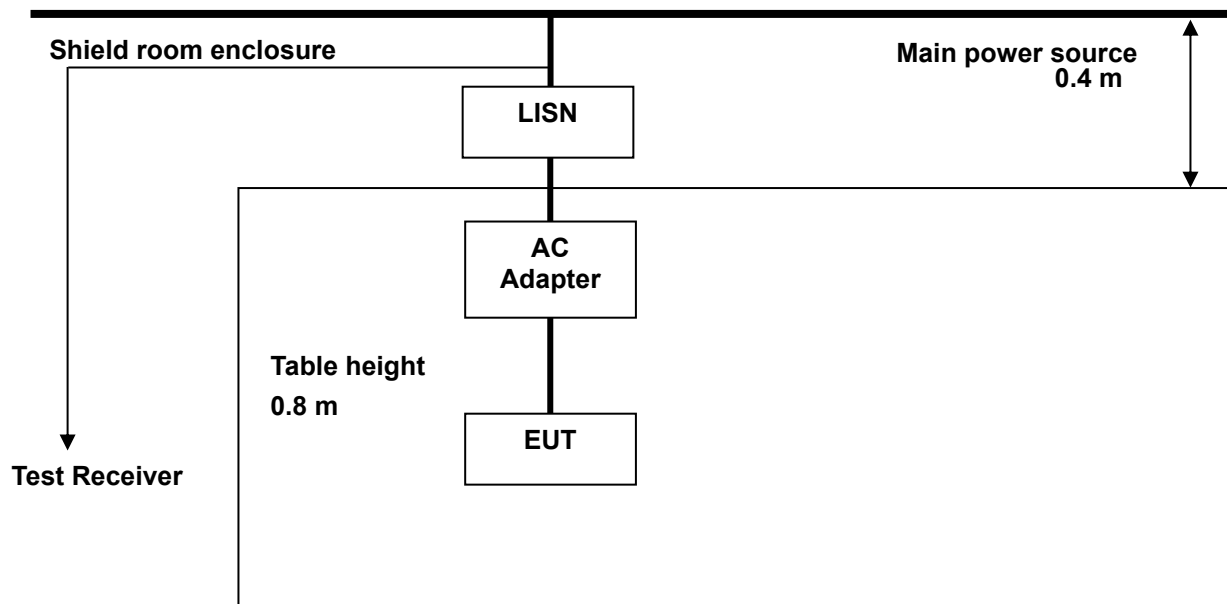
**- Test plots**

Operation Mode: GFSK

Operation Mode: 8DPSK

# 8. AC Power Line Conducted Emission

## 8.1. Test Setup



## 8.2. Limit

According to §15.207(a), for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 ㎑ to 30 ㎒, shall not exceed the limits in the following table, as measured using a 50 $\mu$H /50 ohms line impedance stabilization network (LISN).

Compliance with the provision of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

| Frequency of emission (㎒) | Conducted limit (dB$\mu$V) | |
|---|---|---|
| | Quasi-peak | Average |
| 0.15-0.5 | 66 to 56* | 56 to 46* |
| 0.5-5 | 56 | 46 |
| 5-30 | 60 | 50 |

* Decreases with the logarithm of the frequency.

## 8.3. Test Procedures

AC conducted emissions from the EUT were measured according to the dictates of ANSI C63.10-2013

1. The test procedure is performed in a 6.5 m × 3.5 m × 3.5 m (L × W × H) shielded room. The EUT along with its peripherals were placed on a 1.0 m (W) × 1.5 m (L) and 0.8 m in height wooden table and the EUT was adjusted to maintain a 0.4 meter space from a vertical reference plane.

2. The EUT was connected to power mains through a line impedance stabilization network (LISN) which provides 50 ohm coupling impedance for measuring instrument and the chassis ground was bounded to the horizontal ground plane of shielded room.

3. All peripherals were connected to the second LISN and the chassis ground also bounded to the horizontal ground plane of shielded room.

4. The excess power cable between the EUT and the LISN was bundled. The power cables of peripherals were unbundled. All connecting cables of EUT and peripherals were moved to find the maximum emission.

## 8.4. Test Results

The following table shows the highest levels of conducted emissions on both phase of Hot and Neutral line.

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

Frequency range        :   0.15 ㎒ - 30 ㎒
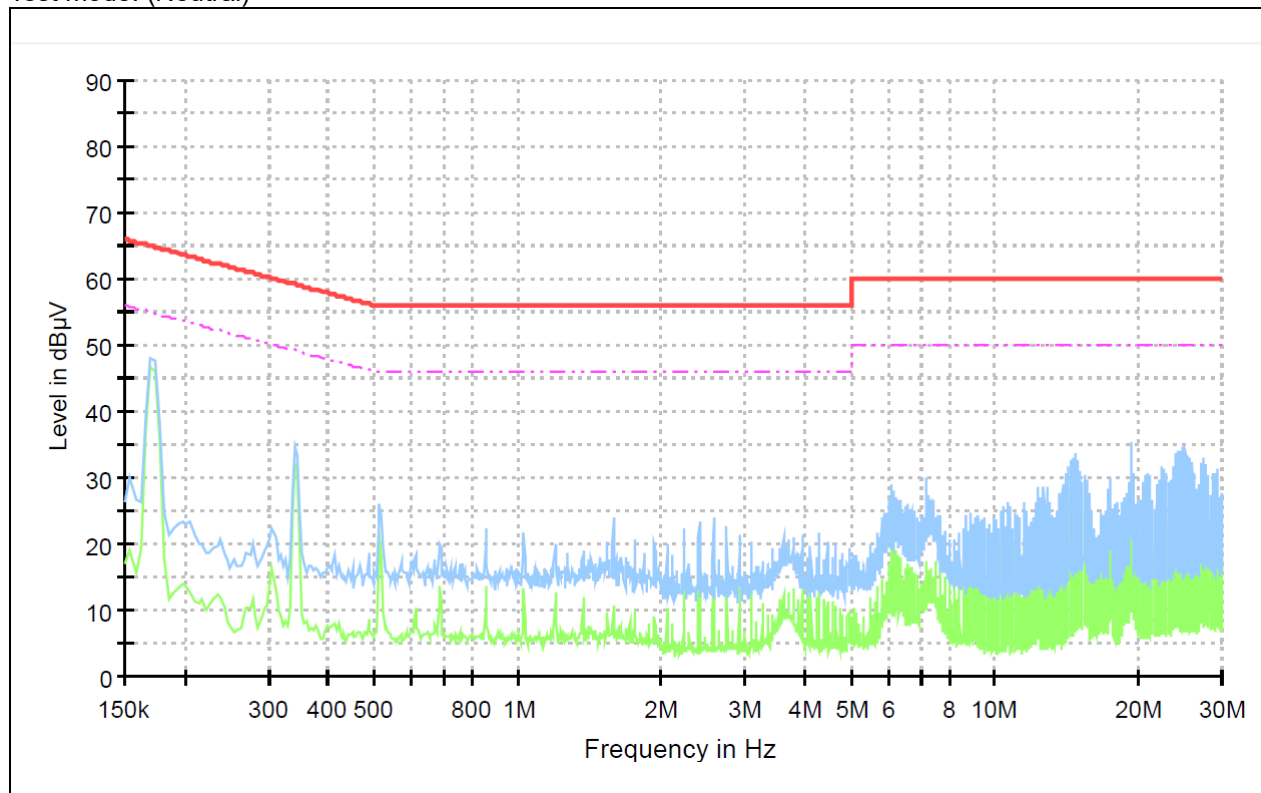Measured Bandwidth     :   9 ㎑

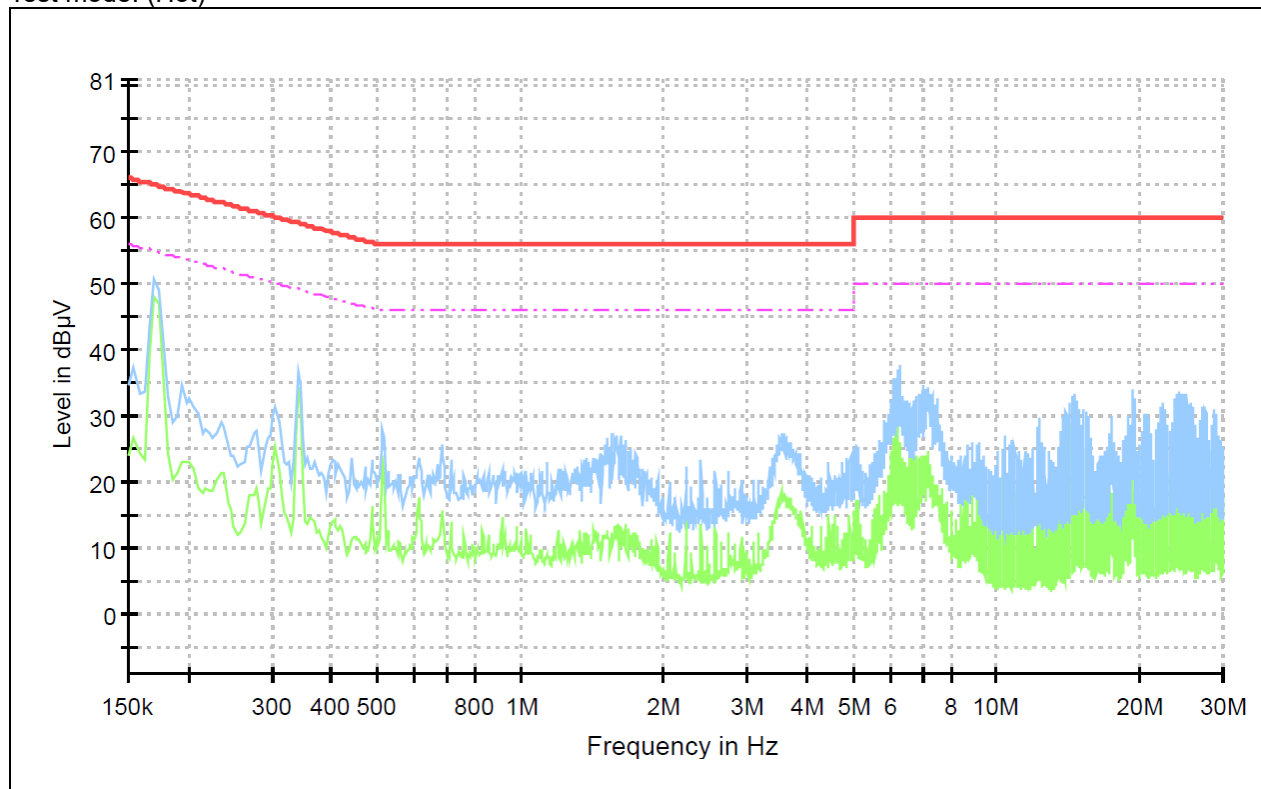| FREQ. | LEVEL (dB㎶) | | LINE | LIMIT (dB㎶) | | MARGIN (dB) | |
|---|---|---|---|---|---|---|---|
| (㎒) | Q-Peak | Average | | Q-Peak | Average | Q-Peak | Average |
| 0.17 | 48.01 | 47.70 | H | 64.96 | 54.96 | 16.95 | 7.26 |
| 0.34 | 33.80 | 32.76 | H | 59.20 | 49.20 | 25.40 | 16.44 |
| 7.22 | 22.18 | 16.29 | H | 60.00 | 50.00 | 37.82 | 33.71 |
| 14.75 | 32.46 | 29.23 | H | 60.00 | 50.00 | 27.54 | 20.77 |
| 19.38 | 30.35 | 24.72 | H | 60.00 | 50.00 | 29.65 | 25.28 |
| 24.67 | 32.86 | 22.83 | H | 60.00 | 50.00 | 27.14 | 26.17 |
| 0.17 | 48.95 | 48.88 | N | 64.96 | 54.96 | 16.01 | 6.08 |
| 0.34 | 35.15 | 34.53 | N | 59.20 | 49.20 | 24.05 | 14.67 |
| 1.55 | 21.12 | 11.58 | N | 56.00 | 46.00 | 34.88 | 34.42 |
| 3.59 | 23.14 | 18.34 | N | 56.00 | 46.00 | 32.86 | 27.66 |
| 6.28 | 35.44 | 29.69 | N | 60.00 | 50.00 | 24.56 | 20.31 |
| 19.36 | 29.30 | 22.81 | N | 60.00 | 50.00 | 30.70 | 27.19 |

**Remark;**

1. Line (H): Hot, Line (N): Neutral.
2. All modes of operation were investigated and the worst-case emissions were reported using **EDR / 3DH5 / Low channel.**
3. The limit for Class B device(s) from 150 ㎑ to 30 ㎒ are specified in Section of the Title 47 CFR.
4. Traces shown in plot were made by using a Quasi peak detector and average detector.
5. Deviations to the Specifications: None.

**SGS**

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## - Test plots

Test mode: (Neutral)



Test mode: (Hot)

# 9. Antenna Requirement

## 9.1. Standard Applicable

For intentional device, according to FCC 47 CFR Section §15.203, an intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. And according to FCC 47 CFR Section §15.247(b) if transmitting antennas of directional gain greater than 6 $dB$ i are used, the power shall be reduced by the amount in $dB$ that the gain of the antenna exceeds 6 $dB$ i.

## 9.2. Antenna Connected Construction

Antenna used in this product is Pattern antenna with gain of 2.28 $dB$ i

**- End of the Test Report -**