



Test Report

Part 15 Subpart C 15.247

Equipment under test LoRa Module

Model name PLM150

FCC ID 2AUV6-PLM150

Applicant PLNetworks, Inc.

Manufacturer PLNetworks, Inc.

Date of test(s) 2021.11.16~2021.11.30

Date of issue 2021.12.03

Issued to

PLNetworks, Inc.

210, HANA EZ Tower, 10, Seongnam-daero 43beon-gil, Bundang-gu,
Gyeonggi-do, Korea
Tel: +82-070-4493-5553, Fax: +82-070-4493-5551

Issued by
KES Co., Ltd.

3701, 40, Simin-daero 365beon-gil, Dongan-gu, Anyang-si,
Gyeonggi-do, 14057, Korea
473-21, Gayeo-ro, Yeoju-si, Gyeonggi-do, Korea
Tel: +82-31-425-6200 / Fax: +82-31-424-0450

| Test and report completed by : | Report approval by : |
|--------------------------------|-------------------------------------|
| | |
| Gu-Bong, Kang Test engineer | Young-Jin, Lee Technical manager |

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KES Co., Ltd.

3701, 40, Simin-daero 365beon-gil,
Dongan-gu, Anyang-si, Gyeonggi-do, 14057, Korea
Tel: +82-31-425-6200 / Fax: +82-31-424-0450
www.kes.co.kr

Report No.:
KES-RF1-21T0213
Page (2) of (36)

Revision history

| Revision | Date of issue | Test report No. | Description |
|----------|---------------|-----------------|-------------|
| - | 2021.12.03 | KES-RF1-21T0213 | Initial |
| | | | |

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TABLE OF CONTENTS

| | | |
|-------------|--|----|
| 1. | General information | 4 |
| 1.1. | EUT description | 4 |
| 1.2. | Test configuration..... | 4 |
| 1.3. | Derivative Model Information..... | 5 |
| 1.4. | Accessory information..... | 5 |
| 1.5. | Sample calculation | 5 |
| 1.6. | Measurement Uncertainty | 5 |
| 1.7. | Frequency/channel operations | 5 |
| 2. | Summary of tests | 6 |
| 3. | Test results..... | 7 |
| 3.1. | 6 dB bandwidth | 7 |
| 3.2. | Output power..... | 9 |
| 3.3. | Power spectral density..... | 11 |
| 3.4. | Radiated restricted band and emissions..... | 13 |
| 3.5. | Conducted spurious emissions & band edge | 30 |
| 3.6. | AC conducted emissions | 33 |
| Appendix A. | Measurement equipment | 35 |
| Appendix B. | Test setup photos | 36 |

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1. General information

Applicant: PLNetworks, Inc.
Applicant address: 210, HANA EZ Tower, 10, Seongnam-daero 43beon-gil, Bundang-gu, Gyeonggi-do, Korea
Test site: KES Co., Ltd.
Test site address: 3701, 40, Simin-daero 365beon-gil, Dongan-gu, Anyang-si, Gyeonggi-do, 14057, Korea
 473-29, Gayeo-ro, Yeoju-si, Gyeonggi-do, Korea
Test Facility: FCC Accreditation Designation No.: KR0100, Registration No.: 444148
FCC rule part(s): 15.247
FCC ID: 2AUV6-PLM150
Test device serial No.: Production Pre-production Engineering

1.1. EUT description

Equipment under test LoRa Module
Frequency range 902.9 MHz ~ 927.3 MHz
Model: PLM150
Modulation technique GFSK
Number of channels 902.9 MHz ~ 927.3 MHz : 40ch
Antenna specification Antenna type : Dipole Antenna, Peak gain : 2.17 dBi
Power source DC 3.3 V
H/W Version 1.0
S/W Version 0.7

1.2. Test configuration

The **PLNetworks, Inc. // LoRa Module // PLM150 // FCC ID: 2AUV6-PLM150** was tested according to the specification of EUT, the EUT must comply with following standards and KDB documents.

FCC Part 15.247
KDB 558074 D01 v05 r02
ANSI C63.10-2013

1.3. Derivative Model Information

N/A

1.4. Accessory information

| Equipment | Manufacturer | Model | Serial No. | Power source |
|-----------|--------------|-------|------------|--------------|
| - | - | - | - | - |

1.5. Sample calculation

Where relevant, the following sample calculation is provided

For all conducted test items :

The offset level is set in the spectrum analyzer to compensate the RF cable loss and attenuator factor between EUT conducted output port and spectrum analyzer. With the offset compensation, the spectrum analyzer reading level is exactly the EUT RF output level.

$$\begin{aligned} \text{Offset(dB)} &= \text{RF cable loss(dB)} + \text{attenuator factor(dB)} \\ &= 0.53 + 10 = 10.53 \text{ (dB)} \end{aligned}$$

For Radiation test :

Field strength level ($\text{dB}\mu\text{V}/\text{m}$) = Measured level ($\text{dB}\mu\text{V}$) + Antenna factor (dB) + Cable loss (dB) – Amplifier gain (dB)

1.6. Measurement Uncertainty

| Test Item | | Uncertainty |
|---|------------|-------------|
| Uncertainty for Conduction emission test | | 2.46 dB |
| Uncertainty for Radiation emission test (include Fundamental emission) | Below 1GHz | 4.40 dB |
| | Above 1GHz | 5.94 dB |

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

1.7. Frequency/channel operations

| Ch. | Frequency (MHz) | Mode |
|-----|-----------------|------|
| 0 | 902.9 | - |
| ⋮ | ⋮ | ⋮ |
| 20 | 915.3 | - |
| ⋮ | ⋮ | ⋮ |
| 39 | 927.3 | - |



2. Summary of tests

| Section in FCC Part 15 | Test description | Test results |
|------------------------|---|--------------|
| 15.247(a)(2) | 6 dB bandwidth | Pass |
| 15.247(b)(3) | Output power | Pass |
| 15.247(e) | Power spectral density | Pass |
| 15.205 15.209 | Radiated restricted band and emission | Pass |
| 15.247(d) | Conducted spurious emission and band edge | Pass |
| 15.207(a) | AC Conducted emissions | Pass |

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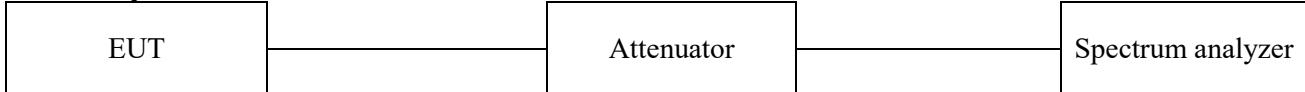
3. Test results

3.1. 6 dB bandwidth

Test procedure

ANSI C63.10-2013 - Section 11.8.2

Test setup



ANSI C63.10-2013 - Section 11.8.2

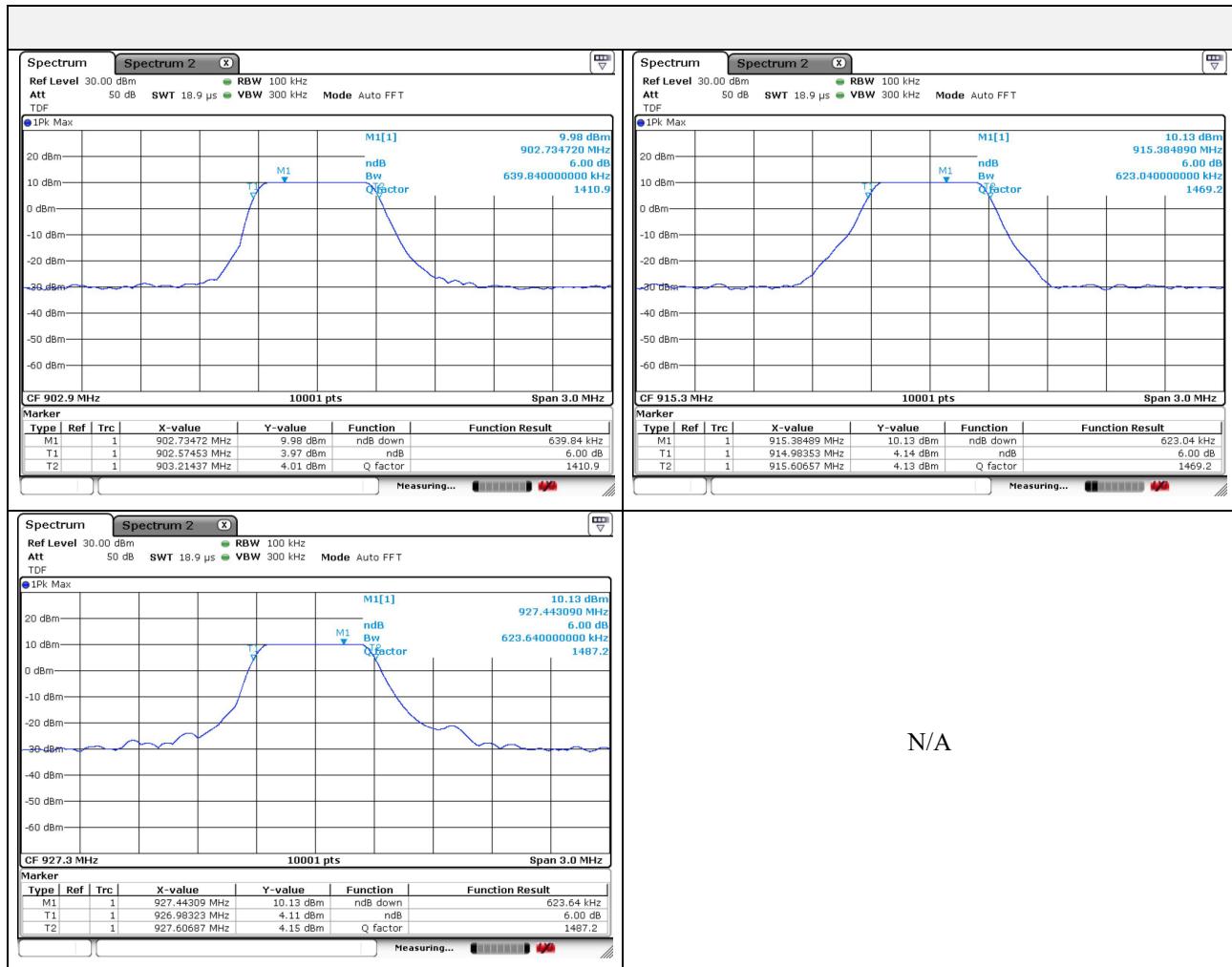
The automatic bandwidth measurement capability of an instrument may be employed using the X dB bandwidth mode with X set to 6 dB, if the functionality described above (i.e., $RBW = 100 \text{ kHz}$, $VBW \geq 3 \times RBW$, peak detector with maximum hold) is implemented by the instrumentation function. When using this capability, care shall be taken so that the bandwidth measurement is not influenced by any intermediate power nulls in the fundamental emission that might be $\geq 6 \text{ dB}$.

Limit

According to §15.247(a)(2), systems using digital modulation techniques may operate 902 ~ 928 MHz, 2 400 ~ 2 483.5 MHz, and 5 725 ~ 5 850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

Test results

| Frequency(MHz) | 6 dB bandwidth(MHz) | Limit(MHz) |
|----------------|---------------------|--------------|
| 902.9 | 0.640 | ≥ 0.500 |
| 915.3 | 0.623 | |
| 927.3 | 0.624 | |



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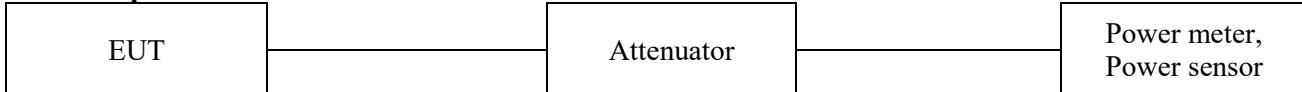
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3.2. Output power

Test procedure

ANSI C63.10-2013 - Section 11.9.1.3 and 11.9.2.3.2

Test setup



ANSI C63.10-2013 - Section 11.9.1.3

The maximum peak conducted output power may be measured using a broadband peak RF power meter. The power meter shall have a video bandwidth that is greater than or equal to the DTS bandwidth and shall use a fast-responding diode detector.

ANSI C63.10-2013 - Section 11.9.2.3.2

Alternatively, measurements may be performed using a wideband gated RF power meter provided that the gate parameters are adjusted such that the power is measured only when the EUT is transmitting at its maximum power control level. Because the measurement is made only during the ON time of the transmitter, no duty cycle correction is required.

Limit

According to §15.247(b)(3), For systems using digital modulation in the 902~928 MHz, 2 400~2 483.5 MHz, and 5 725~5 850 MHz bands: 1 Watt. As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted out-put power. Maximum Conducted Out-put Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.

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3701, 40, Simin-daero 365beon-gil,
Dongan-gu, Anyang-si, Gyeonggi-do, 14057, Korea
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Report No.:
KES-RF1-21T0213
Page (10) of (36)

Test results

| Mode | 902.9 MHz | | 915.3 MHz | | 927.3 MHz | | |
|------|------------------|---------------|------------------|---------------|------------------|---------------|-------|
| | Average (dBm) | Peak (dBm) | Average (dBm) | Peak (dBm) | Average (dBm) | Peak (dBm) | |
| Tx | 12.50 | 12.53 | 12.54 | 12.58 | 12.60 | 12.64 | 30.00 |

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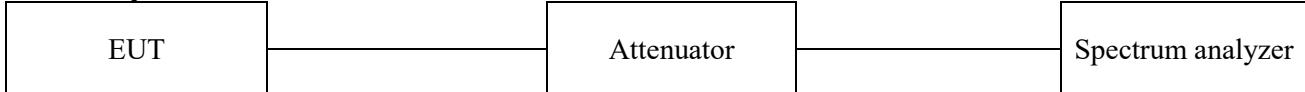
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3.3. Power spectral density

Test procedure

ANSI C63.10-2013 - Section 11.10.2

Test setup



Section 10.2 & ANSI C63.10-2013 - Section 11.10.2

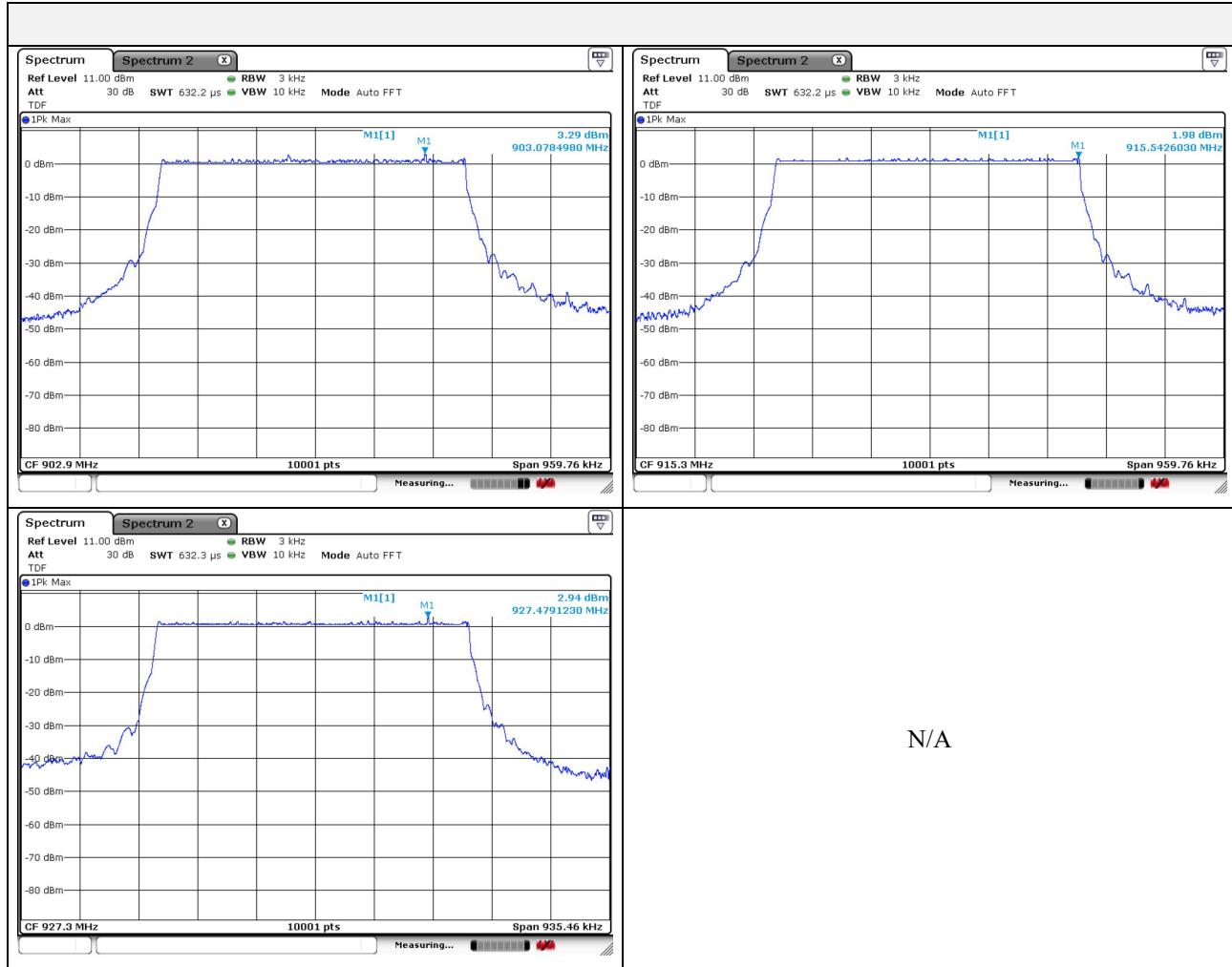
- a. Set analyzer center frequency to DTS channel center frequency.
- b. Set the span to 1.5 times the DTS bandwidth.
- c. Set the RBW to $3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$
- d. Set the VBW $\geq [3 \times \text{RBW}]$.
- e. Detector = peak.
- f. Sweep time = auto couple.
- g. Trace mode = max hold.
- h. Allow trace to fully stabilize.
- i. Use the peak marker function to determine the maximum amplitude level within the RBW.
- j. If measured value exceeds requirement, then reduce RBW (but no less than 3 kHz) and repeat.

Limit

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

Results

| Frequency(MHz) | PSD (dBm) | Limit(dBm) |
|----------------|-----------|------------|
| 902.9 | 3.29 | 8 |
| 915.3 | 1.98 | |
| 927.3 | 2.94 | |



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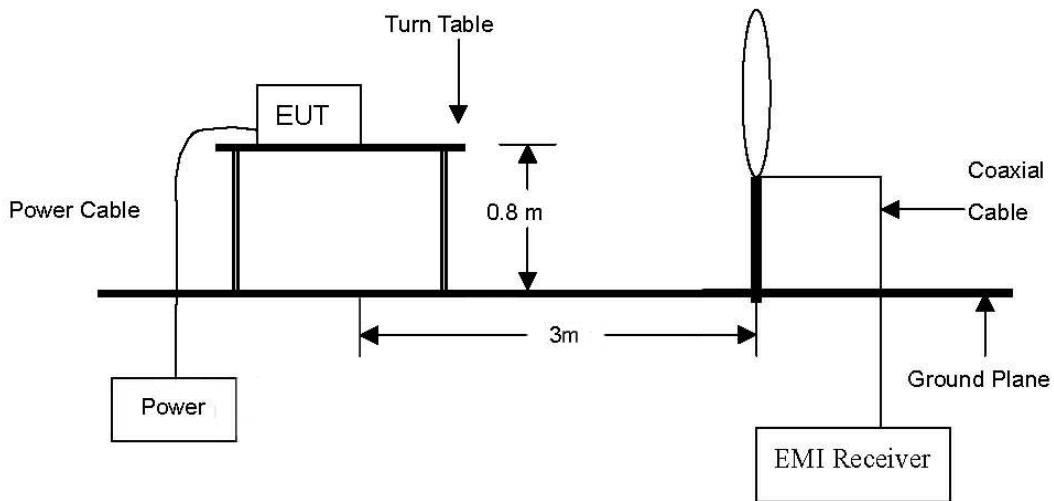
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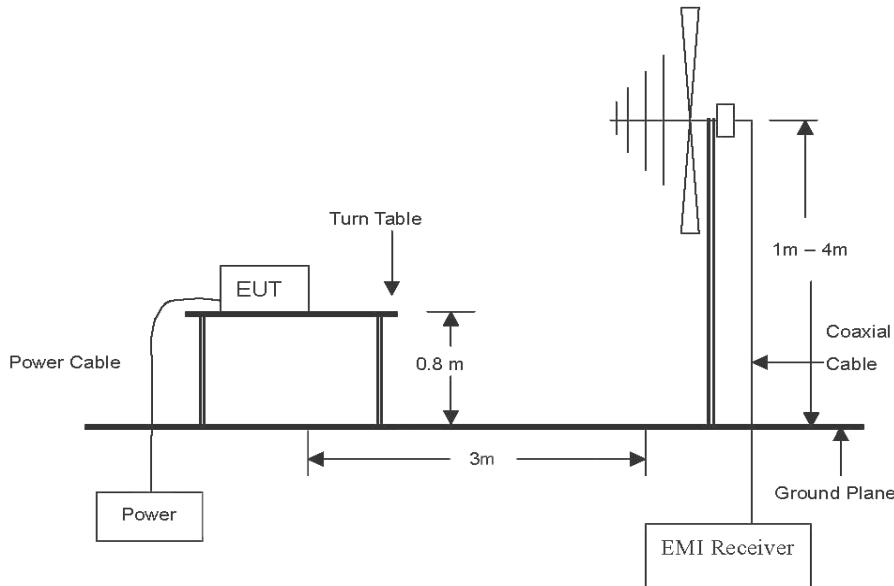
3.4. Radiated restricted band and emissions

Test setup

The diagram below shows the test setup that is utilized to make the measurements for emission from 9 kHz to 30 MHz Emissions.



The diagram below shows the test setup that is utilized to make the measurements for emission from 30 MHz to 1 GHz emissions.

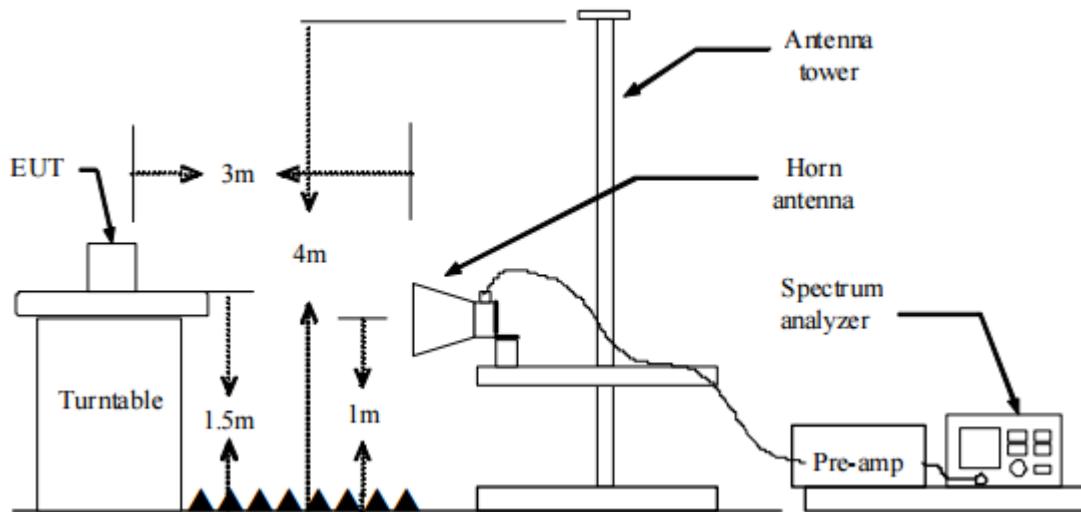


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The diagram below shows the test setup that is utilized to make the measurements for emission from 1 GHz to the tenth harmonic of the highest fundamental frequency or to 40 GHz emissions, whichever is lower.



Test procedure

Radiated emissions from the EUT were measured according to the dictates in section 11.11 & 11.12 of ANSI C63.10-2013.

Test procedure below 30 MHz

1. The EUT was placed on the top of a rotating table 0.8 meters above the ground at a 3 meter anechoic chamber test site. The table was rotated 360 degrees to determine the position of the highest radiation.
2. Then antenna is a loop antenna is fixed at one meter above the ground to determine the maximum value of the field strength. Both parallel, ground parallel and perpendicular of the antenna are set to make the measurement. It was determined that parallel was worst-case orientation; therefore, all final radiated testing was performed with the EUT in parallel.
3. For each suspected emission, the EUT was arranged to its worst case and then the table was turned from 0 degrees to 360 degrees to find the maximum reading.
4. The test-receiver system was set to average or quasi peak detect function and Specified Bandwidth with Maximum hold mode.

Test procedure above 30 MHz

1. The EUT was placed on the top of a rotating table 1.5 meters above the ground at a 3 meter anechoic chamber test site. The table was rotated 360 degrees to determine the position of the highest radiation.
2. The antenna is a bi-log antenna, a horn antenna ,and its height are 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.
3. 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 table was turned from 0 degrees to 360 degrees to find the maximum reading.
4. The test receiver system was set to Peak Detect Function and Specified Bandwidth with Maximum Hold Mode.

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5. Spectrum analyzer settings for $f < 1$ GHz:

- ① Span = wide enough to fully capture the emission being measured
- ② RBW = 100 kHz
- ③ VBW \geq RBW
- ④ Detector = quasi peak
- ⑤ Sweep time = auto
- ⑥ Trace = max hold

6. Spectrum analyzer settings for $f \geq 1$ GHz: Peak

- ① Analyzer center frequency was set to the frequency of the radiated spurious emission of interest
- ② RBW = 1 MHz
- ③ VBW ≥ 3 MHz
- ④ Detector = peak
- ⑤ Sweep time = auto
- ⑥ Trace = max hold
- ⑦ Trace was allowed to stabilize

7. Spectrum analyzer settings for $f \geq 1$ GHz: Average

- ① Analyzer center frequency was set to the frequency of the radiated spurious emission of interest
- ② RBW = 1 MHz
- ③ VBW $\geq 3 \times$ RBW
- ④ Detector = RMS, if span/(# of points in sweep) \leq (RBW/2). Satisfying this condition may require increasing the number of points in the sweep or reducing the span. If this condition cannot be satisfied, then the detector mode shall be set to peak.
- ⑤ Averaging type = power(i.e., RMS)
 - 1) As an alternative, the detector and averaging type may be set for linear voltage averaging.
 - 2) Some instruments require linear display mode in order to use linear voltage averaging. Log or dB averaging shall not be used.
- ⑥ Sweep = auto
- ⑦ Trace = max hold
- ⑧ Perform a trace average of at least 100 traces.
- ⑨ A correction factor shall be added to the measurement results prior to comparing to the emission limit in order to compute the emission level that would have been measured had the test been performed at 100 percent duty cycle. The correction factor is computed as follows:
 - 1) If power averaging (RMS) mode was used in step ⑤, then the applicable correction factor is $10 \log(1/x)$, where x is the duty cycle.
 - 2) If linear voltage averaging mode was used in step ⑤, then the applicable correction factor is $20 \log(1/x)$, where x is the duty cycle.
 - 3) If a specific emission is demonstrated to be continuous (\geq 98 percent duty cycle) rather than turning on and off with the transmit cycle, then no duty cycle correction is required for that emission.

**Note.**

1. $f < 30 \text{ MHz}$, extrapolation factor of 40 dB/decade of distance. $F_d = 40 \log(D_m/D_s)$
2. $f \geq 30 \text{ MHz}$, extrapolation factor of 20 dB/decade of distance. $F_d = 20 \log(D_m/D_s)$

Where:

F_d = Distance factor in dB
 D_m = Measurement distance in meters
 D_s = Specification distance in meters

3. Field strength(dB μ V/m) = Level(dB μ V) + CF (dB) + or DCF(dB)
4. Emissions below 18 GHz were measured at a 3 meter test distance while emissions above 18 GHz were measured at a 1 meter test distance with the application of a distance correction factor.
5. The fundamental of the EUT was investigated in three orthogonal orientations X, Y and Z, it was determined that **X orientation** was worst-case orientation; therefore, all final radiated testing was performed with the EUT in **X orientation**.
6. The worst-case emissions are reported however emissions whose levels were not within 20 dB of respective limits were not reported.
7. According to exploratory test no any obvious emission were detected from 9 kHz to 30 MHz. Although these tests were performed other than open field site, adequate comparison measurements were confirmed against 30 m open field site. Therefore sufficient tests were made to demonstrate that the alternative site produces results that correlate with the ones of tests made in an open field based on KDB 414788.

Limit

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

| Frequency (MHz) | Distance (Meters) | Radiated (μ V/m) |
|-----------------|-------------------|-----------------------|
| 0.009 ~ 0.490 | 300 | 2400/F(kHz) |
| 0.490 ~ 1.705 | 30 | 24000/F(kHz) |
| 1.705 ~ 30.0 | 30 | 30 |
| 30 ~ 88 | 3 | 100** |
| 88 ~ 216 | 3 | 150** |
| 216 ~ 960 | 3 | 200** |
| Above 960 | 3 | 500 |

**Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this Section shall not be located in the frequency bands 54 ~ 72 MHz, 76 ~ 88 MHz, 174 ~ 216 MHz or 470 ~ 806 MHz. However, operation within these frequency bands is permitted under other sections of this Part, e.g., Sections 15.231 and 15.241.

Duty cycle

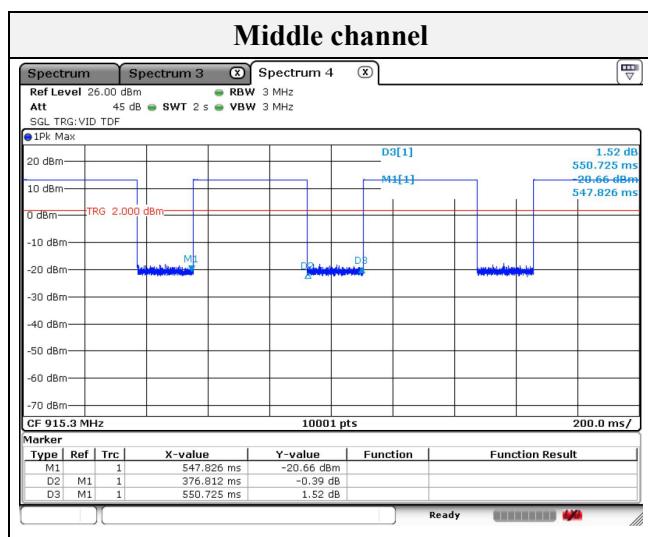
Regarding to KDB 558074 D01_v05 r02, 6. Measurements of duty cycle and transmission duration shall be performed using one of the following techniques:

- a) A diode detector and an oscilloscope that together have sufficiently short response time to permit accurate measurements of the on- and off-times of the transmitted signal.
- b) The zero-span mode on a spectrum analyzer or EMI receiver if the response time and spacing between bins on the sweep are sufficient to permit accurate measurements of the on- and off-times of the transmitted signal.

| T _{on} time (ms) | Period (ms) | Duty cycle (Linear) | Duty cycle (%) | Duty cycle correction factor (dB) |
|------------------------------|----------------|------------------------|-------------------|--------------------------------------|
| 376.812 | 550.725 | 0.684 | 68.421 | 1.65 |

Duty cycle (Linear) = T_{on} time/Period

DCF(Duty cycle correction factor (dB)) = 10log(1/duty cycle)



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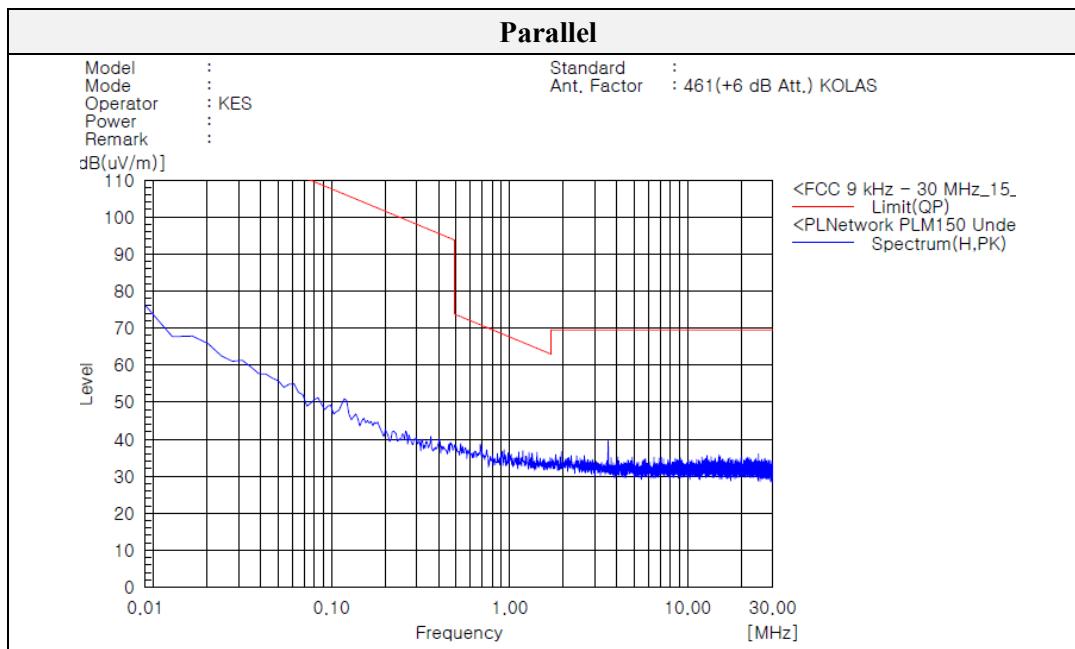
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Test results (Below 30 MHz)

Distance of measurement: 3 meter

Channel: 39



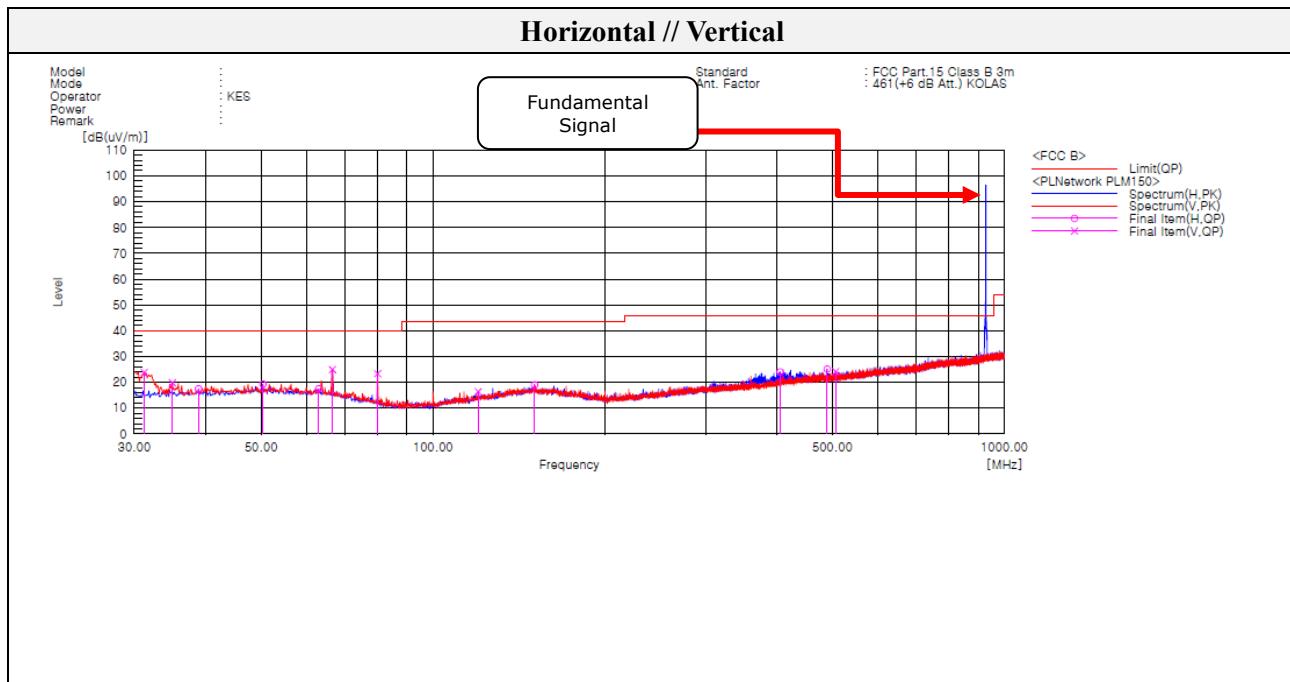
Note.

1. No spurious emission were detected at under 30 MHz.

Test results (Below 1 000 MHz)

Distance of measurement: 3 meter

Channel: 39


Final Result

| No. | Frequency [MHz] | (P) QP [dB(uV)] | Reading c,f [dB(1/m)] | Result QP [dB(uV/m)] | Limit QP [dB(uV/m)] | Margin QP [dB] | Height [cm] | Angle [deg] | Remark |
|-----|-----------------|-----------------|-----------------------|----------------------|---------------------|----------------|-------------|-------------|--------|
| 1 | 31.213 | V 37.8 | -13.9 | 23.9 | 40.0 | 16.1 | 149.8 | 87.6 | |
| 2 | 34.971 | V 33.7 | -13.9 | 19.8 | 40.0 | 20.2 | 135.0 | 43.1 | |
| 3 | 38.851 | H 30.9 | -13.4 | 17.5 | 40.0 | 22.5 | 225.0 | 217.8 | |
| 4 | 50.370 | H 31.9 | -12.6 | 19.3 | 40.0 | 20.7 | 207.0 | 117.3 | |
| 5 | 63.101 | H 30.8 | -13.3 | 17.5 | 40.0 | 22.5 | 178.0 | 299.1 | |
| 6 | 66.618 | V 38.8 | -13.8 | 25.0 | 40.0 | 15.0 | 151.0 | 244.1 | |
| 7 | 79.955 | V 40.4 | -17.1 | 23.3 | 40.0 | 16.7 | 143.0 | 1.3 | |
| 8 | 119.968 | V 31.7 | -15.3 | 16.4 | 43.5 | 27.1 | 128.0 | 348.0 | |
| 9 | 150.523 | H 31.4 | -12.4 | 19.0 | 43.5 | 24.5 | 385.0 | 204.4 | |
| 10 | 405.148 | H 33.3 | -9.3 | 24.0 | 46.0 | 22.0 | 100.0 | 332.1 | |
| 11 | 489.538 | H 32.6 | -7.5 | 25.1 | 46.0 | 20.9 | 115.0 | 84.3 | |
| 12 | 506.634 | V 31.5 | -7.3 | 24.2 | 46.0 | 21.8 | 107.0 | 261.8 | |
| 13 | 927.493 | H ----- | 0.8 | ----- | 46.0 | ----- | 100.0 | 0.0 | |

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**Test results (Above 1 000 MHz)**

Distance of measurement: 3 meter

Channel: 00

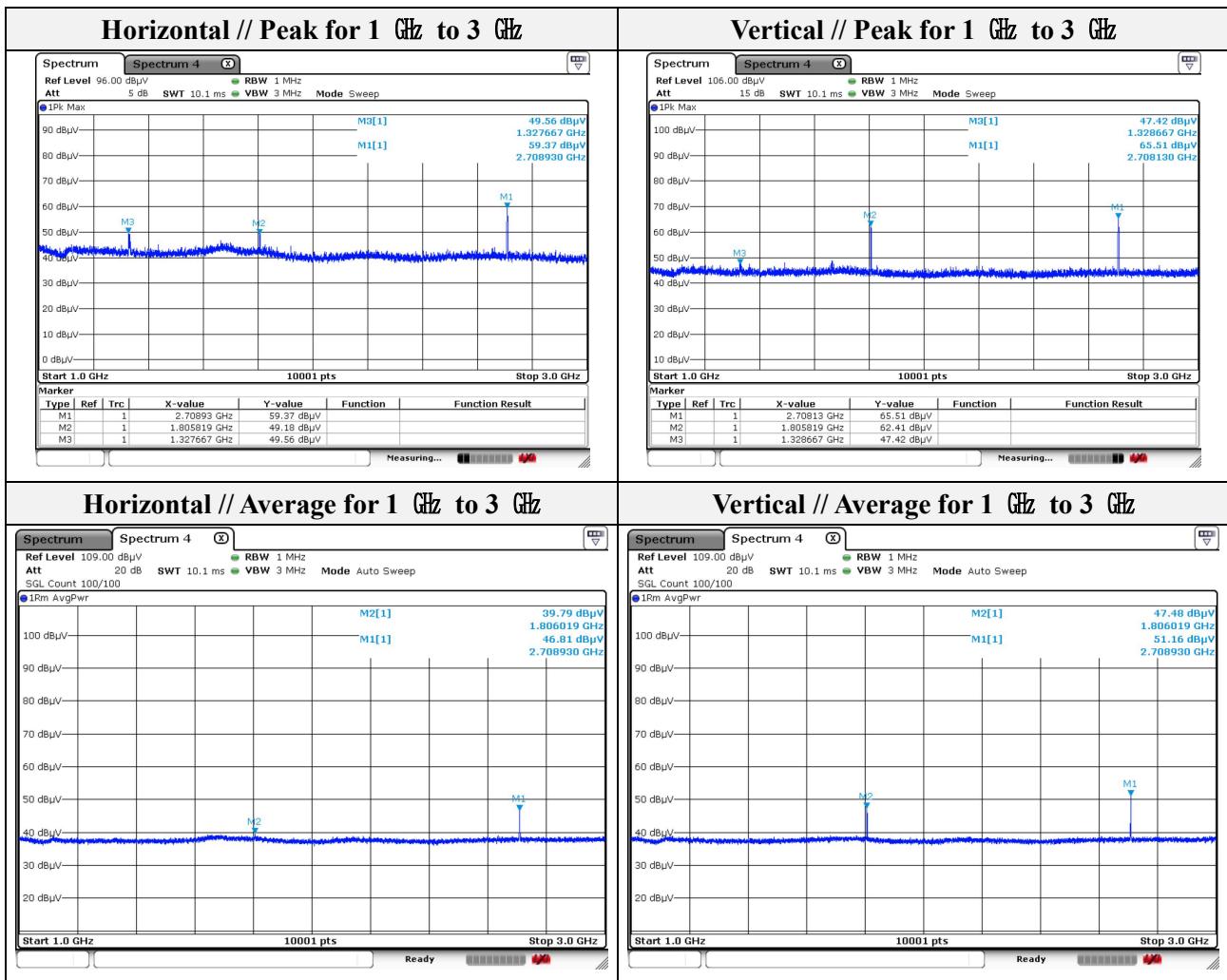
- Spurious

| Frequency (MHz) | Level (dB μ V) | Detect mode | Ant. Pol. (H/V) | CF (dB) | DCF (dB) | Field strength (dB μ V/m) | Limit (dB μ V/m) | Margin (dB) |
|-----------------|--------------------|-------------|-----------------|---------|----------|-------------------------------|----------------------|-------------|
| 1 327.67 | 49.56 | Peak | H | -9.41 | - | 40.15 | 74.00 | 33.85 |
| 1 328.67 | 47.42 | Peak | V | -9.41 | - | 38.01 | 74.00 | 35.99 |
| 1 805.82 | 49.18 | Peak | H | -6.04 | - | 43.14 | 74.00 | 30.86 |
| 1 805.82 | 62.41 | Peak | V | -6.04 | - | 56.37 | 74.00 | 17.63 |
| 1 805.82 | 47.48 | Average | V | -6.04 | 1.65 | 43.09 | 54.00 | 10.91 |
| 2 708.83 | 59.37 | Peak | H | -1.71 | | 57.66 | 74.00 | 16.34 |
| 2 708.83 | 46.81 | Average | H | -1.71 | 1.65 | 46.75 | 54.00 | 7.25 |
| 2 708.13 | 65.51 | Peak | V | -1.72 | | 63.79 | 74.00 | 10.21 |
| 2 708.13 | 51.16 | Average | V | -1.72 | 1.65 | 51.09 | 54.00 | 2.91 |
| 3 612.70 | 49.89 | Peak | V | 0.51 | | 50.40 | 74.00 | 23.60 |

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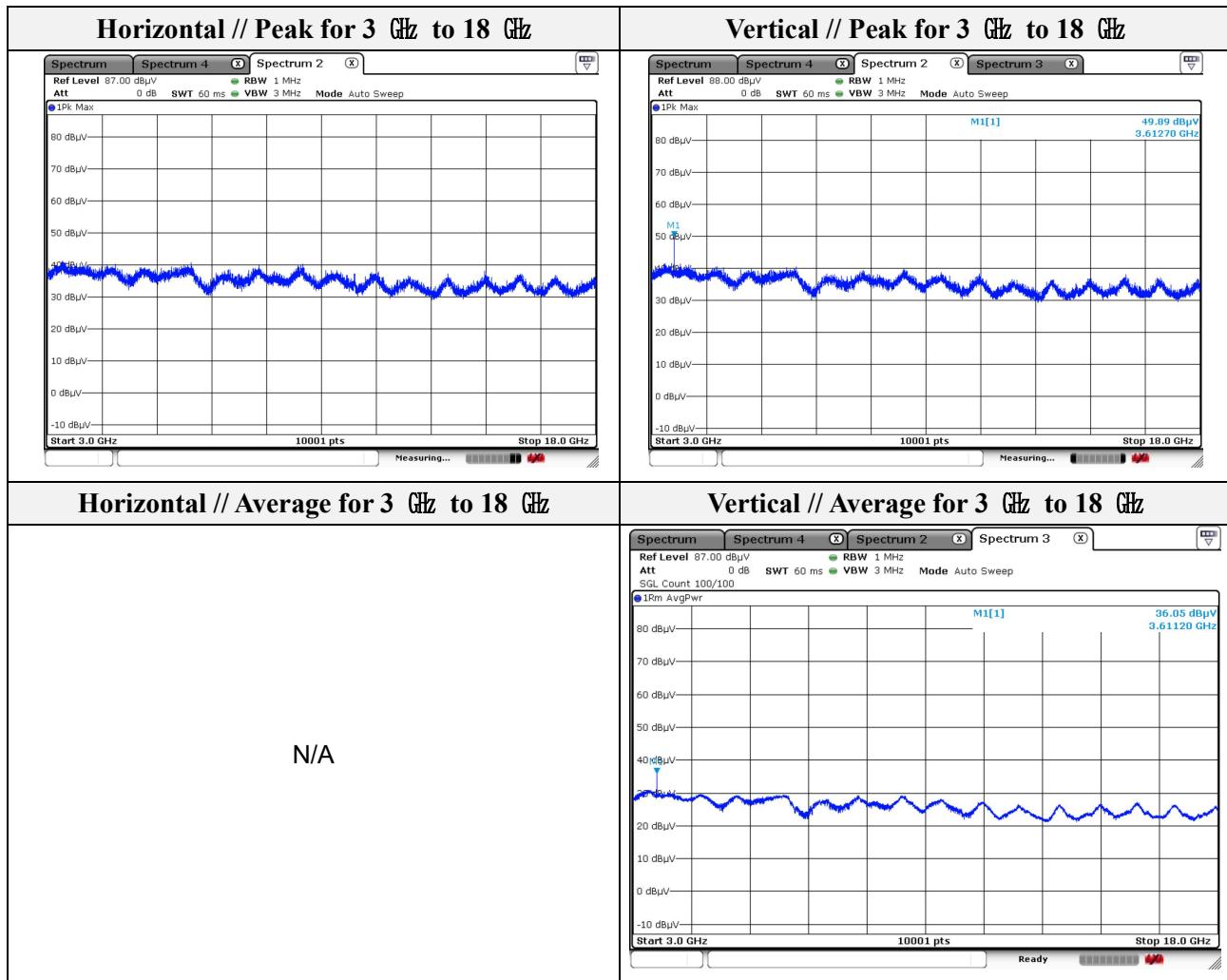
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The authenticity of the test report, contact shchoi@kes.co.kr



Note.

1. No spurious emission were detected at horizontal above 3 GHz.

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KES Co., Ltd.

3701, 40, Simin-daero 365beon-gil,
Dongan-gu, Anyang-si, Gyeonggi-do, 14057, Korea
Tel: +82-31-425-6200 / Fax: +82-31-424-0450
www.kes.co.kr

Report No.:
KES-RF1-21T0213
Page (23) of (36)

Distance of measurement: 3 meter

Channel: 20

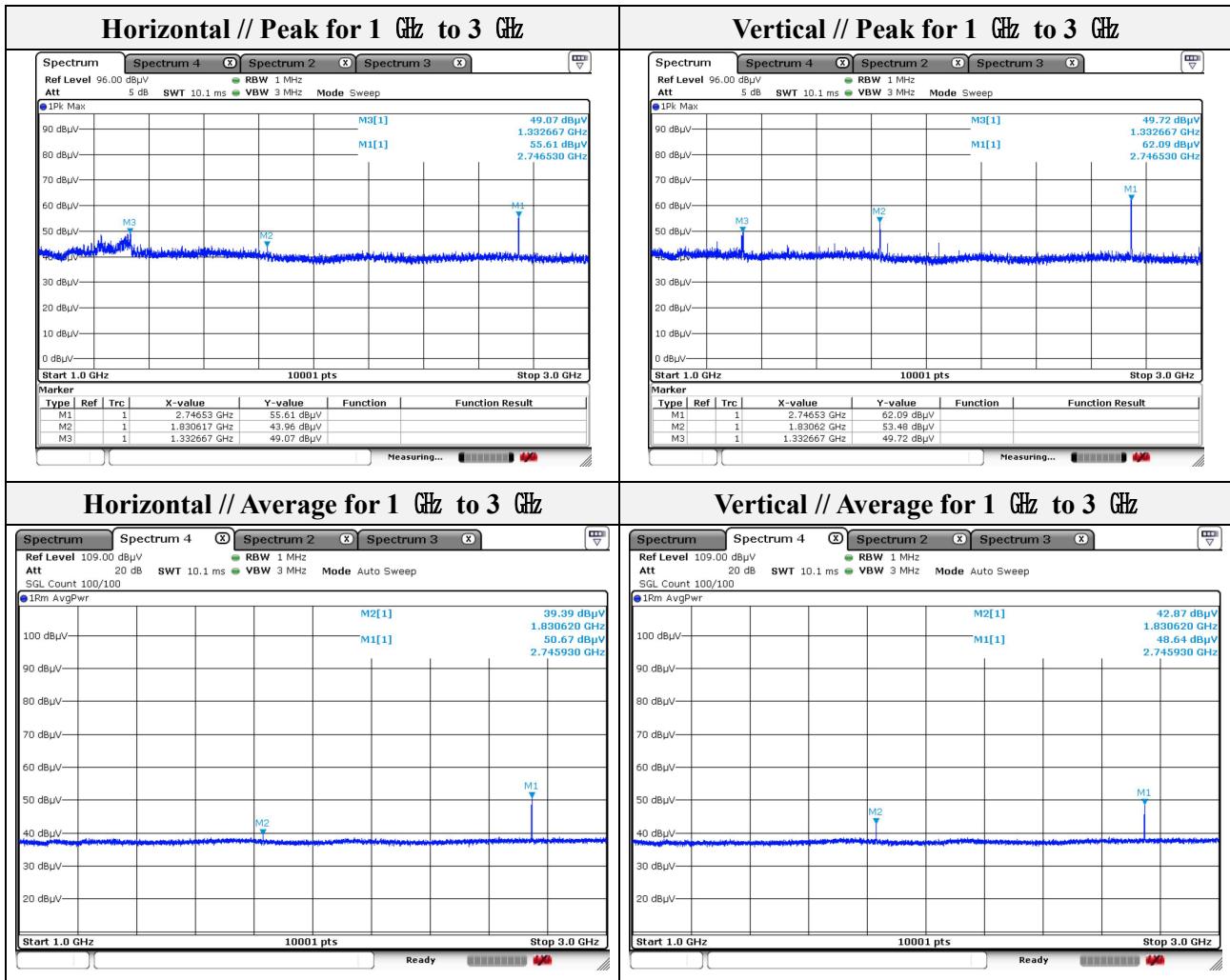
- Spurious

| Frequency (MHz) | Level (dB μ V) | Detect mode | Ant. Pol. (H/V) | CF (dB) | DCF (dB) | Field strength (dB μ V/m) | Limit (dB μ V/m) | Margin (dB) |
|-----------------|--------------------|-------------|-----------------|---------|----------|-------------------------------|----------------------|-------------|
| 1 332.67 | 49.07 | Peak | H | -9.39 | - | 39.68 | 74.00 | 34.32 |
| 1 332.67 | 49.72 | Peak | V | -9.39 | - | 40.33 | 74.00 | 33.67 |
| 1 830.62 | 43.96 | Peak | H | -5.83 | - | 38.13 | 74.00 | 35.87 |
| 1 830.62 | 53.48 | Peak | V | -5.83 | - | 47.65 | 74.00 | 26.35 |
| 2 746.53 | 55.61 | Peak | H | -1.59 | | 54.02 | 74.00 | 19.98 |
| 2 746.53 | 50.67 | Average | H | -1.59 | 1.65 | 50.73 | 54.00 | 3.27 |
| 2 746.53 | 62.09 | Peak | V | -1.59 | | 60.50 | 74.00 | 13.50 |
| 2 746.53 | 48.64 | Average | V | -1.59 | 1.65 | 48.70 | 54.00 | 5.30 |
| 3 662.20 | 49.67 | Peak | V | 0.80 | | 50.47 | 74.00 | 23.53 |
| 6 408.40 | 43.13 | Peak | V | 8.03 | | 51.16 | 74.00 | 22.84 |

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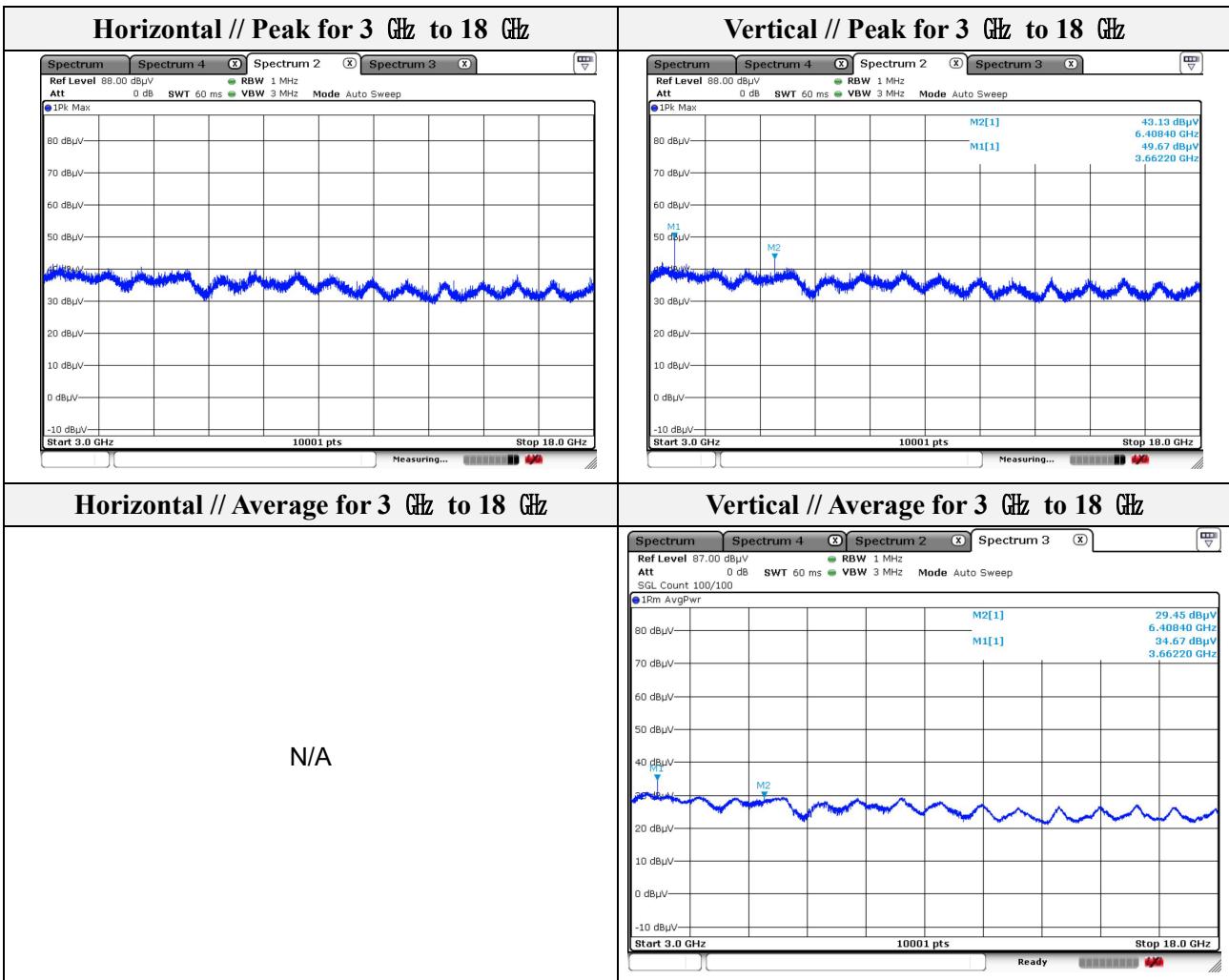
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1. No spurious emission were detected at horizontal above 3 GHz.