TEST REPORT

CTK Co., Ltd.
(Ho-dong), 113, Yejik-ro, Cheoin-gu,
Yongin-si, Gyeonggi-do, Korea
Tel: +82-31-339-9970
Fax: +82-31-624-9501

Report No.:
CTK-2024-01254

1. Applicant

◦ Name : Hyundai Autoever Corp.

◦ Address : 510 Teheran-ro, Gangnam-gu, Seoul, Republic of Korea

◦ Date of Receipt : 2024-03-11

2. Manufacturer

◦ Name : TEIA Co.,Ltd

◦ Address : Suite B-303/304, 33 Gwacheon-daero 7-gil, Gwacheon-si, Gyeonggi-do, Republic of Korea

3. Use of Report : For FCC Certification

4. Test Sample / Model : Integrated Tool Tag / TTU-C40 (HAE-ST-UWB-E-N-P-005)

5. Date of Test : 2024-03-18 to 2024-03-25

6. Test Standard(method) used : FCC 47 CFR part 15 subpart C 15.517

7. Testing Environment: refer to 7 page

8. Test Results : Compliance

9. Location of Test : ☒ Permanent Testing Lab ☐ On Site Testing
(Address : 5, Dongbu-ro 221beon-gil, Cheoin-gu, Yongin-si, Gyeonggi-do, Korea)

Approval	Tested by Bong-seok Kim: (Signature)	Technical Manager Young-taek Lee: (Signature)

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

2024-04-26

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REPORT REVISION HISTORY

Date	Revision	Page No
2024-04-26	Issued (CTK-2024-01254)	all

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1. General Description

1.1 Client Information

Company	Hyundai Autoever Corp.
Contact Point	510 Teheran-ro, Gangnam-gu, Seoul, Republic of Korea
Contact Person	Name : Yun Su Shim E-mail : ysshim@hyundai-autoever.com

1.2 Product Information

FCC ID	2BFPQ-TTU-C40
Product Description	Integrated Tool Tag
Model name	TTU-C40 (HAE-ST-UWB-E-N-P-005)
Variant Model name	-
Charging Frequency	6 489.6 MHz
Antenna Type	PCB Pattern
Power Source	DC 3.7 V

1.3 Antenna Information

☒	Integral antenna (antenna permanently attached)	
	☐	Temporary RF connector provided
	☒	No temporary RF connector provided. Transmit chains bypass antenna and soldered temporary RF connector provided for connected measurement. In case of conducted measurements the transmitter shall be connected to the measuring equipment via a suitable attenuator and correct for all losses in the RF path.
☐	External antenna (dedicated antennas)	

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2. Accreditations

2.1 Laboratory Accreditations and Listings

Country	Agency	Registration Number
USA	FCC	805871
CANADA	ISED	CN : 8737A CAB ID : KR0025
KOREA	NRRA	KR0025

2.2 Calibration Details of Equipment Used for Measurement

Test equipment and test accessories are calibrated on regular basis. The maximum time between calibrations is one year or what is recommended by the manufacturer, whichever is less. All test equipment calibrations are traceable to the Korea Research Institute of Standards and Science (KRISS), therefore, all test data recorded in this report is traceable to KRISS.

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3. Test Specifications

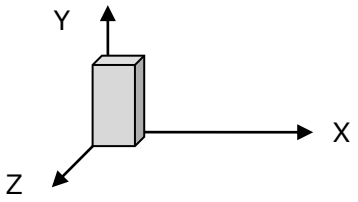
3.1 Standards

FCC Part Section(s)	Test item	Status (Note 1)	Report Clause
15.203	Antenna Requirement	C	1.3
15.503(d) / 15.517(b)	Emission Bandwidth	C	4.1
15.517(c) / 15.209	Radiated Emissions	C	4.2
15.517(d)	Radiated emissions within the 1164 MHz to 1240 MHz and 1559 MHz to 1610 MHz frequency ranges.	C	4.2
15.517(e)	Peak power of fundamental frequency within a 50 MHz bandwidth	C	4.2
15.207	AC Power Line Conducted Emissions	C	4.3
Note 1: C=Complies NC=Not Complies NT=Not Tested NA=Not Applicable			
Note 2: The data in this test report are traceable to the national or international standards.			
Note 3: The sample was tested according to the following specification: ANSI C63.10-2013.			

3.2 Mode of operation during the test

The sample transmits UWB signals continuously.

Measurement Configuration

Tests Item	Radiated Emissions
Condition	Radiated measurement
User Position	☐ EUT will be placed in fixed position.
	☒ EUT will be placed in mobile position and operating multiple positions.
	☐ EUT will be a hand-held or body-worn battery-powered devices and operating multiple positions.
EUT faces identified relative to view from receiving antenna	

3.3 Peripheral Devices

No.	Device	Manufacturer	Model No.	Serial No.
-	-	-	-	-

3.4 Measurement Uncertainty

The value of the measurement uncertainty for the measurement of each parameter.
Coverage factor k = 2, Confidence levels of 95 %

Test Item	Uncertainty
Occupied Bandwidth	0.1 MHz (C.L.: Approx. 95 %, k = 2)
Radiated Emissions (f ≤ 1 GHz)	3.88 dB (C.L.: Approx. 95 %, k = 2)
Radiated Emissions (f > 1 GHz)	4.50 dB (C.L.: Approx. 95 %, k = 2)
Line Conducted Emission	2.08 dB (C.L.: Approx. 95 %, k = 2)

3.5 Test Software

Radiated Test	EP5RE Ver. 6.0.10, ES10 Ver. 2022.04.000
Line Conducted Test	EMC32 Ver. 10.50.00

3.6 Testing Environment

Test Item	Test Date	Temperature (℃)	Relative Humidity (%)
Emission Bandwidth	2024-03-25	20 ~ 22	29 ~ 35
Radiated Emissions (below 1GHz)	2024-03-19	21 ~ 23	21 ~ 27
Radiated Emissions (above 1GHz)	2024-03-18	20 ~ 22	30 ~ 36
Radiated emissions within the 1164 MHz to 1240 MHz and 1559 MHz to 1610 MHz frequency ranges.	2024-03-18	20 ~ 22	30 ~ 36
Peak power of fundamental frequency within a 50 MHz bandwidth	2024-03-18	20 ~ 22	30 ~ 36
AC Power Line Conducted Emissions	2024-03-25	19 ~ 21	26 ~ 32

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4. Technical Characteristic Test

4.1 Emission Bandwidth

Requirement

§15.517(b) The UWB bandwidth of a UWB system operating under the provisions of this section must be contained between 3100 MHz and 10,600 MHz.

§15.503(d) An intentional radiator that, at any point in time, has a fractional bandwidth equal to or greater than 0.20 or has a UWB bandwidth equal to or greater than 500 MHz, regardless of the fractional bandwidth.

Test Procedures

ANSI C63.10-2013, clause 10.1

The frequency at which the maximum power level is measured with the peak detector is designated f_M. The peak power measurements shall be made using a spectrum analyzer or EMI receiver with a 1 MHz resolution bandwidth and a video bandwidth of 1 MHz or greater. The instrument shall be set to peak detection using the maximum-hold trace mode. The outermost 1 MHz segments above and below f_M, where the peak power falls by 10 dB relative to the level at f_M, are designated as f_H and f_L, respectively:

a) For the lowest frequency bound f_L, the emission is searched from a frequency lower than f_M that has, by inspection, a peak power much lower than 10 dB less than the power at f_M and increased toward f_M until the peak power indicates 10 dB less than the power at f_M. The frequency of that segment is recorded.

b) This process is repeated for the highest frequency bound f_H, beginning at a frequency higher than f_M that has, by inspection, a peak power much lower than 10 dB below the power at f_M. The frequency of that segment is recorded.

c) The two recorded frequencies represent the highest f_H and lowest f_L bounds of the UWB transmission, and the −10 dB bandwidth is defined as $(f_H - f_L)$. The center frequency (f_C) is mathematically determined from $(f_H - f_L) / 2$.

d) The fractional bandwidth is defined as $2(f_H - f_L) / (f_H + f_L)$.

e) Determine whether the −10 dB bandwidth $(f_H - f_L)$ is ≥500 MHz, or whether the fractional bandwidth $2(f_H - f_L) / (f_H + f_L)$ is ≥0.2.

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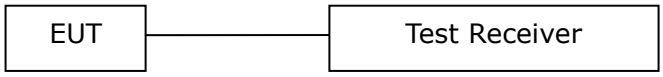
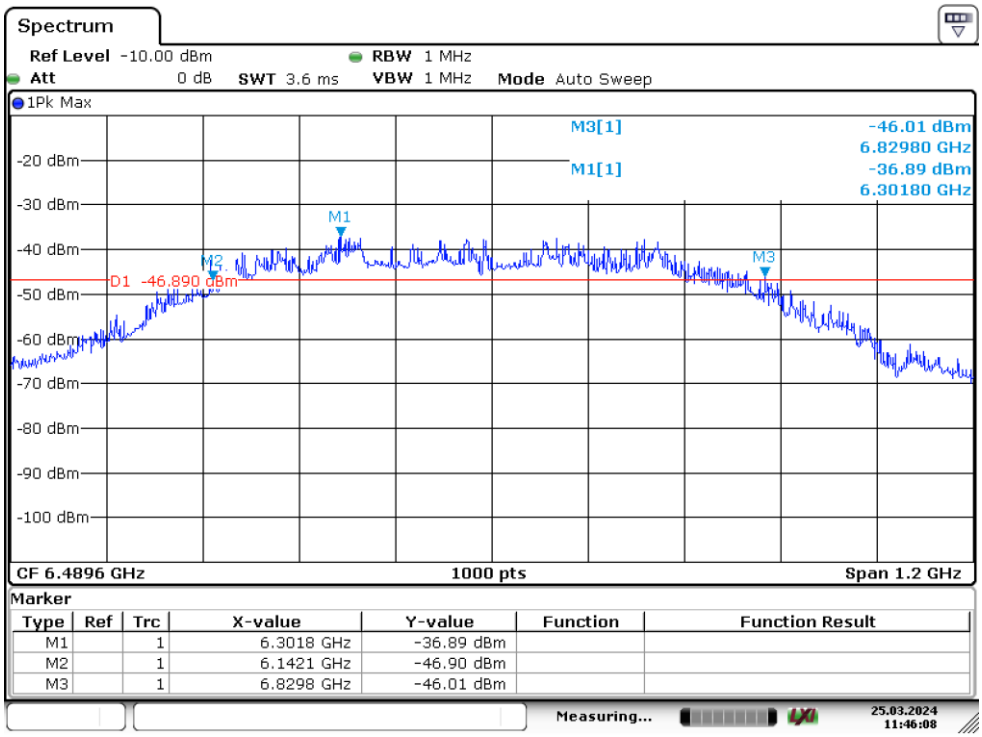
Test Setup



Test results

The requirements are:
☒ Complies

f_H	f_L	-10 dB bandwidth (f_H - f_L)	Limit
6 829.8 MHz	6 142.1 MHz	687.7 MHz	Great than 500 MHz



4.2 Radiated emission

Requirement

§15.517(c) The radiated emissions at or below 960 MHz from a device operating under the provisions of this section shall not exceed the emission levels in §15.209.

Frequency [MHz]	Field Strength [uV/m]	Field Strength [dBuV/m]	Measurement Distance [meters]
0.009-0.490	2400/F(kHz)	48.5 – 13.8	300
0.490-1.705	24000/F(kHz)	33.8 – 23	30
1.705-30	30	29.5	30
30-88	100**	40	3
88-216	150**	43.5	3
216-960	200**	46	3
Above 960	500	54	3

The radiated emissions above 960 MHz from a device operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of 1 MHz:

Frequency in MHz	EIRP in dBm	Field Strength at 3 m [dBuV/m]
960 - 1 610	-75.3	20
1 610 - 1 990	-53.3	42
1 990 – 3 100	-51.3	44
3 100 - 10 600	-41.3	54
Above 10 600	-51.3	44

§15.517(d) In addition to the radiated emission limits specified in the table above, UWB transmitters operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of no less than 1 kHz:

Frequency in MHz	EIRP in dBm	Field Strength at 3 m [dBuV/m]
1 164 – 1 240	-85.3	10
1 559 – 1 610	-85.3	10

§15.517(e) There is a limit on the peak level of the emissions contained within a 50 MHz bandwidth centered on the frequency at which the highest radiated emission occurs, f_M. That limit is 0 dBm EIRP.

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Test Procedures

1) Radiated measurement procedure below 960 MHz

Test Method	
☒	Refer as ANSI C63.10-2013, clause 6.4(Radiated emissions from unlicensed wireless devices below 30 MHz).
☒	Radiated emission tests shall be performed in the frequency range of 9 kHz to 30 MHz, using a calibrated loop antenna. When perpendicular to the ground plane, the lowest height of the magnetic antenna shall be 1 m above the ground and shall be positioned at the specified distance from the EUT. During the measurement the Loop Test Antenna rotates about its vertical axis for maximum response at each azimuth about the EUT.
	☒ The results shall be by using the square of an inverse linear distance extrapolation factor(40 dB/decade).
☒	Refer as ANSI C63.10-2013, clause 6.5(Radiated emissions from unlicensed wireless devices in the frequency range of 30 MHz to 1000 MHz).
☒	In the frequency rage above 30 MHz, Bi-Log Test Antenna(30 MHz to 1 GHz) is used. Test Antenna height is carried from 1m to 4m above the ground to determine the maximum value of the field strength. The emissions levels at both horizontal and vertical polarizations should be tested.
☒	Emissions more than 20 dB below the limit do not need to be reported.

Measuring instrument Settings	
Frequency Range	9 kHz – 1 000 MHz
RBW	200 Hz (9 kHz – 150 kHz) 9 kHz (150 kHz – 30 MHz) 120 kHz (30 MHz – 1 000 MHz)
VBW	≥ RBW
Sweep time	auto couple
Detector function	CISPR quasi-peak(below 1 000 MHz)

2) Radiated measurement procedure above 960 MHz

ANSI C63.10-2013, clause 10.3

[Determination of EIRP]

When an isotropic transmitting antenna is assumed, the following relationships in equation may be employed to relate EIRP to field strength(E) at a specified measurement distance of 3 m:

$$EIRP\ (dBm) = E(dBuV/m) - 95.3$$

[Peak power within 50 MHz bandwidth]

The peak detector of the instrument is selected and the maximum hold feature activated.

It is acceptable to employ an RBW of less than 50 MHz (but no less than 1 MHz) when performing the required peak power measurements. When this approach is employed, the peak emissions EIRP limit (0 dBm / 50 MHz) is converted to a limit commensurate with the RBW by employing a [20 log (RBW/50 MHz)] relationship. For example, the peak power limit could be expressed in a 10 MHz bandwidth as follows in Equation:

$$EIRP_{50MHz} = EIRP_{10MHz} + 20*\log(50\ MHz / 1\ MHz)$$

[Average power spectral density]

a) Set the RBW to 1 MHz.
b) Set the VBW to be at least 1 MHz (a VBW of 3 MHz is desirable).
c) Set the frequency span to examine the spectrum across a convenient frequency segment (e.g., 600 MHz).
d) Select the power averaging (rms) detector.
e) Set the sweep time so that there is no more than a 1 ms integration period over each measurement bin.

[Spectral line measurement]

Another test required for these types of devices involves the measurement of the maximum of the average power contained in any spectral lines present within the 1164 MHz to 1240 MHz and 1559 MHz to 1610 MHz frequency ranges. The measurement setup is similar to that described in [Average power spectral density]. The rms detector is selected, and the sweep time and number of measurement bins are set to provide the requisite 1 ms integration time. In this test, the RBW may be reduced to a minimum of 1 kHz (30 kHz is recommended) to enhance the resolution of the individual spectral lines. A ratio of VBW / RBW > 3 shall be maintained when possible.

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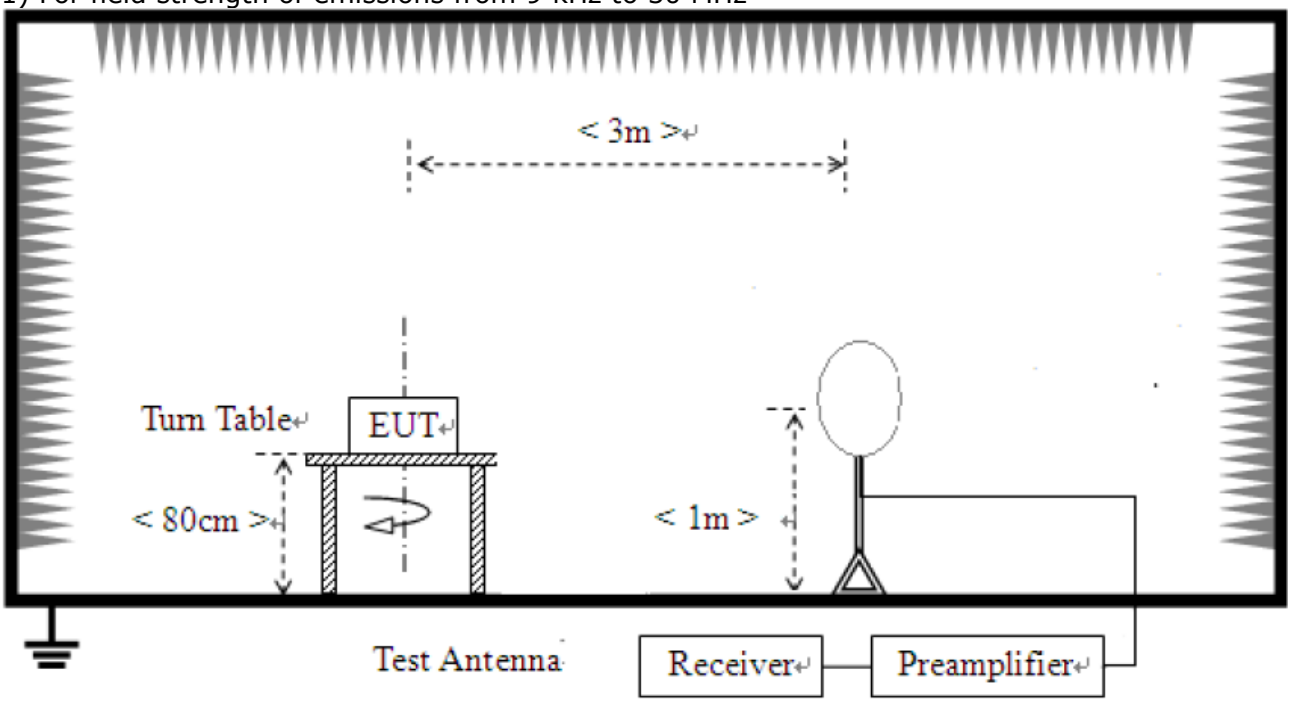
Test Location

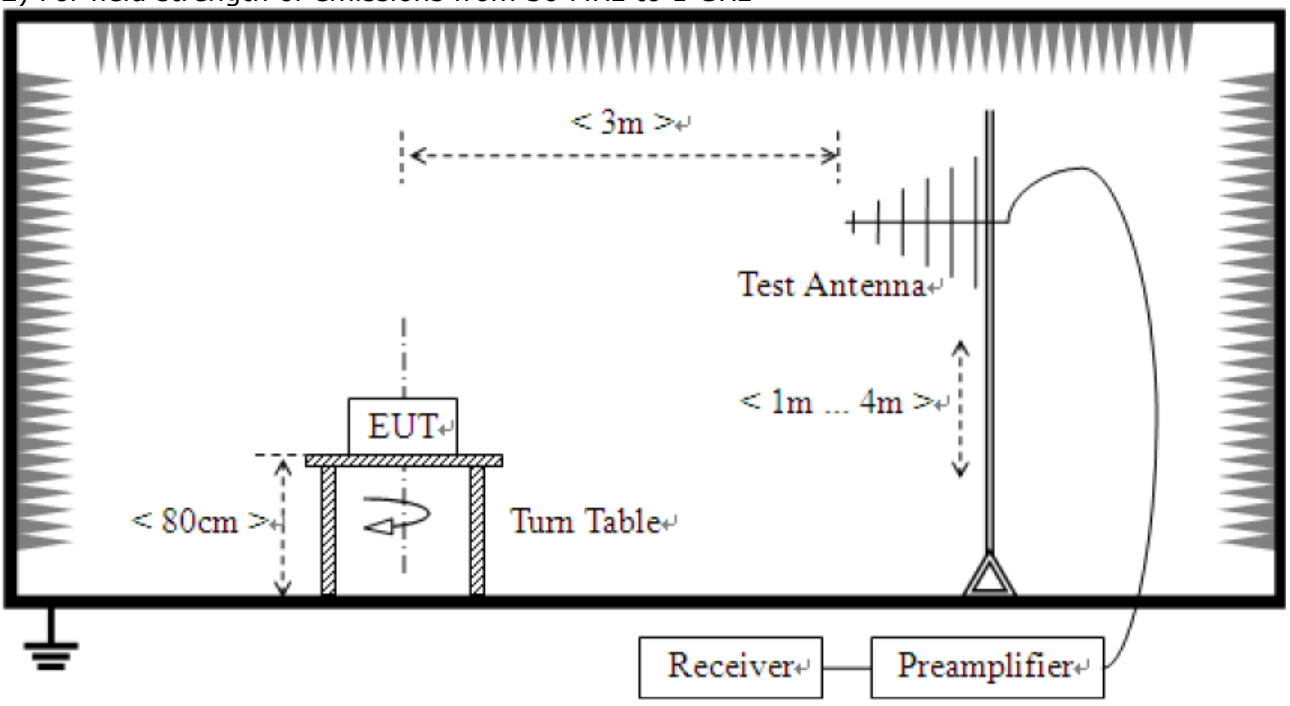
☒ 10 m SAC (test distance : ☐ 10 m, ☒ 3 m)

Test Setup

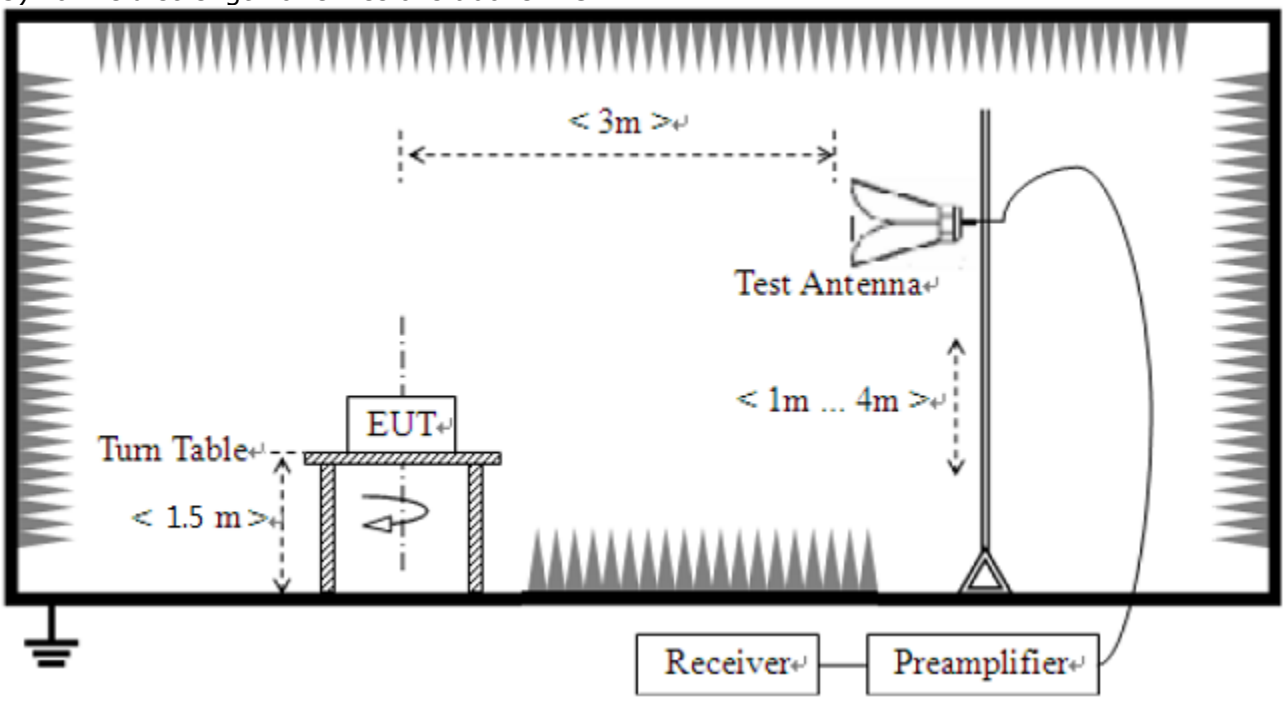
1) For field strength of emissions from 9 kHz to 30 MHz



2) For field strength of emissions from 30 MHz to 1 GHz



3) For field strength of emissions above 1 GHz



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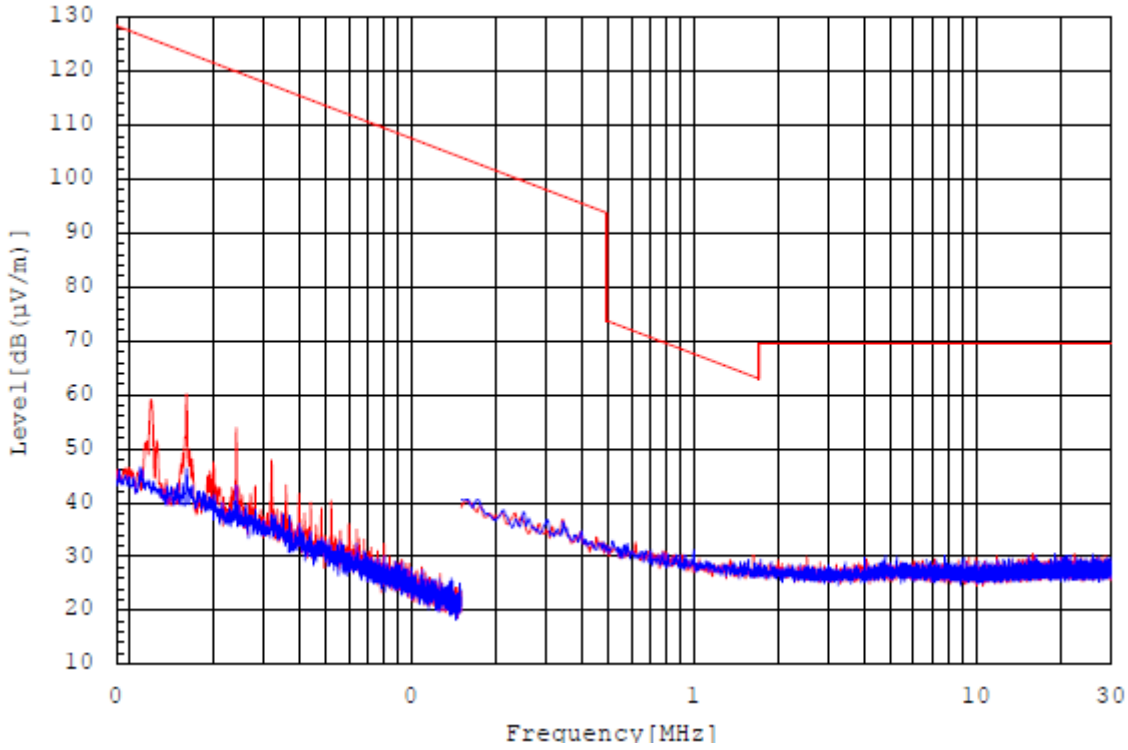
Test results

The requirements are:
☒ Complies

1) Radiated emissions in the frequency range of 9 kHz to 30 MHz

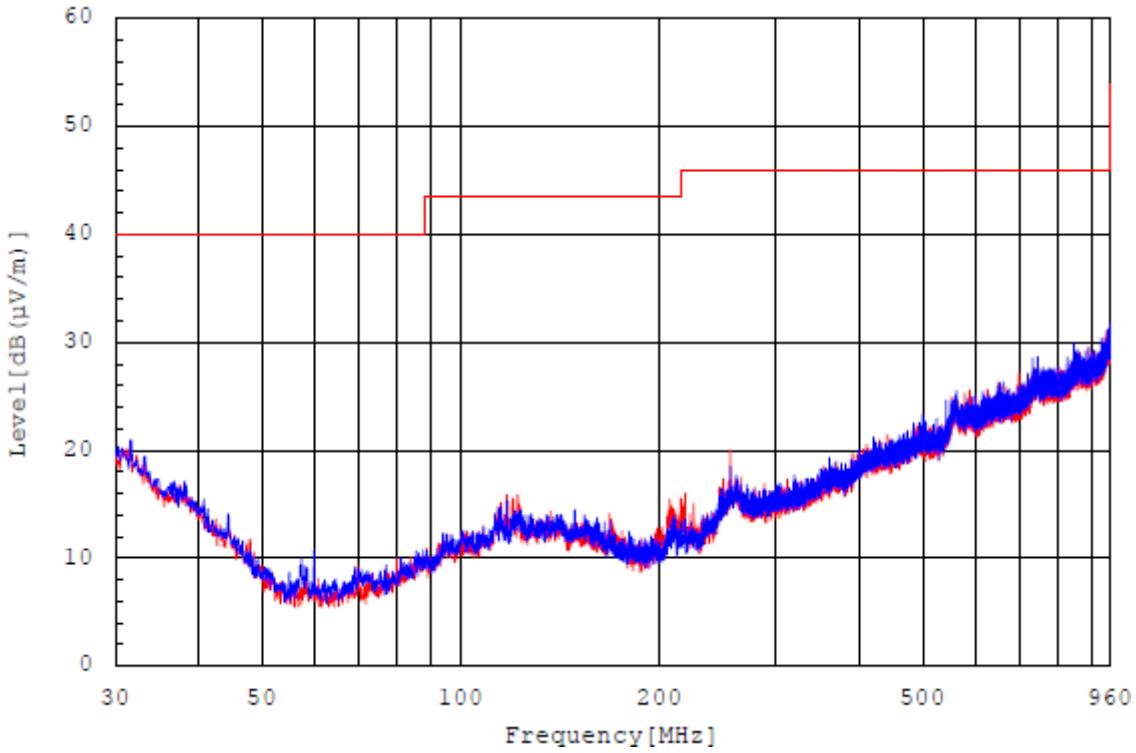


No.	Frequency [MHz]	Reading [dBuV]	c.f [dB/m]	Result [dBuV/m]	Limit [dBuV/m]	Margin[dB]	Remark
Emissions more than 20 dB below the limit do not need to be reported.							

Remark :

1. Result = Reading + c.f(correction factor)
2. Correction factor = Antenna factor + Cable loss + 6 dB attenuator
3. This graph is the result measured by peak detection.

2) Radiated emissions in the frequency range of 30 MHz to 960 MHz



No.	Frequency [MHz]	Pol.	Reading [dBuV]	c.f [dB/m]	Result [dBuV/m]	Limit [dBuV/m]	Margin[dB]	Remark
Emissions more than 20 dB below the limit do not need to be reported.								

Remark :
1. Result = Reading + c.f(Correction factor)
2. Correction factor = Antenna factor + Cable loss + 6 dB attenuator - Amp Gain
3. This graph is the result measured by peak detection.

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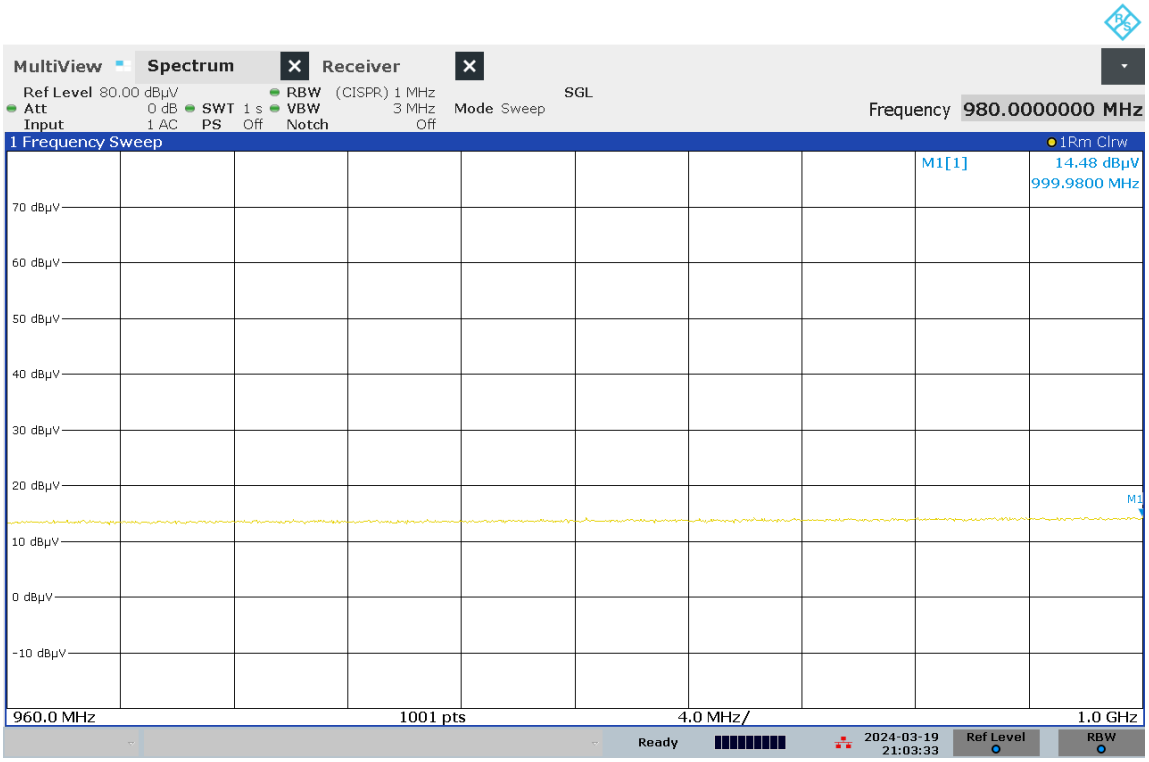
3) Radiated emissions in the frequency range of 960 MHz to 1 000 MHz

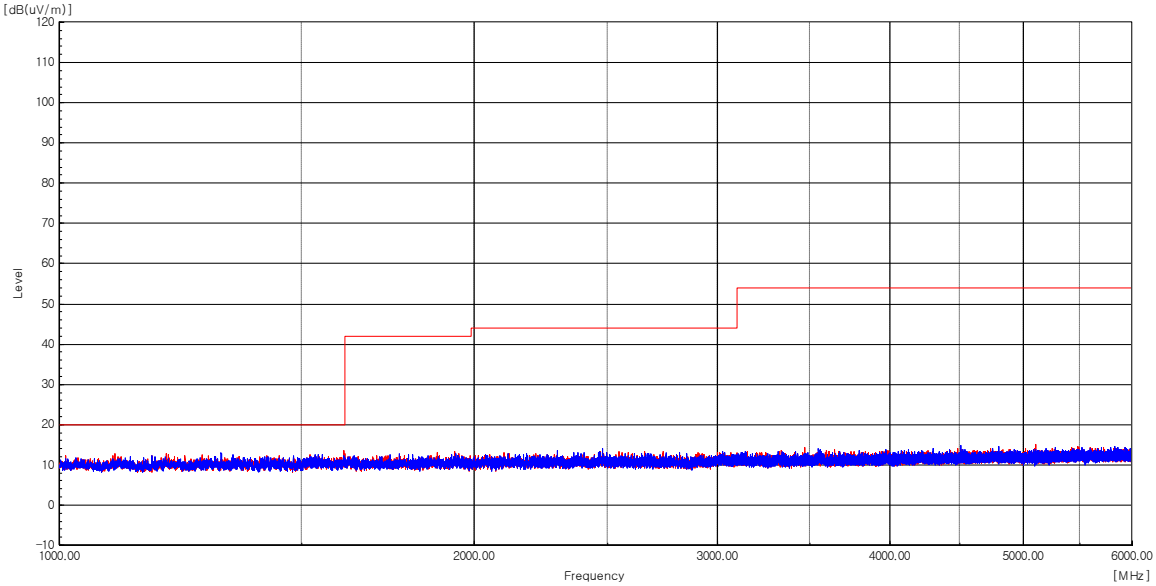


No.	Frequency [MHz]	Pol.	Reading [dBuV]	c.f [dB/m]	Result [dBuV/m]	Result [dBm]	Limit [dBm]	Margin[dB]	Remark
Not detected									

Remark :
1. Result = Reading + c.f(Correction factor)
2. Correction factor = Antenna factor + Cable loss - Amp Gain
3. Limit : -75.3 dBm => 20 dBuV/m at 3m

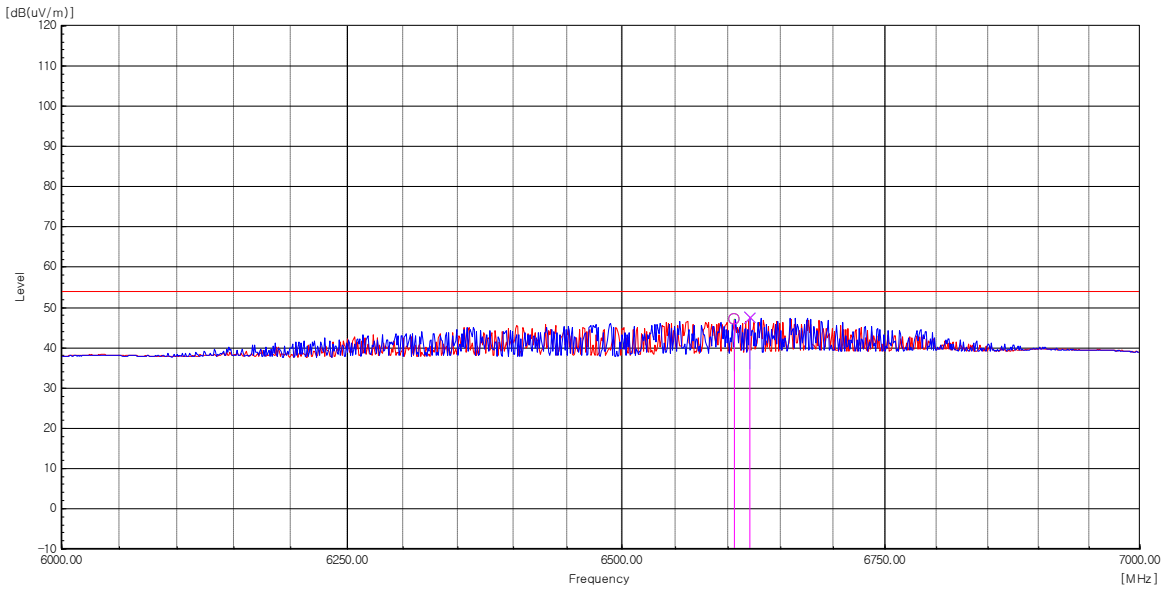
4) Radiated emissions in the frequency range of 1 GHz to 40 GHz

[1 GHz ~ 6 GHz]



No.	Frequency [MHz]	Pol.	Reading [dBuV]	c.f [dB/m]	Result [dBuV/m]	Result [dBm]]	Limit [dBm]	Margin[dB]	Remark
Not detected									

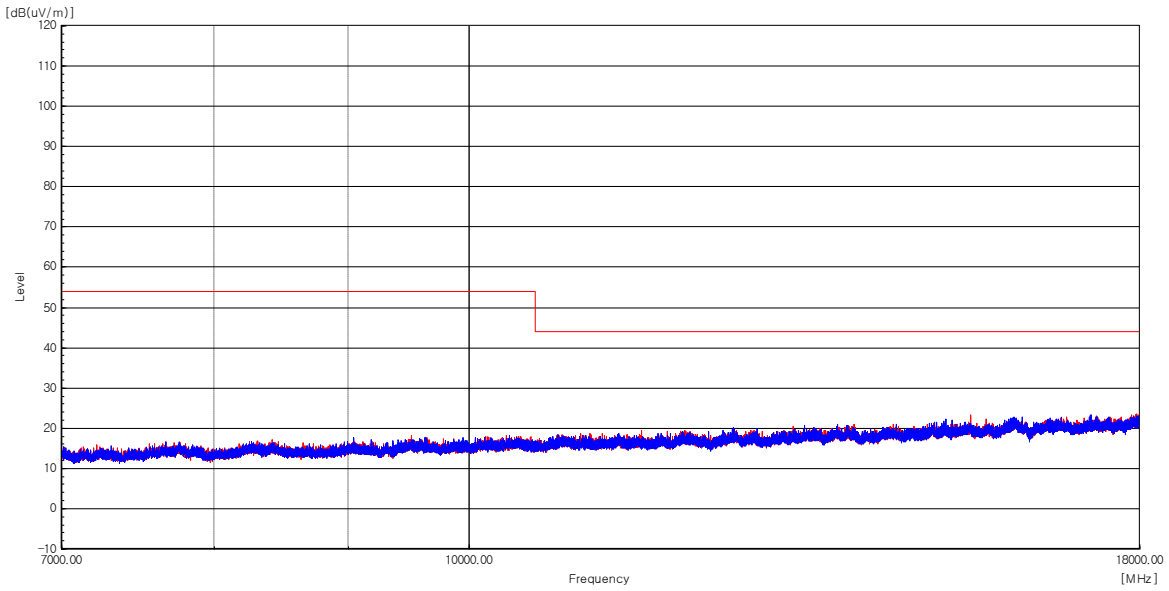
[6 GHz ~ 7 GHz]



No.	Frequency [MHz]	Pol.	Reading [dBuV]	c.f [dB/m]	Result [dBuV/m]	Result [dBm]	Limit [dBm]	Margin[dB]	Remark
1	6 605.61	H	40.5	6.6	47.1	-48.2	-41.3	6.9	
2	6 620.62	V	40.8	6.7	47.5	-47.8	-41.3	6.5	

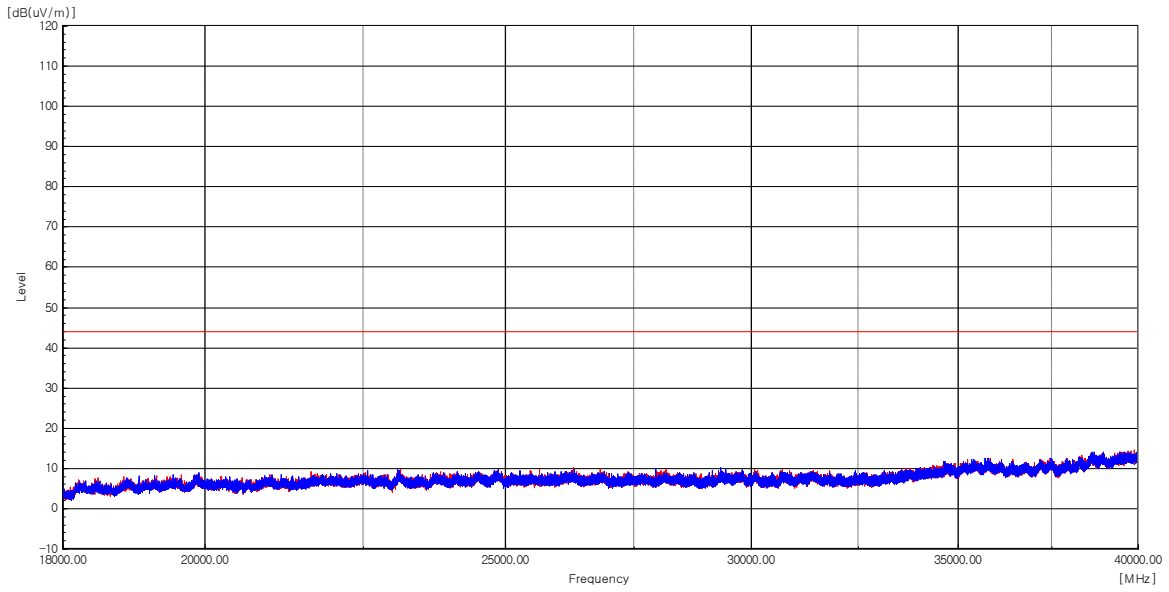
Remark :
1. Result = Reading + c.f(Correction factor)
2. Correction factor = Antenna factor + Cable loss - Amp Gain
3. Result [dBm] = Result [dBuV/m] - 95.3

[7 GHz ~ 18 GHz]



No.	Frequency [MHz]	Pol.	Reading [dBuV]	c.f [dB/m]	Result [dBuV/m]	Result [dBm]	Limit [dBm]	Margin[dB]	Remark
Not detected									

[18 GHz ~ 40 GHz]



No.	Frequency [MHz]	Pol.	Reading [dBuV]	c.f [dB/m]	Result [dBuV/m]	Result [dBm]	Limit [dBm]	Margin[dB]	Remark
Not detected									

Remark :
1. Result = Reading + c.f(Correction factor)
2. Correction factor = Antenna factor + Cable loss - Amp Gain

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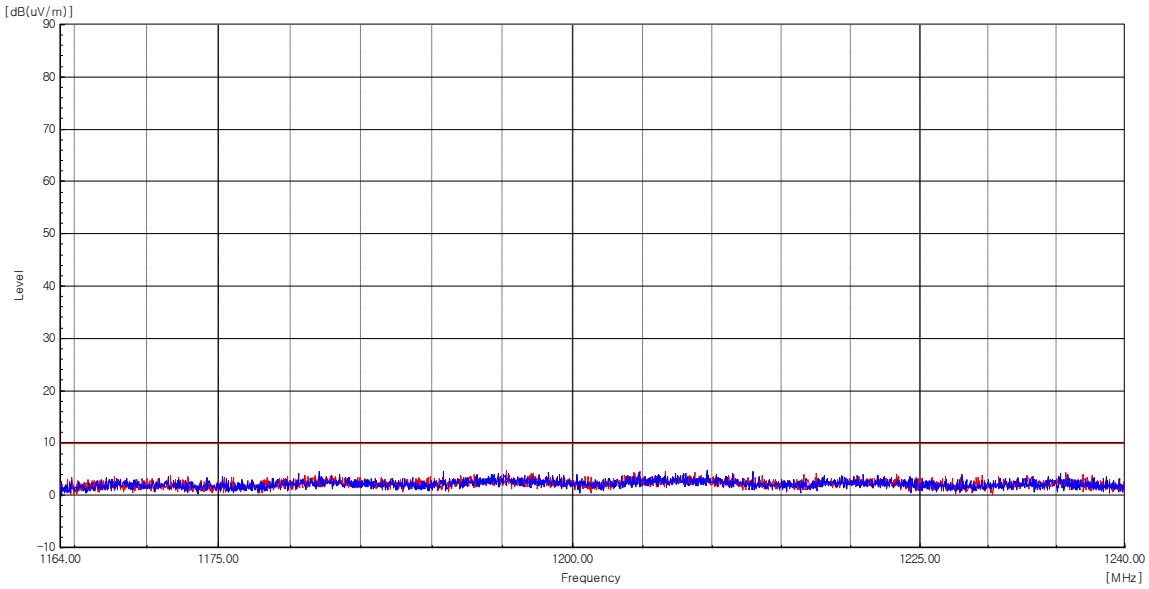
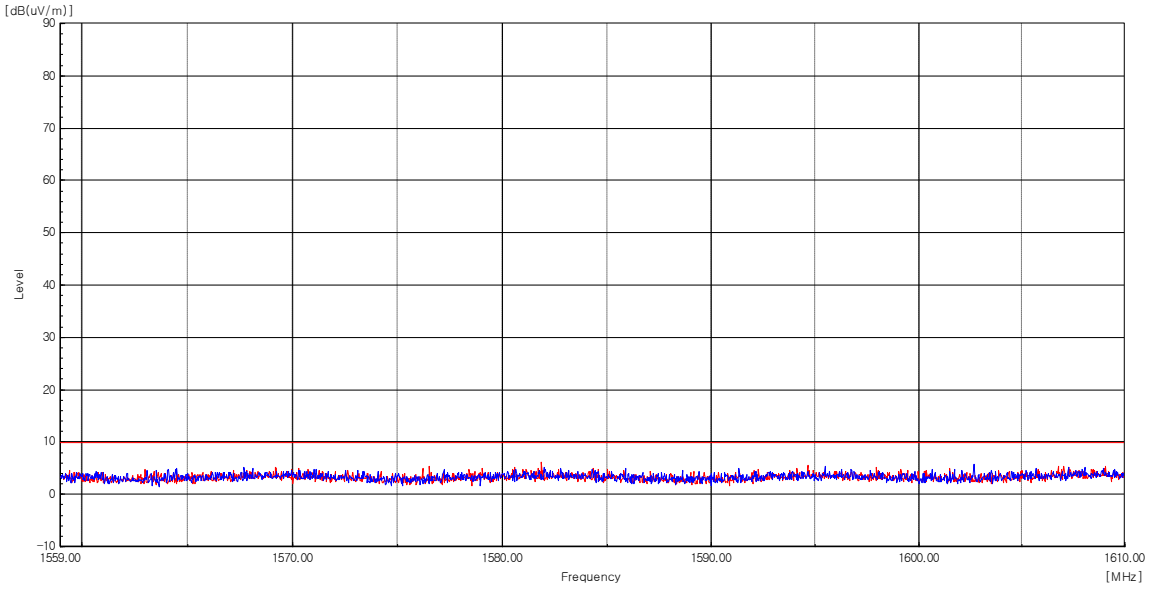
5) Radiated emissions within the 1 164 MHz to 1 240 MHz and 1 559 MHz to 1 610 MHz frequency ranges.

[1 164 MHz ~ 1 240 MHz]



No.	Frequency [MHz]	Pol.	Reading [dBuV]	c.f [dB/m]	Result [dBuV/m]	Result [dBm]	Limit [dBm]	Margin[dB]	Remark
Not detected									

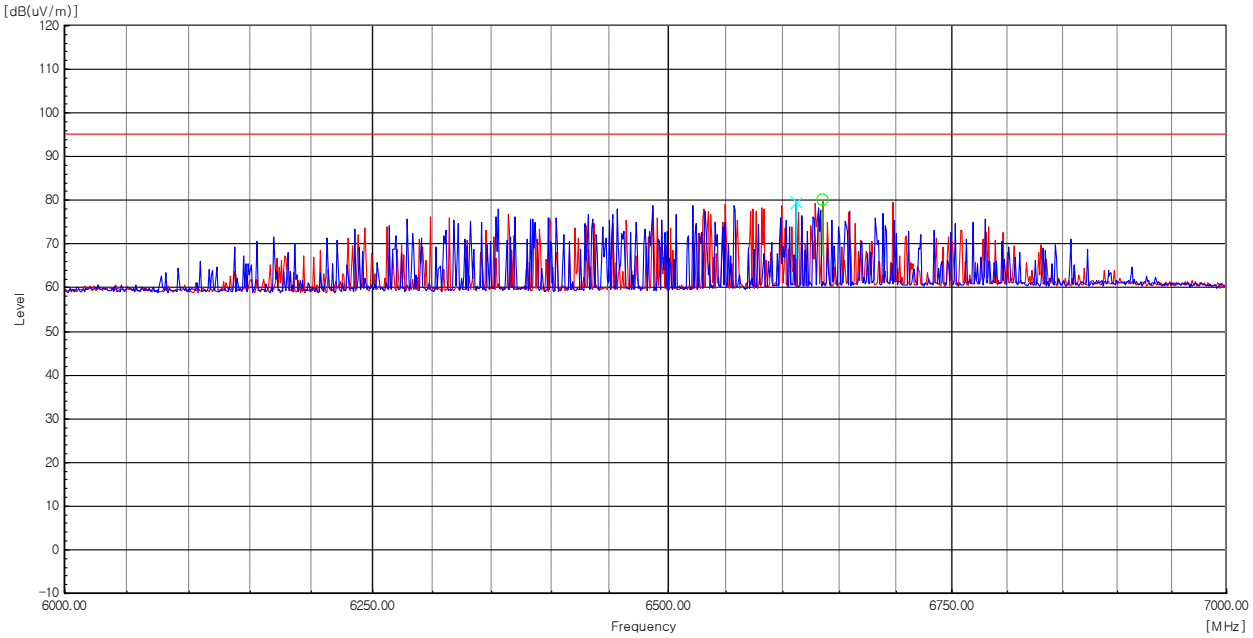
[1 559 MHz ~ 1 610 MHz]



No.	Frequency [MHz]	Pol.	Reading [dBuV]	c.f [dB/m]	Result [dBuV/m]	Result [dBm]	Limit [dBm]	Margin[dB]	Remark
Not detected									

Remark :
1. Result = Reading + c.f(Correction factor)
2. Correction factor = Antenna factor + Cable loss - Amp Gain

6) Peak power of fundamental frequency within a 50 MHz bandwidth



No.	Frequency [MHz]	Pol.	Reading [dBuV]	c.f [dB/m]	Result (10MHz RBW) [dBuV/m]	Result (10MHz RBW) [dBm]	Result (50MHz RBW) [dBm]	Limit [dBm]	Remark
1	6 634.63	H	73.3	6.7	80.0	-15.3	-1.3	0	
2	6 611.61	V	72.8	6.7	79.5	-15.8	-1.8	0	

Remark :
1. Result = Reading + c.f(Correction factor)
2. Correction factor = Antenna factor + Cable loss - Amp Gain
3. This graph is measured at 10MHz bandwidth.
4. Result(10MHz RBW) [dBm] = Result(10MHz RBW) [dBuV/m] - 95.3
5. Result(50MHz RBW) [dBm] = Result(10MHz RBW) [dBm] + 20*log(50 MHz / 10 MHz)
   = Result(10MHz RBW) [dBm] + 14

4.3 AC Power Line Conducted Emissions

FCC Requirement

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 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50 μH/50 ohms line impedance stabilization network (LISN). Compliance with the provisions 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 (MHz)	Conducted Limit (dBuV)	
	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.

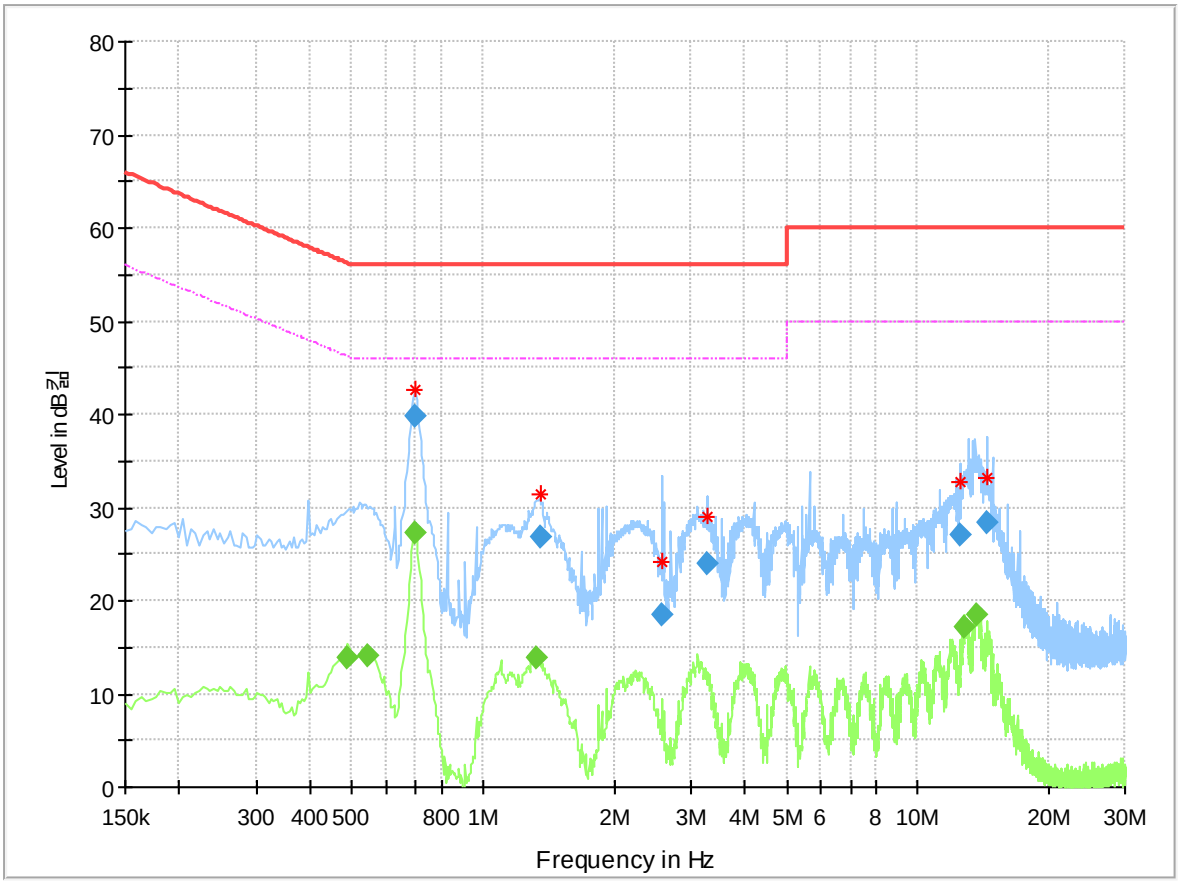
Test Procedures

Refer as ANSI C63.10-2013, clause 6.2(Standard test method for ac power-line conducted emissions from unlicensed wireless devices).

Test Results

The requirements are:
☒ Complies

Full Spectrum



Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.487500	---	13.91	46.21	32.30	15000.0	9.000	N	ON	9.8
0.541500	---	14.17	46.00	31.83	15000.0	9.000	N	ON	9.8
0.699000	---	27.28	46.00	18.72	15000.0	9.000	N	ON	9.8
0.699000	39.72	---	56.00	16.28	15000.0	9.000	N	ON	9.8
1.329000	---	13.77	46.00	32.23	15000.0	9.000	N	ON	9.7
1.356000	26.86	---	56.00	29.14	15000.0	9.000	N	ON	9.7
2.580000	18.36	---	56.00	37.64	15000.0	9.000	N	ON	9.7
3.277500	23.99	---	56.00	32.01	15000.0	9.000	N	ON	9.7
12.498000	27.02	---	60.00	32.98	15000.0	9.000	N	ON	9.9
12.849000	---	17.12	50.00	32.88	15000.0	9.000	N	ON	9.9
13.744500	---	18.53	50.00	31.47	15000.0	9.000	N	ON	9.9
14.383500	28.33	---	60.00	31.67	15000.0	9.000	N	ON	9.9

APPENDIX A – Test Equipment Used For Tests

No.	Name of Equipment	Manufacturer	Model No.	Serial No.	Date of Calibration	Due Date
1	EMI Test Receiver	R&S	ESW44	102039	2023-05-03	2024-05-03
2	Active Loop Antenna	SCHWARZBECK	FMZB 1513	1513-125	2022-04-15	2024-04-15
3	BILOG ANTENNA	TESEQ	CBL6111D	60654	2023-08-21	2025-08-21
4	AMPLIFIER	SONOMA INSTRUMENT	310N	411011	2023-08-04	2024-08-04
5	6dB Attenuator	PASTERNACK	PE7AP006-06	L20210504000023	2023-08-04	2024-08-04
6	ATTENUATOR	NONE	6dB	190557	2023-09-25	2024-09-25
7	Double Ridged Guide Antenna	ETS-Lindgren	3115	00078895	2023-04-13	2024-04-13
8	PREAMPLIFIER	HP	8449B	3008A00620	2023-04-21	2024-04-21
9	HORN ANTENNA	SCHWARZBECK	BBHA9170	1153	2023-10-19	2024-10-19
10	LOW NOISE AMPLIFIER	TESTEK	TK-PA1840H	210124-L	2023-10-23	2024-10-23
11	Spectrum Analyzer	R&S	FSV40	101574	2024-01-15	2025-01-15
12	Signal Analyzer	R&S	FSV30	100925	2023-12-05	2024-12-05
13	EMI Receiver	R&S	ESR3	102826	2023-05-03	2024-05-03
14	LISN	R&S	ENV216	102698	2023-05-03	2024-05-03

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