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

1. Client

◦ Name : Wavelabs Co., Ltd.

◦ Address : 705, Readers building, 42, Jangmi-ro, Bundang-gu, Seongnam-si, Gyeonggi-do, Republic of Korea

◦ Date of Receipt : 2020-10-23

2. Manufacturer

◦ Name : Wavelabs Co., Ltd.

◦ Address : 705, Readers building, 42, Jangmi-ro, Bundang-gu, Seongnam-si, Gyeonggi-do, Republic of Korea

3. Use of Report : For FCC Conformance / ISED Conformance

4. Test Sample / Model: 2.4GHz wireless modem / WL-DCM2400

5. Date of Test : 2021-01-20 to 2021-01-27

6. Test Standard(method) used : FCC 47 CFR part 15 subpart C 15.247
RSS-247 & RSS-Gen

7. Testing Environment: Temp.: (24 ± 1) ℃, Humidity: (49 ± 3) % R.H.

8. Test Results : Compliance

The results shown in this test report refer only to the sample(s) tested unless otherwise stated. This Test Report cannot be reproduced, except in full.

Affirmation	Tested by Ji-Hye, Kim: (Signature)	Technical Manager Won-Jae, Hwang: (Signature)

2021-02-02

Republic of KOREA **CTK Co., Ltd.**

REPORT REVISION HISTORY

Date	Revision	Page No
2021-02-02	Issued (CTK-2021-00375)	all

This report shall not be reproduced except in full, without the written approval of CTK Co., Ltd. This document may be altered or revised by CTK Co., Ltd. personnel only, and shall be noted in the revision section of the document. Any alteration of this document not carried out by CTK Co., Ltd. will constitute fraud and shall nullify the document.

CONTENTS

1. General Product Description 4
1.1 Client Information 4
1.2 Product Information 4
1.3 Peripheral Devices 4
1.4 Model Differences 4
2. Facility and Accreditations 5
2.1 Test Facility 5
2.2 Laboratory Accreditations and Listings 5
2.3 Calibration Details of Equipment Used for Measurement 5
3. Test Specifications 6
3.1 Standards 6
3.2 Mode of operation during the test 6
3.3 Maximum Measurement Uncertainty 7
3.4 Test Software 7
4. Technical Characteristic Test 8
4.1 Carrier Frequency Separation 8
4.2 Number of Hopping Frequencies 10
4.3 20 dB bandwidth & 99% Bandwidth 12
4.4 Time of Occupancy 15
4.5 Maximum peak Conducted Output Power 18
4.6 Unwanted Emissions (Conducted) 22
4.7 Radiated Emission 28
4.8 AC Power Line Conducted Emissions 47
4.9 Frequency Hopping System Requirements 50
APPENDIX A – Test Equipment Used For Tests 52

1. General Product Description

1.1 Client Information

Company	Wavelabs Co., Ltd.
Contact Point	705, Readers building, 42, Jangmi-ro, Bundang-gu, Seongnam-si, Gyeonggi-do, Republic of Korea
Contact Person	Name : Lee Jong Woo E-mail : jwlee@wavelabs.co.kr Tel : +82-31-8017-7628 Fax : +82-31-8017-7629

1.2 Product Information

FCC ID	2AZDSFCWLDCM2400A
ISED	27085-ICWLDCM2400
Product Description	2.4GHz wireless modem
Model name	WL-DCM2400
Variant Model name	-
Operating Frequency	2 402 MHz - 2 480 MHz
RF Output Power	29.402 dBm (871.365 mW)
Antenna Specification	Antenna type : Dipole antenna <Peak Gain> ANT A : 5.0 dBi ANT B : 5.8 dBi
Number of channels	79
Channel Spacing	1 MHz
Type of Modulation	GFSK (FHSS)
Power Source	DC 12 V
Hardware Rev	1.0
Software Rev	1.0

1.3 Peripheral Devices

Device	Manufacturer	Model No.	Serial No.
Note Computer	HP	15-bs563TU	CND7253QPR
AC/DC Adapter	HP	HSTNN-LA40	-

1.4 Model Differences

Not applicable

2. Facility and Accreditations

2.1 Test Facility

The measurement facility is located at (Ho-dong), 113, Yejik-ro, Cheoin-gu, Yong-in-si, Gyeonggi-do, Korea.

2.2 Laboratory Accreditations and Listings

Country	Agency	Registration Number
USA	FCC	805871
CANADA	ISED	8737A-2
KOREA	NRRA	KR0025

2.3 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.

3. Test Specifications

3.1 Standards

Section in FCC	Section in RSS	Requirement(s)	Status (Note 1)	Test Condition
15.247(a)	RSS-247 5.1(b)	Carrier Frequency Separation	C	Conducted
15.247(a)	RSS-247 5.1(d)	Number of Hopping Frequencies	C	
15.247(a)	RSS-247 5.1(a)	20 dB Bandwidth	C	
15.247(a)	RSS-247 5.1(d)	Time of occupancy (Dwell Time)	C	
15.247(b)	RSS-247 5.4(b)	Maximum peak conducted output power	C	
15.247(d)	RSS-247 5.5	Unwanted emission	C	
15.209	RSS-Gen 6.13	Transmitter emission	C	Radiated
15.207(a)	RSS-Gen 8.8	AC Conducted Emission	C	Line Conducted
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: FCC Part 15.247, ANSI C63.10-2013, RSS-247 Issue 2, RSS-GEN Issue 5				

3.2 Mode of operation during the test

The EUT is operated in a manner representative of the typical of the equipments.
During at testing, system components were manipulated within the confines of typical usage to maximize each emission. All modulation modes were tests.
The results are only attached worst cases.

Test Frequency

Lowest channel	Middle channel	Highest channel
2 402 MHz	2 441 MHz	2 480 MHz

Test mode

Modulation	Duty Cycle
GFSK (FHSS)	10.1 %

3.3 Maximum Measurement Uncertainty

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

Description	Uncertainty
Conducted RF Output Power	± 1.5 dB
Occupied Bandwidth	± 0.1 MHz
Unwanted Emission(conducted)	± 3.0 dB
Radiated Emissions (f ≤ 1 GHz)	± 4.0 dB
Radiated Emissions (f > 1 GHz)	± 5.0 dB

3.4 Test Software

Conducted Test	Ics Pro Ver. 6.0.3
Radiated Test	TOYO EMI software EP5RE Ver. 6.0.1.0
Line Conducted Test	ESCI7, ESCI3 : EMC32 Ver. 8.50.0 ESR7 : EMC32 Ver. 8.53.0

4. Technical Characteristic Test

4.1 Carrier Frequency Separation

Test Procedures

ANSI C63.10-2013 - Section 7.8.2

The carrier frequency separation was measured with a spectrum analyzer connected to the antenna terminal, while EUT has its hopping function enabled.
After the trace being stable, the reading value between the peaks of the adjacent channels using the marker-delta function was recorded as the measurement results.

The spectrum analyzer is set to:

a) Span = 5 MHz (wide enough to capture the peaks of two adjacent channels)
b) RBW = 30 kHz (Start with the RBW set to approximately 30% of the channel spacing; adjust as necessary to best identify the center of each individual channel)
c) VBW = 30 kHz (≥ RBW)
d) Sweep = auto
e) Detector function = peak
f) Trace = max hold

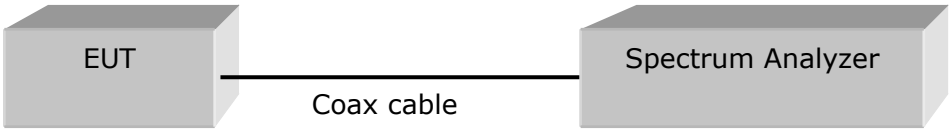


Figure 1 : Measurement setup for the carrier frequency separation

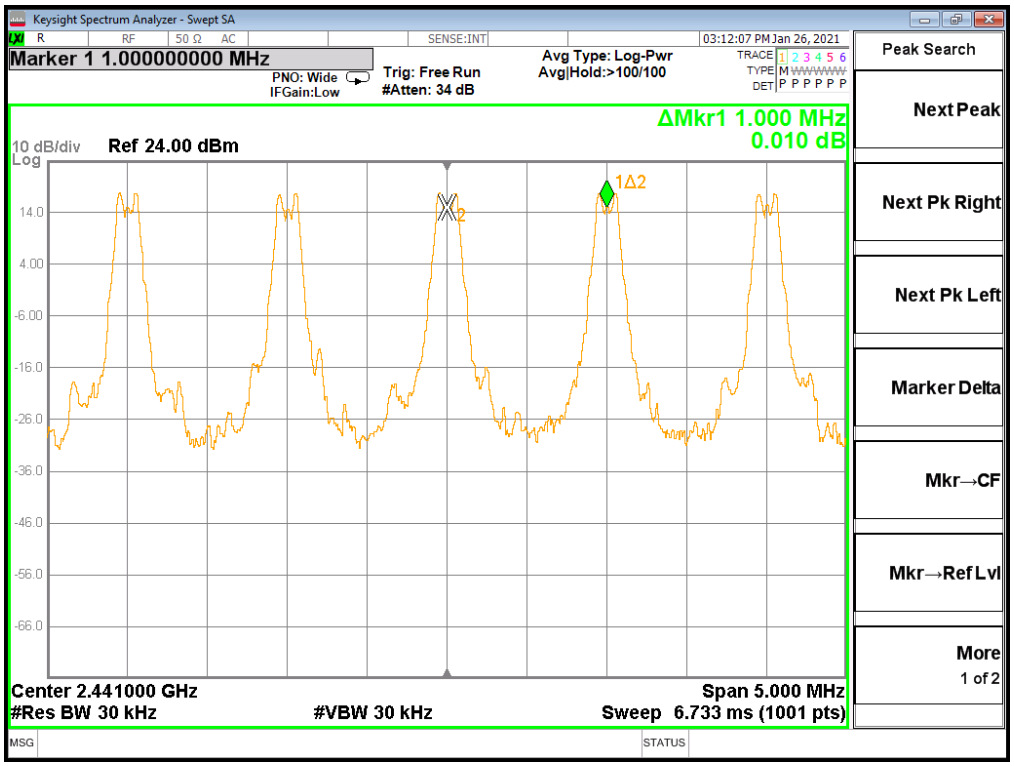
Limit

FHSS operating in the band 2400-2483.5 MHz may have hopping channel carrier frequencies that are separated by 25 kHz or two thirds of the -20 dB bandwidth of the hopping channel, whichever is greater.

Test Results

Channel	Adjacent Hopping Channel Separation [kHz]	Two-third of 20dB bandwidth [kHz]	Minimum Bandwidth [kHz]	Result
Middle	1 000	158.73	25	Complies

See next pages for actual measured spectrum plots.


Keysight Spectrum Analyzer - Swept SA
Marker 1 1.000000000 MHz
PNO: Wide
IFGain:Low
Trig: Free Run
#Atten: 34 dB
Avg Type: Log-Pwr
Avg|Hold:>100/100
03:12:07 PM Jan 26, 2021
ΔMkr1 1.000 MHz
0.010 dB
10 dB/div
Log
Ref 24.00 dBm
1Δ2
Center 2.441000 GHz
#Res BW 30 kHz
#VBW 30 kHz
Span 5.000 MHz
Sweep 6.733 ms (1001 pts)
Peak Search
Next Peak
Next Pk Right
Next Pk Left
Marker Delta
Mkr→CF
Mkr→Ref Lvl
More
1 of 2

4.2 Number of Hopping Frequencies

Test Procedures

ANSI C63.10-2013 - Section 7.8.3

The number of hopping frequencies was measured with a spectrum analyzer connected to the antenna terminal, while EUT had its hopping function enabled.

The spectrum analyzer is set to:

a) Frequency range 1: Start = 2389.5 MHz, Stop = 2439.5 MHz
2: Start = 2439.5 MHz, Stop = 2489.5 MHz

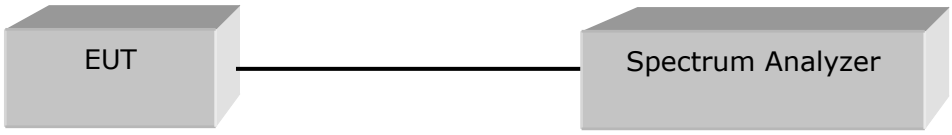
b) RBW = 300 kHz (To identify clearly the individual channels, set the RBW to less than 30% of the channel spacing or the 20 dB bandwidth, whichever is smaller)

c) VBW = 300 kHz (≥ RBW)

d) Sweep = auto

e) Detector function = peak

f) Trace = max hold



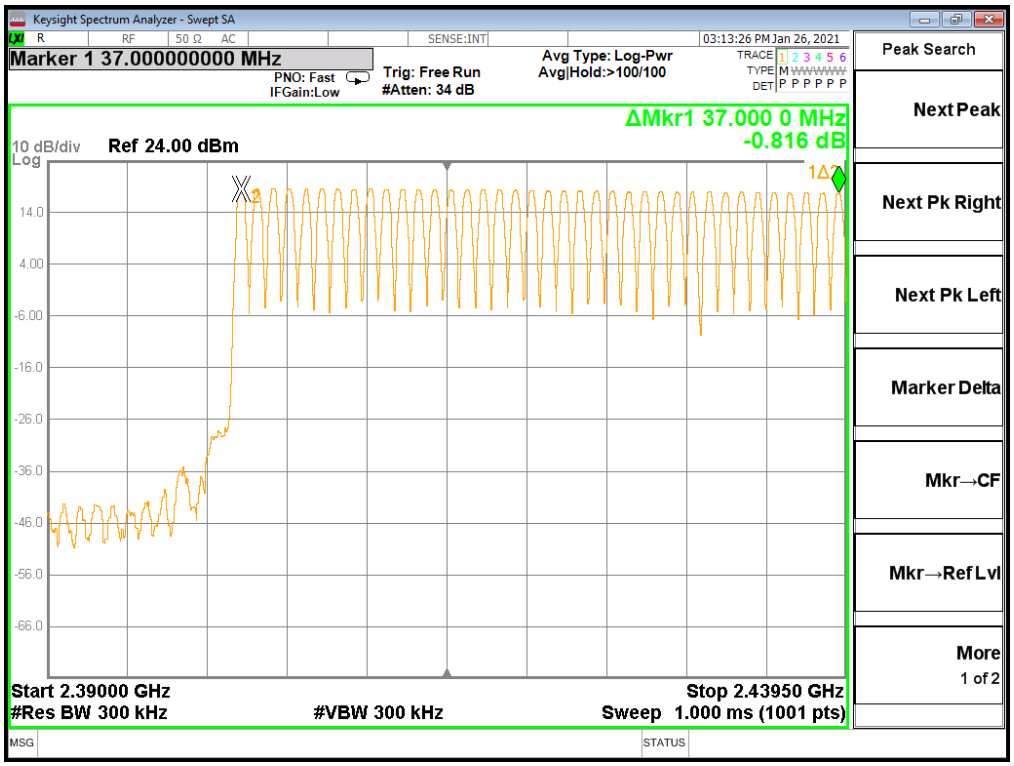
Limit

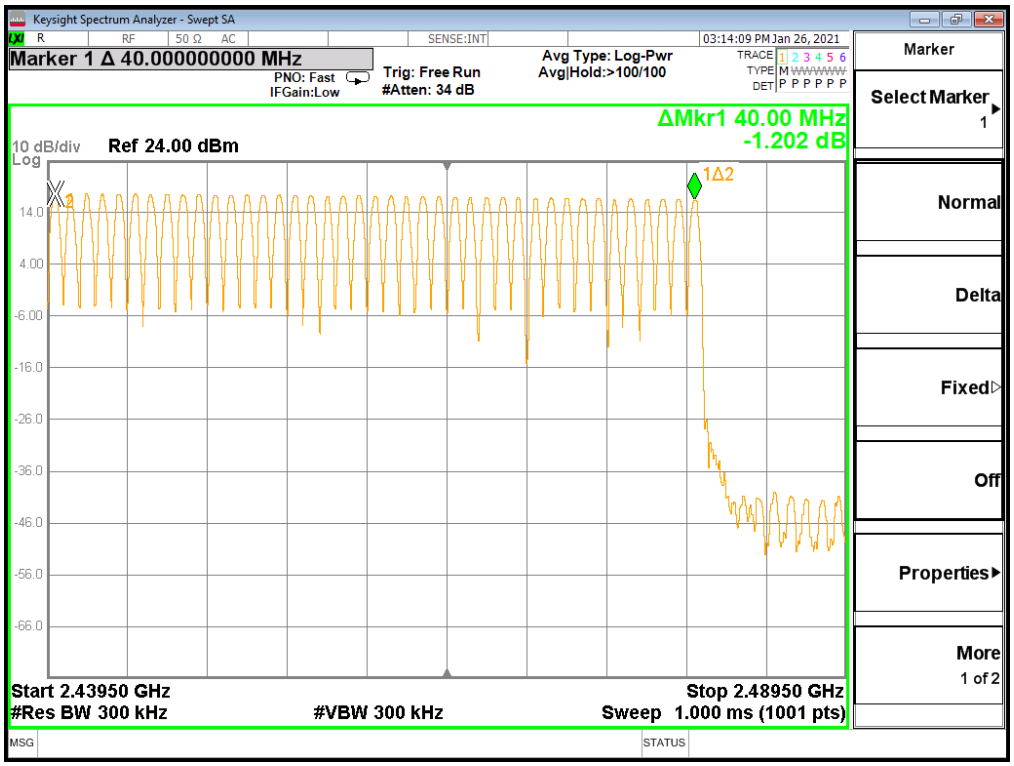
FHSs operating in the band 2400-2483.5 MHz shall use at least 15 hopping channels.

Test Results

Total number of Hopping Channels	Result
79	Complies

See next pages for actual measured spectrum plots.


Keysight Spectrum Analyzer - Swept SA
Marker 1 37.000000000 MHz
PNO: Fast
IFGain:Low
Trig: Free Run
#Atten: 34 dB
Avg Type: Log-Pwr
Avg|Hold:>100/100
03:13:26 PM Jan 26, 2021
ΔMkr1 37.000 0 MHz
-0.816 dB
10 dB/div
Ref 24.00 dBm
Start 2.39000 GHz
#Res BW 300 kHz
#VBW 300 kHz
Stop 2.43950 GHz
Sweep 1.000 ms (1001 pts)
Peak Search
Next Peak
Next Pk Right
Next Pk Left
Marker Delta
Mkr→CF
Mkr→Ref Lvl
More
1 of 2


Keysight Spectrum Analyzer - Swept SA
Marker 1 Δ 40.000000000 MHz
PNO: Fast
IFGain:Low
Trig: Free Run
#Atten: 34 dB
Avg Type: Log-Pwr
Avg|Hold:>100/100
03:14:09 PM Jan 26, 2021
ΔMkr1 40.00 MHz
-1.202 dB
10 dB/div
Ref 24.00 dBm
Start 2.43950 GHz
#Res BW 300 kHz
#VBW 300 kHz
Stop 2.48950 GHz
Sweep 1.000 ms (1001 pts)
Marker
Select Marker
1
Normal
Delta
Fixed
Off
Properties
More
1 of 2

4.3 20 dB bandwidth & 99% Bandwidth

Test Procedures

ANSI C63.10-2013 - Section 6.9.2
RSS-GEN Issue 5 - Section 6.7

Measure the maximum width of the emission that is constrained by the frequencies associated with the two outermost amplitude points (upper and lower frequencies) that are attenuated by 20 dB relative to the maximum level measured in the fundamental emission.

Test Procedures

ANSI C63.10-2013 - Section 6.9.3
RSS-GEN Issue 5 - Section 6.7

The occupied bandwidth is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers are each equal to 0.5% of the total mean power of the given emission.
Use the 99% power bandwidth function of the instrument and report the measured bandwidth.

The spectrum analyzer is set to:

Center frequency = the highest, middle and the lowest channels

a) Span = 3 MHz (between 2 times and 5 times the OBW)

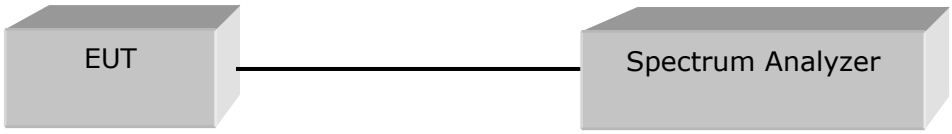
b) RBW = 30 kHz (1% to 5% of the OBW)

c) VBW = 100 kHz (approximately 3 times RBW)

d) Sweep = auto

e) Detector function = peak

f) Trace = max hold



Limit

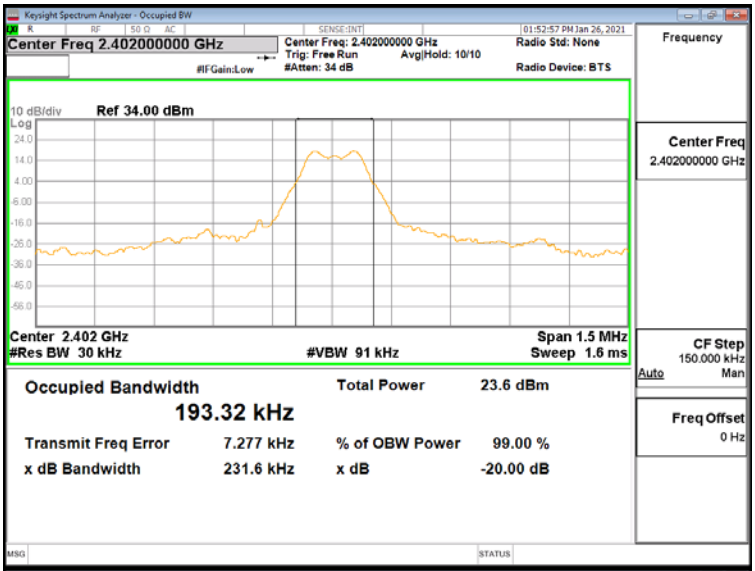
Limit : N/A

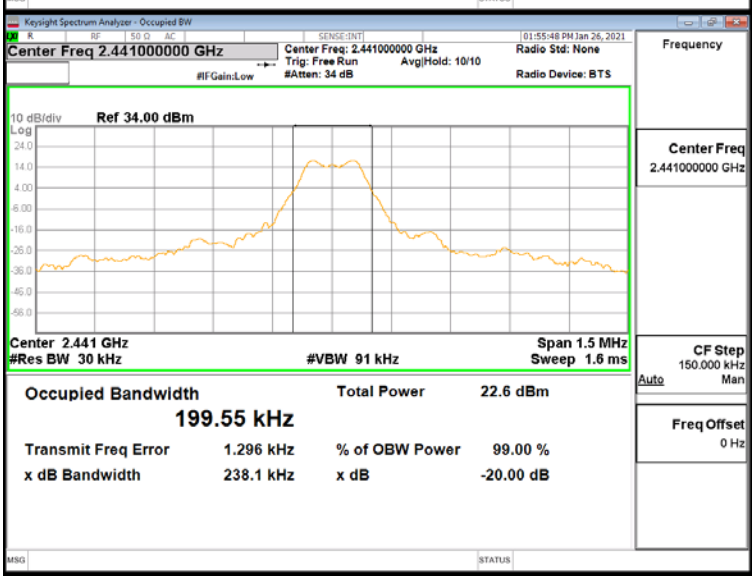
Test Results

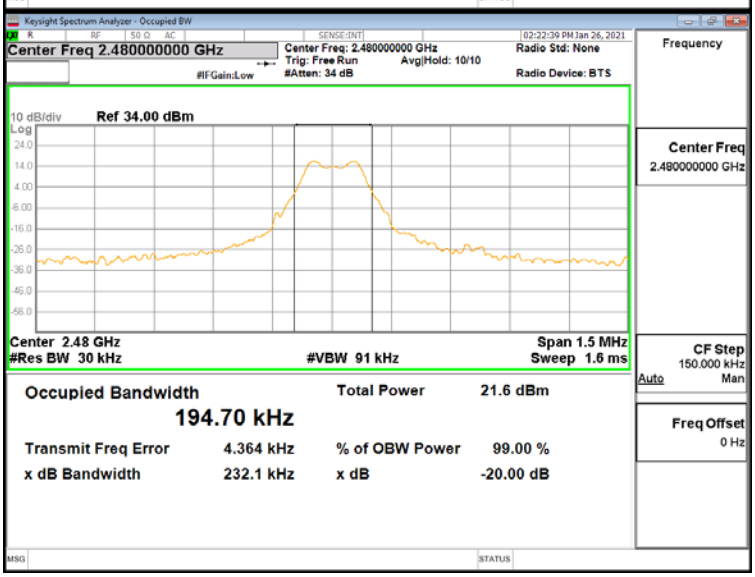
Test mode : GFSK

Channel	Frequency [MHz]	20 dB Bandwidth [MHz]	99% Bandwidth [MHz]	Result
Low	2 402	0.232	0.193	Complies
Middle	2 441	0.238	0.200	Complies
High	2 480	0.232	0.195	Complies

See next pages for actual measured spectrum plots.


Keysight Spectrum Analyzer - Occupied BW
Center Freq 2.402000000 GHz
Center Freq: 2.402000000 GHz
Trig: Free Run
Avg|Hold: 10/10
#Atten: 34 dB
Radio Std: None
Radio Device: BTS
01:52:57 PM Jan 26, 2021
10 dB/div
Ref 34.00 dBm
Center 2.402 GHz
#Res BW 30 kHz
#VBW 91 kHz
Span 1.5 MHz
Sweep 1.6 ms
Occupied Bandwidth
193.32 kHz
Total Power 23.6 dBm
Transmit Freq Error 7.277 kHz
% of OBW Power 99.00 %
x dB Bandwidth 231.6 kHz
x dB -20.00 dB
Frequency
Center Freq
2.402000000 GHz
CF Step
150.000 kHz
Auto Man
Freq Offset
0 Hz


Keysight Spectrum Analyzer - Occupied BW
Center Freq 2.441000000 GHz
Center Freq: 2.441000000 GHz
Trig: Free Run
Avg|Hold: 10/10
#Atten: 34 dB
Radio Std: None
Radio Device: BTS
01:55:48 PM Jan 26, 2021
10 dB/div
Ref 34.00 dBm
Center 2.441 GHz
#Res BW 30 kHz
#VBW 91 kHz
Span 1.5 MHz
Sweep 1.6 ms
Occupied Bandwidth
199.55 kHz
Total Power 22.6 dBm
Transmit Freq Error 1.296 kHz
% of OBW Power 99.00 %
x dB Bandwidth 238.1 kHz
x dB -20.00 dB
Frequency
Center Freq
2.441000000 GHz
CF Step
150.000 kHz
Auto Man
Freq Offset
0 Hz


Keysight Spectrum Analyzer - Occupied BW
Center Freq 2.480000000 GHz
Center Freq: 2.480000000 GHz
Trig: Free Run
Avg|Hold: 10/10
#Atten: 34 dB
Radio Std: None
Radio Device: BTS
02:22:39 PM Jan 26, 2021
10 dB/div
Ref 34.00 dBm
Center 2.48 GHz
#Res BW 30 kHz
#VBW 91 kHz
Span 1.5 MHz
Sweep 1.6 ms
Occupied Bandwidth
194.70 kHz
Total Power 21.6 dBm
Transmit Freq Error 4.364 kHz
% of OBW Power 99.00 %
x dB Bandwidth 232.1 kHz
x dB -20.00 dB
Frequency
Center Freq
2.480000000 GHz
CF Step
150.000 kHz
Auto Man
Freq Offset
0 Hz

4.4 Time of Occupancy

Test Procedures

ANSI C63.10-2013 - Section 7.8.4

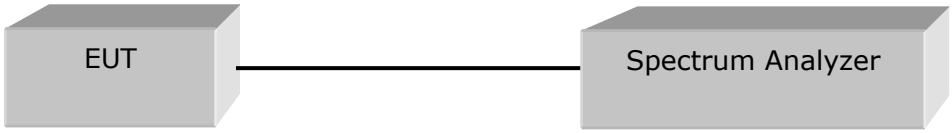
The dwell time was measured with a spectrum analyzer connected to the antenna terminal, while EUT has its hopping function enabled.

a) Span: Zero span, centered on a hopping channel.
b) RBW shall be ≤ channel spacing and where possible RBW should be set >> 1 / T, where T is the expected dwell time per channel.
c) Sweep: As necessary to capture the entire dwell time per hopping channel; where possible use a video trigger and trigger delay so that the transmitted signal starts a little to the right of the start of the plot. The trigger level might need slight adjustment to prevent triggering when the system hops on an adjacent channel; a second plot might be needed with a longer sweep time to show two successive hops on a channel.
d) Detector function: Peak.
e) Trace: Max hold.

Use the marker-delta function to determine the transmit time per hop. If this value varies with different modes of operation (data rate, modulation format, number of hopping channels, etc.), then repeat this test for each variation in transmit time.

Repeat the measurement using a longer sweep time to determine the number of hops over the period specified in the requirements. The sweep time shall be equal to, or less than, the period specified in the requirements. Determine the number of hops over the sweep time and calculate the total number of hops in the period specified in the requirements, using the following equation:

Number of hops in the period specified in the requirements =
(number of hops on spectrum analyzer) × (period specified in the requirements / analyzer sweep time)



Limit

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.

Test Results

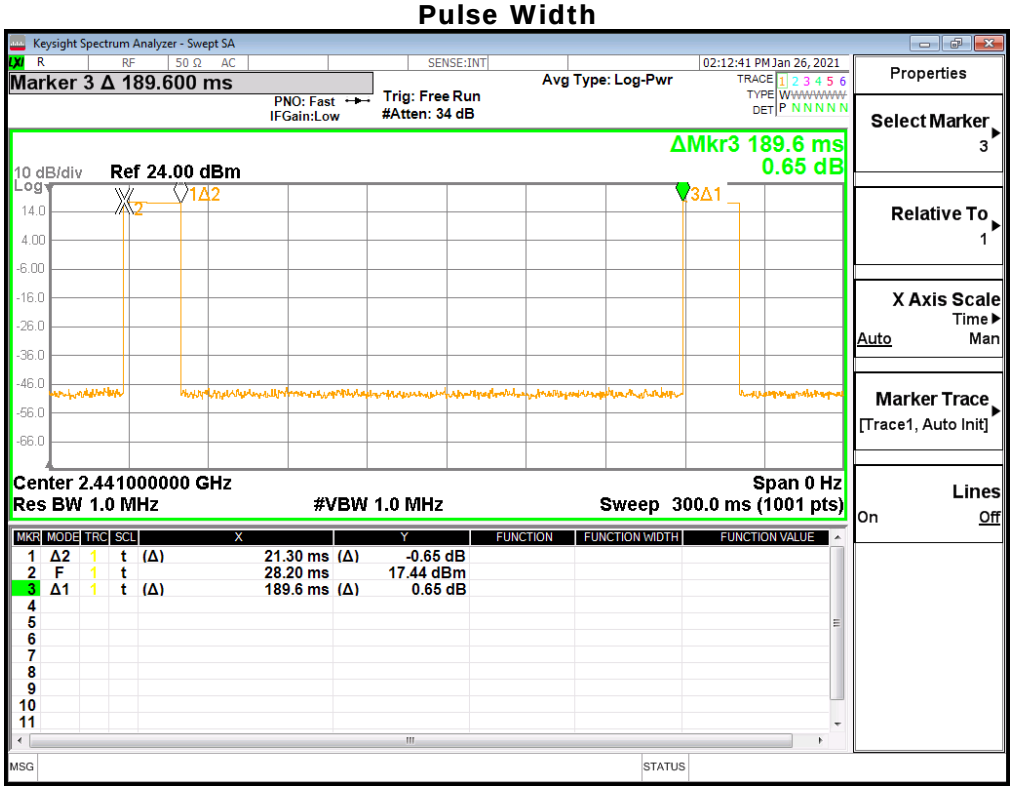
Pulse Width (msec)	Number of Pulses in 31.6 seconds	Time of Occupancy Result (msec)	Limit (msec)
21.30	12	**255.6**	400

※ Remark:

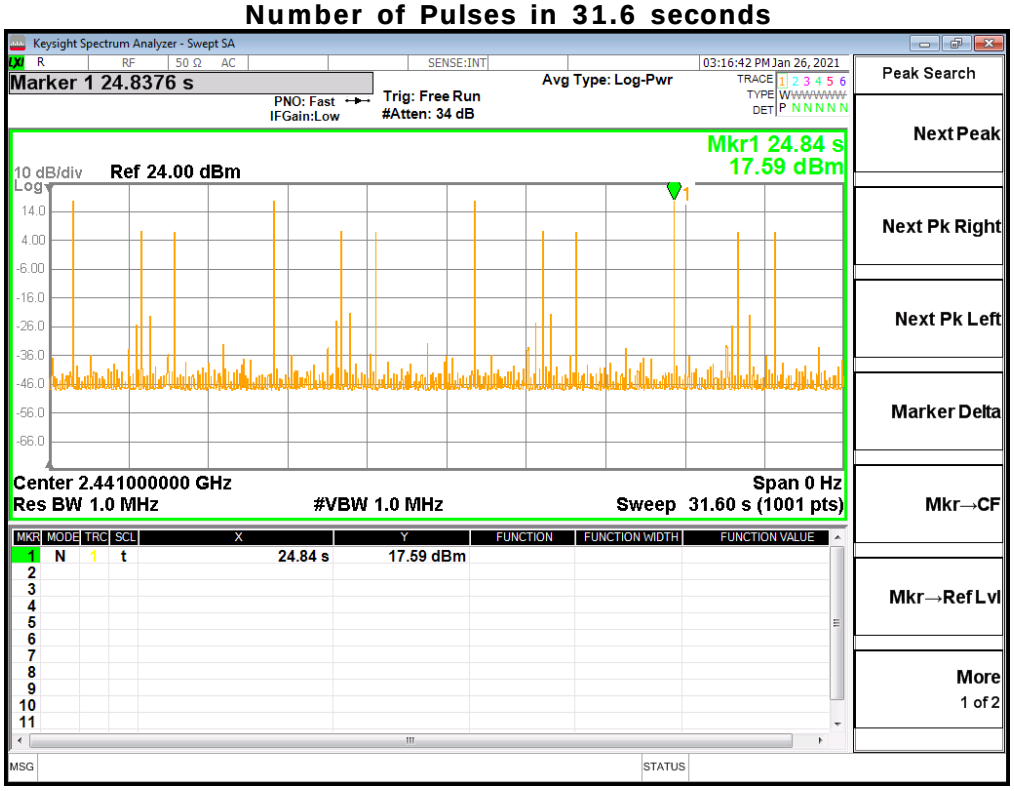
Average time of occupancy = Transmit time per hop * Number of hopping channels in 31.6s

See next pages for actual measured spectrum plots.

Pulse Width



Number of Pulses in 31.6 seconds



4.5 Maximum peak Conducted Output Power

Test Procedures

ANSI C63.10-2013 - Section 7.8.5

This is an RF-conducted test to evaluate maximum peak output power. Use a direct connection between the antenna port of the unlicensed wireless device and the spectrum analyzer, through suitable attenuation. The hopping shall be disabled for this test.

The spectrum analyzer is set to:

Center frequency = the highest, middle and the lowest channels

a) Span = 5 MHz (approximately 5 times of the 20 dB bandwidth)

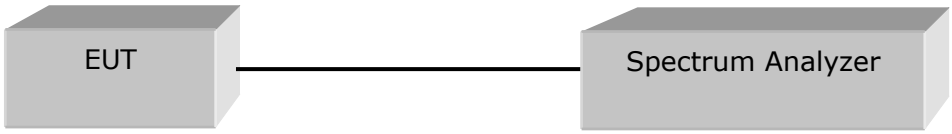
b) RBW = 3 MHz (greater than the 20 dB bandwidth of the emission being measured)

c) VBW = 3 MHz (≥ RBW)

d) Detector = peak

e) Trace = max hold

f) Sweep = auto



Limit

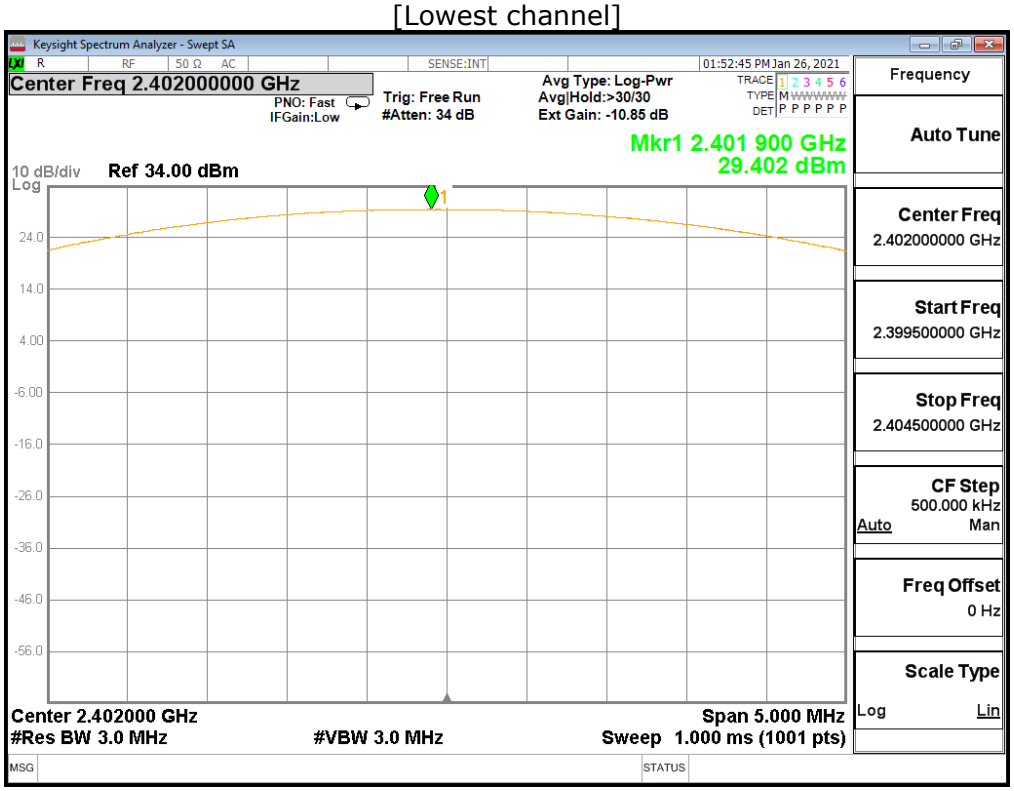
For FHSs operating in the band 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1.0 W and the e.i.r.p. shall not exceed 4 W if the hopset uses 75 or more hopping channels.

Test Results

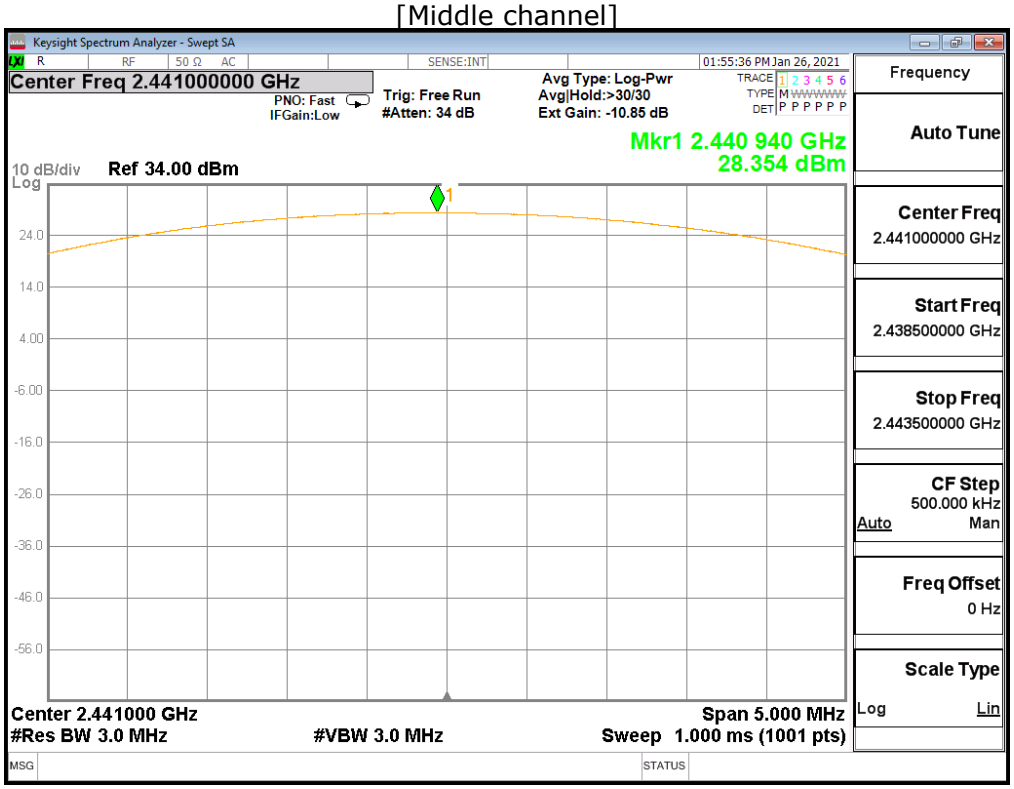
Channel	Frequency [MHz]	Output Power [dBm]	Output power [mW]	Result
Low	2 402	29.402	871.365	Complies
Middle	2 441	28.354	684.542	Complies
High	2 480	27.292	536.043	Complies

See next pages for actual measured spectrum plots.

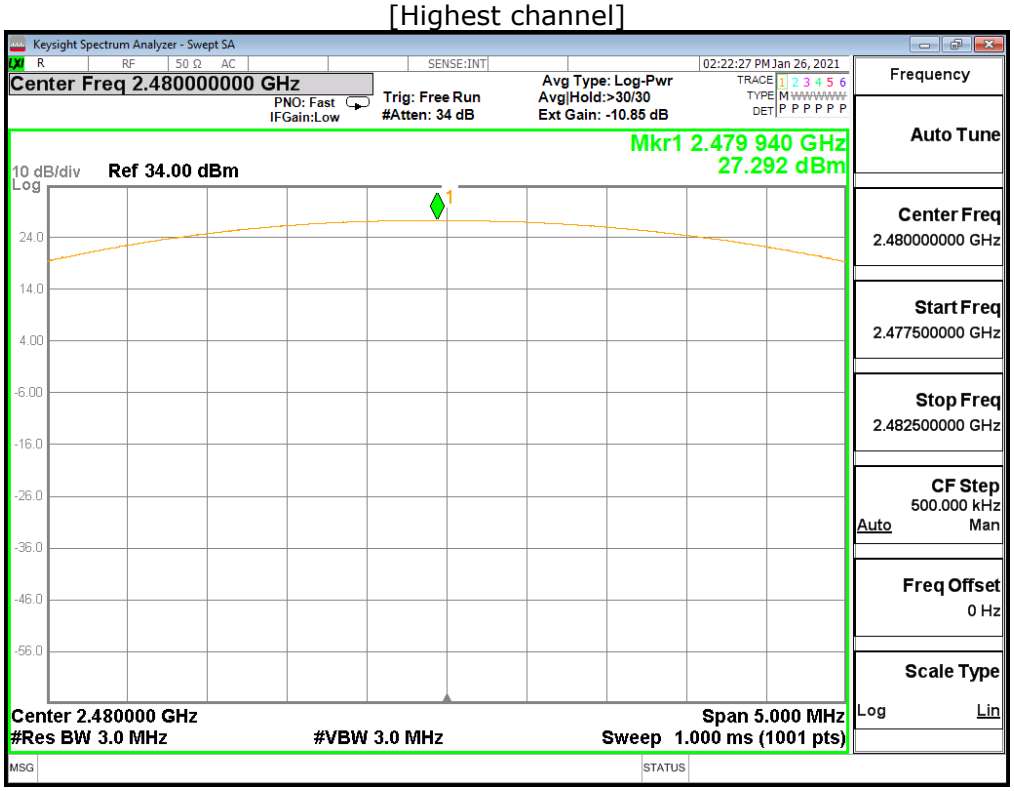
[Lowest channel]



[Middle channel]



[Highest channel]



4.6 Unwanted Emissions (Conducted)

Test Procedures

ANSI C63.10-2013 - Section 7.8.6, 7.8.8

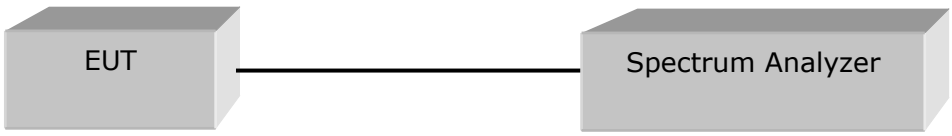
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under Section 5.4(4), the attenuation required shall be 30 dB instead of 20 dB.

The bandwidth at 20 dB down from the highest inband spectral density was measured with a spectrum analyzer connected to the antenna terminal, while EUT has its hopping function disabled at the highest, middle and the lowest available channels.

The spectrum analyzer is set to:

Center frequency = the highest, middle and the lowest channels

a) RBW = 100 kHz
b) VBW = 300 kHz (≥ RBW)
c) Span = 10 MHz
d) Detector = peak
e) Trace = max hold
f) Sweep = auto



Limit

> 20 dBc

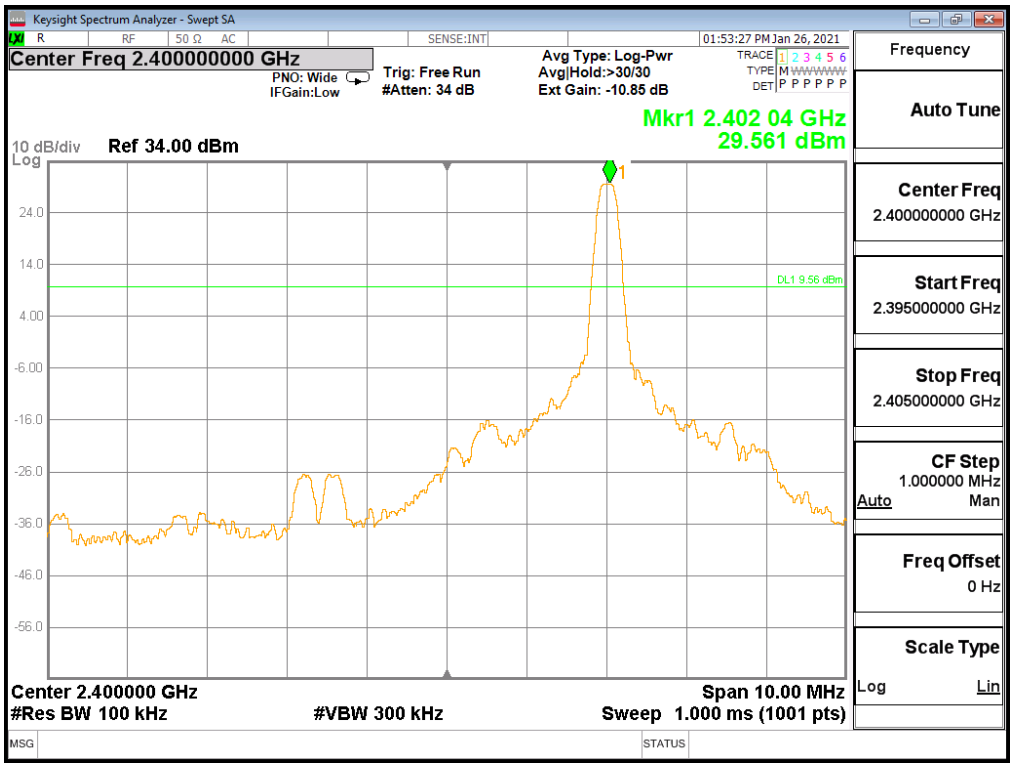
Test Results

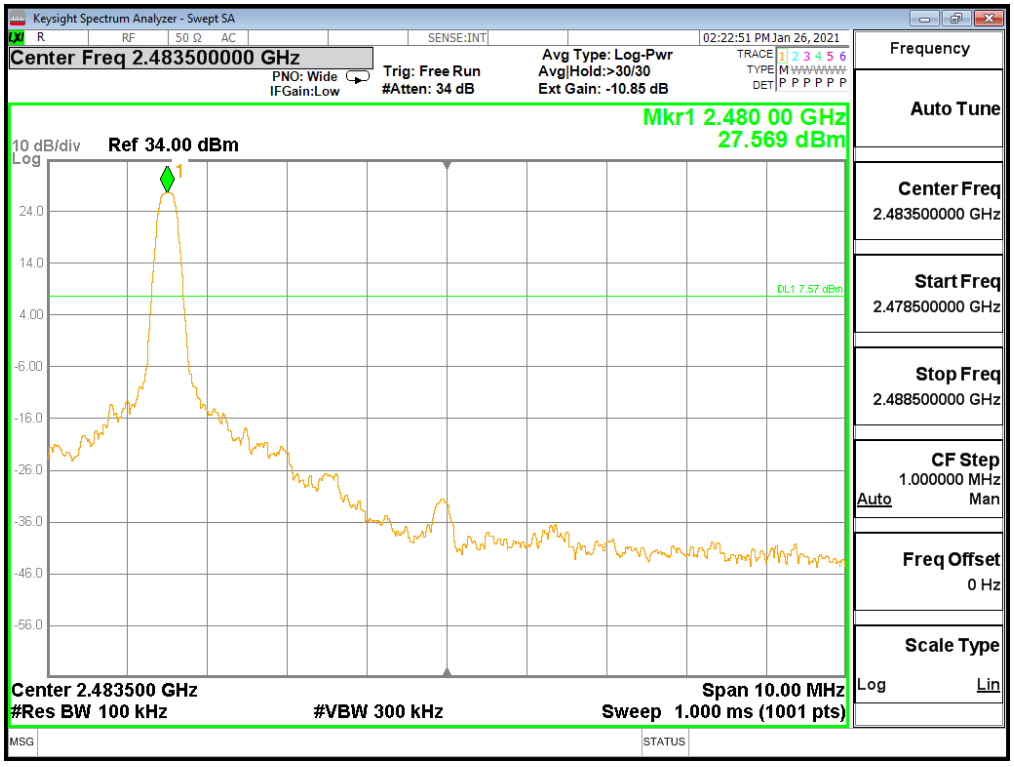
All conducted emission in any 100 kHz bandwidth outside of the spectrum band was at least 20 dB lower than the highest level of the in-band spectral density.
Therefore the applying equipment meets the requirement.

See next pages for actual measured spectrum plots.

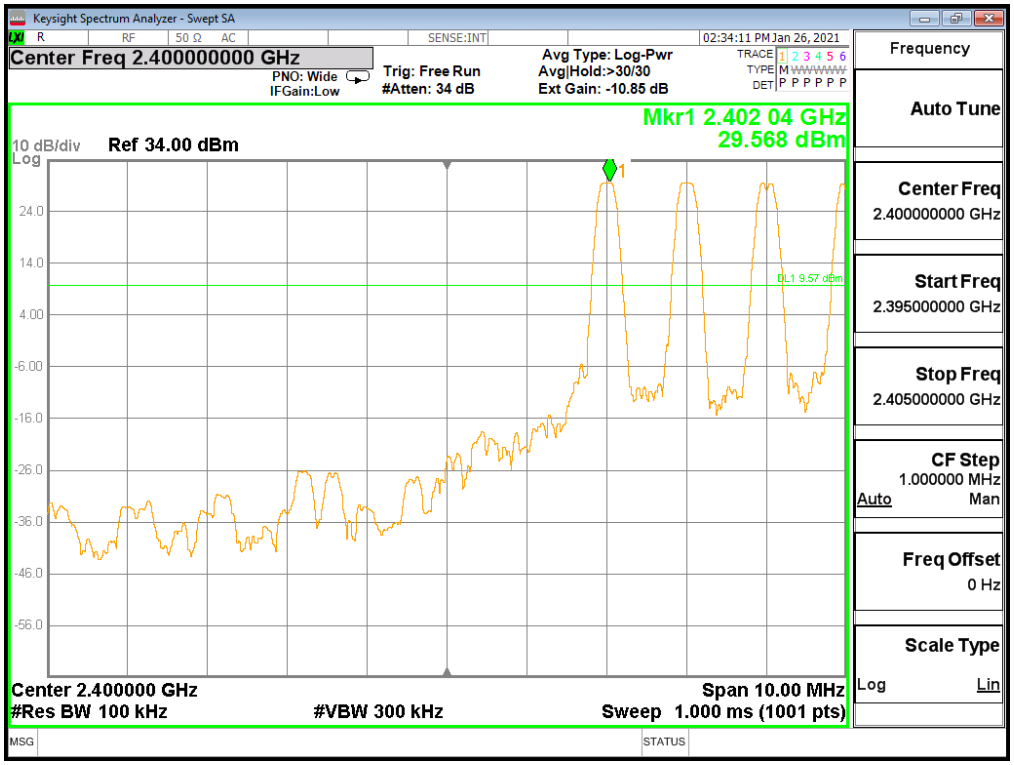
Band Edge

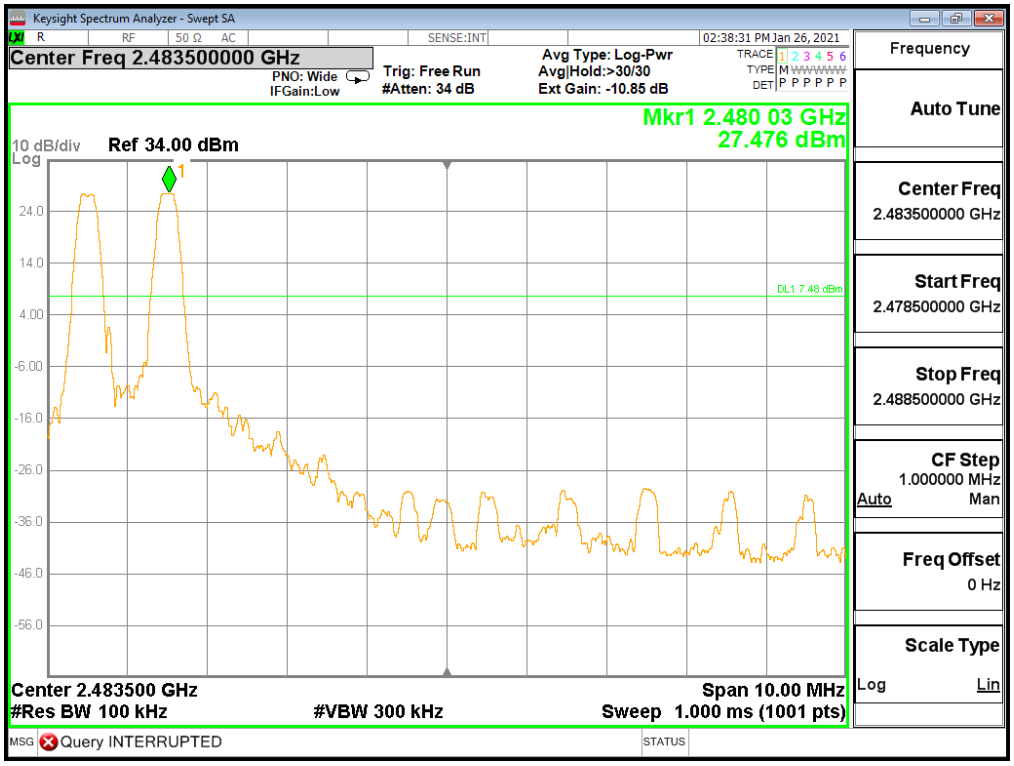
Test Mode : Non Hopping mode





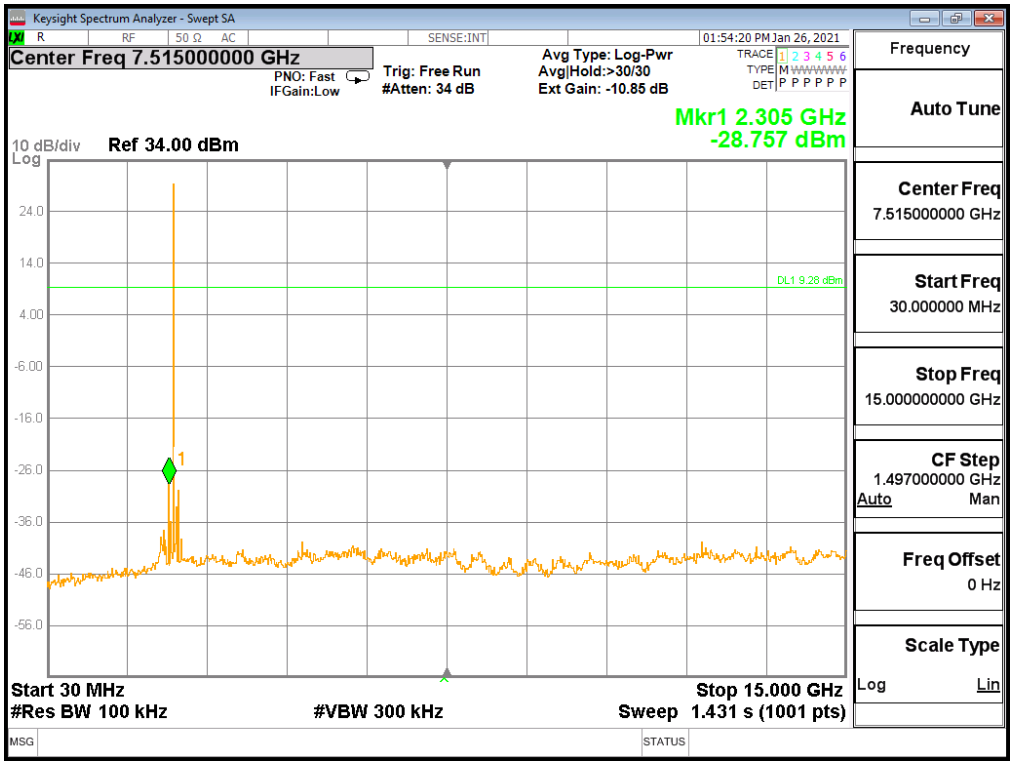
Test Mode : Hopping mode

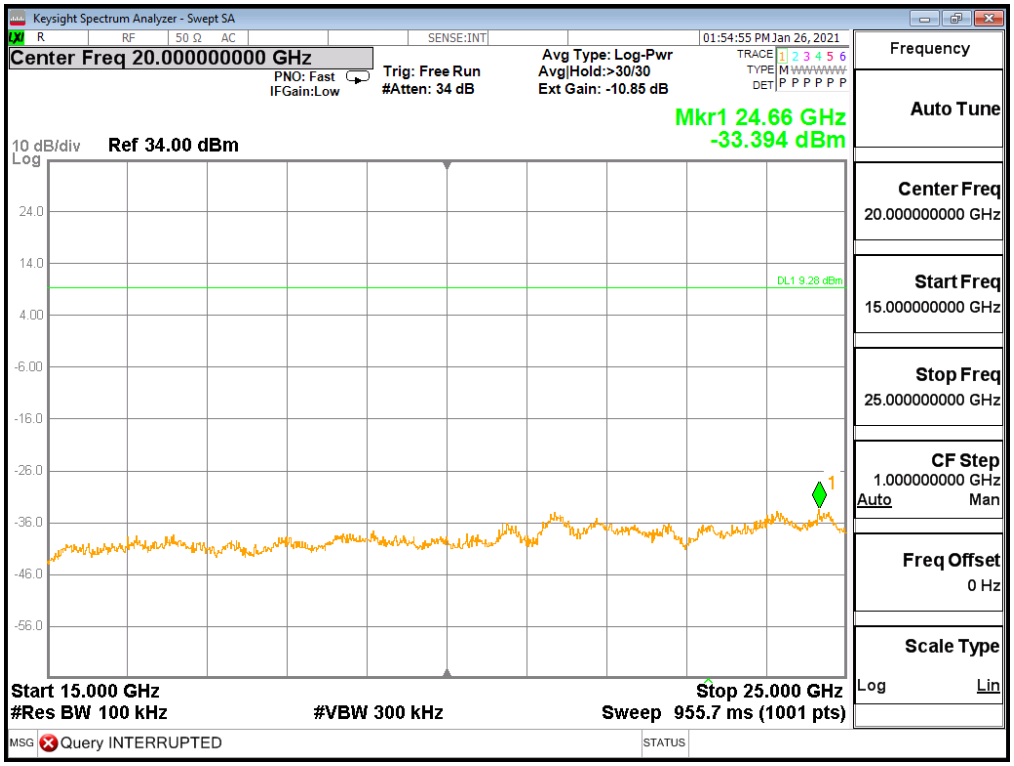




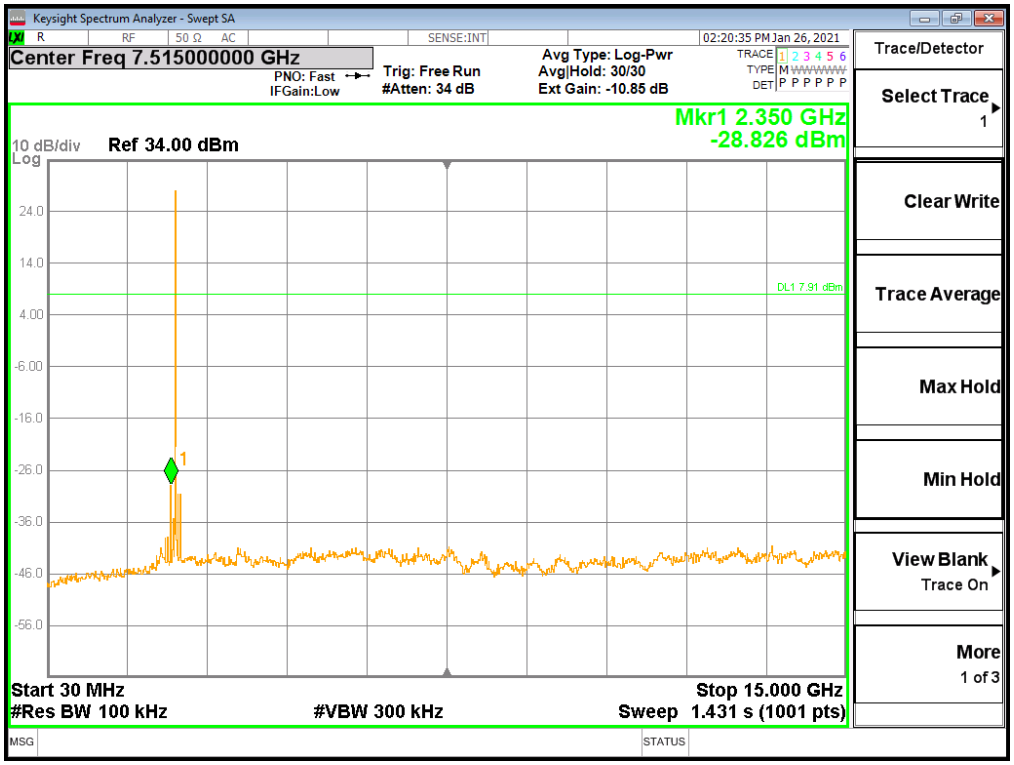
Spurious Emission

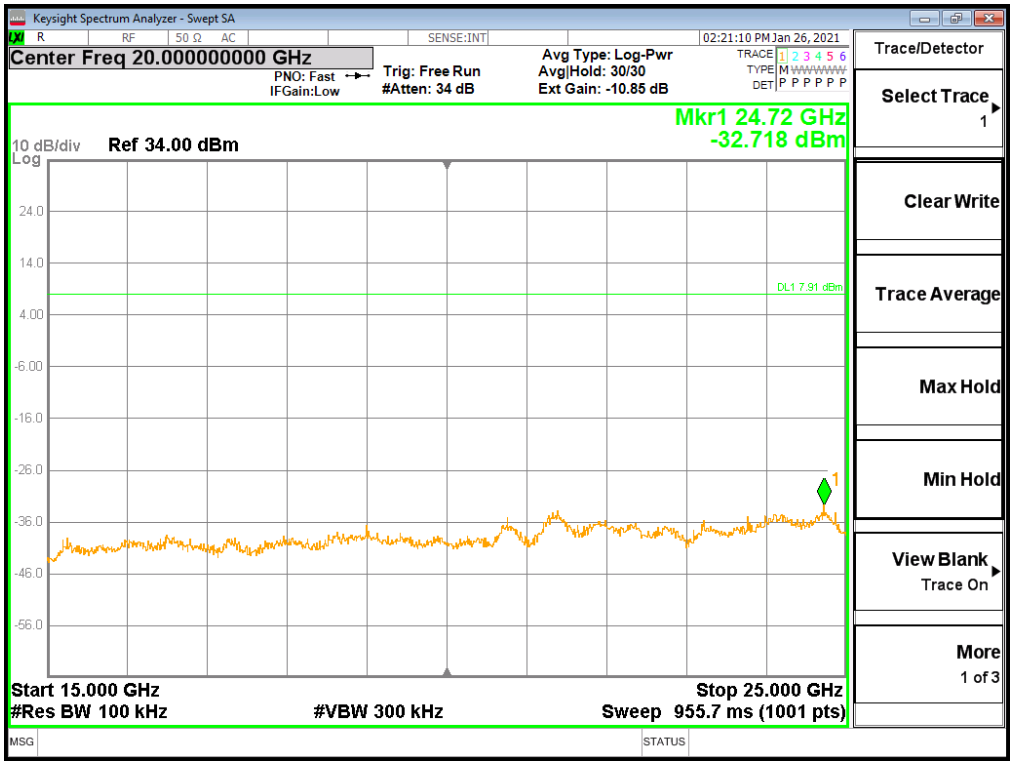
[Lowest channel]



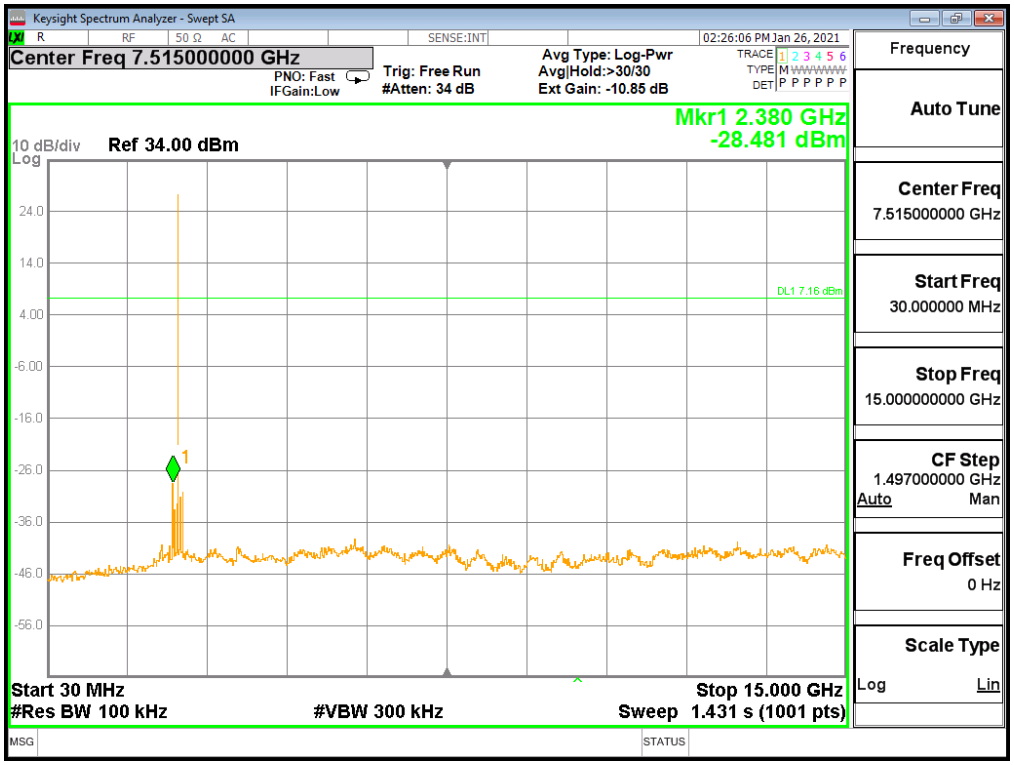


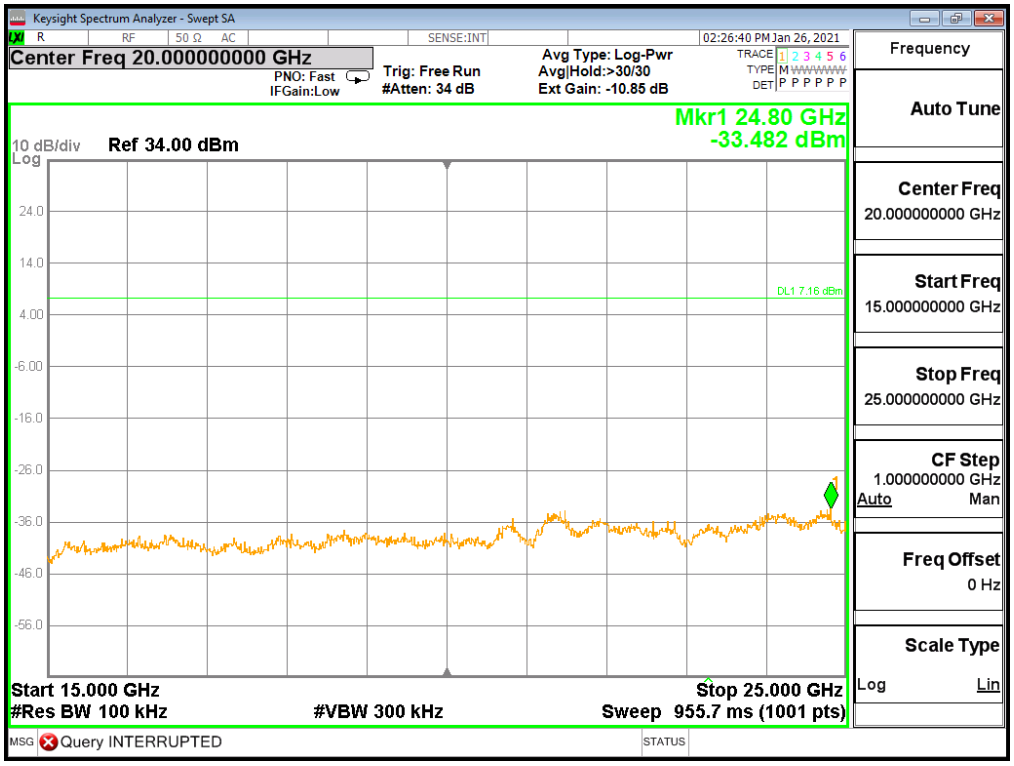
[Middle Channel]





[Highest Channel]





4.7 Radiated Emission

Test Location

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

Test Procedures

ANSI C63.10-2013 - Section 6.5, 6.6

1) In the frequency range of 9 kHz to 30 MHz, magnetic field is measured with Loop Antenna. The center of the Loop Test Antenna is 1m above the ground. During the measurement the Loop Test Antenna rotates about its vertical axis for maximum response at each azimuth about the EUT.
2) In the frequency rage above 30 MHz, Bi-Log Test Antenna(30 MHz to 1 GHz) and Horn Test Antenna(above 1 GHz) are used. Test Antenna is 3m away from the EUT. 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.

Instrument Settings

Frequency Range = 9 kHz ~ 25 GHz (2.4 GHz 10th harmonic)

a) RBW = 1 MHz for f ≥ 1 GHz, 100 kHz for f < 1 GHz, 9 kHz for f < 30 MHz

b) VBW ≥ RBW

c) Sweep time = auto couple

Limit :

Unwanted emissions that do not fall within the restricted frequency bands of Table 1 shall comply either with the limits specified in the applicable RSS or with those specified in this RSS-Gen.

FCC Part 15 § 15.205 (a) Except as shown in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

Table 1. Restricted Frequency Bands

MHz	MHz	MHz	MHz	MHz	GHz
0.09-0.11	8.37626-8.38675	73-74.6	399.9-410	2690-2900	10.6-12.7
[1]0.495-0.505	8.41425-8.41475	74.8-75.2	608-614	3260-3267	13.25-13.4
2.1735-2.1905	12.29-12.293	108-121.94	960-1240	3332-3339	14.47-14.5
4.125-4.128	12.51975-12.52025	123-138	1300-1427	3345.8-3358	15.35-16.2
4.17725-4.17775	12.57675-12.57725	149.9-150.05	1435-1626.5	3600-4400	17.7-21.4
4.20725-4.20775	13.36-13.41	156.52475-156.52525	1645.5-1646.5	4500-5150	22.01-23.12
6.215-6.218	16.42-16.423	156.7-156.9	1660-1710	5350-5460	23.6-24
6.26775-6.26825	16.69475-16.69525	162.0125-167.17	1718.8-1722.2	7250-7750	31.2-31.8
6.31175-6.31225	16.80425-16.80475	167.72-173.2	2200-2300	8025-8500	36.43-36.5
8.291-8.294	25.5-25.67	240-285	2310-2390	9000-9200	[2]Above 38.6
8.362-8.366	37.5-38.25	322-335.4	2483.5-2500	9300-9500	

[1] Until February 1, 1999, this restricted band shall be 0.490-0.510 MHz.

[2] Above 38.6

§ 15.205 (b) Except as provided in paragraphs (d) and (e), the field strength of emissions appearing within these frequency bands shall not exceed the limits shown is Section 15.209. At frequencies equal to or less than 1000 MHz, compliance with the limits in Section 15.209 shall be demonstrated using measurement instrumentation employing a CISPR quasi-peak detector. Above 1000 MHz, compliance with the emission limits in Section 15.209 shall be demonstrated based on the average value of the measured emissions. The provisions in Section 15.35 apply to these measurements.

FCC Part 15 § 15.209 (a) Except as provided elsewhere in this Subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table :

Except when the requirements applicable to a given device state otherwise, emissions from licence-exempt transmitters shall comply with the field strength limits shown in Table 2 Additionally, the level of any transmitter emission shall not exceed the level of the transmitter's fundamental emission.

Table 2. General Field Strength Limits for Licence-Exempt Transmitters

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

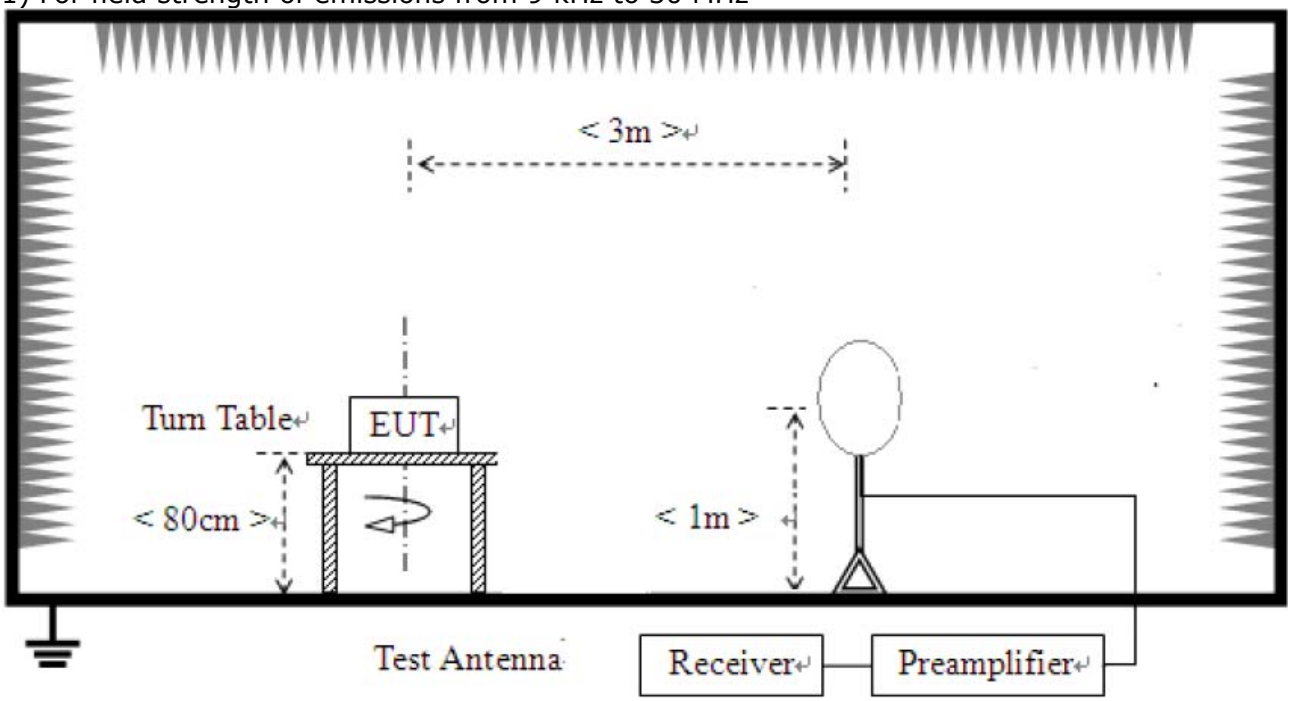
** Except as provided in 15.209(g).fundamental emissions from intentional radiators operating under this Section shall not be located in the frequency bands 54-72MHz, 76-88MHz, 174-216MHz, 470-806MHz. However, operation within these frequency bands is permitted under other sections of this Part, e.g.15.231 and 15.241.

Note :

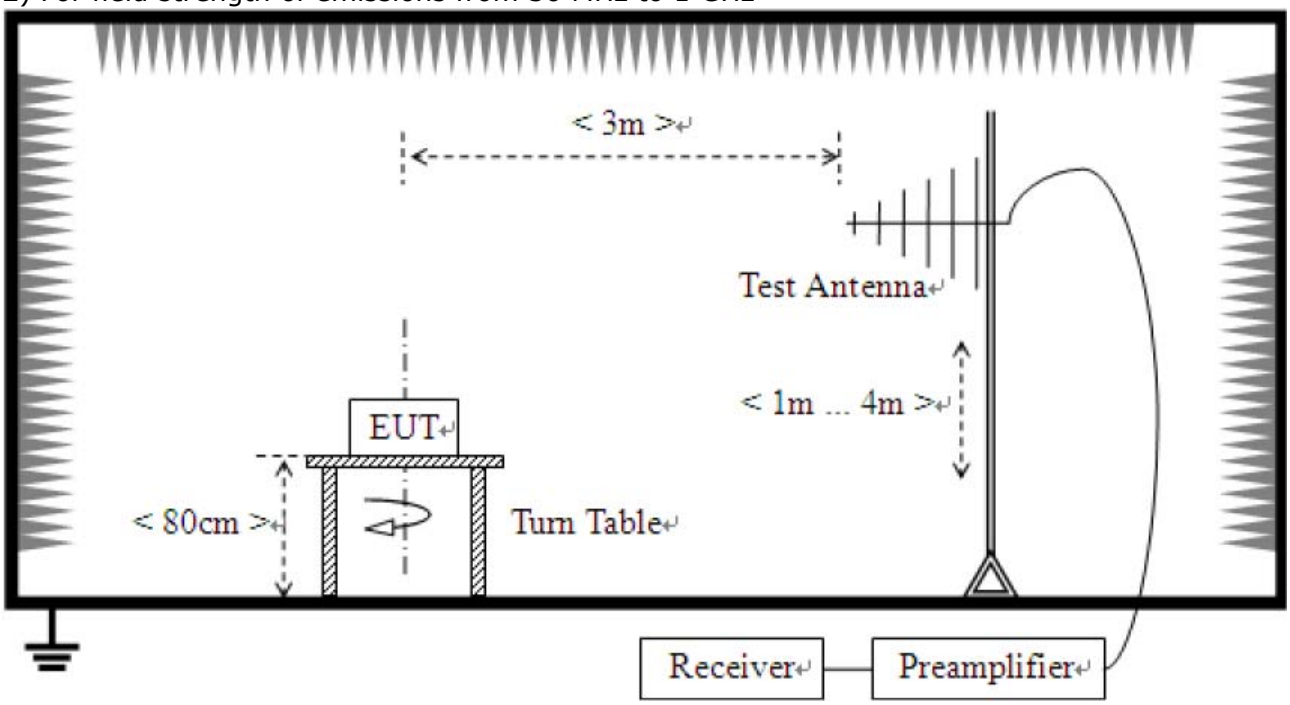
1) For above 1 GHz, the emission limit in this paragraph is based on measurement instrumentation employing an average detector, measurement using instrumentation with a peak detector function, corresponding to 20 dB above the maximum permitted average limit.
2) For above 1 GHz, limit field strength of harmonics : 54 dBuV/m@3m (AV) and 74 dBuV/m@3m (PK)
3) Taking a RMS average measurement while the EUT is transmitting in operational duty cycle – The RMS average detector of a spectrum analyzer can be used for making average measurements with the EUT operating on its operational duty cycle. If the EUT supports more than one operational duty cycle the worst case value should be used, i.e., the highest operational duty cycle. The measured RMS value using this method is compared against the limits and no other corrections are permitted. The spectrum analyzer settings shall meet the requirements of ANSI C63.10 for making Average measurements. This measurement refers to spectrum analyzer settings in either 11.12.2.5.2 or 11.12.2.5.3 in ANSI C63.10; except when using 11.12.2.5.2, set Trace mode = Max Hold and the measurement correction factor in 11.12.2.5.2 i) is not added.

Test Setup:

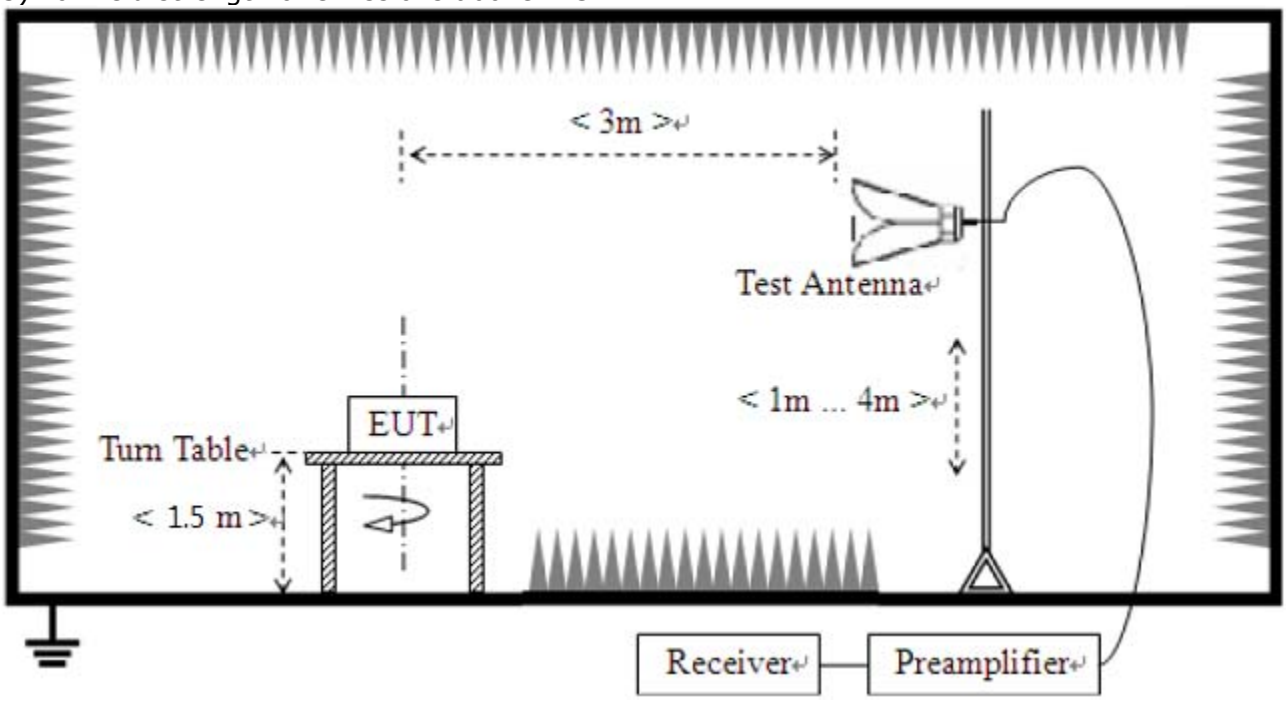
1) For field strength of emissions from 9 kHz to 30 MHz



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



3) For field strength of emissions above 1 GHz



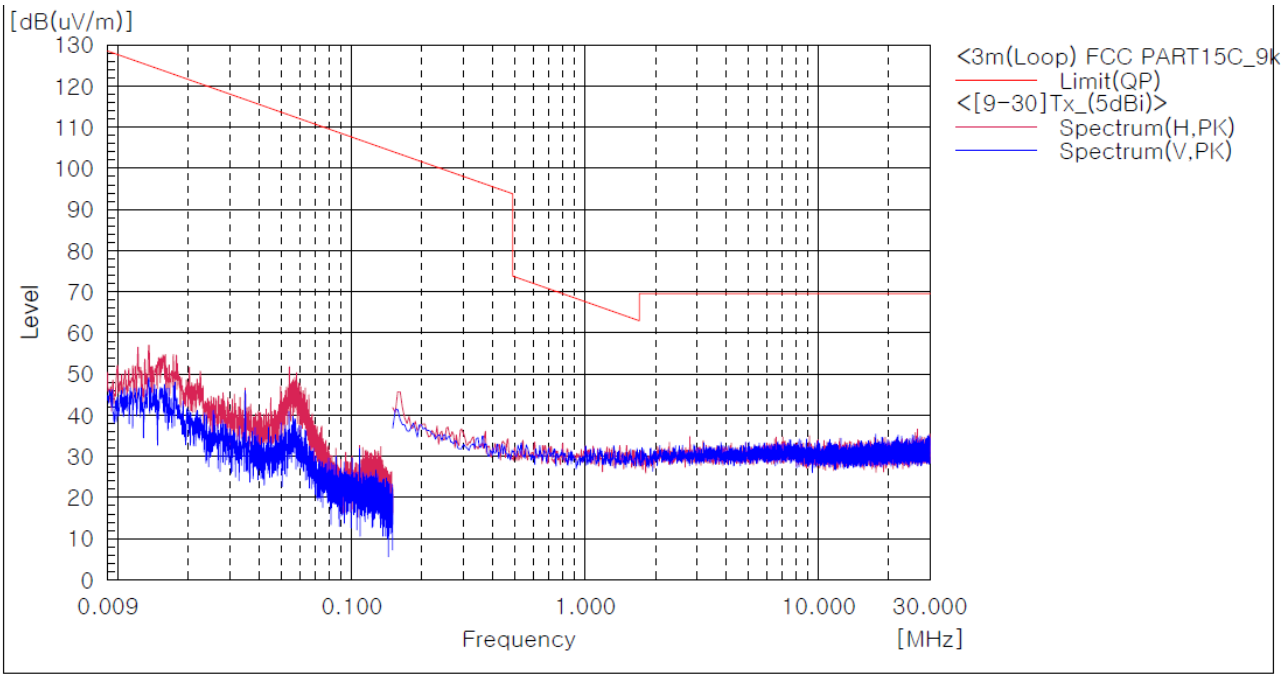
Test results

1) 9 kHz to 30 MHz

Test mode : ANT A_Transmitter (Worst Case)

The requirements are:
☒ Complies

Test Data



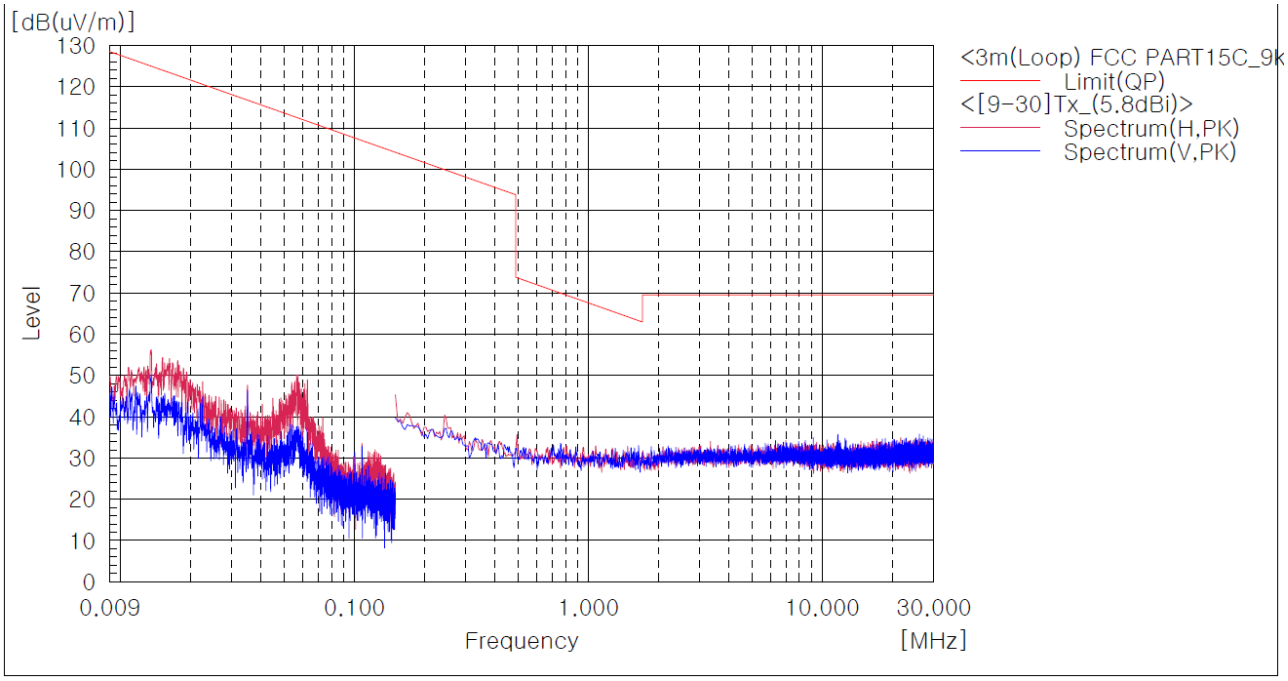
Frequency [MHz]	(P)	Reading [dBuV]	c.f [dB(1/m)]	Level [dB(uV/m)]	Limit [dB(uV/m)]	Margin [dB]
The emissions 9 kHz to 30 MHz were 20 dB lower than the limit.						

Remark :
1. The unwanted emission was measured in the following position: EUT stand-up position(Z axis), lie-down positon(X,Y axis). The worst emission was found in lie-down position(X axis) and the worst case was recorded.
2. Result = Reading + c.f(Correction factor)
3. Correction factor = Antenna factor + Cable loss + 6 dB attenuator - Amp Gain
4. This data is the Peak(PK) value.

Test mode : ANT B_Transmitter (Worst Case)

The requirements are:
☒ Complies

Test Data



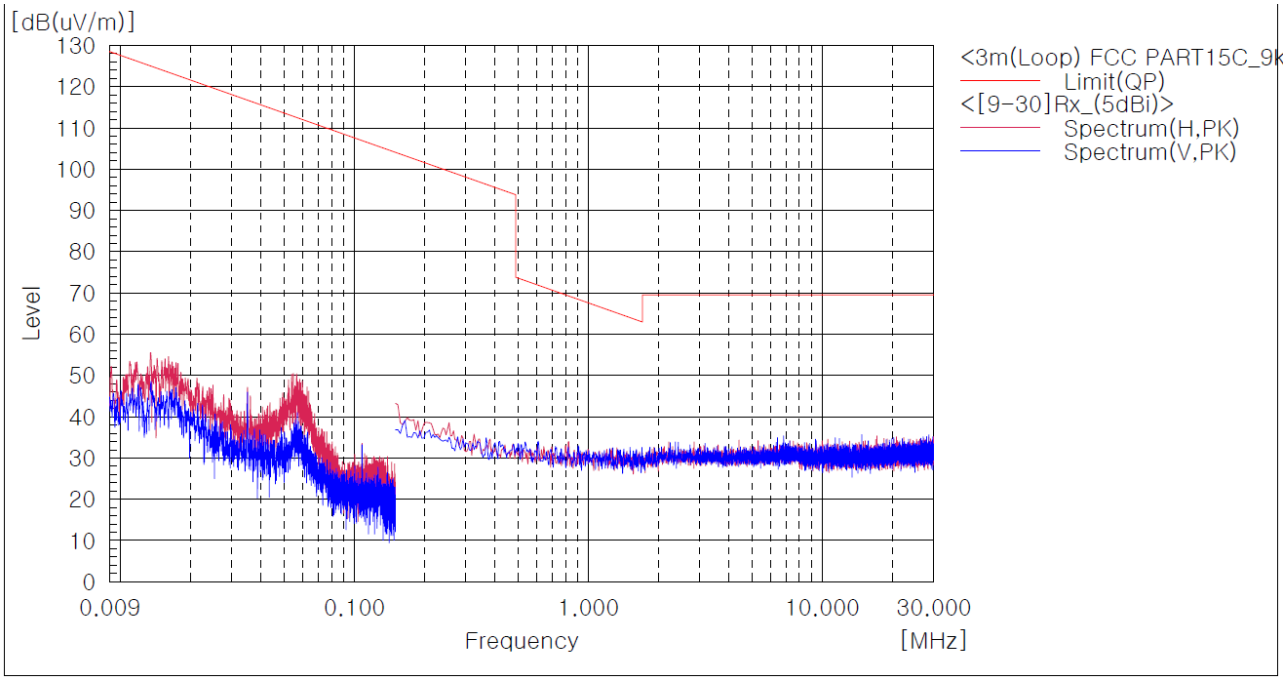
Frequency [MHz]	(P)	Reading [dBuV]	c.f [dB(1/m)]	Level [dB(uV/m)]	Limit [dB(uV/m)]	Margin [dB]
The emissions 9 kHz to 30 MHz were 20 dB lower than the limit.						

Remark :
1. The unwanted emission was measured in the following position: EUT stand-up position(Z axis), lie-down position(X,Y axis). The worst emission was found in lie-down position(X axis) and the worst case was recorded.
2. Result = Reading + c.f(Correction factor)
3. Correction factor = Antenna factor + Cable loss + 6 dB attenuator - Amp Gain
4. This data is the Peak(PK) value.

Test mode : ANT A_Receiver (Worst Case)

The requirements are:
☒ Complies

Test Data



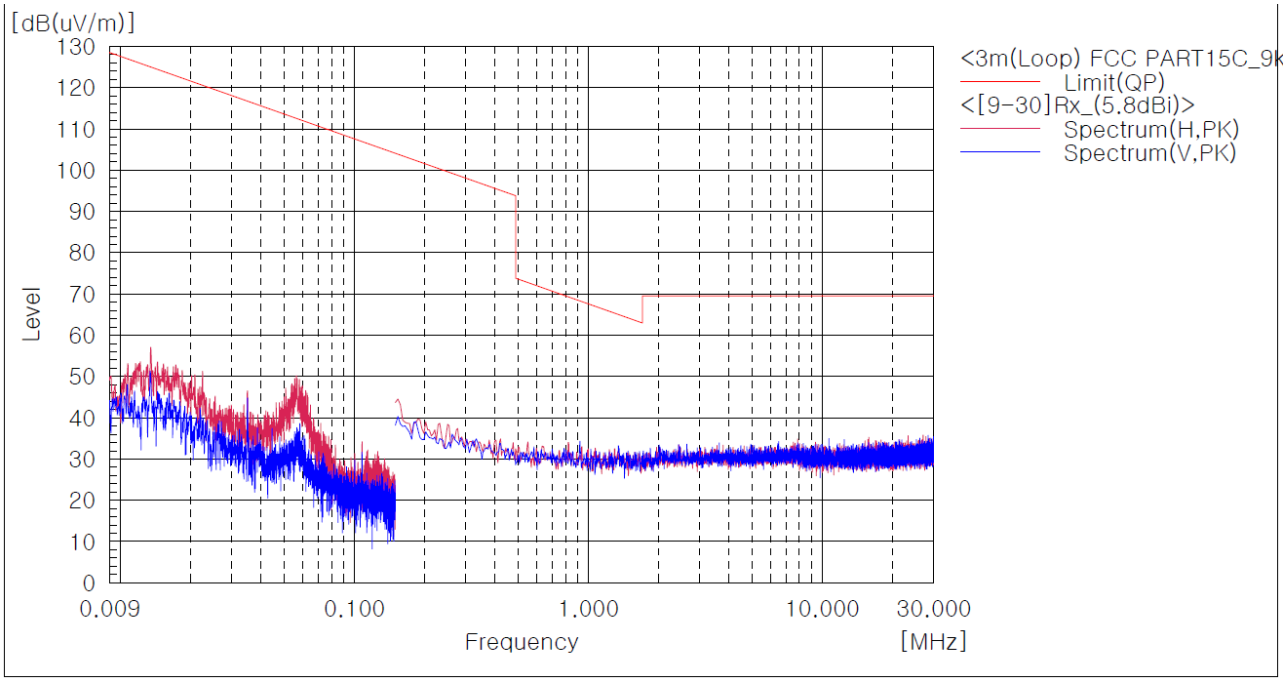
Frequency [MHz]	(P)	Reading [dBuV]	c.f [dB(1/m)]	Level [dB(uV/m)]	Limit [dB(uV/m)]	Margin [dB]
The emissions 9 kHz to 30 MHz were 20 dB lower than the limit.						

Remark :
1. The unwanted emission was measured in the following position: EUT stand-up position(Z axis), lie-down positon(X,Y axis). The worst emission was found in lie-down position(X axis) and the worst case was recorded.
2. Result = Reading + c.f(Correction factor)
3. Correction factor = Antenna factor + Cable loss + 6 dB attenuator - Amp Gain
4. This data is the Peak(PK) value.

Test mode : ANT B_Receiver (Worst Case)

The requirements are:
☒ Complies

Test Data



Frequency [MHz]	(P)	Reading [dBuV]	c.f [dB(1/m)]	Level [dB(uV/m)]	Limit [dB(uV/m)]	Margin [dB]
The emissions 9 kHz to 30 MHz were 20 dB lower than the limit.						

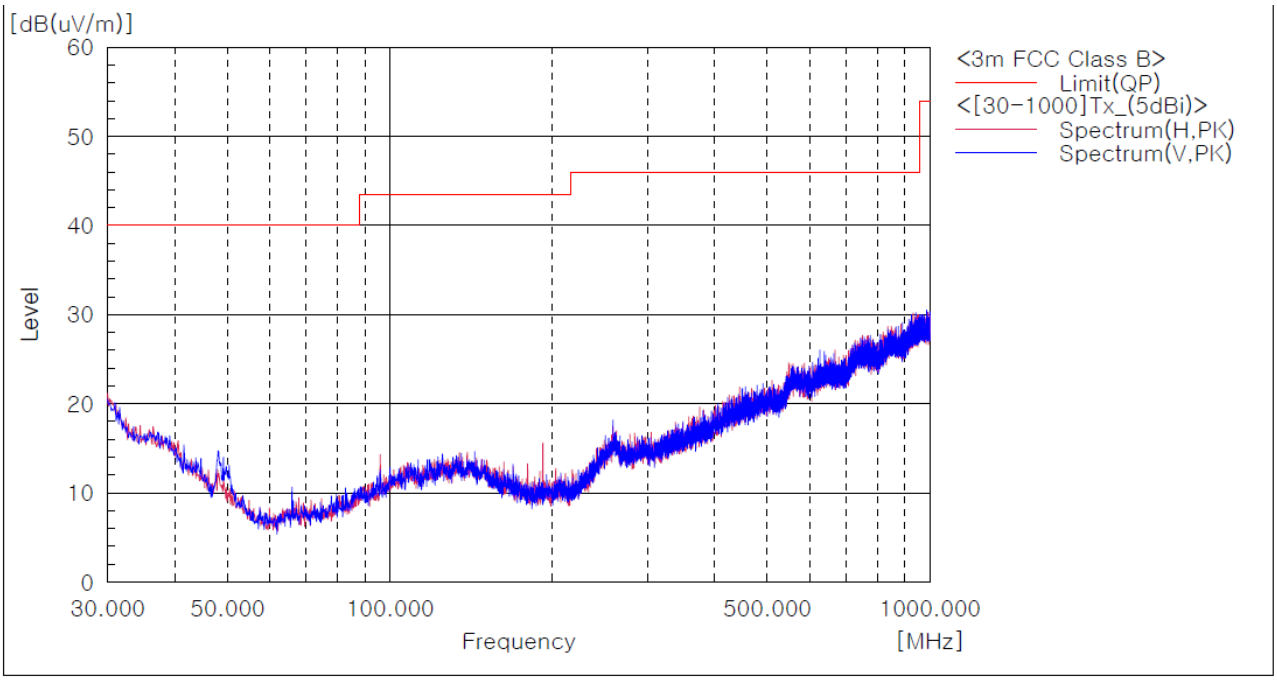
Remark :
1. The unwanted emission was measured in the following position: EUT stand-up position(Z axis), lie-down position(X,Y axis). The worst emission was found in lie-down position(X axis) and the worst case was recorded.
2. Result = Reading + c.f(Correction factor)
3. Correction factor = Antenna factor + Cable loss + 6 dB attenuator - Amp Gain
4. This data is the Peak(PK) value.

2) 30 MHz to 1 GHz

Test mode : ANT A_Transmitter (Worst Case)

The requirements are:
☒ Complies

Test Data



Final Result

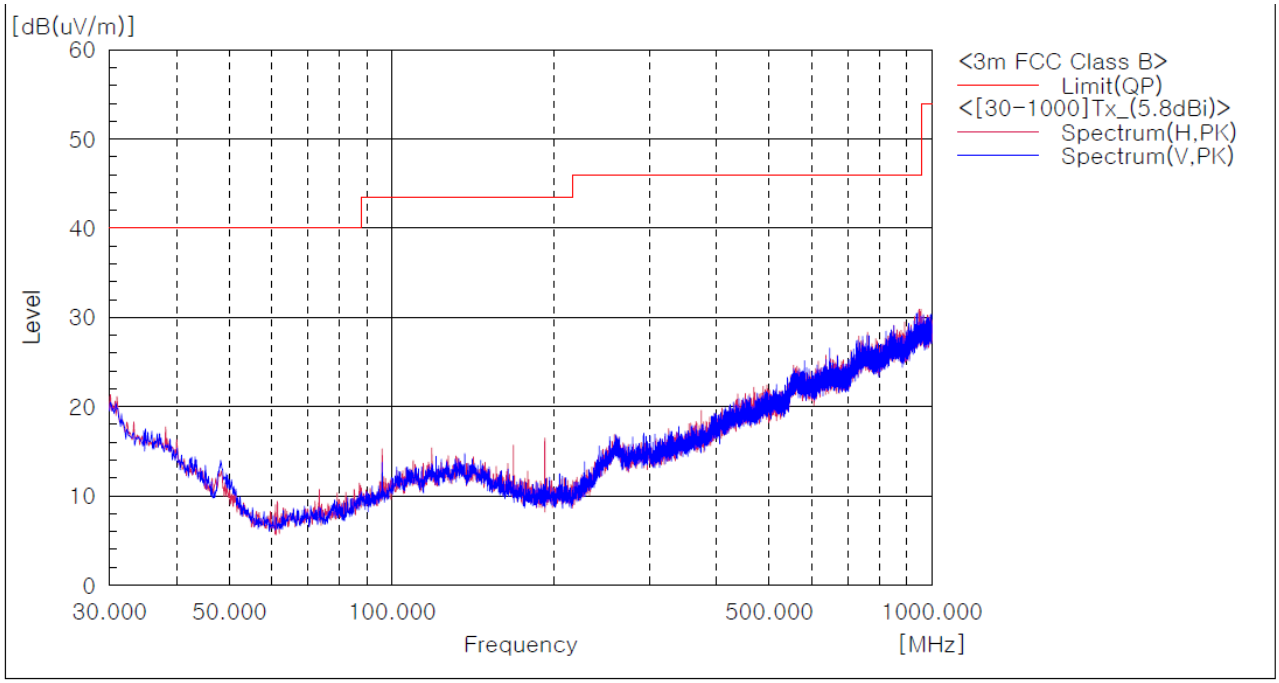
No.	Frequency [MHz]	(P)	c.f [dB(1/m)]	Height [cm]	Angle [deg]

Remark :
1. The unwanted emission was measured in the following position: EUT stand-up position(Z axis), lie-down positon(X,Y axis). The worst emission was found in lie-down position(X axis) and the worst case was recorded.
2. Result = Reading + c.f(Correction factor)
3. Correction factor = Antenna factor + Cable loss + 6 dB attenuator - Amp Gain

Test mode : ANT B_Transmitter (Worst Case)

The requirements are:
☒ Complies

Test Data



Final Result

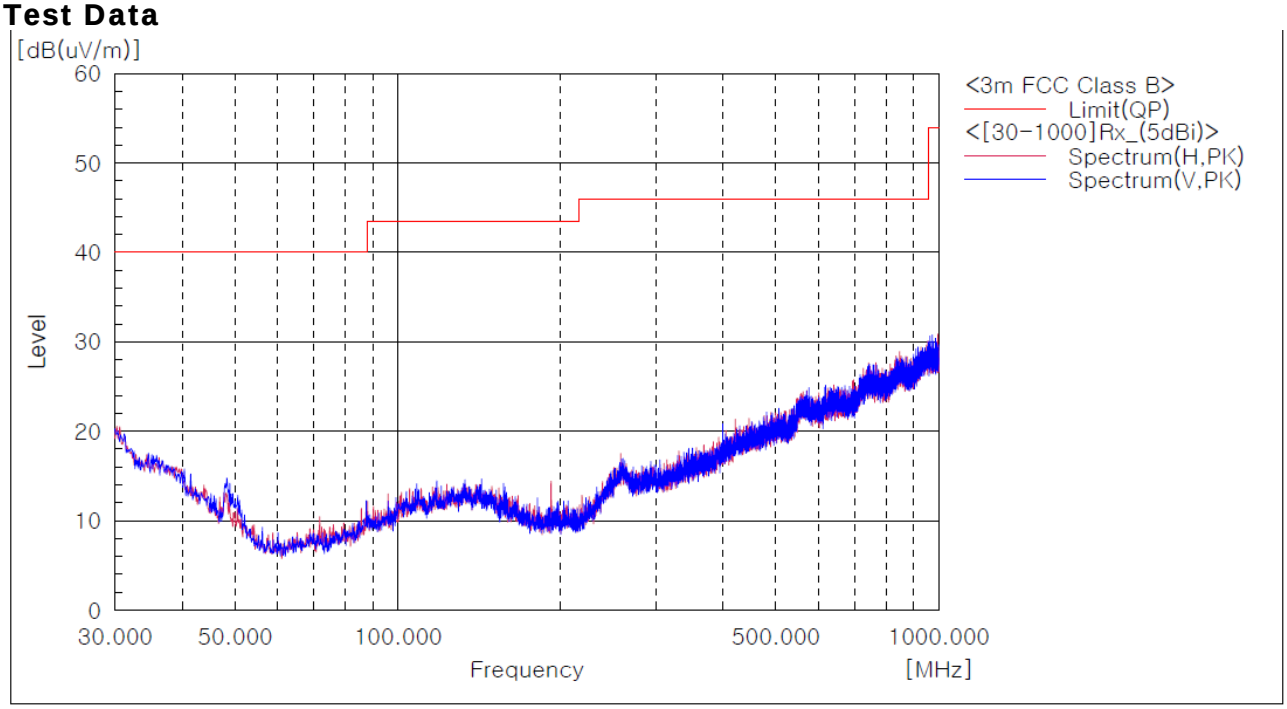
No.	Frequency [MHz]	(P)	c.f [dB(1/m)]	Height [cm]	Angle [deg]

Remark :
1. The unwanted emission was measured in the following position: EUT stand-up position(Z axis), lie-down position(X,Y axis). The worst emission was found in lie-down position(X axis) and the worst case was recorded.
2. Result = Reading + c.f(Correction factor)
3. Correction factor = Antenna factor + Cable loss + 6 dB attenuator - Amp Gain

Test mode : ANT A_Receiver (Worst Case)

The requirements are:
☒ Complies

Test Data



Final Result

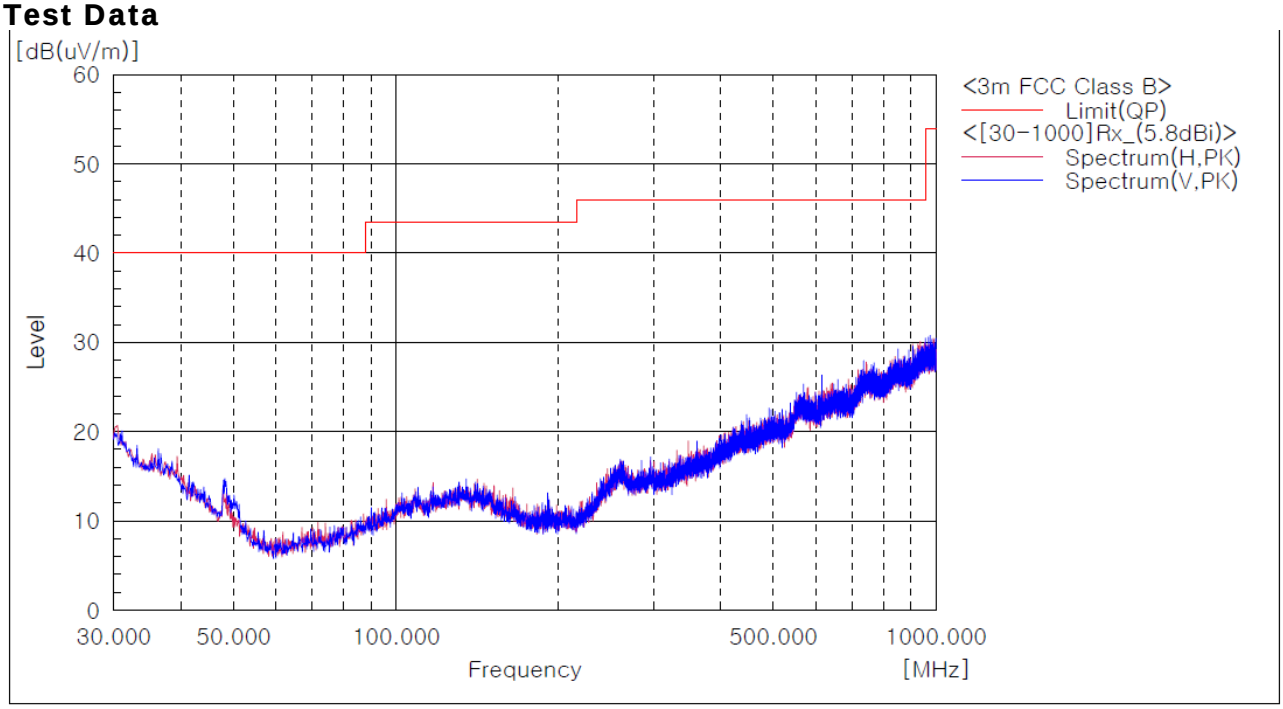
No.	Frequency [MHz]	(P)	c.f [dB(1/m)]	Height [cm]	Angle [deg]

Remark :
1. The unwanted emission was measured in the following position: EUT stand-up position(Z axis), lie-down positon(X,Y axis). The worst emission was found in lie-down position(X axis) and the worst case was recorded.
2. Result = Reading + c.f(Correction factor)
3. Correction factor = Antenna factor + Cable loss + 6 dB attenuator - Amp Gain

Test mode : ANT B_Receiver (Worst Case)

The requirements are:
☒ Complies

Test Data



Final Result

No.	Frequency [MHz]	(P)	c.f [dB(1/m)]	Height [cm]	Angle [deg]

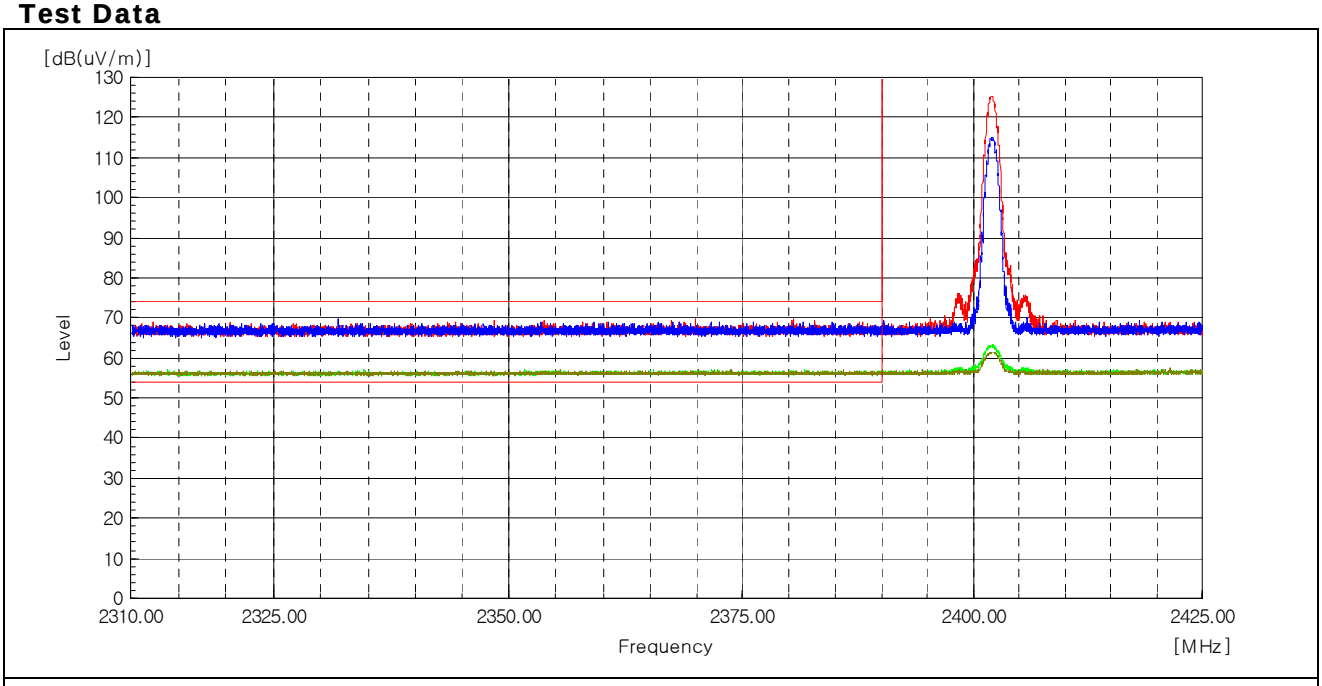
Remark :
1. The unwanted emission was measured in the following position: EUT stand-up position(Z axis), lie-down position(X,Y axis). The worst emission was found in lie-down position(X axis) and the worst case was recorded.
2. Result = Reading + c.f(Correction factor)
3. Correction factor = Antenna factor + Cable loss + 6 dB attenuator - Amp Gain

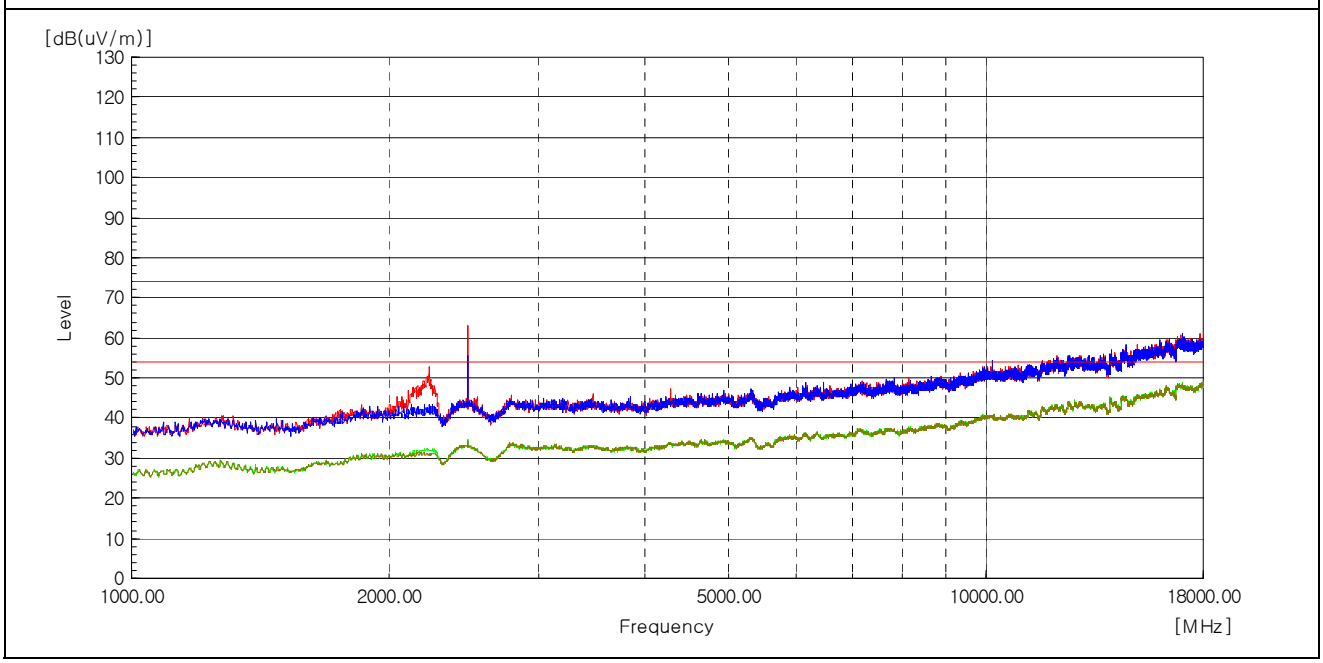
3) above 1 GHz

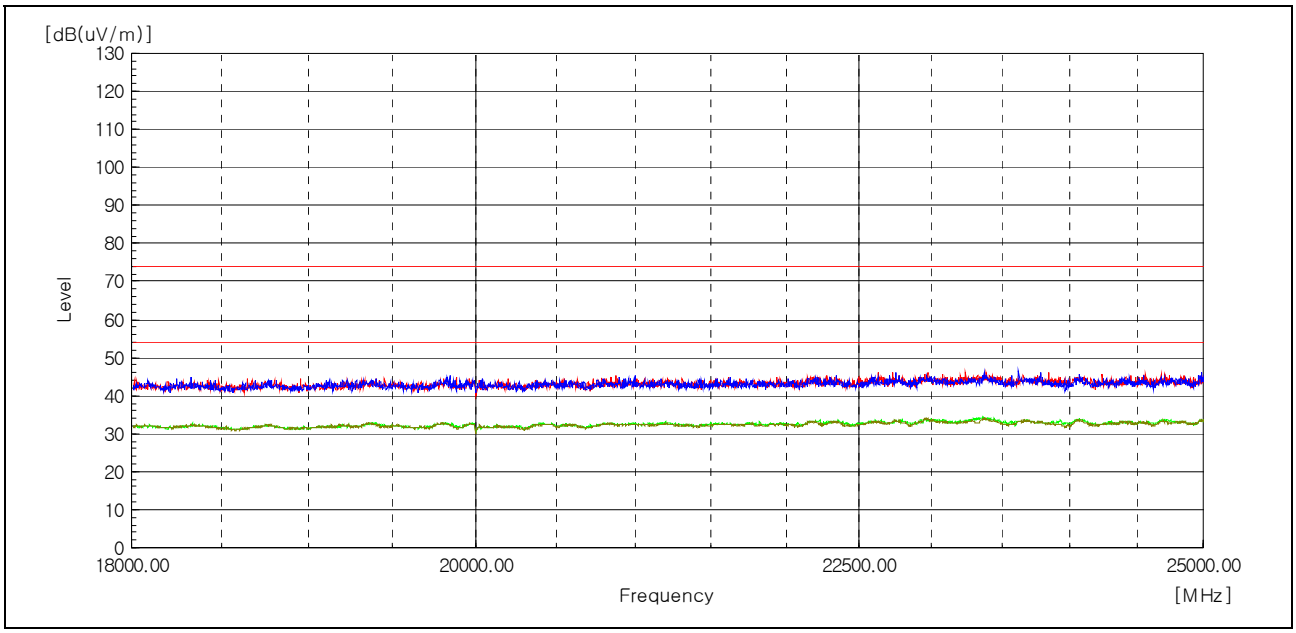
The requirements are:
☒ Complies

Test mode : Transmitter (Worst Case)

Test Data






[dB(uV/m)]
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Level
18000.00
20000.00
22500.00
25000.00
Frequency
[MHz]

Test mode : ANT A_Transmitter

Lowest frequency(2 402 MHz)

Frequency [MHz]	(P)	Reading PK [dBuV]	Reading AV [dBuV]	c.f [dB(1/m)]	Level PK [dB(uV/m)]	Level AV [dB(uV/m)]	Limit PK [dB(uV/m)]	Limit AV [dB(uV/m)]	Margin PK [dB]	Margin AV [dB]
4 804.05	H	49.9	-----	1.3	51.2	-----	74.0	-----	22.8	-----
4 804.13	H	-----	33.8	1.3	-----	35.1	-----	54.0	-----	18.9
4 803.98	V	49.4	-----	1.3	50.7	-----	74.0	-----	23.3	-----
4 803.90	V	-----	33.2	1.3	-----	34.5	-----	54.0	-----	19.5

Middle frequency(2 441 MHz)

Frequency [MHz]	(P)	Reading PK [dBuV]	Reading AV [dBuV]	c.f [dB(1/m)]	Level PK [dB(uV/m)]	Level AV [dB(uV/m)]	Limit PK [dB(uV/m)]	Limit AV [dB(uV/m)]	Margin PK [dB]	Margin AV [dB]
4 881.92	H	46.3	-----	1.5	47.8	-----	74.0	-----	26.2	-----
4 882.86	H	-----	33.2	1.5	-----	34.7	-----	54.0	-----	19.3
4 881.76	V	47.5	-----	1.5	49.0	-----	74.0	-----	25.0	-----
4 881.92	V	-----	33.0	1.5	-----	34.5	-----	54.0	-----	19.5

Highest frequency(2 480 MHz)

Frequency [MHz]	(P)	Reading PK [dBuV]	Reading AV [dBuV]	c.f [dB(1/m)]	Level PK [dB(uV/m)]	Level AV [dB(uV/m)]	Limit PK [dB(uV/m)]	Limit AV [dB(uV/m)]	Margin PK [dB]	Margin AV [dB]
4 960.09	H	47.9	-----	1.6	49.5	-----	74.0	-----	24.5	-----
4 960.02	H	-----	34.0	1.6	-----	35.6	-----	54.0	-----	18.4
4 959.67	V	46.5	-----	1.6	48.1	-----	74.0	-----	25.9	-----
4 959.65	V	-----	33.0	1.6	-----	34.6	-----	54.0	-----	19.4

Remarks

1. The unwanted emission was measured in the following position: EUT stand-up position(Z axis), lie-down positon(X,Y axis). The worst emission was found in lie-down position(X axis) and the worst case was recorded.
2. Correction factor = Antenna factor + Cable loss - Amp Gain

Test mode : ANT B_Transmitter

Lowest frequency(2 402 MHz)

Frequency [MHz]	(P)	Reading PK [dBuV]	Reading AV [dBuV]	c.f [dB(1/m)]	Level PK [dB(uV/m)]	Level AV [dB(uV/m)]	Limit PK [dB(uV/m)]	Limit AV [dB(uV/m)]	Margin PK [dB]	Margin AV [dB]
4 803.78	H	54.5	-----	1.3	55.8	-----	74.0	-----	18.2	-----
4 804.03	H	-----	34.5	1.3	-----	35.8	-----	54.0	-----	18.2
4 803.96	V	52.0	-----	1.3	53.3	-----	74.0	-----	20.7	-----
4 803.84	V	-----	33.8	1.3	-----	35.1	-----	54.0	-----	18.9

Middle frequency(2 441 MHz)

Frequency [MHz]	(P)	Reading PK [dBuV]	Reading AV [dBuV]	c.f [dB(1/m)]	Level PK [dB(uV/m)]	Level AV [dB(uV/m)]	Limit PK [dB(uV/m)]	Limit AV [dB(uV/m)]	Margin PK [dB]	Margin AV [dB]
4 881.90	H	47.2	-----	1.5	48.7	-----	74.0	-----	25.3	-----
4 881.73	H	-----	33.3	1.5	-----	34.8	-----	54.0	-----	19.2
4 881.86	V	46.7	-----	1.5	48.2	-----	74.0	-----	25.8	-----
4 882.54	V	-----	32.9	1.5	-----	34.4	-----	54.0	-----	19.6

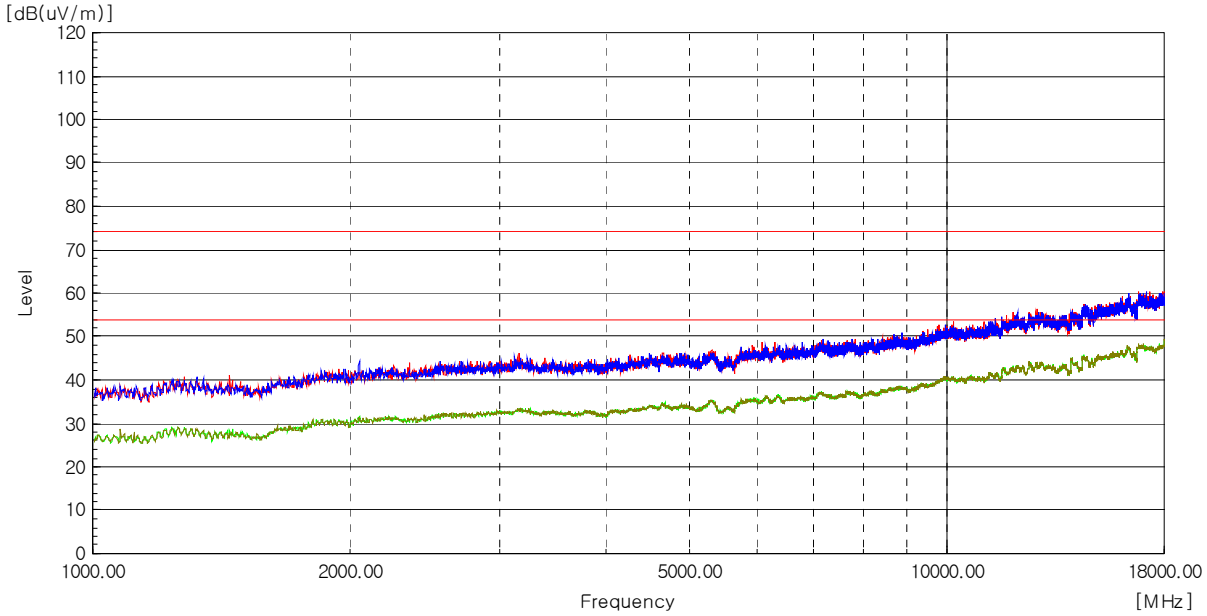
Highest frequency(2 480 MHz)

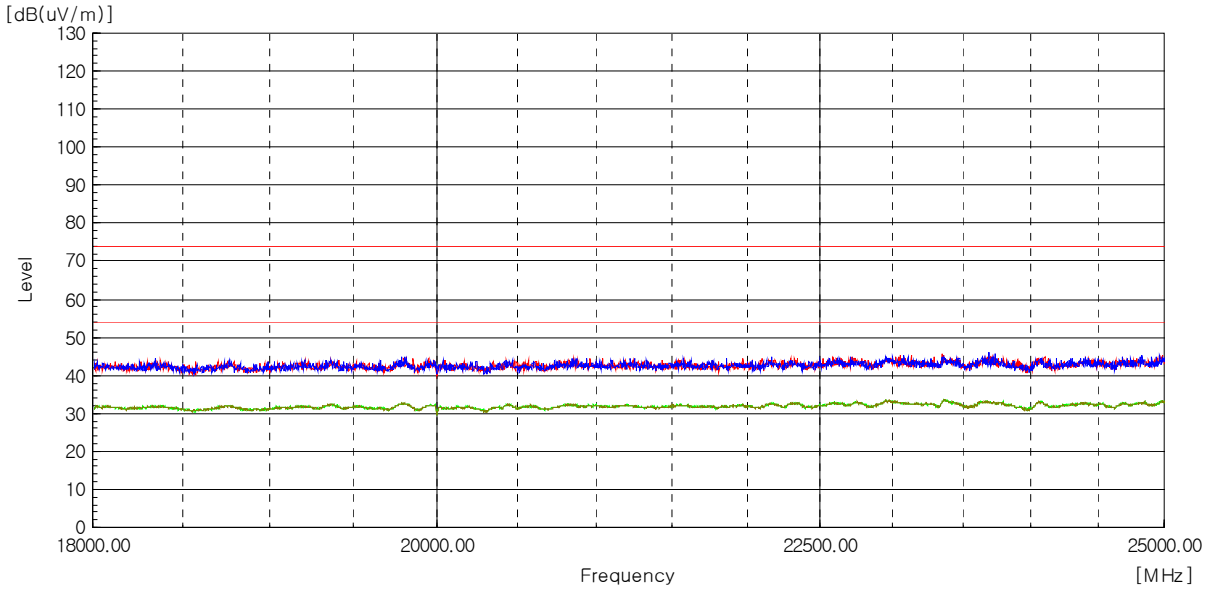
Frequency [MHz]	(P)	Reading PK [dBuV]	Reading AV [dBuV]	c.f [dB(1/m)]	Level PK [dB(uV/m)]	Level AV [dB(uV/m)]	Limit PK [dB(uV/m)]	Limit AV [dB(uV/m)]	Margin PK [dB]	Margin AV [dB]
4 959.82	H	47.4	-----	1.6	49.0	-----	74.0	-----	25.0	-----
4 960.07	H	-----	34.3	1.6	-----	35.9	-----	54.0	-----	18.1
4 960.09	V	45.6	-----	1.6	47.2	-----	74.0	-----	26.8	-----
4 958.20	V	-----	32.9	1.6	-----	34.5	-----	54.0	-----	19.5

Remarks

1. The unwanted emission was measured in the following position: EUT stand-up position(Z axis), lie-down positon(X,Y axis). The worst emission was found in lie-down position(X axis) and the worst case was recorded.
2. Correction factor = Antenna factor + Cable loss - Amp Gain

Test mode : Receiver (Worst Case)





Test mode : Receiver (Worst Case)

Frequency [MHz]	(P)	Reading PK [dBuV]	Reading AV [dBuV]	c.f [dB(1/m)]	Level PK [dB(uV/m)]	Level AV [dB(uV/m)]	Limit PK [dB(uV/m)]	Limit AV [dB(uV/m)]	Margin PK [dB]	Margin AV [dB]
The emissions above 1 GHz were 20 dB lower than the limit.										

Remarks

1. The unwanted emission was measured in the following position: EUT stand-up position(Z axis), lie-down positon(X,Y axis). The worst emission was found in lie-down position(X axis) and the worst case was recorded.
2. Correction factor = Antenna factor + Cable loss - Amp Gain

4.8 AC Power Line Conducted Emissions

A radio apparatus that is designed to be connected to the public utility (AC) power line shall ensure that the radio frequency voltage, which is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz-30 MHz, shall not exceed the limits.

Instrument Settings

IF Band Width: 9 kHz

Test Procedures

RSS-Gen - Section 8.8

The EUT was placed on a non-metallic table 0.8m above the metallic, grounded floor and 0.4m from the reference ground plane wall. The distance to other metallic surfaces was at least 0.8m.
Amplitude measurements were performed with a quasi-peak detector and an average detector.

Limit

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

* The level decreases linearly with the logarithm of the frequency.
** A linear average detector is required.

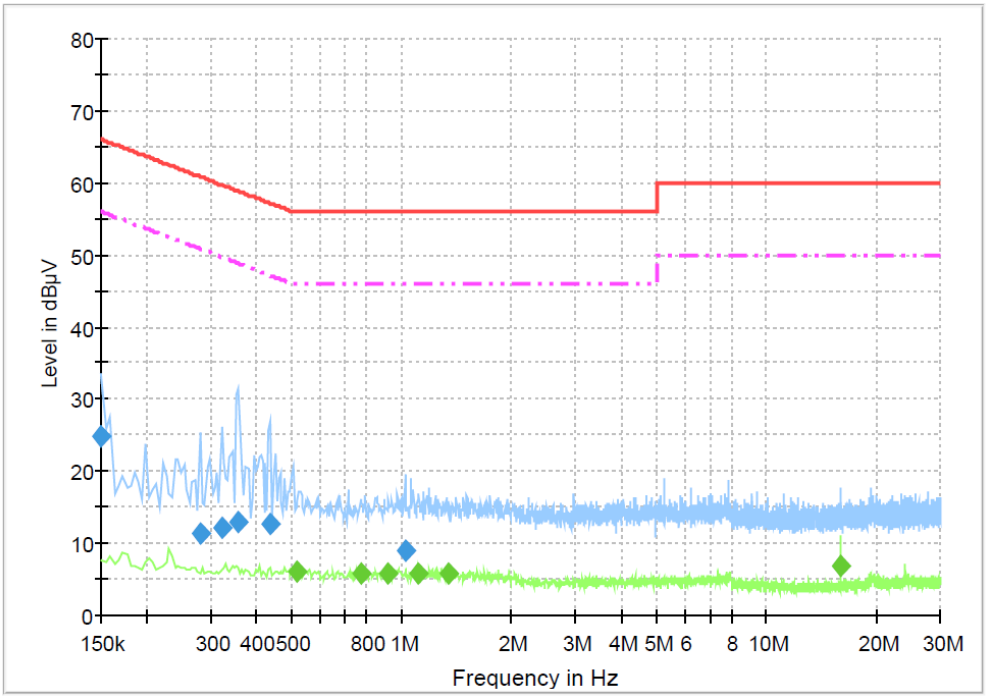
Test Results

The requirements are:
☒ Complies

Test Data

[LINE]

3CE_Class B_L1



Final Result 1

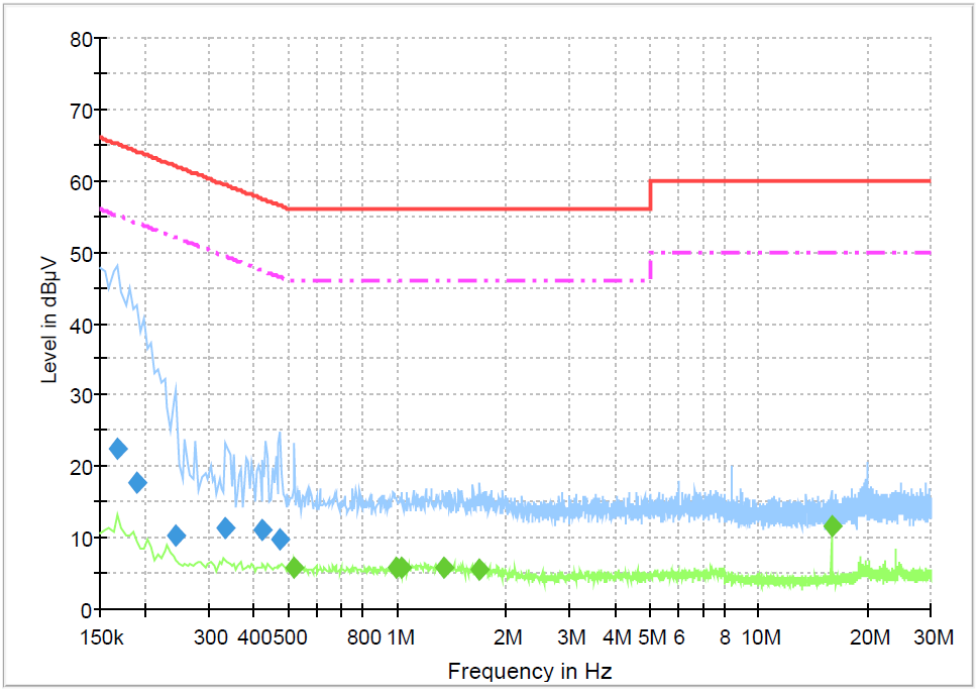
Frequency (MHz)	QuasiPeak (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	Filter	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.150000	24.7	1000.0	9.000	On	L1	9.7	41.3	66.0
0.280500	11.2	1000.0	9.000	On	L1	9.7	49.6	60.8
0.321000	12.2	1000.0	9.000	On	L1	9.8	47.4	59.7
0.357000	13.1	1000.0	9.000	On	L1	9.9	45.7	58.8
0.438000	12.7	1000.0	9.000	On	L1	9.9	44.4	57.1
1.023000	8.9	1000.0	9.000	On	L1	9.8	47.1	56.0

Final Result 2

Frequency (MHz)	CAverage (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	Filter	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.514500	6.0	1000.0	9.000	On	L1	9.9	40.0	46.0
0.775500	5.9	1000.0	9.000	On	L1	9.9	40.1	46.0
0.919500	5.9	1000.0	9.000	On	L1	9.8	40.1	46.0
1.113000	5.8	1000.0	9.000	On	L1	9.8	40.2	46.0
1.347000	5.8	1000.0	9.000	On	L1	9.8	40.2	46.0
15.927000	6.8	1000.0	9.000	On	L1	10.0	43.2	50.0

[NEUTRAL]

3CE_Class B_N



Final Result 1

Frequency (MHz)	QuasiPeak (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	Filter	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.168000	22.5	1000.0	9.000	On	N	10.0	42.5	65.1
0.190500	17.7	1000.0	9.000	On	N	9.9	46.3	64.0
0.244500	10.4	1000.0	9.000	On	N	9.7	51.5	61.9
0.334500	11.3	1000.0	9.000	On	N	9.9	48.0	59.3
0.424500	11.0	1000.0	9.000	On	N	9.9	46.3	57.4
0.474000	9.8	1000.0	9.000	On	N	9.9	46.7	56.4

Final Result 2

Frequency (MHz)	CAverage (dBµV)	Meas. Time (ms)	Bandwidth (kHz)	Filter	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.519000	5.9	1000.0	9.000	On	N	9.9	40.1	46.0
0.996000	5.8	1000.0	9.000	On	N	9.8	40.2	46.0
1.032000	5.8	1000.0	9.000	On	N	9.8	40.2	46.0
1.351500	5.7	1000.0	9.000	On	N	9.8	40.3	46.0
1.693500	5.5	1000.0	9.000	On	N	9.8	40.5	46.0
15.891000	11.6	1000.0	9.000	On	N	10.0	38.4	50.0

4.9 Frequency Hopping System Requirements

Standard Applicable

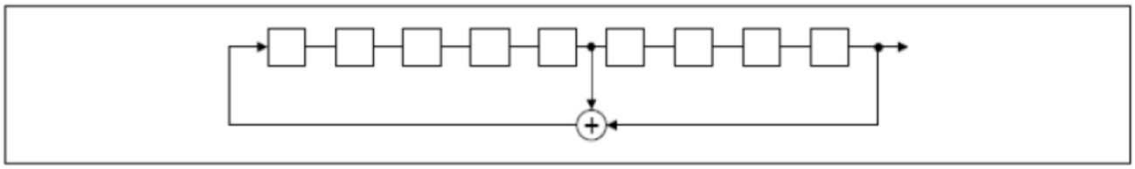
According to FCC Part 15.247(a)(1), The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

(g) Frequency hopping spread spectrum systems are not required to employ all available hopping channels during each transmission. However, the system, consisting of both the transmitter and the receiver, must be designed to comply with all of the regulations in this section should the transmitter be presented with a continuous data (or information) stream. In addition, a system employing short transmission bursts must comply with the definition of a frequency hopping system and must distribute its transmissions over the minimum number of hopping channels specified in this section.

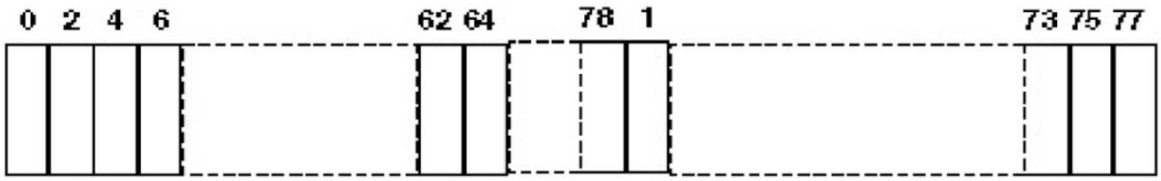
(h) The incorporation of intelligence within a frequency hopping spread spectrum system that permits the system to recognize other users within the spectrum band so that it individually and independently chooses and adapts its hopsets to avoid hopping on occupied channels is permitted. The coordination of frequency hopping systems in any other manner for the express purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters is not permitted.

EUT Pseudorandom Frequency Hopping Sequence

The pseudo random sequence may be generated in a nine-stage shift register whose 5th and 9th stage outputs are added in a modulo-two addition stage, and the result is fed back to the input of the first stage. The sequence begins with the first ONE of 9 consecutive ONEs; i.e. the shift register is initialized with nine ones. Number of shift register stages: 9 Length of pseudo-random sequence: 2^9-1 = 511 bits Longest sequence of zeros: 8 (non-inverted signal)



Linear Feedback Shift Register for Generation of the PRBS sequence



Each frequency used equally on the average by each transmitter. The system receiver have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shift frequencies in synchronization with the transmitted signals.

Frequency Hopping System

This transmitter device is frequency hopping device, and complies with FCC part 15.247 rule. This device uses frequency hopping radio which operates in 2400-2483.5 MHz band. Uses a radio technology called frequency-hopping spread spectrum, which chops up the data being sent and transmits chunks of it on up to 79 bands (1 MHz each; centred from 2402 to 2480 MHz) in the range 2,400-2,483.5 MHz.

*Example for a frequency hopping device using channel numbers would be :
Ch 44, 35, 78, 03, 15, 21, 76, 40, 56, 13, 02, 19, 67, 39, 78, 20, 21, 64, 75 etc.

APPENDIX A – Test Equipment Used For Tests

	Name of Equipment	Manufacturer	Model No.	Serial No.	Date of Calibration	Due Date
1	Signal Analyzer	Agilent	N9020A	MY50200512	2020-05-25	2021-05-25
2	Signal Generator	Rohde & Schwarz	SMB100A	175528	2020-04-28	2021-04-28
3	EMI Test Receiver	Rohde & Schwarz	ESCI7	100814	2020-10-20	2021-10-20
4	Bilog Antenna	Schaffner	CBL6111C	2551	2020-05-26	2022-05-26
5	Active Loop Antenna	SCHWARZBECK	FMZB 1513	1513-126	2020-05-20	2022-05-20
6	6dB Attenuator	R&S	DNF	272.4110.50-2	2020-10-23	2021-10-23
7	6dB Attenuator	BIRD	5W 6dB	1744	2020-12-17	2021-12-17
8	AMPLIFIER	SONOMA	310	291721	2021-01-22	2022-01-22
9	EMI Test Receiver	Rohde & Schwarz	ESU40	100336	2021-01-12	2022-01-12
10	Preamplifier	Agilent	8449B	3008A01504	2020-12-17	2021-12-17
11	Horn Antenna	ETS-Lindgren	3117	00154525	2020-10-14	2021-10-14
12	Horn Antenna	SCHWARZBECK	BBHA9170	00967	2020-06-02	2021-06-02
13	Band Reject Filter	Micro Tronics	BRM50702	G233	2021-01-14	2022-01-14
14	Low Noise Amplifier	TESTEK	TK-PA1840H	200115-L	2020-05-29	2021-05-29
15	LISN	Rohde & Schwarz	ENV216	101235	2021-01-12	2022-01-12
16	Dual-Tracking DC Power Supply	Topward Electric Instruments Co.,Ltd.	6303D	711196	2021-01-14	2022-01-14
17	Dual-Tracking DC Power Supply	Topward Electric Instruments Co.,Ltd.	6303D	997931	2020-07-08	2021-07-08
18	DC Power Supply	HP	E3642A	KR93300203	2021-01-07	2022-01-07

	Cable	Manufacturer	Model No.	Serial No.	Check Date
1	RF Cable	Canare Corporation	L-5D2W	N/A	2021-01-14
2	RF Cable	Junkosha Inc.	MWX221	1512S127	2021-01-21
3	RF Cable	HUBER+SUHNER	SUCOFLEX 102	MY073/2	2020-05-19
4	RF Cable	HUBER+SUHNER	SUCOFLEX 104	MY27558/4	2020-05-29
5	RF Cable	HUBER+SUHNER	SUCOFLEX 104	N/A	2020-05-29
6	RF Cable	HUBER+SUHNER	SUCOFLEX 104	MY27573/4	2020-05-29
7	RF Cable	HUBER+SUHNER	SUCOFLEX 106	N/A	2020-05-29
8	RF Cable	HUBER+SUHNER	SUCOFLEX 102	803010/2	2020-10-27
9	RF Cable	HUBER+SUHNER	SUCOFLEX 102	803742/2	2020-10-27
10	RF Cable	HUBER+SUHNER	SUCOFLEX 102	MY2374/2	2020-05-07
11	RF Cable	HUBER+SUHNER	SUCOFLEX 102	MY4728/2	2020-05-07