DFS TEST REPORT

Part 15 Subpart E 15.407

Equipment under test	NUGU candle SE
Model name	NU110
FCC ID	2A9KPNU110SE
Applicant	LISMA CO., LTD.
Manufacturer	DongGuan Hajen Electro-mechanics Co., Ltd.
Date of test(s)	2022.12.01 ~ 2023.01.03
Date of issue	2023.01.12

Issued to
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Test and report completed by :	**Report approval by :**
	
Gu-Bong, Kang Test engineer	Yeong-Jun Cho Technical manager

This test report is not related to KS Q ISO/IEC 17025 and KOLAS

Revision history

Revision	Date of issue	Test report No.	Description
-	2023.01.12	KES-RF-23T0016	Initial

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1. General information

Applicant:	LISMA CO., LTD.
Applicant address:	358, Samil-daero, Jung-gu, Seoul, Republic of Korea
Test site:	KES Co., Ltd.
Test site address:	☐3701, 40, Simin-daero 365beon-gil, Dongan-gu, Anyang-si, Gyeonggi-do, 14057, Korea ☒473-21, Gayeo-ro, Yeoju-si, Gyeonggi-do, Korea
Test Facility	FCC Accreditation Designation No.: KR0100, Registration No.: 444148 ISED Registration No.: 23298
FCC rule part(s):	15.407
FCC ID:	2A9KPNU110SE
Test device serial No.:	☒ Production ☐ Pre-production ☐ Engineering

1.1. EUT description

Equipment under test	NUGU candle SE
Frequency range	2 402 ㎒ ~ 2 480 ㎒ (BDR / EDR)
	2 402 ㎒ ~ 2 480 ㎒ (LE 1 Mbps)
	2 412 ㎒ ~ 2 462 ㎒ (802.11b/g/n_HT20)
	2 422 ㎒ ~ 2 452 ㎒ (802.11n_HT40)
	UNII-1 5 180 ㎒ ~ 5 240 ㎒ (802.11a/n_HT20)
	5 190 ㎒ ~ 5 230 ㎒ (802.11n_HT40)
	UNII-2A 5 260 ㎒ ~ 5 320 ㎒ (802.11a/n_HT20)
	5 270 ㎒ ~ 5 310 ㎒ (802.11n_HT40)
	UNII-2C 5 500 ㎒ ~ 5 720 ㎒ (802.11a/n_HT20)
	5 510 ㎒ ~ 5 710 ㎒ (802.11n_HT40)
	UNII-3 5 745 ㎒ ~ 5 825 ㎒ (802.11a/n_HT20)
	5 755 ㎒ ~ 5 795 ㎒ (802.11n_HT40)
Model	NU110
Modulation technique	GFSK, π/4DQPSK, 8DPSK, **DSSS, OFDM**
Number of channels	2 402 ㎒ ~ 2 480 ㎒ (BDR / EDR) : 79 ch
	2 402 ㎒ ~ 2 480 ㎒ (LE 1 Mbps) : 40 ch
	2 412 ㎒ ~ 2 462 ㎒ (802.11b/g/n_HT20) : 11 ch
	2 422 ㎒ ~ 2 452 ㎒ (802.11n_HT40) : 7 ch
	UNII-1 5 180 ㎒ ~ 5 240 ㎒ (802.11a/n_HT20) : 4 ch
	5 190 ㎒ ~ 5 230 ㎒ (802.11n_HT40) : 2 ch
	UNII-2A 5 260 ㎒ ~ 5 320 ㎒ (802.11a/n_HT20) : 4 ch
	5 270 ㎒ ~ 5 310 ㎒ (802.11n_HT40) : 2 ch
	UNII-2C 5 500 ㎒ ~ 5 720 ㎒ (802.11a/n_HT20) : 12 ch
	5 510 ㎒ ~ 5 710 ㎒ (802.11n_HT40) : 6 ch
	UNII-3 5 745 ㎒ ~ 5 825 ㎒ (802.11a/n_HT20) : 5 ch
	5 755 ㎒ ~ 5 795 ㎒ (802.11n_HT40) : 2 ch
Antenna specification	BDR/EDR : Chip Antenna // Peak gain: 3.0 dBi
	LE 1 Mbps : Chip Antenna // Peak gain: 3.0 dBi
	WLAN 2.4 ㎓ : Chip Antenna // Peak gain: 3.0 dBi
	WLAN 5 ㎓ : Chip Antenna // Peak gain: 3.3 dBi
Power source	AC 120 V (AC/DC adapter output 15 V)
H/W version	V0.2
S/W version	130020312

1.2. Test configuration

The **LISMA CO., LTD. // NUGU candle SE // NU110 // FCC ID: 2A9KPNU110SE** was tested according to the specification of EUT, the EUT must comply with following standards and KDB documents.

FCC Part 15.407
KDB 905462 D02 v02
ANSI C63.10-2013

1.3. Information about derivative model

N/A

1.4. Accessory information

Equipment	Manufacturer	Model	Serial No.	Power source
AC/DC adapter	Dongguan RuiHeng Electronic Technology Co.,LTD	RH-150200US	221010000111	AC 120 V input, DC 15 V, 2.0 A output

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.

Offset(dB) = RF cable loss(dB) + attenuator factor(dB).
= 1.83 + 10 = 11.83 (dB)

For Radiation test :
Field strength level (dBμV/m) = Measured level (dBμV) + Antenna factor (dB) + Cable loss (dB) – Amplifier gain (dB)

1.6. Measurement Uncertainty

Test Item		Uncertainty
Uncertainty for Conduction emission test		2.38 dB (SHIELD ROOM #6)
Uncertainty for Radiation emission test (include Fundamental emission)	Below 1 ㎓	4.50 dB (SAC #6)
	Above 1 ㎓	4.90 dB (SAC #5)
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 (㎒)	Rate(Mbps)
00	2 402	BDR 1 Mbps, EDR 2 Mbps, EDR 3 Mbps
.	.	.
40	2 442	BDR 1 Mbps, EDR 2 Mbps, EDR 3 Mbps
.	.	.
78	2 480	BDR 1 Mbps, EDR 2 Mbps, EDR 3 Mbps

Ch.	Frequency (㎒)	Rate(Mbps)
00	2 402	LE 1 Mbps
.	.	.
20	2 442	LE 1 Mbps
.	.	.
39	2 480	LE 1 Mbps

Ch.	Frequency (㎒)	Rate(Mbps)
01	2 412	802.11b/g/n_HT20
.	.	.
06	2 437	802.11b/g/n_HT20
.	.	.
11	2 462	802.11b/g/n_HT20

Ch.	Frequency (㎒)	Rate(Mbps)
03	2 422	802.11n_HT40
.	.	.
06	2 437	802.11n_HT40
.	.	.
09	2 452	802.11n_HT40

UNII-1

Ch.	Frequency (㎒)
36	5 180
44	5 220
48	5 240

UNII-2A

Ch.	**Frequency (㎒)**
52	**5 260**
56	**5 280**
64	**5 320**

UNII-2C

Ch.	**Frequency (㎒)**
100	**5 500**
120	**5 600**
144	**5 720**

UNII-3

Ch.	Frequency (㎒)
149	5 745
157	5 785
165	5 825

802.11a/n_HT20 mode

UNII-1

Ch.	Frequency (㎒)
38	5 190
46	5 230

UNII-2A

Ch.	**Frequency (㎒)**
54	**5 270**
62	**5 310**

UNII-2C

Ch.	**Frequency (㎒)**
102	**5 510**
118	**5 590**
142	**5 710**

UNII-3

Ch.	Frequency (㎒)
151	5 755
159	5 795

802.11n_HT40 mode

2. Summary of tests

Section in FCC Part 15	Parameter	Test results
15.407 (h)(iii)(iv)	Channel Move Time	Pass
	Channel Closing Transmission Time	Pass
	Non-Occupancy Period	Pass

3. DFS (Dynamic Frequency Selection) test description

3.1. Applicability

The following table from KDB 905462 D02 v02 lists the applicable requirements for the DFS testing.
The device evaluated in this report is considered a client device without radar detection capability.

Requirement	Operational Mode		
	Master	Client Without Radar Detection	Client With Radar Detection
Non-Occupancy Period	Yes	Not required	Yes
DFS Detection Threshold	Yes	Not required	Yes
Channel Availability Check Time	Yes	Not required	Not required
U-NII Detection Bandwidth	Yes	Not required	Yes

Table 2.1. DFS Applicability

Requirement	Operational Mode	
	Master Device or Client with Radar Detection	Client Without Radar Detection
DFS Detection Threshold	Yes	Not required
Channel Closing Transmission Time	Yes	Yes
Channel Move Time	Yes	Yes
U-NII Detection Bandwidth	Yes	Not required
Non-Occupancy Period	NA/Yes	Yes

Additional requirements for devices with multiple	Master Device or Client with Radar Detection	Client Without Radar Detection
U-NII Detection Bandwidth and statistical Performance Check	All BW modes must be tested	Not required
Channel Move Time and Channel Closing Transmission Time	Test using widest BW mode available	Test using the widest BW mode available for the link
All other tests	Any single BW mode	Not required
Note: Frequencies selected for statistical performance check (Section 7.8.4) should include several frequencies within the radar detection bandwidth and frequencies near the edge of the radar detection bandwidth. For 802.11 devices it is suggested to select frequencies in each of the bonded 20 MHz channels and the channel center frequency.		

Table 2.2. DFS Applicability During normal operation

3.2. Requirements

KDB 905462 D02 v02 the following are the requirements for Client Devices:

a) A Client Device will not transmit before having received appropriate control signals from a Master Device.
b) A Client Device will stop all its transmissions whenever instructed by a Master Device to which it is associated and will meet the Channel Move Time and Channel Closing Transmission Time requirements. The Client Device will not resume any transmissions until it has again received control signals from a Master Device.
c) If a Client Device is performing In-Service Monitoring and detects a Radar Waveform above the DFS Detection Threshold, it will inform the Master Device. This is equivalent to the Master Device detecting the Radar Waveform and d) through f) of section 5.1.1 apply.
d) Irrespective of Client Device or Master Device detection the Channel Move Time and Channel Closing Transmission Time requirements remain the same.
e) The client test frequency must be monitored to ensure no transmission of any type has occurred for 30 minutes. Note: If the client moves with the master, the device is considered compliant if nothing appears in the client non-occupancy period test. For devices that shutdown (rather than moving channels), no beacons should appear

Parameter	Value
Non-occupancy period	Minimum 30 minutes
Channel Availability Check Time	60 seconds
Channel Move Time	10 seconds See Note 1.
Channel Closing Transmission Time	200 milliseconds + an Aggregate of 60 milliseconds over remaining 10 second period. See Notes 1 and 2.
U-NII Detection Bandwidth	Minimum 100% of the U-NII 99% transmission power bandwidth. See Note3.
Note 1: Channel Move Time and the Channel Closing Transmission Time should be performed with Radar Type 0. The measurement timing begins at the end of the Radar Type 0 burst. **Note 2:** The Channel Closing Transmission Time is comprised of 200 milliseconds starting at the beginning of the Channel Move Time plus any additional intermittent control signals required to facilitate a Channel move (and aggregate of 60 milliseconds) during the remainder of the 10 second period. The aggregate duration of control signals will not count quiet periods in between transmissions. **Note 3:** During the U-NII Detection Bandwidth detection test, radar type 0 should the used. For each frequency step the minimum percentage of detection is 90 percent. Measurements are performed with no data traffic.	

Table 2.3. DFS Response Requirement Values

3.3. DFS Detection Thresholds

The DFS detection thresholds are defined for Master devices and Client Devices with In-service monitoring. These detection Thresholds are listed in the following table.

Maximum Transmit Power	Value (See Notes 1, 2, and 3)
EIRP ≥ 200 milliwatt	-64 dBm
EIRP< 200 milliwatt and Power spectral density < 10 dBm/㎒	-62 dBm
EIRP < 200 milliwatt that do not meet the power spectral density requirement	-64 dBm
Note 1: This is the level at the input of the receiver assuming a 0 dBi receive antenna. **Note 2:** Throughout these test procedures an additional 1 dB has been added to the amplitude of the test transmission waveforms to account for variations in measurement equipment. This will ensure that the test signal is at or above the detection threshold level to trigger a DFS respons. **Note 3:** EIRP is based on the highest antenna gain. For MIMO devices refer to KDB Publication 662911 D01	

Table 2.4. DFS Detection Thresholds for Master Devices and Client Devices With Radar Detection

3.4. Parameters of DFS Test Signals

As the EUT is a Client Device with no Radar Detection only Zero type radar pulse is required for the testing.
Radar Pulse type 0 was used in the evaluation of the Client device for the purpose of measuring the channel Move Time and the Channel Closing Transmission Time.

Radar Type	Pulse Width (μsec)	PRI (μsec)	Number of Pulses	Minimum Percentage of Successful Detection	Mnimum Number of Trials
0	1	1428	18	See Note 1	See Note 1
1	1	Test A: 15 unique PRI values randomly selected from the list of 23 PRI values in Table 5a	Roundup: {(1/360)*(19*10^6 PRI μsec)}	60%	30
		Test B: 15 unique PRI values randomly selected within the range of 518-3066 μsec, with a minimum increment of 1 μsec, excluding PRI values selected in Test A			
2	1-5	150-230	23-29	60%	30
3	6-10	200-500	16-18	60%	30
4	11-20	200-500	12-16	60%	30
Aggregate (Radar Types 1-4)				80%	120
Note 1: Short Pulse Radar Type 0 should be used for the detection bandwidth test, channel move time, and channel closing time tests.					

Table 2.5. Short Pulse Radar Test Waveforms

Radar Type	Pulse Width (μsec)	Chirp Width (MHz)	PRI (μsec)	Pulses per Burst	Number of Bursts	Minimum Percentage of Successful Detection	Minimum Trials
5	50-100	5-20	1000-2000	1-3	8-20	80%	30

Table 2.6. Short Pulse Radar Test Waveforms

Radar Type	Pulse Width (μsec)	PRI (μsec)	Pulses Per Hop	Hopping Rate (kHz)	Hopping Sequence Length (msec)	Minimum Percentage of Successful Detection	Minimum Trials
6	1	333	9	0.333	300	70%	30

Table 2.7. Frequency Hopping Radar Test Waveform

4. Test results

4.1. DFS (Dynamic Frequency Selection)

Test setup

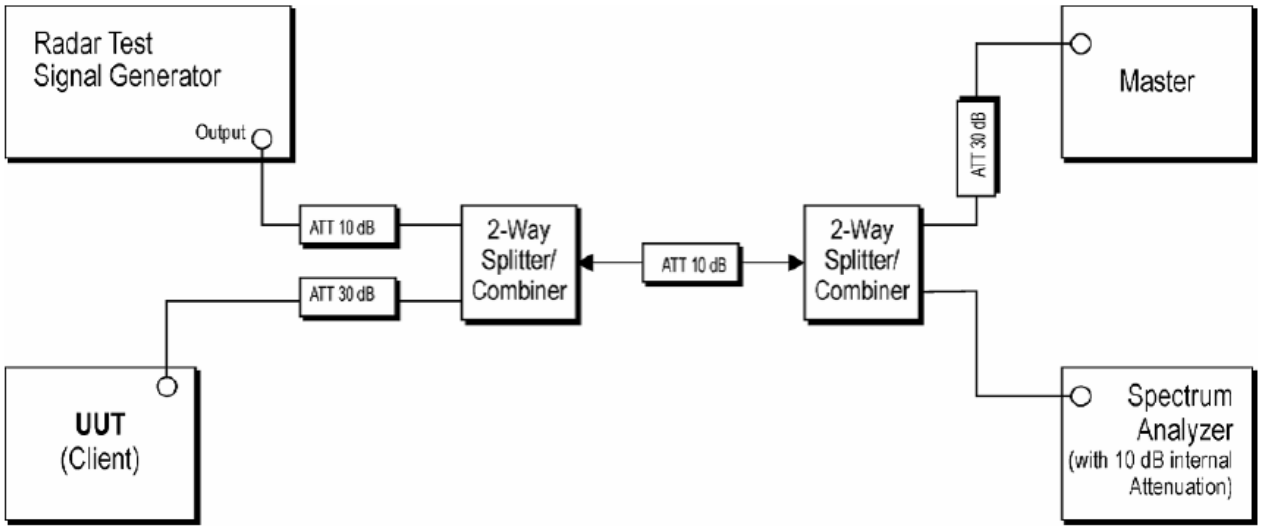


Figure 1: Conducted Test Setup for DFS

Test procedure

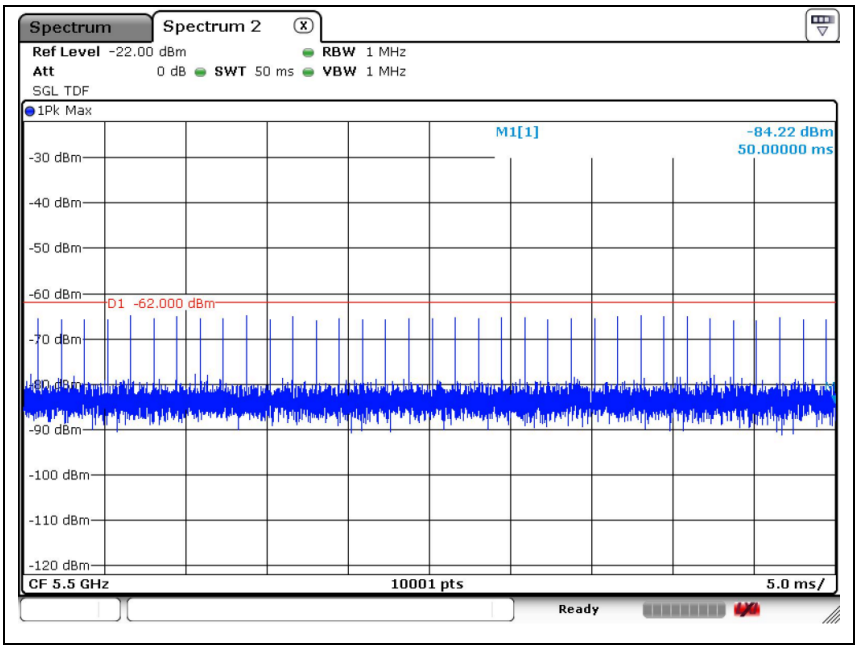
KDB 905462 D02 v02 describes a radiated test setup and a conducted test setup. The conducted test setup was used for this testing. Figure 1 shows the typical test setup.

1. One frequency will be chosen from the Operating Channels of the UUT within the 5250 ~5350 ㎒ or 5470 ~5725 ㎒ bands.
2. The Client Device (EUT) is setup per the diagram in Firure1 and communications between the Master device and the Client is established.
3. An MPEG or data file that is typical for the device is streamed from the Master to the Client to properly load the network.

4.1.1 Radar waveform

Mode: 802.11n (UNII-2C)

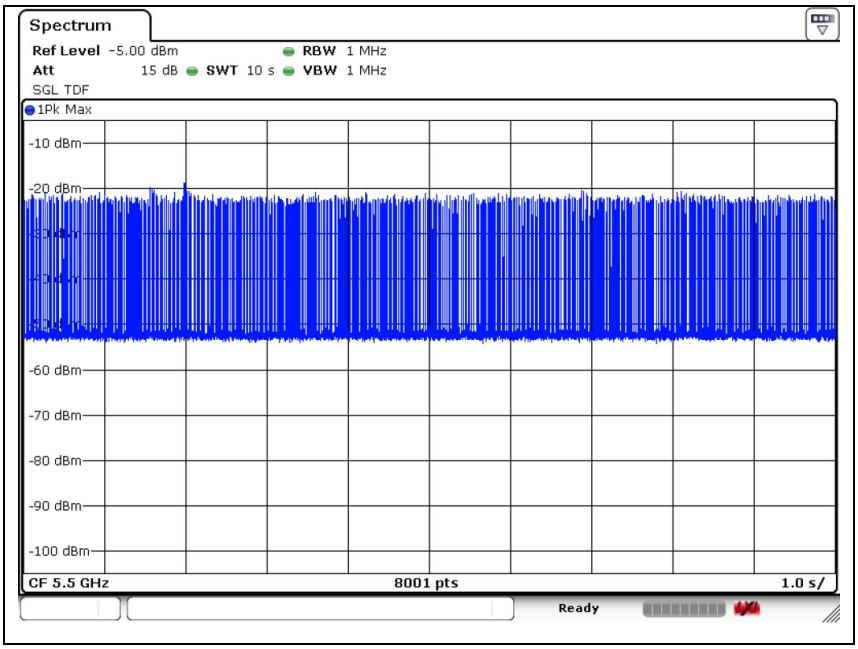
Operating frequency: 5 500 ㎒



4.1.2 LAN Traffic

Mode: 802.11n (UNII-2C)

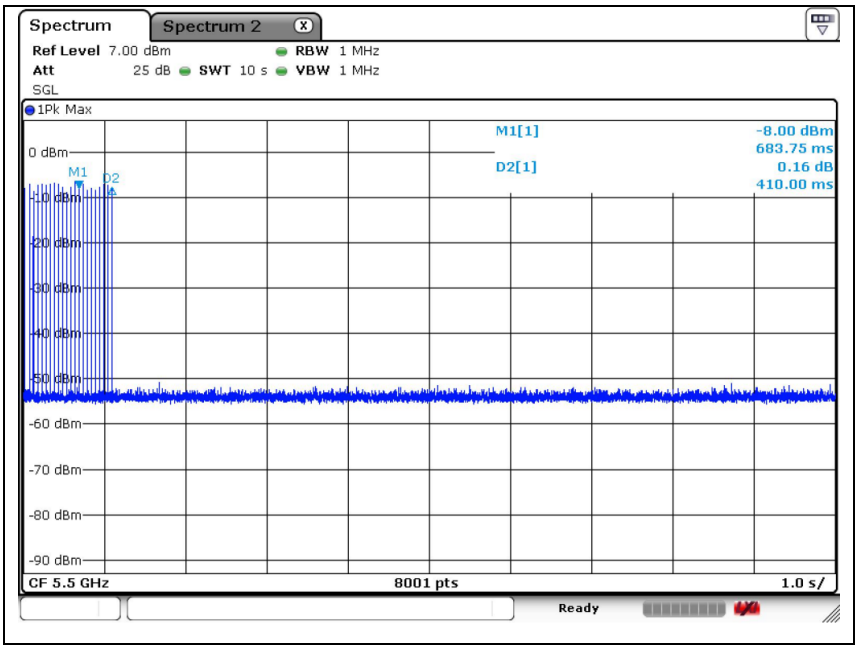
Operating frequency: 5 500 ㎒



4.1.3 Channel move time & aggregate channel closing transmission time

Mode: 802.11n (UNII-2C)

Operating frequency: 5 500 ㎒



Channel closing transmission time calculated	Test results
Sweep time[S] sec	10
Sampling bins[B]	8 001
Number of sampling bins in 10 sec[N]	1
Closing transmission time [C] ms	1.250

Channel move time (s)	Limit
0.410	≤ 10 s

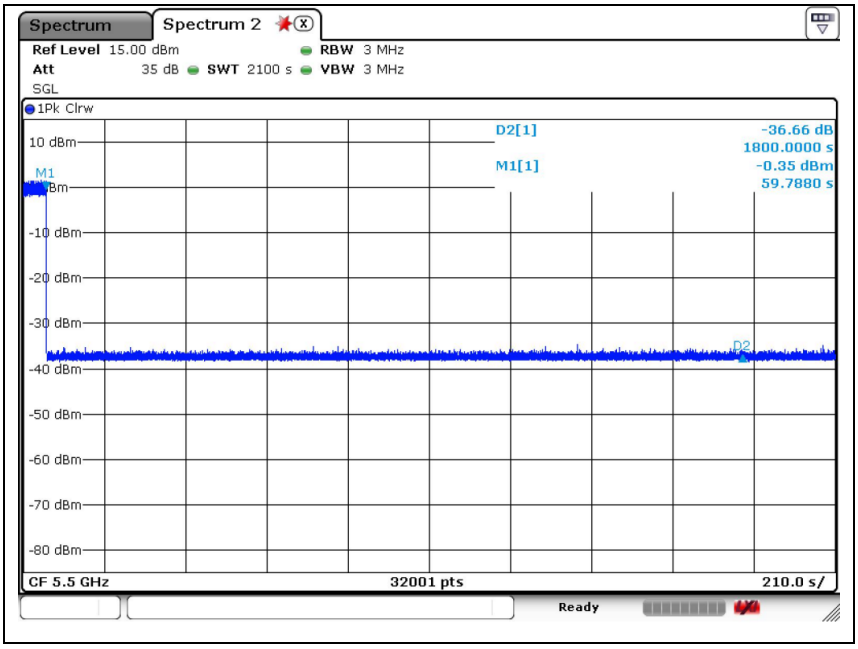
Note:
Dwell = S/B;
Where **dwell** is the dwell time per spectrum analyzer sampling bin, **S** is the sweep time and **B** is the number of spectrum analyzer sampling bins.

An upper bound of the aggregate duration of the channel closing transmission time is calculated by:
C = N × Dwell;
Where **C** is the closing time, **N** is the number of spectrum analyzer sampling bins showing a U-NII transmission and dwell is the dwell time per bin.
Dwell = [S] / [B] = 10 / 8 001 = 0.001 250
Closing Transmission Time[C] = [N] × [Dwell] = 1 × 0.001 250 = 0.001 250 s = 1.250 ms

4.1.4 Non-occupancy period

Mode: 802.11n (UNII-2C)

Operating frequency: 5 500 ㎒



Appendix A. Measurement equipment

Equipment	Manufacturer	Model	Serial No.	Calibration interval	Calibration due.
Spectrum Analyzer	R&S	FSV3044	101272	1 year	2023.03.14
MXG Vector SIGNAL GENERATOR	AGILENT	N5182A	MY50143829	1 year	2023.01.14
Attenuator	HP	30dB ATTENUATOR	3318A05137	1 year	2023.01.14
Attenuator	SRT	F04-H930-01	17041002	1 year	2023.01.14
Attenuator	Mini-Circuits	BW-S10-2W263+	2	1 year	2023.01.17
Attenuator	Mini-Circuits	BW-S10-2W263+	3	1 year	2023.01.17
Splitter	MINI-CIRCUITS	ZFSC-2-10G+	FG63701930-1	1 year	2023.06.16
Splitter	MINI-CIRCUITS	ZFSC-2-10G+	FG63701930-2	1 year	2023.06.16

Peripheral devices

Device	Manufacturer	Model No.	Serial No.	Note.
Access Point (Master)	Synology	MR220ac	2090RERGTR86M	FCC ID: YOR-MR200AC
Notebook computer	LG Electronics Inc.,	LGS53	306QCZP560949	Notebook computer