FCC/ISED - TEST REPORT

Report Number	:	**709502403822-00D Rev1**	Date of Issue:	October 31, 2024

Model	:	**Lime-CCU23**
Product Type	:	CCU
Applicant	:	Neutron Holdings, Inc.
Address	:	85 2nd St, San Francisco, CA 94105 USA
Production Facility	:	Quectel Wireless Solutions Co., Ltd.
Address	:	Building 5, Shanghai Business Park Phase lll (Area B), No.1016 Tianlin Road.Minhang District, Shanghai 200233, China

Test Result	:	■ **Positive**	☐ **Negative**
Total pages including Appendices	:	41	

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2 Details about the Test Laboratory

Details about the Test Laboratory
Test Site 1

Company name:	TÜV SÜD Certification and Testing (China) Co., Ltd. Shanghai Branch No.16 Lane, 1951 Du Hui Road, Shanghai 201108, P.R. China
Telephone:	+86 21 6141 0123
Fax:	+86 21 6140 8600
FCC Registration No.:	820234
FCC Designation Number:	CN1183
ISED CAB identifier	CN0101
IC Registration No.:	31668

3 Description of the Equipment under Test

Description of the Equipment Under Test

Product:	CCU
Model no.:	Lime-CCU23
Hardware Version Identification No. (HVIN)	Lime-CCU23
Product Marketing Name (PMN)	Lime-CCU23
FCC ID:	2APB2-LIME-CCU23
IC:	32977-LIMECCU23
Options and accessories:	NA
Rating:	DC 42V/54V
RF Transmission Frequency:	For 2.4G Wi-Fi: For 802.11b/g/n-HT20: 2412~2462 MHz For 5G Wi-Fi: 5180~5240 MHz (U-NII-1) 5260~5320 MHz (U-NII-2A) 5500~5720 MHz (U-NII-2C) 5745~5825 MHz (U-NII-3) The device shall not be capable of transmitting in the 5600-5650 MHz band. The device shall not be capable of transmitting in the 5600-5650 MHz band. For BLE (Module1): 2402~2480 MHz For EDR (Module1): 2402~2480 MHz For BLE (Module2): 2402~2480 MHz For EDR (Module2): 2402~2480 MHz
No. of Operated Channel:	For 2.4G Wi-Fi: 11 for 802.11b/802.11g/802.11n(H20) For 5G Wi-Fi:

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	5180~5240 MHz (U-NII-1) 5260~5320 MHz (U-NII-2A) 5500~5590, 5660~5720 MHz (U-NII-2C) 5745~5825 MHz (U-NII-3) For BLE (Module1): 40 For EDR (Module1): 79 For BLE (Module2): 40 For EDR (Module2): 79
Modulation:	For 2.4G Wi-Fi: Direct Sequence Spread Spectrum (DSSS) for 802.11b Orthogonal Frequency Division Multiplexing (OFDM) for 802.11g/n For 5G Wi-Fi: Orthogonal Frequency Division Multiplexing (OFDM) for 802.11a/n/ac For BLE (Module1): GFSK For EDR (Module1): GFSK, π/4 DQPSK, 8DPSK For BLE (Module2): GFSK For EDR (Module2): GFSK, π/4 DQPSK, 8DPSK
Hardware Version:	EG21GGFR07A01M4G_OCPU_NCFG_QDM549_01.200.01.002
Software Version:	V1.2
Data speed:	For 2.4G Wi-Fi: 11b 1-11Mbps 11g 6-54Mbps 11n(H20) 6.5-72.2Mbps For 5G Wi-Fi: 11a 6 ~ 54Mbps, 11n HT20 6.5 ~ 72.2Mbps, 11ac VHT20 6.5 ~ 86.7Mbps, 11ac VHT40 13.5 ~ 200Mbps, 11ac VHT80 29.3 ~ 433.3Mbps For BLE (Module1): 1Mbps For EDR (Module1): 1Mbps, 2Mbps, 3Mbps For BLE (Module2): 1Mbps, 2Mbps

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For EDR (Module2): 1Mbps, 2Mbps, 3Mbps

Channel list:

For 2.4G Wi-Fi:

802.11b/g/n(HT20)			
Ch	Fre(MHz)	Ch	Fre(MHz)
1	2412	7	2442
2	2417	8	2447
3	2422	9	2452
4	2427	10	2457
5	2432	11	2462
6	2437		

For 5G Wi-Fi:

Band (GHz)	Operating Channel Number	Channel center frequencies for 20MHz bandwidth (MHz)
5.15GHz~5.25GHz	36	5180
	40	5200
	44	5220
	48	5240
5.25GHz~5.35GHz	52	5260
	56	5280
	60	5300
	64	5320
5.5GHz~5.7GHz	100	5500
	104	5520
	108	5540
	112	5560
	116	5580
	132	5660
	136	5680
	140	5700
	144	5720
5.725GHz~5.825GHz	149	5745
	153	5765
	157	5785
	161	5805
	165	5825

Band (GHz)	Operating Channel Number	Channel center frequencies for 40MHz bandwidth (MHz)
5.15GHz~5.25GHz	38	5190
	46	5230
5.25GHz~5.35GHz	54	5270
	62	5310
5.5GHz~5.7GHz	102	5510

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	110	5550
	134	5670
	142	5710
5.725GHz~5.825GHz	151	5755
	159	5795

Band (GHz)	Operating Channel Number	Channel center frequencies for 80MHz bandwidth (MHz)
5.15GHz~5.25GHz	42	5210
5.25GHz~5.35GHz	58	5290
5.5GHz~5.7GHz	106	5530
	138	5690
5.725GHz~5.825GHz	155	5775

For BLE

Ch	Fre(MHz)	Ch	Fre(MHz)	Ch	Fre(MHz)	Ch	Fre(MHz)
0	2402	10	2422	20	2442	30	2462
1	2404	11	2424	21	2444	31	2464
2	2406	12	2426	22	2446	32	2466
3	2408	13	2428	23	2448	33	2468
4	2410	14	2430	24	2450	34	2470
5	2412	15	2432	25	2452	35	2472
6	2414	16	2434	26	2454	36	2474
7	2416	17	2436	27	2456	37	2476
8	2418	18	2438	28	2458	38	2478
9	2420	19	2440	29	2460	39	2480

For EDR

Ch	Fre (MH)	Ch	Fre (MH)	Ch	Fre (MH)	Ch	Fre (MH)	Ch	Fre (MHz)
1	2402	17	2418	33	2434	49	2450	65	2466
2	2403	18	2419	34	2435	50	2451	66	2467
3	2404	19	2420	35	2436	51	2452	67	2468
4	2405	20	2421	36	2437	52	2453	68	2469
5	2406	21	2422	37	2438	53	2454	69	2470
6	2407	22	2423	38	2439	54	2455	70	2471
7	2408	23	2424	39	2440	55	2456	71	2472
8	2409	24	2425	40	2441	56	2457	72	2473
9	2410	25	2426	41	2442	57	2458	73	2474
10	2411	26	2427	42	2443	58	2459	74	2475
11	2412	27	2428	43	2444	59	2460	75	2476
12	2413	28	2429	44	2445	60	2461	76	2477
13	2414	29	2430	45	2446	61	2462	77	2478
14	2415	30	2431	46	2447	62	2463	78	2479
15	2416	31	2432	47	2448	63	2464	79	2480
16	2417	32	2433	48	2449	64	2465		

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Antenna Type:	For 2.4G Wi-Fi: FPC For 5G Wi-Fi: FPC For BLE (Module1): FPC For EDR (Module1): FPC For BLE (Module2): FPC For EDR (Module2): FPC
Antenna Gain:	For 2.4G Wi-Fi: 1.96 dBi For 5G Wi-Fi: 3.52 dBi For BLE (Module1): 1.96 dBi For EDR (Module1): 1.96 dBi For BLE (Module2): 3.16 dBi For EDR (Module2): 3.16 dBi
Description of the EUT:	The Equipment Under Test (EUT) is a CCU with Wi-Fi Module, BLE/EDR Module and LTE Module. The EUT support Wi-Fi operated at 2.4GHz and 5GHz.
Test sample no.:	SHA-843416-2 (Radiated sample) SHA-843416-3 (Conducted sample)

The sample's mentioned in this report is/are submitted/ supplied/ manufactured by client. The laboratory therefore assumes no responsibility for accuracy of information on the brand name, model number, origin of manufacture, consignment, antenna gain or any information supplied.

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4 Summary of Test Standards

Test Standards	
FCC Part 15 Subpart C 10-1-2023 Edition	PART 15 - RADIO FREQUENCY DEVICES Subpart C - Intentional Radiators
RSS-Gen Issue 5 April 2018 + Amendment 1 March 2019 + Amendment 2 February 2021	General Requirements for Compliance of Radio Apparatus
RSS-247 Issue 3 August 2023	Digital Transmission Systems (DTSS), Frequency Hopping Systems (FHSS) and License-Exempt Local Area Network (LE-LAN) Devices

All the test methods were according to KDB 558074 D01 15.247 Measurement Guidance v05r02 and ANSI C63.10-2013.

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5 Summary of Test Results

Technical Requirements							
FCC Part 15 Subpart C & RSS-247 Issue 3/RSS-Gen Issue 5							
Test Condition			Pages	Test Site	Test Result		
					Pass	Fail	N/A
§15.207	RSS-GEN 8.8	Conducted emission AC power port	---	Site 1	☒	☐	☐
§15.247 (b) (3)	RSS-247 5.4(d)	Conducted peak output power	17-18	Site 1	☒	☐	☐
	RSS-247 5.4(d)	Equivalent Isotropic Radiated Power	17-18	Site 1	☒	☐	☐
§15.247(a)(1)	RSS-247 5.1(a) & RSS-Gen 6.7	20dB bandwidth and 99% Occupied Bandwidth	---	---	☐	☐	☒
§15.247(a)(1)	RSS-247 5.1(b)	Carrier frequency separation	---	---	☐	☐	☒
§15.247(a)(1)(iii)	RSS-247 5.1(d)	Number of hopping frequencies	---	---	☐	☐	☒
§15.247(a)(1)(iii)	RSS-247 5.1(d)	Dwell Time - Average Time of Occupancy	---	---	☐	☐	☒
§15.247(a)(2)	RSS-247 5.2(a) & RSS-GEN 6.7	6dB bandwidth and 99% Occupied Bandwidth	19-21	Site 1	☒	☐	☐
§15.247(e)	RSS-247 5.2(b)	Power spectral density	19-21	Site 1	☒	☐	☐
§15.247(d)	RSS-247 5.5	Spurious RF conducted emissions	19-21	Site 1	☒	☐	☐
§15.247(d)	RSS-247 5.5	Band edge	19-21	Site 1	☒	☐	☐
§15.247(d) & §15.209 & §15.205	RSS-247 5.5 & RSS-Gen 6.13	Spurious radiated emissions for transmitter	19-21	Site 1	☒	☐	☐
§15.203	RSS-Gen 6.8	Antenna requirement	See note 1		☒	☐	☐

Remark 1: N/A – Not Applicable.
Remark 2: The EUT only operation at 2.4G Wi-Fi and 5G Wi-Fi UNII Band (5180MHz-5240MHz, 5260~5320 MHz, 5500~5720 MHz, 5745MHz-5825MHz).

Note 1: The EUT uses a FPC antenna, which gain is 1.96 dBi for 2.4GWi-Fi, 3.52 dBi for 5GWi-Fi. In accordance to §15.203 and RSS-Gen 6.8, It is considered sufficiently to comply with the provisions of this section.

15.203 requirement: An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator, the manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. 15.247(c) (1)(i) requirement: (i) Systems operating in the 2400-2483.5 MHz band that is used exclusively for fixed. Point-to-point operations may employ transmitting antennas with directional gain greater than 6dBi provided the maximum conducted output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6dBi

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6 General Remarks

Remarks

This submittal(s) (test report) is intended for FCC ID: 2APB2-LIME-CCU23, IC: 32977-LIMECCU23 complies with Section 15.207, 15.209, 15.247 of the FCC Part 15, Subpart C Rules and RSS-247, RSS-GEN.

This report is only for BLE (Module1) test report, for the 5GHz Wi-Fi test report please refer to 709502403822-00A, for the 2.4GHz Wi-Fi test report please refer to 709502403822-00C, for the EDR (Module1) test report please refer to 709502403822-00E, for the BLE (Module2) test report please refer to 709502403822-00F, for the EDR (Module2) test report please refer to 709502403822-00G.

We tested it and listed the worst data in this report.

SUMMARY:

All tests according to the regulations cited on page 10 were

■ - Performed
☐ - **Not** Performed
The Equipment under Test
■ - **Fulfills** the general approval requirements.
☐ - **Does not** fulfill the general approval requirements.

Sample Received Date:	July 4, 2024
Testing Start Date:	August 2, 2024
Testing End Date:	August 26, 2024

- TÜV SÜD Certification and Testing (China) Co., Ltd. Shanghai Branch

Reviewed by:	Prepared by:	Tested by:
Hui TONG	Wenqiang LU	Chengjie GUO
Review Engineer	Project Engineer	Test Engineer

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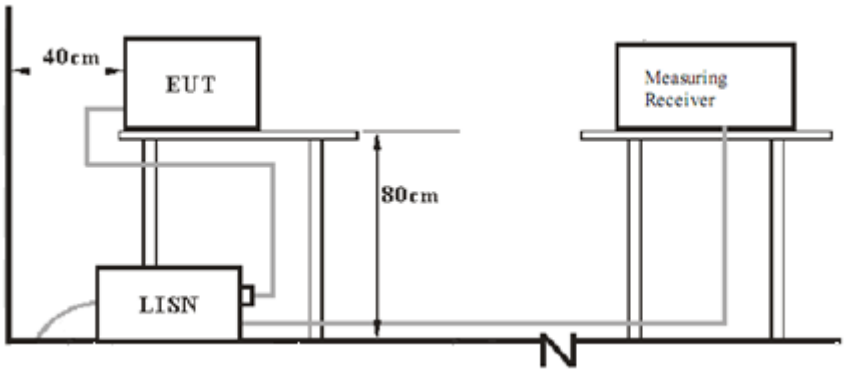
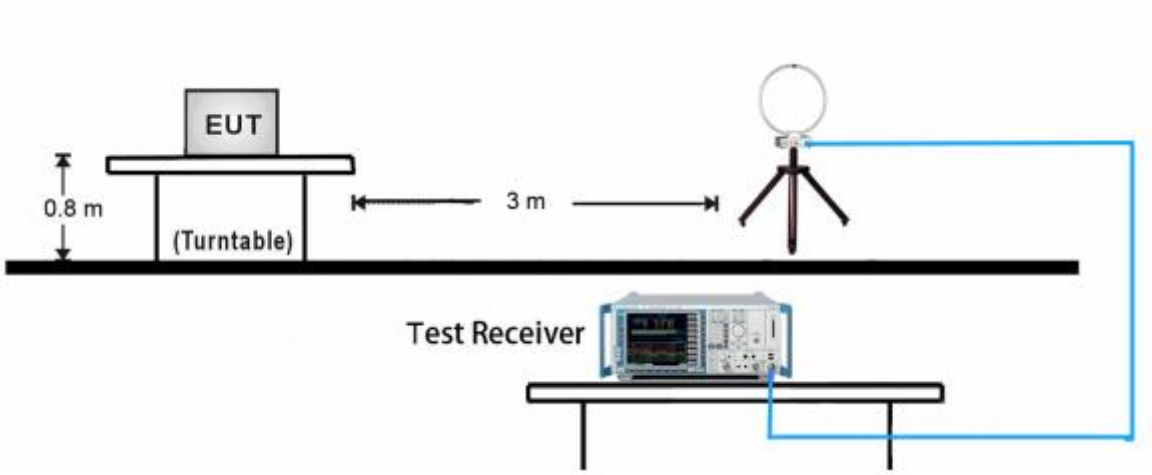
7 Test Setups

7.1 AC Power Line Conducted Emission test setups



7.2 Radiated test setups

9kHz ~ 30MHz Test Setup:



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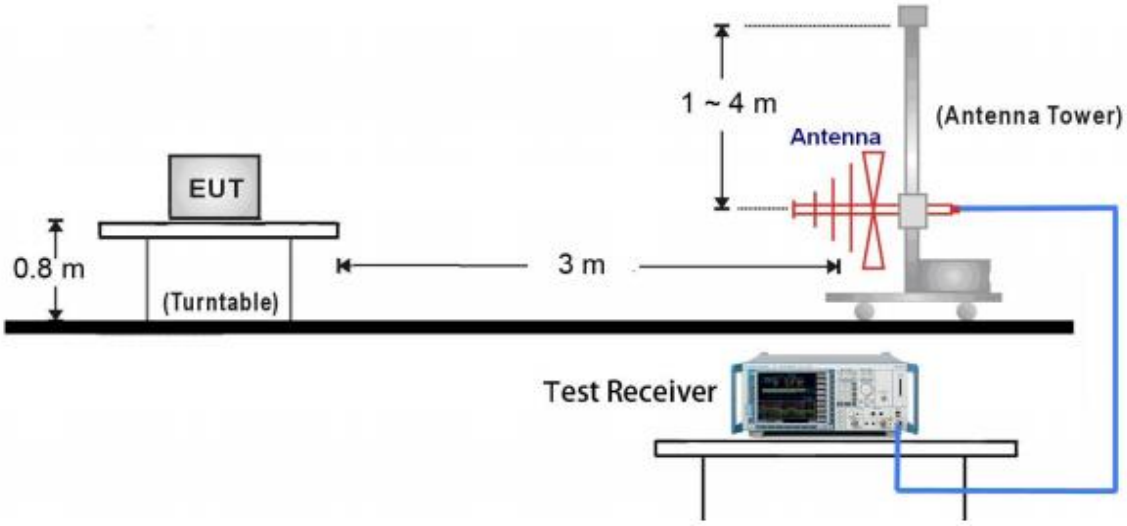
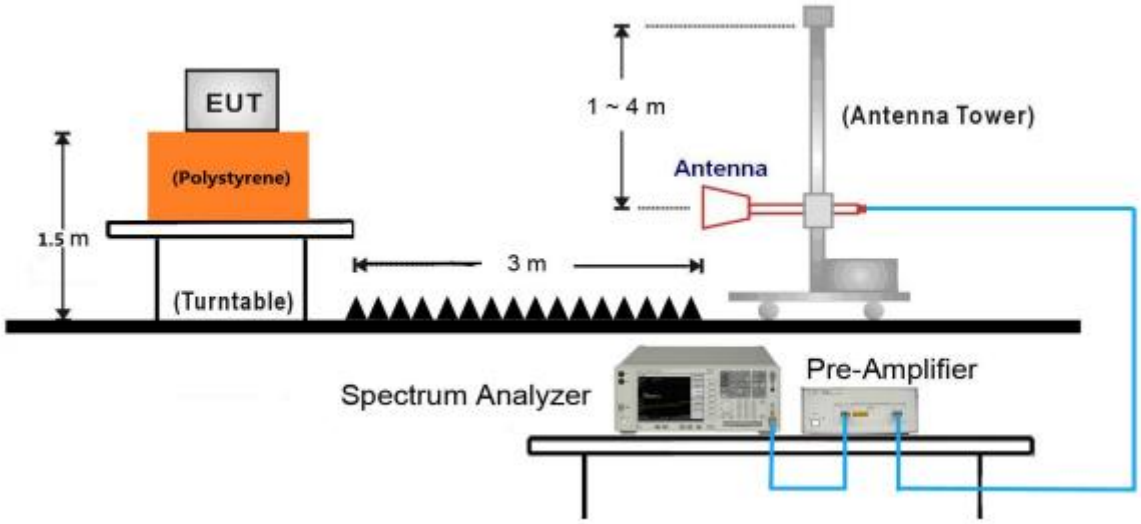
30MHz ~ 1GHz Test Setup:



1GHz ~ 18GHz Test Setup:



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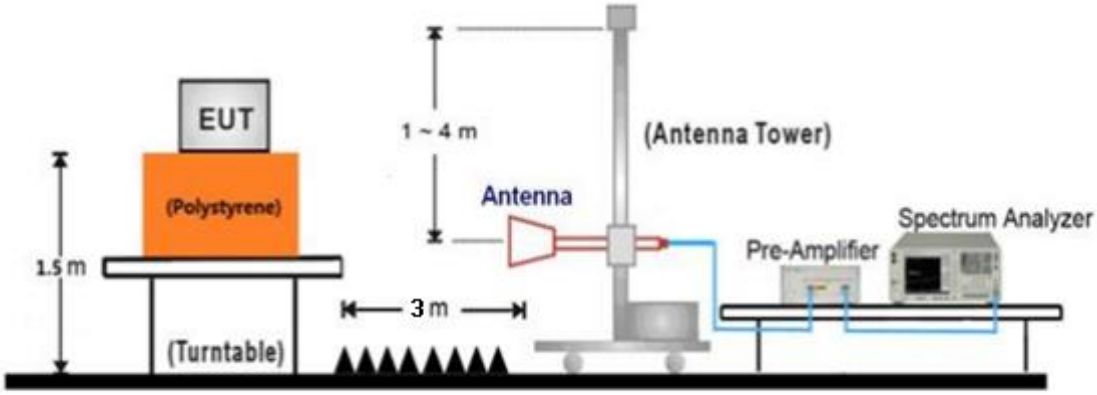
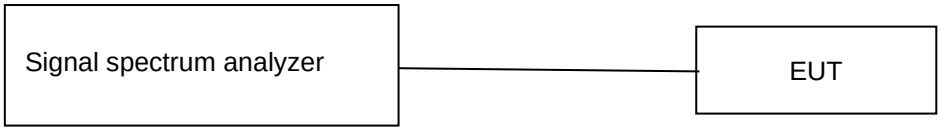
18GHz ~ 25GHz Test Setup:



7.3 Conducted RF test setups



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8 Systems test configuration

Auxiliary Equipment Used during Test:

DESCRIPTION	MANUFACTURER	MODEL NO.(SHIELD)	S/N(LENGTH)
Notebook	Lenove	E470	PF-OU5TS7 17/09

Test software: adb.exe, which used to control the EUT in continues transmitting mode.

The system was configured to channel 0, 19, and 39 for the test.

Test Mode Applicability and Tested Channel Detail:

Mode	Tested Channel	Data Rate (Mbps)	Modulation	Power level setting
Bluetooth LE	0	1	GFSK	Default
	19	1	GFSK	Default
	39	1	GFSK	Default

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9 Technical Requirement

9.1 Conducted peak output power & EIRP

Test Method

1. Use the following spectrum analyzer settings:
   RBW > the 6 dB bandwidth of the emission being measured, VBW≥3RBW, Span≥3RBW
   Sweep = auto, Detector function = peak, Trace = max hold.
2. Add a correction factor to the display.
3. Allow the trace to stabilize. Use the marker-to-peak function to set the marker to the peak of the emission. The indicated level is the peak output power.

Limits

According to §15.247 (b) (3) & RSS-247 5.4(d), conducted peak output power limit as below:

	Frequency Range	Limit	Limit
	MHz	W	dBm
Conducted peak output power	2400-2483.5	≤1	≤30
e.i.r.p.	2400-2483.5	≤4	≤36

Test result as below table

Frequency MHz	Conducted Peak Output Power dBm	E.I.R.P dBm	Result
Low channel 2402MHz	-2.67	-0.71	Pass
Middle channel 2440MHz	-2.08	-0.12	Pass
High channel 2480MHz	**-2.06**	-0.1	Pass

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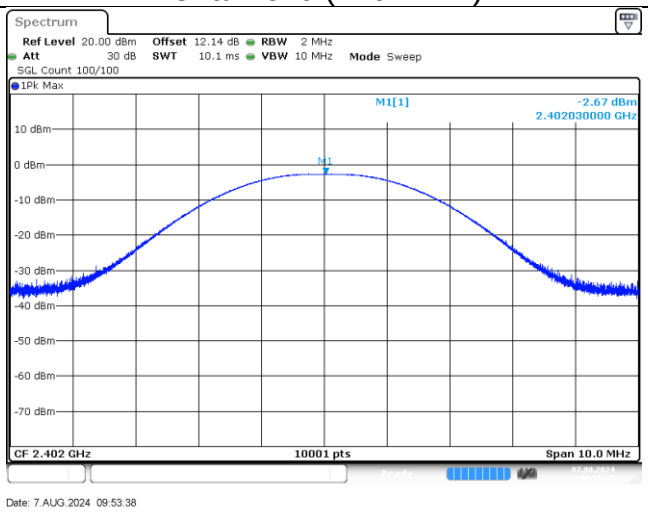
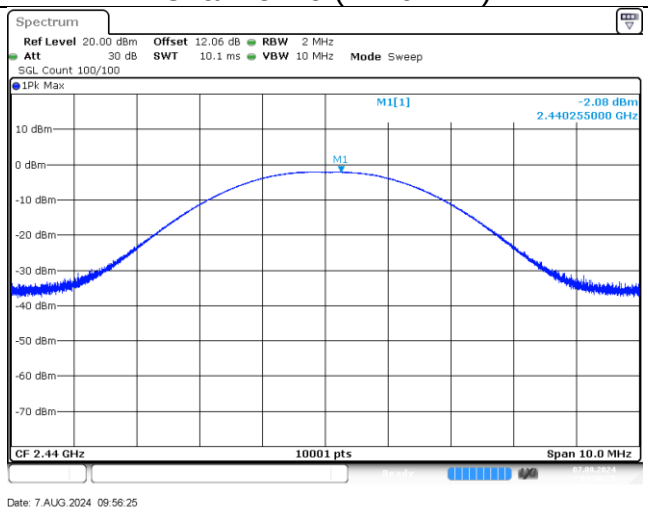
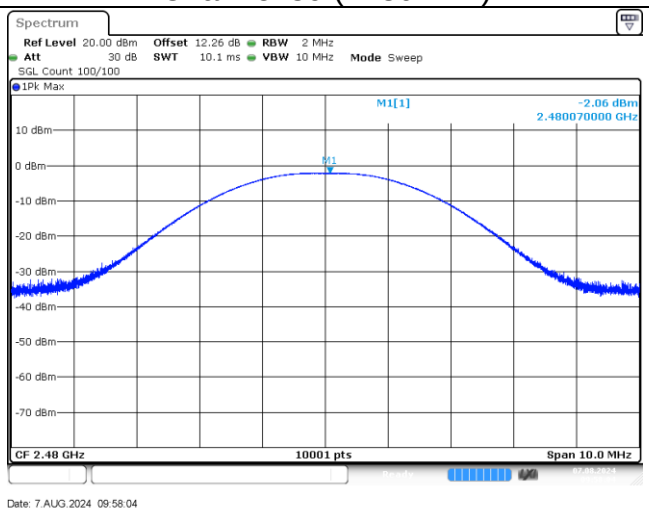
Peak output power (1Mbps)	
Channel 0 (2402MHz)	Channel 19 (2440MHz)
	
Channel 39 (2480MHz)	
	

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9.2 6dB bandwidth and 99% Occupied Bandwidth

Test Method for 6 dB Bandwidth

1. The RF output of EUT was connected to the spectrum analyzer. The path loss was compensated to the results for each measurement.
2. Set to the maximum power setting, the instrument center frequency is set to the nominal EUT channel center frequency enable the EUT transmit continuously.
3. Use the following spectrum analyzer settings:
   RBW=100KHz, VBW≥3RBW, Sweep = auto, Detector function = peak, Trace = max hold
4. Use the automatic bandwidth measurement capability of an instrument, use the X dB bandwidth mode with X set to 6 dB.
5. Allow the trace to stabilize, record the 6 dB Bandwidth value.

Test Method for 99 % Bandwidth

1. Connect EUT test port to spectrum analyzer.
   Use the following spectrum analyzer settings:
   RBW=1% to 5% of the actual occupied, VBW≥3RBW, Sweep = auto,
   Detector function = peak, Trace = max hold
2. Use the occupied bandwidth measurement capability of test receiver.
3. Allow the trace to stabilize, record the occupied bandwidth value.

Limit

According to §15.247(a)(2), 6dB bandwidth limit as below:

6dB bandwidth Limit [kHz]	**99% bandwidth Limit [kHz]**
≥500	--

Test result

Frequency MHz	6dB bandwidth kHz	**99% Bandwidth kHz**	Result
Top channel 2402MHz	667	1060	Pass
Middle channel 2440MHz	669	1058	Pass
Bottom channel 2480MHz	681	1060	Pass

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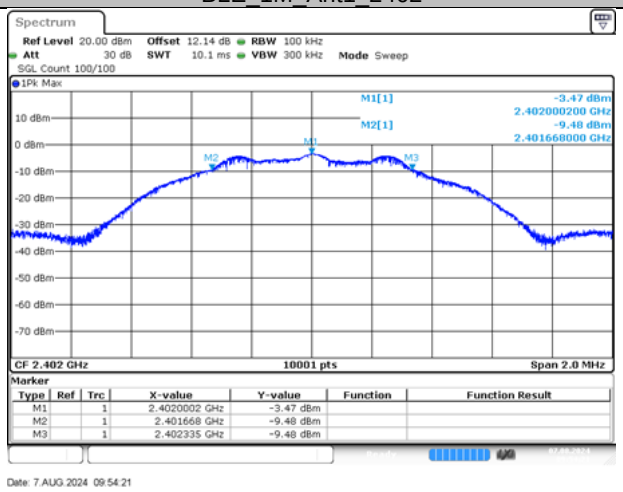
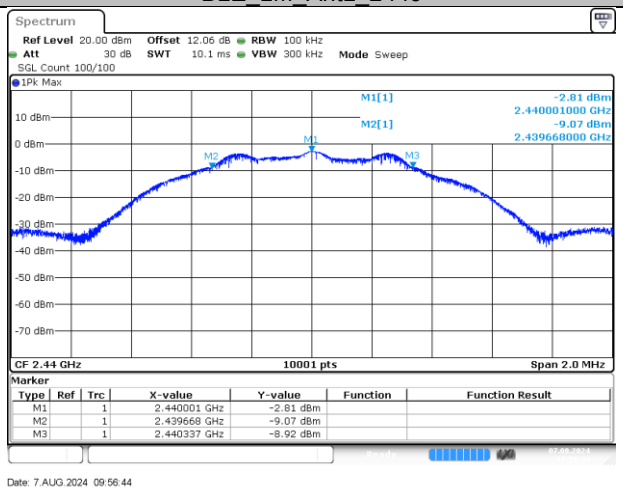
6dB Bandwidth

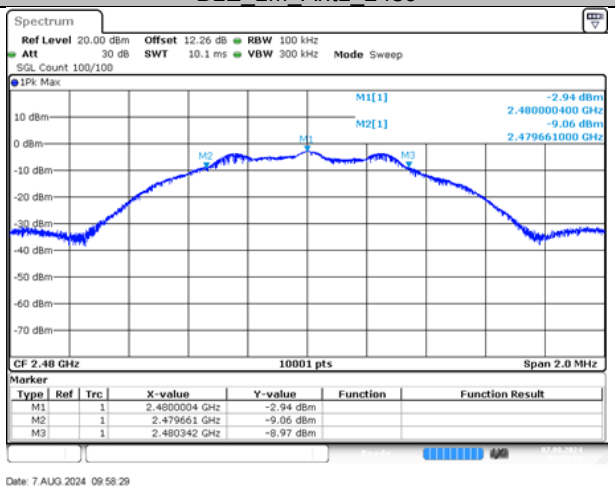
BLE_1M_Ant1_2402



BLE_1M_Ant1_2440

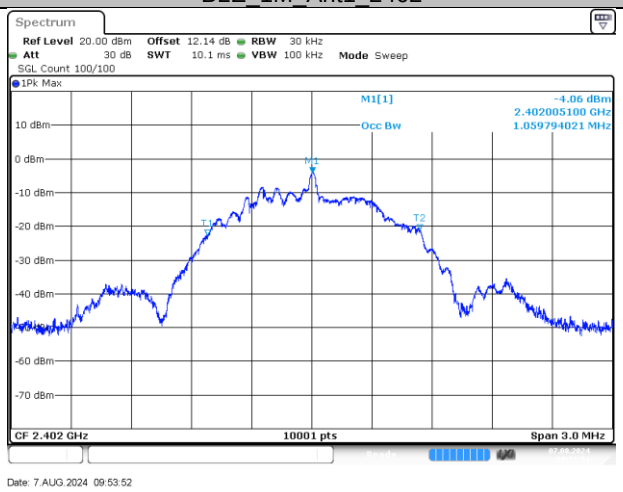


BLE_1M_Ant1_2480

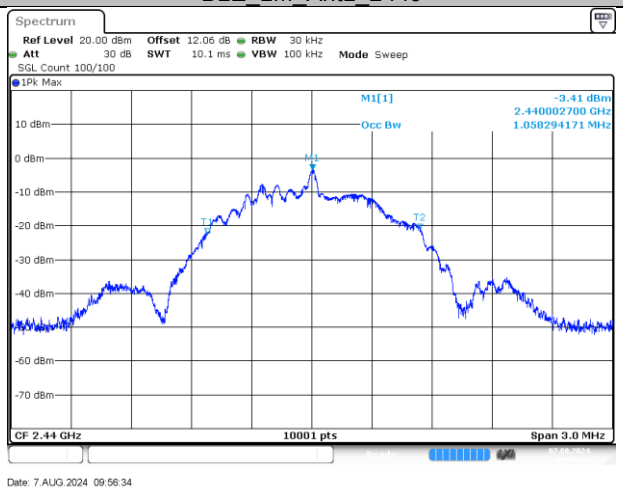


99% Occupied Bandwidth

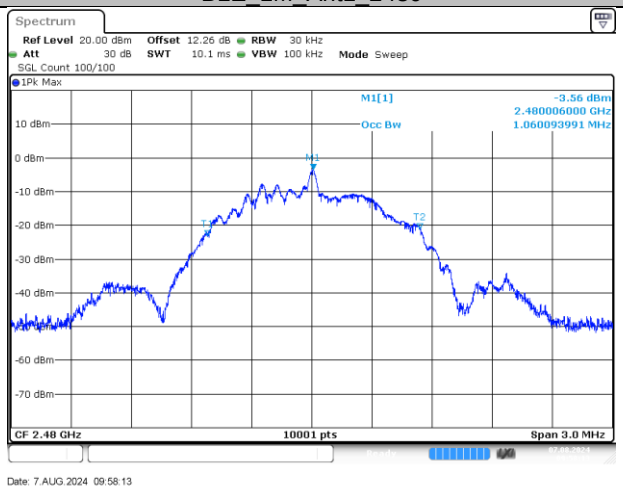
BLE_1M_Ant1_2402



BLE_1M_Ant1_2440



BLE_1M_Ant1_2480



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9.3 Power spectral density

Test Method

This procedure shall be used if maximum peak conducted output power was used to demonstrate compliance:

1. The RF output of EUT was connected to the spectrum analyzer. The path loss was compensated to the results for each measurement.
2. Set to the maximum power setting, the instrument center frequency is set to the nominal EUT channel center frequency enable the EUT transmit continuously.
3. Use the following spectrum analyzer settings:
4. Set analyzer center frequency to DTS channel center frequency. RBW=3kHz, VBW≥3RBW, Span=1.5 times DTS bandwidth, Detector=Peak, Sweep=auto, Trace= max hold.
5. Allow trace to fully stabilize, use the peak marker function to determine the maximum amplitude level within the RBW.
6. Repeat above procedures until other frequencies measured were completed.

Limit

Limit [dBm/3KHz]
≤8

Test result

Frequency **MHz**	Power spectral density **dBm/3kHz**	Result
Top channel 2402MHz	-17.65	Pass
Middle channel 2440MHz	-16.87	Pass
Bottom channel 2480MHz	-16.98	Pass

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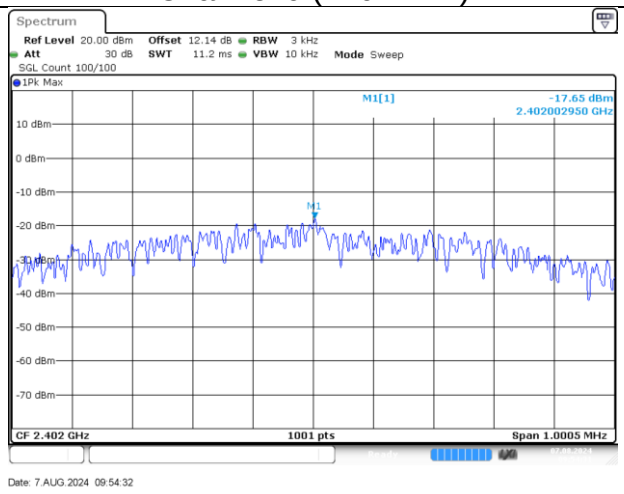
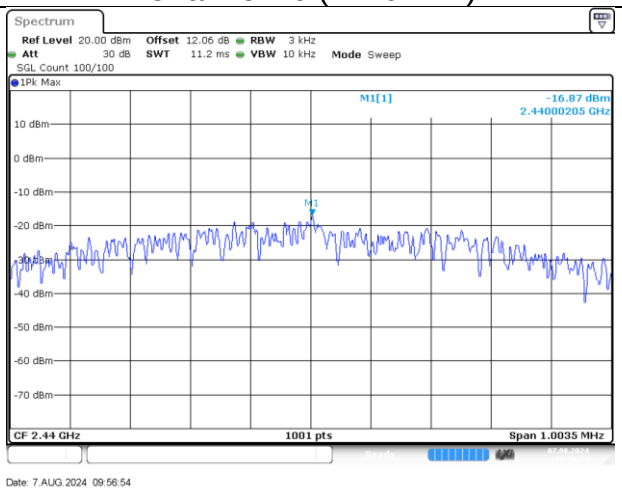
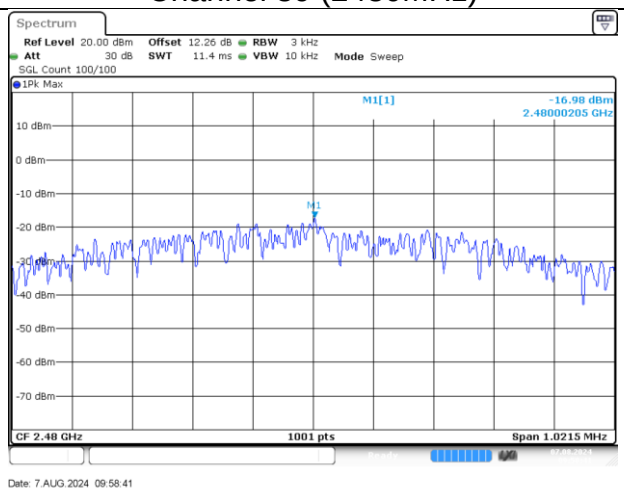
PK PSD (1Mbps)	
Channel 0 (2402MHz)	Channel 19 (2440MHz)
	
Channel 39 (2480MHz)	
	

9.4 Spurious RF conducted emissions

Test Method

1. The RF output of EUT was connected to the spectrum analyzer by RF cable. The path loss was compensated to the results for each measurement.
2. Set to the maximum power setting, the instrument center frequency is set to the nominal EUT channel center frequency enable the EUT transmit continuously.
3. Use the following spectrum analyzer settings:
   Span = wide enough to capture the peak level of the in-band emission and all spurious emissions (e.g., harmonics) from the lowest frequency generated in the EUT up through the 10th harmonic. Typically, several plots are required to cover this entire span.
   RBW = 100 kHz, VBW≥3RBW, Sweep = auto, Detector function = peak, Trace = max hold
4. Allow the trace to stabilize. Set the marker on the peak of any spurious emission recorded.
5. The level displayed must comply with the limit specified in this Section. Submit these plots.
6. Repeat above procedures until all frequencies measured were complete.

Limit

According to §15.247(d), spurious RF conducted emissions limit as below:

Frequency Range MHz	Limit (dBc)
30-25000	-20

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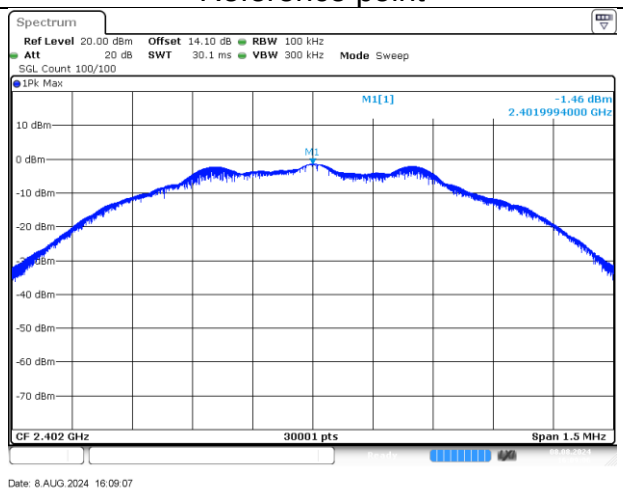
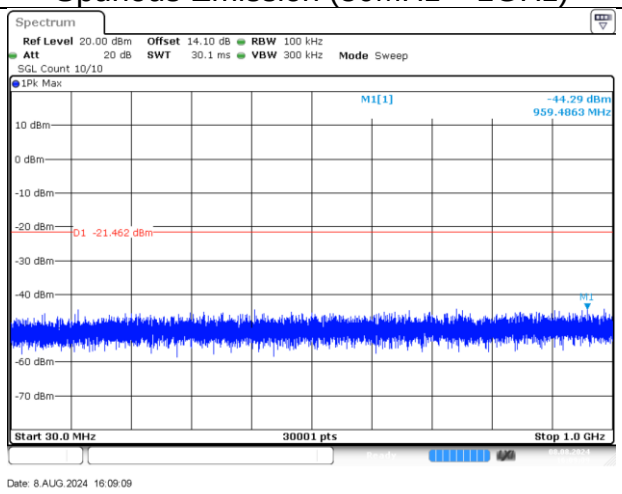
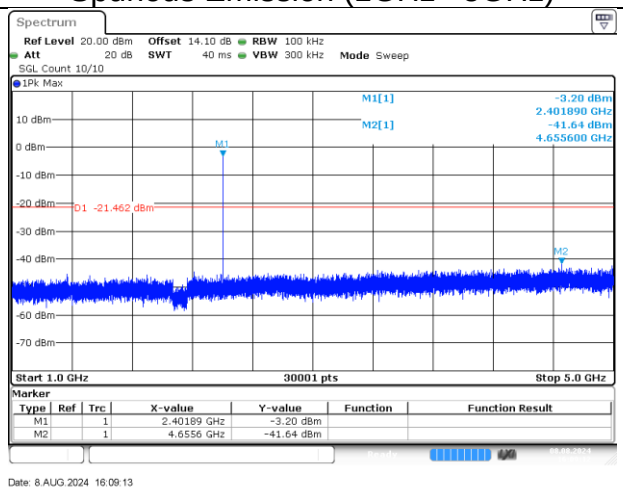
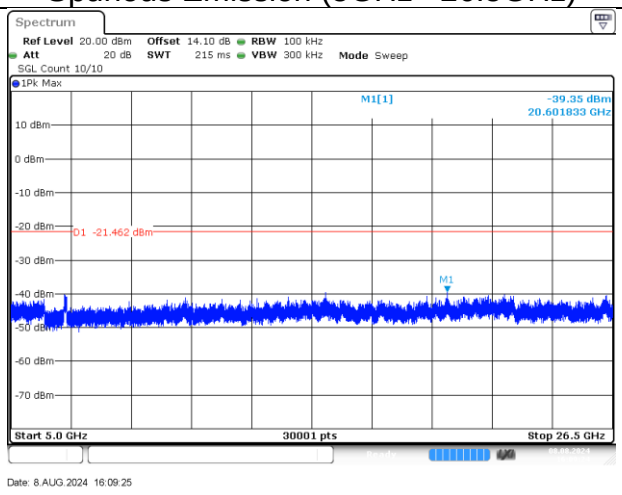
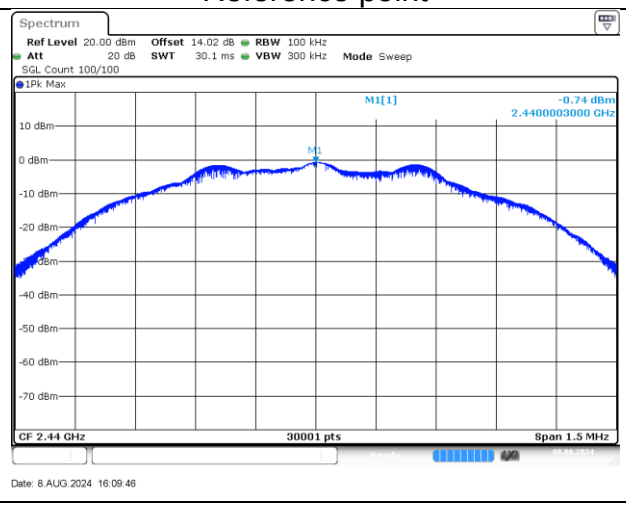
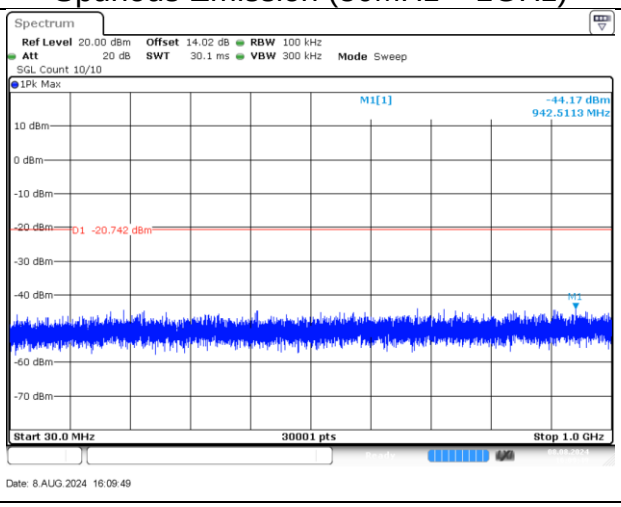
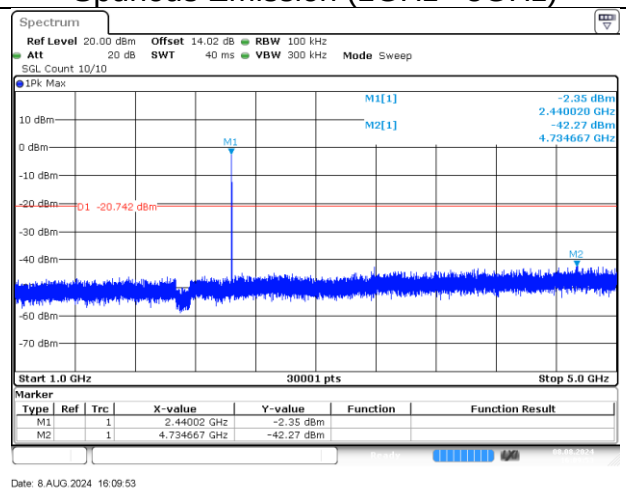
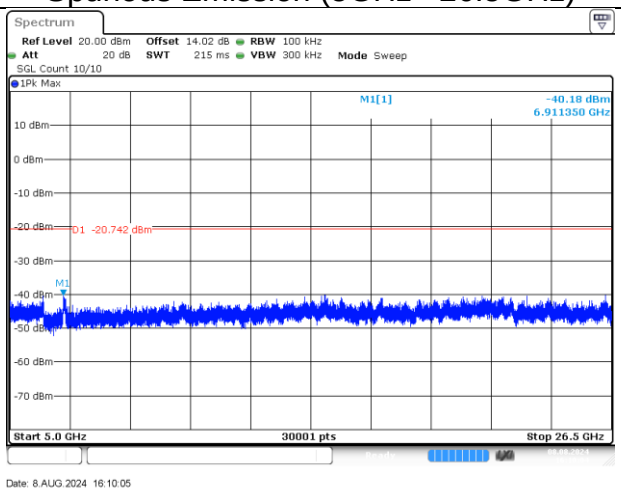
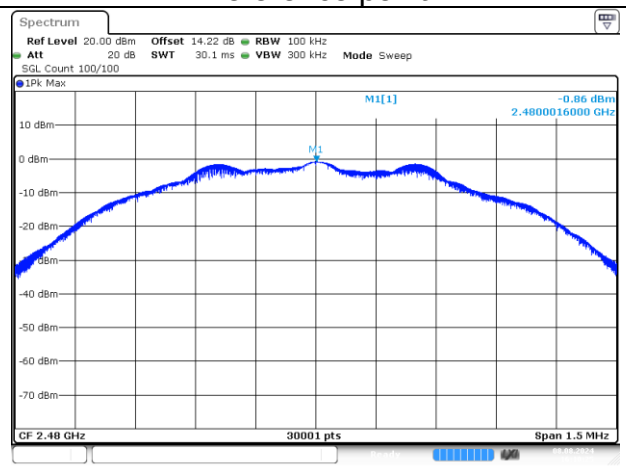
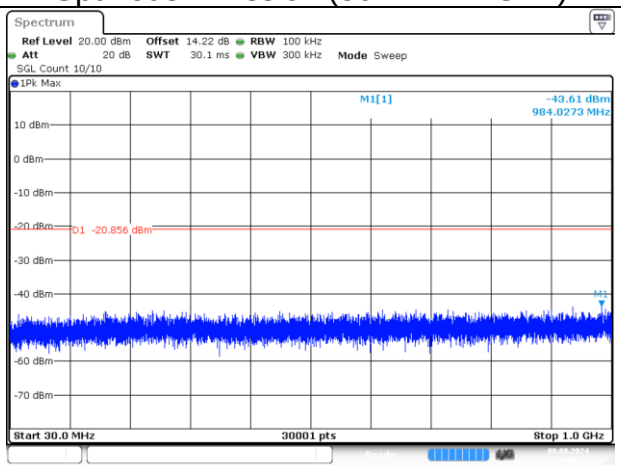
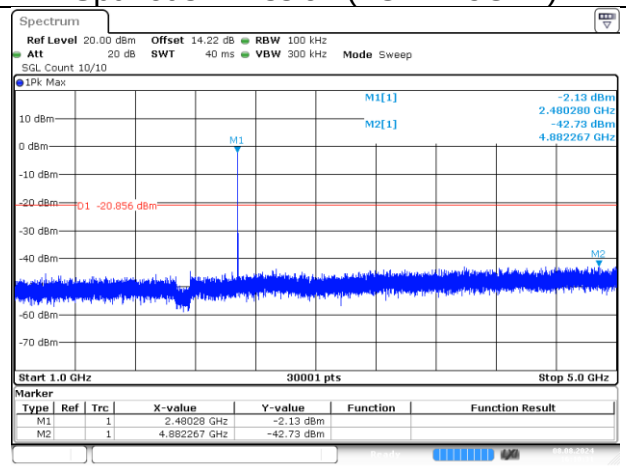
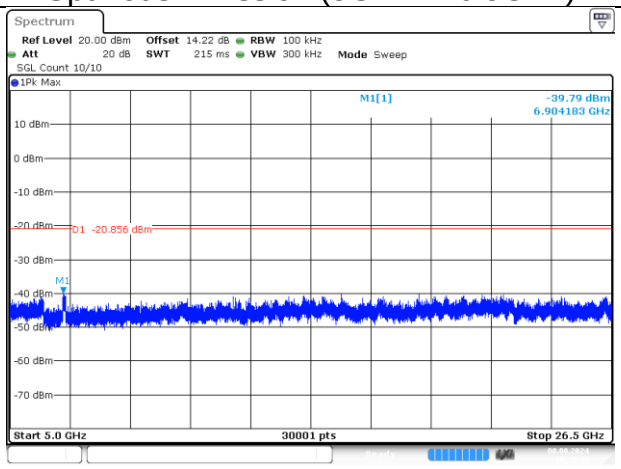
Spurious RF conducted emissions

Out-of-Band Emissions (1Mbps)	
Channel 0 (2402MHz)	
Reference point	Spurious Emission (30MHz – 1GHz)
	
Spurious Emission (1GHz –5GHz)	Spurious Emission (5GHz –26.5GHz)
	

Out-of-Band Emissions (1Mbps)	
Channel 19 (2440MHz)	
Reference point	Spurious Emission (30MHz – 1GHz)
	
Spurious Emission (1GHz –5GHz)	Spurious Emission (5GHz –26.5GHz)
	

Out-of-Band Emissions (1Mbps)	
Channel 39 (2480MHz)	
Reference point	Spurious Emission (30MHz – 1GHz)
	
Spurious Emission (1GHz –5GHz)	Spurious Emission (5GHz –26.5GHz)
	

9.5 Band edge

Test Method

1. The RF output of EUT was connected to the spectrum analyzer by RF cable. The path loss was compensated to the results for each measurement.
2. Set to the maximum power setting, the instrument center frequency is set to the nominal EUT channel center frequency enable the EUT transmit continuously.
3. Use the following spectrum analyzer settings:
   Span = wide enough to capture the peak level of the in-band emission and all spurious
   RBW = 100 kHz, VBW≥3RBW, Sweep = auto, Detector function = peak, Trace = max hold
4. Allow the trace to stabilize, use the peak and delta measurement to record the result.
5. The level displayed must comply with the limit specified in this Section.
6. Repeat above procedures until all frequencies measured were complete and submit all the plots.

Limit:

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 RMS averaging over a time interval, as permitted under § 15.247(b)(3) and RSS-247 section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB.

According to §15.247(d), band edge limit as below:

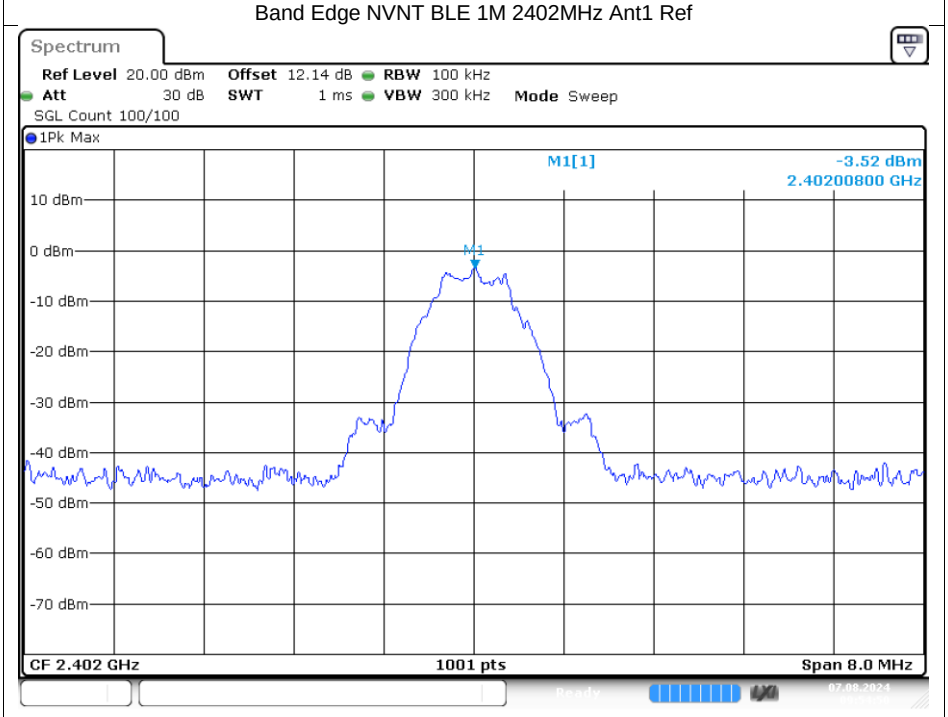
Frequency Range MHz	Limit (dBc)
30-25000	-20

Test result

1Mbps

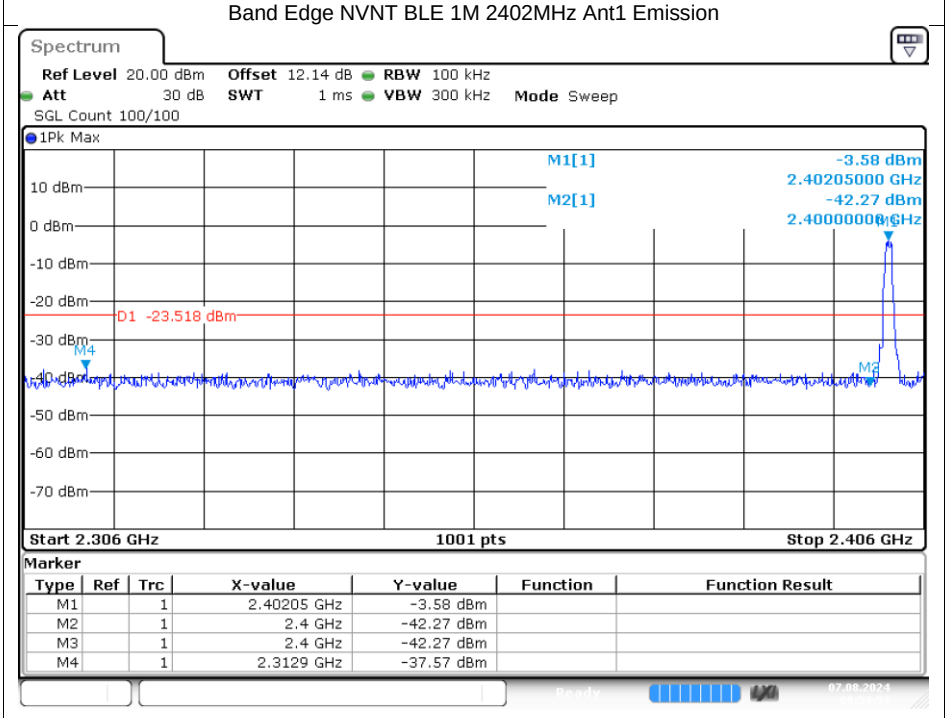
Test Graphs

Band Edge NVNT BLE 1M 2402MHz Ant1 Ref



Date: 7.AUG.2024 09:54:51

Band Edge NVNT BLE 1M 2402MHz Ant1 Emission



Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	2.40205 GHz	-3.58 dBm		
M2		1	2.4 GHz	-42.27 dBm		
M3		1	2.4 GHz	-42.27 dBm		
M4		1	2.3129 GHz	-37.57 dBm		

Date: 7.AUG.2024 09:54:54

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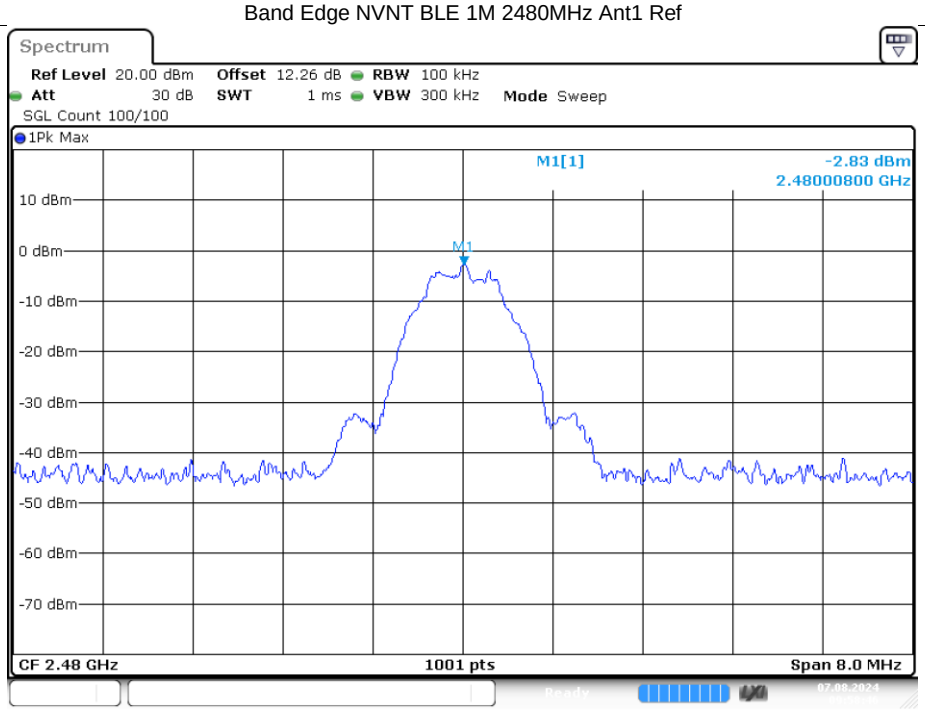
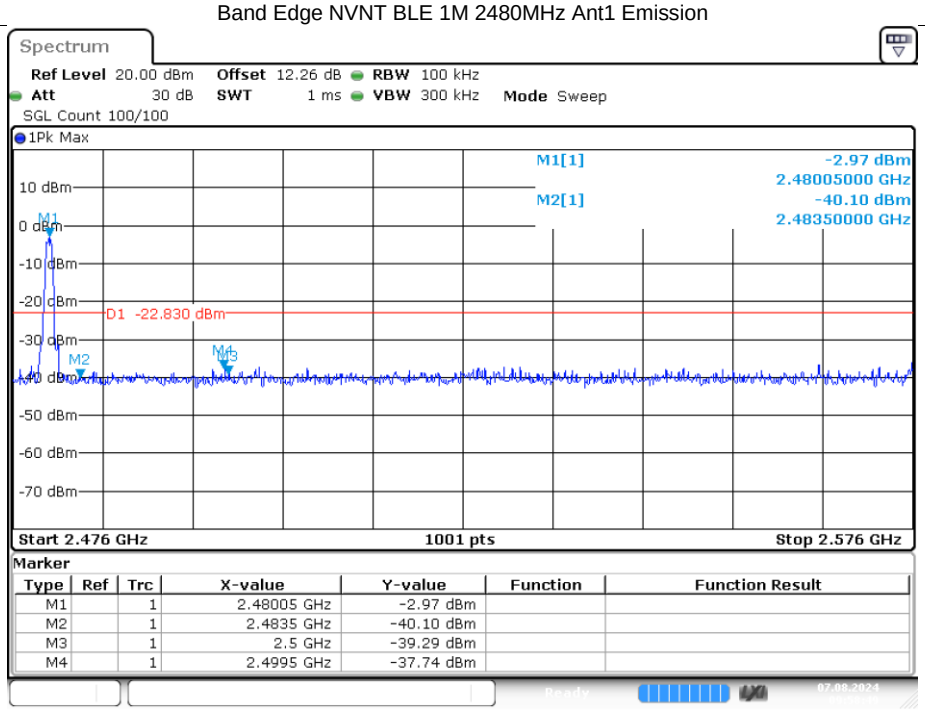
Band Edge NVNT BLE 1M 2480MHz Ant1 Ref



Date: 7.AUG.2024 09:58:47

Band Edge NVNT BLE 1M 2480MHz Ant1 Emission



Date: 7.AUG.2024 09:58:49

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9.6 Spurious radiated emissions for transmitter

Test Method

1. The EUT was place on a turn table which is 1.5m above ground plane for above 1GHz and 0.8m above ground for below 1GHz at 3 meter chamber room for test. The table was rotated 360 degrees to determine the position of the highest radiation.
2. The EUT was set 3 meters away from the interference – receiving antenna, which was mounted on the top of a variable – height antenna tower.
3. The height of antenna is 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.
4. 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 rotatable table was turned from 0 degrees to 360 degrees to find the maximum reading.
5. Use the following spectrum analyzer settings According to C63.10

   1) Procedure for Unwanted Emissions Measurements Below 1000 MHz

   Span = wide enough to capture the peak level of the in-band emission and all spurious RBW = 100 kHz to 120kHz, VBW≥RBW for peak measurement, Sweep = auto, Detector function = peak, Trace = max hold.

   2) For Peak unwanted emissions Above 1GHz:

   Span = wide enough to capture the peak level of the in-band emission and all spurious RBW = 1MHz, VBW≥RBW for peak measurement, Sweep = auto, Detector function = peak, Trace = max hold.

   Procedures for average unwanted emissions measurements above 1GHz

   a) RBW = 1MHz.

   b) VBW \ [3 × RBW].

   c) Detector = RMS (power averaging), if [span / (# of points in sweep)] \ RBW / 2. Satisfying this condition can require increasing the number of points in the sweep or reducing the span. If the condition is not satisfied, then the detector mode shall be set to peak.

   d) Averaging type = power (i.e., rms) (As an alternative, the detector and averaging type may be set for linear voltage averaging. Some instruments require linear display mode to use linear voltage averaging. Log or dB averaging shall not be used.)

   e) Sweep time = auto.

   f) Perform a trace average of at least 100 traces if the transmission is continuous. If the transmission is not continuous, then the number of traces shall be increased by a factor of 1 / D, where D is the duty cycle. For example, with 50% duty cycle, at least 200 traces shall be averaged. (If a specific emission is demonstrated to be continuous—i.e., 100% duty cycle—then rather than turning ON and OFF with the transmit cycle, at least 100 traces shall be averaged.)

   g) If tests are performed with the EUT transmitting at a duty cycle less than 98%, then a correction factor shall be added to the measurement results prior to comparing with the emission limit, to compute the emission level that would have been measured had the test been performed at 100% duty cycle. The correction factor is computed as follows:

   1) If power averaging (rms) mode was used in the preceding step e), then the correction factor is [10 log (1 / D)], where D is the duty cycle. For example, if the transmit duty cycle was 50%, then 3 dB shall be added to the measured emission levels.

   2) If linear voltage averaging mode was used in the preceding step e), then the correction

factor is [20 log (1 / D)], where D is the duty cycle. For example, if the transmit duty cycle was 50%, then 6 dB shall be added to the measured emission levels.
3) If a specific emission is demonstrated to be continuous (100% duty cycle) rather than turning ON and OFF with the transmit cycle, then no duty cycle correction is required for that emission (AV) at frequency above 1GHz.

Limit

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 RMS averaging over a time interval, as permitted under § 15.247(b)(3) and RSS 247 section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in § 15.209(a) and RSS-Gen is not required. In addition, radiated emissions which fall in the restricted bands, as defined in§ 15.205(a) and RSS-Gen scetion8.9, must also comply with the radiated emission limits specified in § 15.209(a) and RSS-Gen section 8.10.

Frequency MHz	Field Strength μV/m	Field Strength dBμV/m	Detector	Measurement distance meters
0.009-0.490	2400/F(kHz)	48.5-13.8	AV	300
0.490-1.705	24000/F(kHz)	33.8-23.0	QP	30
1.705-30	30	29.5	QP	30
30-88	100	40	QP	3
88-216	150	43.5	QP	3
216-960	200	46	QP	3
960-1000	500	54	QP	3
Above 1000	500	54	AV	3
Above 1000	5000	74	PK	3

Note 1: Limit 3m(dBμV/m)=Limit 300m(dBμV/m)+40Log(300m/3m) (Below 30MHz)
Note 2: Limit 3m(dBμV/m)=Limit 30m(dBμV/m)+40Log(30m/3m) (Below 30MHz)

Spurious Radiated Emissions for Transmitter

According to C63.10, if the peak (or quasi-peak) measured value complies with the average limit, it is unnecessary to perform an average measurement, so AV emission value did not show in below table if the peak value complies with average limit.
Data of measurement within frequency range 9kHz-30MHz is the noise floor or attenuated more than 20dB below the permissible limits or the field strength is too small to be measured, so test data does not present in this report.

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Above 1GHz Transmitting spurious emission test result as below:

1Mbps
2402MHz

Frequency	Emission Level	Polarization	Limit	Detector	Margin	Result
MHz	dBuV/m		dBµV/m		dBµV/m	
2380.25	40.10	Horizontal	74	PK	33.90	Pass
4803.53	44.44	Horizontal	74	PK	29.56	Pass
9606.51	48.65	Horizontal	74	PK	25.35	Pass
2384.82	40.55	Veritical	74	PK	33.45	Pass
4804.00	48.66	Veritical	74	PK	25.34	Pass
7204.61	46.91	Veritical	74	PK	27.09	Pass
9608.24	49.16	Veritical	74	PK	24.84	Pass

2440MHz

Frequency	Emission Level	Polarization	Limit	Detector	Margin	Result
MHz	dBuV/m		dBµV/m		dBµV/m	
4879.58	44.66	Horizontal	74	PK	29.34	Pass
7320.15	47.75	Horizontal	74	PK	26.25	Pass
9760.60	49.21	Horizontal	74	PK	24.79	Pass
4879.45	49.91	Veritical	74	PK	24.09	Pass
7319.09	47.00	Veritical	74	PK	27.00	Pass
9759.03	49.05	Veritical	74	PK	24.95	Pass

2480MHz

Frequency	Emission Level	Polarization	Limit	Detector	Margin	Result
MHz	dBuV/m		dBµV/m		dBµV/m	
2482.76	42.26	Horizontal	74	PK	31.74	Pass
4960.66	45.06	Horizontal	74	PK	28.94	Pass
7439.63	49.10	Horizontal	74	PK	24.90	Pass
9919.47	49.27	Horizontal	74	PK	24.73	Pass
2483.05	43.37	Veritical	74	PK	30.63	Pass
4959.61	48.65	Veritical	74	PK	25.35	Pass
7438.75	47.86	Veritical	74	PK	26.14	Pass
9919.40	47.19	Veritical	74	PK	26.81	Pass

Remark:

(1) Emission level= Original Receiver Reading + Correct Factor
(2) Correct Factor = Antenna Factor + Cable Loss -Amplifier gain
(3) Margin = limit – Corrected Reading

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The worst case of Radiated Emission below 1GHz:

30-1000MHz Radiated Emission

EUT Information

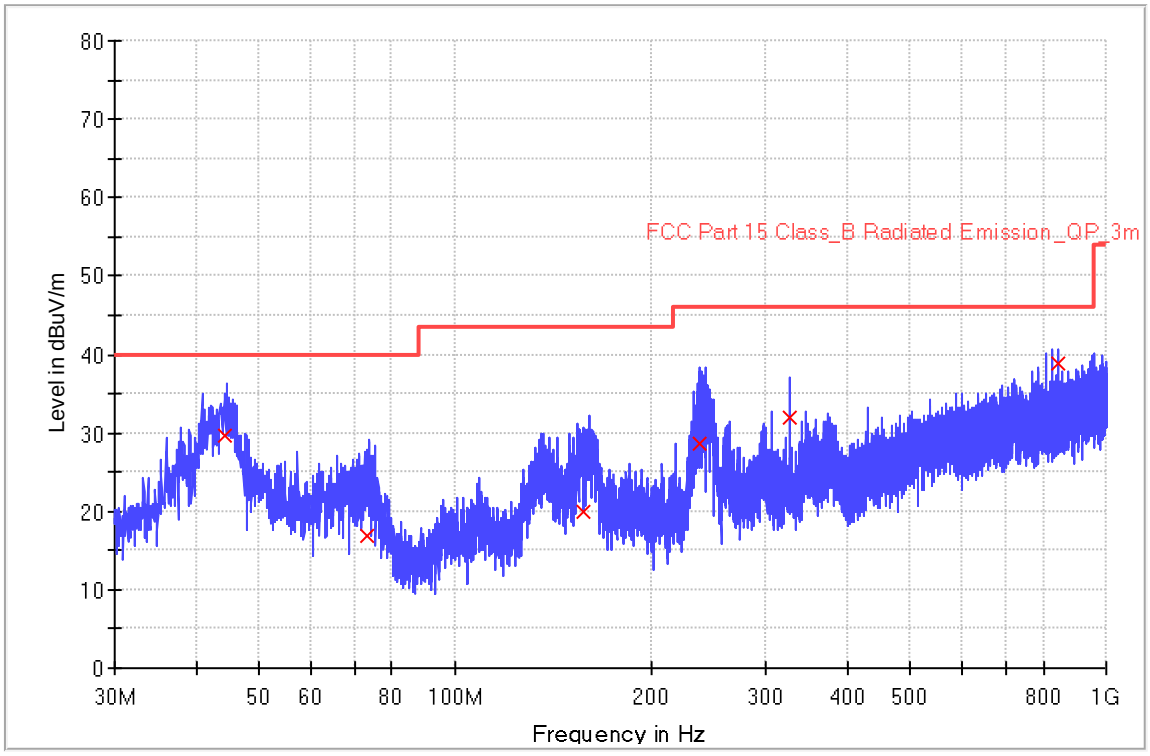
EUT Name:	CCU
Model:	Lime-CCU23
Client:	Neutron Holdings, Inc.
Op Cond:	Power on,TX_2480MHz
Operator:	Chengjie GUO
Test Spec:	FCC Part 15.247
Comment:	Horizontal
Sample No:	SHA-843416-2

Sweep Setup: RE_VULB9168_pre_Cont_30-1000 [EMI radiated]

Hardware Setup:	RE_VULB9168
Receiver:	[ESR 3]
Level Unit:	dBuV/m

Subrange	Step Size	Detectors	Bandwidth	Sweep Time	Preamp
30 MHz - 1 GHz	48.5 kHz	PK+	120 kHz	0.2 s	20 dB

RE_VULB9168_pre_Cont_30-1000



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Limit and Margin

Frequency (MHz)	QuasiPeak (dBuV/m)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Margin - QPK (dB)	Limit - QPK (dBuV/m)
44.200000	29.5	1000.0	120.000	135.0	H	150.0	20.4	10.5	40.0
73.320000	16.9	1000.0	120.000	124.0	H	193.0	18.0	23.1	40.0
157.600000	19.8	1000.0	120.000	155.0	H	158.0	21.1	23.7	43.5
237.080000	28.8	1000.0	120.000	165.0	H	169.0	19.5	17.2	46.0
326.400000	31.9	1000.0	120.000	150.0	H	154.0	22.7	14.1	46.0
844.800000	38.9	1000.0	120.000	176.0	H	135.0	32.7	7.1	46.0

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30-1000MHz Radiated Emission

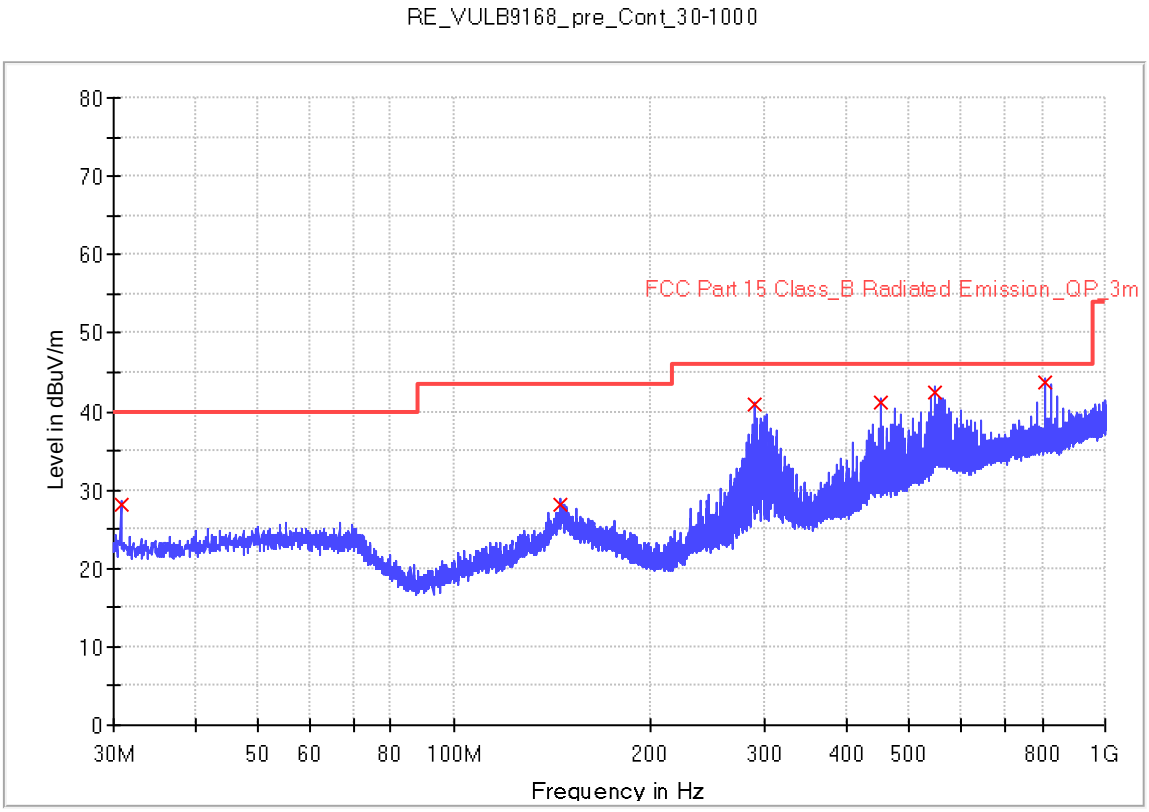
EUT Information

EUT Name:	CCU
Model:	Lime-CCU23
Client:	Neutron Holdings, Inc.
Op Cond:	Power on, TX_2480MHz
Operator:	Chengjie GUO
Test Spec:	FCC Part 15.247
Comment:	Vertical
Sample No:	SHA-843416-2

Sweep Setup: RE_VULB9168_pre_Cont_30-1000 [EMI radiated]

Hardware Setup:	RE_VULB9168
Receiver:	[ESR 3]
Level Unit:	dBuV/m

Subrange	Step Size	Detectors	Bandwidth	Sweep Time	Preamp
30 MHz - 1 GHz	48.5 kHz	PK+	120 kHz	0.2 s	20 dB



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Limit and Margin

Frequency (MHz)	QuasiPeak (dBuV/m)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Margin - QPK (dB)	Limit - QPK (dBuV/m)
30.840000	28.0100	1000.0	120.000	200.0	V	358.0	18.9	12.0	40.0
145.880000	28.2000	1000.0	120.000	200.0	V	358.0	21.0	15.3	43.5
289.880000	40.9700	1000.0	120.000	200.0	V	358.0	21.6	5.0	46.0
453.400000	41.1000	1000.0	120.000	200.0	V	358.0	26.1	4.9	46.0
546.240000	42.5200	1000.0	120.000	200.0	V	358.0	27.7	3.5	46.0
806.400000	43.8100	1000.0	120.000	200.0	V	358.0	32.9	2.2	46.0

Note 1: Measure Level (dBuV/m) = Reading Level (dBuV) + Factor (dB)
Factor (dB) = Cable Loss (dB) + Antenna Factor (dB/m)
Note 2: The test trace is same as the ambient noise and the amplitude of the emissions are attenuated more than 20dB below the permissible (the test frequency range: 9kHz ~ 30MHz, 18GHz ~ 25GHz), therefore no data appear in the report

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10 Test Equipment List

List of Test Instruments
Test Site1

	DESCRIPTION	MANUFACTURER	MODEL NO.	SERIAL NO.	CAL. DATE	CAL. DUE DATE
C	Signal spectrum analyzer	Agilent	N9020B	MY59050168	2024-2-19	2025-2-18
RE	EMI Test Receiver	Rohde & Schwarz	ESR3	101906	2024-8-1	2025-7-31
	Signal Analyzer	Rohde & Schwarz	FSV40	101091	2024-8-1	2025-7-31
	Trilog Super Broadband Test Antenna	Schwarzbeck	VULB 9168	961	2021-9-23	2024-9-22
	Double-ridged waveguide horn antenna	Rohde & Schwarz	HF907	102868	2024-4-14	2027-4-13
	Pre-amplifier	Shenzhen HzEMC	HPA-081843	HYPA23026	2024-4-16	2025-4-15
	Loop antenna	Rohde & Schwarz	HFH2-Z2	100443	2024-6-26	2025-6-25
	Double Ridged Horn Antenna	ETS-Lindgren	3116C	00246076	2023-7-7	2026-7-6
	3m Semi-anechoic chamber	TDK	9X6X6	----	2025-4-15	2027-5-7

Measurement Software Information			
Test Item	Software	Manufacturer	Version
C	MTS 8310	MWRFtest	3.0.0.0
RE	EMC 32	Rohde & Schwarz	V10.50.40

C - Conducted RF tests

- Conducted peak output power
- 6dB bandwidth and 99% Occupied Bandwidth
- Power spectral density*
- Spurious RF conducted emissions
- Band edge

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11 System Measurement Uncertainty

For a 95% confidence level, the measurement expanded uncertainties for defined systems, in accordance with the recommendations of ISO 17025 were:

Items	Extended Uncertainty
Radiated Disturbance	9kHz to 30MHz, 3.52dB 30MHz to 1GHz, 5.03dB (Horizontal) 5.12dB (Vertical) 1GHz to 18GHz, 5.49dB 18GHz to 40GHz, 5.63dB
RF Conducted Measurement	Power related： 1.16dB Frequency related： 6.00×10^{-8}

Measurement Uncertainty Decision Rule:

Determination of conformity with the specification limits is based on the decision rule according to IEC Guide 115: 2023, clause 4.3.3.

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12 Photographs of Test Set-ups

Refer to the < Test Setup photos >.

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13 Photographs of EUT

Refer to the < External Photos > & < Internal Photos >.

----------End of Test Report----------

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