FCC/ISED - TEST REPORT

Report Number	:	**709502403822-00C Rev1**	Date of Issue:	November 4, 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	:	65	

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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

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. 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: 5180~5240 MHz (U-NII-1)

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5260~5320 MHz (U-NII-2A)
5500~5700 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

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For BLE (Module2): 1Mbps, 2Mbps

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

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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
	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

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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		

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)

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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 Amendment 2 February 2021	General Requirements for the Certification 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 average output power	18-26	Site 1	☒	☐	☐
	RSS-247 5.4(d)	Equivalent Isotropic Radiated Power	18-26	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	27-33	Site 1	☒	☐	☐
§15.247(e)	RSS-247 5.2(b)	Power spectral density	34-37	Site 1	☒	☐	☐
§15.247(e)	RSS-247 5.5	Spurious RF conducted emissions	38-47	Site 1	☒	☐	☐
§15.247(d)	RSS-247 5.5	Band edge	48-54	Site 1	☒	☐	☐
§15.247(d) & §15.209 & §15.205	RSS-247 5.5 & RSS-Gen 6.13	Spurious radiated emissions for transmitter	55-61	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.

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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 2.4GHz Wi-Fi test report, for the 5GHz Wi-Fi test report please refer to 709502403822-00A, for the BLE (Module1) test report please refer to 709502403822-00D, 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.

SUMMARY:

All tests according to the regulations cited on page 6 were

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

Sample Received Date:	June 19, 2024
Testing Start Date:	June 21, 2024
Testing End Date:	November 4, 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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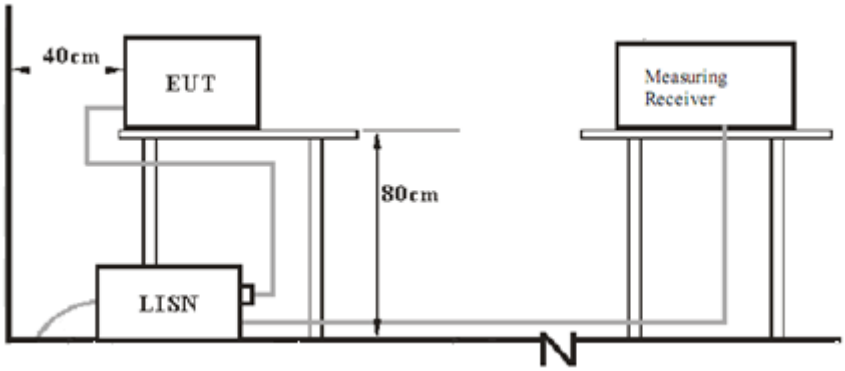
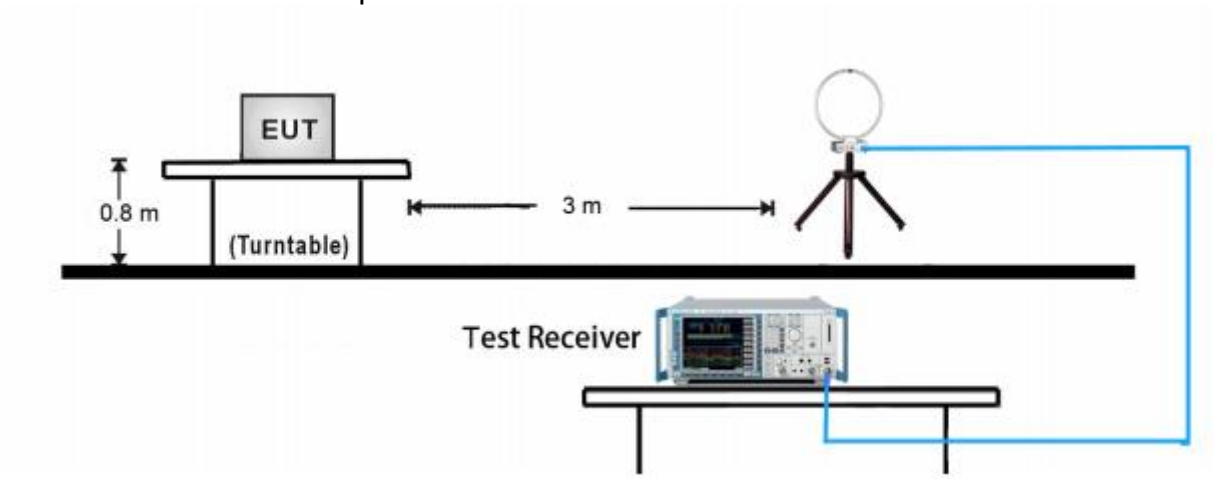
7 Test Setups

7.1 AC Power Line Conducted Emission test setups



7.2 Radiated test setups

9kHz ~ 30MHz Test Setup:



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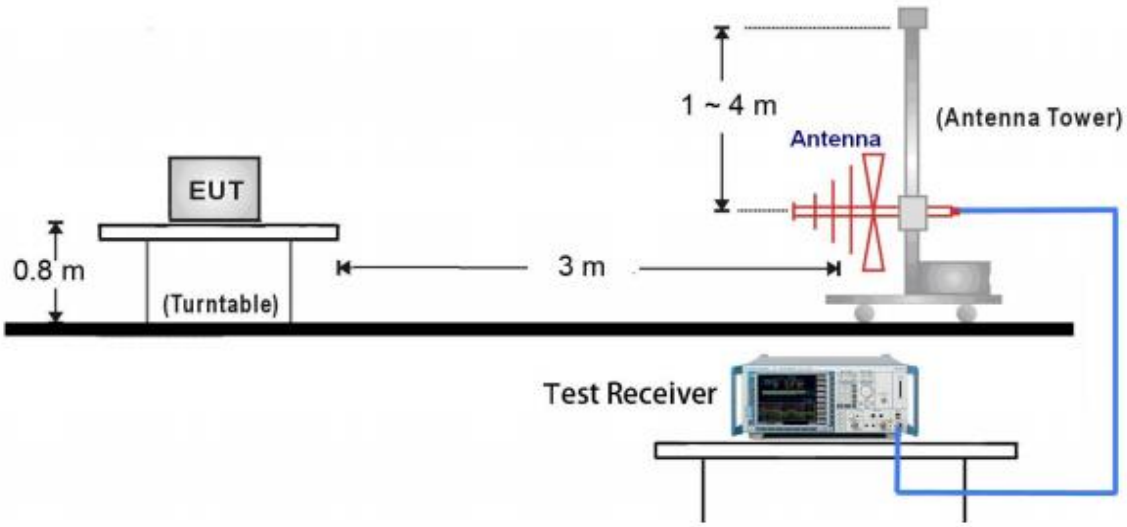
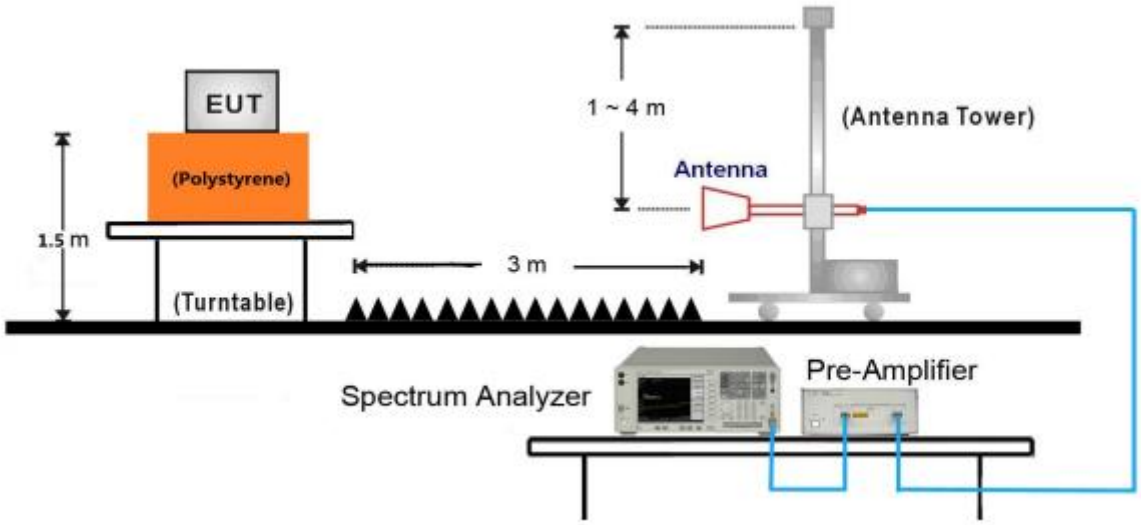
30MHz ~ 1GHz Test Setup:



1GHz ~ 18GHz Test Setup:



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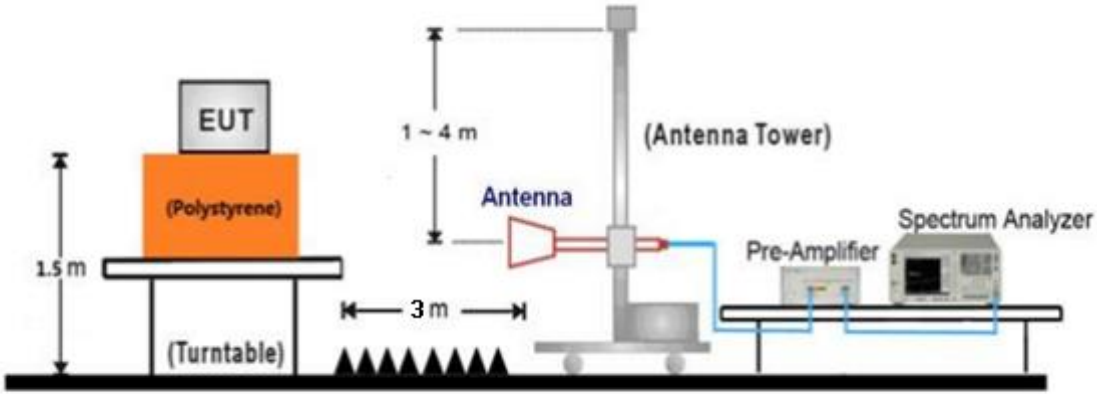
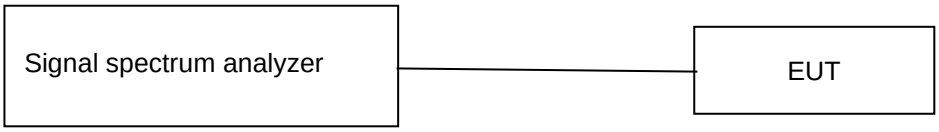
18GHz ~ 25GHz Test Setup:



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 1(2412MHz), 6(2437MHz), and 11(2462MHz).

Test Mode Applicability and Tested Channel Detail:

Mode	Tested Channel	Data Rate (Mbps)	Modulation	Index Value (Power level setting)
802.11b	1	1	CCK	20
	6	1	CCK	20
	11	1	CCK	20
802.11g	1	6	OFDM	19
	6	6	OFDM	19
	11	6	OFDM	19
802.11n HT20	1	MCS0	OFDM	18
	6	MCS0	OFDM	18
	11	MCS0	OFDM	18

Non-hopping mode: The system was configured to operate at a signal channel transmitting. The test software allows the configuration and operation at the worst-case duty and the highest transmit power.

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9 Technical Requirement

9.1 Conducted Average output power and EIRP

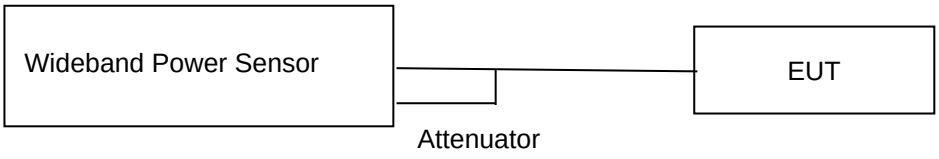
Test Method (1)

1. Measure the duty cycle D of the transmitter output signal.
2. Set span to at least 1.5 times the OBW.
3. Set RBW = 1% to 5% of the OBW, not to exceed 1 MHz.
4. Set VBW ≥ [3 × RBW].
5. Number of points in sweep ≥ [2 × span / RBW]. (This gives bin-to-bin spacing ≤ RBW / 2, so that narrowband signals are not lost between frequency bins.)
6. Sweep time = auto.
7. Detector = RMS (i.e., power averaging), if available. Otherwise, use the sample detector mode.
8. Do not use sweep triggering. Allow the sweep to “free run.”
9. Trace average at least 100 traces in power averaging (rms) mode; however, the number of traces to be averaged shall be increased above 100 as needed such that the average accurately represents the true average over the ON and OFF periods of the transmitter.
10. Compute power by integrating the spectrum across the OBW of the signal using the instrument’s band power measurement function with band limits set equal to the OBW band edges. If the instrument does not have a band power function, then sum the spectrum levels (in power units) at intervals equal to the RBW extending across the entire OBW of the spectrum.
11. Add [10 log (1 / D)], where D is the duty cycle, to the measured power to compute the average power during the actual transmission times (because the measurement represents an average over both the ON and OFF times of the transmission).

Test Method (2)

1) The EUT is configured to transmit continuously, or to transmit with a constant duty cycle.
2) At all times when the EUT is transmitting, it shall be transmitting at its maximum power control level.
3) The integration period of the power meter exceeds the repetition period of the transmitted signal by at least a factor of five.

4) Measure the peak power of the transmitter. This measurement is a peak over both the ON and OFF periods of the transmitter.



Wideband Power Sensor conducted test setup

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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 (average power) as below table

802.11B

Frequency	Duty cycle Factor	Conducted Power	Total Power(average)	e.i.r.p.	Result
MHz	**dB**	**dBm**	**dBm**	**dBm**	
Low channel 2412MHz	0	18.69	18.69	20.65	Pass
Middle channel 2437MHz	0	20.26	20.26	22.22	Pass
High channel 2462MHz	0	18.83	18.83	20.79	Pass

802.11G

Frequency	Duty cycle Factor	Conducted Power	Total Power(average)	e.i.r.p.	Result
MHz	**dB**	**dBm**	**dBm**	**dBm**	
Low channel 2412MHz	0.3	16.9	17.2	19.16	Pass
Middle channel 2437MHz	0.23	18.19	18.42	20.38	Pass
High channel 2462MHz	0.25	16.85	17.1	19.06	Pass

802.11N20

Frequency	Duty cycle Factor	Conducted Power	Total Power(average)	e.i.r.p.	Result
MHz	**dB**	**dBm**	**dBm**	**dBm**	
Low channel 2412MHz	0.32	15.54	15.86	17.82	Pass
Middle channel 2437MHz	0.33	16.97	17.3	19.26	Pass
High channel 2462MHz	0.26	15.96	16.22	18.18	Pass

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Duty Cycle

Condition	Mode	Frequency (MHz)	Antenna	Duty Cycle (%)	Correction Factor (dB)
NVNT	b	2412	Ant1	99.12	0
NVNT	b	2437	Ant1	99.12	0
NVNT	b	2462	Ant1	99.12	0
NVNT	g	2412	Ant1	93.24	0.3
NVNT	g	2437	Ant1	94.77	0.23
NVNT	g	2462	Ant1	94.5	0.25
NVNT	n20	2412	Ant1	92.79	0.32
NVNT	n20	2437	Ant1	92.75	0.33
NVNT	n20	2462	Ant1	94.12	0.26

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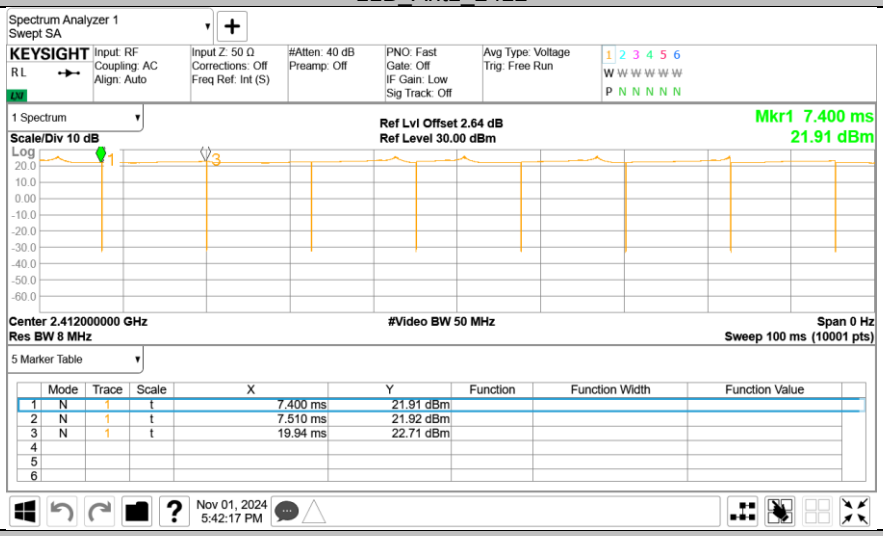
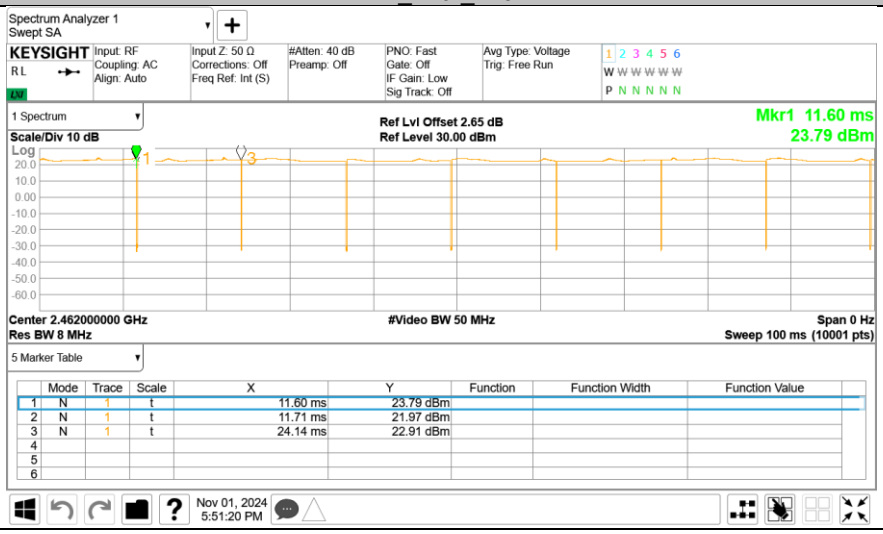
Duty Cycle

11B_Ant1_2412



11B_Ant1_2437

11B_Ant1_2462



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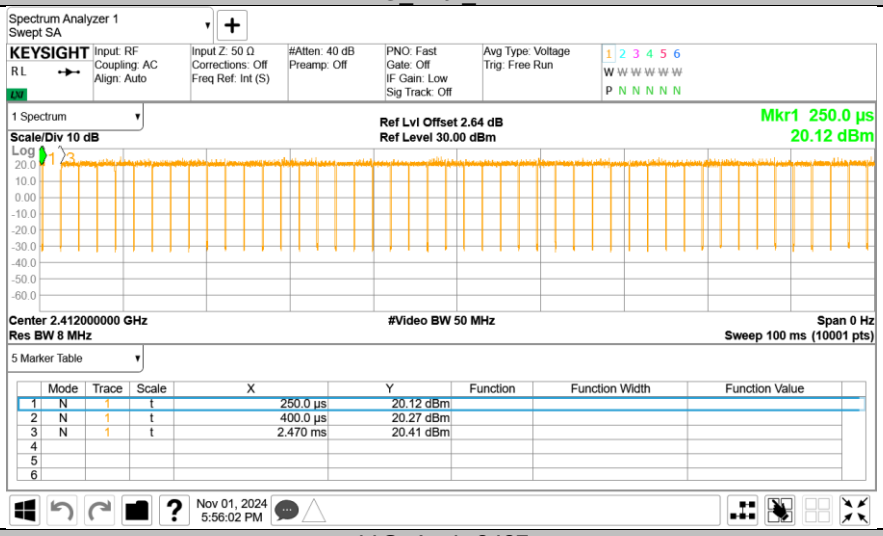

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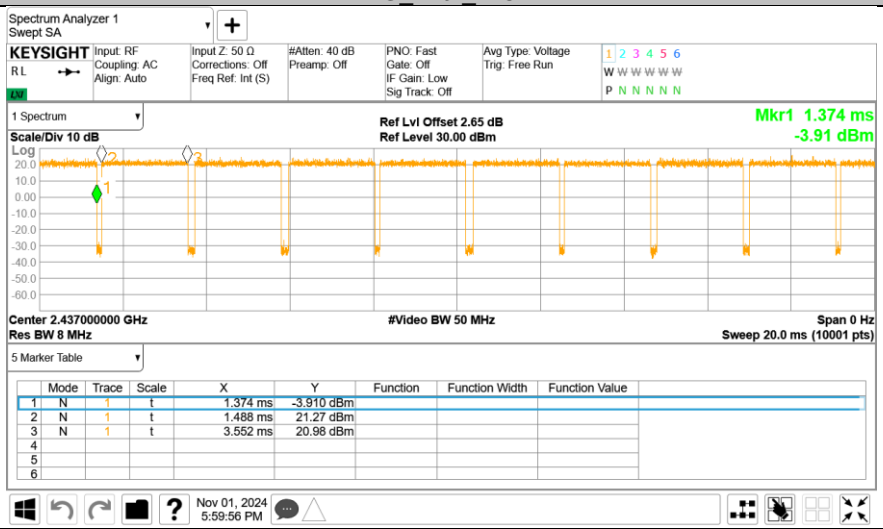
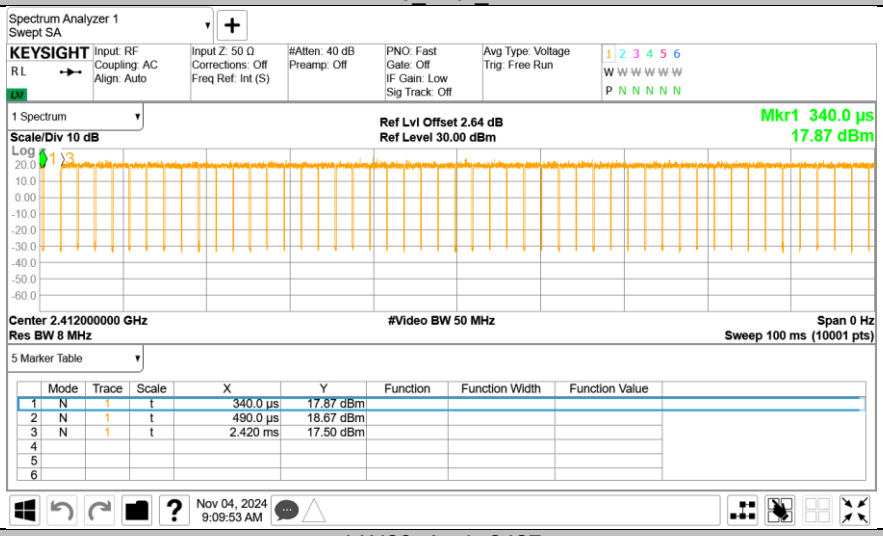


11G_Ant1_2462

11N20_Ant1_2412



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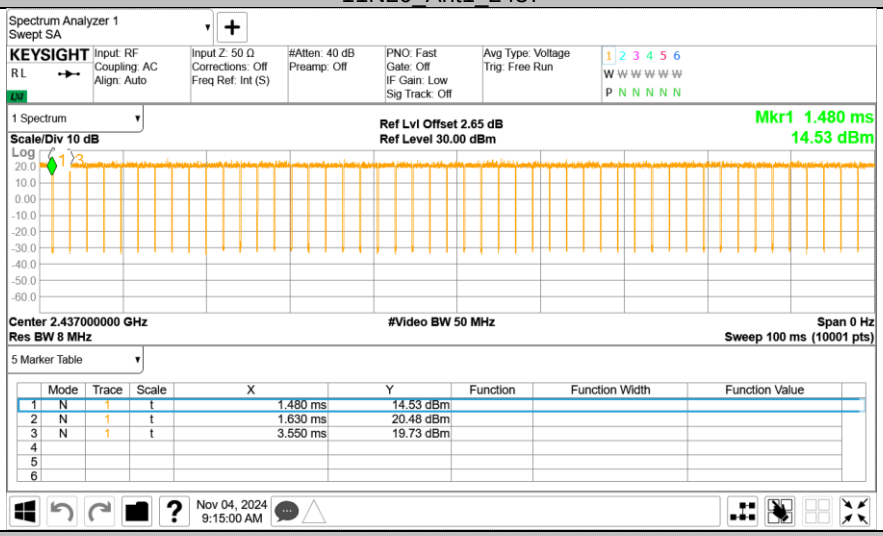

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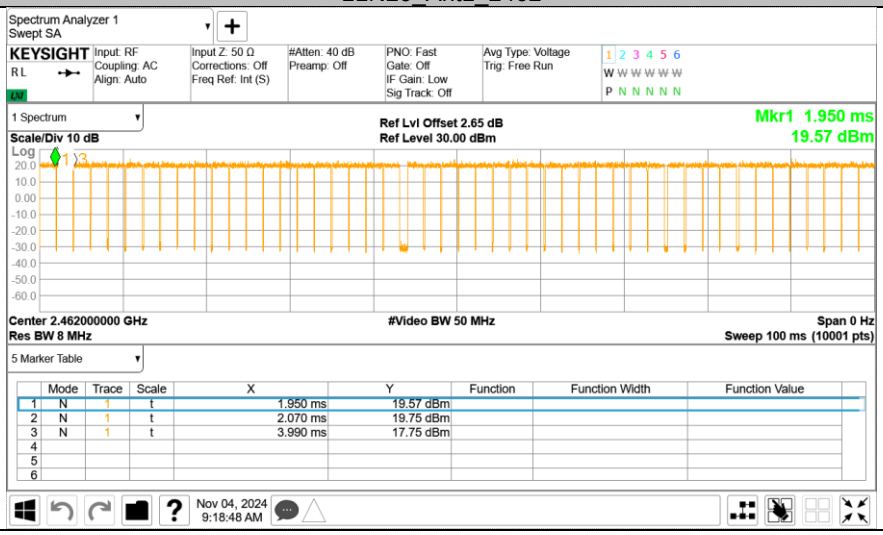
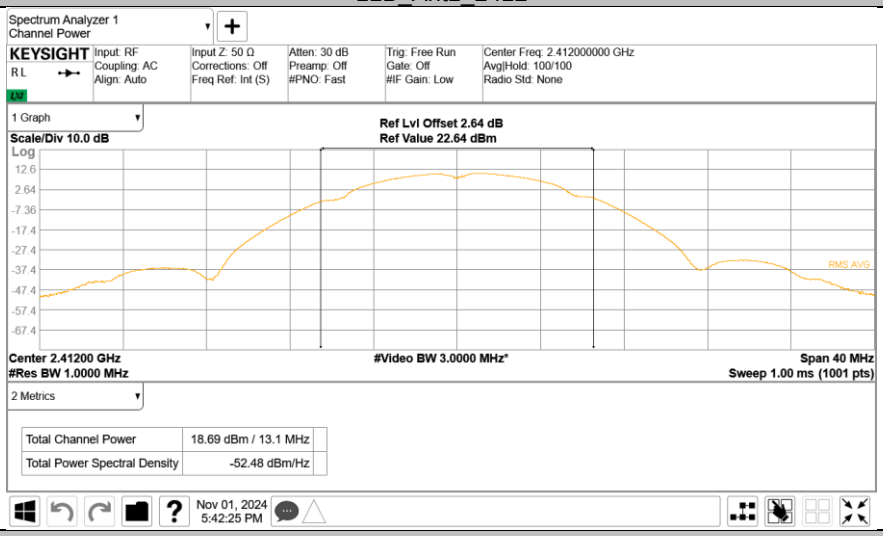


Average Power

11B_Ant1_2412



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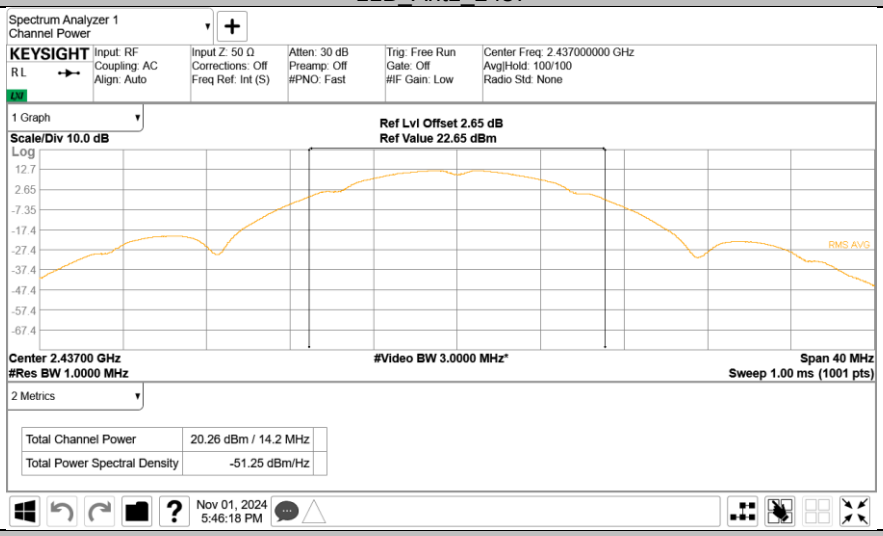

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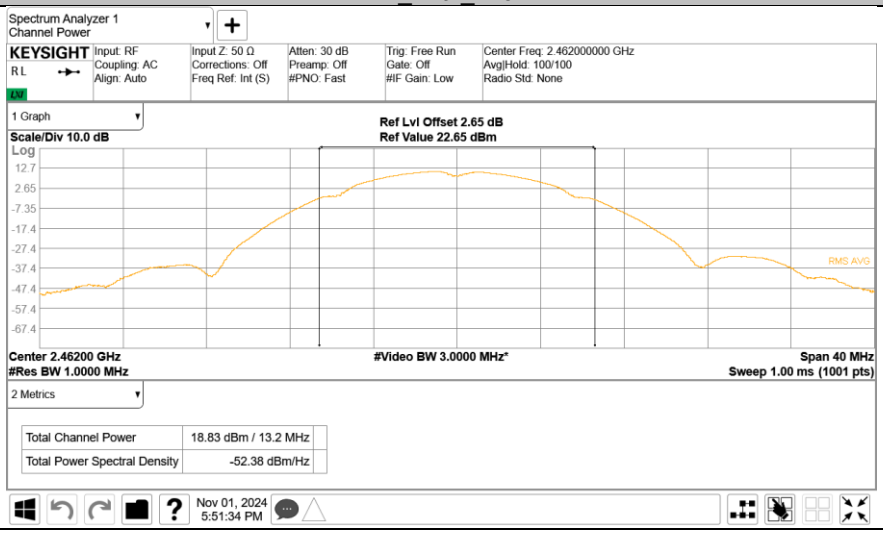

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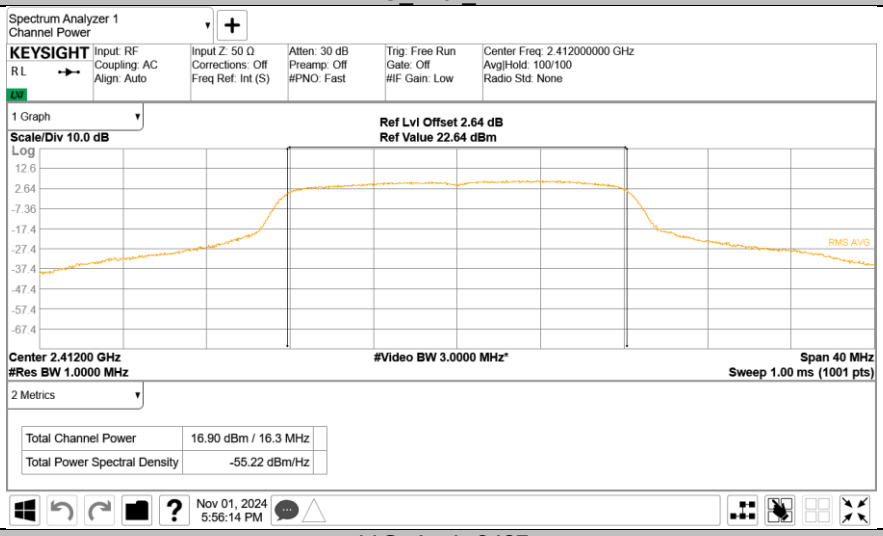

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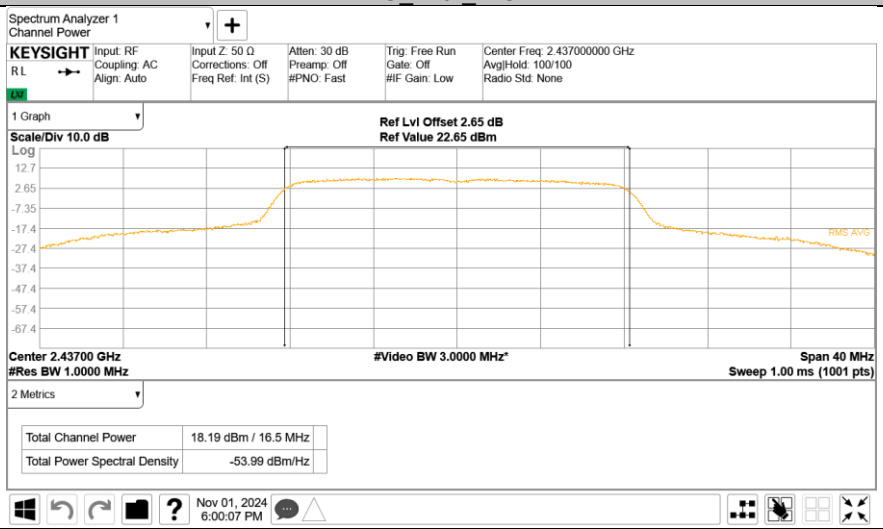

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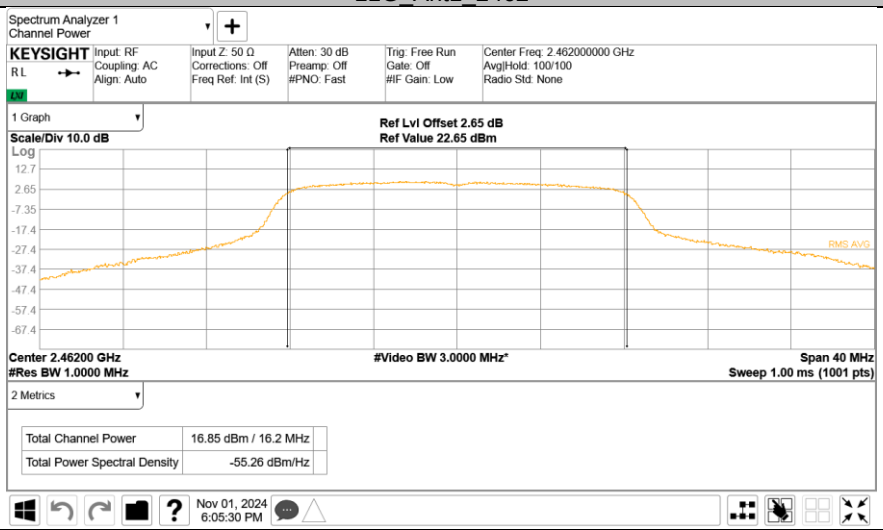

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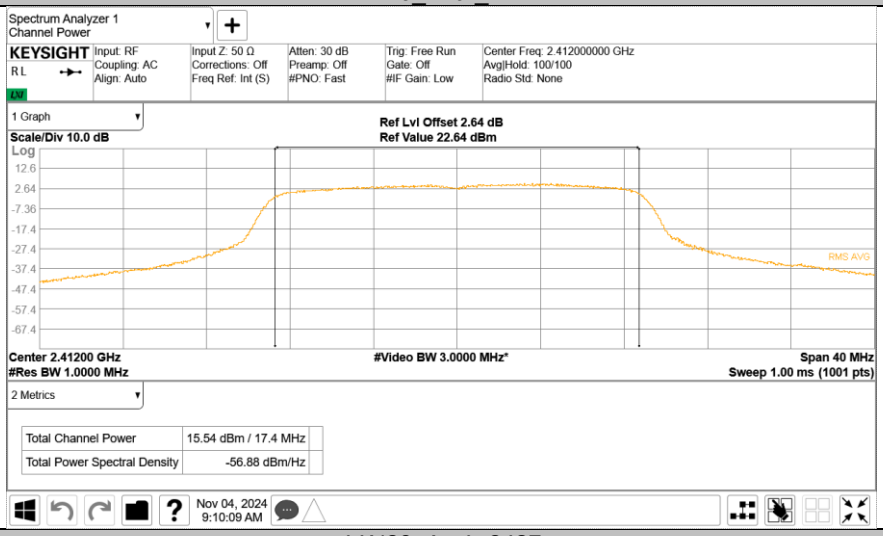

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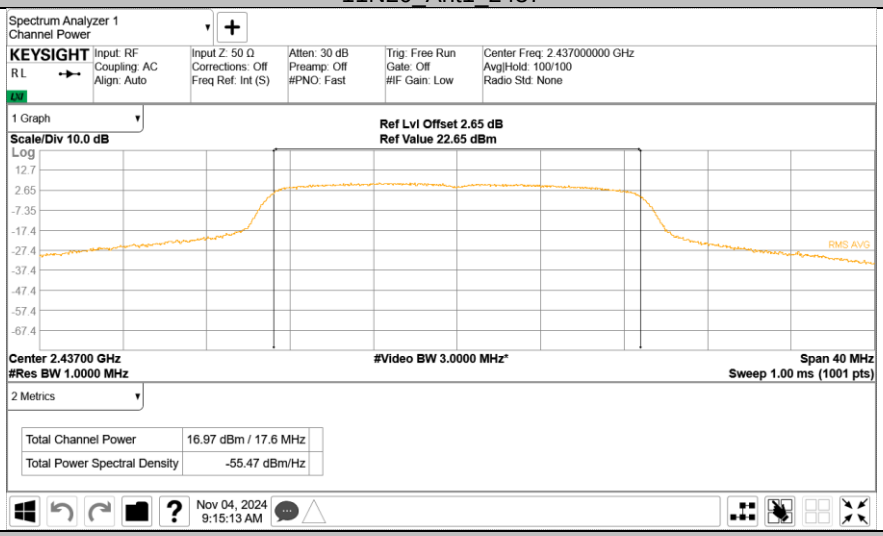

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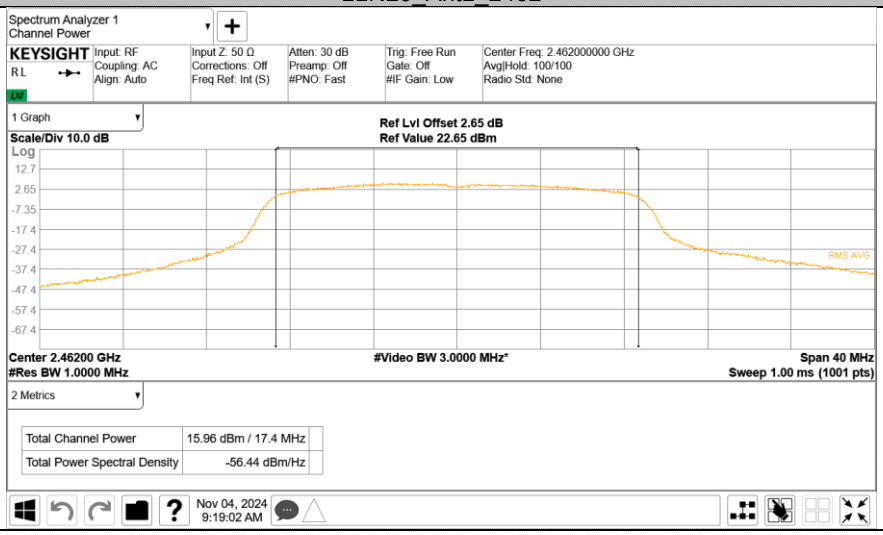

9.2 6dB bandwidth and 99% Occupied Bandwidth

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

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

Test result

Test Mode	Frequency MHz	6dB bandwidth (MHz)		Result	99% occupied bandwidth MHz
		result	limit	verdict	
802.11b	2412	8.264	≥0.5	Pass	13.095
	2437	9.169	≥0.5	Pass	14.167
	2462	8.618	≥0.5	Pass	13.228
802.11g	2412	15.743	≥0.5	Pass	16.299
	2437	15.935	≥0.5	Pass	16.521
	2462	15.322	≥0.5	Pass	16.243
802.11n(HT20)	2412	16.768	≥0.5	Pass	17.442
	2437	16.853	≥0.5	Pass	17.554
	2462	16.564	≥0.5	Pass	17.37

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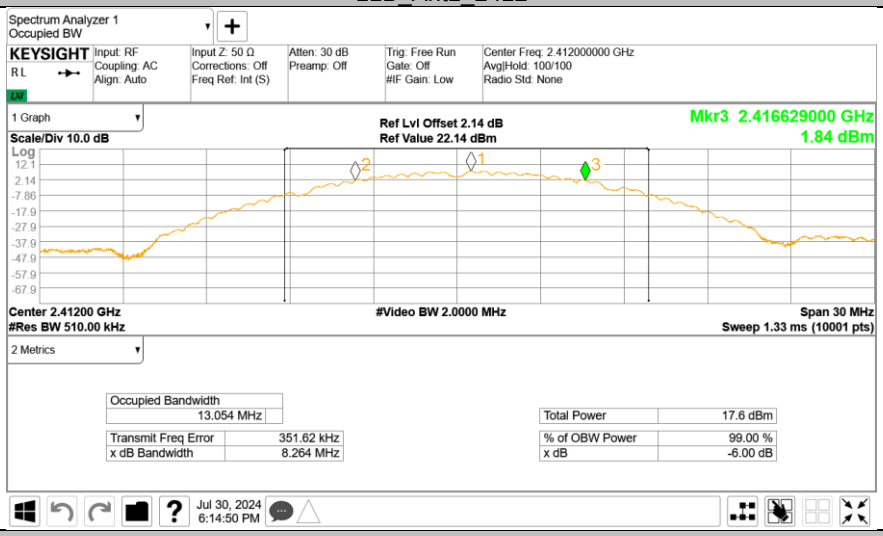
6 dB Bandwidth

11B_Ant1_2412



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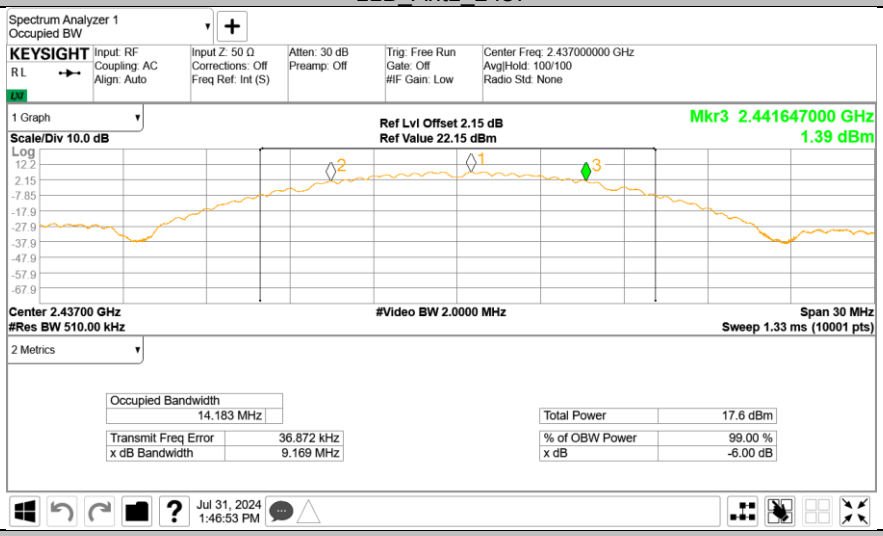

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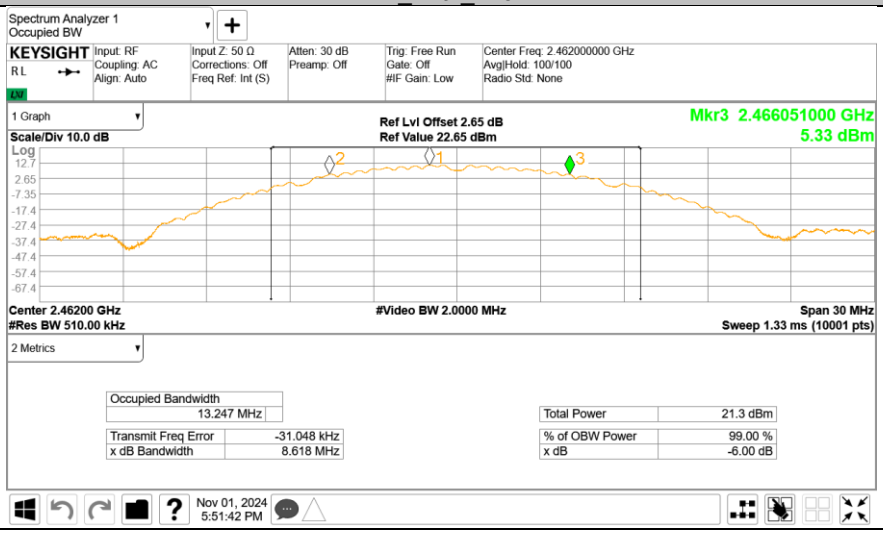
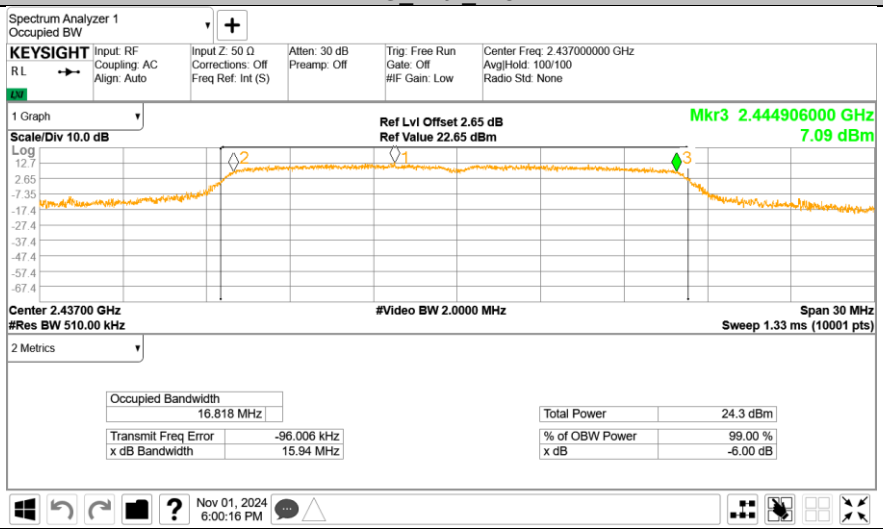


11G_Ant1_2412

11G_Ant1_2437



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