

FCC §15.247(a) (1) - CHANNEL SEPARATION TEST

Applicable Standard

Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400-2483.5 MHz band 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 provided the systems operate with an output power no greater than 125 mW. 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.

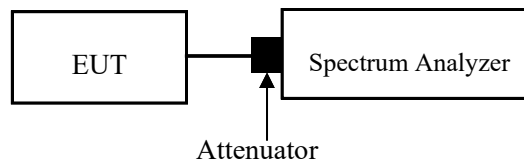
Test Procedure

Test Method: ANSI C63.10-2013 Clause 7.8.2

The EUT shall have its hopping function enabled. Use the following spectrum analyzer settings:

- a) Span: Wide enough to capture the peaks of two adjacent channels.
- b) RBW: 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) Video (or average) bandwidth (VBW) $\geq$ RBW.
- d) Sweep: Auto.
- e) Detector function: Peak.
- f) Trace: Max hold.
- g) Allow the trace to stabilize.

Use the marker-delta function to determine the separation between the peaks of the adjacent channels. Compliance of an EUT with the appropriate regulatory limit shall be determined.



Test Data

Environmental Conditions

Temperature:	26.2~26.8 °C
Relative Humidity:	55~59 %
ATM Pressure:	101 kPa

The testing was performed by Cheeb Huang from 2024-08-16 to 2024-09-07.

EUT operation mode: Transmitting

Test Result: Compliant.

Antenna	Test Frequency (MHz)	Channel Separation (MHz)	Limits (MHz)
ANT1	2402	1.003	0.628
	2440	1.003	0.629
	2478	1.006	0.628
ANT2	2402	1.001	0.648
	2440	1.003	0.647
	2478	1.006	0.627
Limit= Two-thirds of the 20 dB bandwidth			

ANT1

Low Channel	Spectrum Ref Level 25.00 dBm Offset 10.50 dB RBW 100 kHz Att 30 dB SWT 10 ms VBW 100 kHz Mode Auto Sweep 1Pk View 20 dBm 10 dBm 0 dBm -10 dBm -20 dBm -30 dBm -40 dBm -50 dBm -60 dBm -70 dBm D2[1] M1[1] 0.00 dB 1.002620 MHz 2.05 dBm 2.402118300 GHz CF 2.4025 GHz 8001 pts Span 3.0 MHz ProjectNo.:2401V86257E-RF Tester:Cheeb Huang Date: 16.AUG.2024 11:26:53
Middle Channel	Spectrum Ref Level 25.00 dBm Offset 10.50 dB RBW 100 kHz Att 30 dB SWT 10 ms VBW 100 kHz Mode Auto Sweep 1Pk View 20 dBm 10 dBm 0 dBm -10 dBm -20 dBm -30 dBm -40 dBm -50 dBm -60 dBm -70 dBm D2[1] M1[1] -0.02 dB 1.003000 MHz 1.63 dBm 2.440117170 GHz CF 2.4405 GHz 8001 pts Span 3.0 MHz ProjectNo.:2401V86257E-RF Tester:Cheeb Huang Date: 16.AUG.2024 11:29:42
High Channel	Ref 33.5 dBm Offset 10.5 dB RBW 100 kHz Att 25 dB VBW 100 kHz SWT 2.5 ms Delta 2 [T1] 1.005769231 MHz -0.01 dB Marker 1 [T1] 1.23 dBm 2.47708769 GHz 1 Pk View -10 -20 -30 -40 -50 -60 1 2 1.23 dBm 2.47708769 GHz Center 2.4775 GHz 300 kHz/ Span 3 MHz ProjectNo.:2401V86257E-RF Tester:Cheeb Huang Date: 7.SEP.2024 16:08:43

ANT2

Low Channel	Spectrum Ref Level 25.00 dBm Att 30 dB Offset 10.50 dB RBW 100 kHz SWT 10 ms VBW 100 kHz Mode Auto Sweep 1Pk View 20 dBm 10 dBm 0 dBm -10 dBm -20 dBm -30 dBm -40 dBm -50 dBm -60 dBm -70 dBm D2[1] M1[1] 0.01 dB 1.000750 MHz 3.47 dBm 2.402112300 GHz CF 2.4025 GHz 8001 pts Span 3.0 MHz ProjectNo.:2401V86257E-RF Tester:Cheeb Huang Date: 16.AUG.2024 10:13:09
Middle Channel	Spectrum Ref Level 25.00 dBm Att 30 dB Offset 10.50 dB RBW 100 kHz SWT 10 ms VBW 100 kHz Mode Auto Sweep 1Pk View 20 dBm 10 dBm 0 dBm -10 dBm -20 dBm -30 dBm -40 dBm -50 dBm -60 dBm -70 dBm D2[1] M1[1] -0.07 dB 1.003370 MHz 2.98 dBm 2.440123920 GHz CF 2.4405 GHz 8001 pts Span 3.0 MHz ProjectNo.:2401V86257E-RF Tester:Cheeb Huang Date: 16.AUG.2024 10:15:25
High Channel	Ref 33.5 dBm Att 25 dB Offset 10.5 dB RBW 100 kHz VBW 100 kHz SWT 2.5 ms Marker 1 [T1] 0.68 dBm 2.477191346 GHz 1 Pk View -10 -20 -30 -40 -50 -60 Delta 2 [T1] 1.59 dB 1.005761231 MHz Center 2.4775 GHz 300 kHz/ Span 3 MHz ProjectNo.:2401V86257E-RF Tester:Cheeb Huang Date: 7.SEP.2024 16:06:28

FCC §15.247(a) (1) - 20 dB EMISSION BANDWIDTH

Applicable Standard

Alternatively, frequency hopping systems operating in the 2400–2483.5 MHz band 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, provided the systems operate with an output power no greater than 125 mW.

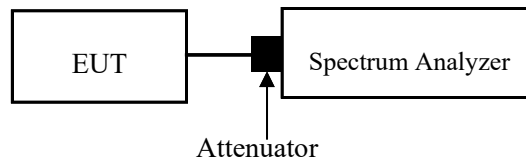
Test Procedure

Test Method: ANSI C63.10-2013 Clause 7.8.7 & Clause 6.9.2

- a) The spectrum analyzer center frequency is set to the nominal EUT channel center frequency. The span range for the EMI receiver or spectrum analyzer shall be between two times and five times the OBW.
- b) The nominal IF filter bandwidth (3 dB RBW) shall be in the range of 1% to 5% of the OBW and video bandwidth (VBW) shall be approximately three times RBW, unless otherwise specified by the applicable requirement.
- c) Set the reference level of the instrument as required, keeping the signal from exceeding the maximum input mixer level for linear operation. In general, the peak of the spectral envelope shall be more than $[10 \log (\text{OBW}/\text{RBW})]$ below the reference level.
- d) Steps a) through c) might require iteration to adjust within the specified tolerances.
- e) The dynamic range of the instrument at the selected RBW shall be more than 10 dB below the target “–xx dB down” requirement; that is, if the requirement calls for measuring the –20 dB OBW, the instrument noise floor at the selected RBW shall be at least 30 dB below the reference value.
- f) Set detection mode to peak and trace mode to max hold.
- g) Determine the reference value: Set the EUT to transmit an un-modulated carrier or modulated signal, as applicable. Allow the trace to stabilize. Set the spectrum analyzer marker to the highest level of the displayed trace (this is the reference value).
- h) Determine the “–xx dB down amplitude” using $[(\text{reference value}) - \text{xx}]$. Alternatively, this calculation may be made by using the marker-delta function of the instrument.
- i) If the reference value is determined by an un-modulated carrier, then turn the EUT modulation on, and either clear the existing trace or start a new trace on the spectrum analyzer and allow the new trace to stabilize. Otherwise, the trace from step g) shall be used for step j).

j) Place two markers, one at the lowest frequency and the other at the highest frequency of the envelope of the spectral display, such that each marker is at or slightly below the “– xx dB down amplitude” determined in step h). If a marker is below this “–xx dB down amplitude” value, then it shall be as close as possible to this value. The occupied bandwidth is the frequency difference between the two markers. Alternatively, set a marker at the lowest frequency of the envelope of the spectral display, such that the marker is at or slightly below the “– xx dB down amplitude” determined in step h). Reset the marker-delta function and move the marker to the other side of the emission until the delta marker amplitude is at the same level as the reference marker amplitude. The marker-delta frequency reading at this point is the specified emission bandwidth.

k) The occupied bandwidth shall be reported by providing plot(s) of the measuring instrument display; the plot axes and the scale units per division shall be clearly labeled. Tabular data may be reported in addition to the plot(s).



Test Data

Environmental Conditions

Temperature:	26.2 °C
Relative Humidity:	55 %
ATM Pressure:	101 kPa

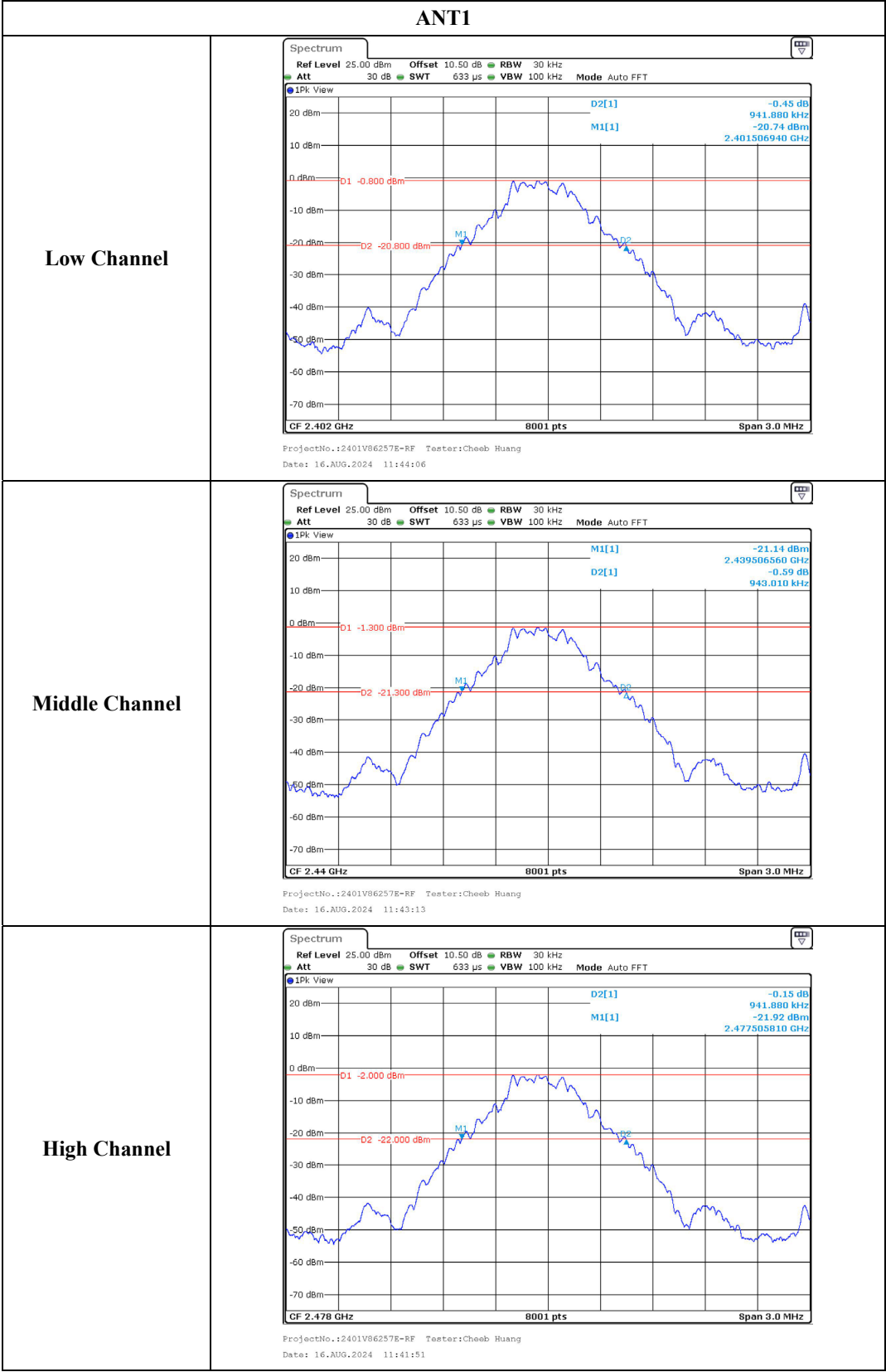
The testing was performed by Cheeb Huang on 2024-08-16.

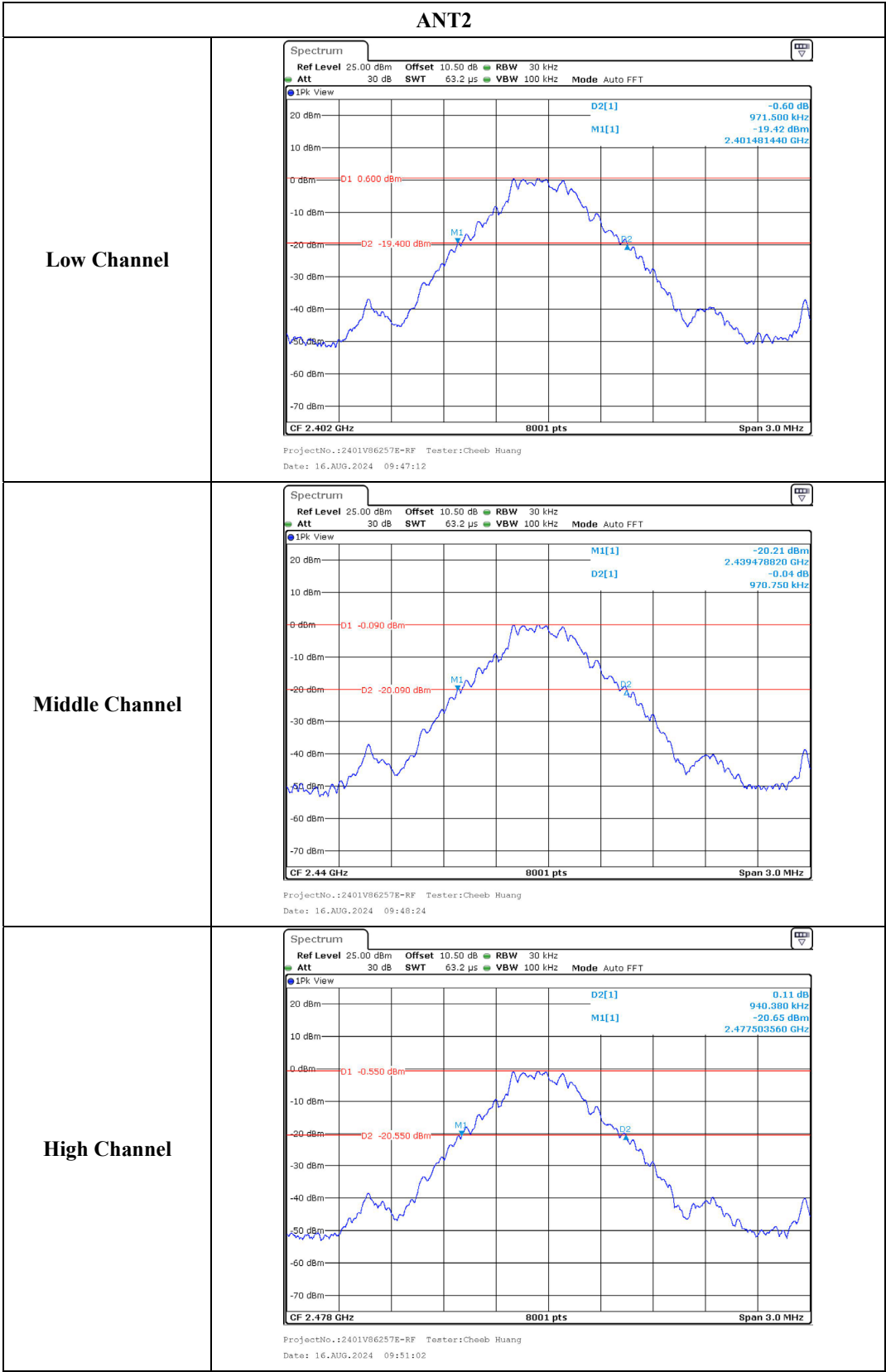
EUT operation mode: Transmitting

Test Result: Compliant.

Antenna	Test Channel	Test Frequency (MHz)	20 dB Bandwidth (MHz)
ANT1	Lowest	2402	0.942
	Middle	2440	0.943
	Highest	2478	0.942
ANT2	Lowest	2402	0.972
	Middle	2440	0.971
	Highest	2478	0.940

20 dB Bandwidth





FCC §15.247(a) (1) (iii) - QUANTITY OF HOPPING CHANNEL TEST**Applicable Standard**

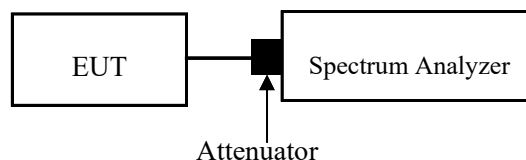
Frequency hopping systems in the 2400–2483.5 MHz band shall use at least 15 channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

Test Procedure

Test Method: ANSI C63.10-2013 Clause 7.8.3

- a) Span: The frequency band of operation. Depending on the number of channels the device supports, it may be necessary to divide the frequency range of operation across multiple spans, to allow the individual channels to be clearly seen.
- b) RBW: 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 $\geq$ RBW.
- d) Sweep: Auto.
- e) Detector function: Peak.
- f) Trace: Max hold.

It might prove necessary to break the span up into sub ranges to show clearly all of the hopping frequencies. Compliance of an EUT with the appropriate regulatory limit shall be determined for the number of hopping channels.

**Test Data****Environmental Conditions**

Temperature:	26.8 °C
Relative Humidity:	59 %
ATM Pressure:	101 kPa

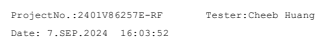
The testing was performed by Cheeb Huang on 2024-09-07.

EUT operation mode: Transmitting

Test Result: Compliant.

Antenna	Frequency Range (MHz)	Number of Hopping Channel	Limits
ANT1	2400-2483.5	77	≥ 15
ANT2	2400-2483.5	77	≥ 15

ANT1



ANT2



FCC §15.247(a) (1) (iii) - TIME OF OCCUPANCY (DWELL TIME)

Applicable Standard

Frequency hopping systems in the 2400-2483.5 MHz shall use at least 15 channels. 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. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

Test Procedure

Test Method: ANSI C63.10-2013 Clause 7.8.4

The EUT shall have its hopping function enabled. Use the following spectrum analyzer settings:

- a) Span: Zero span, centered on a hopping channel.
- b) RBW shall be $\leq$ channel spacing and where possible RBW should be set $\gg 1 / T$, 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.

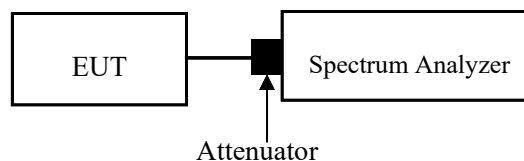
Use the marker-delta function to determine the transmit time per hop. If this value varies with different modes of operation (data rate, modulation format, number of hopping channels, etc.), then repeat this test for each variation in transmit time.

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:

$$\begin{aligned} &(\text{Number of hops in the period specified in the requirements}) = (\text{number of hops on spectrum analyzer}) \\ &\times (\text{period specified in the requirements} / \text{analyzer sweep time}) \end{aligned}$$

The average time of occupancy is calculated from the transmit time per hop multiplied by the number of hops in the period specified in the requirements. If the number of hops in a specific time varies with different modes of operation (data rate, modulation format, number of hopping channels, etc.), then repeat this test for each variation.

The measured transmit time and time between hops shall be consistent with the values described in the operational description for the EUT.



Test Data

Environmental Conditions

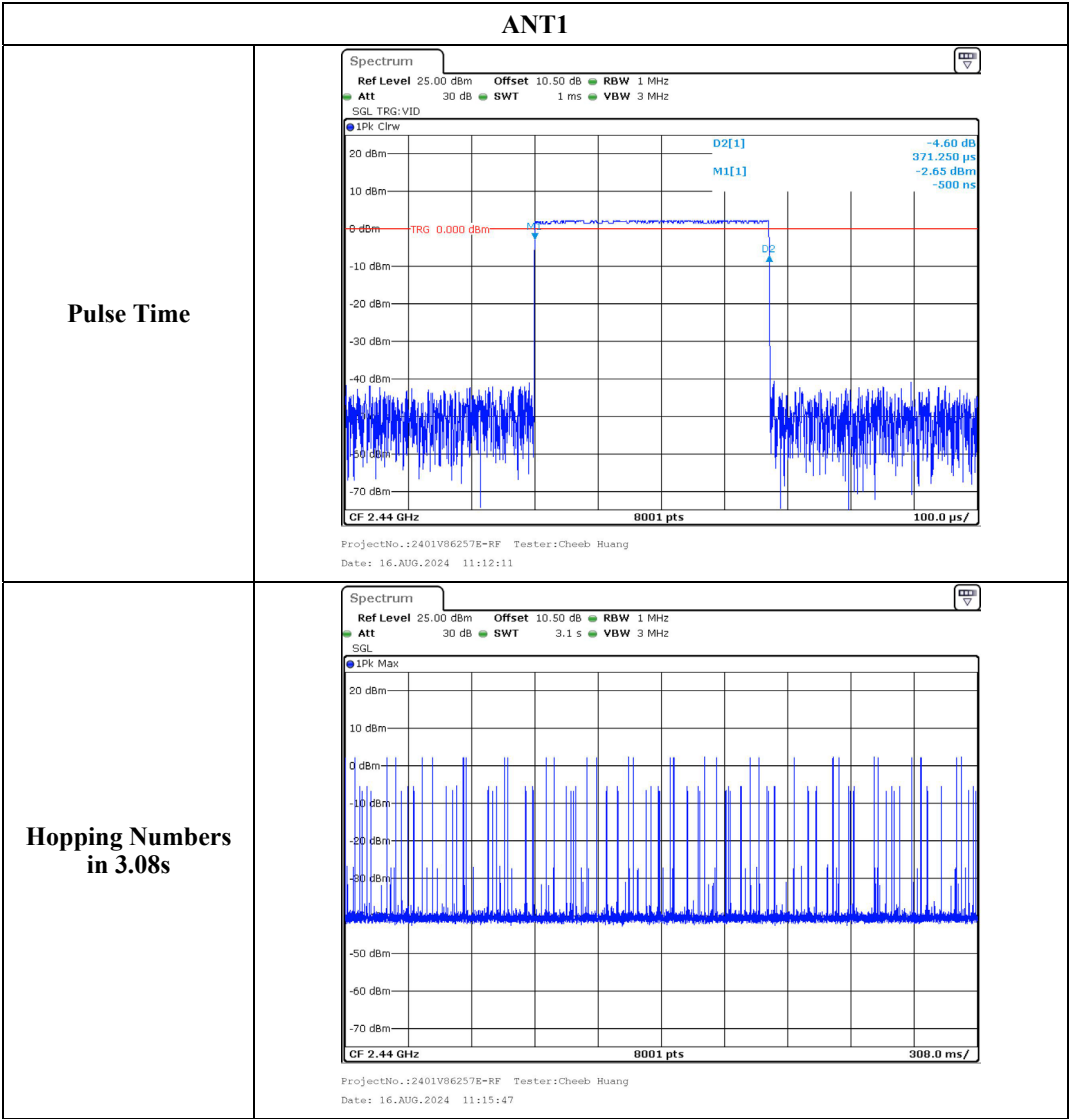
Temperature:	26.2 °C
Relative Humidity:	55 %
ATM Pressure:	101 kPa

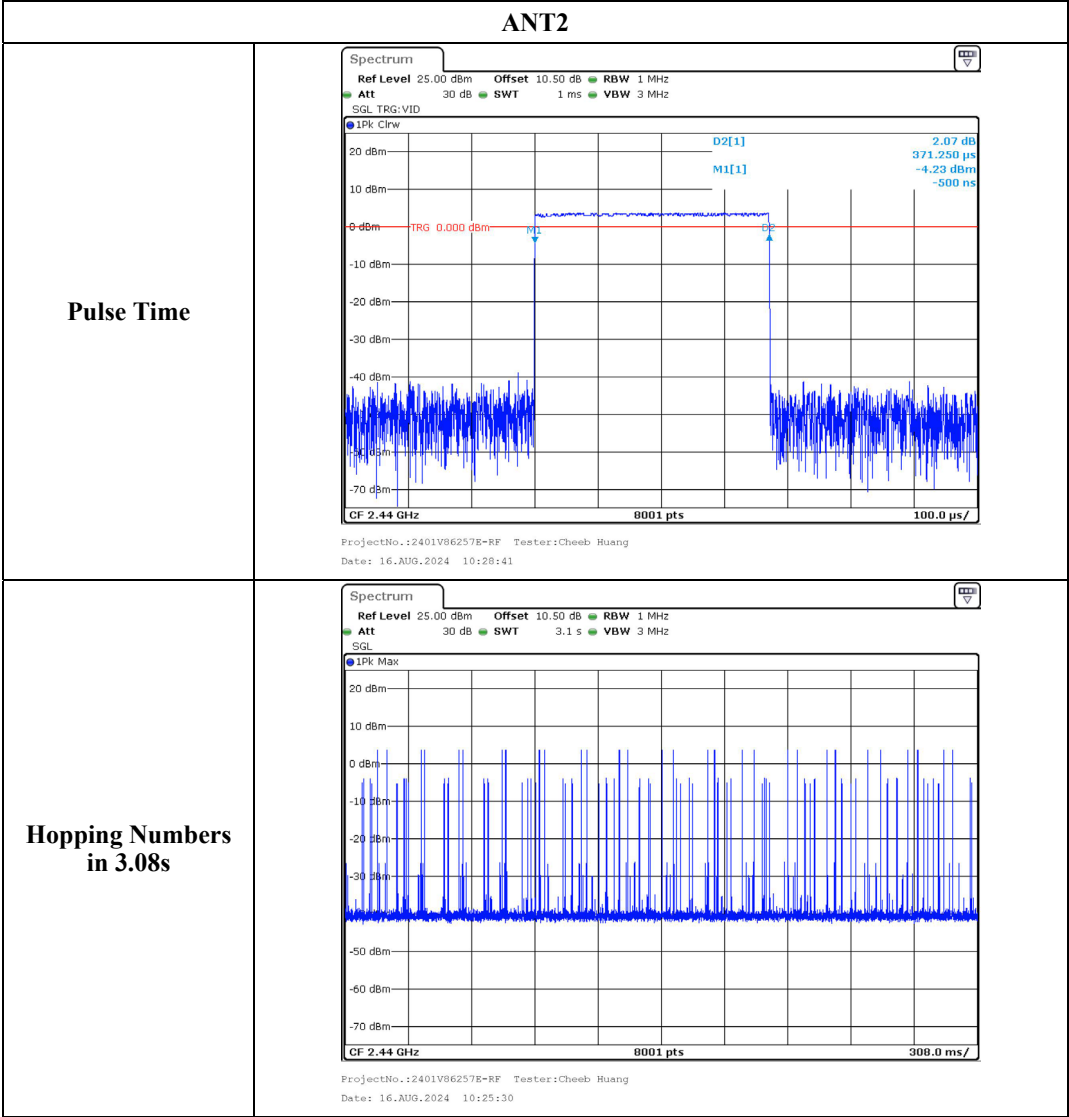
The testing was performed by Cheeb Huang on 2024-08-16.

EUT operation mode: Transmitting

Test Result: Compliant.

Antenna	Test Frequency (MHz)	Pulse Width (ms)	Observation Time (s)	Hopping Numbers in Observation time	Dwell Time (s)	Limit (s)
ANT1	2440	0.371	30.8	340	0.126	0.400
ANT2	2440	0.371	30.8	350	0.130	0.400
Note: Observation time= Hopping Channel Number× 0.4=77*0.4=30.8s Hopping Numbers in Observation time =Hopping Number in 3.08s*10 Dwell Time= Pulse Width* Hopping Numbers in Observation time						





FCC §15.247(b) (1) - PEAK OUTPUT POWER MEASUREMENT

Applicable Standard

According to §15.247(b) (1), for frequency hopping systems operating in the 2400–2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725–5850 MHz band: 1 watt. And for all other frequency hopping systems in the 2400–2483.5 MHz band: 0.125 watts.

Test Procedure

Test Method: ANSI C63.10-2013 Clause 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:

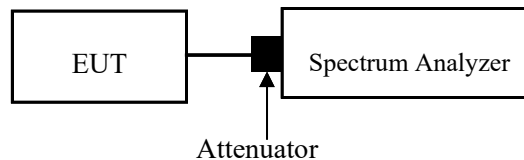
a) Use the following spectrum analyzer settings:

- 1) Span: Approximately five times the 20 dB bandwidth, centered on a hopping channel.
- 2) RBW > 20 dB bandwidth of the emission being measured.
- 3) VBW $\geq$ RBW.
- 4) Sweep: Auto.
- 5) Detector function: Peak.
- 6) Trace: Max hold.

b) Allow trace to stabilize.

c) Use the marker-to-peak function to set the marker to the peak of the emission.

d) The indicated level is the peak output power, after any corrections for external attenuators and cables.



Test Data

Environmental Conditions

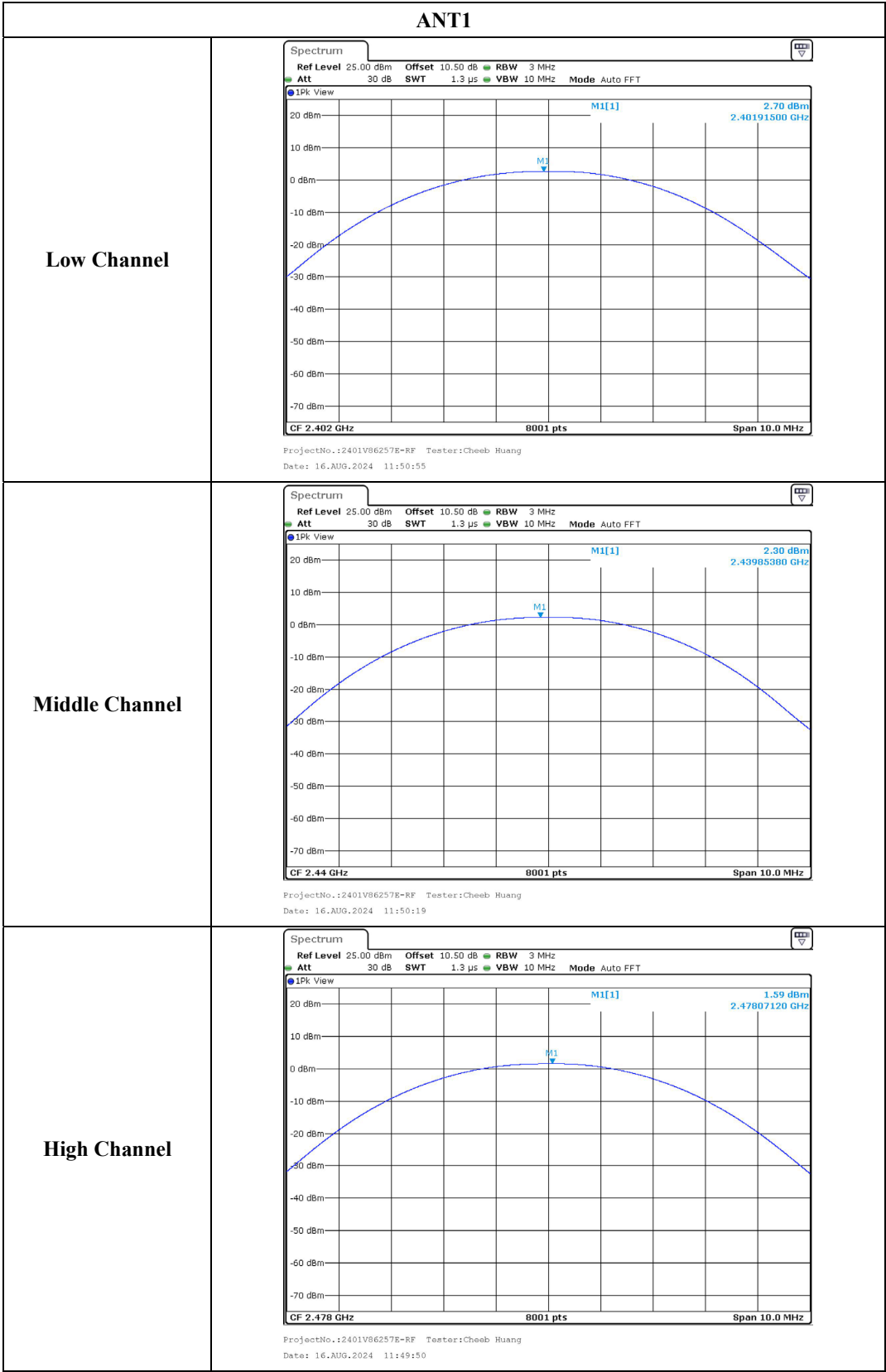
Temperature:	26.2 °C
Relative Humidity:	55 %
ATM Pressure:	101 kPa

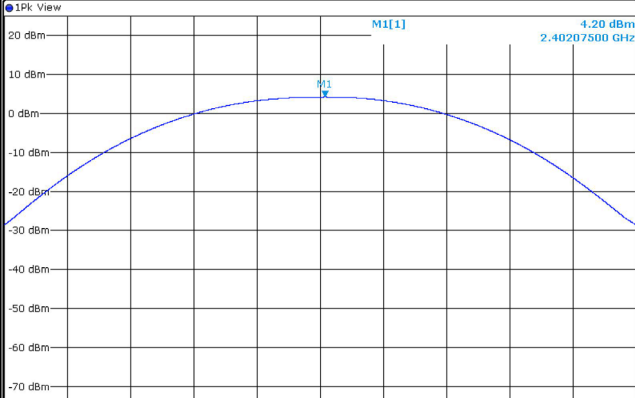
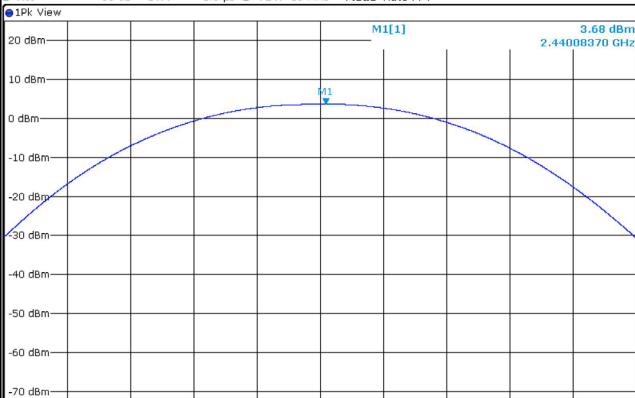
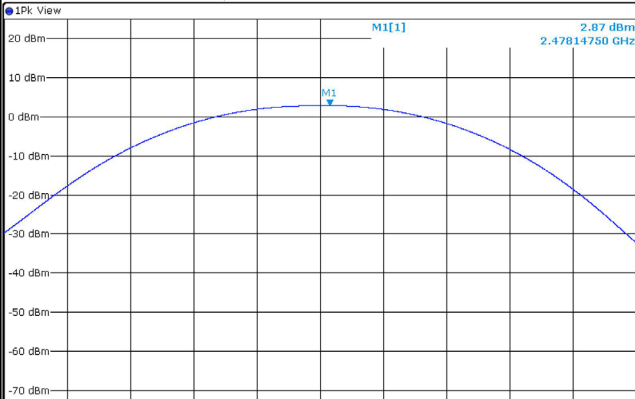
The testing was performed by Cheeb Huang on 2024-08-16.

EUT operation mode: Transmitting

Test Result: Compliant.

Antenna	Test Frequency (MHz)	Peak Conducted Output Power (dBm)	Limits (dBm)
ANT1	2402	2.70	21
	2440	2.30	21
	2478	1.59	21
ANT2	2402	4.20	21
	2440	3.68	21
	2478	2.87	21



ANT2 Low Channel	Spectrum Ref Level 25.00 dBm Att 30 dB Offset 10.50 dB SWT 1.3 μs RBW 3 MHz VBW 10 MHz Mode Auto FFT 1Pk View M1[1] 4.20 dBm 2.40207500 GHz  CF 2.402 GHz 8001 pts Span 10.0 MHz ProjectNo.:2401V86257E-RF Tester:Cheeb Huang Date: 16.AUG.2024 09:23:26
Middle Channel	Spectrum Ref Level 25.00 dBm Att 30 dB Offset 10.50 dB SWT 1.3 μs RBW 3 MHz VBW 10 MHz Mode Auto FFT 1Pk View M1[1] 3.68 dBm 2.44008370 GHz  CF 2.44 GHz 8001 pts Span 10.0 MHz ProjectNo.:2401V86257E-RF Tester:Cheeb Huang Date: 16.AUG.2024 09:25:14
High Channel	Spectrum Ref Level 25.00 dBm Att 30 dB Offset 10.50 dB SWT 1.3 μs RBW 3 MHz VBW 10 MHz Mode Auto FFT 1Pk View M1[1] 2.87 dBm 2.47814750 GHz  CF 2.478 GHz 8001 pts Span 10.0 MHz ProjectNo.:2401V86257E-RF Tester:Cheeb Huang Date: 16.AUG.2024 09:25:47

FCC §15.247(d) § 5.5 - BAND EDGES TESTING

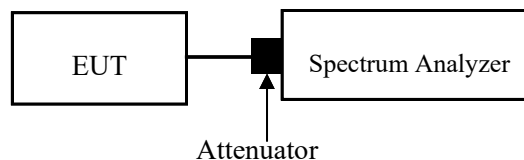
Applicable Standard

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator 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 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 paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

Test Procedure

Test Method: ANSI C63.10-2013 Clause 7.8.6 & Clause 6.10

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Remove the antenna from the EUT and then connect to a low loss RF cable from the antenna port to a EMI test receiver, then turn on the EUT and make it operate in transmitting mode. Then set it to Low Channel and High Channel within its operating range, and make sure the instrument is operated in its linear range.
3. Set RBW of spectrum analyzer to 100 kHz with a convenient frequency span including 100 kHz bandwidth from band edge.
4. Measure the highest amplitude appearing on spectral display and set it as a reference level. Plot the graph with marking the highest point and edge frequency.
5. Repeat above procedures until all measured frequencies were complete.



Test Data

Environmental Conditions

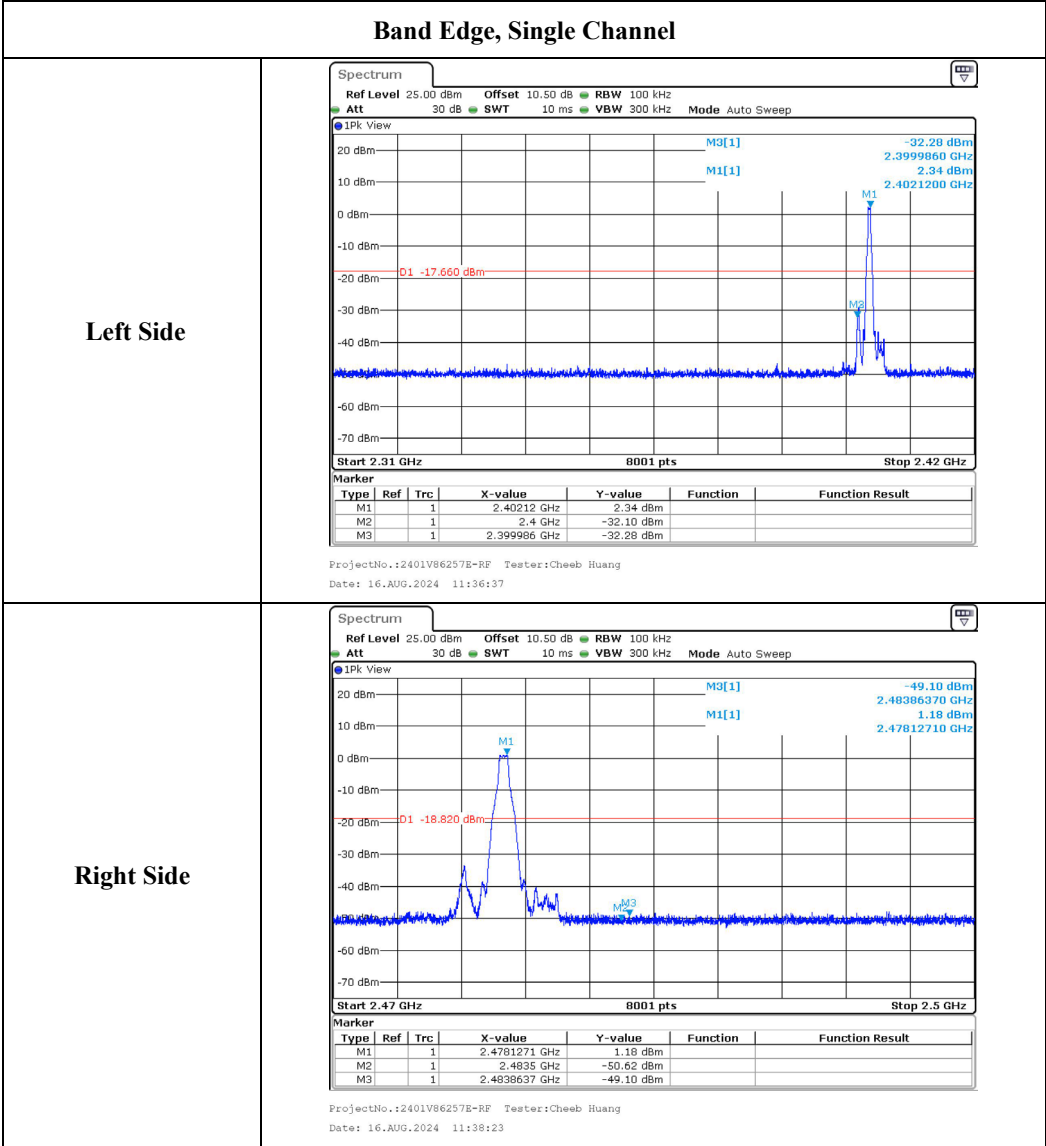
Temperature:	26.2~26.8 °C
Relative Humidity:	55~59 %
ATM Pressure:	101 kPa

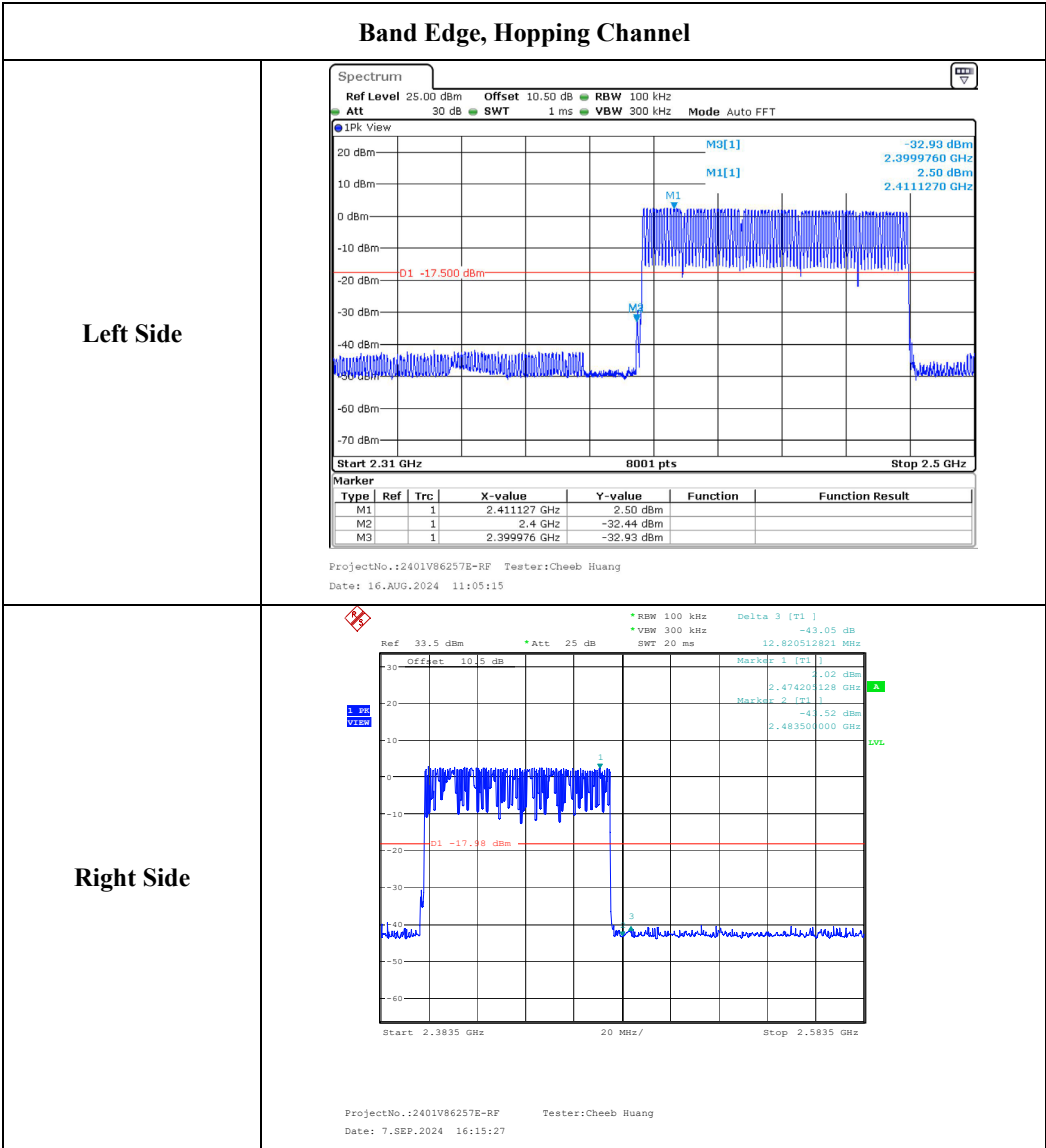
The testing was performed by Cheeb Huang from 2024-08-16 to 2024-09-07.

EUT operation mode: Transmitting

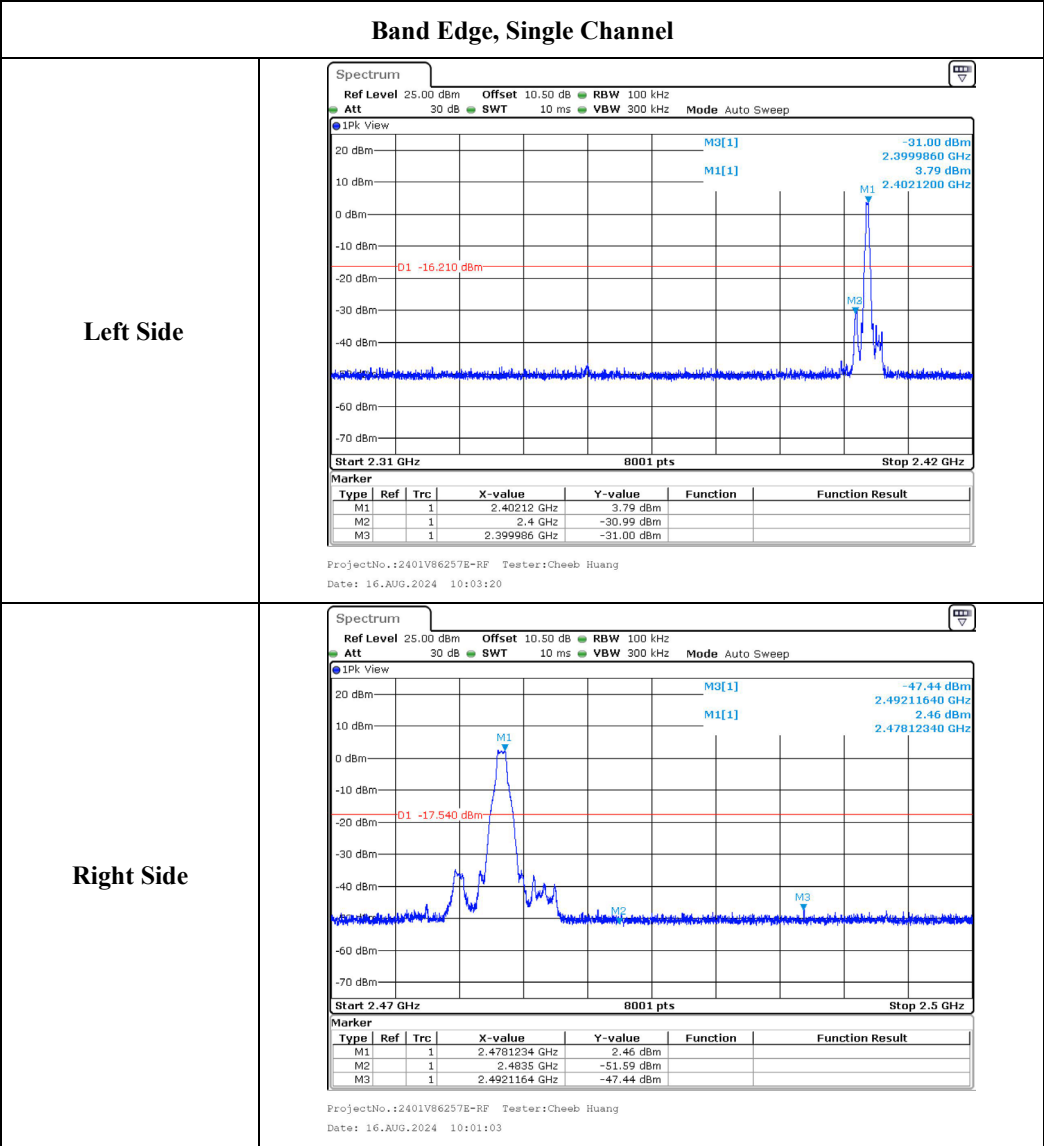
Test Result: Compliant.

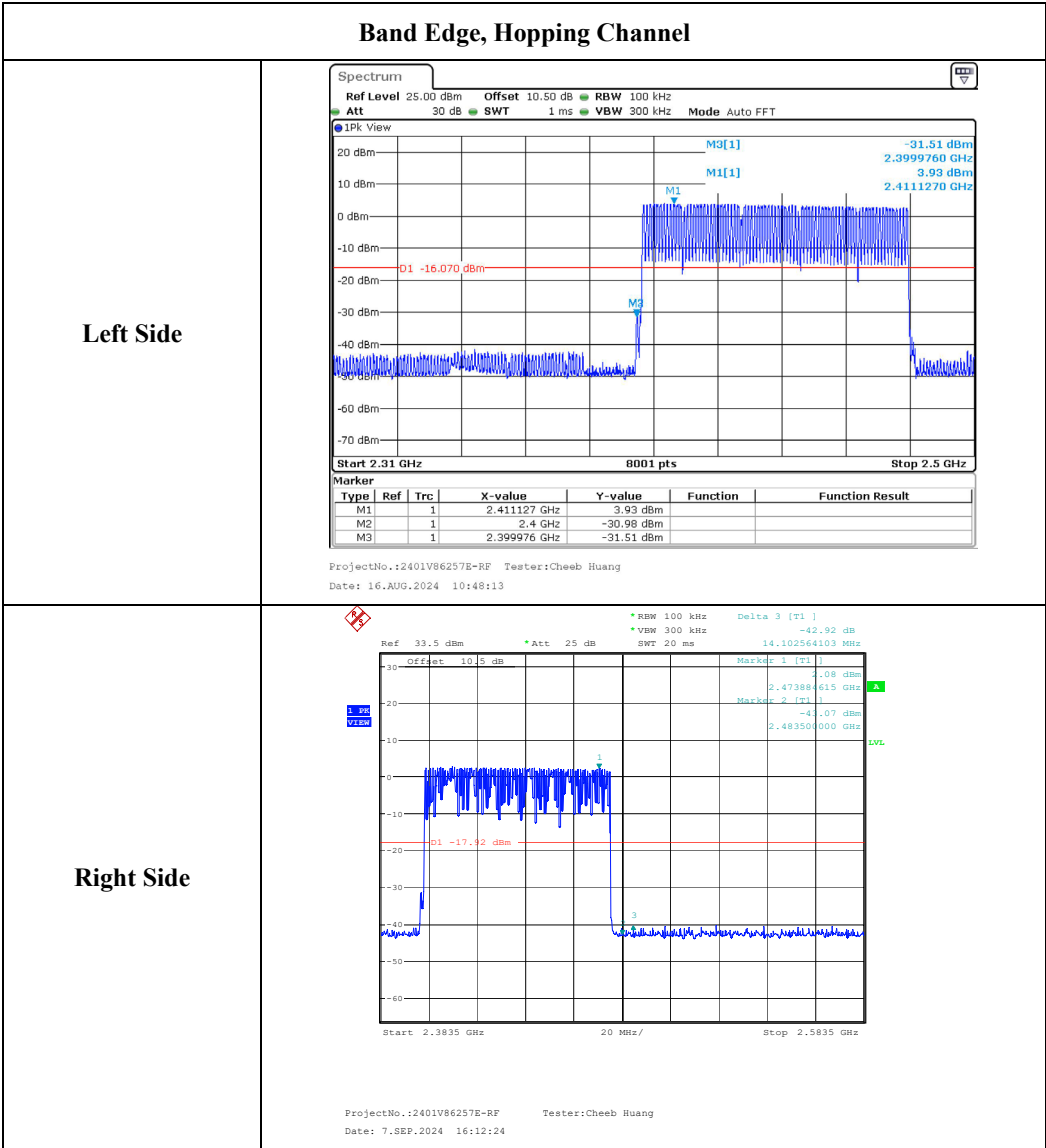
ANT1





ANT2





EUT PHOTOGRAPHS

Please refer to the attachment 2401V86257E-RF External photo and 2401V86257E-RF Internal photo.

TEST SETUP PHOTOGRAPHS

Please refer to the attachment 2401V86257E-RFA Test Setup photo.

******* END OF REPORT *******