

11. Time of Occupancy (Dwell Time) test

11.1 Test Description

The Equipment Under Test (EUT) was set up to perform the dwell time measurements. The EUT was connected to the spectrum analyzer via a short coax cable. The dwell time is calculated by:

$$\text{Dwell time} = \text{time slot length} * \text{hop rate} / \text{number of hopping channels} * 31.6\text{s}$$

with:

- hop rate = $1600 * 1/\text{s}$ for DH1 packets = 1600 s^{-1}
- hop rate = $1600/3 * 1/\text{s}$ for DH3 packets = 533.33 s^{-1}
- number of hopping channels = 79
- $31.6 \text{ s} = 0.4 \text{ seconds multiplied by the number of hopping channels} = 0.4 \text{ s} * 79$

The highest value of the dwell time is reported.

11.2 Test SET-UP (Block Diagram of Configuration)



11.3 Measurement Equipment Used:

EQUIPMENT TYPE	MFR	MODEL NUMBER	SERIAL NUMBER	Characteristics	LAST CAL.	CAL DUE.
Spectrum Analyzer	Rohde & Schwarz	FSV30	1321.3008K	10Hz-30GHz	05/16/2018	05/15/2019
Coaxial Cable	CDS	79254	46107086	10Hz-30GHz	05/16/2018	05/15/2019
Antenna Connector	ARTHUR-YANG	2244-N1TG1	N/A	10Hz-30GHz	05/16/2018	05/15/2019

Remark: The temporary antenna connector is soldered on the PCB board in order to perform conducted tests and this temporary antenna connector is listed in the equipment list.

11.4 Test Requirements / Limits

FCC Part 15, Subpart C, §15.247 (a) (1) (iii)

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. Since the Bluetooth technology uses 79 channels this period is calculated to be 31.6seconds. Refer to attached data chart.

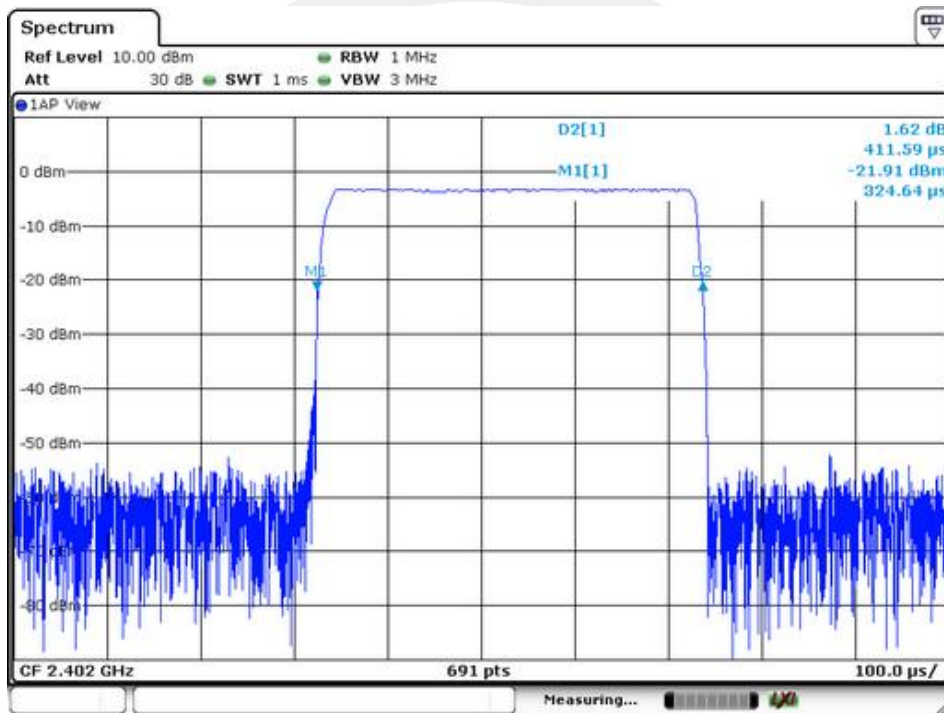
11.5 Test result

GFSK:

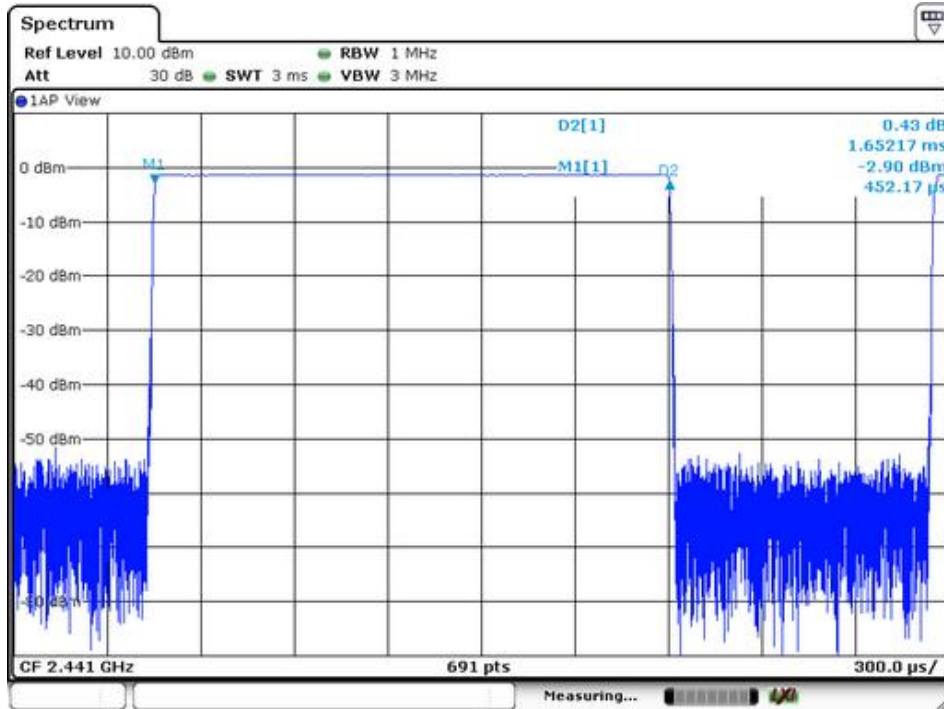
Mode	Number of transmission in a 31.6(79 Hopping*0.4)	Length of transmissions time(msec)	Result (msec)	Limit (msec)
DH1	$1600/(2*79) \times 31.6 = 320$	0.412	131.84	400
DH3	$1600/(4*79) \times 31.6 = 160$	1.652	264.32	400
DH5	$1600/(6*79) \times 31.6 = 106.67$	2.906	309.98	400

Remark: The results of worst cased was recorded.

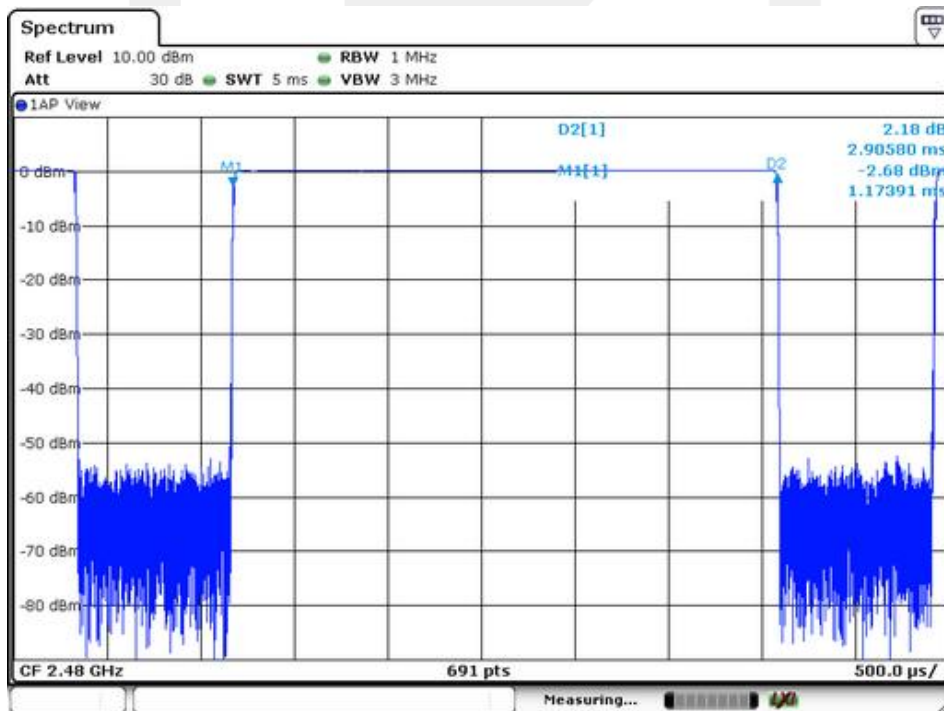
DH1:



DH3:



DH5:



12. MAXIMUM PEAK OUTPUT POWER TEST

12.1 Measurement Procedure

- a. Check the calibration of the measuring instrument(SA) using either an internal calibrator or a known signal from an external generator.
- b. Turn on the EUT and connect it to measurement instrument. Then set it to any one convenient frequency within its operating range. Set a reference level on the measuring instrument equal to the highest peak value.
- c. The center frequency of the spectrum analyzer is set to the fundamental frequency and using proper RBW and VBW setting.
- d. Measure the captured power within the band and recording the plot.
- e. Repeat above procedures until all frequencies required were complete.

12.2 Test SET-UP (Block Diagram of Configuration)



12.3 Measurement Equipment Used:

EQUIPMENT TYPE	MFR	MODEL NUMBER	SERIAL NUMBER	Characteristics	LAST CAL.	CAL DUE.
Spectrum Analyzer	Rohde & Schwarz	FSV30	1321.3008K	10Hz-30GHz	05/23/2019	05/22/2020
Coaxial Cable	CDS	79254	46107086	10Hz-30GHz	05/23/2019	05/22/2020
Antenna Connector	ARTHUR-YANG	2244-N1TG1	N/A	10Hz-30GHz	05/23/2019	05/22/2020

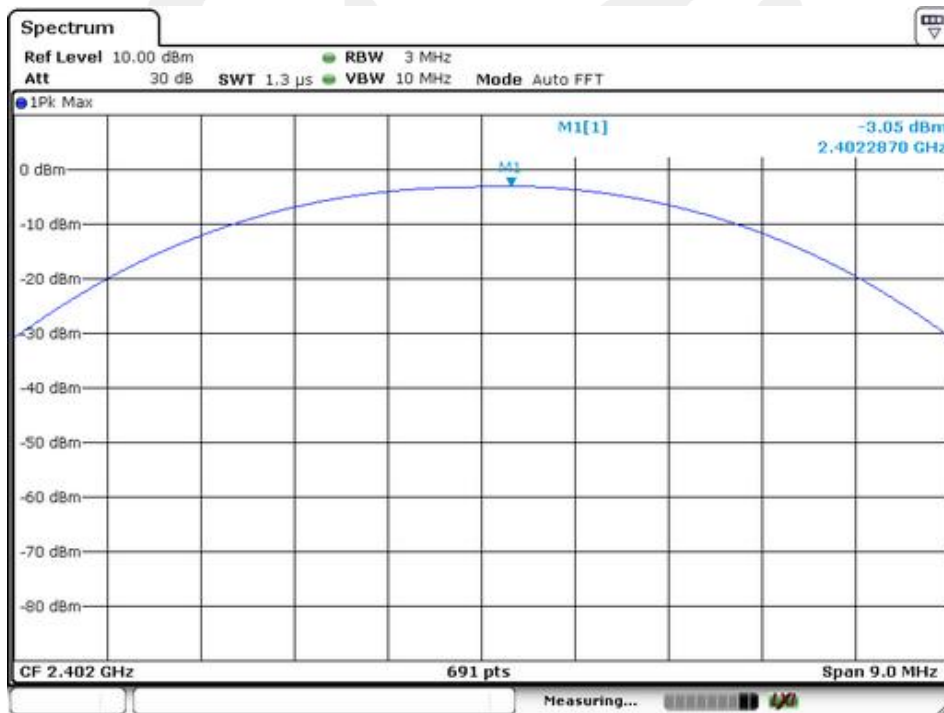
Remark: The temporary antenna connector is soldered on the PCB board in order to perform conducted tests and this temporary antenna connector is listed in the equipment list.

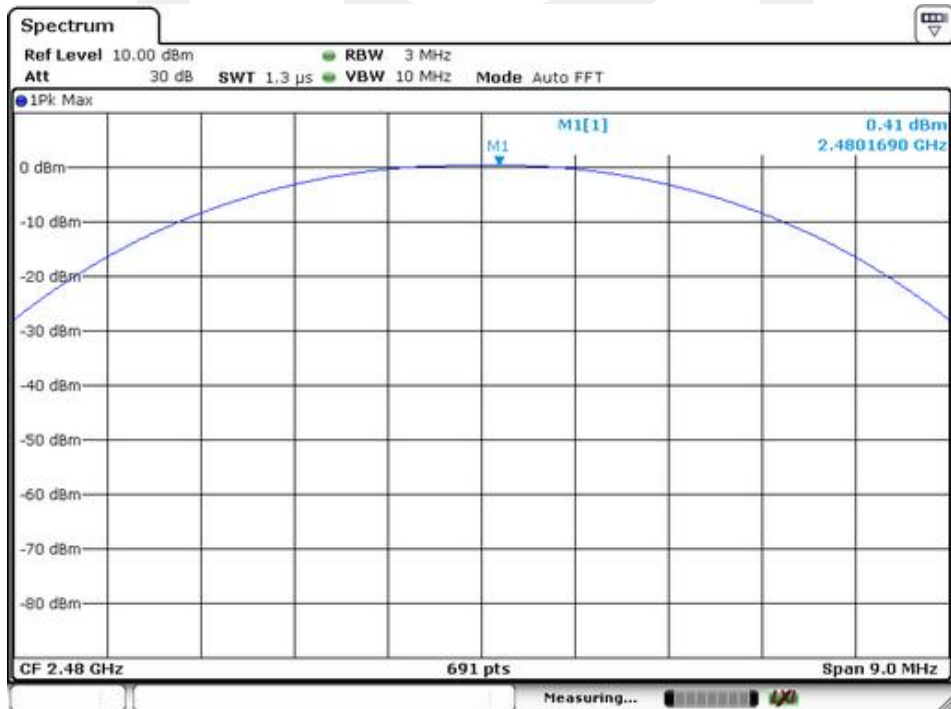
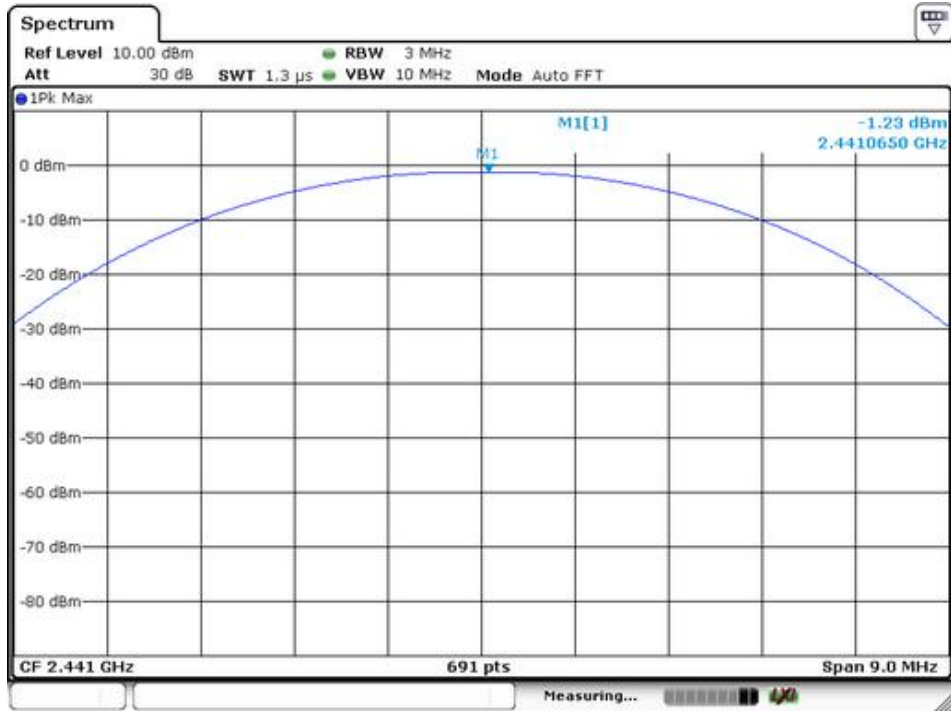
12.4 Measurement Results:

Refer to attached data chart.

Spectrum Detector:	PK	Test Date :	December 20, 2019
Test By:	Leon	Temperature :	24 °C
Test Result:	PASS	Humidity :	55 %
Modulation:	GFSK		

Channel number	Channel Frequency (MHz)	Peak Power output(dBm)	Peak Power output(mW)	Peak Power Limit(mW)	Pass/Fail
01	2402	-3.05	0.495	125	PASS
40	2441	-1.23	0.753	125	PASS
79	2480	0.41	1.099	125	PASS



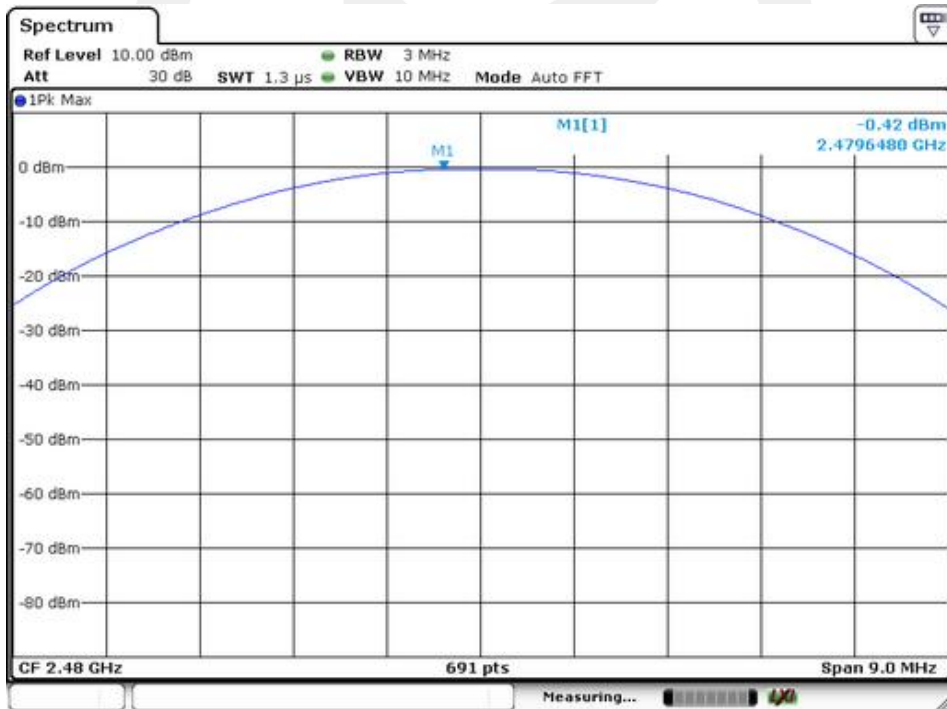


Spectrum Detector: PK
 Test By: Andy
 Test Result: PASS
 Modulation: $\pi/4$ -DQPSK

Test Date : December 20, 2019
 Temperature : 24 °C
 Humidity : 55 %

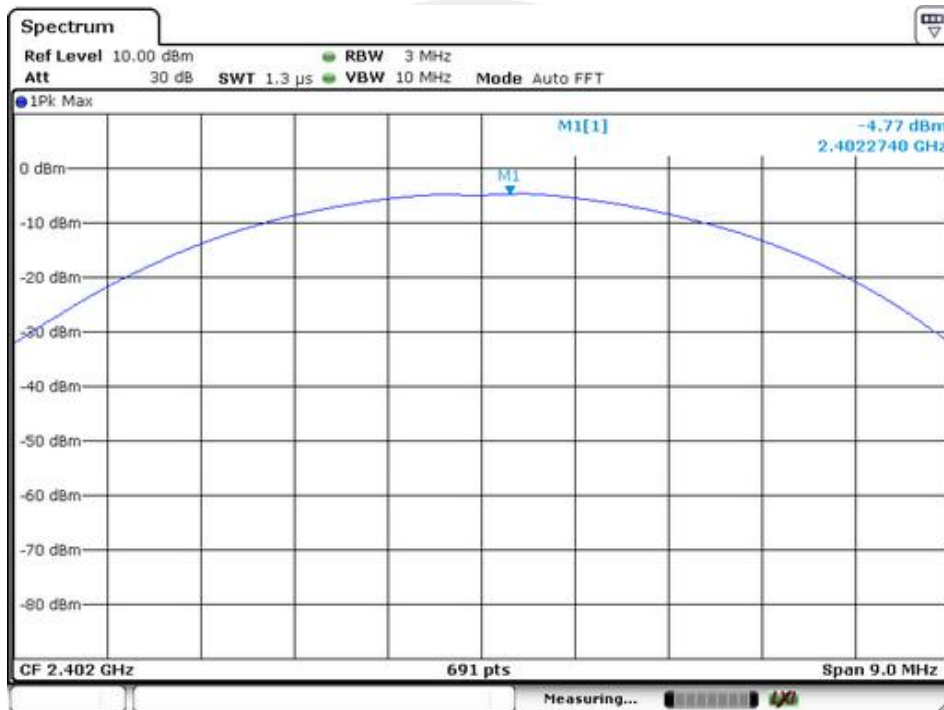
Channel number	Channel Frequency (MHz)	Peak Power output(dBm)	Peak Power output(mW)	Peak Power Limit(mW)	Pass/Fail
01	2402	-4.79	0.332	125	PASS
40	2441	-2.23	0.598	125	PASS
79	2480	-0.42	0.908	125	PASS

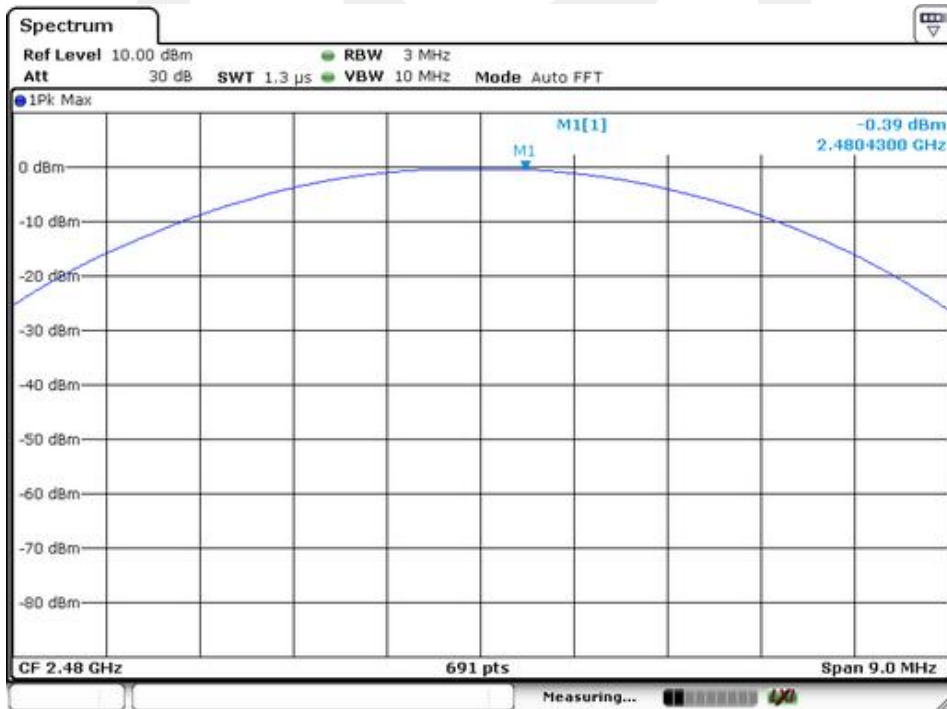
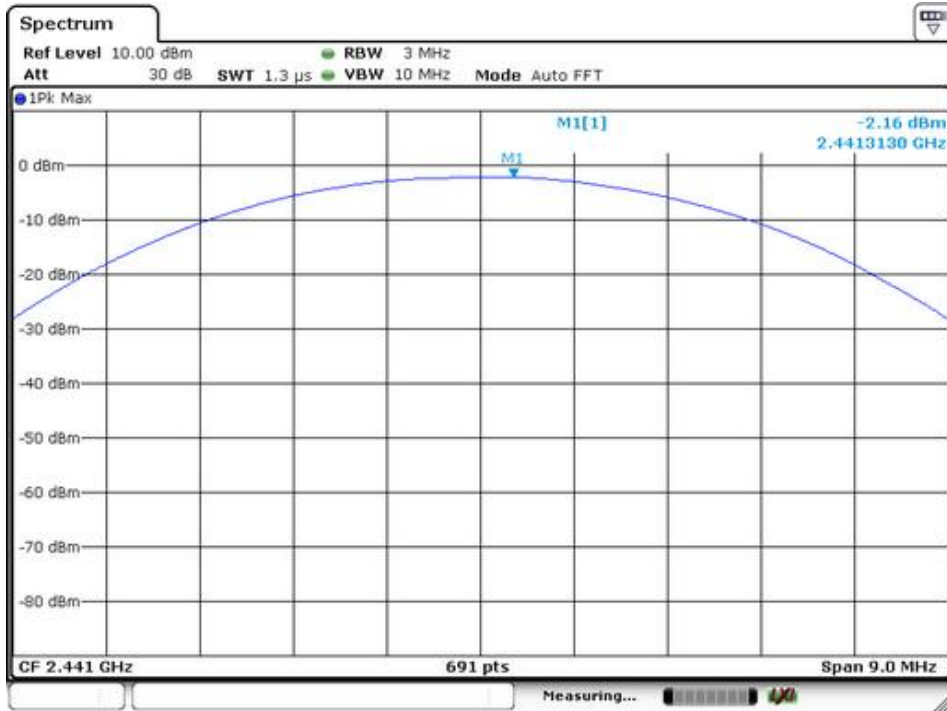




Spectrum Detector: PK
 Test By: Andy
 Test Result: PASS
 Modulation: 8DPSK

Test Date : December 20, 2019
 Temperature : 24 °C
 Humidity : 55 %





13. Band EDGE test

13.1 Measurement Procedure

For Conducted Test

1. The transmitter output is connected to a spectrum analyzer. The resolution bandwidth is set to 100KHz. The video bandwidth is set to 300KHz.
2. The spectrum from 30MHz to 26 GHz is investigated with the transmitter set to the lowest, middle, and highest channels.

EMI Test Receiver	Setting
Attenuation	Auto
RBW	100KHz
VBW	300KHz
Detector	Peak
Trace	Max hold

For Radiated emission Test

The EUT was placed on a styrofoam table which is 1.5m above ground plane.

The measurement procedure at the ban edges was simplified by performing the measurement in just one plot. Both, the in-band-emission and the unwanted emission were be encompassed by the span. After trace stabilization, the maximum peak was be determined by a peak detector and the value was marked by an appropriate limit line. The second limit line, which is 20dB below the first, marks the limit for the emissions in the unrestricted band. A maximum-peak-detector marks the highest emission in the unrestricted band next to the band edge.

The measurements were performed at the lower end of the 2.4GHz band.

Use the following spectrum analyzer settings:

For Restricted Band, When spectrum scanned above 1GHz setting resolution bandwidth 1MHz, video bandwidth 3MHz:

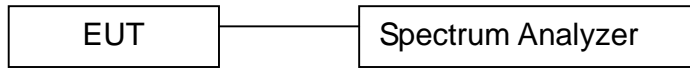
EMI Test Receiver	Setting
Attenuation	Auto
RBW	1MHz
VBW	3MHz
Detector	Peak
Trace	Max hold

For Non-Restricted Band, When spectrum scanned above 1GHz setting resolution bandwidth 100KHz, video bandwidth 300KHz:

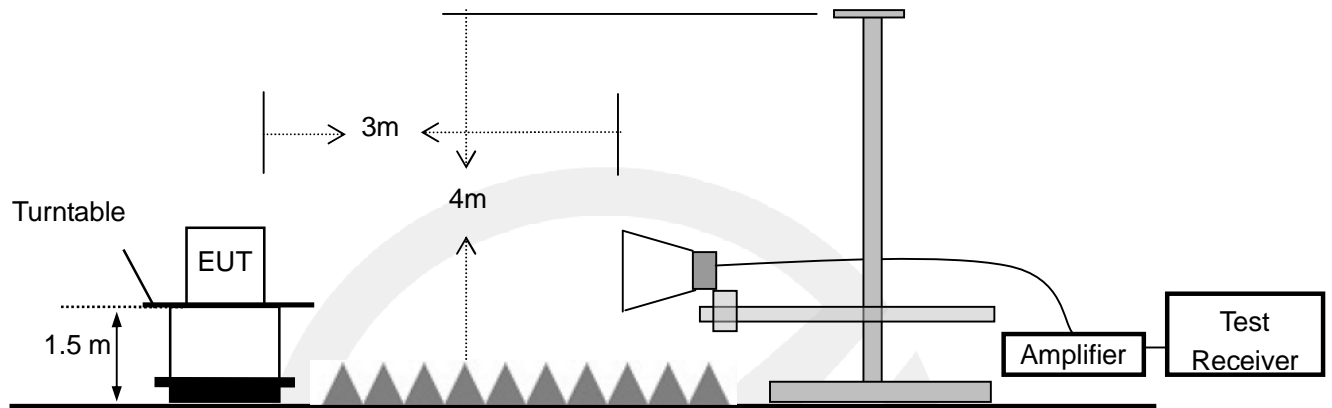
EMI Test Receiver	Setting
Attenuation	Auto
RBW	100KHz
VBW	300KHz
Detector	Peak
Trace	Max hold

13.2 Test SET-UP (Block Diagram of Configuration)

For Conducted Test



For Radiated emission Test



13.3 Measurement Equipment Used:

For Conducted Test

EQUIPMENT TYPE	MFR	MODEL NUMBER	SERIAL NUMBER	Characteristics	LAST CAL.	CAL DUE.
Spectrum Analyzer	Rohde & Schwarz	FSV30	1321.3008K	10Hz-30GHz	05/23/2019	05/22/2020
Coaxial Cable	CDS	79254	46107086	10Hz-30GHz	05/23/2019	05/22/2020
Antenna Connector	ARTHUR-YANG	2244-N1TG1	N/A	10Hz-30GHz	05/23/2019	05/22/2020

Remark: The temporary antenna connector is soldered on the PCB board in order to perform conducted tests and this temporary antenna connector is listed in the equipment list.

For Radiated emission Test

Item	Equipment	Manufacturer	Model No.	Serial No.	Characteristics	Last Cal.	Cal. Interval
1	Signal Analyzer	Rohde & Schwarz	FSV30	103040	9KHz-40GHz	05/23/2019	1 Year
2	Horn Antenna	Schwarzbeck	BBHA9120D	9120D-1272	1GHz-18GHz	05/23/2019	1 Year
3	Power Amplifier	LUNAR EM	LNA1G18-40	J10100000081	1GHz-26.5GHz	05/23/2019	1 Year
4	Cable	H+S	CBL-26	N/A	1GHz-26.5GHz	05/23/2019	1 Year
5	Cable	H+S	CBL-26	N/A	1GHz-26.5GHz	05/23/2019	1 Year
6	Cable	H+S	CBL-26	N/A	1GHz-26.5GHz	05/23/2019	1 Year

13.4 Measurement Results:

Refer to attached data chart.

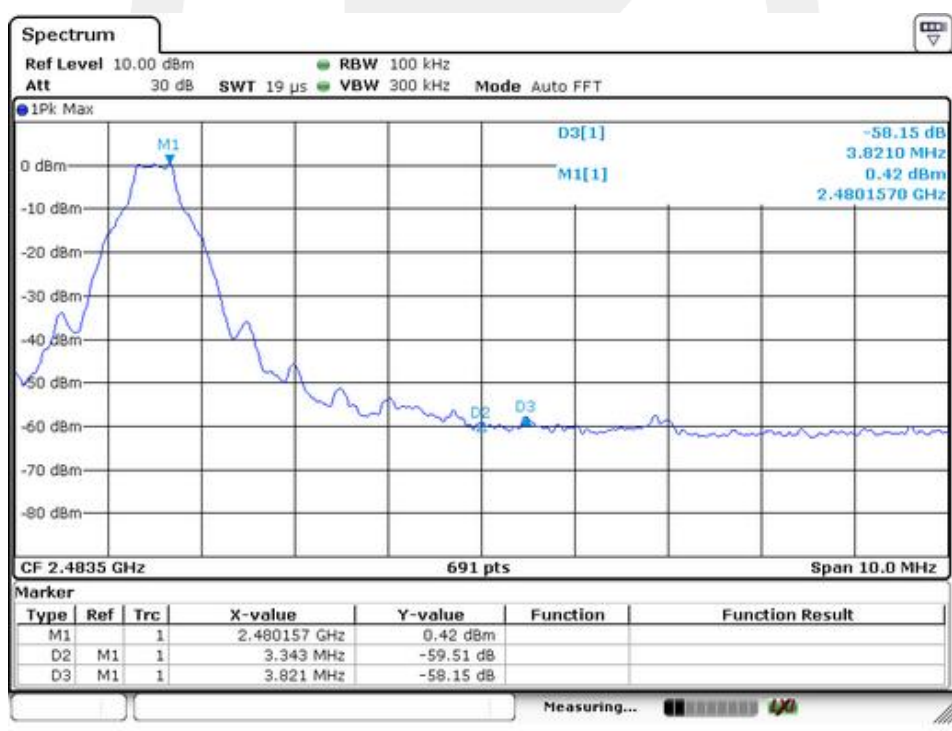
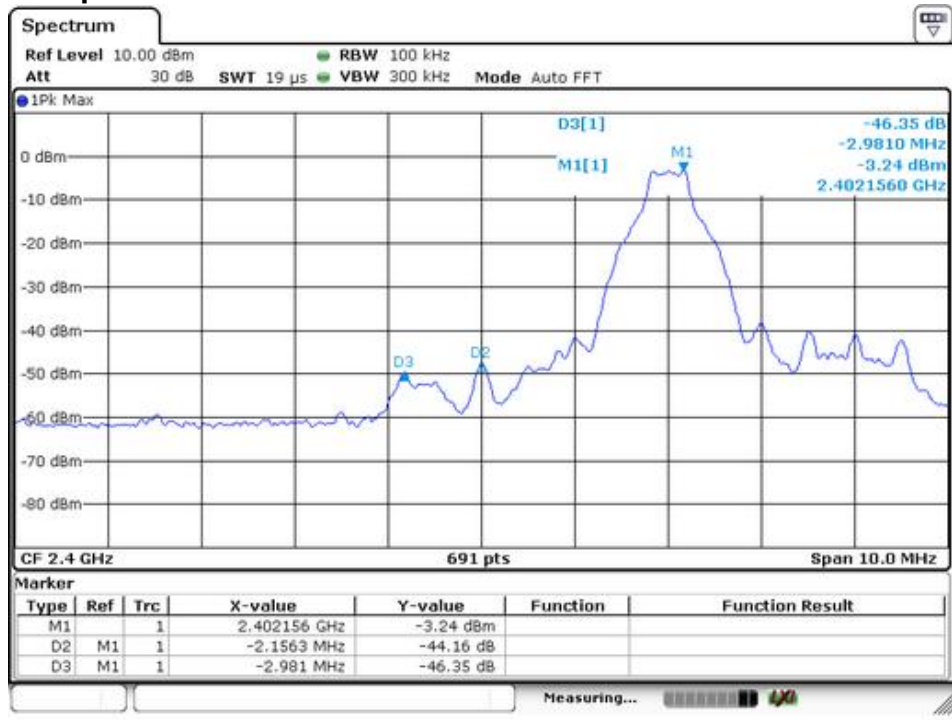
Spectrum Detector:	PK	Test Date :	December 20, 2019
Test By:	Andy	Temperature :	24 °C
Test Result:	PASS	Humidity :	58 %

1. Conducted Test

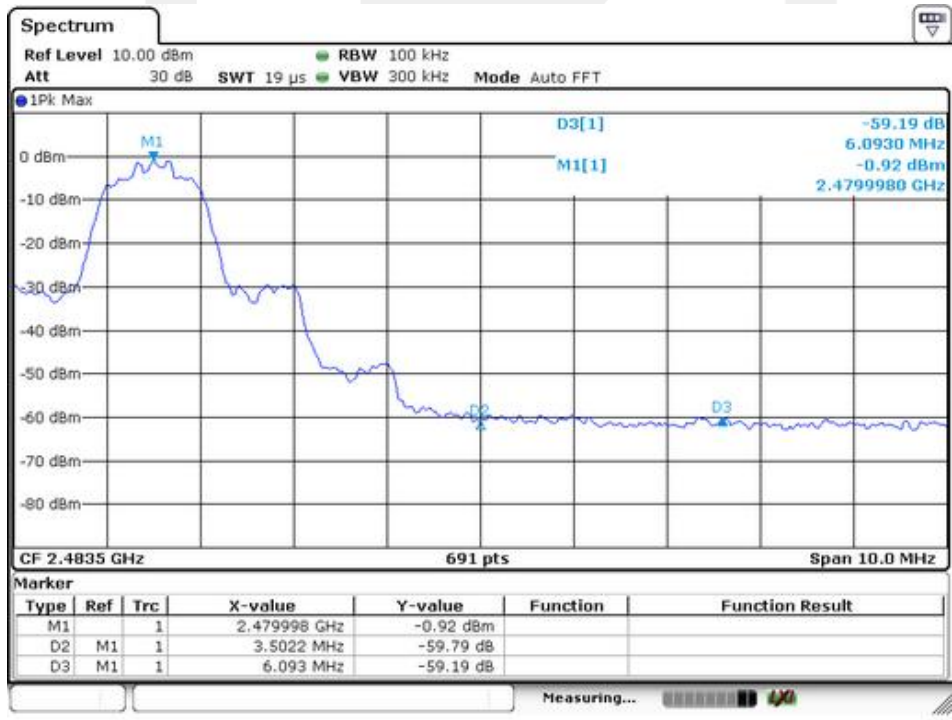
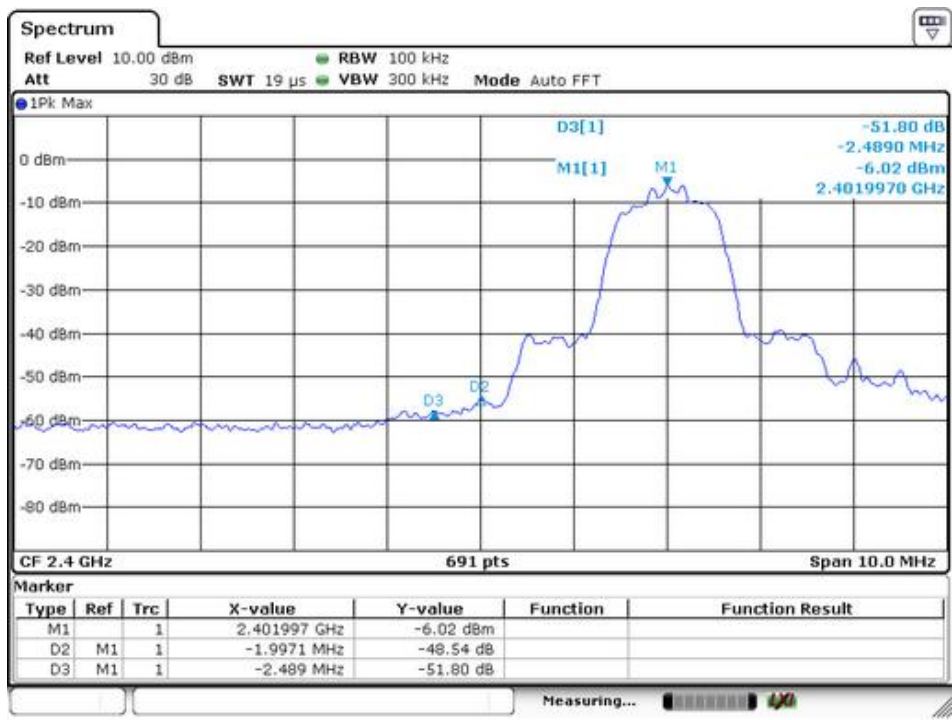
For Non-Hopping Mode:

Frequency (MHz)	Modulation	Peak Power Output(dBm)	Result of Band edge(dBc)	Band edge Limit(dBc)
2402	GFSK	-3.24	46.35	>20dBc
2402	pi/4-DQPSK	-6.02	51.8	>20dBc
2402	8DPSK	-5.93	51.36	>20dBc
2480	GFSK	0.42	58.15	>20dBc
2480	pi/4-DQPSK	-0.92	59.19	>20dBc
2480	8DPSK	-0.85	58.06	>20dBc

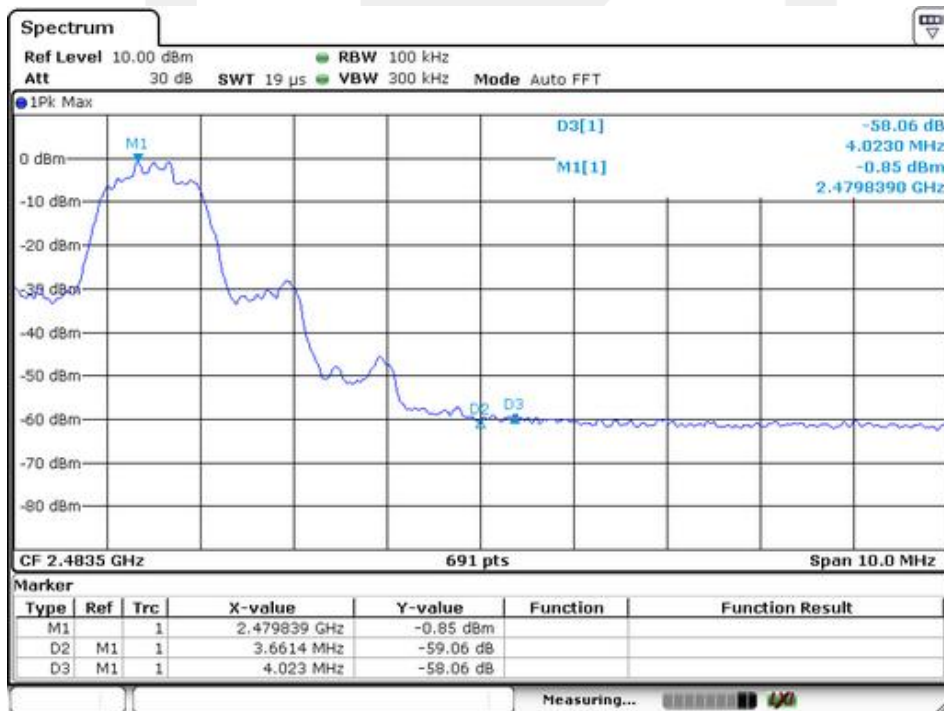
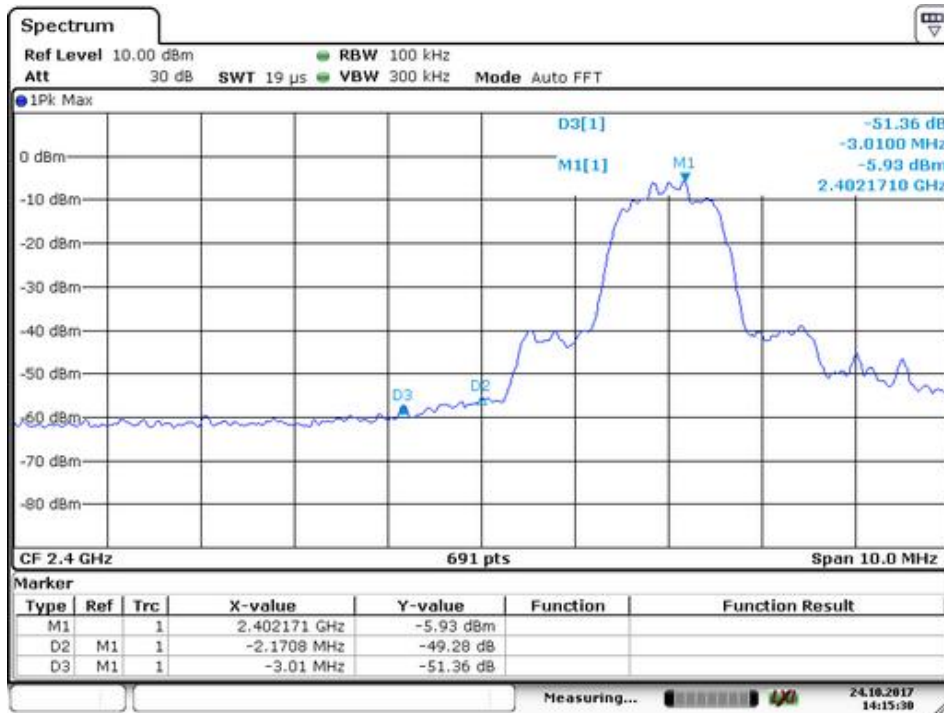
Test plots of GFSK



Test plots of pi/4-DQPSK



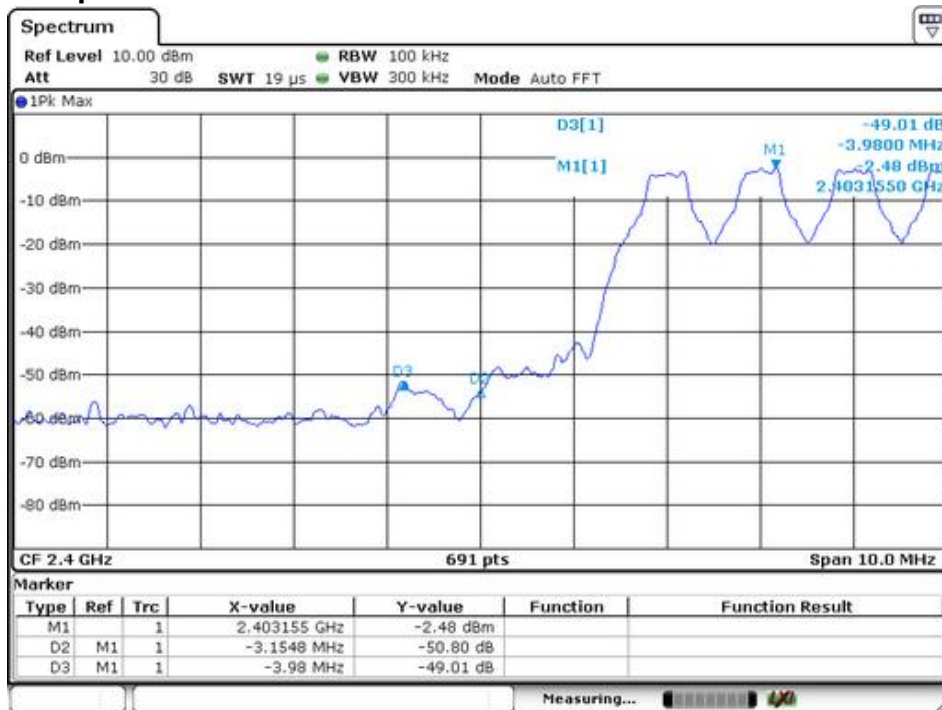
Test plots of 8DPSK

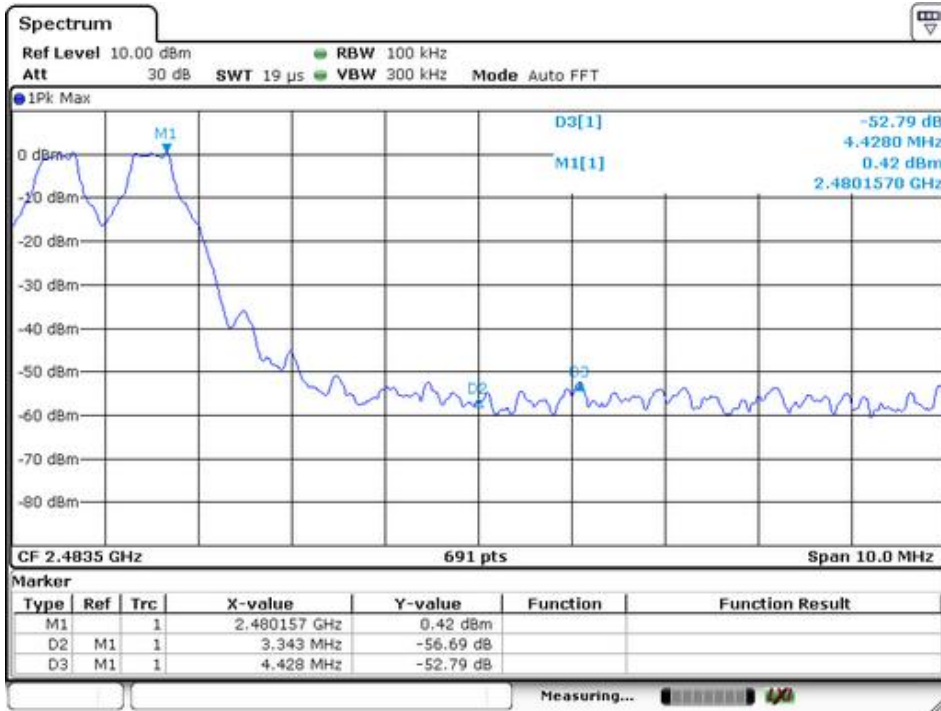


For Hopping Mode:

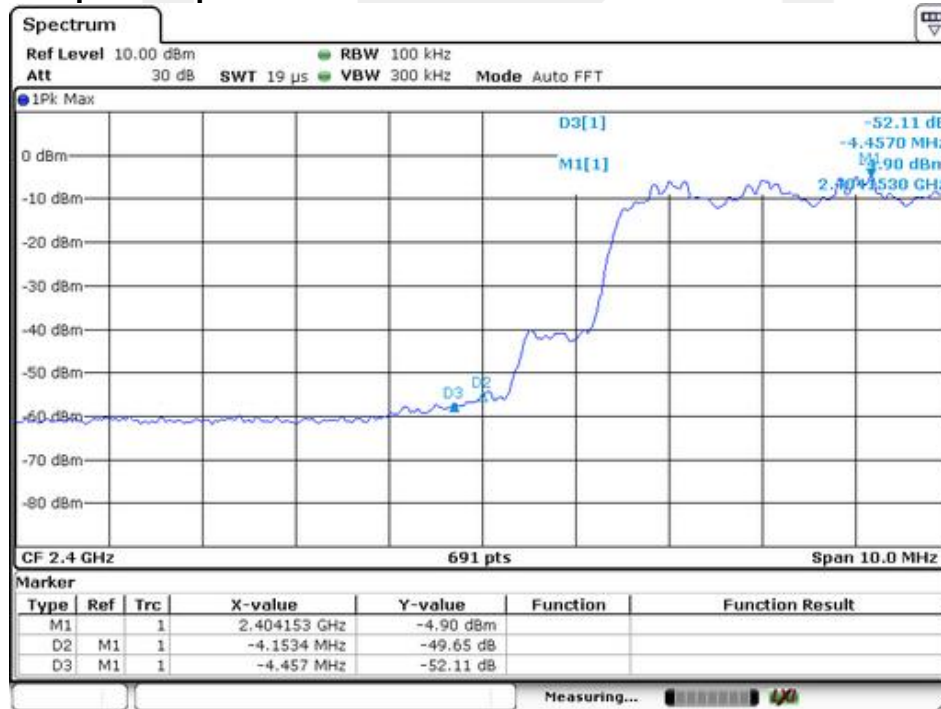
Frequency (MHz)	Modulation	Peak Power Output(dBm)	Result of Band edge(dBc)	Band edge Limit(dBc)
2396.86	GFSK	-2.48	49.01	>20dBc
2396.93	pi/4-DQPSK	-4.9	52.11	>20dBc
2396.87	8DPSK	-5.02	52.68	>20dBc
2484.53	GFSK	0.42	52.79	>20dBc
2484.75	pi/4-DQPSK	-0.98	56.01	>20dBc
2484.53	8DPSK	-0.85	56.32	>20dBc

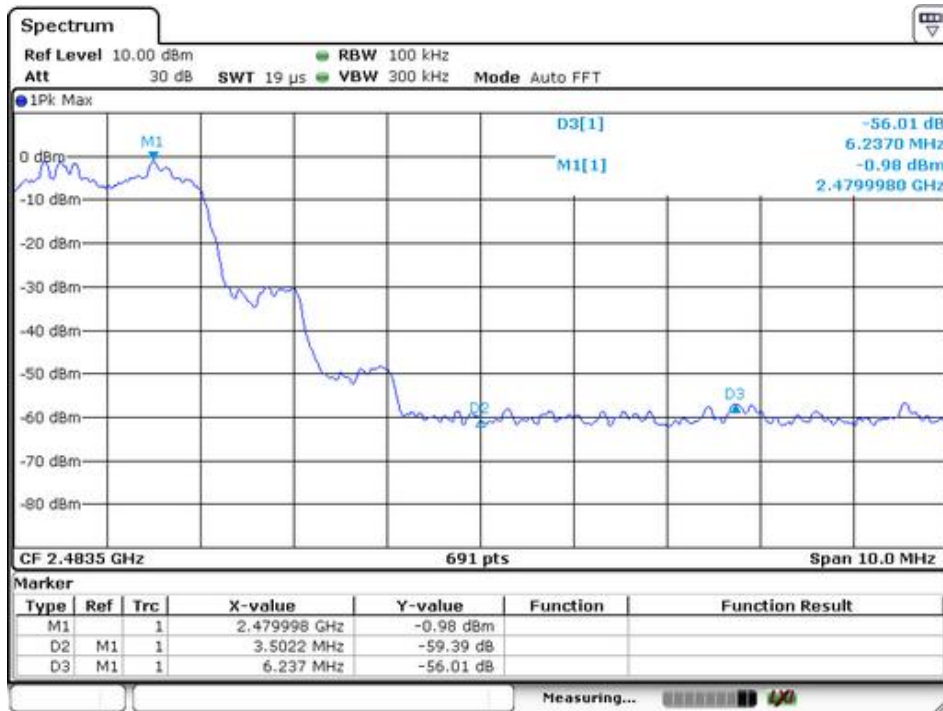
Test plots of GFSK



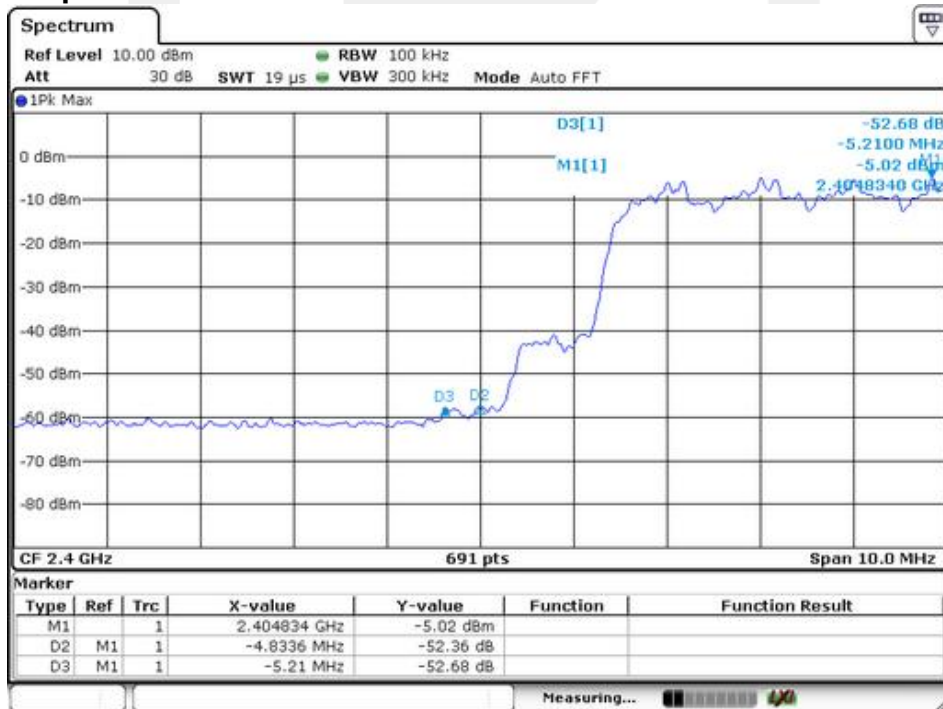


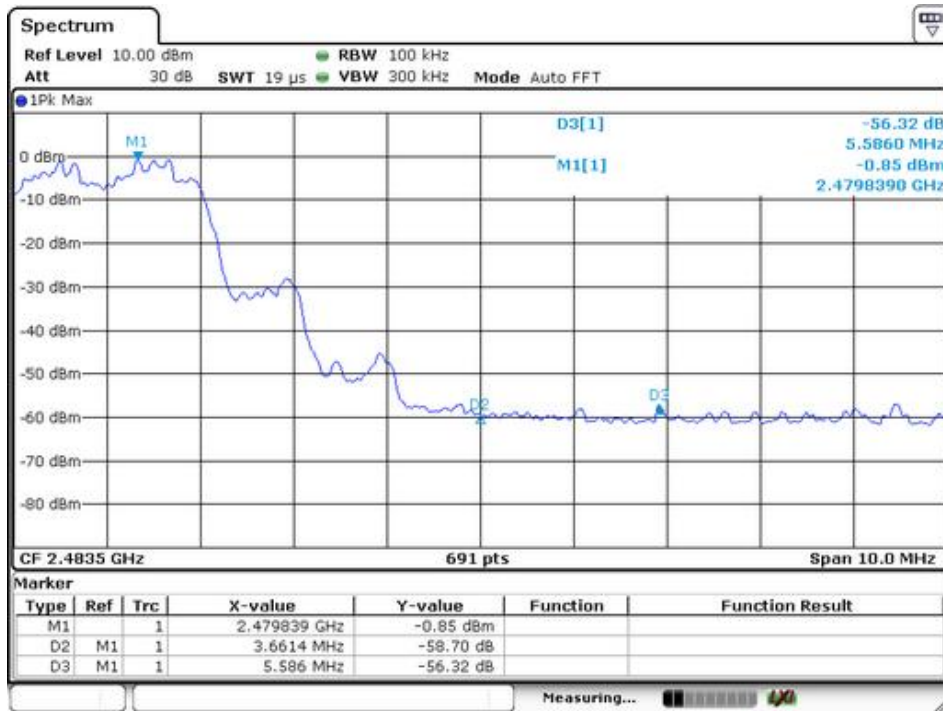
Test plots of pi/4-DQPSK



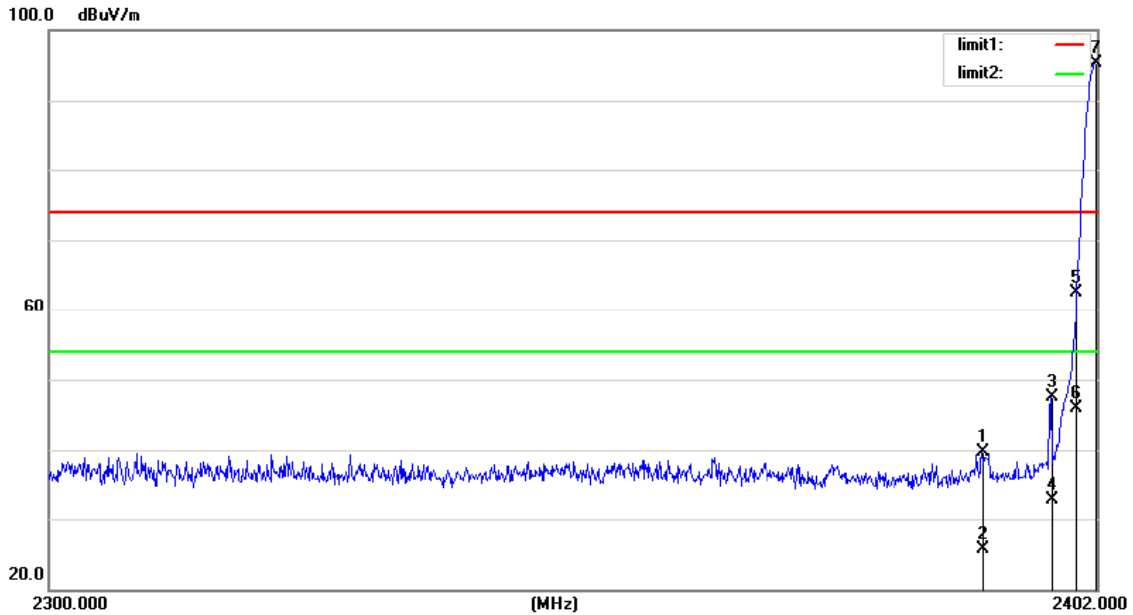


Test plots of 8DPSK





2. Radiated emission Test
Worst test modulation GFSK
 For Non-Hopping Mode:

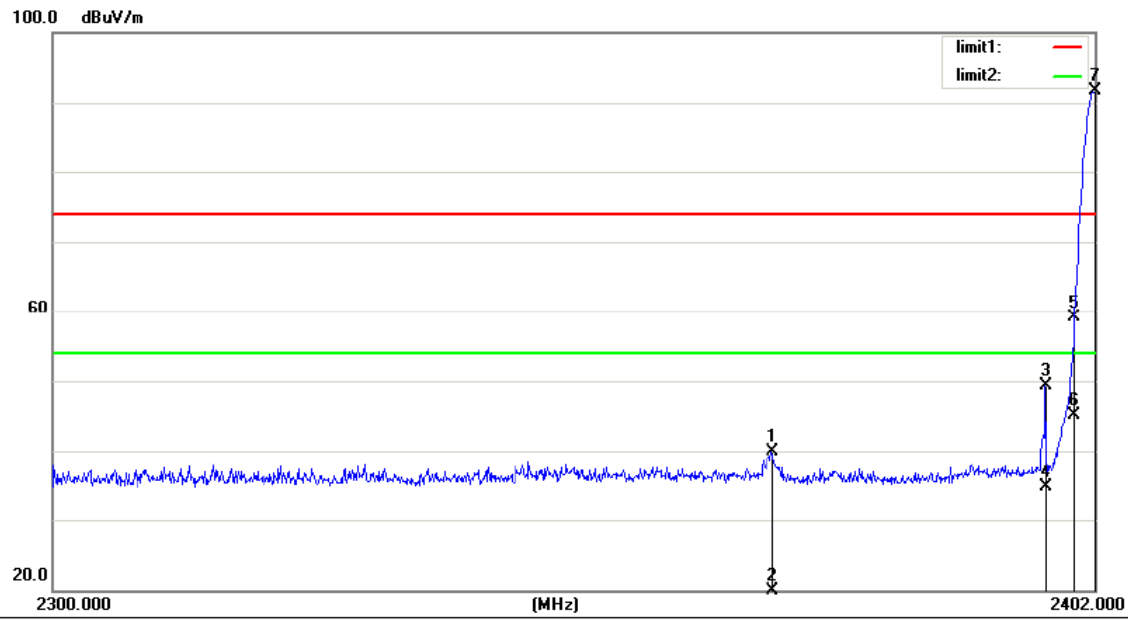


Site site #1 Polarization: **Horizontal** Temperature: 26
 Limit: (RE)FCC PART 15 C 3m_PEAK Power: Battery 3.7V Humidity: 55 %
 Mode:TX2402
 Note:

No.	Mk.	Freq.	Reading Level	Correct Factor	Measurement	Limit	Over	Antenna Height	Table Degree
		MHz	dBuV	dB	dBuV/m	dBuV/m	dB	cm	degree
1		2390.576	58.18	-18.55	39.63	74.00	-34.37	peak	0
2		2390.576	44.20	-18.55	25.65	54.00	-28.35	AVG	0
3		2397.614	66.05	-18.51	47.54	74.00	-26.46	peak	0
4		2397.614	51.26	-18.51	32.75	54.00	-21.25	AVG	0
5		2400.000	81.09	-18.50	62.59	74.00	-11.41	peak	0
6		2400.000	64.44	-18.50	45.94	54.00	-8.06	AVG	0
7	*	2401.796	113.73	-18.49	95.24	74.00	21.24	peak	0

*:Maximum data x:Over limit !:over margin

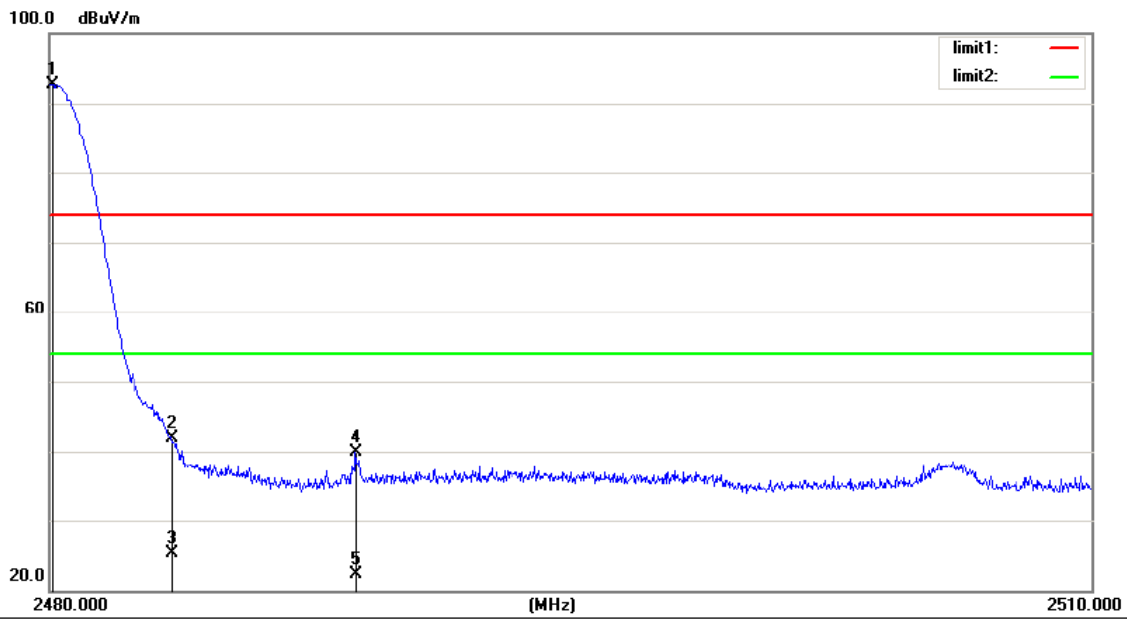
Operator: Washington



Site site #1 Polarization: **Vertical** Temperature: 26
 Limit: (RE)FCC PART 15 C 3m_PEAK Power: Battery 3.7V Humidity: 55 %
 Mode:TX2402
 Note:

No.	Mk.	Freq.	Reading Level	Correct Factor	Measurement	Limit	Over	Antenna Height	Table Degree	
		MHz	dBuV	dB	dBuV/m	dBuV/m	dB	cm	degree	Comment
1		2369.972	58.52	-18.68	39.84	74.00	-34.16	peak	0	
2		2369.972	30.36	-18.68	11.68	54.00	-42.32	AVG	0	
3		2397.206	67.76	-18.52	49.24	74.00	-24.76	peak	0	
4		2397.206	53.25	-18.52	34.73	54.00	-19.27	AVG	0	
5		2400.000	77.64	-18.50	59.14	74.00	-14.86	peak	0	
6		2400.000	63.55	-18.50	45.05	54.00	-8.95	AVG	0	
7	*	2402.000	110.15	-18.49	91.66	74.00	17.66	peak	0	

*:Maximum data x:Over limit !:over margin Operator: Washington

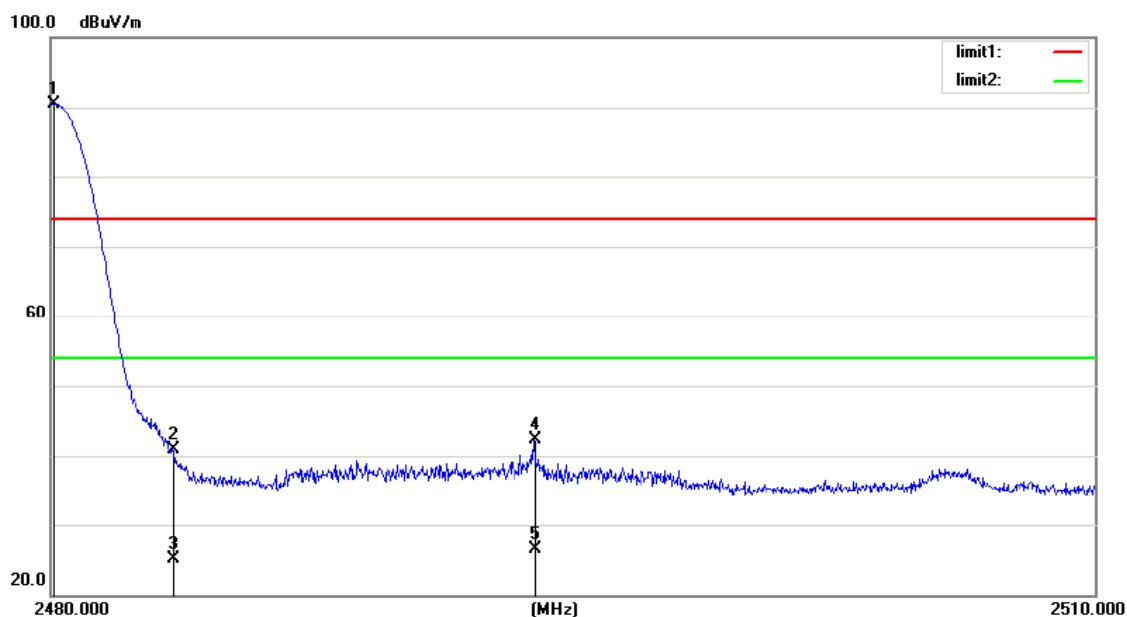


Site site #1 Polarization: **Horizontal** Temperature: 26
 Limit: (RE)FCC PART 15 C 3m_PEAK Power: Battery 3.7V Humidity: 55 %
 Mode: TX2480
 Note:

No.	Mk.	Freq.	Reading Level	Correct Factor	Measurement	Limit	Over	Antenna Height	Table Degree	Comment
		MHz	dBuV	dB	dBuV/m	dBuV/m	dB	cm	degree	
1	*	2480.060	110.75	-18.03	92.72	74.00	18.72	peak	0	
2		2483.500	59.99	-18.01	41.98	74.00	-32.02	peak	0	
3		2483.500	43.25	-18.01	25.24	54.00	-28.76	AVG	0	
4		2488.760	57.92	-17.98	39.94	74.00	-34.06	peak	0	
5		2488.760	40.36	-17.98	22.38	54.00	-31.62	AVG	0	

*:Maximum data x:Over limit l:over margin

Operator: Washington



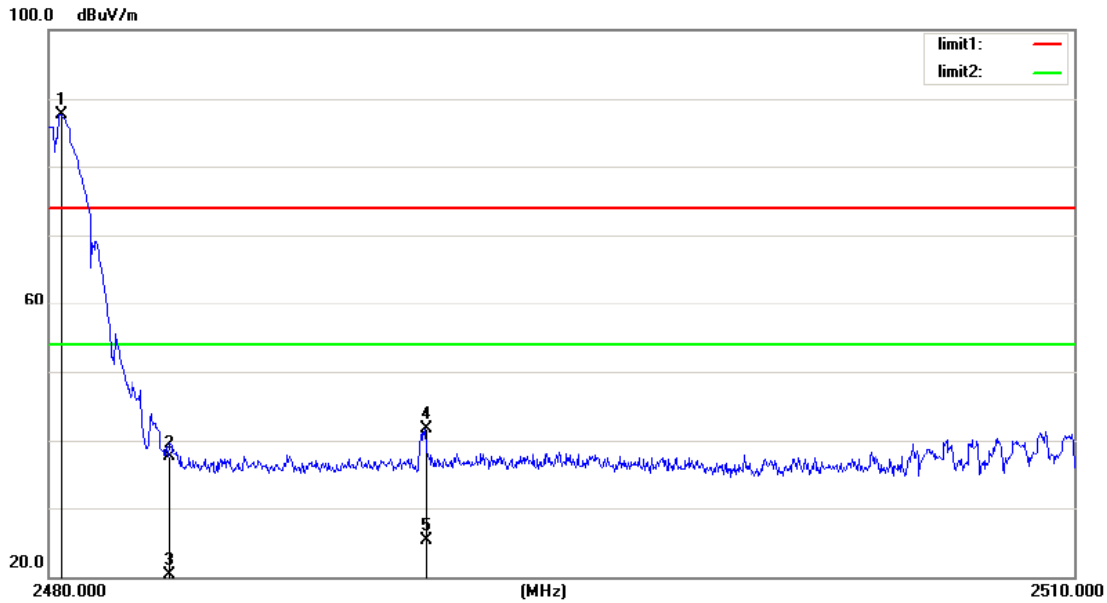
Site site #1 Polarization: **Vertical** Temperature: 26
 Limit: (RE)FCC PART 15 C 3m_PEAK Power: Battery 3.7V Humidity: 55 %
 Mode: TX2480
 Note:

No.	Mk.	Freq.	Reading Level	Correct Factor	Measurement	Limit	Over	Antenna Height	Table Degree	
		MHz	dBuV	dB	dBuV/m	dBuV/m	dB	cm	degree	Comment
1	*	2480.060	108.55	-18.03	90.52	74.00	16.52	peak	0	
2		2483.500	58.94	-18.01	40.93	74.00	-33.07	peak	0	
3		2483.500	43.12	-18.01	25.11	54.00	-28.89	AVG	0	
4		2493.860	60.32	-17.95	42.37	74.00	-31.63	peak	0	
5		2493.860	44.47	-17.95	26.52	54.00	-27.48	AVG	0	

*:Maximum data x:Over limit !:over margin

Operator: Washington

For Hopping Mode:

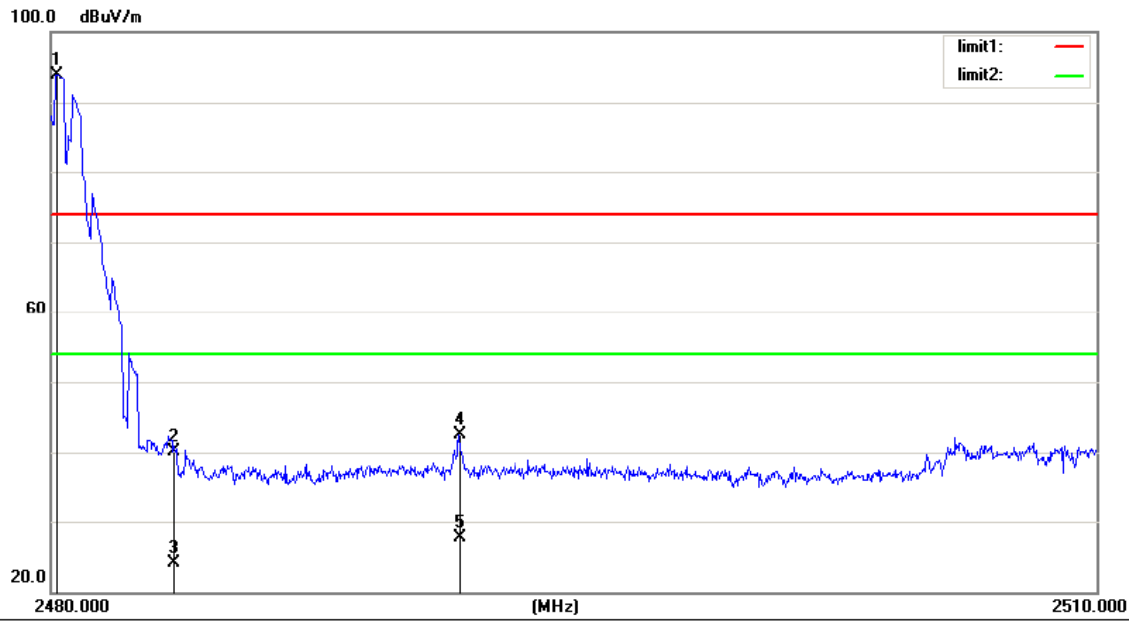


Site site #1 Polarization: **Horizontal** Temperature: 26
 Limit: (RE)FCC PART 15 C 3m_PEAK Power: Battery 3.7V Humidity: 55 %
 Mode:Hopping
 Note:

No.	Mk.	Freq.	Reading Level	Correct Factor	Measurement	Limit	Over	Antenna Height	Table Degree
		MHz	dBuV	dB	dBuV/m	dBuV/m	dB	cm	degree
1	*	2480.330	105.80	-18.03	87.77	74.00	13.77	peak	0
2		2483.500	55.55	-18.01	37.54	74.00	-36.46	peak	0
3		2483.500	38.25	-18.01	20.24	54.00	-33.76	AVG	0
4		2490.980	59.64	-17.96	41.68	74.00	-32.32	peak	0
5		2490.980	43.25	-17.96	25.29	54.00	-28.71	AVG	0

*:Maximum data x:Over limit !:over margin

Operator: Washington

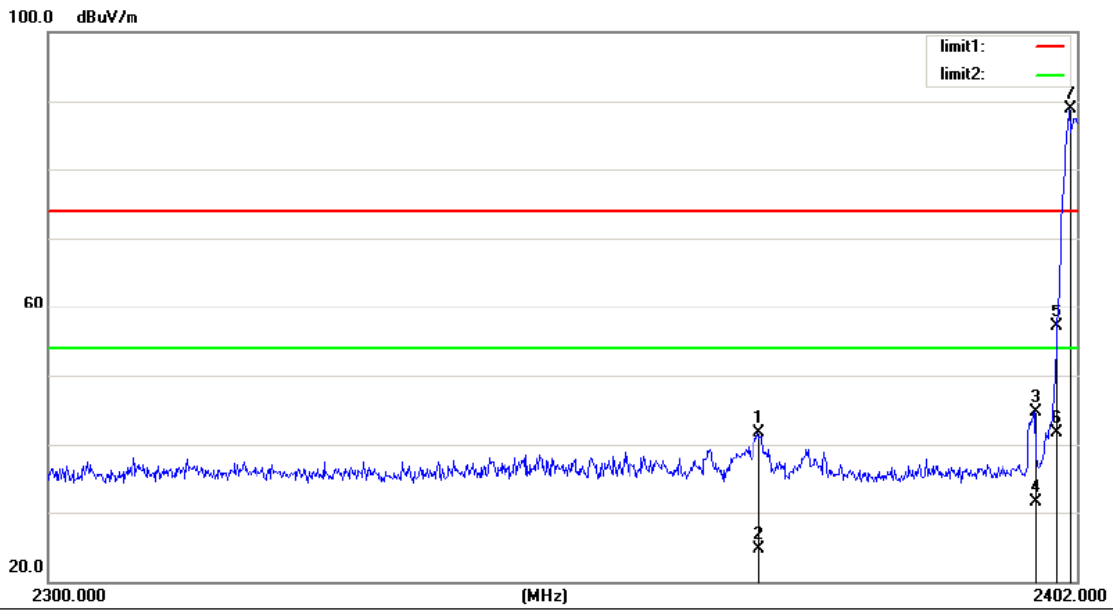


Site: site #1 Polarization: **Vertical** Temperature: 26
 Limit: (RE)FCC PART 15 C 3m_PEAK Power: Battery 3.7V Humidity: 55 %
 Mode: Hopping
 Note:

No.	Mk.	Freq. MHz	Reading Level dBuV	Correct Factor dB	Measure- ment dBuV/m	Limit dBuV/m	Over dB	Detector	Antenna Height cm	Table Degree	Comment
1	*	2480.150	111.95	-18.03	93.92	74.00	19.92	peak		0	
2		2483.500	58.19	-18.01	40.18	74.00	-33.82	peak		0	
3		2483.500	42.15	-18.01	24.14	54.00	-29.86	AVG		0	
4		2491.670	60.38	-17.97	42.41	74.00	-31.59	peak		0	
5		2491.670	45.66	-17.97	27.69	54.00	-26.31	AVG		0	

*:Maximum data x:Over limit !:over margin

Operator: Washington

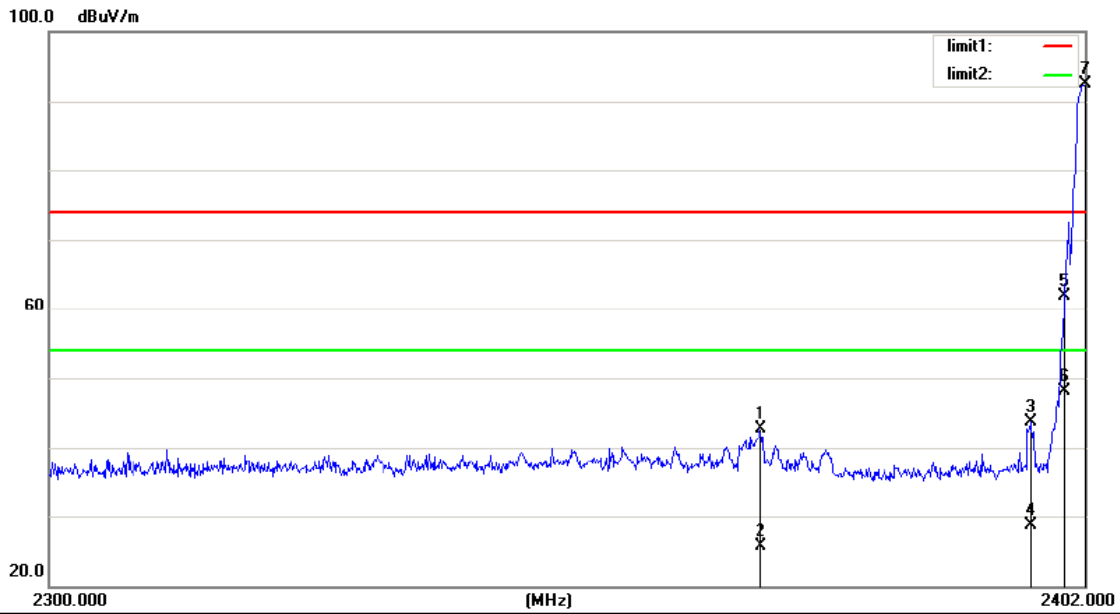


Site site #1 Polarization: **Horizontal** Temperature: 26
 Limit: (RE)FCC PART 15 C 3m_PEAK Power: Battery 3.7V Humidity: 55 %
 Mode: Hopping
 Note:

No.	Mk.	Freq. MHz	Reading Level dBuV	Correct Factor dB	Measure- ment dBuV/m	Limit dBuV/m	Over dB	Antenna Height cm	Table Degree	Comment
1		2369.972	60.38	-18.68	41.70	74.00	-32.30	peak	0	
2		2369.972	43.28	-18.68	24.60	54.00	-29.40	AVG	0	
3		2397.818	63.23	-18.51	44.72	74.00	-29.28	peak	0	
4		2397.818	50.01	-18.51	31.50	54.00	-22.50	AVG	0	
5		2400.000	75.70	-18.50	57.20	74.00	-16.80	peak	0	
6		2400.000	60.25	-18.50	41.75	54.00	-12.25	AVG	0	
7	*	2401.286	107.45	-18.49	88.96	74.00	14.96	peak	0	

*:Maximum data x:Over limit !:over margin

Operator: Washington



Site site #1 Polarization: **Vertical** Temperature: 26
 Limit: (RE)FCC PART 15 C 3m_PEAK Power: Battery 3.7V Humidity: 55 %
 Mode: Hopping
 Note:

No.	Mk.	Freq.	Reading Level	Correct Factor	Measurement	Limit	Over	Antenna Height	Table Degree	
		MHz	dBuV	dB	dBuV/m	dBuV/m	dB	cm	degree	Comment
1		2369.564	61.45	-18.67	42.78	74.00	-31.22	peak	0	
2		2369.564	44.36	-18.67	25.69	54.00	-28.31	AVG	0	
3		2396.594	62.13	-18.52	43.61	74.00	-30.39	peak	0	
4		2396.594	47.15	-18.52	28.63	54.00	-25.37	AVG	0	
5		2400.000	80.42	-18.50	61.92	74.00	-12.08	peak	0	
6		2400.000	66.58	-18.50	48.08	54.00	-5.92	AVG	0	
7	*	2402.000	110.91	-18.49	92.42	74.00	18.42	peak	0	

*:Maximum data x:Over limit !:over margin

Operator: Washington

14. Antenna Application

14.1 Antenna requirement

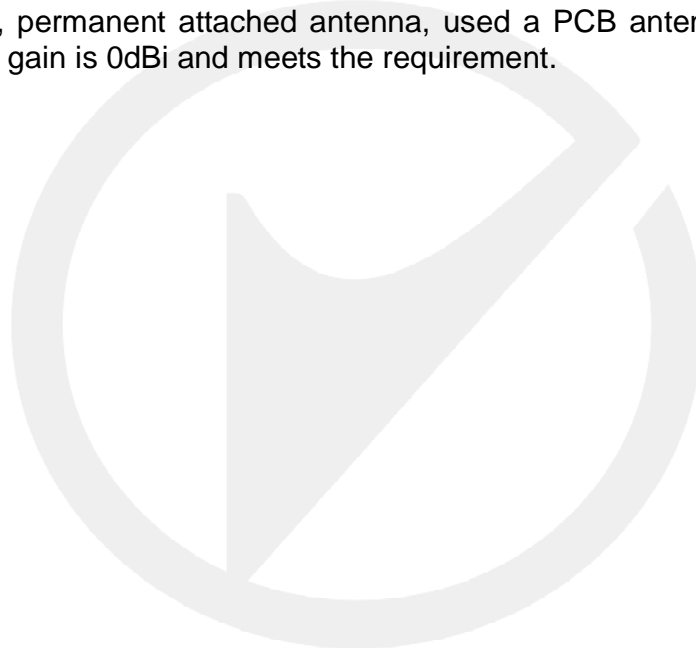
The EUT'S antenna is met the requirement of FCC part 15C section 15.203 and 15.247.

FCC part 15C section 15.247 requirements:

Systems operating in the 2402-2480MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6dBi provided the maximum peak output power of the intentional radiator is reduced by 1dB for every 3dB that the directional gain of the antenna exceeds 6dBi.

14.2 Result

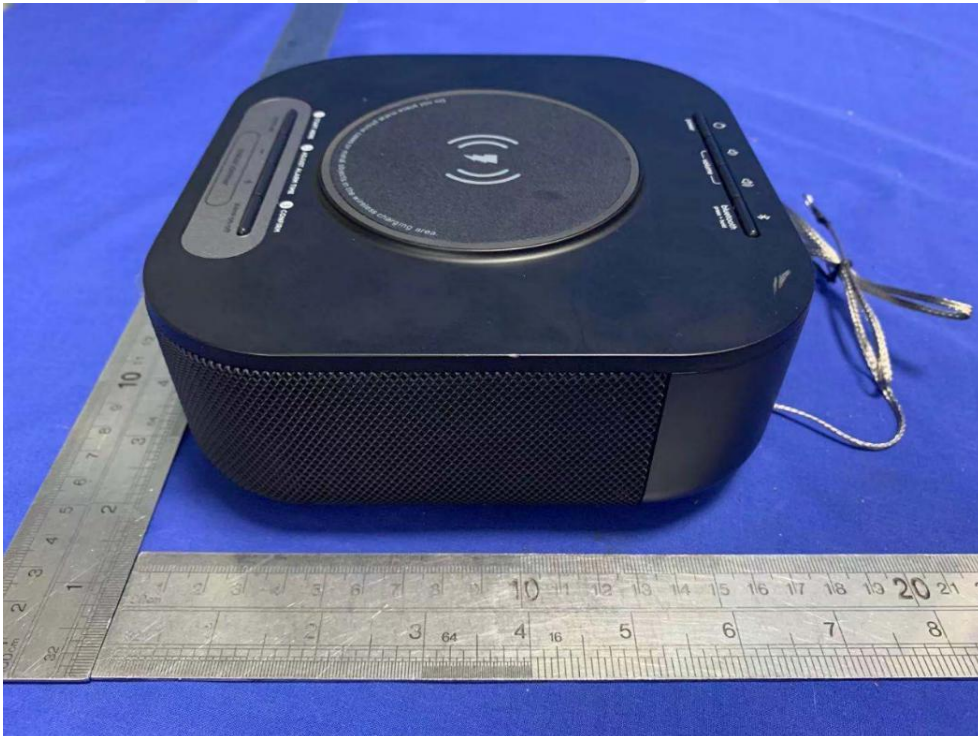
The EUT's antenna, permanent attached antenna, used a PCB antenna and integrated on PCB, The antenna's gain is 0dBi and meets the requirement.



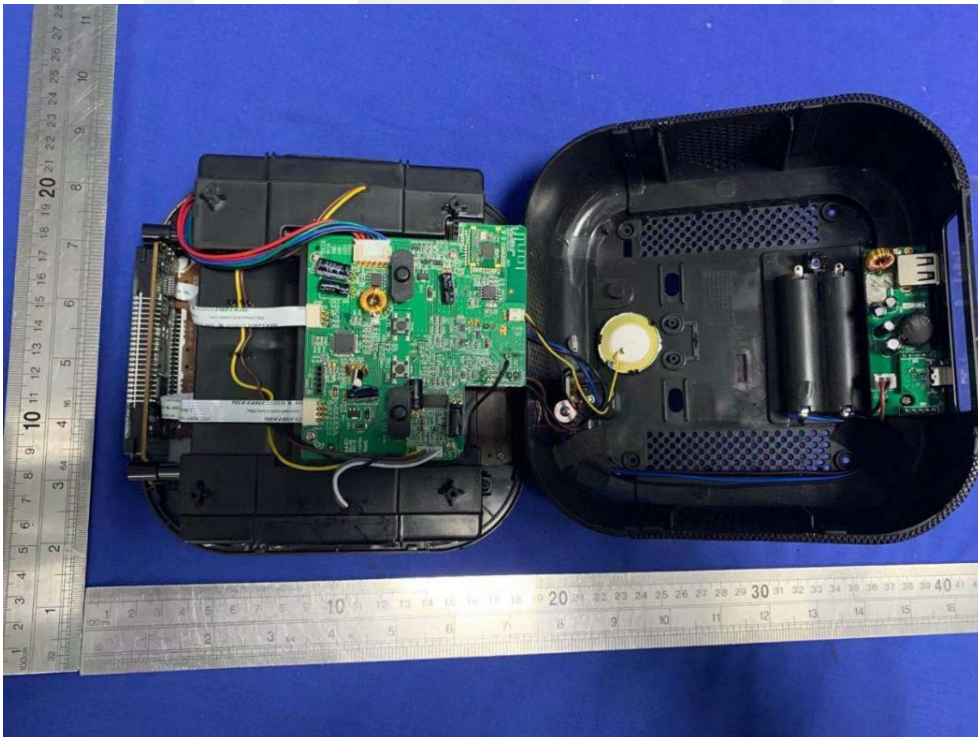
APPENDIX I (Photos of EUT)

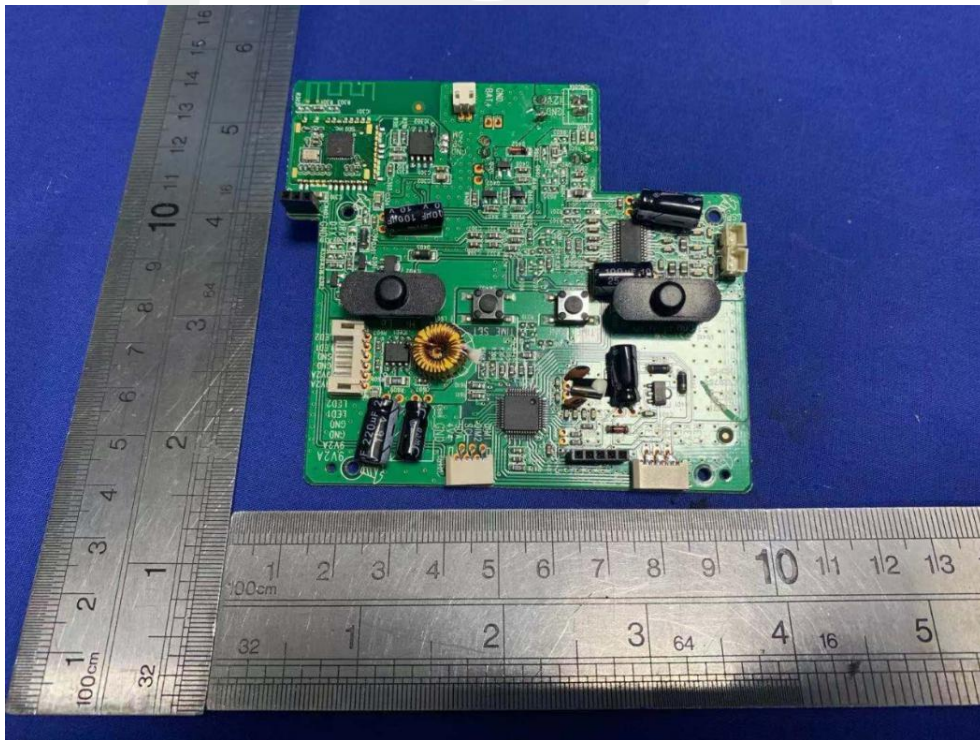
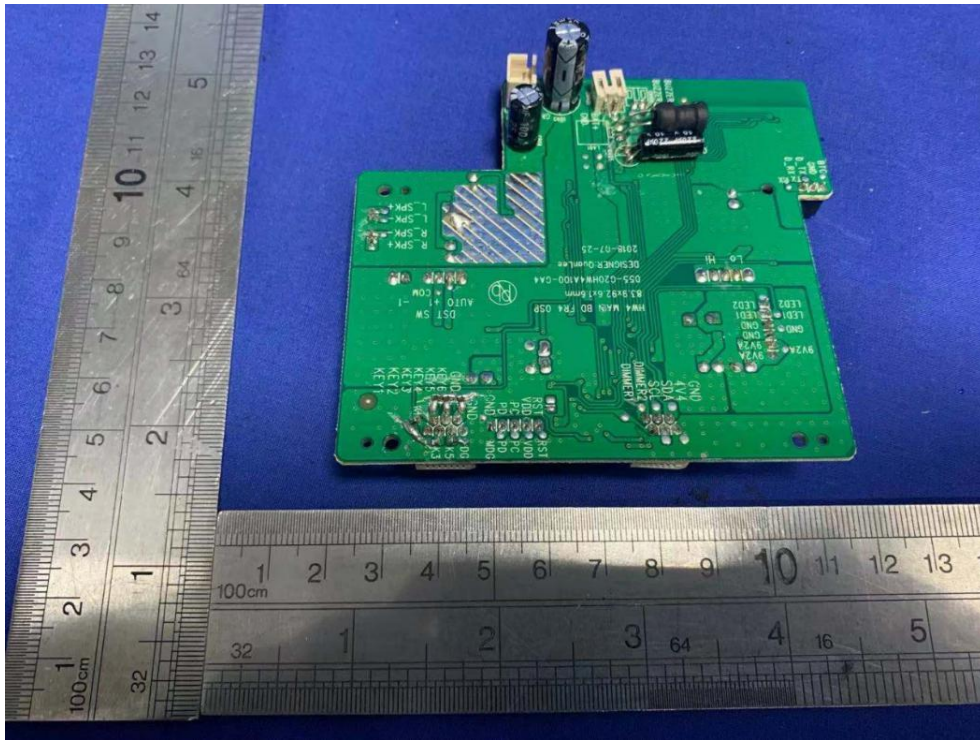


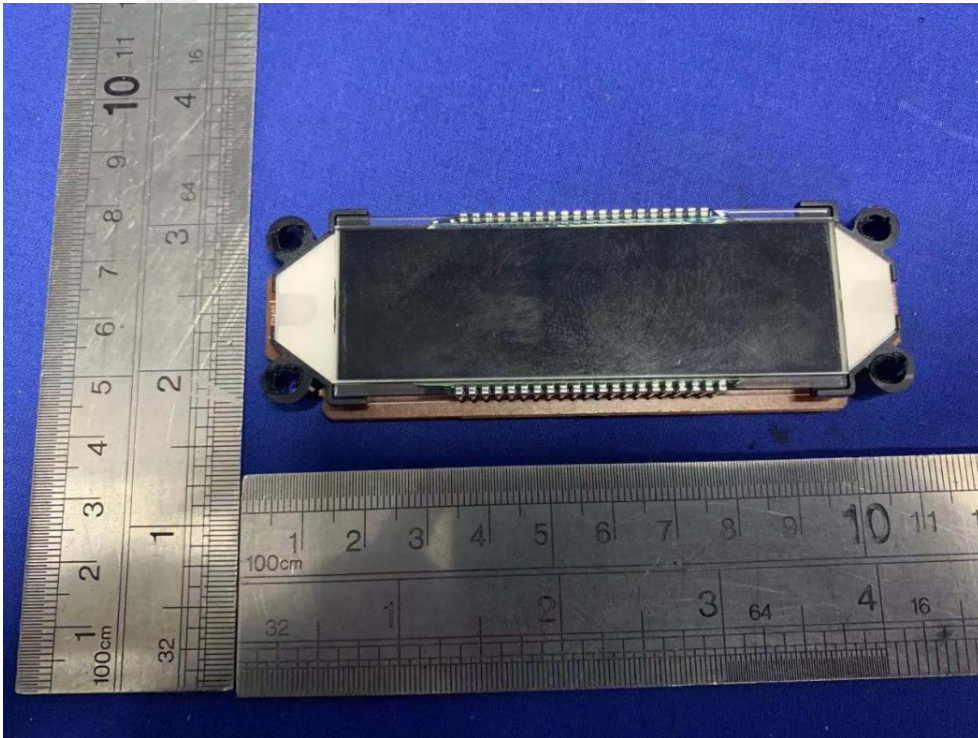
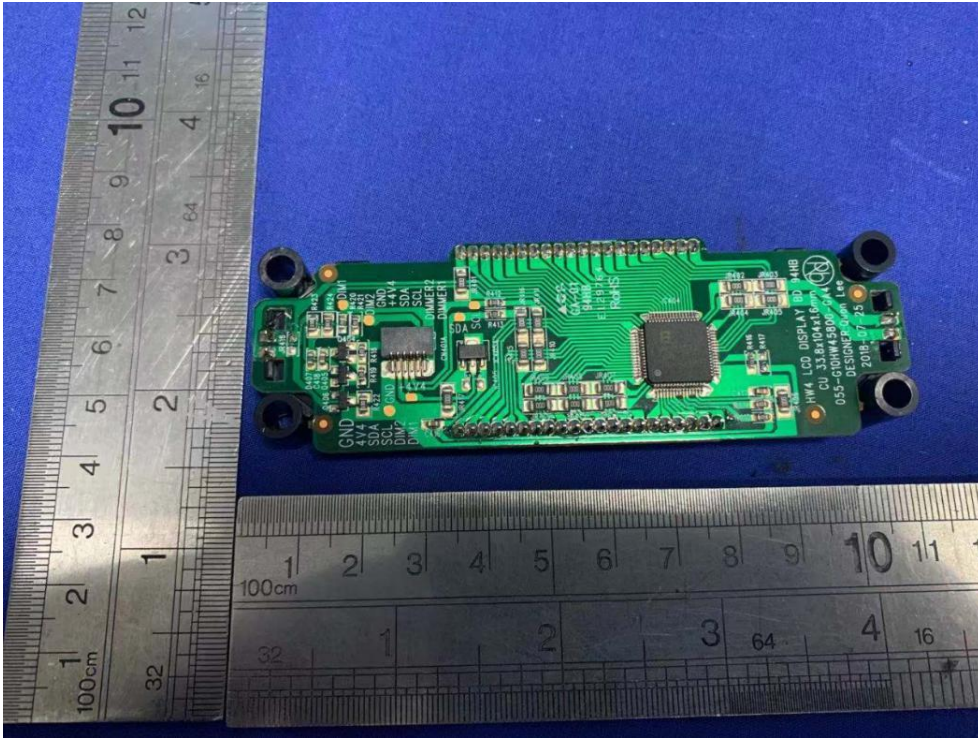


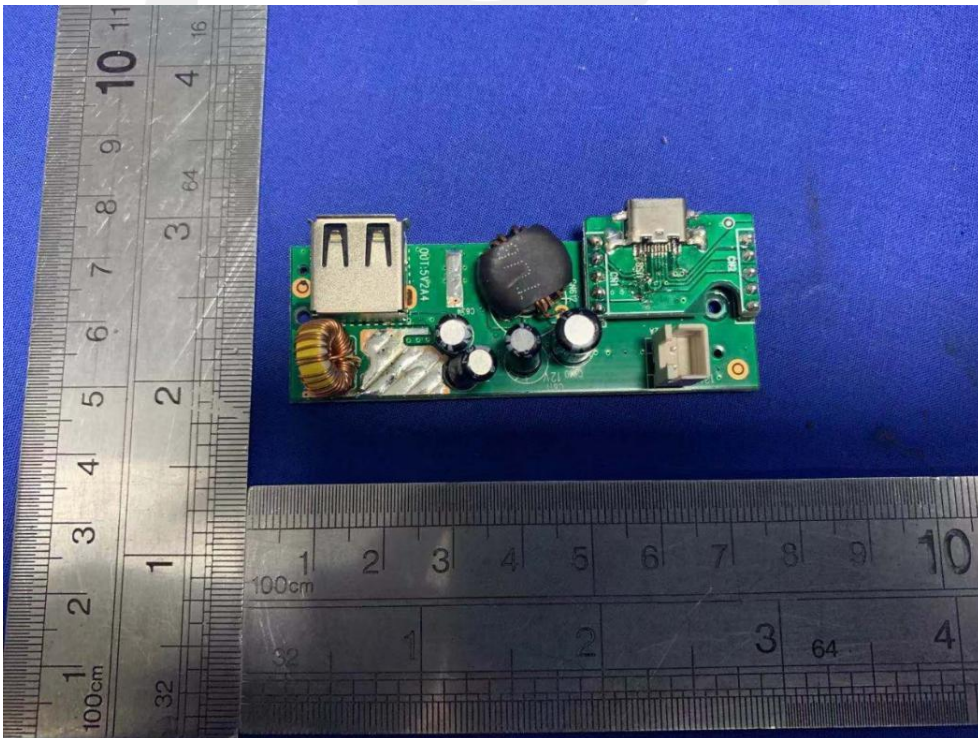
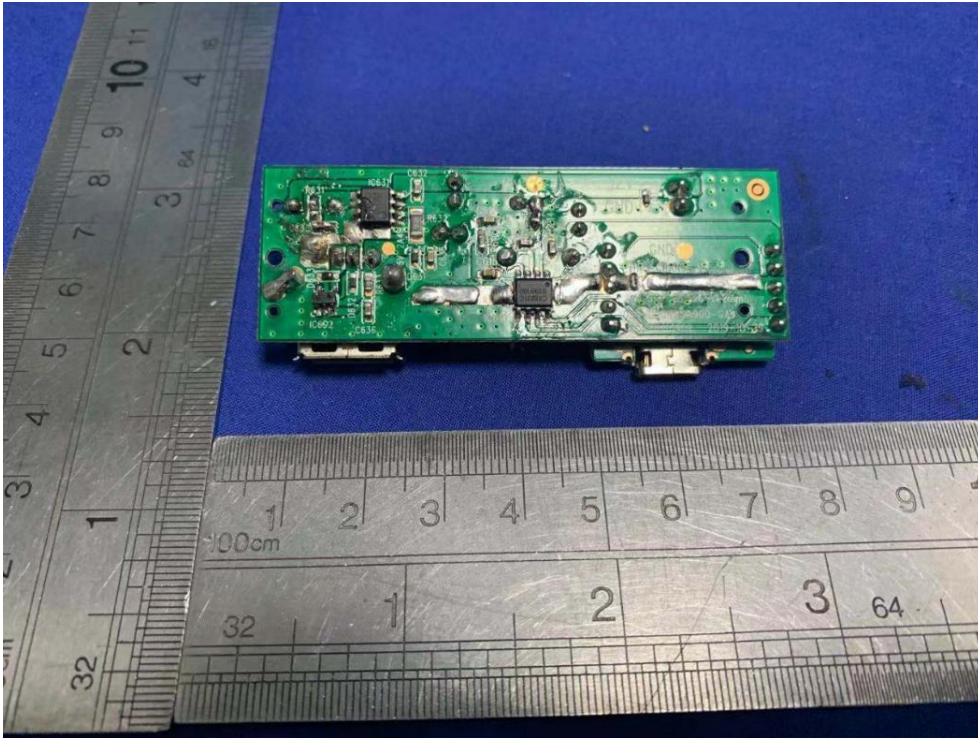


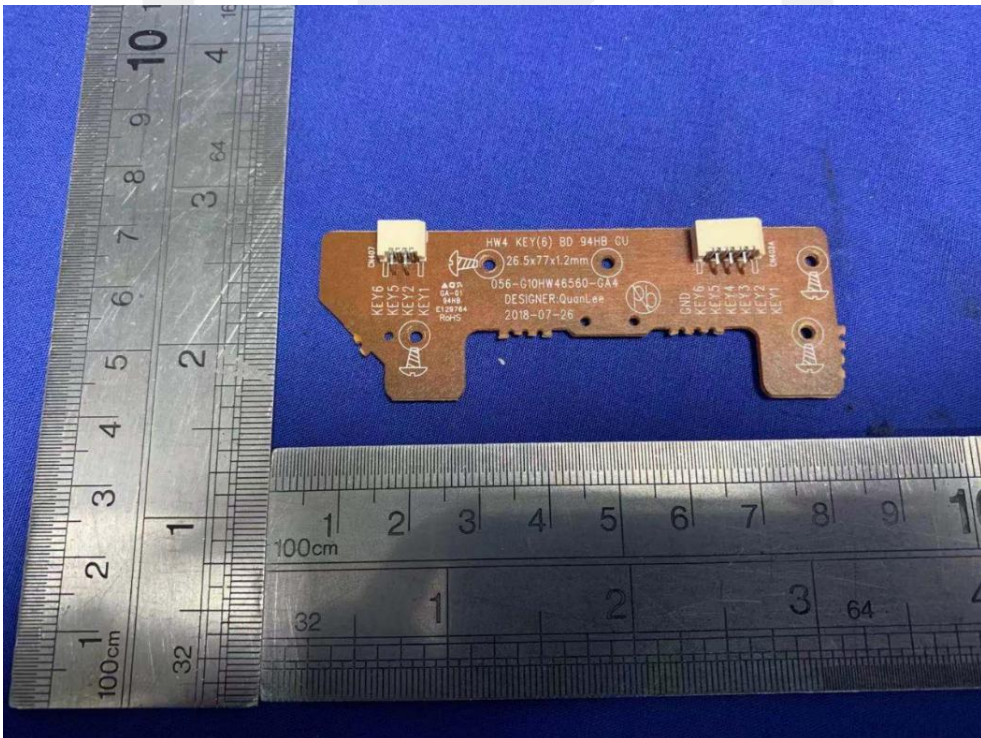
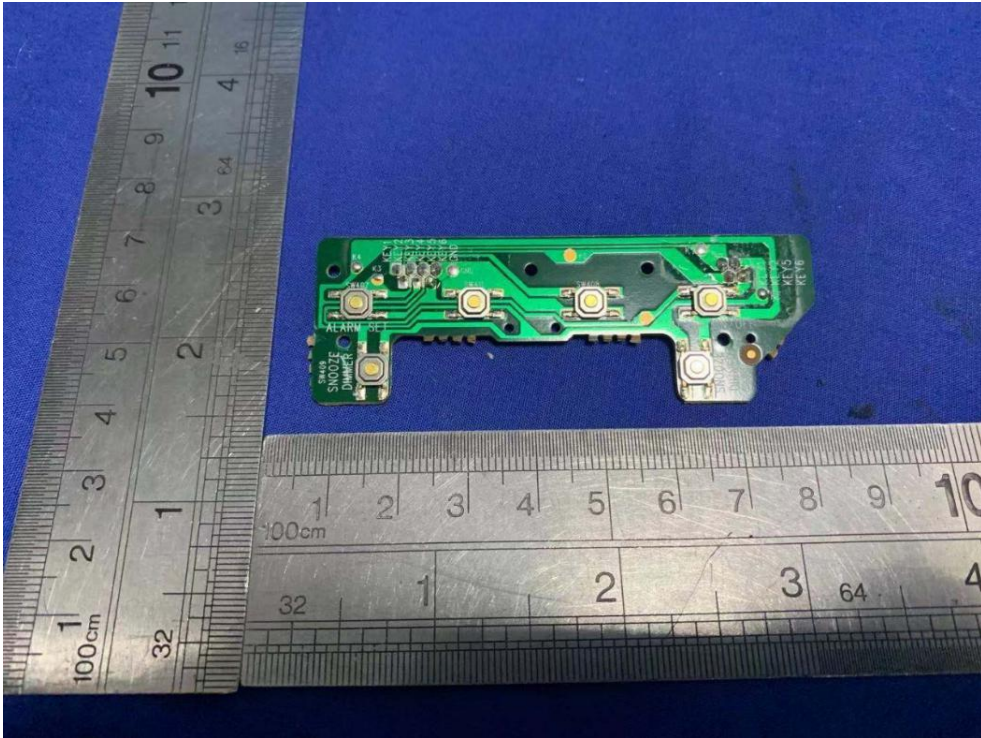


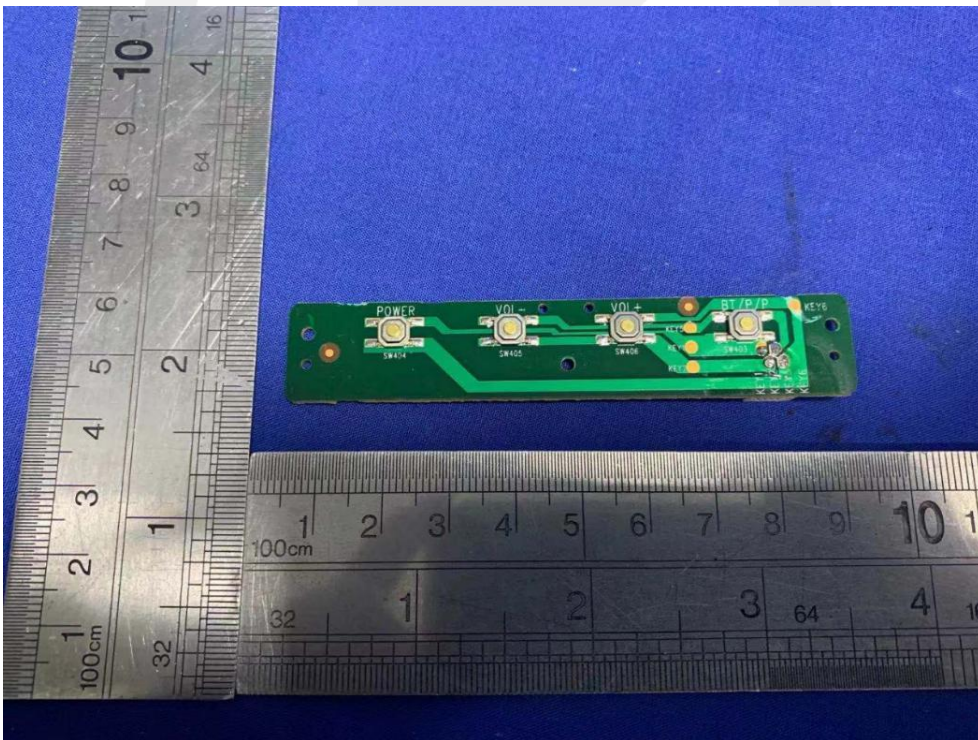
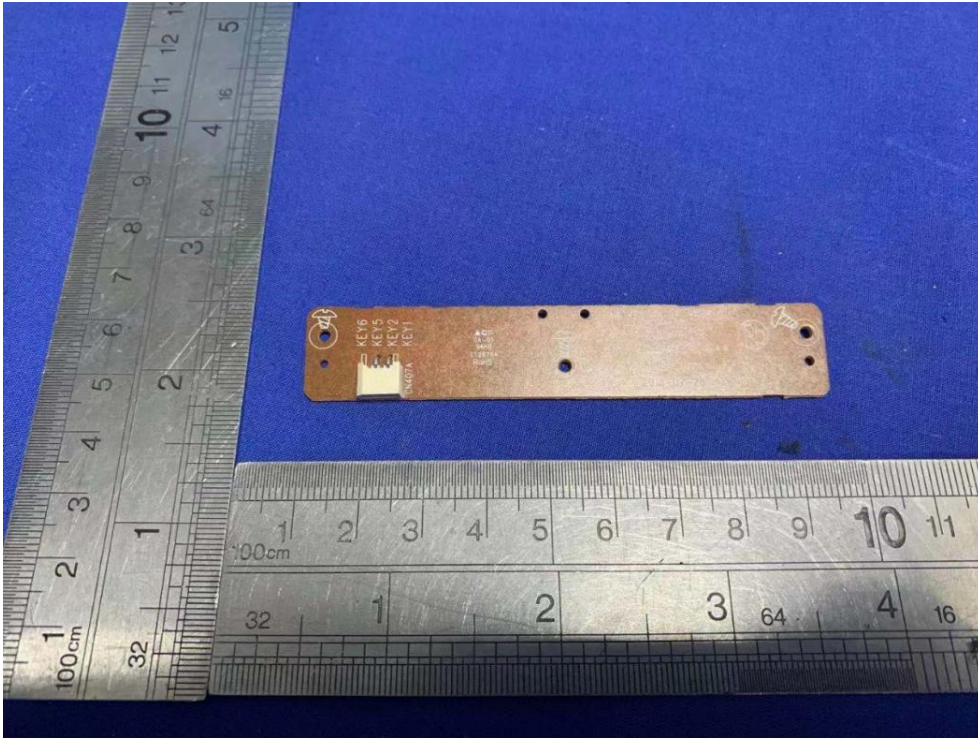














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