ACCREDITED
TESTING LABORATORY
CERTIFICATE # 4821.01

BACL
Bay Area Compliance Labs Corp.

FCC PART 15.247

TEST REPORT

For

Shenzhen Rakwireless Technology Co.,Ltd.

Room 506, Bldg B, New Compark, Pingshan First Road, Taoyuan Street,XiLi town Nanshan District, Shenzhen, China

FCC ID: 2AF6B-RAK4630

Report Type:	**Product Type:**
Original Report	LoRa Module

Report Number:	RSZ200716006-00A
Report Date:	2020-10-23
Reviewed By:	Jacob Kong RF Engineer
Prepared By:	Bay Area Compliance Laboratories Corp. (Shenzhen) 6/F., West Wing, Third Phase of Wanli Industrial Building, Shihua Road, Futian Free Trade Zone, Shenzhen, Guangdong, China Tel: +86-755-33320018 Fax: +86-755-33320008 www.baclcorp.com.cn

Note: This report may contain data that are not covered by the A2LA accreditation and are marked with an asterisk "★".

BACL is not responsible for the authenticity of any test data provided by the applicant. Data included from the applicant that may affect test results are marked with an asterisk '*'. Customer model name, addresses, names, trademarks etc. are not considered data.

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GENERAL INFORMATION

Product Description for Equipment under Test (EUT)

Product	LoRa Module
Tested Model	RAK4630
Multiple Model	RAK4631
Model Differences	Refer to the DoS letter
Frequency Range	902.3-914.9 MHz
Maximum Conducted Average Output Power	15.58dBm
Technique	Hybrid System
Antenna Specification*	3.0dBi (It is provided by the applicant)
Voltage Range	DC 3.3V
Date of Test	2020-07-28 to 2020-10-22
Sample serial number	RSZ200716006-RF-S1 (Assigned by BACL, Shenzhen)
Received date	2020-07-16
Sample/EUT Status	Good condition

Objective

This test report is in accordance with Part 2-Subpart J, Part 15-Subparts A and C of the Federal Communication Commission's rules.

The tests were performed in order to determine compliance with FCC Part 15, Subpart C, and section 15.203, 15.205, 15.207, 15.209 and 15.247 rules.

Test Methodology

All measurements contained in this report were conducted with ANSI C63.10-2013, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices.

And KDB 558074 D01 15.247 Meas Guidance v05r02.

All emissions measurement was performed at Bay Area Compliance Laboratories Corp. (Shenzhen). The radiated testing was performed at an antenna-to-EUT distance of 3 meters.

Measurement Uncertainty

Parameter		uncertainty
Occupied Channel Bandwidth		±5%
RF output power, conducted		±0.73dB
Unwanted Emission, conducted		±1.95dB
Radiated Emissions	Below 1GHz	±4.75dB
	Above 1GHz	±4.88dB
Temperature		±1℃
Supply voltages		±0.4%

Note: The extended uncertainty given in this report is obtained by combining the standard uncertainty times the coverage factor K with the 95% confidence interval.Otherwise required by the applicant or Product Regulations, Decision Rule in this report did not consider the uncertainty.

Test Facility

The Test site used by Bay Area Compliance Laboratories Corp. (Shenzhen) to collect test data is located on the 6/F., West Wing, Third Phase of Wanli Industrial Building, Shihua Road, Futian Free Trade Zone, Shenzhen, Guangdong, China.

The test site has been approved by the FCC under the KDB 974614 D01 and is listed in the FCC Public Access Link (PAL) database, FCC Registration No. : 342867, the FCC Designation No. : CN1221.

The test site has been registered with ISED Canada under ISED Canada Registration Number 3062B.

SYSTEM TEST CONFIGURATION

Description of Test Configuration

The system was configured for testing in engineering mode.

Channel	Freq.(MHz)	Channel	Freq.(MHz)	Channel	Freq.(MHz)	Channel	Freq.(MHz)
0	902.3	16	905.5	32	908.7	48	911.9
1	902.5	17	905.7	33	908.9	49	912.1
2	902.7	18	905.9	34	909.1	50	912.3
3	902.9	19	906.1	35	909.3	51	912.5
4	903.1	20	906.3	36	909.5	52	912.7
5	903.3	21	906.5	37	909.7	53	912.9
6	903.5	22	906.7	38	909.9	54	913.1
7	903.7	23	906.9	39	910.1	55	913.3
8	903.9	24	907.1	40	910.3	56	913.5
9	904.1	25	907.3	41	910.5	57	913.7
10	904.3	26	907.5	42	910.7	58	913.9
11	904.5	27	907.7	43	910.9	59	914.1
12	904.7	28	907.9	44	911.1	60	914.3
13	904.9	29	908.1	45	911.3	61	914.5
14	905.1	30	908.3	46	911.5	62	914.7
15	905.3	31	908.5	47	911.7	63	914.9

Channel 0, 32 and 63 were tested.

Equipment Modifications

No modification was made to the EUT tested.

EUT Exercise Software

"SSCOM V5.13.1.exe"* exercise software was used and power level is 17*. The software and power level was provided by the applicant.

Special Accessories

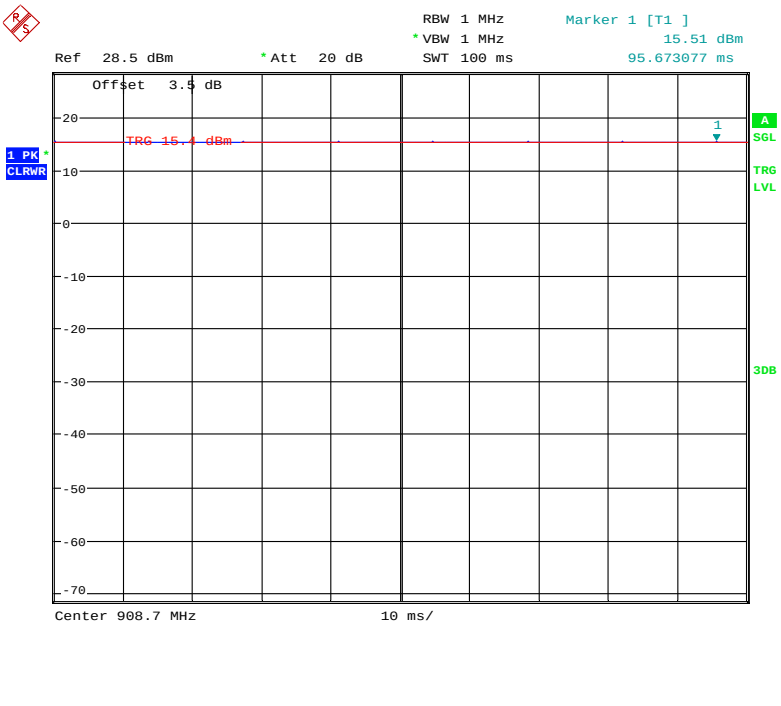
No special accessory.

Equipment Modifications

No modification was made to the EUT tested.

Duty cycle

Hybrid system



Mode	Ton (ms)	Ton+off (ms)	Duty Cycle (%)
Hybrid system	--	--	100

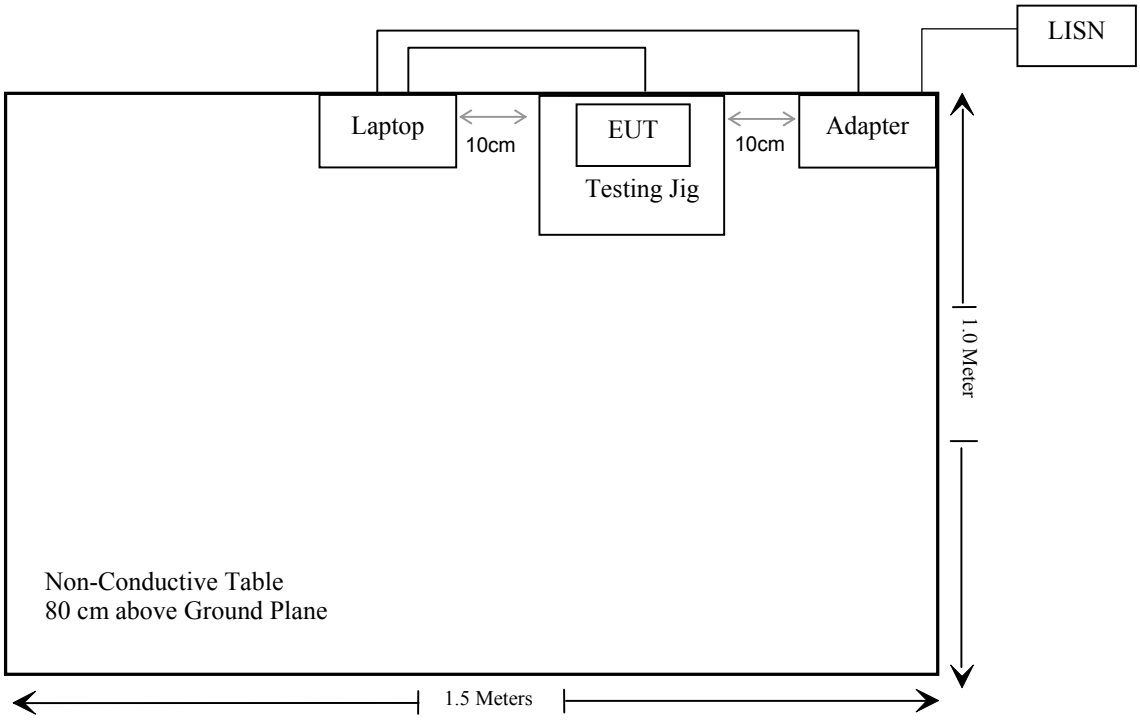
Support Equipment List and Details

Manufacturer	Description	Model	Serial Number
Rakwireless	Testing Jig	RAK5005	RAK5005-0 V1.0
Toshiba	Laptop	Satellite C600	PSCZNQ-00G006
Toshiba	AC/DC Adapter	PA3715E-1AC3	T0311043001798DA

External I/O Cable

Cable Description	Length (m)	From Port	To
Unshielded Detachable AC Cable	1.6	LISN	Adapter
Unshielded Un-Detachable DC Cable	1.6	Adapter	Laptop
Unshielded Detachable USB Cable	0.6	Laptop	Testing Jig

Block Diagram of Test Setup



SUMMARY OF TEST RESULTS

FCC Rules	Description of Test	Result
§15.247 (i), §2.1091	Maximum Permissible Exposure(MPE)	Compliance
§15.203	Antenna Requirement	Compliance
§15.207(a)	AC Line Conducted Emissions	Compliance
§15.205, §15.209 & §15.247(d)	Radiated Emissions	Compliance
§15.247(a)(1)	20 dB Emission Bandwidth	Compliance
§15.247(a)(1)(i)	Channel Separation Test	Compliance
§15.247(f)	Time of Occupancy (Dwell Time)	Compliance
§15.247(b)(3)	Peak Output Power Measurement	Compliance
§15.247(d)	Band edges	Compliance
§15.247(f)	Power Spectral Density	Compliance

TEST EQUIPMENT LIST

Manufacturer	Description	Model	Serial Number	Calibration Date	Calibration Due Date
Conducted Emissions Test					
Rohde & Schwarz	EMI Test Receiver	ESCI	101120	2019/08/04	2020/08/03
Rohde & Schwarz	LISN	ENV216	101613	2019/08/04	2020/08/03
Rohde & Schwarz	Transient Limitor	ESH3Z2	DE25985	2019/11/29	2020/11/28
Unknown	CE Cable	CE Cable	UF A210B-1-0720-504504	2019/11/29	2020/11/28
Rohde & Schwarz	CE Test software	EMC 32	V8.53.0	NCR	NCR
Radiated Emission Test (below 1G)					
R&S	EMI Test Receiver	ESR3	102455	2020/7/9	2021/7/8
Sonoma instrument	Pre-amplifier	310 N	186238	2020/7/9	2021/7/8
Sunol Sciences	Broadband Antenna	JB1	A040904-1	2017/12/22	2020/12/21
Unknown	Cable 2	RF Cable 2	F-03-EM197	2019/11/29	2020/11/28
Unknown	Cable	Chamber Cable 1	F-03-EM236	2019/11/29	2020/11/28
Rohde & Schwarz	Auto test software	EMC 32	V9.10	NCR	NCR
Radiated Emission Test (above 1G)					
Rohde & Schwarz	Spectrum Analyzer	FSV40-N	102259	2020/08/04	2021/08/03
COM-POWER	Pre-amplifier	PA-122	181919	2019/11/29	2020/11/28
Sunol Sciences	Horn Antenna	DRH-118	A052604	2017/12/22	2020/12/21
Insulted Wire Inc.	RF Cable	SPS-2503-3150	02222010	2019/11/29	2020/11/28
Unknown	RF Cable	W1101-EQ1 OUT	F-19-EM005	2019/11/29	2020/11/28
RF Conducted Test					
Rohde & Schwarz	SPECTRUM ANALYZER	FSU26	200120	2020/04/03	2021/04/02
Agilent	USB Wideband Power Sensor	U2021XA	MY54250003	2020/08/04	2021/08/03
WEINSCHEL	3dB Attenuator	Unknown	F-03-EM230	2019/11/29	2020/11/28
Unknown	RF Cable	Unknown	2301 276	2019/11/29	2020/11/28

*** Statement of Traceability:** Bay Area Compliance Laboratories Corp. (Shenzhen) attests that all calibrations have been performed in accordance to requirements that traceable to National Primary Standards and International System of Units (SI).

FCC §15.247 (i) & §2.1091- MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Applicable Standard

According to subpart 15.247 (i) and subpart 2.1091 systems operating under the provisions of this section shall be operated in a manner that ensures the public is not exposed to RF energy level in excess of the communication guidelines.

Limits for General Population/Uncontrolled Exposure

Limits for General Population/Uncontrolled Exposure				
Frequency Range (MHz)	**Electric Field Strength (V/m)**	**Magnetic Field Strength (A/m)**	**Power Density (mW/cm^2)**	**Averaging Time (Minutes)**
0.3-1.34	614	1.63	*(100)	30
1.34-30	824/f	2.19/f	*($180/f^2$)	30
30-300	27.5	0.073	0.2	30
300-1500	/	/	f/1500	30
1500-100,000	/	/	1.0	30

f = frequency in MHz
* = Plane-wave equivalent power density

Result

Calculated Formulary:

Predication of MPE limit at a given distance

$$S = \frac{PG}{4\pi R^2}$$

S = power density (in appropriate units, e.g. mW/cm2)
P = power input to the antenna (in appropriate units, e.g., mW).
G = power gain of the antenna in the direction of interest relative to an isotropic radiator, the power gain factor, is normally numeric gain.
R = distance to the center of radiation of the antenna (appropriate units, e.g., cm)

For simultaneously transmit system, the calculated power density should comply with:

$$\sum_i \frac{S_i}{S_{Limit,i}} \le 1$$

Mode	Frequency (MHz)	Antenna Gain		Tune up conducted power		Evaluation Distance (cm)	Power Density (mW/cm^2)	MPE Limit (mW/cm^2)
		(dBi)	(numeric)	(dBm)	(mW)			
Lora(125k)	902.3-914.9	3.0	2	16	39.81	20	0.016	0.60
Lora(500k)	903-914.2	3.0	2	16	39.81	20	0.016	0.602
BT	2402-2480	2.23	1.67	4.5	2.82	20	0.001	1

Note:

1) To maintain compliance with the FCC's RF exposure guidelines, place the equipment at least 20cm from nearby persons.

2) Bluetooth and Lora can transmit simultaneously for this device.

3) Simultaneous transmitting consideration:

The ratio=MPE_{BLE}/limit+MPE_{Lora}/limit=0.001/1+0.016/0.60=0.028＜1.0, so it comply with simultaneous exposure requirement.

Result: Pass

FCC §15.203 - ANTENNA REQUIREMENT

Applicable Standard

According to § 15.203, 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 shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the user of a standard antenna jack or electrical connector is prohibited. The structure and application of the EUT were analyzed to determine compliance with section §15.203 of the rules. §15.203 state that the subject device must meet the following criteria:

a. Antenna must be permanently attached to the unit.
b. Antenna must use a unique type of connector to attach to the EUT.

Unit must be professionally installed, and installer shall be responsible for verifying that the correct antenna is employed with the unit.
And according to FCC 47 CFR section 15.247 (b), if the transmitting antennas of directional gain greater than 6dBi are used, the power shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

Antenna Connector Construction

The EUT has an external antenna with standard UFL antenna connector and the antenna gain is 3.0dBi, fulfill the requirement of this section. Please refer to the EUT photos.

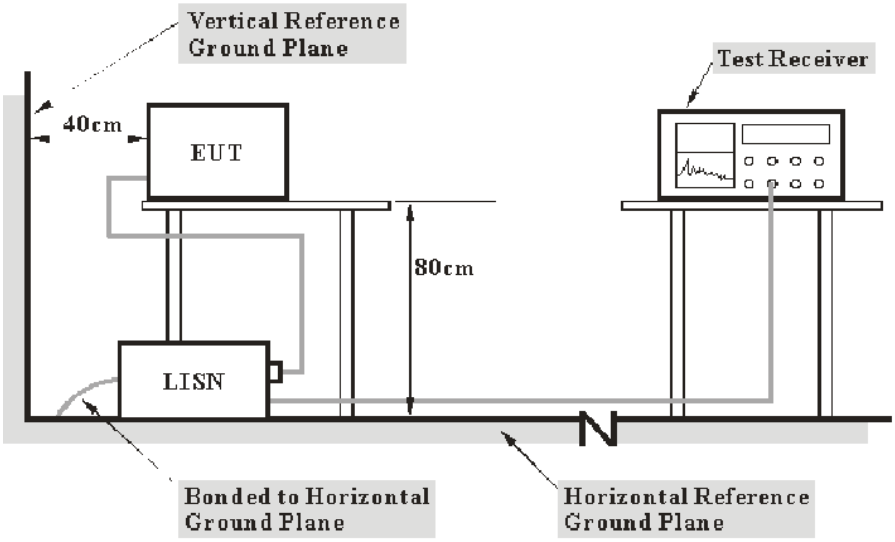
Result: Pass

FCC §15.207 (a) – AC LINE CONDUCTED EMISSIONS

Applicable Standard

FCC §15.207(a)

EUT Setup



Note: 1. Support units were connected to second LISN.
2. Both of LISNs (AMN) 80 cm from EUT and at the least 80 cm from other units and other metal planes support units.

The measurement procedure of EUT setup is according with ANSI C63.10-2013. The related limit was specified in FCC Part 15.207.

The spacing between the peripherals was 10 cm.

EMI Test Receiver Setup

The EMI test receiver was set to investigate the spectrum from 150 kHz to 30 MHz.

During the conducted emission test, the EMI test receiver was set with the following configurations:

Frequency Range	IF B/W
150 kHz – 30 MHz	9 kHz

Test Procedure

During the conducted emission test, the adapter was connected to the outlet of the LISN.

Maximizing procedure was performed on the six (6) highest emissions of the EUT.

All final data was recorded in the Quasi-peak and average detection mode.

Corrected Factor & Margin Calculation

The Corrected factor is calculated by adding LISN VDF (Voltage Division Factor), Cable Loss and Transient Limiter Attenuation. The basic equation is as follows:

Correction Factor = LISN VDF + Cable Loss + Transient Limiter Attenuation

The "**Margin**" column of the following data tables indicates the degree of compliance with the applicable limit. For example, a margin of 7 dB means the emission is 7 dB below the limit. The equation for margin calculation is as follows:

Margin = Limit – Corrected Amplitude

Test Data

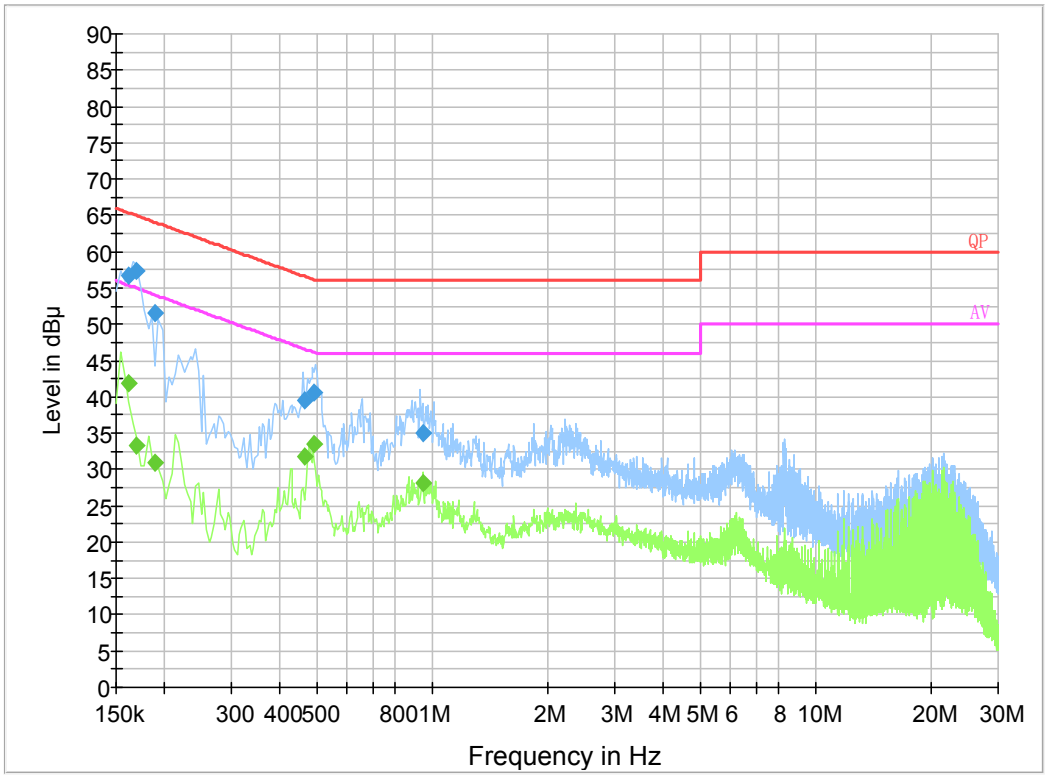
Environmental Conditions

Temperature:	25 ℃
Relative Humidity:	65 %
ATM Pressure:	101.0 kPa

The testing was performed by Haiguo Li on 2020-07-28.

EUT operation mode: Transmitting (the worst case is Low channel)

AC 120V/60 Hz, Line



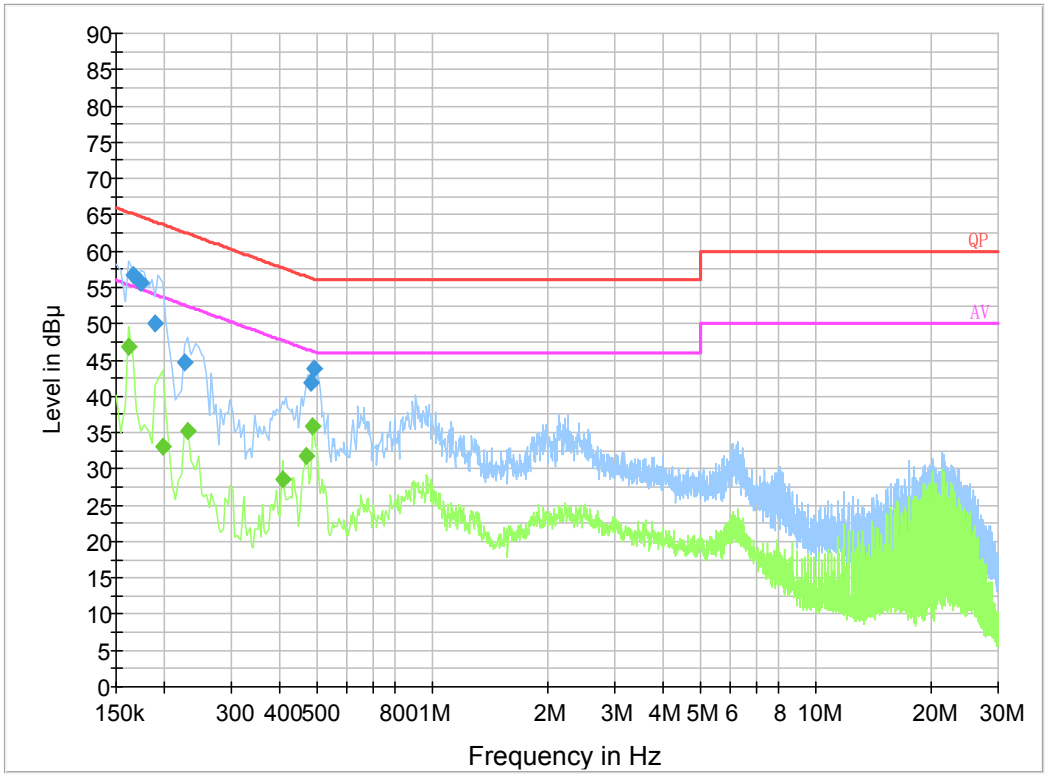
Final Result 1

Frequency (MHz)	QuasiPeak (dBµV)	Bandwidth (kHz)	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.161500	56.8	9.000	L1	19.9	8.6	65.4
0.169500	57.3	9.000	L1	19.9	7.7	65.0
0.189500	51.5	9.000	L1	19.8	12.6	64.1
0.467070	39.5	9.000	L1	19.8	17.1	56.6
0.494530	40.6	9.000	L1	19.8	15.5	56.1
0.943990	34.9	9.000	L1	19.8	21.1	56.0

Final Result 2

Frequency (MHz)	Average (dBµV)	Bandwidth (kHz)	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.161500	41.8	9.000	L1	19.9	13.6	55.4
0.169500	33.3	9.000	L1	19.9	21.7	55.0
0.189500	30.9	9.000	L1	19.8	23.2	54.1
0.467070	31.7	9.000	L1	19.8	14.9	46.6
0.494530	33.5	9.000	L1	19.8	12.6	46.1
0.943990	28.1	9.000	L1	19.8	17.9	46.0

AC 120V/60 Hz, Neutral



Final Result 1

Frequency (MHz)	QuasiPeak (dBµV)	Bandwidth (kHz)	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.166501	56.6	9.000	N	19.8	8.5	65.1
0.173500	55.7	9.000	N	19.8	9.1	64.8
0.189500	50.0	9.000	N	19.8	14.1	64.1
0.225500	44.6	9.000	N	19.8	18	62.6
0.482830	41.8	9.000	N	19.8	14.5	56.3
0.490650	43.7	9.000	N	19.8	12.5	56.2

Final Result 2

Frequency (MHz)	Average (dBµV)	Bandwidth (kHz)	Line	Corr. (dB)	Margin (dB)	Limit (dBµV)
0.162000	46.7	9.000	N	19.8	8.7	55.4
0.198000	33.1	9.000	N	19.8	20.6	53.7
0.230000	35.2	9.000	N	19.8	17.2	52.4
0.410000	28.7	9.000	N	19.8	18.9	47.6
0.470000	31.7	9.000	N	19.8	14.8	46.5
0.490000	35.9	9.000	N	19.8	10.3	46.2

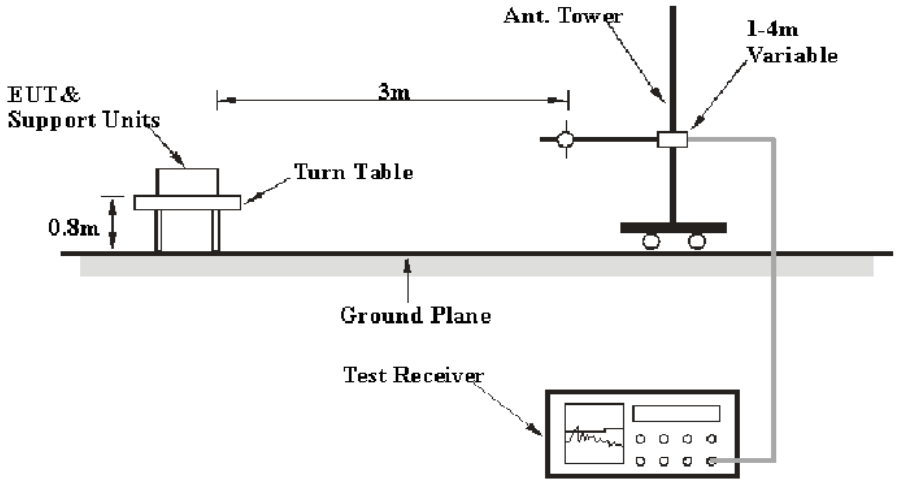
FCC §15.209, §15.205 & §15.247(d) - SPURIOUS EMISSIONS

Applicable Standard

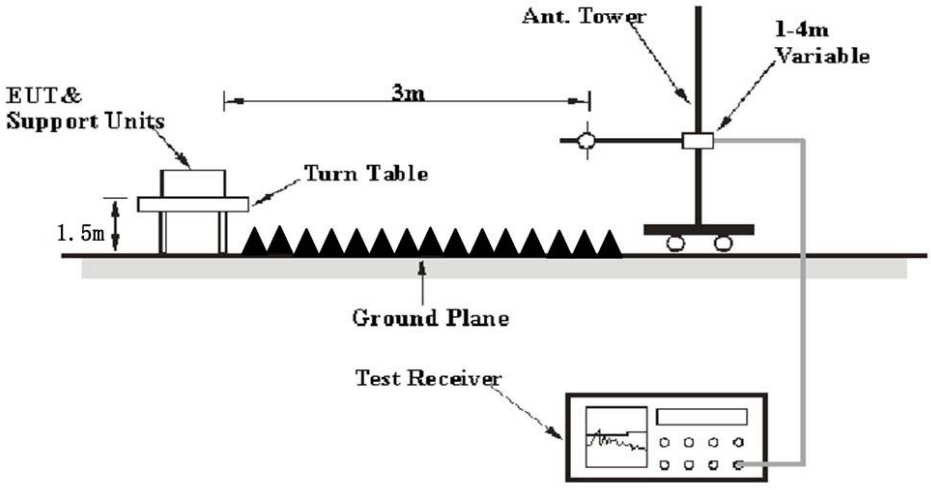
FCC §15.247 (d); §15.209; §15.205;

EUT Setup

Below 1 GHz:



Above 1GHz:



The radiated emission tests were performed in the 3 meters test site, using the setup accordance with the ANSI C63.10-2013. The specification used was the FCC 15.209, and FCC 15.247 limits.

EMI Test Receiver & Spectrum Analyzer Setup

During the radiated emission test, the EMI test receiver & Spectrum Analyzer Setup were set with the following configurations:

Frequency Range	RBW	Video B/W	IF B/W	Measurements
30 MHz – 1000 MHz	100 kHz	300 kHz	120 kHz	QP
Above 1 GHz	1MHz	3 MHz	/	PK
	1MHz	10 Hz	/	Ave.

Test Procedure

Maximizing procedure was performed on the highest emissions to ensure that the EUT complied with all installation combinations.

Data was recorded in Quasi-peak detection mode for frequency range of 30 MHz-1 GHz, peak and Average detection modes for frequencies above 1 GHz.

Corrected Amplitude & Margin Calculation

The Corrected Amplitude is calculated by adding the Antenna Factor and Cable Loss, and subtracting the Amplifier Gain from the Meter Reading. The basic equation is as follows:

Corrected Amplitude = Meter Reading + Antenna Factor + Cable Loss - Amplifier Gain

The "**Margin**" column of the following data tables indicates the degree of compliance with the applicable limit. For example, a margin of 7dB means the emission is 7dB below the limit. The equation for margin calculation is as follows:

Margin = Limit – Corrected Amplitude

Test Data

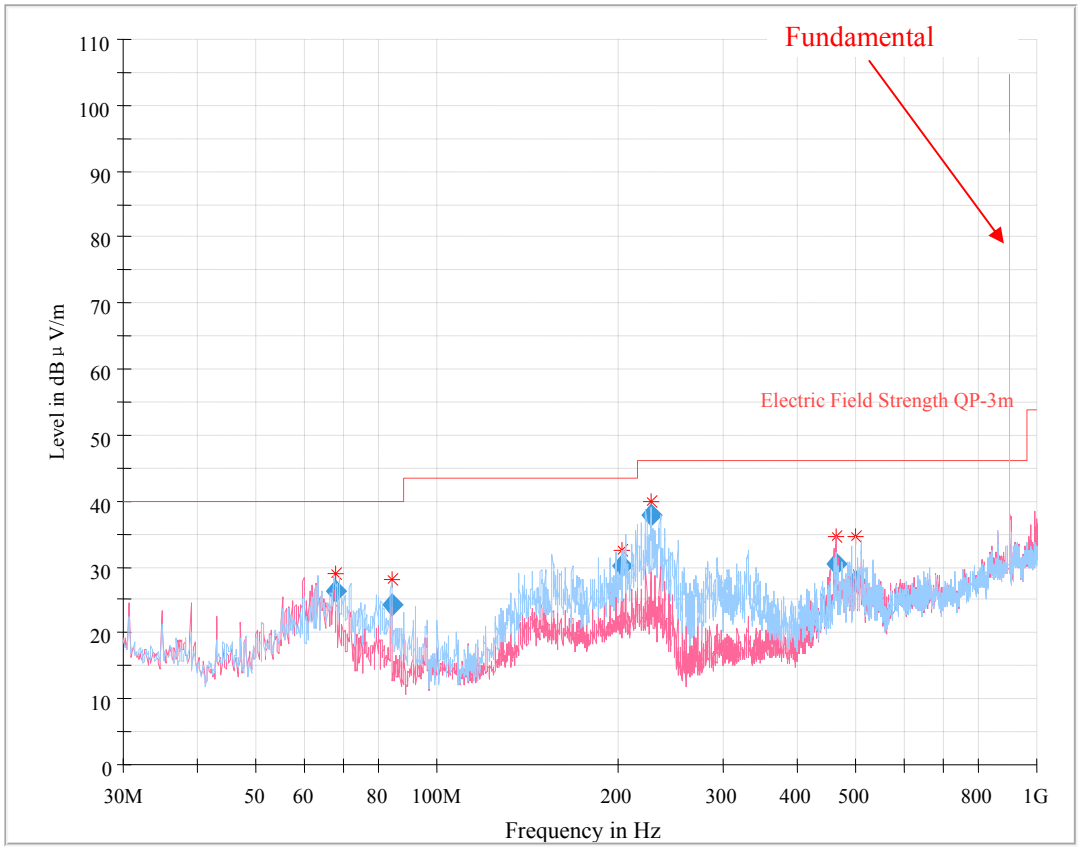
Environmental Conditions

Temperature:	26~29 ℃
Relative Humidity:	43~60 %
ATM Pressure:	101.0~101.1 kPa

The testing was performed by Harris He on 2020-08-03 for below 1GHz and Lovan Liang on 2020-09-22 for above 1GHz.

EUT operation mode: Transmitting

30 MHz~1 GHz: *(worst case is low channel)*



Final_Result

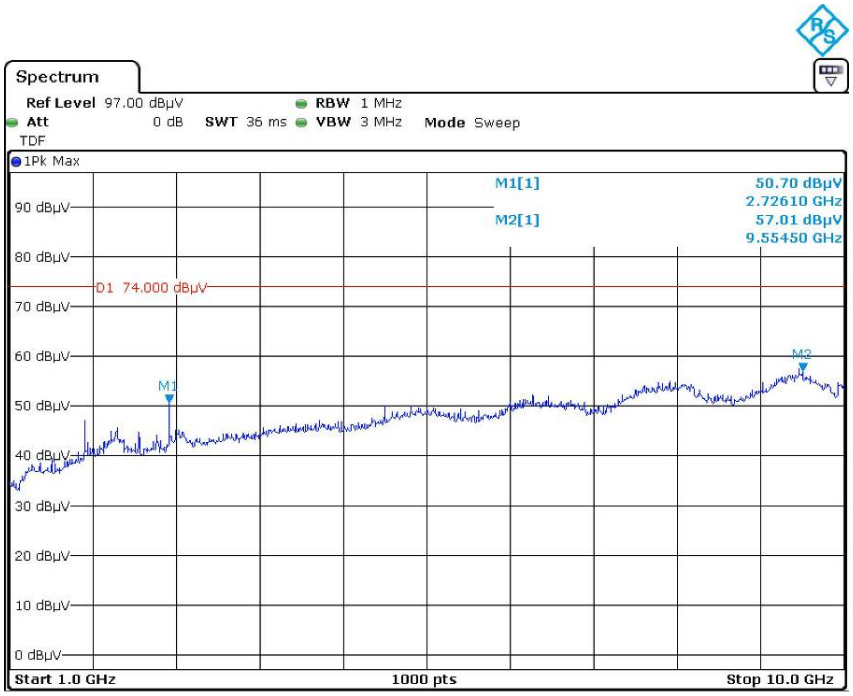
Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
67.578875	26.25	40.00	13.75	305.0	H	349.0	-20.5
83.996750	24.37	40.00	15.63	354.0	H	344.0	-19.6
202.761000	30.30	43.50	13.20	127.0	H	337.0	-13.8
228.098000	37.93	46.00	8.07	143.0	H	90.0	-14.0
461.670625	30.58	46.00	15.42	128.0	V	57.0	-7.5
497.637375	27.75	46.00	18.25	104.0	H	296.0	-5.3

1 GHz - 10 GHz:

Frequency (MHz)	Receiver		Turntable Degree	Rx Antenna		Corrected Factor (dB)	Corrected Amplitude (dBμV/m)	FCC Part 15.247/205/209	
	Reading (dBμV)	Detector (PK/QP/Ave.)		Height (m)	Polar (H/V)			Limit (dBμV/m)	Margin (dB)
902.3MHz									
1804.60	55.68	PK	132	2.0	V	-1.65	54.03	74	19.97
1804.60	52.46	Ave.	132	2.0	V	-1.65	50.81	54	3.19
2706.90	53.64	PK	49	1.2	V	1.09	54.73	74	19.27
2706.90	50.56	Ave.	49	1.2	V	1.09	51.65	54	2.35
908.7MHz									
1817.40	55.25	PK	0	2.2	V	-1.55	53.70	74	20.30
1817.40	52.04	Ave.	0	2.2	V	-1.55	50.49	54	3.51
2726.10	53.12	PK	279	2.0	V	1.19	54.31	74	19.69
2726.10	50.56	Ave.	279	2.0	V	1.19	51.75	54	2.25
914.9MHz									
1829.80	55.84	PK	294	1.4	V	-1.55	54.29	74	19.71
1829.80	52.50	Ave.	294	1.4	V	-1.55	50.95	54	3.05
2744.70	53.76	PK	271	2.1	V	1.19	54.95	74	19.05
2744.70	50.47	Ave.	271	2.1	V	1.19	51.66	54	2.34

Note:
Corrected Factor = Antenna factor (RX) + Cable Loss – Amplifier Factor
Corrected Amplitude = Corrected Factor + Reading
Margin = Limit - Corrected. Amplitude
The other spurious emission which is 20dB to the limit was not recorded.

Pre-scan with middle channel Peak
Horizontal



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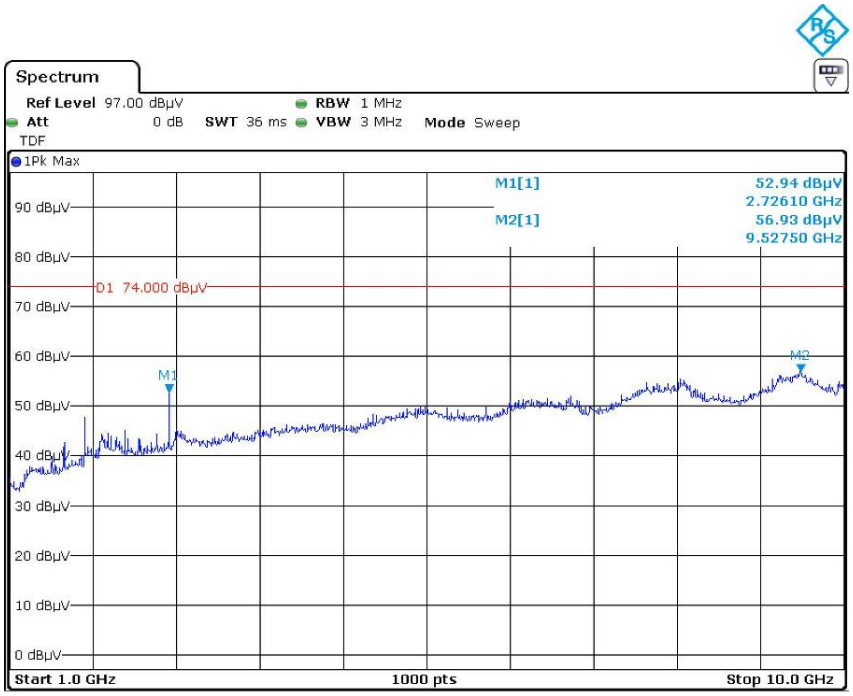
Vertical



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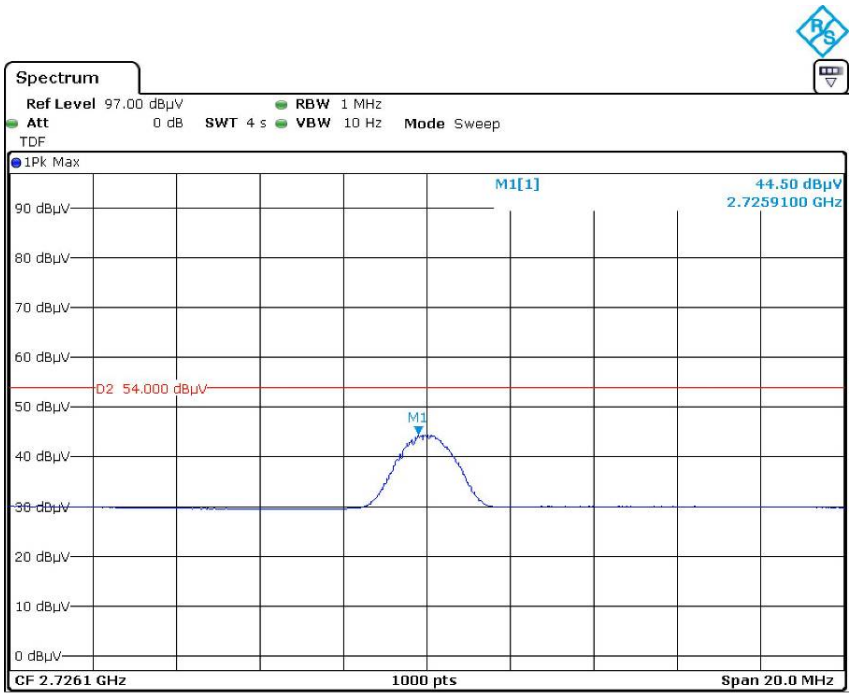
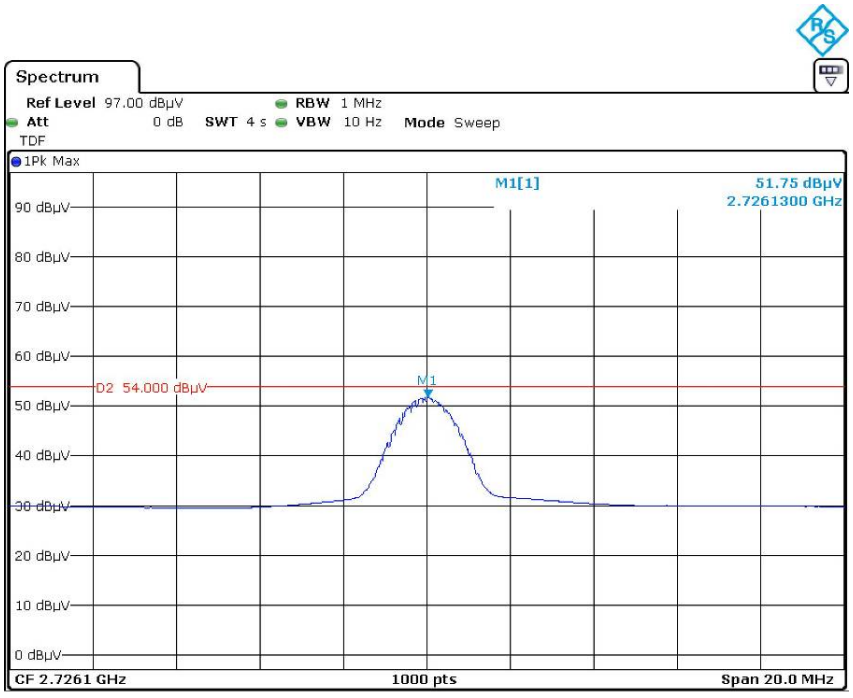
Pre-scan for Average
Horizontal



Vertical



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

Applicable Standard

Frequency hopping systems shall have hoping 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.

Test Procedure

1. Set the EUT in transmitting mode, maxhold the channel.
2. Set the adjacent channel of the EUT and maxhold another trace.
3. Measure the channel separation.

Test Data

Environmental Conditions

Temperature:	25 ℃
Relative Humidity:	53 %
ATM Pressure:	101.0 kPa

The testing was performed by Coco Liu on 2020-10-14.

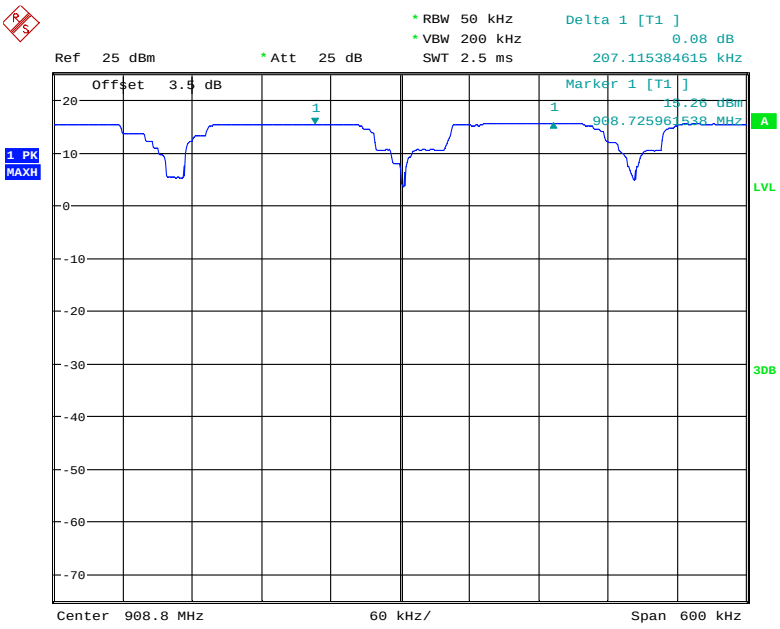
EUT operation mode: Transmitting

Test Result: Pass

Please refer to following table and plots

Test Mode	Frequency [MHz]	Frequency Separation [MHz]	20dB Bandwidth [MHz]	Verdict
Hybrid System	Hop	0.207	0.149	Pass

Note: Limit = 20 dB bandwidth



Date: 14.OCT.2020 11:03:54

FCC §15.247(a) (1) (i)– 20 dB EMISSION BANDWIDTH

Applicable Standard

According to §15.247(a) (1) (i) For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.

Test Procedure

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Position the EUT without connection to measurement instrument. 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.
3. Measure the frequency difference of two frequencies that were attenuated 20 dB from the reference level. Record the frequency difference as the emission bandwidth.
4. Repeat above procedures until all frequencies measured were complete.

Test Data

Environmental Conditions

Temperature:	25 ℃
Relative Humidity:	53 %
ATM Pressure:	101.0 kPa

The testing was performed by Coco Liu on 2020-10-14.

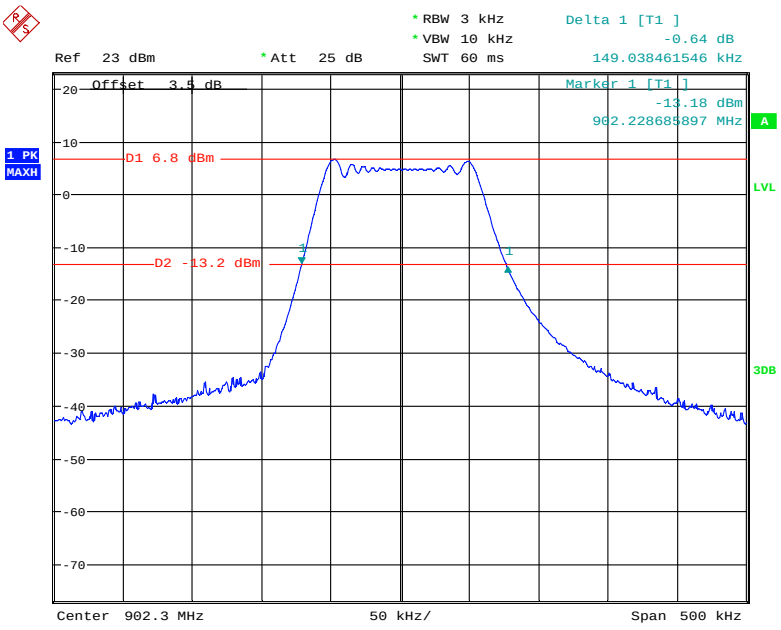
EUT operation mode: Transmitting

Test Result: Pass

Please refer to following table and plots.

Channel	Frequency (MHz)	20 dB Emission Bandwidth (MHz)
Low	902.3	0.149
Middle	908.7	0.147
High	914.9	0.148

Low Channel



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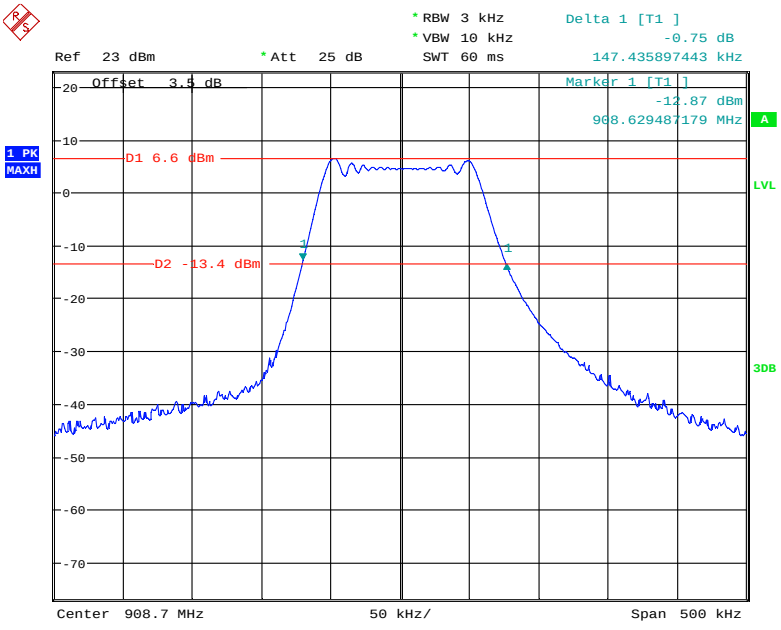
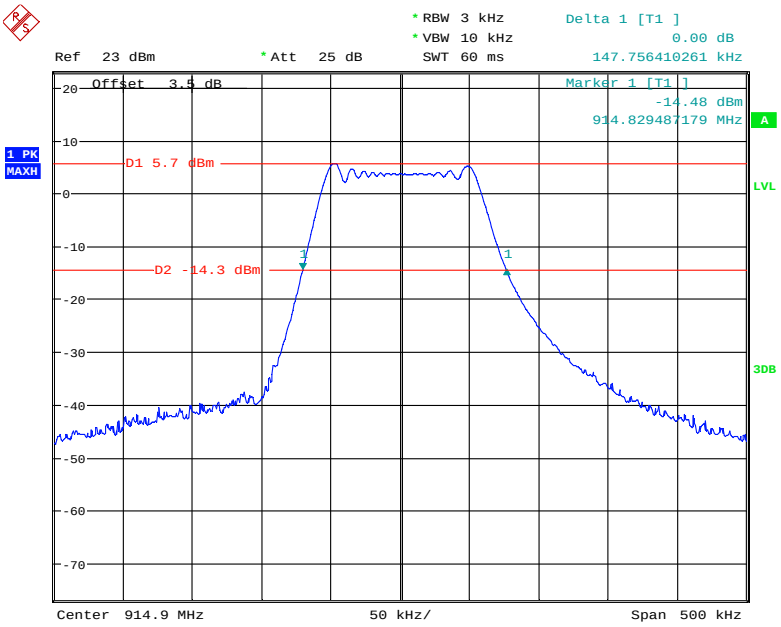
Middle Channel



Date: 14.OCT.2020 10:34:05

High Channel



Date: 14.OCT.2020 10:27:52

FCC §15.247(f) - TIME OF OCCUPANCY (DWELL TIME)

Applicable Standard

(f) For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques. The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned-off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The power spectral density conducted from the intentional radiator to the antenna due to the digital modulation operation of the hybrid system, with the frequency hopping operation turned off, shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

Test Procedure

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 $\leqslant$ channel spacing and where possible RBW should be set >> 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:

(Number of hops in the period specified in the requirements) =
(number of hops on spectrum analyzer) × (period specified in the requirements / analyzer sweep time)

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.

Test Data

Environmental Conditions

Temperature:	25 ℃
Relative Humidity:	53 %
ATM Pressure:	101.0 kPa

The testing was performed by Coco Liu on 2020-10-14.

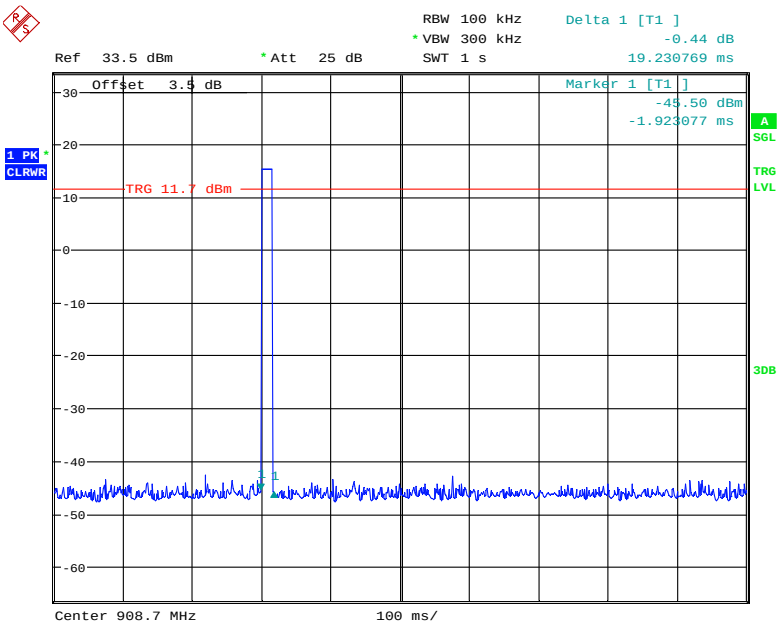
EUT operation mode: Transmitting

Test Result: Pass

Please refer to following table and plots.

Frequency (MHz)	Observe time (s)	Pulse width (ms)	Total Hops	Dwell time (s)	Limit (s)
908.7	25.6	19.23	1	0.019	0.4
Note: Observe time=0.4s*channel number=0.4s*64=25.6s					

Note: the second high signal is from other channels.



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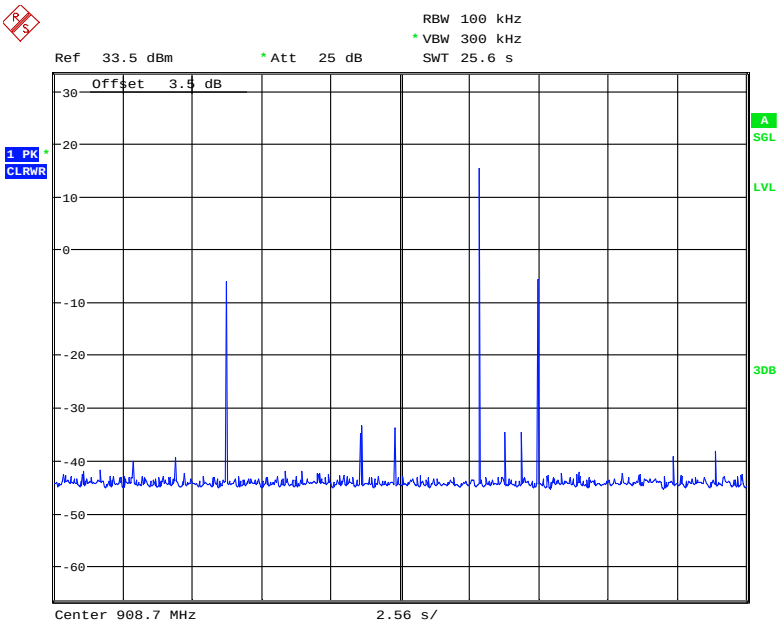


Date: 14.OCT.2020 09:53:03

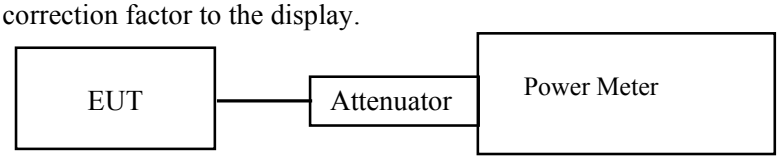
FCC §15.247(b) (3) - MAXIMUM CONDUCTED OUTPUT POWER

Applicable Standard

(3) For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands: 1 Watt. As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted output power. Maximum Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the *maximum conducted output power* is the highest total transmit power occurring in any mode.

Test Procedure

1. Place the EUT on a bench and set it in transmitting mode.
2. Remove the antenna from the EUT and then connect a low loss RF cable from the antenna port to one test equipment.
3. Add a correction factor to the display.



Test Data

Environmental Conditions

Temperature:	25 ℃
Relative Humidity:	53 %
ATM Pressure:	101.0 kPa

The testing was performed by Coco Liu on 2020-10-14.

Test Result: Pass

Please refer to following table.

EUT operation mode: Transmitting

Test Mode	Frequency (MHz)	Max Conducted Peak Output Power (dBm)	Limit[dBm]	Verdict
Hybrid System	902.3	15.58	<=30	Pass
	908.7	15.57		Pass
	914.9	14.46		Pass

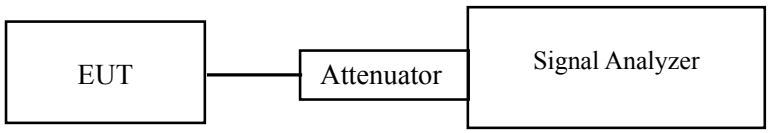
FCC §15.247(d) – 100 kHz BANDWIDTH OF FREQUENCY BAND EDGE

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

1. Check the calibration of the measuring instrument using either an internal calibrator or a known signal from an external generator.
2. Position the EUT without connection to measurement instrument. Turn on the EUT and connect its antenna terminal to measurement instrument via a low loss cable. Then set it to any one measured frequency within its operating range, and make sure the instrument is operated in its linear range.
3. Set RBW to 100 kHz and VBW of spectrum analyzer to 300 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:	25 ℃
Relative Humidity:	53 %
ATM Pressure:	101.0 kPa

The testing was performed by Coco Liu on 2020-10-14.

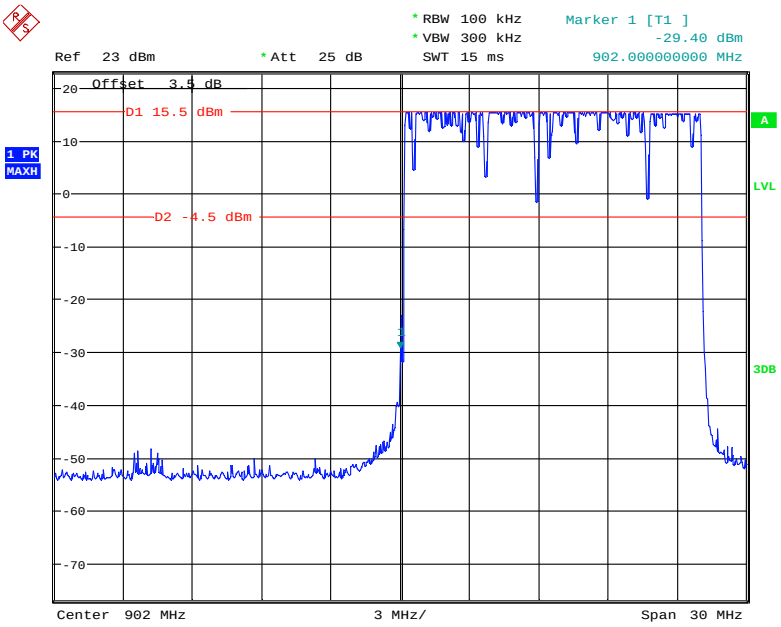
EUT operation mode: Transmitting

Test Result: Pass

Please refer to following plots.

Low Channel

Hopping



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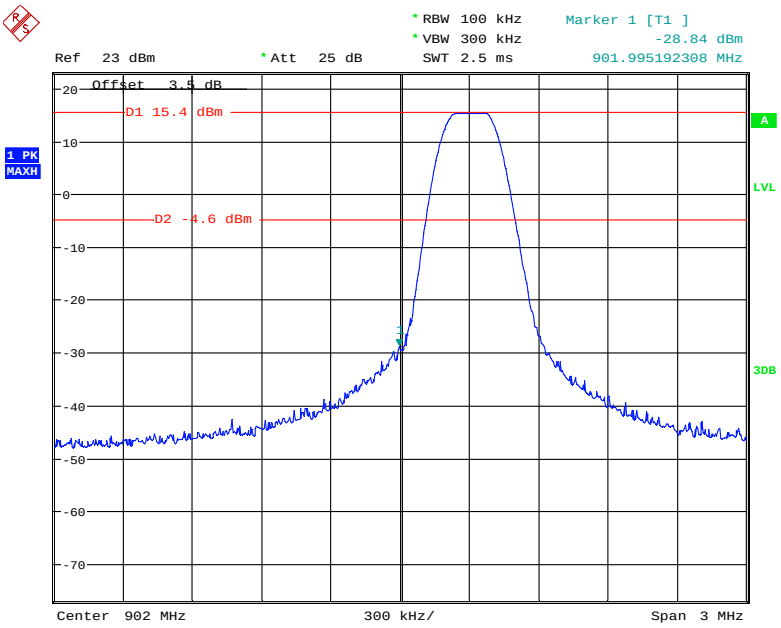
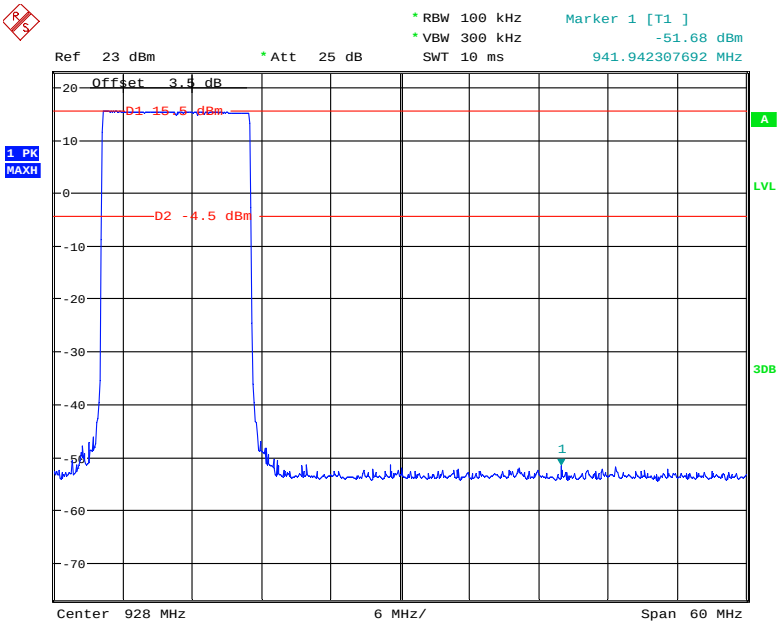
Single



Date: 14.OCT.2020 10:19:45

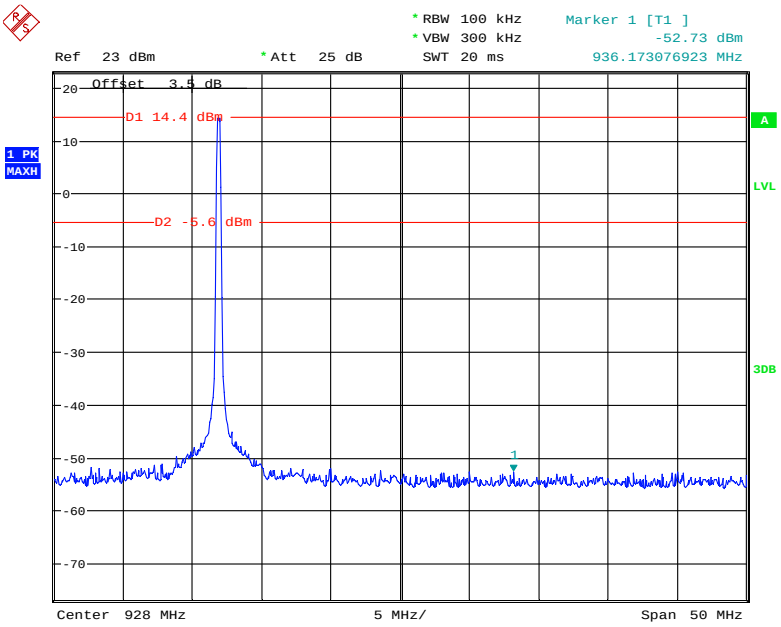
High Channel

Hopping



Date: 14.OCT.2020 10:53:41

Single



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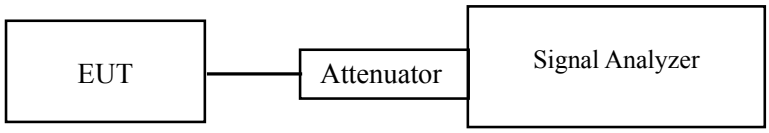
FCC §15.247(f) - POWER SPECTRAL DENSITY

Applicable Standard

(f) For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques. The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned-off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The power spectral density conducted from the intentional radiator to the antenna due to the digital modulation operation of the hybrid system, with the frequency hopping operation turned off, shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

Test Procedure

1. Use this procedure when the maximum peak conducted output power in the fundamental emission is used to demonstrate compliance.
2. Set the RBW to: 3kHz≤ RBW≤100 kHz.
3. Set the VBW ≥ 3×RBW.
4. Set the span to 1.5 times the DTS bandwidth.
5. Detector = Peak.
6. Sweep time = auto couple.
7. Trace max hold.
8. Allow trace to fully stabilize.
9. Use the peak marker function to determine the maximum amplitude level within the RBW.
10. If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat.



Test Data

Environmental Conditions

Temperature:	25 ℃
Relative Humidity:	53 %
ATM Pressure:	101.0 kPa

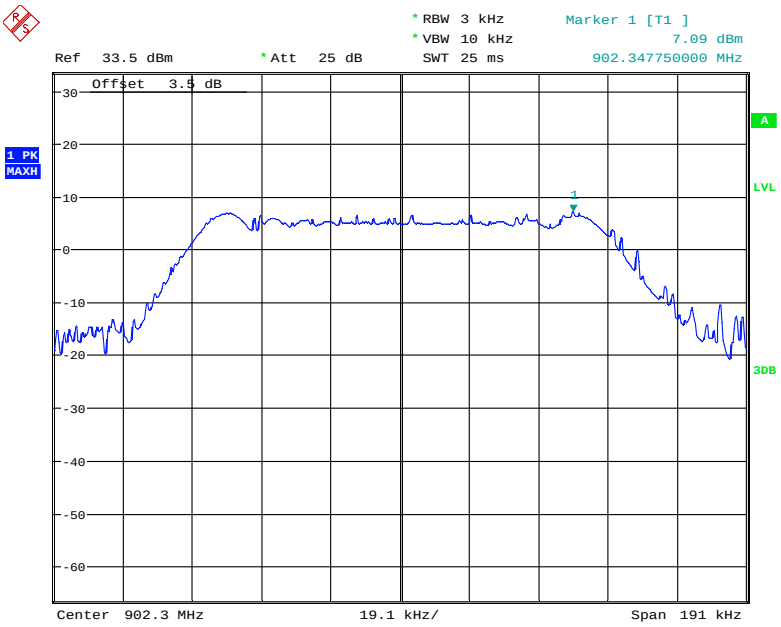
The testing was performed by Coco Liu on 2020-10-14.

EUT operation mode: Transmitting

Test Result: Pass

Test Mode	Frequency (MHz)	Result [dBm/3kHz]	Limit [dBm/3kHz]	Verdict
Hybrid System	902.3	7.09	≤8	Pass
	908.7	6.57		Pass
	914.9	5.73		Pass

Power Spectral Density, Low Channel



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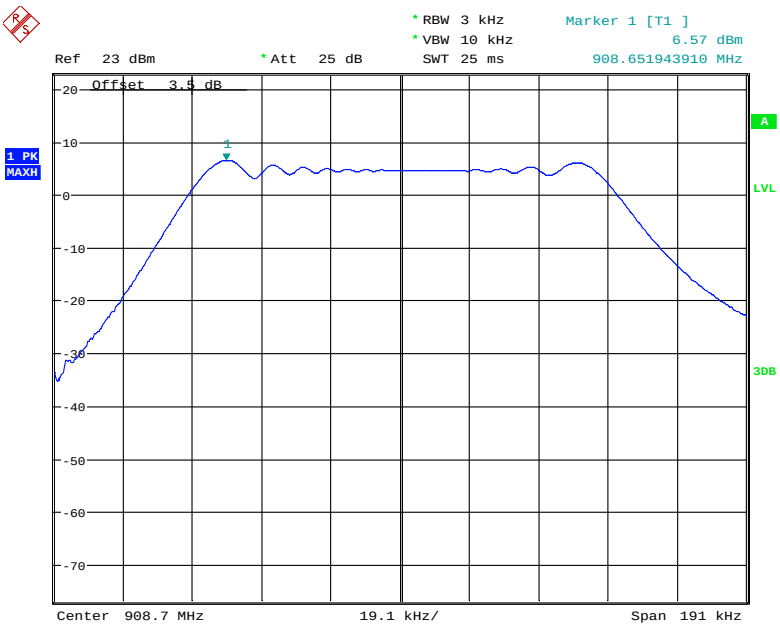
Power Spectral Density, Middle Channel



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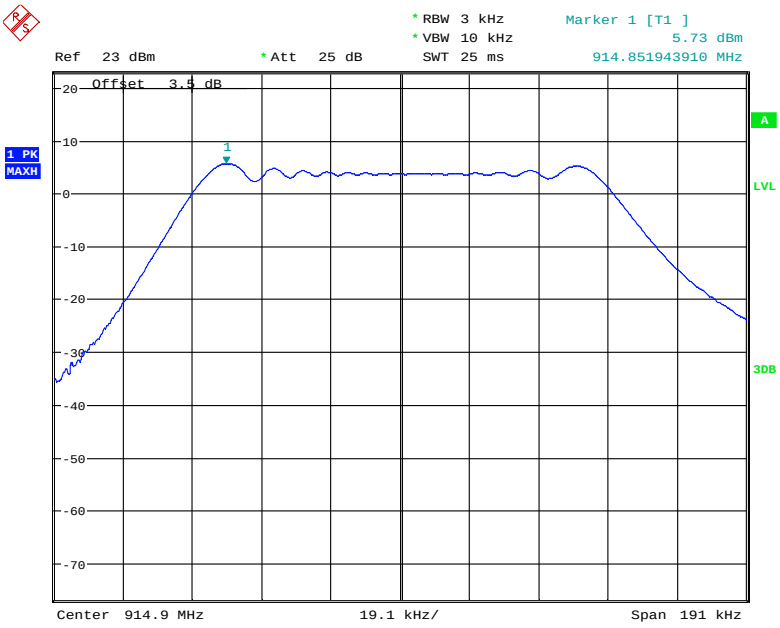
Power Spectral Density, High Channel



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