FCC PART 15, SUBPART C

TEST REPORT

For

Roku, Inc.

150 Winchester Cir

Los Gatos, CA 95032, USA

FCC ID: TC2-R1026

Report Type:	**Model:**
Original Report	100002421

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Report Number:	R1905296-247 (DSS)
Report Date:	2019-08-21
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ACCREDITED
CERTIFICATE #3297.02

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DOCUMENT REVISION HISTORY

Revision Number	Report Number	Description of Revision	Date of Revision
0	R1905296-247 (BT)	Original Report	2019-08-21

1 General Description

1.1 Product Description for Equipment Under Test (EUT)

This test and measurement report was prepared on behalf of *Roku, Inc., Model: 100002421,* FCC ID: TC2-R1026.

1.2 Objective

This report is prepared on behalf of *Roku, Inc,* in accordance with Part 2, Subpart J, and Part 15, Subparts B and C of the Federal Communication Commission's rules.

The objective is to determine compliance with FCC Part 15.247 rules for Output Power, Antenna Requirements, 20 dB Bandwidth, 100 kHz Bandwidth of Band Edges Measurement, Conducted and Radiated Spurious Emissions, Number of Hopping Channels, Dwell Time, and Hopping Channel Separation.

1.3 Related Submittal(s)/Grant(s)

FCC Part 15, Subpart C, Equipment DTS with FCC ID: TC2-R1026
FCC Part 15, Subpart E, Equipment NII with FCC ID: TC2-R1026

1.4 Test Methodology

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

1.5 Measurement Uncertainty

All measurements involve certain levels of uncertainties, especially in the field of EMC. The factors contributing to uncertainties are spectrum analyzer, cable loss, antenna factor calibration, antenna directivity, antenna factor variation with height, antenna phase center variation, antenna factor frequency interpolation, measurement distance variation, site imperfections, mismatch (average), and system repeatability.

Parameter	Measurement uncertainty
Occupied Channel Bandwidth	±5 %
RF output power, conducted	±0.57 dB
Power Spectral Density, conducted	±1.48dB
Unwanted Emissions, conducted	±1.57dB
All emissions, radiated	±4.0 dB
AC power line Conducted Emission	±2.0 dB
Temperature	±2 º C
Humidity	±5 %
DC and low frequency voltages	±1.0 %
Time	±2 %
Duty Cycle	±3 %

1.6 Test Facility Registrations

BACLs test facilities that are used to perform Radiated and Conducted Emissions tests are currently recognized by the Federal Communications Commission as Accredited with NIST Designation Number US1129.

BACL's test facilities that are used to perform Radiated and Conducted Emissions tests are currently registered with Industry Canada under Registration Numbers: 3062A-1, 3062A-2, and 3062A-3.

BACL is a Chinese Taipei Bureau of Standards Metrology and Inspection (BSMI) validated Conformity Assessment Body (CAB), under Appendix B, Phase I Procedures of the APEC Mutual Recognition Arrangement (MRA). BACL's BSMI Lab Code Number is: SL2-IN-E-1002R

BACL's test facilities that are used to perform AC Line Conducted Emissions, Telecommunications Line Conducted Emissions, Radiated Emissions from 30 MHz to 1 GHz, and Radiated Emissions from 1 GHz to 6 GHz are currently recognized as Accredited in accordance with the Voluntary Control Council for Interference [VCCI] Article 15 procedures under Registration Number A-0027.

1.7 Test Facility Accreditations

Bay Area Compliance Laboratories Corp. (BACL) is:

A- ***An independent, 3rd-Party, Commercial Test Laboratory accredited to ISO/IEC 17025:2005 by A2LA (Test Laboratory Accreditation Certificate Number 3279.02)*****,** in the fields of: Electromagnetic Compatibility and Telecommunications. Unless noted by an Asterisk (*) in the Compliance Matrix (See Section 3 of this Test Report), BACL's ISO/IEC 17025:2005 Scope of Accreditation includes all of the Test Method Standards and/or the Product Family Standards detailed in this Test Report..

BACL's ISO/IEC 17025:2005 Scope of Accreditation includes a comprehensive suite of EMC Emissions, EMC Immunity, Radio, RF Exposure, Safety and wireline Telecommunications test methods applicable to a wide range of product categories. These product categories include Central Office Telecommunications Equipment [including NEBS - Network Equipment Building Systems], Unlicensed and Licensed Wireless and RF devices,

Information Technology Equipment (ITE); Telecommunications Terminal Equipment (TTE); Medical Electrical Equipment; Industrial, Scientific and Medical Test Equipment; Professional Audio and Video Equipment; Industrial and Scientific Instruments and Laboratory Apparatus; Cable Distribution Systems, and Energy Efficient Lighting.

B- ***A Product Certification Body accredited to ISO/IEC 17065:2012 by A2LA (Product Certification Body Accreditation Certificate Number 3279.03)*** to certify

- For the USA (Federal Communications Commission):
  - 1- All Unlicensed radio frequency devices within FCC Scopes A1, A2, A3, and A4;
  - 2- All Licensed radio frequency devices within FCC Scopes B1, B2, B3, and B4;
  - 3- All Telephone Terminal Equipment within FCC Scope C.
- For the Canada (Industry Canada):
  - 1 All Scope 1-Licence-Exempt Radio Frequency Devices;
  - 2 All Scope 2-Licensed Personal Mobile Radio Services;
  - 3 All Scope 3-Licensed General Mobile & Fixed Radio Services;
  - 4 All Scope 4-Licensed Maritime & Aviation Radio Services;
  - 5 All Scope 5-Licensed Fixed Microwave Radio Services
  - 6 All Broadcasting Technical Standards (BETS) in the Category I Equipment Standards List.
- For Singapore (Info-Communications Development Authority (IDA)):
  - 1 All Line Terminal Equipment: All Technical Specifications for Line Terminal Equipment – Table 1 of IDA MRA Recognition Scheme: 2011, Annex 2
  - 2. All Radio-Communication Equipment: All Technical Specifications for Radio-Communication Equipment – Table 2 of IDA MRA Recognition Scheme: 2011, Annex 2
- For the Hong Kong Special Administrative Region:
  - 1 All Radio Equipment, per KHCA 10XX-series Specifications;
  - 2 All GMDSS Marine Radio Equipment, per HKCA 12XX-series Specifications;
  - 3 All Fixed Network Equipment, per HKCA 20XX-series Specifications.
- For Japan:
  - 1 MIC Telecommunication Business Law (Terminal Equipment):
    - All Scope A1 - Terminal Equipment for the Purpose of Calls;
    - All Scope A2 - Other Terminal Equipment
  - 2 Radio Law (Radio Equipment):
    - All Scope B1 - Specified Radio Equipment specified in Article 38-2-2, paragraph 1, item 1 of the Radio Law
    - All Scope B2 - Specified Radio Equipment specified in Article 38-2-2, paragraph 1, item 2 of the Radio Law
    - All Scope B3 - Specified Radio Equipment specified in Article 38-2-2, paragraph 1, item 3 of the Radio Law

C- ***A Product Certification Body accredited to ISO/IEC 17065:2012 by A2LA (Product Certification Body Accreditation Certificate Number 3279.01)*** to certify Products to USA's Environmental Protection Agency (EPA) ENERGY STAR Product Specifications for:

1 Electronics and Office Equipment:
- for Telephony (ver. 3.0)
- for Audio/Video (ver. 3.0)
- for Battery Charging Systems (ver. 1.1)
- for Set-top Boxes & Cable Boxes (ver. 4.1)
- for Televisions (ver. 6.1)
- for Computers (ver. 6.0)
- for Displays (ver. 6.0)
- for Imaging Equipment (ver. 2.0)

- for Computer Servers (ver. 2.0)

2 Commercial Food Service Equipment
- for Commercial Dishwashers (ver. 2.0)
- for Commercial Ice Machines (ver. 2.0)
- for Commercial Ovens (ver. 2.1)
- for Commercial Refrigerators and Freezers

3 Lighting Products
- For Decorative Light Strings (ver. 1.5)
- For Luminaires (including sub-components) and Lamps (ver. 1.2)
- For Compact Fluorescent Lamps (CFLs) (ver. 4.3)
- For Integral LED Lamps (ver. 1.4)

4 Heating, Ventilation, and AC Products
- for Residential Ceiling Fans (ver. 3.0)
- for Residential Ventilating Fans (ver. 3.2)

5 Other
- For Water Coolers (ver. 3.0)

D- ***A NIST Designated Phase-I and Phase-II Conformity Assessment Body (CAB) for the following economies and regulatory authorities under the terms of the stated MRAs/Treaties:***

- Australia: ACMA (Australian Communication and Media Authority) – APEC Tel MRA -Phase I;
- Canada: (Innovation, Science and Economic development Canada - ISEDC) Foreign Certification Body – FCB – APEC Tel MRA -Phase I & Phase II;
- Chinese Taipei (Republic of China – Taiwan):
  - BSMI (Bureau of Standards, Metrology and Inspection) APEC Tel MRA -Phase I;
  - NCC (National Communications Commission) APEC Tel MRA -Phase I;
- European Union:
  - EMC Directive 2014/30/EU US-EU EMC & Telecom MRA CAB (NB)
  - Radio Equipment (RE) Directive 2014/53/EU US-EU EMC & Telecom MRA CAB (NB)
  - Low Voltage Directive (LVD) 2014/35/EU
- Hong Kong Special Administrative Region: (Office of the Telecommunications Authority – OFTA) APEC Tel MRA -Phase I & Phase II
- Israel – US-Israel MRA Phase I
- Republic of Korea (Ministry of Communications - Radio Research Laboratory) APEC Tel MRA -Phase I
- Singapore: (Infocomm Media Development Authority - IMDA) APEC Tel MRA -Phase I & Phase II;
- Japan: VCCI - Voluntary Control Council for Interference US-Japan Telecom Treaty VCCI Side Letter-
- USA:
  - ENERGY STAR Recognized Test Laboratory – US EPA
  - Telecommunications Certification Body (TCB) – US FCC;
  - Nationally Recognized Test Laboratory (NRTL) – US OSHA
- Vietnam: APEC Tel MRA -Phase I;

2 System Test Configuration

2.1 Justification

The EUT was configured for testing in accordance to ANSI C63.10-2013

The worst-case data rates are determined by measuring the peak power across all data rates.

2.2 EUT Exercise Software

The test software used was Putty, the software is compliant with the standard requirements being tested against.

Modulation	Frequency (MHz)	Power Setting
GFSK	2402	23
	2441	23
	2480	23
π/4-DQPSK	2402	23
	2441	23
	2480	23
8DPSK	2402	23
	2441	23
	2480	23

2.3 Duty Cycle Correction Factor

According to ANSI C63.10-2013 section 7.5:

Unless otherwise specified, when the radiated emission limits are expressed in terms of the average value of the emission, and pulsed operation is employed, the measurement field strength shall be determined by averaging over one complete pulse train, including blanking intervals, as long as the pulse train does not exceed 0.1 s (100 ms). In cases where the pulse train exceeds 0.1 s, the measured field strength shall be determined during a 0.1 s interval. The following procedure is an example of how the average value may be determined. The average field strength may be found by measuring the peak pulse amplitude (in log equivalent units) and determining the duty cycle correction factor (in dB) associated with the pulse modulation as shown in following equation:

$\delta(dB) = 20\log(\Delta)$

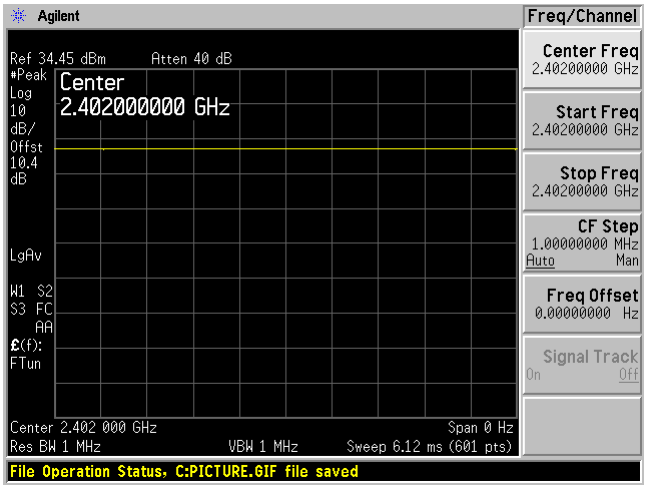
where
δ is the duty cycle correction factor (dB)
Δ is the duty cycle (dimensionless)

Radio Mode	Duty Cycle (%)	Duty Cycle Correction Factor (dB)
GFSK	100	0
π/4-DQPSK	100	0
8DPSK	100	0

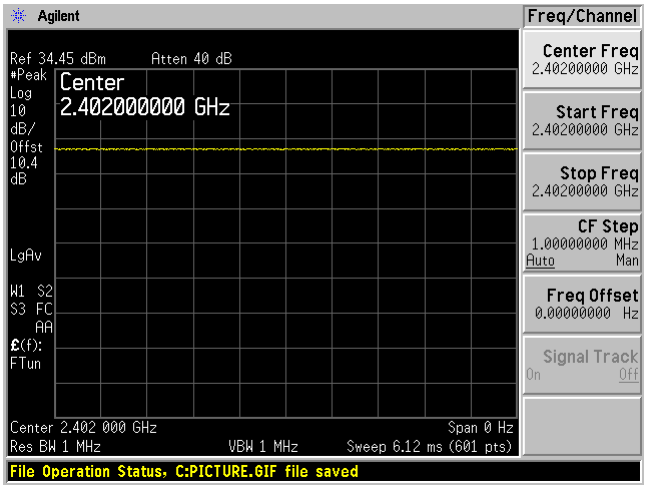
Duty Cycle = On Time (ms)/ Period (ms)

Please refer to the following plots.

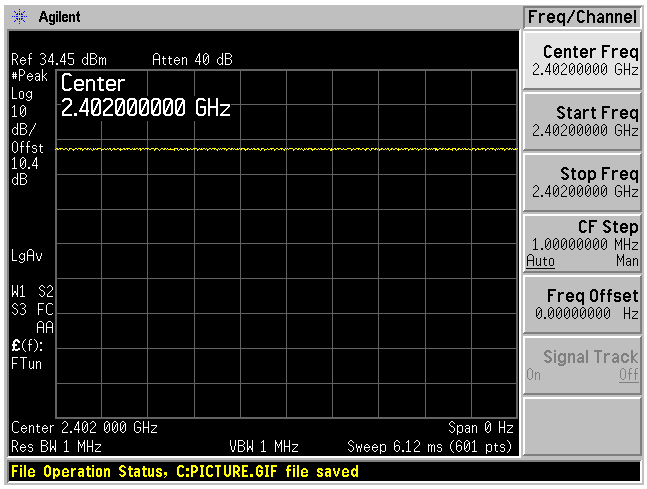
GFSK Mode



π/4-DQPSK Mode



8DPSK Mode



2.4 Equipment Modifications

N/A

2.5 Local Support Equipment

Manufacturer	Description	Model
Dell	Laptop	Latitude E7450
Dell	Laptop	Latitude E6410

2.6 Support Equipment

Manufacturer	Description	Model
Roku	Debug Board	Unknown

2.7 Interface Ports and Cabling

Cable Description	Length (m)	To	From
USB Cable	< 1 m	Laptop	EUT
RF Cable	< 1 m	EUT	PSA

3 Summary of Test Results

Results reported relate only to the product tested.

FCC Rules	Description of Test	Results
FCC §15.203	Antenna Requirement	Compliant
FCC §15.207	AC Line Conducted Emissions	Compliant
FCC §2.1091, §15.247(i)	RF Exposure	Compliant
FCC §2.1051, §15.247 (d)	Spurious Emissions at Antenna Port	Compliant
FCC §2.1053, §15.205, §15.209, §15.247(d)	Radiated Spurious Emissions	Compliant
FCC §15.247(a)(1)	20 dB and 99% Emission Bandwidth	Compliant
FCC §15.247(b)(1)	Maximum Peak Output Power	Compliant
FCC §15.247(d)	100 kHz Bandwidth of Frequency Band Edge	Compliant
FCC §15.247(a)(1)(iii)	Number of Hopping Channels	Compliant
FCC §15.247(a)(1)	Hopping Channel Separation	Compliant
FCC §15.247(a)(1)(iii)	Dwell Time	Compliant

4 FCC §15.203 - Antenna Requirements

4.1 Applicable Standards

According to FCC §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 use of a standard antenna jack or electrical connector is prohibited.

And according to FCC §15.247 (b) (4), if transmitting antennas of directional gain greater than 6 dBi are used the power shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

4.2 Antenna Description

The antennas used by the EUT are permanent attached antennas.

Antenna usage	Band of Operation (GHz)	Maximum Antenna Gain (dBi)
Bluetooth	2400-2483.5	1.8

5 FCC §2.1091, §15.247(i) - RF Exposure

5.1 Applicable Standards

According to FCC §15.407(f) and §1.1307(b)(1), systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy level in excess of the Commission's guidelines.

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)
Limits for General Population/Uncontrolled Exposure				
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

5.2 MPE Prediction

Predication of MPE limit at a given distance, Equation from OET Bulletin 65, Edition 97-01

$$S = PG/4\pi R^2$$

Where: S = power density
P = power input to antenna
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the center of radiation of the antenna

5.3 MPE Results

Radio 1

5 GHz Wi-Fi

Maximum output power at antenna input terminal (dBm):	21.91
Tuned up maximum output power at antenna input terminal (dBm):	22.91
Tuned up maximum output power at antenna input terminal (mW):	195.4339
Prediction distance (cm):	20
Prediction frequency (MHz):	5745
Maximum Antenna Gain, typical (dBi):	2.6
Maximum Antenna Gain (numeric):	1.82
Power density of prediction frequency at 20.0 cm (mW/cm^2):	0.0708
FCC MPE limit for uncontrolled exposure at prediction frequency (mW/cm^2):	1.0

The device is compliant with the requirement MPE limit for uncontrolled exposure. The maximum power density at the distance of 20 cm is 0.0708 mW/cm^2. Limit is 1.0 mW/cm^2.

2.4 GHz Wi-Fi

Maximum peak output power at antenna input terminal (dBm):	22.47
Tuned up maximum output power at antenna input terminal (dBm):	23.47
Tuned up maximum output power at antenna input terminal (mW):	222.331
Prediction distance (cm):	20
Prediction frequency (MHz):	2437
Maximum Antenna Gain, typical (dBi):	1.8
Maximum Antenna Gain (numeric):	1.51
Power density of prediction frequency at 20.0 cm (mW/cm^2):	0.0670
FCC MPE limit for uncontrolled exposure at prediction frequency (mW/cm^2):	1.0

The device is compliant with the requirement MPE limit for uncontrolled exposure. The maximum power density at the distance of 20 cm is 0.0670 mW/cm^2. Limit is 1.0 mW/cm^2.

Radio 2

5 GHz Wi-Fi

Maximum output power at antenna input terminal (dBm):	19.18
Tuned up maximum output power at antenna input terminal (dBm):	20.18
Tuned up maximum output power at antenna input terminal (mW):	104.232
Prediction distance (cm):	20
Prediction frequency (MHz):	5745
Maximum Antenna Gain, typical (dBi):	2.6
Maximum Antenna Gain (numeric):	1.82
Power density of prediction frequency at 20.0 cm (mW/cm^2):	0.0378
FCC MPE limit for uncontrolled exposure at prediction frequency (mW/cm^2):	1.0

The device is compliant with the requirement MPE limit for uncontrolled exposure. The maximum power density at the distance of 20 cm is 0.0378 mW/cm^2. Limit is 1.0 mW/cm^2.

2.4 GHz Wi-Fi

Maximum peak output power at antenna input terminal (dBm):	22.02
Tuned up maximum output power at antenna input terminal (dBm):	23.02
Tuned up maximum output power at antenna input terminal (mW):	200.45
Prediction distance (cm):	20
Prediction frequency (MHz):	2412
Maximum Antenna Gain, typical (dBi):	1.8
Maximum Antenna Gain (numeric):	1.51
Power density of prediction frequency at 20.0 cm (mW/cm^2):	0.0604
FCC MPE limit for uncontrolled exposure at prediction frequency (mW/cm^2):	1.0

The device is compliant with the requirement MPE limit for uncontrolled exposure. The maximum power density at the distance of 20 cm is 0.0604 mW/cm^2. Limit is 1.0 mW/cm^2.

2.4 GHz Classic Bluetooth

Maximum peak output power at antenna input terminal (dBm):	12.81
Tuned up maximum output power at antenna input terminal (dBm):	13.81
Tuned up maximum output power at antenna input terminal (mW):	24.04
Prediction distance (cm):	20
Prediction frequency (MHz):	2402
Maximum Antenna Gain, typical (dBi):	1.8
Maximum Antenna Gain (numeric):	1.51
Power density of prediction frequency at 20.0 cm (mW/cm^2):	0.00724
FCC MPE limit for uncontrolled exposure at prediction frequency (mW/cm^2):	1.0

The device is compliant with the requirement MPE limit for uncontrolled exposure. The maximum power density at the distance of 20 cm is 0.00724mW/cm^2. Limit is 1.0 mW/cm^2.

Worst case colocation Radio 1 5 GHz Wi-Fi, Radio 2 2.4 GHz Wi-Fi and 2.4 GHz Classic Bluetooth:

Frequency Band	Tuned up Max Conducted Power(dBm)	Evaluated Distance (cm)	Worst-Case MPE (mW/cm^2)	MPE Limit (mW/cm^2)	Worst-Case MPE Ratios	Sum of MPE Ratios	Limit
Worst Case							
Radio 1 5 GHz WiFi	22.91	20	0.0708	1.0	7.08%	13.844%	100%
Radio 2 2.4 GHz WiFi	23.02	20	0.0604	1.0	6.04%		
2.4 GHz Classic BT	13.81	20	0.00724	1.0	0.724%		

6 FCC §15.207 - AC Line Conducted Emissions

6.1 Applicable Standards

As per FCC §15.207 Conducted limits:

For an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz shall not exceed the limits in the following table, as measured using a 50 μH/50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequencies ranges.

Frequency of Emission (MHz)	Conducted Limit (dBuV)	
	Quasi-Peak	Average
0.15-0.5	66 to 56 Note 1	56 to 46 Note 2
0.5-5	56	46
5-30	60	50

Note 1: Decreases with the logarithm of the frequency.
Note 2: A linear average detector is required

6.2 Test Setup

The measurement was performed at shield room, using the setup per ANSI C63.10-2013 measurement procedure. The specification used was FCC §15.207 limits.

External I/O cables were draped along the edge of the test table and bundle when necessary.

The AC/DC power adapter of the EUT was connected with LISN-1 which provided 120 V / 60 Hz AC power.

6.3 Test Procedure

During the conducted emissions test, the power cord of the EUT host system was connected to the mains outlet of the LISN-1 and the power cords of support equipment were connected to LISN-2.

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

All data were recorded in the peak detection mode, quasi-peak, and average detection mode. Quasi-Peak readings are distinguished with a “QP.” Average readings are distinguished with an “Ave”.

6.4 Corrected Amplitude and Margin Calculation

The Corrected Amplitude (CA) is calculated by adding the Cable Loss (CL), the Attenuator Factor (Atten) to indicated Amplitude (Ai) reading. The basic equation is as follows:

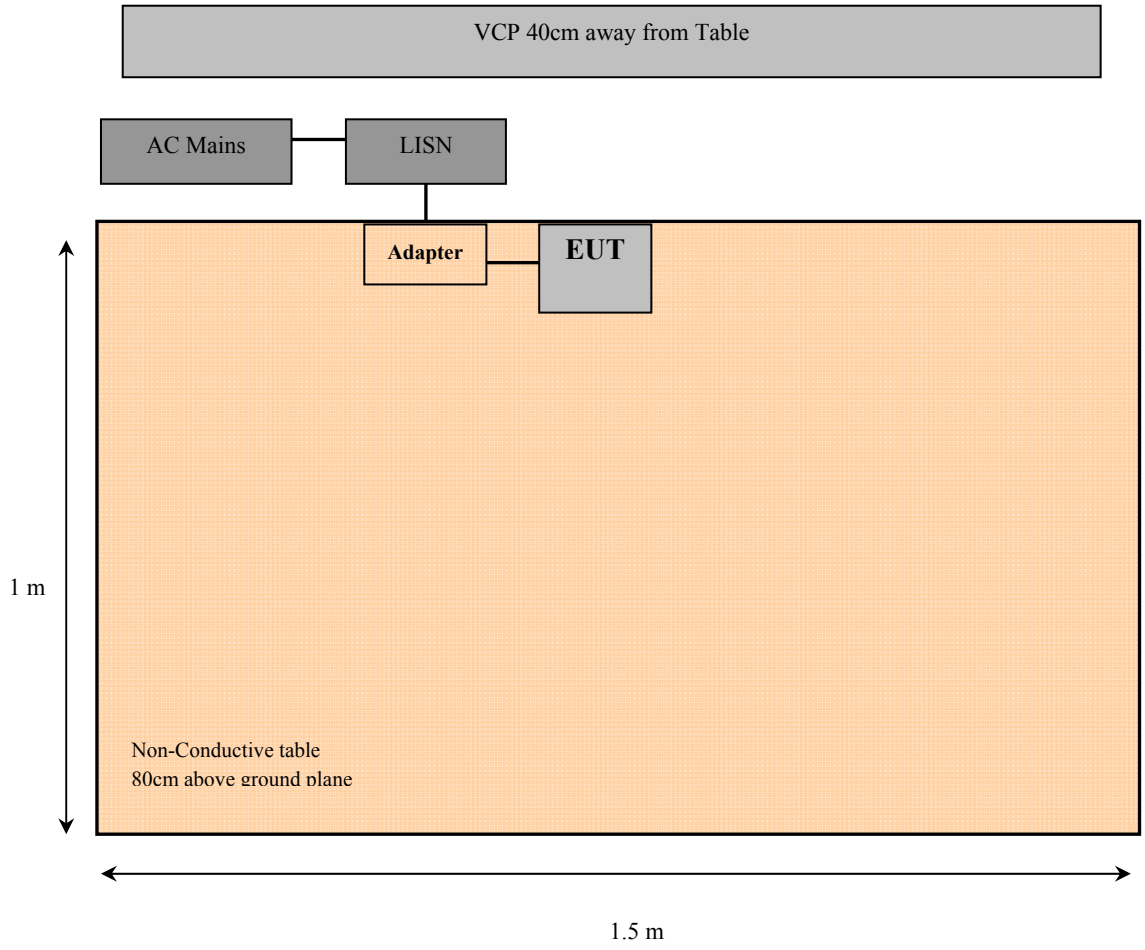
CA = Ai + CL + Atten

For example, a corrected amplitude of 46.2 dBuV = Indicated Reading (32.5 dBuV) + Cable Loss (3.7 dB) + Attenuator (10 dB)

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

Margin = Corrected Amplitude – Limit

6.5 Test Setup Block Diagram



6.6 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Rohde and Schwarz	EMI Test Receiver	ESCI 1166.5950K03	100044	2017-09-18	2 years
Rohde and Schwarz	Impulse Limiter	ESH3-Z2	101964	2018-07-28	1 year
Keysight Technologies	RF Limiter	11867A	MY42242931	2018-09-04	1 year
Solar Electronics Company	High Pass Filter	Type 7930-100	7930150202	2019-02-25	1 year
Fairview Microwave	Micro-Coaxial Cable	FMC0101223-360	102515	2019-07-18	1 year
FCC	LISN	FCC-LISN-50-25-2-10-CISPR16	160130	2019-04-11	1 year
Vasona	Test software	V6.0 build 11	10400213	N/R	N/R

Statement of Traceability: BACL Corp. *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

6.7 Test Environmental Conditions

Temperature:	22 ºC
Relative Humidity:	43 %
ATM Pressure:	101.8 kPa

The testing was performed by Corey Phan on 2019-07-23 in the outside emission test site.

6.8 Summary of Test Results

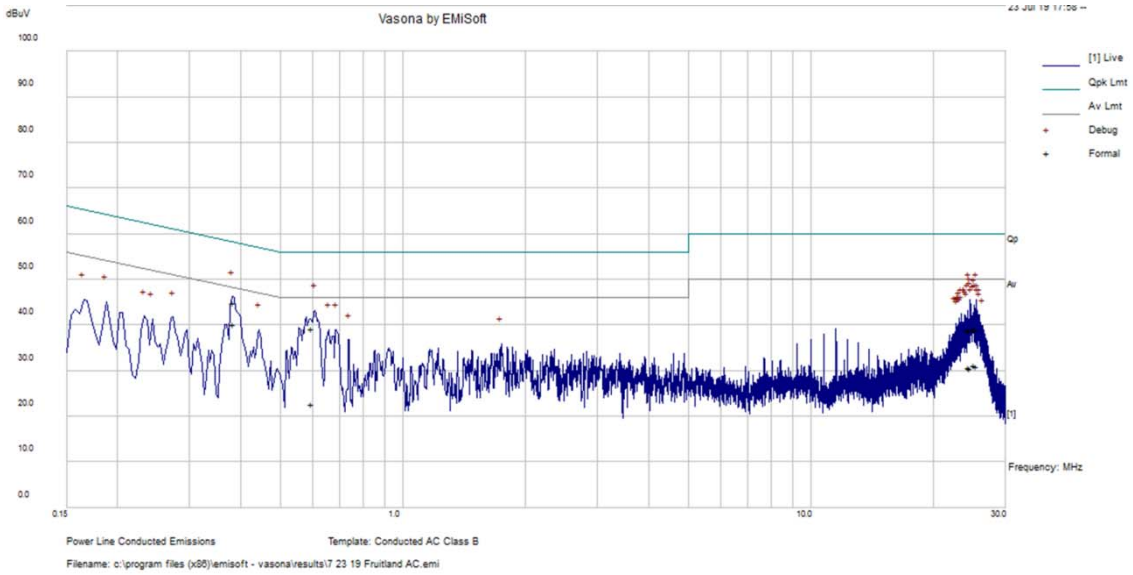
According to the recorded data in following table, the EUT complied with the FCC 15C standard's conducted emissions limits, with the margin reading of:

Connection: AC/DC adapter connected to 120 V/60 Hz, AC			
Margin (dB)	**Frequency (MHz)**	**Conductor Mode (Line/Neutral)**	**Range (MHz)**
-8.05	0.383621	Line	0.15-30

6.9 Conducted Emissions Test Plots and Data

2.4 GHz Wi-Fi, b mode, 2437 MHz Radio 1; 2.4GHz Wi-Fi b mode, 5240 MHz Radio 2 and 2.4 GHz Classic Bluetooth π/4-DQPSK (2402 MHz)

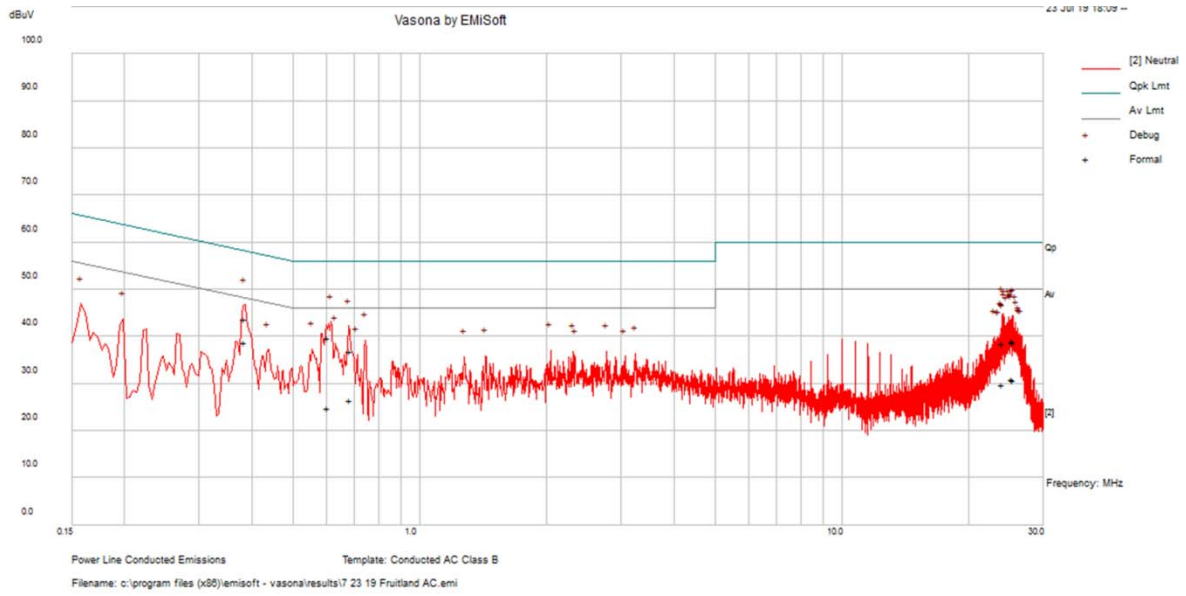
120 V, 60 Hz – Line



Frequency (MHz)	Corrected Amplitude (dBuV)	Conductor (Line/Neutral)	Limit (dBuV)	Margin (dB)	Detector (QP/Ave.)
0.383621	44.97	Line	58.2	-13.23	QP
0.599975	39.27	Line	56	-16.73	QP
24.452059	38.91	Line	60	-21.09	QP
25.424853	38.89	Line	60	-21.11	QP
24.58086	38.7	Line	60	-21.3	QP
25.144369	39.28	Line	60	-20.72	QP

Frequency (MHz)	Corrected Amplitude (dBuV)	Conductor (Line/Neutral)	Limit (dBuV)	Margin (dB)	Detector (QP/Ave.)
0.383621	**40.16**	**Line**	**48.2**	**-8.05**	**Ave**
0.599975	22.68	Line	46	-23.32	Ave
24.452059	30.62	Line	50	-19.38	Ave
25.424853	30.99	Line	50	-19.01	Ave
24.58086	30.49	Line	50	-19.51	Ave
25.144369	31.11	Line	50	-18.89	Ave

120 V, 60 Hz – Neutral



Frequency (MHz)	Corrected Amplitude (dBuV)	Conductor (Line/Neutral)	Limit (dBuV)	Margin (dB)	Detector (QP/Ave.)
0.385157	43.68	Neutral	58.17	-14.49	QP
0.604324	39.6	Neutral	56	-16.4	QP
0.685075	36.77	Neutral	56	-19.23	QP
23.994903	38.56	Neutral	60	-21.44	QP
25.398756	38.75	Neutral	60	-21.25	QP
25.336248	38.9	Neutral	60	-21.1	QP

Frequency (MHz)	Corrected Amplitude (dBuV)	Conductor (Line/Neutral)	Limit (dBuV)	Margin (dB)	Detector (QP/Ave.)
0.385157	38.76	Neutral	48.17	-9.4	Ave
0.604324	24.9	Neutral	46	-21.1	Ave
0.685075	26.5	Neutral	46	-19.5	Ave
23.994903	29.79	Neutral	50	-20.21	Ave
25.398756	30.76	Neutral	50	-19.24	Ave
25.336248	30.88	Neutral	50	-19.12	Ave

7 FCC §15.209, §15.247(d) - Spurious Radiated Emissions

7.1 Applicable Standards

As per FCC §15.35(d): Unless otherwise specified, on any frequency or frequencies above 1000 MHz, the radiated emission limits are based on the use of measurement instrumentation employing an average detector function. Unless otherwise specified, measurements above 1000 MHz shall be performed using a minimum resolution bandwidth of 1 MHz.

As Per FCC §15.205(a), only spurious emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.090 – 0.110 0.495 – 0.505 2.1735 – 2.1905 4.125 – 4.128 4.17725 – 4.17775 4.20725 – 4.20775 6.215 – 6.218 6.26775 – 6.26825 6.31175 – 6.31225 8.291 – 8.294 8.362 – 8.366 8.37625 – 8.38675 8.41425 – 8.41475 12.29 – 12.293 12.51975 – 12.52025 12.57675 – 12.57725 13.36 – 13.41	16.42 – 16.423 16.69475 – 16.69525 25.5 – 25.67 37.5 – 38.25 73 – 74.6 74.8 – 75.2 108 – 121.94 123 – 138 149.9 – 150.05 156.52475 – 156.52525 156.7 – 156.9 162.0125 –167.17 167.72 – 173.2 240 – 285 322 – 335.4 399.9 – 410 608 – 614	960 – 1240 1300 – 1427 1435 – 1626.5 1645.5 – 1646.5 1660 – 1710 1718.8 – 1722.2 2200 – 2300 2310 – 2390 2483.5 – 2500 2690 – 2900 3260 – 3267 3.332 – 3.339 3 3458 – 3 358 3.600 – 4.400	4. 5 – 5. 15 5. 35 – 5. 46 7.25 – 7.75 8.025 – 8.5 9.0 – 9.2 9.3 – 9.5 10.6 – 12.7 13.25 – 13.4 14.47 – 14.5 15.35 – 16.2 17.7 – 21.4 22.01 – 23.12 23.6 – 24.0 31.2 – 31.8 36.43 – 36.5 Above 38.6

As per FCC §15.209(a): Except as provided elsewhere in this Subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

Frequency (MHz)	Field Strength (micro volts/meter)	Measurement Distance (meters)
0.009 - 0.490	2400/F(kHz)	300
0.490 - 1.705	24000/F(kHz)	30
1.705 - 30.0	30	30
30 - 88	100**	3
88 - 216	150**	3
216 - 960	200**	3
Above 960	500	3

** Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this Section shall not be located in the frequency bands 54-72 MHz, 76-88 MHz, 174-216 MHz or 470-806 MHz. However, operation within these frequency bands is permitted under other sections of this Part, e.g., Sections 15.231 and 15.241.

As per FCC §15.247 (d) 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).

7.2 Test Setup

The radiated emissions tests were performed in the 5-meter Chamber, using the setup in accordance with ANSI C63.10-2013. The specification used was the FCC 15 Subpart C limits.

The spacing between the peripherals was 10 centimeters.

External I/O cables were draped along the edge of the test table and bundle when necessary.

7.3 Test Procedure

For the radiated emissions test, the EUT host, and all support equipment power cords was connected to the AC floor outlet.

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

The EUT was set 3 meter away from the testing antenna, which was varied from 1-4 meter, and the EUT was placed on a turntable, which was 0.8 meter and 1.5 meter above the ground plane for below and above 1000 MHz measurements, the table shall be rotated for 360 degrees to find out the highest emission. The receiving antenna should be changed the polarization both of horizontal and vertical.

The spectrum analyzer or receiver is set as:

Below 1000 MHz:

RBW = 100 kHz / VBW = 300 kHz / Sweep = Auto

Above 1000 MHz:

(1) Peak: RBW = 1MHz / VBW = 1MHz / Sweep = Auto
(2) Average: RBW = 1MHz / VBW = 10Hz or 1/T/ Sweep = Auto

7.4 Corrected Amplitude and Margin Calculation

The Corrected Amplitude (CA) is calculated by adding the Antenna Factor (AF), the Cable Loss (CL), the Attenuator Factor (Atten) and subtracting the Amplifier Gain (Ga) to indicated Amplitude (Ai) reading. The basic equation is as follows:

CA = Ai + AF + CL + Atten – Ga

For example, a corrected amplitude of 40.3 dBuV/m = Indicated Reading (32.5 dBuV) + Antenna Factor (+23.5dB) + Cable Loss (3.7 dB) + Attenuator (10 dB) - Amplifier Gain (29.4 dB)

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

Margin = Corrected Amplitude – Limit

7.5 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Rohde and Schwarz	Receiver, EMI Test	ESCI 1166.5950K03	100044	2018-10-26	2 years
Rohde and Schwarz	Analyzer, Spectrum	FSV40	1321.3008K39-101203-UW	2018-07-23	1 year
Sunol Sciences	System Controller	SC99V	011003-1	N/R	N/A
Sunol Sciences	Antenna, Biconi-Log	JB1	A013105-3	2018-02-26	2 years
EMCO	Antenna, Horn	3115	9511-4627	2018-03-28	2 years
Agilent	Amplifier, Pre	8447D	2443A04374	2018-08-13	1 year
Insulated Wire INC	157 Series 2.92 SM (x2) Armored 33 ft. Cable	KPS-1501AN-3960-KPS	DC 1807	2018-03-13	2 years
-	SMA cable	-	C0002	Each time[1]	N/A
HP/Agilent	Pre-Amplifier	8449B	3008A01978	2018-08-17	1 year
Wisewave	Antenna, Horn	ARH-4223-02	10555-01	2018-02-14	2 years
Sunol Sciences	Antenna, Horn	DRH-118	A052704	2019-04-02	2 years
Vasona	Test software	V6.0 build 11	10400213	N/R	N/R

Note[1]: cable and attenuator included in the test set-up will be checked each time before testing.
Statement of Traceability: BACL *attests that all calibrations have been performed per the A2LA requirements, traceable to NIST.*

7.6 Test Environmental Conditions

Temperature:	23 ºC
Relative Humidity:	42 %
ATM Pressure:	102.7 kPa

The testing was performed by Christian McCaig on from 2019-07-22 in 5m chamber 3.

7.7 Summary of Test Results

According to the data hereinafter, the EUT complied with FCC Title 47, Part 15C standard's radiated emissions limits, and had the worst margin of:

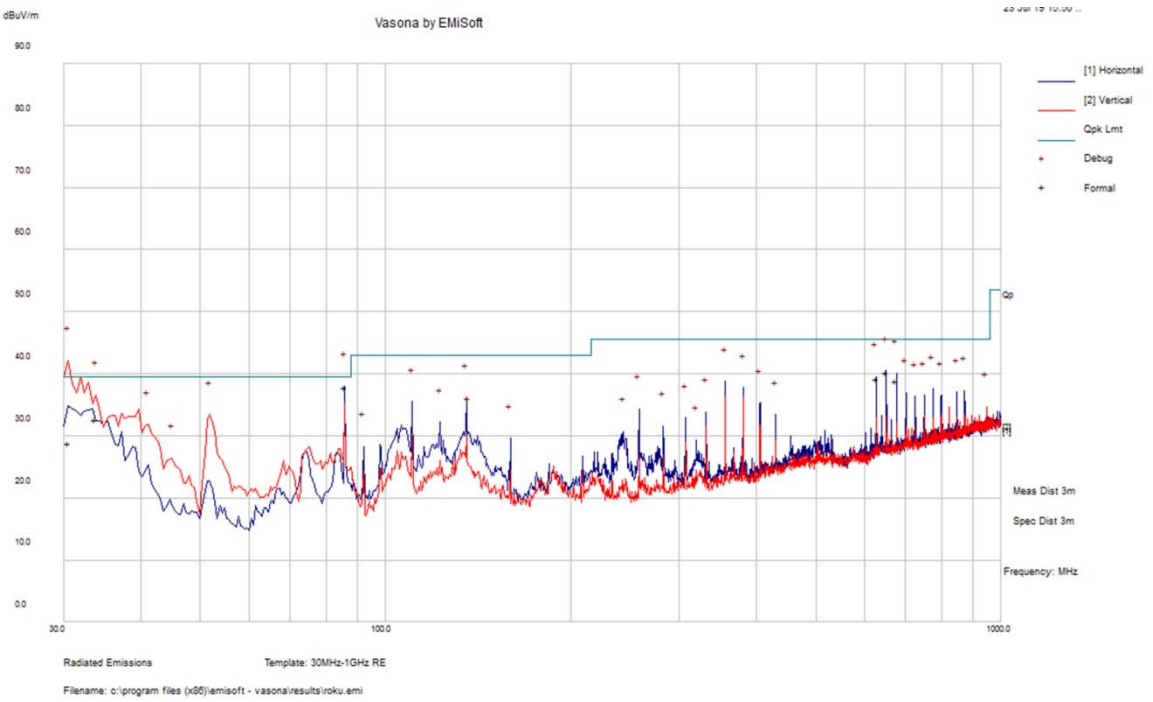
Mode: Transmitting			
Margin (dB)	**Frequency (MHz)**	**Polarization (Horizontal/Vertical)**	**Mode, Channel**
-8.79	7323	Vertical	π/4-DQPSK, Middle Channel

Please refer to the following table and plots for specific test result details.

7.8 Radiated Emissions Test Results

1) 30 MHz – 1 GHz Worst Case, Measured at 3 meters

Worst Case Colocation, Radio 1-2.4 GHz Wi-Fi b mode (2437 MHz), Radio 2-2.4 GHz Wi-Fi b mode (2412 MHz) and 2.4 GHz Classic Bluetooth π/4-DQPSK (2402 MHz)



Frequency (MHz)	Corrected Amplitude (dBµV/m)	Antenna Height (cm)	Antenna Polarity (H/V)	Turntable Azimuth (degrees)	Limit (dBµV/m)	Margin (dB)	Comment
30.5395	28.85	121	V	81	39.5	-10.65	QP
86.00775	37.9	238	H	0	39.5	-1.6	QP
33.75925	32.69	145	V	90	39.5	-6.81	QP
651.25025	40.28	104	H	340	45.5	-5.22	QP
675.846	38.82	105	H	130	45.5	-6.68	QP
626.68575	39.17	117	H	356	45.5	-6.33	QP

2) 1–25 GHz Measured at 3 meters

GFSK mode

Frequency (MHz)	S.A. Reading (dBµV)	Turntable Azimuth (degrees)	Test Antenna			Cable Loss (dB)	Pre-Amp. (dB)	Cord. Reading (dBµV/m)	FCC		Comments
			Height (cm)	Polarity (H/V)	Factor (dB/m)				Limit (dBµV/m)	Margin (dB)	
Low Channel 2402 MHz											
2390	48.43	232	112	H	28.87	5.73	36.16	46.86	74	-27.14	PK
2390	35.87	232	112	H	28.87	5.73	36.16	34.30	54	-19.70	AV
2390	50.44	35	116	V	28.89	5.73	36.16	48.90	74	-25.10	PK
2390	38.62	35	116	V	28.89	5.73	36.16	37.08	54	-16.92	AV
4804	46.13	29	130	H	32.46	8.40	35.90	51.08	74	-22.92	PK
4804	32.47	29	130	H	32.46	8.40	35.90	37.42	54	-16.58	AV
4804	46.11	345	144	V	32.45	8.40	35.90	51.06	74	-22.94	PK
4804	33.96	345	144	V	32.45	8.40	35.90	38.91	54	-15.09	AV
7206	45.66	0	100	H	36.90	10.56	35.25	57.87	74	-16.13	PK
7206	30.56	0	100	H	36.90	10.56	35.25	42.77	54	-11.23	AV
7206	45.52	0	100	V	36.75	10.56	35.25	57.59	74	-16.41	PK
7206	30.58	0	100	V	36.75	10.56	35.25	42.65	54	-11.35	AV
Middle Channel 2441 MHz											
4882	46.26	94	144	H	32.77	8.62	35.80	51.85	74	-22.15	PK
4882	33.67	94	144	H	32.77	8.62	35.80	39.26	54	-14.74	AV
4882	46.33	344	150	V	32.73	8.62	35.80	51.89	74	-22.11	PK
4882	34.04	344	150	V	32.73	8.62	35.80	39.60	54	-14.40	AV
7323	44.84	0	100	H	37.08	10.76	35.28	57.40	74	-16.60	PK
7323	30.16	0	100	H	37.08	10.76	35.28	42.72	54	-11.28	AV
7323	44.97	0	100	V	37.04	10.76	35.28	57.50	74	-16.51	PK
7323	30.13	0	100	V	37.04	10.76	35.28	42.66	54	-11.35	AV
High Channel 2480 MHz											
2483.5	51.86	257	190	H	28.87	5.73	36.16	50.29	74	-23.71	PK
2483.5	38.16	257	190	H	28.87	5.73	36.16	36.59	54	-17.41	AV
2483.5	52.26	29	137	V	28.89	5.73	36.16	50.72	74	-23.28	PK
2483.5	38.68	29	137	V	28.89	5.73	36.16	37.14	54	-16.86	AV
4960	46.41	94	159	H	32.73	8.81	35.73	52.23	74	-21.78	PK
4960	34.85	94	159	H	32.73	8.81	35.73	40.67	54	-13.34	AV
4960	48.22	342	158	V	32.74	8.81	35.73	54.04	74	-19.96	PK
4960	36.75	342	158	V	32.74	8.81	35.73	42.57	54	-11.43	AV
7440	44.85	0	100	H	37.09	10.94	35.33	57.55	74	-16.45	PK
7440	29.56	0	100	H	37.09	10.94	35.33	42.26	54	-11.74	AV
7440	45.26	0	100	V	37.07	10.94	35.33	57.94	74	-16.06	PK
7440	29.57	0	100	V	37.07	10.94	35.33	42.25	54	-11.75	AV

π/4-DQPSK mode

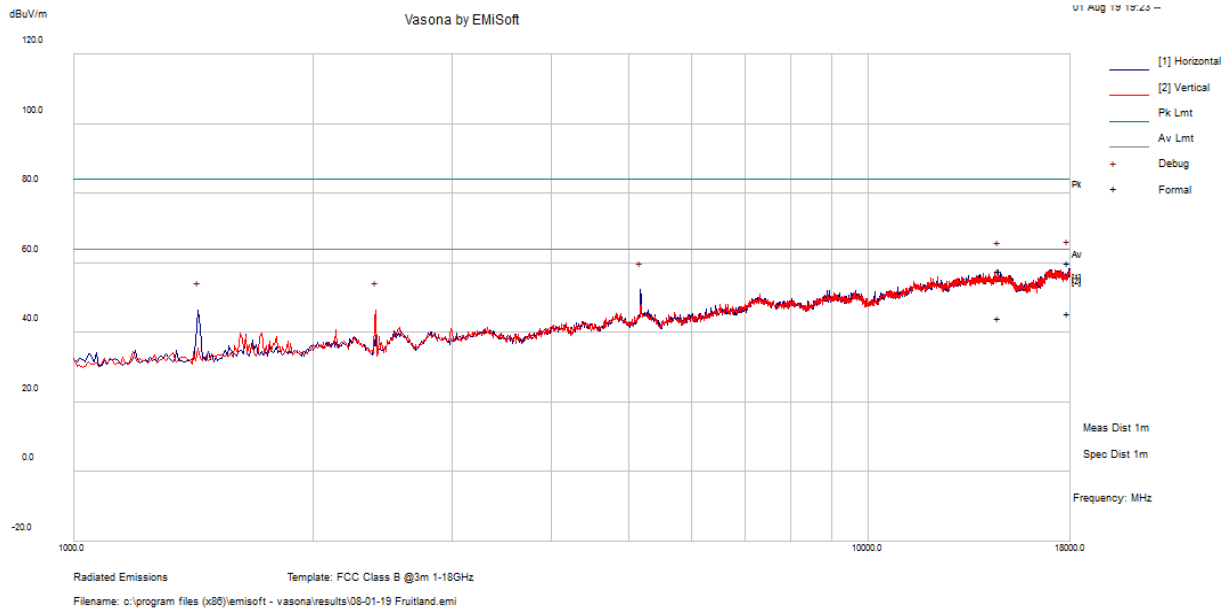
Frequency (MHz)	S.A. Reading (dBµV)	Turntable Azimuth (degrees)	Test Antenna			Cable Loss (dB)	Pre-Amp. (dB)	Cord. Reading (dBµV/m)	FCC		Comments
			Height (cm)	Polarity (H/V)	Factor (dB/m)				Limit (dBµV/m)	Margin (dB)	
Low Channel 2402 MHz											
2390	47.00	257	229	H	28.87	5.73	36.16	45.43	74	-28.57	PK
2390	35.56	257	229	H	28.87	5.73	36.16	33.99	54	-20.01	AV
2390	48.31	94	100	V	28.89	5.73	36.16	46.77	74	-27.23	PK
2390	36.10	94	100	V	28.89	5.73	36.16	34.56	54	-19.44	AV
4804	47.67	133	95	H	32.46	8.40	35.90	52.62	74	-21.38	PK
4804	41.19	133	95	H	32.46	8.40	35.90	46.14	54	-7.86	AV
4804	46.23	0	183	V	32.45	8.40	35.90	51.18	74	-22.82	PK
4804	35.68	0	183	V	32.45	8.40	35.90	40.63	54	-13.37	AV
7206	45.09	0	100	H	36.90	10.56	35.25	57.30	74	-16.70	PK
7206	32.88	0	100	H	36.90	10.56	35.25	45.09	54	-8.91	AV
7206	45.31	0	100	V	36.75	10.56	35.25	57.38	74	-16.62	PK
7206	32.69	0	100	V	36.75	10.56	35.25	44.76	54	-9.24	AV
Middle Channel 2441 MHz											
4882	45.91	296	99	H	32.77	8.62	35.80	51.50	74	-22.50	PK
4882	32.78	296	99	H	32.77	8.62	35.80	38.37	54	-15.63	AV
4882	44.57	304	267	V	32.73	8.62	35.80	50.13	74	-23.87	PK
4882	34.63	304	267	V	32.73	8.62	35.80	40.19	54	-13.81	AV
7323	45.19	0	100	H	37.08	10.76	35.28	57.75	74	-16.25	PK
7323	32.62	0	100	H	37.08	10.76	35.28	45.18	54	-8.82	AV
7323	46.59	0	100	V	37.04	10.76	35.28	59.12	74	-14.89	PK
7323	32.68	0	100	V	37.04	10.76	35.28	45.21	54	-8.79	AV
High Channel 2480 MHz											
2483.5	54.12	208	103	H	28.87	5.73	36.16	52.55	74	-21.45	PK
2483.5	40.54	208	103	H	28.87	5.73	36.16	38.97	54	-15.03	AV
2483.5	59.42	54	106	V	28.89	5.73	36.16	57.88	74	-16.12	PK
2483.5	44.40	54	106	V	28.89	5.73	36.16	42.86	54	-11.14	AV
4960	44.85	176	99	H	32.73	8.81	35.73	50.67	74	-23.34	PK
4960	32.29	176	99	H	32.73	8.81	35.73	38.11	54	-15.90	AV
4960	46.74	0	162	V	32.74	8.81	35.73	52.56	74	-21.44	PK
4960	36.27	0	162	V	32.74	8.81	35.73	42.09	54	-11.91	AV
7440	44.47	0	95	H	37.09	10.94	35.33	57.17	74	-16.83	PK
7440	31.89	0	95	H	37.09	10.94	35.33	44.59	54	-9.41	AV
7440	43.84	0	100	V	37.07	10.94	35.33	56.52	74	-17.48	PK
7440	31.78	0	100	V	37.07	10.94	35.33	44.46	54	-9.54	AV

8DPSK mode

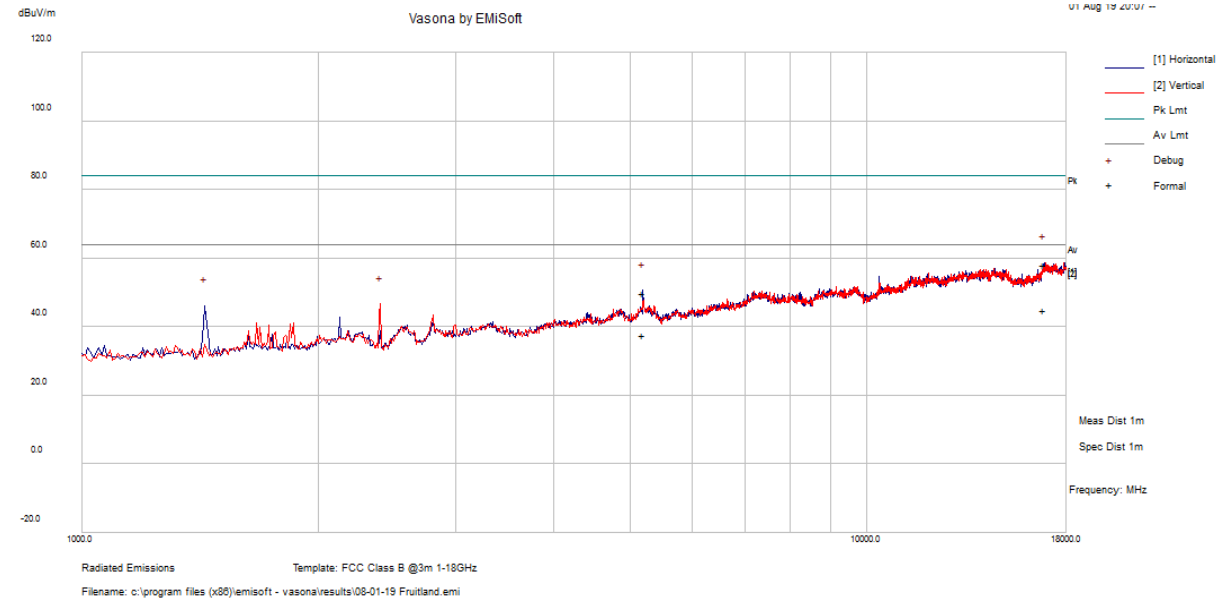
Frequency (MHz)	S.A. Reading (dBµV)	Turntable Azimuth (degrees)	Test Antenna			Cable Loss (dB)	Pre-Amp. (dB)	Cord. Reading (dBµV/m)	FCC		Comments
			Height (cm)	Polarity (H/V)	Factor (dB/m)				Limit (dBµV/m)	Margin (dB)	
Low Channel 2402 MHz											
2390	48.70	155	155	H	28.87	5.73	36.16	47.13	74	-26.87	PK
2390	34.90	155	155	H	28.87	5.73	36.16	33.33	54	-20.67	AV
2390	46.59	104	102	V	28.89	5.73	36.16	45.05	74	-28.95	PK
2390	35.36	104	102	V	28.89	5.73	36.16	33.82	54	-20.18	AV
4804	45.26	94	100	H	32.46	8.40	35.90	50.21	74	-23.79	PK
4804	33.73	94	100	H	32.46	8.40	35.90	38.68	54	-15.32	AV
4804	48.28	53	100	V	32.45	8.40	35.90	53.23	74	-20.77	PK
4804	36.97	53	100	V	32.45	8.40	35.90	41.92	54	-12.08	AV
7206	45.33	0	100	H	36.90	10.56	35.25	57.54	74	-16.46	PK
7206	32.68	0	100	H	36.90	10.56	35.25	44.89	54	-9.11	AV
7206	44.11	0	100	V	36.75	10.56	35.25	56.18	74	-17.82	PK
7206	32.91	0	100	V	36.75	10.56	35.25	44.98	54	-9.02	AV
Middle Channel 2441 MHz											
4882	45.94	34	116	H	32.77	8.62	35.80	51.53	74	-22.47	PK
4882	35.08	34	116	H	32.77	8.62	35.80	40.67	54	-13.33	AV
4882	45.59	308	98	V	32.73	8.62	35.80	51.15	74	-22.85	PK
4882	33.52	308	98	V	32.73	8.62	35.80	39.08	54	-14.92	AV
7323	43.46	0	100	H	37.08	10.76	35.28	56.02	74	-17.98	PK
7323	32.48	0	100	H	37.08	10.76	35.28	45.04	54	-8.96	AV
7323	43.90	0	100	V	37.04	10.76	35.28	56.43	74	-17.58	PK
7323	32.55	0	100	V	37.04	10.76	35.28	45.08	54	-8.93	AV
High Channel 2480 MHz											
2483.5	56.44	75	95	H	28.87	5.73	36.16	54.87	74	-19.13	PK
2483.5	41.82	75	95	H	28.87	5.73	36.16	40.25	54	-13.75	AV
2483.5	59.93	54	113	V	28.89	5.73	36.16	58.39	74	-15.61	PK
2483.5	44.09	54	113	V	28.89	5.73	36.16	42.55	54	-11.45	AV
4960	44.46	33	137	H	32.73	8.81	35.73	50.28	74	-23.73	PK
4960	34.30	33	137	H	32.73	8.81	35.73	40.12	54	-13.89	AV
4960	46.53	360	211	V	32.74	8.81	35.73	52.35	74	-21.65	PK
4960	37.21	360	211	V	32.74	8.81	35.73	43.03	54	-10.97	AV
7440	43.85	0	100	H	37.09	10.94	35.33	56.55	74	-17.45	PK
7440	31.95	0	100	H	37.09	10.94	35.33	44.65	54	-9.35	AV
7440	43.86	0	100	V	37.07	10.94	35.33	56.54	74	-17.46	PK
7440	31.86	0	100	V	37.07	10.94	35.33	44.54	54	-9.46	AV

1 GHz – 18 GHz Worst Case Scan at 1 meter

Worst Case Colocation, Radio 1-2.4 GHz Wi-Fi, Radio 2-2.4 GHz Wi-Fi and 2.4 GHz Classic Bluetooth

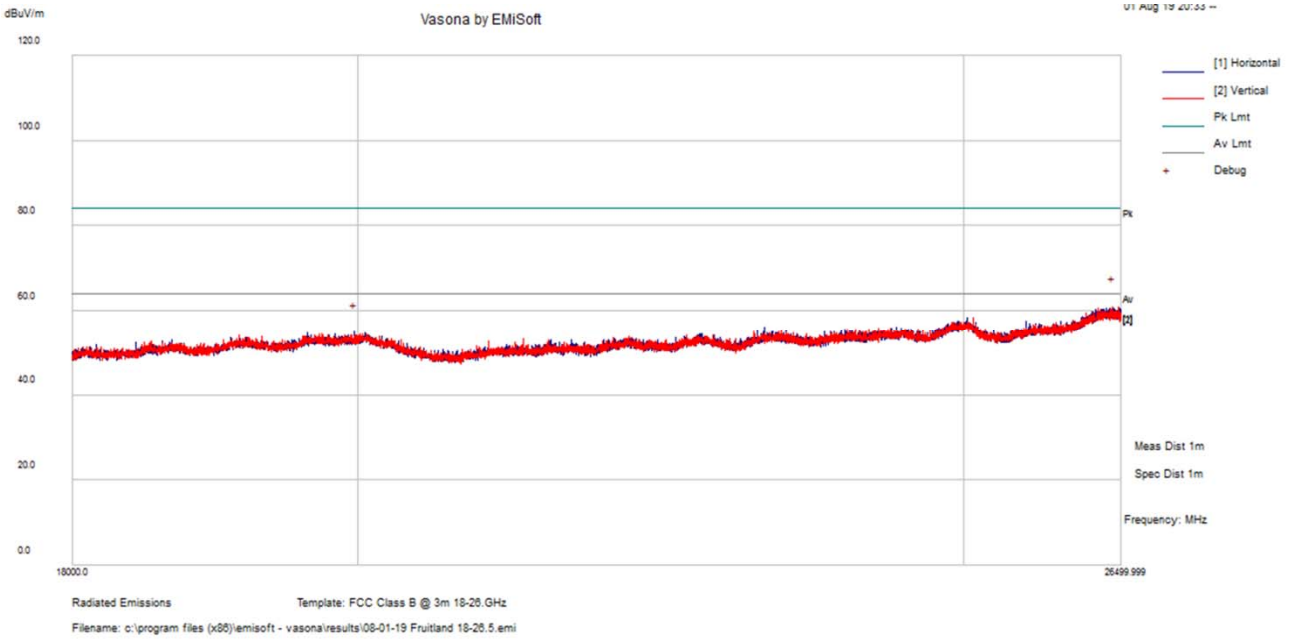


Worst Case Colocation, Radio 1-5 GHz Wi-Fi, Radio 2-5 GHz Wi-Fi and 2.4 GHz Classic Bluetooth

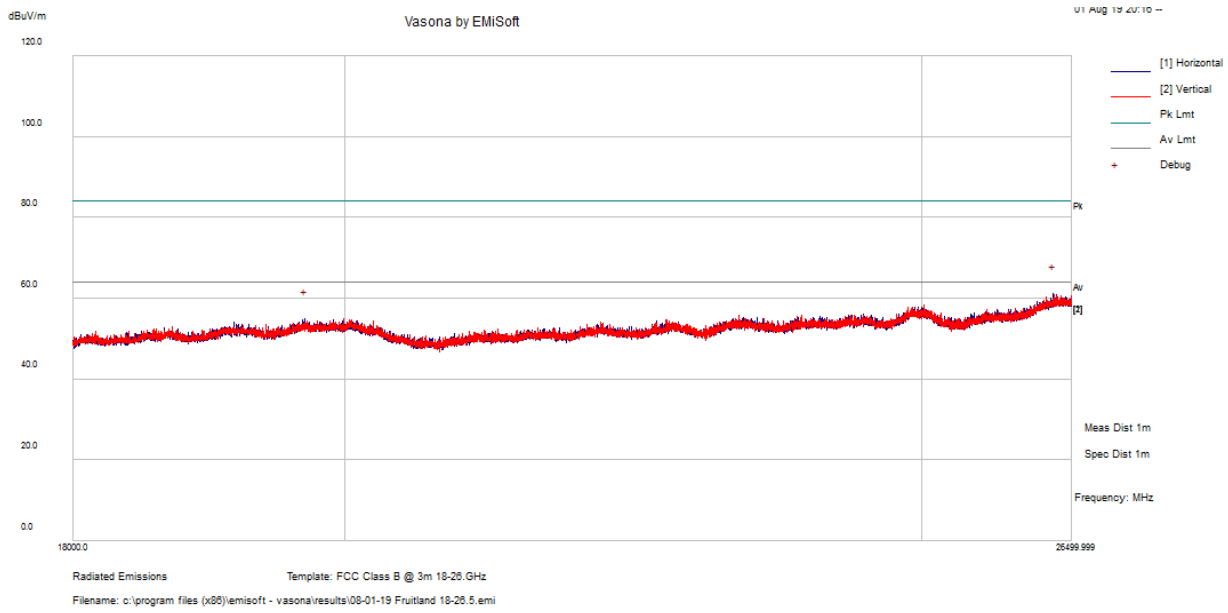


18 GHz – 26.5 GHz Worst Case Scan at 1 meter

Worst Case Colocation, Radio 1-2.4 GHz Wi-Fi, Radio 2-2.4 GHz Wi-Fi and 2.4 GHz Classic Bluetooth

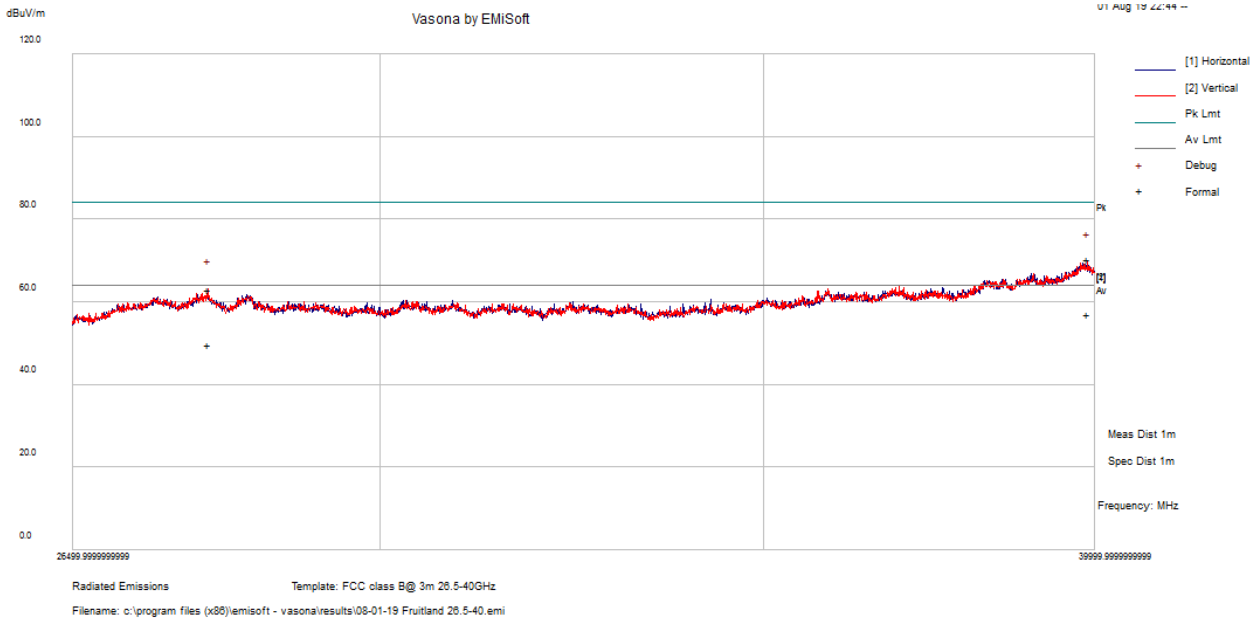


Worst Case Colocation, Radio 1-5 GHz Wi-Fi, Radio 2-5 GHz Wi-Fi and 2.4 GHz Classic Bluetooth



26.5 GHz – 40 GHz Worst Case Scan at 1 meter

Worst Case Colocation, Radio 1-5 GHz Wi-Fi, Radio 2-5 GHz Wi-Fi and 2.4 GHz Classic Bluetooth



8 FCC §15.247(a) (1)- Emission Bandwidth

8.1 Applicable Standards

According to FCC §15.247(a) (1): the maximum 20 dB bandwidth of the hopping channel shall be presented.

8.2 Measurement Procedure

Span = approximately 2 to 5 times the 99% occupied bandwidth, centered on a hopping channel

RBW = 1% to 5 % of the 99% occupied bandwidth or 100kHz

VBW = 3RBW

Sweep = auto

Detector function = peak

Trace = max hold

8.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Rohde & Schwarz	Analyzer, Spectrum	FSQ26	200749	2019-03-14	2 years
-	RF cable	-	-	Each time[1]	N/A
-	10 dB attenuator	-	-	Each time[1]	N/A

Note[1]: cable and attenuator included in the test set-up will be checked each time before testing.
Statement of Traceability: BACL Corp. *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

8.4 Test Environmental Conditions

Temperature:	22ºC
Relative Humidity:	42 %
ATM Pressure:	102.6 KPa

The testing was performed by Christian McCaig on 2019-07-26 in RF site.

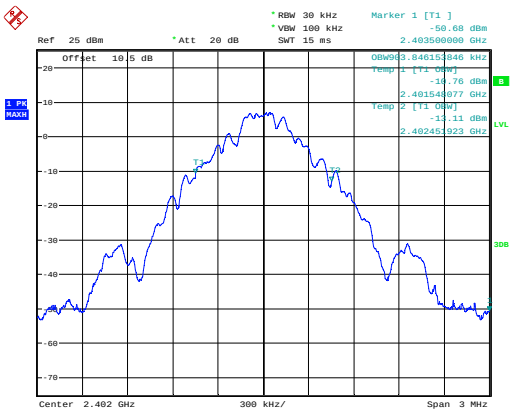
8.5 Test Results

Channel	Frequency (MHz)	99% OBW (kHz)	20 dB OBW (kHz)
GFSK			
Low	2402	903.8	894.2
Middle	2441	908.6	894.2
High	2480	908.7	899.1
π/4-DQPSK			
Low	2402	1327	1356
Middle	2441	1337	1351
High	2480	1269	1356
8DPSK			
Low	2402	1346	1284
Middle	2441	1346	1226
High	2480	1322	1279

Please refer to the following plots for detailed test results.

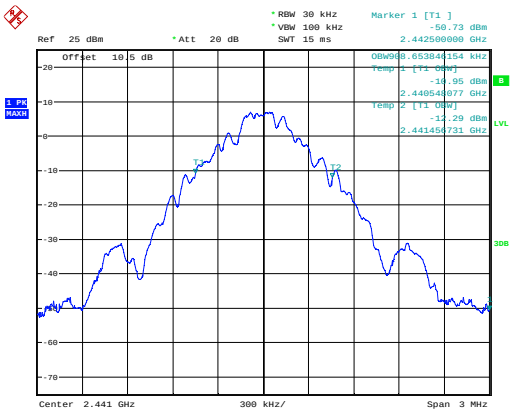
99% OBW
GFSK

Low Channel 2402 MHz



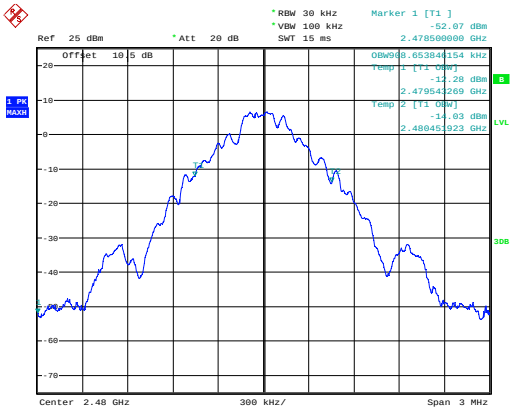
Date: 26.JUL.2019 14:06:36

Middle Channel 2441 MHz



Date: 26.JUL.2019 14:05:38

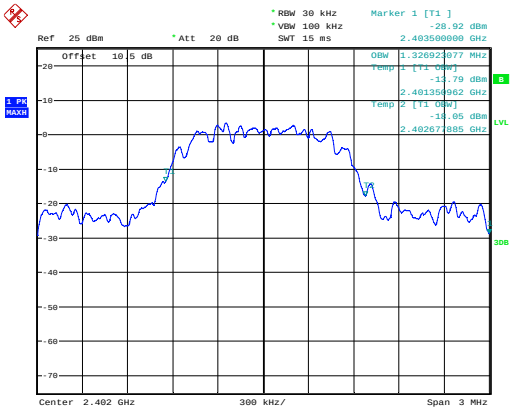
High Channel 2480 MHz



Date: 26.JUL.2019 14:06:09

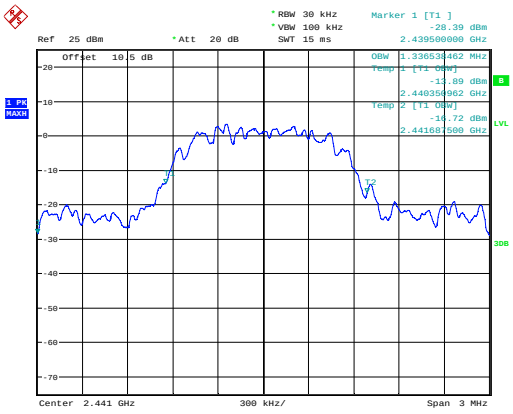
π/4-DQPSK

Low Channel 2402 MHz



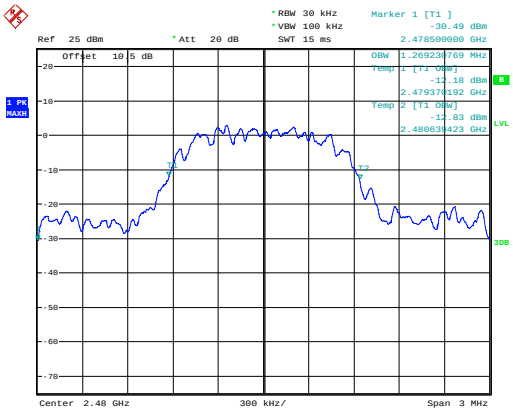
Date: 26.JUL.2019 14:07:21

Middle Channel 2441 MHz



Date: 26.JUL.2019 14:07:43

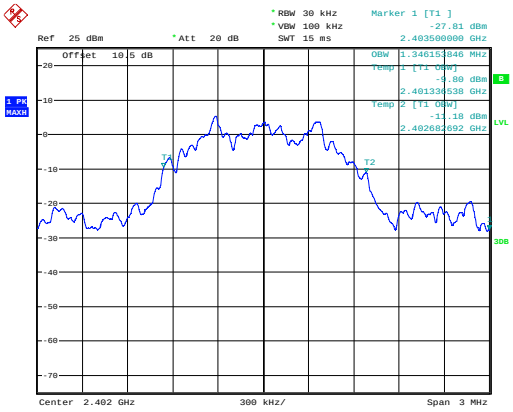
High Channel 2480 MHz



Date: 26.JUL.2019 14:08:07

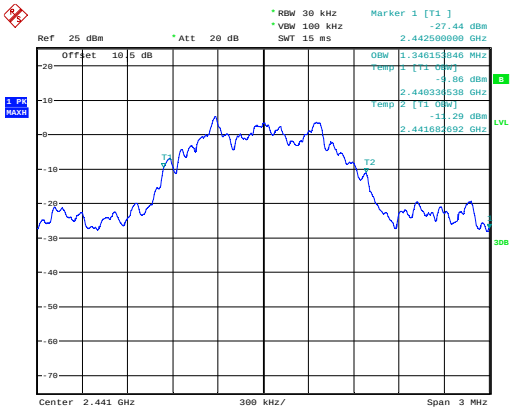
8DPSK

Low Channel 2402 MHz



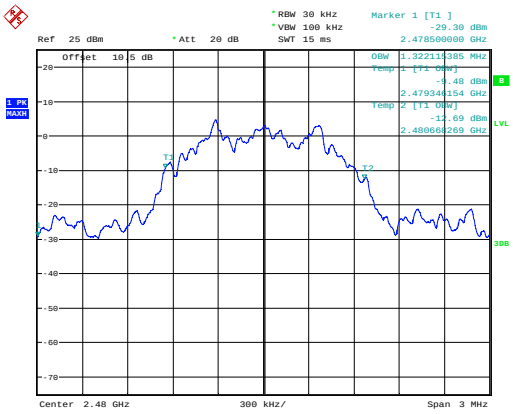
Date: 26.JUL.2019 14:09:40

Middle Channel 2441 MHz



Date: 26.JUL.2019 14:09:12

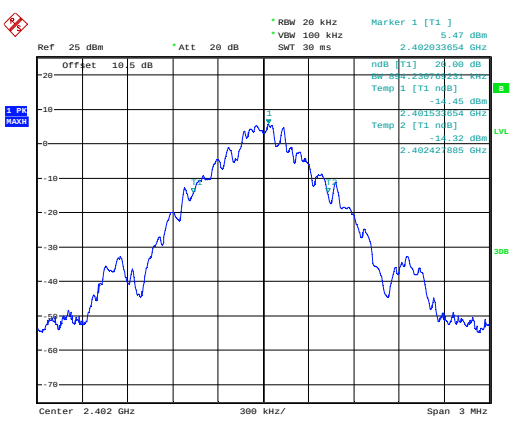
High Channel 2480 MHz



Date: 26.JUL.2019 14:08:46

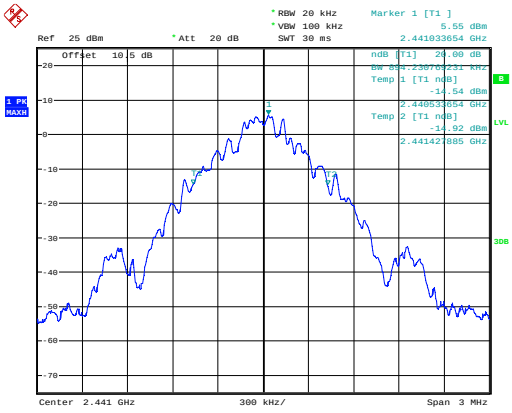
20dB BW
GFSK

Low Channel 2402 MHz



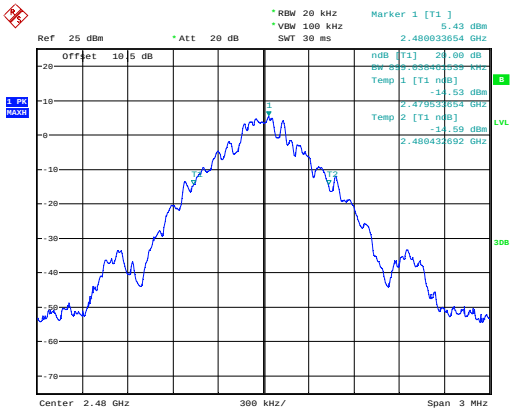
Date: 26.JUL.2019 12:30:59

Middle Channel 2441 MHz



Date: 26.JUL.2019 12:30:23

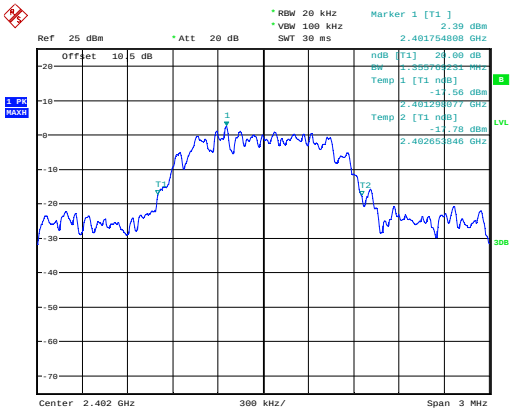
High Channel 2480 MHz



Date: 26.JUL.2019 12:29:58

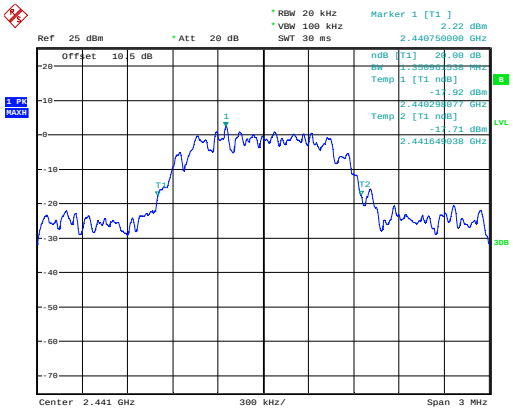
π/4-DQPSK

Low Channel 2402 MHz



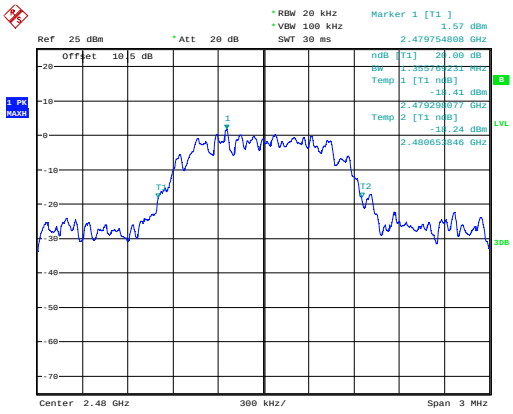
Date: 26.JUL.2019 12:26:12

Middle Channel 2441 MHz



Date: 26.JUL.2019 12:27:21

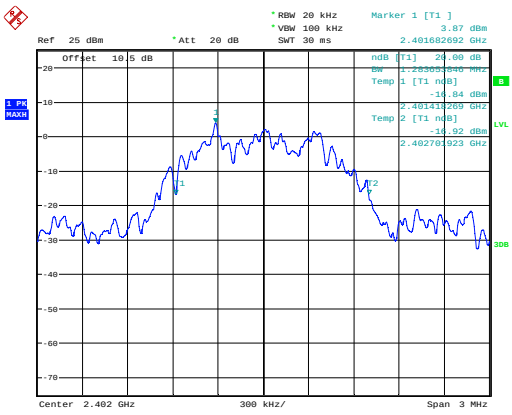
High Channel 2480 MHz



Date: 26.JUL.2019 12:27:51

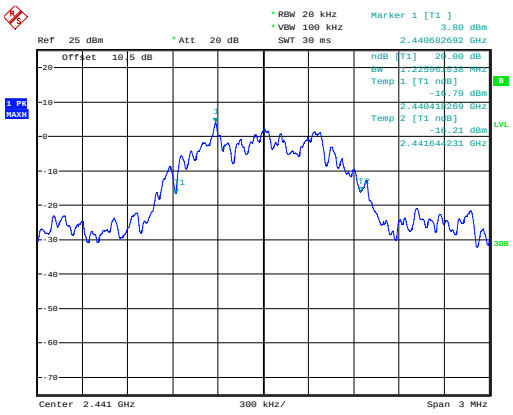
8DPSK

Low Channel 2402 MHz



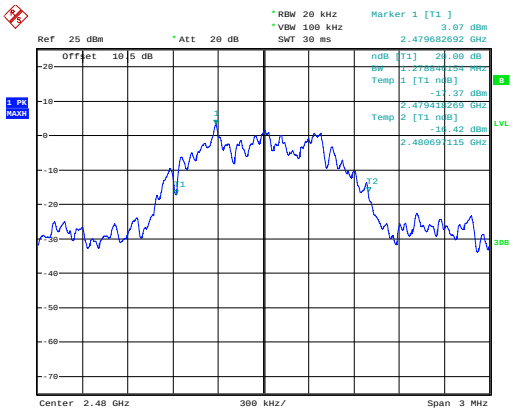
Date: 26.JUL.2019 12:31:48

Middle Channel 2441 MHz



Date: 26.JUL.2019 12:32:17

High Channel 2480 MHz



Date: 26.JUL.2019 12:32:44

9 FCC §15.247(b) (1) - Output Power

9.1 Applicable Standards

According to FCC §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. For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 watts.

9.2 Measurement Procedure

Span = approximately 5 times the 20 dB bandwidth, centered on a hopping channel
RBW > the 20 dB bandwidth of the emission being measured
VBW ≥ RBW
Sweep = auto
Detector function = peak
Trace = max hold

9.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Agilent	Analyzer, Spectrum	E4440A	US45303156	2019-03-06	1 year
-	RF cable	-	-	Each time[1]	N/A
-	10dB attenuator	-	-	Each time[1]	N/A

Note[1]: cable and attenuator included in the test set-up will be checked each time before testing.
Statement of Traceability: BACL Corp. *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

9.4 Test Environmental Conditions

Temperature:	23 ºC
Relative Humidity:	42 %
ATM Pressure:	102.9 KPa

The testing was performed by Zhao Zhao on 2019-07-23 in RF site.

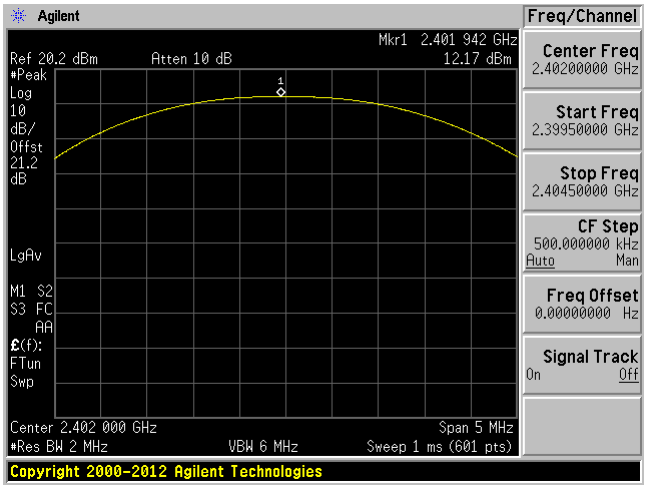
9.5 Test Results

Channel	Frequency (MHz)	Conducted Output Power (dBm)	Limit (dBm)
GFSK			
Low	2402	12.17	30
Middle	2441	12.47	30
High	2480	11.85	30
Π/4-DQPSK			
Low	2402	12.75	30
Middle	2441	12.67	30
High	2480	12.41	30
8DPSK			
Low	2402	12.81	30
Middle	2441	12.79	30
High	2480	12.49	30

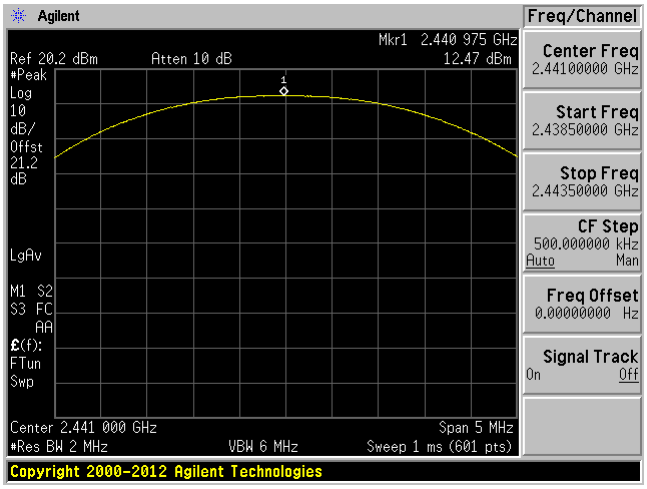
Please refer to the following plots for detailed test results.

GFSK

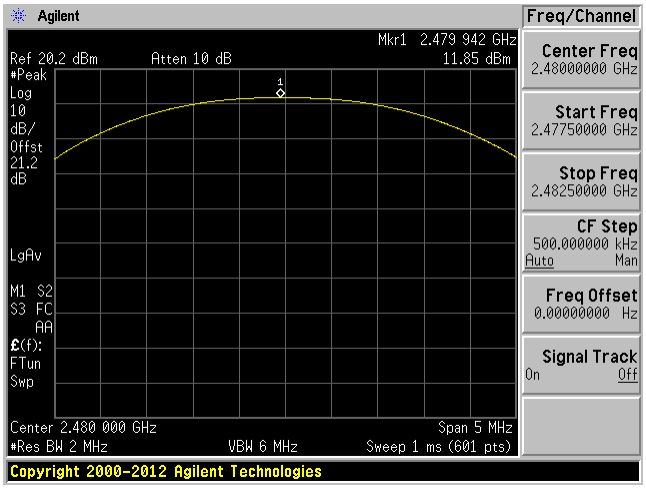
Low Channel 2402 MHz



Middle Channel 2441 MHz

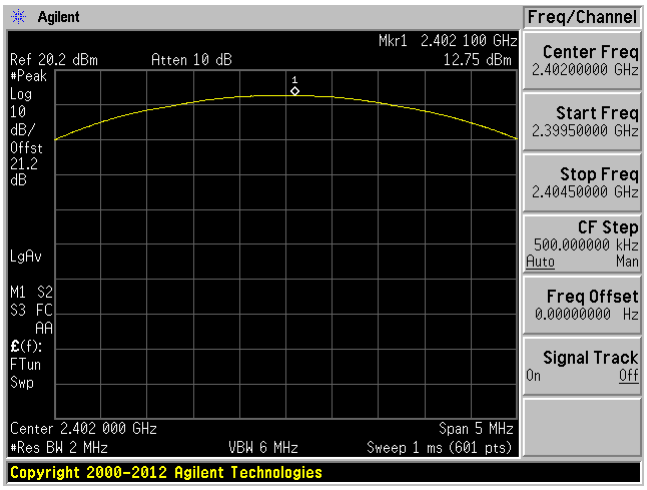


High Channel 2480 MHz

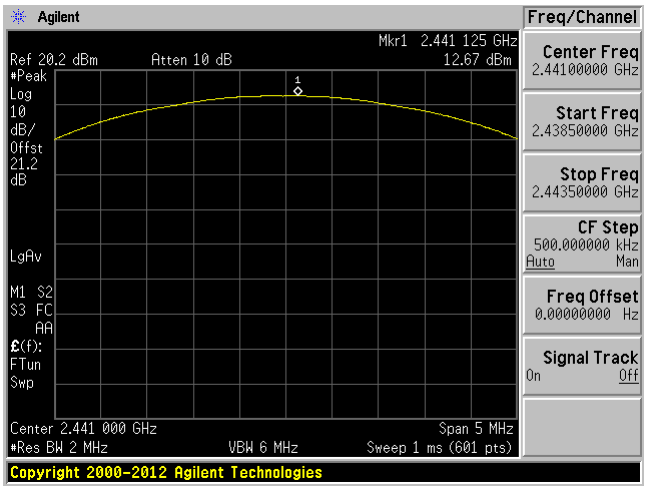


π/4-DQPSK

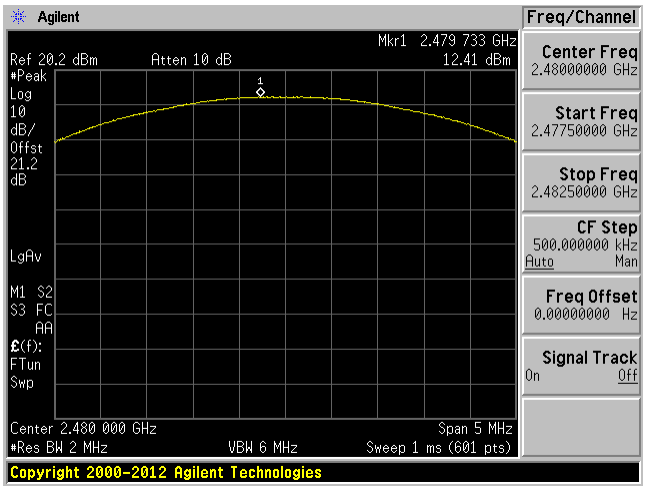
Low Channel 2402 MHz



Middle Channel 2441 MHz

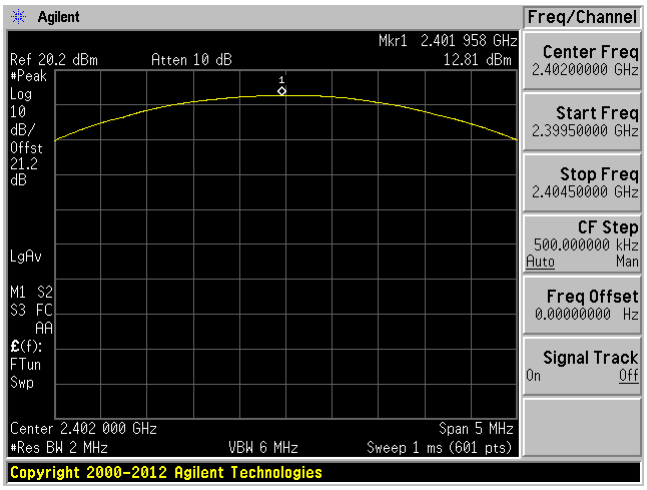


High Channel 2480 MHz

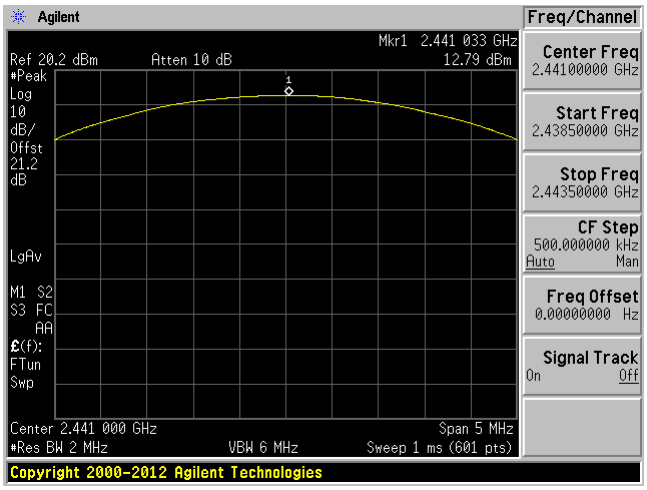


8DPSK

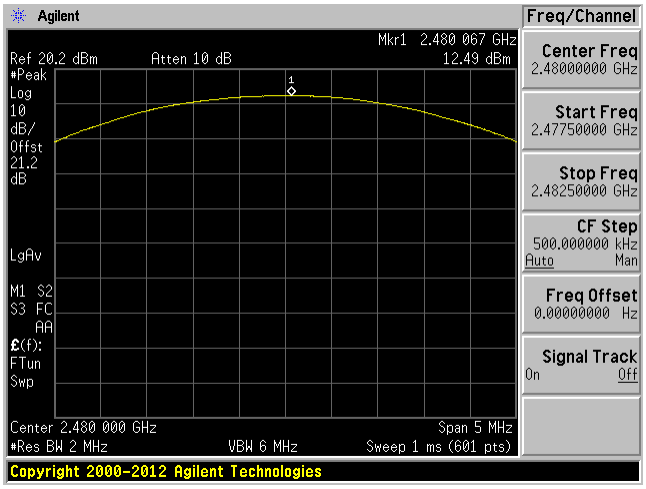
Low Channel 2402 MHz



Middle Channel 2441 MHz



High Channel 2480 MHz



10 FCC §15.247(d) - 100 kHz Bandwidth of Band Edges

10.1 Applicable Standards

According to FCC §15.247(d), in any 100 kHz bandwidth outside the frequency bands in which the spread spectrum 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. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emissions limits specified in §15.209(a) see §15.205(c).

10.2 Measurement Procedure

Span = wide enough to capture the peak level of the emission operating on the channel closest to the band edge, as well as any modulation products which fall outside of the authorized band of operation

RBW = 100 kHz
VBW = 300 kHz
Sweep = coupled
Detector function = peak
Trace = max hold

10.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Agilent	Analyzer, Spectrum	E4440A	US45303156	2019-03-06	1 year
-	RF cable	-	-	Each time[1]	N/A
-	10 dB attenuator	-	-	Each time[1]	N/A

Note[1]: cable and attenuator included in the test set-up will be checked each time before testing.
Statement of Traceability: BACL Corp. *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

10.4 Test Environmental Conditions

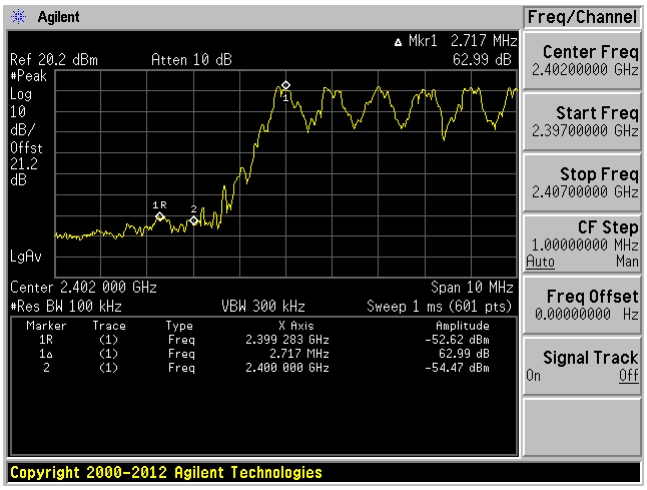
Temperature:	22 ℃
Relative Humidity:	42 %
ATM Pressure:	102.6 KPa

The testing was performed by Zhao Zhao on 2019-07-23 in RF site.

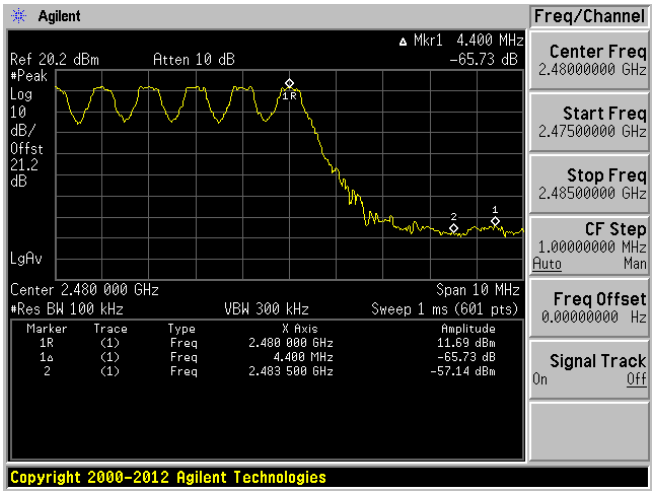
10.5 Test Results

Hopping Mode
GFSK

Low Channel 2402 MHz

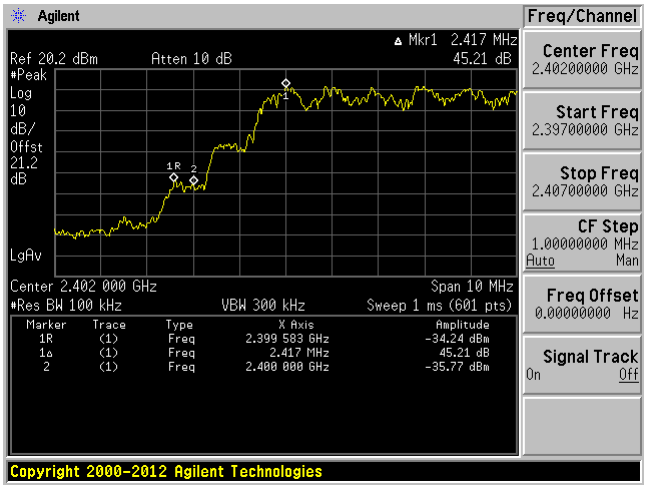


High Channel 2480 MHz

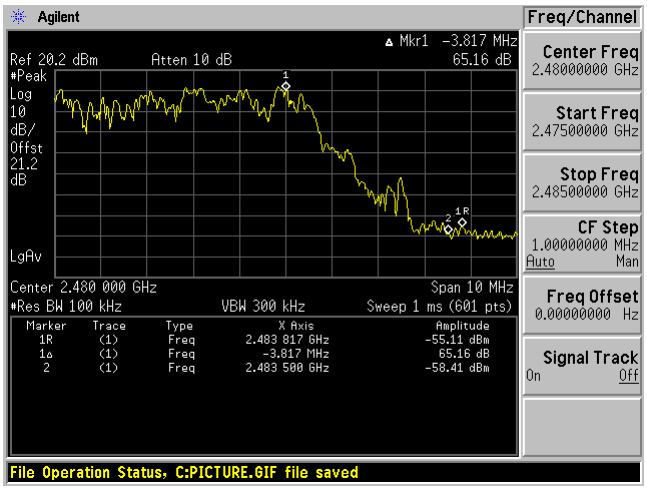


π/4-DQPSK

Low Channel 2402 MHz

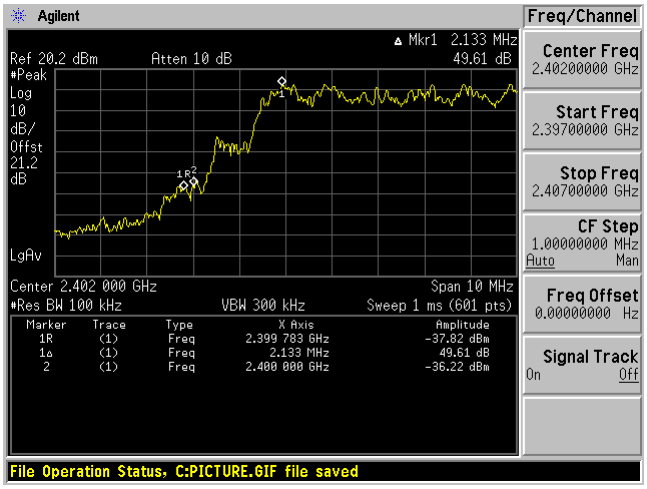


High Channel 2480 MHz

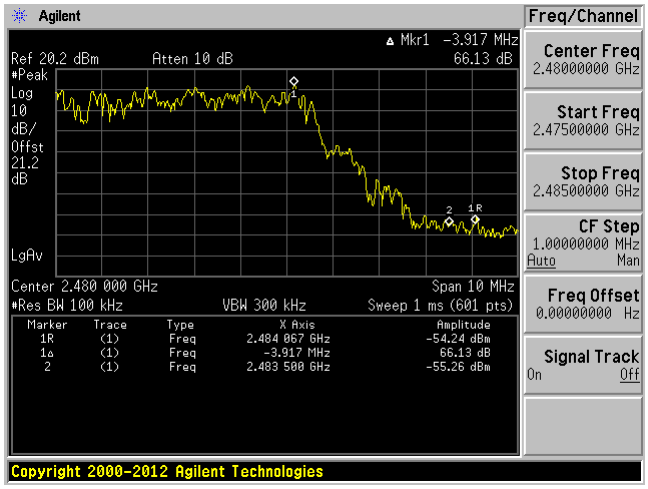


8DPSK

Low Channel 2402 MHz

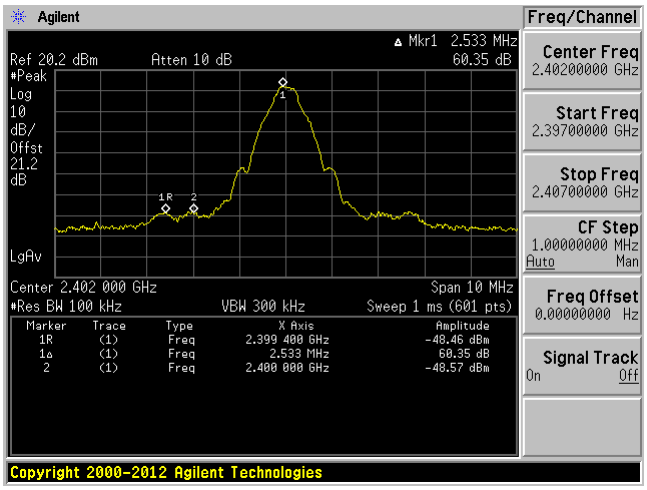


High Channel 2480 MHz

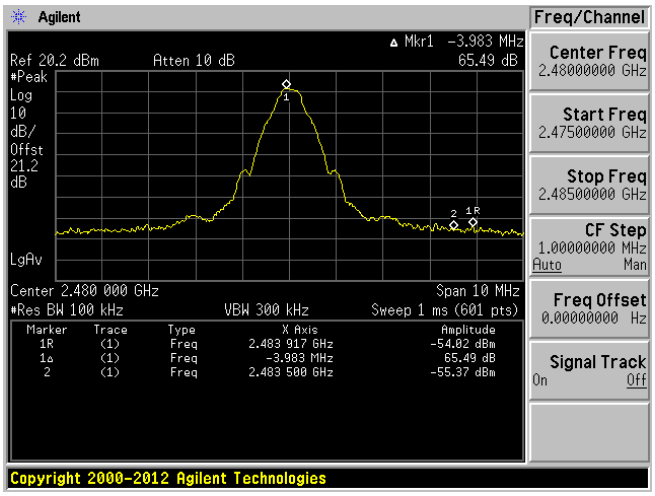


Hopping Mode OFF
GFSK

Low Channel 2402 MHz

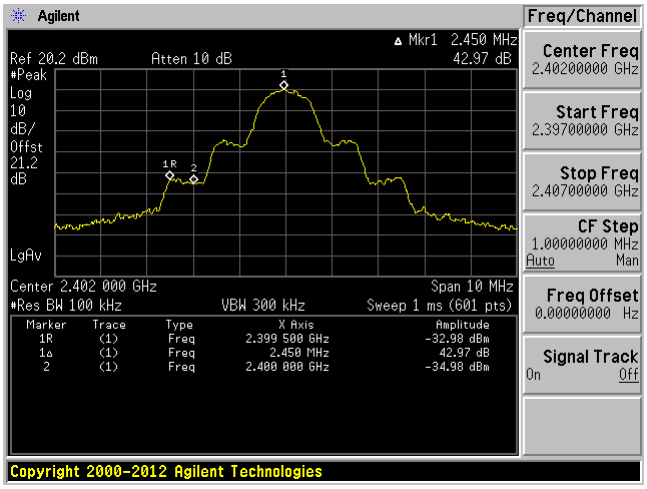


High Channel 2480 MHz

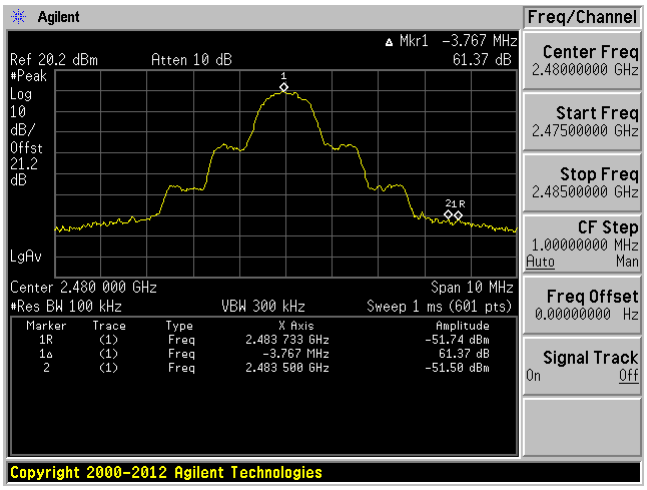


π/4-DQPSK

Low Channel 2402 MHz

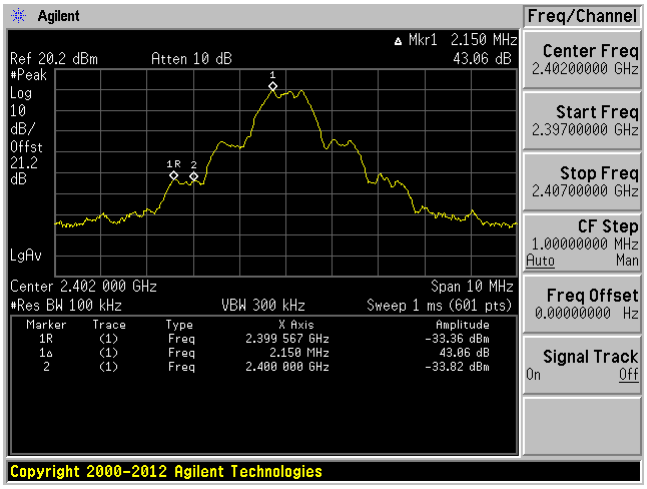


High Channel 2480 MHz

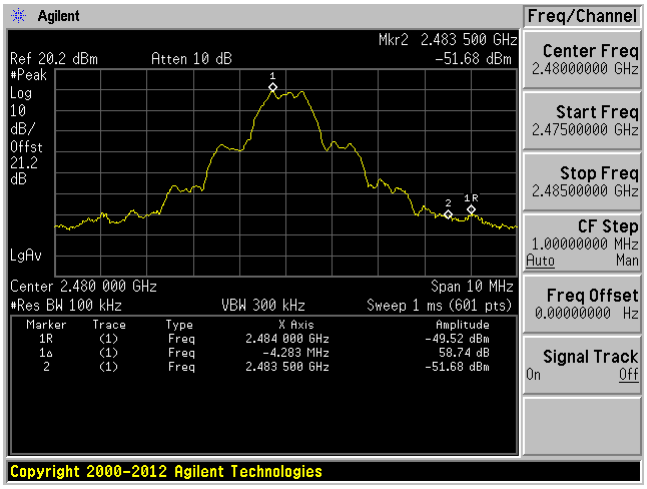


8DPSK

Low Channel 2402 MHz



High Channel 2480 MHz



11 FCC §15.247(a) (1) (iii) - Dwell Time

11.1 Applicable Standards

According to FCC §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. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

11.2 Measurement Procedure

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

Span = zero span, centered on a hopping channel
RBW ≤ channel spacing and where possible RBW should be set >> 1/*T*, where *T* is the expected dwell time per channel
Sweep = as necessary to capture the entire dwell time per hopping channel
Detector function = peak
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) x (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. 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.

11.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Agilent	Analyzer, Spectrum	E4440A	US45303156	2019-03-06	1 year
-	RF cable	-	-	Each time[1]	N/A
-	10 dB attenuator	-	-	Each time[1]	N/A

Note[1]: cable and attenuator included in the test set-up will be checked each time before testing.
Statement of Traceability: BACL Corp. *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

11.4 Test Environmental Conditions

Temperature:	22 ºC
Relative Humidity:	42 %
ATM Pressure:	102.5 KPa

The testing was performed by Zhao Zhao on 2019-07-23 in RF site.

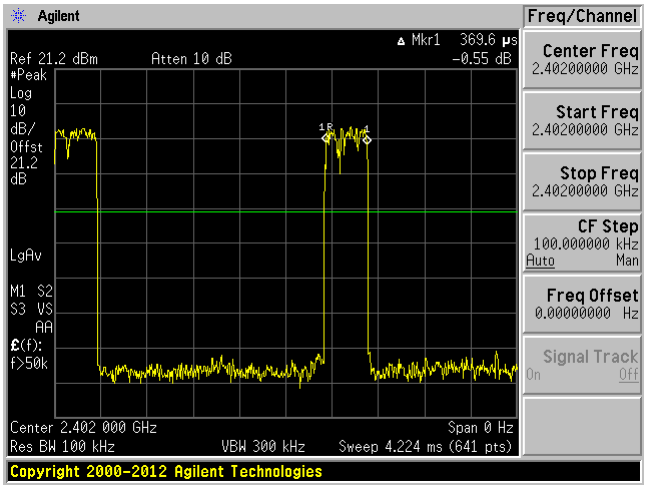
11.5 Test Results

Mode		Channel	Pulse Width (ms)	Dwell Time(s)	Limit(s)	Result
BDR (GFSK)	DH1	Low	0.37	0.118	0.4	Pass
		Middle	0.37	0.118	0.4	Pass
		High	0.36	0.116	0.4	Pass
		Note: DH1: Dwell time = Pulse time*(1600/2/79)*31.6				
	DH3	Low	1.62	0.259	0.4	Pass
		Middle	1.62	0.259	0.4	Pass
		High	1.62	0.259	0.4	Pass
		Note: DH3 Dwell time = Pulse time*(1600/4/79) *31.6				
	DH5	Low	2.85	0.304	0.4	Pass
		Middle	2.88	0.307	0.4	Pass
		High	2.88	0.307	0.4	Pass
		Note: DH5: Dwell time = Pulse time*(1600/6/79) *31.6				
EDR (π/4-DQPSK)	2DH1	Low	0.37	0.118	0.4	Pass
		Middle	0.38	0.120	0.4	Pass
		High	0.38	0.120	0.4	Pass
		Note: DH1: Dwell time = Pulse time*(1600/2/79) *31.6				
	2DH3	Low	1.63	0.261	0.4	Pass
		Middle	1.63	0.261	0.4	Pass
		High	1.62	0.259	0.4	Pass
		Note: DH3: Dwell time = Pulse time*(1600/4/79) *31.6				
	2DH5	Low	2.85	0.304	0.4	Pass
		Middle	2.85	0.304	0.4	Pass
		High	2.85	0.304	0.4	Pass
		Note: DH5: Dwell time = Pulse time*(1600/6/79) *31.6				
EDR (8DPSK)	3DH1	Low	0.38	0.120	0.4	Pass
		Middle	0.38	0.120	0.4	Pass
		High	0.38	0.120	0.4	Pass
		Note: DH1: Dwell time = Pulse time*(1600/2/79) *31.6				
	3DH3	Low	1.63	0.261	0.4	Pass
		Middle	1.63	0.261	0.4	Pass
		High	1.63	0.261	0.4	Pass
		Note: DH3: Dwell time = Pulse time*(1600/4/79) *31.6				
	3DH5	Low	2.88	0.307	0.4	Pass
		Middle	2.85	0.304	0.4	Pass
		High	2.90	0.309	0.4	Pass
		Note: DH5: Dwell time = Pulse time*(1600/6/79) *31.6				

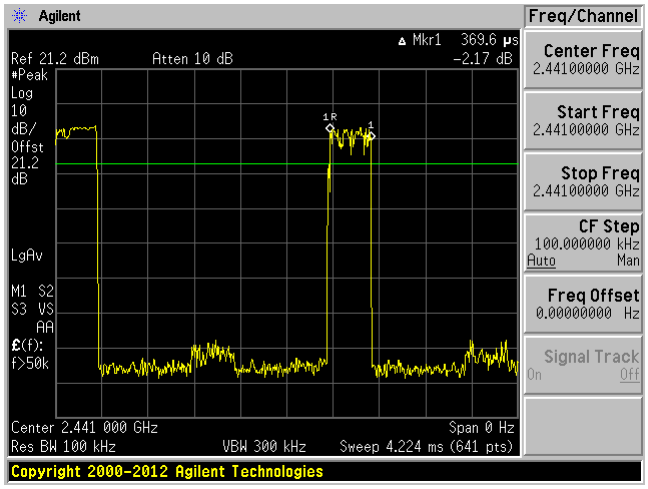
Please refer to the following plots for detailed test results.

GFSK, DH1 Pulse Width

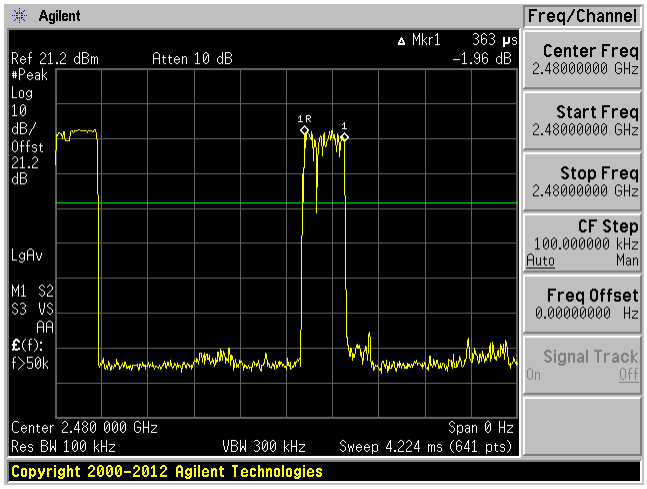
Low Channel 2402 MHz



Middle Channel 2441 MHz

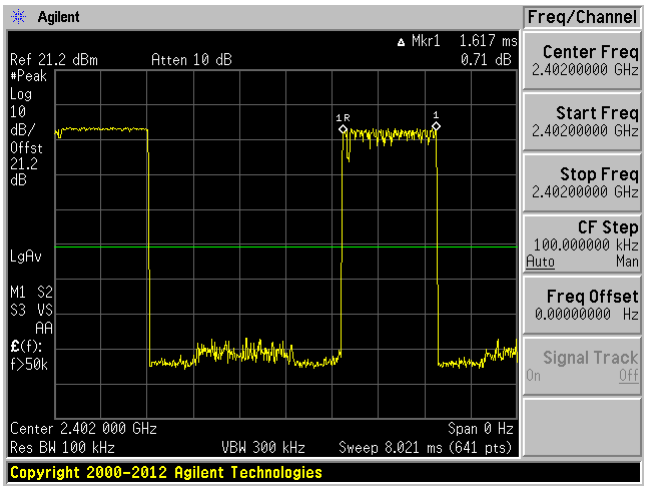


High Channel 2480 MHz

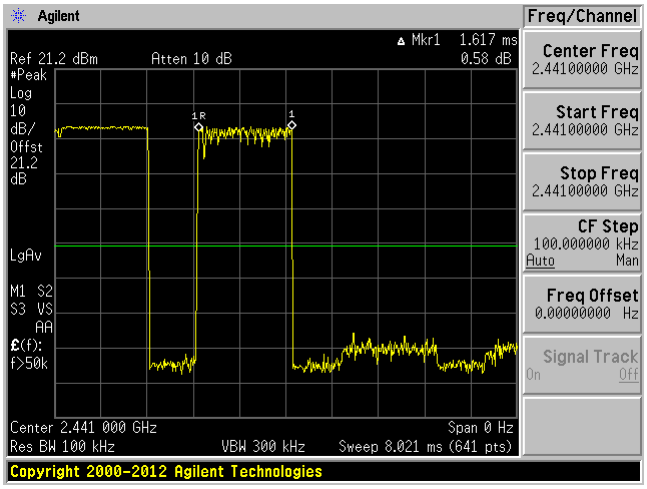


GFSK, DH3 Pulse Width

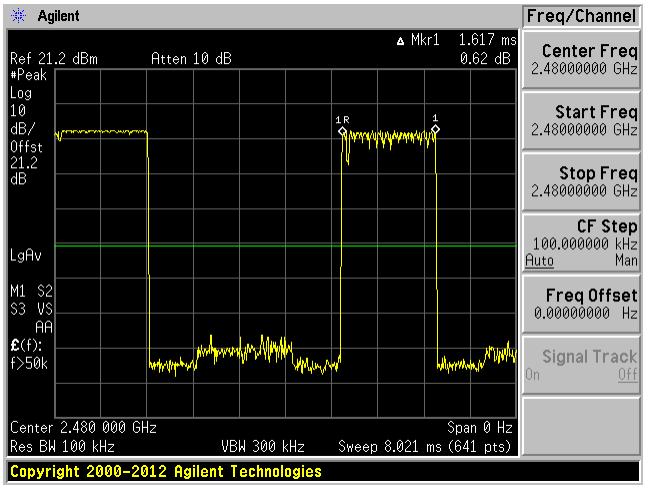
Low Channel 2402 MHz



Middle Channel 2441 MHz

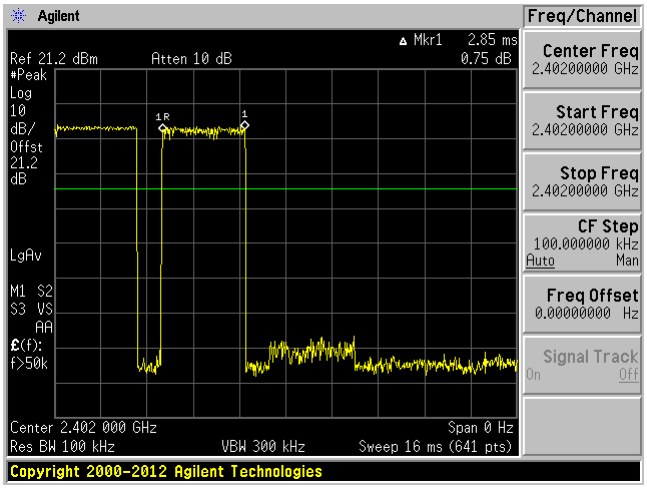


High Channel 2480 MHz

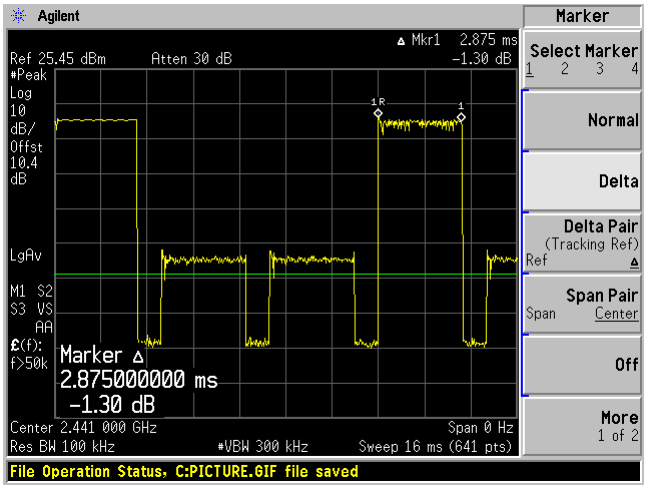


GFSK, DH5 Pulse Width

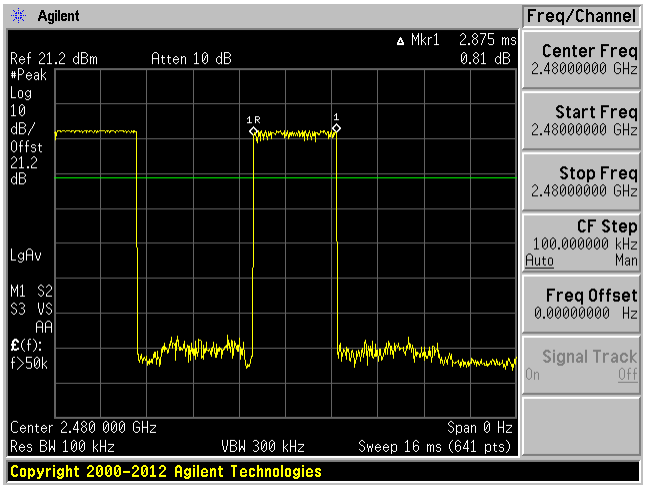
Low Channel 2402 MHz



Middle Channel 2441 MHz

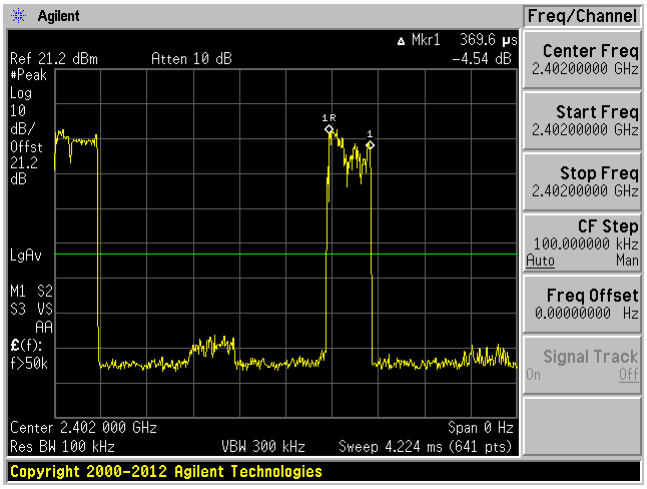


High Channel 2480 MHz

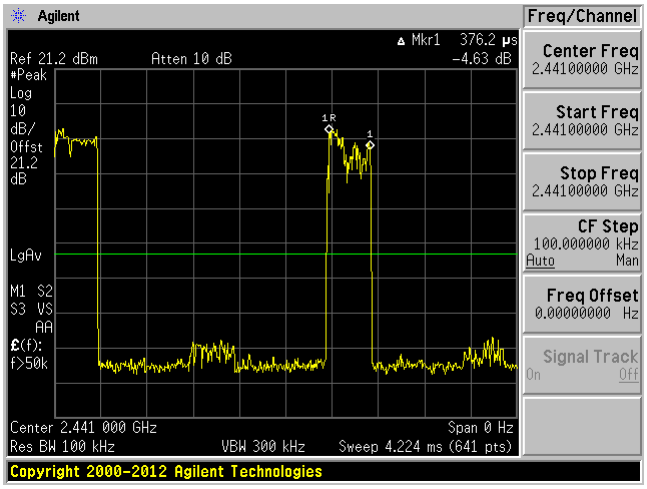


Π/4-DQPSK, DH1 Pulse Width

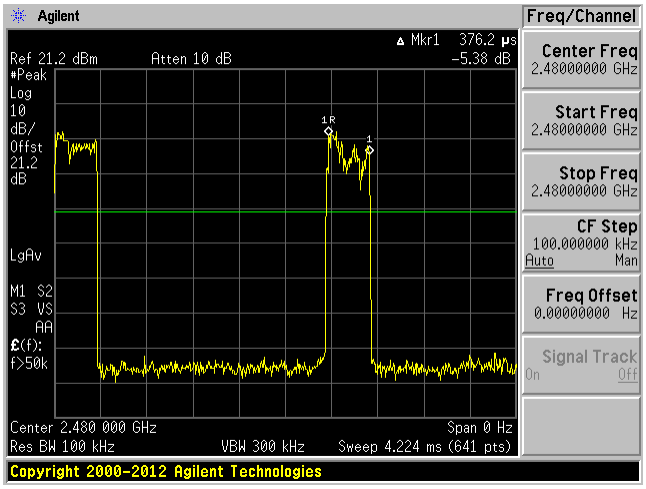
Low Channel 2402 MHz



Middle Channel 2441 MHz

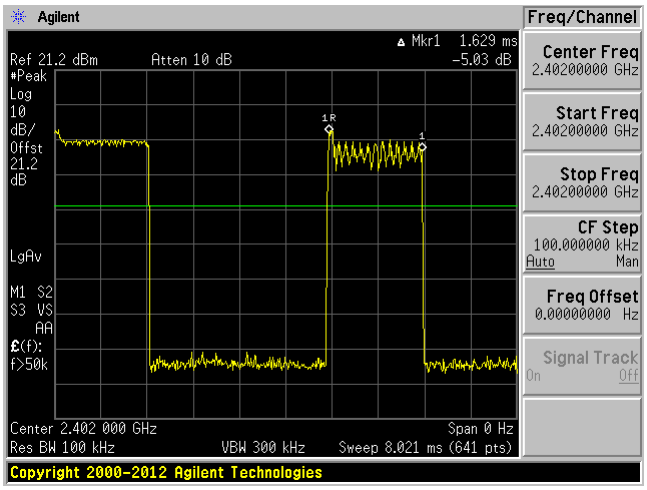


High Channel 2480 MHz

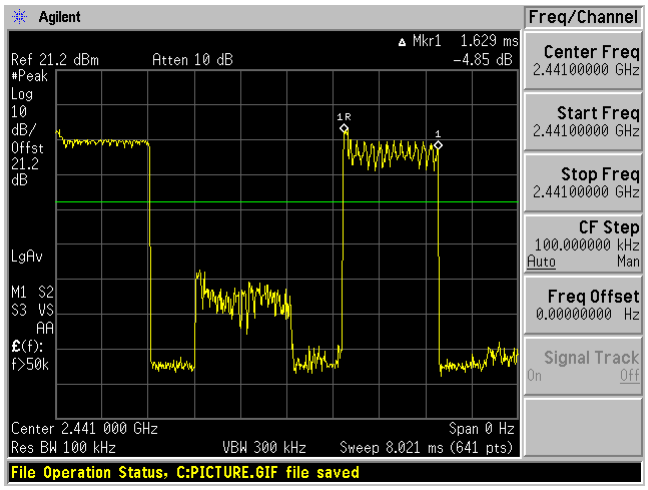


Π/4-DQPSK, DH3 Pulse Width

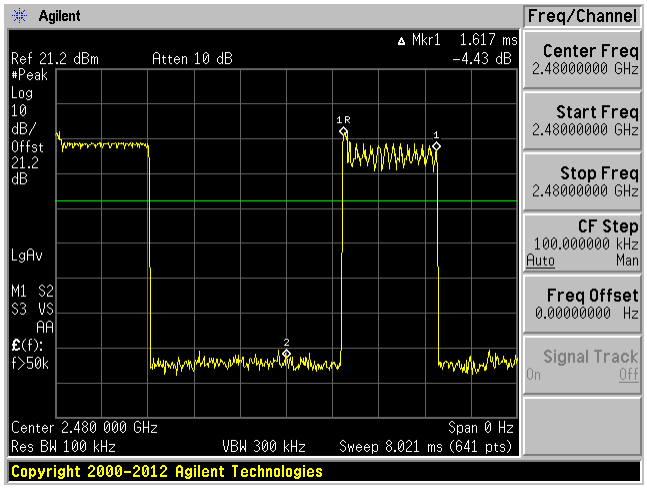
Low Channel 2402 MHz



Middle Channel 2441 MHz

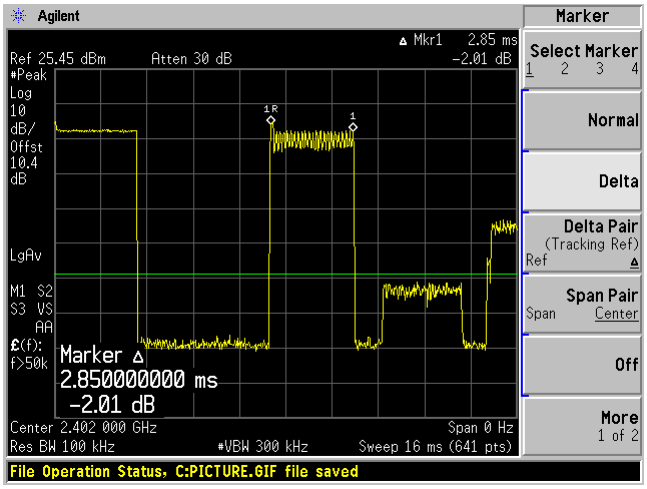


High Channel 2480 MHz

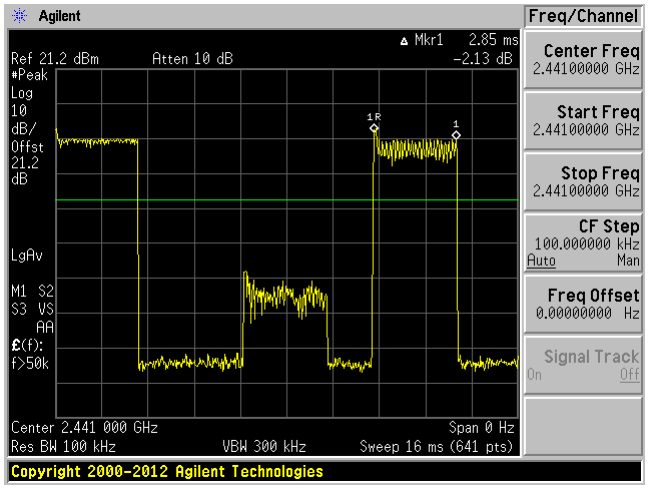


Π/4-DQPSK, DH5 Pulse Width

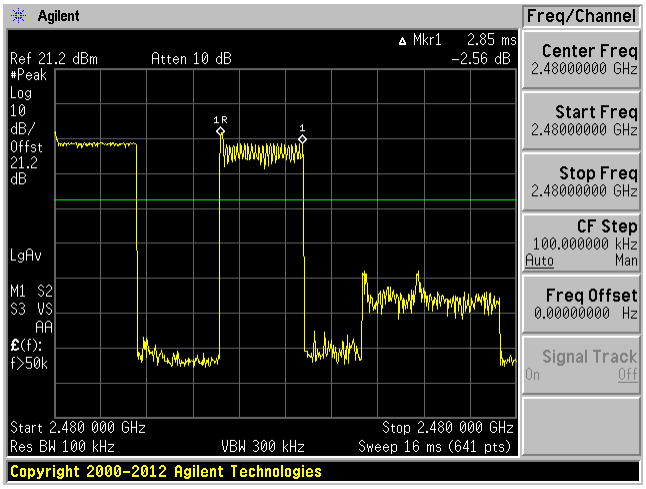
Low Channel 2402 MHz



Middle Channel 2441 MHz

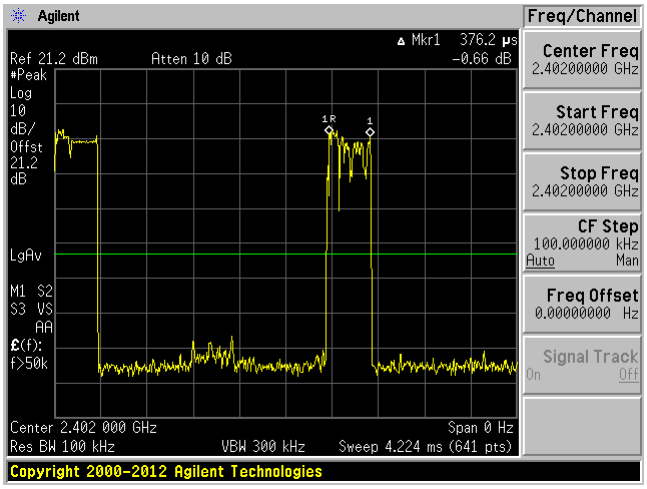


High Channel 2480 MHz

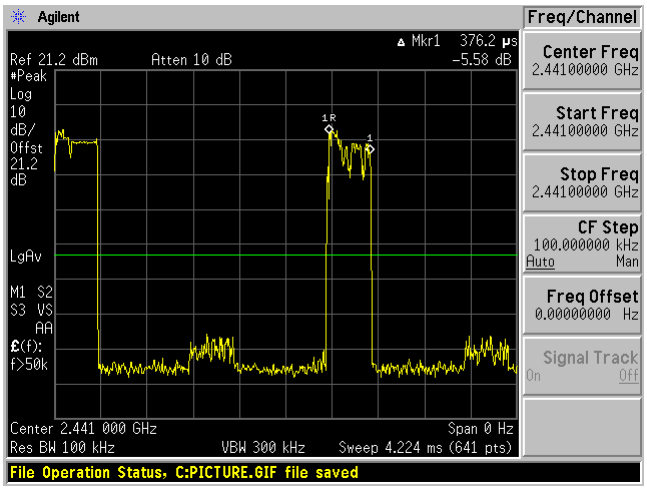


8DPSK, DH1 Pulse Width

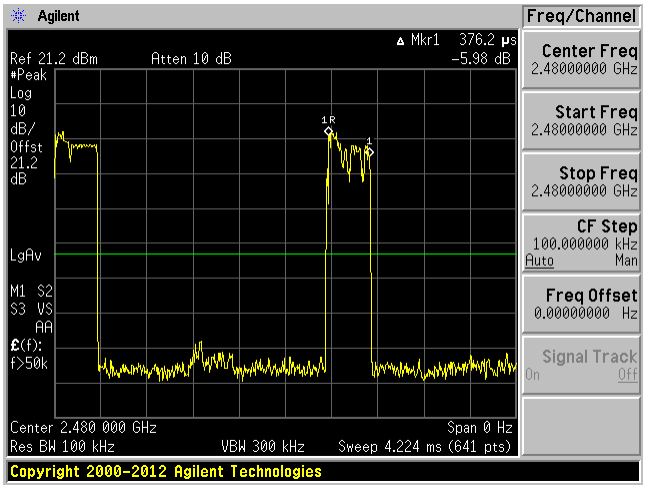
Low Channel 2402 MHz



Middle Channel 2441 MHz

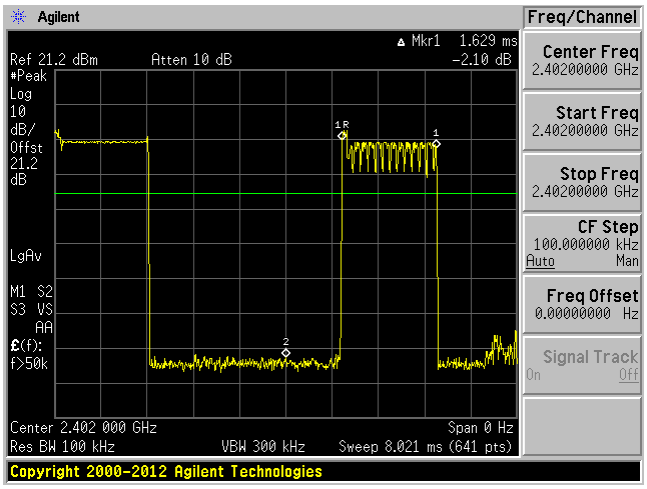


High Channel 2480 MHz

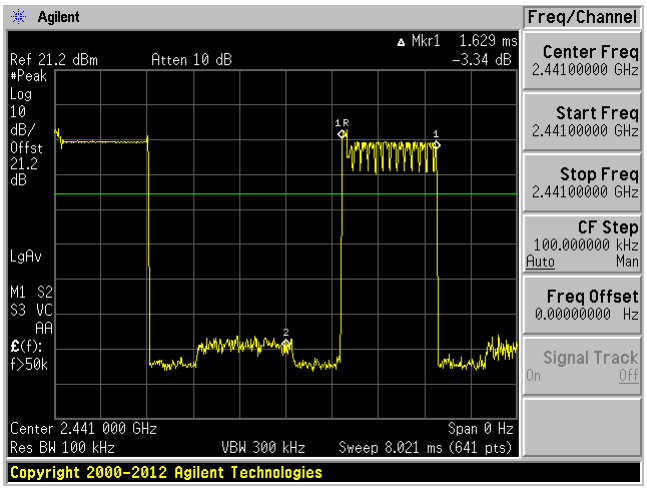


8DPSK, DH3 Pulse Width

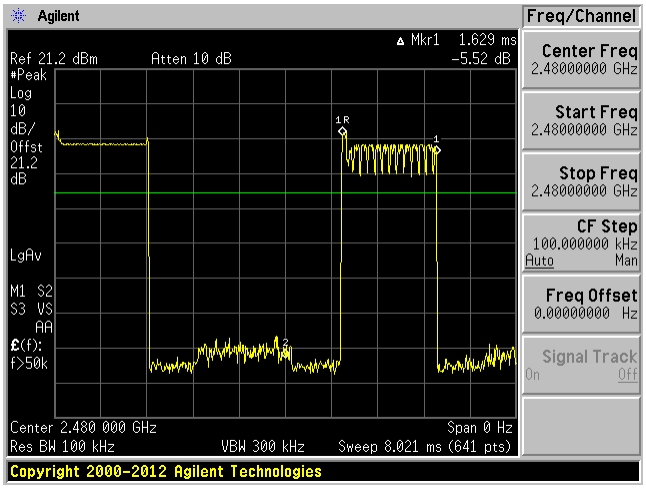
Low Channel 2402 MHz



Middle Channel 2441 MHz

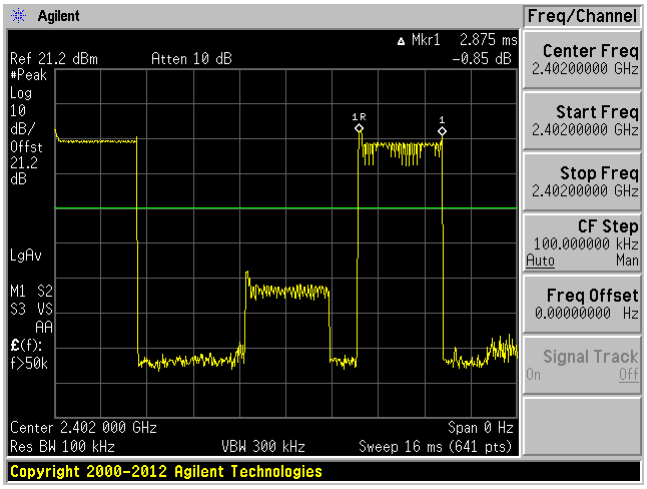


High Channel 2480 MHz

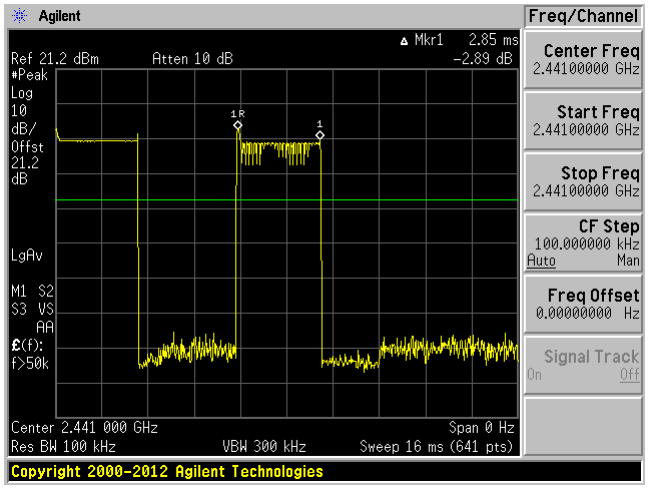


8DPSK, DH5 Pulse Width

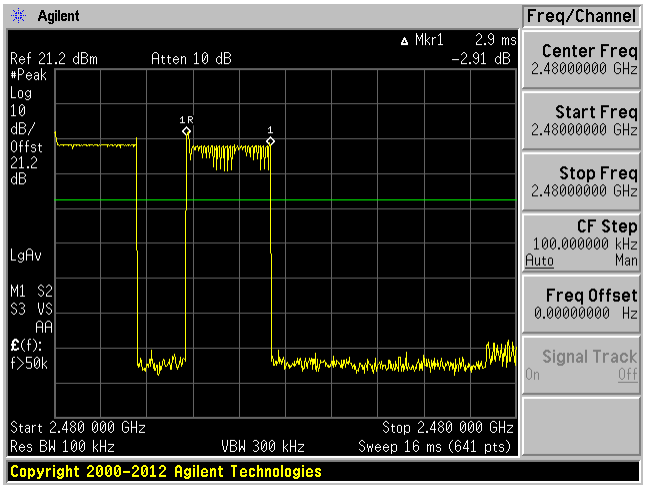
Low Channel 2402 MHz



Middle Channel 2441 MHz



High Channel 2480 MHz



12 FCC §15.247(a)(1)(iii) - Number of Hopping Channels

12.1 Applicable Standards

According to FCC §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. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

12.2 Test Procedure

Span = the frequency band of operation

RBW < 30% of the channel spacing or the 20 dB bandwidth, whichever is smaller
VBW ≥ RBW
Sweep = auto
Detector function = peak
Trace = max hold

12.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Agilent	Analyzer, Spectrum	E4440A	US45303156	2019-03-06	1 year
-	RF cable	-	-	Each time[1]	N/A
-	10 dB attenuator	-	-	Each time[1]	N/A

Note[1]: cable and attenuator included in the test set-up will be checked each time before testing.
Statement of Traceability: BACL Corp. *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

12.4 Test Environmental Conditions

Temperature:	23 ºC
Relative Humidity:	42 %
ATM Pressure:	102.5 KPa

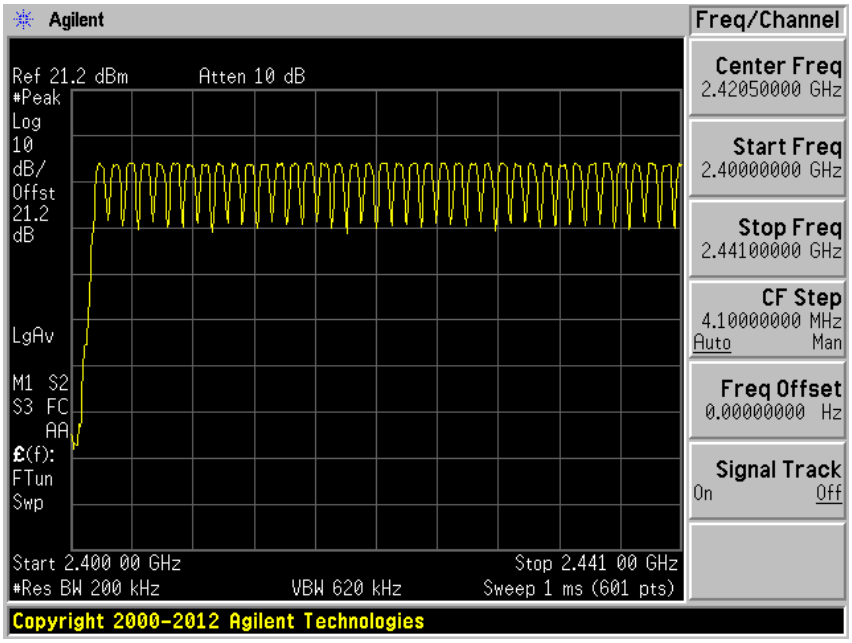
The testing was performed by Christian McCaig on 2019-04-09 in RF site.

12.5 Test Results

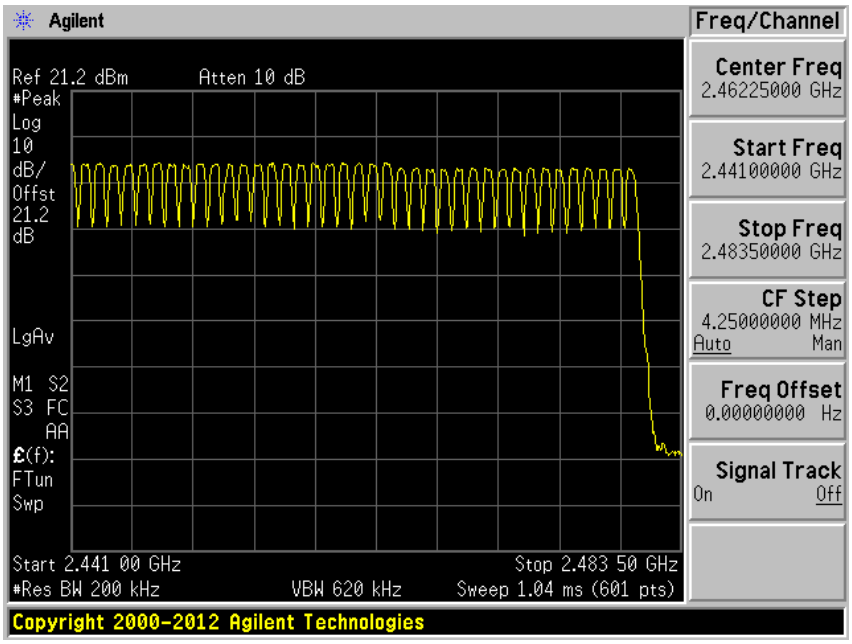
Total 79 channels; please refer to the plots hereinafter.

GFSK

39 Channels between 2400 to 2441 MHz

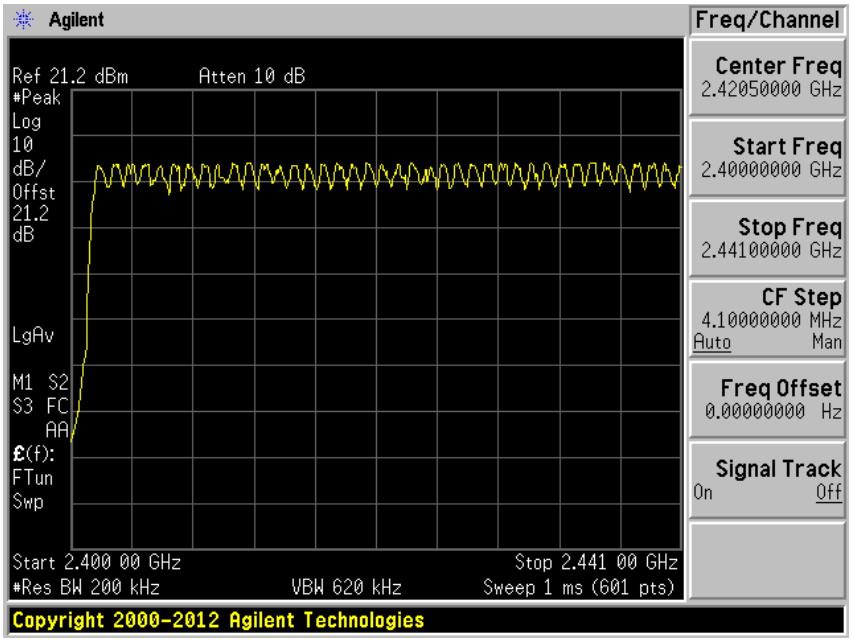


40 Channels between 2441 to 2483.5 MHz

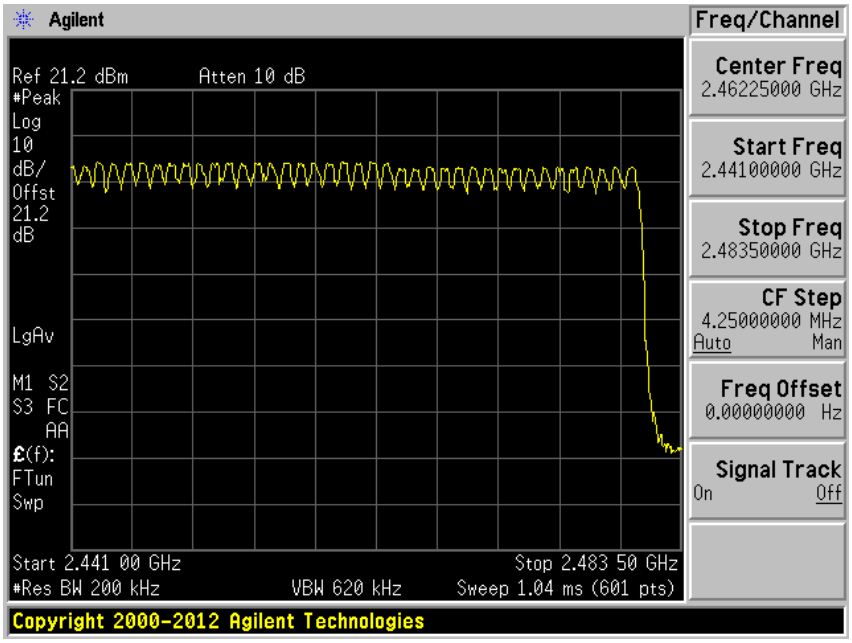


π/4-DQPSK

39 Channels between 2400 to 2441 MHz

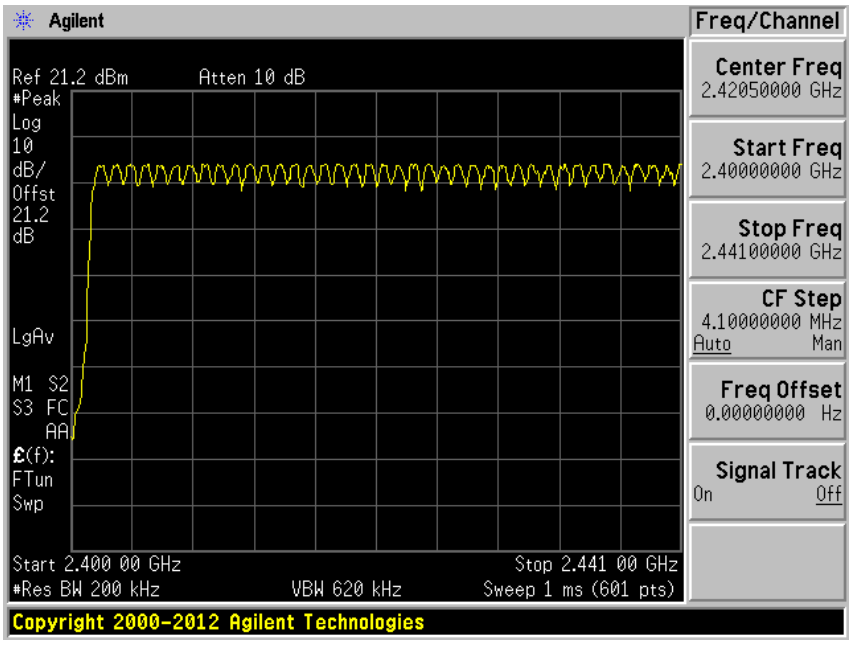


40 Channels between 2441 to 2483.5 MHz

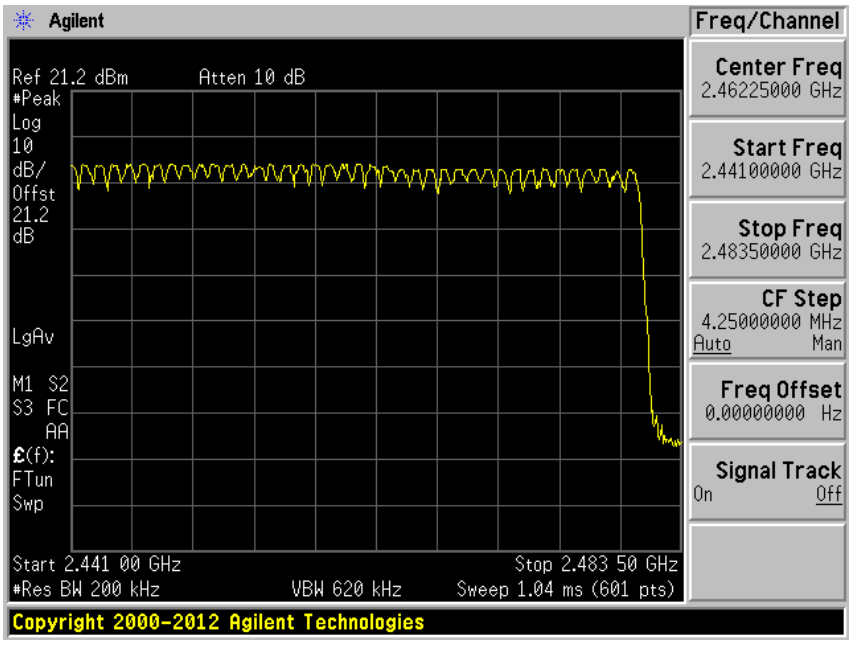


8DPSK

39 Channels between 2400 to 2441 MHz



40 Channels between 2441 to 2483.5 MHz



13 FCC §15.247(a) (1) - Hopping Channel Separation

13.1 Applicable Standards

According to FCC §15.247(a) (1): 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.

13.2 Test Procedure

Span = wide enough to capture the peaks of two adjacent channels
Resolution (or IF) Bandwidth (RBW) ≈ 30% of the channel spacing, adjust as necessary to best identify the center of each individual channel

Video (or Average) Bandwidth (VBW) ≥RBW
Sweep = auto
Detector function = peak
Trace = max hold

13.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Agilent	Analyzer, Spectrum	E4440A	US45303156	2019-03-06	1 year
-	RF cable	-	-	Each time[1]	N/A
-	10dB attenuator	-	-	Each time[1]	N/A

Note[1]: cable and attenuator included in the test set-up will be checked each time before testing.
Statement of Traceability: BACL Corp. *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

13.4 Test Environmental Conditions

Temperature:	23 ºC
Relative Humidity:	42 %
ATM Pressure:	102.5 KPa

The testing was performed by Zhao Zhao on 2019-07-23 in RF site.

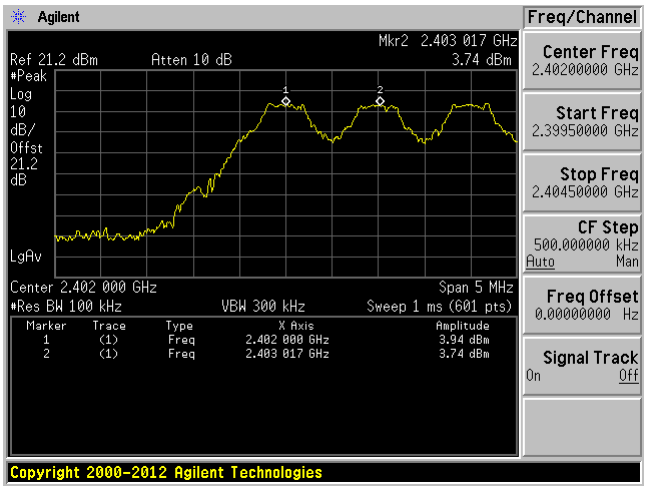
13.5 Test Results

Channel	Frequency (MHz)	Channel Separation (kHz)	Limit > 2/3 20 dB OBW (kHz)
GFSK			
Low	2402	1017	596.13
Middle	2441	1000	596.13
High	2480	950	599.40
π/4-DQPSK			
Low	2402	941	904.00
Middle	2441	1000	900.67
High	2480	875	904.00
8DPSK			
Low	2402	1158	856.00
Middle	2441	1042	817.33
High	2480	1025	852.67

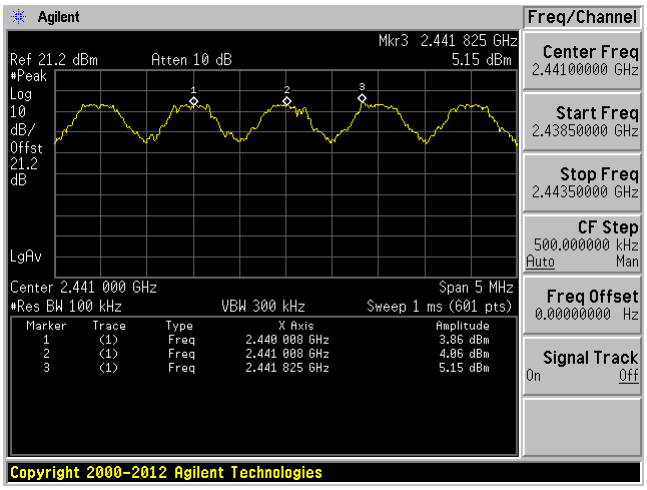
Please refer to following plots.

GFSK

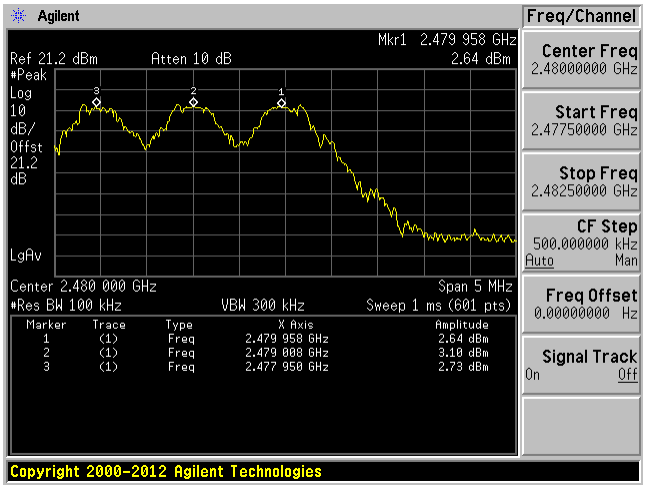
Low Channel 2402 MHz



Middle Channel 2441 MHz

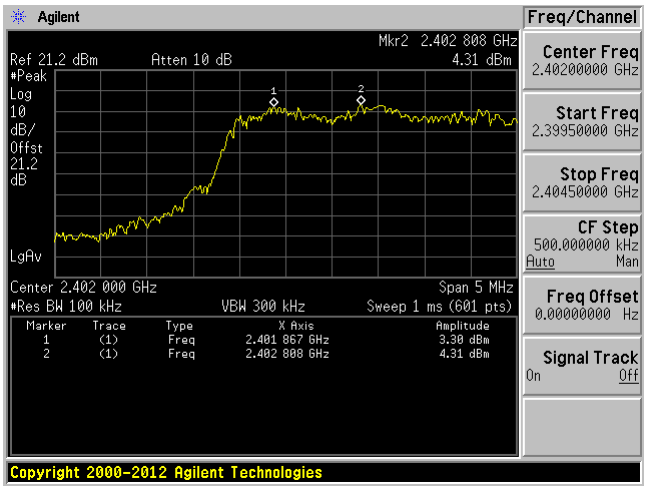


High Channel 2480 MHz

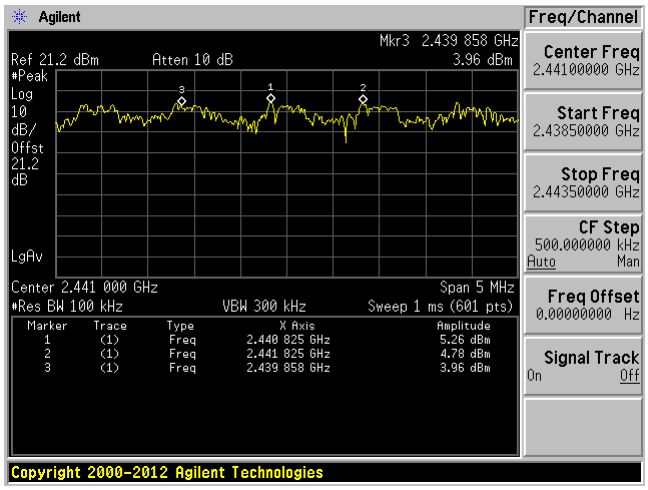


π/4-DQPSK

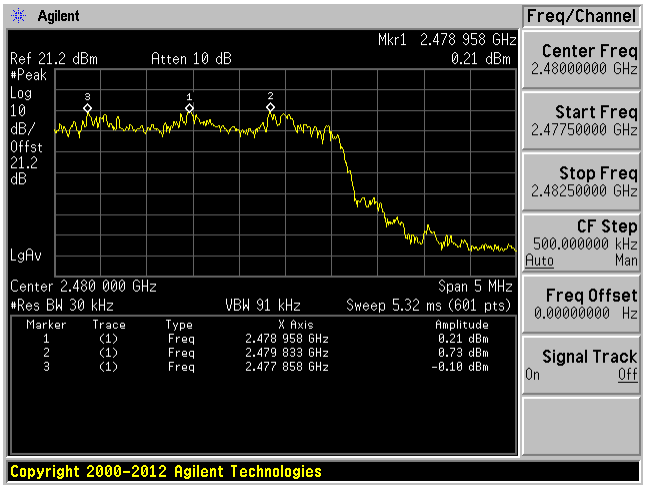
Low Channel 2402 MHz



Middle Channel 2441 MHz

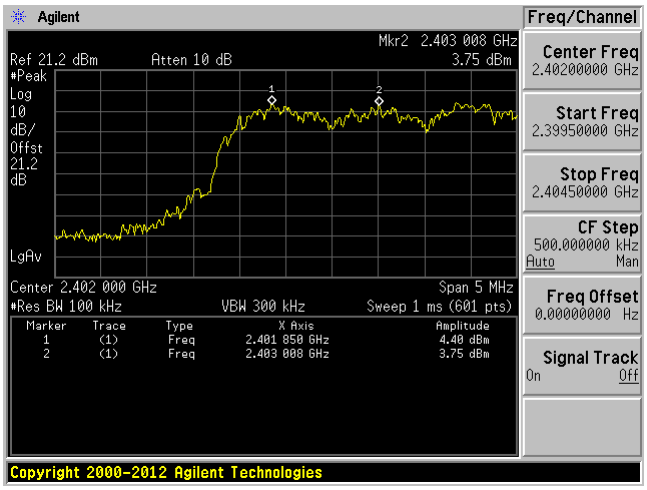


High Channel 2480 MHz

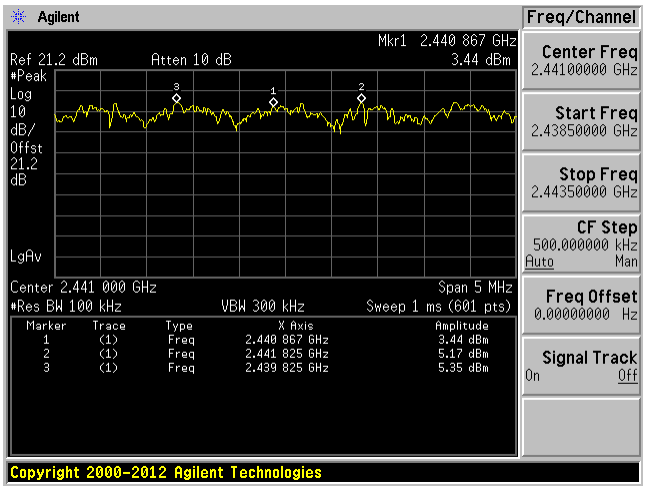


8DPSK

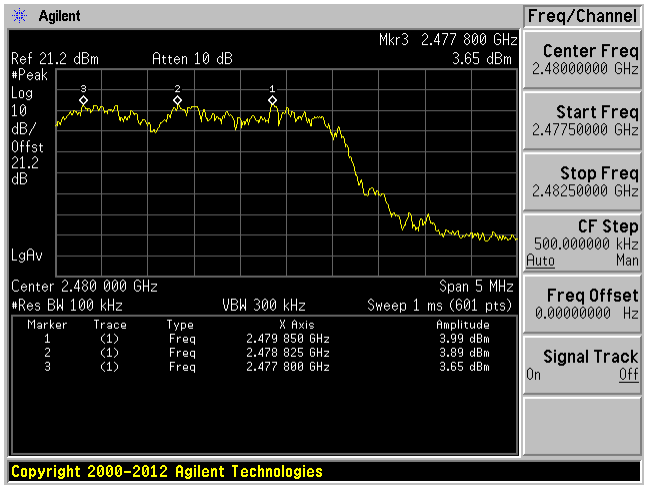
Low Channel 2402 MHz



Middle Channel 2441 MHz



High Channel 2480 MHz



14 FCC §15.247(d) - Spurious Emissions at Antenna Terminals

14.1 Applicable Standards

For FCC §15.247(d) 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)).

14.2 Test Procedure

The RF output of the EUT was connected to a spectrum analyzer through appropriate attenuation. The resolution bandwidth of the spectrum analyzer was set at 100 kHz. Sufficient scans were taken to show any out of band emissions up to 10th harmonic.

14.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Agilent	Analyzer, Spectrum	E4440A	US45303156	2019-03-06	1 year
-	RF cable	-	-	Each time[1]	N/A
-	10dB attenuator	-	-	Each time[1]	N/A

Note[1]: cable and attenuator included in the test set-up will be checked each time before testing.
Statement of Traceability: BACL Corp. *attests that all calibrations have been performed per the A2LA requirements, traceable to the NIST.*

14.4 Test Environmental Conditions

Temperature:	23º C
Relative Humidity:	42 %
ATM Pressure:	102.5 KPa

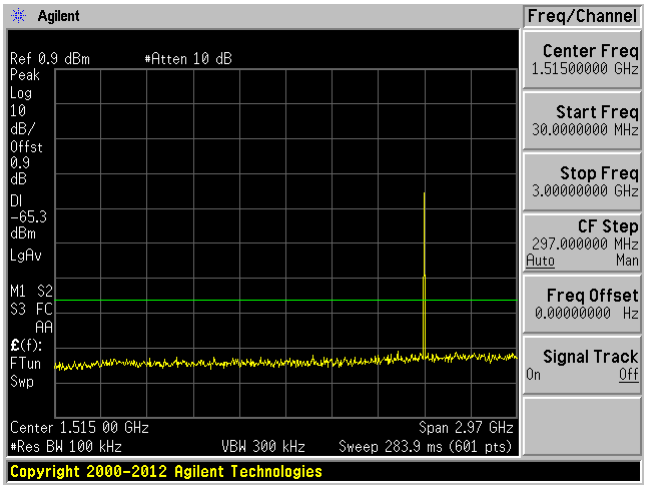
The testing was performed by Zhao Zhao on 2019-07-19 in RF site.

14.5 Test Results

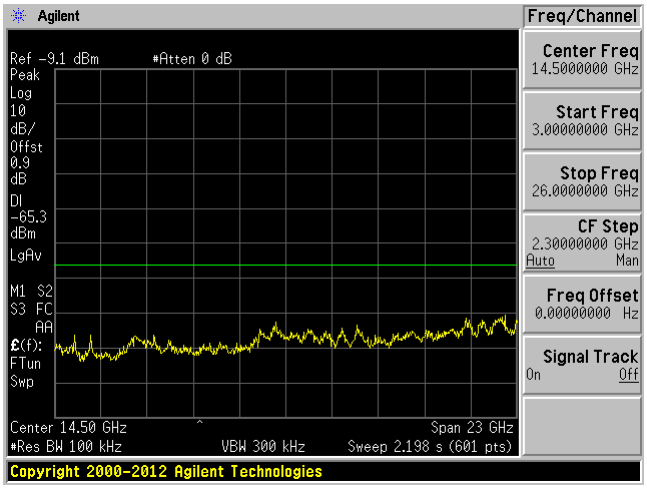
Please refer to following plots.

GFSK

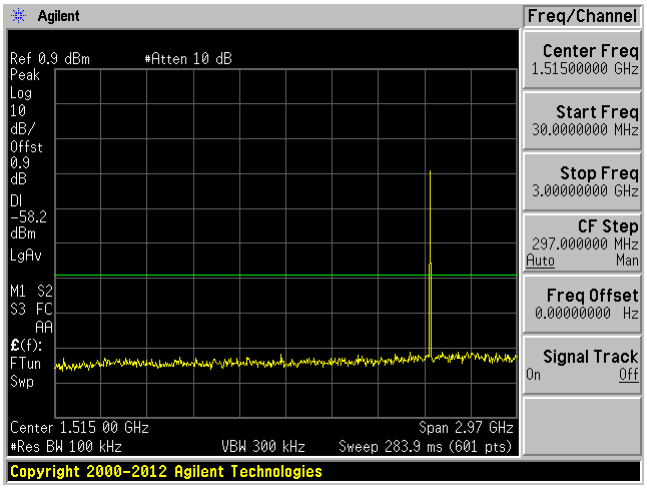
Low Channel 30 MHz – 3 GHz



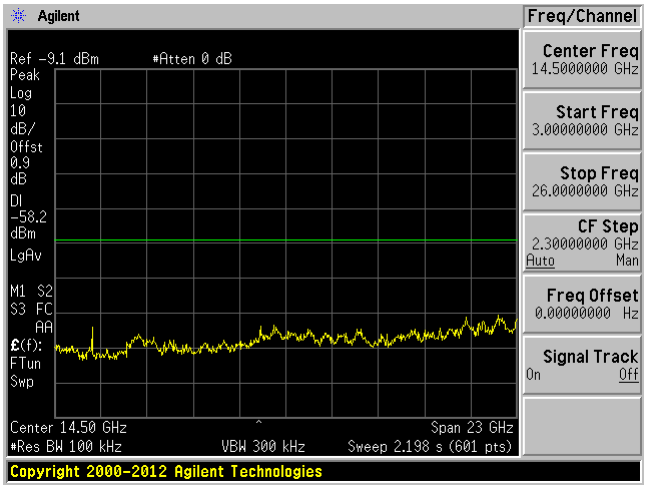
Low Channel 3 GHz – 26 GHz



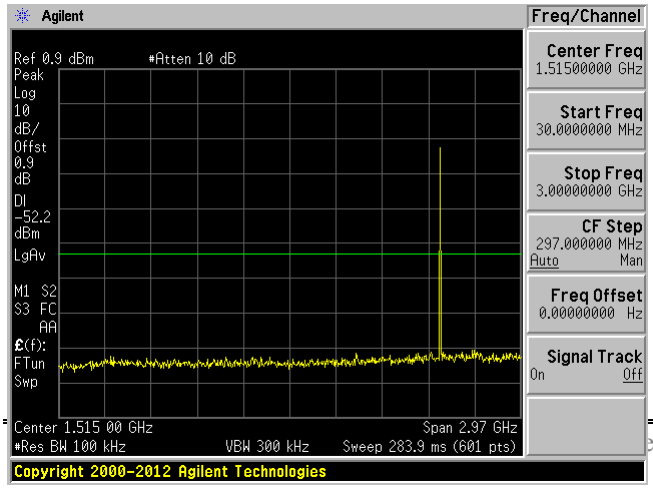
Middle Channel 30 MHz – 3 GHz



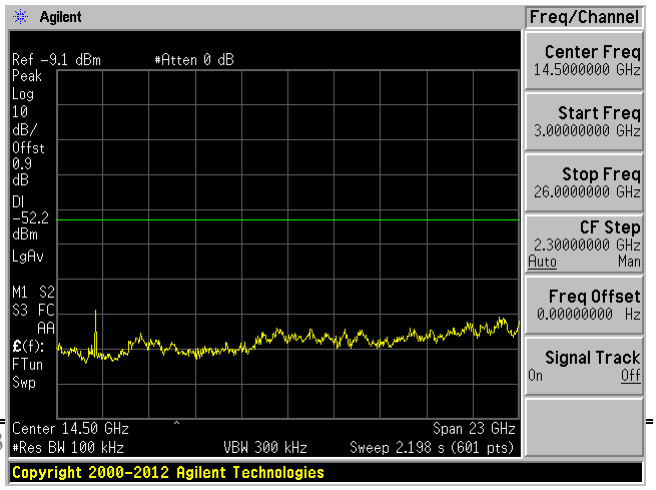
Middle Channel 3 GHz – 26 GHz



High Channel 30 MHz – 3 GHz

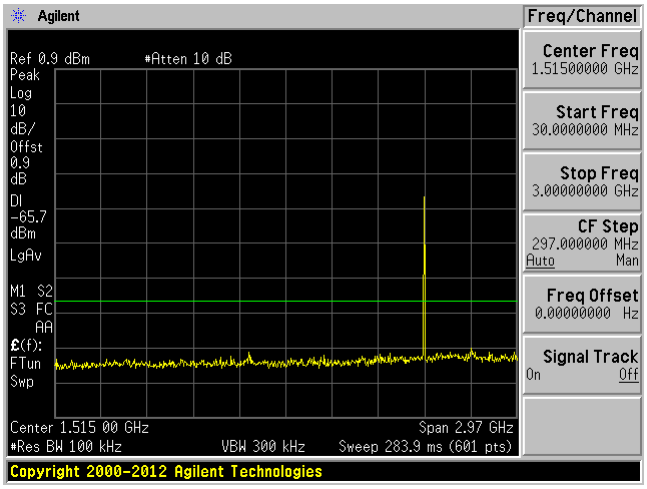


High Channel 3 GHz – 26 GHz

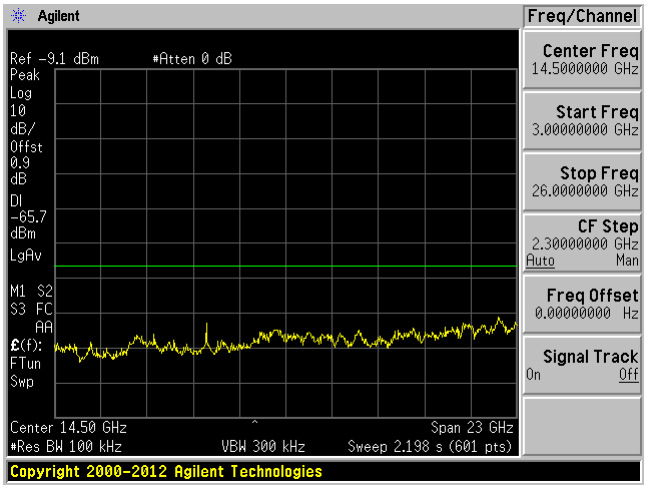


π/4-DQPSK

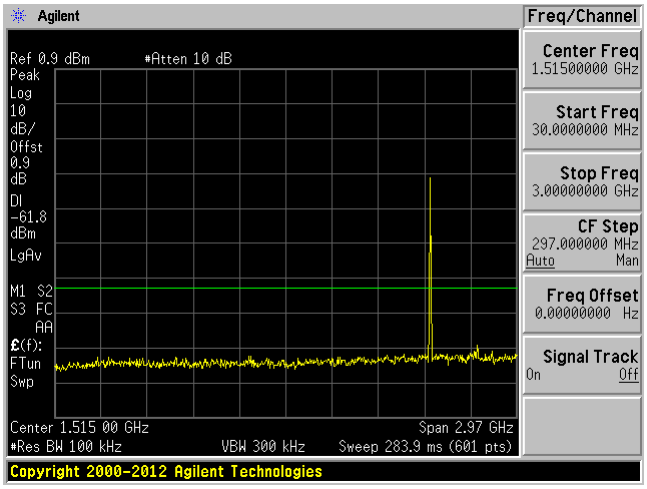
Low Channel 30 MHz – 3 GHz



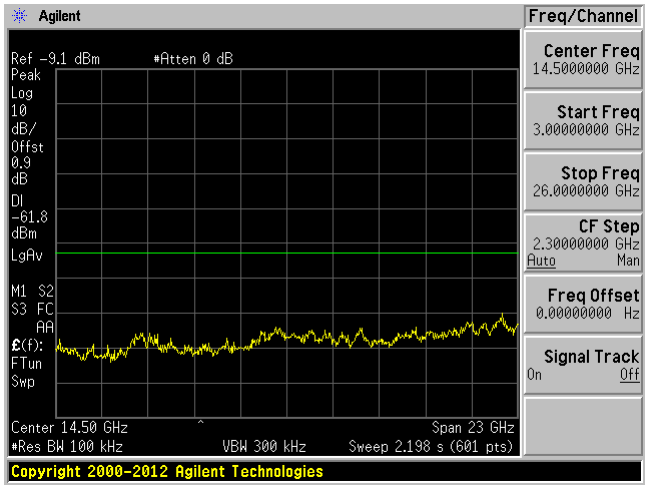
Low Channel 3 GHz – 26 GHz



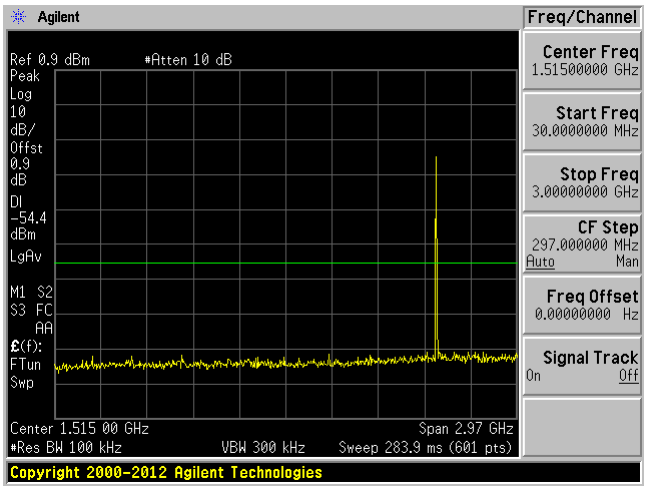
Middle Channel 30 MHz – 3 GHz



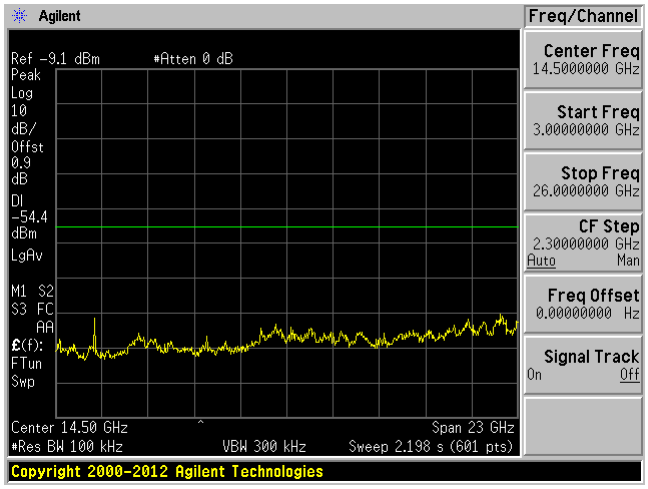
Middle Channel 3 GHz – 26 GHz



High Channel 30 MHz – 3 GHz

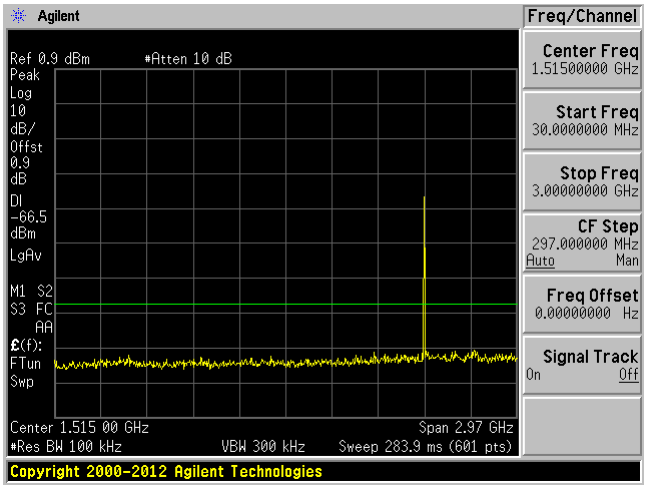


High Channel 3 GHz – 26 GHz

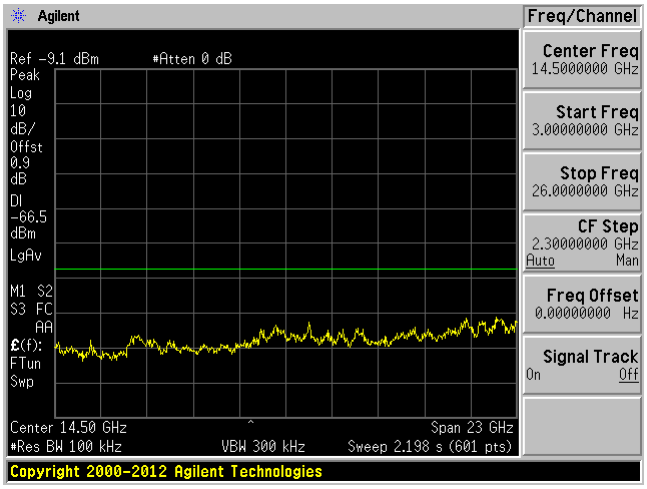


8DPSK

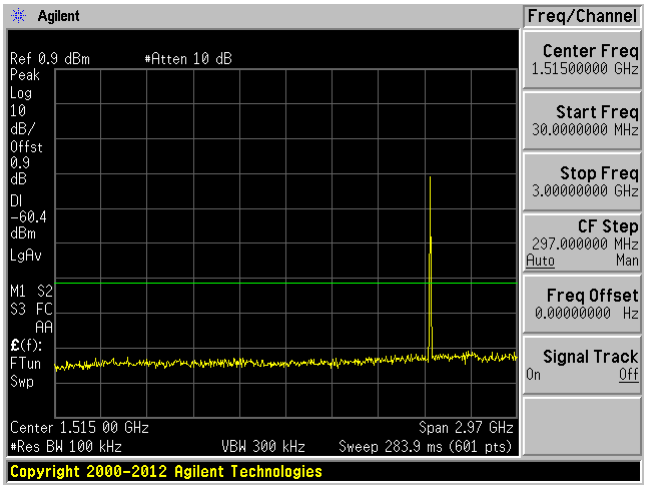
Low Channel 30 MHz – 3 GHz



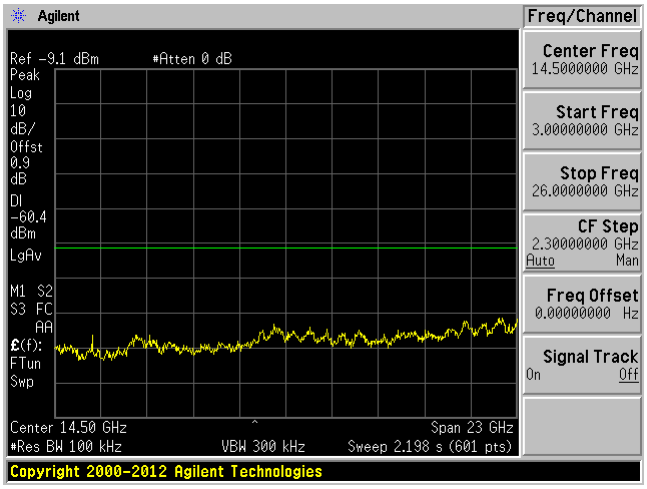
Low Channel 3 GHz – 26 GHz



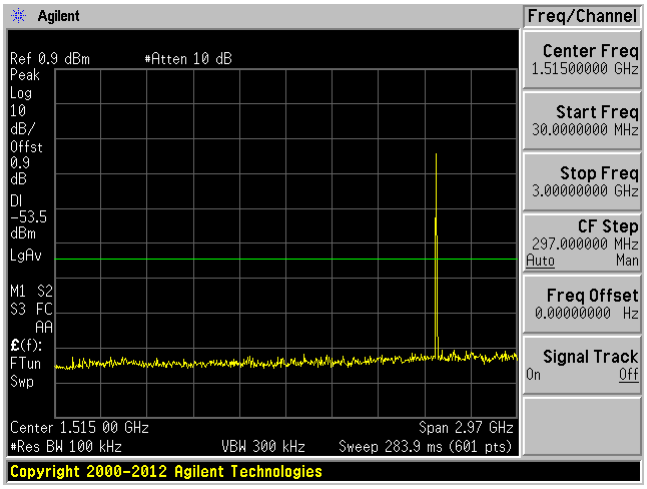
Middle Channel 30 MHz – 3 GHz



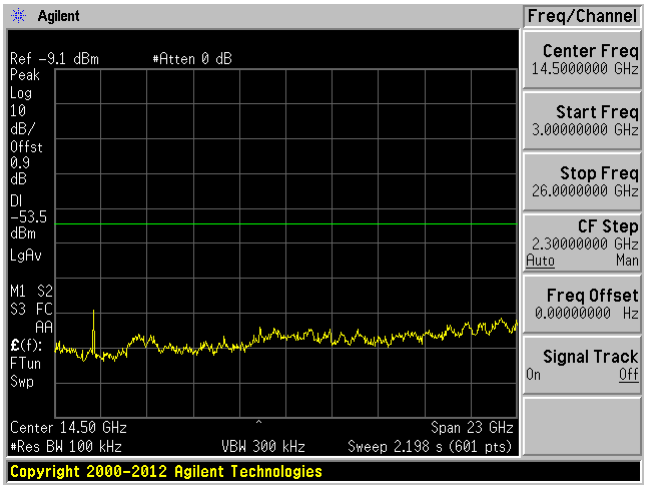
Middle Channel 3 GHz – 26 GHz



High Channel 30 MHz – 3 GHz



High Channel 3 GHz – 26 GHz



15 Annex A (Normative) – EUT Test Setup Photographs

Please refer to the attachment.

16 Annex B (Normative) – EUT External Photographs

Please refer to the attachment.

17 Annex C (Normative) – EUT Internal Photographs

Please refer to the attachment.

18 Annex D (Normative) – Plots

Please refer to the attachment.

19 Annex E (Normative) - A2LA Electrical Testing Certificate

Accredited Laboratory

A2LA has accredited

BAY AREA COMPLIANCE LABORATORIES CORP.

Sunnyvale, CA

for technical competence in the field of

Electrical Testing

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005 *General requirements for the competence of testing and calibration laboratories*. This laboratory also meets A2LA *R222 - Specific Requirements EPA ENERGY STAR Accreditation Program*. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system *(refer to joint ISO-ILAC-IAF Communiqué dated April 2017)*.

Presented this 2nd day of October 2018.

Vice President, Accreditation Services
For the Accreditation Council
Certificate Number 3297.02
Valid to September 30, 2020
Revised June 5, 2019

For the tests to which this accreditation applies, please refer to the laboratory's Electrical Scope of Accreditation.

Please follow the web link below for a full ISO 17025 scope

https://www.a2la.org/scopepdf/3297-02.pdf

--- END OF REPORT ---