



Test Report

Date : 2023-05-30
No. : HMD23050007

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Applicant : The Singing Machine Company, Inc.
6301 NW 5th Way, Suite 2900, Fort Lauderdale, FL 33309, USA

Supplier / Manufacturer : ZHUHAI FULLWING ELECTRONIC CO., LTD ZHONGSHAN
BRANCH
4/F&5/F, No 10, Xingye Road, Xinxu, San Xiang, Zhongshan,
Guangdong, China

Description of Sample(s) : Submitted sample(s) said to be
Product: CUBE MINI
Brand Name: Singing Machine
Model No.: SML668G
FCC ID: 2AAXO-SML668

Date Samples Received : 2023-05-12

Date Tested : 2023-05-12 to 2023-05-24

Investigation Requested : Perform Electro Magnetic Interference measurement in accordance with FCC 47CFR [Codes of Federal Regulations] Part 15 and ANSI C63.10:2013 for FCC Certification.

Conclusions : The submitted product COMPLIED with the requirements of Federal Communications Commission [FCC] Rules and Regulations Part 15. The tests were performed in accordance with the standards described above and on Section 2.2 in this Test Report.

Remarks : Bluetooth FHSS (GFSK / $\pi/4$ -DQPSK/ 8DPSK)
For additional model(s) details, please see page 3.

Test by Susu


Dr.CHAN Kwok Hung, Brian
Authorized Signatory



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1.0 General Details

1.1 Test Laboratory

The Hong Kong Standards and Testing Centre Ltd.
EMC Laboratory
10 Dai Wang Street, Taipo Industrial Estate, New Territories, Hong Kong
Telephone: 852 2666 1888
Fax: 852 2664 4353

1.2 Equipment Under Test [EUT]

Description of Sample(s)

Product: CUBE MINI
Supplier: ZHUHAI FULLWING ELECTRONIC CO., LTD
ZHONGSHAN BRANCH
4/F&5/F, No 10, Xingye Road, Xinxu, San Xiang, Zhongshan,
Guangdong, China
Brand Name: Singing Machine
Model Number: SML668G
Additional Model Number: SML668, SML668W, SML669, SML675, SML2422
Rating: 5.0Vd.c. by Type C port
3.7Vd.c. (lithium battery * 1)

The AC/DC adapter was provided by the laboratory as auxiliary equipment.

Remark: AC mains mode and battery mode have been investigated and the worst-case test results are recorded in this report.

1.2.1 Description of EUT Operation

The Equipment Under Test (EUT) is a CUBE MINI. The transmission signal is digital modulated with channel frequency range 2402-2480MHz. The R.F. signal was modulated by IC; the type of modulation used was frequency hopping spread spectrum Modulation.

1.3 Date of Order

2023-05-12

1.4 Submitted Sample(s):

1 Sample

1.5 Test Duration

2023-05-12 to 2023-05-24

1.6 Country of Origin

China

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1.7 RF Module Details

Module Model Number: N/A
Module FCC ID: N/A
Module Transmission Type: Bluetooth 5.0 BR+EDR
Modulation: FHSS (GFSK / $\pi/4$ -DQPSK/ 8DPSK)
Data Rates: 1MBps: GFSK
2 MBps: $\pi/4$ -DQPSK
3 MBps: 8DPSK
Frequency Range: 2400-2483.5MHz
Carrier Frequencies: 2402MHz – 2480MHz

Module Specification (specification provided by manufacturer)

1.8 Antenna Details

Antenna Type: PCB antenna
Antenna Gain: -0.58 dBi

1.9 Channel List

Channel	Frequency (MHz)	Channel	Frequency (MHz)
0	2402	42	2444
1	2403	43	2445
2	2404	44	2446
3	2405	45	2447
4	2406	46	2448
5	2407	47	2449
6	2408	48	2450
7	2409
8	2410	67	2469
9	2411	68	2470
...	...	69	2471
33	2435	70	2472
34	2436	71	2473
35	2437	72	2474
36	2438	73	2475
37	2439	74	2476
38	2440	75	2477
39	2441	76	2478
40	2442	77	2479
41	2443	78	2480

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2.0 Technical Details

2.1 Investigations Requested

Perform Electromagnetic Interference measurements in accordance with FCC 47CFR [Codes of Federal Regulations] Part 15 Regulations and ANSI C63.10:2013 for FCC Certification. The device was realized by test software and the RF power select “0”.





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2.2 Test Standards and Results Summary Tables

EMISSION Results Summary						
Test Condition	Test Requirement	Test Method	Class / Severity	Test Result		
				Pass	Failed	N/A
Maximum Peak Conducted Output Power	FCC 47CFR 15.247(b)(1)	ANSI C63.10: 2013	N/A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Radiated Spurious Emissions	FCC 47CFR 15.209, FCC 47CFR 15.205	ANSI C63.10: 2013	N/A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AC Mains Conducted Emissions	FCC 47CFR 15.207	ANSI C63.10: 2013	N/A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Conducted Spurious Emissions	FCC 47CFR 15.247(d)	ANSI C63.10: 2013	N/A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Number of Hopping Frequency	FCC 47CFR 15.247 (b)(1)	ANSI C63.10: 2013	N/A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20dB Bandwidth	FCC 47CFR 15.247(a)(2)	ANSI C63.10: 2013	N/A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hopping Channel Separation	FCC 47CFR 15.247(a)(1)	ANSI C63.10: 2013	N/A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Band-edge measurement (Radiated)	FCC 47CFR 15.247(d)	ANSI C63.10: 2013	N/A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pseudorandom Hopping Algorithm	FCC 47CFR 15.247(a)(1)	N/A	N/A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Time of Occupancy (Dwell Time)	FCC 47CFR 15.247(a)(1)(iii)	ANSI C63.10: 2013	N/A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Antenna requirement	FCC 47CFR 15.203	N/A	N/A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Note: N/A - Not Applicable

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2.3 Table for Test Modes

Preliminary tests were performed in different data rate to find the worst radiated emission. The data rate in the table below is the worst case rate with respect to the specific test item.

Investigation has been done on all the possible configurations for searching the worst cases.

The following table is a list of the test modes shown in this test report.

Test Items	Mode	Data Rate
Maximum Peak Conducted Output Power	GFSK / $\pi/4$ -DQPSK / 8DPSK	1MBps / 2MBps / 3MBps
Hopping Channel Separation	GFSK / $\pi/4$ -DQPSK / 8DPSK	1MBps / 2MBps / 3MBps
Number of Hopping Frequency	GFSK / $\pi/4$ -DQPSK / 8DPSK	1MBps / 2MBps / 3MBps
Time of Occupancy(Dwell Time)	8DPSK (3DH1 / 3DH3 / 3DH5)	3MBps
Radiated Spurious Emissions	GFSK / $\pi/4$ -DQPSK / 8DPSK	1MBps / 2MBps / 3MBps
Band-edge compliance of Conducted Emission	GFSK / $\pi/4$ -DQPSK / 8DPSK	1MBps / 2MBps / 3MBps

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3.0 Test Results

3.1 Emission

3.1.1 Maximum Peak Conducted Output Power

Test Requirement: FCC 47CFR 15.247(b) (1)
Test Method: ANSI C63.10: 2013

Test Date: 2023-05-15
Mode of Operation: Tx mode

Ambient Temperature: 25°C Relative Humidity: 51% Atmospheric Pressure: 101 kPa

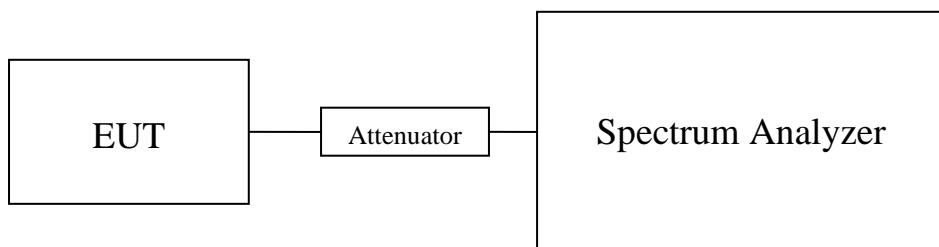
Test Method:

A temporary antenna connector was soldered to the RF output. The RF output of the EUT was connected to the spectrum analyzer. All the attenuation or cable loss will be added to the measured maximum output power. The results are recorded in Watt.

Spectrum Analyzer Setting:

RBW = 3 MHz, VBW= 3MHz, Sweep = Auto, Span: Approximately five times the 20 dB bandwidth
Detector = Peak, Trace = Max. hold

Test Setup:



Note: a temporary antenna connector was soldered to the RF output.

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Limits for Maximum Peak Conducted Output Power [FCC 47CFR 15.247]:

The maximum peak output power shall not exceed the following limits:
For frequency hopping systems employing at least 75 hopping channels: 1 Watt
For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 Watts
For Digital Transmission systems in 2400-2483.5 MHz Band: 1 Watt

Results of Bluetooth Communication mode (GFSK) (Fundamental Power): Pass

Channel	Frequency (MHz)	Conducted power(dBm)	Antenna Gain(dBi)	E.I.R.P(dBm)	E.I.R.P (Watt)
0	2402	-1.022	-0.58	-1.602	0.000692
39	2441	-0.602	-0.58	-1.182	0.000762
78	2480	-3.927	-0.58	-4.507	0.000354

Results of Bluetooth Communication mode (PI/4DQPSK) (Fundamental Power): Pass

Channel	Frequency (MHz)	Conducted power(dBm)	Antenna Gain(dBi)	E.I.R.P(dBm)	E.I.R.P (Watt)
0	2402	-1.018	-0.58	-1.598	0.000692
39	2441	-0.568	-0.58	-1.148	0.000768
78	2480	-3.982	-0.58	-4.562	0.000350

Results of Bluetooth Communication mode (8DPSK) (Fundamental Power): Pass

Channel	Frequency (MHz)	Conducted power(dBm)	Antenna Gain(dBi)	E.I.R.P(dBm)	E.I.R.P (Watt)
0	2402	-1.038	-0.58	-1.618	0.000689
39	2441	-0.587	-0.58	-1.167	0.000764
78	2480	-3.962	-0.58	-4.542	0.000351

Calculated measurement uncertainty : 30MHz to 1GHz 1.7dB
1GHz to 18GHz 1.7dB

Remark:

1. All test data for each data rate were verified, but only the worst case was reported.
2. The EUT is programmed to transmit signals continuously for all testing.

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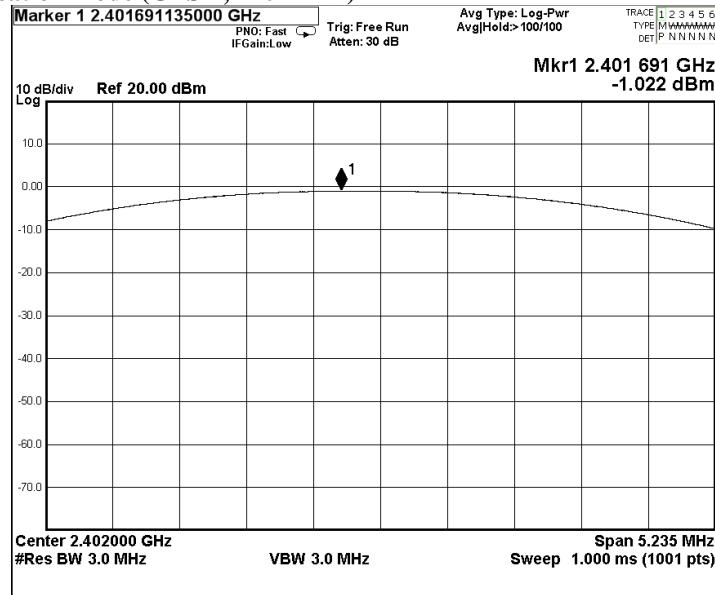
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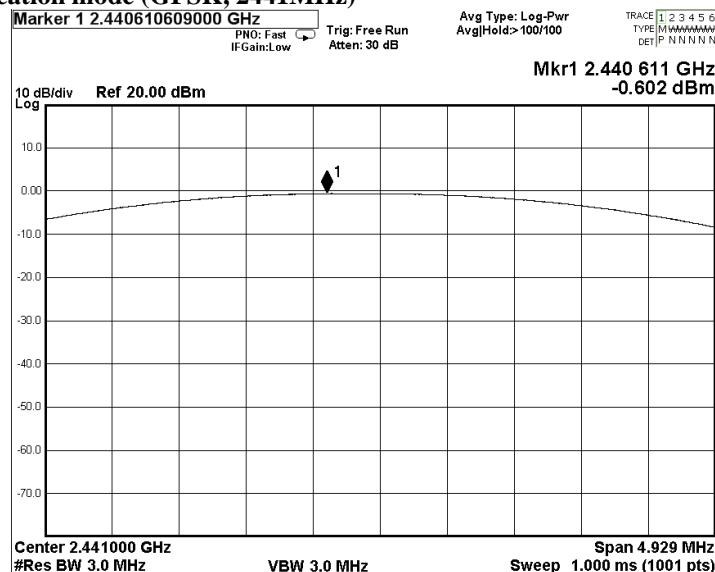
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Test plot of Maximum Peak Conducted Output Power:

Bluetooth Communication mode (GFSK, 2402MHz)



Bluetooth Communication mode (GFSK, 2441MHz)



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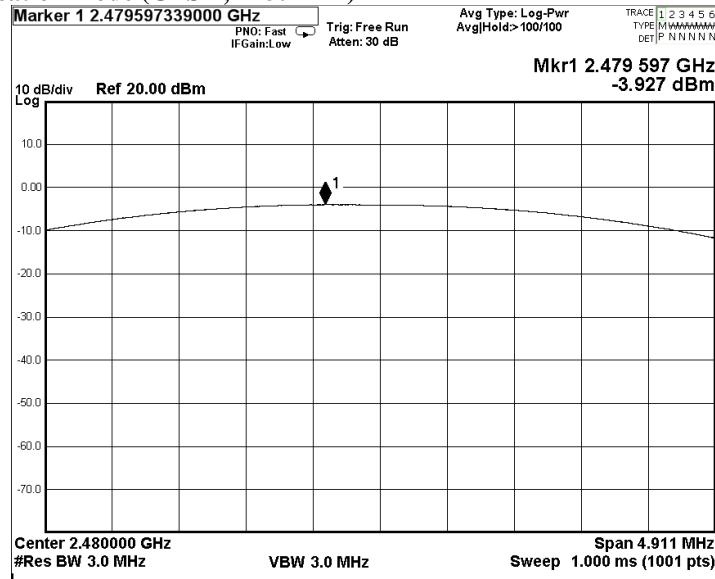


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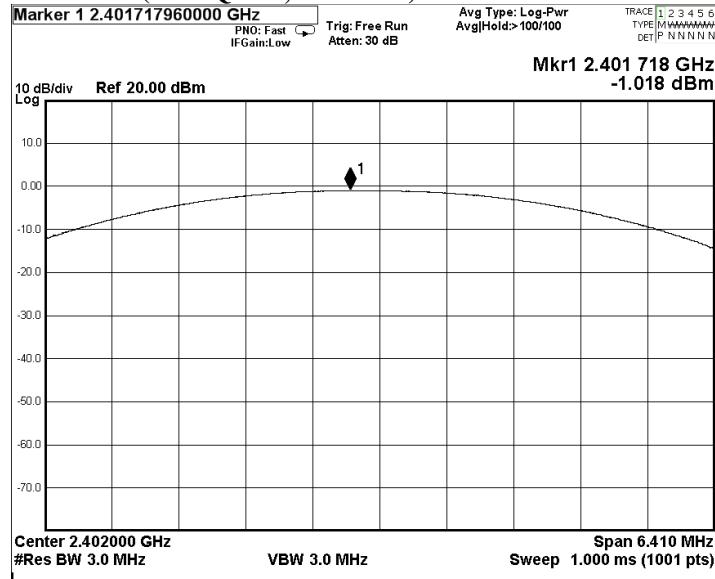
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Bluetooth Communication mode (GFSK, 2480MHz)



Bluetooth Communication mode ($\pi/4$ DQPSK, 2402MHz)



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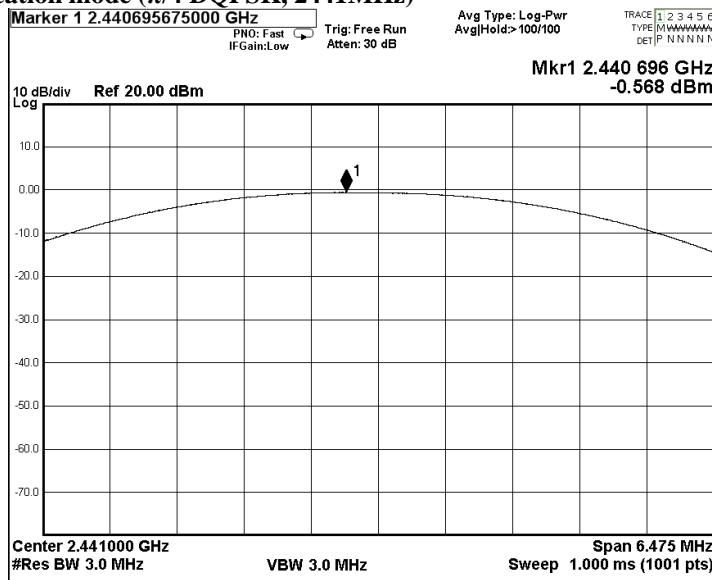
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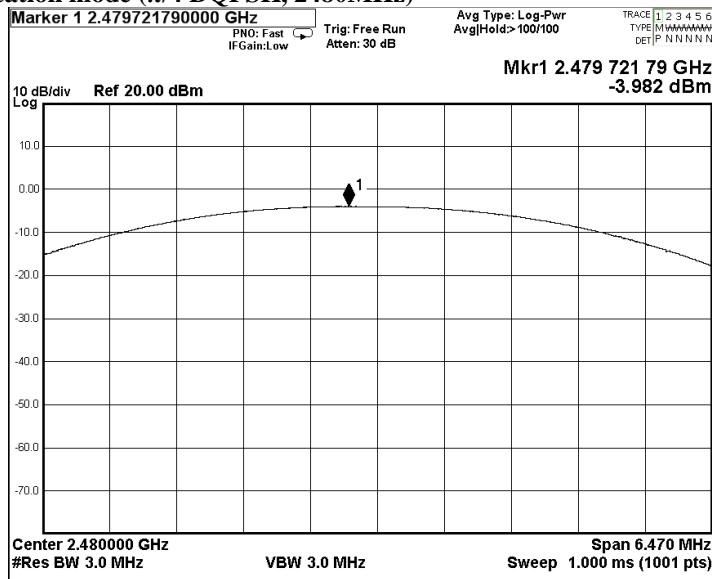
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Bluetooth Communication mode ($\pi/4$ DQPSK, 2441MHz)



Bluetooth Communication mode ($\pi/4$ DQPSK, 2480MHz)



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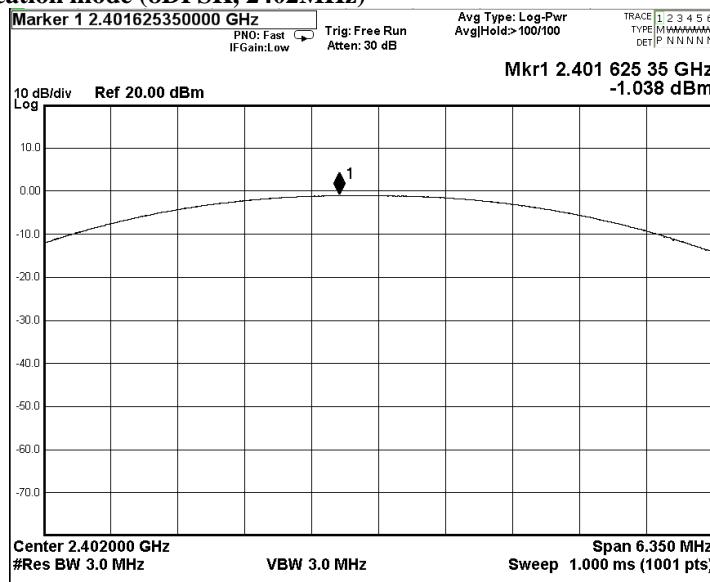


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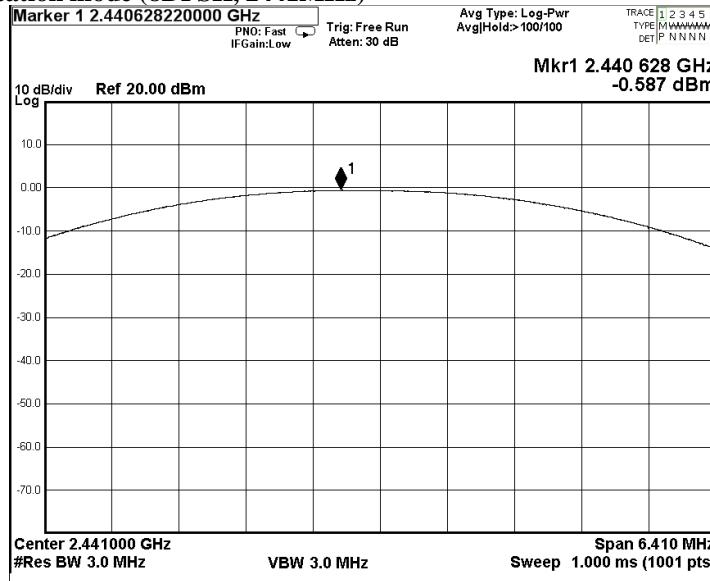
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Bluetooth Communication mode (8DPSK, 2402MHz)



Bluetooth Communication mode (8DPSK, 2441MHz)



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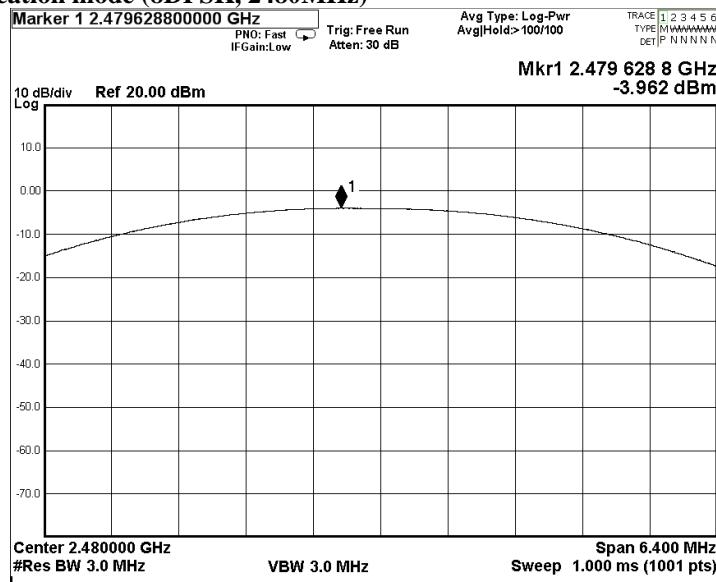


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Bluetooth Communication mode (8DPSK, 2480MHz)



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3.1.2 Radiated Spurious Emissions

Test Requirement:	FCC 47CFR 15.209
Test Method:	ANSI C63.10:2013
Test Date:	2023-05-15 to 2023-05-24
Mode of Operation:	Tx mode / Bluetooth play mode (GFSK)

Ambient Temperature: 26.8°C Relative Humidity: 43.9% Atmospheric Pressure: 100.8 kPa

Test Method:

For emission measurements at or below 1 GHz, the sample was placed 0.8m above the ground plane of semi-anechoic Chamber*. For emission measurements above 1 GHz, the sample was placed 1.5m above the ground plane of semi-anechoic Chamber*. Measurements in both horizontal and vertical polarities were performed. During the test, each emission was maximized by: having the EUT continuously working, investigated all operating modes, rotated about all 3 axis (X, Y & Z) and considered typical configuration to obtain worst position, manipulating interconnecting cables, rotating turntable, varying antenna height from 1m to 4m in both horizontal and vertical polarizations. The emissions worst-case are shown in Test Results of the following pages.

* Semi-Anechoic chamber located on the G/F of The Hong Kong Standards and Testing Centre Ltd. with
Registration Number: HK0001
Test Firm Registration Number: 367672

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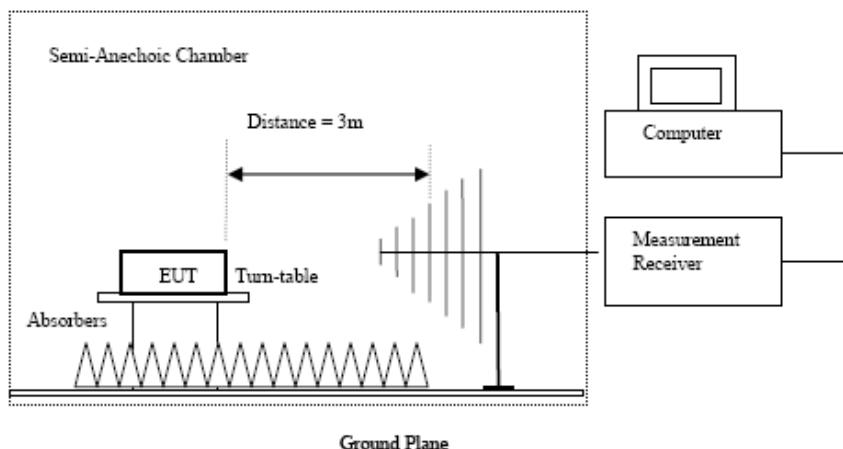
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Spectrum Analyzer Setting:

9KHz – 30MHz (Pk & AVG)	RBW: 10kHz VBW: 30kHz Sweep: Auto Span: Fully capture the emissions being measured Trace: Max. hold
30MHz – 1GHz (QP)	RBW: 120kHz VBW: 120kHz Sweep: Auto Span: Fully capture the emissions being measured Trace: Max. hold
Above 1GHz (Pk & AVG)	RBW: 1MHz VBW: 1MHz Sweep: Auto Span: Fully capture the emissions being measured Trace: Max. hold

Test Setup:



- Absorbers placed on top of the ground plane are for measurements above 1000MHz only.
- Measurements between 30MHz to 1000MHz made with Bi-log antennas, above 1000MHz horn antennas are used, 9kHz to 30MHz loop antennas are used.



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Limits for Radiated Emissions FCC 47 CFR 15.247 Class B]:

Frequency Range [MHz]	Quasi-Peak Limits [μ V/m]
0.009-0.490	2400/F (kHz)
0.490-1.705	24000/F (kHz)
1.705-30	30
30-88	100
88-216	150
216-960	200
Above 960	500

The emission limits shown in the above table are based on measurement employing a CISPR quasi-peak detector and above 1000MHz are based on measurements employing an average detector.

Result of Tx mode (2402.0 MHz) (GFSK) (9kHz – 30MHz): Pass

Field Strength of Spurious Emissions Peak Value						
Frequency MHz	Measured Level dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Field Strength uV/m	Limit uV/m	E-Field Polarity
Emissions detected are more than 20 dB below the FCC Limits						

Result of Tx mode (2402.0 MHz) (GFSK) (Above 1GHz): Pass

Field Strength of Spurious Emissions Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4804.0	57.0	0.8	57.8	74.0	16.2	Vertical
4804.0	57.2	0.5	57.7	74.0	16.3	Horizontal
7206.0	49.4	7.0	56.4	74.0	17.6	Vertical
7206.0	49.2	6.5	55.7	74.0	18.3	Horizontal
9608.0	46.1	8.5	54.6	74.0	19.4	Vertical
9608.0	46.2	8.3	54.5	74.0	19.5	Horizontal
12010.0	45.0	10.9	55.9	74.0	18.1	Vertical
12010.0	45.3	10.8	56.1	74.0	18.0	Horizontal

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Field Strength of Spurious Emissions						
Average Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4804.0	41.0	0.8	41.8	54.0	12.2	Vertical
4804.0	41.2	0.5	41.7	54.0	12.3	Horizontal
7206.0	35.1	7.0	42.1	54.0	11.9	Vertical
7206.0	34.0	6.5	40.5	54.0	13.5	Horizontal
9608.0	31.3	8.5	39.8	54.0	14.2	Vertical
9608.0	32.0	8.3	40.3	54.0	13.7	Horizontal
12010.0	30.1	10.9	41.0	54.0	13.0	Vertical
12010.0	30.2	10.8	41	54.0	13.0	Horizontal

Result of Tx mode (2441.0 MHz) (GFSK) (9kHz – 30MHz): Pass

Field Strength of Spurious Emissions						
Peak Value						
Frequency MHz	Measured Level dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Field Strength uV/m	Limit uV/m	E-Field Polarity
Emissions detected are more than 20 dB below the FCC Limits						

Result of Tx mode (2441.0 MHz) (GFSK) (Above 1GHz): Pass

Field Strength of Spurious Emissions						
Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4882.0	56.8	0.8	57.6	74.0	16.4	Vertical
4882.0	56.6	0.5	57.1	74.0	16.9	Horizontal
7223.0	50.1	7.0	57.1	74.0	16.9	Vertical
7223.0	50.3	6.5	56.8	74.0	17.2	Horizontal
9764.0	48.1	8.5	56.6	74.0	17.4	Vertical
9764.0	47.7	8.3	56.0	74.0	18.0	Horizontal
12205.0	45.0	10.9	55.9	74.0	18.1	Vertical
12205.0	45.4	10.8	56.2	74.0	17.8	Horizontal

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Field Strength of Spurious Emissions Average Value						
Frequency MHz	Measured Level @3m dBuV	Correction Factor dB/m	Field Strength dBuV/m	Limit @3m dBuV/m	Margin dB	E-Field Polarity
4882.0	41.2	0.8	42.0	54.0	12.0	Vertical
4882.0	41.1	0.5	41.6	54.0	12.4	Horizontal
7323.0	35.3	7.0	42.3	54.0	11.7	Vertical
7323.0	35.2	6.5	41.7	54.0	12.3	Horizontal
9764.0	33.1	8.5	41.6	54.0	12.4	Vertical
9764.0	32.4	8.3	40.7	54.0	13.3	Horizontal
12205.0	30.3	10.9	41.2	54.0	12.8	Vertical
12205.0	30.1	10.8	40.9	54.0	13.1	Horizontal

Result of Tx mode (2480.0 MHz) (GFSK) (9kHz – 30MHz): Pass

Field Strength of Spurious Emissions Peak Value						
Frequency MHz	Measured Level dBuV	Correction Factor dB/m	Field Strength dBuV/m	Field Strength uV/m	Limit uV/m	E-Field Polarity
Emissions detected are more than 20 dB below the FCC Limits						

Result of Tx mode (2480.0 MHz) (GFSK) (Above 1GHz): Pass

Field Strength of Spurious Emissions Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4960.0	55.5	0.8	56.3	74.0	17.7	Vertical
4960.0	55.6	0.5	56.1	74.0	17.9	Horizontal
7440.0	48.4	7.0	55.4	74.0	18.6	Vertical
7440.0	48.7	6.5	55.2	74.0	18.8	Horizontal
9920.0	47.0	8.5	55.5	74.0	18.5	Vertical
9920.0	47.2	8.3	55.5	74.0	18.5	Horizontal
12400.0	45.1	10.9	56.0	74.0	18.0	Vertical
12400.0	45.3	10.8	56.1	74.0	17.9	Horizontal

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Field Strength of Spurious Emissions						
Average Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4960.0	41.3	0.8	42.1	54.0	11.9	Vertical
4960.0	41.1	0.5	41.6	54.0	12.4	Horizontal
7440.0	34.5	7.0	41.5	54.0	12.5	Vertical
7440.0	35.4	6.5	41.9	54.0	12.1	Horizontal
9920.0	33.2	8.5	41.7	54.0	12.3	Vertical
9920.0	31.1	8.3	39.4	54.0	14.6	Horizontal
12400.0	30.2	10.9	41.1	54.0	12.9	Vertical
12400.0	30.3	10.8	41.1	54.0	12.9	Horizontal

Result of Tx mode (2402.0 MHz) ($\pi/4$ -DQPSK) (9kHz – 30MHz): Pass

Field Strength of Spurious Emissions						
Peak Value						
Frequency MHz	Measured Level dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Field Strength uV/m	Limit uV/m	E-Field Polarity
Emissions detected are more than 20 dB below the FCC Limits						

Result of Tx mode (2402.0 MHz) ($\pi/4$ -DQPSK) (Above 1GHz): Pass

Field Strength of Spurious Emissions						
Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4804.0	57.0	0.8	57.8	74.0	16.2	Vertical
4804.0	57.0	0.5	57.5	74.0	16.5	Horizontal
7206.0	49.5	7.0	56.5	74.0	17.5	Vertical
7206.0	50.2	6.5	56.7	74.0	17.3	Horizontal
9608.0	46.4	8.5	54.9	74.0	19.1	Vertical
9608.0	47.2	8.3	55.5	74.0	18.5	Horizontal
12010.0	45.1	10.9	56.0	74.0	18.0	Vertical
12010.0	45.4	10.8	56.2	74.0	17.8	Horizontal

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Field Strength of Spurious Emissions Average Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4804.0	41.2	0.8	42.0	54.0	12.0	Vertical
4804.0	41.1	0.5	41.6	54.0	12.4	Horizontal
7206.0	35.3	7.0	42.3	54.0	11.7	Vertical
7206.0	35.0	6.5	41.5	54.0	12.5	Horizontal
9608.0	32.4	8.5	40.9	54.0	13.1	Vertical
9608.0	33.0	8.3	41.3	54.0	12.7	Horizontal
12010.0	30.4	10.9	41.3	54.0	12.7	Vertical
12010.0	31.1	10.8	41.9	54.0	12.1	Horizontal

Result of Tx mode (2441.0 MHz) ($\pi/4$ -DQPSK) (9kHz – 30MHz): Pass

Field Strength of Spurious Emissions Peak Value						
Frequency MHz	Measured Level dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Field Strength uV/m	Limit uV/m	E-Field Polarity
Emissions detected are more than 20 dB below the FCC Limits						

Result of Tx mode (2441.0 MHz) ($\pi/4$ -DQPSK) (Above 1GHz): Pass

Field Strength of Spurious Emissions Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4882.0	57.0	0.8	57.8	74.0	16.2	Vertical
4882.0	56.8	0.5	57.3	74.0	16.7	Horizontal
7323.0	50.0	7.0	57.0	74.0	17.0	Vertical
7323.0	50.1	6.5	56.6	74.0	17.4	Horizontal
9764.0	48.2	8.5	56.7	74.0	17.3	Vertical
9764.0	47.3	8.3	55.6	74.0	18.4	Horizontal
12205.0	45.1	10.9	56.0	74.0	18.0	Vertical
12205.0	45.3	10.8	56.1	74.0	18.0	Horizontal

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Field Strength of Spurious Emissions						
Average Value						
Frequency MHz	Measured Level @3m dBuV	Correction Factor dB/m	Field Strength dBuV/m	Limit @3m dBuV/m	Margin dB	E-Field Polarity
4882.0	41.3	0.8	42.1	54.0	11.9	Vertical
4882.0	41.1	0.52	41.6	54.0	12.4	Horizontal
7323.0	35.2	7	42.2	54.0	11.8	Vertical
7323.0	35.1	6.5	41.6	54.0	12.4	Horizontal
9764.0	32.4	8.5	40.9	54.0	13.1	Vertical
9764.0	33.1	8.3	41.4	54.0	12.6	Horizontal
12205.0	31.2	10.9	42.1	54.0	11.9	Vertical
12205.0	30.5	10.8	41.3	54.0	12.7	Horizontal

Result of Tx mode (2480.0 MHz) ($\pi/4$ -DQPSK) (9kHz – 30MHz): Pass

Field Strength of Spurious Emissions						
Peak Value						
Frequency MHz	Measured Level dBuV	Correction Factor dB/m	Field Strength dBuV/m	Field Strength uV/m	Limit uV/m	E-Field Polarity
Emissions detected are more than 20 dB below the FCC Limits						

Result of Tx mode (2480.0 MHz) ($\pi/4$ -DQPSK) (Above 1GHz): Pass

Field Strength of Spurious Emissions						
Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4960.0	56.2	0.8	57.0	74.0	17.0	Vertical
4960.0	56.1	0.5	56.6	74.0	17.4	Horizontal
7440.0	49.2	7.0	56.2	74.0	17.8	Vertical
7440.0	50.4	6.5	56.9	74.0	17.1	Horizontal
9920.0	47.0	8.5	55.5	74.0	18.5	Vertical
9920.0	47.4	8.3	55.7	74.0	18.3	Horizontal
12400.0	45.1	10.9	56.0	74.0	18.0	Vertical
12400.0	45.2	10.8	56.0	74.0	18.0	Horizontal

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Field Strength of Spurious Emissions						
Average Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4960.0	40.0	0.8	40.8	54.0	13.2	Vertical
4960.0	40.4	0.5	40.9	54.0	13.1	Horizontal
7440.0	34.2	7.0	41.2	54.0	12.8	Vertical
7440.0	34.7	6.5	41.2	54.0	12.8	Horizontal
9920.0	33.1	8.5	41.6	54.0	12.4	Vertical
9920.0	32.5	8.3	40.8	54.0	13.2	Horizontal
12400.0	30.4	10.9	41.3	54.0	12.7	Vertical
12400.0	30.2	10.8	41.0	54.0	13.0	Horizontal

Result of Tx mode (2402.0 MHz) (8DPSK) (9kHz – 30MHz): Pass

Field Strength of Spurious Emissions						
Peak Value						
Frequency MHz	Measured Level dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Field Strength uV/m	Limit uV/m	E-Field Polarity
Emissions detected are more than 20 dB below the FCC Limits						

Result of Tx mode (2402.0 MHz) (8DPSK) (Above 1GHz): Pass

Field Strength of Spurious Emissions						
Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4804.0	56.1	0.8	56.9	74.0	17.1	Vertical
4804.0	56.7	0.5	57.2	74.0	16.8	Horizontal
7206.0	48.7	7.0	55.7	74.0	18.3	Vertical
7206.0	49.8	6.5	56.3	74.0	17.7	Horizontal
9608.0	47.1	8.5	55.6	74.0	18.4	Vertical
9608.0	47.2	8.3	55.5	74.0	18.5	Horizontal
12010.0	45.3	10.9	56.2	74.0	17.8	Vertical
12010.0	44.7	10.8	55.5	74.0	18.5	Horizontal

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Field Strength of Spurious Emissions						
Average Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4804.0	41.0	0.8	41.8	54.0	12.2	Vertical
4804.0	40.5	0.5	41.0	54.0	13.0	Horizontal
7206.0	34.4	7.0	41.4	54.0	12.6	Vertical
7206.0	35.0	6.5	41.5	54.0	12.5	Horizontal
9608.0	32.7	8.5	41.2	54.0	12.8	Vertical
9608.0	33.3	8.3	41.6	54.0	12.4	Horizontal
12010.0	30.7	10.9	41.6	54.0	12.4	Vertical
12010.0	30.4	10.8	41.2	54.0	12.8	Horizontal

Result of Tx mode (2441.0 MHz) (8DPSK) (9kHz – 30MHz): Pass

Field Strength of Spurious Emissions						
Peak Value						
Frequency MHz	Measured Level dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Field Strength uV/m	Limit uV/m	E-Field Polarity
Emissions detected are more than 20 dB below the FCC Limits						

Result of Tx mode (2441.0 MHz) (8DPSK) (Above 1GHz): Pass

Field Strength of Spurious Emissions						
Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4882.0	57.0	0.8	57.8	74.0	16.2	Vertical
4882.0	57.1	0.5	57.6	74.0	16.4	Horizontal
7223.0	49.1	7.0	56.1	74.0	17.9	Vertical
7223.0	49.3	6.5	55.8	74.0	18.2	Horizontal
9764.0	47.4	8.5	55.9	74.0	18.1	Vertical
9764.0	47.5	8.3	55.8	74.0	18.2	Horizontal
12205.0	45.1	10.9	56.0	74.0	18.0	Vertical
12205.0	45.4	10.8	56.2	74.0	17.8	Horizontal

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Field Strength of Spurious Emissions						
Average Value						
Frequency MHz	Measured Level @3m dBuV	Correction Factor dB/m	Field Strength dBuV/m	Limit @3m dBuV/m	Margin dB	E-Field Polarity
4882.0	40.6	0.8	41.4	54.0	12.6	Vertical
4882.0	41.0	0.5	41.5	54.0	12.5	Horizontal
7323.0	34.1	7.0	41.1	54.0	12.9	Vertical
7323.0	35.0	6.5	41.5	54.0	12.5	Horizontal
9764.0	33.2	8.5	41.7	54.0	12.3	Vertical
9764.0	33.4	8.3	41.7	54.0	12.3	Horizontal
12205.0	30.7	10.9	41.6	54.0	12.4	Vertical
12205.0	30.5	10.8	41.3	54.0	12.7	Horizontal

Result of Tx mode (2480.0 MHz) (8FPSK) (9kHz – 30MHz): Pass

Field Strength of Spurious Emissions						
Peak Value						
Frequency MHz	Measured Level dBuV	Correction Factor dB/m	Field Strength dBuV/m	Field Strength uV/m	Limit uV/m	E-Field Polarity
Emissions detected are more than 20 dB below the FCC Limits						

Result of Tx mode (2480.0 MHz) (8DPSK) (Above 1GHz): Pass

Field Strength of Spurious Emissions						
Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4960.0	56.2	0.8	57.0	74.0	17.0	Vertical
4960.0	56.0	0.5	56.5	74.0	17.5	Horizontal
7440.0	49.1	7.0	56.1	74.0	17.9	Vertical
7440.0	49.2	6.5	55.7	74.0	18.3	Horizontal
9920.0	47.0	8.5	55.5	74.0	18.5	Vertical
9920.0	47.1	8.3	55.4	74.0	18.6	Horizontal
12400.0	45.2	10.9	56.1	74.0	17.9	Vertical
12400.0	45.3	10.8	56.1	74.0	17.9	Horizontal

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Field Strength of Spurious Emissions						
Average Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
4960.0	41.2	0.8	42.0	54.0	12.0	Vertical
4960.0	41.1	0.5	41.6	54.0	12.4	Horizontal
7440.0	34.1	7.0	41.1	54.0	12.9	Vertical
7440.0	35.3	6.5	41.8	54.0	12.2	Horizontal
9920.0	32.4	8.5	40.9	54.0	13.1	Vertical
9920.0	32.6	8.3	40.9	54.0	13.1	Horizontal
12400.0	30.1	10.9	41.0	54.0	13.0	Vertical
12400.0	30.7	10.8	41.5	54.0	12.5	Horizontal

Remarks:

No additional spurious emissions found between lowest internal used/generated frequency and 30 MHz
* Denotes restricted band of operation.

Measurements were made using a peak detector. Any emission less than 1000MHz and falling within the restricted bands of FCC Rules Part 15 Section 15.205 and the limits of FCC Rules Part 15 Section 15.209 were applied.

Correction Factor included Antenna Factor and Cable Attenuation.

Calculated measurement (9kHz-30MHz): 2.0dB
uncertainty (30MHz -1GHz): 4.9dB
(1GHz -6GHz): 4.02dB
(6GHz -26.5GHz): 4.03dB

Emissions in the vertical and horizontal polarizations have been investigated and the worst-case test results are recorded in this report.

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Radiated Emissions Measurement:

Limit :

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. Attenuation below the general limits specified in Section 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 5.205(c)).

Result: RF Radiated Emissions (Lowest)-GFSK

Field Strength of Band-edge Compliance Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
2390.0	48.1	-4.8	43.3	74.0	30.7	Vertical
2390.0	48.2	-4.7	43.5	74.0	30.5	Horizontal

Field Strength of Band-edge Compliance Average Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
2390.0	42.4	-4.8	37.6	54.0	16.4	Vertical
2390.0	42.1	-4.7	37.4	54.0	16.6	Horizontal

Result: RF Radiated Emissions (Highest) -GFSK

Field Strength of Band-edge Compliance Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
2483.5	55.7	-4.8	50.9	74.0	23.1	Vertical
2483.5	54.0	-4.7	49.3	74.0	24.7	Horizontal

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Field Strength of Band-edge Compliance Average Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
2483.5	43.8	-4.8	39.0	54.0	15.0	Vertical
2483.5	44.2	-4.7	39.5	54.0	14.5	Horizontal

Result: RF Radiated Emissions (Lowest)- $\pi/4$ -DQPSK

Field Strength of Band-edge Compliance Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
2390.0	48.0	-4.8	43.2	74.0	30.8	Vertical
2390.0	47.8	-4.7	43.1	74.0	30.9	Horizontal

Field Strength of Band-edge Compliance Average Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
2390.0	42.8	-4.8	38.0	54.0	16.0	Vertical
2390.0	42.7	-4.7	38.0	54.0	16.0	Horizontal

Result: RF Radiated Emissions (Highest) - $\pi/4$ -DQPSK

Field Strength of Band-edge Compliance Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
2483.5	56.4	-4.8	51.6	74.0	22.4	Vertical
2483.5	56.1	-4.7	51.4	74.0	22.6	Horizontal

Field Strength of Band-edge Compliance Average Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
2483.5	44.0	-4.8	39.2	54.0	14.8	Vertical
2483.5	44.1	-4.7	39.4	54.0	14.6	Horizontal

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Result: RF Radiated Emissions (Lowest)- 8DPSK

Field Strength of Band-edge Compliance Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
2390.0	48.2	-4.8	43.4	74.0	30.6	Vertical
2390.0	47.8	-4.7	43.1	74.0	30.9	Horizontal

Field Strength of Band-edge Compliance Average Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
2390.0	43.2	-4.8	38.4	54.0	15.6	Vertical
2390.0	42.7	-4.7	38.0	54.0	16.0	Horizontal

Result: RF Radiated Emissions (Highest) -8DPSK

Field Strength of Band-edge Compliance Peak Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
2483.5	56.9	-4.8	52.1	74.0	21.9	Vertical
2483.5	56.2	-4.7	51.5	74.0	22.5	Horizontal

Field Strength of Band-edge Compliance Average Value						
Frequency MHz	Measured Level @3m dB μ V	Correction Factor dB/m	Field Strength dB μ V/m	Limit @3m dB μ V/m	Margin dB	E-Field Polarity
2483.5	45.0	-4.8	40.2	54.0	13.8	Vertical
2483.5	44.8	-4.7	40.1	54.0	13.9	Horizontal

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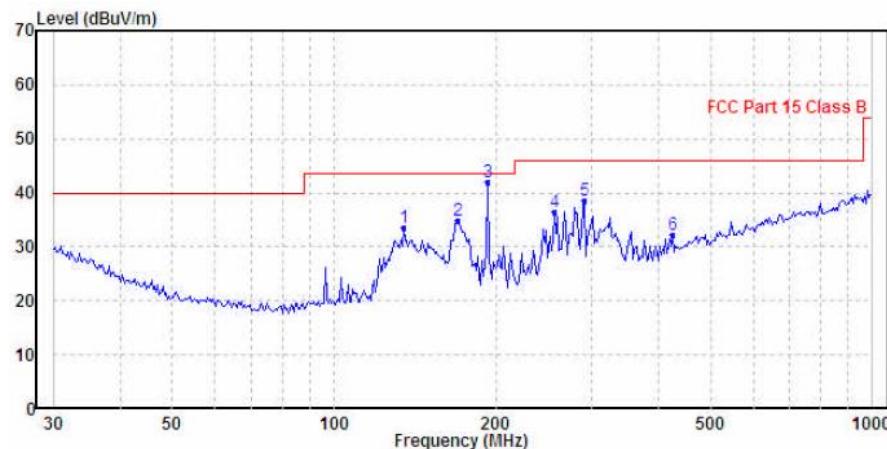
Limits for Radiated Emissions FCC 47 CFR 15.247 Class B:

Frequency Range [MHz]	Quasi-Peak Limits [μ V/m]
0.009-0.490	2400/F (kHz)
0.490-1.705	24000/F (kHz)
1.705-30	30
30-88	100
88-216	150
216-960	200
Above 960	500

The emission limits shown in the above table are based on measurement employing a CISPR quasi-peak detector and above 1000MHz are based on measurements employing an average detector.

Results of Bluetooth mode (GFSK 2402.0 MHz) (30MHz – 1GHz): Pass

Horizontal



Ambient Temperature: 25C

Relative Humidity : 50%

Freq	Level	Limit		Over Line Limit	Remark	Pol/Phase
		MHz	dBuV/m			
1	134.559	33.53	43.50	-9.97	QP	Horizontal
2	169.599	34.98	43.50	-8.52	QP	Horizontal
3	192.419	41.90	43.50	-1.60	QP	Horizontal
4	256.521	36.37	46.00	-9.63	QP	Horizontal
5	291.036	38.58	46.00	-7.42	QP	Horizontal
6	425.028	32.35	46.00	-13.65	QP	Horizontal

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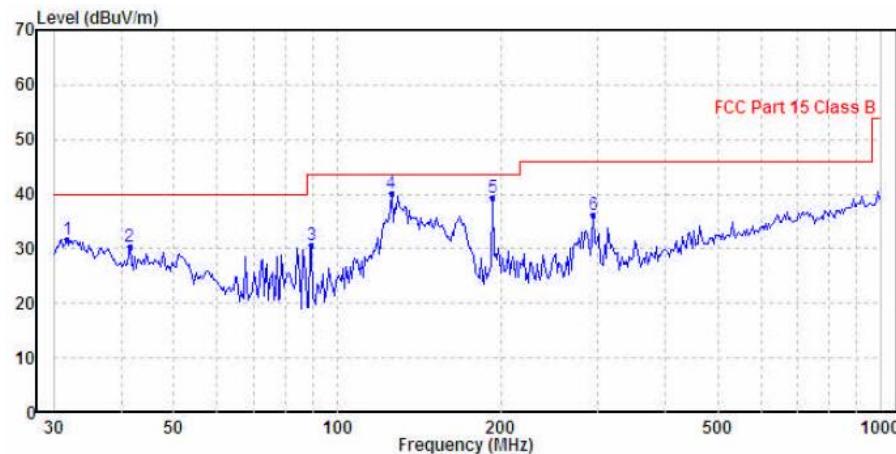
Limits for Radiated Emissions FCC 47 CFR 15.247 Class B:

Frequency Range [MHz]	Quasi-Peak Limits [μ V/m]
0.009-0.490	2400/F (kHz)
0.490-1.705	24000/F (kHz)
1.705-30	30
30-88	100
88-216	150
216-960	200
Above 960	500

The emission limits shown in the above table are based on measurement employing a CISPR quasi-peak detector and above 1000MHz are based on measurements employing an average detector.

Results of Bluetooth mode (GFSK 2402.0 MHz) (30MHz – 1GHz): Pass

Vertical



Ambient Temperature: 25C

Relative Humidity : 50%

Freq	Level	Limit		Over	Remark	Pol/Phase
		Line	Limit			
1	31.731	31.68	40.00	-8.32	QP	Vertical
2	41.422	30.33	40.00	-9.67	QP	Vertical
3	89.590	30.65	43.50	-12.85	QP	Vertical
4	125.446	40.04	43.50	-3.46	QP	Vertical
5	192.419	39.36	43.50	-4.14	QP	Vertical
6	295.147	36.26	46.00	-9.74	QP	Vertical

Remarks: Calculated measurement uncertainty (30MHz – 1GHz): 4.9dB

Emissions in the vertical and horizontal polarizations have been investigated and the worst-case test results are recorded in this report.

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3.1.3 AC Mains Conducted Emissions (0.15MHz to 30MHz)

Test Requirement:	FCC 47CFR 15.207
Test Method:	ANSI C63.10:2013
Test Date:	2023-05-17
Mode of Operation:	TX mode
Test Voltage:	120V a.c. 60Hz

Ambient Temperature: 25°C Relative Humidity: 51% Atmospheric Pressure: 101 kPa

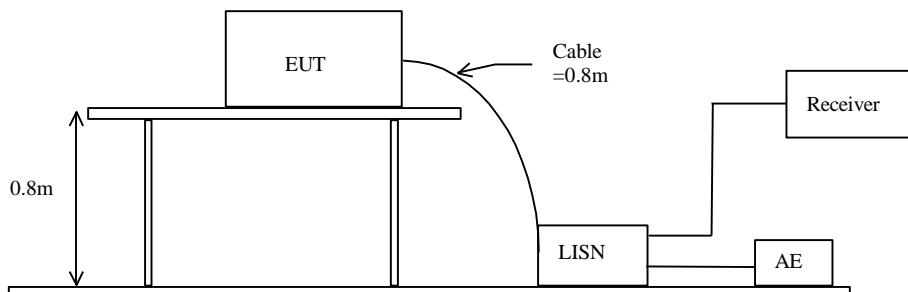
Test Method:

The test was performed in accordance with ANSI C63.10:2013, with the following: an initial measurement was performed in peak and average detection mode on the live line, any emissions recorded within 30dB of the relevant limit line were re-measured using quasi-peak and average detection on the live and neutral lines with the worst case recorded in the table of results.

Receiver Setting:

Bandw. = 9 kHz, Meas. Time= 10.0 ms, Step Width = 5.0kHz
 Detector = MaxPeak and CISPR AV

Test Setup:



Limits for Conducted Emissions (FCC 47 CFR 15.207):

Frequency Range [MHz]	Quasi-Peak Limits [dB μ V]	Average [dB μ V]
0.15-0.5	66 to 56*	56 to 46*
0.5-5.0	56	46
5.0-30.0	60	50

* Decreases with the logarithm of the frequency.

Remarks:

Calculated measurement uncertainty (0.15MHz – 30MHz): 3.25dB

-*- Emission(s) that is far below the corresponding limit line.

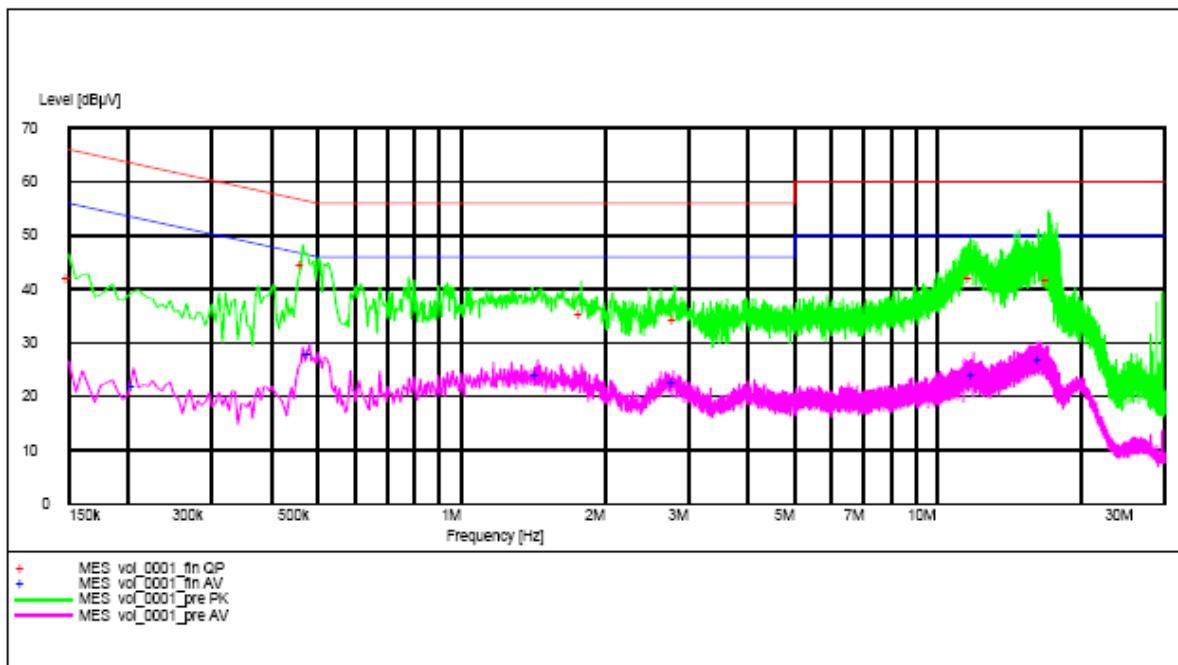
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Results of Bluetooth mode (L): PASS

Please refer to the following diagram for individual results.



MEASUREMENT RESULT: "vol_0001_fin QP"

Frequency MHz	Level dB μ V	Transd dB	Limit dB μ V	Margin dB	Line	PE
0.150000	42.00	9.7	66	24.0	L1	GND
0.465000	44.60	9.7	57	12.0	L1	GND
1.785000	35.40	9.8	56	20.6	L1	GND
2.805000	34.10	9.8	56	21.9	L1	GND
11.710000	42.10	10.1	60	17.9	L1	GND
17.080000	41.70	10.3	60	18.3	L1	GND

MEASUREMENT RESULT: "vol_0001_fin AV"

Frequency MHz	Level dB μ V	Transd dB	Limit dB μ V	Margin dB	Line	PE
0.205000	21.80	9.7	53	31.6	L1	GND
0.480000	27.90	9.7	46	18.4	L1	GND
1.445000	23.80	9.8	46	22.2	L1	GND
2.790000	22.50	9.8	46	23.5	L1	GND
11.900000	24.00	10.1	50	26.0	L1	GND
16.420000	27.00	10.3	50	23.0	L1	GND

vol_0001

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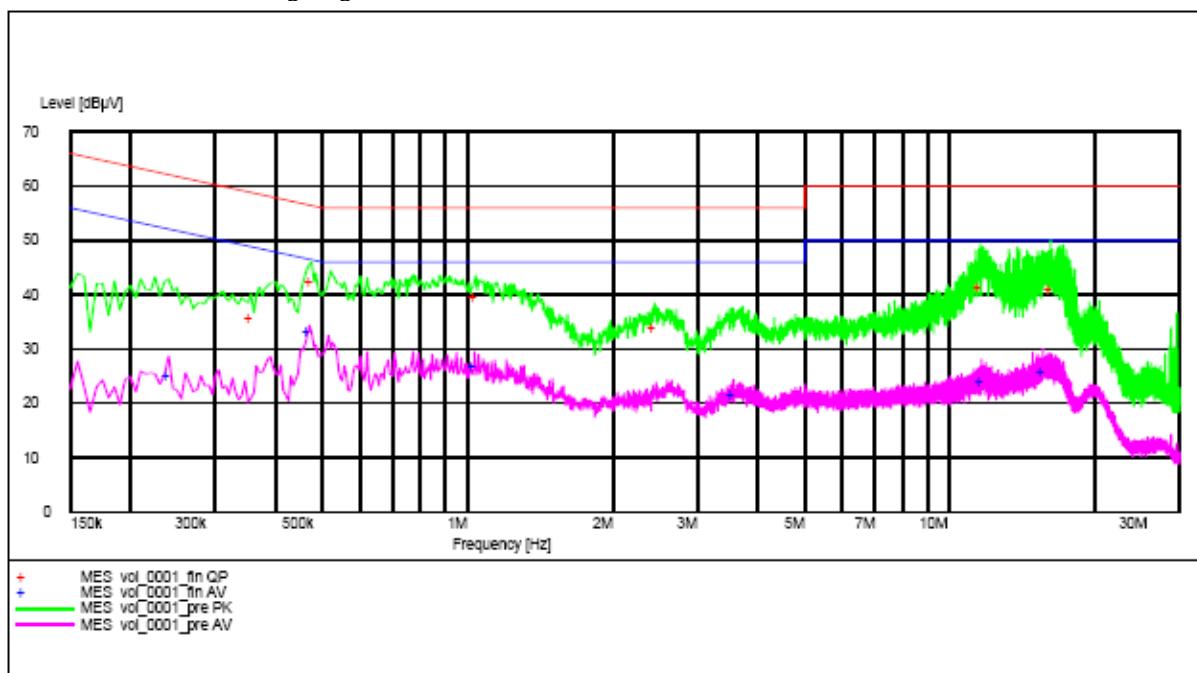
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Results of Bluetooth mode (N): PASS

Please refer to the following diagram for individual results.



MEASUREMENT RESULT: "vol_0001_fin QP"

Frequency MHz	Level dB μ V	Transd dB	Limit dB μ V	Margin dB	Line	PE
0.355000	35.70	9.7	59	23.1	N	GND
0.475000	42.40	9.7	56	14.0	N	GND
1.040000	39.60	9.7	56	16.4	N	GND
2.445000	33.80	9.8	56	22.2	N	GND
11.565000	41.30	10.1	60	18.7	N	GND
16.225000	40.80	10.3	60	19.2	N	GND

MEASUREMENT RESULT: "vol_0001_fin AV"

Frequency MHz	Level dB μ V	Transd dB	Limit dB μ V	Margin dB	Line	PE
0.240000	25.10	9.7	52	27.0	N	GND
0.470000	33.20	9.7	47	13.4	N	GND
1.035000	26.90	9.7	46	19.1	N	GND
3.565000	21.40	9.8	46	24.6	N	GND
11.670000	24.20	10.1	50	25.8	N	GND
15.620000	25.90	10.2	50	24.1	N	GND

vol_0001

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3.1.4 Number of Hopping Frequency

Ambient Temperature: 25°C Relative Humidity: 51% Atmospheric Pressure: 101 kPa

Limit of Number of Hopping Frequency

Frequency hopping systems in the 2400–2483.5 MHz band shall use at least 15 channels

Test Method:

The RF output of the EUT was connected to the spectrum analyzer by a low loss cable.

Spectrum Analyzer Setting:

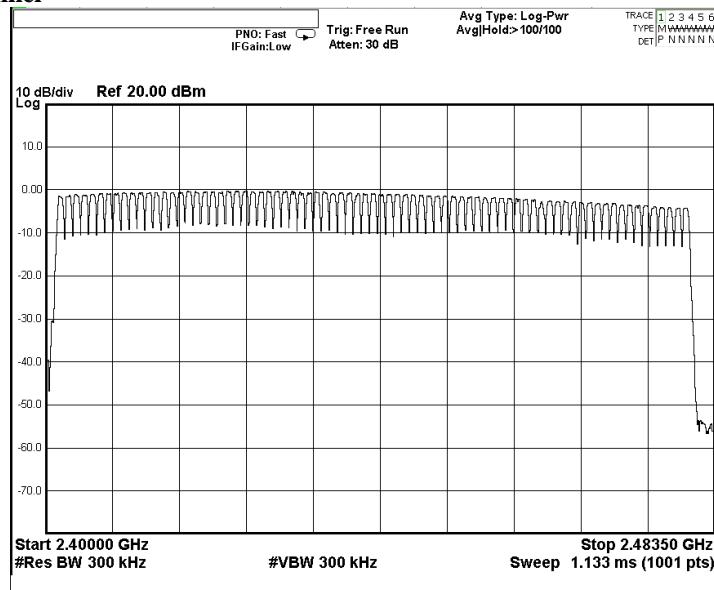
RBW = 300kHz, VBW \geq RBW, Sweep = Auto, Span = the frequency band of operation
Detector = Peak, Trace = Max. hold

Test Setup:

As Test Setup of clause 3.1.1 in this test report.

Measurement Data:

GFSK: 79 of 79 Channel



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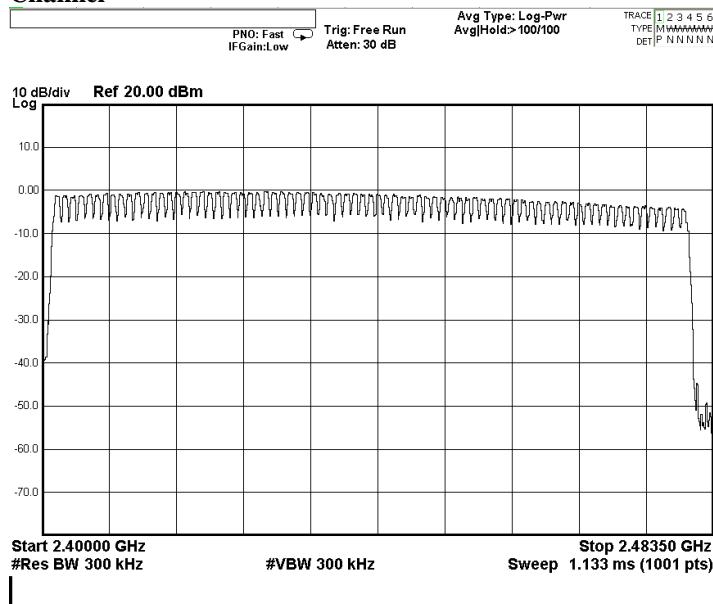


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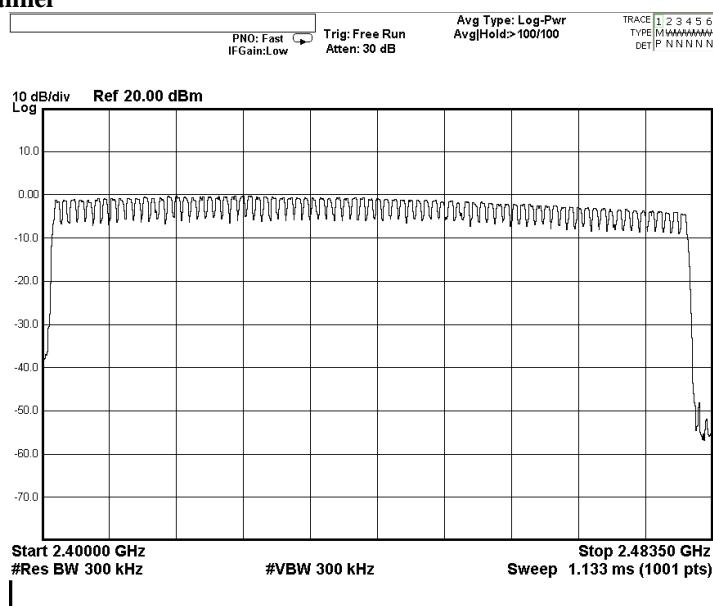
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π/4-DQPSK: 79 of 79 Channel



8DPSK: 79 of 79 Channel



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3.1.5 20dB Bandwidth

Test Requirement: FCC 47CFR 15.247(a)(1)
Test Method: ANSI C63.10:2013
Test Date: 2023-05-18
Mode of Operation: Tx mode

Ambient Temperature: 25°C Relative Humidity: 51% Atmospheric Pressure: 101 kPa

Remark:

The result has been done on all the possible configurations for searching the worst cases.

Test Method:

The bandwidth is measured at an amplitude level reduced from the reference level by a specified ratio. The reference level is the level of the highest amplitude signal observed from the transmitter at the fundamental frequency. Once the reference level is established, the equipment is conditioned with typical modulating signal to produce the worst-case (i.e. the widest) bandwidth.

Spectrum Analyzer Setting:

RBW = 30kHz, VBW \geq RBW, Sweep = Auto, Span = two times and five times the OBW
Detector = Peak, Trace = Max. hold

Test Setup:

As Test Setup of clause 3.1.1 in this test report.

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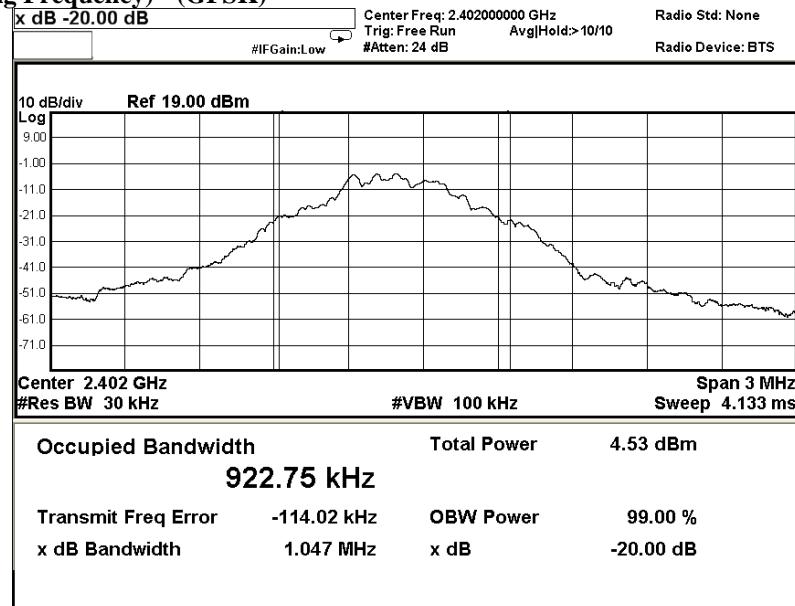
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Fundamental Frequency [MHz]	20dB Bandwidth [MHz]	FCC Limits [MHz]
2402	1.047	Within 2400-2483.5

(Lowest Operating Frequency) - (GFSK)



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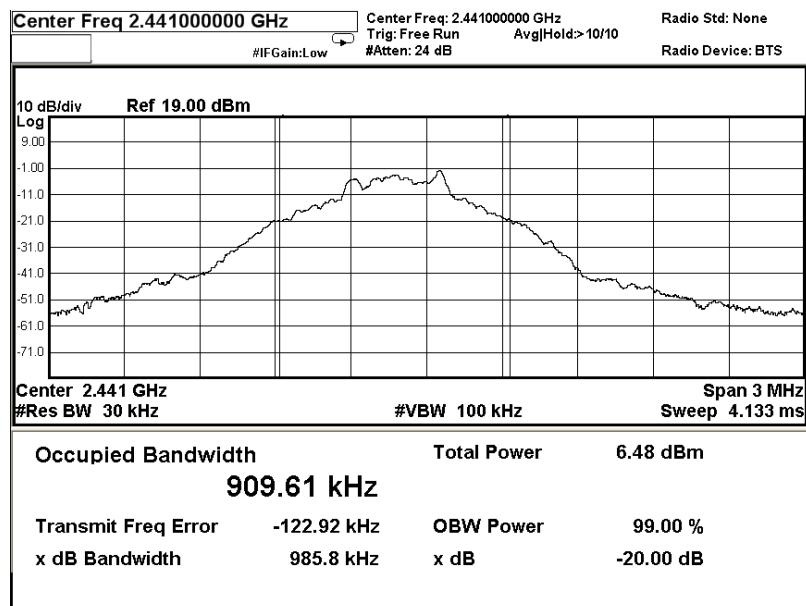
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Fundamental Frequency [MHz]	20dB Bandwidth [MHz]	FCC Limits [MHz]
2441	0.9858	Within 2400-2483.5

(Middle Operating Frequency) - (GFSK)



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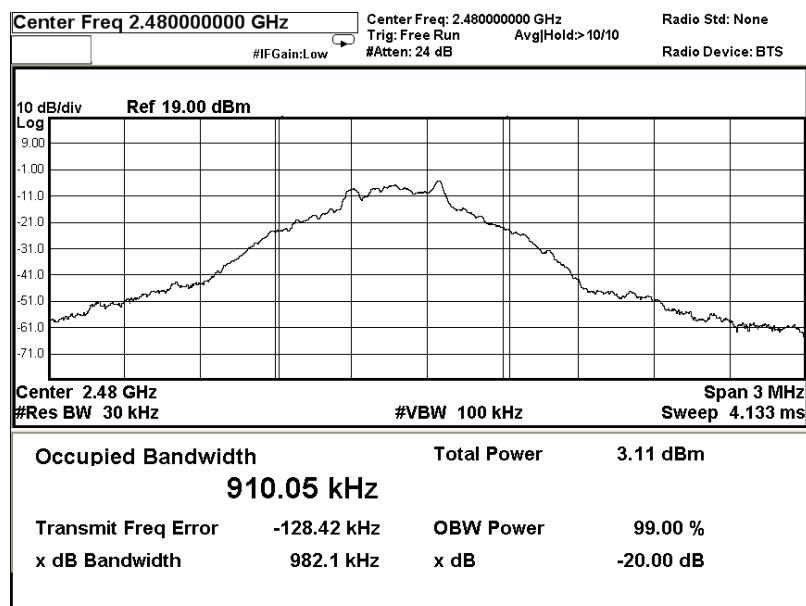
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Fundamental Frequency [MHz]	20dB Bandwidth [MHz]	FCC Limits [MHz]
2480	0.9821	Within 2400-2483.5

(Highest Operating Frequency) - (GFSK)



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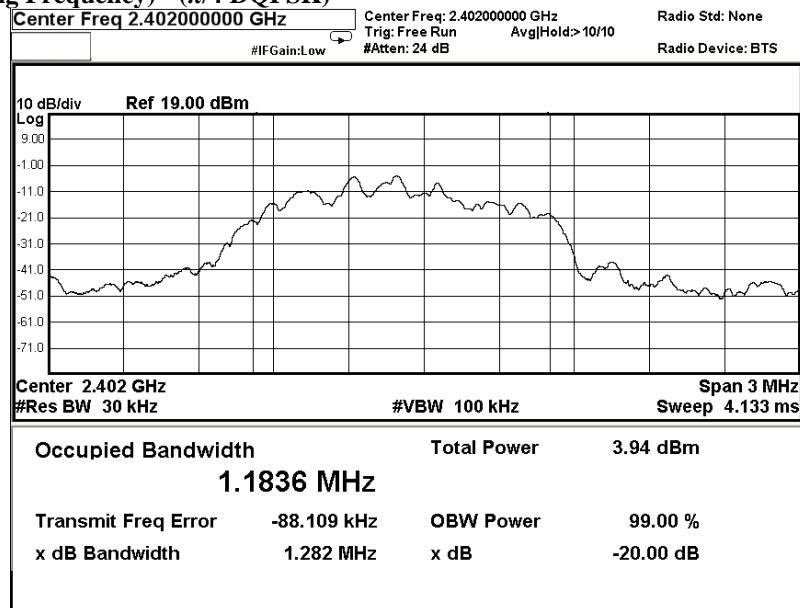
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Fundamental Frequency [MHz]	20dB Bandwidth [MHz]	FCC Limits [MHz]
2402	1.282	Within 2400-2483.5

(Lowest Operating Frequency) - ($\pi/4$ DQPSK)



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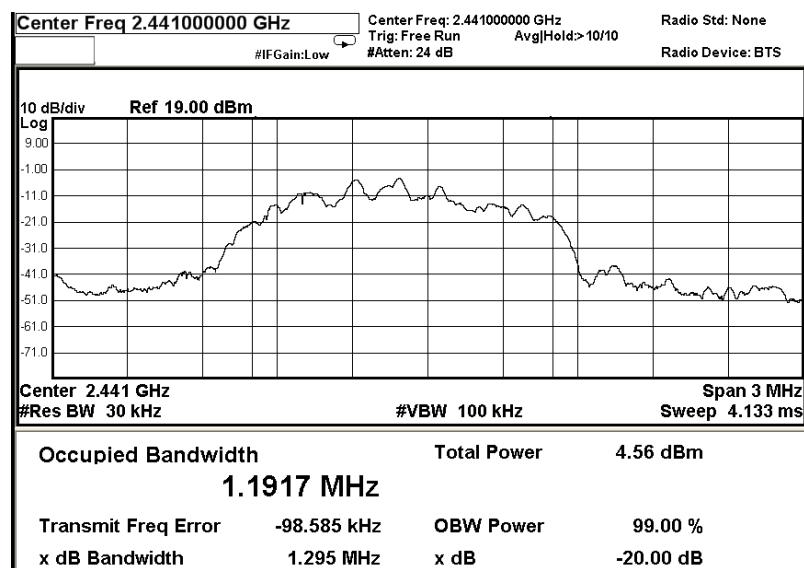
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Fundamental Frequency [MHz]	20dB Bandwidth [MHz]	FCC Limits [MHz]
2441	1.295	Within 2400-2483.5

(Middle Operating Frequency) - ($\pi/4$ DQPSK)



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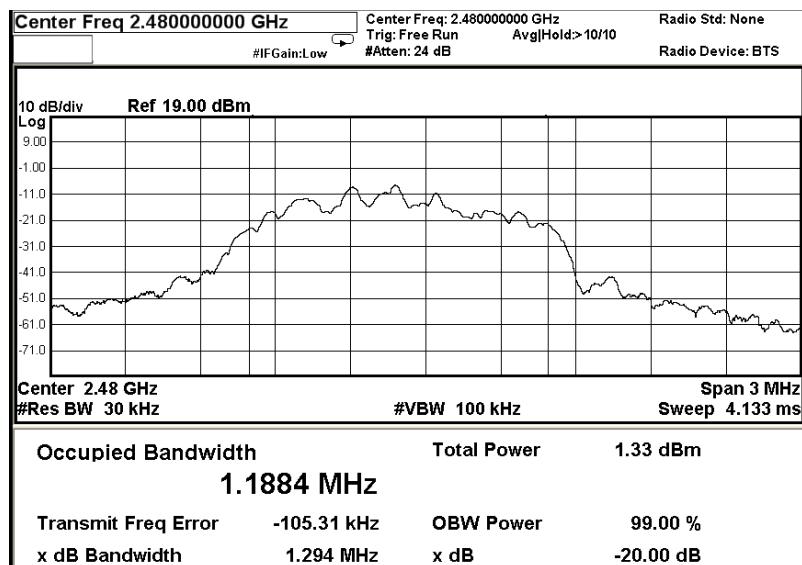
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Fundamental Frequency [MHz]	20dB Bandwidth [MHz]	FCC Limits [MHz]
2480	1.294	Within 2400-2483.5

(Highest Operating Frequency) - ($\pi/4$ DQPSK)



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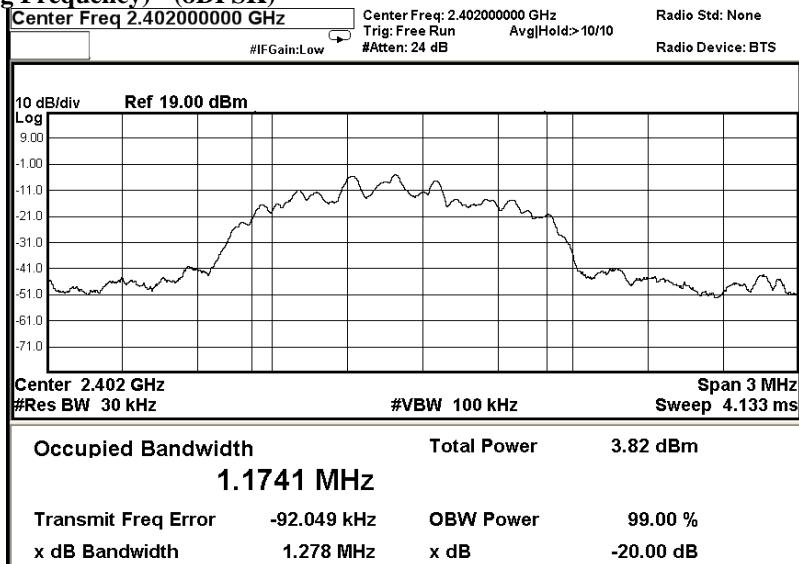
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Fundamental Frequency [MHz]	20dB Bandwidth [MHz]	FCC Limits [MHz]
2402	1.278	Within 2400-2483.5

(Lowest Operating Frequency) - (8DPSK)



Occupied Bandwidth
1.1741 MHz

Transmit Freq Error -92.049 kHz
x dB Bandwidth 1.278 MHz

Total Power 3.82 dBm

OBW Power 99.00 %

x dB -20.00 dB

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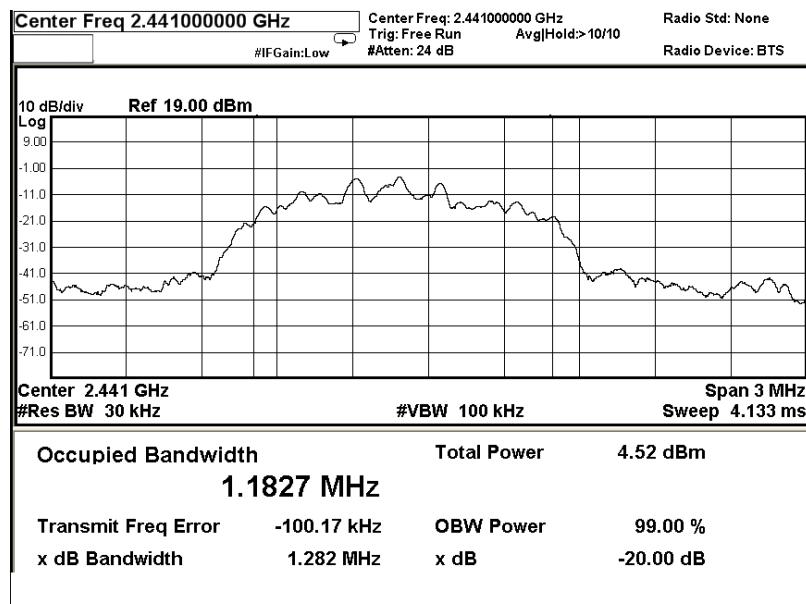
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Fundamental Frequency [MHz]	20dB Bandwidth [MHz]	FCC Limits [MHz]
2441	1.282	Within 2400-2483.5

(Middle Operating Frequency) - (8DPSK)



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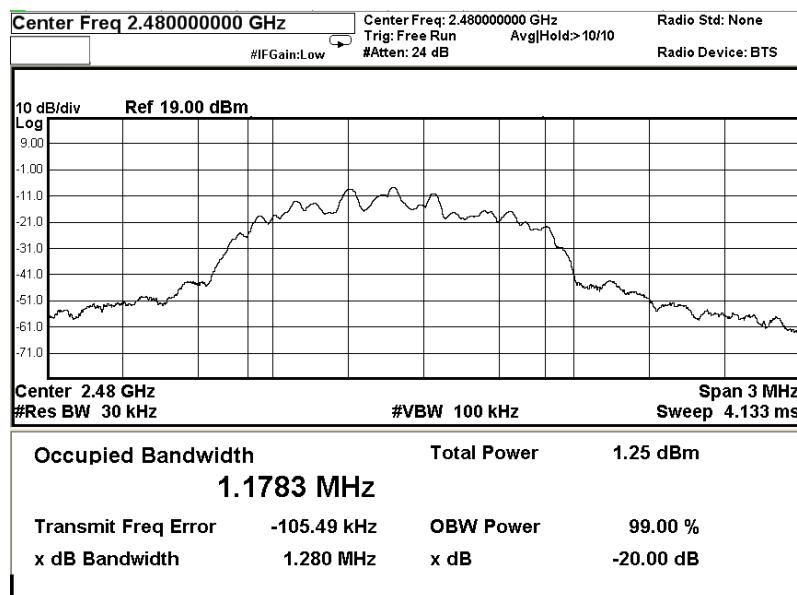
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Fundamental Frequency [MHz]	20dB Bandwidth [MHz]	FCC Limits [MHz]
2480	1.280	Within 2400-2483.5

(Highest Operating Frequency) - (8DPSK)



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3.1.6 Hopping Channel Separation

Ambient Temperature: 25°C Relative Humidity: 51% Atmospheric Pressure: 101 kPa

Requirements:

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.

Spectrum Analyzer Setting:

RBW = 300kHz, VBW \geq RBW, Sweep = Auto,
Span = Wide enough to capture the peaks of two adjacent channels
Detector = Peak, Trace = Max. hold

Limit:

The measured maximum bandwidth=1295 kHz

The measured maximum bandwidth * 2/3 = 1295KHz * 2/3 = 863.33kHz

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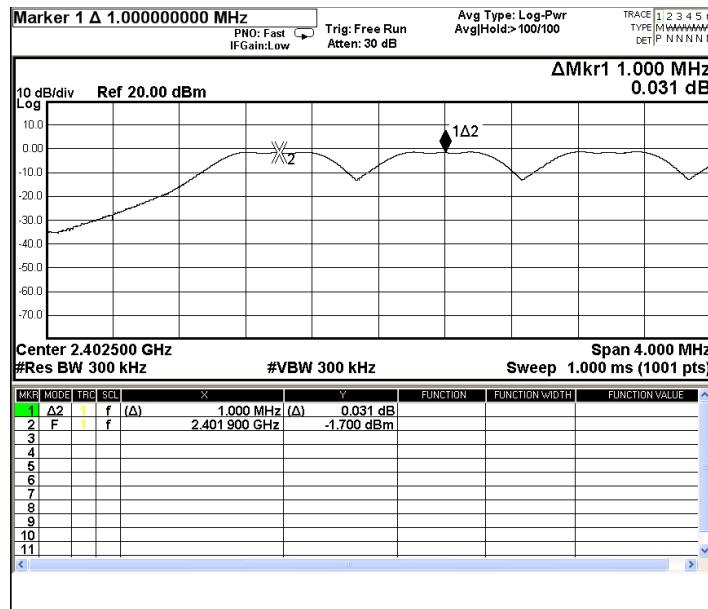


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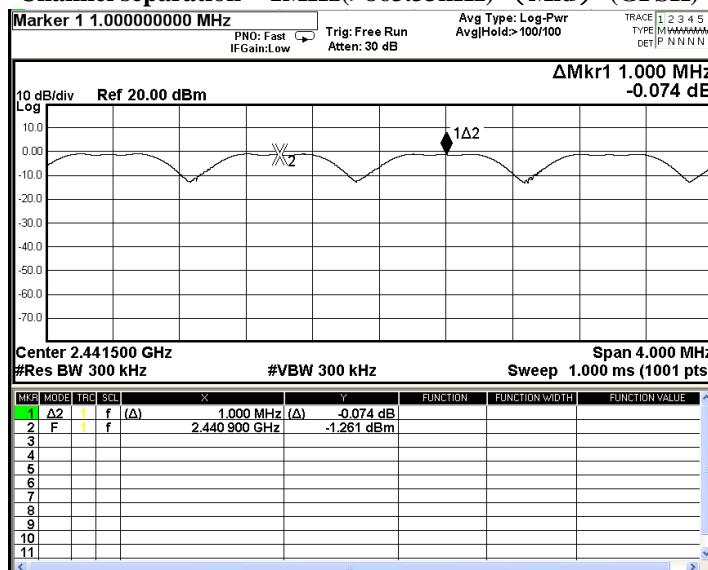
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Channel separation = 1MHz (>863.33kHz) (Lowest) (GFSK)



Channel separation = 1MHz(>863.33kHz) (Mid) (GFSK)



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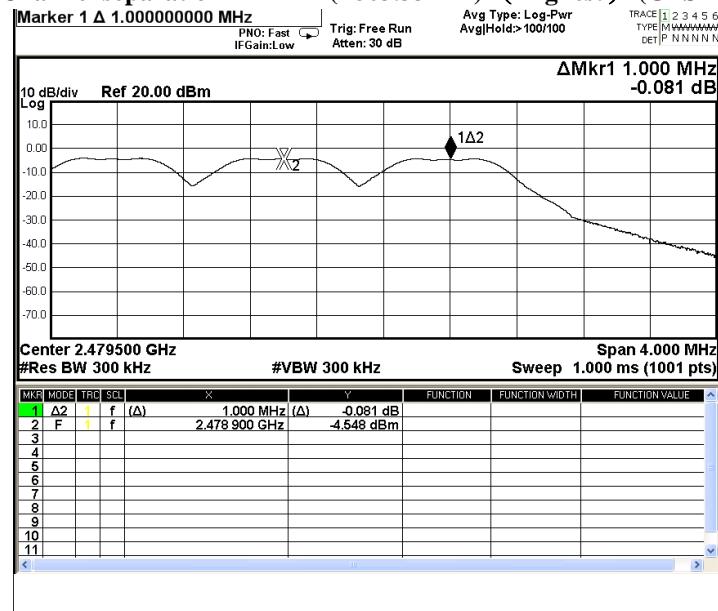
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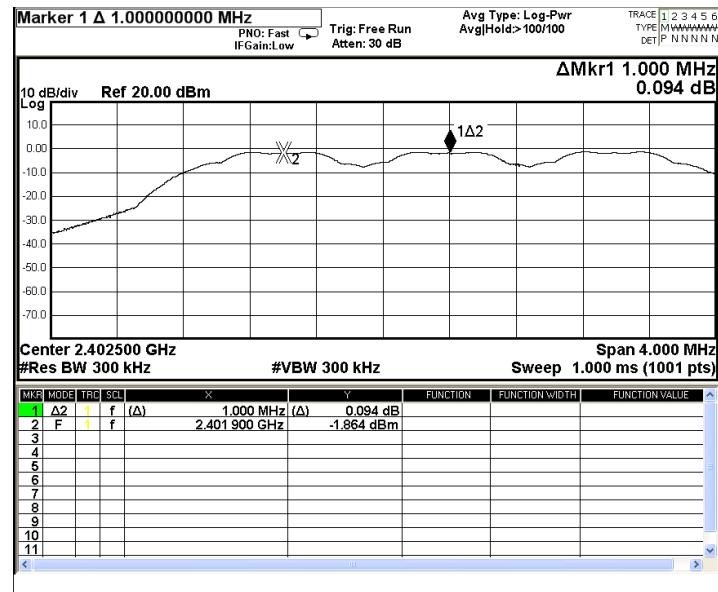
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Channel separation = 1MHz (>863.33kHz) (Highest) (GFSK)



Channel separation = 1MHz (>863.33kHz) (Lowest) ($\pi/4$ DQPSK)



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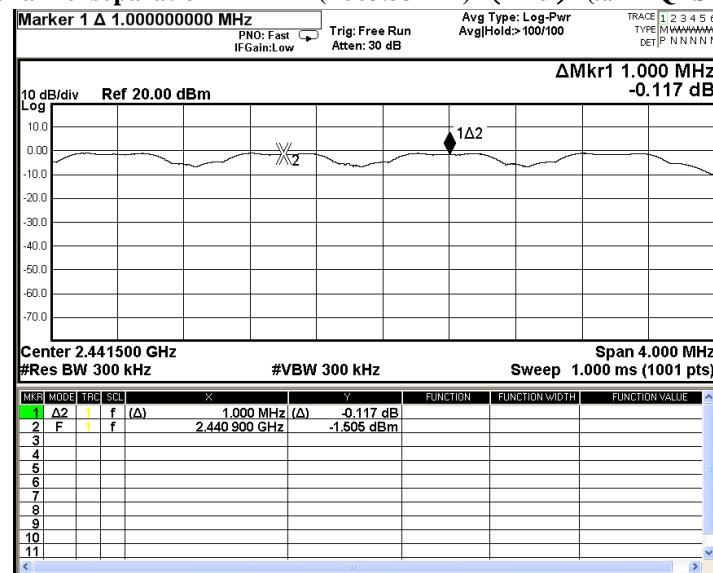


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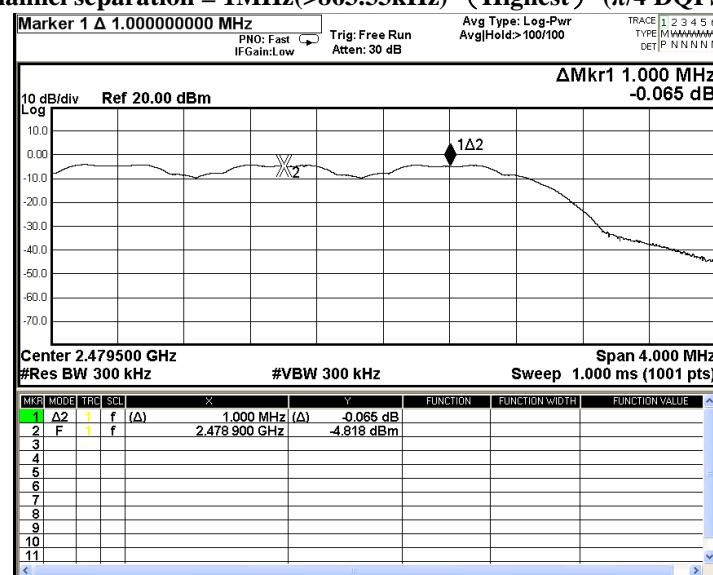
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Channel separation = 1MHz (>863.33kHz) (Mid) ($\pi/4$ DQPSK)



Channel separation = 1MHz(>863.33kHz) (Highest) ($\pi/4$ DQPSK)



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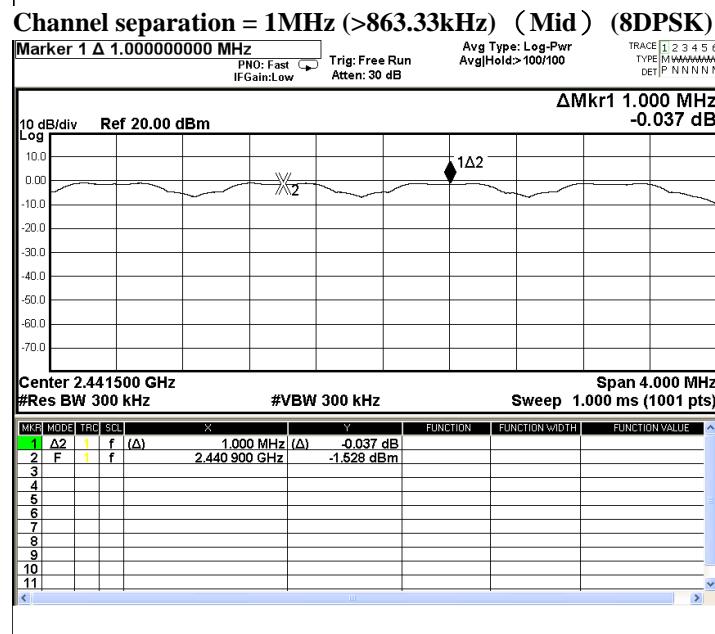
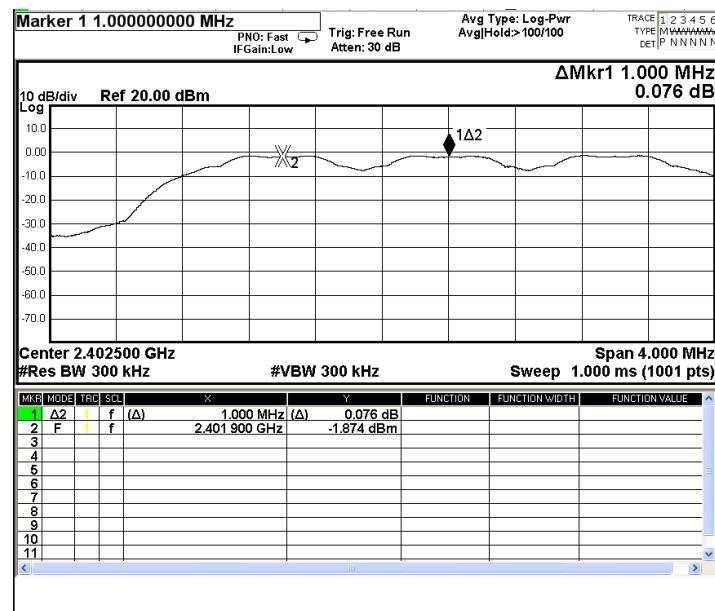


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Channel separation = 1MHz (>863.33kHz) (Lowest) (8DPSK)



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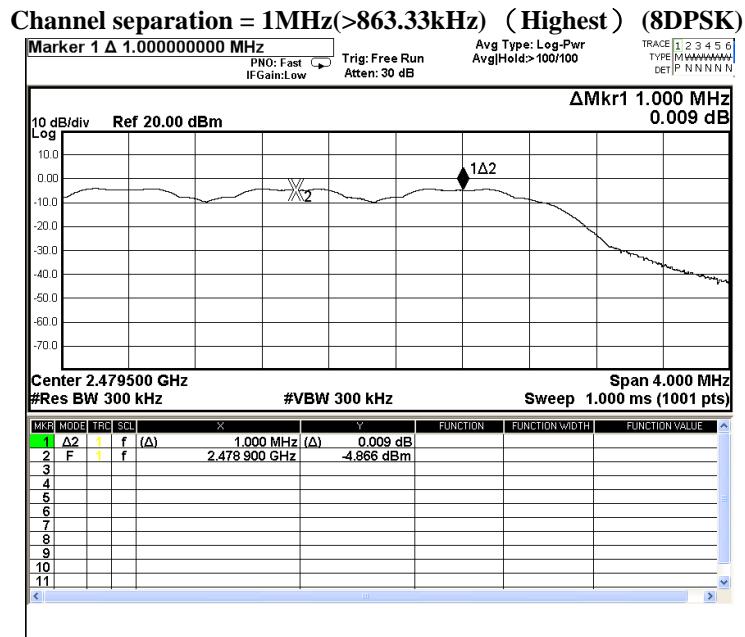
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3.1.7 Band-edge Compliance of RF Conducted Emissions Measurement:

Ambient Temperature: 25°C Relative Humidity: 51% Atmospheric Pressure: 101 kPa

Limit :

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. Attenuation below the general limits specified in Section 15.209(a) is not required.

According to the test method DA 00-705.

Spectrum Analyzer Setting:

RBW = 100kHz, VBW= 300kHz, Sweep = Coupled,

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 that fall outside of the authorized band of operation.

Detector = Peak, Trace = Max. hold

Remark: Emissions under the fixed frequency mode and hopping mode have been investigated, the worst-case measurement results were recorded in the test report

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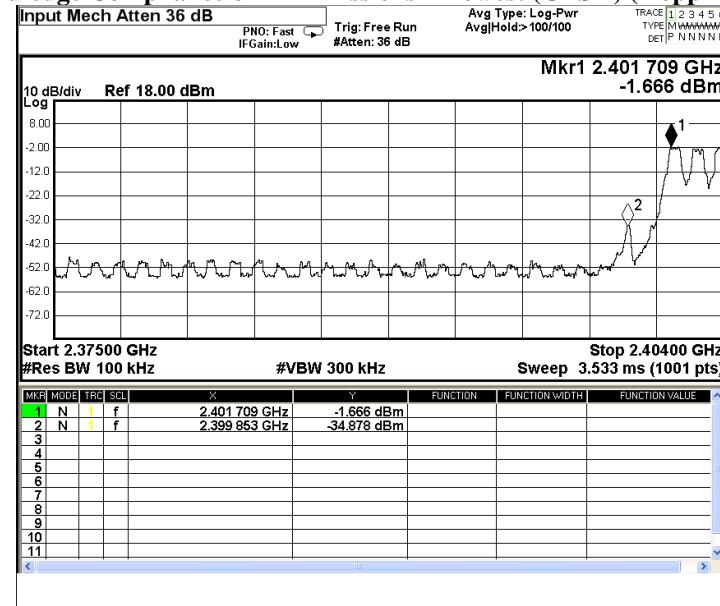
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Band-edge Compliance of RF Conducted Emissions Measurement:

Frequency Range	Reference level	Limit	The highest conducted band edge emission	Result
[MHz]	[dBm]	[dBm]	[dBm]	
2400 – Lowest Fundamental (2402)	-1.666	-21.666	-34.878	PASS

Band-edge Compliance of RF Emissions – Lowest (GFSK) (Hopping on)



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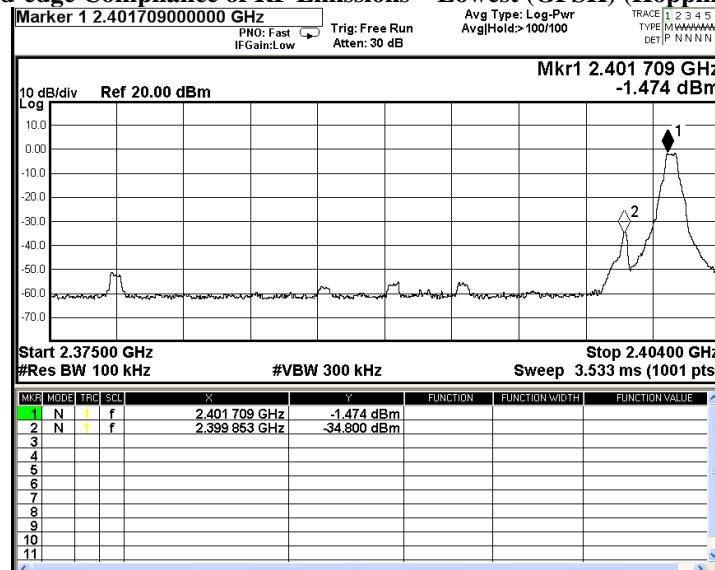
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Band-edge Compliance of RF Conducted Emissions Measurement:

Frequency Range	Reference level	Limit	The highest conducted band edge emission	Result
[MHz]	[dBm]	[dBm]	[dBm]	
2400 – Lowest Fundamental (2402)	-1.474	-21.474	-34.800	PASS

Band-edge Compliance of RF Emissions – Lowest (GFSK) (Hopping off)



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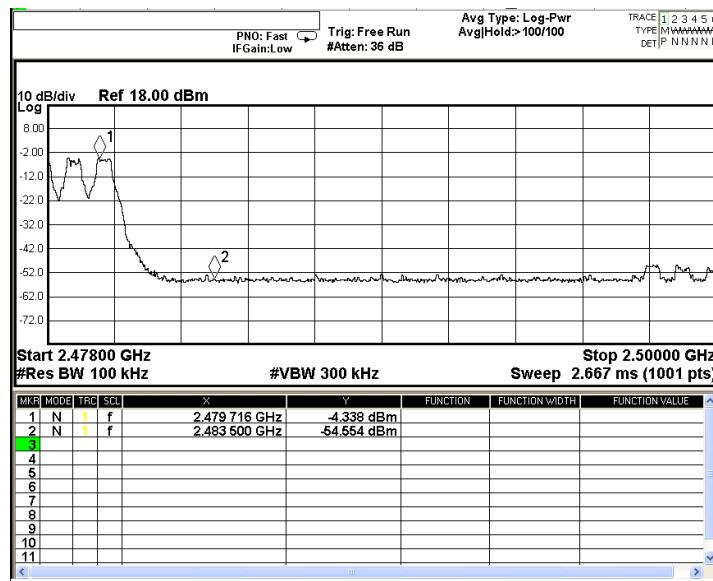
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Band-edge Compliance of RF Conducted Emissions Measurement:

Frequency Range	Reference level	Limit	The highest conducted band edge emission	Result
[MHz]	[dBm]	[dBm]	[dBm]	
2483.5 - Highest Fundamental (2480)	-4.338	-24.338	-54.554	PASS

Band-edge Compliance of RF Emissions – Highest (GFSK) (Hopping on)



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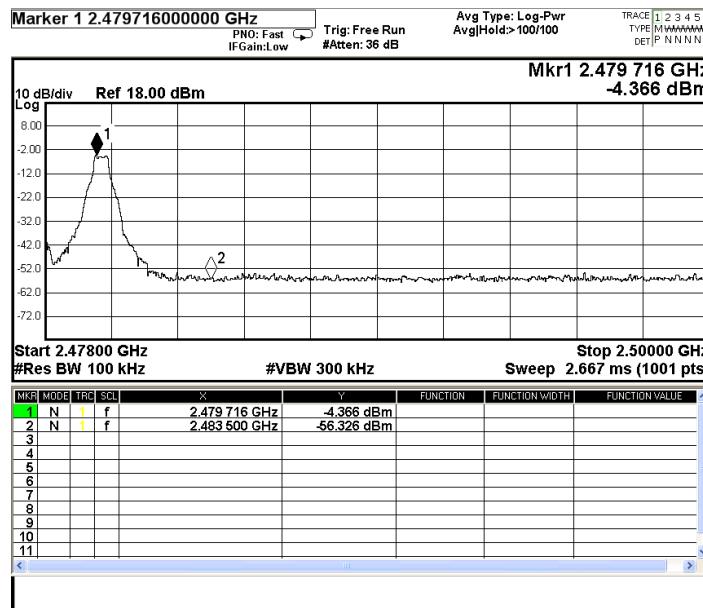
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Band-edge Compliance of RF Conducted Emissions Measurement:

Frequency Range	Reference level	Limit	The highest conducted band edge emission	Result
[MHz]	[dBm]	[dBm]	[dBm]	
2483.5 - Highest Fundamental (2480)	-4.366	-24.366	-56.326	PASS

Band-edge Compliance of RF Emissions – Highest (GFSK) (Hopping off)



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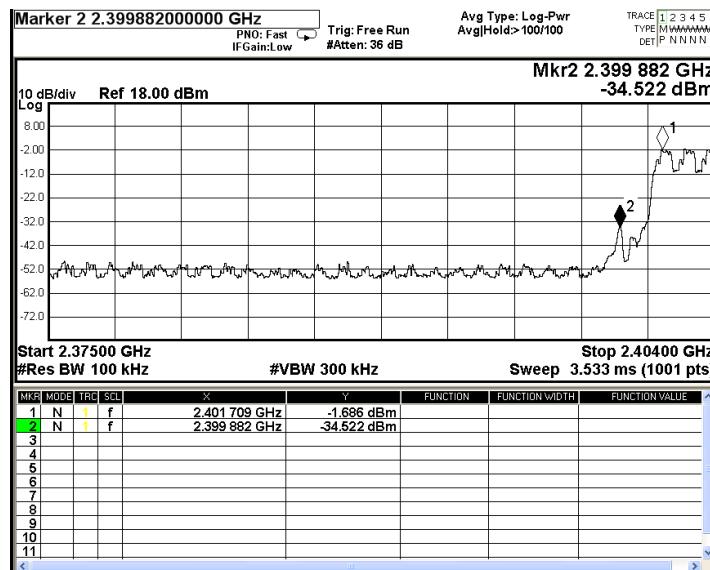
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Band-edge Compliance of RF Conducted Emissions Measurement:

Frequency Range	Reference level	Limit	The highest conducted band edge emission	Result
[MHz]	[dBm]	[dBm]	[dBm]	
2400 – Lowest Fundamental (2402)	-1.686	-21.686	-34.522	PASS

Band-edge Compliance of RF Emissions – Lowest ($\pi/4$ DQPSK) (Hopping on)



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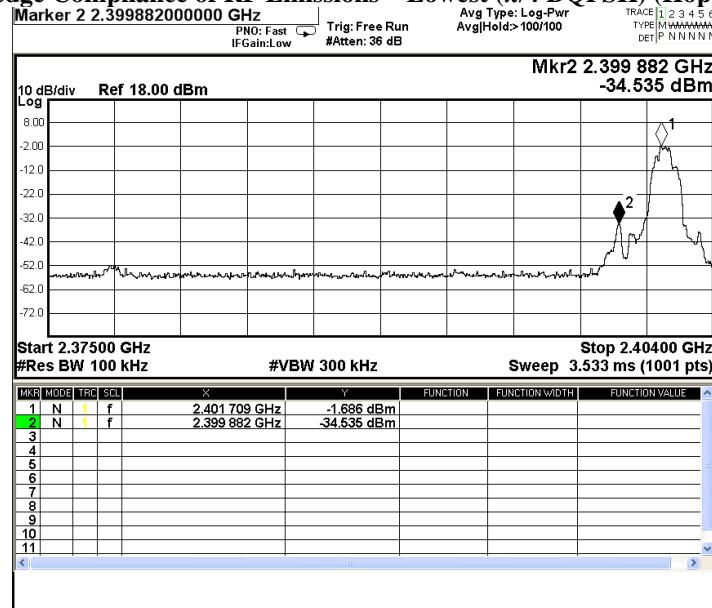
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Band-edge Compliance of RF Conducted Emissions Measurement:

Frequency Range	Reference level	Limit	The highest conducted band edge emission	Result
[MHz]	[dBm]	[dBm]	[dBm]	
2400 – Lowest Fundamental (2402)	-1.686	-21.686	-34.535	PASS

Band-edge Compliance of RF Emissions – Lowest ($\pi/4$ DQPSK) (Hopping off)



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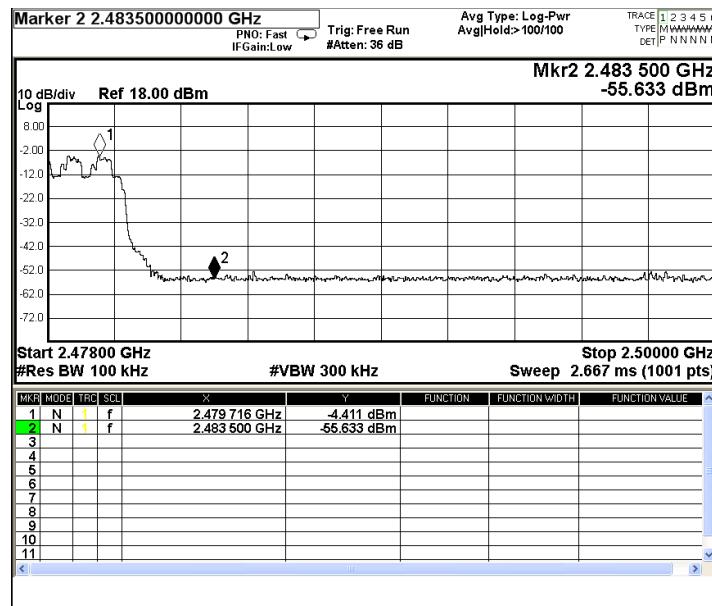
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Band-edge Compliance of RF Conducted Emissions Measurement:

Frequency Range	Reference level	Limit	The highest conducted band edge emission	Result
[MHz]	[dBm]	[dBm]	[dBm]	
2483.5 - Highest Fundamental (2480)	-4.411	-24.411	-55.633	PASS

Band-edge Compliance of RF Emissions – Highest ($\pi/4$ DQPSK) (Hopping on)



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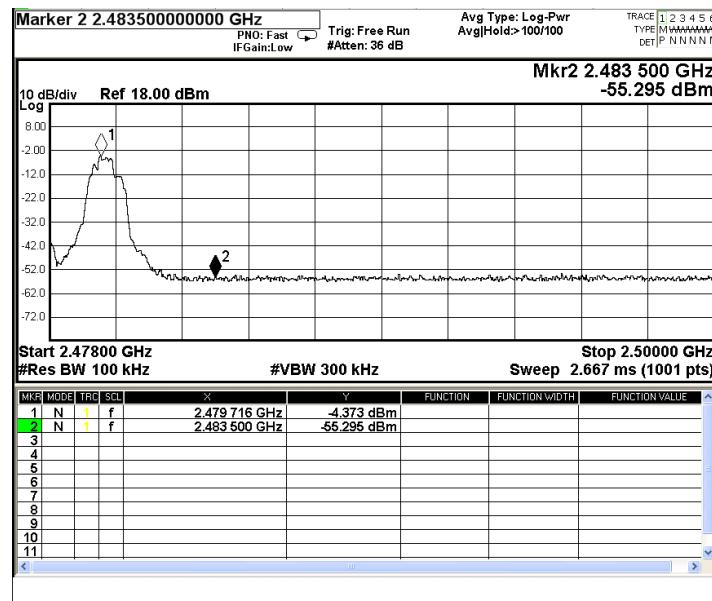
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Band-edge Compliance of RF Conducted Emissions Measurement:

Frequency Range	Reference level	Limit	The highest conducted band edge emission	Result
[MHz]	[dBm]	[dBm]	[dBm]	
2483.5 - Highest Fundamental (2480)	-4.373	-24.373	-55.295	PASS

Band-edge Compliance of RF Emissions – Highest ($\pi/4$ DQPSK) (Hopping off)



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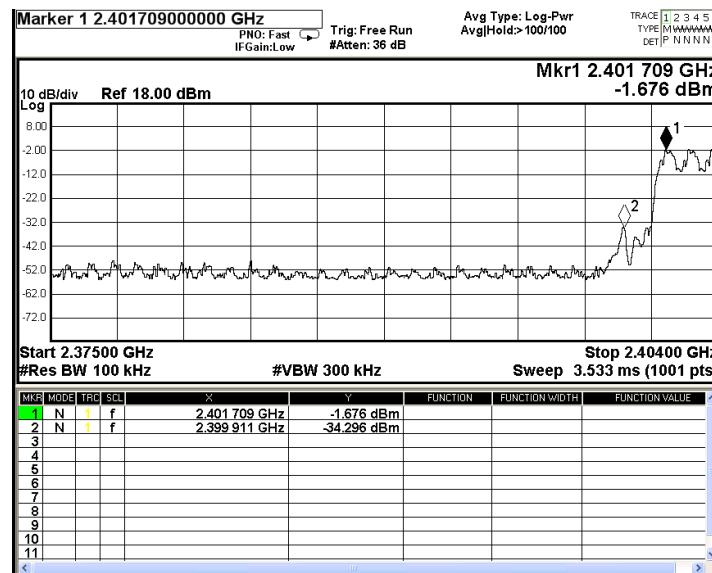
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Band-edge Compliance of RF Conducted Emissions Measurement:

Frequency Range	Reference level	Limit	The highest conducted band edge emission	Result
[MHz]	[dBm]	[dBm]	[dBm]	
2400 – Lowest Fundamental (2402)	-1.676	-21.676	-34.296	PASS

Band-edge Compliance of RF Emissions – Lowest (8DPSK) (Hopping on)



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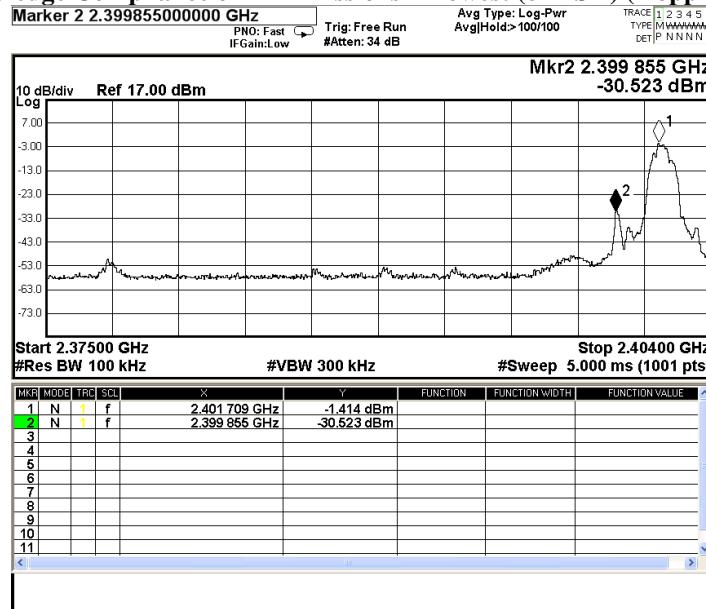
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Band-edge Compliance of RF Conducted Emissions Measurement:

Frequency Range	Reference level	Limit	The highest conducted band edge emission	Result
[MHz]	[dBm]	[dBm]	[dBm]	
2400 – Lowest Fundamental (2402)	-1.414	-21.414	-30.523	PASS

Band-edge Compliance of RF Emissions – Lowest (8DPSK) (Hopping off)



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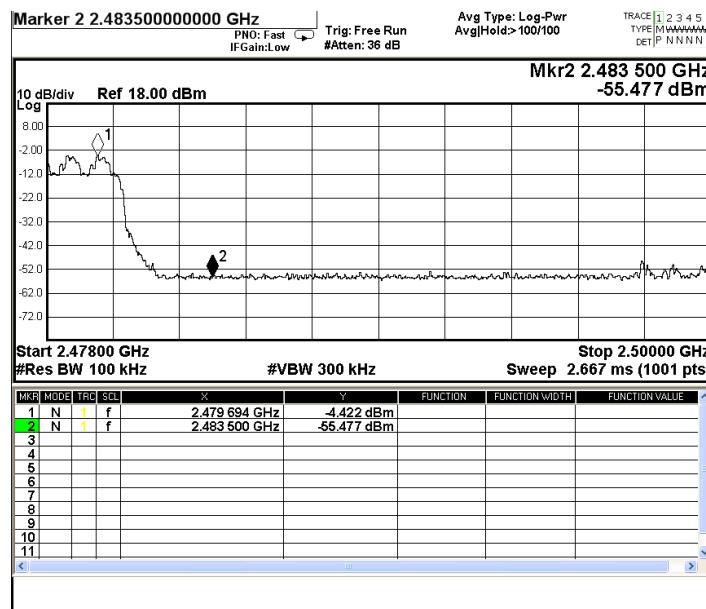
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Band-edge Compliance of RF Conducted Emissions Measurement:

Frequency Range	Reference level	Limit	The highest conducted band edge emission	Result
[MHz]	[dBm]	[dBm]	[dBm]	
2483.5 - Highest Fundamental (2480)	-4.422	-24.422	-55.477	PASS

Band-edge Compliance of RF Emissions – Highest (8DPSK) (Hopping on)



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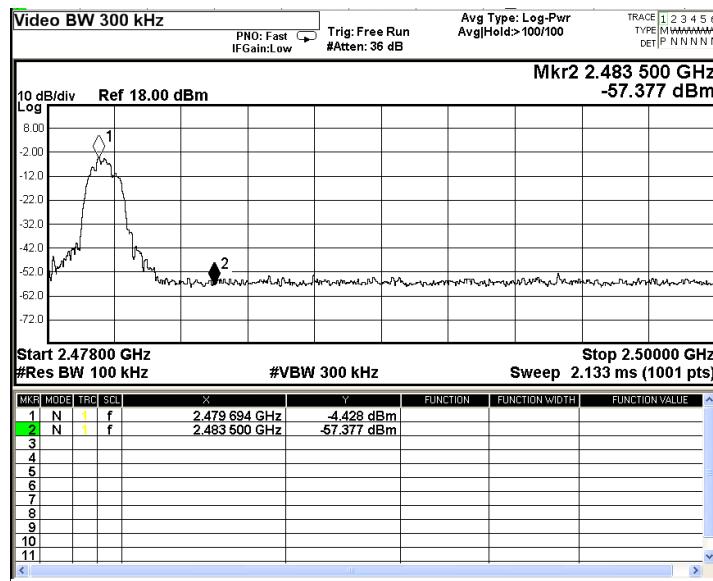
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Band-edge Compliance of RF Conducted Emissions Measurement:

Frequency Range	Reference level	Limit	The highest conducted band edge emission	Result
[MHz]	[dBm]	[dBm]	[dBm]	
2483.5 - Highest Fundamental (2480)	-4.428	-24.428	-57.377	PASS

Band-edge Compliance of RF Emissions – Highest (8DPSK) (Hopping off)



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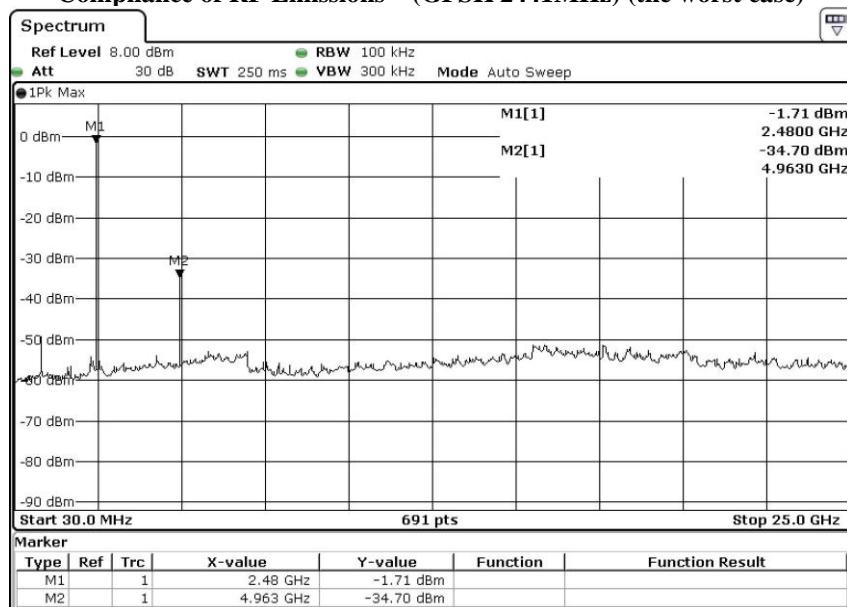
Compliance of RF Conducted Emissions Measurement:

Limit :

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. Attenuation below the general limits specified in Section 15.209(a) is not required.

Remark: Emissions under the fixed frequency mode and hopping mode have been investigated, the worst-case measurement results were recorded in the test report

Compliance of RF Emissions – (GFSK 2441MHz) (the worst case)



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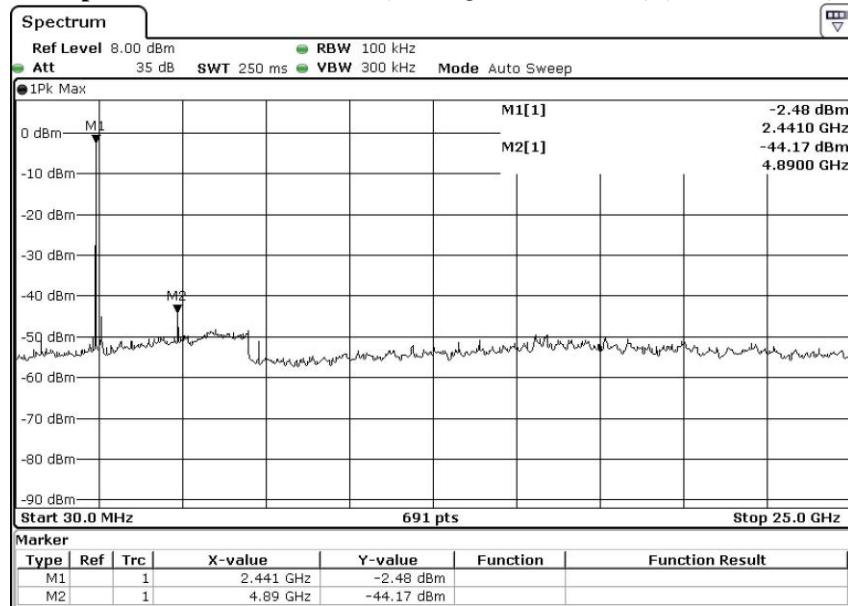


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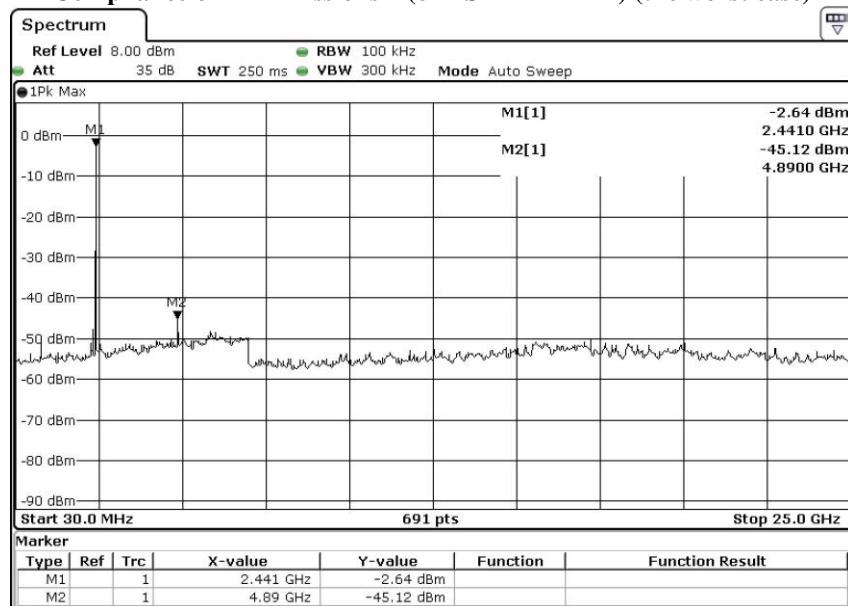
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Compliance of RF Emissions – ($\pi/4$ -DQPSK 2441MHz) (the worst case)



Compliance of RF Emissions – (8DPSK 2441MHz) (the worst case)



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3.1.8 Time of Occupancy (Dwell Time)

Ambient Temperature: 25°C Relative Humidity: 51% Atmospheric Pressure: 101 kPa

Requirements:

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 channel employed.
No requirements for Digital Transmission System.

Spectrum Analyzer Setting:

RBW = 300kHz, VBW \geq RBW,

Sweep = A longer sweep time to show two successive hops on a channel,

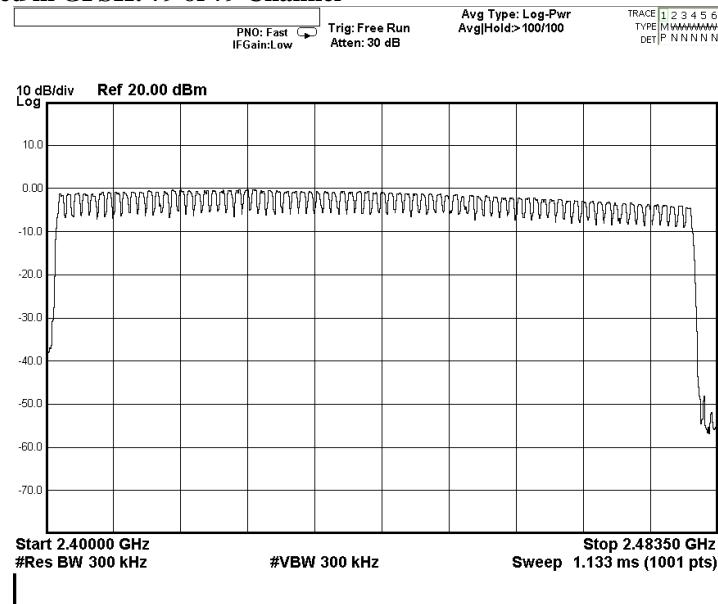
Span = Zero, Detector = Peak, Trace = Max. hold

Dwell Time = Pulse Duration * hop rate / number of channel * observation duration

Observed duration: 0.4s x 79 = 31.6s

Measurement Data:

Channel Occupied in GFSK: 79 of 79 Channel



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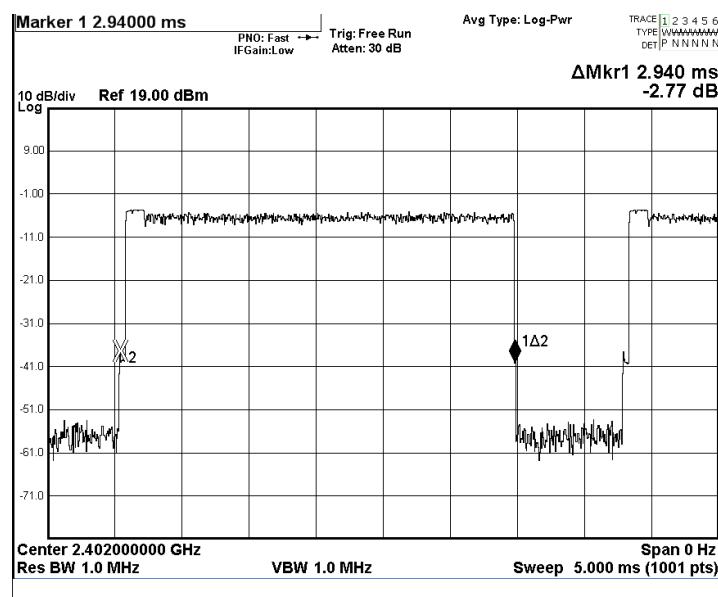
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3DH5 Packet:

3DH5 Packet permit maximum $1600/79/6 = 3.37$ hops per second in each channel (5 time slots RX, 1 time slot TX). The Dwell time is the time duration of the pulse times $3.37 \times 31.6 = 106.6$ within 31.6 seconds

Fig. A
[Pulse duration of Lowest Channel]



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Fig. B

[Pulse duration of Middle Channel]

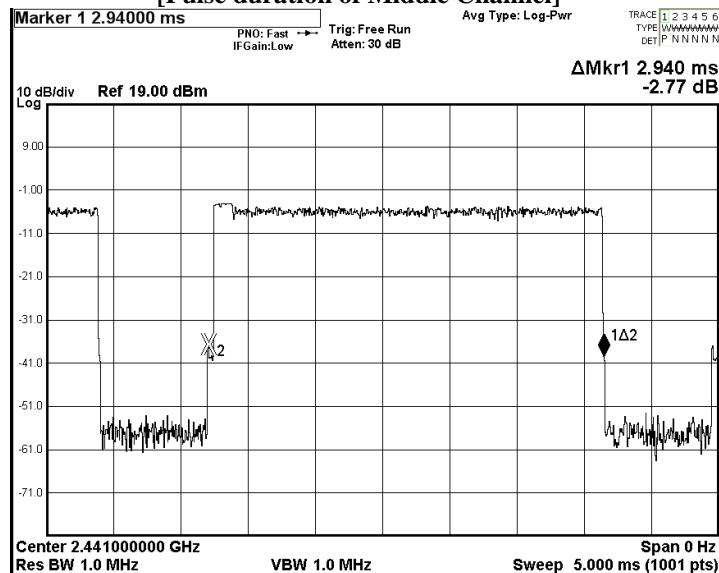
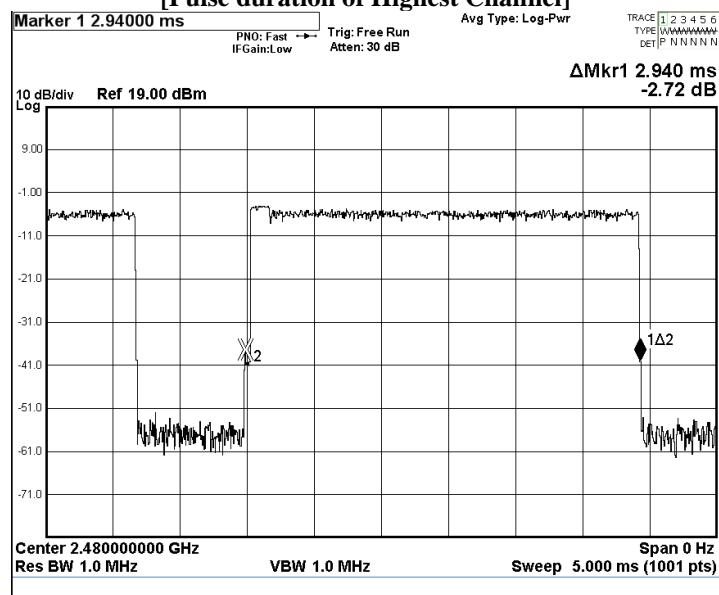


Fig. C

[Pulse duration of Highest Channel]



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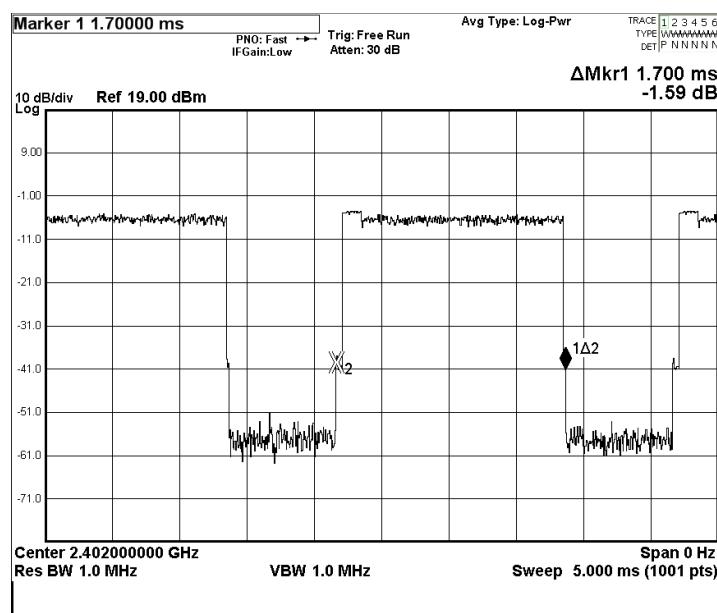
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3DH3 Packet:

3DH3 Packet permit maximum $1600/79/4 = 5.06$ hops per second in each channel (3 time slots RX, 1 time slot TX). The Dwell time is the time duration of the pulse times $5.06 \times 31.6 = 160$ within 31.6 seconds

Fig. D
[Pulse duration of Lowest Channel]



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Fig. E
[Pulse duration of Middle Channel]

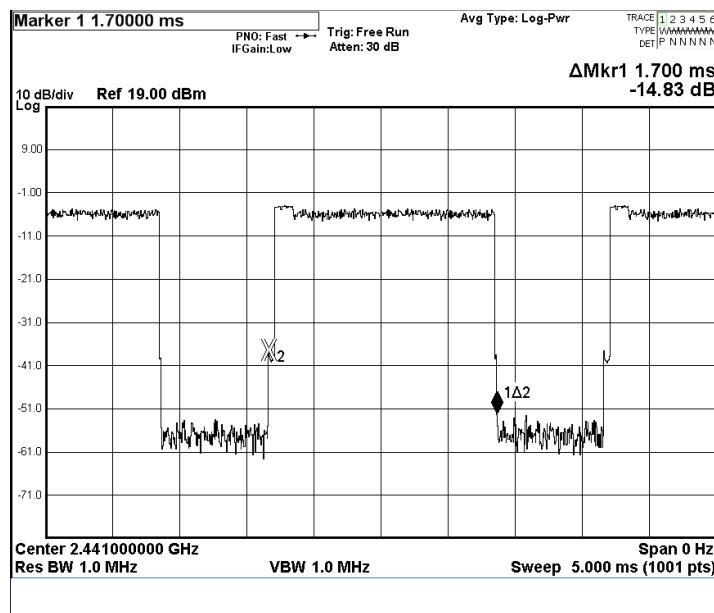
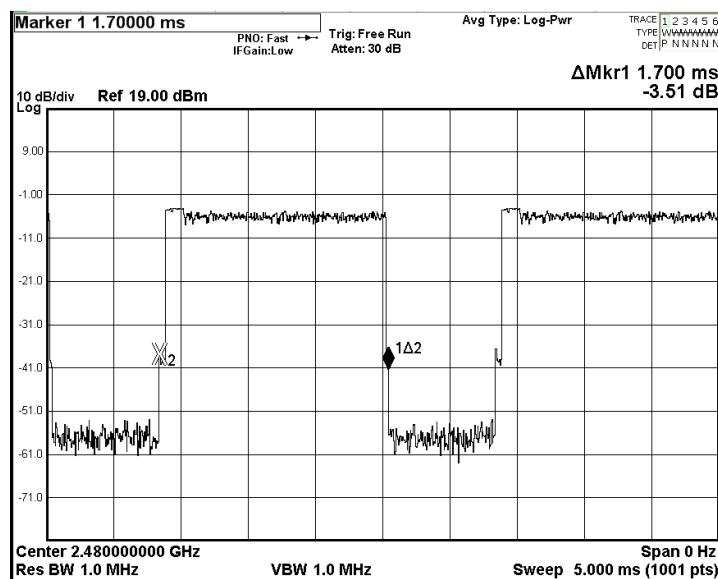


Fig. F
[Pulse duration of Highest Channel]



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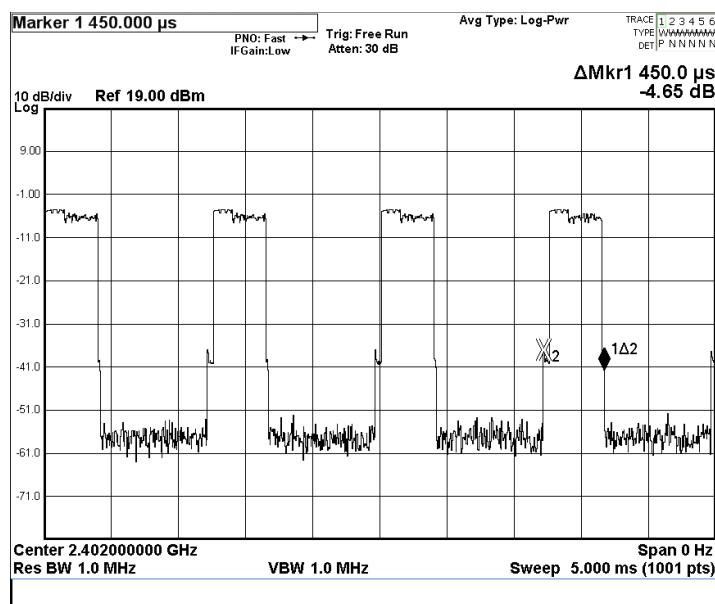
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3DH1 Packet:

3DH1 Packet permit maximum $1600/79/2 = 10.12$ hops per second in each channel (3 time slots RX, 1 time slot TX). The Dwell time is the time duration of the pulse times $10.12 \times 31.6 = 320$ within 31.6 seconds

Fig. G
[Pulse duration of Lowest Channel]



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Fig. H

[Pulse duration of Middle Channel]

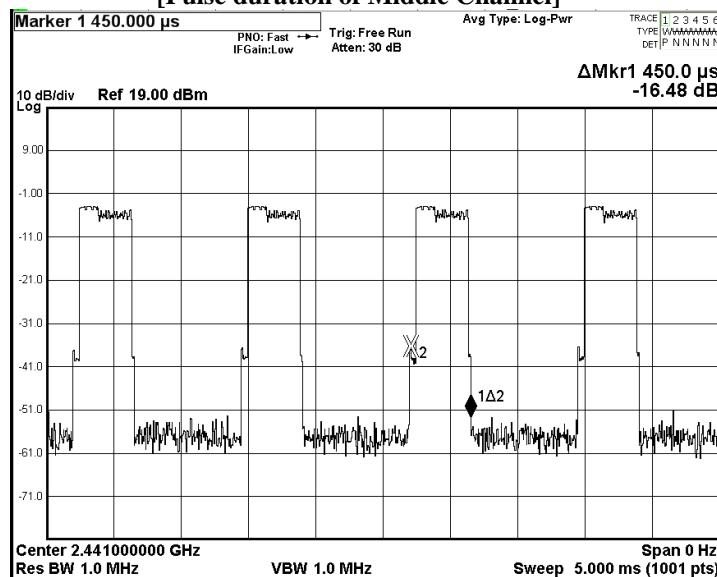
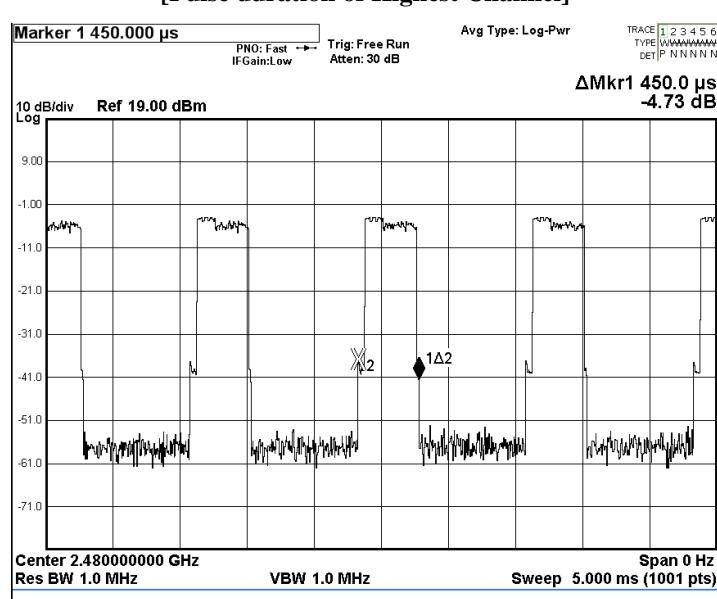


Fig. I

[Pulse duration of Highest Channel]



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Time of occupancy (Dwell Time):

Data Packet	Frequency (MHz)	Pulse Duration (ms)	Dwell Time (s)	Limits (s)	Test Results
3DH5	2402	2.940	0.313	0.400	Complies
3DH5	2441	2.940	0.313	0.400	Complies
3DH5	2480	2.940	0.313	0.400	Complies
3DH3	2402	1.700	0.272	0.400	Complies
3DH3	2441	1.700	0.272	0.400	Complies
3DH3	2480	1.700	0.272	0.400	Complies
3DH1	2402	0.450	0.144	0.400	Complies
3DH1	2441	0.450	0.144	0.400	Complies
3DH1	2480	0.450	0.144	0.400	Complies

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3.1.9 Channel Centre Frequency

Ambient Temperature: 25°C

Relative Humidity: 51%

Atmospheric Pressure: 101 kPa

Requirements:

Frequency hopping system in the 2400-2483.5MHz band shall use at least 79 (Channel 1 to 79) non-overlapping channels.

The EUT operates in according with the Bluetooth system specification within the 2400 - 2483.5 MHz frequency band.

RF channels for Bluetooth systems are spaced 1 MHz and are ordered in channel number k. In order to comply with out-of-band regulations, a lower frequency guard band of 2.0 MHz and a higher frequency guard band of 3.5MHz is used.

The operating frequencies of each channel are as follows:

First RF channel start from 2400MHz + 2MHz guard band = 2402MHz

Frequency of RF Channel = 2402+k MHz, k = 0,...,78 (Channel separation = 1MHz)

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3.1.10 Pseudorandom Hopping Algorithm

Ambient Temperature: 25°C Relative Humidity: 51% Atmospheric Pressure: 101 kPa

Requirements:

The channel frequencies shall be selected from a pseudorandom ordered list of hopping frequencies. Each frequency must be used equally by the transmitter.

EUT Pseudorandom Hopping Algorithm

The EUT is a Bluetooth device, the Pseudo-random hopping pattern; hopping characteristics and algorithm are based on the Bluetooth specification.

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3.1.11 Antenna Requirement

Ambient Temperature: 25°C Relative Humidity: 51% Atmospheric Pressure: 101 kPa

Test Requirements: § 15.203

Test Specification:

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.

Test Results:

This is PCB antenna. There is no external antenna, the antenna gain = -0.58 dBi. User is unable to remove or changed the Antenna.

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Appendix A

List of Measurement Equipment

Radiated Emission

EQP NO.	DESCRIPTION	MANUFACTURER	MODEL NO.	SERIAL NO.	LAST CAL	DUE CAL
EM215	MULTIDEVICE CONTROLLER	EMCO	2090	00024676	N/A	N/A
EM217	ELECTRIC POWERED TURNTABLE	EMCO	2088	00029144	N/A	N/A
EM218	ANECHOIC CHAMBER	ETS-LINDGREN	FACT-3	--	2019/04/16	2024/04/16
EM356	ANTENNA POSITIONING TOWER	ETS-LINDGREN	2171B	00150346	N/A	N/A
EM293	SPECTRUM ANALYZER	AGILENT TECHNOLOGIES	N9020A	MY50510152	2022/11/25	2024/11/25
EM299	BROADBAND HORN ANTENNA	ETS-LINDGREN	3115	00114120	2022/11/24	2024/11/24
EM300	PYRAMIDAL STANDARD GAIN HORN ANTENNA	ETS-LINDGREN	3160-09	00130130	2022/11/25	2024/11/25
EM301	PYRAMIDAL STANDARD GAIN HORN ANTENNA	ETS-LINDGREN	3160-10	00130988	2022/11/25	2024/11/25
EM353	LOOP ANTENNA	ETS-LINDGREN	6502	00206533	2022/06/10	2024/09/10
EM355	Biconilog Antenna	ETS-Lindgren	3143B	00094856	2022/06/17	2024/09/17
EM200	DUAL CHANNEL POWER METER	R & S	NRVD	100592	2022/10/11	2025/10/11
EM012	PRE-AMPLIFIER	HP	HP8448B	3008A00262	2022/11/08	2025/11/08
EM215	MULTIDEVICE CONTROLLER	EMCO	2090	00024676	N/A	N/A

Line Conducted

EQP NO.	DESCRIPTION	MANUFACTURER	MODEL NO.	SERIAL NO.	LAST CAL	DUE CAL
EM232	LISN	SCHAFFNER	NNB41	04/100082	2022/07/20	2023/07/20
EM181	EMI TEST RECEIVER	ROHDE & SCHWARZ	ESIB7	100072	2022/05/30	2023/05/30
EM179	PULSE LIMITER	ROHDE & SCHWARZ	ESH3-Z2	357.8810.52/54	2023/03/17	2025/03/17
EM154	SHIELDING ROOM	SIEMENS MATSUSHITA COMPONENTS	N/A	803-740-057-99A	2022/02/02	2027/02/02
N/A	MEASUREMENT AND EVALUATION SOFTWARE	ROHDE & SCHWARZ	BSIB-K1	V1.20	N/A	N/A

Remarks:-

CM CORRECTIVE MAINTENANCE
N/A NOT APPLICABLE
TBD TO BE DETERMINED

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Appendix B

Photographs of EUT

View of the product



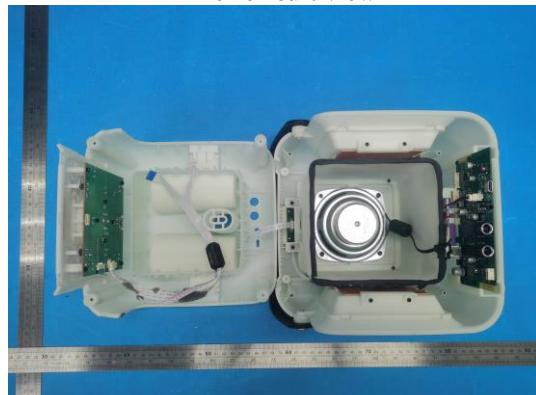
View of the product



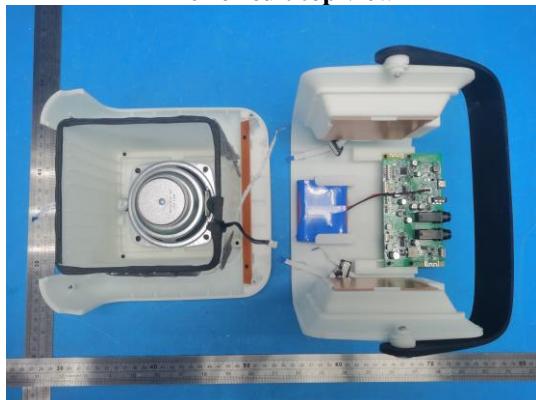
View of the product



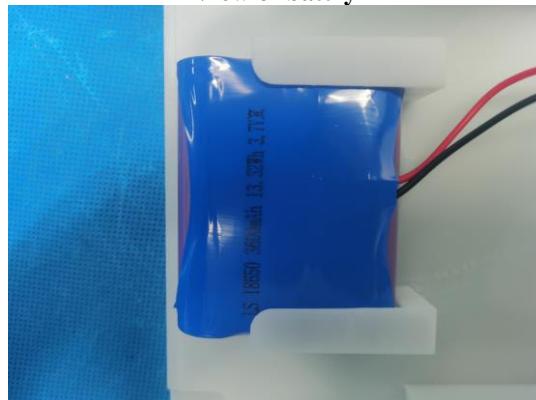
Inner circuit view



Inner circuit top view



View of battery



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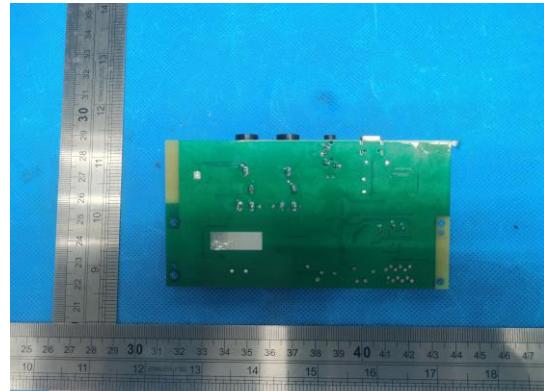
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Photographs of EUT

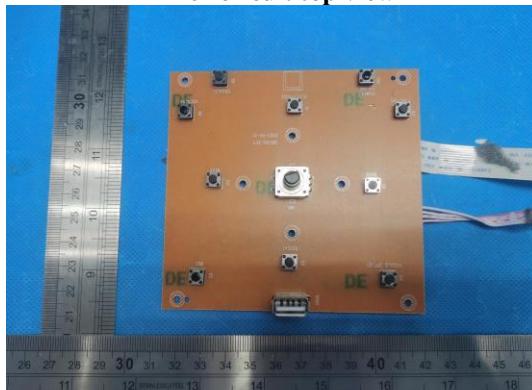
Inner circuit top view



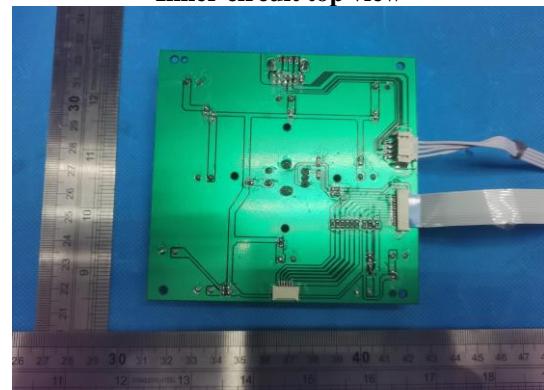
Inner circuit bottom view



Inner circuit top view



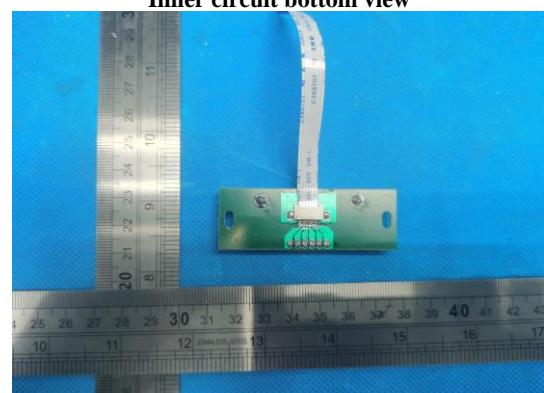
Inner circuit top view



Inner circuit top view



Inner circuit bottom view



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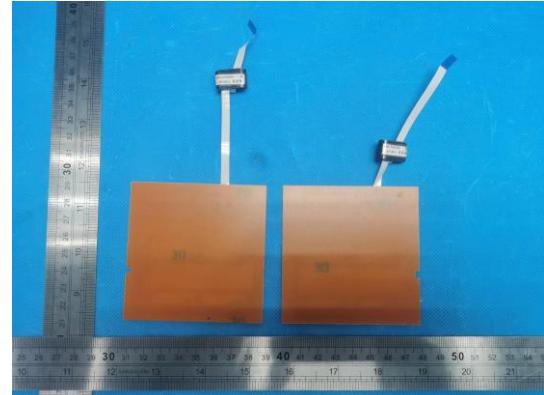
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Photographs of EUT

Inner circuit top view



Inner circuit bottom view



Inner circuit top view



Inner circuit bottom view



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Photographs of EUT

Measurement of Radiated Emission Test Set Up (9kHz – 30MHz)



Measurement of Radiated Emission Test Set Up (30MHz to 1000MHz)



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Photographs of EUT

Measurement of Radiated Emission Test Set Up (Above 1000MHz)



Measurement of Conducted Emission Test Set Up



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