# **TEST REPORT**

# DT&C Co., Ltd.

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1. Report No: DRTFCC1712-0275

**Dt&C** 

- 2. Customer
  - Name : Innomdle Lab Co., Ltd.
  - Address : #720, 815, Daewangpangyo-ro, Sujeong-gu, Seongnam-si, Gyeonggi-do, South Korea, 13449
- 3. Use of Report : FCC Original Grant
- 4. Product Name / Model Name : SGNL / IM-S001 FCC ID : 2AOK2IM-S001
- 5. Test Method Used : ANSI C63.10-2013 Test Specification : FCC Part 15 Subpart C.247
- 6. Date of Test : 2017.12.11 ~ 2017.12.19
- 7. Testing Environment : See appended test report.
- 8. Test Result : Refer to the attached test result.

Affirmation	Tested by	Technical Manager					
	Name : SunGeun Lee (Signature)	Name : HyunSu Son (SQ 413)					
The tes	st results presented in this test report are limited	only to the sample supplied by applicant and					
the use of	this test report is inhibited other than its purpose	e. This test report shall not be reproduced except					
	in full, without the written appro	val of DT&C Co., Ltd.					
	2017.12.19.						
DT&C Co., Ltd.							
	If this report is required to confirmation of authenticity, please contact to report@dtnc.net						

# **Test Report Version**

Test Report No.	Date	Description
DRTFCC1712-0275	Dec. 19, 2017	Initial issue

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# **1. General Information**

# 1.1 Testing Laboratory

### DT&C Co., Ltd.

The 3 m test site and conducted measurement facility used to collect the radiated data are located at the 42, Yurim-ro, 154beon-gil, Cheoin-gu, Yongin-si, Gyeonggi-do, Korea 17042. The site is constructed in conformance with the requirements.

#### - FCC MRA Accredited Test Firm No. : KR0034

www.dtnc.net		
Telephone	:	+ 82-31-321-2664
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## **1.2 Testing Environment**

Ambient Condition	
<ul> <li>Temperature</li> </ul>	+21 °C ~ +24 °C
Relative Humidity	41 % ~ 45 %

#### **1.3 Measurement Uncertainty**

The measurement uncertainties shown below were calculated in accordance with requirements of ANSI C63.4-2014 and ANSI C63.10-2013. All measurement uncertainty values are shown with a coverage factor of k = 2 to indicate a 95 % level of confidence.

Test items	Measurement uncertainty
Transmitter Output Power	0.7 dB (The confidence level is about 95 %, $k = 2$ )
Conducted spurious emission	1.0 dB (The confidence level is about 95 %, $k = 2$ )
AC conducted emission	2.4 dB (The confidence level is about 95 %, k = 2)
Radiated spurious emission (1 GHz Below)	5.1 dB (The confidence level is about 95 %, k = 2)
Radiated spurious emission (1 GHz ~ 18 GHz)	5.4 dB (The confidence level is about 95 %, $k = 2$ )
Radiated spurious emission (18 GHz Above)	5.3 dB (The confidence level is about 95 %, $k = 2$ )

# 1.4 Details of Applicant

Applicant	:	Innomdle Lab Co., Ltd.
Address	:	#720, 815, Daewangpangyo-ro, Sujeong-gu, Seongnam-si, Gyeonggi-do, South Korea 13449
Contact person	:	Jinyong Kim

# 1.5 Description of EUT

EUT	SGNL
Model Name	IM-S001
Add Model Name	NA
Serial Number	Identical prototype
Hardware version	2.2
Software version	1.0
Power Supply	DC 3.7 V
Frequency Range	2402 MHz ~ 2480 MHz
Modulation Technique	GFSK, π/4DQPSK, 8DPSK
Number of Channels	79
Antenna Type /Antenna Gain	Chip Antenna / PK : 1.99 dBi

# 1.6 Support Equipment

Equipment	Manufacturer	Model No.	Note
-	-	-	-
-	-	-	-

### **1.7 Information about the FHSS characteristics**

- This Bluetooth module has been tested by a Bluetooth Qualification Lab, and we confirm the following :
  - A) The hopping sequence is pseudorandom
    - Note 1 : Pseudorandom Frequency Hopping Sequence Table as below:
      - Channel: 08, 24, 40, 56, 42, 54, 72, 09, 01, 11, 33, 41, 34, 42, 65, 73, 53, 69, 06, 22, 04, 20, 36, 52, 38, 46, 70, 78, 68, 76, 21, 29, 10, 26, 41, 58, 44, 60, 76, 13, 03, 11, 35, 43, 37, 45, 69, 77, 52, 71, 08, 24, 06, 24, 48, 56, 45, 46, 70, 01, 72, 06, 25, 33, 12, 28, 49, 60, 45, 58, 74, 13, 05, 18, 37, 49 etc
      - The System receiver have input bandwidths that match the hopping channel badwidths of Their corresponding transmitters and shift frequencies in synchroniztation with the transmit Ted signals.
  - B) All channels are used equally on average
  - C) The receiver input bandwidth equals the transmit bandwidth
  - D) The receiver hops in sequence with the transmit signal
- 15.247(g) : In accordance with the Bluetooth Industry Standard, the system is designed to comply with all
  of the regulations in Section 15.247 when the transmitter is presented with a continuous data
  (or information) system.
- 15.247(h) : In accordance with the Bluetooth Industry Standard, the system does not coordinate its channels selection / hopping sequence with other frequency hopping systems for the express purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters.
- 15.247(h) : The EUT employs Adaptive Frequency Hopping (AFH) which identifies sources of interference namely devices operating in 802.11 WLAN and excludes them from the list of available channels. The process of re-mapping reduces the number of test channels from 79 channels to a minimum number of 20 channels.

# **1.8 Test Equipment List**

Туре	Manufacturer	Model	Cal.Date (yy/mm/dd)	Next.Cal.Date (yy/mm/dd)	S/N
Spectrum Analyzer	Agilent Technologies	N9020A	17/07/12	18/07/12	MY46471601
Spectrum Analyzer	Agilent Technologies	N9020A	17/09/05	18/09/05	MY46471251
Multimeter	FLUKE	17B	17/04/12	18/04/12	26030065WS
DC Power Supply	Agilent	66332A	17/01/11	18/01/11	US37473831
Signal Generator	Rohde Schwarz	SMBV100A	17/01/04	18/01/04	255571
Signal Generator	Rohde Schwarz	SMF100A	17/04/21	18/04/21	102341
Thermohygrometer	BODYCOM	BJ5478	17/04/11	18/04/11	120612-2
Power Splitter	Anritsu	K241B	17/01/11	18/01/11	1301183
Bluetooth Tester	TESCOM	TC-3000B	17/01/04	18/01/04	3000B770243
Loop Antenna	Schwarzbeck	FMZB1513	16/04/22	18/04/22	1513-128
BILOG ANTENNA	Schwarzbeck	VULB 9160	16/08/05	18/08/05	9160-3362
Horn Antenna	ETS-LINDGREN	3117	16/05/03	18/05/03	00140394
Horn Antenna	A.H.Systems Inc.	SAS-574	17/07/31	19/07/31	155
PreAmplifier	Agilent	8449B	17/09/05	18/09/05	3008A002108
PreAmplifier	TSJ	MLA-010K01- B01-27	17/03/06	18/03/06	1844539
EMI Test Receiver	Rohde Schwarz	ESR7	17/02/16	18/02/16	101061
High-pass filter	Wainwright	WHKX12- 2580-3000- 18000-80SS	17/09/05	18/09/05	3
High-pass filter	Wainwright	WHNX6-6320- 8000-26500- 40CC	17/09/05	18/09/05	1
Power Meter & Wide Bandwidth Sensor	Anritsu	ML2496A MA2411B	17/04/11	18/04/11	1338004 1306053
EMI Test Receiver	R&S	ESCI	17/02/26	18/02/16	100364
PULSE LIMITER	ROHDE&SCHWARZ	ESH3-Z2	17/01/03	18/01/03	101334
LISN	SCHWARZBECK	NNLK 8121	17/04/03	18/04/03	6182

Note: The measurement antennas were calibrated in accordance to the requirements of ANSI C63.5-2017.

# 1.9 Summary of Test Results

FCC Part RSS Std.	Parameter	<b>Limit</b> (Using in 2400~ 2483.5 MHz)	Test Condition	Status Note 1
	Carrier Frequency Separation	>= 25 kHz or >= Two thirds of the 20 dB BW, whichever is greater.		с
15.247(a) RSS-247(5.1)	Number of Hopping Frequencies	>= 15 hops		С
100 247(0.1)	20 dB Bandwidth	N/A		С
	Dwell Time	=< 0.4 seconds		С
15.247(b) RSS-247(5.4)	Transmitter Output Power	For FCC =< 1 Watt , if CHs >= 75 Others =< 0.125 W For IC if CHs >= 75 =< 1 Watt For Conducted Power =< 4 Watt For e.i.r.p, Others =< 0.125 W For Conducted Power. =< 4 Watt For e.i.r.p	Conducted	с
15.247(d) RSS-247(5.5)	Conducted Spurious Emissions	The radiated emission to any 100 kHz of out-band shall be at least 20 dB below the highest in-band spectral density.		с
RSS Gen(6.6)	Occupied Bandwidth (99 %)	N/A	•	NA
15.247(d) 15.205 & 209 RSS-247(5.5) RSS-Gen (8.9 & 8.10)	Radiated Spurious Emissions	FCC 15.209 Limits	Radiated	C Note2, 3
15.207 RSS-Gen(8.8)	AC Conducted Emissions	FCC 15.207 Limits	AC Line Conducted	С
15.203 -	Antenna Requirements	FCC 15.203	-	С
	bly NC = Not Comply NT = Not item was performed in each axis and ted emission tests below 30 MHz we	the worst case data was reported.	amber which is o	correlated

with OATS.



# 1.10 Conclusion of worst-case and operation mode

The EUT has three type of modulation (GFSK,  $\pi$ /4DQPSK and 8DPSK). Therefore all applicable requirements were tested with all the modulations. And packet type was tested at the worst case(DH5).

Tested frequency information,

- Hopping Function : Enable

	TX Frequency (MHz)	RX Frequency (MHz)
Hopping Band	2402 ~ 2480	2402 ~ 2480

- Hopping Function : Disable

	TX Frequency (MHz)	RX Frequency (MHz)		
Lowest Channel	2402	2402		
Middle Channel	2441	2441		
Highest Channel	2480	2480		



# 2. Maximum Peak Output Power Measurement

# 2.1 Test Setup

Refer to the APPENDIX I.

# 2.2 Limit

#### FCC Requirements

The maximum peak output power of the intentional radiator shall not exceed the following :

- 1. §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.
- §15.247(b)(1), For frequency hopping systems operating in the 2400 2483.5 MHz employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725 5805 MHz band : 1 Watt.

#### IC Requirements

1. RSS-247(5.4), For FHSs operating in the band 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1.0 W if the hopset uses 75 or more hopping channels; the maximum peak conducted output power shall not exceed 0.125 W if the hopset uses less than 75 hopping channels. The e.i.r.p. shall not exceed 4 W.

## 2.3 Test Procedure

- 1. The RF output power was measured with a spectrum analyzer connected to the RF Antenna connector (conducted measurement) while EUT was operating in transmit mode at the appropriate center frequency, A spectrum analyzer was used to record the shape of the transmit signal.
- 2. The bandwidth of the fundamental frequency was measured with the spectrum analyzer using ;

Span = approximately 5 times of the 20 dB bandwidth, centered on a hopping channel

RBW ≥ 20 dB BW VBW ≥ RBW Sweep = auto Detector function = peak Trace = max hold

# 2.4 Test Results

Modulation	Tested Channel		Average t Power	Peak Output Power		
Woddiation	resteu Ghanner	dBm	mW	dBm	mW	
	Lowest	-1.95	0.64	-1.09	0.78	
<u>GFSK</u>	Middle	-0.65	0.86	-0.04	0.99	
	Highest	-1.32	0.74	-0.68	0.86	
<u>π/4DQPSK</u>	Lowest	-5.15	0.31	-1.92	0.64	
	Middle	-3.92	0.41	-0.86	0.82	
	Highest	-4.67	0.34	-2.30	0.59	
<u>8DPSK</u>	Lowest	-5.16	0.31	-1.49	0.71	
	Middle	-3.88	0.41	-0.37	0.92	
	Highest	-4.62	0.35	-1.92	0.64	

Note 1 : The frame average output power was tested using an average power meter for reference only. Note 2 : See next pages for actual measured spectrum plots.



### Lowest Channel & Modulation : GFSK



# Peak Output Power <u>Middle Channel & Modulation : GFSK</u>





#### Highest Channel & Modulation : GFSK



#### Peak Output Power

#### Lowest Channel & Modulation : π/4DQPSK





# Middle Channel & Modulation : π/4DQPSK



#### Peak Output Power

## Highest Channel & Modulation : π/4DQPSK





#### Lowest Channel & Modulation : 8DPSK



#### Peak Output Power

#### Middle Channel & Modulation : 8DPSK





# Highest Channel & Modulation : 8DPSK



# 3. 20 dB BW

# 3.1 Test Setup

Refer to the APPENDIX I.

# 3.2 Limit

Limit : Not Applicable

# 3.3 Test Procedure

- 1. The 20 dB bandwidth were measured with a spectrum analyzer connected to RF antenna Connector (conducted measurement) while EUT was operating in transmit mode. The analyzer center frequency was set to the EUT carrier frequency, using the analyzer.
- 2. The bandwidth of the fundamental frequency was measured with the spectrum analyzer using below setting: RBW shall be in the range of 1% to 5% of the 20 dB bandwidth and VBW ≥ 3 × RBW, Span = between two times and five times the 20 dB bandwidth.

Modulation	Tested Channel	20 dB BW (MHz)
	Lowest	0.951
<u>GFSK</u>	Middle	0.956
	Highest	0.925
	Lowest	1.335
<u>π/4DQPSK</u>	Middle	1.351
	Highest	1.344
	Lowest Middle	1.344
<u>8DPSK</u>	Middle	1.345
	Highest	1.345

## 3.4 Test Results

Lowest Channel & Modulation : GFSK

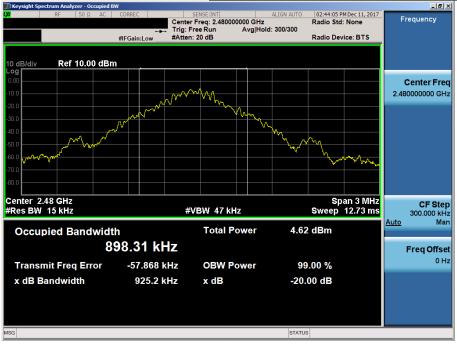


## 20 dB Bandwidth

# Middle Channel & Modulation : GFSK



# Highest Channel & Modulation : GFSK

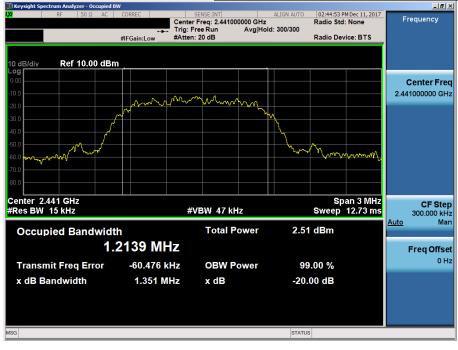


#### 20 dB Bandwidth

# Lowest Channel & Modulation : π/4DQPSK



# Middle Channel & Modulation : π/4DQPSK

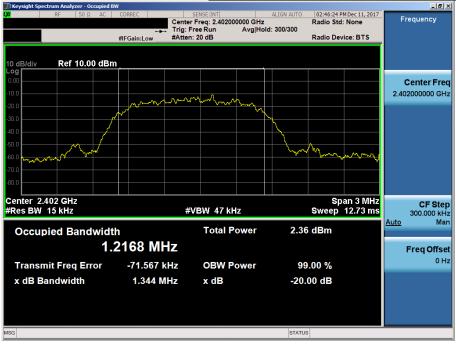


#### 20 dB Bandwidth

# Highest Channel & Modulation : π/4DQPSK





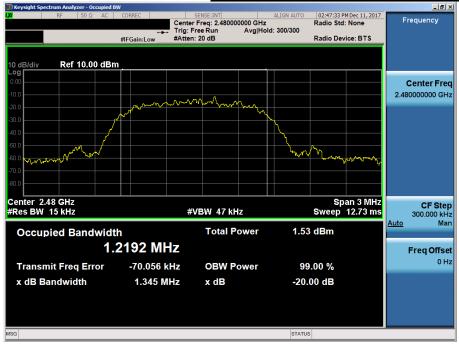


#### 20 dB Bandwidth

# Middle Channel & Modulation : 8DPSK



### Highest Channel & Modulation : 8DPSK





# 4. Carrier Frequency Separation

# 4.1 Test Setup

Refer to the APPENDIX I.

# 4.2 Limit

Limit :  $\geq$  25 kHz or  $\geq$  Two-Thirds of the 20 dB BW whichever is greater.

# 4.3 Procedure

The carrier frequency separation was measured with a spectrum analyzer connected to the antenna terminal, while EUT had its hopping function enabled.

After the trace being stable, the reading value between the peaks of the adjacent channels using the markerdelta function was recorded as the measurement results.

The spectrum analyzer is set to :

Span = wide enough to capture the peaks of two adjacent channels

RBW = Start with the RBW set to approximately 30% of the channel spacing; adjust as necessary to best identify the center of each individual channel.

VBW ≥ RBW	Sweep = auto
Detector function = peak	Trace = max hold

## 4.4 Test Results

#### FH mode

Hopping Mode	Modulation	Peak of center channel (MHz)	Peak of adjacent Channel (MHz)	Test Result (MHz)
	GFSK	2440.949	2441.949	1.000
Enable	π/4DQPSK	2440.945	2441.945	1.000
	8DPSK	2441.097	2442.097	1.000

#### AFH mode

Hopping Mode	Modulation	Peak of center channel (MHz)	Peak of adjacent Channel (MHz)	Test Result (MHz)
	GFSK	2410.950	2411.950	1.000
Enable	π/4DQPSK	2410.943	2411.943	1.000
	8DPSK	2411.093	2412.093	1.000

Note 1 : See next pages for actual measured spectrum plots.

#### - Minimum Standard :

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





# **Carrier Frequency Separation (FH)**





#### **Carrier Frequency Separation (FH)**

## <u>Hopping mode : Enable & π/4DQPSK</u>





# Carrier Frequency Separation (FH)

## Hopping mode : Enable & 8DPSK







# Carrier Frequency Separation (AFH) <u>Hopping mode : Enable & GFSK</u>



# **Carrier Frequency Separation (AFH)**

# <u>Hopping mode : Enable & π/4DQPSK</u>







# **Carrier Frequency Separation (AFH)**

# Hopping mode : Enable & 8DPSK

Avg Type: Log-Pwr         Trace         Trace <th></th> <th>ım Analyzer - Swept SA</th> <th></th> <th></th> <th></th> <th></th> <th>_ 5 :</th>		ım Analyzer - Swept SA					_ 5 :
PNO: Wide         Trig: Free Run         Arty 192-Exg 1 m         Trig: Free Run         Auto T           0 dE/div         Ref 10.00 dBm         -0.16 dB         -0.16 dB         -0.16 dB         2.411000000           0 0         -0.16 dB         -0.16 dB         -0.16 dB         2.411000000         -0.16 dB         2.411000000           0 0         -0.16 dB         -0.16 dB         -0.16 dB         2.411000000         -0.16 dB         2.411000000         -0.16 dB         2.411000000         -0.16 dB         2.411000000         -0.16 dB         2.41100000000         -0.16 dB         2.4110000000         -0.16 dB         -0.16 dB         2.4110000000         -0.16 dB         2.4110000000         -0.16 dB		RF 50 Ω AC	CORREC	SENSE:INT	ALIGN AUTO	09:59:23 AM Dec 11, 2017	Frequency
IFGainLow       Atten: 20 dB       Der DINNNA         Auto T       Auto T       Auto T       Auto T         10 dB/div       Ref 10.00 dBm       -0.16 dB       Center I         000       -0.16 dB       -0.16 dB       -0.16 dB         000       -0.16 dB			PNO: Wido	Trig: Free Run	Avg Type: Log-Pwr	TYPE M WAARAAAA	
Content 1.000 MHz       Center 1         0.0       -0.16 dB         2       -0.16 dB         3       -0.16 dB         3       -0.16 dB         3       -0.16 dB         3       -0.16 dB						DET PNNNN	
0 0 B/div       Ref 10.00 dBm       -0.16 dB         0 00       -0.00       -0.10       -0.10         0 00       -0.00       -0.10       -0.10         0 00       -0.00       -0.10       -0.10         0 00       -0.00       -0.10       -0.10         0 00       -0.00       -0.10       -0.10         0 00       -0.00       -0.00       -0.10       -0.10         0 00       -0.00       -0.00       -0.00       -0.00       -0.10         0 00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00         0 00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00         0 00       -0.00					Δ	Mkr1 1.000 MHz	Auto Tune
Control         Start         C	dB(div B	2ef 10.00 dBm					
100         200 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>							
200       300	.00					1∆2	Center Free
200         30000         MIR         200         200         MIR         200<	0.0	m mmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmm		mm K2		when and	2.411000000 GH
300       3		* • • • • •	· man m			and the prove	
40.0       40.0       50.0							
2.403000000         2.403000000           600         600           700         600           700         700           800         700           800         700           800         700           800         700           800         700           800         700           800         700           800         700           800         700           800         800           800         800           800         800           800         800           800         800           800         800           800         800           800         800           800         800           800         800           800         800           800         800           800         800           800         900           800         900           800         900           800         900           800         900           800         900           800         900							Start Fre
60.0         70.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         50.0         60.0 <t< td=""><td>0.0</td><td></td><td></td><td></td><td></td><td></td><td>2.409500000 GH</td></t<>	0.0						2.409500000 GH
To 0         Stop F           2.412500000         Center 2.411000 GHz           #Res BW 30 kHz         #VBW 91 kHz           Sweep 3.200 ms (3001 pts)           MMR MODE THE SCL         X           1         Δ2         1           7         1           4         1           5         1	0.0						
70.0          70.0         70.0 <t< td=""><td>0.0</td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	0.0						
60.0         Span 3.000 MHz         Center 2.411000 GHz         Span 3.000 MHz         Cer F 3.000 MHz           #Res BW 30 KHz         #VBW 91 KHz         Sweep 3.200 ms (3001 pts)         Auto         Auto           1         Δ2         1         f         (Δ)         -0.16 dB         Function         Function value         Freq Of           3         4         5         6	0.0						Stop Fre
Center 2.411000 GHz         #VBW 91 kHz         Span 3.000 MHz         Auto           MRR MODE TRC SCL         X         Y         FUNCTION         FUNCTION WIDTH         FUNCTION VALUE         Auto           1         Δ2         1         f         (Δ)         -0.16 dB         Function         Function Value         Freq OI           3         4         4         4         4         Function         Function         Function         Freq OI	1.0						2.412500000 GH
#Res BW 30 kHz         #VBW 91 kHz         Sweep 3.200 ms (3001 pts)         300.000           MRR MODE TRC SCL         X         Y         FUNCTION         FUNCTION WIDTH         FUNCTION VALUE         Auto           1         A2         1         f         (A)         1.000 MHz (A)         -0.16 dB         FUNCTION         FUNCTION WIDTH         FUNCTION VALUE         Function Value         Function Value         Freq Of           3         -							
#Res BW 30 kHz         #VBW 91 kHz         Sweep 3.200 ms (3001 pts)         300.000           MKR MODE TRC SCL         X         Y         FUNCTION         FUNCTION WIDTH         FUNCTION VALUE         Auto           1         A2         1         f         (A)         1.000 MHz         (A)         -0.16 dB         Function         Function width         Function value         Function value         Function value         Final value<	enter 2.411	1000 GHz				Span 3.000 MHz	CF Ste
MMR MODE TRC SCI X Y FUNCTION FUNCTION WIDTH FUNCTION VALUE Auto			#VBW	91 kHz	Sweep	3.200 ms (3001 pts)	300.000 k⊢
Δ2         1         f         (Δ)         1.000 MHz         (Δ)         -0.16 dB           2         F         1         f         2.411 093 GHz         -7.63 dBm         Freq Of           3         -         -         -         -7.63 dBm         Freq Of           4         -         -         -         -         -		scil x		Y			Auto Ma
2         F         1         f         2.411 093 GHz         -7.63 dBm           3         -         -         -         -         -         Freq Of           4         -         -         -         -         -         -         Freq Of           6         -         -         -         -         -         -         -         Freq Of			1.000 MHz (Δ)		I I I I I I I I I I I I I I I I I I I		
		f 2.41	1 093 GHz	-7.63 dBm			Freq Offse
5							0 H
	8						
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SG STATUS	2				STATU	JS	



# **5. Number of Hopping Frequencies**

## 5.1 Test Setup

Refer to the APPENDIX I.

# 5.2 Limit

Limit : >= 15 hops

# 5.3 Procedure

The number of hopping frequencies was measured with a spectrum analyzer connected to the antenna terminal, while EUT had its hopping function enabled.

To get higher resolution, two frequency ranges for FH mode within the 2400 ~ 2483.5 MHz were examined.

The spectrum analyzer is set to :

Span for FH mode = 50 MHz	Start Frequency = 2391.5 MHz,	Stop Frequency = 2441.5 MHz						
	Start Frequency = 2441.5 MHz,	Stop Frequency = 2491.5 MHz						
Span for AFH mode = 30 MHz	Start Frequency = 2396.0 MHz,	Stop Frequency = 2426.0 MHz						
RBW = To identify clearly the individual channels, set the RBW to less than 30% of the channel spacing or the 20 dB bandwidth, whichever is smaller.								
VBW ≥ RBW	Sweep = auto							
Detector function = peak	Trace = max hold							

## 5.4 Test Results

#### FH mode

Hopping mode	Modulation	Test Result (Total Hops)
	GFSK	79
Enable	π/4DQPSK	79
	8DPSK	79

#### AFH mode

Hopping mode	Modulation	Test Result (Total Hops)
	GFSK	20
Enable	π/4DQPSK	20
	8DPSK	20

Note 1 : See next pages for actual measured spectrum plots.

#### - Minimum Standard :

At least 15 hopes



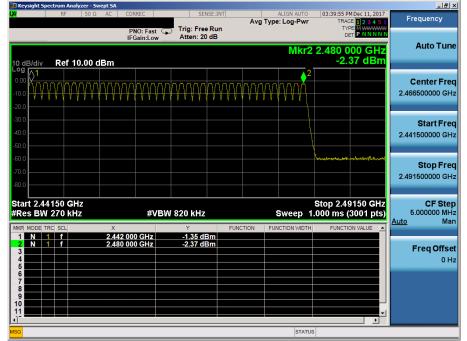
# Number of Hopping Frequencies 1(FH)

# Hopping mode : Enable & GFSK

RF 50 Ω AC	CORREC	SENSE:INT	ALIGN AUTO Avg Type: Log-Pwr	03:38:56 PM Dec 11, 2017 TRACE 1 2 3 4 5 6	Frequency
	PNO: Fast 😱	Trig: Free Run	Avg Type. Log-Fwi	TYPE M WAWWAW	
	IFGain:Low	Atten: 20 dB		DET P NNNNN	Auto Tune
			Mkr2	2.441 000 GHz	Autorune
10 dB/div Ref 10.00 dBm				-1.54 dBm	
0.00 Q <sup>1</sup>					Center Freq
-10.0	ነለለለለለለ	ממממח	176666666666	מהההההו	2.416500000 GHz
[]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]	* * * * * * * *	* * * * * * * * *	* * * * * * * * * * * * *		2.416500000 GHZ
-20.0					
-30.0					Start Freq
-40.0					2.391500000 GHz
-50.0					
-60.0 Annual and annual state					
-70.0					Stop Freq
-80.0					2.441500000 GHz
-00.0					
Start 2.39150 GHz				Stop 2.44150 GHz	CF Step
#Res BW 270 kHz	#VBW	820 kHz	Sweep 1	.000 ms (3001 pts)	5.000000 MHz Auto Man
MKR MODE TRC SCL X			FUNCTION   FUNCTION WIDTH	FUNCTION VALUE	<u>Auto</u> Man
	000 GHz 000 GHz	-1.74 dBm -1.54 dBm			
3		-1.04 UBIII			Freq Offset
4					0 Hz
6					
7 8					
9					
10					
MSG			STATU	s	

# Number of Hopping Frequencies 2(FH)

### Hopping mode : Enable & GFSK





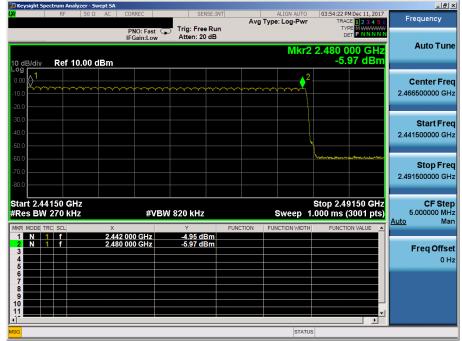
# Number of Hopping Frequencies 1(FH)

# Hopping mode : Enable & π/4DQPSK

<u>xi</u>	RF	50 Ω	AC	CORREC			SENSE		Avg		LIGN AUTO	TR/	PM Dec 11, 2017	Frequenc	у
				PNO: I IFGain	Fast 🖵 Low		: Free F en: 20 d				Mkr2	2.441	000 GHz	Auto 1	ſune
10 dB/div 0.00	Ret	10.00 c	01	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	ᠰ᠆ᠰ᠆ᠰ	łu – e –	~~~~	~~~~		¥~Y~Y			<b></b>	Center 2.416500000	
-30.0 -40.0 -50.0														Start 2.391500000	
-60.0	arder of the second	<sup>ا</sup> لەرغىيىتىل												Stop 2.441500000	-
Start 2.39 #Res BW					#VBV	/ 820	kHz			ş	Sweep 1	Stop 2.4 .000 ms	4150 GHz (3001 pts)	CF : 5.000000	Step MHz Man
MKR MODE TR	RC SCL		X	0.000 C		Y	47.40		NCTION	FUN	CTION WIDTH	FUNCT	ION VALUE		
1 N 1 2 N 1 3 4 5 5	f			2 000 GI 1 000 GI			17 dBn 09 dBn							Freq O	o <b>ffset</b> 0 Hz
6 7 8 9 9 10 10 10 10 10 10 10 10 10 10 10 10 10															
11															
MSG			_							_	STATU	6			
	_		_		_	_		_		_					_

# Number of Hopping Frequencies 2(FH)

# Hopping mode : Enable & π/4DQPSK





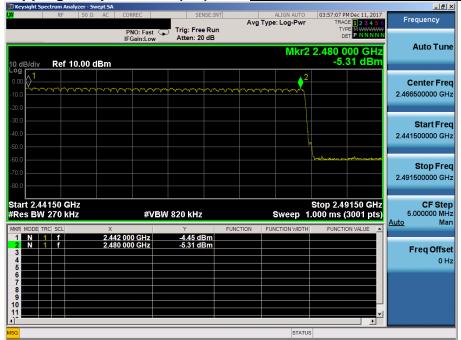
# Number of Hopping Frequencies 1(FH)

# Hopping mode : Enable & 8DPSK

Keysight Spectrum Analyzer -							
<b>LX</b> I RF 50 :	Ω AC CORREC	SENSE:IN	Avg Typ	ALIGN AUTO	TRAC	Dec 11, 2017	Frequency
10 dB/div Ref 10.00	PNO: Fast IFGain:Lov	Trig: Free Run Atten: 20 dB	1	Mkr2	2.441 0	00 GHz 33 dBm	Auto Tune
10.00 -10.0				~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	~~~~~	~~~~~~	Center Freq 2.416500000 GHz
-30.0 -40.0 -50.0							Start Freq 2.391500000 GHz
-60.0							<b>Stop Freq</b> 2.441500000 GHz
Start 2.39150 GHz         Stop 2.44150 GHz           #Res BW 270 kHz         #VBW 820 kHz         Sweep 1.000 ms (3001 pts)						150 GHz 3001 pts)	<b>CF Step</b> 5.000000 MHz <u>Auto</u> Man
MKR MODE TRC SCL           1         N         1         f           2         N         1         f           3         1         f         f           4         5         5         f           7         1         f         f           9         1         f         f           11         1         f         f	× 2.402 000 GHz 2.441 000 GHz	-4.48 dBm -4.33 dBm	FUNCTION FL	UNCTION WIDTH	FUNCTIO		Freq Offset 0 Hz
MSG				STATUS	6		

# Number of Hopping Frequencies 2(FH)

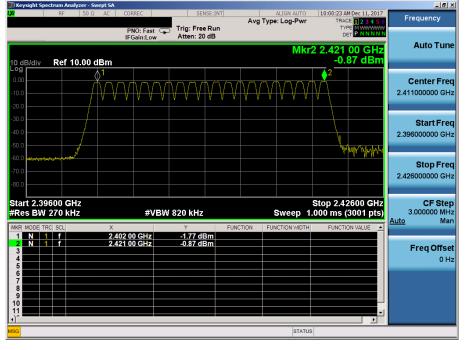
# Hopping mode : Enable & 8DPSK





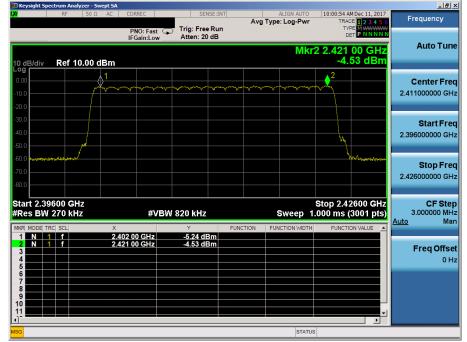
# Number of Hopping Frequencies 1(AFH)

# Hopping mode : Enable & GFSK



# Number of Hopping Frequencies 1(AFH)

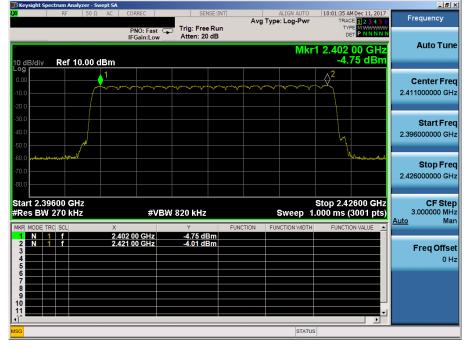
## Hopping mode : Enable & π/4DQPSK





# Number of Hopping Frequencies 1(AFH)

# Hopping mode : Enable & 8DPSK



# 6. Time of Occupancy (Dwell Time)

## 6.1 Test Setup

Refer to the APPENDIX I.

# 6.2 Limit

The maximum permissible time of occupancy is 400 ms within a period of 400 ms multiplied by the number of hopping channels employed.

# 6.3 Test Procedure

The dwell time was measured with a spectrum analyzer connected to the antenna terminal, while EUT had its hopping function enabled.

The spectrum analyzer is set to :

 Center frequency = 2441 MHz
 Span = zero

 RBW = 1 MHz (RBW shall be ≤ channel spacing and where possible RBW should be set >> 1 / T, where T is the expected dwell time per channel)

 VBW ≥ RBW
 Detector function = peak

 Trace = max hold

# 6.4 Test Results

FH mode

Hopping mode	Packet Type	Number of hopping Channels	Burst On Time (ms)	Period (ms)	Test Result (sec)
Enable	DH 5	79	2.880	3.750	0.307
	2 DH 5	79	2.880	3.750	0.307
	3 DH 5	79	2.880	3.750	0.307

AFH mode

Hopping mode	Packet Type	Number of hopping Channels	Burst On Time (ms)	Period (ms)	Test Result (sec)
Enable	DH 5	20	2.880	3.750	0.154
	2 DH 5	20	2.880	3.750	0.154
	3 DH 5	20	2.880	3.750	0.154

Note 1 : Dwell Time =  $0.4 \times$  Hopping channel × Burst ON time ×

((Hopping rate ÷ Time slots) ÷ Hopping channel)

- Time slots for DH5 = 6 slots (TX = 5 slot / RX = 1 slot)
- Hopping Rate = 1600 for FH mode & 800 for AFH mode

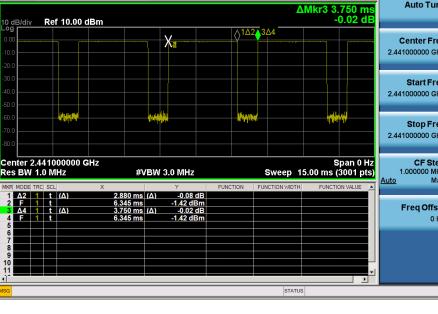
Note 2 : See next pages for actual measured spectrum plots.

Hopping mode : Enable & DH5

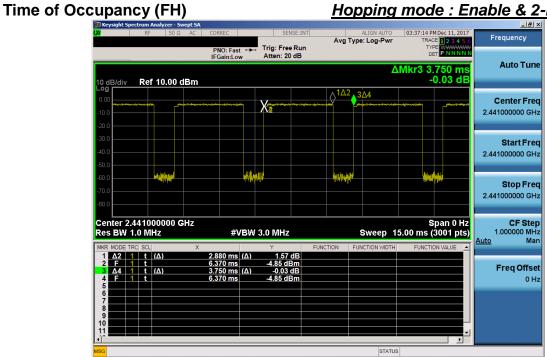




# Time of Occupancy (FH)



# Hopping mode : Enable & 2-DH5





Time of Occupancy (FH)

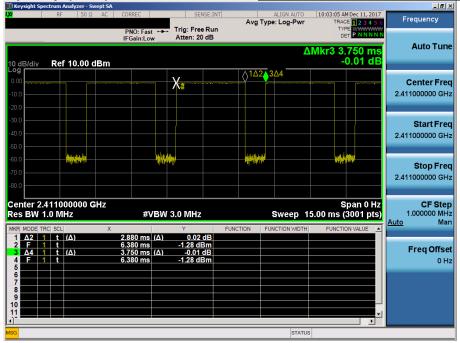
# Hopping mode : Enable & 3-DH5

#### - 8 × 03:37:57 PM Dec 11, 2017 Avg Type: Log-Pwr Frequency 234 Trig: Free Run Atten: 20 dB PNO: Fast IFGain:Low Auto Tune ΔMkr3 3.750 ms -0.03 dB Ref 10.00 dBm Center Freq 2.441000000 GHz Xs Start Freq 2.441000000 GHz (Trapp Stop Freq 2.441000000 GHz CF Step 1.000000 MHz Man Center 2.441000000 GHz Res BW 1.0 MHz Span 0 Hz Sweep 15.00 ms (3001 pts) #VBW 3.0 MHz <u>Auto</u> i (Δ) <u>(Δ)</u> -4.92 -4.92 dBm -0.03 dB -4.92 dBm 5 ms 0 ms (Δ) Freq Offset <u>(Δ)</u> 0 Hz -STATUS



# Hopping mode : Enable & DH5

# Time of Occupancy (AFH)



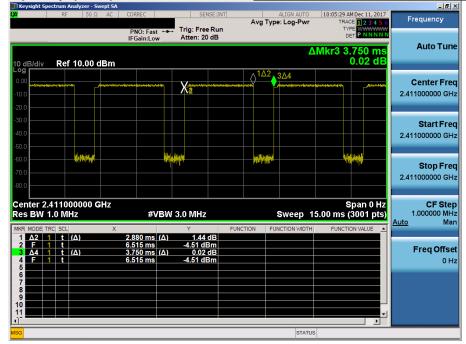
# Time of Occupancy (AFH)





Time of Occupancy (AFH)

# Hopping mode : Enable & 3-DH5





# 7. Transmitter Radiated Spurious Emissions and Conducted Spurious Emission

# 7.1 Test Setup

Refer to the APPENDIX I.

# 7.2 Limit

According to §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 section §15.209(a) is not required. In addition, radiated emission which in the restricted band, as define in section §15.205(a), must also comply the radiated emission limits specified in section §15.205(c))

According to § 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)	Limit (uV/m)	Measurement Distance (meter)
0.009 ~ 0.490	2400/F (kHz)	300
0.490 ~ 1705	24000/F (kHz)	30
1705 ~ 30.0	30	30
30 ~ 88	100 **	3
88 ~ 216	150 **	3
216 ~ 960	200 **	3
Above 960	500	3

\*\* Except as provided in 15.209(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. 15.231 and 15.241.

According to § 15.205(a) and (b), only spurious emissions are permitted in any of the frequency bands listed below :

MHz	MHz	MHz	MHz	GHz	GHz
0.009 ~ 0.110	8.41425 ~ 8.41475	108 ~ 121.94	1300 ~ 1427	4.5 ~ 5.15	14.47 ~ 14.5
0.495 ~ 0.505	12.29 ~ 12.293	123 ~ 138	1435 ~ 1626.5	5.35 ~ 5.46	15.35 ~ 16.2
2.1735 ~ 2.1905	12.51975 ~ 12.52025	149.9 ~ 150.05	1645.5 ~ 1646.5	7.25 ~ 7.75	17.7 ~ 21.4
4.125 ~ 4.128	12.57675 ~ 12.57725	156.52475 ~ 156.52525	1660 ~ 1710	8.025 ~ 8.5	22.01 ~ 23.12
4.17725 ~ 4.17775	13.36 ~ 13.41	156.7 ~ 156.9	1718.8 ~ 1722.2	9.0 ~ 9.2	23.6 ~ 24.0
4.20725 ~ 4.20775	16.42 ~ 16.423	162.0125 ~ 167.17	2200 ~ 2300	9.3 ~ 9.5	31.2 ~ 31.8
6.215 ~ 6.218	16.69475 ~ 16.69525	167.72 ~ 173.2	2310 ~ 2390	10.6 ~ 12.7	36.43 ~ 36.5
6.26775 ~ 6.26825	16.80425 ~ 16.80475	240 ~ 285	2483.5 ~ 2500	13.25 ~ 13.4	Above 38.6
6.31175 ~ 6.31225	25.5 ~ 25.67	322 ~ 335.4	2655 ~ 2900		
8.291 ~ 8.294	37.5 ~ 38.25	399.90 ~ 410	3260 ~ 3267		
8.362 ~ 8.366	73 ~ 74.6	608 ~ 614	3332 ~ 3339		
8.37625 ~ 8.38675	74.8 ~ 75.2	960 ~ 1240	3345.8 ~ 3358		
			3600 ~ 4400		

The field strength of emissions appearing within these frequency bands shall not exceed the limits shown in §15.209. At frequencies equal to or less than 1000 MHz, compliance with the limits in §15.209 shall be demonstrated using measurement instrumentation employing a CISPR quasi-peak detector. Above 1000 MHz, compliance with the emission limits in §15.209 shall be demonstrated based on the average value of the measured emissions. The provisions in §15.35 apply to these measurements.



# 7.3. Test Procedures

#### 7.3.1. Test Procedures for Radiated Spurious Emissions

- 1. The EUT is placed on a non-conductive table. For emission measurements at or below 1 GHz, the table height is 80 cm. For emission measurements above 1 GHz, the table height is 1.5 m. The table was rotated 360 degrees to determine the position of the highest radiation.
- 2. During performing radiated emission below 1 GHz, the EUT was set 3 meters away from the interference receiving antenna, which was mounted on the top of a variable-height antenna tower. During performing radiated emission above 1 GHz, the EUT was set 1 or 3 meter away from the interference-receiving antenna.
- 3. For measurements above 1GHz absorbers are placed on the floor between the turn table and the antenna mast in such a way so as to maximize the reduction of reflections. For measurements below 1 GHz, the absorbers are removed.
- 4. The antenna is a broadband antenna, and its height is varied from one meter to four meters above the ground to determine the maximum value of the field strength. Both horizontal and vertical polarizations of the antenna are set to make the measurement.
- 5. For each suspected emission, the EUT was arranged to its worst case and then the antenna was tuned to heights from 1 meter to 4 meters and the table was turned from 0 degrees to 360 degrees to find the maximum reading.
- 6. The test-receiver system was set to Peak Detect Function and Specified Bandwidth with Maximum Hold Mode.
- 7. If the emission level of the EUT in peak mode was 10 dB lower than the limit specified, then testing could be stopped and the peak values of the EUT would be reported. Otherwise the emissions that did not have 10 dB margin would be re-tested one by one using peak, quasi-peak or average method as specified and then reported in a data sheet.

Note: The radiated spurious emission was tested with below settings.

- Frequencies less than or equal to 1000 MHz The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 120 kHz for Quasi-peak detection (QP) at frequency below 1 GHz.
- Frequencies above 1000 MHz
   The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 1 MHz for Peak detection and frequency above 1 GHz.
   The result of Average measurement is calculated using PK result and duty correction factor.