

11. Time of Occupancy (Dwell Time) test

11.1 Test Description

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

Dwell time = time slot length * hop rate / number of hopping channels * 31.6s

with:

- hop rate = $1600 \times 1/s$ for DH1 packets = 1600 s^{-1}

- hop rate = $1600/3 \times 1/s$ for DH3 packets = 533.33 s^{-1}

- number of hopping channels = 79

- 31.6 s = 0.4 seconds multiplied by the number of hopping channels = 0.4 s * 79

The highest value of the dwell time is reported.

11.2 Test SET-UP (Block Diagram of Configuration)



Spectrum Analyzer

11.3 Measurement Equipment Used:

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

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

11.4 Test Requirements / Limits

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

Frequency hopping systems in the 2400-2483.5 MHz band shall use at least 15 channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Since the Bluetooth technology uses 79 channels this period is calculated to be 31.6seconds. Refer to attached data chart.

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11.5 Test result

GFSK:

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

Remark: The results of worst cased was recorded.

DH1:

.









DH5:





12. MAXIMUM PEAK OUTPUT POWER TEST

12.1 Measurement Procedure

a. Check the calibration of the measuring instrument(SA) using either an internal calibrator or a known signal from an external generator.

b. Turn on the EUT and connect it to measurement instrument. Then set it to any one convenient frequency within its operating range. Set a reference level on the measuring instrument equal to the highest peak value.

c. The center frequency of the spectrum analyzer is set to the fundamental frequency and using proper RBW and VBW setting.

d. Measure the captured power within the band and recording the plot.

e. Repeat above procedures until all frequencies required were complete.

12.2 Test SET-UP (Block Diagram of Configuration)



12.3 Measurement Equipment Used:

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

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



12.4Measurement Results:

Refer to attached data chart.

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

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





• 1Pk Max • 1D dBm • 10 dBm	-1.23 dBm 2,4410650 GHz
0 dBm	-1.23 dBm 2.4410650 GHz
0 dBm	
-10 dBm	
-20 dBm	
-30 dBm-	
-40 dBm	
-50 d8m-	
-60 dBm	
-70 dBm	
-80 dBm	
CF 2.441 GHz 691 pts	Span 9.0 MHz
Measuring	40

Spectrum

1





Spectrum Detector: Test By: Test Result: Modulation: PK Andy PASS Π/4-DQPSK Test Date : Temperature : Humidity : December 20, 2019 24 ℃ 55 %

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





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691 pts

-50 d8m-

-60 dBm-

-70 dBm

CF 2.48 GHz

Measuring...

Span 9.0 MHz



Spectrum Detector: Test By: Test Result: Modulation: PK Andy PASS 8DPSK Test Date : Temperature : Humidity : December 20, 2019 24 ℃ 55 %

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13. **Band EDGE test**

13.1 **Measurement Procedure**

For Conducted Test

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

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

For Radiated emission Test

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

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

The measurements were performed at the lower end of the 2.4GHz band. Use the following spectrum analyzer settings:

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

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

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

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

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13.2 Test SET-UP (Block Diagram of Configuration)

For Conducted Test



For Radiated emission Test



13.3 Measurement Equipment Used:

For Conducted Test

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

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

For Radiated emission Test

Item	Equipment	Manufacturer	Model No.	Serial No.	Characteristics	Last Cal.	Cal. Interval
1	Signal Analyzer	Rohde & Schwarz	FSV30	103040	9KHz-40GHz	05/23/2019	1 Year
2	Horn Antenna	Schwarzbeck	BBHA9120D	9120D-12 72	1GHz-18GHz	05/23/2019	1 Year
3	Power Amplifier	LUNAR EM	LNA1G18-40	J1010000 0081	1GHz-26.5GHz	05/23/2019	1 Year
4	Cable	H+S	CBL-26	N/A	1GHz-26.5GHz	05/23/2019	1 Year
5	Cable	H+S	CBL-26	N/A	1GHz-26.5GHz	05/23/2019	1 Year
6	Cable	H+S	CBL-26	N/A	1GHz-26.5GHz	05/23/2019	1 Year



13.4 Measurement Results:

Refer to attached data chart.

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

1. Conducted Test

For Non-Hopping Mode:

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

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Test plots of pi/4-DQPSK







Test plots of 8DPSK

Spect	rum							
Ref Le	vel 1	0.00 dB	m B SWT 19	B RB	W 100 kHz W 300 kHz Mod	e Auto FET		
1Pk M	lax			p5 - 16		a suco i i i		
0 dBm-						D3[1] M1[1]	M1	-51.36 dB -3.0100 MHz -5.93 dBm
-10 dBn	n		_				m	2.4021710 GHz
-20 d8n	n			-				
-30 dBn	n		-	-				
-40 d8n	n		-			m		por
-50 dBn	n			+	D3 DE			Land
60 d8n	and	~~~	-	maro	Am			
-70 dBn	n			-				
-80 dBn	n						-	
CF 2.4	GHz	2			691 pts			Span 10.0 MHz
larker	2							
Type	Ref	Trc	X-valu	ie	Y-value	Function	Fund	tion Result
M1		1	2,402	171 GHz	-5.93 dBm			
D3	M1 M1	1	-2.1	.01 MHz	-49.28 dB -51.36 dB			
	1.)(Measuring.		24.10.2017 14:15:30
Spect	rum							
Ref Le	vel 1	0.00 dB 30 d	m B SWT 19		W 100 kHz W 300 kHz Mod	e Auto FFT		
P1Pk M	lax							
- 28		MI	1			D3[1]		-58.06 dB 4.0230 MHz
0 dBm-		m		-		M1[1]		-0.85 dBm





For Hopping Mode:

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

Test plots of GFSK





Spect	rum					(B)
Ref Le	vel 10	m8b 00.0	BWT 10 up B VB	V 100 kHz	e Auto EET	
P1Pk Ma	ах	50 05	3WT 19 µs • VB	- 500 KH2 MIDU	B AULO FFI	
0 dBm		M1			D3[1] M1[1]	-52.79 dB 4.4280 MHz 0.42 dBm 2.4801570 GHz
-20 d8m	Y					
-30 dBm	-					
-40 dBm			1			
-50 dBm			1 h	ma	mm	mont
-60 dBm	1					
-70 dBm	-					
-80 dBm	+					
CF 2.48	335 GI	Hz	1	691 pts		Span 10.0 MHz
Marker						· · · · · · · · · · · · · · · · · · ·
Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1	8.81	1	2,480157 GHz	0.42 dBm		
D3	M1	1	4.428 MHz	-52.79 dB		
		1			Measuring	• (

Test plots of pi/4-DQPSK





Spect	rum							₩ ₩
Ref Le	vel 10	0.00 dBm	👄 RE	W 100 kHz				1
Att		30 dB	SWT 19 µs 🖷 VE	W 300 kHz Mod	e Auto FFT			
Physical Physics Ph	ах				a second second			-
		100			D3[1]		-56.0	01 dE
0 dBm-	_	MI					6.2370	MH
M	hill	m			M1[1]		-0.98	dBn
-10 dBm	-						2.4799980	GH
00 d0m								
-20 080			1					
-30 d8m			hand					
10.00								
~40 d8m	1							
-50 dBm			100	non -		_		_
						D3		0
-60 dBm	1		10	martin	man	mar	proven .	~
-70 d8m				_		_		
-80 dBm	-					-		
05.0.40		la la		601 sts			Comp 10.01	ALL IN
GF 2.40	533 G	12		091 pts			apan 10.01	1112
Type	Ref	Trc	X-value	Y-value	Function	Fun	ction Result	
M1		1	2.479998 GHz	-0.98 dBm				
D2	M1	1	3.5022 MHz	-59.39 dB				
D3	M1	1	6.237 MHz	-56.01 dB				
5	1.6	1			Measuring	ORRESIDE .	430	

Test plots of 8DPSK



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Spect	rum						l m →		
Ref Le	vel 10	0.00 dBm	ewr 10 us a VB	W 100 kHz W 300 kHz Mod	e Auto EET				
1Pk M	ах	30 05	3W1 19 ps - 40	W 500 KH2 M00	B AULU FFI				
0 dBrp-		M1			D3[1] M1[1]		-56.32 dB 5.5860 MHz -0.85 dBm		
-10 dBm	m			_			2.4798390 GHz		
-20 d8m						-			
-30 dBm	-		hung						
40 d8m						_			
-50 dBm	+		h	\wedge					
-60 dBm			10 5 2	mole	man	Am	man		
-70 dBm	-				_	_			
-80 dBm	+								
CF 2.4	835 G	Hz		691 pts	12. 12.		Span 10.0 MHz		
tarker		- 1			-				
M1	Ket	1	2,479839 GHz	-0.85 dBm	Function	Fun	iction Result		
D2 D3	M1 M1	1	3.6614 MHz 5.586 MHz	-58.70 d8 -56.32 dB					
		1] Measuring.		1 494		



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





Note:

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

*:Maximum data

x:Over limit 1:over margin

Operator: Washington





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

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

Operator: Washington

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No. N	٨k.	Freq.	Reading Level	Correct Factor	Measure- ment	Limit	Over		Antenna Height	Table Degree	
		MHz	dBuV	dB	dBuV/m	dBuV/m	dB	Detector	cm	degree	Comment
1 '	* 24	180.060	110.75	-18.03	92.72	74.00	18.72	peak		0	
2	24	83.500	59.99	-18.01	41.98	74.00	-32.02	peak		0	
3	24	183.500	43.25	-18.01	25.24	54.00	-28.76	AVG		0	
4	24	88.760	57.92	-17.98	39.94	74.00	-34.06	peak		0	
5	24	88.760	40.36	-17.98	22.38	54.00	-31.62	AVG		0	

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

Operator: Washington

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

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

Operator: Washington

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For Hopping Mode:



Note:

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

*:Maximum data x:Over limit 1:over margin Operator: Washington

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

*:Maximum data x:Over limit 1:over margin

Operator: Washington

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Note:

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

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

Operator: Washington

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

*:Maximum data x:Over limit 1:over margin Operator: Washington

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14. Antenna Application

14.1 Antenna requirement

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

FCC part 15C section 15.247 requirements:

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

14.2 Result

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





APPENDIX I (Photos of EUT)































5 0 9 N 5 . 4 3 11 12 13 100 cm 10 0 2 3 N 5







2 5 4 3 11 10 2 3 4 1 T 100cm N 4 3 64 16 100cm





















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