Report on the Radio Testing of:

HUE ENGINE

Model(s): 9290019683

In accordance with
47 CFR FCC Part 15C

PSB Singapore

Add value.
Inspire trust.

Prepared for:
Signify (China) Investment Co., Ltd.
Building 9, Lane 888, Tianlin Road, Minhang District Shanghai, China

COMMERCIAL-IN-CONFIDENCE

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RESPONSIBLE FOR	NAME	DATE	SIGNATURE
Project Management	Foo Kai Maun	16 Jul 2019	
Authorised Signatory	Quek Keng Huat	16 Jul 2019	

Signatures in this approval box have checked this document in line with the requirements of TÜV SÜD PSB document control rules.

EXECUTIVE SUMMARY
A sample of this product was tested and found to be compliant with the mentioned standard(s).

TÜV SÜD PSB

ilac-MRA

Accredited Laboratory SAC-SINGLAS

LA-2007-0380-A	LA-2007-0385-E
LA-2007-0381-F	LA-2007-0386-C
LA-2007-0382-B	LA-2010-0464-D
LA-2007-0383-G	LA-2018-0702-B
LA-2007-0384-G	LA-2018-0703-G

The results reported herein have been performed in accordance with the terms of accreditation under the Singapore Accreditation Council. Inspections/Calibrations/Tests marked "Not SAC-SINGLAS Accredited" in this Report are not included in the SAC-SINGLAS Accreditation Schedule for our inspection body/laboratory.

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Contents

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1 Report Summary

1.1 Report Modification Record

Alterations and additions to this report will be issued to the holders of each copy in the form of a complete document.

Issue	Description of Change	Date of Issue
1	First Issue	16 Jul 2019

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1.2 Introduction

Applicant	:	Signify (China) Investment Co., Ltd. Building 9, Lane 888, Tianlin Road, Minhang District Shanghai, China
Manufacturer	:	Same as applicant
Factory	:	Same as applicant
Model Number(s)	:	9290019683
Serial Number(s)	:	Conducted: EB2572 Radiated: A14E18
Number of Samples Tested	:	1
Test Sample(s) Condition	:	Good
Quotation Reference	:	5219630
Test Specification/Issue/Date	:	FCC 47 CFR Part 15C
Test Sample(s) Received Date	:	2 Jul 2019
Start of Test	:	10 Jul 2019
Finish of Test	:	12 Jul 2019

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1.3 Brief Summary of Results

A brief summary of the tests carried out in accordance with specifications as shown below.

Specification Clause	Test Description	Result	Comments/Base Standard
47 CFR FCC Part 15			
15.107(a), 15.207	Conducted Emissions	Pass	ANSI C63.4: 2014 ANSI C63.10: 2013 KDB 558074 D01 DTS Measurement Guidance V05R02: 2018
15.109(a), 15.205, 15.209	Radiated Emissions (Spurious Emissions Inclusive Restricted Bands Requirement)	Pass	ANSI C63.4: 2014 ANSI C63.10: 2013 KDB 558074 D01 DTS Measurement Guidance V05R02: 2019
15.247(a)(2)	Spectrum Bandwidth (6dB Bandwidth Measurement)	Pass	ANSI C63.10: 2013 KDB 558074 D01 DTS Measurement Guidance V05R02: 2019
15.247(b)(3)	Maximum Peak Power	Pass	ANSI C63.10: 2013 KDB 558074 D01 DTS Measurement Guidance V05R02: 2019
15.247(d)	RF Conducted Spurious Emissions (Non-Restricted Bands)	Pass	ANSI C63.10: 2013 KDB 558074 D01 DTS Measurement Guidance V05R02: 2019
15.247(d)	RF Conducted Spurious Emissions (Restricted Bands)	Pass	ANSI C63.10: 2013 KDB 558074 D01 DTS Measurement Guidance V05R02: 2019
15.247(d)	Band Edge Compliance (Conducted)	Pass	ANSI C63.10: 2013 KDB 558074 D01 DTS Measurement Guidance V05R02: 2019
15.247(d)	Band Edge Compliance (Radiated)	Pass	ANSI C63.10: 2013 KDB 558074 D01 DTS Measurement Guidance V05R02: 2019
15.247(e)	Peak Power Spectral Density	Pass	ANSI C63.10: 2013 KDB 558074 D01 DTS Measurement Guidance V05R02: 2019
15.35(c)	Duty Cycle Factor Computation	Not Applicable *See Note 4	ANSI C63.10: 2013 KDB 558074 D01 DTS Measurement Guidance V05R02: 2019
2.1091	Maximum Permissible Exposure	*See Note 5	

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Notes

1. All the measurements in section 15.247 were done based on conducted measurements except Band Edge Compliance (Radiated) test.

2. The EUT is a Class B device when in non-transmitting state and meets the 47 CFR FCC Part15B Class B requirements.

3. The maximum measured RF power of the Equipment Under Test is 7.32dBm.

4. The EUT was operated in continuous transmission, i.e. 100% duty cycle.

5. Specific Absorption Rate (SAR) exemption for this product was carried out. Please refer to Signify (China) Investment Co., Ltd. for more details.

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1.4 Product Information

1.4.1 Technical Description

Description	:	The Equipment Under Test(s) (EUT(s)) is a **HUE ENGINE.**
Microprocessor	:	Silicon Labs EFR32™
Operating Frequency	:	Bluetooth: 2.402GHz – 2.480GHz
Clock / Oscillator Frequency	:	40MHz
Modulation	:	Bluetooth: Gaussian Frequency Shift Keying (GFSK)
Antenna Gain	:	3.48 dBi
Port / Connectors	:	Nil
Rated Power	:	24Vdc
Accessories	:	Nil

1.4.2 Test Configuration and Modes of Operation

Mode(s)	**Description**
Maximum RF power transmission	The EUT was tested using fully charged batteries with DC voltage of 24V. The EUT was exercised in the mode, transmitting at lower, middle and upper channels as shown below one at a time with all supported modulation schemes were evaluated. For Band Edge Compliance, only lower and upper channels were evaluated.

Transmit Channel	Frequency (GHz)
Channel 0 (Lower Channel)	2.402
Channel 19 (Middle Channel)	2.440
Channel 39 (Upper Channel)	2.480

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1.5 Deviations from the Standard

Nil.

1.6 EUT Modification Record

No modifications were made.

1.7 Test Location(s)

TÜV SÜD PSB Pte Ltd
Electrical & Electronics Centre (EEC), Product Services,
No. 1 Science Park Drive, Singapore 118221

1.8 Test Facilities Registrations

Requirements	Registration Numbers
FCC	994109 (Test Firm Registration Number) SG0002 (Designation Number)
ISED	SGAP01 (CAB Identifier) Science Park 2932I-1 (3m and 10m Semi-Anechoic Chamber) International Business Park 2932N-1 (10m Semi-Anechoic Chamber)
VCCI	Science Park R-1335 (10m ANC) C-2306 (C.E @ Lab 3) T-1471 (Telecom Ports @ Lab 3) International Business Park R-3324 (10m ANC), G-203 (10mANC) C-4933 (C.E @ CEIBP) T-2403 (Telecom Ports @ CEIBP)
BSMI	SL2-IS-E-6001R *[CNS-13803 (ISM Equipment)]* SL2-IN-E-6001R *[CNS-13438 (IT Equipment)]* SL2-R1/R2-E-6001R *[CNS-13439 (Broadcast Receivers)]* SL2-A1-E-6001R *[CNS-13783-1 (Household Appliances)]* SL2-L1-E-6001R *[CNS-14115 (Lighting Equipment)]*
SABS	SABS/A-LAB/0029/2018

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1.9 Supporting Equipment

Equipment Description (Including Brand Name)	Model, Serial & FCC ID Number	Cable Description (List Length, Type & Purpose)
Lenovo R400 Laptop	M/N: 7440-C97 S/N: L3-ALB2G 09/05 FCC ID: DoC	Nil
Lenovo AC Adapter	M/N: 42T4432 S/N: 11S42T4432Z1ZF3J0170HL FCC ID: DoC	1.80m unshielded power cable
Aztech AC Adapter	M/N: LDC50H S/N: Nil FCC ID: DoC	1.00m unshielded power cable

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2 Test Details

2.1 Conducted Emissions

2.1.1 Test Limits

Frequency Range (MHz)	Limit Values (dBµV)	
	Quasi-peak (Q-P)	Average (AV)
0.15 - 0.5	66 – 56 *	56 – 46 *
0.5 - 5.0	56	46
5.0 - 30.0	60	50
* Decreasing linearly with the logarithm of the frequency		

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2.1.2 Test Setup

2.1.2.1 The EUT and supporting equipment were set up in accordance with the requirements of the standard as shown in the setup photos.

2.1.2.2 The power supply for the EUT was fed through a 50Ω/50μH EUT LISN, connected to filtered mains.

2.1.2.3 The RF OUT of the EUT LISN was connected to the EMI test receiver via a low-loss coaxial cable.

2.1.2.4 All other supporting equipment were powered separately from another LISN.

2.1.3 Test Method

2.1.3.1 The EUT was switched on and allowed to warm up to its normal operating condition.

2.1.3.2 A scan was made on the NEUTRAL line over the required frequency range using an EMI test receiver.

2.1.3.3 High peaks, relative to the limit line, were then selected.

2.1.3.4 The EMI test receiver was then tuned to the selected frequencies and the necessary measurements made with a receiver bandwidth setting of 9kHz. Both Quasi-peak and Average measurements were made.

2.1.3.5 The measurements were then repeated for the LIVE line .

Sample Calculation Example

At 20 MHz Q-P limit = 60.0 dBμV
Transducer factor of LISN, pulse limiter & cable loss at 20 MHz = 11.2 dB Q-P reading obtained directly from EMI Receiver = 40.0 dBμV (Calibrated for system losses)
Therefore, Q-P margin = 60.0 - 40.0 = 20.0 i.e. 20.0 dB below Q-P limit

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2.1.4 Test Results

Test Input Power	120V 60Hz	Temperature	23ºC
Line Under Test	AC Mains	Relative Humidity	60%
		Atmospheric Pressure	1030mbar
		Tested By	Chang Wai Kit
		Test Date	12 Jul 2019

Frequency (MHz)	Q-P Value (dBµV)	Q-P Limit (dBµV)	Q-P Margin (dB)	AV Value (dBµV)	AV Limit (dBµV)	AV Margin (dB)	Line	Channel (Worst)
0.5303	43.5	56.0	12.5	33.1	46.0	12.9	Neutral	19
0.5411	43.5	56.0	12.5	33.8	46.0	12.2	Live	19
0.5721	39.2	56.0	16.8	29.5	46.0	16.5	Live	19
0.6533	35.2	56.0	20.8	25.6	46.0	20.4	Live	19
0.6558	35.2	56.0	20.8	25.9	46.0	20.1	Neutral	19
0.8470	32.1	56.0	23.9	24.9	46.0	21.1	Live	19

Notes

1.	All possible modes of operation were investigated from 150kHz to 30MHz. Only the worst case emissions measured, using the correct CISPR detectors, are reported. All other emissions were relatively insignificant.
2.	A "positive margin" indicates a PASS as it refers to the margin present below the limit line at the particular frequency. Conversely, a "negative margin" indicates a FAIL.
3.	EMI receiver Resolution Bandwidth (RBW) and Video Bandwidth (VBW) settings: 9kHz - 30MHz RBW: 9kHz VBW: 30kHz

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2.2 Radiated Emissions (Spurious Emissions Inclusive Restricted Bands Requirement)

2.2.1 Test Limits

Frequency Range (MHz)	Quasi-Peak Limit Values (dBµV/m)
0.009 - 0.490 *	20 log [2400 / F (kHz)] @ 300m
0.490 - 1.705	20 log [24000 / F (kHz)] @ 30m
1.705 - 30.0	30.0 @ 30m
30 – 88	40.0 @ 3m
88 – 216	43.5 @ 3m
216 – 960	46.0 @ 3m
Above 960 *	54.0 @ 3m
* For frequency bands 9kHz – 90kHz, 110kHz – 490kHz and above 1GHz, average detector was used. A peak limit of 20dB above the average limit does apply.	

Restricted Bands

MHz			MHz			MHz			GHz		
0.090	-	0.110	16.42	-	16.423	399.9	-	410	4.5	-	5.15
0.495	-	0.505	16.69475	-	16.69525	608	-	614	5.35	-	5.46
2.1735	-	2.1905	16.80425	-	16.80475	960	-	1240	7.25	-	7.75
4.125	-	4.128	25.5	-	25.67	1300	-	1427	8.025	-	8.5
4.17725	-	4.17775	37.5	-	38.25	1435	-	1626.5	9.0	-	9.2
4.20725	-	4.20775	73	-	74.6	1645.5	-	1646.5	9.3	-	9.5
6.215	-	6.218	74.8	-	75.2	1660	-	1710	10.6	-	12.7
6.26775	-	6.26825	108	-	121.94	1718.8	-	1722.2	13.25	-	13.4
6.31175	-	6.31225	123	-	138	2200	-	2300	14.47	-	14.5
8.291	-	8.294	149.9	-	150.05	2310	-	2390	15.35	-	16.2
8.362	-	8.366	156.52475	-	156.52525	2483.5	-	2500	17.7	-	21.4
8.37625	-	8.38675	156.7	-	156.9	2690	-	2900	22.01	-	23.12
8.41425	-	8.41475	162.0125	-	167.17	3260	-	3267	23.6	-	24.0
12.29	-	12.293	167.72	-	173.2	3332	-	3339	31.2	-	31.8
12.51975	-	12.52025	240	-	285	3345.8	-	3358	36.43	-	36.5
12.57675	-	12.57725	322	-	335.4	3600	-	4400	Above 38.6		
13.36	-	13.41									

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2.2.2 Test Setup

2.2.2.1 The EUT and supporting equipment were set up in accordance with the requirements of the standard as shown in the setup photos.

2.2.2.2 The filtered power supply for the EUT and supporting equipment were tapped from the appropriate power sockets located on the turntable.

2.2.2.3 The relevant broadband antenna was set at the required test distance away from the EUT and supporting equipment boundary.

2.2.3 Test Method

2.2.3.1 The EUT was switched on and allowed to warm up to its normal operating condition.

2.2.3.2 A prescan was carried out to pick the worst emission frequencies from the EUT. For EUT which is a portable device, the prescan was carried out by rotating the EUT through three orthogonal axes to determine which altitude and equipment arrangement produces such emissions.

2.2.3.3 The test was carried out at the selected frequency points obtained from the pre-scan. Maximization of the emissions, was carried out by rotating the EUT, changing the antenna polarization, and adjusting the antenna height in the following manner:

a. Vertical or horizontal polarisation (whichever gave the higher emission level over a full rotation of the EUT) was chosen.
b. The EUT was then rotated to the direction that gave the maximum emission.
c. Finally, the antenna height was adjusted to the height that gave the maximum emission

2.2.3.4 A Quasi-peak measurement was made for that frequency point if it was less than or equal to 1GHz.For frequency point in range of 9kHz – 90kHz, 110kHz – 49k0kHz and above 1GHz, both Peak and Average measurements were carried out.

2.2.3.5 The measurements were repeated for the next frequency point, until all selected frequency points were measured.

2.2.3.6 The frequency range covered was from the lowest radio frequency signal generated from the EUT, without going below 9kHz to 10th harmonics of the EUT fundamental frequency, using the loop antenna for frequency below 30MHz, Bi-log antenna for frequencies from 30MHz up to 1GHz, and the Horn antenna above 1GHz.

Sample Calculation Example

At 300 MHz	Q-P limit = 46.0 dBμV/m
Log-periodic antenna factor & cable loss at 300 MHz = 18.5 dB Q-P reading obtained directly from EMI Receiver = 40.0 dBμV/m (Calibrated level including antenna factors & cable losses)	
Therefore, Q-P margin = 46.0 - 40.0 = 6.0	i.e. 6.0 dB below Q-P limit

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2.2.5 Test Results

Test Input Power	24Vdc	Temperature	24ºC
Test Distance	3m (<30MHz) 3m (≥30MHz – 25GHz)	Relative Humidity	60%
		Atmospheric Pressure	1030mbar
		Tested By	Dylan Lin
		Test Date	12 Jul 2019

Spurious Emissions ranging from 9kHz – 30MHz (for 9kHz – 90kHz, 110kHz – 490kHz) *See Note 2 & 3

Freq (GHz)	Peak Value (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	AV Value (dBµV/m)	AV Limit (dBµV/m)	AV Margin (dB)	Height (cm)	Azimuth (Degrees)	Pol (H/V)	Ch
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Spurious Emissions ranging from 9kHz – 30MHz *See Note 2 & 3

Frequency (MHz)	Q-P Value (dBµV/m)	Q-P Limit (dBµV/m)	Q-P Margin (dB)	Height (cm)	Azimuth (Degrees)	Pol (H/V)	Channel
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Spurious Emissions ranging from 30MHz – 1GHz

Frequency (MHz)	Q-P Value (dBµV/m)	Q-P Limit (dBµV/m)	Q-P Margin (dB)	Height (cm)	Azimuth (Degrees)	Pol (H/V)	Channel (Worst)
45.1850	33.8	40.0	6.2	100	276	V	19
51.7490	29.4	40.0	10.6	299	188	V	19
63.4080	27.0	40.0	13.0	100	294	V	19
138.4530	28.8	43.5	14.7	200	360	H	19
151.5810	27.8	43.5	15.7	200	155	H	19
575.7910	34.1	46.0	11.9	100	189	V	19

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Spurious Emissions above 1GHz – 25GHz

Freq (GHz)	Peak Value (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	AV Value (dBµV/m)	AV Limit (dBµV/m)	AV Margin (dB)	Height (cm)	Azimuth (Degrees)	Pol (H/V)	Ch
4.8029	48.1	74.0	25.9	39.6	54.0	14.4	300	17	H	0
4.8101	46.9	74.0	27.1	42.0	54.0	12.0	300	355	V	0
6.0000	44.8	74.0	29.2	37.6	54.0	16.4	100	301	V	0
7.2072	46.0	74.0	28.0	35.6	54.0	18.4	100	42	H	0
14.1380	52.5	74.0	21.5	41.2	54.0	12.8	300	203	H	0
17.7273	55.2	74.0	18.8	43.7	54.0	10.3	100	252	H	0

Spurious Emissions above 1GHz – 25GHz

Freq (GHz)	Peak Value (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	AV Value (dBµV/m)	AV Limit (dBµV/m)	AV Margin (dB)	Height (cm)	Azimuth (Degrees)	Pol (H/V)	Ch
1.4141	40.1	74.0	33.9	39.0	54.0	15.0	398	39	V	19
1.5080	44.5	74.0	29.5	30.8	54.0	23.2	398	359	V	19
1.5937	38.3	74.0	35.7	33.1	54.0	20.9	398	359	V	19
2.1249	45.4	74.0	28.6	30.3	54.0	23.7	398	169	V	19
2.2401	40.2	74.0	33.8	32.4	54.0	21.6	300	340	V	19
4.5005	44.3	74.0	29.7	41.0	54.0	13.0	200	253	V	19

Spurious Emissions above 1GHz – 25GHz

Freq (GHz)	Peak Value (dBµV/m)	Peak Limit (dBµV/m)	Peak Margin (dB)	AV Value (dBµV/m)	AV Limit (dBµV/m)	AV Margin (dB)	Height (cm)	Azimuth (Degrees)	Pol (H/V)	Ch
1.5981	49.8	74.0	24.2	30.6	54.0	23.4	200	344	V	39
2.2399	46.1	74.0	27.9	29.1	54.0	24.9	102	334	V	39
4.5005	45.9	74.0	28.1	41.1	54.0	12.9	200	256	V	39
4.8101	44.4	74.0	29.6	40.9	54.0	13.1	200	40	V	39
4.9601	51.0	74.0	23.0	45.6	54.0	8.4	102	313	H	39
6.0000	53.2	74.0	20.8	38.6	54.0	15.4	200	106	V	39

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Notes

1.	All possible modes of operation were investigated. Only the worst case emissions measured, using the correct CISPR detectors, are reported. All other emissions were relatively insignificant.
2.	"--" indicates no emissions were found and shows compliance to the limits.
3.	The measurement was done at 3m. The measured results were extrapolated to the specified test limits as specified in § 15.209 (a) based on 40dB/decade.
4.	Quasi-peak measurement was used for frequency measurement up to 1GHz. Average and peak measurements were used for emissions above 1GHz. The average measurement was done by averaging over a complete cycle of the pulse train, including the blanking interval as the pulse train duration does not exceed 0.1 second.
5.	A "positive margin" indicates a PASS as it refers to the margin present below the limit line at the particular frequency. Conversely, a "negative margin" indicates a FAIL.
6.	EMI receiver Resolution Bandwidth (RBW) and Video Bandwidth (VBW) settings: 30MHz - 1GHz RBW: 120kHz VBW: 1MHz >1GHz RBW: 1MHz VBW: 3MHz
7.	The upper frequency of radiated emission investigations was according to requirements stated in Section 15.33 (a) for intentional radiators & Section 15.33 (b) for unintentional radiators.
8.	The channel in the table refers to the transmit channel of the EUT.

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2.3 Spectrum Bandwidth (6db Bandwidth Measurement)

2.3.1 Test Limits

The EUT shows compliance to the requirements of this section, which states that the minimum bandwidth of the EUT employing digital modulation techniques shall be at least 500kHz.

2.3.2 Test Setup

2.3.2.1 The EUT and supporting equipment were set up as shown in the set up photo.

2.3.2.2 The power supply for the EUT was connected to a filtered mains.

2.3.2.3 The RF antenna connector was connected to the spectrum analyser via a low-loss coaxial cable.

2.3.2.4 The resolution bandwidth (RBW) and the video bandwidth (VBW) of the spectrum analyser were respectively set to 100kHz and 3 times of RBW.

2.3.2.5 All other supporting equipment were powered separately from another filtered mains.

2.3.3 Test Method

2.3.3.1 The EUT was switched on and allowed to warm up to its normal operating condition. The EUT was then configured to operate in the test mode at lower channel.

2.3.3.2 The center frequency of the spectrum analyser was set to the transmitting frequency with the frequency span wide enough to capture the 6dB bandwidth of the transmitting frequency.

2.3.3.3 The spectrum analyser was set to max hold to capture the transmitting frequency. The signal capturing was continuous until no further changes were observed.

2.3.3.4 The peak of the transmitting frequency was detected with the marker peak function of the spectrum analyser. The frequencies below the 6dB peak frequency at lower (f_L) and upper (f_H) sides of the transmitting frequency were marked and measured by using the marker-delta function of the spectrum analyser.

2.3.3.5 The 6dB bandwidth of the transmitting frequency is the frequency difference between the marked lower and upper frequencies, $| f_H - f_L |$.

2.3.3.6 The measurements were repeated if the EUT supports more than one modulation and data rate.

2.3.3.7 The measurements were repeated with the transmitting frequency was set to middle and upper channel respectively.

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2.3.4 Test Results

Test Input Power	24Vdc	Temperature	24ºC
Attached Plots	1 – 3	Relative Humidity	60%
		Atmospheric Pressure	1030mbar
		Tested By	Chang Wai Kit
		Test Date	10 Jul 2019

Channel	Channel Frequency (GHz)	6dB Bandwidth (MHz) *See Note 1	Limit (kHz)
Lower	2.402	1.383	≥ 500
Middle	2.440	1.323	≥ 500
Upper	2.480	1.380	≥ 500

Notes

1.	Only the largest measured bandwidths were reported. Refer to plots for all measured bandwidth.

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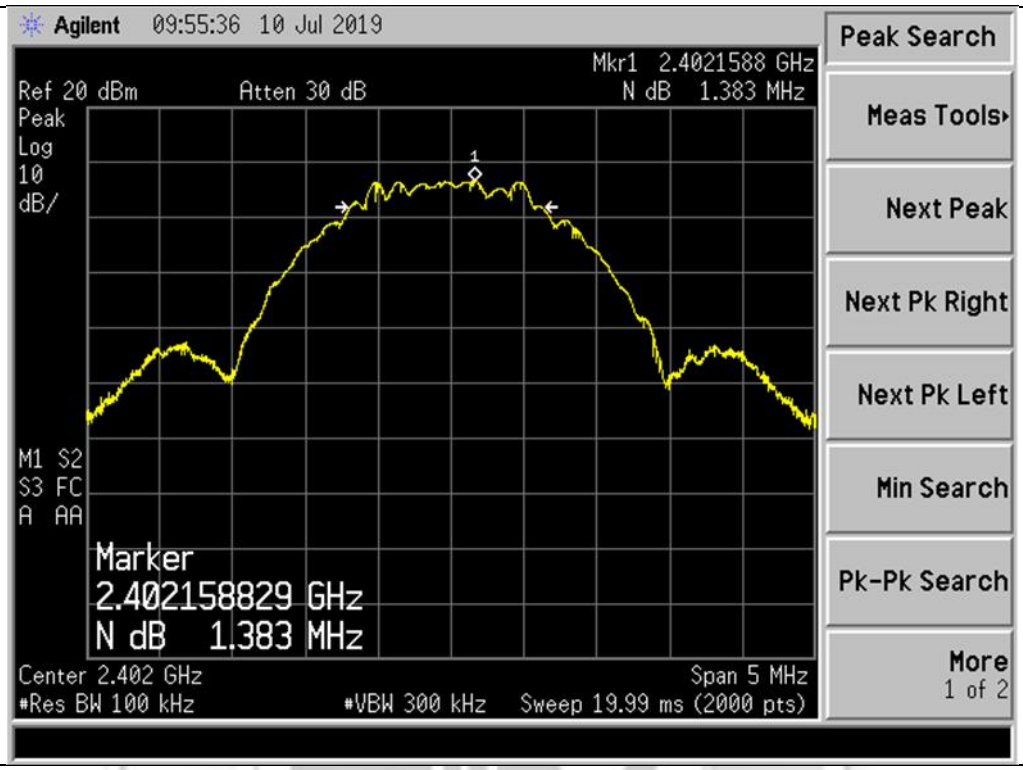
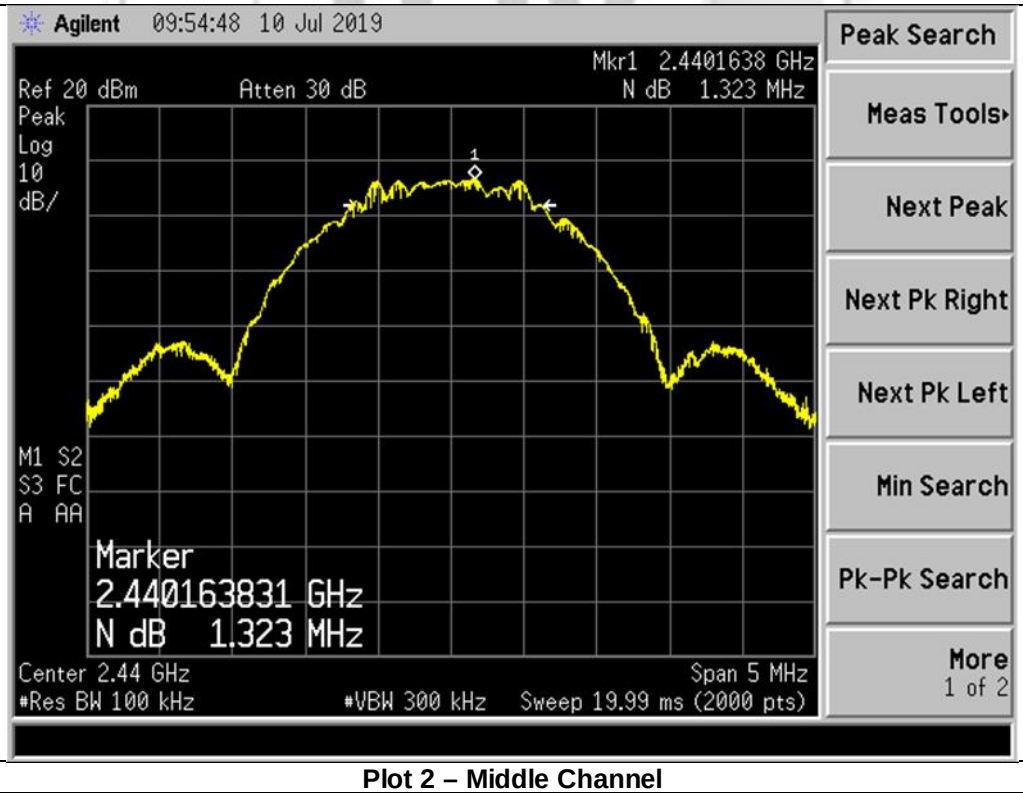
Spectrum Bandwidth (6dB Bandwidth Measurement) Plots



Plot 1 – Lower Channel



Plot 2 – Middle Channel

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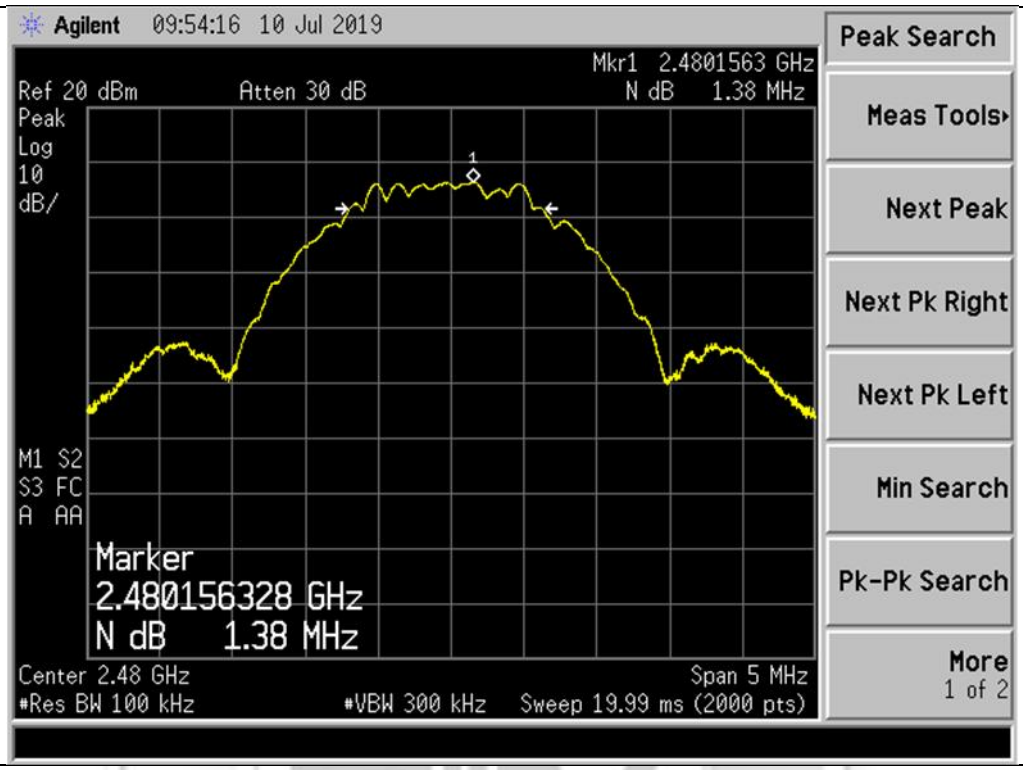
Spectrum Bandwidth (6dB Bandwidth Measurement) Plots



Plot 3 – Upper Channel

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2.4 Maximum Peak Power

2.4.1 Test Limits

The EUT shows compliance to the requirements of this section, which states the maximum peak power of the EUT employing digital modulation shall not exceed 1W (30dBm).

2.4.2 Test Setup

2.4.2.1 The EUT and supporting equipment were set up as shown in the setup photo.

2.4.2.2 The power supply for the EUT was connected to a filtered mains.

2.4.2.3 The RF antenna connector was connected to a power meter.

2.4.2.4 All other supporting equipment were powered separately from another filtered mains.

2.4.3 Test Method

2.4.3.1 The EUT was switched on and allowed to warm up to its normal operating condition. The EUT was then configured to operate in the test mode at lower channel.

2.4.3.2 The maximum peak power of the transmitting frequency was detected and recorded.

2.4.3.3 The measurements were repeated if the EUT supports more than one modulation and data rate.

2.4.3.4 The measurement was repeated with the transmitting frequency was set to middle channel and upper channel respectively.

PSB Singapore

2.4.4 Test Results

Test Input Power	24Vdc	Temperature	24ºC
Antenna Gain	3.48 dBi	Relative Humidity	60%
		Atmospheric Pressure	1030mbar
		Tested By	Chang Wai Kit
		Test Date	10 Jul 2019

Channel	Channel Frequency (GHz)	Maximum Peak Power (W) *See Note 1	Limit (W)
Lower	2.402	0.0050	1.0
Middle	2.440	0.0054	1.0
Upper	2.480	0.0053	1.0

Notes

1.	Only the highest measured peak power were reported.

PSB Singapore

2.5 RF Conducted Spurious Emissions (Non-Restricted Bands)

2.5.1 Test Limits

The EUT shows compliance to the requirements of this section, which states in any 100kHz bandwidth outside the frequency band in which the spread spectrum intentional radiator (EUT) is operating, the radio frequency power that is produced by the EUT shall be at least 20dB below that in the 100kHz bandwidth within the band that contains the highest level of desired power.

2.5.2 Test Setup

2.5.2.1 The EUT and supporting equipment were set up as shown in the setup photo.

2.5.2.2 The power supply for the EUT was connected to a filtered mains.

2.5.2.3 The RF antenna connector was connected to the spectrum analyser via a low-loss coaxial cable.

2.5.2.4 The resolution bandwidth (RBW) and the video bandwidth (VBW) of the spectrum analyser were respectively set to 100kHz and 3 times of RBW.

2.5.2.5 All other supporting equipment were powered separately from another filtered mains.

2.5.3 Test Method

2.5.3.1 The EUT was switched on and allowed to warm up to its normal operating condition. The EUT was then configured to operate in the test mode, with transmitting frequency at lower channel.

2.5.3.2 The start and stop frequencies of the spectrum analyser were set to 30MHz and 10GHz.

2.5.3.3 The spectrum analyser was set to max hold to capture any spurious emissions within the span. The signal capturing was continuous until no further spurious emissions were detected.

2.5.3.4 The measurements were repeated with frequency span was set from 10GHz to 25GHz.

2.5.3.5 The measurements were repeated if the EUT supports more than one modulation and data rate.

2.5.3.6 The measurements were repeated with the transmitting frequency was set to middle channel and upper channel respectively.

PSB Singapore

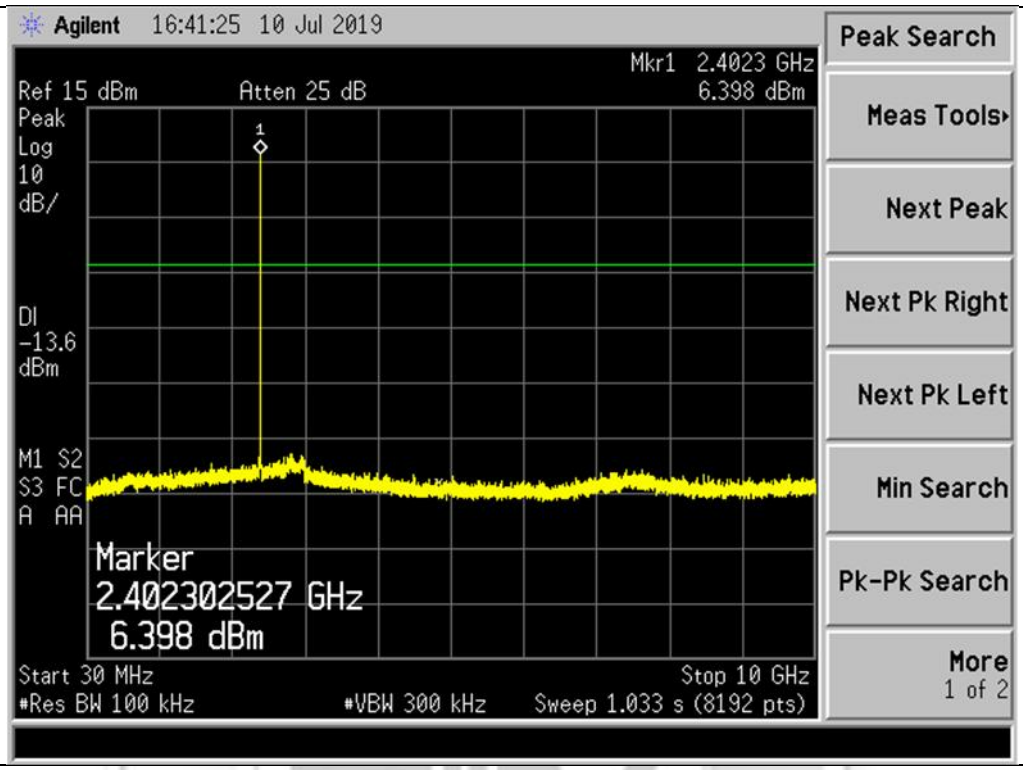
2.5.4 Test Results

Test Input Power	24Vdc	Temperature	24ºC
Attached Plots	4 – 9	Relative Humidity	60%
		Atmospheric Pressure	1030mbar
		Tested By	Chang Wai Kit
		Test Date	10 Jul 2019

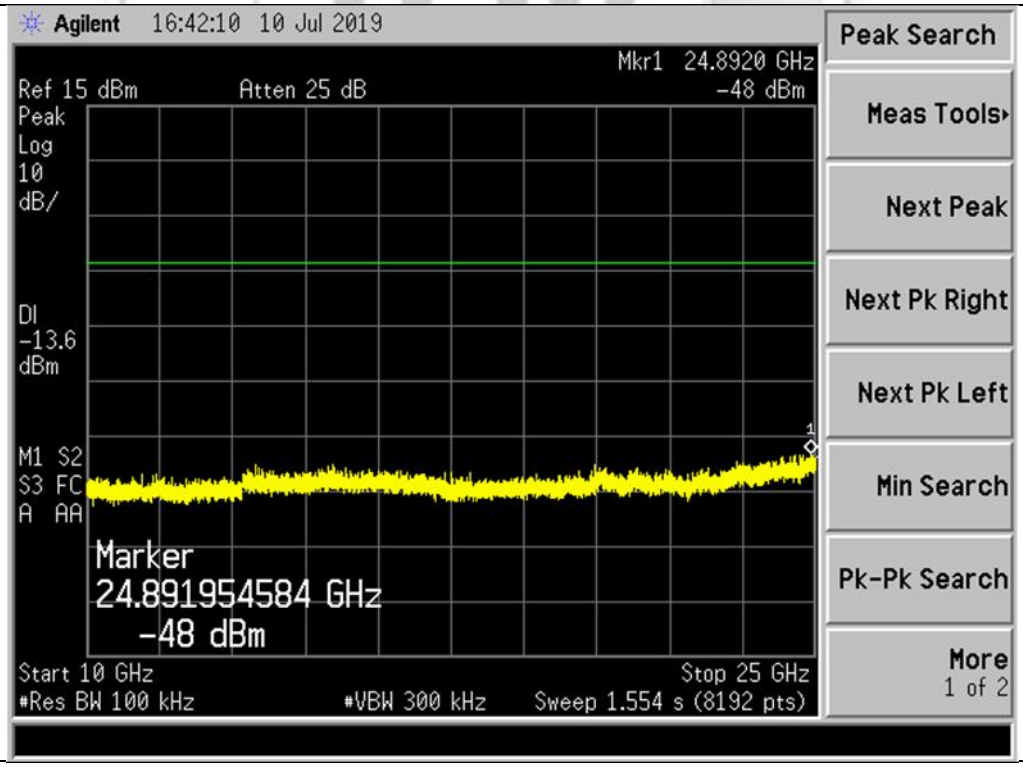
All spurious signals found were below the specified limit. Please refer to the attached plots.

PSB Singapore

RF Conducted Spurious Emissions (Non-Restricted Bands) Plots



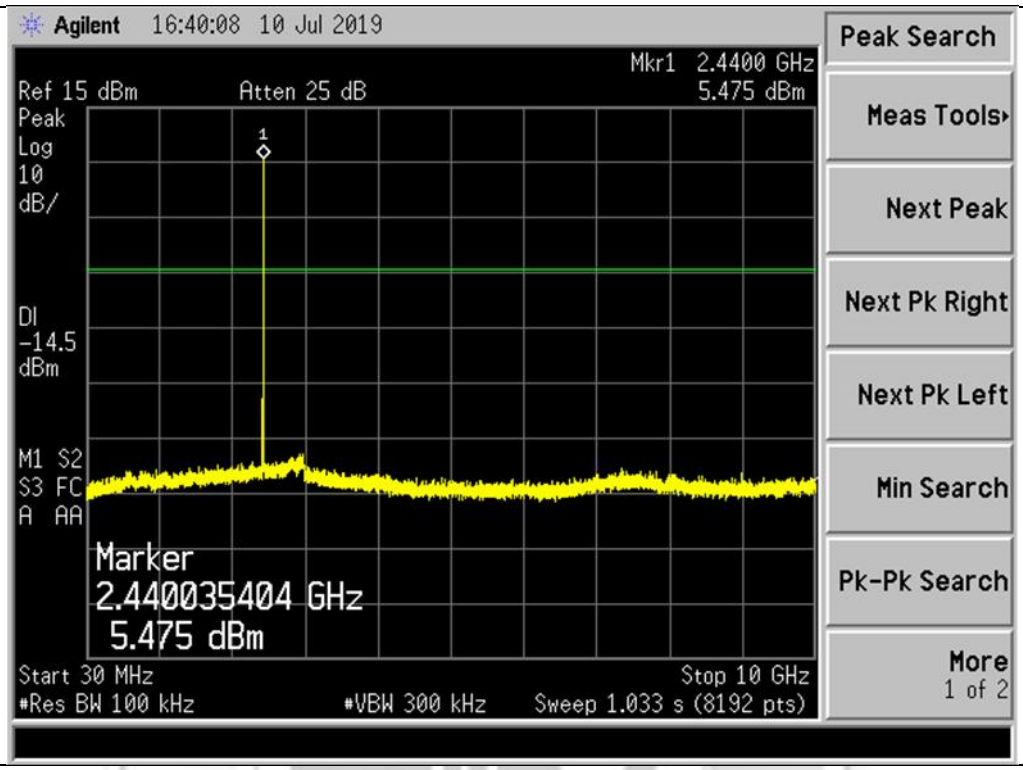
Plot 4 – Lower Channel



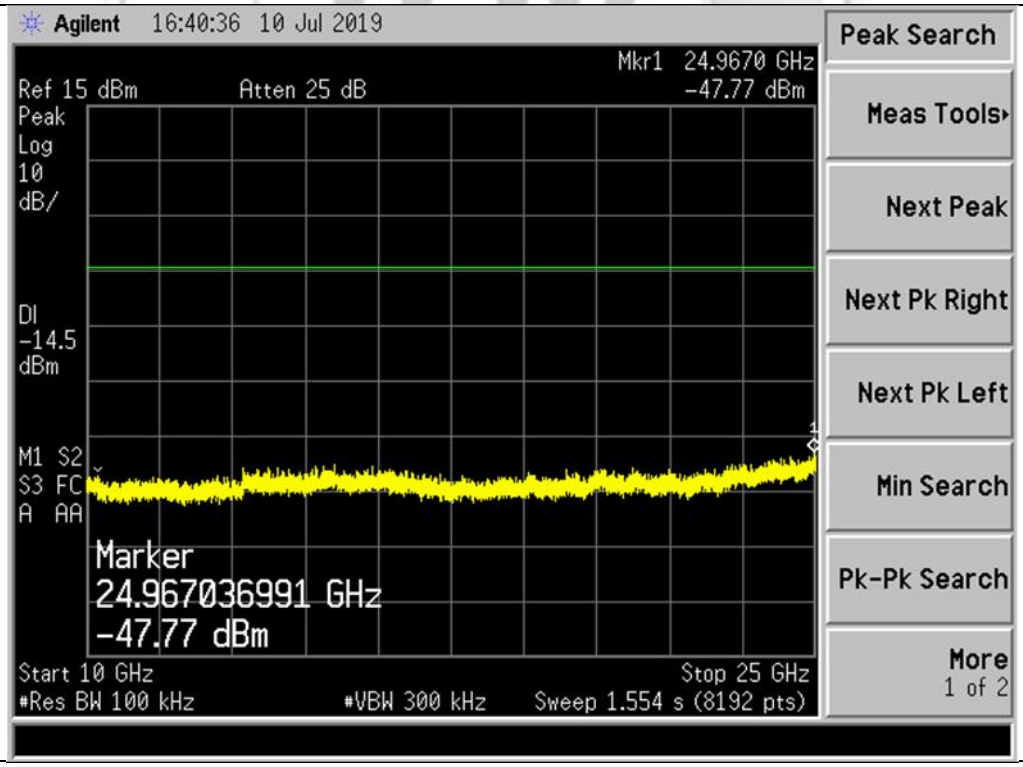
Plot 5 – Lower Channel

PSB Singapore

RF Conducted Spurious Emissions (Non-Restricted Bands) Plots



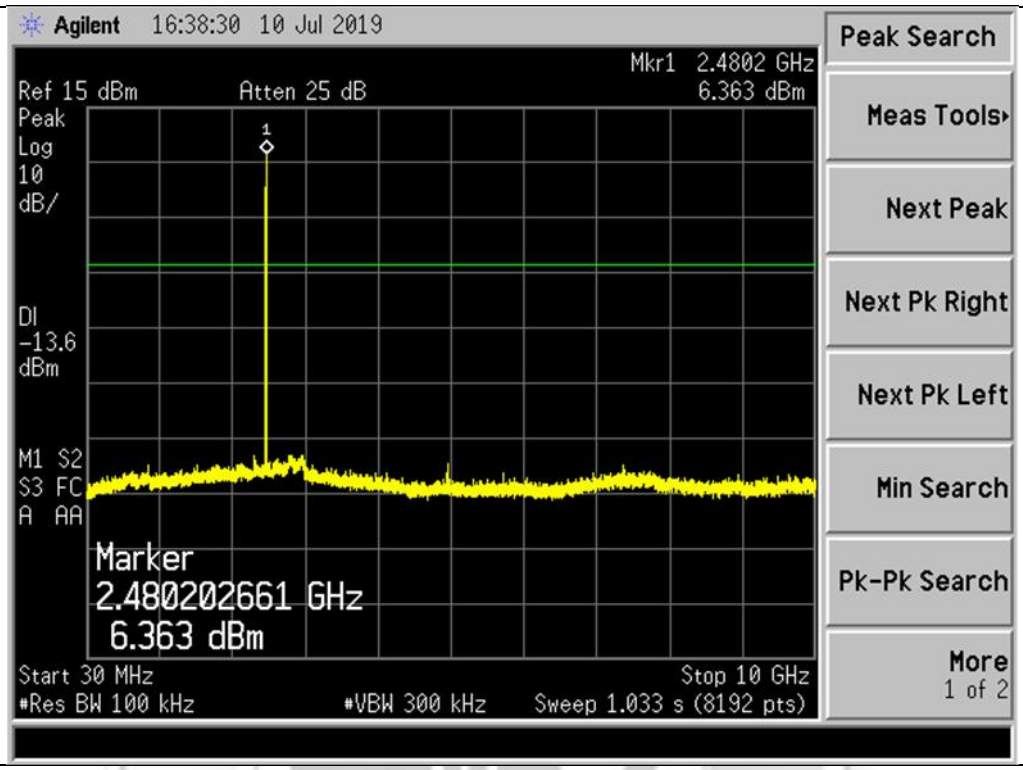
Plot 6 – Middle Channel



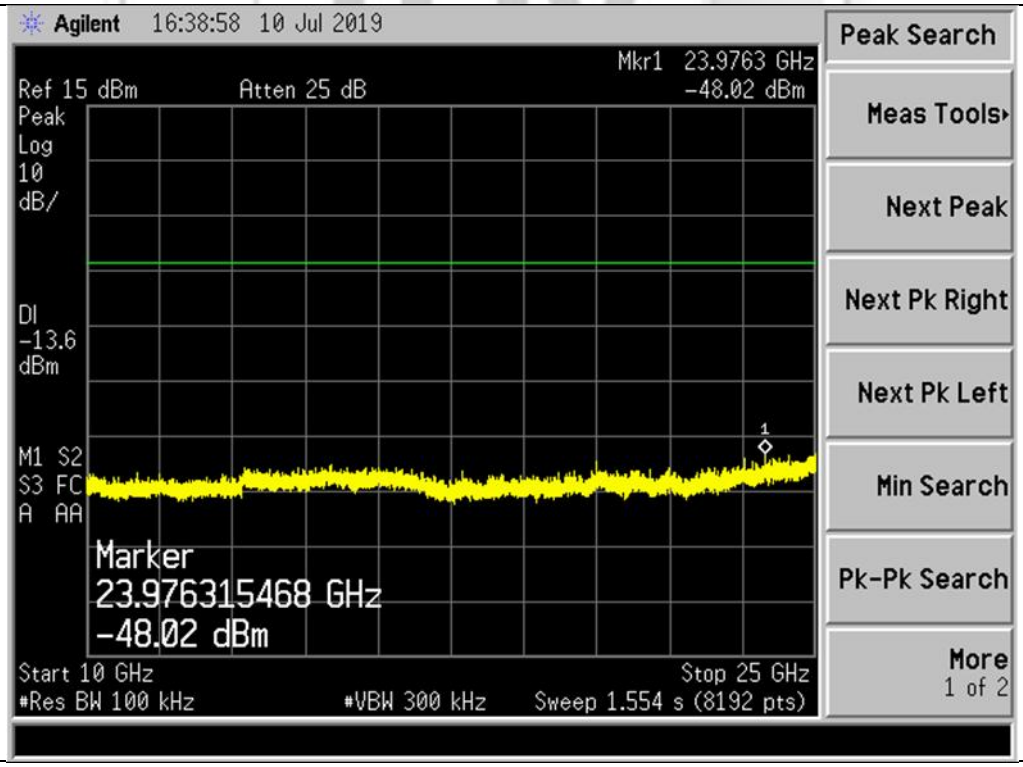
Plot 7 – Middle Channel

PSB Singapore

RF Conducted Spurious Emissions (Non-Restricted Bands) Plots



Plot 8 – Upper Channel



Plot 9 – Upper Channel

PSB Singapore

2.6 RF Conducted Spurious Emissions (Restricted Bands)

2.6.1 Test Limits

The EUT shows compliance to the requirements of this section, which states that emissions which fall in the restricted bands must comply with the radiated emission limits specified in the table below:

Frequency Range (MHz)	EIRP (dBm)	Radiated Emissions (dBµV/m)
0.009 – 0.490	-6.7 – (-41.4) **	67.6 – 20logF* @ 300m **
0.490 – 1.705	-41.4 – (-52.3) **	87.6 – 20logF* @ 30m **
1.705 – 30	-45.7	29.5 @ 30m
30 - 88	-55.2	40.0 @ 3m
88 - 216	-51.7	43.5 @ 3m
216 - 960	-49.2	46.0 @ 3m
>960	-41.2 ***	54.0 @ 3m ***
* F is frequency in kHz.		
** Decreasing linearly with the logarithm of the frequency.		
*** Above 1GHz, a peak limit of 20dB above the average limit does apply.		

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MHz			MHz			MHz			GHz		
0.090	-	0.110	16.42	-	16.423	399.9	-	410	4.5	-	5.15
0.495	-	0.505	16.69475	-	16.69525	608	-	614	5.35	-	5.46
2.1735	-	2.1905	16.80425	-	16.80475	960	-	1240	7.25	-	7.75
4.125	-	4.128	25.5	-	25.67	1300	-	1427	8.025	-	8.5
4.17725	-	4.17775	37.5	-	38.25	1435	-	1626.5	9.0	-	9.2
4.20725	-	4.20775	73	-	74.6	1645.5	-	1646.5	9.3	-	9.5
6.215	-	6.218	74.8	-	75.2	1660	-	1710	10.6	-	12.7
6.26775	-	6.26825	108	-	121.94	1718.8	-	1722.2	13.25	-	13.4
6.31175	-	6.31225	123	-	138	2200	-	2300	14.47	-	14.5
8.291	-	8.294	149.9	-	150.05	2310	-	2390	15.35	-	16.2
8.362	-	8.366	156.52475	-	156.52525	2483.5	-	2500	17.7	-	21.4
8.37625	-	8.38675	156.7	-	156.9	2690	-	2900	22.01	-	23.12
8.41425	-	8.41475	162.0125	-	167.17	3260	-	3267	23.6	-	24.0
12.29	-	12.293	167.72	-	173.2	3332	-	3339	31.2	-	31.8
12.51975	-	12.52025	240	-	285	3345.8	-	3358	36.43	-	36.5
12.57675	-	12.57725	322	-	335.4	3600	-	4400	Above 38.6		
13.36	-	13.41									

PSB Singapore

2.6.2 Test Setup

2.6.2.1 The EUT and supporting equipment were set up as shown in the setup photo.

2.6.2.2 The power supply for the EUT was connected to a filtered mains.

2.6.2.3 The RF antenna connector was connected to the spectrum analyser via a low-loss coaxial cable.

2.6.2.4 The resolution bandwidth (RBW) of the spectrum analyser was set to the following settings. The video bandwidth (VBW) was set to at least three times of the RBW.

Frequency (MHz)	RBW (kHz)
0.009 – 0.150	0.2
0.150 – 30.0	9.0
30.0 - 1000	100.0
> 1000	1000.0

2.6.2.5 The detector of the spectrum analyser was set to peak detection mode.

2.6.2.6 All other supporting equipment were powered separately from another filtered mains.

2.6.3 Test Method

Measurement in the range 9kHz – 1000MHz

2.6.3.1 The EUT was switched on and allowed to warm up to its normal operating condition. The EUT was then configured to operate in the test mode, with the transmitting frequency was set to lower channel.

2.6.3.2 The start and stop frequencies of the spectrum analyser were set according to the supported RBW.

2.6.3.3 The spectrum analyser was set to max hold to capture any spurious emissions within the span. The signal capturing was continuous until no further spurious emissions were detected. The antenna gain of the EUT was added to the captured spurious emissions.

2.6.3.4 No further measurement was required if all the captured emissions complied to the limits. Else, the spectrum analyser was set to zoom to the captured emission with the detector of the spectrum analyser was set to quasi-peak. The emission level of the captured frequency was measured.

2.6.3.5 The measurements were repeated until all the captured emissions which exceeding the limits were measured.

2.6.3.6 The measurements were repeated if the EUT supports more than one modulation and data rate.

2.6.3.7 The measurements were repeated with the transmitting frequency was set to middle and upper channel respectively

PSB Singapore

Measurement above 1000MHz

2.6.3.8 The EUT was switched on and allowed to warm up to its normal operating condition. The EUT was then configured to operate in the test mode, with the transmitting frequency was set to lower channel.

2.6.3.9 The start and stop frequencies of the spectrum analyser were set according to the supported frequency band of the set RBW with the number of points in a sweep was set to equal or greater than 2 times of the ratio of span over RBW.

2.6.3.10 The detector of the spectrum analyser was set to power average (RMS) mode with the sweep time was set to equal or greater than 10 times of the product of number of measurement points in a sweep and transmission symbol time.

2.6.3.11 The spectrum analyser was then allowed to capture any spurious emissions within a single sweep. The peak marker function of the spectrum analyser was used to locate the highest power level. The antenna gain of the EUT was added to the captured spurious emissions.

2.6.3.12 The measurements were repeated until all the required frequency bands were measured.

2.6.3.13 The measurements were repeated if the EUT supports more than one modulation and data rate.

2.6.3.14 The measurements were repeated with the transmitting frequency was set to middle and upper channel respectively.

2.6.3.15 The measurements were repeated with the detector of the spectrum analyser was set to peak detecting mode. The sweep time was set to auto coupler.

PSB Singapore

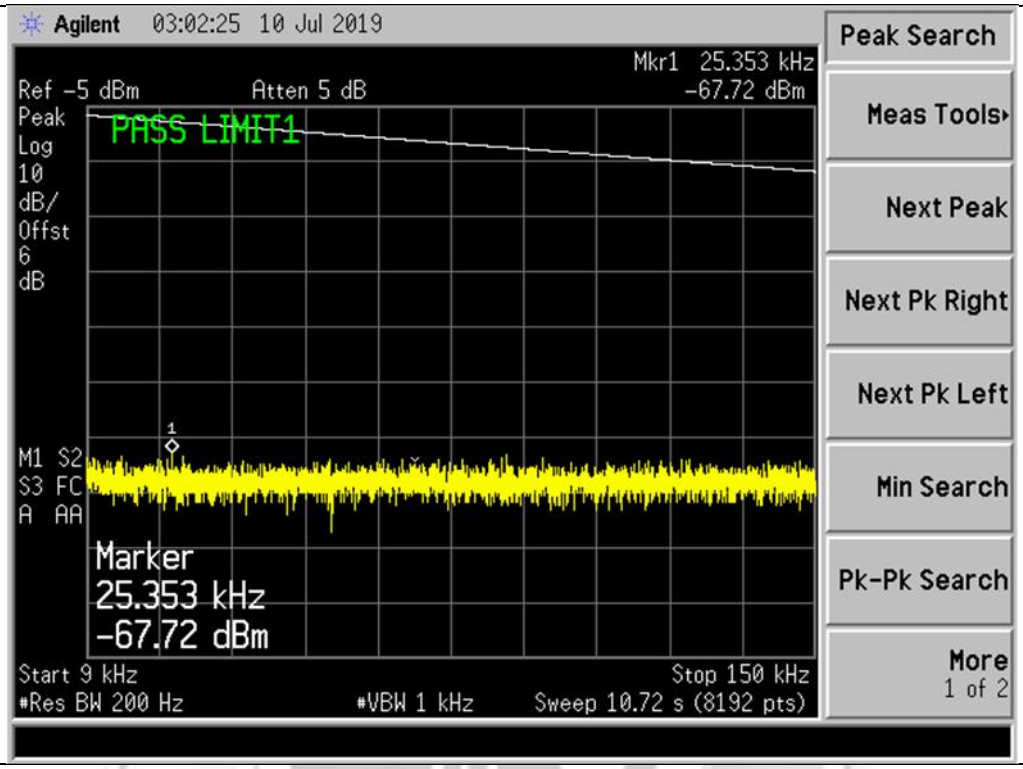
2.6.4 Test Results

Test Input Power	24Vdc	Temperature	24ºC
Attached Plots	10 – 29 (Peak)	Relative Humidity	60%
		Atmospheric Pressure	1030mbar
		Tested By	Chang Wai Kit
		Test Date	10 Jul 2019

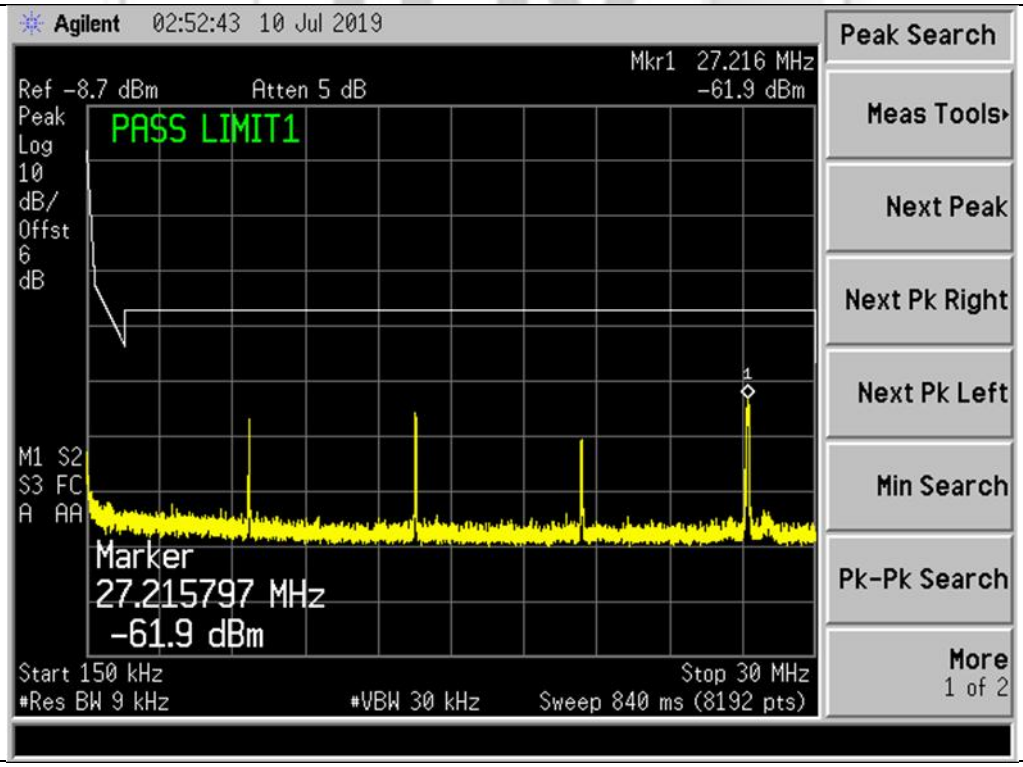
All spurious signals found were below the specified limit. Please refer to the attached plots.

PSB Singapore

RF Conducted Spurious Emissions (Restricted Bands) Plots – Peak



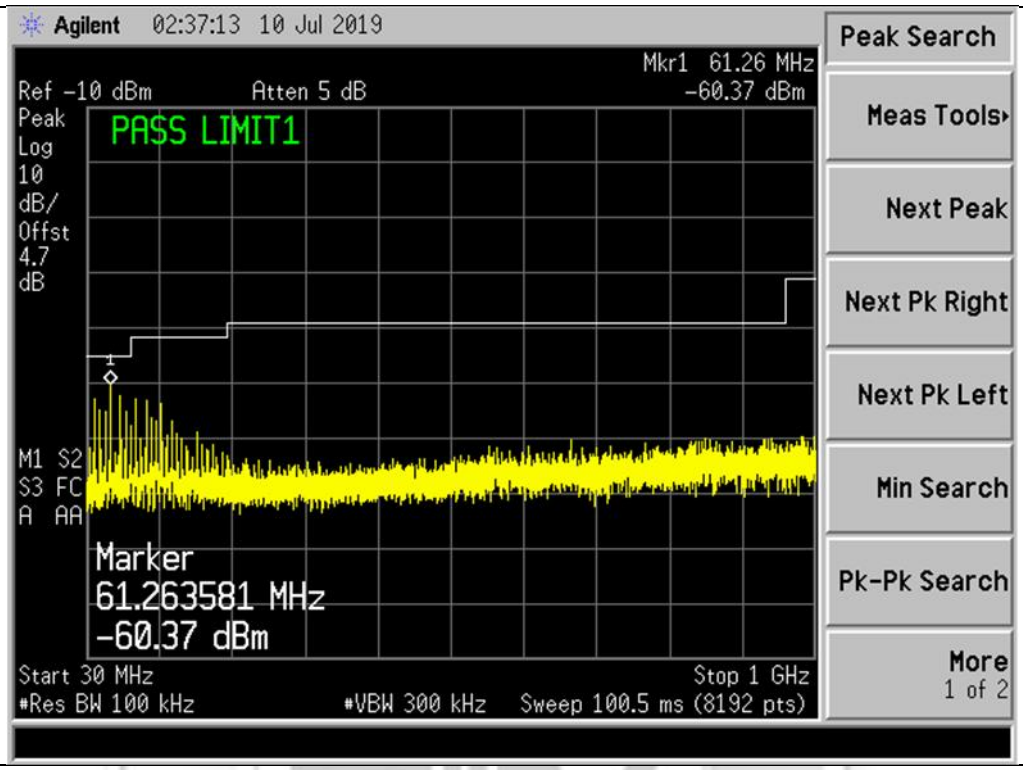
Plot 10 – Lower Channel



Plot 11 – Lower Channel

PSB Singapore

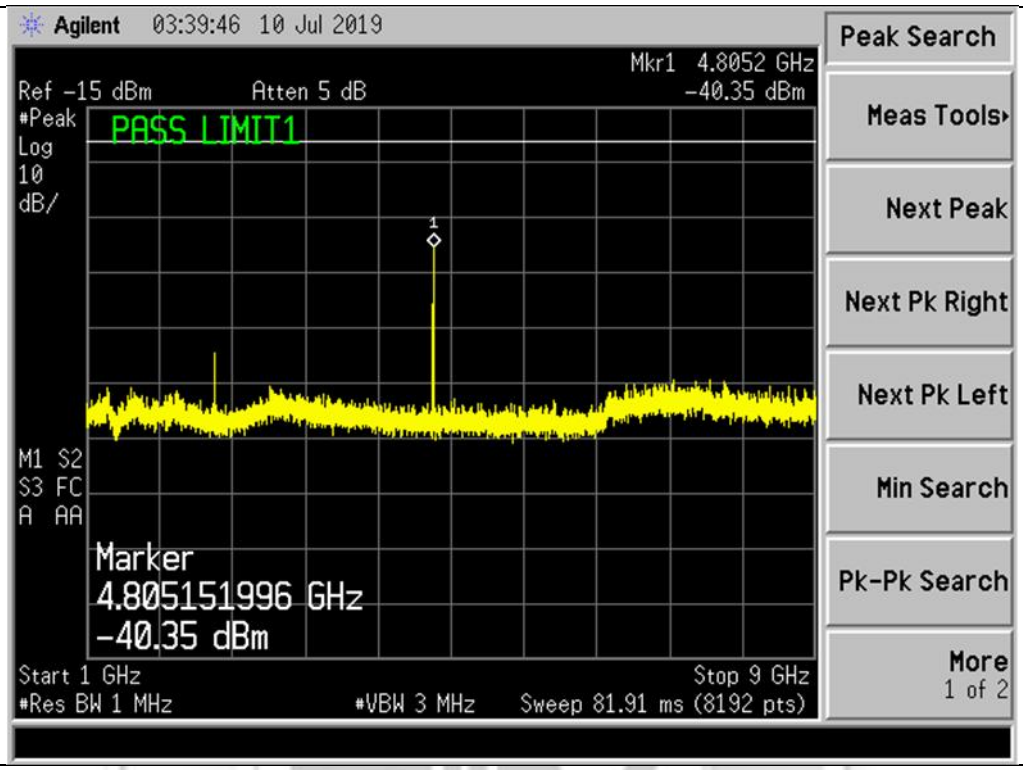
RF Conducted Spurious Emissions (Restricted Bands) Plots – Peak



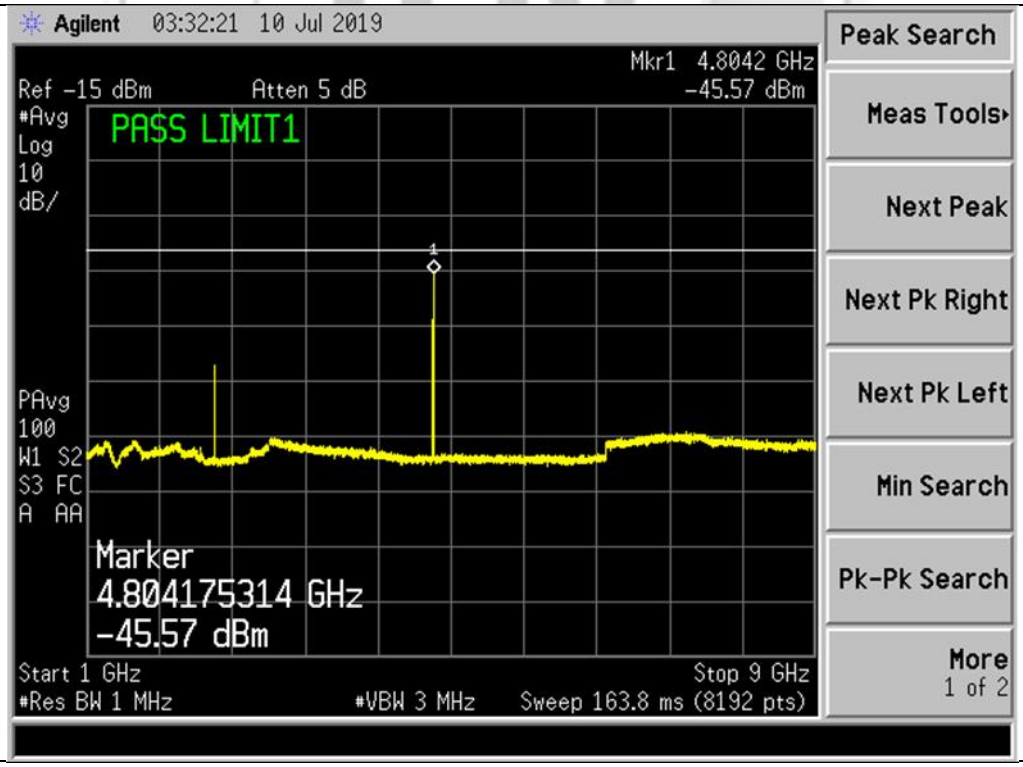
Plot 12 – Lower Channel

PSB Singapore

RF Conducted Spurious Emissions (Restricted Bands) Plots – Peak & Average



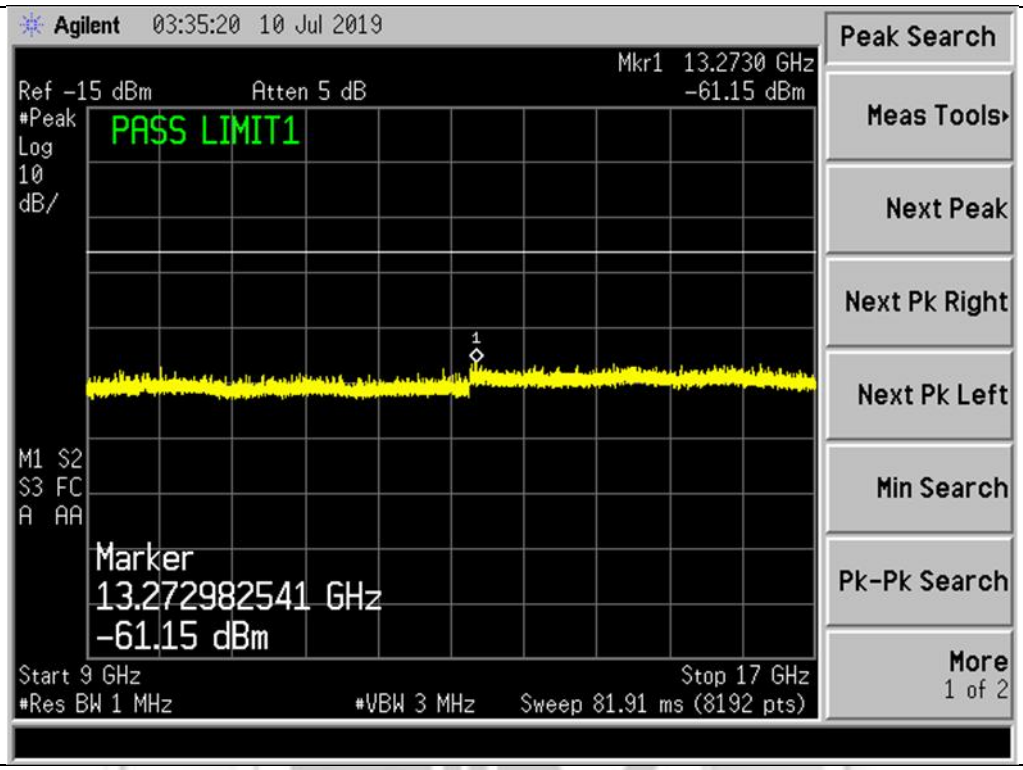
Plot 13 – Lower Channel



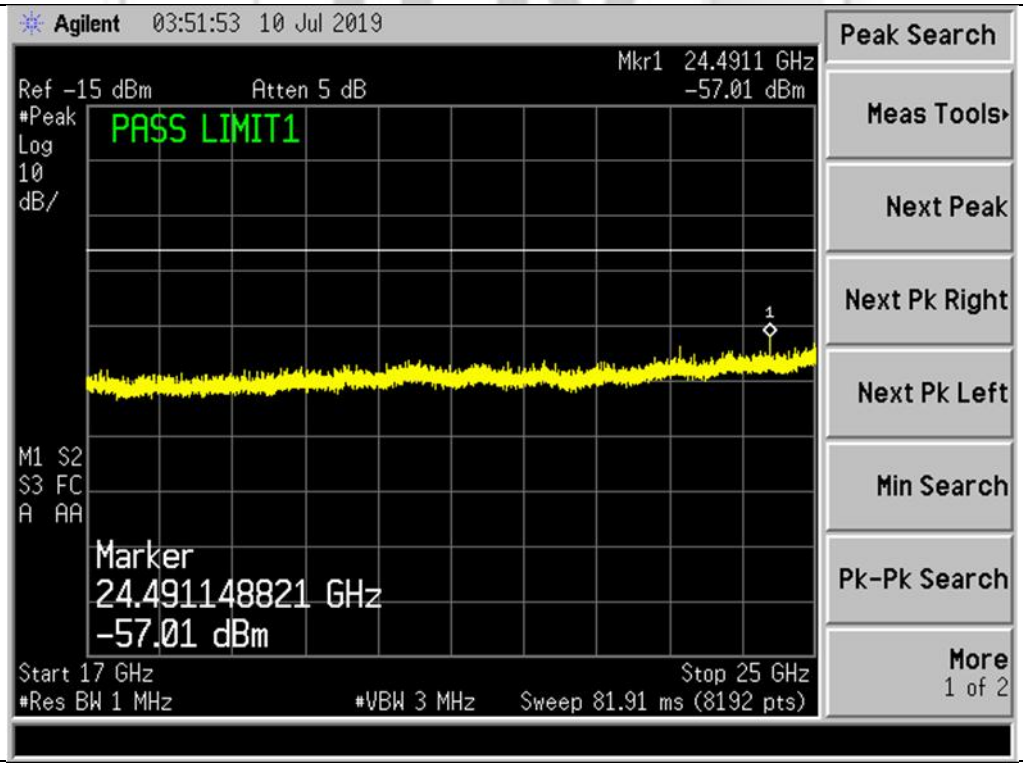
Plot 14 – Lower Channel

PSB Singapore

RF Conducted Spurious Emissions (Restricted Bands) Plots – Peak



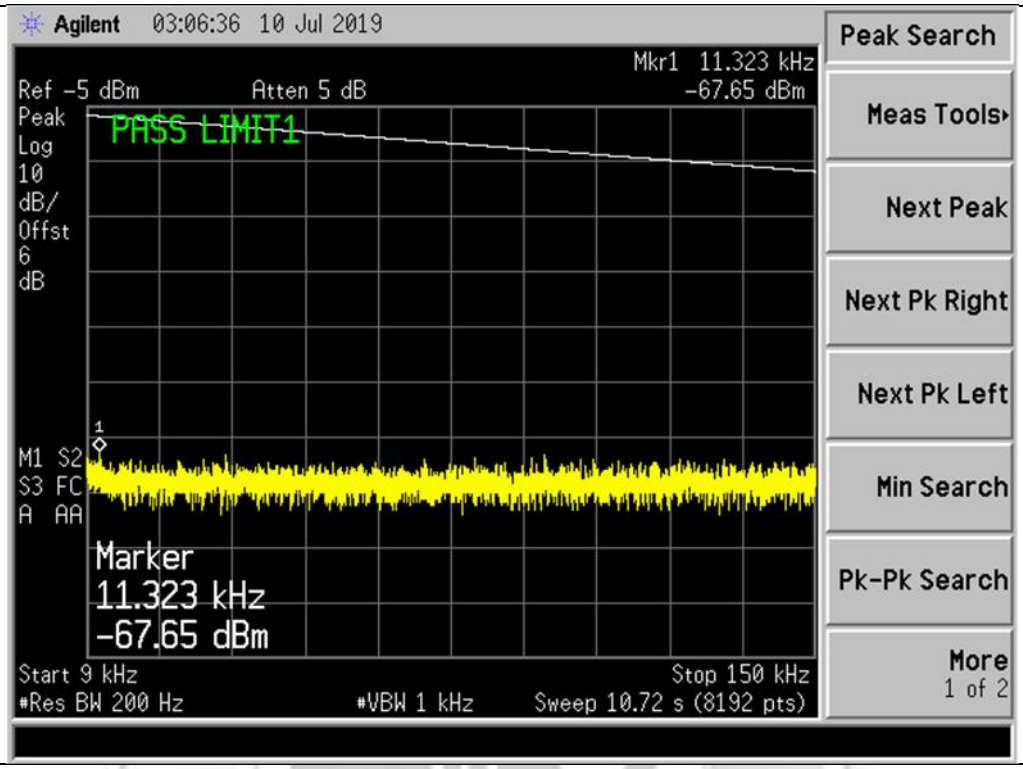
Plot 15 – Lower Channel



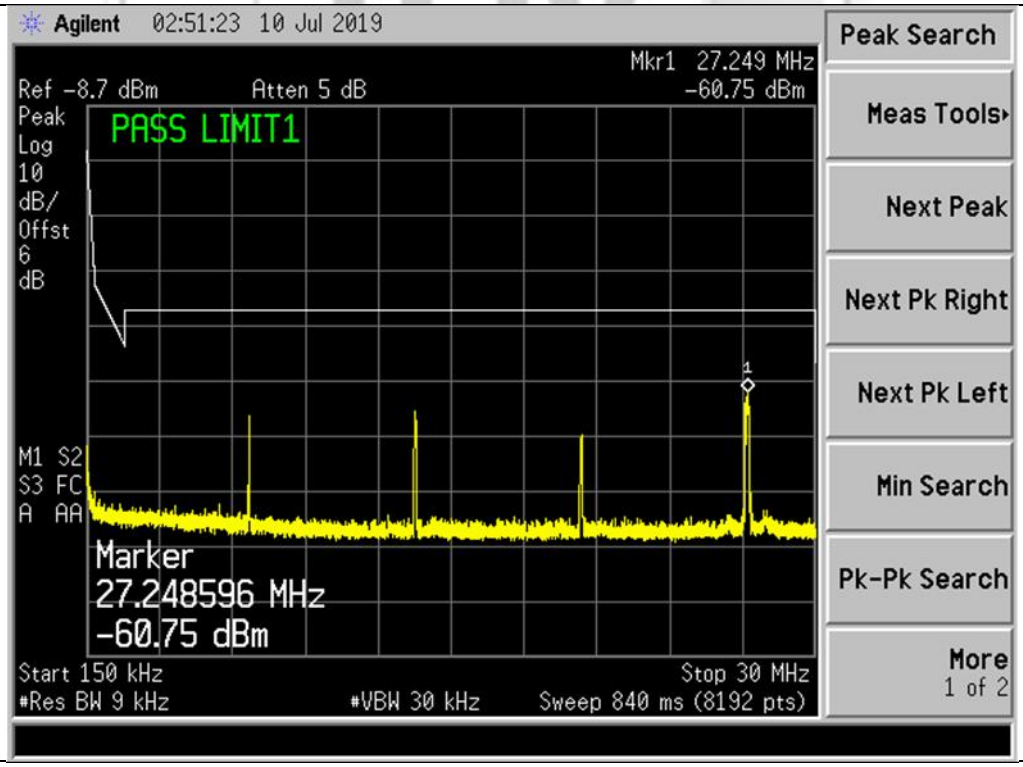
Plot 16 – Lower Channel

PSB Singapore

RF Conducted Spurious Emissions (Restricted Bands) Plots – Peak



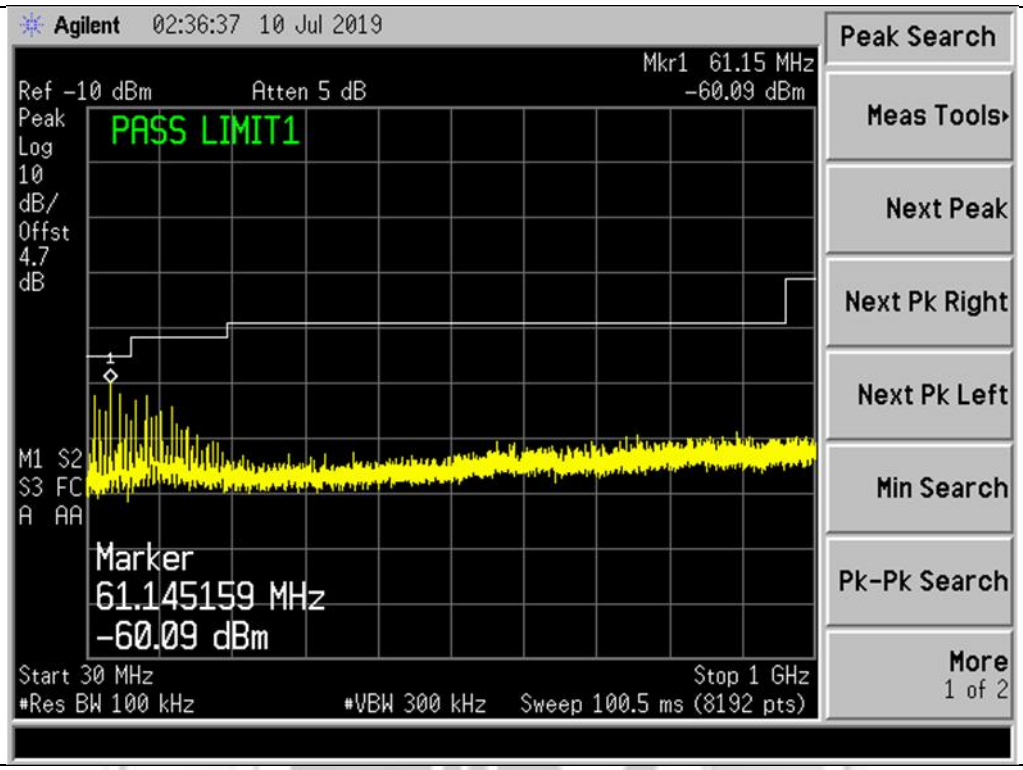
Plot 17 – Middle Channel



Plot 18 – Middle Channel

PSB Singapore

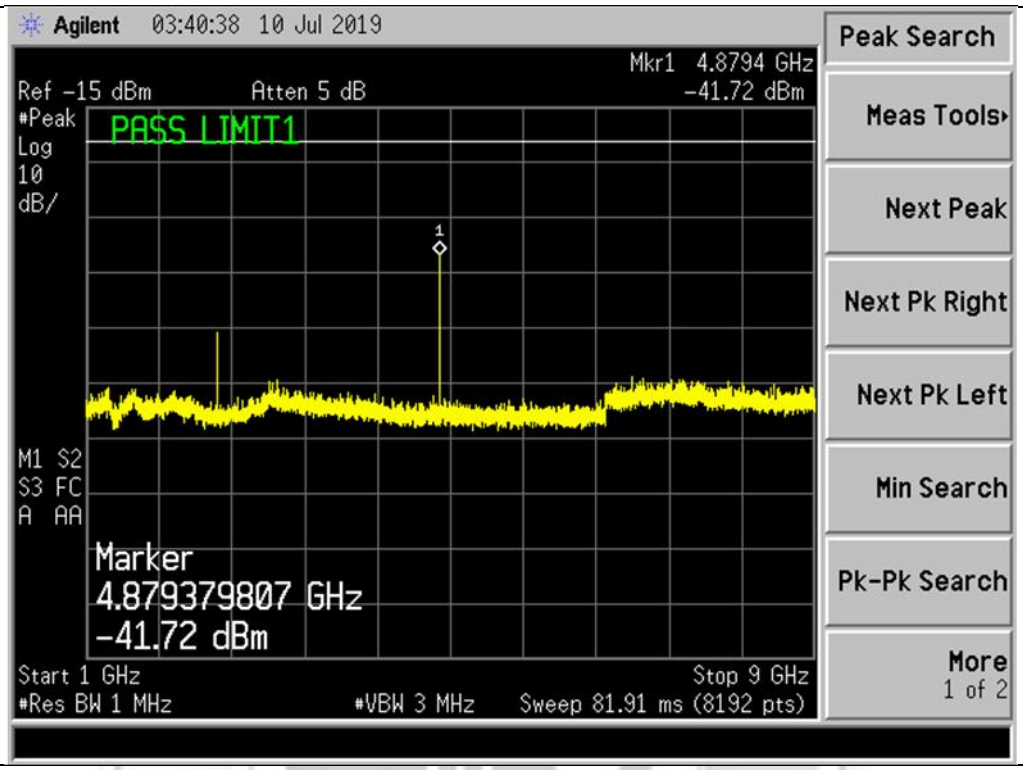
RF Conducted Spurious Emissions (Restricted Bands) Plots – Peak



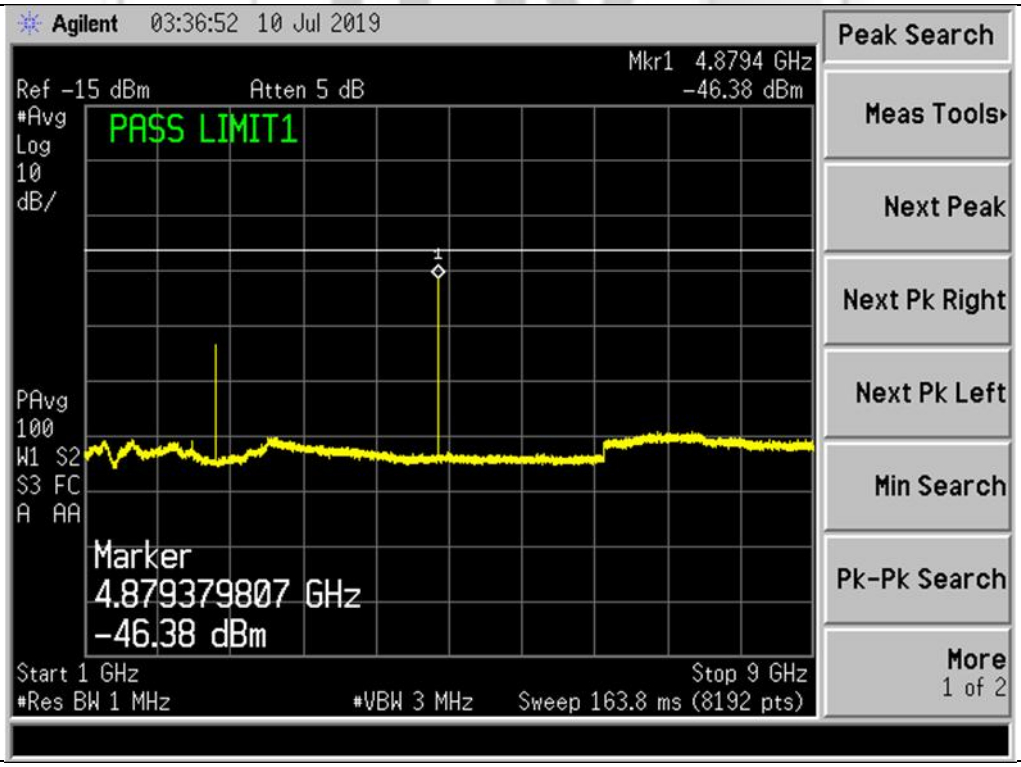
Plot 19 – Middle Channel

PSB Singapore

RF Conducted Spurious Emissions (Restricted Bands) Plots – Peak & Average



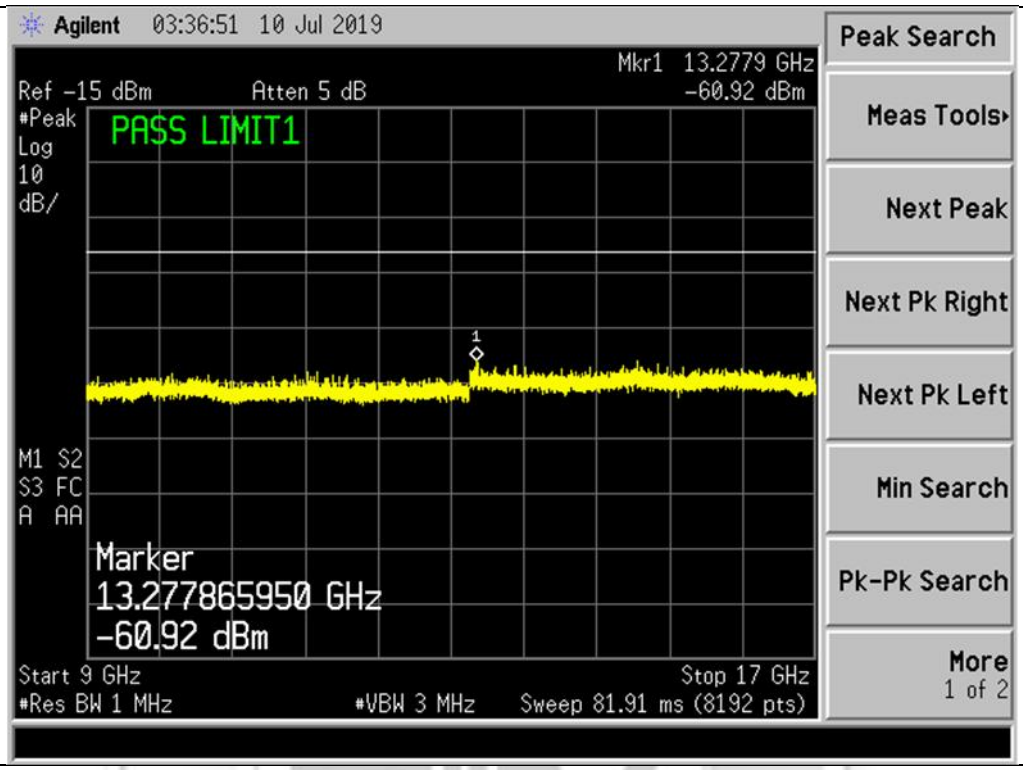
Plot 20 – Middle Channel



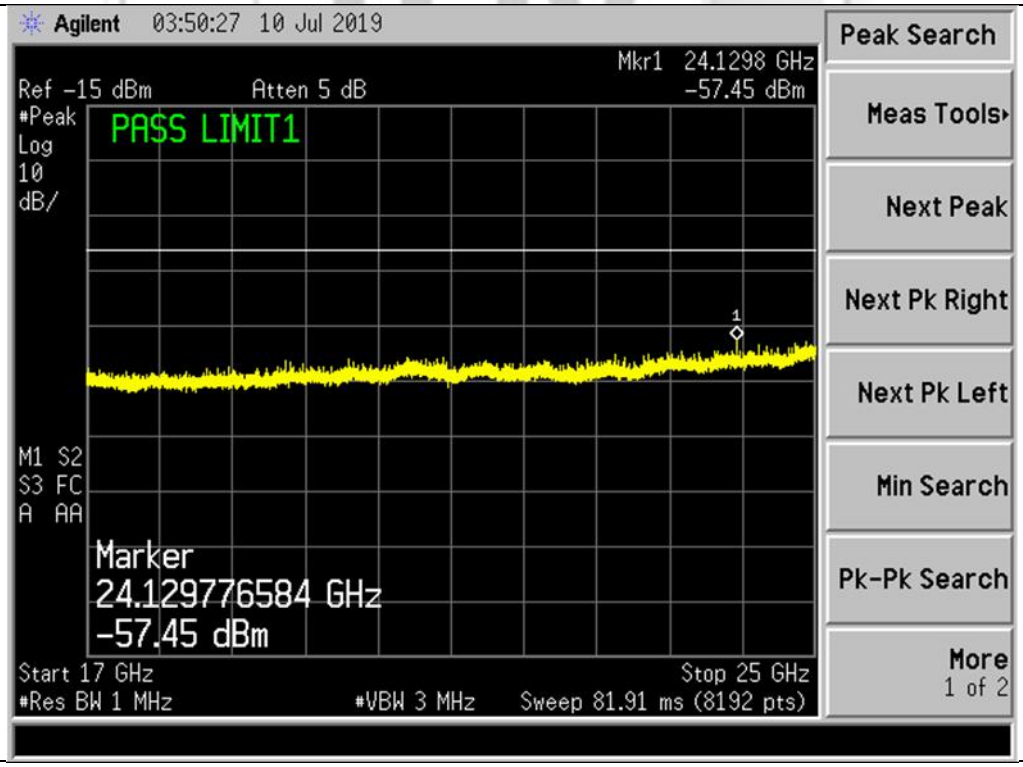
Plot 21 – Middle Channel

PSB Singapore

RF Conducted Spurious Emissions (Restricted Bands) Plots – Peak



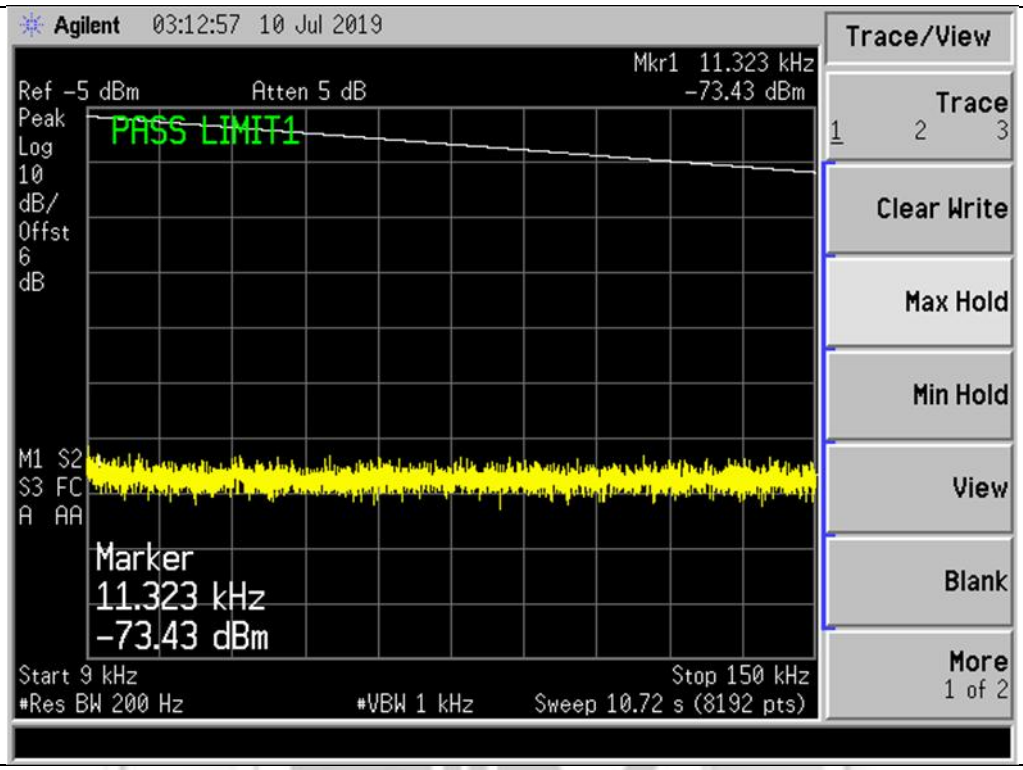
Plot 22 – Middle Channel



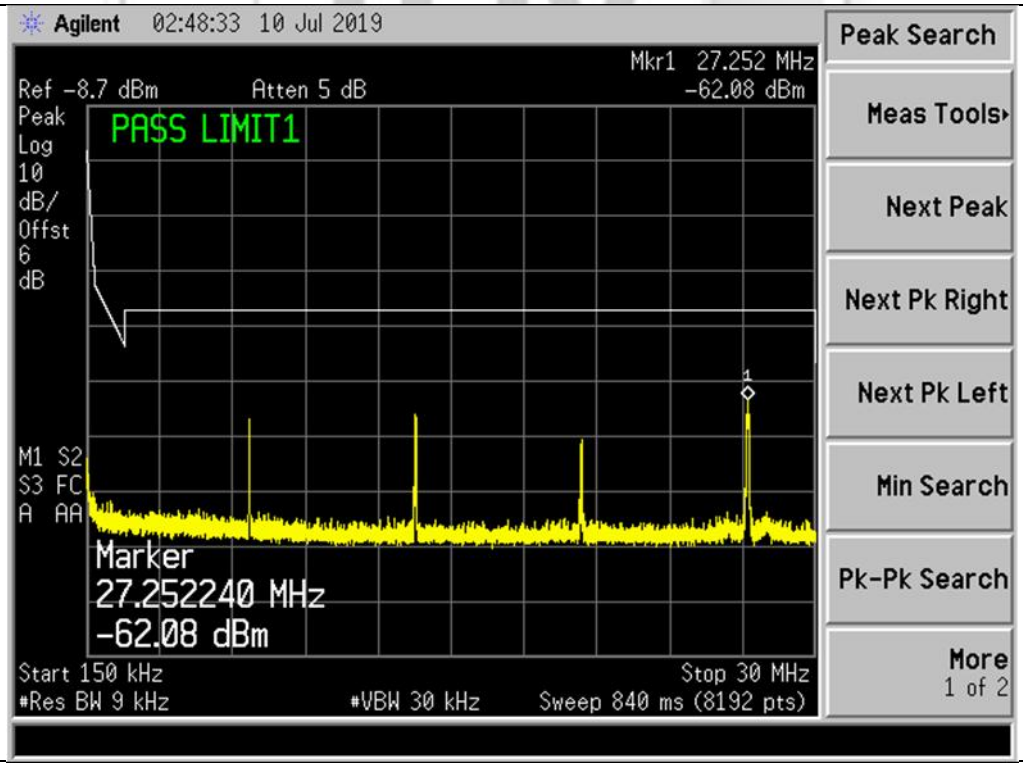
Plot 23 – Middle Channel

PSB Singapore

RF Conducted Spurious Emissions (Restricted Bands) Plots – Peak



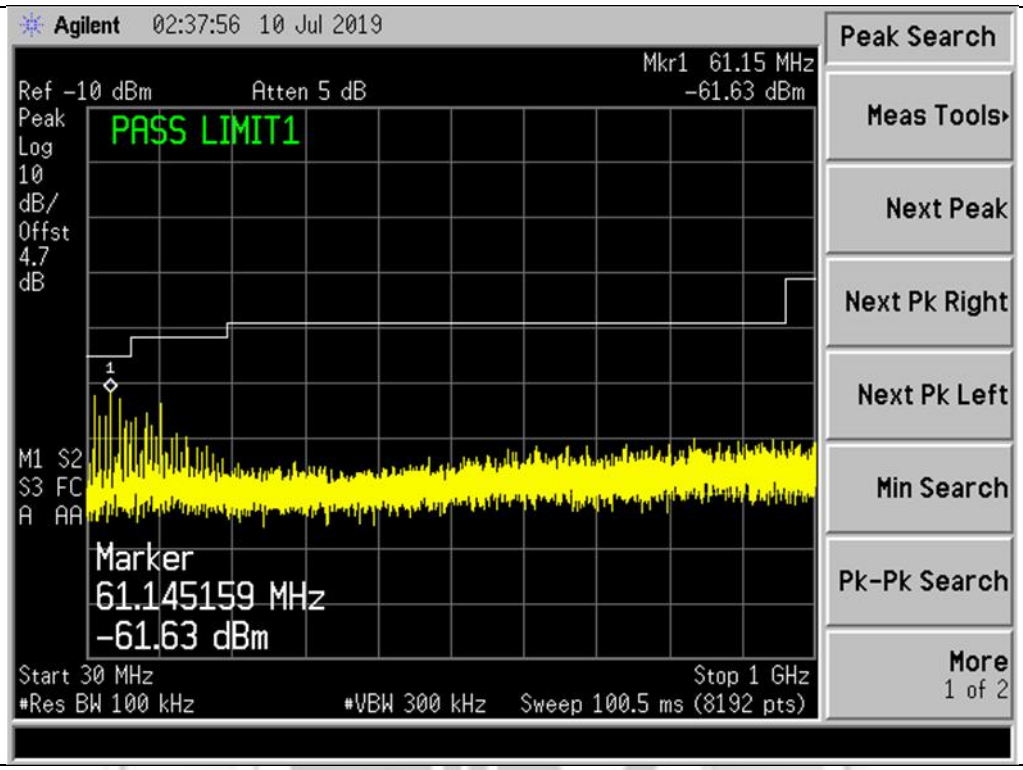
Plot 24 – Upper Channel



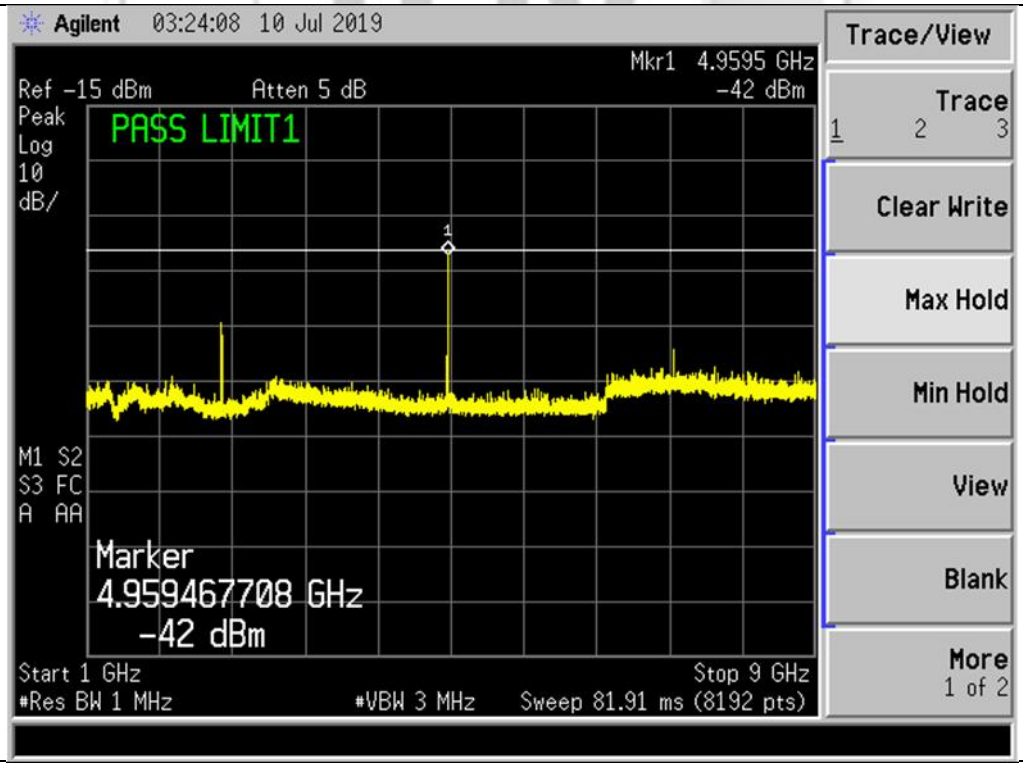
Plot 25 – Upper Channel

PSB Singapore

RF Conducted Spurious Emissions (Restricted Bands) Plots – Peak



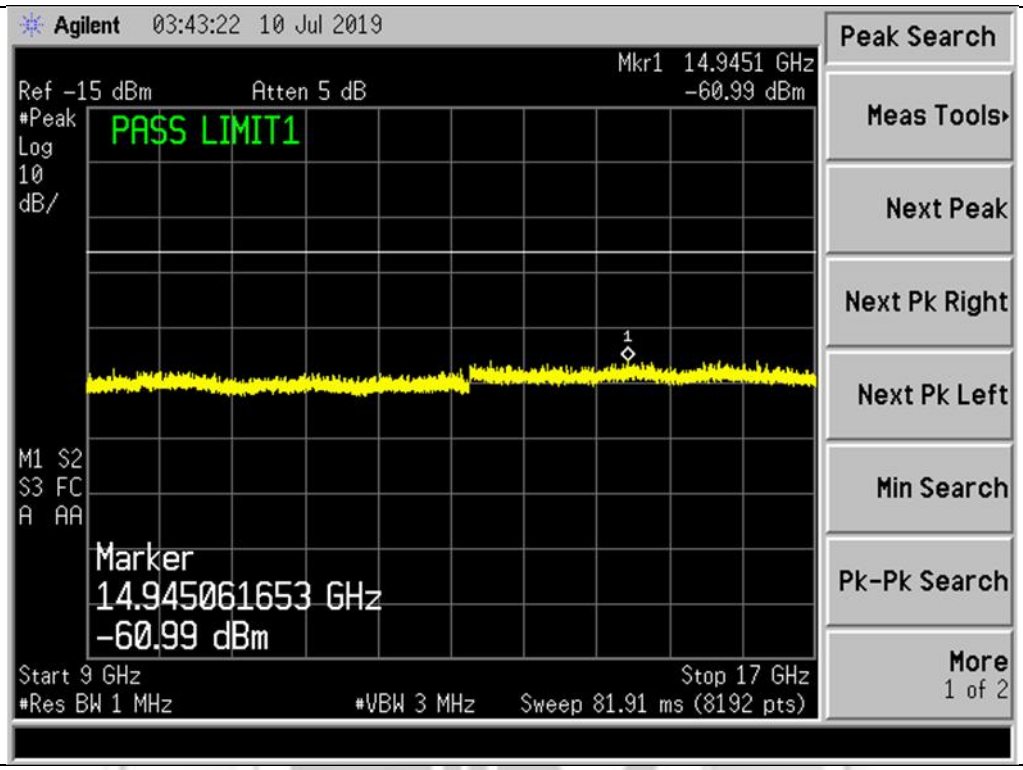
Plot 26 – Upper Channel



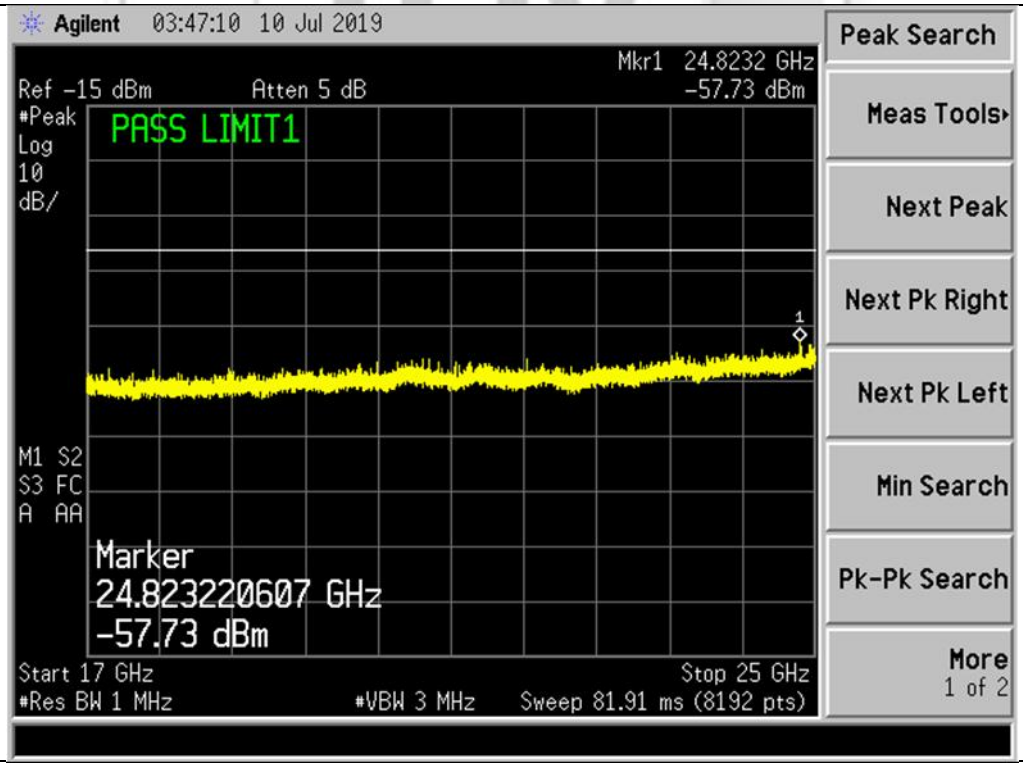
Plot 27 – Upper Channel

PSB Singapore

RF Conducted Spurious Emissions (Restricted Bands) Plots – Peak



Plot 28 – Upper Channel



Plot 29 – Upper Channel

PSB Singapore

2.7 Band Edge Compliance (Conducted)

2.7.1 Test Limits

The EUT shows compliance to the requirements of this section, which states in any 100kHz bandwidth outside the frequency band in which the spread spectrum intentional radiator (EUT) is operating, the radio frequency power that is produced by the EUT shall be at least 20dB below that in the 100kHz bandwidth within the band that contains the highest level of desired power.

2.7.2 Test Setup

2.7.2.1 The EUT and supporting equipment were set up as shown in the setup photo.

2.7.2.2 The power supply for the EUT was connected to a filtered mains.

2.7.2.3 The RF antenna connector was connected to the spectrum analyser via a low-loss coaxial cable.

2.7.2.4 The resolution bandwidth (RBW) and the video bandwidth (VBW) of the spectrum analyser were respectively set to 100kHz and 300kHz.

2.7.2.5 All other supporting equipment were powered separately from another filtered mains.

2.7.3 Test Method

2.7.3.1 The EUT was switched on and allowed to warm up to its normal operating condition. The EUT was then configured to operate in the test mode.

2.7.3.2 The frequency span of the spectrum analyser was set to wide enough to capture the lower band edge of the transmission band, 2.400GHz and any spurious emissions at the band edge (within 2MHz of the band edge).

2.7.3.3 The spectrum analyser was set to max hold to capture any spurious emissions within the span. The signal capturing was continuous until no further spurious emissions were detected.

2.7.3.4 The measurements were repeated if the EUT supports more than one modulation and data rate.

2.7.3.5 The measurements were repeated with the frequency span of the spectrum analyser was set to wide enough to capture the upper band edge frequency of the transmission band, 2.4835GHz and the any spurious emissions at the band-edge.

PSB Singapore

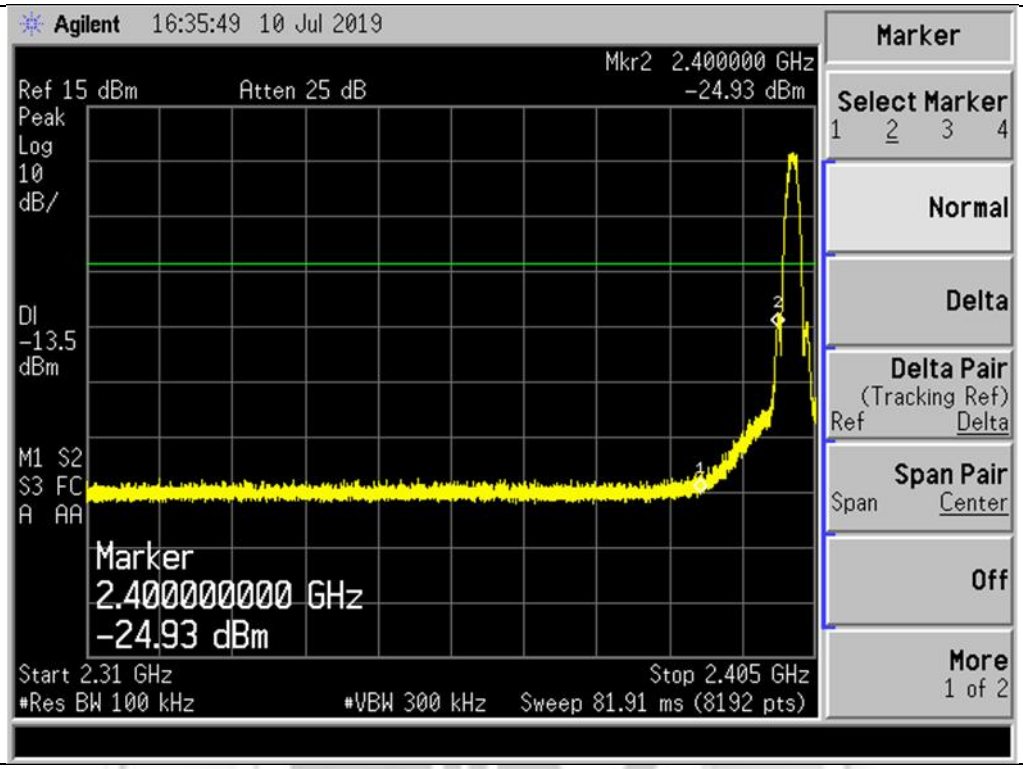
2.7.4 Test Results

Test Input Power	24Vdc	Temperature	24ºC
Attached Plots	30 – 31	Relative Humidity	60%
		Atmospheric Pressure	1030mbar
		Tested By	Chang Wai Kit
		Test Date	10 Jul 2019

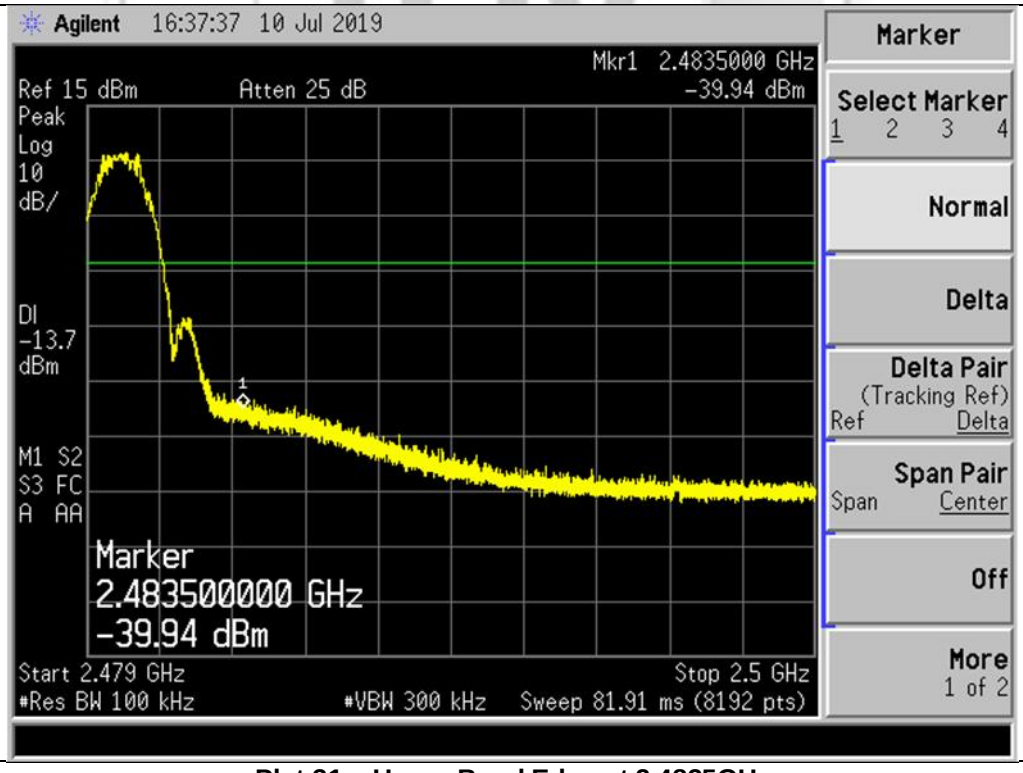
No significant signal was found and they were below the specified limit.

PSB Singapore

Band Edge Compliance (Conducted) Plots



Plot 30 – Lower Band Edge at 2.4000GHz



Plot 31 – Upper Band Edge at 2.4835GHz

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2.8 Band Edge Compliance (Radiated)

2.8.1 Test Limits

The EUT shows compliance to the requirements of this section, which states in any 100kHz bandwidth outside the frequency band in which the spread spectrum intentional radiator (EUT) is operating, the radio frequency power that is produced by the EUT shall be at least 20dB below that in the 100kHz bandwidth within the band that contains the highest level of the desired power. In addition, radiated emissions which fall in the restricted bands shall comply to the radiated emission limits specified in 15.209.

2.8.2 Test Setup

2.8.2.1 The EUT and supporting equipment were set up as shown in the setup photo.

2.8.2.2 The power supply for the EUT was connected to a filtered mains.

2.8.2.3 The resolution bandwidth (RBW) and the video bandwidth (VBW) of the spectrum analyser were respectively set to 100kHz and 300kHz to show compliance of spurious at band edges are at least 20dB below the carriers. For restricted band spurious at band edges, peak and average measurement plots were taken using the following setting:

a. Peak Plot:
RBW = 1MHz, VBW = 3RBW

b. Average Plot
RBW = 1MHz, VBW = 10Hz

2.8.2.4 All other supporting equipment were powered separately from another filtered mains.

2.8.3 Test Method

2.8.3.1 The EUT was switched on and allowed to warm up to its normal operating condition. The EUT was then configured to operate in the test mode.

2.8.3.2 The frequency span of the spectrum analyser was set to wide enough to capture the lower band edge of the transmission band, 2.400GHz and any spurious emissions at the band edge.

2.8.3.3 The spectrum analyser was set to max hold to capture any spurious emissions within the span. The signal capturing was continuous until no further spurious emissions were detected.

2.8.3.4 The measurements were repeated if the EUT supports more than one modulation and data rate.

2.8.3.5 The measurements were repeated with the frequency span of the spectrum analyser was set to wide enough to capture the upper band edge frequency of the transmission band, 2.4835GHz and the any spurious emissions at the band-edge.

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2.8.4 Test Results

Test Input Power	3.7Vdc	Temperature	24ºC
Attached Plots	32 – 37	Relative Humidity	60%
		Atmospheric Pressure	1030mbar
		Tested By	Dylan Lin
		Test Date	12 Jul 2019

No significant signal was found and they were below the specified limit.

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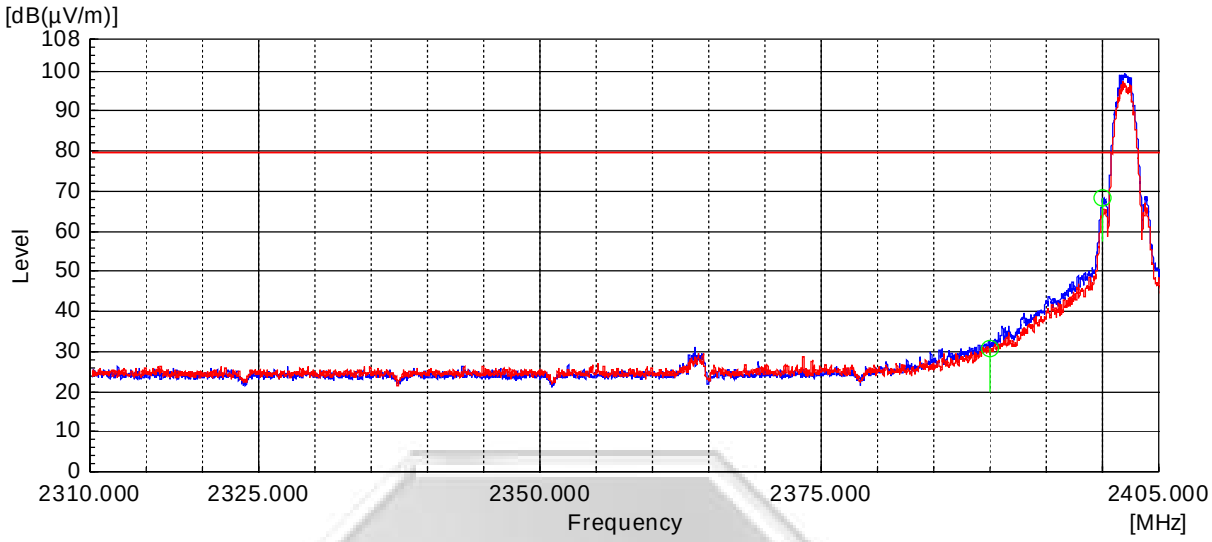
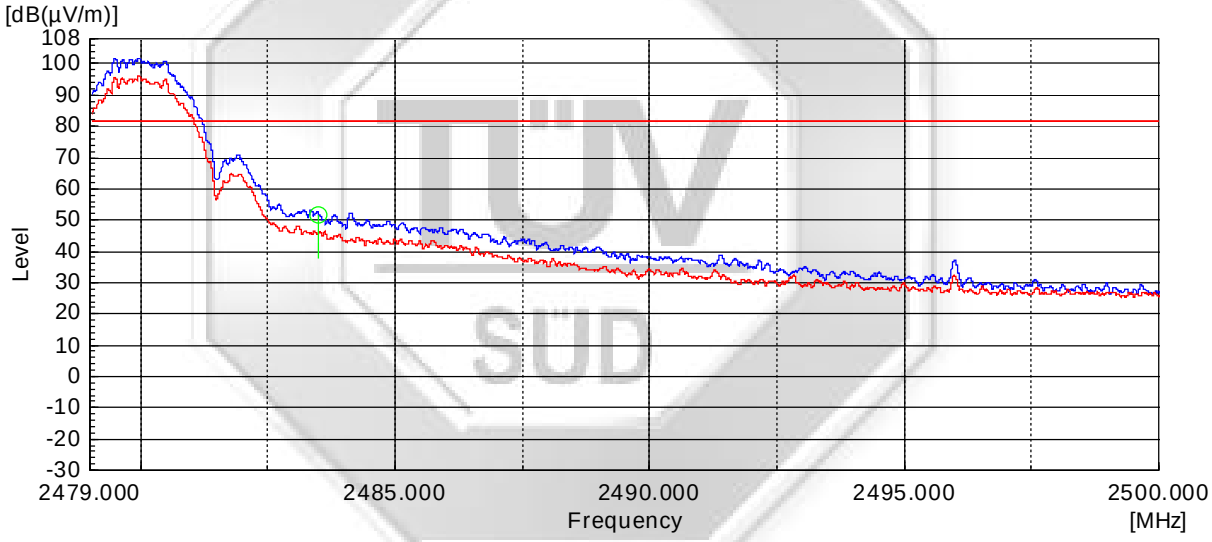
Band Edge Compliance (Radiated) Plots (20dB Delta from Carrier at Band Edge)



Plot 32 – Lower Band Edge at 2.4000GHz



Plot 33 – Upper Band Edge at 2.4835GHz

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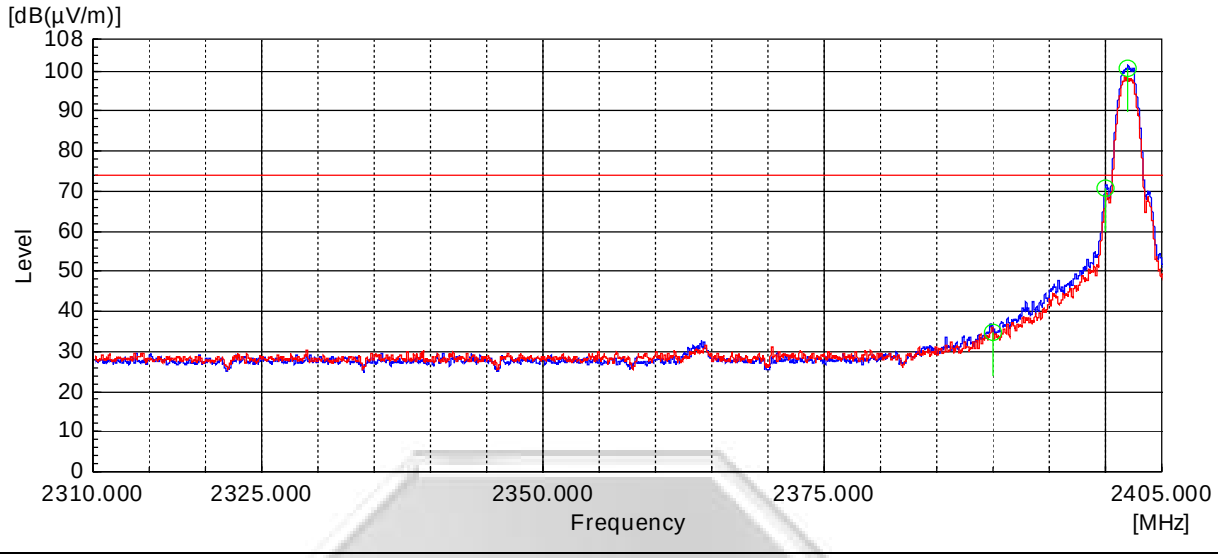
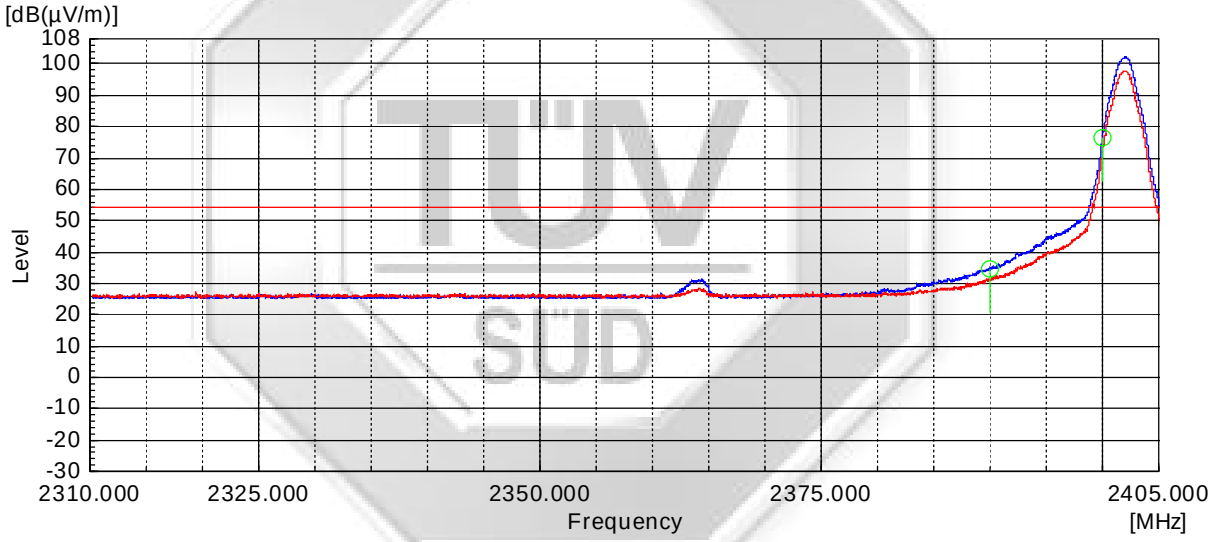
Band Edge Compliance (Radiated) Plots (Restricted Band)



Plot 34 – Peak Plot at Lower Band Edge at 2.4000GHz



Plot 35 – Average Plot at Lower Band Edge at 2.4000GHz

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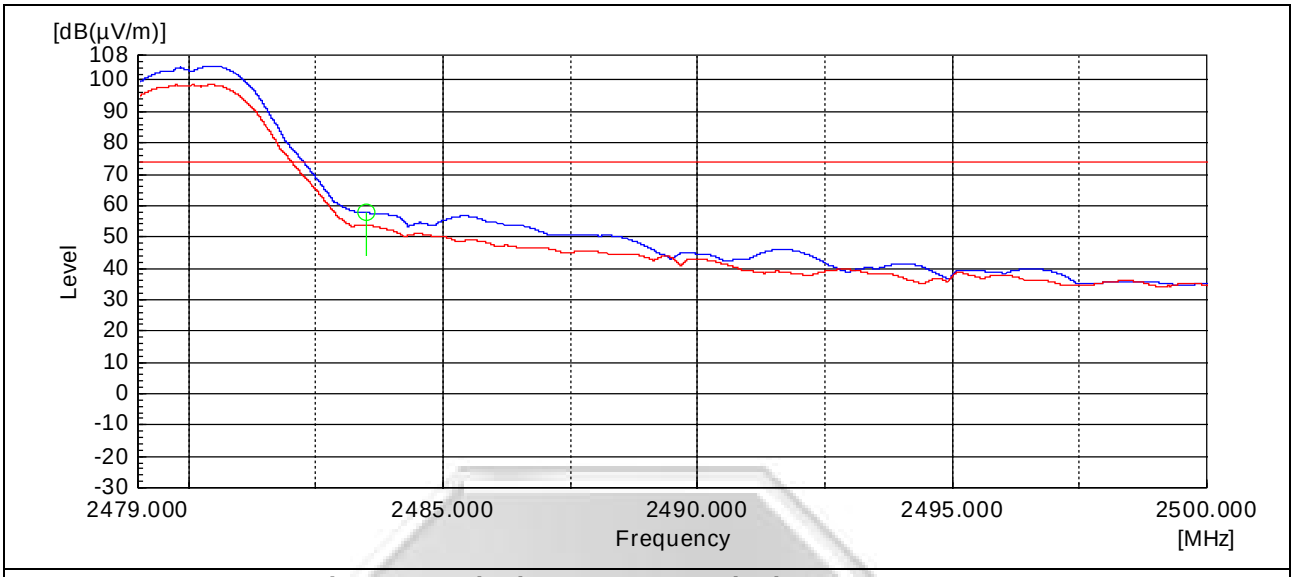
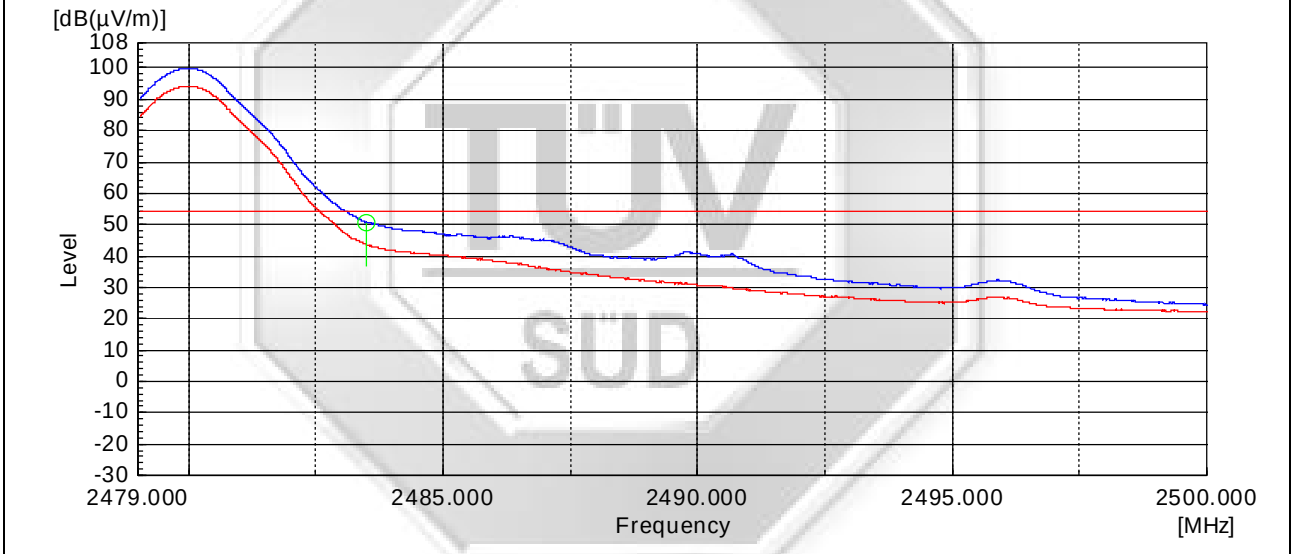
Band Edge Compliance (Radiated) Plots (Restricted Band)



Plot 36 – Peak Plot at Upper Band Edge at 2.4835GHz



Plot 37 – Average Plot at Upper Band Edge at 2.4835GHz

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2.9 Peak Power Spectral Density

2.9.1 Test Limits

The EUT shows compliance to the requirements of this section, which states the peak power spectral density conducted from the intentional radiator (EUT) to the antenna shall not be greater than 8dBm (6.3mW) in any 3kHz band during any time interval of continuous transmission.

2.9.2 Test Setup

2.9.2.1 The EUT and supporting equipment were set up as shown in the setup photo.

2.9.2.2 The power supply for the EUT was connected to a filtered mains.

2.9.2.3 The RF antenna connector was connected to the spectrum via a low-loss coaxial cable.

2.9.2.4 The resolution bandwidth (RBW) and the video bandwidth (VBW) of the spectrum analyser were set to the following:
RBW = 3kHz
VBW = 3RBW
Span = 1.5 times the channel bandwidth (6dB Bandwidth)
Sweep time = auto couple

2.9.2.5 All other supporting equipment were powered separately from another filtered mains.

2.9.3 Test Method

2.9.3.1 The EUT was switched on and allowed to warm up to its normal operating condition. The EUT was then configured to operate in the test mode at lower channel.

2.9.3.2 The peak of the transmitting frequency was detected with the marker peak function of the spectrum analyser.

2.9.3.3 The peak power density of the transmitting frequency was plotted and recorded.

2.9.3.4 The measurements were repeated if the EUT supports more than one modulation and data rate.

2.9.3.5 The measurement was repeated with the transmitting frequency was set to middle channel and upper channel respectively.

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2.9.4 Test Results

Test Input Power	24Vdc	Temperature	24ºC
Attached Plots	38 – 40	Relative Humidity	60%
		Atmospheric Pressure	1030mbar
		Tested By	Chang Wai Kit
		Test Date	10 Jul 2019

Channel	Channel Frequency (GHz)	Peak Power Spectral Density (mW) *See Note 1	Limit (mW)
Lower	2.402	0.103	6.3
Middle	2.440	0.101	6.3
Upper	2.480	0.097	6.3

Notes

1.	Only the highest measured peak power spectral density was reported. Refer to plots for all measured peak power spectral density.

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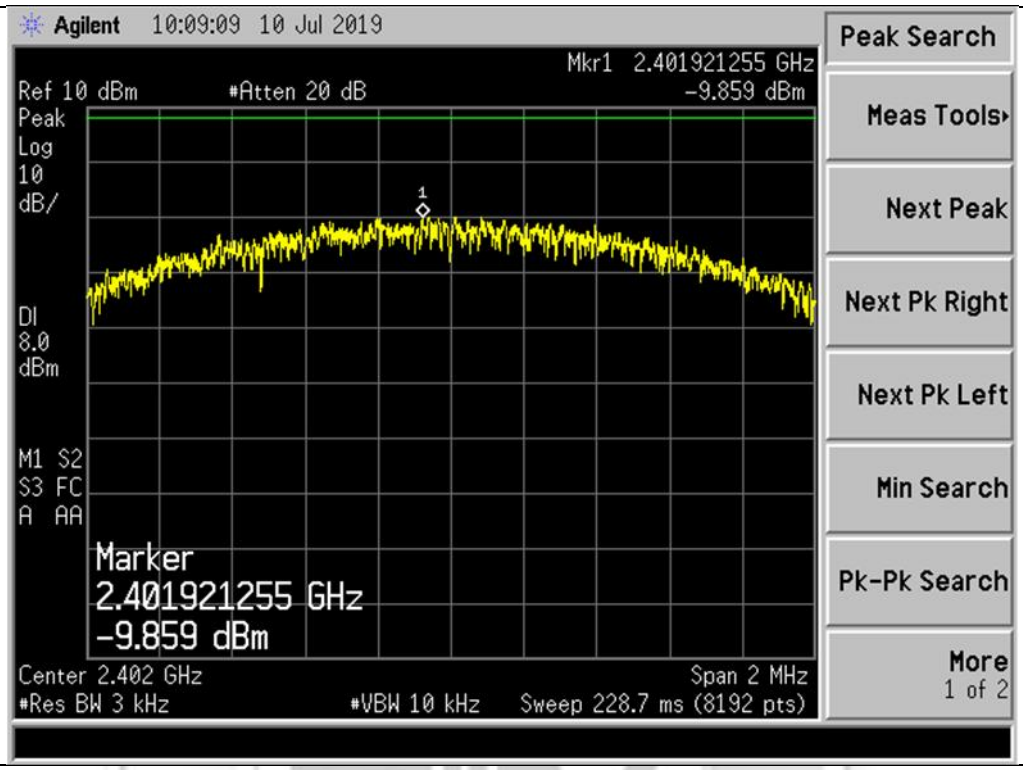
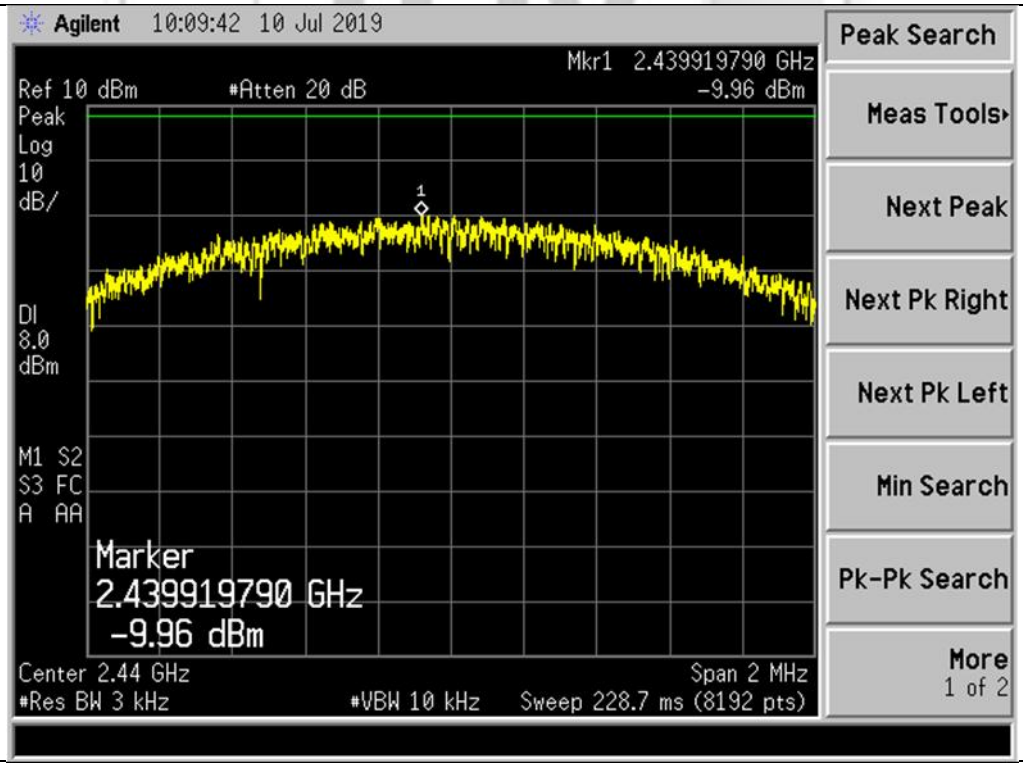
Peak Power Spectral Density Plots



Plot 38 – Lower Channel



Plot 39 – Middle Channel

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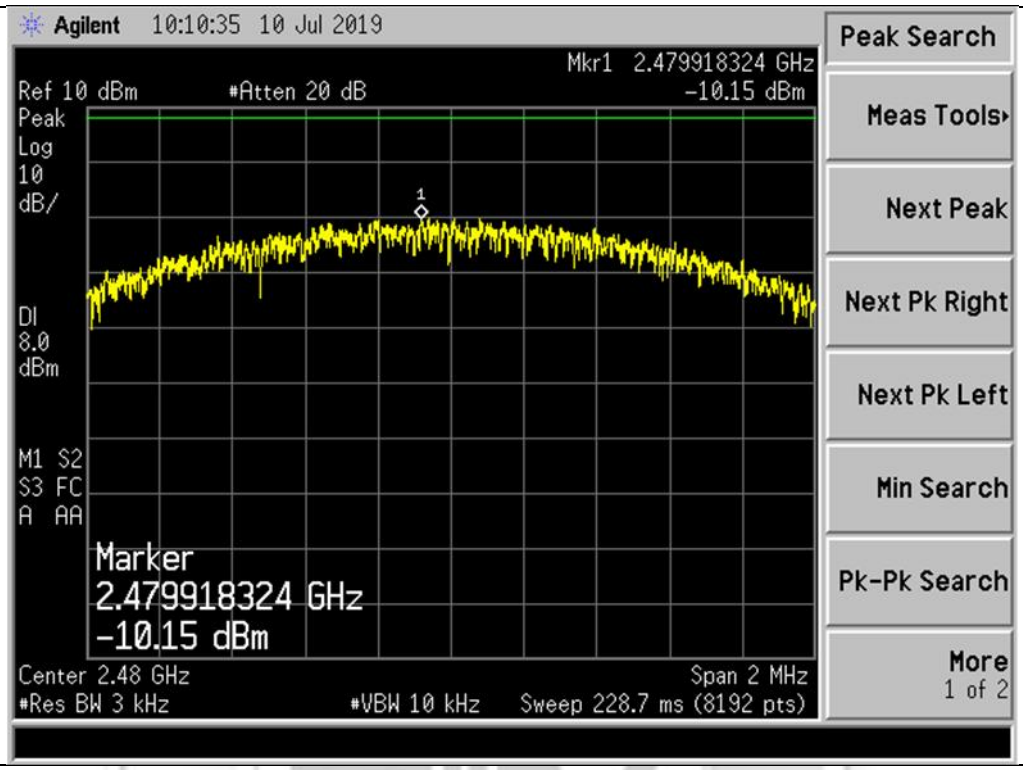
Peak Power Spectral Density Plots



Plot 40 – Upper Channel

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4 Test Equipment

Instrument	Model	S/No	Cal Due Date
Conducted Emissions			
R&S Test Receiver	ESPI3	100349	01 Feb 2020
Agilent EMC Analyzer	E7403A	US41160166	06 Oct 2019
Schaffner LISN	NNB42	00008	08 May 2020
Schaffner LISN (EUT)	NNB42	04/10055	04 Oct 2019
Radiated Emissions (Spurious Emissions Inclusive Restricted Bands Requirement)			
R&S EMI Test Receiver	ESW44	101661	30 May 2020
Schaffner Bilog Antenna (30MHz-2GHz)	CBL6112B	2597	27 Mar 2020
TDK-RF Horn Antenna	HRN-0118	130256	20 Mar 2020
ETS Horn Antenna (18GHz-40GHz)	3116	0004-2474	07 Jan 2020
Com-Power Preamplifier (1MHz-1GHz)	PAM-103	441158	18 Jul 2019
R&S Preamplifier (1GHz -18GHz)	SCU18	102191	15 Jan 2020
Agilent Preamplifier (1GHz-26.5GHz)	8449D	3008A02305	28 Sep 2019
Micro-tronics Bandstop Filter (2.4GHz)	BRM50701-02	007	13 Aug 2019
Spectrum Bandwidth (6dB Bandwidth Measurement), RF Conducted Spurious Emissions (Non-Restricted Bands), Band Edge Compliance (Conducted), Peak Power Spectral Density			
Agilent EMC Analyzer	E7405A	MY40240195	16 Apr 2020
Agilent DC Power Supply	E3620A	MY40000448	Output Monitor
Maximum Peak Power			
Boonton RF Power Meter	4532	97701	13 Aug 2019
Boonton Power Sensor	56218-S/1	1414	13 Aug 2019
RF Conducted Spurious Emissions (Restricted Bands)			
Agilent EMC Analyzer	E7405A	MY40240195	16 Apr 2020
Agilent DC Power Supply	E3620A	MY40000448	Output Monitor
Micro-tronics Bandstop Filter (2.4GHz)	BRM50701-02	007	13 Aug 2019
Band Edge Compliance (Radiated)			
R&S EMI Test Receiver	ESW44	101661	30 May 2020
TDK-RF Horn Antenna	HRN-0118	130256	20 Mar 2020
R&S Preamplifier (1GHz -18GHz)	SCU18	102191	15 Jan 2020

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5 Measurement Uncertainty

All test measurements carried out are traceable to national standards. The uncertainty of the measurement at a confidence level of approximately 95%, with a coverage factor of 2.

Test Name	Measurement Uncertainty
Conducted Emissions	9kHz to 30MHz, ±2.4dB
Radiated Emissions	9kHz to 30MHz @ 10m, ±2.3dB 30MHz to 1GHz @ 10m, ±4.0dB 30MHz to 1GHz @ 3m, ±5.6dB >1GHz to 40GHz @3m, ±5.0dB
Maximum Permissible Exposure	0.1MHz – 3GHz is ±15.0%

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July 2011

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End of the Test Report