TEST REPORT

Test Report No. : UL-RPT-RP12935566-616A V2.0

Customer	:	ROLI Ltd
Model No.	:	LKB01
FCC ID	:	2AFT3-LKB01
Technology	:	*Bluetooth* – Low Energy
Test Standard(s)	:	FCC Parts 15.207, 15.209(a) & 15.247
Test Laboratory	:	UL VS LTD, Basingstoke, Hampshire, RG24 8AH, United Kingdom

1. This test report shall not be reproduced except in full, without the written approval of UL VS LTD.
2. The results in this report apply only to the sample(s) tested.
3. The sample tested is in compliance with the above standard(s).
4. The test results in this report are traceable to the national or international standards.
5. Version 2.0 supersedes all previous versions.

Date of Issue: 12 December 2019

Checked by:

Sarah Williams
Senior Test Engineer, Radio Laboratory

Company Signatory:

Ian Watch
Senior Test Engineer, Radio Laboratory
UL VS LTD

0644

Customer Information

Company Name:	ROLI Ltd
Address:	2 Glebe Road London E8 4BD United Kingdom

Report Revision History

Version Number	Issue Date	Revision Details	Revised By
1.0	29/10/2019	Initial Version	Ian Watch
2.0	12/12/2019	Addition of RSE below 30 MHz	Sarah Williams

Table of Contents

1. Attestation of Test Results

1.1. Description of EUT

The Equipment Under Test was a light-up MIDI keyboard with *Bluetooth*® Low Energy and ShockWave transceivers.

The antenna was integral to the unit and could not be accessed by the user.

1.2. General Information

Specification Reference:	47CFR15.247
Specification Title:	Code of Federal Regulations Volume 47 (Telecommunications): Part 15 Subpart C (Intentional Radiators) – Section 15.247
Specification Reference:	47CFR15.207 and 47CFR15.209
Specification Title:	Code of Federal Regulations Volume 47 (Telecommunications): Part 15 Subpart C (Intentional Radiators) – Sections 15.207 and 15.209
Site Registration:	621311
Location of Testing:	UL VS LTD, Unit 3 Horizon, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, G24 8AH, United Kingdom
Test Dates:	19 September 2019 to 11 December 2019

1.3. Summary of Test Results

FCC Reference (47CFR)	Measurement	Result
Part 15.247(a)(2)	Transmitter Minimum 6 dB Bandwidth	✓
Part 15.35(c)	Transmitter Duty Cycle	Note 1
Part 15.247(b)(3)	Transmitter Maximum Peak Output Power	✓
Part 15.247(e)	Transmitter Power Spectral Density	Note 2
Part 15.247(d)/15.209(a)	Transmitter Radiated Emissions	✓
Part 15.247(d)/15.209(a)	Transmitter Band Edge Radiated Emissions	✓
Part 15.207	Transmitter AC Conducted Emissions	✓
Key to Results ✓ = Complied ✗ = Did not comply		

Note(s):

1. The measurement was performed to assist in the calculation of the level of the emissions. The EUT cannot transmit continuously and sweep triggering/signal gating cannot be implemented.
2. In accordance with ANSI C63.10 Section 11.10.1, PSD measurements are not required if the maximum conducted output power is less than the PSD limit of 8 dBm / 3 kHz. The PSD level is therefore deemed be equal to the measured output power.

1.4. Deviations from the Test Specification

For the measurements contained within this test report, there were no deviations from, additions to, or exclusions from the test specification identified above.

2. Summary of Testing

2.1. Facilities and Accreditation

The test site and measurement facilities used to collect data are located at Unit 3 Horizon, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, United Kingdom. The following table identifies which facilities were utilised for radiated emission measurements documented in this report. Specific facilities are also identified in the test results sections.

Site 1	X
Site 2	-
Site 17	X

UL VS LTD is accredited by UKAS. The tests reported herein have been performed in accordance with its terms of accreditation.

2.2. Methods and Procedures

Reference:	ANSI C63.10-2013
Title:	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
Reference:	KDB 558074 D01 15.247 Meas Guidance v05r02, April 2, 2019
Title:	Guidance for Compliance Measurements on Digital Transmission System, Frequency Hopping Spread Spectrum System, and Hybrid System Devices Operating Under Section 15.247 of the FCC Rules
Reference:	KDB 174176 D01 Line Conducted FAQ v01r01 June 3, 2015
Title:	AC Power-Line Conducted Emissions Frequently Asked Questions

2.3. Calibration and Uncertainty

Measuring Instrument Calibration

In accordance with UKAS requirements all the measurement equipment is on a calibration schedule. All equipment was within the calibration period on the date of testing.

Measurement Uncertainty

No measurement or test can ever be perfect and the imperfections give rise to error of measurement in the results. Consequently the result of a measurement is only an approximation to the value measured (the specific quantity subject to measurement) and is only complete when accompanied by a statement of the uncertainty of the approximation.

The expression of uncertainty of a measurement result allows realistic comparison of results with reference values and limits given in specifications and standards.

The uncertainty of the result may need to be taken into account when interpreting the measurement results.

The reported expanded uncertainties below are based on a standard uncertainty multiplied by an appropriate coverage factor such that a confidence level of approximately 95% is maintained. For the purposes of this document “approximately” is interpreted as meaning “effectively” or “for most practical purposes”.

Measurement Type	Range	Confidence Level (%)	Calculated Uncertainty
Duty Cycle	2.4 GHz to 2.4835 GHz	95%	±1.14 %
Minimum 6 dB Bandwidth	2.4 GHz to 2.4835 GHz	95%	±4.59 %
Conducted Maximum Peak Output Power	2.4 GHz to 2.4835 GHz	95%	±1.13 dB
Radiated Spurious Emissions	9 kHz to 30 MHz	95%	±4.39 dB
Radiated Spurious Emissions	30 MHz to 1 GHz	95%	±3.30 dB
Radiated Spurious Emissions	1 GHz to 25 GHz	95%	±2.94 dB
AC Conducted Spurious Emissions	0.15 MHz to 30 MHz	95%	±1.96 dB

The methods used to calculate the above uncertainties are in line with those recommended within the various measurement specifications. Where measurement specifications do not include guidelines for the evaluation of measurement uncertainty the published guidance of the appropriate accreditation body is followed.

2.4. Test and Measurement Equipment

Test Equipment Used for Transmitter Conducted Tests

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2001	Thermohygrometer	Testo	608-H1	45041824	06 Jan 2020	12
M1996	Signal Analyser	Rohde & Schwarz	FSV13	100975	16 Jan 2020	12
A2525	Attenuator	AtlanTecRF	AN18W5-10	832827#3	Calibrated before use	-
G0615	Vector Signal Generator	Rohde & Schwarz	SMBV100A	260473	08 May 2020	36

Test Equipment Used for Transmitter Radiated Emissions Tests

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
K0017	3m RSE Chamber	Rainford EMC	N/A	N/A	16 Feb 2020	12
M2003	Thermohygrometer	Testo	608-H1	45046641	06 Jan 2020	12
M1995	Test Receiver	Rohde & Schwarz	ESU40	100428	08 May 2020	12
A3167	Pre-Amplifier	Com-Power	PAM-103	18020010	11 Feb 2020	12
A2863	Pre-Amplifier	Agilent	8449B	3008A02100	12 Feb 2020	12
A3142	Pre-Amplifier	Schwarzbeck	BBV 9718 B	00020	12 Feb 2020	12
A2893	Pre-Amplifier	Schwarzbeck	BBV 9721	9721-021	31 July 2020	12
A490	Antenna	Chase	CBL6111A	1590	21 May 2020	12
A2889	Antenna	Schwarzbeck	BBHA 9120B	BBHA 9120 B653	12 Feb 2020	12
A2890	Antenna	Schwarzbeck	HWRD 750	014	12 Feb 2020	12
A2892	Antenna	Schwarzbeck	BBHA 9170	9170-727	01 Aug 2020	12
A2916	Attenuator	AtlanTecRF	AN18W5-10	832827#1	20 Feb 2020	12
A3036	Low Pass Filter	AtlanTecRF	AFL-02000	15062902848	13 May 2020	12
A2914	High Pass Filter	AtlanTecRF	AFH-03000	2155	20 Feb 2020	12
A2947	High Pass Filter	AtlanTecRF	AFH-07000	1601900001	20 Feb 2020	12
M2040	Thermohygrometer	Testo	608-H1	45124934	06 Jan 2020	12
K0001	5m RSE Chamber	Rainford EMC	N/A	N/A	16 Oct 2020	12
M2044	Test Receiver	Rohde & Schwarz	ESU26	100122	01 Apr 2020	12
A3198	Mag Loop Antenna	ETS-Lindgren	6502	00221887	27 Mar 2020	12

Test and Measurement Equipment (continued)

Test Equipment Used for Transmitter Band Edge Radiated Emissions Tests

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
K0017	3m RSE Chamber	Rainford EMC	N/A	N/A	16 Feb 2020	12
M2003	Thermohygrometer	Testo	608-H1	45046641	06 Jan 2020	12
M1995	Test Receiver	Rohde & Schwarz	ESU40	100428	08 May 2020	12
A2863	Pre-Amplifier	Agilent	8449B	3008A02100	12 Feb 2020	12
A2889	Antenna	Schwarzbeck	BBHA 9120B	BBHA 9120 B653	12 Feb 2020	12
A2916	Attenuator	AtlanTecRF	AN18W5-10	832827#1	20 Feb 2020	12

Test Equipment Used for Transmitter AC Conducted Spurious Emissions:

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2037	Thermohygrometer	Testo	608-H1	45124925	06 Jan 2020	12
A649	LISN	Rohde & Schwarz	ESH3-Z5	825562/008	08 Aug 2020	12
A1830	Pulse Limiter	Rohde & Schwarz	ESH3-Z2	100668	10 Apr 2020	12
M1273	Test Receiver	Rohde & Schwarz	ESIB 26	100275	18 Dec 2019	12
M1269	Multimeter	Fluke	179	90250210	17 Apr 2020	12

Test Measurement Software/Firmware Used:

Name	Version	Release Date
Rohde & Schwarz EMC32	6.30.0	2008

3. Equipment Under Test (EUT)

3.1. Identification of Equipment Under Test (EUT)

Brand Name:	ROLI
Model Name or Number:	LKB01
Test Sample Serial Number:	F9217024401002077 *(Conducted RF sample)*
Hardware Version:	V7
Firmware Version:	Special Radio Test (RF) Version 5.0
FCC ID:	2AFT3-LKB01

Brand Name:	ROLI
Model Name or Number:	LKB01
Test Sample Serial Number:	LKBPROTOTYPED181 *(Radiated sample #1)*
Hardware Version:	V7
Firmware Version:	Special Radio Test (RF) Version 5.0
FCC ID:	2AFT3-LKB01

Brand Name:	ROLI
Model Name or Number:	LKB01
Test Sample Serial Number:	LKBPROTOTYPED174 *(Radiated sample #2)*
Hardware Version:	V7
Firmware Version:	Special Radio Test (RF) Version 5.0
FCC ID:	2AFT3-LKB01

3.2. Modifications Incorporated in the EUT

No modifications were applied to the EUT during testing.

3.3. Additional Information Related to Testing

Technology Tested:	*Bluetooth* Low Energy (Digital Transmission System)		
Type of Unit:	Transceiver		
Channel Spacing:	2 MHz		
Modulation:	GFSK		
Data Rate: LE	1 Mbps		
Data Rate: LE2M	2 Mbps		
Power Supply Requirement(s):	Nominal	3.7 VDC	
Maximum Conducted Output Power:	0.7 dBm		
Transmit Frequency Range:	2402 MHz to 2480 MHz		
Transmit Channels Tested:	**Channel ID**	**Channel Number**	**Channel Frequency (MHz)**
	Bottom	37	2402
	Middle	17	2440
	Top	39	2480

Technology Tested:	ShockBurst		
Type of Unit:	Transceiver		
Channel Spacing:	2 MHz		
Modulation:	GFSK		
Data Rate:	2 Mbps		
Power Supply Requirement(s):	Nominal	3.7 VDC	
Maximum Conducted Output Power:	0.5 dBm		
Transmit Frequency Range:	2402 MHz to 2480 MHz		
Transmit Channels Tested:	**Channel ID**	**Channel Number**	**Channel Frequency (MHz)**
	Bottom	37	2402
	Middle	17	2440
	Top	39	2480

3.4. Description of Available Antennas

The radio utilizes an integrated antenna, with the following maximum gain:

Frequency Range (MHz)	Antenna Gain (dBi)
2400-2480	0

3.5. Description of Test Setup

Support Equipment

The following support equipment was used to exercise the EUT during testing:

Description:	Laptop PC
Brand Name:	Lenovo
Model Name or Number:	Thinkpad L470
Serial Number:	PF10T3HL

Description:	Switched mode power supply
Brand Name:	RS
Model Name or Number:	HNP06UK-USB
Serial Number:	N/A

Description:	USB Hub
Brand Name:	Hama
Model Name or Number:	00078498
Serial Number:	098825891600

Description:	Laptop PC
Brand Name:	Dell
Model Name or Number:	Lattiude E5400
Serial Number:	JX19G4J

Description:	USB cable. Length 3 metres
Brand Name:	Not marked or stated
Model Name or Number:	Not marked or stated
Serial Number:	Not marked or stated

Operating Modes

The EUT was tested in the following operating mode(s):

- Transmitting at maximum power in the following modes with modulation and maximum possible data length available:
    - *Bluetooth* LE
    - *Bluetooth* LE2M
    - ShockBurst
- AC Conducted Emissions: continuously transmitting at maximum power on middle channel in *Bluetooth* LE mode.

Configuration and Peripherals

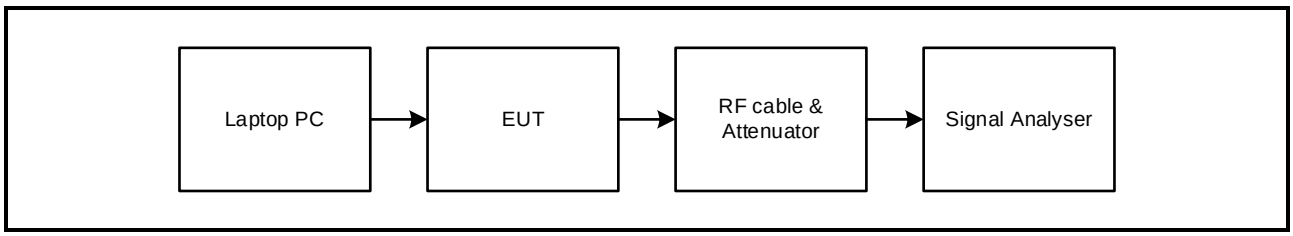
The EUT was tested in the following configuration(s):

- Controlled in test mode using test firmware on the EUT. The EUT was controlled from a laptop PC running Teraterm application. The firmware was used to enable a continuous transmission and to select the test channels as required. The customer supplied a document containing the setup instructions 'LKB01 Setup Instructions - Google Docs.pdf' dated 02 September 2019. The transmitter was set to the default power level of 0 dBm.
- The EUT was powered by a USB connection from a laptop PC during conducted RF tests.
- The EUT was powered from the internal battery during radiated tests.
- The customer provided an EUT with a U.FL connector in order to perform conducted RF measurements.
- Transmitter radiated spurious emissions tests were performed with the EUT transmitting in LE2M mode as this was found to transmit the highest power. PSD was not measured as the output power is less than 10 dBm.
- All active ports were terminated using the appropriate terminations during radiated emissions testing.
- The customer did not provide an AC power adaptor for AC conducted emissions testing as they do not provide one with the final product. A standard off-the-shelf switched mode power supply was used for testing which provided 5 VDC on a USB output from an AC input of 90 to 264 VAC.

Test Setup Diagrams

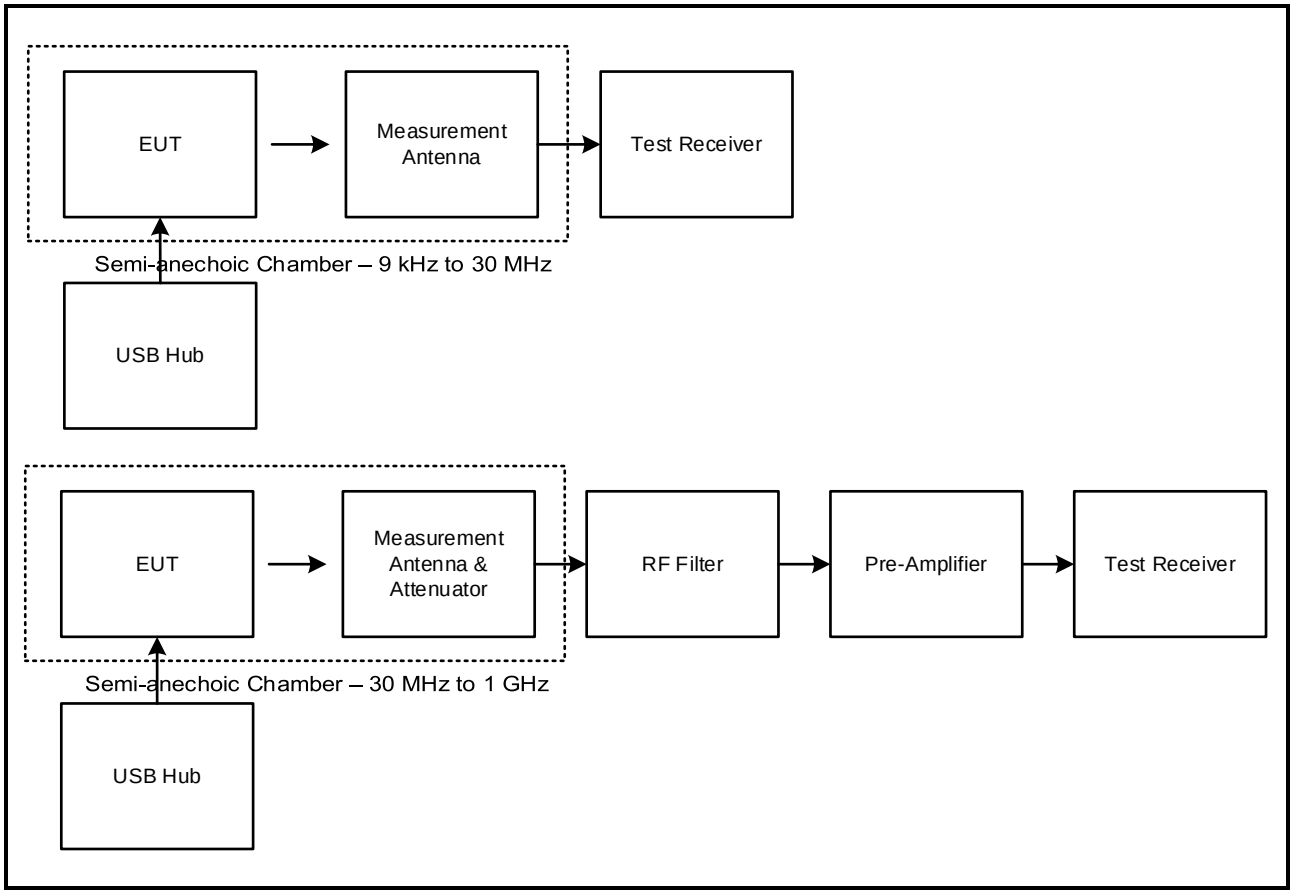
Conducted Tests:

Test Setup for Transmitter Conducted Tests



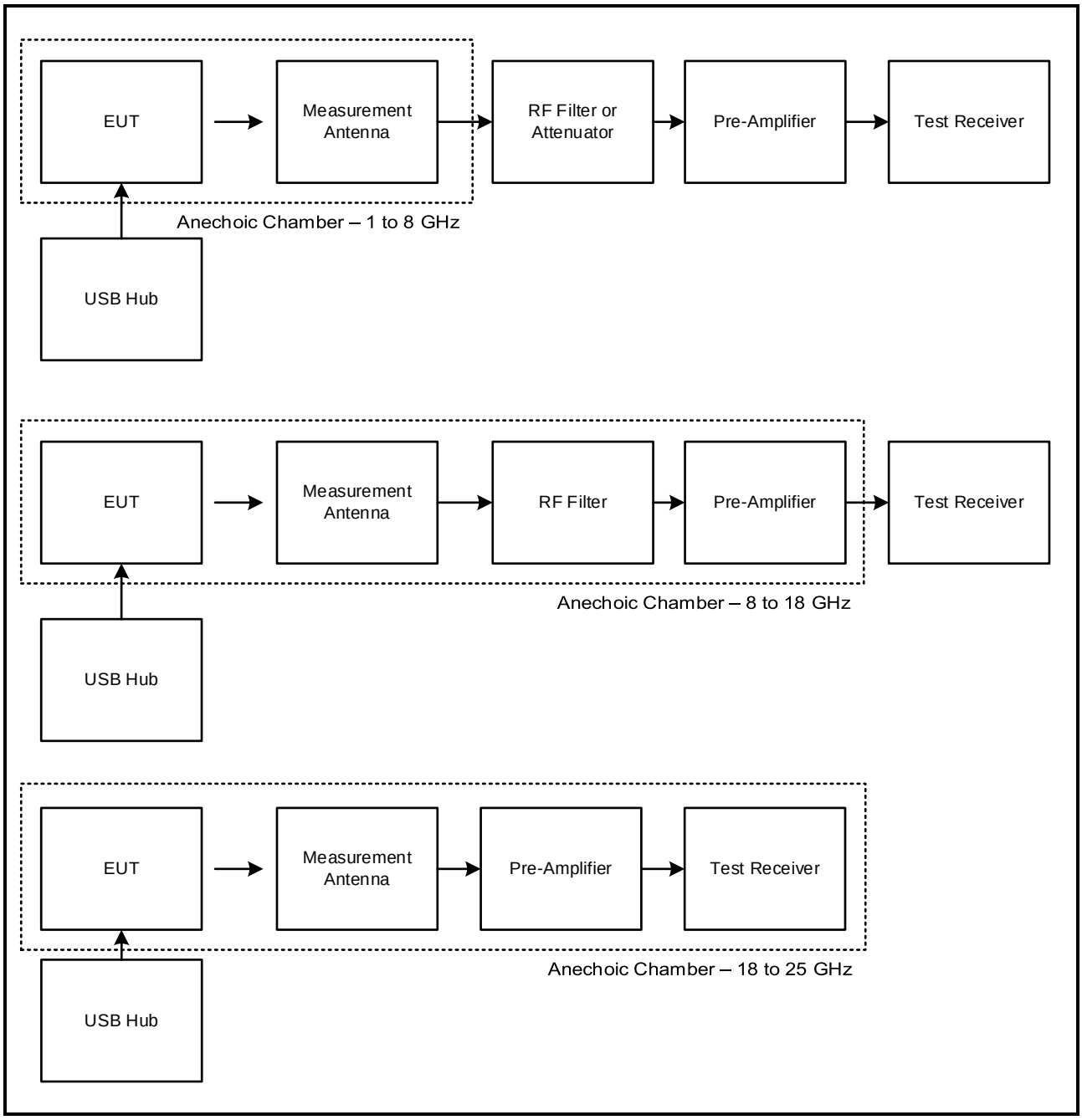
Radiated Tests:

Test Setup for Transmitter Radiated Emissions



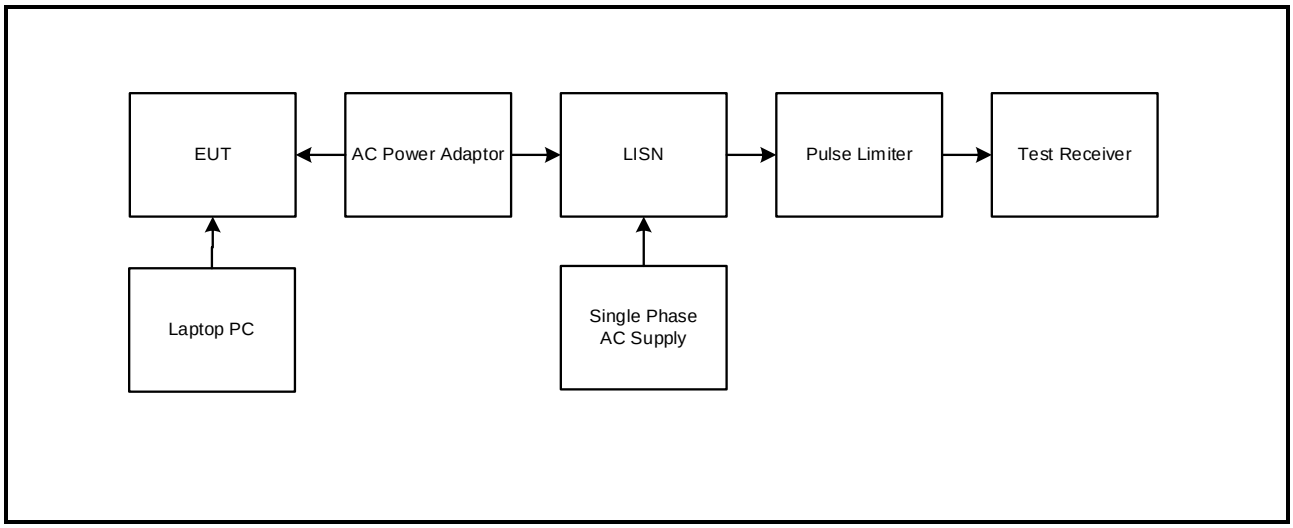
Test Setup Diagrams (continued)

Test Setup for Transmitter Radiated Emissions



Test Setup Diagrams (continued)

Test Setup for Transmitter AC Conducted Spurious Emissions



4. Antenna Port Test Results

4.1. Transmitter Minimum 6 dB Bandwidth

Test Summary:

Test Engineer:	Matthew Botfield	**Test Dates:**	19 September 2019 & 20 September 2019
Test Sample Serial Number:	F9217024401002077		

FCC Reference:	Part 15.247(a)(2)
Test Method Used:	FCC KDB 558074 Section 8.2 referencing ANSI C63.10 Section 11.8.1

Environmental Conditions:

Temperature (°C):	22
Relative Humidity (%):	50

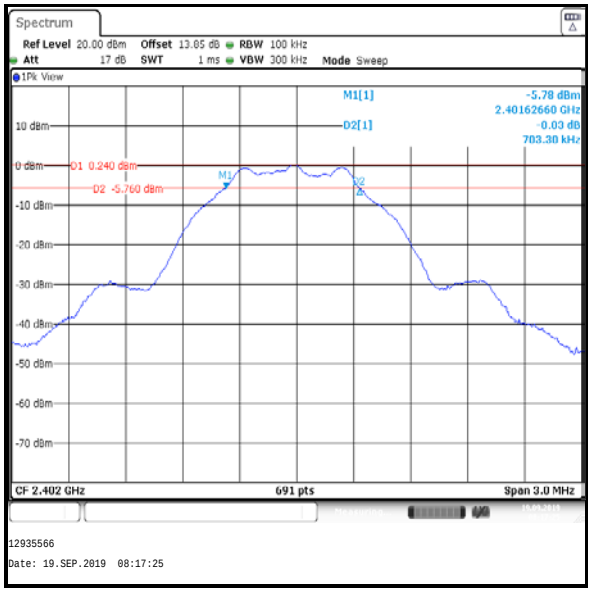
Note(s):

1. 6 dB DTS bandwidth tests were performed using a signal analyser in accordance with ANSI C63.10 Section 11.8.1 Option 1 measurement procedure. The signal analyser resolution bandwidth was set to 100 kHz and video bandwidth 300 kHz. A peak detector was used, sweep time was set to auto and the trace mode was Max Hold. The DTS bandwidth was measured at 6 dB down from the peak of the signal.
2. The signal analyser was connected to the RF port on the EUT using suitable attenuation and RF cable.

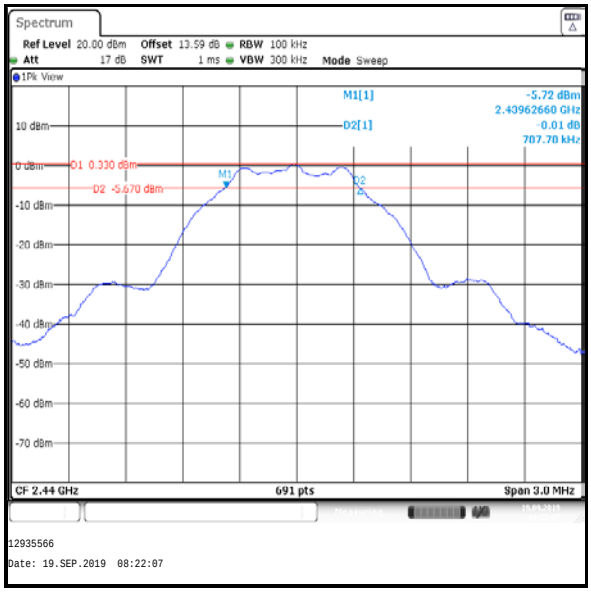
Transmitter Minimum 6 dB Bandwidth (continued)

Results: LE

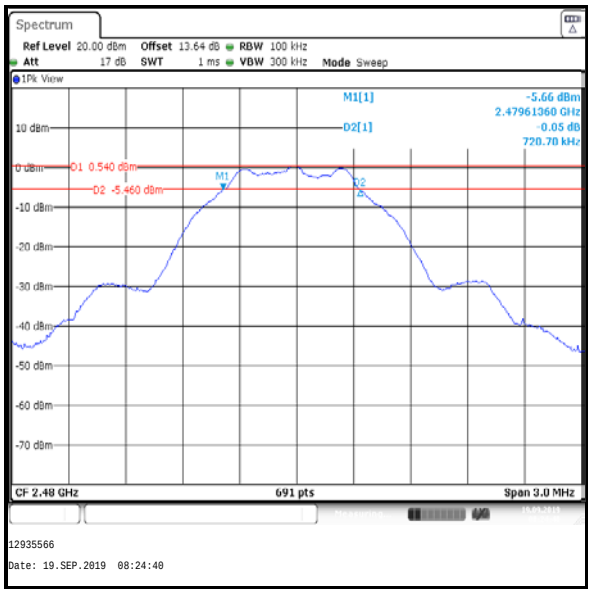
Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
Bottom	703.300	≥500	203.300	Complied
Middle	707.700	≥500	207.700	Complied
Top	720.700	≥500	220.700	Complied



Bottom Channel



Middle Channel

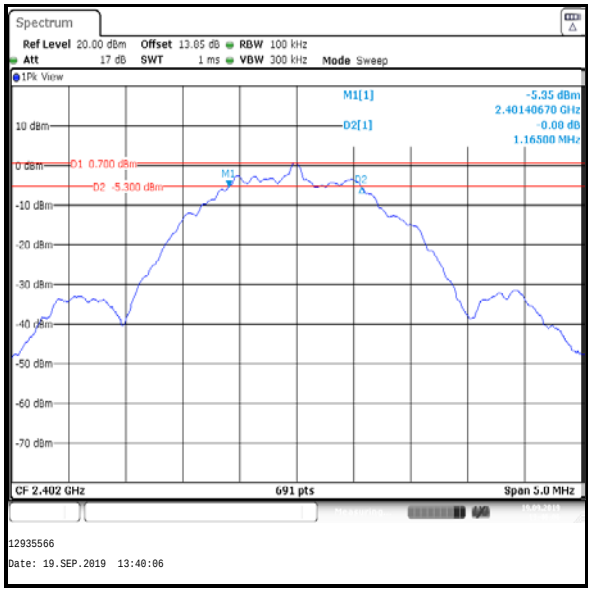


Top Channel

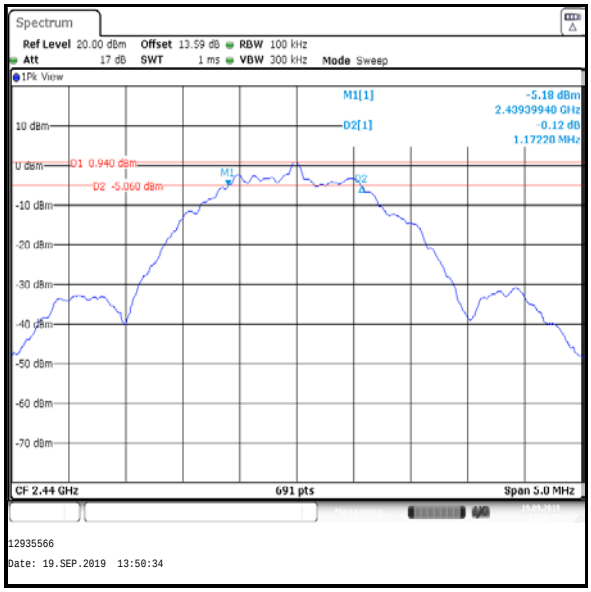
Transmitter Minimum 6 dB Bandwidth (continued)

Results: LE2M

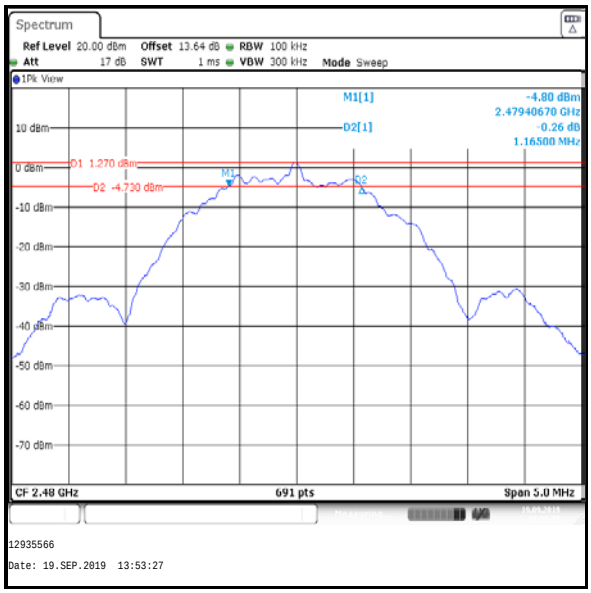
Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
Bottom	1165.000	≥500	665.000	Complied
Middle	1172.200	≥500	672.200	Complied
Top	1165.000	≥500	665.000	Complied



Bottom Channel



Middle Channel

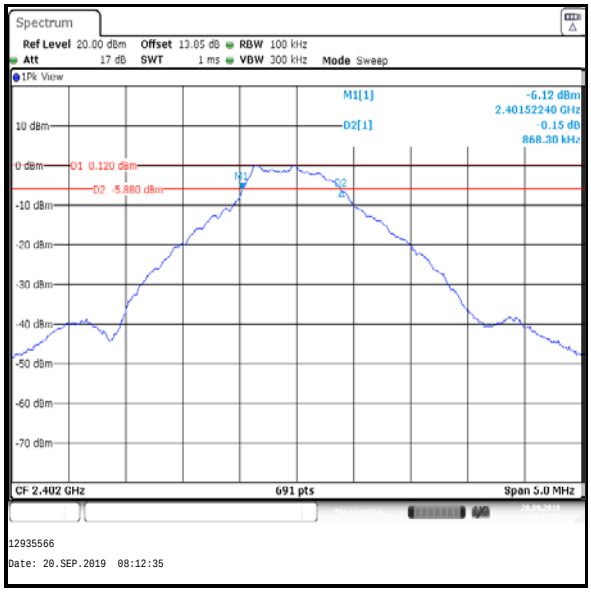


Top Channel

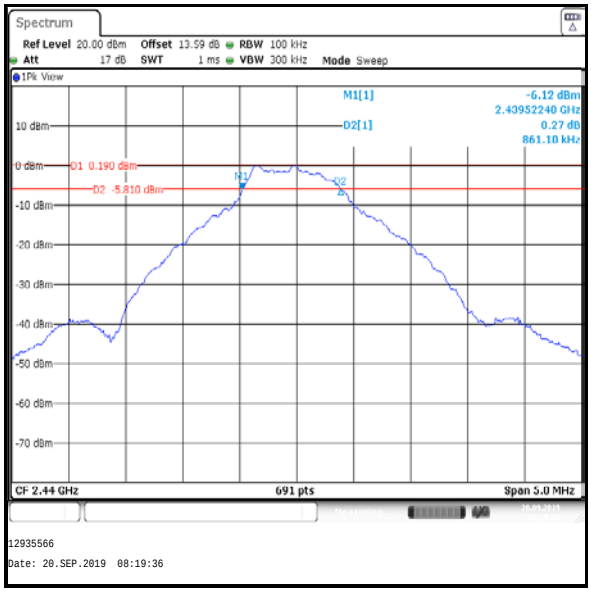
Transmitter Minimum 6 dB Bandwidth (continued)

Results: ShockBurst

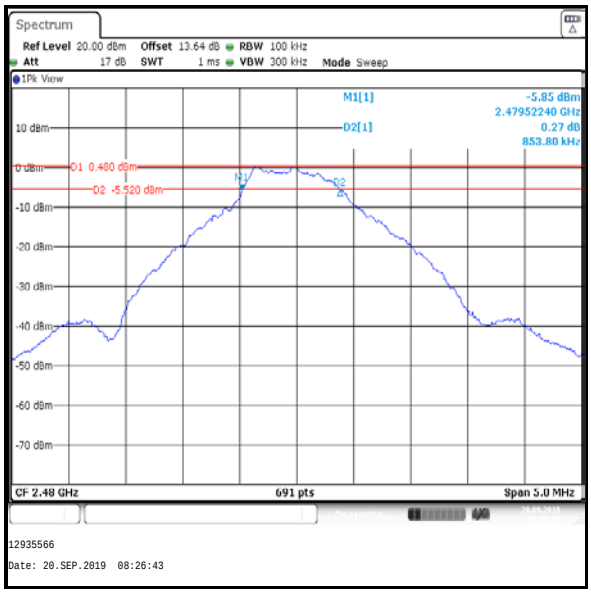
Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
Bottom	868.300	≥500	368.300	Complied
Middle	861.100	≥500	361.100	Complied
Top	853.800	≥500	353.800	Complied



Bottom Channel



Middle Channel



Top Channel

4.2. Transmitter Duty Cycle

Test Summary:

Test Engineer:	Matthew Botfield	**Test Date:**	20 September 2019
Test Sample Serial Number:	F9217024401002077		

FCC Reference:	Part 15.35(c)
Test Method Used:	FCC KDB 558074 Section 6 referencing ANSI C63.10 Section 11.6

Environmental Conditions:

Temperature (°C):	22
Relative Humidity (%):	50

Note(s):

1. In order to assist with the determination of the average level of spurious emissions field strength, measurements were made of duty cycle to determine the transmission duration and the silent period time of the transmitter. The transmitter duty cycle was measured using a signal analyser in the time domain and calculated as shown below:

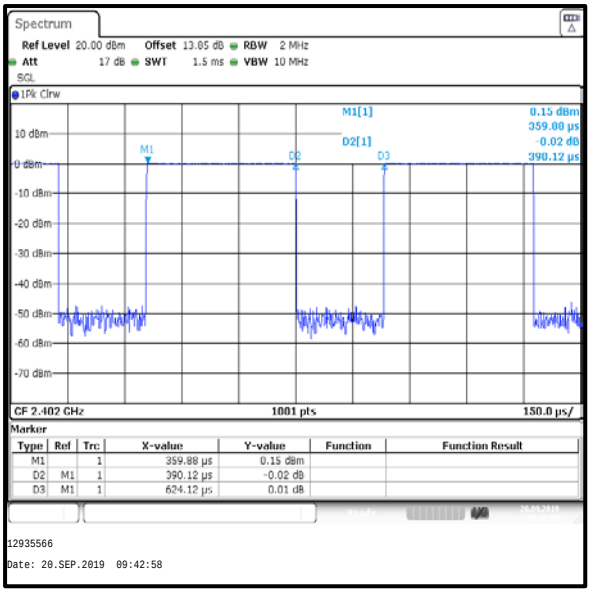
10 log (1 / (On Time / [Period or 100 ms whichever is the lesser])).

LE duty cycle: 10 log (1 / (390.120 µs / 624.120 µs)) = 2.0 dB
LE2M duty cycle: 10 log (1 / (201.000 µs / 625.500 µs)) = 4.9 dB
ShockBurst duty cycle: 10 log (1 / (320.000 µs / 2085.000 µs)) = 8.1 dB

Transmitter Duty Cycle (continued)

Results: LE

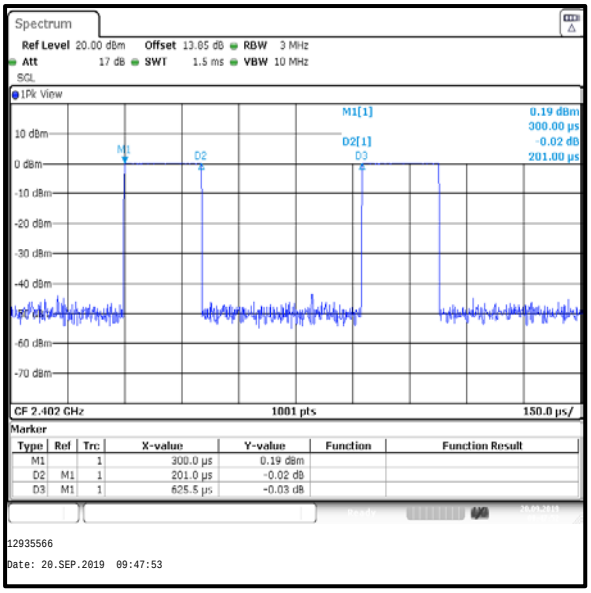
Pulse Duration (µs)	Period (µs)	Duty Cycle (dB)
390.120	624.120	2.0



Transmitter Duty Cycle (continued)

Results: LE2M

Pulse Duration (µs)	Period (µs)	Duty Cycle (dB)
201.000	625.500	4.9

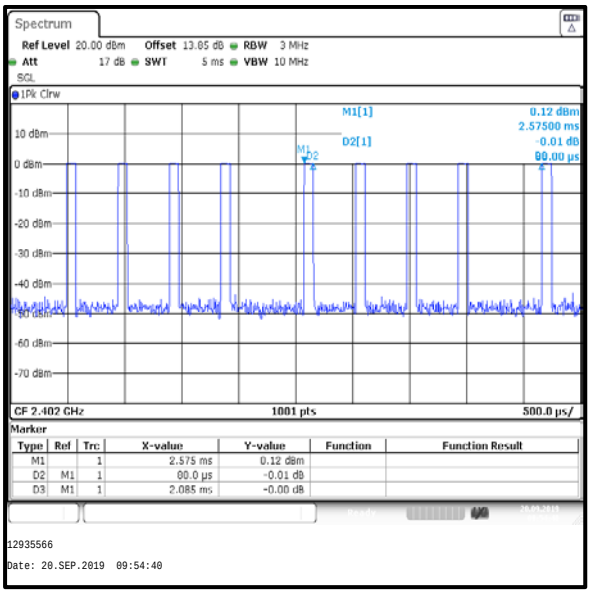


Transmitter Duty Cycle (continued)

Results: ShockBurst

Pulse	Pulse Duration (µs)
1	80
2	80
3	80
4	80
Total Pulse Duration:	320

Pulse Duration (µs)	Period (µs)	Duty Cycle (dB)
320.000	2085.000	8.1



4.3. Transmitter Maximum Peak Output Power

Test Summary:

Test Engineer:	Matthew Botfield	**Test Date:**	20 September 2019
Test Sample Serial Number:	F9217024401002077		

FCC Reference:	Part 15.247(b)(3)
Test Method Used:	FCC KDB 558074 Section 8.3.1.1 referencing ANSI C63.10 Section 11.9.1.1 and Notes below

Environmental Conditions:

Temperature (°C):	22
Relative Humidity (%):	50

Note(s):

1. Conducted power tests were performed using a signal analyser in accordance with ANSI C63.10 Section 11.9.1.1 with the RBW ≥ DTS bandwidth procedure.
2. The signal analyser resolution bandwidth was set to 1 MHz (LE / ShockBurst) or 2 MHz (LE2M) and video bandwidth of 3 MHz (LE / ShockBurst) or 10 MHz (LE2M). A peak detector was used, sweep time was set to auto and trace mode was Max Hold. The span was set to 3 MHz (LE / ShockBurst) or 10 MHz (LE2M). A marker was placed at the peak of the signal and the results recorded in the tables below.
3. The signal analyser was connected to the RF port on the EUT using suitable attenuation and RF cable. An RF level offset was entered on the signal analyser to compensate for the loss of the attenuator and RF cable.
4. The conducted power was added to the declared antenna gain to obtain the EIRP.

Transmitter Maximum Peak Output Power (continued)

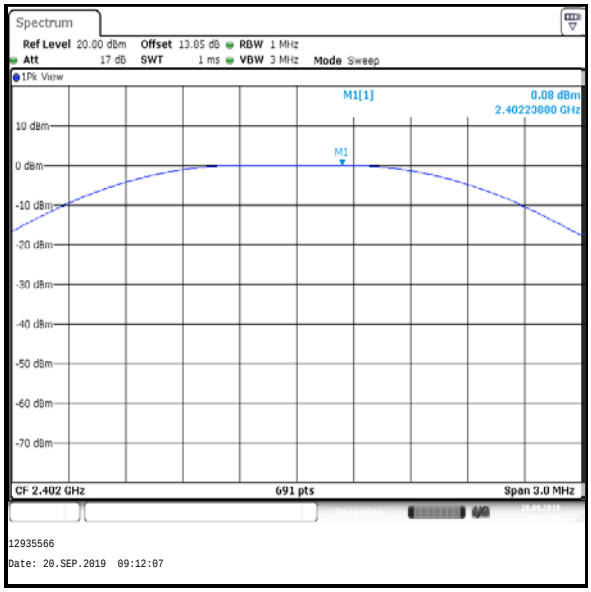
Results: LE

Channel	Conducted Peak Power (dBm)	Conducted Peak Power Limit (dBm)	Margin (dB)	Result
Bottom	0.1	30.0	29.9	Complied
Middle	0.2	30.0	29.8	Complied
Top	0.6	30.0	29.4	Complied

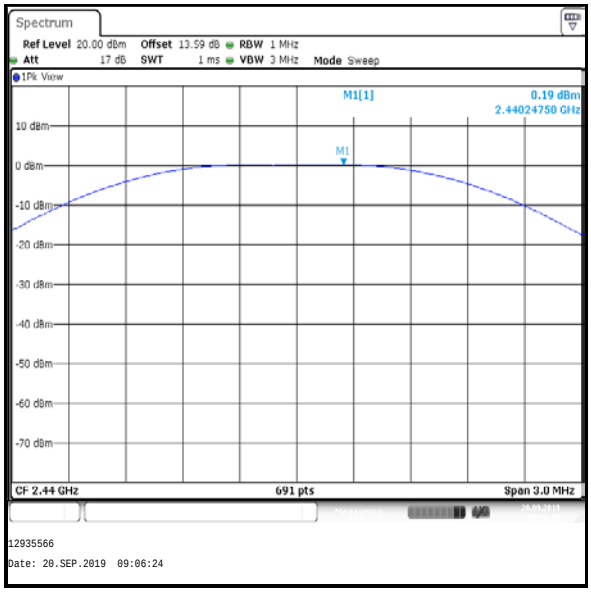
Channel	Conducted Peak Power (dBm)	Declared Antenna Gain (dBi)	EIRP (dBm)	De Facto EIRP Limit (dBm)	Margin (dB)	Result
Bottom	0.1	0.0	0.1	36.0	35.9	Complied
Middle	0.2	0.0	0.2	36.0	35.2	Complied
Top	0.6	0.0	0.6	36.0	35.4	Complied

Transmitter Maximum Peak Output Power (continued)

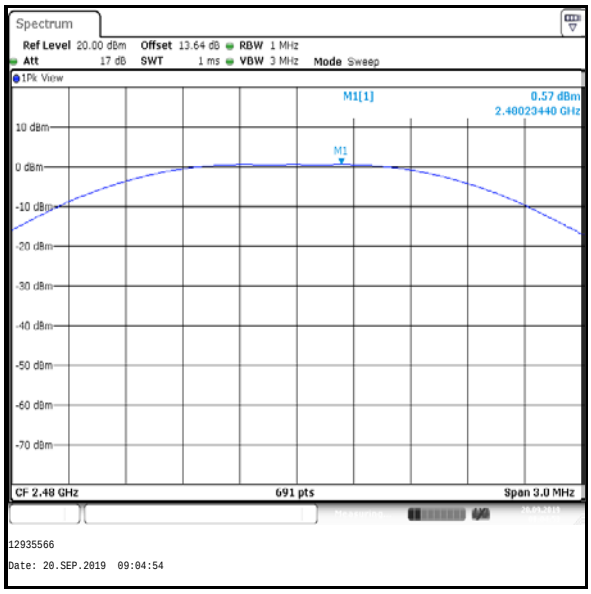
Results: LE



Bottom Channel



Middle Channel



Top Channel

Transmitter Maximum Peak Output Power (continued)

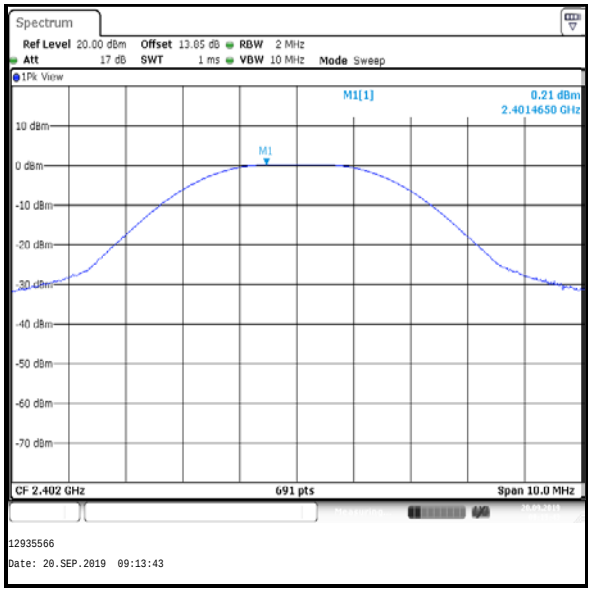
Results: LE2M

Channel	Conducted Peak Power (dBm)	Conducted Peak Power Limit (dBm)	Margin (dB)	Result
Bottom	0.2	30.0	29.8	Complied
Middle	0.4	30.0	29.6	Complied
Top	0.7	30.0	29.3	Complied

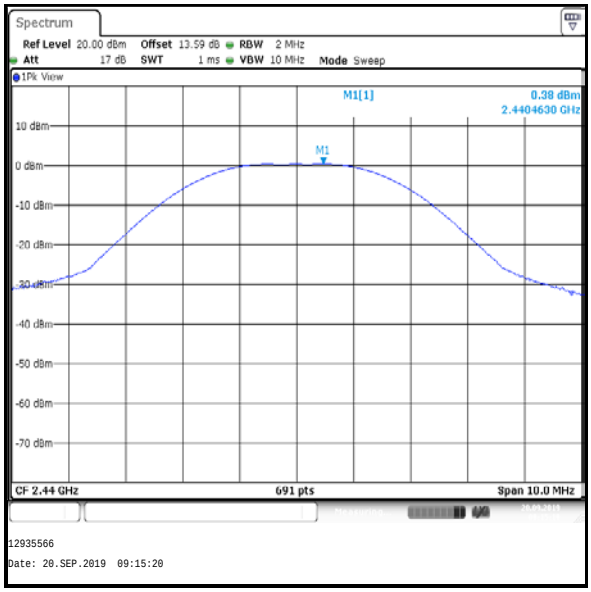
Channel	Conducted Peak Power (dBm)	Declared Antenna Gain (dBi)	EIRP (dBm)	De Facto EIRP Limit (dBm)	Margin (dB)	Result
Bottom	0.2	0.0	0.2	36.0	35.8	Complied
Middle	0.4	0.0	0.4	36.0	35.6	Complied
Top	0.7	0.0	0.7	36.0	35.3	Complied

Transmitter Maximum Peak Output Power (continued)

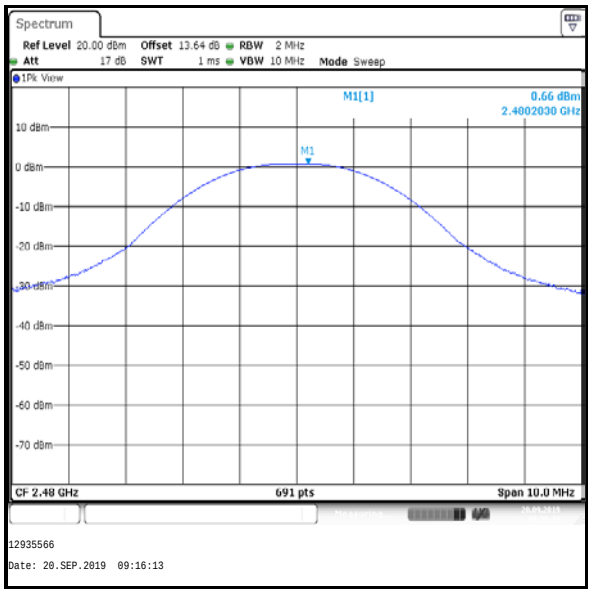
Results: LE2M



Bottom Channel



Middle Channel



Top Channel

Transmitter Maximum Peak Output Power (continued)

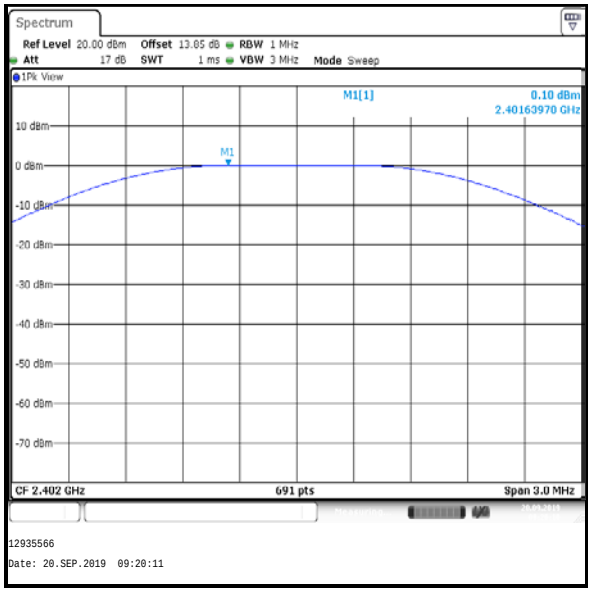
Results: ShockBurst

Channel	Conducted Peak Power (dBm)	Conducted Peak Power Limit (dBm)	Margin (dB)	Result
Bottom	0.1	30.0	29.9	Complied
Middle	0.3	30.0	29.7	Complied
Top	0.5	30.0	29.5	Complied

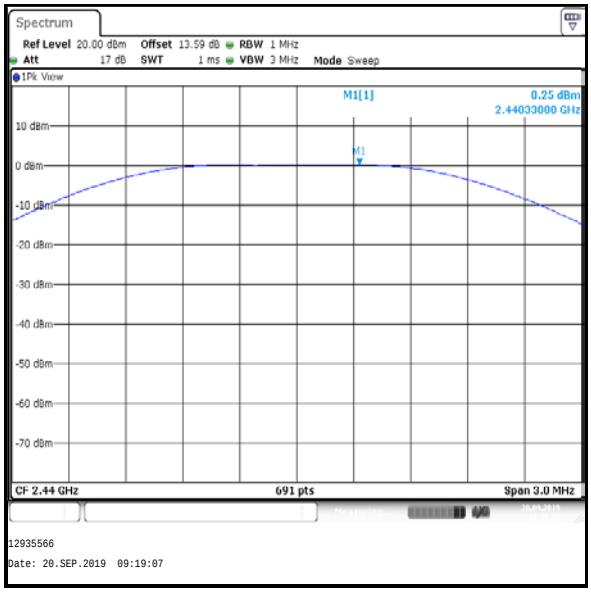
Channel	Conducted Peak Power (dBm)	Declared Antenna Gain (dBi)	EIRP (dBm)	De Facto EIRP Limit (dBm)	Margin (dB)	Result
Bottom	0.1	0.0	0.1	36.0	35.9	Complied
Middle	0.3	0.0	0.3	36.0	35.7	Complied
Top	0.5	0.0	0.5	36.0	35.5	Complied

Transmitter Maximum Peak Output Power (continued)

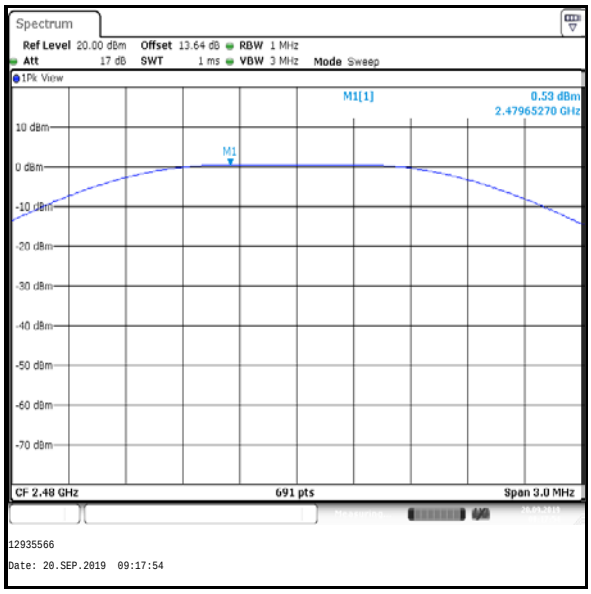
Results: ShockBurst



Bottom Channel



Middle Channel



Top Channel

5. Radiated Test Results

5.1. Transmitter Radiated Emissions <1 GHz

Test Summary:

Test Engineers:	Marco Zunarelli & Andrew Edwards	**Test Dates:**	23 September 2019 & 11 December 2019
Test Sample Serial Numbers:	LKBPROTOTYPED181 & LKBPROTOTYPED174		

FCC Reference:	Parts 15.247(d) & 15.209(a)
Test Method Used:	ANSI C63.10 Sections 6.3 and 6.5
Frequency Range	9 kHz to 1000 MHz

Environmental Conditions:

Temperature (°C):	23
Relative Humidity (%):	37 to 42

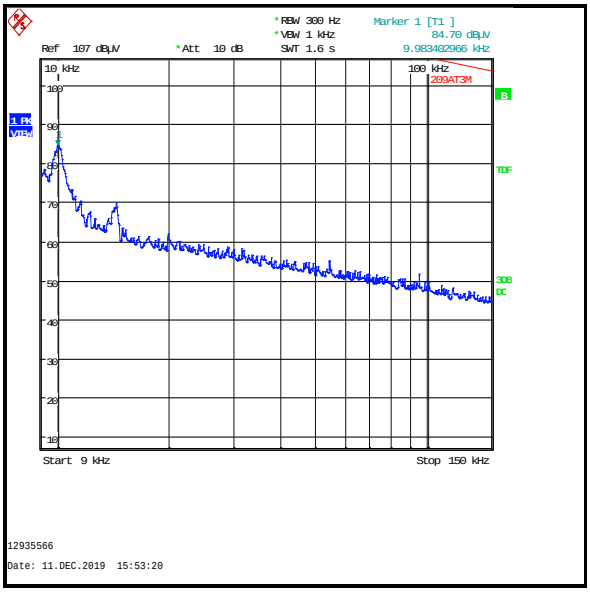
Note(s):

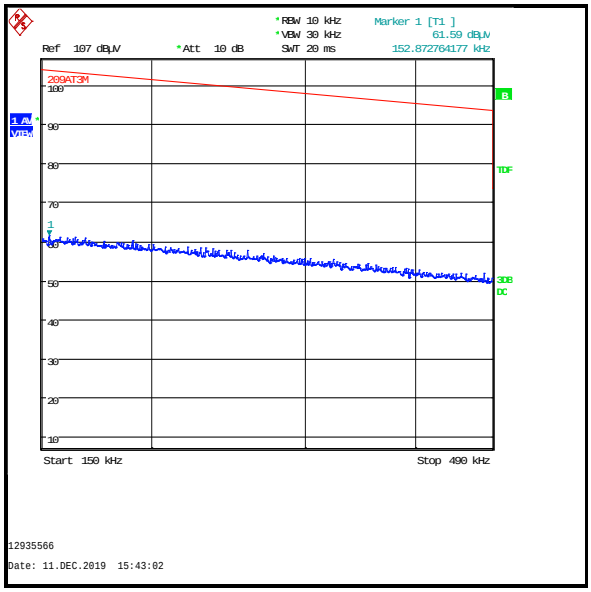
1. The final measured value, for the given emission, in the table below incorporates the calibrated antenna factor and cable loss.
2. The preliminary scans showed similar emission levels below 1 GHz, for each channel of operation. Therefore final radiated emissions measurements were performed with the EUT set to the middle channel only.
3. In accordance with FCC KDB 414788, an alternative test site may be used for the measurements below 30 MHz and they were performed in a semi-anechoic chamber (Asset Number K0001) at a distance of 3 metres. The EUT was placed at a height of 80 cm above the reference ground plane in the centre of the chamber turntable. The limit was extrapolated to 3 metres in accordance with ANSI C63.10 Section 6.4.4.2. Correlation data between the semi-anechoic chamber and an open-field test site is available upon request.
4. Measurements between 30 MHz to 1 GHz were performed in a semi-anechoic chamber (Asset Number K0017) at a distance of 3 metres. The EUT was placed at a height of 80 cm above the reference ground plane in the centre of the chamber turntable. Maximum emission levels were determined by height searching the measurement antenna over the range 1 metre to 4 metres.
5. No spurious emissions were detected above the noise floor of the measuring receiver therefore the highest peak noise floor reading of the measuring receiver was recorded as shown in the table below.
6. There are ambient emissions seen between 2 to 30 MHz on pre-scan plot 490 kHz to 30 MHz performed in the semi-anechoic chamber. A background scan between 490 kHz to 30 MHz is stored on the company server and is available for inspection on request.
7. Pre-scans were performed, and markers placed on the highest measured levels. For measurements below 150 kHz: The test receiver resolution bandwidth was set to 300 Hz and video bandwidth 1 kHz. A peak detector was used, sweep time was set to auto and trace mode was Max Hold. For measurements between 150 to 490 kHz: The test receiver resolution bandwidth was set to 10 kHz and video bandwidth 30 kHz. An average detector was used, sweep time was set to auto and trace mode was Max Hold. For measurements between 490 kHz to 30 MHz: The test receiver resolution bandwidth was set to 10 kHz and video bandwidth 30 kHz. A peak detector was used, sweep time was set auto and trace mode was Max Hold. For measurements between 30 MHz to 1 GHz: The test receiver resolution bandwidth was set to 120 kHz and video bandwidth 500 kHz. A peak detector was used, sweep time was set auto and trace mode was Max Hold.

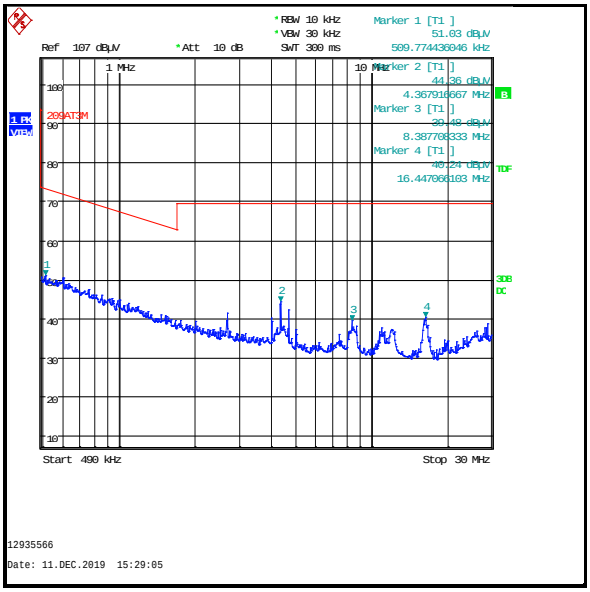
Transmitter Radiated Emissions (continued)

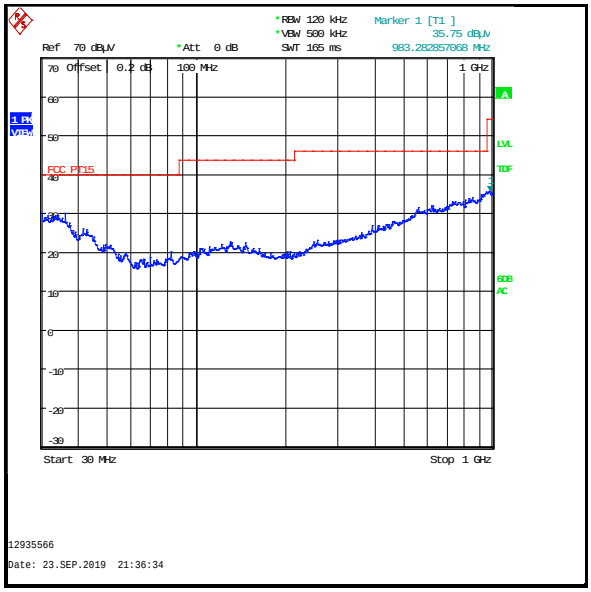
Results: Peak / Middle Channel / LE2M

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
983.283	Horizontal	35.8	54.0	18.2	Complied









5.2. Transmitter Radiated Emissions >1 GHz

Test Summary:

Test Engineers:	Marco Zunarelli & Tom Sleigh	**Test Dates:**	23 September 2019 to 02 October 2019
Test Sample Serial Numbers:	LKBPROTOTYPED181 & LKBPROTOTYPED174		

FCC Reference:	Parts 15.247(d) & 15.209(a)
Test Method Used:	FCC KDB 558074 Sections 8.1 c)3), 8.5 & 8.6 referencing ANSI C63.10 Sections 6.3, 6.6, 11.11 & 11.12
Frequency Range	1 GHz to 25 GHz

Environmental Conditions:

Temperature (°C):	23 to 24
Relative Humidity (%):	45 to 48

Note(s):

1. The final measured value, for the given emission, in the table below incorporates the calibrated antenna factor and cable loss.
2. The emission shown on the 1 GHz to 4 GHz plot is the EUT fundamental.
3. Pre-scans above 1 GHz were performed in a fully anechoic chamber (Asset Number K0017) at a distance of 3 metres. The EUT was placed at a height of 1.5 metres above the test chamber floor in the centre of the chamber turntable. All measurement antennas were placed at a fixed height of 1.5 metres above the test chamber floor, in line with the EUT.
4. Final measurements above 1 GHz were performed in a semi-anechoic chamber (Asset Number K0017) at a distance of 3 metres. The EUT was placed at a height of 1.5 m above the reference ground plane in the centre of the chamber turntable. Maximum emission levels were determined by height searching the measurement antenna over the range 1 metre to 4 metres.
5. Pre-scans were performed and a marker placed on the highest measured level of the appropriate plot. The test receiver resolution bandwidth was set to 1 MHz and video bandwidth 3 MHz. The sweep time was set to auto. Peak and average measurements were performed with their own appropriate detectors during the pre-scan measurements.
6. **As the EUT had a duty cycle < 98% the duty cycle correction factor has been applied to the average results. The corrected levels were calculated as shown below:

Average result + duty cycle correction = Corrected level

Transmitter Radiated Emissions (continued)

Results: Peak / Bottom Channel / LE2M

Frequency (MHz)	Antenna Polarity	Peak Level (dBµV/m)	Peak Limit (dBµV/m)	Margin (dB)	Result
4670.739	Horizontal	50.1	74.0	23.9	Complied
4802.974	Vertical	51.6	74.0	22.4	Complied
4853.463	Vertical	50.3	74.0	23.7	Complied

Results: Average / Bottom Channel / LE2M

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Duty cycle correction (dB)	Corrected Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
4670.739	Horizontal	22.2	4.9	27.1**	54.0	26.9	Complied
4803.967	Vertical	41.8	4.9	46.7**	54.0	7.3	Complied
4853.848	Vertical	22.1	4.9	27.0**	54.0	27.0	Complied

Results: Peak / Middle Channel / LE2M

Frequency (MHz)	Antenna Polarity	Peak Level (dBµV/m)	Peak Limit (dBµV/m)	Margin (dB)	Result
4670.051	Horizontal	51.4	74.0	22.6	Complied
4878.974	Vertical	53.4	74.0	20.6	Complied

Results: Average / Middle Channel / LE2M

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Duty cycle correction (dB)	Corrected Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
4670.265	Horizontal	22.9	4.9	27.8**	54.0	26.2	Complied
4879.935	Vertical	43.0	4.9	47.9**	54.0	6.1	Complied

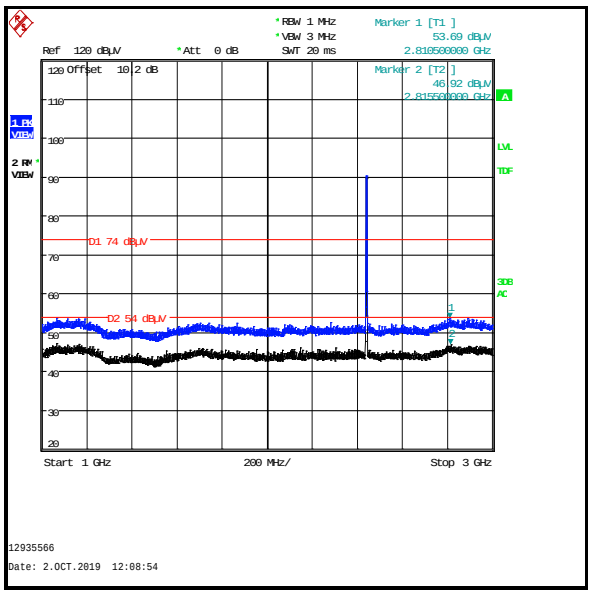
Results: Peak / Top Channel / LE2M

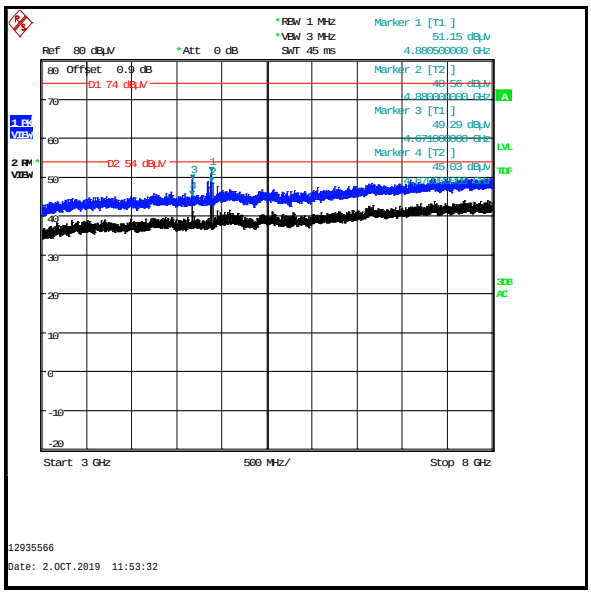
Frequency (MHz)	Antenna Polarity	Peak Level (dBµV/m)	Peak Limit (dBµV/m)	Margin (dB)	Result
4670.740	Horizontal	49.4	74.0	24.6	Complied
4959.968	Vertical	53.7	74.0	20.3	Complied

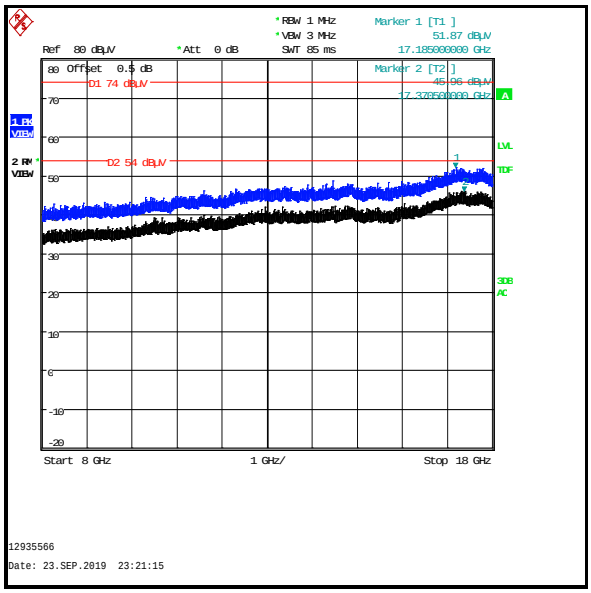
Results: Average / Top Channel / LE2M

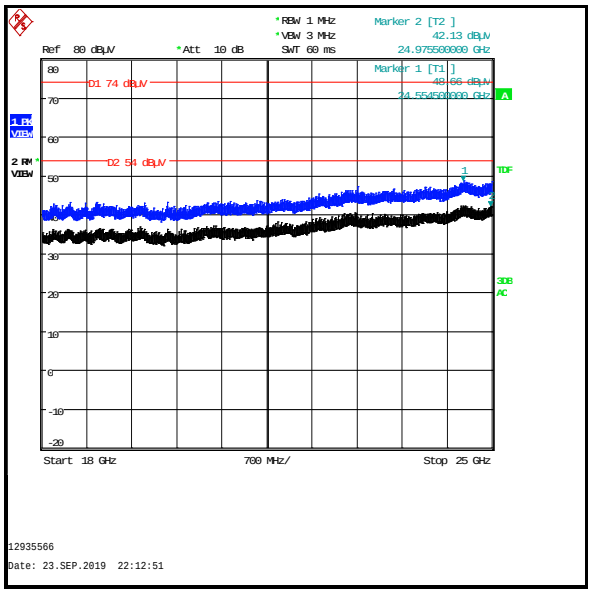
Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Duty cycle correction (dB)	Corrected Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
4670.579	Horizontal	22.3	4.9	27.2**	54.0	26.8	Complied
4959.856	Vertical	42.9	4.9	47.8**	54.0	6.2	Complied

Transmitter Radiated Emissions (continued)









Note: The above plots are pre-scans and for indication purposes only. For final measurements, see accompanying tables.

5.3. Transmitter Band Edge Radiated Emissions

Test Summary:

Test Engineer:	Marco Zunarelli	**Test Dates:**	20 September 2019 & 24 September 2019
Test Sample Serial Number:	LKBPROTOTYPED181		

FCC Reference:	Parts 15.247(d) & 15.209(a)
Test Method Used:	KDB 558074 Section 8.7 referencing ANSI C63.10 Sections 11.11, 11.12 & 11.13

Environmental Conditions:

Temperature (°C):	24 to 25
Relative Humidity (%):	40 to 49

Transmitter Band Edge Radiated Emissions (continued)

Note(s):

1. The final measured value, for the given emission, in the table below incorporates the calibrated antenna factor and cable loss.
2. The maximum peak conducted output power was previously measured. In accordance with ANSI C63.10 Section 11.11.1(a), the lower band edge measurement was performed with a peak detector and the -20 dBc limit applied.
3. As the lower band edge is adjacent to a non-restricted band, only peak measurements are required. In accordance with ANSI C63.10 Section 11.11.1, the test method in Section 11.11.3 was followed: the test receiver resolution bandwidth was set to 100 kHz and video bandwidth 300 kHz. A peak detector was used, sweep time was set to auto and trace mode was Max Hold. The test receiver was left to sweep for a sufficient length of time in order to maximise the carrier level and out-of-band emissions. A marker and corresponding reference level line were placed on the peak of the carrier. As the maximum peak conducted output power was measured using an peak detector in accordance with ANSI C63.10 Section 11.9.1.1 an out-of-band limit line was placed 20 dB (ANSI C63.10 Section 11.11.1(a)) below the peak level. A marker was placed on the band edge spot frequencies. Marker frequency and levels were recorded.
4. As the upper band edge is adjacent to a restricted band, both peak and average measurements were recorded by placing a marker at the edge of the band. For peak measurements the test receiver resolution bandwidth was set to 1 MHz and the video bandwidth 3 MHz. A peak detector was used, sweep time was set to auto and trace mode was Max Hold. For average measurements the test receiver resolution bandwidth was set to 1 MHz and the video bandwidth 3 MHz. An RMS detector was used, sweep time was set to auto and trace mode was trace averaging over 300 sweeps. A marker was placed on the band edge spot frequencies and a second marker placed on the highest emission level in the adjacent restricted band of operation (where a higher level emission was present). Marker frequencies and levels were recorded.
5. There is a restricted band 10 MHz below the lower band edge. The test receiver was set up as follows: the RBW set to 1 MHz, the VBW set to 3 MHz, with the sweep time set to auto couple. Peak and average measurements were performed with peak and RMS detectors respectively. Markers were placed on the highest point on each trace.
6. * -20 dBc limit.
7. **As the EUT had a duty cycle < 98% the duty cycle correction factor has been applied to the upper band edge average result. The corrected levels were calculated as shown below:

   Upper Band Average result + duty cycle = Corrected band edge level

   LE Upper Band Average result + 2.0 = LE Corrected band edge level
   LE2M Upper Band Average result + 4.9 = LE2M Corrected band edge level
   ShockBurst Upper Band Average result + 8.1 = ShockBurst Corrected band edge level
8. All other emissions were greater than 20 dB below the limit.

Transmitter Band Edge Radiated Emissions (continued)

Results: Peak / LE

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2400.000	Horizontal	44.0	68.5*	24.5	Complied
2483.500	Horizontal	58.7	74.0	15.3	Complied

Results: Average / LE

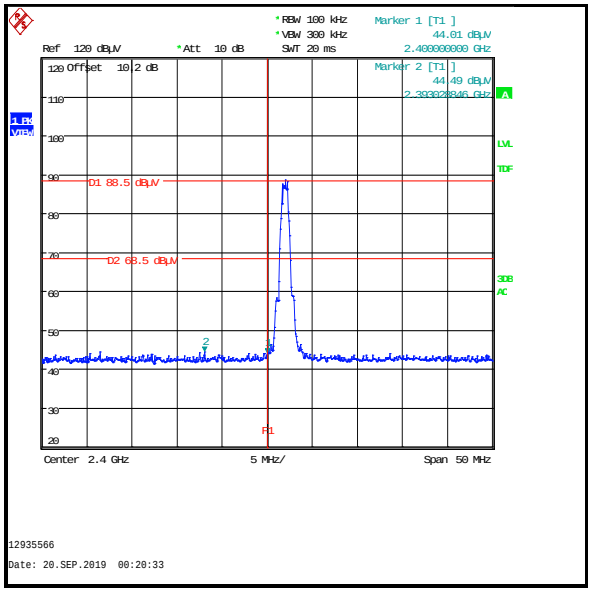
Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Duty cycle correction (dB)	Corrected Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Horizontal	45.1	2.0	47.1**	54.0	6.9	Complied

Results: 2310 MHz to 2390 MHz Restricted Band / Peak / LE

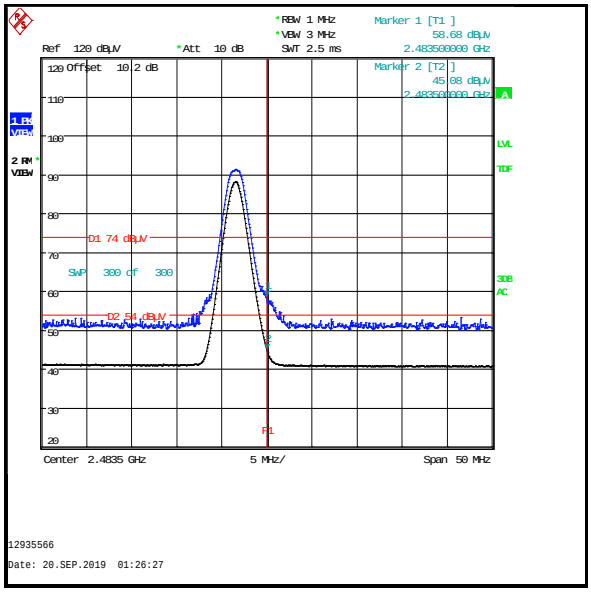
Frequency (MHz)	Antenna Polarity	Peak Level (dBµV/m)	Average Limit (dBµV/m)	Margin (dB)	Result
2387.949	Horizontal	52.8	54.0	1.2	Complied

Transmitter Band Edge Radiated Emissions (continued)

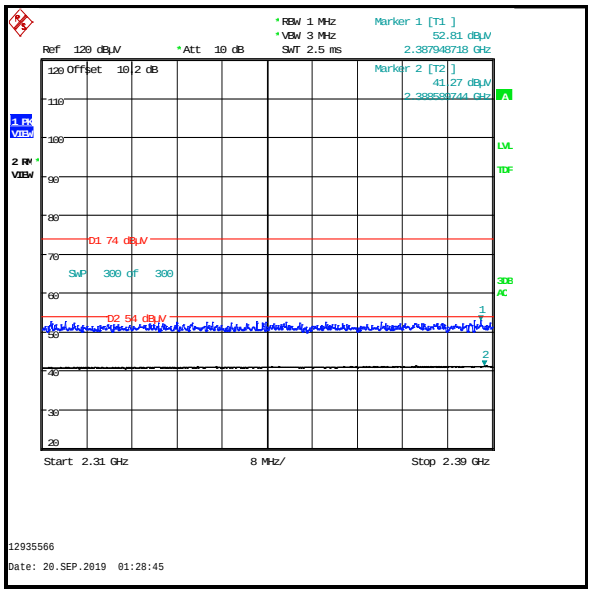
Results: LE



Lower Band Edge



Upper Band Edge



2310 MHz to 2390 MHz Restricted Band

Transmitter Band Edge Radiated Emissions (continued)

Results: Peak / LE2M

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2399.920	Horizontal	55.8	69.7*	13.9	Complied
2400.000	Horizontal	55.5	69.7*	14.2	Complied
2483.500	Horizontal	58.7	74.0	15.3	Complied

Results: Average / LE2M

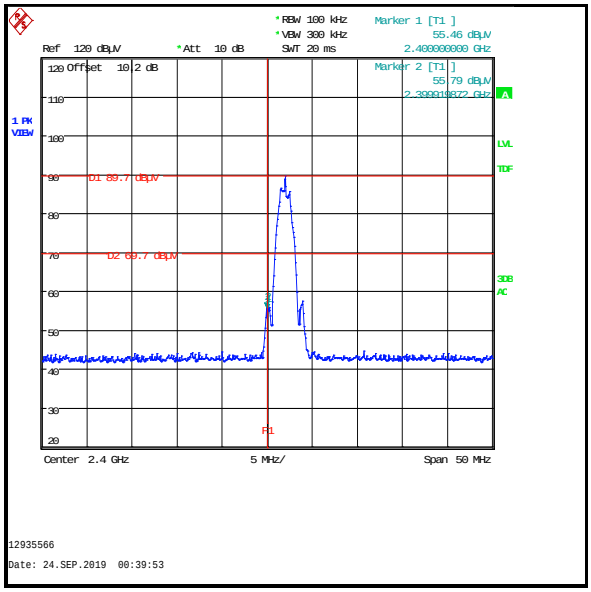
Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Duty cycle correction (dB)	Corrected Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Horizontal	46.3	4.9	51.2**	54.0	2.8	Complied

Results: 2310 MHz to 2390 MHz Restricted Band / Peak / LE2M

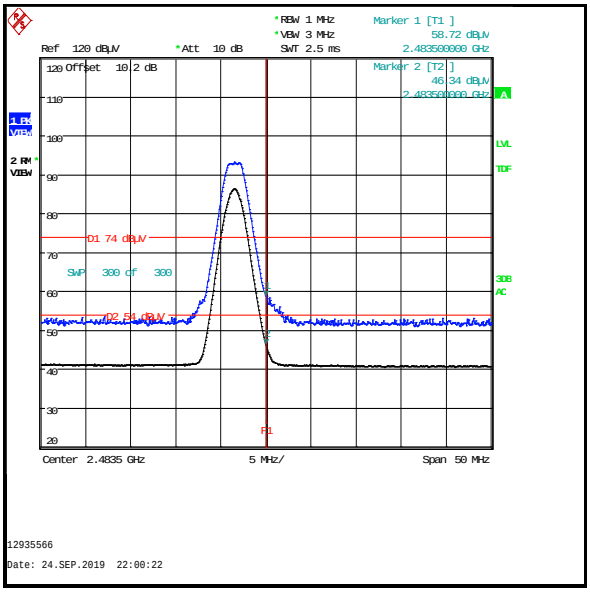
Frequency (MHz)	Antenna Polarity	Peak Level (dBµV/m)	Average Limit (dBµV/m)	Margin (dB)	Result
2334.615	Horizontal	53.1	54.0	0.9	Complied

Transmitter Band Edge Radiated Emissions (continued)

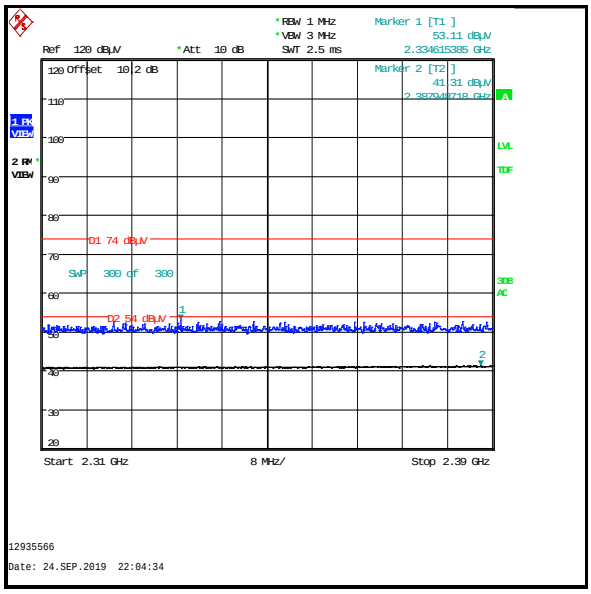
Results: LE2M



Lower Band Edge



Upper Band Edge



2310 MHz to 2390 MHz Restricted Band

Transmitter Band Edge Radiated Emissions (continued)

Results: Peak / ShockBurst

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2399.920	Horizontal	50.3	69.5*	19.2	Complied
2400.000	Horizontal	50.0	69.5*	19.5	Complied
2483.500	Horizontal	61.1	74.0	12.9	Complied

Results: Average / ShockBurst

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Duty cycle correction (dB)	Corrected Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2483.500	Horizontal	42.9	8.1	51.0**	54.0	3.0	Complied

Results: 2310 MHz to 2390 MHz Restricted Band / Peak / ShockBurst

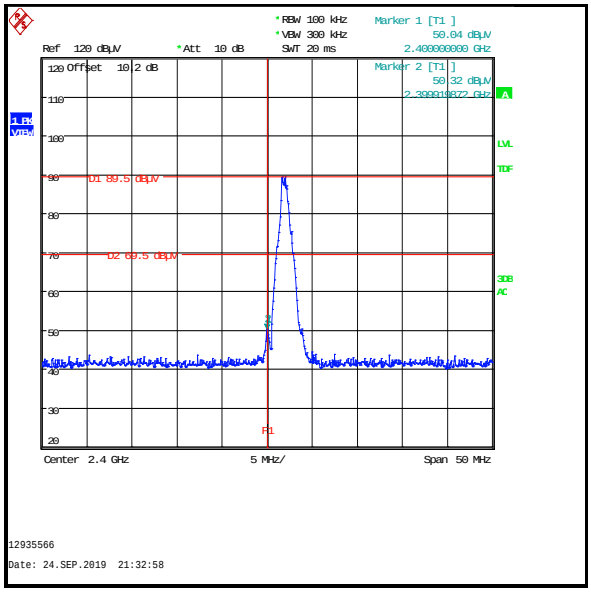
Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2388.205	Horizontal	54.2	74.0	19.8	Complied

Results: 2310 MHz to 2390 MHz Restricted Band / Average / ShockBurst

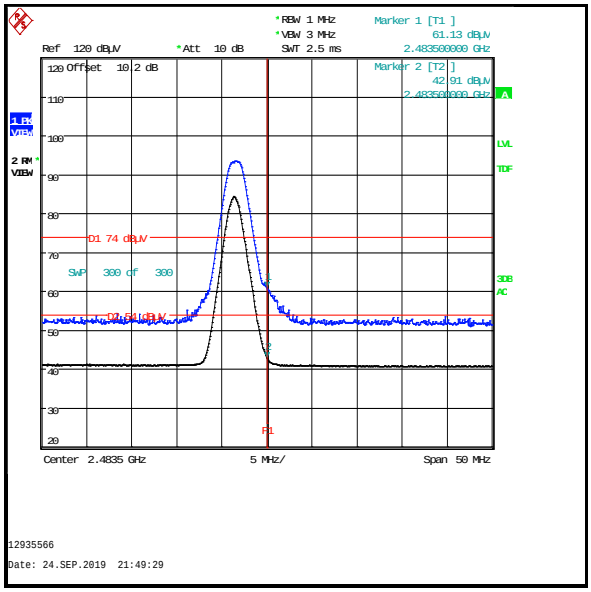
Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
2384.231	Horizontal	41.2	54.0	12.8	Complied

Transmitter Band Edge Radiated Emissions (continued)

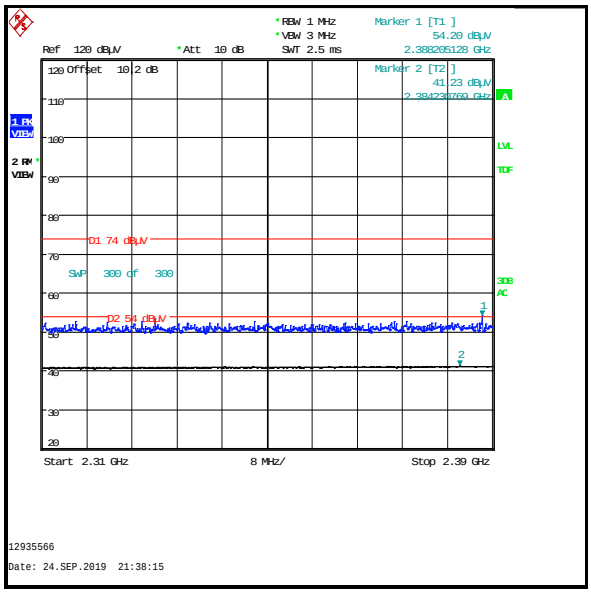
Results: ShockBurst



Lower Band Edge



Upper Band Edge



2310 MHz to 2390 MHz Restricted Band

6. AC Power Line Conducted Emissions Test Results

6.1. Transmitter AC Conducted Spurious Emissions

Test Summary:

Test Engineer:	Alison Johnston	**Test Date:**	20 September 2019
Test Sample Serial Number:	LKBPROTOTYPED181		

FCC Reference:	Part 15.207
Test Method Used:	ANSI C63.10 Section 6.2 / FCC KDB 174176 and notes below

Environmental Conditions:

Temperature (°C):	23
Relative Humidity (%):	47

Note(s):

1. The EUT was connected to a switched mode power supply output via USB cable. The switched mode power supply input was connected to 120 VAC 60 Hz single phase supply via a LISN.
2. In accordance with FCC KDB 174176 Q4, tests were also performed with a 240 VAC 60 Hz single phase supply as this was within the input voltage range marked on the switched mode power supply.
3. A pulse limiter was fitted between the LISN and the test receiver.
4. Pre-scans were performed and markers placed on the highest live and neutral measured levels. Final measurements were performed on the marker frequencies and the results entered into the tables below.

Transmitter AC Conducted Spurious Emissions (continued)

Results: Live / Quasi Peak / 120 VAC 60 Hz

Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.546	Live	36.3	56.0	19.7	Complied
0.573	Live	36.3	56.0	19.7	Complied
0.744	Live	31.1	56.0	24.9	Complied
1.424	Live	28.1	56.0	27.9	Complied
17.673	Live	25.7	60.0	34.3	Complied
23.960	Live	26.3	60.0	33.7	Complied

Results: Live / Average / 120 VAC 60 Hz

Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.582	Live	20.6	46.0	25.4	Complied
0.618	Live	22.1	46.0	23.9	Complied
0.740	Live	16.2	46.0	29.8	Complied
1.532	Live	15.5	46.0	30.5	Complied
9.029	Live	16.7	50.0	33.3	Complied
24.005	Live	16.5	50.0	33.5	Complied

Results: Neutral / Quasi Peak / 120 VAC 60 Hz

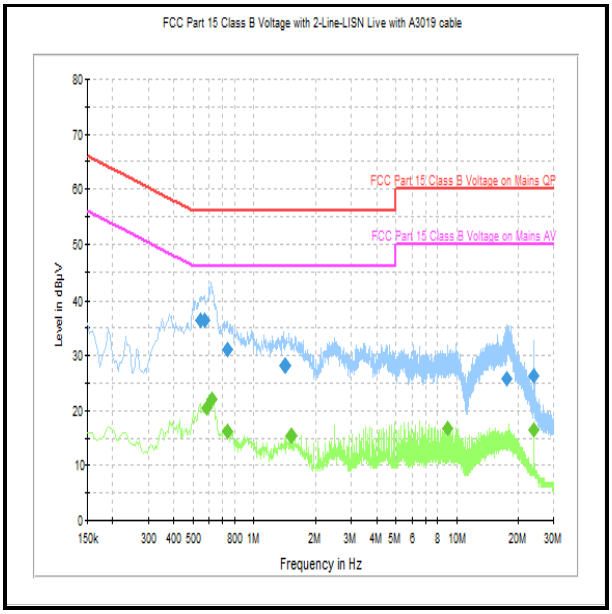
Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.551	Neutral	29.8	56.0	26.2	Complied
0.600	Neutral	30.5	56.0	25.5	Complied
1.392	Neutral	20.7	56.0	35.3	Complied
2.409	Neutral	19.8	56.0	36.2	Complied
4.317	Neutral	17.7	56.0	38.3	Complied
18.402	Neutral	24.8	60.0	35.2	Complied

Results: Neutral / Average / 120 VAC 60 Hz

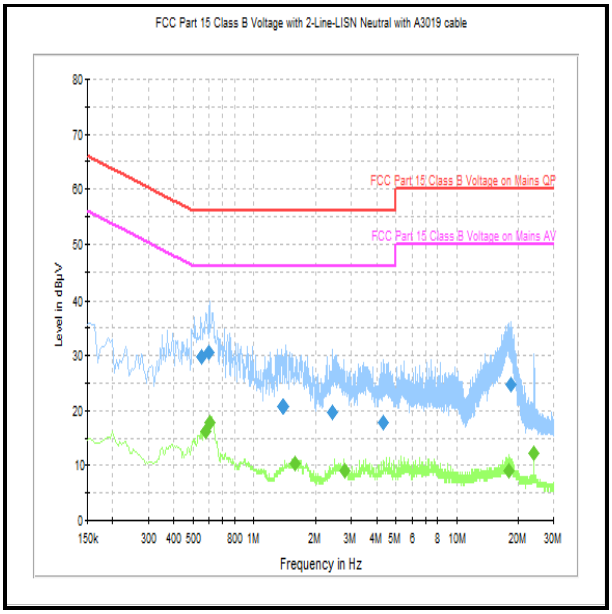
Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.578	Neutral	16.3	46.0	29.7	Complied
0.609	Neutral	17.9	46.0	28.1	Complied
1.572	Neutral	10.4	46.0	35.6	Complied
2.774	Neutral	9.0	46.0	37.0	Complied
18.051	Neutral	9.1	50.0	40.9	Complied
24.005	Neutral	12.1	50.0	37.9	Complied

Transmitter AC Conducted Spurious Emissions (continued)

Results: 120 VAC 60 Hz



Live



Neutral

Note: These plots are pre-scans and for indication purposes only. For final measurements, see accompanying tables.

Transmitter AC Conducted Spurious Emissions (continued)

Results: Live / Quasi Peak / 240 VAC 60 Hz

Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.537	Live	37.6	56.0	18.4	Complied
0.659	Live	38.1	56.0	17.9	Complied
0.875	Live	35.7	56.0	20.3	Complied
1.487	Live	32.8	56.0	23.2	Complied
2.058	Live	32.2	56.0	23.8	Complied
3.431	Live	29.1	56.0	26.9	Complied

Results: Live / Average / 240 VAC 60 Hz

Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.551	Live	24.8	46.0	21.2	Complied
0.654	Live	25.1	46.0	20.9	Complied
0.857	Live	24.5	46.0	21.5	Complied
2.112	Live	19.7	46.0	26.3	Complied
3.431	Live	18.1	46.0	27.9	Complied
4.911	Live	19.0	46.0	27.0	Complied

Results: Neutral / Quasi Peak / 240 VAC 60 Hz

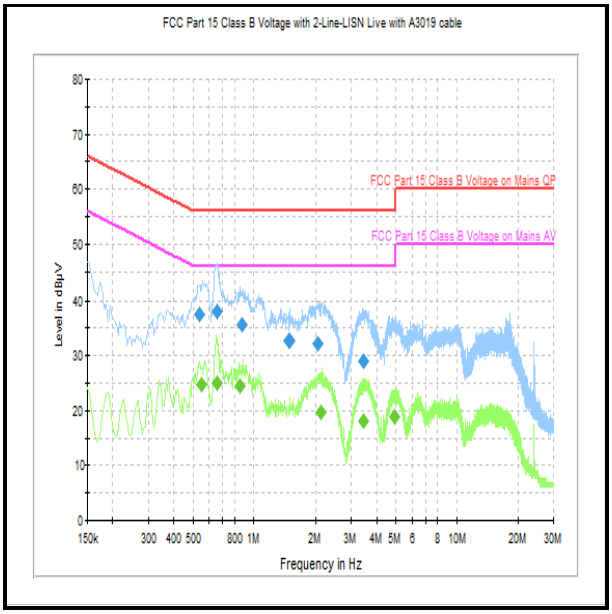
Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.560	Neutral	32.1	56.0	23.9	Complied
0.654	Neutral	32.6	56.0	23.4	Complied
1.091	Neutral	30.5	56.0	25.5	Complied
1.334	Neutral	27.7	56.0	28.3	Complied
3.611	Neutral	23.0	56.0	33.0	Complied
17.961	Neutral	14.6	60.0	45.4	Complied

Results: Neutral / Average / 240 VAC 60 Hz

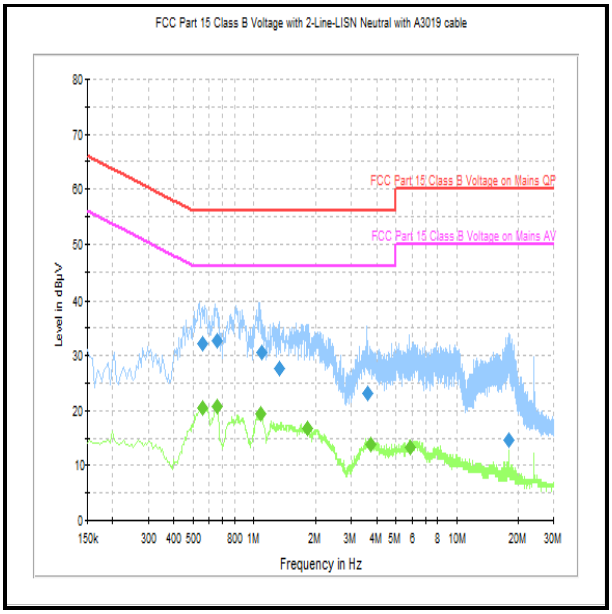
Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.555	Neutral	20.6	46.0	25.4	Complied
0.654	Neutral	20.7	46.0	25.3	Complied
1.086	Neutral	19.3	46.0	26.7	Complied
1.820	Neutral	16.8	46.0	29.2	Complied
3.750	Neutral	13.7	46.0	32.3	Complied
5.838	Neutral	13.2	50.0	36.8	Complied

Transmitter AC Conducted Spurious Emissions (continued)

Results: 240 VAC 60 Hz



Live



Neutral

Note: These plots are pre-scans and for indication purposes only. For final measurements, see accompanying tables.

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