

ALEPH OBJECTS INC. TEST REPORT

SCOPE OF WORK

EMC TESTING ON LULZBOT MINI 2 3D PRINTER, MODEL(S): LULZBOT MINI 2

REPORT NUMBER

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EMC TEST REPORT (FULL COMPLIANCE)

Report Number: 103436795LAX-001

Project Number: G103436795

Report Issue Date: 21-March-2018

Model(s) Tested: LulzBot Mini 2

Standards: FCC 47CFR Part 15 Subpart B: 2017
Title 47 CFR Part 15 Subpart B: Unintentional Radiators

ICES-003 Issue 6
Published: January 2016 Updated: April 2017
Spectrum Management and Telecommunications Interference-Causing
Equipment Standard Information Technology Equipment (Including Digital
Apparatus) – Limits and Methods of Measurement

Tested by:

Intertek Testing Services NA, Inc.
25800 Commercentre Drive
Lake Forest, CA 92630
USA

Client:

Aleph Objects Inc.
626 W 66th St.
Loveland, CO 80538
USA

Report prepared by:



Melvin Sanchez
EMC Project Engineer

Report reviewed by



Meak Nget
EMC Engineering Supervisor

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1 Introduction and Conclusion

The tests indicated in section 2.0 were performed on the product constructed as described in section 4.0. The remaining test sections are the verbatim text from the actual data sheets used during the investigation. These test sections include the test name, the specified test Method, a list of the actual Test Equipment Used, documentation Photos, Results and raw Data. No additions, deviations, or exclusions have been made from the standard(s) unless specifically noted.

Based on the results of our investigation, we have concluded the product tested **complies** with the requirements of the standard(s) indicated. The results obtained in this test report pertain only to the item(s) tested. Intertek does not make any claims of compliance for samples or variants which were not tested.

2 Test Summary

Section	Test full name	Result
3	Client Information	--
4	Description of Equipment Under Test and Variant Models	--
5	System Setup and Method	--
6	Radiated Emissions (FCC Part15B:2017, ICES 003:2017, Class B)	Complies
7	AC Mains Conducted Emissions (FCC Part15B:2017, ICES 003:2017, Class B)	Complies
8	Revision History	--

3 Client Information

This EUT was tested at the request of:

Client: Aleph Objects Inc.
626 W 66th St.
Loveland, CO 80538
USA

Contact: Steven Abadie
Telephone: 970-377-1111 Ext 611

Email: steven@alephobjects.com

4 Description of Equipment Under Test and Variant Models

Manufacturer: Aleph Objects Inc.
626 W 66th St.
Loveland, CO 80538
USA

Equipment Under Test			
Description	Manufacturer	Model Number	Serial Number
3D Printer	Aleph Objects Inc.	LulzBot Mini 2	KT-PR0047-0004

Receive Date:	03/09/2018
Received Condition:	Good
Type:	Production

Description of Equipment Under Test (provided by client)

The LulzBot Mini 3D printer is a 3D printer that extrudes plastic to form 3D objects. It is high performance machine that makes 3D printing easy, for everyone. For more details refer to manufacturer's operating manual.

Equipment Under Test Power Configuration			
Rated Voltage	Rated Current	Rated Frequency	Number of Phases
100-240 VAC	3.2 A.	50-60 Hz	Single

Operating modes of the EUT:

No.	Descriptions of EUT Exercising
1	The EUT was set to run Print from SD card.

Software used by the EUT:

No.	Descriptions of EUT Exercising
1	Mini 2 Aerostruder V2

Variant Models:

The following variant models were not tested as part of this evaluation, but have been identified by the manufacturer as being electrically identical models, depopulated models, or with reasonable similarity to the model(s) tested. Intertek does not make any claims of compliance for samples or variants which were not tested.

- None

5 System Setup and Method

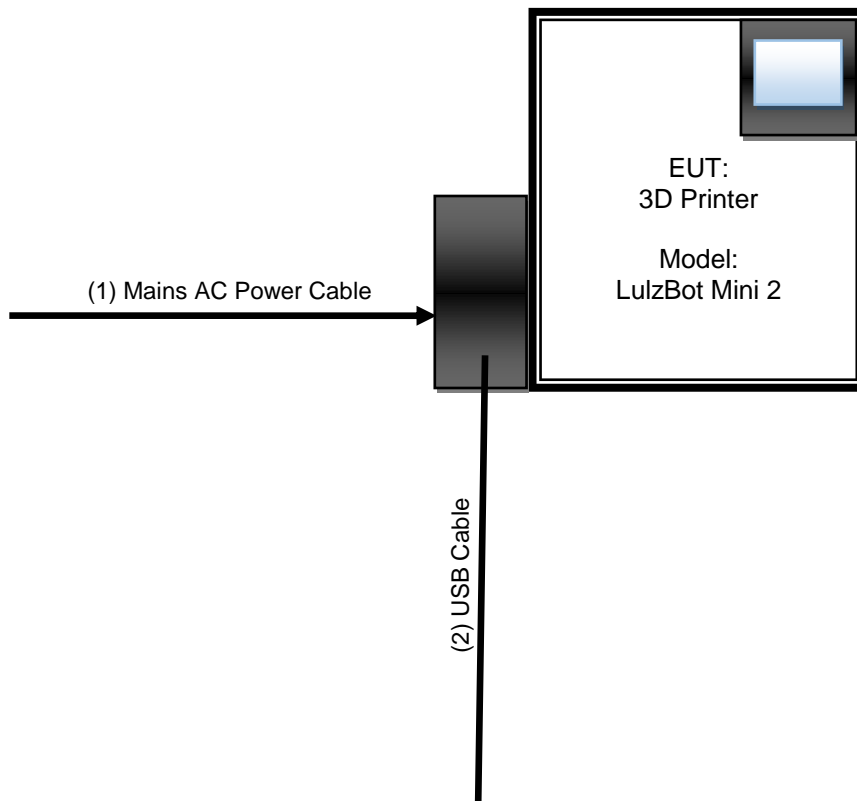
Cables					
ID	Description	Length (m)	Shielding	Ferrites	Termination
1	Mains AC Cable	1.5	None	None	AC Source - EUT
2	USB Cable	2.0	None	Yes (2x)	None

Support Equipment			
Description	Manufacturer	Model Number	Serial Number
None	N/A	N/A	N/A

5.1 Method:

Configuration as required by ANSI C63.4, CISPR 16, FCC Part15B & ICES-003.

5.2 EUT Block Diagram:



6 Radiated Emissions

6.1 Method

Tests are performed in accordance with ANSI C63.4, CISPR 16-2-3, FCC Part15.109 & ICES-003.

TEST SITE: 3m ALSE

The test facility is located at 25791 Commercentre Dr., Lake Forest, CA 92630.

Radiated emission measurements are performed in a 3 meter Semi-Anechoic Chamber. The chamber is a shielded enclosure used to control and maintain a predictable EMI environment within the test region. A lining of RF absorbing material (Absorber) and other anechoic materials are installed over all interior wall and ceiling surfaces as to completely shroud exposed metallic components and disrupt reflective properties. The ground plane is an exposed RF reflective surface. The turntable is flush mounted, 2 meters in diameter, and remotely controlled. The antenna mast can be positioned at 3 meters away from the turntable. The antenna mast is remote controlled and can lower/raise an antenna between 1 – 4 meters. The antenna mast can also rotate between horizontal and vertical polarizations.

Measurement Uncertainty

Measurement	Frequency Range	Expanded Uncertainty (k=2)	U _{cispr}
Radiated Emissions, 3m	30-1000 MHz	4.5 dB	6.3 dB
Radiated Emissions, 3m	1-6 GHz	4.7 dB	5.2 dB

As shown in the table above our radiated emissions U_{lab} is less than the corresponding U_{CISPR} reference value in CISPR 16-4-2 Table 1, hence the compliance of the product is only based on the measured value, and no measurement uncertainty correction is required, based on CISPR 22 and CISPR 11 (for 2006 and later revisions) Clause 11.

Sample Calculation

The field strength is calculated by adding the Antenna Factor and Cable Factor, and subtracting the Amplifier Gain (if any) from the measured reading. The basic equation with a sample calculation is as follows:

$$FS = RA + AF + CF - AG$$

Where

- FS = Field Strength in dB μ V/m
- RA = Receiver Amplitude (including preamplifier) in dB μ V
- CF = Cable Attenuation Factor in dB
- AF = Antenna Factor in dB
- AG = Amplifier Gain in dB

In the following table(s), the reading shown on the data table reflects the preamplifier gain. An example for the calculations in the following table is as follows.

Assume a receiver reading of 52.0 dB μ V is obtained. The antenna factor of 7.4 dB and cable factor of 1.6 dB is added. The amplifier gain of 29 dB is subtracted, giving a field strength of 32 dB μ V/m. This value in dB μ V/m was converted to its corresponding level in μ V/m.

RA = 52.0 dB μ V
 AF = 7.4 dB/m
 CF = 1.6 dB
 AG = 29.0 dB
 FS = 32 dB μ V/m

To convert from dB μ V to μ V or mV the following was used:

$UF = 10^{(NF / 20)}$ where UF = Net Reading in μ V
 NF = Net Reading in dB μ V

Example:

$FS = RA + AF + CF - AG = 52.0 + 7.4 + 1.6 - 29.0 = 32.0$
 $UF = 10^{(32 \text{ dB}\mu\text{V} / 20)} = 39.8 \mu\text{V/m}$

6.2 Test Equipment Used:

Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due
001140	EMI Test Receiver	Rohde & Schwarz	ESCI7	100825	02/28/2018	02/28/2019
001147	Bilog Antenna	TESEQ Gmbh	CBL 6112D	32852	11/16/2017	11/16/2018
001576	Preamplifier 100kHz - 1 Ghz	Rhode & Schwarz	TS-PR1	102068	06/20/2017	06/20/2018
001556	Preamplifier 1 - 18GHz	Rhode & Schwarz	TS-PR18	102144	07/29/2017	07/29/2018
000692	Double-Ridged Horn for frequency 1-18 GHz	ETS Lindgren	3115	00031626	07/25/2017	07/25/2018
000690	Spectrum Analyzer, 9 KHz - 40 GHz	Rohde & Schwarz	FSP40	100027	02/28/2018	02/28/2019
001517	RF Cable 30Mhz - 18Ghz	Rohde & Schwarz	TSPR-B7	101528	07/13/2017	07/13/2018
001518	RF Cable 30Mhz - 18Ghz	Rohde & Schwarz	TSPR-B7	101529	07/13/2017	07/13/2018
000637	EMC Emissions	Panashield	3m Chamber	250831-D-2	12/21/2015	12/21/2018
001014	Lab Monitor	Omega	iBTHX-W	0480395	12/20/2017	12/20/2018

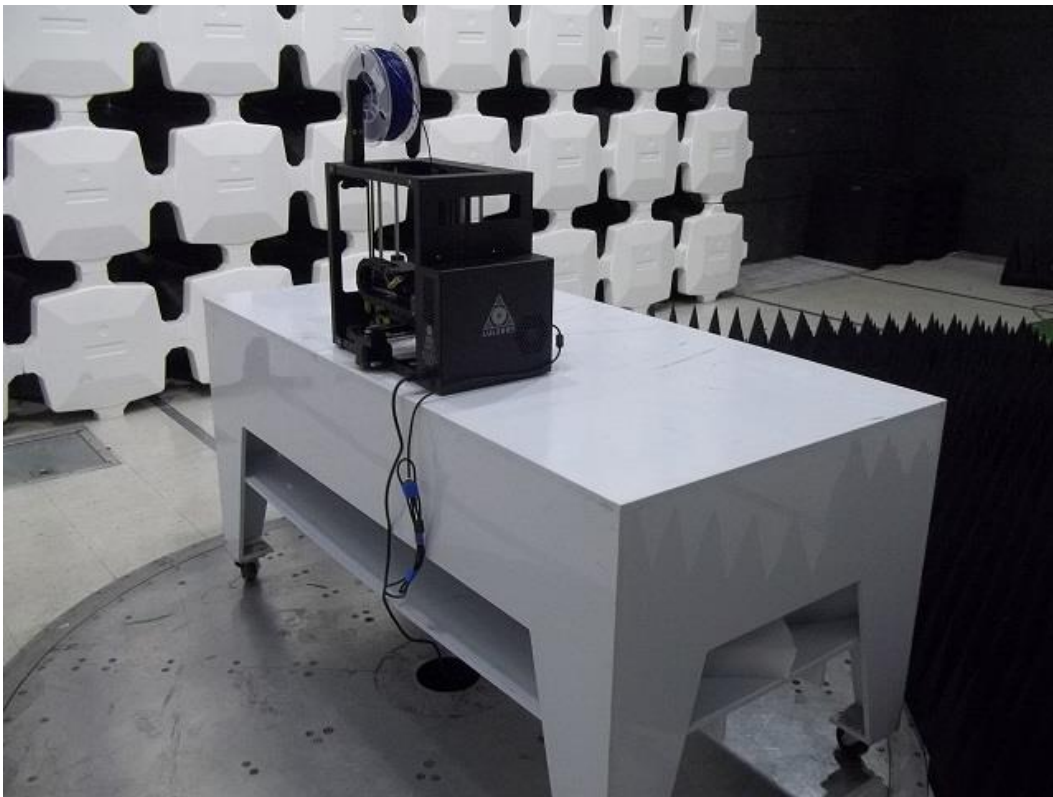
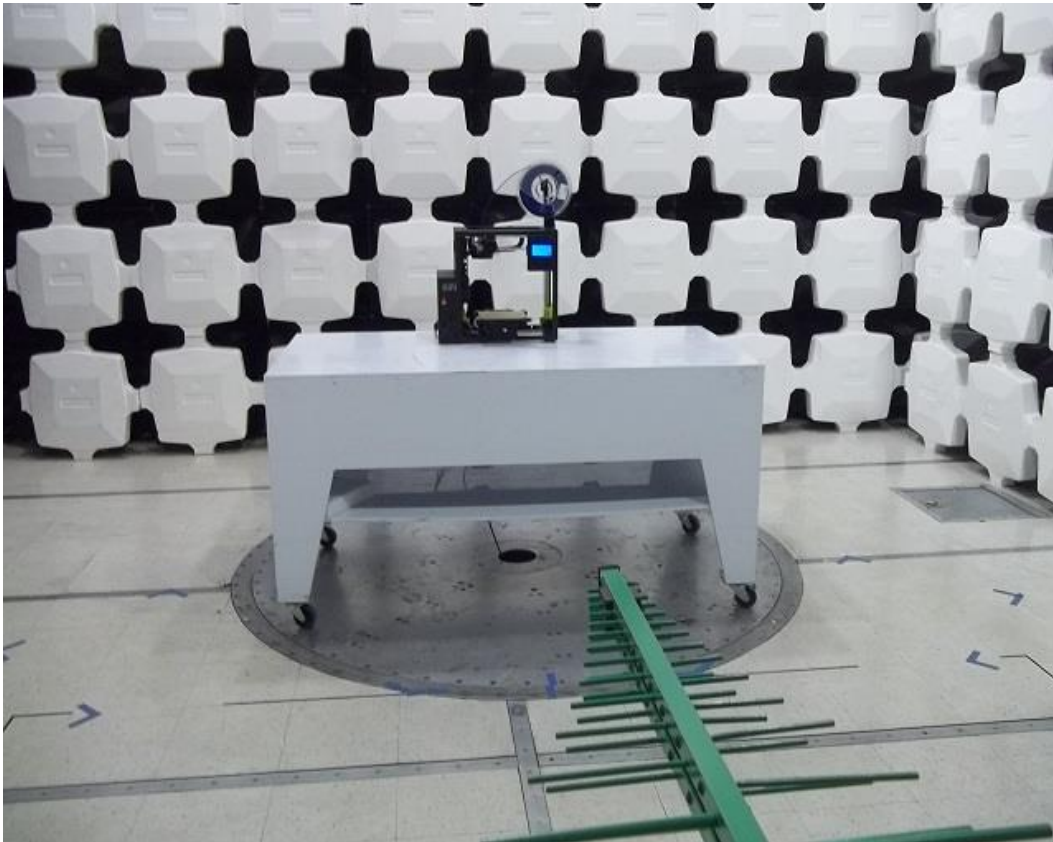
Software Utilized:

Name	Manufacturer	Version
Tile	Quantum Change	4.1
Tile	Quantum Change	3.4.k.29

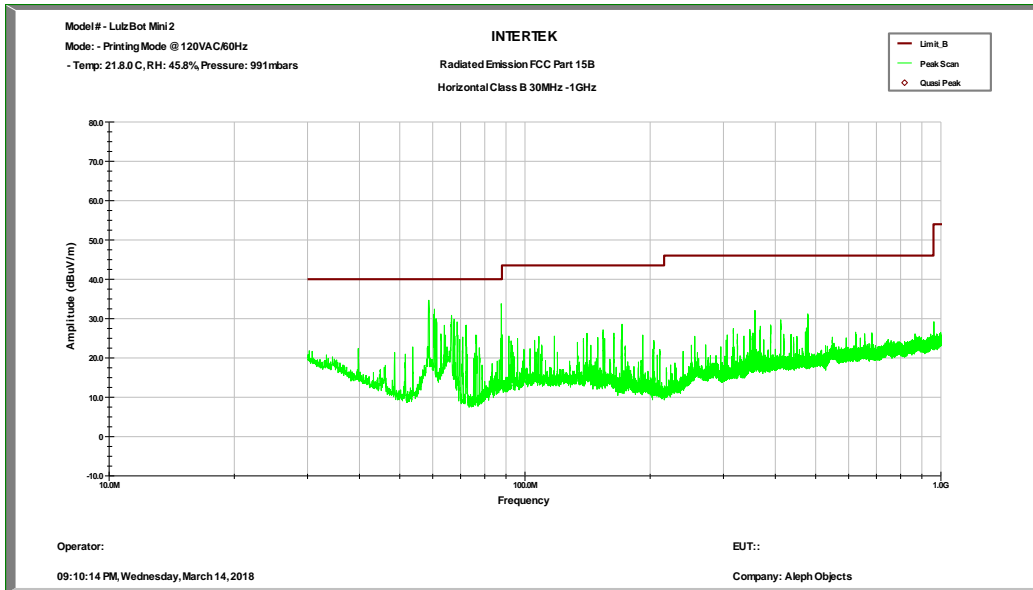
6.3 Results:

The sample tested was found to Comply.

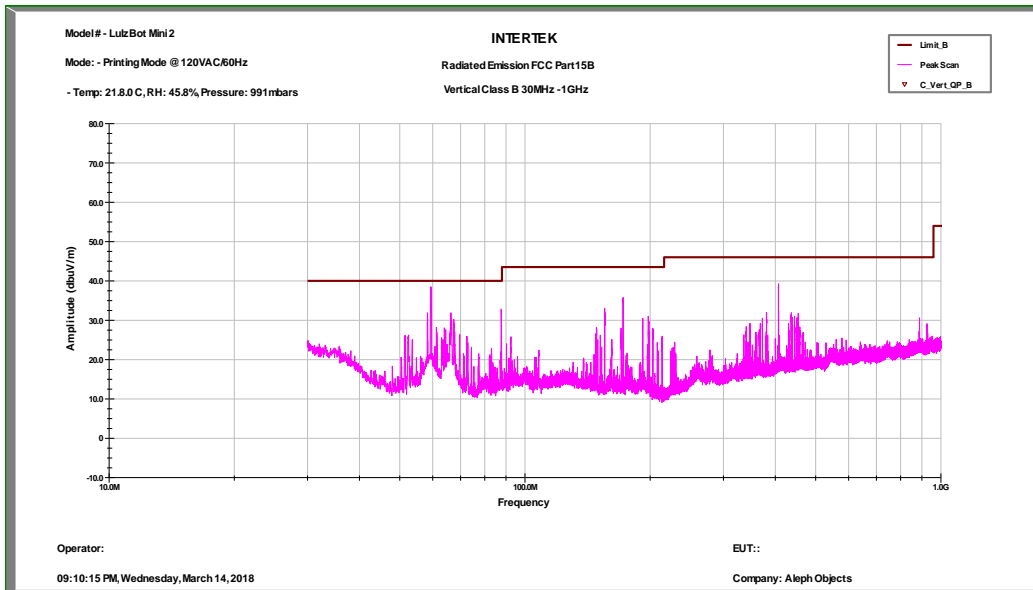
6.4 Setup Photographs:



6.5 Plots:

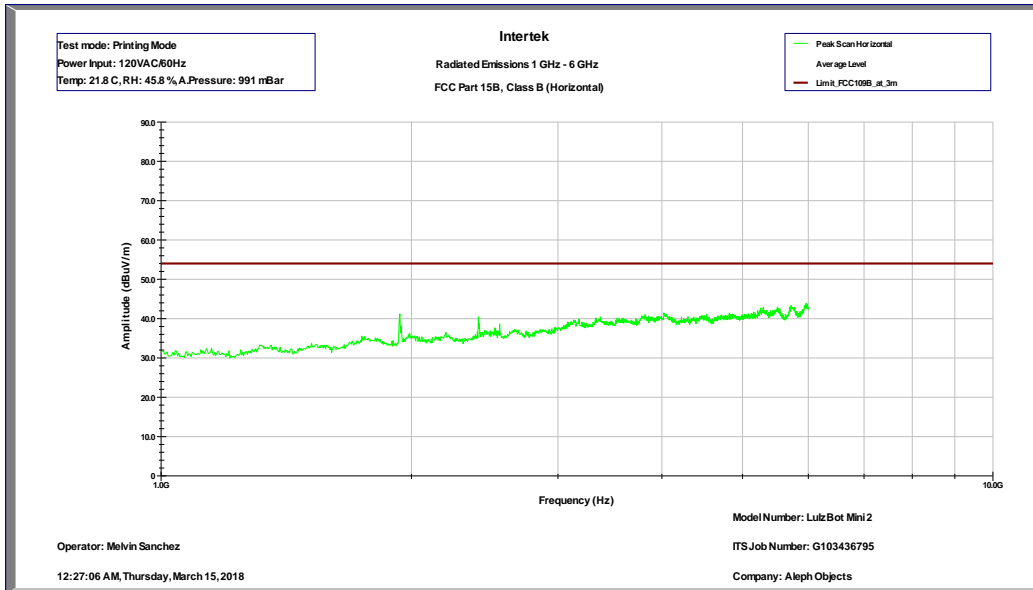


Radiated Emissions, Peak Scan Horizontal Polarization @ 120VAC/60Hz

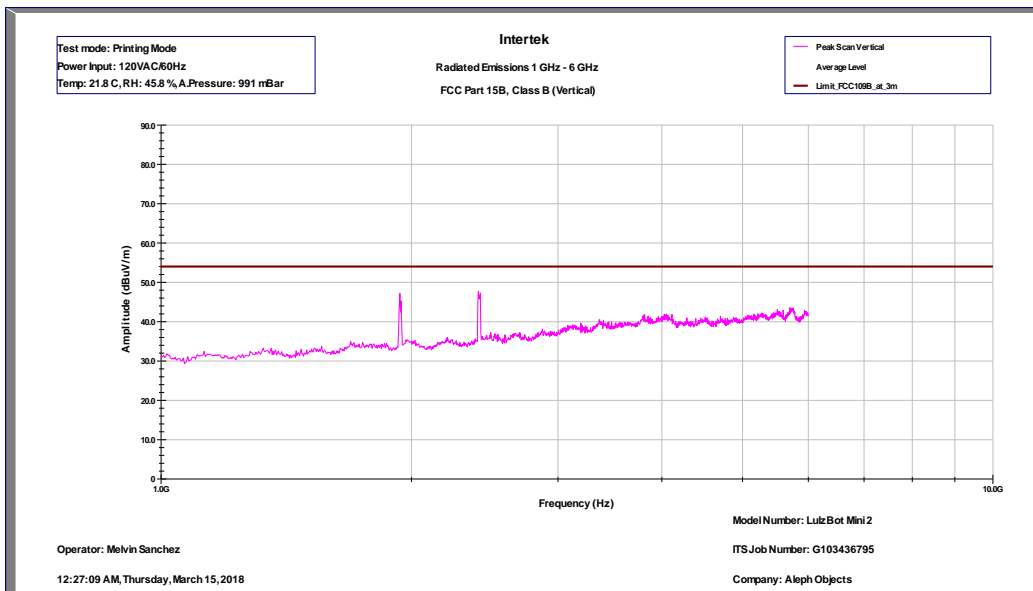


Radiated Emissions, Peak Scan Vertical Polarization @ 120VAC/60Hz

6.6 Plots:



Radiated Emissions, Peak Scan Horizontal Polarization @ 120VAC/60Hz Above 1GHz



Radiated Emissions, Peak Scan Vertical Polarization @ 120VAC/60Hz Above 1GHz

6.7 Data:

Test Personnel:	<u>Melvin Sanchez</u>	Test Date:	<u>03/14/2018</u>
Supervising/Reviewing Engineer:	<u>Meak Nget</u>	Limit Applied:	<u>Class B</u>
(Where Applicable) Product Standard:	<u>FCC Part15.109/ICES 003</u>	Ambient Temperature:	<u>21.8 °C</u>
Input Voltage:	<u>120VAC/60Hz</u>	Relative Humidity:	<u>45.8 %</u>
Pretest Verification w/ Ambient Signals or BB Source:	<u>Yes</u>	Atmospheric Pressure:	<u>991 mbars</u>

FCC Part15.109/ICES 003, Radiated Emissions, Class B (Quasi-Peak Horizontal)							
Frequency MHz	QP FS (dBuV)	Limit @ 3m dB(dBuV)	Margin (dB)	RA (dBuV)	AG dB	AF dB(1/m)	CF dB
58.673	11.46	40	-28.54	27.856	30.499	12.2	1.903
60.539	21.716	40	-18.284	38.235	30.465	12.046	1.9
66.614	27.587	40	-12.413	44.004	30.407	12.1	1.891
*87.713	7.883	40	-32.117	21.177	30.234	14.814	2.125
Detectors/Bandwidths (Det/RBW/VBW)= 120/300kHz							

FCC Part15.109/ICES 003, Radiated Emissions, Class B (Quasi-Peak Vertical)							
Frequency MHz	QP FS (dBuV)	Limit @ 3m dB(dBuV)	Margin (dB)	RA (dBuV)	AG dB	AF dB(1/m)	CF dB
59.444	25.232	40	-14.768	41.658	30.482	12.156	1.902
66.388	19.774	40	-20.226	36.192	30.409	12.1	1.891
87.691	25.579	40	-14.421	38.881	30.234	14.808	2.124
155.413	11.248	43.52	-32.272	22.459	29.827	16.259	2.357
172.128	20.389	43.52	-23.131	32.354	29.76	15.6	2.195
406.799	17.836	46.02	-28.184	22.925	29.674	22.28	2.305
Detectors/Bandwidths (Det/RBW/VBW)= 120/300kHz							

QP FS – Quasi-Peak Field Strength
 RA – Receiver (Q-peak) Amplitude
 AG – Preamp Gain
 AF – Antenna Factor
 CF – Cable Factor

Test Result: (*)The **EUT PASSED** Radiated Emission test with – 12.413 dB margin at 87.713 MHz

Deviations, Additions, or Exclusions: None

6.8 Data:

Test Personnel: <u>Melvin Sanchez</u>	Test Date: <u>03/14/2018</u>
Supervising/Reviewing Engineer: <u>Meak Nget</u>	
(Where Applicable) Product Standard: <u>FCC Part15.109/ICES 003</u>	Limit Applied: <u>Class B</u>
Input Voltage: <u>120VAC/60Hz</u>	
Pretest Verification w/ Ambient Signals or BB Source: <u>Yes</u>	Ambient Temperature: <u>21.8 °C</u>
	Relative Humidity: <u>45.8 %</u>
	Atmospheric Pressure: <u>991 mbars</u>

FCC Part15.109/ICES 003, Radiated Emissions, Class B (Average Peak Horizontal)							
Frequency MHz	Av Level (dB)	Limit@3m (dBuV/m)	Av Margin (dB)	Raw (dBuV)	Cable (dB)	Preamp (dB)	AF dB(1/m)
1937.640	20.6	54	-33.4	39.6	3.4	50	27.6
2406.230	21.9	54	-32.1	39.6	3.8	49.8	28.3
*5959.850	29.9	54	-24.1	38.1	6.3	49.7	35.2
Detectors/Bandwidths (Det/RBW/VBW)= 1MHz/3MHz							

FCC Part15.109/ICES 003, Radiated Emissions, Class B (Average Peak Vertical)							
Frequency MHz	Av Level (dB)	Limit@3m (dBuV/m)	Av Margin (dB)	Raw (dBuV)	Cable (dB)	Preamp (dB)	AF dB(1/m)
1936.070	9.9	54	-44.1	29.3	3.4	50	27.3
2406.000	15.7	54	-38.3	33.6	3.8	49.8	28
5755.420	22.8	54	-31.2	31.9	6.1	49.7	34.5
Detectors/Bandwidths (Det/RBW/VBW)= 1MHz/3MHz							

Avg Peak FS – (Final) Avg Peak Field Strength
 RA – Receiver (quasi peak) Amplitude
 AG – Preamp Gain
 AF – Antenna Factor
 CF – Cable Factor

Test Result: (*)The EUT PASSED Radiated Emission test with -24.1 dB margin at 5959.85 MHz

Deviations, Additions, or Exclusions: None

7 AC Mains Conducted Emissions

7.1 Method

Tests are performed in accordance with ANSI C63.4, CISPR 16-2-1, FCC Part15.107 & ICES-003.

TEST SITE: 3m Emission Chamber

The test is performed in the 3 meter semi-anechoic chamber located at 25791 Commercentre Drive, Lake Forest, CA 92630. This site meets the requirements of CISPR 16-1.

TEST SETUP

The EUT shall be located so that the distance between the boundary of the EUT and the closest surface of the AMN is 0.8m.

If a flexible mains cord is provided by the manufacturer that is in excess of 1m, the excess cable shall be folded back and forth as far as possible to form a bundle not exceeding 0.4m in length.

The EUT shall be arranged and connected with cables terminated in accordance with the product specification. Conducted disturbance shall be measured between each current carrying conductor and the reference ground. Each measured values shall be reported.

If EUT is intended for tabletop use, the EUT shall be placed on a table whose top is 0.8m above the ground plane. A vertical, metal reference plane is being placed 0.4m from the EUT. The vertical metal reference-plane is at least 2m by 2m. The EUT shall be kept at least 0.8m from any other metal surface or other ground plane not being part of the EUT. The table shall be constructed of non-conductive materials. Its dimensions are at least 1m by 1.5m, but may be extended for larger EUT.

If EUT is floor standing, the floor standing EUT shall be placed on a horizontal metal ground plane and isolated from the ground plane by up to 12 mm of insulating material. The metal ground plane shall extend at least 0.5m beyond the boundaries of the EUT and had minimum dimensions of 2m by 2m.

Equipment setup for conducted disturbance tests shall follow the guidelines of CISPR 16.

Measurement Uncertainty

Measurement	Frequency Range	Expanded Uncertainty (k=2)	U _{cispr}
AC Line Conducted Emissions	150 kHz - 30 MHz	2.6 dB	3.4dB
Telco Port Emissions	150 kHz - 30 MHz	2.6 dB	5.0dB

As shown in the table above our conducted emissions U_{lab} is less than the corresponding U_{CISPR} reference value in CISPR 16-4-2 Table 1, hence the compliance of the product is only based on the measured value, and no measurement uncertainty correction is required, based on CISPR 22 and CISPR 11 (for 2006 and later revisions) Clause 11.

Sample Calculations

The following is how net line-conducted readings were determined:

$$NF = RF + LF + CF + AF$$

Where NF = Net Reading in dB μ V

RF = Reading from receiver in dB μ V

LF = LISN or ISN Correction Factor in dB

CF = Cable Correction Factor in dB

AF = Attenuator Loss Factor in dB

To convert from dB μ V to μ V or mV the following was used:

$$UF = 10^{(NF / 20)} \text{ where } UF = \text{Net Reading in } \mu\text{V}$$

NF = Net Reading in dB μ V

Example:

$$NF = RF + LF + CF + AF = 28.5 + 0.2 + 0.4 + 20.0 = 49.1 \text{ dB}\mu\text{V}$$

$$UF = 10^{(49.1 \text{ dB}\mu\text{V} / 20)} = 285.1 \mu\text{V/m}$$

7.2 Test Equipment Used:

Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due
001140	EMI Test Receiver	Rohde & Schwarz	ESCI7	100825	02/28/2018	02/28/2019
000667	LISN	TESEQ	NNB 51	36060	12/26/2017	12/26/2018
001470	RF Cable	Megaphase	TM18-N1N1-600	none	06/16/2017	06/16/2018
001314	Portable Vertical Ground Plane	Intertek	ANSI C63.4 Sec.5.2.2	none	VBU 03/15/2018	VBU 03/15/2018
001014	Lab Monitor	Omega	iBTHX-W	0480395	12/20/2017	12/20/2018

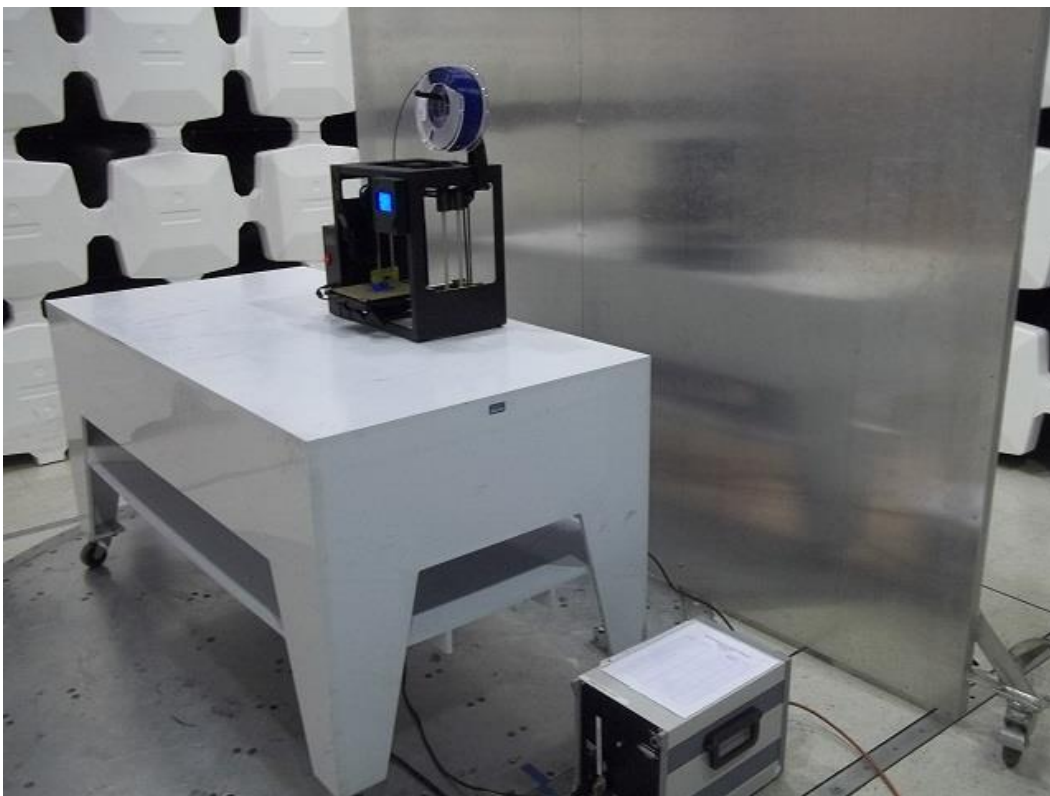
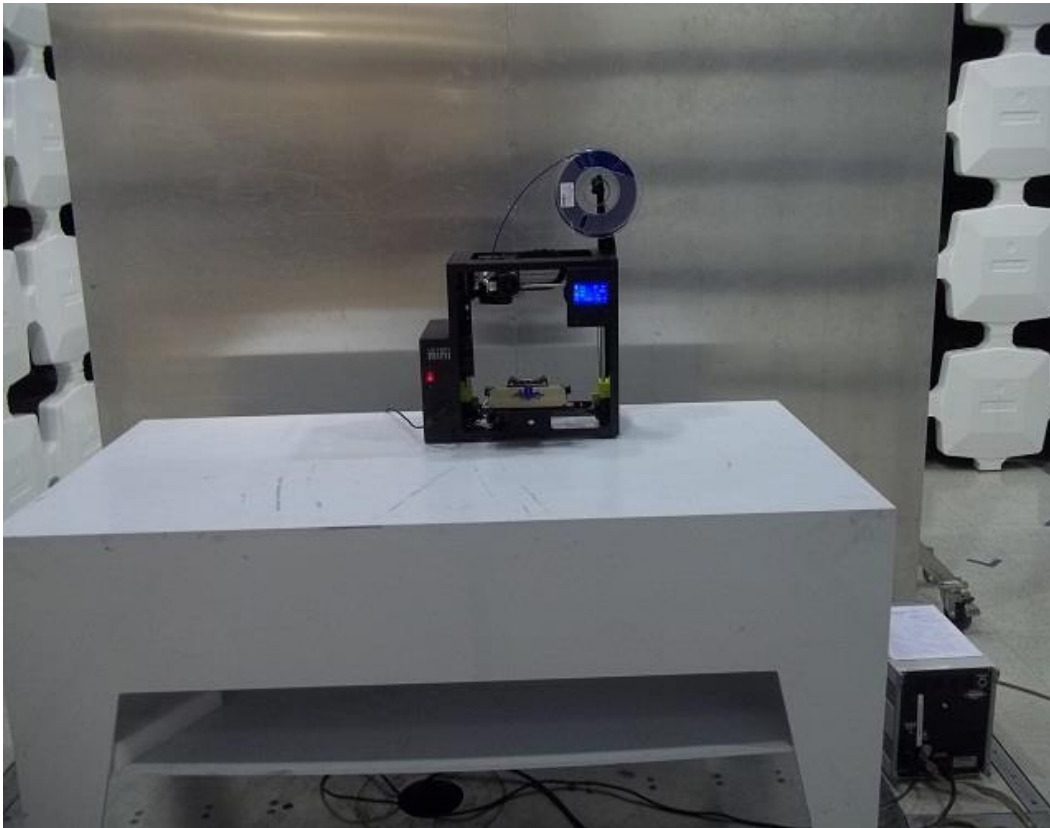
Software Utilized:

Name	Manufacturer	Version
Tile	Quantum Change	4.1

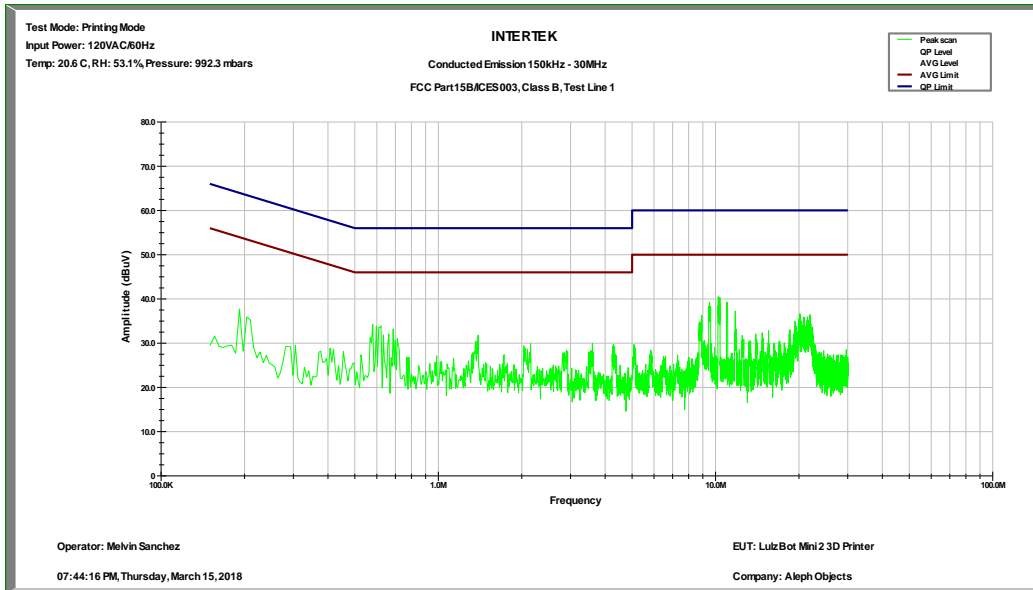
7.3 Results:

The sample tested was found to Comply.

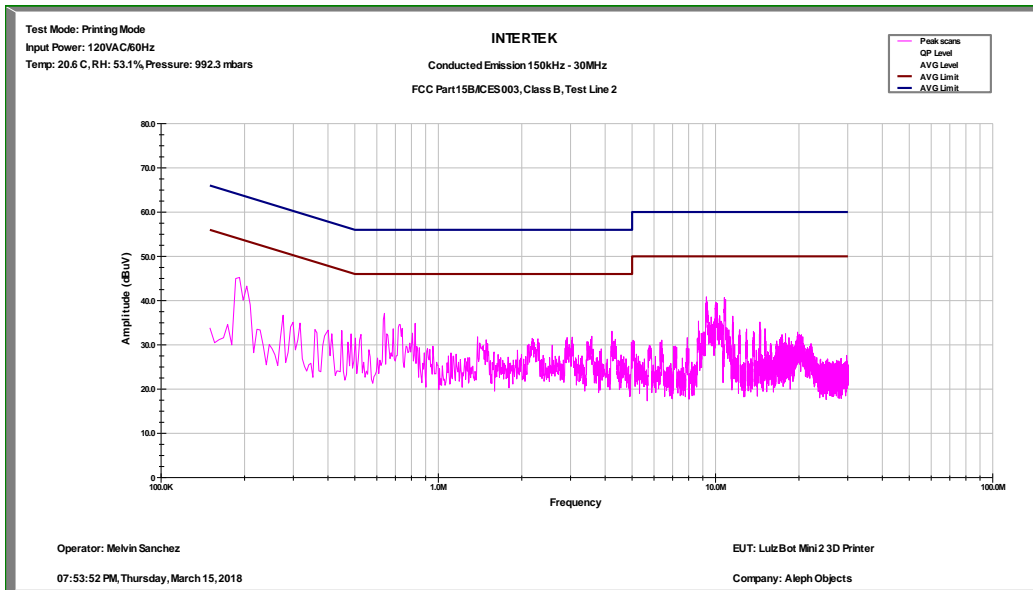
7.4 Setup Photographs:



7.5 Plots:



Conducted Emissions Peak Scan - Line 1 @ 120VAC/60Hz



Conducted Emissions Peak Scan - Line 2 @ 120VAC/60Hz

7.6 Data:

Test Personnel: Melvin Sanchez
 Supervising/Reviewing Engineer: _____
 (Where Applicable) Engineer: Meak Nget
 Product Standard: FCC Part15.107/ICES 003
 Input Voltage: 120VAC/60Hz
 Pretest Verification w/ Ambient Signals or BB Source: Yes

Test Date: 03/15/2018
 Limit Applied: Class B
 Ambient Temperature: 20.6 °C
 Relative Humidity: 53.1 %
 Atmospheric Pressure: 992.3 mbars

FCC Part15.107/ICES 003, Conducted Emissions, Class B (Line 1)						
Frequency MHz	Av Level (dBuV)	QP Level (dBuV)	Av Limit (dBuV)	QP Limit (dBuV)	Av Margin (dB)	QP Margin (dB)
0.193	29.93	40.265	54.751	64.751	-24.821	-24.486
0.203	29.947	40.441	54.459	64.459	-24.512	-24.018
0.584	15.069	30.527	46	56	-30.931	-25.473
9.520	26.815	35.119	50	60	-23.185	-24.881
10.277	29.537	35.38	50	60	-20.463	-24.62
10.935	27.093	36.048	50	60	-22.907	-23.952
Detectors/Bandwidths (Det/RBW/VBW)= 9/30kHz						

FCC Part15.107/ICES 003, Conducted Emissions, Class B (Line 2)						
Frequency MHz	Av Level (dBuV)	QP Level (dBuV)	Av Limit (dBuV)	QP Limit (dBuV)	Av Margin (dB)	QP Margin (dB)
0.193	34.415	44.67	54.751	64.751	-20.336	-20.081
*0.204	34.472	43.972	54.452	64.452	-19.98	-20.48
0.641	20.019	33.421	46	56	-25.981	-22.579
9.291	26.911	34.6	50	60	-23.089	-25.4
10.165	27.181	34.291	50	60	-22.819	-25.709
10.739	27.311	35.091	50	60	-22.689	-24.909
Detectors/Bandwidths (Det/RBW/VBW)= 9/30kHz						

Test Result: (*) The EUT **PASSED** Conducted Emission test with -19.98 dB margin at 0.204 MHz

Deviations, Additions, or Exclusions: None

8 Revision History

Revision Level	Date	Report Number	Prepared By	Reviewed By	Notes
0	03/21/2018	103436795LAX-001	MS	MN	Original Issue