



# **TEST REPORT**

**Test Report No. : UL-RPT-RP13041774JD10A V2.0**

**Customer** : Apple Inc.  
**Model No.** : A2251  
**FCC ID** : BCGA2251  
**Test Standard(s)** : FCC Part 15.207

**Test Laboratory** : UL VS LTD, Basingstoke, Hampshire, RG24 8AH, United Kingdom

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2. The results in this report apply only to the sample(s) tested.
3. This 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 1.0.

**Date of Issue:** 21 April 2020

**Checked by:**

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Senior Test Engineer, Radio Laboratory

**Company Signatory:**

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UL VS LTD

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## **UL VS LTD**

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**Customer Information**

|                      |                                                             |
|----------------------|-------------------------------------------------------------|
| <b>Company Name:</b> | Apple Inc.                                                  |
| <b>Address:</b>      | One Apple Park Way<br>Cupertino, California 95014<br>U.S.A. |
| <b>Contact Name:</b> | Stuart Thomas                                               |

**Report Revision History**

| <b>Version Number</b> | <b>Issue Date</b> | <b>Revision Details</b>              | <b>Revised By</b> |
|-----------------------|-------------------|--------------------------------------|-------------------|
| 1.0                   | 12/03/2020        | Initial Version                      | Ian Watch         |
| 2.0                   | 21/04/2020        | Antenna gains in section 3.4 updated | Sarah Williams    |

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## **1. Attestation of Test Results**

### **1.1. Description of EUT**

The Equipment Under Test (EUT) was a Laptop Computer with *Bluetooth*, *Bluetooth* Low Energy and 802.11 a/b/g/n/ac capabilities in the 2.4 GHz and 5.0 GHz bands.

### **1.2. General Information**

|                                 |                                                                                                                           |
|---------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| <b>Specification Reference:</b> | 47CFR15.207                                                                                                               |
| <b>Specification Title:</b>     | Code of Federal Regulations Volume 47 (Telecommunications):<br>Part 15 Subpart C (Intentional Radiators) - Section 15.207 |
| <b>Site Registration:</b>       | 621311                                                                                                                    |
| <b>Location of Testing:</b>     | UL VS LTD, Unit 3 Horizon, Wade Road, Kingsland Business Park,<br>Basingstoke, Hampshire, RG24 8AH, United Kingdom        |
| <b>Test Dates:</b>              | 31 December 2019 to 03 January 2020                                                                                       |

### **1.3. Summary of Test Results**

| <b>FCC Reference (47CFR)</b> | <b>Measurement</b>                 | <b>Result</b> |
|------------------------------|------------------------------------|---------------|
| Part 15.207                  | Transmitter AC Conducted Emissions | Complied      |

#### **Note(s):**

1. There are two vendors of the WiFi/*Bluetooth* radio modules, Vendor 1 and Vendor 2.

The WiFi/*Bluetooth* radio modules have the same mechanical outline (i.e. the same packaging dimension and pin layout), use the same on-board antenna matching circuit, have an identical antenna structure and are built and tested to conform to the same specification and to operate within the same tolerances.

Baseline testing was performed on the two vendors to determine the worst case.

### **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.

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**

|                   |                                                                                                |
|-------------------|------------------------------------------------------------------------------------------------|
| <b>Reference:</b> | ANSI C63.10-2013                                                                               |
| <b>Title:</b>     | American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices |
| <b>Reference:</b> | KDB 174176 D01 Line Conducted FAQ v01r01 June 3, 2015                                          |
| <b>Title:</b>     | 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 |
|---------------------------------|--------------------|----------------------|------------------------|
| 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 AC Conducted 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  | 825563/008 | 08 Aug 2020          | 12                     |
| A1830     | Pulse Limiter     | Rohde & Schwarz | ESH3-Z2  | 100668     | 10 Apr 2020          | 12                     |
| M1124     | EMI Test Receiver | Rohde & Schwarz | ESIB 26  | 100046     | 11 Oct 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)**

|                                   |                                  |
|-----------------------------------|----------------------------------|
| <b>Brand Name:</b>                | Apple                            |
| <b>Model Name or Number:</b>      | A2251                            |
| <b>Test Sample Serial Number:</b> | C02ZG00KP22J ( <i>Vendor 1</i> ) |
| <b>Hardware Version:</b>          | REV 1.0                          |
| <b>Software Version:</b>          | 19C19                            |
| <b>FCC ID:</b>                    | BCGA2251                         |

|                                   |                                  |
|-----------------------------------|----------------------------------|
| <b>Brand Name:</b>                | Apple                            |
| <b>Model Name or Number:</b>      | A2251                            |
| <b>Test Sample Serial Number:</b> | C02ZH002P1YX ( <i>Vendor 2</i> ) |
| <b>Hardware Version:</b>          | REV 1.0                          |
| <b>Software Version:</b>          | 19C19                            |
| <b>FCC ID:</b>                    | BCGA2251                         |

#### **3.2. Modifications Incorporated in the EUT**

No modifications were applied to the EUT during testing.

**3.3. Additional Information Related to Testing**

|                                |                      |                |                         |
|--------------------------------|----------------------|----------------|-------------------------|
| Tested Technology:             | Bluetooth            |                |                         |
| Type of Unit:                  | Transceiver          |                |                         |
| Channel Spacing:               | 1 MHz                |                |                         |
| Mode:                          | Enhanced Data Rate   |                |                         |
| Modulation:                    | 8DPSK                |                |                         |
| Packet Type: (Maximum Payload) | 3DH5                 |                |                         |
| Data Rate (Mbit/s):            | 3 Mbit/s             |                |                         |
| Power Supply Requirement(s):   | Nominal              | 120 VAC 60 Hz  |                         |
| Transmit Frequency Range:      | 2402 MHz to 2480 MHz |                |                         |
| Transmit Channels Tested:      | Channel ID           | Channel Number | Channel Frequency (MHz) |
|                                | Middle               | 38             | 2440                    |

|                            |                                                    |                |                         |
|----------------------------|----------------------------------------------------|----------------|-------------------------|
| Technology Tested:         | Bluetooth Low Energy (Digital Transmission System) |                |                         |
| Type of Unit:              | Transceiver                                        |                |                         |
| Channel Spacing:           | 2 MHz                                              |                |                         |
| Modulation:                | GFSK                                               |                |                         |
| Data Rate:                 | 1 Mbit/s                                           |                |                         |
| Power Supply Requirements: | Nominal                                            | 120 VAC 60 Hz  |                         |
| Transmit Frequency Range:  | 2402 MHz to 2480 MHz                               |                |                         |
| Transmit Channels Tested:  | Channel ID                                         | Channel Number | Channel Frequency (MHz) |
|                            | Middle                                             | 17             | 2440                    |

|                              |                                                       |                         |  |
|------------------------------|-------------------------------------------------------|-------------------------|--|
| Technology Tested:           | WLAN (IEEE 802.11b,g,n) / Digital Transmission System |                         |  |
| Type of Unit:                | Transceiver                                           |                         |  |
| Modulation Type:             | DBPSK                                                 |                         |  |
| Data Rates:                  | 802.11b                                               | 1 Mbit/s                |  |
| Power Supply Requirement(s): | Nominal                                               | 120 VAC 60 Hz           |  |
| Channel Spacing:             | 20 MHz                                                |                         |  |
| Transmit Frequency Range:    | 2412 MHz to 2462 MHz                                  |                         |  |
| Transmit Channels Tested:    | Channel Number                                        | Channel Frequency (MHz) |  |
|                              | 7                                                     | 2442                    |  |



**Additional Information Related to Testing (continued)**

|                              |                                  |                |                         |
|------------------------------|----------------------------------|----------------|-------------------------|
| Technology Tested:           | WLAN (IEEE 802.11a,n,ac) / U-NII |                |                         |
| Type of Unit:                | Transceiver                      |                |                         |
| Modulation:                  | BPSK                             |                |                         |
| Data Rate:                   | 802.11n HT20                     | MCS0           |                         |
| Power Supply Requirement(s): | Nominal                          | 120 VAC 60 Hz  |                         |
| Channel Spacing:             | 20 MHz                           |                |                         |
| Transmit Frequency Band:     | 5150 MHz to 5250 MHz             |                |                         |
| Transmit Channels Tested:    | Channel ID                       | Channel Number | Channel Frequency (MHz) |
|                              | Bottom                           | 36             | 5180                    |
|                              | Middle                           | 40             | 5200                    |
| Transmit Frequency Band:     | 5750 MHz to 5850 MHz             |                |                         |
| Transmit Channels Tested:    | Channel ID                       | Channel Number | Channel Frequency (MHz) |
|                              | Top                              | 165            | 5825                    |

**3.4. Description of Available Antennas**

The radio utilizes 4 integrated antennas, with the following maximum gains:

| <b>Frequency Band (MHz)</b> | <b>G<sub>Antenna Core 0</sub> (dBi)</b> | <b>G<sub>Antenna Core 1</sub> (dBi)</b> | <b>G<sub>Antenna Core 2</sub> (Also AUX Core) (dBi)</b> |
|-----------------------------|-----------------------------------------|-----------------------------------------|---------------------------------------------------------|
| 2400-2480 (BT)              | -                                       | 1.1                                     | -                                                       |
| 2400-2480 (WLAN)            | 1.8                                     | 1.1                                     | 2.2                                                     |
| 5150-5250                   | 5.6                                     | 5.0                                     | 4.0                                                     |
| 5250-5350                   | 5.2                                     | 4.2                                     | 3.3                                                     |
| 5470-5725                   | 4.3                                     | 3.2                                     | 3.0                                                     |
| 5725-5850                   | 4.4                                     | 3.2                                     | 3.0                                                     |

### **3.5. Description of Test Setup**

#### **Support Equipment**

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

|                              |                        |
|------------------------------|------------------------|
| <b>Description:</b>          | 61W USB C power supply |
| <b>Brand Name:</b>           | Apple                  |
| <b>Model Name or Number:</b> | A1947                  |
| <b>Serial Number:</b>        | Not marked or stated   |

|                              |                             |
|------------------------------|-----------------------------|
| <b>Description:</b>          | USB C cable. Length 1 metre |
| <b>Brand Name:</b>           | Not marked or stated        |
| <b>Model Name or Number:</b> | Not marked or stated        |
| <b>Serial Number:</b>        | Not marked or stated        |

|                              |                                          |
|------------------------------|------------------------------------------|
| <b>Description:</b>          | USB A cable. Length 3 metres. Quantity 3 |
| <b>Brand Name:</b>           | Not marked or stated                     |
| <b>Model Name or Number:</b> | Not marked or stated                     |
| <b>Serial Number:</b>        | Not marked or stated                     |

|                              |                      |
|------------------------------|----------------------|
| <b>Description:</b>          | USB Hub              |
| <b>Brand Name:</b>           | Hama                 |
| <b>Model Name or Number:</b> | Not marked or stated |
| <b>Serial Number:</b>        | 00078498             |

|                              |                                  |
|------------------------------|----------------------------------|
| <b>Description:</b>          | USB C to USB adaptor. Quantity 4 |
| <b>Brand Name:</b>           | Apple                            |
| <b>Model Name or Number:</b> | A1632                            |
| <b>Serial Number:</b>        | Not marked or stated             |

|                              |                      |
|------------------------------|----------------------|
| <b>Description:</b>          | PHF                  |
| <b>Brand Name:</b>           | Apple                |
| <b>Model Name or Number:</b> | Apple EarPods        |
| <b>Serial Number:</b>        | Not marked or stated |

## **Operating Modes**

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

- Continuously transmitting at maximum power on the bottom, middle and top channels as required.
- The EUT was tested in the following operating mode(s): Pre-scans were performed with the EUT transmitting in *Bluetooth* EDR, *Bluetooth* LE, 2.4 GHz WLAN and 5.0 GHz WLAN modes individually or simultaneously. The worst case mode was found to be 2.4 GHz WLAN transmitting individually. Final measurements were performed in this configuration.

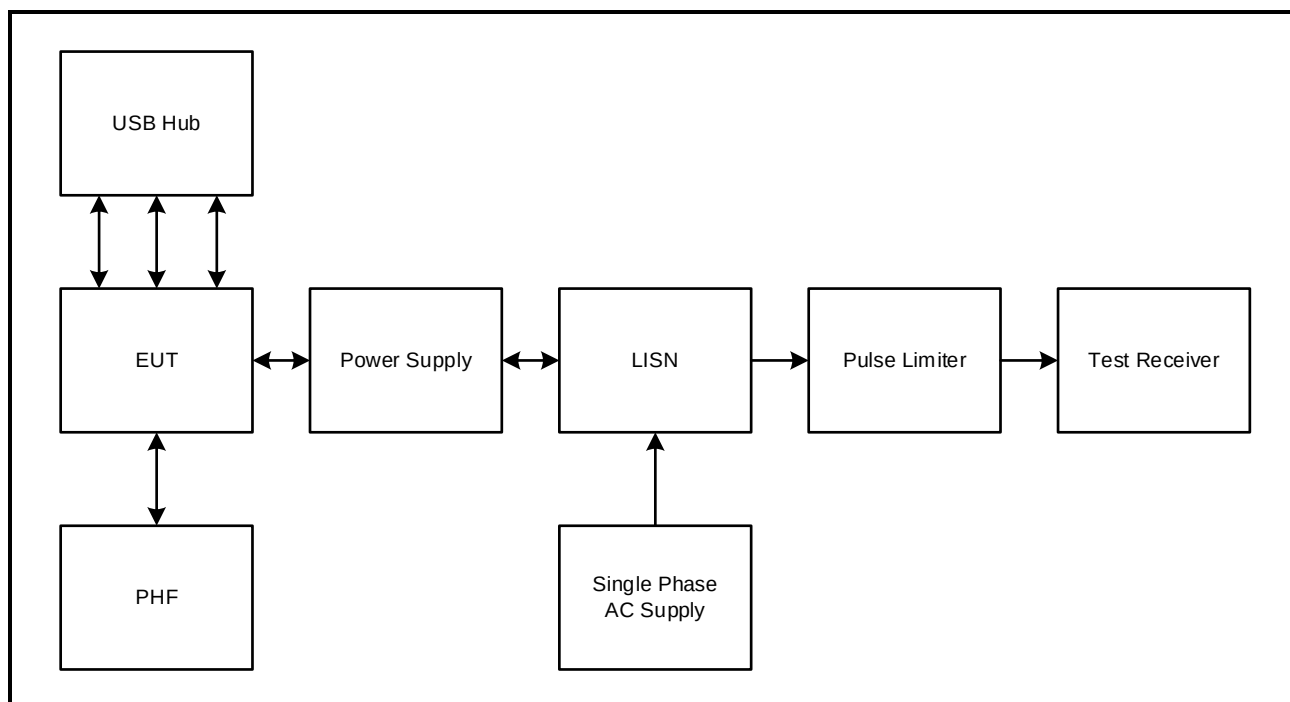
## **Configuration and Peripherals**

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

- Final measurements were performed with the EUT configured to transmit at maximum output power using 2.4 GHz WLAN on channel 7.
- Pre-scan plots for all configurations tested are archived on the UL VS LTD IT server and available for inspection if required.
- Controlled in test mode using a software application on the EUT 'MAC\_WIFI.sh' supplied by the customer. The application was used to enable a continuous transmission and to select the test channels as required, The customer also supplied a document containing the setup instructions 'MAC\_WIFI\_SOP.docx'.
- The EUT was powered from a 120 VAC 60 Hz single phase mains supply unless otherwise stated.
- All the unused USB C ports were terminated into a USB hub.

## **Test Setup Diagrams**

### **Test Setup for Transmitter AC Conducted Emissions**



## **4. AC Power Line Conducted Emissions Test Results**

### **4.1. Transmitter AC Conducted Spurious Emissions**

#### **Test Summary:**

|                                   |              |                    |                                       |
|-----------------------------------|--------------|--------------------|---------------------------------------|
| <b>Test Engineer:</b>             | Nick Tye     | <b>Test Dates:</b> | 31 December 2019 &<br>03 January 2020 |
| <b>Test Sample Serial Number:</b> | C02ZH002P1YX |                    |                                       |

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

#### **Environmental Conditions:**

|                               |          |
|-------------------------------|----------|
| <b>Temperature (°C):</b>      | 22 to 24 |
| <b>Relative Humidity (%):</b> | 36 to 42 |

#### **Note(s):**

1. The EUT was connected to a 120 VAC 60 Hz single phase supply via a LISN.
2. In accordance with FCC KDB 174176 Q4, tests were performed with a 240 VAC 60 Hz single phase supply as this was within the voltage range marked on the power supply.
3. A pulse limiter was fitted between the LISN and the test receiver.
4. Pre-scans were performed with the EUT transmitting *Bluetooth* EDR, *Bluetooth* LE, 2.4 GHz WLAN and 5 GHz WLAN modes individually, along with *Bluetooth* technology transmitting in combination with 5 GHz WLAN and 2.4 GHz WLAN transmitting in combination with 5 GHz WLAN.
5. The worst case mode observed during pre-scans was found to be the EUT with Vendor 2 radio modules when transmitting 2.4 GHz WLAN only. The final measurements were performed in this mode only. Pre-scan result plots for Vendor 1 modules / other modes are archived on the UL VS LTD IT server and available for inspection if required.

**Transmitter AC Conducted Spurious Emissions (continued)****Results: Live / Quasi Peak / 120 VAC 60 Hz**

| Frequency (MHz) | Line | Level (dB $\mu$ V) | Limit (dB $\mu$ V) | Margin (dB) | Result   |
|-----------------|------|--------------------|--------------------|-------------|----------|
| 0.208500        | Live | 49.4               | 63.3               | 13.9        | Complied |
| 0.271500        | Live | 32.3               | 61.1               | 28.8        | Complied |
| 0.366000        | Live | 30.4               | 58.6               | 28.2        | Complied |
| 0.438000        | Live | 27.6               | 57.1               | 29.5        | Complied |
| 0.573000        | Live | 36.1               | 56.0               | 19.9        | Complied |
| 2.112000        | Live | 38.4               | 56.0               | 17.6        | Complied |

**Results: Live / Average / 120 VAC 60 Hz**

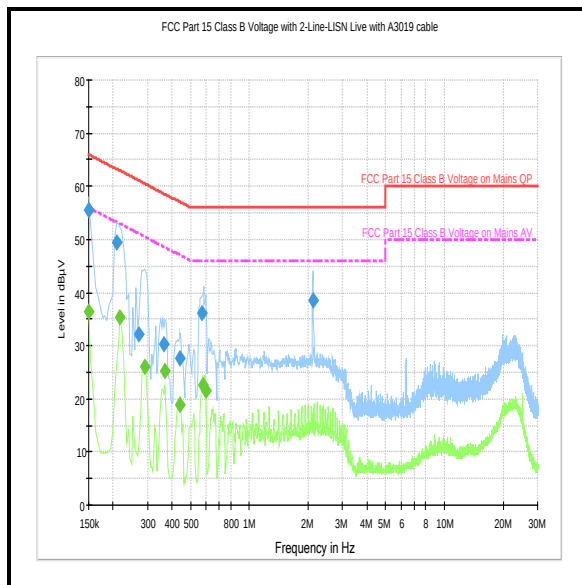
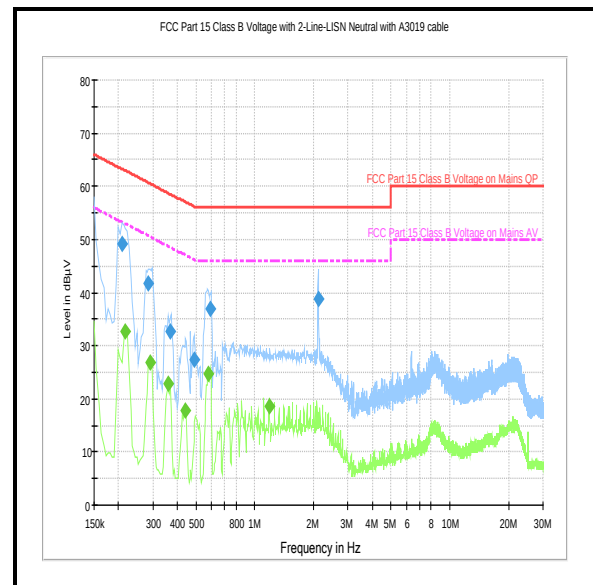
| Frequency (MHz) | Line | Level (dB $\mu$ V) | Limit (dB $\mu$ V) | Margin (dB) | Result   |
|-----------------|------|--------------------|--------------------|-------------|----------|
| 0.217500        | Live | 35.3               | 52.9               | 17.6        | Complied |
| 0.289500        | Live | 26.1               | 50.5               | 24.4        | Complied |
| 0.370500        | Live | 25.3               | 48.5               | 23.2        | Complied |
| 0.442500        | Live | 18.9               | 47.0               | 28.1        | Complied |
| 0.577500        | Live | 22.5               | 46.0               | 23.5        | Complied |
| 0.595500        | Live | 21.6               | 46.0               | 24.4        | Complied |

**Results: Neutral / Quasi Peak / 120 VAC 60 Hz**

| Frequency (MHz) | Line    | Level (dB $\mu$ V) | Limit (dB $\mu$ V) | Margin (dB) | Result   |
|-----------------|---------|--------------------|--------------------|-------------|----------|
| 0.208500        | Neutral | 49.1               | 63.3               | 14.2        | Complied |
| 0.285000        | Neutral | 41.7               | 60.7               | 19.0        | Complied |
| 0.370500        | Neutral | 32.8               | 58.5               | 25.7        | Complied |
| 0.487500        | Neutral | 27.3               | 56.2               | 28.9        | Complied |
| 0.591000        | Neutral | 37.0               | 56.0               | 19.0        | Complied |
| 2.112000        | Neutral | 38.7               | 56.0               | 17.3        | Complied |

**Results: Neutral / Average / 120 VAC 60 Hz**

| Frequency (MHz) | Line    | Level (dB $\mu$ V) | Limit (dB $\mu$ V) | Margin (dB) | Result   |
|-----------------|---------|--------------------|--------------------|-------------|----------|
| 0.217500        | Neutral | 32.8               | 52.9               | 20.1        | Complied |
| 0.289500        | Neutral | 26.9               | 50.5               | 23.6        | Complied |
| 0.361500        | Neutral | 23.0               | 48.7               | 25.7        | Complied |
| 0.442500        | Neutral | 17.7               | 47.0               | 29.3        | Complied |
| 0.577500        | Neutral | 24.6               | 46.0               | 21.4        | Complied |
| 1.189500        | Neutral | 18.6               | 46.0               | 27.4        | 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 (dB $\mu$ V) | Limit (dB $\mu$ V) | Margin (dB) | Result   |
|-----------------|------|--------------------|--------------------|-------------|----------|
| 0.186000        | Live | 49.8               | 64.2               | 14.4        | Complied |
| 0.244500        | Live | 46.4               | 61.9               | 15.5        | Complied |
| 0.307500        | Live | 43.4               | 60.0               | 16.6        | Complied |
| 0.568500        | Live | 38.2               | 56.0               | 17.8        | Complied |
| 2.112000        | Live | 38.8               | 56.0               | 17.2        | Complied |
| 10.414500       | Live | 28.2               | 60.0               | 31.8        | Complied |

**Results: Live / Average / 240 VAC 60 Hz**

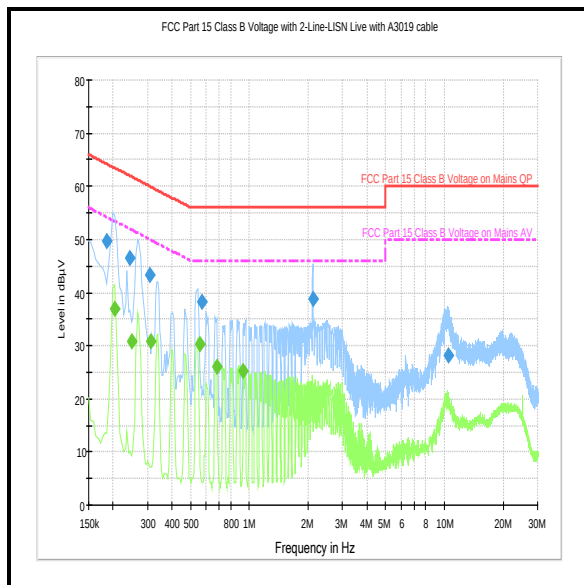
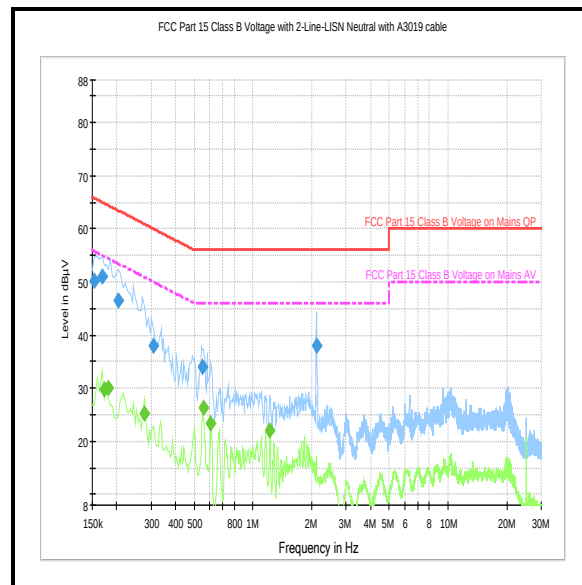
| Frequency (MHz) | Line | Level (dB $\mu$ V) | Limit (dB $\mu$ V) | Margin (dB) | Result   |
|-----------------|------|--------------------|--------------------|-------------|----------|
| 0.204000        | Live | 37.0               | 53.4               | 16.4        | Complied |
| 0.249000        | Live | 30.8               | 51.8               | 21.0        | Complied |
| 0.312000        | Live | 30.8               | 49.9               | 19.1        | Complied |
| 0.559500        | Live | 30.3               | 46.0               | 15.7        | Complied |
| 0.681000        | Live | 26.1               | 46.0               | 19.9        | Complied |
| 0.928500        | Live | 25.2               | 46.0               | 20.8        | Complied |

**Results: Neutral / Quasi Peak / 240 VAC 60 Hz**

| Frequency (MHz) | Line    | Level (dB $\mu$ V) | Limit (dB $\mu$ V) | Margin (dB) | Result   |
|-----------------|---------|--------------------|--------------------|-------------|----------|
| 0.154500        | Neutral | 50.2               | 65.8               | 15.6        | Complied |
| 0.168000        | Neutral | 51.0               | 65.1               | 14.1        | Complied |
| 0.204000        | Neutral | 46.4               | 63.4               | 17.0        | Complied |
| 0.307500        | Neutral | 38.2               | 60.0               | 21.8        | Complied |
| 0.550500        | Neutral | 34.0               | 56.0               | 22.0        | Complied |
| 2.112000        | Neutral | 37.9               | 56.0               | 18.1        | Complied |

**Results: Neutral / Average / 240 VAC 60 Hz**

| Frequency (MHz) | Line    | Level (dB $\mu$ V) | Limit (dB $\mu$ V) | Margin (dB) | Result   |
|-----------------|---------|--------------------|--------------------|-------------|----------|
| 0.172500        | Neutral | 29.7               | 54.8               | 25.1        | Complied |
| 0.181500        | Neutral | 29.9               | 54.4               | 24.5        | Complied |
| 0.276000        | Neutral | 25.4               | 50.9               | 25.5        | Complied |
| 0.555000        | Neutral | 26.3               | 46.0               | 19.7        | Complied |
| 0.609000        | Neutral | 23.4               | 46.0               | 22.6        | Complied |
| 1.221000        | Neutral | 22.2               | 46.0               | 23.8        | 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.*

**--- END OF REPORT ---**