



TEST REPORT

Test Report No. : UL-RPT-RP11265293JD07H V2.0

Manufacturer : Apple Inc.
Model No. : A1785
FCC ID : BCG-E3088A
Technology : NFC – 13.56 MHz
Test Standard(s) : FCC Parts 2.1049, 15.207, 15.209(a) & 15.225

1. This test report shall not be reproduced in full or partial, 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:

03 August 2016

Checked by:

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Company Signatory:

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Service Lead, Radio Laboratory UL
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This laboratory is accredited by UKAS.
The tests reported herein have been
performed in accordance with its terms
of accreditation.

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1. Customer Information

Company Name:	Apple Inc.
Address:	1 Infinite Loop Cupertino, CA 95014 U.S.A

2. Summary of Testing

2.1. General Information

Specification Reference:	47CFR15.225
Specification Title:	Code of Federal Regulations Volume 47 (Telecommunications): Part 15 Subpart C (Radio Frequency Devices) - Section 15.225
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:	209735
Location of Testing:	UL VS LTD, Unit 3 Horizon, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, United Kingdom
Test Dates:	22 June 2016 to 18 July 2016

2.2. Summary of Test Results

FCC Reference (47CFR)	Measurement	Result
Part 15.207	Transmitter AC Conducted Emissions	
Part 15.225(a)(b)(c)(d)	Transmitter Fundamental Field Strength	
Part 15.209(a)/15.225(d)	Transmitter Radiated Emissions	
Part 15.209(a)/15.225(c)(d)	Transmitter Band Edge Radiated Emissions	
Part 2.1049	Transmitter 20 dB Bandwidth	
Part 15.225(e)	Transmitter Frequency Stability (Temperature & Voltage Variation)	
Key to Results  = Complied  = Did not comply		

2.3. Methods and Procedures

Reference:	ANSI C63.10-2013
Title:	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
Reference:	FCC KDB Publication Number 937606 Date: 10/10/2014
Title:	Test Site Requirements for Part 15 and 18 Devices Operating Below 30 MHz
Reference:	KDB 174176 D01 Line Conducted FAQ v01r01 June 3, 2015
Title:	AC Power-Line Conducted Emissions Frequently Asked Questions

2.4. 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.

3. Equipment Under Test (EUT)

3.1. Identification of Equipment Under Test (EUT)

Brand Name:	Apple
Model Name or Number:	A1785
Test Sample Serial Number:	C39RV01FHFML (<i>Radiated sample / AC conducted emissions sample – Standard antenna</i>)
Hardware Version:	REV1.0
Firmware Version:	0x1D0301AE
Test Utility software:	V1.23
FCC ID:	BCG-E3088A

Brand Name:	Apple
Model Name or Number:	A1785
Test Sample Serial Number:	C39RW01SHFML (<i>Radiated sample used for frequency stability measurements</i>)
Hardware Version:	REV1.0
Firmware Version:	0x1D0301AE
Test Utility software:	V1.23
FCC ID:	BCG-E3088A

Brand Name:	Apple
Model Name or Number:	A1785
Test Sample Serial Number:	C39RV00THFMT (<i>AC conducted emissions sample – Modified antenna</i>)
Hardware Version:	REV1.0
Firmware Version:	0x1D0301AE
Test Utility software:	V1.23
FCC ID:	BCG-E3088A

3.2. Description of EUT

The Equipment Under Test was a mobile phone with GSM/GPRS/EGPRS/UMTS/LTE/TD-SCDMA and CDMA technologies. It also supports IEEE 802.11a/b/g/n/ac, Bluetooth®, GPS and NFC. The rechargeable battery is not user accessible.

3.3. Modifications Incorporated in the EUT

No modifications were applied to the EUT during testing.

3.4. Additional Information Related to Testing

Tested Technology:	NFC	
Category of Equipment:	Transceiver	
Channel Spacing:	Single channel device	
Modulation:	Manchester	
Transmit Frequency Range:	13.56 MHz	
Power Supply Requirement:	Nominal	3.8 VDC
	Minimum	3.4 VDC
	Maximum	4.3 VDC
Tested Temperature Range:	Minimum	-20°C
	Maximum	50°C

3.5. Support Equipment

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

Description:	Laptop PC
Brand Name:	Apple
Model Name or Number:	MacBook Pro
Serial Number:	C2QQN40SG8WP

Description:	USB diagnostic cable
Brand Name:	Not marked or stated
Model Name or Number:	Kong
Serial Number:	20750E

Description:	Personal Hands Free (PHF)
Brand Name:	Apple
Model Name or Number:	Apple Ear Plugs
Serial Number:	Not stated

Description:	USB Power Adapter
Brand Name:	Apple
Model Name or Number:	A1357
Serial Number:	Not marked or stated

4. Operation and Monitoring of the EUT during Testing

4.1. Operating Modes

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

- Constantly transmitting at full power with a modulated carrier in NFC test mode.
- Constantly transmitting at full power with an unmodulated carrier in NFC test mode.

4.2. Configuration and Peripherals

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

- NFC transmitter test mode was enabled using the combination of a terminal application and an application tool *NCI_UART_RTM3_A2_v1.2.3_06012016* on a laptop PC supplied by the customer. The laptop PC was connected to the EUT via a USB diagnostic cable. Once the EUT was in test mode the USB cable and laptop PC were disconnected from the EUT. The customer supplied instructions *NFC_Setup_V2_0.docx*. Procedures shown within this document were used to place the EUT into NFC test mode.
- The EUT supports ten different NFC tag and a reader modes. Preliminary checks were performed on all modes and the reader mode / Type A / 106 kbit/s produced the highest level of fundamental field strength, therefore final measurements were performed in this mode only. Results for all other modes are stored on the UL VS LTD IT server and available for inspection if required.
- AC conducted emissions tests were performed with the EUT connected to a USB charger output via a USB cable. The power supply input was connected to a 120 VAC 60 Hz / 240 VAC 60 Hz single phase supply via a LISN.
- Testing for frequency stability and measurements at temperature and voltage extremes was performed using a conducted sample supplied by the customer. Short 4-wire DC flying leads were connected internally to the device in place of the battery, and exited through a hole in the casing. These leads were then extended to a DC power supply for testing purposes.
- Transmitter radiated tests were performed with the EUT connected to the PHF as the customer declared it was the worst case accessory with respect to emissions. The EUT was placed in three orthogonal orientations X, Y and Z to determine the worst case orientation for radiated spurious emissions. Worst case was Z.
- The worst-case radiated emission among all accessories, is determined by the manufacturer to be with the headset connected. The compliance lab performed final testing only with the headset attached.
- All unused active ports were terminated.
- Transmitter frequency stability measurements were performed with the EUT transmitting an unmodulated carrier. All other measurements were performed with a modulated NFC carrier.
- Refer to Appendix 1 of this test report for details of radiated tests on an open field test site.

5. Measurements, Examinations and Derived Results

5.1. General Comments

Measurement uncertainties are evaluated in accordance with current best practice. Our reported expanded uncertainties are based on standard uncertainties, which are multiplied by an appropriate coverage factor to provide a statistical confidence level of approximately 95%. Please refer to *Section 6: Measurement Uncertainties* for details.

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.

5.2. Test Results

5.2.1. Transmitter AC Conducted Spurious Emissions

Test Summary:

Test Engineer:	Matthew Galbraith	Test Dates:	05 July 2016 & 18 July 2016
Test Sample Serial Number:	C39RV01FHFML & C39RV00THFMT		

FCC Reference:	Part 15.207
Test Method Used:	ANSI C63.10 Section 6.2 / FCC KDB 174176 D01 and Notes below

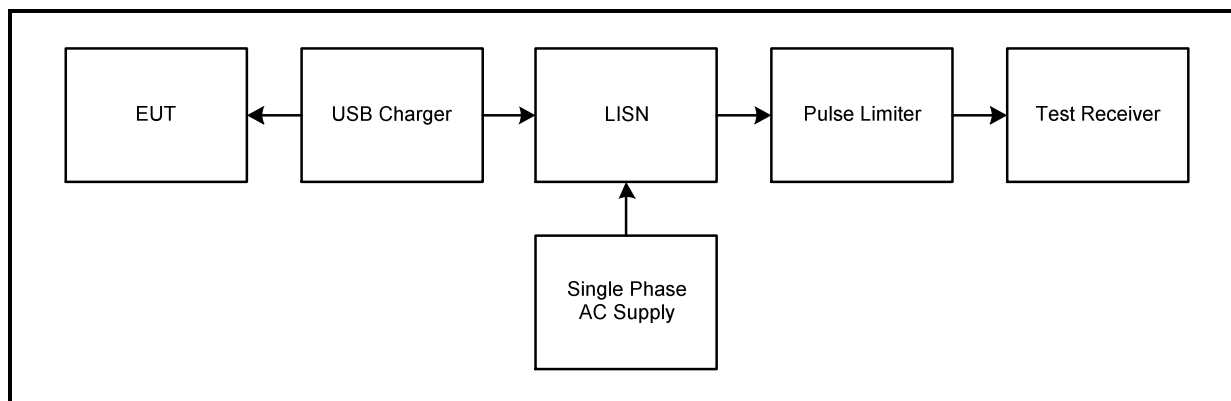
Environmental Conditions:

Temperature (°C):	23 to 25
Relative Humidity (%):	43 to 45

Note(s):

- AC conducted emissions tests were performed with the EUT connected to a USB charger output via a USB cable. The power supply input was connected to a 120 VAC 60 Hz single phase supply via a LISN.
- In accordance with FCC KDB 174176 D01 Q4, pre-scans were also performed with the power supply connected to a 240 VAC 60 Hz single phase supply as this was within the voltage range marked on the USB charger. Results were found to be the same as with a 120 VAC supply and not recorded in this report.
- A pulse limiter was fitted between the LISN and the test receiver.
- 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.
- The EUT was initially tested with the standard antenna connected (Test sample serial number C39RV01FHFML) and using a 120 VAC 60 Hz single phase supply. An emission at the approximate carrier frequency of 13.56 MHz was found to be non-compliant as it exceeded the test limit. The customer supplied a second, modified sample (Test sample serial number C39RV00THFMT). The standard antenna was disconnected and a 50 Ohm termination fitted in accordance with FCC KDB 174176 D01. The test was repeated and the EUT was found to be compliant.
- *Test results prior to modification of the EUT (standard antenna).
- **Test results with modified sample Serial No. C39RV00THFMT (transmitter terminated into 50 Ohm load in accordance with FCC KDB 174176 D01).

Test setup:



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

Frequency (MHz)	Line	Level (dBμV)	Limit (dBμV)	Margin (dB)	Result
0.348	Live	22.6*	59.0	36.4	Complied
0.812	Live	17.2*	56.0	38.8	Complied
2.927	Live	15.8*	56.0	40.2	Complied
3.935	Live	16.5*	56.0	39.5	Complied
13.574	Live	12.0**	60.0	48.0	Complied
27.119	Live	37.2*	60.0	22.8	Complied

Results: Live / Average / 120 VAC 60 Hz

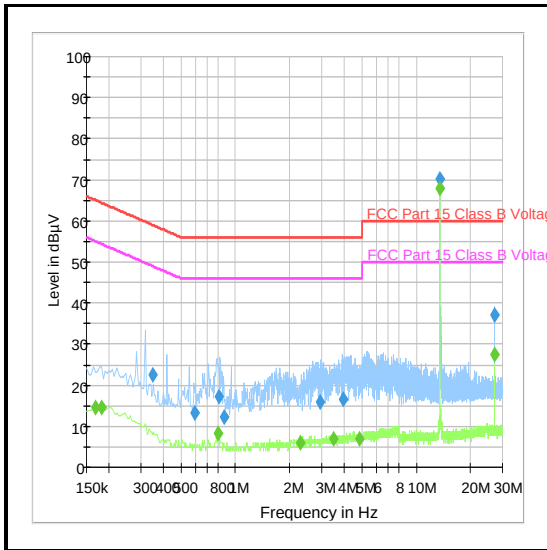
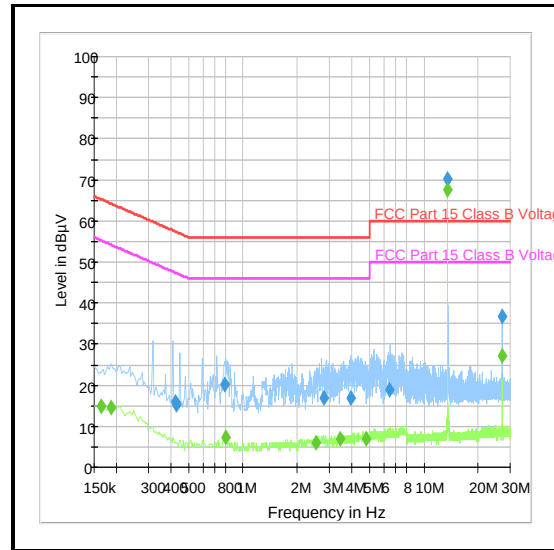
Frequency (MHz)	Line	Level (dBμV)	Limit (dBμV)	Margin (dB)	Result
0.182	Live	14.6*	54.4	39.8	Complied
0.798	Live	14.3*	46.0	37.9	Complied
3.489	Live	6.9*	46.0	39.1	Complied
4.821	Live	7.0*	46.0	39.0	Complied
13.650	Live	6.9**	50.0	43.1	Complied
27.119	Live	27.5*	50.0	22.5	Complied

Results: Neutral / Quasi Peak / 120 VAC 60 Hz

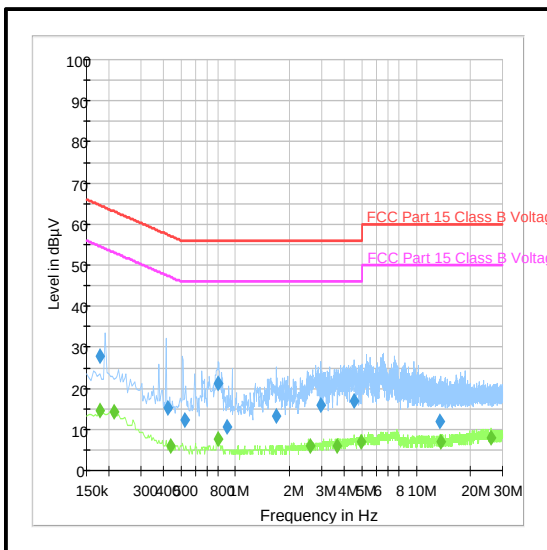
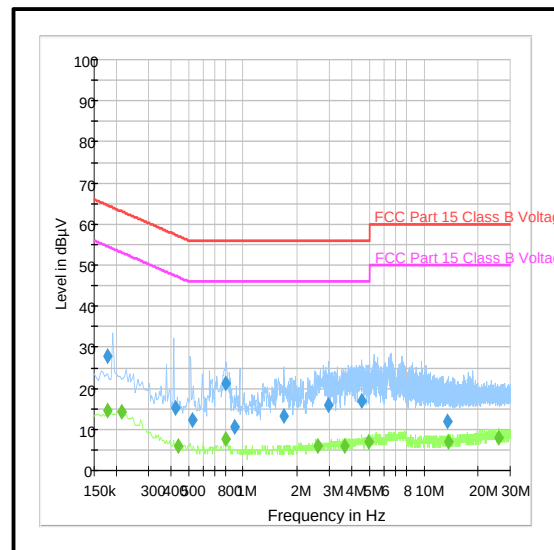
Frequency (MHz)	Line	Level (dBμV)	Limit (dBμV)	Margin (dB)	Result
0.789	Neutral	20.3*	56.0	35.7	Complied
2.796	Neutral	16.8*	56.0	39.2	Complied
3.939	Neutral	16.7*	56.0	39.3	Complied
6.468	Neutral	19.0*	60.0	41.0	Complied
13.574	Neutral	12.0**	60.0	48.0	Complied
27.119	Neutral	36.8*	60.0	23.2	Complied

Results: Neutral / Average / 120 VAC 60 Hz

Frequency (MHz)	Line	Level (dBμV)	Limit (dBμV)	Margin (dB)	Result
0.186	Neutral	14.6*	54.2	39.6	Complied
0.798	Neutral	7.4*	46.0	38.6	Complied
3.453	Neutral	6.9*	46.0	39.1	Complied
4.772	Neutral	7.0*	46.0	39.0	Complied
13.650	Neutral	6.9**	50.0	43.1	Complied
27.119	Neutral	27.2*	50.0	22.8	Complied

Transmitter AC Conducted Spurious Emissions (continued)**Live / 120 VAC 60 Hz****Neutral / 120 VAC 60 Hz**

Test results prior to modification of the EUT (standard antenna)

**Live / 120 VAC 60 Hz****Neutral / 120 VAC 60 Hz**

Test results with modified sample (transmitter terminated into 50 Ohm load)

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

Transmitter AC Conducted Spurious Emissions (continued)**Test Equipment Used:**

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2014	Thermohygrometer	Testo	608-H1	45046246	10 Jun 2017	12
K0001	5m RSE Chamber	Rainford EMC	N/A	N/A	12 Jan 2017	12
M1273	Test Receiver	Rohde & Schwarz	ESIB26	100275	11 Apr 2017	12
A004	LISN	Rohde & Schwarz	ESH3-Z5	890604/027	08 Feb 2017	12
A1829	Pulse Limiter	Rohde & Schwarz	ESH3-Z2	100671	05 May 2017	12

5.2.2. Transmitter Fundamental Field Strength**Test Summary:**

Test Engineers:	Andrew Edwards & Stefan Ho	Test Dates:	22 June 2016 to 12 July 2016
Test Sample Serial Number:	C39RV01FHFML		

FCC Reference:	Part 15.225(a)(b)(c)(d)
Test Method Used:	ANSI C63.10 Section 6.4 and notes below

Environmental Conditions:

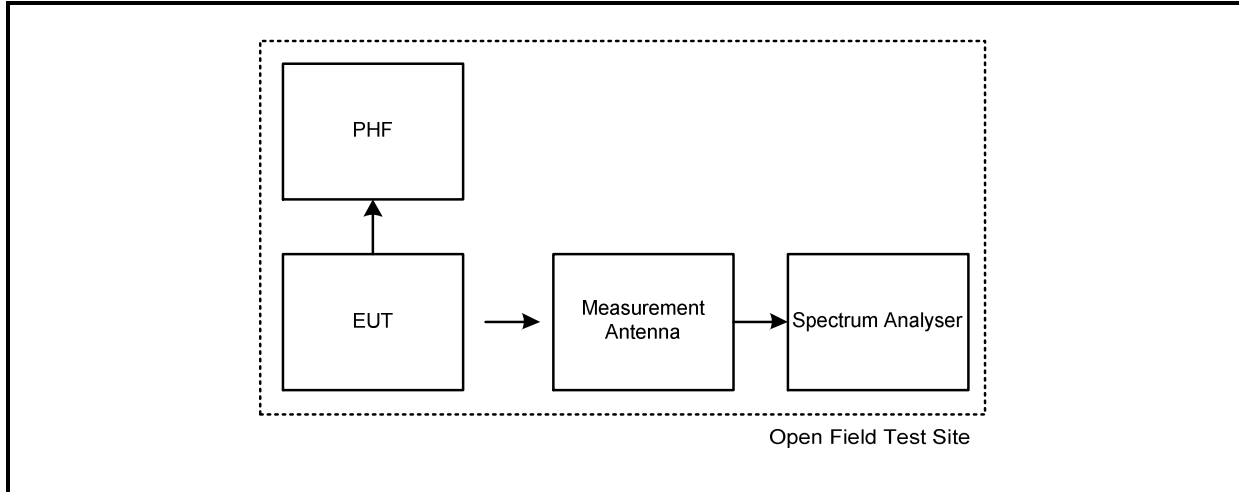
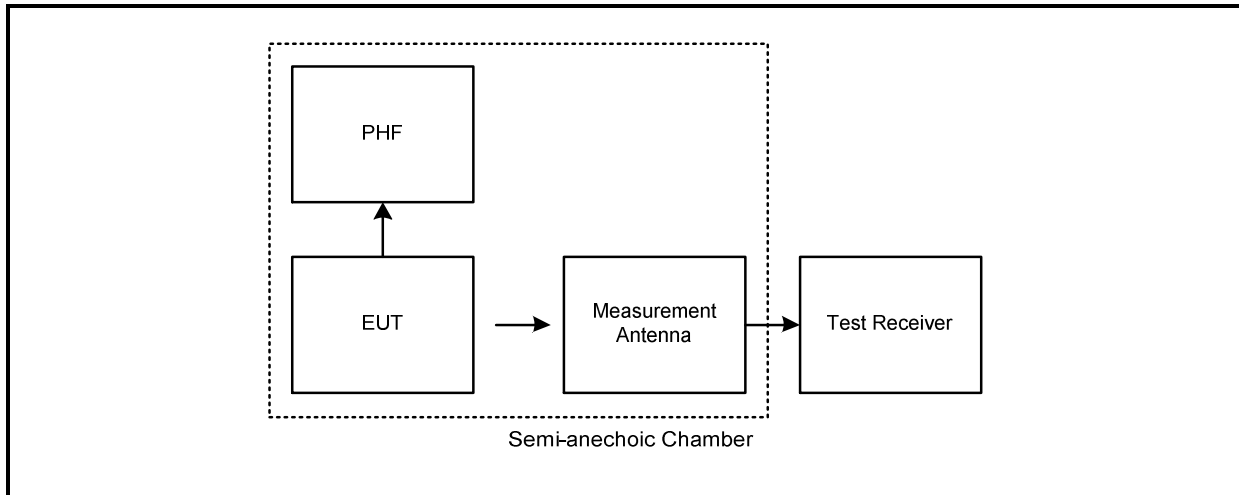
Temperature (°C):	20 to 25
Relative Humidity (%):	41 to 70

Note(s):

1. The limit is specified at a test distance of 30 metres. However, as specified by FCC Section 15.31 (f)(2), measurements may be performed at a closer distance and the measured level corrected to the specified measurement distance by using the square of an inverse linear distance extrapolation factor (40dB/decade).
2. In accordance with FCC KDB 937606, a *bona fide* attempt was made to perform measurements at the distances specified in Part 15.209(a). It was not possible to determine the emission value at the test distances specified below 30 MHz on an open field test site, therefore in accordance with 47 CFR 15.31(f), measurements were made at closer distances. Attempts were made to measure the fundamental at 30 metres on an open field test site on 22 June 2016 and 23 June 2016. Unfortunately the fundamental could not be seen above the ambient emissions or the noise floor of the measurement system at a distance of 30 metres, therefore the measurement was repeated at a reduced measurement distance of 3 metres using a measurement bandwidth of 10 kHz.
3. The fundamental field strength level was maximized by rotating the measurement antenna and EUT. A peak level of 65.9 dBµV/m in a 10 kHz measurement bandwidth, at a measurement distance of 3 metres was recorded and shown on the pre-scan plots below. The measurement was repeated in a semi-anechoic chamber at 3 metres on 12 July 2016. An RF level offset on the test receiver was used to correlate the field strength measurement made in the semi-anechoic chamber to the same measurement performed at 3 metres on the open field test site. Refer to result plot '*Fundamental field strength and spectrum mask / measured at 3 metres in a semi-anechoic chamber*'. This illustrates that the value of the RF level offset is 0.9 dB, since the fundamental field strength is 65.9 dBµV/m at a measurement distance of 3 metres.
4. Further measurements were performed in the semi-anechoic chamber using a spectrum analyser with a peak detector and measurement bandwidth of 10 kHz. An RF level offset of -39.1 dB was used on the spectrum analyser. This offset includes the 0.9 dB offset as explained in Note 3 above and a further -40 dB to extrapolate the level measured at 3 metres to the required distance of 30 metres (one decade). The fundamental field strength was maximized by rotating the measurement antenna and EUT. A peak level of 25.8 dBµV/m at a measurement distance of 3 metres (extrapolated to 30 metres) was recorded and shown on the pre-scan plot below. The spectrum analyser was then switched to test receiver mode and the final measurement on the maximized level was performed. In accordance with ANSI C63.10 Clause 4.1.4.2.1 and CISPR 16-1-1, a quasi-peak detector was used in conjunction with a measurement bandwidth of 9 kHz and 0.2 second sweep time. A quasi-peak level of 26.0 dBµV/m was recorded.
5. Due to the ambient emissions present on the open field test site, compliance with the spectrum mask is shown by measurements performed in a semi-anechoic chamber. Background scans of the open field test site and further information are shown in Appendix 1 of this test report.

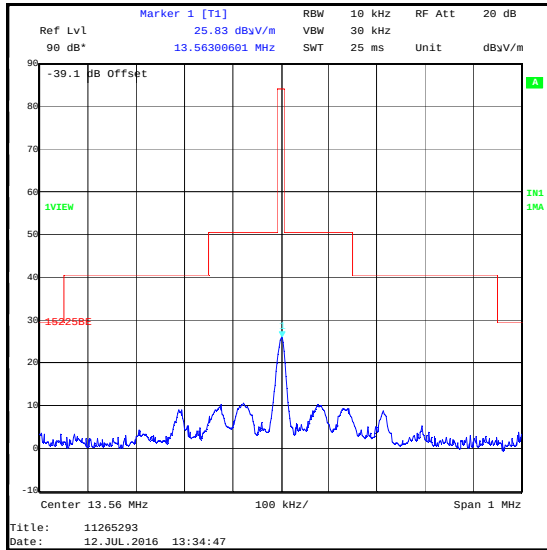
Transmitter Fundamental Field Strength (continued)**Notes:**

6. A transducer factor was used on the spectrum analyser during open field tests. This factor includes correction between the fixed gain of the magnetic loop antenna and the calibration values. It also includes the insertion loss of the RF cable used to connect the antenna to the spectrum analyser which was incorporated into the annual calibration of the magnetic loop antenna.

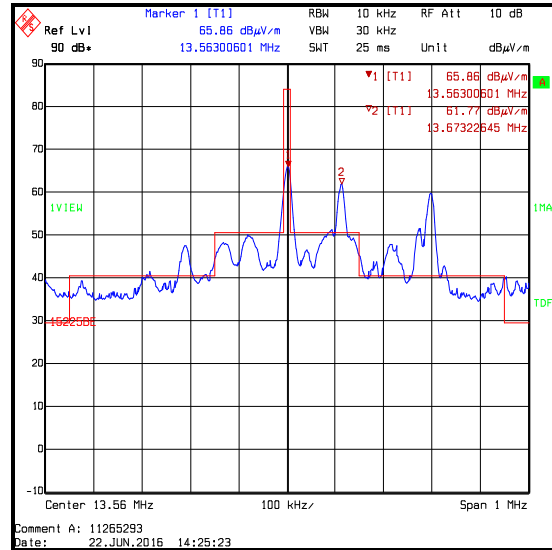
Transmitter Fundamental Field Strength (continued)**Test setup for fundamental field strength measurements:****Measurements on an open field test site****Measurements in a semi-anechoic chamber**

Transmitter Fundamental Field Strength (continued)**Results: Quasi Peak**

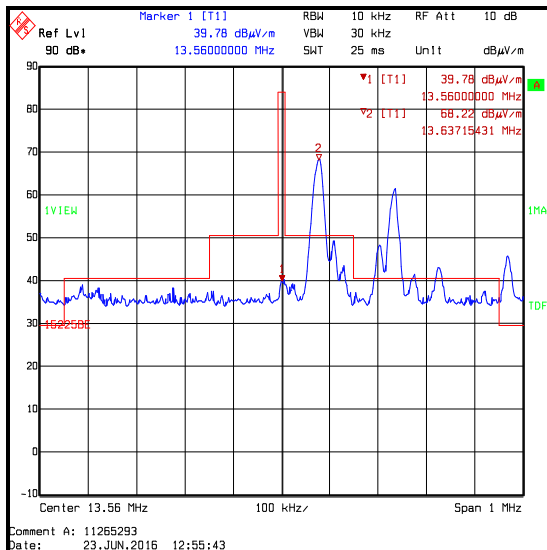
Frequency (MHz)	Measurement Antenna Position	Level (dB μ V/m)	Limit at 30 m (dB μ V/m)	Margin (dB)	Result
13.56	Tip of antenna 90° from EUT	26.0	84.0	58.0	Compiled



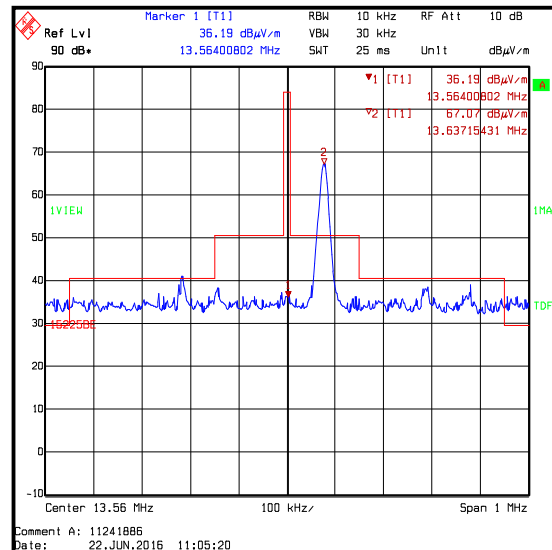
**Fundamental field strength and spectrum mask /
measured at 3 metres extrapolated to 30 metres /
measured in a semi-anechoic chamber**



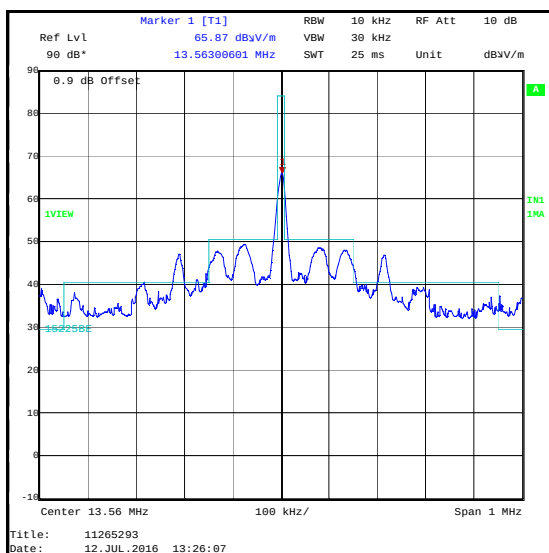
**Fundamental field strength / EUT operating / measured
at 3 metres / measured on an open field test site**



**Fundamental field strength / EUT operating / measured
at 30 metres / measured on an open field test site**



**EUT off / Background scan of the open field test site
showing an unwanted ambient emission at 13.637 MHz**

Transmitter Fundamental Field Strength (continued)

**Fundamental field strength and spectrum mask /
 measured at 3 metres / measured in a semi-anechoic
 chamber**

Test Equipment Used:

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2015	Thermohygrometer	Testo	608-H1	45046424	10 Jun 2017	12
M127	Spectrum Analyser	Rohde & Schwarz	FSEB30	842659/016	11 Aug 2016	12
M1568	Magnetic Loop Antenna	Rohde & Schwarz	HFH2-Z2	879284/2	23 May 2017	12
M1956	Precision Steel Rule	Rabone	(64SR) 0-35-406	4501361/2204	22 Apr 2020	60
A2686	Distance Measuring Wheel	Rolson Quality Tools	50799	Not stated	Calibrated before use	-
A2955	Protractor	Not marked or stated	9781907550 980	#1	Calibration not required	-
M2014	Thermohygrometer	Testo	608-H1	45046246	10 Jun 2017	12
K0001	5m RSE Chamber	Rainford EMC	N/A	N/A	12 Jan 2017	12
M1273	Test Receiver	Rohde & Schwarz	ESIB26	100275	11 Apr 2017	12

5.2.3. Transmitter Radiated Spurious Emissions

Test Summary:

Test Engineers:	Andrew Edwards & Stefan Ho	Test Dates:	22 June 2016 to 12 July 2016
Test Sample Serial Number:	C39RV01FHFML		

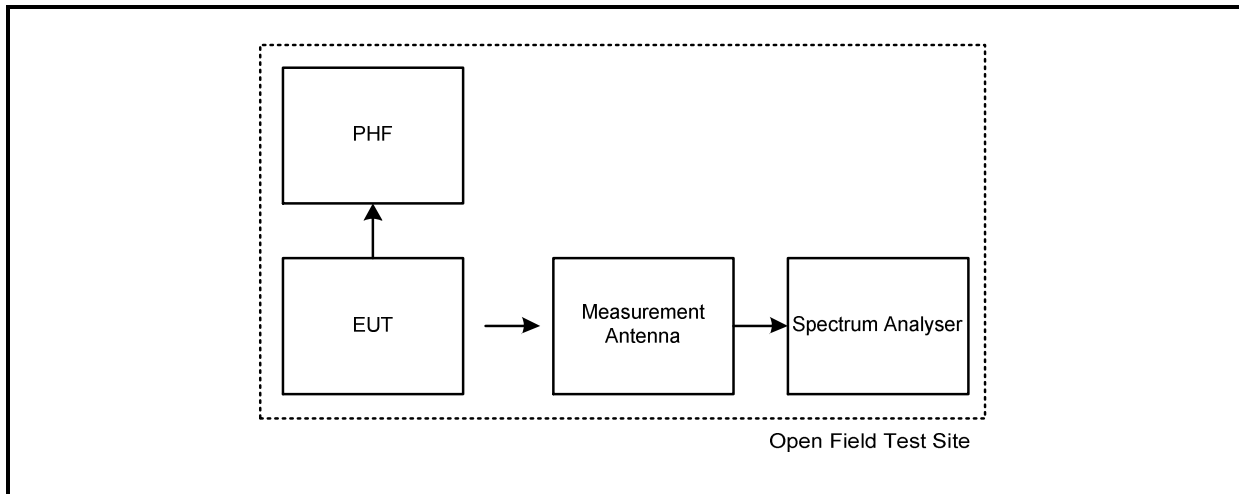
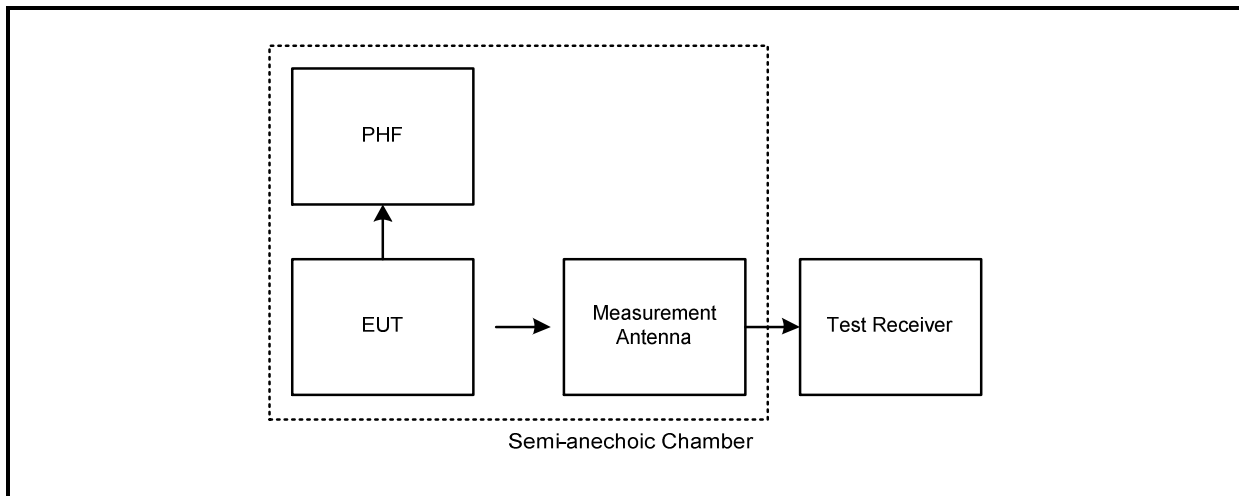
FCC Reference:	Parts 15.225(d) & 15.209(a)
Test Method Used:	ANSI C63.10 Sections 6.3, 6.4 and 6.5 and notes below
Frequency Range:	9 kHz to 1000 MHz

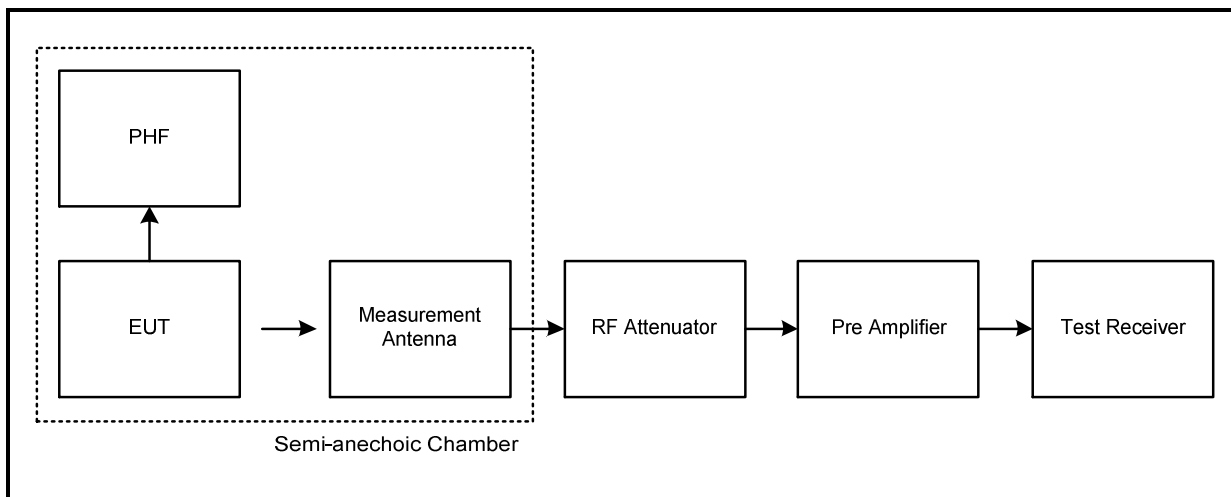
Environmental Conditions:

Temperature (°C):	20 to 25
Relative Humidity (%):	45 to 70

Note(s):

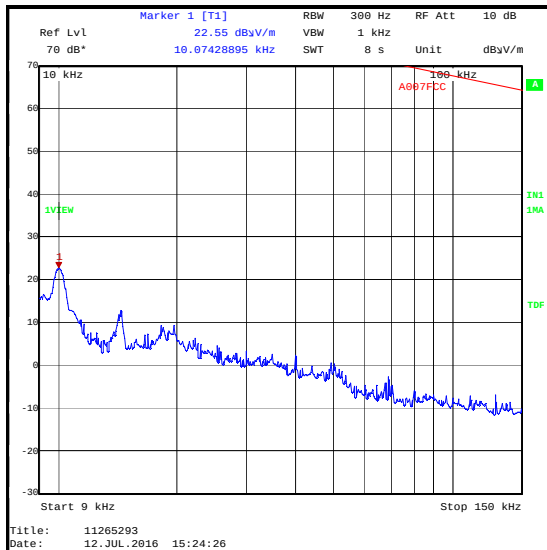
1. In accordance with FCC KDB 937606, a *bona fide* attempt was made to perform measurements at the distances specified in Part 15.209(a) on an open field test site. It was not possible to determine the spurious emission values at the test distances specified below 30 MHz on an open field test site, therefore in accordance with 47 CFR 15.31(f), measurements were made at closer distances. Attempts were made to measure spurious emissions at 3, 30 and 300 metres on an open field test site on 22 to 23 June 2016. Unfortunately, spurious emissions from the EUT could not be seen above the ambient emissions present at the open field test site or the noise floor of the measurement system. Final measurement results from the semi-anechoic chamber tests on 12 July 2016 are shown in this section. In addition, the open field test result plots for measurements between 9 kHz and 30 MHz are also shown. These measurement plots are identical to background scan plots of the open field test site. Background scans of the open field test site and further information are shown in Appendix 1 of this test report.
2. The final measured value, for the given emission, in the table below incorporates the calibrated antenna factor and cable loss. Only spurious emissions in the range 30 MHz to 1 GHz were recorded. Markers were placed on the peaks of the pre-scan plot and final measurements were performed using a quasi-peak detector.
3. All emissions were greater than 20 dB below the applicable limit, below the noise floor of the measurement system or ambient. Therefore the highest noise floor has been recorded in the table below.
4. Measurements on 12 July 2016 were performed in a semi-anechoic chamber (UL VS LTD 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. Between 30 MHz and 1 GHz, maximum emission levels were determined by height searching the measurement antenna over the range 1 metre to 4 metres.
5. Measurement plots in this section for tests between 9 kHz and 30 MHz on an open field test site have markers placed on the highest level ambient emissions. This is for information only.
6. All emissions on the 9 kHz to 150 kHz semi-anechoic chamber plot were investigated and found to be radiating from the test site turntable.
7. A transducer factor was used on the spectrum analyser during open field tests. This factor includes correction between the fixed gain of the magnetic loop antenna and the calibration values. It also includes the value of the RF cable used to connect the antenna to the spectrum analyser which was incorporated into the annual calibration of the magnetic loop antenna.

Transmitter Radiated Spurious Emissions (continued)**Test setup for radiated measurements:****Measurements below 30 MHz on an open field test site****Measurements below 30 MHz in a semi-anechoic chamber**

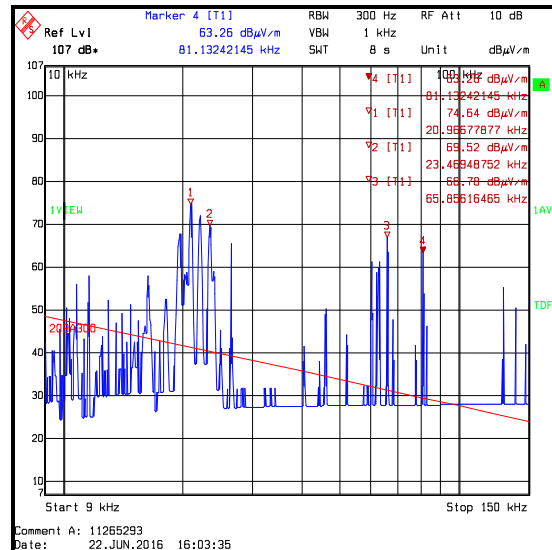
Transmitter Radiated Spurious Emissions (continued)**Test setup for radiated measurements:****Measurements above 30 MHz in a semi-anechoic chamber**

Transmitter Radiated Spurious Emissions (continued)**Results: Quasi Peak**

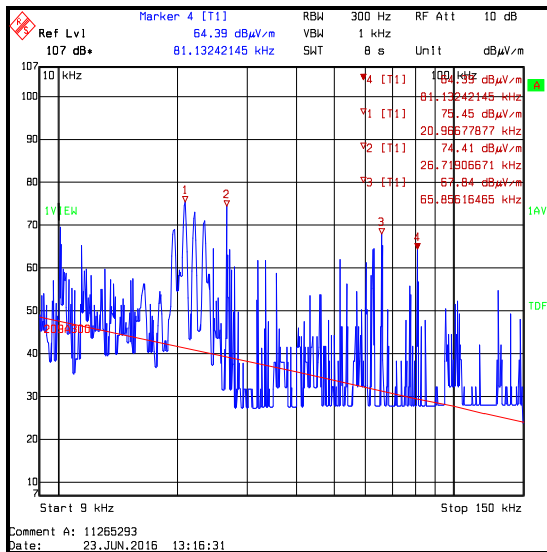
Frequency (MHz)	Antenna Polarity	Level (dB μ V/m)	Limit (dB μ V/m)	Margin (dB)	Result
35.459	Vertical	10.2	40.0	29.8	Complied



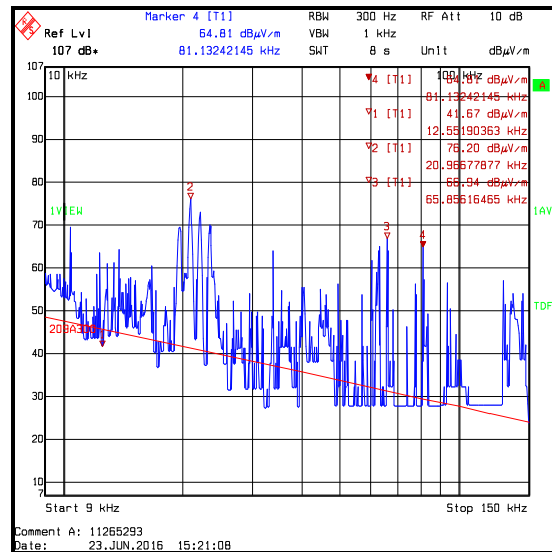
9 kHz to 150 kHz / peak detector / measured at 3 metres extrapolated to 30 metres / measured in a semi-anechoic chamber



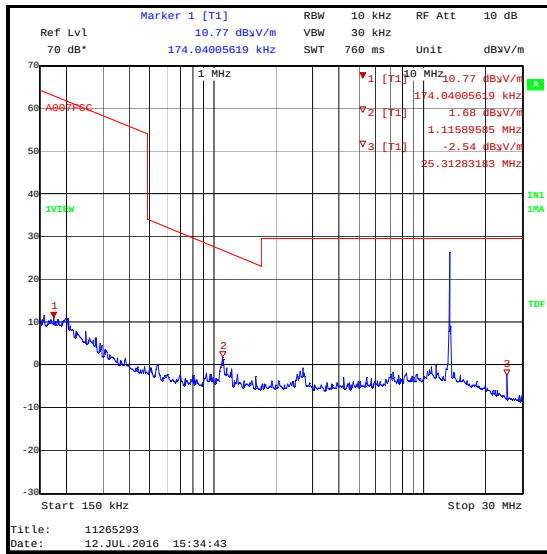
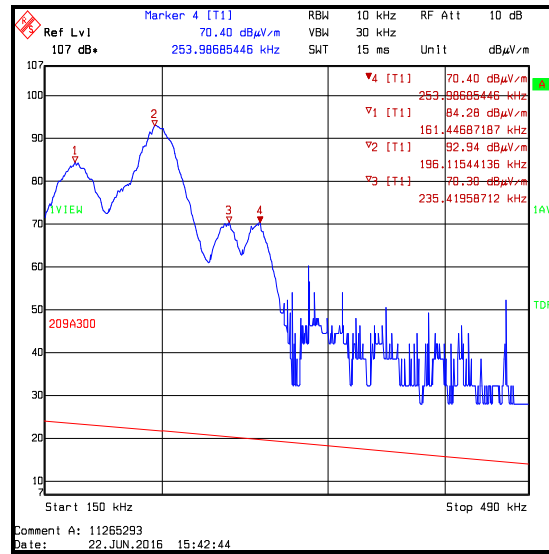
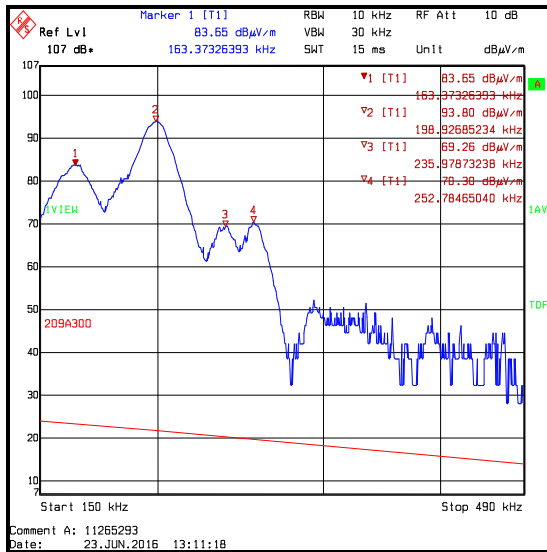
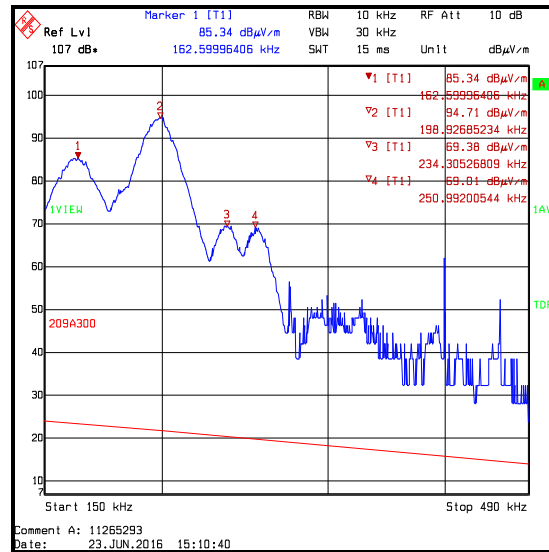
9 kHz to 150 kHz / average detector / EUT operating / measured at 3 metres on an open field test site

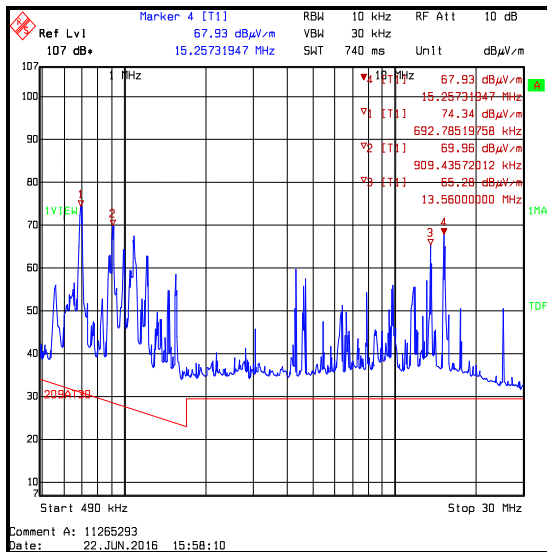


9 kHz to 150 kHz / average detector / EUT operating / measured at 30 metres on an open field test site

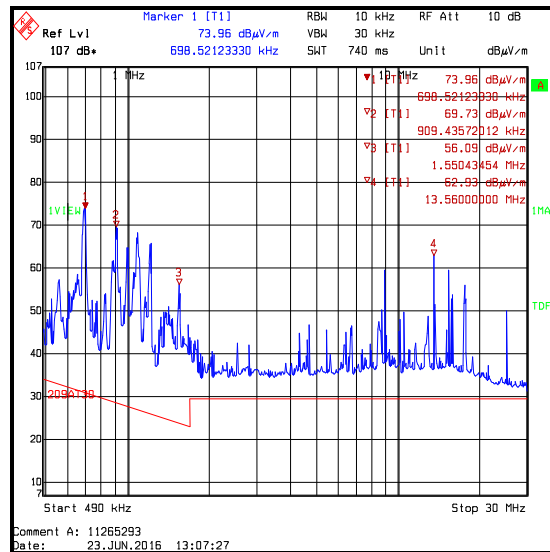


9 kHz to 150 kHz / average detector / EUT operating / measured at 300 metres on an open field test site

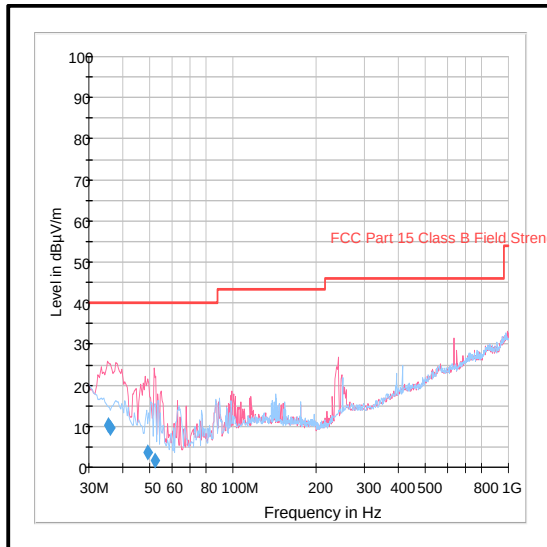
Transmitter Radiated Spurious Emissions (continued)**150 kHz to 30 MHz / peak detector (worst case) / EUT operating / measured at 3 metres extrapolated to 30 metres / measured in a semi-anechoic chamber****150 kHz to 490 kHz / average detector / EUT operating / measured at 3 metres on an open field test site****150 kHz to 490 kHz / average detector / EUT operating / measured at 30 metres on an open field test site****150 kHz to 490 kHz / average detector / EUT operating / measured at 300 metres on an open field test site**

Transmitter Radiated Spurious Emissions (continued)

490 kHz to 30 MHz / peak detector / EUT operating / measured at 3 metres on an open field test site



490 kHz to 30 MHz / peak detector / EUT operating / measured at 30 metres on an open field test site



30 MHz to 1 GHz / peak detector (worst case) / measured at 3 metres in a semi-anechoic chamber

Transmitter Radiated Spurious Emissions (continued)**Test Equipment Used:**

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2015	Thermohygrometer	Testo	608-H1	45046424	10 Jun 2017	12
M127	Spectrum Analyser	Rohde & Schwarz	FSEB30	842659/016	11 Aug 2016	12
M1568	Magnetic Loop Antenna	Rohde & Schwarz	HFH2-Z2	879284/2	23 May 2017	12
M1956	Precision Steel Rule 1 m/39 in	Rabone	(64SR) 0-35-406	4501361/2204	22 Apr 2020	60
A2686	Distance Measuring Wheel	Rolson	50799	Not stated	Calibrated before use	-
A2955	Protractor	Not marked or stated	9781907550 980	#1	Calibration not required	-
M2014	Thermohygrometer	Testo	608-H1	45046246	10 Jun 2017	12
K0001	5m RSE Chamber	Rainford EMC	N/A	N/A	12 Jan 2016	12
M1273	Test Receiver	Rohde & Schwarz	ESIB26	100275	11 Apr 2017	12
A259	Antenna	Chase	CBL6111	1513	19 Jul 2016	12
A1834	Attenuator	Hewlett Packard	8491B	10444	30 Mar 2017	12
G0547	Amplifier	Sonoma Instrument	310N	230801	09 Dec 2016	6

5.2.4. Transmitter Band Edge Radiated Emissions**Test Summary:**

Test Engineers:	Andrew Edwards & Stefan Ho	Test Dates:	22 June 2016 to 12 July 2016
Test Sample Serial Number:	C39RV01FHFML		

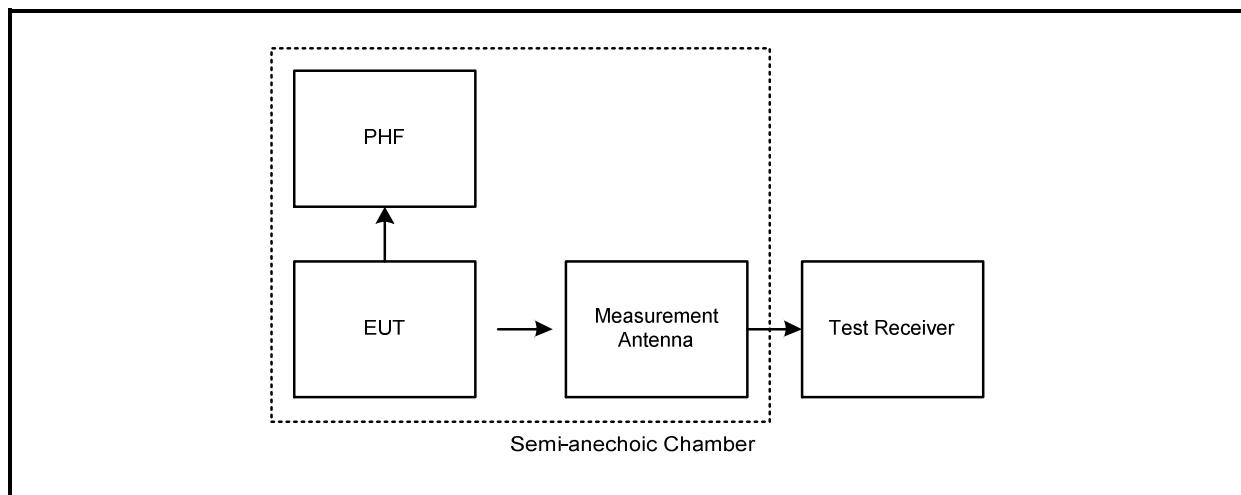
FCC Reference:	Parts 15.225(c)(d) & 15.209(a)
Test Method Used:	ANSI C63.10 Section 6.4 and notes below

Environmental Conditions:

Temperature (°C):	20 to 25
Relative Humidity (%):	41 to 70

Note(s):

1. In accordance with FCC KDB 937606, a *bona fide* attempt was made to perform measurements at the distances specified in Part 15.209(a). It was not possible to determine the band edge emission values at the test distances specified below 30 MHz on an open field test site due to the presence of ambient emissions, therefore in accordance with 47 CFR 15.31(f), measurements were made at closer distances. Attempts were made to measure the fundamental and band edges at 3 metres on an open field test site on 22 June 2016 and 23 June 2016. Unfortunately the emission could not be seen above the ambient emissions or the noise floor of the measurement system. Therefore the results from the semi-anechoic chamber tests on 12 July 2016 are shown in this section of the test report. Background scans of the open field test site are shown in Appendix 1 of this test report.
2. For the field strength measurements in a semi-anechoic chamber, an RF level offset of -39.1 dB was used to extrapolate the results at 3 metres to a distance of 30 metres and correlate measurements in a semi-anechoic chamber with measurements on an open field test site. For details on the calculations see Notes 3 and 4 in Section 5.2.2 of this test report.
3. The spectrum analyser resolution bandwidth was set to 10 kHz and video bandwidth 30 kHz. A peak detector was used, sweep time was set to auto and the trace mode was Max Hold. The span was set to 1 MHz. Markers were placed at the lower and upper band edges. The results are given in the tables below.

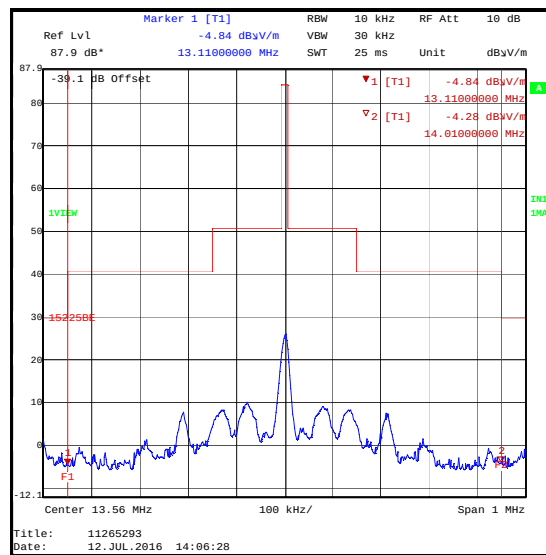
Test setup:

Transmitter Band Edge Radiated Emissions (continued)**Results: Peak / Lower Band Edge**

Frequency (MHz)	Level (dB μ V/m)	Limit (dB μ V/m)	Margin (dB)	Result
13.11	-4.8	29.5	34.3	Complied

Results: Peak / Upper Band Edge

Frequency (MHz)	Level (dB μ V/m)	Limit (dB μ V/m)	Margin (dB)	Result
14.01	-4.3	29.5	33.8	Complied

**Test Equipment Used:**

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2014	Thermohygrometer	Testo	608-H1	45046246	10 Jun 2017	12
M1568	Magnetic Loop Antenna	Rohde & Schwarz	HFH2-Z2	879284/2	23 May 2017	12
K0001	5m RSE Chamber	Rainford EMC	N/A	N/A	12 Jan 2017	12
M1273	Test Receiver	Rohde & Schwarz	ESIB26	100275	11 Apr 2017	12

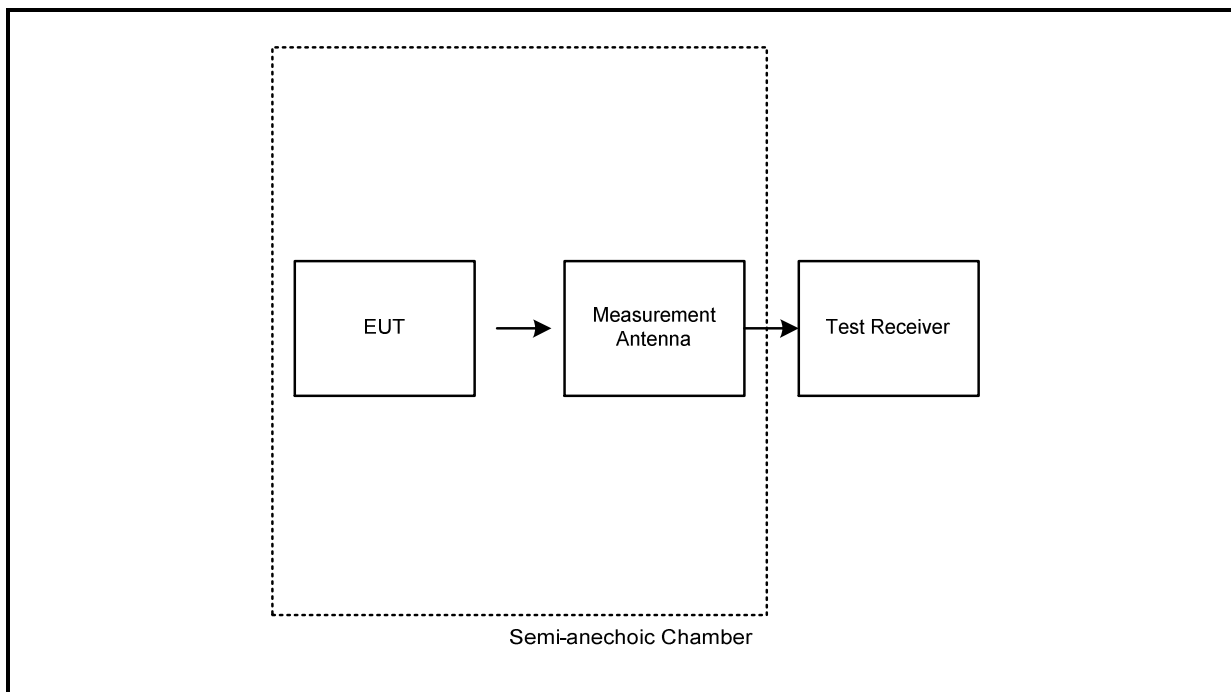
5.2.5. Transmitter 20 dB Bandwidth**Test Summary:**

Test Engineer:	Stefan Ho	Test Date:	12 July 2016
Test Sample Serial Number:	C39RV01FHFML		

FCC Reference:	Part 2.1049
Test Method Used:	ANSI C63.10 Section 6.9.2

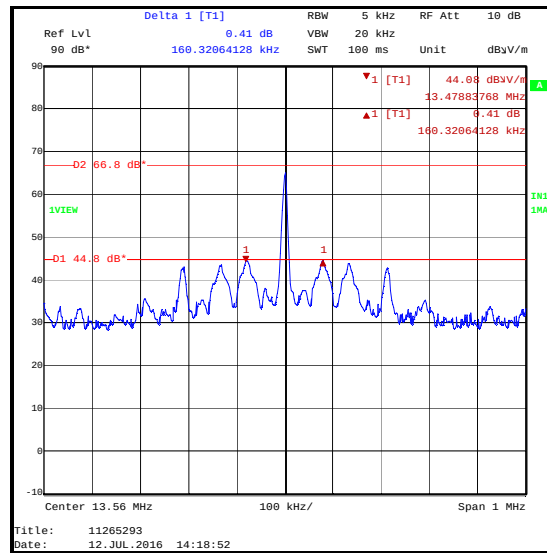
Environmental Conditions:

Temperature (°C):	23
Relative Humidity (%):	41

Test setup:

Transmitter 20 dB Bandwidth (continued)**Results:**

20 dB Bandwidth (kHz)
160.321

**Test Equipment Used:**

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2014	Thermohygrometer	Testo	608-H1	45046246	10 Jun 2017	12
K0001	5m RSE Chamber	Rainford EMC	N/A	N/A	12 Jan 2017	12
M1273	Test Receiver	Rohde & Schwarz	ESIB26	100275	11 Apr 2017	12
M1568	Magnetic Loop Antenna	Rohde & Schwarz	HFH2-Z2	879284/Z2	23 May 2017	12

5.2.6. Transmitter Frequency Stability (Temperature & Voltage Variation)**Test Summary:**

Test Engineer:	Matthew Galbraith	Test Date:	13 July 2016
Test Sample Serial Number:	C39RW01SHFML		

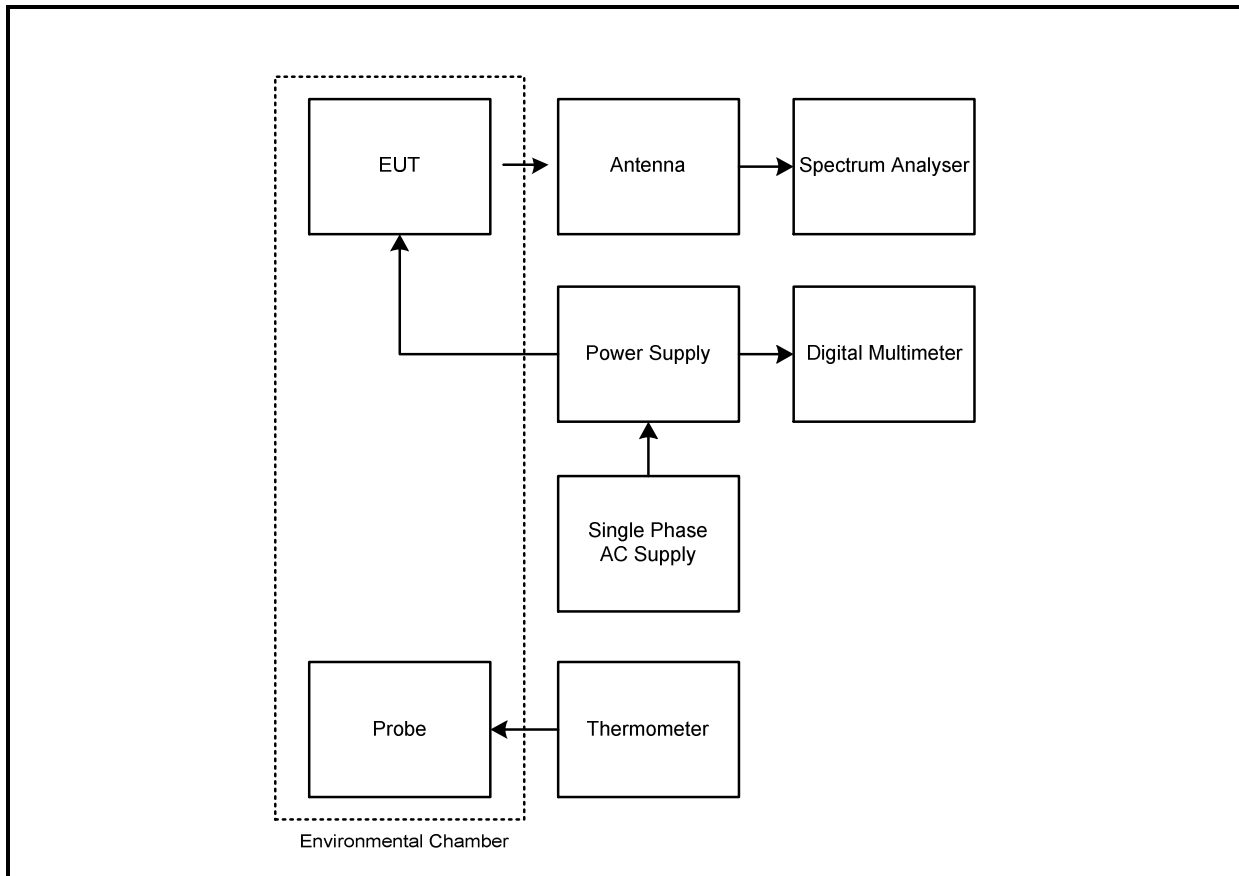
FCC Reference:	Parts 15.225(e) & 2.1055
Test Method Used:	ANSI C63.10 Sections 6.8.1 and 6.8.2

Environmental Conditions:

Ambient Temperature (°C):	25
Ambient Relative Humidity (%):	42

Note(s):

1. Testing at voltage extremes was performed with the EUT powered by an external DC power supply.
2. Frequency stability measurements were performed with an unmodulated carrier. The measurements were performed using the test receiver marker counter function. The marker counter function was set to 1 Hz before any measurements were performed.
3. Temperature was monitored throughout the test with a calibrated digital thermometer.
4. Voltage was monitored throughout the test with a calibrated digital voltmeter.

Test setup:

Transmitter Frequency Stability (Temperature & Voltage Variation) (continued)**Results: Maximum frequency error of the EUT with variations in ambient temperature**

Temperature (°C)	Time after Start-up			
	0 minutes	2 minutes	5 minutes	10 minutes
-20	13.559785 MHz	13.559789 MHz	13.559790 MHz	13.559790 MHz
20	13.559760 MHz	13.559755 MHz	13.559744 MHz	13.559744 MHz
50	13.559662 MHz	13.559660 MHz	13.559659 MHz	13.559659 MHz

Frequency with Worst Case Deviation (MHz)	Frequency Error (Hz)	Frequency Error (%)	Limit (%)	Margin (%)	Result
13.559659	341	0.002515	0.01	0.007485	Complied

Results: Maximum frequency error of the EUT with variations in nominal operating voltage at an ambient temperature of 20°C

Supply Voltage (V)	Nominal Frequency (MHz)	Measured Frequency (MHz)	Frequency Error (Hz)	Frequency Error (%)	Limit (%)	Margin (%)	Result
3.4	13.56	13.559755	245	0.001807	0.01	0.008193	Complied
3.8	13.56	13.559760	240	0.001770	0.01	0.008230	Complied
4.3	13.56	13.559764	236	0.001740	0.01	0.008260	Complied

Test Equipment Used:

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M1659	Thermohygrometer	JM Handelspunkt	30.5015.13	Not stated	02 Apr 2017	12
E0513	Environmental Chamber	TAS	LT600 Series 3	23900506	Calibrated before use	-
M1249	Thermometer	Fluke	52II	88800049	27 May 2017	12
M1251	Multimeter	Fluke	175	89170179	13 May 2017	12
S0557	Power Supply	TTi	EL303R	395819	Calibrated before use	-
M127	Test Receiver	Rohde & Schwarz	FSEB30	842659/016	11 Aug 2016	12
M1568	Magnetic Loop Antenna	Rohde & Schwarz	HFH2-Z2	879284/2	23 May 2017	12

6. 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 of the measurand (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%	±4.69 dB
Frequency Stability	13 MHz to 14 MHz	95%	±0.92 ppm
Radiated Spurious Emissions	9 kHz to 30 MHz	95%	±3.73 dB
Radiated Spurious Emissions	30 MHz to 1000 MHz	95%	±5.65 dB
Transmitter Fundamental Field Strength	13 MHz to 14 MHz	95%	±3.73 dB
Occupied Bandwidth	13 MHz to 14 MHz	95%	±4.59%

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.

7. Report Revision History

Version Number	Revision Details		
	Page No(s)	Clause	Details
1.0	-	-	Initial Version
2.0	10	-	At the request of the TCB: Section 4.2. Inserted Bullet 6

8. Appendix 1

Test setup/arrangement of EUT during open field tests on 22 and 23 June 2016

Refer to

11265293JD07H_JD08H Set up Photos.doc

GPS coordinates

Mag loop location (lower marker on photo)

N51° 08.739' W001° 26.328'

30 metre test point (middle marker on photo)

N51° 08.755' W001° 26.325'

300 metre test point (upper marker on photo)

N51° 08.895' W001° 26.289'



Details of 3 metre and 30 metre open field test site used on 22 to 23 June 2016

Temperature: 21°C to 25°C

Relative Humidity: 67% to 70%

Ground conditions: Dry

Refer to

Refer to

11265293JD07H_JD08H Set up Photos.doc**11265293JD07H_JD08H Set up Photos.doc****Set up for 3 metre measurements****Set up for 30 metre measurements**

Measurements at 3 and 30 metres

The test site was free from underground metal objects.

The EUT was powered at its nominal voltage from its internal battery. The PHF was connected to the EUT to populate all active ports.

The EUT was placed on a plastic table at a height of 0.8 metres above ground level. All associated cables and support equipment were arranged according to ANSI C63.10-2013 Section 6.12.

The spectrum analyser used for measurements was located in a vehicle 30 metres from the magnetic loop antenna. Power to the measurement equipment was from a single phase agricultural supply.

The test distance was from the centre of the mag loop antenna to the closest periphery of the EUT. This distance was maintained as the EUT was rotated.

Initially, The EUT was rotated through 360 degrees in 60 degree steps at both measurement distances. The mag loop antenna was rotated through 90 degrees in 30 degree steps at every position the EUT was moved to. The EUT and mag loop antenna were then rotated in small increments in order to maximise emission levels.

Details of 300 metre open field test site used on 23 June 2016

Temperature: 22°C

Relative Humidity: 78%

Ground conditions: wet

Refer to

11265293JD07H_JD08H Set up Photos.doc

Set up for 300 metre measurements

Measurements at 300 metres

The test site was free from underground metal objects.

The EUT was powered at its nominal voltage from its internal battery. The PHF was connected to the EUT to populate all active ports.

The EUT was placed on a plastic table at a height of 0.8 metres above ground level. All associated cables were arranged according to ANSI C63.10-2013 Section 6.12.

The spectrum analyser used for measurements was located in a vehicle 30 metres from the magnetic loop antenna. Power to the measurement equipment was from a single phase agricultural supply.

The test distance was from the centre of the mag loop antenna to the closest periphery of the EUT. This distance was maintained as the EUT was rotated.

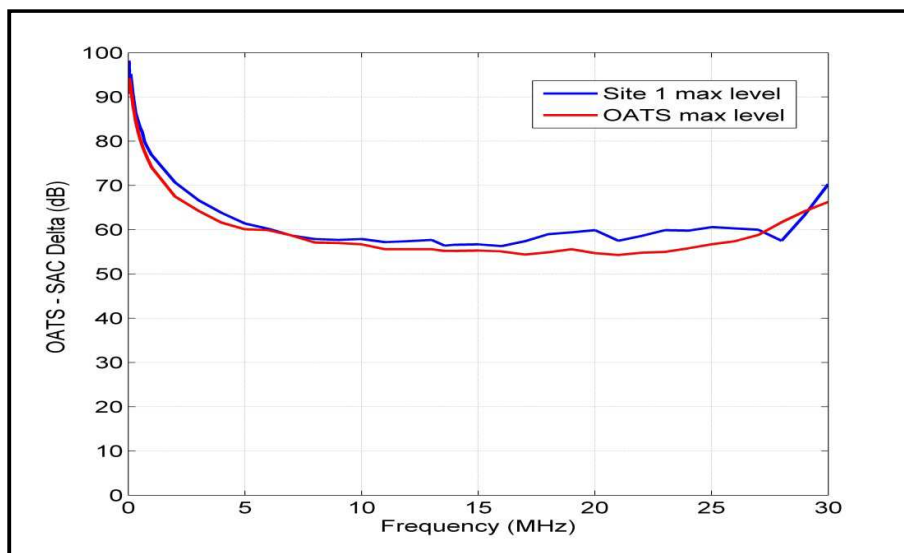
Initially, The EUT was rotated through 360 degrees in 60 degree steps at both measurement distances. The mag loop antenna was rotated through 90 degrees in 30 degree steps at every position the EUT was moved to. The EUT and mag loop antenna were then rotated in small increments in order to maximise emission levels.

Comparison of open field test site with semi-anechoic chamber measurements at 3 metres

Radiated measurements were performed on an open field test site and within a 5 metre semi-anechoic chamber.

For the signal source, a modified loop antenna was connected to a signal generator at the transmit side. A standard active magnetic loop antenna was connected to a spectrum analyser at the receive side. The signal generator was set to its maximum supported output power and the signal was transmitted to the spectrum analyser via the two antennas and associated RF cables.

A sweep in small frequency increments was performed from 9 kHz to 30 MHz. The sweep was repeatedly performed with both antennas rotated about the axis in various orientations. Received levels for all orientations were recorded and the maximum levels for the open field test site and the semi-anechoic chamber are shown on the graph below. Full data for both tests are archived on the UL VS LTD IT server and available for inspection on request.



The conclusion was that the open field test site compares well with the semi-anechoic chamber at a measurement distance of 3 metres. If anything, the semi-anechoic chamber results are generally slightly higher. This means that if the measurement passes in the semi-anechoic chamber, it will pass with a higher margin on an open field test site.

The magnetic loop antenna used to perform these measurements is the same antenna or same type of antenna used during measurements contained in this test report.

Verification of open field test site and semi-anechoic chamber measurements at 3 metres prior to performing measurements (continued)

Two reference units are used for verification of the measurement system before testing commences. Both reference units are door entry systems modified by the manufacturer for test purposes only.

One reference unit transmits a continuous, modulated signal at a fixed frequency of 125 kHz when a 12 Volt battery is connected. The output power is fixed and known to be stable.

The second transmits a continuous, modulated signal at a fixed frequency of 13.56 MHz when a 12 Volt battery is connected. The output power is fixed and known to be stable.

Both frequencies are commonly used RFID/NFC frequencies.

A UL VS LTD internal verification document explains the procedure in detail. A brief description is given below.

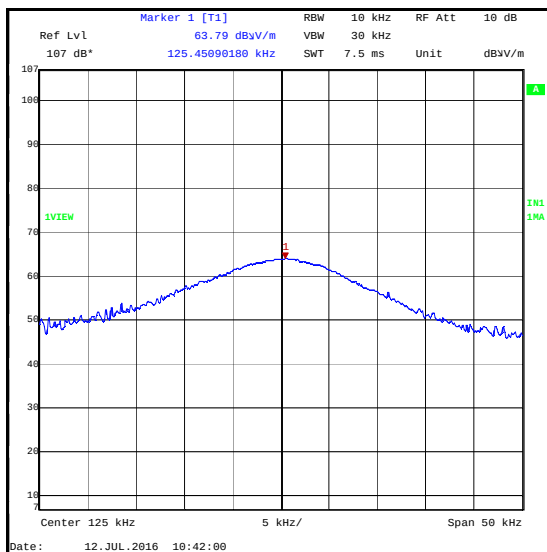
The centre of the magnetic loop antenna is placed exactly 3 metres from the reference unit. The reference unit is placed on a plastic table at a height of 0.8 metres above floor level and the centre of the mag loop antenna is 1 metre above the floor level. The mag loop antenna and reference unit are oriented in certain positions to ensure repeatability.

Each reference unit is connected to a 12 Volt battery and once transmitting, the maximum raw received level at each of the two frequencies is read on the spectrum analyser by using the marker peak function. The measured level has to be within certain levels as specified in the UL VS LTD internal test procedure. The plot of the verification measurement is archived on the UL VS LTD IT server. The peak level of each reference unit is recorded on a spreadsheet which is also archived on the UL VS LTD IT server.

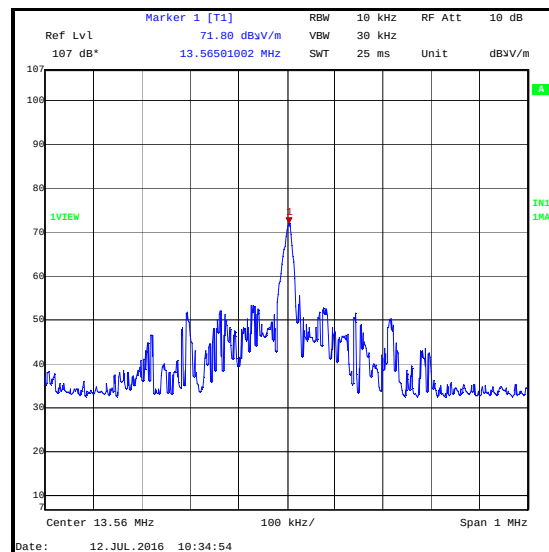
The internal verification procedure and verification plots are available for inspection on request.

Radiated measurements below 30 MHz were performed in a semi-anechoic chamber at a distance of 3 metres.

Verification plots of the two reference units at a measurement distance of 3 metres are shown on the following page. Plots were taken on an open field test site (22 June 2016 / 23 June 2016) and in a semi-anechoic chamber (12 July 2016).

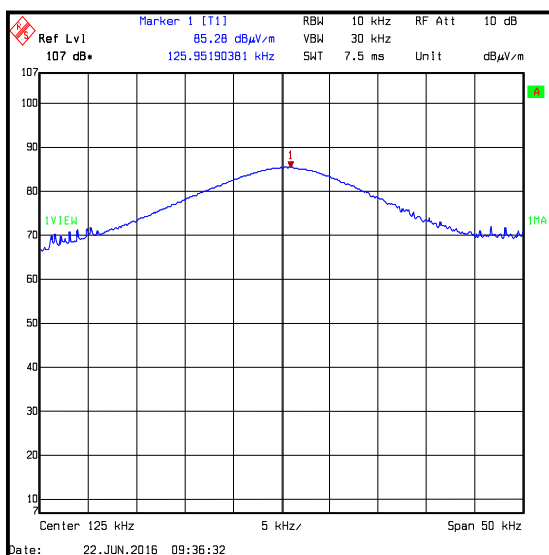


125 kHz reference unit signal at 3 metres in a semi-anechoic chamber on 12 July 2016

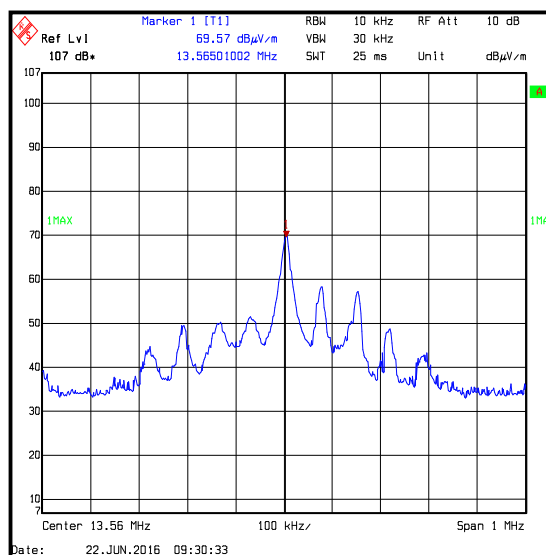


13.56 MHz reference unit signal at 3 metres in a semi-anechoic chamber on 12 July 2016

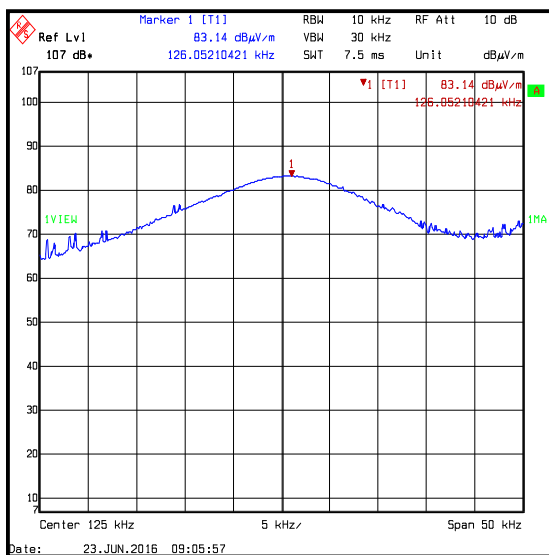
Verification of open field test site and semi-anechoic chamber measurements at 3 metres prior to performing measurements (continued)



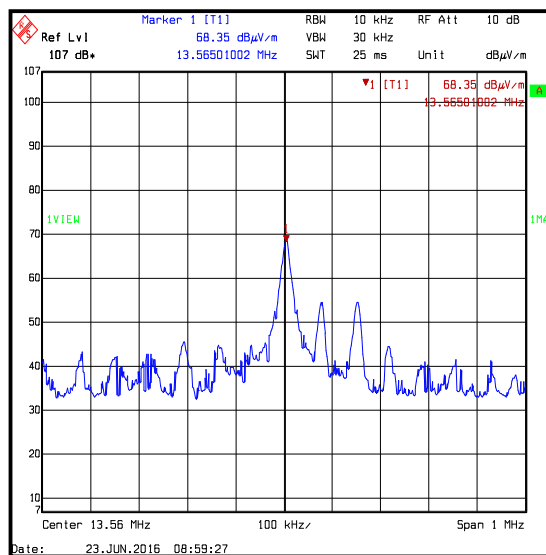
125 kHz reference unit signal at 3 metres on an open field test site on 22 June 2016



13.56 MHz reference unit signal at 3 metres on an open field test site on 22 June 2016



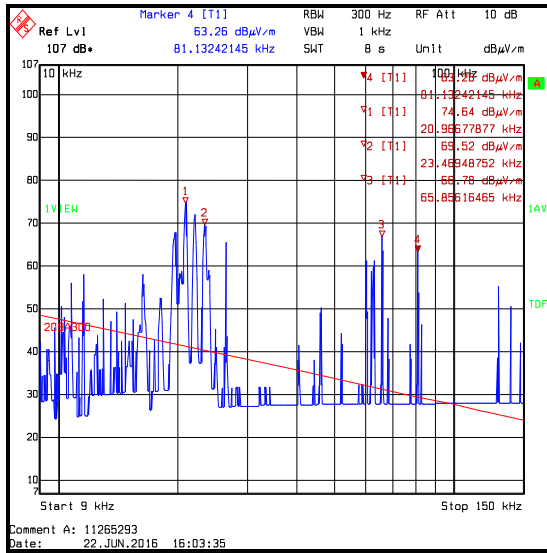
125 kHz reference unit signal at 3 metres on an open field test site on 23 June 2016



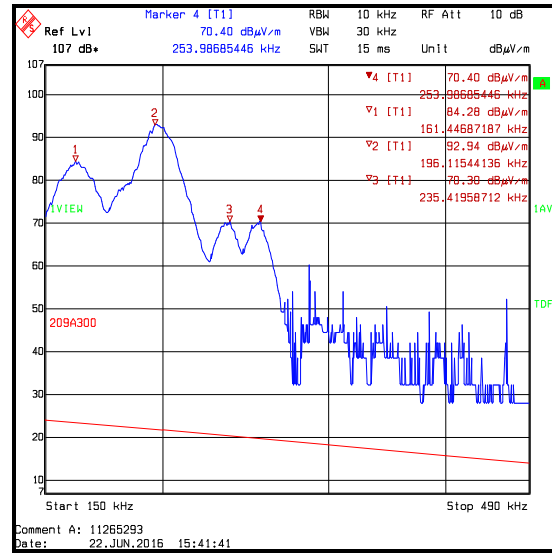
13.56 MHz reference unit signal at 3 metres on an open field test site on 23 June 2016

Note(s):

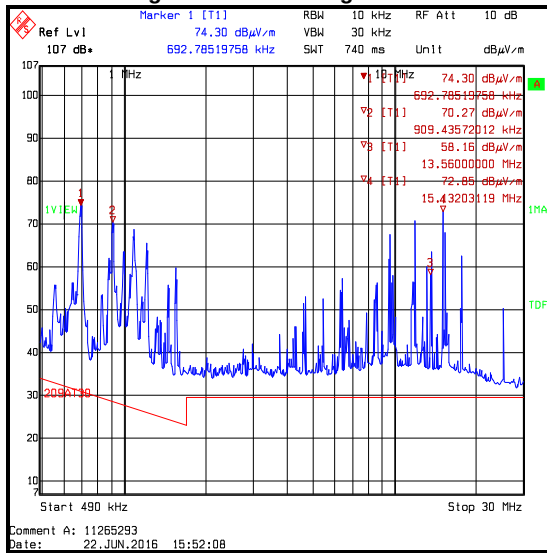
1. The above plots show comparable measurements of reference units on an open field test site and in a semi-anechoic chamber at spot frequencies.

Background scans of the open field test site

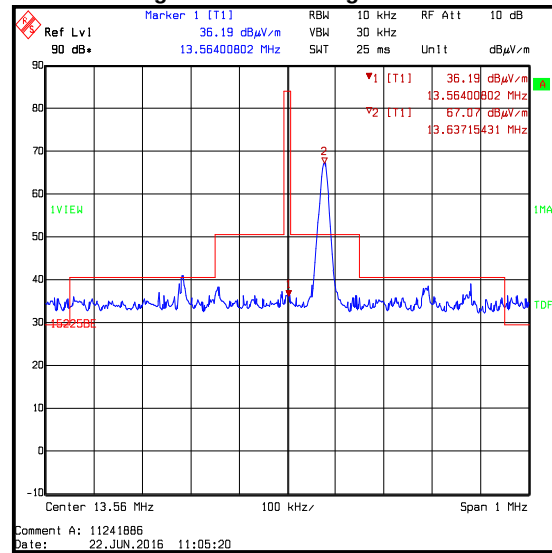
**Frequency range: 9 kHz to 150 kHz
Average detector / background scan**



**Frequency range: 150 kHz to 490 kHz
Average detector / background scan**



**Frequency range: 490 kHz to 30 MHz
Peak detector / background scan**



**Frequency range: 13.06 MHz to 14.06 MHz
Peak detector / background scan of the open field test site**

Note(s):

1. The above plots are background scans of the open field test site. The EUT was turned off when the background scans were performed.

--- END OF REPORT ---