TEST REPORT

Test Report No. : UL-RPT-RP11625806JD03A

Manufacturer	:	Belimo Automation AG
Model No.	:	ZIP-BT-NFC
FCC ID	:	2ALENZIP-BT-NFC
Technology	:	NFC – 13.56 MHz
Test Standard(s)	:	FCC Parts 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 1.0.

Date of Issue: 11 May 2017

Checked by:

Georgios Vrezas
Engineer, Radio Laboratory

Company Signatory:

Sarah Williams
Senior Engineer, Radio Laboratory
UL VS LTD

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:	Belimo Automation AG
Address:	Brunnenbachstrasse 1 8340 Hinwil Switzerland

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:	07 March 2017 to 29 March 2017

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 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 414788 Date: April 18, 2017
Title:	TEST SITES FOR RADIATED EMISSION MEASUREMENTS
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:	Belimo Automation AG
Model Name or Number:	ZIP-BT-NFC
Test Sample Serial Number:	Not marked or stated *(Radiated sample #1)*
Hardware Version:	13860
Software Version:	1.0.0
FCC ID:	2ALENZIP-BT-NFC

Brand Name:	Belimo Automation AG
Model Name or Number:	ZIP-BT-NFC
Test Sample Serial Number:	Not marked or stated *(Radiated sample #2 with external power cables)*
Hardware Version:	13860
Software Version:	1.0.0
FCC ID:	2ALENZIP-BT-NFC

Brand Name:	Belimo Automation AG
Model Name or Number:	ZIP-BT-NFC
Test Sample Serial Number:	Labelled as ‘NFC Terminated’ *(Dummy load in place of antenna)*
Hardware Version:	13860
Software Version:	1.0.0
FCC ID:	2ALENZIP-BT-NFC

3.2. Description of EUT

The Equipment Under Test was a 13.56 MHz NFC device that also includes an FCC / ISED Canada certified BT LE module. It is powered from an internal rechargeable battery.

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	
Transmit Frequency Range:	13.56 MHz	
Power Supply Requirement:	Nominal	3.7 VDC
	Minimum	3.42 VDC
	Maximum	4.255 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:	USB Travel Adaptor
Brand Name:	Samsung
Model Name or Number:	ETA0U10UBE
Serial Number:	RT3F905AS/7-E

Description:	Laptop PC
Brand Name:	Dell
Model Name or Number:	Latitude E5410
Serial Number:	Not marked or stated

Description:	USB Cable – length 1 metre
Brand Name:	Not marked or stated
Model Name or Number:	Not marked or stated
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.

4.2. Configuration and Peripherals

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

- A laptop PC was connected to the EUT using a USB cable. A serial terminal application (Tera Term V4.79) on the laptop PC was used to communicate to the EUT. The customer supplied a test mode document (Setup information V1.0 Date: 01-03-2017) and the NFC test mode instructions were followed. The test command 'nfc test' was sent from Tera Term to the EUT to enable NFC test mode. Once the EUT was set to transmit in NFC test mode, the USB cable and laptop PC were disconnected and removed.
- For AC conducted emissions, fundamental field strength, radiated spurious emissions and band edge radiated emissions tests, a USB Travel Adaptor was connected to the EUT USB port via USB cable.
- Refer to Appendix 1 of this test report for details of radiated tests on an open-field test site.
- Radiated sample #1 was used for AC conducted emission, fundamental field strength, radiated spurious emissions, and band edge emissions tests.
- The customer supplied a modified sample (Radiated sample #2) with external power cables for frequency stability testing at voltage extremes. The power cables were connected to a bench power supply and the voltage monitored by a calibrated digital multimeter.
- The sample labelled as 'NFC Terminated' was supplied with a dummy load in place of the antenna. This sample was used for AC power-line tests.

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:	Richard Johnson	**Test Dates:**	20 March 2017 & 29 March 2017
Test Sample Serial Numbers:	Not marked or stated *(Radiated sample #1)* and 'NFC Terminated'		

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

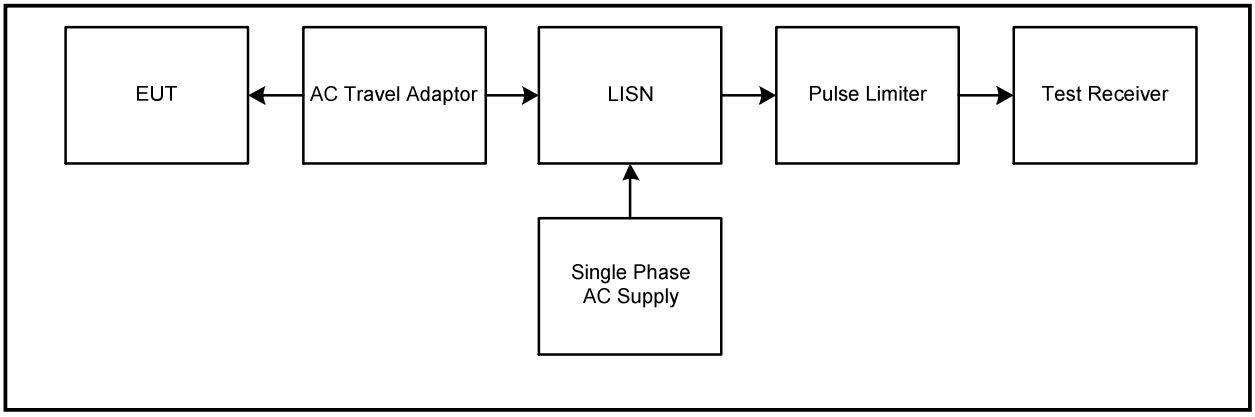
Environmental Conditions:

Temperature (℃):	21 to 24
Relative Humidity (%):	40 to 49

Note(s):

1. A USB Travel Adaptor and associated USB cable were connected to the EUT's USB port. The USB Travel Adaptor input was connected to a 120 VAC 60 Hz single phase supply via a LISN.
2. A pulse limiter was fitted between the LISN and the test receiver.
3. 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.
4. The EUT (*Radiated sample #1*) was initially tested with the standard internal antenna connected 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 ('NFC Terminated'). The standard antenna on the second sample was disconnected and a dummy load fitted in accordance with FCC KDB 174176 Q5. The test was repeated and the EUT was found to be compliant.
5. In accordance with FCC KDB 174176 Q4, tests were also performed with a 240 VAC 60 Hz single phase supply as this was within the voltage range marked on the USB Travel Adaptor.
6. * Test results with standard EUT sample (*Radiated sample #1*).
7. ** Test results with EUT sample marked as 'NFC terminated.

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
0.451500	Live	27.2*	56.8	29.6	Complied
2.238000	Live	24.2*	56.0	31.8	Complied
3.547500	Live	25.2*	56.0	30.8	Complied
4.020000	Live	25.4*	56.0	30.6	Complied
7.561500	Live	27.3*	60.0	32.7	Complied
13.560000	Live	16.0**	60.0	44.0	Complied

Results: Live / Average / 120 VAC 60 Hz

Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.258000	Live	14.0*	51.5	37.5	Complied
2.256000	Live	12.5*	46.0	33.5	Complied
3.516000	Live	14.6*	46.0	31.4	Complied
3.970500	Live	15.2*	46.0	30.8	Complied
7.606500	Live	14.5*	50.0	35.5	Complied
13.560000	Live	10.9**	50.0	39.1	Complied

Transmitter AC Conducted Spurious Emissions (continued)

Results: Neutral / Quasi Peak / 120 VAC 60 Hz

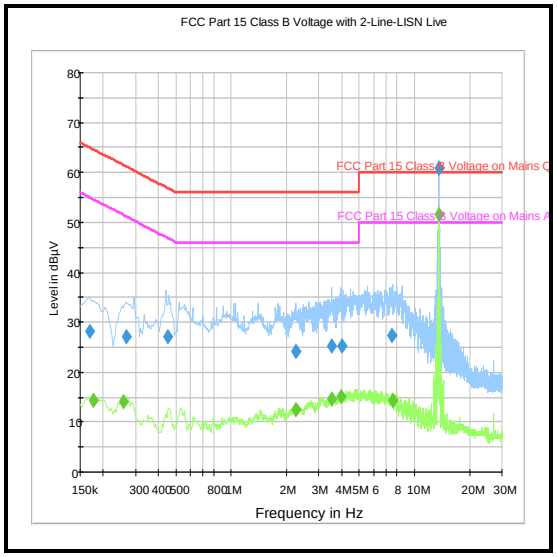
Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.438000	Neutral	27.4*	57.1	29.7	Complied
2.431500	Neutral	27.1*	56.0	28.9	Complied
2.737500	Neutral	27.4*	56.0	28.6	Complied
3.327000	Neutral	28.1*	56.0	27.9	Complied
4.438500	Neutral	29.2*	56.0	26.8	Complied
13.560000	Neutral	22.2**	60.0	37.8	Complied

Results: Neutral / Average / 120 VAC 60 Hz

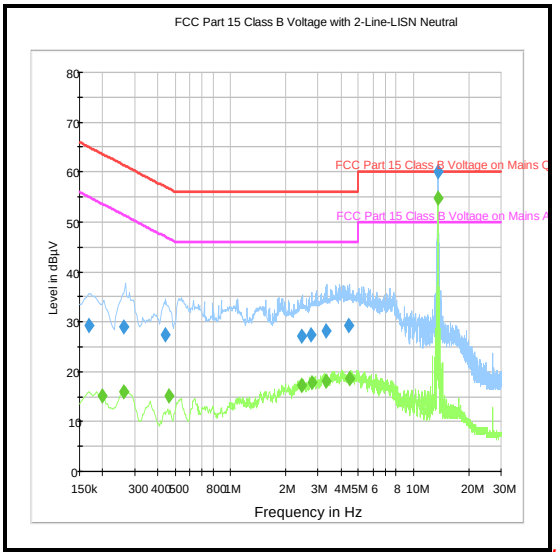
Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.460500	Neutral	15.1*	46.7	31.6	Complied
2.436000	Neutral	17.2*	46.0	28.8	Complied
2.796000	Neutral	17.9*	46.0	28.1	Complied
3.340500	Neutral	18.1*	46.0	27.9	Complied
4.488000	Neutral	18.7*	46.0	27.3	Complied
13.560000	Neutral	14.2**	50.0	35.8	Complied

Transmitter AC Conducted Spurious Emissions (continued)

Results: 120 VAC 60 Hz with unmodified sample (antenna present)

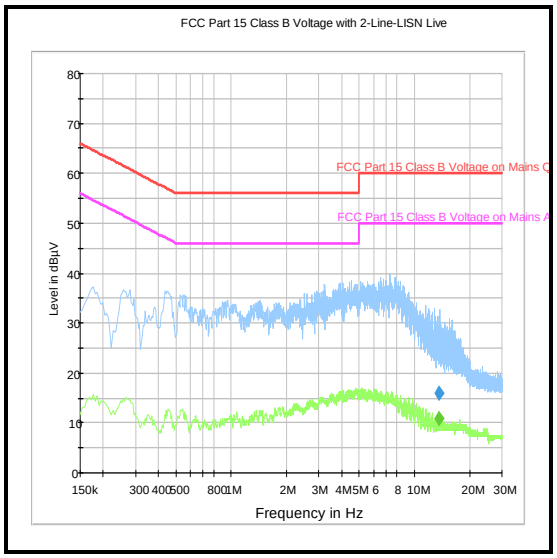


Live

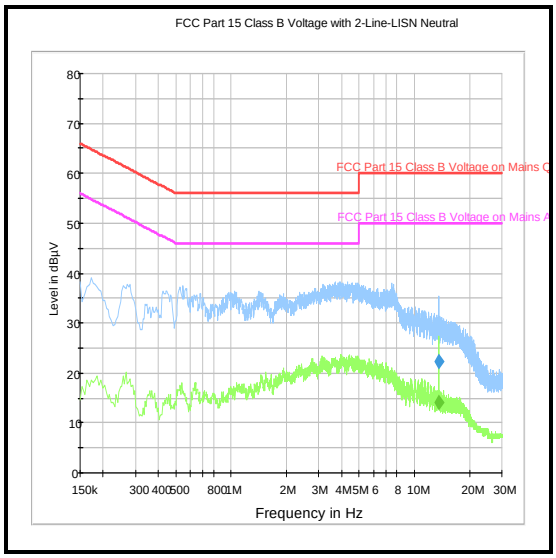


Neutral

Results: 120 VAC 60 Hz with modified sample (transmitter terminated into a dummy load)



Live



Neutral

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

Transmitter AC Conducted Spurious Emissions (continued)

Results: Live / Quasi Peak / 240 VAC 60 Hz

Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.190500	Live	28.4*	64.0	35.6	Complied
0.271500	Live	29.6*	61.1	31.5	Complied
2.283000	Live	26.8*	56.0	29.2	Complied
2.989500	Live	27.9*	56.0	28.1	Complied
4.857000	Live	30.3*	56.0	25.7	Complied
13.560000	Live	21.8**	60.0	38.2	Complied

Results: Live / Average / 240 VAC 60 Hz

Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.177000	Live	14.4*	54.6	40.2	Complied
0.262500	Live	15.6*	51.4	35.8	Complied
2.287500	Live	15.6*	46.0	30.4	Complied
2.976000	Live	16.7*	46.0	29.3	Complied
4.875000	Live	18.2*	46.0	27.8	Complied
13.560000	Live	13.7**	50.0	36.3	Complied

Transmitter AC Conducted Spurious Emissions (continued)

Results: Neutral / Quasi Peak / 240 VAC 60 Hz

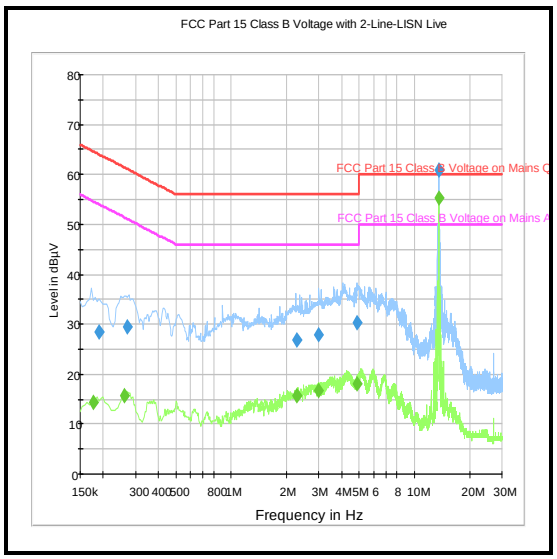
Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.532500	Neutral	27.3*	56.0	28.7	Complied
1.104000	Neutral	27.5*	56.0	28.5	Complied
1.995000	Neutral	26.1*	56.0	29.9	Complied
7.026000	Neutral	30.3*	60.0	29.7	Complied
7.854000	Neutral	29.7*	60.0	30.3	Complied
13.560000	Neutral	15.6**	60.0	44.4	Complied

Results: Neutral / Average / 240 VAC 60 Hz

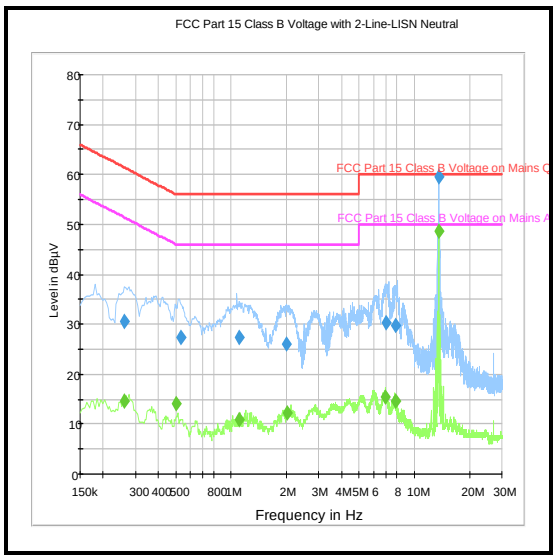
Frequency (MHz)	Line	Level (dBµV)	Limit (dBµV)	Margin (dB)	Result
0.501000	Neutral	14.1*	46.0	31.9	Complied
1.104000	Neutral	11.0*	46.0	35.0	Complied
2.031000	Neutral	12.1*	46.0	33.9	Complied
6.954000	Neutral	15.3*	50.0	34.7	Complied
7.854000	Neutral	14.6*	50.0	35.4	Complied
13.560000	Neutral	10.1**	50.0	39.9	Complied

Transmitter AC Conducted Spurious Emissions (continued)

Results: 240 VAC 60 Hz with unmodified sample (antenna present)

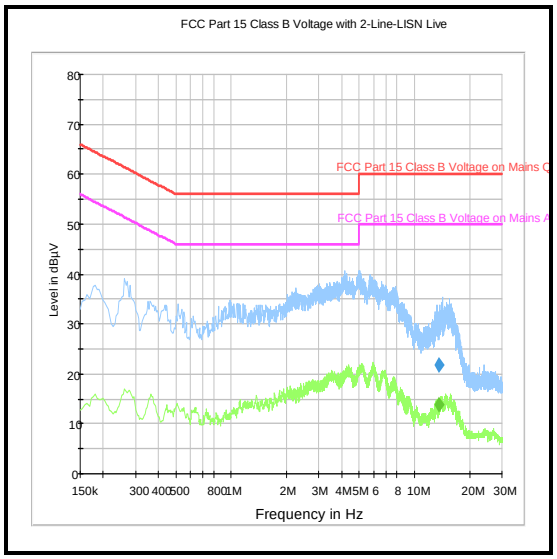


Live

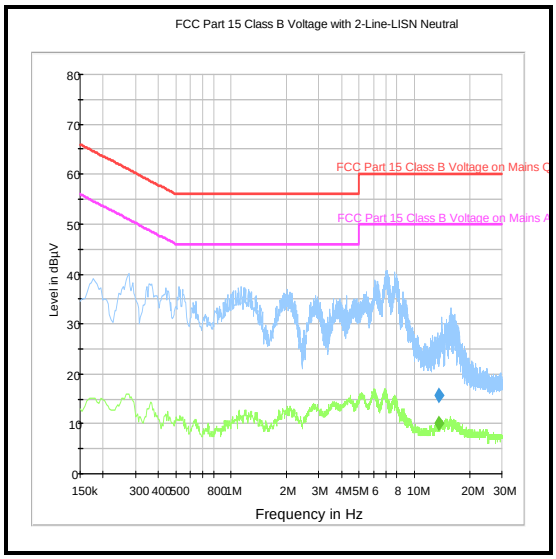


Neutral

Results: 240 VAC 60 Hz with modified sample (transmitter terminated into a dummy load)



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)

Test Equipment Used:

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2013	Thermohygrometer	JM Handelspunkt	608-H1	None stated	10 Jun 2017	12
A067	LISN	Rohde & Schwarz	ESH3-Z5	890603/002	20 Jul 2017	12
A1829	Pulse Limiter	Rohde & Schwarz	ESH3-Z2	100671	05 May 2017	12
M1263	Test Receiver	Rohde & Schwarz	ESIB7	100265	07 Nov 2017	12

5.2.2. Transmitter Fundamental Field Strength

Test Summary:

Test Engineers:	Richard Johnson & Ian Watch	**Test Dates:**	07 March 2017 to 14 March 2017
Test Sample Serial Number:	Not marked or stated *(Radiated sample #1)*		

FCC Reference:	Part 15.225(a)(b)(c)(d)
Test Method Used:	FCC Part 15.31(d); ANSI C63.10 Section 6.4 and Notes below

Environmental Conditions:

Temperature (℃):	16 to 22
Relative Humidity (%):	38 to 45

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 Part 15.31(d) and ANSI C63.10 Section 5.3.2, an attempt was made to perform measurements at the distance specified in Part 15.209(a) on an open-field test site. It was not possible to determine the emission value at the test distance 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 07 March 2017. 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 on the open-field test site 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 61.1 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.
4. Final measurements were performed in the semi-anechoic chamber 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 maximum level of 61.1 dBµV/m was recorded at a distance of 3 metres on an open-field test site. A further 40 dB was subtracted to extrapolate the level measured at 3 metres to the required distance of 30 metres:

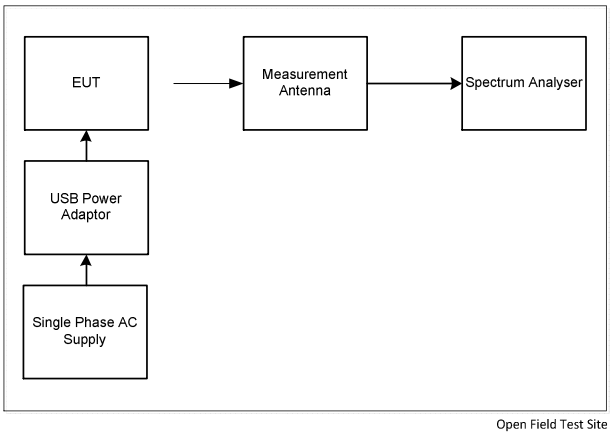
   Corrected level 61.1 – 40 = 21.1 dBµV/m at 30 metres

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. For the field strength measurements in a semi-anechoic chamber, an RF level offset of -41.9 dB was used to simulate a measurement at 3 metres on 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.
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.
7. UL Assets M1956 Steel Rule, A2686 Measuring Wheel and A2955 Protractor, were used to support offsite measurements. The calibrated steel rule was used to verify the accuracy of the measuring wheel and the protractor used to ensure the accuracy of the EUT position during testing.

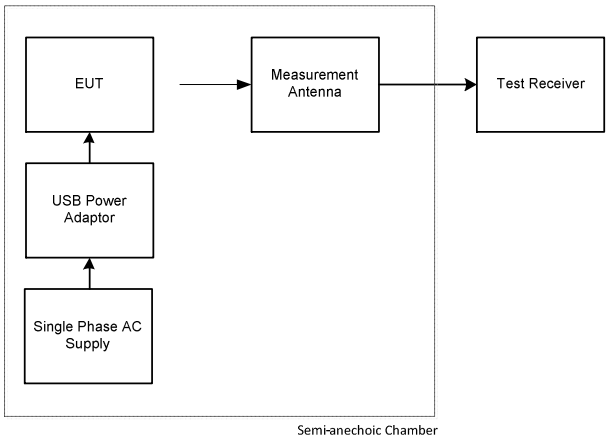
Transmitter Fundamental Field Strength (continued)

Test setup for fundamental field strength measurements:

Measurements on an Open-field Test Site



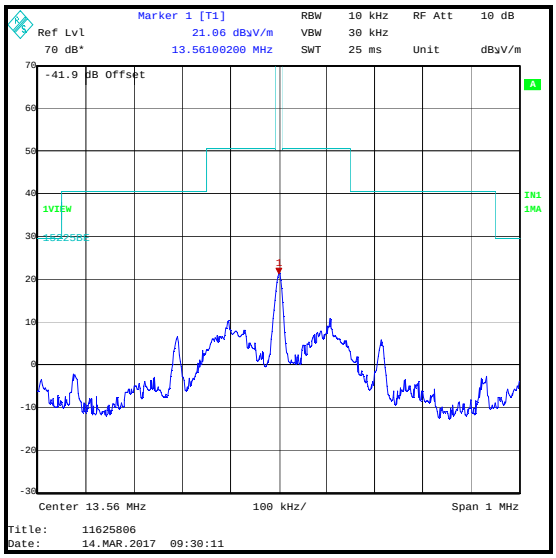
Measurements in a semi-anechoic chamber



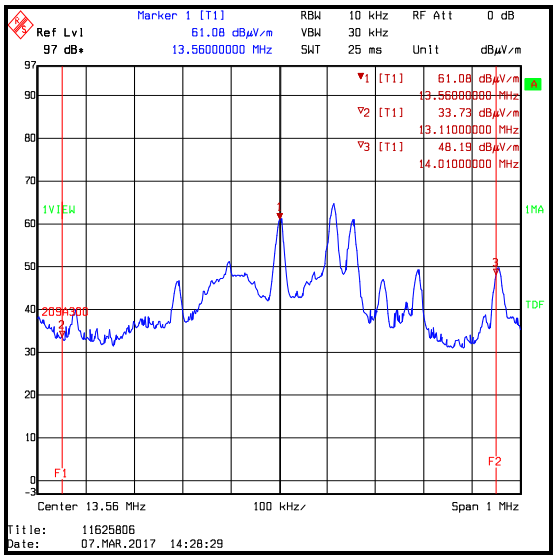
Transmitter Fundamental Field Strength (continued)

Results: Quasi Peak

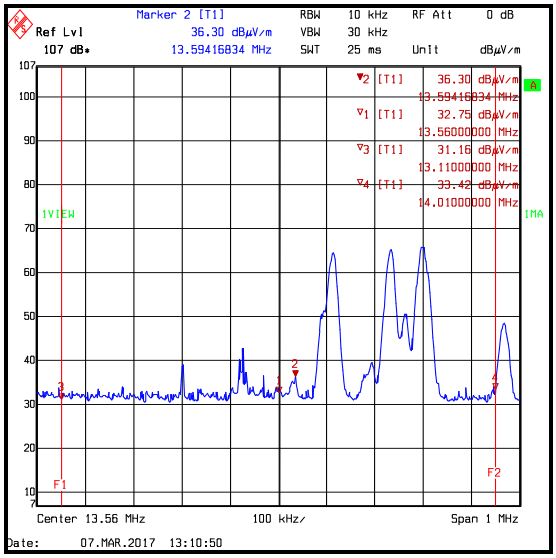
Frequency (MHz)	Measurement Antenna Position	Level (dBµV/m)	Limit at 30 m (dBµV/m)	Margin (dB)	Result
13.56	Tip 90° from EUT	21.1	84.0	62.9	Complied



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 carrier not visible due to ambient emissions and noise floor level)

Transmitter Fundamental Field Strength (continued)

Test Equipment Used:

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2016	Thermohygrometer	Testo	608-H1	45046428	22 Feb 2018	12
M127	Spectrum Analyser	Rohde & Schwarz	FSEB30	842659/016	08 Sep 2017	12
A007	Magnetic Loop Antenna	Rohde & Schwarz	HFH2-Z2	880458/020	21 Oct 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	9781907550980	#1	Calibration not required	-
M2014	Thermohygrometer	Testo	608-H1	45046246	10 Jun 2017	12
K0001	5m RSE Chamber	Rainford EMC	N/A	N/A	07 Dec 2017	12
M1273	Test Receiver	Rohde & Schwarz	ESIB 26	100275	11 Apr 2017	12
A007	Magnetic Loop Antenna	Rohde & Schwarz	HFH-Z2	880458/020	21 Oct 2017	12

5.2.3. Transmitter Radiated Spurious Emissions

Test Summary:

Test Engineer:	Ian Watch	**Test Dates:**	07 March 2017 to 14 March 2017
Test Sample Serial Number:	Not marked or stated *(Radiated sample #1)*		

FCC Reference:	Parts 15.225(d) & 15.209(a)
Test Method Used:	FCC Part 15.31(d); ANSI C63.10 Sections 6.3, 6.4, 6.5 and Notes below
Frequency Range:	9 kHz to 1000 MHz

Environmental Conditions:

Temperature (℃):	9 to 22
Relative Humidity (%):	45 to 61

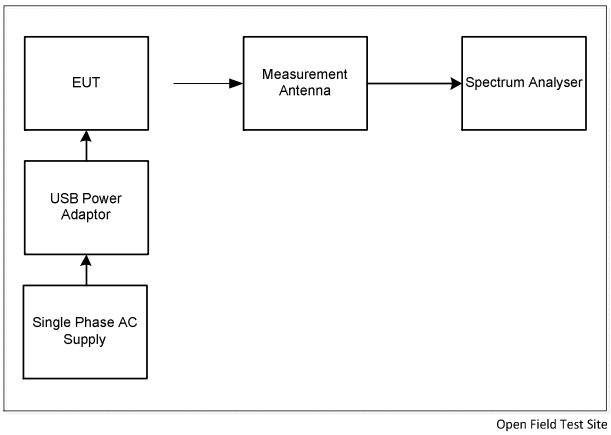
Note(s):

1. In accordance with FCC Part 15.31(d) and ANSI C63.10 Section 5.3.2, an 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 07 March 2017. 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 14 March 2017 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 similar 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 other emissions were greater than 20 dB below the applicable limit, below the noise floor of the measurement system or ambient.
4. Measurements on 14 March 2017 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. Limit lines shown on open-field test site plots from 9 kHz to 490 kHz have been extrapolated using a factor of 40 dB/decade to a test distance of 30 metres and are for indication only.
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.

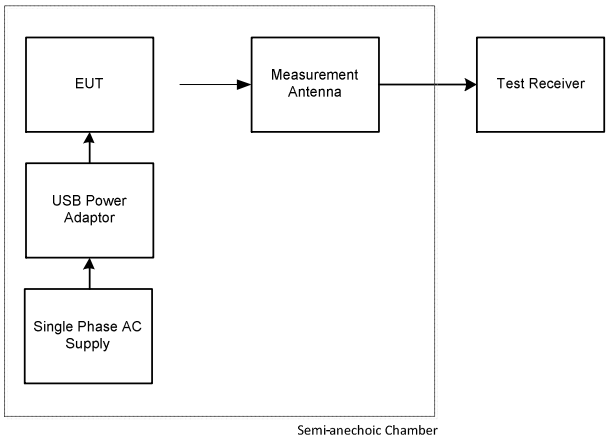
Transmitter Radiated Spurious Emissions (continued)

Test setup for radiated measurements:

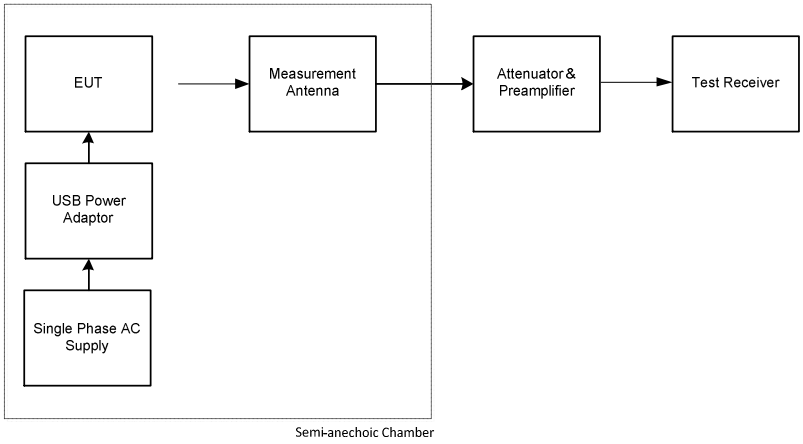
Measurements on an Open-field Test Site



Measurements below 30 MHz in a semi-anechoic chamber



Measurements above 30 MHz in a semi-anechoic chamber

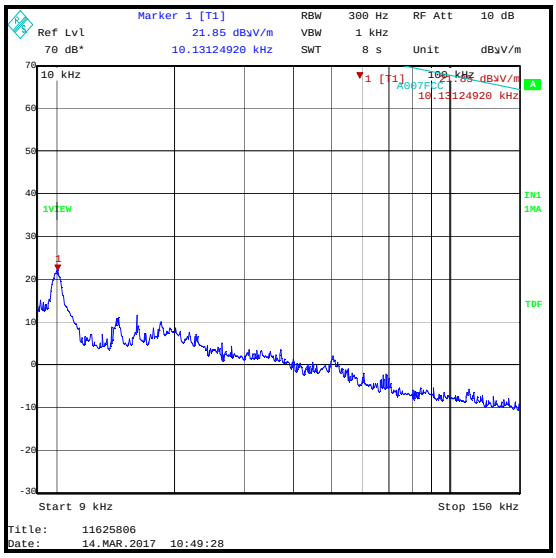


Transmitter Radiated Spurious Emissions (continued)

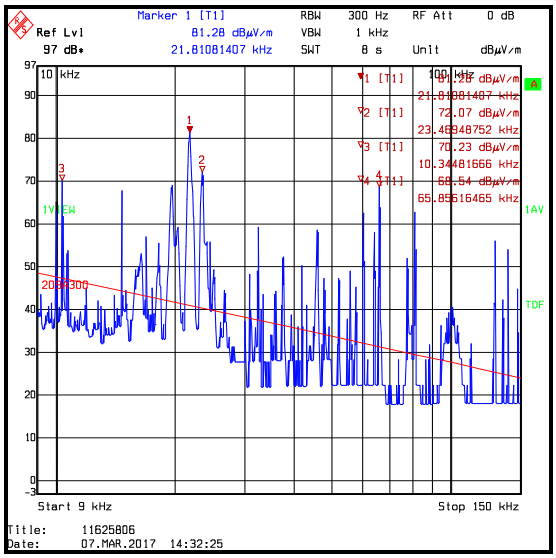
Results: Quasi Peak

Frequency (MHz)	Antenna Polarity	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
40.658517	Vertical	19.0	40.0	21.0	Complied
67.791182	Vertical	16.7	40.0	23.3	Complied
81.349499	Vertical	21.9	40.0	18.1	Complied
162.697796	Vertical	23.0	43.5	20.5	Complied
189.822445	Vertical	32.4	43.5	11.1	Complied
903.315030	Vertical	21.9	46.0	24.1	Complied

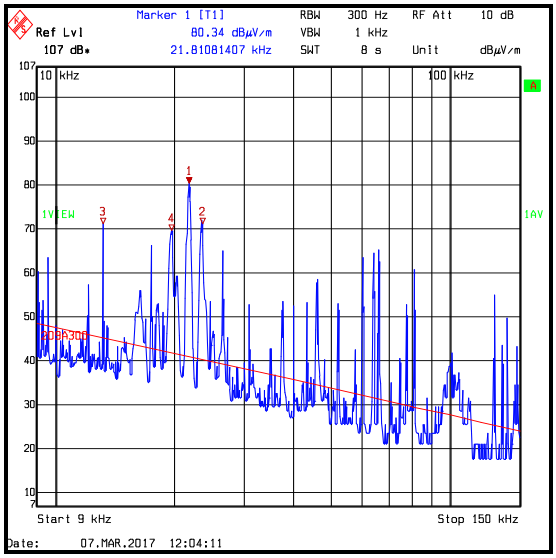
Transmitter Radiated Spurious Emissions (continued)



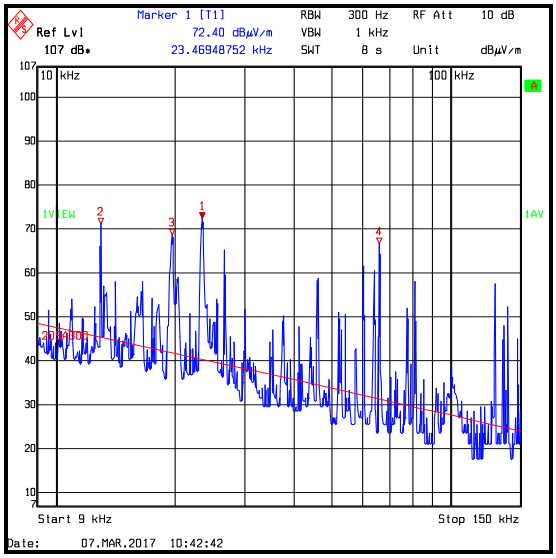
9 kHz to 150 kHz / peak detector / measured at 3 metres extrapolated to 30 metres / measured in a semi-anechoic chamber



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



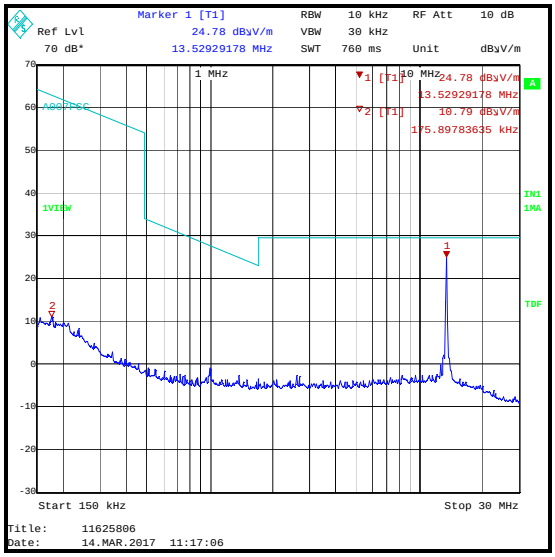
9 kHz to 150 kHz / average detector / EUT operating / measured at 30 metres on an open-field test site



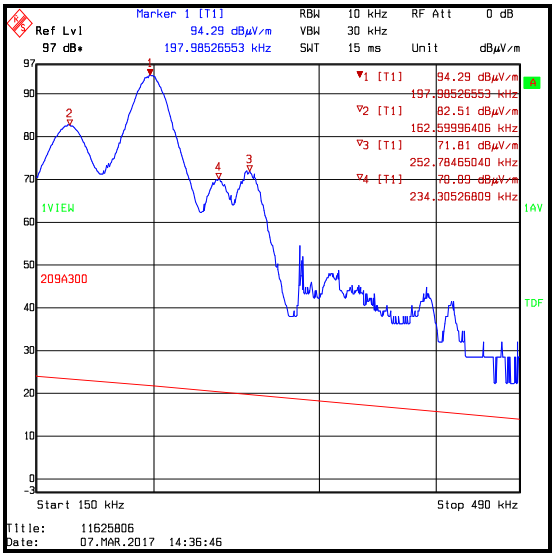
9 kHz to 150 kHz / average detector / EUT operating / measured at 300 metres on an open-field test site

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

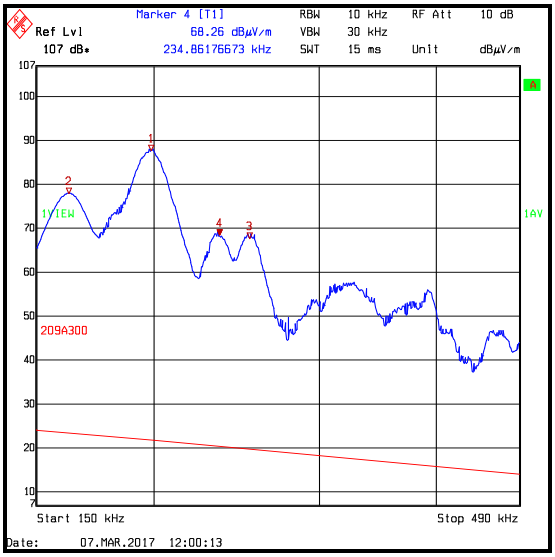
Transmitter Radiated Spurious Emissions (continued)



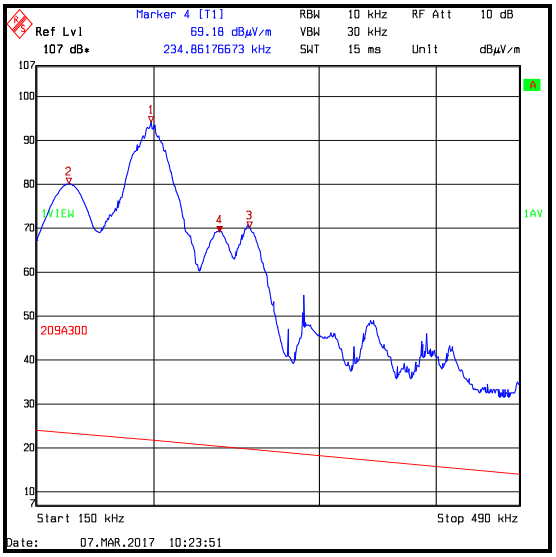
150 kHz to 30 MHz / peak detector (worst case) / EUT operating / measured at 3 metres extrapolated to 30 metres / measured in a semi-anechoic chamber



150 kHz to 490 kHz / average detector / EUT operating / measured at 3 metres on an open-field test site



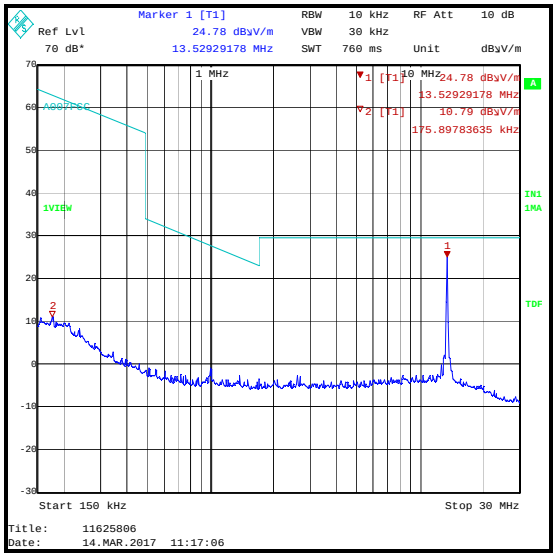
150 kHz to 490 kHz / average detector / EUT operating / measured at 30 metres on an open-field test site



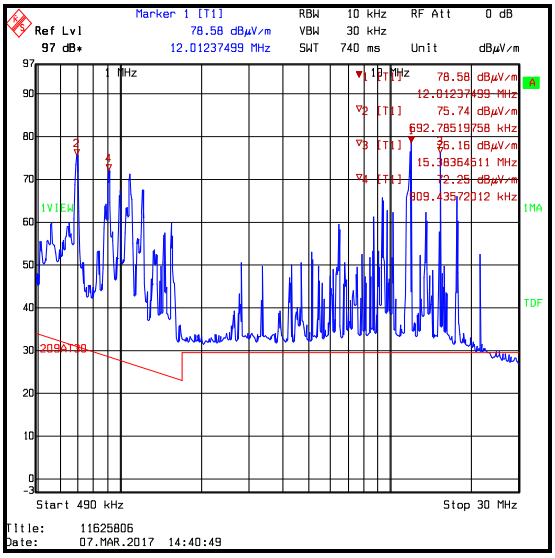
150 kHz to 490 kHz / average detector / EUT operating / measured at 300 metres on an open-field test site

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

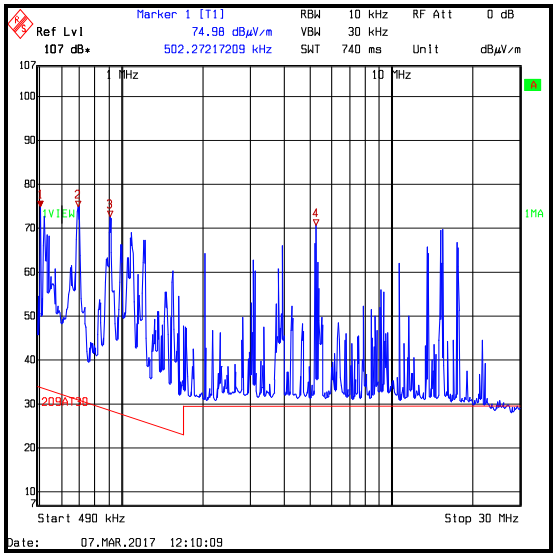
Transmitter Radiated Spurious Emissions (continued)



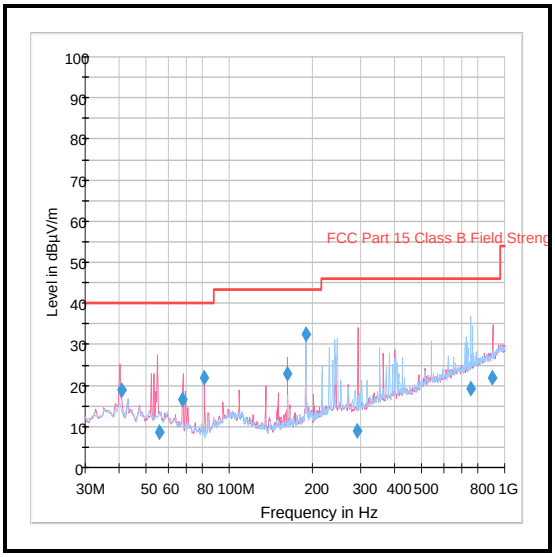
150 kHz to 30 MHz / peak detector / measured at 3 metres extrapolated to 30 metres / measured in a semi-anechoic chamber



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

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

Transmitter Radiated Spurious Emissions (continued)

Test Equipment Used:

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2016	Thermohygrometer	Testo	608-H1	45046428	22 Feb 2018	12
M127	Spectrum Analyser	Rohde & Schwarz	FSEB30	842659/016	08 Sep 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	9781907550980	#1	Calibration not required	-
M2014	Thermohygrometer	Testo	608-H1	45046246	10 Jun 2017	12
K0001	5m RSE Chamber	Rainford EMC	N/A	N/A	07 Dec 2017	12
M1273	Test Receiver	Rohde & Schwarz	ESIB 26	100275	11 Apr 2017	12
G0543	Preamplifier	Sonoma	310N	230801	09 Jun 2017	6
A2959	Antenna	Schwarzbeck	VULB 9163	9163-967	08 Sep 2017	12
A1834	Attenuator	HP	8491B	10444	30 Mar 2017	12
A007	Magnetic Loop Antenna	Rohde & Schwarz	HFH-Z2	880458/020	21 Oct 2017	12

5.2.4. Transmitter Band Edge Radiated Emissions

Test Summary:

Test Engineers:	Richard Johnson & Ian Watch	**Test Date:**	14 March 2017
Test Sample Serial Number:	Not marked or stated *(Radiated sample #1)*		

FCC Reference:	Parts 15.225(c)(d) & 15.209(a)
Test Method Used:	FCC Part 15.31(d); ANSI C63.10 Section 6.10.4 and Notes below

Environmental Conditions:

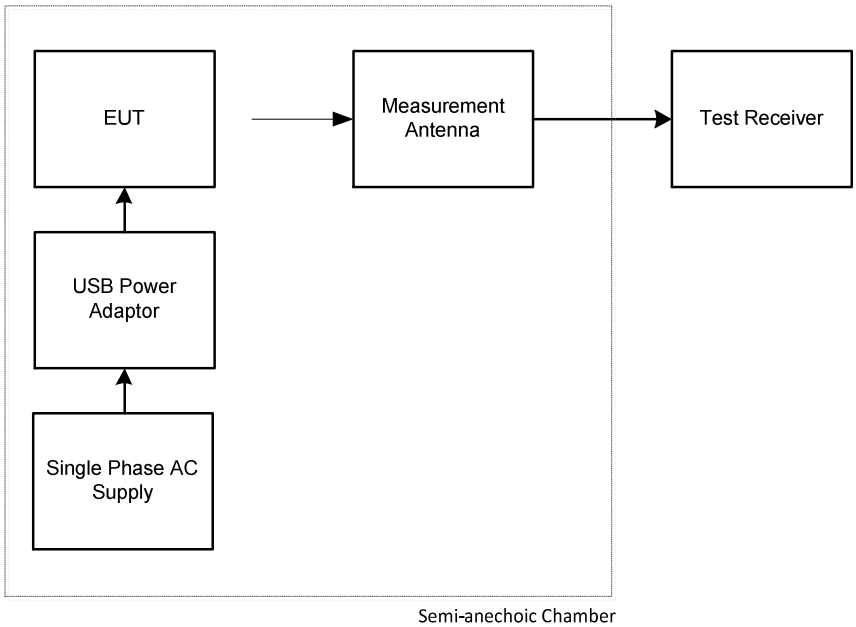
Temperature (℃):	22
Relative Humidity (%):	42

Note(s):

1. In accordance with FCC Part 15.31(d) and ANSI C63.10 Section 5.3.2, an 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 07 March 2017. 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 14 March 2017 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 -41.9 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.

Transmitter Band Edge Radiated Emissions (continued)

Test setup:



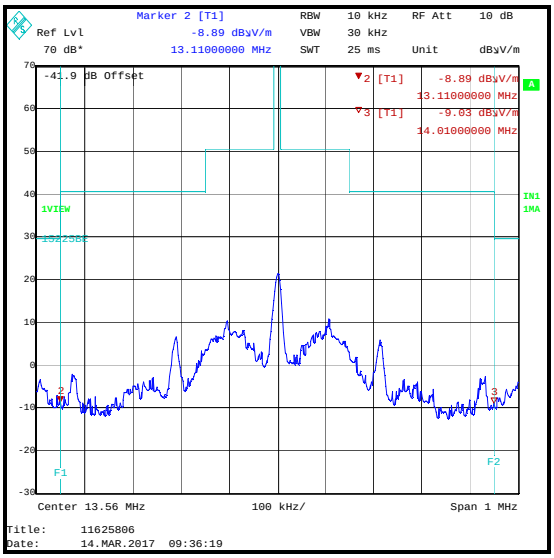
Transmitter Band Edge Radiated Emissions (continued)

Results: Peak / Lower Band Edge

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
13.11	-8.9	29.5	38.4	Complied

Results: Peak / Upper Band Edge

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Result
14.01	-9.0	29.5	38.5	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
K0001	5m RSE Chamber	Rainford EMC	N/A	N/A	07 Dec 2017	12
M1273	Test Receiver	Rohde & Schwarz	ESIB 26	100275	11 Apr 2017	12
A007	Magnetic Loop Antenna	Rohde & Schwarz	HFH-Z2	880458/020	21 Oct 2017	12

5.2.5. Transmitter Frequency Stability (Temperature & Voltage Variation)

Test Summary:

Test Engineer:	Richard Johnson	**Test Date:**	15 March 2017
Test Sample Serial Number:	Not marked or stated *(Radiated sample #2)*		

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

Environmental Conditions:

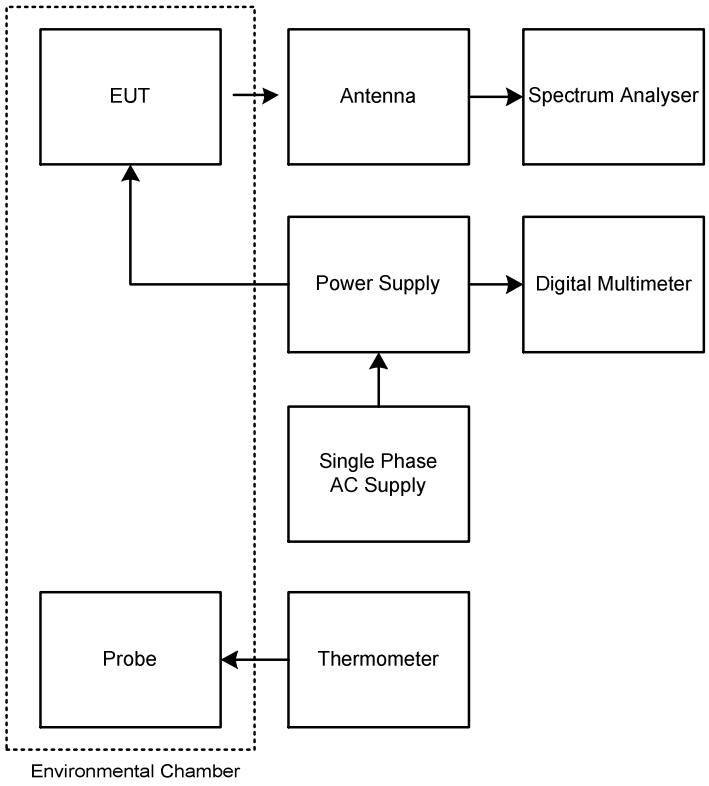
Ambient Temperature (℃):	24
Ambient Relative Humidity (%):	42

Note(s):

1. Testing at voltage extremes was performed with the EUT powered by an external DC power supply. The EUT's battery was disconnected and the power supply was connected to the EUT's power cables.
2. Frequency stability measurements were performed with a modulated carrier. The measurements were performed using the spectrum analyser marker counter function. The marker counter function was set to 1 Hz before any measurements were performed.
3. The EUT would not operate below 3.42 Volts and tests at lower voltage extremes were performed at this level.
4. Frequency error was measured using a calibrated spectrum analyser.
5. Temperature was monitored throughout the test with a calibrated digital thermometer.
6. Voltage was monitored throughout the test with a calibrated digital voltmeter.

Transmitter Frequency Stability (Temperature & Voltage Variation) (continued)

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	13.559509	13.559509	13.559509	13.559509
20	13.559589	13.559589	13.559589	13.559589
50	13.559569	13.559569	13.559569	13.559569

Frequency with Worst Case Deviation (MHz)	Frequency Error (Hz)	Frequency Error (%)	Limit (%)	Margin (%)	Result
13.559509	491	0.00362	0.01	0.00638	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
3.42	13.56	13.559589	411	0.0030	0.01	0.0070	Complied
3.7	13.56	13.559589	411	0.0030	0.01	0.0070	Complied
4.255	13.56	13.559589	411	0.0030	0.01	0.0070	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	None stated	22 Feb 2018	12
E0513	Environmental Chamber	TAS	LT600 Series 3	23900506	Calibrated before use	-
M1249	Thermometer	Fluke	52II	88800049	27 May 2017	12
M1229	Multimeter	Fluke	179	87640015	21 Apr 2017	12
S0562	Power Supply	Thurlby Thandar	PL330QMD	054895	Calibrated before use	-
M127	Spectrum Analyser	Rohde & Schwarz	FSEB30	842659/016	08 Sep 2017	12
A007	Magnetic Loop Antenna	Rohde & Schwarz	HFH-Z2	880458/020	21 Oct 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
20 dB Bandwidth	13 MHz to 14 MHz	95%	±4.59 %
Frequency Stability	13 MHz to 14 MHz	95%	±1.62 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

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

8. Appendix 1

Test setup/arrangement of EUT during open-field tests on 07 March 2017

Refer to UL-RPT-RP11625806JD03 FCC Photos.pdf

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 07 March 2017

Temperature: 9℃ to 15℃ Relative Humidity: 45% to 61%

Ground conditions: Dry

Refer to UL-RPT-RP11625806JD03 FCC Photos.pdf	**Refer to UL-RPT-RP11625806JD03 FCC Photos.pdf**
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 USB cable was inserted and connected to the USB charger. The USB charger was connected to a single phase supply. A power cable was run across the site to the EUT via the USB charger and associated USB cable. An RCD was fitted to the power source.

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 test equipment was from a single phase 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 07 March 2017

Temperature: 9℃ to 15℃ Relative Humidity: 45% to 61%

Ground conditions: Dry

Refer to UL-RPT-RP11625806JD03 FCC Photos.pdf

Set up for 300 metre measurements

Refer to UL-RPT-RP11625806JD03 FCC Photos.pdf

Set up for 300 metre measurements
(EUT end facing towards the mag loop antenna)

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 USB cable was inserted and connected to the USB charger. The USB charger was connected to a single phase supply from a portable generator. A power cable was run across the field to the USB charger. An RCD was fitted to the power source.

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 test 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.

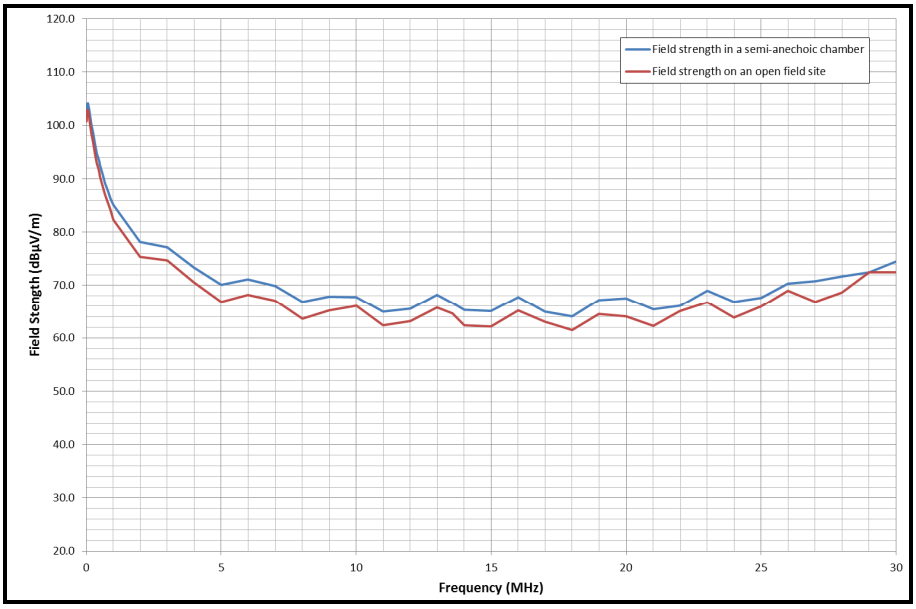
Initially, The EUT was rotated through 360 degrees in 60 degree steps at both measurement distances. The mag loop antenna was rotated through 90 degrees in 30 degree steps at every position the EUT was moved to. The EUT and mag loop antenna were then rotated in small increments in order to maximise emission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

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

In accordance with FCC KDB 414788 Section 2, radiated measurements were performed 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

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, unmodulated 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, unmodulated 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 frequencies.

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

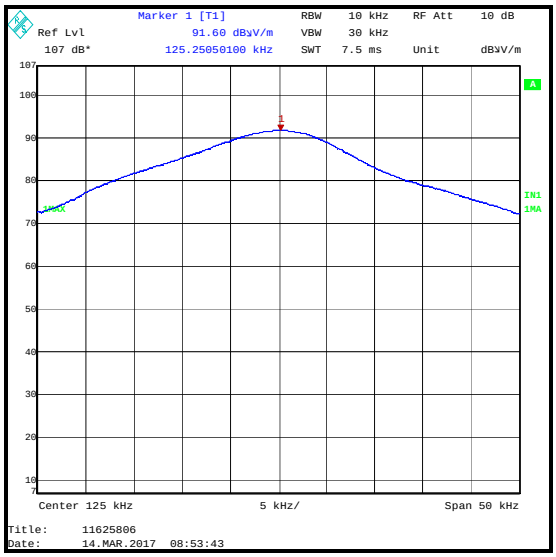
The centre of the magnetic loop antenna is placed exactly 3 metres from the reference unit. The reference unit is placed on a plastic table at a height of 0.8 metres above floor level and the centre of the mag loop antenna is 1 metre above the floor level. The mag loop antenna and reference unit are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

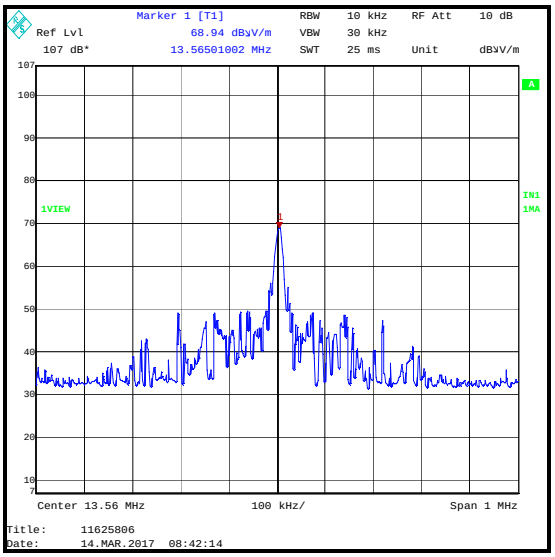
The internal verification procedure and verification plots are available for inspection on request.

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

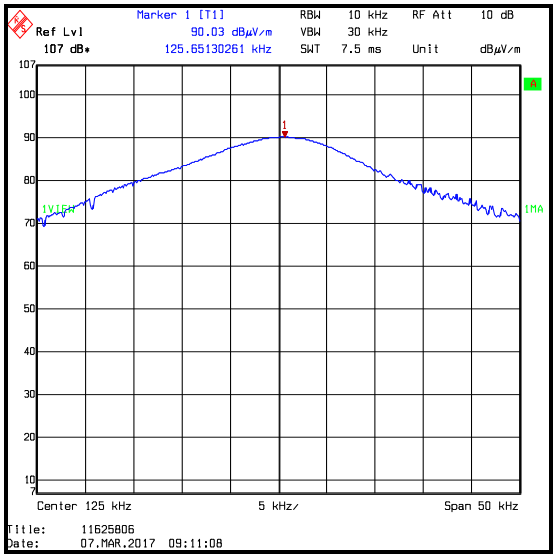
Verification plots of the two reference units at a measurement distance of 3 metres are shown on the following page. Plots were taken on an open-field test site (07 March 2017) and in a semi-anechoic chamber (14 March 2017).



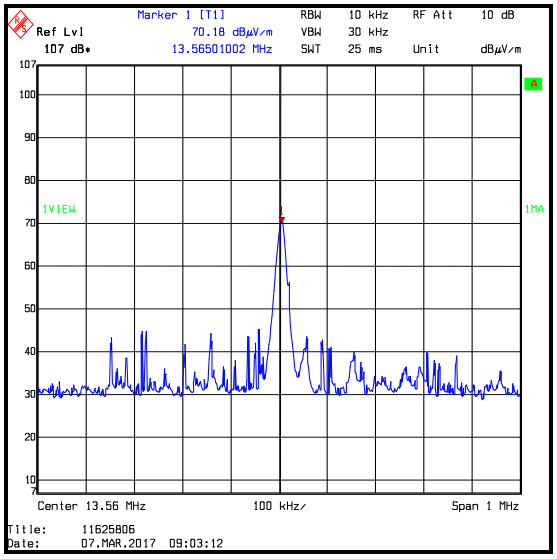
125 kHz reference unit signal at 3 metres in a semi-anechoic chamber on 14 March 2017



13.56 MHz reference unit signal at 3 metres in a semi-anechoic chamber on 14 March 2017



125 kHz reference unit signal at 3 metres on an open-field test site on 07 March 2017

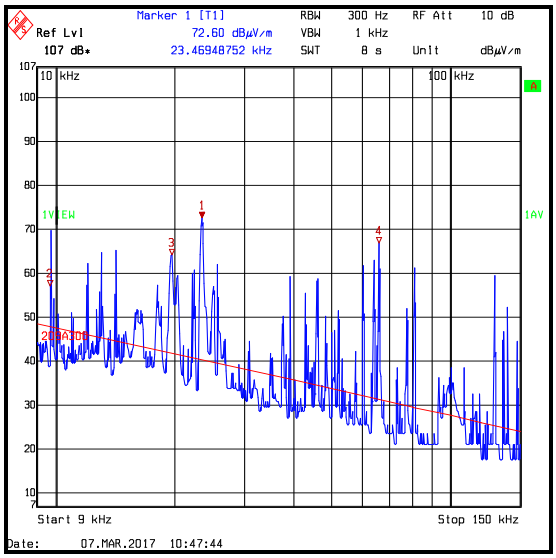


13.56 MHz reference unit signal at 3 metres on an open-field test site on 07 March 2017

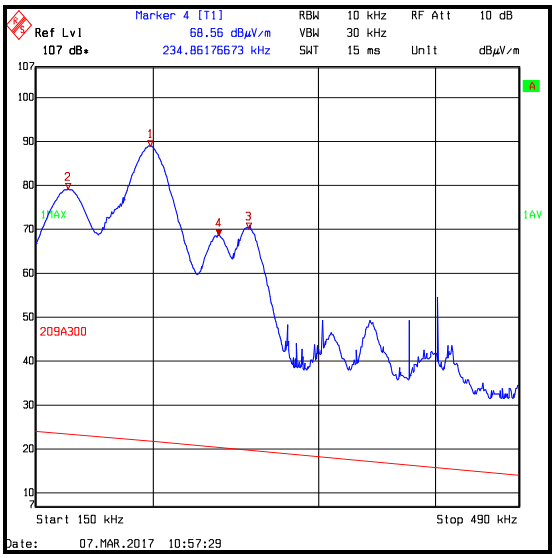
Note(s):

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.

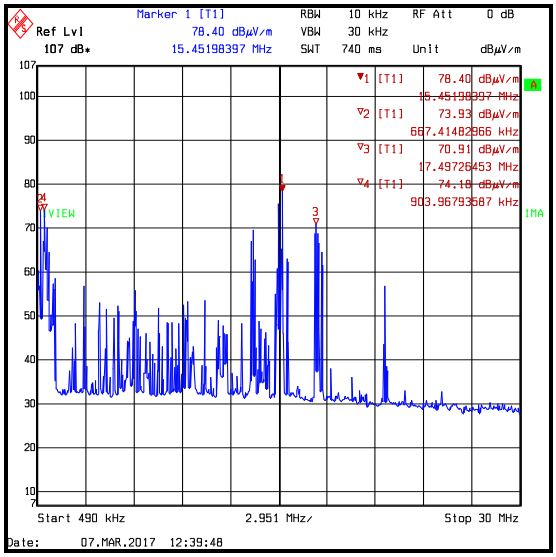
Background scans of the open-field test site



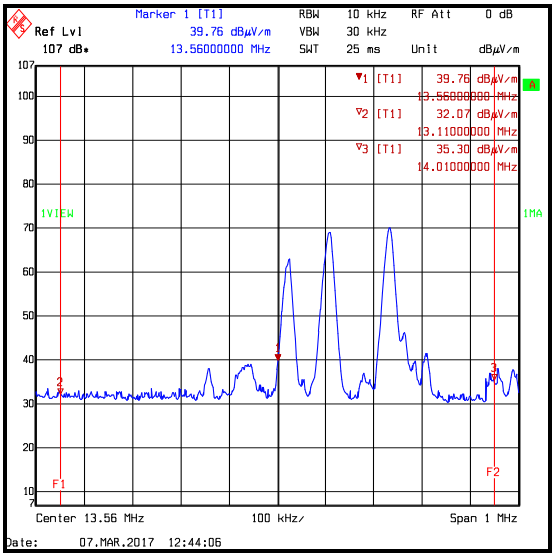
Frequency range: 9 kHz to 150 kHz
Average detector / background scan



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
/ 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.

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