A RADIO TEST REPORT

FOR

TACX BV

ON

Satori Smart

DOCUMENT NO.TRA-021371WUS2a

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TRaC Wireless Test Report	**:** TRA-021371WUS2a
Applicant	**:** TACX BV.
Apparatus	**:** Satori Smart
Specification(s)	**:** CFR47 Part 15.249 IC RSS-210 A2.9
Purpose of Test	**: Certification**
FCCID	**:** 2AAMI-T2400
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Authorised by	**:** 
	: Radio Product Manager
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Contents

Section 1: Introduction

1.1 General

This report contains an assessment of an apparatus against Electromagnetic Compatibility Standards based upon tests carried out on samples submitted to the Laboratory.

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1.2 Tests Requested By

This testing in this report was requested by:

TACX BV

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1.3 Manufacturer

As Above

1.4 Apparatus Assessed

The following apparatus was assessed between 12th June 2014 – 28th July 2014:

Satori Smart

The apparatus was a roller mechanism for converting a conventional bicycle into a stationary exercise bike, the apparatus contained an ANT+ transceiver to communicate information from the roller to exercise software on an ANT+ device.

The apparatus can also communicate in Bluetooth Low Energy mode, the Bluetooth Low Energy assessment is not detailed in this report.

1.5 Test Result Summary

Full details of test results are contained within Appendix A. The following table summarises the results of the assessment.

The statements relating to compliance with the standards below apply ONLY as qualified in the notes and deviations stated in sections 1.6 to 1.7 of this test report.

Full details of test results are contained within Appendix A. The following table summarises the results of the assessment.

Test Type	Regulation		Measurement standard	Result
	Title 47 of the CFR: Part 15 Subpart (c)	Industry Canada		
Intentional Emission Field Strength	15.249 (a)	IC RSS-210 A2.9(a)	ANSI C63.10:2009	Pass
Intentional Emission Band Occupancy	15.215 (c)	IC RSS-GEN 4.6.1	ANSI C63.10:2009	Pass
Spurious Emissions Radiated <1000MHz	15.209 & 15.249 (a) (d)	IC RSS-GEN 4.9 & RSS-210 A2.9(b)	ANSI C63.10:2009	Pass
Unintentional Radiated Spurious Emissions	15.109	IC RSS-GEN 4.10	ANSI C63.10:2009	Pass

Abbreviations used in the above table:

CFR : Code of Federal Regulations
REFE : Radiated Electric Field Emissions
ANSI : American National Standards Institution
PLCE : Power Line Conducted Emissions

1.6 Notes Relating To The Assessment

With regard to this assessment, the following points should be noted:

The results contained in this report relate only to the items tested and were obtained in the period between the date of initial receipt of samples and the date of issue of the report.

The apparatus was set up and exercised using the configurations, modes of operation and arrangements defined in this report only.

Particular operating modes, apparatus monitoring methods and performance criteria required by the standards tested to have been performed except where identified in Section 1.7 of this test report (Deviations from Test Standards).

For emissions testing, throughout this test report, “Pass” indicates that the results for the sample as tested were below the specified limit (refer also to Section 2, Measurement Uncertainty).

Where relevant, the apparatus was only assessed using the monitoring methods and susceptibility criteria defined in this report.

All testing was performed under the following environmental conditions:

Temperature	: 17 to 23 °C
Humidity	: 45 to 75 %
Barometric Pressure	: 86 to 106 kPa

All dates used in this report are in the format dd/mm/yy.

This assessment has been performed in accordance with the requirements of CFR47 Part 2 & RSS-Gen.

1.7 Deviations from Test Standards

There were no deviations from the standards tested to.

Section 2: Measurement Uncertainty

2.1 Measurement Uncertainty Values

For the test data recorded in accordance with note (iii) of Section 2.1 the following measurement uncertainty was calculated:

Radio Testing – General Uncertainty Schedule

Parameter	Uncertainty
Radio frequency	± 1 x 10^{-7}
RF power, conducted	± 1.5 dB
Maximum frequency deviation: - within 300 Hz and 6 kHz of audio frequency - within 6 kHz and 25 kHz of audio frequency	 ±5 % ±3 dB
Adjacent channel power	±3 dB
Conducted spurious emission of transmitter, valid up to 6 GHz	±3 dB
Conducted emission of receivers	±3 dB
Radiated emission of transmitter, valid up to 6 GHz	±6 dB
Radiated emission of receiver, valid up to 6 GHz	±6 dB
RF level uncertainty for a given BER	±1.5 dB
Temperature	±1^{o}C
Humidity	±10 %

Section 3: Modifications

3.1 Modifications Performed During Assessment

No modifications were performed during the assessment

Section 4 **General Test Procedures**

4.1 Radiated Test Setup and Procedures

Radiated electromagnetic emissions from the EUT are checked first by preview scans. Preview scans for all spectrum and modulation characteristics are checked, using a peak detector and where applicable worst case determined for function, operation, orientation etc for both vertical and horizontal polarisations

If the EUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.10 are followed. Alternatively, a layout closest to normal use (as declared by the provider) is employed, (see EUT setup photographs for more detail).

For devices with intentional emissions below 30 MHz, a shielded loop antenna is used as the test antenna. It is placed at a 1 meter receive height and appropriate low frequency magnetic field extrapolation to the regulatory limit distance is employed. The EUT is rotated through 360˚ in the azimuth.

Emissions between 30 MHz and 1 GHz are measured using calibrated broadband antennas. Emissions above 1 GHz are characterized using standard gain horn antennas. Pre-amplifiers and filters are used where required. Care is taken to ensure that test receiver resolution bandwidth, video bandwidth and detector type(s) meet the regulatory requirements.

For both horizontal and vertical polarizations, the EUT is then rotated through 360˚ in azimuth until the highest emission is detected. At the previously determined azimuth the test antenna is raised and lowered from 1 to 4 m in height until a maximum emission level is detected, this maximum value is recorded.

Where regulations allow for direct measurement of field strength, power values measured on the test receiver / analyzer are converted to dBuV/m at the regulatory distance, using:

$$FS = PR + AF + CL - PA + KG + DC - CF \text{ (dBuV/m)}$$

Where:

PR is the power recorded on receiver / spectrum analyzer (dBuV),
AF is the test antenna factor in dB/m,
CL is the cable loss in dB,
PA is the pre-amplifier gain dB (when applicable),
DC is duty correction factor (when applicable) in dB, and
CF is a distance correction (employed only for measurements at alternate distance to limit) in dB.

This field strength value is then compared with the regulatory limit.

If effective radiated power (ERP) or effective isotropic radiated power (EIRP) is required, it is computed as per ANSI C63.10

$$P = \frac{(Ed)^2}{30G}$$

Where

P is the power, in W
E is the measured peak field strength, in V/m
d is the distance at which the measurement was made, in m
G is the numeric gain of the radiating element

If the gain of the radiating element is not known, then either the effective radiated power (ERP) or the effective isotropic radiated power (EIRP) may be calculated from the measured peak field strength, by using either G = 1.64 or G = 1, respectively.

4.2 AC Powerline Conducted Emissions Test Setup and Procedures

AC Powerline Conducted Emissions from the EUT are checked first by preview scans with Peak and average detectors covering both live and neutral lines. A spectrum analyser is used to determine if any periodic emissions are present. Preview scans are performed in standby or receive mode if the device is subject to these requirements. For transmit mode of operation the device is set to one of the following modes.

- Transmitting operating at full power (single mode device)
- Transmitting at freq / modulation that gives highest output power (multi mode device)
- Transmitter operating in normal TX mode (e.g. FHSS, TDMA etc)

Formal measurements using the correct detector(s) and bandwidth are made on frequencies identified from the preview scans.

Battery Power devices are not subject to power line conducted emissions measurements when it is powered solely by its internal battery.

4.3 Antenna Port Conducted Emissions

Antenna port conducted emissions can include, but are not limited to, Carrier power, Power Spectral Density, Occupied bandwidth and spurious emission.

Spurious Emissions from the EUT are checked first by preview scans. Preview scans for all spectrum and modulation characteristics are checked to identify frequencies to perform formal measurements on.

Formal measurements are made on frequencies identified from the preview scans and fundamental emission(s). Measurements are made using the correct instrumentation (inc. power meter, receiver, spectrum analyser) that operate with the required detector(s) and bandwidth.

Care is taken to ensure the measurement instrument is not overloaded by the presence of the transmitted signal by use of external attenuation and filtering where required.

Measured levels are corrected for cables, attenuators, and filters. If applicable, for the specific measurement, antenna gain is also taken into account.

4.4 Power Supply Variation

Tests at extreme supply voltages are made if required by the procedures specified in the test standard, and results of this testing are detailed in this report.

In the case the EUT is designed for operation from a lead-acid battery power source, the extreme test voltages are evaluated between 90% and 130% of the nominal battery voltage declared by the manufacturer.

For float charge applications using gel-cell type batteries, extreme test voltages are evaluated between 85% and 115% of the nominal battery voltage declared.

For all battery operated equipment, worst case intentional and spurious emissions are re-checked employing a new (fully charged) battery.

4.5 Thermal Variation

Tests at extreme temperatures are made if required by the procedures specified in the test standard, and results of this testing are detailed in this report.

Tests are performed at the upper and lower extremes as required and typically at 10˚ steps between.

Before any temperature measurements are made, the equipment is allowed to reach a thermal balance in the test chamber.

4.6 Time Domain Measurements

Time domain measurements are made for (but not limited to) use in duty cycle correction, to ensure compliance with time restrictions on certain types of devices.

If measurements of a transmitter's on time are required these are performed with a spectrum analyser in the time domain or with an oscilloscope and RF detector. If time on a specific frequency is required (e.g. FHSS timing) the measurement can only be made with a spectrum analyser.

The triggering, timescale and amplitude settings are adjusted according to the signal to be measured on a case by case basis.

For devices with sharp rise/fall times measurements are made between RF reaching full power (T_{on}) and RF dropping to the measurement instrument noise floor (T_{off}). For longer rise times measurements are made for T_{on} and T_{off} at the RF level required by the occupied bandwidth measurement (e.g. 6 dB, 20 dB etc).

Appendix A: Formal Emission Test Results

Abbreviations used in the tables in this appendix:

Spec	: Specification
Mod	: Modification
EUT	: Equipment Under Test
SE	: Support Equipment
L	: Live Power Line
N	: Neutral Power Line
E	: Earth Power Line
Pk	: Peak Detector
QP	: Quasi-Peak Detector
Av	: Average Detector
CDN	: Coupling & decoupling network

ALSR	: Absorber Lined Screened Room
OATS	: Open Area Test Site
ATS	: Alternative Test Site
Ref	: Reference
Freq	: Frequency
MD	: Measurement Distance
SD	: Spec Distance
Pol	: Polarisation
H	: Horizontal Polarisation
V	: Vertical Polarisation

A1 Transmitter Intentional Emission Radiated

Test Details:	
Regulation	Title 47 of the CFR, Part 15.249 (a) IC RSS-210 A2.9(a)
Measurement standard	ANSI C63.10:2009
EUT sample number	S03
Modification state	0
SE in test environment	S01
SE isolated from EUT	None
EUT set up	Refer to Appendix C
Temperature	23˚C
Photographs	Appendix E

FREQ. (MHz)	DETE-CTOR	MEASUREMENT Rx. READING (dBµV)	CABLE LOSS (dB)	ANT FACTOR (dB/m)	PRE AMP (dB)	DUTY CYCLE ADJUSTMENT (dB)	FIELD STRENGTH (dBµV/m)	FIELD STRENGTH (mV/m)
2403	Peak	57.31	4.8	29.6	N/A	N/A	91.71	38.50
2403	Ave.	56.71	4.8	29.6	N/A	N/A	91.11	35.89
2442	Peak	54.22	4.7	29.8	N/A	N/A	88.72	27.29
2442	Ave.	53.37	4.7	29.8	N/A	N/A	87.87	24.75
2480	Peak	53.81	4.9	29.9	N/A	N/A	88.61	26.95
2480	Ave.	52.85	4.9	29.9	N/A	N/A	87.65	24.13
Limit value @ fc				50mV/m @ 3m				

Notes:
1 Results quoted are extrapolated as indicated
2 Receiver detector @ fc Average 1MHz bandwidth
3 When battery powered the EUT was powered with new batteries

Test Method:
1 As per Radio – Noise Emissions, ANSI C63.10:2009
2 Measuring distances 3m
3 EUT 0.8 metre above ground plane
4 Emissions maximised by rotation of EUT, on an automatic turntable.
Raising and lowering the receiver antenna between 1m & 4m.
Horizontal and vertical polarisations, of the receive antenna.
EUT orientation in three orthagonal planes.
Maximum results recorded

A2 Transmitter Bandwidth

Test Details:	
Regulation	Title 47 of the CFR, Part 15.215 (c) IC RSS-GEN 4.6.1
Measurement standard	ANSI C63.10:2009
EUT sample number	S03
Modification state	0
SE in test environment	None
SE isolated from EUT	None
EUT set up	Refer to Appendix C
Temperature	22˚C

Band occupancy @ -20 dBc			
FREQ. (MHz)	**f lower (MHz)**	**f higher (MHz)**	**Occ BW (kHz)**
2403	2402.146363	2403.847363	1701.000
2442	2441.110838	2442831838	1721.000
2480	2479.168972	2480.810972	1642.000

Notes:

The 20dB Bandwidth of the carrier must be contained within the frequency band 2400 - 2483.5 MHz.

A3 Radiated Electric Field Emissions

Preliminary scans were performed using a peak detector with the RBW = 100kHz. The radiated electric filed emission test applies to all spurious emissions and harmonics emissions. The maximum permitted field strength is listed in Section 15.209. The EUT was set to transmit as required.

The following test site was used for final measurements as specified by the standard tested to:

3m open area test site : ☐ 3m alternative test site : ☒

The effect of the EUT set-up on the measurements is summarised in note (c) below.

Test Details:	
Regulation	Title 47 of the CFR, Part 15.209, 15.249 (a) & (d), Annex 2 A2.9(a) IC RSS-GEN4.9 & RSS-210 A2.9(b)
Measurement standard	ANSI C63.10:2009
Frequency range	30MHz -25GHz
EUT sample number	S03
Modification state	0
SE in test environment	S01
SE isolated from EUT	None
EUT set up	Refer to Appendix C
Temperature	23˚C
Photographs	Appendix E

The radiated emission measurements for spurious emissions and harmonics that fall at the band edges are listed below:

Test Details: EUT Transmitting @ 2403 MHz										
DET	**FREQ. (MHz)**	**MEAS Rx (dBµV)**	**CABLE LOSS (dB)**	**ANT FACT. (dB/m)**	**PRE AMP (dB)**	**DUTY CYCLE (dB)**	**1m - 3m EXTRAP. (dB)**	**FIELD ST'GH (dBµV/m)**	**FIELD ST'GH (µV/m)**	**LIMIT (µV/m)**
Pk	2400	53.49	5.3	29.6	34.62	N/A	N/A	53.77	488.09	5000
Av	2400	46.05	5.3	29.6	34.62	N/A	N/A	46.33	207.25	500

Test Details: EUT Transmitting @ 2480 MHz										
DET	**FREQ. (MHz)**	**MEAS Rx (dBµV)**	**CABLE LOSS (dB)**	**ANT FACT. (dB/m)**	**PRE AMP (dB)**	**DUTY CYCLE (dB)**	**1m - 3m EXTRAP. (dB)**	**FIELD ST'GH (dBµV/m)**	**FIELD ST'GH (µV/m)**	**LIMIT (µV/m)**
Pk	2483.5	52.58	4.9	29.9	34.64	N/A	N/A	52.74	425.60	5000
Av	2483.5	43.09	4.9	29.9	34.64	N/A	N/A	43.25	142.72	500

No further emissions were detected within 10dB of the limits.

Notes:

1 Any testing performed below 30 MHz was performed using a magnetic loop antenna in accordance with ANSI C63.10:2009: section 4.5, Table 1 For emissions below 30MHz the cable losses are assumed to be negligible.
2 In accordance with 15.35(b), above 1 GHz, emissions measured using a peak detector shall not exceed a level 20 dB above the average limit.
3 Testing was performed with the EUT orientated in three orthogonal planes and the maximum emissions level recorded. In addition, the EUT antenna was varied within its range of motion in order to maximise emissions.
4 For Frequencies below 1 GHz, RBW= 120 kHz, testing was performed with CISPR16 compliant test receiver with QP detector. Above 1 GHz tests were performed using a spectrum analyser using the following settings:

Peak	RBW= 1MHz, VBW ≥ RBW
Average	RBW= 1MHz, VBW ≥ RBW

The upper and lower frequency of the measurement range was decided according to 47 CFR Part 15 Clause 15.33(a) and 15.33(a)(1).

Radiated emission limits 47 CFR Part 15: Clause 15.209 for all emissions:

Frequency of emission (MHz)	Field strength μV/m	Measurement Distance m	Field strength dBμV/m
0.009-0.490	2400/F(kHz)	300	67.6/F (kHz)
0.490-1.705	24000/F(kHz)	30	87.6/F (kHz
1.705-30	30	30	29.5
30-88	100	3	40.0
88-216	150	3	43.5
216-960	200	3	46.0
Above 960	500	3	54.0

(a) Where results have been measured at one distance, and a signal level displayed at another, the results have been extrapolated using the following formula:

$$\text{Extrapolation}\,(\text{dB}) = 20\log_{10}\left(\frac{\text{measurement distance}}{\text{specification distance}}\right)$$

(b) The levels may have been rounded for display purposes.

(c) The following table summarises the effect of the EUT operating mode, internal configuration and arrangement of cables / samples on the measured emission levels :

	See (i)	See (ii)	See (iii)	See (iv)
Effect of EUT operating mode on emission levels	✓			
Effect of EUT internal configuration on emission levels		✓		
Effect of Position of EUT cables & samples on emission levels	✓			

(i) Parameter defined by standard and / or single possible, refer to Appendix C
(ii) Parameter defined by client and / or single possible, refer to Appendix C
(iii) Parameter had a negligible effect on emission levels, refer to Appendix C
(iv) Worst case determined by initial measurement, refer to Appendix C

A4 Unintentional Radiated Emissions

Preliminary scans were performed using a peak detector with the RBW = 100kHz. The radiated electric field emission test applies to all spurious emissions not directly related to the transmitter. The maximum permitted field strength is listed in Section 15.109. The EUT was set to operate in a transmit standby / receive mode.

The following test site was used for final measurements as specified by the standard tested to:

3m open area test site : [ ] 3m alternative test site : [X]

The effect of the EUT set-up on the measurements is summarised in note (c) below.

Test Details:	
Regulation	Title 47 of the CFR, Part 15 Subpart (b) Clause 15.109 IC RSS-GEN 4.10
Measurement standard	ANSI C63.10:2009
EUT sample number	S03
Modification state	0
SE in test environment	S01
SE isolated from EUT	None
EUT set up	Refer to Appendix C
Temperature	23
Photographs	Appendix E

No emissions were detected within 10dB of the limits.

Notes:

1 Any testing performed below 30 MHz was performed using a magnetic loop antenna in accordance with ANSI C63.10:2009: section 4.5, Table 1 For emissions below 30MHz the cable losses are assumed to be negligible.

2 In accordance with 15.35(b), above 1 GHz, emissions measured using a peak detector shall not exceed a level 20 dB above the average limit.

3 Testing was performed with the EUT orientated in three orthogonal planes and the maximum emissions level recorded. In addition, the EUT antenna was varied within its range of motion in order to maximise emissions.

4 For Frequencies below 1 GHz, RBW = 120 kHz, testing was performed with CISPR16 compliant test receiver with QP detector. Above 1 GHz tests were performed using a spectrum analyser using the following settings:

Peak	RBW= 1MHz, VBW ≥ RBW
Average	RBW= 1MHz, VBW ≥ RBW

The upper and lower frequency of the measurement range was decided according to 47 CFR Part 15: Clause 15.33(a) and 15.33(a)(1).

Radiated emission limits 47 CFR Part 15: Clause 15.109 for all emissions:

Frequency of emission (MHz)	Field strength μV/m	Measurement Distance m	Field strength dBμV/m
0.009-0.490	2400/F(kHz)	300	67.6/F (kHz)
0.490-1.705	24000/F(kHz)	30	87.6/F (kHz
1.705-30	30	30	29.5
30-88	100	3	40.0
88-216	150	3	43.5
216-960	200	3	46.0
Above 960	500	3	54.0

(a) Where results have been measured at one distance, and a signal level displayed at another, the results have been extrapolated using the following formula:

$$\text{Extrapolation}\,(\text{dB}) = 20\log_{10}\left(\frac{\text{measurement distance}}{\text{specification distance}}\right)$$

(b) The levels may have been rounded for display purposes.

(c) The following table summarises the effect of the EUT operating mode, internal configuration and arrangement of cables / samples on the measured emission levels :

	See (i)	See (ii)	See (iii)	See (iv)
Effect of EUT operating mode on emission levels	✓			
Effect of EUT internal configuration on emission levels		✓		
Effect of Position of EUT cables & samples on emission levels	✓			

(i) Parameter defined by standard and / or single possible, refer to Appendix C
(ii) Parameter defined by client and / or single possible, refer to Appendix C
(iii) Parameter had a negligible effect on emission levels, refer to Appendix C
(iv) Worst case determined by initial measurement, refer to Appendix C

Appendix B: Supporting Graphical Data

This appendix contains graphical data obtained during testing.

Notes:

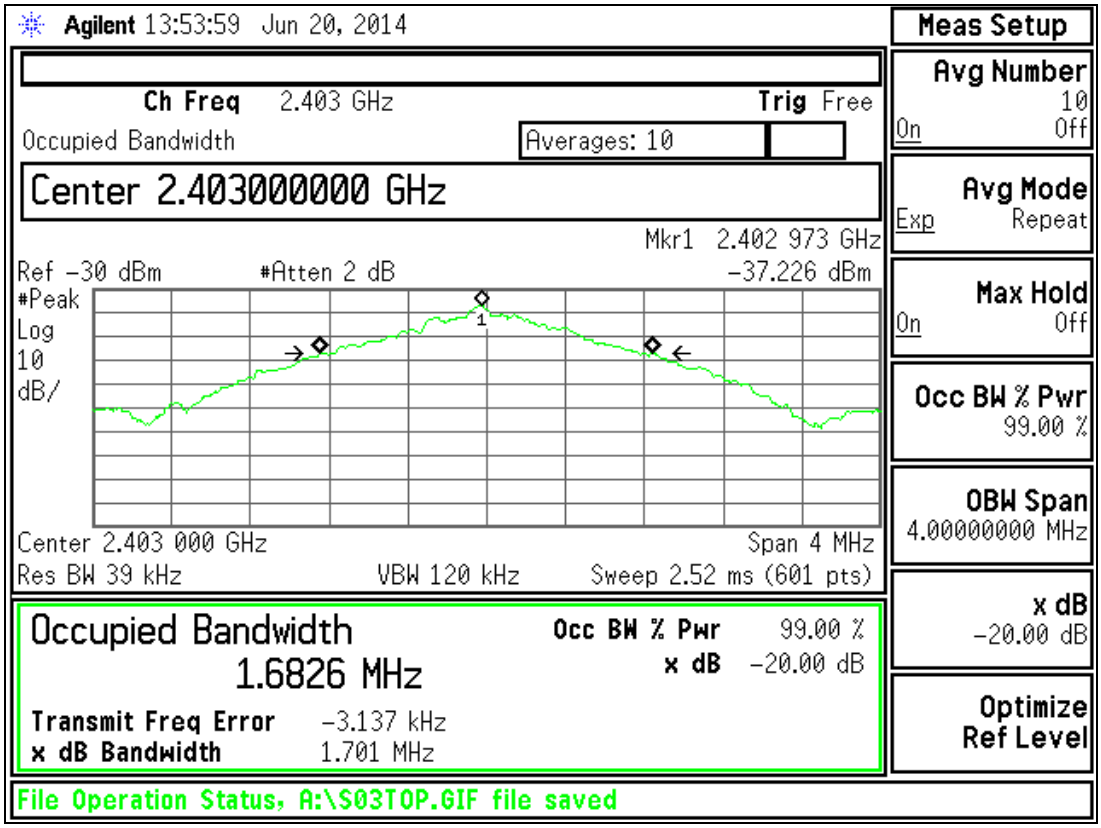
(a) The radiated electric field emissions and conducted emissions graphical data in this appendix is preview data. For details of formal results, refer to Appendix A.

(b) The time and date on the plots do not necessarily equate to the time of the test.

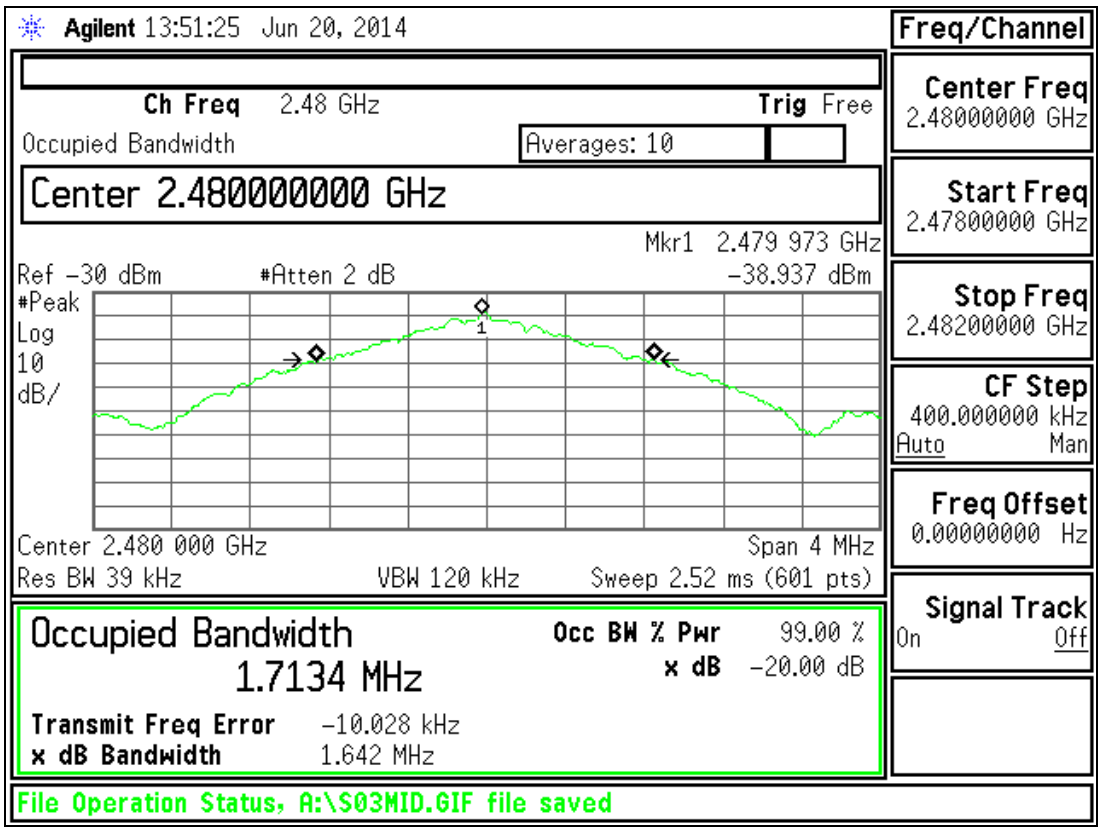
(c) Where relevant, on power line conducted emission plots, the limit displayed is the average limit, which is stricter than the quasi peak limit.

(d) Appendix C details the numbering system used to identify the sample and its modification state.

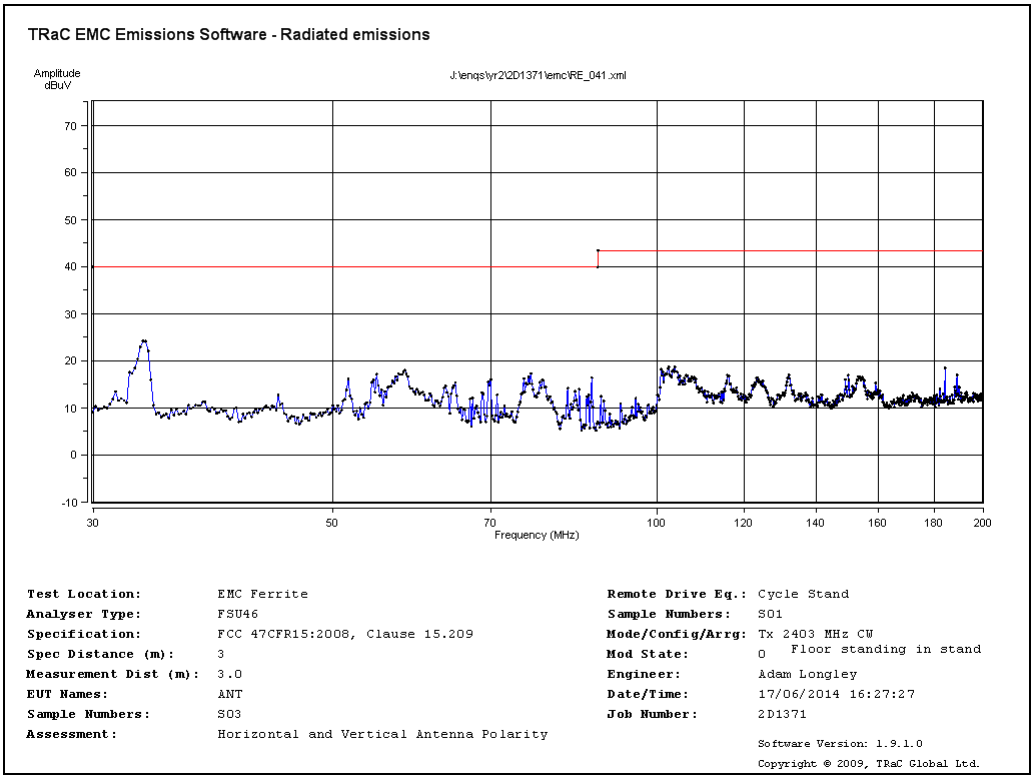
(e) The plots presented in this appendix may not be a complete record of the measurements performed, but are a representative sample, relative to the final assessment.



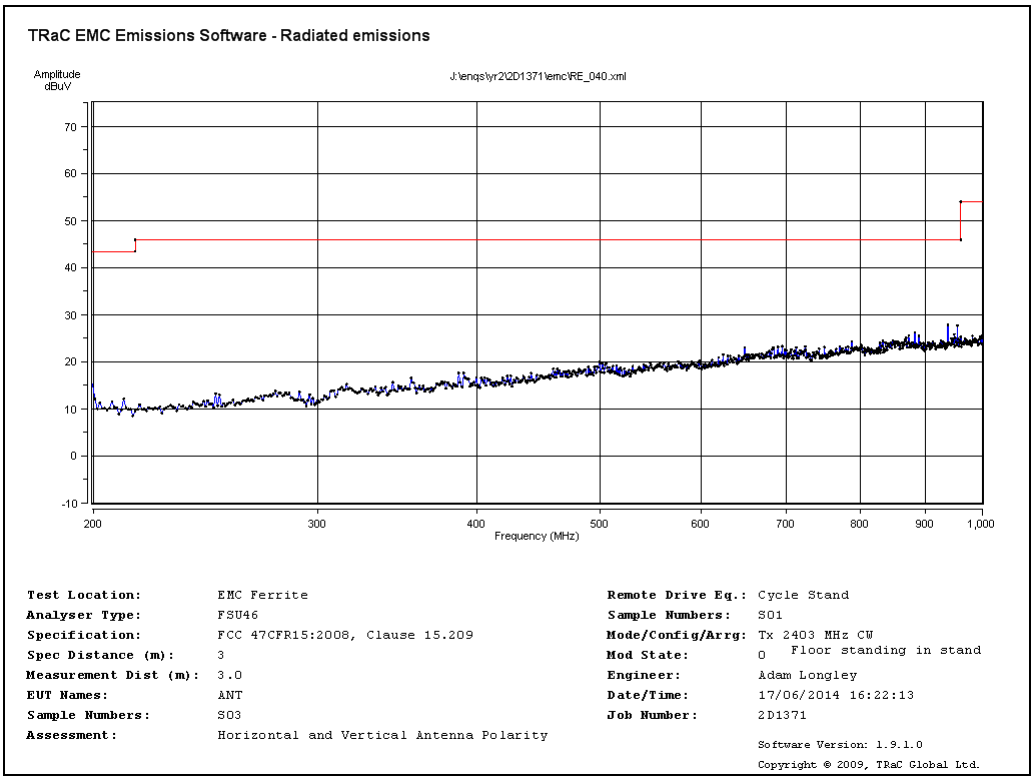
Fc = 2403 MHz - 20dB Bandwidth



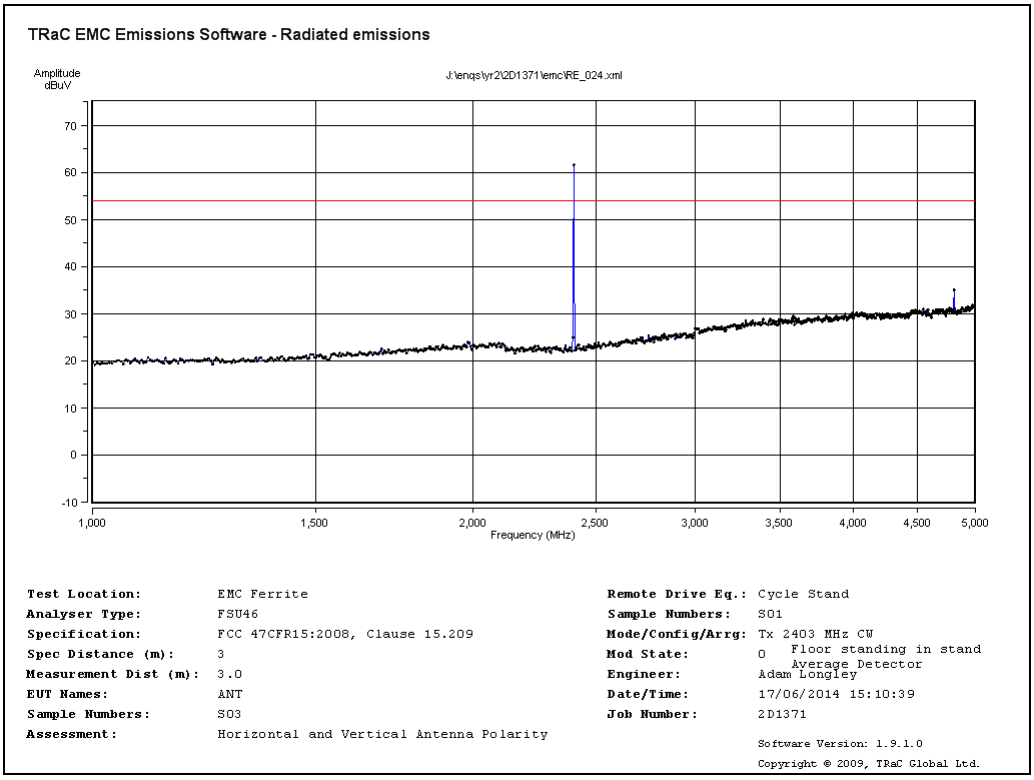
Fc = 2483.5 MHz - 20dB Bandwidth



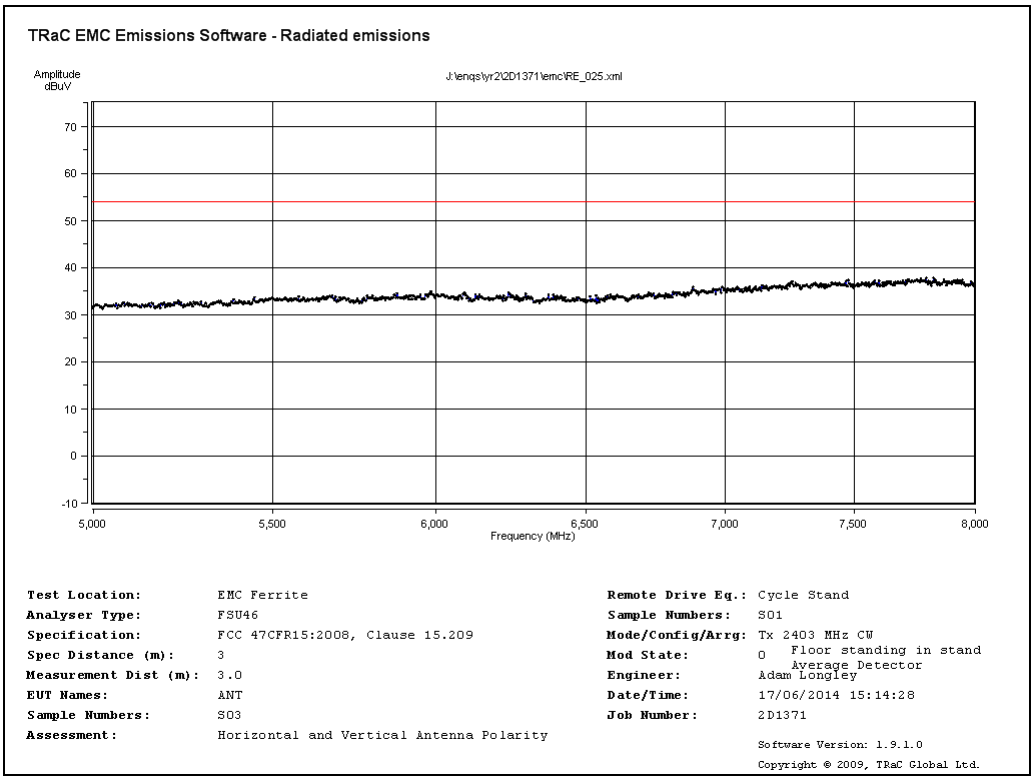
Fc = 2403 MHz Radiated spurious emissions 30 MHz to 200 MHz



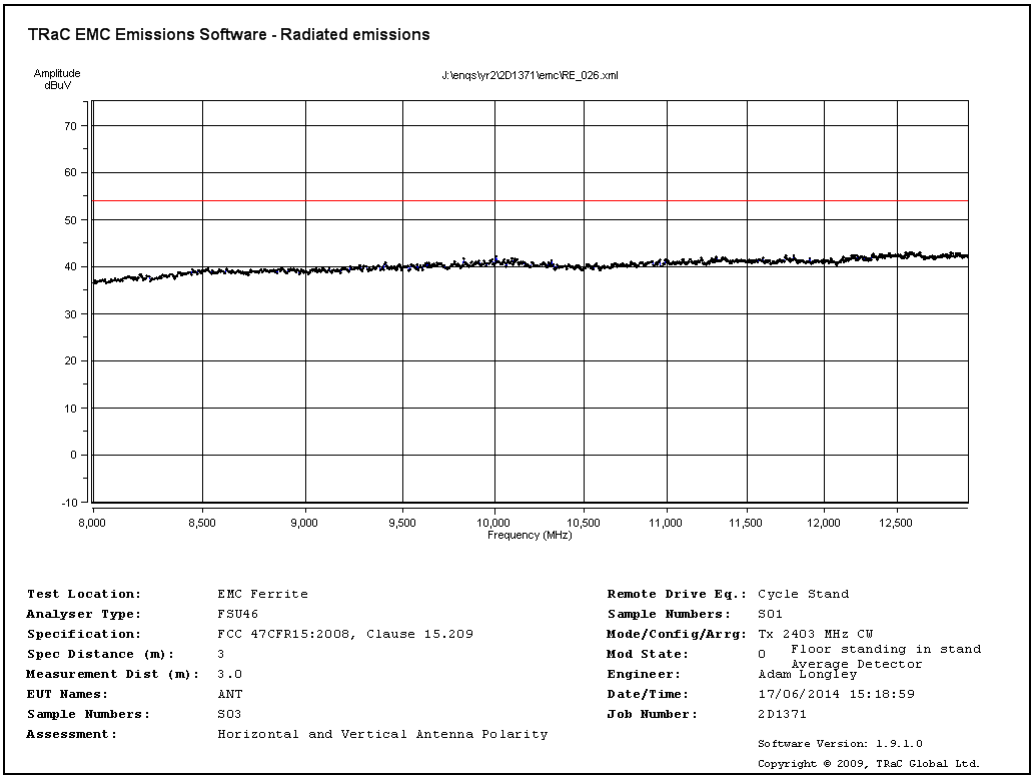
Fc = 2403 MHz Radiated spurious emissions 200 MHz to 1 GHz



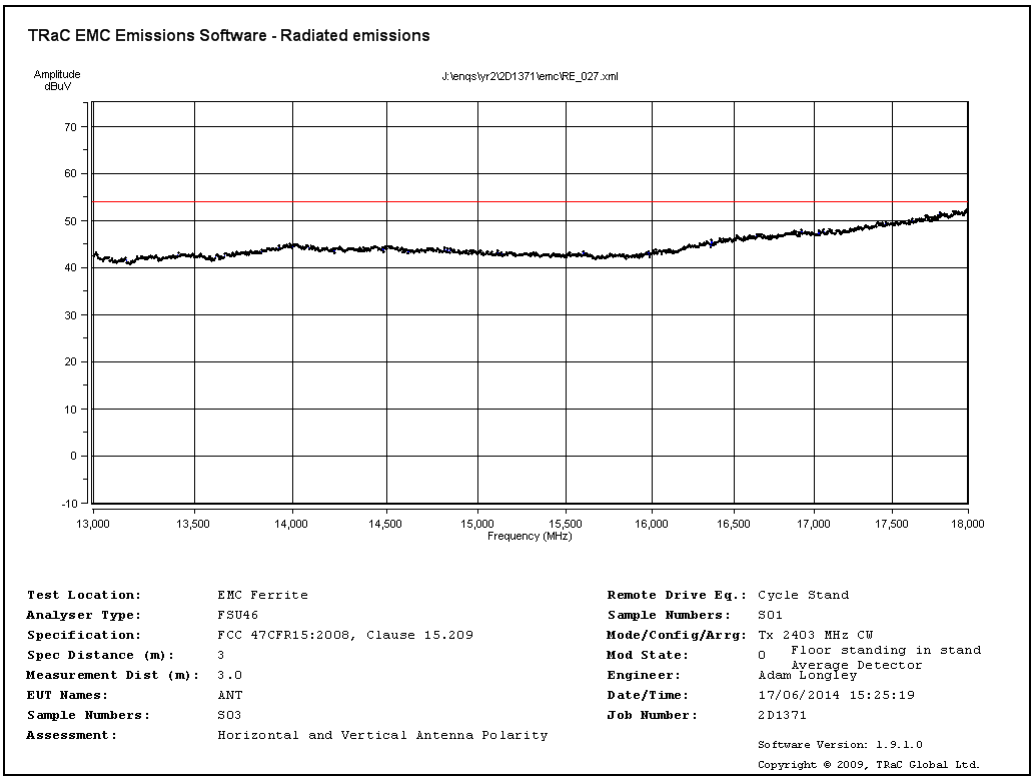
Fc = 2403 MHz Radiated spurious emissions 1 GHz to 5 GHz



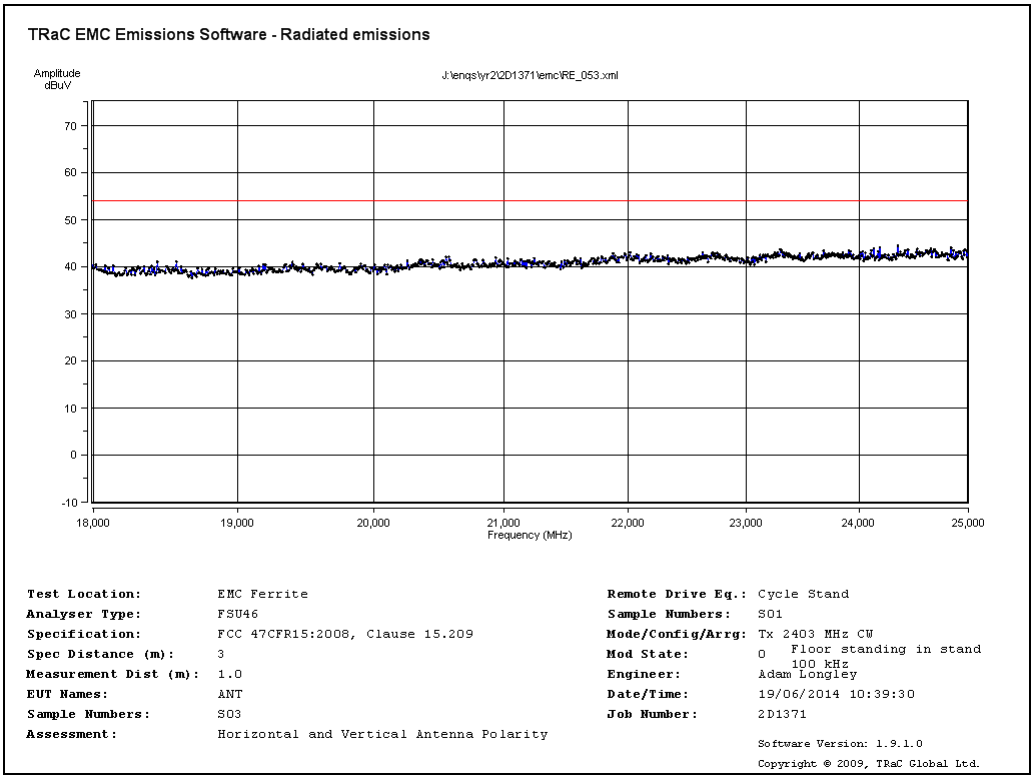
Fc = 2403 MHz Radiated spurious emissions 5 GHz to 8 GHz



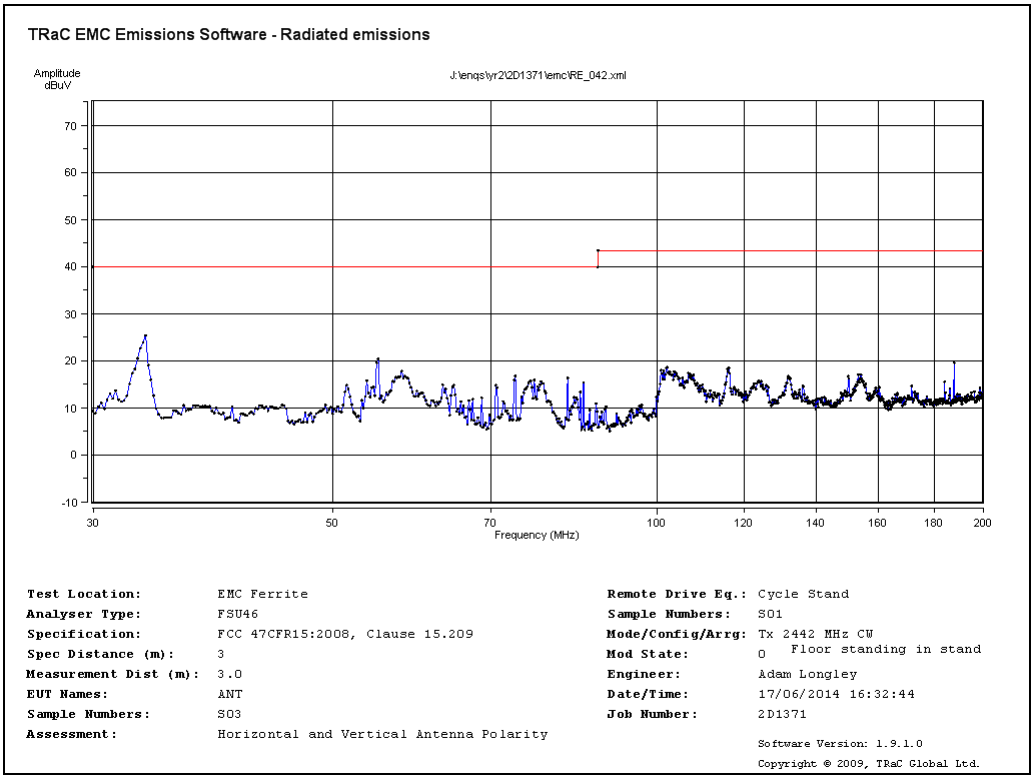
Fc = 2403 MHz Radiated spurious emissions 8 GHz to 13 GHz



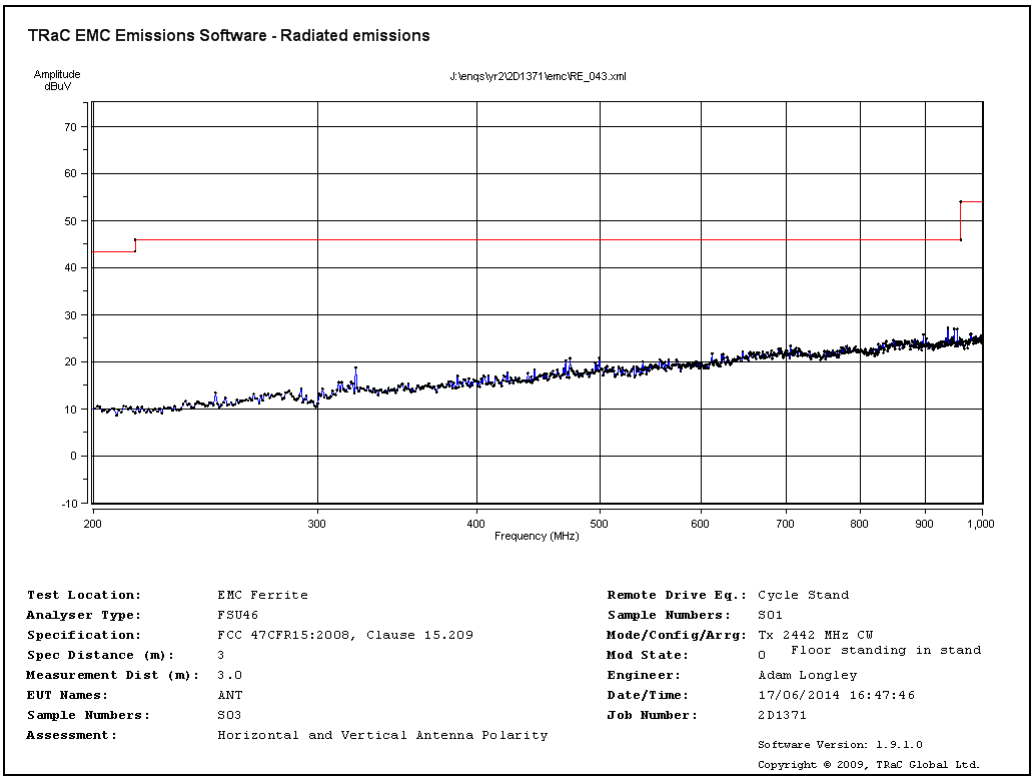
Fc = 2403 MHz Radiated spurious emissions 13 GHz to 18 GHz



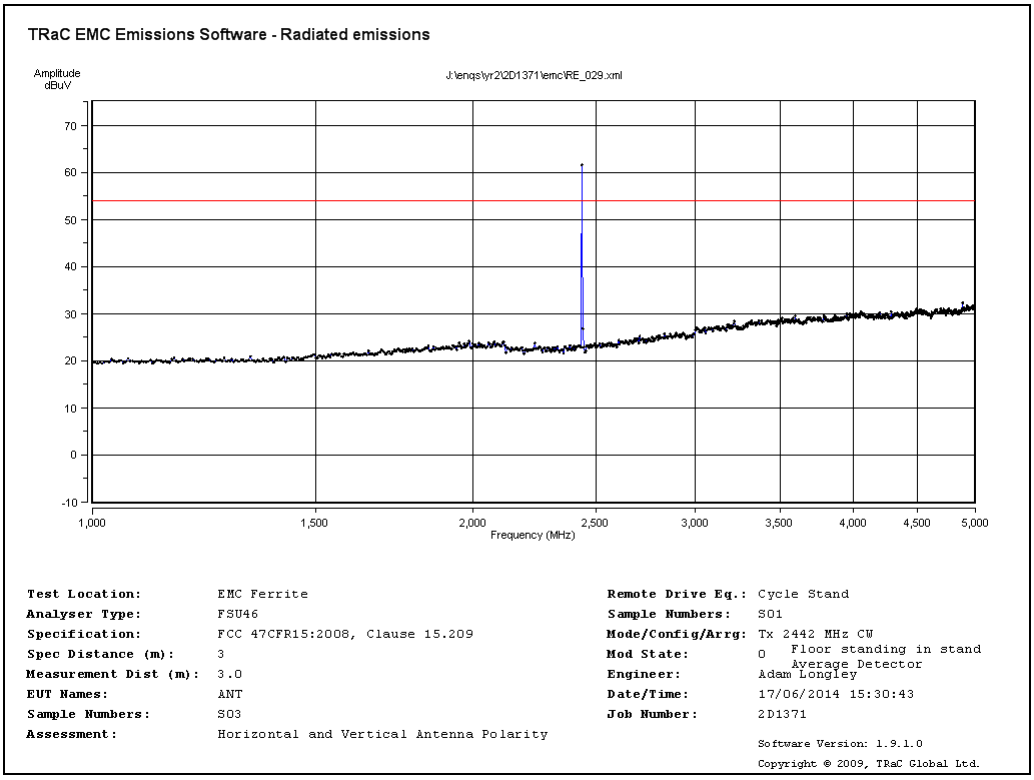
Fc = 2403 MHz Radiated spurious emissions 18 GHz to 25 GHz



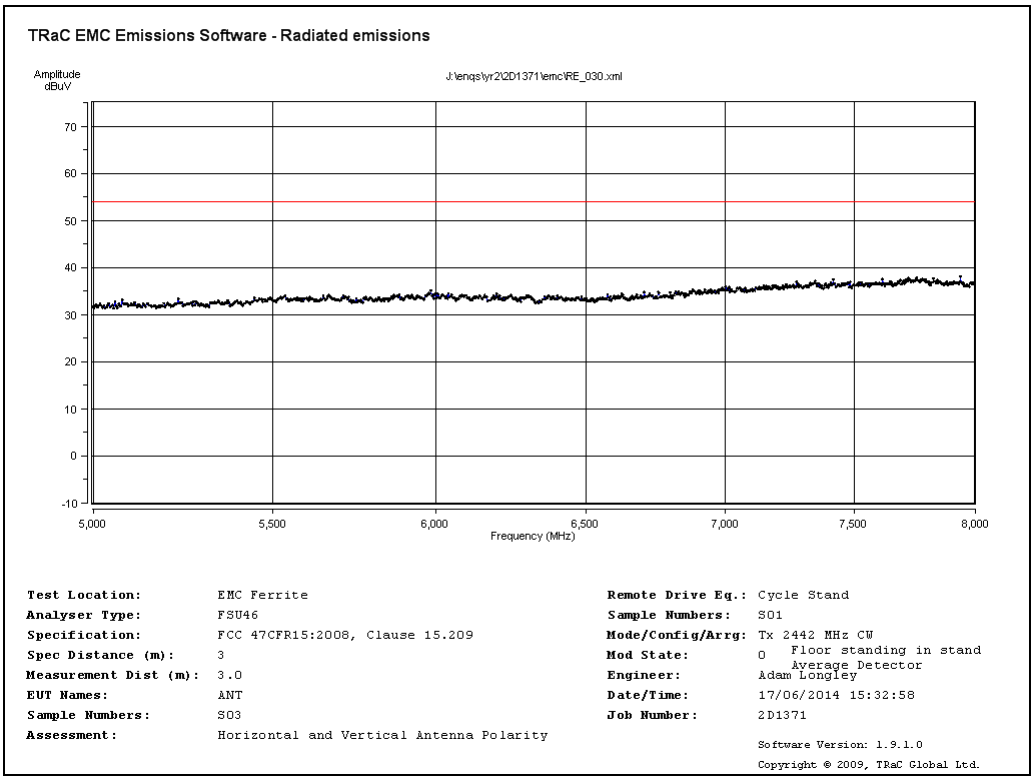
Fc = 2442 MHz Radiated spurious emissions 30 MHz to 200 MHz



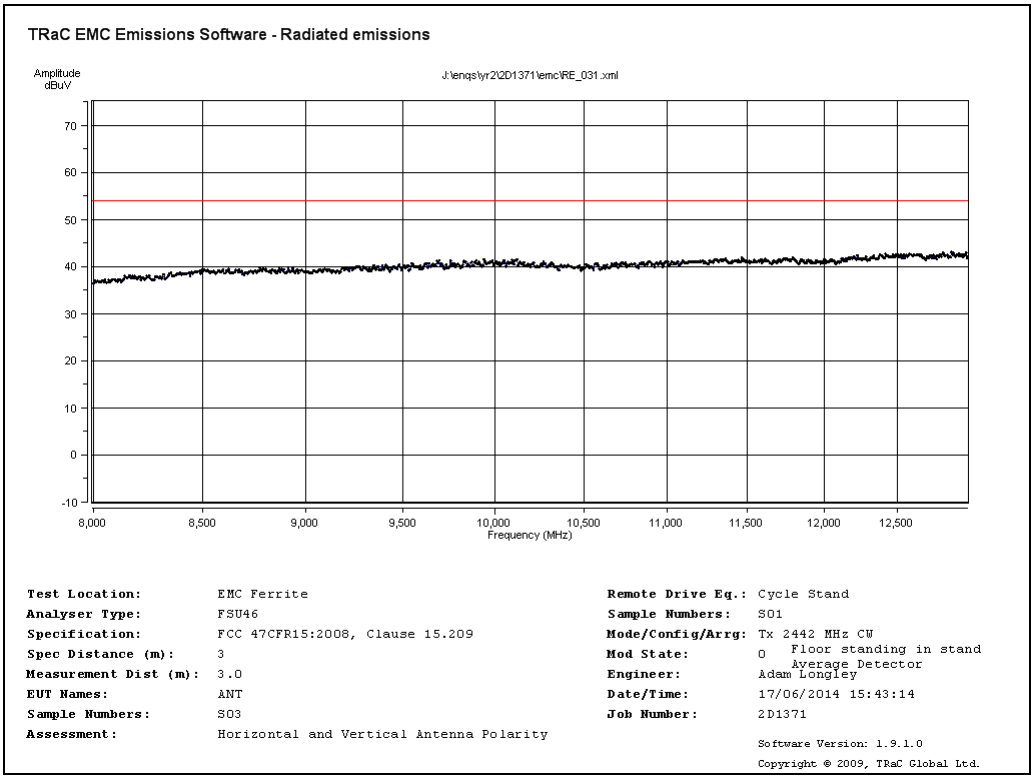
Fc = 2442 MHz Radiated spurious emissions 200 MHz to 1 GHz



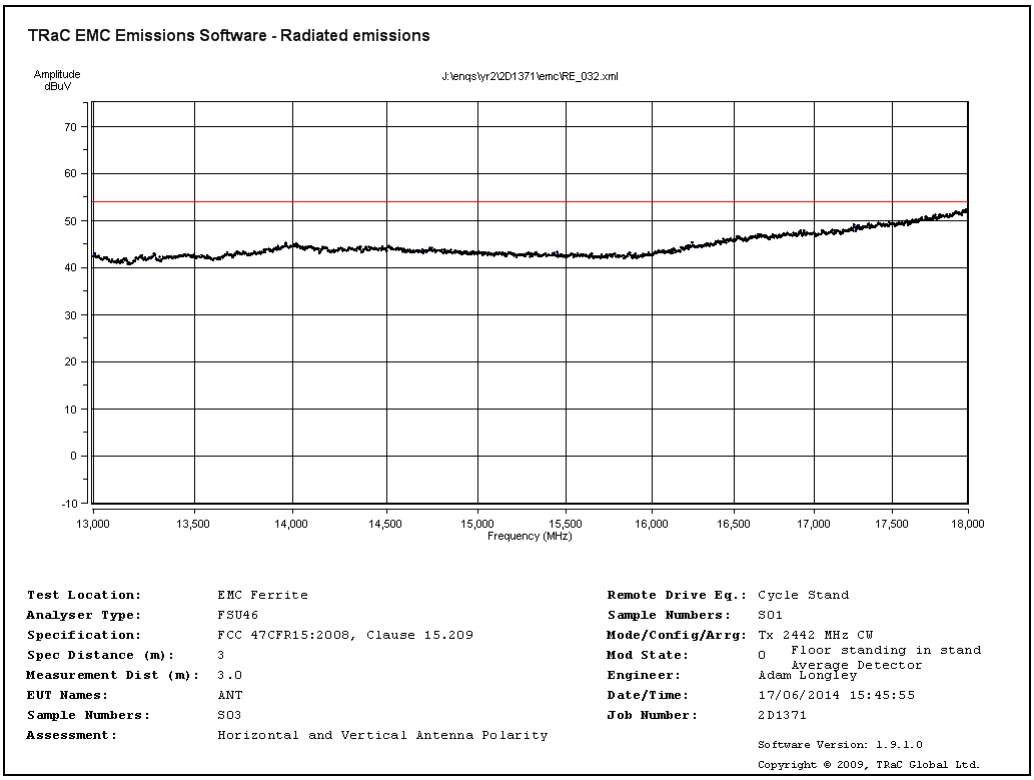
Fc = 2442 MHz Radiated spurious emissions 1 GHz to 5 GHz



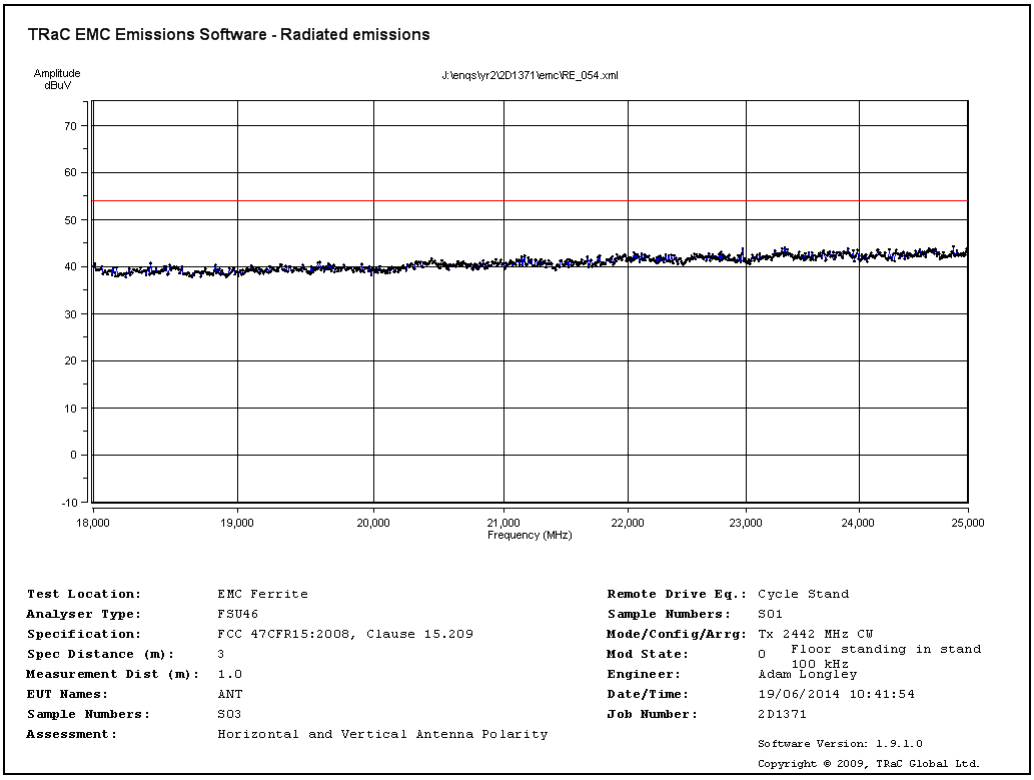
Fc = 2442 MHz Radiated spurious emissions 5 GHz to 8 GHz



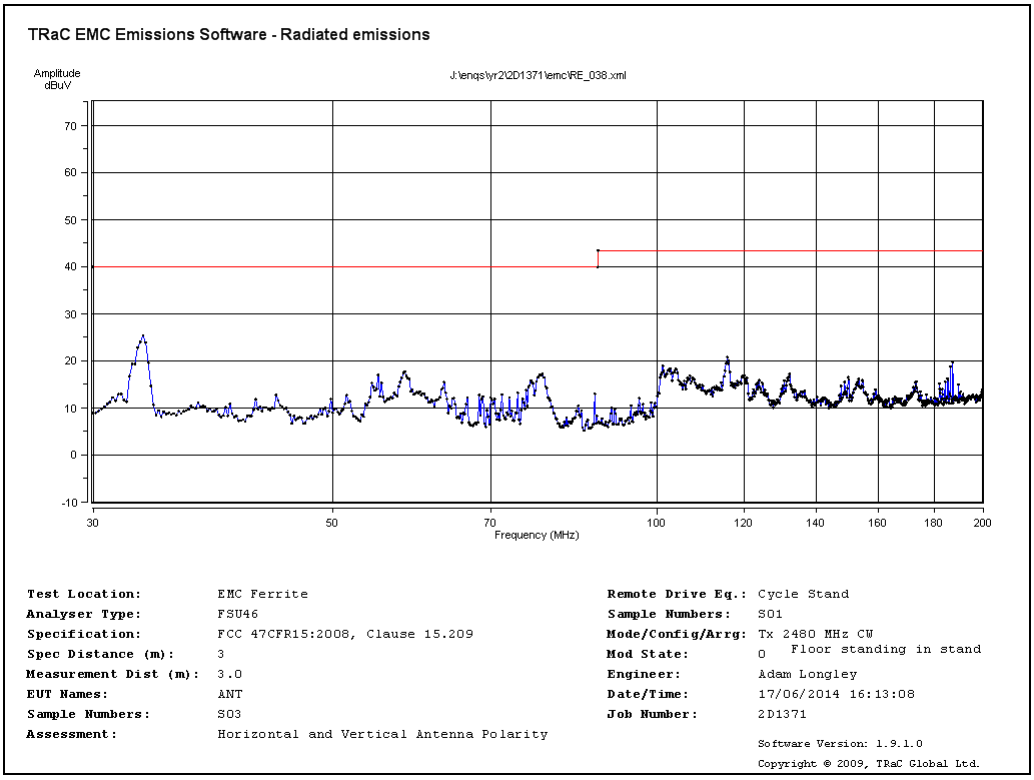
Fc = 2442 MHz Radiated spurious emissions 8 GHz to 13 GHz



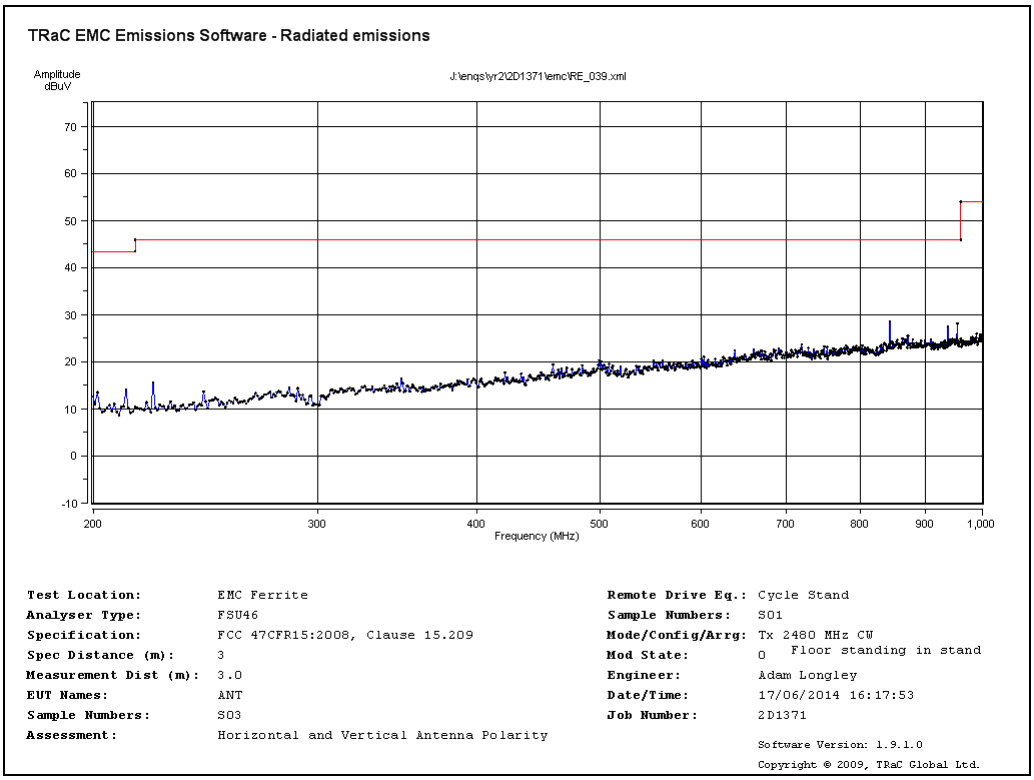
Fc = 2442 MHz Radiated spurious emissions 13 GHz to 18 GHz



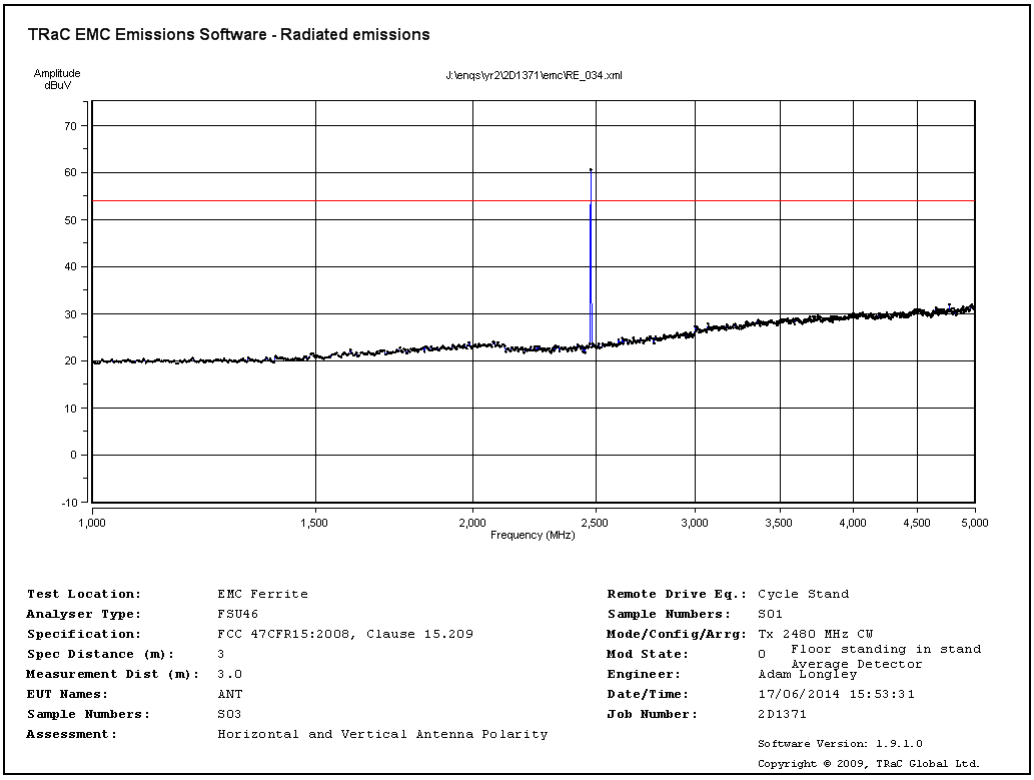
Fc = 2442 MHz Radiated spurious emissions 18 GHz to 25 GHz



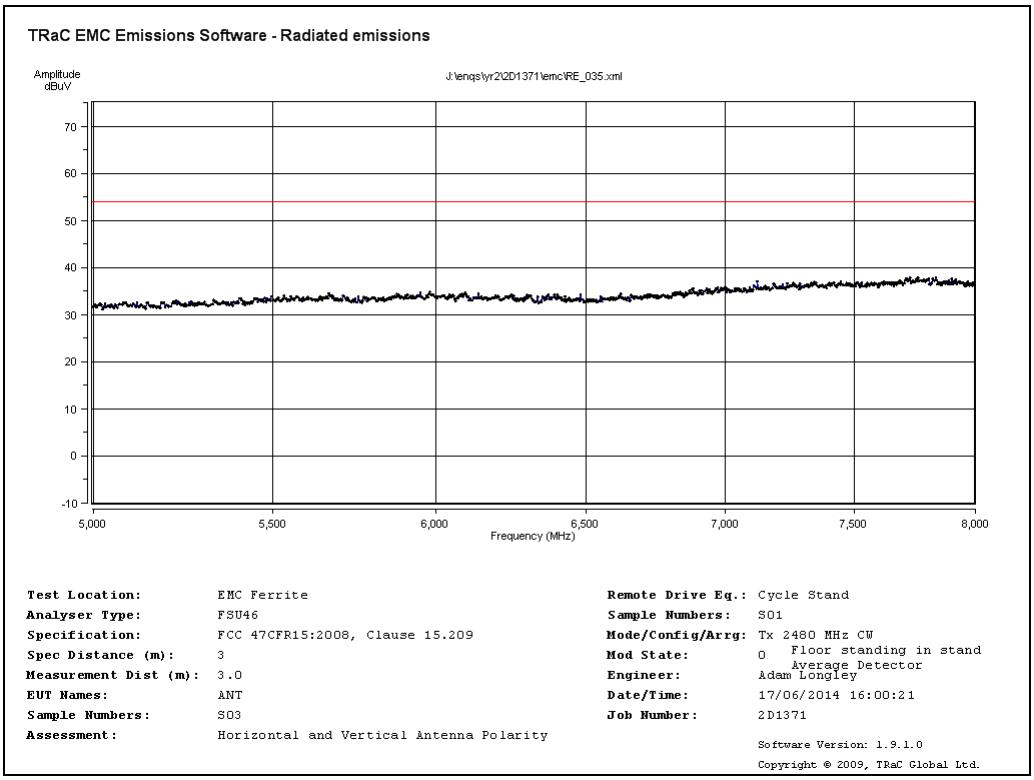
Fc = 2480 MHz Radiated spurious emissions 30 MHz to 200 MHz



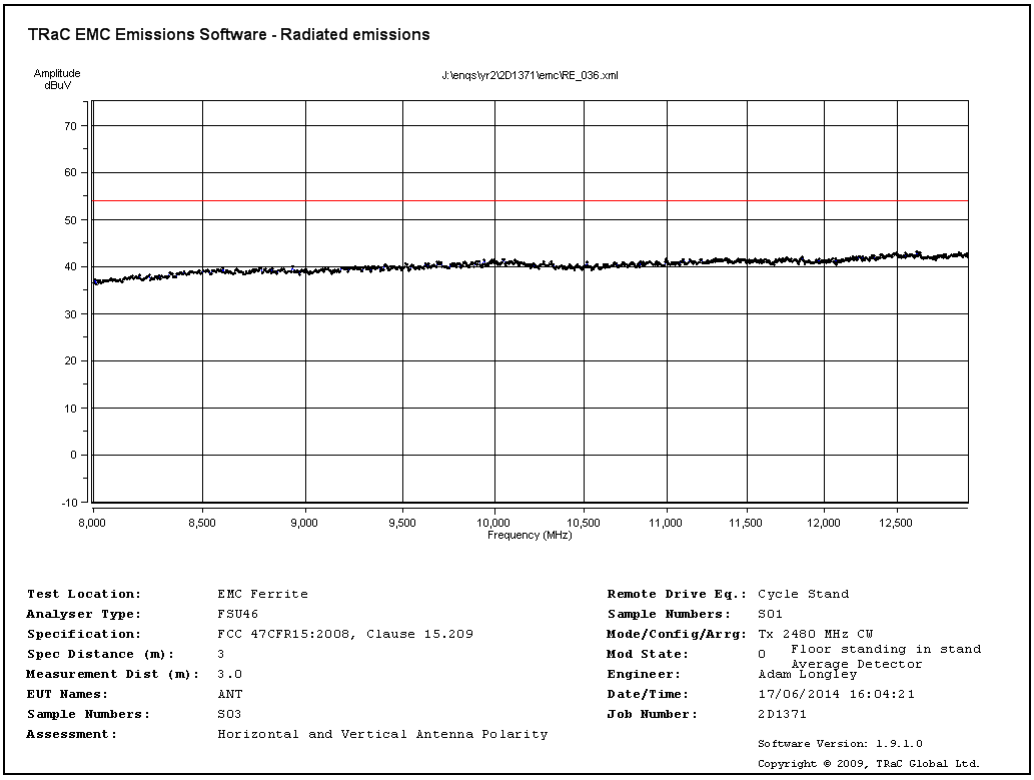
Fc = 2480 MHz Radiated spurious emissions 200 MHz to 1 GHz



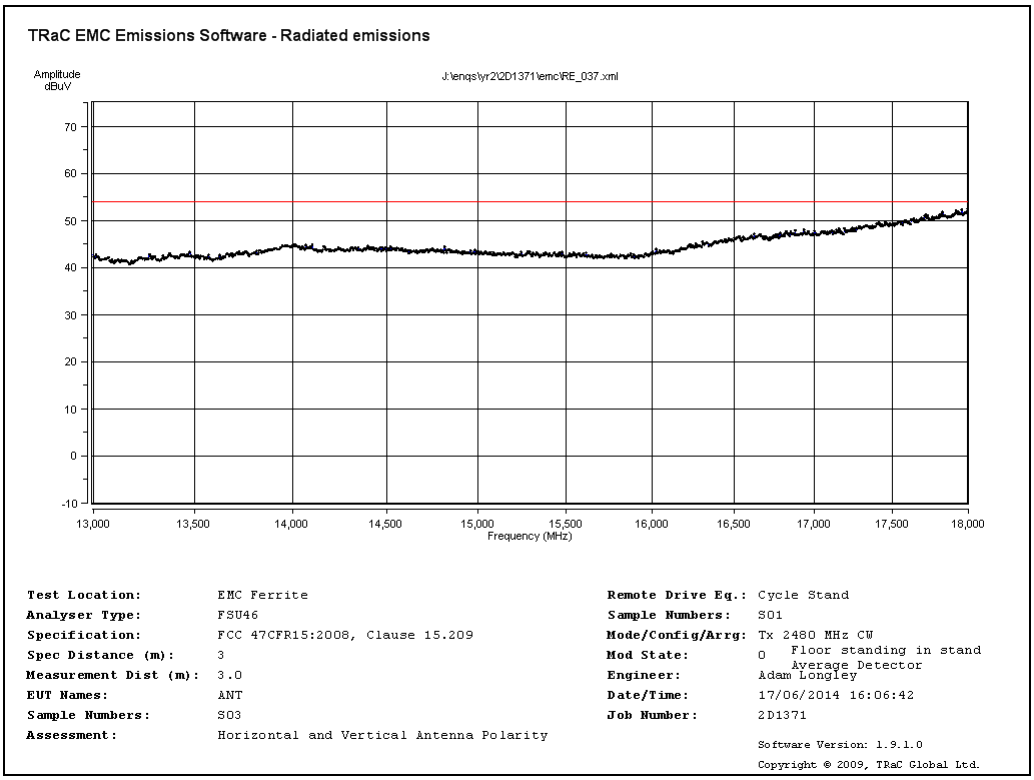
Fc = 2480 MHz Radiated spurious emissions 1 GHz to 5 GHz



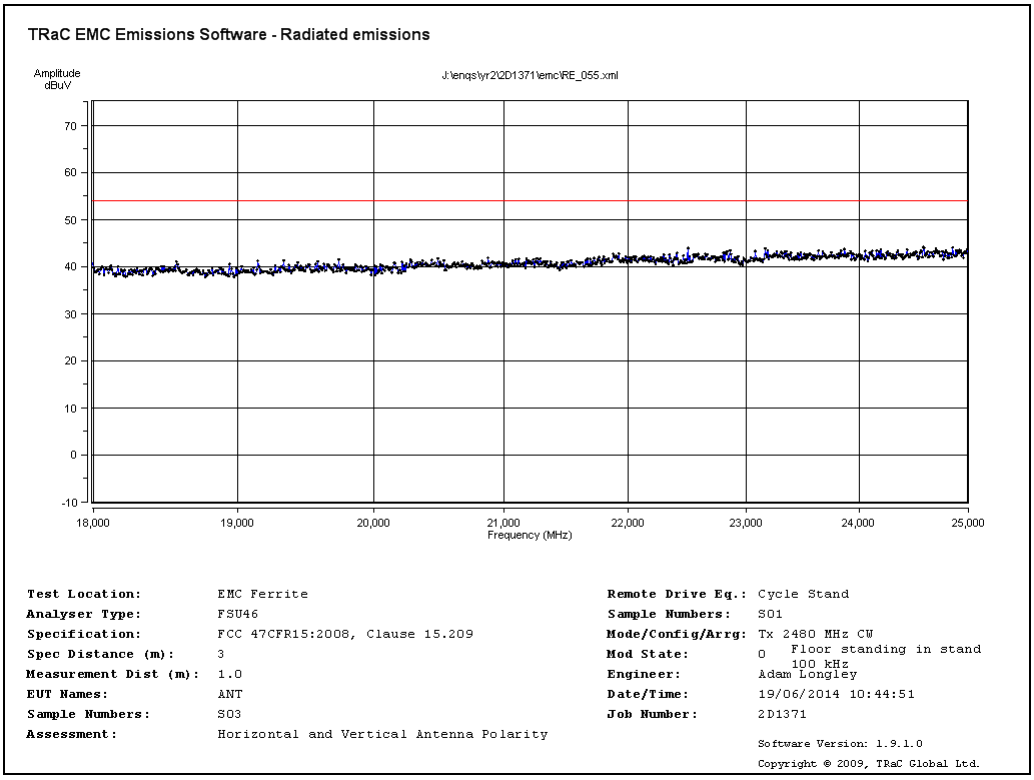
Fc = 2480 MHz Radiated spurious emissions 5 GHz to 8 GHz



Fc = 2480 MHz Radiated spurious emissions 8 GHz to 13 GHz

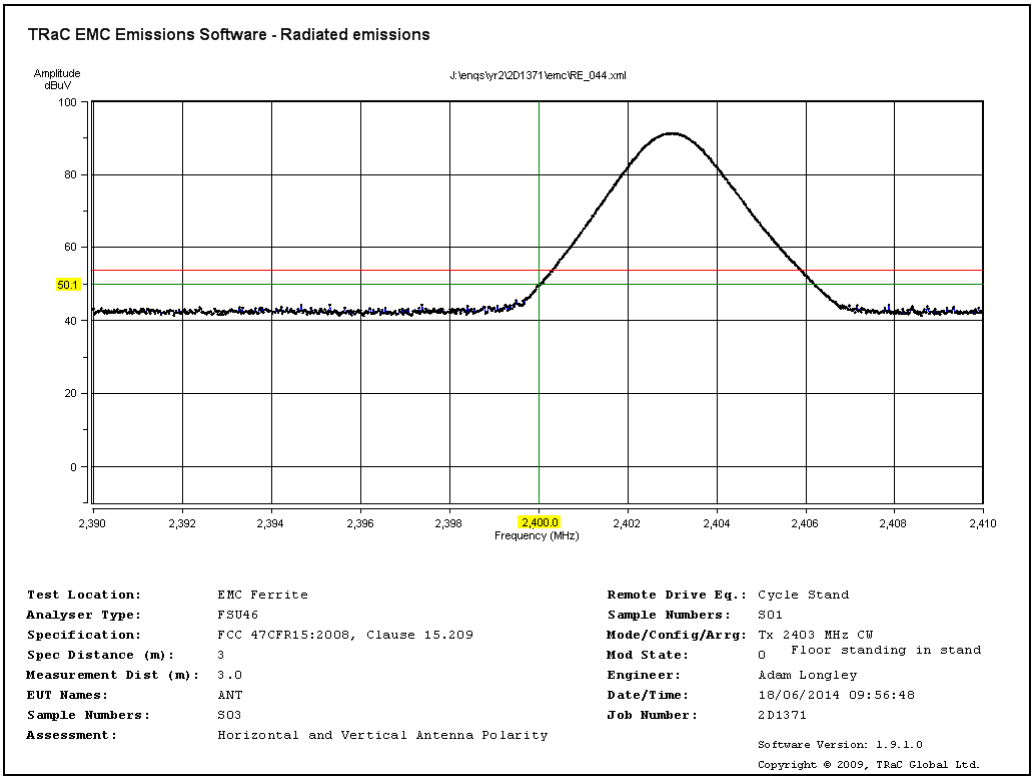


Fc = 2480 MHz Radiated spurious emissions 13 GHz to 18 GHz

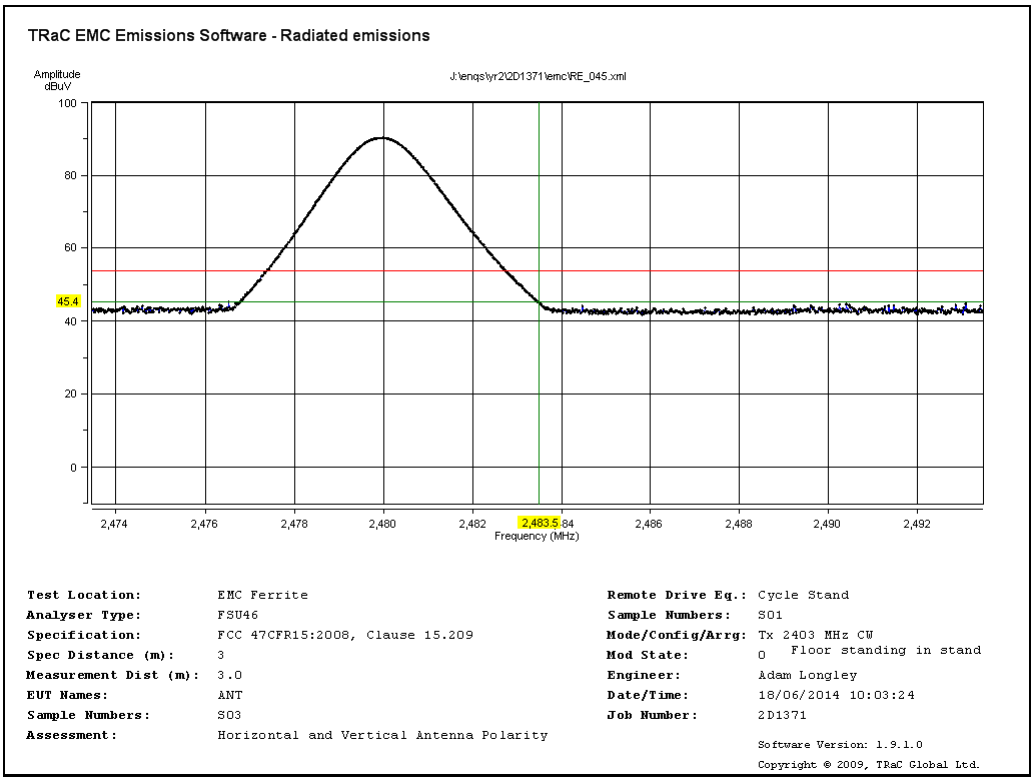


Fc = 2480 MHz Radiated spurious emissions 18 GHz to 25 GHz

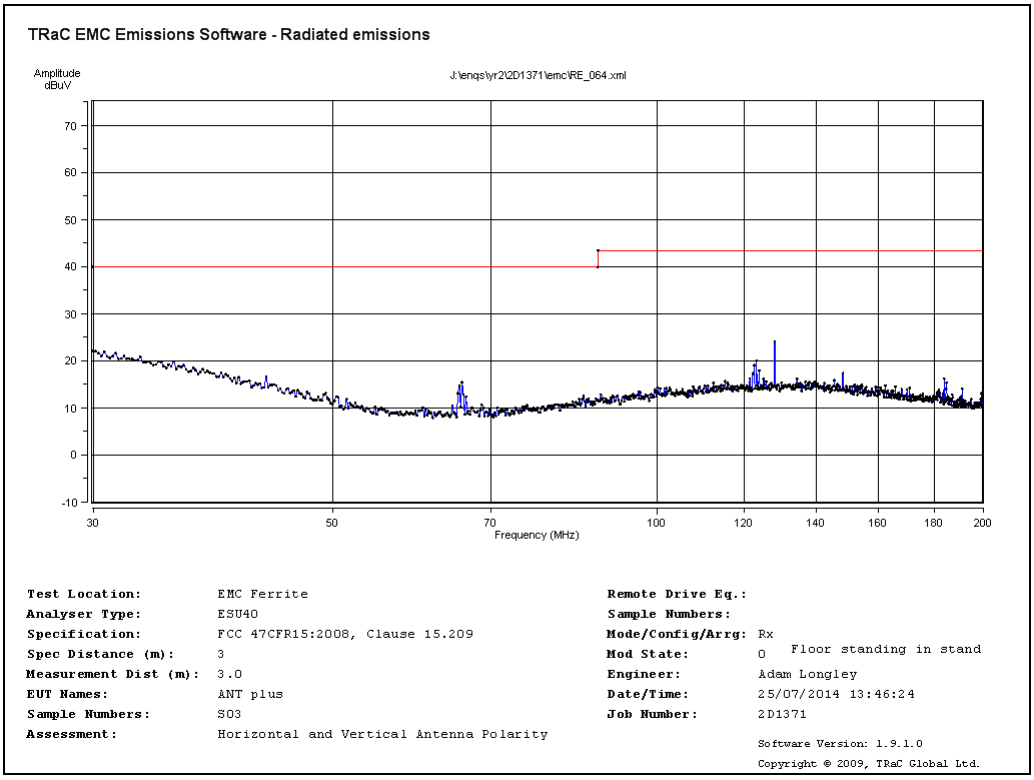
Radiated Band Edge Compliance



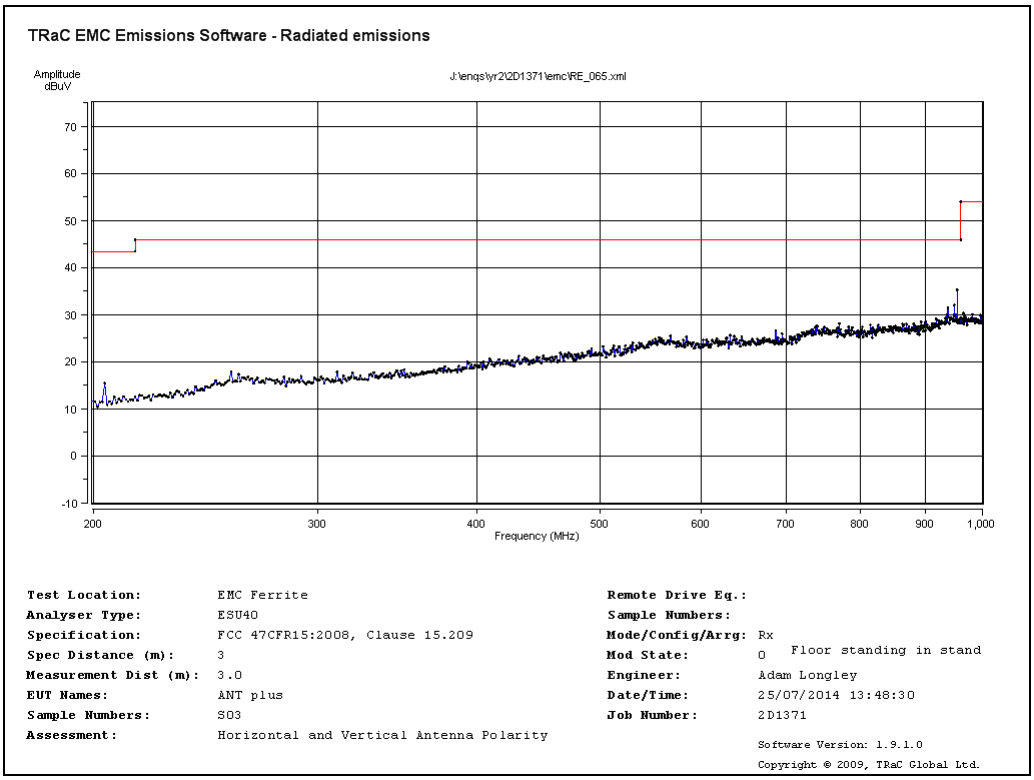
Fc = 2403 MHz Lower Band Edge



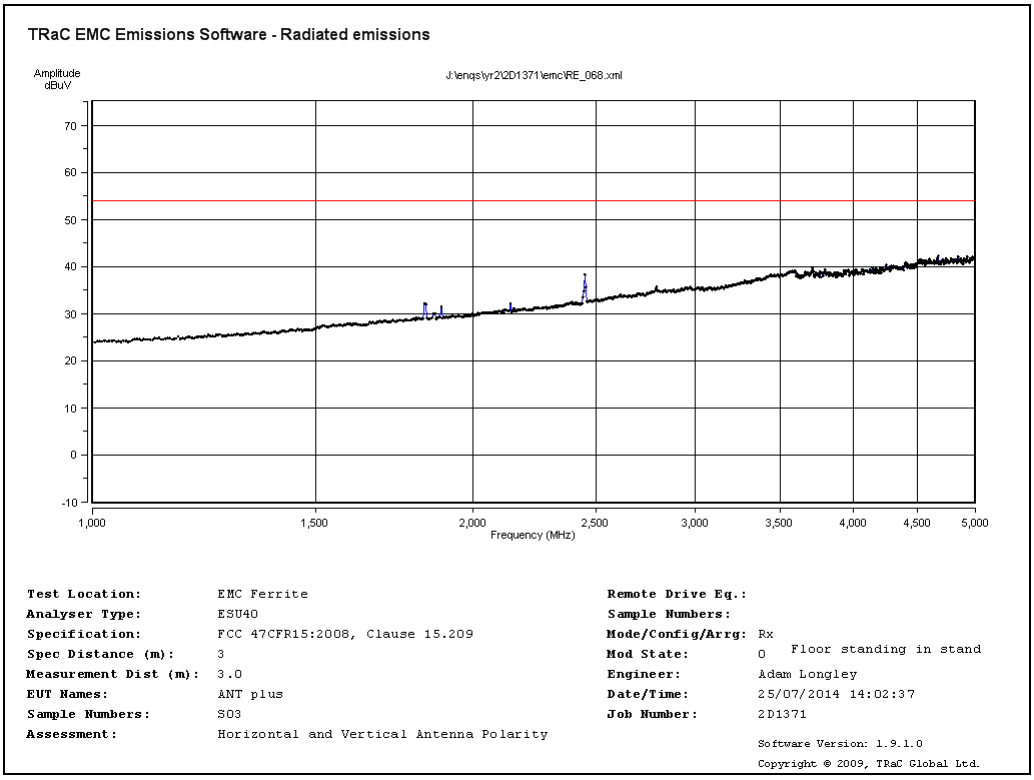
Fc = 2480 MHz Upper Band Edge



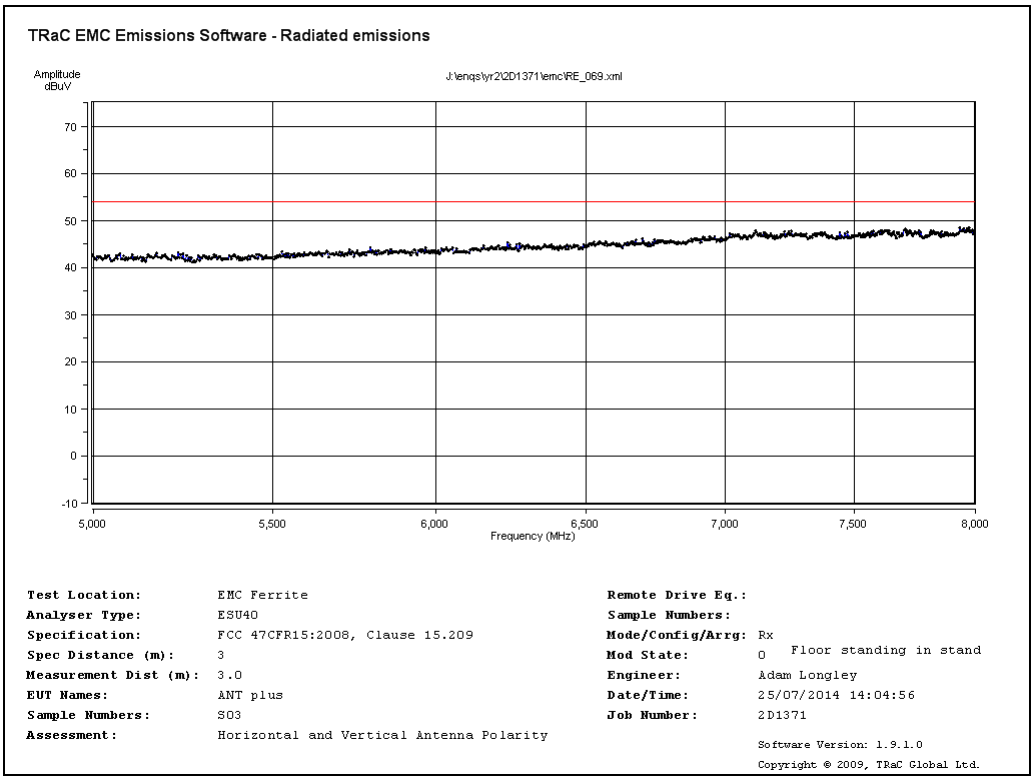
Unintentional Radiated spurious emissions 30 MHz to 200 MHz



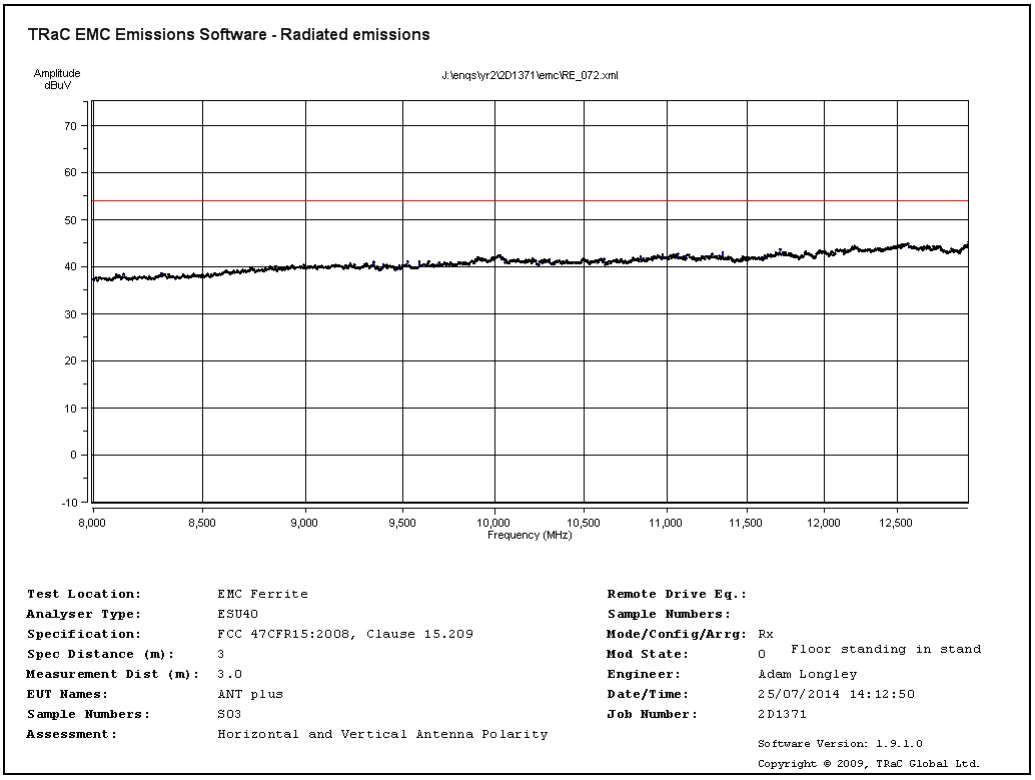
Unintentional Radiated spurious emissions 200 MHz to 1 GHz



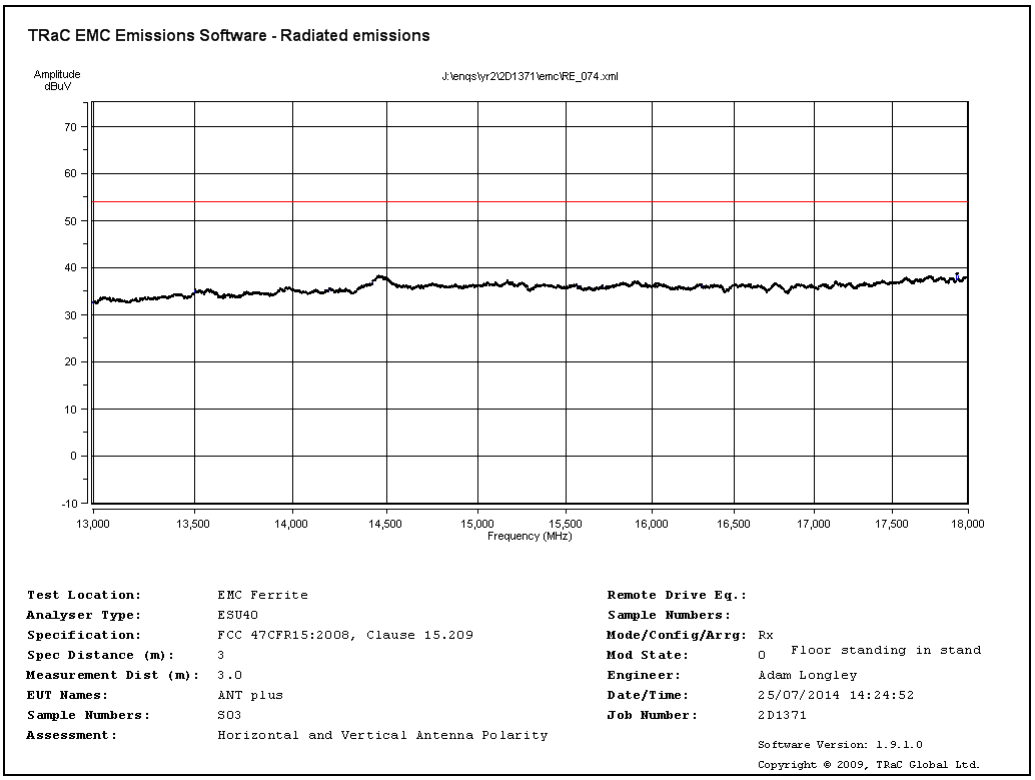
Unintentional Radiated spurious emissions 1 GHz to 5 GHz



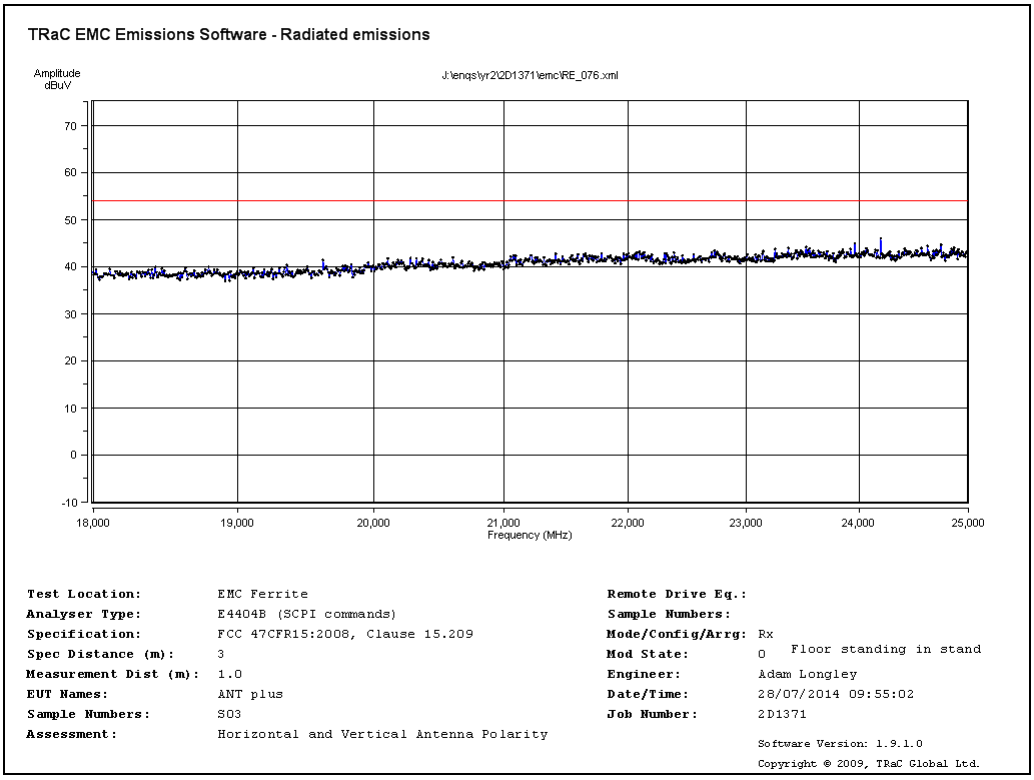
Unintentional Radiated spurious emissions 5 GHz to 8 GHz



Unintentional Radiated spurious emissions 8 GHz to 13 GHz



Unintentional Radiated spurious emissions 13 GHz to 18 GHz



Unintentional Radiated spurious emissions 18 GHz to 25 GHz

Appendix C: Additional Test and Sample Details

This appendix contains details of:

1. The samples submitted for testing.
2. Details of EUT operating mode(s)
3. Details of EUT configuration(s) (see below).
4. EUT arrangement (see below).

Throughout testing, the following numbering system is used to identify the sample and it's modification state:

Sample No: Sxx Mod w

where:

xx = sample number eg. S01
w = modification number eg. Mod 2

The following terminology is used throughout the test report:

Support Equipment (SE) is any additional equipment required to exercise the EUT in the applicable operating mode. Where relevant SE is divided into two categories:

SE in test environment: The SE is positioned in the test environment and is not isolated from the EUT (e.g. on the table top during REFE testing).

SE isolated from the EUT: The SE is isolated via filtering from the EUT. (e.g. equipment placed externally to the ALSR during REFE testing).

EUT configuration refers to the internal set-up of the EUT. It may include for example:

Positioning of cards in a chassis.
Setting of any internal switches.
Circuit board jumper settings.
Alternative internal power supplies.

Where no change in EUT configuration is **possible**, the configuration is described as “single possible configuration”.

EUT arrangement refers to the termination of EUT ports / connection of support equipment, and where relevant, the relative positioning of samples (EUT and SE) in the test environment.

For further details of the test procedures and general test set ups used during testing please refer to the related document "EMC Test Methods - An Overview", which can be supplied by TRaC Global upon request.

C1) Test samples

The following samples of the apparatus were submitted by the client for testing:

Sample No.	Description	Identification
S03	Satori Smart T2400 cycle trainer	None

The following samples of apparatus were submitted by the client as host, support or drive equipment (auxiliary equipment):

Sample No.	Description	Identification
S01	Metal stand	None

During testing S03 was installed with test firmware which provided transmit and receive modes using the ANT+ protocol.

C2) EUT Operating Mode During Testing.

During testing, the EUT was exercised as described in the following tables:

Test	Description of Operating Mode
All tests detailed in this report other than those listed in the tables below	EUT transmitting in ANT+ mode on 2403, 2442 or 2480MHz as required (without modulation).

Test	Description of Operating Mode
Occupied Bandwidth Power Spectral Density	EUT transmitting in ANT+ mode on 2403, 2442 or 2480MHz as required (with modulation).

Test	Description of Operating Mode:
Unintentional radiated spurious emissions	EUT active but non-transmitting.

C3) EUT Configuration Information.

The EUT was submitted for testing in one single possible configuration.

C4) List of EUT Ports

The EUT as provided for testing did not have any ports.

The single “cable” connected to the EUT was not an electrical connection but was a tensioning cable for the roller wheel.

C5 Details of Equipment Used

For Radiated Measurements:

TRAC REF/RFG No.	Type	Description	Manufacturer	Date Calibrated.	Calibration Due
REF886	ATS	Ferrite Lined Chamber	TRaC	21/07/14	21/07/15
095		Biconical Antenna	EMCO	09/05/13	09/05/16
191		Log Periodic Antenna	EMCO	09/05/13	09/05/16
RFG682	HL050	GHz Log Periodic Antenna	Rhode & Schwarz	16/07/13	16/07/14
RFG629		Horn Antenna	Q-Par	19/09/13	19/07/14
REF927	310	Pre-Amp (9kHz – 1GHz)	Sonoma	01/07/14	01/07/16
REF913	8449B	Pre-Amp (1 – 26.5GHz)	Agilent	05/02/14	05/02/15
RFG452		SMA RF coaxial cable		03/07/13	03/07/15
REF881		N-Type RF coaxial cable		01/07/13	01/07/15
REF882		N-Type RF coaxial cable		01/07/13	01/07/15
REF884		N-Type RF coaxial cable		01/07/13	01/07/15
REF885		N-Type RF coaxial cable		01/07/13	01/07/15
RFG832		K-Type RF coaxial cable	Teleydyne	17/07/14	17/07/15
RFG919		K-Type RF coaxial cable	Teleydyne	17/07/14	17/07/15
REF910	FSU	Spectrum Analyser	Rhode & Schwarz	31/03/14	31/03/15
REF837	E4440A	Spectrum Analyser	Agilent	19/05/14	19/05/15

For Conducted RF Measurements:

TRAC REF/RFG No.	Type	Description	Manufacturer	Date Calibrated.	Calibration Due
REF910	FSU	Spectrum Analyser	Rhode & Schwarz	31/03/14	31/03/15
REF837	E4440A	Spectrum Analyser	Agilent	19/05/14	19/05/15

Appendix D: **Additional Information**

Antenna data sheet:

Design Note DN0007

2.4 GHz Inverted F Antenna

By Audun Andersen

Keywords

- *CC2400*
- *CC2420*
- *CC2430*
- *CC2431*
- *CC2500*
- *CC2510*
- *CC2511*
- *CC2550*
- *CC2520*
- *CC2480*
- *PCB Antenna*
- *2.4 GHz*
- *Inverted F Antenna*

1 Introduction

This document describes a PCB antenna design that can be used with all 2.4 GHz transceivers and transmitters from Texas Instruments. Maximum gain is measured to be +3.3 dB and overall size requirements for this antenna are 25.7 x 7.5 mm. Thus, this is a compact, low cost and high performance antenna.

Table of Contents

2 Abbreviations

CC2480	Z-Accel ZigBee Processor
EM	Evaluation Module
IFA	Inverted F Antenna
ISM	Industrial, Scientific, Medical
PCB	Printed Circuit Board

3 Description of the Inverted F Antenna Design

Since the impedance of the Inverted F Antenna is matched directly to 50 ohm no external matching components are needed.

3.1 Implementation of the Inverted F Antenna

It is important to make an exact copy of the antenna dimensions to obtain optimum performance. The easiest approach to implement the antenna in a PCB CAD tool is to import the antenna layout from either a gerber or DXF file. Such files are included in CC2430DB reference design [1]. The gerber file is called "Inverted_F_Antenna.spl" and the DXF file is called "Inverted_F_Antenna.dxf". If the antenna is implemented on a PCB that is wider than the antenna it is important to avoid placing components or having a ground plane close to the end points of the antenna. If the CAD tool being used doesn't support import of gerber or DXF files, Figure 1 and Table 1 can be used.

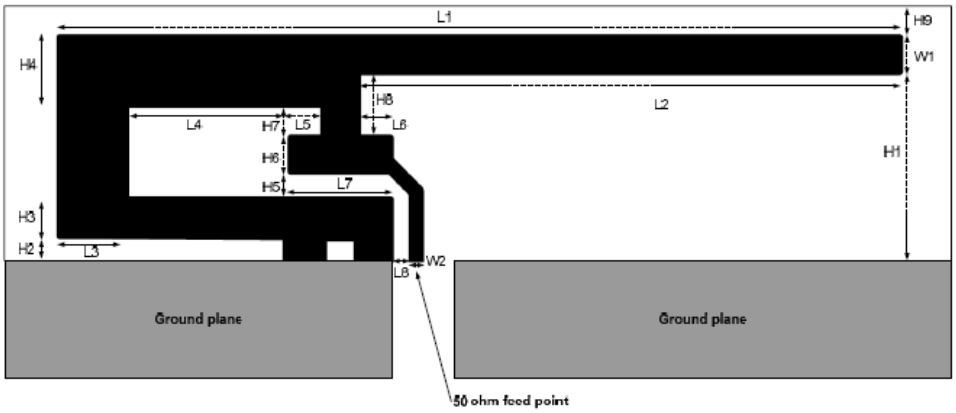


Figure 1. IFA Dimensions

H1	5.70 mm	W2	0.46 mm
H2	0.74 mm	L1	25.58 mm
H3	1.29 mm	L2	16.40 mm
H4	2.21 mm	L3	2.18 mm
H5	0.66 mm	L4	4.80 mm
H6	1.21 mm	L5	1.00 mm
H7	0.80 mm	L6	1.00 mm
H8	1.80 mm	L7	3.20 mm
H9	0.61 mm	L8	0.45 mm
W1	1.21 mm		

Table 1. IFA Dimensions

Since there is no ground plane beneath the antenna, PCB thickness will have little effect on the performance. The results presented in this design note are based on an antenna implemented on a PCB with 1 mm thickness.

4 Results

All results presented in this chapter are based on measurements performed with CC2430DB [1].

4.1 Radiation Pattern

Figure 2 shows how to relate all the radiation patterns to the orientation of the antenna. The radiation patterns were measured with CC2430 programmed to 0 dBm output power.

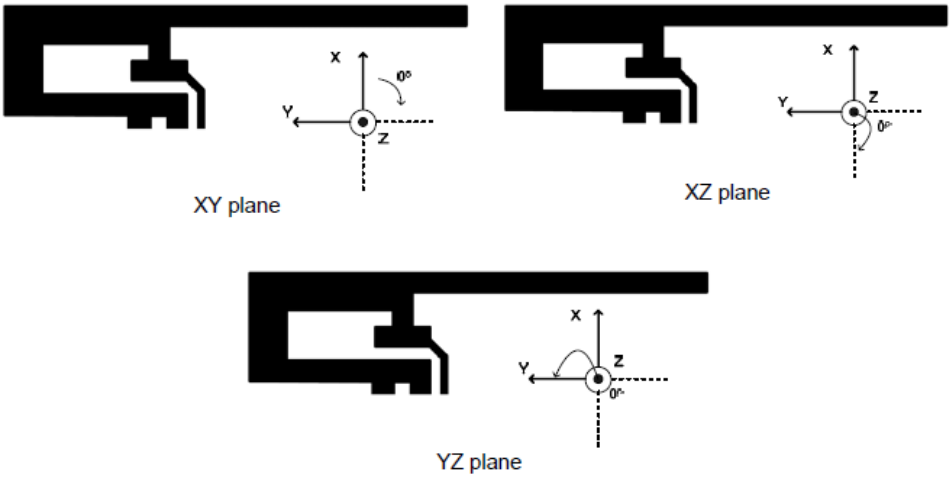


Figure 2. How to Relate the Antenna to the Radiation Patterns

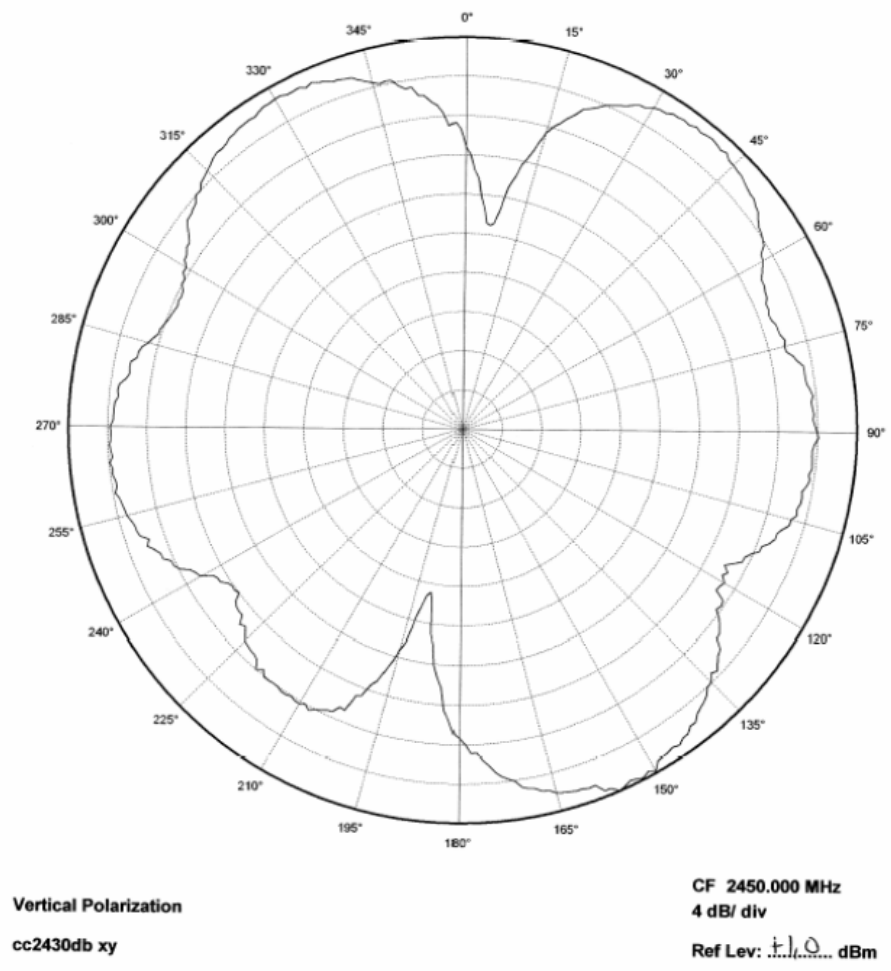


Figure 3. XY Plane Vertical Polarization

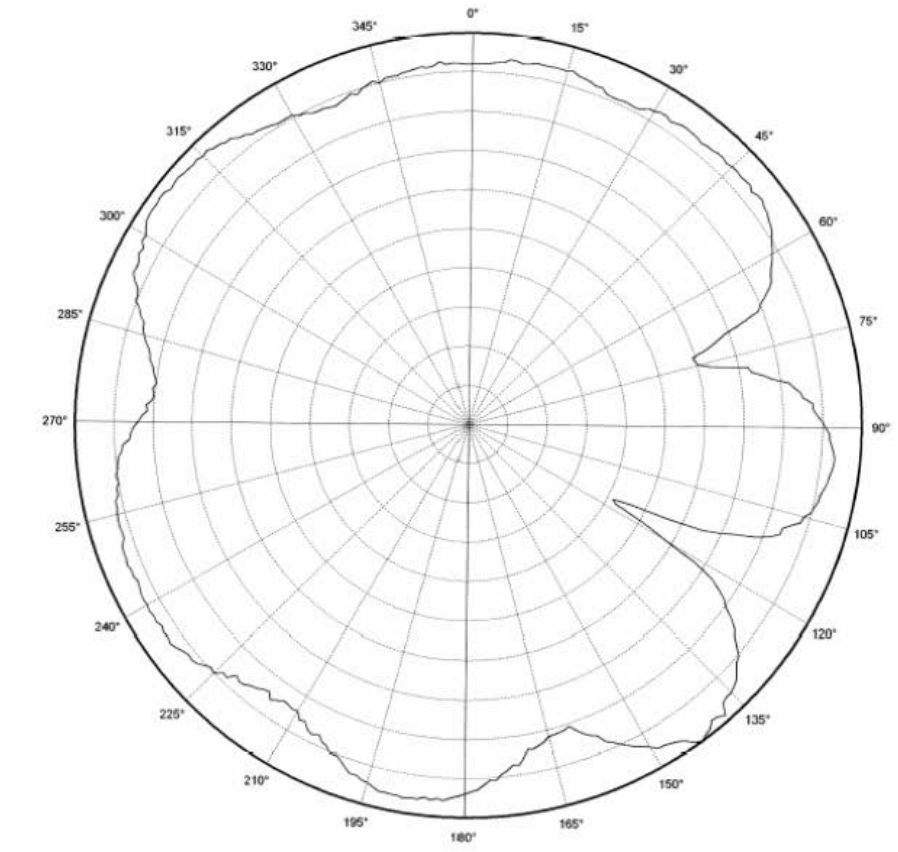


Figure 4. XY Plane Horizontal Polarization

Design Note DN0007

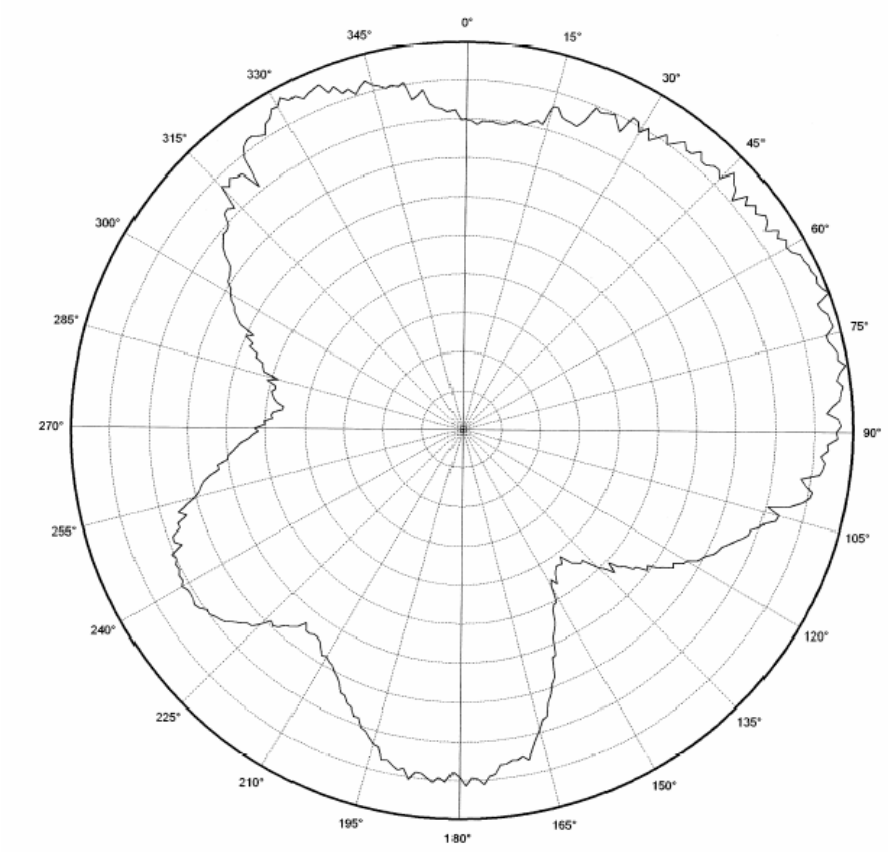


Figure 5. XZ Plane Vertical Polarization

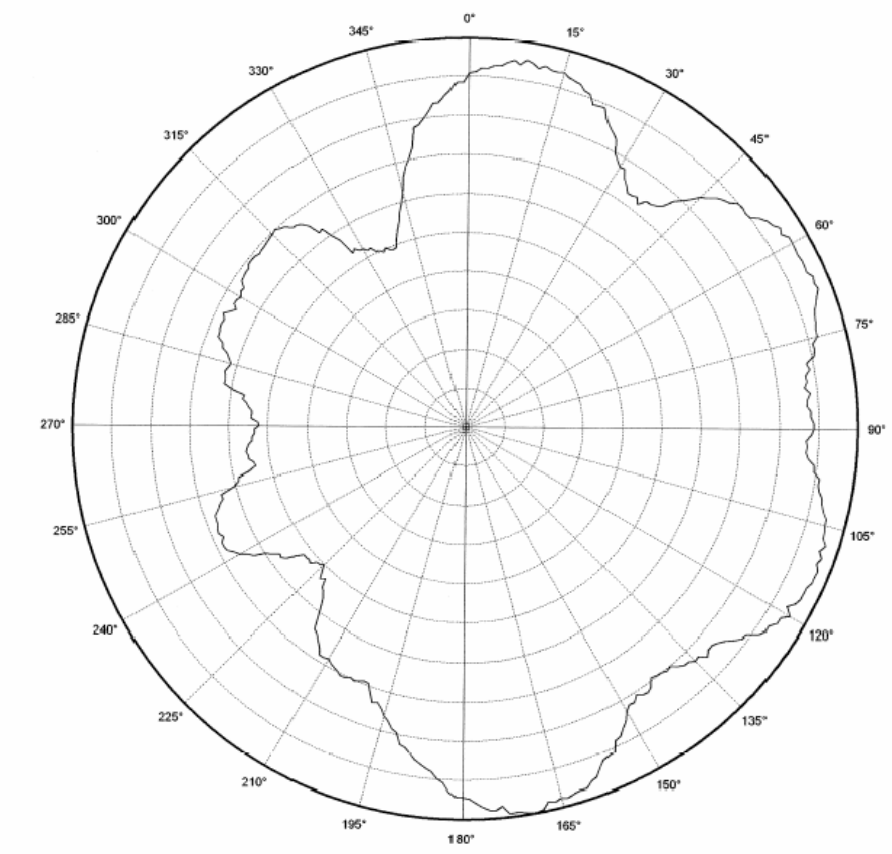


Figure 6. XZ Plane Horizontal Polarization

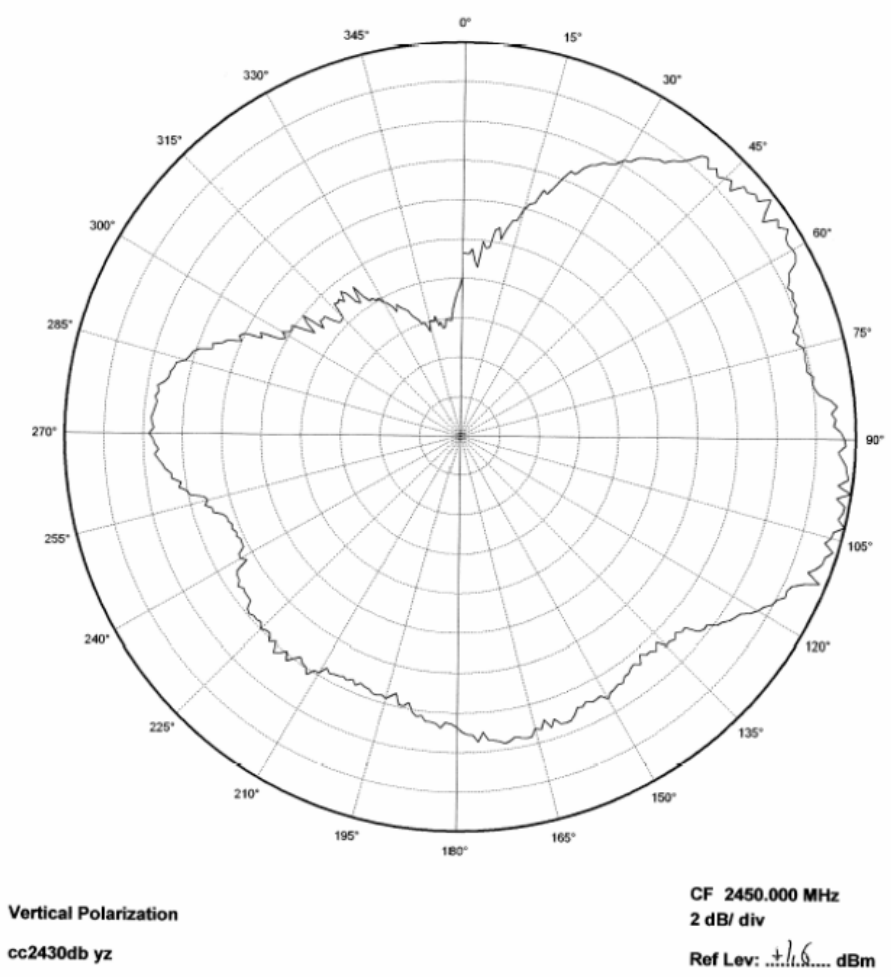


Figure 7. YZ Plane Vertical Polarization

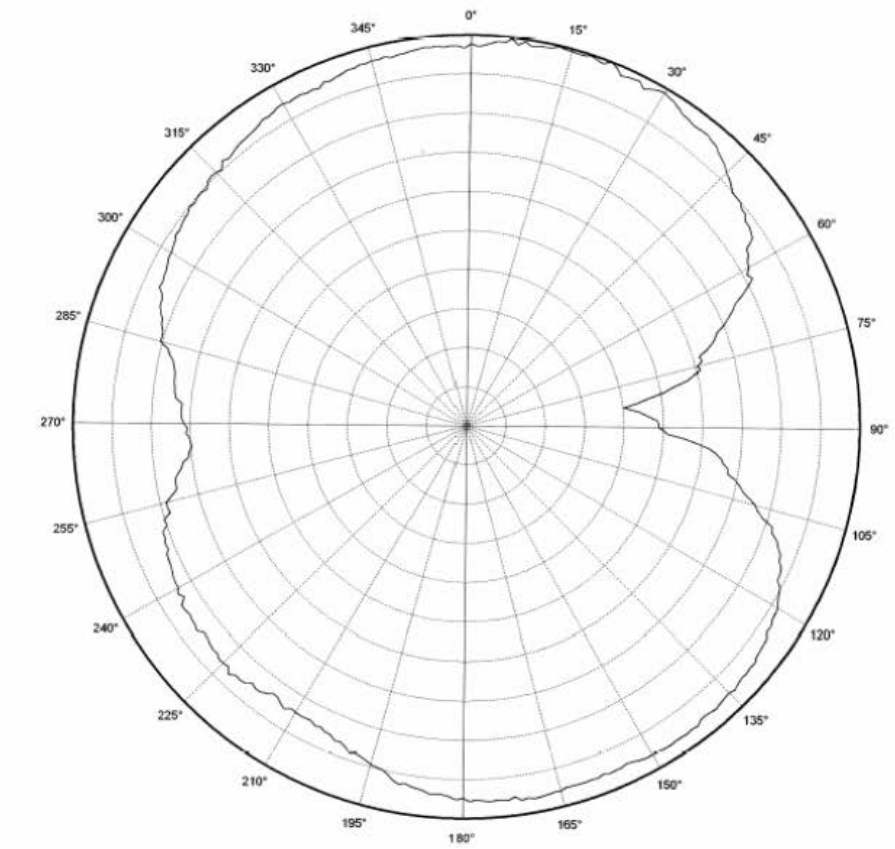


Figure 8. YZ Plane Horizontal Polarization

4.2 Reflection

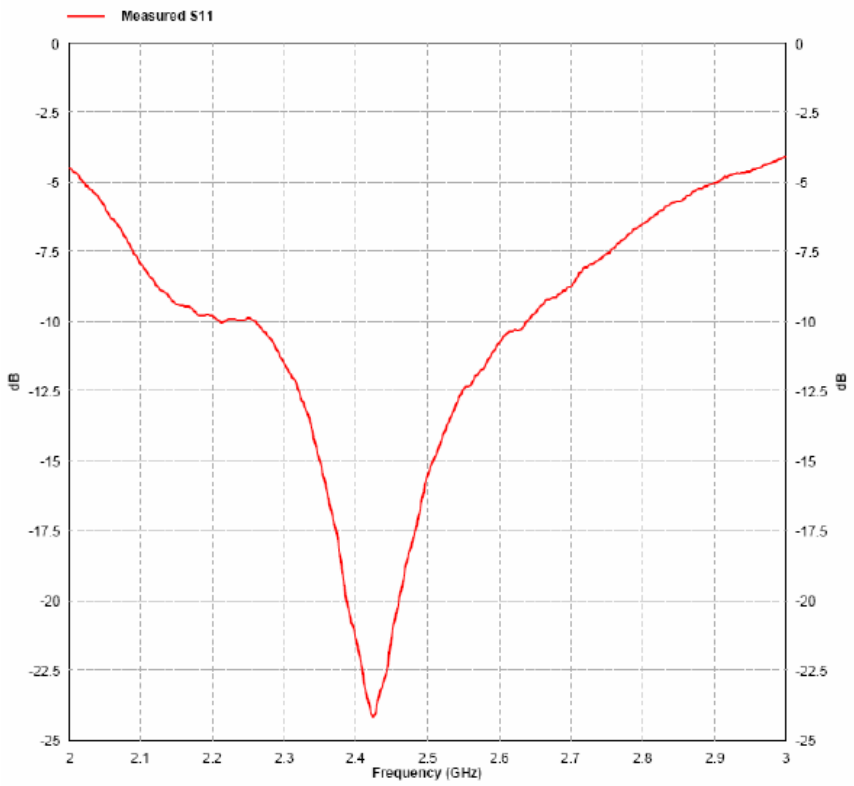


Figure 9. Measured Reflection at the Feed Point of the Antenna

Figure 9 show that the IFA ensures less than 10 % reflection of the available power for a bandwidth of more than 300 MHz. A large bandwidth makes the antenna less sensitive to detuning due to plastic encapsulation or other objects in the vicinity of the antenna.

4.3 Bandwidth

Another way of measuring the bandwidth after the antenna is implemented on a PCB and connected to a transmitter is to write test software that steps a carrier across the frequency band of interest. By using the "Max hold" function on a spectrum analyzer the variation in output power across frequency can easily be measured. Figure 10 shows how the output power varies on the IFA when the PCB is horizontally oriented and the receiving antenna has horizontal polarization. This measurement was not performed in an anechoic chamber thus the graph shows only the relative variation for the given frequency band.

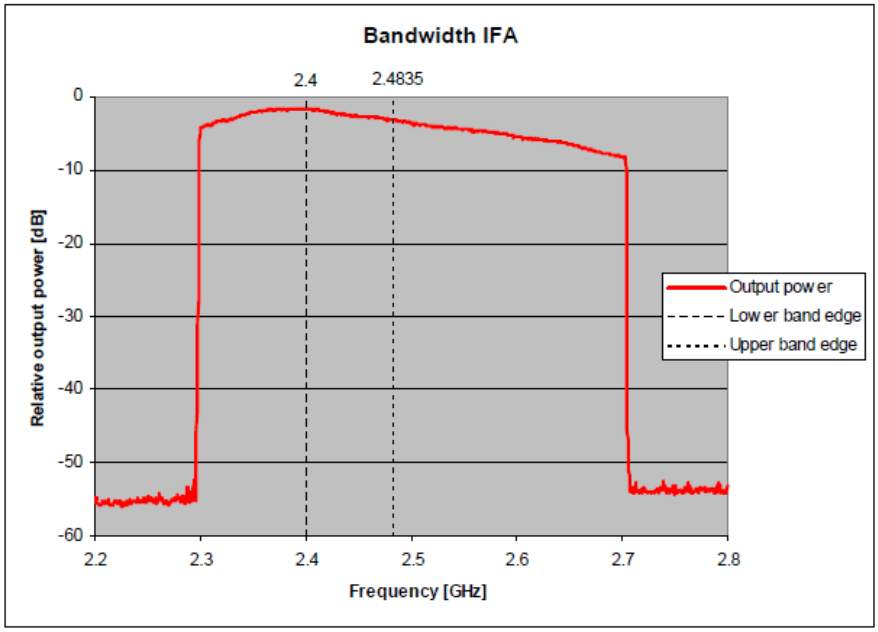


Figure 10. Bandwidth of IFA

5 Conclusion

The PCB antenna presented in this document performs well for all frequencies in the 2.4 GHz ISM band. Except for two narrow dips, the antenna has an omni directional radiation pattern in the plane of the PCB. These properties will ensure stable performance regardless of operating frequency and positioning of the antenna. Table 2 lists the most important properties for the inverted F antenna.

Gain in XY Plane	1.1 dB
Gain in XZ Plane	3.3 dB
Gain in YZ Plane	1.6 dB
Reflection	< -15 dB
Antenna Size	25.7 x 7.5 mm

Table 2. Summery of the Properties of the IFA

6 References

[1] CC2430DB Reference Design (swrr034.zip)

7 General Information

7.1 Document History

Revision	Date	Description/Changes
SWRU120B	2008-04-04	Renamed CCZACC06 to CC2480
SWRU120A	2008-02-28	Added reference to CCZACC06 and CC2520
SWRU120	2007-04-16	Initial release.

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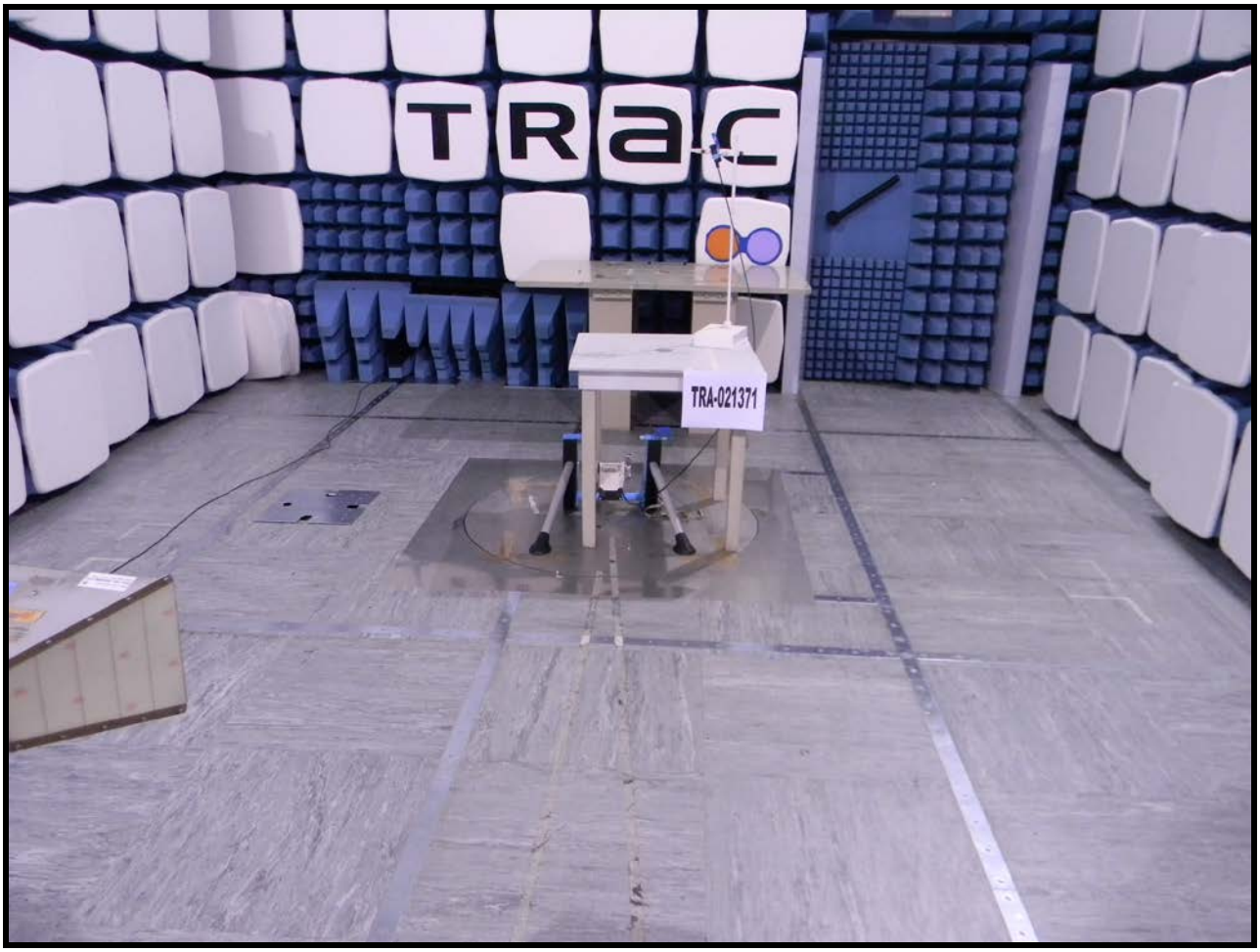
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Telephony	www.ti.com/telephony
RF/IF and ZigBee® Solutions	www.ti.com/lprf	Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

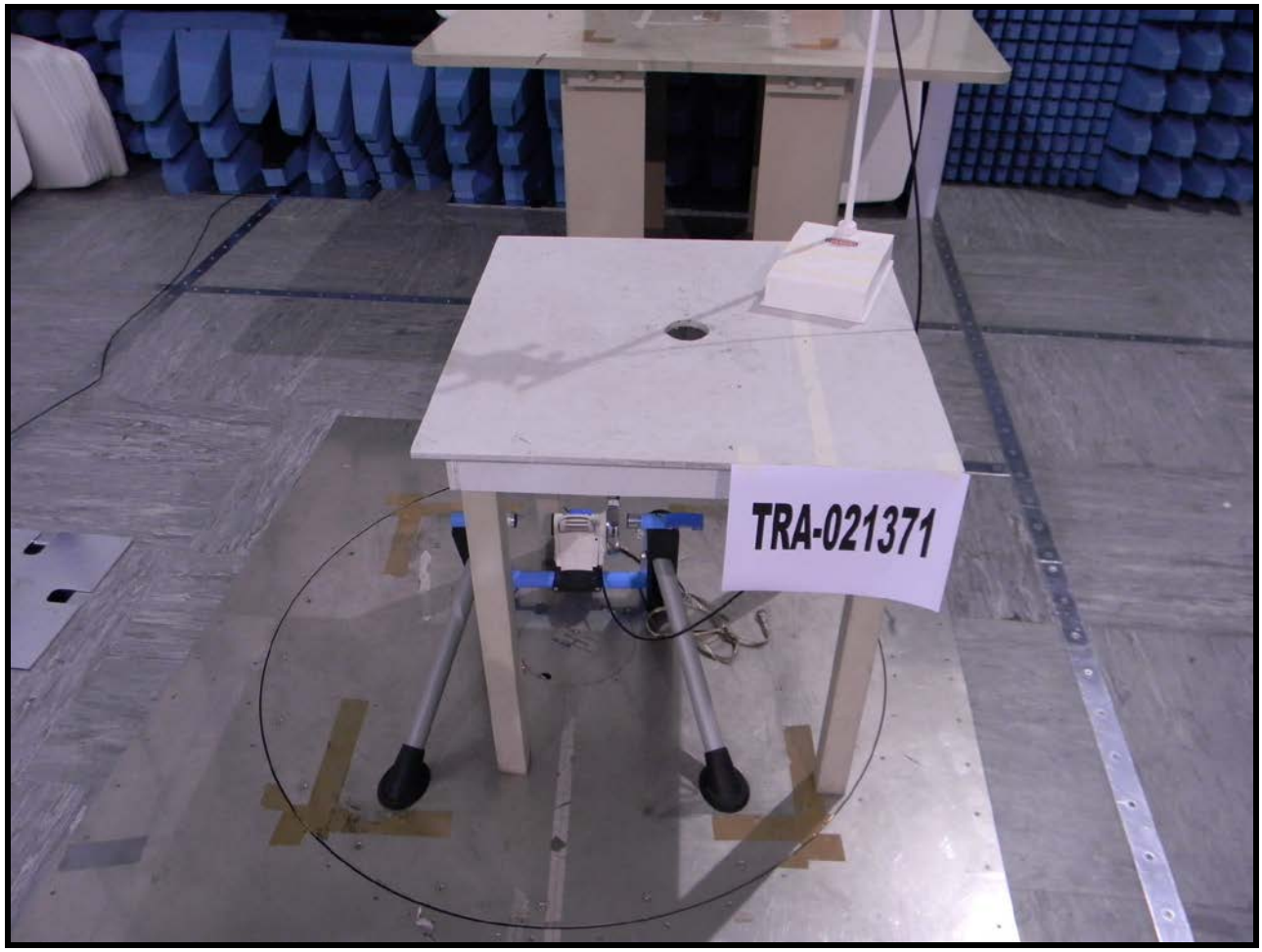
Appendix E: Photographs and Figures

The following photographs were taken of the test samples:

1. Radiated electric field emissions arrangement: Overview.
2. Radiated electric field emissions arrangement: Close up.



Photograph 1



Photograph 2

Appendix F: General SAR test reduction and exclusion guidance and MPE calculation

KDB 447498

Section 4.3 General SAR test reduction and exclusion guidance

For Standalone SAR exclusion consideration, when SAR Exclusion Threshold requirement in KDB 447498 is satisfied, standalone SAR evaluation for general population exposure conditions by measurement or numerical simulation is not required.

In the frequency range below 100 MHz to 6 GHz and test separation distance of 50mm, the SAR Test Exclusion Threshold for operation in the 2400 – 2483.5 MHz band will be determined as follows

SAR Exclusion Threshold

NT= $\{ [(MP/TSD) * \sqrt{f_{GHz}}] + (TSD – 50mm) * 10] \}$

Where:

NT	=	Numeric Threshold (3.0 for 1-g SAR and 7.5 for 10-g SAR)
MP	=	Max Power of channel (mW) (inc tune up)
TSD	=	Min Test separation Distance (mm) = 50
f_{GHz}	=	Transmit frequency (or 100MHz if lower)

We can transpose this formula to allow us to find the maximum power of a channel allowed and compare this to the measured maximum power.

MP= $\{ [(NT \times TSD) / \sqrt{f_{GHz}}] + (TSD – 50) * 10] \}$

Operating Frequency 2.402 GHz

MP= $\{ [(3.0 \times 50) / \sqrt{2.403}] + (50 – 50) * 10 \}$
MP= { [150 / 1.55] + (0 * 10 }
MP= 96.77mW

Operating Frequency 2.442 GHz

MP= $\{ [(3.0 \times 50) / \sqrt{2.442}] + (50 – 50) * 10 \}$
MP= { [150 / 1.56] + (0 * 10 }
MP= 96.15mW

Operating Frequency 2.480 GHz

MP= $\{ [(3.0 \times 50) / \sqrt{0.92760}] + (50 – 50) * 10 \}$
MP= { [150 / 1.57] + (0 * 10 }
MP= 95.54mW

Channel Frequency (MHz)	EIRP (mW)	SAR Exclusion Threshold	SAR Evaluation
2403	0.34	96.77	Not Required
2442	0.16	96.15	Not Required
2480	0.16	95.54	Not Required

Therefore standalone SAR evaluation for general population exposure conditions by measurement or numerical simulation is not required.

As per KDB 447498

47 CFR §§1.1307 and 2.1091

2.1091 Radio frequency radiation exposure evaluation: Portable devices.

For purposes of these requirements mobile devices are defined by the FCC as transmitters designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimetres is normally maintained between radiating structures and the body of the user or nearby persons. These devices are normally evaluated for exposure potential with relation to the MPE limits. As the 20cm separation specified under FCC rules may not be achievable under normal operation of the EUT, an RF exposure calculation is needed to show the minimum distance required to be less than 0.6mW/cm^2 power density limit, as required under FCC rules

Prediction of MPE limit at a given distance

Equation from KDB 447498 D01

$$S = \frac{1.64ERP}{4\pi R^2} \quad \text{re-arranged } R = \sqrt{\frac{1.64ERP}{S4\pi}}$$

where:

S = power density
R = distance to the centre of radiation of the antenna
ERP = EUT Maximum power

Result:

Prediction Frequency (MHz)	Maximum ERP (mW)	Power density limit (S) (mW/cm^2)	Distance (R) cm required to be less than 0.6mW/cm^2 (cm)
2403	0.21	0.6	0.21

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