A Radio Test Report

FOR

TACX BV

ON

Satori Smart

DOCUMENT NO. TRA-021371WUS1a

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TRaC Wireless Test Report	**:** TRA-021371WUS1a
Applicant	**:** TACX BV
Apparatus	**:** Satori Smart
Specification(s)	**:** CFR47 Part 15.247 (October 2013 Edition) IC RSS-210 Annex 8 Issue 8 (December 2010)
FCCID	**:** 2AAMI-T2400
ICID	**:** 11353A-T2400
Purpose of Test	**: Certification**
Authorised by	**:** 
	: Radio Product Manager
Issue Date	**:**26th September 2014
Authorised Copy Number	**:** *PDF*

Total number of pages : 80

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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 :

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1.3 Manufacturer

As above

1.4 Apparatus Assessed

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

Satori Smart

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

The apparatus can also communicate in ANT+ mode, the ANT+ 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
Radiated spurious emissions	Title 47 of the CFR: Part 15 Subpart C; 15.247	IC RSS-210 A8.5	ANSI C63.10:2009	Pass
Lower Band Edge emissions (Non-restricted bands)	Title 47 of the CFR: Part 15 Subpart C; 15.247	IC RSS-210 A8.5	ANSI C63.10:2009	Pass
Occupied Bandwidth	Title 47 of the CFR : Part 15 Subpart C; 15.247(a)(2)	IC RSS-210 A8.2 (a)	ANSI C63.10:2009	Pass
Carrier Power	Title 47 of the CFR : Part 15 Subpart C; 15.247(b)	IC RSS-210 A8.4 (4)	ANSI C63.10:2009	Pass
Power Spectral Density	Title 47 of the CFR : Part 15 Subpart C; 15.247(e)	IC RSS-210 A8.2 (b)	ANSI C63.10:2009	Pass
Unintentional Radiated Spurious Emissions	Title 47 of the CFR: Part 15 Subpart B; 15.109	IC RSS-210 A8.5	ANSI C63.10:2009	Pass
RF Safety	Title 47 of the CFR : Part 15 Subpart C; 15.247(b)(5)	-	-	-

Abbreviations used in the above table:

Mod : Modification
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 with the exception of testing at the Open Area Test Site 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 ISO/IEC 17025.

1.7 Deviations from Test Standards

There were no deviations from the standards tested to.

Section 2: Measurement Uncertainty

2.1 Application of Measurement Uncertainty

The following table contains the measurement uncertainties for measurements

The following procedure is used when determining the result of a measurement :

(i) If specification limits are not exceeded by the measured result, extended by the positive component of the expanded uncertainty interval at a confidence level of 95%, then a pass result is recorded.

(ii) Where a specification limit is exceeded by the result even when the result is decreased by the negative component of the expanded uncertainty interval, a fail result is recorded.

(iii) Where measured result is below a limit, but by a margin less than the positive measurement uncertainty component, it is not possible to record a pass based on a 95% confidence level. However, the result indicates that a pass result is more probable than a fail result.

(iv) Where a measured result is above a limit, but by a margin less than the negative measurement uncertainty component, it is not possible to record a fail based on a 95% confidence level. However the result indicates that a fail is more probable than a pass.

2.2 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 6 dB Bandwidth

Title 47 of the CFR: Part 15 Subpart (c) 15.247(a)(2) requires the measurement of the bandwidth of the transmission between the -6 dB points on the transmitted spectrum.

Test Details:	
Regulation	Title 47 of the CFR: Part 15 Subpart (c) 15.247(a)(2) IC RSS-210 8.2(a)
EUT sample number	S02
Modification state	0
SE in test environment	None
SE isolated from EUT	None
Temperature	20
EUT set up	Refer to Appendix C

Channel Frequency (MHz)	F_{lower} (MHz)	F_{Higher} (MHz)	Measured 6 dB Bandwidth (kHz)	Limit (kHz)	Result
2402	2401.641261	2402.319180	677.919	>500	Pass
2440	2439.640487	2440.311923	671.436	>500	Pass
2480	2479.633771	2480.318939	685.168	>500	Pass

Plots of the 6 dB bandwidth are contained in Appendix B of this test report.

A2 Transmitter Peak Output Power

Carrier power was verified with the EUT transmitting on its lowest, centre and highest carrier frequency in turn.

Test Details:	
Regulation	Title 47 of the CFR: Part15 Subpart (c) 15.247(b)(3) IC RSS-210 A8.4(4)
Measurement standard	ANSI C63.10
EUT sample number	S02
Modification state	0
SE in test environment	S01
SE isolated from EUT	None
EUT set up	Refer to Appendix C
Temperature	23

Channel Frequency (MHz)	Conducted Peak Carrier Power (W)	Antenna Gain (dBm)	EIRP (W)	Limit (W)	Result
2402	0.000064	3.3	0.000138	1	Pass
2440	0.000080	3.3	0.000172	1	Pass
2480	0.000141	3.3	0.000301	1	Pass

Notes:

Conducted Measurement

Measured Peak Carrier power includes highest gain of any antenna to be used.
Highest Gain of any antenna to be used = 3.3 dBi
Conducted measurements were performed with a test fixture which was calibrated using radiated EIRP measurements.

A3 Transmitter Power Spectral Density

Transmitter Power Spectral Density was verified with the EUT transmitting on its lowest, centre and highest carrier frequency in turn.

Test Details:	
Regulation	Title 47 of the CFR: Part15 Subpart (c) 15.247(b)(3) IC RSS-210 A8.2(b)
Measurement standard	ANSI C63.10
EUT sample number	S02
Modification state	0
SE in test environment	None
SE isolated from EUT	None
EUT set up	Refer to Appendix C
Temperature	23

Channel Frequency (MHz)	Conducted Peak Power Spectral Density (dBm/3kHz)	Limit (dBm/3kHz)	Result
2402	-23.3	8	Pass
2440	-24.6	8	Pass
2480	-23.7	8	Pass

Notes:

Conducted Measurement

Measured Power Spectral Density includes highest gain of any antenna to be used.
Highest Gain of any antenna to be used = 3.3 dBi
Conducted measurements were performed with a test fixture, carrier power measurements were taken in the test fixture to allow correlation with radiated results.
The resolution bandwidth on the analyser was set to 3kHz and trace set to max hold.
The span is set to 1.5MHz

A4 Lower Band-Edge Compliance

Preliminary scans were performed using a peak detector with the RBW = 100kHz. The radiated power test applies to spurious emissions that fall at the non-restricted band edges (see Section 15.205). The maximum permitted radiated power is 20dB below the carrier. The EUT was set to transmit on its lowest carrier frequency (the upper band edge falls in a restricted band see Appendix A5 of this report).

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: 2402 MHz	
Regulation	Title 47 of the CFR, Part 15 Subpart (c) Clause 15.247(d) and Clause 15.205 IC RSS-210 A8.5
Measurement standard	ANSI C63.10
Frequency range	30MHz – 25GHz
EUT sample number	S02
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)	1 & 2

Measurements were made, using a 100kHz RBW, of the carrier in the 2402MHz channel and of the signal received at the band edge (2400MHz) whilst the 2402MHz channel was active. The measured signal level at the lower band edge was 47.9dB below the carrier.

A5 Radiated Electric Field Emissions within the Restricted Bands of 15.205

Preliminary scans were performed using a peak detector with the RBW = 100kHz. The radiated electric field emission test applies to spurious emissions and harmonics that fall within the restricted bands listed in Section 15.205. The maximum permitted field strength is listed in Section 15.209. The EUT was set to transmit on its lowest, centre and highest carrier frequency.

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: 2402 MHz	
Regulation	Title 47 of the CFR, Part 15 Subpart (c) Clause 15.247(d) and Clause 15.205 IC RSS-210 A8.5
Measurement standard	ANSI C63.10
Frequency range	30MHz – 25GHz
EUT sample number	S02
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)	1 & 2

There were no spurious emissions detected within 20dB of the limit line.

Radiated Electric Field Emissions within the Restricted Band 15.205 continued:

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

Test Details: 2440 MHz	
Regulation	Title 47 of the CFR: Part 15 Subpart (c) Clause 15.247(d) and Clause 15.205 IC RSS-210 A8.5
Measurement standard	ANSI C63.10
Frequency range	30MHz to 25 GHz
EUT sample number	S02
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)	1 & 2

There were no spurious emissions detected within 20dB of the limit line.

Radiated Electric Field Emissions within the Restricted Band 15.205 continued:

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

Test Details: 2480 MHz	
Regulation	Title 47 of the CFR: Part 15 Subpart (c) Clause 15.247(d) and Clause 15.205 IC RSS-210 A8.5
Measurement standard	ANSI C63.10
Frequency range	30MHz to 25 GHz
EUT sample number	S02
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)	1 & 2

The worst case radiated emission measurements for spurious emissions and harmonics that fall within the restricted bands are listed below:

Ref No.	FREQ. (MHz)	Det	MEAS Rx (dBµV)	CABLE LOSS (dB)	ANT FACT. (dB/m)	PRE AMP (dB)	FIELD ST'GH (dBµV/m)	EXTRAP FACT (dB)	FIELD ST'GH (µV/m)	LIMIT (µV/m)
1.	2483.5	Pk	52.8	4.9	29.9	34.6	53.0	0	446.7	5000
2.	2483.5	Av	43.7	4.9	29.9	34.6	43.8	0	154.9	500

There were no further spurious emissions detected within 20dB of the limit line.

Notes:

1 Any testing performed below 30 MHz was performed using a magnetic loop antenna in accordance with ANSI C63.10: section 4.5, Table 1
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 Measurements at 2400 & 2483.5 MHz were made to ensure band edge compliance.
4 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.
5 For Frequencies below 1 GHz, RBW= 100 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=VBW= 1MHz
Average RBW=VBW= 1MHz

These settings as per ANSI C63.10

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 emissions falling within the restricted bands defined in 15.205(a):

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

Notes:

(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:

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

The results displayed take into account applicable antenna factors and cable losses.

(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

A7 Antenna Gain

The maximum antenna gain for the antenna types to be used with the EUT, as declared by the client, is 3.3 dBi.

A8 Unintentional Radiated Electric Field Emissions - 15.109

Preliminary scans were performed using a peak detector with the RBW = 100kHz. The maximum permitted field strength is listed in Section 15.109. The EUT was set to receive only 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]

Test Details: Receive Mode	
Regulation	Title 47 of the CFR: Part 15 Subpart (b) Clause 15.109 IC RSS-210 A8.5
Measurement standard	ANSI C63.10
Frequency range	30MHz to 25 GHz
EUT sample number	S02
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)	1 & 2

There were no spurious emissions detected within 20dB of the limit line.

Notes:

1 Any testing performed below 30 MHz was performed using a magnetic loop antenna in accordance with ANSI C63.10: section 4.5, Table 1

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 For Frequencies below 1 GHz, RBW= 100 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=VBW= 1MHz
Average RBW=VBW= 1MHz

These settings as per ANSI C63.10

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):

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

Notes:

(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:

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

The results displayed take into account applicable antenna factors and cable losses.

(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:

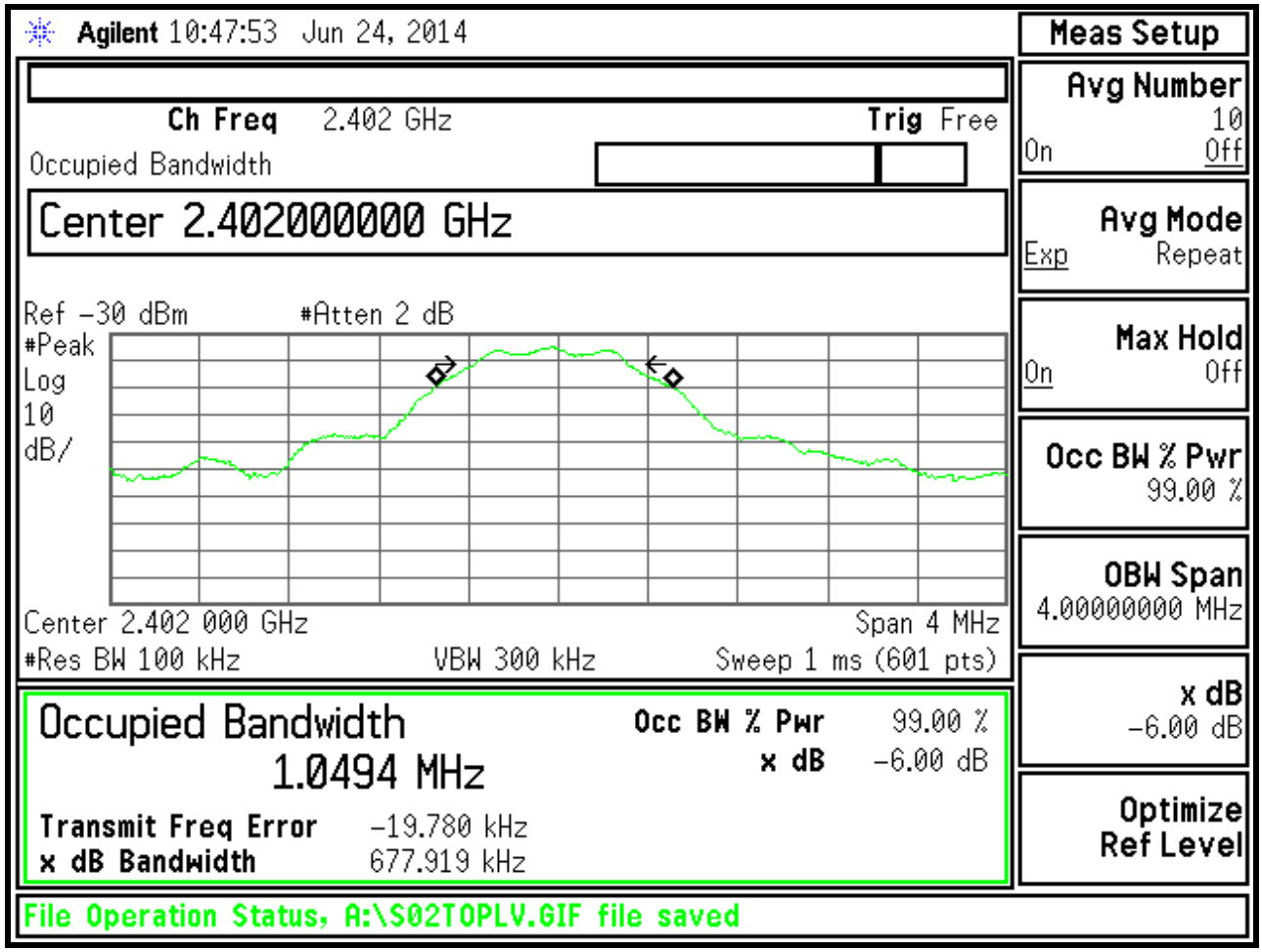
(a) The radiated electric field emissions and conducted emissions graphical data in this appendix is preview data. For details of formal results, refer to Appendix A and Appendix B.

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

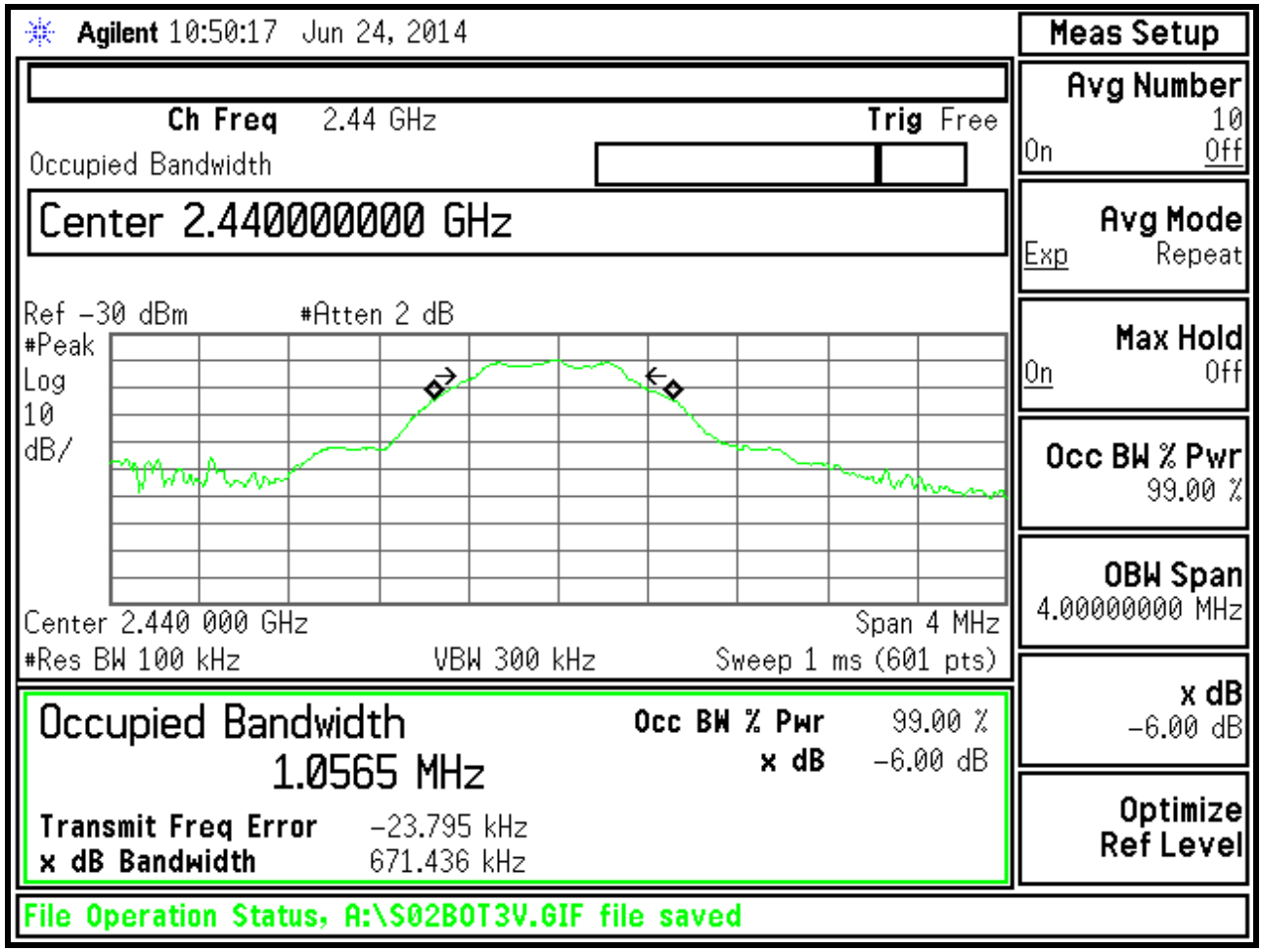
(c) Where relevant, on power line conducted emission plots, the limit displayed is the average limit, which is stricter than the quasi peak limit.

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

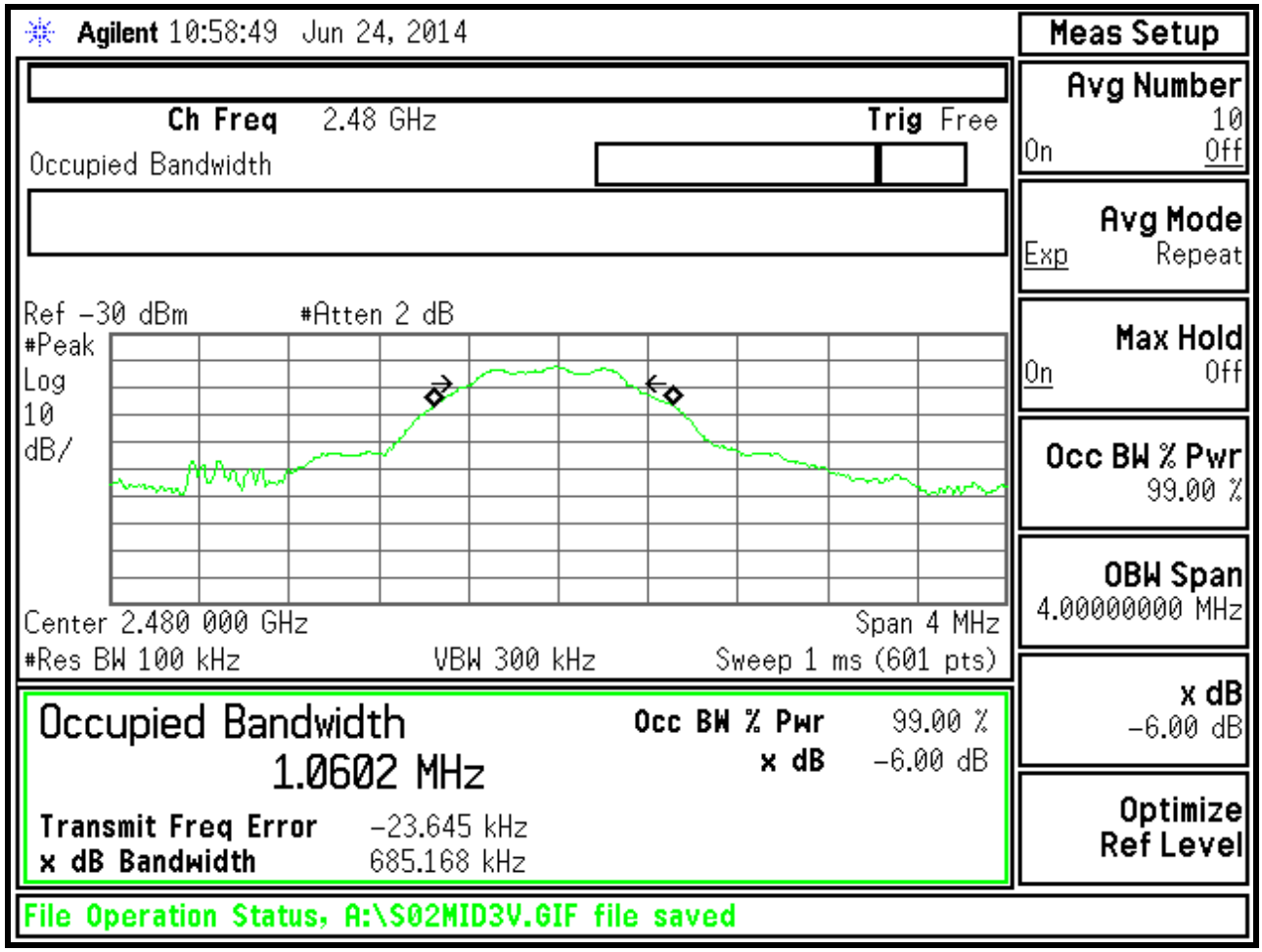
(e) The plots presented in this appendix may not be a complete record of the measurements performed, but are a representative sample, relative to the final assessment.



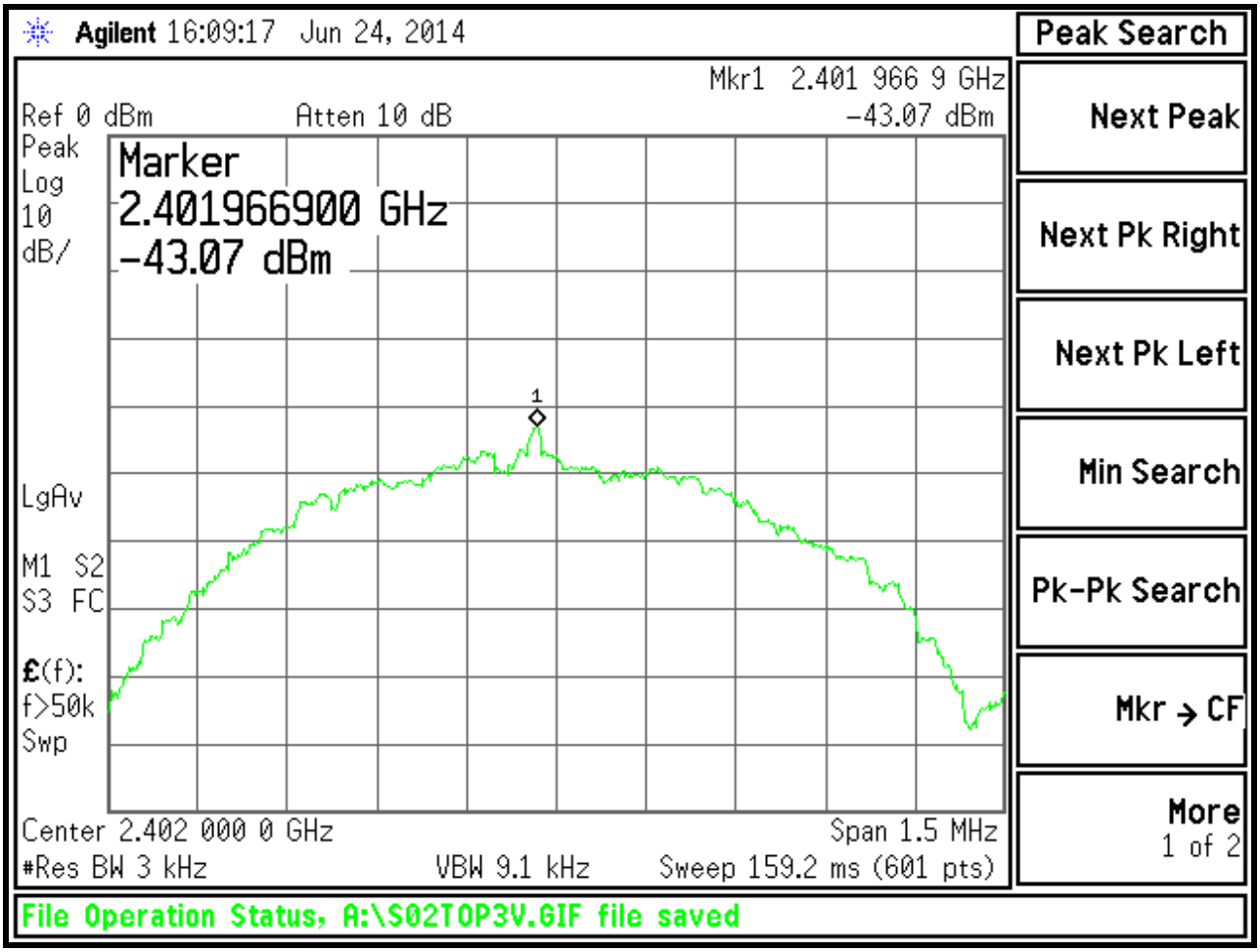
6dB Bandwidth – 2402MHz channel



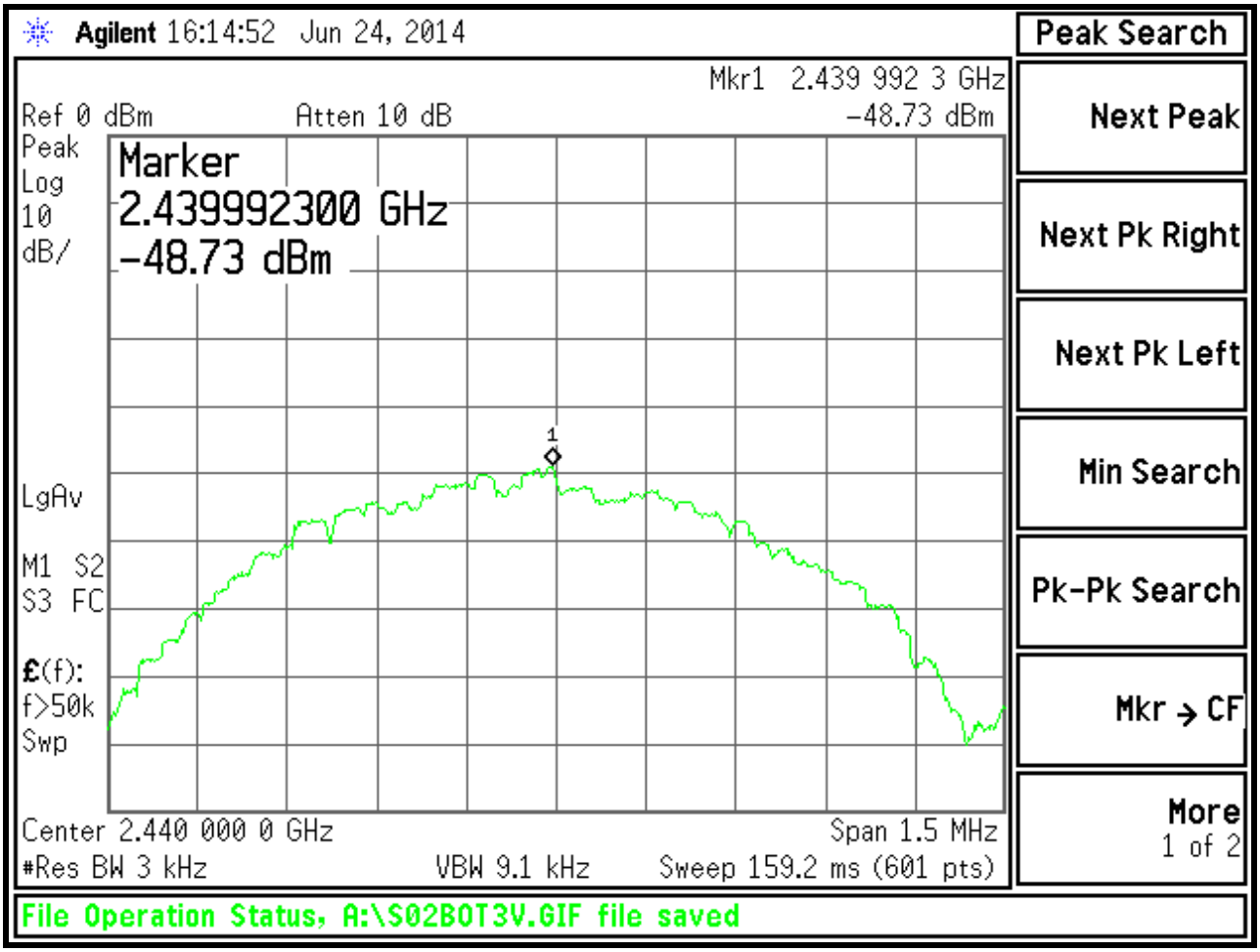
6dB Bandwidth – 2440MHz channel



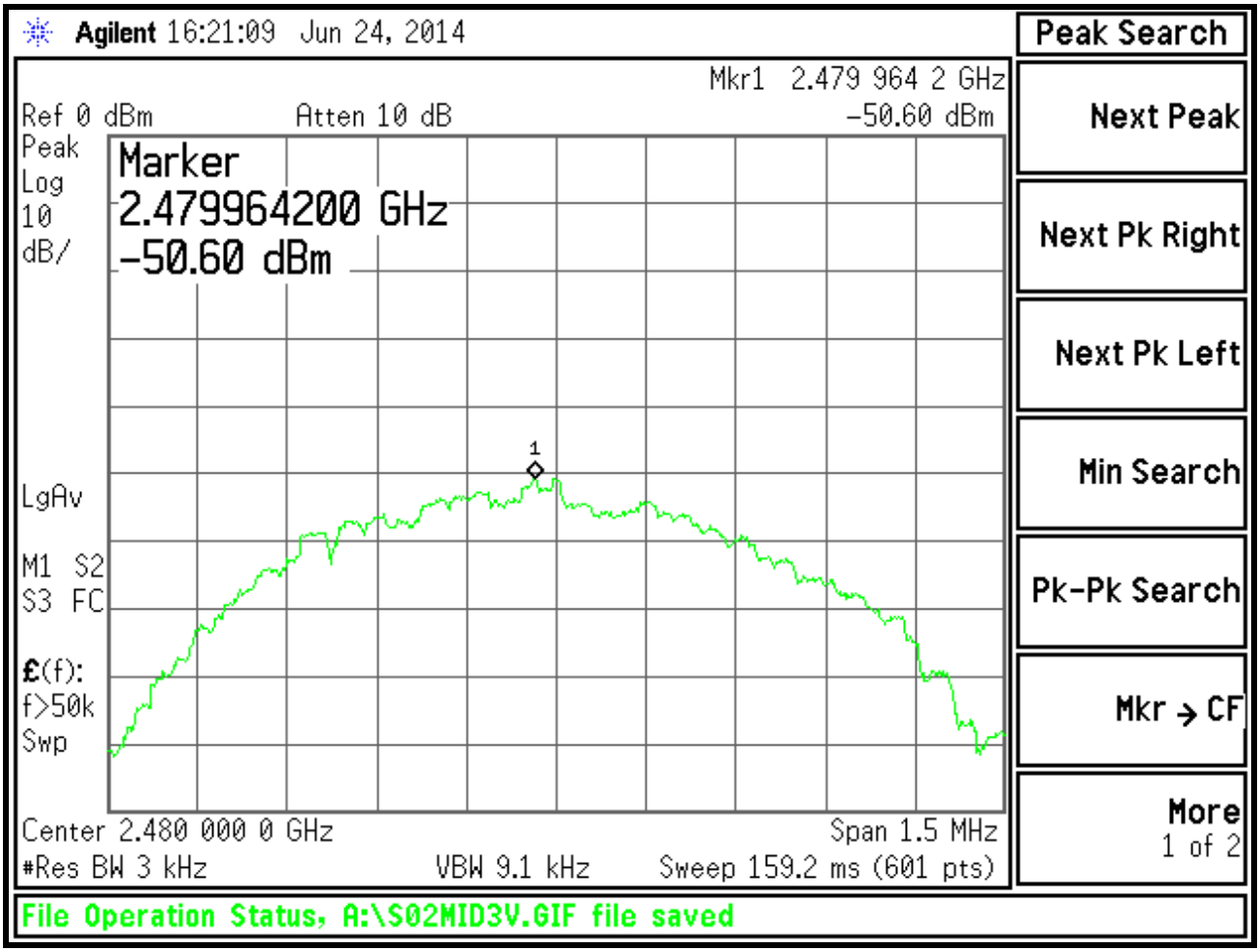
6dB Bandwidth – 2480MHz channel



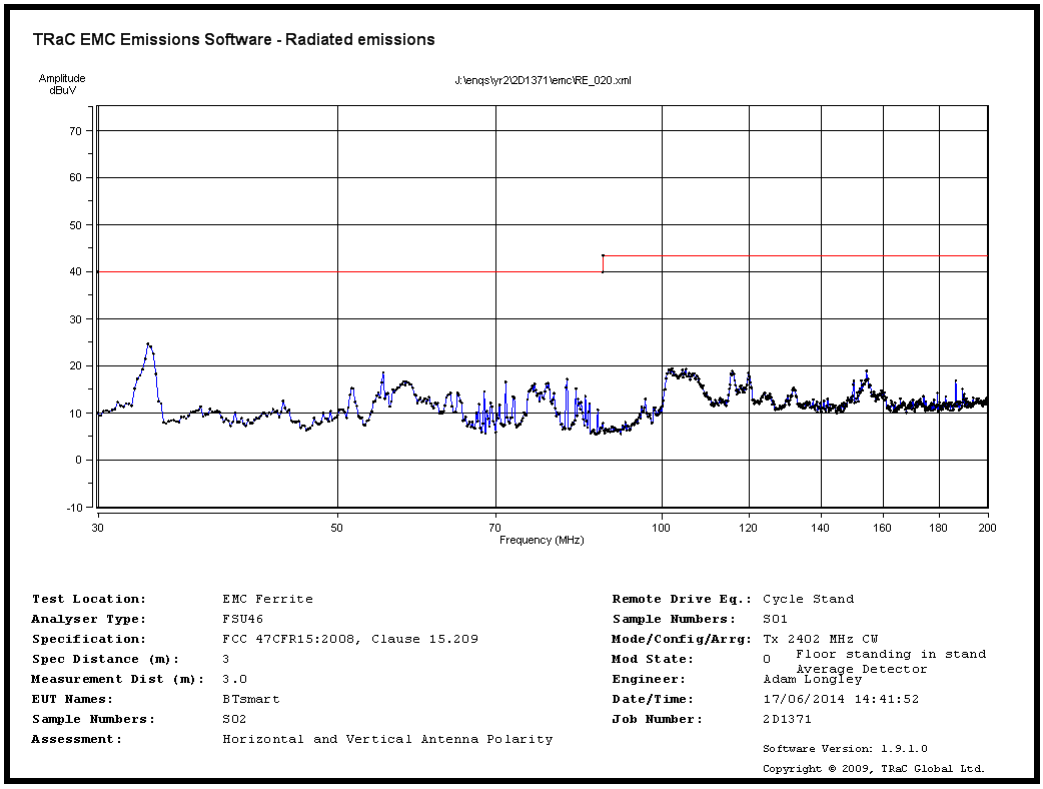
Conducted power spectral density 2402MHz
Test Fixture correction : +19.75 dB



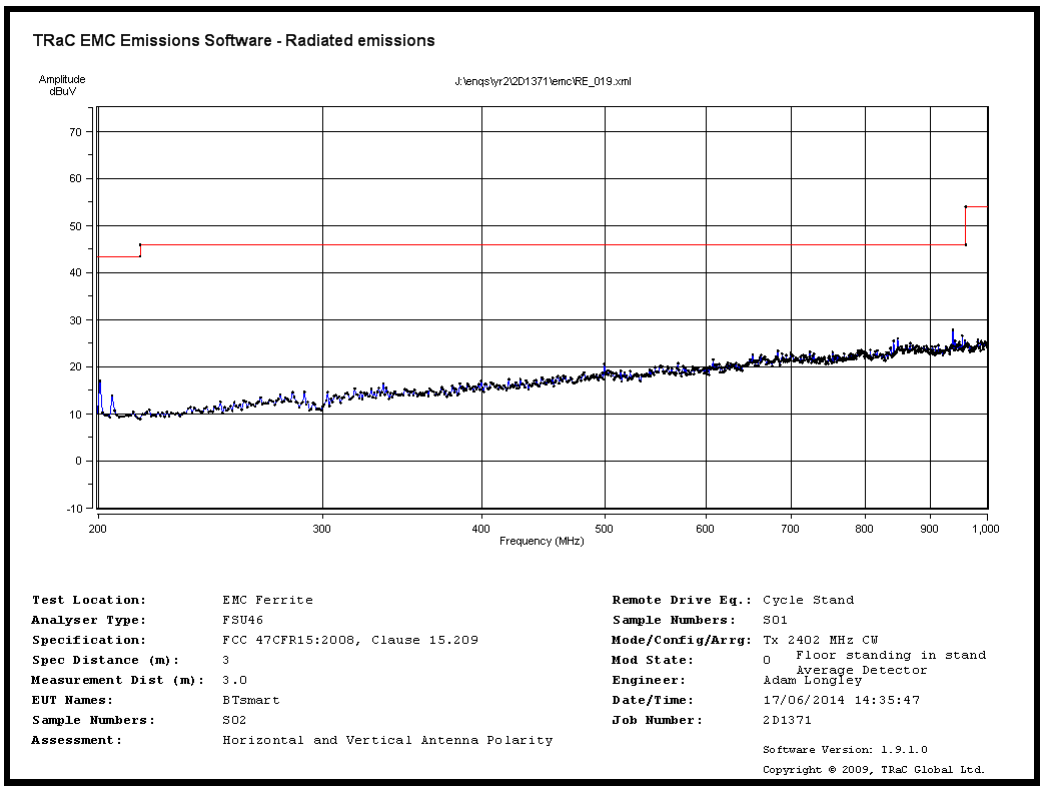
Conducted power spectral density 2440 MHz
Test Fixture correction : +24.18dB



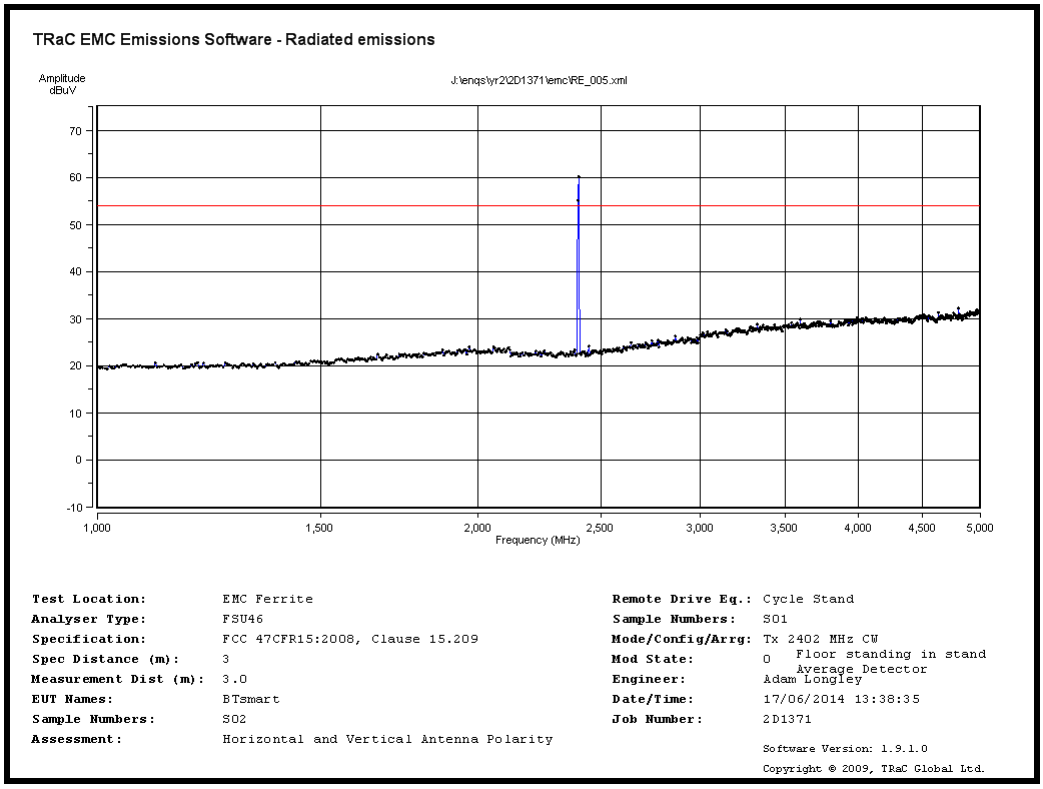
Conducted power spectral density 2480 MHz
Test Fixture correction : +26.93dB



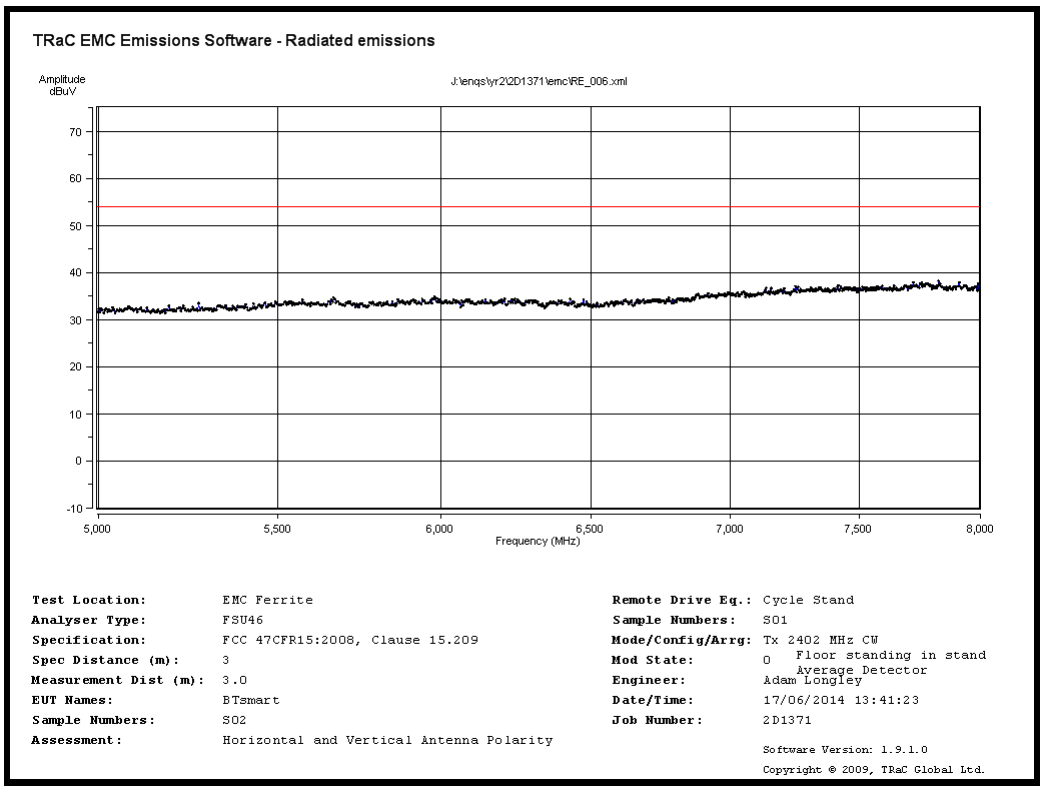
Radiated Spurious emissions 30 MHz to 200 MHz – 2402MHz



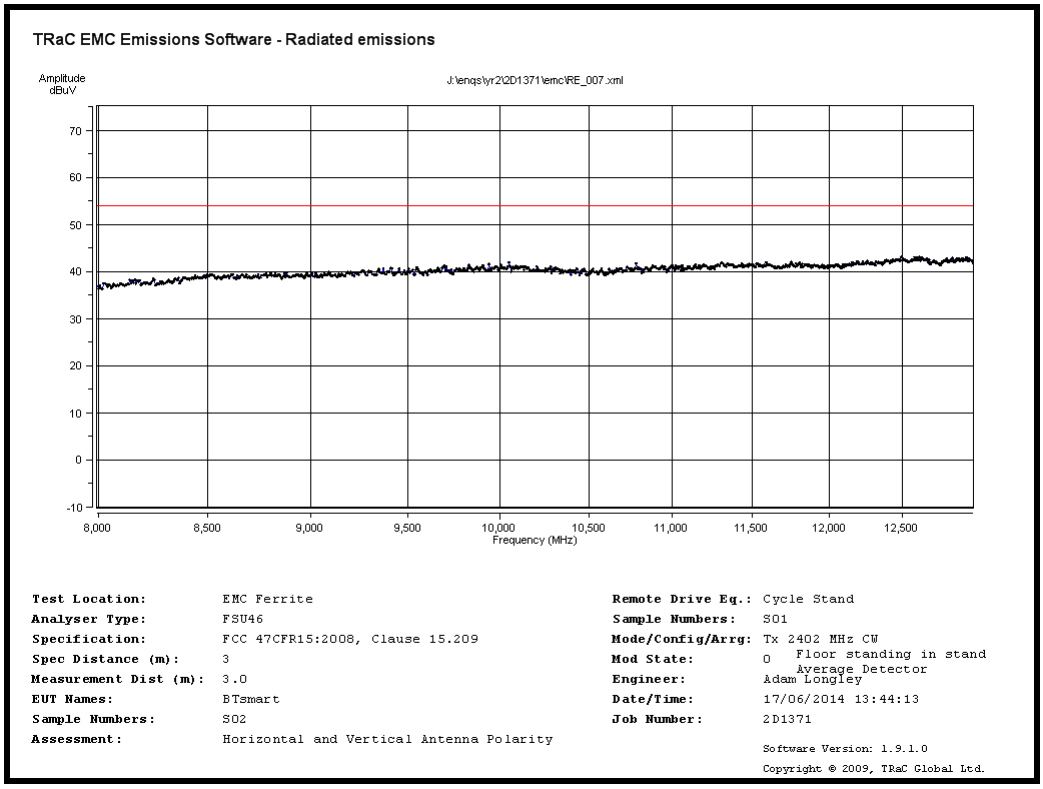
Radiated Spurious emissions 200 MHz to 5 GHz – 2402MHz



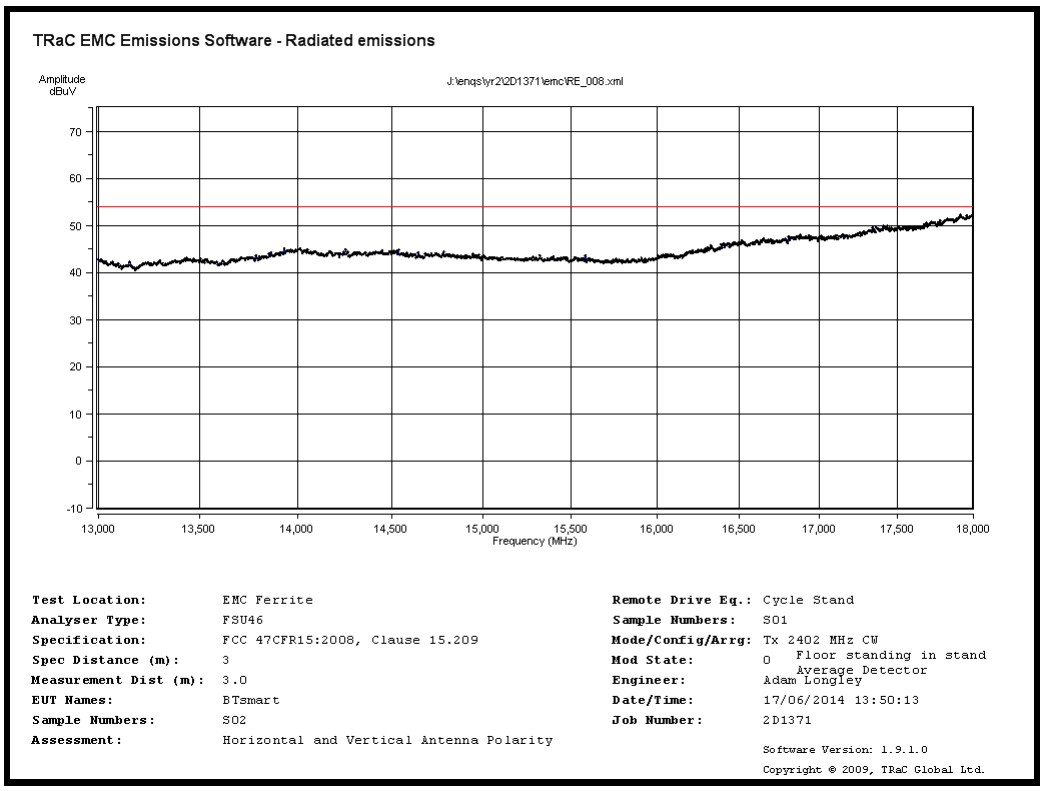
Radiated Spurious emissions 1 GHz to 5 GHz – 2402MHz



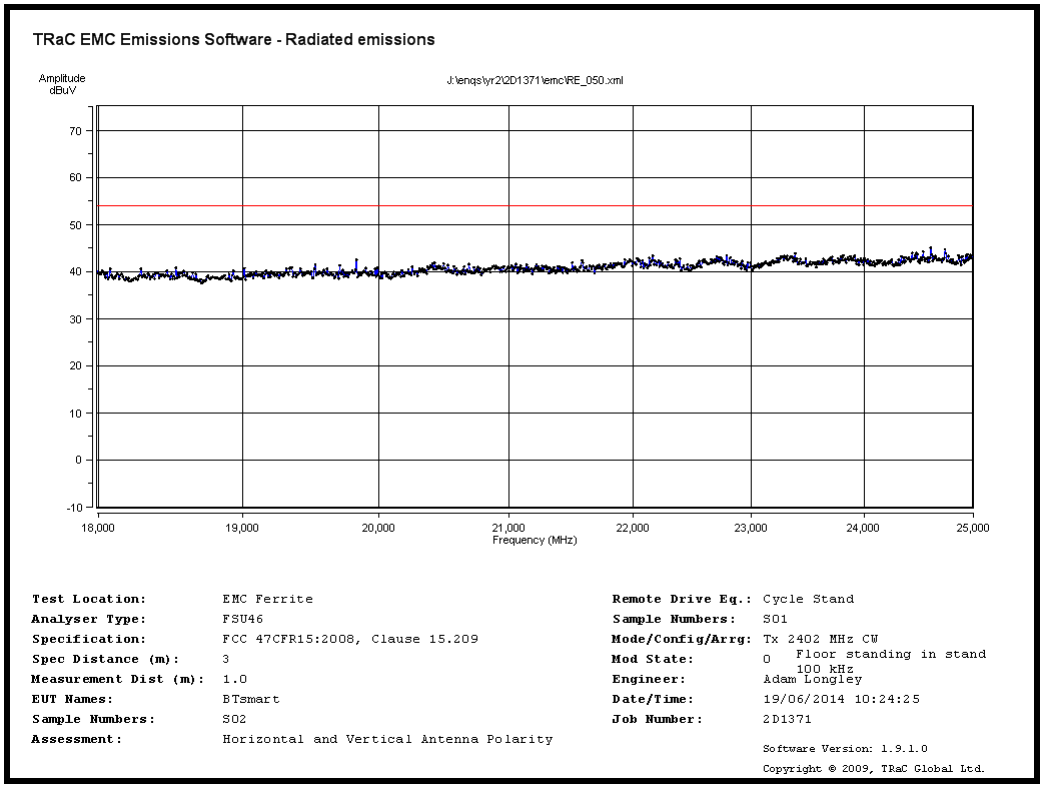
Radiated Spurious emissions 5 GHz to 8 GHz – 2402MHz



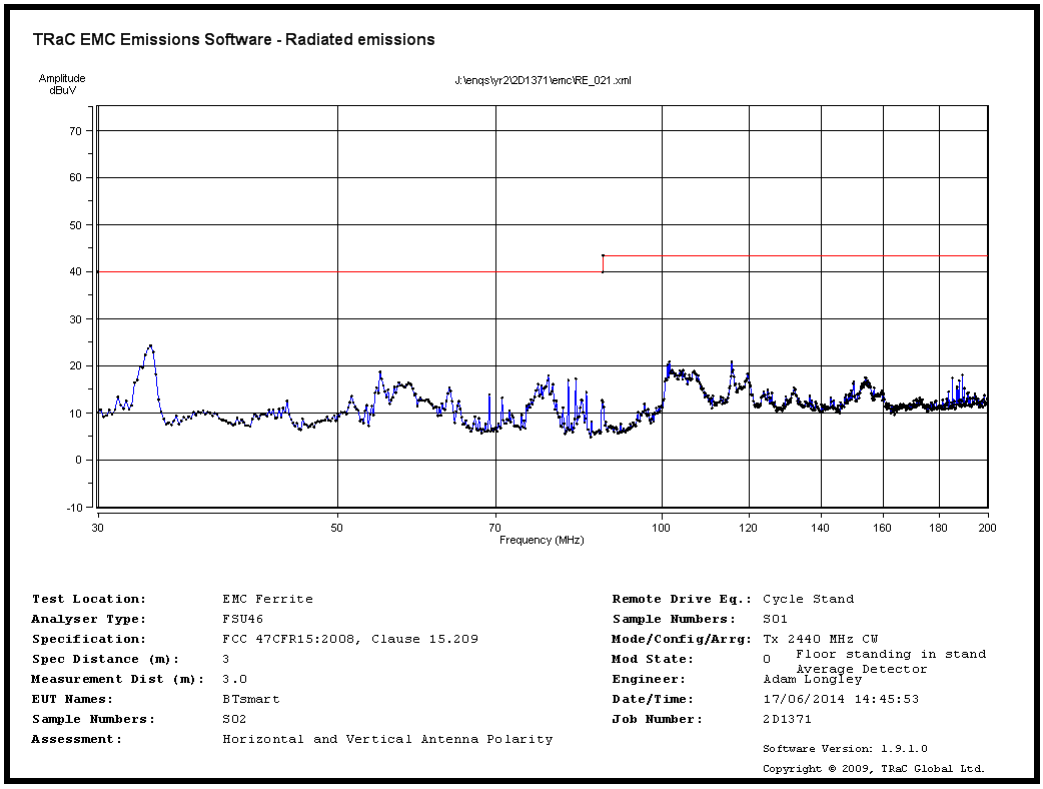
Radiated Spurious emissions 8 GHz to 13 GHz – 2402MHz



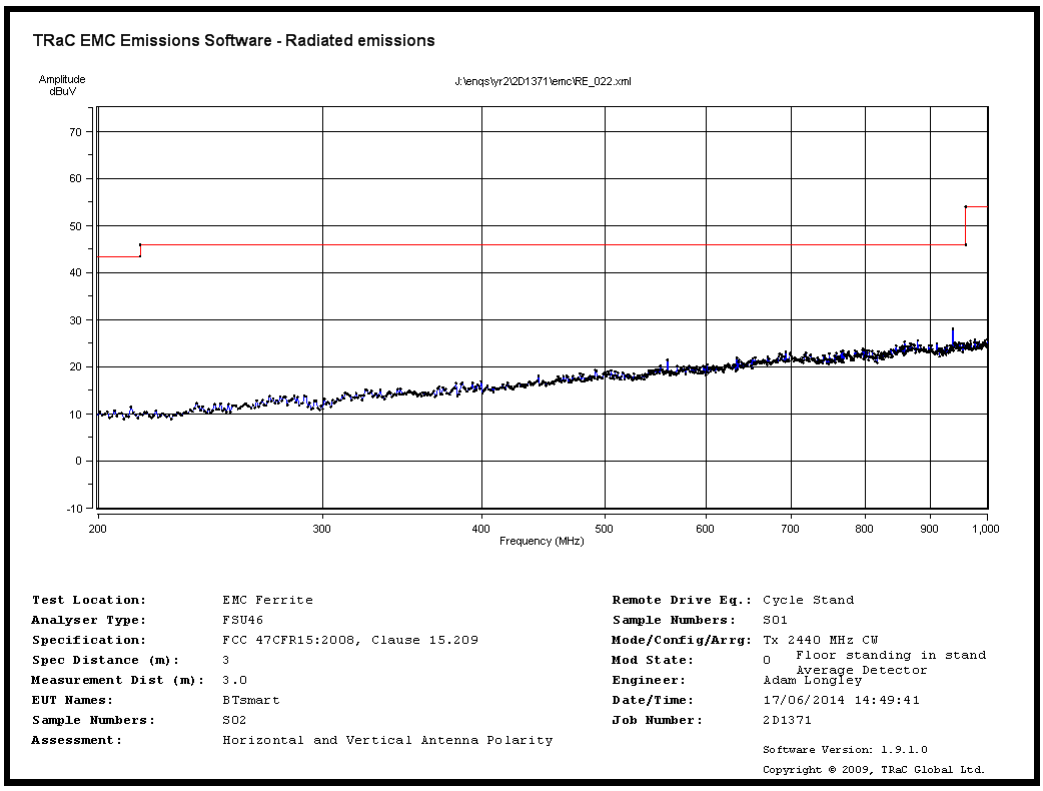
Radiated Spurious emissions 13 GHz to 18GHz – 2402MHz



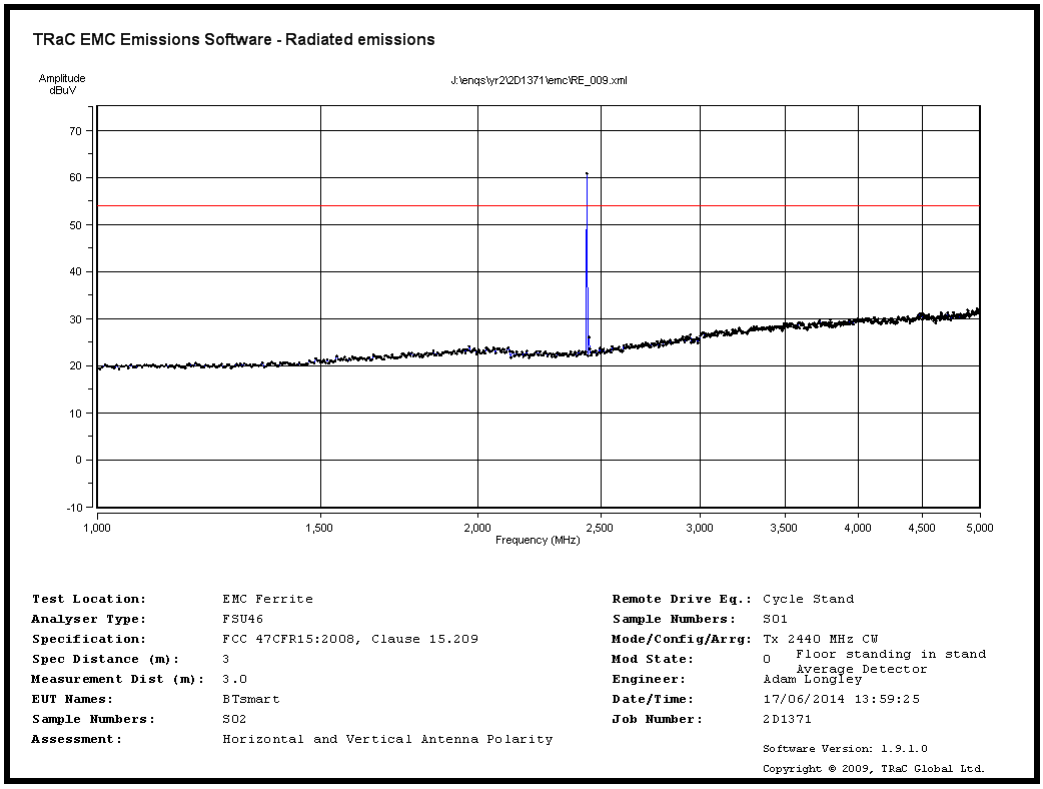
Radiated Spurious emissions 18 GHz to 25 GHz – 2402MHz



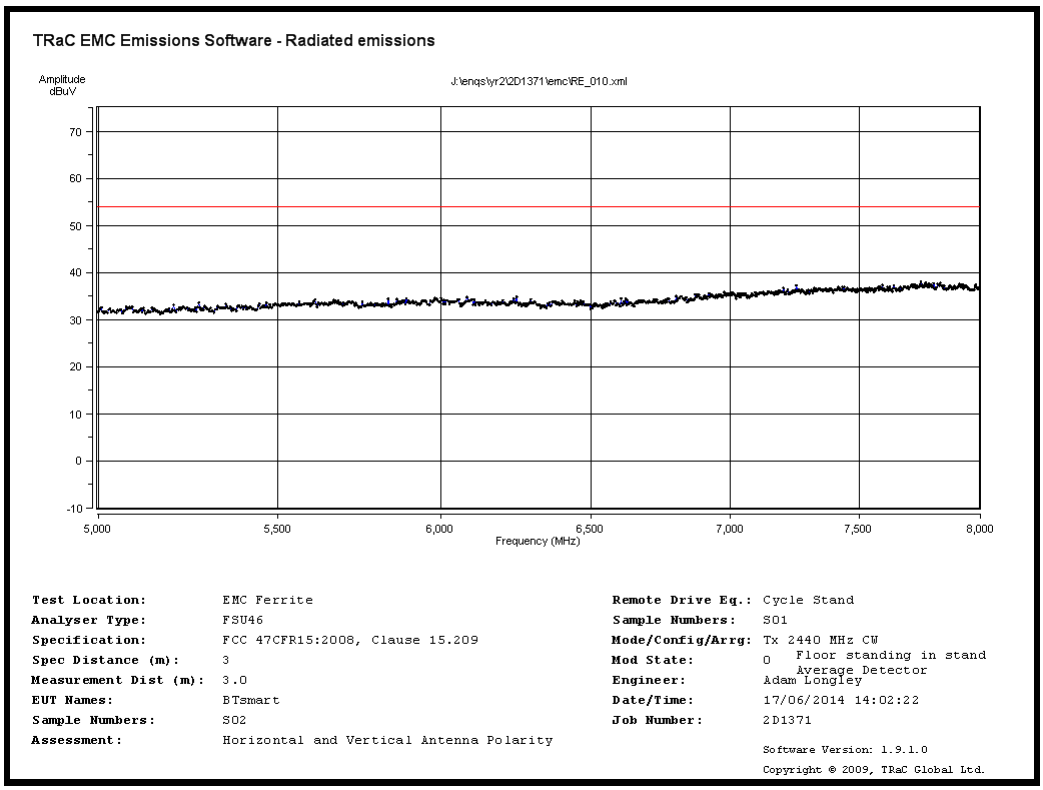
Radiated Spurious emissions 30 MHz to 200 MHz – 2440MHz



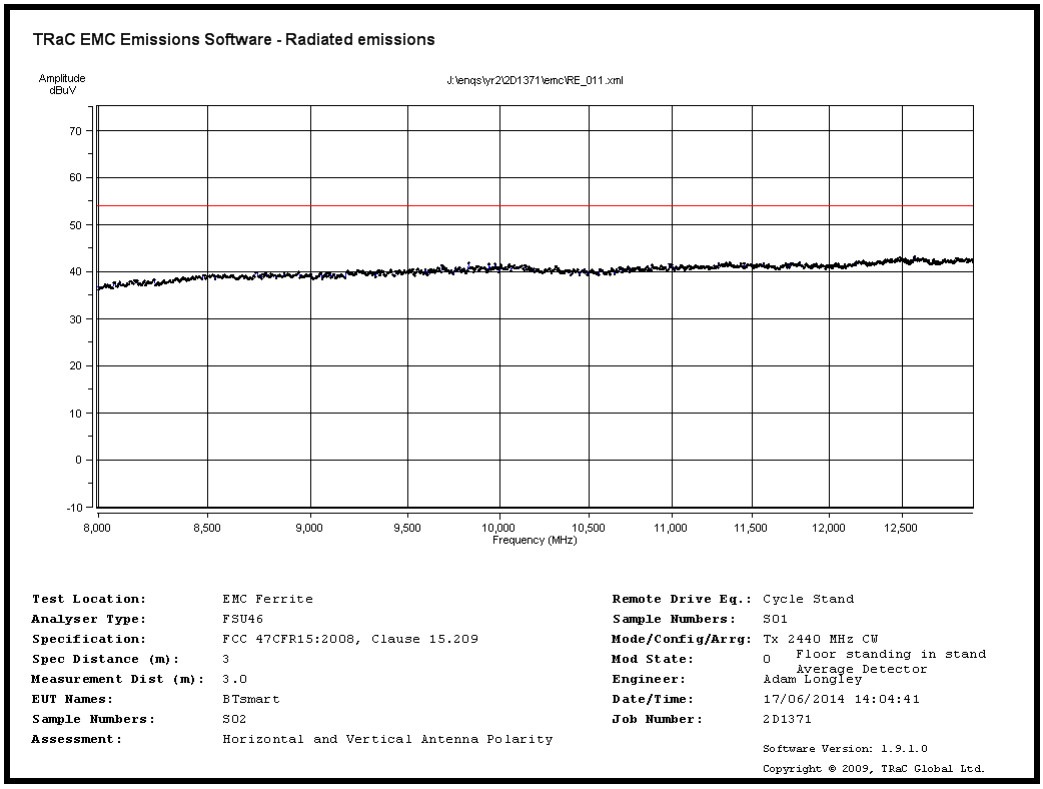
Radiated Spurious emissions 200 MHz to 1 GHz – 2440MHz



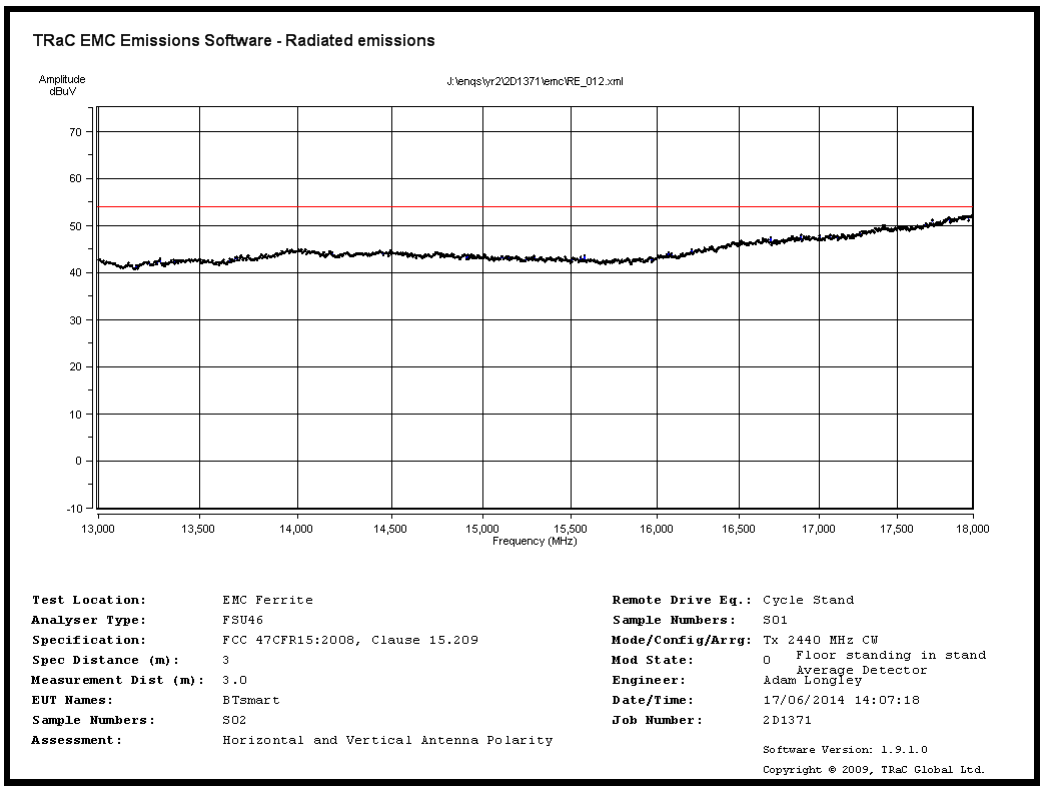
Radiated Spurious emissions 1 GHz to 5 GHz – 2440MHz



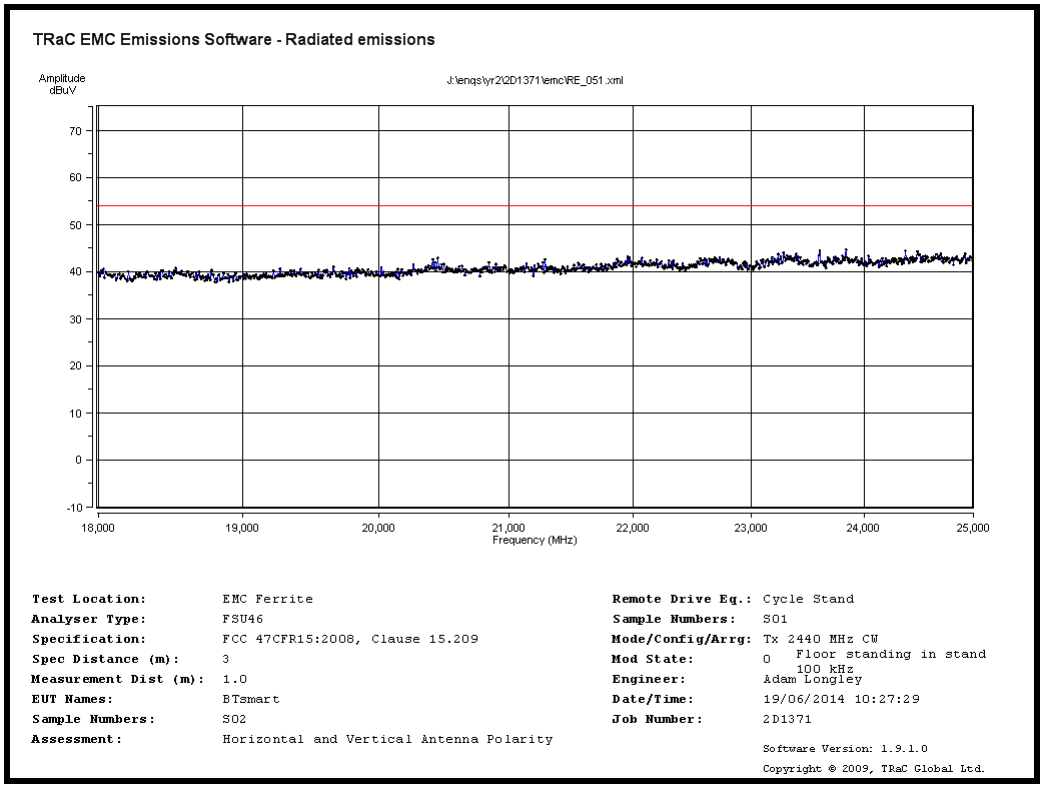
Radiated Spurious emissions 5 GHz to 8 GHz – 2440MHz



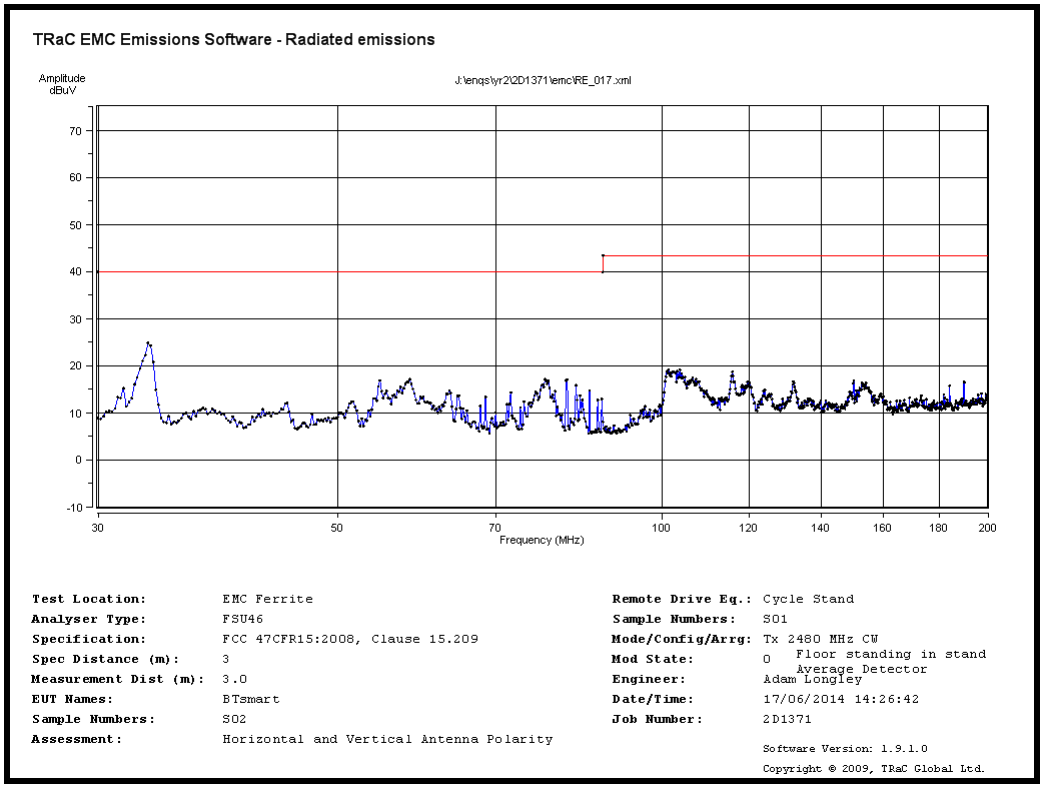
Radiated Spurious emissions 8 GHz to 13 GHz – 2440MHz



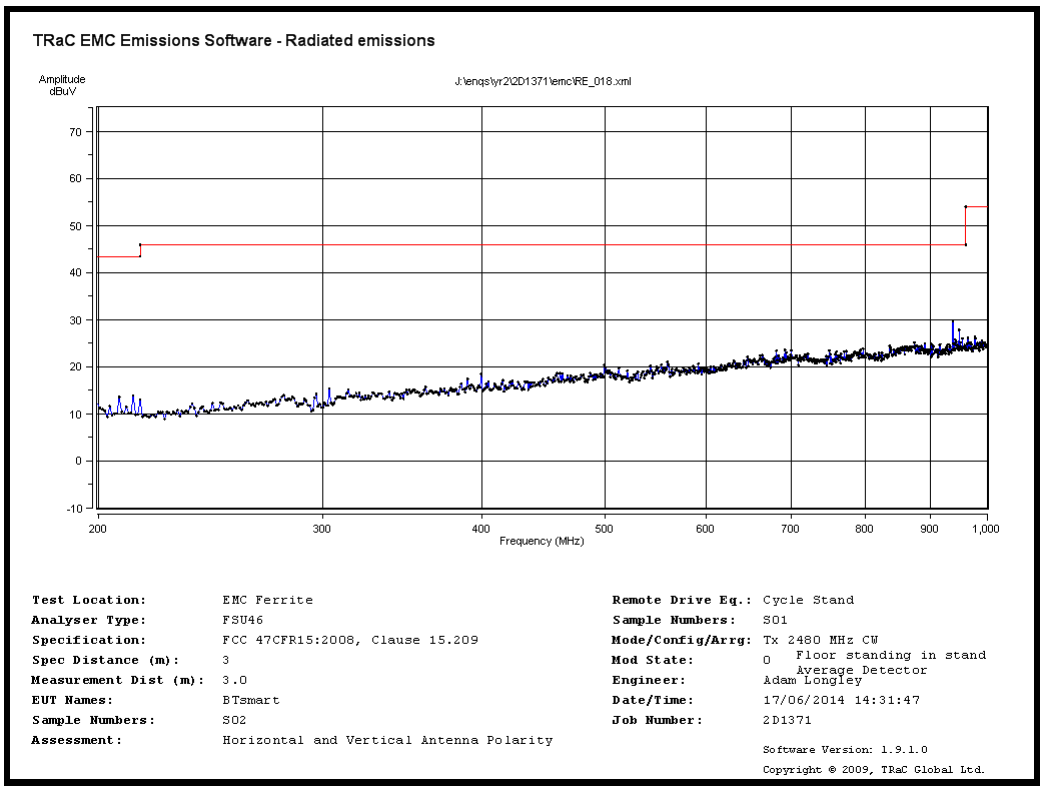
Radiated Spurious emissions 13 GHz to 18GHz – 2440MHz



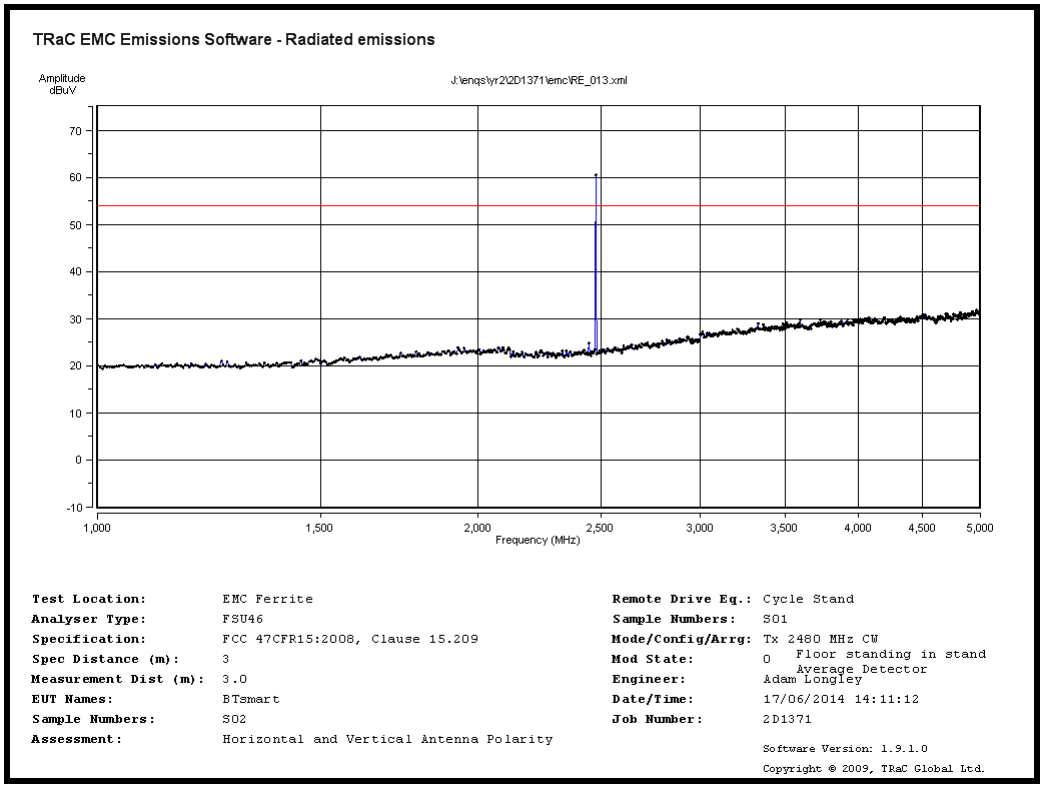
Radiated Spurious emissions 18 GHz to 25 GHz – 2440MHz



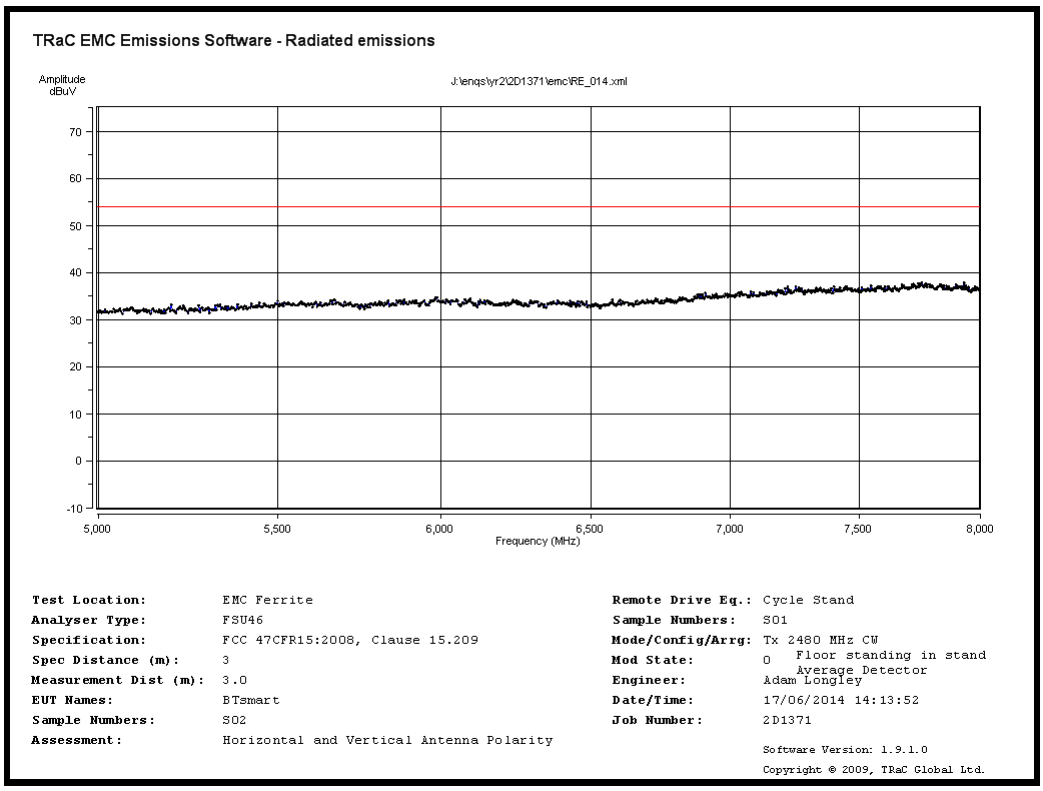
Radiated Spurious emissions 30 MHz to 200 MHz – 2480MHz



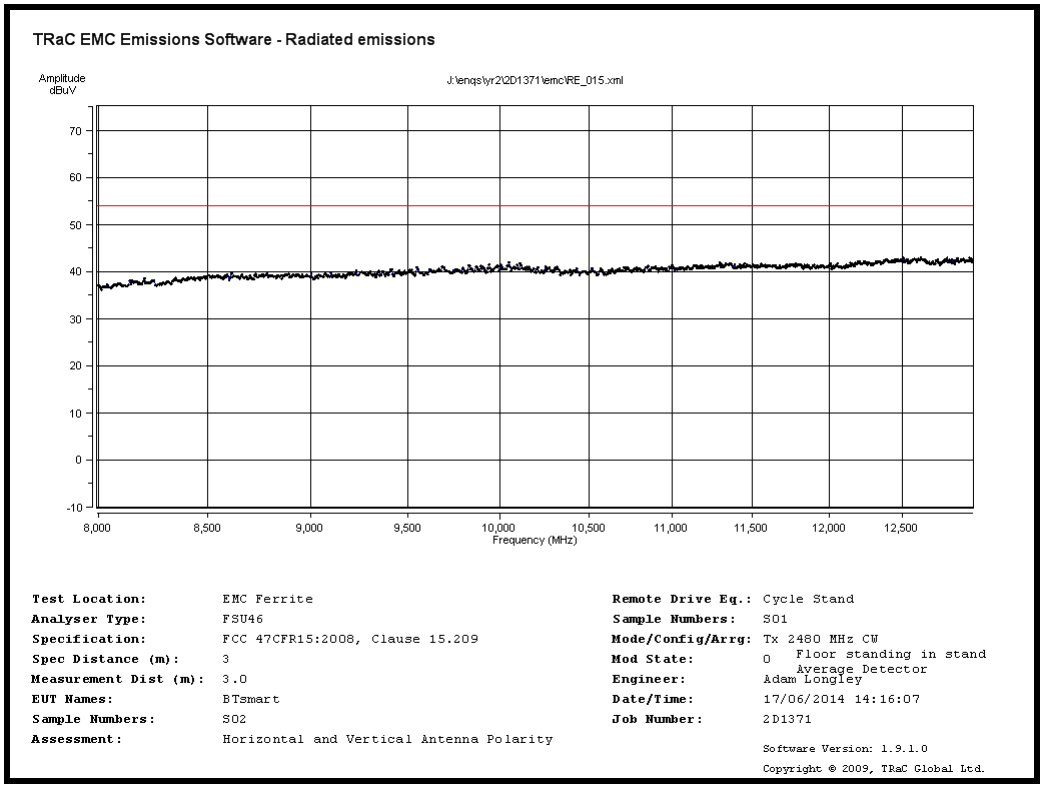
Radiated Spurious emissions 200 MHz to 1 GHz – 2480MHz



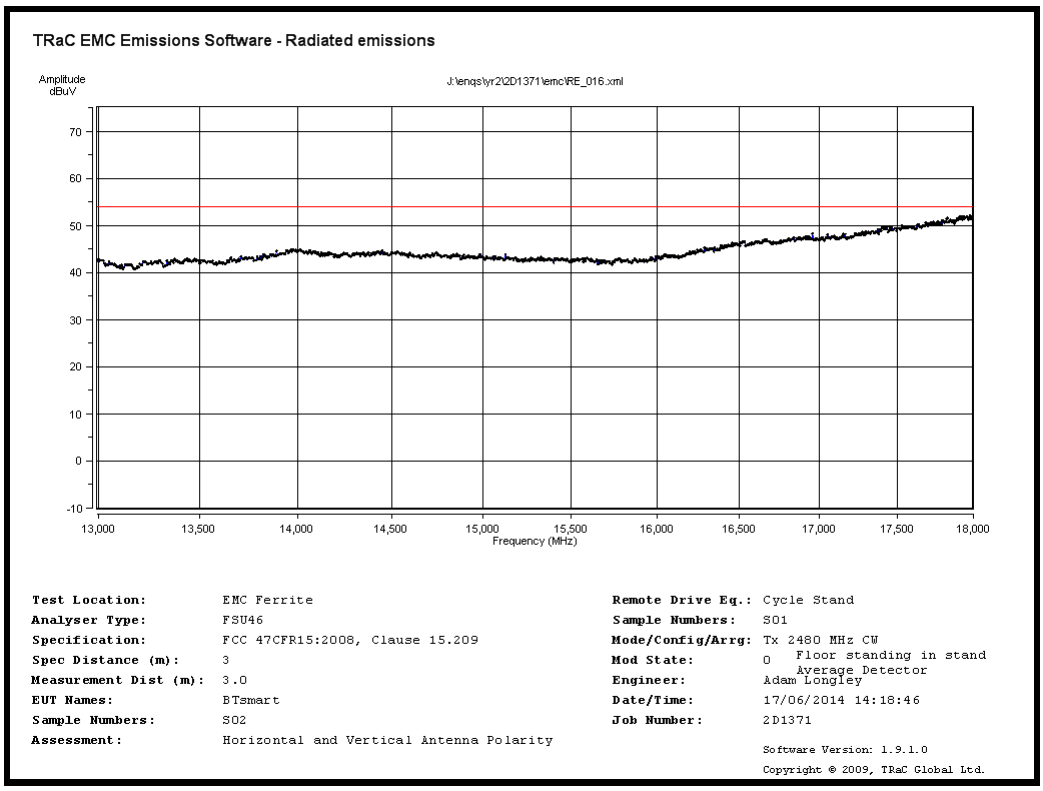
Radiated Spurious emissions 1 GHz to 5 GHz – 2480MHz



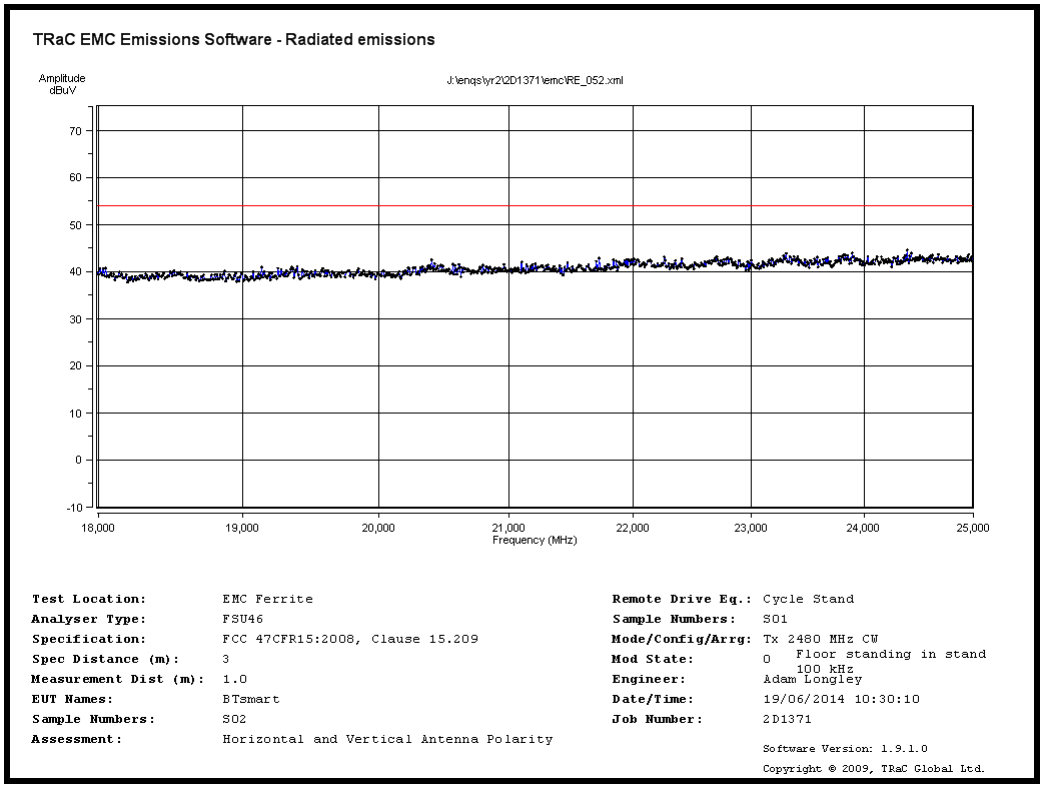
Radiated Spurious emissions 5 GHz to 8 GHz – 2480MHz



Radiated Spurious emissions 8 GHz to 13 GHz – 2480MHz

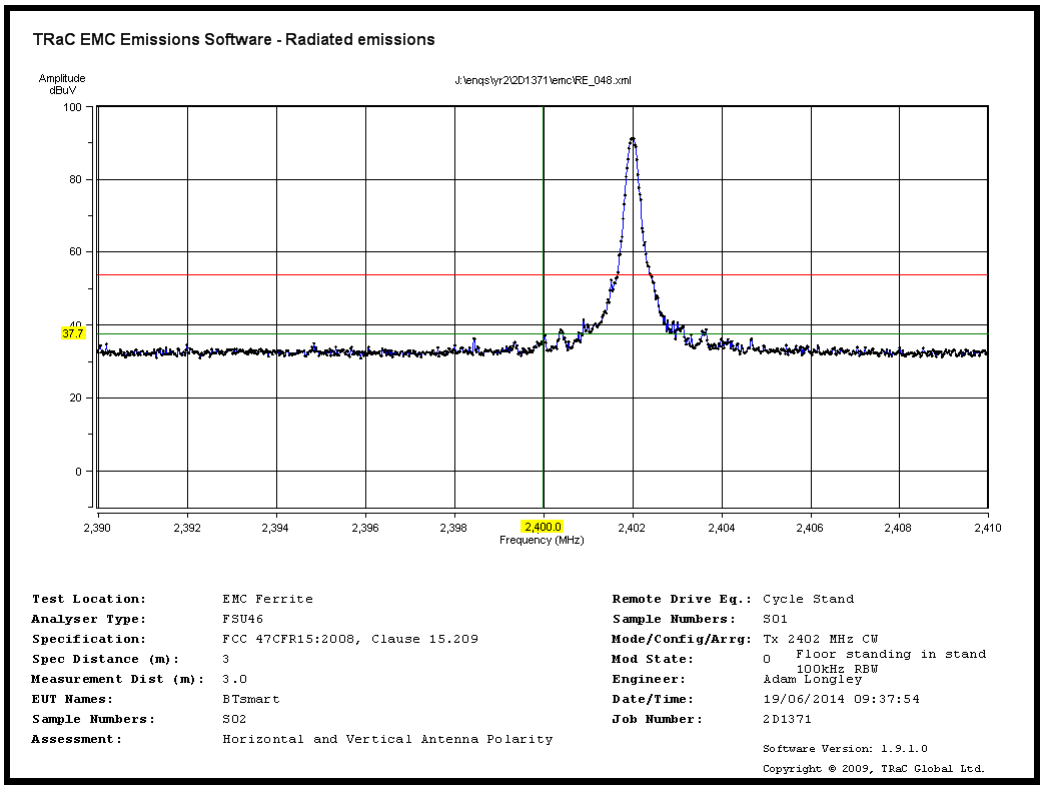


Radiated Spurious emissions 13 GHz to 18GHz – 2480MHz

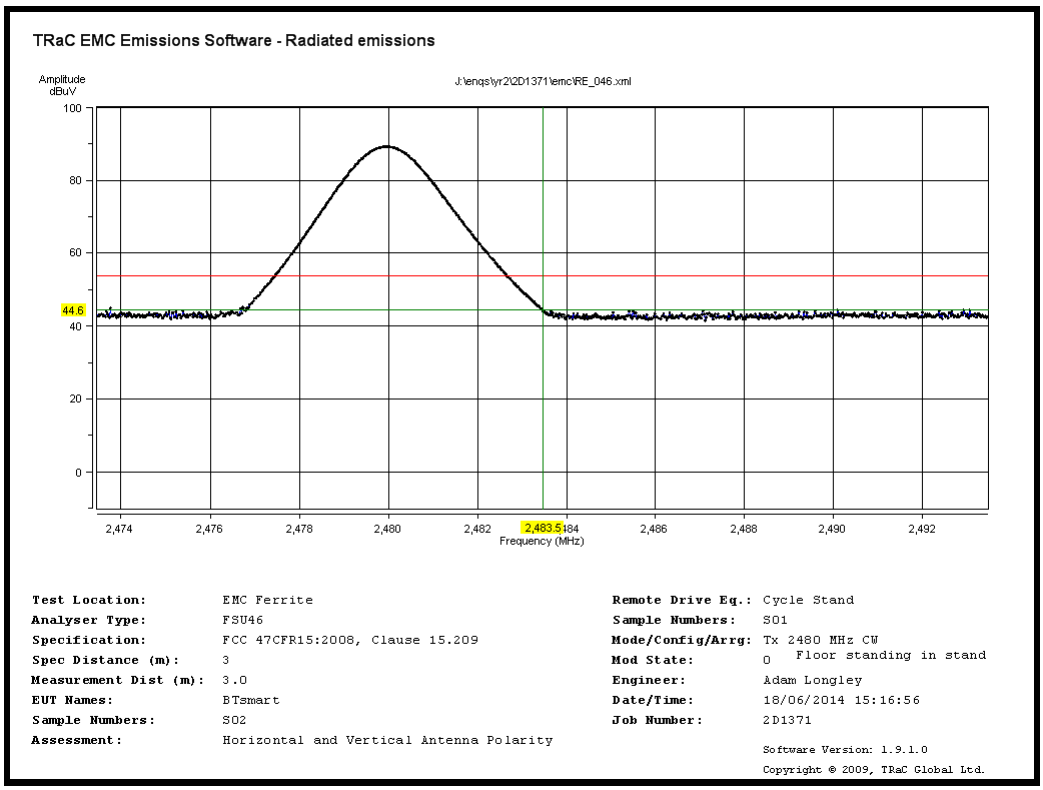


Radiated Spurious emissions 18 GHz to 25 GHz – 2480MHz

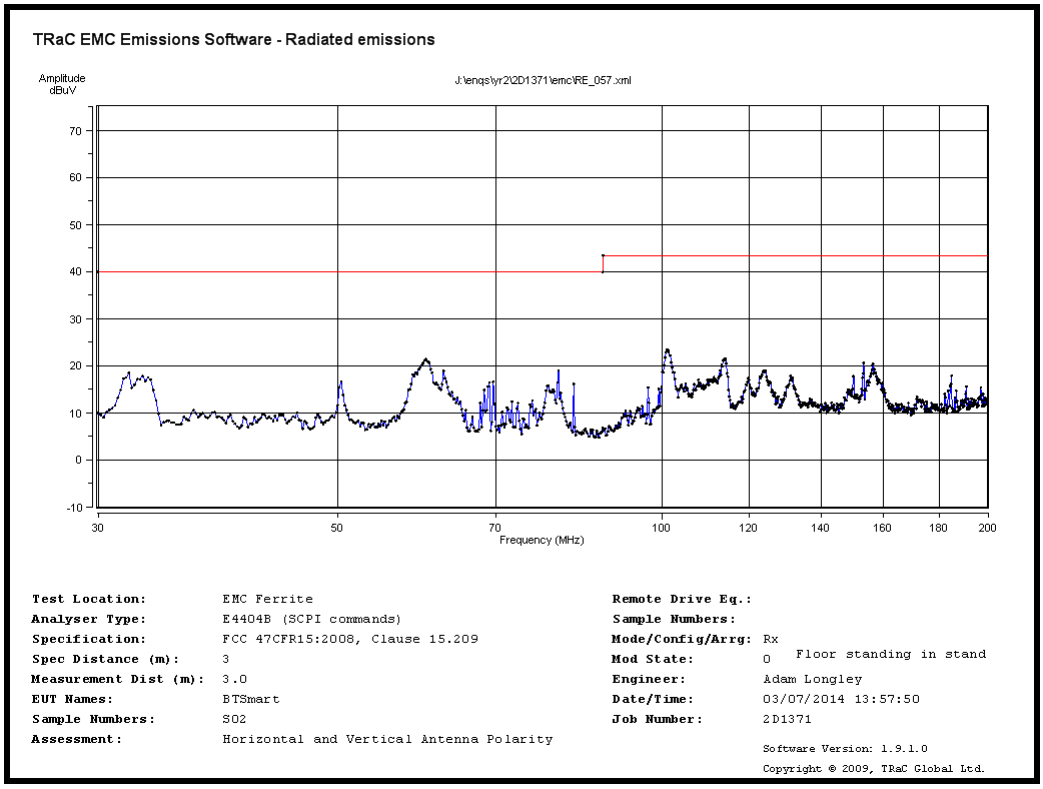
Radiated Bandedge Compliance



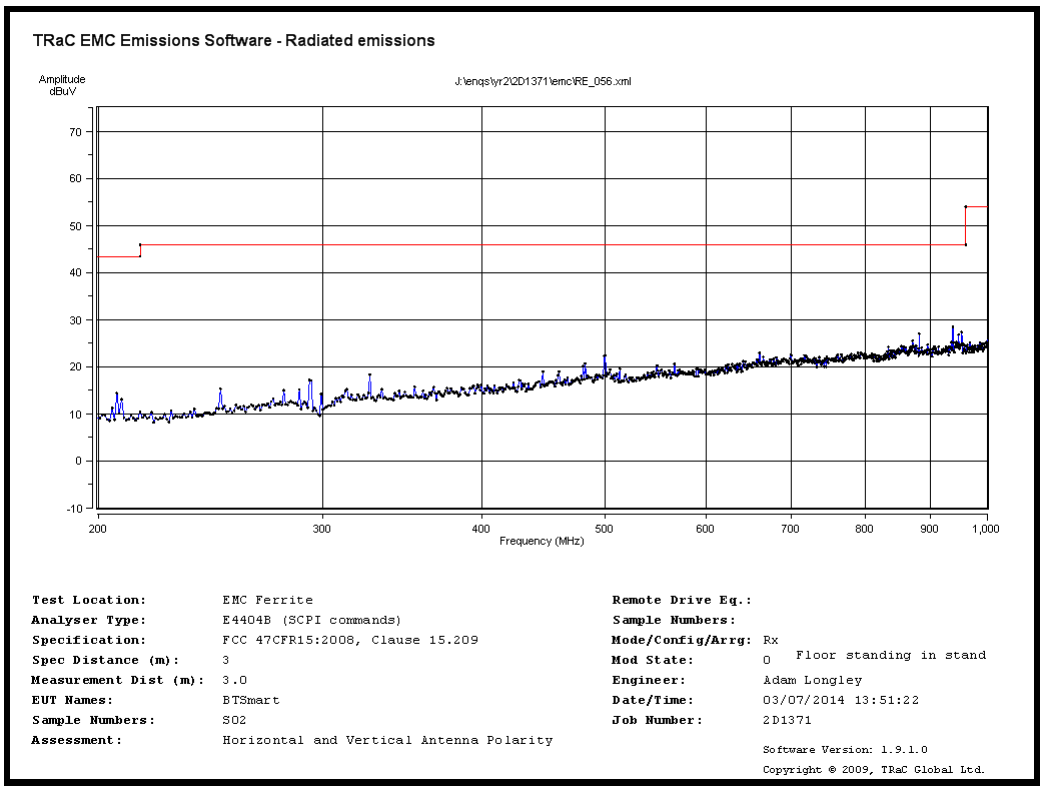
Lower Bandedge



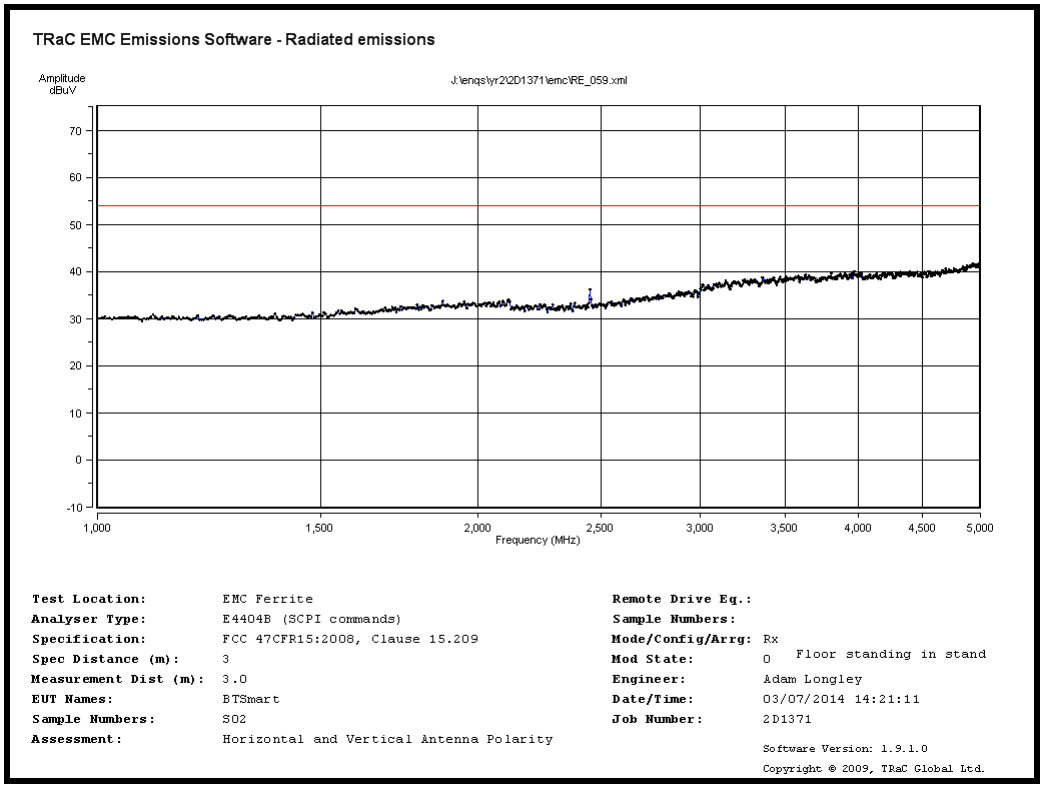
Upper Bandedge



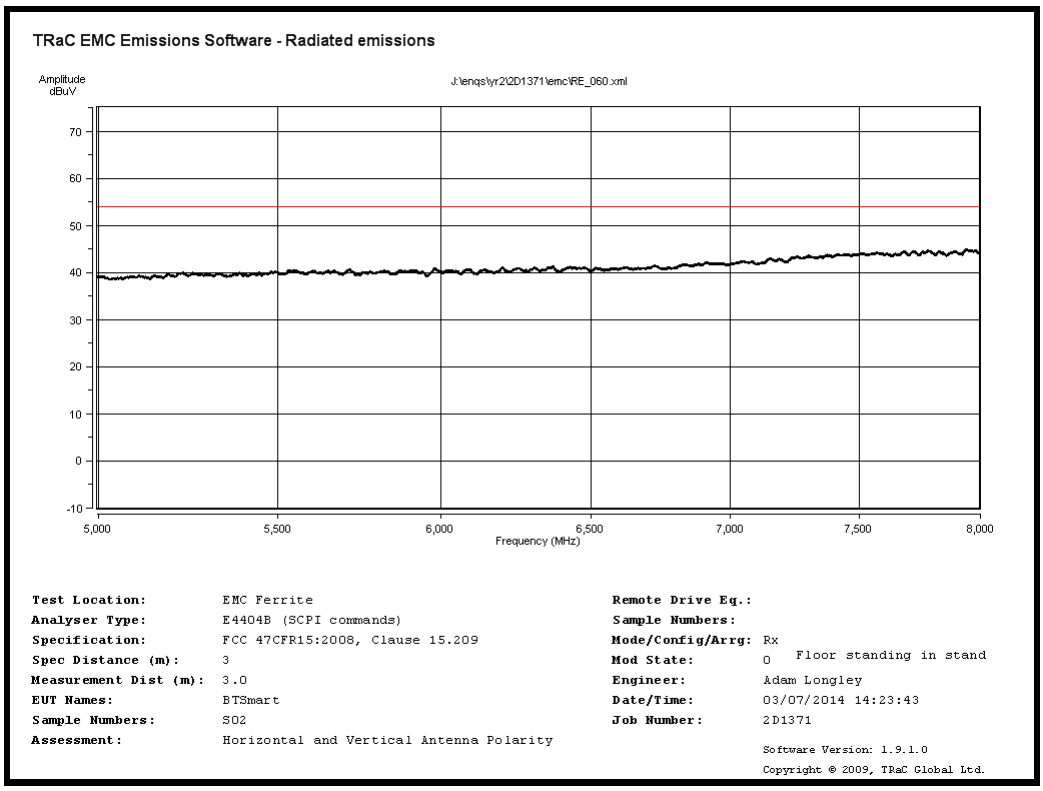
Radiated Spurious emissions 30 MHz to 200 MHz



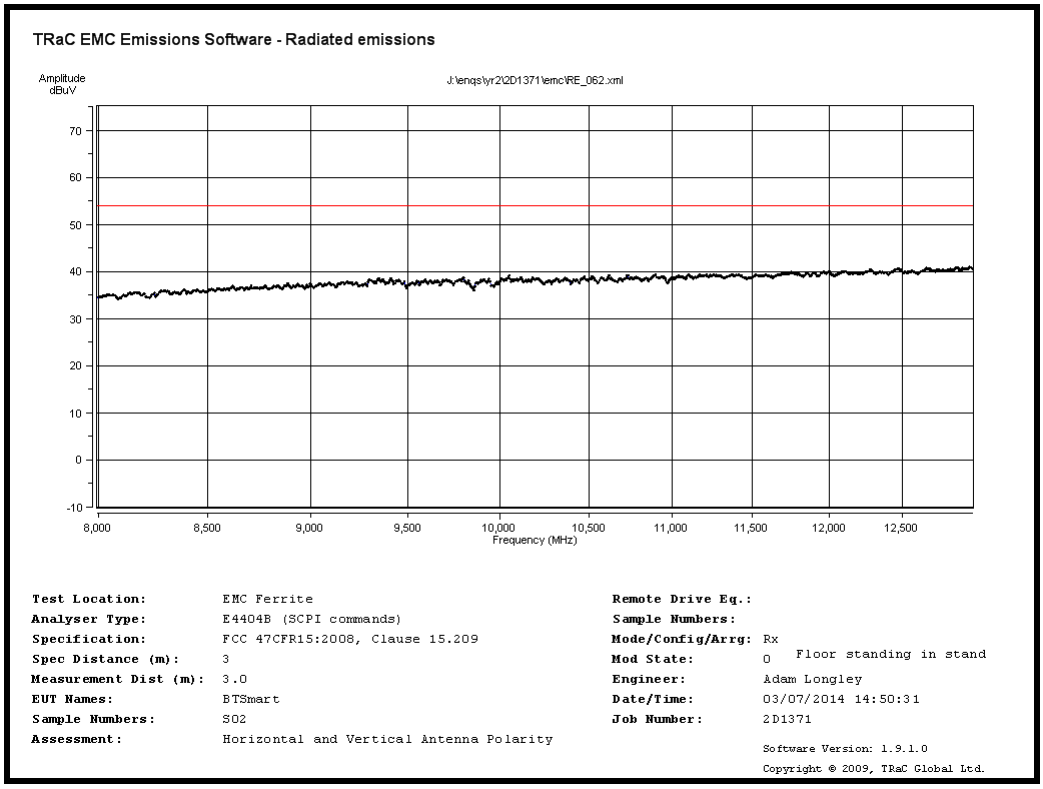
Radiated Spurious emissions 200 MHz to 1 GHz



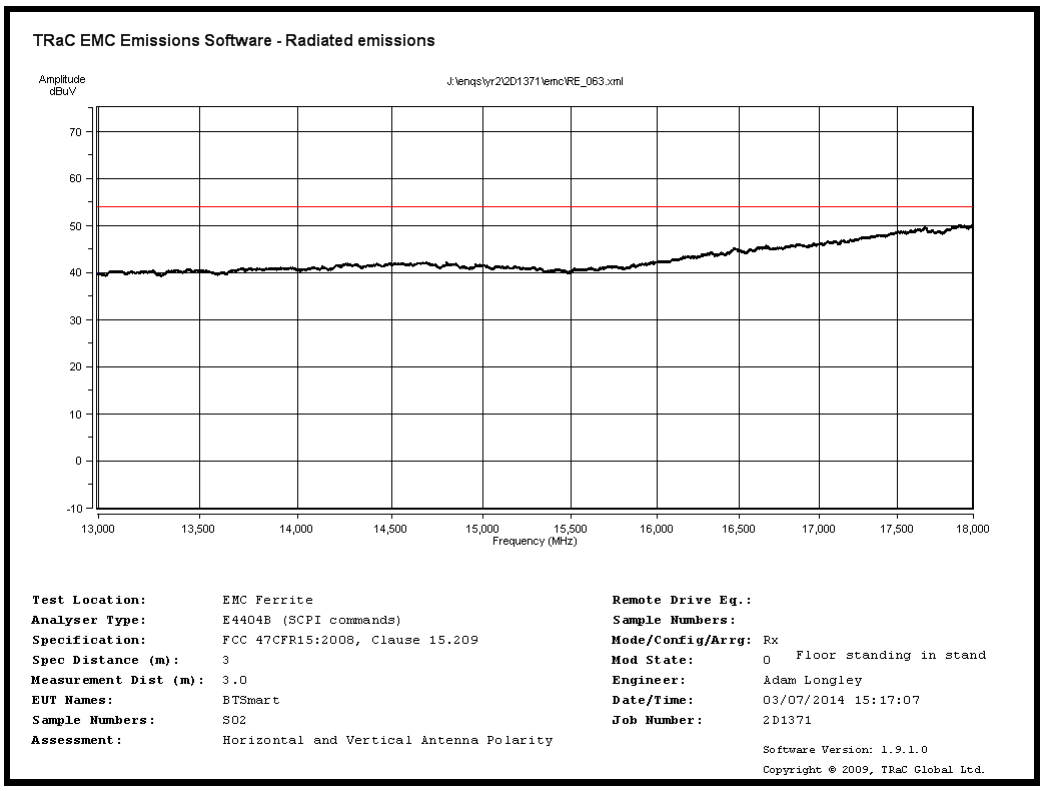
Radiated Spurious emissions 1 GHz to 5 GHz



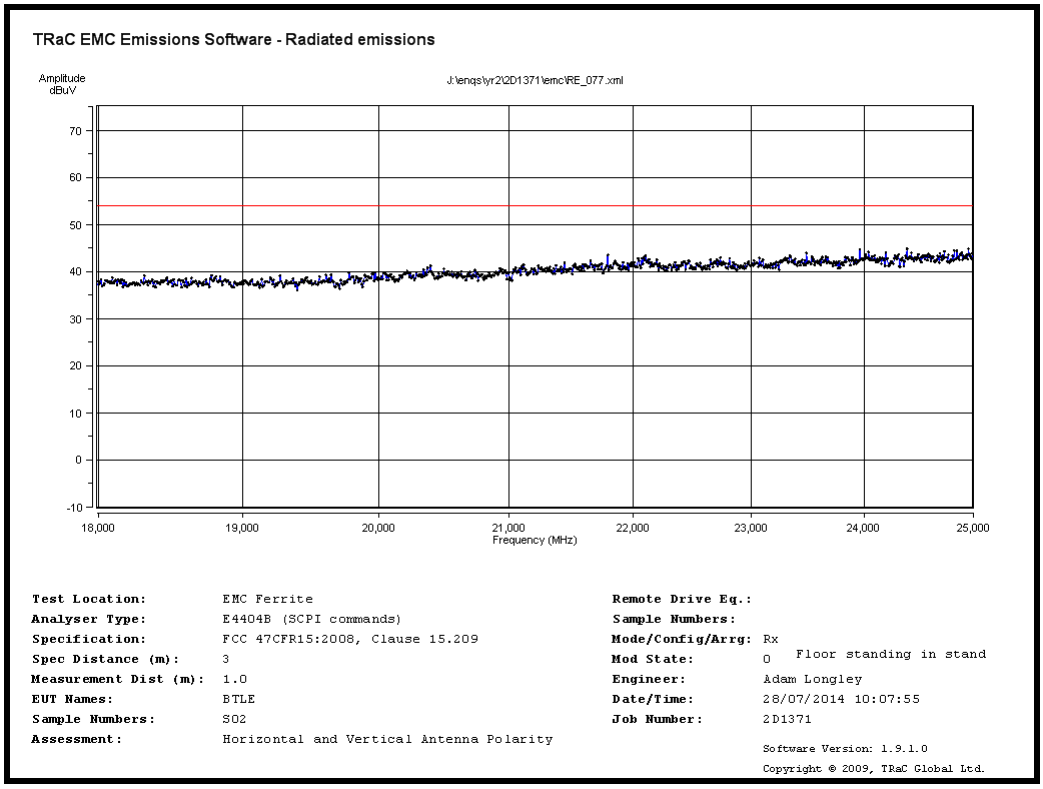
Radiated Spurious emissions 5 GHz to 8 GHz



Radiated Spurious emissions 8 GHz to 13 GHz



Radiated Spurious emissions 13 GHz to 18GHz



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
S02	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 S02 was installed with test firmware which provided transmit and receive modes using the BlueTooth Low Energy (BTLE) 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 BTLE mode on 2402, 2440 or 2480MHz as required (without modulation).

Test	Description of Operating Mode
Occupied Bandwidth Power Spectral Density	EUT transmitting in BTLE mode on 2402, 2440 or 2480MHz as required (with modulation).

Test	Description of Operating Mode:
Receiver radiated (ERP) 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.

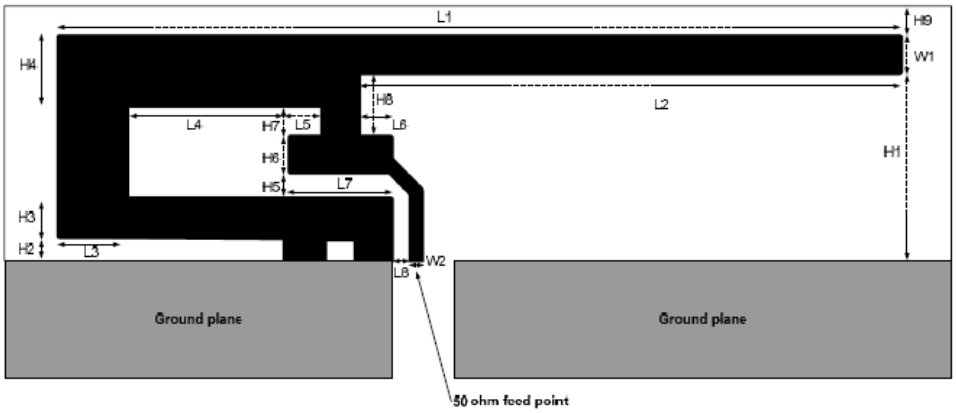


Figure 1. IFA Dimensions

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.

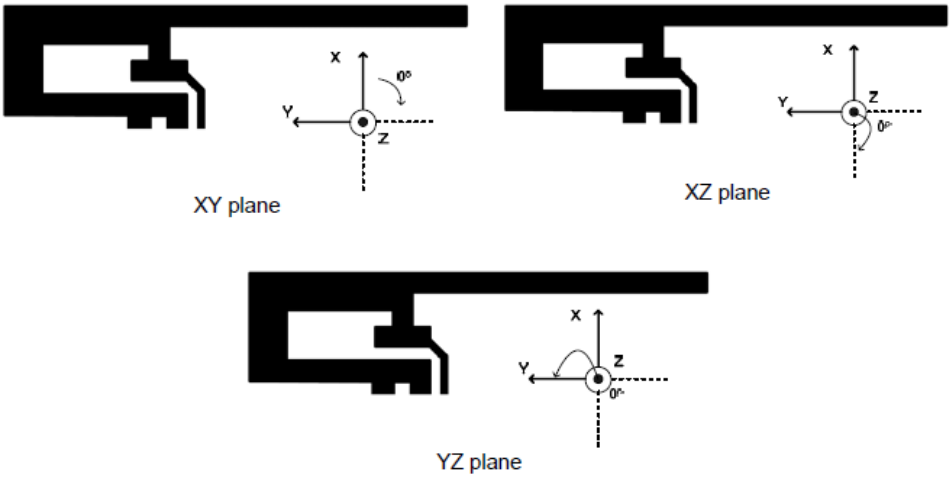


Figure 2. How to Relate the Antenna to the Radiation Patterns

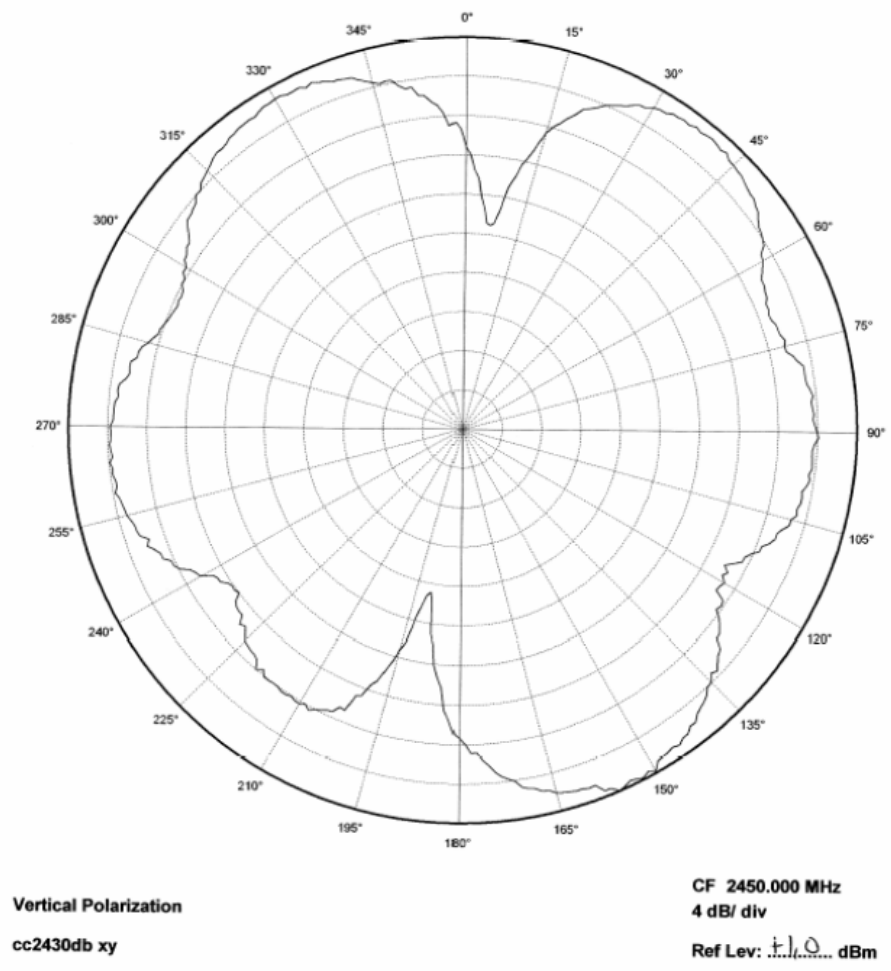


Figure 3. XY Plane Vertical Polarization

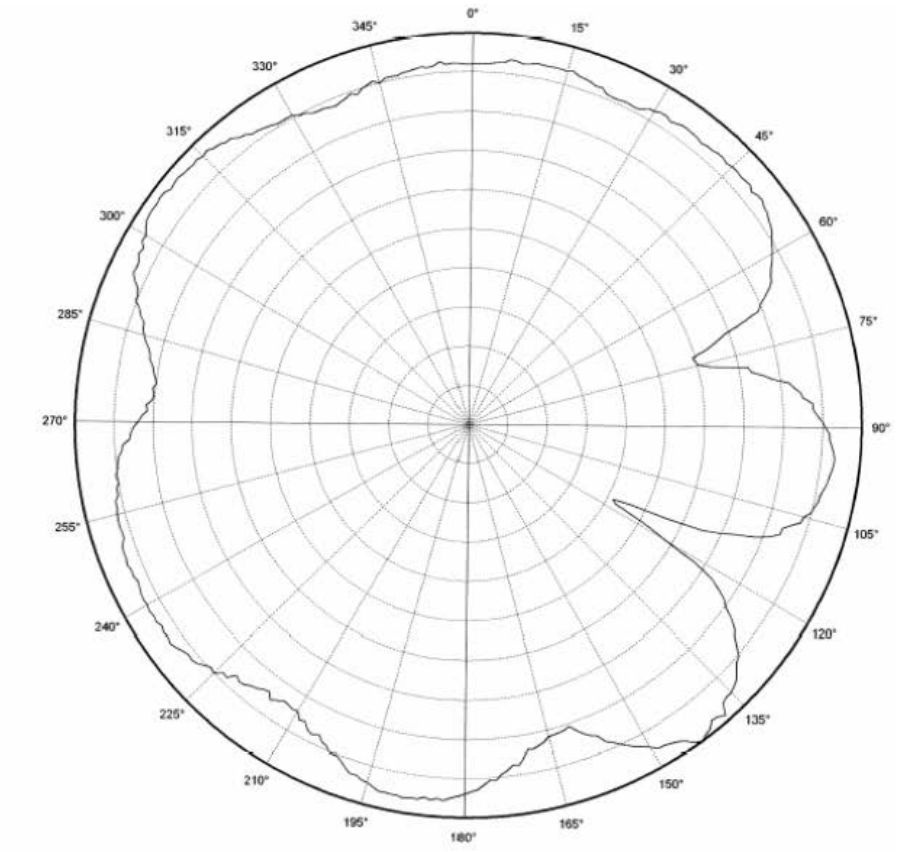


Figure 4. XY Plane Horizontal Polarization

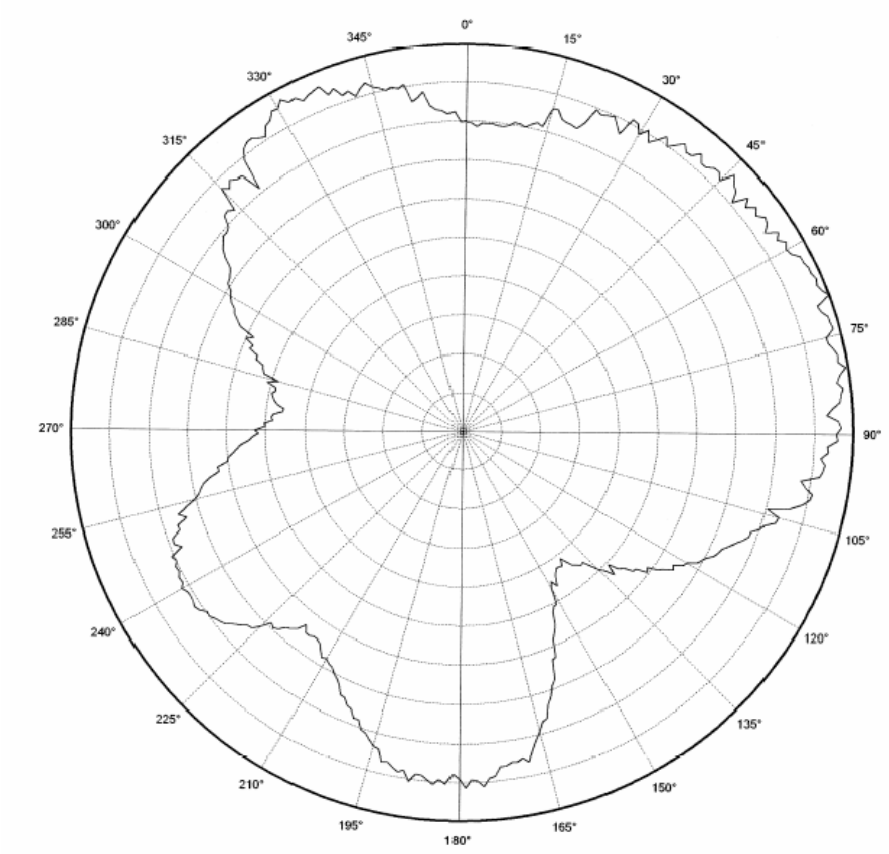


Figure 5. XZ Plane Vertical Polarization

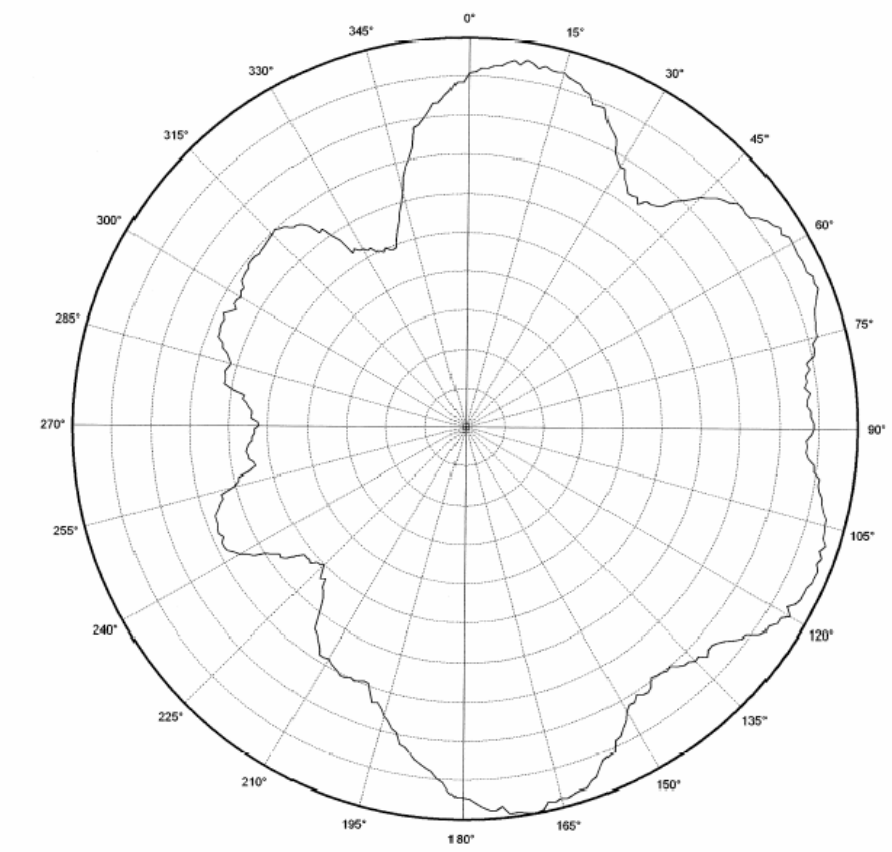


Figure 6. XZ Plane Horizontal Polarization

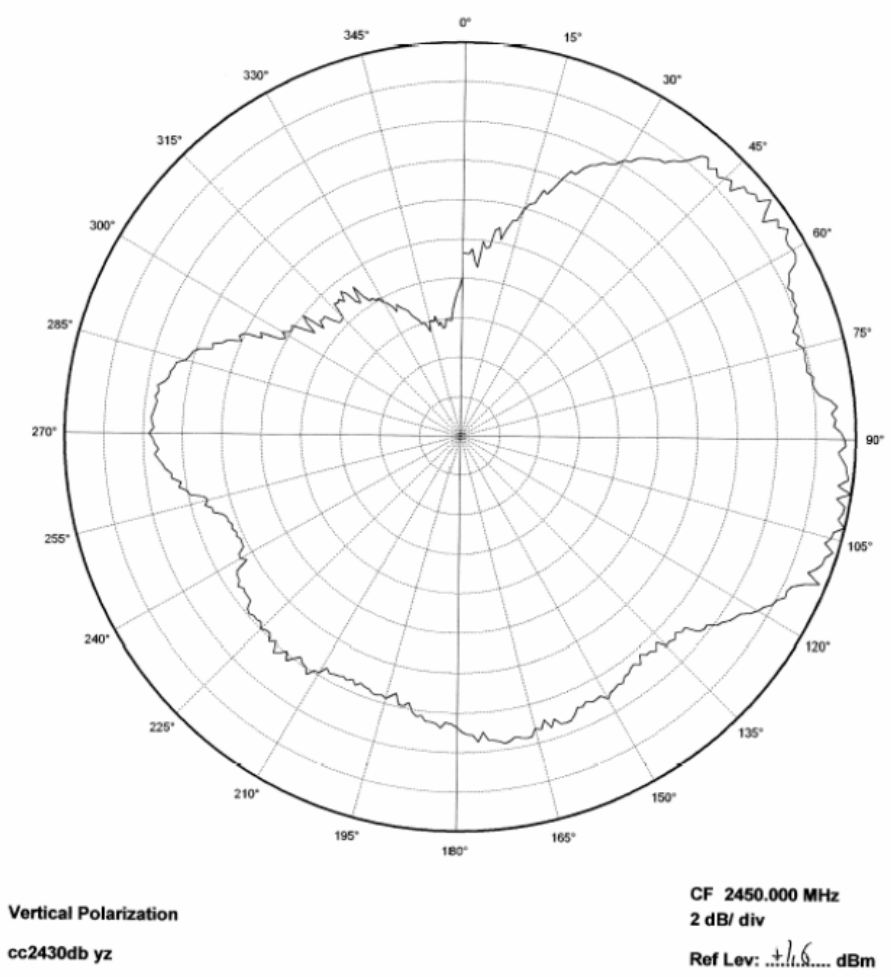


Figure 7. YZ Plane Vertical Polarization

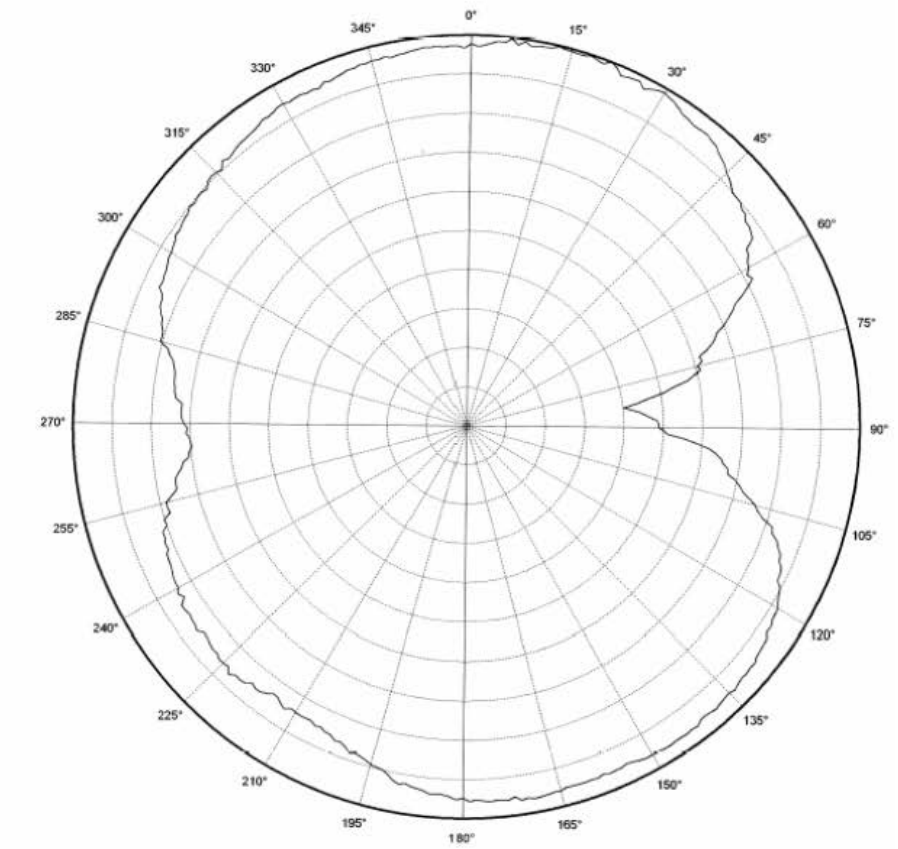


Figure 8. YZ Plane Horizontal Polarization

4.2 Reflection

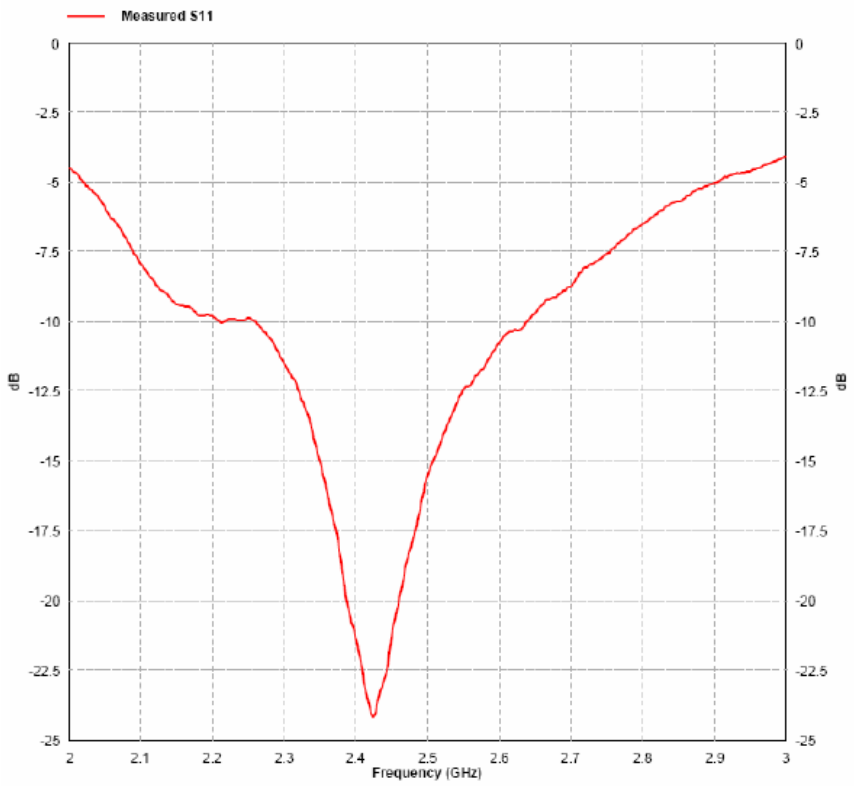


Figure 9. Measured Reflection at the Feed Point of the Antenna

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.

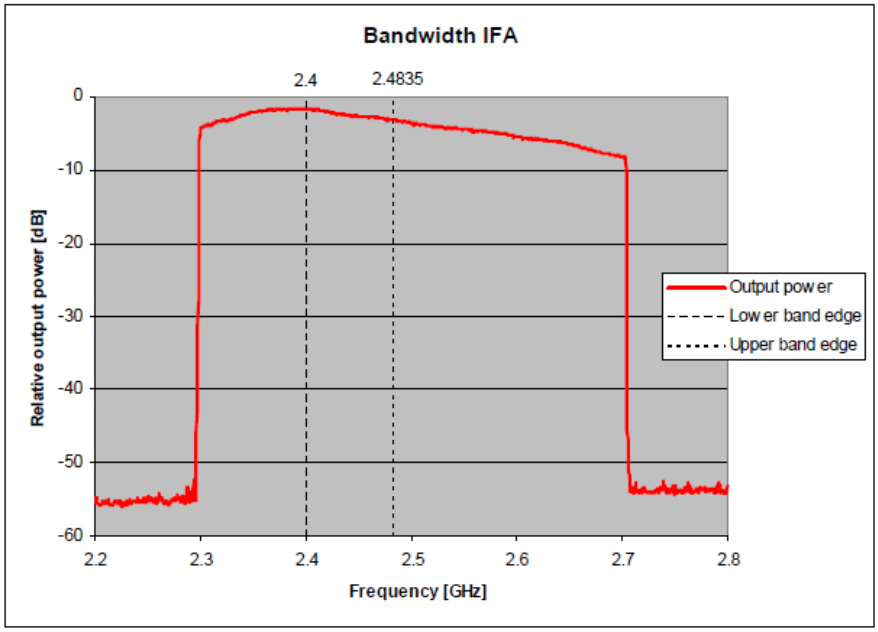


Figure 10. Bandwidth of IFA

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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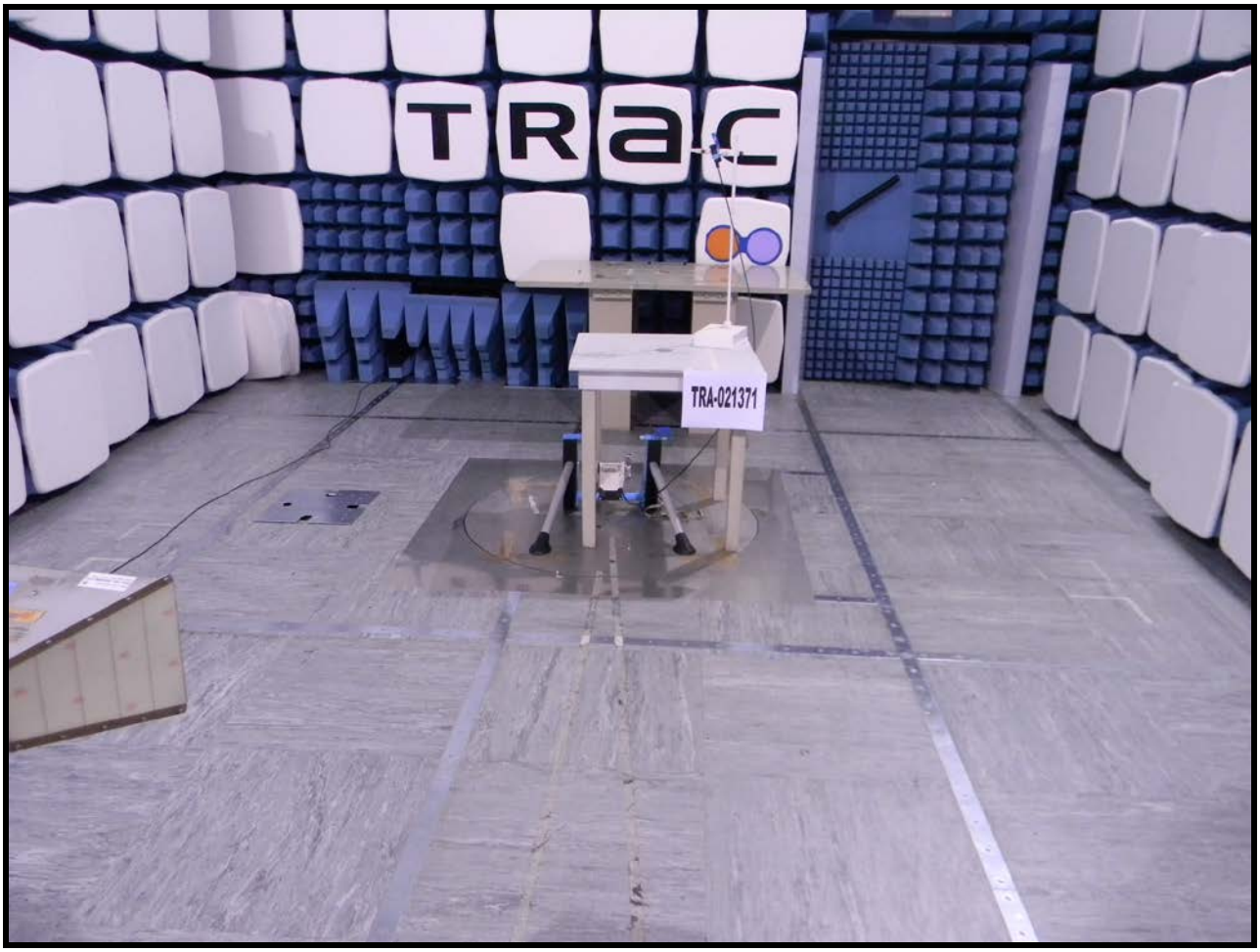
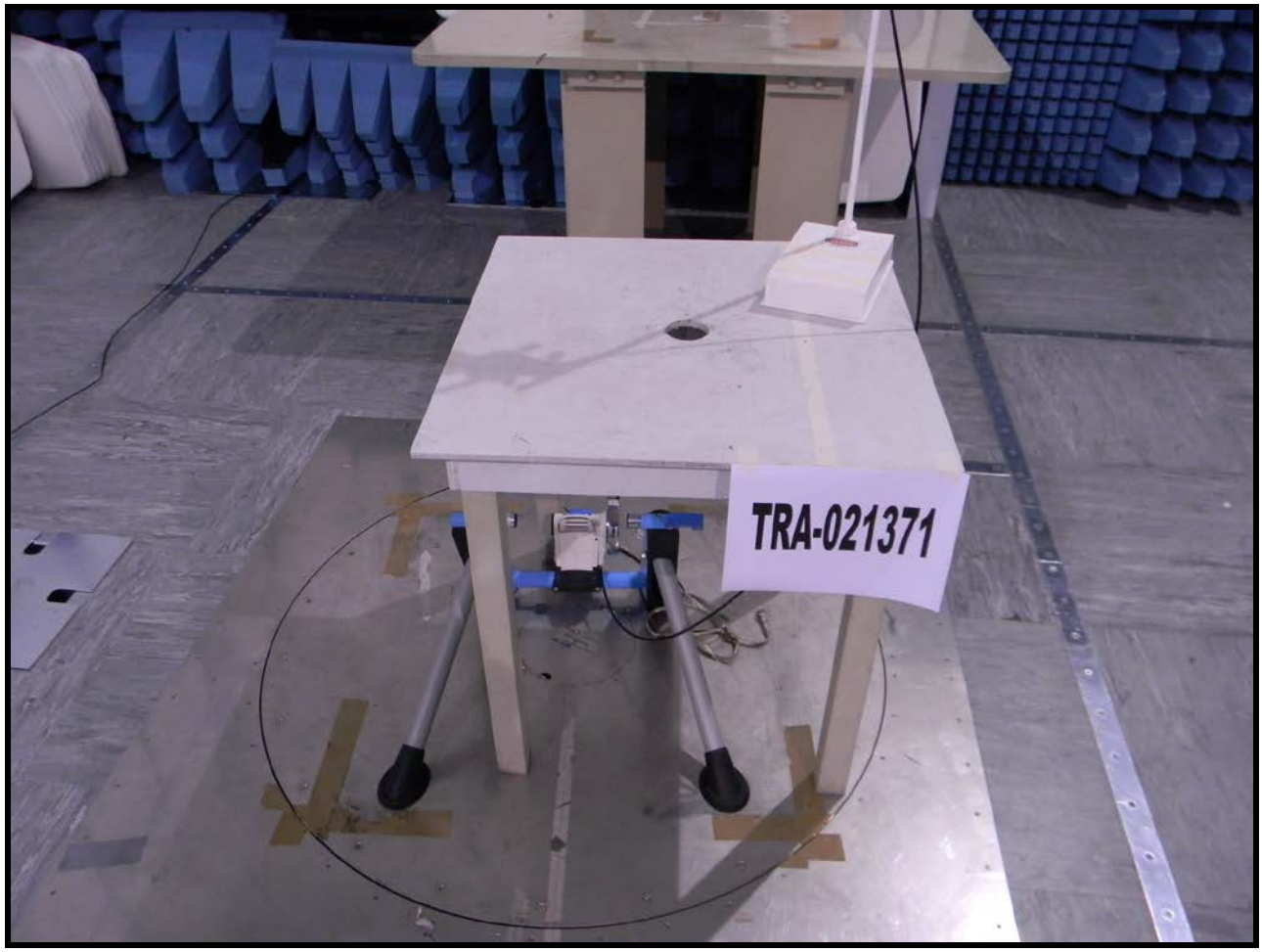
Appendix E: Photographs and Figures

The following photographs were taken of the test samples:

1. Radiated electric field emissions arrangement: front view.
2. Radiated electric field emissions arrangement: close up.



Photograph 1



Photograph 2

Appendix G: 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 between 100 MHz and 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 x TSD) / $\sqrt{f_{GHz}}$] + (TSD – 50) * 10] }

Operating Frequency 2.402 GHz

MP= { [(3.0 x 50) / √2.402] + (50 – 50) * 10 }
MP= { [150 / 1.55] + (0 * 10 }
MP= 96.77mW

Operating Frequency 2.440 GHz

MP= { [(3.0 x 50) / √2.44] + (50 – 50) * 10 }
MP= { [150 / 1.56] + (0 * 10 }
MP= 96.15mW

Operating Frequency 2.480 GHz

MP= { [(3.0 x 50) / √0.92760] + (50 – 50) * 10 }
MP= { [150 / 1.57] + (0 * 10 }
MP= 95.54mW

Channel Frequency (MHz)	EIRP (mW)	SAR Exclusion Threshold (mW)	SAR Evaluation
2402	0.14	96.77	Not Required
2440	0.17	96.15	Not Required
2480	0.30	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)
2480	0.18	0.6	0.20

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