Test Report for S100 Controller

To CFR 47 Chapter 1 FCC Rules Part 15 Radio Frequency Devices

Radiated Spurious Emissions

Test Report Number: 593/1024

Approved	Adil Abbas International Compliance Manager		10/01/2005
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Report Date	27/12/2004	Test Date	16/12/2004 to 23/12/2004

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1 Purpose of Tests

The purpose of the tests was to demonstrate that the EUT (Raymarine RF S100 Controller) meets the requirements of FCC rules 15.247 (d) & (i) with respect to radiated spurious emissions when operating within the 2400–2483.5 MHz band and with regard to exposure levels of RF energy from the EUT.

This report will form part of a grant application to be submitted to both FCC and Industry Canada.

2 Description of Equipment under Test (EUT)

(To include all equipment being tested)

Date of Receipt:	15 December 2004
Client:	Data and Vessel Control Team, Raymarine
Brand Name:	Raymarine
Product Range:	RF remote products
Country of Manufacture:	United Kingdom
Operational voltage range:	(3 V d.c. nominal) (two AA Batteries)

Unit 1

Model Name or Number:	**S100 Controller**
Unique Type Identification:	A18104
Serial Number:	EMC171104b
Circuit Diagram Number(s) & Issue:	4593-003 Issue b
PCB Assembly Number(s) & Issue:	3015-359 Issue b
Software Version:	Ember Range test Software Version 1.0 September 1st 2004. 15:40:28
Modifications to Unit:	XTAL3 and 4 replaced with Raymarine Part Number 9602CR32P769.

Other Information:	

3 Description of Auxiliary Equipment

(To include all equipment associated with the EUT(s) which are NOT directly subjected to the test)

Item	Unique Type Identification & Serial Number

4 General

Supply Voltage	Ambient Temperature	Relative Humidity
3.0V d.c.	20 - 22°C	30 - 33%

5 Test Configuration

(See Section 2 Description of Equipment under Test (EUT) and Section 6 Description of Auxiliary Equipment for Description of Equipment)

Raymarine Keyfob Remote

Title	Description
Test Set-up and Operating Mode	Set-up as per diagram Section 5 and photographs in section 7. The EUT is a hand held device with internal batteries. The EUT was placed on a 0.8m high table, no other equipment was required. In the receive mode below 2GHz the EUT was tested in parallel with the S1000 Autopilot, also in receive mode; these units are sold together as a system. Using special test software to enable efficient testing of the EUT the RF section was configured to continuous transmission or receiving mode as required during the course of the testing. Channels on which the RF section was operating were selected as required.

6 Description of Test Chamber

The test chamber used for the radiated emissions measurements is FCC listed (registration no. 970522) and registered with Industry Canada (registration no. IC 5650-1).

The test site is within a fully enclosed chamber on a ground plane of dimensions 9.3 x 6.3m. The walls, ceiling and door are completely lined with 6.7mm thickness Samwha ferrite tiles. Additional hybrid pyramidal absorber, type SLM500 and SLM850 is fitted to areas of the ceiling, sidewalls and the end wall nearest the turntable. The test volume is a cylinder 2m in height and 1.5m in diameter centred on the axis of the turntable.

The ground plane consists of galvanised steel sheets continuously bonded together with copper strip. The sheets at the edges of the ground plane are bonded, in a similar manner, to the walls of the chamber. To prevent flexing or warping, the edges of each individual steel sheet of the ground plane are secured to a wooden deck with screws at 10cm intervals.

The non-conductive turntable has the following characteristics:

a) mounted on the ground plane
b) fibre optic remote control
c) base diameter of 1.2m
d) base platform height 2cm above ground plane
e) hole in centre for EUT grounding and power source
f) power to centre via 20mm steel conduit bonded to ground plane
g) 360 degree rotation
h) the turntable, drive belt, drive shaft, couplings and turntable base are non-conductive.
i) A metallic shielded enclosure, located against the wall of the chamber, contains the motor and the electronics required to rotate the turntable.

The receiving antenna mast has the following characteristics:

a) fibre optic remote control
b) 1-4 metre search height
c) pneumatic antenna polarization change
d) the mast, carrier, boom, platform and drive belt are non-conductive.
e) A metallic shielded enclosure, located at the base of the tower, contains the motor and the electronics required to control the antenna carrier.

7 Photographs

Figure 1 View from within chamber showing turntable base and mast set-up.

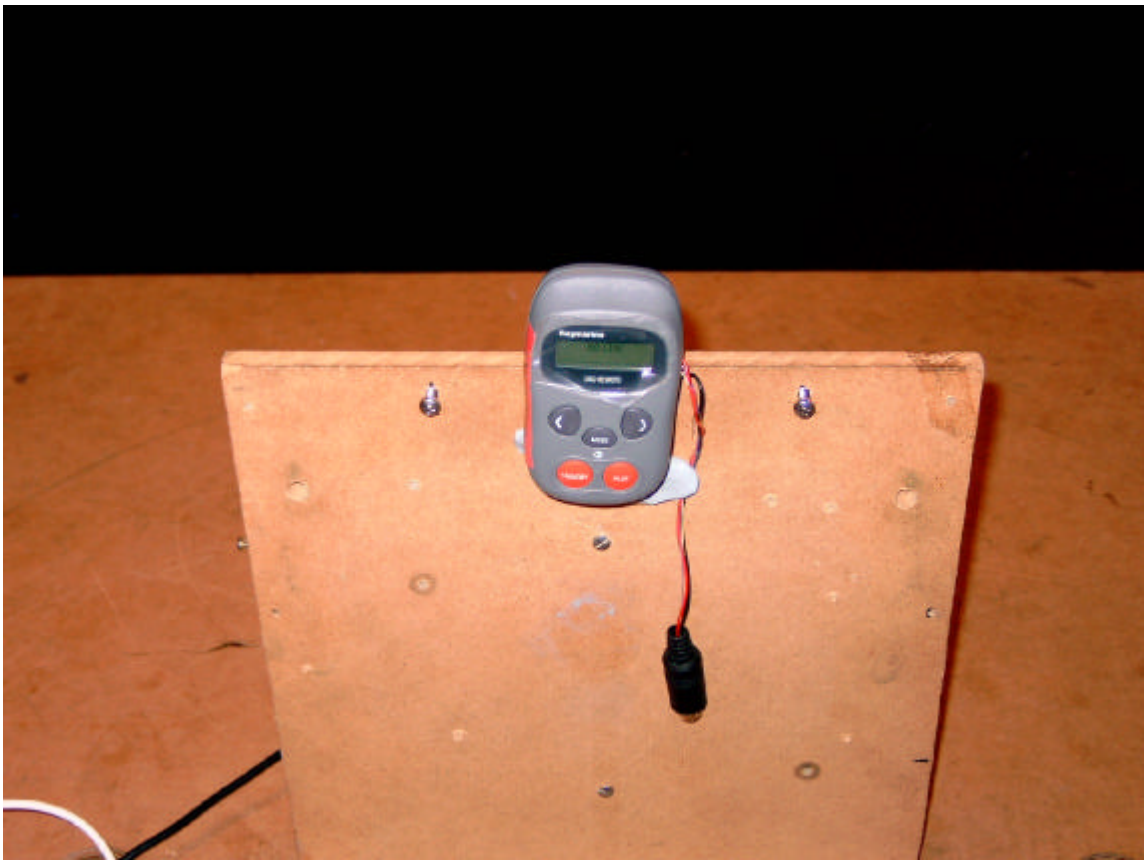

Figure 2 EUT mounted on supporting bracket on turntable in test chamber.

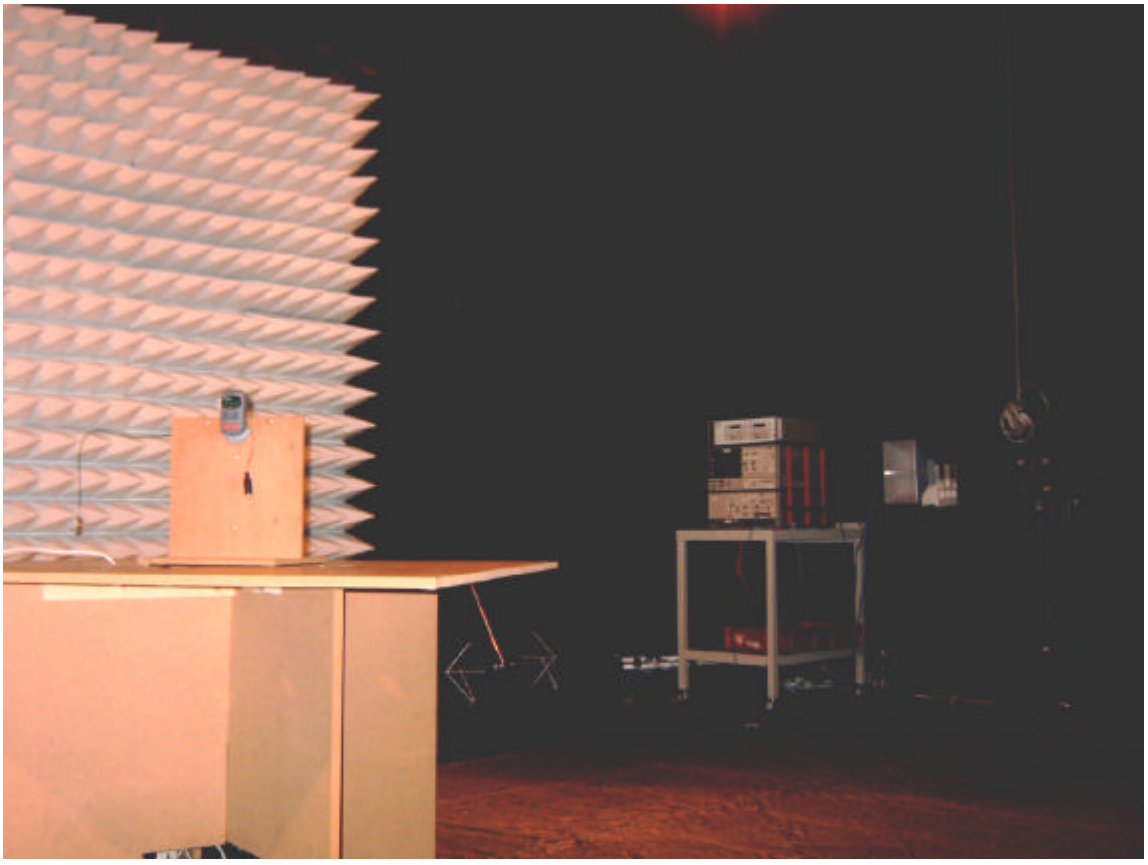

Figure 3 Set up in chamber for 2GHz-7GHz measurements at 3m.

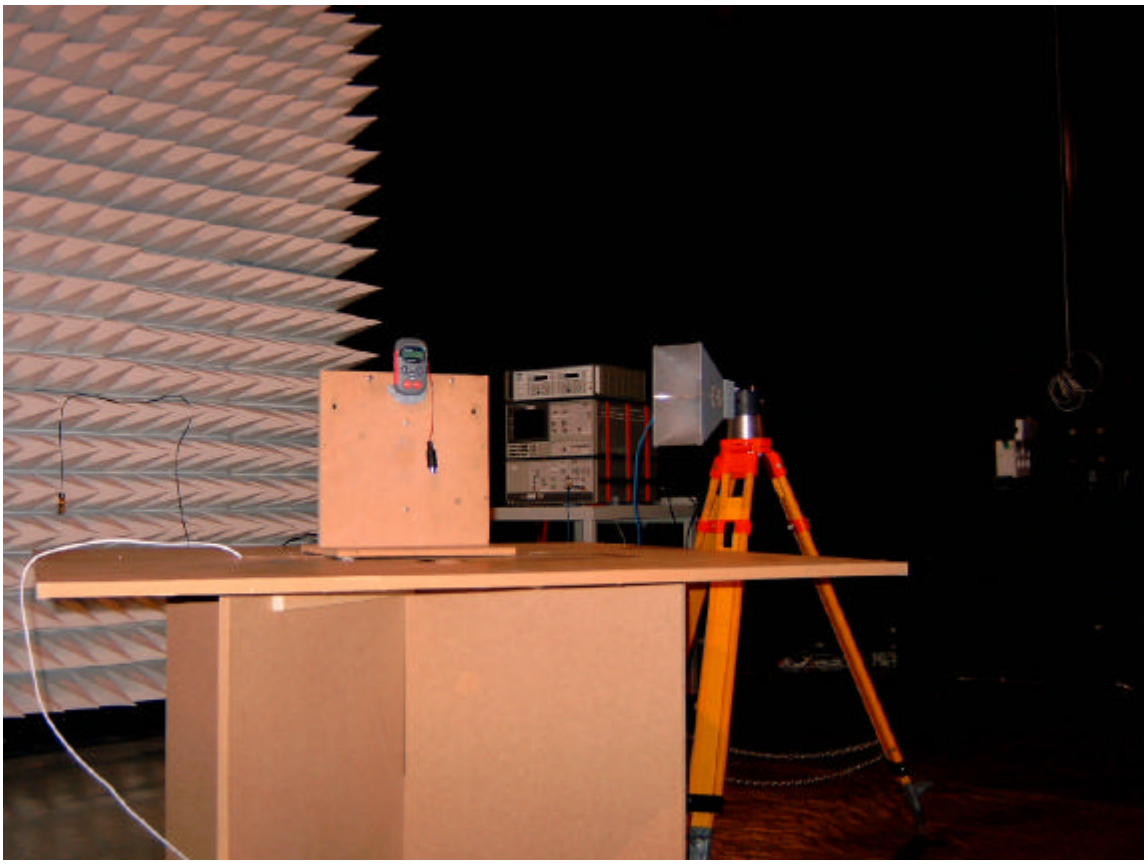

Figure 4 Set up showing measurements above 7GHz at 1m.

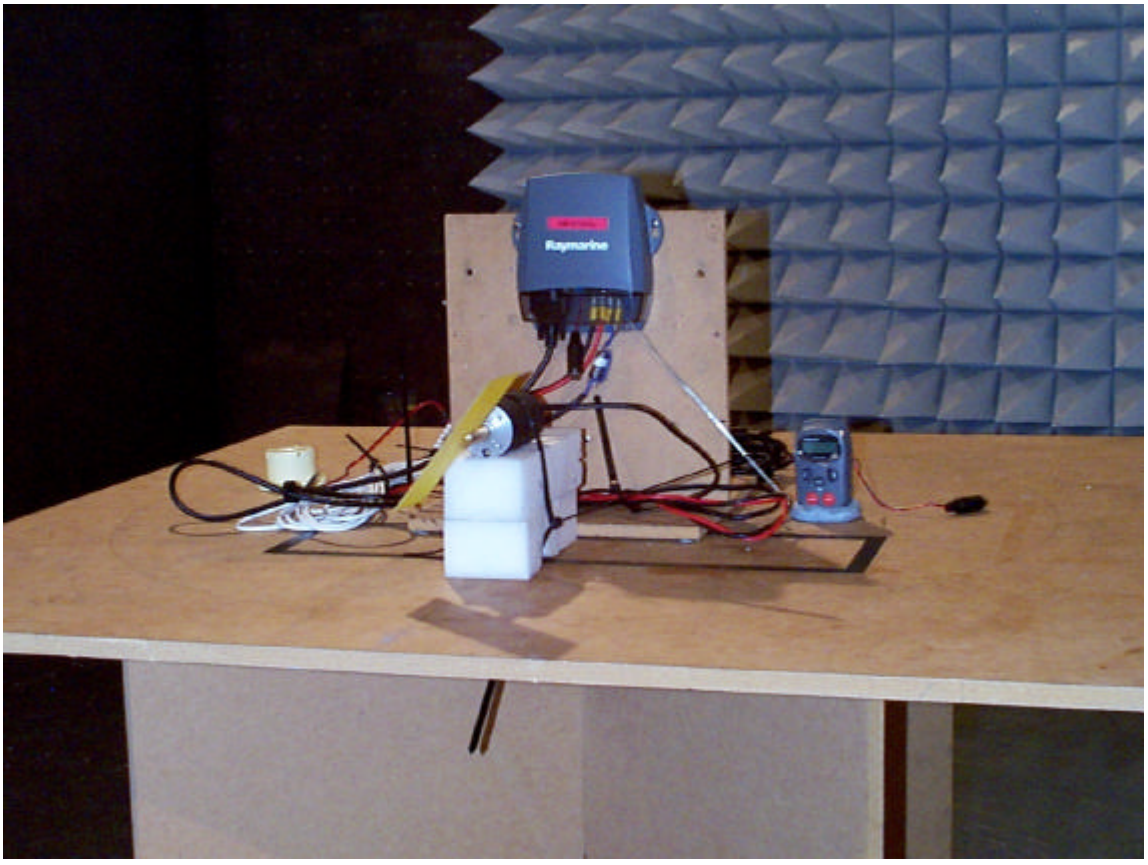

Figure 5 Setup for Receive mode below 2GHz

8 Method of test

The EUT was placed on the turntable and powered from two internal 1.5V AAA batteries. The purpose of the EUT is to control the Raymarine S1000 Autopilot via an RF link.

In normal use the EUT only transmits in response to a keypress to send data to the S1000 Autopilot or a heart beat during auto mode. Therefore the normal application code was substituted with alternative software to enable control of the EUT transceiver module with a PC via an RS232 connection. This allowed the EUT to be operated on any of the 15 available channels and configured to function in either a continuous receive mode or to transmit a continuous tone. An investigative sweep to identify any spurious emissions for detailed investigation was carried out in transmit mode and then repeated in receive mode, each sweep being conducted on channel 7. The results of these tests have been presented separately in this report (see sections 9 and 10). The method used was to conduct the measurements within each test band on four orthogonally opposed faces of the EUT in order to identify any spurious emissions that would require further, detailed examination. Composite plots from these investigative sweeps are presented below in sections 9 and 10.

In the bands below 2 GHz any frequencies identified for further investigation were measured with the EUT transmitting/receiving on channel 7 only. Radiated spurious emissions within these bands are not likely to be affected by the channel of operation of the EUT transceiver.

At frequencies above 2GHz any emissions identified during the investigative sweeps were then re-measured on channels 0, 7 and 15 (i.e. lower, middle and upper channels) as the channel of operation was more likely to have a significant impact on the emission level. The levels recorded are presented in tables and HP70000 screenshots of the worst-case measurements are presented below in sections 9 and 10.

<u>9kHz-30MHz</u>
These measurements were carried out within the test chamber at a distance of 3m. The limits against which the emissions were measured have been extrapolated using a factor of 40dB/decade as per FCC rule 15.31 (f)(2). Frequency scans and any spurious emissions investigations were carried out using a Chase automated EMC measurement system to control the measuring receiver, antenna height and turntable angle. The automated measurement system was operated from outside the test chamber. There is no requirement to test below 30MHz with the EUT in receive/standby mode therefore data from these bands relates only to the EUT in transmit mode.

30MHz-2GHz

Measurements between 30MHz and 2GHz were carried out in accordance with the recommendations of ANSI C63.4-2000 section 8. The separation distance between the periphery of the EUT and the test receive antenna was 3 metres as defined by FCC rule 15.209. Frequency scans and spurious emissions investigations were carried out using an EMC measurement system utilising Chase software to control the measuring receiver, antenna height and turntable angle. The automated measurement system was operated from outside the test chamber.

Above 2GHz sweeps

These measurements were carried out manually from within the EMC chamber using an HP70000 spectrum analyser. This was done to reduce cable losses by shortening the length of the receive cable and therefore enabling noise floor levels to be kept to a minimum. The antenna height and turntable angle were also controlled manually via an EMCO 2090 multi device controller.

The spurious emissions from these frequency sweeps were captured with an HP70000 peak detector in max hold mode. During these sweeps the EUT was set to transmit continuously on channel 7. For each frequency sweep the receive antenna was maintained at 1.0m while the turntable was rotated through 360°. This process was repeated with the spectrum analyser remaining in max hold mode and using the opposite antenna polarisation so that a trace was obtained comprising the worst case emissions obtained for both antenna polarities on all radials from the EUT.

The frequency and level data from the HP70000 traces was extracted to an excel file using SoftPlot measurement presentation software. All the data obtained from the individual sweeps was then combined into a single spreadsheet and corrected for cable loss and antenna factors. Graphs were then produced from the final corrected figures to show the spurious emissions in the 2GHz to 25GHz band (see Figure 12 and Figure 20 below).

Any emissions observed to be above the noise floor were then investigated more thoroughly on channels 0, 7 and 15 to determine the worst-case frequency, level, antenna height (where possible) and turntable angle. This was then captured using SoftPlot. These investigations were carried out at the frequencies of interest with the HP70000 amplitude offset to account for cable losses and antenna correction factors. The plots are presented below (see figures 13 to 15 and figure 21)

The frequency sweeps were as follows:

2GHz-7GHz
The separation distance between the EUT and the test receive antenna was kept to 3 metres. HP70000 resolution bandwidth was 1MHz

7GHz-12GHz
In order to maintain the noise floor sufficiently below the specification limit it was necessary to reduce the separation distance between the EUT and the test receive antenna to 1m. The limits against which the emissions were measured have been extrapolated using a factor of 20dB/decade as per FCC rule 15.31 (f)(1). The extrapolated limit was calculated to be 63.5dBµV/m. The near field / far field transition at 7 GHz is:

? at 7GHz = 0.042m

$$d > \frac{2l^2}{l} \qquad \text{(l=2.7cm)}$$

$$d > \frac{2(0.027)^2}{0.042} = 0.0347 \text{ m}$$

= 35 mm

Therefore all measurements made above 7GHz at 1m are within the far field. The HP70000 resolution bandwidth was 1MHz

12GHz-16.5GHz
Measured at 1m-separation distance, resolution bandwidth was 1MHz.

16.5GHz-20GHz
Measured at a 1m-separation distance, resolution bandwidth was 1MHz.

20GHz-25GHz
Measured at a 1m-separation distance. The resolution bandwidth was reduced to 215kHz in order to allow enough margin between the noise floor and the specification limit to identify any spurious emissions that may be present.

Frequency band	Resolution bandwidth	Remarks
9kHz – 150 kHz	200 Hz	
150 kHz – 30 MHz	9 kHz	
30 MHz – 1 GHz	120 kHz	
1 GHz – 20GHz	1 MHz	
20 GHz – 25 GHz	215 kHz	Resolution bandwidth reduced to lower system noise floor.

Table 1 Summary of resolution bandwidths used during emissions measurements.

9 Radiated emissions results – intentional radiator

9.1 Test measurement limits.

The EUT was tested for spurious emissions between 9kHz and 25GHz (i.e. above 10th harmonic) against the following limits:

- -20dBc as defined in FCC rule 15.247(d)
- Within restricted bands (see table under rule 15.205) the limits of table 15.209 were applied.
- Additionally a peak limit of 74dBµV/m was applied as defined in FCC rule 15.35(b)

For measurements above 2GHz, radiated spurious emissions were recorded using an HP70000 spectrum analyser with a peak detector in max hold mode. The tests were carried out with the EUT transmitting continuously, however in normal use the maximum transmission duration during any 100ms period is 40ms. An equivalent average value of each emission has therefore been derived from the peak measurement by application of the following conversion factor (ref rule 15.35(c)):

$$20\log\left(\frac{40ms}{100ms}\right) = -7.96 \text{ dB}$$

9.2 Test results

9.2.1 9KHz – 150kHz

There were no emissions detected above the measurement system noise floor. The noise floor was greater than 40dB below the specification limit. A composite graph combining 6 sweeps taken at 120° angles and with the loop antenna orientation rotated by 90° is presented in Figure 6 below.

9.2.2 150kHz - 30MHz

There were no emissions detected above the measurement system noise floor. The noise floor was greater than 30dB below the specification limit. A composite graph combining 6 sweeps taken at 120° intervals around the EUT and with the loop antenna orientation rotated by 90° is presented in Figure 7 below.

9.2.3 30MHz – 50MHz

A composite graph combining sweeps taken at 90° intervals around the EUT in both vertical and horizontal polarisations is presented in Figure 8 below.

The following restricted band frequencies were investigated:

Freq (MHz)	QP level (dBµV/m)	Antenna polarity	Antenna height (m)	Turntable angle (Degrees)	Limit (dBµV/m)	? Limit (dB)
37.2	30.3	Horizontal	2.3	075	40	-9.7
37.56	30.5	Horizontal	1.7	171	40	-9.5
38.04	29.2	Vertical	2.7	163	40	-10.8

Table 2 Quasi peak results for emissions in 30MHz – 50 MHz band.

All other emissions within this band were below -20dBc.

9.2.4 50MHz – 300MHz

All emissions occurring within restricted bands in this sweep were greater than 10dB below the specification limits and therefore did not warrant further measurements using a quasi-peak detector. All other emissions outside of the restricted bands were below -20dBc. A composite graph combining sweeps taken at 90° intervals around the EUT in both vertical and horizontal polarisations is presented in Figure 9 below.

9.2.5 300MHz – 1GHz

There were no emissions detected above the measurement system noise floor. The noise floor was greater than 8dB below specification limits. A composite graph combining sweeps taken at 90° intervals around the EUT in both vertical and horizontal polarisations is presented in Figure 10 below.

9.2.6 1GHz – 2GHz

There were no emissions detected above the measurement system noise floor. The noise floor was greater than 8dB below the specification limits. A composite graph combining sweeps taken at 90° intervals around the EUT in both vertical and horizontal polarisations is presented in Figure 11 below.

9.2.7 2GHz – 25GHz

Measurements were carried out in the 2.4 GHz – 2.4835 GHz band on channel 0, 7 and 15 in order to determine the maximum peak level of the fundamental emission. The maximum level may then be referenced back to emissions that are outside the restricted bands to ensure they meet the –20dBc requirement of FCC rule 15.247(4)(d). A table summarising the results is presented below and a plot of the highest level recorded is presented in Figure 13.

Channel No.	Freq (GHz)	Peak level (dBµV/m)	Antenna polarity	Antenna height (m)	Turntable angle (Degrees)
0	2.405313	98.0	Vertical	1.05	75
0	2.405313	96.3	Horizontal	1.07	348
7	2.440438	98.1	Vertical	1.07	81
7	2.440438	95.8	Horizontal	1.05	349
15	2.480438	98.9	Vertical	1.06	85
15	2.480438	96.9	Horizontal	1.04	30

Table 3 Summary of results of fundamental frequency levels for channels 0, 7, 15.

The frequency sweeps above 2GHz clearly indicated an emission at the 2nd and 3rd harmonic frequencies of the EUT (see Figure 12 below). This was investigated in more detail on channels 0, 7 and 15. The results from these measurements have been presented in table 4 below and a plot of the highest recorded emissions are presented in figures 14 and 15.

There were no other emissions identified or investigated in the 2GHz to 25GHz band.

Channel No.	Freq (GHz)	Max peak level (dBµV/m)	Peak limit (dBµV/m)	Average level (dBµV/m) Note 1	Average Limit (dBµV/m)	Ae polarity	Ae height (m)	Turntable angle (Degrees)	? Limit (dB)
0	4.810088	52.6	74.0	43.8	54.0	Hor	1.05	136	10.2
0	4.810088	53.5	74.0	40.8	54.0	Ver	1.03	333	13.2
7	4.879987	53.3	74.0	44.0	54.0	Hor	1.37	231	10.0
7	4.879987	53.2	74.0	43.0	54.0	Ver	1.01	340	11.0
15	4.960087	55.3	74.0	47.9	54.0	Hor	1.04	298	6.1
15	4.960087	55.7	74.0	45.8	54.0	Ver	1.04	45	8.2
0	7.215313	55.3	74.0	46.8	63.5 Note 2	Hor	1.05	188	16.7
0	7.215313	54.6	74.0	46.6	63.5 Note 2	Ver	1.05	130	16.9
7	7.321314	59.3	74.0	51.3	63.5 Note 2	Hor	1.05	127	12.2
7	7.321314	57.4	74.0	49.4	63.5 Note 2	Ver	1.05	188	14.1
15	7.441314	64.8	74.0	56.8	63.5 Note 2	Hor	1.05	132	6.7
15	7.441314	60.4	74.0	52.4	63.5 Note 2	Ver	1.05	180	11.1

Note 1: Average level is maximum-recorded peak level with applied relaxation factor as described in section 9.1 above.
Note 2: Limit shown reflects measurement taken at 1m from EUT.

Table 4 Summary of results for radiated spurious emissions in 2GHz – 25GHz band.

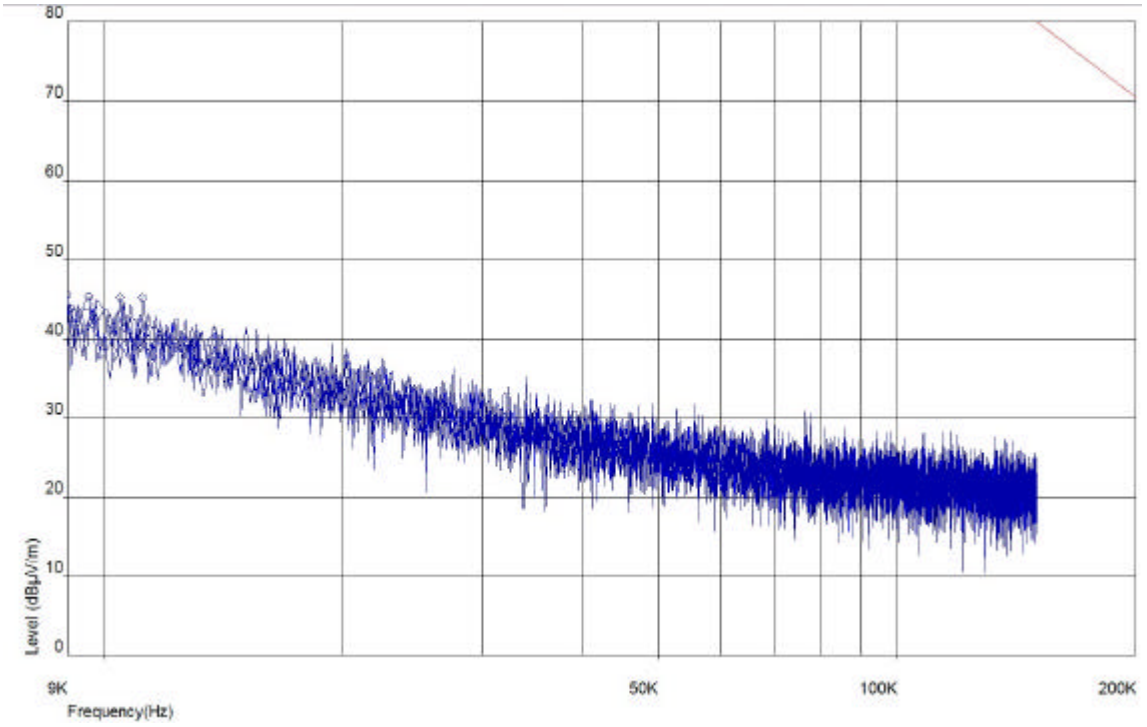

Figure 6 Composite graph of radiated emissions (9kHz – 150 kHz) from EUT

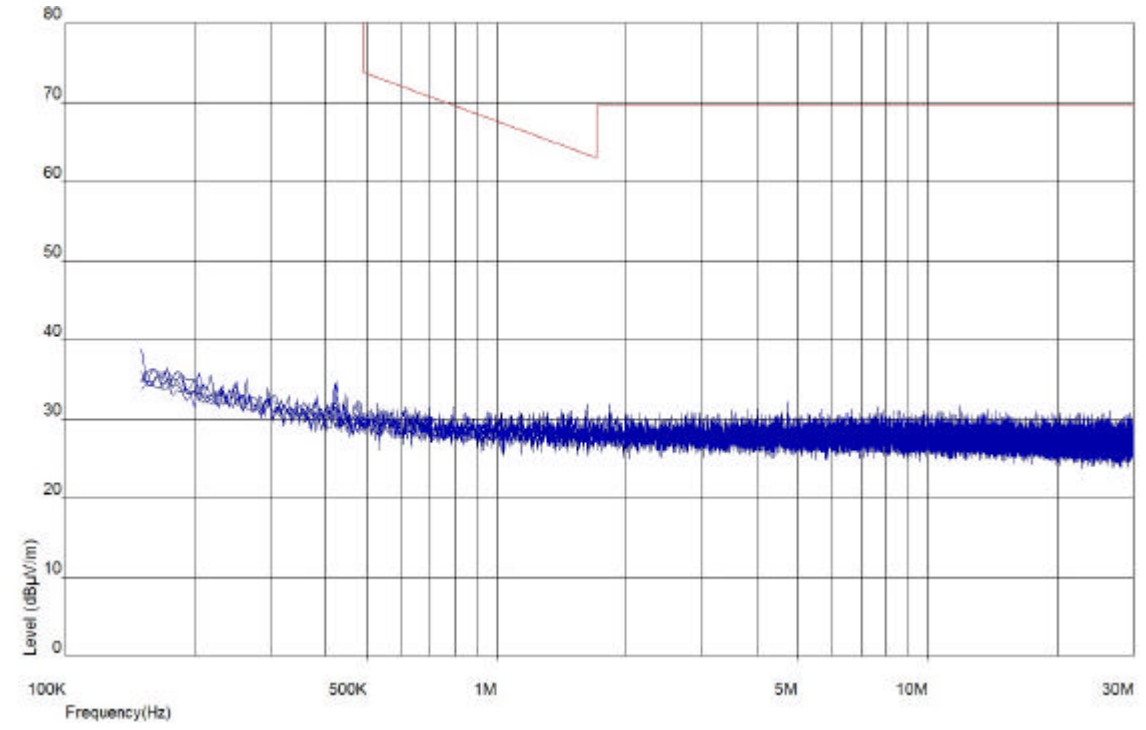

Figure 7 Composite graph of radiated emissions (150kHz–30MHz) from EUT

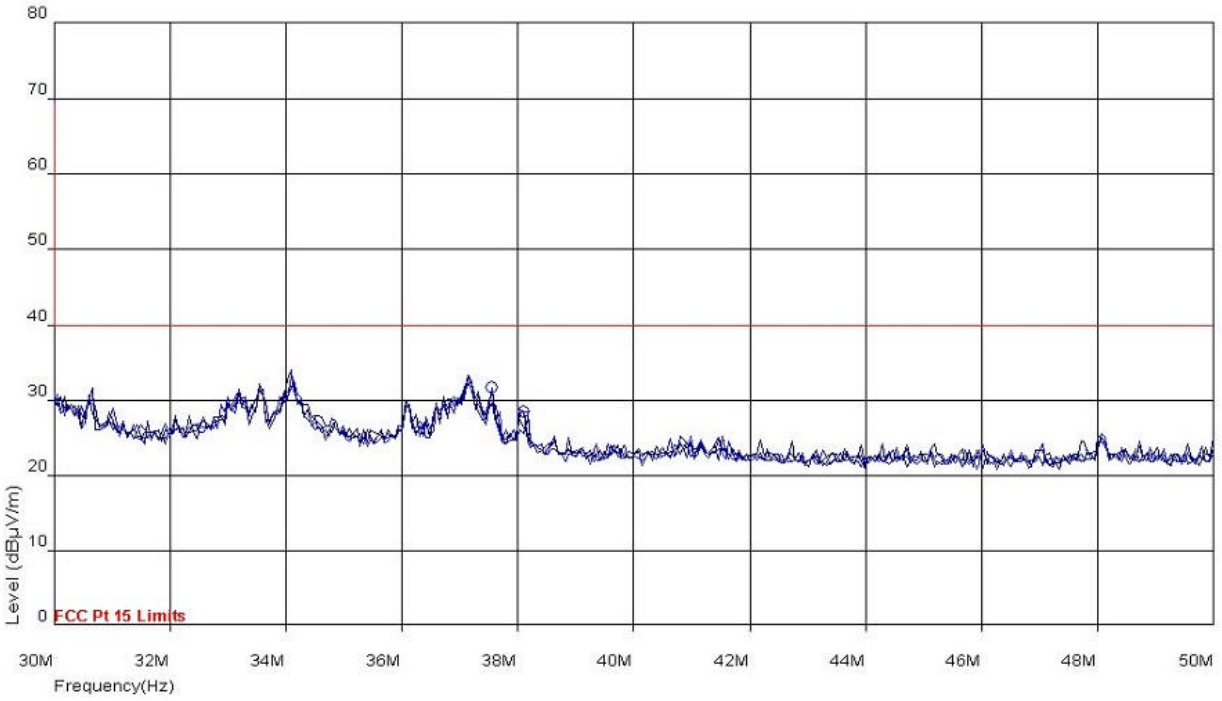

Figure 8 Composite graph of radiated emissions (30MHz–50 MHz) from EUT

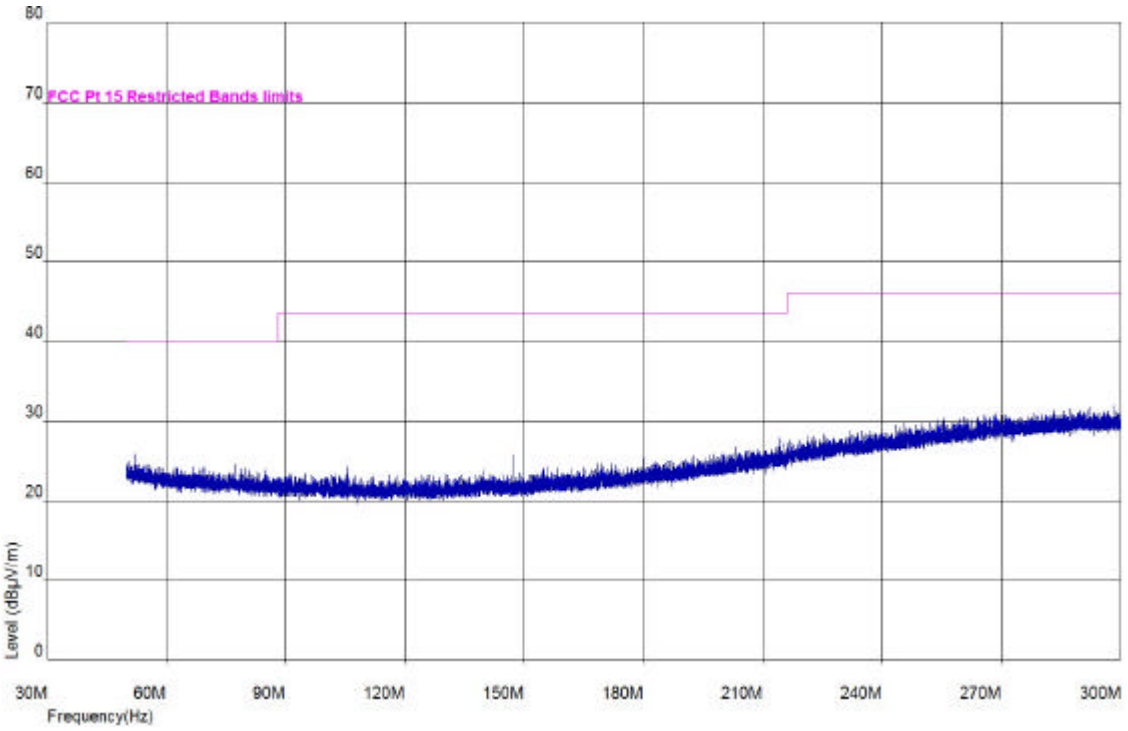

Figure 9 Composite graph of radiated emissions (50MHz-300MHz) from EUT

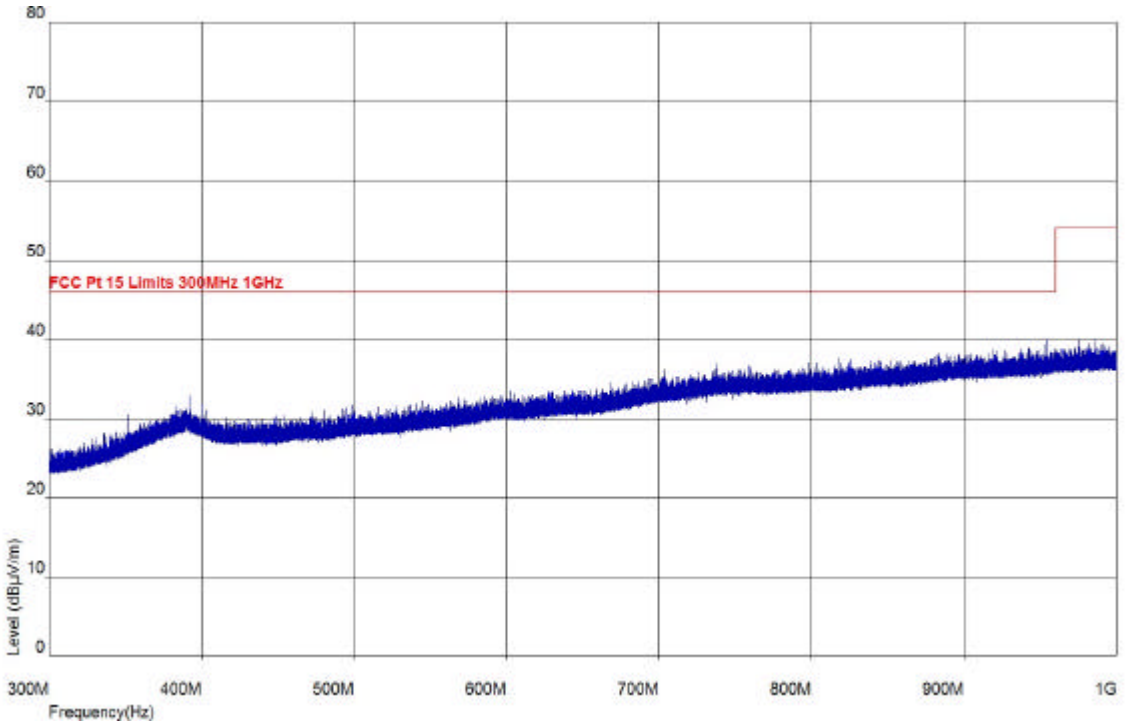

Figure 10 Composite graph of radiated emissions (300 MHz–1GHz) from EUT

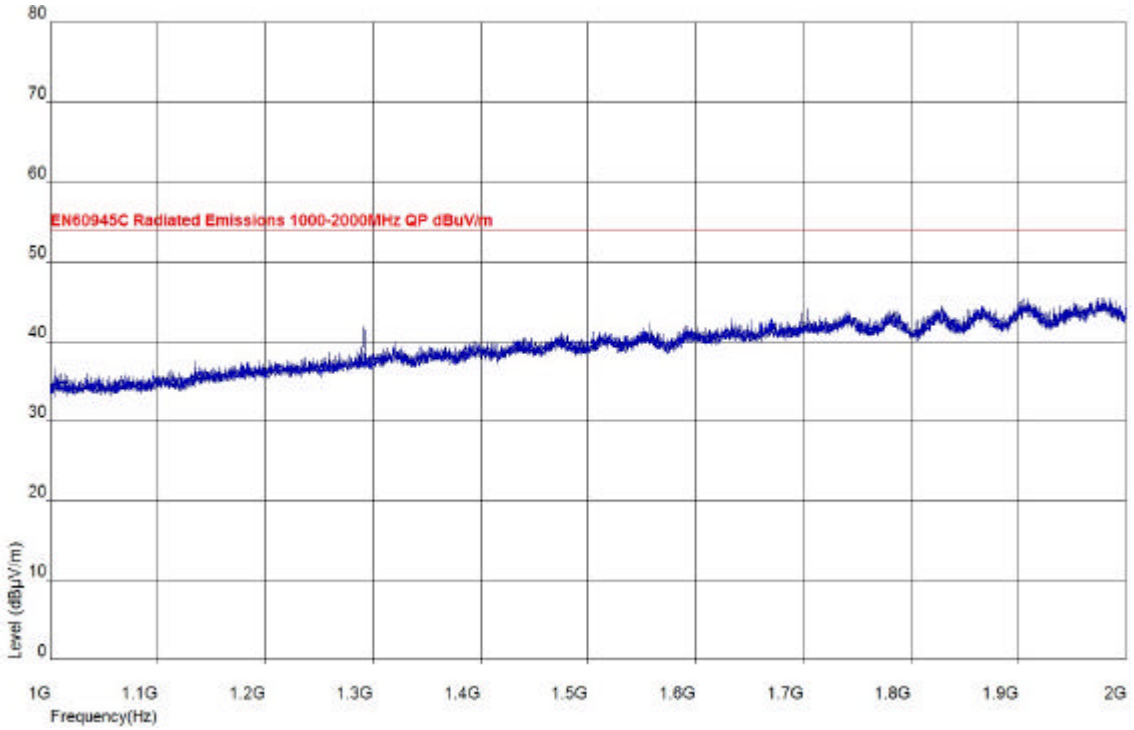

Figure 11 Composite graph of radiated emissions (1GHz-2GHz) from EUT

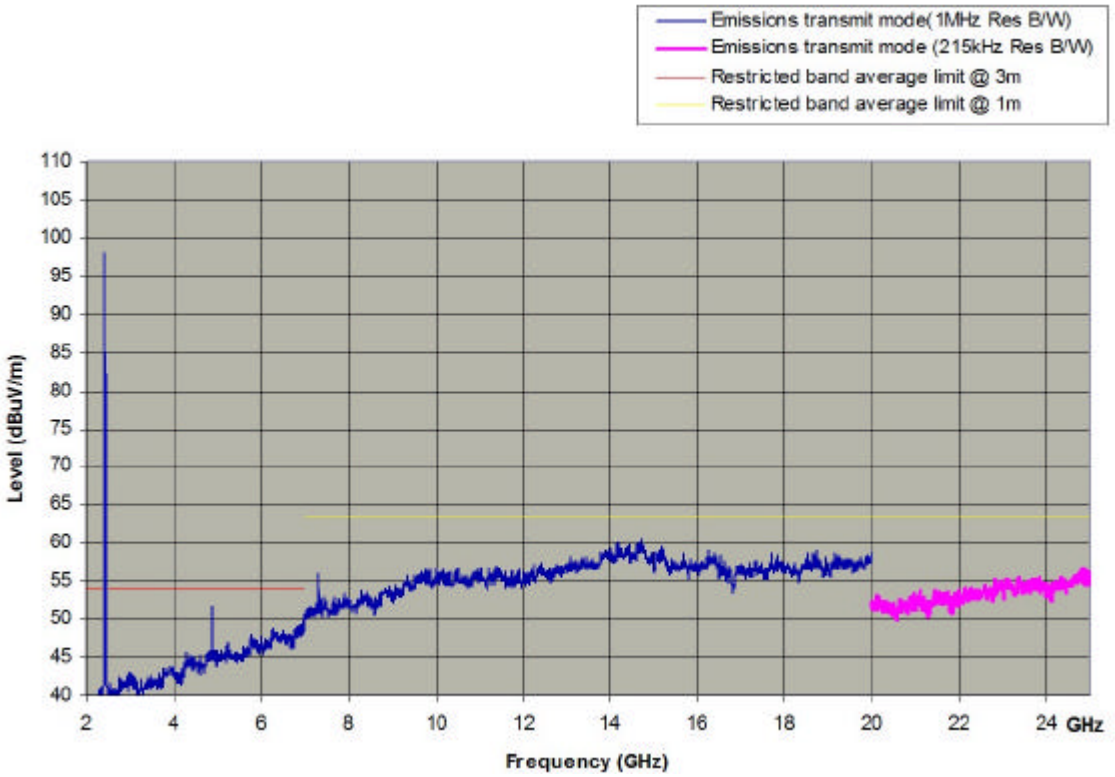

Figure 12 Composite graph of radiated emissions (2GHz-25GHz). EUT Tx on Ch7.

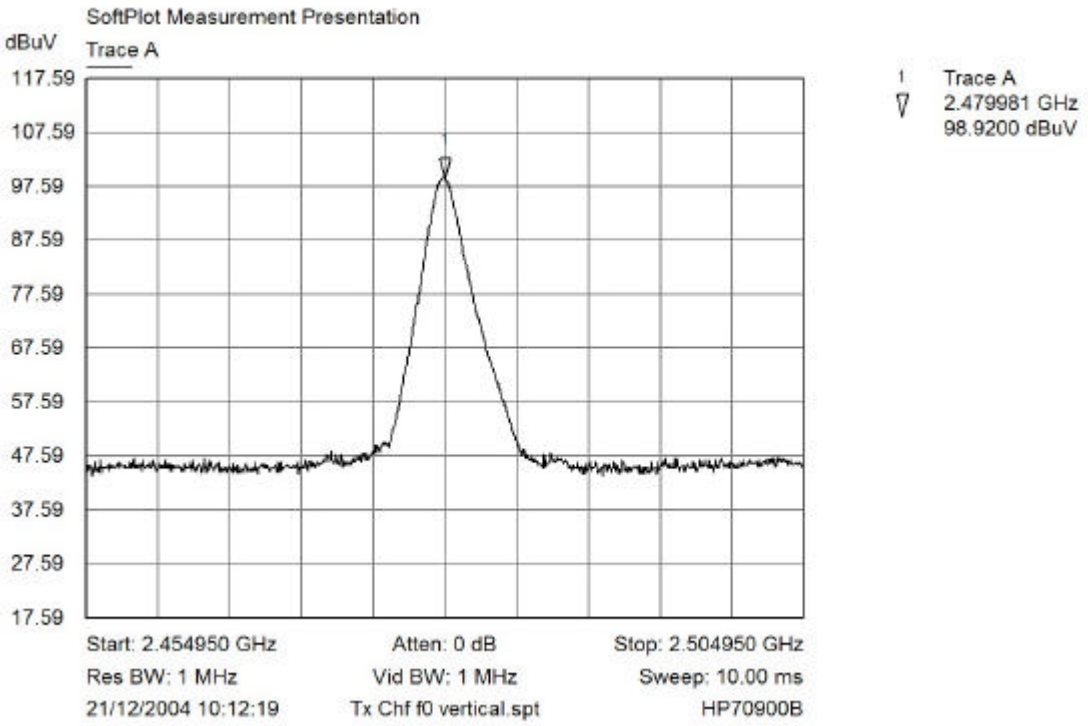

Figure 13 Channel 7 vertical (Highest recorded fundamental frequency)

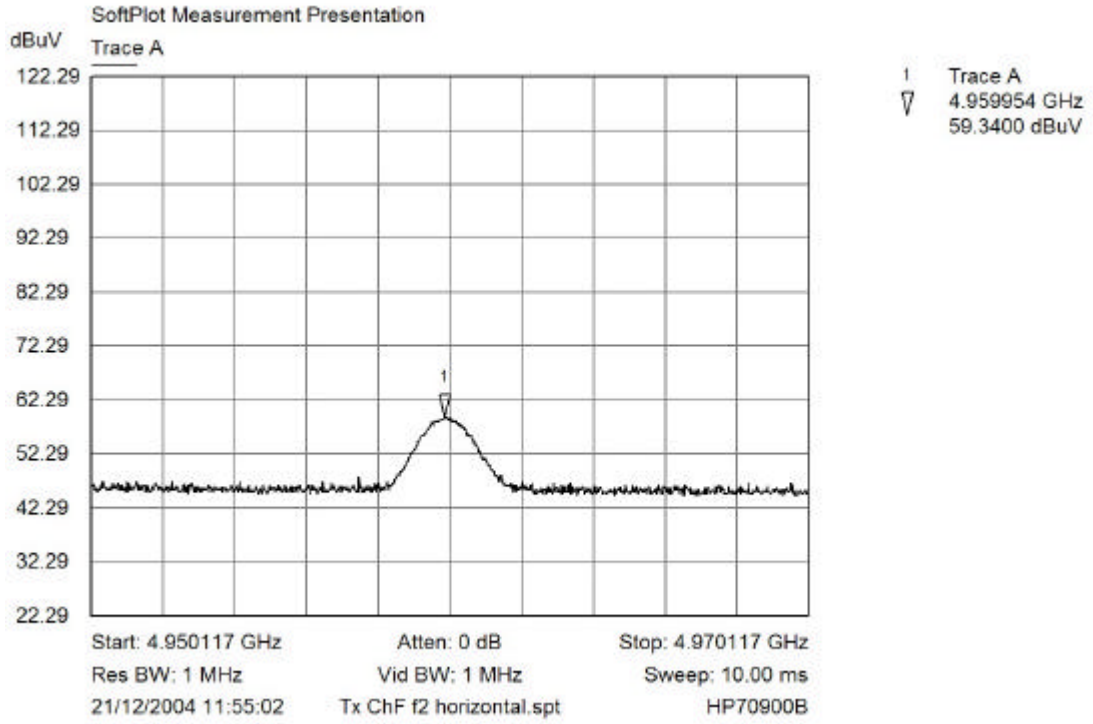

Figure 14 Channel 15 horizontal (Highest recorded 2nd harmonic)

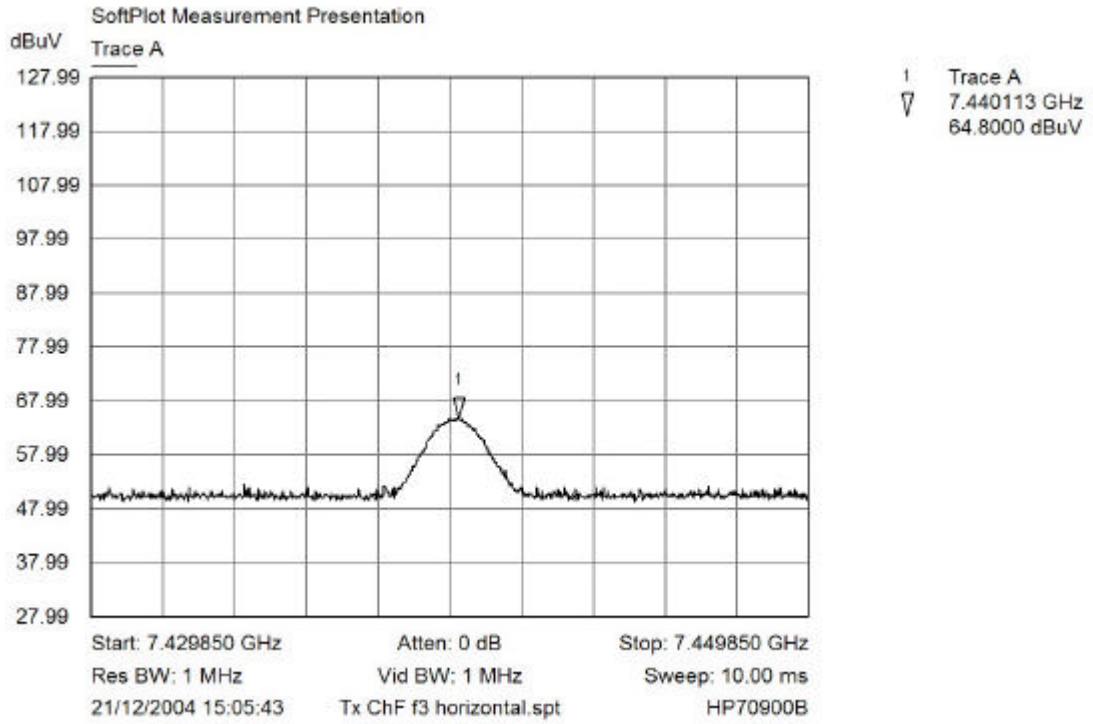

Figure 15 Channel 0 horizontal (Highest recorded 3rd harmonic)

10 Radiated emissions results – unintentional radiator

10.1 Test measurement limits.

The EUT was tested for spurious emissions between 30MHz and 25GHz (i.e. above 10th harmonic) against the following limits:

- Table of rule 15.109 (a)

Below 2GHz the EUT was tested with the S1000 Autopilot next to the S100 Controller on the table. All emissions found below 2GHz were due to the motor on the S1000 Autopilot.

10.2 Test results

10.2.1 30MHz – 50MHz

A composite graph combining sweeps taken at 90° intervals around the EUT in both vertical and horizontal polarisations is presented in Figure 16 below.

The following frequencies were investigated:

Freq (MHz)	QP level (dBµV/m)	Antenna polarity	Antenna height (m)	Turntable angle (Degrees)	Limit (dBµV/m)	? Limit (dB)
34.14	34.5	Vertical	1.01	056	40	5.5
37.20	30.4	Vertical	1.01	341	40	9.6
38.10	26.7	Vertical	1.06	304	40	13.3

Table 5 Quasi peak results for emissions in 30MHz – 50 MHz band.

10.2.2 50MHz – 300MHz

A composite graph combining sweeps taken at 90° intervals around the EUT in both vertical and horizontal polarisations is presented in Figure 17 below.

The following frequencies were investigated with a quasi-peak detector, all the emissions investigated were from the motor on the S1000 Autopilot:

Freq (MHz)	QP level (dBµV/m)	Antenna polarity	Antenna height (m)	Turntable angle (Degrees)	Limit (dBµV/m)	? Limit (dB)
74.78	18.5	Vertical	1.26	039	40.0	21.5
115.22	19.7	Vertical	1.06	164	43.5	23.8
118.52	18.0	Horizontal	1.89	278	43.5	25.5
130.16	15.0	Vertical	3.14	057	43.5	28.5
133.82	16.9	Vertical	1.25	012	43.5	26.6
137.00	14.8	Vertical	1.01	023	43.5	28.7
269.72	23.2	Horizontal	1.26	029	46.0	22.8
285.14	23.2	Vertical	1.01	075	46.0	22.8

Table 6 Quasi peak results for emissions in 50 – 300MHz band

The other identified peaks within this band were all greater than 10dB below the limit.

10.2.3 300MHz – 1GHz

A composite graph combining sweeps taken at 90° intervals around the EUT in both vertical and horizontal polarisations is presented in Figure 18 below.

All peaks found were from the motor in the S1000 Autopilot, a plot without the motor running shows no peaks. The following frequencies were investigated with a quasi-peak detector:

Freq (MHz)	QP level (dBµV/m)	Antenna polarity	Antenna height (m)	Turntable angle (Degrees)	Limit (dBµV/m)	? Limit (dB)
525.66	22.9	Horizontal	1.86	066	46.0	23.1
525.96	22.9	Vertical	1.66	091	46.0	23.1
535.92	23.1	Horizontal	2.72	270	46.0	22.9

10.2.4 1GHz – 2GHz

There were no peak emissions detected above 10dB below the limit. The noise floor was greater than 8dB below the specification limits (worse case). A composite graph combining sweeps taken at 90° intervals around the EUT in both vertical and horizontal polarisations is presented in Figure 19 below.

10.2.5 2GHz – 25GHz

The frequency sweeps above 2GHz clearly indicated a spurious emission radiating from the EUT (see Figure 20 below). This was investigated in more detail on channels 0, 7 and 15. The worst-case peak emission in max hold mode was measured on channel 15 at 4.956038 GHz. A plot of this measurement is shown in Figure 21 below.

There were no other emissions identified or investigated in the 2GHz to 25GHz band.

Channel No.	Freq (GHz)	Max peak level (dBµV/m)	Average Limit (dBµV/m)	Ae polarity	Ae height (m)	Turntable angle (Degrees)	? Limit (dB)
0	4.806137	49.0	54	Hor	1.16	127	5.0
0	4.805812	NF	54	Ver	-	-	-
7	4.876062	49.6	54	Hor	1.09	172	4.4
7	4.875987	NF	54	Ver	-	-	-
15	4.956020	49.3	54	Hor	1.05	126	4.7
15	4.956063	NF	54	Ver	-	-	-

* Margin quoted based on max peak measurement only.

Table 7 Summary of results for radiated spurious emissions in 2GHz – 25GHz band.

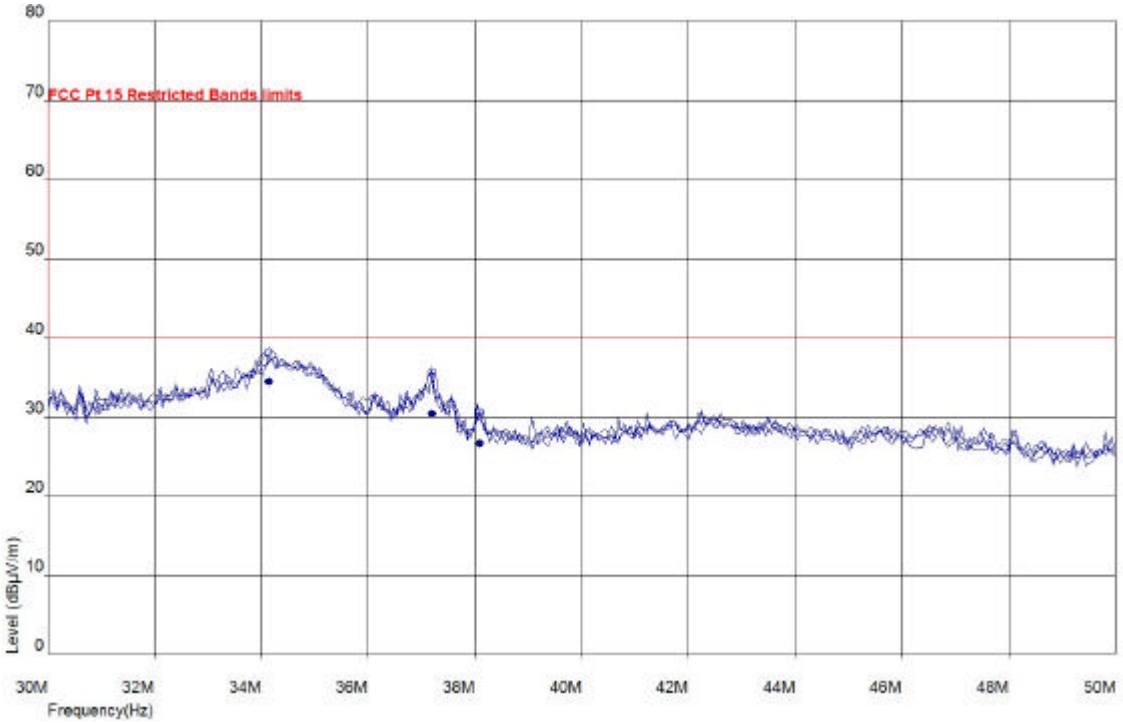

Figure 16 Composite graph of radiated emissions (30MHz–50 MHz) from EUT

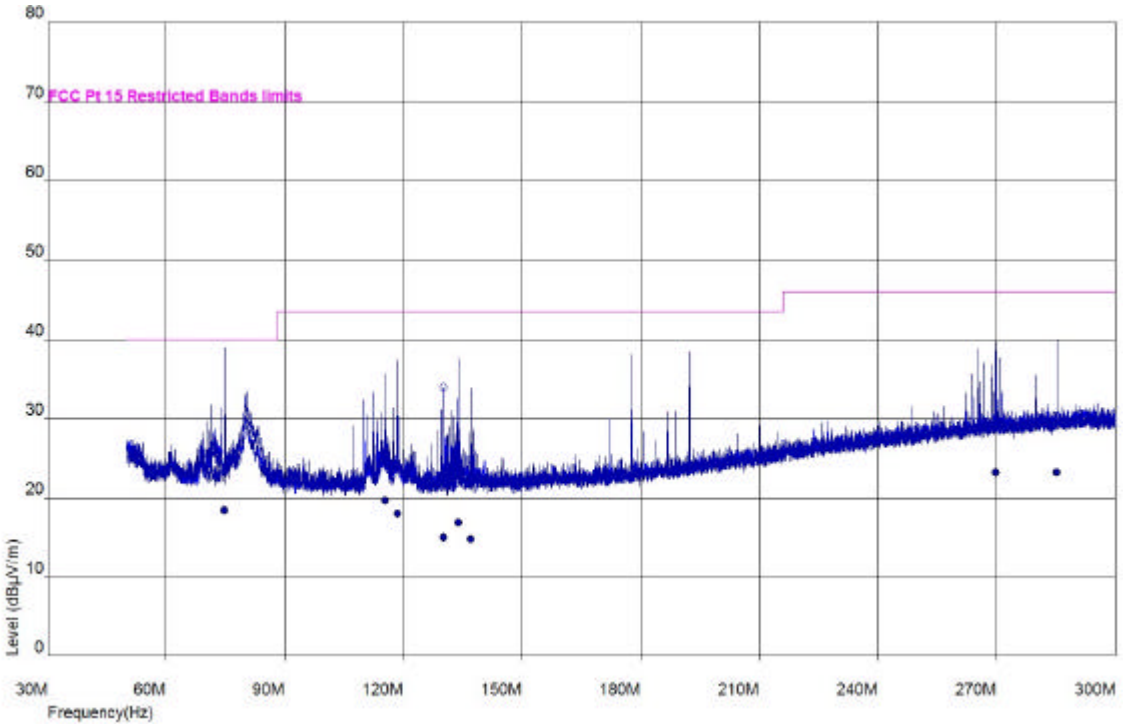

Figure 17 Composite graph of radiated emissions (50MHz-300MHz) from EUT

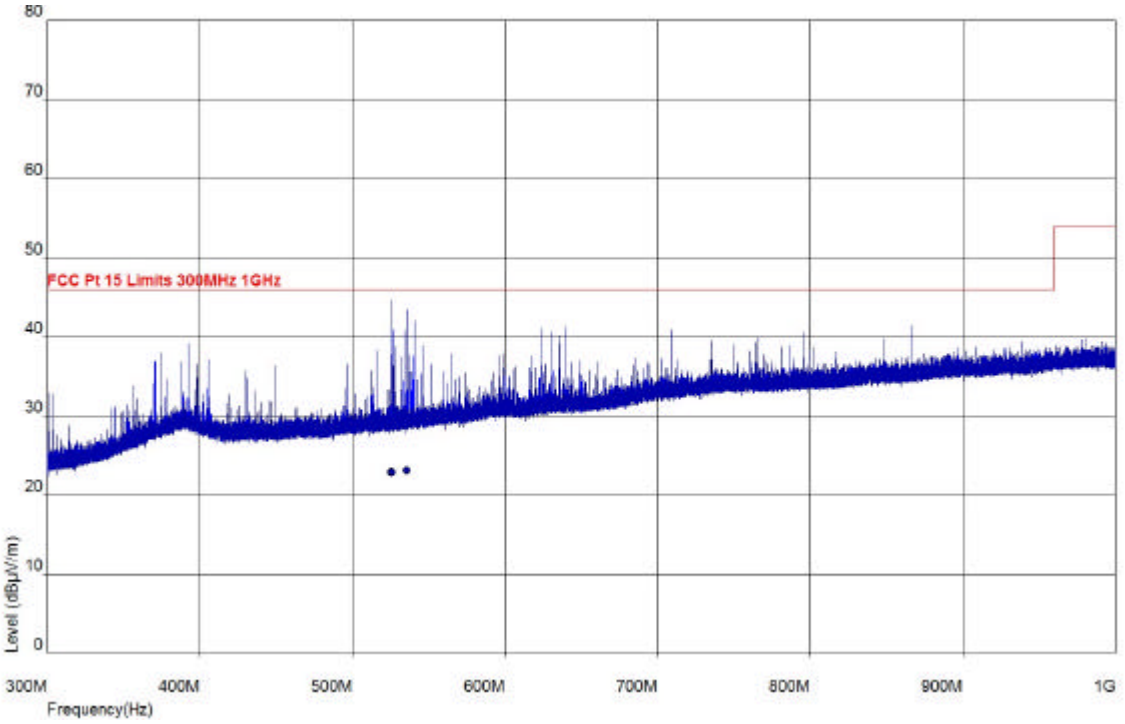

Figure 18 Composite graph of radiated emissions (300MHz-1GHz) from EUT

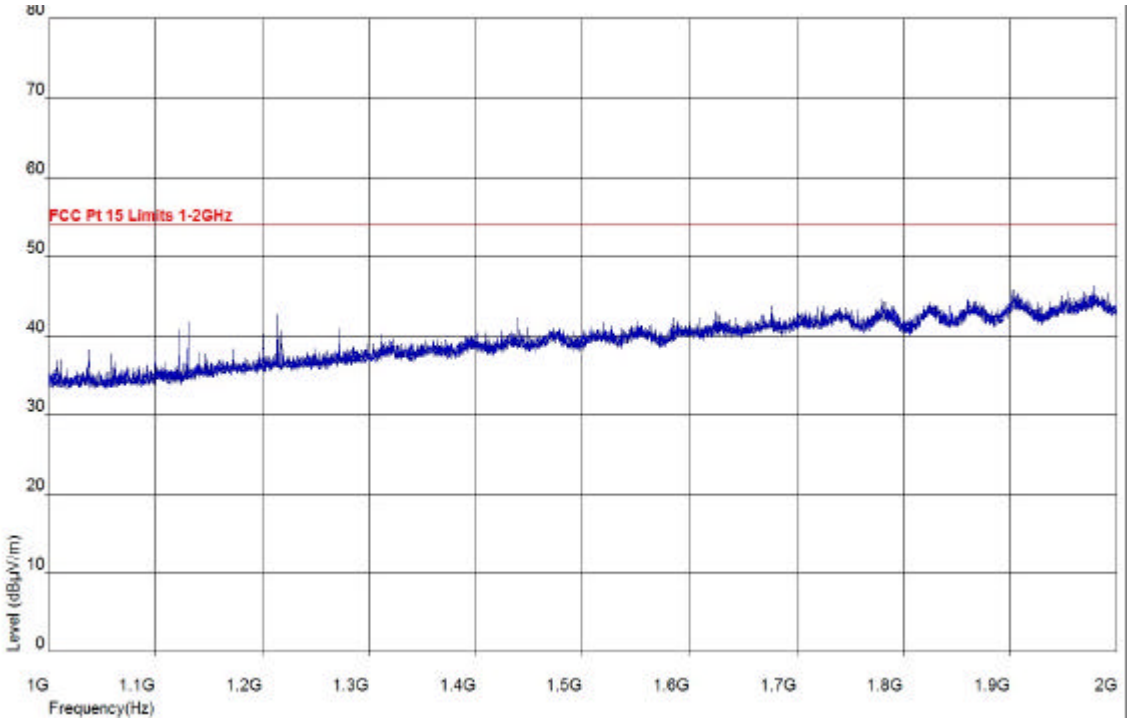

Figure 19 Composite graph of radiated emissions (1GHz-2GHz) from EUT

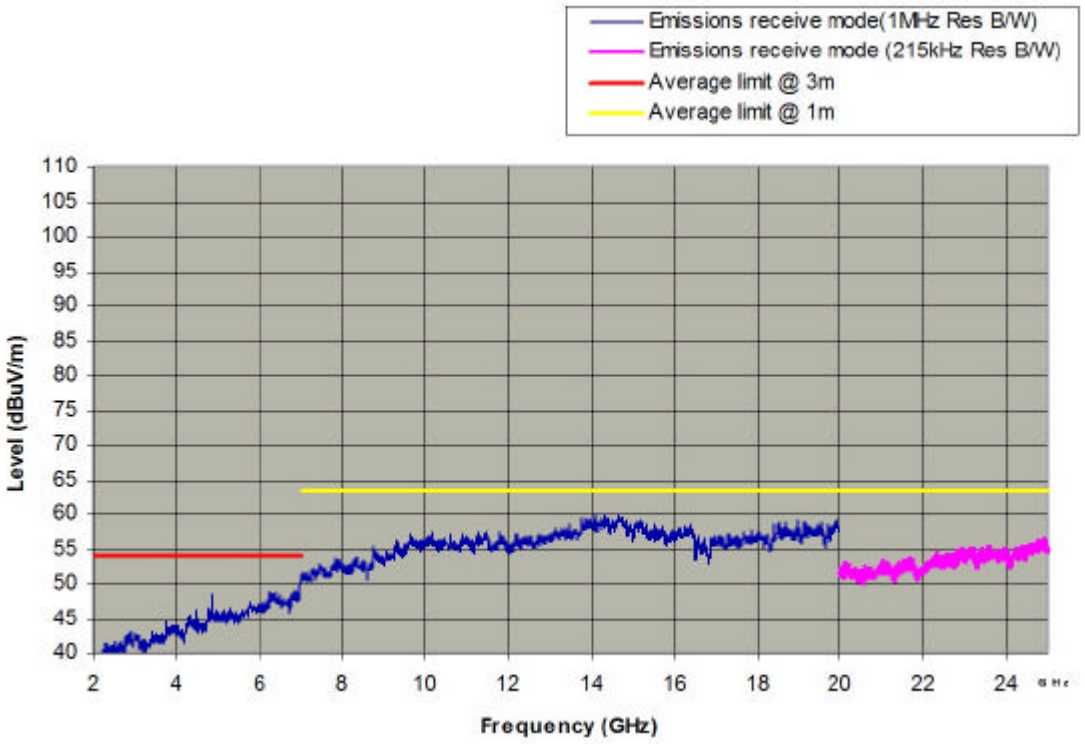

Figure 20 Composite graph of radiated emissions (2GHz-25GHz). EUT Rx on Ch 7

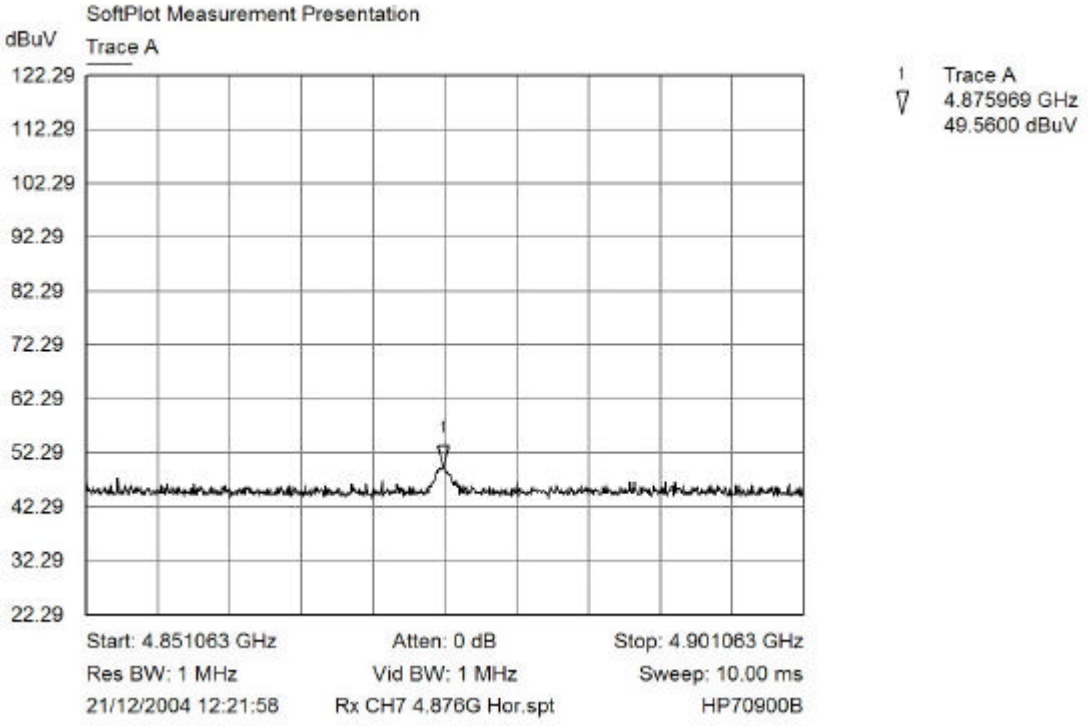

Figure 21 Channel 7 @ 4.876 GHz; horizontal (peak detector)

11 Test equipment list

Test Equipment Type	Manufacturer and Type Number	Serial Number	TE No.
Semi-Anechoic Chamber, Site 3	Global EMC	GE002	
Biconical Antenna, 30-300MHz	Schwarzbeck VHBB9124/BBAK9137	285	**0968**
Log-Periodic Antenna, 0.3-3.0GHz	Emco EM6946	112	**0969**
Antenna Horn 1-18GHz	Chase BBHA9120D	128	**1446**
Antenna Horn 18-26GHz	Credowan 20-R-2843-0007	36755	**1448**
Active Loop Antenna 9kHz - 30MHz	Chase EMC HLA6120	1122	**0904**
RF receive cable 2GHz – 26GHz	Amp Inc. Testline 18	1087200-4	
Loop Antenna PSU/Charger	Chase EMC CBP9720	1076	**1424**
Antenna Mast (Site 3)	EMCO 2075 4m Mini-Mast		**1526**
Turntable (Site 3)	EMCO Lo-Pro Turntable		**1527**
Mast/Turntable/Antenna Controller (Site 3)	EMCO 2090 Multi-Device Controller	9712-1278	**1525**
EMI Test Receiver 9kHz-6.5GHz	Hewlett-Packard 8546A	3625A00329/3448A00219	**1432/33**
Spectrum Analyser 20Hz - 26.5GHz	HP70000 series	3230A05180	**1605**
R.F. Preamplifier 9kHz-1.3GHz	Hewlett-Packard 8477F	3113A05581	**1822**
Power Supply Unit	Palstar PS30M	92534722	**1454A**
Computer	Dell Optiplex Pentium GX1 400	T742	**N/A**
Emissions Software	Schaffner-Chase CES9985 v1.11	VCQZPC	**N/A**

In accordance with UKAS requirements, all measuring equipment is on a calibration cycle.