Part 2

7 Photographs (Continued)

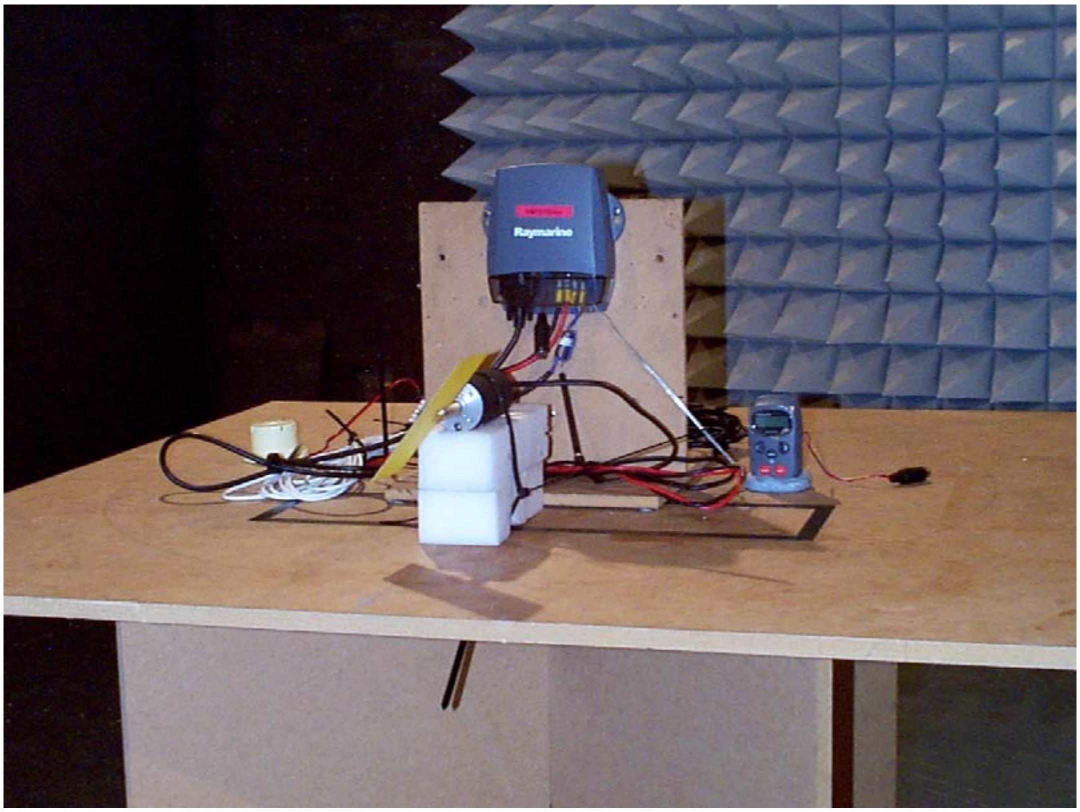

Figure 1 Setup for Receive mode below 2GHz

8 Method of test

The EUT was placed on the turntable and powered from a 12V PSU. The purpose of the EUT is to automatically pilot a boat on a set course and to enable transmission of SeaTalk data via an RF link between the EUT and a Raymarine remote handset.

In normal use the EUT only transmits in response to a data request or a command received from a Raymarine handheld RF device registered to it. 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 9 and Figure 16 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 16, 17 and figure 23)

The frequency sweeps were as follows:

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

<u>7GHz-12GHz</u>
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:

λ at 7GHz = 0.042m

$$d > \frac{2l^2}{\lambda} \qquad \text{(l=4.83cm)}$$

$$d > \frac{2(0.0483)^2}{0.042} = 0.111 \text{ m}$$

$$= 111 \text{ mm}$$

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

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

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

<u>20GHz-25GHz</u>
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)):

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

9.2 Test results

9.2.1 9KHz – 150kHz

All emission detected were greater than 20dB below the required limit. 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 2 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 3 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 4 below.

The following frequencies were investigated:

Freq (MHz)	**QP level (dBµV/m)**	**Antenna polarity**	**Antenna height (m)**	**Turntable angle (Degrees)**	**Limit (dBµV/m)**	**Δ Limit (dB)**
34.14	31.1	Vertical	1.25	245	40	-8.9
34.92	34.6	Vertical	1.01	056	40	-5.4
37.14	28.7	Vertical	1.01	164	40	-11.3
37.56	30.4	Vertical	2.17	118	40	-9.6
44.64	25.7	Vertical	1.01	253	40	-14.3
45.30	25.8	Vertical	1.01	234	40	-14.2

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

A composite graph combining sweeps taken at 90˚ intervals around the EUT in both vertical and horizontal polarisations is presented in Figure 5 below.

The following frequencies were investigated:

Freq (MHz)	**QP level (dBµV/m)**	**Antenna polarity**	**Antenna height (m)**	**Turntable angle (Degrees)**	**Limit (dBµV/m)**	**Δ Limit (dB)**
73.82	17.8	Vertical	1.45	288	40.0	-22.2
134.66	15.4	Vertical	3.58	057	43.5	-28.1
135.32	16.0	Vertical	1.78	147	43.5	-27.5
260.00	21.9	Horizontal	1.45	297	46.0	-24.1
261.98	20.6	Horizontal	1.06	030	46.0	-25.4

Table 3 Quasi peak results for emissions in 50MHz – 300MHz band.

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

9.2.5 300MHz – 1GHz

A composite graph combining sweeps taken at 90˚ intervals around the EUT in both vertical and horizontal polarisations is presented in Figure 6 below.

The following frequencies were investigated:

Freq (MHz)	QP level (dBµV/m)	Antenna polarity	Antenna height (m)	Turntable angle (Degrees)	Limit (dBµV/m)	Δ Limit (dB)
409.32	20.3	Vertical	3.56	133	46.0	25.7
410.46	21.8	Vertical	3.20	052	46.0	24.2
547.32	23.5	Vertical	3.39	146	46.0	22.5
562.80	22.9	Horizontal	1.77	297	46.0	23.1
767.10	26.4	Horizontal	1.01	277	46.0	19.6

Table 4 Quasi peak results for emissions in 300MHz – 1GHz band.

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

9.2.6 1GHz – 2GHz

A composite graph combining sweeps taken at 90˚ intervals around the EUT with the motor running in both vertical and horizontal polarisations is presented in Figure 7 below. A second graph with identical setup, but without the motor running is shown in Figure 8 below. It can be seen from the two graphs that all the emissions are due to the motor running, the selection of peaks measured were selected across the band to show the average of the emissions are below the required limit.

The following frequencies were investigated:

Freq (MHz)	QP level (dBµV/m)	Antenna polarity	Antenna height (m)	Turntable angle (Degrees)	Limit (dBµV/m)	Δ Limit (dB)
1.038	24.2	Horizontal	1.25	086	54.0	29.8
1.039	24.2	Vertical	2.41	158	54.0	29.8
1.062	24.1	Vertical	2.97	103	54.0	29.9
1.078	24.3	Horizontal	1.76	121	54.0	29.7
1.102	24.7	Vertical	3.55	156	54.0	29.3
1.126	24.5	Horizontal	1.25	002	54.0	29.5
1.166	25.5	Horizontal	2.61	067	54.0	28.5
1.284	27.0	Vertical	2.17	076	54.0	27.0
1.296	26.9	Vertical	1.84	185	54.0	27.1
1.360	27.9	Horizontal	3.59	124	54.0	26.1
1.742	33.0	Horizontal	2.97	276	54.0	21.0

Table 5 Quasi peak results for emissions in 1 - 2GHz band.

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

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 10.

Channel No.	Freq (GHz)	Peak level (dBμV/m)	Antenna polarity	Antenna height (m)	Turntable angle (Degrees)
0	2.405313	96.6	Vertical	1.10	267
0	2.405313	93.4	Horizontal	1.03	135
7	2.440438	91.1	Vertical	1.11	271
7	2.440438	98.9	Horizontal	1.10	137
15	2.480438	97.3	Vertical	1.01	132
15	2.480438	99.3	Horizontal	1.10	266

Table 6 Summary of results of fundamental frequency levels for channels 0, 7, 15.

The frequency sweeps above 2GHz clearly indicated an emission at the 2nd harmonic frequency of the EUT (see Figure 9 below). This was investigated in more detail on channels 0, 7 and 15. The results from these measurements have been presented in Table 6 and 7 and a plot of the highest recorded emission presented in Figure 10.

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)	Δ Limit (dB)
0	4.810088	50.3	74.0	42.3	54.0	Hor	1.08	330	11.7
0	4.810088	52.0	74.0	44.0	54.0	Ver	1.06	026	11.0
7	4.879987	57.1	74.0	49.1	54.0	Hor	1.05	323	4.9
7	4.879987	55.1	74.0	47.1	54.0	Ver	1.03	028	6.9
15	4.960087	55.3	74.0	47.5	54.0	Hor	1.00	327	6.5
15	4.960087	60.3	74.0	52.3	54.0	Ver	1.00	030	1.7

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

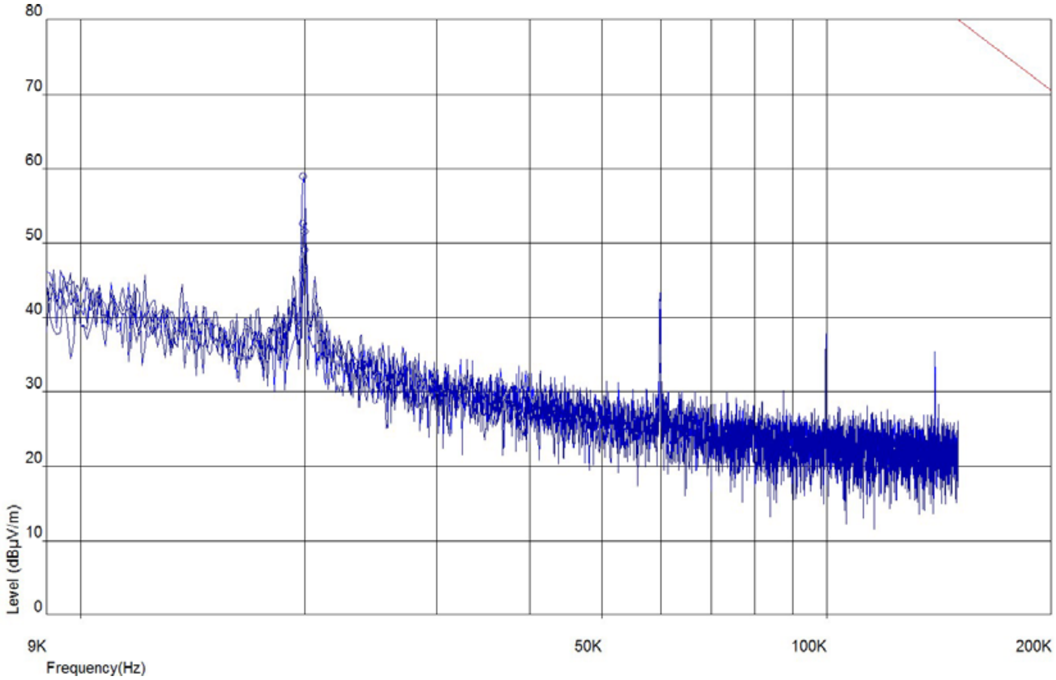

Figure 2 Composite graph of radiated emissions (9kHz – 150 kHz) from EUT

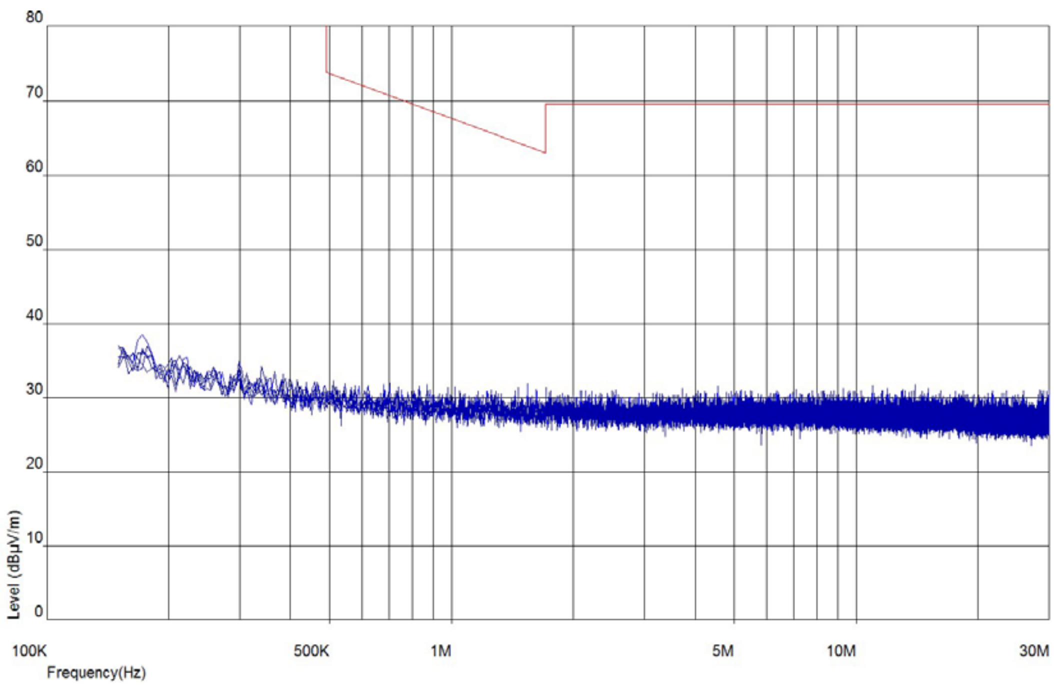

Figure 3 Composite graph of radiated emissions (150kHz–30MHz) from EUT

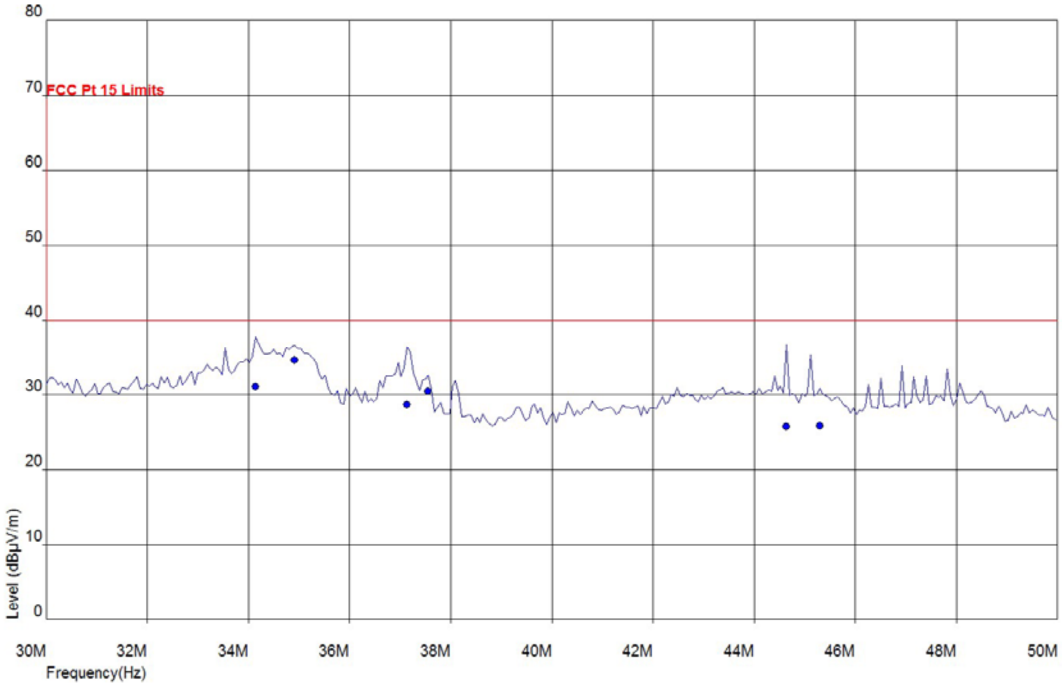

Figure 4 Composite graph of radiated emissions (30MHz–50 MHz) from EUT

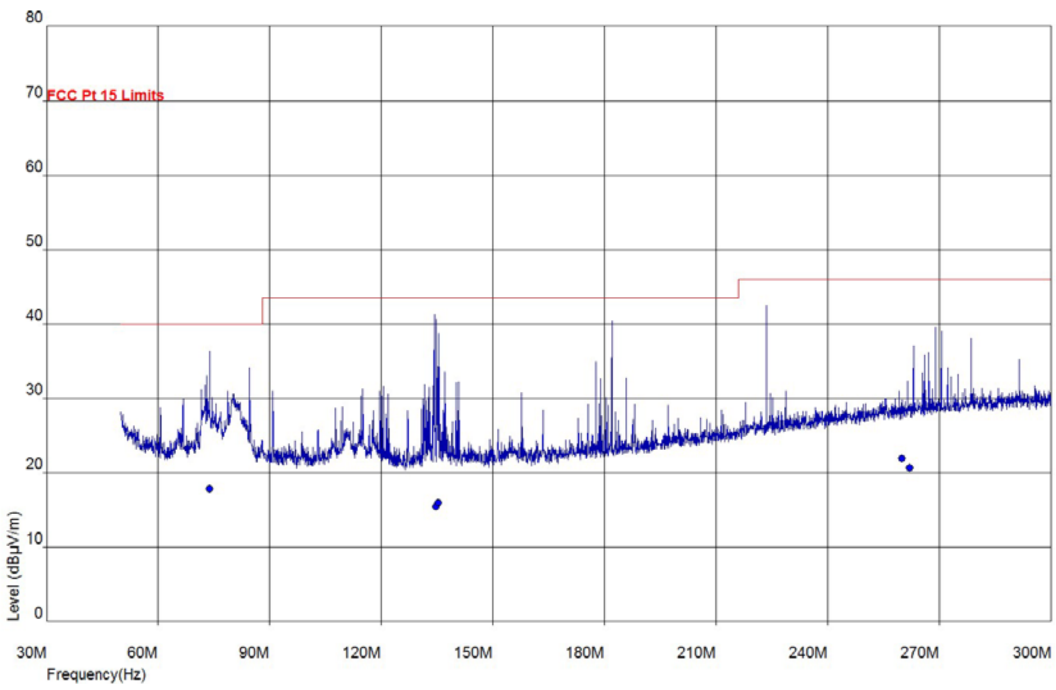

Figure 5 Composite graph of radiated emissions (50MHz-300MHz) from EUT

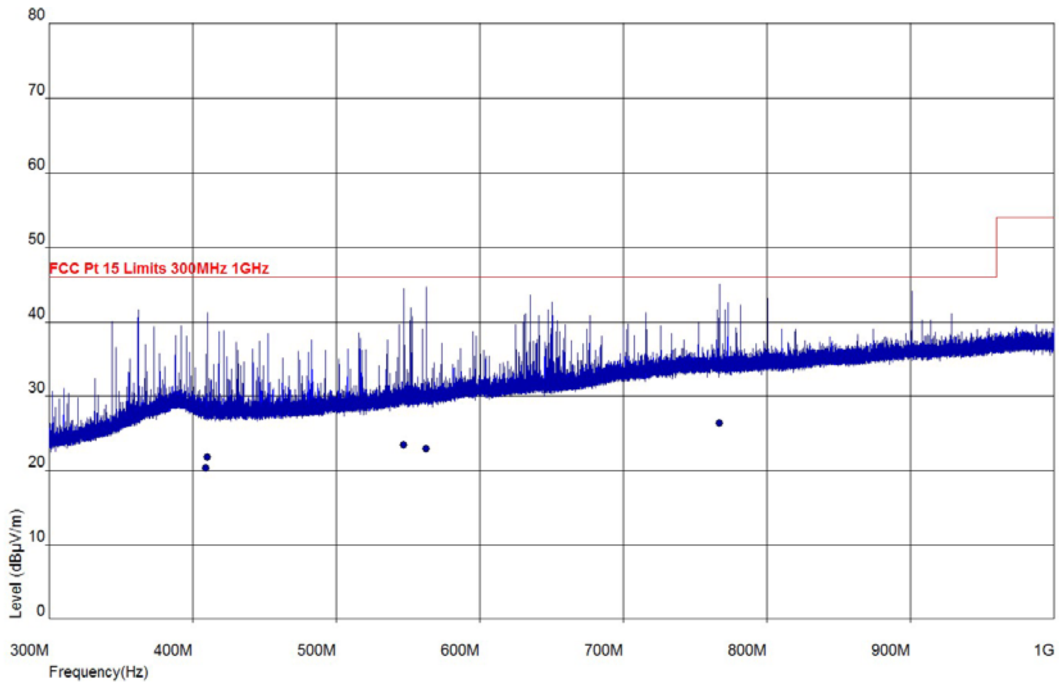

Figure 6 Composite graph of radiated emissions (300 MHz–1GHz) from EUT

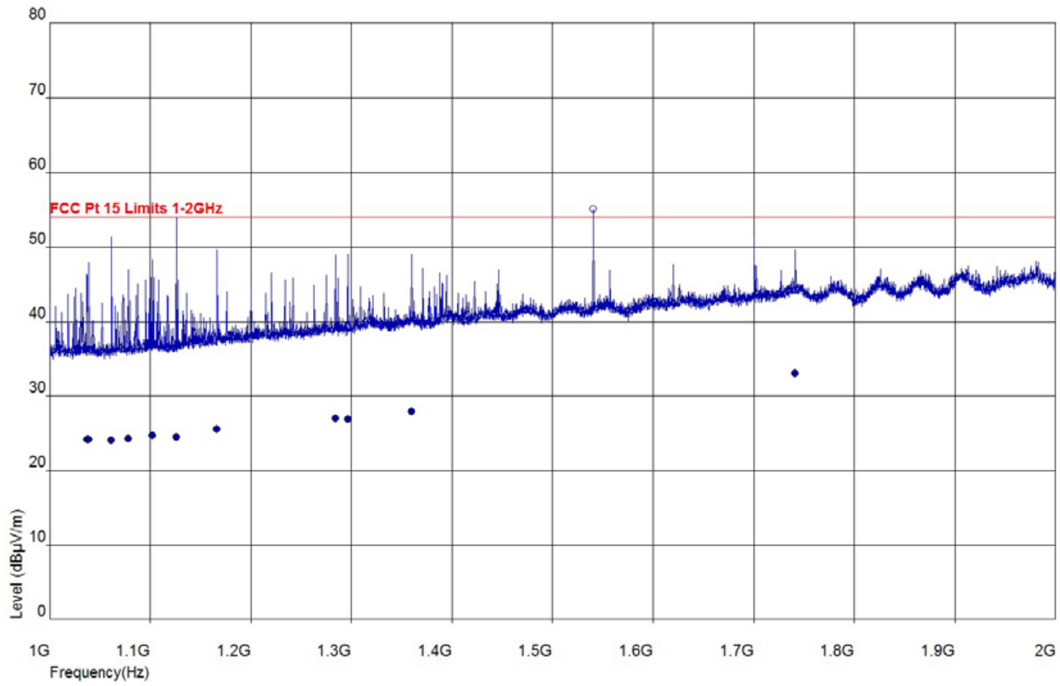

Figure 7 Graph of radiated emissions (1GHz-2GHz) from EUT- Motor Running

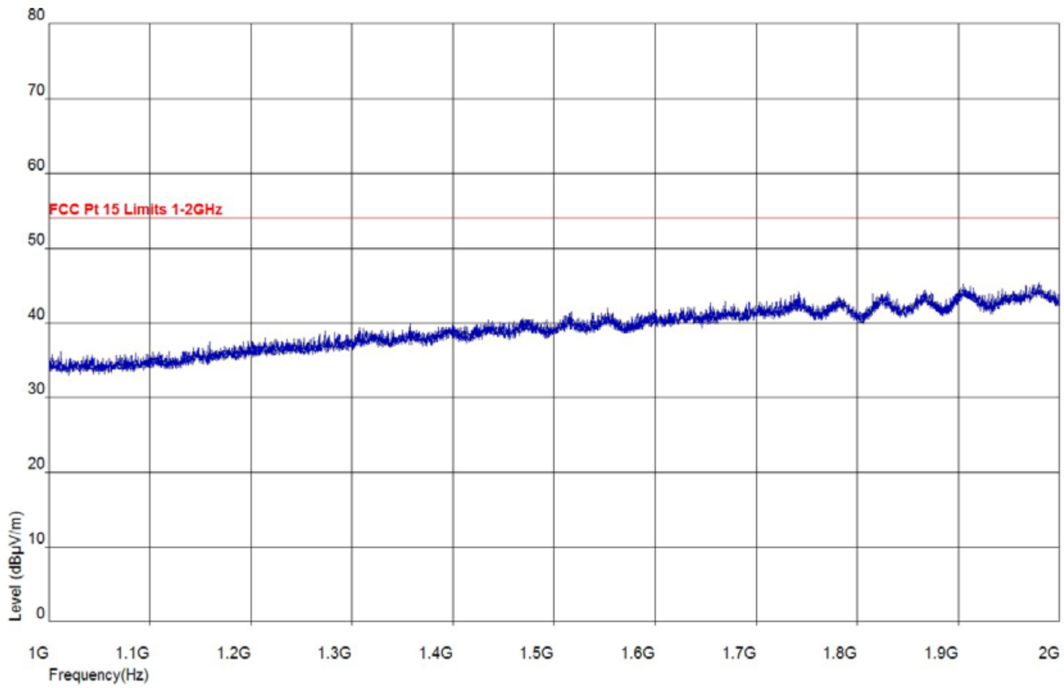

Figure 8 Graph of radiated emissions (1GHz-2GHz) from EUT- Motor not Running

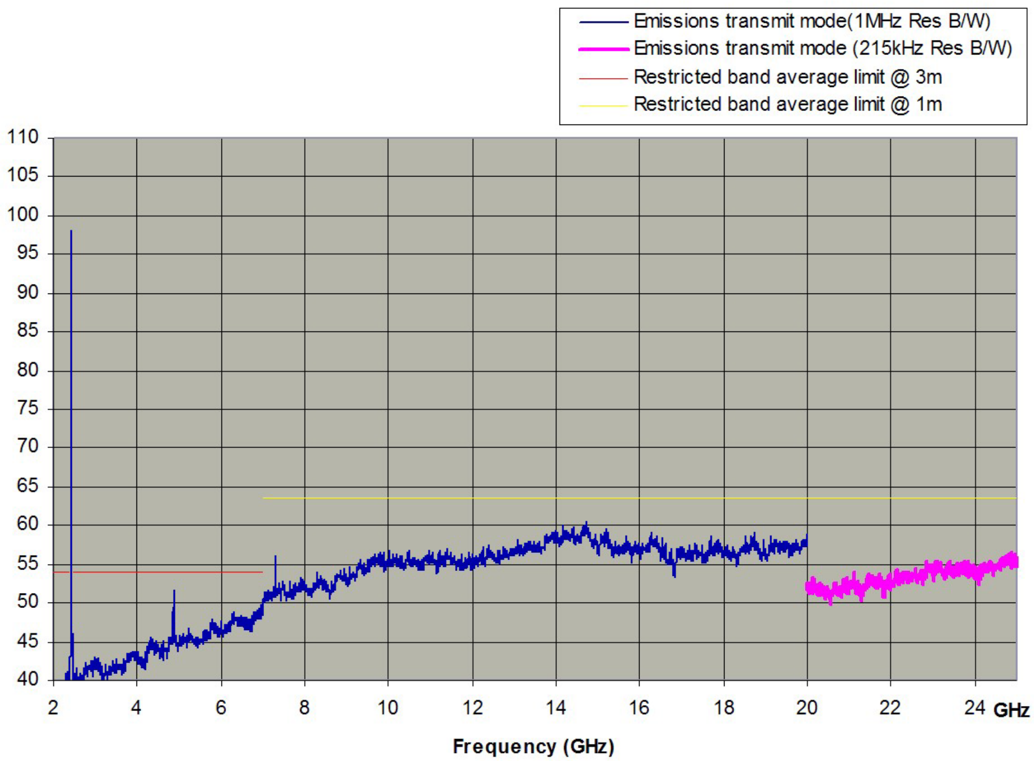

Figure 9 Composite graph of radiated emissions (2GHz-25GHz). EUT Tx on Ch7.

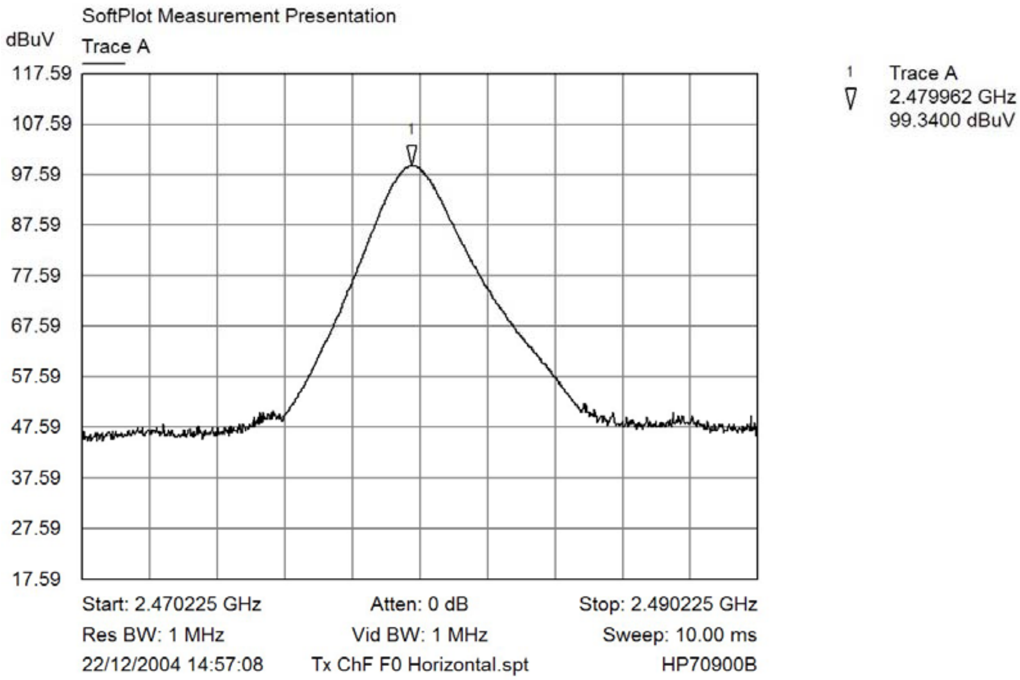

Figure 10 Channel 7 vertical (Highest recorded fundamental frequency)

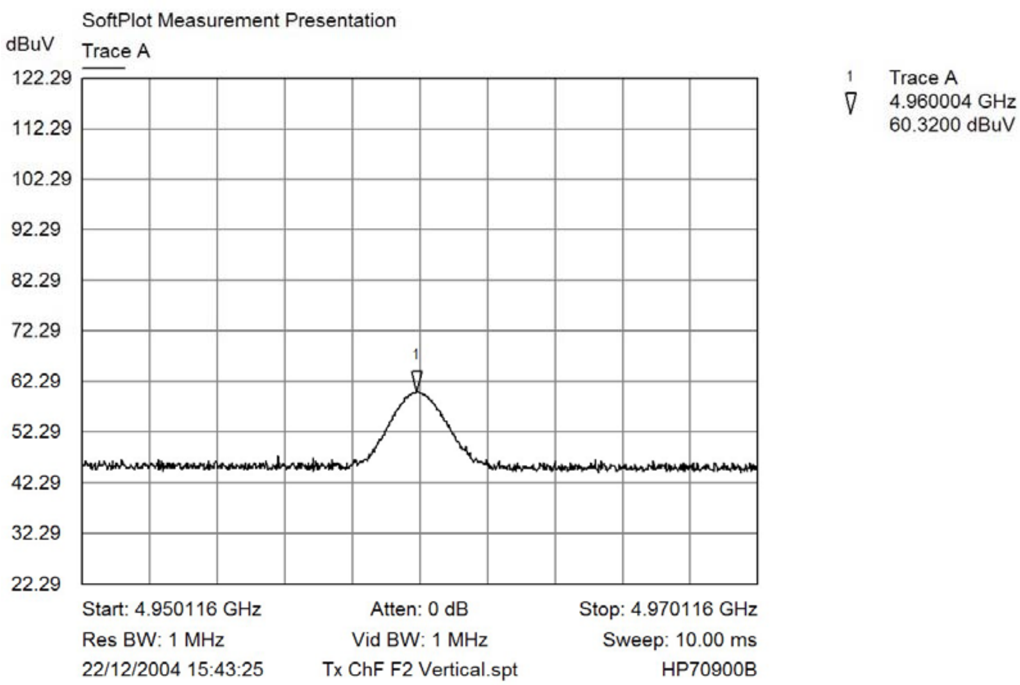

Figure 11 Channel 15 horizontal (Highest recorded 2nd harmonic)

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 S100 Controller next to the S1000 Autopilot 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 12 below.

The following frequencies were investigated:

Freq (MHz)	QP level (dBμV/m)	Antenna polarity	Antenna height (m)	Turntable angle (Degrees)	Limit (dBμV/m)	Δ 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 8 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 13 below.

The following frequencies were investigated with a quasi-peak detector, all the emissions found above the noise floor were from the motor on the S1000 Autopilot, those investigated gave quasi-peak levels more than 20dB below the limit:

Freq (MHz)	QP level (dBμV/m)	Antenna polarity	Antenna height (m)	Turntable angle (Degrees)	Limit (dBμV/m)	Δ 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 9 Quasi peak results for emissions in 50 – 300MHz band

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 14 below.

The following frequencies were investigated with a quasi-peak detector, all the emissions found above the noise floor were from the motor on the S1000 Autopilot, those investigated gave quasi-peak levels more than 20dB below the limit:

Freq (MHz)	QP level (dBµV/m)	Antenna polarity	Antenna height (m)	Turntable angle (Degrees)	Limit (dBµV/m)	Δ 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 15 below.

10.2.5 2GHz – 25GHz

The frequency sweeps above 2GHz clearly indicated a spurious emission radiating from the EUT (see Figure 16 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 0 at 4.796063 GHz. A plot of this measurement is shown in Figure 17 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)	Δ Limit (dB)
0	4.796063	50.5	54	Hor	1.13	322	3.5
0	4.805812	49.5	54	Ver	-	-	4.5
7	4.876062	50.3	54	Hor	1.21	315	3.7
7	4.875987	-	54	Ver	-	-	-
15	4.956020	50.3	54	Hor	1.10	312	3.7
15	4.956063	48.9	54	Ver	1.09	270	5.1

* Margin quoted based on max peak measurement only.

Table 10 Summary of results for radiated spurious emissions in 2GHz – 25GHz band.

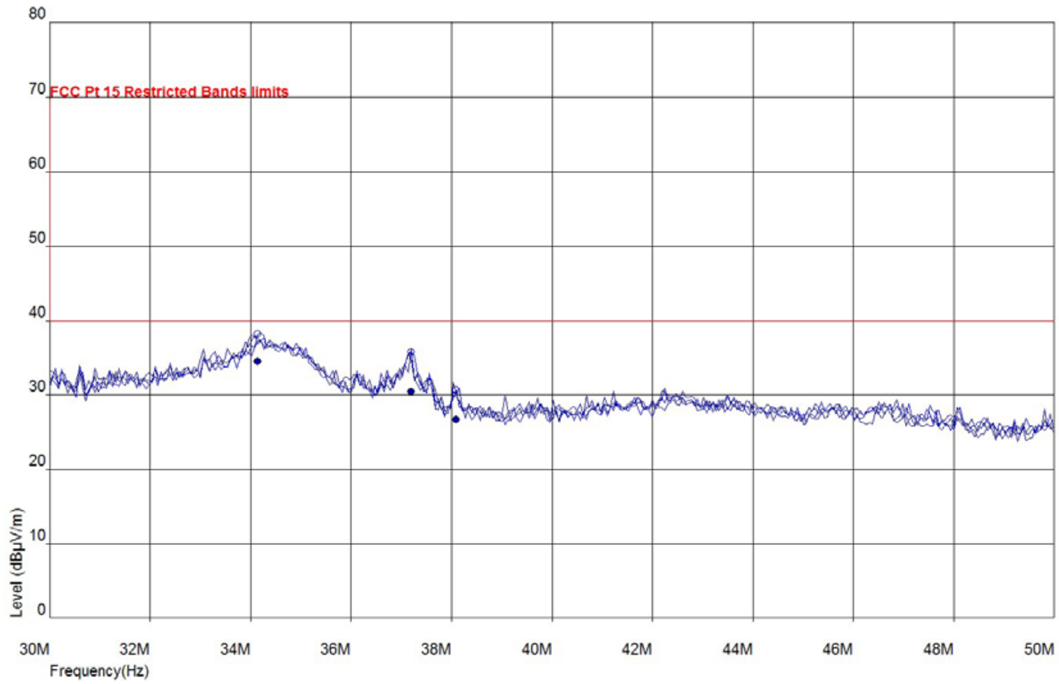

Figure 12 Composite graph of radiated emissions (30MHz–50 MHz) from EUT

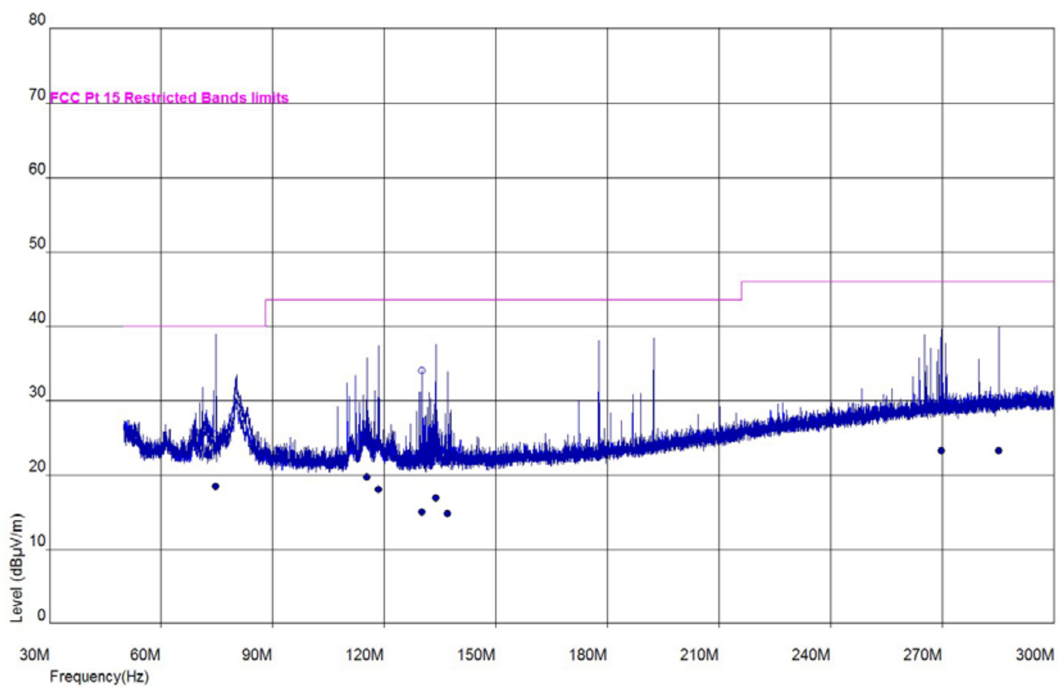

Figure 13 Composite graph of radiated emissions (50MHz-300MHz) from EUT

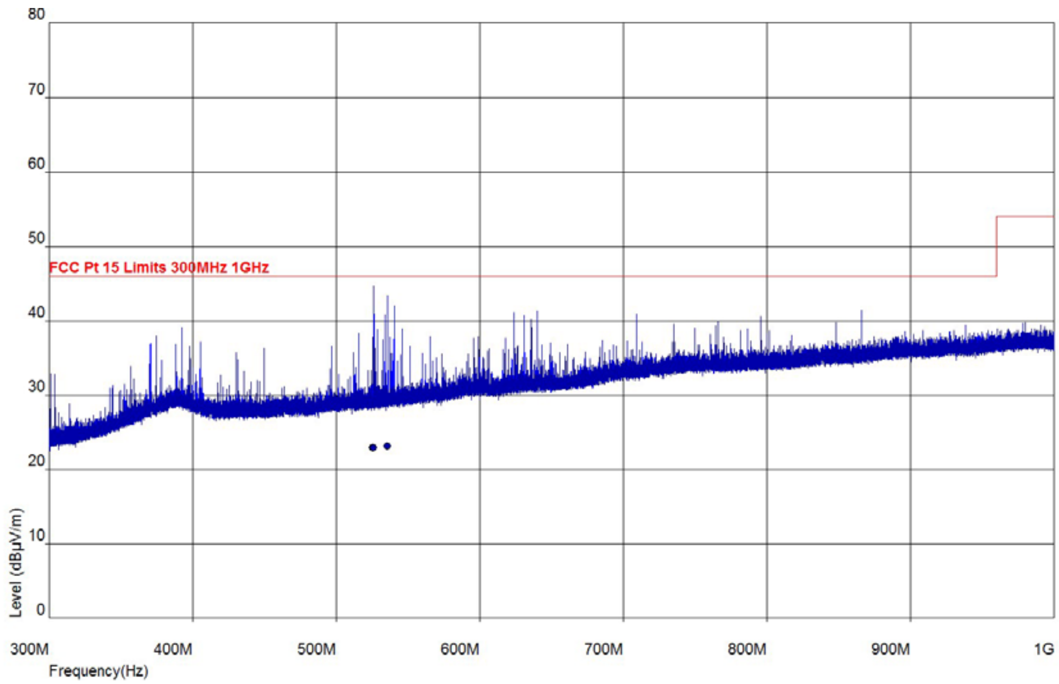

Figure 14 Composite graph of radiated emissions (300MHz-1GHz) from EUT

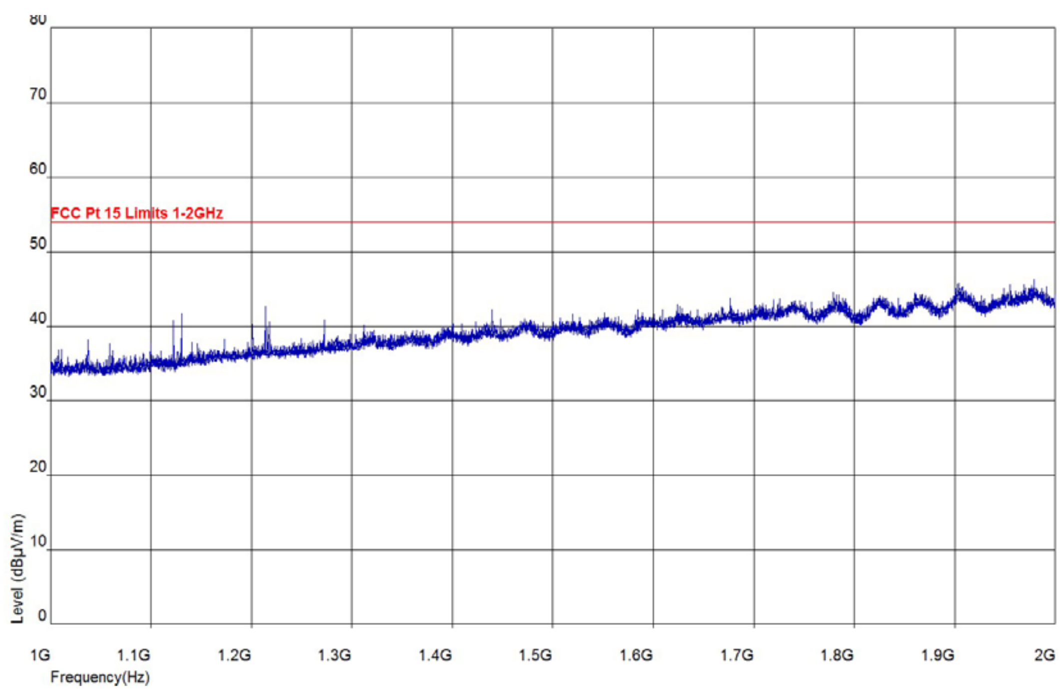

Figure 15 Composite graph of radiated emissions (1GHz-2GHz) from EUT

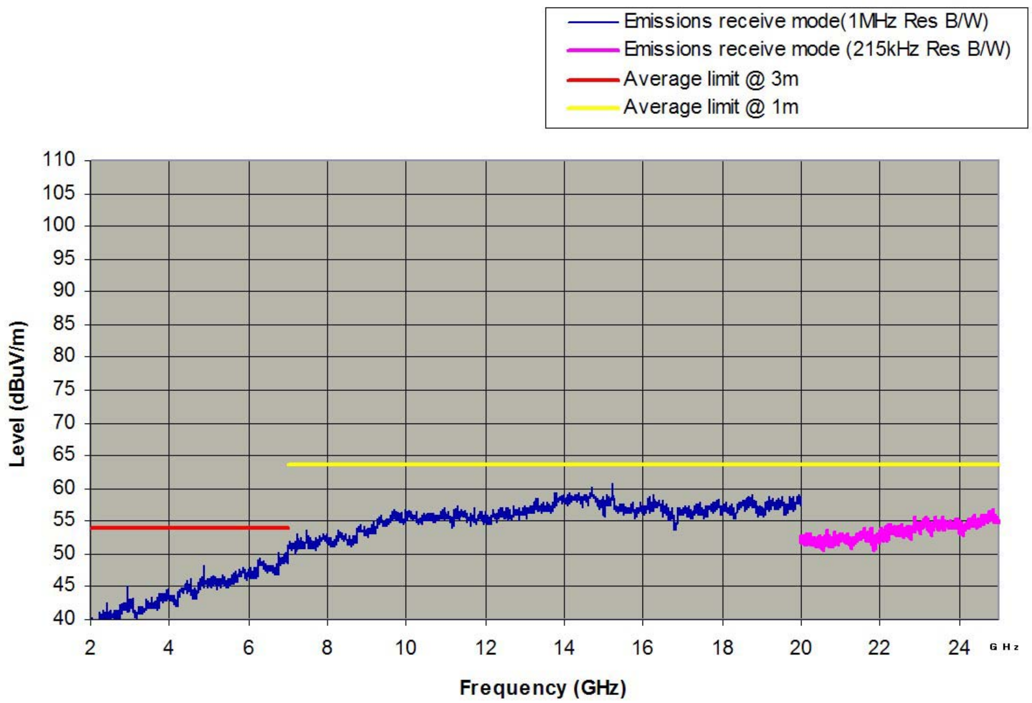

Figure 16 Composite graph of radiated emissions (2GHz-25GHz). EUT Rx on Ch 7

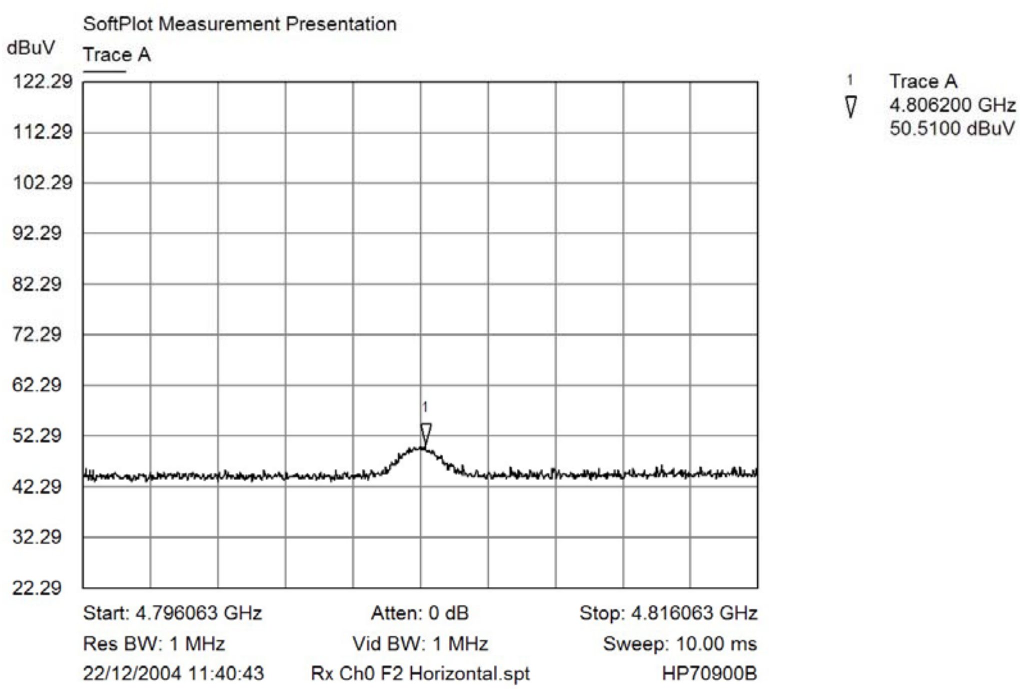

Figure 17 Channel 0 @ 4.796 GHz; horizontal (peak detector)

11 RF Exposure calculations

An assessment of the RF exposure from the EUT is required under FCC rule 15.247(i) to ensure the public are not exposed to levels of RF energy in excess of the FCC guidelines. The assessment for this EUT is presented below.

The level against which the assessment is made is 1mW/cm^2, this figure is quoted in table 1 (B) of rule 1.1310 for frequencies above 1.5GHz. The following calculation will use this level and assume a separation distance of at least 20cm between the human body and the EUT.

EIRP from the EUT = 4.7dBm. (From RFI measurements)

Conversion of radiated power to a power density:

$$P_r = P_t / 4\pi \, . \, r^2 \;\; (W/m^2); \;\; P_t \text{ in watts; } r \text{ in metres}$$

$$P_r = 0.00295/(4\pi \times 0.04)$$

$$=5.686 \; mW/m^2$$

Converting this to cm^2;

$$=0.6 \; \mu W/cm^2$$

This assumes a continuous transmission from the EUT. In normal use the EUT will transmit for only 40ms every 1sec therefore the actual level of exposure will be considerably less.

12 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.