Test Report for LifeTag

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

Radiated Spurious Emissions & Maximum Permissible Exposure

Test Report Number: TP/629/1012

Approved	Peter Bowen EMC Team Leader		16/05/2006
Checked	Andy Little EMC Engineer		09/05/2006
Report	Michael Howes EMC Engineer		03/05/2006
Report Date	02/05/2006	Test Date	23/03/2006 to 30/03/2006

Any reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a level of confidence of approximately 95%. Any uncertainty evaluation has been carried out with reference to CISPR16-4:2002.

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Table of Contents

1 Purpose of Tests

To demonstrate that the EUT (Raymarine LifeTag) meets the radiated spurious emissions 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 type acceptance applications to be submitted to the FCC and Industry Canada.

2 Description of Equipment Under Test (EUT)

(To include all equipment being tested)

Date of Receipt:	23rd March 2006
Client:	Data Vessel and Control Group, Raymarine
Brand Name:	Raymarine
Product Range:	MOB
Country of Manufacture:	Hungary
Operational voltage range:	3V dc nominal (CR2 lithium battery)

Unit 1

Model Name or Number:	**LifeTag**
Unique Type Identification:	E15026
Serial Number:	EMC140306c
Circuit Diagram Number(s) & Issue:	4629-001 Issue D
PCB Assembly Number(s) & Issue:	3015-394 Issue C
Software Version:	0.4
Modifications to Unit:	None

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
3V	22°C	34%

5 Test Configuration

(See Section 2 Description of Equipment Under Test (EUT)and Section 3 Description of Auxiliary Equipment

Raymarine LifeTag

Title	Description
Test Setup and Operating Mode	The EUT is a body worn 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 LifeTag Base Station, 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 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.

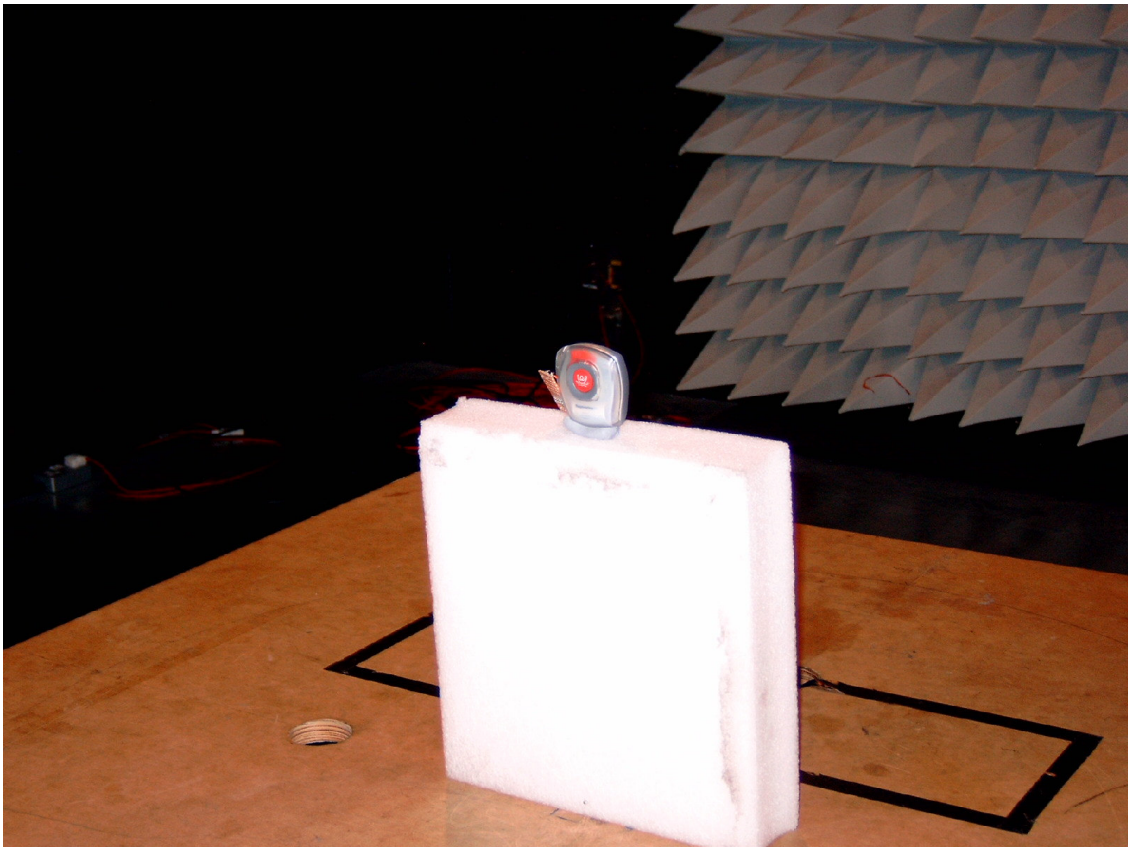

Figure 2 EUT mounted on foam support on turntable in test chamber.

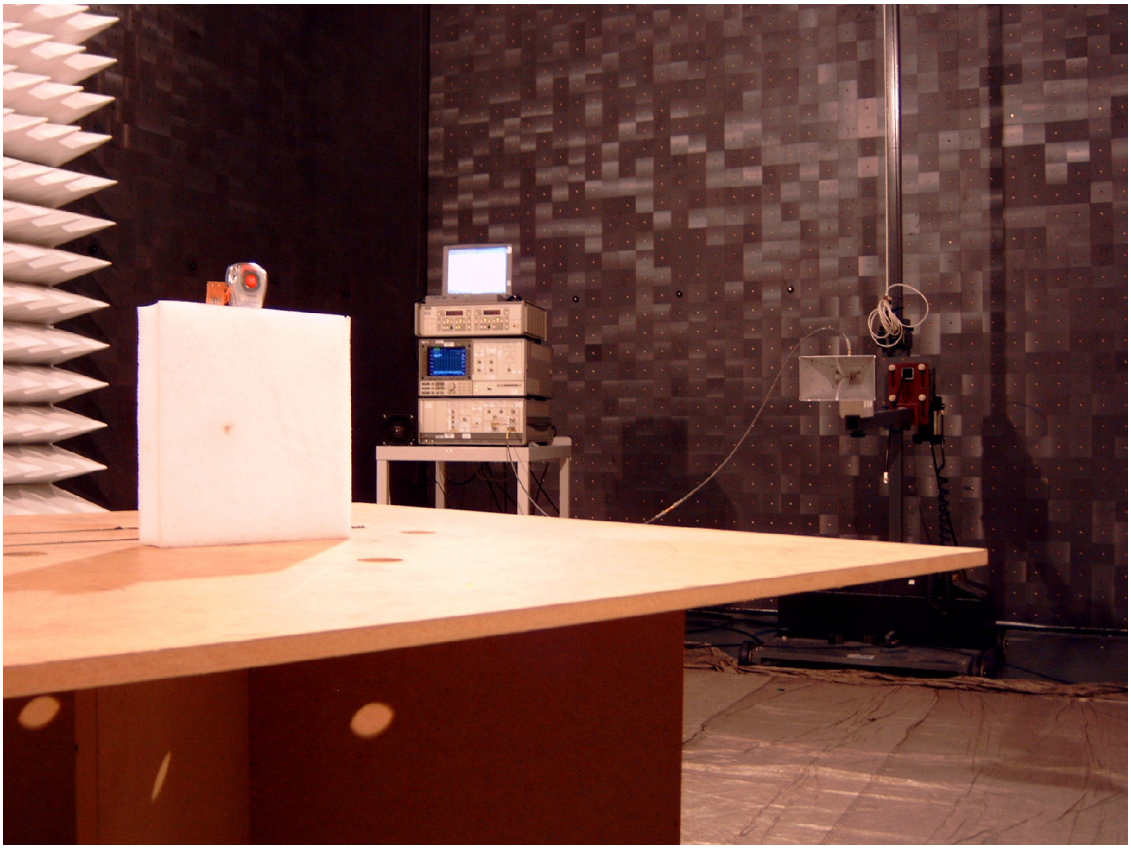

Figure 3 Set up in chamber for 2GHz – 7GHz measurements at 3m.

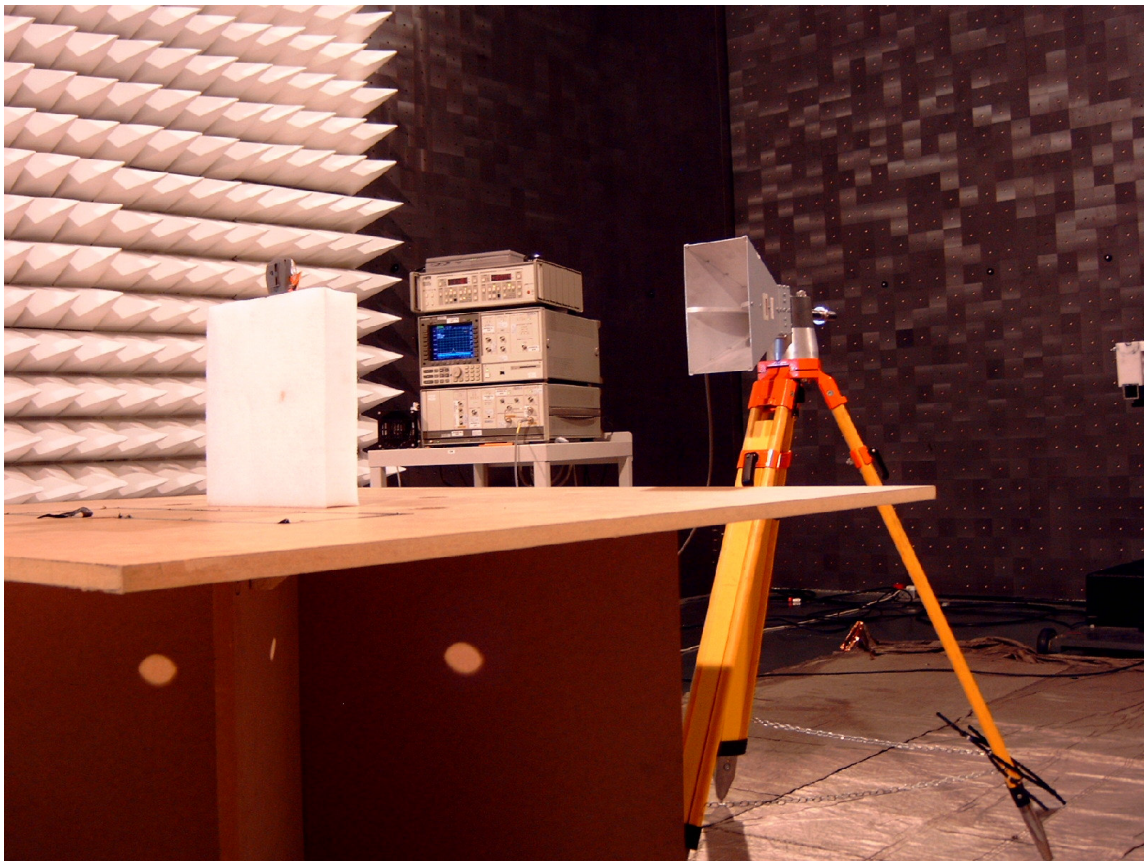

Figure 4 Set up showing measurements above 7GHz at 1m.

8 Method of Test

The EUT was placed on the turntable and powered from an internal 3.0V lithium battery. The purpose of the EUT is to initiate an alarm whenever the LifeTag Base Station loses communication with the LifeTag for more than 10 seconds or when the alarm is raised manually from the LifeTag.

In normal use the EUT transmits a heart beat every 2 seconds. 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 16 available channels and configured to function in either a continuous receive or transmit mode.

An investigative sweep to identify any spurious emissions for detailed investigation was carried out in continuous transmit mode and then repeated in continuous receive mode, each sweep being conducted on channel 18. The results of these tests, and composite plots of the 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 on channel 18 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 11, 18 and 26 (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 or graphs presented below in sections 9 and 10.

9kHz-30MHz

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 Radimation 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 C63.4-2003 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 Radimation 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 antenna to analyser cable, 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 the HP70000 peak detector in max hold mode. During these sweeps the EUT was operating continuously on channel 18. For each frequency sweep the receive antenna was maintained at a height level with the centre of the EUT 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 recorded 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 figures 12 and 19 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 14 to 16 and figure 22)

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:

λ at 7GHz = 0.042m

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

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

= 111 mm

Therefore all measurements made above 7GHz at 1m are considered to be 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 20dB above the restricted band average limit 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 transmission duration during any 100ms period is 18.85µs. 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)):

$$20\log\left(\frac{18.85\mu s}{100mS}\right) = \text{-74.49 dB}$$

Due to the short 100mS average duty cycle resulting in a large relaxation factor, the maximum allowed relaxation factor of 20dB was applied to the peak measurements.

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 4 sweeps taken at 90˚ angles and with the loop antenna orientation rotated by 90˚ is presented in figures 5 and 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 4 sweeps taken at 90˚ intervals around the EUT and with the loop antenna orientation rotated by 90˚ is presented in figures 7 and 8 below.

9.2.3 30MHz – 300MHz

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 4 sweeps taken at 90˚ intervals around the EUT and with the loop antenna orientation rotated by 90˚ is presented in figure 9 below.

9.2.4 300MHz – 1GHz

All emissions within this band 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 10 below.

9.2.5 1GHz – 2GHz

There were no emissions detected above the measurement system noise floor. A composite graph combining sweeps taken at 90˚ intervals around the EUT in both vertical and horizontal polarisations is presented in figure 11 below.

9.2.6 2GHz – 25GHz

Measurements were carried out in the 2.4 GHz – 2.4835 GHz band on channel 11, 18 and 26 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)
11	2.40485	93.36	Horizontal	113	355
11	2.40488	94.73	Vertical	121	125
18	2.43990	94.04	Horizontal	140	155
18	2.43988	96.90	Vertical	112	95
26	2.47990	93.52	Horizontal	115	165
26	2.47988	97.02	Vertical	110	75

Table 2 Summary of results of fundamental frequency levels for channels 11, 18, 26.

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 11, 18 and 26. The results from these measurements have been presented in table 4 below and plots 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)	Δ Limit (dB)
11	4.80975	61.16	74.0	41.16	54.0	Hor	126	240	-12.84
11	4.80988	63.36	74.0	43.36	54.0	Ver	130	175	-10.64
18	4.87985	59.70	74.0	39.70	54.0	Hor	110	260	-14.3
18	4.87978	64.36	74.0	44.36	54.0	Ver	141	140	-9.64
26	4.95993	54.54	74.0	34.54	54.0	Hor	115	235	-19.46
26	4.95993	60.32	74.0	40.32	54.0	Ver	120	170	-13.68
11	7.21483	63.54	83.5	43.54	63.5 Note 2	Hor	110	207	-19.96
11	7.21493	61.75	83.5	41.75	63.5 Note 2	Ver	110	124	-21.75
18	7.31980	67.64	83.5	47.64	63.5 Note 2	Hor	110	210	-15.86
18	7.31983	65.31	83.5	44.31	63.5 Note 2	Ver	110	136	-19.19
26	7.43988	68.69	83.5	48.69	63.5 Note 2	Hor	110	205	-14.81
26	7.43988	67.74	83.5	47.74	63.5 Note 2	Ver	110	130	-15.76

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

10 Radiated Emissions Graphs

10.1 9kHz to 150kHz

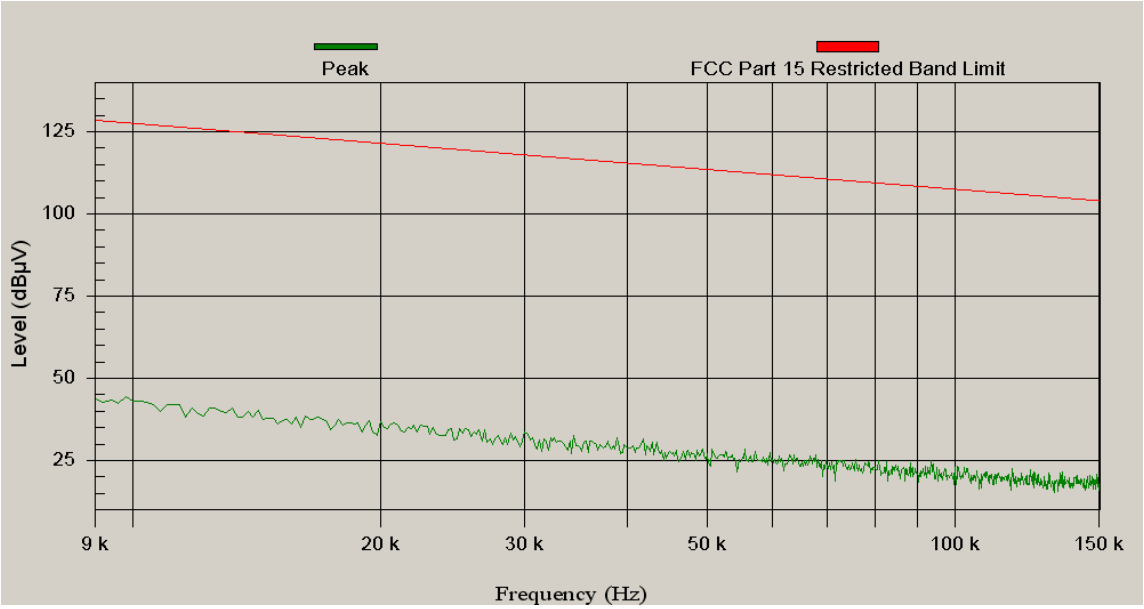

Figure 5 Composite graph of radiated emissions, antenna edge on from EUT

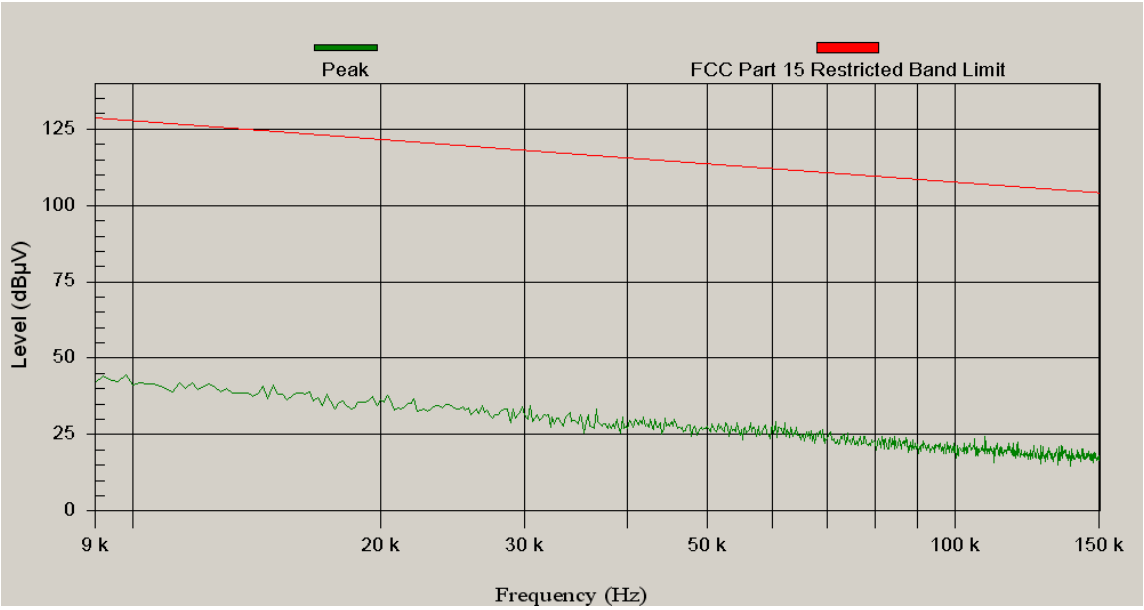

Figure 6 Composite graph of radiated emissions, antenna face on from EUT

10.2 150kHz to 30MHz

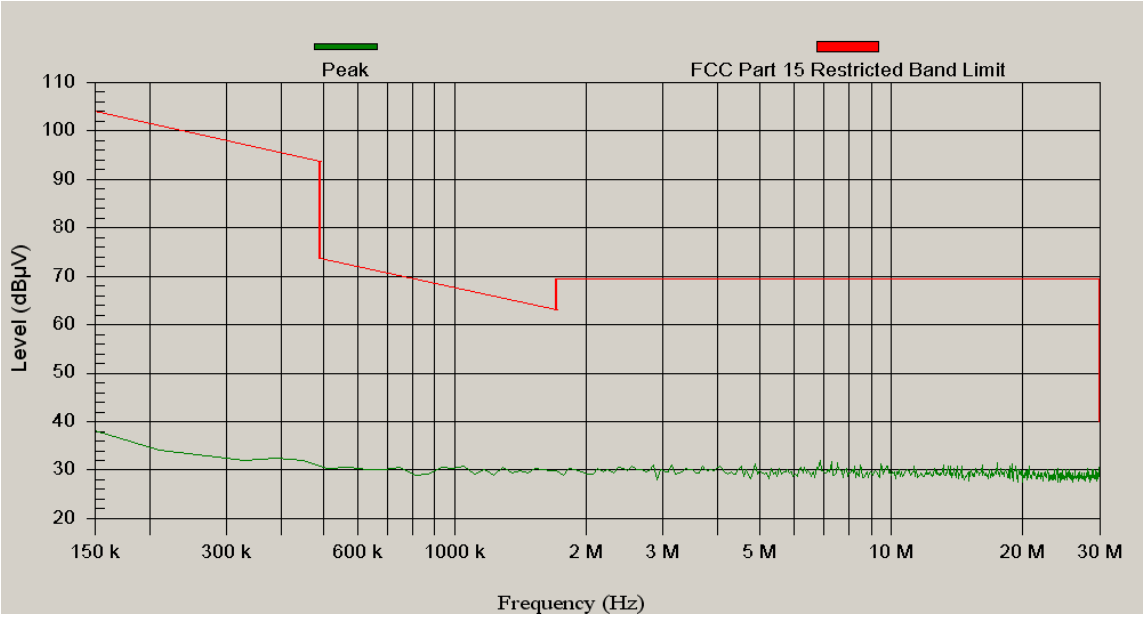

Figure 7 Composite graph of radiated emissions, antenna edge on from EUT

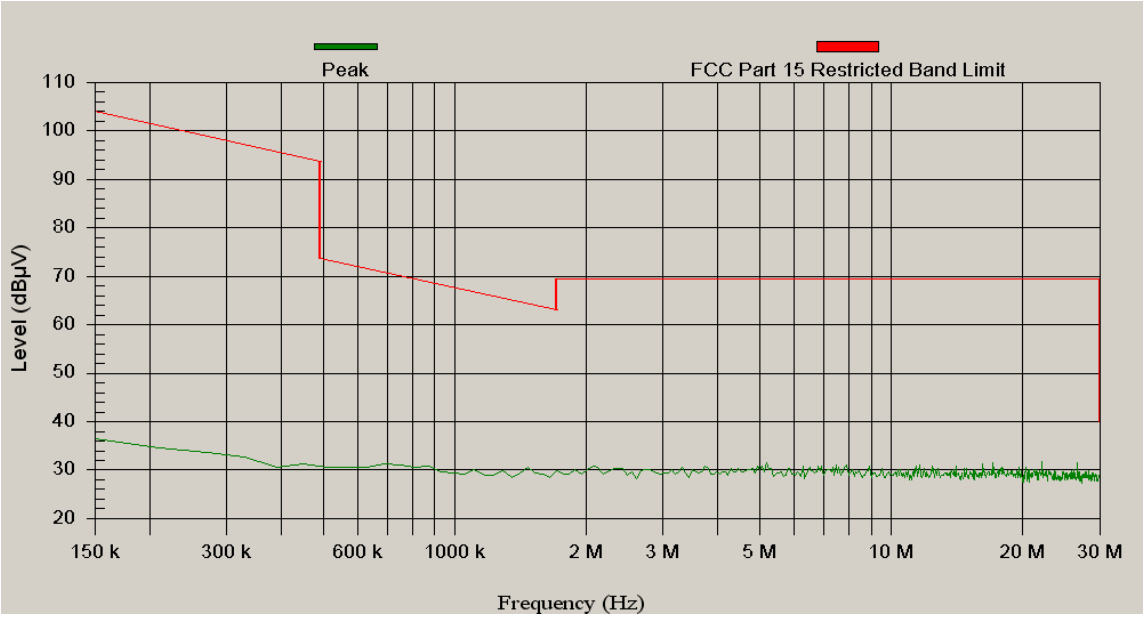

Figure 8 Composite graph of radiated emissions, antenna face on from EUT

10.3 30MHz to 300MHz

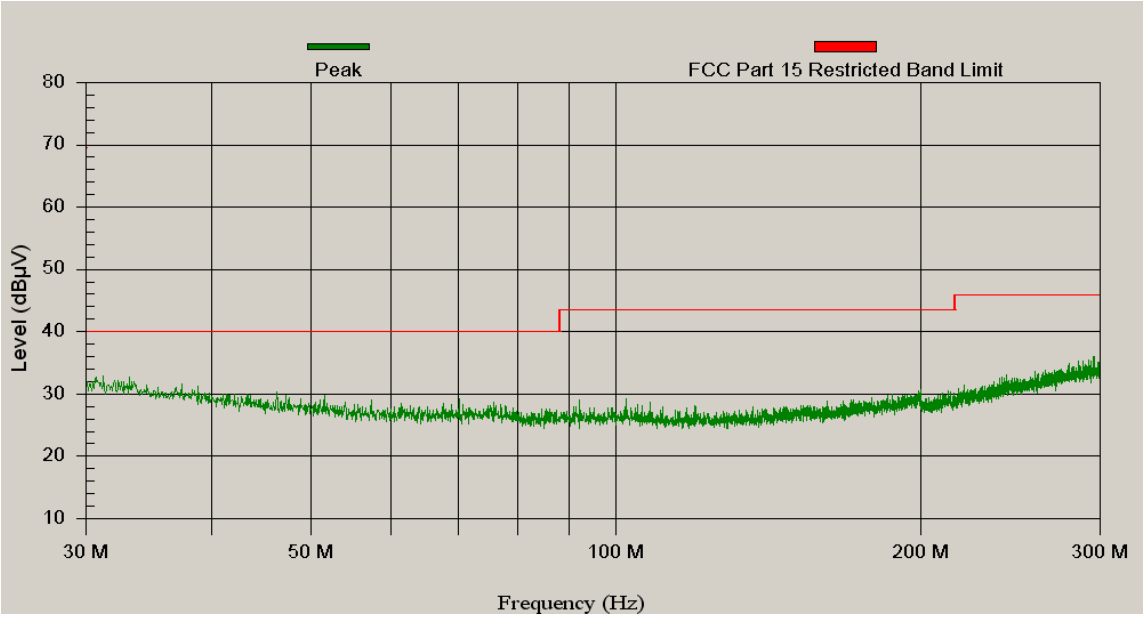

Figure 9 Composite graph of radiated emissions from EUT

10.4 300MHz to 1000MHz

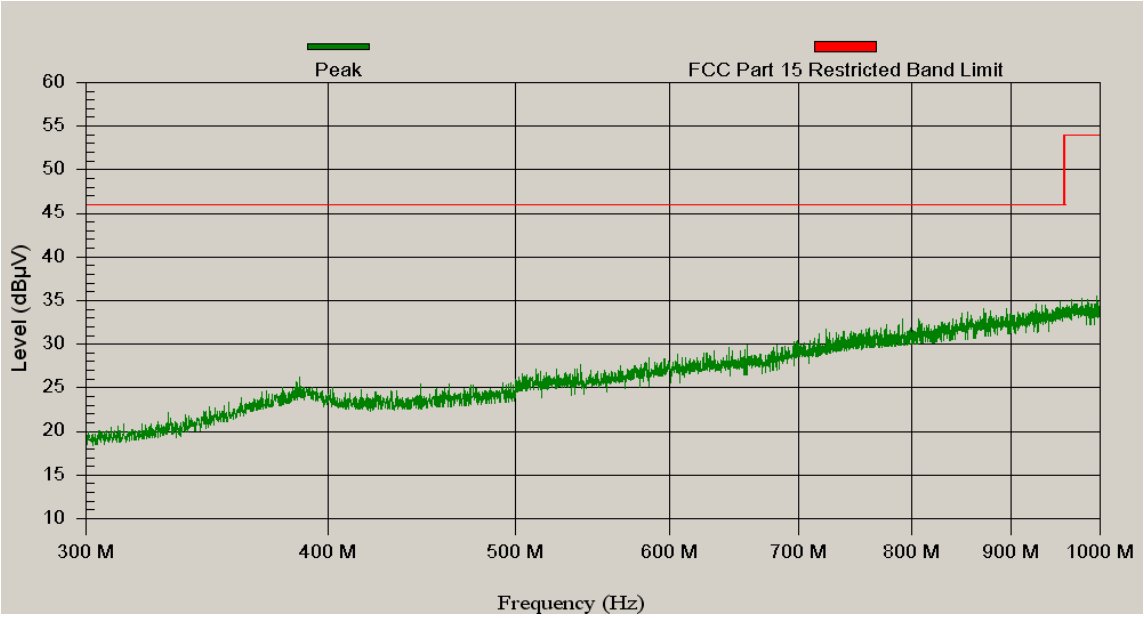

Figure 10 Composite graph of radiated emissions from EUT

10.5 1GHz to 2GHz

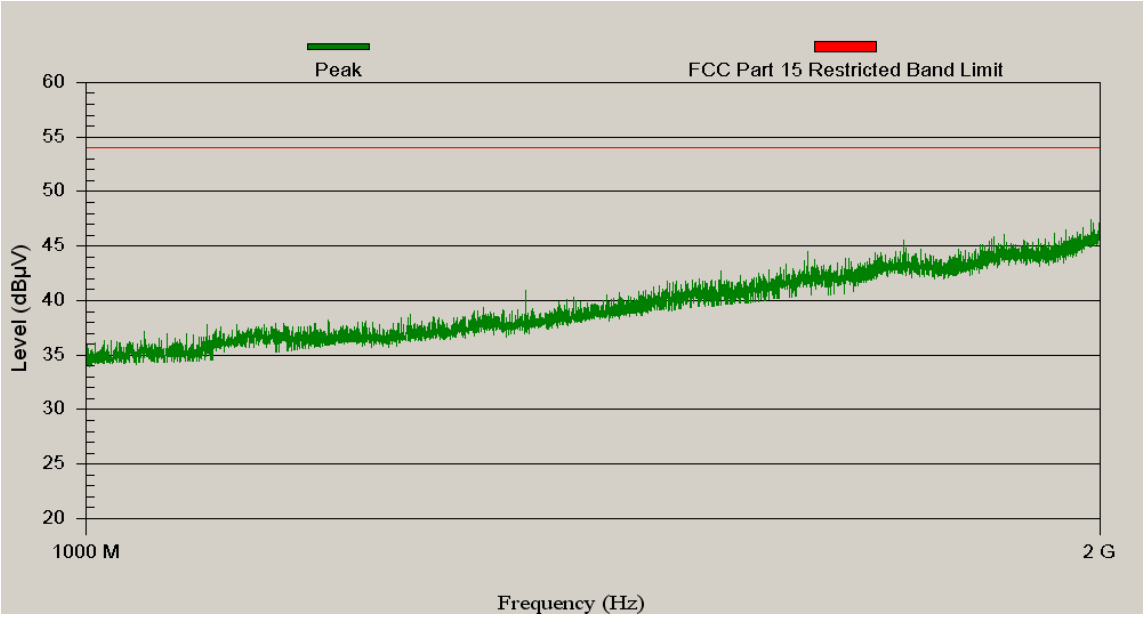

Figure 11 Composite graph of radiated emissions from EUT

10.6 2GHz to 25GHz

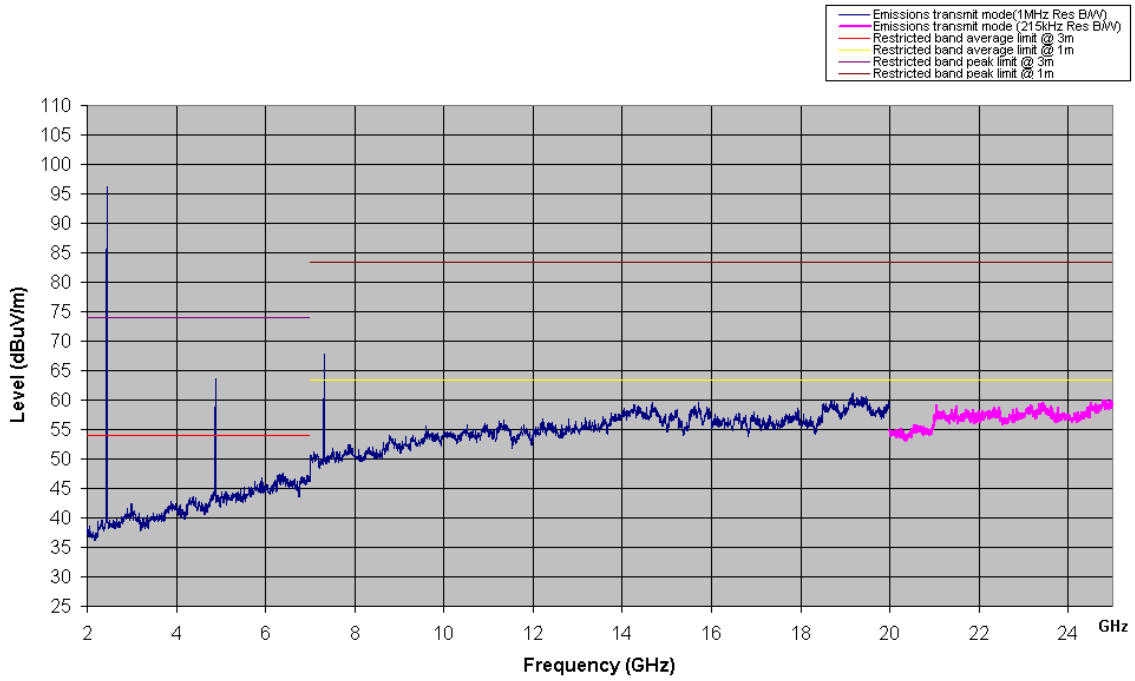

Figure 12 Composite graph of radiated emissions. EUT in Tx mode, channel 18

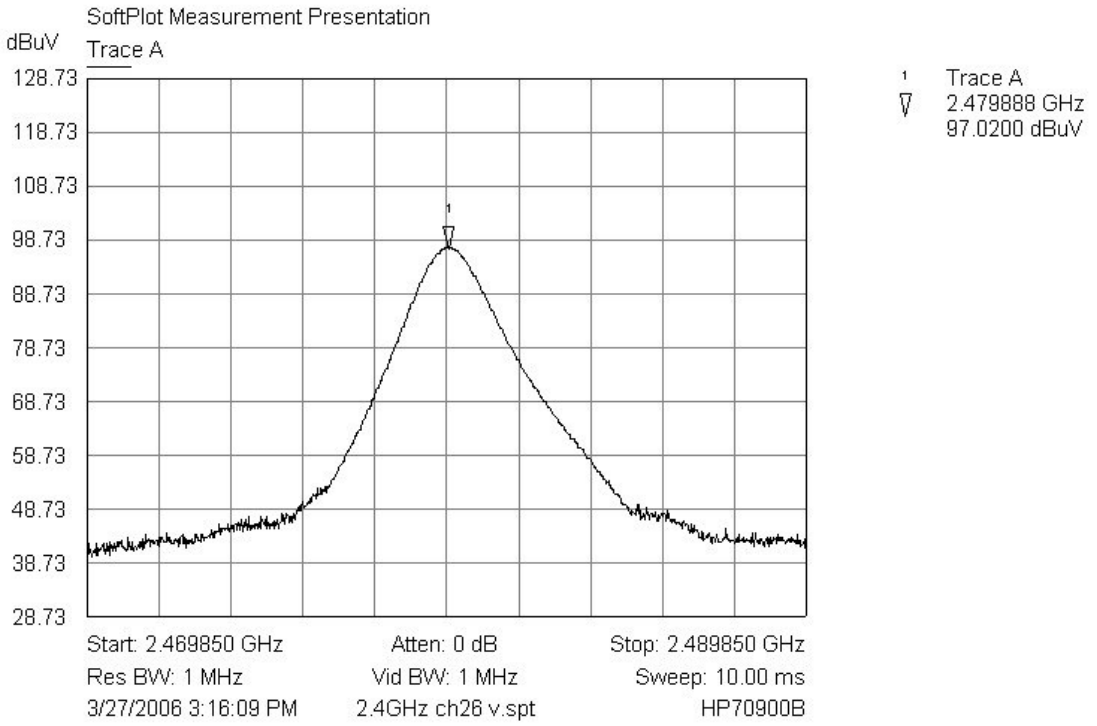

Figure 13 Channel 26 Vertical (Highest recorded fundamental frequency)

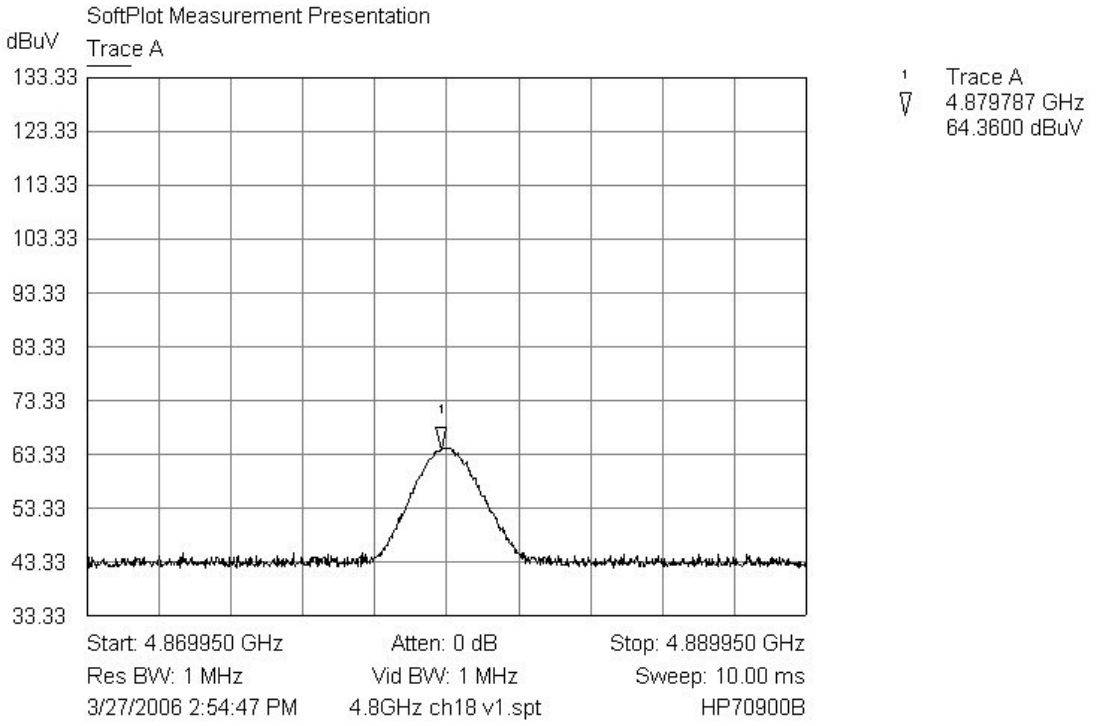

Figure 14 Channel 18 Vertical (Highest recorded 2nd harmonic)

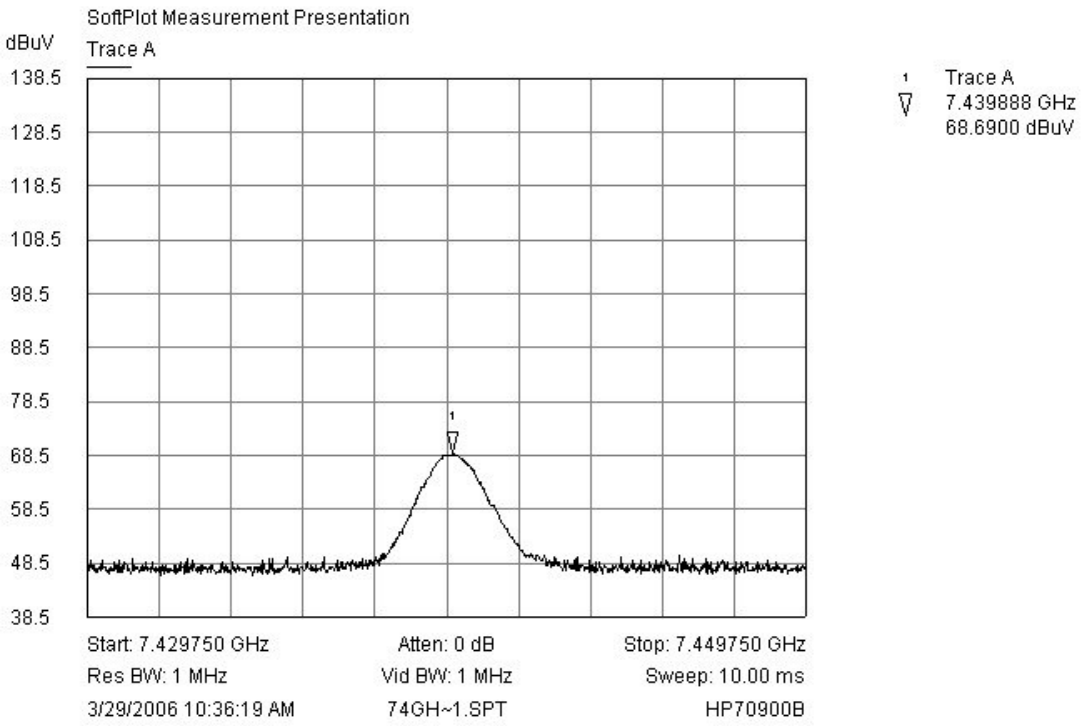

Figure 15 Channel 26 Horizontal (Highest recorded 3rd harmonic)

11 Radiated Emissions Results – Unintentional Radiator

11.1 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 LifeTag Base Station next to the LifeTag on the table.

11.2 Test Results

11.2.1 30MHz – 300MHz

All emissions within this band 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 16 below.

11.2.2 300MHz – 1GHz

All emissions within this band 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 17 below.

11.2.3 1GHz – 2GHz

There were no emissions detected above the measurement system noise floor. A composite graph combining sweeps taken at 90˚ intervals around the EUT in both vertical and horizontal polarisations is presented in figure 18 below.

11.2.4 2GHz – 25GHz

The frequency sweeps above 2GHz clearly indicated a spurious emission radiating from the EUT (see figure 19 below). This was investigated in more detail on channels 11, 18 and 26. The worst-case peak emission in max hold mode was measured on channel 26 at 4.951933GHz. A plot of this measurement is shown in figure 20 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)
11	4.801928	48.21	54	Hor	140	125	-5.79
11	4.801933	49.33	54	Ver	110	335	-4.67
18	4.871939	50.77	54	Hor	136	145	-3.23
18	4.871943	50.67	54	Ver	110	290	-3.33
26	4.951933	51.69	54	Hor	112	140	-2.31
26	4.951944	51.64	54	Ver	110	340	-2.36

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

11.3 30MHz to 300MHz

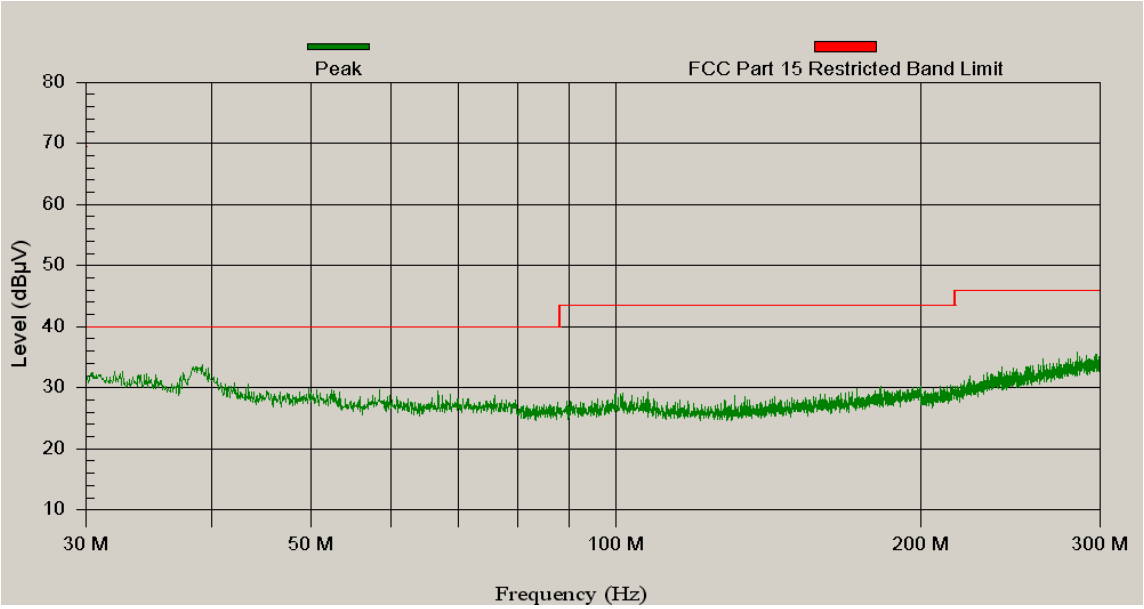

Figure 16 Composite graph of radiated emissions from EUT

11.4 300MHz to 1000MHz

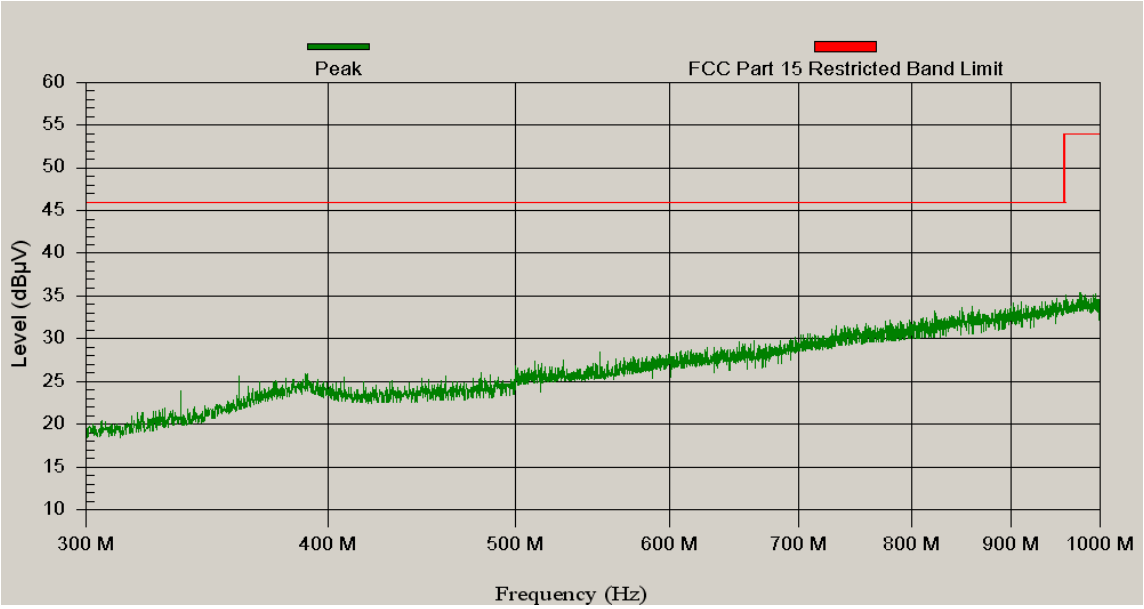

Figure 17 Composite graph of radiated emissions from EUT

11.5 1GHz to 2GHz

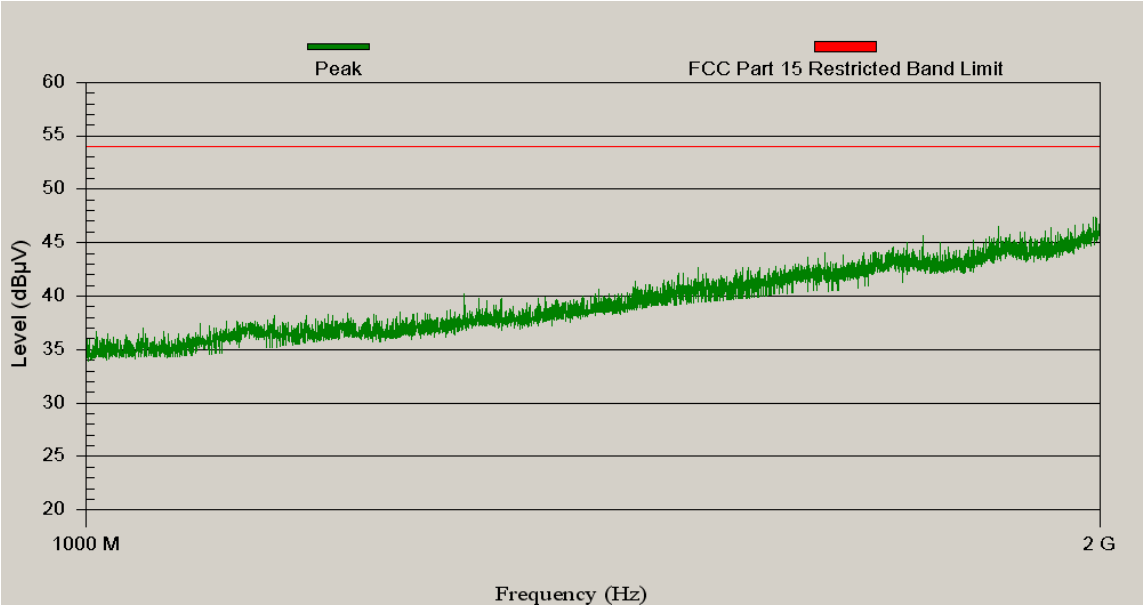

Figure 18 Composite graph of radiated emissions from EUT

11.6 2GHz to 25GHz

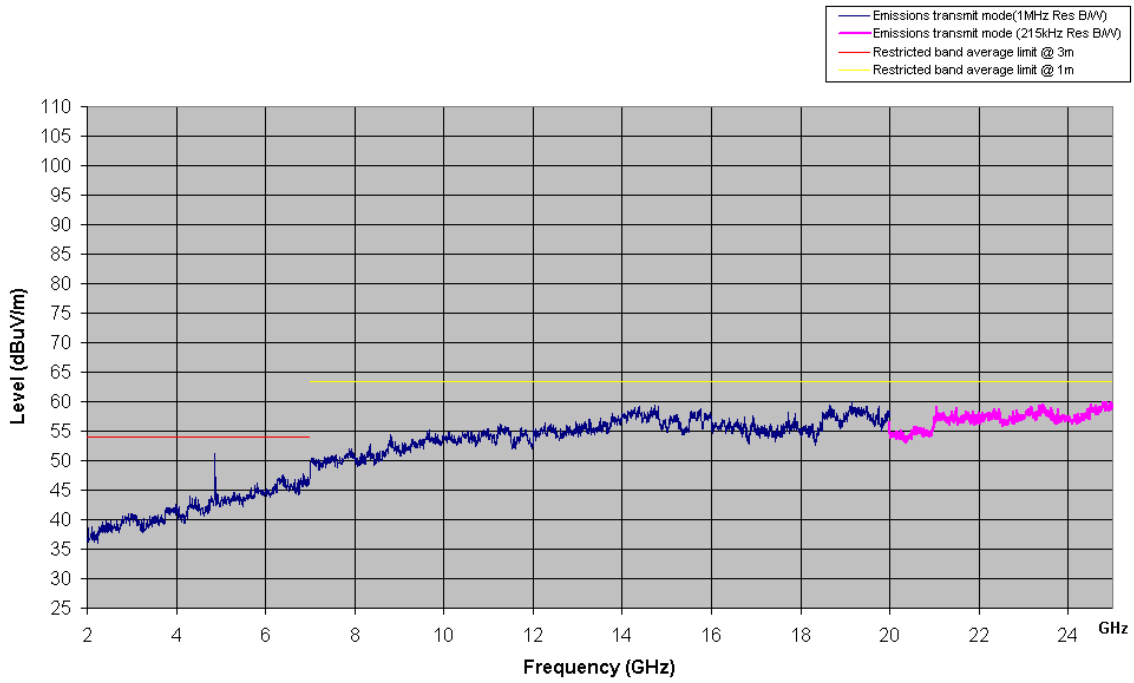

Figure 19 Composite graph of radiated emissions. EUT in Rx mode, channel 18

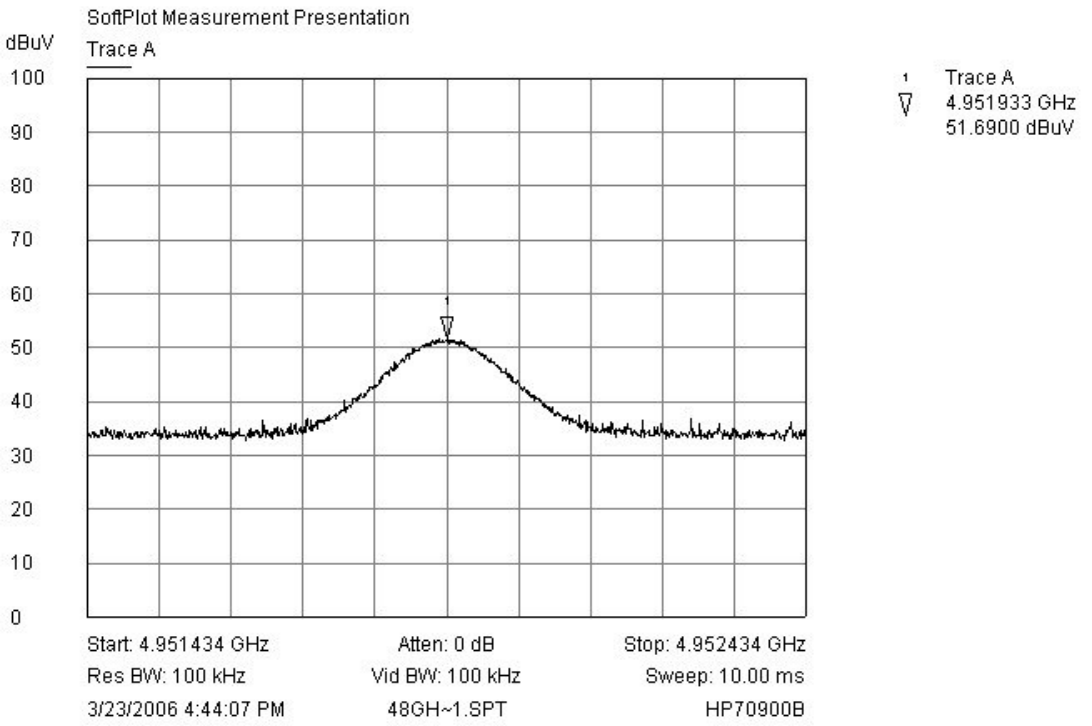

Figure 20 Channel 26 Vertical (Highest recorded 2nd harmonic)

12 RF Exposure Calculations

An assessment of the RF exposure from the EUT is required under FCC rule 15.247(b) to ensure that 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 1cm between the human body and the EUT.

EIRP from the EUT = 2.6dBm. (See RFI report no. RP48098JD05A)

Conversion of radiated power to a power density:

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

$P_r = 0.00181/(4\pi \times 0.002)$

$= 72.4$ mW/m^2

Converting this to cm^2;

$= 0.72$ mW/cm^2

This assumes a continuous transmission from the EUT. In normal use the EUT will transmit for only 377µs every 2seconds; therefore the actual level of exposure will be considerably less.

13 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 20Hz - 26.5GHz	Rhode & Schwarz ESI26	832692/006	**886**
Spectrum Analyser 100Hz - 26.5GHz	HP70000 series	3230A05180	**1605**
Emissions Software	Radimation v4.3.73	VCQZPC	**N/A**
Power Supply Unit	Palstar PS30M	92534722	**1454A**

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