Test Report
for
Command Center (G-Series Wireless Keyboard)
FCC ID: PJ5-CCTR

To CFR 47 Part 15C - Radio Frequency Devices - Intentional Radiators

Test Report Number: 673/1028

Approved	Peter Bowen Compliance Manager		29/10/2007
Checked	Mike Thompson EMC Engineer		17/08/2007
Report	Andrew Sartin EMC Engineer		12/08/2007
Issue Date	12/08/2007	Test Date	08/08/2007 to 09/08/2007

The test data and results contained within this report relate only to the items tested.

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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.

Table of Contents

1 Purpose of Tests

To demonstrate that the EUT (G-Series Command Center), also known as the G-Series Wireless Keyboard, meets the requirements of the applicable subsections of the following Part 15C FCC rules:
15.203 - Antenna requirement
15.205 - Restricted bands of operation
15.209 - Radiated emissions limits, general requirements
15.215 - Additional provisions to the general radiated emissions limitations
15.247 - Operation within the bands 902 - 928MHz, 2400 - 2483.5MHz and 5725 - 5875MHz.

2 Description of Equipment Under Test (EUT)

(To include all equipment being tested)

Date of Receipt:	06th May 2007
Client:	Navigation systems – G Jones
Brand Name:	Raymarine
Product Range:	G-Series
Country of Manufacture:	Hungary
Operational voltage:	3.6V dc nominal (3x 1.2V lithium battery)

Unit 1

Model Name or Number:	G-Series Command Center
Unique Type Identification:	E02044
Serial Number:	EMC070607b
Antenna Reference: FCC 15.203	Integral Antenna – Gain 2.4dBi.
Assigned Operating Frequency Band: FCC 15.205	2400 - 2483.5MHz. (Does not fall within a restricted band)
Circuit Diagram Number(s) & Issue:	4673-002-D
PCB Assembly Number(s) & Issue:	4673-001-D
Software Version:	0.92
Modifications to Unit:	Addition of Unit 2 – Wireless Upgrade Kit
Unit 2	
Model Name or Number:	G-Series Command Center Wireless Upgrade Kit
Unique Type Identification	E02046
Serial Number	None (integrated into Unit 1)

Other Information:	Measurements of rf signals and noise are made in accordance with ANSI C63.4:2003. Emission Designator is 2M64M2D— Testing was carried out in accordance with FCC Part 15 Rules dated 26th August 2003, which was the version in force during the dates of testing. However, any changes in the newly-issued 20th September 2007 version of the Rules which affect the tests or appropriate test clauses reported are shown within the body of the report. Otherwise, test clauses may be taken as applying equally to both versions of the Rules.

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
None	

4 General

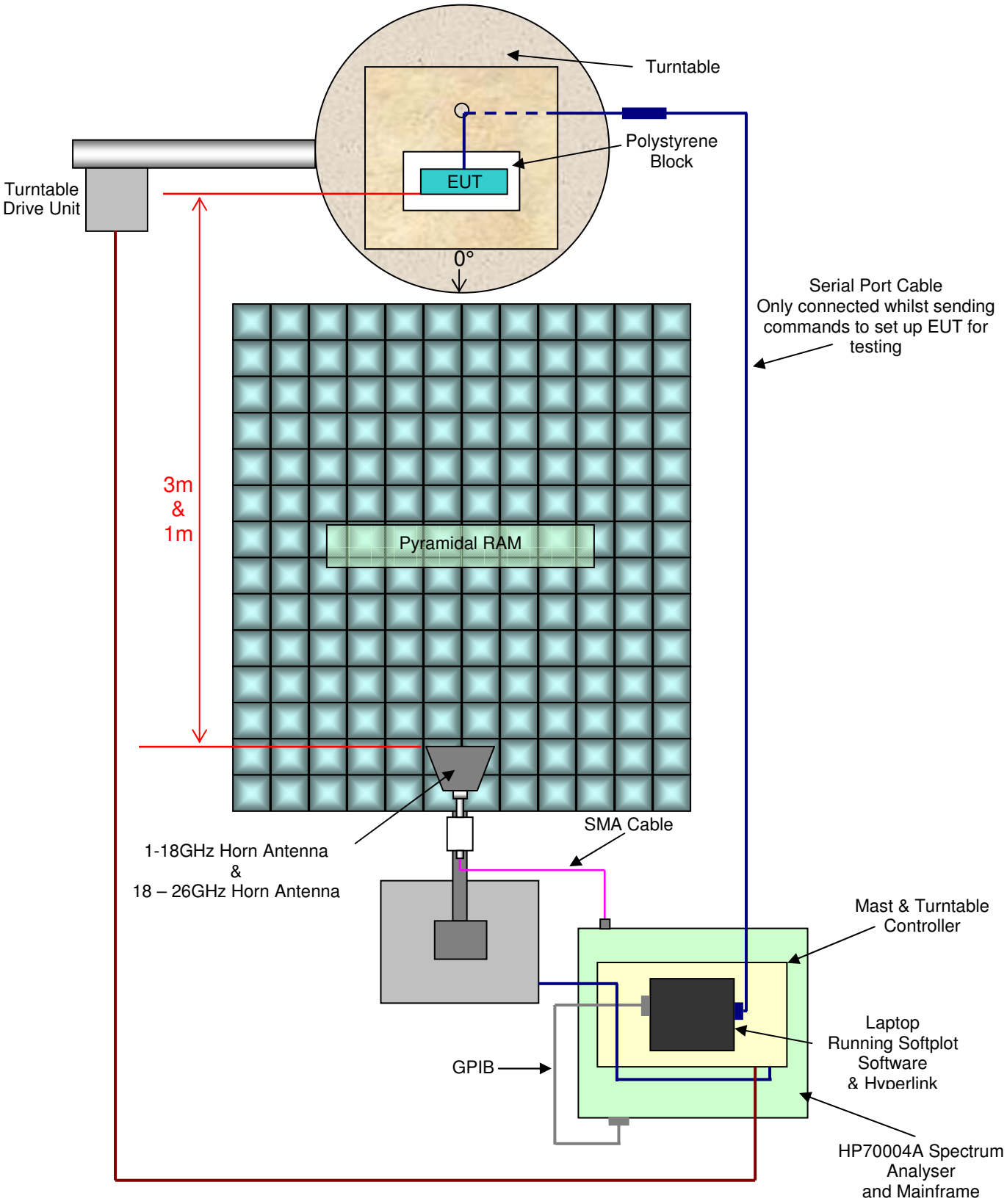
Supply Voltage Range	Ambient Temperature	Relative Humidity
3.6V battery pack	22°C	34%

5 Test Configuration

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

Title	Description
Test Setup and Operating Mode	The EUT is a hand held device with internal batteries. The EUT was placed on a polystyrene block, atop a 0.8m high table. No other equipment was required. Using special test software to enable efficient testing of the EUT, the RF section was configured to continuous transmission (TxTone) or standby mode (Receive) as required during the course of the testing. Channels on which the RF section was operating were selected as required

Test setup:


Turntable
Polystyrene Block
EUT
Turntable Drive Unit
0°
Serial Port Cable
Only connected whilst sending commands to set up EUT for testing
3m & 1m
Pyramidal RAM
SMA Cable
1-18GHz Horn Antenna & 18 – 26GHz Horn Antenna
Mast & Turntable Controller
Laptop Running Softplot Software & Hyperlink
GPIB
HP70004A Spectrum Analyser and Mainframe

6 Description of Test Chamber

The test chamber used for the radiated emissions measurements is FCC listed (registration no. 970522).

The 3m 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. Additionally, 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.

Additional ferrite and pyramidal absorber is fitted to the floor between the mast and turntable for measurements above 1GHz.

7 Photographs

Figure 1 View from within chamber showing turntable, base and mast set-up for measurements from 1 - 40GHz. Antenna shown covers 1 - 18GHz. Floor absorber is removed for tests below 1GHz.

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

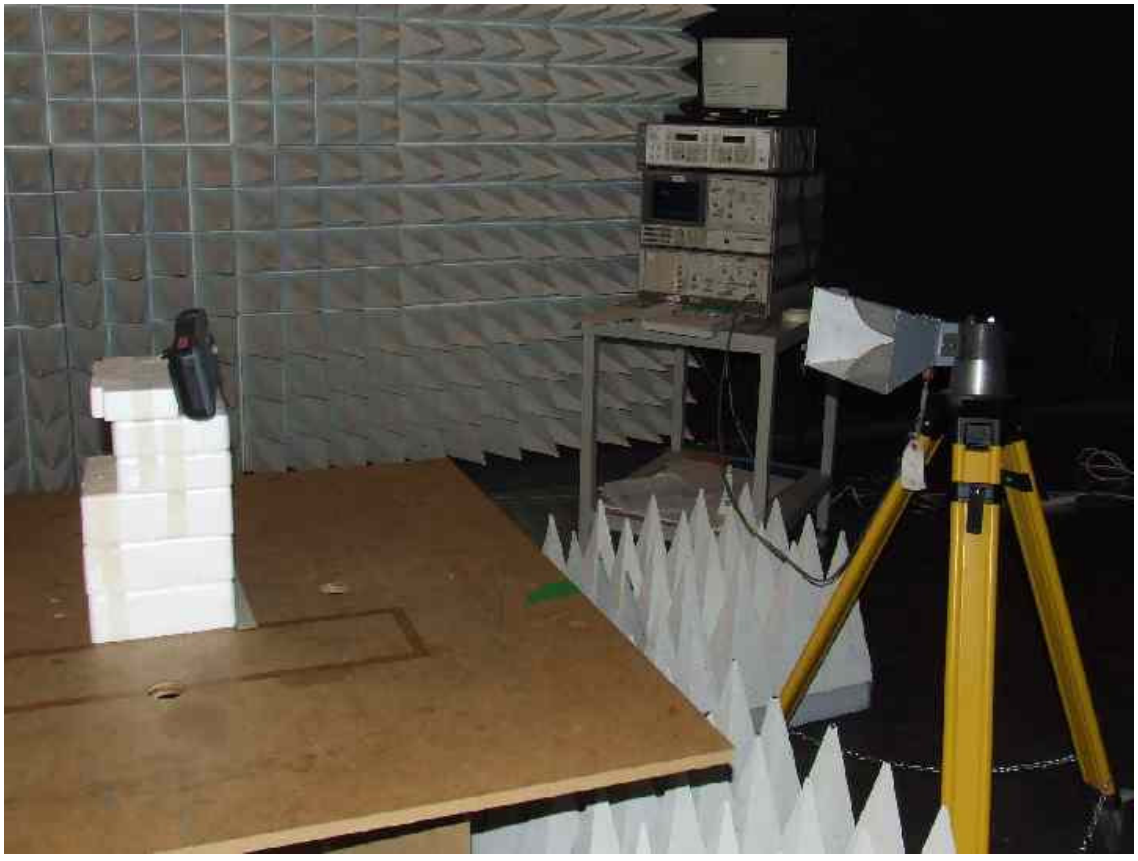


Figure 3 **Set up showing measurements above 7GHz at 1m. Antenna shown is for measurements up to 18GHz.**

8 Method of Test

The EUT was placed on the turntable and powered from three internal 1.2V lithium batteries. The output power of the EUT was set to the maximum of 3dBm.

For the purpose of this test, 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, 10 and 11.

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 in sections 9, 10 and 11.

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 in accordance with FCC 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 15.209(a). 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 setup was used 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 alternate antenna polarisation so that a trace was recorded comprising the worst case emissions 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, antenna factors and measurement uncertainties. Graphs were then produced from the final corrected figures to show the spurious emissions in the 2GHz to 25GHz band (see figures 11 and 15 below).
Any emissions observed to be above the noise floor were investigated more thoroughly on channels 11, 18 and 26, 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 include cable, antenna and measurement uncertainty corrections. The plots are presented below (see figures 13 and 14).

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 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 in 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 which may be present.

Frequency band	Resolution bandwidth Standby - receive	Resolution bandwidth Operating - transmit	Remarks
9kHz – 150 kHz	Not tested. Operating mode deemed to be worst case.	200Hz	
150 kHz – 30 MHz		9 kHz	
30 MHz – 1 GHz		120 kHz	
1 GHz – 2 GHz		1 MHz	
2 GHz – 20 GHz	1MHz	1MHz	
20 GHz – 25GHz	215 kHz	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 15.247(c)[26-8-03] or 15.247(d)[20-9-07]
- Within restricted bands (see table under 15.205) the limits of the table in 15.209(a) were applied.
- Additionally a peak limit of 20dB above the restricted band average limit was applied as defined in FCC 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 25ms period is approximately 600µs. 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)):

$$20\log(600\mu S/25ms) = -32dB$$

Due to the short 25mS 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

No emissions exceeded the given limits. A composite graph combining sweeps taken at 90˚ intervals around the EUT in both vertical and horizontal polarisations is presented in Figures 4 and 5 below.

9.2.2 150kHz - 30MHz

No emissions exceeded the given limits. A composite graph combining sweeps taken at 90˚ intervals around the EUT in both vertical and horizontal polarisations is presented in Figures 6 and 7 below.

9.2.3 30MHz – 300MHz

No emissions exceeded the given limits. A composite graph combining sweeps taken at 90˚ intervals around the EUT in both vertical and horizontal polarisations is presented in Figure 8 below.

9.2.4 300MHz – 1GHz

No emissions exceeded the given limits. 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 1GHz – 2GHz

No emissions exceeded the given 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 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 15.247(c)[26-8-03] or 15.247(d)[20-9-07]. A table summarising the results is presented below and a plot of the highest level recorded is shown in figure 12.

Channel No.	Freq (GHz)	Peak level (dBµV/m)	Antenna polarity	Antenna height (m)	Turntable angle (Degrees)
11	2.404888	98.86	Horizontal	173	120
11	2.404888	99.48	Vertical	116	280
18	2.439862	99.96	Horizontal	158	117
18	2.439862	99.25	Vertical	119	279
26	2.479887	98.69	Horizontal	150	115
26	2.479862	97.91	Vertical	116	057

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

The frequency sweeps above 2GHz indicated an emission at the 2nd and 3rd harmonic frequencies of the EUT (see figure 11 below). This was investigated in more detail on channels 11, 18 and 26. The results from these measurements have been presented in table 3 below and plots of the highest recorded emissions are presented in figures 12 (fundamental), 13 and 14.

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)
11	4.809913	60.54	74.0	40.54	54.0	Hor	105	229
11	4.809913	58.62	74.0	38.62	54.0	Ver	113	187
18	4.880013	57.43	74.0	37.43	54.0	Hor	114	213
18	4.879837	56.49	74.0	36.49	54.0	Ver	113	189
26	4.959837	55.94	74.0	35.94	54.0	Hor	114	221
26	4.959912	56.26	74.0	36.26	54.0	Ver	112	167
11	7.214782	54.45	83.5	34.45	63.5 Note 2	Hor	110	189
11	7.214844	56.48	83.5	36.48	63.5 Note 2	Ver	110	183
18	7.319787	55.06	83.5	35.06	63.5 Note 2	Hor	110	198
18	7.319762	57.02	83.5	37.02	63.5 Note 2	Ver	110	156
26	7.439687	55.89	83.5	35.89	63.5 Note 2	Hor	110	186
26	7.439863	58.32	83.5	38.32	63.5 Note 2	Ver	110	154

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

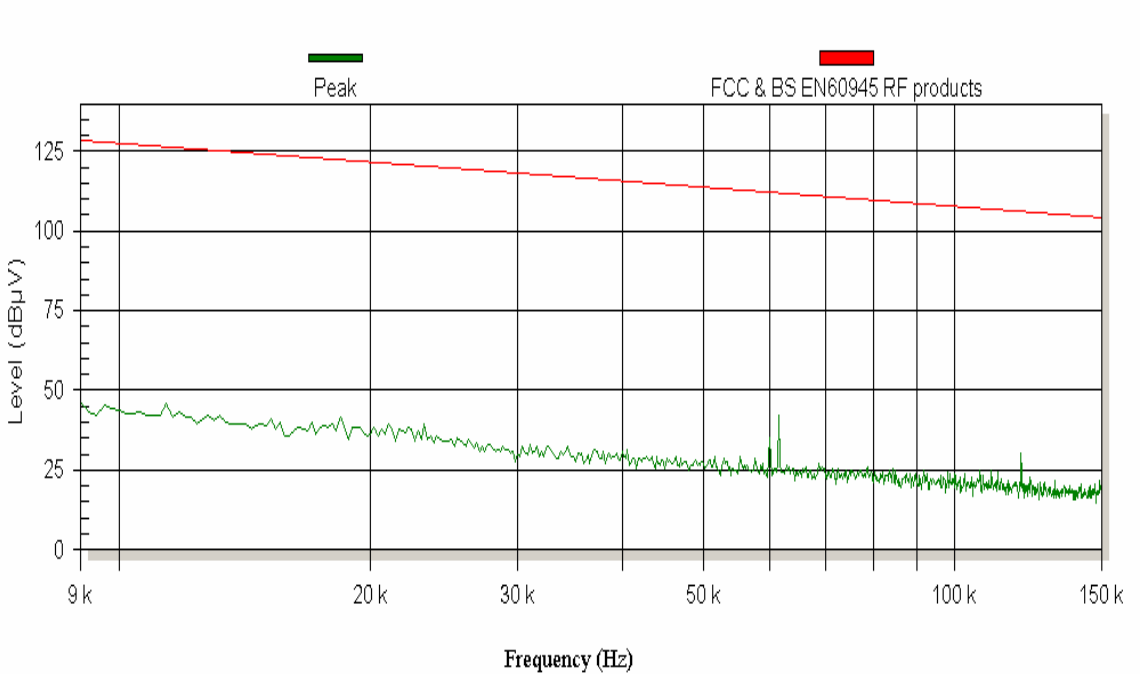


Figure 4 Composite graph of radiated emissions, antenna edge on from EUT

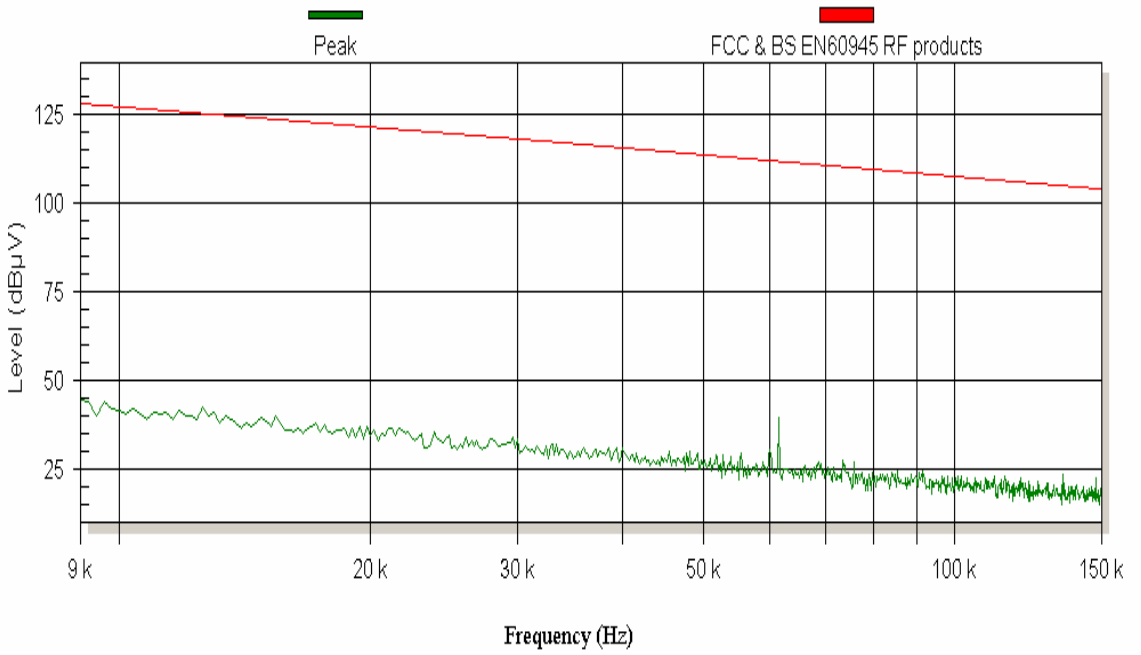


Figure 5 Composite graph of radiated emissions, antenna face on from EUT

10.2 150kHz to 30MHz

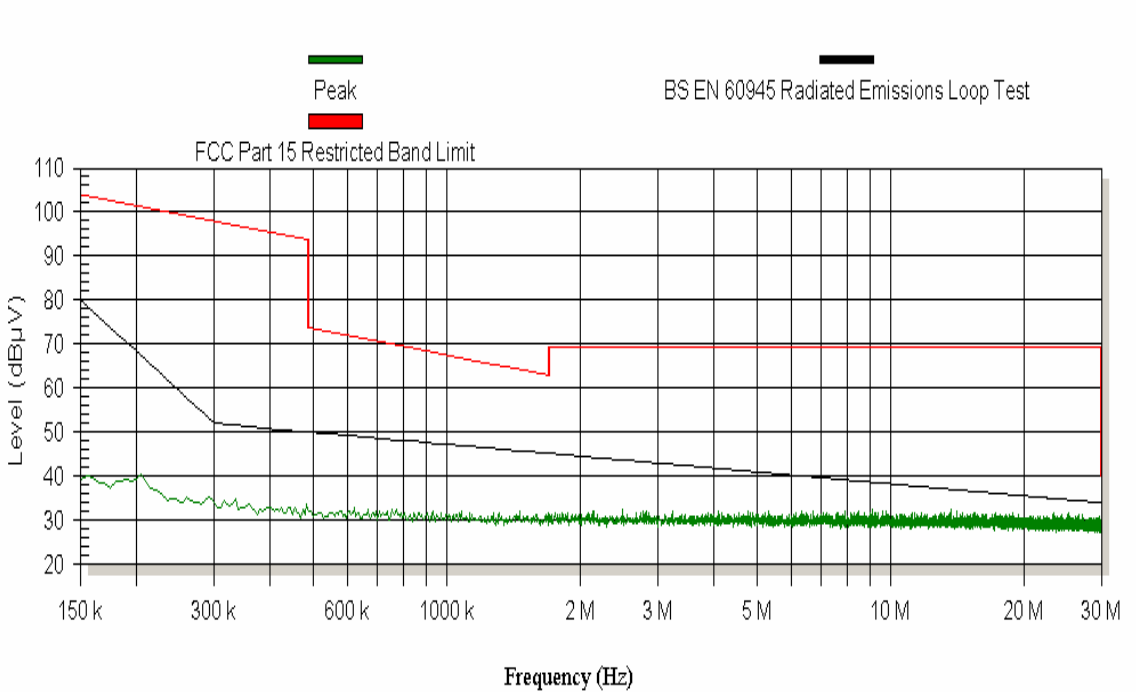


Figure 6 Composite graph of radiated emissions, antenna edge on from EUT

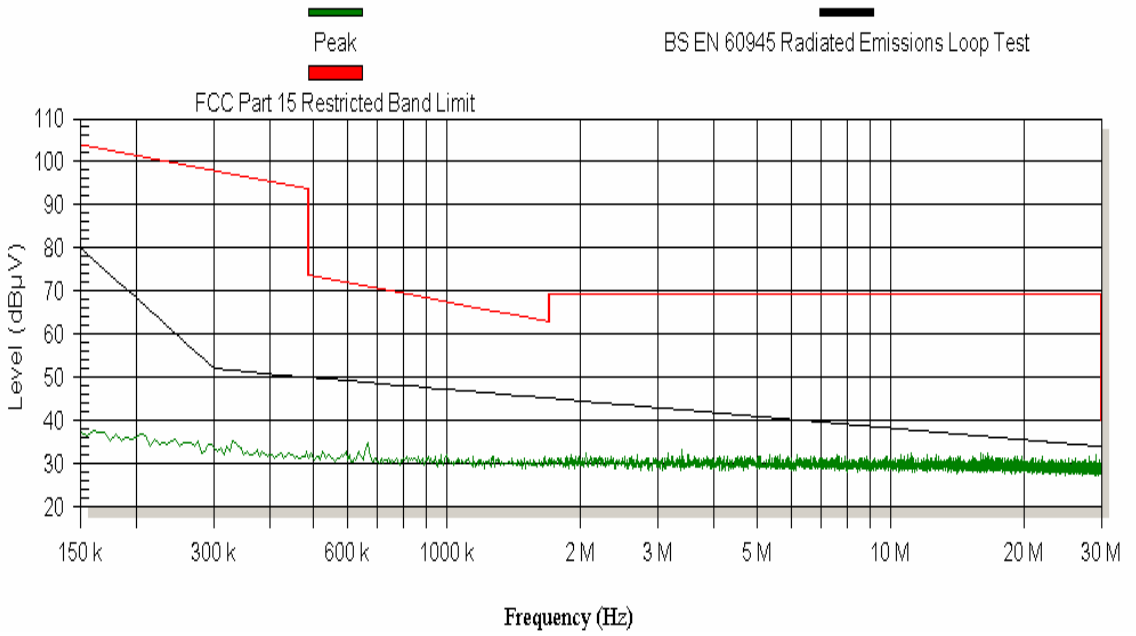


Figure 7 Composite graph of radiated emissions, antenna face on from EUT

10.3 30MHz to 300MHz

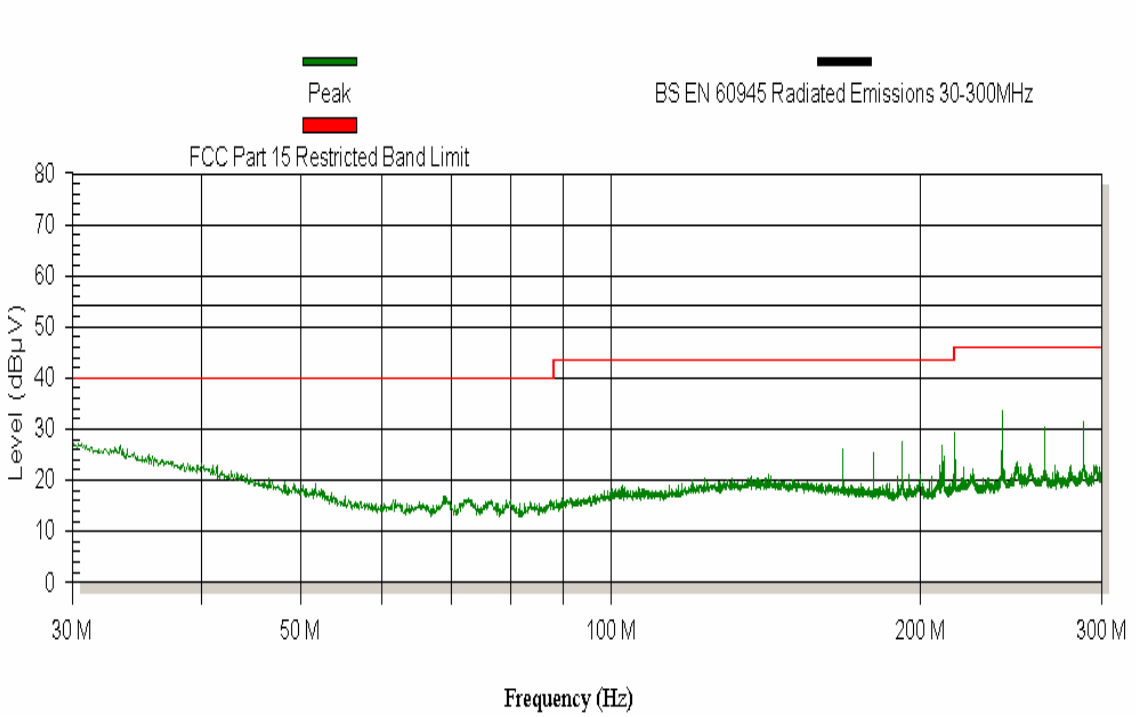


Figure 8 Composite graph of radiated emissions from EUT

10.4 300MHz to 1000MHz

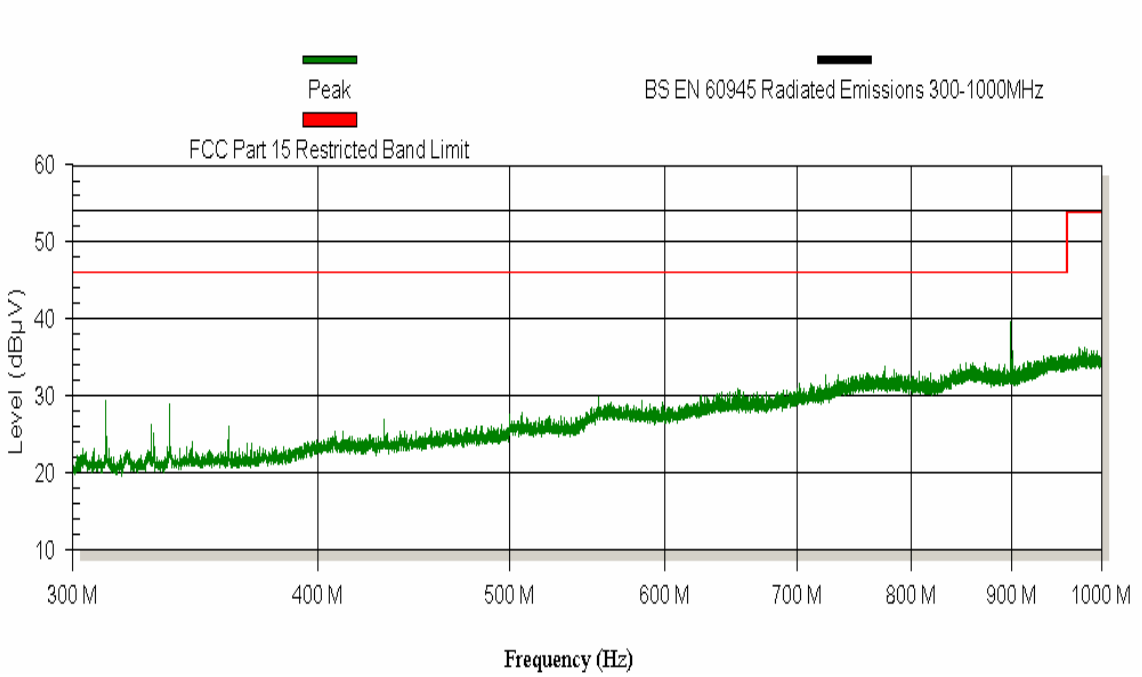


Figure 9 Composite graph of radiated emissions from EUT

10.5 1GHz to 2GHz

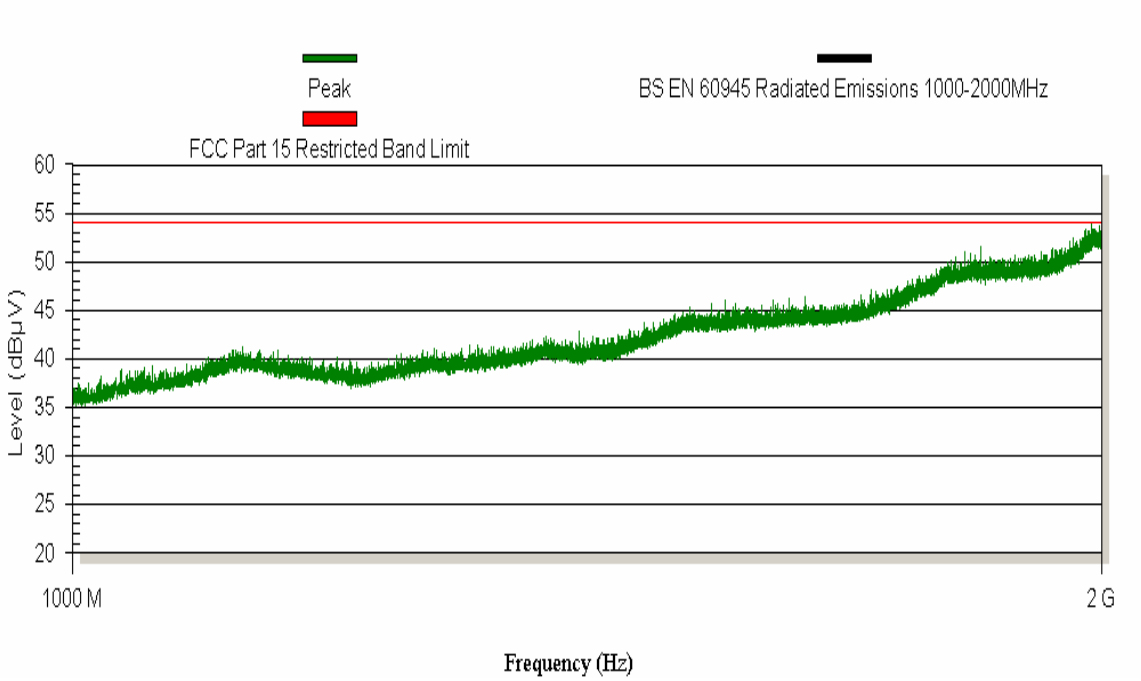


Figure 10 Composite graph of radiated emissions from EUT

10.6 2GHz to 25GHz

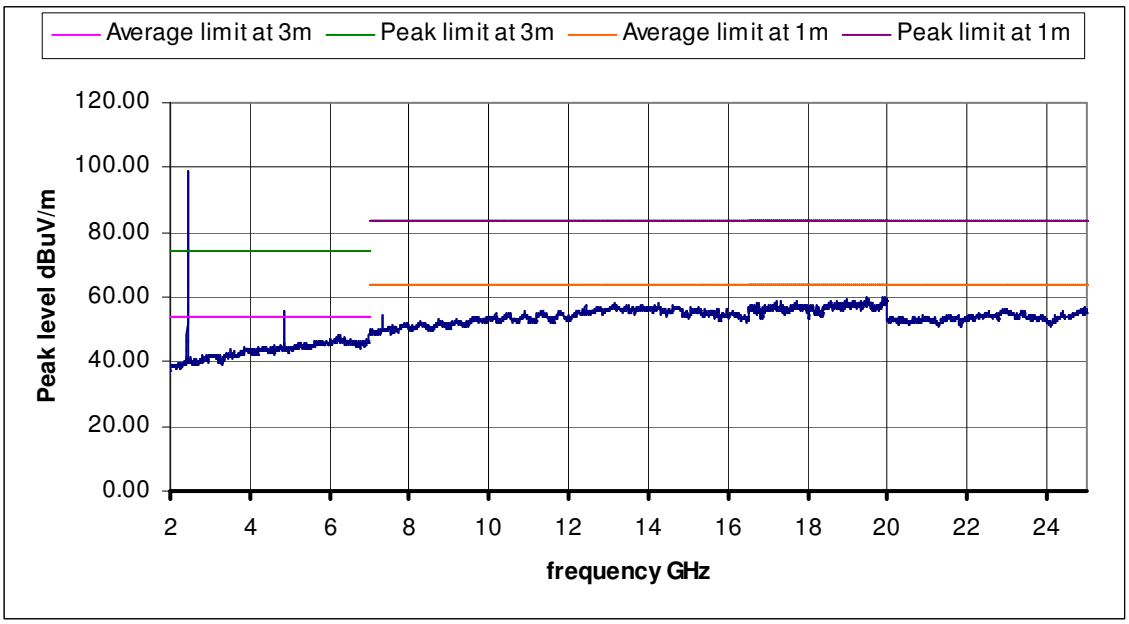


Figure 11 Composite graph of peak radiated emissions. EUT in Tx mode, channel 18

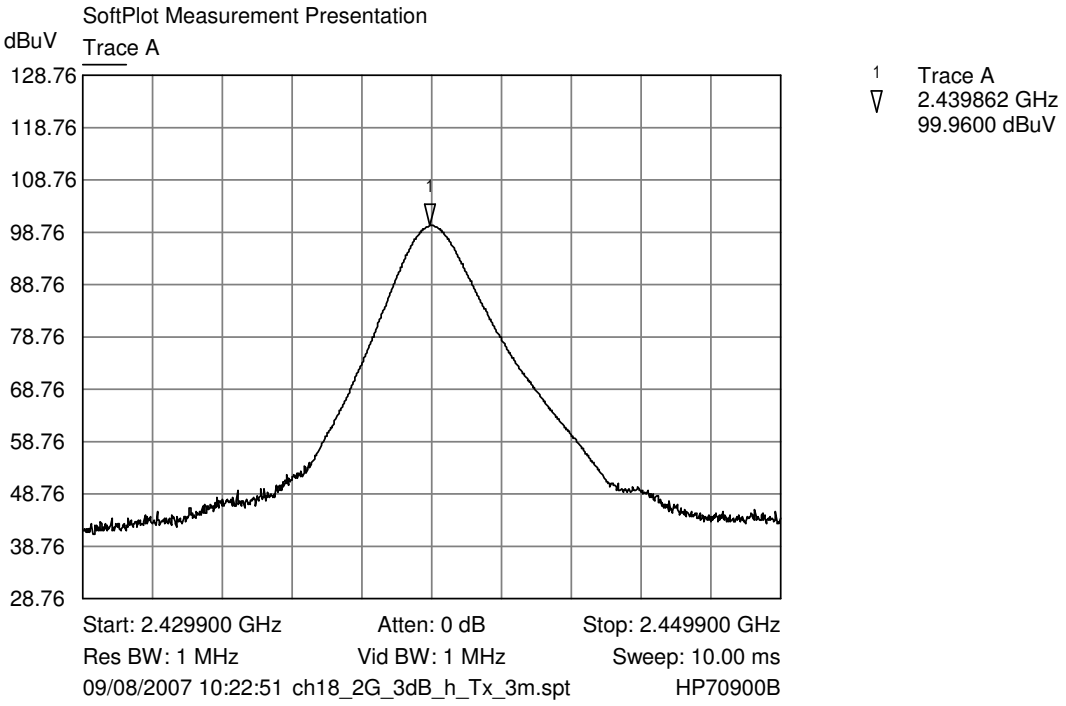


Figure 12 Channel 18 Horizontal (Highest recorded fundamental frequency)

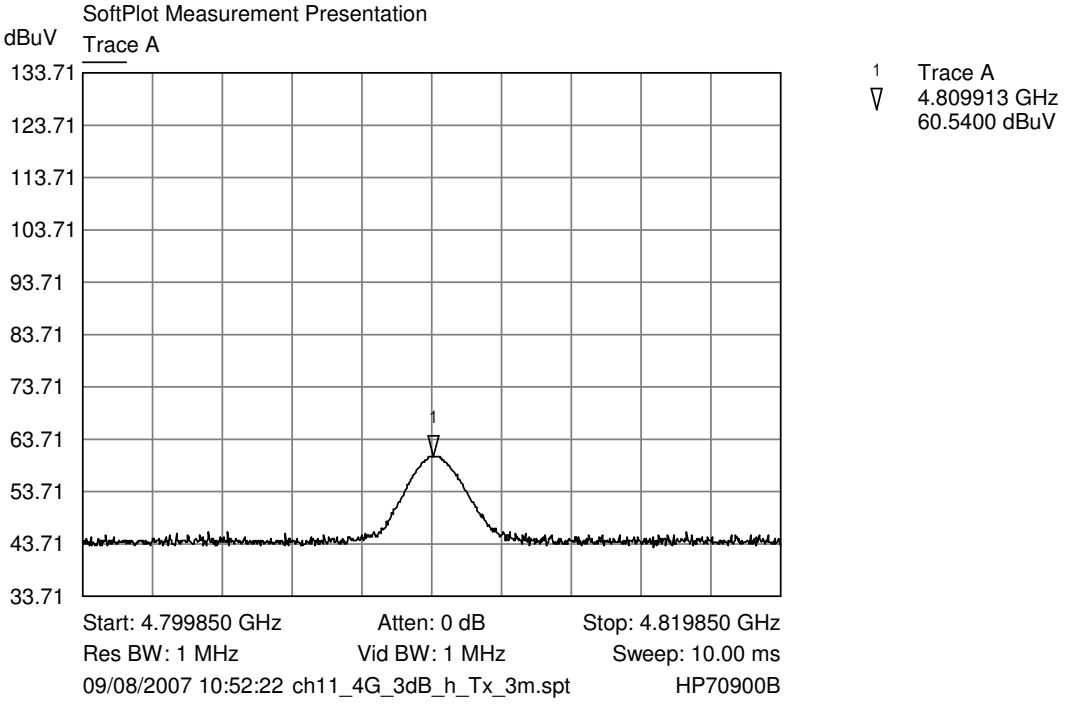


Figure 13 Channel 11 Horizontal (Highest recorded 2nd harmonic)

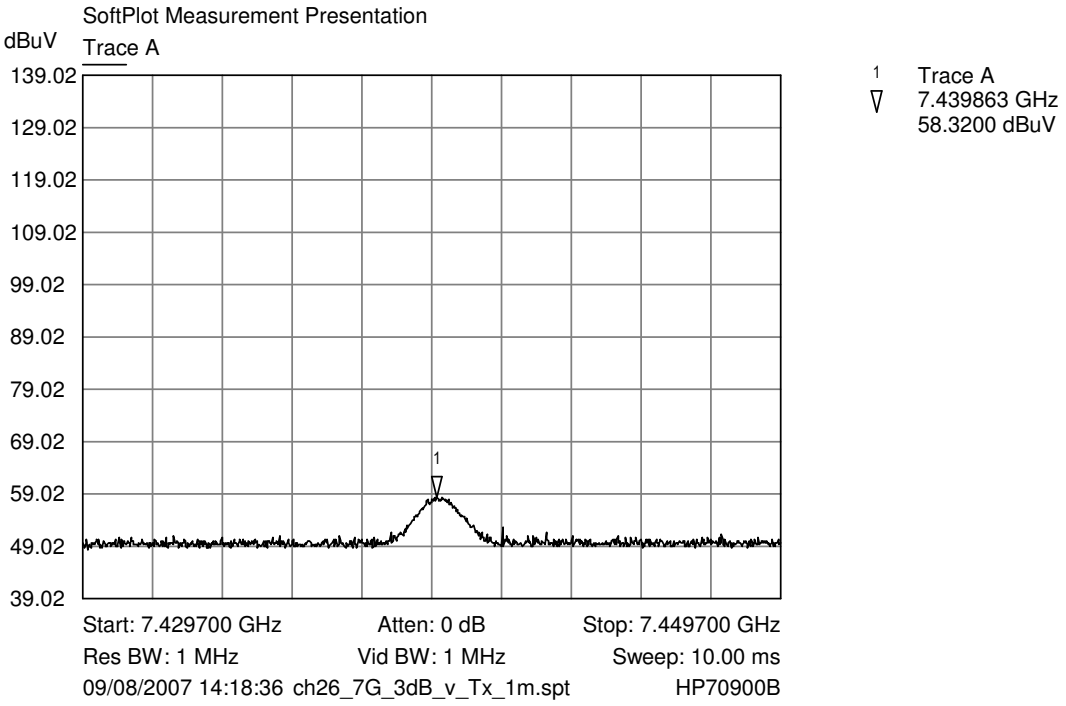


Figure 14 Channel 26 Vertical (Highest recorded 3rd harmonic)

11 Radiated Emissions Results – Standby

11.1 Test Measurement Limits.

The EUT was tested for spurious emissions between 2-25GHz (i.e. above 10th harmonic) against the following limits while in continuous receive (standby) mode:

Table of FCC 15.109 (a)

11.2 Test Results

2GHz – 25GHz

The frequency sweeps above 2GHz showed no spurious emissions radiating from the EUT (see Figure 15 below).

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

2GHz to 25GHz

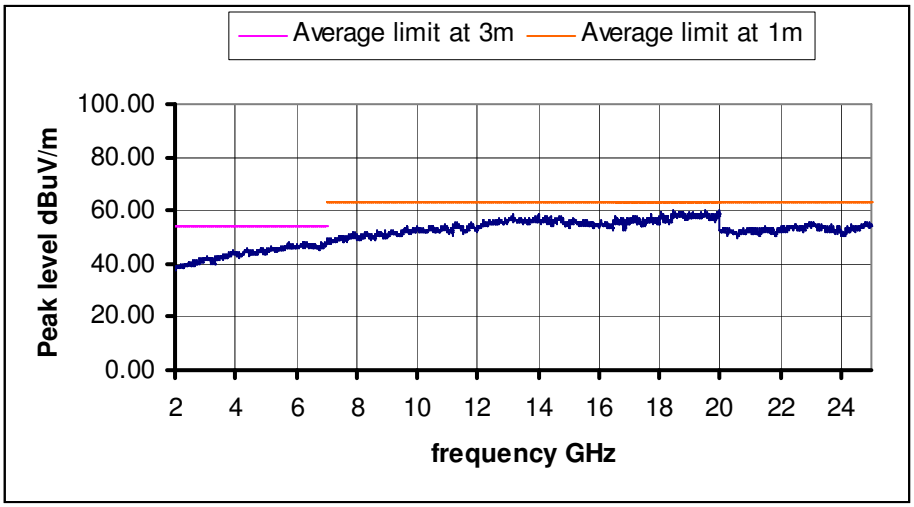


Figure 15 Composite graph of peak radiated emissions. EUT in Rx mode, channel 18

12 6dB Bandwidth - FCC 15.247(a)(2)

Utilising the special test software, the EUT was set to continuous transmit with typical modulation. Using a HP70000 spectrum analyser, the power envelope was displayed and the maximum level noted. Using the marker delta function, the frequencies either side of the maximum level which were 6dB lower than the peak level were noted. The lower frequency was subtracted from the higher and the resultant was recorded as the -6dB bandwidth.

Result: -6dB bandwidth 1.539MHz

The occupied bandwidth (99% of the power envelope) was measured in a similar manner by taking the two points on either side of the peak level which were 20dB below the peak.

Result: -20dB bandwidth 2.644MHz

13 Maximum peak output power & power spectral density

13.1 Maximum peak output power – FCC 15.247(b)(3)

The maximum field strength from the EUT was measured during the tests for radiated spurious emissions and was found to be 99.96dBuV/m (0.09954V/m). This was converted to peak output power using the formula

$$P_t = (E.d)^2 / 30$$

Where P_t = watts, d = metres, E = V/m.

Result: Max peak output power (e.i.r.p) 3mW (4.8dBm)

13.2 Power spectral density – FCC 15.247(d)[26-8-03] or 15.247(e)[20-9-07]

The power spectral density in any 3kHz band was measured using conducted power test methods. For these tests, the antenna was removed and a temporary rf connector was fitted to the pcb. Measurements of the power conducted to the antenna were made with the transmitter using DSSS modulation with a data rate of 255kBits/s. The power spectral density in a 3kHz band measured at the antenna port was 1.77mW (2.48 dBm)

Result: Power spectral density in any 3kHz 1.77mW (2.5dBm)

14 RF Exposure - FCC 15.247(b)(5)[26-8-03] or 15.247(i)[20-9-07]

An assessment of the RF exposure from the EUT is required 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 10cm between the human body and the EUT.

EIRP from the EUT = 4.8dBm (3mW).

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

$P_r = 0.003/(4\pi \times 0.001)$

$= 238.7 mW/m^2$

Converting this to cm^2;

$= 23.87 uW/cm^2$

The calculation assumes a continuous transmission from the EUT. In normal use the EUT will transmit for only 600µs every 25ms; therefore the average power density is 573nW/cm^2 and the actual level of exposure will be proportionately reduced.

Results:

Peak power density: 23.87uW/cm^2

Average power density: 573nW/cm^2

15 Test Equipment List

Test Equipment Type	Manufacturer and Type Number	Serial No.	Cal Ref.	Cal Due
Semi-Anechoic Chamber, Site 3	Global EMC	GE002	**00973**	**31.05.08**
Biconical Antenna, 30-300MHz	Schwarzbeck VHBB9124/BBAK9137	285	**00968**	**08.03.09**
Log-Periodic Antenna, 0.3-3.0GHz	Emco EM6946	112	**00969**	**08.03.09**
Antenna Horn 1-18GHz	Chase BBHA9120D	128	**00852**	**23.09.08**
Antenna Horn 18-26GHz	Credowan 20-R-2843-0007	36755	**00482**	**29.09.08**
Active Loop Antenna 9kHz - 30MHz	Chase EMC HLA6120	1122	**00442**	**06.01.08**
Loop Antenna PSU/Charger	Chase EMC CBP9720	1076	**00450**	**06.01.08**
Antenna Mast (Site 3)	EMCO 2075 4m Mini-Mast		**01059**	**N/A**
Turntable (Site 3)	EMCO Lo-Pro Turntable		**01058**	**N/A**
Mast/Turntable/Antenna Controller (Site 3)	EMCO 2090 Multi-Device Controller	9906-1432	**01060**	**N/A**
EMI Test Receiver 20Hz - 26.5GHz	Rhode & Schwarz ESI26	832692/006	**00886**	**08.01.08**
Spectrum Analyser 100Hz - 26.5GHz	HP70000 series	3230A05180	**00425/34**	**16.08.09**
Emissions Software	Radimation v4.3.73	VCQZPC	**N/A**	**N/A**

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

16 Measurement Uncertainty

Measurement uncertainty has been calculated after reference to CISPR16-4:2002. In order to determine compliance with the limit for emissions tests, the specification states that, where the calculated uncertainty exceeds the value of Ucispr, the difference in dB is to be added to the instrument reading. The corrections shown in the table below have therefore been added to the reported measurements before assessing compliance with the limits.

Measurement Type	Confidence Level (k = 2)	Calculated Uncertainty	Ucispr	Correction
Radiated Emissions: Electric Field Strength 30MHz - 1GHz	95%	+/6.2dB	4.5dB(<300MHz) 5.2dB(>300MHz)	+1.7dB(<300MHz) +1.0dB(>300MHz)
Radiated Emissions: Electric Field Strength 1GHz - 26.5GHz	95%	+/-6.9dB	Assumed 5.2dB	+1.7dB
Radiated Emissions: Electric Field Strength 26.5 - 40GHz	95%	+/-7.1dB	Assumed 5.2dB	+1.9dB