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Change Log

Date	Issue	Change
Tuesday, 06 December 2005	0.1	Initial drafting of document after the completion of the first phase of EMC testing

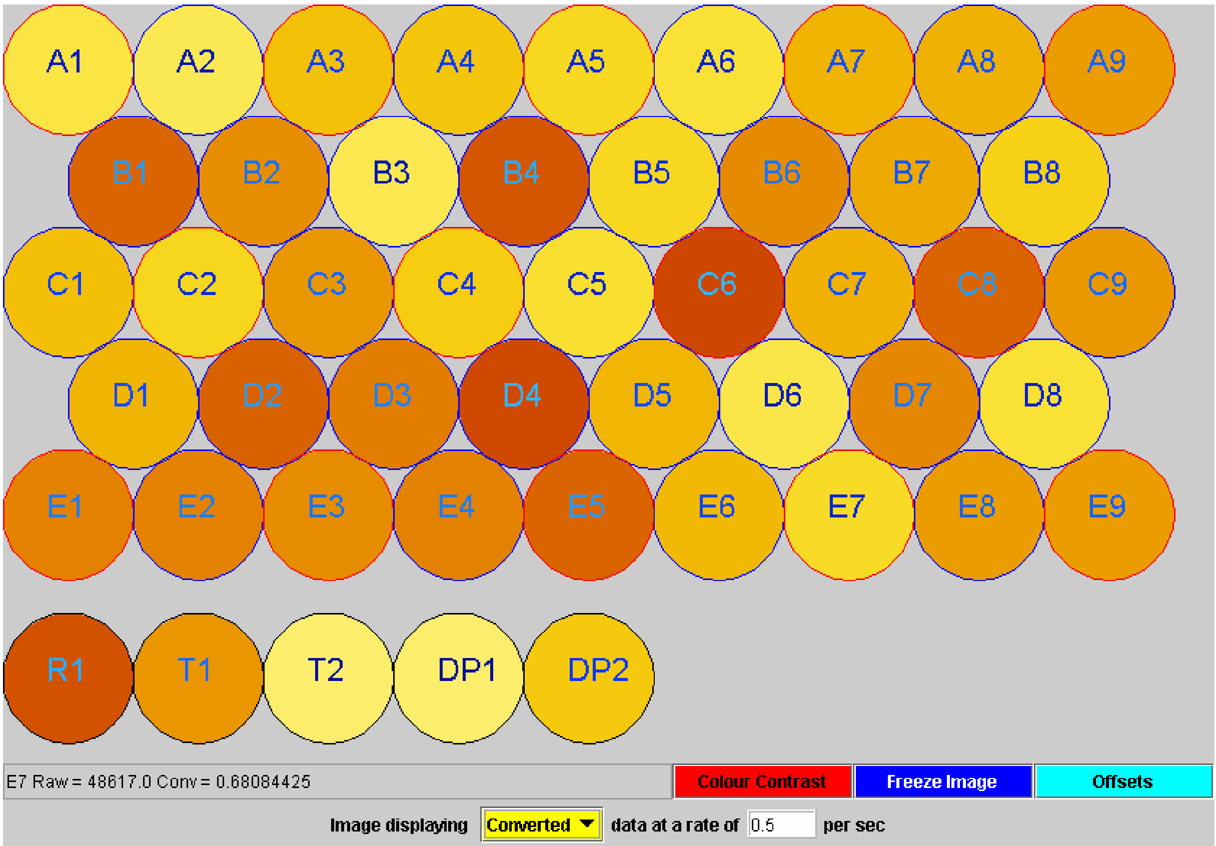
1. Scope

This document reports and documents the RS susceptibility tests carried out at Astrium OTN on the SPIRE CQM instrument during the period 28-Nov-2005 to 2-Dec-2005 as well as the supplementary tests carried out during the period 12-Dec-2005 through 14-Dec-2005.

2. Reference Documents

RD1: ''PLM EQM EMC Test Procedure, HP-2-ASED-PR-0033, dated 21.09.05
RD2: "SPIRE EQM EMC Test Procedure" SPIRE-RAL-PRC-002545, Issue: 2.0 pre-release

3. Channels monitored during testing



It was envisaged that R1 could be used as a diagnostic, to differentiate between EMI currents injected across the detector and noise pickup within the DRCU.. This was not possible as R1 is listed as open circuit in the EIDP.

4. Nominal detector parameters

Bias frequency: 130Hz
Bias amplitude: 16.47mV (0x60)
Sampling frequency: 43.26Hz
Demodulation phase: 168 (0x119)
Vss = -1.49V (0x76)

5. Susceptibility Threshold

The derivation of the susceptibility criteria for SPIRE is contained in RD-2. In Summary, the noise budget for SPIRE is contained in the BDA Sub-system Specification Document where the contribution to the overall noise figure for the detectors is to be less than 5nV/√Hz over the signal band (up to ~5Hz). No distinction is made between the noise contribution from direct coupling of EMI into the detectors causing heating and EMI coupling into the warm electronics. The simplifying assumption is therefore made that the total noise (rms) from both contributions must be arithmetically summed.

6. Test uncertainties

The following factors are enumerated that degrade the confidence in the results of the EMC testing. No attempt is made in this document to rank their severity. It is also noted that many of these issues were known and judged to be an acceptable risk during the planning of the test campaign.

- The Warm Electronics is not flight representative, in particular:
    - The DRCU is not form and fit compliant with flight
    - The PSU is not present and the DRCU is powered by a bench power supply connected to the mains
    - Many boards are missing from the DRCU
    - Extra SPIRE harnesses were present (mechanisms test harness and detector bias isolation harness)
- Only the PLW detector chain is implemented. The PSW, PMW, SSW and SLW detector chains are not implemented
    - Only a subset of the SPIRE cryoharness was implemented
- The test was not carried out in an anechoic EMC test facility
- Various items of EGSE (e.g. CCS harnesses) and MGSE (e.g. cryogen pumping ports, cryostat dolly) were present.
- There were several NCRs on the cryoharness manufacture (which were given the disposition use-as-is for the EQM programme)
- There are several (TBD) differences, not covered by the cryoharness NCRs, between the implementation of the EQM cryoharness and the PFM cryoharness
- The detector sampling rate was set to a higher rate than
- The susceptibility of the detectors in flight will depend on both the as-delivered performance of the detector and various environmental variables; in particular the “bath” temperature of the detectors, the photon background, the optimum detector bias level etc. Improvement in these factors between the EQM (i.e. CQM) and the PFM will increase the susceptibility of the detector chain.

7. Data analysis and reduction

As outlined in the SPIRE EMC test procedure, there are two basic test methods for EMC testing. The first, is a frequency sweep to carry out a low sensitivity survey of potential susceptibilities within a defined spectral range. The second is a follow up, higher sensitivity test of the susceptibility at spot frequencies identified either in the sweep survey or alternatively in the spacecraft frequency plan.

In order to experimentally differentiate between extraneous signal/noise sources from temperature drifts in the cryostat and/or changes in the ambient stray-light within the cryostat, the EMI source was duty-cycle modulated at 1Hz. The extraneous detector noise sources (temperature and stray-light) are confined to the very low portion of the frequency spectrum (below say 100mHz). Duty cycling the EMI disturbance at 1Hz shifts any pickup out of the very low frequency portion of the spectrum.

7.1 Analysis of Sweep Survey Tests

The test parameters used to generate the spectral and temporal content of the EMI test signal were as follows:

Parameter	Description
T_{dwell}	The dwell time for each step in the frequency sweep; typically no more than several seconds.
F_0	The starting frequency for the sweep
F_n	The last frequency in the sweep
n	The number of steps in the sweep (minus one!)
A	The log-linear frequency step according to: $f_i = f_0 A^i$
t_{on}	time that the signal is switched on during each cycle. In all cases this was 860ms
t_{off}	time that the signal is switched off during each cycle. In all cases this was 140ms yielding a repetition frequency of 1/(860 + 140)ms = 1Hz

Table 1 – Test parameters for the EMI frequency during the sweep

Prior to the commencement of each sweep, a quiescent reference case was generated over a period of 180sec. The data was time tagged in the telemetry with Step==1. This data was extracted from the database and converted to fits format and then broken down into a series of data segments (of length 2 seconds). The rms noise of the signal was calculated for each of these segments and then the average rms noise over the 180 second period was calculated. This was done by taking the arithmetic average of the noise calculated in each segment. This technique effectively limits the spectral content of the measured noise to be greater than ~ 0.5Hz and thereby removes any spurious signal modulation observed during the generation of the quiescent reference case data. This was repeated for all 48 detector channels in the PLW array.

During the sweep, the telemetry was time tagged with Step==2. The rms signal noise is calculated at a range of time steps in the sweep using an analogous method to that used in the calculation of the noise in the quiescent reference case. The actual average (log-linear) frequency sweep rate was calculated from the duration of the sweep and the start and ending frequencies. This was then used to relate the time from the start of the sweep to the injection frequency at that particular time.

Two data sets are generated for each sweep. The first is the absolute rms noise for each channel of PLW array vs. frequency. The second set is the increase in rms noise under the test from the quiescent noise figures.

EMI couples into the instrument in two coupling paths; (a) EMI directly injected into the front-end electronics and (b) EMI currents injected into the cryogenic detector circuit giving rise to bolometer heating. As the data analysis technique used during the sweep does retrieve any spectral information from the detector noise data, it is not possible to differentiate between the two sources, and thus the results are not used to make any conclusions about susceptibility thresholds or coupling mechanisms. They can be used, however in a semi-quantitative manner to make conclusions about the relative strengths of any susceptibilities found.

7.2 Analysis of Spot Tests

The spot tests described in RD 2 are used to follow up on the survey and the spacecraft frequency plan to evaluate in more detail the susceptibility of the instrument to EMI. The spot tests are carried out by generating quiescent reference data for each channel of the detector and then comparing these with noise data from the instrument integrated over a period (typically 180s) when the EMI disturbance is switched on.

The technique of duty-cycle modulation of the disturbance at 1Hz in order to shift the EMI pickup in the instrument away from the frequencies where the thermal/stray-light noise sources are located was adopted during the spot frequency tests.

The intention of the spot tests is to obtain a *quantitative* measure of the susceptibility threshold under the particular test conditions seen during the EQM EMC testing. In doing this, it is important to distinguish between the contributions from direct detector heating from EMI coupling into the other parts of the detector chain. These are treated separately below:

7.2.1 Direct detector heating

Under the (hypothetical) conditions of an EMC test where there is no detector noise and 0.5uV equivalent heating of the detector, the output from the detector will be as illustrated in Figure 1. When the EMI source is switched on, the detector will heat and the output will fall by 0.5uV. When the source is switched off, the detector output will return to the quiescent level. The time constant of the detector is in the order of several 10^{-3}s, so the signal when sampled at 43.26Hz will closely resemble a perfect square wave. The rms amplitude of a square wave duty cycled at 86% is 0.182uV. There is thus, a factor of 0.5uV/0.182uV=2.75 between the rms voltage seen in the test conditions when the disturbance is modulated and the magnitude of the voltage due to detector heating.

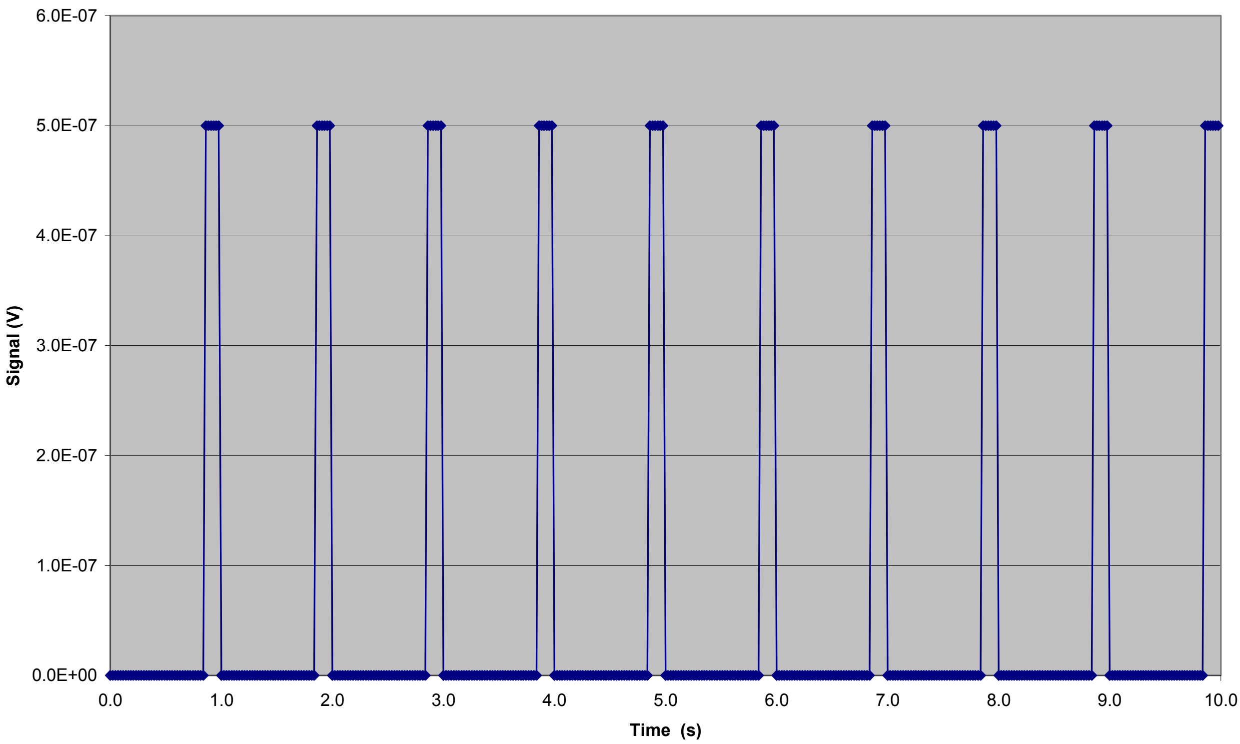


Figure 1 – See text for description.

Fourier analysis can be used to show that this signal is the sum of sinusoids at f=1Hz and every harmonic above this. The theoretical bandwidth of each of the Fourier components is zero and the amplitude of the components decrease with increasing frequency. When a FFT algorithm is applied to the signal illustrated in Figure 1, it can be seen that spectral leakage causes there to be a finite bandwidth to the components of the signal at the primary frequency and its' harmonics (See Figure 2). Aliasing of frequencies above the Nyquist frequencies introduces an amplitude distortion of the computed spectra.

This spectra can be used to calculate a precise value of the rms of the signal by converting the spectral density at each frequency to power spectral density and computing the square root of the sum of squares. However a quick estimate of the rms of the signal can be made by summing only the frequency bins in a narrow band around 1Hz and the first few harmonics. For example, if the rms signal amplitude is estimated by summing the frequency bins within 0.15Hz of 1Hz and the harmonics up to 5Hz (i.e. the 3dB point of the SPIRE low-pass filters) contains 94% of the signal content. Thus a quantitative estimate of the amplitude of the detector heating can be estimated by summing a small number of the frequency bins.

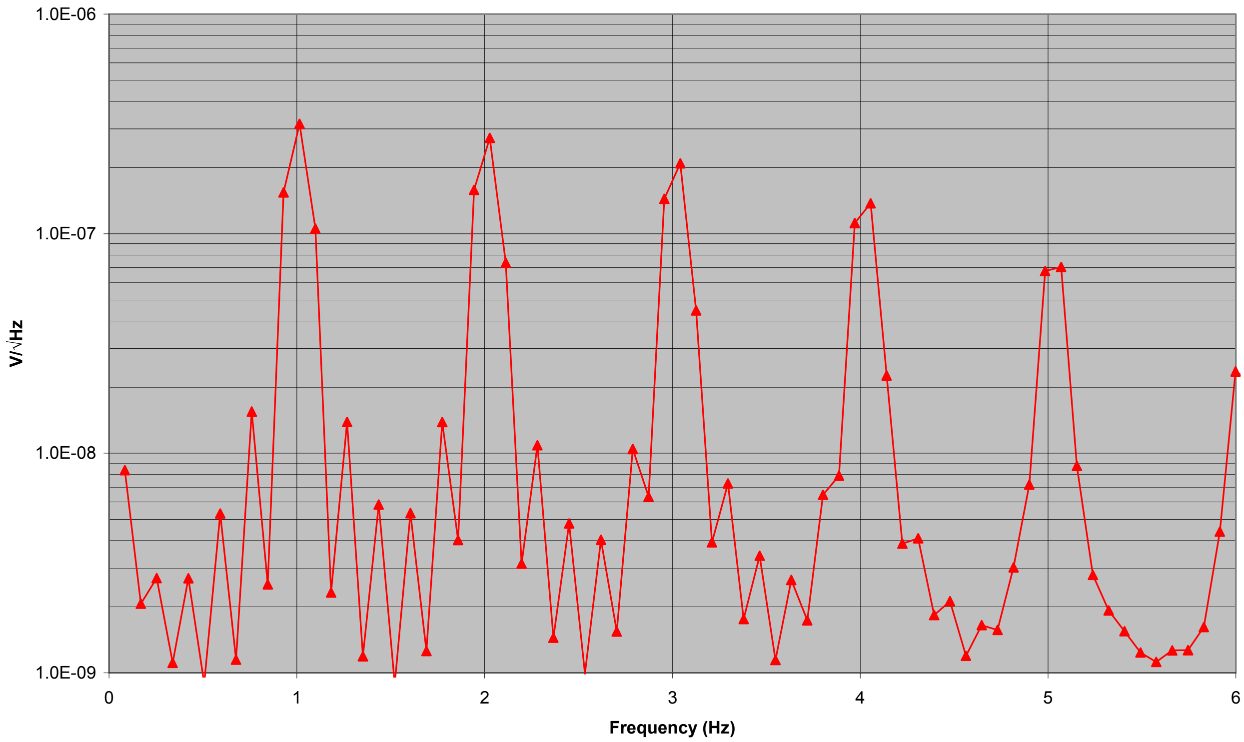


Figure 2 – Spectra of the data in Figure 1 computed by an FFT algorithm. The data was converted into seven segments of 1024 points and averaged. The DC offset and very low frequency components of the signal were removed by subtracting a least square first order polynomial from the data.

7.2.2 Broadband EMI

The amplitude of the EMI being injected into the detector signal (without being injected as EMI currents in the bolometer) can be calculated by computing the spectral density of the signal as outlined above. The rms amplitude of the noise can also be calculated by taking the square root of the sum of squares of the power spectral density. As the instrument is irradiated with an 86% duty cycle, the noise measured under test need to be scaled by:

$$noise_{rms|EMI} = noise_{rms|quiescent} + \frac{(noise_{rms|EMI|measured} - noise_{rms|quiescent})}{86\%}$$

To validate the data processing procedure, a uniform 30nV/√Hz white noise source and a 60nV/√Hz source, duty cycled at 86% were analysed (see Figure 3). The calculated spectral density of the modulated signal was 56.5nV/√Hz, which agrees closely with the theoretical figure.

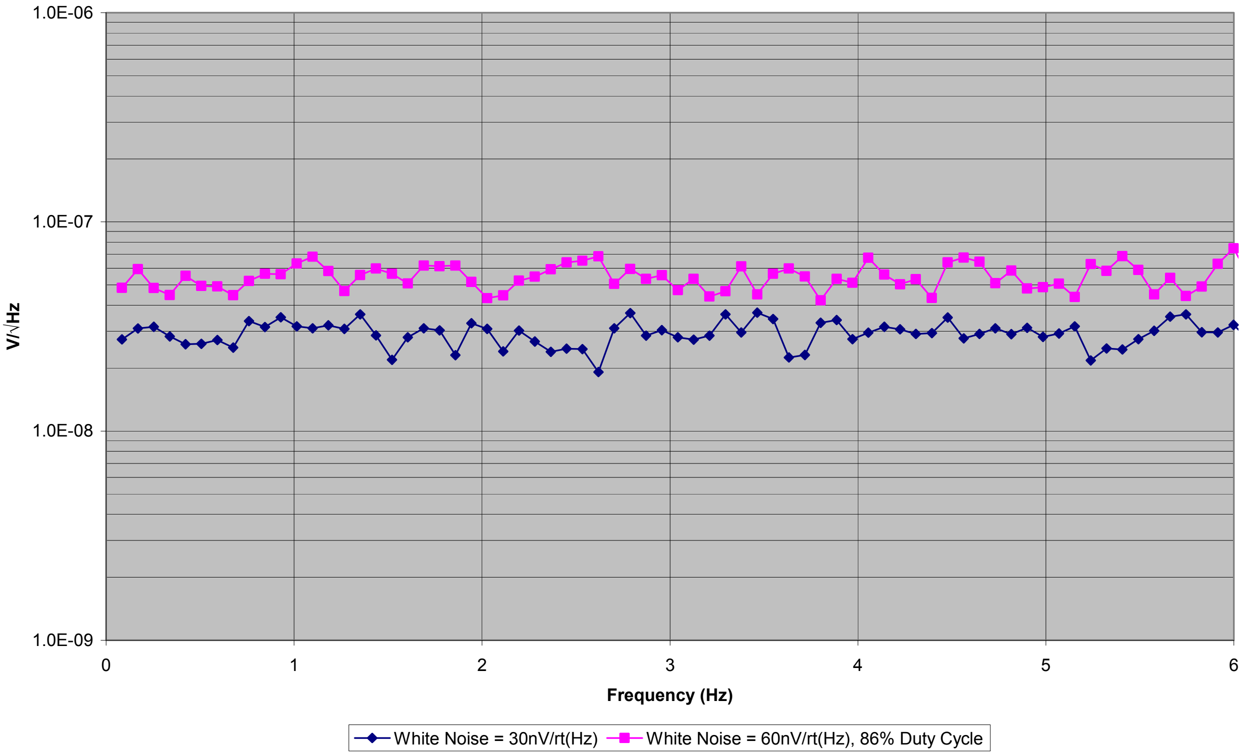


Figure 3 – Spectral content of a 30nV/√Hz white noise source and of a 60nV/√Hz source duty cycled at 86%, 1Hz.

7.2.3 Simultaneous Direct detector heating and broad band noise estimation

It is required that both the direct heating component and broad band EMI noise estimates be made simultaneously. As can be seen from Figure 2, outside the narrow band around 1Hz and the first few harmonics, the calculated spectral density of a strong detector heating noise source modulated at 86%, 1Hz is 20 to 40dB lower than the peak.

Under the condition that the noise spectral density of any direct detector heating is sufficiently higher than the noise level between the 1Hz harmonics, the amplitude of the signal resulting from the EMI currents heating the detector can be estimated by taking the difference between the rms amplitude of the detector signal under test and under quiescent conditions as per §7.2.1.

When the amplitude of any direct heating EMI falls below the noise floor under test, then the estimation of the direct heating becomes unreliable due to the numerical ill conditioned nature of the problem.

The estimate of the broad band noise can be made by subtracting the noise spectral density of the direct heating component of the noise outside the band close to the 1Hz harmonics from the noise measured under test in this band, then subtracting the quiescent noise in this band and then correcting for the 86% duty cycle.

When the amplitude of the direct heating EMI is much larger than the broad band noise, then the estimation of the noise according to this method becomes unreliable due to the ill conditioned nature of the problem.

Figure 4 illustrates many of these concepts. In the narrow band around 1Hz and the harmonics, the composite spectra of the 5uV ‘Direct Heating’ noise source and the 60nV/√Hz white noise source closely matches the spectra of a 5uV ‘Direct Heating’ noise source and can thus be used to make a good estimate of the level of direct bolometer heating. Outside of these narrow bands, the composite spectra closely resembles the spectra of a 60nV/√Hz noise source, and can be used with the appropriate corrections to estimate the increase in the broad band noise.

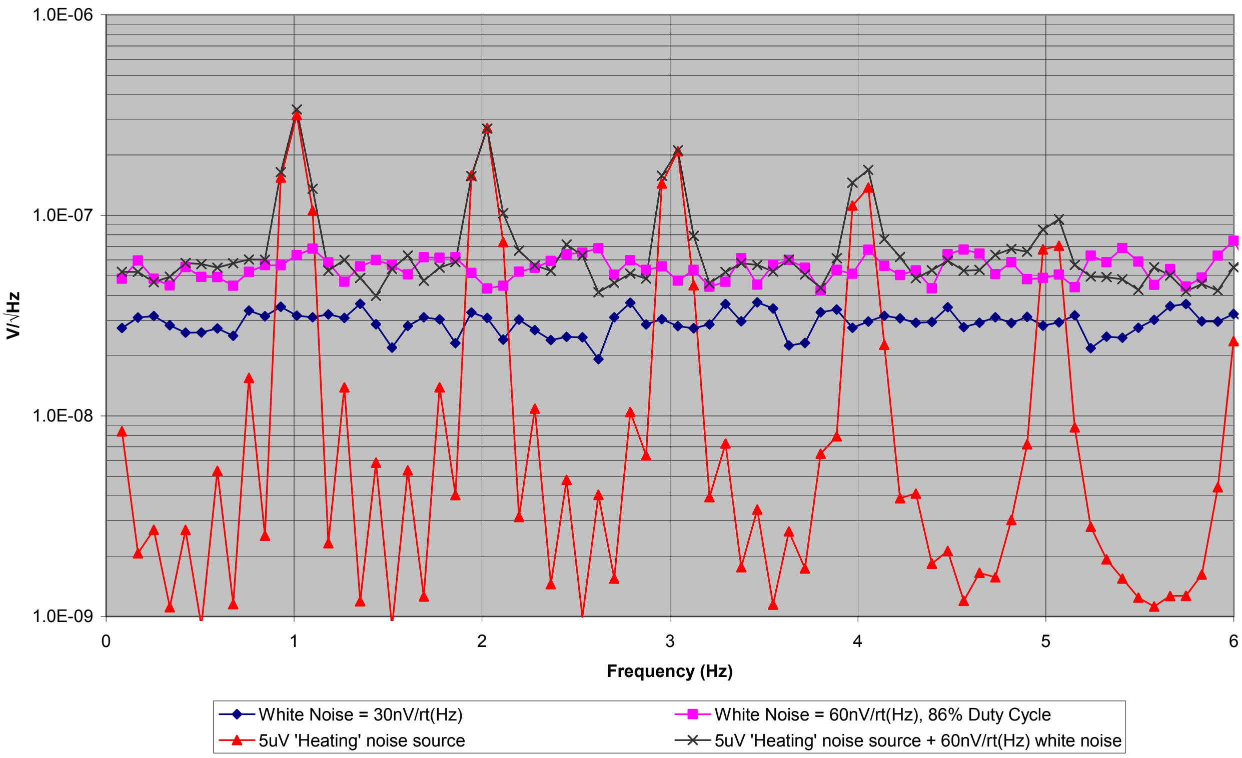


Figure 4 – See text for description

The lock-in amplifiers used to readout the SPIRE photometer detectors is low pass filtered with $f_c(-3dB) = 5Hz$ and an attenuation above this of -12dB/oct. For the purpose of the analysis, it is assumed that the filter has a flat response between 0 and 5Hz and has zero pass above this. Thus, only the information in the signal below 5Hz is used to estimate the noise figures.

The code written to process the data analyses the data in the following way:

1. The house keeping fits file for the test is scanned to determine the start and end times for each step.
2. The data within these two times is extracted from the detector fits file. For each detector, the noise spectral density is calculated along with the estimates of the total rms noise, the rms noise in the narrow bands close to the 1Hz harmonics and the rms noise outside these bands.
3. This data is written to a file named; "XXX_YY.csv" where XXX is the (hex) ObsID and YY is the step number.
4. The data for each test step is differenced from the data in the appropriate quiescent reference step and the estimates of the voltage offset due to direct bolometer heating and due to an increase in the broad band noise from the detectors is estimated and written to a file named; "XXX_YY_ZZ.csv" where XXX is the (hex) ObsID, YY is the test step number and ZZ is the reference step number.

The key assumption in this data processing procedure is that the spectral intensity of the broad band EMI does not overlap the EMI seen at 1Hz and the harmonics. The degree to which this is true will determine the accuracy of the estimation of the ratio of broad band EMI and bolometer heating EMI.

8. H-Field Testing

8.1 H-Field Sweeps

8.1.1 Sweep 1 (30Hz-50kHz): 0xB0000018

Sweep aborted due to temperature oscillations in the EQM cryostat.

8.1.2 *Sweep 2 (30Hz-50kHz): 0xB000001C*

SPIRE EQM EMC Sweep Test Sheet		**Sheet Number**	**Sheet 1 of** 2
Test Location:	EADS Ottobrunn	Field Type	H-Field
Date of Test:	28 November 2005	Antenna location	Location # 1
Start Frequency	30 Hz	Photograph of set-up	1838, 1839, 1840
Stop Frequency	50 kHz	Polarization	NA
Amplitude modulation	86%, 1Hz duty cycle	Antenna Ref	IABG loop antenna
Test Start time (CCS)	SPIRE-IMT-START-TEST.tcl 15:55:38	SPIRE Signature	
Test End Time (CCS)	SPIRE-IMT-END-TEST.tcl 16:31:58	ESA Signature	
Start quiescent reference case duration	180 s	Astrium Signature	
End quiescent reference case duration	180 s	F(n+1) = Fn * 1.05	
Step dwell time	5 seconds		
Number of steps in sweep	~154		
Estimated sweep duration			
Observation ID	0xB000001C		
Channels monitored in QLA	C5		

Observations (susceptibilities during test)		
Time	**Estimated Frequency**	**Notes**
15:56:29 (QLA)	NA	Quiescent Reference case Start
15:59:27 (QLA)	NA	Quiescent Reference case End
15:59:51 (QLA)		Start Sweep
Start + 2:55	63.3 Hz	AC Noise
Start + 03:46	80.7 Hz	Signal returns to normal
Start + 05:23	125.2 Hz	Possible DC shift
Start + 7:06	204.0 Hz	AC Noise
Start + 9:00	366.4 Hz	AC Noise
Start + 10:06	491.0 Hz	AC Noise

Start + 10:		Normal again
Start + 10:55		
Start + 11:40	761.6 Hz	AC for 10 sec
Start + 13:17	1240.6 Hz	AC
Start + 14:35	1745.7 Hz	AC for 10 sec
Start + 15:		AC for sec
Start + 19:		DC shift
Start + 23:24	21019.2 Hz	DC shift
16:26:21 (QLA)		End sweep
Start + 26:56 (16:26:45 QLA)		Quiescent reference case start
16:29:44(QLA)		End quiescent reference case

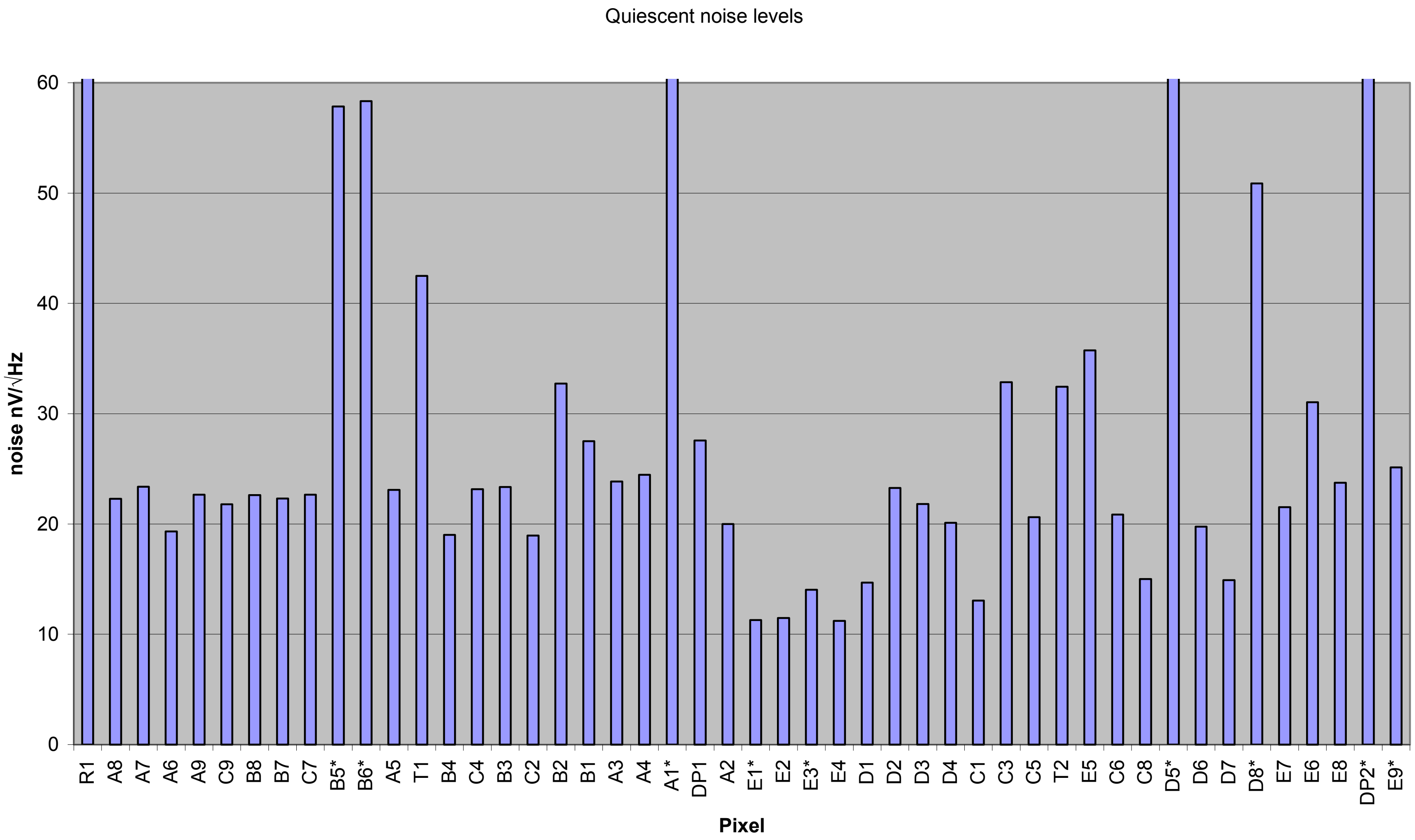


Figure 5 – Quiescent noise for Step 1 of Sweep 0xB000001C

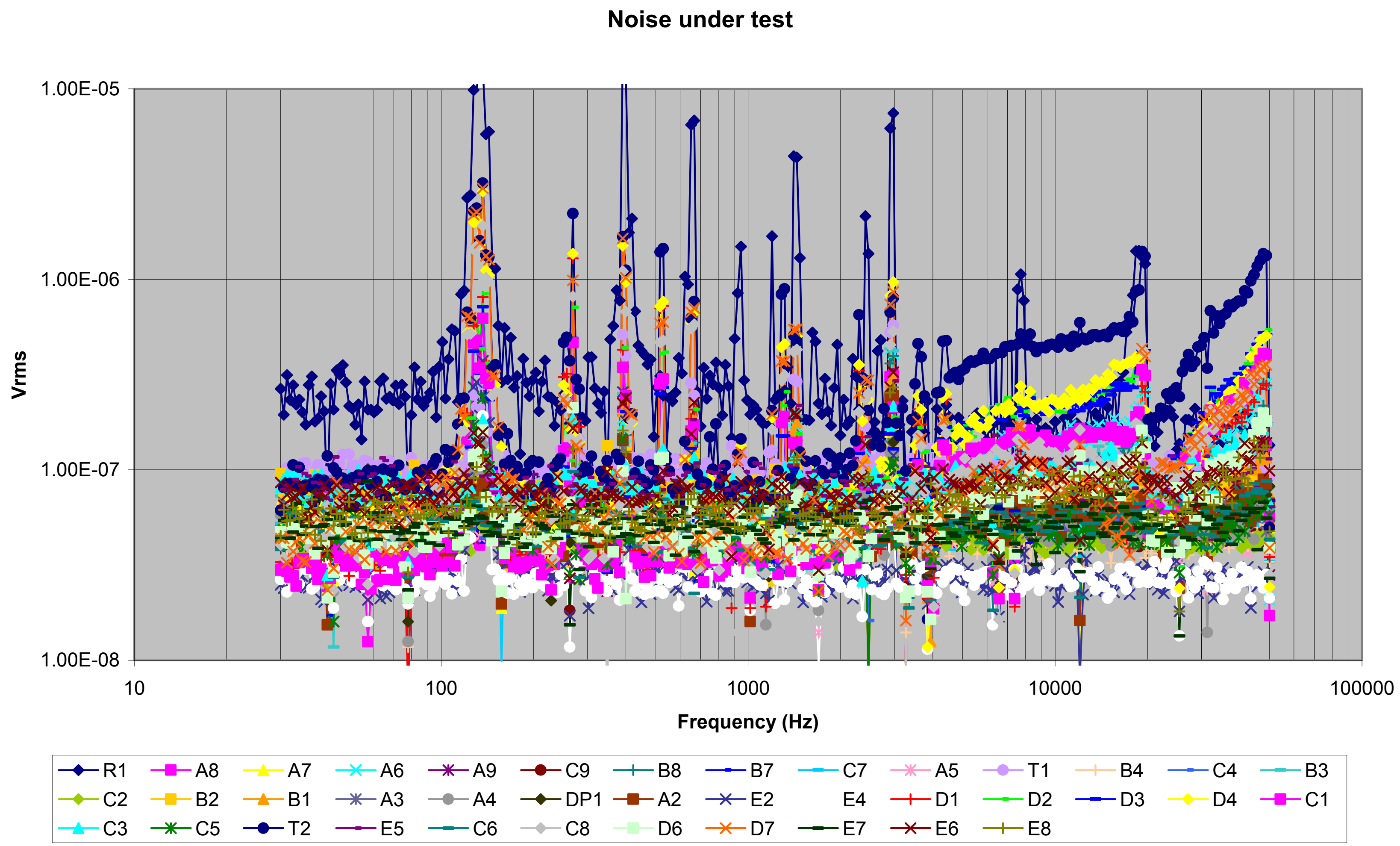


Figure 6 – Noise during sweep 0xB000001C

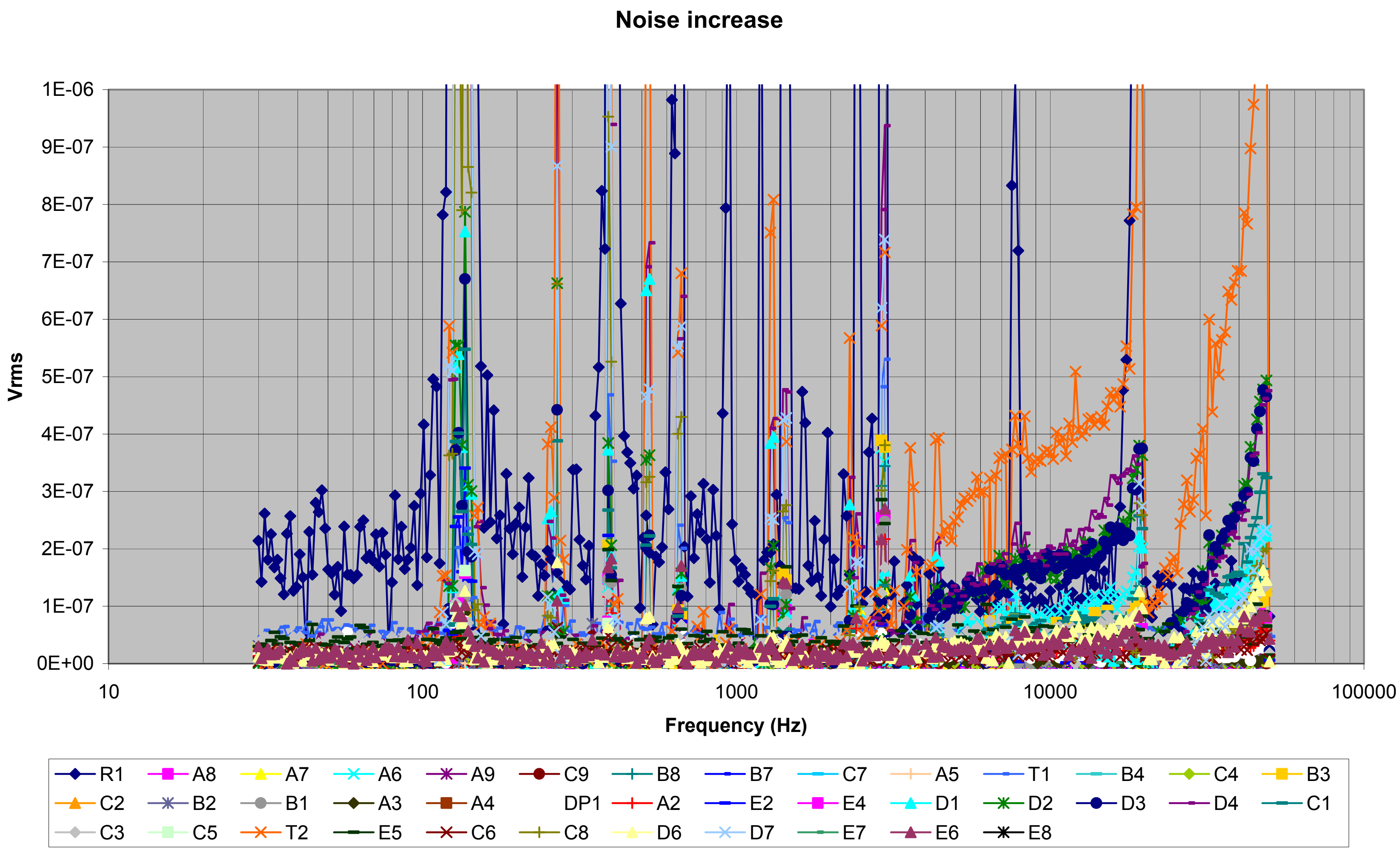


Figure 7 – Noise increase above the quiescent levels for sweep 0xB000001C

~134Hz
~257Hz
~400Hz
~517Hz
~652Hz
~1.34kHz
~2.41kHz
~2.97kHz
increasing between 4-19kHz
increasing between 20-50kHz

Table 2 - Principal susceptible frequencies identified during sweep 0xB000001C

8.1.3 Sweep 3 (30Hz-50kHz): 0xB000002B

8.2 H-Field Spot Frequency Tests

8.2.1 H-Field Spots (Full field strength): 0xB000002F

SPIRE EQM EMC Spot Test Sheet		Sheet Number	Sheet 1 of 2
Test Location:	EADS Ottobrunn	Observation ID	0xB000002F
Date of Test:	29 November 2005	Channels monitored in QLA	
Start Frequency	N.A.	Field Type	B – Field
Stop Frequency	N.A.	Antenna location	Loc^N 1
Amplitude modulation	86%, 1Hz duty cycle	Photograph of set-up	1838, 1839, 1840
Test Start time (CCS)	SPIRE-IMT-START-TEST.tcl 10:25:40	Polarization	NA
Test End Time (CCS)	SPIRE-IMT-END-TEST.tcl 12:34:00	Antenna Ref	IABG self made loop
Start quiescent reference case duration	180 sec	SPIRE Signature	
End quiescent reference case duration	180 sec	ESA Signature	
Step dwell time	180 sec	Astrium Signature	
Estimated test duration			

Observations (susceptibilities during test)			
Step	**Time**	**Frequency**	**Notes**
1	10:27:45 (CCS) S: 10:27:14 (QLA) E: 10:30:13 (QLA)	NA	Quiescent reference test

2	S: 10:31:05 (QLA) E: 10:34:04 (QLA)	247 Hz	NO GROSS EFFECT
3	10:35:00 (CCS) S: 10:34:28 (QLA) E: 10:37:27 (QLA)	260 Hz	SUSCEPTIBILITY SEEN (FULL 3 MINUTES)
4	10:38:36 (CCS)	273 Hz	NO GROSS EFFECT
5	10:41:58 (CCS)	348 Hz	NO GROSS EFFECT
6	10:45:12 (CCS)	366 Hz	NO GROSS EFFECT
7	10:48:24 (CCS) S: 10:47:53 (QLA) E: 10:50:52 (QLA)	384 Hz	SUSCEPTIBILITY SEEN
8	10:51:42 (CCS)	445 Hz	NO GROSS EFFECT
9	10:54:59 (CCS)	467Hz	NO GROSS EFFECT
10	10:58:16 (CCS)	490 Hz	POSSIBLY SMALL
11	11:02:32 (CCS)	NA	QUIESCENT REFERENCE TEST
12	11:06:41 (CCS)	1020 Hz	POSSIBLY SMALL
13	11:10:01 (CCS)	1071 Hz	NO GROSS
14	11:13:34 (CCS)	1125 Hz	NO GROSS
15	11:16:53 (CCS)	1367 Hz	SMALL INCREASE (SUB-K INCREASING DURING SPOT)
16	11:20:05 (CCS)	1436 Hz	NOISE INCREASE
17	11:23:34 (CCS)	1507 Hz	NO GROSS
18	11:27:13 (CCS)	2020 Hz	NO GROSS
19	11:30:34 (CCS) S: 11:30:03 (QLA) E: 11:33:01 (QLA)	2986 Hz	LARGE INTERFERENCE SEEN
20	11:34:02 (CCS)	4631 Hz	NO GROSS
21	11:37:17 (CCS)	4863 Hz	NO GROSS
22	11:40:30 (CCS)	5106 Hz	NO GROSS
23	11:43:47 (CCS)	NA	QUIESCENT REFERENCE TEST
24	11:47:08 (CCS)	19065 Hz	NO GROSS
25	11:50:29 (CCS)	20018 Hz	
26	11:54:09 (CCS)	21019 Hz	
27			MIS-TEST IGNORE

28	12:01:09 (CCS)	48 176 Hz	No gross effect (slightly more DC shift than previous)
29	12:04:19 (CCS) S: 12:03:48 (QLA) E: 12:06:46 (QLA)	50 000 Hz	No gross effect (slightly more DC shift than previous)
30	12:08:00 (CCS)	45882 Hz	Repeat of step 27 No gross effect (slightly more DC shift than previous)
31	12:11:31 (CCS)	NA	Quiescent reference test
32	12:14:36 (CCS)	657 Hz	Overall RMS noise increase
33	12:17:43 (CCS)	690 Hz	Noise reduced wrt to previous
34	12:21:02 (CCS)	NA	Quiescent reference test

8.2.2 Step 2 – 247Hz Full Field Strength

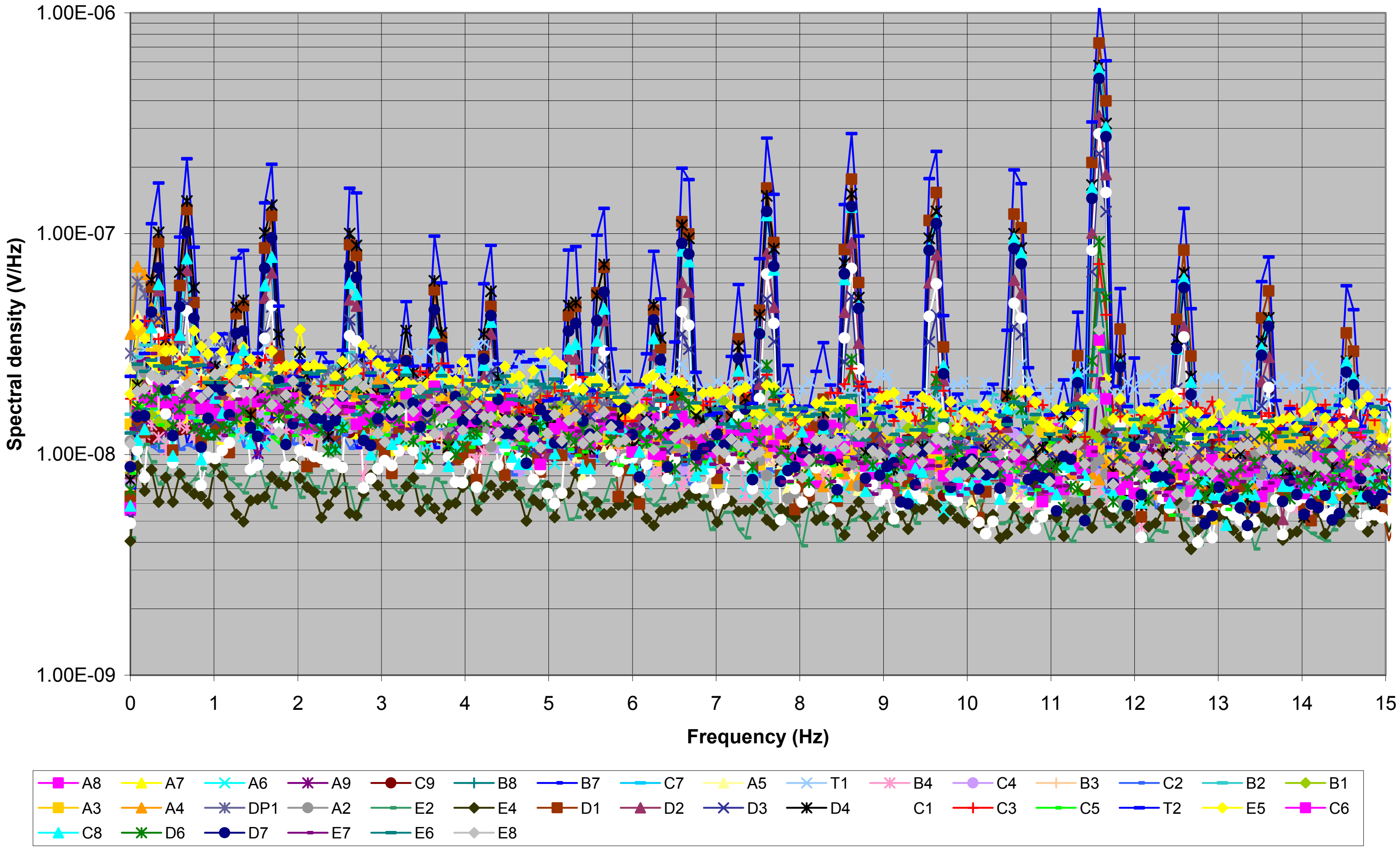


Figure 8 – Spectral density of detector output for oxB000002F – Step 2 (247Hz)

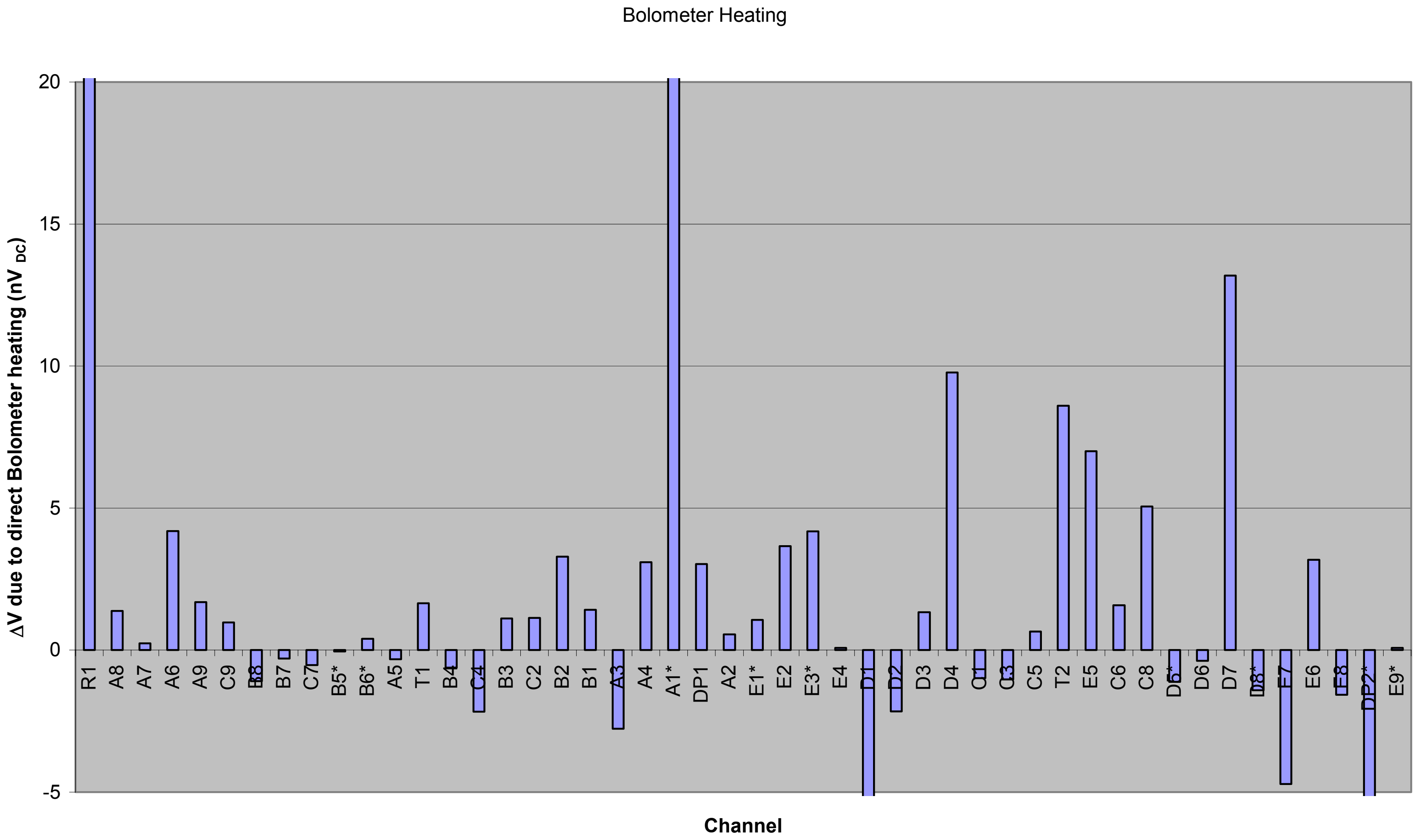


Figure 9 – Estimate of the Δ voltage induced on the detector signal due to heating.

A1*	A2	A3	A4	A5	A6	A7	A8	A9
7915.7 nV	0.6 nV	-2.8 nV	3.1 nV	-0.3 nV	4.2 nV	0.2 nV	1.4 nV	1.7 nV

B1	B2	B3	B4	B5*	B6*	B7	B8
1.4 nV	3.3 nV	1.1 nV	-0.6 nV	0.0 nV	0.4 nV	-0.3 nV	-1.1 nV

C1	C2	C3	C4	C5	C6	C7	C8	C9
-1.0 nV	1.1 nV	-1.0 nV	-2.2 nV	0.7 nV	1.6 nV	-0.5 nV	5.1 nV	1.0 nV

D1	D2	D3	D4	D5*	D6	D7	D8*
-76.2 nV	-2.2 nV	1.3 nV	9.8 nV	-1.1 nV	-0.4 nV	13.2 nV	-1.4 nV

E1*	E2	E3*	E4	E5	E6	E7	E8	E9*
1.1 nV	3.7 nV	4.2 nV	0.1 nV	7.0 nV	3.2 nV	-4.7 nV	-1.6 nV	0.1 nV

DP1	DP2*	T1	T2	R1
3.0 nV	-419.0 nV	1.6 nV	8.6 nV	56.6 nV

Figure 10 - Estimate of the Δ voltage induced on the detector signal due to heating.

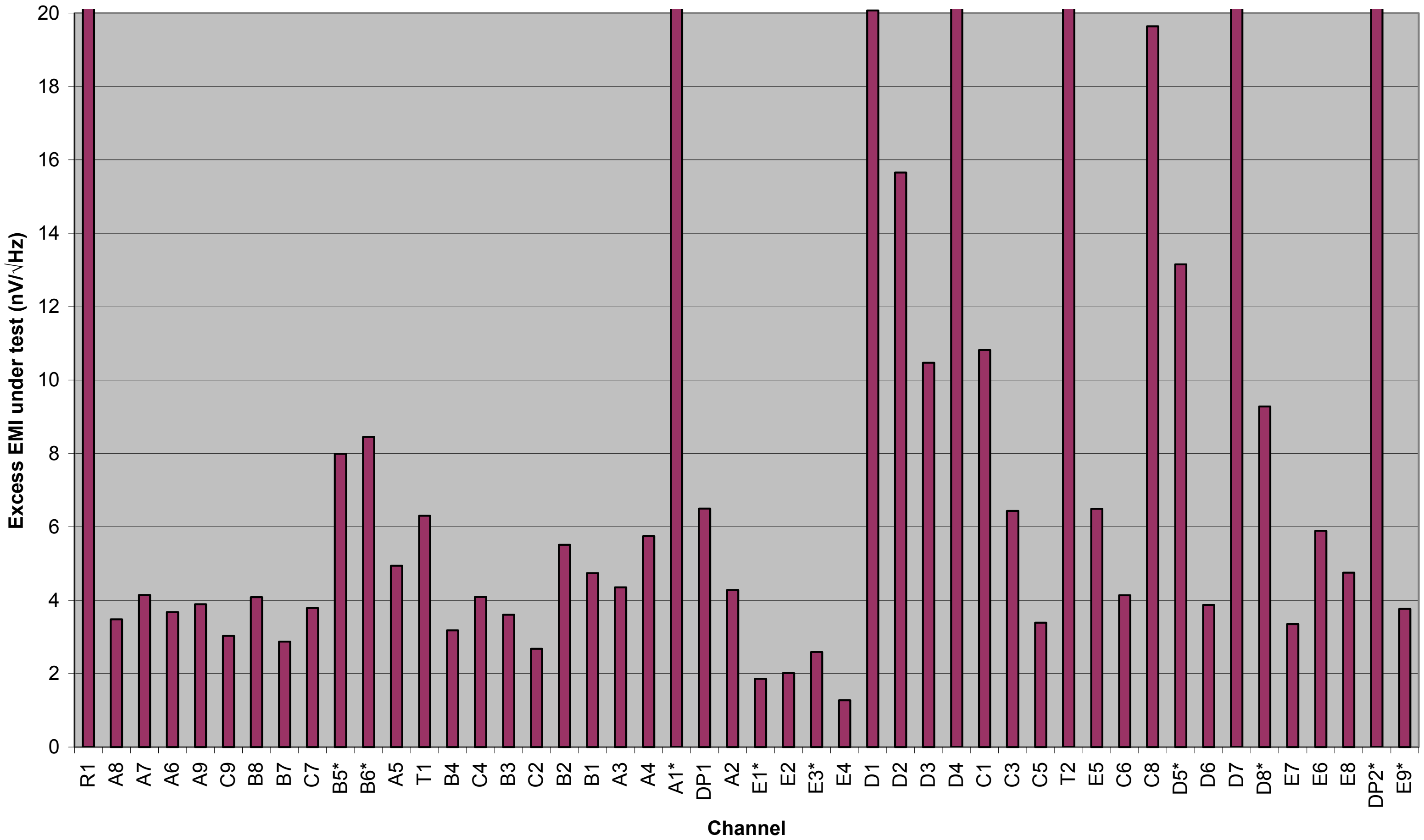


Figure 11 – Estimate of the excess noise injected onto the detector due to direct coupling into the detector readout electronics.

A1*	A2	A3	A4	A5	A6	A7	A8	A9
7409.5nV/vHz	4.3 nV	4.3 nV	5.7 nV	4.9 nV	3.7 nV	4.1 nV	3.5 nV	3.9 nV

B1	B2	B3	B4	B5*	B6*	B7	B8
4.7 nV	5.5 nV	3.6 nV	3.2 nV	8.0 nV	8.5 nV	2.9 nV	4.1 nV

C1	C2	C3	C4	C5	C6	C7	C8	C9
10.8 nV	2.7 nV	6.4 nV	4.1 nV	3.4 nV	4.1 nV	3.8 nV	19.6 nV	3.0 nV

D1	D2	D3	D4	D5*	D6	D7	D8*
20.1 nV	15.7 nV	10.5 nV	36.0 nV	13.2 nV	3.9 nV	25.9 nV	9.3 nV

E1*	E2	E3*	E4	E5	E6	E7	E8	E9*
1.9 nV	2.0 nV	2.6 nV	1.3 nV	6.5 nV	5.9 nV	3.4 nV	4.8 nV	3.8 nV

DP1	DP2*	T1	T2	R1
6.5 nV	474.7 nV	6.3 nV	55.8 nV	27.8 nV

Figure 12 - Estimate of the excess noise injected onto the detector due to direct coupling into the detector readout electronics

8.2.3 Step 3 – 260Hz Full Field Strength

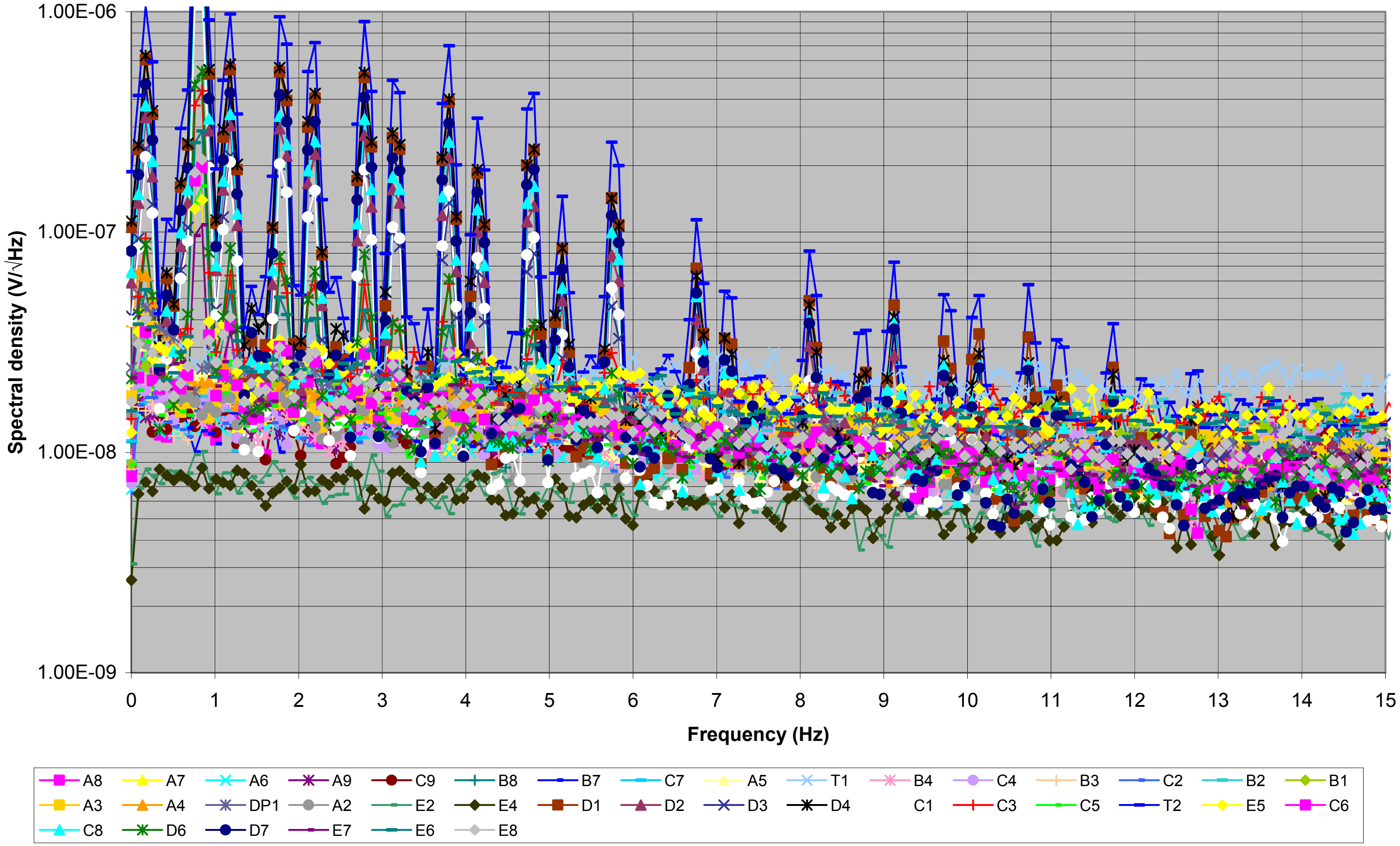


Figure 13 Spectral density of detector output for oxB000002F – Step 3 (260Hz)

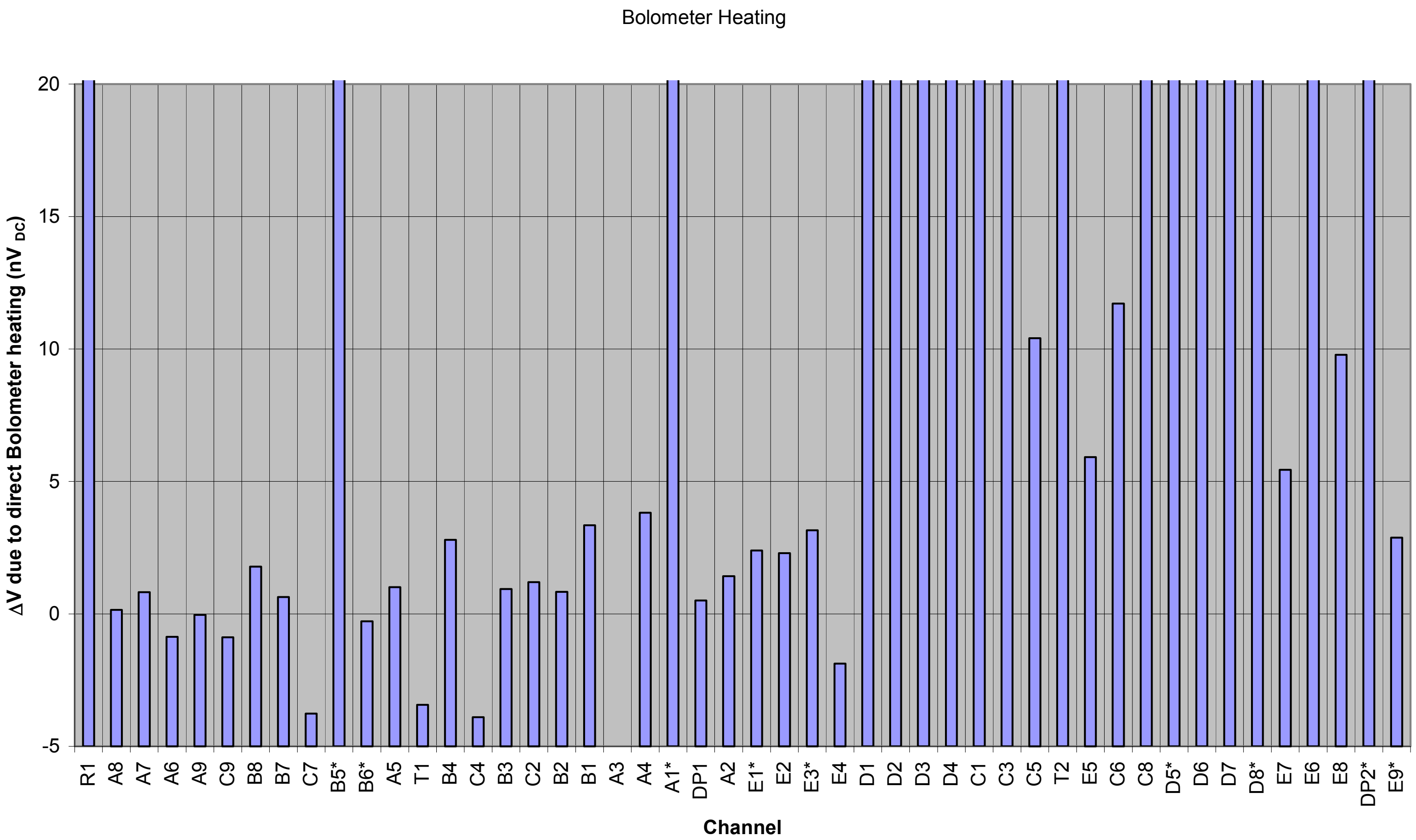


Figure 14– Estimate of the Δ voltage induced on the detector signal due to heating.

A1*	A2	A3	A4	A5	A6	A7	A8	A9
1491.8 nV	1.4 nV	-5.7 nV	3.8 nV	1.0 nV	-0.9 nV	0.8 nV	0.2 nV	0.0 nV

B1	B2	B3	B4	B5*	B6*	B7	B8
3.4 nV	0.8 nV	0.9 nV	2.8 nV	22.7 nV	-0.3 nV	0.6 nV	1.8 nV

C1	C2	C3	C4	C5	C6	C7	C8	C9
207.2 nV	1.2 nV	31.2 nV	-3.9 nV	10.4 nV	11.7 nV	-3.8 nV	354.9 nV	-0.9 nV

D1	D2	D3	D4	D5*	D6	D7	D8*
498.6 nV	297.6 nV	201.5 nV	599.3 nV	127.6 nV	61.4 nV	451.3 nV	80.5 nV

E1*	E2	E3*	E4	E5	E6	E7	E8	E9*
2.4 nV	2.3 nV	3.2 nV	-1.9 nV	5.9 nV	28.3 nV	5.4 nV	9.8 nV	2.9 nV

DP1	DP2*	T1	T2	R1
0.5 nV	48.3 nV	-3.4 nV	1020.5 nV	74.0 nV

Figure 15 Figure 16 - Estimate of the Δ voltage induced on the detector signal due to heating.

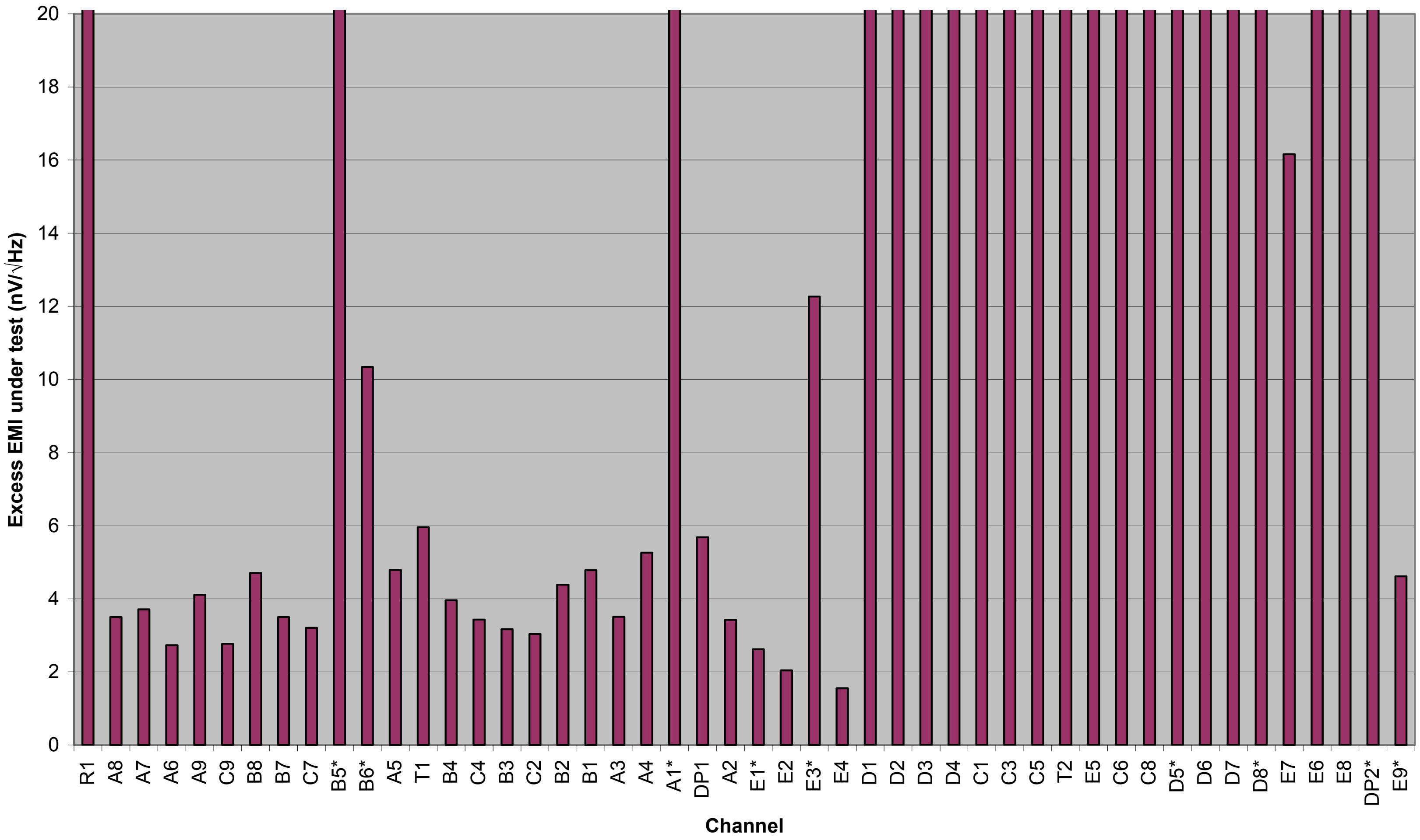


Figure 17– Estimate of the excess noise injected onto the detector due to direct coupling into the detector readout electronics.

A1*	A2	A3	A4	A5	A6	A7	A8	A9
7454.8nV/vHz	3.4 nV	3.5 nV	5.3 nV	4.8 nV	2.7 nV	3.7 nV	3.5 nV	4.1 nV

B1	B2	B3	B4	B5*	B6*	B7	B8
4.8 nV	4.4 nV	3.2 nV	4.0 nV	58.7 nV	10.3 nV	3.5 nV	4.7 nV

C1	C2	C3	C4	C5	C6	C7	C8	C9
259.0 nV	3.0 nV	76.7 nV	3.4 nV	26.4 nV	33.0 nV	3.2 nV	432.0 nV	2.8 nV

D1	D2	D3	D4	D5*	D6	D7	D8*
683.4 nV	377.3 nV	272.4 nV	728.7 nV	223.9 nV	99.0 nV	542.8 nV	149.8 nV

E1*	E2	E3*	E4	E5	E6	E7	E8	E9*
2.6 nV	2.0 nV	12.3 nV	1.5 nV	21.5 nV	50.0 nV	16.2 nV	35.9 nV	4.6 nV

DP1	DP2*	T1	T2	R1
5.7 nV	746.9 nV	6.0 nV	1229.2 nV	45.1 nV

Figure 18 Estimate of the excess noise injected onto the detector due to direct coupling into the detector readout electronics

9. E-Field 14kHz-30MHz Band

9.1 Upper Antenna Position

9.2 Lower Antenna Position

10. E-Field 30MHz-1GHz Band

10.1 Upper Antenna Position

10.1.1 Vertical Polarization

10.1.2 Horizontal Polarization

10.2 Lower Antenna Position

10.2.1 Vertical Polarization

10.2.1.1 Sweep 1 (30MHz – 1GHz): 0xB0000038

SPIRE EQM EMC Sweep Test Sheet		**Sheet Number**	**Sheet 1 of** 2
Test Location:	EADS Ottobrunn	Field Type	E-Field
Date of Test:	29 November 2005	Antenna location	Location # 1
Start Frequency	30 MHz	Photograph of set-up	1847, 1846
Stop Frequency	1 GHz	Polarization	Horizontal
Amplitude modulation	1Hz 86% duty cycle 1kHz, 30% Square Wave	Antenna Ref	Log-periodic / Biconic
Test Start time (CCS)	SPIRE-IMT-START-TEST.tcl 15:34:23 (QLA)	SPIRE Signature	
Test End Time (CCS)	SPIRE-IMT-END-TEST.tcl 16:49:12 (QLA)	ESA Signature	
Start quiescent reference case duration	180 s	Astrium Signature	
End quiescent reference case duration	180 s	F(n+1) = Fn * 1.01	
Step dwell time			
Number of steps in sweep			
Estimated sweep duration			
Observation ID	0xB0000038		
Channels monitored in QLA	C5		

Observations (susceptibilities during test)		
Time	**Estimated Frequency**	**Notes**
15:40:15 (CCS) 15:39:43 (QLA)	NA	Quiescent Reference case Start
15:43:15 (CCS) 15:42:41 (QLA)	NA	Quiescent Reference case End

15:45:50 (CCS) 15:45:18		Start Sweep and immediate dramatic EMI observed
Start +41:55	631 MHz	Slope changes
Start + 44:00	740 MHz	Slope changes
16:34:12 (CCS) 16:33:39 (QLA)		End sweep
16:36:31 (CCS)		Quiescent reference case start
16:39:30 (CCS)		End quiescent reference case

10.2.2 Horizontal Polarization

11. E-Field 1GHz-18GHz Band

11.1 Upper Antenna Position

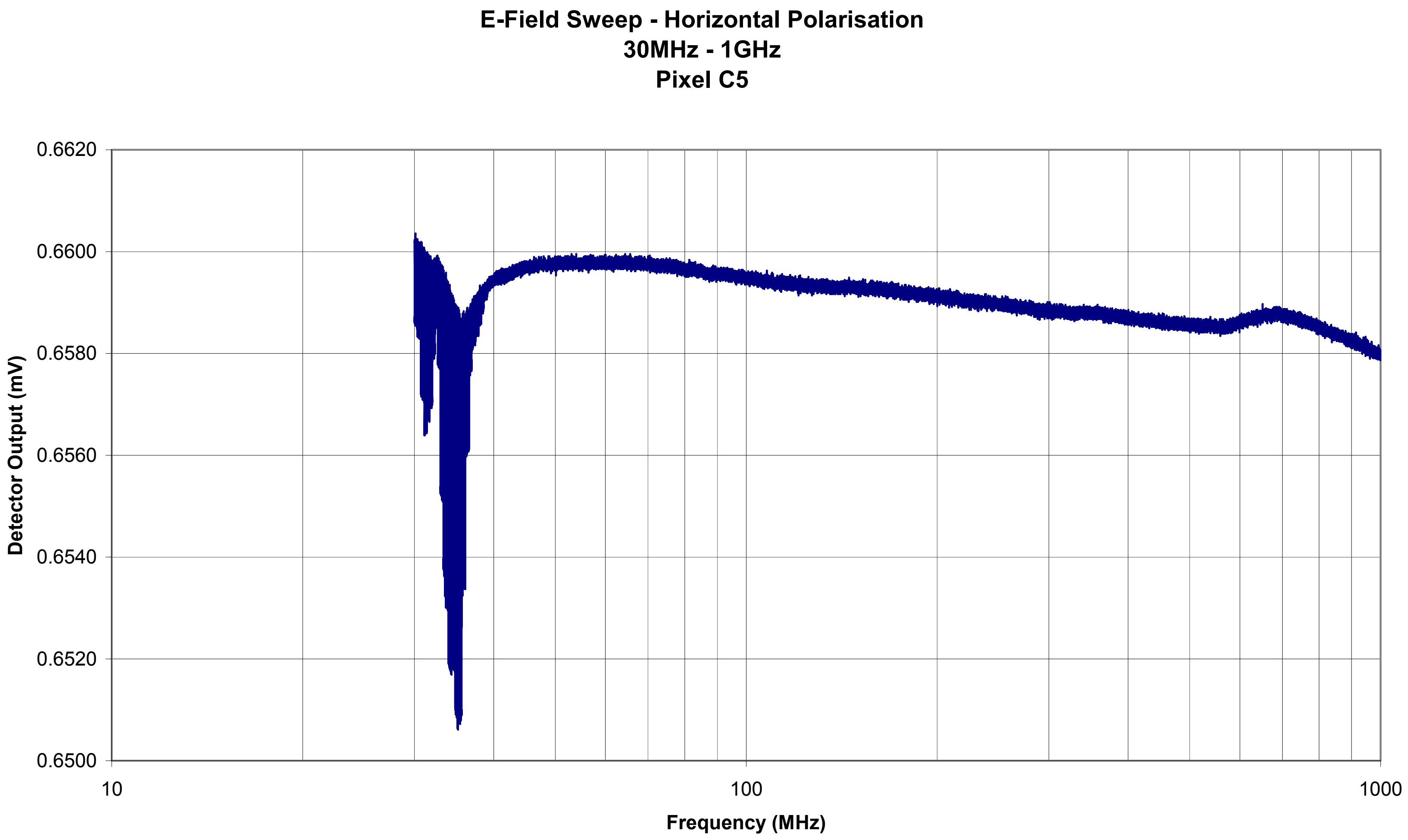
11.1.1 Vertical Polarization

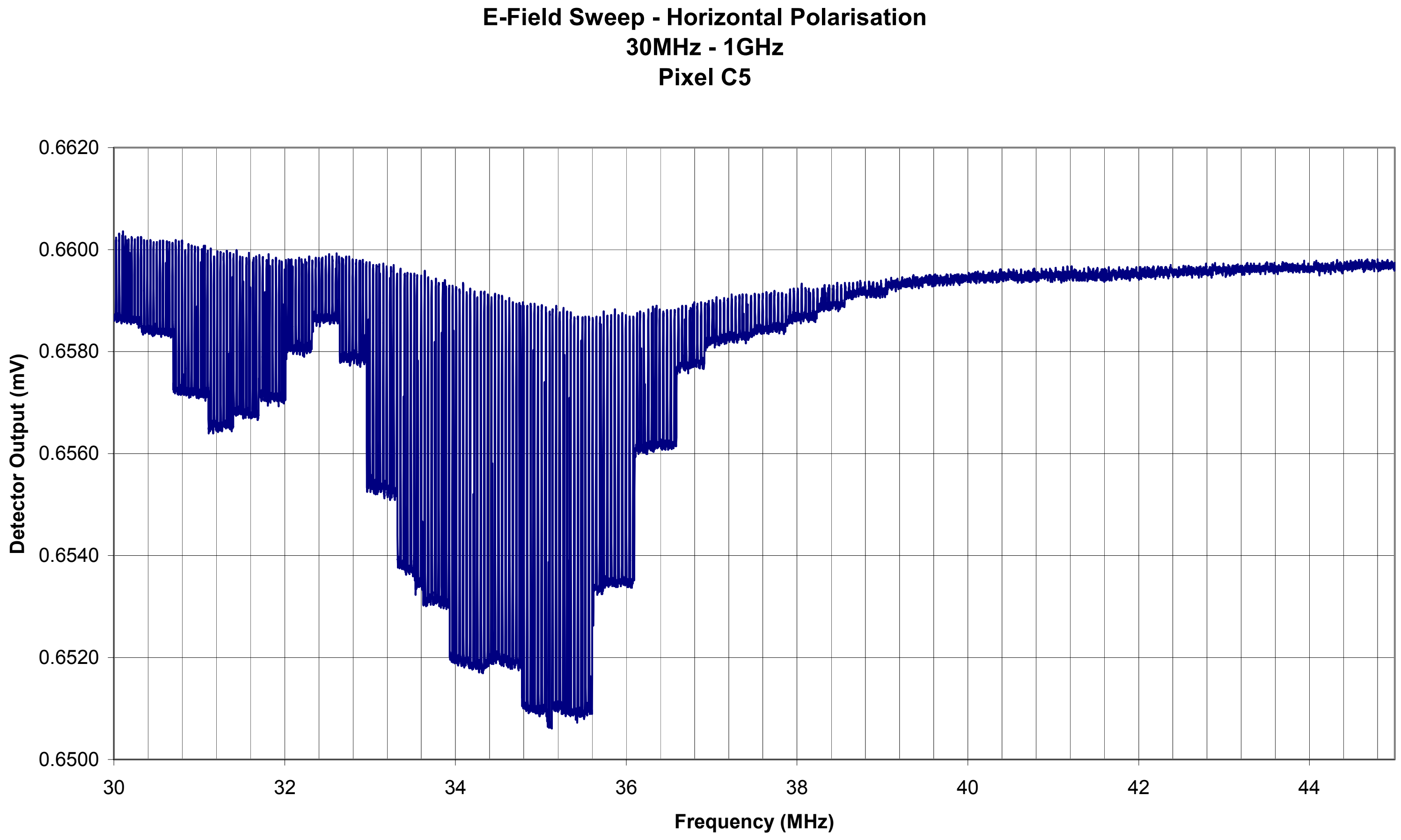
11.1.2 Horizontal Polarization

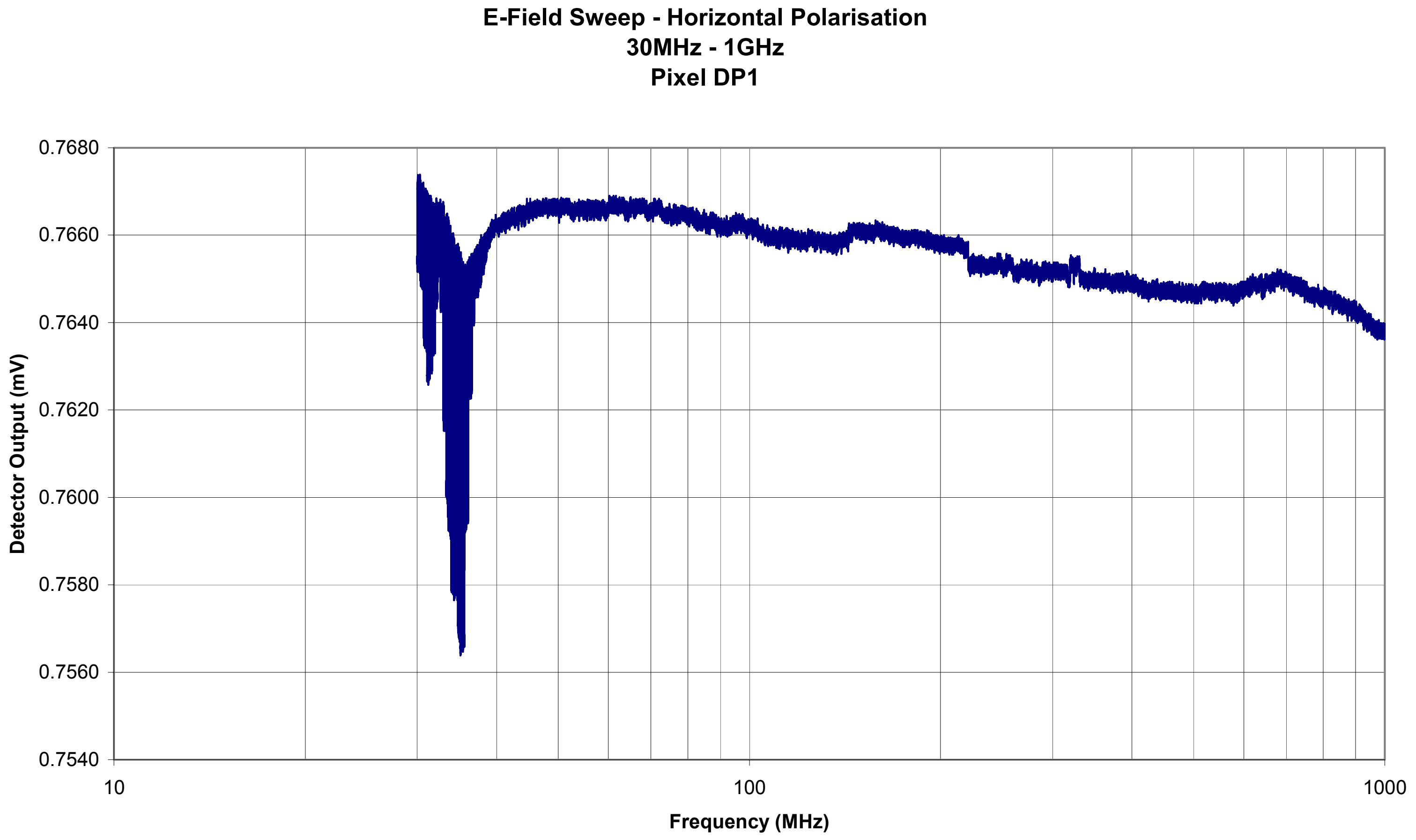
11.2 Lower Antenna Position

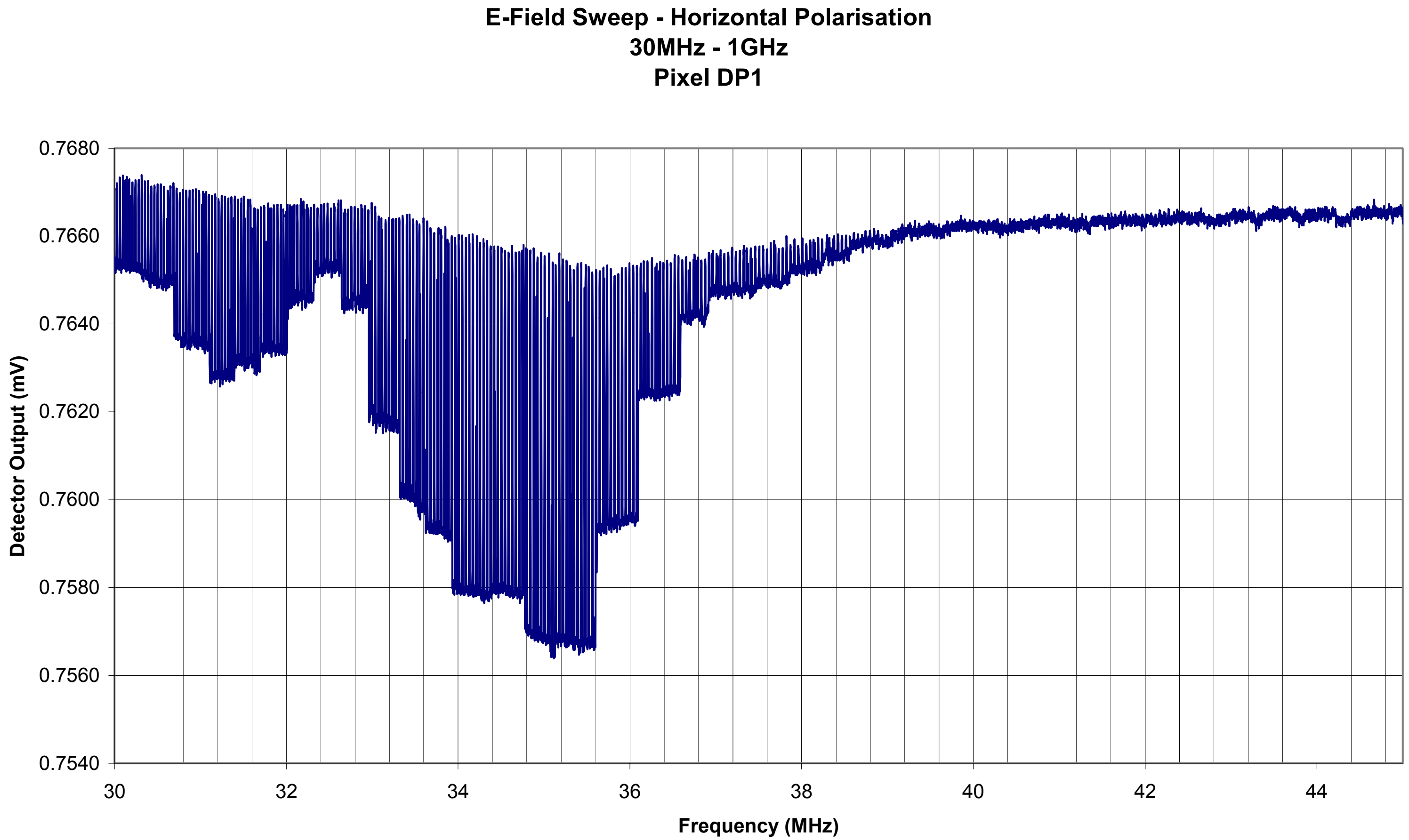
11.2.1 Vertical Polarization

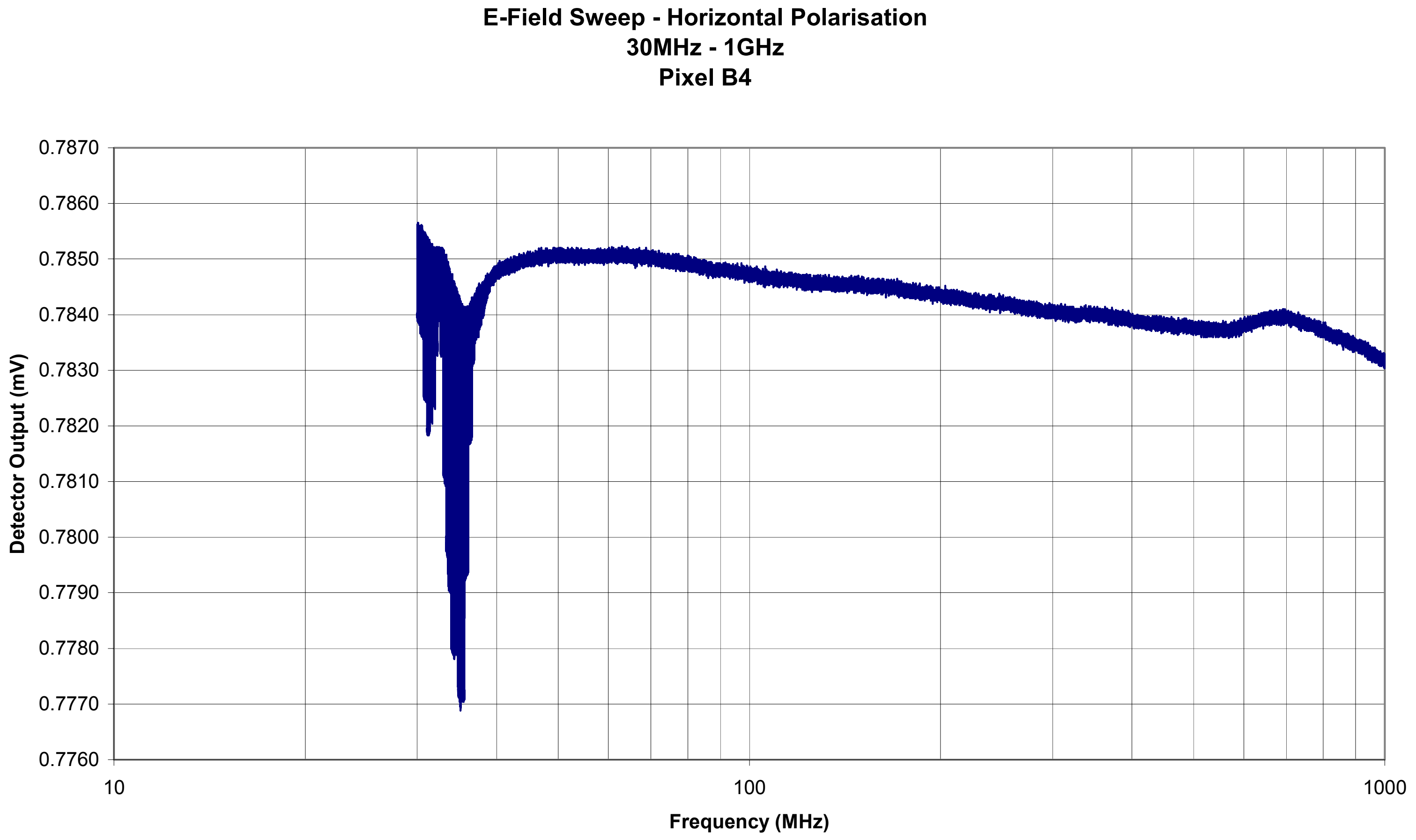
11.2.2 Horizontal Polarization

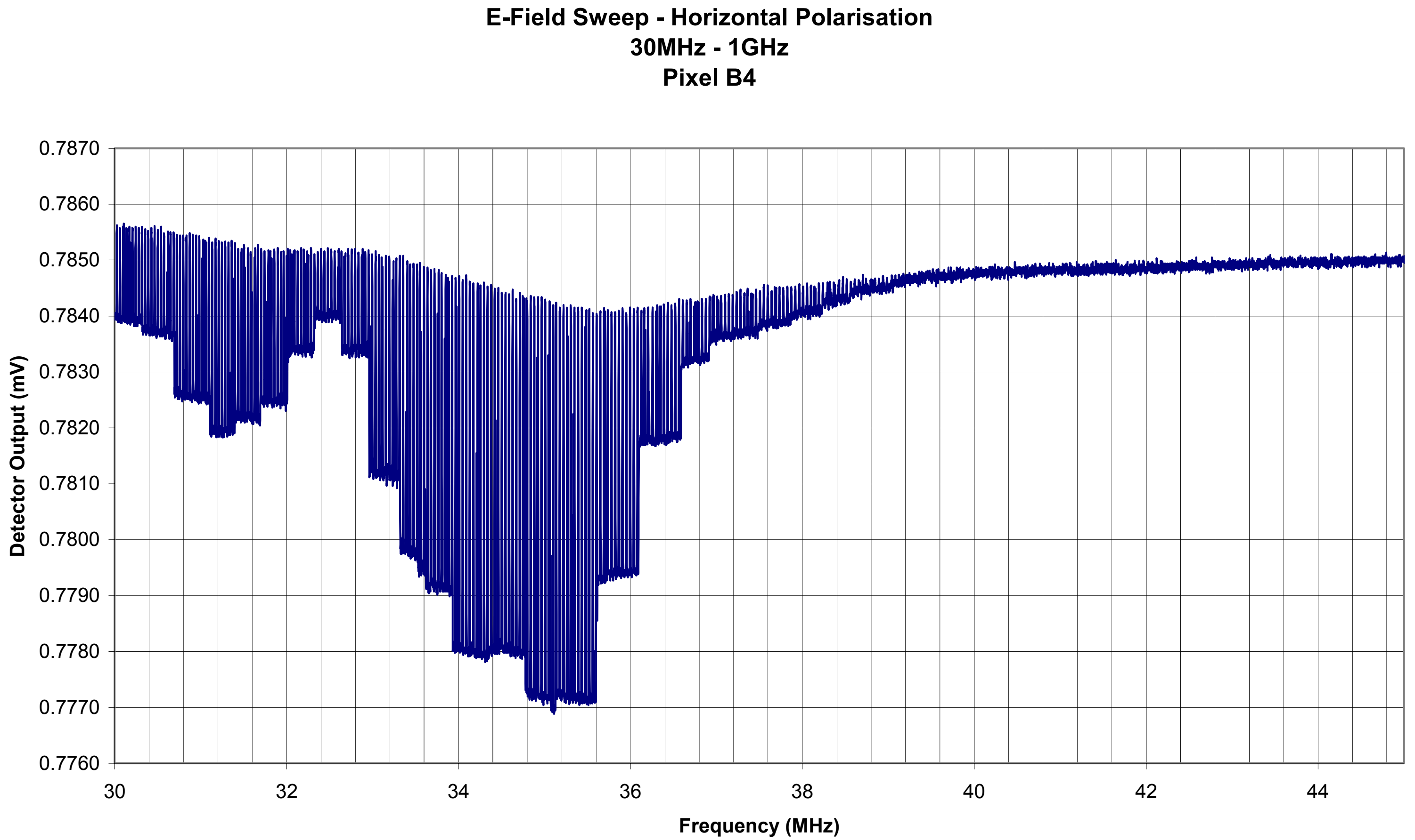

E-Field Sweep - Horizontal Polarisation
30MHz - 1GHz
Pixel C5
Detector Output (mV)
0.6620
0.6600
0.6580
0.6560
0.6540
0.6520
0.6500
10
100
1000
Frequency (MHz)

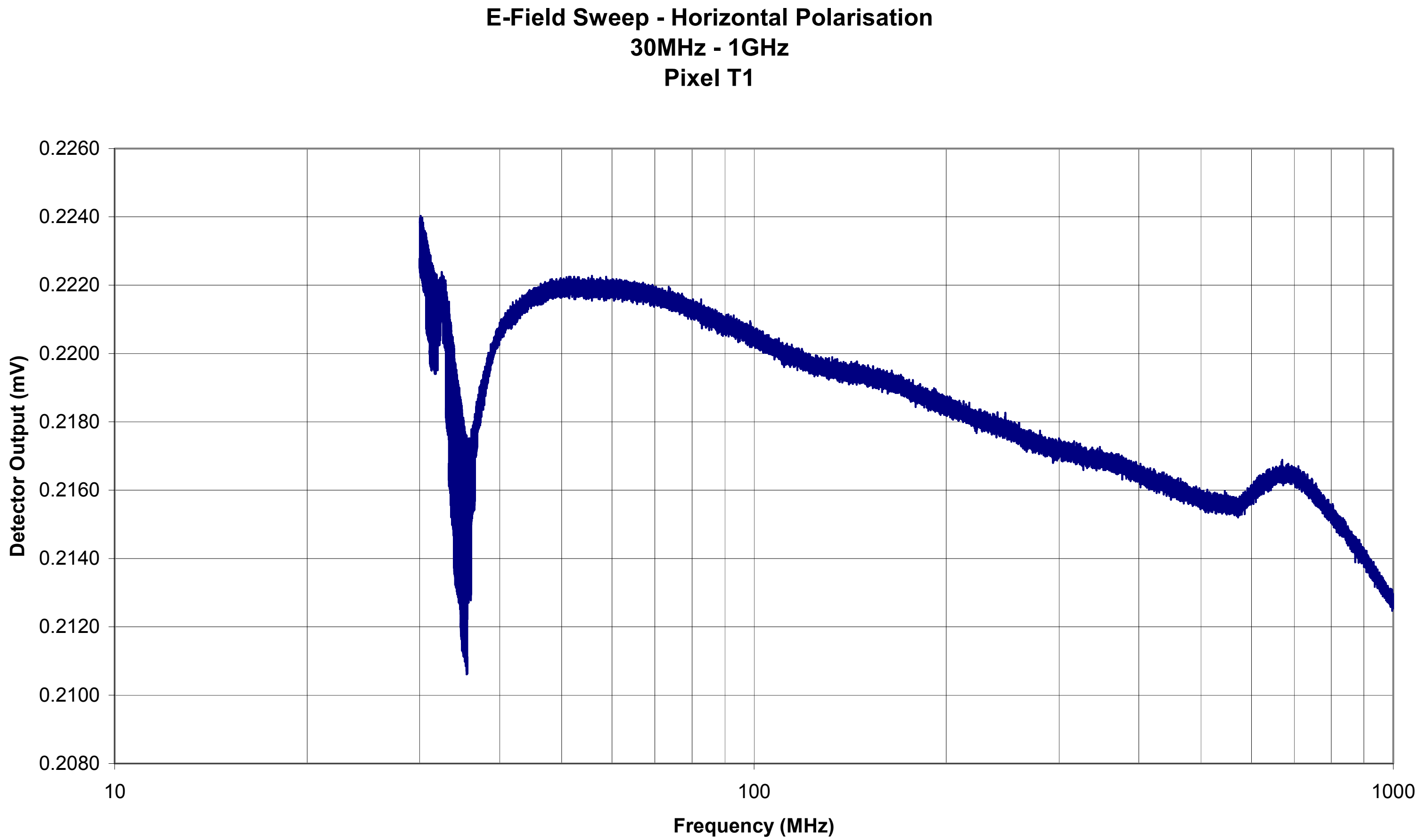

E-Field Sweep - Horizontal Polarisation
30MHz - 1GHz
Pixel C5
Detector Output (mV)
0.6620
0.6600
0.6580
0.6560
0.6540
0.6520
0.6500
30
32
34
36
38
40
42
44
Frequency (MHz)

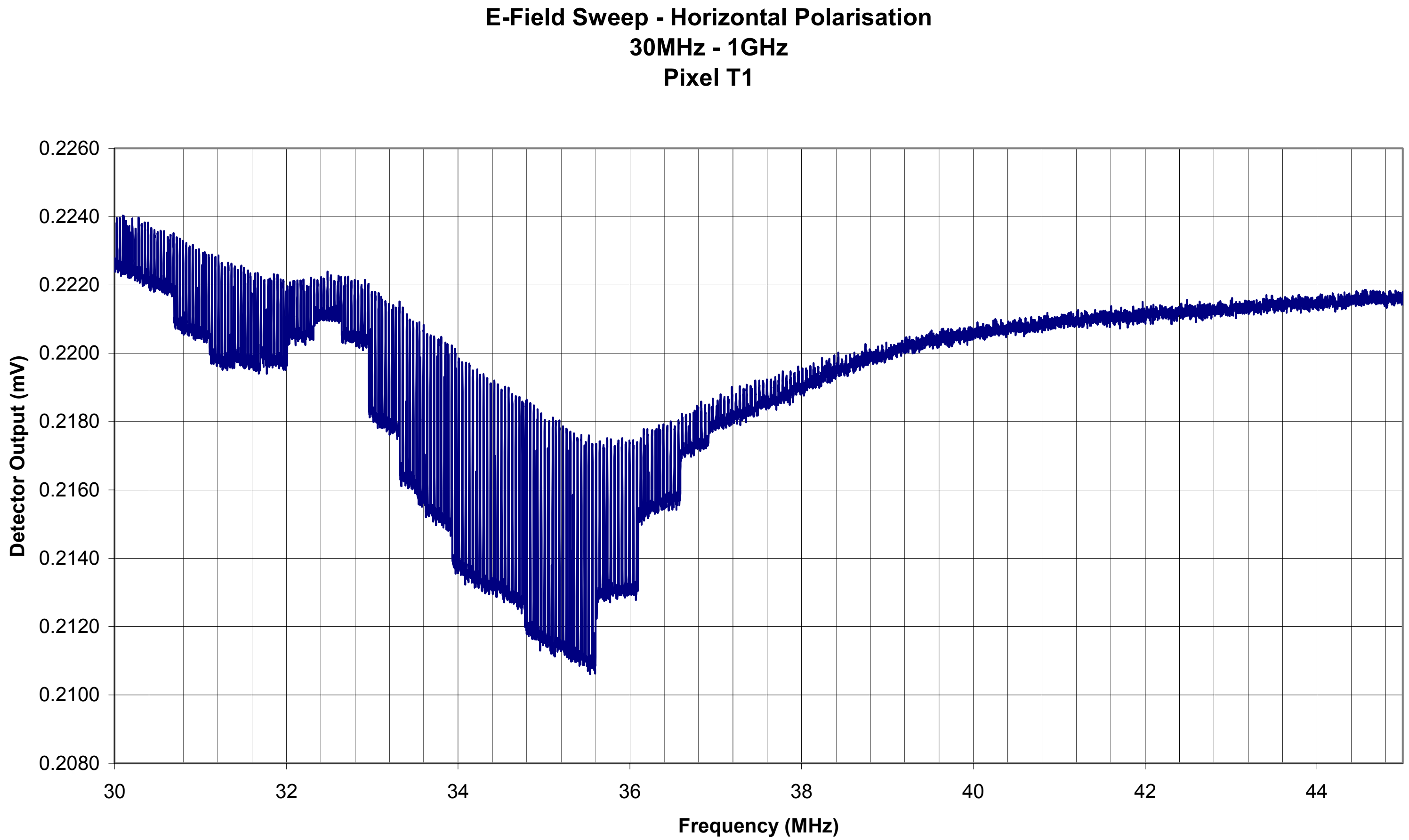

E-Field Sweep - Horizontal Polarisation
30MHz - 1GHz
Pixel DP1
0.7680
0.7660
0.7640
0.7620
0.7600
0.7580
0.7560
0.7540
Detector Output (mV)
10
100
1000
Frequency (MHz)


E-Field Sweep - Horizontal Polarisation
30MHz - 1GHz
Pixel DP1
Detector Output (mV)
0.7680
0.7660
0.7640
0.7620
0.7600
0.7580
0.7560
0.7540
30
32
34
36
38
40
42
44
Frequency (MHz)


E-Field Sweep - Horizontal Polarisation
30MHz - 1GHz
Pixel B4
Detector Output (mV)
0.7870
0.7860
0.7850
0.7840
0.7830
0.7820
0.7810
0.7800
0.7790
0.7780
0.7770
0.7760
10
100
1000
Frequency (MHz)


E-Field Sweep - Horizontal Polarisation
30MHz - 1GHz
Pixel B4
Detector Output (mV)
0.7870
0.7860
0.7850
0.7840
0.7830
0.7820
0.7810
0.7800
0.7790
0.7780
0.7770
0.7760
30
32
34
36
38
40
42
44
Frequency (MHz)


E-Field Sweep - Horizontal Polarisation
30MHz - 1GHz
Pixel T1
Detector Output (mV)
0.2260
0.2240
0.2220
0.2200
0.2180
0.2160
0.2140
0.2120
0.2100
0.2080
10
100
1000
Frequency (MHz)


E-Field Sweep - Horizontal Polarisation
30MHz - 1GHz
Pixel T1
Detector Output (mV)
0.2260
0.2240
0.2220
0.2200
0.2180
0.2160
0.2140
0.2120
0.2100
0.2080
30
32
34
36
38
40
42
44
Frequency (MHz)

12. E-Field Spots (Susceptibility threshold): 0xB000051

SPIRE EQM EMC Spot Test Sheet		**Sheet Number**	Sheet 1 **of** 2
Test Location:	EADS Ottobrunn	Observation ID	0xB0000051
Date of Test:	30 November 2005	Channels monitored in QLA	
Start Frequency	N.A.	Field Type	E – Field
Stop Frequency	N.A.	Antenna location	Loc^{N} 1
Amplitude modulation	1Hz 86% duty cycle 1kHz, 30% Square Wave	Photograph of set-up	1846, 1847
Test Start time (CCS)		Polarization	Horizontal
Test End Time (CCS)		Antenna Ref	Log-periodic / Biconic
Start quiescent reference case duration	180 sec	SPIRE Signature	
End quiescent reference case duration	180 sec	ESA Signature	
Step dwell time	180 sec	Astrium Signature	
Estimated test duration			

Observations (susceptibilities during test)

Step	Time	Frequency	Notes
1	08:52:11 (CCS)		Quiescent reference test
2	08:56:15 (CCS)		Zero dB
3	09:00:00 (CCS)		-10 dB returns close to quiescent
4	09:07:09(CCS)		Zero dB Mis-test Ignore
5	09:11:18 (CCS)		Zero dB
6	(CCS)		-10 dB 300-mK Temp rising!
7	(CCS)		Zero dB Still rising
8	(CCS)		-10 dB rising V. fast

9	(CCS)		Zero dB - still rising
10	(CCS)		-10 dB still rising more slowly
11	(CCS)		Zero dB
12	(CCS)		-10 dB decrease in dT/dt
13	(CCS)		Zero dB very little injection into R1
14	(CCS)		-10 dB
15	(CCS)		Zero dB
16	(CCS)		-10 dB
17	(CCS)		dB
18	(CCS)		Zero dB, Bias Off
19	(CCS)		Zero dB, Bias Off noise increase
20	(CCS)		Zero dB, Bias Off noise increase
21	(CCS)		Zero dB, Bias Off
22	(CCS)		Zero dB, Bias Off
23	(CCS)		Zero dB, Bias Off
24	(CCS)		Zero dB, Bias Off

13. E-Field Spots 0xB00005E

Section A: 15:31:00 – 16:00:00
Section B: 15:55:00 – 16:24:00
Section C: 16:20:00 – 17:02:00

SPIRE EQM EMC Spot Test Sheet		**Sheet Number**	SHEET 1 **of** 2
Test Location:	EADS OTTOBRUNN	Observation ID	0XB000005E
Date of Test:	30 NOVEMBER 2005	Channels monitored in QLA	
Start Frequency	N.A.	Field Type	E – FIELD
Stop Frequency	N.A.	Antenna location	LOC^{N} 1
Amplitude modulation	1HZ 86% DUTY CYCLE 1KHZ, 30% SQUARE WAVE	Photograph of set-up	1846, 1847
Test Start time (CCS)	SPIRE-IMT-START-TEST.TCL 2005 11 30 15:31:21	Polarization	HORIZONTAL
Test End Time (CCS)	SPIRE-IMT-END-TEST.TCL 2005 11 30 16:59:53	Antenna Ref	LOG-PERIODIC / BICONIC
Start quiescent reference case duration	180 SEC	SPIRE Signature	
End quiescent reference case duration	180 SEC	ESA Signature	
Step dwell time	180 SEC	Astrium Signature	
Estimated test duration			

Observations (susceptibilities during test)			
Step	**Time**	**Frequency**	**Notes**
1	15:32:32 (CCS)	NA	QUIESCENT REFERENCE TEST
2	15:35:56 (CCS)	502.2 MHZ	2 V/M NO APPARENT EFFECT

3	15:39:15 (CCS)	507.2 MHz	2 V/M
4	15:42:30 (CCS)	512.2 MHz	
5	15:45:43 (CCS)	517.4 MHz	
6	15:49:56 (CCS)	52.26 MHz	
7	15:53:09 (CCS)	52.78 MHz	
8		NA	
9	16:06:10 (CCS)	600.68 MHz	
10	16:10:08 (CCS)	704.34 MHz	
11	16.13.27 (CCS)	903.3 MHz	
12	16:16:48 (CCS)	1 GHz	
13	16:23:52		Mis-test
14	16:30:36		A sweep 200MHz to 6700MHz 1% increment, 10 sec step 2 V/m

14. E-Field Spots 0xB000062

97 SPIRE-IMT-START-TEST.tcl SPIRE FLIGHT 2005 11 30 17:01:43 Coordinated Universal Time 2005 11 30 17:01:59 Coordinated Universal Time 0 success b0000062

98 SPIRE-IMT-END-TEST.tcl SPIRE FLIGHT 2005 11 30 17:32:44 Coordinated Universal Time 2005 11 30 17:32:54 Coordinated Universal Time 0 success b0000063

15. E-Field Spots 0xB000066

101 SPIRE-IMT-START-TEST.tcl SPIRE FLIGHT 2005 11 30 17:33:48 Coordinated Universal Time 2005 11 30 17:34:04 Coordinated Universal Time 0 success b0000066

102 SPIRE-IMT-END-TEST.tcl SPIRE FLIGHT 2005 11 30 17:45:23 Coordinated Universal Time 2005 11 30 17:45:34 Coordinated Universal Time 0 success b0000067

16. E-Field Spots 0xB000073

114 SPIRE-IMT-START-TEST.tcl SPIRE FLIGHT 2005 12 01 09:49:46 Coordinated Universal Time 2005 12 01 09:50:03 Coordinated Universal Time 0 success b0000073

115 SPIRE-IMT-END-TEST.tcl SPIRE FLIGHT 2005 12 01 10:35:44 Coordinated Universal Time 2005 12 01 10:35:55 Coordinated Universal Time 0 success b0000074

17. E-Field Spots 0xB000077

Section A: 12:12:23 – 13:40:57
Section B: 13:09:23 - 14:06:59
Section C: 14:00:00 – 15:00:00
Section D: 14:55:00 – 15:55:00
Section E: 15:50:00 – 16:43:00

SPIRE EQM EMC Spot Test Sheet		**Sheet Number**	SHEET 1 **of** 2
Test Location:	EADS OTTOBRUNN	Observation ID	0xB0000077
Date of Test:	01 DECEMBER 2005	Channels monitored in QLA	C5, R1
Start Frequency	N.A.	Field Type	E – FIELD
Stop Frequency	N.A.	Antenna location	LOC^{N} 1
Amplitude modulation	1HZ 86% DUTY CYCLE 1KHZ, 30% SQUARE WAVE	Photograph of set-up	1846, 1847
Test Start time (CCS)	SPIRE-IMT-START-TEST.TCL 2005 12 01 12:12:23	Polarization	VERTICAL
Test End Time (CCS)	SPIRE-IMT-END-TEST.TCL 2005 12 01 16:40:	Antenna Ref	LOG-PERIODIC / BICONIC
Start quiescent reference case duration	180 SEC	SPIRE Signature	
End quiescent reference case duration	180 SEC	ESA Signature	
Step dwell time	180 SEC	Astrium Signature	
Estimated test duration			

Observations (susceptibilities during test)			
Step	**Time**	**Frequency**	**Notes**

1	12:13:25 (CCS-START) 12:12:51 (QLA-S) 12:16:29 (CCS-END) 12:15:53 (QLA-E)	NA	QUIESCENT REFERENCE
2	12:17:01 (CCS-START) 12:20:02 (CCS-END) 12:16:27 (QLA-S) 12:19:27 (QLA-E)	33,32 MHz	0.025 V/M
3	12:19:54 (QLA-S) 12:22:54 (QLA-E)	33.32 MHz	0.1 V/M
4	12:23:34 (QLA-S) 12:26:49 (QLA-E)	33.32 MHz	0.050 V/M
5	12:27:32 (QLA-S) 12:31:10 (QLA-E)	33.32 MHz	0.2 V/M (NOTE: FIRST 30 SECONDS ARE WITH THE AMPLIFIER OFF!!!)
6	12:32:07 (QLA-S) 12:34:20 (QLA-E)		
7	12:45:21 (QLA-S) 12:48:23 (QLA-E)		
8	12:48:45 (QLS-S) 12:51:47 (QLA-E)		
9	12:52:08 (QLA-S) 12:55:15 (QLA-E)		
10	12:55:54 (QLA-S) 12:58:54 (QLA-E)		
11	12:59:31 (QLA-S) 13:02:34 (QLA-E)		
12	13:03:38 (QLA-S) 13:06:04 (QLA-E)		
13	13:06:14 (QLA-S) 13:09:14 (QLA-E)		
14	13:09:42 (QLA-S) 13:12:43 (QLA-E)		
15	W		

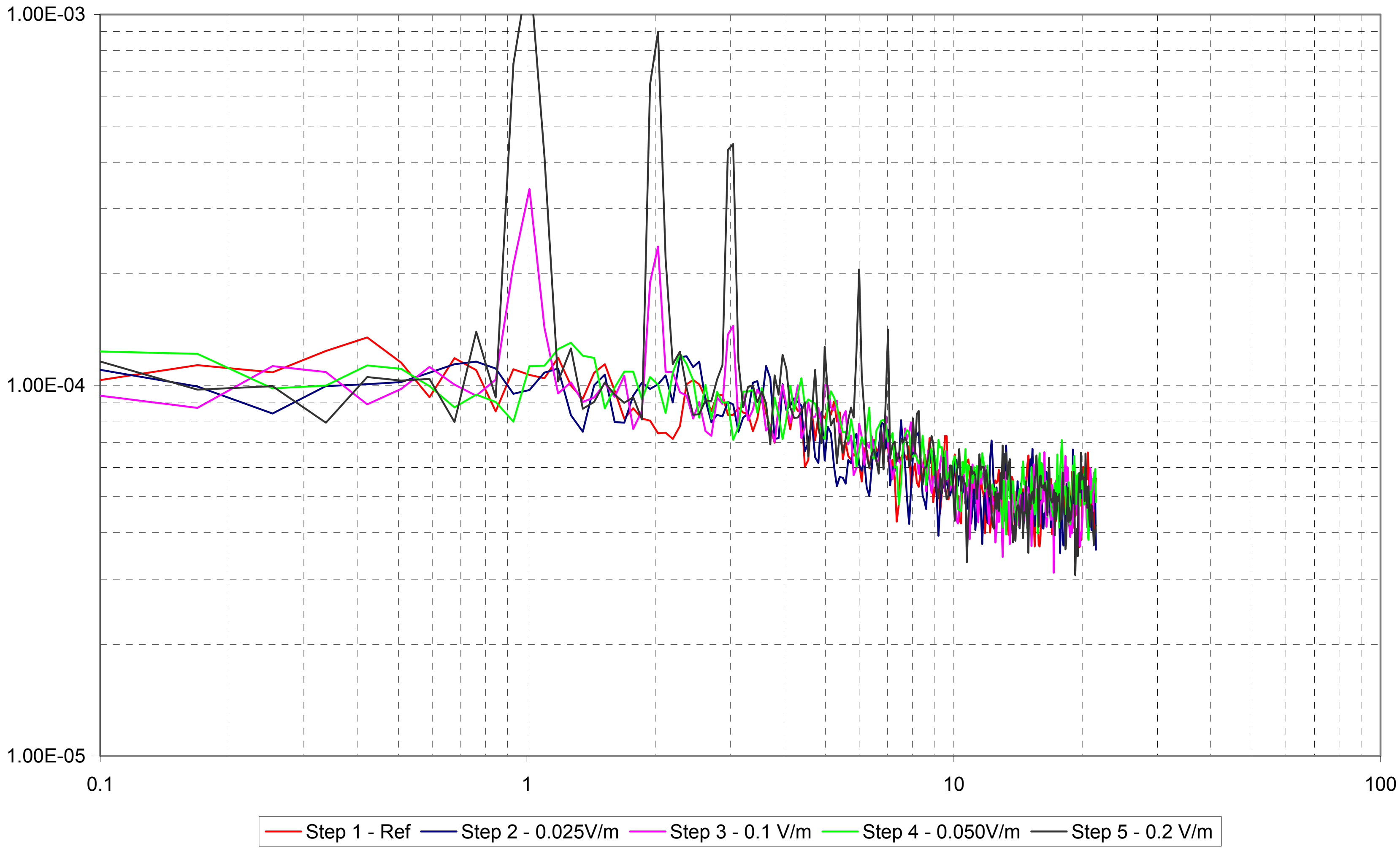


Figure 19 - Pixel C5 for various levels at 33.32 MHz

Step	Condition	Vrms	Δ
1	Ref	4.71E-05	0.0%
2	0.025 V/m	4.73E-05	0.4%
3	0.100 V/m	5.25E-05	11.4%
4	0.050 V/m	4.69E-05	-0.4%
5	0.200 V/m	1.05E-04	122.7%

Table 3 – Calculated Vrms of the C5 detector output

18. E-Field Spots 0xB000095

147 SPIRE-IMT-START-TEST.tcl SPIRE FLIGHT 2005 12 02 06:24:39 Coordinated Universal Time 2005 12 02 06:24:55 Coordinated Universal Time 0 success b0000095

148 SPIRE-IMT-END-TEST.tcl SPIRE FLIGHT 2005 12 02 07:30:54 Coordinated Universal Time 2005 12 02 07:31:04 Coordinated Universal Time 0 success b0000096

19. E-Field Spots 0xB000099

151 SPIRE-IMT-START-TEST.tcl SPIRE FLIGHT 2005 12 02 07:31:56 Coordinated Universal Time 2005 12 02 07:32:13 Coordinated Universal Time 0 success b0000099

152 SPIRE-IMT-END-TEST.tcl SPIRE FLIGHT 2005 12 02 08:54:26 Coordinated Universal Time 2005 12 02 08:54:37 Coordinated Universal Time 0 success b000009a

20. E-Field Spots 0xB00009D

155 SPIRE-IMT-START-TEST.tcl SPIRE FLIGHT 2005 12 02 09:14:49 Coordinated Universal Time 2005 12 02 09:15:06 Coordinated Universal Time 0 success b000009d

156 SPIRE-IMT-END-TEST.tcl SPIRE FLIGHT 2005 12 02 10:43:35 Coordinated Universal Time 2005 12 02 10:43:45 Coordinated Universal Time 0 success b000009e

21. E-Field Sweep 1GHz - 6GHz, Vertical Polarization, Antenna loc^n 1 (0xB0000B7)

22. E-Field Spots 1GHz - 6GHz, V and H Polarizations, Antenna loc^n 1 (0xB0000BA)

23. E-Field Sweep 1GHz - 6GHz, Horizontal Polarization, Antenna loc^n 1 (0xB0000BE)

24. E-Field Sweep 1GHz - 6GHz, Horizontal Polarization, Antenna loc^n 1 (0xB0000C2)

25. E-Field Spots 1GHz - 6GHz, V and H Polarizations, Antenna loc^n 1 (0xB0000C6)

26. E-Field Sweep 1GHz - 6GHz, Vertical Polarization, Antenna loc^n 1 (0xB0000??)

26.1 Example of the sweep continuation test-sheet

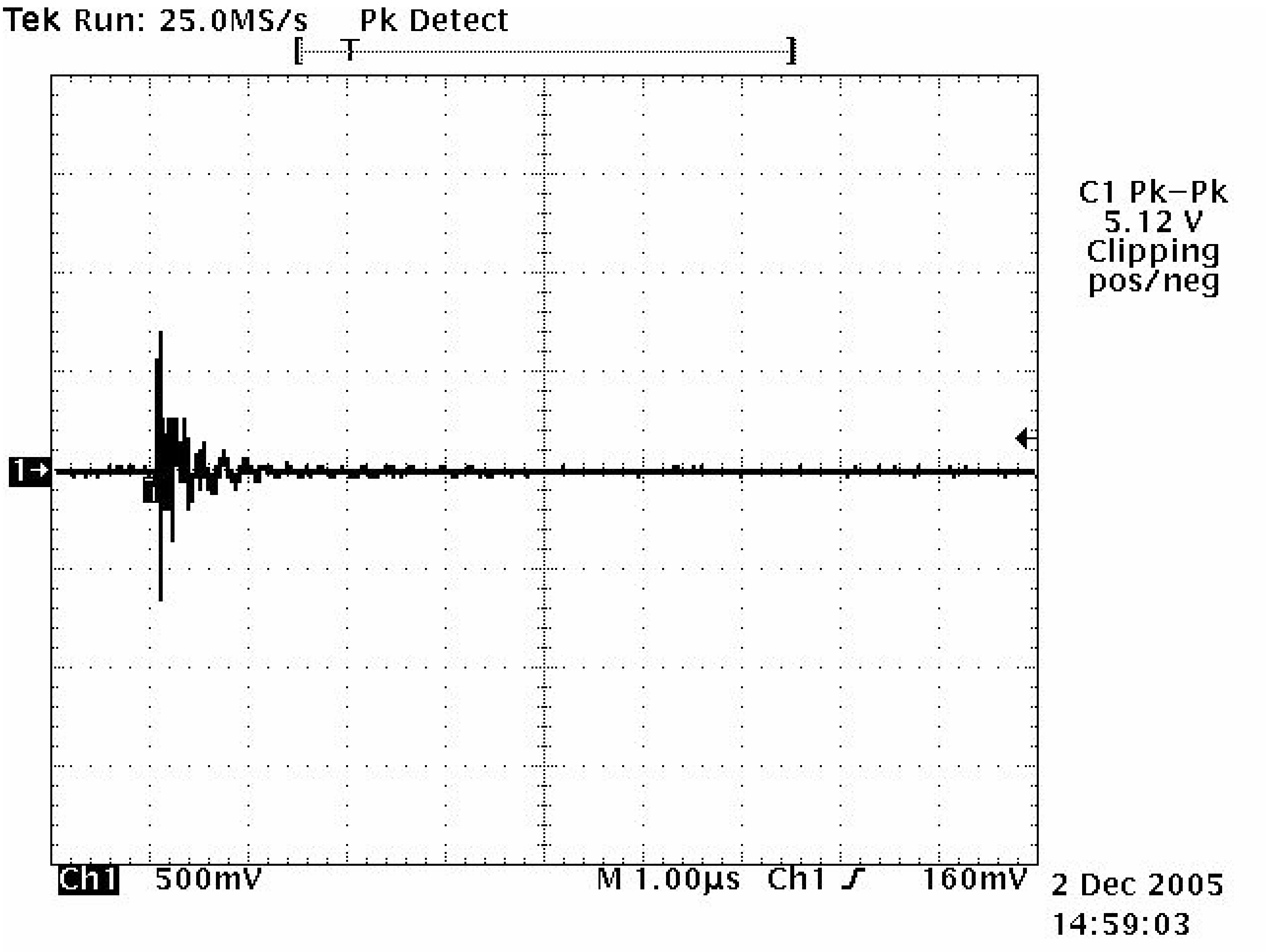


Figure 20 - Signal from low frequency antenna coupled to a high input impedance oscilloscope.

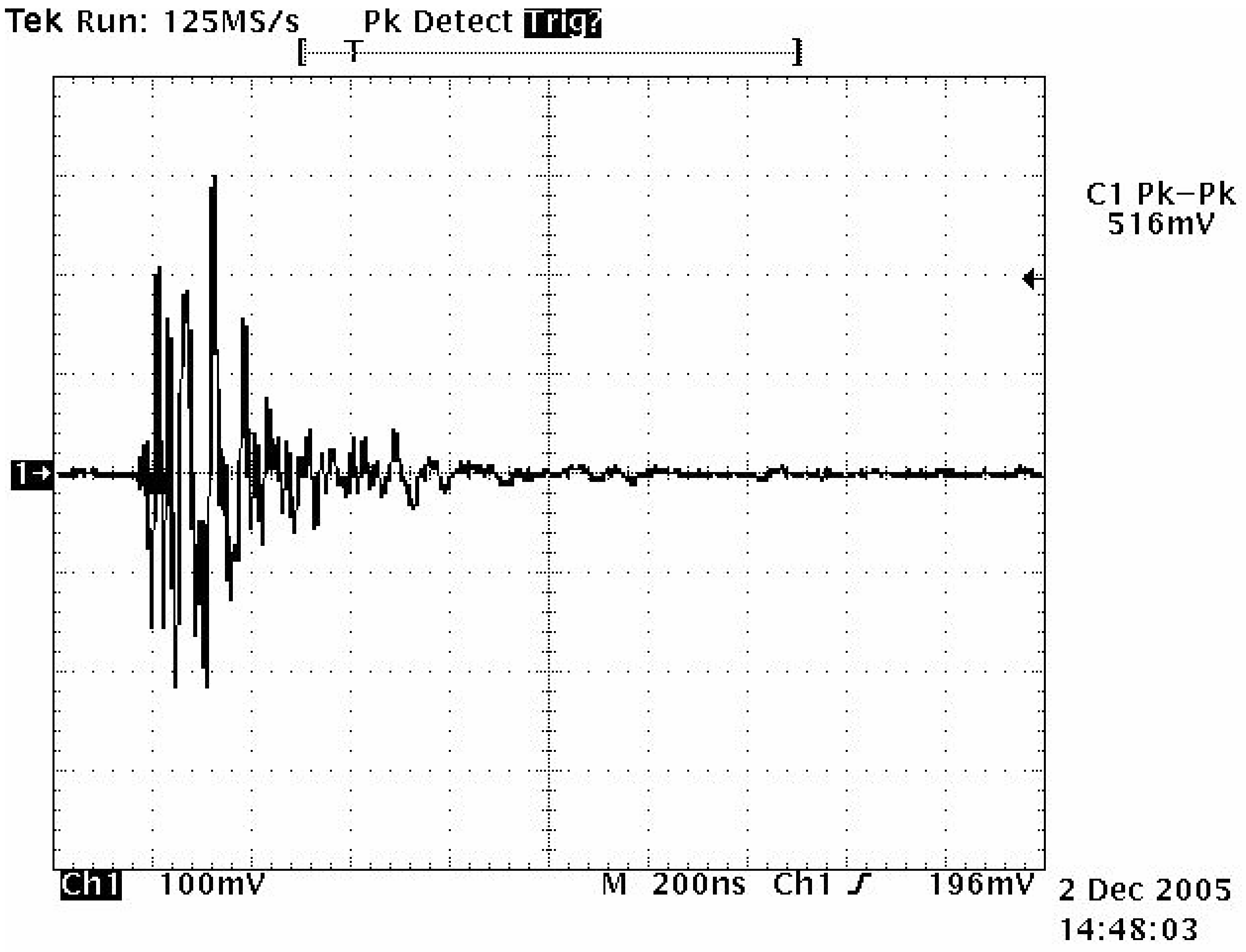


Figure 21 - Signal from low frequency antenna coupled to a high input impedance oscilloscope.

27. Photographs of Test setup

Figure 22 - View of Loop antenna for H-Field tests. The antenna is behind the cryostat dolly and the antenna is ~ 1m from the SPIRE SVM-CB (1838.jpg)

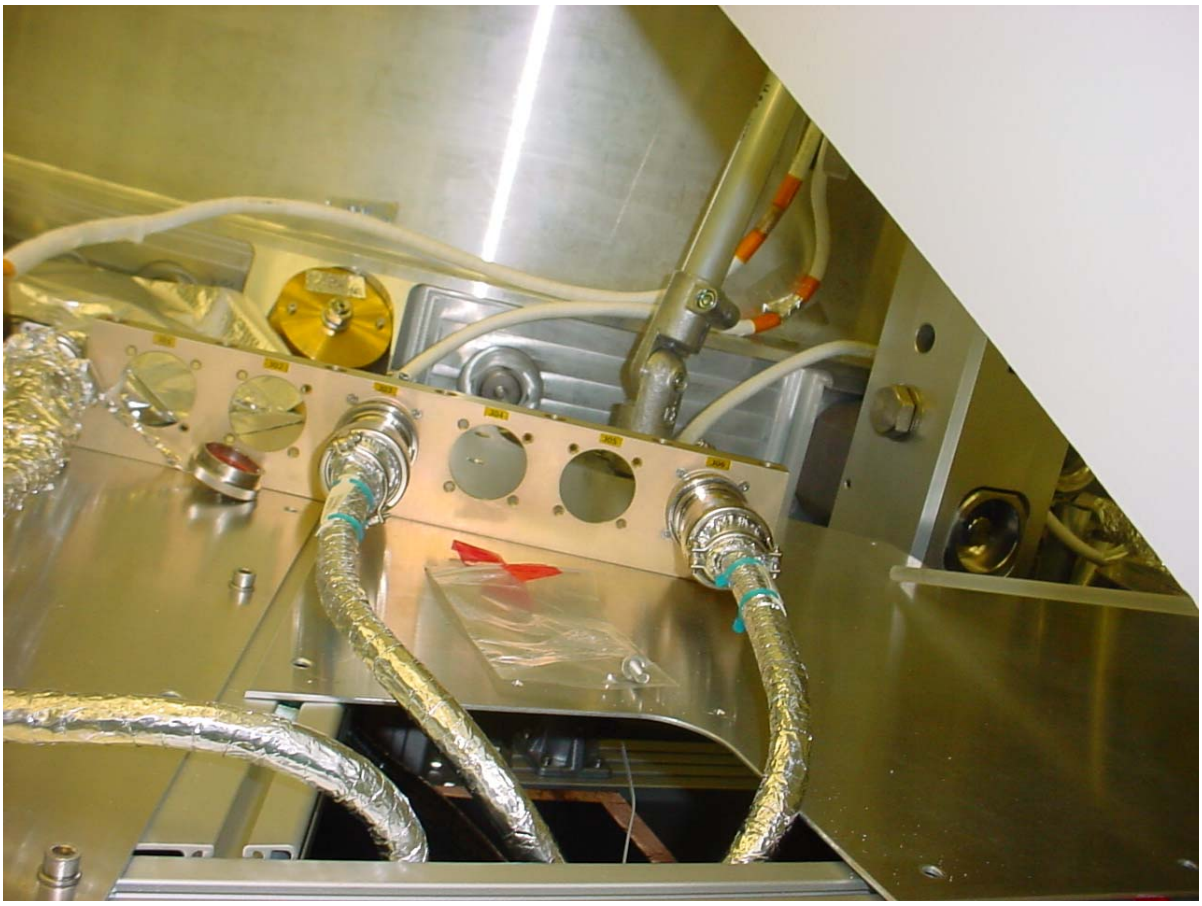


Figure 23 - View of location where the loop antenna was directed during H-Field Tests. Plastic rod seen on the right hand side of the picture shows the point 1m from the centre of the loop antenna. (1839.jpg)

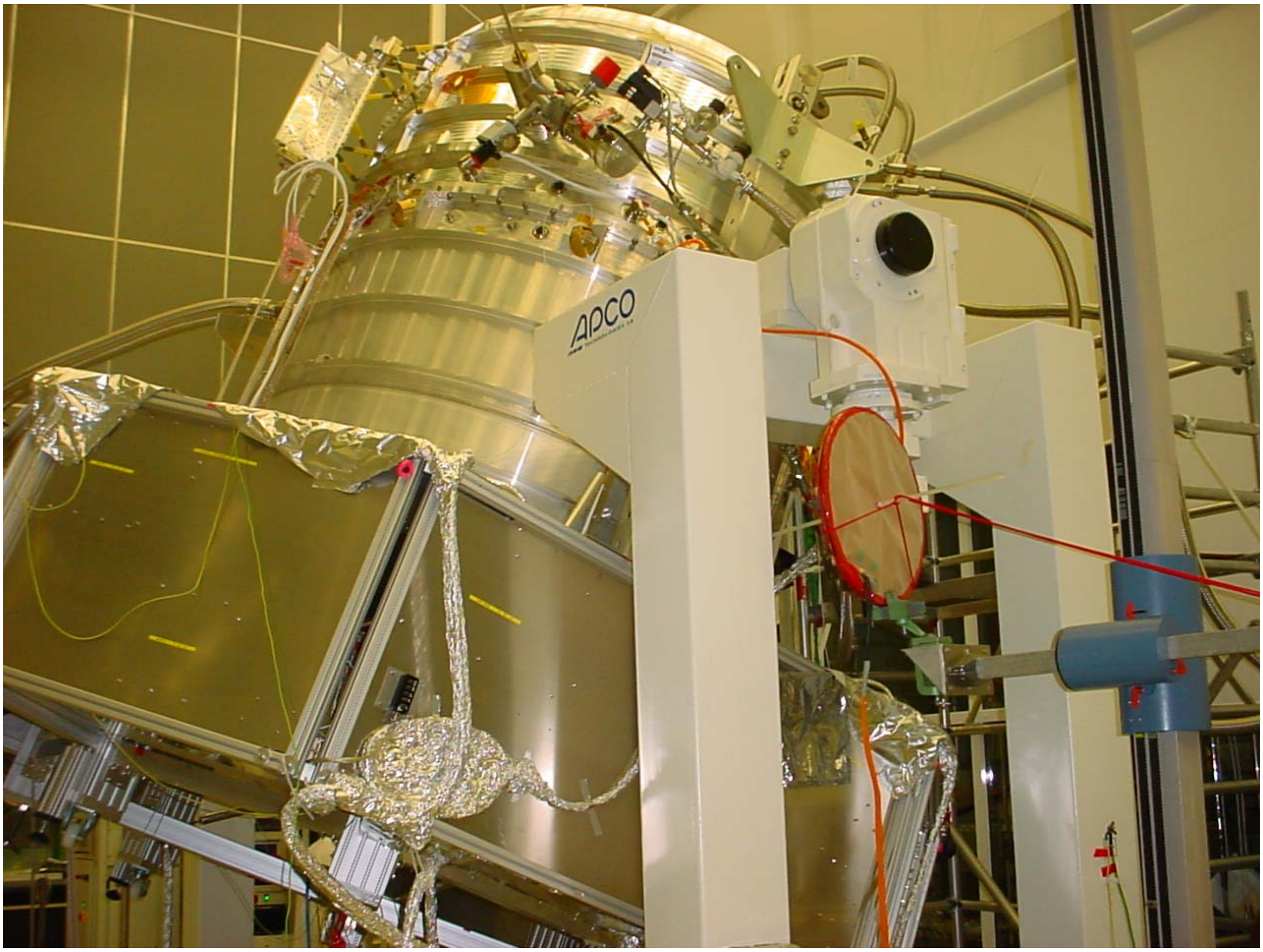


Figure 24 - View of the EQM cryostat during the H-Field testing. The DRCU and DPU are mounted inside the SVM on the panel facing the camera (1840.jpg).

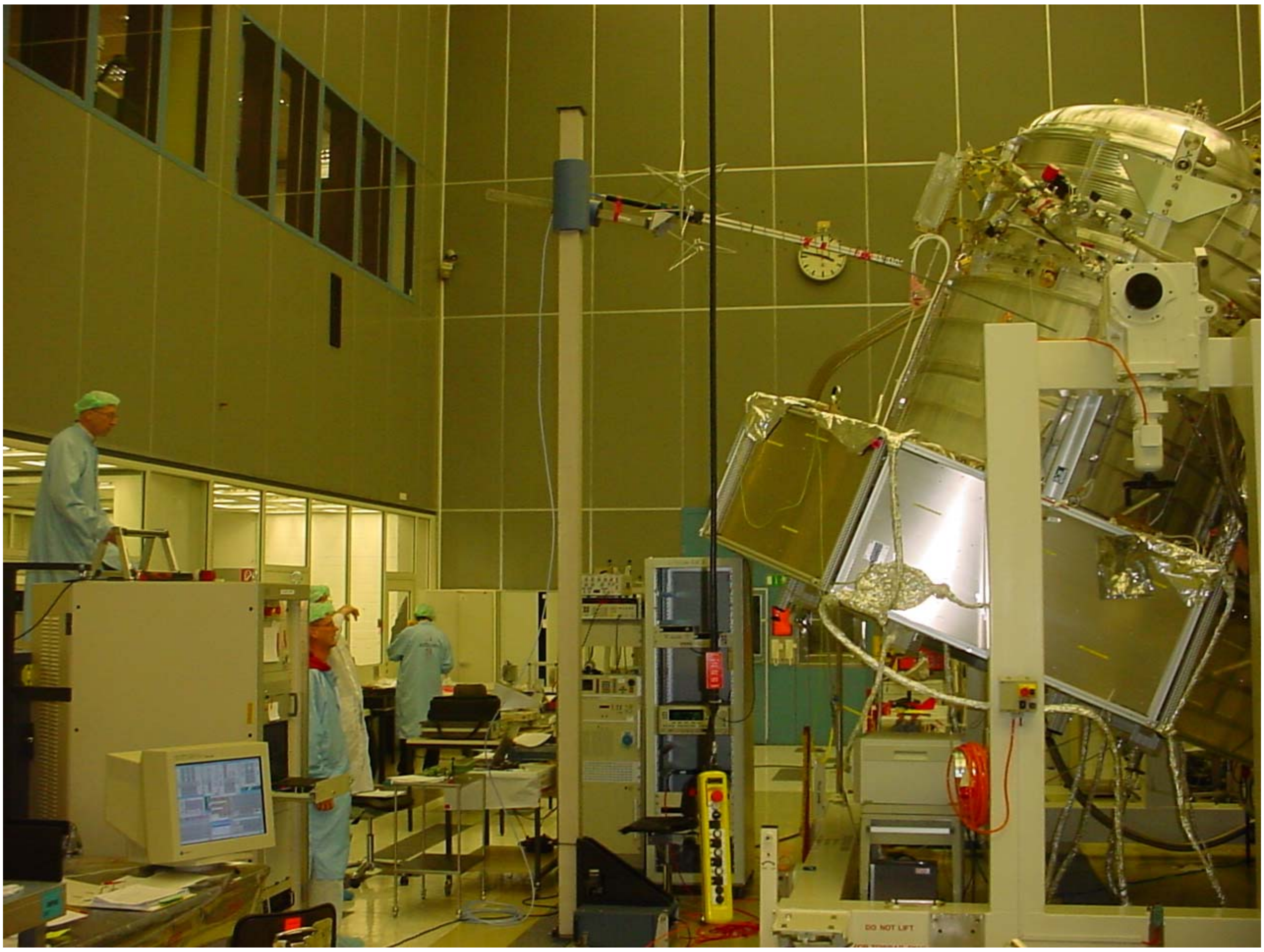


Figure 25 - Antenna Location #1 for E-Field 30MHz-1GHz Horizontal polarization. (1841.jpg)

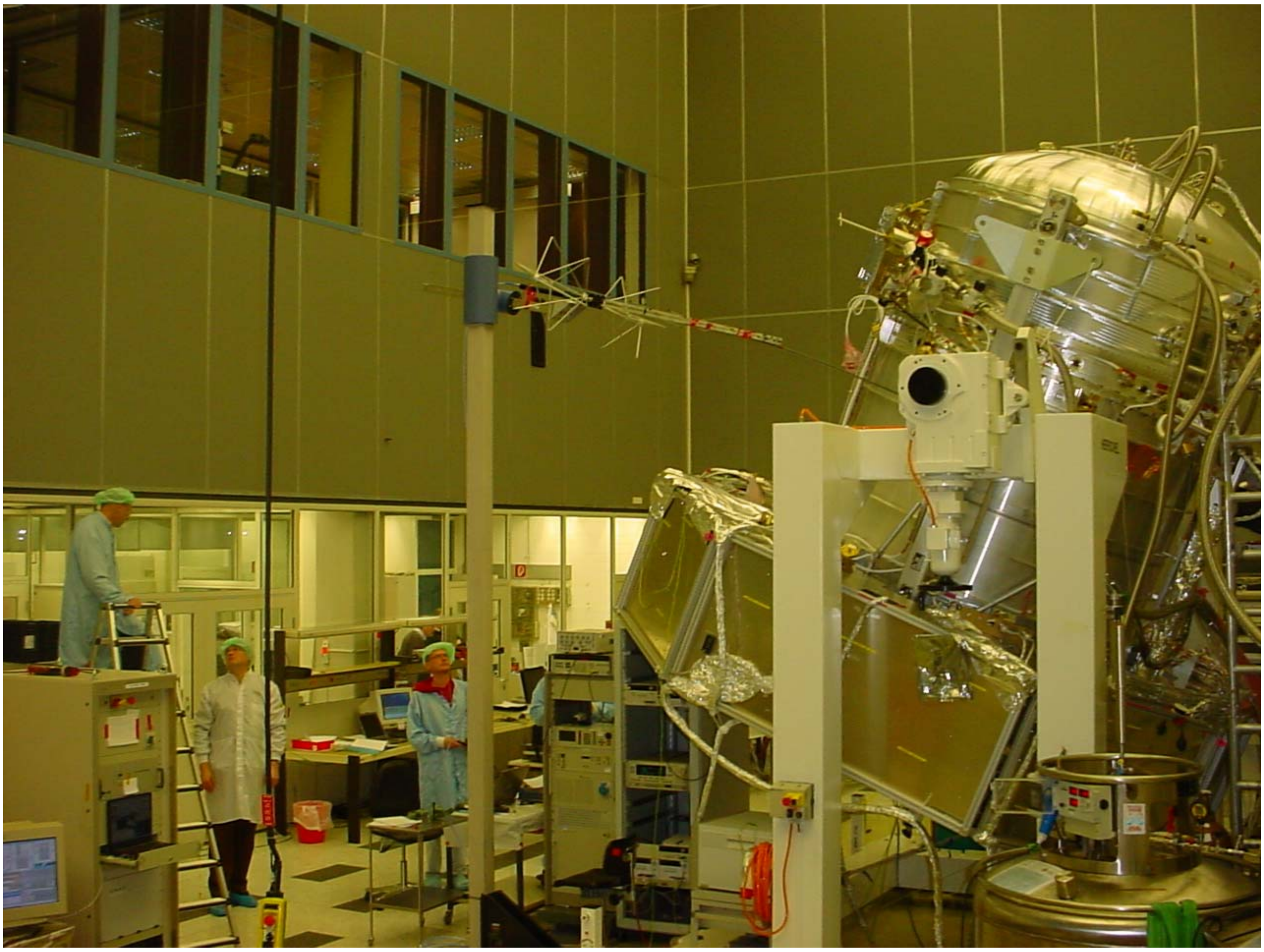


Figure 26 - Antenna Location #1 for E-Field 30MHz-1GHz Horizontal polarization. (1842.jpg)

Figure 27 - Antenna Location #1 for E-Field 30MHz-1GHz Horizontal polarization. (1845.jpg)

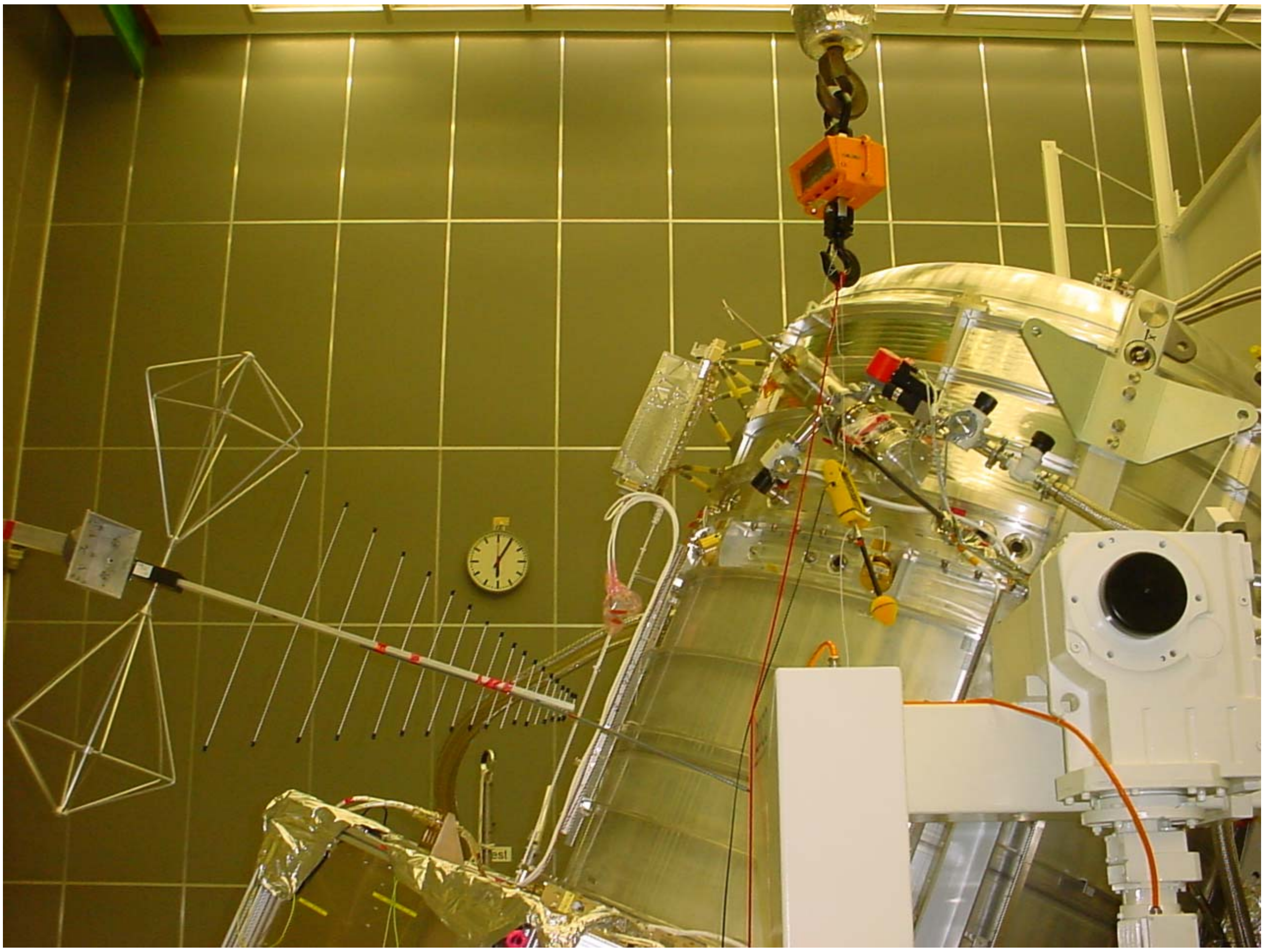


Figure 28 - Antenna Location #1 for E-Field 30MHz-1GHz Vertical polarization. (1852.jpg)

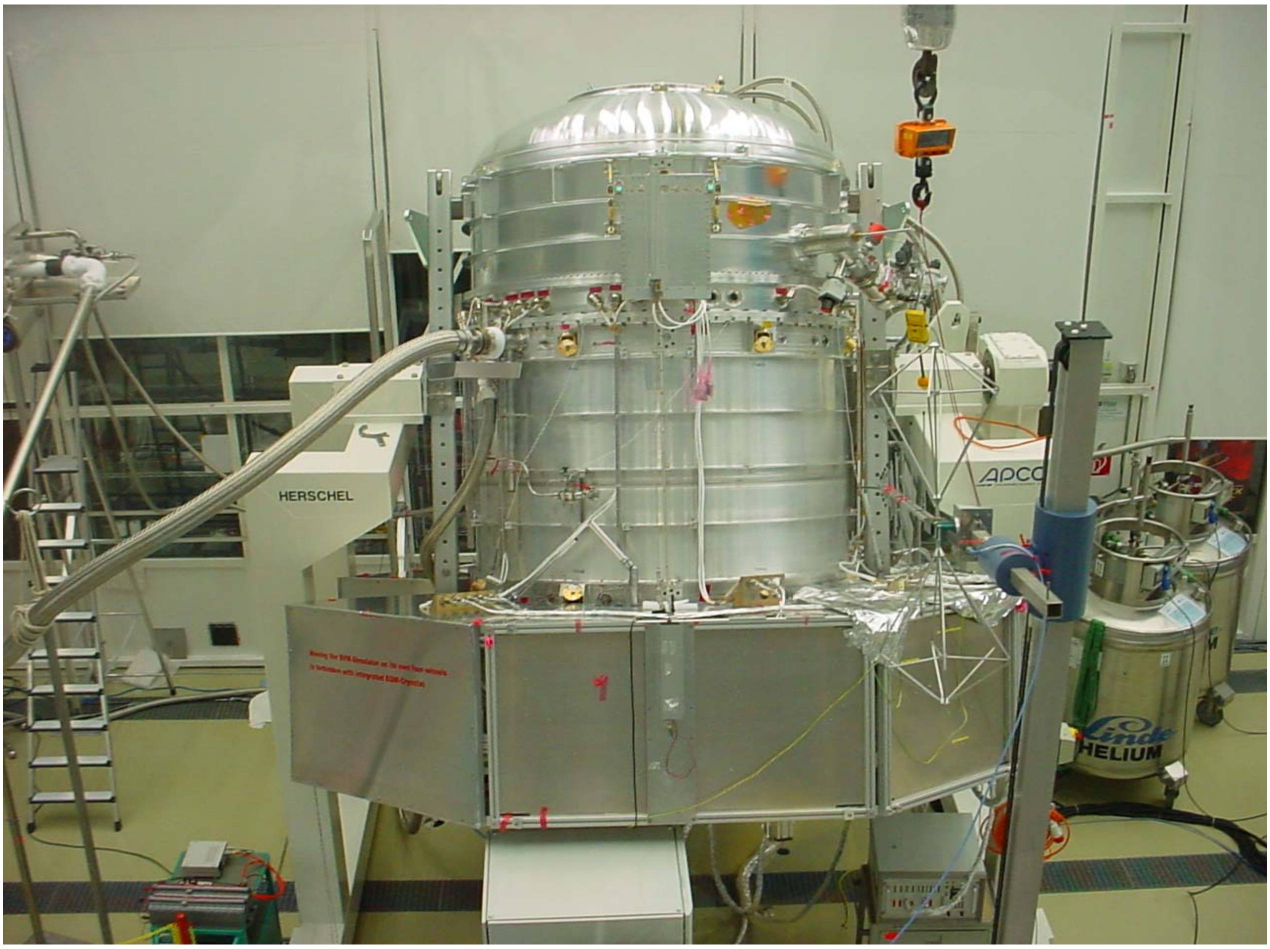


Figure 29 - Antenna Location #1 for E-Field 30MHz-1GHz Vertical polarization. (1857.jpg)

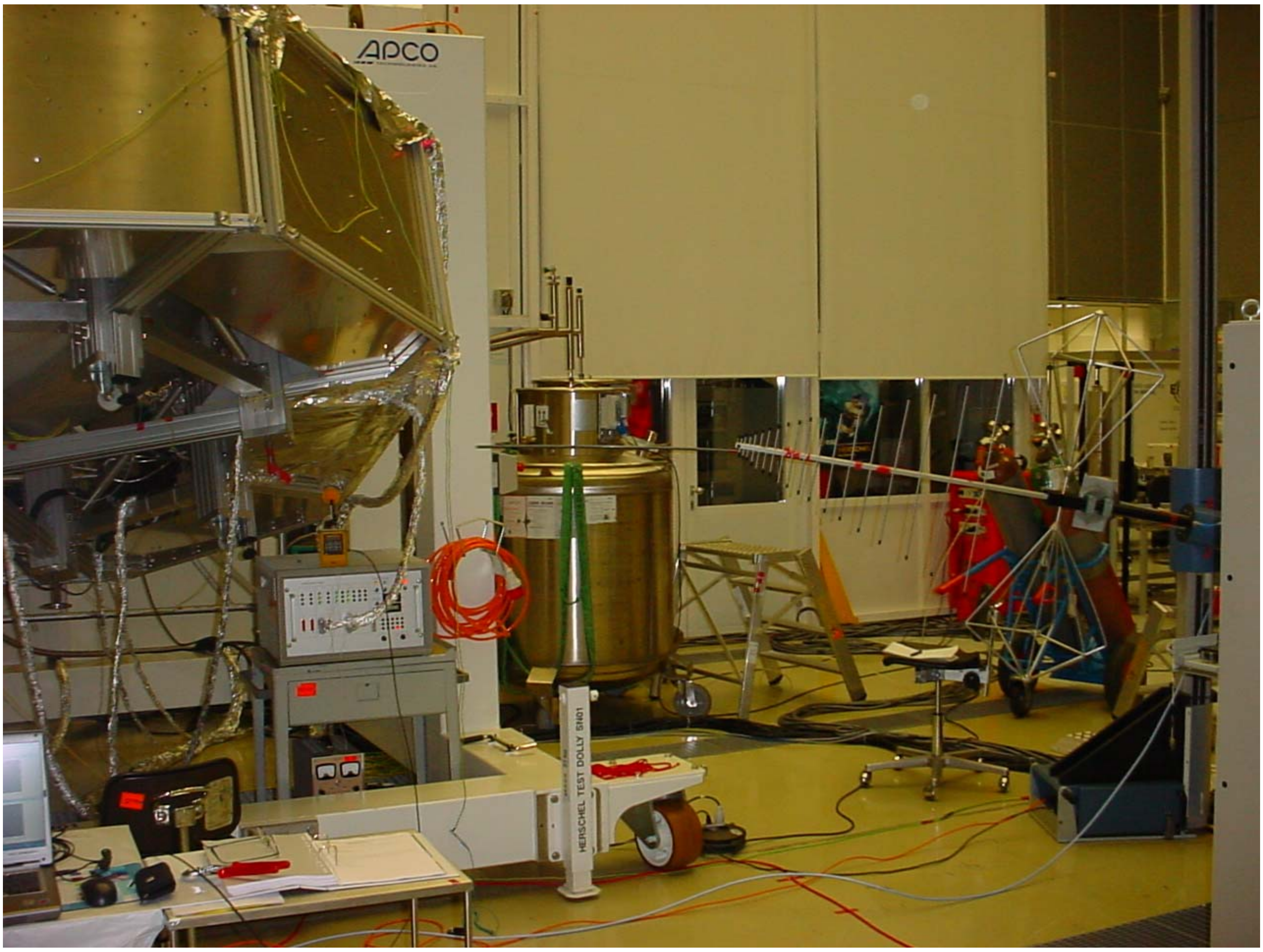


Figure 30 - Antenna Location #2 for E-Field 30MHz-1GHz Vertical polarization. (1861.jpg)

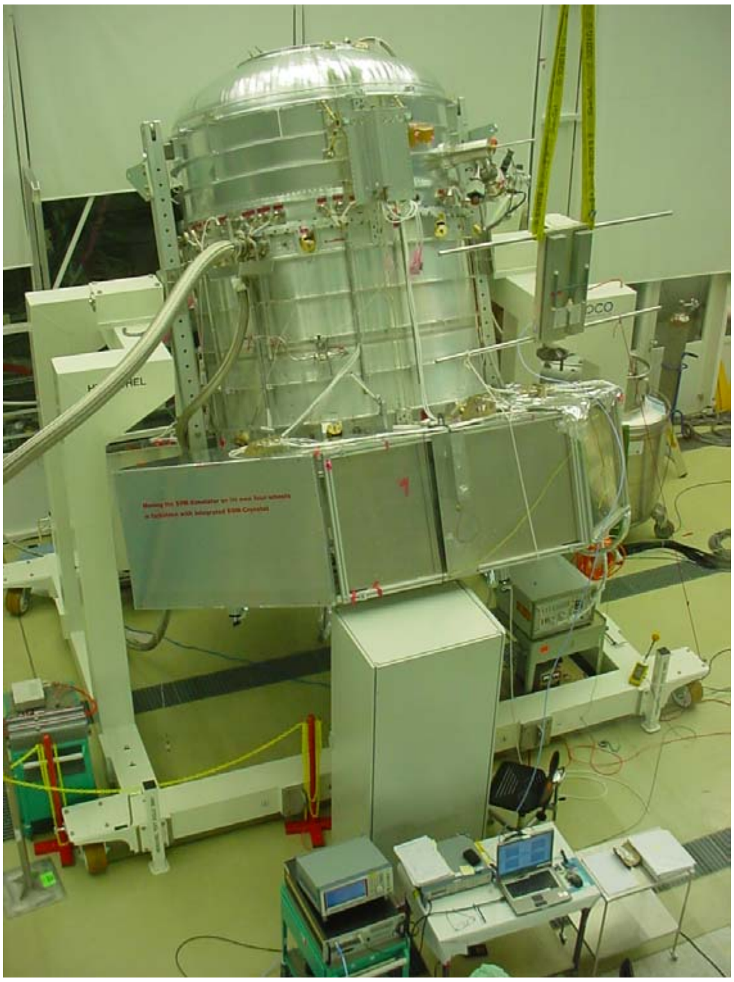


Figure 31 - Antenna Location #1 for E-Field 14kHz-30MHz Horizontal polarization. (1865.jpg)

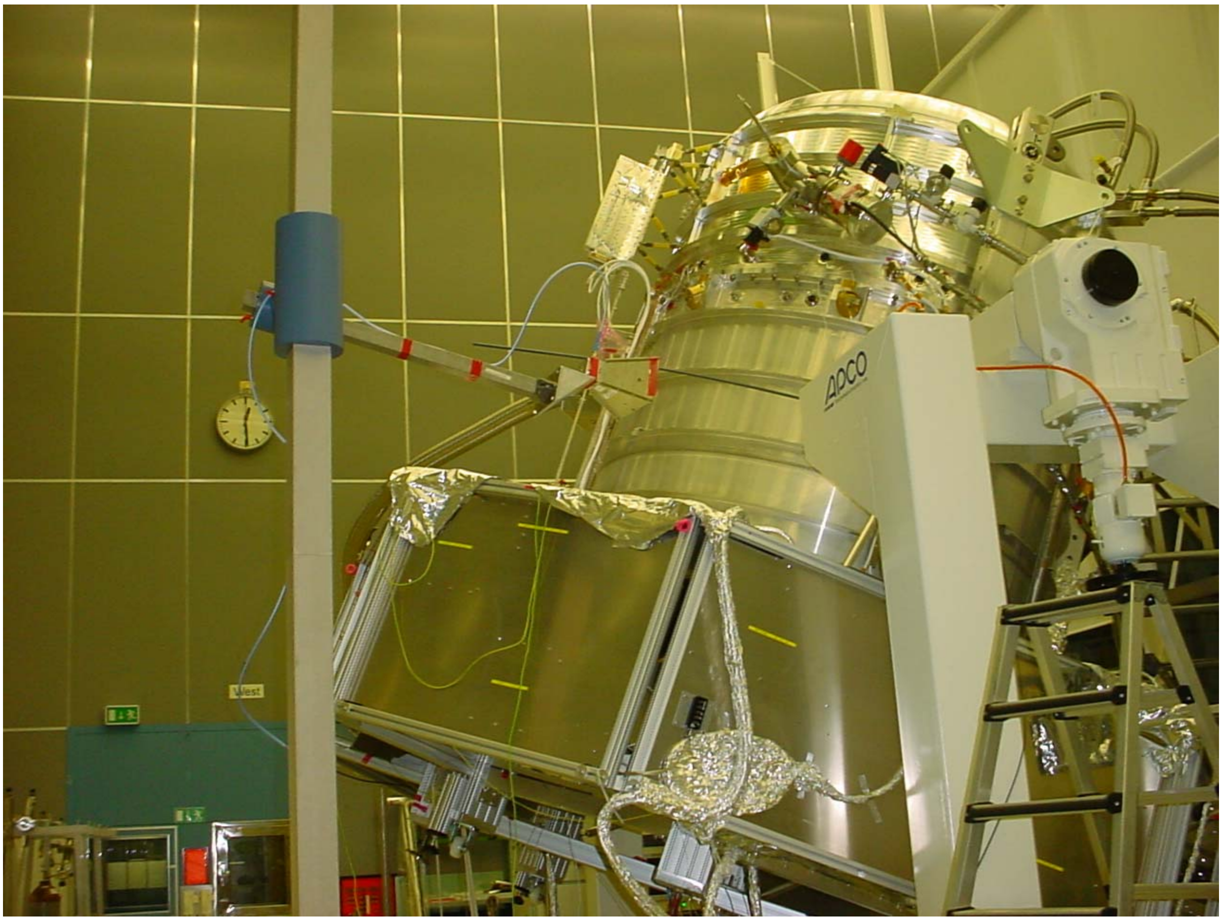


Figure 32 – Antenna location position 1, Vertical polarisation, 1-18GHz (1869.jpg)

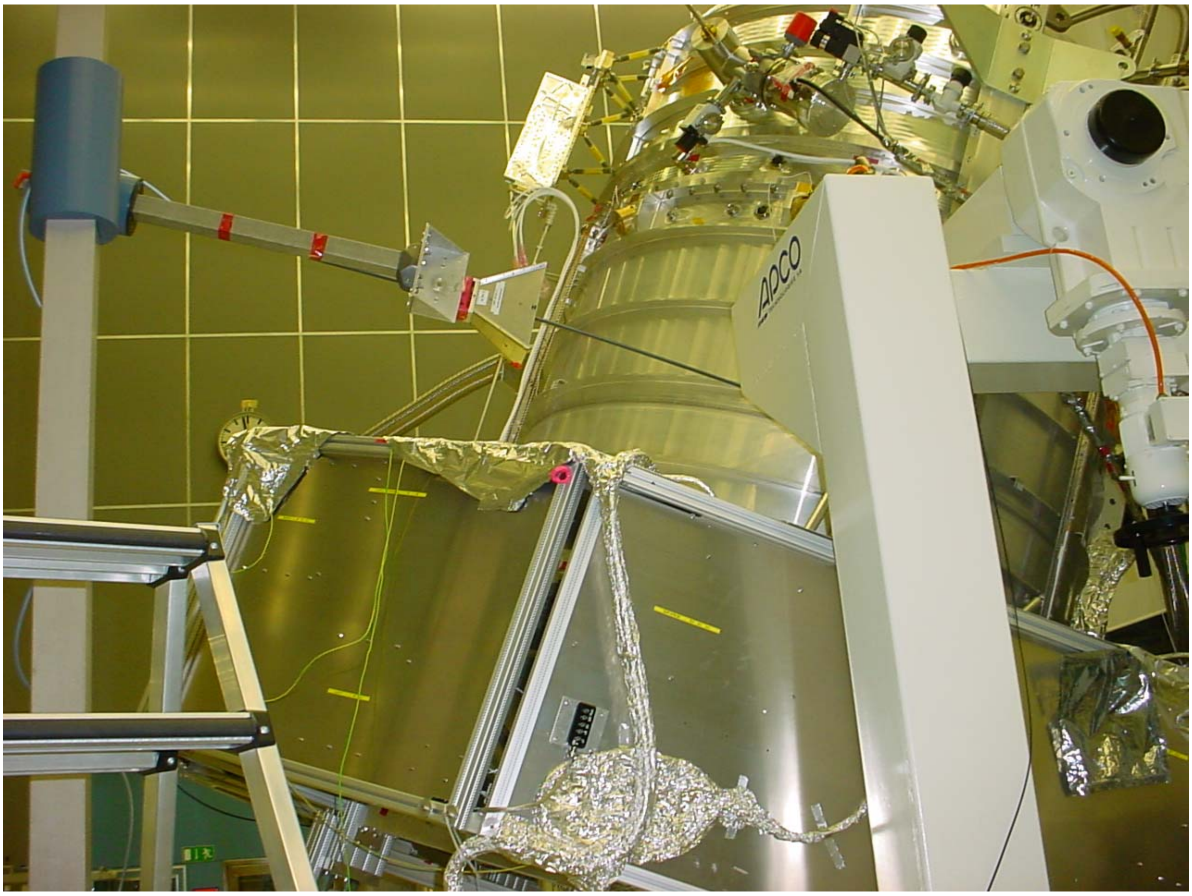


Figure 33 Antenna location position 1, Horizontal polarisation, 1-18GHz (1870.jpg)

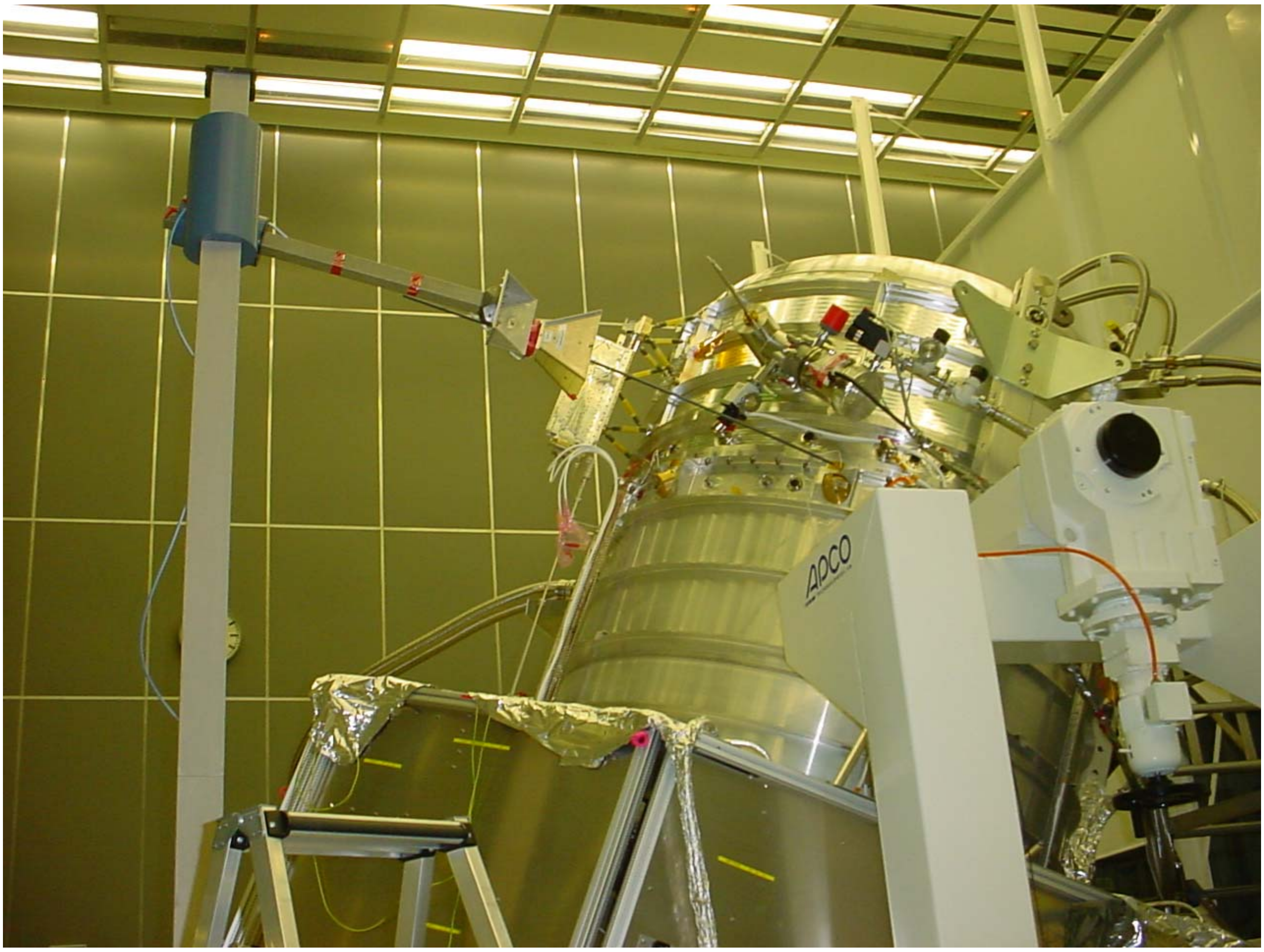


Figure 34- Antenna location position 2, Horizontal polarisation, 1-18GHz (1871.jpg)