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## Change Log

Date	Issue	Change
Friday, 25 November 2005	1.0	Circulated for initial comment
		Added requisite to Test Preparation procedures that Bus Profile be set to SPIRE Nominal
		Specify that the CUS is updated so that the detector will be sampled at 35Hz
		Added comment regarding the handling mistakes in the SPOT test procedure (§8)

## 1. Scope

This note sets out the detailed test sequence, derivation and specification of the test susceptibility criterion and the spot frequency integration period for the SPIRE EQM RS EMC tests.

## 2. Applicable/Reference Documents

AD1: "PLM EQM EMC Test Procedure, HP-2-ASED-PR-0033, dated 21.09.05

AD 2: BDA Sub-system Specification Document (Issue 3.1 19 Feb 2002).

AD 3: SPIRE COOLER RECYCLING SCOS PROCEDURE, SPIRE-RAL-PRC-002267

AD 4: Short Functional Test (SFT) Procedure for the CCS, SPIRE-RAL-PRC-002494, Issue 1.3, 23/09/05

AD 5: SPIRE Integrated Module Tests (IMT) procedures for the CCS, SPIRE-RAL-PRC-002512, Issue 1.1, 23/09/05



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## 3. Test preparation first day

Preconditions:

Bus profile set to SPIRE nominal

Procedure Step	Operation Description	Start Mode	End Mode	Approx Duration	Pass/Fail Criterion
1	Execute SPIRE-IMT-START-TEST.tcl and record ObsID	REDY	REDY	3 minutes	
2	SPIRE Cooler recycle as per AD 5, page 10: SPIRE-IMT-CREC.tcl	REDY	REDY	2 hours	Cooler temperature asymptotes to below 300mK
3	SPIRE-IMT-END-TEST.tcl				
4	Mode transition from REDY to PHOTSTBY SPIRE-PARALLEL-PDET-ON-STEP1.tcl	REDY	REDY	10 min	LIA status "on" LIA LEDs green on PSU
5	Check that CUS sets the detector sampling to 35Hz SPIRE-PARALLEL-PDET-ON-STEP2.tcl	REDY	PHOTSTBY		Check DCU parameters: PLWJFETSTAT (0x30) PLWJFETVSS1(-1.5V) PLWJFETVSS2(-1.5)
6	SPIRE-IMT-RESET-OFFSETS-P.tcl	PHOTSTBY	PHOTSTBY	2 minutes	
7	SPIRE-PARALLEL-PCAL-FLASH.tcl	PHOTSTBY	PHOTSTBY	2 minutes	SPIRE confirm that detectors operating nominally



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## 4. Test preparation when cooler recycled the previous evening

Preconditions:

Bus profile set to SPIRE nominal

Procedure Step	Operation Description	Start Mode	End Mode	Approx Duration	Pass/Fail Criterion
1	Mode transition from REDY to PHOTSTBY SPIRE-PARALLEL-PDET-ON-STEP1.tcl	REDY	REDY	10 min	LIA status "on" LIA LEDs green on PSU
2	SPIRE-PARALLEL-PDET-ON-STEP2.tcl	REDY	PHOTSTBY		Check DCU parameters: PLWJFETSTAT (0x30) PLWJFETVSS1(-1.5V) PLWJFETVSS2(-1.5)
3	SPIRE-IMT-RESET-OFFSETS-P.tcl	PHOTSTBY	PHOTSTBY	2 minutes	
4	SPIRE-PARALLEL-PCAL-FLASH.tcl	PHOTSTBY	PHOTSTBY	2 minutes	SPIRE confirm that detectors operating nominally



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## 5. End of EMC testing for the day (cooler recycle)

Procedure Step	Operation Description	Start Mode	End Mode	Approx Duration	Pass/Fail Criterion
1	SPIRE-IMT-STOP-P.tcl	PHOTSTBY	PHOTSTBY	2 min	Check command successful
2	SPIRE-PARALLEL-PDET-OFF.tcl	PHOTSTBY	REDY	2 min	JFET off Vss = 0V LIA LEDs off
3	Execute SPIRE-IMT-START-TEST.tcl and record ObsID	REDY	REDY	3 minutes	
4	SPIRE Cooler recycle as per AD 5, page 10: SPIRE-IMT-CREC.tcl	REDY	REDY	2 hours	Cooler temperature asymptotes to below 300mK
5	SPIRE-IMT-END-TEST.tcl				

## 6. End of EMC testing for the day (no cooler recycle)

Procedure Step	Operation Description	Start Mode	End Mode	Approx Duration	Pass/Fail Criterion
1	SPIRE-IMT-STOP-P.tcl	PHOTSTBY	PHOTSTBY	2 min	Check command successful
2	SPIRE-PARALLEL-PDET-OFF.tcl	PHOTSTBY	REDY	2 min	JFET off Vss = 0V LIA LEDs off



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## 7. Swept Frequency EMC Test

- Preconditions:
  - o Cooler is recycled
  - o Thermal transients permit EMC testing
  - o SPIRE interface temperatures compliant to IID-B values
  - o Cryo cover ~ 4K
  - o Instrument is in PHOTSTBY mode:
    - PLW JFETs on
    - Det bias frequency at 70Hz
    - Det bias amplitude 16.47mV
    - Det. Sampling at 35Hz

Procedure Step	Operation Description	Approx Duration	Pass/Fail Criterion
1	Fill out Sweep test-sheet with CCS operator and EMC test engineer	10 minutes	
2	Set up SPIRE QLA to monitor PLW detectors	1 minute	
3	Execute SPIRE-IMT-START-TEST.tcl Record ObsID on test sheet	1 minute	
4	Check with EMC test engineer that he is ready to commence the test		Test engineer acknowledges that test can start
5	Execute SPIRE-CCS-EMC-SWEEP.tcl	3minutes	Step finishes
6	Synchronise and start of the next step of SPIRE-EMC-SWEEP.tcl with: CCS Operator SPIRE EMC Test Engineer with Stopwatch EMC Test Engineer starting frequency sweep	TBD	
7	- SPIRE EMC test engineer monitors SPIRE QLA for any apparent increase in the noise and/or changes in the detector output level indicating susceptibilities. Any observations to be noted ion the Sweep Test Sheet along with the time that the observation was made - EMC Test Engineer to signal the end of the sweep to synchronise the ending of the test with the CCS operator		
8	Quiescent reference case initiated by CCS operator	3 minutes	



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Procedure Step	Operation Description	Approx Duration	Pass/Fail Criterion
9	End quiescent reference case		
10	Execute SPIRE-IMT-END-TEST.tcl		

## 8. SPOT Frequency EMC Test

- Preconditions:
  - o Cooler is recycled
  - o Thermal transients permit EMC testing
  - o SPIRE interface temperatures compliant to IID-B values
  - o Cryo cover ~ 4K
  - o Instrument is in PHOTSTBY mode:
    - PLW JFETs on
    - Det bias frequency at 70Hz
    - Det bias amplitude 16.47mV
    - Det. Sampling at 35Hz

Procedure Step	Operation Description	Approx Duration	Pass/Fail Criterion
1	Fill out Spot test-sheet with CCS operator and EMC test engineer	10 minutes	
2	Set up SPIRE QLA to monitor PLW detectors	1 minute	
3	Execute SPIRE-IMT-START-TEST.tcl Record ObsID on test sheet	1 minute	
4	Check with EMC test engineer that he is ready to commence the test		Test engineer acknowledges that test can start
5	Execute SPIRE-CCS-EMC-SPOT.tcl	3minutes	
6	CCS Operator to check with EMC Test Engineer that the test can commence and then starts quiescent reference case	3 minutes	
7	CCS Operator asks EMC Test Engineer to commence irradiating at test condition "n"		
8	EMC Test Engineer switches on the EMI and signals CCS operator that the test has commenced		
9	CCS Operator starts the data on this test case	3 minutes	



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Procedure Step	Operation Description	Approx Duration	Pass/Fail Criterion
10	SPIRE EMC test engineer monitors SPIRE QLA for any apparent increase in the noise and/or changes in the detector output level indicating susceptibilities. Any observations to be noted on the Spot Test Sheet		
11	CCS operator signals EMC test engineer when the test step has finished EMC test engineer sets up for next frequency		
12	SPIRE QLA data generated giving estimates of the DC and AC components of noise		
13	Loop to Procedure Step 7 until all spot frequencies / reference cases generated	3 minutes	
14	Execute SPIRE-IMT-END-TEST.tcl		

Prior to commencing the test, the frequencies and amplitudes are to be agreed and documented on the Test sheet. During the test, errors/mistakes can occur for a variety of reasons. If this occurs, then the baseline is to:

1. skip the particular test step
2. continue the test with the next frequency agreed prior to starting the test
3. at the end of the list of agreed frequencies, add an extra step to the test sheet in real time and repeat the frequency (hopefully without any mistakes!)

If the is catastrophic, then at the discretion of the test director, the script will be aborted. In this case, it is important that SPIRE-IMT-END-TEST.tcl is executed so that the subsequent instrument data is not corrupted.

## 9. Data Analysis

There are three levels of data analysis as described below.

### 9.1 Level 0 (real time QLA)

During the Sweep and Spot tests, the output from a subset of the PLW detectors will be monitored in real time by QLA. Examples of these windows is given in Figure 1 and Figure 2.

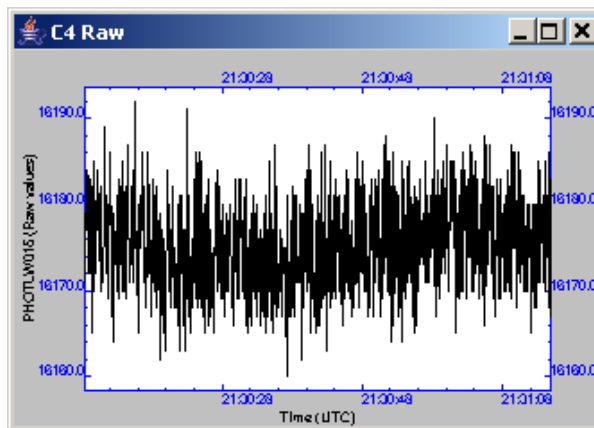


Figure 1 - Example detector output in real time from QLA (compress mode)

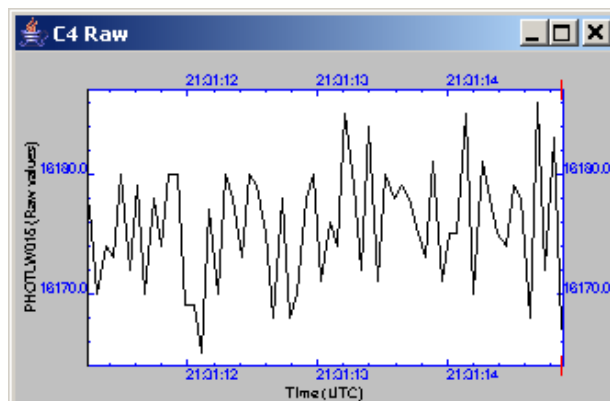


Figure 2 - Example detector output from QLA (follow mode).

Excess noise will be seen as an increase in the amplitude of the noise envelope. Heating of the detectors will be seen as a drop in the DC offset of the detectors. The results obtained from these windows are qualitative. Any observations made during the testing will be noted in the Test sheets.

### 9.2 Level 1 (near-real time QLA)

No meaningful near-real-time data analysis can be made on the Swept frequency tests as it is a survey for gross susceptibilities.





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The Spot frequency tests will use a QLA script to analyse the data from each step of the test. During each integration period (either a quiescent reference test or a test step under EMI), the mean and the standard deviation of the detector data for all 48 PLW channels is computed.



## 10. Appendix A: EMC Susceptibility limit criterion

The SPIRE noise budget is contained in Table 3-3-3 of AD2. This budget is reproduced below in Figure 3 for information only. For the PLW detector the noise contribution from EMI is to be  $< 5nV/\sqrt{Hz}$  referred to the detector.

**Table 3-3-3 Nominal Noise\* Budget (in nV/√Hz)**

	P/LW	P/MW	P/SW	S/LW	S/SW
Photon	21	26	30	24	30
Phonon	9	9	9	9	9
Johnson	7	7	7	7	7
Load resistor	2	2	2	2	2
JFET	7	7	7	7	7
LIA	6	6	6	6	6
A/D	4	4	4	3	3
Quad. Subtotal	26	30	33	28	34
Thermal†	< 6	< 6	< 7	< 11	< 11
EMI/EMC	< 5	< 5	< 5	< 5	< 5
Microphonic	< 5	< 5	< 5	< 5	< 5
Bias lines	< 4	< 4	< 4	< 4	< 4
Quad. Total	< 28	< 32	< 35	< 31	< 37

**Figure 3- SPIRE Noise budget reproduced from AD2 (for information only).**

EMI currents and voltages coupled into the detector system can be manifested as (1) excess noise in the detector signals and/or (2)  $I^2R$  heating of the detectors. Excess noise will be observed as an increase in the RMS amplitude of the detector signal while direct heating of the detectors will be observed as a reduction in the DC signal from the detectors .

The practical problem of translating this requirement into a test specification / susceptibility threshold is done by calculating the RMS AC component at the output of the lock-in amplifiers when a white noise source of  $5nV/\sqrt{Hz}$  is generated in the detectors. When this noise source is integrated over the detection bandwidth, it corresponds to a 5.06uV rms signal at the output from the readout amplifier (LIA) see Appendix C.

Assuming that there is a margin of 20dB (i.e. ratio of 10 in the NB field strength) between the susceptibility levels and the expected levels seen on the spacecraft, we can then define the pass fail criterion as:

$$\frac{\sqrt{(\text{Noise}_{AC-EMI-LIA} - \text{Noise}_{AC-Qui-LIA})^2 + (\text{DetSig}_{DC-EMI-LIA} - \text{DetSig}_{DC-Qui-LIA})^2}}{20\text{db}} < 5.06\text{nV rms}$$

or:

$$\sqrt{(\text{Noise}_{AC-EMI-LIA} - \text{Noise}_{AC-Qui-LIA})^2 + (\text{DetSig}_{DC-EMI-LIA} - \text{DetSig}_{DC-Qui-LIA})^2} < 50.6\text{nV rms}$$

Where:

$\text{Noise}_{AC-EMI-LIA}$  is the estimated rms detector noise at the output from the LIA under test conditions

$\text{Noise}_{AC-Qui-LIA}$  is the estimated rms detector noise at the output from the LIA under quiescent conditions (reference test)



Noise<sub>DC-EMI-LIA</sub> is the estimated DC detector output from the LIA under test conditions

Noise<sub>DC-Qui-LIA</sub> is the estimated DC detector output from the LIA under quiescent conditions (reference test).

## 11. Appendix B: SPOT Test Dwell Time Calculation

- The measurement of the detector signal includes both AC and DC components.
  - AC due to excess noise
  - DC due to detector heating
- The S/N ratio for a 5nV/√Hz signal buried in a 30nV/rt/Hz background is very low (See Appendix C)
- The measurement of the quiescent detector output or the EMI detector output will consist of the estimates of the detector noise and the DC signal output **plus** some a statistical uncertainty
- If the statistical uncertainty in these estimates is large compared with the difference between the quiescent noise and the susceptibility threshold, then the test has little statistical significance. Under these conditions it is not possible to draw conclusions regarding the immunity of the instrument to EMI.
- The statistical uncertainty in the measurement of the RMS detector noise was estimated by taking a long sample of detector data under quiet and stable conditions (the data came from the PFM-2 test campaign 29-09-05 21:00 to 21:30)
  - The data was broken up into short periods of time (approximately 8 second intervals)
  - For each interval, a polynomial of the form  $y=A_0+A_1t+A_2t^2$  was fitted to the data
  - This polynomial was then used to remove the DC component of the detector signal
  - An FFT algorithm was then used to estimate the RMS of the remaining detector signal
  - The standard deviation of the estimate of the signal RMS was then calculated on the sample of noise estimates
  - The procedure was repeated for each detector in the array
- The statistical uncertainty in the measurement of the DC component of the detector signal was made by using the same detector data
  - The RMS of the polynomial ( $y=A_0+A_1t+A_2t^2$ ) was calculated for each time interval. This was taken to be the DC component of the detector signal

$$\sqrt{\frac{1}{te} \times \int_0^{te} (A_0 + A_1 \times t + A_2 \times t^2)^2 dt} \rightarrow \left[ \frac{1}{te} \times \left[ \frac{1}{5} \times (A_2)^2 \times te^5 + \frac{1}{2} \times A_1 \times A_2 \times te^4 + \frac{2}{3} \times te^3 \times A_0 \times A_2 + \frac{1}{3} \times te^3 \times (A_1)^2 + A_0 \times A_1 \times te^2 + (A_0)^2 \times te \right] \right]^{\frac{1}{2}}$$

- Once again the standard deviation of the sample was taken
- The RMS was also taken by estimating the DC signal using a simple arithmetic average of the detector signal output over the interval. These results were very similar to the results gained by calculating the RMS of the fitted polynomial
- The results for the test data are given in Figure 4.
  - It can be seen that the estimate of the variance in the composite signal is dominated by the variance of the DC estimate. This is due to the fact that there was an underlying thermal drift during the test period. This can be seen from the trace showing the data from PLW detector pixel D4 in Figure 5.
  - If this long term drift in the DC signal is removed by fitting a straight line to the period, then the standard deviation in the DC estimate are reduced by roughly a factor of 3 to 4
  - This gives a standard deviation of the DC measurement of around 13uV and 5uV for the AC measurement for an 8 second integration period.
  - Converting this to an overall standard deviation for the combined measurement gives a standard deviation of 14uV (referenced to the output from the LIA)

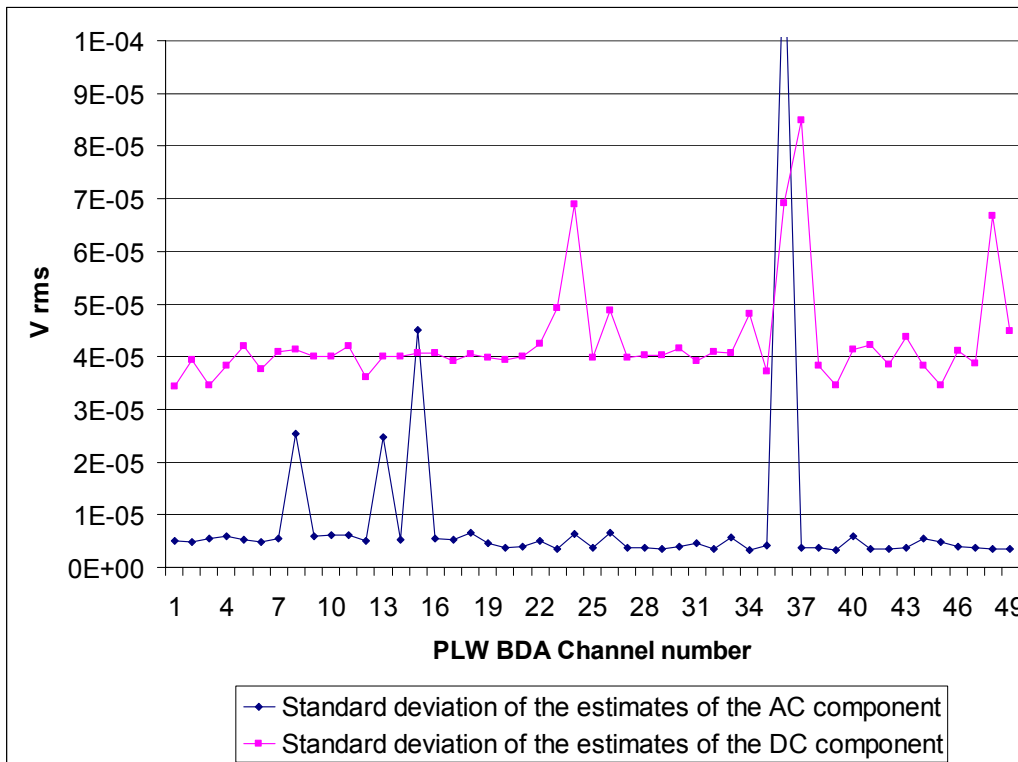


Figure 4 - Sample standard deviation in the estimates of the AC and DC components of the detector signals.

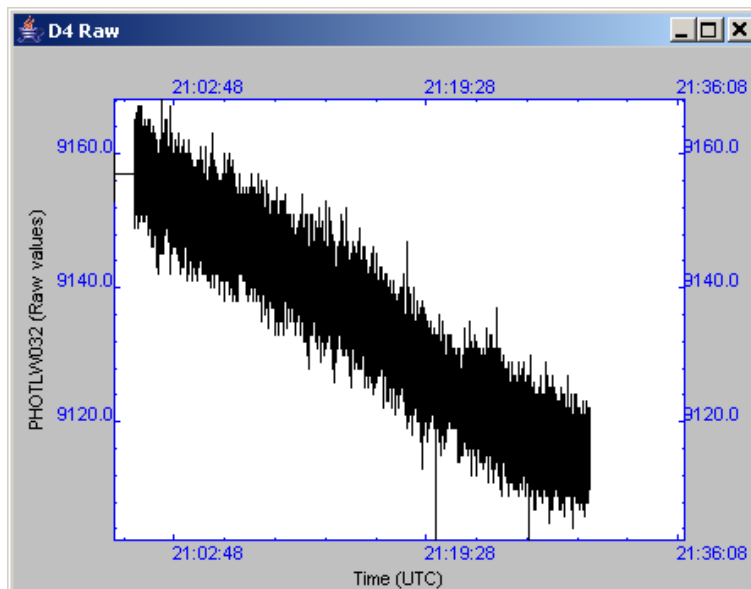


Figure 5 - Underlying detector trend due to thermal transients in instrument

- To assess how long the signals from the test need to be integrated we need to agree on the two conclusions that can be drawn from a single SPOT test. We will call them  $H_0$  and  $H_1$ 
  - $H_0$ : The excess noise is within the noise budget
  - $H_1$ : The excess noise exceeds the noise budget

- The following matrix (Table 1) outlines the different possible conclusions drawn from the results of the test.

**Table 1 - Range of possible conclusions and their accuracy to be drawn from the results of the SPOT test**

Test Assessment	H <sub>0</sub> is True	H <sub>0</sub> is False
<p style="text-align: center;"><b>Accept H<sub>0</sub></b>  <i>(Test indicates that we are within the noise budget)</i></p>	Correct	Type-II Error (False negative – we have exceeded the noise budget but the test has not revealed this fact)
<p style="text-align: center;"><b>Reject H<sub>0</sub></b>  <i>(Test indicates that the noise budget has been exceeded)</i></p>	Type-I Error (False positive – the noise is within budget, but we have actually exceeded it)	Correct

- The detector output must be sampled for a sufficiently long period so that the probability of making a Type-I or a Type-II error is small<sup>1</sup>
- The probability of a Type-I error can be calculated by integrating the normal probability distribution function for the measurement of the quiescent noise condition multiplied by the cumulative probability distribution for the noise measured under EMC test.

$$P_{fp}(nb, nq, \sigma_m, mar) := \int_{nq-4\sigma_m}^{nq+4\sigma_m} dn \cdot \text{dnorm}(n, nq, \sigma_m) \cdot \left[ 1 - \text{pnorm}\left[\sqrt{n^2 + nb^2}, \sqrt{nq^2 + (mar \cdot nb)^2}, \sigma_m\right] \right]$$

Where:

- nm: Estimate of Noise during EMC test
- nq: Noise measured under quiescent conditions
- σ<sub>m</sub>: Std. dev. of the uncertainty in the noise measurement
- dnorm: Normal distribution Probability Density Function
- pnorm: Cumulative probability distribution function
- mar: Margin by which the noise budget has been met

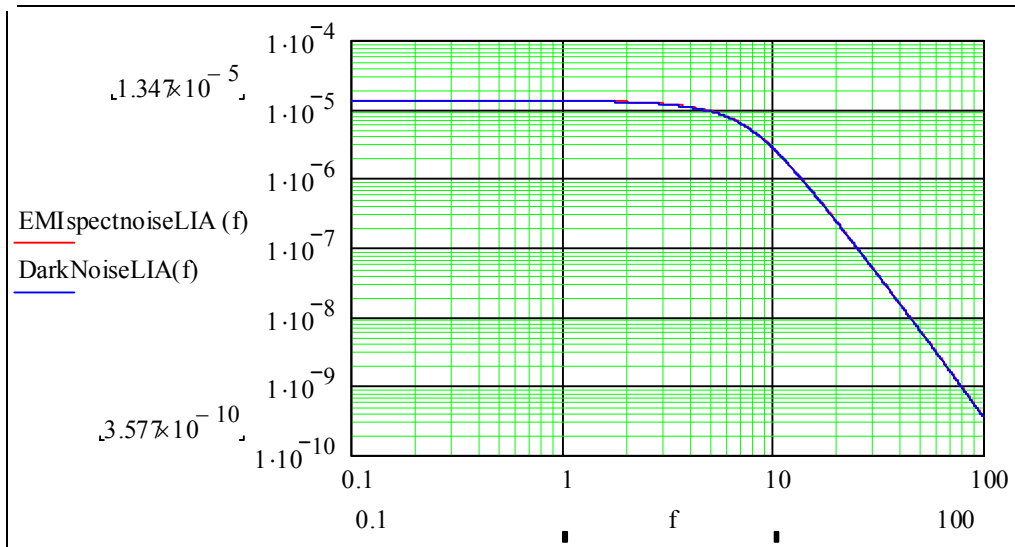
### Equation 1

- Similarly, the probability of a Type-II error can be calculated as a function of the quiescent noise level, the indicated noise under irradiation, the standard deviation of the noise estimates and the test margin.
- Calculations with a quiescent noise level of 30nV rms (as seen during EQM ILT) yields a probability of a Type-I error of 11% when the noise is within budget by a margin by 10% and the data is integrated over a 160 second interval
- Calculations with a quiescent noise level of 30nV rms (as seen during EQM ILT) yields a probability of a Type-II error of 12% when the noise is out of specification by a margin by 10% and the data is integrated over a 160 second interval
- This level of uncertainty is acceptable and the integration time will be set to 180 seconds (3 minutes) to keep to round figures

<sup>1</sup> It should be noted that when the measured noise level is very close to the budget value, it becomes increasingly difficult to draw statistically significant conclusions on the results. This is not an issue as we are most interested in finding large non-compliances rather than differentiating between marginal cases.

## 12. Appendix C: Equivalent signal from a white noise source in the detector

Using a detector bias frequency of 70Hz, a white noise source of  $5\text{nV}/\sqrt{\text{Hz}}$  on a  $30\text{nV}/\sqrt{\text{Hz}}$  detector background will have the following spectral content after passing through the anti-aliasing filter.



Integrating these signals over the frequency range yields:

EMI Budget noise at amplifier output:  $5.06\mu\text{V rms}$


Dark Noise Signal:  $30.34\mu\text{V rms}$

Dark noise + EMI Budget:  $30.76\mu\text{V rms}$

Signal to Noise ratio with  $30\text{nV}/\sqrt{\text{Hz}}$  non-EMI noise:

$$\text{SigNoise} := \frac{\text{EMIthresholdDet} - \text{DarkNoiseDet}}{\text{DarkNoiseDet}}$$

$$\text{SigNoise} = 0.01379$$

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## 13. Appendix D – Sweep test-sheet example

### 13.1 Example of the sweep front test-sheet

SPIRE EQM EMC Sweep Test Sheet		Sheet Number	Sheet 1 of 2
Test Location:	EADS OTTOBRUNN	Field Type	E – FIELD
Date of Test:	28 NOVEMBER 2005	Antenna location	+X SIDE OF SVM
Start Frequency	50 KHZ	Photograph of set-up	IMG_I1782.JPG
Stop Frequency	100 KHZ	Polarization	V
Amplitude modulation	30%	Antenna Ref	S/N 12345
Test Start time (CCS)	11:10:00	SPIRE Signature	
Test End Time (CCS)	12:10:10	ESA Signature	
Start quiescent reference case duration	180 s	Astrium Signature	
End quiescent reference case duration	180 s		
Step dwell time	5 SECONDS		
Number of steps in sweep	1234		
Estimated sweep duration	60 MIN		
Observation ID	0xABCD1234		
Channels monitored in QLA	A2, B4		
<b>Observations (susceptibilities during test)</b>			
<b>Time</b>	<b>Estimated Frequency</b>	<b>Notes</b>	
11:20:11	87.2 KHZ	INCREASE IN THE RMS NOISE SEEN	
11:30:11	92.5 KHZ	DETECTOR TEMPERATURE FALLS	



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## 13.2 Example of the sweep continuation test-sheet

<b>SPIRE EQM EMC Sweep Test Sheet</b>		<b>Sheet Number</b>	<b>Sheet 2 of 2</b>
Observation ID	0xABCD1234		
<b>Observations (susceptibilities during test)</b>			
<b>Time</b>	<b>Estimated Frequency</b>	<b>Notes</b>	
12:10:11	1100. KHZ	TEST COMPLETED NORMALLY	




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## 14. Appendix E – Spot test-sheet example


### 14.1 Example of the spot front test-sheet

SPIRE EQM EMC Spot Test Sheet		Sheet Number	SHEET 1 of 2
Test Location:	EADS OTTOBRUNN	Observation ID	0xABCDI235
Date of Test:	28 NOVEMBER 2005	Channels monitored in QLA	A2, B4
Start Frequency	50 KHZ	Field Type	E – FIELD
Stop Frequency	100 KHZ	Antenna location	+X SIDE OF SVM
Amplitude modulation	30% @ 1KHZ 100% @ 1 HZ (80% DUTY CYCLE)	Photograph of set-up	IMG_1783.JPG
Test Start time (CCS)	11:10:00	Polarization	V
Test End Time (CCS)	12:10:10	Antenna Ref	S/N 12345
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	60 MIN		
<b>Observations (susceptibilities during test)</b>			
Step	Time	Frequency	Notes
1	11:10:11	NA – QUIESCENT NOISE TEST	
2	11:13:30	50 KHZ	OK
3	11:15:01	75 KHZ	MIS-TEST (TO BE REPEATED AT THE END)
4	11:18:01	100 KHZ	EXCESS NOISE SEEN
5	11:21:01	75 KHZ	
6	11:24:01	NA - QUIESCENT NOISE TEST	



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**14.2 Example of the spot continuation test-sheet**

<b>SPIRE EQM EMC Spot Test Sheet</b>		<b>Sheet Number</b>	SHEET 2 of 2
Observation ID	0xABCDI235		
<b>Observations (susceptibilities during test)</b>			
<b>Step</b>	<b>Time</b>	<b>Frequency</b>	<b>Notes</b>

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SPIRE EQM EMC Test Procedure Doug Griffin		

## 15. Appendix F – Test log sheet example

		Herschel SPIRE ASSEMBLY INTEGRATION AND TEST RECORD		 <b>CCLRC</b> <small>Rutherford Appleton Laboratory</small>	
Main Activity	EQM RS EMC Test Log	Location	EADS OTN Munich		
Date	28-Nov-2005				
Time UT	Activity	Signature			
07:30	Recycle cooler	DG			
08:00	Test planning meeting	DG			
09:30	Cooler recycle finished	DG			
11:30	Thermal transients low enough for testing to commence	DG			
12:00	H-Field sweep tests	DG			
17:30	End of EMC testing	DG			
18:00	Cooler recycle	DG			

Checked By:

CCLRC  
 Space Science and Technology Department  
 PRODUCT ASSURANCE

## 16. Appendix G – Detector System Gain Calculation

The detector output is a balanced differential analogue signal with high output impedance. The output impedance is converted by a JFET amplifier with a gain of approximately 0.95.

This signal is sent to the DCU via the cryoharness. The first stage of the readout amplifier is a band pass filter. The transfer function of this stage is:

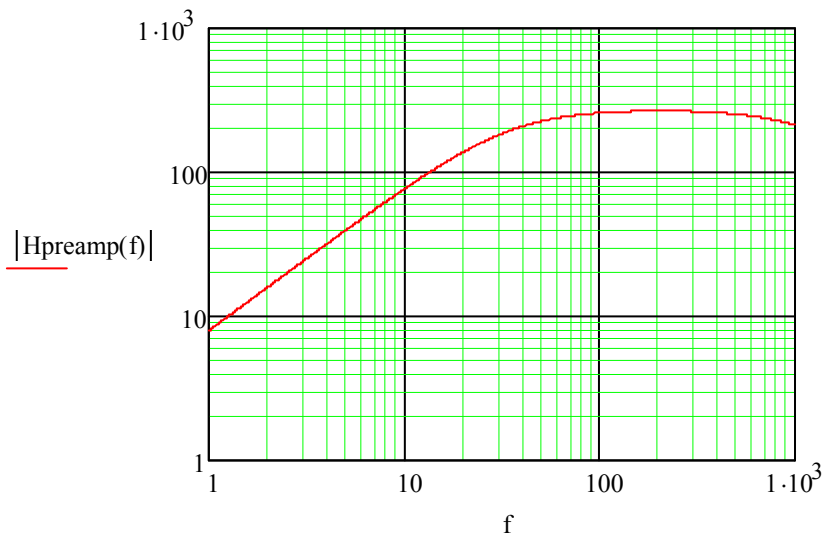
$$H_{\text{preamp}}(f) := 262.8 \times \frac{4.7 \times 10^{-3} \times p(f)}{1 + 4.7 \times 10^{-3} \times p(f) + 5.85 \times 10^{-7} \times p(f)^2}$$

Where:

$p(f)$ :  $2\pi f$

$f$ : detector bias frequency

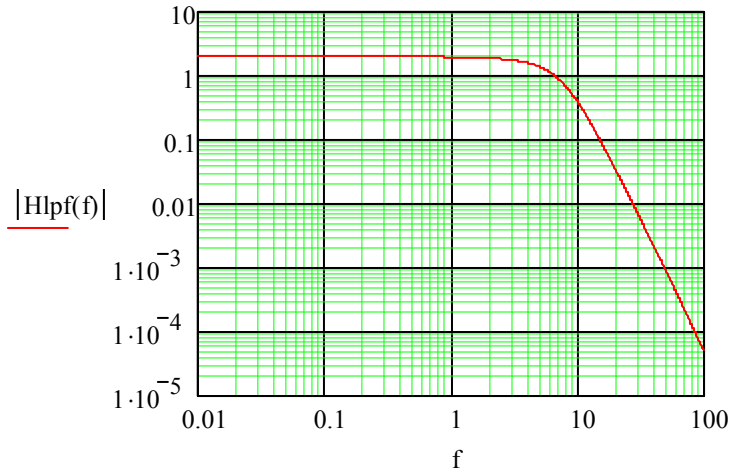
The amplitude response of this stage is:



The output of this filter is rectified by a demodulator. It is then filtered by a low pass filter:

$$H_{\text{lpf}}(f) := 1.93 \times \frac{1}{1 + 42.58 \times 10^{-3} p(f) + 503.1 \times 10^{-6} \times p(f)^2} \times \frac{1}{1 + 24.96 \times 10^{-3} \times p(f) + 400 \times 10^{-6} \times p(f)^2} \times \frac{1}{1 + 1 \times 10^{-3} p(f)}$$

with a amplitude response of:

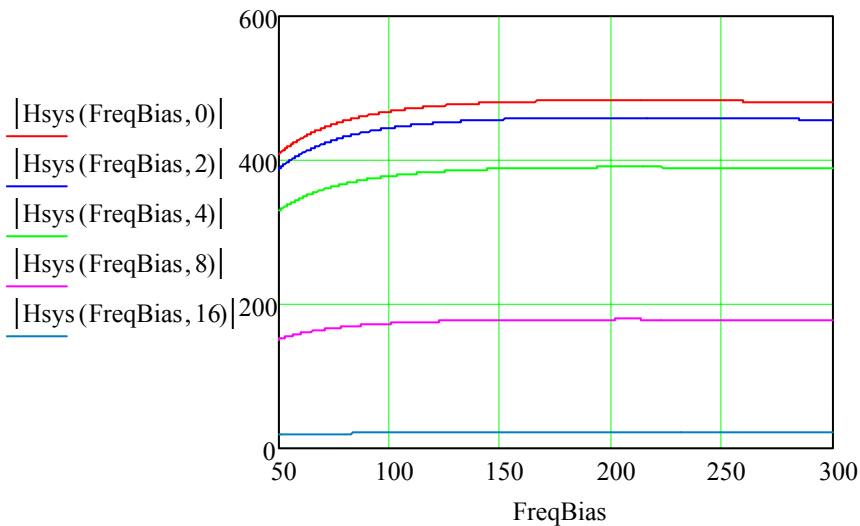


**Figure 6 - Amplitude of the anti-aliasing low pass filter**

The overall system amplitude response is given by the product of the amplitudes of these transfer functions:

$$H_{\text{sys}}(f, \text{sigf}) := H_{\text{lpf}}(\text{sigf}) \times H_{\text{demod}} \times H_{\text{preamp}}(f) \times H_{\text{fjet}}$$

and is plotted in Figure 7 for a range of detector signal frequencies.



**Figure 7 - Overall detector system gain vs. bias frequency for a range of detector signal frequencies.**

The gain for a DC signal at 70Hz (nominal detector bias frequency) is 442.8

## 17. Appendix H – SPIRE Grounding Diagram

