TITLE:	**Planck-LFI In-Orbit Calibration and Verification Phase Report: Executive Summary**
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CHANGE RECORD

Issue	Date	Sheet	Description of Change	Release
1.0	October, 30th 2009	All	First release	
1.1	November, 27th 2009	All	Added section on in flight performance compared to ground tests	

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1 ACRONYMS

AIV	Assembly, Integration, Verification
AR	Anomaly Report
ASW	Application Software
BEM	Back End Module
BEU	Back End Unit
CCS	Central Check-out System
CDMU	Central Data Management Unit
CoP	Commissioning Phase
CPV	Calibration and Performance Verification
CSL	Centre Spatiale de Liège
DAE	Data Acquisition Electronics
DPU	Digital Processing Unit
EGSE	Electrical ground Support Equipment
FEM	Front End Module
I-EGSE	Instrument EGSE
ILT	Instrument Level Tests
IST	Integrated Satellite Test
OBC	On Board Clock
RAA	Radiometer Array Assembly
REBA	Radiometric Electronic Box Assembly
S/C	Spacecraft
SCOE	Spacecraft Control and Operation System
SPU	Signal Processing Unit
SUSW	Start- Up Software
SVM	Service Module
TBC	To Be Checked
TBW	To Be Written
TC	Telecommand
TM	Telemetry
UFT	Unit Functional Test

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable Documents

[AD1] Herschel/Planck Instrument Interface document Part A, SCI-PT-IIDA-04624 Issue 3.3

[AD2] Herschel/Planck Instrument Interface document Part B, SCI-PT-IIDB-04142 Issue 3.1

[AD3] Herschel/Planck Instrument Interface document Part B, SCI-PT-IIDB-04142 Issue 3.1, Annex 3, ICD 750800115

[AD4] Herschel/Planck Instrument Interface document Part A, SCI-PT-IIDA-04624 Issue 3.3 Annex 10

[AD5] Data analysis and scientific performance of the LFI FM instrument, PL-LFI-PST-AN-006 3.0

[AD6] Planck-LFI TV-TB test report: executive summary, PL-LFI-PST-RP-040 1.1

[AD7] Planck-LFI In-Orbit Commissioning report, PL-LFI-PST-RP-079 1.0

2.2 Reference Documents

[RD1] Planck Instrument Testing at PFM S/C levels, H-P-3-ASP-TN-0676, Issue 1.0

[RD2] Planck LFI User Manual, PL-LFI-PST-MA-001 Issue 4.0

[RD3] Testing Plan of the LFI instrument during the Planck commissioning and CPV phase, PL-LFI-PST-PL-013 Issue 4.2

[RD4] Planck LFI Operation Plan, PST-PL-011 Issue 3.0

[RD5] Planck LFI Scientific performance, PST-RP-041 Issue 1.0

3 INTRODUCTION

3.1 Purpose and Scope

This document summarises the results obtained during the commissioning tests performed on the LFI integrated on the Planck satellite. Tests have been conducted from June the 4th 2009 to June 26th 2009.

Details of the performed activities are discussed in specific reports that will be available after the CPV.

3.2 Test configuration

The test configuration is the following

SCOS 2K EGSE 3.1 Release 1.2
RTSILib version 1.0
RTSI Client version 1.2
LEVEL1 (TMH/TQL) version 5.1
LIFE Machine version OM 3.00

LFI Personnel involved during the test is:

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Industry support	Paola Battaglia, Paolo Leutenegger

4 List of detailed test reports

4.1 Reports relative to planned tests during CPV phase

All LFI activities are documented in the test reports listed in the next table.
Activities performed during the visibility period are enhanced in light yellow.

#	Instr ID	Activity ID	Start Date	OD	Duration (hr)	Title	Test Report
1	LFI_01_1	P_PVP_LFI_0050_01	6/04/09 18:40	22	04:00	Spike test 01 part 1	PL-LFI-PST-RP-061
2	LFI_01_2	P_PVP_LFI_0001_01	6/11/09 20:00	29	04:30	Cryo01 - part 1	PL-LFI-PST-RP-062
3	LFI_01_2	P_PVP_LFI_0101_01	6/12/09 12:37	30	04:30	Cryo01 - part 2	PL-LFI-PST-RP-062
4	LFI_01_2	P_PVP_LFI_0201_01	6/13/09 15:35	31	04:30	Cryo01 - part 3	PL-LFI-PST-RP-062
5	LFI_25	P_PVP_LFI_0025_01	6/13/09 20:00	31	16:00	Spike test 02	PL-LFI-PST-RP-061
6	LFI_01_1	P_PVP_LFI_0150_01	6/14/09 14:00	31	04:00	Spike test 01 part 2	PL-LFI-PST-RP-061
7	LFI_02_2	P_PVP_LFI_0002_01	6/14/09 21:20	32	03:00	Drain current verification	PL-LFI-PST-RP-063
8	LFI_03	P_PVP_LFI_0003_01	6/16/09 02:20	33	02:00	Cryo02	PL-LFI-PST-RP-064
9	LFI_05_1	P_PVP_LFI_0005_01	6/16/09 10:30	34	26:20	Matrix Pre-Tuning	PL-LFI-PST-RP-067
10	LFI_04	P_PVP_LFI_0004_01	6/17/09 21:30	35	10:00	Phase Switch Tuning	PL-LFI-PST-RP-065
11	LFI_02_1	P_PVP_LFI_0102_01	6/19/09 16:45	35	12:00	Stability Check	PL-LFI-PST-RP-066
12	LFI_04set	P_PVP_LFI_0104_01	6/19/09 16:07	36	01:30	Set Phase Switch	PL-LFI-PST-RP-065
13	LFI_05_2	P_PVP_LFI_0105_01	6/19/09 19:00	36	33:15	Matrix Tuning 1	PL-LFI-PST-RP-068
14	LFI_05_2	P_PVP_LFI_0105_02	6/22/09 22:00	40	33:15	Matrix Tuning 2	PL-LFI-PST-RP-068
15	LFI_05_2	P_PVP_LFI_0105_03	6/25/09 13:30	43	33:15	Matrix Tuning 3	PL-LFI-PST-RP-068
16	LFI_05_2	P_PVP_LFI_0105_04	7/07/09 13:00	55	33:15	Matrix Tuning 4	PL-LFI-PST-RP-068
17	LFI_05_2	P_PVP_LFI_0206_01	7/13/09 09:30	61	00:05	Set ACA parameters	PL-LFI-PST-RP-068
18	LFI_09	P_PVP_LFI_0009_01	7/13/09 12:00	61	23:00	DAE tuning	PL-LFI-PST-RP-069
19	LFI_04bis	P_PVP_LFI_0104_01	7/15/09 16:00	63	10:00	Phase Switch Tuning 2	PL-LFI-PST-RP-065
20	LFI_08	P_PVP_LFI_0108_01	7/16/09 02:00	64	02:00	Cryo02 2	PL-LFI-PST-RP-064
21	LFI_14	P_PVP_LFI_0014_01	7/16/09 04:00	64	01:00	Blanking Time	PL-LFI-PST-RP-073
22	LFI_09	P_PVP_LFI_0109_01	7/16/09 09:25	64	00:05	Set DAE parameters	PL-LFI-PST-RP-069
23	LFI_13	P_PVP_LFI_0013_01	7/16/09 09:55	64	04:00	DAE tuning verification	PL-LFI-PST-RP-069
24	LFI_10	P_PVP_LFI_0010_01	7/16/09 15:00	64	03:01	REBA Tuning	PL-LFI-PST-RP-072
25	LFI_02_2	P_PVP_LFI_0002_02	7/17/09 11:24	65	03:00	Drain current verification	PL-LFI-PST-RP-085
26	LFI_13	P_PVP_LFI_0013_02	7/17/09 14:30	65	04:00	DAE tuning verification	PL-LFI-PST-RP-069
27	LFI_08	P_PVP_LFI_0108_02	7/17/09 16:30	65	02:00	Cryo02 3	PL-LFI-PST-RP-064
28	LFI_14	P_PVP_LFI_0014_02	7/17/09 18:30	65	01:00	Blanking Time	PL-LFI-PST-RP-073

29	LFI_10	P_PVP_LFI_0110_01	7/19/09 10:23	67	00:30	Set REBA parameters	PL-LFI-PST-RP-072
30	LFI_11	P_PVP_LFI_0011_01	7/19/09 21:30	67	24:00	REBA check	PL-LFI-PST-RP-072
31	LFI_07	P_PVP_LFI_0007_01	7/21/09 11:00	69	33:15	Matrix Tuning verification 1	PL-LFI-PST-RP-071
32	LFI_07	P_PVP_LFI_0007_02	7/23/09 20:21	71	33:15	Matrix Tuning verification 2	PL-LFI-PST-RP-071
33			7/24/09 10:00	72	03:00	Noise investigation	
34	LFI_07	P_PVP_LFI_0107_01	7/25/09 10:00	73	00:05	Set ACA parameters	PL-LFI-PST-RP-071
35	LFI_09	P_PVP_LFI_0009_02	7/25/09 10:21	73	02:30	DAE tuning (reduced)	PL-LFI-PST-RP-069
36	LFI_02_2	P_PVP_LFI_0002_03	7/25/09 14:56	73	03:00	Drain current verification	PL-LFI-PST-RP-085
37			7/26/09 10:00	74	03:00	44 GHz RCAs investigation	
38	LFI_09	P_PVP_LFI_0009_03	7/27/09 10:10	75	02:30	DAE tuning (reduced)	PL-LFI-PST-RP-069
39	LFI_10	P_PVP_LFI_0010_02	7/27/09 14:00	75	03:01	REBA Tuning	PL-LFI-PST-RP-072
40	LFI_18	P_PVP_LFI_0018_01	7/27/09 18:00	75	12:30	Noise Properties 4KHz off	PL-LFI-PST-RP-074
41	LFI_08	P_PVP_LFI_0008_01	7/28/09 09:30	76	02:50	Reference test	PL-LFI-PST-RP-070
42	LFI_02_2	P_PVP_LFI_0002_03	7/28/09 12:30	76	03:00	Drain current verification	PL-LFI-PST-RP-085
43	LFI_23	P_PVP_LFI_0023_01	7/29/09 06:00	76	04:00	Dynamical Thermal model verification	PL-LFI-PST-RP-078
44	LFI_10	P_PVP_LFI_0110_02	7/29/09 10:00	77	00:30	Set REBA parameters	PL-LFI-PST-RP-072
45	LFI_11	P_PVP_LFI_0011_02	7/29/09 10:30	77	24:00	REBA check	PL-LFI-PST-RP-072
46	LFI_19	P_PVP_LFI_0019_02	7/30/09 11:00	77	12:00	Noise Properties 4KHz on	PL-LFI-PST-RP-074
47	LFI_27	P_PVP_LFI_0027_01	7/30/09 12:00	78	16:00	Spike test 03	PL-LFI-PST-RP-061
48	LFI_16	P_PVP_LFI_0016_01	8/07/09 11:00	86	24:00	Thermal Susceptibility	PL-LFI-PST-RP-075

5 Summary of results

5.1 LFI Functionality Verification Tests

5.1.1 P_PVP_LFI_0050_01: Spike test 01

The objective of this test is to characterise 1Hz spikes caused by the DAE housekeeping sequencer in the LFI output when only the DAE box is on. The test was completed without major problems and the spikes were correctly characterised and compared with those obtained in a equivalent on ground test conducted with the satellite in cold conditions during TV-TB tests in CSL.

Verification matrix

CPV	**P_PVP_LFI_0050_01**	
June, 04 2009 18:40z	**DoY 155**	**OD 22**
Duration	**4:00:00**	
Test name:	Spike test 01	
Test objectives:	Characterise DAE frequency spikes with FEMs and BEMs off. Once the Scientific Telemetry is active and the SCS cool down is proceeding this test can be conducted in parallel and it is used for a reference point because the same test was performed on ground during TV-TB test campaign. LFI is in DAE Set-up mode: power groups are still OFF.	

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected events packets (LFI IOT expects OOL alarm for the FPU sensors)	Yes		4 KHz phase switch was not initialised in DAE. Therefore data appeared to be switching but in reality were not. This unwanted effect was cured in data analysis		
No unexpected features	Yes				
Data saved and stored at DPC	Yes				

Results

The procedure has been run on June 4th, 2008 without any problem and the test was completed successfully.

Observed spikes compared very well in frequency and amplitude with those characterised during Cannes and CSL tests. Spikes at 1 Hz and multiple frequencies disappear when the HK sequencer is switched off, some spikes still remain as it was already observed during Cannes and CSL tests.

In summary frequency spikes in the DAE output have been stable in frequency and amplitude throughout the ground test campaign and also in flight.

5.1.2 P_PVP_LFI_0001_01, P_PVP_LFI_0101_01, P_PVP_LFI_0201_01: Cryo-01

The objective of this test is to check the functionality of each active component (amplifier and phase switches) in the LFI front-end modules. The test was completed without major problems. Only in for one

RCA (LFI21) a wrong DAE offset setting caused signal saturation. Once recognised the problem the procedure was run again for the affected RCA.

Verification matrix

CPV	**P_PVP_LFI_0001_01, P_PVP_LFI_0101_01, P_PVP_LFI_0201_01**
June, 11-13 2009 20:00z	**DoY 162-164 OD 29-31**
Duration	**13:48:10**
Test name:	**CRYO 01**
Test objectives:	This test is dedicated to the radiometer part of LFI and it will be used during flight. This procedure is basically the same procedure run during TV/TB tests: all the power groups are switched on so all the FEMs are exercised.

Verification matrix					
Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected events packets	Yes				
Science production telemetry as expected		No	During second part of CRYO-01 there was a problem in the real time telemetry link. It was recovered by switching to the redundant real time server (CHAN-B)	Yes	
Every ACA is responding to biases stimuli as expected	Yes				
Every P/S is responding to bias stimuli as expected	Yes				
Correct cryogenic biases are applied	Yes				
No unexpected features (spikes, pop-corn noise, etc)		No	There was a mistake in the procedure, so that wrong offsets were applied to LFI 21 that therefore showed a saturated signal. It was recovered by correcting the procedure and rerunning CRYO_01 on LFI21	Yes	
Real time data available	Yes				
Data saved and stored at DPC	Yes				

Results

The procedure has run in three days during DTCP on June 11th, 12th and 13th, 2009 with minor procedural problems (see verification matrix above)

The test confirmed the functionality of the front-end active components at cold conditions.

5.1.3 P_PVP_LFI_0025_01: Spike test 02

The objective of this test is to characterise 1Hz spikes caused by the DAE housekeeping sequencer in the LFI output when the full instrument is on in all four possible phase switch configurations. The test was completed without major problems and the spikes were correctly characterised and compared with those obtained in CSL in cold conditions.

Verification matrix

CPV	**P_PVP_LFI_0025_01**
June, 13-14 2009	**DoY 164-165 OD 31**
Duration	**16:00:00**
Test name:	Spike test 02
Test objectives:	Once the Scientific Telemetry is active and the SCS cool down is proceeding this test can be conducted in parallel and it will used for a reference point because the same test was performed on ground during TV-TB test campaign. LFI is in Normal Science mode: power groups are ON and nominal biases (resulting from TV-TB test campaign) are set.

Verification matrix

Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected events packets (LFI IOT expects OOL alarm for the FPU sensors)	Yes				
No unexpected features	Yes				
Data saved and stored at DPC	Yes				

Results

The procedure has been run on June 13-14th, 2009 without any problems and the test was completed successfully.

The results confirm findings of the spike01 test. Spikes are observed, the majority of them are correlated with the DAE HK sequencer status and appear to be stable in frequency (many of them also in amplitude) over time.

No additional frequency spikes are introduced by the receiver front-ends in the four phase switch configurations. As a similar test was not run in CSL we have compared the spikes from the data acquired during the SPIKE-02 test with those from the data acquired during the CRYO-02 test in CSL.

5.1.4 P_PVP_LFI_0150_01: Spike test 01 bis

The objective of this test is to characterise 1Hz spikes caused by the DAE housekeeping sequencer in the LFI output when only the DAE box and the radiometer BEMs are on. The test was completed without major problems and the spikes were correctly characterised and compared with those obtained in a equivalent on ground test conducted with the satellite in cold conditions during TV-TB tests in CSL.

Verification matrix

CPV	**P_PVP_LFI_0150_01**	
June, 14 2009 14:00z	**DoY 165**	**OD 31**
Duration	**4:00:00**	
Test name:	Spike test 01 part B	
Test objectives:	Characterise DAE frequency spikes with FEMs off. Once the Scientific Telemetry is active and the SCS cool down is proceeding this test can be conducted in parallel and it is used for a reference point because the same test was performed on ground during TV-TB test campaign. LFI is in Normal Science mode: power groups are ON but biases are set in order to have FEMs off.	

Verification matrix					
Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected events packets (LFI IOT expects OOL alarm for the FPU sensors)	Yes				
No unexpected features	Yes				
FEM on again at the end of the test	Yes				
Data saved and stored at DPC	Yes				

Results

The procedure has been run on June 14th, 2009 without any problem and the test was completed successfully.

Observed spikes compared very well in frequency and amplitude with those characterised during CSL tests. Spikes at 1 Hz and multiple frequencies disappear when the HK sequencer is switched off, some spikes still remain as was already observed during CSL tests.

5.1.5 P_PVP_LFI_0002_01: Drain Current Verification

This test has the objective to characterise the I-V response of LNAs when Vg1 and Vg2 are varied independently and to check the suitability of the matrix tuning tables in case the drain currents measured at the first switch on of the LFI at 20 K do not match with the ones measured during CSL tests. Possible changes in the radiometers response could be generated by ground shift in the cryo harness or to any other possible non ideal effect.
In the case different results are found w.r.t. the same test performed at satellite level in CSL, the new I -V curves substitute the old ones and are used to build the PRE- Tuning hyper-matrices.

Verification matrix

CPV	**P_PVP_LFI_0002_01**
June, 14 2009 21:20z	**DoY 165 OD 32**
Duration	**3:02:14**
Test name:	**Drain current verification**
Test objectives:	Characterise the I-V response of LNAs when Vg1 and Vg2 are independently changed over a defined set of values. It allows to investigate possible drain chganges due to ground shift or any other possible non ideal response of LNAs. Eventually correct Hyper Matrix tables accounting for bias shift. Channels are grouped in six groups.

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected events packets	Yes				
TC procedure	Yes				
No unexpected features	Yes		The agreement with on ground tests was very good. Hyper matrix tables were not corrected		
Real time data available	Yes				
Data saved and stored at DPC	Yes				

Results

The full test took about three hours, performed during day 14-06-2009 in visibility. It started on June 14th at 21.15 UTC and was completed on June 15th at 00.16.
The 4K reference Load temperature (sensor HD028260 measured temperature in the range 22.64K: 22.54K (required 22K < Tref < 35K, depending on the 4K cooldown profile)
DAE offset values were set to maximum value (2.5 V) on all channels, to avoid possible saturations.

Data analysis showed an impressive repeatability of the behaviour already measured during tests in CSL. As output, the test produced:

- A complete check of the functionality of each stage (Vg1 or Vg2) of the LNAs;
- 88 I-V Curves (44 × Vg1 + 44 × Vg2);
- The comparison with the same curves in CSL;
- The new drain currents matrixes to be used as input for the Pre – Tuning in the case some behaviour was different w.r.t. the CSL results (used to draw the Pre – Tuning matrixes).

The test demonstrated that:

- Each LNA stage responds as expected to the Vg bias changes;
- I-V curves are exactly the same as measured in CSL;
- The drain current matrices measured at CSL can be used to update the Matrixes used for the Pre Tuning phase.

As sub product, I-V curves have been used to guess at first level the Vg1 Vg2 pairs possibly providing optimal bias: it was verified that these points (one per ACA) were covered by the Pre tuning bias regions drawn for the Pre Tuning and these quadruplets were explicitly included into the 625 combinations used for the HYPER Matrix Tuning Step 1 to 4.

5.1.6 P_PVP_LFI_0003_01: Cryogenic functional test Cryo-02

This test has the objective of verifying the functionality of the LFI when it is fully switched on at 20 K for the first time. In particular we want to verify that drain currents are comparable with the values measured during CSL tests and that no unexpected features (i.e. pop-corn noise, spikes, etc) are present in the scientific data.

Verification matrix

CPV	**P_PVP_LFI_0003_01**	
June, 16 2009 02:20z	**DoY 167**	**OD 33**
Duration	**2:00:34**	
Test name:	**Cryogenic functional test CRYO_02**	
Test objectives:	This test is the same test performed on ground at cryogenic temperature during TV-TB test campaign in CSL, with exactly the same biases, and front end module at 20 K stable temperature (TSA tuned).	

Verification matrix					
Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected events packets	Yes				
TC procedure	Yes				
Power consumption as expected	Yes				
No unexpected features	Yes				
Current consumption from FEMs as expected	Yes				
Data saved and stored at DPC	Yes				

Results

The procedure has run on June 16th, 2009 without any problem and the test was completed successfully. The test has shown the functionality of the LFI instrument at 20K

Drain currents have been very close to those measured during CSL tests. In particular 43 channels showed differences within ±2% with respect to CSL. One channel, namely LFI26M2, however, showed a drain current ~8.6% higher than CSL, i.e. about 3.6% higher than the limit of 5% indicated in [RD3].

Although this discrepancy has not been understood yet, the receiver appears functional in every respect: in particular:

- Voltage outputs are consistent with CSL values once the different level of input temperature and back-end temperatures are considered
- The radiometer works correctly in switching mode, i.e. is able to reduce the knee frequency well below 1 Hz
- Data after differencing the sky and reference samples clearly show the sky signal, which is another indication that the switching scheme is working

Finally, known anomalies from CSL concerning LFI23M (which displays anomalous switching in the B/D switching configuration) and LFI28 (which inverts sky and reference tags in the configuration B/D switching, A/C = 0), have been both correctly reproduced.

5.1.7 P_PVP_LFI_0108_01-02, P_PVP_LFI_0008_01: Reference Functional Test

The Reference functional test is made of two parts each devoted to different tasks.

The first part is identical to the Cryo02 (§ 5.1.6) and is devoted to check the functionality of radiometers in all the possible phase switch and 4KHz combinations, after the HYM Tuning and to compare with the previous results. In particular, the LNAs drain currents will be compared, together with the noise properties as 1/f, white noise, spikes. The output voltage can be compared just roughly considering the sky signal, because the ref signal decreases due to 4K cooler cooldown: this rough comparison must take into account possible differences in the SCS temperature (driving the FPU temperature and hence the LNAs gain) and the radiometer Isolation (the signal leaking from the Reference loads and mixing with the Sky signal is proportional to the Reference Load temperature) .

The second part is identical to the same test performed in CSL [AD6], but it is performed with the LNAs bias set to the final configuration outcome from the HYM Tuning. This test, similar from the procedural point of view to the Cryo01, sets a reference point for the future of the survey, characterizing one by one all the LNAs measuring both the scientific output and the bias (drain currents). This operation can be repeated at any time during the survey, with a minimum effect on other channels not under test.

Verification matrix

CPV	**P_PVP_LFI_0108_01, P_PVP_LFI_0108_02**	
July, 16, 17th 2009	**DoY 196, 197**	**OD 64, 66**
Duration	**2:00:34**	
Test name:	**Cryogenic functional test CRYO_02**	
Test objectives:	This test is the same test performed on ground at cryogenic temperature during TV-TB test campaign in CSL, with exactly the same biases, and front end module at 20 K stable temperature (TSA tuned). The test has been performed once at the beginning of the CPV when not yet in final thermal conditions	

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected events packets	Yes				
TC procedure	Yes				
Power consumption as expected	Yes				
Current consumption from FEMs as expected	Yes				
No unexpected features		no	During the PS tuning verification tests, an oscillation effect on RCA 24 created saturation effect on RCA 27 (see AR 34). The test was performed again a few days later, July the 17th-18th	yes	
Data saved and stored at DPC	Yes				

CPV	**P_PVP_LFI_0008_01**
July, 28th 2009	**DoY 209 OD 76**
Duration	**2:50:48**
Test name:	**Reference functional test "flight like sequence"**
Test objectives:	The objective of the test is to perform a complete functional test of the radiometric part in stable temperature condition. The aim of this test is also to perform a functional test that mimics the one that will be done during flight and will be the reference point for any other functional test during mission. For instance if there is the need to perform a functional test on a single radiometer, there is in principle no need to switch off all the other radiometers to perform the test: all radiometers are kept on and science can be stored as usual. This is more a reference point than a functional one because at this point LFI is surely functioning as expected.

Verification matrix					
Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected event Packets	Yes				
TC procedure	Yes				
Every ACA is responding to Bias stimuli as expected	Yes				
Every P/S is responding to bias stimuli as expected	Yes				
Correct cryogenic biases are applied	Yes				
No unexpected features	Yes				
Real time data available	Yes				
Data saved and stored at DPC	Yes				

Results

LFI-0108. When one ACA is switched off to test the coupled one, on the coupled radiometer of the same RCA a power increase is registered (as expected): this caused saturation in those channels having voltage output close to the DAE limit (because of the DAE gain and offset table applied). However, this is not an indication of a problem in the radiometers but of the wrong choice in the DAE gain offset table applied.

Recommendation: when and if the test will be repeated in flight, it is important to have the possibility to modify the Gain-offset bias table in order to avoid saturation effects.

Due to the problem found on RCA 23 in the days immediately before the Reference test (inducing instabilities on other channels when the P/S is biased 1), the instrument was operated without changing the status of the P/S. The procedure was further simplified keeping the 4KHz disabled when the RCA 23 was under test.

LFI-0008. The data analysis suggested that all the units behaved as expected, at least from a qualitative point of view. In fact, this test was executed for the first time under this bias setup and hence can not have a numerical counterpart in the previous tests. However, all the radiometers seem to respond as expected to the bias stimulus: the signal increasing / decreasing is observed when switching on/off one ACA, meaning that LNAs respond properly; the signal separation is observed when changing the P/S status or at least when the I1 or I2 currents powering the phase switches are lowered /increased: it means that the phase switch respond as expected.

5.1.8 P_PVP_LFI_0027_01: Spike test 03

This test is aimed at the characterisation of the DAE frequency spikes when the full instrument is on and in nominal conditions. It consists of two acquisitions with the LFI in nominal mode, one with the DAE HK sequencer off and the second one is conducted with the DAE HK sequencer on.

The objectives of this test is to check for 1Hz frequency spikes and build spike templates for frequency domain removal.

Verification matrix

CPV	**P_PVP_LFI_0027_01**	
July, 30-31st 2009	**DoY 211-212**	**OD 78-79**
Duration	**16:00:00**	
Test name:	Spike test 03	
Test objectives:	Once the LFI is in nominal configuration with final settings (biases and science processing) this test will used for a reference point because the same test was performed on ground during TV-TB test campaign.	

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected events packets	Yes				
No unexpected features	Yes				
Data saved and stored at DPC	Yes				

Results

The test was run successfully and the results show that 1 Hz spikes are not detectable when the instrument is working in its nominal configuration.

Longer datasets will be necessary to reduce receiver noise and detect the effect in time and/or frequency domains.

5.1.9 P_PVP_LFI_0002_02-03-04: Drain Current Verification

As for the same test performed before the Hyper matrix tuning (§ 5.1.5), this test was devoted to characterise the IV response of LNAs when Vg1 and Vg2 are independently changed over a defined set of values.

In particular, it is aimed at two main purposes:

a) compare the radiometers IV response with data acquired before Hyper Matrix Tuning: this check allows to sort out any possible problems related with the functionality of the LNAs, after the many bias changes characterizing the HYM Tuning procedure.

b) Provide a detailed characterization of the radiometer response, with respect to bias changes, in the final operative conditions, that is when the optimal tuned bias are set. In fact, the accurate knowledge of the IV curves could be useful in order to check, at any time of the Planck mission, possible changes in the radiometers response due to aging, bias fluctuation or to any other criticality.

Verification matrix

CPV	**P_PVP_LFI_0002_02, P_PVP_LFI_0002_03, P_PVP_LFI_0002_04**
July, 17, 25, 28th 2009	**DoY 198, 206, 209 OD 65, 73, 76**
Duration	**3:02:14**
Test name:	**Drain current verification**
Test objectives:	Characterise the I-V response of LNAs when Vg1 and Vg2 are independently changed over a defined set of values. It allows to investigate possible drain chganges due to ground shift or any other possible non ideal response of LNAs. Channels are grouped in six groups.

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected events packets	Yes				
TC procedure	Yes		The procedure has been repeated every time new biases have been applied		
No unexpected features	Yes				
Data saved and stored at DPC	Yes				

Results

The procedure was successfully run without any problem, all biases were applied in the correct order.

Results have shown an impressive repeatability of the behaviour already measured during the previous test. Moreover, despite of the very ambiguous bias setup, also the results from P_PVP_LFI_0002_02 show a general agreement with P_PVP_LFI_0002_01.

The test output is:

- A complete check of the functionality of each stage (Vg1 or Vg2) of the LNAs;
- 88 IV Curves (44 × Vg1 + 44 × Vg2);
- A guess of the optimal bias region for each radiometer. Moreover, from this first order noise analysis, optimal noise Vg1 Vg2 pairs were identified.

From a qualitative point of view, the test showed that:

- Each LNA stage responds as expected to the Vg bias changes.
- IV curves are very similar to the corresponding curves measured in the previous test P_PVP_LFI_0002_01

5.2 LFI Tuning Tests

5.2.1 P_PVP_LFI_0005_01: ACA Hyper Matrix Pre-tuning

The Pre – Tuning is aimed at exploring the Front End LNAs bias space changing simultaneously the four Vg bias powering each radiometer (different procedure from that followed during satellite level tests in CSL), in order to focus the bias region expected to provide the best performance.

Noise Temperature is the figure of merit. It is measured roughly calculating Y factor basing on the sky – ref unbalancing over the same BEM diode when the 4KHz switching is enabled. Previous tests conducted on data from CSL campaign demonstrated that a good agreement between this rough calculation and the true Y-factor method (based on two reference temperatures provided by the 4K stage cooldown) is achievable.

Verification matrix

CPV	**P_PVP_LFI_0005_01**	
June, 16-17 2009 10:30z	**DoY 167-168**	**OD 34-35**
Duration	**26:18:12**	
Test name:	**ACA hyper matrix pre-tuning**	
Test objectives:	This test is the first check to optimise the radiometer noise temperature by tuning the Vg1 and Vg2 of every LNA for each channel. Apply an Hyper Matrix of Vg1xVg2xVg1xVg2 biases over a wide range to seek for the optimal noise and gain balance region each radiometer. Pre-Tuning is performed by setting the bias values once and recording scientific data. The 4K cooler stage temperature is required 25 K < T < 22 K, Data analysis is performed at the end of the test: Hyper Matrix tables will be produced to be used as input for Hyper Matrix Tuning	

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected event Packets	Yes				
TC procedure	Yes				
Every ACA is responding to Biases stimulus as expected	Yes				
No unexpected features	Yes				
Temperature requirement met		No	4K stage temperature is slightly below what expected, around 21.7 K but it is acceptable	Yes	
Hyper matrix tables produced	Yes				
Data saved and stored at DPC	Yes				

Results

The procedure was successfully run without any problem. All the bias applied were verified to be compliant with the input matrices.
For all the 22 radiometers it was possible to identify the minimum noise temperature regions and to produce the sampling of 22 × 22 points. In order to avoid possible errors committed by the automatic routine (sometimes unable to cover with a good accuracy the best noise temperature regions) we preferred to sample regions by hands, mostly filling the best noise temperature contour levels.
All the 22 Matrixes to be used as input for the Hyper Matrix Tuning have been produced. In addition, several consistency checks have been performed on the Pre-Tuning data, in order to have a further confirmation of the method : they are described in the next paragraphs.
Comparison with the CSL results demonstrated that CSL performance were a sub-sample of the hyper matrix tuning, in agreement with performance foreseen by the Hyper Matrix Analysis.
Pre Tuning analysis was also applied to the 1st run of the hyper matrix tuning, showing that performance showed by the re-sampled hyper bias regions are in agreement with those from the pre tuning run. This is important because it confirms that radiometers do not suffer abrupt changes in performance when bias are changed slightly in the four dimensional space.

5.2.2 P_PVP_LFI_0004_01, P_PVP_LFI_0104_01: PS tuning verification

The objective of this test, composed by two steps, is to find the optimal bias currents to the front-end phase switches that balance the wave amplitude in the two phase switch states. An optimal balance has an impact on the receiver isolation, therefore the first part of the test (P_PVP_LFI_0004_01, namely tuning) was performed before the tuning of the front-end modules amplifiers.

The second part (P_PVP_LFI_0104_01, namely verification) was performed after the tuning of the front-end modules to verify the impact on phase switch balancing of different amplifiers biases.

The test was performed only on 30 and 44GHz RCAs as planned.

Verification matrix

CPV	**P_PVP_LFI_0004_01**	
June, 17 2009 21:30z	**DoY 168**	**OD 35**
Duration	**9:59:46**	
Test name:	**P/S tuning verification**	
Test objectives:	The main objective of the test is to perform a verification of the balance of the two diodes in each PS of each FEM unit. The test is performed only on the 33 and 44 GHz RCAs, as on the 70 GHz radiometers the currents are maximized in order to reduce the transition time of the output signal between the two states of the PS. In principle the nominal bias condition derived from the RAA tests shall be the optimal one. The test is performed on each ACA, biasing each channel separately. For this purpose the ACA coupled with the one under test is switched-off. The phase switch is activated, thus producing two different output signal traces for the radiometer under test when the PS is not balanced. The balancing philosophy is described in the procedure	

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected events packets	Yes				
TC procedure	Yes				
Every P/S is responding to bias stimuli as expected	Yes				
Correct biases for P/S balancing Applied and Checked	Yes				
No unexpected features	Yes				
Data saved and stored at DPC	Yes				

CPV	**P_PVP_LFI_0104_01**
July, 15th 2009	**DoY 195 OD 63**
Duration	**9:59:46**
Test name:	**P/S tuning verification**
Test objectives:	The main objective of the test is to verify the balance of the two diodes in each PS of each FEM unit once ACA biased are tuned. The test is performed only on the 33 and 44 GHz RCAs, as on the 70 GHz radiometers the currents are maximized in order to reduce the transition time of the output signal between the two states of the PS. In principle the nominal bias condition derived from the RAA tests shall be the optimal one. The test is performed on each ACA, biasing each channel separately. For this purpose the ACA coupled with the one under test is switched-off. The phase switch is activated, thus producing two different output signal traces for the radiometer under test when the PS is not balanced. The balancing philosophy is described in the procedure

Verification matrix

Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected events packets	Yes				
TC procedure	Yes				
Every P/S is responding to bias stimuli as expected	Yes				
Correct biases for P/S balancing Applied and Checked	Yes				
No unexpected features		no	The test was performed using the new bias values resulting from previous HYM tuning tests. During the test, performed outsides visibility, each arm of every RCA is switched off and back on. While applying RCA 24 soft switch on procedure (tested on ground and in flight on CSL biases), RCA 24 S1 went in an oscillation mode that created saturation effects on RCA 27 (resident in the same power group). The effect was exactly the same already seen in CSL that indeed was cured by using the ad-hoc soft switch on procedure. Since this is a verification test and the results on the other RCAs confirmed the validity of previous values, it has been agreed the test does not need to be redone.	yes	
Data saved and stored at DPC	Yes				

Results

The following table summarizes the final optimal phase switch currents resulting from the first step. We remind that this tuning is performed only on the 30 and 44 GHz receivers. The 70 GHz receivers are biased at maximum current as lower currents would increase too much the phase switch rise time.

					I1		I2							I1		I2	
CH27	00	00	M1	LP001320	148	94	220	DC	CH28	18	00	M1	LP025320	130	82	160	A0
CH27	01	01	M2	LP002320	145	91	205	CD	CH28	19	01	M2	LP026320	127	7F	228	E4
CH27	02	10	S1	LP003320	127	7F	184	B8	CH28	1A	10	S1	LP027320	127	7F	222	DE
CH27	03	11	S2	LP004320	148	94	195	C3	CH28	1B	11	S2	LP028320	103	67	165	A5
CH24	04	00	M2	LP005320	77	4D	185	B9	CH20	1C	00	S2	LP029320	255	FF	255	FF
CH24	05	01	M1	LP006320	98	62	215	D7	CH20	1D	01	S1	LP030320	255	FF	255	FF
CH24	06	10	S2	LP007320	86	56	205	CD	CH20	1E	10	M1	LP031320	255	FF	255	FF
CH24	07	11	S1	LP008320	84	54	235	EB	CH20	1F	11	M2	LP032320	255	FF	255	FF
CH21	08	00	S2	LP009320	255	FF	255	FF	CH19	20	00	S2	LP033320	255	FF	255	FF
CH21	09	01	S1	LP010320	255	FF	255	FF	CH19	21	01	S1	LP034320	255	FF	255	FF
CH21	0A	10	M1	LP011320	255	FF	255	FF	CH19	22	10	M1	LP035320	255	FF	255	FF
CH21	0B	11	M2	LP012320	255	FF	255	FF	CH19	23	11	M2	LP036320	255	FF	255	FF
CH22	0C	00	S2	LP013320	255	FF	255	FF	CH18	24	00	S2	LP037320	255	FF	255	FF
CH22	0D	01	S1	LP014320	255	FF	255	FF	CH18	25	01	S1	LP038320	255	FF	255	FF
CH22	0E	10	M1	LP015320	255	FF	255	FF	CH18	26	10	M1	LP039320	255	FF	255	FF
CH22	0F	11	M2	LP016320	255	FF	255	FF	CH18	27	11	M2	LP040320	255	FF	255	FF
CH23	10	00	S2	LP017320	255	FF	255	FF	CH26	28	00	M2	LP041320	153	99	165	A5
CH23	11	01	S1	LP018320	255	FF	255	FF	CH26	29	01	M1	LP042320	108	6C	255	FF
CH23	12	10	M1	LP019320	255	FF	255	FF	CH26	2A	10	S2	LP043320	93	5D	225	E1
CH23	13	11	M2	LP020320	255	FF	255	FF	CH26	2B	11	S1	LP044320	135	87	235	EB
CH25	14	00	M1	LP021320	154	9A	245	F5									
CH25	15	01	M2	LP022320	79	4F	255	FF									
CH25	16	10	S1	LP023320	79	4F	205	CD									
CH25	17	11	S2	LP024320	119	77	225	E1									

Also the 4KHz status was provided as an output of the analysis. Since no problems were observed in the output voltage for each PS tuning, the baseline values were used and reported in the following table.

		4KHZ A/C		4KHZ B/D		PS A/C		PS B/D	
CH27	LP049320	C24	0	C25	1	C26	0	C27	0
CH24	LP050320	C24	0	C25	1	C26	0	C27	0
CH21	LP051320	C24	0	C25	1	C26	1	C27	0
CH22	LP052320	C24	0	C25	1	C26	1	C27	0
CH23	LP053320	C24	1	C25	0	C26	1	C27	0
CH25	LP054320	C24	0	C25	1	C26	0	C27	0
CH28	LP055320	C24	0	C25	1	C26	1	C27	0
CH20	LP056320	C24	0	C25	1	C26	1	C27	0
CH19	LP057320	C24	0	C25	1	C26	1	C27	0
CH18	LP058320	C24	0	C25	1	C26	1	C27	0
CH26	LP059320	C24	0	C25	1	C26	0	C27	0

The comparison with CSL showed a good matching and the robustness of the tuning strategy.

Due to the oscillation in the RCA24 and the saturation on the RCA27 the purpose of this test was not reached. Even if at first order the PSW tuning test results were confirmed, any second order effects on PSW tuning due to the different amplifier biases may not be found with this test.

One AR was raised during the test (see also § Error: Reference source not found):

AR	Date	Description
P_SC-34	7/15/2009	During the PS Tuning Test on DOY196 the RCA24 S1 arm showed oscillatory behaviour. This was seen during the data analysis.

5.2.3 P_PVP_LFI_0102_01: Stability Check

This test is a 12 hours data acquisition in switched mode and pseudo-stable thermal conditions. The only relevant instability is determined by the sky signal and by the 4K cooler that during this test is slowly drifting with a level of fluctuations which is not nominal (the cooler is not tuned yet at this stage).

The objective of this test is to verify that no particular signal instabilities are present in the radiometric data (e.g. pop-corn noise or unknown frequency spikes).

Knee frequencies are calculated from differenced data and a qualitative check is done in order to be sure that differencing is effective in reducing 1/f instabilities. No requirement can be put at this stage (i.e. with the un-tuned 4K at ~20K) on the actual value of the knee frequency.

Verification matrix

CPV	**P_PVP_LFI_0102_01**	
June, 18 2009 16:45z	**DoY 169**	**OD 35-36**
Duration	**12:00:00**	
Test name:	**Stability check**	
Test objectives:	Check for instabilities (Scientific signal and HK) in undisturbed conditions to verify no un-expected features (Pop-corn noise, spike, current drops) are present.	

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected events packets	Yes				
TC procedure			N/A		
No unexpected features	Yes				
Data saved and stored at DPC	Yes				

Results

The acquisition has been performed starting on June, 18th 2009 and no problems have been evidenced. All channels behaved as expected. In particular spikes were consistent with those measured during the Spike-02 test and during the Cryo-02 test. No sign of pop-corn noise or other anomalous jumps has been seen in the radiometric data or in the drain currents.

All knee frequencies are reduced by several times by the differencing scheme and for several channels the value after differencing is even less than 0.1 Hz. The most noticeable source of instability (apart from the sky, which is clearly visible in time and frequency domains) is from the 4K reference load temperature. This is of course expected given the non-optimised conditions in which the test has been run.

5.2.4 P_PVP_LFI_0105_01, P_PVP_LFI_0105_02, P_PVP_LFI_0105_03: ACA Hyper Matrix tuning step 1, 2, 3, 4

The main objective of this test is to find the optimal bias voltages (gate 1 and gate 2 voltage) for the two paired ACAs of each radiometer, following the same scheme of the PRE – Hyper Matrix Tuning. A fine Tuning is also performed over 15 Vg quadruplets per each ACA, that are expected to provide the best performance following the analysis of Pre Tuning Data.

Hence, the HYM Tuning will provide 22 settings (one per radiometer) of 6 parameters each ($Vg1_i$, $Vg2_i$, $Vg1_j$, $Vg2_j$, Vdi, Vd_j, where i and j are two paired ACAs) allowing to get the best performance from the LFI radiometers.

Figure of merit in the analysis are Noise Temperature and Isolation.

Tuning is performed by running the procedure four times at different temperatures of the 4K Reference Load, ranging from about 22K to 4K.

Although only two temperatures with enough separation (20K and 4K) are enough to provide information about Noise temperature and the Isolation, four steps also allow characterizing with a good accuracy the linear response of radiometers.

The Input matrixes contain 625 quadruplets and are the result from the Pre – Tuning analysis.

Verification matrix

In the verification matrix reported below we show in red the event on LFI24 that prevented the first tuning step to be completed on LFI24. This was recovered in a subsequent additional step.

CPV	**P_PVP_LFI_0105_01**
June, 19-21 2009 19:00z	**DoY 170-172 OD 37-38**
Duration	**33:12:32**
Test name:	**ACA hyper matrix tuning step 1**
Test objectives:	The scope of this test is to check the optimisation of the radiometer noise temperature by tuning the Vg1, Vg2 and Vdrain of every LNA for each channel. Apply an Hyper Matrix of Vg1xVg2xVg1xVg2 biases to seek for the optimal noise and gain balance each radiometer.For each radiometer, also the drain voltage is tuned over three values corresponding to the best 15 Vg quadruplets. Tuning is performed by setting the bias values four times (at four different temperature states of the 4K Reference Load) and recording scientific data. The first temperature state is before the start of the 4K cooler cooldown, i.e. at about 23 K.

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected event Packets	Yes				
TC procedure	Yes				
Every ACA is responding to Biases stimulus as expected	Yes				
No unexpected features	Yes				
Temperature requirement met		No	4K stage temperature is below what expected, around 19.5 K, but cooldown can not be stopped or slow down. This is acceptable	Yes	
Data saved and stored at DPC	Yes				

CPV P_PVP_LFI_0105_02
June, 22-24 2009 22:00z DoY 173-175 OD 40-41
Duration 33:12:32
Test name: **ACA hyper matrix tuning step 2**

Test objectives:

The scope of this test is to check the optimisation of the radiometer noise temperature by tuning the Vg1, Vg2 and Vdrain of every LNA for each channel. Apply an Hyper Matrix of Vg1xVg2xVg1xVg2 biases to seek for the optimal noise and gain balance each radiometer.For each radiometer, also the drain voltage is tuned over three values corresponding to the best 15 Vg quadruplets. Tuning is performed by setting the bias values four times (at four different temperature states of the 4K Reference Load) and recording scientific data. The second temperature state is when the 4K temperature stabilizes around the LVHX1 temperature (18K)

Verification matrix

Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected event Packets	Yes				
TC procedure	Yes				
Every ACA is responding to Biases stimulus as expected	Yes				
No unexpected features	Yes				
Temperature requirement met	Yes		4K stage temperature is as expected, around 18.6 K		
Data saved and stored at DPC	Yes				

CPV P_PVP_LFI_0105_03
June, 25-26 2009 13:30z DoY 176-177 OD 43-44
Duration 33:12:32
Test name: **ACA hyper matrix tuning step 3**

Test objectives:

The scope of this test is to check the optimisation of the radiometer noise temperature by tuning the Vg1, Vg2 and Vdrain of every LNA for each channel. Apply an Hyper Matrix of Vg1xVg2xVg1xVg2 biases to seek for the optimal noise and gain balance each radiometer.For each radiometer, also the drain voltage is tuned over three values corresponding to the best 15 Vg quadruplets. Tuning is performed by setting the bias values four times (at four different temperature states of the 4K Reference Load) and recording scientific data. The third temperature state is when 16K <T4K< 14K.

Verification matrix

Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected event Packets	Yes				
TC procedure	Yes				
Every ACA is responding to Biases stimulus as expected	Yes				
No unexpected features	Yes				
Temperature requirement met		No	4K stage temperature is slightly above what expected, around 16.7 K, but it was already agreed that this is acceptable	Yes	
Data saved and stored at DPC	Yes				

CPV	**P_PVP_LFI_0105_04**
July, 7th-10th 2009 13:00z	**DoY 188-190 OD 55-58**
Duration	**33:12:32**
Test name:	**ACA hyper matrix tuning step 4**
Test objectives:	The scope of this test is to check the optimisation of the radiometer noise temperature by tuning the Vg1, Vg2 and Vdrain of every LNA for each channel. Apply an Hyper Matrix of Vg1xVg2xVg1xVg2 biases to seek for the optimal noise and gain balance each radiometer.For each radiometer, also the drain voltage is tuned over three values corresponding to the best 15 Vg quadruplets. Tuning is performed by setting the bias values four times (at four different temperature states of the 4K Reference Load) and recording scientific data. The fourth temperature state is after the cooldown is completed (at ~ 4.5 K). Data analysis is performed at the end of the fourth step according to the procedure specified

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected event Packets	Yes				
TC procedure	Yes				
Every ACA is responding to Biases stimulus as expected	Yes				
No unexpected features		no	The LFI went into an expected mode (REBA crash) due to the time verification TC. See AR P_SC-25. The test has been repeated.	yes	
Temperature requirement met		no	4K fluctuations above the requirements, some blocks have been repeated	yes	
Correct biases Produced, Applied and Checked	Yes				
Data saved and stored at DPC	Yes				

Results

The procedure was successfully run without any problem. All the bias effectively applied were verified to be compliant with the input matrixes, using an IDL code extracting bias from the test data and comparing with the test procedure.

Despite of the long duration and of the complicate procedure run, the Hyper Matrix Tuning was completed successfully. Actually, the HFI team was able to provide 4K reference load thermal conditions close to the requirement, enabling to perform the data analysis with a good accuracy.

Results revealed a very good internal consistency. In fact, all results obtained at the end of the fourth step were in good agreement with the Pre-Tuning analysis and with results from the CSL Tuning, at least for those bias points common to the two tests.

The non linear model, applied to the 30 and 44 GHz channels, provided optimal bias not far from the points chosen. Moreover, the analysis performed only on the fourth run using the pre-tuning method (to minimize the non linear behaviour of the radiometers) showed a good agreement with the linear model.

The tuning activity resulted in a new bias table where almost all the gate voltage bias have been changed w.r.t. the CSL values.

In several cases (four) the Drain voltage Tuning suggested that new drain voltage pairs could improve results.

For almost all the radiometers, tuning resulted in new bias configurations characterized by having , w.r.t. CSL setup:

- Lower noise temperature;
- Improved Isolation;

- Better LNAs drain current balancing.

One AR was raised during the test (see § 6.1):

AR	Date	Description
P_SC-25	7/4/2009	LFI Deactivation during HYM#4.

5.2.5 P_PVP_LFI_0009_01-2-3, P_PVP_LFI_0109_01-2-3,P_PVP_LFI_0013_01 -2: DAE offset & gain tuning and verification

In this report we show the results of the DAE calibration activity performed during the CPV test phase of the Planck/LFI instrument. The activity has the purpose of funding the best gain and offset values for the 44 ACA implemented in the LFI, and to characterize the so-called "offset problem", i.e. a spurious offset that the DAE applies to scientific data under some conditions.

These two objectives are accomplished by a test in which all the offset and gain stages are exercised and the corresponding voltage output is recorded.

During the CPV phase the DAE calibration has been repeated twice, because after the first calibration a new configuration for the LFI ACA biases has been loaded and the absolute voltage levels fed to the DAE have changed consequently.

Verification matrix

CPV	**P_PVP_LFI_0009_01, P_PVP_LFI_0109_01, P_PVP_LFI_0013_01 & _02**
July, 13-14th 2009	**DoY 193-194 OD 61-62**
Duration	**23:00:00**
Test name:	**DAE offset/gain tuning & verification**
Test objectives:	The objective of this test is to exercise the offset circuitry in order to verify the DAE offset and gain values at the end of the amplifier chain. During the FM test was discovered that the offset value applied by circuitry has some dependence from the input signal, so a sort of calibration/adjustment activity is foreseen to obtain data that could be checked for performances of the instrument. (Refer to FM Test Report or to NC 4122)

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected event Packets	Yes				
TC procedure	Yes				
No unexpected features		no	The test was performed using the new bias values resulting from previous HYM tuning tests. During the test, performed outsides visibility, each arm of every RCA is switched off and back on. While applying RCA 24 soft switch on procedure (tested on ground and in flight on CSL biases), RCA 24 S1 went in an oscillation mode that created saturation effects on RCA 27 (resident in the same power group). The effect was exactly the same already seen in CSL that indeed was cured by using the ad-hoc soft switch on procedure. Since this is a verification test and the results on the other RCAs confirmed the validity of previous values, it has been agreed the test does not need to be redone.	yes	
Data saved and stored at DPC	Yes				

CPV	**P_PVP_LFI_0009_02, P_PVP_LFI_0109_02**
July, 25th 2009	**DoY 205** **OD 73**
Duration	**2:30:00**
Test name:	**DAE offset/gain tuning & verification**
Test objectives:	The objective of this test is to exercise the offset circuitry in order to verify the DAE offset values at the end of the amplifier chain. During the FM test was discovered that the offset value applied by circuitry has some dependence from the input signal, so a sort of calibration/adjustment activity is foreseen to obtain data that could be checked for performances of the instrument. (Refer to FM Test Report or to NC 4122)

Verification matrix

Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected event Packets	Yes				
TC procedure	Yes				
No unexpected features	Yes				
Data saved and stored at DPC	Yes				

CPV	**P_PVP_LFI_0009_03, P_PVP_LFI_0109_03**
July, 27th 2009	**DoY 207** **OD 75**
Duration	**2:30:00**
Test name:	**DAE offset/gain tuning & verification**
Test objectives:	The objective of this test is to exercise the offset circuitry in order to verify the DAE offset values at the end of the amplifier chain. During the FM test was discovered that the offset value applied by circuitry has some dependence from the input signal, so a sort of calibration/adjustment activity is foreseen to obtain data that could be checked for performances of the instrument. (Refer to FM Test Report or to NC 4122)

Verification matrix

Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected event Packets	Yes				
TC procedure	Yes				
No unexpected features	Yes				
Data saved and stored at DPC	Yes				

Results

In this report we discussed the procedures and the results of the DAE calibration activity during the CPV phase. The calibration has the purpose of finding the best values for the offset and the gain applied by the DAE to the input voltage before the digitization. Finding the best parameters means to find a couple (g; V_{ofs}) of values for each of the 44 ADC that makes the following statements true:
(1) there are no saturations in the signal leaving the DAE, and (2) the output optimally uses the allowed digital range $[0; 2^{14} - 1]$. Also, an unwanted offset introduced in some special situations by the DAE (the so-called "no-fly zone" effect) requires to be handled with great care in order not to introduce systematic effects in the measured signal.

The calibration of the DAE has been performed twice during the CPV, as after the first configuration the LFI calibration team decided to alter the FEM biases of a few channels, therefore changing the absolute level of the signal. This in turns invalidated the first analysis and required us to repeat the process.
The analysis of the two data sets has been discussed in this document. The results can be schematized as follows:
1. Both calibrations have been performed successfully. The procedure developed during the RAA QM/FM tests and the tests at CSL has been consolidated and is now semi-automatic, requiring no more than a few hours to produce a sound calibration table;
2. We have the proof that the ”no-fly zone" effect is remarkably stable, as from the analysis of the CPV tests we have found the very same results of the RAA FM test campaign (Summer 2006). Also, we finally have the evidence that this effect - which impacts the offset applied to the data - does not depend on the DAE gain.

5.2.6 P_PVP_LFI_0014_01: Blanking Time

This test consists in five steps, of about 15 minutes, with different blanking times: 15 µs, 7.5 µs, 22.5 µs, 30 µs and again 15 µs. In particular we want to verify that:

- no current drops or abrupt variations are observed in FEM drain currents;
- no frequency spikes are observed besides those already characterised during the Spike-02 test;
- frequency spikes are not affected by the different blanking time values;
- no pop-corn noise is detected in radiometer voltage outputs.

Verification matrix

CPV	**P_PVP_LFI_0014_01**	
July, 16, 17th 2009	**DoY 196, 197**	**OD 64, 66**
Duration	**1:00:00**	
Test name:	**Blanking Time**	
Test objectives:	Check receiver noise properties in different DAE blanking time conditions: - Check that whine noise scales correctly with Blanking Time - Check that frequency spikes do not change with Blanking Time	

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected event Packets	Yes				
TC procedure	Yes				
No unexpected errors during software optimization runs	Yes				
No unexpected features		no	During the PS tuning verification tests, an oscillation effect on RCA 24 created saturation effect on RCA 27 (see AR P_SC-34). The test was performed again a few days later, July the 17th-18th	yes	
Data saved and stored at DPC	Yes				

Results

The Blanking Time Verification Test has been correctly run and the data have been analysed. We can summarise the results as follows:

- drain currents showed a very good stability

• the spikes observed during this test appear to be the usual well known 1 Hz spikes from the DAE housekeeping sequencer and they are independent from the blanking time, as expected;
• no pop-corn noise is detected in radiometer voltage outputs;
• un-calibrated white noise are quite the same changing the blanking time.

5.2.7 P_PVP_LFI_0010_01-2, P_PVP_LFI_0110_01-2, P_PVP_LFI_0011_01-2: REBA tuning and check

The LFI SPU is a module of the REBA whose main purpose is to compress the scientific data acquired by the radiometers and digitized by the DAE. The data compression is a crucial feature of Planck, since its angular resolution and high data acquisition frequency forbid the transmission to Earth of the full data acquired during the mission.

The compressor uses a mix of high-level techniques that reduce the data size by discarding information that is either not scientifically relevant (e.g. at very high frequencies) or dominated by the intrinsic radiometric noise. It is therefore extremely important to calibrate the SPU so that no scientifically relevant information is discarded during the compression.

Each calibration test is made by two parts:

1. The first part requires the acquisition mode to be set to AVR1 (uncompressed acquisition) for 45 minutes per detector. The data acquired during the first part are used to find 44 sets of parameters (one per each detector) for the REBA compressor.

2. After the REBA has been programmed with these parameters, a second acquisition in compressed mode (COM5) of 22 h is done. The performances of the compressor are derived from these data and compared with the expectations.

The purpose of the test is to produce a set of 44 parameters (one per each LFI channel) that allows the instrument to compress the data with a compression ratio $c_r \sim 2.4$ and a quantization error which is the lowest possible (ε_q/σ must be less than 0.1 for the differenced and the total-power signals).

The calibration of the compressor had to be done twice. This was needed because a number of evidences showed that the ACA biases needed further tuning after the first calibration. The second calibration produced the parameters used during the First Light Survey (FLS) and the subsequent “nominal" acquisition that is still ongoing.

The test is then followed by the REBA check. The verification of the calibration of the REBA compressor is conceptually simple: the LFI is kept in its nominal state with the 44 detectors acquiring data in COM5 (compressed) mode and with one detector at time acquiring data in AVR1 (uncompressed) mode for 15 minutes as well. The time required to have enough data for a verification would be 22 hours (i.e. having two AVR1 chunks of 15 minutes each per each detector).

Verification matrix

CPV **P_PVP_LFI_[illegible], P_PVP_LFI_[illegible], P_PVP_LFI_[illegible]**
July, [illegible] th [illegible] DOY [illegible] OD [illegible]
Duration [illegible]
Test name: **REBA tuning verification**
Test objectives: Some parameters in the REBA have to be optimized in function of the signal input to have the best performance of the compressor. The optimization is done by software but there is the need to acquire some data for each radiometer in Type one mode with nominal N Averaging parameters.

Verification matrix					
Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected event Packets	Yes				
TC procedure	Yes				
No unexpected errors during software optimization runs	Yes				
List of REBA Parameters updated in LFI		no	During the setting of the new REBA compression parameters, a problem occurred that prevented the prosecution of the test (see P_SC-[illegible]) The SPU has been resetted and this operation cured the problem but the reason why this happened is still under investigation.	yes	
Data saved and stored at DPC	Yes				

CPV **P_PVP_LFI_[illegible], P_PVP_LFI_[illegible], P_PVP_LFI_[illegible]**
July, [illegible] th [illegible] DOY [illegible] OD [illegible]
Duration [illegible]
Test name: **REBA tuning verification**
Test objectives: Some parameters in the REBA have to be optimized in function of the signal input to have the best performance of the compressor. The optimization is done by software but there is the need to acquire some data for each radiometer in Type one mode with nominal N Averaging parameters.

Verification matrix					
Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected event Packets	Yes				
TC procedure	Yes		The test (P_PVP_LFI_[illegible]) has been repeated because new biases have been setted.		
No unexpected errors during software optimization runs	Yes				
List of REBA Parameters updated in LFI		no	As before (see P_PVP_LFI_[illegible] P_SC-[illegible]) during the setting of the new REBA compression parameters, a problem occurred that prevented the prosecution of the test. The SPU has been resetted and this operation cured the problem.	yes	
Data saved and stored at DPC	Yes				

Results

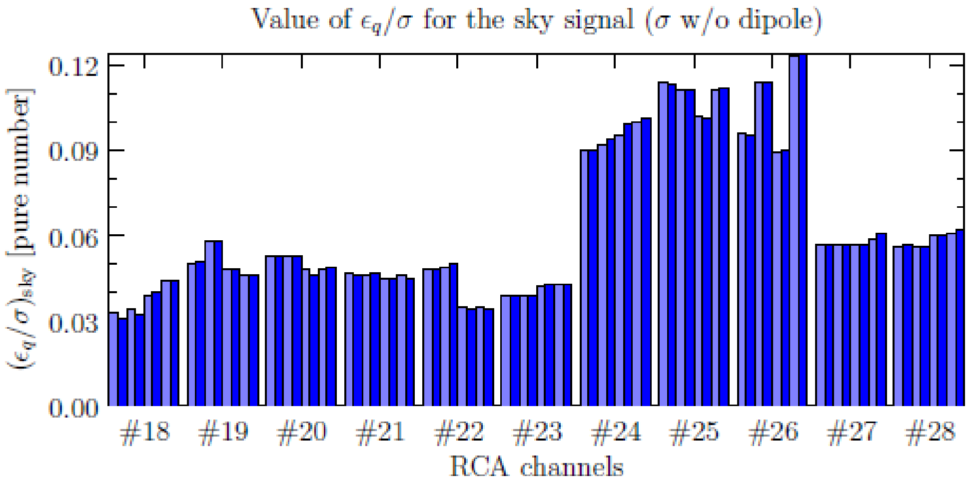
The results of the two calibration are shown in the following tables. Plots of the compression ratio, data rate and quantization errors are also shown.

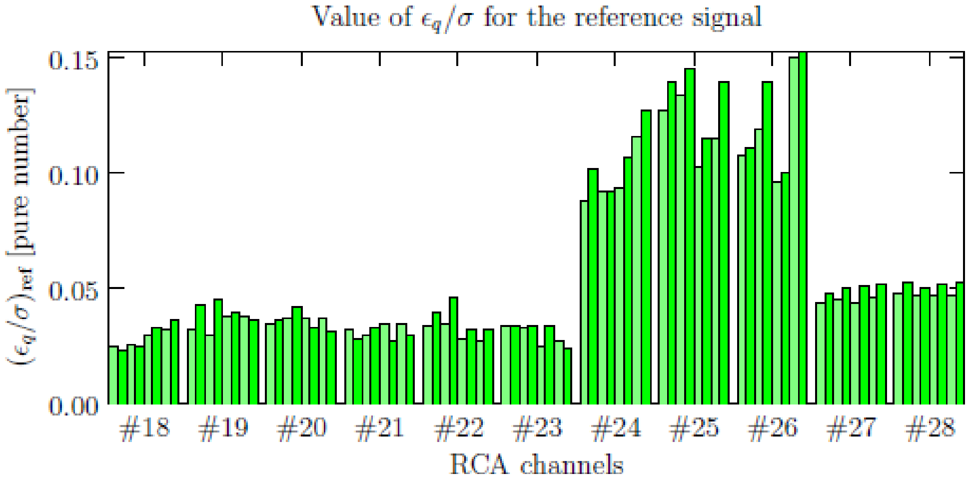
Ch.	c_r	$\epsilon_q/\sigma_{\rm sky}$	$\epsilon_q/\sigma_{\rm ref}$	$\epsilon_q/\sigma_{\rm dif}$	Data rate [bps]
1800	2.40	0.0202	0.0096	0.1576	1102.85
1801	2.40	0.0873	0.0297	0.0430	1101.45
1810	2.40	0.0488	0.0326	0.0531	1098.65
1811	2.40	0.1228	0.0703	0.0373	1100.93
1900	2.38	0.0489	0.0341	0.0488	1110.15
1901	2.38	0.0552	0.0345	0.0433	1108.36
1910	2.39	0.0533	0.0403	0.0447	1104.94
1911	2.38	0.0501	0.0378	0.0464	1107.75
2000	2.36	0.0549	0.0400	0.0412	1118.39
2001	2.36	0.0571	0.0384	0.0407	1117.48
2010	2.40	0.0512	0.0340	0.0488	1102.89
2011	2.40	0.0529	0.0352	0.0480	1101.81
2100	2.40	0.0525	0.0269	0.0569	1102.57
2101	2.40	0.0499	0.0262	0.0579	1104.09
2110	2.40	0.1519	0.0706	0.0369	1102.26
2111	2.40	0.0562	0.0312	0.0564	1100.43
2200	2.38	0.0517	0.0347	0.0492	1112.53
2201	2.38	0.0531	0.0346	0.0491	1110.67
2210	2.36	0.0327	0.0272	0.0768	1116.63
2211	2.35	0.0316	0.0269	0.0800	1121.22
2300	2.38	0.0469	0.0334	0.0491	1109.75
2301	2.37	0.0430	0.0327	0.0522	1113.97
2310	2.38	0.0397	0.0296	0.0581	1110.39
2311	2.36	0.0391	0.0306	0.0538	1117.27
2400	2.40	0.1248	0.1125	0.0370	650.84
2401	2.40	0.1456	0.1206	0.0367	651.20
2410	2.40	0.1409	0.1095	0.0374	651.57
2411	2.40	0.1355	0.1058	0.0378	651.80
2500	2.44	0.0501	0.0446	0.0565	640.14
2501	2.44	0.0523	0.0425	0.0524	640.63
2510	2.40	0.1014	0.0829	0.0374	650.96
2511	2.40	0.0875	0.0611	0.0372	651.95
2600	2.40	0.0964	0.0826	0.0380	650.64
2601	2.40	0.1125	0.0901	0.0370	649.49
2610	2.40	0.0984	0.0865	0.0374	651.22
2611	2.40	0.1106	0.0900	0.0464	650.60
2700	2.39	0.1269	0.1229	0.0396	456.28
2701	2.40	0.0702	0.0468	0.0598	455.43
2710	2.40	0.1230	0.1266	0.0384	455.35
2711	2.40	0.0890	0.0886	0.0399	455.16
2800	2.41	0.0643	0.0484	0.0477	452.95
2801	2.40	0.0645	0.0496	0.0476	454.93
2810	2.40	0.1303	0.1222	0.0385	455.12
2811	2.40	0.1315	0.1320	0.0385	454.80

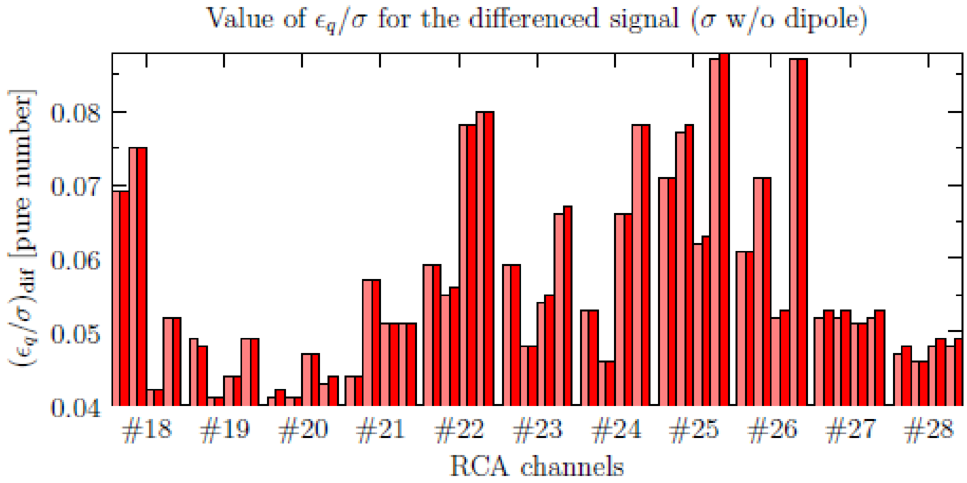
Ch.	c_r	$\epsilon_q/\sigma_{\rm sky}$	$\epsilon_q/\sigma_{\rm ref}$	$\epsilon_q/\sigma_{\rm dif}$	Data rate [bps]
1800	2.36	0.0328	0.0252	0.0694	1120.452
1801	2.38	0.0338	0.0255	0.0751	1114.205
1810	2.36	0.0394	0.0303	0.0419	1120.726
1811	2.39	0.0444	0.0315	0.0522	1110.492
1900	2.38	0.0505	0.0318	0.0487	1111.321
1901	2.38	0.0579	0.0298	0.0408	1111.843
1910	2.37	0.0478	0.0384	0.0444	1116.942
1911	2.37	0.0458	0.0384	0.0489	1116.180
2000	2.36	0.0527	0.0346	0.0411	1121.387
2001	2.35	0.0532	0.0367	0.0410	1124.873
2010	2.37	0.0481	0.0370	0.0469	1118.127
2011	2.35	0.0480	0.0370	0.0432	1125.904
2100	2.38	0.0466	0.0319	0.0444	1111.377
2101	2.40	0.0463	0.0300	0.0566	1102.517
2110	2.39	0.0452	0.0346	0.0508	1110.618
2111	2.38	0.0460	0.0347	0.0514	1113.168
2200	2.42	0.0479	0.0337	0.0593	1097.263
2201	2.42	0.0489	0.0349	0.0551	1097.643
2210	2.41	0.0354	0.0284	0.0784	1101.955
2211	2.40	0.0348	0.0274	0.0795	1106.093
2300	2.36	0.0391	0.0341	0.0592	1121.624
2301	2.36	0.0387	0.0331	0.0483	1123.747
2310	2.39	0.0418	0.0249	0.0539	1110.207
2311	2.41	0.0430	0.0265	0.0660	1101.303
2400	2.44	0.0902	0.0884	0.0528	641.233
2401	2.45	0.0917	0.0923	0.0462	640.213
2410	2.44	0.0946	0.0938	0.0658	641.981
2411	2.44	0.1001	0.1155	0.0783	640.996
2500	2.45	0.1136	0.1266	0.0712	639.419
2501	2.45	0.1106	0.1338	0.0769	639.632
2510	2.45	0.1016	0.1025	0.0624	640.806
2511	2.43	0.1107	0.1153	0.0875	644.624
2600	2.45	0.0956	0.1083	0.0613	639.300
2601	2.45	0.1141	0.1193	0.0706	638.572
2610	2.45	0.0890	0.0960	0.0525	639.405
2611	2.45	0.1226	0.1495	0.0866	639.810
2700	2.39	0.0570	0.0444	0.0521	458.010
2701	2.38	0.0568	0.0451	0.0523	459.102
2710	2.39	0.0567	0.0443	0.0508	457.829
2711	2.39	0.0593	0.0462	0.0520	457.129
2800	2.40	0.0563	0.0482	0.0474	456.442
2801	2.38	0.0556	0.0473	0.0458	460.034
2810	2.40	0.0597	0.0468	0.0479	456.080
2811	2.41	0.0613	0.0468	0.0477	454.355

Table Forecasts of the first (left) and second (right) calibration runs. The total COM5 data rate was respectively 38 028bit/s and 38055 bit/s.

The ratio between the quantization error and the intrinsic RMS of the sky, reference and differenced signals are shown below for the second REBA calibration (light bars) and verification (dark bars) tests.







The telemetry rate used to transmit COM5 compressed data (i.e. excluding the calibration channel and housekeeping information) is reported in the following table:

		Calibration	Verification
First run	(OD67)	37 342	> 23 117
Second run	(OD77)	38 057	37 114

The quantization measured during the verification tests compares quite well with the values estimated during the calibration. During OD77 we measured in many cases higher values in the value of the compression ratio, c_r. The quantization level in the differenced signal was better during the first calibration, the average of $(\varepsilon_q/\sigma)_{dif}$ being 4.7% in the 1st and 5.7% in the 2nd test. Note also that the 44 GHz channels have a higher quantization rate in the second calibration (which however helps in improving the compression ratio c_r). This is due to the less refined strategy used to calibrate the data: we applied a number of different calibration strategies during the first calibration, while the second one was performed automatically.

5.2.8 P_PVP_LFI_0007_01, P_PVP_LFI_0007_02: ACA Matrix tuning verification

Tuning of the LFI has been accomplished at several stages of integration, with different procedures. During these procedures, the system noise temperature (T_{sys}) and isolation have been used as the figures of merit for optimising performance, since they can be estimated with high signal to noise in a short period of time. In fact, for the LFI receivers, the calibrated noise and 1/f characteristics are the true indicators of scientific performance.

In principle, calibrated white noise can be derived directly from the system temperature and noise effective bandwidth, but in practice there are noise contributions and other complications which make it hard to be sure that white noise predicted by T_{sys} and bandwidth will be achieved. With a receiver topology as complex as LFI, it is even possible that optimising T_{sys} and isolation may cause us to miss the actual optimum white noise bias point.

With this in mind we developed the following verification test based on the Hypermatrix tuning:

- Set LFI for nominal operations (DAE gain and offset tuned to allow measurement of the true radiometer white noise);
- Acquire data (30 seconds) at each of the nominal hypermatrix tuning bias points, in the same manner as was done for the hypermatrix tuning. This samples the LFI bias space around the points most likely to yield good performance;
- Change the 4K load temperature by a known amount. This change is provided by the HFI team using the PID controller of the 4K stage;
- Again acquire data at all the hypermatrix bias points;
- White noise is estimated from each 30 second period, and then calibrated using the corresponding data from the known temperature step of the 4K load.

Verification matrix

CPV	**P_PVP_LFI_0007_01, P_PVP_LFI_0007_02**
July, 21st-24th 2009	**DoY 202-205 OD 69-72**
Duration	**66:26:04**
Test name:	**ACA hyper matrix tuning verification**
Test objectives:	The scope of this test is to verify the radiometer bias tuning by running the hypermatrix tuning procedure at two temperatures levels of the 4K cooler (with a temperature difference of ~ 80 mK)

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected event Packets	Yes				
TC procedure	Yes				
Every ACA is responding to Biases stimulus as expected	Yes				
No unexpected features	Yes				
Temperature requirement met	Yes				
Correct biases Produced, Applied and Checked	Yes				
Data saved and stored at DPC	Yes				

Results

The results of the white noise hypermatrix are consistent with the normal hypermatrix tuning but provide no extra power to optimise the bias. This result was unexpected. Based on both analytical and montecarlo calculations before flight we estimated only a few percent error in the calibrated white noise, which would have been sufficient.

Based on extensive tests with other data from the CPV campaign, the large scatter is not associated with the receivers per se, but probably with the very short periods available for white noise estimation. Our pre-flight estimates did not account for signal, which is problematic for integration times shorter than a single rotation of the telescope. Still, with an amplitude of 3 mK from the CMB dipole, we still shouldn't expect such large scatter. A possible explanation is in the settling time for the receivers after bias changes. In analyzing this test we allow a few seconds settling time, but it is possible that the noise characteristics are not stable in this short a time. Given the time limitations on the test, we could not consider integrations times of order 5 minutes or more per bias point, which might have given more stable and discriminatory results.

5.2.9 P_PVP_LFI_0018_01, P_PVP_LFI_0019_01: Noise Properties, 4KHz on and off

The assessment of the noise properties of the LFI instrument is the main objective of this test.

The test is split into two parts:

1. in the first part the LFI is run un-switched acquiring data in all four phase switch configurations. Power spectra from un-switched data is compared in order to assess whether there is any configuration that is preferable from the point of 1/f noise slope;

2. in the second part the LFI is run switched for several hours and the full noise properties are characterised in both switching configurations (A/C or B/D) while the non switching phase switch is kept in its nominal position.

Verification matrix

CPV	**P_PVP_LFI_0018_01**
July, 29-30th 2009	**DoY 201-211** **OD 77-78**
Duration	**24:00:00**
Test name:	Noise properties 4KHz on
Test objectives:	To characterise LFI noise properties in switched conditions in both A/C and B/D switching (apart from LFI23 for which switching configuration is not changed)

Verification matrix

Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected events packets	Yes				
No unexpected features	Yes				
Data saved and stored at DPC	Yes				

CPV	**P_PVP_LFI_0019_01**
July, 30th 2009	**DoY 211** **OD 78**
Duration	**12:30:00**
Test name:	Noise properties 4KHz off
Test objectives:	To characterise LFI noise properties in unswitched conditions in all four switch configurations (apart from LFI23 for which switching configuration is not changed)

Verification matrix

Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected events packets	Yes				
No unexpected features		No	For a procedural error data were acquired in COM5 instead than in AVR1. During data analysis, however, it was clear that the compressor was able to handle also total power data without loss of information	Yes	
Data saved and stored at DPC	Yes				

Results

The noise properties test run during the CPV has shown that the instrument behaves as expected from the point of view of the noise. Furthermore we can summarise the following conclusions:

1. the default phase switch configuration is B/D switching apart from LFI23 (A/C switching);
2. this configuration is optimal for all radiometer apart from LFI26 and LFI24M;
3. in these cases a reduction of about a factor 2 in knee frequency can be obtained by changing from B/D switching to A/C switching;
4. there is no appreciable difference in the un-switched behaviour in any of the 4 phase switch positions.

From these conclusions we can formulate the following recommendation:

1. verify feasibility of changing the switching configuration for LFI26 and LFI24M, and verify that a change in noise properties is not problematic for map-making;
2. assess the benefit of such reduction in knee frequency from the scientific point of view;

3. in case the assessment is positive implement the change in phase switch configuration.

5.2.10 P_PVP_LFI_0023_01: Dynamical Thermal Model

The purpose of the test is to characterize the dynamic behaviour of the LFI Focal Plane with no active control of the TSA temperature, evaluate transfer functions between FPU sensors and compare results with previous tests and thermal model predictions.

The test was run after a steady period of 12 hours when the instruments were working in nominal conditions, so that the comparison between the TSA on nominal setup and the TSA off is also possible as an additional information for the thermal susceptibility test.

The duration of 4 hours was agreed in order to have a sufficient number of cooler cycle monitored and at the same time to minimize the time the system is kept out of the nominal state, so to avoid other cryochain parts than LFI FPU interface to be affected.

The source of fluctuations is characterized by two main periods which are the sorption cooler typical periods:

1. the bed cycle time, which is set to 940 seconds during the test;
2. the complete cooler period which is six times larger: 5640 seconds in our case.

Two methods for evaluating the transfer functions were used. The first method consists on performing a DFT of the sensor timestreams and than evaluating the ratio of the amplitude and the difference of the phases found at the relevant frequencies of interest. The second method consists in fitting the sensor timestreams with a double sinusoidal function.

Verification matrix

CPV	**P_PVP_LFI_0023_01**
July, 29 2009	**OD 77**
Duration	**4 hours**
Test name:	**TSA failure and thermal dynamic response**
Test objectives:	Characterise the dynamic behaviour of Thermal Model and susceptibility.

Verification matrix					
Check	**Passed?**			**Recovered?**	
	Yes	**No**	**Notes**	**Yes**	**No**
No unexpected events packets	Yes				
Housekeeping and Science production telemetry as expected	Yes				
Test sequence succesfully run		No	Duration was agreed to be reduced to 4 hours. Data are enough for the analysis to be run.	Yes	
Real time data available	Yes				
Data saved and stored at DPC	Yes				

Results

The analysis carried out provides the reference values of in flight transfer functions.
The two methods give a good agreement when comparing the 1.12 mHZ to the 1.064 mHz results (the frequencies closest to the 940 s period fluctuation), see table below.
These results will be also used to optimize the flight focal plane thermal model.

	0.998 mHz		1.12 mHz		1.064 mHz		0.177 mHz	
Sensor ID	*TF Amp*	*Phase (rad)*	*TF Amp*	*Phase (rad)*	*TF Amp*	*Phase (rad)*	*TF Amp*	*Phase (rad)*
TSL1	0.132	1.58	0.113	1.99	0.113	1.79	0.520	0.95
TSL2	0.184	1.09	0.139	1.21	0.153	1.13	0.560	0.81
TSL3	0.289	0.64	0.253	0.60	0.266	0.60	0.600	0.60
TSL4	0.130	1.60	0.113	2.04	0.112	1.83	0.522	0.96
TSL5	0.164	1.27	0.125	1.50	0.136	1.37	0.554	0.87
TSL6	0.136	1.51	0.112	1.91	0.110	1.70	0.483	0.98
TSR1	0.417	0.36	0.393	0.32	0.402	0.33	0.660	0.41
TSR2	0.244	0.88	0.205	0.88	0.218	0.86	0.583	0.68
TSR3	0.250	0.86	0.209	0.85	0.222	0.84	0.589	0.68
TSR4	0.333	0.53	0.302	0.48	0.313	0.49	0.616	0.52
TSR5	0.253	0.86	0.210	0.85	0.224	0.84	0.586	0.68
TSR6	0.184	1.17	0.146	1.32	0.158	1.23	0.545	0.81

Table: Results for transfer functions evaluated from the DFT (left) and double sinusoidal function method (right)

In addition a dedicated 24 time, with all temperatures in the focal plane in a steady condition, was allocated to analyse the main characteristics of the sensors. The average temperature, standard deviation and peak-to-peak amplitude are reported in the table below.

Sensor Id	Mean T (K)	Δ T rms (K)	Δ T p-p (K)
TSA	18.50059	0.02311	0.21227
TSL1	20.44637	7.04331E-4	0.00669
TSL2	20.29393	8.10118E-4	0.00667
TSL3	19.89597	0.00128	0.01176
TSL4	20.56603	7.73461E-4	0.00554
TSL5	20.38185	5.00818E-4	0.004
TSL6	20.63433	5.03124E-4	0.00401
TSR1	19.67198	0.00344	0.03553
TSR2	20.32162	8.91561E-4	0.00667
TSR3	20.21499	8.63764E-4	0.00777
TSR4	19.84482	0.00145	0.0154
TSR5	20.20399	5.85881E-4	0.00467
TSR6	20.40109	5.14072E-4	0.004

5.2.11 P_PVP_LFI_0016_01: Thermal Susceptibility

The SCS PID was used to characterise the radiometers front end thermal susceptibility (THF). The temperature of the LFI focal plane (FPU) is changed over 4 values, each step having a duration > 3h, depending on the step. The temperature variations are of about 0.3 K each.

The measured receivers output will be characterized as a function of FPU temperature variations.

Verification matrix

CPV	**P_PVP_LFI_0016_01**	
August, 11-12 2009	**OD 89-91**	**Starting time: 09:15z Aug, 11**
Duration	**30 hours**	
Test name:	**Lfi Thermal Susceptibility**	
Test objectives:	The SCS PID will be used to characterise the radiometers THF (temperature is changed over 4 values, each step having a duration > 3h , depending on the step). Instrument FPU is excited with delta T variations of about 0.5 K each. Space and time thermal gradient are monitored	

Verification matrix					
Check	Passed?			Recovered?	
	Yes	No	Notes	Yes	No
No unexpected events packets	Yes				
Housekeeping and Science production telemetry as expected	Yes				
Test sequence succesfully run	Yes		All four steady temperature stages reached. Stability is enough for a correct data analysis		
Real time data available	Yes				
No unexpected features		No	One detector saturated (RCA24-11). Susceptibility of the 24 Side arm canl be evaluated by means of 24 Main arm, and then checked from Dynamic response test.	Yes	
Data saved and stored at DPC	Yes				

Results

In flight transfer functions between radiometer outputs and main FPU sensors temperature fluctuations are obtained. Results confirms that fluctuations in the main frame are reduced in the signal by a factor of 10 to 200 (comparable with ground test results).

This let the high resolution sensors mean fluctuation peak-to-peak amplitudes, of about 4 mK in steady condition, be reduced of at least one order of magnitude in the output timestream.

6 Anomaly Status

A few Anomalies were raised during the CPV phase. Here a short report on all of them

6.1 P_SC-25: LFI Deactivation during HYM#4

During the pass on OD52, the LFI REBA was declared Invalid. The last TM seen from LFI was the TM(1,1) acknowledgement for the on-going Hyper Matrix Tuning. At around this time the Time Verification command was executed in Real-Time during the DTCP operations.

The symptoms were similar to previous REBA Crash incidents (P-SVT1a and CSL testing), albeit with potentially different EAT/OBCP conditions for LFI during these tests. During the NNO pass the re-activation of LFI failed twice when the DPU-to-SPU connectivity was re-established due to a not appropriate TC sequence for this contingency.

Activities restarted on the CEB pass and LFI was recovered to nominal science mode.

6.2 P_SC-30: LFI SPU De-synchronization Anomaly

During the pass on DOY200 as part of the REBA Tuning Verification activity, a series of TM(5,1) reports were generated. The REBA parameters were indeed successfully updated. The VC1 was re-established at 200.10.29.06 with PFLCSAN Science Activation, but shortly afterwards the VC1 stopped [200.10.35.48].

Science deactivation was performed, reset of the SPU was commanded at 200.12.47 after passivation of the FEM. The subsequent attempt to re-establish nominal DPU-SPU-DAE connectivity failed to bring the desired configuration and the safe configuration was left on LFI into NNO LOS. At the following CEB pass, the recovery activities focused on running the LFI as during the Commissioning activities after resetting the SPU. This way the full functioning of LFI was recovered.

During the REBA Tuning Verification Check on DOY210 there was a repeat of the SPU anomaly. The same recovery procedure as last time was exercised and the nominal configuration was recovered.

In case of persistent problems the agreed action is to power off LFI REBA and perform a restart using the full commissioning power-on sequences.

6.3 P_SC-34: LFI Oscillations seen on RCA during PS Tuning Test

During the PS Tuning Test on DOY196 the RCA24 S1 arm showed oscillatory behaviour. This was seen during the data analysis.

During the following pass, the problem was cured by applying the "zero current configuration" on RCA 24 S1 and then applying RCA 24 “soft switch on procedure” using CSL biases. Finally the RCA 24 was set again to the nominal values.

6.4 P_SC-38: LFI Autonomous Function for TM-Rate triggered after activation

One AR was raised at the very end of the CPV, during the pass on DOY217 when the LFI configuration was set to the Final Configuration with the activation of the internal Monitoring and Autonomous functions (with procedure PFCPLFI_CTNC) at 10.18.

Thereafter there were TM-Rate 'Events' consistent with the Monitoring Function detecting excessive TM (above its 48kbps 24-average setting). After the final 'recovery' report at 217.13.27.07 there were no further events seen. This may have been aided by the subsequent reset commands coming in under 24hours of each other.

Because of the concern that the Reset of the MF occurring during each DTCP is not always within 24 hours of the last reset, it was decided to disable the TM-Rate MF until a clean way forward can be agreed.

The problem was indeed due to the initial time reset at the enabling of the MF, while the (TM Algorithm) COUNTER WAS NOT RESET. Applying the correct procedure the problem was not encountered any more.

6.5 P_SC-21: EDAC Intervention

Since LFI switch on (June 4th) many event reports have been generated all indicating that EDAC single errors have been encountered. The average rate is about 1 every 3 days. The corresponding memory areas are spread on DPU and SPU and both on Data and Program RAM. By now these memory areas were outside the used region of memories.

These types of events are indeed foreseen and indicate that the EDAC is working as expected. No double errors arose up to now, that would cause an error report TM(5,4), meaning that there is no memory damage.

7 Summary of measured in-flight performance compared to ground tests

Here we summarise the measured in-flight noise performance and compare them with the ground measurements performed in CSL [RD5]. A more detailed discussion will be provided in an update of [RD5].

In Tables 1 and 2 we summarise the calibrated white noise sensitivities measured in flight during the First Light Survey (data from OD94 to OD96 have been used) and in CSL during the XXX_0203 test. We essentially find the same noise level apart from two radiometers, LFI21S and LFI24M, for which the sensitivity has improved thanks to the hypermatrix tuning activity.

Table 1 - White noise sensitivities (in micro-K * sqrt(s)) per detector, per radiometer and per frequency channel calculated from FLS data (OD94-96). In boldface we indicate the channels that improved their sensitivity after hypermatrix tuning

From First Light Survey

RCA ID	M-00	M-01	M-10	M-11	RCA ID	M	S	Req.
LFI18	664	665	604	541	**LFI18**	470	403	
LFI19	709	680	659	677	**LFI19**	491	472	
LFI20	682	719	759	739	**LFI20**	495	529	
LFI21	535	560	**650**	**757**	**LFI21**	387	**493**	*362*
LFI22	593	598	743	748	**LFI22**	421	527	
LFI23	653	599	649	667	**LFI23**	441	465	
LFI24	**594**	**701**	579	518	**LFI24**	**453**	386	
LFI25	559	526	580	494	**LFI25**	383	376	*276*
LFI26	603	698	612	520	**LFI26**	457	396	
LFI27	364	366	390	413	**LFI27**	258	284	*232*
LFI28	440	437	403	392	**LFI28**	310	281	

Freq.	**Noise (uK*sqrt(s)) Measured**	**Req.**
70 GHz	133	*105*
44 GHz	165	*113*
30 GHz	141	*116*

Table 2 - White noise sensitivities (in micro-K * sqrt(s)) per detector, per radiometer and per frequency channel calculated from CSL data (test XXX_0203).

From CSL tests (extrapolated at flight input temperature + 1K telescope contribution)

RCA ID	M-00	M-01	M-10	M-11	RCA ID	M	S	Req.
LFI18	683	671	625	581	**LFI18**	479	426	
LFI19	718	675	654	669	**LFI19**	492	467	
LFI20	694	726	769	733	**LFI20**	502	530	
LFI21	542	571	828	1029	**LFI21**	393	645	*362*
LFI22	604	615	673	677	**LFI22**	431	477	
LFI23	644	596	643	656	**LFI23**	437	459	
LFI24	687	863	644	579	**LFI24**	537	431	
LFI25	601	578	634	522	**LFI25**	417	403	*276*
LFI26	669	727	634	535	**LFI26**	492	409	
LFI27	394	396	408	424	**LFI27**	279	294	*232*
LFI28	463	457	415	400	**LFI28**	325	288	

Freq.	**Noise (uK*sqrt(s)) Measured**	**Req**
70 GHz	135	*105*
44 GHz	180	*113*
30 GHz	148	*116*

In Table 3 we report sensitivities per pixel after 14 months integration on square pixels of 33', 24' and 14', respectively.

Table 3 - Sensitivity per pixel after 14 months integration for square pixels of 33', 24' and 14' respectively. Goal and requirement values are compared to measurements performed in flight (FLS) and on ground (CSL)

Noise per pixel per frequency (thermodynamic T)	30	44	70
Goal values (blue book)			
DT/T per pixel (I)	2.0	2.7	4.7
DT/T per pixel (Q,U)	2.8	3.9	6.7
Requirement values			
DT/T per pixel (I)	2.7	3.3	6.8
DT/T per pixel (Q,U)	3.8	4.7	9.6
Measured values (FLS)			
DT/T per pixel (I)	3.2	4.8	8.6
DT/T per pixel (Q,U)	4.6	6.8	12.2
Measured values (CSL)			
DT/T per pixel (I)	3.6	5.5	9.0
DT/T per pixel (Q,U)	5.0	7.7	12.7

In Tables 4 and 5 we report the 1/f noise parameters (knee frequency and slope) measured in flight during FLS and on ground at CSL. The comparison show that in flight 1/f noise performance is slightly higher (especially on the low frequency channels) compared to the ground measurements. This discrepancy is somewhat expected as the offset between the sky and reference inputs in higher in flight compared to CSL (where we had essentially perfect balance); furthermore this offset has a larger impact on the low frequency channels, for which the gain modulation factor differs more from the unity compared to the 70 GHz channels.

Although there is no clear indications of other systematic effects that might contribute to this discrepancy more in flight than on ground routine instrument data analysis activity will try to identify possible other contributions to low frequency instabilities in 30 and 44 GHz channels.

Overall the 1/f noise performance of the LFI instrument is very good; for many channels the knee frequency is smaller than the 50 mHz requirement and for all channels map making has already shown to be able to perform at its best.

Table 4 - 1/f knee frequency and slope per detector calculated from FLS data (OD94-96).

From First Light Survey (Input offset, sky - ref temperatures, ~1.5 K)

	Knee frequency (mHz)					***Slope***			
RCA ID	**M-00**	**M-01**	**M-10**	**M-11**	**RCA ID**	**M-00**	**M-01**	**M-10**	**M-11**
LFI18	23	34	21	22	**LFI18**	-0.85	-0.88	-0.88	-0.81
LFI19	18	21	79	98	**LFI19**	-0.75	-0.78	-1.03	-1.05
LFI20	9	8	18	17	**LFI20**	-0.76	-0.76	-0.76	-0.78
LFI21	33	34	22	7	**LFI21**	-0.92	-0.90	-0.84	-0.79
LFI22	23	18	44	11	**LFI22**	-0.70	-0.67	-0.79	-0.67
LFI23	101	58	37	40	**LFI23**	-0.88	-0.84	-0.88	-0.83
LFI24	66	40	50	36	**LFI24**	-0.74	-0.74	-0.75	-0.64
LFI25	8	10	15	27	**LFI25**	-0.49	-0.45	-0.58	-0.58
LFI26	128	82	124	131	**LFI26**	-0.81	-0.76	-0.75	-0.76
LFI27	129	118	67	49	**LFI27**	-0.63	-0.61	-0.65	-0.66
LFI28	73	48	42	47	**LFI28**	-0.64	-0.64	-0.68	-0.70

Table 5 - 1/f knee frequency and slope per detector calculated from CSL data (test XXX_0203).

From CSL tests (input offset, sky - ref temperatures, essentially negligible)

	Knee frequency (mHz)					*Slope*			
RCA ID	**M-00**	**M-01**	**M-10**	**M-11**	**RCA ID**	**M-00**	**M-01**	**M-10**	**M-11**
LFI18	11	19	23	21	**LFI18**	-1.61	-1.40	-1.53	-1.23
LFI19	11	18	19	20	**LFI19**	-1.44	-1.36	-1.31	-1.25
LFI20	15	17	17	15	**LFI20**	-1.23	-1.22	-1.47	-1.41
LFI21	18	18	9	9	**LFI21**	-1.46	-1.31	-1.55	-1.25
LFI22	29	15	16	19	**LFI22**	-0.96	-1.43	-1.42	-1.31
LFI23	14	18	37	67	**LFI23**	-1.67	-1.51	-1.20	-0.89
LFI24	17	19	28	24	**LFI24**	-1.34	-1.01	-0.97	-1.11
LFI25	20	31	13	49	**LFI25**	-0.94	-0.88	-1.37	-0.77
LFI26	48	23	26	35	**LFI26**	-0.78	-1.17	-1.16	-1.10
LFI27	26	33	40	21	**LFI27**	-1.41	-1.20	-1.12	-1.41
LFI28	25	23	27	24	**LFI28**	-1.30	-1.33	-1.41	-1.28

The CPV and FLS analysis of systematic rejection has confirmed the levels already measured on ground and the good systematic rejection of the LFI differential measurement strategy. More in particular the main systematics can be summarised as follows:

- **Bandpass mismatch**: this effect arises from the different in-band response shapes of the two radiometers connected to the two OMT outputs. This effect is known since ground tests and is of course present in flight, limiting, if not accounted for in data analysis, the accuracy of polarisation measurements.
  A plan is already in place to use measured bandpass information to correct measured data to guarantee optimal polarisation reconstruction. Preliminary results in this direction are already encouraging.
- **1 Hz frequency spikes**: in flight measurements have fully confirmed ground test results: 1 Hz frequency spikes coming from the DAE housekeeping sequencer are very reproducible in frequency and amplitude and their effect is highly suppressed in the differenced data, especially at 30 and 70 GHz. The residual effect will in any case be removed in time domain thanks to the synchronised characteristics of the spurious signal that can be reconstructed in time domain from the data themselves.
- **4K reference load temperature fluctuations**: in flight thermal stability of the 4K stage has shown to be generally better than that measured during ground tests. In particular at the level of the 70 GHz receivers the fluctuation level is about 5 times less than on ground.
  At the level of 30 and 44 GHz there is an improved stability in the high frequency component but a low frequency component (not present in CSL) makes the overall peak-to-peak temperature fluctuation about twice the CSL level. This does not represent a primary concern for science being the result of a slow fluctuation easily removed by map-making; analysis will however be performed to assess the effect of this instability in the radiometric data.
- **Front-end temperature fluctuations**: the level of focal plane temperature fluctuations measured in flight is comparable with ground measurements apart from an unexpected peak at low frequency (less than 50 mHz, i.e. 20 sec) that is responsible, presumably, of the low frequency component in the 4K temperature. On the other hand the FPU thermal damping is larger (more than a factor 2) compared to thermal model predictions. This result (measured on ground and confirmed in flight) makes the rejection level of the current FPU thermal fluctuations within the scientific requirement.
- **Back-end temperature fluctuations**: a 24 hours fluctuation of about 0.2 K peak-to-peak has been observed and recognised as the effect of the 24 hours DTCP transponder

activity. Although this effect is currently carefully monitored, it lies within the LFI requirement of 0.2 K/hour.

8 Conclusions and recommendations

All the LFI activities foreseen during the Calibration and Performance Verification phase have been successfully completed.

The LFI functionality has been characterised in a wide range of conditions. The instrument response has been found very close to the one experienced in CSL.

All the tuning activities have been performed successfully. In particular the hypermatrix pretuning (that was not run in CSL) yielded very satisfactory results and allowed do optimise the bias space for the four steps of the bias hypermatrix tuning. Phase switch tuning has been successfully completed providing clear indications of the optimal bias currents to be used. The bias hypermatrix tuning was also successfully completed and allowed a significant improvement on the performance of a few channels. The REBA tuning was accomplished and, with respect to CSL, allowed to improve the quantization also on the total power staying with the requirements.

In summary the LFI is healthy and ready to enter the routine operations.

9 Acknowledgements

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