TITLE:	**A critical data analysis of the RCA27 Flight Spare Tuning**
DOC. TYPE:	**TECHNICAL NOTE**
PROJECT REF.:	**PL-LFI-PST-TN-084** **PAGE:**
ISSUE/REV.:	**1.0 DRAFT** **DATE: April 2008**

Prepared by	**L. TERENZI** **F. CUTTAIA** **S. GRASSI**	**Date:** April, 2008 **Signature:**
Agreed by	**C. BUTLER** **LFI Program Manager**	**Date:** April, 2008 **Signature:**
Approved by	**N. MANDOLESI** **LFI Principal Investigator**	**Date:** April, 2008 **Signature:**

DISTRIBUTION LIST

Recipient	Company / Institute	E-mail address	Sent
LFI CTA 2 - Radiometer		planck-cta02@fisica.unimi.it	Yes

CHANGE RECORD

Issue	Date	Sheet	Description of Change	Release
0.1 DRAFT	April 2008	All	First draft of Document	

TABLE OF CONTENTS

1 ACRONYMS

BEM	Back End Module
BEU	Back End Unit
DAE	Data Acquisition Electronics
FEM	Front End Module
LNA	Low Noise Amplifier
PH/SW	Phase Switch
P/S	Phase Shifter
RAA	Radiometer Array Assembly
RCA	Radiometer Chain Assembly
REBA	Radiometric Electronic Box Assembly
S/C	Spacecraft
TBC	To Be Checked
TBD	To Be Defined
TBW	To Be Written

2 INTRODUCTION

2.1 Purpose and Scope

Scope of this document is to give a description of the perceptive analysis of the RCA27 Flight Spare tuning test results. These tests have been performed to test and verify the feasibility of different procedures for the LFI tuning to be performed in the CSL tests and in flight CPV phase.

3 APPLICABLE AND REFERENCE DOCUMENTS

3.1 Applicable Documents

3.2 Reference Documents

4 TEST SUMMARY

Three tests have been conducted on RCA27 FS :

Classic Tuning:
The same method used during RCA FM , changing REF load temperature
Just the LEG under tuning ON
Tuning performed firstly on Vg1 for each leg, then on Vg2 for both legs.

Ramp CSL like Tuning
Changing SKY load temperature, as could be foreseen in CSL (but using the reference load decreasing temperature during cooldown from 20 to 4 K).

In the flight spare tests it was performed in the following way:
First step (high temperature) in steady state (about 25K)
Vg1 ramp for both legs, one per time
The other leg is off

Second step (low temperature): three Vg1 ramps corresponding to T SKY about 18 K: each ramp is performed in a portion of the temperature curve characterized by having a different slope mK/s
The second ramp should correspond to the CSL characteristic slope (about 5mK/s)

Just the LEG under tuning is ON.

Matrix Tuning
Hypothetic method for CPV phase
Changing REF load temperature, from 25 K to 10K (the sky load temperature should be stable but actually it was at 12.9 K, during reference hot step at 25 K, and at about 11.5 K, when reference load was at 10K)
Comparison between two possible frames:

1) JUST the LEG under tuning is ON
2) BOTH LEGS coupled are ON when one is tuned.

The aim is to investigate how tuning changes by switching ON/OFF the coupled leg (because, until now, at RCA and FM level – it was always performed with the coupled leg OFF)
Vg1 ramp for several Vg2 values in both steps (high and low temperature)
In the case 1) only T_noise can be calculated
In the case 2) both T_noise and Isolation can be calculated.

The above tests produced very **different results:** aim of this analysis is to understand what can contribute to cause this differences.
Differences found are very peculiar, suggesting that something very critical affected some tests.
Baseline tuning parameters are:

Leg	Vg1 (dec)	Vg2 (dec)	Vd (dec)
S1	208	54	164
S2	208	53	164

5 Data analysis and discussion of procedures applied

Performing the analysis and looking results we observed that:

A.) Classical tuning produced a Vg1 curve substantially in agreement with JBO results (concerning the position of minimum) and with Matrix Tuning with two legs on.
B.) CSL-LIKE tuning with temperature ramps produced results far from the JBO predictions.

Results from 4 ramps in CSL like (steady state and ramps) are similar in shape (minimum position) but show considerable differences in the absolute values.
At a first glance it could seem that results **depend** on the Load chosen for changing temperature.
Another consequence is that results are substantially **independent** on having one LEG or two LEGS ON (from comparison between results at point A.)

However: <u>it does not seem reasonable</u> that just changing choice for the load we can obtain so different results. A possible thermal explanation could be related with the effective FEM temperature, but a first analysis of currents suggested that variations are not enough to justify a similar difference.
Starting from the more significant results found, attention was paid to check for some features possibly producing such a dramatic effect.
In particular, together with temperature of the loads, the values of the Phase Switch biases and status, 4KHz status, amplifiers drain and gate voltages were collected for the different tests.

The first comment is that, in the case B, the test conduction showed some discrepancies, with respect to:

<u>The procedure applied:</u>
This test is foreseen to be performed with just one leg on: it means that the 4KHz must be disabled, since it is impossible to separate between sky and ref with just one LNA on. 4KHz on can introduce and/or remove spurious signals coming from the other leg, although nominally biased as OFF: in any case, the separation between sky and ref is fictitious and could produce rubbish.

BASELINE TUNING		LOAD	TREF	TSKY	T BEM	LEG ON	PHSW STATUS		4KHz STATUS		I1 C	I2 C	I1 D	I2 D	LEG TUN
TUN091447	HOT	REF	25	12.7	315	1 per time	1	0	0	0	207	201	202	207	S1/S2
TUN091622	COLD		10	11.87	315	1 per time	1	0	0	0	207	201	202	207	S1/S3
CSL LIKE TUNING		LOAD	TREF	TSKY	T BEM	LEG ON	PHSW STATUS		4KHz STATUS		I1 C	I2 C	I1 D	I2 D	LEG
TUN181214	HOT	SKY	11	25	315	1 per time	0	0	1	0	182	202	0	0	S1
							0	0	0	1	0	0	177	232	S2
1st RAMP	COLD			18.3	315	1 per time	0	0	1	0	182	202	0	0	S1
							1	0	0	0	0	0	177	232	S2
2nd RAMP	COLD			18.2	315	1 per time	1	0	0	0	182	202	0	0	S1
							1	0	0	0	0	0	177	232	S2
3 rd RAMP	COLD			18.2	315	1 per time	1	0	0	0	182	202	0	0	S1
							1	0	0	0	0	0	177	232	S2
MATRIX 1		LOAD	TREF	TSKY	T BEM	LEG ON	PHSW STATUS		4KHz STATUS		I1 C	I2 C	I1 D	I2 D	LEG
TUN181619	HOT	REF	25	12.87	319.3	1 per time	0	0	1	0	182	202	0	0	S1
TUN281706				12.81	321		0	0	1	0	182	202	177	232	S2
TUN311338	COLD		10	11.45	??	1 per time	0	0	1	0	182	202	177	232	S1
TUN011529				11.42	321.5	1 per time	0	0	1	0	182	202	177	232	S2
MATRIX 2		LOAD	TREF	TSKY	T BEM	LEG ON	PHSW STATUS		4KHz STATUS		I1 C	I2 C	I1 D	I2 D	LEG
TUN280415	HOT	REF	25	12.97	??	2 per time	0	0	1	0	182	202	177	232	S1(S2)
TUN010237	COLD		10	11.35	??	2 per time	0	0	1	0	182	202	177	232	S1(S2)
TUN290557	HOT	REF	25	12.97	320.2	2 per time	0	0	1	0	182	202	177	232	S2(S1)
TUN021616	COLD		10	11.35	318.6	2 per time	0	0	1	0	182	202	177	232	S2(S1)

Figure 1 Vg1 TUN and VG2 TUN when MATRIX Tuning procedure is applied

<u>The values set:</u>
The test is started (hot step) with certain values and status (polarization) for the phase switches and very often finished (cold step) with different settings.

Moreover, the test is started in switching conditions (that is wrong) and completed in non switching conditions (that would be procedurally correct, but in the aim of the comparison is not correct)

The Classic Tuning and the MATRIX with two legs ON are instead correct with respect to the above points. Here follows a table summarizing the comparison between tests.

BASELINE TUNING		LOAD	TREF	TSKY	T BEM	LEG ON	PHSW STATUS		4KHz STATUS		I1 C	I2 C	I1 D	I2 D	LEG TUN
TUN121748	HOT	REF	25	12.23	315	2 per time	1	0	0	0	182	202	177	232	S1S2
TUN131410	COLD		10	11.84	315	2 per time	1	0	0	0	182	202	177	232	S1S2
CSL LIKE TUNING		LOAD	TREF	TSKY	T BEM	LEG ON	PHSW STATUS		4KHz STATUS		I1 C	I2 C	I1 D	I2 D	LEG
TUN201228	HOT	SKY	11	14.8	319.5	2 per time	1	0	1	0	182	202	177	232	S1S2
TUN230955	COLD		11	12	318.3	2 per time	0	0	1	0	182	202	177	232	S1S2

Figure 2 Vg2 TUN For Baseline TUN and CSL like TUN

The two tables above show the comparison between hot and cold steps for each test. In particular, possible causes of failures are highlighted by colouring cells in green or yellow.
Green represents some inconsistency between the hot and cold states (for example changes in PH/SW or 4KHz status).
Yellow represents any wrong setting (for instance 4KHz enabled when just one leg is on)
A green-yellow grid means that both features are present together.

To summarize in the following some comments to the test conduction are given.

Baseline Tuning:
VG1
It is well done and hot and cold states are consistent both for S1 and S2 tuning. Just phase switches currents are set with values to be checked.
Phase switch on the LEG off is correctly disabled.
The temperature step is quite large (15 K) compared to changes in the still load (sky temperature variation is about 0.8K); BEM temperature is about stable.
VG2
Well done with consistent hot and cold states.
Phase switch values different w.r.t. VG1 tuning.
Small variation in the still load (sky temperature variation is about 0.4 K); BEM temperature about stable.

CSL Like tuning:

VG1
Hot step:
It is wrong, since the 4KHz is switching when just one leg is on
Cold steps:
1st: just S1 TUN is consistent with Hot step, since it is still (although this is wrong) switching.
S2 TUN is not consistent with hot step, since 4KHz is turned OFF and the PH SW status is changed to 1 on the other LEG!

2nd & 3rd STEPS:
Both wrong, since inconsistent with HOT step: actually 4KHz is here disabled (correct) but must be compared with Hot step where it was enabled; moreover the status of PH-SW on S1 is here changed to 1 (was 0) .

VG2
Inconsistency in the PH/SW status between Hot and Cold steps
The temperature variation on changing load is very small (2.8K), in particular if compared to change on BEM temperature (1.2 K)

MATRIX TUNING 1 (1 LEG ON):

S1: it is wrong, since the 4KHz is enabled with just one leg on
S2: it could be close to be correct , since 4KHz is still enabled but in the leg OFF; however the PH/SW on the leg (S1) OFF is ON, possibly allowing some spurious radiation to income the hybrid.

MATRIX TUNING 2 (2 LEG ON):

It is correct, the 4KHz is switching in both hot and cold states and the PH SW maintains the same polarization for all the test (00)

From Matrix Tuning 2 it is clear the effect induced by the tuning procedure on the coupled LEG still (not under tuning): current increasing on the tuned LEG causes a current decreasing on the coupled leg. This means that the best way to find the exact values is to tune with both legs on (what you see is exactly what you set!); otherwise, the Tuned values found with just one leg on will be modified when also the coupled leg is switched on.

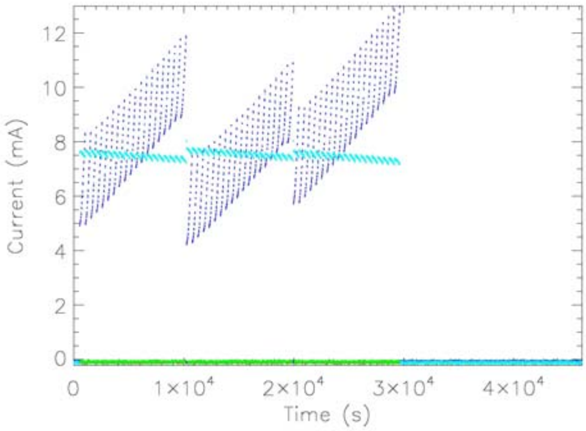


Figure 3 Drain currents behaviour during one of the matrix tuning tests

Electrical Cross talk, on this channel, is about 0.200 mA for a 3 mA variation on the leg under tuning.

6 Results and conclusion

From the above considerations it comes out that:
Just baseline tuning and MATRIX 2 tuning are consistent and can be compared.
Comparison must however take into account that baseline VG1 Tun is performed with PH/SW bias settings different from MATRIX 2.
CSL Like TUN is not performed in the correct way
MATRIX 1 TUN could be useful just regarding channel S2: however results mast be considered very carefully since it is performed with PH/SW biased on the leg that should be off.

In the following we then discuss main results and problems.

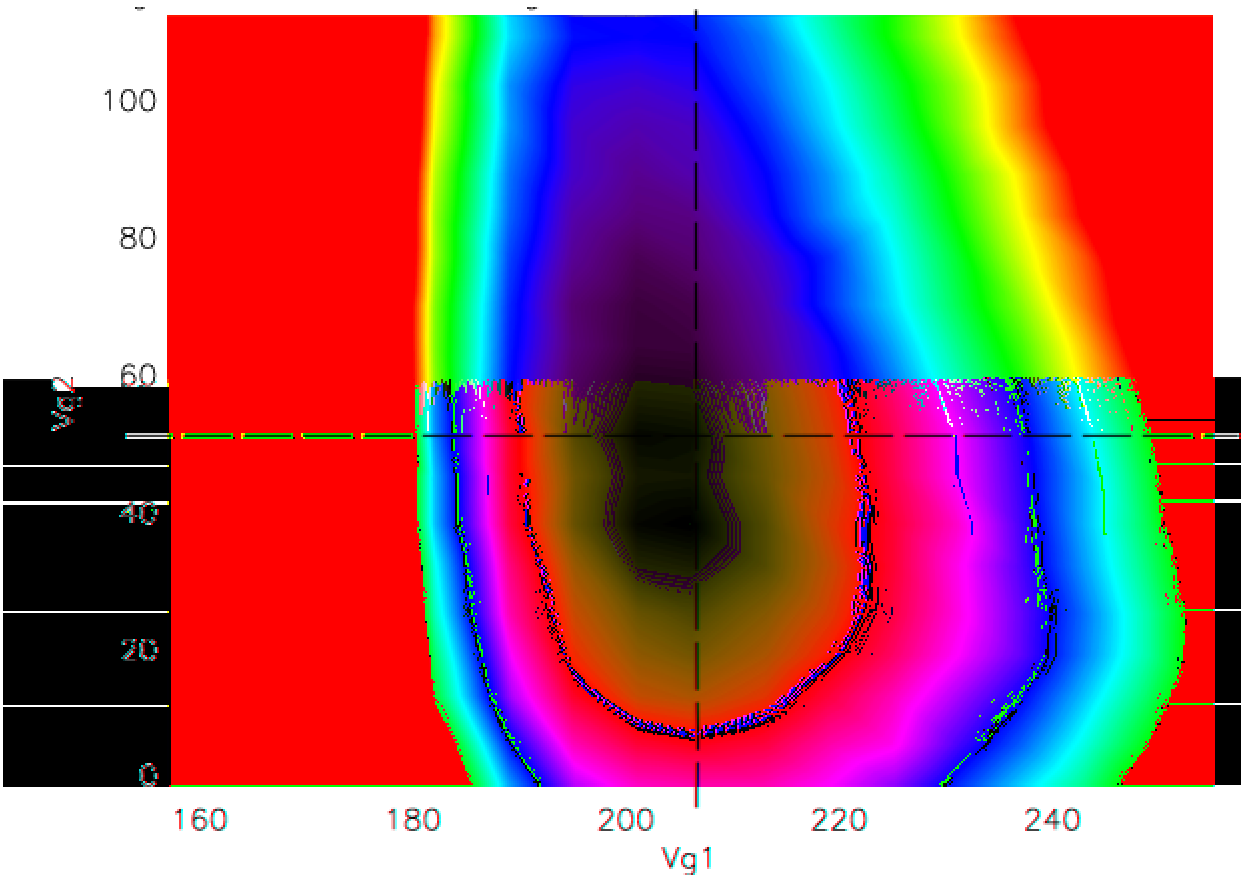


Figure 4. An example of noise temperature results from a tuning performed with a Vg1-Vg2 matrix. It refers to the S1 tuning with S2 on. The minimum of Tn = 21.8 K for detector C is located at vg1 = 206 and vg2 = 38 where Isolation is: -13.9 dB

6.1 Vg1 tuning

The final comparison reported in this section is driven by the above considerations.
In the first plot the Vg1 tuning results for the S1 amplifier are shown for several tests.

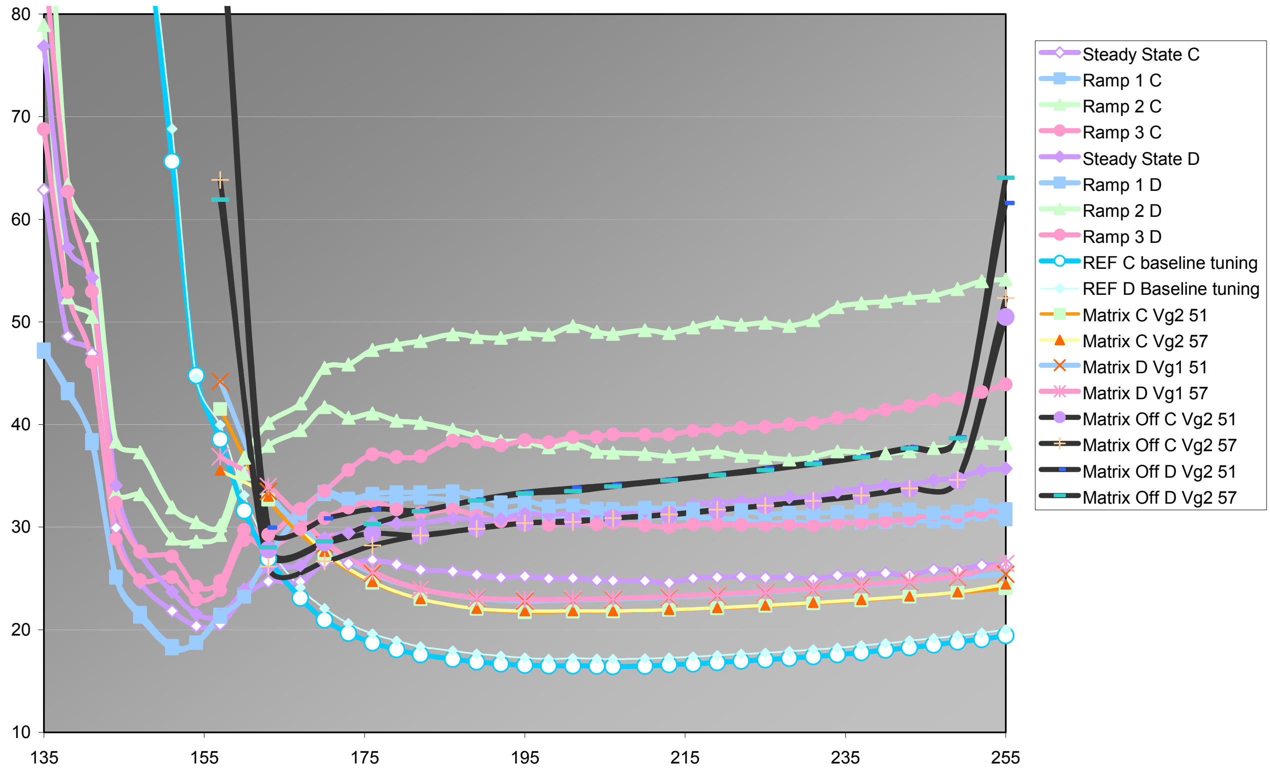


Figure 5 Comparison between S1 Vg1 tunings performed in different ways.

We selected a cut in the matrix noise temperature evaluation at the level of Vg2 51 (the horizontal cut shown in the contour plot above) and 57.
It is evident as the baseline and matrix with both leg on tests, performed in a correct and consistent way give comparable results, while CSL-like and matrix with only one leg on are far from nominal behaviour.

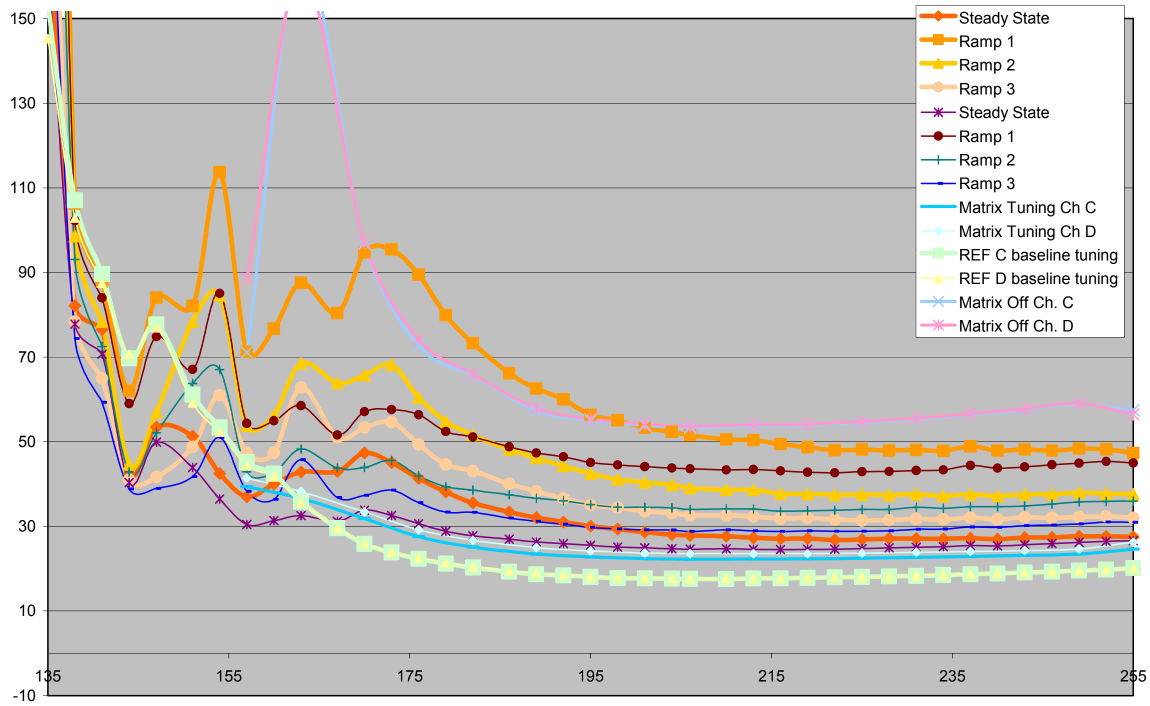


Figure 6 Comparison between S2 Vg1 tunings performed in different ways.

6.2 Vg2 tuning

The main problem arising from the Vg2 tuning analysis was, in the evaluation of the isolation, the presence of non-real numbers deriving from the logarithm of a negative number in the formula:

$$Is_{dB} = 10Log\frac{\Delta V_{fixed}}{\Delta V_{fixed} + \Delta V_{changed}}$$

where ΔV_{fixed} and $\Delta V_{changed}$ are the variation in the radiometer output referring to the load whose temperature is varying or stable.
This is an issue which is appearing in almost all vg2 tuning sessions for this flight spare run.
Some analyses were performed to check in detail this effect.
In the CSL-like tuning it appears that for about half the curve the low temperature steady stage reference signal is crossing the higher temperature signals, producing a negative ΔV, in the isolation formula.

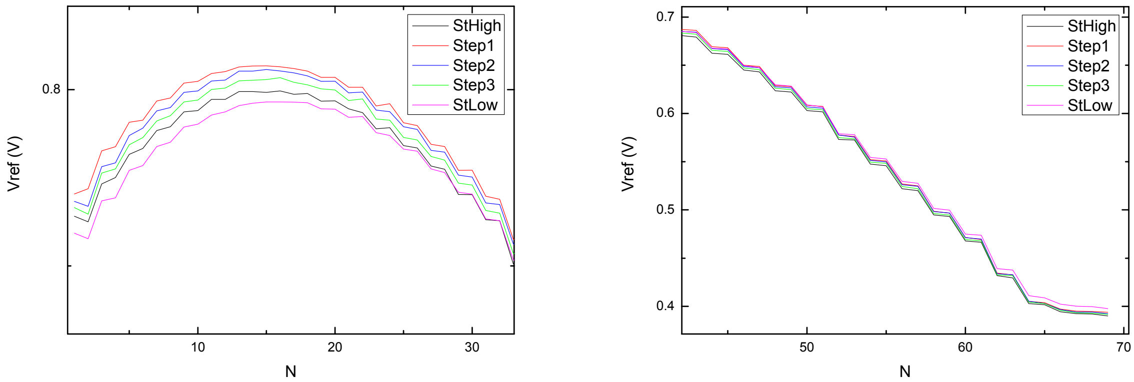


Figure 7 Comparison between the reference output during different stages of CSL Vg2 tuning (steps in sky temperature). The low temperature stage ref signal (purple curve) is crossing other.

In the following, reference temperature and BEM temperature curves during the same time ranges are reported.

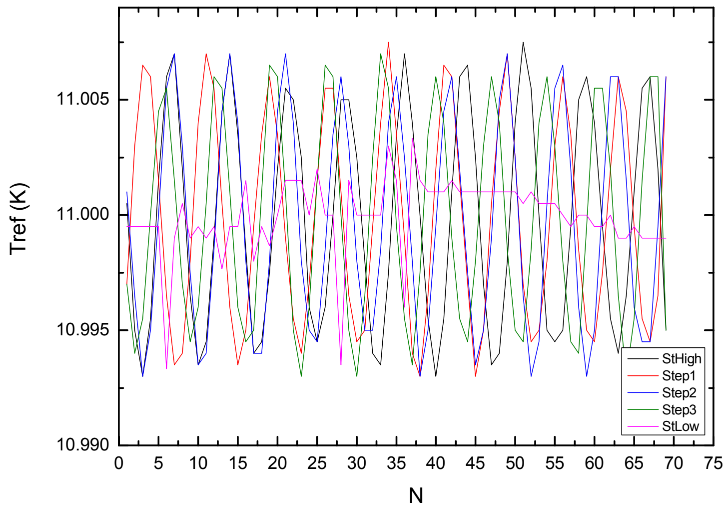


Figure 8 The reference load temperature is about stable

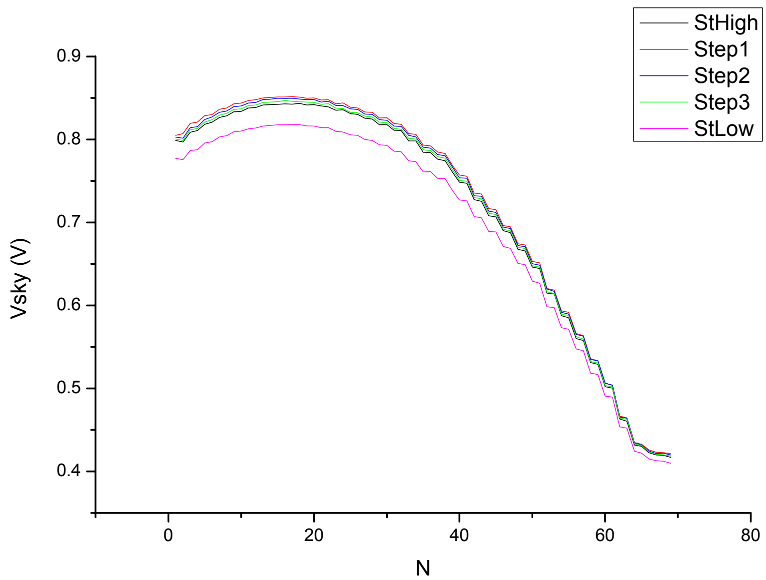


Figure 9 Comparison between the sky output during different stages of CSL Vg2 tuning. The behaviour of the sky signal is similar to the refernce one but the larger difference in the temperature observed is avoiding the crossing of the low temperature sky signal with respect to others.

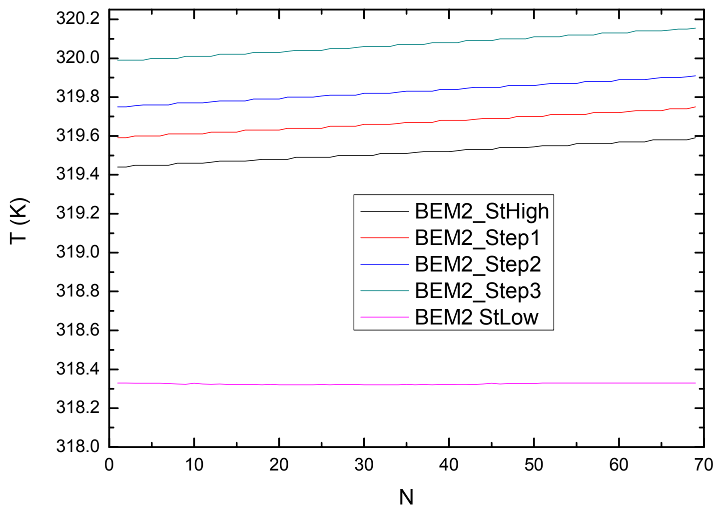


Figure 10 The BEM temperature has a gap between high and low temperature stages

A more detailed study of the whole set of vg2 tuning test, shows that the BEM temperature behaviour is systematically correlated with the cases of negative isolation.

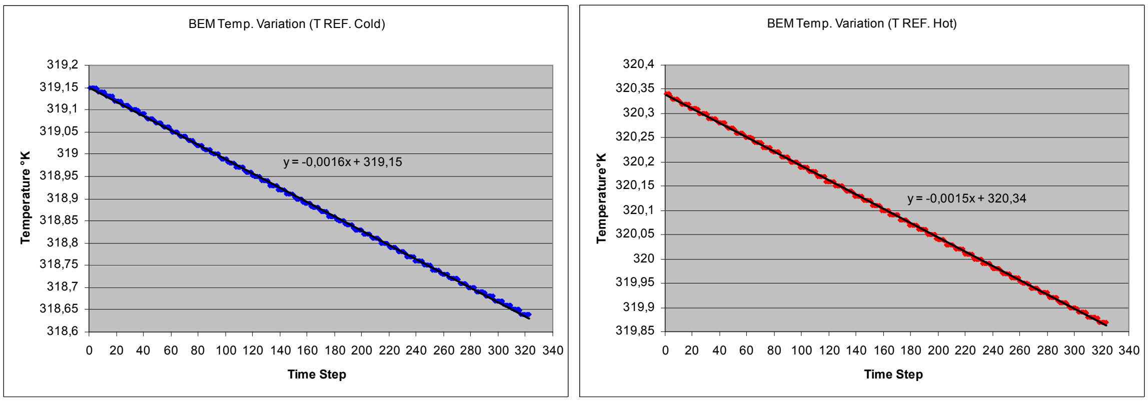


Figure 11 The BEM temperature behaviour during hot and cold phase of the S1 matrix tuning test with S2 on

We report two significant cases.
The first case of S1 matrix tuning with Vd nominal and S2 on, where the BEM temperature behaviour is similar in both cases of hot and cold reference temperature.
The Isolation plot shows no unwanted holes due to the logarithm, of a negative number.

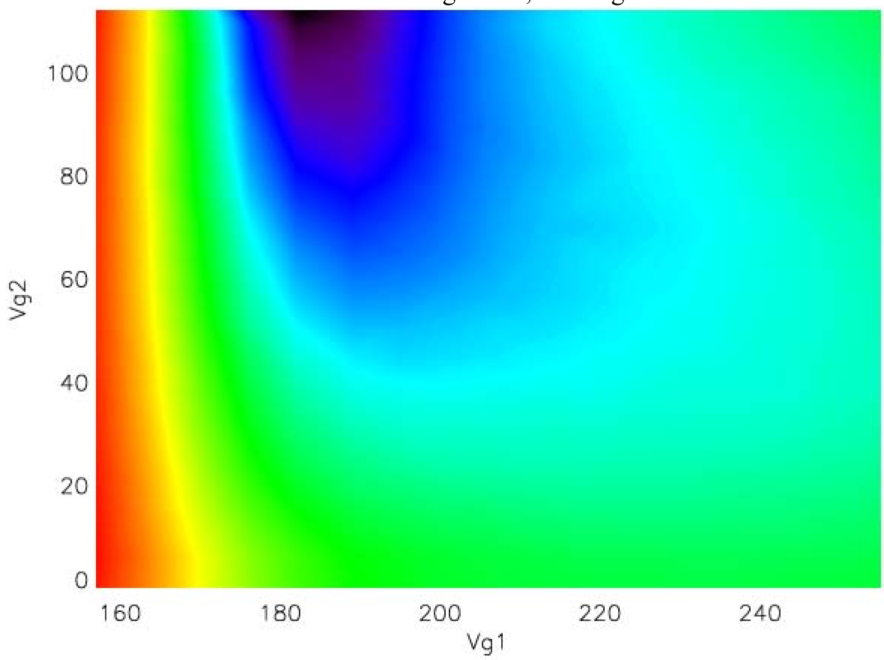


Figure 12 Isolation measured for the matrix tuning of the S1 leg with S2 on

Then the case of the S2 matrix tuning with S1 on, where the BEM temperature has opposite behaviour in the cases of hot and cold reference temperatures and in the Isolation plot a red “hole” appears indicating a non-real number value.

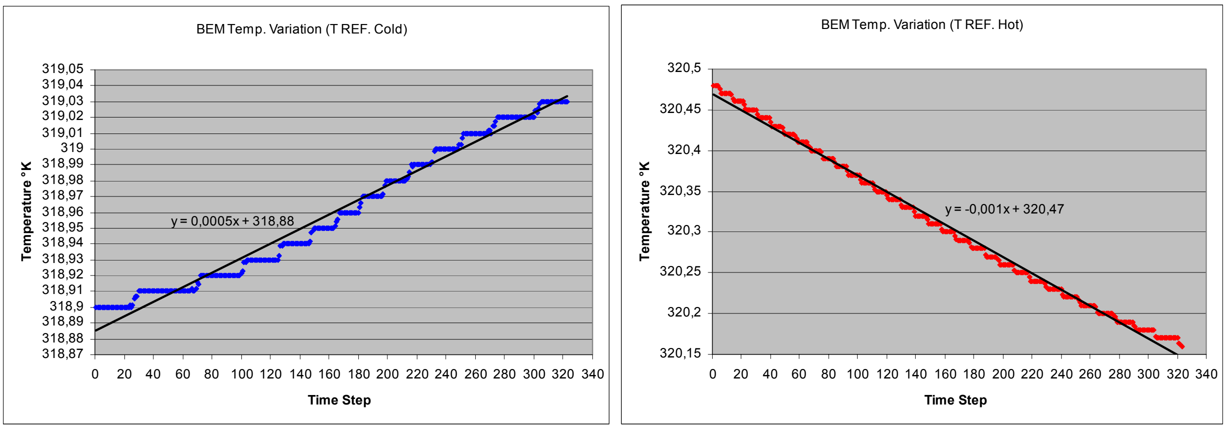


Figure 13 The BEM temperature behaviour during hot and cold phase of the S2 matrix tuning test with S1 on

As a last analysis we plotted, for the matrix tuning of the two amplifiers, the noise temperature vs isolation in order to help selecting a limited range of Vg1-Vg2 values close to the nominal to be explored during tuning test in CSL, where the time allocated for such a test of all the 11 LFI radiometer chains could be an issue.
It is evident that it is sufficient to stay within a few percent from the minimum of the noise temperature to keep isolation at a good level with respect to requirements (13dB).
At the same time, scanning a range of drain current values within the 15% with respect to the one associated to the minimum noise temperature is sufficient to cover biases allowing the right optimization.

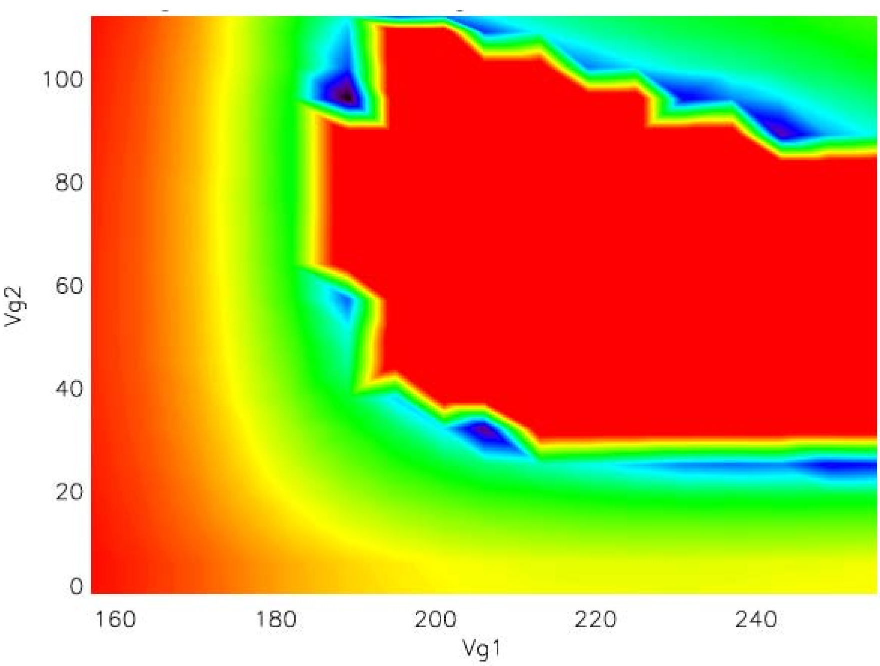
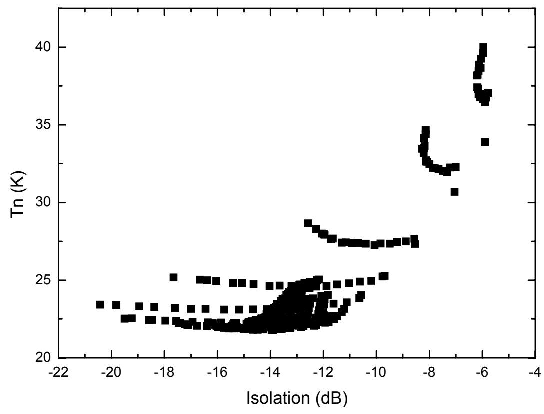


Figure 14 Isolation measured for the matrix tuning of the S2 leg with S1 on



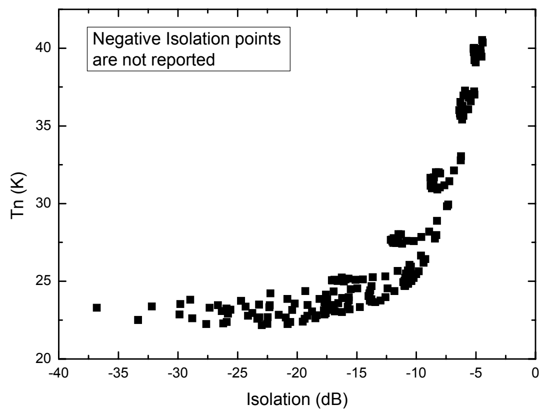


Figure 15 Noise temperature vs Isolation for S1 (left plot) and S2 (right plot) during matrix tuning.

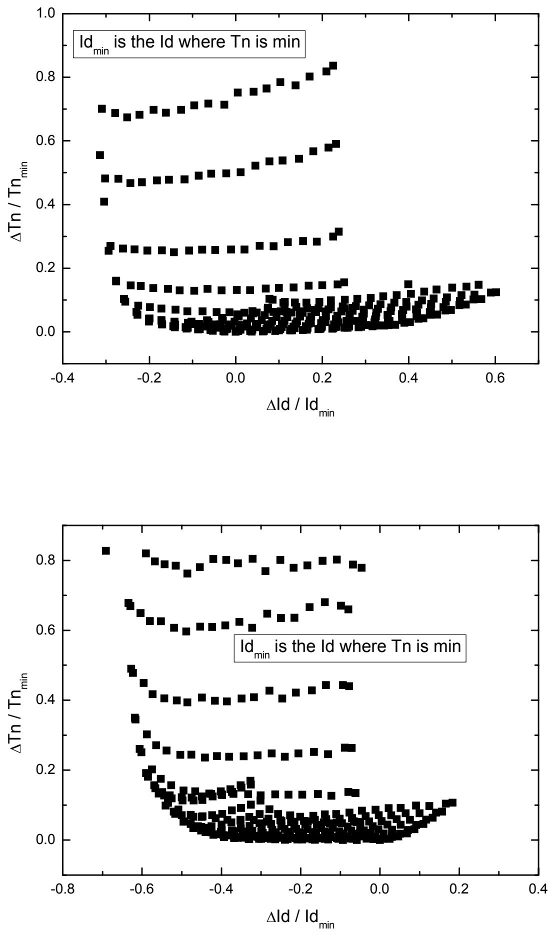


Figure 16 Relative change in noise temperature vs cahnge in drain current with respect to those corresponding to minimum noise temperature for S1 (left plot) and S2 (right plot) during matrix tuning.

We can conclude that matrix tuning is a viable method for radiometer tuning but it is needed to have a good control of the stability of the whole system when test is performed.