TITLE: # FM 30GHz RCA28 Data Analysis Report

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1 INTRODUCTION AND SCOPE

This document reports on the RCA28 Flight Model on – ground calibration. Tests were performed from 06 March 2006 to 29 March 2006 (including functional tests) at Alcatel Alenia Space – Milano according to the LFI Calibration Plan.

RCA_ELE has not been performed due to setup problem
RCA_THB has not performed.

The following tests have been performed:

Date	Filename	Notes
6/3/2006	030LFI28_RCA_FM_AMB_200603061648	LNA and Phase Switches preliminary test at room temperature
6/3/2006	030LFI28_RCA_FM_AMB_200603061728	RCA_AMB test (radiometer is fully on, in nominal operation condition)
15/3/2006	030LFI28_RCA_FM_CRY_200603151134	RCA_CRY test (radiometer is fully on, in nominal operation condition)
15/3/2006	030LFI28_RCA_FM_XXX_200603151248	RCA signal acquisition with JBO nominal cryogenic bias values
15/3/2006	030LFI28_RCA_FM_XXX_200603151400	PS/SW diodes IV curve check
15/3/2006	030LFI28_RCA_FM_XXX_200603151509	PS/SW balancing. RACHEL crashed during file closing!
15/3/2006	030LFI28_RCA_FM_XXX_200603151745	RACHEL file opening/closing test
15/3/2006	030LFI28_RCA_FM_TUN_200603151746	VG1 tuning --- 1st T step
15/3/2006	030LFI28_RCA_FM_XXX_200603151923	RCA signal acquisition with JBO nominal cryogenic LNA bias values --- phase switched tuned current values --- all night acquisition
16/3/2006	030LFI28_RCA_FM_XXX_200603160359	"
16/3/2006	030LFI28_RCA_FM_TUN_200603161010	VG1 tuning --- 2 nd T step
16/3/2006	030LFI28_RCA_FM_TUN_200603161230	VG2 tuning --- 1 st T step (high)
16/3/2006	030LFI28_RCA_FM_TUN_200603161537	DAE PGA gain and offset tuning
16/3/2006	030LFI28_RCA_FM_LIS_200603161908	LIS extended test with changing T on sky (12 points) and ref (24 points)
17/3/2006	030LFI28_RCA_FM_LIS_200603170342	"
17/3/2006	030LFI28_RCA_FM_LIS_200603171216	"
17/3/2006	030LFI28_RCA_FM_LIS_200603172049	"
18/3/2006	030LFI28_RCA_FM_LIS_200603180523	"
18/3/2006	030LFI28_RCA_FM_LIS_200603181356	"
18/3/2006	030LFI28_RCA_FM_LIS_200603182229	"
19/3/2006	030LFI28_RCA_FM_LIS_200603190703	"
19/3/2006	030LFI28_RCA_FM_LIS_200603191536	"
20/3/2006	030LFI28_RCA_FM_LIS_200603200009	"
20/3/2006	030LFI28_RCA_FM_LIS_200603200843	"
20/3/2006	030LFI28_RCA_FM_XXX_200603201129	RCA 28 spikes check. RACHEL crashed during file opening!
20/3/2006	030LFI28_RCA_FM_XXX_200603201210	RCA 28 spikes check. CU/SS heater still on
20/3/2006	030LFI28_RCA_FM_XXX_200603201313	RCA 28 spikes check. All heaters off; environm. Param. Off
20/3/2006	030LFI28_RCA_FM_XXX_200603201340	RCA 28 spikes check. Heaters all on (nominal), different freq. env. Par. Acquisition
20/3/2006	030LFI28_RCA_FM_XXX_200603201505	RCA 28 spikes check. Heaters all off, env. par. acquisition off
20/3/2006	030LFI28_RCA_FM_XXX_200603201535	RCA 28 spikes check. Heaters all off, env. par. acquisition off. PGA gain and offset applied
20/03/2006	030LFI28_RCA_FM_XXX_200603201624	T controllers unplugged, env acquisition off
20/03/2006	030LFI28_RCA_FM_ST3_200603201803	RCA noise measurement in stable, chopped conditions
21/03/2006	030LFI28_RCA_FM_ST3_200603200244	"
21/03/2006	030LFI28_RCA_FM_ST3_200603211641	RCA offset step with ref temp. step
21/03/2006	030LFI28_RCA_FM_UNC_200603211903	RCA unchopped test (Tref=Tsky=9.2K)
22/03/2006	030LFI28_RCA_FM_UNC_200603220342	
22/03/2006	030LFI28_RCA_FM_SPR_200603221233	Power input -36dBm
22/03/2006	030LFI28_RCA_FM_SPR_200603221422	Power input -30dBm trigger at 26.85GHz. Rachel crashed after file closing

22/03/2006	030LFI28_RCA_FM_SPR_200603221532	Power input -30dBm trigger at 26.85GHz. PGA gain=1, DAE offset=0. Rachel crashed after file closing
22/03/2006	030LFI28_RCA_FM_SPR_200603221625	Power input -30dBm trigger at 26.85GHz
22/03/2006	030LFI28_RCA_FM_TNG_200603221809	RCA TNG test with steps on sky load from 9.2K to 20k and back to 9.2K
23/03/2006	030LFI28_RCA_FM_TNG_200603230243	"
23/03/2006	030LFI28_RCA_FM_THF_200603231217	RCA susceptibility to temperature changes in the FEM
23/03/2006	030LFI28_RCA_FM_XXX_200603231537	Check of radiometer functionality
23/03/2006	030LFI28_RCA_FM_TNG_200603232002	RCA noise temp. test with sky steps (ref at 13K)
24/03/2006	030LFI28_RCA_FM_TNG_200603240243	"
24/03/2006	030LFI28_RCA_FM_THV_200603241519	RCA susceptibility to temperature changes in the VG3
24/03/2006	030LFI28_RCA_FM_XXX_200603241924	RCA long acquisition in normal operating conditions
25/03/2006	030LFI28_RCA_FM_XXX_200603250400	"
25/03/2006	030LFI28_RCA_FM_XXX_200603251234	"
25/03/2006	030LFI28_RCA_FM_XXX_200603252107	"
26/03/2006	030LFI28_RCA_FM_XXX_200603260641	"
26/03/2006	030LFI28_RCA_FM_XXX_200603261514	Disk full.
27/03/2006	030LFI28_RCA_FM_XXX_200603271839	Final check on PS/SW diodes (I-V curve)
29/03/2006	030LFI28_RCA_FM_AMB_200603291510	Radiometer functional check

2 APPLICABLE DOCUMENTS

[AD 1] M.Bersanelli, *Planck-LFI Calibration Plan*, PL-LFI-PST-PL-008, Issue/Rev 1.0, July 2003

3 REFERENCE DOCUMENTS

[RD 1] P. Battaglia, *RCA #28 at 30 GHz FM Test Report, PL-LFI-LAB-RP-069*

4 TUNING

4.1 Radiometer tuning

See RD1

4.2 Back End Module offset

BEM offset is determined by recording each detector output when the FEM is off. The values stored are used in data analysis when required. The values are reported in Table 5-1.

Table 5-1: BEM offset values.

	BEM offset (Volts)
Detector A	0.0210
Detector B	0.0190
Detector C	0.0180
Detector D	0.0230

5 BASIC PERFORMANCES

5.1 RCA_OFT: Radiometer offset (LucaV)

To be written

5.2 RCA_LING: Linearity, Isolation, Noise and Gain

This test includes both the RCA_LIS and the RCA_TNG. Files are named LIS. The linearity has been evaluated extensively by changing both the REF and the SKY temperature in several steps. From this data the noise temperature, isolation and gain can be also evaluated.

Specifically the analysis has been performed on the following datasets:

reference load temperature steps:

sky load temperature steps:

From these datasets the characteristic curves V output Vs. T input were built for each detector and then linear and parabolic fits have been performed, as reported in next sections. In addition a gain model has been developed and results are reported as a "*gain-model*" fit.

5.2.1 Reference temperature steps

The data used are discussed in the Annex ????. For the linear and parabolic fits all the curve points were used, while for the gain-model fit the input data used for the analysis are reported in **Table 1**:

***Table 1:** Input data used to derive the calibration curve of the RCA using temperature steps on REF. All the temperature are Antenna Temperature (Kelvin). Voltages are in Volts.*

Detectors A and B			Detector C and D		
T REF	Detector A Voltage	Detector B Voltage	T REF	Detector C Voltage	Detector D Voltage
11.01767	0.886	1.00302	9.82	0.95633	1.25833
11.79888	0.91375	1.03374	10.77069	0.99152	1.30448
12.61762	0.94321	1.06539	11.74306	1.02715	1.35147
13.46772	0.97264	1.09708	12.73237	1.06272	1.39798
14.34416	1.0027	1.12944	13.73522	1.0979	1.44389
15.24291	1.03336	1.16243	14.74905	1.13338	1.48998
16.16067	1.06373	1.19513	15.77189	1.16786	1.53486
17.04948	1.09432	1.22795	16.80227	1.20239	1.57974
18.04291	1.12468	1.26039	17.83897	1.23641	1.62431
19.00329	1.15487	1.29267	18.88107	1.27019	1.66778
19.97374	1.18498	1.32495	19.9275	1.30386	1.71158

The following fits have been performed (V is voltage in Volt and T is the input antenna temperature in Kelvin):

- linear fit: `V=a0+a1*T`
- parabolic fit V(T): `V=a0+a1*T+a2*T^2`
- inverse parabolic fit T(V): `T=a0+a1*V+a2*V^2`
- gain-model fit V(T) : `V = G*(T+T0)/(1+b*G*(T+T0)) (T0 is the Tn)`

The fit results are reported here:

***Table 6-2**: Fitting parameters for REF steps.*

	Linear		Parabolic V(T)			Inverse Parabolic T(V)		
	a0	a1	a0	a1	a2	a0	a1	a2
Detector A	0.52352	0.03327	0.45035	0.04288	-3.0714E-4	-6.73574	12.67686	8.33598
Detector B	0.61455	0.03574	0.52881	0.047	-3.59897E-4	-6.43712	9.50974	7.87935
Detector C	0.62675	0.03418	0.56633	0.04247	-2.7395E-4	-9.42233	13.53172	6.88316
Detector D	0.82955	0.04455	0.74436	0.05623	-3.86193E-4	-8.8176	9.28936	4.38396

Gain-Model Fit V(T)

G	T0	B
0.05677	8.44293	0.2239
0.06653	8.47861	0.22651
0.05615	11.0458	0.19206
0.07635	10.72213	0.15707

Based on the fit results the noise temperatures have been estimated from the reference load temperature steps and are reported in table

Table 3: Noise Temperatures estimated from four different fitting function applied on data with REF steps.

	T noise (K) Linear Fit	T noise (K) Parabolic Fit V(T)	T noise (K) Inverse Parabolic Fit T(V)	T noise (K) Parabolic Fit (average)	T noise (K) Gain-Model Fit V(T)
Detector A	15.7355	9.8129	6.7357	8.2743	8.44293
Detector B	17.195	10.4199	6.4371	8.4285	8.47861
Detector C	18.3367	12.3509	9.4223	10.8866	11.0458
Detector D	18.6207	12.2133	8.8176	10.51545	10.72213

5.2.1.1 Photometric gain with REF variations

The overall photometric gain can be calculated as follows:

- linear fit: G0=a1 (K/V)
- parabolic fit V(T): G1=dV/dT (V/K)
- inverse parabolic fit T(V): G2=dT/dV (K/V)
- gain-model fit V(T) : G3= G/(1+b*G*(T+T0))

In the case of non linear fit the photometric gain depends on the input temperature. The gain functions are reported hereafter:

Photometric Gain from Linear fit

Detector A: G0 = 0.03327 (V/K)
Detector B: G0 = 0.03574 (V/K)
Detector C: G0 = 0.03418 (V/K)
Detector D: G0 = 0.04455 (V/K)

Photometric Gain from Parabolic V(T) fit

Detector A: G1 = 0.04288 -6.1428E-04 * T (V/K)
Detector B: G1 = 0.047 -7.20E-04 * T (V/K)
Detector C: G1 = 0.04247 -5.48E-04 * T (V/K)
Detector D: G1 = 0.05623 -7.72E-04 * T (V/K)

Photometric Gain from inverse parabolic T(V) fit

Detector A: G2 = 12.67686 + 16.68 * V (K/V)
Detector B: G2 = 9.50974 + 15.76 * V (K/V)

Detector C: `G2 = 13.53172 + 13.76 * V (K/V)`
Detector D: `G2 = 9.28936 + 8.76 * V (K/V)`

Photometric Gain from Gain-Model V(T) fit

Detector A: `G3 = 0.05677/(1.10733+0.0127*T) (V/K)`
Detector B: `G3 = 0.06653/(1.12777+0.0151*T) (V/K)`
Detector C: `G3 = 0.05615/(1.11912+0.0108*T) (V/K)`
Detector D: `G3 = 0.07635/(1.12858+0.0120*T) (V/K)`

5.2.2 Sky Temperature Steps

The temperature sensor used for the analysis is the SMON_TMP (ID = 09) which is the thermometer located on the Eccosorb SKY LOAD pyramids. Standard deviation of T and V has not taken into account on the fit.

Using the RaNa routine receiver_basic_properties the temperature (physical) and the voltages have been carried out for each single data file. Then all the values have been combined to perform the fits (in IDL) outside the RaNa environment. The data are reported in the following tables. The red values were not used in the fit because of the apparent saturation.

Table 4: Input data as derived from receiver_basic_properties RaNa routine used to perform the fits. Only T change and Vchange data have been used. Temperatures are in Kelvin, Voltages in Volts.

T SKYMON	Detector A Voltage	Detector B Voltage	Detector C Voltage	Detector D Voltage
12.2923	0.91123217	1.0489372	1.0921113	1.4247988
14.4410	0.98493604	1.1315744	1.1743676	1.5311308
16.6025	1.0565607	1.2114990	1.2536216	1.6335421
18.7700	1.1265781	1.2895235	1.3311182	1.7329620
20.9430	1.1928522	1.3631496	1.4039198	1.8269442
23.1250	1.2566741	1.4337583	1.4737970	1.9156599
25.3093	1.3222114	1.5060900	1.5459325	2.0073596
27.4900	1.3867780	1.5766259	1.5733611	2.0841309
29.6641	1.4498833	1.5772019	1.5733611	2.0841309
31.8620	1.4554924	1.5772019	1.5733611	2.0841309

As in the previous case (Reference steps) the following fits have been performed (V is voltage in Volt and T is the input antenna temperature in Kelvin):

- linear fit: `V=a0+a1*T`
- parabolic fit V(T): `V=a0+a1*T+a2*T^2`
- inverse parabolic fit T(V): `T=a0+a1*V+a2*V^2`
- gain-model fit V(T) : `V = G*(T+T0)/(1+b*G*(T+T0)) (T0 is the Tn)`

The parameters of the linear and parabolic fits have been reported hereafter. Note that all the fits have been performed in antenna temperature and not in physical temperature.

Table 5: Fitting parameters for SKY steps.

	Linear	Parabolic V(T)	Inverse Parabolic T(V)

	a0	a1	a0	a1	a2	a0	a1	a2
Detector A	0.55238	0.03149	0.47677	0.04036	-2.45179E-4	-7.89569	14.24976	7.82265
Detector B	0.6504	0.03503	0.55867	0.04579	-2.97431E-4	-7.4295	10.89453	6.89577
Detector C	0.69689	0.03475	0.60526	0.0455	-2.97115E-4	-7.90232	10.14162	7.05041
Detector D	0.91814	0.04462	0.78854	0.05983	-4.20232E-4	-6.8266	6.21257	4.70981

Gain-Model Fit V(T)		
G	T0	B
0.05153	9.90879	0.19435
0.0604	9.98176	0.1856
0.06134	10.37908	0.18646
0.08332	10.72213	0.15533

Based on the fit results the noise temperatures have been estimated from the reference load temperature steps and are reported in table

Table 6: *Noise Temperatures estimated from three different fitting function applied on data with REF steps.*

	T noise (K) Linear Fit	T noise (K) Parabolic Fit V(T)	T noise (K) Inverse Parabolic Fit T(V)	T noise (K) Parabolic Fit (average)	T noise (K) Gain-Model Fit V(T)
Detector A	17.5414	11.0687	7.8957	9.4822	9.90879
Detector B	18.5669	11.3621	7.4295	9.3958	9.98176
Detector C	20.0544	12.3118	7.9023	10.10705	10.77733
Detector D	20.5769	12.1439	6.8266	9.48525	10.37908

5.2.2.1 Photometric Gain with SKY variations

The overall photometric gain can be calculated as follows:

- linear fit: `G0=a1 (K/V)`
- parabolic fit V(T): `G1=dV/dT (V/K)`
- inverse parabolic fit T(V): `G2=dT/dV (K/V)`
- gain-model fit V(T) : `G3= G/(1+b*G*(T+T0))`

In the case of non linear fit the photometric gain depends on the input temperature. The gain functions are reported hereafter:

Photometric Gain from Linear fit

Detector A: `G0 = 0.03149 (V/K)`
Detector B: `G0 = 0.03503 (V/K)`
Detector C: `G0 = 0.03475 (V/K)`
Detector D: `G0 = 0.04462 (V/K)`

Photometric Gain from Parabolic V(T) fit

Detector A: `G1 = 0.04036 -4.90E-04 * T (V/K)`

Detector B: `G1 = 0.04579 -5.94E-04 * T (V/K)`
Detector C: `G1 = 0.0455 -5.94E-04 * T (V/K)`
Detector D: `G1 = 0.05983 -8.40E-04 * T (V/K)`

Photometric Gain from inverse parabolic T(V) fit

Detector A: `G2 = 14.24976 + 15.64 * V (K/V)`
Detector B: `G2 = 10.89453 + 13.80 * V (K/V)`
Detector C: `G2 = 10.14162 + 14.10 * V (K/V)`
Detector D: `G2 =  6.21257 +  9.42 * V (K/V)`

Photometric Gain from Gain-Model V(T) fit

Detector A: `G3 = 0.05153/(1.09924+0.0100*T) (V/K)`
Detector B: `G3 = 0.06040/(1.11190+0.0112*T) (V/K)`
Detector C: `G3 = 0.06134/(1.12327+0.0114*T) (V/K)`
Detector D: `G3 = 0.08332/(1.13433+0.0129*T) (V/K)`

5.2.3 Consistency of the Results based on SKY steps and Parabolic fit

The white noise limit has been calculated and compared with the requirement. The white noise limit is defined at a given SKY temperature as follows:

Eq. 1:

$$\Delta T = \sqrt{2}\cdot\frac{T_{SKY}+T_{SYS}}{\sqrt{B}}\cdot 1000\left[\mathrm{mK}\cdot\sqrt{\mathrm{sec}}\right]$$

where B is the bandwidth [Hz], τ is the integration time [sec], T_{SKY} and T_{SYS} are the Skyload antenna temperature [K] and noise system temperature [K] respectively.
From measurements the white noise limit is calculated as follows:

Eq. 2:

$$\Delta T = G[K/V]\cdot\frac{1}{\sqrt{2}}\cdot WN\cdot\sqrt{\frac{\tau}{\tau-\tau_{BT}}}$$

where *WN* is the white noise as derived from RaNA, τ is the 122 microSec (1/8KHz) integration time and τ_{BT} is the blanking time (7.5 microSec). G is the gain (K/V) which needs to be know from RCA_TNG tests.

The requirements has been calculated assuming Tsys = 10.7 Kelvin and B = 6.0 GHz (see [AD 2]), while the white noise limit form measurements has been derived in three ways:

1. From the Tsys and B derived from tests applying the Eq. 1. Tsys values were obtained from parabolic fit V(T) and B were obtained from RCA_SPR test

2. Directly From WN measurements applying the Eq. 2 where *WN* is the white noise level derived from RaNA FFT module when the detector output is calibrated. Firstly the white noise limit has been derived form *RaNA_FFT* module selecting a stable (~600 sec) calibrated acquisition data chunk. The White noise of differenced calibrated[1] detectors has been selected (A–B and C–D). Then the number has been corrected by the Blanking time.
3. White noise derived from B obtained from WN level (from RaNA FFT) and Tsys from LIS results.

Note that the consistency check has been repeated also using data with SKY = 20K and REF = 20K.

Data file used are the following:

Dataset:	030LFI28_RCA_FM_ST3_200603201803
Selection range	10000 - 10600
Bin	1

for the SKY at 9.19 K and

Dataset:	030LFI28_RCA_FM_ST3_200603210244
Selection range	22800 - 23400
Bin	1

for the SKY at 20.35 K.

***Table 6-7**: white noise as derived from measurements **(Tsys, B from SPR, calibrated WN)** compared with the requirements*

	Requirement	From Measured Tsys & B	Ratio over requirement	From Data After calibration	Ratio over requirement	Consistency ratio
	mK*Sqrt(s)	mK*Sqrt(s)		mK*Sqrt(s)		
			SKY = 9.19 K REF = 8 K			
Detector A B	0.35028981	0.38862014	1.11	0.33681821	0.96	**0.87**
Detector C D		0.41040278	1.17	0.37066982	1.06	**0.90**
			SKY = 20.35 K REF = 20 K			
Detector A B	0.55395573	0.76252603	1.38	0.54705489	0.99	**0.72**
Detector C D		0.63141785	1.14	0.59494874	1.07	**0.94**

***Table 6-8**: white noise as derived from measurements **(Tsys, B from WN diff, calibrated WN)** compared with the requirements*

	Requirement	From Measured Tsys & B	Ratio over requirement	From Data After calibration	Ratio over requirement	Consistency ratio
	mK*Sqrt(s)	mK*Sqrt(s)		mK*Sqrt(s)		
			SKY = 9.19 K REF = 8 K			
Detector A B	0.35028981	0.30211320	0.86	0.33681821	0.96	**1.11**
Detector C D		0.32906580	0.94	0.37066982	1.06	**1.13**
			SKY = 20.22 K REF = 20 K			
Detector A B	0.53948136	0.44375891	0.80	0.54705489	0.99	**1.23**
Detector C D		0.46735563	0.84	0.59494874	1.07	**1.27**

[1] The calibration has been obtained in the following way:

5.2.4 Consistency of the Results based on SKY steps with “gain – model” fit

The white noise limit has been calculated and compared with the requirement. The white noise limit is defined at a given SKY temperature as follows:

Eq. 3:

$$\Delta T = \sqrt{2} \cdot \frac{T_{SKY} + T_{SYS}}{\sqrt{B}} \cdot 1000 \left[\mathrm{mK} \cdot \sqrt{\sec} \right]$$

where B is the bandwidth [Hz], τ is the integration time [sec], T_{SKY} and T_{SYS} are the Skyload antenna temperature [K] and noise system temperature [K] respectively.
From measurements the white noise limit is calculated as follows:

Eq. 4:

$$\Delta T = G[K/V] \cdot \frac{1}{\sqrt{2}} \cdot WN \cdot \sqrt{\frac{\tau}{\tau - \tau_{BT}}}$$

where *WN* is the white noise as derived from RaNA, τ is the 122 microSec (1/8KHz) integration time and τ_{BT} is the blanking time (7.5 microSec). G is the gain (K/V) which needs to be know from RCA_TNG tests.

The requirements has been calculated assuming Tsys = 10.6 Kelvin and B = 6.0 GHz (see [AD 2]), while the white noise limit form measurements has been derived in three ways:

1. From the Tsys and B derived from tests applying the Eq. 1. Tsys values were obtained from the gain-model fit V(T) and B were obtained from RCA_SPR test
2. Directly From WN measurements applying the Eq. 2 where *WN* is the white noise level derived from RaNA FFT module. Firstly the white noise limit has been derived form *RaNA_FFT* module selecting a stable (~600 sec) calibrated acquisition data chunk. The White noise of differenced calibrated[2] detectors has been selected (A–B and C–D). Then the number has been corrected by the Blanking time.
3. White noise derived from B obtained from WN level (from RaNA FFT) and Tsys from LIS results.

Note that the consistency check has been repeated also using data with SKY = 20K and REF = 20K. Moreover the consistency check has been performed also using the noise temperatures derived from linear extrapolation at Tin = 0.

Table 6-9: white noise as derived from measurements (Tsys, B from SPR, calibrated WN) compared with the requirements

	Requirement	From Measured Tsys & B	Ratio over requirement	From Data After calibration	Ratio over requirement	Consistency ratio
	mK*Sqrt(s)	mK*Sqrt(s)		mK*Sqrt(s)		

[2] The calibration has been obtained in the following way:

SKY = 8.6 K REF = 8.6 K (AB=10.986, CD=9.6)						
Detector A B	0.32866456	0.44099873	1.30	0.31492101	0.93	**0.71**
Detector C D		0.36610636	1.08	0.34981082	1.03	**0.96**
SKY = 20 K REF = 20 K						
Detector A B	0.54751725	0.72243375	1.32	0.47401115	0.87	**0.66**
Detector C D		0.59174408	1.08	0.51041012	0.93	**0.86**

***Table 6-10:** white noise as derived from measurements (Tsys, B from WN diff, calibrated WN) compared with the requirements*

	Requirement	From Measured Tsys & B	Ratio over requirement	From Data After calibration	Ratio over requirement	Consistency ratio
	mK*Sqrt(s)	mK*Sqrt(s)		mK*Sqrt(s)		
SKY = 8.6 K REF = 8.6 K (AB=10.986, CD=9.6)						
Detector A B	0.33959155	0.27365654	0.81	0.31492101	0.93	**1.15**
Detector C D		0.29354841	0.86	0.34981082	1.03	**1.19**
SKY = 20 K REF = 20 K						
Detector A B	0.54751725	0.42042685	0.77	0.47401115	0.87	**1.13**
Detector C D		0.43799035	0.80	0.51041012	0.93	**1.17**

Expected White noise at Flight conditions has been calculated using Eq. 1 with Tnoise gain-model V(T) fit and B derived from SPR tests. Here the results:

***Table 6-11:** white noise extrapolated at Flight conditions (SKY = 2.73 K) compared (Tsys from Gain-Model V(T) fit, B from SPR) compared with the requirements*

	Requirement	From Measured Tsys & B	Ratio over requirement	From Data After calibration	Ratio over requirement	Consistency ratio
	mK*Sqrt(s)	mK*Sqrt(s)		mK*Sqrt(s)		
EXTRAPOLATED AT FLIGHT CONDITIONS						
Detector A B	0.23803072	0.30353306	1.28	N/A	N/A	**N/A**
Detector C D		0.25589413	1.07	N/A	N/A	**N/A**

Tsys that gives consistency ratio = 1 (beta from SPR test, value is an average of both channels)		
beta-A (GHz)	3.27	
beta-B (GHz)	3.28	
beta A-B (GHz)	**3.275**	
Optimal noise temperature	**4.25**	*0.998*
beta that gives consistency ratio = 1 (Tsys from gain-model fit, value is an average of both channels)		
Tsys-A (K)	9.90879	
Tsys-B (K)	9.98176	
Tsys A-B (K)	**9.945275**	
Optimal eff bandwidth	**6.5**	*1.006*

Tsys that gives consistency ratio = 1 (beta from SPR test, value is an average of both channels)					
beta-C (GHz)	5.01				
beta-D (GHz)	5.18				
beta C-D (GHz)	**5.095**				
Optimal noise temperature	**9.5**	*1.004*			
beta that gives consistency ratio = 1 (Tsys from gain-model fit, value is an average of both channels)					
Tsys-C (K)	10.77733				
Tsys-D (K)	10.37908				
Tsys C-D (K)	**10.578205**				
Optimal eff bandwidth	**5.6**	*1.002*			

5.2.5 Consistency of the Results based on REF steps

Input data

	SPR Bandwidth	WN Bandwidth @ 8 K	WN Bandwidth @ 20 K
Detector A	3.27	8.23	9.13
Detector B	3.28	8.78	10.21
Detector C	5.01	7.91	9.29
Detector D	5.18	7.94	9.31

Table 6-12: white noise as derived from measurements (Tsys, B from SPR, calibrated WN) compared with the requirements

	Requirement	From Measured Tsys & B	Ratio over requirement	From Data After calibration	Ratio over requirement	Consistency ratio
	mK*Sqrt(s)	mK*Sqrt(s)		mK*Sqrt(s)		
SKY = 8.6 K REF = 8.6 K (AB=10.986, CD=9.6)						
Detector A B	0.32866456	0.40431352	1.20	0.29295117	0.87	**0.72**
Detector C D		0.38007168	1.10	0.38073394	1.10	**1.10**
SKY = 20 K REF = 20 K						
Detector A B	0.54751725	0.68574854	1.25	0.45022508	0.82	**0.66**
Detector C D		0.59780200	1.09	0.55084893	1.00	**0.92**

Table 6-13: white noise as derived from measurements (Tsys, B from WN diff, calibrated WN) compared with the requirements

	Requirement	From Measured Tsys & B	Ratio over requirement	From Data After calibration	Ratio over requirement	Consistency ratio
	mK*Sqrt(s)	mK*Sqrt(s)		mK*Sqrt(s)		
SKY = 8.6 K REF = 8.6 K (AB=10.986, CD=9.6)						
Detector A B	0.33959155	0.25089197	0.74	0.29295117	0.87	**1.17**

Detector C D		0.30474597	0.88	0.38073394	1.10	**1.25**
SKY = 20 K REF = 20 K						
Detector A B	0.54751725	0.39907756	0.73	0.45022508	0.82	**1.13**
Detector C D		0.44247423	0.81	0.55084893	1.00	**1.24**

Expected White noise at Flight conditions has been calculated using Eq. 1 with Tnoise gain-model V(T) fit and B derived from SPR tests. Here the results:

***Table 6-14:** white noise extrapolated at Flight conditions (SKY = 2.73 K) compared (**Tsys from Gain-Model V(T) fit, B from SPR**) compared with the requirements*

	Requirement	From Measured Tsys & B	Ratio over requirement	From Data After calibration	Ratio over requirement	Consistency ratio
	mK*Sqrt(s)	mK*Sqrt(s)		mK*Sqrt(s)		
EXTRAPOLATED AT FLIGHT CONDITIONS						
Detector A B	0.23803072	0.26684723	1.12	N/A	N/A	**N/A**
Detector C D		0.26195275	1.10	N/A	N/A	**N/A**

Tsys that gives consistency ratio = 1 (beta from SPR test, value is an average of both channels)		
beta-A (GHz)	3.27	
beta-B (GHz)	3.28	
beta A-B (GHz)	**3.275**	
Optimal noise temperature	**3.25**	*1.005*
beta that gives consistency ratio = 1 (Tsys from gain-model fit, value is an average of both channels)		
Tsys-A (K)	8.44293	
Tsys-B (K)	8.47861	
Tsys A-B (K)	**8.46077**	
Optimal eff bandwidth	**6.25**	*1.001*

Tsys that gives consistency ratio = 1 (beta from SPR test, value is an average of both channels)		
beta-C (GHz)	5.0100	
beta-D (GHz)	5.1800	
beta C-D (GHz)	**5.095**	
Optimal noise temperature	**11.25**	*1.003*
beta that gives consistency ratio = 1 (Tsys from gain-model fit, value is an average of both channels)		
Tsys-C (K)	11.0458	
Tsys-D (K)	10.72213	
Tsys C-D (K)	**10.883965**	
Optimal eff bandwidth	**4.9**	*0.9997*

5.3 RCA_SPR: BANDPASS MEASUREMENT

Same problems of the RCA 27 on bandpass measurements have been found.
Summary is reported in ANNEX RCA26_SPR_1449.pdf

6 NOISE PROPERTIES

6.1 RCA_STN

Long acquisition time has been performed with the aim to derive noise spectra.
The complete data set of the RCA_STn test is composed by the following files:
`030LFI28_RCA_FM_ST3_200603201803`
`030LFI28_RCA_FM_ST3_200603210244`

The temperature step sequence is reported in Table 7-1

Table 7-1: Reference Temperature steps for Noise properties test (STn)

SKY Temperature	REF Temperature	Duration
8.6 K	8.5 K	3 hours
9.2 K	15.0 K	3 hours
9.9 K	20.0 K	3 hours
20.0 K	20.0 K	≤ 3 hours

6.1.1 One–Over–F Noise

A fourier transform has been applied on data to obtain the 1/f knee frequency and noise properties. The following data set have been used:

8.6 / 8.5 Selected from **7000** – **10600** sec, bin 10 for FFT and 1/f from file
`030LFI28_RCA_FM_ST3_200603201803`
9.2 / 15.0 Selected from **17900** – **21500** sec, bin 10 for FFT and 1/f from file
`030LFI28_RCA_FM_ST3_200603201803`
9.9 / 20.0 Selected from **26400** – **30000** sec, bin 10 for FFT and 1/f from file
`030LFI28_RCA_FM_ST3_200603201803`
20.0 / 20.0 Selected from **19800** – **23400** sec, bin 10 for FFT and 1/f from file
`030LFI28_RCA_FM_ST3_200603210244`

In the following table the 1/f characteristics obtained by an optimized fitting is reported. The numbers of point used for the low frequency fit is reported for each detector. BIN = 10 is used (fsampl =`409.600`).

T sky = 8.6 K T ref = 8.5 K	Detector A	Detector B	Detector C	Detector D
N points	120	130	27	27

[3] Thanks to ESA – ESTEC
[4] Thanks to Segio Mariotti INAF/IRA - Bologna
[5] Thanks to ESA – ESTEC

1/f knee frequency	0.0411270	0.0406524	0.0199266	0.0194111
R factor	0.93868361	0.95483659	1.0583206	1.0502508
1/f Slope	-1.59711	-1.57117	-1.38754	-1.20385

T sky = 9.2 K T ref = 15 K	Detector A	Detector B	Detector C	Detector D
N points	100	110	82	82
1/f knee frequency	0.051784532	0.0437655	0.0462369	0.0423866
R factor	0.81662024	0.83565258	0.89597573	0.89132625
1/f Slope	-1.3737749	-1.23390	-1.13360	-1.25349

T sky = 9.9 K T ref = 20 K	Detector A	Detector B	Detector C	Detector D
N points	24	22	43	36
1/f knee frequency	0.0754681	0.0519269	0.0426395	0.0557212
R factor	0.74671658	0.76698219	0.81253275	0.81067767
1/f Slope	-1.16370	-1.24400	-1.41669	-1.16681

T sky = 9.9 K T ref = 20 K	Detector A	Detector B	Detector C	Detector D
N points	100	80	80	80
1/f knee frequency	0.030927974	0.024622454	0.032203700	0.032739252
R factor	0.99494704	1.0138974	1.0566149	1.0455069
1/f Slope	-1.2593622	-1.0752823	-1.2303181	-1.1160063

6.1.2 White Noise Level and Equivalent Bandwidth

The white noise level has been calculated with the *RaNA_FFT* module using the high frequency part of the amplitude spectrum. From the white noise limit the equivalent bandwidth has been derived. Same data stream as the 1/f calculation has been used. Data were not binned and 10 minutes have been taken for each reference temperature step. For each step the last 600 seconds of the data taken for 1/f noise have been taken for this analysis.

T sky = 8.6 K T ref = 8.5 K	White noise level [V/Sqrt(Hz)]			Effective bandwidth [GHz]		
	Sky	*Load*	*Diff*	*Sky*	*Load*	*Diff*
DETECTOR A	1.7676478e-005	1.9014729e-005	2.5171969e-005	8.34	8.18	8.23
DETECTOR B	1.9919220e-005	2.0665936e-005	2.8097697e-005	8.74	8.91	8.78
DETECTOR C	2.2634158e-005	2.0095489e-005	3.1123934e-005	7.48	8.47	7.91
DETECTOR D	2.9196465e-005	2.6793230e-005	4.0553876e-005	7.66	8.24	7.94

T sky = 9.2 K T ref = 15 K	White noise level [V/Sqrt(Hz)]			Effective bandwidth [GHz]		
	Sky	*Load*	*Diff*	*Sky*	*Load*	*Diff*
DETECTOR A	1.8713734e-005	2.1503626e-005	2.5692657e-005	8.08	9.17	8.57
DETECTOR B	2.0453572e-005	2.3468274e-005	2.8395621e-005	8.96	9.74	9.29
DETECTOR C	2.2890152e-005	2.3614591e-005	3.1191979e-005	7.84	9.17	8.44
DETECTOR D	2.9912508e-005	3.1546170e-005	4.1046212e-005	7.86	8.89	8.34

T sky = 9.9 K T ref = 20 K	White noise level [V/Sqrt(Hz)]			Effective bandwidth [GHz]		
	Sky	*Load*	*Diff*	*Sky*	*Load*	*Diff*
DETECTOR A	1.9256558e-005	2.4261021e-005	2.6478727e-005	8.21	9.26	8.68
DETECTOR B	2.0943341e-005	2.5670030e-005	2.8823709e-005	9.16	10.35	9.67
DETECTOR C	2.3616078e-005	2.6356184e-005	3.1851554e-005	7.85	9.53	8.63

DETECTOR D	3.0646931e-005	3.4911418e-005	4.1786862e-005	8.00	9.36	8.60

T sky = 20 K T ref = 20 K	White noise level [V/Sqrt(Hz)]			Effective bandwidth [GHz]		
	Sky	*Load*	*Diff*	*Sky*	*Load*	*Diff*
DETECTOR A	2.5266307e-005	2.4521306e-005	3.5183186e-005	8.85	9.49	9.13
DETECTOR B	2.6848029e-005	2.6433554e-005	3.7979841e-005	10.22	10.25	10.21
DETECTOR C	2.9594617e-005	2.6772578e-005	4.1024081e-005	8.92	9.76	9.29
DETECTOR D	3.8200114e-005	3.5751216e-005	5.3411983e-005	9.10	9.50	9.31

6.2 RCA_UNC: Unchopped data

Noise properties have been derived also from unchopped data, i.e. with all the phase switches off. The knee frequencies reported in the table below are in Hz.

13.0 / 8.5 Selected from **26400** – **30000** sec, bin 10 for FFT and 1/f from file
`030LFI28_RCA_FM_UNC_200603211903`
In this data set, the diode configuration is: PS/SW ln1 diode reverse, ln2 diode forward on all channels.

T sky = 9.2 K T ref = 9.2 K	Detector A	Detector B	Detector C	Detector D
		SKY		
N points	100	59	80	130
1/f knee frequency	188.83705	107.48376	87.035462	77.786917
1/f Slope	-0.62322687	-0.69198948	-0.69784898	-0.69660877
		REF		
N points	102	60	100	130
1/f knee frequency	136.53989	100.24259	70.171125	88.997653
1/f Slope	-0.64057637	-0.69520137	-0.71405040	-0.68671868

The white noise level has been calculated with the *RaNA_FFT* module using the high frequency part of the amplitude spectrum. From the white noise limit the equivalent bandwidth has been derived. Same data stream as the 1/f calculation has been used. Data were not binned and 10 minutes have been taken for each reference temperature step. For each step the last 600 seconds of the data taken for 1/f noise have been taken for this analysis.

T sky = 9.2 K T ref = 9.2 K	White noise level [V/Sqrt(Hz)]			Effective bandwidth [GHz]		
	Sky	*Load*	*Diff*	*Sky*	*Load*	*Diff*
DETECTOR A	1.9489108e-005	1.9516290e-005	2.7598123e-005	8.31	8.28	8.29
DETECTOR B	2.0603291e-005	2.0591410e-005	2.9077590e-005	8.74	8.75	8.78
DETECTOR C	2.3340300e-005	2.3283980e-005	3.2976703e-005	7.60	7.64	7.62
DETECTOR D	2.7718830e-005	2.7727531e-005	3.9174014e-005	8.37	8.36	8.38

7 SUSCEPTIBILIY TESTS

Any thermal and electrical variation on the RCA subsystem units produces a variation of the output signal from each of the four detector.
The relationship between the thermal (or electrical variation) and the variation of the output signal is:

$$(\bullet\, T^{param}_{meas}) = f_{param} \text{ x } (\bullet P)$$

where the f_{param} represents a transfer function that can also be derived from analytical models of the LFI receivers and $\bullet P$ the variation of the parameter.

7.1 RCA_THB: Susceptibility to BEM Temperature variations

Not performed.

7.2 RCA_THV: Susceptibility to V-Groove Temperature variations

The test consists in three steps in the T_{vg3}(the coldest): 61.5, 63.5, 65.5 K respectively. The following graphics show the T_{vg3} temperature sensor measurements.

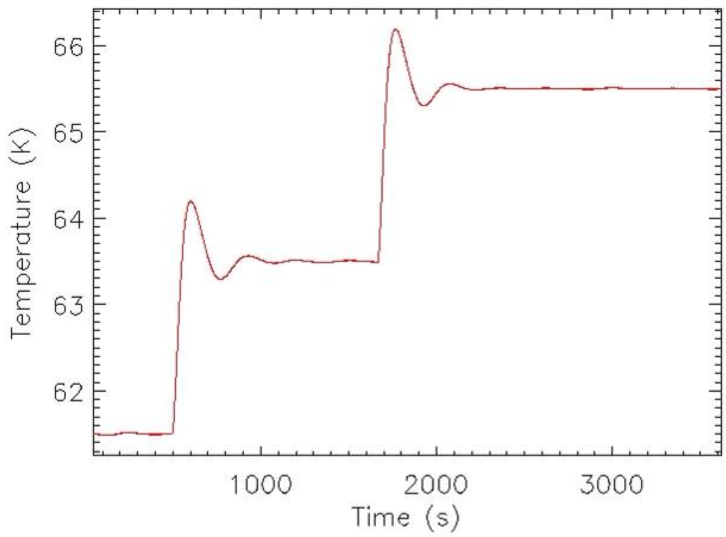


Figure 8-1: *VG3 temperature variation during the RCA_THV test.*

Sky load and reference load were stabilized during the test so that only VG3 temperature where varied.
The T_{sky} and T_{ref} behavior during the test is reported in **Figure 8-2**

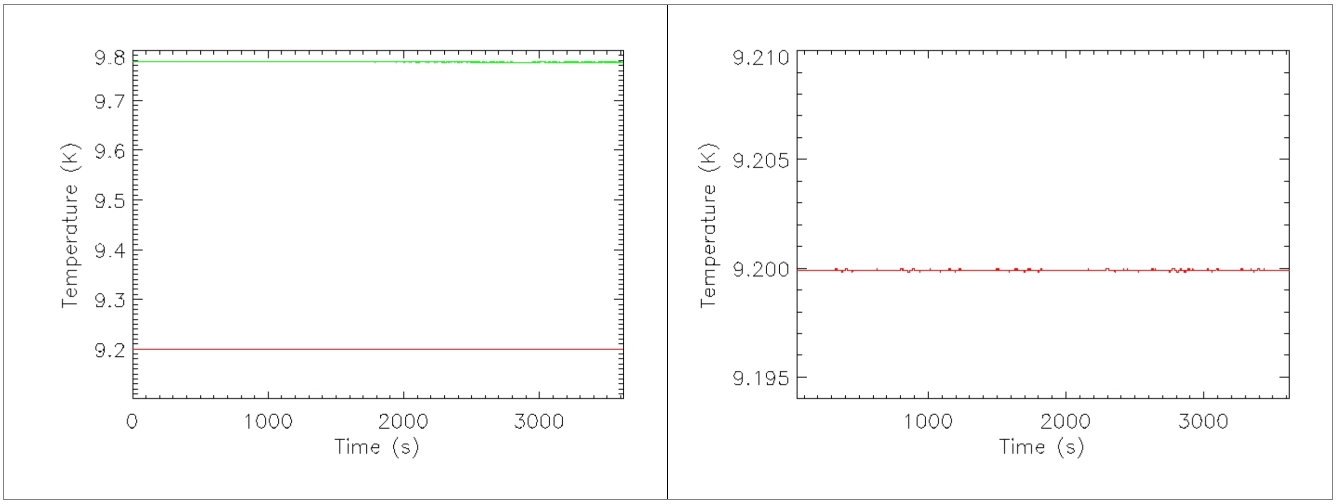


***Figure 8-2**: Left – Sky Load: (SKY_TEMP) probe (red) and (SMON_TMP) probe (green) temperature behaviour during the RCA_THF test; right – Ref Load (REF_TEMP) probe*

Also the FEM and BEM temperatures were controlled during the test. They are reported in **Figure -8-3**

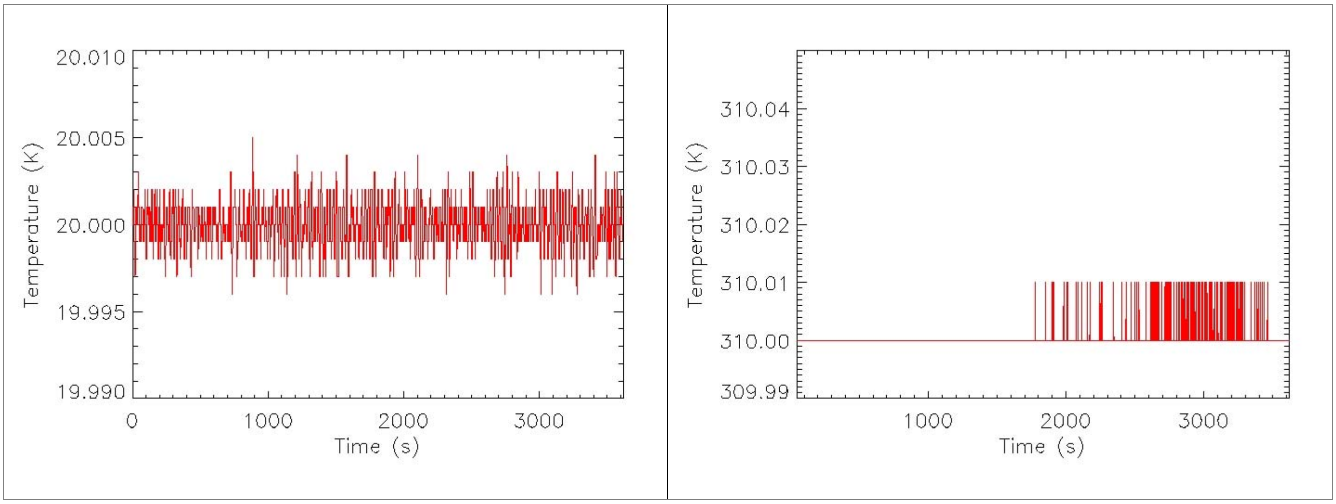


***Figure -8-3:** FEM (left) and BEM (right) temperature behaviour during the RCA_THV test*

7.2.1 Detector A analysis

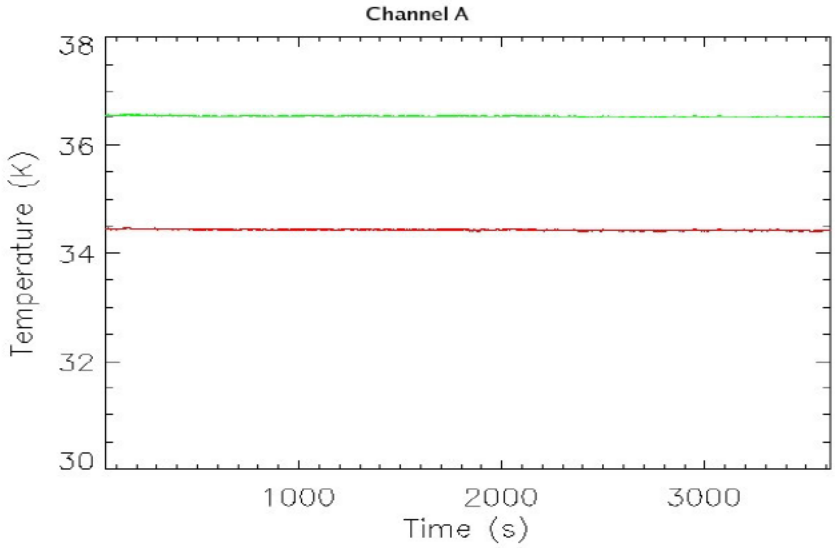


Figure -8-4: Detector A calibrated output

Receiver parameters used in the computation of the theoretical transfer functions:

Frequency (GHz)	30
$L_{feed-OMT}$ (dB)	0.1
r	0.94221686
G_{F1} (dB)	35
G_{F2} (dB)	35
L_{WG1} (dB)	0.03
L_{WG2}(dB)	1.08
L_{WG3} (dB)	0.11
L_{WG4} (dB)	0.15
L_{WG5} (dB)	0.13
G (V/K)	0.024

7.2.1.1 Analysis using the SKY_TEMP probe as sky load temperature:

The transfer functions obtained with RaNA:

Fmeas (K/K)	-0.00008805
Ftheo (K/K)	0.00000297

The complete RaNA output:

```
Vgrooves susceptibility
INPUT
Frequency (GHz) =        30
```

```
Channel :       A
Load correct :  Yes
r =   0.94221686
Model:          FM
Gain calibration factor (V/K) =     0.024
LfeedOMT_dB =   0.1
Vgroove number =         1 coldest
LWG1_dB =       0.03
LWG2_dB =       1.08
LWG3_dB =       0.11
LWG4_dB =       0.15
LWG5_dB =       0.13
GF1_dB =        35
GF2_dB =        35

There are       3        time windows
      tmin      tmax
      45        446
      1277      1645
      2193      3620

Sky Sensor =    SKY_TEMP
Ref Sensor =    REF_TEMP
Vgroove Sensor =         VG3_TEMP

      SKY_TEMP  REF_TEMP  VG3_TEMP
      9.19996738         9.1999321 61.49825668
      9.1999712 9.19993114          63.49811935
      9.20010376         9.19997692          65.4988327

Radiometer outputs (K)
      Tsky      Tref
      34.441056 36.553216
      34.429322 36.539881
      34.417993 36.528044

      Tsky-r*Tref
      0.0008297639
      0.00065359997

OUTPUT
      ftheo (K/K)        fmeas (K/K)
      0.00000297         -0.00008805
```

7.2.1.2 Analysis using the SMON_TMP probe as sky load temperature:

The transfer functions obtained with RaNA:

Fmeas (K/K)	0.00004780
Ftheo (K/K)	0.00000297

The complete RaNA output:

```
Vgrooves susceptibility
INPUT
Frequency (GHz) =        30
Channel :       A
Load correct :  Yes
r =   0.94221686
Model:          FM
Gain calibration factor (V/K) =     0.024
LfeedOMT_dB =   0.1
Vgroove number =         1 coldest
LWG1_dB =       0.03
LWG2_dB =       1.08
LWG3_dB =       0.11
LWG4_dB =       0.15
LWG5_dB =       0.13
GF1_dB =        35
GF2_dB =        35

There are       3        time windows
      tmin      tmax
      45        446
      1277      1645
      2193      3620

Sky Sensor =    SMON_TMP
Ref Sensor =    REF_TEMP
Vgroove Sensor =         VG3_TEMP

      SMON_TMP  REF_TEMP  VG3_TEMP
      9.77702808         9.1999321 61.49825668
      9.77692795         9.19993114          63.49811935
      9.77678871         9.19997692          65.4988327

Radiometer outputs (K)
      Tsky      Tref
```

```
        34.441056 36.553216
        34.429426 36.539881
        34.418369 36.528044

        Tsky-r*Tref
        0.0009337144
        0.0010293476

OUTPUT
        ftheo (K/K)          fmeas (K/K)
        0.00000297           0.00004780
```

7.2.2 Detector B Analysis

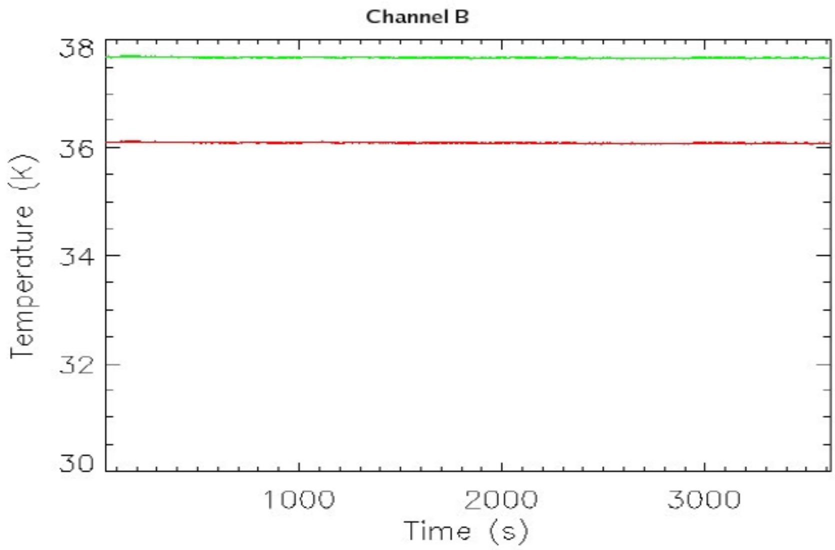


Figure 8-5: Detector B calibrated output

Receiver parameters used in the computation of the theoretical transfer functions:

Frequency (GHz)	30
$L_{feed-OMT}$ (dB)	0.1
r	0.9581238
G_{F1} (dB)	35
G_{F2} (dB)	35
L_{WG1} (dB)	0.03
L_{WG2}(dB)	1.08
L_{WG3} (dB)	0.11
L_{WG4} (dB)	0.15
L_{WG5} (dB)	0.13
G (V/K)	0.026

7.2.2.1 Analysis using the SKY_TEMP probe as sky load temperature:

The transfer functions obtained with RaNA:

Fmeas (K/K)	-0.00044097
Ftheo (K/K)	0.00000215

The complete RaNA output:

```
Vgrooves susceptibility
INPUT
Frequency (GHz) =        30
Channel :        B
Load correct :  Yes
r =   0.95812381
Model:           FM
Gain calibration factor (V/K) =     0.026
LfeedOMT_dB =   0.1
Vgroove number =         1 coldest
LWG1_dB =        0.03
LWG2_dB =        1.08
LWG3_dB =        0.11
LWG4_dB =        0.15
LWG5_dB =        0.13
GF1_dB =         35
GF2_dB =         35

There are        3         time windows
      tmin       tmax
      45         446
      1277       1645
      2193       3620

Sky Sensor =     SKY_TEMP
Ref Sensor =     REF_TEMP
Vgroove Sensor =          VG3_TEMP

      SKY_TEMP  REF_TEMP  VG3_TEMP
      9.19996738          9.1999321 61.49825668
      9.1999712 9.19993114          63.49811935
      9.20010376          9.19997692          65.4988327

Radiometer outputs (K)
      Tsky       Tref
      36.107255 37.685375
      36.095027 37.671442
      36.0856   37.662525

      Tsky-r*Tref
      0.0011211031
      0.00023885494

OUTPUT
      ftheo (K/K)         fmeas (K/K)
      0.00000215          -0.00044097
```

7.2.2.2 Analysis using the SMON_TMP probe as sky load temperature:

The transfer functions obtained with RaNA:

Fmeas (K/K)	-0.00030512
Ftheo (K/K)	0.00000215

The complete RaNA output:

```
Vgrooves susceptibility
INPUT
Frequency (GHz) =        30
Channel :        B
Load correct :  Yes
r =   0.95812381
Model:           FM
Gain calibration factor (V/K) =     0.026
LfeedOMT_dB =   0.1
Vgroove number =         1 coldest
LWG1_dB =        0.03
LWG2_dB =        1.08
LWG3_dB =        0.11
LWG4_dB =        0.15
LWG5_dB =        0.13
GF1_dB =         35
GF2_dB =         35

There are        3         time windows
      tmin       tmax
      45         446
      1277       1645
      2193       3620

Sky Sensor =     SMON_TMP
```

```
Ref Sensor =     REF_TEMP
Vgroove Sensor =          VG3_TEMP

      SMON_TMP  REF_TEMP  VG3_TEMP
      9.77702808          9.1999321 61.49825668
      9.77692795          9.19993114          63.49811935
      9.77678871          9.19997692          65.4988327

Radiometer outputs (K)
      Tsky      Tref
      36.107255 37.685375
      36.095131 37.671442
      36.085976 37.662525

      Tsky-r*Tref
      0.0012250536
      0.00061460262

OUTPUT
      ftheo (K/K)         fmeas (K/K)
      0.00000215          -0.00030512
```

7.2.3 Detector C Analysis

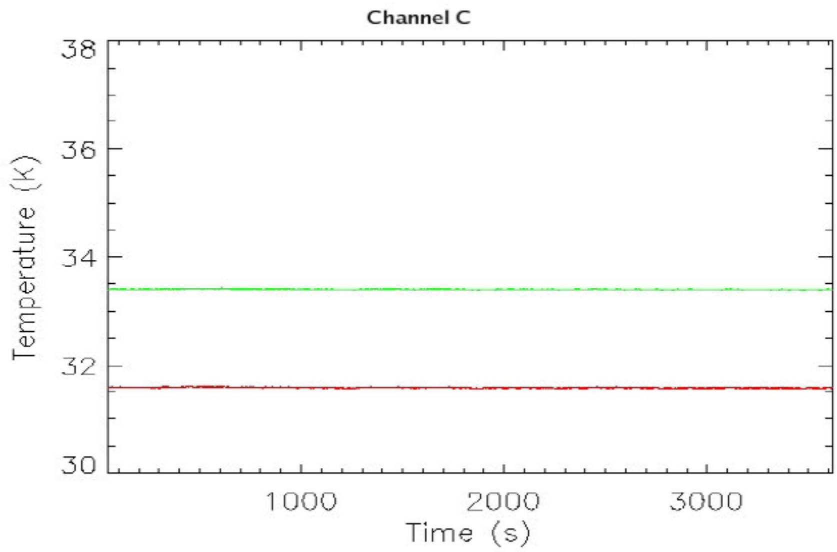


***Figure 8-6:** Detector C calibrated output*

Receiver parameters used in the computation of the theoretical transfer functions:

Frequency (GHz)	30
$L_{feed\text{-}OMT}$ (dB)	0.1
r	0.94548700
G_{F1} (dB)	35
G_{F2} (dB)	35
L_{WG1} (dB)	0.03
L_{WG2}(dB)	1.08
L_{WG3} (dB)	0.11
L_{WG4} (dB)	0.15
L_{WG5} (dB)	0.13
G (V/K)	0.0293

7.2.3.1 Analysis using the SKY_TEMP probe as sky load temperature:

The transfer functions obtained with RaNA:

Fmeas (K/K)	0.00013842
Ftheo (K/K)	0.00000280

The complete RaNA output:

```
Vgrooves susceptibility
INPUT
Frequency (GHz) =   30
Channel : C
Load correct :      Yes
r =         0.945487
Model:    FM
Gain calibration factor (V/K) =        0.0293
LfeedOMT_dB =       0.1
Vgroove number =    1 coldest
LWG1_dB = 0.03
LWG2_dB = 1.08
LWG3_dB = 0.11
LWG4_dB = 0.15
LWG5_dB = 0.13
GF1_dB =  35
GF2_dB =  35

There are 3         time windows
          tmin      tmax
          45        446
          1277      1645
          2193      3620

Sky Sensor =        SKY_TEMP
Ref Sensor =        REF_TEMP
Vgroove Sensor =    VG3_TEMP

          SKY_TEMP  REF_TEMP  VG3_TEMP
          9.19996738          9.1999321 61.49825668
          9.1999712 9.19993114          63.49811935
          9.20010376          9.19997692          65.4988327

Radiometer outputs  (K)
          Tsky      Tref
          31.586027 33.407151
          31.58285  33.405061
          31.576462 33.398012

          Tsky-r*Tref
          -0.0012006287
          -0.00092368423

OUTPUT
ftheo (K/K)         fmeas (K/K)
0.00000280          0.00013842
```

7.2.3.2 Analysis using the SMON_TMP probe as sky load temperature:

The transfer functions obtained with RaNA:

Fmeas (K/K)	0.00027427
Ftheo (K/K)	0.00000280

The complete RaNA output:

```
Vgrooves susceptibility
INPUT
Frequency (GHz) =         30
Channel :         C
Load correct :  Yes
r =   0.945487
Model:          FM
Gain calibration factor (V/K) =     0.0293
LfeedOMT_dB =   0.1
Vgroove number =          1 coldest
LWG1_dB =       0.03
LWG2_dB =       1.08
LWG3_dB =       0.11
LWG4_dB =       0.15
LWG5_dB =       0.13
GF1_dB =        35
GF2_dB =        35

There are       3         time windows
```

```
      tmin      tmax
      45        446
      1277      1645
      2193      3620

Sky Sensor =    SMON_TMP
Ref Sensor =    REF_TEMP
Vgroove Sensor =         VG3_TEMP

      SMON_TMP  REF_TEMP  VG3_TEMP
      9.77702808          9.1999321 61.49825668
      9.77692795          9.19993114          63.49811935
      9.77678871          9.19997692          65.4988327

Radiometer outputs (K)
      Tsky      Tref
      31.586027 33.407151
      31.582954 33.405061
      31.576838 33.398012

      Tsky-r*Tref
      -0.0010966782
      -0.00054793655

OUTPUT
      ftheo (K/K)         fmeas (K/K)
      0.00000280          0.00027427
```

7.2.4 Detector D Analysis

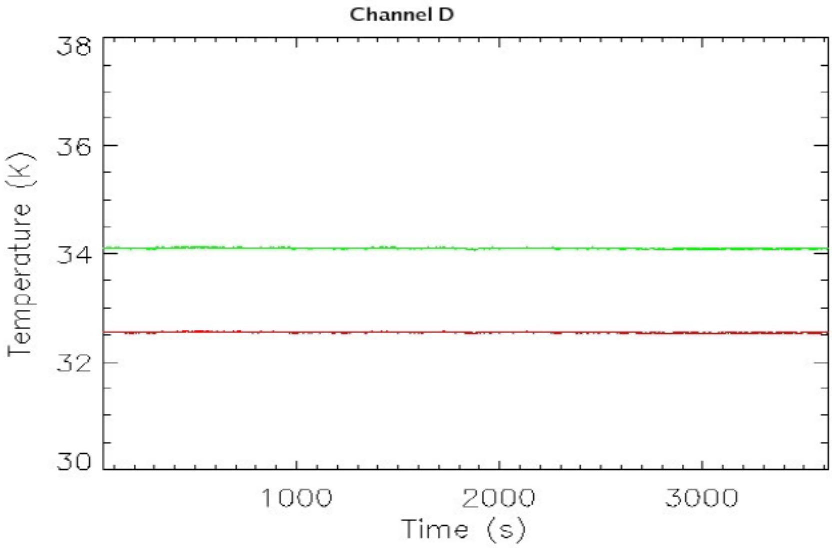


Figure 8-7: Detector D calibrated output

Receiver parameters used in the computation of the theoretical transfer functions:

Frequency (GHz)	30
$L_{feed-OMT}$ (dB)	0.1
r	0.95427260
G_{F1} (dB)	35
G_{F2} (dB)	35
L_{WG1} (dB)	0.03
L_{WG2}(dB)	1.08
L_{WG3} (dB)	0.11
L_{WG4} (dB)	0.15
L_{WG5} (dB)	0.13
G (V/K)	0.038

7.2.4.1 Analysis using the SKY_TEMP probe as sky load temperature:

The transfer functions obtained with RaNA:

Fmeas (K/K)	-0.00043225
Ftheo (K/K)	0.00000235

The complete RaNA output:

```
Vgrooves susceptibility
INPUT
Frequency (GHz) =          30
Channel :          D
Load correct :  Yes
r =   0.9542726
Model:             FM
Gain calibration factor (V/K) =      0.038
LfeedOMT_dB =   0.1
Vgroove number =           1 coldest
LWG1_dB =          0.03
LWG2_dB =          1.08
LWG3_dB =          0.11
LWG4_dB =          0.15
LWG5_dB =          0.13
GF1_dB =           35
GF2_dB =           35

There are          3          time windows
      tmin        tmax
      45          446
      1277        1645
      2193        3620

Sky Sensor =       SKY_TEMP
Ref Sensor =       REF_TEMP
Vgroove Sensor =              VG3_TEMP

      SKY_TEMP  REF_TEMP  VG3_TEMP
      9.19996738          9.1999321 61.49825668
      9.1999712 9.19993114          63.49811935
      9.20010376          9.19997692          65.4988327

Radiometer outputs (K)
      Tsky        Tref
      32.542617 34.102013
      32.544138 34.10297
      32.533949 34.093199

      Tsky-r*Tref
      0.00060767002
      -0.00025714561

OUTPUT
      ftheo (K/K)          fmeas (K/K)
      0.00000235           -0.00043225
```

7.2.4.2 Analysis using the SMON_TMP probe as sky load temperature:

The transfer functions obtained with RaNA:

Fmeas (K/K)	-0.0002964
Ftheo (K/K)	0.00000235

The complete RaNA output:

```
Vgrooves susceptibility
INPUT
Frequency (GHz) =          30
Channel :          D
Load correct :  Yes
r =   0.9542726
Model:             FM
Gain calibration factor (V/K) =      0.038
LfeedOMT_dB =   0.1
Vgroove number =           1 coldest
LWG1_dB =          0.03
LWG2_dB =          1.08
LWG3_dB =          0.11
LWG4_dB =          0.15
LWG5_dB =          0.13
GF1_dB =           35
GF2_dB =           35

There are          3          time windows
```

```
      tmin      tmax
      45        446
      1277      1645
      2193      3620

Sky Sensor =    SMON_TMP
Ref Sensor =    REF_TEMP
Vgroove Sensor =          VG3_TEMP

      SMON_TMP  REF_TEMP  VG3_TEMP
      9.77702808          9.1999321 61.49825668
      9.77692795          9.19993114          63.49811935
      9.77678871          9.19997692          65.4988327

Radiometer outputs (K)
      Tsky      Tref
      32.542617 34.102013
      32.544241 34.10297
      32.534325 34.093199

      Tsky-r*Tref
      0.00071162052
      0.00011860207

OUTPUT
      ftheo (K/K)         fmeas (K/K)
      0.00000235          -0.0002964
```

7.3 RCA_THF: SUSCEPTIBILITY TO FEM TEMPERATURE VARIATIONS

The test has been performed by varying the temperature of the FEM keeping constant the temperatures of the other thermal interfaces.
The temperature of the FEM has been set to 20K (nominal), 22K, 24K, and 27K as seen in **Figure -8-8**

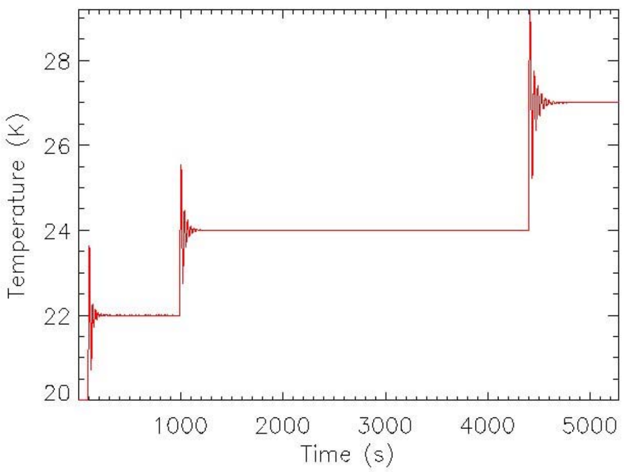


Figure -8-8: *FEM temperature step during the RCA_THF test*

The temperature behaviour of the other thermal interfaces are reported in the next figures (**Figure 8-9** and **Figure 8-10**) showing the sky load (SKY_TEMP and SMON_TMP) and reference load temperatures , and the BEM temperature.

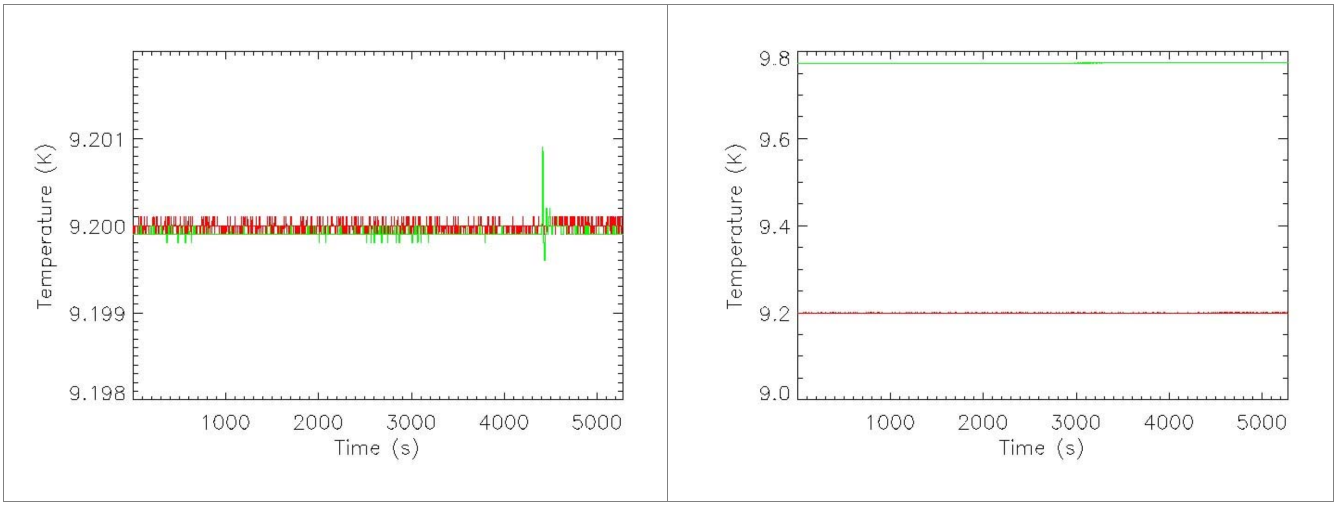


Figure 8-9: *Left – Sky Load (SKY_TEMP) probe (red) and Reference Load (green) temperature behaviour during the RCA_THF test; right – SKY_TEMP probe (red) and SMON_TMP probe (green)*

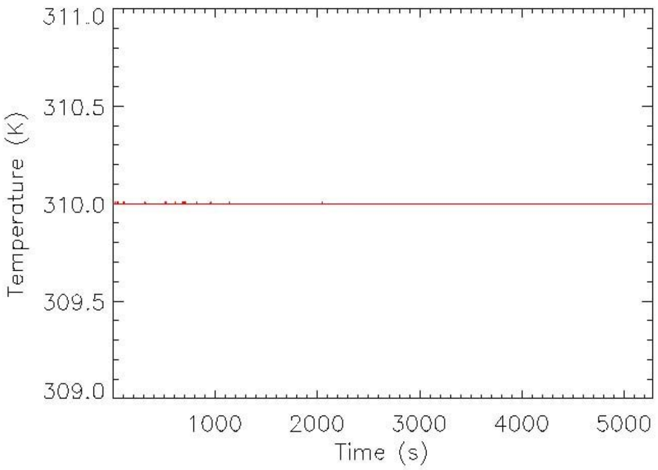


Figure 8-10: *BEM temperature behaviour during the RCA_THF test*

To do the analysis, the radiometric output for each channel in the three steps was recorded. We can see the output of the channels in the figures below:

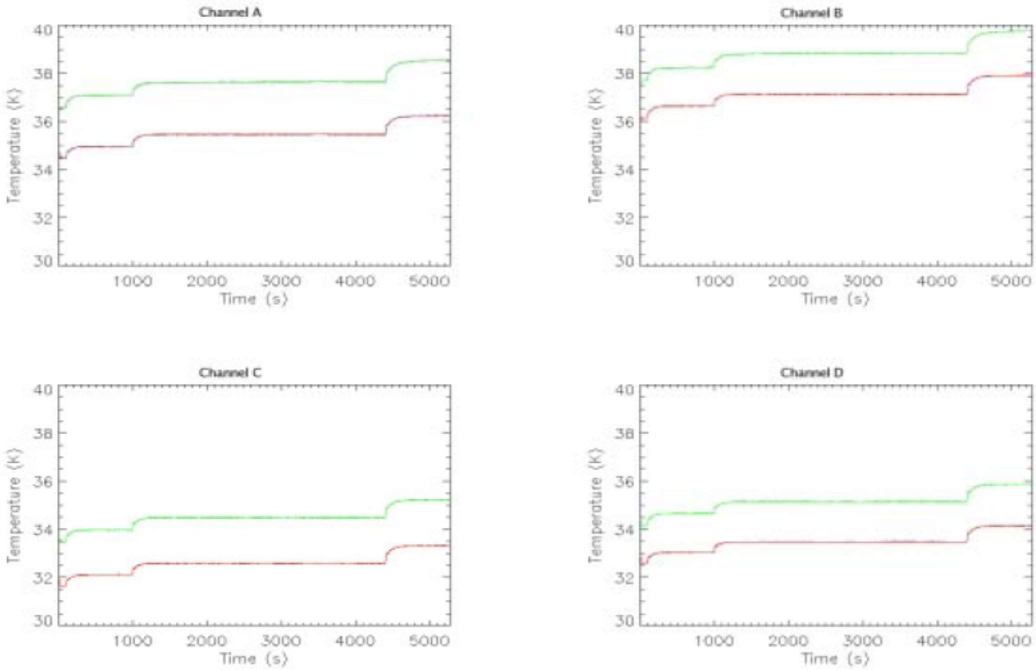


Figure -8-11: Radiometric output of the 4 detectors during the RCA_THF test

7.3.1.1 Analysis using the SKY_TEMP probe as sky load temperature:

The default parameters for the four channels are:

Table 8-1: Default input parameters for RCA_THF analysis

	Ch. A	Ch. B	Ch. C	Ch. D
Freq (*GHz*)	30			
$L_{feed-OMT}$ (*dB*)	0.1			
L_{4k} (*dB*)	0.1			
r	0.94340612	0.95825588	0.94434556	0.95426438
T_{sky} (*K*)	9.199997			
T_{ref} (*K*)	9.199897			
G_{F1}^{dB} (*dB*)	35			
G_{F2}^{dB} (*dB*)	35			
T_{nF1} (*K*)	20	20	20	20
T_{nF2} (*K*)	20	20	20	20
$\partial G_{F1}^{dB} / \partial T_{phys}^{FE}$ (*dB/K*)	-0.05	-0.05	-0.05	-0.05
$\partial G_{F2}^{dB} / \partial T_{phys}^{FE}$ (*dB/K*)	-0.05	-0.05	-0.05	-0.05
$\partial T_{nF1} / \partial T_{phys}^{FE}$ (*K/K*)	0.08	0.08	0.08	0.08
$\partial T_{nF2} / \partial T_{phys}^{FE}$ (*K/K*)	0.08	0.08	0.08	0.08

Gain Calibration Factor (V/K)	0.024	0.026	0.0293	0.038

Calculating the theoretical and the measured transfer functions with RaNA, we obtain:

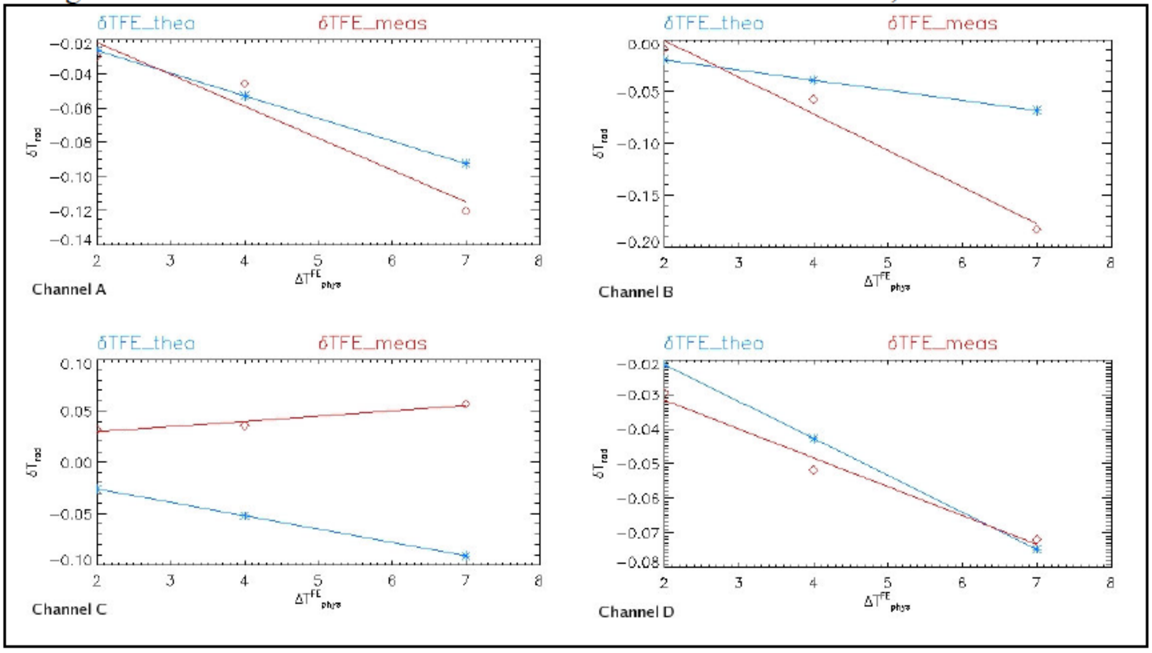


***Figure -8-12**: RCA_THF theoretical (blue) Vs measured (red) transfer function*

***Table -8-2:** RCA_THF Analysis Result based on default parameters*

	Channel A	Channel B	Channel C	Channel D
$f_{therm}^{front-end}$ **(K/K) theoretical**	-0.013226	-0.009756	-0.013006	-0.010688
$f_{therm}^{front-end}$ **(K/K) measured**	-0.018607	-0.035322	0.005094	-0.008343

The complete RaNA output:

```
FEM susceptibility
INPUT
Frequency (GHz) =   30
Channel : A
Load correct :      Yes
r =        0.94340612
Model:    FM
Gain calibration factor (V/K) =         0.024
LfeedOMT_dB =        0.1
L4K_dB =  0.1
GF1_dB =  35
GF2_dB =  35
TnF1_K =  20
TnF2_K =  20
dGF1_dB_dTFEphys_K =          -0.05
dGF2_dB_dTFEphys_K =          -0.05
dTn1_dTFEphys_K =    0.08
dTn2_dTFEphys_K =    0.08

There are 4         time windows
          tmin       tmax
          1          87
          283        954
          1215       4351
          4756       5200
```

```
FEM susceptibility
INPUT
Frequency (GHz) =   30
Channel : B
Load correct :      Yes
r =        0.95825588
Model:    FM
Gain calibration factor (V/K) =         0.026
LfeedOMT_dB =        0.1
L4K_dB =  0.1
GF1_dB =  35
GF2_dB =  35
TnF1_K =  20
TnF2_K =  20
dGF1_dB_dTFEphys_K =          -0.05
dGF2_dB_dTFEphys_K =          -0.05
dTn1_dTFEphys_K =    0.08
dTn2_dTFEphys_K =    0.08

There are 4         time windows
          tmin       tmax
          1          87
          283        954
          1215       4351
          4756       5200
```

Sky Sensor = SKY_TEMP Ref Sensor = REF_TEMP FEM Sensor = FEM_TEMP SKY_TEMP REF_TEMP FEM_TEMP 9.19999695 9.19989681 19.99991035 9.20002937 9.19986153 22.00007629 9.19973564 9.19967365 23.99995804 9.19997978 9.19994164 27.00001526 Radiometer outputs (K) Tsky Tref 34.485854 36.554622 34.959616 37.088436 35.462409 37.638168 36.227321 38.527968 Tsky-r*Tref -0.029840849 -0.045669091 -0.12019913 OUTPUT ftheo (K/K) fmeas (K/K) -0.013226 -0.018607	Sky Sensor = SKY_TEMP Ref Sensor = REF_TEMP FEM Sensor = FEM_TEMP SKY_TEMP REF_TEMP FEM_TEMP 9.19999695 9.19989681 19.99991035 9.20002937 9.19986153 22.00007629 9.19973564 9.19967365 23.99995804 9.19997978 9.19994164 27.00001526 Radiometer outputs (K) Tsky Tref 36.127361 37.701163 36.636725 38.242149 37.14027 38.818244 37.903099 39.745099 Tsky-r*Tref -0.0090386872 -0.05753993 -0.18287637 OUTPUT ftheo (K/K) fmeas (K/K) -0.009756 -0.035322
FEM susceptibility INPUT Frequency (GHz) = 30 Channel : C Load correct : Yes r = 0.94434556 Model: FM Gain calibration factor (V/K) = 0.0293 LfeedOMT_dB = 0.1 L4K_dB = 0.1 GF1_dB = 35 GF2_dB = 35 TnF1_K = 20 TnF2_K = 20 dGF1_dB_dTFEphys_K = -0.05 dGF2_dB_dTFEphys_K = -0.05 dTn1_dTFEphys_K = 0.08 dTn2_dTFEphys_K = 0.08 There are 4 time windows tmin tmax 1 87 283 954 1215 4351 4756 5200 Sky Sensor = SKY_TEMP Ref Sensor = REF_TEMP FEM Sensor = FEM_TEMP SKY_TEMP REF_TEMP FEM_TEMP 9.19999695 9.19989681 19.99991035 9.20002937 9.19986153 22.00007629 9.19973564 9.19967365 23.99995804 9.19997978 9.19994164 27.00001526 Radiometer outputs (K) Tsky Tref 31.639373 33.50402 32.115203 33.973947 32.588431 34.471194 33.320044 35.22369 Tsky-r*Tref 0.032056856 0.035711624 0.056708863 OUTPUT ftheo (K/K) fmeas (K/K) -0.013006 0.005094	FEM susceptibility INPUT Frequency (GHz) = 30 Channel : D Load correct : Yes r = 0.95426438 Model: FM Gain calibration factor (V/K) = 0.038 LfeedOMT_dB = 0.1 L4K_dB = 0.1 GF1_dB = 35 GF2_dB = 35 TnF1_K = 20 TnF2_K = 20 dGF1_dB_dTFEphys_K = -0.05 dGF2_dB_dTFEphys_K = -0.05 dTn1_dTFEphys_K = 0.08 dTn2_dTFEphys_K = 0.08 There are 4 time windows tmin tmax 1 87 283 954 1215 4351 4756 5200 Sky Sensor = SKY_TEMP Ref Sensor = REF_TEMP FEM Sensor = FEM_TEMP SKY_TEMP REF_TEMP FEM_TEMP 9.19999695 9.19989681 19.99991035 9.20002937 9.19986153 22.00007629 9.19973564 9.19967365 23.99995804 9.19997978 9.19994164 27.00001526 Radiometer outputs (K) Tsky Tref 32.644433 34.209002 33.042381 34.657056 33.478648 35.137551 34.155246 35.867703 Tsky-r*Tref -0.029613464 -0.051865463 -0.072026322 OUTPUT ftheo (K/K) fmeas (K/K) -0.010688 -0.008343

To improve the results obtained with the default parameters, I am going to change any of them. In particular, I change the $\partial G^{dB}_{FE}/\partial T^{FE}_{phys}$ and $\partial T_{nFE}/\partial T^{FE}_{phys}$. The best values will be:

Table -8-3: *Optimized parameters of RCA_THF test*

	Ch. A	Ch. B	Ch. C	Ch. D
$\partial G_{F1}^{dB} / \partial T_{phys}^{FE}$ (dB/K)	-0.061	-0.133	-0.028	-0.049
$\partial G_{F2}^{dB} / \partial T_{phys}^{FE}$ (dB/K)	-0.061	-0.133	-0.028	-0.049
$\partial T_{nF1} / \partial T_{phys}^{FE}$ (K/K)	0.06	0.028	0.25	0.124
$\partial T_{nF2} / \partial T_{phys}^{FE}$ (K/K)	0.06	0.028	0.25	0.124

and calculating the transfer functions, the new results:

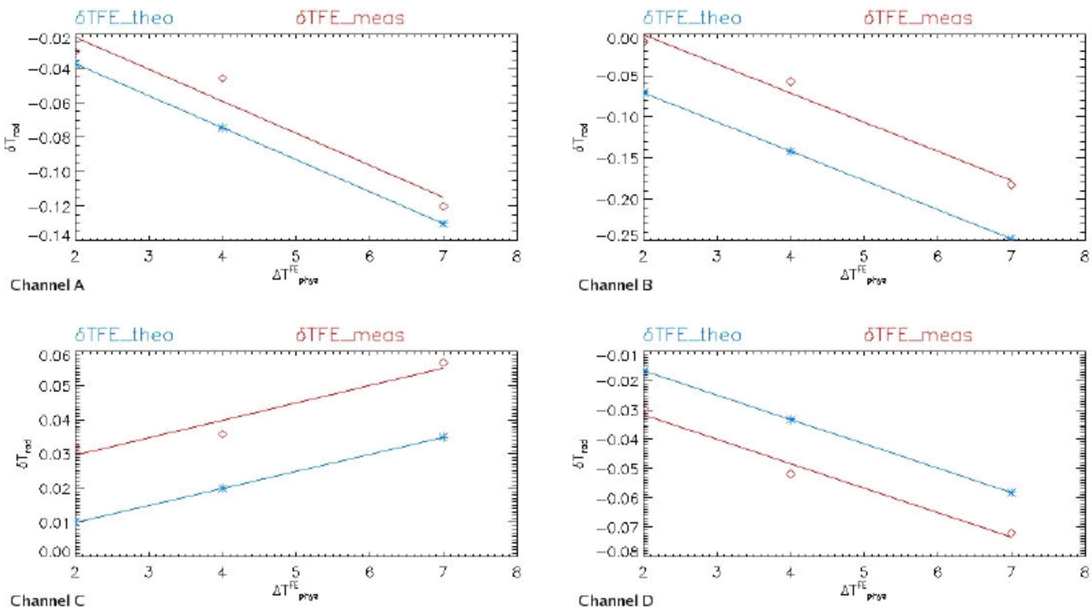


Figure -8-13: RCA_THF theoretical Vs measured transfer function after optimisation of the parameters.

Table -8-4: RCA_THF Optimal transfer function Vs. theoretical

	Channel A	Channel B	Channel C	Channel D
$f_{therm}^{front-end}$ (K/K) theoretical	-0.018603	-0.035458	0.004973	-0.008319
$f_{therm}^{front-end}$ (K/K) measured	-0.018607	-0.03532	0.005094	-0.008343

The complete RaNA output:

```
FEM susceptibility
INPUT
Frequency (GHz) =   30
Channel : A
Load correct :      Yes
r =      0.94340612
Model:    FM
Gain calibration factor (V/K) =          0.024
LfeedOMT_dB =        0.1
L4K_dB =   0.1
GF1_dB =   35
GF2_dB =   35
TnF1_K =   20
TnF2_K =   20
dGF1_dB_dTFEphys_K =          -0.061
```

```
FEM susceptibility
INPUT
Frequency (GHz) =   30
Channel : B
Load correct :      Yes
r =      0.95825588
Model:    FM
Gain calibration factor (V/K) =          0.026
LfeedOMT_dB =        0.1
L4K_dB =   0.1
GF1_dB =   35
GF2_dB =   35
TnF1_K =   20
TnF2_K =   20
dGF1_dB_dTFEphys_K =          -0.133
```

```
dGF2_dB_dTFEphys_K =          -0.061
dTn1_dTFEphys_K =   0.06
dTn2_dTFEphys_K =   0.06

There are 4         time windows
          tmin      tmax
          1         87
          283       954
          1215      4351
          4756      5200

Sky Sensor =        SKY_TEMP
Ref Sensor =        REF_TEMP
FEM Sensor =        FEM_TEMP

          SKY_TEMP  REF_TEMP  FEM_TEMP
          9.19999695          9.19989681          19.99991035
          9.20002937          9.19986153          22.00007629
          9.19973564          9.19967365          23.99995804
          9.19997978          9.19994164          27.00001526

Radiometer outputs (K)
          Tsky      Tref
          34.485854 36.554622
          34.959616 37.088436
          35.462409 37.638168
          36.227321 38.527968

          Tsky-r*Tref
          -0.029840849
          -0.045669091
          -0.12019913

OUTPUT
          ftheo (K/K)         fmeas (K/K)
          -0.018603 -0.018607
```

```
dGF2_dB_dTFEphys_K =          -0.133
dTn1_dTFEphys_K =   0.028
dTn2_dTFEphys_K =   0.028

There are 4         time windows
          tmin      tmax
          1         87
          283       954
          1215      4351
          4756      5200

Sky Sensor =        SKY_TEMP
Ref Sensor =        REF_TEMP
FEM Sensor =        FEM_TEMP

          SKY_TEMP  REF_TEMP  FEM_TEMP
          9.19999695          9.19989681          19.99991035
          9.20002937          9.19986153          22.00007629
          9.19973564          9.19967365          23.99995804
          9.19997978          9.19994164          27.00001526

Radiometer outputs (K)
          Tsky      Tref
          36.127361 37.701163
          36.636725 38.242149
          37.14027  38.818244
          37.903099 39.745099

          Tsky-r*Tref
          -0.0090386872
          -0.05753993
          -0.18287637

OUTPUT
          ftheo (K/K)         fmeas (K/K)
          -0.035458 -0.035322
```

```
FEM susceptibility
INPUT
Frequency (GHz) =   30
Channel : C
Load correct :      Yes
r =       0.94434556
Model:    FM
Gain calibration factor (V/K) =         0.0293
LfeedOMT_dB =       0.1
L4K_dB =  0.1
GF1_dB =  35
GF2_dB =  35
TnF1_K =  20
TnF2_K =  20
dGF1_dB_dTFEphys_K =          -0.028
dGF2_dB_dTFEphys_K =          -0.028
dTn1_dTFEphys_K =   0.25
dTn2_dTFEphys_K =   0.25

There are 4         time windows
          tmin      tmax
          1         87
          283       954
          1215      4351
          4756      5200

Sky Sensor =        SKY_TEMP
Ref Sensor =        REF_TEMP
FEM Sensor =        FEM_TEMP

          SKY_TEMP  REF_TEMP  FEM_TEMP
          9.19999695          9.19989681          19.99991035
          9.20002937          9.19986153          22.00007629
          9.19973564          9.19967365          23.99995804
          9.19997978          9.19994164          27.00001526

Radiometer outputs (K)
          Tsky      Tref
          31.639373 33.50402
          32.115203 33.973947
          32.588431 34.471194
          33.320044 35.22369

          Tsky-r*Tref
          0.032056856
          0.035711624
          0.056708863

OUTPUT
          ftheo (K/K)         fmeas (K/K)
          0.004973  0.005094
```

```
FEM susceptibility
INPUT
Frequency (GHz) =   30
Channel : D
Load correct :      Yes
r =       0.95426438
Model:    FM
Gain calibration factor (V/K) =         0.038
LfeedOMT_dB =       0.1
L4K_dB =  0.1
GF1_dB =  35
GF2_dB =  35
TnF1_K =  20
TnF2_K =  20
dGF1_dB_dTFEphys_K =          -0.049
dGF2_dB_dTFEphys_K =          -0.049
dTn1_dTFEphys_K =   0.124
dTn2_dTFEphys_K =   0.124

There are 4         time windows
          tmin      tmax
          1         87
          283       954
          1215      4351
          4756      5200

Sky Sensor =        SKY_TEMP
Ref Sensor =        REF_TEMP
FEM Sensor =        FEM_TEMP

          SKY_TEMP  REF_TEMP  FEM_TEMP
          9.19999695          9.19989681          19.99991035
          9.20002937          9.19986153          22.00007629
          9.19973564          9.19967365          23.99995804
          9.19997978          9.19994164          27.00001526

Radiometer outputs (K)
          Tsky      Tref
          32.644433 34.209002
          33.042381 34.657056
          33.478648 35.137551
          34.155246 35.867703

          Tsky-r*Tref
          -0.029613464
          -0.051865463
          -0.072026322

OUTPUT
          ftheo (K/K)         fmeas (K/K)
          -0.008319 -0.008343
```

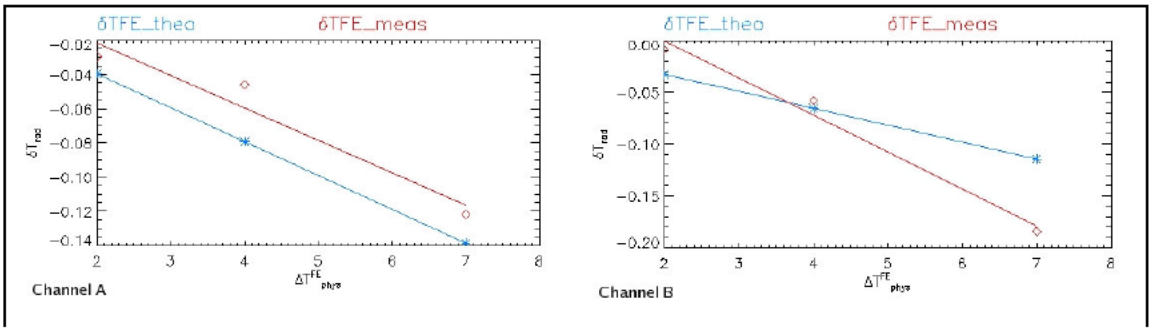
7.3.1.2 Analysis using the SMON_TMP probe as sky load temperature:

The default parameters for the four channels are:

Table -8-5: Default input parameters for RCA_THF analysis

	Ch. A	Ch. B	Ch. C	Ch. D
Freq (*GHz*)	30			
$L_{feed-OMT}$ (*dB*)	0.1			
L_{4k} (*dB*)	0.1			
r	0.94340612	0.95825588	0.94434556	0.95426438
T_{sky} (*K*)	9.7732			
T_{ref} (*K*)	9.1999			
G_{F1}^{dB} **(*dB*)**	35			
G_{F2}^{dB} **(*dB*)**	35			
T_{nF1} (*K*)	20	20	20	20
T_{nF2} (*K*)	20	20	20	20
$\partial G_{F1}^{dB} / \partial T_{phys}^{FE}$ **(*dB/K*)**	-0.05	-0.05	-0.05	-0.05
$\partial G_{F2}^{dB} / \partial T_{phys}^{FE}$ **(*dB/K*)**	-0.05	-0.05	-0.05	-0.05
$\partial T_{nF1} / \partial T_{phys}^{FE}$ **(*K/K*)**	0.08	0.08	0.08	0.08
$\partial T_{nF2} / \partial T_{phys}^{FE}$ **(*K/K*)**	0.08	0.08	0.08	0.08
Gain Calibration Factor (*V/K*)	0.024	0.026	0.0293	0.038

Calculating the theoretical and the measured transfer functions with RaNA, we obtain:



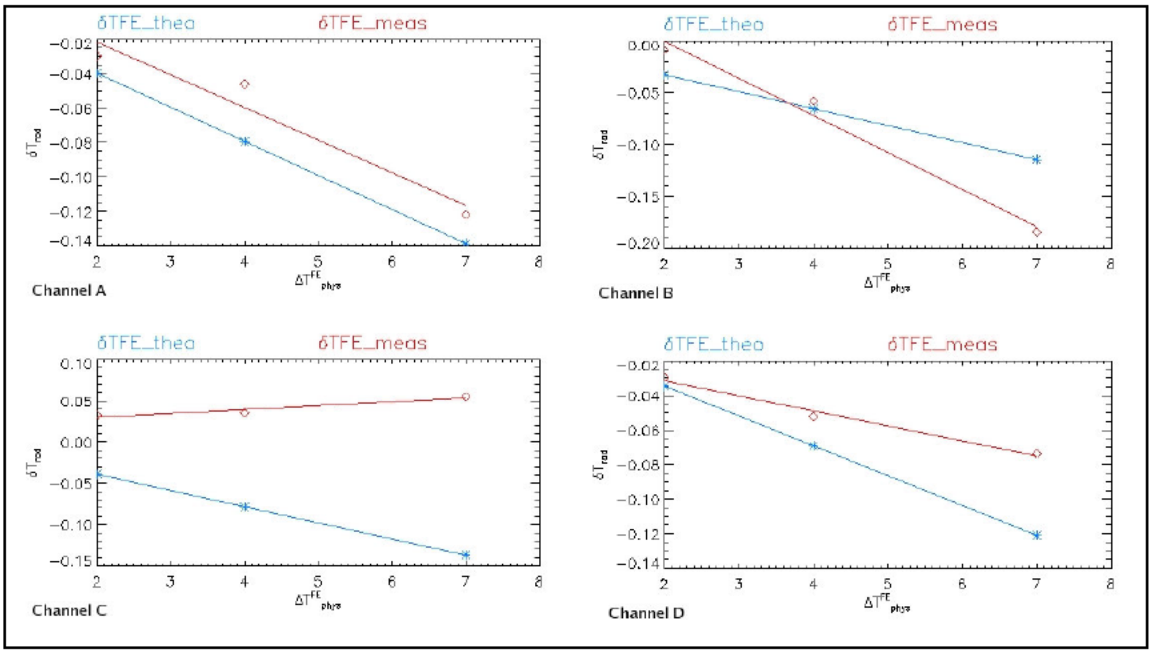


Figure -8-14: RCA_THF theoretical (blue) Vs measured (red) transfer function

Table -8-6: RCA_THF Analysis Result based on default parameters

	Channel A	Channel B	Channel C	Channel D
$f^{front-end}_{therm}$ **(K/K) theoretical**	-0.019812	-0.016342	-0.019593	-0.017275
$f^{front-end}_{therm}$ **(K/K) measured**	-0.01896	-0.035674	0.0047	-0.0087

The complete RaNA output:

FEM susceptibility INPUT Frequency (GHz) = 30 Channel : A Load correct : Yes r = 0.94340612 Model: FM Gain calibration factor (V/K) = 0.024 LfeedOMT_dB = 0.1 L4K_dB = 0.1 GF1_dB = 35 GF2_dB = 35 TnF1_K = 20 TnF2_K = 20 dGF1_dB_dTFEphys_K = -0.05 dGF2_dB_dTFEphys_K = -0.05 dTn1_dTFEphys_K = 0.08 dTn2_dTFEphys_K = 0.08 There are 4 time windows tmin tmax 1 87 283 954 1215 4351 4756 5200 Sky Sensor = SMON_TMP	FEM susceptibility INPUT Frequency (GHz) = 30 Channel : B Load correct : Yes r = 0.95825588 Model: FM Gain calibration factor (V/K) = 0.026 LfeedOMT_dB = 0.1 L4K_dB = 0.1 GF1_dB = 35 GF2_dB = 35 TnF1_K = 20 TnF2_K = 20 dGF1_dB_dTFEphys_K = -0.05 dGF2_dB_dTFEphys_K = -0.05 dTn1_dTFEphys_K = 0.08 dTn2_dTFEphys_K = 0.08 There are 4 time windows tmin tmax 1 87 283 954 1215 4351 4756 5200 Sky Sensor = SMON_TMP

```
Ref Sensor =        REF_TEMP
FEM Sensor =        FEM_TEMP

          SMON_TMP  REF_TEMP  FEM_TEMP
          9.77321625          9.19989681          19.99991035
          9.77312279          9.19986153          22.00007629
          9.77340031          9.19967365          23.99995804
          9.77482128          9.19994164          27.00001526

Radiometer outputs (K)
          Tsky      Tref
          34.485854 36.554622
          34.959742 37.088436
          35.461964 37.638168
          36.225699 38.527968

          Tsky-r*Tref
          -0.029714964
          -0.046114457
          -0.12182133

OUTPUT
          ftheo (K/K)         fmeas (K/K)
          -0.019812 -0.01896
```

```
Ref Sensor =        REF_TEMP
FEM Sensor =        FEM_TEMP

          SMON_TMP  REF_TEMP  FEM_TEMP
          9.77321625          9.19989681          19.99991035
          9.77312279          9.19986153          22.00007629
          9.77340031          9.19967365          23.99995804
          9.77482128          9.19994164          27.00001526

Radiometer outputs (K)
          Tsky      Tref
          36.127361 37.701163
          36.636851 38.242149
          37.139825 38.818244
          37.901477 39.745099

          Tsky-r*Tref
          -0.0089128022
          -0.057985296
          -0.18449857

OUTPUT
          ftheo (K/K)         fmeas (K/K)
          -0.016342 -0.035674
```

```
FEM susceptibility
INPUT
Frequency (GHz) =   30
Channel : C
Load correct :      Yes
r =       0.94434556
Model:    FM
Gain calibration factor (V/K) =        0.0293
LfeedOMT_dB =       0.1
L4K_dB =  0.1
GF1_dB =  35
GF2_dB =  35
TnF1_K =  20
TnF2_K =  20
dGF1_dB_dTFEphys_K =          -0.05
dGF2_dB_dTFEphys_K =          -0.05
dTn1_dTFEphys_K =   0.08
dTn2_dTFEphys_K =   0.08

There are 4         time windows
          tmin      tmax
          1         87
          283       954
          1215      4351
          4756      5200

Sky Sensor =        SMON_TMP
Ref Sensor =        REF_TEMP
FEM Sensor =        FEM_TEMP

          SMON_TMP  REF_TEMP  FEM_TEMP
          9.77321625          9.19989681          19.99991035
          9.77312279          9.19986153          22.00007629
          9.77340031          9.19967365          23.99995804
          9.77482128          9.19994164          27.00001526

Radiometer outputs (K)
          Tsky      Tref
          31.639373 33.50402
          32.115329 33.973947
          32.587986 34.471194
          33.318422 35.22369

          Tsky-r*Tref
          0.032182741
          0.035266259
          0.055086663

OUTPUT
          ftheo (K/K)         fmeas (K/K)
          -0.019593 0.004741
```

```
FEM susceptibility
INPUT
Frequency (GHz) =   30
Channel : D
Load correct :      Yes
r =       0.95426438
Model:    FM
Gain calibration factor (V/K) =        0.038
LfeedOMT_dB =       0.1
L4K_dB =  0.1
GF1_dB =  35
GF2_dB =  35
TnF1_K =  20
TnF2_K =  20
dGF1_dB_dTFEphys_K =          -0.05
dGF2_dB_dTFEphys_K =          -0.05
dTn1_dTFEphys_K =   0.08
dTn2_dTFEphys_K =   0.08

There are 4         time windows
          tmin      tmax
          1         87
          283       954
          1215      4351
          4756      5200

Sky Sensor =        SMON_TMP
Ref Sensor =        REF_TEMP
FEM Sensor =        FEM_TEMP

          SMON_TMP  REF_TEMP  FEM_TEMP
          9.77321625          9.19989681          19.99991035
          9.77312279          9.19986153          22.00007629
          9.77340031          9.19967365          23.99995804
          9.77482128          9.19994164          27.00001526

Radiometer outputs (K)
          Tsky      Tref
          32.644433 34.209002
          33.042506 34.657056
          33.478203 35.137551
          34.153623 35.867703

          Tsky-r*Tref
          -0.029487579
          -0.052310829
          -0.073648522

OUTPUT
          ftheo (K/K)         fmeas (K/K)
          -0.017275 -0.008696
```

To improve the results obtained with the default parameters, I am going to change any of them. In particular, I change the $\partial G^{dB}_{FE}/\partial T^{FE}_{phys}$ and $\partial T_{nFE}/\partial T^{FE}_{phys}$. The best values will be:

Table -8-7: Optimized parameters of RCA_THF test

	Ch. A	Ch. B	Ch. C	Ch. D
$\partial G_{F1}^{dB} / \partial T_{phys}^{FE}$ **(dB/K)**	-0.048	-0.092	-0.0256	-0.035
$\partial G_{F2}^{dB} / \partial T_{phys}^{FE}$ **(dB/K)**	-0.048	-0.092	-0.0256	-0.035
$\partial T_{nF1} / \partial T_{phys}^{FE}$ **(K/K)**	0.077	0.035	0.29	0.123
$\partial T_{nF2} / \partial T_{phys}^{FE}$ **(K/K)**	0.077	0.035	0.29	0.123

and calculating the transfer functions, the new results:

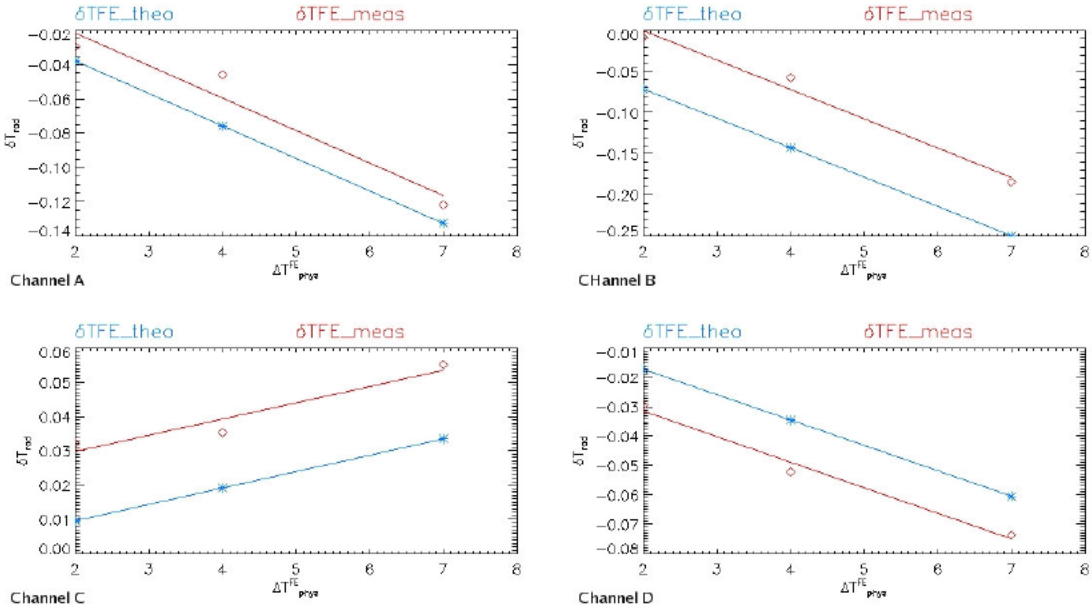


Figure -8-15: RCA_THF theoretical Vs measured transfer function after optimization of the parameters.

*Table -8-8: **RCA_THF Optimal transfer function Vs. theoretical***

	Channel A	Channel B	Channel C	Channel D
$f_{therm}^{front-end}$ **(K/K) theoretical**	-0.018955	-0.035679	0.004784	-0.008637
$f_{therm}^{front-end}$ **(K/K) measured**	-0.01896	-0.035674	0.00474	-0.008696

The complete RaNA output:

```
FEM susceptibility
INPUT
Frequency (GHz) =   30
Channel : A
Load correct :      Yes
r =        0.94340612
Model:    FM
Gain calibration factor (V/K) =          0.024
LfeedOMT_dB =        0.1
L4K_dB =   0.1
GF1_dB =  35
GF2_dB =  35
TnF1_K =  20
TnF2_K =  20
dGF1_dB_dTFEphys_K =          -0.048
```

```
FEM susceptibility
INPUT
Frequency (GHz) =   30
Channel : B
Load correct :      Yes
r =        0.95825588
Model:    FM
Gain calibration factor (V/K) =          0.026
LfeedOMT_dB =        0.1
L4K_dB =   0.1
GF1_dB =  35
GF2_dB =  35
TnF1_K =  20
TnF2_K =  20
dGF1_dB_dTFEphys_K =          -0.092
```

```
dGF2_dB_dTFEphys_K =          -0.048
dTn1_dTFEphys_K =   0.077
dTn2_dTFEphys_K =   0.077

There are 4         time windows
          tmin      tmax
          1         87
          283       954
          1215      4351
          4756      5200

Sky Sensor =        SMON_TMP
Ref Sensor =        REF_TEMP
FEM Sensor =        FEM_TEMP

          SMON_TMP  REF_TEMP  FEM_TEMP
          9.77321625          9.19989681          19.99991035
          9.77312279          9.19986153          22.00007629
          9.77340031          9.19967365          23.99995804
          9.77482128          9.19994164          27.00001526

Radiometer outputs (K)
          Tsky      Tref
          34.485854 36.554622
          34.959742 37.088436
          35.461964 37.638168
          36.225699 38.527968

          Tsky-r*Tref
          -0.029714964
          -0.046114457
          -0.12182133

OUTPUT
          ftheo (K/K)         fmeas (K/K)
          -0.018955 -0.01896
```

```
dGF2_dB_dTFEphys_K =          -0.092
dTn1_dTFEphys_K =   0.035
dTn2_dTFEphys_K =   0.035

There are 4         time windows
          tmin      tmax
          1         87
          283       954
          1215      4351
          4756      5200

Sky Sensor =        SMON_TMP
Ref Sensor =        REF_TEMP
FEM Sensor =        FEM_TEMP

          SMON_TMP  REF_TEMP  FEM_TEMP
          9.77321625          9.19989681          19.99991035
          9.77312279          9.19986153          22.00007629
          9.77340031          9.19967365          23.99995804
          9.77482128          9.19994164          27.00001526

Radiometer outputs (K)
          Tsky      Tref
          36.127361 37.701163
          36.636851 38.242149
          37.139825 38.818244
          37.901477 39.745099

          Tsky-r*Tref
          -0.0089128022
          -0.057985296
          -0.18449857

OUTPUT
          ftheo (K/K)         fmeas (K/K)
          -0.035679 -0.035674
```

```
FEM susceptibility
INPUT
Frequency (GHz) =   30
Channel : C
Load correct :      Yes
r =       0.94434556
Model:    FM
Gain calibration factor (V/K) =         0.0293
LfeedOMT_dB =       0.1
L4K_dB =  0.1
GF1_dB =  35
GF2_dB =  35
TnF1_K =  20
TnF2_K =  20
dGF1_dB_dTFEphys_K =          -0.0256
dGF2_dB_dTFEphys_K =          -0.0256
dTn1_dTFEphys_K =   0.29
dTn2_dTFEphys_K =   0.29

There are 4         time windows
          tmin      tmax
          1         87
          283       954
          1215      4351
          4756      5200

Sky Sensor =        SMON_TMP
Ref Sensor =        REF_TEMP
FEM Sensor =        FEM_TEMP

          SMON_TMP  REF_TEMP  FEM_TEMP
          9.77321625          9.19989681          19.99991035
          9.77312279          9.19986153          22.00007629
          9.77340031          9.19967365          23.99995804
          9.77482128          9.19994164          27.00001526

Radiometer outputs (K)
          Tsky      Tref
          31.639373 33.50402
          32.115329 33.973947
          32.587986 34.471194
          33.318422 35.22369

          Tsky-r*Tref
          0.032182741
          0.035266259
          0.055086663

OUTPUT
          ftheo (K/K)         fmeas (K/K)
          0.004784  0.004741
```

```
FEM susceptibility
INPUT
Frequency (GHz) =   30
Channel : D
Load correct :      Yes
r =       0.95426438
Model:    FM
Gain calibration factor (V/K) =         0.038
LfeedOMT_dB =       0.1
L4K_dB =  0.1
GF1_dB =  35
GF2_dB =  35
TnF1_K =  20
TnF2_K =  20
dGF1_dB_dTFEphys_K =          -0.035
dGF2_dB_dTFEphys_K =          -0.035
dTn1_dTFEphys_K =   0.123
dTn2_dTFEphys_K =   0.123

There are 4         time windows
          tmin      tmax
          1         87
          283       954
          1215      4351
          4756      5200

Sky Sensor =        SMON_TMP
Ref Sensor =        REF_TEMP
FEM Sensor =        FEM_TEMP

          SMON_TMP  REF_TEMP  FEM_TEMP
          9.77321625          9.19989681          19.99991035
          9.77312279          9.19986153          22.00007629
          9.77340031          9.19967365          23.99995804
          9.77482128          9.19994164          27.00001526

Radiometer outputs (K)
          Tsky      Tref
          32.644433 34.209002
          33.042506 34.657056
          33.478203 35.137551
          34.153623 35.867703

          Tsky-r*Tref
          -0.029487579
          -0.052310829
          -0.073648522

OUTPUT
          ftheo (K/K)         fmeas (K/K)
          -0.008637 -0.008696
```

7.4 RCA_ELE: Susceptibility to Disturbance on Bias Lines

Test not performed due to setup problem.

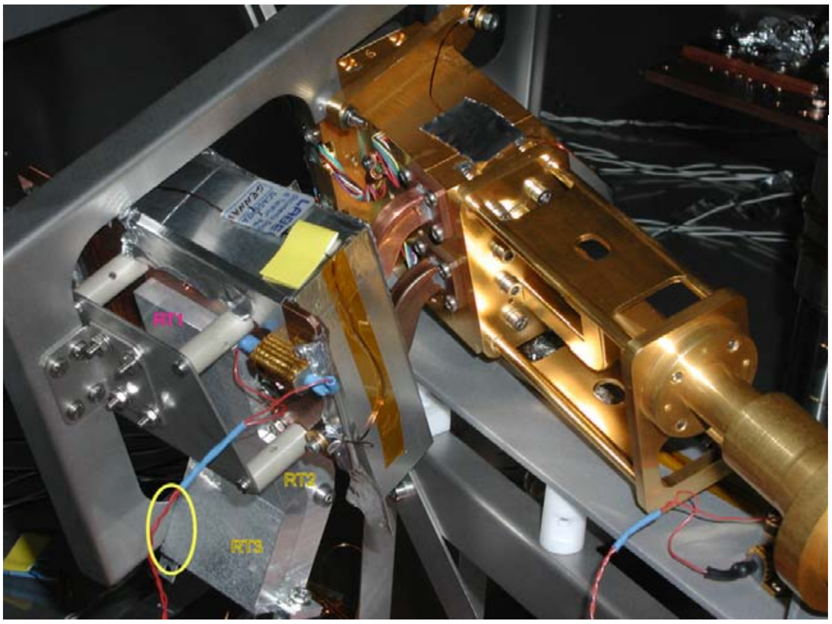
L. Terenzi - 15 May 2006

1 Introduction

During the FM RCA 27 and 28 test runs some uncertainties about the reference targets temperature arose, due to difficulties found in the data analysis.
The visual inspection of the cryochamber setup after the RCA 28 test has given some possible explaination for the discrepancies found.
In the RCA27 test run, an additional sensor was put on the back of one of the reference targets in order to verify the source of this systematic.
Actually the Reference Load assembly mounted in the chamber was very close to its insulating support, in such a way that during cooldown a possible contact would have caused an unwanted heat flow through the 4K RL.
In this report a thermal analysis of such a kind of thermal contact has been performed and its consequences on the data analysis are discussed.

2 The thermal model of the experimental setup

The reference load is located in front of the reference horns and mechanically mounted on the FEM structure by means of an insulating supporting structure (**Fig. 1**, left).



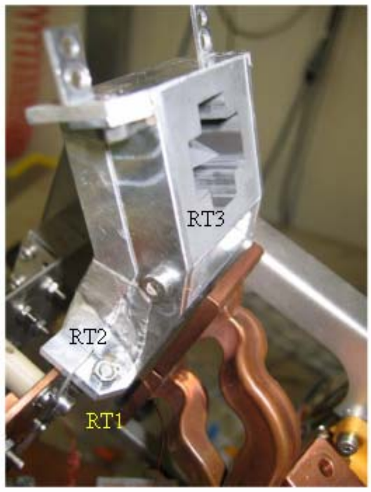
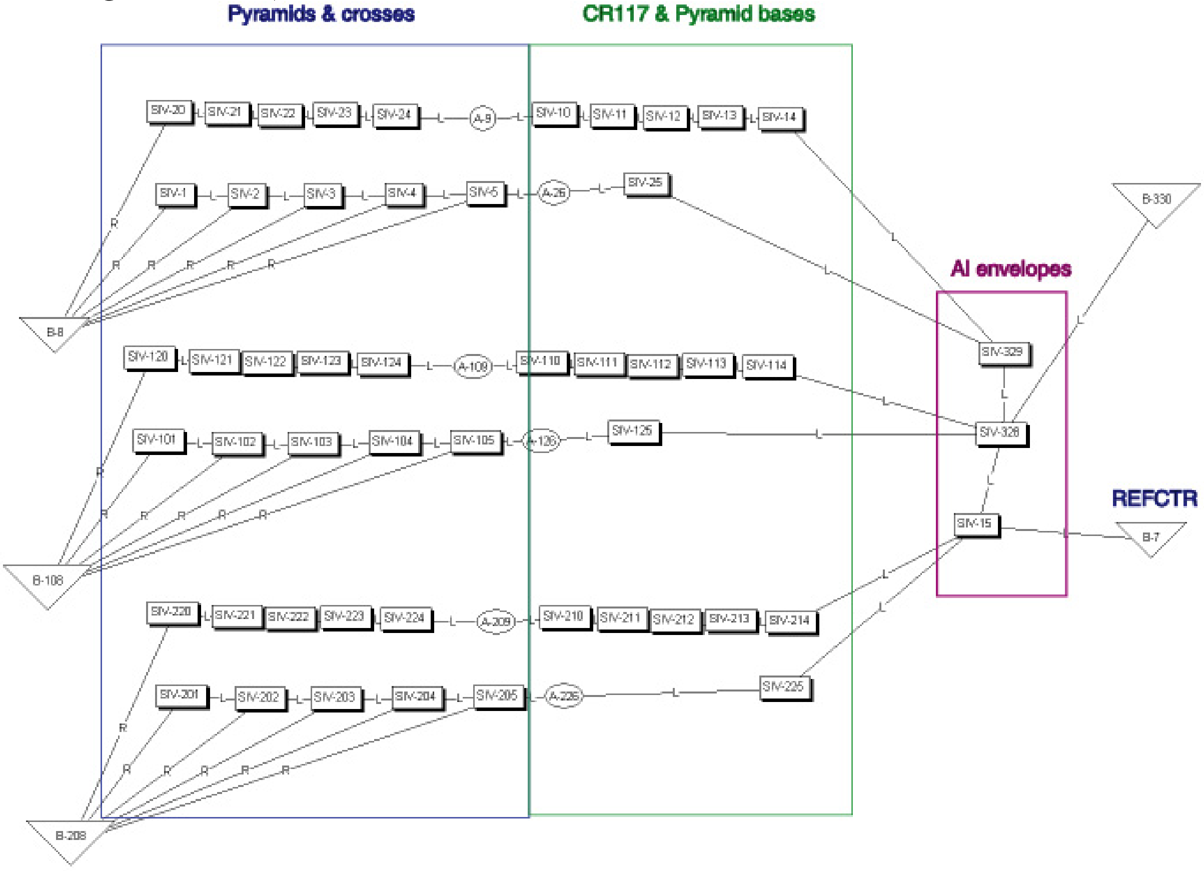


Fig. 1 The 4K RL mounted in the RCA28 test (left). In the yellow circle a possible contact between the target RT3 and the supporting structure is visible. In the RCA27 calibration run a similar contact can be considered at the level of the RT2 envelope..

In the two different 30 GHz RCAs the 4K RL had a different mounting direction, so that the possible contact point is different in the two cases (**Fig. 1**).

The corresponding thermal models differs only for this thermal conductor. The models contain also a radiative load from an environment of 30 K (the 4K antennas are at about 20 K but I wanted to increase the radiative heat load considering that a small contribution would come also from the surrounding 50 K shield).



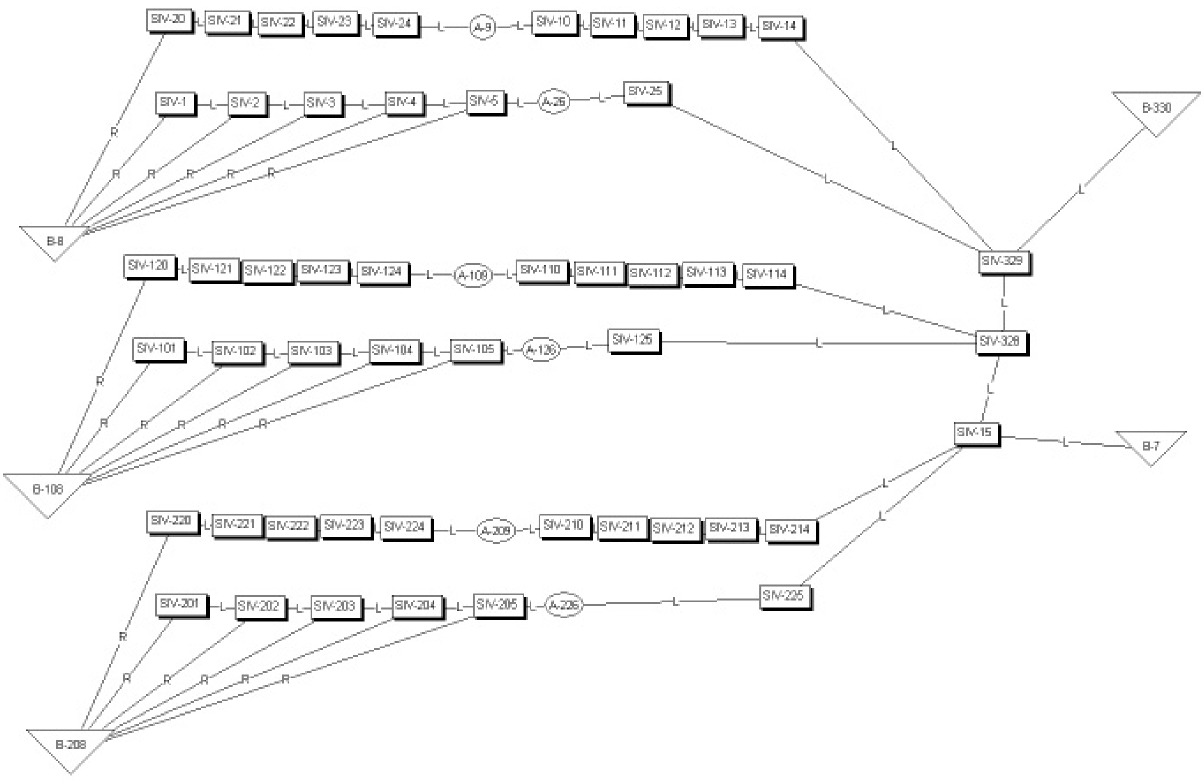


Fig. 2 The thermal models for the RCA 27 (upper diagram) ad RCA28 (lower diagram) differ only in the conductor linking the contact node (triangular in the upper right part of the diagrams) to the 4K RL.

3 RCA27 data analysis

I started my analysis from the RCA27 where two sensor data, one on the copper control stage (REFCTR) and one on the back of the RT2 (REFMON) could be used.
Data used in this analysis are taken from the 030LFI27_RCA_FM_LIS_200604081545 dataset.
Assuming a thermal contact between the stainless steel support (at about 21.5 K) and the RT2, the temperatures of the RT1 and RT2, at the steady state, are then depending mainly on three thermal conductances:
K1 is the thermal conductance between RT1 and the copper control stage;
K2 is the thermal conductance between RT2 and RT1;
K3 is the contact between support and RT2 envelope.
The analysis consisted of three main steps.

4 First step

Trying to reproduce only the steady temperature differences REFMON sensor and the REFCTR sensor, mounted on the copper control stage, We can estimate the ratio between two conductances, apply the equation:

$$K3 * \Delta T_{SS-RT2} = \frac{1}{\frac{1}{K1} + \frac{1}{K2}} \cdot \Delta T_{RT2-CTR}$$

The absolute conductances are estimated using the transient steps and fitting the measured curves with the simulated ones .

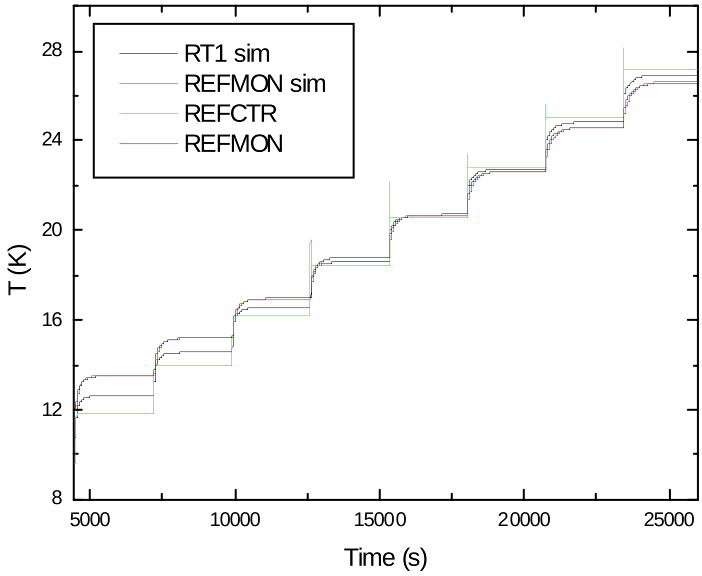
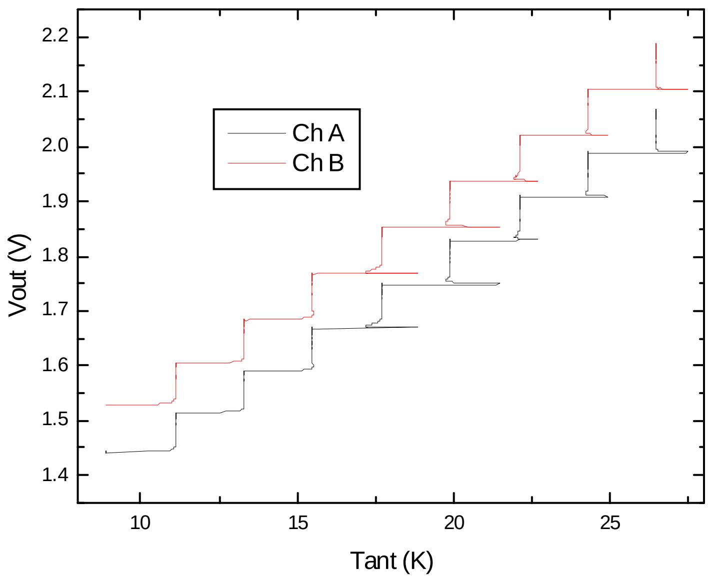


Fig. 3 Comparison between simulated and measured temperatures. REFCTR is the input to the simulation so that the simulated and measured curves are equivalent

On the lowest steady state, the total heat flow through the reference load is about 36 mW, with 35.34 mW coming from the conductive link so that we could neglect the radiative load.

5 Second step

After having fixed a good matching between simulated and measured thermal data, I study the correlation between the temperature curves of RT2 and the RCA outputs A and B.
In Fig. 4 I plot the ChA, ChB and Ch C, Ch D voltage outputs vs the antenna temperature conversion of REFCTR sensor; it is evident how this temperature is not significant of the radiometer outputs.



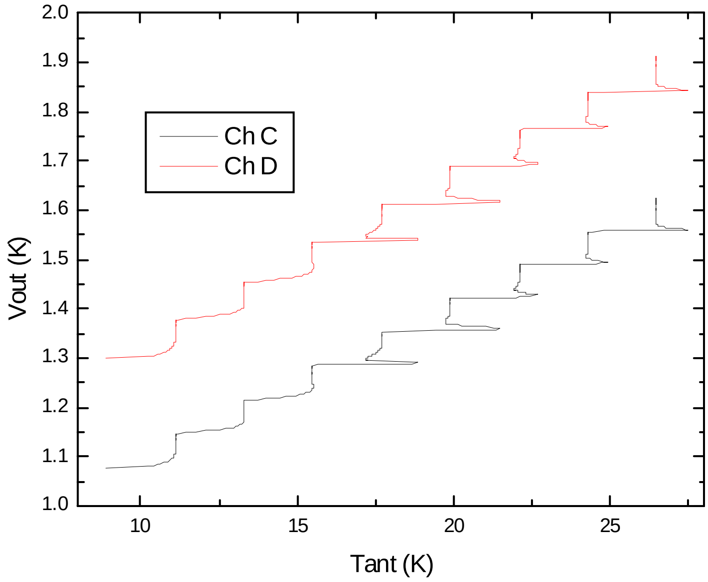
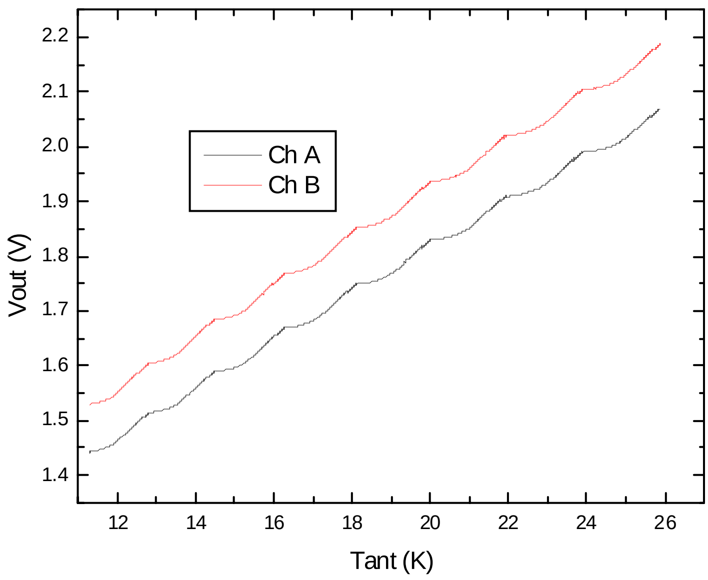


Fig. 4 The V vs REFCTR temperature plots of the radiometer outputs (A, B on top panel and C, D on bottom panel). We can see how the voltage varies with a long delay with respect to temperature variation.

The REFMON has a better correlation to detectors. In the case of A and B detectors show a small delay as expected since we suppose that the a significant tracer of the radiometer signal has to be located at the level of the target pyramid. In th case of C and D the detectors are varying more rapidly at the beginning of the temperature steps as they observe the RT1 which is closer to control stage and then is reacting to power injection before the RT2.



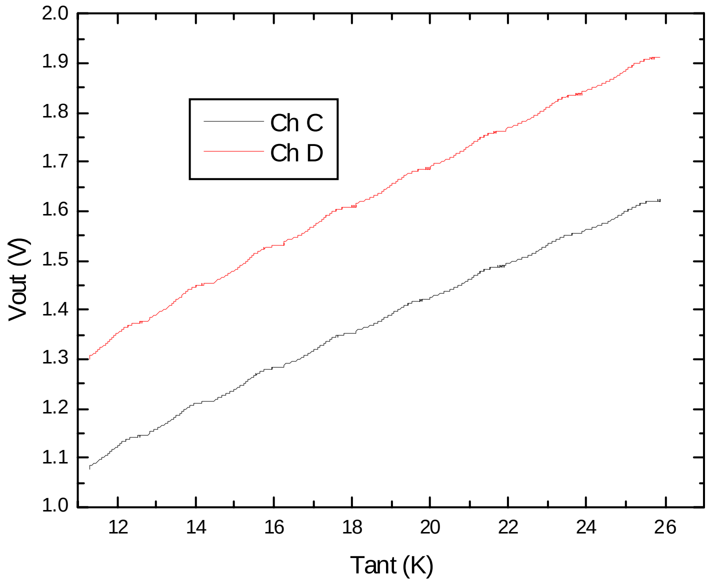


Fig. 5 The V vs REFMON temperature plots of the radiometer outputs (A, B on top panel and C, D on bottom panel)..

Then I take as a reference a thermal node at half the pyramid height of RT2 and correlate its simulated (antenna) temperature to the BEM voltage. The corresponding Voltage vs Temperature curves are shown in Fig. 6

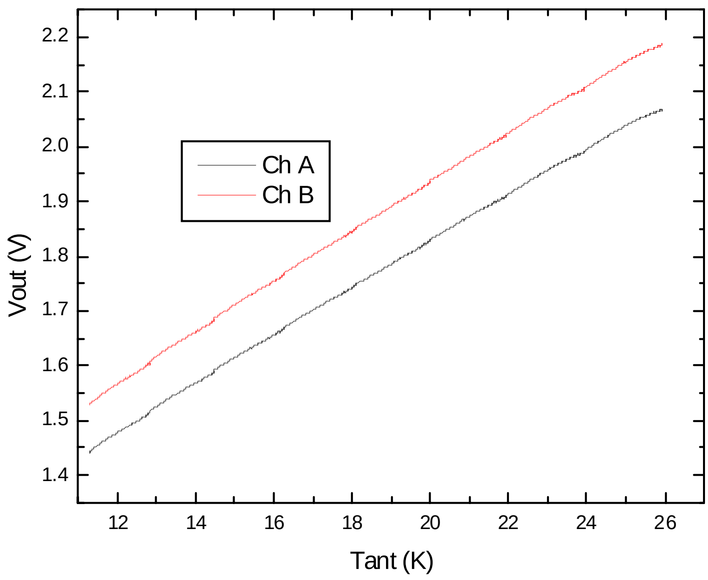


Fig. 6 The V vs T curves whose fit is used to estimate the noise temperatures for channels A and B

It is evident how the correlation between temperature and radiometer output is very accurate.

6 Third step

Finally I modulate K1 and K2 in order to have a correlation between the simulated RT1 and channels C and D output comparable to the RT2 one, also during transient steps, in order to estimate the right RT1 temperature to be used in the data analysis. The result is shown in Fig. 7

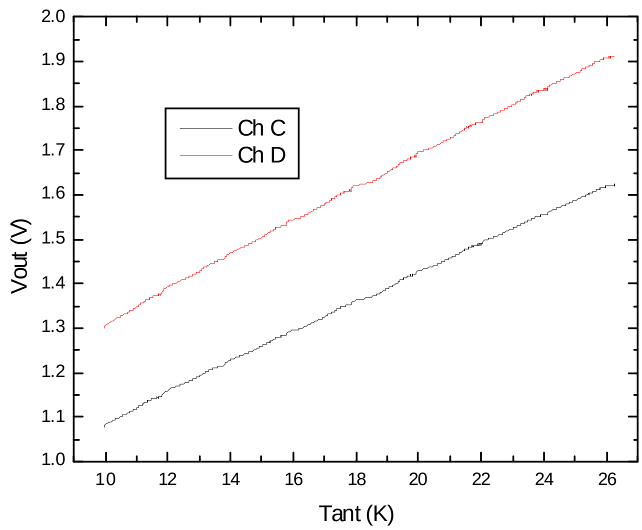


Fig. 7 The V vs T curves whose linear fit is used to estimate the noise temperatures for channels C and D

7 RCA28 data analysis

I then performed a similar simulation on the RCA28 model (Fig. 2 bottom panel). Using the same model changing only the contact point a good result is found.
The V vs T plots are shown in Fig. 8 and Fig. 9.

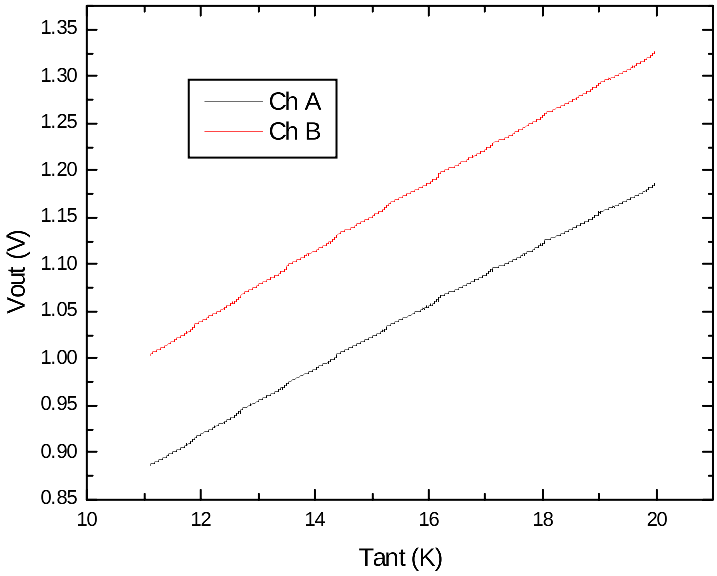


Fig. 8 The V vs T curves whose fit is used to estimate the noise temperatures for RCA28 channels A and B

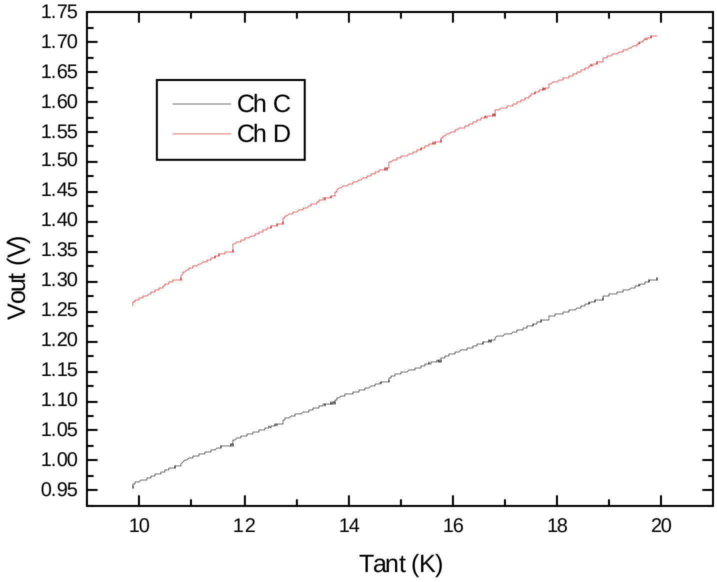


Fig. 9 The V vs T curves whose fit is used to estimate the noise temperatures for RCA28 channels C and D

8 Conclusions

A thermal model of the 4 K reference load mounted on the RCA cryochamber during the RCA27 and RCA28 test run was developed in order to estimate the reference targets actual temperature observed by the reference horns. The use of a sensor located on the back of one of the targets in RCA27 provided us a good check for the model. Then the correlation between the radiometer outputs and pyramids temperature was used to estimate the noise temperatures of the radiometer chains.
The tables below summarize the RCA parameters evaluated

8.1 DETECTOR	TnRef ParFit (K)	TnSky ParFit (K)
RCA27 A	13.82721	12.80
RCA27 B	13.49102	12.43
RCA27 C	15.70097	13.78
RCA27 D	16.83996	13.71
RCA28 A	8.2743	9.4822
RCA28 B	8.4285	9.3958
RCA28 C	10.8866	10.10705
RCA28 D	10.51545	9.48525

RADIOMETER GAIN MODEL

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IASF – Bologna
17 May 2006

A new gain model has been developed based on paper of “William C. Daywitt, *Radiometer Equation and Analysis of Systematic Errors for the NIST Automated Radiometers*, 1989 ” modified for the case of LFI.
The hypothesis are the following:

The FEM has constant gain and Tnoise.

$$FEM: \begin{cases} Gain = G^{(FEM)} \\ Noise = T_N^{(FEM)} \end{cases}$$

The BEM has a gain which depends on the BEM input power as follows

$$BEM: \begin{cases} Gain = G^{BEM} = \dfrac{G_0^{BEM}}{1 + b \cdot G_0^{BEM} \cdot p} \\ Noise = T_N^{BEM} \end{cases}$$

Where *p* is the power entering the BEM and *a* is a parameter defining the non linearity of the BEM.
Of course this is a particular gain model but some consideration can be appointed:

1) For $b = 0$ the radiometer is linear.
2) For *b* = infinity the BEM has a G= 0
3) For p = infinity the BEM is completely compressed and G = 0 has expected

The power entering the BEM (we neglect the attenuation of the WGs which may be included in the FEM parameters) is:

$p = k \cdot B \cdot G_0^{FEM} \cdot \left(T_A + T_N^*\right)$, Where $T_N^* = T_N^{FEM} + \dfrac{T_N^*}{G_0^{FEM}}$

So at the output of the BEM we have (the diode constant is considered inside the BEM gain)

$$V_{out} = k \cdot B \cdot G_0^{FEM} \cdot \frac{G_0^{BEM} \cdot \left(T_A + T_N^*\right)}{1 + b \cdot k \cdot B \cdot G_0^{BEM} \cdot \left(T_A + T_N^*\right)} = G_0 \cdot \left[\frac{1}{1 + b \cdot G_0 \cdot \left(T_A + T_N^*\right)}\right] \cdot \left(T_A + T_N^*\right)$$

$$G_0 = G_0^{FEM} \cdot G_0^{BEM} \cdot k \cdot B$$

Or in a compact way

$$V_{out} = G_{tot} \cdot \left(T_A + T_N^*\right)$$

$$G_{tot} = G_0 \cdot \left[\frac{1}{1 + b \cdot G_0 \cdot \left(T_A + T_N^*\right)}\right]$$

Gtot is the radiometer gain which depends on the input antenna temperature.

A fit on the data has been performed with this following function:

$$V_{out} = G_0 \cdot \left[\frac{1}{1 + b \cdot G_0 \cdot \left(T_A + T_N^*\right)}\right] \cdot \left(T_A + T_N^*\right)$$

With a fit G_0, T_N^* and b can de derived form data taken on RCA_LIS test.

0.1 RANA_SPR_001

Data from file set: 030LFI28_RCA_FM_SPR_200603221625
Contained in directory: /home/villa/030LFI28_RCA_FM_SPR_200603221625

0.1.1 Input Data

Frequency: 30 GHz
Trigger Detector: C
F_min: 26.50 GHz
F_max: 40.00 GHz
Step: 0.05 GHz
Threshold: 0.0700 V/s
Useful Data: 50.00 %
Calibration File: /media/VILAS/cal_spr_FM_30GHz_01.dat

0.1.2 Comments

SPR test results calibrated considering standard WR28 attenuation (normalized to 30GHz).
test properties(from log file):

- RCA_SPR: power level = −30 dBm
- Trigger sequence = [6,0,3,0] at 26.85 GHz
- Number of points = 271 (0.05 GHz step)

0.1.3 Output Data

Table 1: Central frequency and equivalent bandwidth.

Channel	Central Frequency (GHz)	Equivalent Bandwidth (GHz)
A	32.35	3.22
B	32.45	3.23
C	31.40	4.94
D	31.35	5.12

0.1.4 Derivative Plots

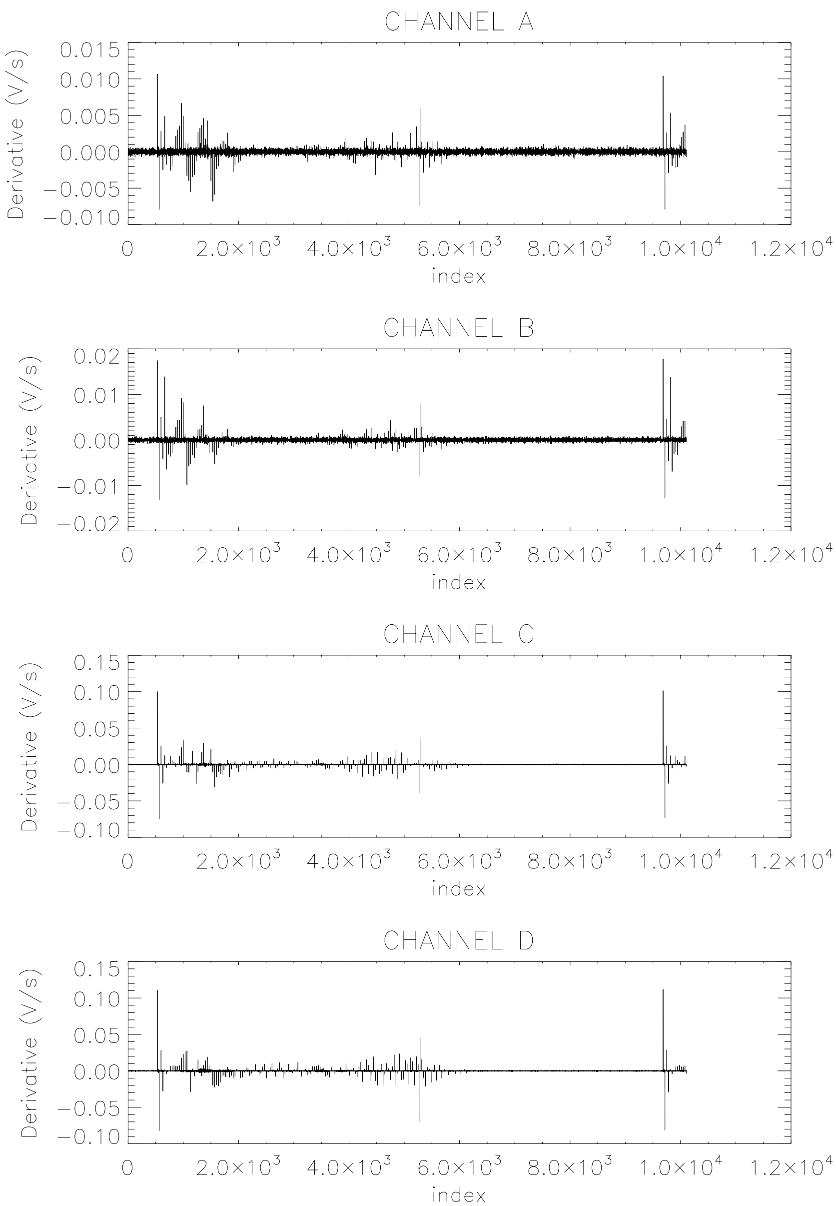

Figure 1: Data binned with a bin equal to 0.

0.1.5 Selected Plots

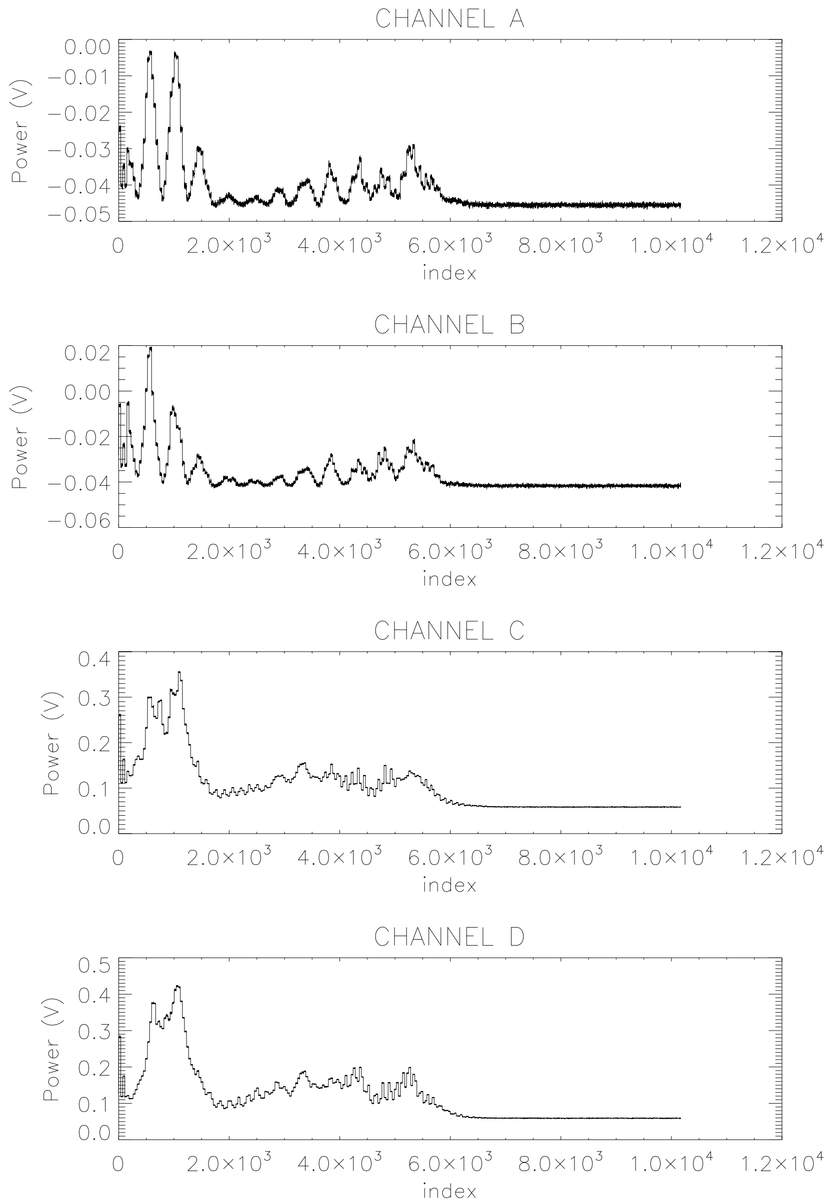

Figure 2: Data binned with a bin equal to 0.

0.1.6 Radiometer Spectral Response

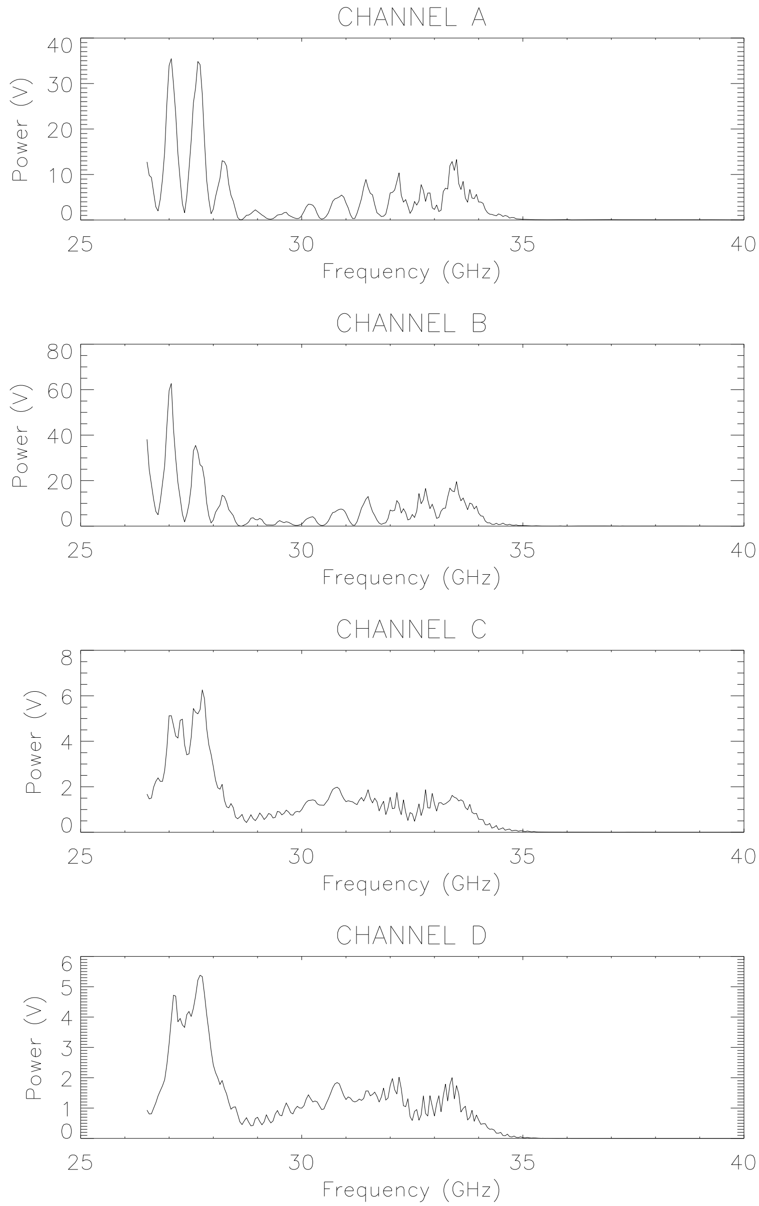

Figure 3: Calibrated data.

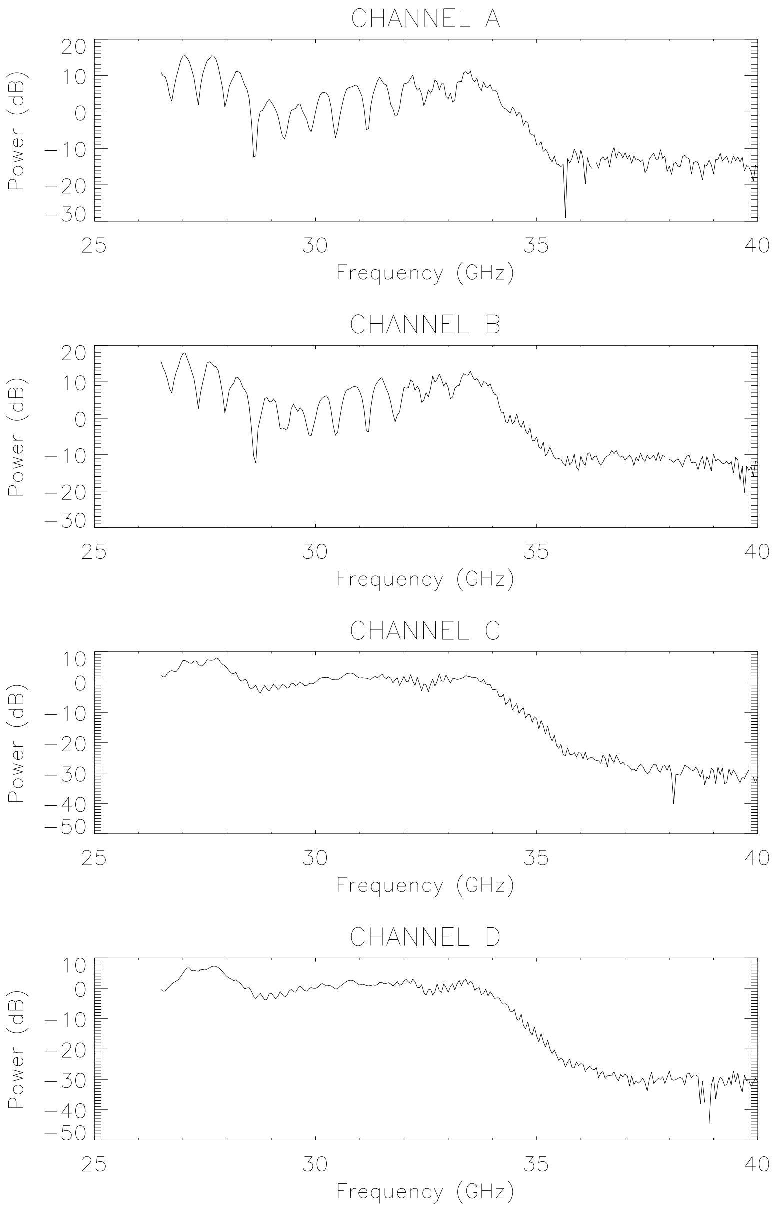

Figure 4: Calibrated data in dB.

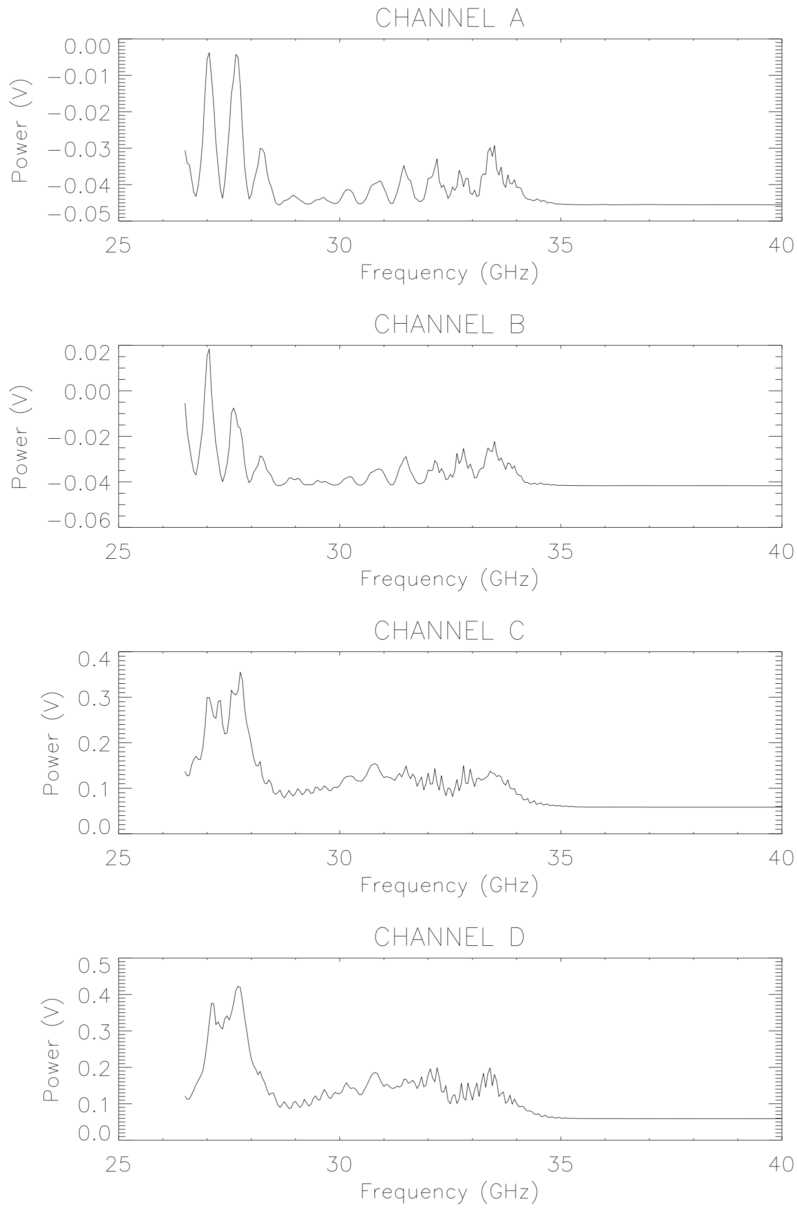

Figure 5: Uncalibrated data.