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# FM 30GHz RCA28 Data Analysis Report

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# **CHANGE RECORD**

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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

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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.

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

Table 5-1: BEM offset values.

# 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**:

, 0110.							
	Detectors A and	В		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		

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.

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<sup>2</sup>
- inverse parabolic fit T(V): T=a0+a1\*V+a2\*V<sup>2</sup>
- gain-model fit V(T): V = G\*(T+T0)/(1+b\*G\*(T+T0)) (T0 is the Tn)

The fit results are reported here:

	Lin	ear		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)									

Table 6-2: Fitting parameters for REF steps.





G	TO	В
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))
	linear fit: parabolic fit V(T): inverse parabolic fit T(V): gain-model fit V(T) :

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

G0 =	0.03327	(V/K)
G0 =	0.03574	(V/K)
G0 =	0.03418	(V/K)
G0 =	0.04455	(V/K)
	G0 = G0 = G0 = G0 =	$\begin{array}{rcl} G0 &=& 0.03327\\ G0 &=& 0.03574\\ G0 &=& 0.03418\\ G0 &=& 0.04455 \end{array}$

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)

<u>Photometric Gain from inverse parabolic T(V) fit</u> Detector A: G2 = 12.67686 + 16.68 \* V (K/V) Detector B: G2 = 9.50974 + 15.76 \* V (K/V)

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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	s RaNa
routine us	ed to perform	the fits. Only 1	T change and	Vchange	e data have be	en used.
Temperatu	ures are in Kelv	in, 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<sup>2</sup>
- •
  - 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)	
IN	AF/IA	SF - BOLOGNA		
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		FM 44	4 GH	Iz RCA2	28 Data	ANALYSIS	Report	Do r Iss	ocument sue/Rev H	t No.: . No.: Date: Page :	PL-LFI-PST-RP-020 1.0 Aug 06 8
	a0	at	l	a0	a1	a2	a0	a1	a2		
Detector A	0.5523	0.03	149	0.47677	0.04036	-2.45179E-4	-7.89569	14.24976	7.82265		
Detector B	0.6504	4 0.03	503	0.55867	0.04579	-2.97431E-4	-7.4295	10.89453	6.89577		
Detector C	0.6968	0.03	475	0.60526	0.0455	-2.97115E-4	-7.90232	10.14162	7.05041		
Detector D	0.9181	4 0.04	462	0.78854	0.05983	-4.20232E-4	-6.8266	6.21257	4.70981		
				Gain-Mo V(T	del Fit )						
		G		то		В					
		0.05153		9.9	0879	0.19435					
		0.0604		9.9	98176	0.1856					
		0.06134		10.3	37908	0.18646					
		0.08332		10.1	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

G0 =	=	0.03149	(V/K)
G0 =	=	0.03503	(V/K)
G0 =	=	0.03475	(V/K)
G0 =	=	0.04462	(V/K)
	G0 = G0 = G0 =	G0 = G0 = G0 = G0 =	$\begin{array}{rcl} G0 &=& 0.03149\\ G0 &=& 0.03503\\ G0 &=& 0.03475\\ G0 &=& 0.04462 \end{array}$

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

G2	=	14.24976	+	15.64	*	V	(K/V)
G2	=	10.89453	+	13.80	*	V	(K/V)
G2	=	10.14162	+	14.10	*	V	(K/V)
G2	=	6.21257	+	9.42	*	V	(K/V)
	G2 G2 G2 G2	G2 = G2 = G2 = G2 =	$\begin{array}{rcl} G2 &=& 14.24976 \\ G2 &=& 10.89453 \\ G2 &=& 10.14162 \\ G2 &=& 6.21257 \end{array}$	$\begin{array}{rcl} G2 &=& 14.24976 &+ \\ G2 &=& 10.89453 &+ \\ G2 &=& 10.14162 &+ \\ G2 &=& 6.21257 &+ \end{array}$	$\begin{array}{rcrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$

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

where B is the bandwidth [Hz],  $\tau$  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,  $\tau$  is the 122 microSec (1/8KHz) integration time and  $\tau_{BT}$  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<sup>1</sup> 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)				
9KY = 9.19 K REF = 8 K								
Detector A B	0.25020004	0.38862014	1.11	0.33681821	0.96	0.87		
Detector C D	0.33020901	0.41040278	1.17	0.37066982	1.06	0.90		
9KY = 20.35 K REF = 20 K								
Detector A B	0 55205572	0.76252603	1.38	0.54705489	0.99	0.72		
Detector C D	0.00090073	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 REF = 8 K	K				
Detector A B	0.25020004	0.30211320	0.86	0.33681821	0.96	1.11		
Detector C D	0.35026961	0.32906580	0.94	0.37066982	1.06	1.13		
SKY = 20.22 K REF = 20 K								
Detector A B	0 52040126	0.44375891	0.80	0.54705489	0.99	1.23		
Detector C D	0.55848130	0.46735563	0.84	0.59494874	1.07	1.27		

<sup>1</sup> 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: 
$$\Delta T = \sqrt{2} \cdot \frac{T_{SKY} + T_{SYS}}{\sqrt{B}} \cdot 1000 \left[ \text{mK} \cdot \sqrt{\text{sec}} \right]$$

where B is the bandwidth [Hz],  $\tau$  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,  $\tau$  is the 122 microSec (1/8KHz) integration time and  $\tau_{BT}$  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<sup>2</sup> 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)		

<sup>2</sup> 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 22066456	0.44099873	1.30	0.31492101	0.93	0.71
Detector C D	0.32000430	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	0.54751725	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 requi	iremen	ts	

	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 22050455	0.27365654	0.81	0.31492101	0.93	1.15	
Detector C D	0.33959155	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	0.54751725	0.43799035	0.80	0.51041012	0.93	1.17	

Expected White noise at Flight conditions has been calculated using Eq. 1 with Thoise 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 22002072	0.30353306	1.28	N/A	N/A	N/A	
Detector C D	0.23603072	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 c	channe	els)		
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=10.98	6, CD=9.6)					
Detector A B	0 22066456	0.40431352	1.20	0.29295117	0.87	0.72			
Detector C D	0.32000430	0.38007168	1.10	0.38073394	1.10	1.10			
SKY = 20 K									
			REF = 20 K						
Detector A B	0 54754725	0.68574854	1.25	0.45022508	0.82	0.66			
Detector C D	0.04751725	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

ſ		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)							
I	Detector A B	0.33959155	0.25089197	0.74	0.29295117	0.87	1.17	





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Detector C D		0.30474597	0.88	0.38073394	1.10	1.25
			SKY = 20 K REF = 20 K			
Detector A B	0 54754705	0.39907756	0.73	0.45022508	0.82	1.13
Detector C D	0.54751725	0.44247423	0.81	0.55084893	1.00	1.24

Expected White noise at Flight conditions has been calculated using Eq. 1 with Thoise 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 22002072	0.26684723	1.12	N/A	N/A	N/A		
Detector C D	0.23803072	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 g	ain-model fit, valu	e is an average	of both cha	nnels)			
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	n gain-model fit, valu	e is an average o	of both ch	annels)			
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	$\leq$ 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

<sup>3</sup> Thanks to ESA – ESTEC

<sup>5</sup> Thanks to ESA – ESTEC



<sup>&</sup>lt;sup>4</sup> Thanks to Segio Mariotti INAF/IRA - Bologna



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)]		Eff	ective bandw [GHz]	idth
	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)]		Eff	ective bandw [GHz]	idth
	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)]		Eff	ective bandw [GHz]	idth
	Sky	Load	Diff	Sky	Load	Diff
DETECTOR A	1.9256558e-005	2.4261021e-005	2.6478727e-005	8.21	9.26	8.68

2.5670030e-005

2.6356184e-005

2.8823709e-005

3.1851554e-005

9.16

7.85

10.35

9.53

9.67

8.63



2.0943341e-005

2.3616078e-005

DETECTOR B

DETECTOR C



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	
		R	EF		
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:

$$\left(\bullet T_{\underline{meas}\,\Box}^{param}\right) = f_{param} \, \mathbf{x} \, (\bullet P)$$





where the  $f_{\text{param}}$  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







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 <sub>feed-OMT</sub> (dB)	0.1
r	0.94221686
GF1 (dB)	35
GF2 (dB)	35
Lwg1 (dB)	0.03
L <sub>WG2</sub> (dB)	1.08
L <sub>WG3</sub> (dB)	0.11
LwG4 (dB)	0.15
L <sub>WG5</sub> (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:

LFI Project System Team



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```
Channel :
Channel : A
Load correct : Yes
        0.94221686
r =
Model:
                       FM
Gain calibration factor (V/K) = 0.024
LfeedOMT_dB = 0.1
Vgroove number =
LWG1_dB = 0.03
                                     1 coldest
                       0.03
LWG2_dB =
LWG3_dB =
                       1.08
LWG4_dB =
LWG5_dB =
                       0.15
0.13
GF1 dB =
                       35
GF2_dB =
                       35
There are
                       3
                                     time windows
         tmin
                        tmax
         45
1277
                       446
1645
        2193
                       3620
Sky Sensor = SKY_TEMP
Ref Sensor = REF_TEMP
Vgroove Sensor =
                                      VG3_TEMP

        SKY_TEMP
        REF_TEMP
        VG3_TEMP

        9.19996738
        9.1999323

        9.1999712
        9.19993114

                                      9.1999321 61.49825668
                                     63.49811935
9.19997692 65
         9.20010376
                                                                  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:

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```
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 =
LWG1_dB = 0.03
                                                             1 coldest
                             LWG2_dB =
LWG3_dB =
LWG4_dB =
                                                1.08
                                                0.15
                             LWG5_dB =
GF1_dB =
                                                 0.13
                                                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
                                                             9.1999321 61.49825668
9.19993114 63
                                     9.77702808
9.77692795
9.77678871
                                                                            63.49811935
65.4988327
                                                            9.19997692
                             Radiometer outputs (K)
                                     Tsky
                                                 Tref
INAF/IASF - BOLOGNA
```



34.441056 36.5532	216
34.429426 36.5398	381
34.418369 36.5280	044
Tsky-r*Tref	
0.0009337144	
0.0010293476	
JUTPUT	-
ftheo (K/K)	Íme
0 00000297	0.0

fmeas (K/K) 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 <sub>feed-OMT</sub> (dB)	0.1
r	0.9581238
G <sub>F1</sub> (dB)	35
G <sub>F2</sub> (dB)	35
Lwg1 (dB)	0.03
Lwg2(dB)	1.08
Lwg3 (dB)	0.11
L <sub>WG4</sub> (dB)	0.15
L <sub>WG5</sub> (dB)	0.13
G (V/K)	0.026

#### 7.2.2.1 Analysis using the SKY\_TEMP probe as sky load temperature:

1

The transfer functions obtained with RaNA:

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



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The complete RaNA output: Vgrooves susceptibility INPUT INPUT Frequency (GHz) = Channel : B Load correct : Yes r = 0.95812381 Model: FM Cain calibration fact 30 

 I = 0.155612561

 Model:
 FM

 Gain calibration factor (V/K) =

 LfeedOMT\_dB = 0.1

 Vgroove number =
 1 coldes

 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

 0.026 1 coldest There are 3 time windows tmax tmin 446 45 1277 2193 1645 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
 114 63.49811935 9.19997692 65 9.20010376 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) -0.00044097

#### 7.2.2.2 Analysis using the SMON\_TMP probe as sky load temperature:

The transfer functions obtained with RaNA:

Ftheo (K/K) 0.000	0215
The complete RaNA output:	
I	
Varooves 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	
$LWG2_{dB} = 1.08$	
$LWG3_{dB} = 0.11$	
$LWG4_{dB} = 0.15$	
$LWG5_{GB} = 0.13$	
GFI_UB = 35	
GF2_GB = 35	
There are 3 time windows	
tmin tmax	
45 446	
1277 1645	
2193 3620	
Sky Sensor = SMON_TMP	



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Ref Sensor = REF TEMP		

Vgroove Sensor =	VG3_TEMP	
SMON_TMP_REF_TEMP 9.77702808 9.77692795 9.77678871	VG3_TEMP 9.1999321 61.498256 9.19993114 9.19997692	68 63.49811935 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) 0.00000215	fmeas (K/K) -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 <sub>feed-OMT</sub> (dB)	0.1
r	0.94548700
GF1 (dB)	35
G <sub>F2</sub> (dB)	35
Lwg1 (dB)	0.03
Lwg2(dB)	1.08
Lwg3 (dB)	0.11
LwG4 (dB)	0.15
L <sub>WG5</sub> (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 l	RaNA or	itmit.			
The complete		"Put.			
Vgrooves susceptib INPUT	ility				
Frequency (GHz) = Channel : C	30				
Load correct :	Yes				
Model: FM					
Gain calibration f	actor (V/K)	=	0.0293		
LfeedOMT_dB =	0.1				
Vgroove number =	1 coldest				
$LWG2_{dB} = 0.03$					
LWG3 dB = 0.11					
LWG4 dB = 0.15					
$LWG5_dB = 0.13$					
$GF1_dB = 35$					
$GF2_{GB} = 35$					
There are 3	time wind	lows			
tmin	tmax				
45	446				
2193	3620				
	2020				
Sky Sensor =	SKY_TEMP				
Ref Sensor =	REF_TEMP				
vgroove sensor =	VG3_TEMP				
SKY_TEMP	REF_TEMP	VG3_TEMP			
9.199967	38	9.1999321	61.49825	668	
9.199971	2 9.1999311 76	.4	63.49811	935	
5.200103	/6	3.1333763	2	05.4500327	
Radiometer outputs	(K)				
Tsky	Tref				
31.58602	7 33.407151				
31.57646	2 33.398012				
Tsky-r*T	ref				
-0.00120	06287				
-0.00092	368423				
OUTPUT					
ftheo (K/K)	fmeas (K/	'K)			
0.0000280	0.0001384	2			

## 7.2.3.2 Analysis using the SMON\_TMP probe as sky load temperature:

The transfer functions obtained with RaNA:

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			Fmeas	(K/K)	0.00027427
			Ftheo	(K/K)	0.0000280
The complete Ra	NA output: Vgrooves suscep	tibility			
	Frequency (GHz) Channel : Load correct : r = 0.945487 Model: Gain calibratio	= C Yes FM n factor	30 (V/K) =	0.0293	
	Vgroove number LWG1_dB = LWG2_dB = LWG2_dB = LWG4_dB = LWG5_dB = GF1_dB = GF2_dB =	0.1 = 0.03 1.08 0.11 0.15 0.13 35 35	1 colde	st	
	There are	3	time wi	ndows	
INAF/	IASF	- <b>BO</b>	LOGN	IA	



tmin 45 1277 2193	tmax 446 1645 3620		
Sky Sensor = Ref Sensor = Vgroove Senso	SMON_TMP REF_TEMP r =	VG3_TEMP	
SMON TM 9.77702 9.77692 9.77678	P REF_TEMP 808 795 871	VG3_TEMP 9.1999321 61.498256 9.19993114 9.19997692	68 63.49811935 65.4988327
Radiometer ou Tsky 31.5860 31.5829 31.5768 Tsky-r* -0.0010 -0.0005	tputs (K) Tref 27 33.407151 54 33.405061 38 33.398012 Tref 966782 4793655		
OUTPUT ftheo ( 0.00000	K/K) 280	fmeas (K/K) 0.00027427	

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### 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 <sub>feed-OMT</sub> (dB)	0.1
r	0.95427260
G <sub>F1</sub> (dB)	35
G <sub>F2</sub> (dB)	35
Lwg1 (dB)	0.03
Lwg2(dB)	1.08
L <sub>WG3</sub> (dB)	0.11
L <sub>WG4</sub> (dB)	0.15
L <sub>WG5</sub> (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)	0.0000235

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 =
LWG1_dB = 0.03
                                 1 coldest
LWG1_dB =
LWG2_dB =
LWG3_dB =
                    1.08
LWG4_dB =
LWG5_dB =
                    0.15
GF1_dB =
GF2_dB =
                    35
35
There are
tmin
                    3
tmax
                                 time windows
        45
1277
                    446
1645
        2193
                    3620
Sky Sensor = SKY_TEMP
Ref Sensor = REF_TEMP
Vgroove Sensor =
                    SKY TEMP
                                  VG3 TEMP
        SKY_TEMP REF_TEMP VG3_TEMP
9.19996738 9.1999322
                                 9.1999321 61.49825668
        9.1999712 9.19993114 63.49811935
9.20010376 9.19997692 65
                                                           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)
                                  -0.00043225
        0.00000235
```

#### 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)	0.0000235
The complete Ra	NA output:				
	Vgrooves suscep INPUT	tibility			
	Frequency (GHz)	=	30		
	channel :	D			
	Load correct :	Yes			
	r = 0.9542726				
	Model:	FM			
	Gain calibration	n factor	(V/K) =	0.038	
	LfeedOMT_dB =	0.1			
	Vgroove number	=	1 colde	st	
	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 wi	ndows	



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tmin 45 1277 2193	tmax 446 1645 3620		

2200	5020		
Sky Sensor = Ref Sensor = Vgroove Sensor	SMON_TMP REF_TEMP =	VG3_TEMP	
SMON_TMP 9.7770280 9.7769279 9.7767887	REF_TEMP 8 5 1	VG3_TEMP 9.1999321 61.498256 9.19993114 9.19997692	58 63.49811935 65.4988327
Radiometer outp Tsky 32.542617 32.544241 32.534325 Tsky-r*Tr 0.0007116 0.0001186	uts (K) Tref 34.102013 34.10297 34.093199 ef 2052 0207		
OUTPUT ftheo (K/ 0.0000023	K) 5	fmeas (K/K) -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:

	Ch. A	Ch. B	Ch. C	Ch. D		
Freq (GHz)	30					
$L_{feed-OMT}$ (dB)		0	.1			
L <sub>4k</sub> ( <i>dB</i> )		0	.1			
r	0.94340612	0.95825588	0.94434556	0.95426438		
T <sub>sky</sub> (K)		9.19	9997			
T <sub>ref</sub> (K)		9.19	9897			
G <sup>dB</sup> <sub>F1</sub> (dB)	35					
G <sup>dB</sup> <sub>F2</sub> (dB)		3	5			
T <sub>nF1</sub> (K)	20	20	20	20		
$\mathbf{T}_{nF2}$ (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					
$\partial T_{nF1} / \partial T_{phys}^{FE}$ (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		

Table 8-1: Default input parameters for RCA\_THF analysis



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





Figure -8-12: RCA\_THF theoretical (blue) Vs measured (red) transfer function

Table -8-2: RCA	THF	' Analysis	Result based	l 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	FEM susceptibility INPUT
Frequency (GHz) = 30	Frequency (GHz) = 30
Channel : A	Channel : B
Load correct : Yes	Load correct : Yes
r = 0.94340612	r = 0.95825588
Model: FM	Model: FM
Gain calibration factor $(V/K) = 0.024$	Gain calibration factor $(V/K) = 0.026$
LfeedOMT_dB = 0.1	LfeedOMT_dB = 0.1
$L4K_{dB} = 0.1$	$L4K_{dB} = 0.1$
GF1_dB = 35	GF1_dB = 35
GF2_dB = 35	$GF2_dB = 35$
TnF1_K = 20	$TnF1_K = 20$
TnF2_K = 20	$TnF2_K = 20$
dGF1_dB_dTFEphys_K = -0.05	dGF1_dB_dTFEphys_K = -0.05
dGF2 dB dTFEphys K = -0.05	$dGF2\_dB\_dTFEphys\_K = -0.05$
dTn1_dTFEphys_K = 0.08	dTn1_dTFEphys_K = 0.08
dTn2 dTFEphys K = 0.08	dTn2 dTFEphys K = 0.08
There are 4 time windows	There are 4 time windows
tmin tmax	tmin tmax
1 87	1 87
283 954	283 954
1215 4351	1215 4351
4756 5200	4756 5200





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Sky Sensor = SKY_TEMP Ref Sensor = REF_TEMP FEM Sensor = FEM_TEMP	PPM TPMD		Sky Senso Ref Senso FEM Senso	r = r = r =	SKY_TEMP REF_TEMP FEM_TEMP	PIPM TIPMD	
9.1999695 9.20002937 9.19973564 9.19997978	9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.99995804 27.00001526		9.19999699 9.2000293 9.19973564 9.19997978	7 1 3	9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.99995804 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			Radiomete	r outputs Tsky 36.127361 36.636725 37.14027 37.903099 Tsky-r*Tre -0.0090384 -0.0575399 -0.1828763	(K) Tref 37.701163 38.242149 38.818244 39.745099 ef 5872 33 37		
OUTPUT ftheo (K/K) -0.013226 -0.018607	fmeas (K/K)		OUTPUT	ftheo (K/H -0.009756	K) -0.035322	fmeas (K/K)	
<pre>FEM susceptibility INPUT Frequency (GHz) = 30 Channel : C Load correct : Yes r = 0.94434556 Model: FM Gain calibration factor (V/K) LfeedOMT_dB = 0.1 L4K_dB = 0.1 GF1_dB = 35 GF2_dB = 35 TnF1_K = 20 dGF1_dB_dTFEphys_K = dGF1_dB_dTFEphys_K = dGF1_dB_dTFEphys_K = 0.08 dTn1_dTFEphys_K = 0.08 dTn2_dTFEphys_K = 0.08 There are 4 time windu tmin tmax 1 87 283 954 1215 4351 4756 5200</pre>	= 0.0293 -0.05 -0.05		FEM susce INPUT Frequency Channel : Load corr r = Model: Gain calii LfeedOMT L4K_dB = GF1_dB = GF2_dB = TnF1_K = dGF1_dB_d dGF1_dB_d dGF1_dB_d dGF2_dB_d TnF2_K = dGF1_dB_d dTn2_dTF5 There are	(GHz) = D ect : 0.95426438 FM oration fau B = 0.1 35 20 20 FFEphys_K = ohys_K = 0hys_K = 4 tmin 1 283 1215 4756 c =	30 Yes 3 ctor (V/K) 0.1 0.08 0.08 time windo tmax 87 954 4351 5200 SKY_TEMP	= 0.038 -0.05 -0.05	
Ref Sensor = REF_TEMP FEM Sensor = FEM_TEMP SKY_TEMP REF_TEMP 9.19999695 9.20002937 9.19973564 9.19997978	FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.9995804 27.00001526	Ref Senso FEM Senso	r = r = SKY_TEMP 9.19999699 9.2000293 9.19973564 9.19997978	REF_TEMP FEM_TEMP REF_TEMP 5 7 4 3	FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.9995804 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			Radiomete	r outputs Tsky 32.644433 33.042381 33.478648 34.155246 Tsky-r*Trr -0.0296134 -0.0518654 -0.0720265	(K) Tref 34.209002 34.657056 35.137551 35.867703 ef 164 163 322		
OUTPUT ftheo (K/K) -0.013006 0.005094	fmeas (K/K)		OUTPUT	ftheo (K/H -0.010688	C) -0.008343	fmeas (K/K)	

To improve the results obtained with the default parameters, I am going to change any of them. In particular, I change the  $\partial G_{FE}^{dB}/\partial T_{phys}^{FE}$  and  $\partial T_{nFE}/\partial T_{phys}^{FE}$ . 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 ThFI K = 20	<pre>FEM susceptibility INPUT Frequency (GHz) = 30 Cchannel : B Load correct : Yes r = 0.95825588 Model: FM Gain calibration factor (V/K) = 0.026 LfeedOMT_dB = 0.1 L4K_dB = 0.1 L4K_dB = 0.1 GF1_dB = 35 GF2_dB = 35 TnF1 K = 20</pre>
TnF1_K = 20	TnF1_K = 20
TnF2_K = 20	TnF2_K = 20
dGF1_dB_dTFEphys_K = -0.061	dGF1_dB_dTFEphys_K = -0.133





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dGF2_dB_dTFEphys_K = dTn1_dTFEphys_K = 0.06 dTn2_dTFEphys_K = 0.06	-0.061		dGF2_dB_dTFEphys_K dTn1_dTFEphys_K = dTn2_dTFEphys_K =	= 0.028 0.028	-0.133	
There are 4 time wi tmin tmax 1 87 283 954 1215 4351	ldows		There are 4 tmin 1 283 1215	time wind tmax 87 954 4351	ows	
4756 5200 Sky Sensor = SKY_TEM Ref Sensor = REF_TEM FEM Sensor = FEM_TEM	2		4756 Sky Sensor = Ref Sensor = FEM Sensor =	5200 SKY_TEMP REF_TEMP FEM_TEMP		
SKY_TEMP REF_TEM 9.19999695 9.20002937 9.19973564 9.19997978	<pre>P FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164</pre>	19.99991035 22.00007629 23.99995804 27.00001526	SKY_TEMP 9.1999965 9.2000293 9.1997356 9.1999797	REF_TEMP 5 7 4 8	FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.99995804 27.00001526
Radiometer outputs (K) Tsky Tref 34.485854 36.5546 34.959616 37.0884 35.462409 37.6381 36.227321 38.5279	22 26 58 8		Radiometer outputs Tsky 36.127361 36.636725 37.14027 37.903099	<pre>(K) Tref 37.701163 38.242149 38.818244 39.745099</pre>		
Tsky-r*Tref -0.029840849 -0.045669091 -0.12019913			Tsky-r*Tr -0.009038 -0.057539 -0.182876	ef 6872 93 37		
OUTPUT ftheo (K/K) -0.018603 -0.0186	fmeas (K/K) )7		OUTPUT ftheo (K/ -0.035458	″K) -0.035322	fmeas (K/K)	
<pre>FEM susceptibility INPUT Frequency (GHz) = 30 Channel : C Load correct : Yes r = 0.94434556 Model: FM Gain calibration factor (V/ LfeedOMT_dB = 0.1 L4K_dB = 0.1 GF1_dB = 35 GF2_dB = 35 TnF1_K = 20 TnF2_K = 20 dGF1_dB_dTFEphys_K = dGF2_dB_dTFEphys_K = 0.25 dTn2_dTFEphys_K = 0.25</pre>	K) = 0.0293 -0.028 -0.028		<pre>FEM susceptibility INPUT Frequency (GHz) = Channel : D Load correct : r = 0.9542643 Model: FM Gain calibration fa LfeedOMT_dB = L4K_dB = 0.1 GF1_dB = 35 GF2_dB = 35 TnF1_K = 20 TnF2_K = 20 dGF1_dB_dTFEphys_K dGF2_dB_dTFEphys_K = dTn2_dTFEphys_K =</pre>	30 Yes 8 actor (V/K) 0.1 = = 0.124 0.124	= 0.038 -0.049 -0.049	
There are 4 time wi tmin tmax 1 87 283 954 1215 4351 4756 5200	ldows		There are 4 tmin 1 283 1215 4756	time wind tmax 87 954 4351 5200	ows	
Sky Sensor = SKY_TEM Ref Sensor = REF_TEM FEM Sensor = FEM_TEM			Sky Sensor = Ref Sensor = FEM Sensor =	SKY_TEMP REF_TEMP FEM_TEMP		
SKY_TEMP REF_TEM 9.19996955 9.20002937 9.19973564 9.1997378	<pre>P FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164</pre>	19.99991035 22.00007629 23.99995804 27.00001526	SKY_TEMP 9.1999965 9.2000293 9.1997356 9.1999797	REF_TEMP 5 7 4 8	FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.99995804 27.00001526
Radiometer outputs (K) Tsky Tref 31.639373 33.5040 32.115203 33.9739 32.588431 34.4711 33.320044 35.2236	2 77 94		Radiometer outputs Tsky 32.644433 33.042381 33.478648 34.155246	(K) Tref 34.209002 34.657056 35.137551 35.867703		
Tsky-r*Tref 0.032056856 0.035711624 0.056708863			Tsky-r*Tr -0.029613 -0.051865 -0.072026	ref 464 463 322		
OUTPUT ftheo (K/K) 0.004973 0.00509	fmeas (K/K)		OUTPUT ftheo (K/ -0.008319	′K) −0.008343	fmeas (K/K)	





#### 7.3.1.2 Analysis using the SMON\_TMP probe as sky load temperature:

The default parameters for the four channels are:

Tuble -0-5. Dejumi input put	Tuble -0-5. Default input parameters for Rest_IIII 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 <sub>sky</sub> (K)		9.7	732					
T <sub>ref</sub> (K)	9.1999							
G <sup>dB</sup> <sub>F1</sub> (dB)	35							
G <sup>dB</sup> <sub>F2</sub> (dB)	35							
$T_{nF1}(K)$	20	20	20	20				
$\mathbf{T}_{nF2}$ (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	0.024	0.026	0.0293	0.038				

Table _8_5 D	efault im	nut nara	meters for	RCAT	HF ana	lusis
1001e -0-J. D	зјаши иц	բա բառ	imeiers joi	KCA_I	III <sup>,</sup> unu	ysis

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
$f_{therm}^{front-end}$ (K/K) theoretical	-0.019812	-0.016342	-0.019593	-0.017275
$f_{therm}^{front-end}$ (K/K) measured	-0.01896	-0.035674	0.0047	-0.0087

The complete RaNA output:

FEM susceptibility INPUT Frequency (GHz) = Channel : A Load correct : r = 0.9434061 Model: FM Gain calibration fa LfeedOMT_dB = L4K_dB = 0.1 GP1_dB = 35 GP2_dB = 35 GP2_dB = 35 GP2_dB = 35 TNF1_K = 20 dGP1_dB_dTFEphys_K dGP1_dB_dTFEphys_K = dTn2_dTFEphys_K = There are 4 tmin	30 Yes 2 ctor (V/K) = 0.024 0.1 = -0.05 = -0.05 0.08 time windows tmax	FEM susceptibility           INPUT           Frequency (GHz) = 3           Channel : B           Load correct : Y           r = 0.95825588           Model: FM           Gain calibration fact           LfeedOMT_dB = 0           L4K_dB = 0.1           GP1_dB = 35           GF2_dB = 35           TnF2_K = 20           TnF2_K = 20           dGF1_dB_dTFEphys_K =           dGF2_dB_dTFEphys_K = 0           dTn2_dTFEphys_K = 0           There are 4         t           tmin <tt< td=""></tt<>	0 tes tor (V/K) = 0.026 0.1 -0.05 -0.05 0.08 0.08 time windows max
There are 4	time windows	There are 4 t	ime windows
Cuin	CIIIAX		ulax
1	87	1 8	
283	754 4751	283 9	251
1215	4351	1215 4	200
4/56	5200	4/56 5	200
Sky Sensor =	SMON_TMP	Sky Sensor = S	MON_TMP





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1.0

Ref Sensor =	REF_TEMP			Ref Senso	r = r -	REF_TEMP		
SMON_TMP 9.7732162 9.7731227 9.7734003 9.7748212 Radiometer outputs	REF_TEMP 55 19 11 28 (K)	FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.99995804 27.00001526	Radiomete	SMON_TMP 9.7732162 9.7731227 9.7734003 9.7748212 r outputs	REF_TEMP 5 9 1 8 (K)	FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.99995804 27.00001526
Tsky 34.485854 34.959742 35.461964 36.225699	Tref 36.554622 37.088436 37.638168 38.527968				Tsky 36.127361 36.636851 37.139825 37.901477	Tref 37.701163 38.242149 38.818244 39.745099		
Tsky-r*Tr -0.029714 -0.046114 -0.121821	ef 964 457 .33				Tsky-r*Tr -0.008912 -0.057985 -0.184498	e± 8022 296 57		
OUTPUT ftheo (K/ -0.019812	(K) -0.01896	fmeas (K/K)		OUTPUT	ftheo (K/ -0.016342	K) -0.035674	fmeas (K/K)	
FEM susceptibility				FEM susce	ptibility			
Frequency (GHz) = Channel : C Load correct :	30 Yes			Frequency Channel : Load corr	(GHz) = D ect :	30 Yes		
r = 0.9443455 Model · FM	6			r = Model·	0.9542643 FM	8		
Gain calibration fa	actor (V/K)	= 0.0293		Gain cali	bration fa	ctor (V/K)	= 0.038	
$L4K_{dB} = 0.1$	0.1			L4K_dB =	0.1	0.1		
$GF1_dB = 35$ $GF2_dB = 35$				GF1_dB = GF2 dB =	35 35			
$TnF1_K = 20$				TnF1_K =	20			
dGF1 dB dTFEphys K	=	-0.05		dGF1 dB d	20 TFEphys K	=	-0.05	
dGF2_dB_dTFEphys_K	=	-0.05		dGF2_dB_d	TFEphys_K	=	-0.05	
dTn2_dTFEphys_K =	0.08			dTn2_dTFE	phys_K = phys_K =	0.08		
There are 4 tmin	time wind tmax	lows		There are	4 tmin	time wind tmax	ows	
1 283	87 954				1 283	87 954		
1215	4351				1215	4351		
4756	5200				4/56	5200		
Sky Sensor = Ref Sensor = FEM Sensor =	SMON_TMP REF_TEMP FEM_TEMP			Sky Senso Ref Senso FEM Senso	r = r = r =	SMON_TMP REF_TEMP FEM_TEMP		
SMON_TMP 9.7732162 9.7731227 9.7734003 9.7734003 9.7748212	REF_TEMP 25 29 21 28	FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.99995804 27.00001526		SMON_TMP 9.7732162 9.7731227 9.7734003 9.7748212	REF_TEMP 5 9 1 8	FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.99995804 27.00001526
Radiometer outputs Tsky 31.639373 32.115329	(K) Tref 33.50402 33.973947			Radiomete	r outputs Tsky 32.644433 33.042506	(K) Tref 34.209002 34.657056		
32.587986 33.318422	34.471194 35.22369				33.478203 34.153623	35.137551 35.867703		
Tsky-r*Tr 0.0321827 0.0352662 0.0550866	ref 241 259 363				Tsky-r*Tr -0.029487 -0.052310 -0.073648	ef 579 829 522		
OUTPUT ftheo (K/ -0.019593	(K) 0.004741	fmeas (K/K)		OUTPUT	ftheo (K/ -0.017275	K) -0.008696	fmeas (K/K)	

To improve the results obtained with the default parameters, I am going to change any of them. In particular, I change the  $\partial G_{FE}^{dB}/\partial T_{phys}^{FE}$  and  $\partial T_{nFE}/\partial T_{phys}^{FE}$ . 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: <b>RCA_TH</b>	IF Optimal transfer f	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	PEM susceptibility INPUT Frequency (GHz) = 30 Channel : B
Load correct : Yes	Load correct : Yes
r = 0.94340612 Model: FM	r = 0.95825588 Model: FM
Gain calibration factor $(V/K) = 0.024$	Gain calibration factor $(V/K) = 0.026$
LfeedOMT_dB = 0.1	LfeedOMT_dB = 0.1
$L4K_{dB} = 0.1$	$L4K_{dB} = 0.1$
GF1 dB = 35	GF1 dB = 35
$GF2_{dB} = 35$	$GF2_{dB} = 35$
TnF1 K = 20	TnF1 K = 20
TnF2 K = 20	TnF2 K = 20
dGF1_dB_dTFEphys_K = -0.048	dGF1_dB_dTFEphys_K = -0.092





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dGF2_dB_dTFEphys_K dTn1_dTFEphys_K = dTn2_dTFEphys_K =	= 0.077 0.077	-0.048		dGF2_dB_d dTn1_dTFE dTn2_dTFE	TFEphys_K phys_K = phys_K =	= 0.035 0.035	-0.092	
There are 4 tmin 1 283	time wind tmax 87 954	ows		There are	4 tmin 1 283	time wind tmax 87 954	OWB	
4756	4351 5200				1215 4756	4351 5200		
Sky Sensor = Ref Sensor = FEM Sensor =	SMON_TMP REF_TEMP FEM_TEMP			Sky Senso Ref Senso FEM Senso	r = r = r =	SMON_TMP REF_TEMP FEM_TEMP		
SMON_TMP 9.7732162 9.7731227 9.7734003 9.7734212	REF_TEMP 5 9 1 8	FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.99995804 27.00001526		SMON_TMP 9.7732162 9.7731227 9.7734003 9.7748212	REF_TEMP 5 9 1 8	FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.99995804 27.00001526
Radiometer outputs Tsky 34.485854 34.959742 35.461964 36.225695	(K) Tref 36.554622 37.088436 37.638168 38.527968			Radiomete	r outputs Tsky 36.127361 36.636851 37.139825 37.901477	<pre>(K) Tref 37.701163 38.242149 38.818244 39.745099</pre>		
Tsky-r*Tr -0.029714 -0.046114 -0.121821	ref 1964 1457 133				Tsky-r*Tr -0.008912 -0.057985 -0.184498	ef 8022 296 57		
OUTPUT ftheo (K/ -0.018955	(K) -0.01896	fmeas (K/K)		OUTPUT	ftheo (K/ -0.035679	K) -0.035674	fmeas (K/K)	
<pre>FEM susceptibility INPUT Frequency (GHz) = Channel : C Load correct : r = 0.9443455 Model: FM Gain calibration fa LfeedOMT_dB = L4K_dB = 0.1 GF1_dB = 35</pre>	30 Yes 66 actor (V/K) 0.1	= 0.0293		FEM susce INPUT Frequency Channel : Load corr r = Model: Gain cali LfeedOMT_ L4K_dB = GF1_dB =	(GHz) = D ect : 0.9542643 FM bration fa dB = 0.1 35	30 Yes 8 ctor (V/K) 0.1	= 0.038	
GF2_dB = 35 ThF1_K = 20 ThF2_K = 20 dGF1_dB_dTFEphys_K dGF2_dB_dTFEphys_K dTn1_dTFEphys_K = dTn2_dTFEphys_K =	= = 0.29 0.29	-0.0256 -0.0256		GF2_dB = TnF1_K = TnF2_K = dGF1_dB_d dGF2_dB_d dTn1_dTFE dTn2_dTFE	35 20 20 TFEphys_K TFEphys_K phys_K = phys_K =	= = 0.123 0.123	-0.035 -0.035	
There are 4 tmin 1 283 1215 4756	time wind tmax 87 954 4351 5200	ows		There are	4 tmin 1 283 1215 4756	time wind tmax 87 954 4351 5200	Swa	
Sky Sensor = Ref Sensor = FEM Sensor =	SMON_TMP REF_TEMP FEM_TEMP			Sky Senso Ref Senso FEM Senso	r = r = r =	SMON_TMP REF_TEMP FEM_TEMP		
SMON_TMP 9.7732162 9.7731227 9.7734003 9.7734212	REF_TEMP 25 29 11 28	FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.99995804 27.00001526		SMON_TMP 9.7732162 9.7731227 9.7734003 9.7748212	REF_TEMP 5 9 1 8	FEM_TEMP 9.19989681 9.19986153 9.19967365 9.19994164	19.99991035 22.00007629 23.99995804 27.00001526
Radiometer outputs Tsky 31.639373 32.115322 32.587986 33.318422	(K) Tref 33.50402 33.973947 34.471194 35.22369			Radiomete	r outputs Tsky 32.644433 33.042506 33.478203 34.153623	(K) Tref 34.209002 34.657056 35.137551 35.867703		
Tsky-r*Tr 0.0321827 0.0352662 0.0550866	ref 241 259 663				Tsky-r*Tr -0.029487 -0.052310 -0.073648	ef 579 829 522		
OUTPUT ftheo (K/ 0.004784	′K) 0.004741	fmeas (K/K)		OUTPUT	ftheo (K/ -0.008637	K) -0.008696	fmeas (K/K)	





## 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:

$$K3 * \Delta T_{SS-RT2} = \frac{1}{\frac{1}{K_1} + \frac{1}{K_2}} \cdot \Delta T_{RT2-CTR}$$

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

		TnRef ParFit (K)	TnSky ParFit (K)
8.1	DETECTOR		
	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**

F.Villa and L.Terenzi 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

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

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:

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

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

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

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

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

Or in a compact way

$$\begin{aligned} V_{out} &= G_{tot} \cdot \left(T_A + T_N^*\right) \\ G_{tot} &= G_0 \cdot \left[\frac{1}{1 + b \cdot G_0 \cdot \left(T_A + T_N^*\right)}\right] \end{aligned}$$

*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

Channel	Central Frequency	Equivalent Bandwidth
	(GHz)	(GHz)
А	32.35	3.22
В	32.45	3.23
$\mathbf{C}$	31.40	4.94
D	31.35	5.12

Table 1: Central frequency and equivalent bandwidth.

#### 0.1.4 Derivative Plots



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



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.