Memorandum

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From: John Effland

Date: 2004-10-27

Revisions:

2003-08-14	jee	Initial
2003-11-24	jee	Added location of spreadsheet to Table 1
2004-01-14	Jee	Changed Pad H from 2 dB to 3 dB. Attached PDF file of schematic and Excel Spreadsheet
2004-03-01	Jee	Changed Pad H from 3 dB to 2 dB. Reduced mxr-preamp gain from 25 to 20 dB Increased noise temp of mxr-preamp from 34K to 63K
2004-07-01	Jee	Changed NF of warm IF amp from 150K to 120K, added 3 dB output pad Added Table 1, enhanced block diagram
2004-10-27	Jee	Fixed total ripple calculation to include gain slope plus ripple, changed preamp VSWR from 2:1 to 2.46:1, reduced warm IF ripple to 2 dB/2GHz, added Figure 2

Subject: Power Variation from Gain and Noise Temp Changes with Frequency for ALMA Band 6 Cartridge

Summary

This memo provides noise temperatures, power levels, and VSWR's at various stages in the Band 6 cartridge and includes calculations of the variation in frequency of the total power output from the cartridge.

Table 1: Summary of Band 6 Cartridge Calculated Noise and Power Values at "Nominal output of cartridge"[1]	
Assumptions	
Mixer-preamp noise temp	77K
Mixer-preamp gain	20 dB
Cold attenuator after mixer-preamp	2 dB
Noise Temperature of Warm IF Amp	120 K (NF = 1.5 dB)
Integral attenuator in Warm IF Amp	3 dB
Gain of warm IF amp (including integral attenuator)	27 dB
Analysis Results	
Variation of total power in 2 GHz	4.65 dB / 2 GHz
Output VSWR	1.33:1
System temperature contribution from warm IF amp	9.3K
Total power output in 8 GHz	-21.1 dBm

[1] "Nominal Output of Cartridge" is defined as the IF output connector on the warm cartridge assembly

Analysis

Gain variation with frequency (ΔG_{TOT}) is one parameter that determines how the power changes with frequency at the sampler inputs, but system noise temperature changes with frequency (ΔP_{Noise}) also contribute to power changes with frequency at the input to the samplers. If the variation with frequency of the total power input to the samplers is ΔP_{TOT} and it is assumed that these two terms are statistically independent, then:

$$\Delta P_{TOT} = \sqrt{(\Delta P_{Noise})^2 + (\Delta G_{TOT})^2}$$

The change in system noise power with frequency ΔP_{Noise} is given by:

$$\Delta P_{Noise} = \frac{\sqrt{(\Delta T_{MXR})^2 + (\Delta T_{IF2@IN})^2}}{T_{SYS}}$$

where:

T_{SYS} is the system noise temperature,

ΔT_{MXR} is the mixer-preamp noise temperature change in 2 GHz. Our measured data includes loss changes with frequency of input components such as windows and IR filters.

$\Delta T_{IF2@IN}$ is the warm IF amp noise temperature change in 2 GHz referred to the mixer-preamp input, which is given by:

$$\Delta T_{IF2@IN} = \Delta T_{IF2}\left(\frac{L_H L_G L_F}{G_D}\right)$$

where:

ΔT_{IF2} is the warm IF amp noise temperature change in 2 GHz. Band 6 plans on using a Miteq AMF-3F-04001200-15-10P amplifier for this, and the gain slope from the data sheets of one of these amplifiers is ±2.9 dB in 2 GHz.

L_H, L_G, L_F are the losses between the mixer-preamp output and the warm IF amp as defined in Bob Freund's "Front End Signal Path Block Diagram", dated 2003-03-27 (Figure 1) and

G_D is the gain of the mixer-preamp.

The total gain variation across a 2 GHz bandwidth at the sampler input ΔG_{TOT} is assumed to be comprised of a number of statistically independent terms:

$$\Delta G_{TOT} = \sqrt{[\Delta G(F_{IF})_{MAX}]^2 + (\Delta G_{MXR})^2 + (\Delta G_{IF2})^2 + (\Delta G_{CABLE})^2}$$

where:

$\Delta G(F_{IF})_{MAX}$ is the worst-case gain variation calculated from predicted VSWR values at a number of IF frequencies,

ΔG_{CABLE} is the gain slope from IF cable losses, and

ΔG_{MXR} is the gain variation obtained from mixer-preamp measurements, and

ΔG_{IF2} is maximum gain variation across 2 GHz obtained from the warm IF amp data sheets.

Table 2 provides the assumptions for each term used to calculate the total power variation in 2 GHz at the sampler inputs. A block diagram of the system analyzed for this memo is "Case II" given in Figure 1 which is from Robert Freund[2]. Table 3 is a copy of Bob Freund's spreadsheet that has been modified to include noise variation calculations and provides the summary values given in Table 2. The modified spreadsheet is located at:

\\cvfiler\cv-cdl-sis\Cartridge\SysEngr\BudgetsV20041027.xls

[2] From Robert Freund and available on ALMA EDM as: http://almaedm.tuc.nrao.edu/forums/alma/dispatch.cgi/iptfemeet/showFile/100096/d20030816004250/No/40.00.00.00-0000.pdf

Table 2:Parameters for Calculating Total Power Variation at Sampler Input			
Parameter	**Value**	**Units**	**Source**
Noise Temperature Variation, Mixer Preamp	+/- 10.0	K / 2 GHz	Specified by Gene Lauria
Gain Slope, Mixer Preamp	+/- 1.5	dB / 2 GHz	Specified by Gene Lauria
Gain Ripple, Mixer Preamp	+/- 1.0	dB / 2 GHz	Specified by Gene Lauria
Noise Temperature Variation, warm IF Amp	+/- 4	K / 2 GHz	Worst case from measured AML amp 0436-103 (See Figure 2)
Noise Temperature Variation, warm IF Amp @ Input	+/- 0.13	K / 2 GHz	Uses smallest loss vs. Freq for cable G
Gain Slope, warm IF Amp	+/- 0.0	dB / 2 GHz	Specified for AML's warm IF amps
Gain Ripple, warm IF Amp	+/- 1.0	dB / 2 GHz	Specified for AML's warm IF amps
Assumed receiver temperature	75	K	
Assumed sky, spillover, atm contribution	30	K	
Total System Noise Temperature	105	K	
Power Variation from Noise Temp Changes	+/- 0.40	dB / 2 GHz	
Worst-case gain change from VSWR	+/- 0.76	dB / 2 GHz	From ripple calculations at 4, 6, 8, 10, and 12 GHz
Gain slope from cable loss	+/- 0.3	dB / 2 GHz	From spreadsheet
Total Gain Changes	+/- 4.32	dB / 2 GHz	
Power Variation from Gain and Noise Temp Changes	+/- 4.65	dB / 2 GHz	

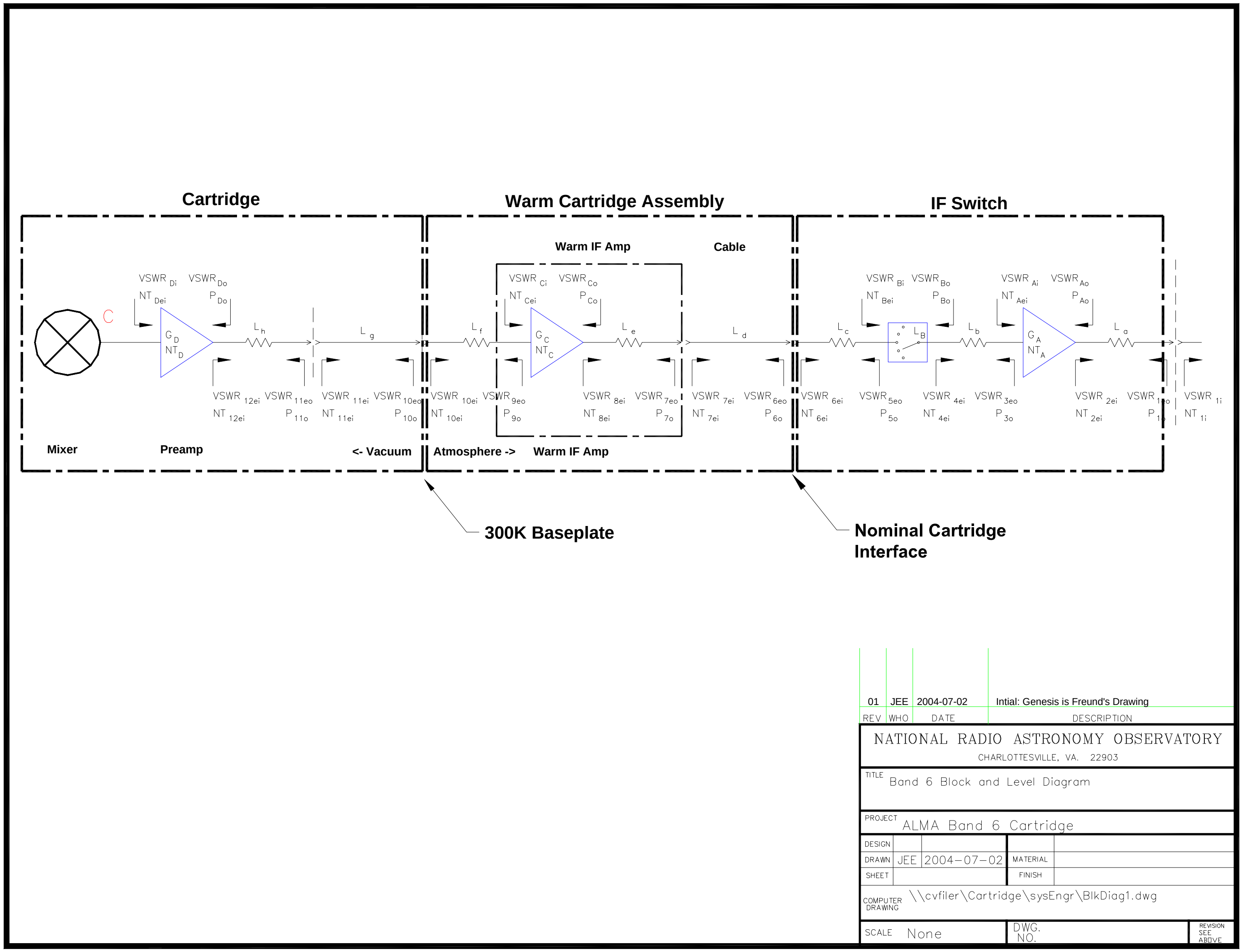

Figure 1: Cartridge Block Diagram showing configuration analyzed in this memo[3]

[3] Genesis is Robert Freund's block diagram stored at \\cvfiler\cv-cdl-sis\Cartridge\SysEngr\BlkDiag.dwg

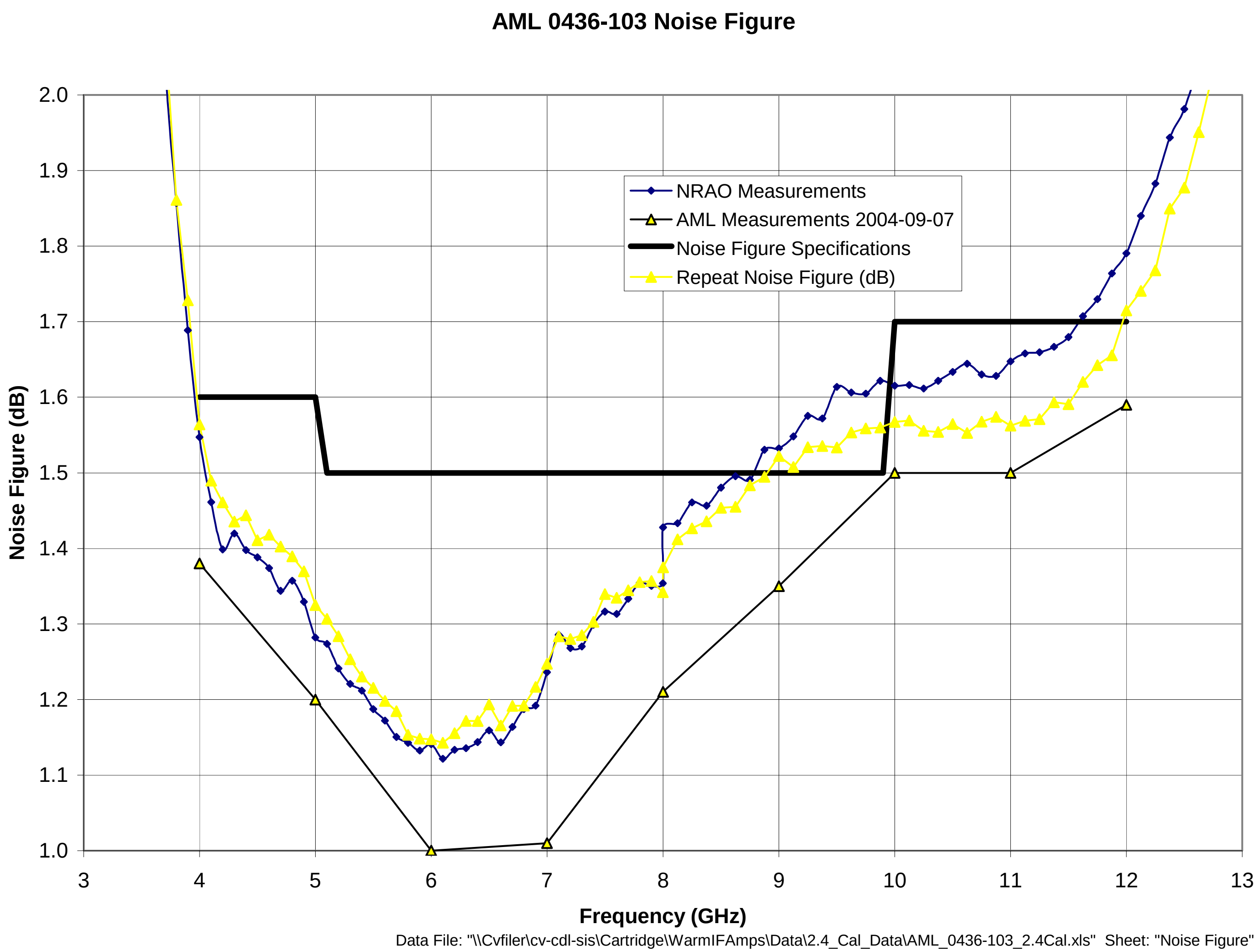

Figure 2: Measured noise temperature data from AML amp showing changes per 2 GHz as 125K (1.55 dB NF) less 92K (1.2 dB NF), which is 33K

Table 3: Level Calculation Details [4,5]

Front End Signal Path Budget										
Version 1 - 2: Bob Freund										
Version 3: 2004-03-01 jee changed preamp gain from 30 to 20 dB and noise temp from 34K to 63K so Amp D Effective NT = 77K										
Version 4: 2004-07-02 jee changed warm IF amp: NT from 150 to 120K, changed Le to 3 dB (to improve output VSWR)										
Version 4.1 2004-08-24 jee added cell for Warm IF NF to NT conversion.										
Version 4.2 2004-10-27 Fixed total ripple calculation to include gain slope plus ripple, changed preamp VSWR from 2:1 to 2.46:1, reduced warm IF ripple to 2 dB/2GHz										
k	*1.38E-23*									
T	*290*	*K*								
T	*15*	*K*								
BW_Full	8.00E+09	Hz								
BW_Seg	2.00E+09	*Hz*								
Maximum output power per 2 GHz band	-27.0	*dBm*								
Input power over full 8 GHz band	3.20E-11	W	-74.95	dBm						
Output power over full 8 GHz band	7.85E-06	W	-21.05	dBm						
Freq			**4.00**	**6.00**	**8.00**	**10.00**	**12.00**	**GHz**		
Total gain			55.16	54.40	53.77	53.21	52.71	dB		
Excess gain			1.19	0.44	-0.20	-0.76	-1.26	dB		

[4] This is modification of Robert Freund's spreadsheet. Original version available on ALMA EDM at: http://almaedm.tuc.nrao.edu/forums/alma/dispatch.cgi/iptfemeet/saveWS/frontends/docProfile/100096/6734681

[5] Version for this memo is stored at \\cvrfiler\cv-cdl-sis\Cartridge\SysEngr\Budgetsv2004-10-27.xls

RSS ripple			1.02	0.96	0.92	0.89	0.87	dB pk-pk		
Achieved noise temperature			68.4	69.4	70.4	71.3	72.3	K		
Second stage noise contribution			5.4	6.4	7.4	8.3	9.3	K		
Back End Input NT 1i	*1000*	*K*	1000	1000	1000	1000	1000	K		
Back End Input VSWR 1i	*1.40*		1.40	1.40	1.40	1.40	1.40			
Back End Input gamma 1i			0.167	0.167	0.167	0.167	0.167			
Pad a to Back End Ripple			0.48	0.48	0.48	0.48	0.48	db pk-pk		
Pad a Output effective gamma 1e0			0.167	0.167	0.167	0.167	0.167			
Pad a Output effective VSWR 1eo			1.40	1.40	1.40	1.40	1.40			
Pad a Integrated Output Power P 1o									-21.1 dBm	
Pad a Output Power P 1o			-25.81	-26.56	-27.20	-27.76	-28.26	dBm		
Pad a Loss La	*3.0*	*dB*	3.0	3.0	3.0	3.0	3.0	dB		
Pad a effective Input NT 2ei			2283.9	2283.9	2283.9	2283.9	2283.9	K		
Pad a Input effective VSWR 2ei			1.18	1.18	1.18	1.18	1.18			
Amp A Output VSWR Ao	*2.0*		2.00	2.00	2.00	2.00	2.00			
Amp A Integrated Output Power P Ao									-18.1 dBm	
Amp A Output Power P Ao			-22.81	-23.56	-24.20	-24.76	-25.26	dBm		
Amp A Gain GA	*30.0*	*dB*	30.00	30.00	30.00	30.00	30.00	dB		
Amp A NT A	*500*	*K*	500	500	500	500	500	K		
Amp A effective NT Aei			502.3	502.3	502.3	502.3	502.3	K		
Amp A Input VSWR Ai	*2.0*		2.00	2.00	2.00	2.00	2.00			
Pad b Output effective VSWR 3eo			1.18	1.18	1.18	1.18	1.18			
Pad b Integrated Output Power P 3o									-48.1 dBm	
Pad b Output Power P 3o			-52.81	-53.56	-54.20	-54.76	-55.26	dBm		

Pad b maximum Loss Lb	*6.0*	*dB*	6.0	6.0	6.0	6.0	6.0	dB		
Pad b effective Input NT bei			2864.1	2864.1	2864.1	2864.1	2864.1	K		
Pad b Input effective VSWR 4ei			1.18	1.18	1.18	1.18	1.18			
Pad b Input effective gamma 4ei			0.084	0.084	0.084	0.084	0.084			
Switch B to Pad b/Amp A Ripple			0.48	0.48	0.48	0.48	0.48	db		
Switch B Output gamma Bo			0.333	0.333	0.333	0.333	0.333			
Switch B Output VSWR Bo	*2.0*		2.0	2.0	2.0	2.0	2.0			
Switch B Integrated Output Power P Bo									-42.1 dBm	
Switch B Output Power P Bo			-46.8	-47.6	-48.2	-48.8	-49.3			
Switch B Loss LB	*4.5*	*dB*	4.5	4.5	4.5	4.5	4.5	dB		
Switch B effective NT bei			8599.6	8599.6	8599.6	8599.6	8599.6	K		
Switch B Input VSWR Bi	*2.0*		2.00	2.00	2.00	2.00	2.00			
Switch B Input gamma Bi			0.333	0.333	0.333	0.333	0.333			
Pad c Output effective VSWR 5eo			1.15	1.14	1.14	1.14	1.14			
Pad c Integrated Output Power P 5o									-37.6 dBm	
Pad c Output Power P 5o			-42.31	-43.06	-43.70	-44.26	-44.76	dBm		
Pad c Loss Lc	*3.0*	*dB*	3.0	3.0	3.0	3.0	3.0	dB		
Pad c effective NT 6ei			17447.0	17447.0	17447.0	17447.0	17447.0	K		
Pad c Input effective VSWR 6ei			1.401	1.401	1.401	1.401	1.401			
Pad c Input equiv. VSWR 6ei			1.388	1.386	1.383	1.381	1.379			
Pad c Input equiv. gamma 6ei			0.163	0.162	0.161	0.160	0.159			
Cable d Output effective VSWR 6eo			1.31	1.31	1.31	1.30	1.30			
Cable d Integrated Output Power P 6o									-34.6 dBm	
Cable d Output Power P 6o			-39.31	-40.06	-40.70	-41.26	-41.76	dBm		
Cable d loss Ld	*45.0*	*dB per 100 ft*	0.23	0.29	0.33	0.37	0.40	dB		
at freq	*10.0*	*GHz*								
Cable d length	*0.25*	*m*								
Cable d NT d			16.0	19.7	22.9	25.7	28.3	K		

Cable d Input effective NT 7ei			18426.5	18654.0	18847.9	19020.4	19177.6	K		
Cable d Input effective VSWR 7ei			1.376	1.371	1.366	1.363	1.359			
Amp C/Pad e to Pad c/Switch Ripple			0.39	0.39	0.39	0.38	0.38	dB		
Pad e Output equiv gamma 7eo			0.139	0.139	0.138	0.137	0.137			
Pad e Output equiv VSWR 7eo			1.324	1.322	1.320	1.318	1.317			
Pad e Output effective VSWR 7eo			1.33	1.33	1.33	1.33	1.33			
Pad e Integrated Output Power P 7o									-34.2 dBm	
Pad e Output Power P 7o			-39.08	-39.78	-40.37	-40.89	-41.36	dBm		
Pad e Loss Le	*3.0*	*dB*	3.00	3.00	3.00	3.00	3.00	dB		
Pad e Input effective NT 8ei			37054.3	37508.2	37895.1	38239.2	38553.0	K		
Pad e Input effective VSWR 8ei			1.172	1.170	1.168	1.167	1.165			
Amp C Output VSWR Co	*1.8*		1.80	1.80	1.80	1.80	1.80			
Amp C Integrated Output Power P Co									-31.2 dBm	
Amp C Output Power P Co			-36.08	-36.78	-37.37	-37.89	-38.36	dBm		
Amp C Gain G C	*30.0*	*dB*	30.00	30.00	30.00	30.00	30.00			NF Warm IF
Amp C NT C	*120*	*K*	120.00	120.00	120.00	120.00	120.00	K		NT Warm IF
Amp C Input effective NT Cei			157.1	157.5	157.9	158.2	158.6	K		
Amp C Input VSWR Ci	*1.8*		1.80	1.80	1.80	1.80	1.80			
Pad f Ouput effective VSWR 9eo			1.299	1.249	1.214	1.188	1.167			
Pad f Integrated Output Power P 9o									-61.2 dBm	
Pad f Output Power P 9o			-66.08	-66.78	-67.37	-67.89	-68.36	dBm		
Pad f Loss Lf	*0.0*	*dB*	0.0	0.0	0.0	0.0	0.0	dB		
Pad f Input effective NT 10ei			157.1	157.5	157.9	158.2	158.6	K		
Pad f Input effective VSWR 10ei			1.800	1.800	1.800	1.800	1.800			
Pad f Input equiv. VSWR 10ei			1.499	1.452	1.416	1.387	1.363			
Pad f Input equiv gamma 10ei			0.200	0.184	0.172	0.162	0.154			
Cable g Output effective VSWR			1.30	1.25	1.21	1.19	1.17			

10eo											
Cable g Integrated Output Power P 10o										-61.2 dBm	
Cable g Output Power P 10o			-66.08	-66.78	-67.37	-67.89	-68.36	dBm			
Cable g Loss Lg	*1500.0*	*dB per 100 ft*	3.11	3.81	4.40	4.92	5.39	dB			
at freq	*10.0*	*GHz*									
Cable g length	*0.1*	*m*									
Cable g NT g			14.8	19.9	24.8	29.8	34.8	K			
Cable g Input effective NT 11ei			336.4	398.8	459.9	521.2	583.4	K			
Cable g Input effective VSWR 11ei			1.324	1.270	1.231	1.203	1.180				
Amp D/Pad h to Pad f/Amp C Ripple			0.65	0.55	0.48	0.43	0.38	dB			
Pad h Output equiv. gamma 11eo			0.186	0.172	0.160	0.151	0.143				
Pad h Output equiv. VSWR 11eo			1.457	1.414	1.382	1.356	1.334				
Pad h Output effective VSWR 11eo			1.73	1.73	1.73	1.73	1.73				
Pad h Integrated Output Power P 11o										-56.9 dBm	
Pad h Output Power P 11o			-62.97	-62.97	-62.97	-62.97	-62.97	dBm			
Pad h Loss Lh	*2.0*	*dB*	2.00	2.00	2.00	2.00	2.00	dB			
Pad h Input effective NT 12ei			541.9	640.8	737.6	834.8	933.4	K			
Pad h Input effective VSWR 12ei			1.324	1.270	1.231	1.203	1.180				
Amp D Output VSWR Do	*2.46*		2.46	2.46	2.46	2.46	2.46				
Amp D Integrated Output Power P Do										-54.9 dBm	
Amp D Output Power P Do			-60.97	-60.97	-60.97	-60.97	-60.97	dBm			
Amp D Gain G D	*20.0*	*dB*	20.00	20.00	20.00	20.00	20.00				
Amp D NT D	*63*	*K*	63.00	63.00	63.00	63.00	63.00	K			
Amp D Input effective NT Dei			68.4	69.4	70.4	71.3	72.3	K			
Integrated Input Power P Di										-74.9 dBm	
Input Power P Di @ 290K	*-81.0*	*dBm*	-81.0	-81.0	-81.0	-81.0	-81.0	dB			

								m		
in 2GHz BW segments										
Total power at Cartridge Output	-34.2	dBm							From J94	
Power Density based on total power	-73.3	dBm / MHz								
Total Power at Each IF										
Power Density at Each IF		dBm / MHz	-78.11	-78.81	-79.40	-79.92	-80.39		From Row 95	
Power Density at Each IF, including ripple		dBm / MHz	-77.73	-78.47	-79.09	-79.63	-80.12		Row 153 + 0.5 * Row 23	
Gain Slope		dB / 2 GHz	0.70	0.59	0.52	0.47	0.47		Diff of adj cols in Row 95	
Ripple		dB / 2 GHz	0.76	0.67	0.62	0.57	0.54		From Row 23	
Output VSWR			1.33	1.33	1.33	1.33	1.33		From Row 93	
Added Noise		K	5.4	6.4	7.4	8.3	9.3			
Noise Temperature Variation, Mixer Preamp	+/- 10.0	K / 2 GHz	Specified by Gene Lauria							
Gain Slope, Mixer-preamp	+/- 1.5	dB / 2 GHz	Specified by Gene Lauria							
Gain Ripple, Mixer-preamp	+/- 1.0	dB / 2 GHz	Specified by Gene Lauria							
Noise Temperature Variation, warm IF Amp	+/- 4.0	K / 2 GHz	Worst case from measured AML amp 0436-103							
Noise Temperature Variation, warm IF Amp @ Input	+/- 0.13	K / 2 GHz	Uses smallest loss vs. Freq for cable G							
Gain Slope, warm IF Amp	+/- 1.0	dB / 2 GHz	Specified for AML's warm IF amps							
Gain Ripple, warm IF Amp	+/- 0.0	dB / 2 GHz	Specified for AML's warm IF amps							
Assumed receiver temperature	75	K								
Assumed sky, spillover, atm contribution	+/- 30.00	K								
Total System Noise Temperature	105	K								
Power Variation from Noise Temp Changes	+/- 0.40	dB / 2 GHz								
Worst-case gain change from VSWR	+/- 0.76	dB / 2 GHz								

Gain Slope from Cable Loss	+/- 0.30	dB / 2 GHz								
Total Gain Changes	+/- 4.32	dB / 2 GHz								