Memorandum

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Date:	2006-06-12	
Rev: -	2006-06-12 jee Initial	

Subject: Cascade Noise Analysis of Band 6 Cartridge

1. Summary

A previous memo[1] showed that the gain slope of the Band 6 cartridge can be improved significantly with an equalizer integrated into the warm IF amplifier. To meet both gain slope as well as total power specifications, the equalizer requires the specifications given in Table 1. These are based on discussions with the current vendor, AML Communications, for modifying their warm IF amp to include an amplitude equalizer.

To confirm that these gain values don't degrade receiver noise temperatures, this memo analyses noise temperatures of the cascade consisting of the cold cartridge, warm IF amps, IF switch, and back end. The sensitivity of receiver noise temperature to changes in subsystem parameters is also analyzed.

Table 1: Specifications Assumed for Warm IF Amp with Integrated Equalizer

Parameter	Value
Gain	22 dB @ 4 GHz 34 dB @ 12 GHz
Noise Figure	2 dB
VSWR	Input: 1.8:1 Output: 1.33:1

Receiver noise temperature is sensitive to the noise figure of the warm IF amps but relatively insensitive to the gain of the IF amps.

2. Cascade Analysis

Bob Freund's noise analysis spreadsheet was modified to perform the analysis here, and sections of the modified spreadsheet are shown in Table 2, Table 3, and Table 4. Figure 1 shows Freund's block diagram modified to include the current IF switch implementation. Freund's spreadsheet was chosen because it includes the ability to calculate performance over a number of IF's, which is useful because it can accommodate gain slope.

Overall cartridge gain was measured by differencing system noise power when the receiver is connected to hot and cold loads and dividing by the difference in the hot and cold load physical temperatures. This is the standard "$\Delta P/\Delta T$" technique and implementation details for the Band 6 cartridge are given on ALMA EDM[2]. Gain of just the cold cartridge, shown in Figure 2, is calculated by subtracting from the overall cartridge gain the gain of the warm IF system, which was measured using a network analyzer. For reference, Figure 2 includes the gain of the

[1] "Band 6 Cartridge Power Density Slope Correction Using Warm IF Amps", FEND-40.02.06.00-098-A-DSN, 2006-06-01, available on ALMA EDM at http://edm.alma.cl/forums/alma/dispatch.cgi/iptfedocs/docProfile/102197.
[2] "Band 6 Cartridge Test Procedure Noise Performance, Gain, and Gain Slope," FEND-40.02.06.00-076-A-PLA, 2006-04-26, http://edm.alma.cl/forums/alma/dispatch.cgi/iptfedocs/docProfile/101778

relevant mixer-preamp measured using the Mixer Test System, which was also calculated from the "ΔP/ΔT" technique.

The noise temperature of the mixer-preamp was set in the spreadsheet Table 4 (*Amp D NT D*), to the mixer's specification values of 136K at 4 and 12 GHz and 83K elsewhere. The input parameter for cold cartridge gain (*Amp D Gain G D*, Table 4) was adjusted so that the cartridge gains calculated in the spreadsheet (*Cold Cartridge Gain*, Table 4) equaled the gains measured in Figure 2.

The warm IF amp parameters are entered in Table 3 at rows *Amp C NT (Warm IF Amp)* and *Amp C Gain (Warm IF Amp*). Cable attenuation for the warm IF plate was measured on a network analyzer and is entered in Table 3 as *Cable d loss Ld at freq* and *Cable c loss Lc at freq*.

The IF switch was configured for worst-case with its variable attenuator set for 15 dB.

Receiver noise temperature in excess of the mixer-preamps' noise temperature is called *2nd Stage Noise Contribution* in the spreadsheet and is calculated in Table 2.

3. Noise Temperature Sensitivity Results

Noise temperature sensitivity, shown in Figure 3, is the difference in receiver noise temperature when various subsystem parameters are changed. Note that for a well-designed receiver, the receiver noise should be dominated by the first stage noise temperature with insignificant noise contribution from latter stages. For the Band 6 Cartridge with nominal component values, the noise temperature contribution of latter stages (called *2nd Stage Noise Increase* in the figure) is 0.7K at 6 GHz and 1.7K at 10 GHz.

Figure 3 shows receiver noise temperature is most sensitive to changes between the mixer-preamp and the warm IF amps as shown when either "Pad H" or "Pad F" are increased by 1 dB. Pad H is the 2 dB cold attenuator installed in the 4K stage to reduce ripple. Pad F isn't actually present, but shows that the receiver noise temperature is sensitive to input cable loss and the noise figure of the warm IF amps.

Receiver noise temperature is relatively insensitive to the gain of the Warm IF amps, the noise figure of the IF switch (Pad B), and the attenuator in the IF switch.

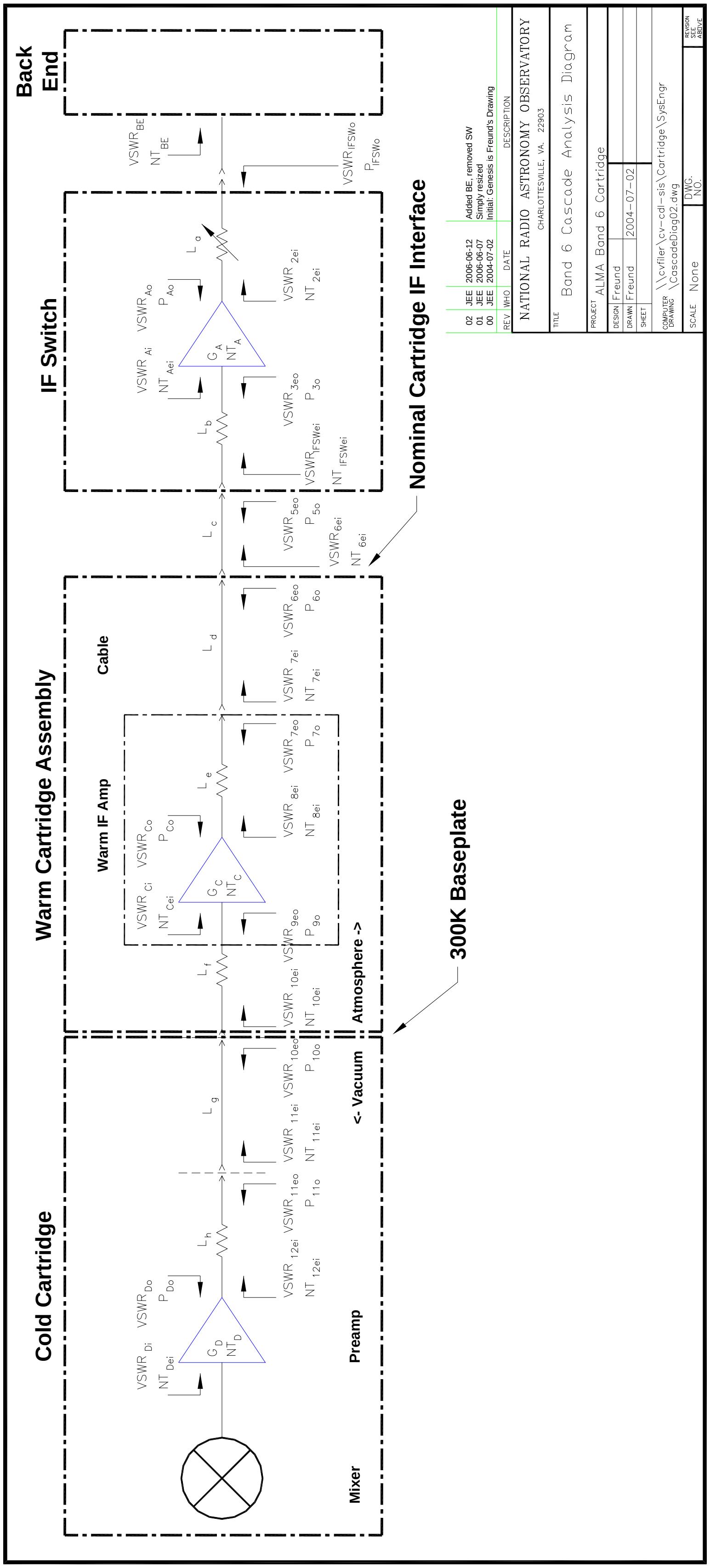

Figure 1: Block diagram of components used in cascade analysis

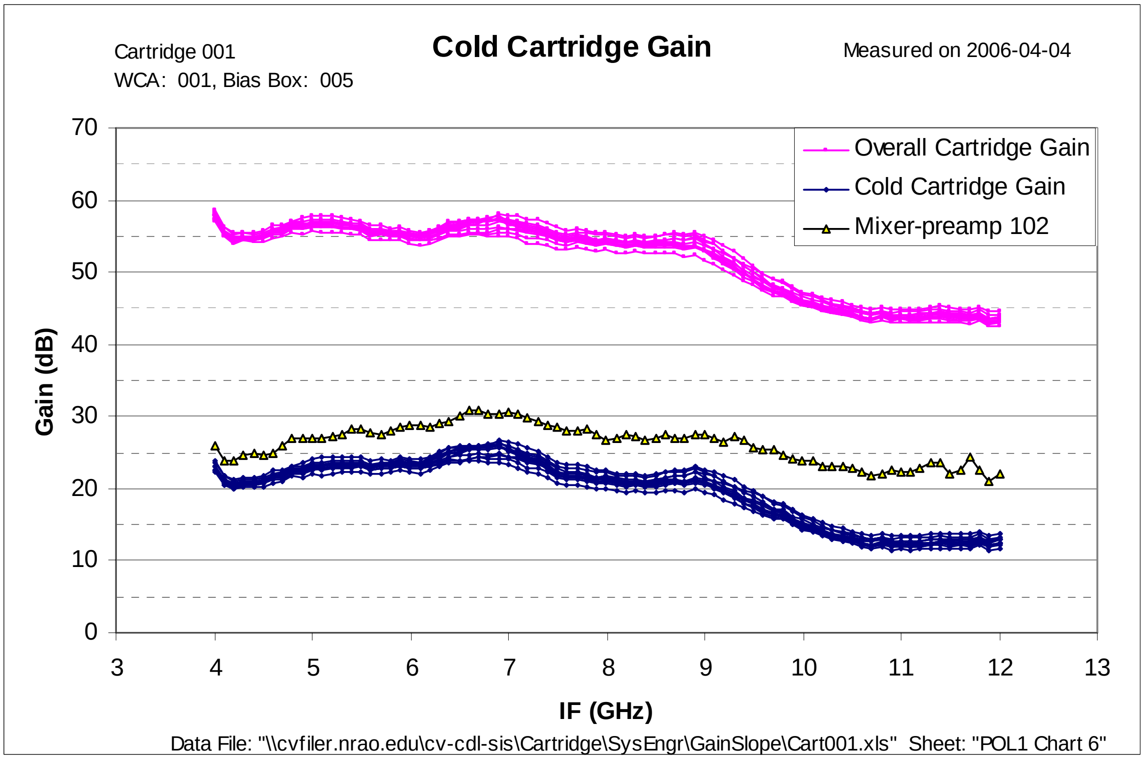

Figure 2: Measured Gain of Overall and Cold Cartridge Compared to Measured Mixer-preamp Gain

	A	B	C	D	E	F	G	H	I	J
1	**Front End Signal Path Budget**									
2	Version 1 - 2: Bob Freund									
3	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									
4	Version 4: 2004-07-02 jee changed warm IF amp: NT from 150 to 120K, changed Le to 3 dB (to improve output VSWR)									
5	Version 4.1 2004-08-24 jee added cell for Warm IF NF to NT conversion.									
6	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									
7	Version 4.3 2006-06-07 jee added measured SS coax data and changed Warm IF NF to 2 dB									
8										
9	*k*	*1.38E-23*								
10	*T*	*300*	*K*							
11	*T for 4K Attn*	*4*	*K*							
12	BW_Full	8.00E+09	Hz							
13	BW_Seg	2.00E+09	*Hz*							
14										
15	Maximum output power per 2 GHz banc	-27.0	*dBm*							
16							10	31		
17	Input power over full 8 GHz band	3.31E-11	W	-74.80	dBm					
18	Output power over full 8 GHz band	3.54E-06	W	-24.51	dBm					
19										
20										
21	***Freq***			**4**	**6**	**8**	**10**	**12**	**GHz**	
22										
23	Total gain			44.13	48.93	51.77	50.62	51.49	dB	
24	Excess gain			-9.69	-4.89	-2.05	-3.20	-2.33	dB	
25										
26	RSS ripple			1.47	1.45	1.44	1.43	1.41	dB pk-pk	
27										
28	Achieved noise temperature			137.6	83.8	83.7	84.7	138.5	K	
29	Second stage noise contribution			1.6	0.8	0.7	1.7	2.5	K	
30										
31										
32	*Back End Input NT BE*	*15 dB*	*<- NF of BE*	8,881	8,881	8,881	8,881	8,881	K	
33	*Back End Input VSWR BEi*	*1.40*		1.40	1.40	1.40	1.40	1.40		
34	*Back End Input Gamma BEi*			0.167	0.167	0.167	0.167	0.167		
35										
36	*IF SW to Back End Ripple*			0.03	0.03	0.03	0.03	0.03	db pk-pk	
37										
38	*IF SW Output effective gamma IFSWo*			0.011	0.011	0.011	0.011	0.011		
39	*IF SW Output effective VSWR IFSWo*			1.02	1.02	1.02	1.02	1.02		
40	*IF SW Integrated Output Power P IFSWo*									-24.5 dBm
41	*IF SW Output Power P IFSWo*			-36.7	-31.9	-29.1	-30.2	-29.3	dBm	
42	*Pad a Maximum Loss La*	*15.0*	*dB*	15.0	15.0	15.0	15.0	15.0	dB	
43	*Pad a effective Input* NT_{2ei}			290,016	290,016	290,016	290,016	290,016	K	
44	*Pad a Input effective* $VSWR_{2ei}$			1.01	1.01	1.01	1.01	1.01		
45										
46	*Amp A Output* $VSWR_{Ao}$	*2.0*		2.00	2.00	2.00	2.00	2.00		
47	*Amp A Integrated Output Power* P_{Ao}									-9.5 dBm
48	*Amp A Output Power* P_{Ao}			-21.7	-16.9	-14.1	-15.2	-14.3	dBm	
49	*Amp A Gain* G_A	*15.0*	*dB*	15.0	15.0	15.0	15.0	15.0	dB	
50	*Amp A* NT_A **(NF IF Switch)**	15.0 dB		8,881	8,881	8,881	8,881	8,881	K	
51	*Amp A effective* NT_{Aei}			18,052	18,052	18,052	18,052	18,052	K	
52	*Amp A Input* $VSWR_{Ai}$	*2.0*		2.00	2.00	2.00	2.00	2.00		
53										

Table 2: Spreadsheet 1

	A	B	C	D	E	F	G	H	I	J
54	Pad b Output effective VSWR $_{3eo}$			1.28	1.27	1.26	1.26	1.25		
55	Pad b Integrated Output Power P $_{3o}$									-24.5 dBm
56	Pad b Output Power P $_{3o}$			-36.7	-31.9	-29.1	-30.2	-29.3	dBm	
57	Pad b Loss L $_{b}$	0.0	dB	0.0	0.0	0.0	0.0	0.0	dB	
58	IFSW effective Input NT $_{IFSWei}$			18,052	18,052	18,052	18,052	18,052	K	
59	IF SW Input effective VSWR $_{IFSWei}$			2.00	2.00	2.00	2.00	2.00		
60	IF SW Input effective gamma IFSWei			0.333	0.333	0.333	0.333	0.333		
61										
62	**Cartridge Interface with IF cables and switch**									
63										
64	Cable c Output effective VSWR 5eo			1.28	1.27	1.26	1.26	1.25		
65	Cable c Integrated Output Power P 5o									**-24.5 dBm**
66	Cable c Output Power P 5o			-36.7	-31.9	-29.1	-30.2	-29.3	dBm	
67	Cable c loss Lc	76.2	dB per 100 ft	0.29	0.36	0.42	0.47	0.51	dB	
68	at freq	18.0	GHz							
69	Cable c length	0.25	m							
70	Cable c NT c			21.1	26.0	30.2	34.0	37.4	K	
71	Cable d Input effective NT 5ei			19,340	19,642	19,900	20,130	20,341	K	
72	Cable d Input effective VSWR 5ei			1.905	1.885	1.869	1.855	1.842		
73										
74	Cable d Output effective VSWR 6eo			1.31	1.30	1.30	1.29	1.29		
75	Cable d Integrated Output Power P 6o									**-24.1 dBm**
76	Cable d Output Power P 6o			-36.4	-31.5	-28.6	-29.7	-28.8	dBm	
77	Cable d loss Ld	76.2	dB per 100 ft	0.29	0.36	0.42	0.47	0.51	dB	
78	at freq	18.0	GHz							
79	Cable d length	0.25	m							
80	Cable d NT d			21.1	26.0	30.2	34.0	37.4	K	
81	Cable d Input effective NT 7ei			19,340	19,642	19,900	20,130	20,341	K	
82	Cable d Input effective VSWR 7ei			1.261	1.248	1.238	1.229	1.221		
83										
84	Pad e to Pad b Ripple			0.79	0.79	0.78	0.78	0.77	dB	
85										
86	Pad e Output equiv gamma 7eo			0.137	0.136	0.135	0.134	0.134		
87	Pad e Output equiv VSWR 7eo			1.317	1.314	1.312	1.310	1.308		
88	Pad e Output effective VSWR 7eo			1.33	1.33	1.33	1.33	1.33		
89	Pad e Integrated Output Power P 7o									-23.6 dBm
90	Pad e Output Power P 7o			-36.1	-31.2	-28.2	-29.3	-28.3	dBm	
91	Pad e Loss Le	0.0	dB	0.0	0.0	0.0	0.0	0.0	dB	
92	Pad e Input effective NT 8ei			19,340	19,642	19,900	20,130	20,341	K	
93	Pad e Input effective VSWR 8ei			1.261	1.248	1.238	1.229	1.221		
94										
95	Amp C Output VSWR Co	1.33		1.33	1.33	1.33	1.33	1.33		
96	Amp C Integrated Output Power P Co						Total Cold Cartridge Power ->			-23.6 dBm
97	Amp C Output Power P Co			-36.1	-31.2	-28.2	-29.3	-28.3	dBm	
98	Amp C Gain **(Warm IF Amp)**			22	25	28	31	34		
99	Amp C NT **(NF Warm IF Amp)**	2.0 dB		170	170	170	170	170	K	
100	Amp C Input effective NT Cei			292	232	201	186	178	K	
101	Amp C Input VSWR Ci	1.8		1.80	1.80	1.80	1.80	1.80		
102										
103	Pad f Ouput effective VSWR 9eo			1.665	1.652	1.641	1.632	1.624		
104	Pad f Integrated Output Power P 9o									-51.7 dBm
105	Pad f Output Power P 9o			-58.1	-56.2	-56.2	-60.3	-62.3	dBm	
106	Pad f Loss Lf	0.0	dB	0.0	0.0	0.0	0.0	0.0	dB	
107	Pad f Input effective NT 10ei			292	232	201	186	178	K	
108	Pad f Input effective VSWR 10ei			1.80	1.80	1.80	1.80	1.80		
109	Pad f Input equiv. VSWR 10ei			1.76	1.76	1.75	1.74	1.74		
110	Pad f Input equiv gamma 10ei			0.277	0.275	0.273	0.271	0.270		
111										

Table 3: Spreadsheet 2

	A	B	C	D	E	F	G	H	I	J
112	*Cold Cartridge Gain*			22.7	24.7	24.6	20.6	18.5	dB	
113										
114	*Cable g Output effective VSWR 10eo*			1.66	1.65	1.64	1.63	1.62		
115	*Cable g Integrated Output Power P 10o*									-51.7 dBm
116	*Cable g Output Power P 10o*			-58.1	-56.2	-56.2	-60.3	-62.3	dBm	
117	*Cable g Loss Lg*	*76.2*	*dB per 100 ft*	0.28	0.35	0.40	0.45	0.49	dB	
118	*at freq*	*18.0*	*GHz*							
119	*Cable g length*	*0.24*	*m*							
120	*Cable g NT g*			1.0	1.2	1.4	1.5	1.7	K	
121	*Cable g Input effective NT 11ei*			312	252	222	207	201	K	
122	*Cable g Input effective VSWR 11ei*			1.731	1.717	1.705	1.695	1.685		
123										
124	*Amp D/Pad h to Pad f/Amp C Ripple*			1.24	1.22	1.21	1.19	1.18	dB	
125										
126	*Pad h Output equiv. gamma 11eo*			0.258	0.256	0.254	0.253	0.252		
127	*Pad h Output equiv. VSWR 11eo*			1.694	1.688	1.682	1.677	1.673		
128	*Pad h Output effective VSWR 11eo*			1.73	1.73	1.73	1.73	1.73		
129	*Pad h Integrated Output Power P 11o*									-51.3 dBm
130	*Pad h Output Power P 11o*			-57.8	-55.8	-55.8	-59.8	-61.8	dBm	
131	*Pad h Loss Lh*	*2.0*	*dB*	2.00	2.00	2.00	2.00	2.00	dB	
132	*Pad h Input effective NT 12ei*			497	402	354	331	320	K	
133	*Pad h Input effective VSWR 12ei*			1.731	1.717	1.705	1.695	1.685		
134										
135	*Amp D Output VSWR Do*	*2.46*		2.46	2.46	2.46	2.46	2.46		
136	*Amp D Integrated Output Power P Do*									-49.3 dBm
137	*Amp D Output Power P Do*			-55.8	-53.8	-53.8	-57.8	-59.8	dBm	
138	*Amp D Gain G D*		*dB*	25.0	27.0	27.0	23.0	21.0		
139	*Amp D NT D*	*83*	*K*	136	83	83	83	136	K	
140	*Amp D Input effective NT Dei*			137.6	83.8	83.7	84.7	138.5	K	
141										

Table 4: Spreadsheet 3

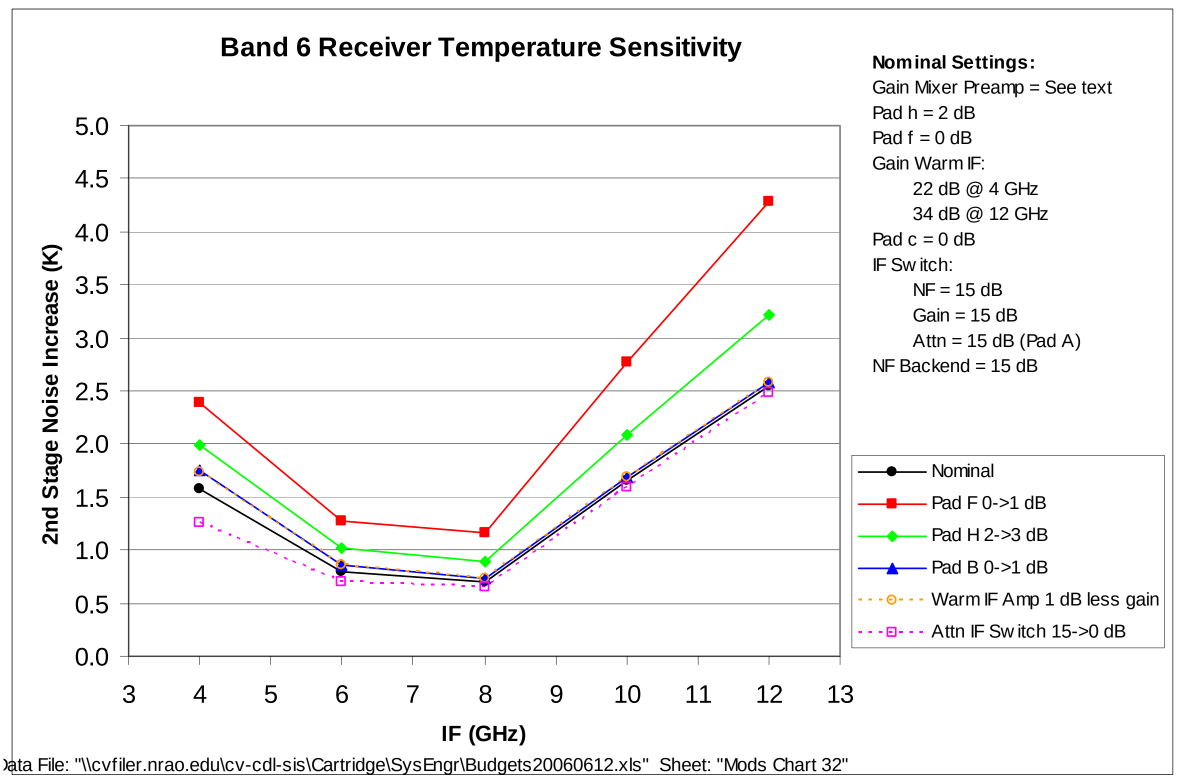

Figure 3: Receiver Temperature Sensitivity