Memorandum

To: File

From: John Effland

Date: 2004-09-15

Revisions:

-	2004-09-15	jee	Initial
A	2004-09-16	jee	Webber's comments: "Prediction" changed to "predetection" and explicit text added about Warm IF amp

Subject: Gain Stability Measurements of Band 6 Prototype Cartridge

Summary

Gain stability of the *prototype* Band 6 cartridge (*sans* the warm IF amps) was measured and compared in Table 1 to earlier data of just the mixer-preamp measured in the JT-2 test system. Measurements are planned for the immediate future that include the warm IF amps.

Data measured in late September of 2003 and documented in a memo[1] that inexplicably was never released (until now) shows gain stability when the mixer's preamp is the only cold InP amplifier in the system. Agreement is good in measured gain stability between the cartridge and mixer-preamp, despite different bias supplies, IF systems, and local oscillators. Another consistency check showing close agreement compared gain stability in the white-noise region to the theoretical limit.

Table 1: Summary of Gain Stability Results

System	$\sqrt{2/BW}$	Measurement Frequency (Hz)			
		1000	100	10	1
Prototype Cartridge (without warm IF amps)	1.6×10^{-5} for BW = 8 GHz	2×10^{-5}	2.3×10^{-5}	6×10^{-5}	2×10^{-4}
Mixer-preamp for JT-2		2.2×10^{-5}	2.6×10^{-5}	6×10^{-5}	2.3×10^{-4}

Equipment Setup

The equipment setup is shown in Figure 1 and uses the prototype Band 6 cartridge along with SN001 Warm Cartridge Assembly (WCA). The components in vacuum for this cartridge are identical to those used in Band 6 production cartridges. Warm IF amplifiers, which are formally part of the cartridges, were not available at the time the data were measured, so their contribution is unknown but thought to be small. The 3 dB IF attenuators located at the output of the Cartridge Connector Plate were not needed for the gain stability testing but were retained to minimize setup changes for other tests. The mixer-preamp details are provided in Table 2.

[1] "Band 6 Gain Stability Measurements of 26 September 2003," NRAO CDL Memo, Effland and Lauria, 2003-09-26, available at http://www.cv.nrao.edu/~jeffland/GainStability2003-09-26.pdf

Table 2: Mixer-Preamps Used in Prototype Cartridge			
Polarization	Mixer-Preamps	Matching Circuits	Mixer Chips
0	14/23/24	IN2	UVA-N10-04-1003-L1360-2-HI-C14,L62-1 UVA-N10-04-1003-L1360-2-HI-C14,L62-3
1	21/32/31	IN2	UVA-N10-04-1003-L1360-2-HI-C14,L56-1 UVA-N10-04-1003-L1360-2-HI-C14,L56-3

An HP 35670A Dynamic Signal Analyzer fourier-transforms the video signal in real time and the results are then dumped to spreadsheets for further analysis and graphing. The frequency range of interest is measured by commanding the 35670 to acquire data over a series of frequency spans and concatenating the results in the spreadsheet. Because the frequency bin-widths are constant, logarithmic scaling produces higher bin densities near the upper end of each measurement range.

Data were output in units of $V_{RMS}/\sqrt{Hz}$ where Hz refers to the bandwidth of each bin. It was determined empirically that the DC voltage (V_{DC}) used for the normalization could be calculated from the zero-frequency term [V(f = 0)] and the bin size (RBW) of the 35670:

$$V_{DC} = V_{(f=0)} \times \sqrt{RBW/2}$$

Gain stability was measured for two values of predetection bandwidth (BW). Data annotated as "8 GHz Bandwidth" includes only a 4 GHz highpass filter at the input of the IF plate. The effective bandwidth appears close to 8 GHz because the measured data is near the theoretical value[2] given by $\sqrt{2/BW}$. Gain stability was also measured using a 500 MHz wide, 4.75 GHz center-frequency bandpass filter before the detector. More details are given in the results section.

Results

Prototype Cartridge with 8 GHz Bandwidth

The normalized spectral density of the prototype cartridge for an 8 GHz bandwidth is shown in Figure 2. A peak near the Sumitomo refrigerator frequency of 1-Hz may be absent because the closed-loop LakeShore 332 temperature controller maintains the mixer temperature at the specified 4K with a default update rate of 1 kHz .

The 20% discrepancy between the theoretical density given by $\sqrt{2/BW}$, shown in Figure 2 by the diamond, and the data measured in the white noise regime, may result from the slope in IF output power of the cartridge[3] causing a reduction in the effective bandwidth. In fact, an effective bandwidth of 5 GHz yields good agreement between the theoretical and measured data.

As a consistency check, gain stability was also measured using a 500 MHz predetection bandwidth and those results are shown in Figure 3. In this case, close agreement between measured and theoretical data (depicted by the triangle) probably results because the power density is more constant over this narrow bandwidth.

[2] "The Measurement of Thermal Radiation at Microwave Frequencies," Dicke, R., *Rev. Sci. Instrum*. 1946, Vol. 17, No. 7, pp. 268-275.

[3] "Cartridge Test Report, Prototype 9," Dan Koller, 2004-07-07, Page 5 available at: \\cvfiler\cv-cdl-sis\CartTstRpt\CartridgeP9_Test_Report.pdf

It is interesting to note that the knee frequency where the 1/f noise begins to dominate the spectral density is around 100 Hz for the wideband case but only 10 Hz for the band-limited case. This may be indicative of influences from out-of-band processes, but close agreement with the JT-2 data, which had a different predetection filtering scheme, probably means some other in-band process is responsible.

Mixer-Preamp Using JT-2 Test System with no cold IF Amp

Gain stability was measured in the JT-2 test system, the predecessor to the Mixer Test System, initially with and later without a cold IF amp in the Dewar. The cold IF amp was another InP 3-stage amp of essentially the same design as the mixer's preamp and hence contributed significantly to the results[4]. Data measured in late September of 2003 and documented in a memo[1] that inexplicably was never released shows gain stability when the only cold InP amplifier in the system is that of the mixer's preamp. Figure 4 shows these results, which agree well with the prototype cartridge results shown in Figure 2. The agreement is even more remarkable when it is remembered that the measurement systems used different local oscillators, IF systems, and mixer and preamp bias supplies.

[4] "Notes on Gain Stability Measurements of 13 June 2003," NRAO CDL Memo, Effland and Lauria, 2003-09-04, available at http://www.cv.nrao.edu/~jeffland/AllanVar1.pdf

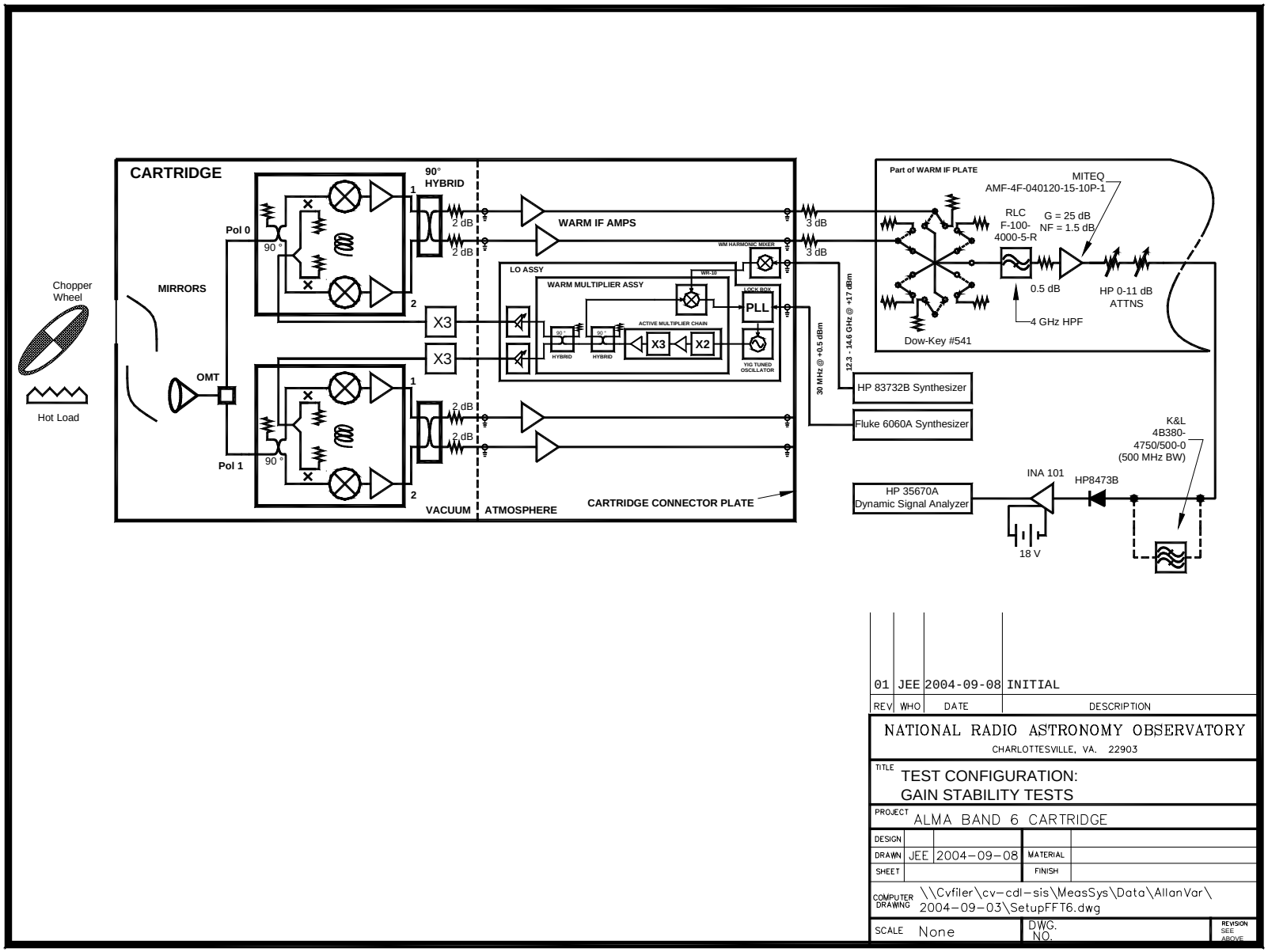

Figure 1: Equipment Setup (Dewar apparatus not shown for clarity)

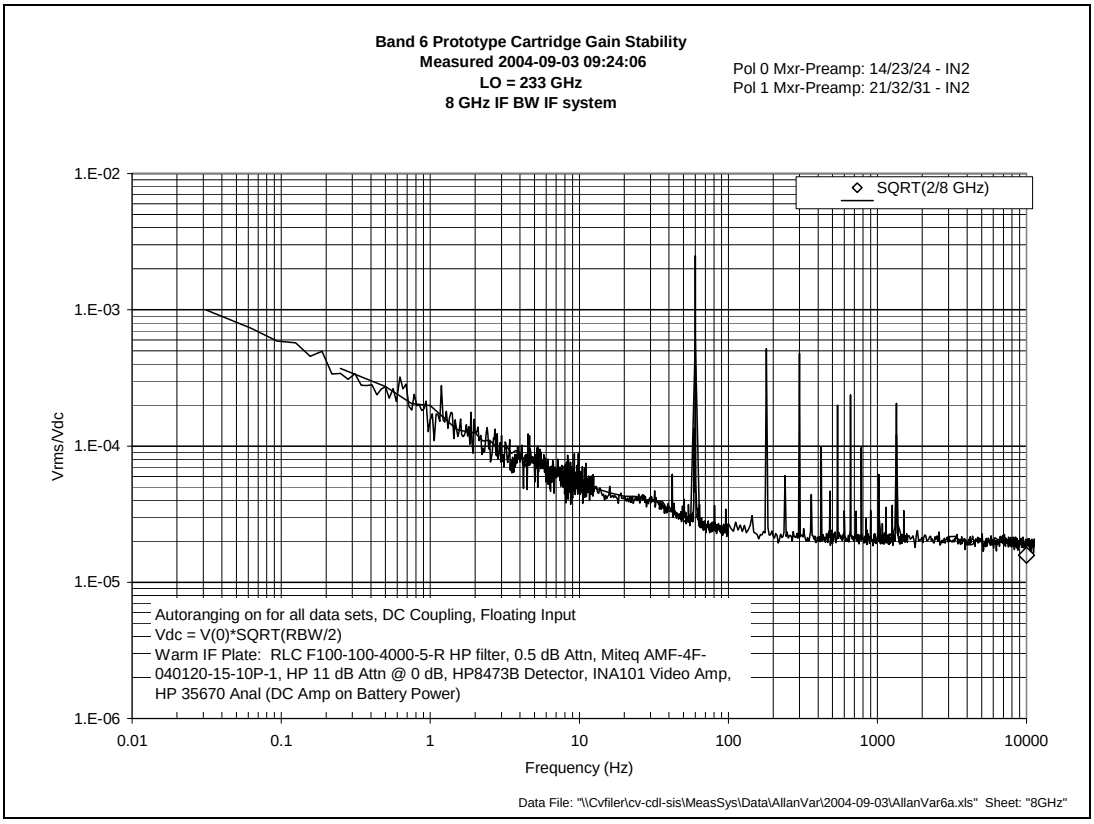

Figure 2: Normalized Spectral Density of prototype cartridge, 8 GHz IF Bandwidth

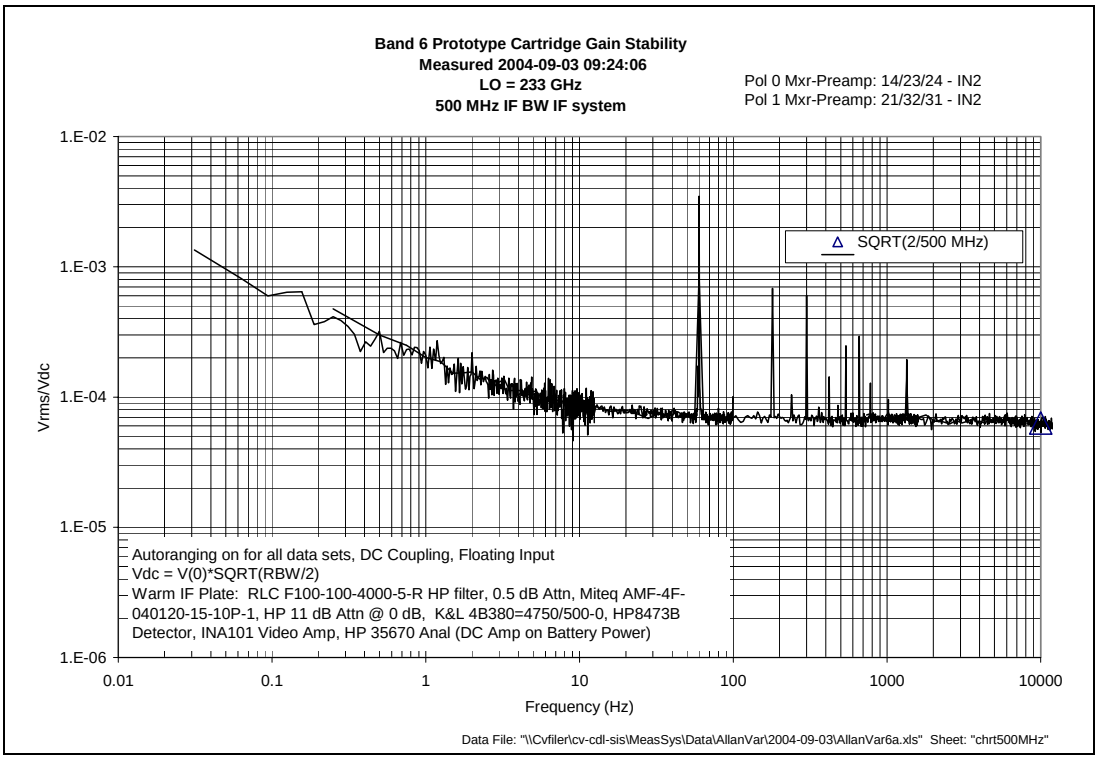

Figure 3: Normalized Spectral Density of prototype cartridge, 500 MHz IF Bandwidth

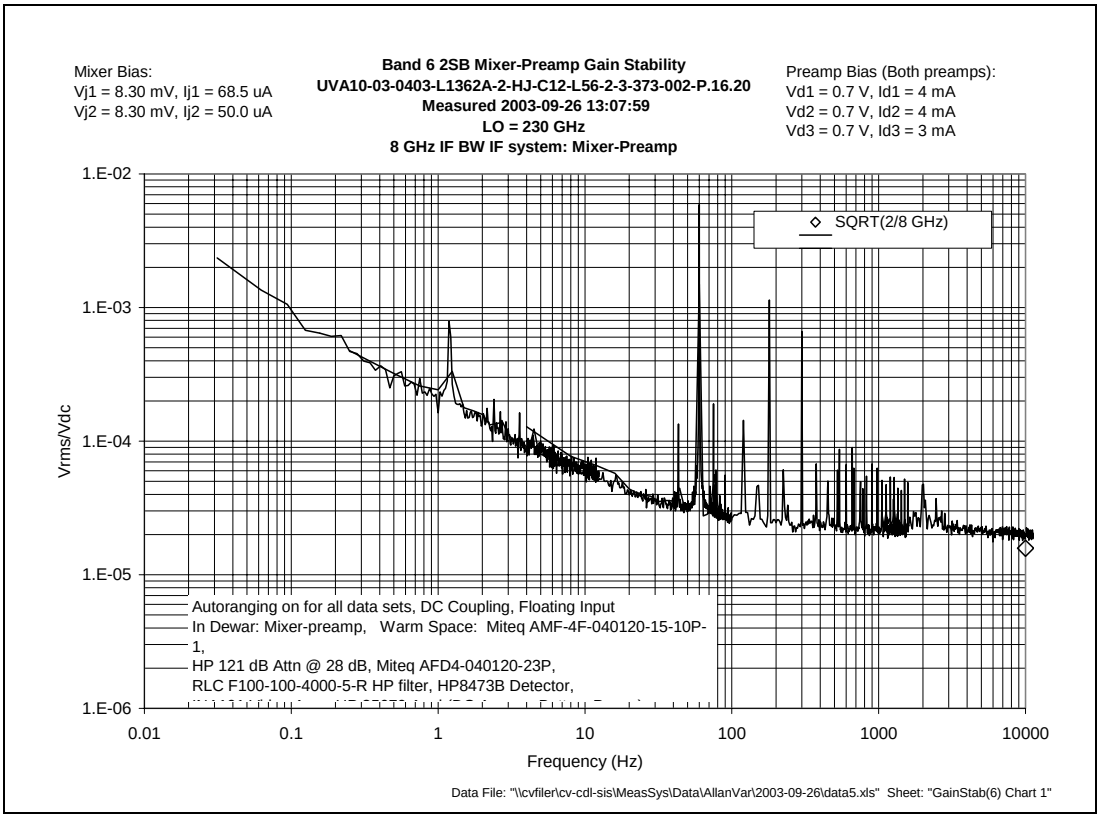

Figure 4: Spectral Density for just mixer-preamp from JT-2 Test Dewar