Memorandum

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From: John Effland
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Date: 2004-02-18

Revision	**Date**	**Who**	**Notes**
00	2004-02-16		Initial
01	2004-02-18	jee	Added spectrum analyzer data as suggested by John Webber and block diagram of test set.

Subject: Initial Measurements of Noise Power Density for an ALMA Band 6 Mixer-Preamp

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Introduction

Noise power density as a function of intermediate frequency was measured for the first production model of a Band 6 mixer-preamp and compared to the specifications. The proposed specifications are IF power variation < 3.5 dB peak-to-peak over 2 GHz and < 4.0 dB peak-to-peak over the entire IF band . Measured data shows 5.7 dB peak-to-peak for both cases. It is important to note that contributions from cartridge cabling and the warm IF amplifiers are not included here.

These initial measurements of noise power density should be used with caution because the large ripple in the data suggests that excessive VSWR might be present in the test system.

Calculation of Noise Power Density

Noise power density provides a convenient measure of frequency dependent power variation at the samplers and is more accurate than simply examining gain variations. Limiting the variation of IF power across the sampler's 2 GHz bandwidth is necessary to maintain acceptable sampler "efficiency". IF power variation is specified for the Band 6 cartridge as[1]:

3.5 dB peak to peak in any 2 GHz portion of the IF band
4.0 dB peak to peak across the whole IF band

To compare measurements with specifications, it is useful to consider noise power density in units of dBW/Hz by taking the log of the power density as described below.

The total power output from the mixer-preamp (P_{MXR}) in watts looking into an ideal, zero temperature load is:

$$P_{MXR} = G_{MXR} k T_{MXR} B \qquad \text{Eq. (1)}$$

where:

G_{MXR} is the gain of the mixer-preamp,

k is Boltzmann's constant (1.38 x 10^{-23} W/K-Hz)

T_{MXR} is the noise temperature of the mixer-preamp, and

B is the noise bandwidth of the system.

Noise power density (ψ) in units of dBW/Hz is obtained by rearranging the factors in Eq. (1):

$$\begin{aligned}\psi &= 10\log\left(\frac{P_{MXR}}{B}\right) \\ &= 10\log\left(G_{MXR} k T_{MXR}\right)\end{aligned} \qquad \text{Eq. (2)}$$

The mixer-preamp gain factor (G_{MXR}) is calculated from the ratio of the gain of the entire receive system normalized by the gain of the IF system. First, gain (G_{RX}) of the receiver is measured from noise powers and physical temperatures using the usual "ΔP/ΔT equation" when the input to the receiver system is connected alternately to a hot and cold load:

$$G_{RX} = \frac{1}{kB}\left(\frac{P_h - P_c}{T_h - T_c}\right) \qquad \text{Eq. (3)}$$

where

P_h is the receiver power output when its input is connected to a hot load,
P_c is the receiver power output when its input is connected to a cold load,
T_h is the physical temperature of the hot load connected,
T_c is the physical temperature of the cold load.

The receive system gain (G_{RX}) includes contributions from the test system's IF chain, so the gain of just the mixer-preamp is found by normalizing G_{RX} by the gain of the IF system (G_{IF}) which is found from a similar "ΔP/ΔT" measurement of the IF system. Noise powers for that measurement are from the usual noise temperature measurements of the IF system by connecting alternately hot and cold loads to the IF system input. The gain of the mixer-preamp is then:

$$G_{MXR} = \frac{G_{RX}}{G_{IF}}\,. \qquad \text{Eq. (4)}$$

Noise power density is calculated from Eq. (2) using the gains calculated above along with measurements of the mixer-preamp noise temperature.

Measured Results

The equipment setup is drawn in Figure 1.

Figure 2 is a graph of the mixer-preamp's gain, noise temperature, and noise power density. All three traces are included to show how the individual components of noise temperature and gain affect the noise power density. The ripple from 4 to 8 GHz, which causes high ripple in the noise power density, may result from excessive VSWR in the test system. The increase in gain above 11.5 GHz may also be caused by test system anomalies and additional measurements are planned to investigate these problems.

While noise temperature data shown here is not corrected for sideband suppression, measurements of sideband suppression at this LO frequency are all above 10 dB and hence the appropriate corrections to noise temperatures are less than about 10%.

The trace labeled "DelP/DelT" in Figure 3 is the noise power density measured using the "$\Delta P/\Delta T$" technique and includes annotations showing the worst-case variation over a 2 GHz bandwidth and over the entire IF band. Table 1 compares measured results with specifications:

Table 1: Measured and Specified IF Power Variation for Band 6 Cartridge

Specifications:	**Measurements**
< 3.5 dB peak-to-peak over any 2 GHz	5.2 dB peak-to-peak
< 4.0 dB peak-to-peak across whole IF band	5.2 dB peak-to-peak

Also shown in Figure 3 are traces for both mixer sidebands obtained with an HP E4408 spectrum analyzer. The spectrum analyzer was connected at the output of the Dewar to eliminate contributions from the warm IF system. While the "DelP/DelT" trace in Figure 3 shows the gain of just the mixer-preamp, the spectrum analyzer traces include contributions from the cold IF amplifier, which is an NRAO 3-13 GHz HFET amp. Agreement between the spectrum analyzer traces and the "DelP/DelT" trace is amazingly good. Also plotted in Figure 3 is the noise floor of the spectrum analyzer obtained by terminating the Dewar end of the coax that connected the Dewar and spectrum analyzer.

These initial measurements of noise power density should be used with caution. Careful checking of the test system is required and we remain optimistic that improvements are possible. The ripple between 4 and 8 GHz is also observed (at a much higher peak level) when the cold IF amplifier in the Dewar is unterminated. This might mean that large mismatches exist between the mixer-preamp output and the cold IF amp. Further, it should be noted that contributions from IF cabling in the cartridge and from the warm IF amplifier in the cartridge are not included here.

Acknowledgements

The authors would like to thank A.R. Kerr for his many useful suggestions, Ralph Groves for assisting in the data collection, and Alex Grichener for enhancing the software to allow faster data acquisition.

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[1] Band 6 Cartridge Technical Specifications, ALMA FEND.40.02.06-00-001-A-SPE (apparently not yet on ALMA EDM)

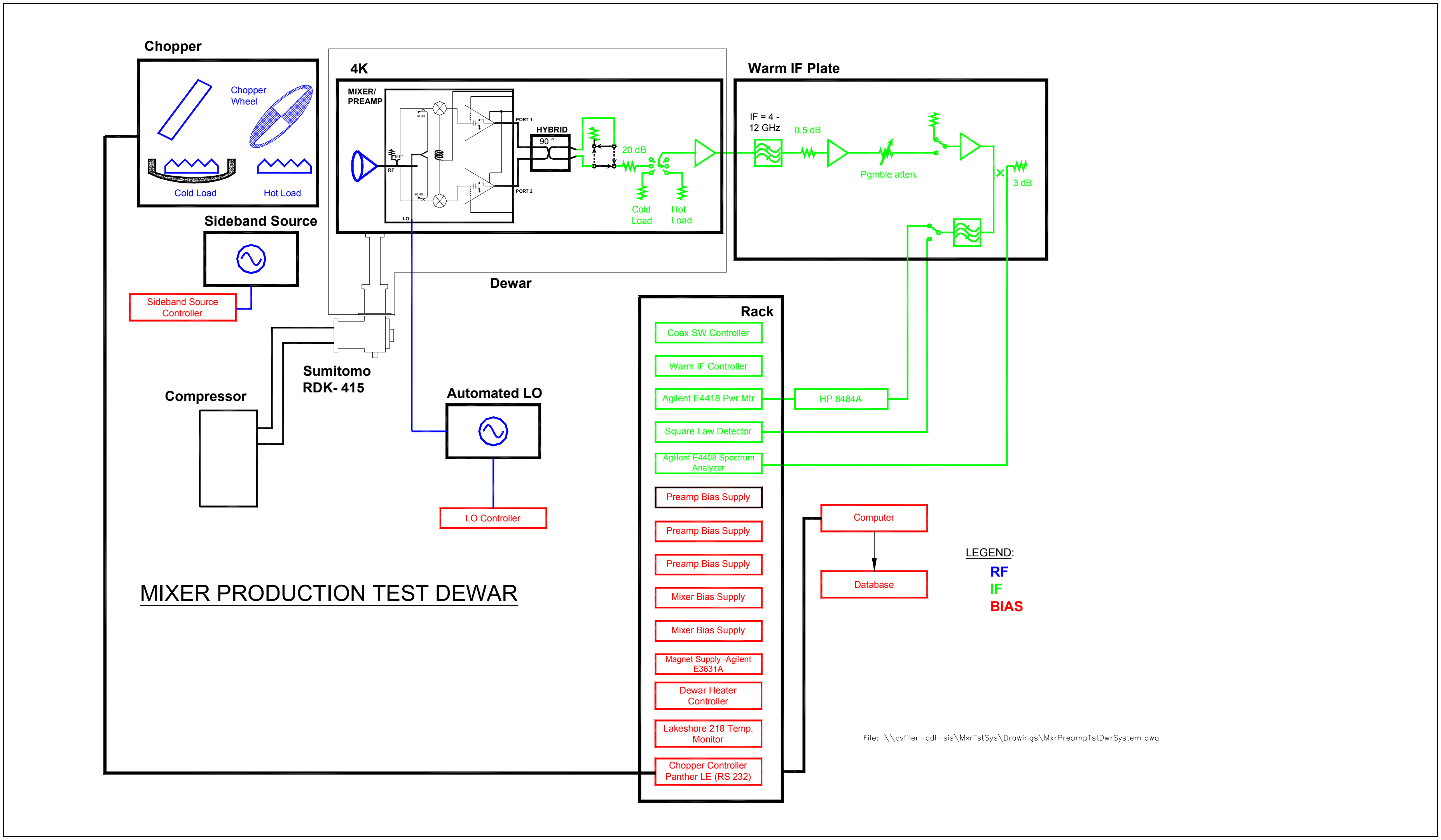
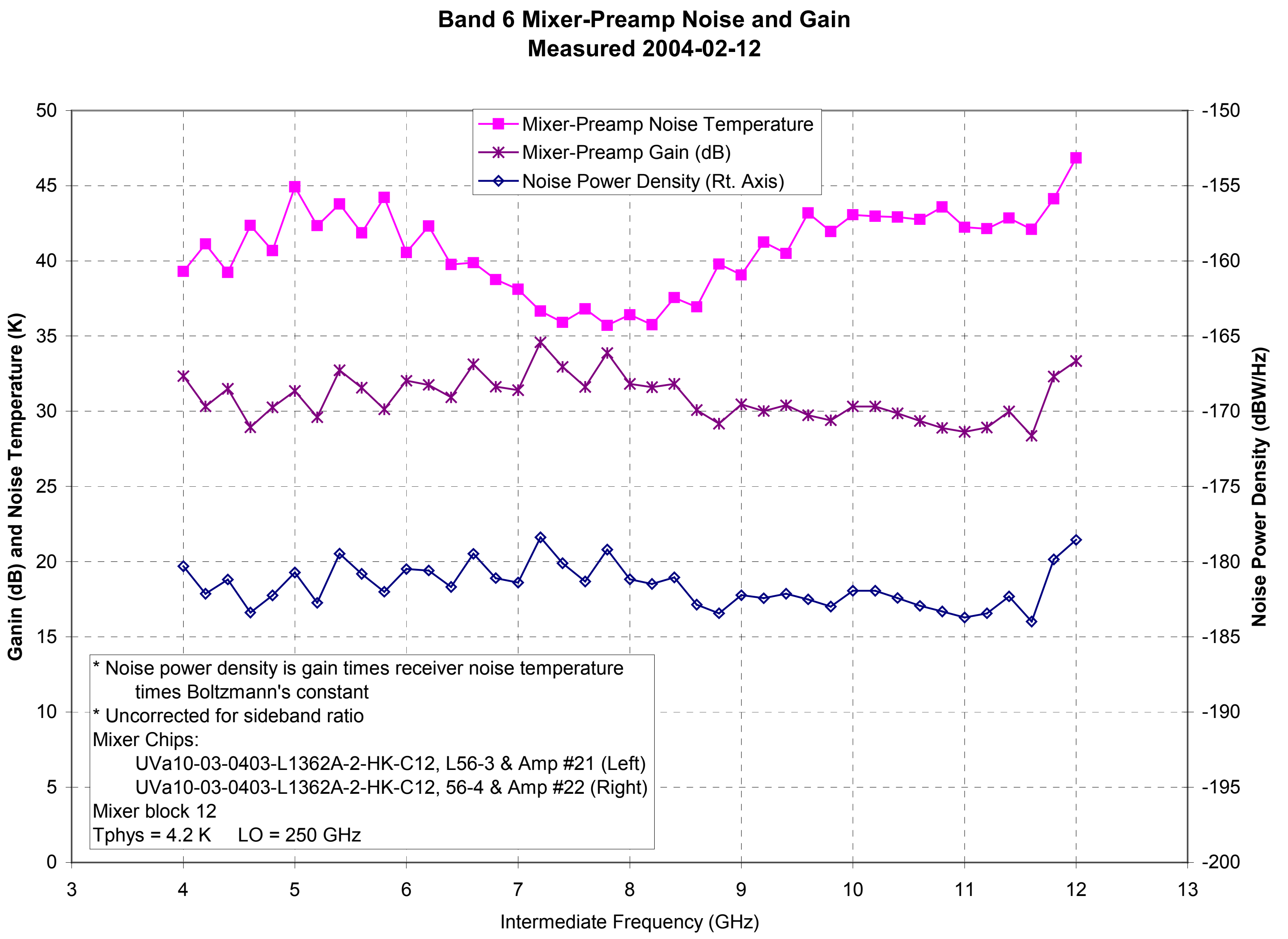


Figure 1: Block Diagram of Test System



Band 6 Mixer-Preamp Noise and Gain
Measured 2004-02-12

* Noise power density is gain times receiver noise temperature
times Boltzmann's constant
* Uncorrected for sideband ratio
Mixer Chips:
UVa10-03-0403-L1362A-2-HK-C12, L56-3 & Amp #21 (Left)
UVa10-03-0403-L1362A-2-HK-C12, 56-4 & Amp #22 (Right)
Mixer block 12
Tphys = 4.2 K   LO = 250 GHz

Data File: "\\CVFILER\cv-cdl-sis\MxrTstSys\Data\Blk012\Blk012Amp021-022FineData.xls" Sheet: "Gain"

Figure 2: Mixer-preamp gain, noise temperature, and noise power density

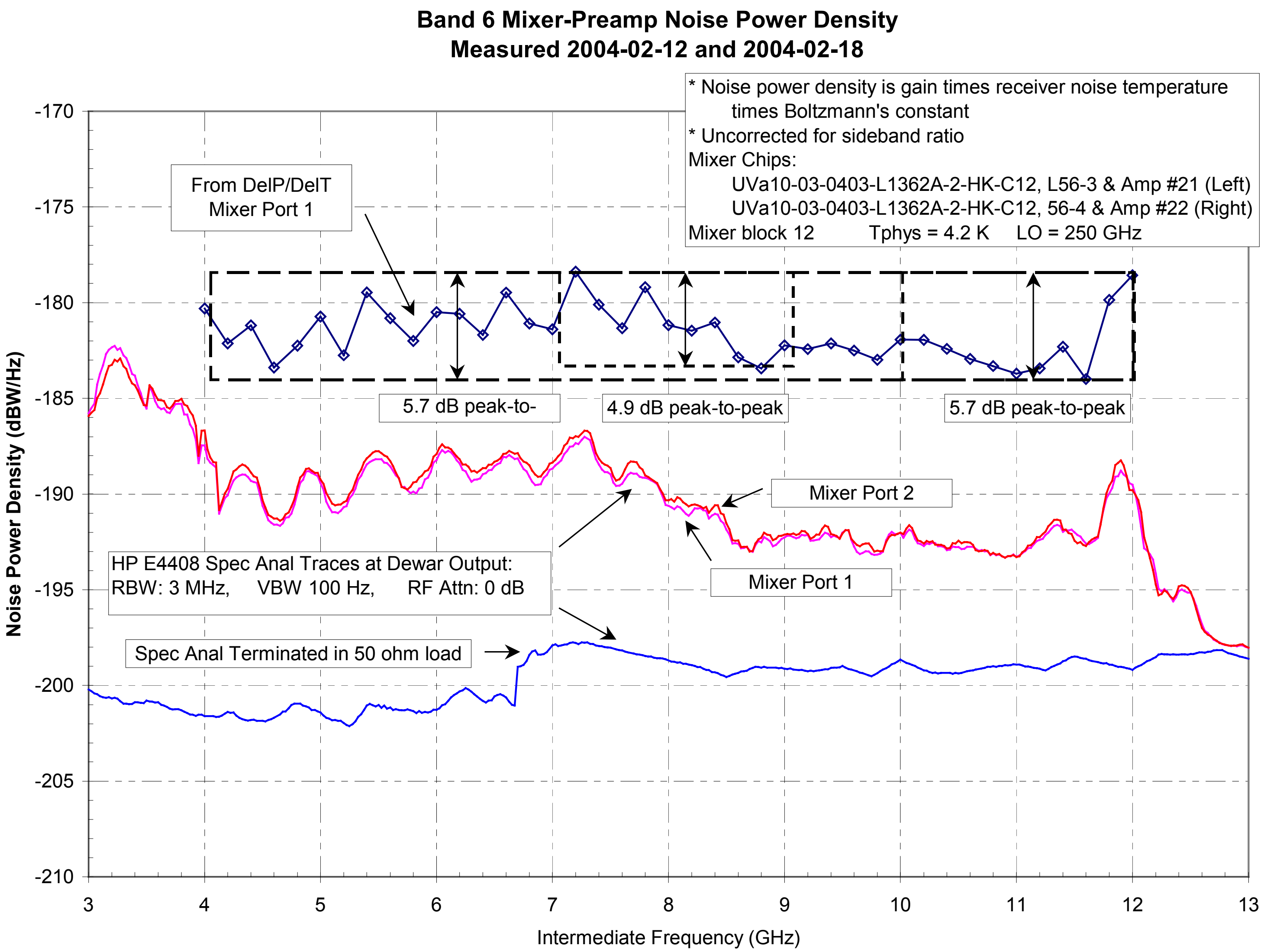


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Figure 3: Noise power density of a Band 6 mixer-preamp