Memorandum

To: File

From: John Effland
Dave Schmitt

Date: 2006-04-28

Revisions:

2006-04-28	jee	Initial
2006-05-01	jee	Minor editorial changes

Subject: Gain Slope Measurements of Band 6 Cartridges 001 and 003

1. Summary

This memo describes gain slope measurements for Band 6 Cartridges 001 and 003. Analysis included below shows passive equalization would reduce total power output below specifications while still exceeding slope specifications by 1 dB.

2. Gain and Gain Slope

Cartridge gain was calculated 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 details are given on ALMA EDM[1].

The Band 6 cartridge specification has two requirements for gain slope:

1) $\leq$ 4 dB peak-to-peak over any 2 GHz IF, and

2) $\leq$ 6 dB peak-to-peak across the entire IF band.

To calculate gain slope over the 2 GHz band, for each LO frequency, absolute values of the maximum and minimum gains over a 2 GHz bandwidth with sliding center frequency are subtracted from each other. The IF band for the Band 6 cartridge formally ranges from 6-10 GHz[2], which is the band where noise temperatures and image rejection specifications are met. For each LO frequency, gain slope for this formal IF band is calculated by subtracting the absolute values of the maximum and minimum gains over this 4 GHz bandwidth. This produces a single gain slope value at each LO frequency.

The bottom curves of the gain slope graphs are plots of cartridge gain for LSB and USB channels for each LO frequency. The graphs include gains spanning 4–12 GHz IF and the bold section of each line corresponds to 6-10 GHz.

[1] "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

[2] Reduced performance is available from 4-12 GHz.

The middle curves are gain slopes calculated over a 2 GHz bandwidth with sliding center frequency. Again, the bold section corresponds to gain slope calculated over the specified 6-10 GHz IF band.

The points shown on the top of the gain slope graphs are gain slopes over the entire, 6-10 GHz IF band.

Cartridge 001 gain and gain slopes are shown in Figure 1 for polarization 0 and Figure 2 for polarization 1. Although only coarse gain measurements are available for Cartridge 003, it is useful to compare gain slopes for that cartridge. Figure 3 shows gain and gain slopes for polarization 0 and Figure 4 shows the results for polarization 1.

3. Total Power

Total power was calculated for each LO frequency using the following equation:

$$P_{tot} = kB \sum_{f=4GHz}^{f=12GHz} [300 + T_{Rx}(f)] G(f)$$

Where: P_{tot} = total noise power (W)
$T_{Rx}(f)$ = receiver noise temperature (K) at the measured IF
$G(f)$ = receiver gain at the measured IF
k = Boltzmann's constant (1.38×10^{-23} W/K-Hz)
B = equivalent noise bandwidth (approx. 100 MHz)
300 = receiver input temperature given in total power specification (K)

Total power for Cartridge 001 is calculated in Figure 5 for polarization 0 and Figure 6 for polarization 1. This calculation was performed for both the 6-10 GHz spec band and the extended 4-12 GHz band.

4. Analysis Assuming Passive Equalization

Passive equalizers can correct excessive gain slope, and slope compensation can also be included in the warm IF amplifiers. Figure 7 and Figure 8 show gain slope across the entire IF band averaged over all LO frequencies with the specified 6-10 GHz band shown again in bold. The gain slope for 4-12 GHz averaged over both sidebands and polarizations is about 1.7 dB / GHz.

If an equalizer is specified with the following parameters:

Minimum insertion loss = 1 dB
Maximum loss (at 4 GHz) = 13 dB,
Minimum loss (at 12 GHz) = 0 dB,

the curves in Figure 9 and Figure 10 show how the slope is corrected. Note that the minimum insertion loss is added to the min/max loss to obtain the net loss of the equalizer. That is, the net insertion loss for the equalizer at 12 GHz is 1 dB and 14 dB at 4 GHz. The resulting gain slope in a 2 GHz bandwidth with sliding center frequency would be approximately 4 dB for polarization 0 but 5 dB for polarization 1, which still exceeds the 4 dB specification.

Such a passive equalizer would also result in total power falling far below specifications, as shown in Figure 11 and Figure 12. This data were calculated using the same technique as Figure 5 and Figure 6 but the gain is modified by the equalizer loss.

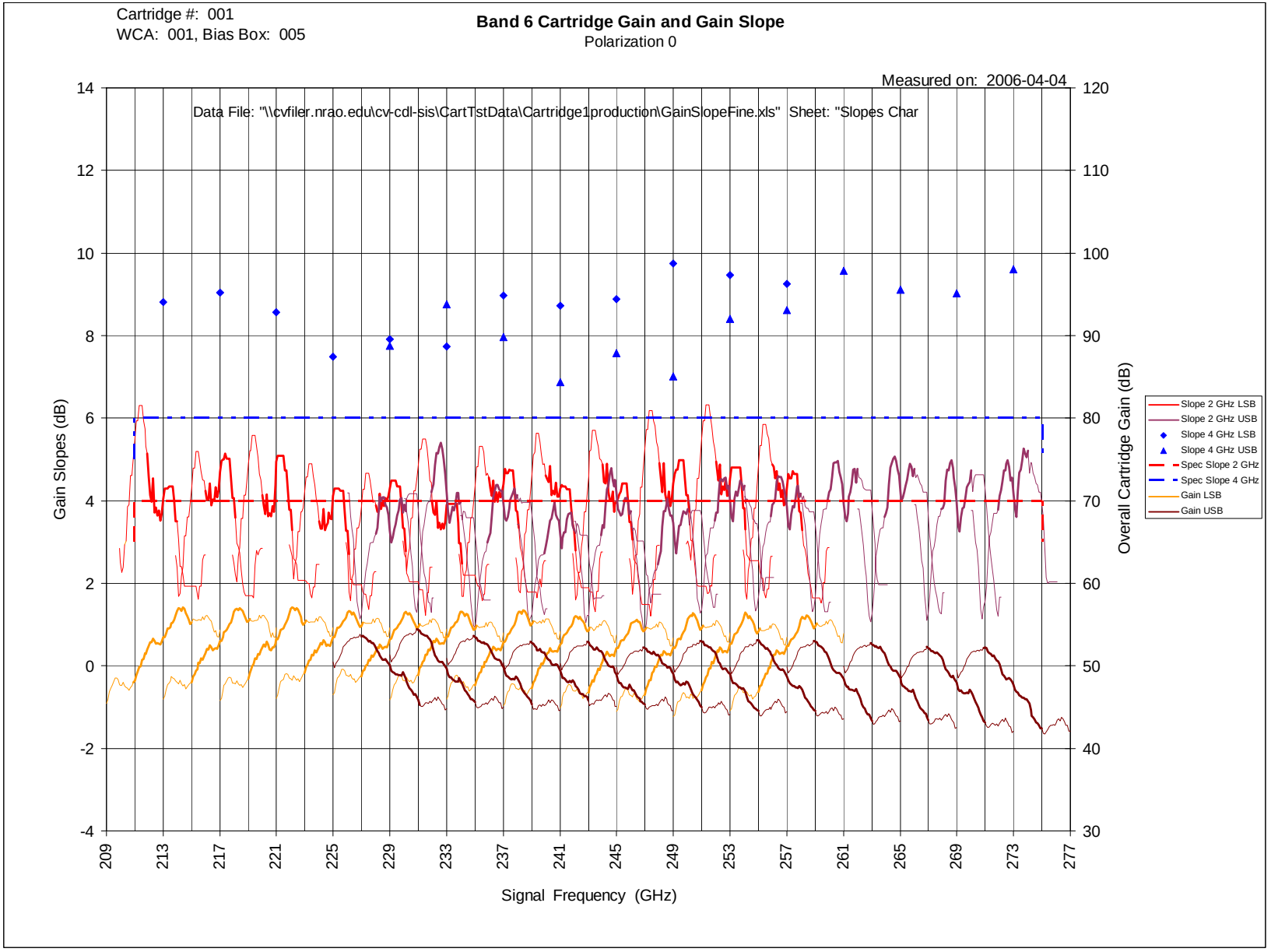

Figure 1: Gain Slope, Cartridge 001, Polarization 0 (Dark curves are spec bandwidth)

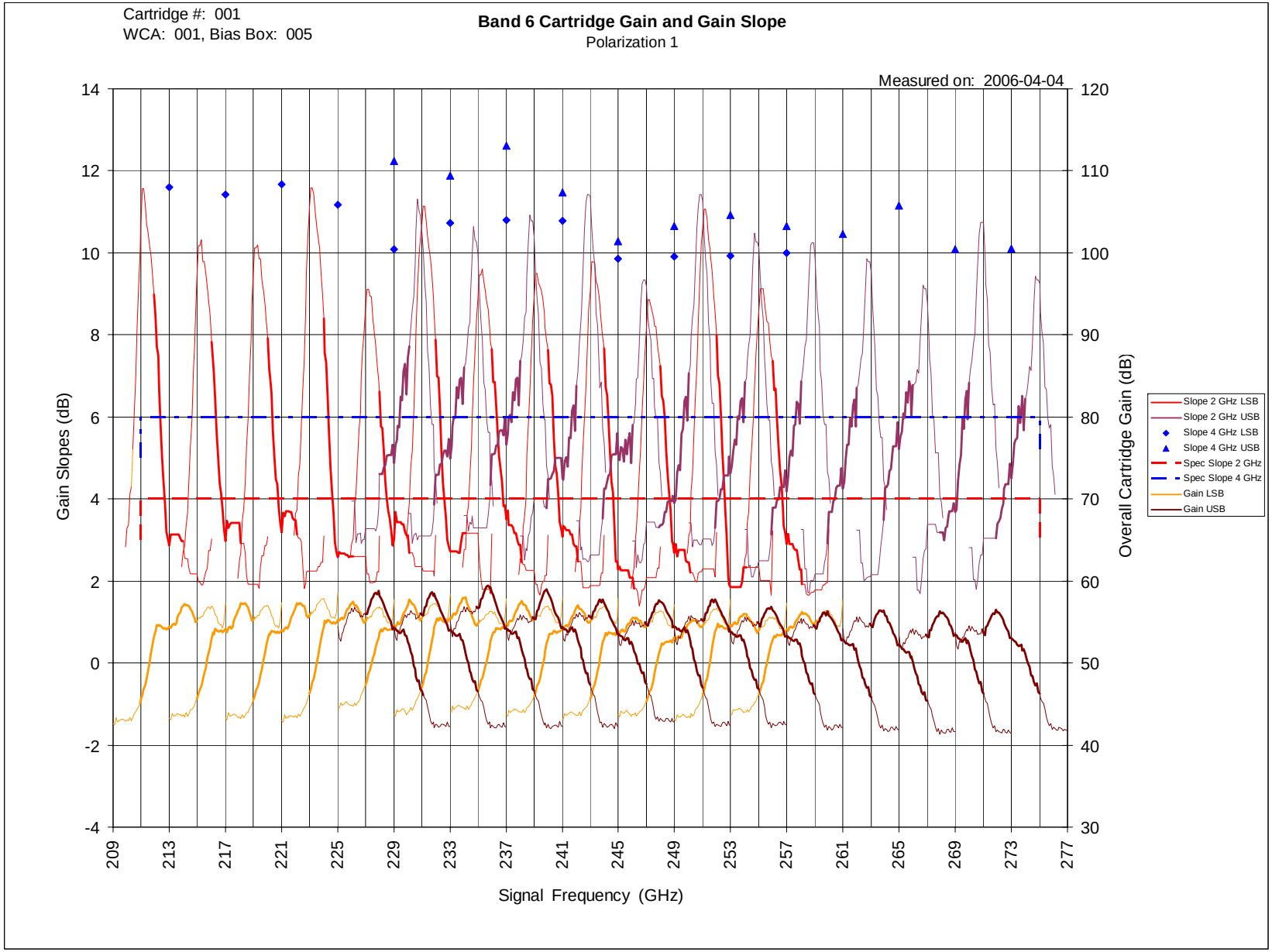

Figure 2: Gain Slope, Cartridge 001, Polarization 1 (Dark curves are spec bandwidth)

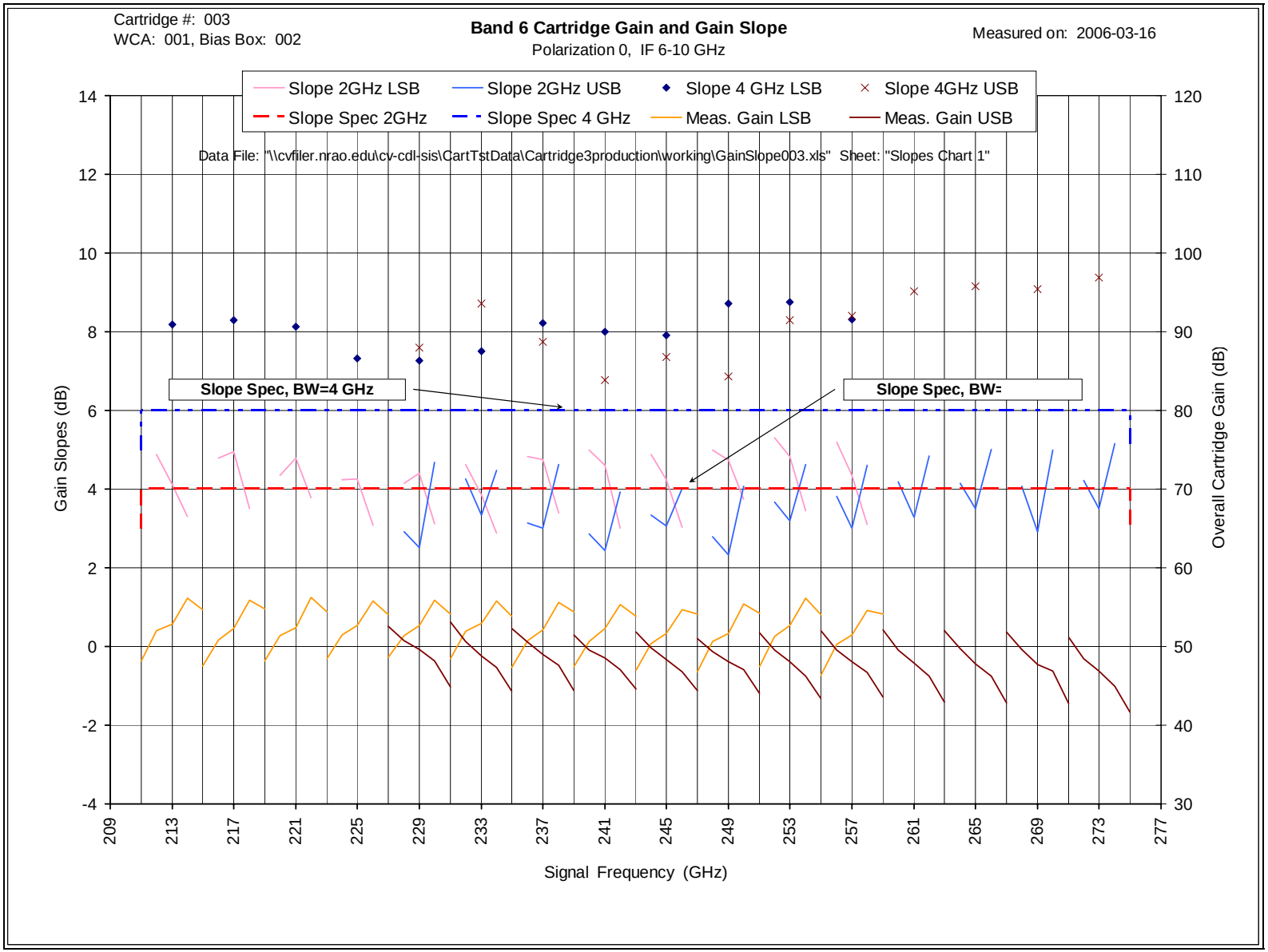

Figure 3: Gain Slope, Cartridge 003, Polarization 0

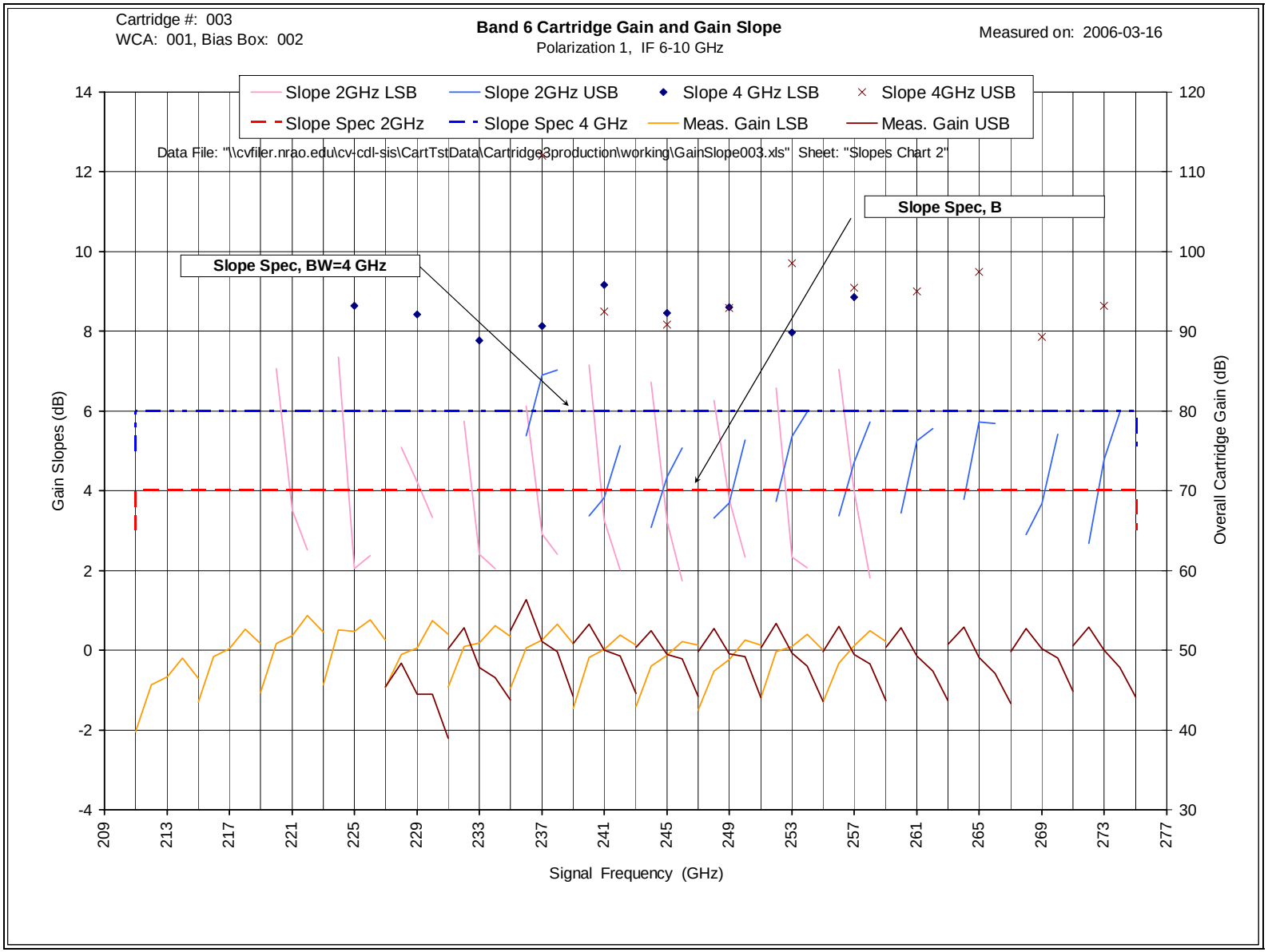

Figure 4: Gain Slope, Cartridge 003, Polarization 1

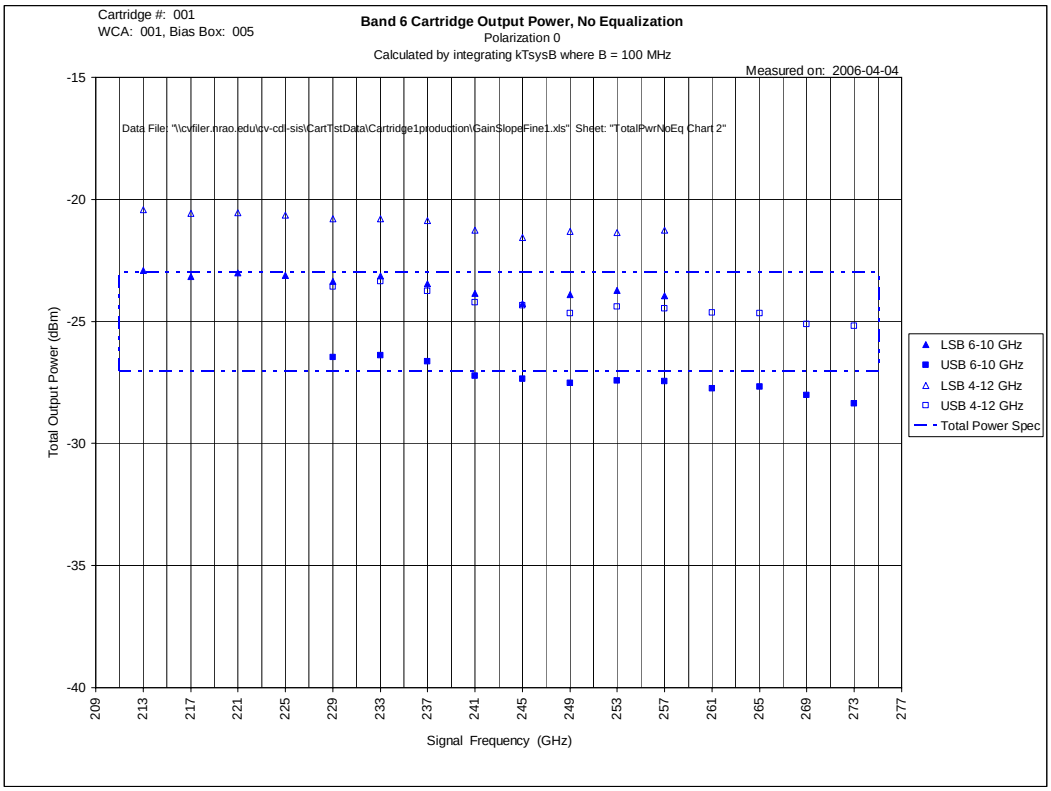

Figure 5: Total Power Calculation, Cartridge 001, Pol 0

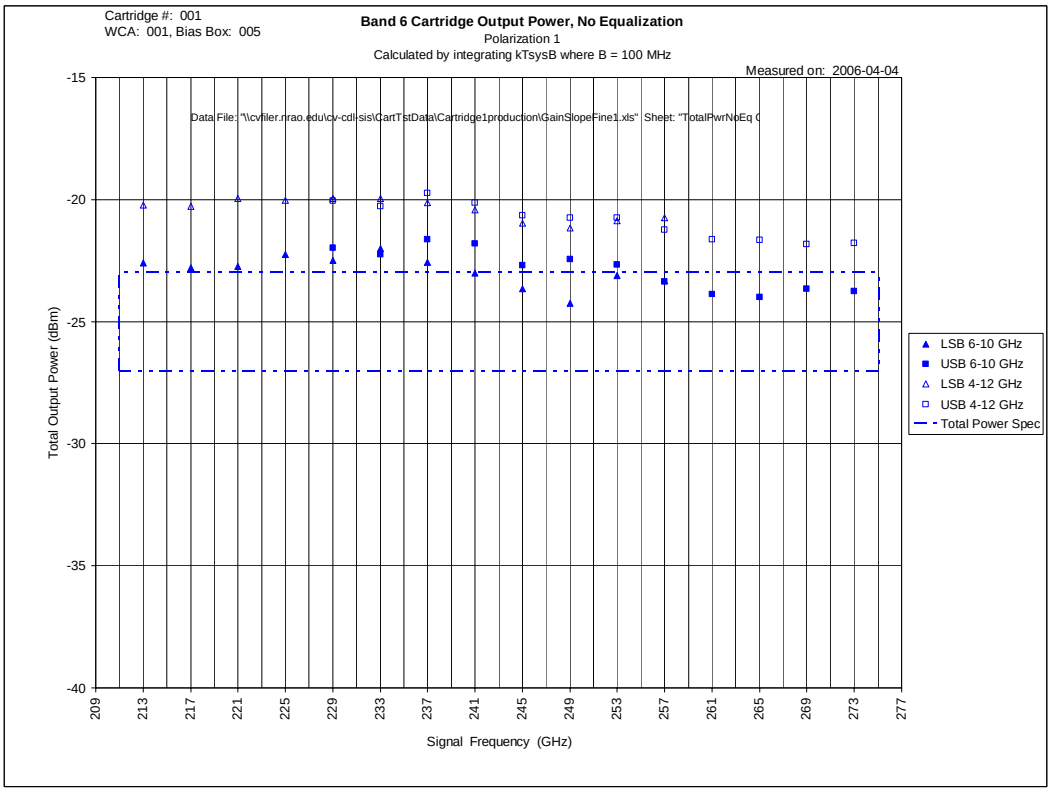

Figure 6: Total Power Calculation, Cartridge 001, Pol 1

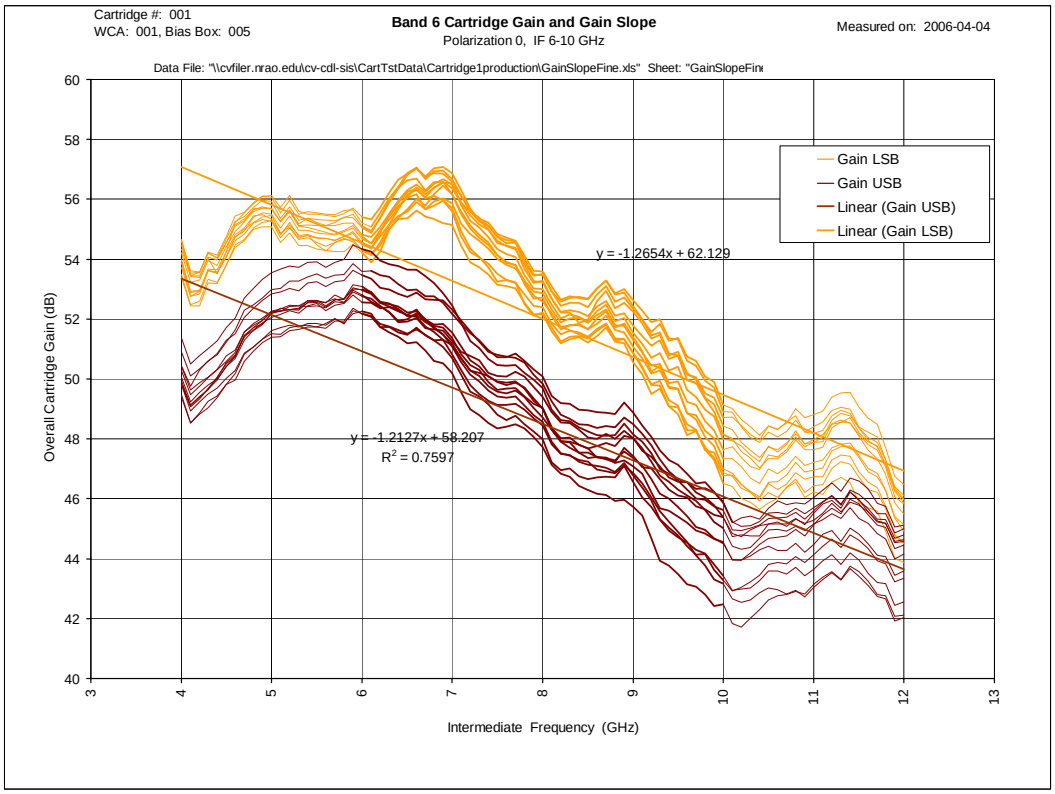

Figure 7: Gain vs. IF, Cartridge 001, Polarization 0

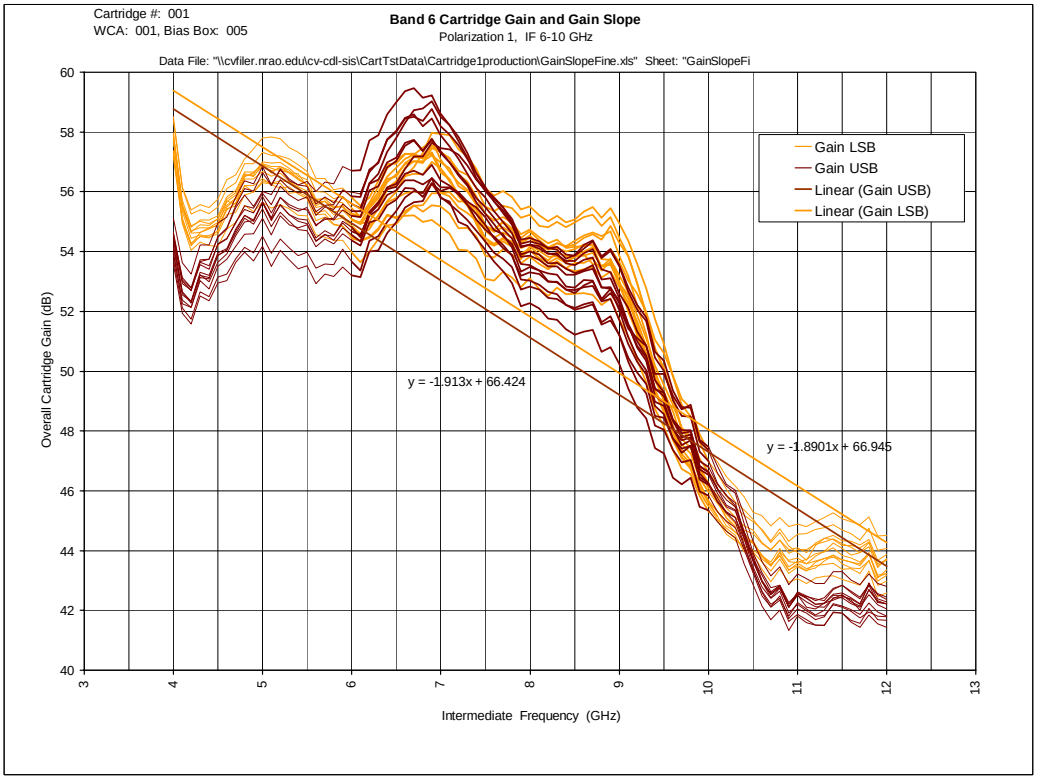

Figure 8: Gain vs. IF, Cartridge 001 Polarization 1

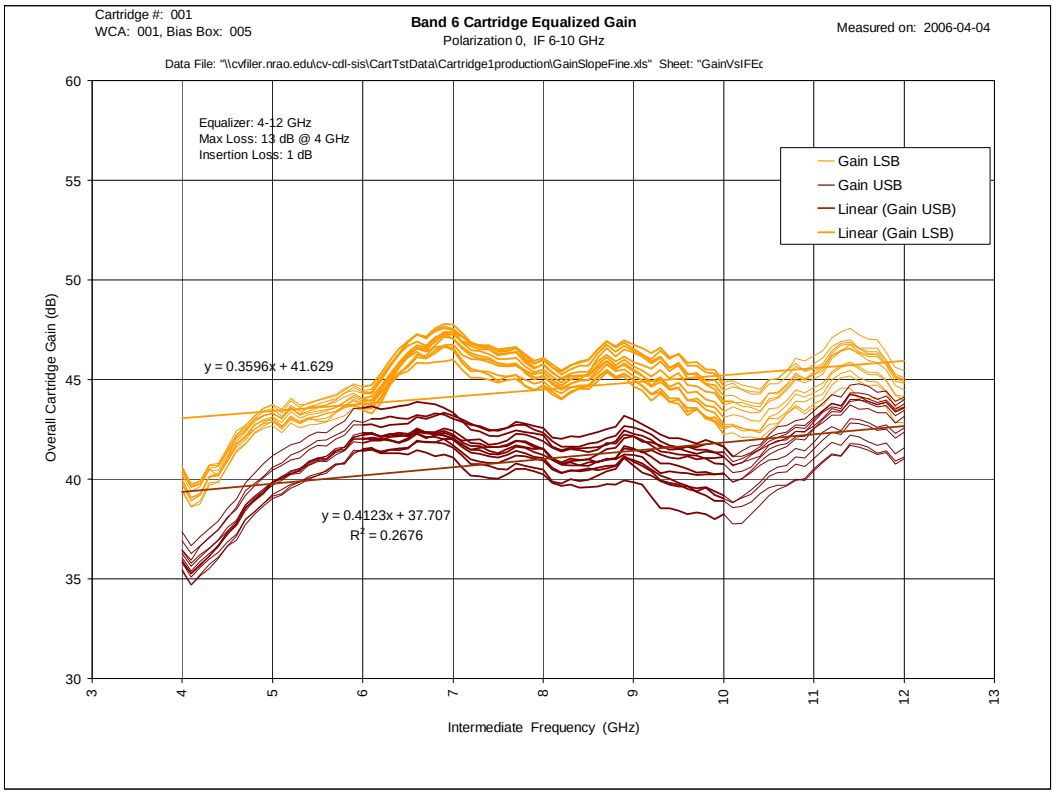

Figure 9: Gain Slope with Equalizer, Cartridge 001, Pol 0

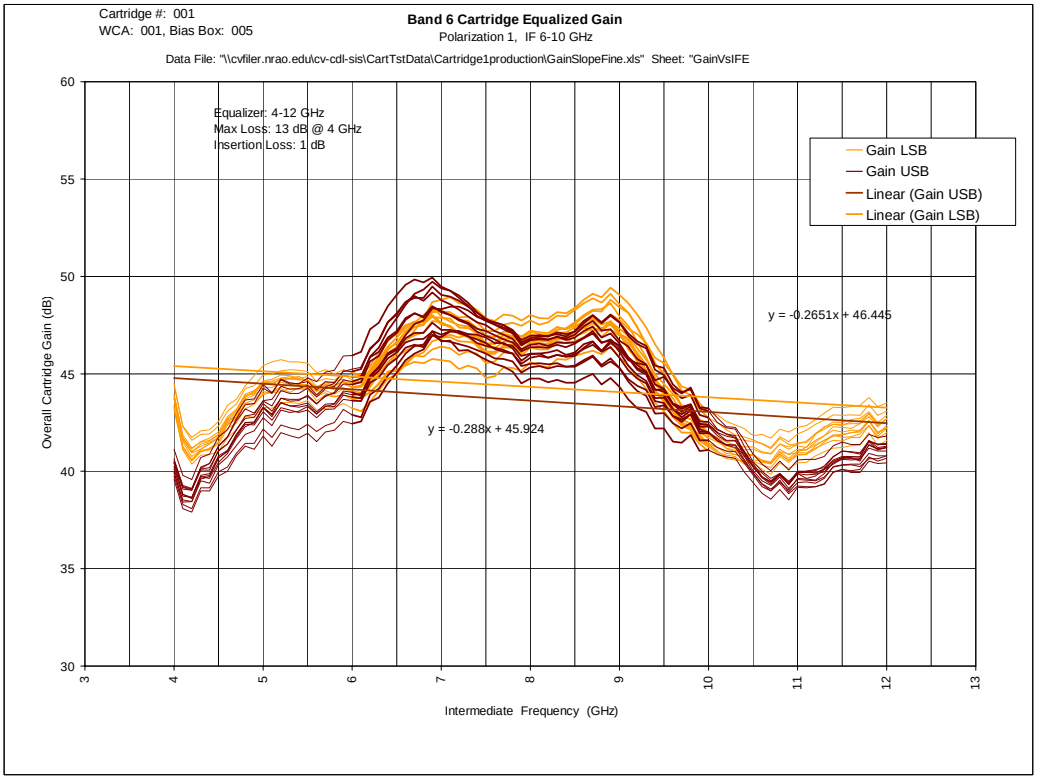

Figure 10: Gain Slope with Equalizer, Cartridge 001, Pol 1

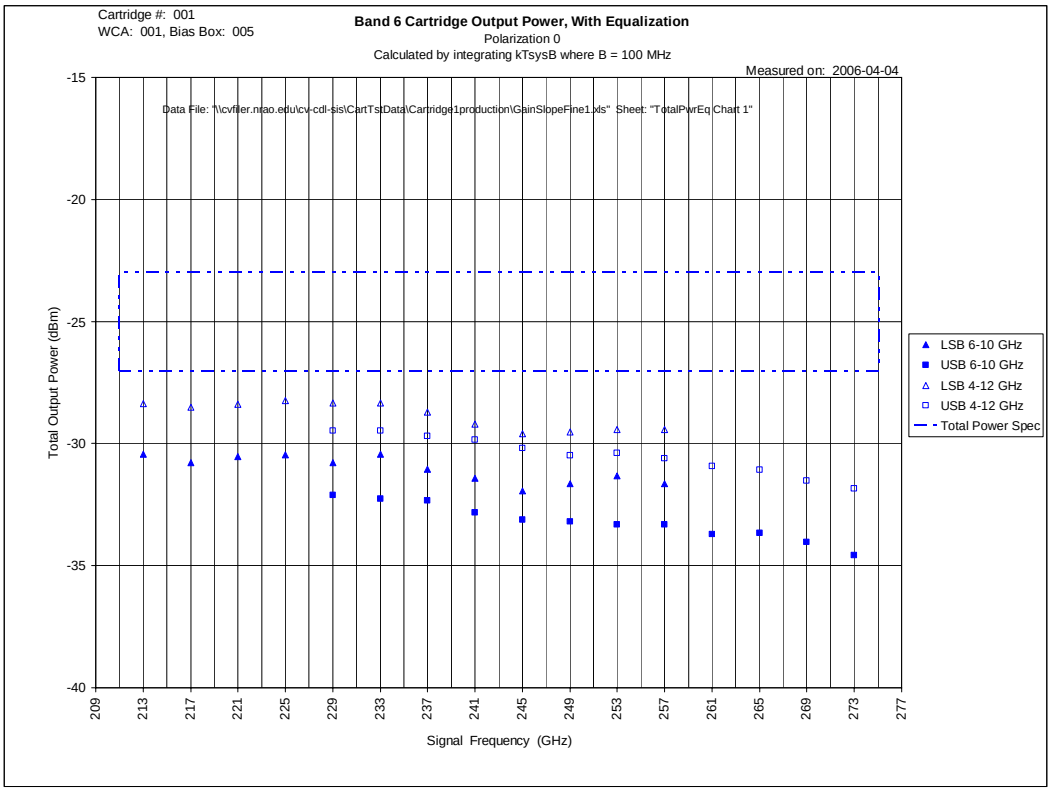

Figure 11:Total Power Calculation, Cartridge 001 with equalizer, Pol 0

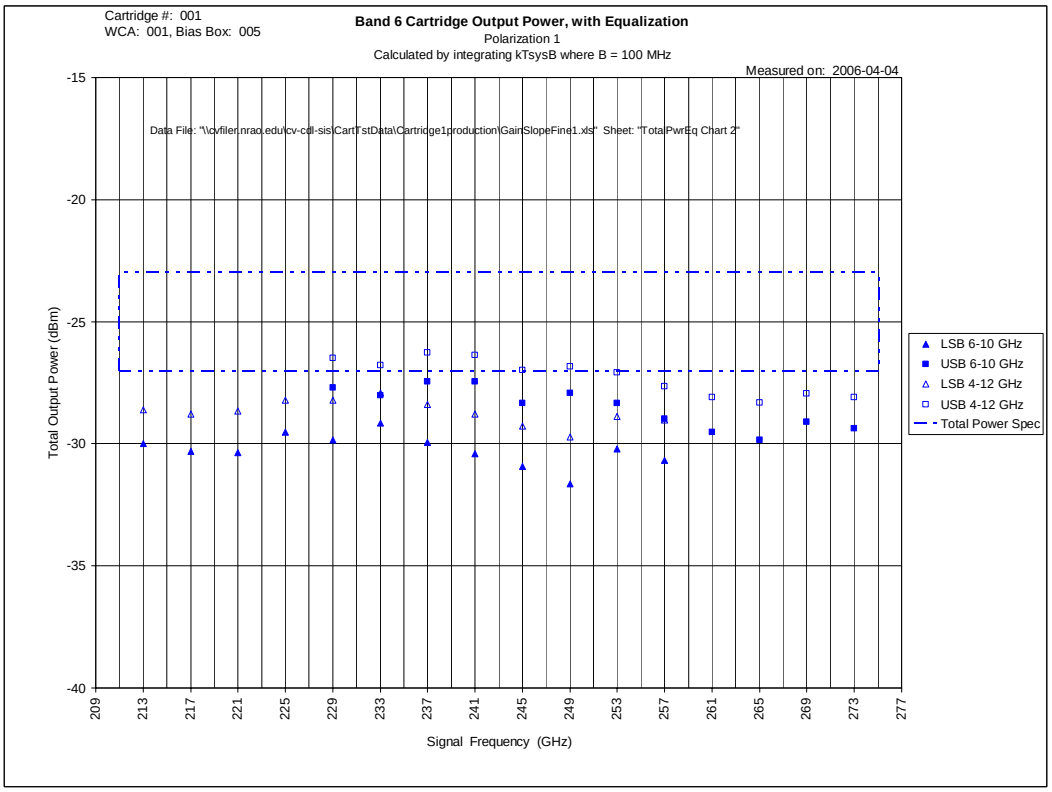

Figure 12: Total Power Calculation, Cartridge 001 with equalizer, Pol 1