Memorandum

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Revisions:

2002-11-26	jee	Initial Draft
2003-02-27	jee	Draft updated with data from mixer-preamp UVA10-01-L-1343C-1202-2-HI-C14-L59-3-375C-104-M375P.05

Subject: Saturation Measurements of Single-Ended SIS Mixer/Preamp for ALMA Band 6

Introduction

Saturation of ALMA receivers must be carefully characterized to achieve the array's stringent overall absolute flux accuracy goal of 1%[1]. A saturation level of 0.5% was measured using an ALMA Band 6 single-ended SIS mixer with integrated preamp[2], which is in close agreement with theoretical values calculated by A.R. Kerr[3]. This memo provides equipment setups, procedures, and measured data.

History

A.R. Kerr's ALMA Memo 401 includes procedures for determining the saturation from noise of SIS mixers by measuring the change in level of an injected signal while hot and cold loads are alternately placed in the path of the receiver's input beam. That procedure was used at the NRAO's CDL to measure the saturation of an ALMA Band 6 single-ended SIS mixer with integrated preamp as documented in this memo.

Equipment Setup

The equipment configuration for measuring mixer-preamp saturation is shown in Figure 1 for mixer-preamp UVaV-L568A-2-F6-2-B3-371C-01 + IF4-12P.04. Another mixer-preamp, UVA10-01-L-1343C-1202-2-HI-C14-L59-3-375C-104-M375P.05 was measured using the almost identical setup shown in Figure 2 except that the YIG filter was not present in the prototype ALMA LO system. The prototype ALMA LO system[4] provided the local oscillator for the mixer and the injected signal was generated from a Gunn oscillator that was stabilized in frequency using a XL 800A Gunn Lock system. Locking the Gunn oscillator reduced amplitude variations in the injected signal that arise from frequency changes.

Total power was band limited with a 10.24 GHz band pass filter exhibiting a 3-dB bandwidth of 240 MHz and measured with an Agilent EPM 441 power meter and an HP 8484A power head. The signal and LO frequencies were adjusted so that the signal fell inside the passband of the 10.24 GHz bandpass filter. The control software calculated a running average of power measurements and the mean was stored in spreadsheet cells after the standard error decreased to less than 10^{-8}.

Saturation is calculated from the ratio of two power measurements: First, signal-plus-noise power is measured when the receiver's beam is directed to a hot load, and then signal-plus-noise power is measured again when the receiver's beam is directed to a cold load. Noise powers when no signal is present are also measured for each case and subtracted from the respective signal-plus-noise powers.

To measure the saturation of the two IF amplifiers located after the mixer/preamp, the test signal was injected after the mixer/preamp into Port 4 shown in the block diagrams. The 6-way IF switch allowed the signal from Port 4 and the noise from the mixer/preamp to be injected simultaneously into the latter IF stages. Impedance mismatch effects from these two 50 ohm lines in shunt were ignored. The saturation of the post-mixer/preamp stages, measured over a period of time, averages 0.25% as shown in Figure 3.

$$Sat_{\%} = 100 \times \left(\frac{P_{sig,hot} - P_{hot}}{P_{sig,cold} - P_{cold}} \right) - Sat_{PostMxr}$$

where

$Sat_{\%}$	is the saturation level in percent,
$P_{sig,hot}$	is the signal power measured at the filter output when a hot load is inserted in the path of the receiver beam,
$P_{sig,cold}$	is the signal power measured at the filter output when a cold load is inserted in the path of the receiver beam,
P_{hot}	is the noise power measured at the filter output with the signal off when a hot load is inserted in the path of the receiver beam,
P_{cold}	is the noise power measured at the filter output with the signal off when a cold load is inserted in the path of the receiver beam,
$Sat_{PostMxr}$	is the saturation level for the amplifiers that following the mixer/preamp.

To determine the stability of the measurement, total noise power was recorded and the saturation was calculated and plotted as a function of time. Figure 4 shows uncorrected saturation measurements for a particular LO frequency and injected signal frequency. In Figure 4, the sinusoidal variation was of interest, so no corrections were made for post mixer/preamp saturation levels or for noise powers when the signal was turned off.

Figure 4 shows that the saturation varies sinusoidally at a nearly-constant 5.5-minute period and that the phase of the sinusoid changes when the cold load is filled. Several weeks were spent attempting to determine the source of the sinusoidal changes and included investigating:

a) changes in either hot- or cold-load physical temperatures,
b) time-varying changes in the saturation of amplifiers following the mixer/preamp,
c) changes in LO or injected signal power levels, and
d) interfering signals leaking into the system.

LO power levels were monitored by using an HP W8486A power head to measure and record the level of the 100-GHz signal on the automated LO plate. An independent check of LO level was made by monitoring SIS mixer current. Finally, the temperature of the hot load was also recorded. All three of these parameters are plotted on the accompanying figures.

The angle of the mirror that reflects the receiver beam into the cold load was changed and more data were recorded and plotted in Figure 5. Changing the mirror angle moves the region of the cold load illuminated by the beam and also changes the electrical length from the cold load to the receiver. The significant difference between the saturation measured in Figure 4 and that of Figure 5 is that the period of the sinusoid now changed each time the cold load was filled. Based on these observed changes, it was concluded that the periodicity in saturation results from an interaction between the mixer and the liquid nitrogen cold load. To eliminate this effect, all saturation data was calculated from the long-term mean of the measured sinusoidally-varying data.

A basic premise of this measurement technique is that the injected signal power is sufficiently low that it doesn't affect the saturation point of the receiver. To confirm this, the level of the injected signal was increased by 10 dB and, as shown in Figure 6, no changes to the measured saturation were observed.

Figure 7 is a saturation measurement with the LO frequency changed to 280 GHz and shows essentially the same saturation level as the 253 GHz data.

Measurement of mixer-preamp UVA10-01-L-1343C-1202-2-HI-C14-L59-3-375C-104-M375P.05

Figure 8 shows saturation results measured using mixer-preamp preamp UVA10-01-L-1343C-1202-2-HI-C14-L59-3-375C-104-M375P.05. The saturation averages about 2.4% (including the saturation contribution from the latter stages) compared to about 0.75% for mixer-preamp UVaV-L568A-2-F6-2-B3-371C-01 + IF4-12P.04. Figure 9 shows the saturation of the amplifier stages following the mixer-preamp. This was measured two ways: First, the setup was kept identical to the configuration used to measure the mixer-preamp saturation as presented in Figure 9. To determine if the final amplifier was contributing to this latter-stage saturation, a 7-dB attenuator was inserted at the input to this amplifier and the pin-diode attenuator was adjusted to maintain the same nominally -22 dBm power level at the power head. Both measurements show the same results,

Results

Figure 10 summarizes the results for mixer-preamp UVaV-L568A-2-F6-2-B3-371C-01 + IF4-12P.04 for several LO frequencies.

Acknowledgments

The authors wish to acknowledge and thank our colleagues A.R. Kerr, John Webber, S.-K. Pan, and W. K. Crady for their assistance in these measurements.

[1] Holdaway, Wootten, Payne, Vaccari *et al*., "Calibration", Chapter 3 of ALMA Project Book, Rev 2001-02-06, Available at http://www.alma.nrao.edu/projectbk/construction/

[2] E. F. Lauria, A. R. Kerr, M. W. Pospieszalski, S.-K. Pan, J. E. Effland, and A. W. Lichtenberger, "A 200-300 GHz SIS Mixer-Preamplifier with 8 GHz IF Bandwidth," 2001 IEEE International Microwave Symposium Digest, pp. 1645-1648, 2001-05. Available as ALMA Memo 378 at http://www.alma.nrao.edu/memos/.

[3] A.R. Kerr, "Saturation by Noise and CW Signals in SIS Mixers," ALMA Memo 401, 2001-12-15, Available at http://www.alma.nrao.edu/memos/

[4] E. W. Bryerton, S. K. Pan, D. Thacker, and K. Saini, "Band 6 Receiver Noise Measurements Using a Pre-Prototype YIG-Tunable LO, ALMA Memo 436, 2002-09-02, Available at http://www.alma.nrao.edu/memos/

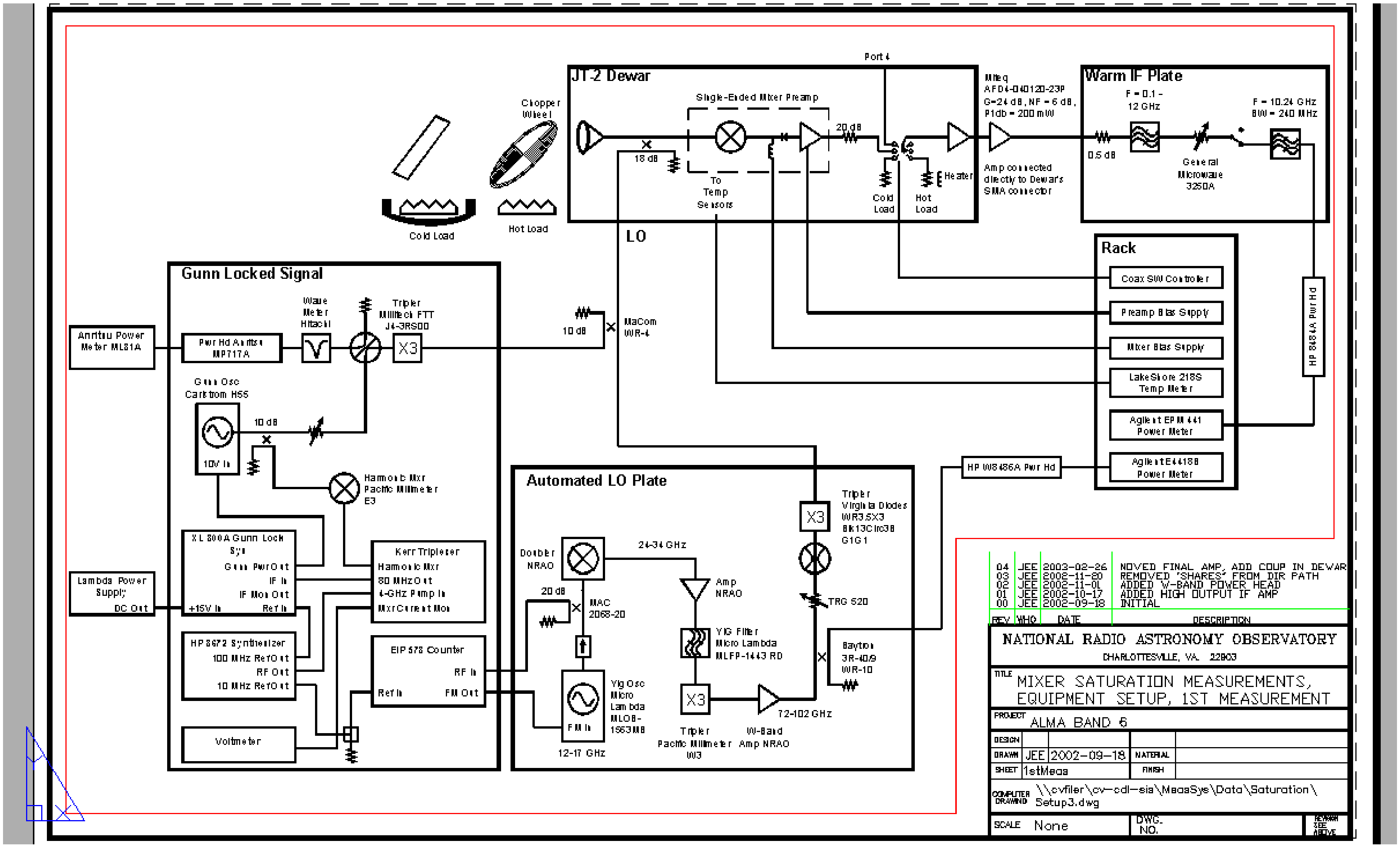

Figure 1: Mixer Saturation Measurement Setup for Mixer-Preamp UVaV-L568A-2-F6-2-B3-371C-01 + IF4-12P.04

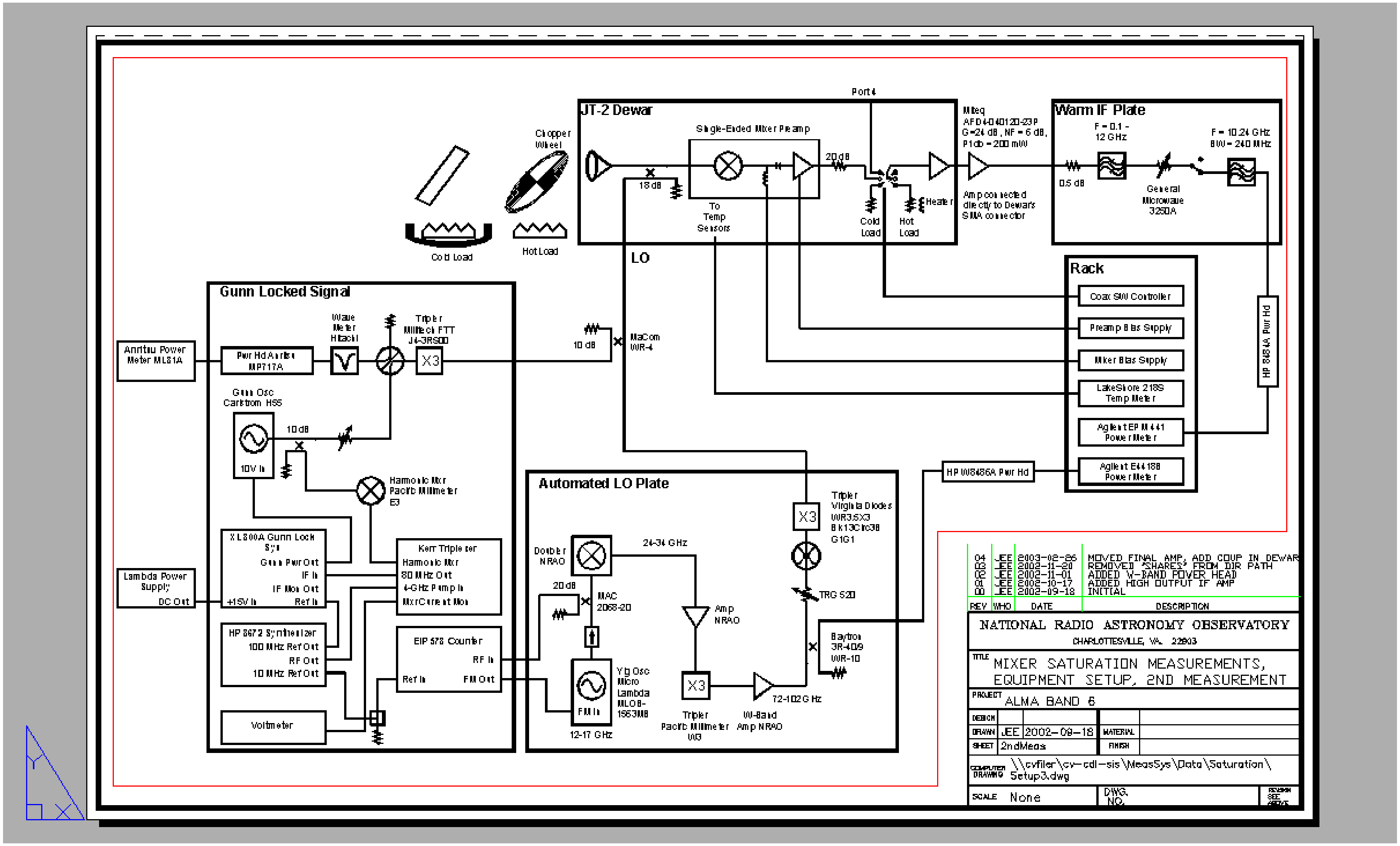

Figure 2: Mixer Saturation Measurement Setup for Mixer-Preamp UVA10-01-L-1343C-1202-2-HI-C14-L59-3-375C-104-M375P.05

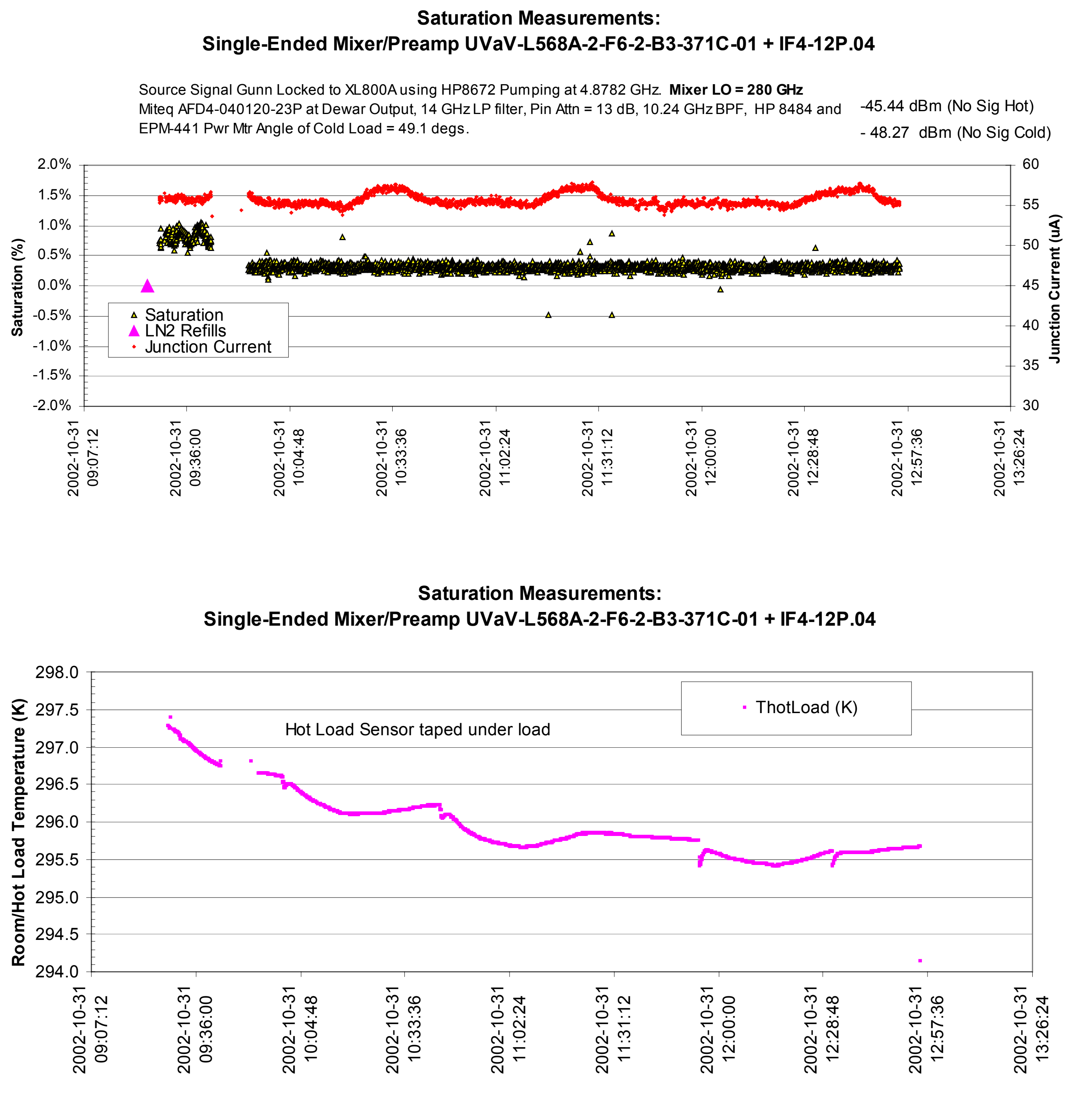

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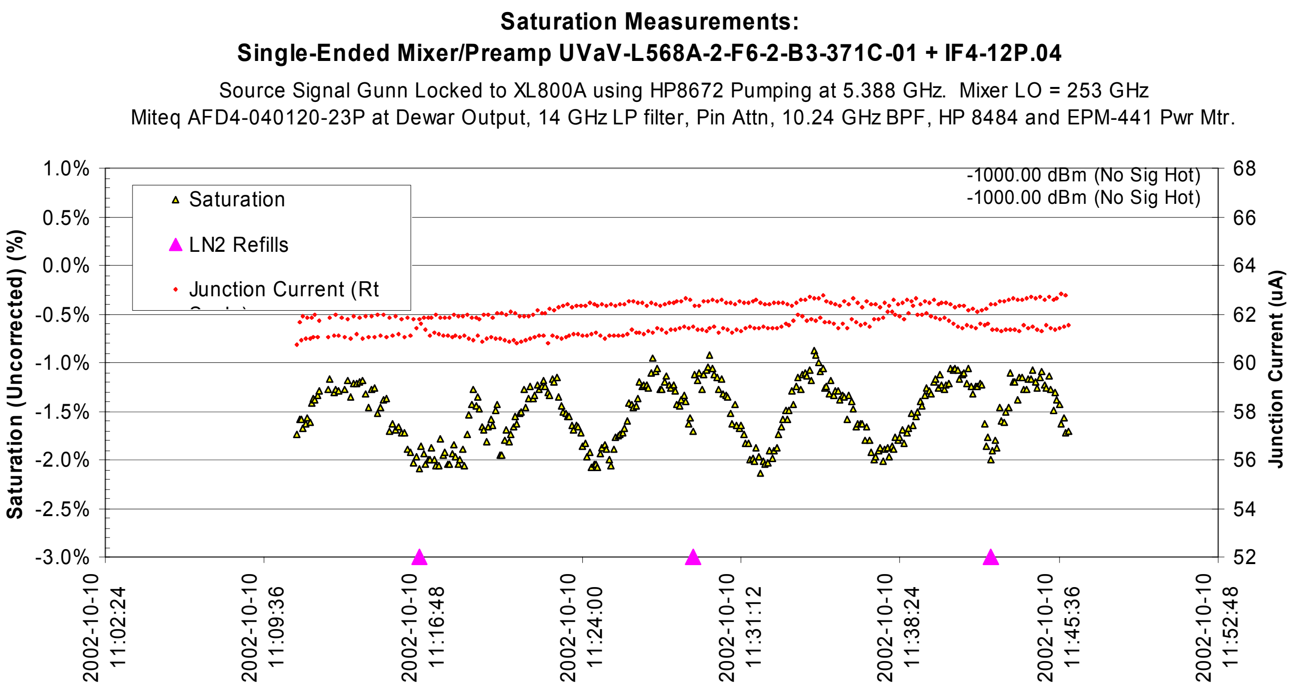
Figure 3: Saturation of latter stages obtained by injecting signal after mixer/preamp into "Port 4" shown Figure 1. The latter stages contribute about 0.5% to the saturation.



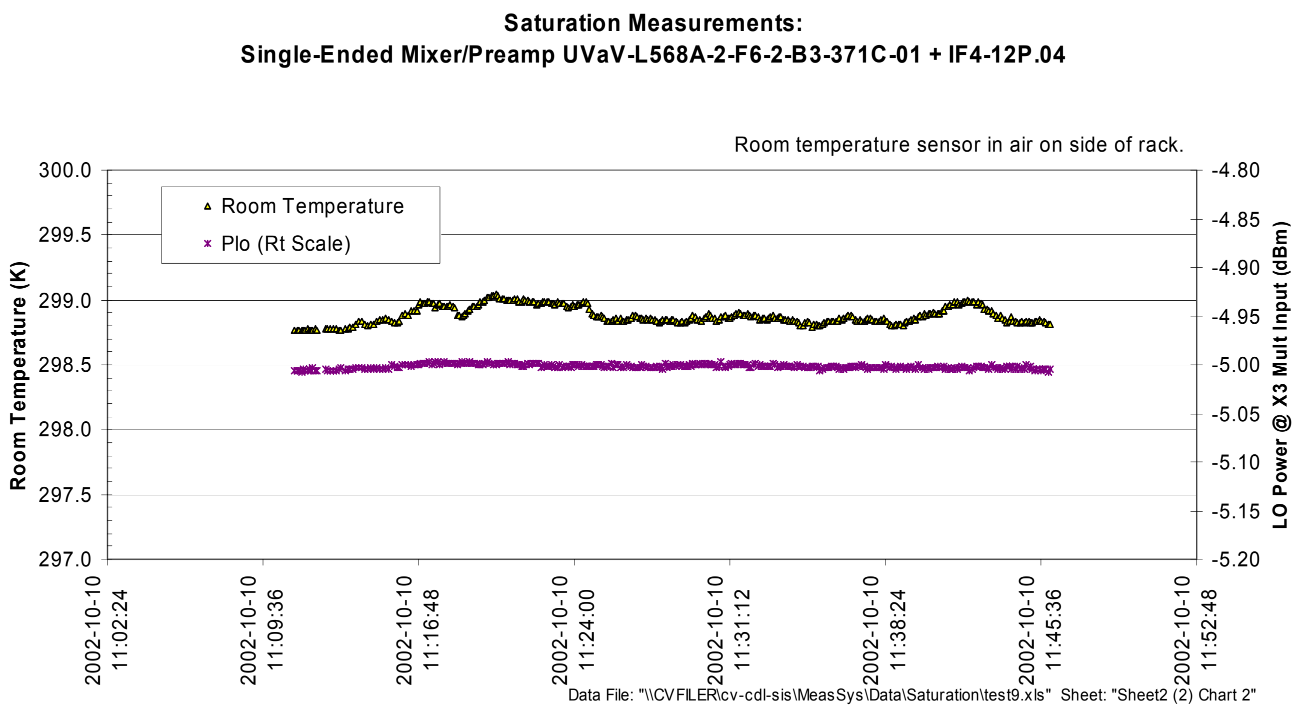
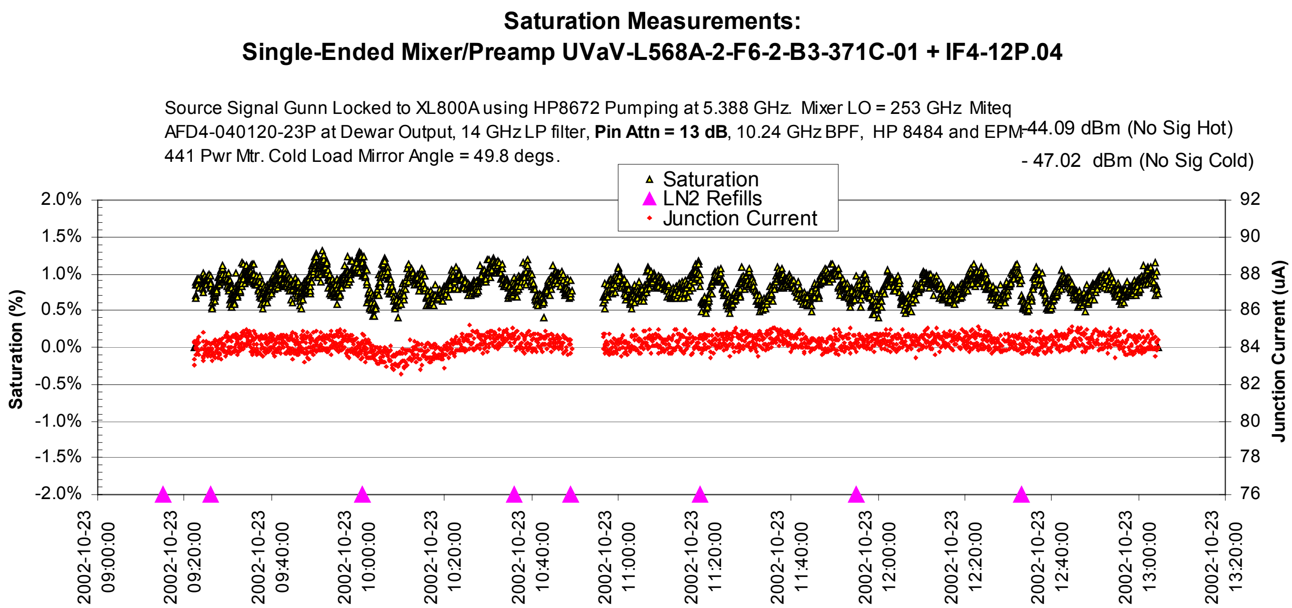
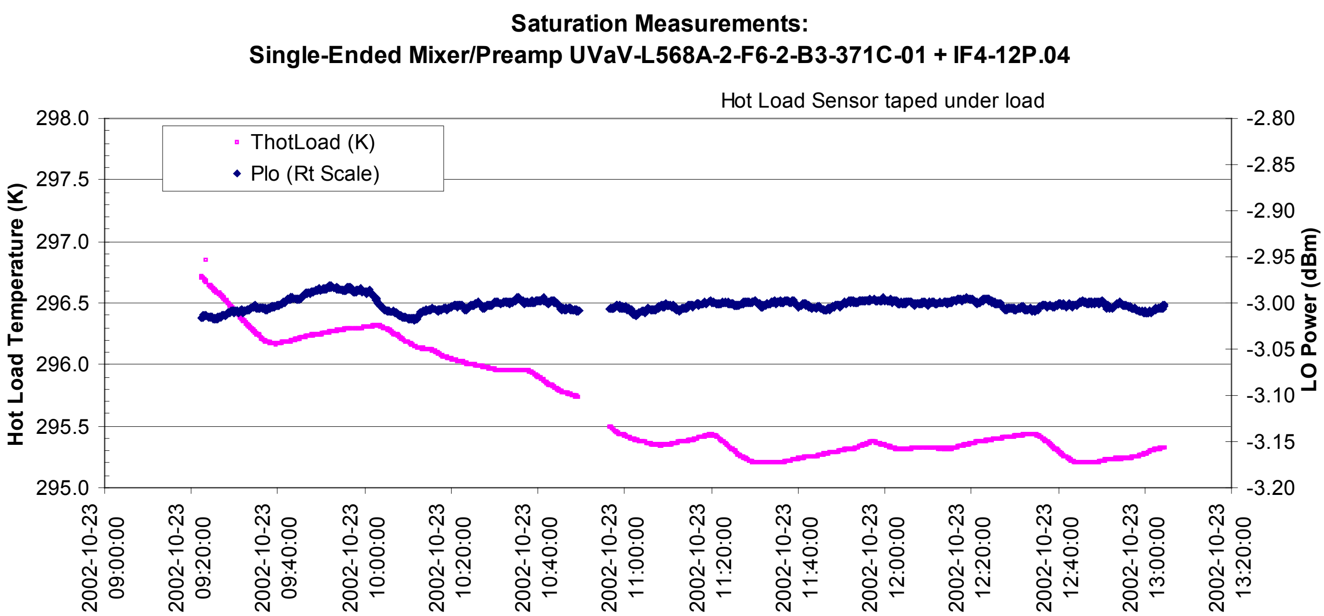


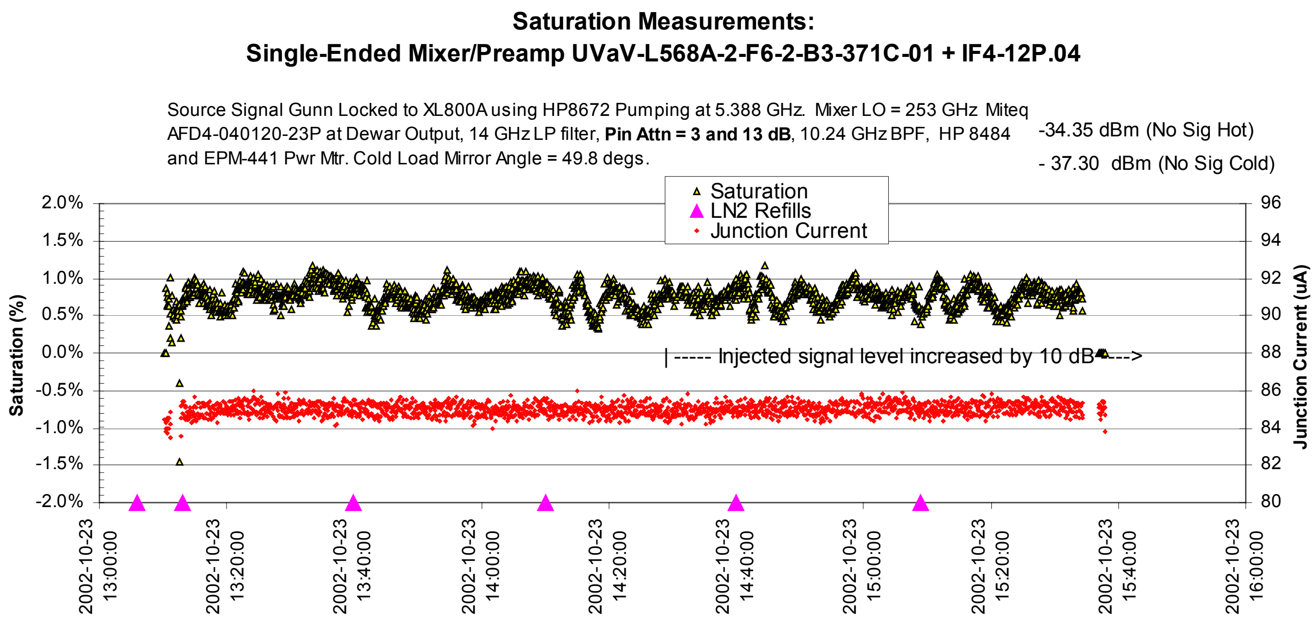
Figure 4: Phase change of ripple in saturation data when cold load is refilled. Cold load mirror angle at 30°.

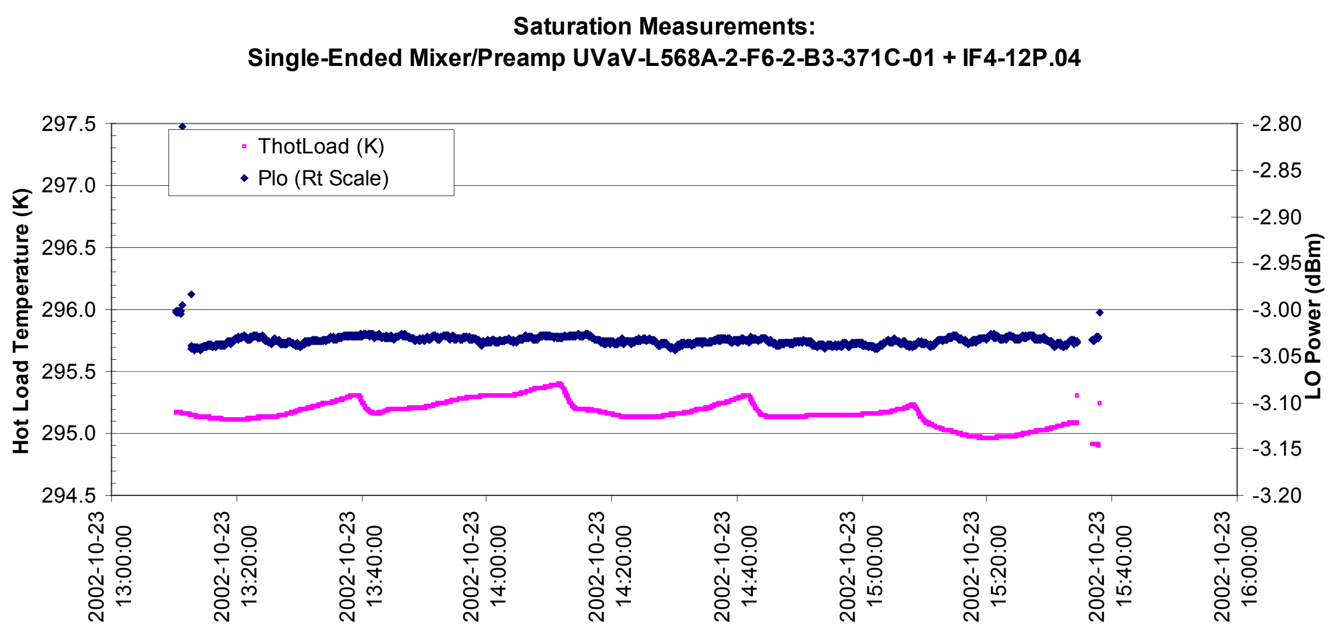




Data File: "\\cvfiler\shares\cv-cdl-sis\MeasSys\Data\Saturation\test20.xls" Sheet: "Sheet1 Chart 2"

Figure 5: Frequency change of ripple in saturation data when cold load is refilled. Cold load mirror angle at 44°.





Data File: "\\cvfiler\shares\cv-cdl-sis\MeasSys\Data\Saturation\test21.xls" Sheet: "Sheet1 Chart 2"

Figure 6: No change in saturation level with 10-dB increase in injected signal

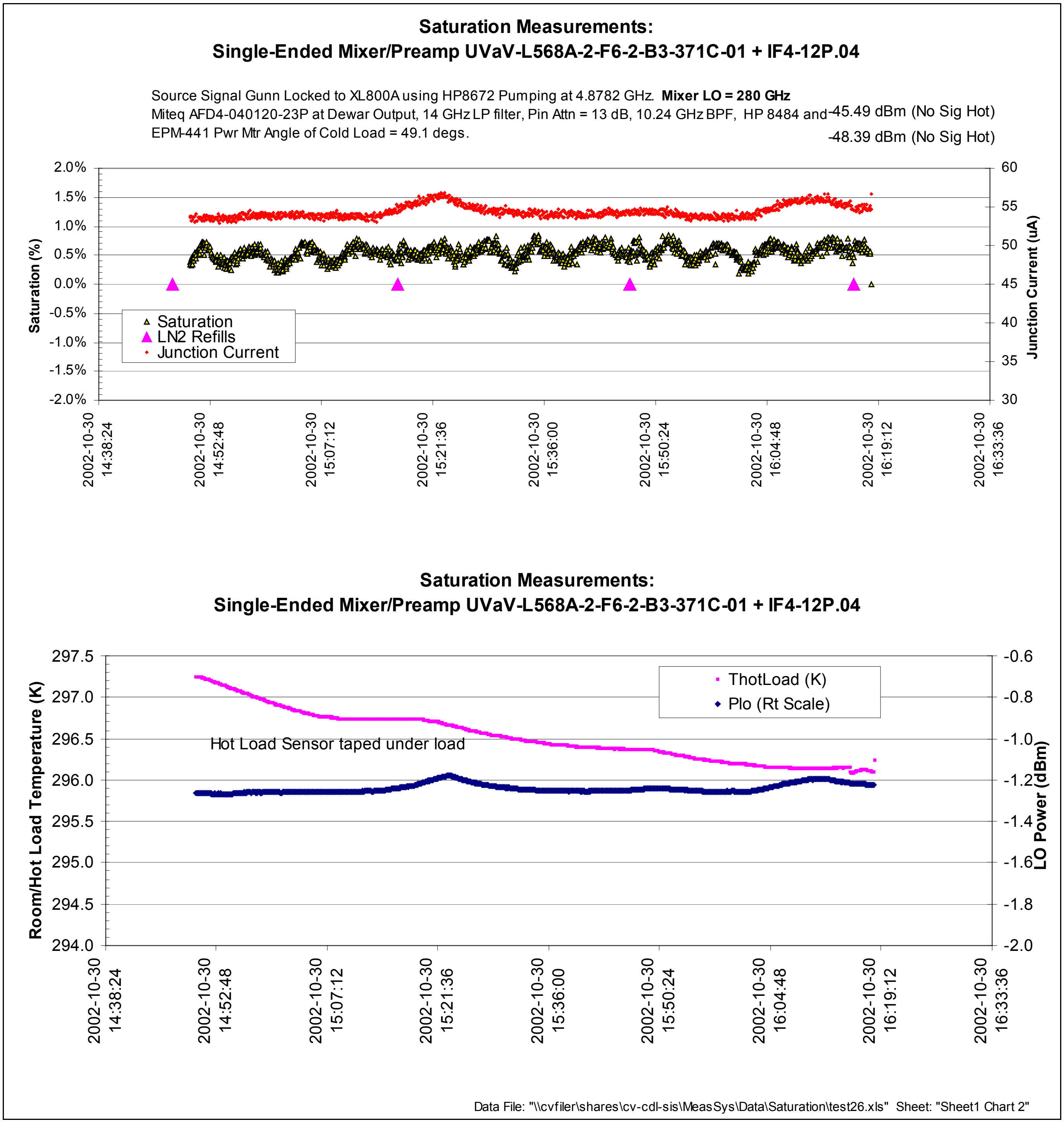
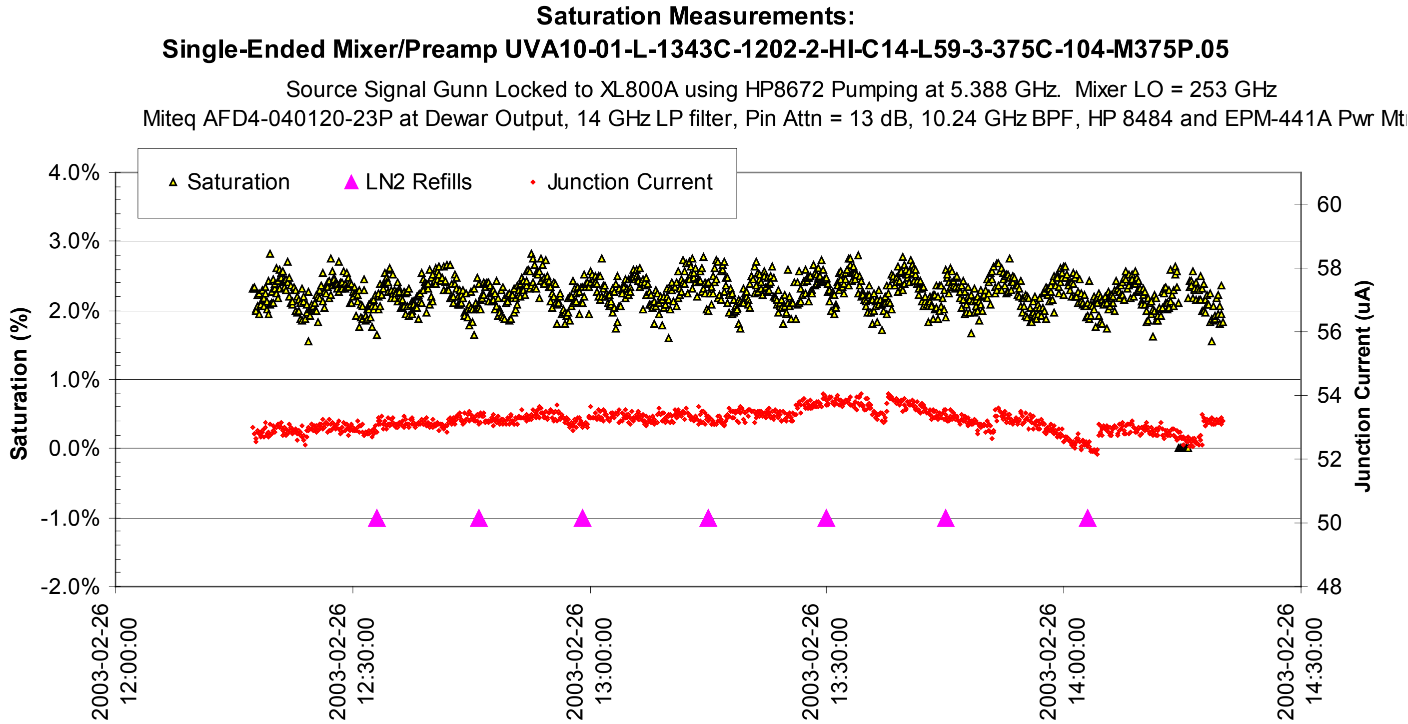


Figure 7: Saturation with LO = 280 GHz



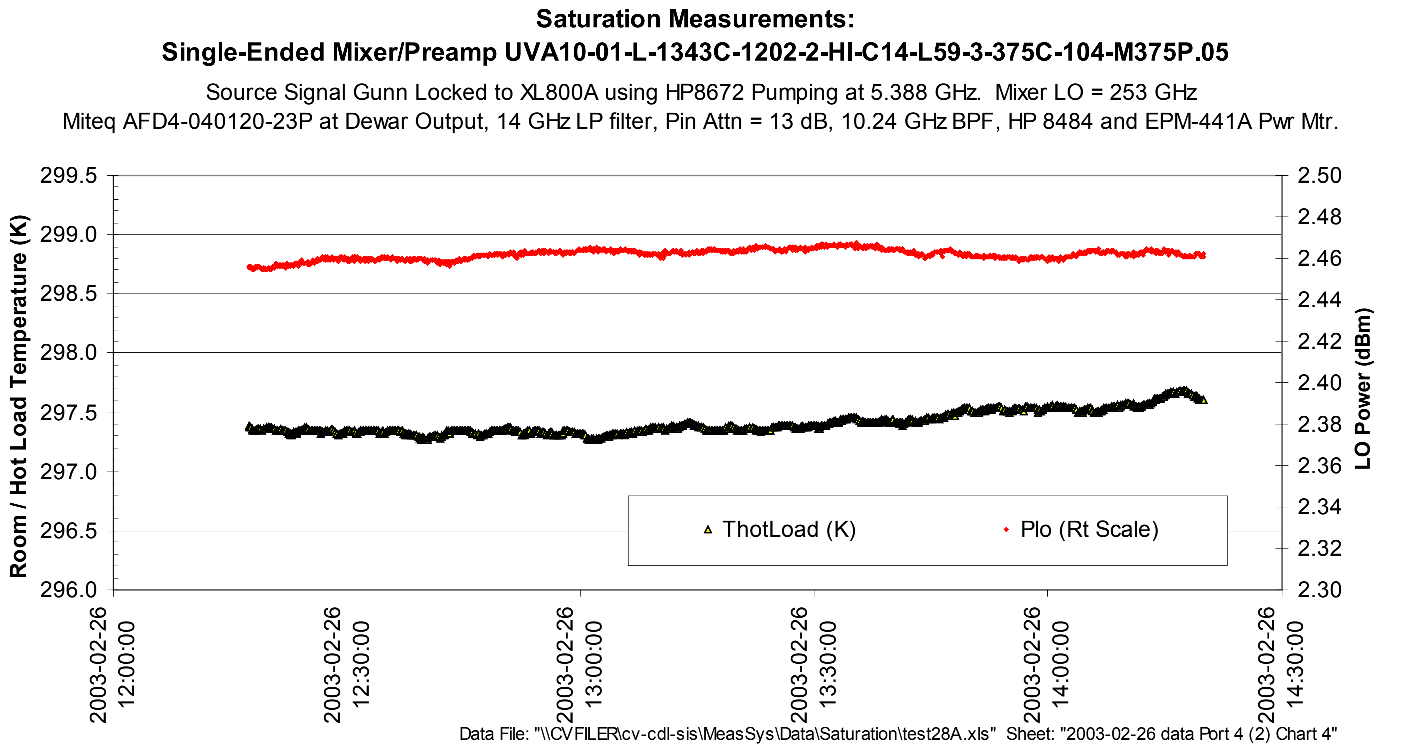


Figure 8: Saturation of UVA10-01-L-1343C-1202-2-HI-C14-L59-3-375C-104-M375P.05 shows that this mixer-preamp has about 2.3% saturation (including 0.5% from latter stages)

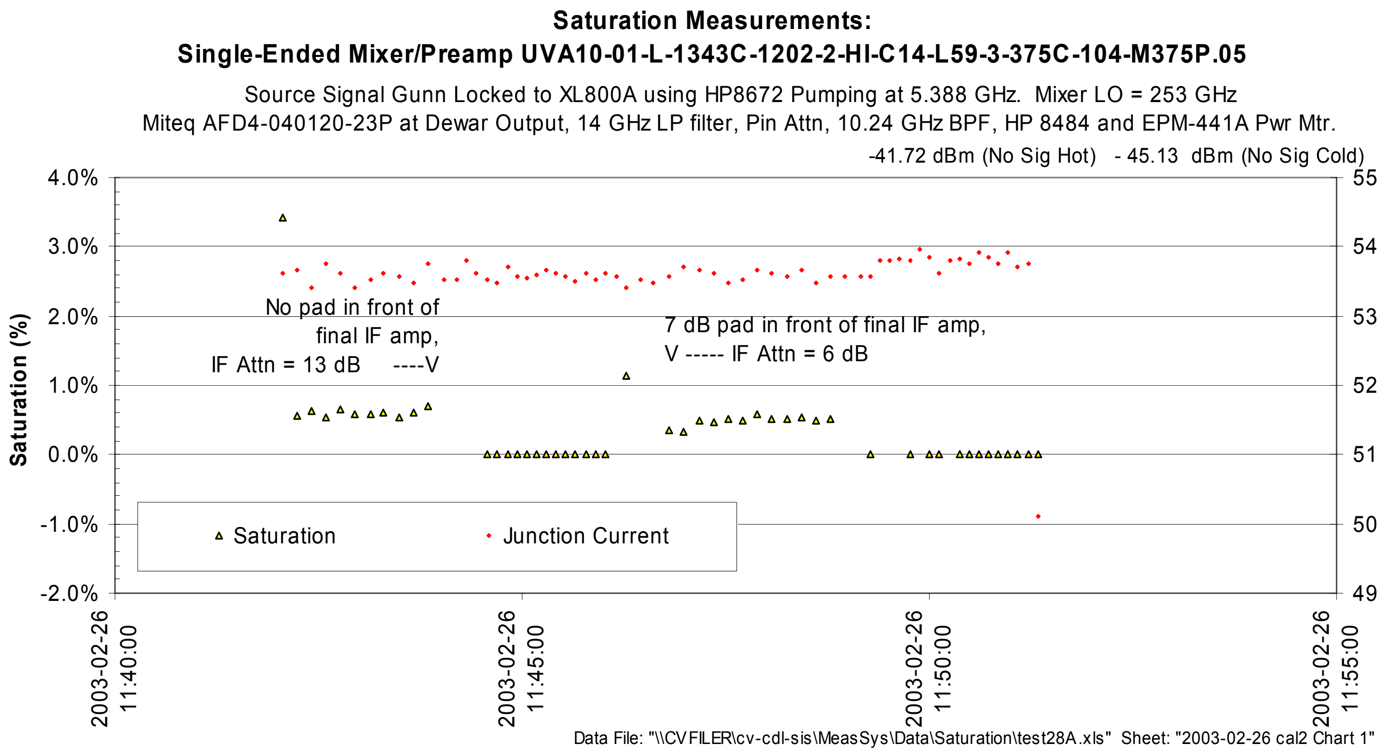


Figure 9: Saturation of latter stages obtained by injecting signal after mixer/preamp into "Port 4" shown Figure 2. The latter stages contribute about 0.5% to the total measurement.

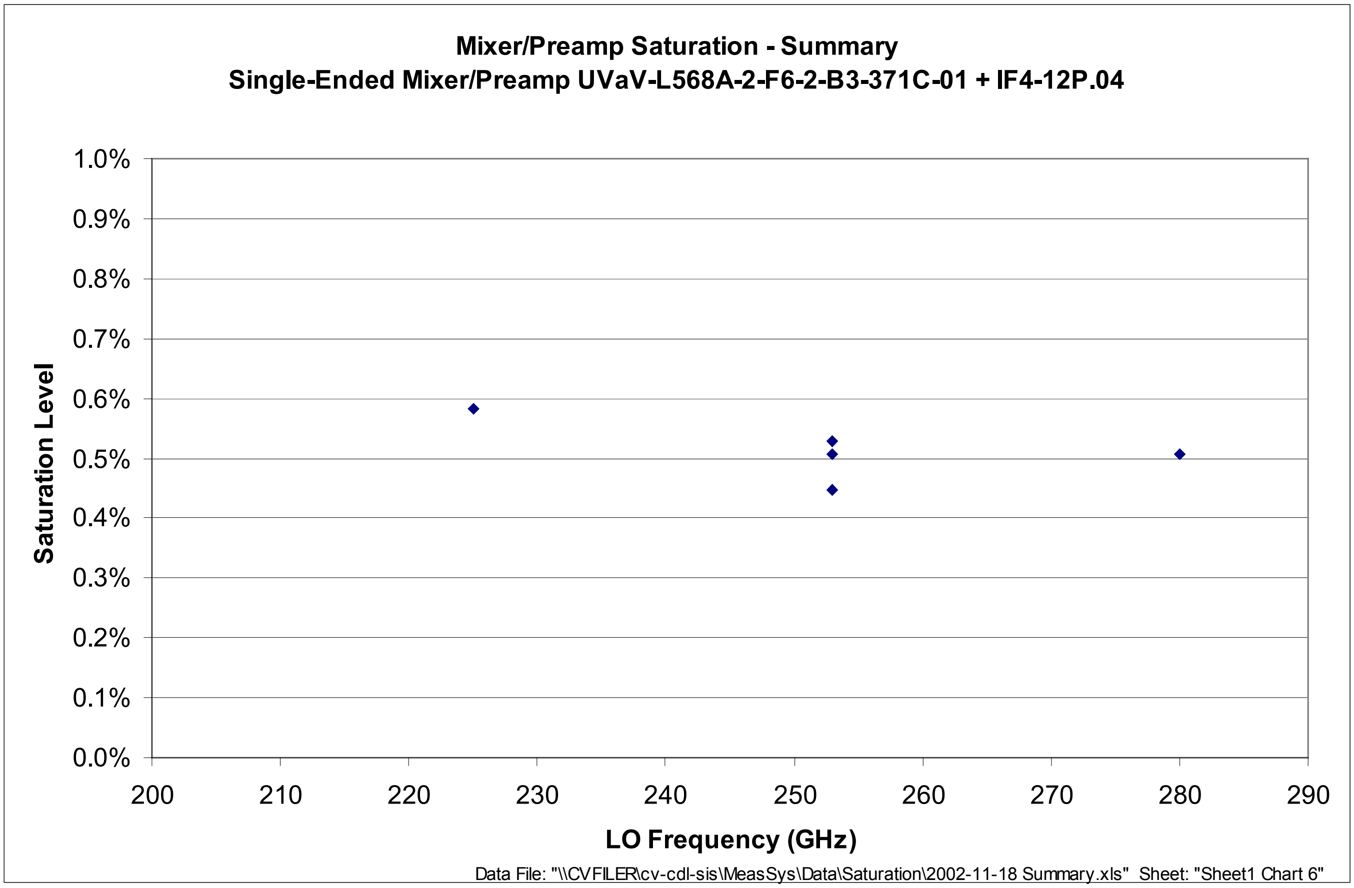


Figure 10: Summary data for single-ended mixer/preamp saturation *vs*. LO frequency