Memorandum

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cc: J. Webber

From: J. Effland, R. Groves

Date: 2002-12-13

Subject: Gain *vs*. LO Power of SIS Mixer-Preamps for ALMA Band 6

Introduction

Gain, noise temperature and total power variation of ALMA mixers as a function of LO power is required to calculate how LO amplitude noise degrades receiver stability. This memo provides measured gain, receiver noise temperature, and total power *vs*. LO levels for ALMA Band 6 mixers [1]. Although unbalanced sideband-separating mixers are planned for the Band 6 receivers, measured data for balanced mixer-preamps are also included here for comparison.

List of Figures

Equipment Setup

The equipment configuration used to measure the gain and noise temperature of the mixer-preamps is shown in Figure 1. Although Figure 1 shows the setup to measure single-ended mixer-preamps, the setup for balanced mixer-preamps is almost the same but includes another mixer bias supply to power the second component mixer.

LO power was measured at the output of the tripler using an Anritsu ML-83A power meter with MP84B1 head. All power levels quoted in this memo are referenced to the output of the LO plate and do not include waveguide and coupling losses between the LO plate and mixer.

Mixer and preamp gains are found using the usual "ΔP/ΔT" equation by taking the ratio of measured noise powers to temperatures when the input is connected to hot and cold loads. The gain of the IF system is obtained by connecting its input to a hot and cold load using the 6-way switch in the Dewar:

$$G_{IF} = \frac{1}{kB}\left(\frac{P_{hIF} - P_{cIF}}{T_{hIF} - T_{cIF}}\right)$$

where

G_{IF} is the IF system gain,
P_{hIF} is the power output from the IF system when its input is connected to a hot load,
P_{cIF} is the power output from the IF system when its input is connected to a cold load,
T_{hIF} is the radiometric temperature of the hot load connected to the IF input,
T_{cIF} is the radiometric temperature of the cold load connected to the IF input.

In a similar fashion, overall system gain is found from a "ΔP/ΔT" equation when power levels are measured with the RF input of the mixer switched to hot and cold loads using the chopper wheel. Gain of just the mixer-preamp is the overall system gain normalized by the IF system gain, which becomes:

$$G_{MXR-PREAMP} = \left(\frac{P_{hRF} - P_{cRF}}{P_{hIF} - P_{cIF}}\right)\left(\frac{T_{hIF} - T_{cIF}}{T_{hRF} - T_{cRF}}\right)$$

where

$G_{MXR-PREAMP}$ is the gain of the mixer-preamp, and
P_{hRF} is the power output from the receiver when its input is connected to a hot load,
P_{cRF} is the power output from the receiver when its input is connected to a cold load,
P_{hIF} is the power output from the IF system when its input is connected to a hot load,
P_{cIF} is the power output from the IF system when its input is connected to a cold load,
T_{hRF} is the radiometric temperature of the hot load connected to the receiver input,
T_{cRF} is the radiometric temperature of the cold load connected to the receiver input,
T_{hIF} is the radiometric temperature of the hot load connected to the IF input, and
T_{cIF} is the radiometric temperature of the cold load connected to the IF input.

The 20 dB attenuator installed between the mixer-preamp and the IF switch helps maintain nearly the same noise power levels when measuring RF and IF system noise with hot and cold loads. This attenuator was measured on a network analyzer and its value must be added to the measured mixer-preamp gain.

Graphs

Figure 2 through Figure 7 show results for a single-ended mixer-preamp. Similar data were measured last spring for balanced mixer-preamp, and those data are shown in Figure 8 through Figure 13.

For the single-ended mixer-preamp operating at optimum LO power levels, gain and receiver noise temperature as a function of IF are shown in Figure 2 for two different LO frequencies. At an LO frequency of 230 GHz, noise temperatures span 40K to 50K as shown in Figure 2, compared to 45K to 55K quoted in Reference 1 for the same mixer-preamp topology. Measured noise temperatures at 260 GHz in Figure 2 span 42K to 70K, compared with 49K to 61K in Reference 1.

Measured mixer-preamp gains in Figure 2 are within measurement error of being the same for both LO frequencies and range from 37 dB to 30 dB. This is essentially the same as the limited gain data presented in Reference 1.

Irregularities are evident in some of the measured points in the mixer-preamp gain and receiver noise temperature data shown in Figure 3 and Figure 4. The irregularities probably result from system gain changes because the data were measured over several days time and the LO powers were not changed monotonically.

Single-ended mixer noise power in the 60 MHz passband of the IF filter is plotted in Figure 5 as a function of LO power at a LO frequency of 230 GHz. The power level at each IF is adjusted using a programmable attenuator on the warm IF plate to maintain a single power meter range when the chopper switches between hot and cold loads. This means that the attenuator value must be added to the IF power reading to find the power level assuming a constant IF attenuation.

Balanced mixer-preamp data is presented for completeness, although the baseline plan for ALMA Band 6 cartridge uses sideband separating, single ended mixers.

The balanced data were measured at 240 GHz and 260 GHz LO frequencies, but through an oversight, the single-ended data were measured with LO frequencies of 230 GHz and 260 GHz. The balanced data, which were measured six months earlier, spans a much narrower range of LO levels than the single-ended data. A much larger LO power range is spanned during measurement of the single-ended data to show more clearly the optimum noise temperature and optimum mixer-preamp gain.

Gain and receiver noise temperature as a function of IF for a balanced mixer-preamp operating at optimum LO power levels is shown in Figure 8. Balanced mixer noise power in the passband of the IF filter is plotted in Figure 11 as a function of LO power at a LO frequency of 240 GHz.

Theoretical Sensitivity to LO Power Variation

Analysis of the mixer using the quasi five-frequency method [2], and assuming a 50-ohm IF load, gives the dependence of gain and noise temperature on LO amplitude shown in Figure 14. Note that the range of LO amplitude shown in the figure is approximately 3 dB – *i.e.*, ± 1.5 dB about the point of minimum noise temperature.

Acknowledgements

The authors wish to thank A. R. Kerr for his many useful suggestions, comments, and his theoretical sensitivity contribution.

References

[1] 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/.

[2] A. R. Kerr, S.-K. Pan, and S. Withington, "Embedding Impedance Approximations in the Analysis of SIS Mixers," IEEE Trans. Microwave Theory Tech., vol. 41, no. 4, pp. 590-594, April 1993. This paper was originally presented at the Third International Symposium on Space Terahertz Technology, March 1992.

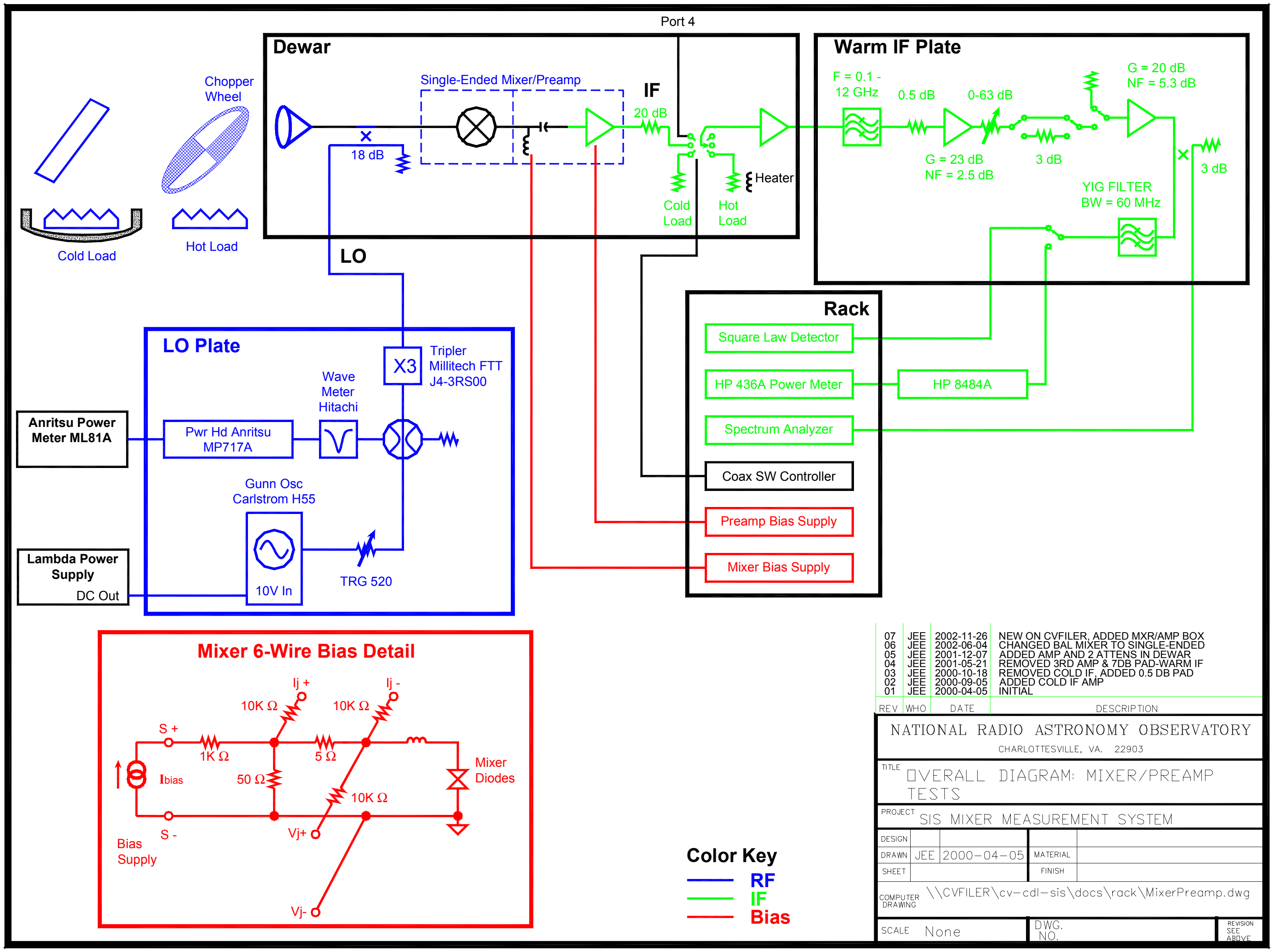

Figure 1: Equipment Setup for Gain vs. LO Power of Single-Ended Mixer-Preamp for ALMA Band 6

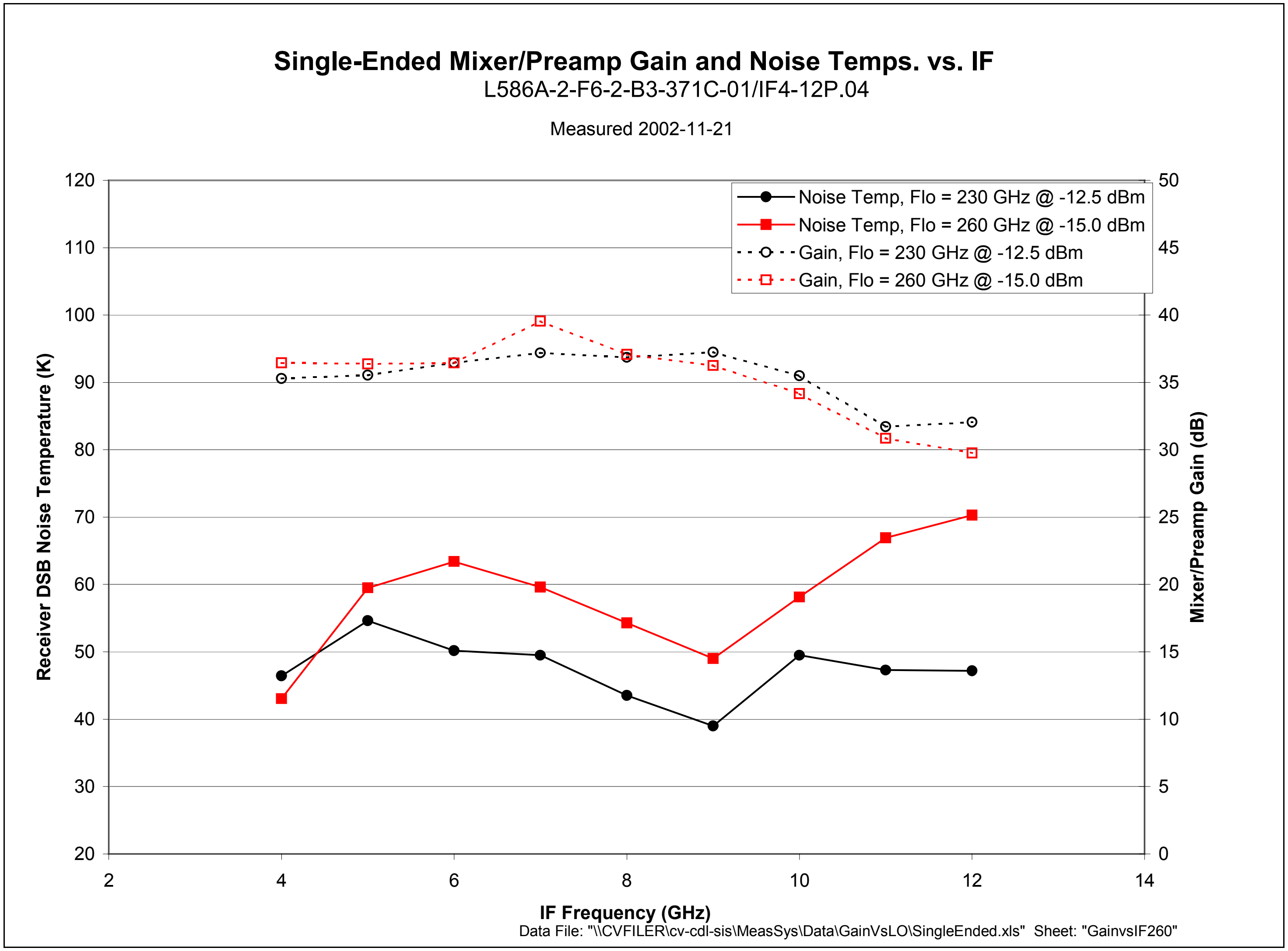

Figure 2: Gain and Noise Temperatures vs. IF, Single-Ended Mixer-Preamp

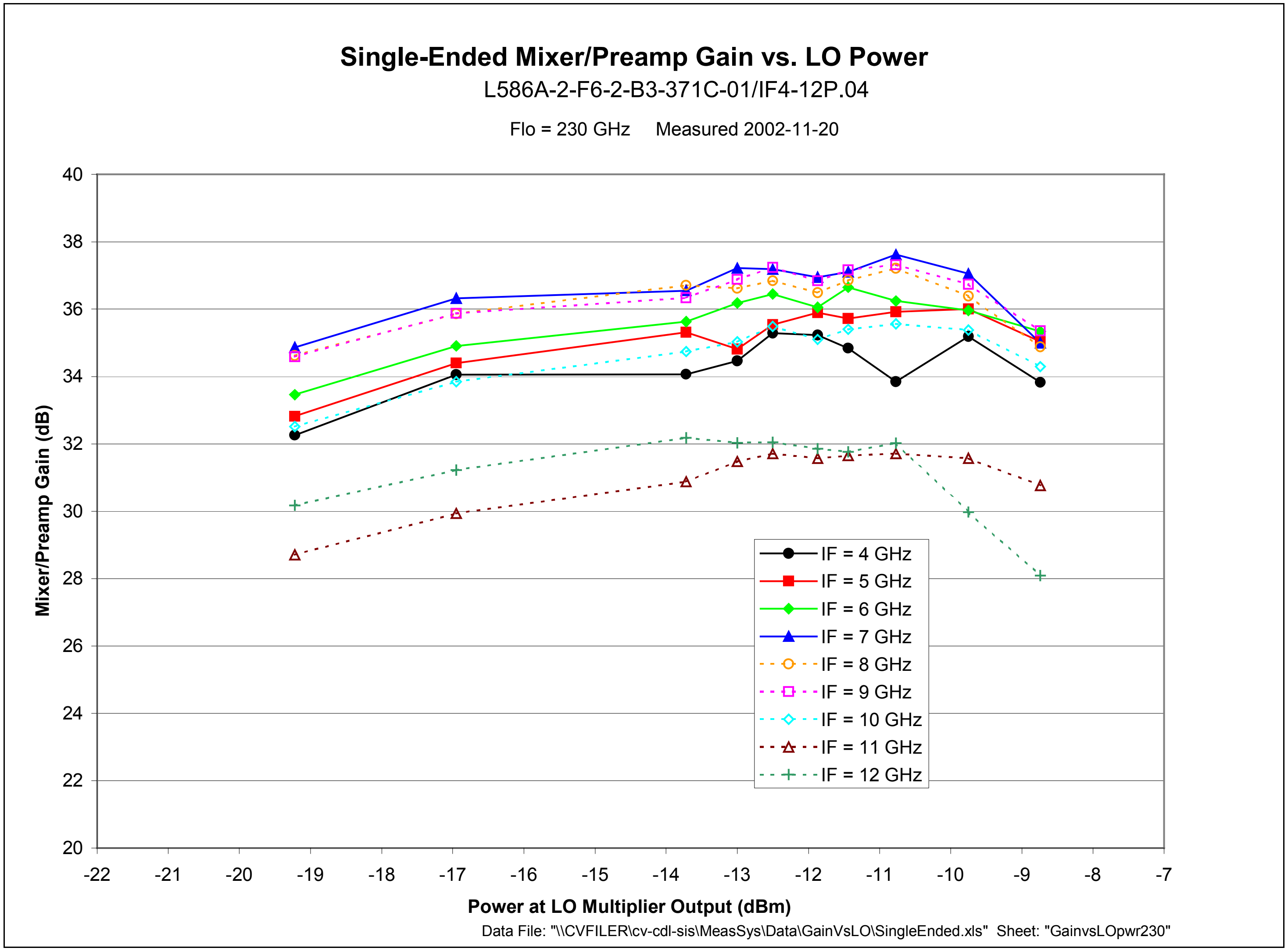

Figure 3: Gain vs. LO Power, 230 GHz, Single-Ended Mixer-Preamp

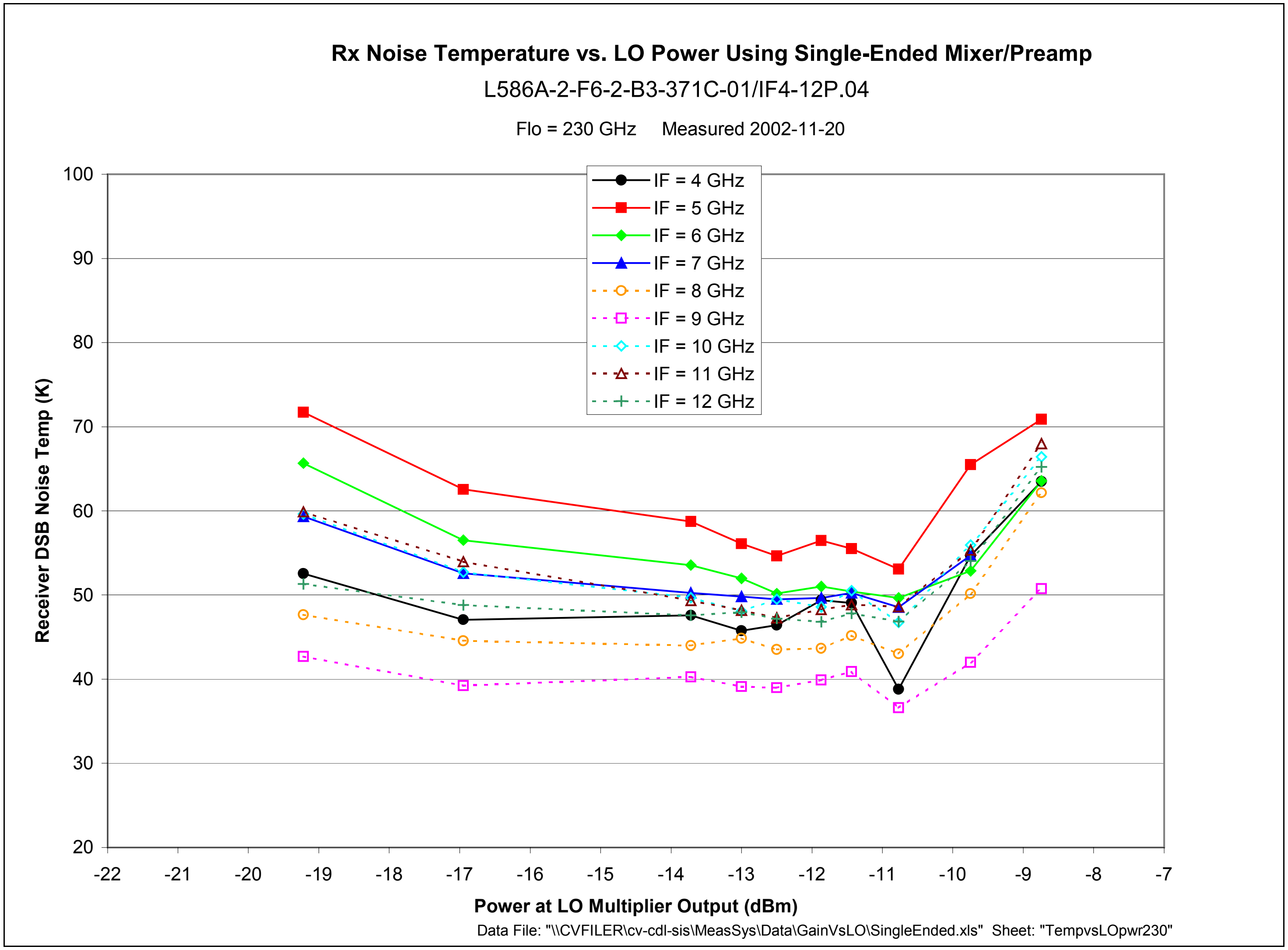

Figure 4: Receiver Noise Temperature vs. LO Power, 230 GHz, Single-Ended Mixer-Preamp

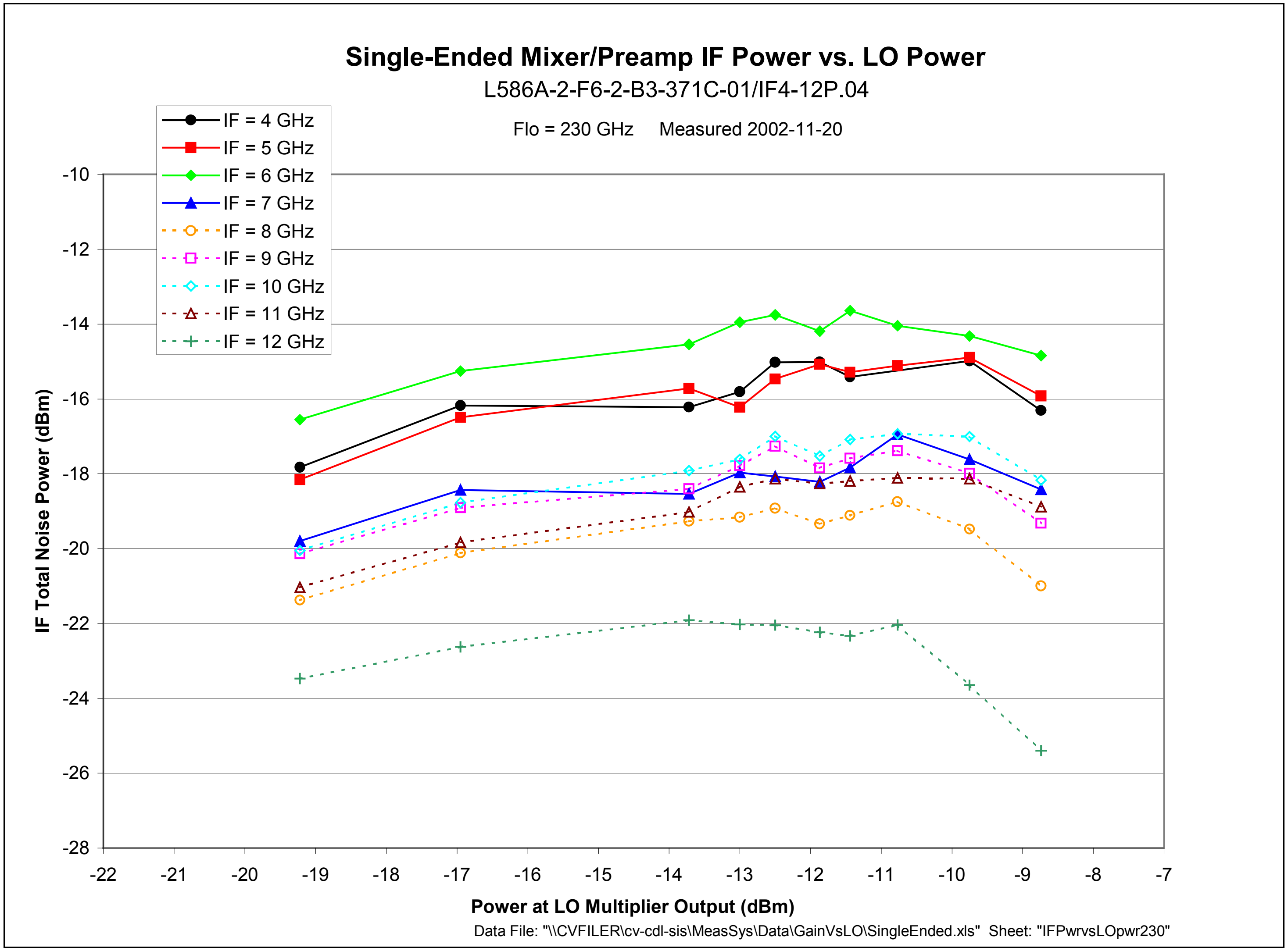

Figure 5: IF Noise Power vs. LO Power, RF Hot Load, 230 GHz, Single-Ended Mixer-Preamp

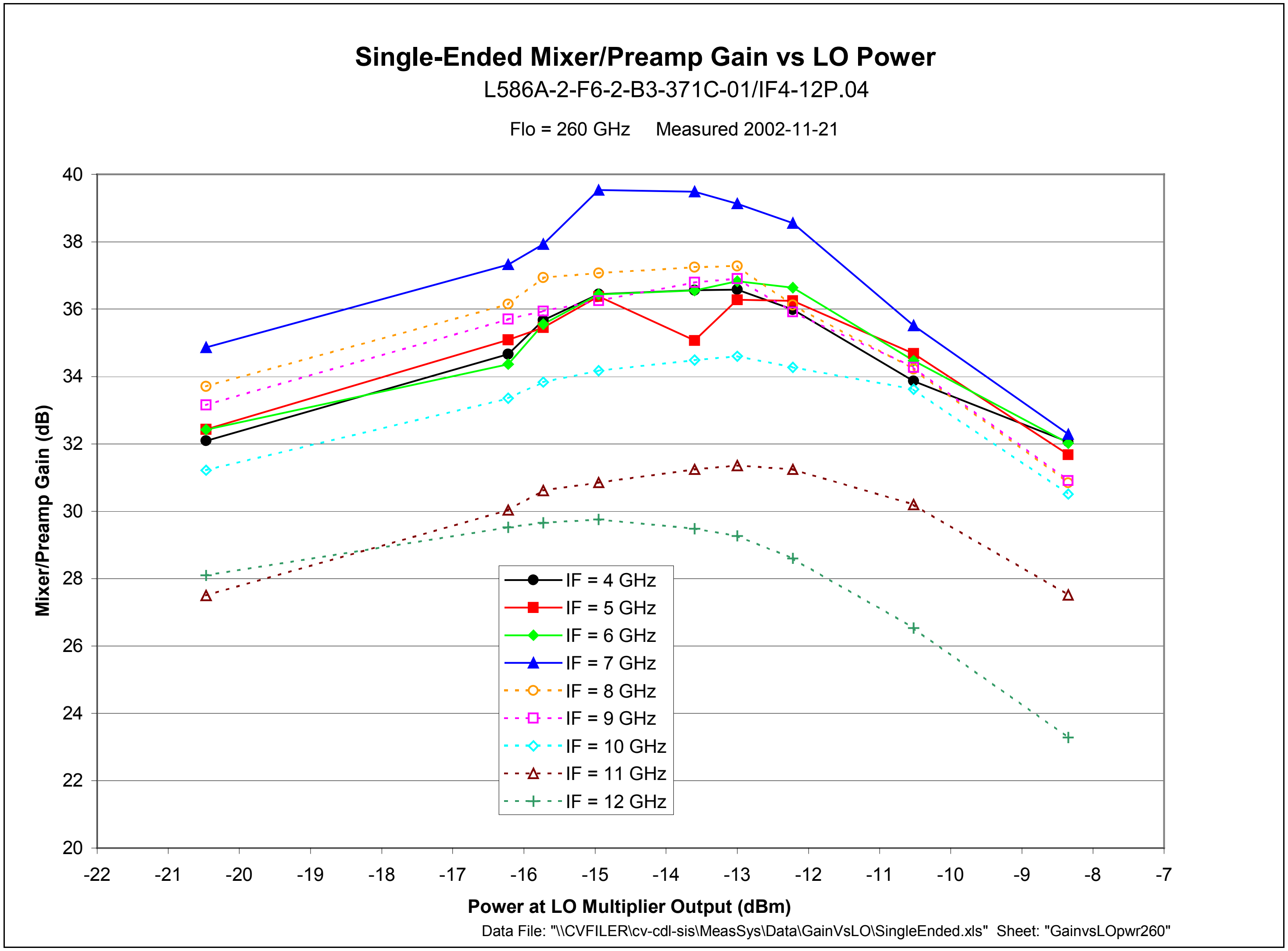

Figure 6: Gain vs. LO Power, 260 GHz, Single-Ended Mixer-Preamp

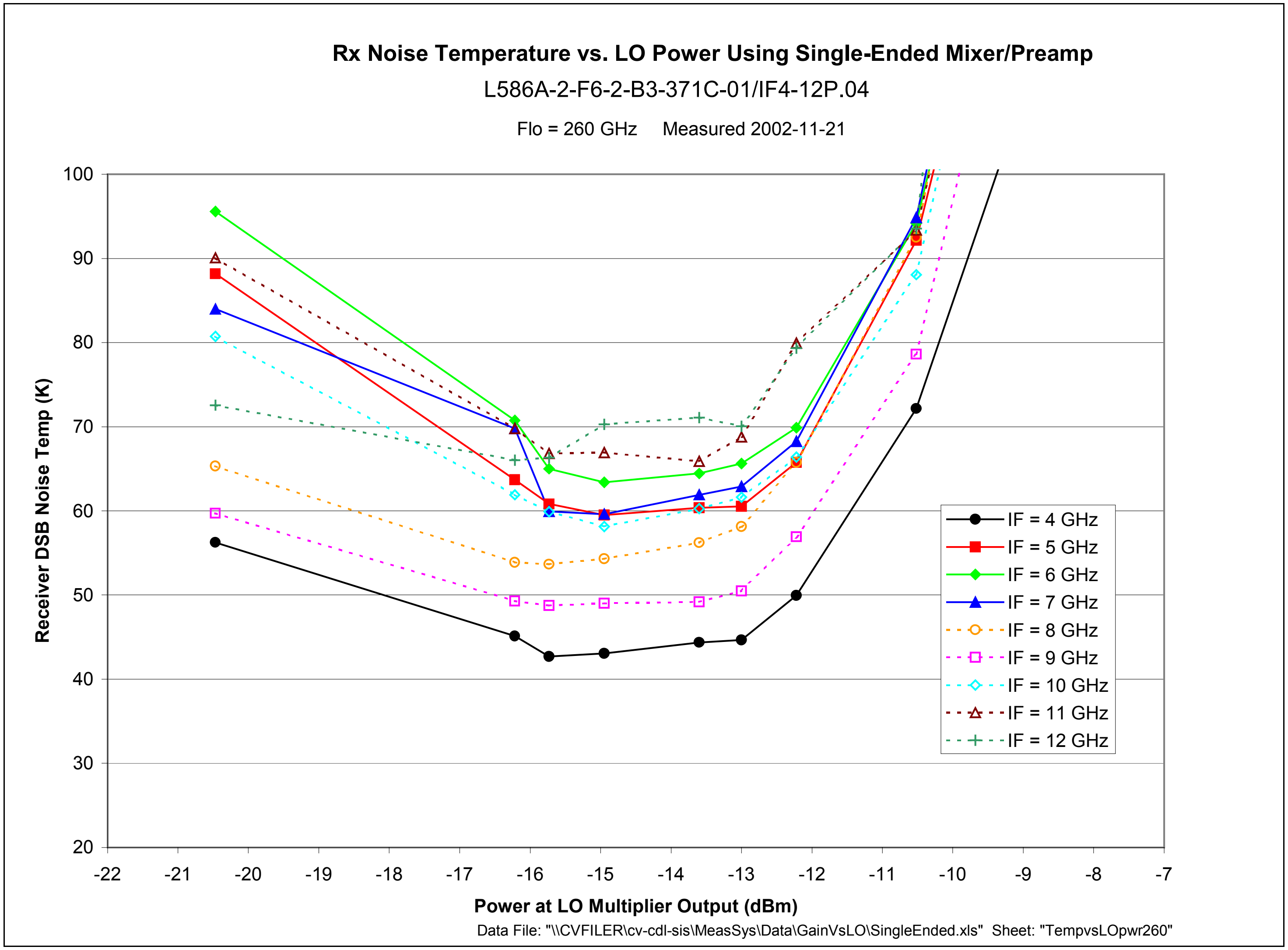

Figure 7: Receiver Noise Temperature vs. LO Power, 260 GHz, Single-Ended Mixer-Preamp

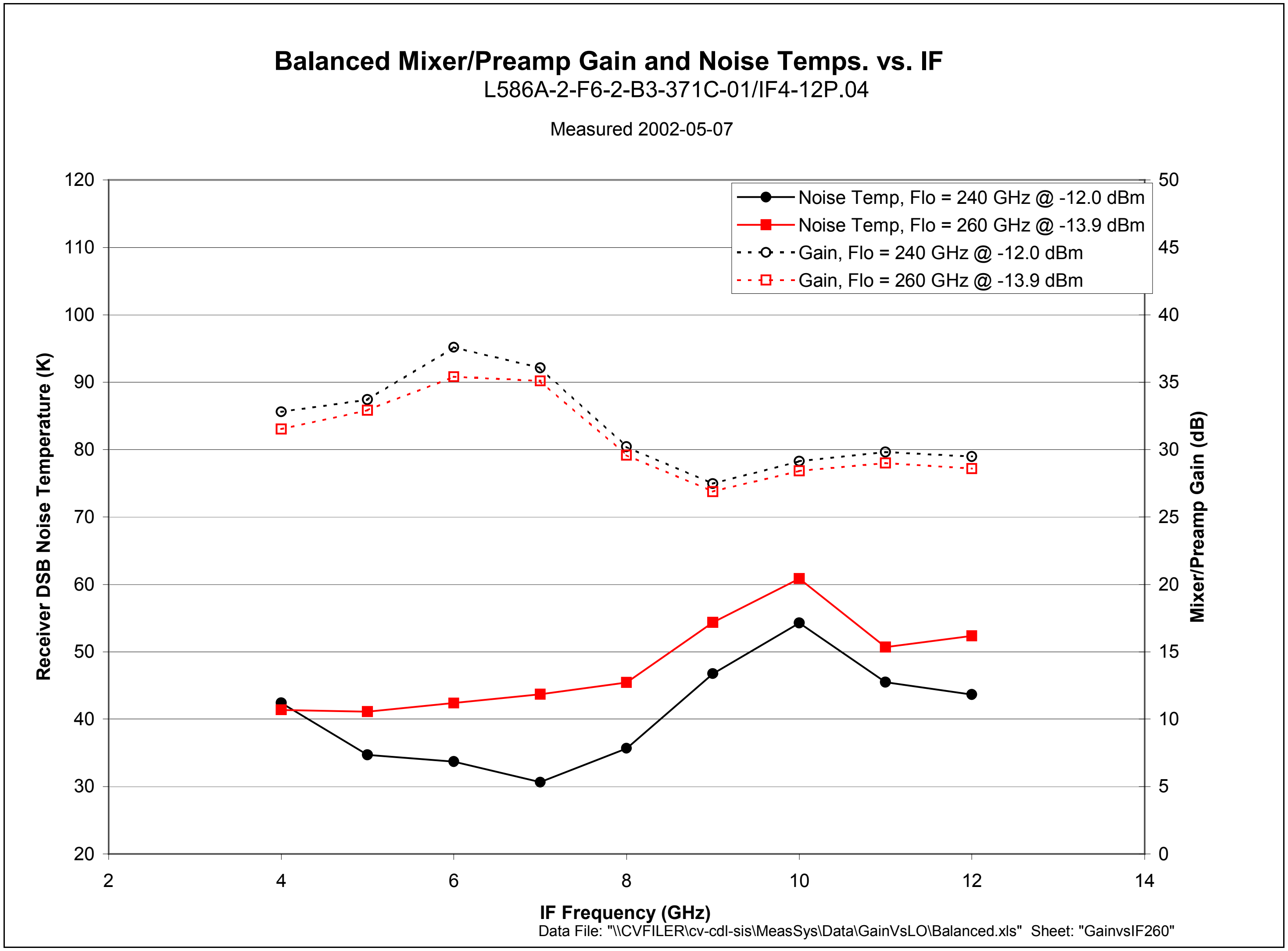

Figure 8: Gain and Noise Temperatures vs. IF, Balanced Mixer-Preamp

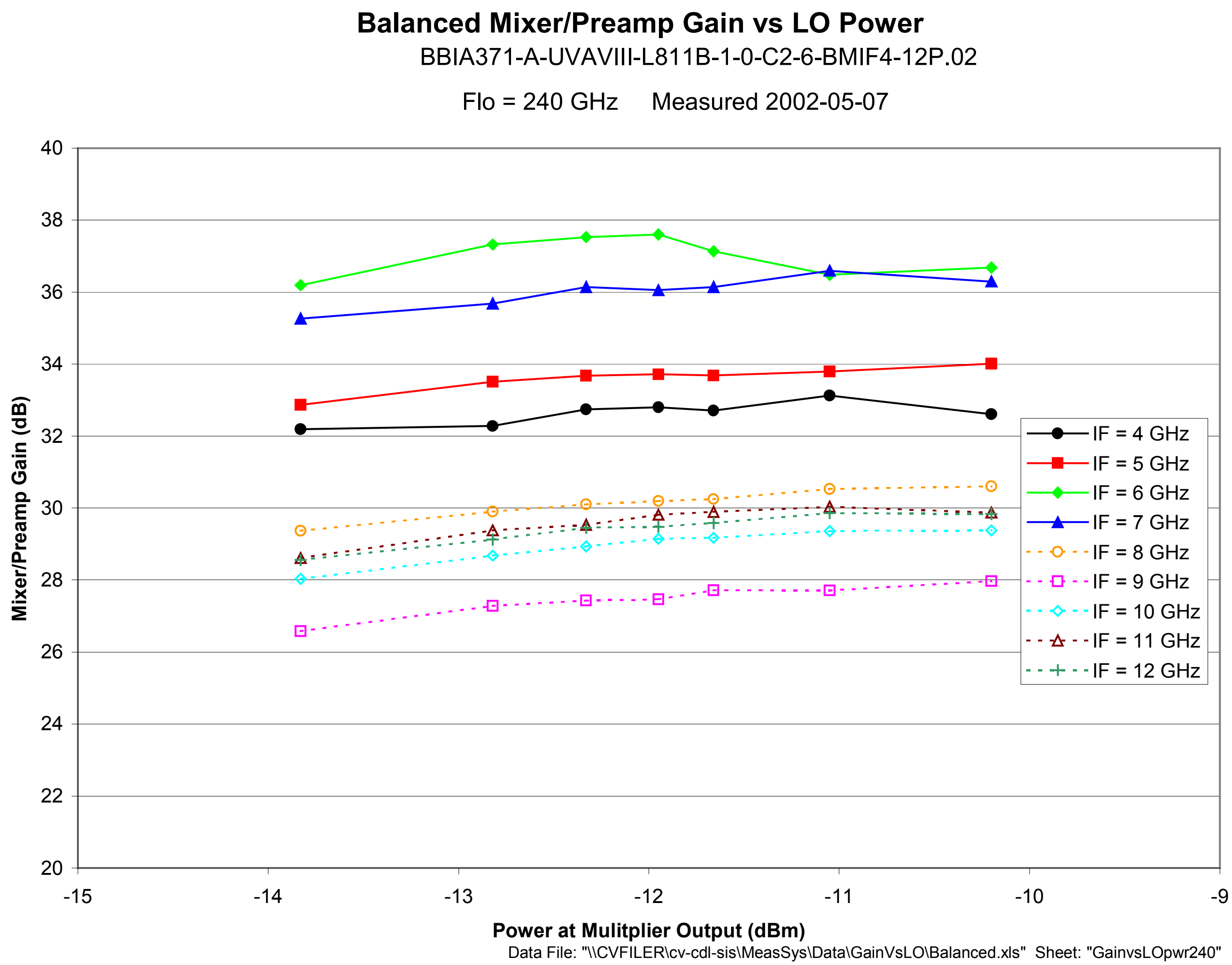

Figure 9: Gain vs. LO Power, 240 GHz, Balanced Mixer-Preamp

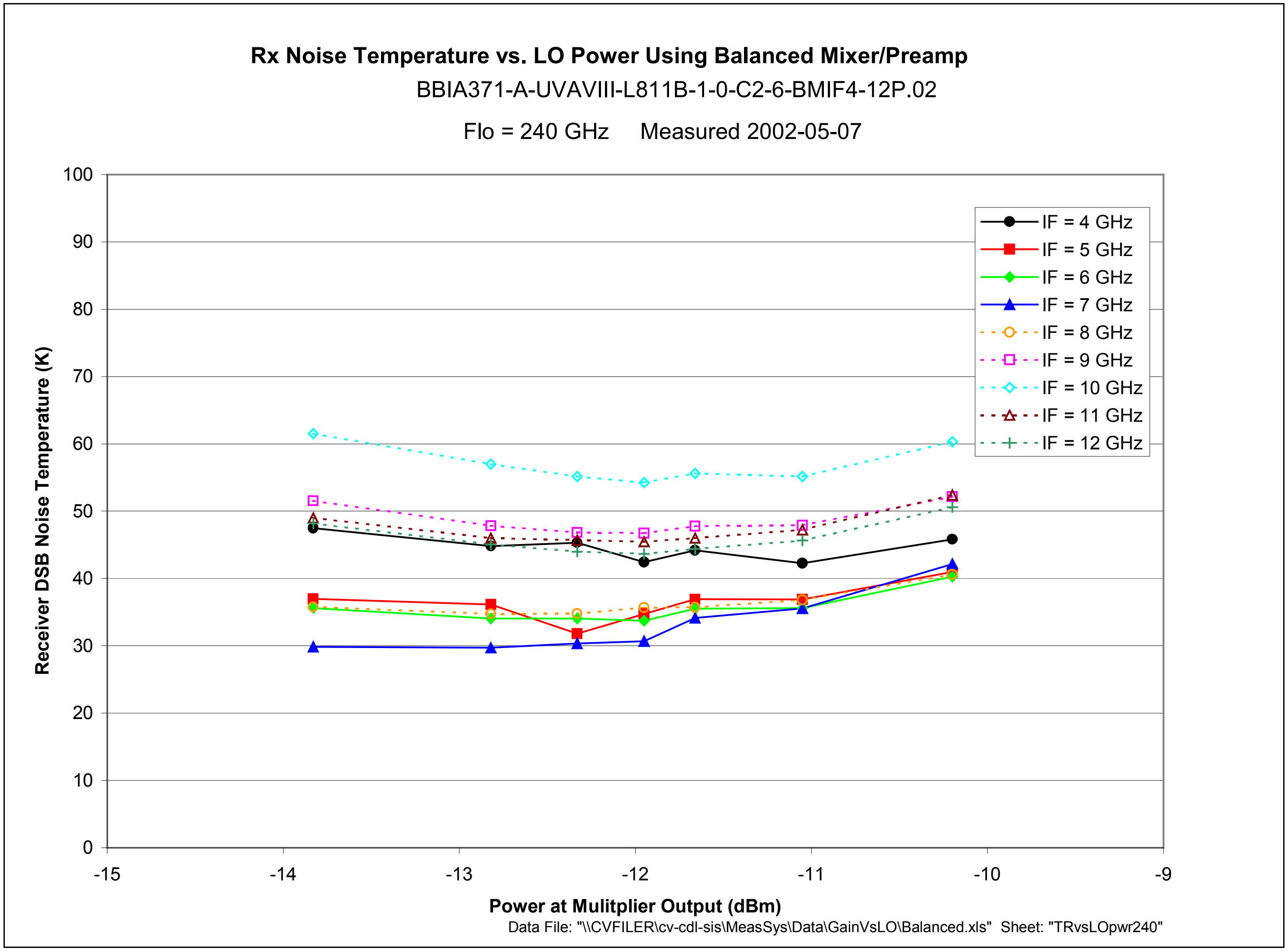

Figure 10: Receiver Noise Temperature vs. LO Power, 240 GHz, Balanced Mixer-Preamp

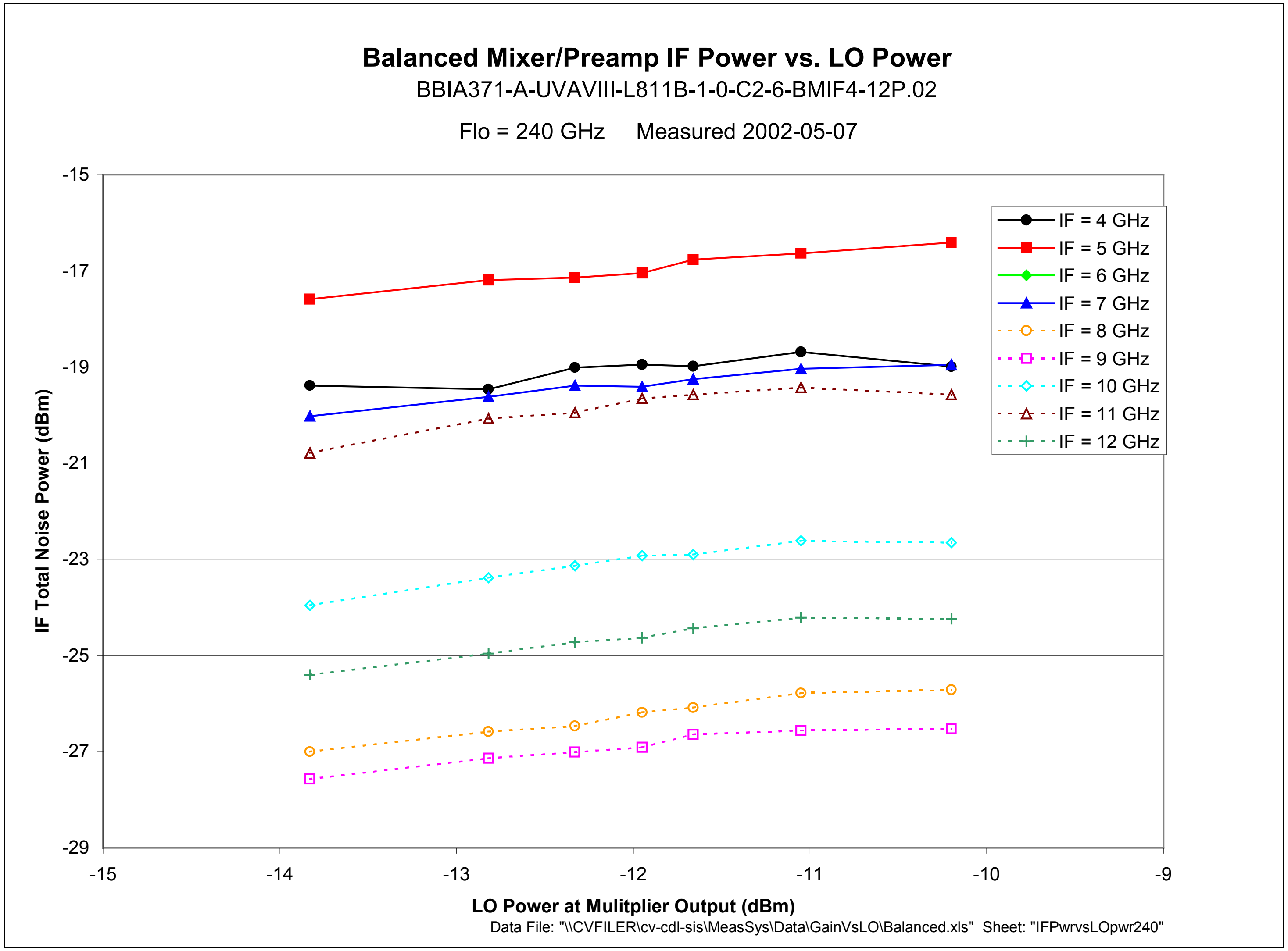

Figure 11: IF Noise Power vs. LO Power, RF Hot Load, 240 GHz, Balanced Mixer-Preamp

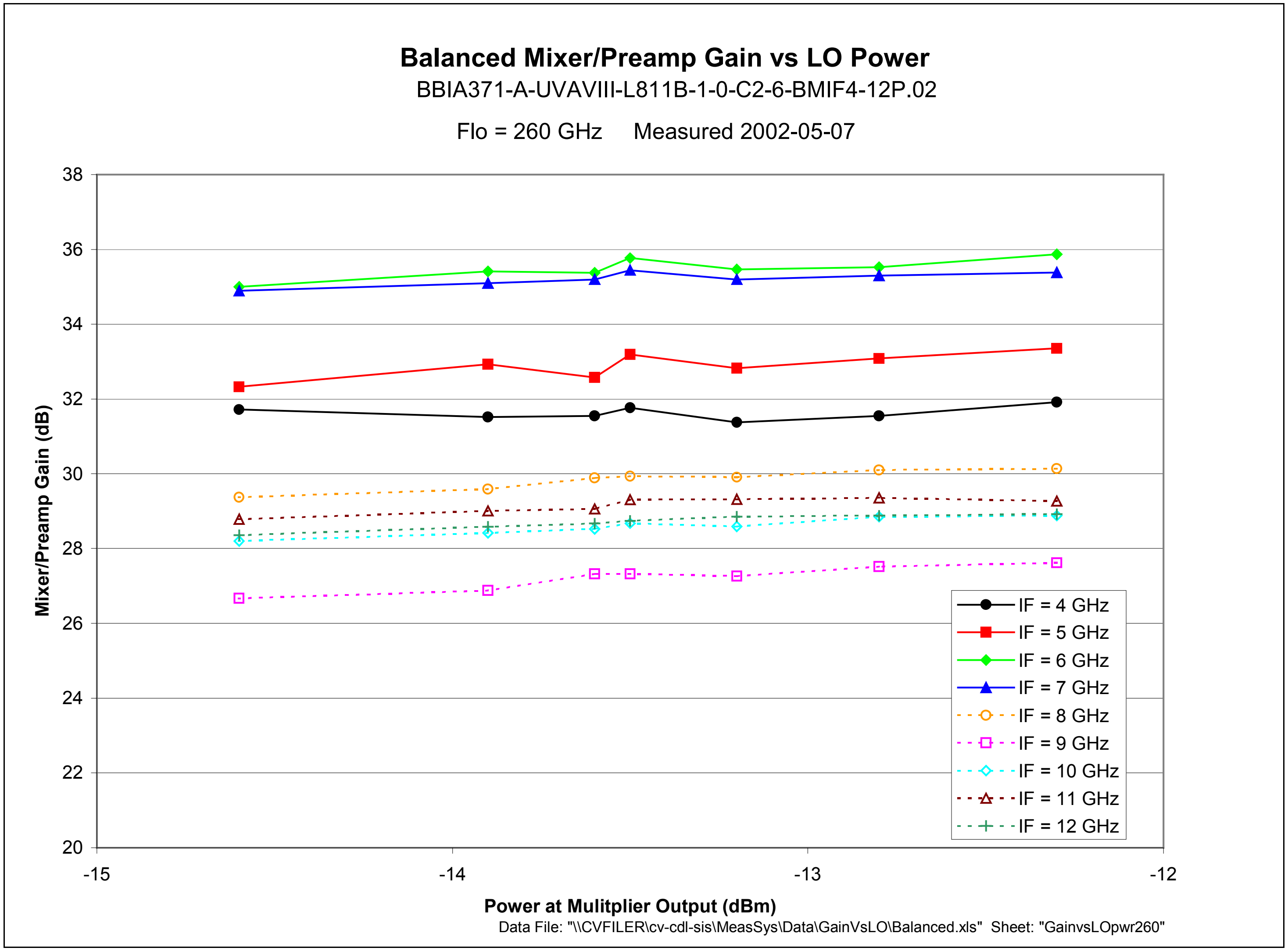

Figure 12: Gain vs. LO Power, 260 GHz, Balanced Mixer-Preamp

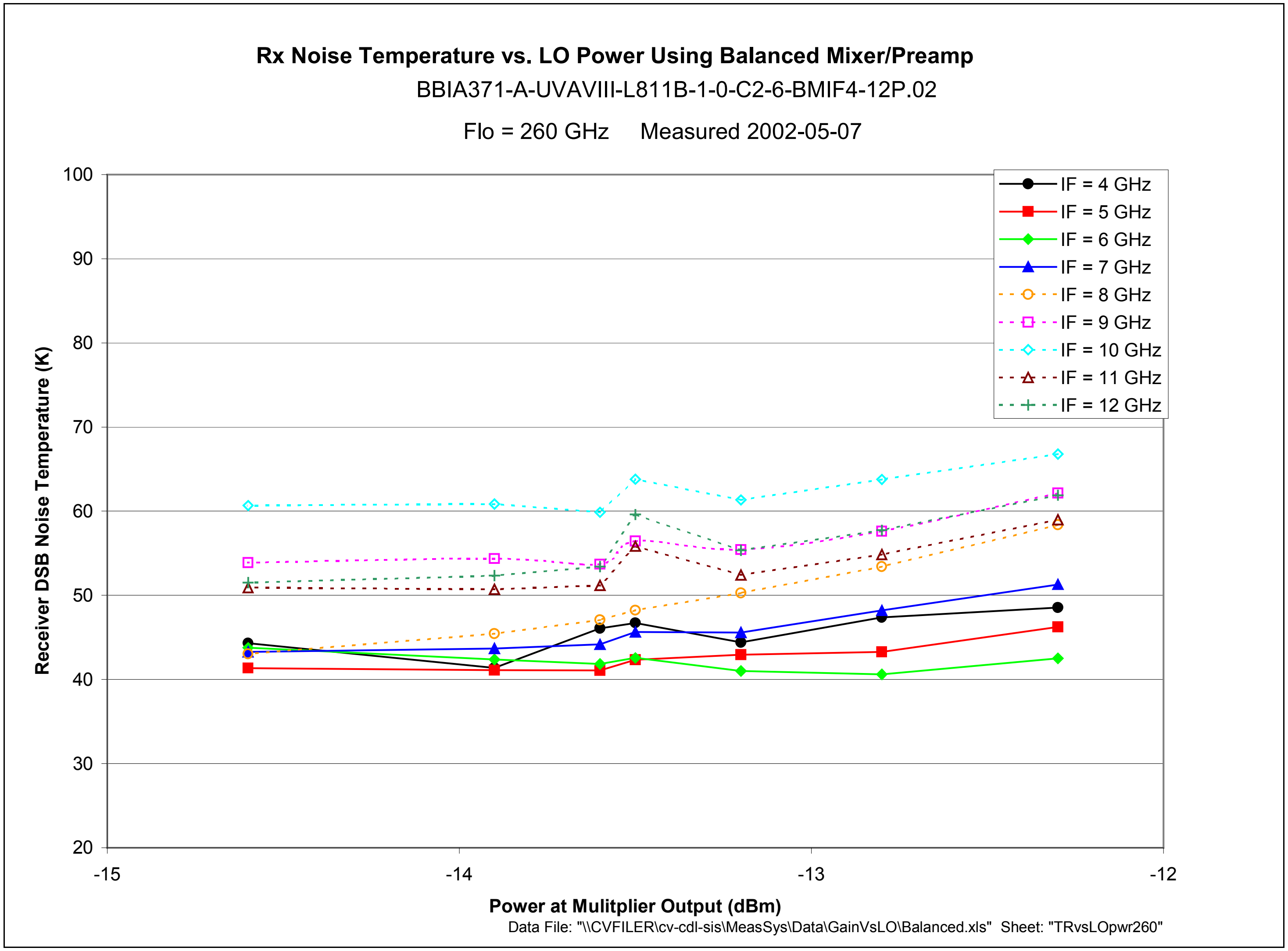

Figure 13: Receiver Noise Temperature vs. LO Power, 260 GHz, Balanced Mixer-Preamp

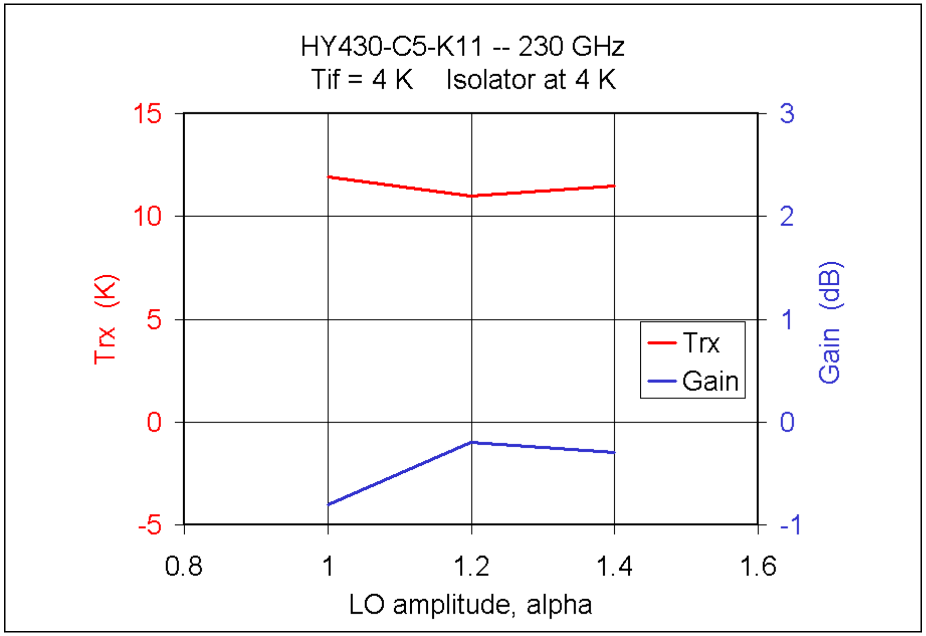

Figure 14: Theoretical dependence of gain and noise temperature on LO amplitude using the quasi five-frequency method and assuming a 50-ohm IF load [2]