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From: J. Effland

Date: 2000-12-04

Subject: Laboratory Measurements of Sideband Separating Mixer:
UVaIX-L989A-A-10-0-L44-C22-BSSM371A-1

1. Summary

This memorandum documents the results and test setups used to measure noise temperature and image rejection of sideband separating balanced mixer UVaIX-L989A-A-10-0-L44-C22-BSSM371A-1.

Noise temperature results are plotted in Figure 13 and show that the lowest SSB receiver noise temperature is about 472K at 200 GHz but rises to 1800K at 300 GHz. At 200 GHz, this corresponds to a SSB mixer noise temperature of 395K. Image rejection (Figure 14) ranges between 6.5 dB and 34 dB end exhibits periodic variation with LO frequency from both outputs. Conversion loss increases from 16 dB at 200 GHz to 22 dB at 300 GHz. Currents of junctions 2 and 3 are balanced within 9 µA across the band, but junctions 1 and 4 differ as much as 60 µA (100%).

2. Noise Temperature Setup

Noise temperatures were measured using the system sketched in Figure 1 and with the Dewar configured as shown in Figure 2. The mixer configuration identifying the junction numbering scheme is sketched in Figure 3. A photo of the Dewar components is included in Figure 4. The chopper wheel system was used to measure noise temperatures, and those measurements assume an effective cold load temperature of 94.5K[1]. The chopper system results were compared to the lab-standard conical loads at 260 GHz.

Standard L-band IF amplifier and isolators were employed for this initial measurement.

The measurement system's accuracy was confirmed to two ways. With a manual hot/cold load at 260 GHz, and by noting that the system measured the expected 3K noise temperature of the L-band IF amplifier. Measurements with the manual load were obtained the day after the chopper-based data was measured, so the 9% difference between the two is not surprising.

Kirk Crady solved an early configuration problem by correctly suggesting that the bias voltages should be opposite in sign for opposing mixers.

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[1] "Recent Data Characterizing the SIS Noise Temperature Measurement System," CDL Internal Memo from J. Effland, 2000-10-18, http://www.cv.nrao.edu/~jeffland/ColdLoadMeas3.pdf

3. Image Rejection Ratio

Image rejection was measured using the source setups shown in Figure 5 with photos in Figure 6 (200-260 GHz) Figure 7 (260-300 GHz). The following procedure was used to collect the data:

1. The receiver LO was tuned to a frequency where noise temperature data was previously measured. The operating point for all mixers was set the same as when noise temperatures were measured.
2. The source Gunn oscillator (and tripler for 260-300 GHz) were tuned 1.5 GHz below the receiver LO frequency.
3. The L-band IF for the LSB port was observed near 1.5 GHz on the IF spectrum analyzer, and the Gunn oscillator for the source was slightly retuned until the signal was observed on the IF spectrum analyzer near the center of the receiver's IF band. Mixer port 1 was confirmed as the LSB port by observing that frequency inversion occurred from this port: The IF frequency decreases as the RF frequency increases.
4. To prevent receiver saturation, the level of the source signal was minimized by setting the signal-to-noise ratio to 10 dB for the signal in the USB output from the mixer. The USB output is the image channel for this configuration. This yields an error of less than 0.5 dB from noise contributions to the signal when comparing signals with large and small signal-to-noise ratios.

   Linearity was also tested separately at 260 GHz and 270 GHz. The possibility of saturation is greatest at 270 GHz, because the image rejection is largest there, because the 10 dB carrier to noise in the image channel is increased by the image rejection value in the desired channel. Figure 8 shows the measured linearity data, where linearity is defined as the deviation from equal signal level changes between the RF input and IF output of the receiver.
5. IF levels from both mixer ports were recorded by averaging 100 traces on the IF spectrum analyzer and using the analyzer's "marker peak search" to display the signal level.
6. The RF signal level was recorded with the Tektronix 2784 spectrum analyzer.
7. Upper sideband levels were measured by adjusting the RF source frequency to fall at the same IF frequency as the LSB signal by observing the mixer's USB signal on the IF spectrum analyzer. The RF source frequency for USB measurements is nominally 1.5 GHz above the local oscillator frequency.

Given the following measurements, the image rejection ratio (in dB) is found at each LO frequency from the following equations:

$$R_1 = \left(P_{IF1} - P_{RF}\right)^{LSB} - \left(P_{IF1} - P_{RF}\right)^{USB}$$

$$R_2 = \left(P_{IF2} - P_{RF}\right)^{LSB} - \left(P_{IF2} - P_{RF}\right)^{USB}$$

where: R_1 , R_2 = Image rejection in dB from mixer ports 1 and 2

and with the source tuned to lower sideband:

P_{RF}^{LSB} = log of IF power from mixer port 1
P_{IF1}^{LSB} = log of IF power from mixer port 1
P_{IF2}^{LSB} = log of IF power from mixer port 2

and with the source tuned to upper sideband:

P_{RF}^{USB} = log of IF power from mixer port 1
P_{IF1}^{USB} = log of IF power from mixer port 1
P_{IF2}^{USB} = log of IF power from mixer port 2.

4. Measured Results

The following figures show the measured results:

I-V Curves at 200 GHz for Junctions 1 – 4: Figure 9, Figure 10, Figure 11, and Figure 12
Noise temperature data - -Figure 13.
Image rejection - Figure 14
Mixer Conversion Loss -- Figure 15
Mixer current -- Figure 16

Software limitations prevent showing the polarity of the I-V curves. The operating points for Junctions 2 and 4 are actually at negative bias, but the I-V curves were swept using positive voltages.

5. Future Work

The SIS mixer bias supplies continue exhibiting stability problems. In particular, the top bias supply oscillates unless the source resistance is 10 KΩ. All the other supplies operate with 2 KΩ sources, but they show various degrees of instability. For example, most of the supplies oscillate if the Josephson spikes are not suppressed by a magnetic field.

The I-V measurement software and plotting software required correction to properly obtain and graph mixers operating with negative bias.

The procedure to measure image rejection is cumbersome, error-prone, and inaccurate. Now that some experience has been gained with this measurement, we can begin to automate the process.

6. Acknowledgements

Thanks to N. Horner, F. Johnson, and A. Marshall for fabricating the mixer. Mark Wharam also quickly fabricated additional mounting brackets for us. Ralph Groves for has careful noise temperature measurements and K. Crady for his useful suggestions.

7. Equipment Setups

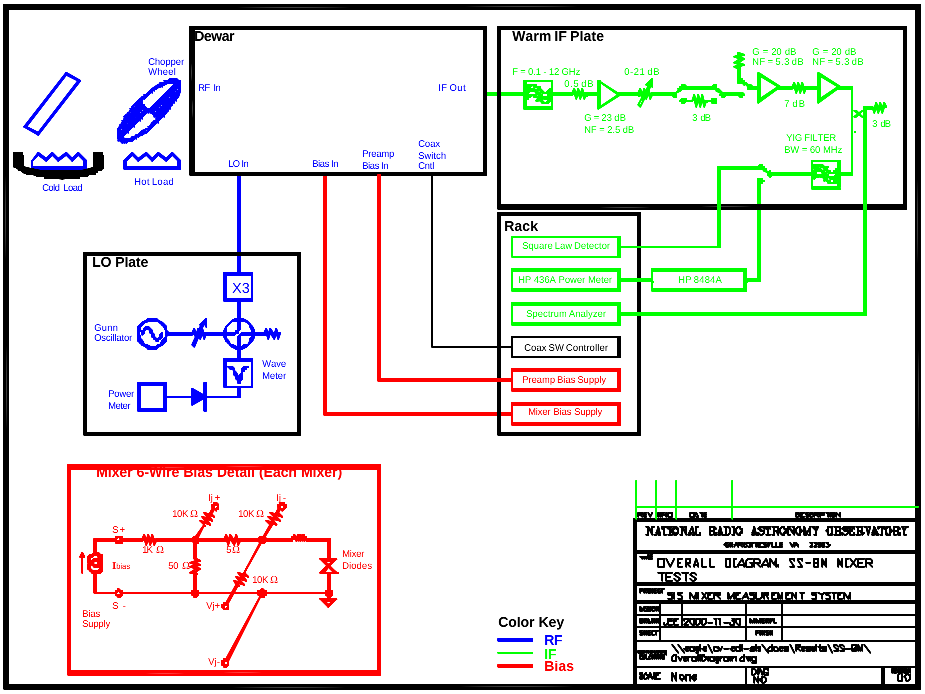
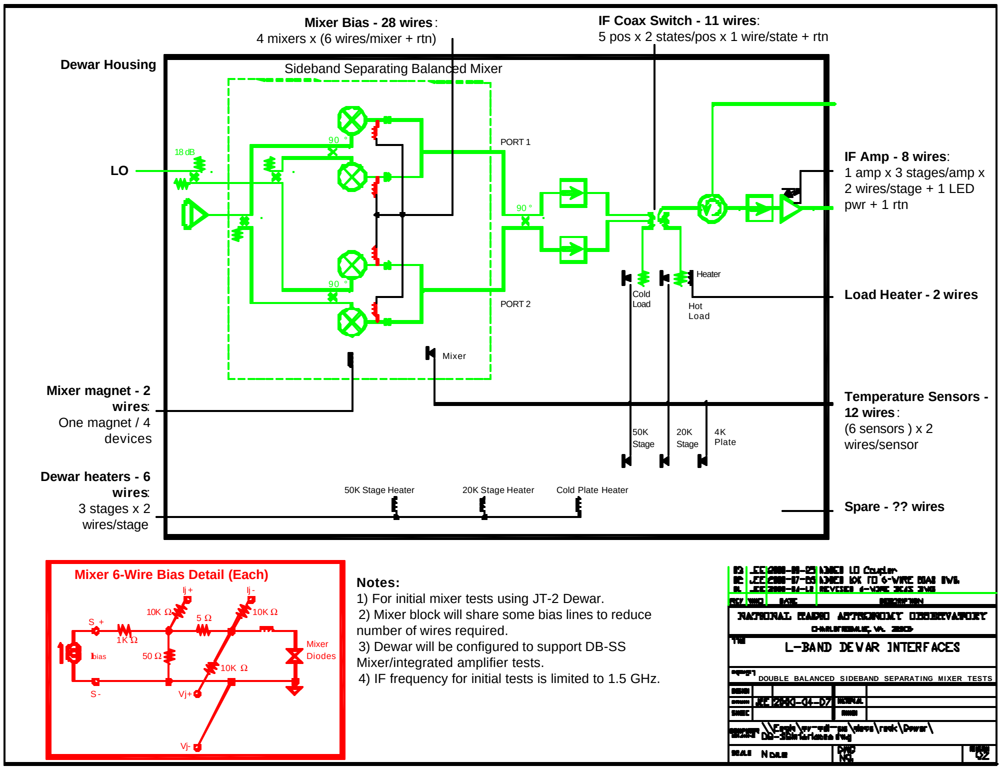


Figure 1: Overall Measurement Configuration



Notes:
1) For initial mixer tests using JT-2 Dewar.
2) Mixer block will share some bias lines to reduce number of wires required.
3) Dewar will be configured to support DB-SS Mixer/integrated amplifier tests.
4) IF frequency for initial tests is limited to 1.5 GHz.

Figure 2: Block Diagram of Dewar Configuration

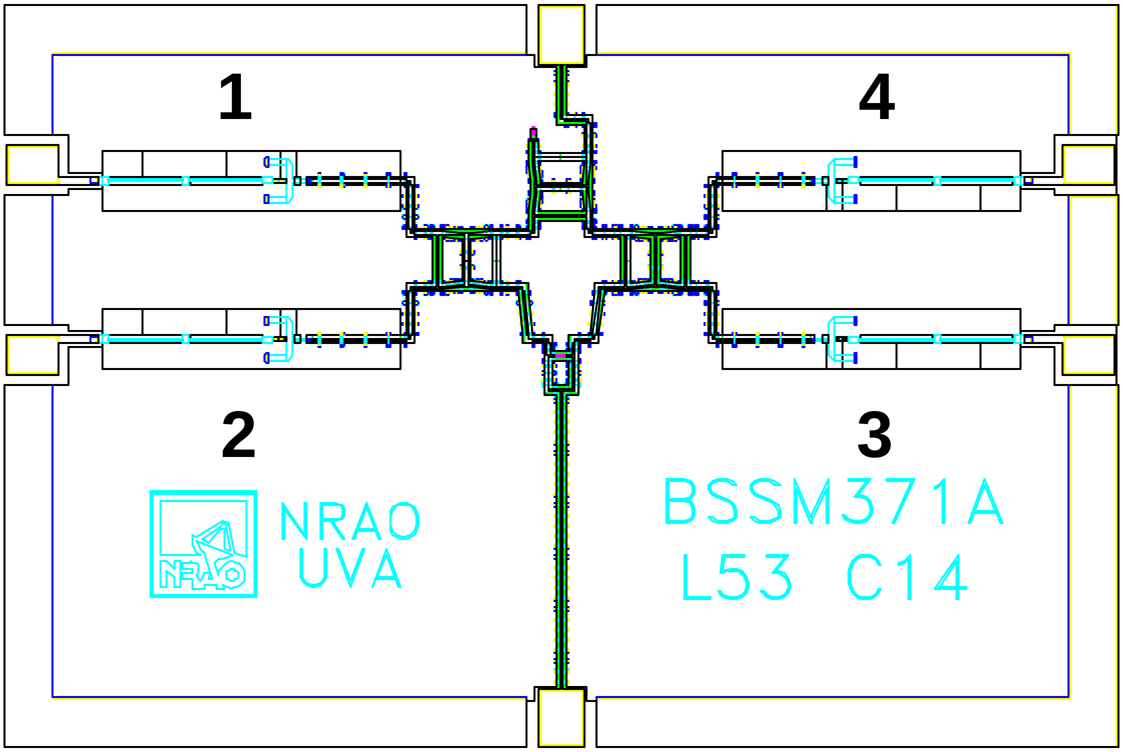


Figure 3: Mixer Chip Configuration

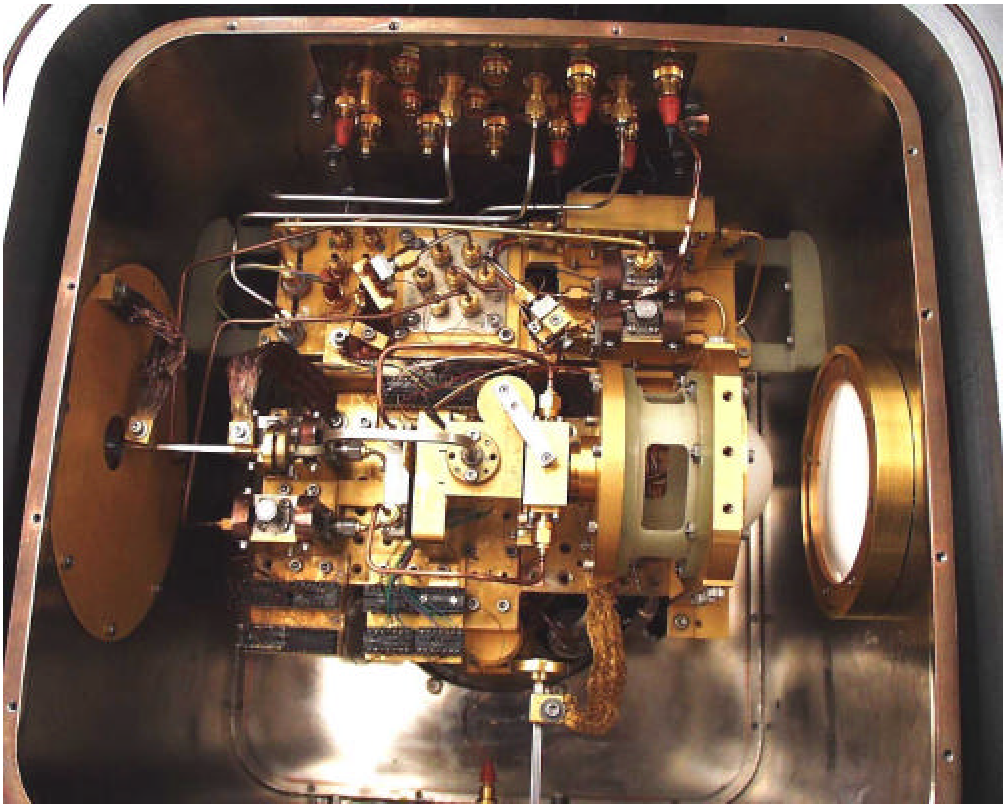


Figure 4: Photo of Dewar Components

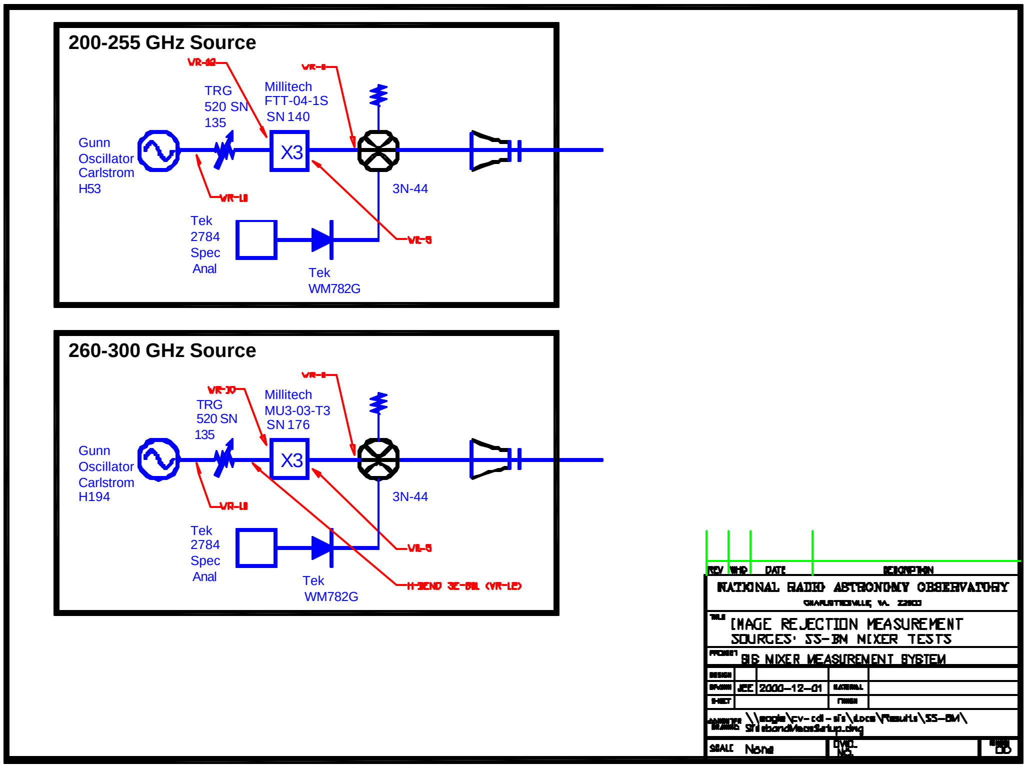


Figure 5: Image Rejection Measurement Sources

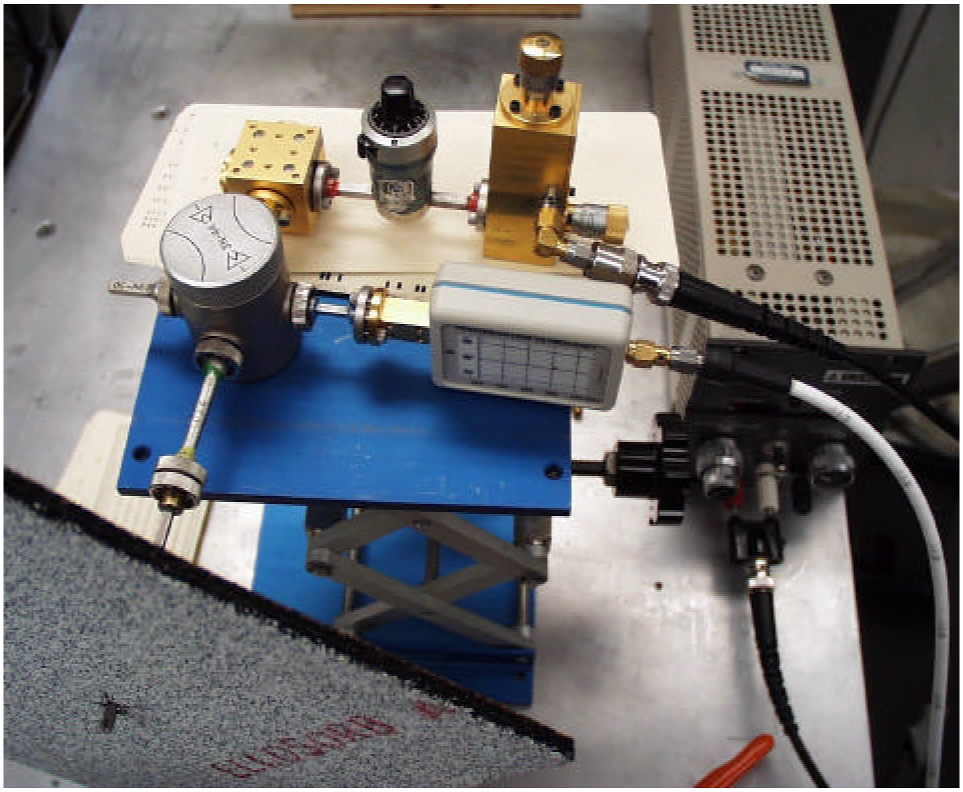


Figure 6 Photo of 200-260 GHz Image Rejection Source

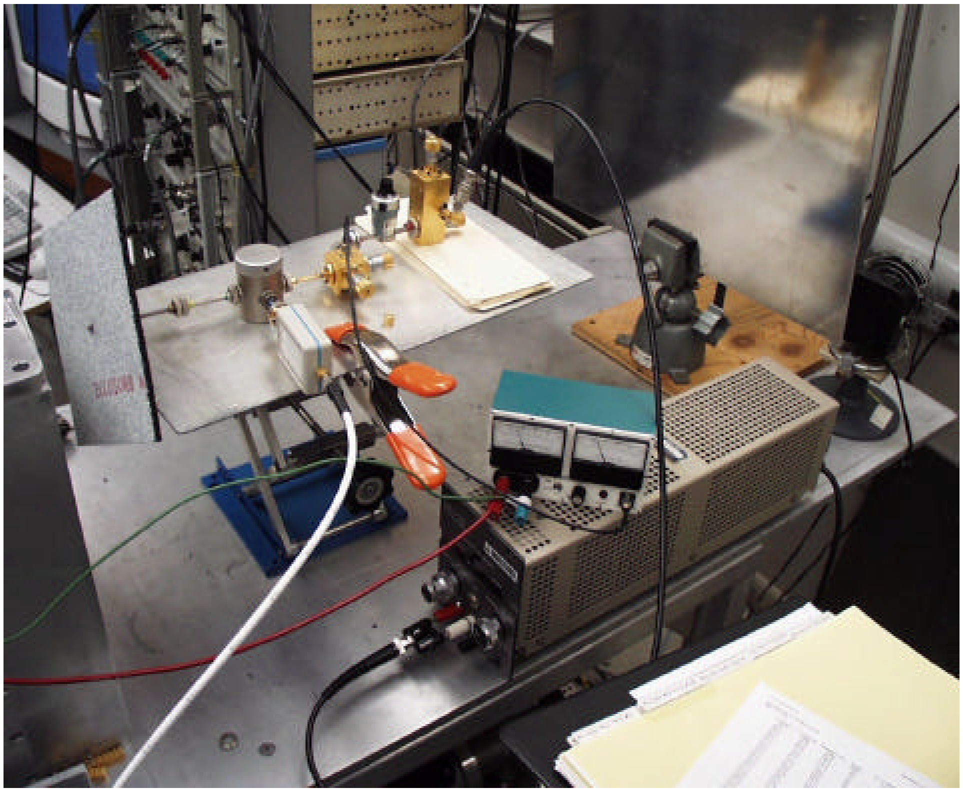


Figure 7: Photo of 260-300 GHz Image Rejection Source

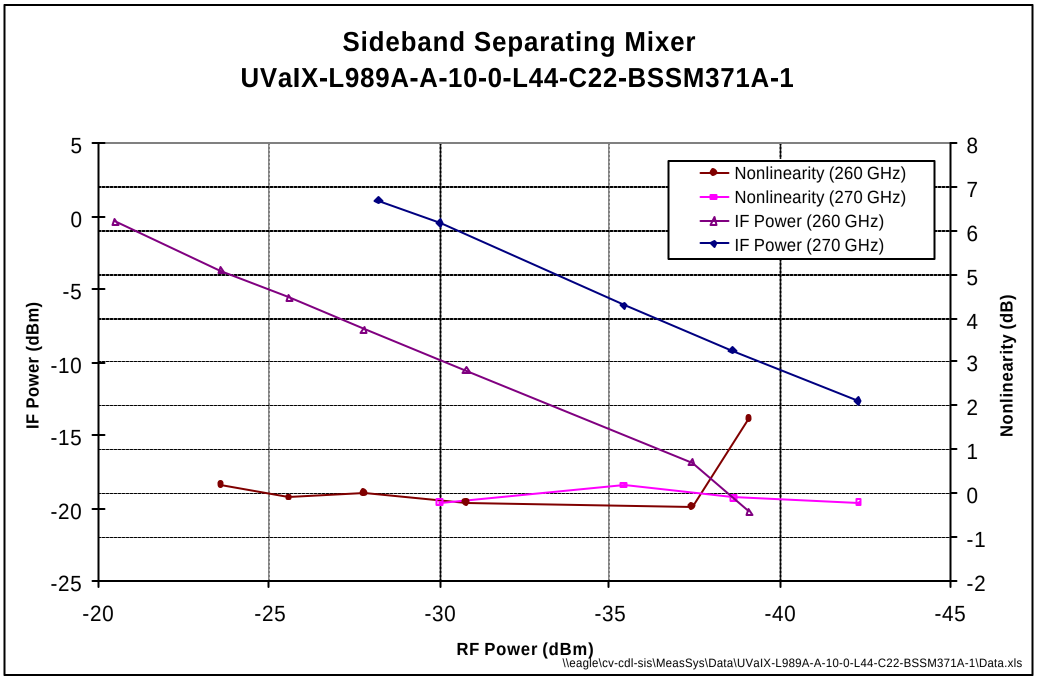


Figure 8: Linearity Measurements for Image Rejection Setup

8. Measured Data

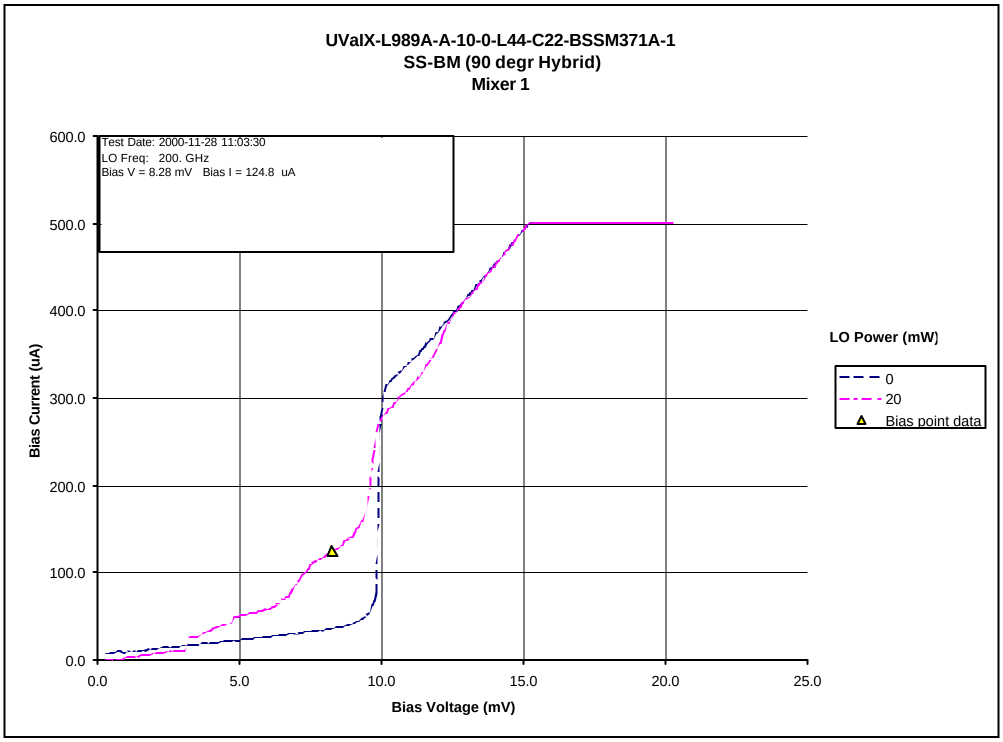


Figure 9: I-V Curve, Junction 1, 200 GHz

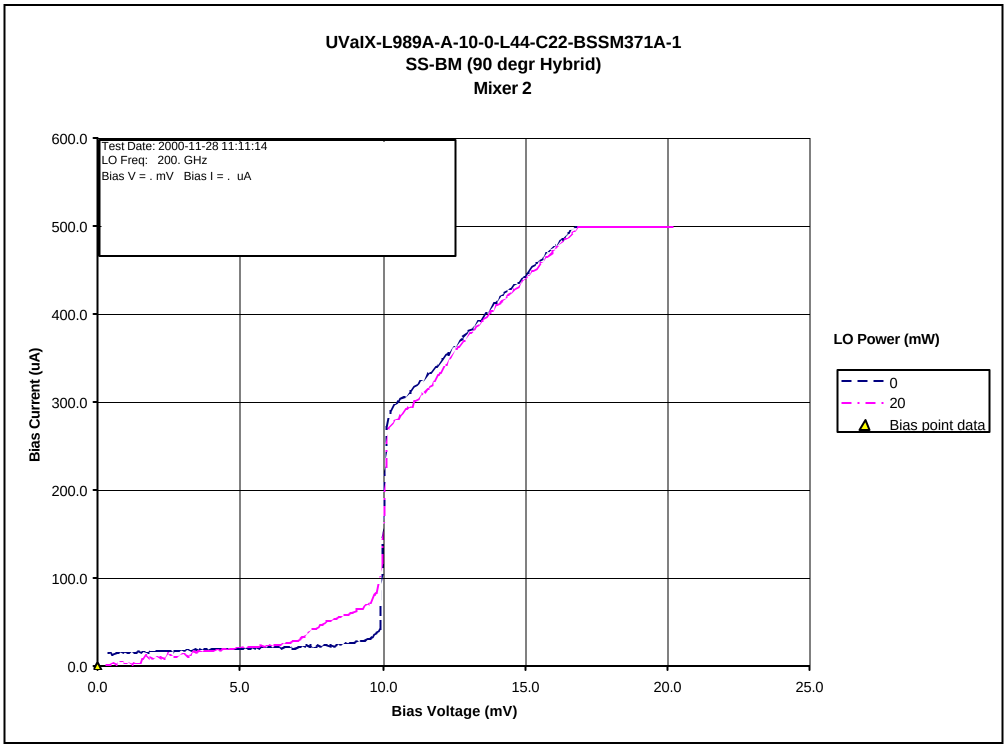


Figure 10: I-V Curve, Junction 2, 200 GHz

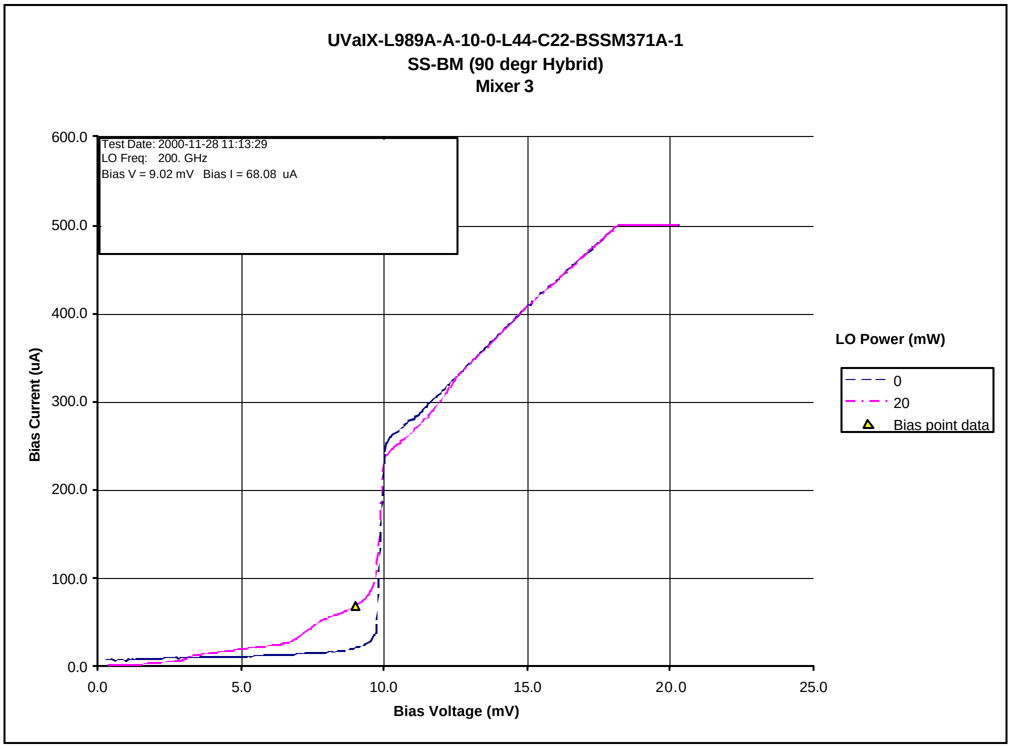


Figure 11: I-V Curve, Junction 3, 200 GHz

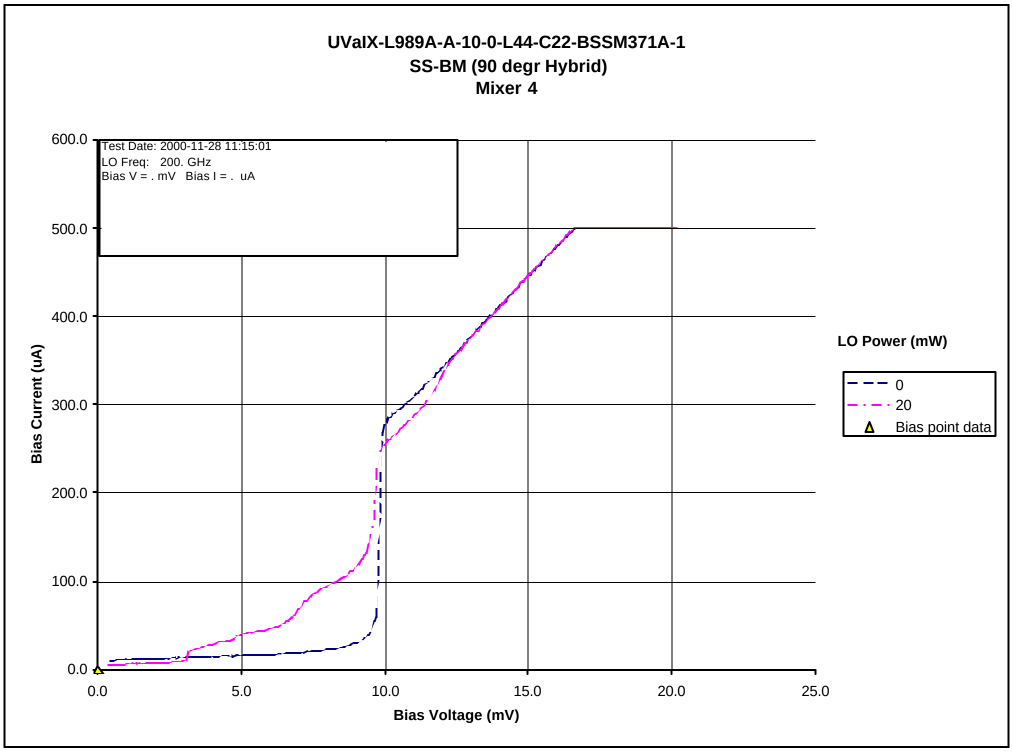


Figure 12: I-V Curve, Junction 4, 200 GHz

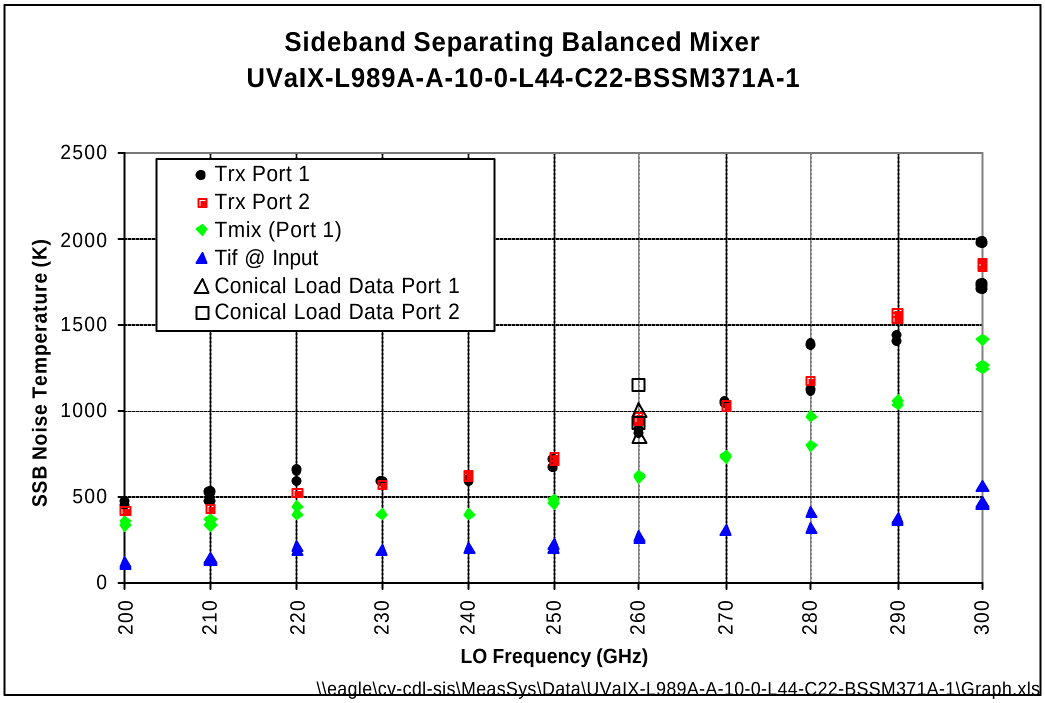


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Figure 13: SSB Receiver and Mixer Noise Temperatures

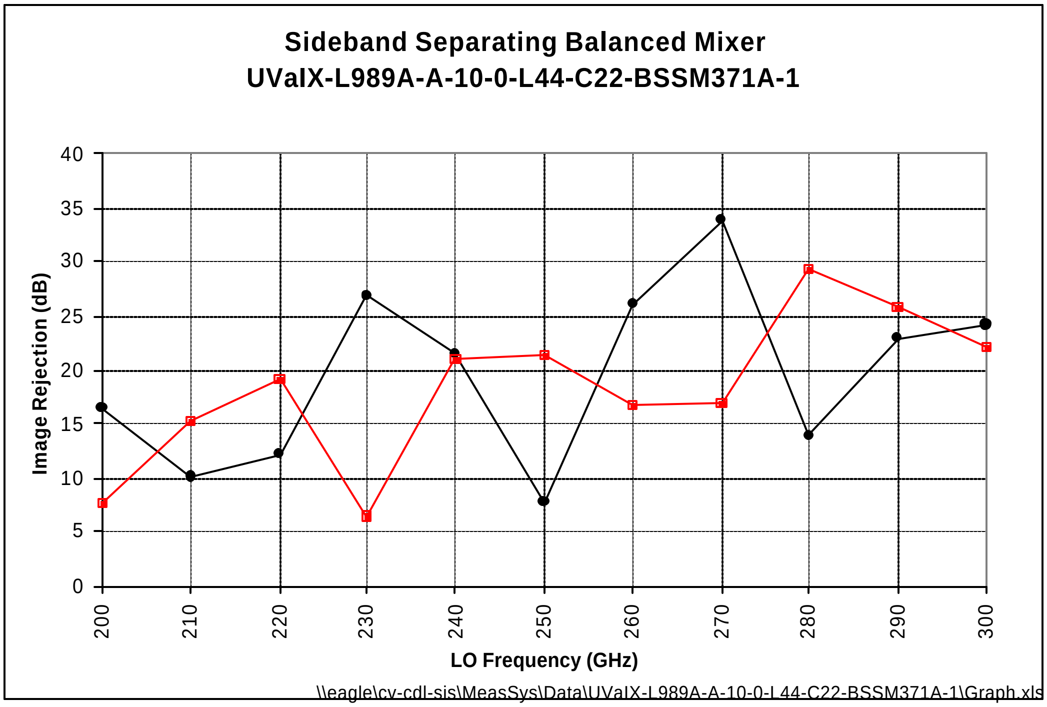

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Figure 14: Image Rejection

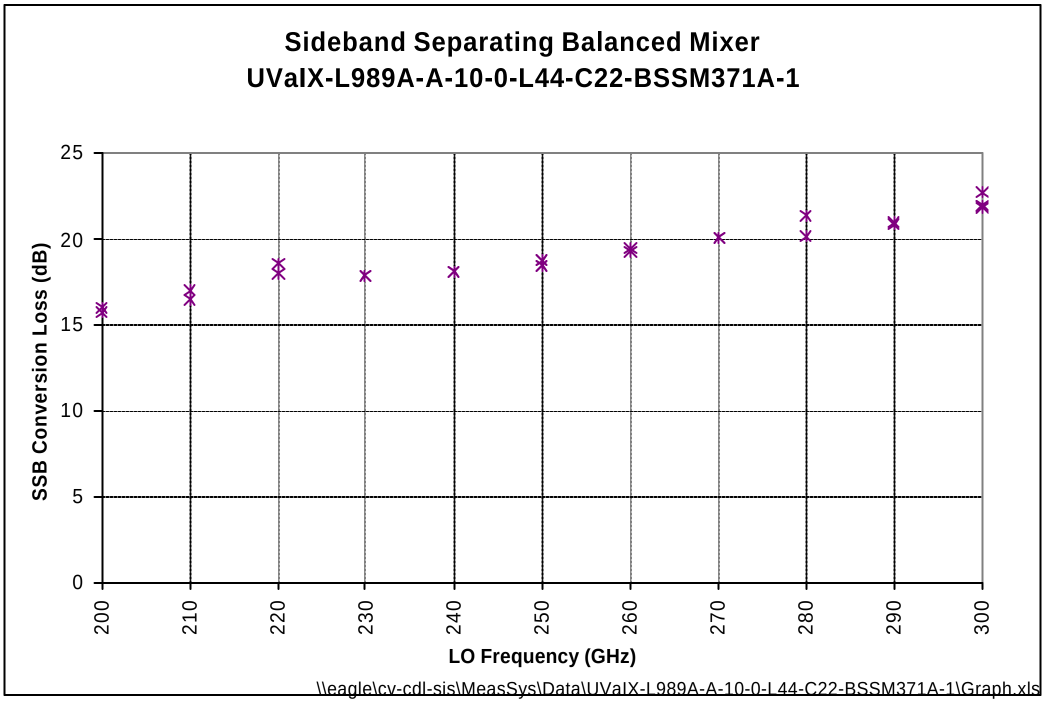

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Figure 15: SSB Conversion Loss

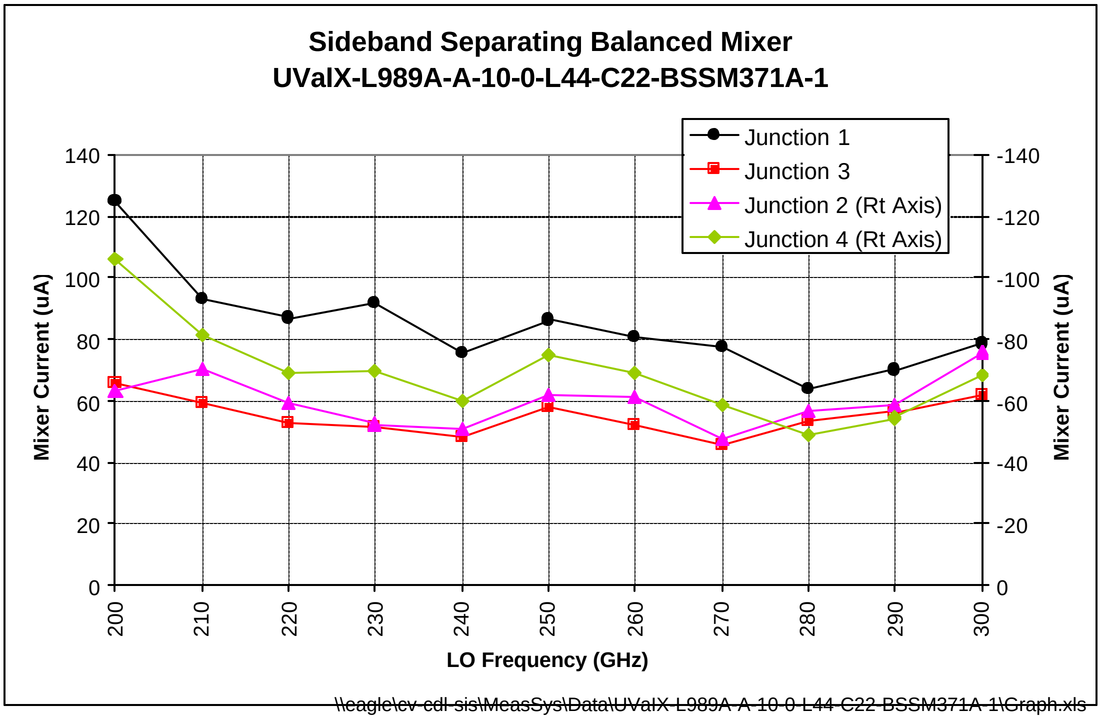

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Figure 16: Mixer Current vs. LO Frequency