Memorandum

To:	A. Grichener	C. Holmstedt		
cc:	R. Groves G. Lauria A. Perfetto	A.R. Kerr G. Ediss	D. Koller J. Payne	
From:	John Effland			
Date:	2004-02-10			

Revisions:

Version	Date	Who	Notes
00	2003-09-05	jee	Initial
01	2003-09-15	jee	Added link to specifications
02	2004-02-03	jee	Updated Fig 1 from Grichener's comments
03	2004-02-06	jee	Updated Fig 3 and added spreadsheet templates
04	2004-02-10	jee	Added bias point data collection

Subject: Mixer Measurement Sequences

1. Summary

The present suite of mixer-preamp measurements using the JT-2 test system employs a measurement sequence that's far from optimum. For example, mixer-preamp noise temperatures are measured separately from sideband rejection data even though the noise temperature data is again measured during the sideband rejection measurements. Also, IF noise temperatures are measured repeatedly at every LO frequency even though the IF noise temperature is not a function of LO frequency.

The purpose of this document is to define a more optimum series of steps required to measure and/or optimize the following mixer parameters:

- Magnetic field optimization
- Mixer bias voltage optimization
- LO power optimization
- Mixer/receiver noise temperature and sideband ratio measurements

These sequences are essential to allow the measurement software to be designed efficiently. Measurement procedures for saturation and gain stability will be developed at a later date.

Software specifications are given at http://www.cv.nrao.edu/~jeffland/CartSWSpecs.pdf.

2. Sequence Diagrams

A type of sequence diagram is used here to diagram the order of steps required to perform a measurement. The top of each diagram shows all the parameters relevant to measuring mixer-preamps, and the sequence starts at the top of each diagram and generally flows to the bottom. Each time a parameter is either changed or recorded, a box corresponding to that parameter is drawn in the appropriate column. Other important parameters, such as mixer and Dewar physical temperatures, are not shown here but will be recorded.

The box labeled "Initial State" shows how certain parameters are set prior to starting the measurement sequence. Boxes labeled "Record Results" depict when certain parameters are stored (ultimately to the database). Parameter stepping blocks give the start, stop, step size, and units for the particular parameter to be stepped.

Arrows show just a single direction of measurement flow, which corresponds to the initial path through the measurement procedure. Upon completion of all steps along this initial path, the sequence returns to each parameter stepping block beginning with the stepping block at the bottom of the diagram. For example, the procedure diagrammed in Figure 1 initially follows the path from the top to the bottom of the diagram. Then the mixer bias voltage is stepped from 0 to 25 mV in 0.1 mV steps and the parameters described in the bottom "Record Results" block are recorded for each new mixer bias voltage. After all the bias voltages have been stepped, the magnet current is increased from 10 to 15 mA and all the mixer bias voltages are again stepped.

3. Assumptions

Because the software will be designed to work with production mixer-preamps, the parameter values for optimum performance should be relatively well known *a priori*. For example, this means that the magnetic field current can be optimized by setting the LO power to achieve about 50 µA of mixer current, even through the optimum mixer current will be found later.

4. Magnetic Field Optimization

The steps for data acquisition to optimize the magnetic field are diagrammed in Figure 1. The LO frequency is set initially to a beginning step value of 210 GHz, mixer bias is set for 8.5 mV, and the LO power is adjusted to provide 50 µA of mixer current. Then the system records LO power as detected from the mixer current, LO frequency, and IF frequency. Next, the magnet current is stepped and for each magnet current value, the mixer junction voltage is stepped. At each of these mixer junction voltage steps, the system records mixer junction voltage, mixer current, magnet current, and IF total power.

This routine collects data to create a series of curves of total IF power *vs*. mixer bias voltage with magnet current as a parameter. The optimum magnetic field occurs for the smoothest total IF power *vs*. mixer bias curve.

5. Mixer Bias Voltage and LO Power Optimization

The procedure for optimizing mixer bias voltage and LO power is diagrammed in Figure 2. For each LO frequency, the LO power is set initially to achieve a mixer current of 50 µA and the magnetic field is set to the optimum value found previously as described in Section 4 above. A number of parameters are stored and then the LO power is set to an initial value that yields 25 µA of mixer current. Next, the IF attenuator value is optimized so that the power meter will remain on a single range as the RF load is changed from hot to cold. After recording the optimum IF attenuator value, the mixer bias is stepped from 7 to 10 mV while the RF load alternates between hot and cold positions. IF noise power is recorded for each RF load position using the fast power meter routines.

6. Receiver and Mixer-Preamp Noise Temperature and Sideband Ratio Measurement

The sequence for measuring both receiver noise temperature and sideband ratio is diagrammed in Figure 3. The sequence is partitioned into individual measurement groups that are independent from each other. This means that their relative position in the sequence can be easily changed. Included in the diagram is the cell address in the spreadsheet template that holds the measured data. The spreadsheet template also holds the equations used to calculate noise temperatures, sideband ratios, and mixer-preamp gain. Each row of the spreadsheet corresponds to a particular IF at a particular LO frequency.

For each LO frequency, the mixer is set for optimum magnet current, optimum bias voltage, and optimum LO power as measured previously.

As shown in Figure 3, first sideband signal levels are measured in the box “Measure Sideband Signal Levels” and copied to the appropriate cell locations. First, the attenuator value is determined while the receiver is view the hot load and before the sideband source is turned on. It will be necessary to check the total power from both mixer-preamp ports in order to set the attenuator to the maximum value. The attenuator value is then written out to the appropriate cell in the spreadsheet. Once set, the attenuator doesn’t change until a new IF frequency is selected.

The box “Auto LO Injects USB” means that the sideband source is turned on and the chopper is configured so the receiver is viewing the hot load. This allows the sideband signal to be injected into the receiver because the injection waveguide is buried in the hot load. The sideband frequency will ultimately be set by the automated LO but initially the software should prompt the user to tune manually the sideband source to the frequency calculated by the software:

$$F_{USB} = F_{LO} + IF$$
$$F_{LSB} = F_{LO} - IF.$$

The sequence shown in Figure 3 minimizes the time required to perform the sideband measurements by assuming that the chopper is commanded to a particular hot- or cold-load state. This sequence can be changed if the chopper wheel is rotated continuously. The box “Adjust LO Level” must be performed manually, so the software needs to prompt the user at this point.

Next, mixer-preamp noise powers are measured “Measure Mixer-Preamp Noise Powers (No Signal)” with the sideband source turned off. This is the usual receiver noise temperature measurement and hot- and cold-load noise powers are measured for each of the two mixer-preamp outputs.

Noise powers of the IF system are measured in the box “Measure Mixer-Preamp Noise Powers (No Signal)” and the procedure is different for the Mixer Test System (MTS) and Cartridge Test System (CTS). The Mixer Test System has coaxial hot- and cold-loads for IF measurements that are selected with the IF switch. The Cartridge Test System uses a noise diode to inject known noise powers into the front of the warm IF plate. The “cold-load” in that case corresponds to the noise diode being OFF, and the hot-load corresponds to the noise diode being on.

Finally, physical temperatures are measured in the box “Measure Physical Temps of Loads” and again they are different for the two test systems. The Mixer Test System temperatures are measured by reading the appropriate channel on the LakeShore Temperature Meter. The effective temperature of the IF hot load for the Cartridge Test System is not a physical temperature but is determined from the excess noise ratio of the noise diode. The IF cold load temperature is just room temperature for this measurement, which is proportional to the amount of noise power injected when the noise diode is OFF.

The effective temperature of the cold load differs for both measurement systems and is a constant determined from experiment.

The sequence repeats until all IF and LO frequencies are measured, with each new measurement frequency entered as a new row on the spreadsheet.

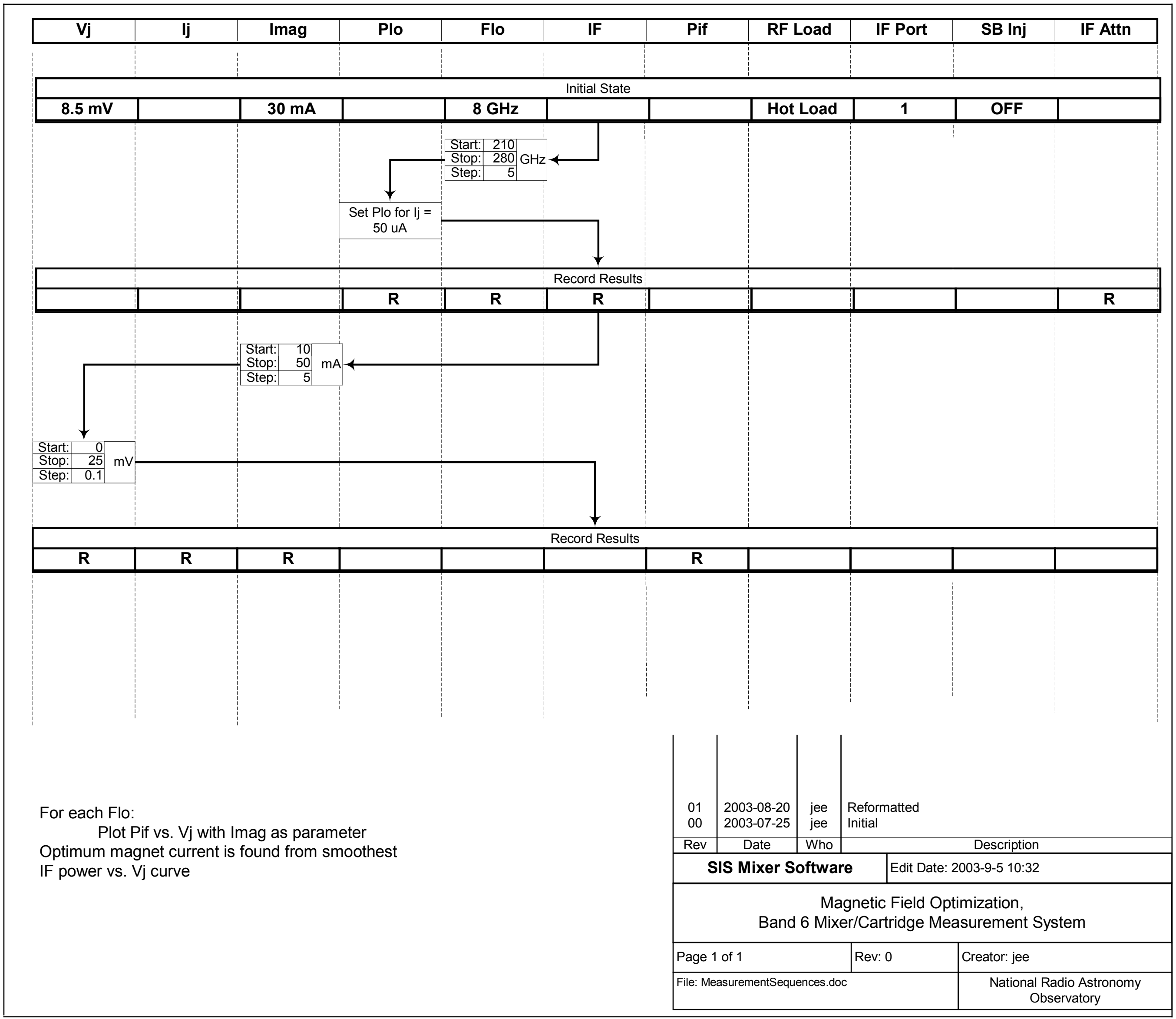

Figure 1: Magnetic field optimization sequence

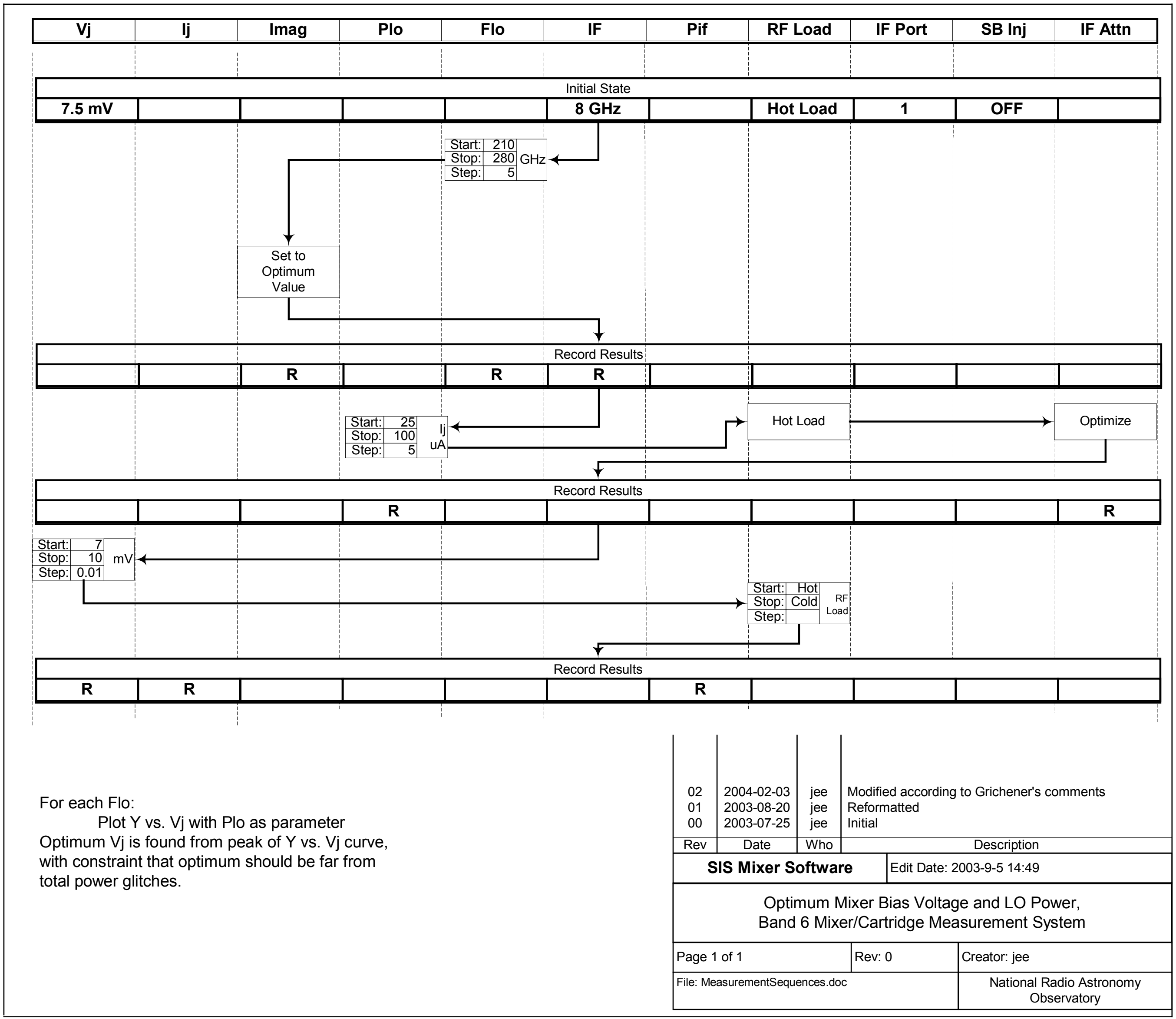

Figure 2: Mixer bias voltage optimization sequence

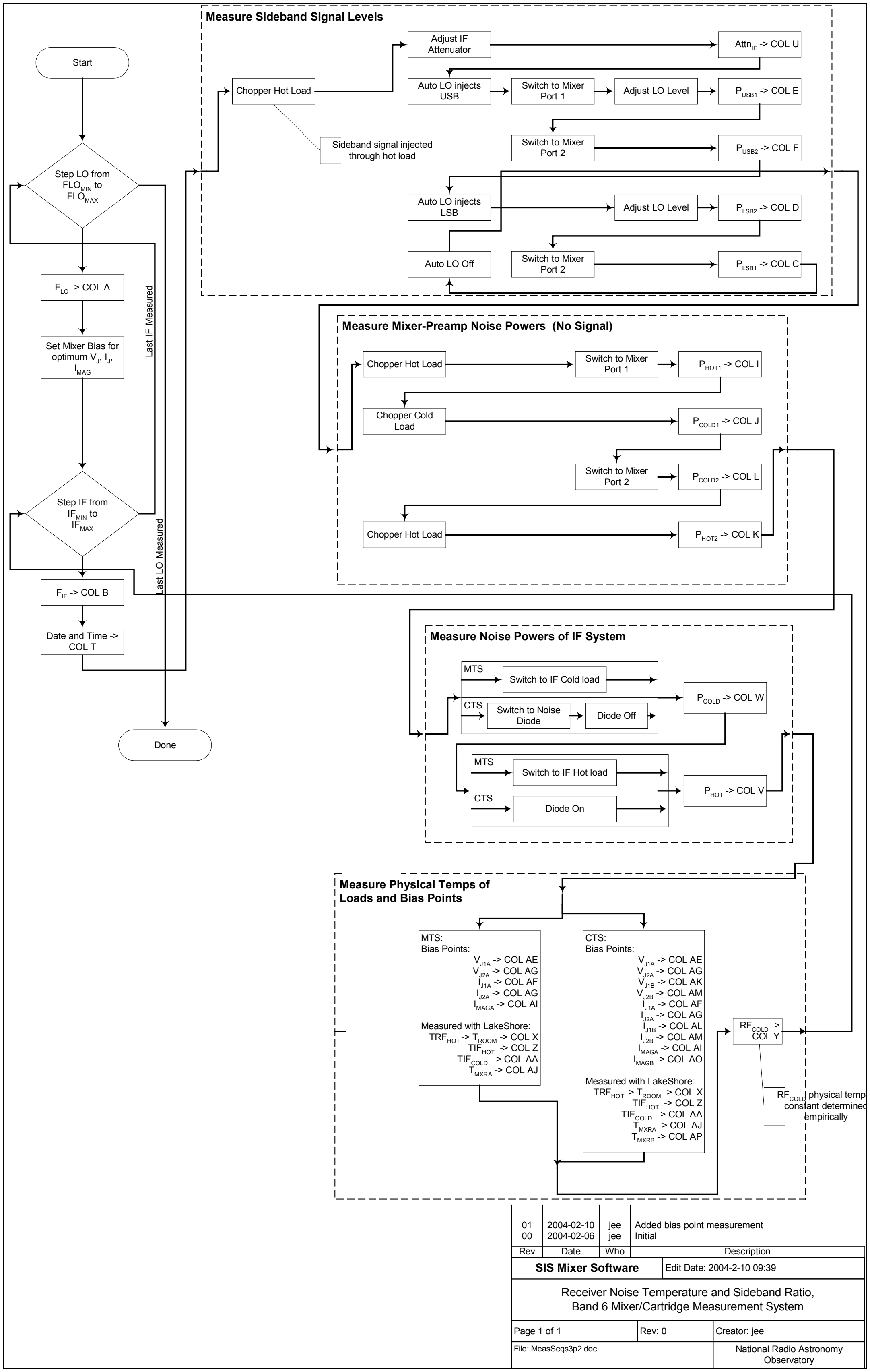

Figure 3: Receiver noise temperature and sideband ratio measurement sequence

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
3	Thot	298																	
4	Tcold	93.5																	
5																			
6																			
7			**LSB**		**USB**				No Signal							RX Noise Temp			
8			IF Levels		IF Levels				IF Port 1		IF Port 2					Uncorrected		Corrected	
9	Freq LO (GHz)	IF (GHz)	Port 1 (USB)	Port 2 (LSB)	Port 1 (USB)	Port 2 (LSB)	M_u (dB)	M_l (dB)	P_{hot1} (dBm)	P_{cold1} (dBm)	P_{hot2} (dBm)	P_{cold2} (dBm)	M_{dsb} (dB)	R_1 (dB)	R_2 (dB)	Port 1	Port 2	Port 1	Port 2
10	230	4	-30.0	-20.0	-20.0	-30.0	10.4	10.4	-40.0	-50.0	-40.0	-50.0	0.0	10.4	10.4	-70.8	-70.8	-77.2	-77.2
11	230	5	-30.0	-20.0	-20.0	-30.0	10.4	10.4	-40.0	-50.0	-40.0	-50.0	0.0	10.4	10.4	-70.8	-70.8	-77.2	-77.2
12	230	6	-30.0	-20.0	-20.0	-30.0	10.4	10.4	-40.0	-50.0	-40.0	-50.0	0.0	10.4	10.4	-70.8	-70.8	-77.2	-77.2
13	230	7	-30.0	-20.0	-20.0	-30.0	10.4	10.4	-40.0	-50.0	-40.0	-50.0	0.0	10.4	10.4	-70.8	-70.8	-77.2	-77.2
14	230	8	-30.0	-20.0	-20.0	-30.0	10.4	10.4	-40.0	-50.0	-40.0	-50.0	0.0	10.4	10.4	-70.8	-70.8	-77.2	-77.2
15	230	9	-30.0	-20.0	-20.0	-30.0	10.4	10.4	-40.0	-50.0	-40.0	-50.0	0.0	10.4	10.4	-70.8	-70.8	-77.2	-77.2
16	230	10	-30.0	-20.0	-20.0	-30.0	10.4	10.4	-40.0	-50.0	-40.0	-50.0	0.0	10.4	10.4	-70.8	-70.8	-77.2	-77.2
17	230	11	-30.0	-20.0	-20.0	-30.0	10.4	10.4	-40.0	-50.0	-40.0	-50.0	0.0	10.4	10.4	-70.8	-70.8	-77.2	-77.2
18	230	12	-30.0	-20.0	-20.0	-30.0	10.4	10.4	-40.0	-50.0	-40.0	-50.0	0.0	10.4	10.4	-70.8	-70.8	-77.2	-77.2
19																			
20																			

Figure 4: Spreadsheet Template for Sideband Ratio and Noise Temperatures (Part I: RF Noise Power Section)

	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1											
2											
3											
4											
5											
6											
7											
8	Date & Time		IF System		Physical Temps (K)						
9	2004-01-28 12:59:00	IF Attn (dB)	P_{hot} (dBm)	P_{cold} (dBm)	T_{RF}Hot	T_{RF}Cold	T_{IF}Hot	T_{IF}Cold	T_{IF}Noise (K)	$G_{MXR-AMP}$ (dB)	$T_{MXR-AMP}$ (K)
10	2004-01-28 12:59:00	1.0	-40.0	-50.0	298.0	91.0	50.0	4.2	48.9	-6.6	-69.7
11	2004-01-28 12:59:00	1.0	-40.0	-50.0	298.0	91.0	50.0	4.2	48.9	-6.6	-69.7
12	2004-01-28 12:59:00	1.0	-40.0	-50.0	298.0	91.0	50.0	4.2	48.9	-6.6	-69.7
13	2004-01-28 12:59:00	1.0	-40.0	-50.0	298.0	91.0	50.0	4.2	48.9	-6.6	-69.7
14	2004-01-28 12:59:00	1.0	-40.0	-50.0	298.0	91.0	50.0	4.2	48.9	-6.6	-69.7
15	2004-01-28 12:59:00	1.0	-40.0	-50.0	298.0	91.0	50.0	4.2	48.9	-6.6	-69.7
16	2004-01-28 12:59:00	1.0	-40.0	-50.0	298.0	91.0	50.0	4.2	48.9	-6.6	-69.7
17	2004-01-28 12:59:00	1.0	-40.0	-50.0	298.0	91.0	50.0	4.2	48.9	-6.6	-69.7
18	2004-01-28 12:59:00	1.0	-40.0	-50.0	298.0	91.0	50.0	4.2	48.9	-6.6	-69.7
19											

Figure 5: Spreadsheet Template for Sideband Ratio and Noise Temperatures (Part I: If Noise and Physical Temps Section)

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP
1												
2												
3												
4												
5												
6												
7												
8	Bias Points, Pol A						Bias Points, Pol B					
9	V_{J1A} (mV)	I_{J1A} (uA)	V_{J2A} (mV)	I_{J2A} (uA)	I_{MAGA} (mA)	T_{MXRA} (K)	V_{J1B} (mV)	I_{J1B} (uA)	V_{J2B} (mV)	I_{J2B} (uA)	I_{MAGB} (mA)	T_{MXRB} (K)
10	8.0	50.0	8.0	50.0	25.0	4.0	8.0	50.0	8.0	50.0	25.0	4.0
11	8.0	50.0	8.0	50.0	25.0	4.0	8.0	50.0	8.0	50.0	25.0	4.0
12	8.0	50.0	8.0	50.0	25.0	4.0	8.0	50.0	8.0	50.0	25.0	4.0
13	8.0	50.0	8.0	50.0	25.0	4.0	8.0	50.0	8.0	50.0	25.0	4.0
14	8.0	50.0	8.0	50.0	25.0	4.0	8.0	50.0	8.0	50.0	25.0	4.0
15	8.0	50.0	8.0	50.0	25.0	4.0	8.0	50.0	8.0	50.0	25.0	4.0
16	8.0	50.0	8.0	50.0	25.0	4.0	8.0	50.0	8.0	50.0	25.0	4.0
17	8.0	50.0	8.0	50.0	25.0	4.0	8.0	50.0	8.0	50.0	25.0	4.0
18	8.0	50.0	8.0	50.0	25.0	4.0	8.0	50.0	8.0	50.0	25.0	4.0
19												

Figure 6: Spreadsheet Template for Sideband Ratio and Noise Temperatures (Part III: Mixer Bias Section)