ALMA Band 6 Cartridge Measurement System

Software Specifications

2003-09-23

Version 1.31

Revisions

Table 1: Document Revisions

Revision Number	Date	Who	Details
1.0	2002-12-18	jee	Initial
1.1	2002-12-19	jee	ARK - Sideband ratio can be measured DK - clean up references to cold IF
1.2	2003-07-22	jee	Added total power measurements to IV curves.
1.3	2003-09-12	jee	1) Removed refrigerator line pressures 2) Added sideband isolation and more temperature monitoring 3) Consolidated measured parameters to a single table
1.31	2003-09-23	jee	Added capability to set nominal bias point

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1. Introduction

This document provides software specifications for the cartridge measurement system. These specifications describe the cartridge characteristics to be measured by the software, the plots provided, and tables available as output data. Such specifications are essential to prevent scope changes that always wreak havoc with software project schedules.

To simplify software design, coding, and testing, the cartridge measurement software will share many design elements with the mixer measurement software.

A related document that discusses the sequences required to measure mixer-preamps is "Mixer Measurement Sequences" found at http://www.cv.nrao.edu/~jeffland/MeasurementSequences.pdf.

2. References

All data will be stored in a database, and the details of that design are available at

http://www.cv.nrao.edu/~jeffland/dbSchema3.pdf.

3. Software Specifications

Section 3.1 below lists what the software will measure and subsequent sections describe how it will be measured.

3.1 Measured Parameters

Table 2 lists cartridge and test receiver characteristics that are measured by the system and will be stored in the database. Note that cartridge noise temperature and gain are calculated from these measured parameters and are listed in Table 3.

RF parameters are measured at each LO frequency and each IF.

Table 2: Measured Parameters -- Cartridge Testing

Parameter	Notes
Mixer Bias	
Voltage	
Current	
Total power	
Magnet current	
LO frequency	Nominal LO steps are 5 GHz.
LO power	Measured indirectly by recording the bias to the W-Band power amplifier
Effective cold load temperature	
Physical Temperatures: RF hot load .... Dewar cold head.. Dewar 90K stage .... Dewar 20K stage	Measured using: .... LakeShore temperature gauge .... LakeShore temperature gauge .... LakeShore temperature gauge .... LakeShore temperature gauge

[1] These may be needed for future temperature measurements, such as LN2 measurement for level control.

Table 2: Measured Parameters -- Cartridge Testing	
Parameter	**Notes**
Dewar 4K stage	.... LakeShore temperature gauge
Room	.... LakeShore temperature gauge
Spare temp 2[1]	.... LakeShore temperature gauge
Spare temp 3	.... LakeShore temperature gauge
90K cartridge stage	.... M&C
20K cartridge stage	.... M&C
4K cartridge stage	.... M&C
Mixer (Polarization A)	.... M&C
Mixer (Polarization B)	.... M&C
Vacuum Levels: Vacuum pump Dewar	
Warm IF system attenuator value	
Frequency of the IF system	Step sizes: • Every 100 MHz for noise temperature measurements (TBC) • Every 500 MHz for sideband measurements (TBC)
Noise powers with: • Test receiver connected to hot load • Test receiver connected to cold load • Warm IF system connected to noise diode turned on • Warm IF system connected to noise diode turned off	

3.2 Calculated Parameters

Table 3 lists the characteristics that are calculated from the measured data stored in the database. The calculated parameters also will be stored in the database but they can always be derived again from the stored measured data.

Table 3: Calculated Parameters -- Cartridge Testing	
Calculated Parameter	**Notes**
Receiver USB and LSB noise temperature	
Cartridge USB and LSB noise temperature	
Cartridge noise temperatures averaged over the entire IF band	
Receiver gain	
Cartridge gain	
Warm IF system noise temperature	
Warm IF system gain	
Standard deviation of mixer bias current	(Identifies instabilities)
LO noise	

3.3 Setting of Nominal Mixer Bias Point

The software will be able to set the mixer-preamp to its nominal mixer bias point for each mixer installed in a particular polarization. This corresponds to setting the following parameters for each polarization:

Table 4: Setting of Nominal Mixer Bias Point

Parameter to be set	Is a function of…	Notes
Component mixer 1 junction voltage	LO frequency	
Component mixer 1 junction current	LO frequency	Set by controlling LO pump power
Component mixer 2 junction voltage	LO frequency	
Component mixer 2 junction current	LO frequency	Set by controlling LO pump power
Mixer magnetic field	LO frequency	

This is accomplished by sending the mixer ID and LO frequency to this routine. The routine will then look up the nominal parameters in the database, then return and adjust mixer bias accordingly.

3.4 Measurement Procedures

Initially, the cartridge test software will use interim bias cards and monitor and control boards provided by Tucson. In most cases, manual control of the interim bias cards and M&C boards *via* a front-panel knob is not possible and requires the computer.

3.4.1 I-V Curves

The system will command the bias voltage to sweep between limits set by the operator. Mixer bias current and voltage will then be read back by the software *via* the monitor and control system and stored in a database. This means the bias voltage stored in the database may not exhibit equal step sizes.

3.4.1.1 Manual Intervention

The operator sweeps the mixer bias voltage, observes the I-V curve on the oscilloscope, and manually adjusts the Tucson-provided magnet current (using the CAN bus) to minimize the Josephson peaks with the LO off. The manual adjustment will be provided *via* a dialog box on the CRT.

3.4.1.2 Risks

The bias supplies and software control must be able to change the bias voltage rapidly so the operator can quickly minimize the Josephson peaks. The interim bias supplies are controlled via the CAN bus and it is unknown how fast the mixer bias voltage can change using the interim supplies. In the production version of the bias supplies, which will be controlled using the I^2C bus, it is essential to specify how fast the bias voltage must change so that the Josephson peaks can be identified and reduced.

3.4.2 Measurement of Magnet Current

The interim system measures magnet current using the Tucson-designed magnet supply that is controlled *via* the CAN bus. The magnet supply on the production system will most likely be controlled using the I^2C bus.

3.4.2.1 Risks

None

3.4.3 LO Frequency and LO power

The system will command the active multiplier and other modules associated with the LO to the proper frequency and power level. The power level will be controlled using the gate voltage on a W-Band power amplifier.

3.4.3.1 Risks

There are no plans to verify independently the frequency or power level of the LO. The measurement system cannot detect if the LO locks on a spurious signal and outputs the LO at an erroneous frequency. In addition, no independent monitoring of LO output level is planned. The LO level will be measured as a function of the amplifier gate voltage *a priori* using a power meter and the results will be stored in a database look-up table. Multiplier changes or even simple waveguide changes could render the lookup table obsolete.

3.4.4 Receiver Noise Temperature

The noise temperature of the entire measurement system, including the cartridge and warm IF systems, will be measured using a chopper wheel to switch automatically between the RF hot and cold loads.

Noise power will be measured with the power meter and perhaps the square law detector. Although the power meter should yield potentially higher accuracy measurements, a noise diode is also planned for the system to provide graphs of estimated receiver noise temperatures in real-time for tuning. It is hoped to use the noise diodes for the formal noise measurements to significantly decrease measurement times.

3.4.4.1 Risks

None

3.4.5 Cartridge and IF Noise Temperatures

The noise temperature of just the cartridge, without the noise added by the warm IF subsystem, will be measured by subtracting from the receiver temperature the noise contribution of the warm IF system. Noise figure and gain of the warm IF subsystem will be measured by using a noise diode to generate a known noise ratio at its input. The noise diode output level will be adjusted using an attenuator to deliver about the same noise power to the warm IF as is delivered by the cartridge.

3.4.5.1 Risks

None

3.4.6 Cartridge and IF Gain

Cartridge gain at each IF is found using the usual "ΔP/ΔT" equation by taking the ratio of measured noise powers to temperatures when the receiver input is connected to hot and cold loads. The gain of the receiver, which includes the cartridge and the warm IF subsystem, is obtained by alternately changing the receiver's beam between hot and cold loads using the chopper wheel:

$$G_{RF} = \frac{1}{kB}\left(\frac{P_{hRF} - P_{cRF}}{T_{hRF} - T_{cRF}}\right)$$

where

G_{RF} is the total receiver gain,
P_{hRF} is the power output from the total receiver when its input is connected to a hot load,
P_{cRF} is the power output from the total receiver when its input is connected to a cold load,
T_{hRF} is the radiometric temperature of the hot load connected to the RF input,
T_{cRF} is the radiometric temperature of the cold load connected to the RF input.

In a similar way, the gain of the warm IF subsystem is measured using a noise diode at its input to provide known noise powers corresponding to the diode's biased (on) and unbiased (off) states.

Gain of just the cartridge is found by normalizing overall receiver gain by the warm IF system gain, which becomes:

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

where

$G_{Cartridge}$ is the gain of the cartridge,
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 biased noise diode,
P_{cIF} is the power output from the IF system when its input is connected to an unbiased noise diode,
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 equivalent noise temperature of the biased noise diode connected to the IF input, and
T_{cIF} is the equivalent noise temperature of the unbiased noise diode connected to the IF input.

3.4.6.1 Risks

None

3.4.7 LO Noise

LO equivalent noise temperature, referred to the Dewar input, will be measured by comparing noise powers when the component mixers are normally biased (*i.e.* mixer bias voltages are of opposite polarities) and when both component mixers are supplied with the same polarity bias voltages. See http://www.cv.nrao.edu/~jeffland/LOTemps6.pdf for the measurement theory.

3.4.7.1 Risks

None

3.4.8 Sideband Rejection Ratio

The sideband rejection ratio will be determined from measuring IF output levels while reversing mixer bias with a constant signal injected by the sideband source. Only one sideband is output from the cartridge, so sideband rejection cannot be measured with the general technique described in Kerr *et. al.'s* ALMA Memo 357.

3.4.8.1 Risks

Measuring sideband rejection ratio with only one IF output available from each polarization hasn't been tested thoroughly so subtle effects may degrade measurements accuracy.

3.4.9 Optimization of IF Levels

The Agilent E4418B power meter using the E4412 power head has a specified total relative accuracy of ±2%. This assumes the power level is below –20 dBm, and in addition, the response time is maximized if the power level is above -40 dBm. Using the IF attenuator, IF levels will be adjusted to - 30 dBm when the system is receiving the maximum power by switching the receiver input into the hot load.

To minimize measurement times, the IF noise temperature and power levels for each IF of interest will be measured separately as a function of IF attenuator setting prior to measuring receiver noise temperatures.

3.5 Results

Table 5 itemizes the graphs of measurement results that will be available from the system. All graphs will be 2-dimensional types because 3-dimensional plots, while useful for R&D purposes, have limited utility for documenting the results of production systems.

Table 5: Graphs Available from Cartridge Measurement Software

Graph Number	Dependent Variable	Independent Variable	Parameter	Notes
MG1	Mixer bias current	Mixer bias voltage	LO ON LO OFF	Pumped and un-pumped I-V curves
MG2	Total power at a particular IF	Mixer bias voltage	Rcvr switched to RF hot load Rcvr switched to RF cold load	Total power can be graphed on the same plot as I-V curve. Y-factor plot also included with total power
MG3	Receiver noise temperature	IF	LO frequency	
		LO frequency	IF	
MG4	Cartridge noise temperature	IF	LO frequency	
MG5		LO frequency	IF	
MG6	Cartridge gain	IF	LO frequency	
MG7		LO frequency	IF	
MG8	IF noise temperature	IF	LO frequency	Referred to receiver input
MG9	IF gain	IF		Referred to receiver input
MG10	Dewar physical temperatures and pressures	Time		

3.6 Optimum Magnet Current

The optimum magnetic field current will be found by finding the smoothest curve of total power vs. junction voltage. The optimum magnetic field for each LO frequency will be stored in the database.

3.7 Optimum Mixer Operating Point

The software will store in the database the optimum mixer operating point for each LO frequency. The optimum operating point is found using the optimum magnet current and varying the junction voltage and LO power to achieve the best noise temperature.

3.8 Diagnostic Tests

Experience with the JT-2 mixer measurement system demonstrates the importance of confirming that the warm IF system is operating nominally by measuring its noise figure and amplitude response as a function of intermediate frequency. The noise temperature and gain will be measured as part of the mixer tests, but a separate software module will be available to measure the noise temperature and amplitude response. The amplitude response will be obtained from the "ΔP/ΔT" technique as described in Section 3.4.6 above.

LO power will be controlled by changing the gate voltage on the HFET in the W-Band power amplifier. Software will measure and store in the database the LO power output from the LO source as the gate voltage is changed.

Table 6: Diagnostic Tests and Data

Dependent Variable	Independent Variable	Parameter	Notes
Gain of warm IF system	IF	IF attenuator value	
Noise Temperature of warm IF system	IF	IF attenuator value	
LO power	LO level control command voltage	LO frequency	

3.9 Automation of Cool-Down Tasks

The software will monitor Dewar temperatures and pressures, and when the Dewar temperature is sufficiently low, the software will automatically throw the vacuum valve and turn off the vacuum pump.