1st LO Reference Synthesizer Test Module Specifications - BEND-56.02.00.00-006-A-SPE

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1 Abstract

A test set is required to provide a coherent 1st LO Reference for use in testing the Front End. The test set is used to provide an input to the ALMA 1st LO cartridge-mounted photomixer as a means of phase-locking the first LO.

What is envisaged is either:
1. A single wavelength laser source modulated with sufficiently high index to create phase coherent sidebands above 100 GHz or…
2. A two-laser phase- or injection-locked system with very low residual phase noise.

2 Technical Requirements

2.1 Input Reference

Single Frequency, low phase-noise RF CW source with +13 dBm power in the range of 8—12 GHz

2.2 Output Connector:

Single Mode Optical Fiber
E2000-APC Connector
Polarization-Maintaining Fiber strongly preferred

2.3 Description of Signal

The light contained on the fiber must consist of at least two optical wavelengths, which are mutually coherent. The two lightwaves will be used to form a millimeter-wave (MMW) heterodyne beat signal when mixed in an external photomixer. This MMW signal must meet a minimum power level requirement and cover an appropriate frequency range.

2.4 Lightwave Wavelength:

Fixed laser: 1556.2 nm
Tunable laser: 1556.4 –1157.4 nm
(see Note 1)

2.5 Frequency Difference Range:

The frequency difference is the difference between the two lightwave frequencies that is necessary to supply the heterodyne beatnote

The frequency difference range required is determined by the frequency range of the Local Oscillators for the first four bands as follows:

	Frequency Range (GHz)	Comment
Band 1	27.3—33	Not currently funded
Band 2	79.0—94.0	Not currently funded
Band 3	92—108	
Band 4	68.5—75.5	Japanese Cartridge
Band 5	87.5—99.5	Not currently funded
Band 6	74.3—87.7	
Band 7	94.3—121.7	
Band 8	79.4—97.6	Japanese Cartridge
Band 9	102.3—118	
Band 10	88.8-104.2	Japanese Cartridge

Table 1- Frequency bands and ranges for 1st LO reference.

Note: These are the frequency ranges required for full coverage. It is permissible to meet this requirement using optical or electronic switching, as devices such as the tunable laser, photomixer, and harmonic mixers would not be expected to cover the entire 27.3-121.7 Hz frequency range. The current ALMA prototype laser synthesizer uses four bands as follows to cover the frequency range shown in Table 1:

Band designator	Frequency Range	ALMA Bands
Band A	27.3 – 33.3 GHz	1
Band B	68.5 – 86.0 GHz	2,4,6,8
Band C	86.0 – 110.0GHz	2,3,5,6,7,8,10
Band D	110.0 – 141.6 GHz	7,9

Table 2 - Band ranges for the current ALMA laser synthesizer prototype

2.6 Output Power:

P1 >= 1 mW
P2 >= 1 mW

Where P1 is the output power from the fixed laser, and P2 is the output power from the tunable laser.

2.7 Phase Noise:

The phase noise requirement is set by the ALMA 1st LO phase noise requirement which is given as τ=53 fsec, where $\varphi = \omega * \tau$ and φ is the phase in radians, ω is the frequency in rad/sec, and τ is the RMS integrated time delay. Of this amount, the LO reference is allowed to contribute 50% of the total. Since the RMS contributions from the reference and the 1st LO oscillator are uncorrelated, they add as sum of squares. Thus, 53 fsec* $\sqrt{2}$ = 37.5 fsec is allowed from the 1st LO reference. The 1st LO reference phase noise may be calculated from the single-sideband phase noise in the usual way:

$$\Phi = 2 * \int_{1e3}^{1e7} L(f_0)df_0 = 2\pi * f * \tau$$

Where f_o is the offset frequency from the millimeter-wave beatnote signal at frequency f. In this equation, it is indicated that the phase noise may be integrated over the limited range of 1 kHZ to 10 MHz. This is because below 1 kHz the phase noise is expected to be common-mode between the 1st LO reference at each antenna. Above 1 kHz, the 1st LO Reference is no longer common mode because of the differential absolute time delays to each antenna. Further, the phase noise contributions above 10 MHZ are expected to be negligible because they will be suppressed by the phase-lock-loop of the 1st LO at the antenna. [see Note 2]

It must be shown that this 37.5 fsec phase noise requirement is met at all frequencies shown in Table 1. It is expected that the microwave synthesizer that supplies the reference frequency input to this device will contribute a significant fraction of the overall phase noise error budget. We allot this synthesizer a contribution of half of the squared-sum of RMS phase noise of 37.5 fsec* $\sqrt{2}$ = 26.5 fsec, and thus the same amount for the contribution from the residual laser phase noise. [see Note 3]

In any implementation, the microwave synthesizer may be expected to contribute a phase noise that is constant in units of fsec for all frequencies, and thus is linear in radians with frequency. That is, for a 26.5 fsec RMS level, the contribution to the 1st LO will be 26.5 fsec at either 27.3 GHz or 121.7 GHz. But the contribution in radians will be 4.5e-3 radians at 27.3 GHz and 20e-3 radians at 121.7 GHz.

If a two-laser solution is implemented, the residual laser phase noise after phase-locking of the lasers may be expected to contribute an amount that is a fixed number of radians. The RMS level in units of fsec will then be greatest at the lowest frequency of 27.3 GHz and highest at 121.7 GHz. For instance, if we again assume a contribution of 26.5 fsec or

4.5e-3 radians at 27.3 GHz, then that same 4.5e-3 radian contribution will be only 5.9 fsec at 121.7 GHz. In this sense, the "tightness" of the phase-locking that is required is 2-3X more difficult to meet for the 27.3-33 GHz Band1. This might suggest a separate single-laser solution just for Band 1.

2.8 Power Supplies:

The power supply used for the testset shall be an AC linear type supply. The mains power and any separate regulated and/or converted supplies in the box shall be well-isolated from the laser sources or any external modulation source so as not to add spurious noise to the laser outputs.

2.9 Package:

The device shall be standard rack mount width. Any significant heat generation shall be attached to a heat sink which radiates to the outside of the module. Cooling fans are discouraged but are permissible as a way of removing heat from the module if the laser sources and optical path are vibration isolated from the fans.

2.10 Tuning Interface:

All functionality shall be available via remote computer interface. This may be accomplished by Ethernet, GPIB, RS-232, or CANbus protocol. [see Note 4]

The monitor and control interface shall include as a provision for the following:

1. Readout and setting (if appropriate) of laser tuning voltages, currents, and temperatures
2. Lock status
3. Laser status
4. Setting and readback of any optical or electronic switches used for switching of bands
5. Readout and setting of laser frequency command
6. Readout of any important electronic or optical voltage/power levels

Devices supplied by NRAO: If necessary for the construction of a prototype version of this Test Set, NRAO will be able to provide a W-Band Harmonic Mixer, a Photomixer, and an optical switch.

3 Notes

1. The lightwave wavelength for the ALMA 1st LO reference is in the range 1556—1558 nm, but this is determined by the master laser wavelength. For the testset described herein, the wavelength need not necessarily be restricted to this range,

as long as the beatnote frequency was in the appropriate range and the wavelengths are sufficiently close to the intended ALMA range.

2. For purposes of testing the phase noise contributions, it is understood that access to millimeter-wave test equipment is not always available. For that reason, a proof-of-concept phase-locking at low frequency is encouraged. When promising results at low frequencies are attained, then the active collaboration between NRAO and the testbox supplier will be arranged for performing the high frequency phase noise measurements.
3. This discussion is framed using the assumption that a two-laser phase-lock-loop solution is used. If a highly-modulated single laser solution is used, then the 37.5 fsec limit must still be met with a microwave reference input that contributes 26.5 fsec.
4. The ALMA Laser Synthesizer will require a CANBUS interface that complies with several ALMA standards (insert references here)