
Atacama
Large
Millimeter
Array

# ALMA Back End
# Central Reference Generator Stability Test for ALMA Phasing Project

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# CHANGE RECORD

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| A | 2013-04-18 | All | - | Initial Release |
| | | | | |

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# 1. Description

## 1.1. Purpose

This test report documents the results of tests meant to determine the suitability of the ALMA Central Reference Generator output signals for use in the ALMA Phasing Project.

# 2. Related Documents and Drawings

## 2.1. Reference Documents

[RD 1] T4-Science iMaser 3000 Installation, Operations, and Maintenance Manual, Doc# T4S-Man-0012

[RD 2] BEND-55.03.00.00-002-A-DWG, ALMA Central Reference Generator Production Block Diagram

[RD 3] Symmetricom 5115A Data sheet, “High Performance Phase Noise and Allan Deviation Test Set, DS 5115A Doc 102612

[RD 4] Symmetricom 5120A/5120A-01/5115A Phase Noise Test Set, Operations and Maintenance Manual, DOC05120A, RevM

## 2.2. Abbreviations and Acronyms

| | |
|---|---|
| ALMA | Atacama Large Millimeter Array |
| APP | ALMA Phasing Project |
| CLOA | Central LO Article |
| CRG | Central Reference Generator |
| CVR | Central Variable Reference |
| LO | Local Oscillator |
| PLL | Phase Locked Loop |
| VCXO | Voltage Controlled Crystal Oscillator |
| VLBI | Very Long Baseline Interferometry |

## 3. Equipment Used in Test

### 3.1. H-Maser

The H-maser used by the ALMA Phasing Project is the T4-Science iMaser3000 **[RD 01]**. This maser was already in operation at Haystack Laboratory, which made Haystack the best location for the testing. The maser has outputs at 5 MHz (2), 10 MHz (4), and 100 MHz (2). The maser specification is

| Time | Allan Dev |
|---|---|
| 1 sec | 8e-14 |
| 10 sec | 1.9e-14 |
| 100 sec | 4e-15 |
| 1000 sec | 2e-15 |

**Table 1- H-Maser Allan Deviation specification**

### 3.2. Central Reference Generator

The Central Reference Generator is a custom ALMA Line Replaceable Unit(LRU) which provides the references for Central LO, Correlator, and Antennas. The block diagram is shown below. The 5 MHz Wenzel VCXO is phase-locked to an external reference (called "Maser" in the diagram) and this phase locked crystal oscillator is used to derive 5 MHz, 10 MHz, 125 MHz, and 2 GHz references as shown in Figure 1. The 10 MHz output in particular must be phase stable for VLBI because it provides the reference for the 1$^{st}$ Local Oscillator Central Variable Reference (CVR) microwave synthesizers.

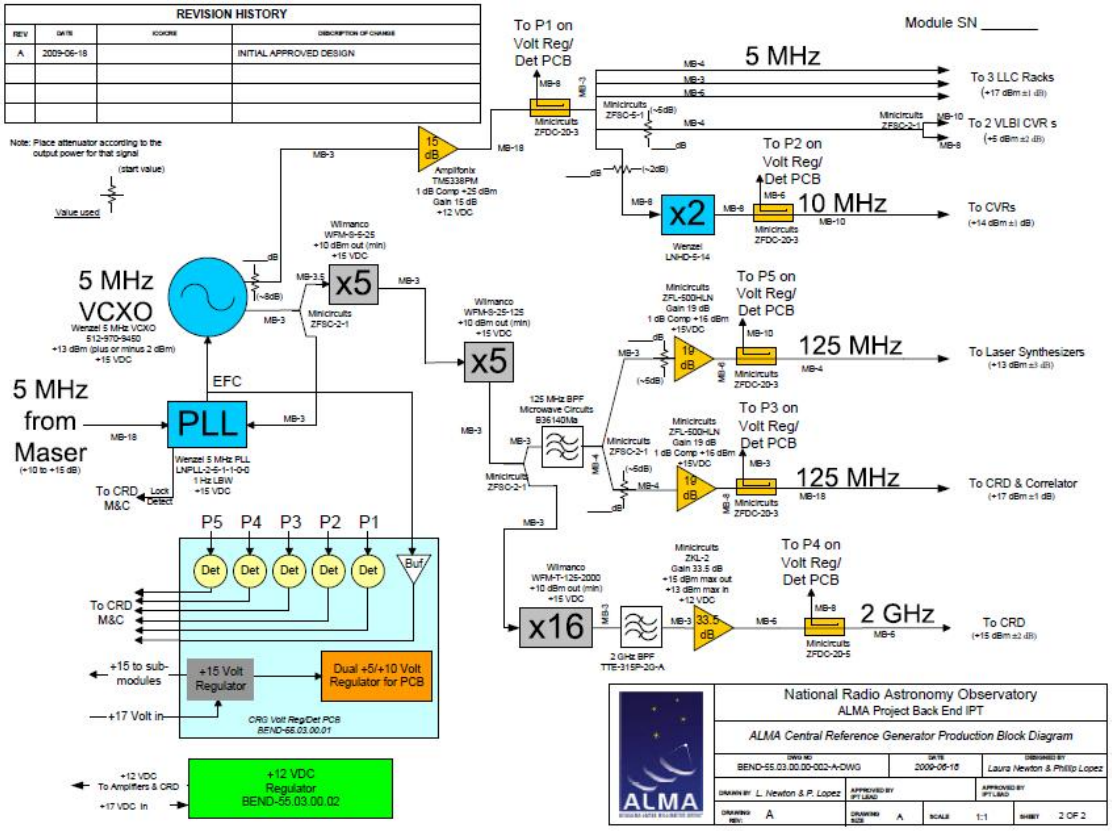


**Figure 1: CRG Block Diagram [RD 02].**

### 3.3. **Phase Noise Test Set**

For the measurements detailed below, the instrument used to measure the output phase and Allan Variance was Symmetricom 5115A Phase Noise Test Set **[RD 03], [RD 04].**

## 4. Test Configuration

Two test configurations were used. In the first, the 5 MHz output of the maser was used to lock the CRG. The phase test set measured between the CRG 10 MHz output and the maser 10 MHz output. This configuration measured the CRG stability (against the maser), as shown in Figure 2.

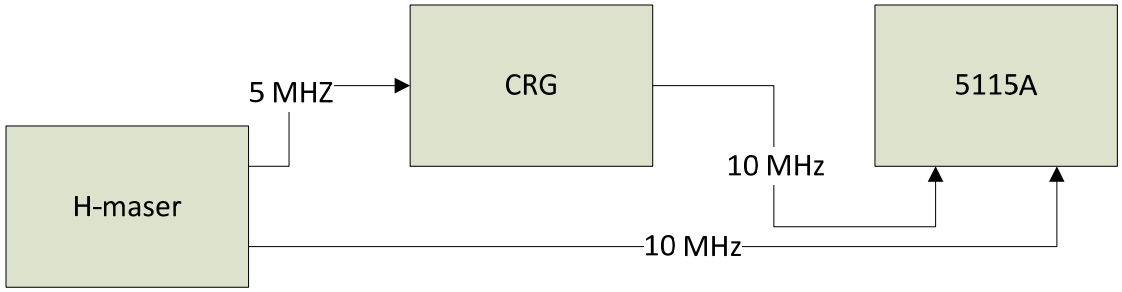


**Figure 2 – 1st Test configuration: CRG stability test**

In the second test configuration, the 5 MHz output of the maser was measured against the 10 MHz output. This configuration measured the stability of the maser 10 MHz output, as shown in Figure 3.

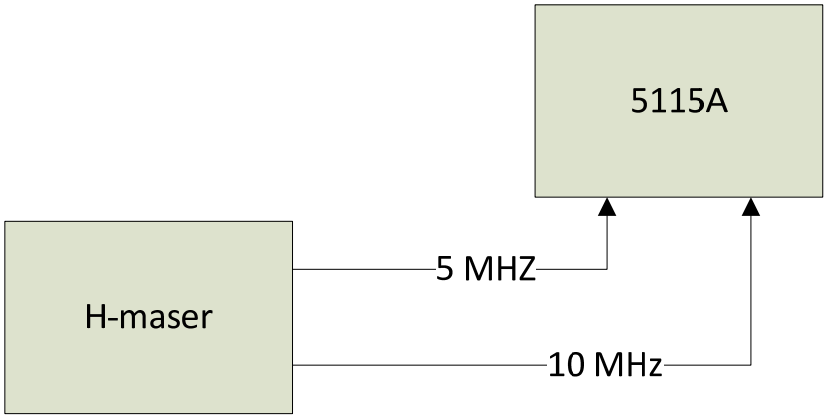


**Figure 3 - 2nd Test configuration: maser stability test**

## 5. Test Results

### 5.1. Allan Deviation and Phase Noise of CRG

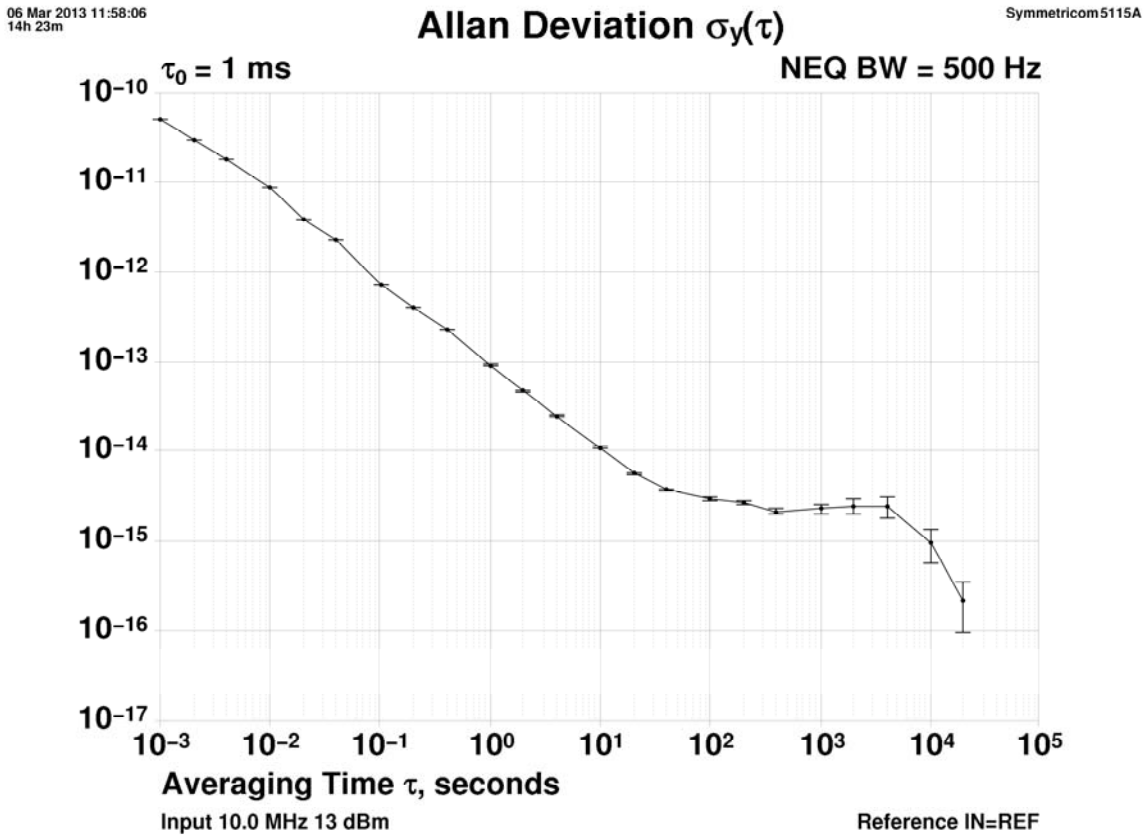


**Figure 4 - Allan Deviation of the CRG 10 MHZ output versus the Maser 10 MHz output**

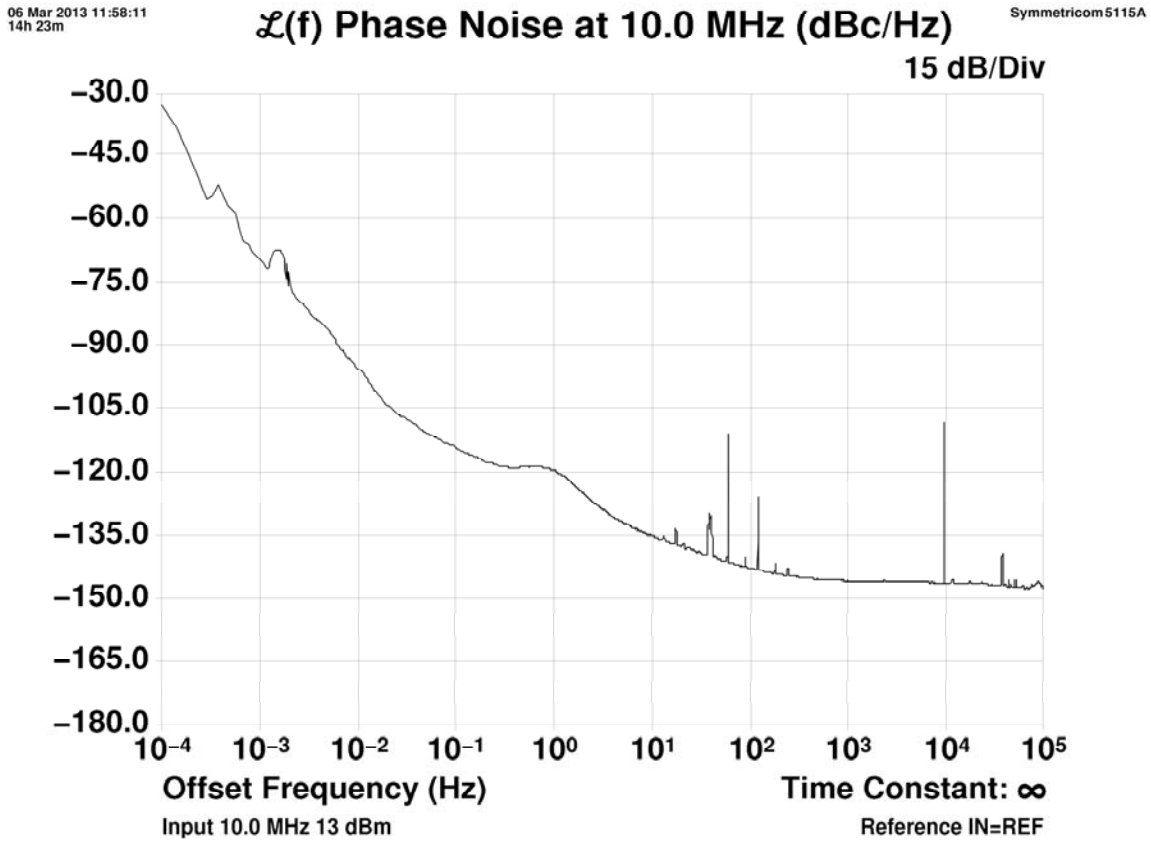


**Figure 5 - Phase Noise measured at CRG 10 MHz output**

## 5.2. **Allan Deviation and Phase Noise of H-Maser 10 MHz**

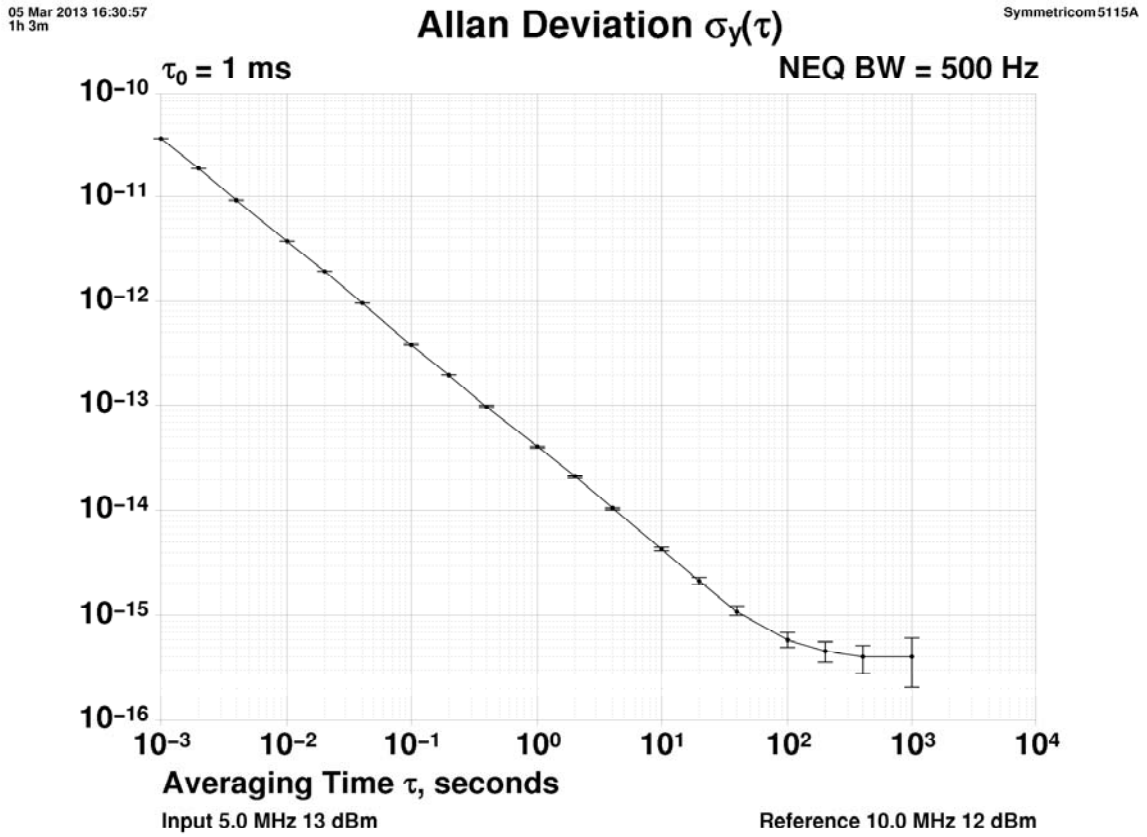


**Figure 6 - Allan Deviation measured between Maser 5 MHz and 10 MHz outputs**

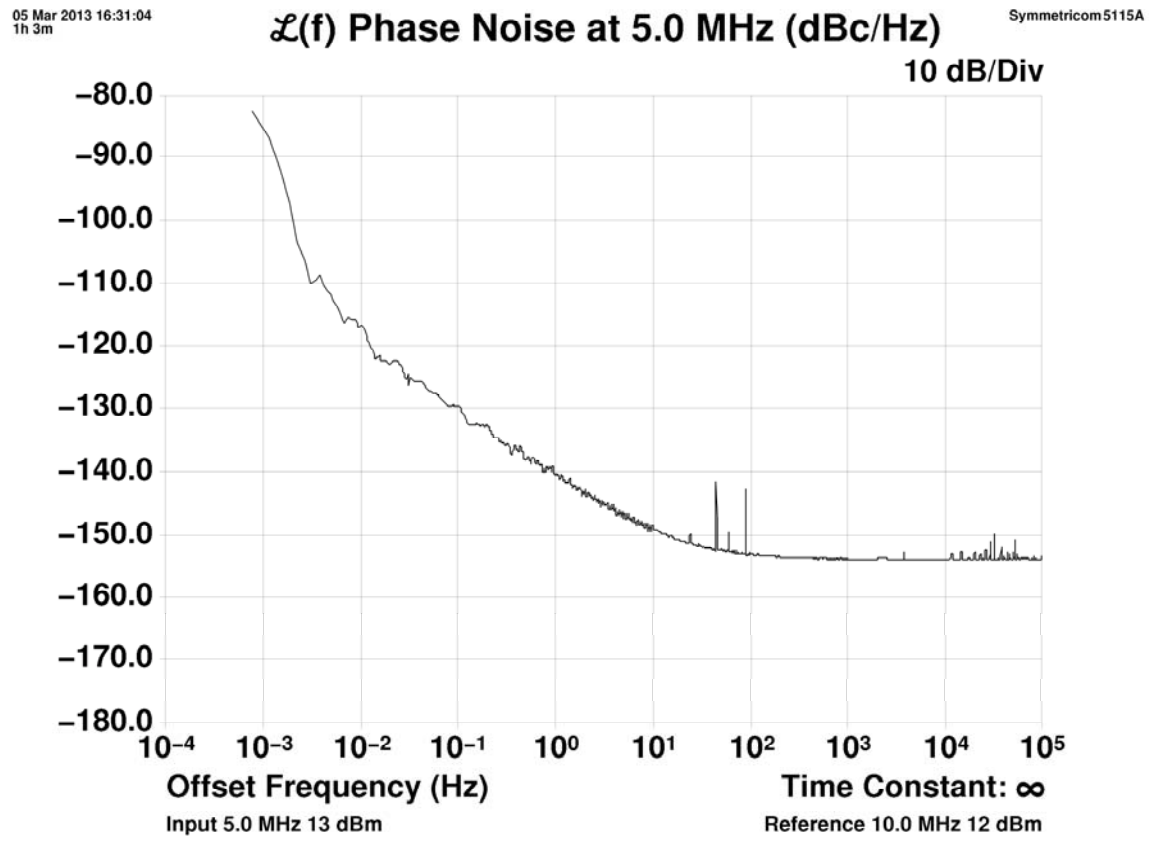


**Figure 7 – Phase Noise measured at H-maser output**

### 5.3. **Discussion**

A comparison of Figure 6 vs. Figure 4, and Figure 7 vs. Figure 5, clearly shows that the CRG introduces unwanted delay and noise. In particular, the Allan deviation plots show and approximate order of magnitude increase in the phase deviation above 100 seconds integration time. This will have a negative impact for the ALMA Phasing Project VLBI.

### 5.4. **Further measurement of Delay Sensitivities**

Further testing was done on the CRG to attempt to pinpoint the cause of the delay sensitivity. The module was opened up, and the temperature of the internal components was perturbed by either physically warming them by hand, or by changing the local air flow. There are three components in the 10 MHz path: the crystal oscillator, Amplifonix 15 dB amplifier, and Wenzel doubler. An initial test of heating by pressing on the components with fingers for 60 seconds appeared to indicate that the amplifier was the most sensitive device, followed by the doubler, and the VCXO was not very sensitive.

The next day (overnight March 5-6), the fan speed was reduced and the CRG warmed from 25.9 to 27 deg C, and the phase change was 140 psec, for a temperature coefficient of 127 psec/ deg C. It was later confirmed that the amplifier was the dominant contributor as its temperature coefficient was measured independently to be -110 psec/deg C (+/- 20%), and the doubler was ~ 20 psec/deg C.

## 6. Conclusion

The CRG 10 MHz output is not stable enough for the APP VLBI science. A remedy should be considered, possibly either:

- Replacing the unstable components in the CRG, or
- Using the 10 MHz output of the maser to directly input to the ALMA CVR.