Phase Noise Measurement Documentation

Alex Mott

October 28, 2009

The purpose of this document is to describe the steps necessary to measure the phase noise of an oscillator. It will assume that the reader knows how to use an SR785 (or similar), but will otherwise be fairly comprehensive. The basic wiring diagrams will be shown, as well as plots from a sample phase noise measurement between an AOM driver and a marconi.

1 Wiring the Feedback Loop

The basic wiring diagram is included in figure 1. Both the RF and LO are oscillators; the RF should have an amplitude roughly 10 dBm lower than the LO. In the figure the feedback is drawn to the LO, but can go to either; the measurement measures the relative phase noise between the LO and the RF, so it is useful to use an oscillator with known, small phase noise for one of these. The low pass filter accepts only the beat signal from the mixer, and the nominal frequency of the oscillators should be tuned to minimize the frequency of this beat signal (to reduce the gain necessary in the feedback loop). This beat signal is then amplified and the output fed back into the RF modulation input of the local oscillator.

The observed beat signal in closed loop mode should be essentially DC. Once this is achieved, the gain of the preamp and frequency response of the LO modulation (Hz/V) should be minimized while still maintaining lock. If using an RF source which is prone to drift (for instance an AOM driver that is still warming up), it is important to let the carrier frequency stabilize, or increase the gain stilghtly and take the measurement quickly. This will avoid having to adjust the gain or carrier frequency of the LO during the measurement.

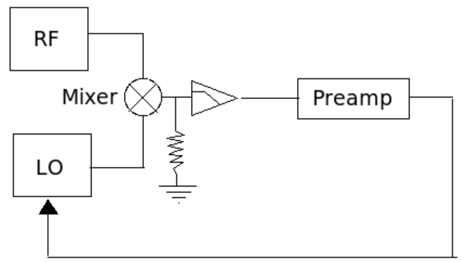

Figure 1: Basic Wiring Diagram for the Phase Noise Measurement

As an example of this procedure, I will be refering to a measurement of the phase noise of an AOM driver. For this measurement the components were as follows:

Element	**Device**	**Setting**
RF	ifr2023A (Marconi)	79.999554 MHz, +10dBm
LO	Isomet AOM driver model 232A-1	80 MHz (nominal) 22.9 dBm
Mixer	Mini-Circuits ZAY-1	
Filter	Mini-Circuits BLP-2.5	
Preamp	SR650	5× gain

2 Basics of the Measurement

The basic block diagram for this measurement is included in Figure 2. We denote the phase noise $\delta\phi$, and the suppressed phase noise $\delta\phi_S$, and define $G \equiv HFA$. From this one can see:

$$\begin{aligned}\delta\phi_S &= \delta\phi - AV_{feedback} \\ &= \delta\phi - G\delta\phi_S \\ \delta\phi_S &= \frac{\delta\phi}{1+G}\end{aligned}$$

so if we measure $\delta\phi_S$ and G, then we know the phase noise. G is easy to measure, it is simply the open loop transfer function of the system, which is convenient to measure on the $V_{feedback}$ section of the system.

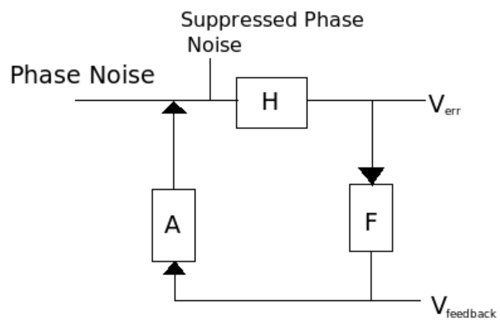

Figure 2: Block Diagram of the feedback system. We will refer to the phase noise as $\delta\phi$ and the suppressed phase noise as$\delta\phi_S$.

The suppressed phase noise can be measured in two steps. First, we measure the PSD of V_{err} (amplifying the V_{err} signal as much as possible to improve SNR), which has units of $\frac{V_{rms}}{\sqrt{Hz}}$. Next we measure the calibration factor of H in units of $\frac{V}{rad}$. This is done simply by removing the feedback, and measuring the V_{rms} of the beat signal. This value is simply the calibration factor of H in $\frac{V}{rad}$. It is important that the gain of the output amplifier not be changed (or any change noted and corrected for) as this will affect the final amplitude of the measured amplitude of the phase noise.

From this $\delta\phi_S = \frac{PSD\ V_{err}}{Calibration\ H}$, which gives $\delta\phi_S$ in units of $\frac{rad}{\sqrt{Hz}}$. The open loop transfer function, G, is measured in dB, so we can convert this to $\frac{V}{V_0}$ and then

$$\delta\phi = \delta\phi_S(1 + G)$$

Which has units of $\frac{V\ rad}{V_0\sqrt{Hz}}$. This is the phase noise between the LO and the RF inputs to the mixer.

Included are examples of the two spectra measured in the calculation (the PSD and G) and a final phase noise measurement.

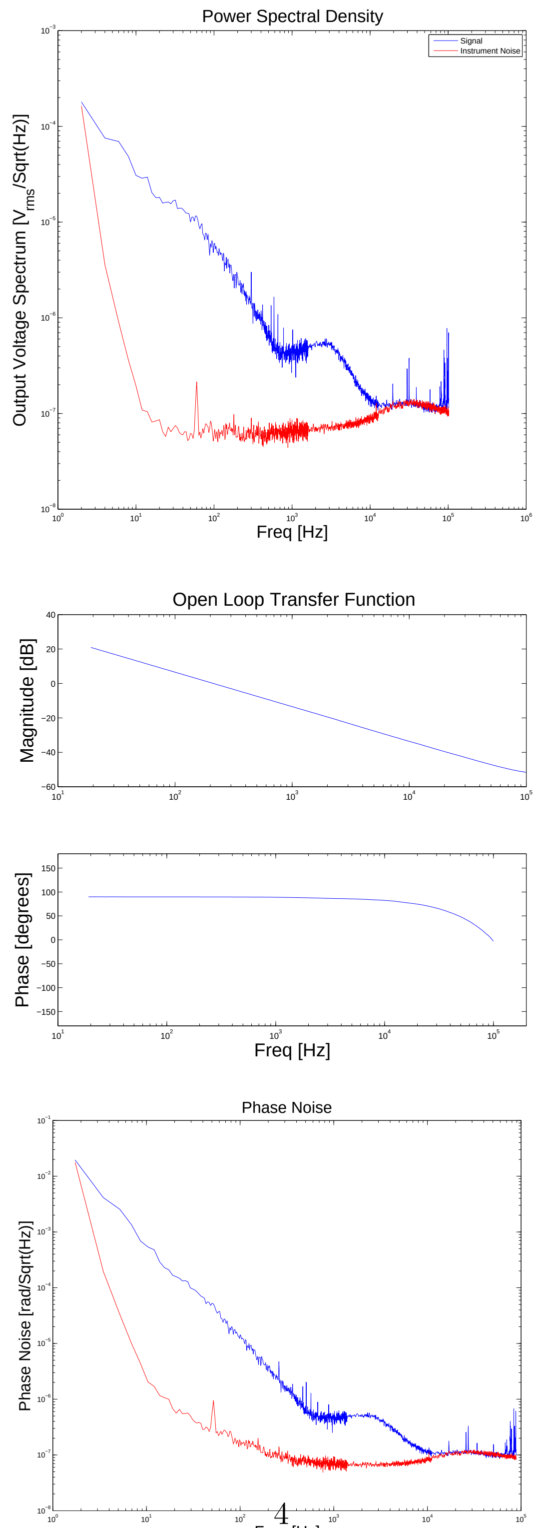

Figure 3: The distributions for the Isomet setup. The red curve indicates the instrument noise, which forms the limit of our measurement ability. It is measured in the PSD spectrum and then propogated through the rest of the calculation.