Calibration Stability in S2

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Calibration lines

Given an input excitation X_i in meters, the spectrum in ASQ shows a peak at that frequency given by:

$$AS\_Q(f_i, t) = X_i \frac{\alpha(t) C_0(f_i)}{1 + \alpha(t) H_0(f_i)}$$

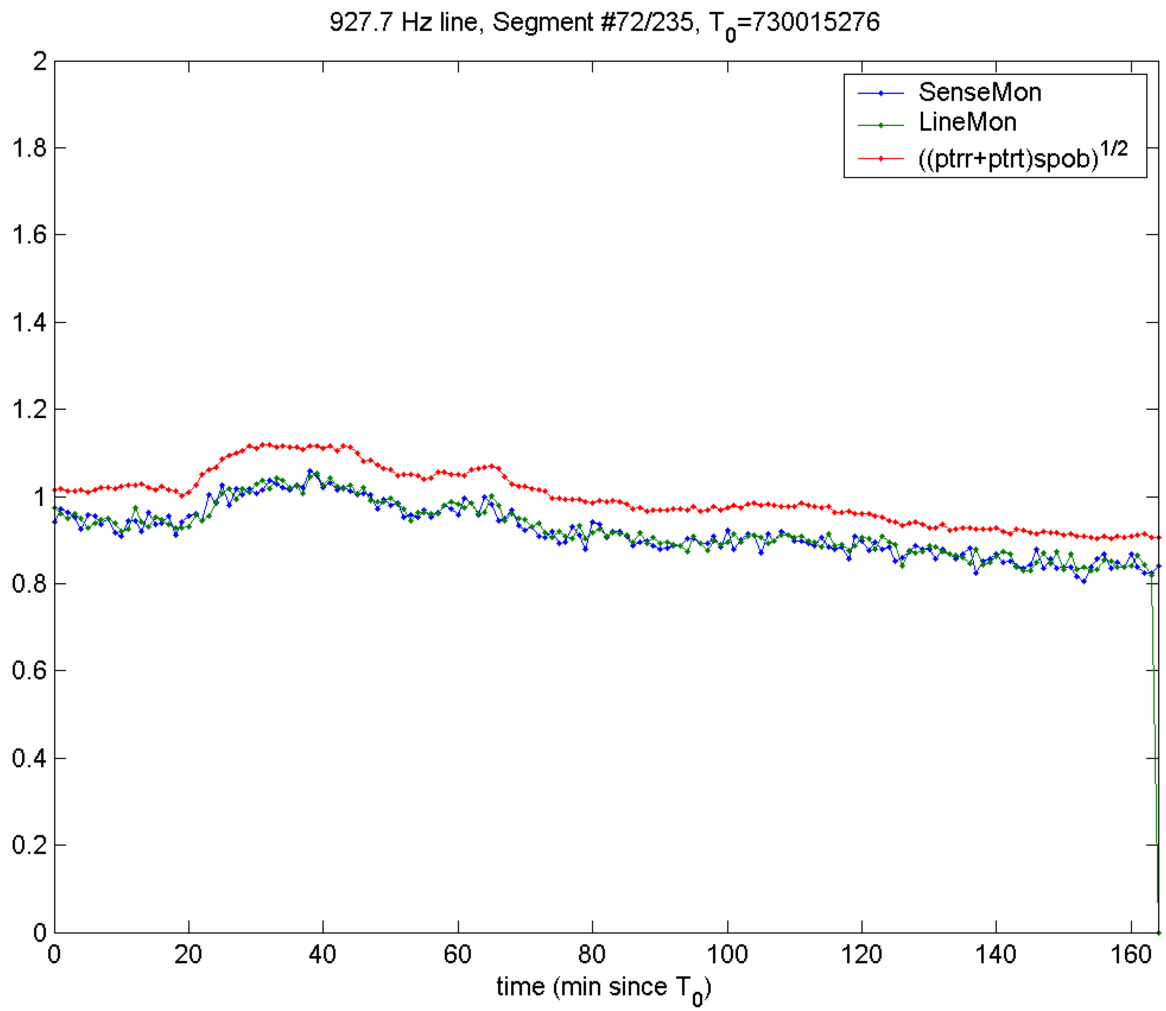
We choose a reference time t_0 when we measure loop gains and have calibration line monitors, then measure the ratio of amplitude in the ASQ spectrum:

$$R_i(t) = \frac{AS\_Q(f_i, t)}{AS\_Q(f_i, t_0)} = \alpha(t) \frac{1 + H_0(f_i)}{1 + \alpha(t) H_0(f_i)}$$

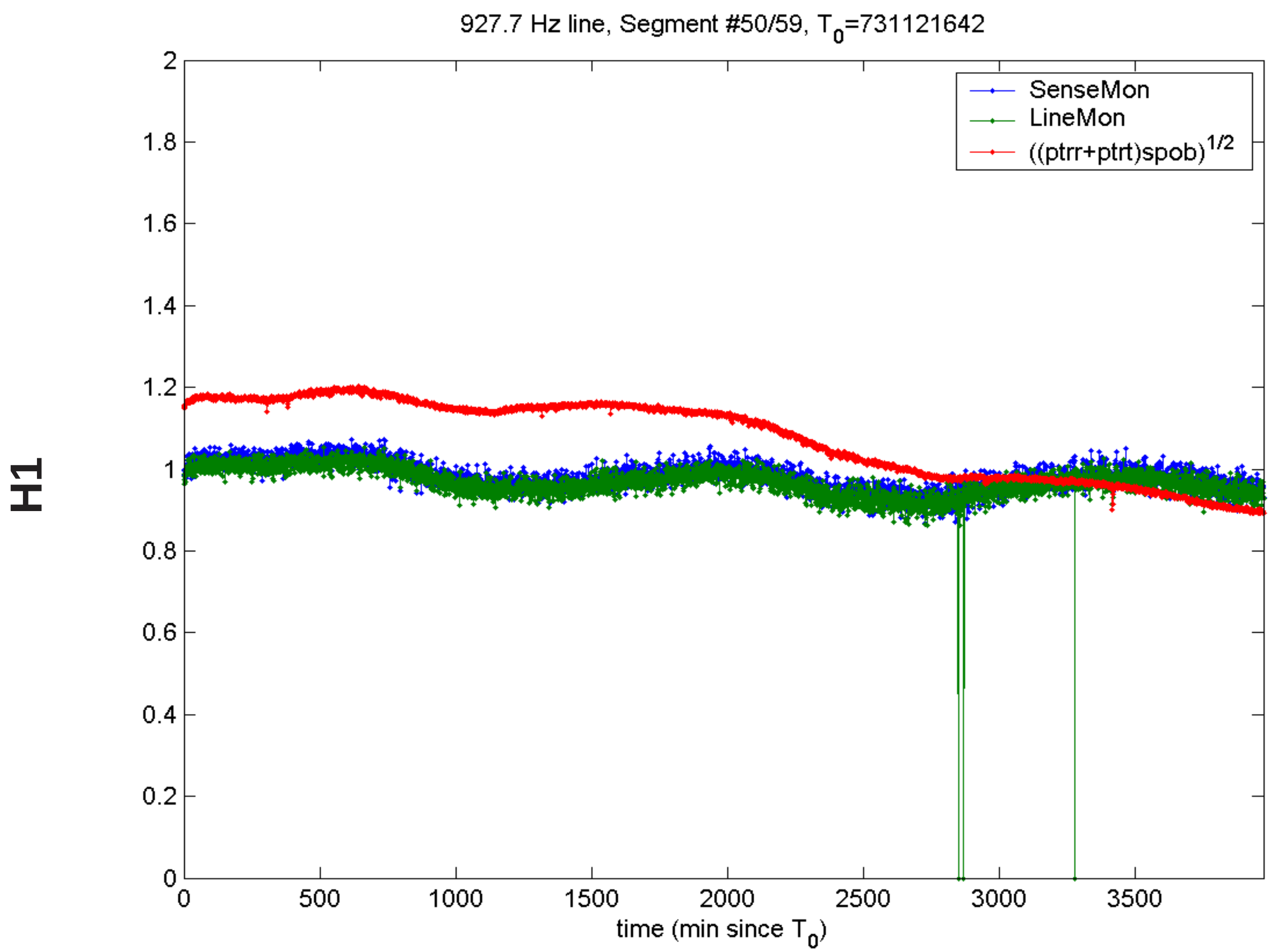
We can solve for α, since we know H_0 and R_i. For high frequency lines where $H_0 \sim 0$, the ratio R_i is close to α itself. We have three
The line amplitude is tracked by two line monitors:
Patrick Sutton's **SenseMon** and Sergey's Klimenko **LineMon**.
We also know that α is proportional to an "alignment function", calculated from carrier power in the arms and sideband power in the recycling cavity.

Three measures of optical gain

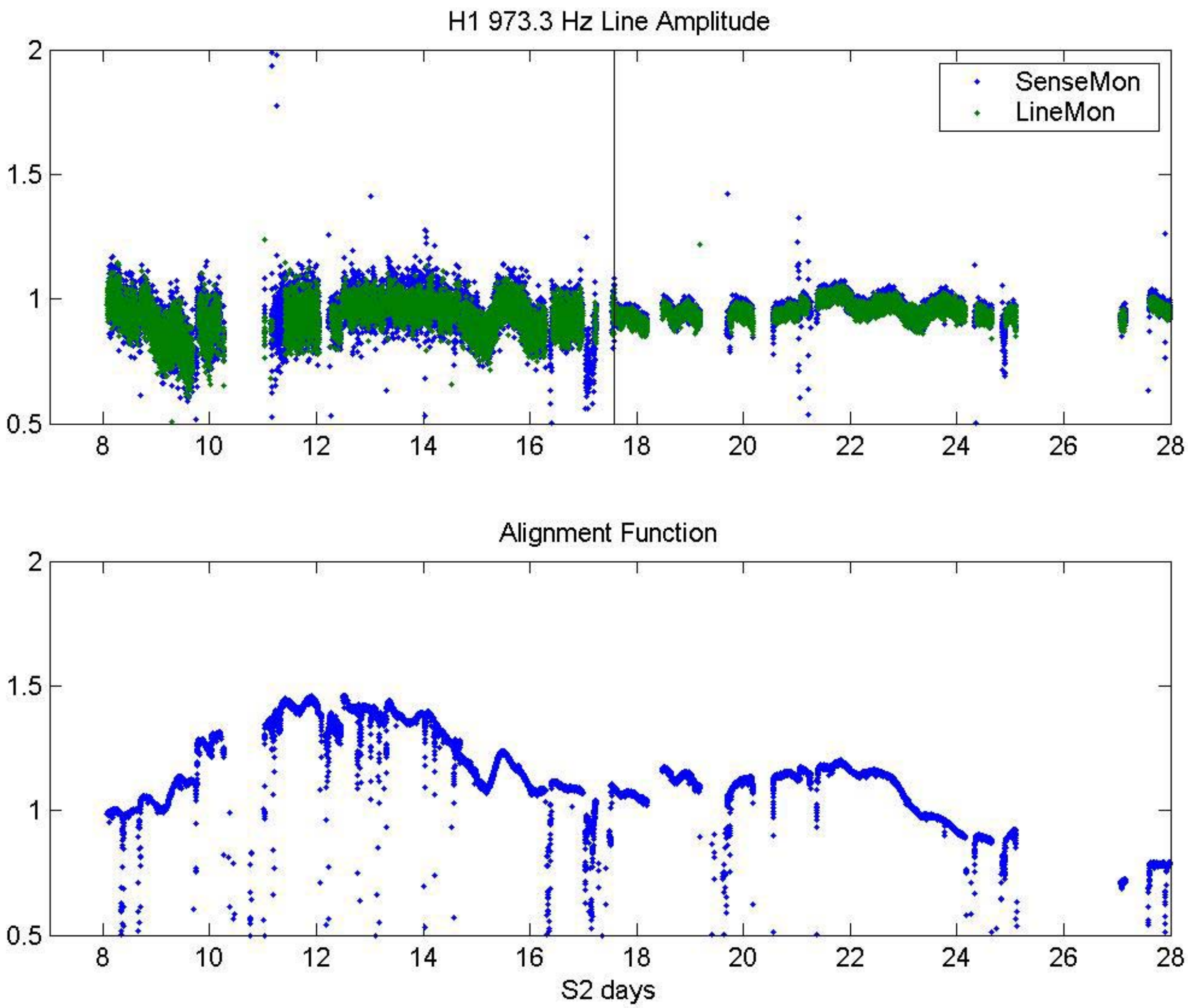
L1



Three measures of optical gain

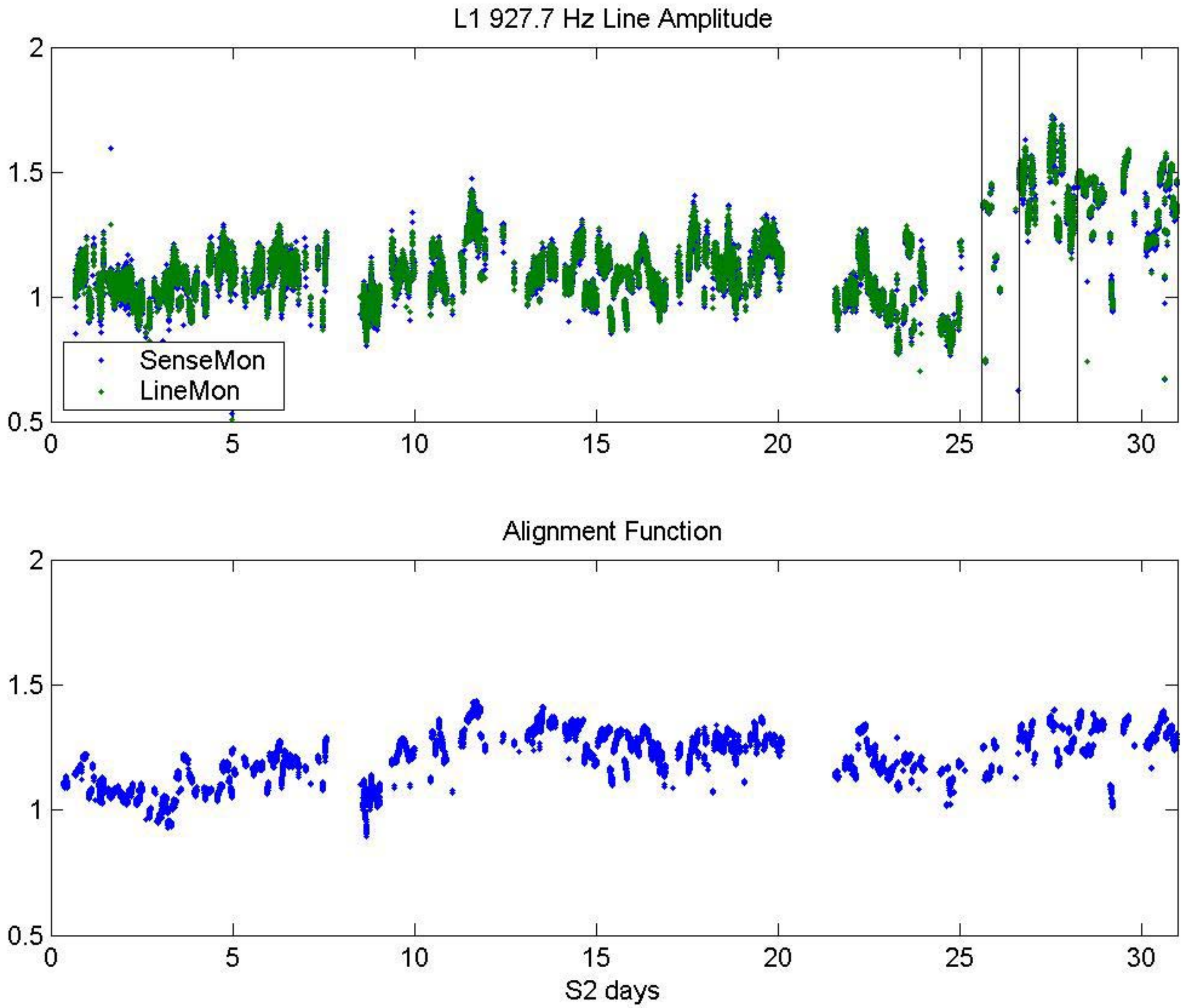


Improving SNR in line estimate



H1: x3
6.5%→2.5%

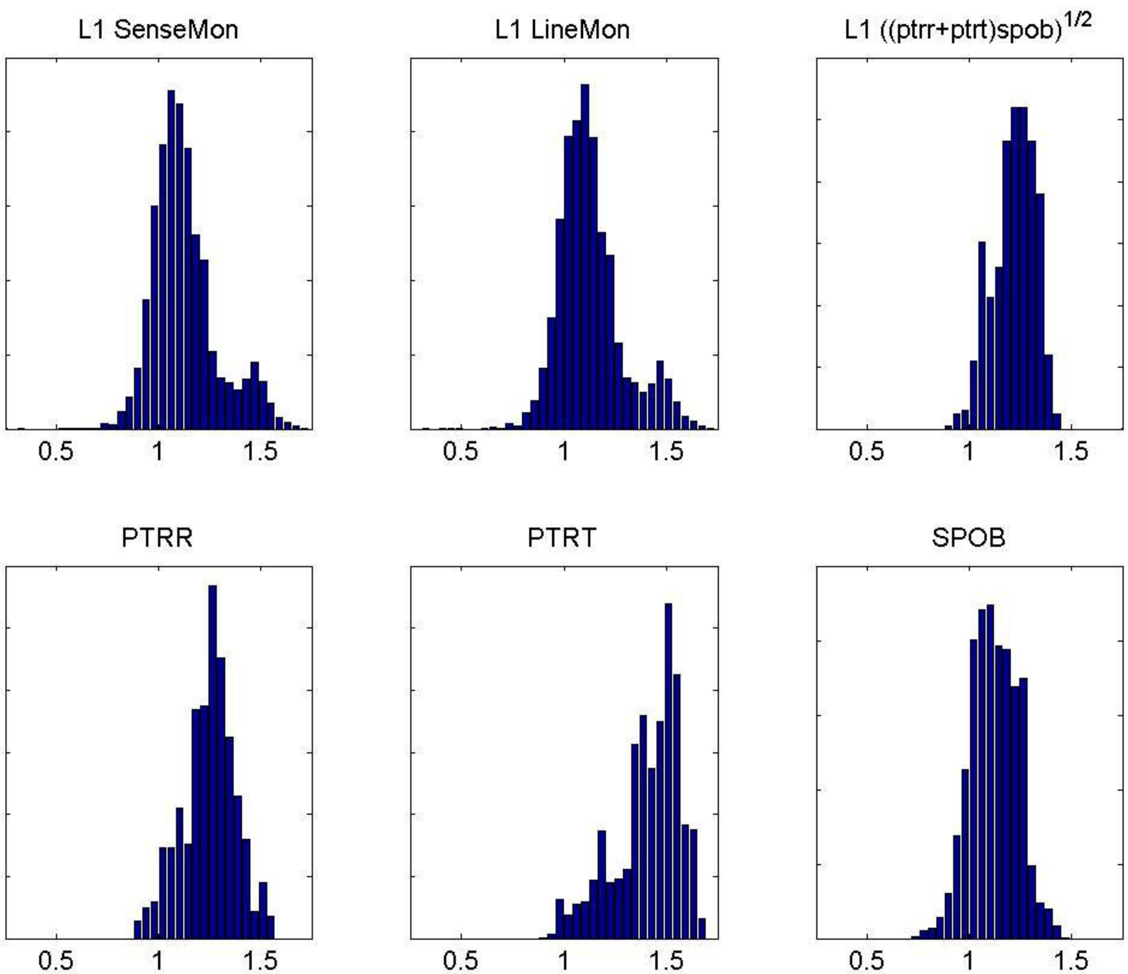
Improving SNR in line estimate



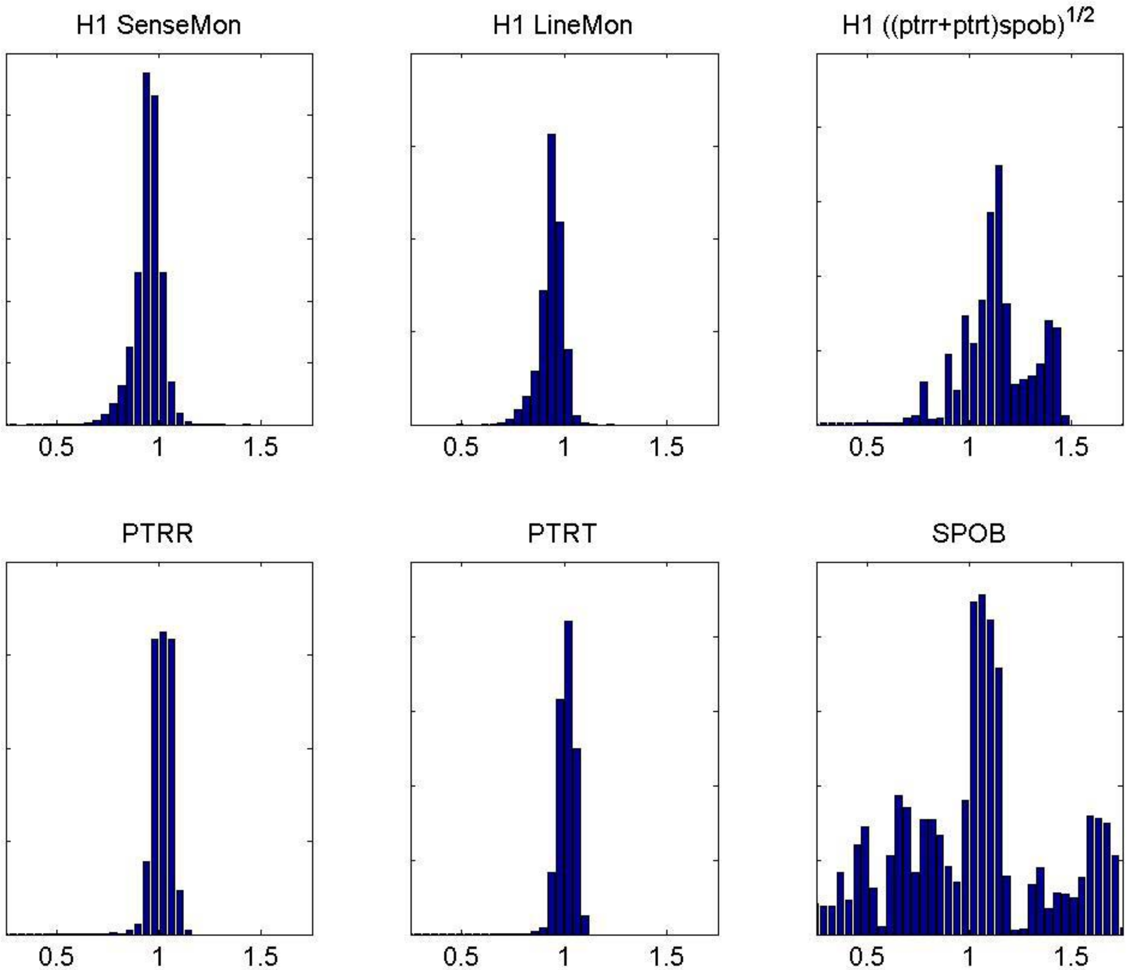
L1: x10

5%→1.5%

Histograms

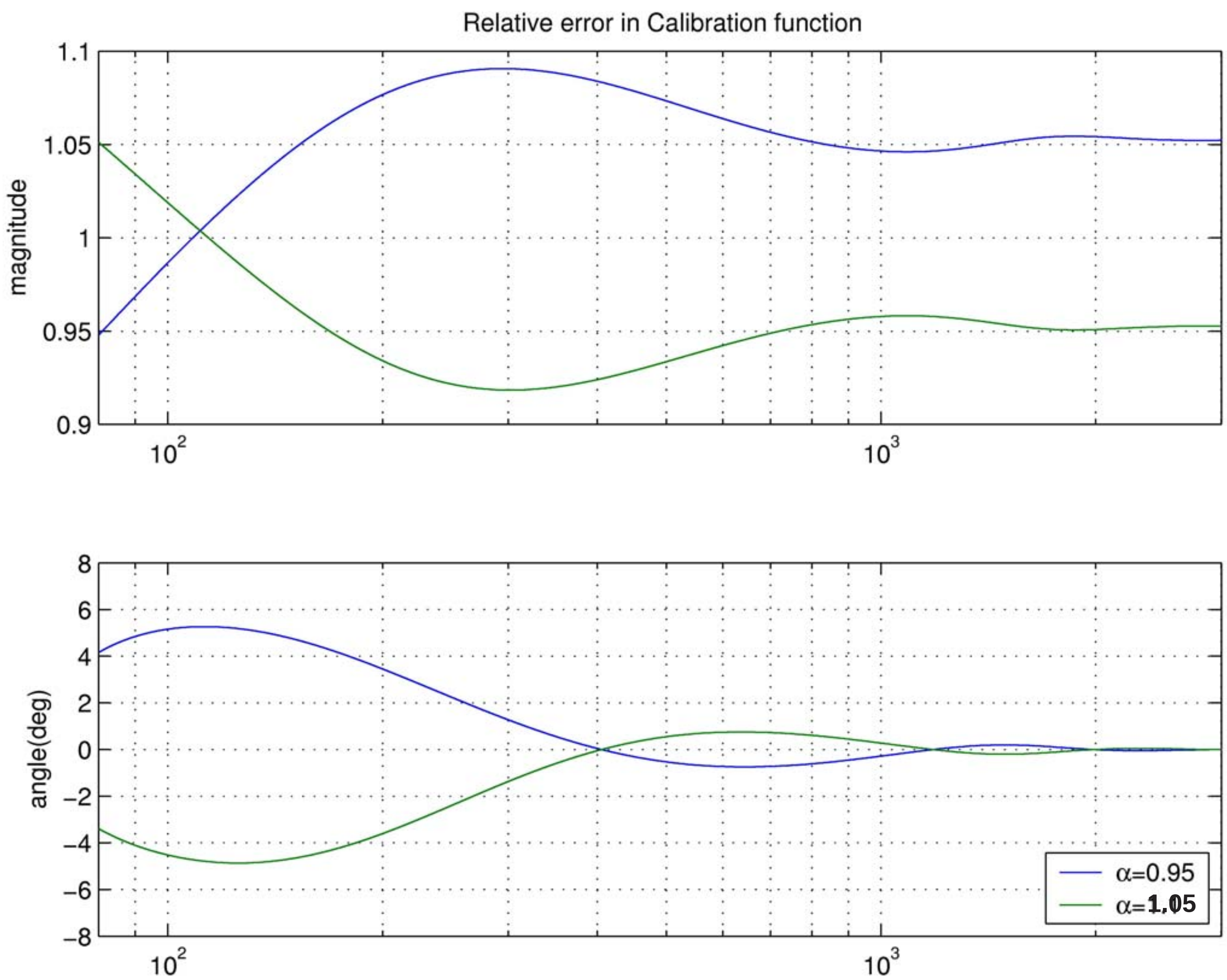

L1 SenseMon
L1 LineMon
L1 ((ptrr+ptrt)spob)1/2
PTRR
PTRT
SPOB
0.5
1
1.5

Histograms

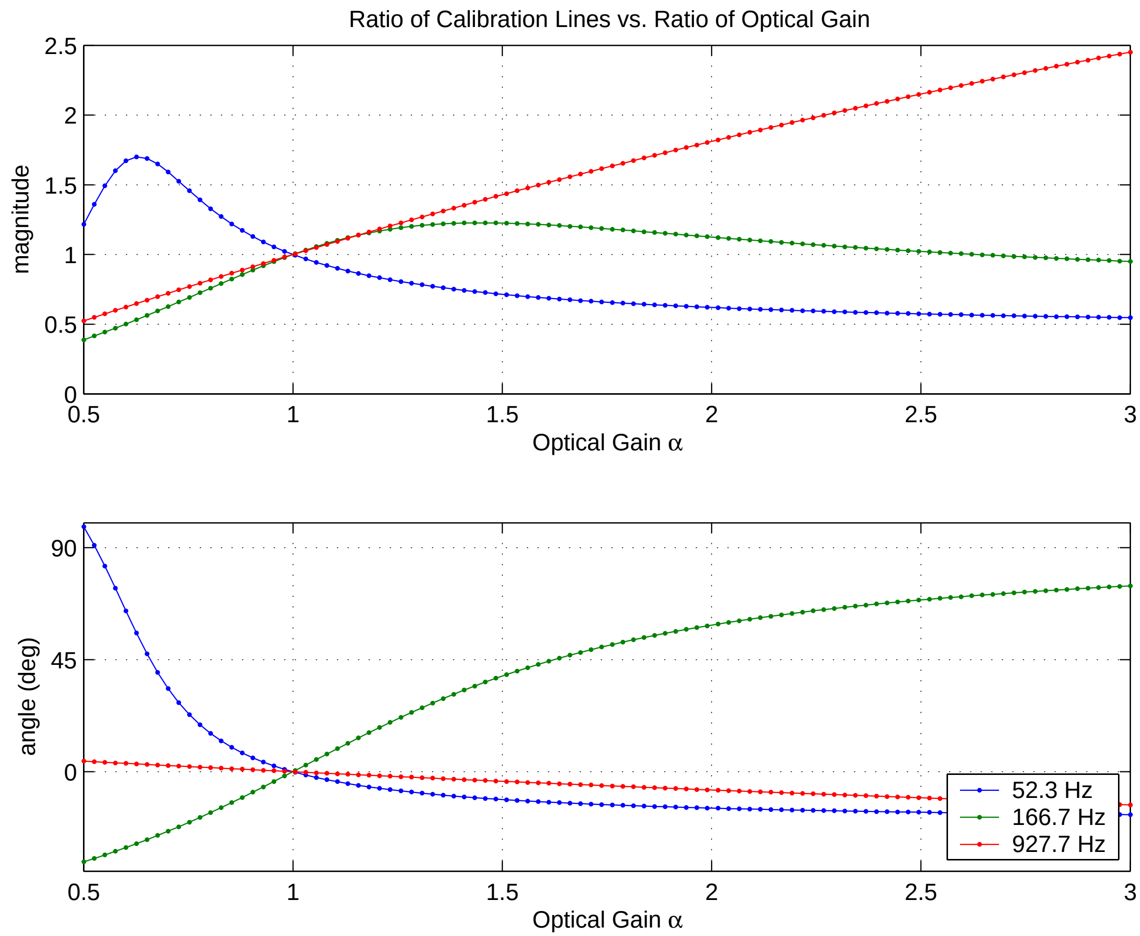


H1 SenseMon
0.5
1
1.5
H1 LineMon
0.5
1
1.5
H1 ((ptrr+ptrt)spob)1/2
0.5
1
1.5
PTRR
0.5
1
1.5
PTRT
0.5
1
1.5
SPOB
0.5
1
1.5

5% error in optical gain
=> freq. dep. error in calibration



Using different calibration lines

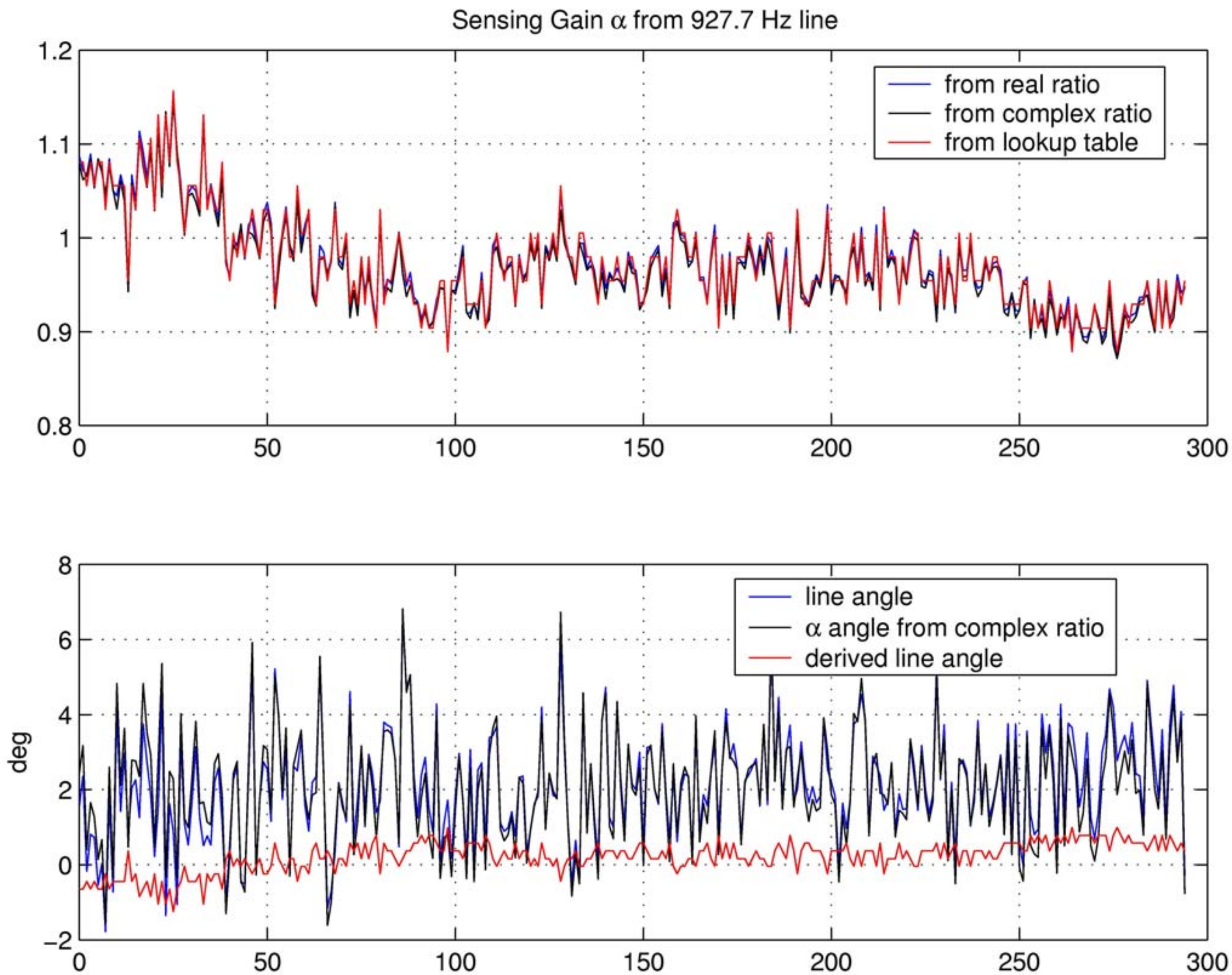


$$AS\_Q(f_i,t) = X_i \frac{\alpha(t) C_0(f_i)}{1+\alpha(t) H_0(f_i)}$$

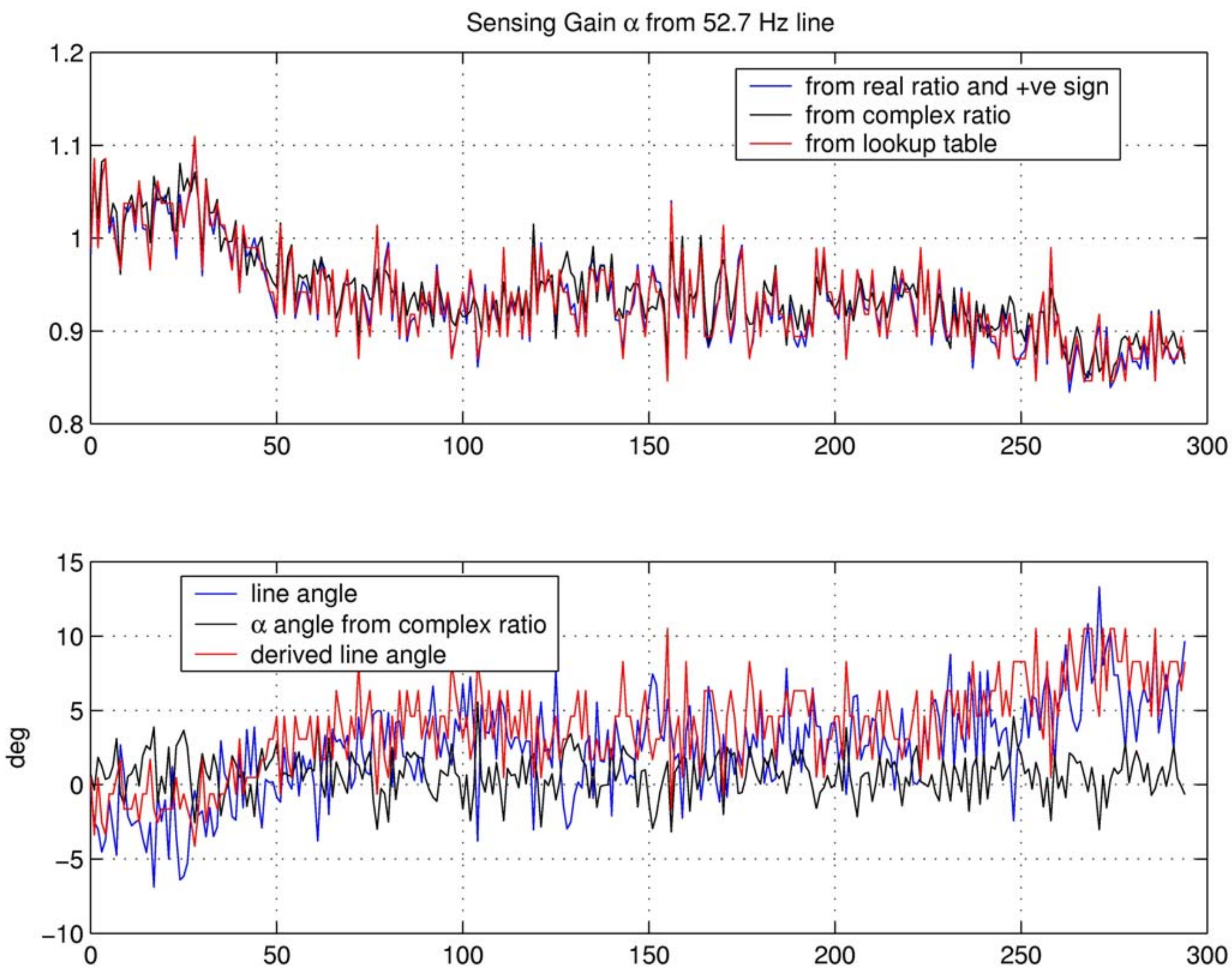
$$R_i(t) = \frac{AS\_Q(f_i,t)}{AS\_Q(f_i,t_0)} = \alpha(t) \frac{1+H_0(f_i)}{1+\alpha(t) H_0(f_i)}$$

- **Method 1**: use $|R|^2$, solve quadratic equation for α
- **Method 2**: use $|R|$, interpolate from R vs α table (we can derive an angle for the line too).
- **Method 3**: Use complex R, get a complex solution for α

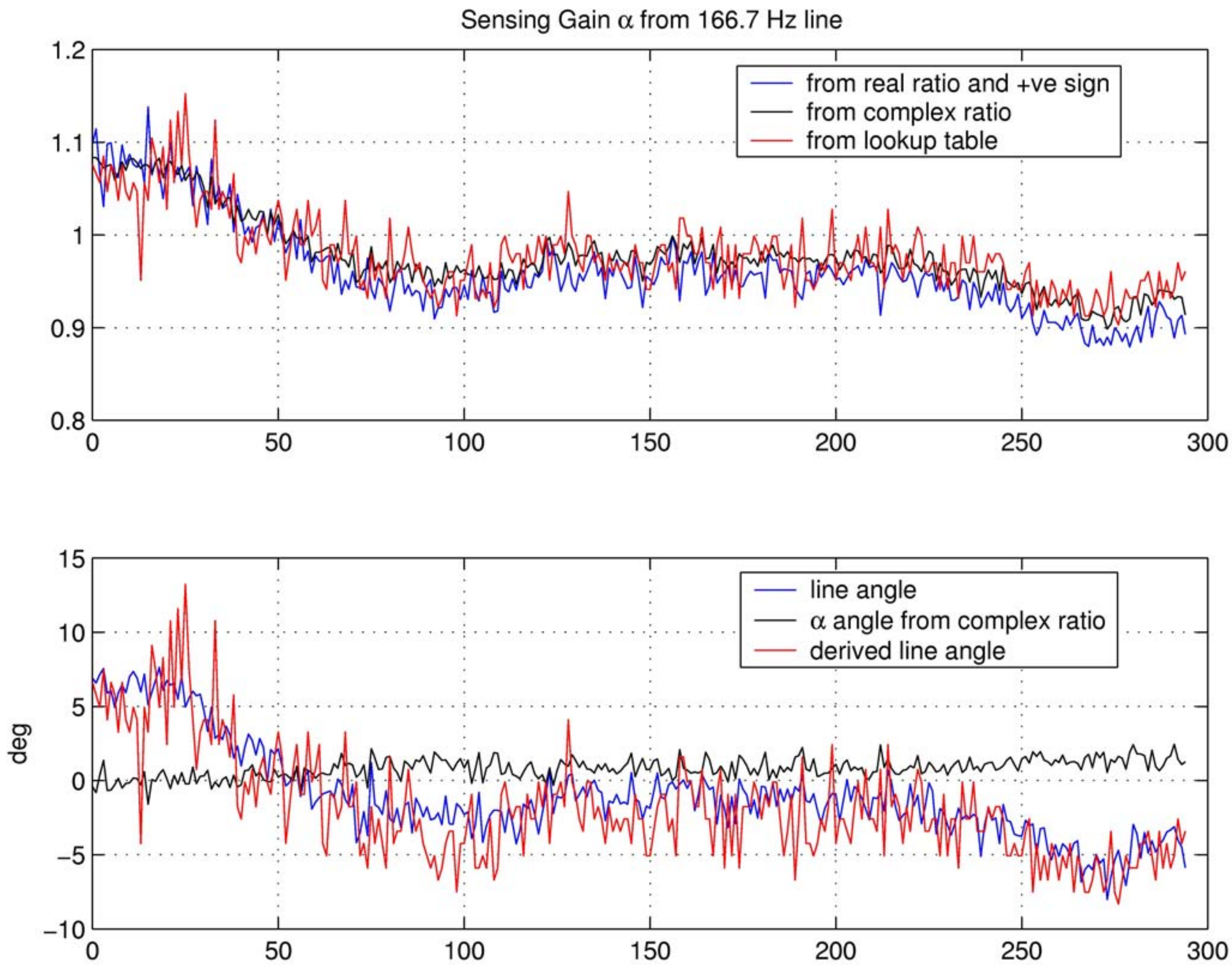
Different methods to get optical gain, same results



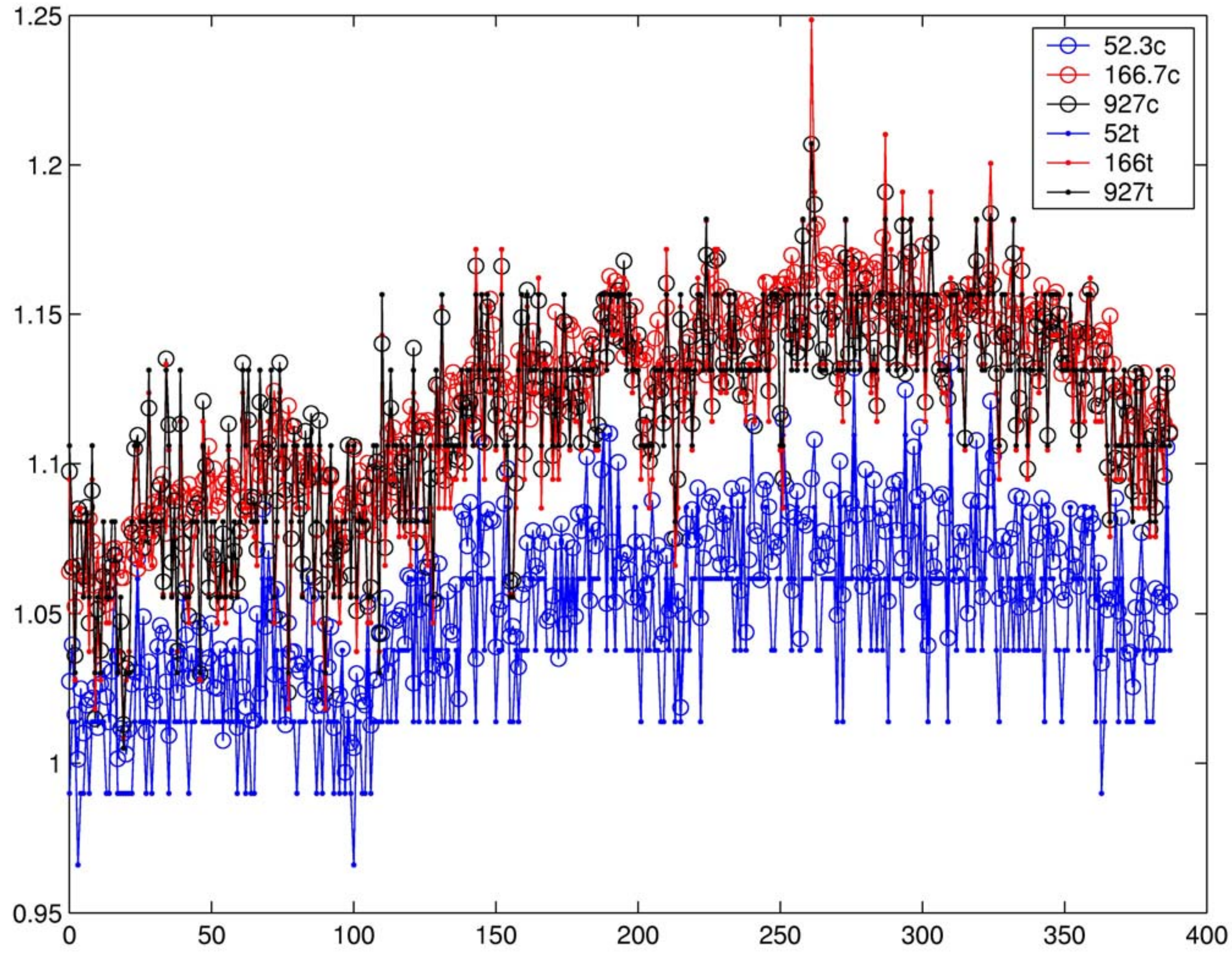
Different methods to get optical gain, same results



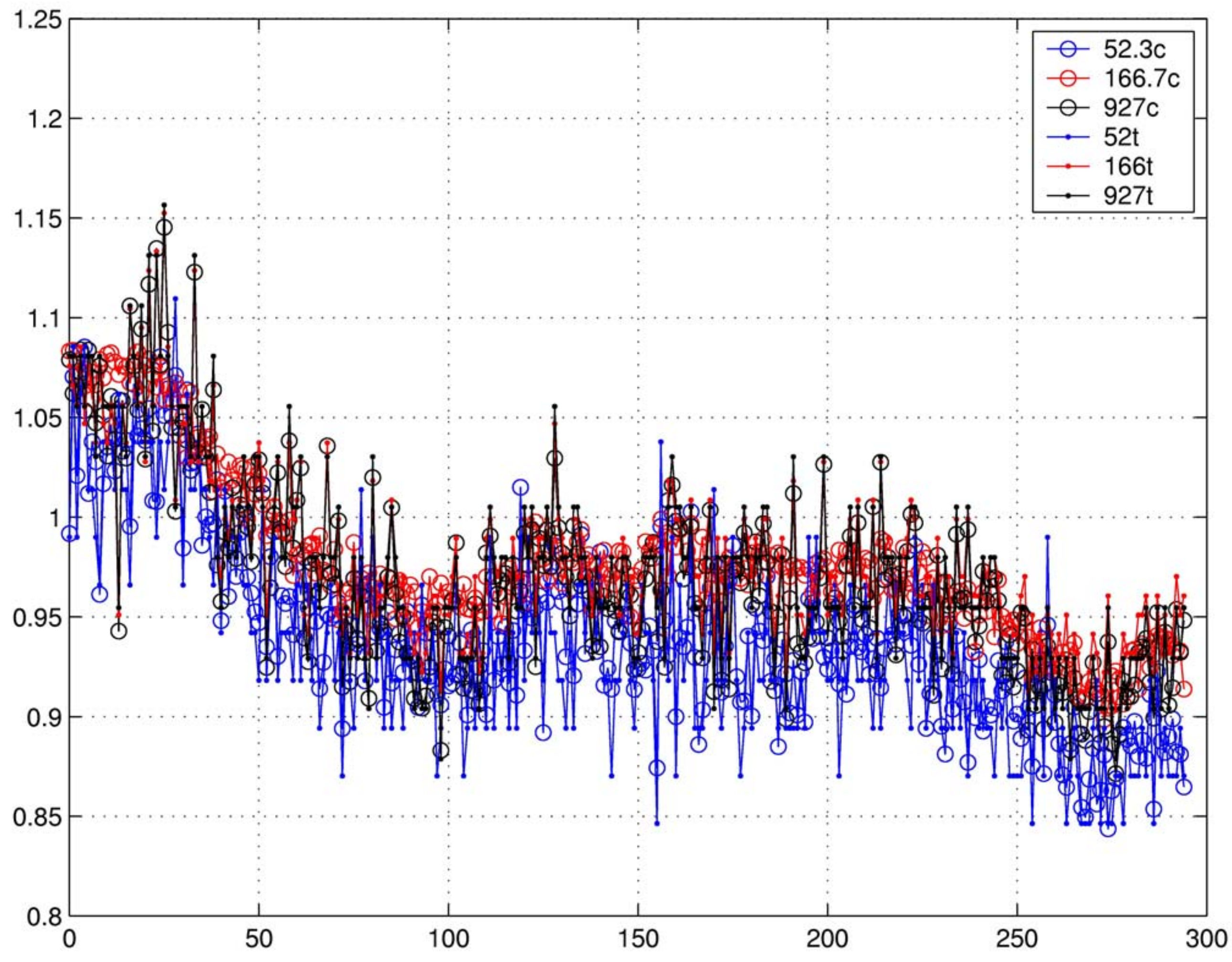
Different methods to get optical gain, same results



Different calibration lines



Different calibration lines



Conclusions

- Variations in calibration are about 40% over weeks, but more than 75-80% of the time we are within 20% of the median value.
  Changes are being tracked by calibration lines.
- Statistics in line estimators have gotten better with higher line amplitudes, from 5-6% to 1.5-2.5%; maybe we want even better?
  Line uncertainty could be improved by averaging over several minutes.
- Complex line estimate (from LineMon) confirms the model of a real α.
- Lines near ugf and high freq line provide consistent estimates for a freq-independent a; not so true for low freq line (?).
- Qualitative (=interesting!) differences between L1 and H1. H2 analysis will come soon.
- Faster fluctuations in calibrations are not tracked (yet); SPOB has ~10% fluctuations with time scales between 6 seconds and 50ms. We hope to track them with (very) loud calibration lines. Important for template matching, parameter estimation, calibration of bursts.