Background to the Calibration

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DCC: LIGO-G030105-00-Z

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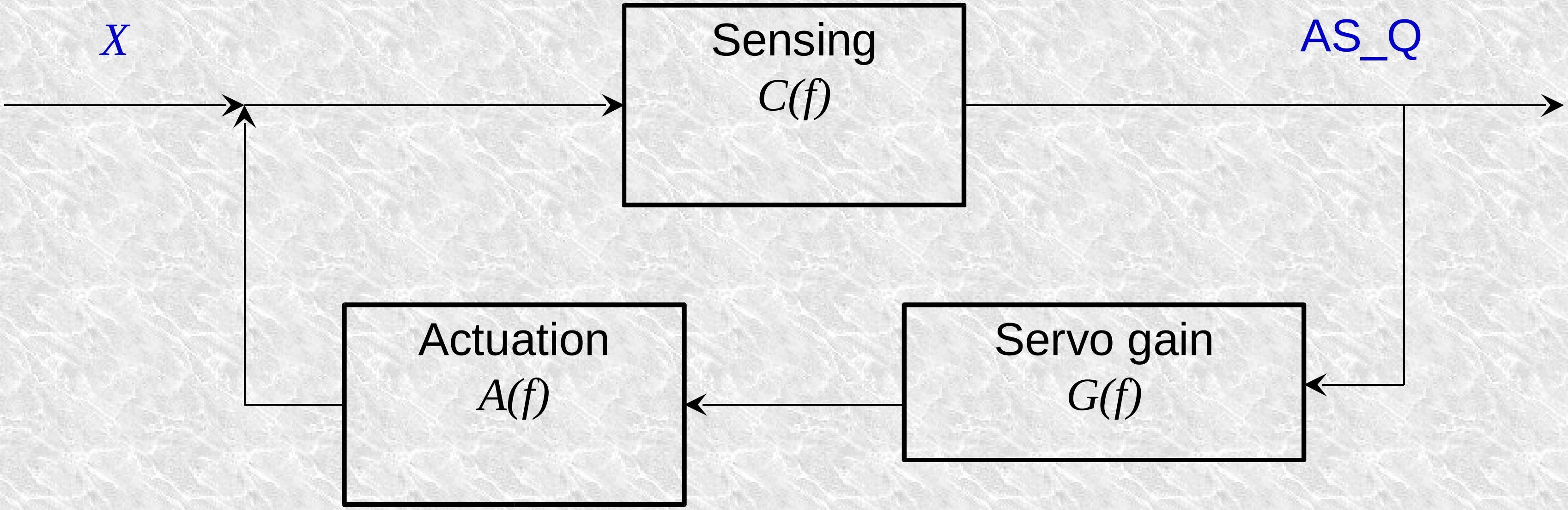
- Some Basics
- Test Mass Calibration
- Calculating the Calibration Functions
- Calibration Accuracy

Basics



Open Loop Gain $H(f) \quad C(f) \quad A(f) \quad G(f)$

Basics

Recall:

$$AS\_Q \quad \frac{X_{exc}}{C_b(f)} \quad \frac{C(f)}{(1 \qquad H(f))} X_{exc}$$

$C_b(f)$: Response function in (strain/count)

$C(f)$: Sensing function in (count/strain)

$A(f)$: Actuation function in (strain/count)

$G(f)$: Digital Filter gain (count/count)

: Tracks Optical Gain Changes

: Tracks Digital Gain Changes

Calibration Procedure

- The Actuation function $A(f)$ is just a simple pendulum.
- The Digital Gain function $G(f)$ is known.
- To calibrate the response we need to measure the sensing function $C(f)$
- That is we need to measure and track the optical gain of the cavities.
- We expect the optical gain to depend on – among other things - the alignment, the attenuation in the **EO** shutter and the alignment of the beam through the shutter
- We can also track this through the quantity:

$$\sqrt{(PTRT \quad PTRR) \quad SPOB}$$

Calibrating the Test Masses

- Allow the Michelson to free swing so as to establish the peak-to-peak AS_Q amplitude in counts.

- This peak-to-peak value corresponds to a length change of $\frac{\;}{4}$

- For small drive amplitudes of the locked Michelson the relationship between *AS_Q* and this peak to peak measurement is:

$$\frac{(AS\_Q)}{(ITMX)} \quad \frac{2 \qquad A}{\;}$$

- Above the u.g.f. of the Michelson loop the Transfer function is just the pendulum response of test mass. We can extrapolate back to **DC** using the known pendulum resonance frequencies (~0.76Hz).

Calibrating the Test Masses

- At Hanford they use a different technique, sign-toggling the Michelson loop gain and calibrating the control signal. However, at the mid-S2 calibration both sites used both techniques, so we should be able to compare them directly.

- To obtain calibrations for the end test masses we lock one arm at a time and measure the transfer function of the **ITM** and the **ETM** **w.r.t**. *AS_I* (the error signal for the loop).

- The advantage of doing things this way is that we get the AC calibration for the test masses and avoid any weird problems at DC. Note however that what we call the DC value of the test mass response is just extrapolated from higher frequencies under the assumption of a single pole at the resonance.

- For hardware injections, which dither the test masses, AC calibrations are the most appropriate.

Calibrating the Test Masses

- From L1 we get in (nm/count):

Date		*BS*		*RM*		*ITMX*		*ITMY*		*ETMX*		*ETMY*	
Pre	*S2*	0.75	0.01	0.00	0.00	0.41	0.01	0.43	0.01	0.39	0.02	0.37	0.03
Mid	*S2*	0.05	0.00	0.76	0.05	0.43	0.02	0.44	0.01	0.42	0.03	0.38	0.03

- Aside from a problem with the BS result (which we don't believe to be real) the numbers agree nicely, indicating that the systematics of the technique are either small or constant.

- The errors come from propagating errors in the initial calibration of *AS_Q* and extrapolating the sweeps to DC. Errors in the transfer functions are negligible.

- The predicted value for the calibration is ~0.44 (nm/ct).

- These DC values for the **ETM**s are what we use in the Autocalibrator.

Calculating Calibration Functions

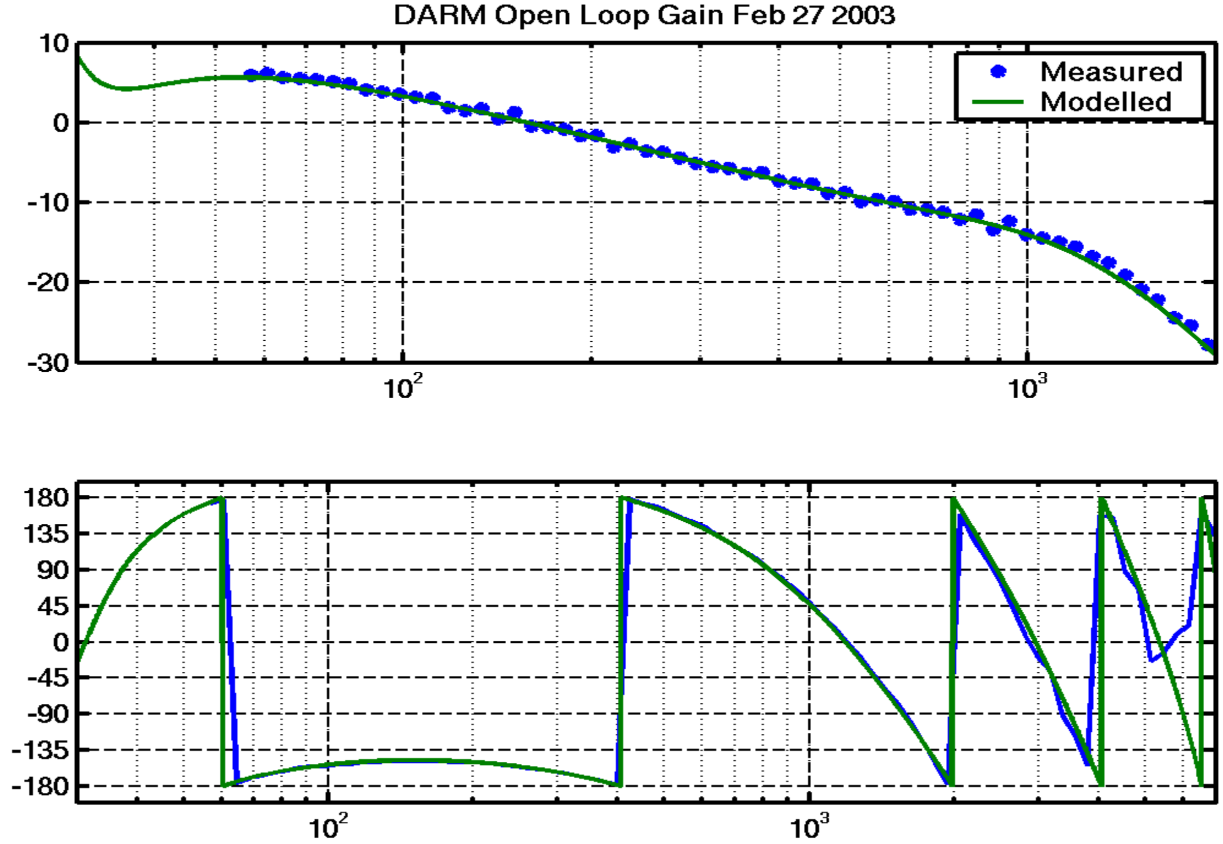
- We have a model of the DARM loop, which evolved from Rana's SIMULINK Model. LHO uses a similar approach but a different model.

- The procedure is to match the measured DARM OLG to the model. This gives us a scale factor the magnitude of which we attribute to changes in the Optical gain due to alignment.

- The matching is done by eye.

- The generated files (with the correct sign!!) are what P.Sutton uses in SenseMon.

Calculating Calibration Functions



Sources of Error

- For the Test Mass calibrations a simple extrapolation of errors shows statistical uncertainties on the order of 2.5 to 8%.

- A comparison of the predicted value for the DARM calibration of 2.2 (nm/ct) (based on Rana's E-log entry of March 14th) with the Test Mass calibration value of 1.95+/-0.08 (nm/ct) shows some significant disagreement. However, the Test Mass calibration value compares well with the measured DARM calibration of 1.9 (nm/ct)

- The issue of how good the approximation of the test mass as a simple pendulum is, still needs to be examined. However, it is safe to say that at least insofar as statistical errors are concerned we are dealing with effects at the level of 10%.

Accuracy of the Calibration

- Our model is not a perfect representation of the real instrument and any discrepancy should be considered as a systematic uncertainty.

- Our “by eye” match between the model and the measurement is another systematic. The error arising from the measurement of the OLG transfer function itself is negligible so long as the coherence is high.

- Discrepancies between the model and the instrument will affect the accuracy of the absolute value of the calibration.

- We plan to make a careful study of these effects using the S2 data.