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- LIGO -
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Calibration of the LIGO detectors for S2

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Abstract

We describe the methods used to calibrate the LIGO interferometer responses for the S2 run. An analysis of uncertainties in the calibration is also presented. These uncertainties are summarized in Table 2.

1 Introduction

The second LIGO Scientific Run, S2, consisted of 62 days of data taking from February 14th 2003 to April 14th 2003. This document is intended as a summary of the techniques used to calibrate the response of the interferometers and an estimate of associated uncertainties. Those readers wishing to skip the details can find a convenient summary in Table 2.

2 Calibration Procedure

We consider the response of the interferometer to an external disturbance (e.g. a gravitational wave) to be that of a simple feedback loop with a gain $\mathrm{G(f)}$ (see Figure 1). This loop can be parameterized by three functions: a "cavity response" or "sensing" function $\mathrm{C(f)}$ which describes the response of the optical cavities, a "Digital Filter" function $\mathrm{D(f)}$ which describes the digital filtering used in the loop and an "Actuation" function $\mathrm{A(f)}$ which describes the mechanical response of the suspended test masses[1]. These functions are related by

$$\mathrm{G(f) = C(f).A(f).D(f).} \tag{1}$$

The strain sensitivity of the interferometer at a time $\mathrm{t_0}$, $\mathrm{h(f,t_0)}$ is related to $\mathrm{AS\_Q}$ by:

$$\mathrm{h(f,t_0)} = \left[\frac{1+\mathrm{G(f,t_0)}}{\mathrm{C(f,t_0)}}\right]\mathrm{AS\_Q(f,t_0)} \tag{2}$$

or:

$$\mathrm{h(f,t_0) = R(f,t_0)AS\_Q(f,t_0).} \tag{3}$$

We call $\mathrm{R(f,t_0)}$ the response function for the interferometer. In practice we can obtain direct measurements of all of the above functions with the exception of the sensing function $\mathrm{C(f,t_0)}$. This function depends on the optical gain of the arm cavities and is very sensitive to fluctuations in the alignment. We use Equation 1 to find $\mathrm{C(f,t_0)}$ from our measurements of $\mathrm{G(f,t_0)}$, $\mathrm{A(f,t_0)}$ and $\mathrm{D(f,t_0)}$.

We assume that the time evolution of the interferometer calibration manifests itself as a linear change in the optical gain of the instrument $i.e.$ $\mathrm{C(f,t)} = \alpha(\mathrm{t})\mathrm{C(f,t_0)}$, and an occasional change in the digital gain tracked by a parameter $\beta(t)$ such that $\mathrm{D(f,t)} = \beta(\mathrm{t})\mathrm{D(f,t_0)}$. During S2 $\beta(t)$ changes on the L1 interferometer were caused by changes in the Input Matrix. These changes were tracked by the CONLOG[2] tool. At H1 there were several different epochs with different

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[1] This is a change of notation from that used in reference [1]

[2] Written and maintained by P. Shawhan.

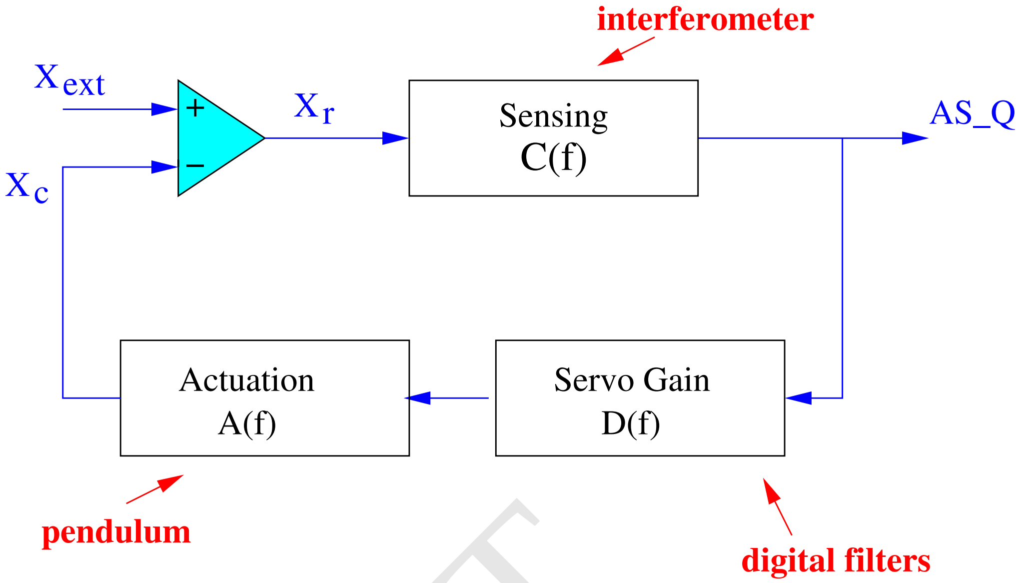

Figure 1: Block diagram of the interferometer

$\beta(t)$ corresponding to different H1:LSC-DARM_GAIN values. For more information on α and β behaviour during S2 see reference [2]. For any given time the strain response is given by:

$$\mathrm{h(f,t)} = \left[\frac{1+\alpha(\mathrm{t})\beta(\mathrm{t})\mathrm{G(f,t_0)}}{\alpha(\mathrm{t})\mathrm{C(f,t_0)}}\right] \mathrm{AS\_Q(f,t_0)} \tag{4}$$

and so,

$$\mathrm{R(f,t)} = \left[\frac{1+\alpha(\mathrm{t})\beta(\mathrm{t})\mathrm{G(f,t_0)}}{\alpha(\mathrm{t})\mathrm{C(f,t_0)}}\right]. \tag{5}$$

The variation in the optical gain is measured by applying sinusoidal excitations (calibration lines) to one of the end test masses and monitoring its amplitude as a function of time. This approach has been shown to yield consistent results when propagating between calibration functions which were determined at different times.

In order to obtain the S2 reference functions and α factors, we followed the following procedure:

- Measure the open loop gain function $G(f, t_0)$ at a chosen 'reference time'.
- Measure the DC gain of the test mass actuation functions and construct $\mathrm{A(f,t_0)}$ assuming a simple pendulum response.
- A combination of measurements of the electronics and known digital filter parameters is used to construct $\mathrm{D(f,t_0)}$.
- The unity gain frequency measured in the first step is used in a MATLAB model [3], to find $\mathrm{C(f,t_0)}$ ($= \mathrm{G(f,t_0)/A(f,t_0)D(f,t_0)}$) at the time of the measurement.

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[3] Written by R. Adhikari and P.Fritschel. The main MATLAB script, and the parameter files used for each interferometer are attached at Appendices to this document.

- Values of $\alpha(t_0)$ and $\beta(t_0)$ are obtained from **SenseMonitor** [3] and determine the normalization for $\alpha(t)$ and $\beta(t)$.
- The response at any given time, $\mathrm{R(f,t)}$, can be calculated from equation 5. The quantities $\alpha(t)$ and $\beta(t)$ are obtained from **SenseMonitor**.

2.1 The Open Loop Gain G

The open loop function is measured by injecting a swept sine excitation into the loop and the IFO:LSC-DARM_EXC point and recording the ratio IFO:LSC-DARM_IN2/IFO:LSC-DARM_IN1. The measurement is taken with the instrument set for normal data taking (but not in Science mode).

2.2 The Actuation Function A

The frequency dependent response of the end test masses (ETMs) to an excitation is the most time consuming and, at least at Livingston, the largest source of uncertainty in the calibration process. Most of the measurement techniques rely on a determination of the actuation functions of the input test masses (ITMs) and propagating these measurements to the ETMs using a single arm lock. The procedure can be summarized as follows:

- Obtain the relationship between counts in AS_Q to meters of displacement of an ITM by either:
  - Measuring the peak to peak excursions of AS_Q with an unlocked Michelson. Then $\mathrm{AS\_Q(counts/meter)} = 2\pi\mathrm{AS\_Q_{p2p}}/\lambda$, so the wavelength of the laser calibrates AS_Q.
  - Perform a swept sine excitation of an ITM with a locked Michelson and measure the AS_Q response. This calibrates the ITM response in meters.

  or,

  - Use the sign toggling or fringe fitting techniques described in reference [4]. These techniques were used on the Hanford interferometers during S2 and resulted in a better determination of the actuation function.
- Lock a single arm and measure the transfer function of both the ITM and the ETM w.r.t. AS_I (the error signal). A ratio of the transfer functions then gives the ETM response relative to the previously measured ITM response.

There are problems with the methods for calibrating the ITM response. The first technique assumes that the response of the ITM is well described by a simple pendulum. In practice (probably due to a poor understanding of the electronic actuation path) this is not true and the extrapolation of the high frequency response to DC reflects this. This technique does have the advantage of measuring the response in the frequency range where the instruments are most sensitive. The techniques described in [4] have the disadvantage of measuring the response at or close to DC while the response we really care about is at higher frequencies. Care must be taken that the extrapolation from DC to AC is done properly.

One other technique which was used during S2 (again at Hanford), was to use the fine actuators on the end chambers to make a known displacement of the end test masses. This technique had uncertainties of $\simeq 7\%$ which are comparable to those coming from the technique listed above, but completely independent systematics. The agreement between both sets of measurements gave us confidence that no large source of systematic uncertainty had been overlooked[4].

The DC actuation function measurements are summarized in Table 1.

IFO	ETMX (nm/ct)	ETMY (nm/ct)
L1	0.40	0.37
H1	0.72	0.83
H2	0.87	0.92

Table 1: Summary of measurements of the DC values of the actuation functions for all three interferometers.

2.3 The Digital Filter function D

This part of the loop is modeled using the actual filter files loaded in the LSC during S2. In general any analog whitening and dewhitening filters in the loop are compensated digitally and should have no effect. This compensation was checked by direct measurement. Uncompensated filters are modeled using information from the parameter files (digital) or from measurement (analog).

3 Calibration Errors

The fractional uncertainty on the magnitude of the response function can be written as:

$$\left(\frac{\Delta|\mathrm{R}|}{|\mathrm{R}|}\right)^2 = \left(\frac{\Delta|\mathrm{A}|}{|\mathrm{A}|}\right)^2 + \left(\frac{\Delta|\mathrm{D}|}{|\mathrm{D}|}\right)^2 + \mathrm{C_R}\left(\frac{\Delta|\mathrm{G}|}{|\mathrm{G}|}\right)^2 + \mathrm{C_R}\left(\frac{\Delta\alpha}{\alpha}\right)^2 + \mathrm{C_I}\Delta\phi_\mathrm{G}^2 \tag{6}$$

and on the phase:

$$\Delta\phi_\mathrm{R}^2 = \Delta\phi_\mathrm{A}^2 + \Delta\phi_\mathrm{D}^2 + \mathrm{C_I}(\alpha^2\Delta|\mathrm{G}|^2 + |\mathrm{G}|^2\Delta\alpha^2) + \mathrm{C_R}\Delta\phi_\mathrm{G}^2 \tag{7}$$

where

$$\mathrm{C_R} = \frac{\Re(1+\alpha\mathrm{G})^2}{|1+\alpha\mathrm{G}|^2} \tag{8}$$

and

$$\mathrm{C_I} = \frac{\Im(1+\alpha\mathrm{G})^2}{|1+\alpha\mathrm{G}|^2} \tag{9}$$

and we have taken α to be real. The coefficients C_R and C_I are plotted in Figure 2 using values from L1. Obviously they enhance or reduce the effect of some contributions depending on the frequency.

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[4] For example the DC values obtained for H2 using the fine actuators had an average of 0.88(0.93) nm/ct for ETMX(ETMY) compared to 0.87(0.92) nm/ct from our swept sine measurement

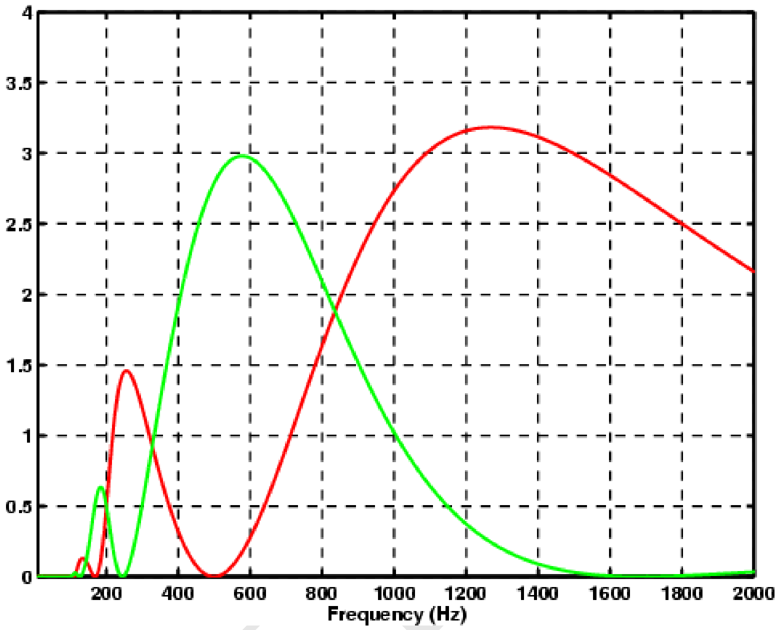

Figure 2: Co-efficients C_R and C_I for the L1 interferometer.

In our treatment of the uncertainties we combine different sources in quadrature, regardless of whether they cause a systematic shift in the 'true' value of the measured quantity or a random variation in that value. When the calibration accuracy improves and we implement other methods with independent systematics it will be desirable to make such a distinction.

3.1 $\Delta|A|$

The uncertainty has contributions from:

- The peak-to-peak measurement of AS_Q obtained with the free swinging Michelson. This was estimated from the standard deviation of ten separate measurements and was found to be of order 0.1% *i.e.* negligible.

- The deviation from a simple pendulum response of the ITM/AS_Q transfer function. This is illustrated in Figure (3). The uncertainty is estimated by taking the standard deviation of the values between 100 and 800 Hz. This gives a contribution of around 5% to the total uncertainty for L1.

- H1 and H2 used a different calibration technique[5], which gave smaller uncertainties, on the order of 1.5% for the ITM calibrations.

- The uncertainty on a transfer function measurement is given by [5]:

$$\frac{\sqrt{1-\gamma^2(f)}}{|\gamma(f)|\sqrt{2\mathrm{N_d}}} \tag{10}$$

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[5] This is the 'Sign Toggling' method described in reference [4]

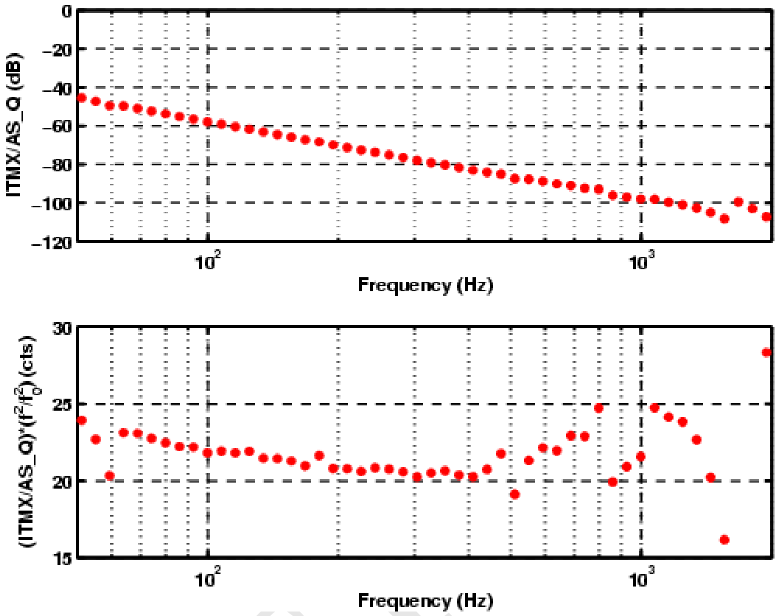

Figure 3: Transfer function of ITMX to AS_Q obtained with a locked simple Michelson. The lower figure shows the response corrected for the simple pendulum. Ideally this should be flat.

where $\gamma(f)$ is the coherence of the measurement and $\mathrm{N_d}$ is the number of averages. The three transfer function measurements used in the calibration *i.e.* ITM/AS_Q, ITM/AS_I and ETM/AS_I, all contribute an uncertainty calculated using the above equation. Since care is taken to keep the coherence high these contributions are small.

- Finally the ratio of the ITM/AS_I and ETM/AS_I transfer functions should ideally be flat. As shown in Figure 4 this is not the case for L1, probably due to a mismatch between the run and acquire filter paths in the coil driver module. This gives a contribution to the uncertainty of $\simeq 6\%$ for L1. The Hanford interferometers can be calibrated in run mode and so this mismatch is not a problem. The transfer function ratios for H1 and H2 are shown in Figures 5 and 6.

- Since the actuation function measurement is an extrapolation to DC we do not quote a frequency dependent uncertainty. Instead we use the mean uncertainty calculated in the range 80-2000 Hz. The different sources of uncertainty from transfer function measurements described above are combined in quadrature.

3.2 $\Delta|D|$

Because of the careful work that was done to match the modeled and measured electronics this uncertainty was negligible for all interferometers. A comparison of the model with the measurement for L1 is shown in Figure 7, for H1 in Figure 8 and for H2 in Figure 9.

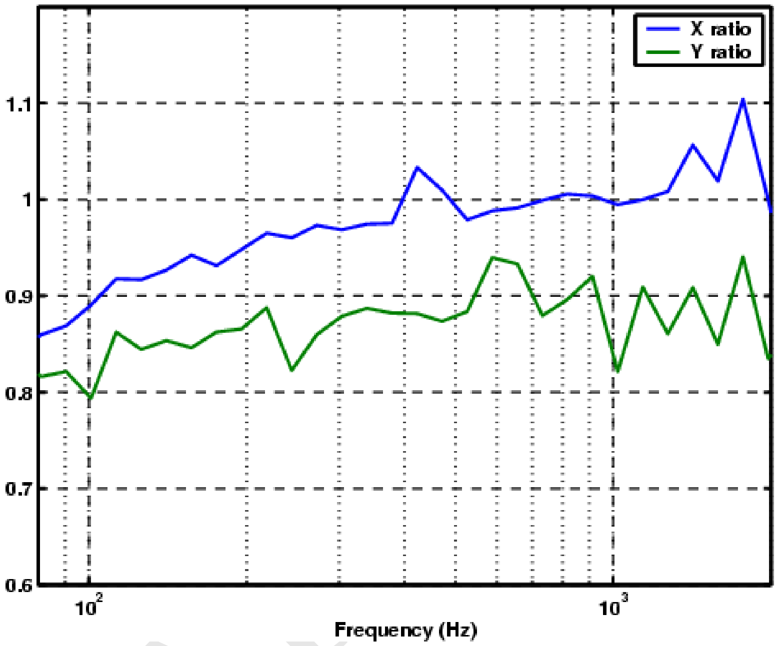

Figure 4: Ratio of the transfer functions of ITM/AS_I and ETM/AS_I for L1.

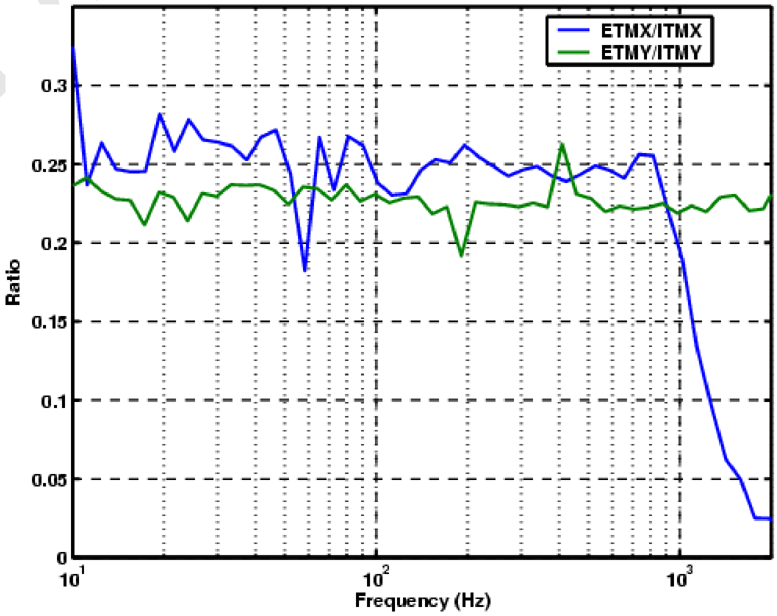

Figure 5: Ratio of the transfer functions of ITM/AS_I and ETM/AS_I for H1.

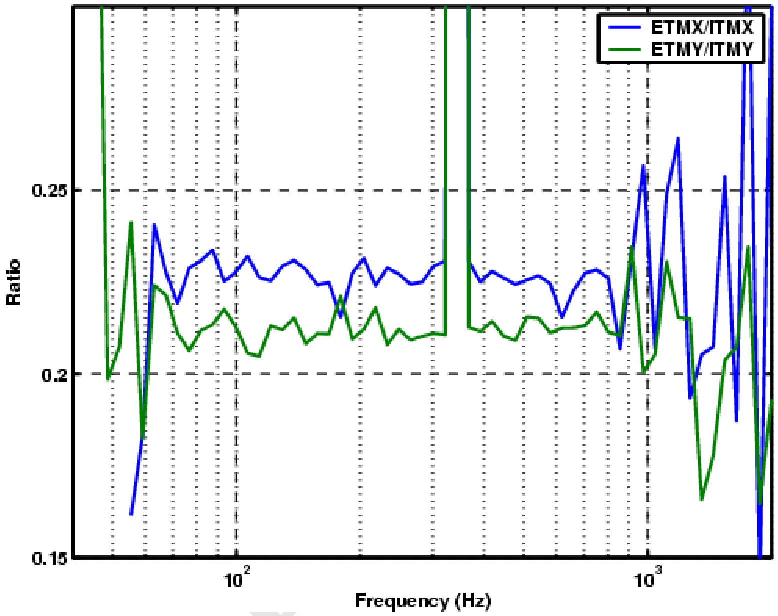

Figure 6: Ratio of the transfer functions of ITM/AS_I and ETM/AS_I for H2. The large spike is due to the violin modes.

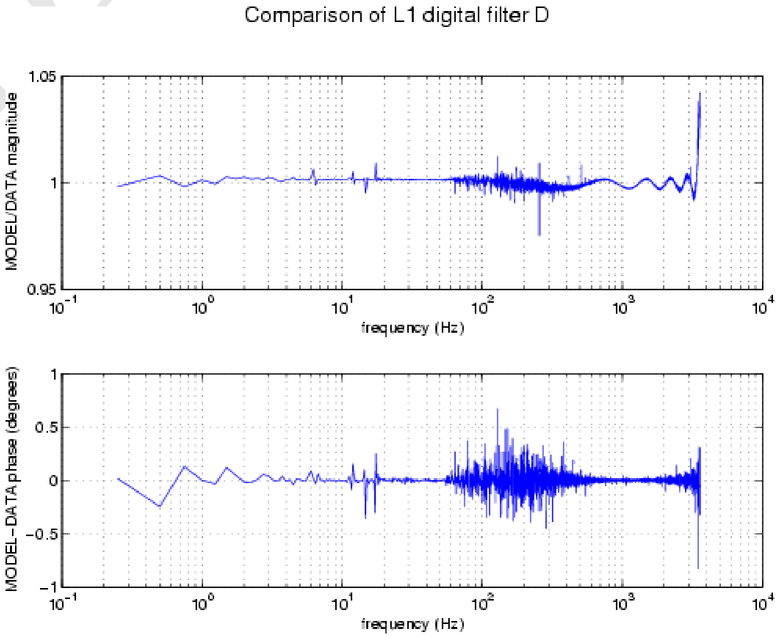

Figure 7: Comparison of model to measurement for the L1 digital transfer function.

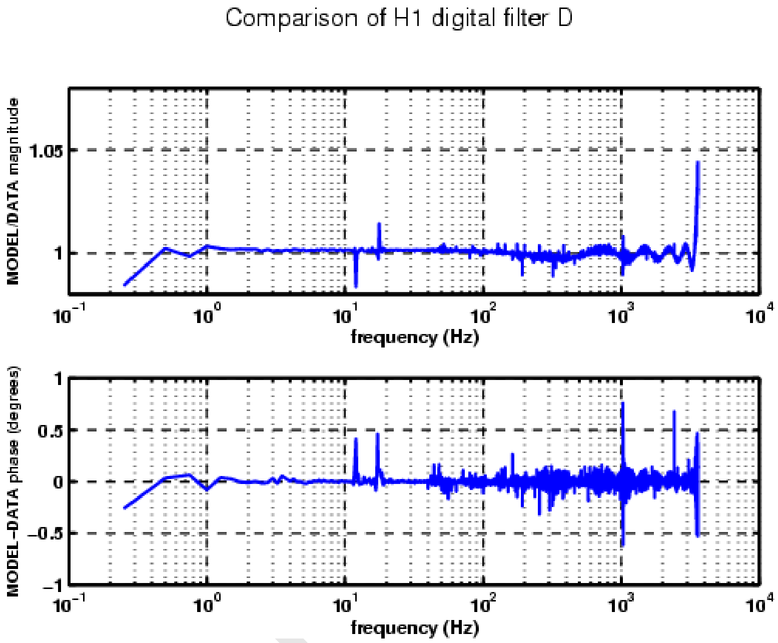

Figure 8: Comparison of model to measurement for the H1 digital transfer function.

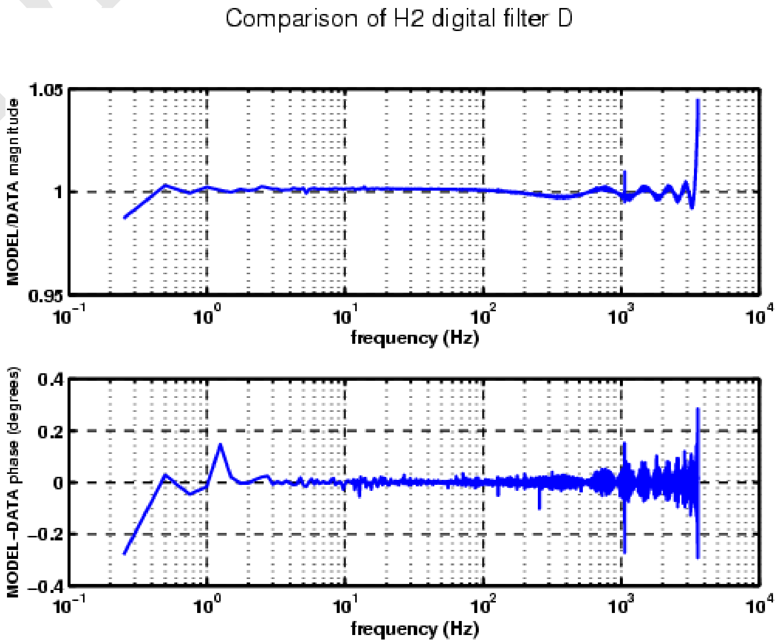

Figure 9: Comparison of model to measurement for the H2 digital transfer function.

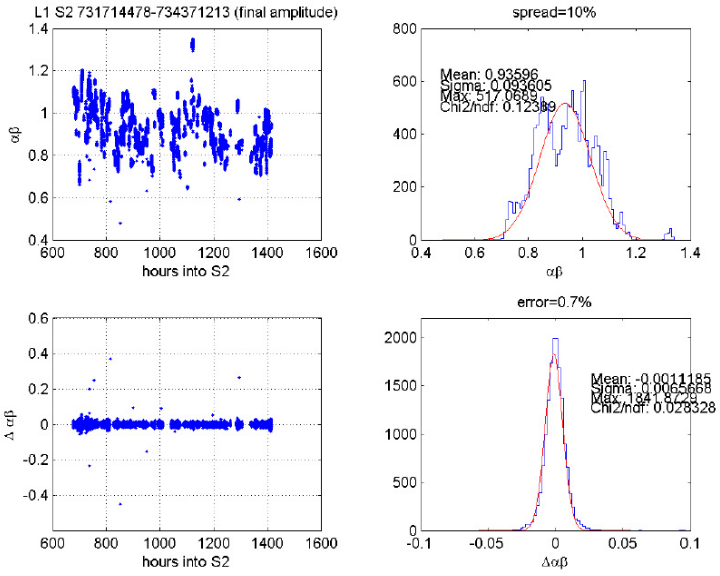

Figure 10: Plot of $\alpha\beta$ for L1 used to estimate the uncertainty.

3.3 $\Delta|G|$

This uncertainty is obtained from the coherence of the measurement using equation (10). Our measurements typically have very high coherence and so this contribution is typically 2% or less for all three interferometers.

3.4 $\Delta\alpha$

For details on how this uncertainty is estimated see reference [2]. The uncertainty is estimated from the difference in values of α obtained in consecutive minutes. These differences are histogrammed and the mean of the histogram is taken to be $\Delta\alpha$ (see Figure 10).

This value is strongly dependent on the amplitude of the high frequency calibration line. During S2 the initial injected amplitude of this line was too low and so the contribution to the uncertainty is higher. For L1 we have (see Figure 11) $\Delta\alpha$ values of 3.4% before GPS time 731714478 and 0.7% afterwards for H1 (figure 12) the values are 9.8% before 730793022, 2.9% afterward; for H2 the initial amplitude of the calibration line was large enough giving value of 3.5% for the entire run.

3.5 $\Delta\phi_A$

Our treatment of the uncertainty in $\Delta|A|$ does not lead easily to a method for estimating $\Delta\phi_A$. However, we would expect any such phase uncertainties to show up in the reconstruction of hardware injections. These injections assume a similar simple pendulum transfer function for the actuation. From analysis of periodic injections we estimate a phase uncertainty of 10° for L1 and 2° for H1 and H2[6]. The reason for the larger uncertainty on L1 is unknown.

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[6] From work by X. Siemens.

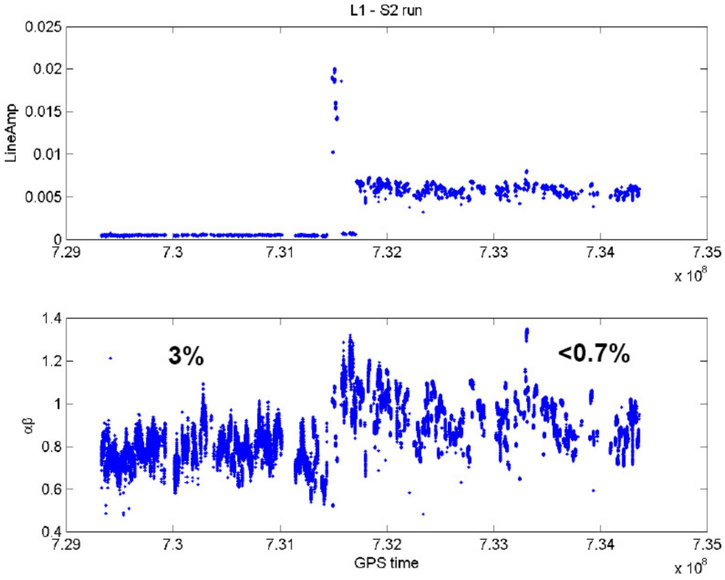

Figure 11: Plot of $\alpha\beta$ for L1 showing the different line amplitudes.

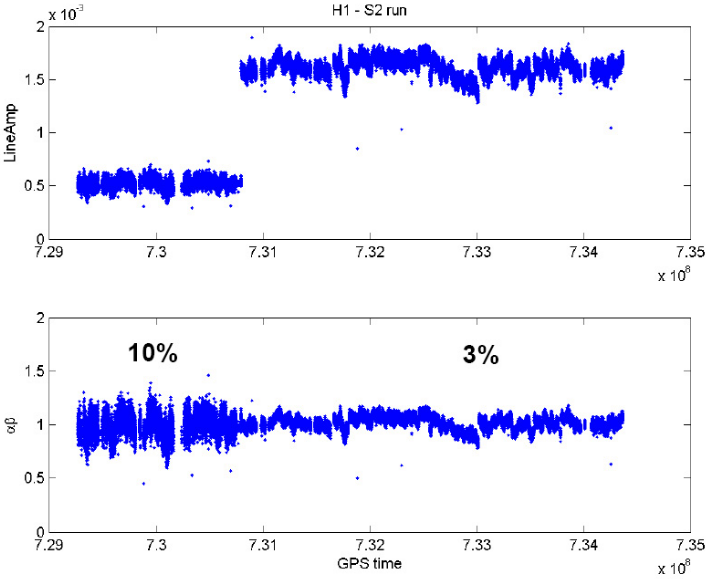

Figure 12: Plot of $\alpha\beta$ for H1 showing the different line amplitudes.

3.6 $\Delta\phi_D$

As for $|D|$ we have no appreciable uncertainty in ϕ_D.

3.7 $\Delta\phi_G$

$\Delta\phi_G$ is also found from the coherence of the transfer function measurement. The equation is the same as equation (10), but now the interpretation is as the standard deviation of ϕ_G and not as a fractional error. Again, because the coherence is high the contribution is typically less than 2 degrees for each interferometer.

The above contributions to the uncertainty in magnitude and phase are plotted for each interferometer in Figures 13 to 22.

4 Results

For most analyses an overall, non-frequency dependent estimate of the uncertainty is sufficient. Table 2 summarizes this information for each interferometer. There are two sets of numbers for L1 and H1 corresponding to the two periods of different calibration line amplitude. Frequency dependent uncertainties are available at the Calibration Home Page [6] for those who require them. These correspond to the “total” curves in Figures 13 to 22.

	Magnitude Uncertainty %	Phase Uncertainty °
L1 before GPS time 731714478	10	11
L1 after GPS time 731714478	9	10
H1 before GPS time 730793022	19	10
H1 after GPS time 730793022	6	4
H2	7	5

Table 2: Summary of uncertainties for the LIGO interferometers during S2. The numbers are a conservative estimate based on Figures 13 to 22.

5 Conclusion

This detailed look at the S2 calibration highlights the contributions of different parts of the process to the final uncertainty. Clearly better actuation function measurements (especially at LLO), and stronger calibration lines would have resulted in a more accurate calibration of the S2 data. However, at some stage we will become systematics limited and it may be that considerably more rigor in assessing and combining sources of uncertainty will be necessary. Having other techniques available for the calibration, (for example a photon calibrator), should help greatly in assessing systematics. Of course at some stage our level of precision will be adequate to the task at hand and further refinements will be driven by inaccuracies in our observations of real sources.

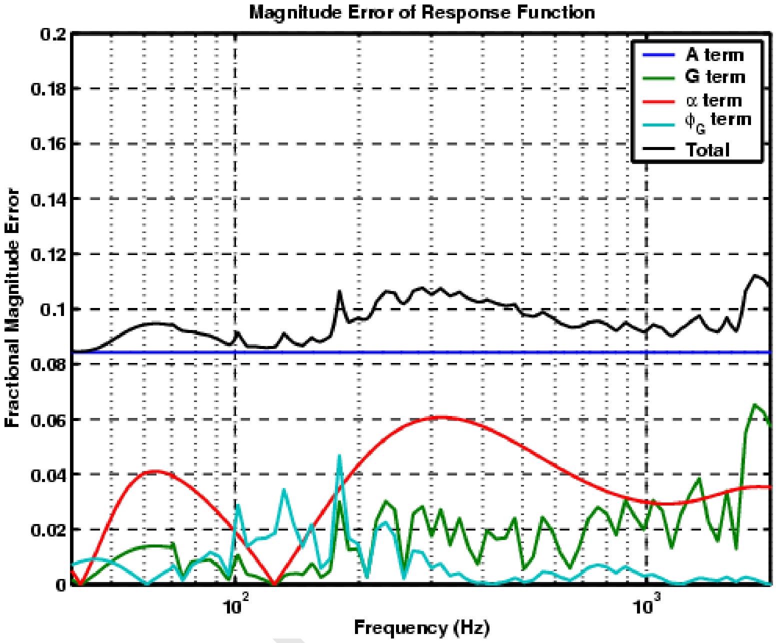

Figure 13: Contributions to the magnitude uncertainty for L1 before GPS time 731714478.

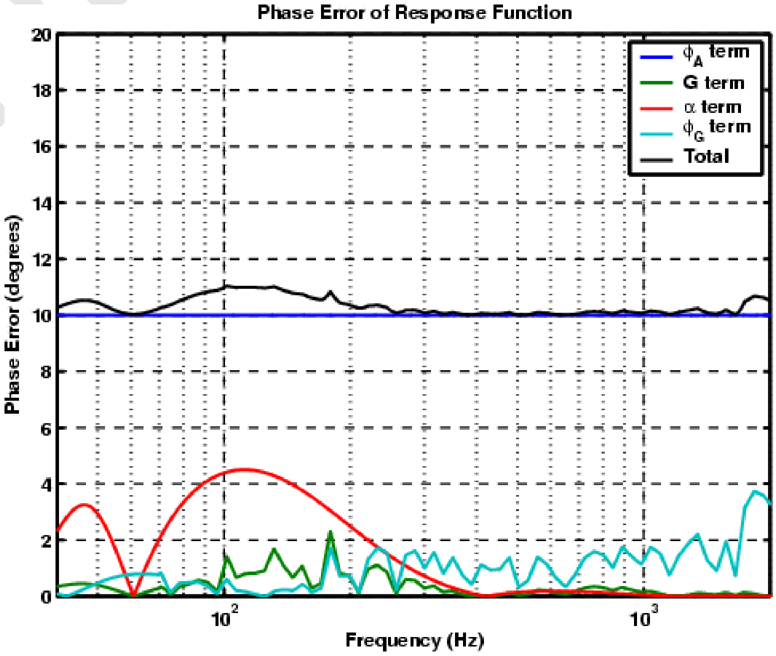

Figure 14: Contributions to the phase uncertainty for L1 before GPS time 731714478.

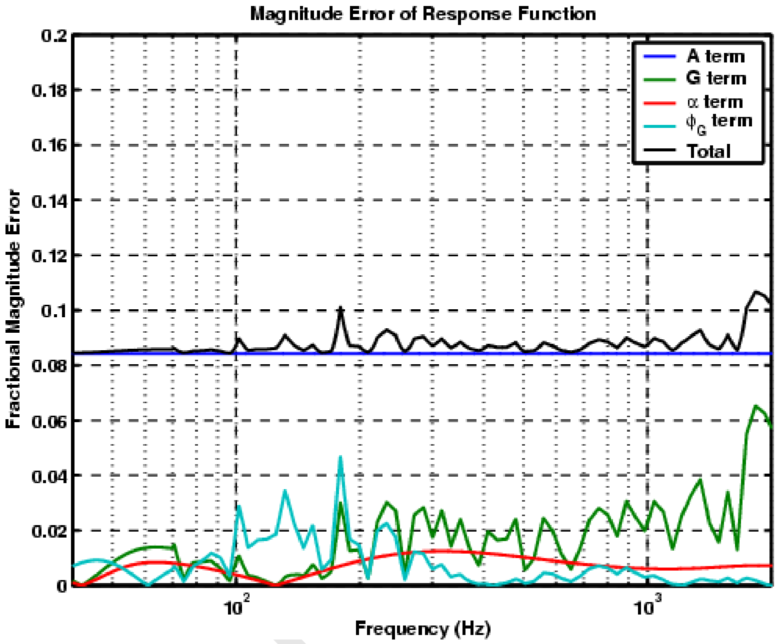

Figure 15: Contributions to the magnitude uncertainty for L1 after GPS time 731714478.

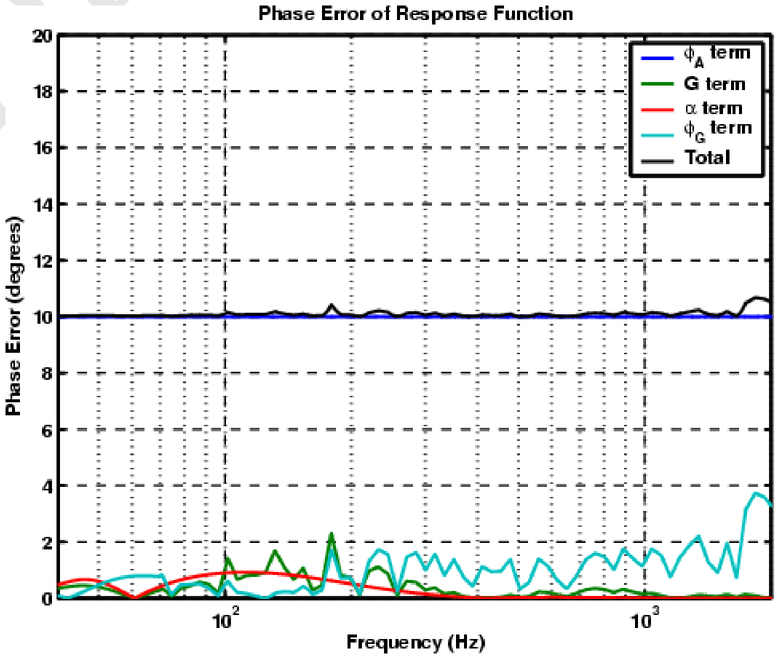

Figure 16: Contributions to the phase uncertainty for L1 after GPS time 731714478.

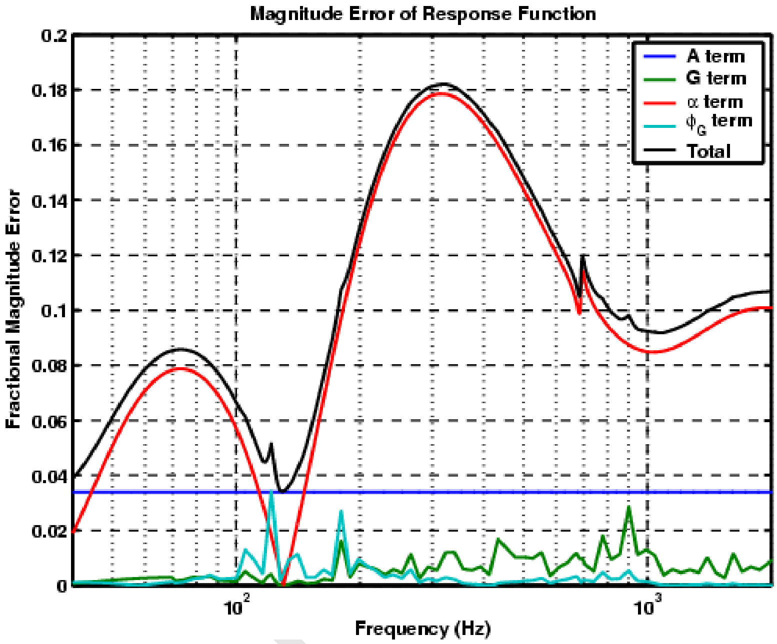

Figure 17: Contributions to the magnitude uncertainty for H1 before GPS time 730793022.

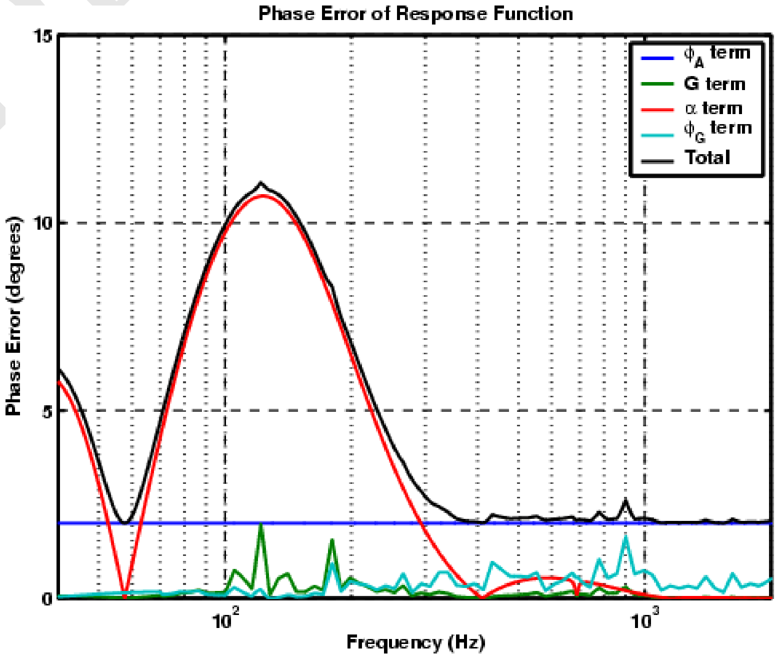

Figure 18: Contributions to the phase uncertainty for H1 before GPS time 730793022.

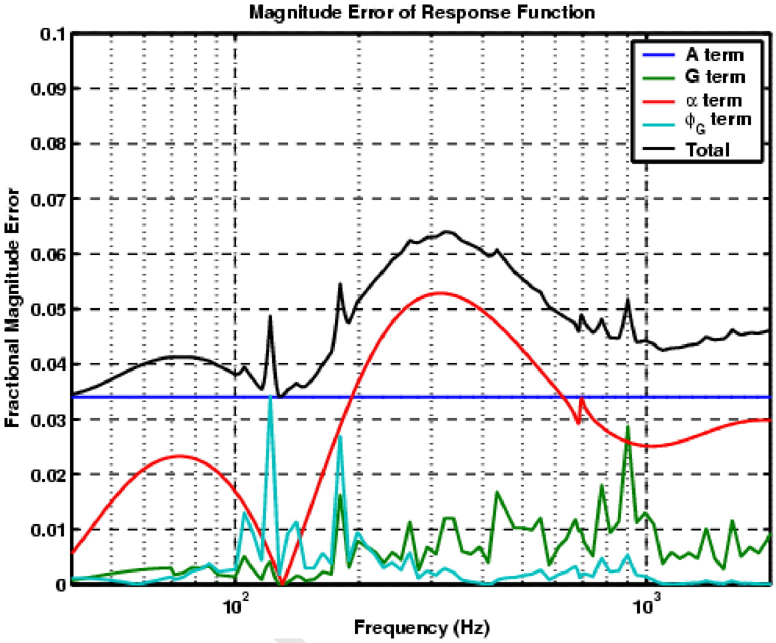

Figure 19: Contributions to the magnitude uncertainty for H1 after GPS time 730793022.

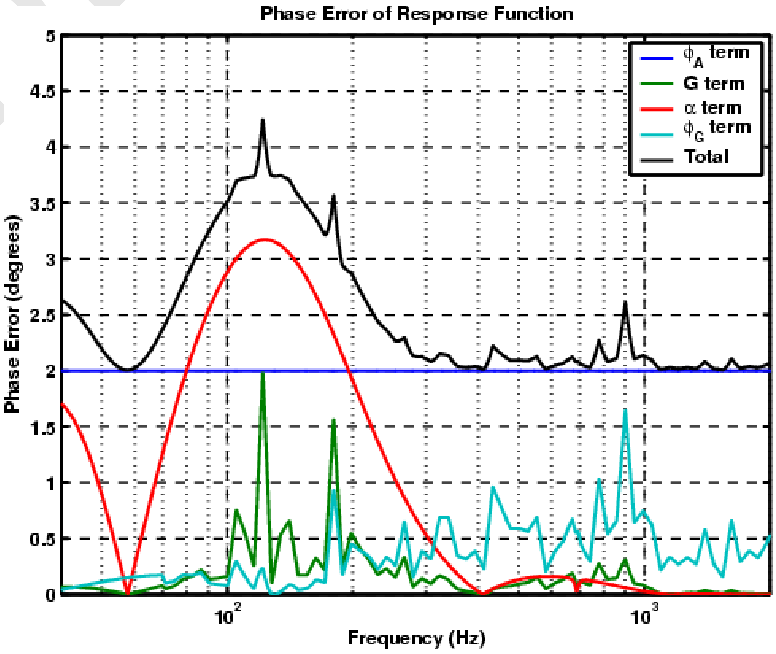

Figure 20: Contributions to the phase uncertainty for H1 after GPS time 730793022.

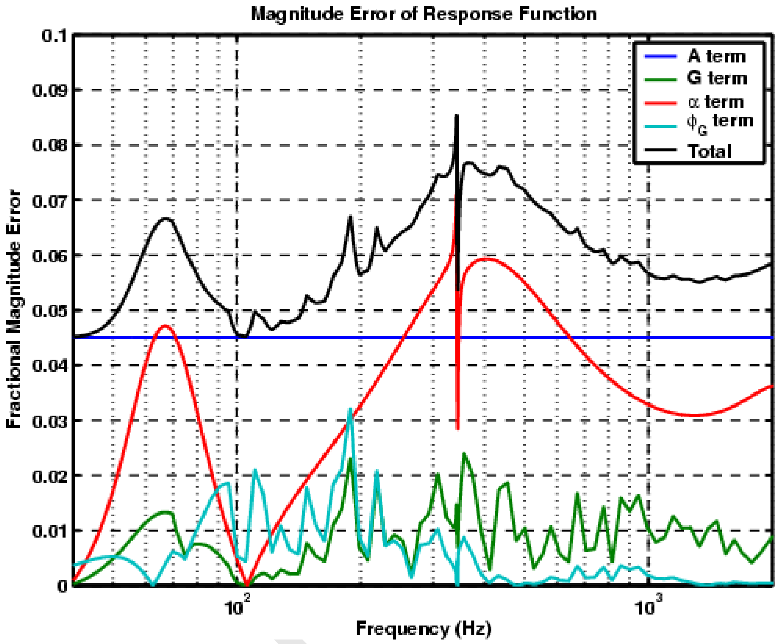

Figure 21: Contributions to the magnitude uncertainty for H2.

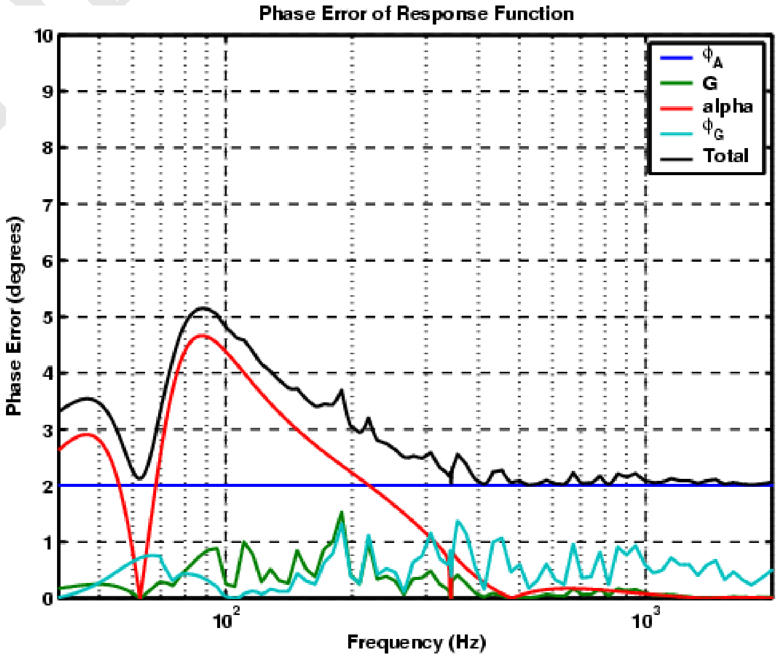

Figure 22: Contributions to the phase uncertainty for H2.

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[1] Adhikari R., Fritschel P., González G., Landry M., Matone L., O'Reilly B.,Radkins H., Takamori A. *Calibration of the LIGO detectors for the First LIGO Scientific Run* `T030097-00-D`

[2] González, G. *LIGO S2 Calibration: Alpha, Beta coefficients* available in `http://www.phys.lsu.edu/faculty/gonzalez/S2Calibration/`

[3] Sutton P., *SenseMonitor: An Inspiral Sensitivity Monitor for the DMT* `T040065-00-Z`

[4] Adhikari R, Evans M, Landry M, Marka S, Matone L and Yamamoto H, *Input Test Mass (ITM) Absolute Calibrations: Fringe Counting, Fringe Fitting, and Sign Toggling Methods* T020141-00-D

[5] Bendat J. S., Piersol A. G. *Random Data Analysis and Measurement Procedures* `Third Edition`

[6] LIGO Amplitude Calibration Homepage
http://blue.ligo-wa.caltech.edu/engrun/Calib_Home/

A MATLAB model of the interferometers

```
function [varargout] = LSCmodel(varargin)
% LSCmodel   -------------------------------------------------------%%%
% Evaluates a model of one of the interferometers LSC feedback loops %%
% Usage:                                                             %%
%        [openloopgain, sensing, actuation, response]                %%
%        = LSCmodel(IFOin,'darm',f,ugf)                              %%
%                                                                    %%
%                                                                    %%
%      Returns the open loop gain (OLG, unitless),                   %%
%      Sensing function (SENSE, in counts/meter), etc.               %%
%       each in a 2 column array, where                              %%
%         the first column is the frequency vector (real) and        %%
%         the second column is the response vector (complex)         %%
%                                                                    %%
%     the response function R is in strain/count                     %%
%        i.e.  h(f) = AS_Q(f) * R(f)                                 %%
% - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
%  v 1.1.0   Aug  4th, 2003
%  v 1.1.1   Aug 14th, 2003  - Some comments added
%  v 1.2.2   Aug 17th, 2003  - Added SUS LSC filters
%  v 1.2.3   Aug 25th, 2003  - added ugf as 4th varargin
%                              + fixed x2 bug in 'hd' calculation
%--------------------------------------------------------------------%%%

global lsc


%----- Parse input arguments -----------------------------%%%%
if nargin < 1
  error('Not enough inputs: specify IFO params!')

elseif nargin > 0
  IFOin = varargin{1};
  loop_name = 'darm';       % default loop is DARM
  lsc = eval(strcat('IFOin.',loop_name));
  ff = logspace(log10(lsc.fl),log10(lsc.fu),lsc.npt);

  if nargin > 1
    loop_name = varargin{2};

    if nargin > 2
      ff = varargin{3};
      fdim = size(ff);
```

```
      if fdim(1) > 1 & fdim(2) == 1
        ff = ff’;
      end

        if nargin > 3                % 4th argument is UGF
          lsc.ugf = varargin{4};
        end
    end
  end

else
  error(’%s’,’Invalid Number of Input Arguments’)
end
%---------------------------------------------------------%%%%



switch upper(loop_name)
 case ’CM’
  module_name = ’LSC’;
 otherwise
  module_name = loop_name;
  mcld = zeros(size(ff))’;
  aod = zeros(size(ff))’;
end

n = 1:length(ff);

if max(ff) < lsc.ugf
   warning(’Specified frequencies are below the UGF’)
   ff_low = log10(max(ff)+1);
   ff_higher = log10(lsc.ugf*3);
   ff_plus = logspace(ff_low,ff_higher,301);
   ff = [ff ff_plus];
   quack = 1;
end



ugf = lsc.ugf;
iugf = min(find(ff>ugf));

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%     Analog portion of loop               %%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
lscpend = pendulum(lsc);

fc = lsc.cavpole;          % cavity pole
cavpole = zpk([], -2*pi*fc, 2*pi*fc);

aa = IFOin.misc.aa;
ai = IFOin.misc.ai;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%% Time Delay  %%%%%%%%%%
[num,den] = pade(lsc.tdelay,4);
tdelay = tf(num,den);

%%%%%%%%%% DAC sample-and-hold  %%%%%%%%%%%%%%%%%%%%
fs = lsc.fs;
d2a = (sin(pi*ff/fs)./(pi*ff/fs)).*exp(-i*pi*ff/fs);

%%%%%%%%%% Coil Driver Snubber Circuit  %%%%%%%%%%%%%%%%%%%
snub = snubber(lsc);

%%%%%%%%%%%%  Sensing function   %%%%%%%%%%%%%%%%%%%
sense = cavpole * lsc.hflowpass * aa * lsc.electronics_gain;
%%%%%%%%%%% Actuation function   %%%%%%%%%%%%%%%%%%%
actuation = lscpend * ai * tdelay * snub;
dcgain(actuation)
%%%%%%%%%  compute freq response vectors  %%%%%%%%%%
hsense = squeeze(freqresp(sense,2*pi*ff));
hact = d2a’ .* squeeze(freqresp(actuation,2*pi*ff));
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%             Digital portion of loop                %%%
%                                                         %%
% First filter file is for the LSC loop (e.g. DARM)        %%
% The 2nd & 3rd are for the SUS modules (e.g. ETMX & ETMY) %%
% It still works even there’s just one mass (e.g. RM)      %%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
filtnums = lsc.digitalfilters;
file = lsc.filterfile;
[sos,dgain,filtname] = ...
    readfilters(file,upper(module_name),filtnums);
clear h
for ii = 1:size(sos,1),
    [b,a] = sos2tf(sos(ii,:));
    h(ii,:) = freqz(b,a,ff,fs);
end
hd = prod(h,1);
hd = shiftdim(hd,1);
```

```
hd = dgain * lsc.lsc_gain * lsc.itmtrx * hd;

if ischar(lsc.susfilterfile1)
  filtnums = lsc.susdigitalfilters1;
  file = lsc.susfilterfile1;
  [sos,dgain,filtname] = ...
    readfilters(file,upper('LSC'),filtnums);
  clear h
  for ii = 1:size(sos,1),
    [b,a] = sos2tf(sos(ii,:));
    h(ii,:) = freqz(b,a,ff,fs);
  end
  hd1 = prod(h,1);
  hd1 = shiftdim(hd1,1);
  if ~ischar(lsc.susfilterfile2)
    hact = hact .* hd1;
  end
end

if ischar(lsc.susfilterfile2)
  filtnums = lsc.susdigitalfilters2;
  file = lsc.susfilterfile2;
  [sos,dgain,filtname] = ...
    readfilters(file,upper('LSC'),filtnums);
  clear h
  for ii = 1:size(sos,1),
    [b,a] = sos2tf(sos(ii,:));
    h(ii,:) = freqz(b,a,ff,fs);
  end
  hd2 = prod(h,1);
  hd2 = shiftdim(hd2,1);
  if ischar(lsc.susfilterfile1)
    hact = hact .* (hd1 + hd2)/2;
  else
    hact = hact .* hd2;
  end
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%       Total loop gain                    %%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
lscolg = hsense .* hact .* hd;
gtemp = abs(lscolg(iugf));
lscolg = lscolg / gtemp;                   % Sensing gain fudged to
hsense = hsense / gtemp;                   % get the UGF right
response = 1./hsense .* (1 + lscolg);
```

```
%%%%%%%%%%%%%%%%% Put returned data into arrays %%%%%%%%%%%
openloopgain = [ff(n)’ lscolg(n)];
sensing = [ff(n)’ hsense(n)];
actuating = [ff(n)’ hact(n)];
response = [ff(n)’ response(n)];
%%%%%%  optional AO loop gain for CM servo %%%%%%%%%%%%%%
switch upper(loop_name)
 case ’CM’
  mcl2f = squeeze(freqresp(lsc.mcl2f,2*pi*ff));
  mcld = lscolg .* mcl2f;
  hact = hact .* mcl2f;

  ao = zpk(cavpole * lsc.hflowpass * lsc.ao_c);
  aod = squeeze(freqresp(ao,2*pi*ff));
  nn = min(find(ff>ugf));
  ao_fudge = abs(aod(nn));                 % Fudges AO to set the UGF
  aod = aod / ao_fudge;

  nn = min(find(ff>lsc.xover));
  mcl_fudge = abs(mcld(nn)/aod(nn));      % Fudges MCL to set xover freq
  mcld = mcld / mcl_fudge;

  hsense = hsense / mcl_fudge;

  lscolg = mcld + aod;

  response = 1./hsense .* (1 + lscolg);
  %%%%%%%%%% Put returned data into arrays %%%%%
  openloopgain = [ff(n)’ lscolg(n) mcld(n) aod(n)];
  sensing = [ff(n)’ hsense(n)];
  actuating = [ff(n)’ hact(n)];
  response = [ff(n)’ response(n)];

end
%%%%%%%%%%%%%%%%% Output Argument Assignments %%%%%%%%%%%
if nargout < 1
    mybodeplot(openloopgain)
elseif nargout > 0
  varargout(1) = {openloopgain};
  if nargout > 1
    varargout(2) = {sensing};
    if nargout > 2
      varargout(3) = {actuating};
      if nargout == 4
```

```
        varargout(4) = {response};
      end
    end
  end
elseif nargout > 4
  error(’Too Many Output Arguments’)
end

return

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% ------------------------------------------------------
% Sub-functions of LSCmodel  -----------------------
% \/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function lscpend = pendulum(lsc)

wp = 2 * pi * lsc.pendf0;
Qp = lsc.pendQ;
sys = tf(wpˆ2, [1 wp/Qp wpˆ2]);
DCcal = lsc.DCcal;
lscpend = DCcal * sys;

return
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function snub = snubber(lsc)

R_ser = lsc.R_ser;
R_snub = lsc.R_snub;
C_snub = lsc.C_snub;
C_cabl = lsc.C_cabl;
R_coil = lsc.R_coil;
H_coil = lsc.H_coil;

A_snub = R_snub * C_snub;
den_s3 = A_snub*C_cabl*H_coil*R_ser;
den_s2 = R_ser*A_snub*R_coil*C_cabl+R_ser*C_cabl*H_coil+ ...
              R_ser*C_snub*H_coil+A_snub*H_coil;
den_s1 = R_ser*A_snub+C_cabl*R_coil+C_snub*R_coil+...
              A_snub*R_coil+H_coil;
den_s0 = R_coil+R_ser;
TF_gain= R_coil + R_ser;
snub = TF_gain * tf([A_snub 1],[den_s3 den_s2 den_s1 den_s0]);
```

```
return
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [sos,gain,name] = readfilters(file,module,varargin)

ret = 1;
fm = [varargin{:}];
fid = fopen(file);
firstflag = 1;
mlen = length(module);

while 1

  tline = fgetl(fid);

  if ˜ischar(tline), break, end

  if strncmp(tline,module,mlen)

    arr = strread(tline,’%s’,’delimiter’,’ ’);
    rfm = str2double(arr(2));

    if ismember(rfm,fm)
      if firstflag
        name = arr(7);
        gain = str2double(arr(8));
        coef = str2double([arr(9) arr(10) arr(11) arr(12)]);
firstflag = 0;
      else
        name = strcat(name,’/’,arr(7));
        gain = gain*str2double(arr(8));
        coef = [coef str2double([arr(9) arr(10) arr(11) arr(12)])];
      end

      nsos = str2double(arr(4));

      if nsos > 1
        for ksos=1:nsos-1
       tline = fgetl(fid);
       arr = strread(tline,’%s’,’delimiter’,’ ’);
       coef = [coef str2double([arr(1) arr(2) arr(3) arr(4)])];
    end;
      end
    end;
  end
end
```

```
fclose(fid);
g = coef;
dim = length(g);
n2b = dim/4;
soscoef = [];

for i = 1:n2b,
   a = [1, g(1+(i-1)*4), g(2+(i-1)*4)];
   b = [1, g(3+(i-1)*4), g(4+(i-1)*4)];
   soscoef = [soscoef; b(1) b(2) b(3) a(1) a(2) a(3)];
end
sos = soscoef;
return
%%%%%% ***************************************************************
```

B Parameter file for L1

```
function L1 = L1IFOparams;
% Parameter file for Interferometer LSC loop model
%
% version 1.0.1      Updated AA & AI filter to match board measurements
% version 1.2.3      Cavity pole -> 82.6  Andri elog ˜August
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
darm.fl  = 9;                                    % lower frequency of ban
darm.fu  = 8000;                                 % upper frequency of ban
darm.npt = 301;                                  % number of points in ba
darm.fs  = 16384;                                % sampling frequency, Hz
darm.ugf = 175;                                  % unity gain frequency o

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
darm.cavpole = 82.6;                             % cavity pole, Hz
darm.pendf0  = 0.76;                             % pendulum eigenfrequenc
darm.pendQ   = 10;                               % pendulum Q
darm.ETMXcal = 0.40e-9;                          % DC calibration of ETMX
darm.ETMYcal = 0.37e-9;                          % DC calibration of ETMY
darm.tdelay  = 160e-6;                           % time delay in loop, se
darm.armlength = 3995.15;                        % arm length in meters
darm.hflowpass = ...
    zpk([],-2*pi*[33e3 33e3 33e3],...
        (2*pi*33e3)ˆ3);                          % RC lowpass in L1 after

%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of DARM digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
darm.filterfile = '/home/irish/FOTON/L1/L1LSC.txt';
darm.digitalfilters = [0,1,2,3,4];

darm.susfilterfile1 = '/home/irish/FOTON/L1/L1SUS_ETMX.txt';
darm.susdigitalfilters1 = [3,4];

darm.susfilterfile2 = '/home/irish/FOTON/L1/L1SUS_ETMY.txt';
darm.susdigitalfilters2 = [3,4];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
darm.darm2etmx =  2.5;                           % Output matrix: DARM to
darm.darm2etmy = -2.5;                           % Output matrix: DARM to
darm.itmtrx = 0.012;                            % Input matrix: AS_Q to D
darm.lsc_gain = -1.0;                           % DARM filter module gain
```

```
darm.DCcal = darm.ETMYcal * darm.darm2etmy -...  % DARM_CTRL cal
             darm.ETMXcal * darm.darm2etmx;

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
darm.R_ser  = 3000;                              % Coil Driver series res
darm.R_snub = 680;                               % snubber series resisto
darm.C_snub = 0.022e-6;                          % snubber series cap
darm.C_cabl = 800e-12;                           % ribbon cable capacitan
darm.R_coil = 22;                                % OSEM coil resistance
darm.H_coil = 3.3e-3;                            % OSEM coil inductance


% Misc Info (mostly unused) --------------------------------------------
darm.opgain = 1.2e9;                          % Calculated watts/meter
darm.efficiency = 0.9;                        % PO fraction * 90/10 split
darm.eta = 0.8;                               % Amps / Volt
darm.Zrf = 140;                               % Tank circuit impedance
darm.Grf = 10;                                % Pre-amp gain
darm.Cable = 0.67;                            % 3.5 dB of loss in 100’ of
darm.PS = 0.707;                              % 3 dB loss in power splitt
darm.Mixer = 0.5;                             % 6 dB loss in mixer
darm.WG = 10ˆ(24/20);                         % 24 dB of whitening gain
darm.AA = 2;                                  % Gain of 2 in single-diff
darm.ADC = 32768/10;                          % 16-bit Analog to Digital
darm.AS1_Q_GAIN = 0.005;                      % Compensates some whitenin

darm.electronics_gain = darm.eta *...        % Counts / Watt
                        darm.Zrf *...
                        darm.Grf *...
                        darm.Cable *...
                        darm.PS *...
                        darm.Mixer *...
                        darm.WG *...
                        darm.AA *...
                        darm.ADC *...
                        darm.AS1_Q_GAIN;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%



%-----------------------------------------------------------------------
```

```
% Parameter file for MICH loop model
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
mich.fl  = 0.9;                                  % lower frequency of ban
mich.fu  = 1000;                                 % upper frequency of ban
mich.npt = 301;                                  % number of points in ba
mich.fs  = 16384;                                % sampling frequency, Hz
mich.ugf = 10;                                   % unity gain frequency o

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
mich.cavpole = 1e6;                              % Something must happen
mich.pendf0  = 0.75;                             % pendulum eigenfrequenc
mich.pendQ   = 10;                               % pendulum Q
mich.RMcal = 0.38e-9;                            % DC calibration of RM,
mich.BScal = 0.8e-9;
mich.tdelay  = 150e-6;                           % time delay in loop, se
mich.schnupp = 0.31;                             % (ly-lx)
mich.hflowpass = ...
    zpk([],-2*pi*[100e3],...
        (2*pi*100e3));                          % RC lowpass in L1 after

%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of MICH digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
mich.filterfile = '/home/irish/FOTON/L1/L1LSC.txt';
mich.digitalfilters = [0,1,2,3,5];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
mich.mich2rm = -10.5;                            % Output matrix: MICH to
mich.mich2bs = 7.4;                              % Output matrix: MICH to
mich.itmtrx = -0.666;                            % Input matrix: POB_Q to
mich.lsc_gain = -0.08;                          % MICH filter module gain

mich.DCcal = (sqrt(2) * mich.BScal * mich.mich2bs +...
                        mich.RMcal * mich.mich2rm) -...
                        mich.RMcal * mich.mich2rm;       % MICH_CTRL cal

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
mich.R_ser  = 3000;                              % series resistor
mich.R_snub = 680;                               % snubber series resisto
mich.C_snub = 0.022e-6;                          % snubber series cap
```

```
mich.C_cabl = 800e-12;                           % cable capacitance
mich.R_coil = 22;                                % coil resistance
mich.H_coil = 3.3e-3;                            % coil inductance

% Misc Info (mostly unused) --------------------------------------------
mich.opgain = 2;                                % Calculated watts/meter
mich.efficiency = 0.9 * 80e-6;                  % EO Shutter, clipping, e
mich.eta = 0.8;                                 % Amps / Volt
mich.Zrf = 380;                                 % Tank circuit impedance
mich.Grf = 10;                                  % Pre-amp gain
mich.Cable = 0.67;                              % 3.5 dB of loss in 100'
mich.PS = 0.707;                                % 3 dB loss in power spli
mich.Mixer = 0.5;                               % 6 dB loss in mixer
mich.WG = 10^(36/20);                           % 24 dB of whitening gain
mich.AA = 2;                                    % Gain of 2 in single-dif
mich.ADC = 32768/10;                            % 16-bit Analog to Digita
mich.POB_Q_GAIN = 0.125;                        % Compensates some whiten

mich.electronics_gain = mich.eta *...       % Counts / Watt
                        mich.Zrf *...
                        mich.Grf *...
                        mich.Cable *...
                        mich.PS *...
                        mich.Mixer *...
                        mich.WG *...
                        mich.AA *...
                        mich.ADC *...
                        mich.POB_Q_GAIN;
%-----------------------------------------------------------------------



%***********************************************************************
% Parameter file for PRC loop model
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
prc.fl  = 9;                                     % lower frequency of ban
prc.fu  = 1000;                                  % upper frequency of ban
prc.npt = 301;                                   % number of points in ba
prc.fs  = 16384;                                 % sampling frequency, Hz
prc.ugf = 30;                                    % unity gain frequency o

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
prc.cavpole = 100e3;                             % PRC pole??
prc.pendf0  = 0.75;                              % pendulum eigenfrequenc
```

```
prc.pendQ   = 10;                                % pendulum Q
prc.RMcal = 0.38e-9;                             % DC calibration of RM,

prc.tdelay  = 170e-6;                            % time delay in loop, se
prc.rclength = 9.204;                            % (l1+l2)/2
prc.hflowpass = ...
    zpk([],-2*pi*[100e3],...
        (2*pi*100e3));                          % RC lowpass in L1 after
                                                % mixer

%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of PRC digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
prc.filterfile = ’/home/irish/FOTON/L1/L1LSC.txt’;
prc.digitalfilters = [0,1,2,3,4,5];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
prc.prc2rm = 7.4;                                % Output matrix: PRC to
prc.itmtrx = 0.17;                               % Input matrix: POB_I to
prc.lsc_gain = -0.125;                           % PRC filter module gain

prc.DCcal = -prc.RMcal * prc.prc2rm;             % PRC_CTRL cal

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
prc.R_ser  = 3000;                               % series resistor
prc.R_snub = 680;                                % snubber series resisto
prc.C_snub = 0.022e-6;                           % snubber series cap
prc.C_cabl = 800e-12;                            % cable capacitance
prc.R_coil = 22;                                 % coil resistance
prc.H_coil = 3.3e-3;                             % coil inductance

% Misc Info (mostly unused) --------------------------------------------
prc.opgain = 1.2e9;                              % Calculated watts/meter
prc.efficiency = mich.efficiency;                % PO fraction * 90/10 sp
prc.eta = mich.eta;                              % Amps / Volt
prc.Zrf = mich.Zrf;                              % Tank circuit impedance
prc.Grf = mich.Grf;                              % Pre-amp gain
prc.Cable = mich.Cable;                          % 3.5 dB of loss in 100’
prc.PS = mich.PS;                                % 3 dB loss in power spl
prc.Mixer = mich.Mixer;                          % 6 dB loss in mixer
prc.WG = 10ˆ(36/20);                             % 36 dB of whitening gai
```

```
prc.AA = mich.AA;                                % Gain of 2 in single-di
prc.ADC = mich.ADC;                              % 16-bit Analog to Digit
prc.POB_I_GAIN = 0.125;                          % Compensates some white

prc.electronics_gain = prc.eta *...        % Counts / Watt
                         prc.Zrf *...
                         prc.Grf *...
                         prc.Cable *...
                         prc.PS *...
                         prc.Mixer *...
                         prc.WG *...
                         prc.AA *...
                         prc.ADC *...
                         prc.POB_I_GAIN;
%************************************************************************


% Parameter file for CARM loop model
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
carm.fl  = 9;                                    % lower frequency of ban
carm.fu  = 8000;                                 % upper frequency of ban
carm.npt = 301;                                  % number of points in ba
carm.fs  = 16384;                                % sampling frequency, Hz
carm.ugf = 150;                                  % unity gain frequency o

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
carm.cavpole = 1;                                % cavity pole, Hz
carm.pendf0  = 0.75;                             % pendulum eigenfrequenc
carm.pendQ   = 10;                               % pendulum Q
carm.ETMXcal = 0.38e-9;                          % DC calibration of ETMX
carm.ETMYcal = 0.38e-9;                          % DC calibration of ETMY
carm.tdelay  = 100e-6;                           % time delay in loop, se
carm.armlength = 3995.15;                        % arm length in meters
carm.hflowpass = ...
    zpk([],-2*pi*[33e3 33e3 33e3],...
        (2*pi*33e3)ˆ3);                          % RC lowpass in L1 after


%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of CARM digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
carm.filterfile = ’/home/irish/FOTON/L1/L1LSC.txt’;
```

```
carm.digitalfilters = [0,1,2];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
carm.carm2etmx = -2.5;                           % Output matrix: CARM to
carm.carm2etmy = -2.5;                           % Output matrix: CARM to
carm.itmtrx = 0.05;                              % Input matrix: REFL_I t
carm.lsc_gain = -1.5;                            % CARM filter module gai

carm.DCcal = carm.ETMXcal * carm.carm2etmx +...
             carm.ETMYcal * carm.carm2etmy;

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
carm.R_ser  = 3000;                              % series resistor
carm.R_snub = 680;                               % snubber series resisto
carm.C_snub = 0.022e-6;                          % snubber series cap
carm.C_cabl = 800e-12;                           % cable capacitance
carm.R_coil = 22;                                % coil resistance
carm.H_coil = 3.3e-3;                            % coil inductance

% Misc Info (mostly unused) --------------------------------------------
carm.opgain = 1.2e9;                          % Calculated watts/meter
carm.efficiency = 0.125;                % PO fraction * 90/10 split
carm.eta = 0.8;                               % Amps / Volt
carm.Zrf = 320;                               % Tank circuit impedance
carm.Grf = 10;                                % Pre-amp gain
carm.Cable = 0.67;                            % 3.5 dB of loss in 100’ of
carm.PS = 0.707;                              % 3 dB loss in power splitt
carm.Mixer = 0.5;                             % 6 dB loss in mixer
carm.WG = 10^(30/20);                         % 36 dB of whitening gain
carm.AA = 2;                                  % Gain of 2 in single-diff
carm.ADC = 32768/10;                          % 16-bit Analog to Digital
carm.REFL_I_GAIN = -1.0;                       % Compensates some whiteni

carm.electronics_gain = carm.eta *...        % Counts / Watt
                          carm.Zrf *...
                          carm.Grf *...
                          carm.Cable *...
                          carm.PS *...
                          carm.Mixer *...
                          carm.WG *...
                          carm.AA *...
                          carm.ADC *...
```

```
                          carm.REFL_I_GAIN;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%



%~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
% - - - Miscellaneous Parameters - - -
%________________________________________________________________________

mc.Lmc = 12.243;                                 % MC round trip L = 25 m
mc.Tmc1 = 2000e-6;                               % Power transmission
mc.Tmc2 = 10e-6;
mc.Tmc3 = 2000e-6;
mc.m_sos = 0.25;                                 % SOS mass in kg
mc.sys = load('/home/irish/mat/cm/mcob.mat');
mc.ao = -zpk(mc.sys.mcsys(7,8));
mc.mcl = -zpk(mc.sys.mcsys(7,11));

los.m = 10.5;                                    % LOS mass in kg
los.phi = 1e-3;                                  % Loss angle of steel wi
los.wirelength = 0.442;                          % LOS wire length
los.fp = 0.75;                                   % LOS pend freq


%%%%%%%%%%%     AA & AI filtering   %%%%%%%%%%%%%%%
[z,p,k] = ellip(4,4,60,2*pi*7570,'s');
misc.ai = zpk(z,p,k*10ˆ(4/20)) * zpk([],-2*pi*13e3,2*pi*13e3);

% Fudged Anti-Imaging Filter
[z,p,k] = ellip(8,0.001,80,2*pi*7570,'s');
misc.aa = zpk(z,p,k*10ˆ(0.001/20)) *...
          zpk([],-2*pi*32768,2*pi*32768);

% Schematic AA Filter
%[z,p,k] = ellip(8,.035,80,2*pi*7570,'s');
%misc.aa = zpk(z,p,k*10ˆ(0.035/20));

misc.c = 299792458;
misc.ec = 1.6022e-19;
misc.lambda = 1064e-9;
misc.nu = misc.c / misc.lambda;
misc.alpha = 1/137.0360;
%________________________________________________________________________
```

```
% Parameter file for Common Mode Servo loop model
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
cm.fl  = 9;                                    % lower frequency of band,
cm.fu  = 100e3;                                 % upper frequency of band
cm.npt = 901;                                  % number of points in band
cm.fs  = 16384;                                % sampling frequency, Hz
cm.ugf = 25000;                                % unity gain frequency of
cm.xover = 250;                                % MCL / AO crossover freq,

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
cm.cavpole = 1;                                % cavity pole, Hz
cm.pendf0  = 1.0;                              % pendulum eigenfrequency,
cm.pendQ   = 10;                               % pendulum Q
cm.MC2cal = 0.44e-9;                           % DC calibration of MC2, m
cm.tdelay  = 60e-6;                           % time delay in loop, sec
cm.armlength = 3995.15;                        % arm length in meters

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
cm.U9 = zpk(-2*pi*1,-2*pi*50,1);                       % Additive Offset
cm.AO_Gain = 10ˆ(4/20);                                % path on the
cm.U15 = zpk(0,-2*pi*5,1);                             % CM board
cm.U16 = zpk(0,-2*pi*5,1);
cm.Bounce_Notch = zpk(twint(16.25,100));               % External Twin-T

cm.AOtf = cm.U9 * cm.U15 * cm.U16 * cm.Bounce_Notch * cm.AO_Gain;
cm.ao_c = cm.AOtf * mc.ao;

cm.mcl2f = mc.mcl;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of CM digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
cm.filterfile = ’/home/irish/FOTON/L1/L1SUS_MC2.txt’;
cm.digitalfilters = [0,3,4,5,6,8,9];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
cm.itmtrx = 0.05;                              % Input matrix: REFL_I to
cm.lsc_gain = -0.0012;                         % MC2_LSC filter module ga

cm.DCcal = cm.MC2cal;

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
cm.R_ser  = 7200;                              % series resistor
cm.R_snub = 10;                               % snubber series resistor
cm.C_snub = 1e-12;                               % snubber series cap
cm.C_cabl = 800e-12;                           % cable capacitance
cm.R_coil = 22;                                % coil resistance
cm.H_coil = 3.3e-3;                            % coil inductance

% Misc Info (mostly unused) ---------------------------------------------
cm.opgain = 1.2e9;                          % Calculated watts/meter
cm.efficiency = 0.125;                       % PO fraction * 90/10 split
cm.eta = 0.8;                               % Amps / Volt
cm.Zrf = 320;                               % Tank circuit impedance
cm.Grf = 10;                                % Pre-amp gain
cm.Cable = 0.84;                            % 1.5 dB of loss in 100’ of R
cm.PS = 0.707;                              % 3 dB loss in power splitter
cm.Mixer = 0.5;                             % 6 dB loss in mixer

cm.cmboost = zpk(-2*pi*3000,-2*pi*30,1);

cm.cmgain = 10ˆ(9/20);

cm.hflowpass = cm.cmgain * cm.cmboost;

cm.WG = 10ˆ(18/20);                         % 18 dB of whitening gain
cm.AA = 2;                                  % Gain of 2 in single-diff co
cm.ADC = 32768/10;                          % 16-bit Analog to Digital co
cm.REFL_I_GAIN = -1.0;                       % Compensates some whitening

cm.electronics_gain =     cm.eta *...        % Counts / Watt
                          cm.Zrf *...
                          cm.Grf *...
                          cm.Cable *...
                          cm.PS *...
                          cm.Mixer *...
                          cm.WG *...
                          cm.AA *...
```

```
                          cm.ADC *...
                          cm.REFL_I_GAIN;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%



L1.darm = darm;
L1.mich = mich;
L1.prc = prc;
L1.carm = carm;
L1.cm = cm;
L1.mc = mc;
L1.los = los;
L1.misc = misc;


return
```

C Parameter file for H1

```
function H1 = H1IFOparams;
% Parameter file for LSCmodel loop
%
% includes DARM, MICH, PRC, CM, MC
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
darm.fl  = 9;                                  % lower frequency of band,
darm.fu  = 8000;                               % upper frequency of band,
darm.npt = 301;                                % number of points in band
darm.fs  = 16384;                              % sampling frequency, Hz
darm.ugf = 152;                                % unity gain frequency of

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
darm.cavpole = 84.8;                           % cavity pole, Hz
darm.pendf0  = 0.764;                          % pendulum eigenfrequency,
darm.pendQ   = 10;                             % pendulum Q
darm.ETMXcal = 0.72e-9/0.891;                  % DC calibration of ETMX,
darm.ETMYcal = 0.83e-9/0.891;                  % DC calibration of ETMY,
darm.tdelay  = 140e-6;                         % time delay in loop, sec
darm.armlength = 3995.064;                     % mean arm length in meter
darm.hflowpass = ...
    zpk([],-2*pi*[100e3],...
        (-2*pi*100e3));                        % RC lowpass in H1 after m

%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of DARM digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
darm.filterfile = 'H1LSC.txt.030214';
%darm.filterfile = '/home/ldas-dev/calibration/s2/model/rana/ranaTF/aug17
%darm.filterfile = '/home/rana/FOTON/H1/H1LSC.txt';
darm.digitalfilters = [0,1,2,3,7];

%% LSC ETMX
%% 0 = TMNotch
%% 3 = TM6622
%% 6 = violin2
darm.susfilterfile1 = 'H1SUS_ETMX.txt';
%darm.susdigitalfilters1 = [0,6];
darm.susdigitalfilters1 = [0,3,6];

%% LSC ETMY
%% 0 = TMNotch
```

```
%% 5 = TM6622
darm.susfilterfile2 = ’H1SUS_ETMY.txt’;
%darm.susdigitalfilters2 = [0,6];
darm.susdigitalfilters2 = [0,5];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
darm.darm2etmx =  1.04;                       % Output matrix: DARM to ET
darm.darm2etmy = -0.90;                       % Output matrix: DARM to ET
darm.itmtrx = -0.003;                         % Input matrix: AS_Q to DAR
darm.lsc_gain = -3.0;                         % DARM filter module gain

darm.DCcal = darm.ETMYcal * darm.darm2etmy -...  % DARM_CTRL cal
             darm.ETMXcal * darm.darm2etmx;

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%% except that for LHO, R_snub is not present    %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
darm.R_ser  = 1010;                              % series resistor
darm.R_snub = 10;                            % snubber series resistor
darm.C_snub = 0.1e-6;                       % snubber series cap
darm.C_cabl = 800e-12;                           % cable capacitance
darm.R_coil = 25;                                % coil resistance
darm.H_coil = 3.3e-3;                            % coil inductance


% Misc Info (mostly unused) ---------------------------------------------
darm.opgain = 1.2e9;                       % Calculated watts/meter
darm.efficiency = 0.9;                     % PO fraction * 90/10 split
darm.eta = 0.8;                               % Amps / Volt
darm.Zrf = 400;                            % Tank circuit impedance
darm.Grf = 10;                                % Pre-amp gain
darm.Cable = 0.67;                            % 3.5 dB of loss in 100’ of
darm.PS = 0.707;                              % 3 dB loss in power splitt
darm.Mixer = 0.5;                             % 6 dB loss in mixer
darm.WG = 10ˆ(18/20);                      % 18 dB of whitening gain
darm.AA = 2;                                  % Gain of 2 in single-diff
darm.ADC = 32768/10;                          % 16-bit Analog to Digital
darm.AS1_Q_GAIN = 0.005;                   % Compensates some whitening g

darm.electronics_gain = darm.efficiency * ...
                        darm.eta *...        % Counts / Watt
                        darm.Zrf *...
                        darm.Grf *...
```

```
                        darm.Cable *...
                        darm.PS *...
                        darm.Mixer *...
                        darm.WG *...
                        darm.AA *...
                        darm.ADC *...
                        darm.AS1_Q_GAIN;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%



%-----------------------------------------------------------------------
% Parameter file for MICH loop model
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
mich.fl  = 0.9;                                  % lower frequency of ban
mich.fu  = 1000;                                 % upper frequency of ban
mich.npt = 301;                                  % number of points in ba
mich.fs  = 16384;                                % sampling frequency, Hz
mich.ugf = 10;                                   % unity gain frequency o

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
mich.cavpole = 1e6;                              % Something must happen
mich.pendf0  = 0.75;                             % pendulum eigenfrequenc
mich.pendQ   = 10;                               % pendulum Q
mich.RMcal = 3*0.38e-9;                            % DC calibration of RM
mich.BScal = 3*0.8e-9;
mich.tdelay  = 150e-6;                           % time delay in loop, se
mich.schnupp = 0.31;                             % (ly-lx)
mich.hflowpass = ...
    zpk([],-2*pi*[100e3],...
        (2*pi*100e3));                          % RC lowpass in H1 after

%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of MICH digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
mich.filterfile = '/home/rana/FOTON/H1/H1LSC.txt';
mich.digitalfilters = [0,1,2,3,5];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
mich.mich2rm = -10.5;                            % Output matrix: MICH to
mich.mich2bs = 7.4;                              % Output matrix: MICH to
mich.itmtrx = -0.666;                            % Input matrix: POB_Q to
```

```
mich.lsc_gain = -0.08;                          % MICH filter module gain

mich.DCcal = (sqrt(2) * mich.BScal * mich.mich2bs +...
                        mich.RMcal * mich.mich2rm) -...
                        mich.RMcal * mich.mich2rm;       % MICH_CTRL cal

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
mich.R_ser  = 3000;                              % series resistor
mich.R_snub = 680;                               % snubber series resisto
mich.C_snub = 0.022e-6;                          % snubber series cap
mich.C_cabl = 800e-12;                           % cable capacitance
mich.R_coil = 22;                                % coil resistance
mich.H_coil = 3.3e-3;                            % coil inductance

% Misc Info (mostly unused) ---------------------------------------------
mich.opgain = 1e14;                           % Calculated watts/meter
mich.efficiency = 0.85;                       % EO Shutter, clipping, etc
mich.eta = 0.8;                               % Amps / Volt
mich.Zrf = 125;                               % Tank circuit impedance
mich.Grf = 10;                                % Pre-amp gain
mich.Cable = 0.67;                            % 3.5 dB of loss in 100’ of
mich.PS = 0.707;                              % 3 dB loss in power splitt
mich.Mixer = 0.5;                             % 6 dB loss in mixer
mich.WG = 10^(36/20);                         % 24 dB of whitening gain
mich.AA = 2;                                  % Gain of 2 in single-diff
mich.ADC = 32768/10;                          % 16-bit Analog to Digital
mich.POB_Q_GAIN = 0.125;                      % Compensates some whitenin

mich.electronics_gain = mich.eta *...       % Counts / Watt
                          mich.Zrf *...
                          mich.Grf *...
                          mich.Cable *...
                          mich.PS *...
                          mich.Mixer *...
                          mich.WG *...
                          mich.AA *...
                          mich.ADC *...
                          mich.POB_Q_GAIN;
%------------------------------------------------------------------------
```

```
%************************************************************************
% Parameter file for PRC loop model
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
prc.fl  = 9;                                     % lower frequency of ban
prc.fu  = 1000;                                  % upper frequency of ban
prc.npt = 301;                                   % number of points in ba
prc.fs  = 16384;                                 % sampling frequency, Hz
prc.ugf = 70;                                    % unity gain frequency o

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
prc.cavpole = 100e3;                             % PRC pole??
prc.pendf0  = 0.75;                              % pendulum eigenfrequenc
prc.pendQ   = 10;                                % pendulum Q
prc.RMcal = 3*0.38e-9;                             % DC calibration of RM

prc.tdelay  = 170e-6;                            % time delay in loop, se
prc.rclength = 9.204;                            % (l1+l2)/2
prc.hflowpass = ...
    zpk([],-2*pi*[100e3],...
        (2*pi*100e3));                          % RC lowpass in H1 after
                                                % mixer

%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of PRC digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
prc.filterfile = ’/home/rana/FOTON/H1/H1LSC.txt’;
prc.digitalfilters = [0,1,2,3,4,5];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
prc.prc2rm = 7.4;                                % Output matrix: PRC to
prc.itmtrx = 0.17;                               % Input matrix: POB_I to
prc.lsc_gain = -0.125;                           % PRC filter module gain

prc.DCcal = -prc.RMcal * prc.prc2rm;             % PRC_CTRL cal

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
prc.R_ser  = 3000;                               % series resistor
prc.R_snub = 680;                                % snubber series resisto
prc.C_snub = 0.022e-6;                           % snubber series cap
prc.C_cabl = 800e-12;                            % cable capacitance
```

```
prc.R_coil = 22;                                 % coil resistance
prc.H_coil = 3.3e-3;                             % coil inductance

% Misc Info (mostly unused) --------------------------------------------
prc.opgain = 1.2e9;                          % Calculated watts/meter
prc.efficiency = 0.9 * 80e-6;                % PO fraction * 90/10 split
prc.eta = 0.8;                               % Amps / Volt
prc.Zrf = 380;                               % Tank circuit impedance
prc.Grf = 10;                                % Pre-amp gain
prc.Cable = 0.67;                            % 3.5 dB of loss in 100’ of
prc.PS = 0.707;                              % 3 dB loss in power splitte
prc.Mixer = 0.5;                             % 6 dB loss in mixer
prc.WG = 10ˆ(36/20);                         % 36 dB of whitening gain
prc.AA = 2;                                  % Gain of 2 in single-diff c
prc.ADC = 32768/10;                          % 16-bit Analog to Digital c
prc.POB_I_GAIN = 0.125;                      % Compensates some whitening

prc.electronics_gain = prc.eta *...        % Counts / Watt
                         prc.Zrf *...
                         prc.Grf *...
                         prc.Cable *...
                         prc.PS *...
                         prc.Mixer *...
                         prc.WG *...
                         prc.AA *...
                         prc.ADC *...
                         prc.POB_I_GAIN;
%************************************************************************



% Parameter file for CARM loop model
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
carm.fl  = 9;                                    % lower frequency of ban
carm.fu  = 8000;                                 % upper frequency of ban
carm.npt = 301;                                  % number of points in ba
carm.fs  = 16384;                                % sampling frequency, Hz
carm.ugf = 150;                                  % unity gain frequency o

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
carm.cavpole = 1;                                % cavity pole, Hz
carm.pendf0  = 0.75;                             % pendulum eigenfrequenc
carm.pendQ   = 10;                               % pendulum Q
carm.ETMXcal = 0.38e-9;                          % DC calibration of ETMX
```

```
carm.ETMYcal = 0.38e-9;                          % DC calibration of ETMY
carm.tdelay  = 100e-6;                           % time delay in loop, se
carm.armlength = 3995.15;                        % arm length in meters
carm.hflowpass = ...
    zpk([],-2*pi*[33e3 33e3 33e3],...
        (2*pi*33e3)ˆ3);                          % RC lowpass in H1 after


%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of CARM digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
carm.filterfile = ’/home/rana/FOTON/H1/H1LSC.txt’;
carm.digitalfilters = [0,1,2];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
carm.carm2etmx = -2.5;                           % Output matrix: CARM to
carm.carm2etmy = -2.5;                           % Output matrix: CARM to
carm.itmtrx = 0.05;                              % Input matrix: REFL_I t
carm.lsc_gain = -1.5;                            % CARM filter module gai

carm.DCcal = carm.ETMXcal * carm.carm2etmx +...
             carm.ETMYcal * carm.carm2etmy;

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
carm.R_ser  = 3000;                              % series resistor
carm.R_snub = 680;                               % snubber series resisto
carm.C_snub = 0.022e-6;                          % snubber series cap
carm.C_cabl = 800e-12;                           % cable capacitance
carm.R_coil = 22;                                % coil resistance
carm.H_coil = 3.3e-3;                            % coil inductance

% Misc Info (mostly unused) --------------------------------------------
carm.opgain = 1.2e9;                          % Calculated watts/meter
carm.efficiency = 0.125;                % PO fraction * 90/10 split
carm.eta = 0.8;                               % Amps / Volt
carm.Zrf = 320;                               % Tank circuit impedance
carm.Grf = 10;                                % Pre-amp gain
carm.Cable = 0.67;                            % 3.5 dB of loss in 100’ of
carm.PS = 0.707;                              % 3 dB loss in power splitt
carm.Mixer = 0.5;                             % 6 dB loss in mixer
carm.WG = 10ˆ(30/20);                         % 36 dB of whitening gain
```

```
carm.AA = 2;                                  % Gain of 2 in single-diff
carm.ADC = 32768/10;                          % 16-bit Analog to Digital
carm.REFL_I_GAIN = -1.0;                       % Compensates some whiteni

carm.electronics_gain = carm.eta *...        % Counts / Watt
                          carm.Zrf *...
                          carm.Grf *...
                          carm.Cable *...
                          carm.PS *...
                          carm.Mixer *...
                          carm.WG *...
                          carm.AA *...
                          carm.ADC *...
                          carm.REFL_I_GAIN;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%



%~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
% - - - Miscellaneous Parameters - - -
%________________________________________________________________________

mc.Lmc = 12.243;                                 % MC round trip L = 25 m
mc.Tmc1 = 2000e-6;                               % Power transmission
mc.Tmc2 = 10e-6;
mc.Tmc3 = 2000e-6;
mc.m_sos = 0.25;                                 % SOS mass in kg
mc.sys = load(’/home/ldas-dev/calibration/s2/model/rana/ranaTF/aug17/mcob
mc.ao = -zpk(mc.sys.mcsys(7,8));
mc.mcl = -zpk(mc.sys.mcsys(7,11));

los.m = 10.5;                                    % LOS mass in kg
los.phi = 1e-3;                                  % Loss angle of steel wi
los.wirelength = 0.442;                          % LOS wire length
los.fp = 0.75;                                   % LOS pend freq


%%%%%%%%%%     AA & AI filtering   %%%%%%%%%%%%%%
[z,p,k] = ellip(4,4,60,2*pi*7570,’s’);
misc.ai = zpk(z,p,k*10ˆ(4/20)) * zpk([],-2*pi*13e3,2*pi*13e3);

[z,p,k] = ellip(8,.035,80,2*pi*7570,’s’);
misc.aa = zpk(z,p,k*10ˆ(0.035/20));
```

```
misc.c = 299792458;
misc.ec = 1.6022e-19;
misc.lambda = 1064e-9;
misc.nu = misc.c / misc.lambda;

%________________________________________________________________________




% Parameter file for Common Mode Servo loop model
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
cm.fl  = 9;                                    % lower frequency of band,
cm.fu  = 100e3;                                 % upper frequency of band
cm.npt = 901;                                  % number of points in band
cm.fs  = 16384;                                % sampling frequency, Hz
cm.ugf = 25000;                                % unity gain frequency of
cm.xover = 250;                                % MCL / AO crossover freq,

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
cm.cavpole = 1;                                % cavity pole, Hz
cm.pendf0  = 1.0;                              % pendulum eigenfrequency,
cm.pendQ   = 10;                               % pendulum Q
cm.MC2cal = 0.44e-9;                           % DC calibration of MC2, m
cm.tdelay  = 180e-6;                           % time delay in loop, sec
cm.armlength = 3995.15;                        % arm length in meters

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
cm.U9 = zpk(-2*pi*1,-2*pi*50,1);                       % Additive Offset
cm.AO_Gain = 10^(4/20);                                % path on the
cm.U15 = zpk(0,-2*pi*5,1);                             % CM board
cm.U16 = zpk(0,-2*pi*5,1);
cm.Bounce_Notch = zpk(twint(16.25,100));               % External Twin-T

cm.AOtf = cm.U9 * cm.U15 * cm.U16 * cm.Bounce_Notch * cm.AO_Gain;
cm.ao_c = cm.AOtf * mc.ao;




%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
```

```
%% specify vector of CM digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
cm.filterfile = ’/home/rana/FOTON/H1/H1SUS_MC2.txt’;
cm.digitalfilters = [0,3,4,5,6,8,9];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
cm.itmtrx = 0.05;                              % Input matrix: REFL_I to
cm.lsc_gain = -0.0012;                         % MC2_LSC filter module ga

cm.DCcal = cm.MC2cal;

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
cm.R_ser  = 7200;                              % series resistor
cm.R_snub = 0;                               % snubber series resistor
cm.C_snub = 10e-12;                               % snubber series cap
cm.C_cabl = 800e-12;                           % cable capacitance
cm.R_coil = 22;                                % coil resistance
cm.H_coil = 3.3e-3;                            % coil inductance

% Misc Info (mostly unused) ---------------------------------------------
cm.opgain = 1.2e9;                          % Calculated watts/meter
cm.efficiency = 0.125;                       % PO fraction * 90/10 split
cm.eta = 0.8;                               % Amps / Volt
cm.Zrf = 320;                               % Tank circuit impedance
cm.Grf = 10;                                % Pre-amp gain
cm.Cable = 0.67;                            % 3.5 dB of loss in 100’ of R
cm.PS = 0.707;                              % 3 dB loss in power splitter
cm.Mixer = 0.5;                             % 6 dB loss in mixer

cm.cmboost = zpk(-2*pi*3000,-2*pi*30,1);

cm.cmgain = 10ˆ(9/20);

cm.hflowpass = cm.cmgain * cm.cmboost;

cm.WG = 10ˆ(30/20);                         % 36 dB of whitening gain
cm.AA = 2;                                  % Gain of 2 in single-diff co
cm.ADC = 32768/10;                          % 16-bit Analog to Digital co
cm.REFL_I_GAIN = -1.0;                       % Compensates some whitening

cm.electronics_gain = cm.eta *...        % Counts / Watt
```

```
                          cm.Zrf *...
                          cm.Grf *...
                          cm.Cable *...
                          cm.PS *...
                          cm.Mixer *...
                          cm.WG *...
                          cm.AA *...
                          cm.ADC *...
                          cm.REFL_I_GAIN;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%



H1.darm = darm;
H1.mich = mich;
H1.prc = prc;
H1.carm = carm;
H1.cm = cm;
H1.mc = mc;
H1.los = los;
H1.misc = misc;


return
```

D Parameter file for H2

```
function H2 = H2IFOparams;
% Parameter file for DARM loop model
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
%darm.fl  = 9;                                    % lower frequency of ba
%darm.fu  = 8000;                                 % upper frequency of ba
%darm.npt = 301;                                  % number of points in b
darm.fl  = 0;                            % lower frequency of band, Hz
darm.fu  = 7000;                         % upper frequency of band, Hz
darm.npt = 448001;                       % number of points in band
darm.fs  = 16384;                        % sampling frequency, Hz
darm.ugf = 185;                          % UGF on 030412, nominal point c
%darm.ugf = 180;                         % UGF on 030317, mid run cal dat
%darm.ugf = 113;                         % UGF on 030412, start run cal d


%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
darm.cavpole = 170;                           % cavity pole, Hz
darm.pendf0  = 0.757;                         % mean pendulum eigenfreque
darm.pendQ   = 10;                            % pendulum Q
darm.ETMXcal = 0.87e-9;                       % DC calibration of ETMX, m
darm.ETMYcal = 0.92e-9*1.032;                 % DC calibration of ETMY, m
%                                               times the increase in the
darm.tdelay  = 145e-6;                        % time delay in loop, sec
darm.armlength = 2009.12;                     % arm length in meters
darm.hflowpass = ...
    zpk([],-2*pi*[100e3],...
        (-2*pi*100e3));                       % RC lowpass in H2 after mi

%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of DARM digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
darm.filterfile = 'H2LSC.txt.030210';
darm.digitalfilters = [0,1,2,3];

%darm.susfilterfile1 = 'H2SUS_ETMX.txt.030212';
darm.susfilterfile1 = 'H2SUS_ETMX.txt.030315';
darm.susdigitalfilters1 = [0,2];
%darm.susdigitalfilters1 = [0];

%darm.susfilterfile2 = 'H2SUS_ETMY.txt.030212';
darm.susfilterfile2 = 'H2SUS_ETMY.txt.030331';
```

```
darm.susdigitalfilters2 = [0,2];
%darm.susdigitalfilters2 = [0];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
darm.darm2etmx =  0.53;                       % Output matrix: DARM to ET
darm.darm2etmy = -0.50;                       % Output matrix: DARM to ET
darm.itmtrx = -0.015;                         % Input matrix: AS_Q to DAR
darm.lsc_gain = -0.6;                        % DARM filter module gain

darm.DCcal = darm.ETMYcal * darm.darm2etmy -...  % DARM_CTRL cal
             darm.ETMXcal * darm.darm2etmx;

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%% except that for LHO, R_snub is not present    %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
darm.R_ser  = 1010;                              % series resistor
darm.R_snub = 10;                            % snubber series resistor
darm.C_snub = 0.1e-6;                       % snubber series cap
darm.C_cabl = 800e-12;                           % cable capacitance
darm.R_coil = 25;                                % coil resistance
darm.H_coil = 3.3e-3;                            % coil inductance


% Misc Info (mostly unused) ---------------------------------------------
darm.opgain = 1.2e9;                       % Calculated watts/meter
darm.efficiency = 0.9;                     % PO fraction * 90/10 split
darm.eta = 0.8;                               % Amps / Volt
darm.Zrf = 400;                            % Tank circuit impedance
darm.Grf = 10;                                % Pre-amp gain
darm.Cable = 0.67;                            % 3.5 dB of loss in 100’ of
darm.PS = 0.707;                              % 3 dB loss in power splitt
darm.Mixer = 0.5;                             % 6 dB loss in mixer
darm.WG = 10ˆ(18/20);                      % 18 dB of whitening gain
darm.AA = 2;                                  % Gain of 2 in single-diff
darm.ADC = 32768/10;                          % 16-bit Analog to Digital
darm.AS1_Q_GAIN = 0.005;                   % Compensates some whitening g

darm.electronics_gain = darm.efficiency * ...
                        darm.eta *...        % Counts / Watt
                        darm.Zrf *...
                        darm.Grf *...
                        darm.Cable *...
                        darm.PS *...
```

```
                        darm.Mixer *...
                        darm.WG *...
                        darm.AA *...
                        darm.ADC *...
                        darm.AS1_Q_GAIN;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%



%------------------------------------------------------------------------
% Parameter file for MICH loop model
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
mich.fl  = 0.9;                                  % lower frequency of ban
mich.fu  = 1000;                                 % upper frequency of ban
mich.npt = 301;                                  % number of points in ba
mich.fs  = 16384;                                % sampling frequency, Hz
mich.ugf = 10;                                   % unity gain frequency o

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
mich.cavpole = 1e6;                              % Something must happen
mich.pendf0  = 0.75;                             % pendulum eigenfrequenc
mich.pendQ   = 10;                               % pendulum Q
mich.RMcal = 3*0.38e-9;                            % DC calibration of RM
mich.BScal = 3*0.8e-9;
mich.tdelay  = 150e-6;                           % time delay in loop, se
mich.schnupp = 0.31;                             % (ly-lx)
mich.hflowpass = ...
    zpk([],-2*pi*[100e3],...
        (2*pi*100e3));                          % RC lowpass in H2 after

%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of MICH digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
mich.filterfile = '/home/rana/FOTON/H2/H2LSC.txt';
mich.digitalfilters = [0,1,2,3,5];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
mich.mich2rm = -10.5;                            % Output matrix: MICH to
mich.mich2bs = 7.4;                              % Output matrix: MICH to
mich.itmtrx = -0.666;                            % Input matrix: POB_Q to
mich.lsc_gain = -0.08;                          % MICH filter module gain
```

```
mich.DCcal = (sqrt(2) * mich.BScal * mich.mich2bs +...
                        mich.RMcal * mich.mich2rm) -...
                        mich.RMcal * mich.mich2rm;       % MICH_CTRL cal

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
mich.R_ser  = 3000;                              % series resistor
mich.R_snub = 680;                               % snubber series resisto
mich.C_snub = 0.022e-6;                          % snubber series cap
mich.C_cabl = 800e-12;                           % cable capacitance
mich.R_coil = 22;                                % coil resistance
mich.H_coil = 3.3e-3;                            % coil inductance

% Misc Info (mostly unused) --------------------------------------------
mich.opgain = 1e14;                           % Calculated watts/meter
mich.efficiency = 0.85;                       % EO Shutter, clipping, etc
mich.eta = 0.8;                               % Amps / Volt
mich.Zrf = 125;                               % Tank circuit impedance
mich.Grf = 10;                                % Pre-amp gain
mich.Cable = 0.67;                            % 3.5 dB of loss in 100’ of
mich.PS = 0.707;                              % 3 dB loss in power splitt
mich.Mixer = 0.5;                             % 6 dB loss in mixer
mich.WG = 10ˆ(36/20);                         % 24 dB of whitening gain
mich.AA = 2;                                  % Gain of 2 in single-diff
mich.ADC = 32768/10;                          % 16-bit Analog to Digital
mich.POB_Q_GAIN = 0.125;                      % Compensates some whitenin

mich.electronics_gain = mich.eta *...       % Counts / Watt
                          mich.Zrf *...
                          mich.Grf *...
                          mich.Cable *...
                          mich.PS *...
                          mich.Mixer *...
                          mich.WG *...
                          mich.AA *...
                          mich.ADC *...
                          mich.POB_Q_GAIN;
%-----------------------------------------------------------------------



%***********************************************************************
% Parameter file for PRC loop model
```

```
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
prc.fl  = 9;                                       % lower frequency of ban
prc.fu  = 1000;                                    % upper frequency of ban
prc.npt = 301;                                     % number of points in ba
prc.fs  = 16384;                                   % sampling frequency, Hz
prc.ugf = 70;                                      % unity gain frequency o

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
prc.cavpole = 100e3;                               % PRC pole??
prc.pendf0  = 0.75;                                % pendulum eigenfrequenc
prc.pendQ   = 10;                                  % pendulum Q
prc.RMcal = 3*0.38e-9;                               % DC calibration of RM

prc.tdelay  = 170e-6;                              % time delay in loop, se
prc.rclength = 9.204;                              % (l1+l2)/2
prc.hflowpass = ...
    zpk([],-2*pi*[100e3],...
        (2*pi*100e3));                            % RC lowpass in H2 after
                                                  % mixer

%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of PRC digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                     %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
prc.filterfile = '/home/rana/FOTON/H2/H2LSC.txt';
prc.digitalfilters = [0,1,2,3,4,5];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%%
prc.prc2rm = 7.4;                                  % Output matrix: PRC to
prc.itmtrx = 0.17;                                 % Input matrix: POB_I to
prc.lsc_gain = -0.125;                             % PRC filter module gain

prc.DCcal = -prc.RMcal * prc.prc2rm;               % PRC_CTRL cal

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                         %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
prc.R_ser  = 3000;                                 % series resistor
prc.R_snub = 680;                                  % snubber series resisto
prc.C_snub = 0.022e-6;                             % snubber series cap
prc.C_cabl = 800e-12;                              % cable capacitance
prc.R_coil = 22;                                   % coil resistance
prc.H_coil = 3.3e-3;                               % coil inductance
```

```
% Misc Info (mostly unused) -------------------------------------
prc.opgain = 1.2e9;                           % Calculated watts/meter
prc.efficiency = 0.9 * 80e-6;                 % PO fraction * 90/10 split
prc.eta = 0.8;                                % Amps / Volt
prc.Zrf = 380;                                % Tank circuit impedance
prc.Grf = 10;                                 % Pre-amp gain
prc.Cable = 0.67;                             % 3.5 dB of loss in 100’ of
prc.PS = 0.707;                               % 3 dB loss in power splitte
prc.Mixer = 0.5;                              % 6 dB loss in mixer
prc.WG = 10^(36/20);                          % 36 dB of whitening gain
prc.AA = 2;                                   % Gain of 2 in single-diff c
prc.ADC = 32768/10;                           % 16-bit Analog to Digital c
prc.POB_I_GAIN = 0.125;                       % Compensates some whitening

prc.electronics_gain = prc.eta *...          % Counts / Watt
                         prc.Zrf *...
                         prc.Grf *...
                         prc.Cable *...
                         prc.PS *...
                         prc.Mixer *...
                         prc.WG *...
                         prc.AA *...
                         prc.ADC *...
                         prc.POB_I_GAIN;
%**********************************************************************



% Parameter file for CARM loop model
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
carm.fl  = 9;                                     % lower frequency of ban
carm.fu  = 8000;                                  % upper frequency of ban
carm.npt = 301;                                   % number of points in ba
carm.fs  = 16384;                                 % sampling frequency, Hz
carm.ugf = 150;                                   % unity gain frequency o

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
carm.cavpole = 1;                                 % cavity pole, Hz
carm.pendf0  = 0.75;                              % pendulum eigenfrequenc
carm.pendQ   = 10;                                % pendulum Q
carm.ETMXcal = 0.38e-9;                           % DC calibration of ETMX
carm.ETMYcal = 0.38e-9;                           % DC calibration of ETMY
carm.tdelay  = 100e-6;                            % time delay in loop, se
```

```
carm.armlength = 3995.15;                        % arm length in meters
carm.hflowpass = ...
    zpk([],-2*pi*[33e3 33e3 33e3],...
        (2*pi*33e3)ˆ3);                          % RC lowpass in H2 after


%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of CARM digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                    %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
carm.filterfile = ’/home/rana/FOTON/H2/H2LSC.txt’;
carm.digitalfilters = [0,1,2];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%
carm.carm2etmx = -2.5;                           % Output matrix: CARM to
carm.carm2etmy = -2.5;                           % Output matrix: CARM to
carm.itmtrx = 0.05;                              % Input matrix: REFL_I t
carm.lsc_gain = -1.5;                            % CARM filter module gai

carm.DCcal = carm.ETMXcal * carm.carm2etmx +...
             carm.ETMYcal * carm.carm2etmy;

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                        %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
carm.R_ser  = 3000;                              % series resistor
carm.R_snub = 680;                               % snubber series resisto
carm.C_snub = 0.022e-6;                          % snubber series cap
carm.C_cabl = 800e-12;                           % cable capacitance
carm.R_coil = 22;                                % coil resistance
carm.H_coil = 3.3e-3;                            % coil inductance

% Misc Info (mostly unused) ---------------------------------------------
carm.opgain = 1.2e9;                          % Calculated watts/meter
carm.efficiency = 0.125;                % PO fraction * 90/10 split
carm.eta = 0.8;                               % Amps / Volt
carm.Zrf = 320;                               % Tank circuit impedance
carm.Grf = 10;                                % Pre-amp gain
carm.Cable = 0.67;                            % 3.5 dB of loss in 100’ of
carm.PS = 0.707;                              % 3 dB loss in power splitt
carm.Mixer = 0.5;                             % 6 dB loss in mixer
carm.WG = 10ˆ(30/20);                         % 36 dB of whitening gain
carm.AA = 2;                                  % Gain of 2 in single-diff
carm.ADC = 32768/10;                          % 16-bit Analog to Digital
```

```
carm.REFL_I_GAIN = -1.0;                       % Compensates some whiteni

carm.electronics_gain = carm.eta *...        % Counts / Watt
                          carm.Zrf *...
                          carm.Grf *...
                          carm.Cable *...
                          carm.PS *...
                          carm.Mixer *...
                          carm.WG *...
                          carm.AA *...
                          carm.ADC *...
                          carm.REFL_I_GAIN;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%



%~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
% - - - Miscellaneous Parameters - - -
%_______________________________________________________________________

mc.Lmc = 12.243;                                % MC round trip L = 25 m
mc.Tmc1 = 2000e-6;                              % Power transmission
mc.Tmc2 = 10e-6;
mc.Tmc3 = 2000e-6;
mc.m_sos = 0.25;                                % SOS mass in kg
mc.sys = load('mcob.mat');
mc.ao = -zpk(mc.sys.mcsys(7,8));
mc.mcl = -zpk(mc.sys.mcsys(7,11));

los.m = 10.5;                                   % LOS mass in kg
los.phi = 1e-3;                                 % Loss angle of steel wi
los.wirelength = 0.442;                         % LOS wire length
los.fp = 0.75;                                  % LOS pend freq


%%%%%%%%%%     AA & AI filtering   %%%%%%%%%%%%%%
[z,p,k] = ellip(4,4,60,2*pi*7570,'s');
misc.ai = zpk(z,p,k*10^(4/20)) * zpk([],-2*pi*13e3,2*pi*13e3);

[z,p,k] = ellip(8,.035,80,2*pi*7570,'s');
misc.aa = zpk(z,p,k*10^(0.035/20));

misc.c = 299792458;
```

```
misc.ec = 1.6022e-19;
misc.lambda = 1064e-9;
misc.nu = misc.c / misc.lambda;

%________________________________________________________________________




% Parameter file for Common Mode Servo loop model
%
%%%%%%%%   frequencies of interest   %%%%%%%%%%%%%%%%
cm.fl  = 9;                                              % lower frequency of band,
cm.fu  = 100e3;                                           % upper frequency of band
cm.npt = 901;                                            % number of points in band
cm.fs  = 16384;                                          % sampling frequency, Hz
cm.ugf = 25000;                                          % unity gain frequency of
cm.xover = 250;                                          % MCL / AO crossover freq,

%%%%%%%%%  parameters of the plant    %%%%%%%%%%%%%%%
cm.cavpole = 1;                                          % cavity pole, Hz
cm.pendf0  = 1.0;                                        % pendulum eigenfrequency,
cm.pendQ   = 10;                                         % pendulum Q
cm.MC2cal = 0.44e-9;                                     % DC calibration of MC2, m
cm.tdelay  = 180e-6;                                     % time delay in loop, sec
cm.armlength = 3995.15;                                  % arm length in meters

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
cm.U9 = zpk(-2*pi*1,-2*pi*50,1);                                 % Additive Offset
cm.AO_Gain = 10^(4/20);                                          % path on the
cm.U15 = zpk(0,-2*pi*5,1);                                       % CM board
cm.U16 = zpk(0,-2*pi*5,1);
cm.Bounce_Notch = zpk(twint(16.25,100));                         % External Twin-T

cm.AOtf = cm.U9 * cm.U15 * cm.U16 * cm.Bounce_Notch * cm.AO_Gain;
cm.ao_c = cm.AOtf * mc.ao;




%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%% digital filters  %%%%%%%%%%%%%%%%%%%%%%%%%%
%% specify vector of CM digital filters engaged %%%
%% Note: FM1 = 0, FM2 = 1, etc                     %%%
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
cm.filterfile = '/home/rana/FOTON/H2/H2SUS_MC2.txt';
cm.digitalfilters = [0,3,4,5,6,8,9];

%%%%%%%%%%% digital gains  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
cm.itmtrx = 0.05;                              % Input matrix: REFL_I to
cm.lsc_gain = -0.0012;                         % MC2_LSC filter module ga

cm.DCcal = cm.MC2cal;

%%%%%%%%%%% snubber component values  %%%%%%%%%%%%%%%%%%%
%% snubber is a series RC (R_snub & C_snub), in  %%%%
%% parallel with the coil                          %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
cm.R_ser  = 7200;                              % series resistor
cm.R_snub = 0;                               % snubber series resistor
cm.C_snub = 10e-12;                                % snubber series cap
cm.C_cabl = 800e-12;                           % cable capacitance
cm.R_coil = 22;                                % coil resistance
cm.H_coil = 3.3e-3;                            % coil inductance

% Misc Info (mostly unused) -----------------------------------------
cm.opgain = 1.2e9;                          % Calculated watts/meter
cm.efficiency = 0.125;                       % PO fraction * 90/10 split
cm.eta = 0.8;                               % Amps / Volt
cm.Zrf = 320;                               % Tank circuit impedance
cm.Grf = 10;                                % Pre-amp gain
cm.Cable = 0.67;                            % 3.5 dB of loss in 100' of R
cm.PS = 0.707;                              % 3 dB loss in power splitter
cm.Mixer = 0.5;                             % 6 dB loss in mixer

cm.cmboost = zpk(-2*pi*3000,-2*pi*30,1);

cm.cmgain = 10^(9/20);

cm.hflowpass = cm.cmgain * cm.cmboost;

cm.WG = 10^(30/20);                         % 36 dB of whitening gain
cm.AA = 2;                                  % Gain of 2 in single-diff co
cm.ADC = 32768/10;                          % 16-bit Analog to Digital co
cm.REFL_I_GAIN = -1.0;                       % Compensates some whitening

cm.electronics_gain = cm.eta *...        % Counts / Watt
                          cm.Zrf *...
                          cm.Grf *...
```

```
                          cm.Cable *...
                          cm.PS *...
                          cm.Mixer *...
                          cm.WG *...
                          cm.AA *...
                          cm.ADC *...
                          cm.REFL_I_GAIN;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%



H2.darm = darm;
H2.mich = mich;
H2.prc = prc;
H2.carm = carm;
H2.cm = cm;
H2.mc = mc;
H2.los = los;
H2.misc = misc;


return
```