Building the new front end calibration pipeline

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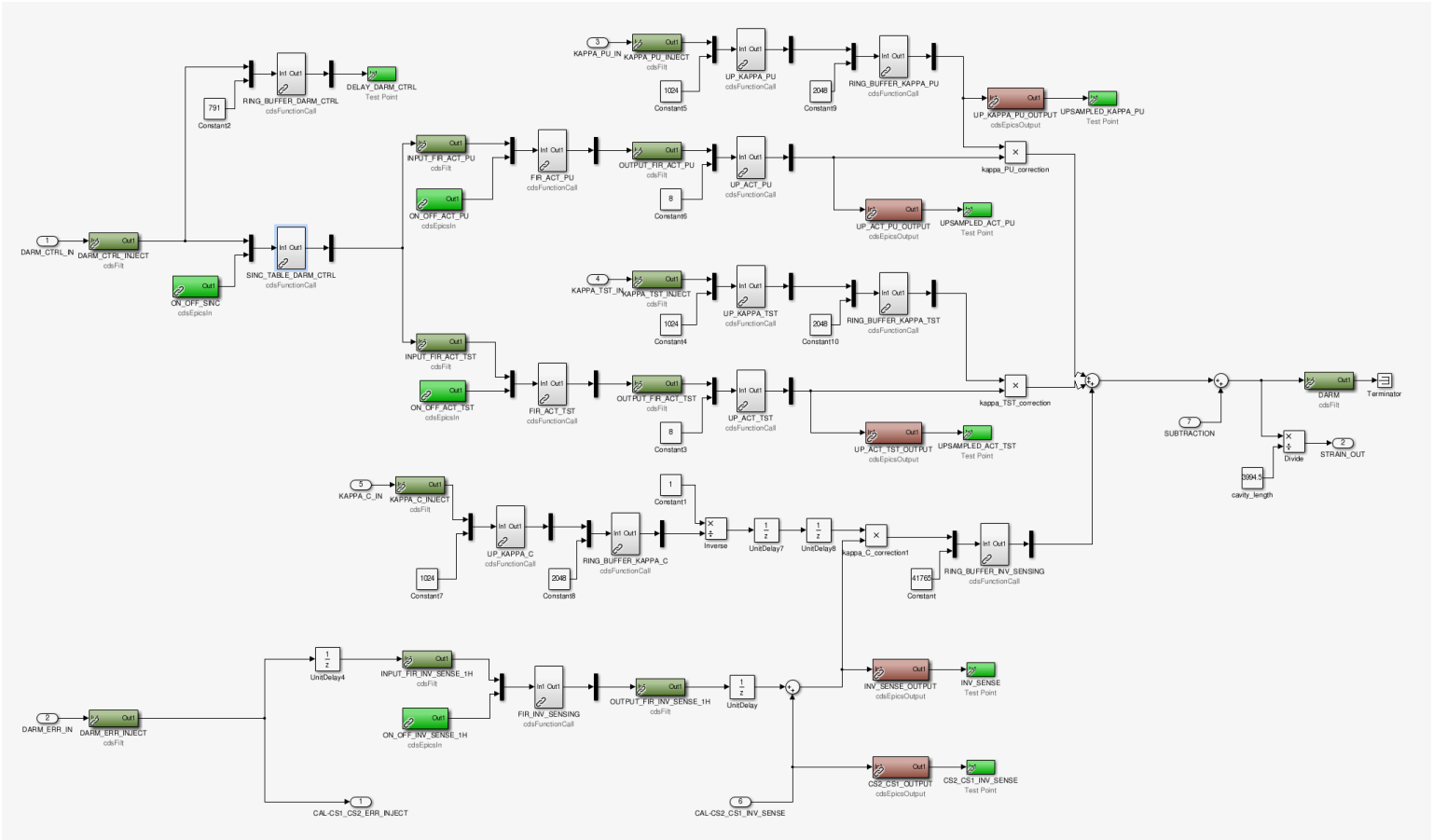
LIGO SURF Program 2017

Outline

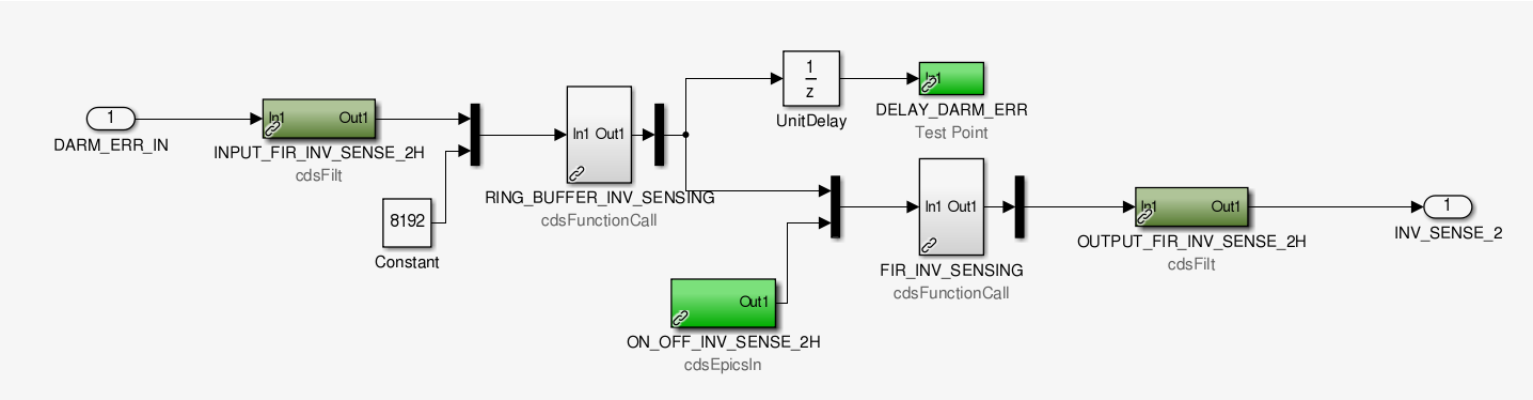
My SURF Project

- Advanced LIGO uses a system of three calibration pipelines to reproduce $h(t)$, each with varying errors and latencies.
- CALCS and GDS generate $h(t)$ online, but the GDS is located in the DMT.
- We have built a new, complete calibration pipeline in the front end computers to yield strain as a raw data product in near real-time.

x2calcs1



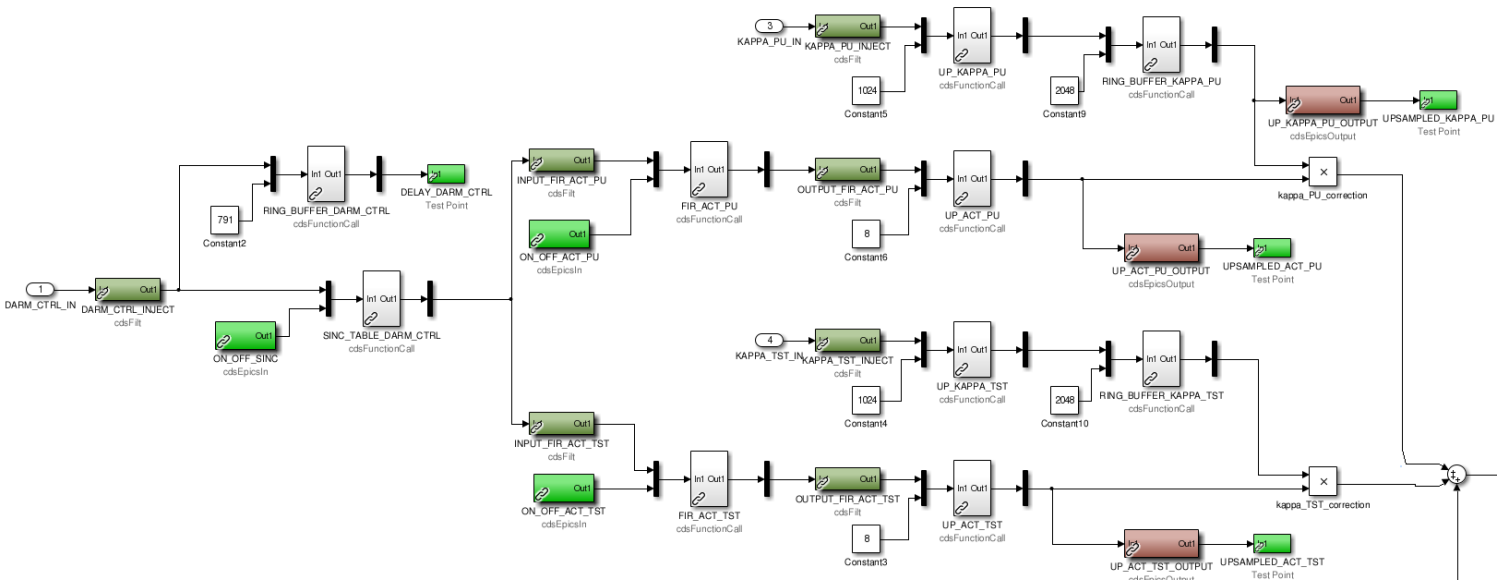
x2calcs2



- x2calcs2 performs half the inverse sensing filtering on a separate CPU.

Actuation PU and TST chains

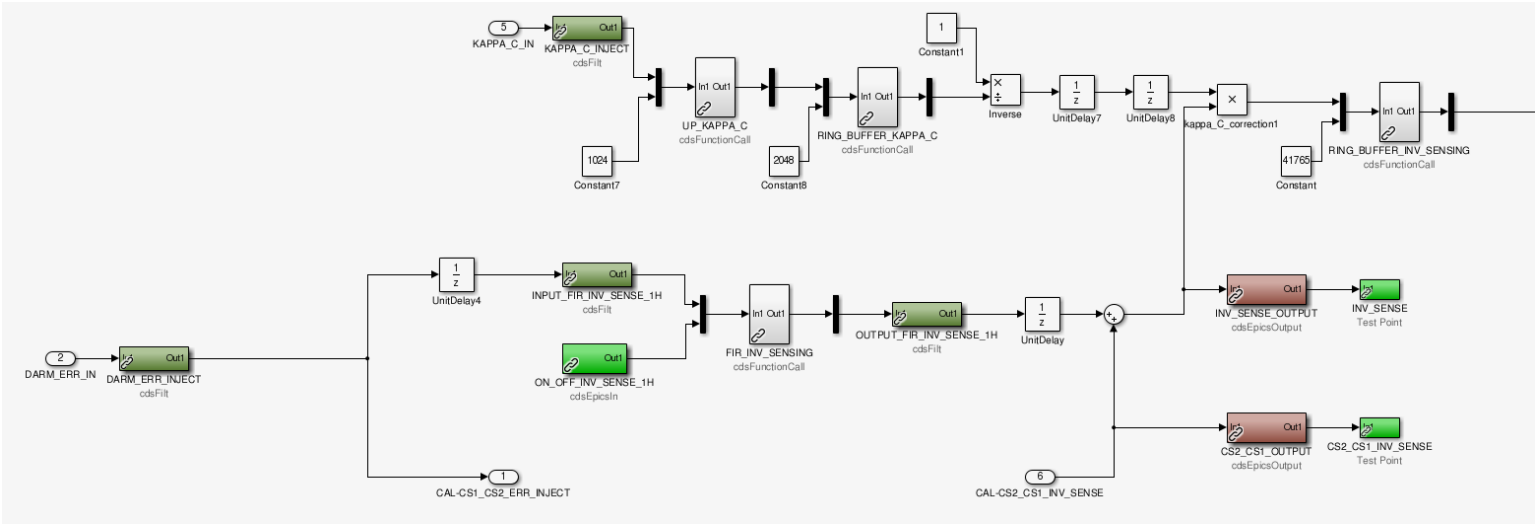
x2calcs1



- 791 cycle delay from sinc table.
- 49152 cycle delay from $A_{\mathrm{PU}}/A_{\mathrm{T}}$ filters with 12288 taps.
- 16 cycle delay from cubic spline upsampling.
- Total delay: 49959 cycles.

Inverse sensing chain

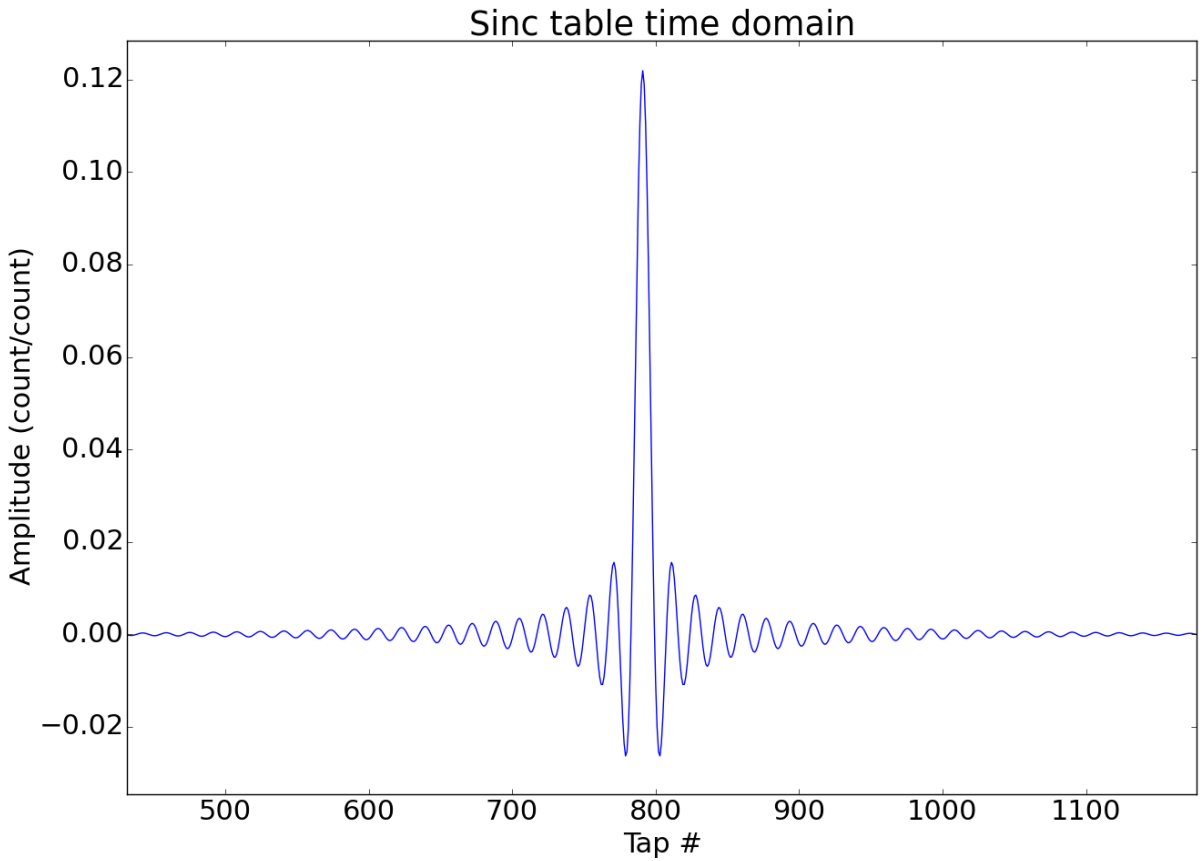
x2calcs1



- 2 cycle delay from sending/receiving signals.
- 8192 cycle delay from C^{-1} filter with 16384 taps.
- Total delay: 8194 cycles.

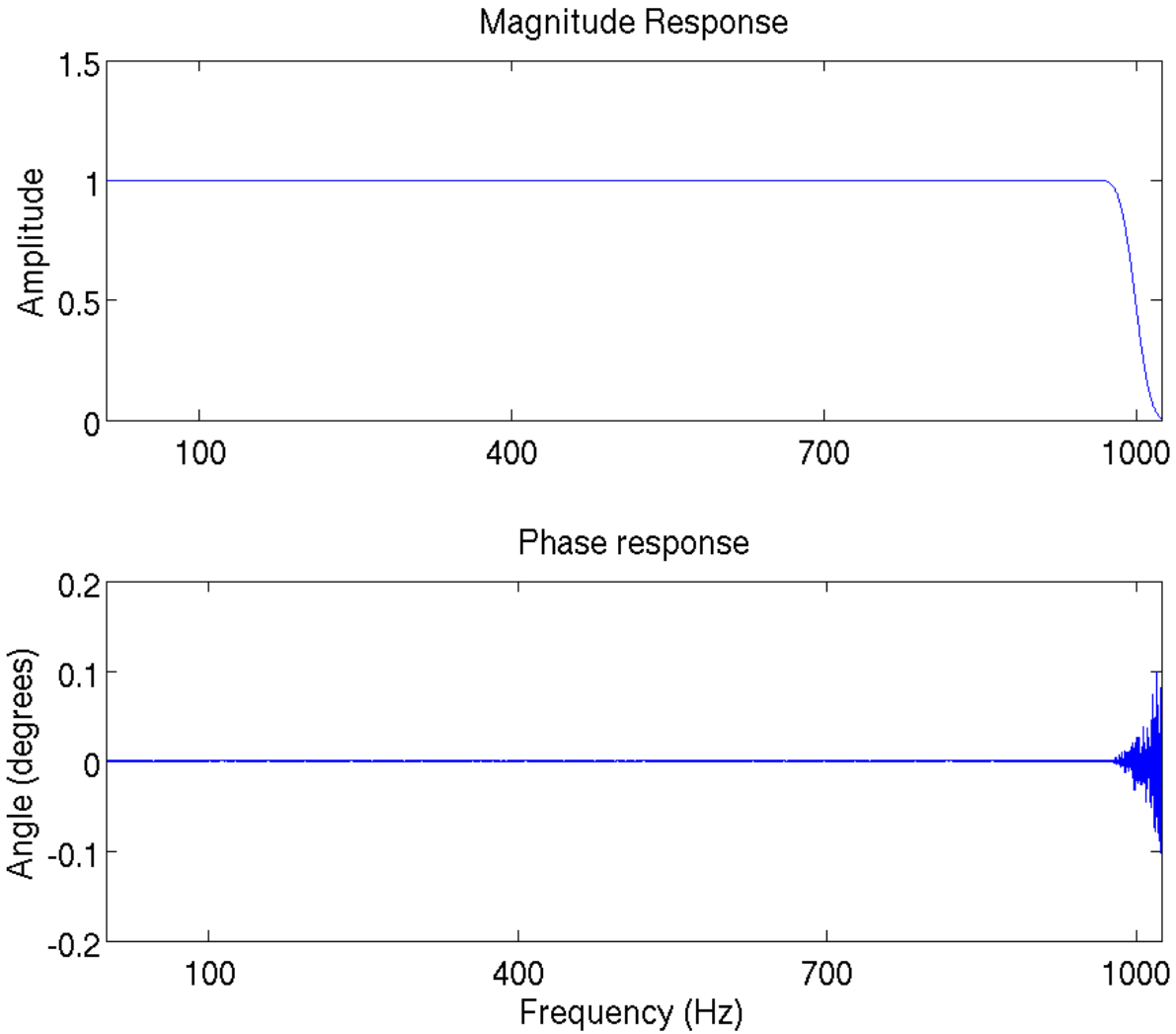
Downsampling

Sinc table, time domain



Downsampling

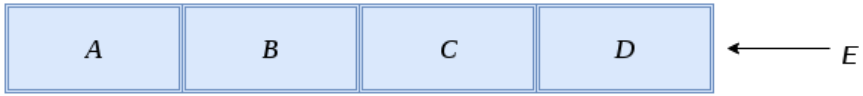
Sinc table, frequency domain



Upsampling

Cubic spline interpolation

CUBIC SPLINE FIR FILTER



every "cadence" sample:

$$\frac{dx}{dt_1} = \frac{C-A}{2}$$

$$\frac{1}{2}\frac{d^2x}{dt_0^2} = B - A - \frac{dx}{dt_1} - 2 \cdot \frac{dx}{dt_0}$$

$$\frac{1}{6}\frac{d^3x}{dt^3} = 2 \cdot (A - B) + \frac{dx}{dt_1} + \frac{dx}{dt_0}$$

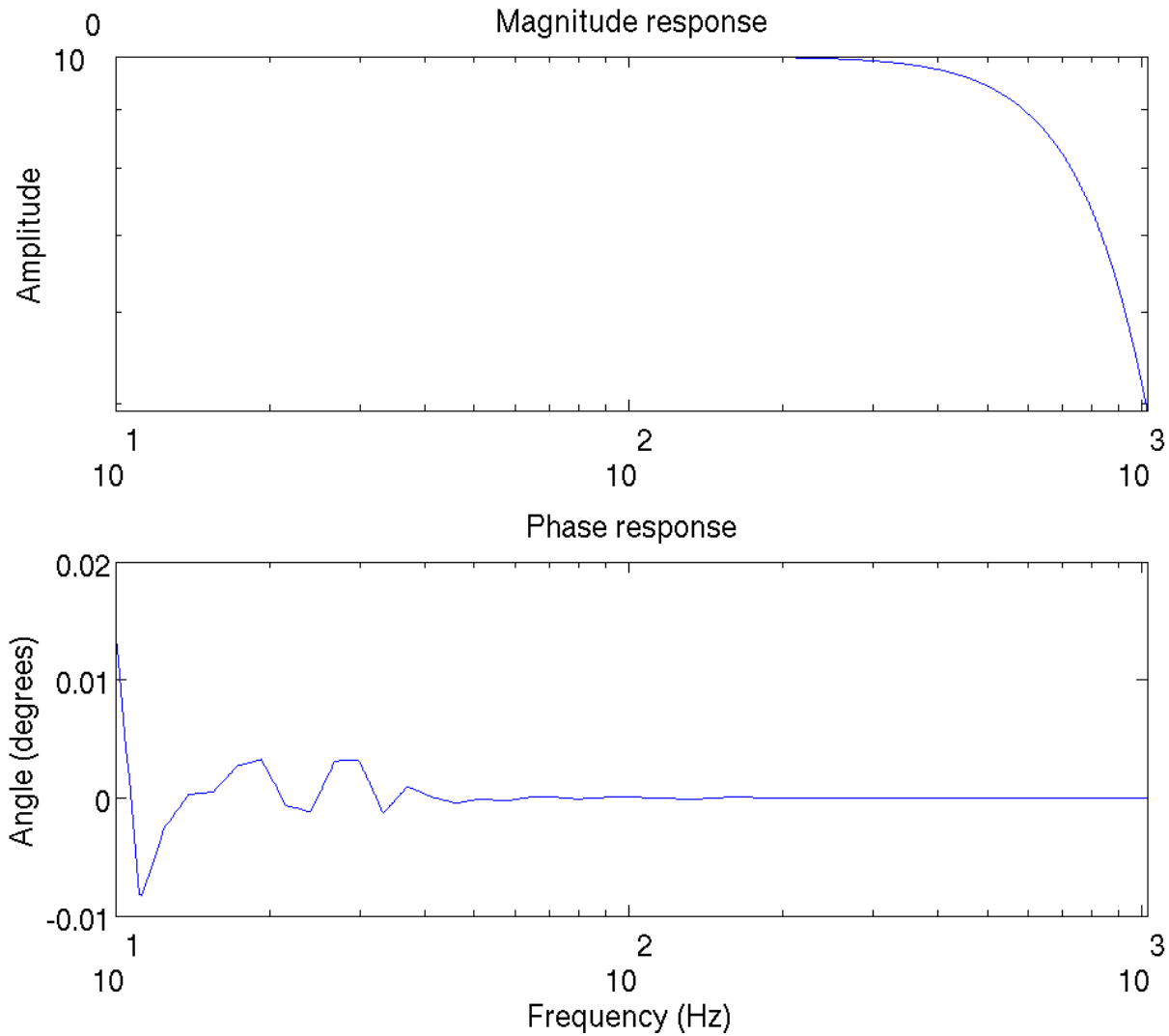
then update values:

$$A = B$$
$$B = C$$
$$C = D$$
$$D = E$$
$$\frac{dx}{dt_0} = \frac{dx}{dt_1}$$

every cycle: $\text{readout} = A + \frac{dx}{dt_0} \cdot \frac{i}{\text{cad}} + \frac{1}{2}\frac{d^2x}{dt_0^2} \cdot \left(\frac{i}{\text{cad}}\right)^2 + \frac{1}{6}\frac{d^3x}{dt^3} \cdot \left(\frac{i}{\text{cad}}\right)^3$

Upsampling

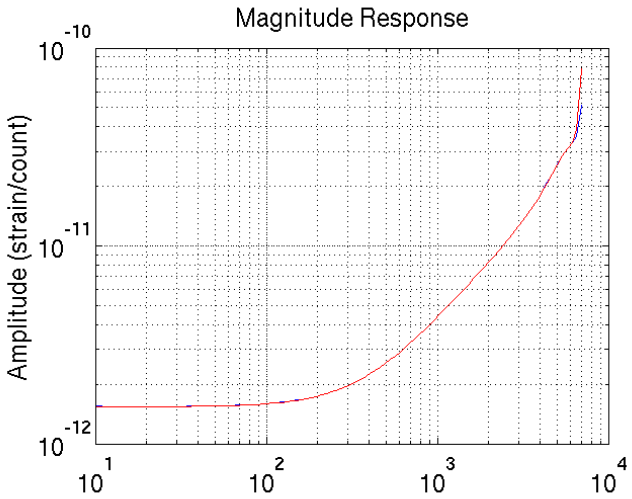
Cubic spline transfer function

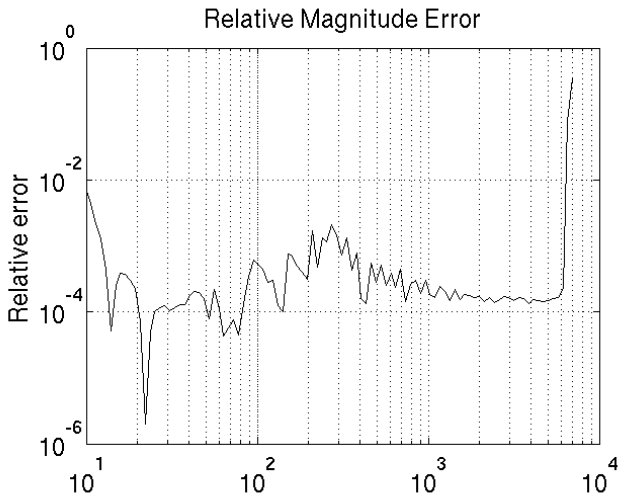


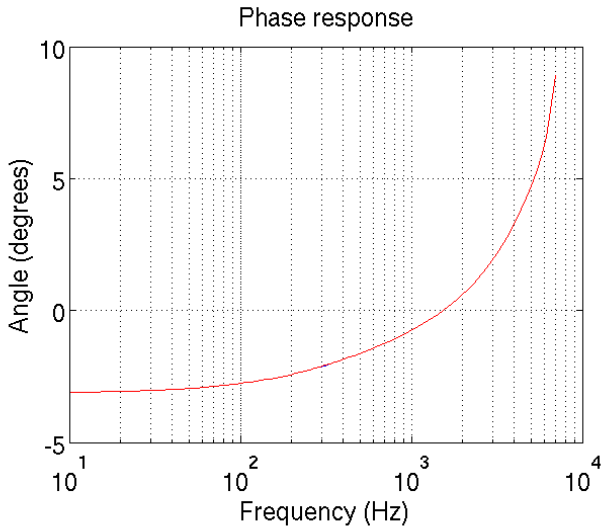
FIR filter comparisons

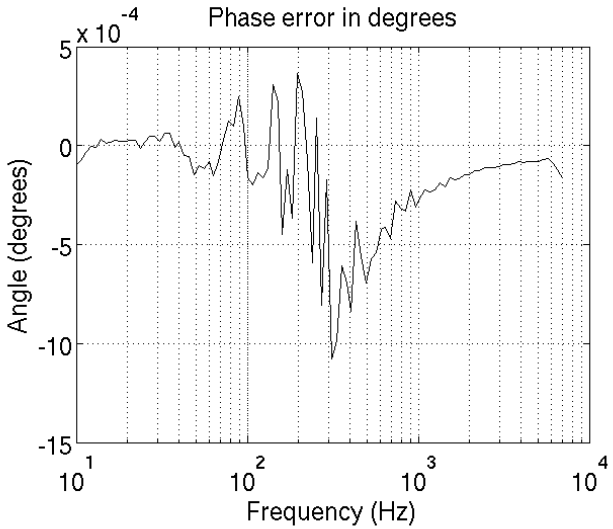
- The FIR filters A_{PU}, A_{T}, and C^{-1} are approximations of front end models of each function.
- To see how closely we replicate each model in the calibration pipeline, we analyze transfer functions.

Inverse sensing filter

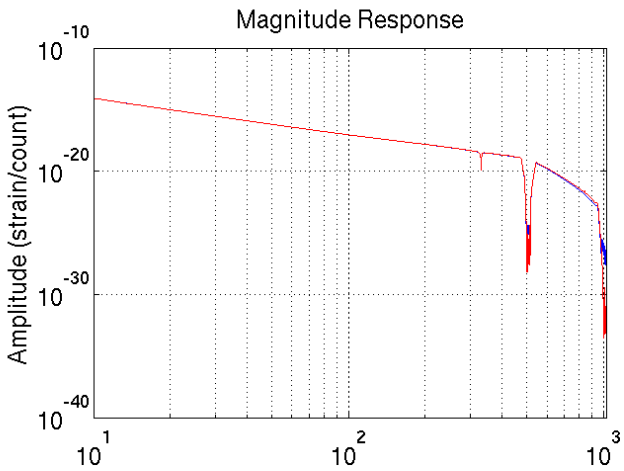


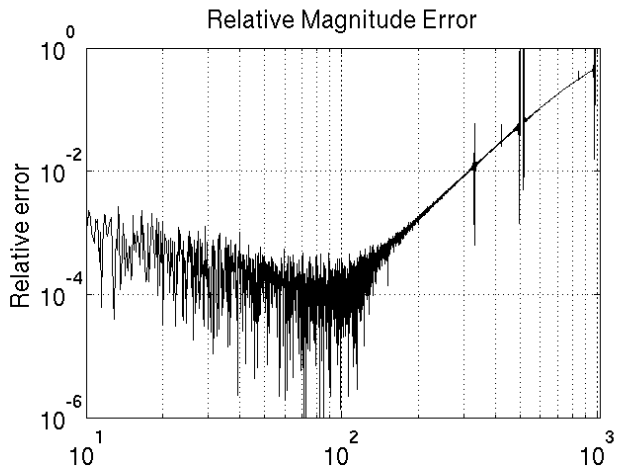


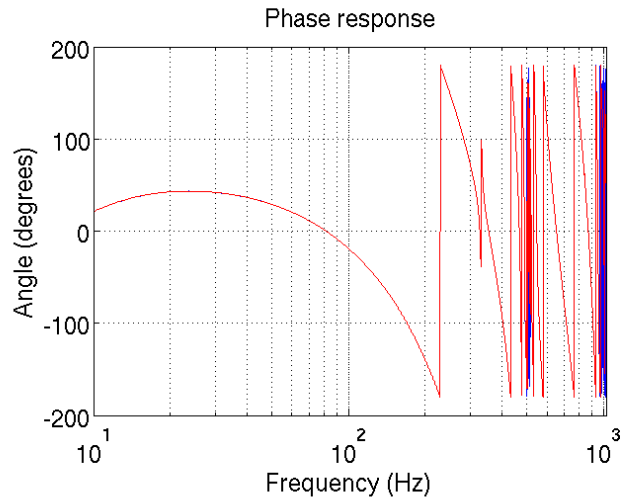


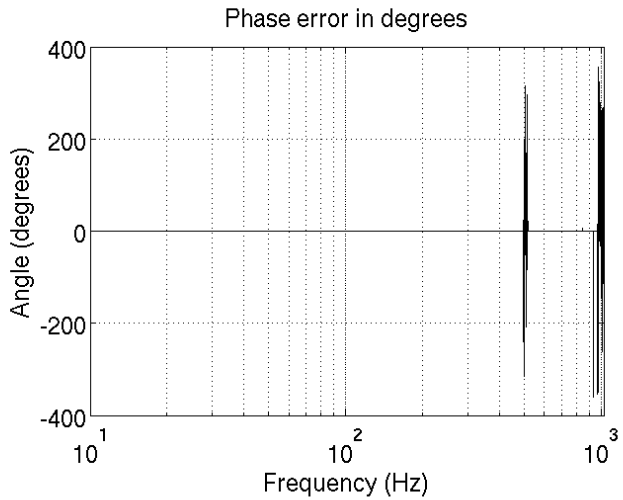


Actuation PU filter

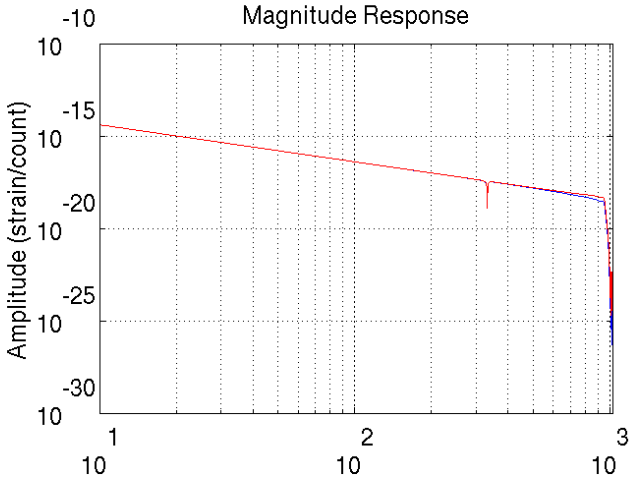


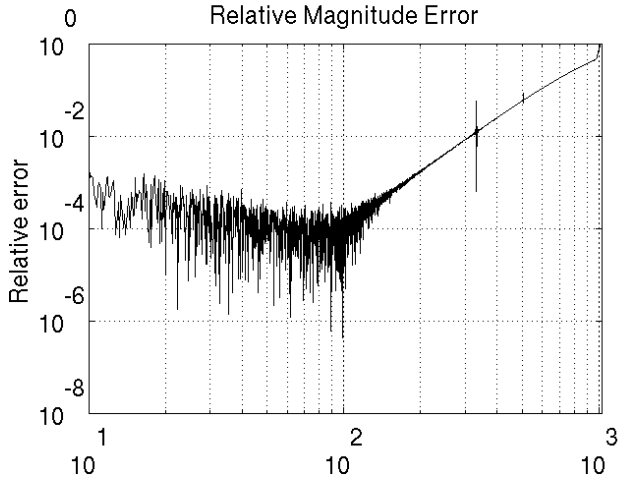


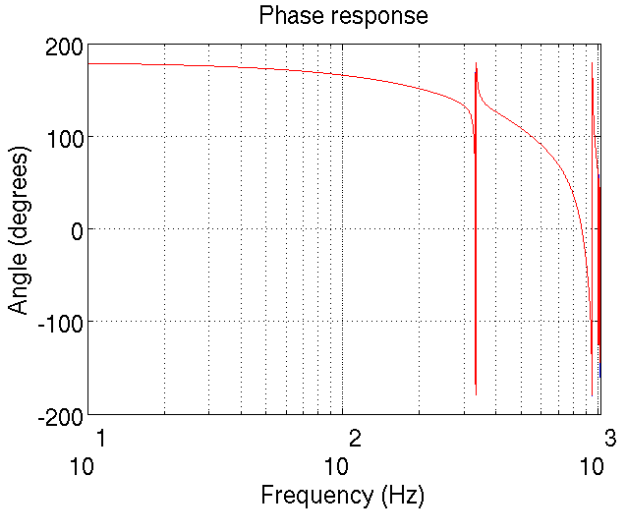


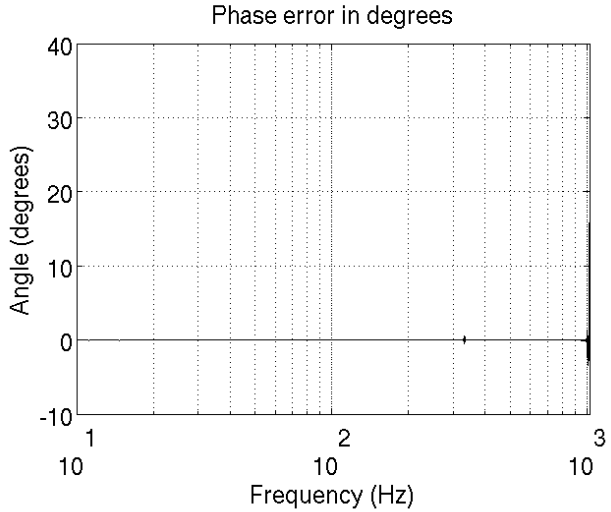


Actuation TST filter



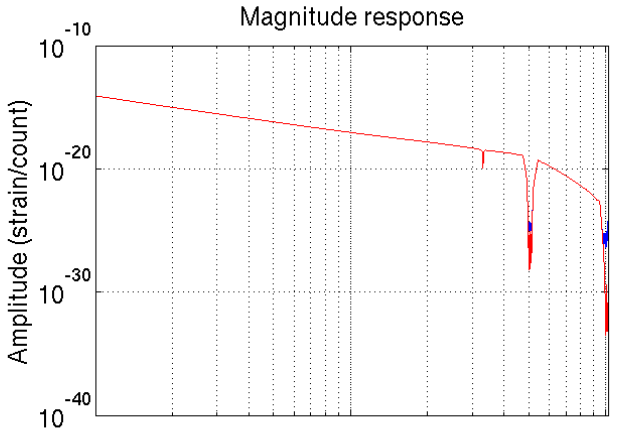


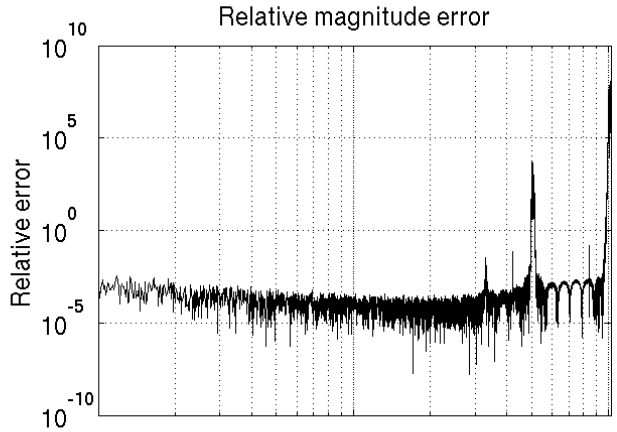


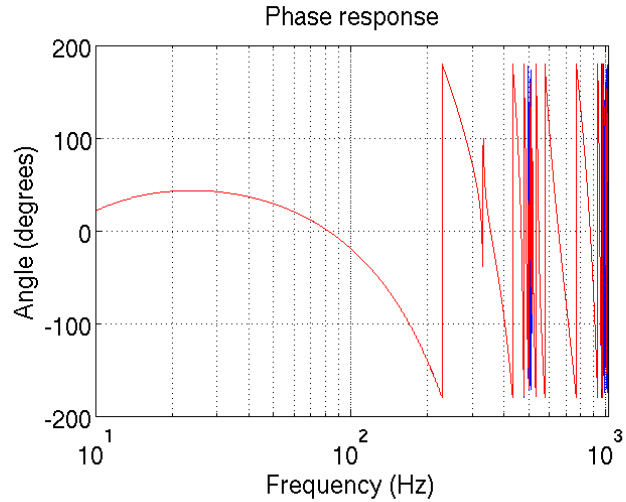


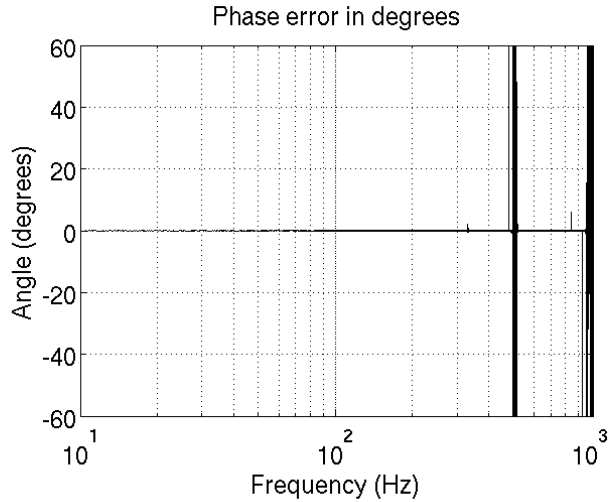
Actuation PU filter

Corrected



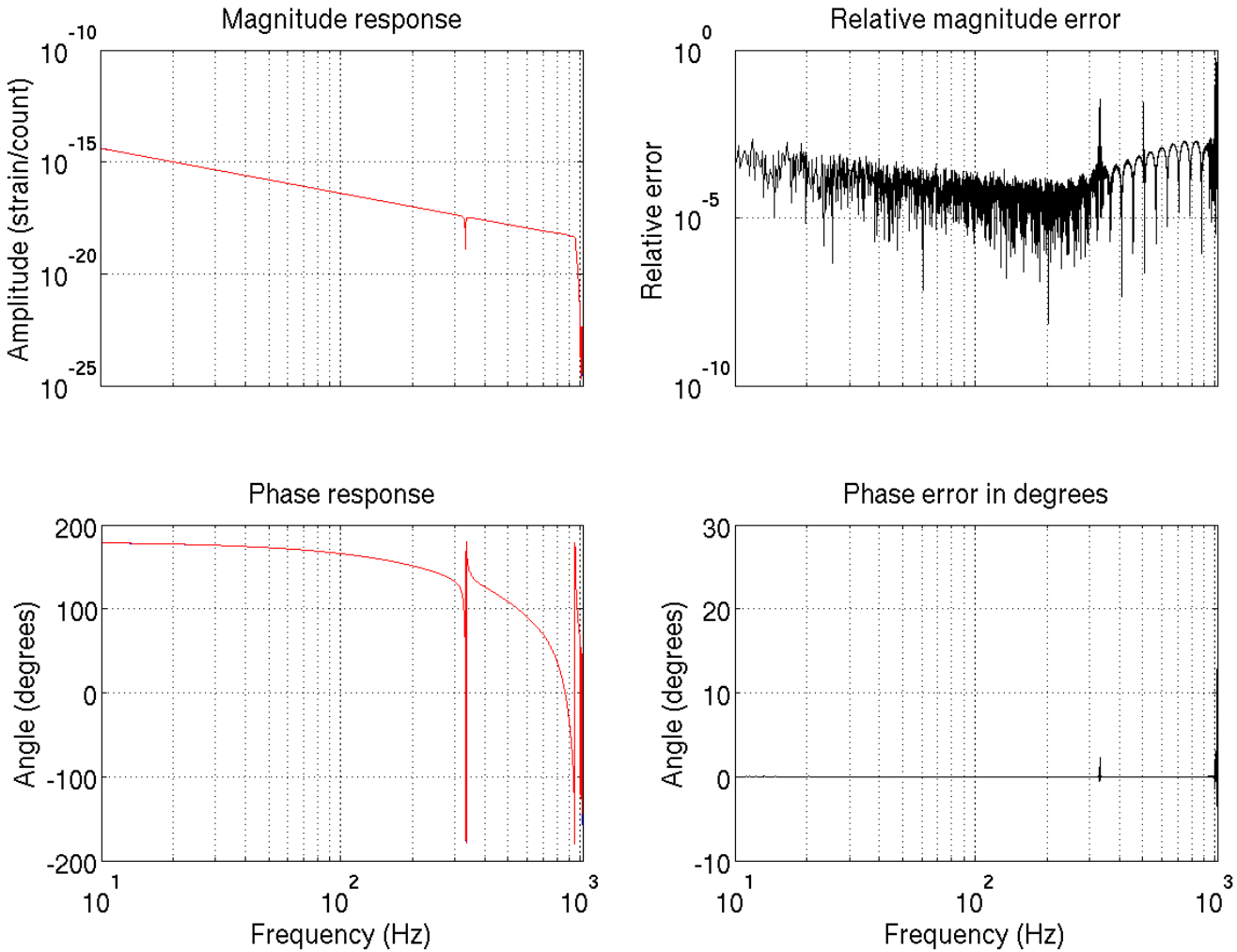






Actuation TST filter

Corrected



Summary

- l1calcs1 and l1calcs2 can be used in upcoming observation runs as primary online source of "best possible" $h(t)$ reproduction.
- The new front end calibration pipeline has a latency just over 3 seconds (49959 cycles at 16384 Hz).
- Work is currently underway in determining overall error in this model's $h(t)$ output at all frequencies. Updates will be made to final paper in DCC.