LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
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S5 V3 $h(t)$ review and validation

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1 Noise comparisons: h_t vs. h_f

1.1 Preliminaries

To compare time domain and frequency domain calibrated data we first assume the relationship between h_t, a Fourier transform of a stretch of time domain calibrated data, and h_f, the same stretch of DARM_ERR calibrated in the frequency domain, can be described by a multiplicative systematic, which we'll call A, plus some noise. This can be written as

$$h_t(f) = A(f)h_f(f) + n(f) \tag{1}$$

where $n(f)$ is noise introduced by the time domain calibration procedure. Hereafter we suppress explicit frequency dependence of our data. We can solve for the noise n as

$$n = h_t - Ah_f \; . \tag{2}$$

If we make the assumption that the distribution of n is Gaussian, we can write a likelihood function L

$$L = Ce^{\sum_k (n_k^2/s)} = Ce^{\sum_k (h_{tk} - Ah_{fk})^2/s} \tag{3}$$

where the index k labels the frequency bins of a Fourier transform of some stretch of data, and thus we sum over time. If we maximize this likelihood function, we find the value A which makes the distribution of $n_k{}'$s look the most Gaussian with mean zero. Since the values which will maximize the function L also maximize the function $\log(L)$, we can take the log of Eq. (3) and maximize it. We need to solve

$$\frac{d}{dA}\log(L) = \frac{d}{dA}\left[C' + \sum_k \frac{(h_{tk} - Ah_{fk})^2}{s}\right] = 0 \tag{4}$$

to find A. A derivative and some simple algebra lets us write the solution as

$$A = \frac{\sum_k h_{tk}h_{fk}}{\sum_k h_{fk}^2} = \frac{\langle h_t h_f \rangle}{\langle h_f^2 \rangle} \; . \tag{5}$$

It is useful to compute the real, A_r, and imaginary, A_i, components of A explicitly. These can be derived from the previous equation to be

$$A_r = \frac{\langle h_{tr}h_{fr} - h_{ti}h_{fi} \rangle}{\langle h_f^2 \rangle} \tag{6}$$

and

$$A_i = \frac{\langle h_{tr}h_{fi} + h_{ti}h_{fr} \rangle}{\langle h_f^2 \rangle} \tag{7}$$

where the r and i subscripts denote real and imaginary components respectively. These equations allow us to calculate the phase of the systematic as $\arctan(A_i/A_r)$ and its magnitude as $|A_r^2 + A_i^2|$. The A_r and A_i values can also be used with Eq. 2 to calculate the n_r and n_i values. We first take the real and imaginary parts of Eq. 2 and write them explicitly as

$$h_{tr} - A_r h_{fr} + A_i h_{fi} = n_r \tag{8}$$

and

$$h_{ti} - A_i h_{fr} - A_r h_{fi} = n_i \ . \tag{9}$$

By calculating n_r and n_i on a bin by bin basis, we can build up statistics about them. This allows us to confirm our assumption that n has a mean close to zero by explicitly calculating it. In addition, we can take these equations to the second, third, and fourth powers before taking an average to be able to compute the second, third, and fourth central moments (which are related to variance, skewness and kurtosis). For example, second moment (and variance) of n_r is $\langle (n_r)^2 \rangle - \langle (n_r) \rangle^2 = \langle (n_r)^2 \rangle + 0$. Similarly the third and fourth moments are simply $\langle {n_r}^3 \rangle$ and $\langle {n_r}^4 \rangle$, respectively. This gives us information about how Gaussian the distributions are. For a Gaussian distribution, the third moment should be zero, while the fourth moment should be 3 times the square of the second moment ($3\sigma^4$).

1.2 Results

Detailed results can be found in:

`http://ldas-jobs.ligo.caltech.edu/~channa/calibration/`. Though we focus on the systematics in this document, some analysis of the residual is also available from the above URL. We will summarize the systematic findings here. Figure 1 shows the magnitude and phase systematics as a function of frequency for the three instruments. The phase error shown in red at 5.5kHz indicates a problem with the filters used in h_t production, in fact a filter is missing from the H1 actuation function. The blue line in the magnitude shows a problem very near the H2 calibration line. We will take these into account in our systematic errors and caveats below.

Table 1 shows the systematic results for all IFOs, frequency bands, and epochs. The magnitudes are the difference between the magnitude of A and 1. The phase is the phase of A. The presented values are the worst systematic values calculated in those bands and epochs, with some caveats listed below. Table 2 was determined from these systematics. It should be emphasized that these errors are only estimates of those between the h_t and h_f calibrations, and that these should be added in quadrature to the h_f errors to get the overall uncertainty of the h_t data.

Figure 2 shows a histogram of $n = h_t - A \times h_f$ for H1 during the first epoch at a frequency of 100 Hz. For a majority of frequencies and times, the noise term was less than 5% of the magnitude of h_t or h_f. However, around strong spectral features the noise can be comparable to the values themselves. Around such spectral features, the size of the noise is a function of the integration time used to calculate A. For longer integration times, the noise improved.

Caveats to using these errors:

1. Some outliers near spectral features were removed. Therefore if analyses are sensitive to what goes on at and around sharp spectral features they will need special attention (such as the Crab analysis). We think these numbers are appropriate to wide band analyses such as stochastic, burst, and inspirals. But pulsar searches that look at frequencies that are within 0.5Hz, perhaps as much as 1Hz, of a line need to be examined more closely; this includes some wide band searches. For other analyses we may have to go on a case by case basis.

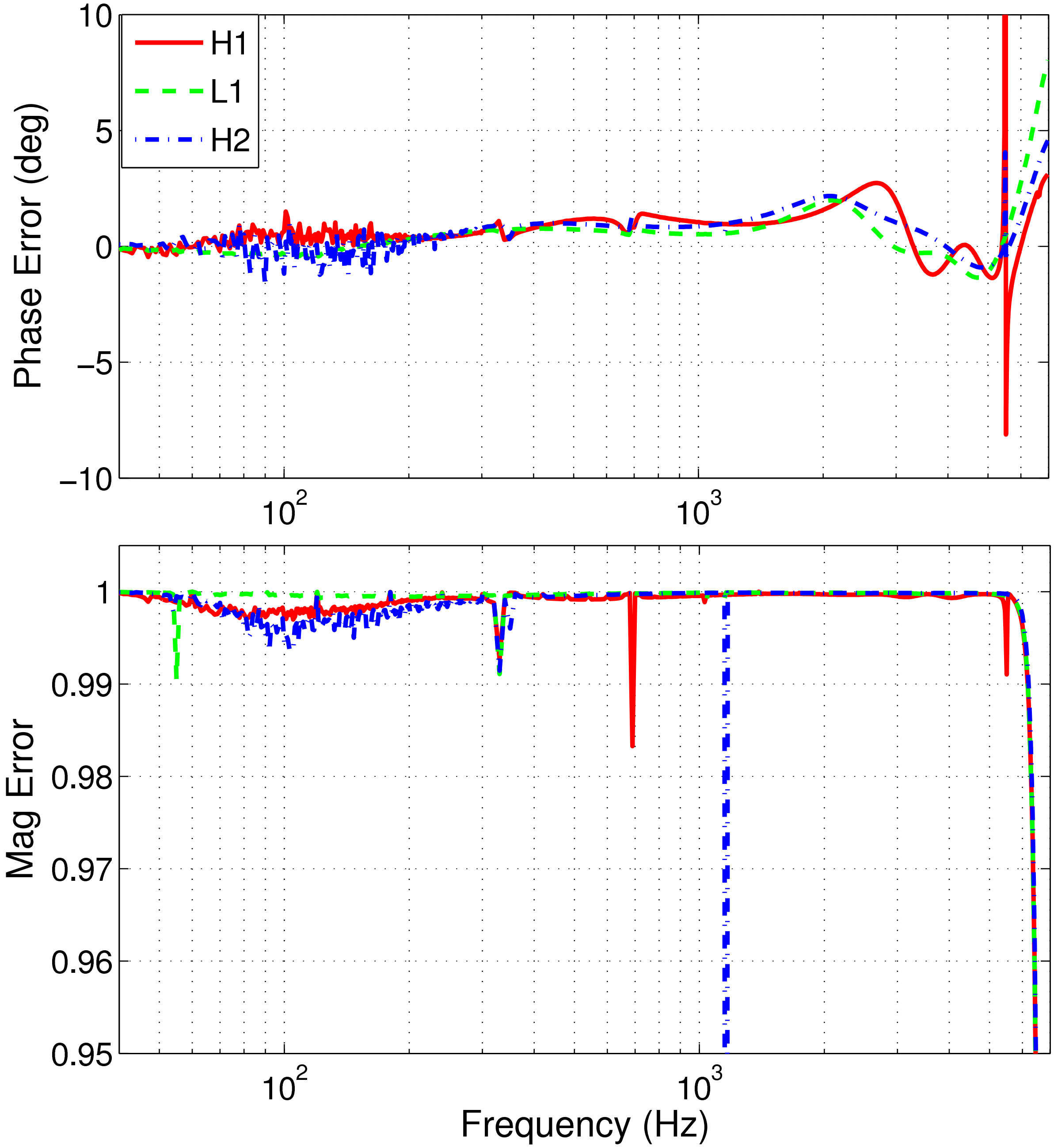

Figure 1: Plot of the magnitude and phase systematics as a function of frequency for the three instruments. The phase error shown in red at 5.5kHz indicates a problem with the filters used in $h(t)$ production, in fact a filter is missing from the H1 actuation function. The blue line in the magnitude shows a problem very near the H2 calibration line.

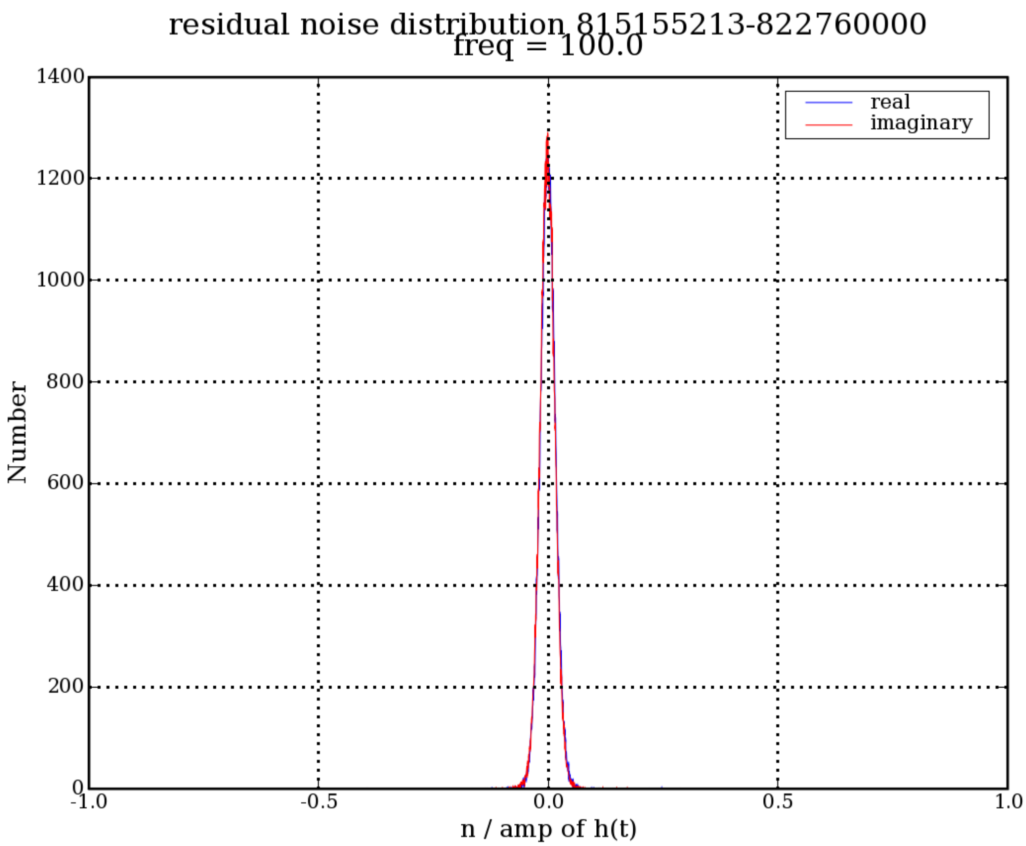

Figure 2: Plot of residual noise distribution after rotating by A.

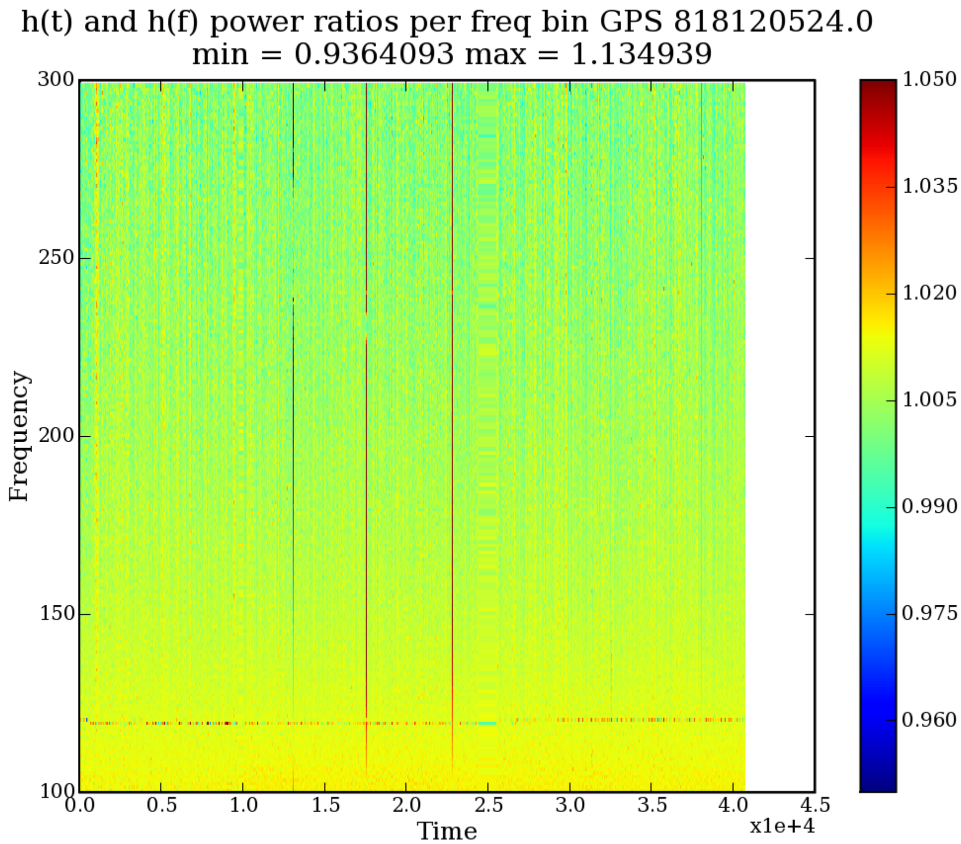

Figure 3: Example spectrogram of the noise ratio between h_t and h_t. The noises are computed in each one Hz band, then averaged over that band, prior to computing the ratio. We made spectrograms of all the data in S5 between 40Hz-6.5kHz. At the top the minimum and maximum values of the ratio are shown. The thin dark vertical line is where the largest outlier is. The origin of the outlier is the short glitch at 60Hz shown in Fig. (4). See Caveat 2.

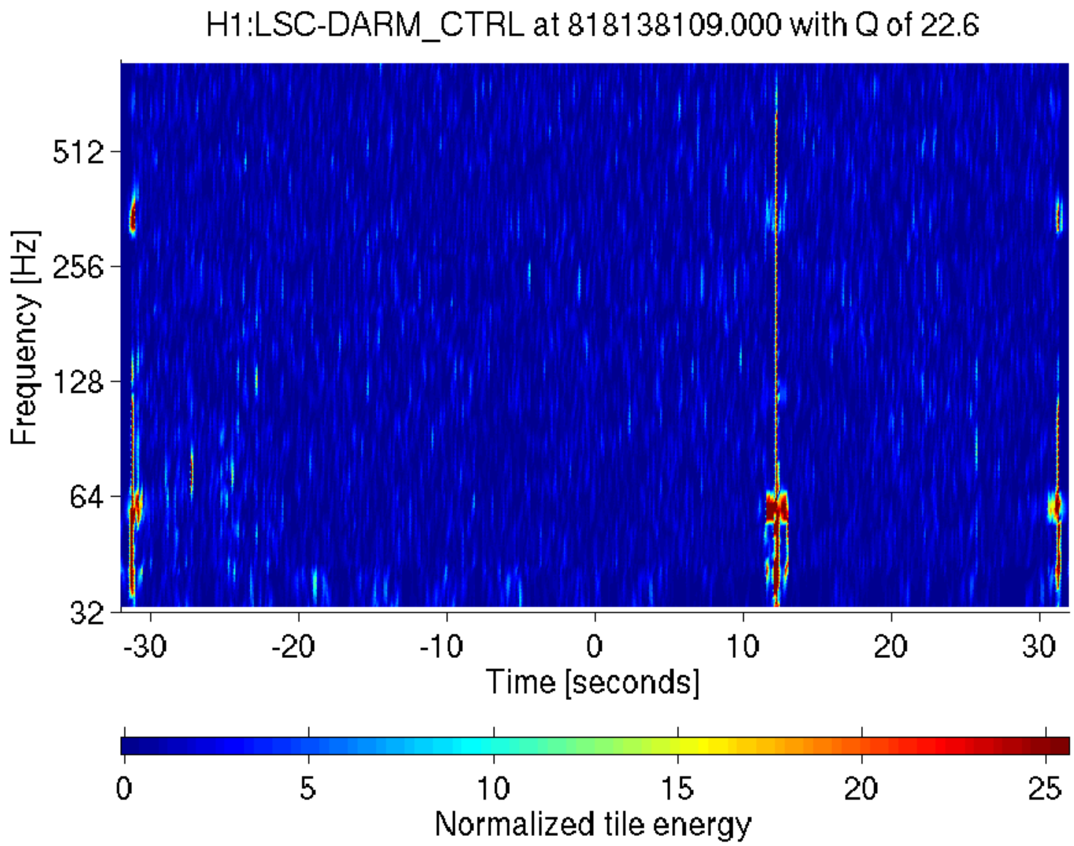

Figure 4: QScan of the data for the outlier in Fig. (3), shows the origin of the difference to be a short glitch at 60Hz. See Caveat 2.

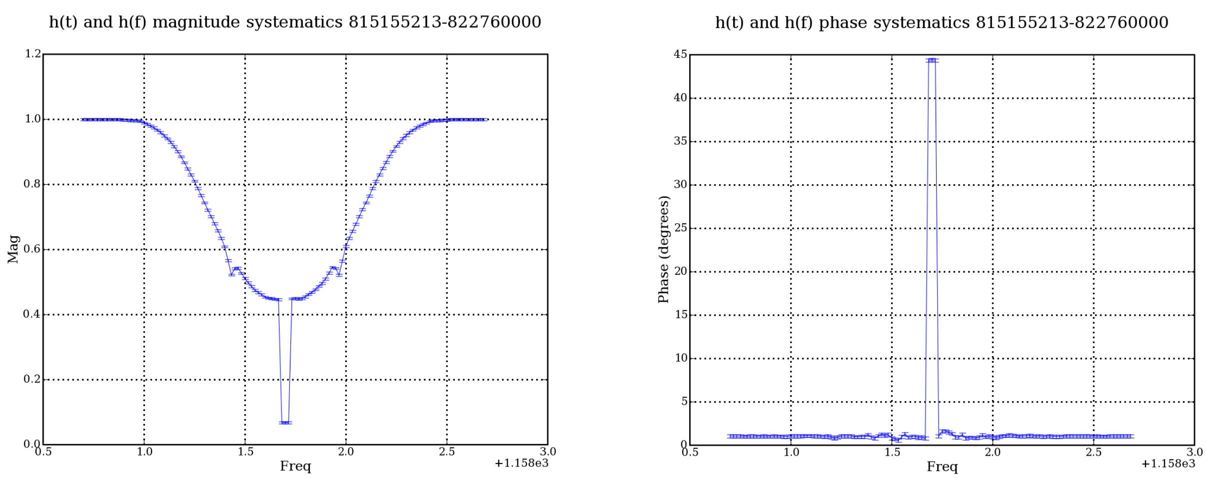

Figure 5: Plot of the value of A for the 1kHz calibration line in H2. There are significant problems out to 1Hz. See Caveat 1.

Freq		H1						H2					L1				
		E1	E2	E3	E4	E5	E6	E1	E2	E3	E4	E5	E1	E2	E3	E4	E5
40-100	Mag	0.002	0.000	0.000	0.002	0.003	0.003	0.002	0.001	0.000	0.001	0.005	0.001	0.000	0.000	0.001	0.000
	Phase	3.622	0.075	0.571	0.902	0.763	0.901	2.779	0.133	0.148	0.590	1.261	0.405	0.342	0.321	0.604	0.356
100-300	Mag	0.001	0.001	0.012	0.006	0.005	0.006	0.020	0.009	0.014	0.001	0.006	0.005	0.009	0.010	0.011	0.001
	Phase	2.088	0.495	0.883	0.584	0.557	0.596	2.118	0.847	0.983	0.793	1.199	0.732	0.830	0.930	1.069	0.670
300-2000	Mag	0.001	0.001	0.001	0.001	0.001	0.001	0.011	0.009	0.006	0.005	0.009	0.001	0.001	0.001	0.001	0.001
	Phase	1.100	1.144	1.368	1.356	1.215	1.524	1.663	1.674	1.667	1.658	1.659	1.429	1.426	1.512	1.523	1.211
2000-5000	Mag	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Phase	2.383	2.429	2.716	2.672	2.329	2.733	2.130	2.164	2.145	2.170	2.170	2.390	2.378	2.474	2.484	1.987
5000-6500	Mag	0.054	0.054	0.053	0.053	0.053	0.054	0.051	0.051	0.051	0.051	0.051	0.053	0.053	0.056	0.056	0.056
	Phase	5.067	5.203	4.803	4.549	5.327	4.916	3.135	3.136	3.153	3.130	3.134	1.810	1.806	6.034	6.023	5.419

Table 1: Systematic Results for each IFO, frequency band, and epoch. Epoch times are listed in 2.3

IFO	Magnitude error (40Hz-5kHz)	Phase error (40Hz-5kHz)	Magnitude error (5kHz-6.5kHz)	Phase error (5kHz-6.5kHz)
H1	1%	3.6	5.5%	5.3
H2	2%	2.8	5.1%	3.2
L1	1%	2.5	5.6%	6

Table 2: Recommended errors —see the caveats list before using these errors

2. We made a list of times when the noise ratio between h_t and h_f exceed 10%. In the end we decided not to flag these times. The reason is that many of the outliers are associated with short glitches in narrow bands times which makes the issue a data quality rather than a calibration issue—we propose that a DQ specialist look at this information and decide what to do. An example of this is shown in Figs. (3) and (4) The errors quoted above include all the times, in any case, including times when outliers were found. Nevertheless the SGR times were checked against our very conservative list of outliers (looking between 100Hz-2000Hz) and *none* of the SGR times were in our list of potentially problematic times.

3. The inspiral analysis still requires understanding of the hardware injections.

4. Around 5.5kHz there seems to be a very large systematic phase problem (70 degrees) in H1, not included in the error budget. A filter was left out of the actuation.

5. Category 1 and 2 vetos were used, in lalapps/src/calibration/ there are three files S5H1_NoiseCompTimes.txt, S5H2_NoiseCompTimes.txt, and S5L1_NoiseCompTimes.txt. See the top of the files for specific DQ flags used. See the Appendix for details.

2 Hardware injection checks

2.1 Stochastic injections

Stochastic injections were recovered down to $\Omega = 6.3 \times 10^{-3}$. As summarized in the table below, there were two hardware injections recovered to within 1-σ and one recovered to within 2-σ of the injected amplitude. This is reasonable as we expect to recover a value within 1-σ about 2/3 of the time.

Hardware injection	Duration (min)	Injected amplitude	Recovered amplitude	Statistical uncertainty	Calibration uncertainty
1	13	1.9	1.8	0.04	0.2
2	29	1.7×10^{-2}	2.3×10^{-2}	0.1×10^{-2}	0.3×10^{-2}
3	215	6.3×10^{-3}	7.0×10^{-3}	0.2×10^{-3}	0.6×10^{-3}

The overall error of 8% (H1) and 13% (L1) includes contributions from

- calibration amplitude 7% (H1), 6% (L1)
- small discrepancy between $h(t)$ and $h(f)$, conservatively taken to be 5% but typically much smaller
- systematic DC 10% in actuation (H1 only).

For comparison, software injections were successfully recovered down to $\Omega = 3.8 \times 10^{-5}$. Results from two software injections are summarized in the following table.

Software injection	Duration (days)	Injected amplitude	Recovered amplitude	Statistical uncertainty
1	520	3.8×10^{-5}	3.6×10^{-5}	0.44×10^{-5}
2	520	3.8×10^{-5}	4.1×10^{-5}	0.44×10^{-5}

2.2 Burst injections

Burst injections were also recovered as expected. See `http://emvogil-3.mit.edu/~bhughey/derrstraincomp.html` for details. The spread in the difference between h_f amplitudes and h_t was about 2% for about 12,000 injections in the 3 IFOs, and no significant systematic effects. There was a problem with injections around 393 Hz. It turns out the injections were loud enough to corrupt the computation of the calibration factors. While this problem is now understood, it underlines the fact that strong signals near the calibration lines can affect h_t generation. Groups should be careful when running injections near the calibration lines and realize that the results of such injections may not be reasonable.

2.3 Pulsar injections

Pulsar injections were recovered as expected. For details see `http://blip.phys.uwm.edu/twiki/bin/view/CW/TDAnalysisS5HWInjectionsUpdate`. Table 2.3 summarizes the results. Injections 0 and 9 were weak and so not recovered with enough signal to noise for accurate amplitude estimation. Injection 1 was not analyzed correctly (wrong spin-down parameter was used).

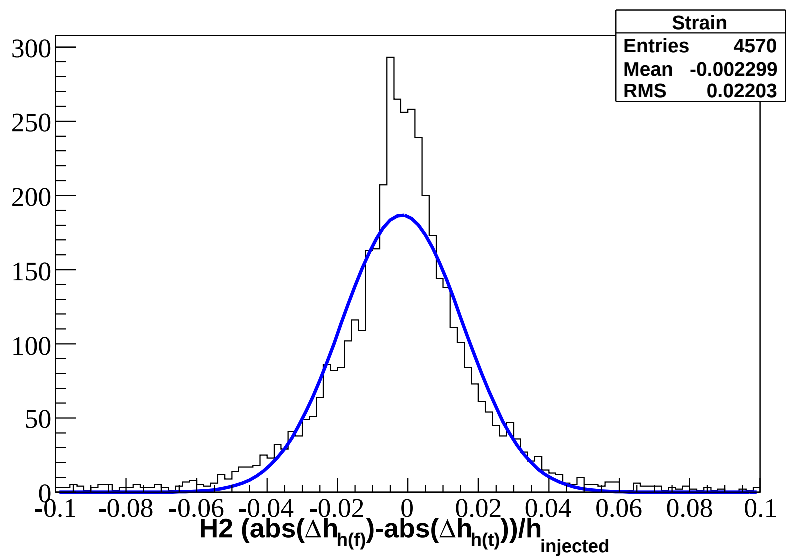

Figure 6: Example of burst hardware injection recovery in H2. Plot shows a histogram of the recovered amplitudes of 4570 injections in h_t and h_f fitted to a Gaussian to estimate the width, which is about 2%. There is no significant systematic.

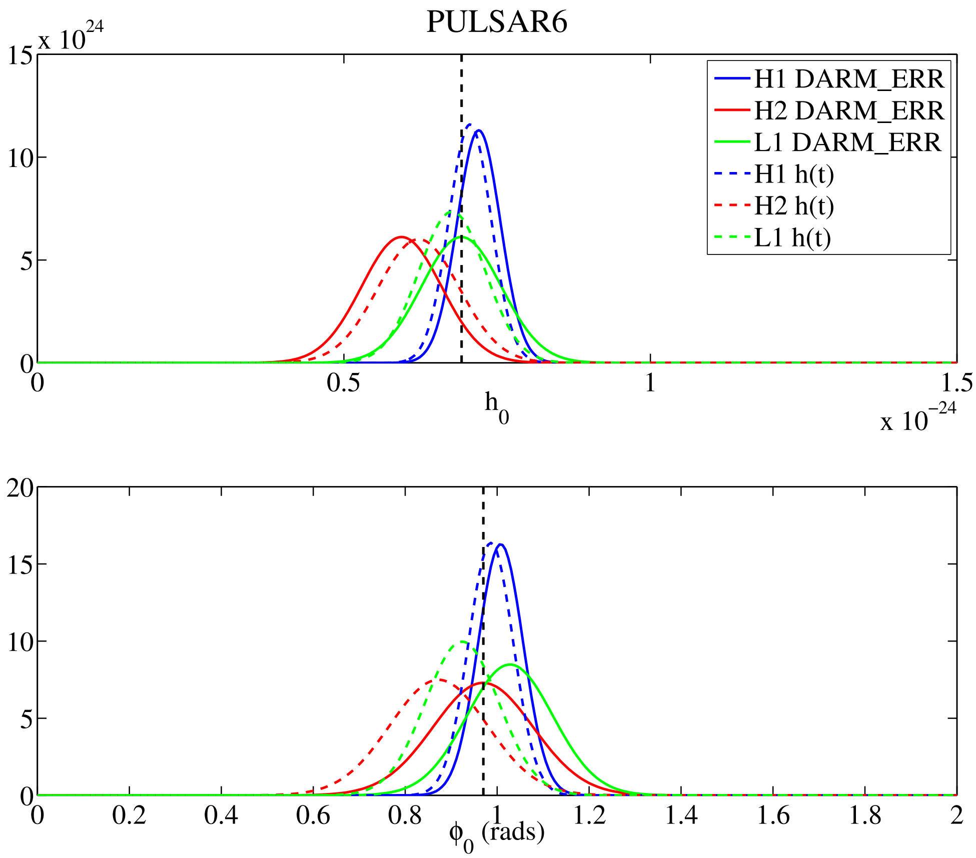

Figure 7: Example of pulsar hardware injection recovery. Plot of the magnitude and phase of hardware injection Pulsar 6 as seen in time domain calibrated data and frequency domain calibrated data.

Injection	frequency (Hz)	injection	H1	H2	L1
PULSAR0	266	2.47x10-25	1.02	1.01	1.28
PULSAR1	849	1.06x10-24	*	*	*
PULSAR2	575	4.02x10-24	1.00	0.99	1.01
PULSAR3	109	1.63x10-24	1.00	1.03	1.01
PULSAR4	1401	4.56x10-23	1.01	1.00	1.01
PULSAR5	53	4.85x10-24	0.98	0.98	1.01
PULSAR6	149	6.92x10-25	1.02	0.96	1.02
PULSAR7	1221	2.20x10-24	0.98	1.01	1.10
PULSAR8	194	1.59x10-23	1.01	1.01	0.99
PULSAR9	764	8.13x10-25	1.03	0.79	1.03

Table 3: Ratio h_f/h_t of recovered amplitudes for hardware injections. Injections 0 and 9 were weak and so not recovered with enough signal to noise for accurate amplitude estimation. Injection 1 was not analyzed correctly (wrong spin-down parameter was used)

Appendix A: Data quality flags used to create the segments analyzed

The data quality flags used are the category 1 and category 2 vetos and additional calibration data quality flags. The segment files are in CVS. In lalapps/src/calibration are the three segment files S5H1_NoiseCompTimes.txt, S5H2_NoiseCompTimes.txt, and S5L1_NoiseCompTimes.txt that were used. See the top of the files for the DQ flags used. They are included here for completeness.

H1 flags

H1:AS_TRIGGER:v1
H1:AS_TRIGGER:v2
H1:AS_TRIGGER:v10
H1:AS_TRIGGER:v11
H1:AS_TRIGGER:v99
H1:ASC_Overflow:v0
H1:ASC_Overflow:v1
H1:ASC_Overflow:v10
H1:ASC_Overflow:v11
H1:ASC_Overflow:v12
H1:ASC_Overflow:v13
H1:ASC_Overflow:v99
H1:ASI_CORR_OVERFLOW:v0
H1:ASI_CORR_OVERFLOW:v1
H1:ASI_CORR_OVERFLOW:v2
H1:ASI_CORR_OVERFLOW:v3
H1:ASI_CORR_OVERFLOW:v10
H1:ASI_CORR_OVERFLOW:v11
H1:ASI_CORR_OVERFLOW:v12
H1:ASI_CORR_OVERFLOW:v99
H1:CALIB_BAD_COEFFS_60:v1
H1:CALIB_BAD_COEFFS_60:v2
H1:CALIB_BAD_COEFFS_60:v10

H1:CALIB_BAD_COEFFS_60:v99
H1:CALIB_DROPOUT_1SAMPLE:v1
H1:CALIB_DROPOUT_1SAMPLE:v3
H1:CALIB_DROPOUT_1SAMPLE:v4
H1:CALIB_DROPOUT_1SAMPLE:v10
H1:CALIB_DROPOUT_1SAMPLE:v11
H1:CALIB_DROPOUT_1SAMPLE:v99
H1:CALIB_DROPOUT_1SEC:v1
H1:CALIB_DROPOUT_1SEC:v3
H1:CALIB_DROPOUT_1SEC:v4
H1:CALIB_DROPOUT_1SEC:v10
H1:CALIB_DROPOUT_1SEC:v11
H1:CALIB_DROPOUT_1SEC:v99
H1:CALIB_DROPOUT_AWG_STUCK:v1
H1:CALIB_DROPOUT_AWG_STUCK:v3
H1:CALIB_DROPOUT_AWG_STUCK:v4
H1:CALIB_DROPOUT_AWG_STUCK:v10
H1:CALIB_DROPOUT_AWG_STUCK:v11
H1:CALIB_DROPOUT_AWG_STUCK:v99
H1:CALIB_GLITCH_ZG:v1
H1:CALIB_GLITCH_ZG:v3
H1:CALIB_GLITCH_ZG:v4
H1:CALIB_GLITCH_ZG:v10
H1:CALIB_GLITCH_ZG:v11
H1:CALIB_GLITCH_ZG:v99
H1:CORRUPTED_RDS_C03_LX:v10
H1:CORRUPTED_RDS_C03_LX:v11
H1:CORRUPTED_RDS_C03_LX:v99
H1:INVALID_DARMERR:v1
H1:INVALID_DARMERR:v10
H1:INVALID_DARMERR:v99
H1:LSC_OVERFLOW:v0
H1:LSC_OVERFLOW:v1
H1:LSC_OVERFLOW:v10
H1:LSC_OVERFLOW:v11
H1:LSC_OVERFLOW:v99
H1:MASTER_OVERFLOW_LSC:v1
H1:MASTER_OVERFLOW_LSC:v10
H1:MASTER_OVERFLOW_LSC:v11
H1:MASTER_OVERFLOW_LSC:v99
H1:MISSING_RAW:v1
H1:MISSING_RAW:v10
H1:MISSING_RAW:v11
H1:MISSING_RAW:v99
H1:MISSING_RDS_C03_L2:v1
H1:MISSING_RDS_C03_L2:v10

H1:MISSING_RDS_C03_L2:v11
H1:MISSING_RDS_C03_L2:v99
H1:MISSING_RDS_LEVEL_1:v1
H1:MISSING_RDS_LEVEL_1:v10
H1:MISSING_RDS_LEVEL_1:v11
H1:MISSING_RDS_LEVEL_1:v99
H1:NO_CALIB_LINE:v1
H1:NO_CALIB_LINE:v10
H1:NO_CALIB_LINE:v11
H1:NO_CALIB_LINE:v99
H1:OUT_OF_LOCK:v1
H1:OUT_OF_LOCK:v10
H1:OUT_OF_LOCK:v11
H1:OUT_OF_LOCK:v99
H1:PRE_LOCKLOSS_30_SEC:v1
H1:PRE_LOCKLOSS_30_SEC:v10
H1:PRE_LOCKLOSS_30_SEC:v11
H1:PRE_LOCKLOSS_30_SEC:v99
H1:SEVERE_LSC_OVERFLOW:v0
H1:SEVERE_LSC_OVERFLOW:v1
H1:SEVERE_LSC_OVERFLOW:v2
H1:SEVERE_LSC_OVERFLOW:v3
H1:SEVERE_LSC_OVERFLOW:v10
H1:SEVERE_LSC_OVERFLOW:v11
H1:SEVERE_LSC_OVERFLOW:v12
H1:SEVERE_LSC_OVERFLOW:v99

H2 flags

H2:AS_TRIGGER:v1
H2:AS_TRIGGER:v2
H2:AS_TRIGGER:v10
H2:AS_TRIGGER:v11
H2:AS_TRIGGER:v99
H2:ASC_Overflow:v0
H2:ASC_Overflow:v1
H2:ASC_Overflow:v10
H2:ASC_Overflow:v11
H2:ASC_Overflow:v12
H2:ASC_Overflow:v99
H2:ASI_CORR_OVERFLOW:v0
H2:ASI_CORR_OVERFLOW:v1
H2:ASI_CORR_OVERFLOW:v2
H2:ASI_CORR_OVERFLOW:v3
H2:ASI_CORR_OVERFLOW:v10
H2:ASI_CORR_OVERFLOW:v11

H2:ASI_CORR_OVERFLOW:v12
H2:ASI_CORR_OVERFLOW:v99
H2:CALIB_BAD_COEFFS_60:v1
H2:CALIB_BAD_COEFFS_60:v2
H2:CALIB_BAD_COEFFS_60:v10
H2:CALIB_BAD_COEFFS_60:v99
H2:CALIB_DROPOUT_1SAMPLE:v1
H2:CALIB_DROPOUT_1SAMPLE:v3
H2:CALIB_DROPOUT_1SAMPLE:v4
H2:CALIB_DROPOUT_1SAMPLE:v10
H2:CALIB_DROPOUT_1SAMPLE:v11
H2:CALIB_DROPOUT_1SAMPLE:v99
H2:CALIB_DROPOUT_1SEC:v1
H2:CALIB_DROPOUT_1SEC:v3
H2:CALIB_DROPOUT_1SEC:v4
H2:CALIB_DROPOUT_1SEC:v10
H2:CALIB_DROPOUT_1SEC:v11
H2:CALIB_DROPOUT_1SEC:v99
H2:CALIB_DROPOUT_AWG_STUCK:v1
H2:CALIB_DROPOUT_AWG_STUCK:v3
H2:CALIB_DROPOUT_AWG_STUCK:v4
H2:CALIB_DROPOUT_AWG_STUCK:v10
H2:CALIB_DROPOUT_AWG_STUCK:v11
H2:CALIB_DROPOUT_AWG_STUCK:v99
H2:CALIB_GLITCH_ZG:v1
H2:CALIB_GLITCH_ZG:v3
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H2:CALIB_GLITCH_ZG:v99
H2:INVALID_DARMERR:v1
H2:INVALID_DARMERR:v10
H2:INVALID_DARMERR:v99
H2:MASTER_OVERFLOW_LSC:v1
H2:MASTER_OVERFLOW_LSC:v10
H2:MASTER_OVERFLOW_LSC:v11
H2:MASTER_OVERFLOW_LSC:v99
H2:MISSING_RAW:v1
H2:MISSING_RAW:v10
H2:MISSING_RAW:v11
H2:MISSING_RAW:v99
H2:MISSING_RDS_C03_L2:v1
H2:MISSING_RDS_C03_L2:v2
H2:MISSING_RDS_C03_L2:v10
H2:MISSING_RDS_C03_L2:v11
H2:MISSING_RDS_C03_L2:v99

H2:MISSING_RDS_LEVEL_1:v1
H2:MISSING_RDS_LEVEL_1:v10
H2:MISSING_RDS_LEVEL_1:v11
H2:MISSING_RDS_LEVEL_1:v99
H2:NO_CALIB_LINE:v1
H2:NO_CALIB_LINE:v10
H2:NO_CALIB_LINE:v11
H2:NO_CALIB_LINE:v99
H2:OUT_OF_LOCK:v1
H2:OUT_OF_LOCK:v10
H2:OUT_OF_LOCK:v11
H2:OUT_OF_LOCK:v99
H2:PRE_LOCKLOSS_30_SEC:v1
H2:PRE_LOCKLOSS_30_SEC:v10
H2:PRE_LOCKLOSS_30_SEC:v11
H2:PRE_LOCKLOSS_30_SEC:v99
H2:SEVERE_LSC_OVERFLOW:v0
H2:SEVERE_LSC_OVERFLOW:v1
H2:SEVERE_LSC_OVERFLOW:v2
H2:SEVERE_LSC_OVERFLOW:v3
H2:SEVERE_LSC_OVERFLOW:v10
H2:SEVERE_LSC_OVERFLOW:v11
H2:SEVERE_LSC_OVERFLOW:v12
H2:SEVERE_LSC_OVERFLOW:v99

L1 flags

L1:AS_TRIGGER:v1
L1:AS_TRIGGER:v2
L1:AS_TRIGGER:v3
L1:AS_TRIGGER:v10
L1:AS_TRIGGER:v11
L1:AS_TRIGGER:v99
L1:ASC_Overflow:v0
L1:ASC_Overflow:v1
L1:ASC_Overflow:v10
L1:ASC_Overflow:v99
L1:ASI_CORR_OVERFLOW:v0
L1:ASI_CORR_OVERFLOW:v1
L1:ASI_CORR_OVERFLOW:v2
L1:ASI_CORR_OVERFLOW:v3
L1:ASI_CORR_OVERFLOW:v10
L1:ASI_CORR_OVERFLOW:v99
L1:BAD_SENSING:v1
L1:BAD_SENSING:v10
L1:BAD_SENSING:v99

L1:BAD_SERVO:v1
L1:BAD_SERVO:v10
L1:BAD_SERVO:v99
L1:CALIB_BAD_COEFFS_60:v1
L1:CALIB_BAD_COEFFS_60:v2
L1:CALIB_BAD_COEFFS_60:v10
L1:CALIB_BAD_COEFFS_60:v99
L1:CALIB_DROPOUT_1SAMPLE:v1
L1:CALIB_DROPOUT_1SAMPLE:v2
L1:CALIB_DROPOUT_1SAMPLE:v3
L1:CALIB_DROPOUT_1SAMPLE:v4
L1:CALIB_DROPOUT_1SAMPLE:v10
L1:CALIB_DROPOUT_1SAMPLE:v11
L1:CALIB_DROPOUT_1SAMPLE:v99
L1:CALIB_DROPOUT_1SEC:v2
L1:CALIB_DROPOUT_1SEC:v3
L1:CALIB_DROPOUT_1SEC:v4
L1:CALIB_DROPOUT_1SEC:v10
L1:CALIB_DROPOUT_1SEC:v11
L1:CALIB_DROPOUT_1SEC:v99
L1:CALIB_DROPOUT_AWG_STUCK:v1
L1:CALIB_DROPOUT_AWG_STUCK:v3
L1:CALIB_DROPOUT_AWG_STUCK:v4
L1:CALIB_DROPOUT_AWG_STUCK:v10
L1:CALIB_DROPOUT_AWG_STUCK:v11
L1:CALIB_DROPOUT_AWG_STUCK:v99
L1:CALIB_DROPOUT_BN:v1
L1:CALIB_DROPOUT_BN:v10
L1:CALIB_DROPOUT_BN:v99
L1:CALIB_GLITCH_ZG:v1
L1:CALIB_GLITCH_ZG:v3
L1:CALIB_GLITCH_ZG:v4
L1:CALIB_GLITCH_ZG:v10
L1:CALIB_GLITCH_ZG:v11
L1:CALIB_GLITCH_ZG:v99
L1:CORRUPTED_RDS_C03_LX:v10
L1:CORRUPTED_RDS_C03_LX:v99
L1:INVALID_DARMERR:v1
L1:INVALID_DARMERR:v10
L1:INVALID_DARMERR:v99
L1:MASTER_OVERFLOW_LSC:v1
L1:MASTER_OVERFLOW_LSC:v10
L1:MASTER_OVERFLOW_LSC:v11
L1:MASTER_OVERFLOW_LSC:v99
L1:MISSING_RDS_C03_L2:v1
L1:MISSING_RDS_C03_L2:v10

L1:MISSING_RDS_C03_L2:v11
L1:MISSING_RDS_C03_L2:v99
L1:MISSING_RDS_LEVEL_1:v1
L1:MISSING_RDS_LEVEL_1:v10
L1:MISSING_RDS_LEVEL_1:v11
L1:MISSING_RDS_LEVEL_1:v99
L1:NO_CALIB_LINE:v1
L1:NO_CALIB_LINE:v10
L1:NO_CALIB_LINE:v11
L1:NO_CALIB_LINE:v99
L1:OUT_OF_LOCK:v1
L1:OUT_OF_LOCK:v10
L1:OUT_OF_LOCK:v11
L1:OUT_OF_LOCK:v99
L1:PRE_LOCKLOSS_30_SEC:v1
L1:PRE_LOCKLOSS_30_SEC:v10
L1:PRE_LOCKLOSS_30_SEC:v11
L1:PRE_LOCKLOSS_30_SEC:v99
L1:SEVERE_LSC_OVERFLOW:v1
L1:SEVERE_LSC_OVERFLOW:v2
L1:SEVERE_LSC_OVERFLOW:v3
L1:SEVERE_LSC_OVERFLOW:v10
L1:SEVERE_LSC_OVERFLOW:v99

Appendix B: Epoch GPS times

H1
EPOCH 1: 815155213-822760000
EPOCH 2: 822760000-824695694
EPOCH 3: 824695694-824862720
EPOCH 4: 824862720-835044014
EPOCH 5: 835044014-843942254
EPOCH 6: 843942254-999999999

L1
EPOCH 1: 816019213-822760000
EPOCH 2: 822760000-824497827
EPOCH 3: 824497827-824862720
EPOCH 4: 824862720-825465258
EPOCH 5: 825465258-999999999

H2
EPOCH 1: 815155213-822760000
EPOCH 2: 822760000-824862720
EPOCH 3: 824862720-824949188
EPOCH 4: 824949188-846138794
EPOCH 5: 846138794-999999999