LIGO Calibration Update

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for the LSC Calibration committee

Frequency Domain Calibration

V3 Calibration

- To facilitate publication of analyses that used the V3 calibration we did the following:
  - Satisfied ourselves and the reviewers that this calibration could be extended to cover the whole run i.e. no further epochs were needed.
  - Corrected the DC gains used for all three instruments based on our complete set of measurements from before, during and after the run using three independent methods – all in close agreement.
  - The one-sigma amplitude errors are 8.1%, 7.2% and 6.0% for H1, H2 and L1 respectively. We use only the official calibration method
  - Phase errors for H1, H2 and L1 are 3, 2 and 2 degrees respectively.
  - These errors are good from 40-2000 Hz.

Time Delay Studies

- For V3 and previous calibrations we found that in order to match the model to the Open Loop Gain measurements we needed an extra time delay of ~200 μs.
- This delay was added to the sensing part of the loop since we felt that this was a conservative approach (most effect on the response function).
- Insight into the DARM loop time delay from 3 independent and different approaches.
  - Our standard method of matching the measured open loop gain to a MATLAB model.
  - Photon Calibrator measurements post-S5 at LHO (~1 μs precision)
  - Recent step-by-step hardware measurements in each component at LHO

Time Delay Studies

- Using these measurements we have a better understanding of the time delays and what part of the DARM loop they belong
- The agreement with the upcoming V4 model, hardware and Pcal measurements is ~10 μs.
- Analyses which use only the LIGO interferometers (V3 or V4) should not be affected since the changes are all in the same direction by very similar amounts.... Negligable relative time shift.

V4 h(f)

- We think the latest incarnation of V3 is very close to a final S5 calibration.
- For V4 we will double-check the time delays and the effect on the response function.
- We will satisfy ourselves and the review committee that we understand the DC gains and that we are satisfied that we are tracking all relevant changes during S5.
- We expect that many of the more mature and CPU intensive analyses will be happy to use V3. But analysis groups must be proceed carefully with V3!

Time Domain Calibration

Noise comparison: Looking for differences between TD and FD calibrations.

Joe Betzwiezer, Chad Hanna, Amber Stuver:
Looking at many small bands of noise in FD calibrated DARM_ERR and compare to noise in h(t).

(1) Compare magnitude of noises to flag bad data.

(2) Look at real and imaginary parts frequency bin by frequency bin in more detail to come up with error bars
for analysis groups.

Excellent progress on this, including novel visualizations and algorithms.
Expect to be done going through all data by end of June.

Hardware injections: Looking for differences between TD and FD calibrations.

Brennan Hughey (Bursts):

Thorough look at burst hardware injections. Agreement between h(t) and h(f) even better than expected. Following up on problematic injections near calibration lines.

Anand Sengupta (Inspirals):

In progress.

Matt Pitkin (Pulsars):

In progress.

Philip Charlton (Stochastic):

Thorough analysis. Agreement within what is expected.

Summary

- Time of V3 validation completion: End of June, beginning of July

- V4 h(t): Once FD calibration is released
    a) Data available in 1-2 months depending on amount of h(t) to be regenerated.
    b) Data validated in 1-2 months after. Time to analyze data and go back and forth with review committee

Time Delay Studies

- The expected time delay is:
  - DAQ processing delay ~ 122 μs
  - DAC sample/hold delay ~ 30 μs
  - Light travel time in arms ~ 13 μs (for 4 km)
  - Total: ~ 165 μs
- The sample/hold delay had the wrong sign in the model. We should have used ~170 μs with the correct delay filter.
- This brings all time delays into agreement at the ~10 μs level