Thoughts on test signal injection for UL algorithm efficiency & pipeline integrity measurement

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Reasons for using test signals

- Easy: How many signals above given threshold at your process output?
- Harder: What is "deconvolved" signal strain or energy as a function of that threshold?
- Really hard (most searches): What is the probability a signal was there and you missed it?
  - ◊ Critical issue for forming and supporting an upper limit
  - ◊ Detection & analysis processes, cuts and vetos are far too complex to project distributions analytically (I think)
  - ◊ Monte-Carlo type evaluation seems inevitable

Hardware Signal Injection

- Could just add dummy signals to acquired frames
  - ◊ should be done as close as possible to raw ADC counts
  - ◊ indeed impractical (?) to do monte carlo with hardware signals alone
    - time/frequency devoted to injected signals for a given search is tainted for all
    - sheer volume of test signals req'd for adequate statistics probably overwhelming
  - ◊ effectiveness depends on knowledge of true detector response function
- Unexpected detector, conversion, preprocessing effects?
- Independent verification of calibration & timing ?
- Connection between applied hardware force & GW strain is *SIMPLE & TRANSPARENT*

Hardware injection (cont'd)

- Philosophically satisfying
  - ◊ Nature always finds a way to invent fake signals AND erase real ones
  - ◊ Confidence in result (from aging experimenter's perspective) varies sensitively with how closely you can assert true "end-to-end" testing of your pipeline
  - ◊ All who have NOT wasted a day analysing the crap out of what turns out to be a dead channel, please raise your hand!

Ways & Means

- Generation (order of “independence”)
  - ◊ GDS excitation engine (analog or digital output)
  - ◊ independent signal generator (analog or digital)
    - – Variant: independent timing reference
- Actuation (order of “independence”)
  - ◊ Digital test signal injected into length control loop
  - ◊ Add analog actuation current to coil drive (analog sum node)
  - ◊ Photon calibrator

Coil Force Calibration

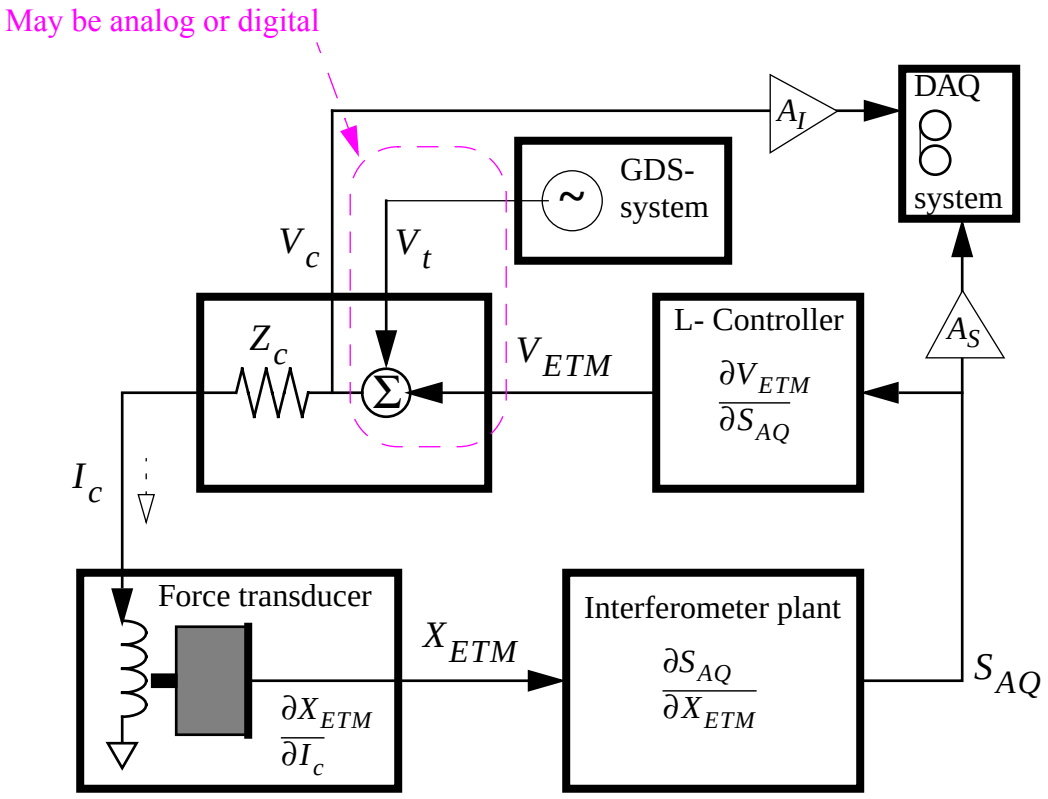

Figure 1: Simplified schematic of primary calibration in operation mode, showing the multiplicative factors subject to initial error or drift.

Photon Calibrator

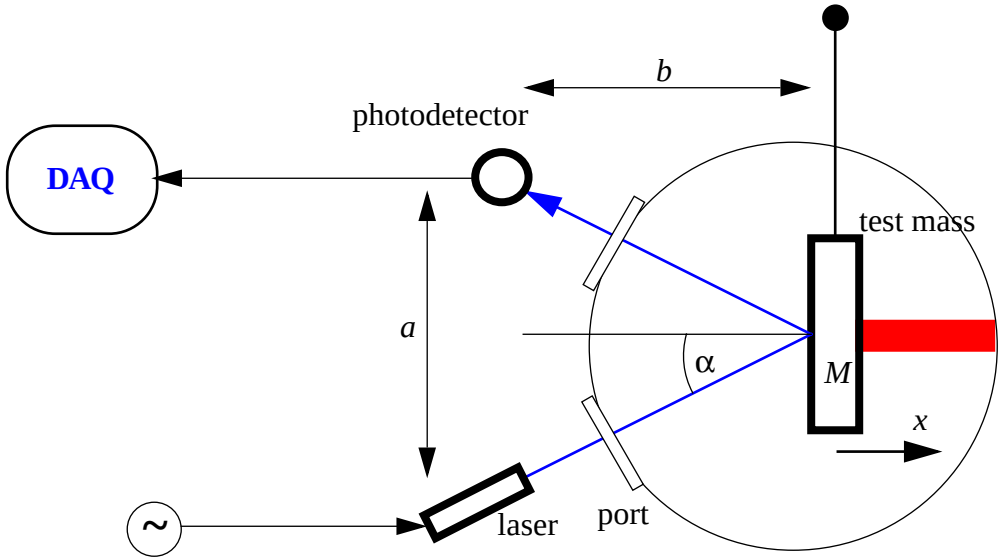

Figure 2: Schematic of a photon-recoil based calibration actuator.

What if things go wrong????

- MUST BE FAILSAFE against inadvertent signal injection
  - ◊ e.g., hung process keeps putting in faint inspirals which are then found and published...
- Suggest layered approach, as for personnel safety
  - ◊ Procedural controls (SOP, “Signal Injection Review Board?”)
  - ◊ Software (password) & hardware (padlock) lockouts on ports
  - ◊ Use of subtly non-physical test signals (if possible w/o affecting search algorithm efficiency) or reserved search spaces (playgrounds)
  - ◊ Probably require minimum of two highly independent controls
  - ◊ One argument for requiring an analog link in signal path (can be locked out and tagged visually)

What is 'easy'

- GDS excitation engine can (will soon?) handle "short" arbitrary waveforms in prepared files
  - ◊ Relatively simple matter & probably sufficient for inspiral, burst tests
    - — Comment: bursties need to decide what kind of waveforms to set upper limits on
  - ◊ Stochastic searches may also be tested adequately with short bursts (?)
- Long-term periodic tests not so easy
  - ◊ Want to span long times (hours-days) to verify efficiency after Doppler/AM & spindown cuts, probe low-SNR end of search volume
  - ◊ Thus need also to run multiple Doppler/AM/spindown/amplitude test cases simultaneously (give up frequency spectrum vs. observing time as for bursts)
  - ◊ Need to come up with a hybrid that is as bulletproof as practical

What groups need to do

- Develop Monte Carlo test plans
- Determine how “blind” to make test signal injection
  - ◊ Designate “red team/blue team” ??
- Apportion the tests between pure SW and HW (& estimate “mass” in each category)
- Discuss signal properties, “degree of independence”, “end-to-endness” etc. with Mike to develop infrastructure and start coordinating groups of tests
- Plan and do trial runs before E6 (EXTREMELY IMPORTANT)
- Schedule and perform injections during E6