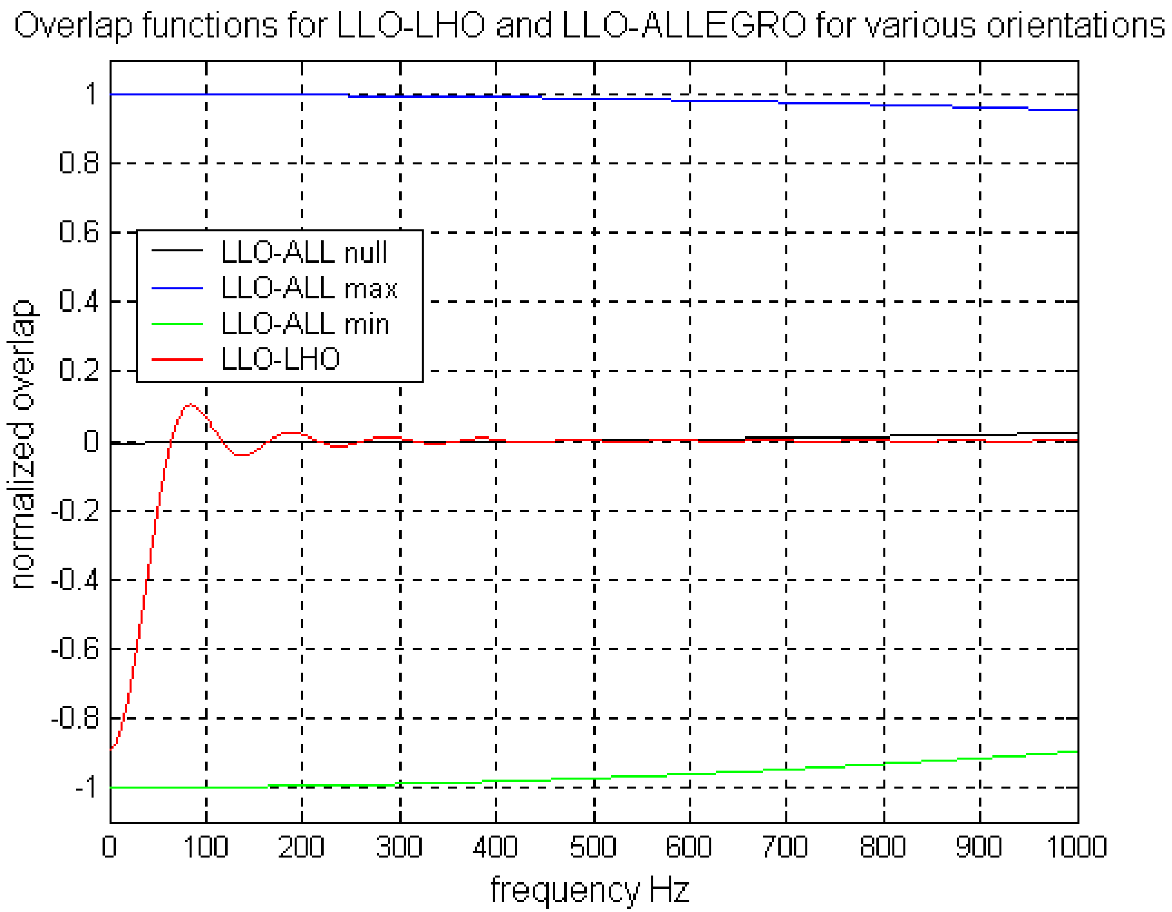
ALLEGRO calibration for the LLO-ALLEGRO stochastic analysis

Martin McHugh

Loyola University New Orleans

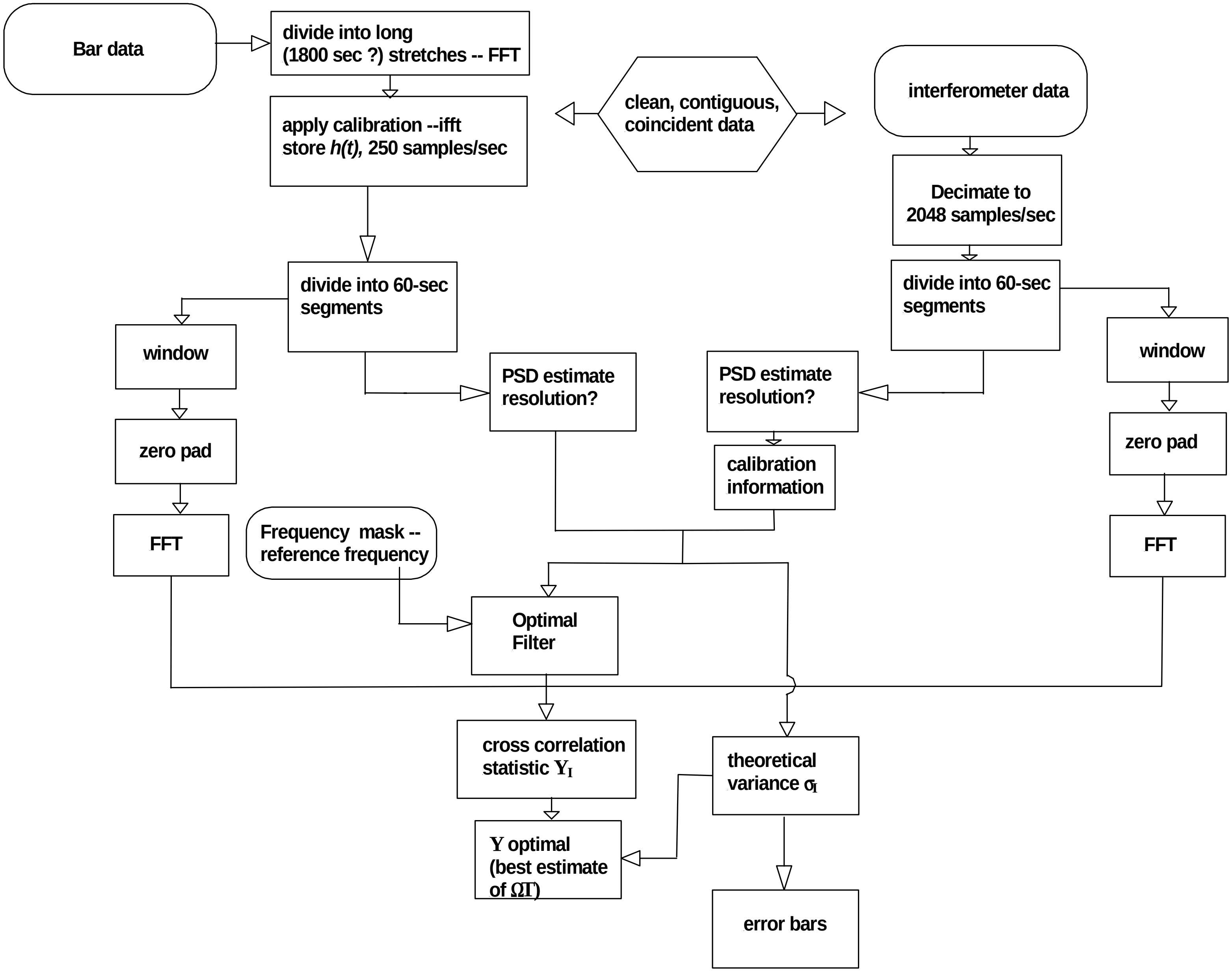
LLO - ALLEGRO correlation

- Good overlap (40 km separation) – sensitive to higher frequency range than LLO-LHO
- Modulate – rotate to align/misalign/anti-align antenna patterns
- Another independent detector

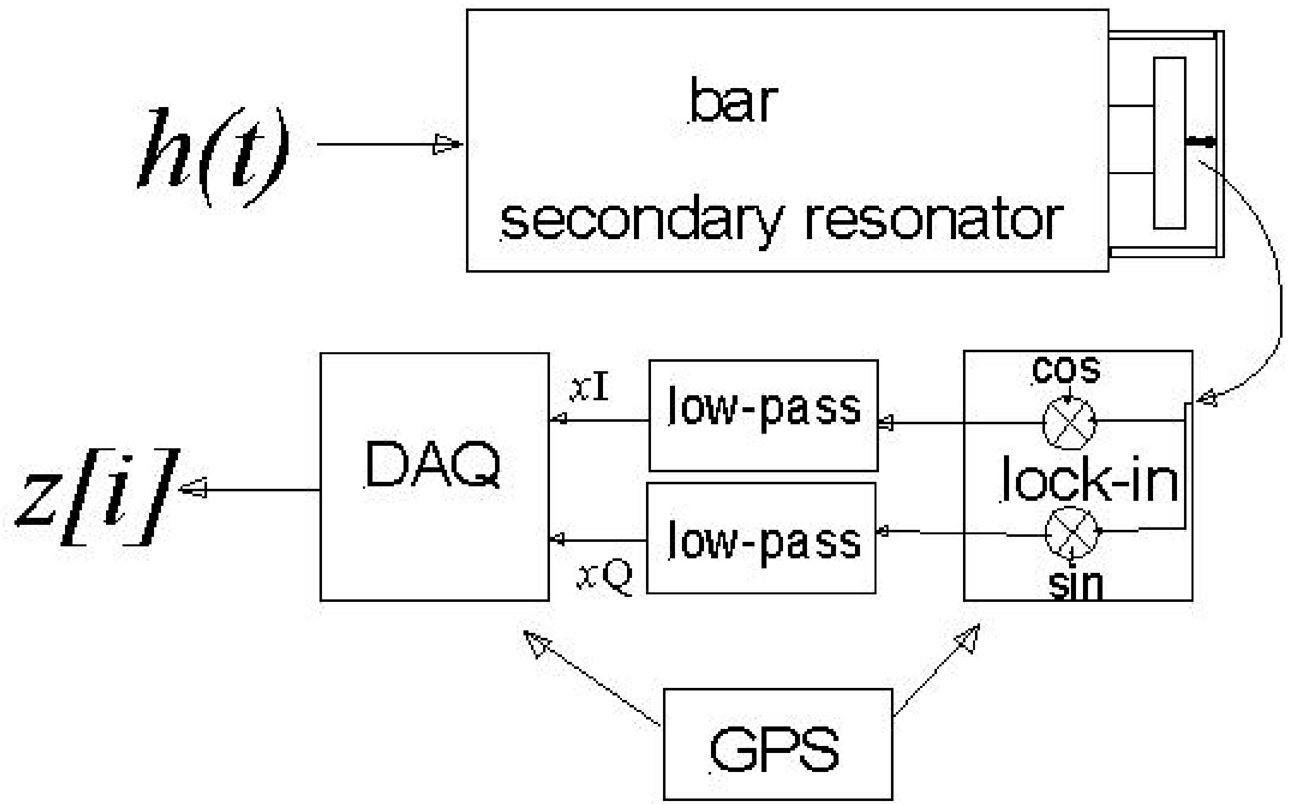


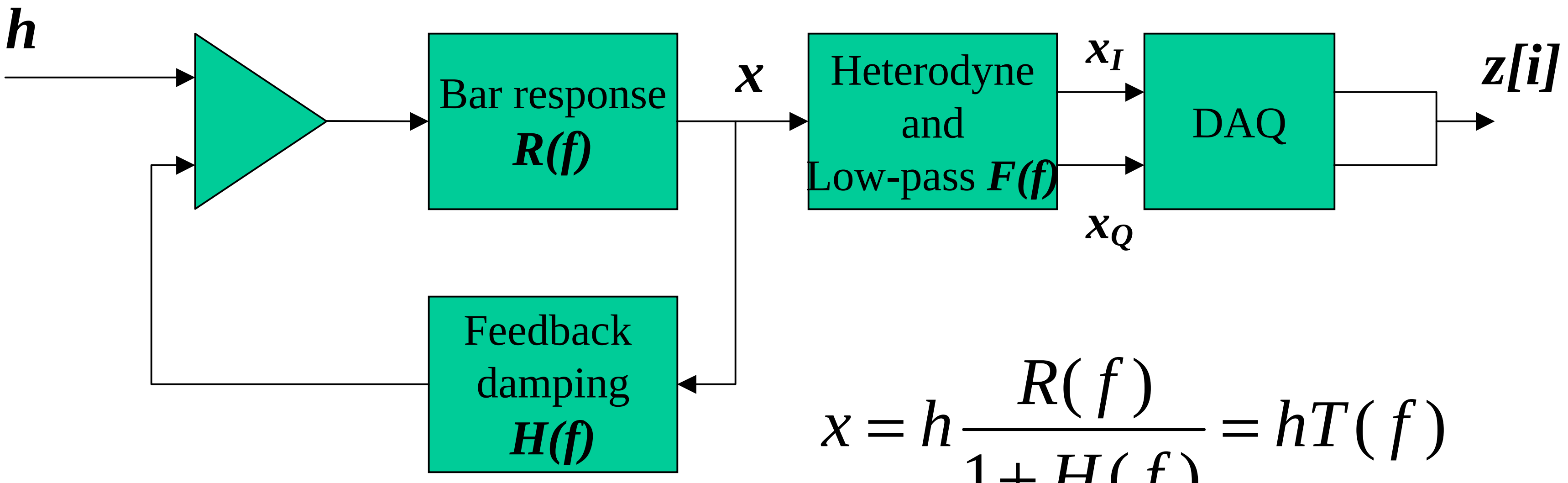
Outline of technique

- Correlate A1 with L1, taking same time stretch from each
  - Sampling rate very different (250Hz for A1, 2048Hz for LIGO) A1 data is heterodyned
- Match bins in frequency domain
- Resonant nature of the detector means long time constant for excitations in the raw data. Easier to calibrate all of the data and then work with *h(t)*


Bar data
divide into long (1800 sec ?) stretches -- FFT
apply calibration --ifft store *h(t)*, 250 samples/sec
clean, contiguous, coincident data
interferometer data
Decimate to 2048 samples/sec
divide into 60-sec segments
divide into 60-sec segments
window
zero pad
FFT
PSD estimate resolution?
PSD estimate resolution?
calibration information
window
zero pad
FFT
Frequency mask -- reference frequency
Optimal Filter
cross correlation statistic Y_I
theoretical variance σ_I
Y optimal (best estimate of ΩT)
error bars

Signal path


h(t)
bar
secondary resonator
z[i]
DAQ
xI
xQ
low-pass
low-pass
cos
lock-in
sin
GPS

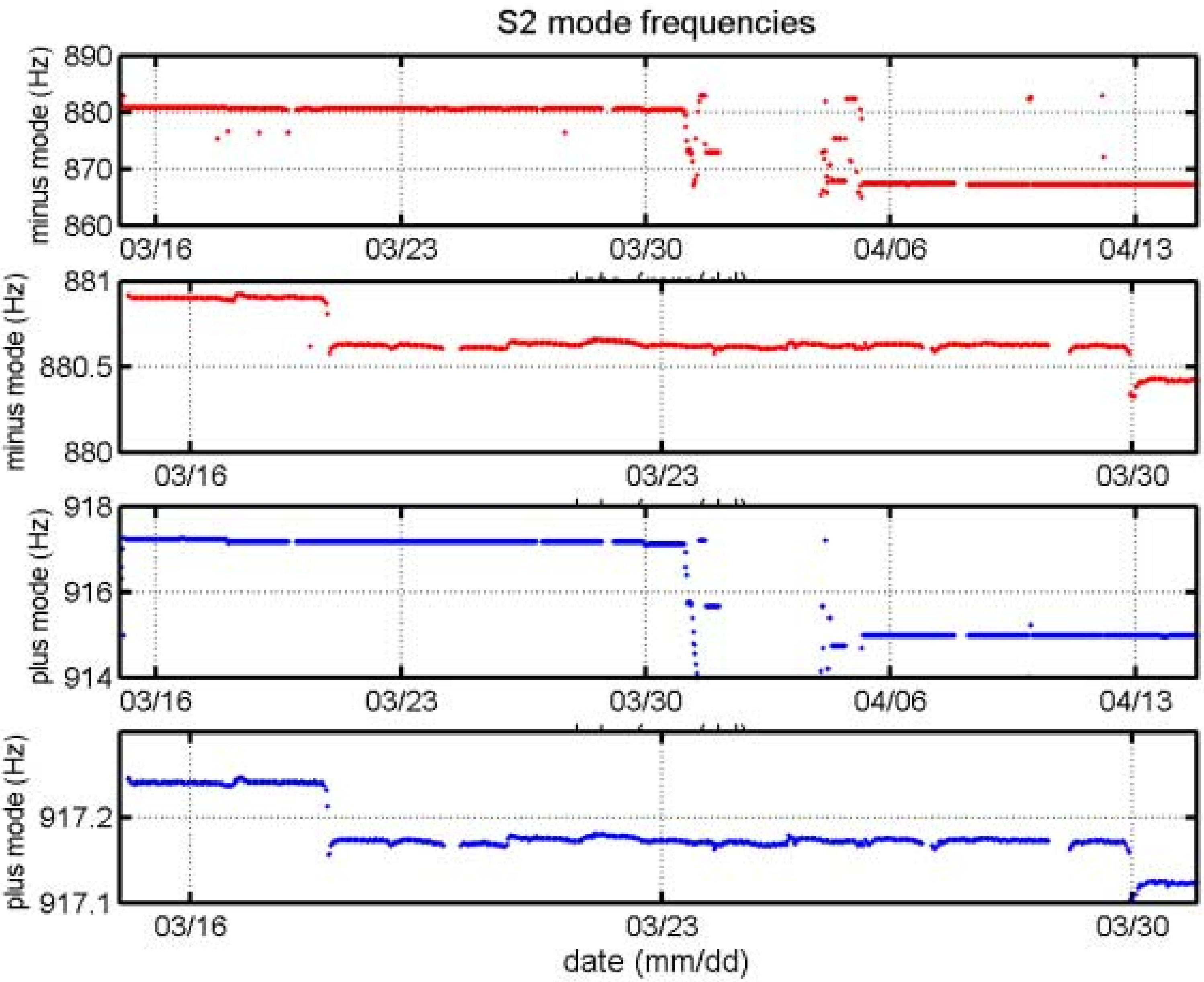


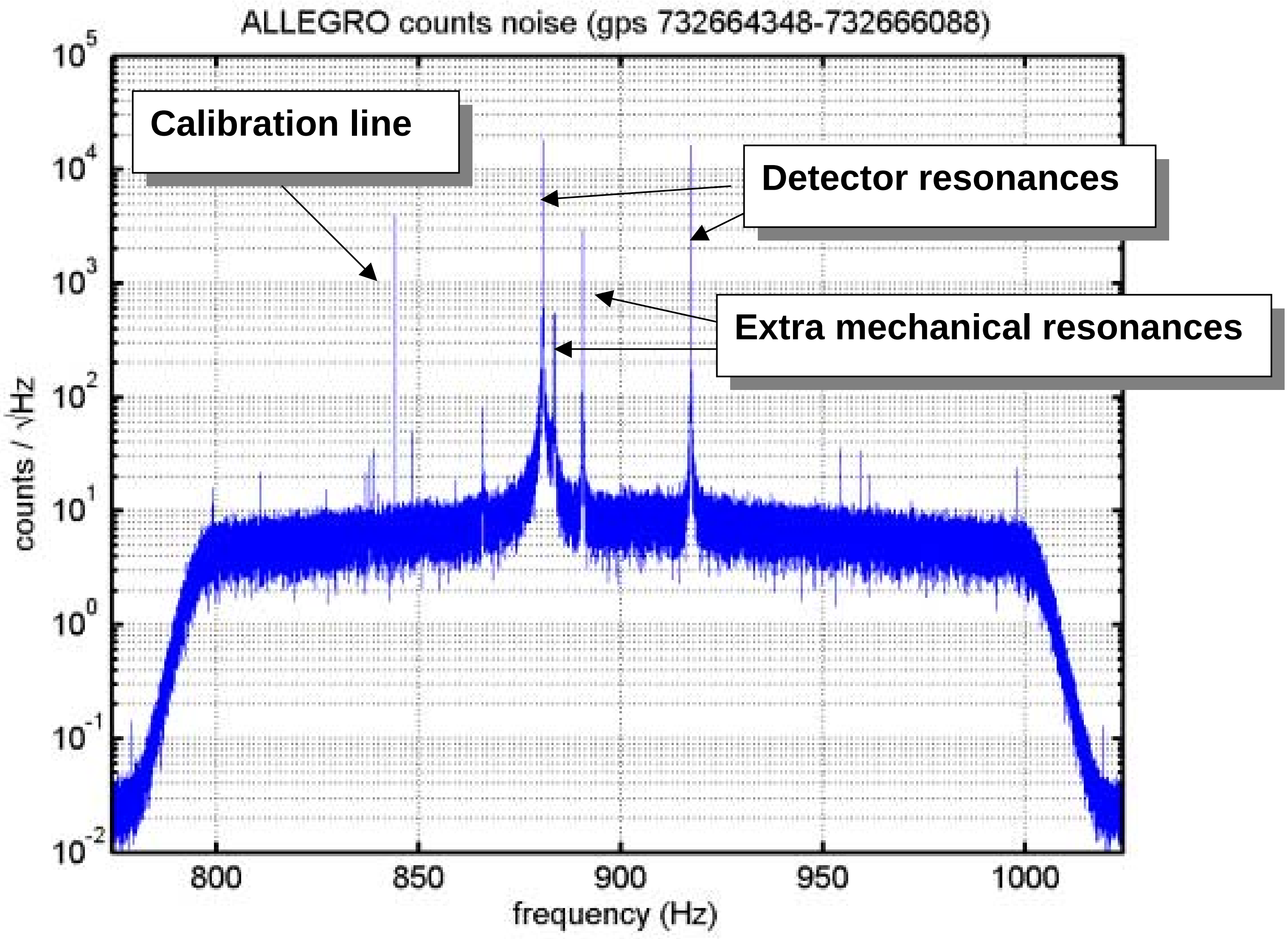
$$x = h\frac{R(f)}{1+H(f)} = hT(f)$$

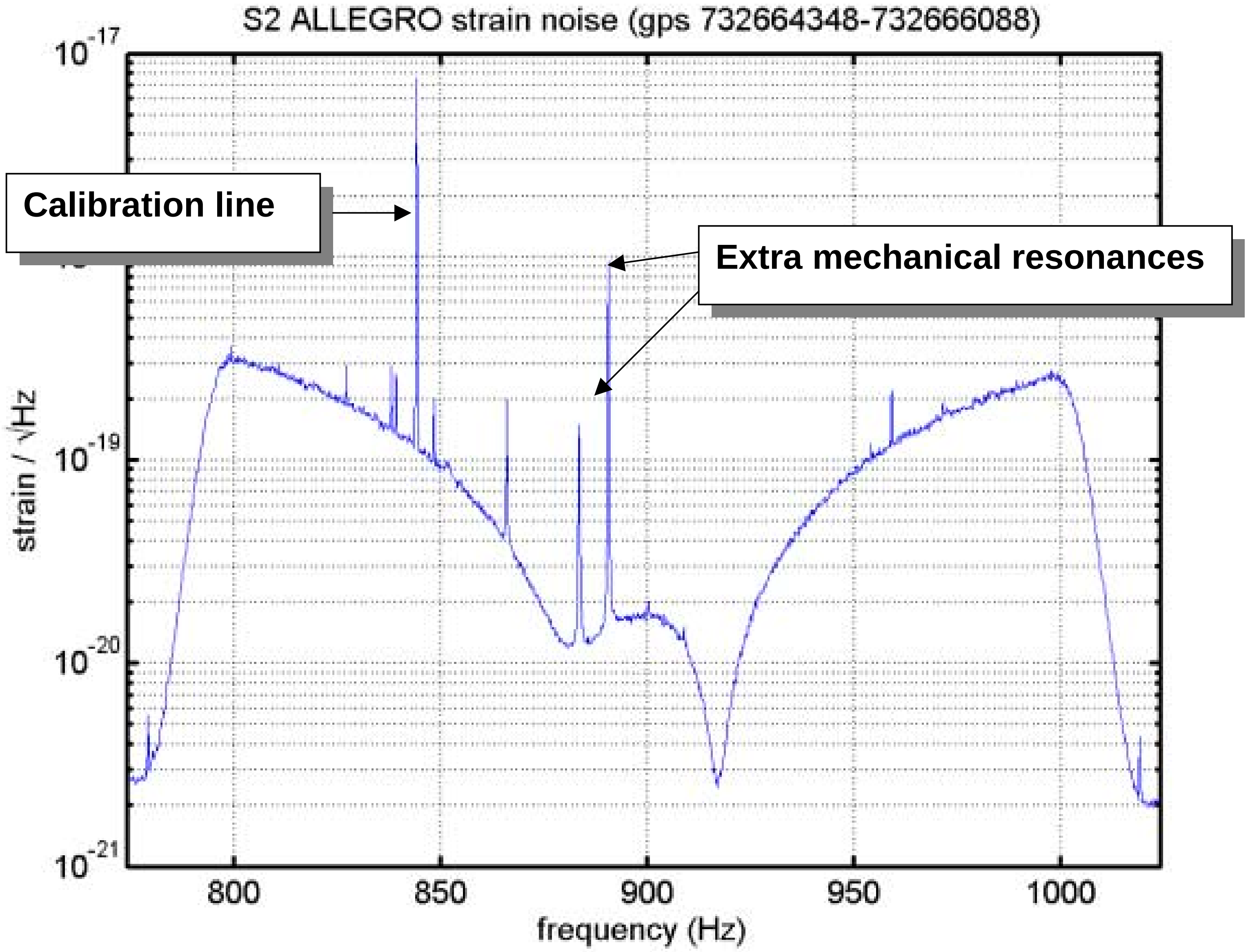
$$h^H[k] = \frac{z[k]}{T[k]\cdot F[k]}$$

Calibration

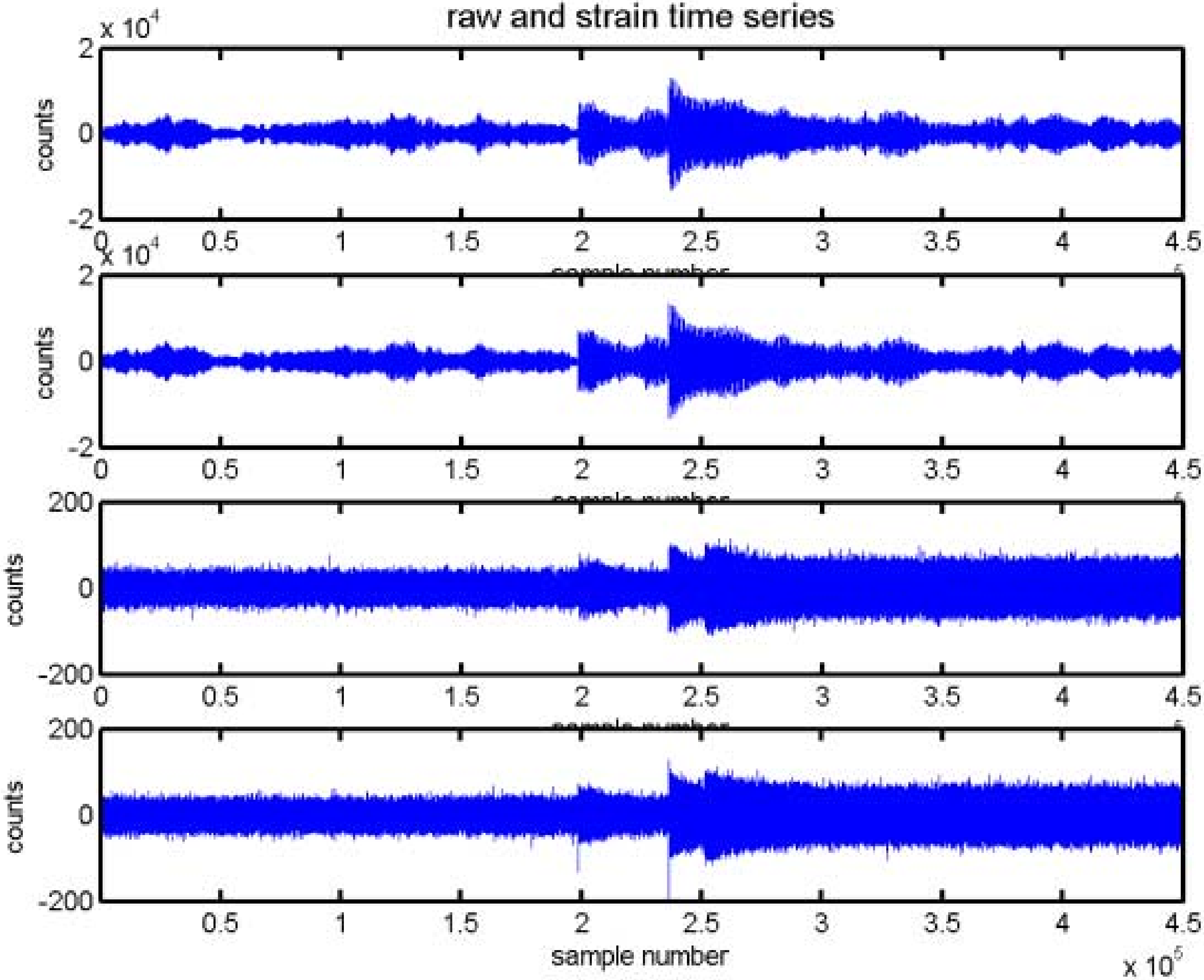
- determine *T[k] F[k]*
- Simple model for bar response (*R*)
  - track mechanical mode frequencies
  - track mode Q's (accounts for feedback – *(H)*)
  - determine overall gain, *T* and *F* combined
  - Need to get phase shifts not included in mechanical response model (mainly electronic *F)*
  - also need overall phase of heterodyne reference with respect overall time standard (gps)
  - Tests indicate we can stitch together strain time series with overlapping stretches

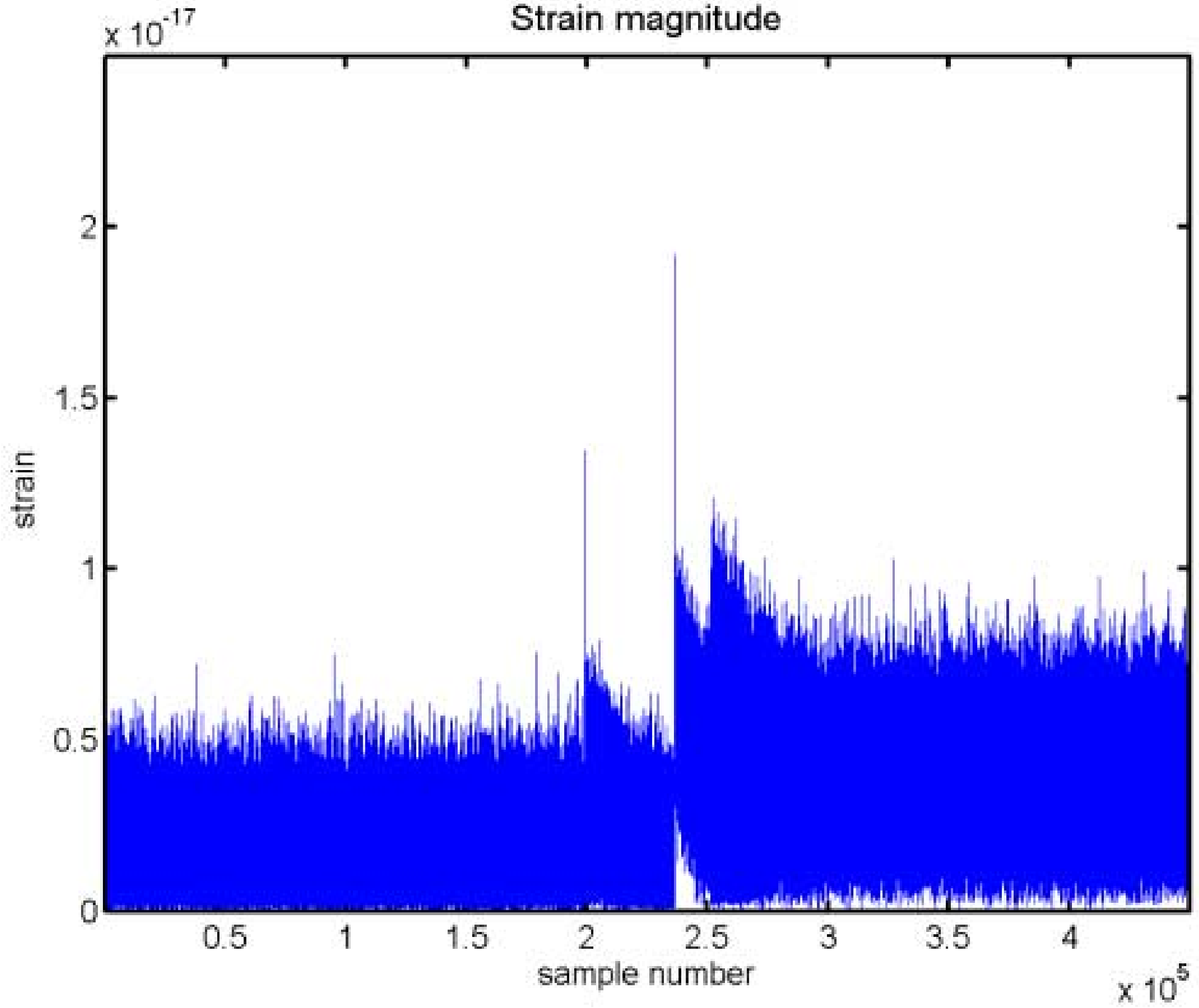

S2 mode frequencies
minus mode (Hz)
890
880
870
860
03/16
03/23
03/30
04/06
04/13
minus mode (Hz)
881
880.5
880
03/16
03/23
03/30
plus mode (Hz)
918
916
914
03/16
03/23
03/30
04/06
04/13
plus mode (Hz)
917.2
917.1
03/16
03/23
03/30
date (mm/dd)


ALLEGRO counts noise (gps 732664348-732666088)
Calibration line
Detector resonances
Extra mechanical resonances
counts / √Hz
frequency (Hz)
800
850
900
950
1000

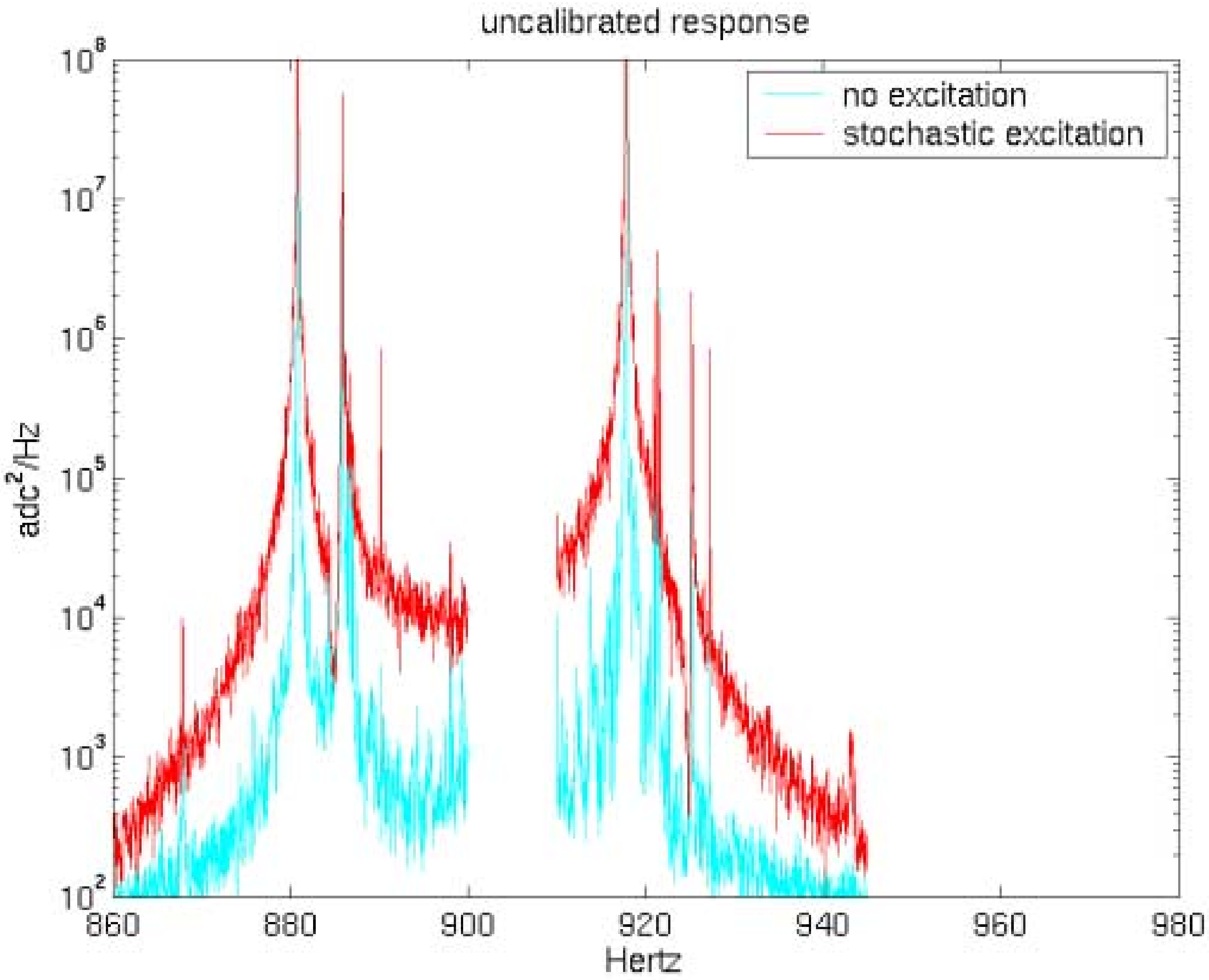

S2 ALLEGRO strain noise (gps 732664348-732666088)
Calibration line
Extra mechanical resonances
strain / √Hz
10-17
10-19
10-20
10-21
800
850
900
950
1000
frequency (Hz)

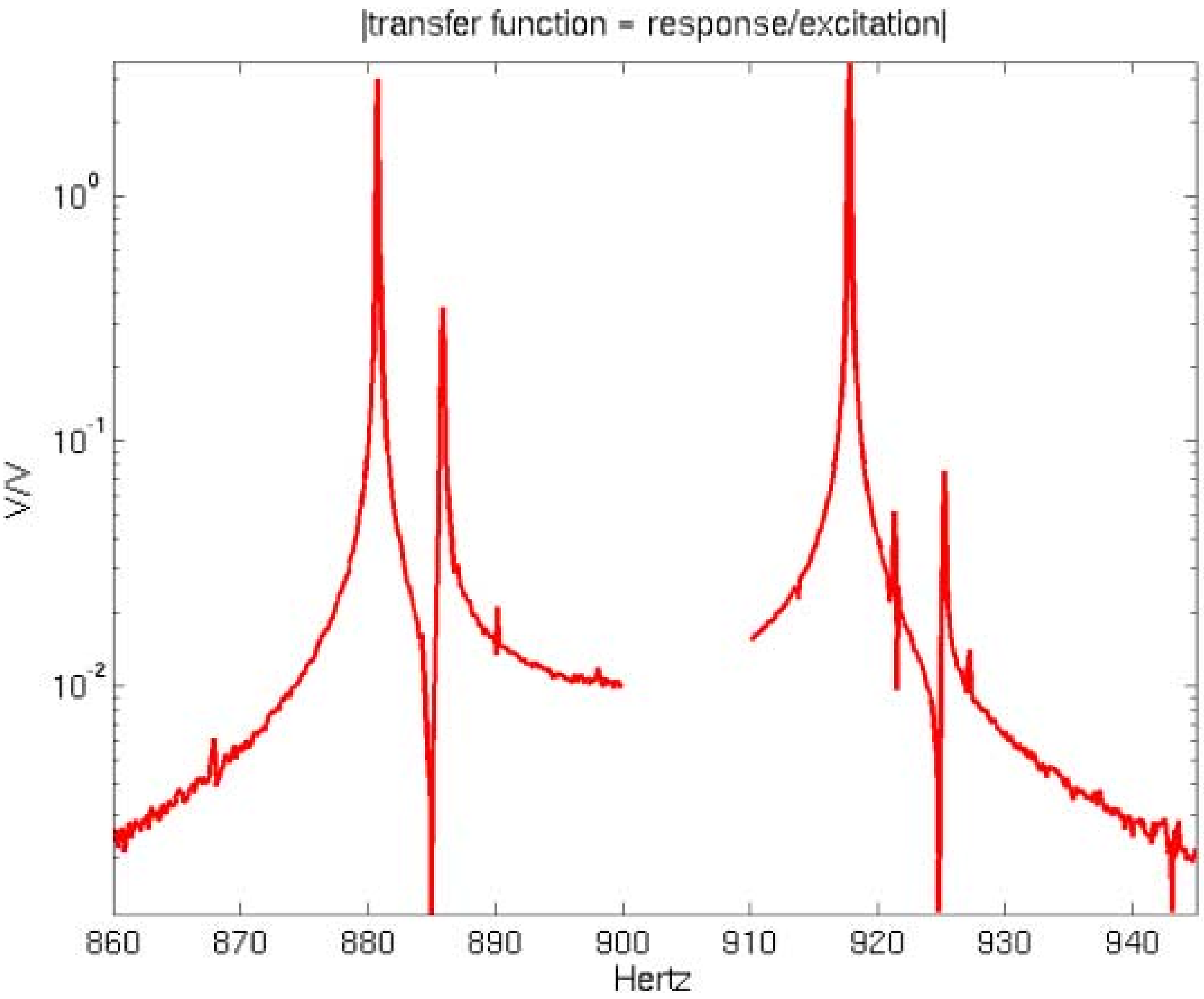
Calibration pulses in raw and strain time series




Strain magnitude
x 10^-17
2
1.5
1
0.5
0
strain
0.5
1
1.5
2
2.5
3
3.5
4
sample number
x 10^5

- ALLEGRO currently running – same mechanical system as S2, mostly same electronics
- Allows us to perform some tests to verify model, measure phase shifts
- Have begun with noise injection measurement


uncalibrated response
no excitation
stochastic excitation
adc²/Hz
10^8
10^7
10^6
10^5
10^4
10^3
10^2
860
880
900
920
940
960
980
Hertz


|transfer function = response/excitation|
10^0
10^{-1}
10^{-2}
V/V
860
870
880
890
900
910
920
930
940
Hertz