Line tracking methods used in LineMon

LIGO-G030615-00-Z

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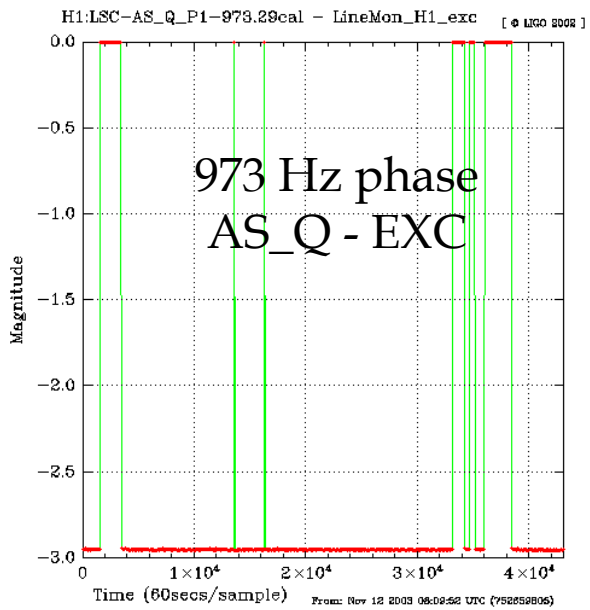
- heterodyning
- Hann heterodyning
- Fourier heterodyning
- fast Fourier heterodyning
- Wiener heterodyning

LineMonitor

- DMT tool for tracking line noise in LIGO interferometers
  - measures lines (and harmonics) amplitude, phase and frequency.
  - track calibration lines, pulsar injections, violin modes, power lines..
  - measures phase of AS_Q calibration lines with respect to calibration lines in excitation channel
- Output:
  - trend data (amplitude, phase, frequency, SNR)
  - html summary: monitored and detecte
- Documentation:
  - LIGO-T010125-01-D
  - available from monitor spi page



Heterodyning Method

- **demodulation of data *s(t)***

$$P(t) = s(t) \cdot \sin(2\pi f t)$$

$$Q(t) = s(t) \cdot \cos(2\pi f t)$$

- **Low-pass filtering: *Δf=1/T***

$$x = \int_0^T P(t)dt$$

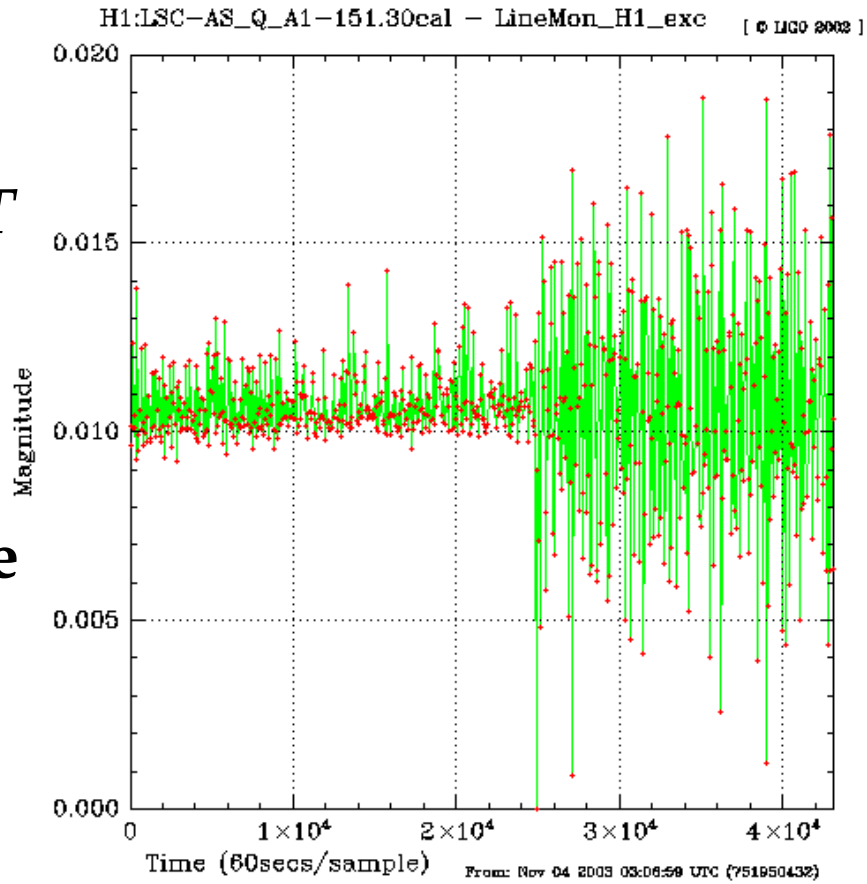
$$y = \int_0^T Q(t)dt$$

- **Line amplitude and phase**

$$A = 2\sqrt{x^2 + y^2}$$

$$\varphi = \arctan(x / y)$$

H1 151 Hz calibration line



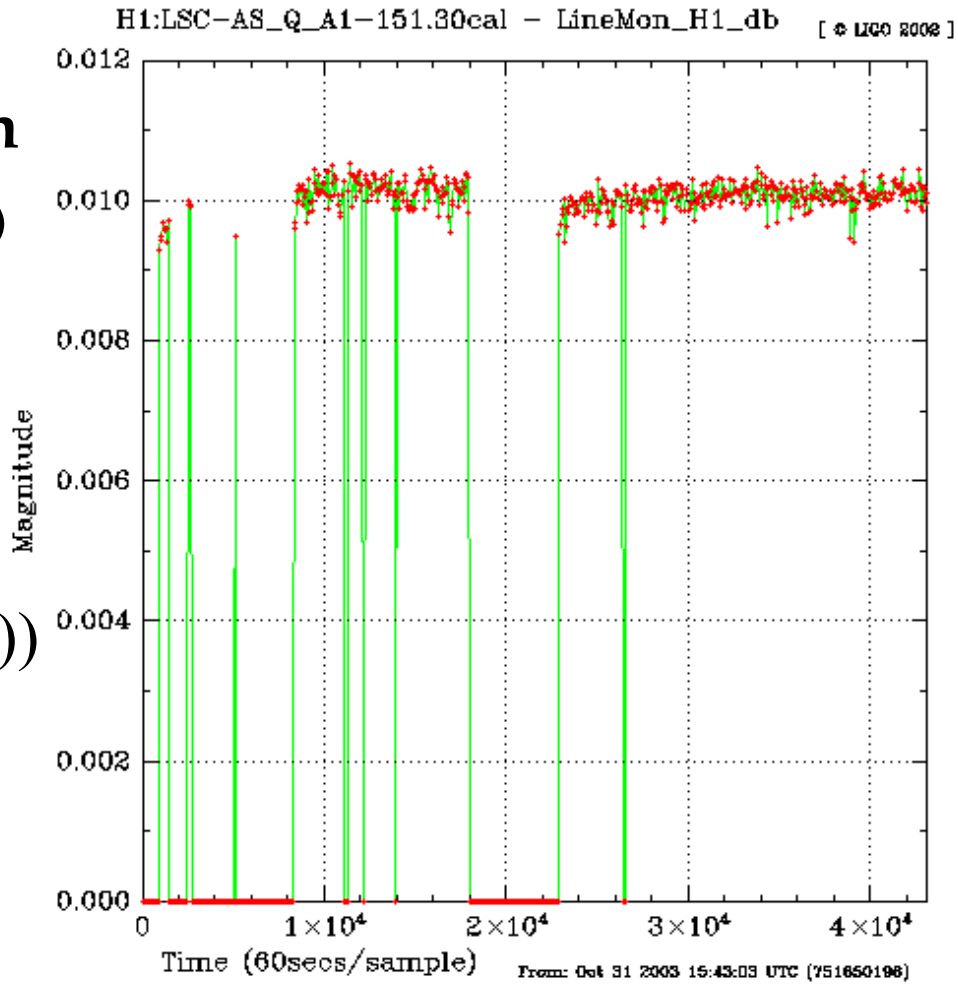
Hann Heterodyning Method

- **Before demodulation apply window to *s(t)***

Hann window

$$s'(t) = s(t) \cdot (1 - \cos(2\pi \frac{t}{T}))$$

H1 151 Hz calibration line



Fourier heterodyning

- sampled signal:

$$s(t_i) = n(t_i) + a\sin(2\pi f t_i + \varphi)$$

  - f - harmonic signal frequency
  - f_S - sampling rate

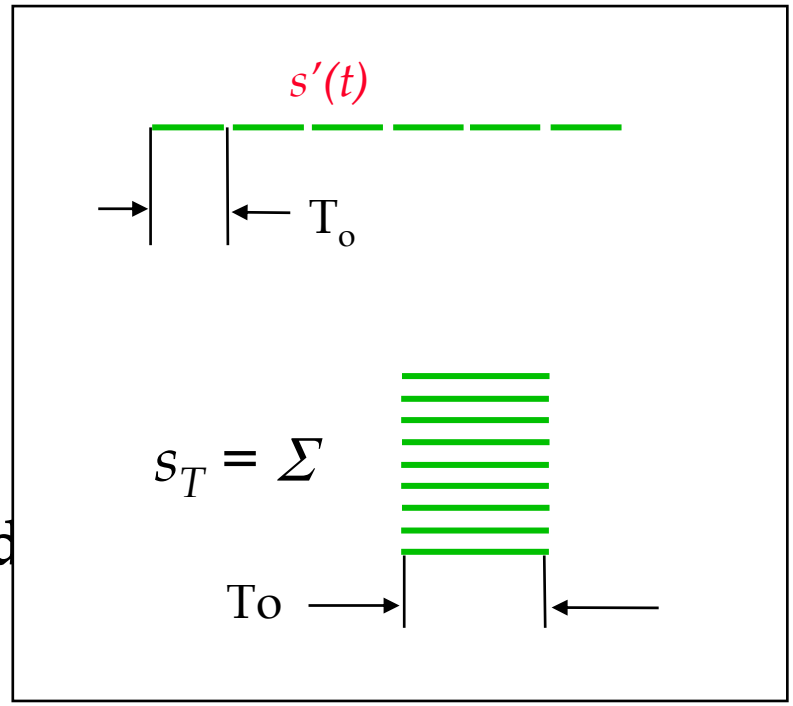
- resample ***s(t)*** at frequency

$$f_s' = f \cdot (\mathrm{int}(f_s / f) + 1)$$

- apply ***fft*** → ***x+iy*** = F_k - line Fourier amplitude corresponding to sum of P and Q line quadratures.
- anti-aliasing → apply windowed ***fft***
- Good for tracking line harmonics (e.g 60 Hz)

fast Fourier heterodyning

- need to know Fourier amplitude at line frequency
- T_o – k line periods
- $s_T(t)$ - average signal for one line period
- $fft(s_T)$ gives Fourier amplitud for line harmonics
- allows avoid *fft* of long data sets



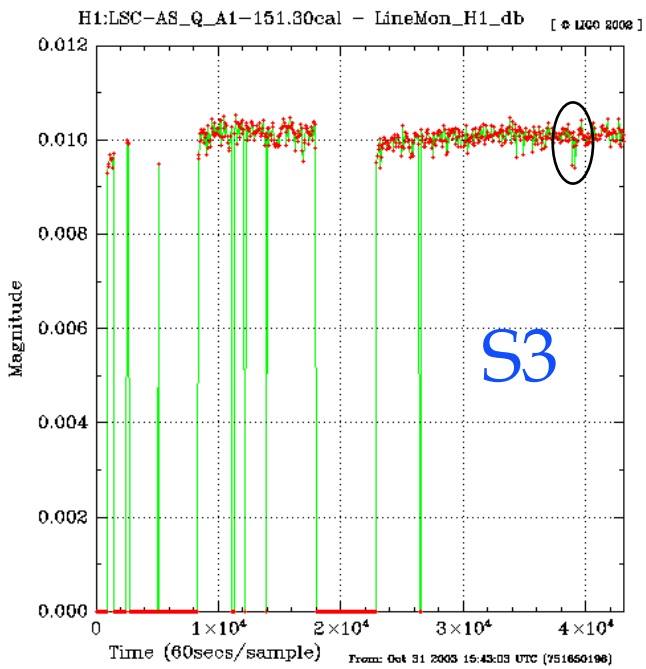
Wiener heterodyning

- apply Weiner filter to line Fourier amplitude

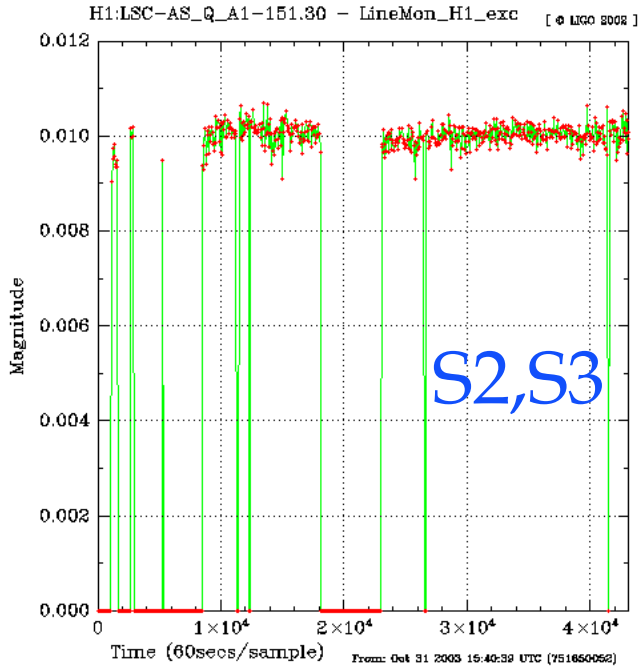
$$F_k' = F_k \cdot \frac{S_L}{S_L + S_N}$$

requires estimation of line (S_L) and noise (S_N) spectral densities

Hann heterodyning



Wiener heterodyning



S.Klimenko, LSC meeting, March 2002

Summary

- straight Heterodyning – implemented, not used
- Hann heterodyning – good for tracking of stable, single lines (pulsar and calibration lines in excitation channel, calibration lines in AS_Q, violin modes). Does not track frequency.
- Fourier heterodyning – not implemented
- fast Fourier heterodyning – can be used for tracking of lines with multiple harmonics and with varying frequency (power lines, violin modes, ….)
- Wiener heterodyning – tracking of lines with estimation of line SNR. Good for lines with varying amplitude, frequency and phase. Used for setting alarms based on crossing the SNR threshold.

S3 line monitoring

- LineMonitor_exc:
  - AS_Q calibration lines (3x2) – monitored both with Hann and Wiener heterodyning.
  - ETMX-EXC_DAQ: 10 pulsar lines – Hann
  - DARM-EXC_DAQ: 3 calibration lines
- LineMonitor_gws: AS_Q
  - 24 violin modes
  - 10 power lines
- LineMonitor_ioo: IOO-MC_F
  - 7 power lines
- LineMonitor_lsc: MICH_CTRL
  - 7 power lines
- Total: 54 lines per IFO + line statistics in 0-2kHz band
  - speed is a concern
- obsidian: 8 LineMon jobs at 55% CPU load

Conclusion

- Already plenty of methods are implemented
- New, more accurate methods are welcome
- Calibration lines are monitored with two different methods
  - Can easily produce two more {α,β} samples on-line