LIGO-G000289-00-D

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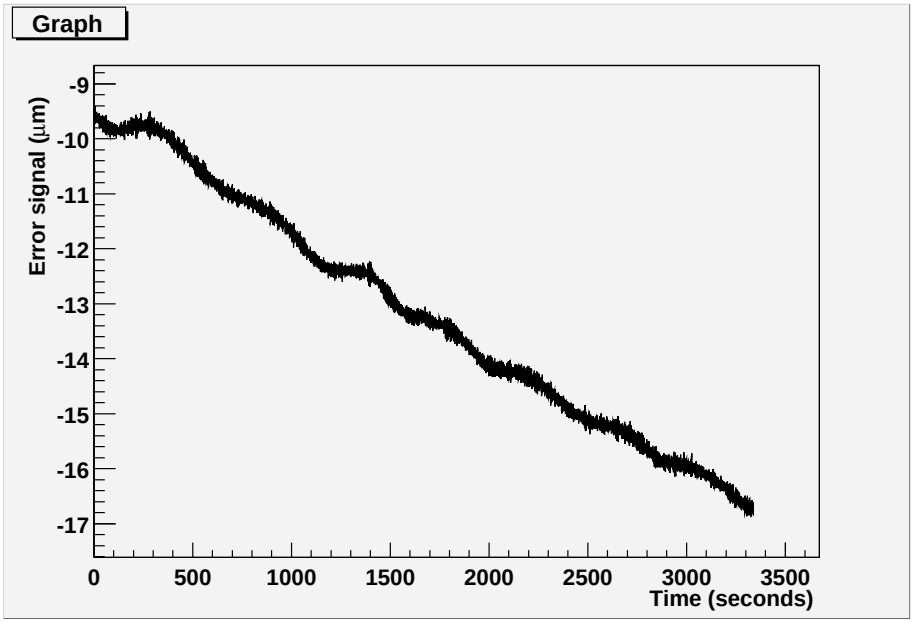
Detecting the micro-seismic peak with tiltmeters

Motivation: Use the tiltmeters as an accelerometer to provide a feed-forward to stabilize the test masses against seismic motion with frequency of ~ 0.15 Hz. (Suggested by Robert Schofield, as an alternative to seismometer feed-forward.)

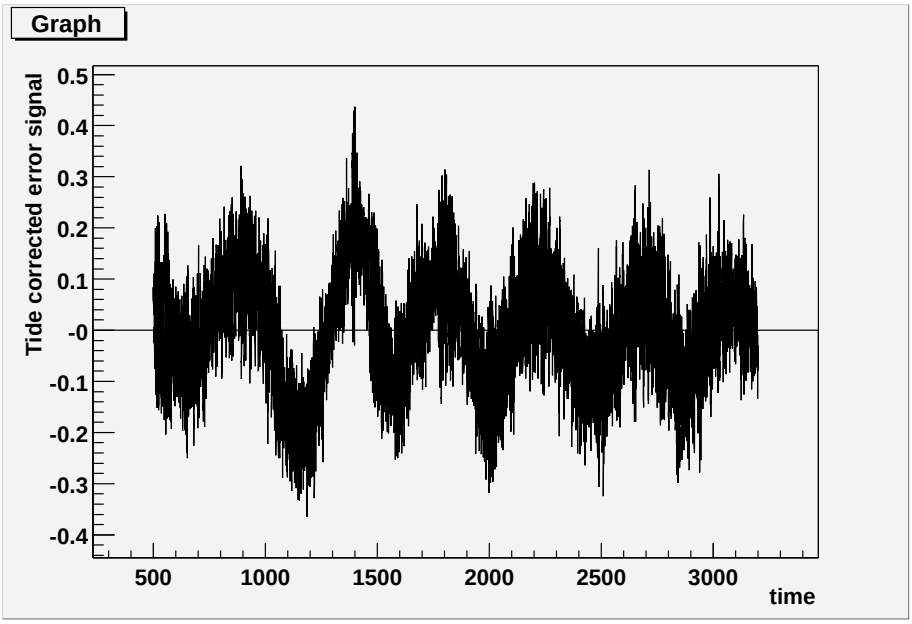
Outline:

- Main features of the low frequency (< 4 Hz) behavior of the error signal from the test run.
- Tiltmeter measurements.
- Attempts to subtract filtered tiltmeter correction from the error signal (equivalent to moving stacks).

Main component of the error signal in the one-armed interferometer test is due to the earth tides:

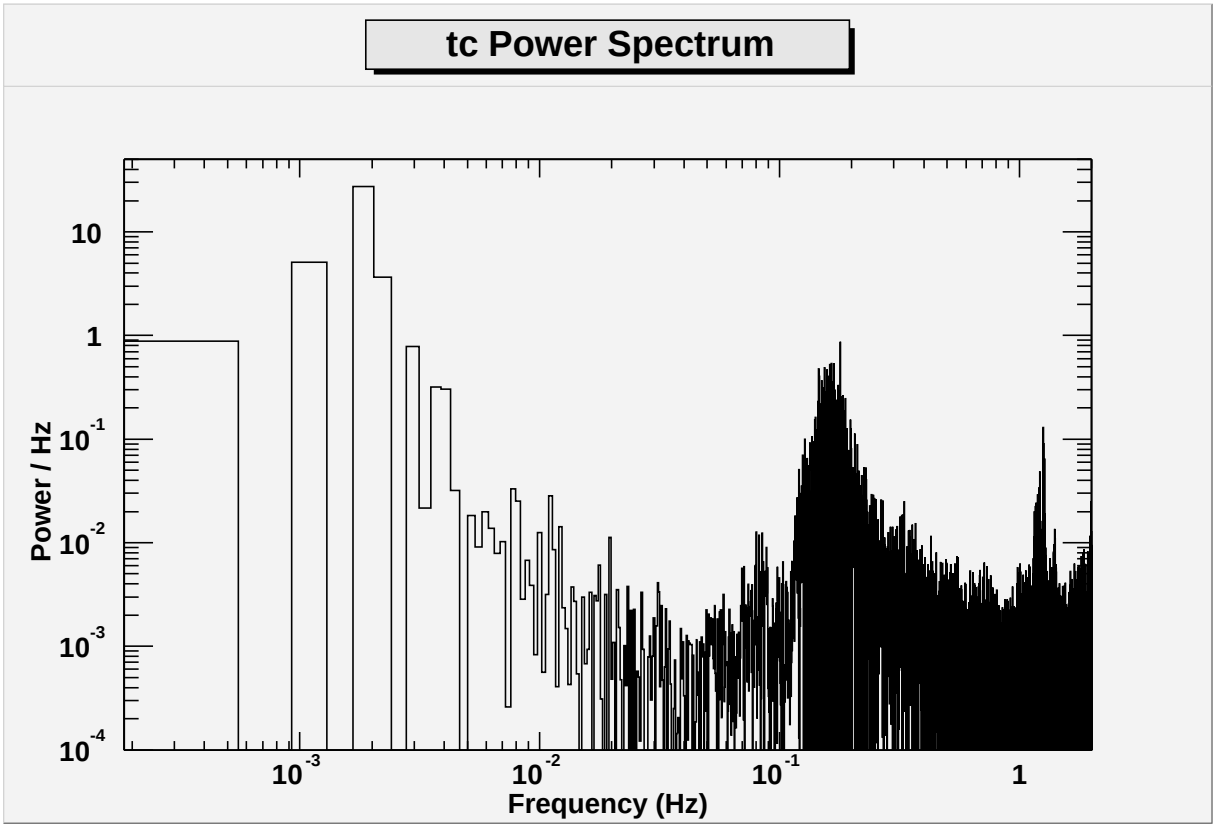


In this study, I use a quadratic correction for the tides. After correction, wiggles of period $\simeq$ 500s remain.



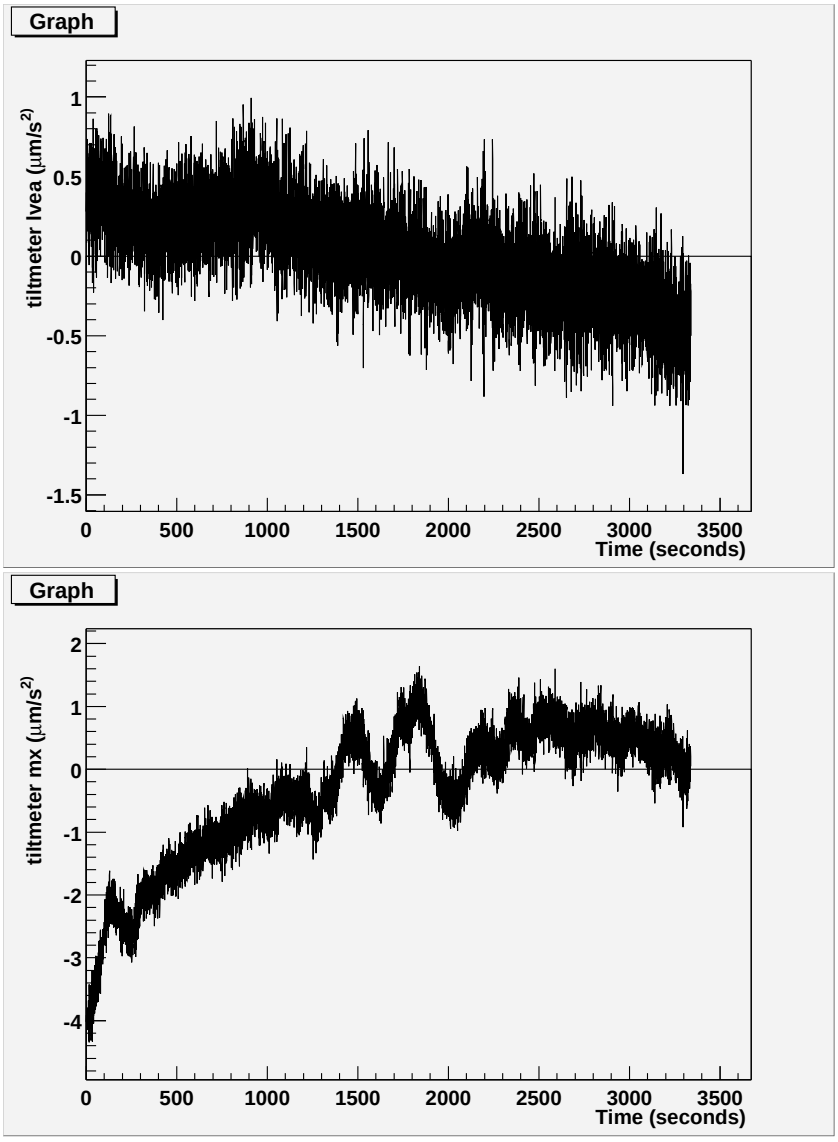
The long period oscillations ($\simeq$ 500 s) are thought to be due to the air handling systems temperature cycle. However, this oscillation is not apparent in any of the temperatures I have examined.

The power spectrum, after the tide correction, is shown below:



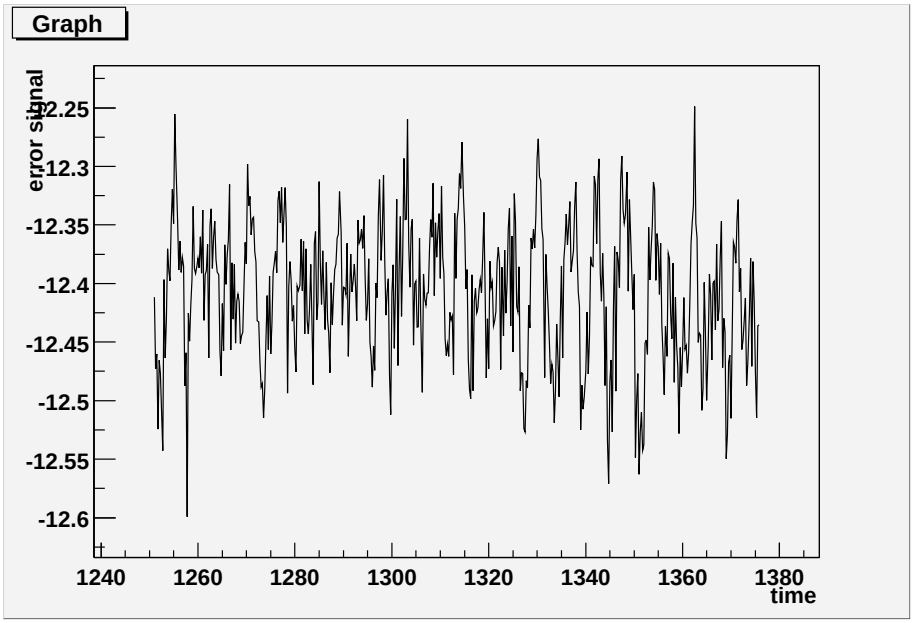
Tiltmeters as Accelerometers

The LIGO tiltmeters are essentially carpenter levels with very sensitive electronic readout. An acceleration of $\simeq g\theta$ will produce the same signal as a tilt of θ. The x-direction tilts at LVEA and MX are shown below:

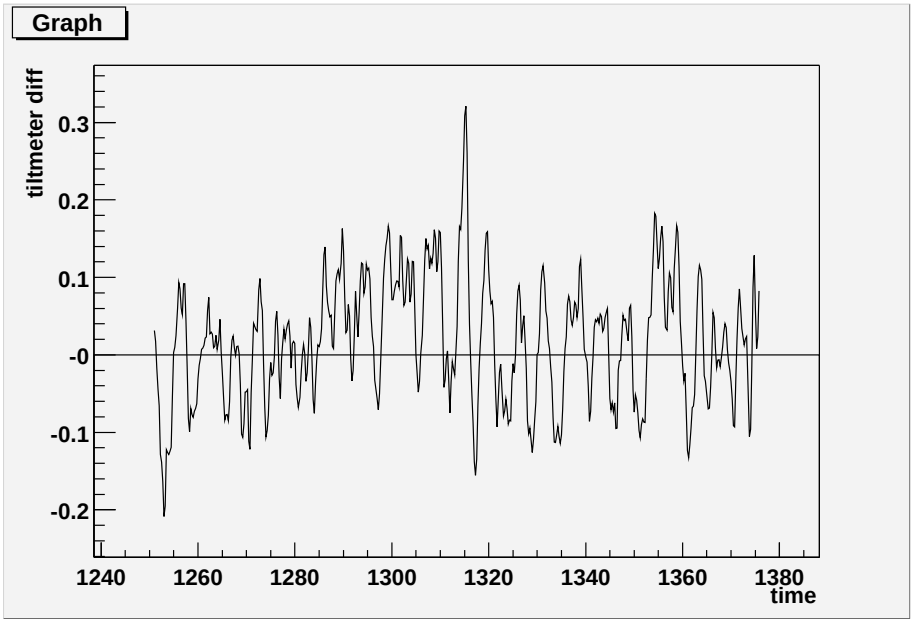


The long term drifts seen in station MX are possibly due to thermal effects (e.g. differential expansion of the tiltmeter legs, this is under investigation).

Error signal



Difference of tiltmeters:



Note: correlation would be larger during periods of high seismic activity.

The error signal is expected to be correlated with the difference between the the tiltmeter signal at the LVEA and MX measurement stations. To get the displacement one can integrate the acceleration twice, but the results would be dominated by true tilts and/or fluctuations.

We filter the tiltmeter signals and compare in the region of the micro-seismic peak.

A crude band-pass filter with unity gain in the region of 0.1 to 1.0 Hz was used.

Fitting (χ^2 fit, assuming 0.1μ m "error" for each bin) for the optimal coefficients for the LVEA and MX signals,

$$\begin{aligned} f_{lvea} &= -0.42 \pm 0.01 \ \mathrm{s}^2 \\ f_{mx} &= 0.23 \pm 0.01 \ \mathrm{s}^2 \end{aligned}$$

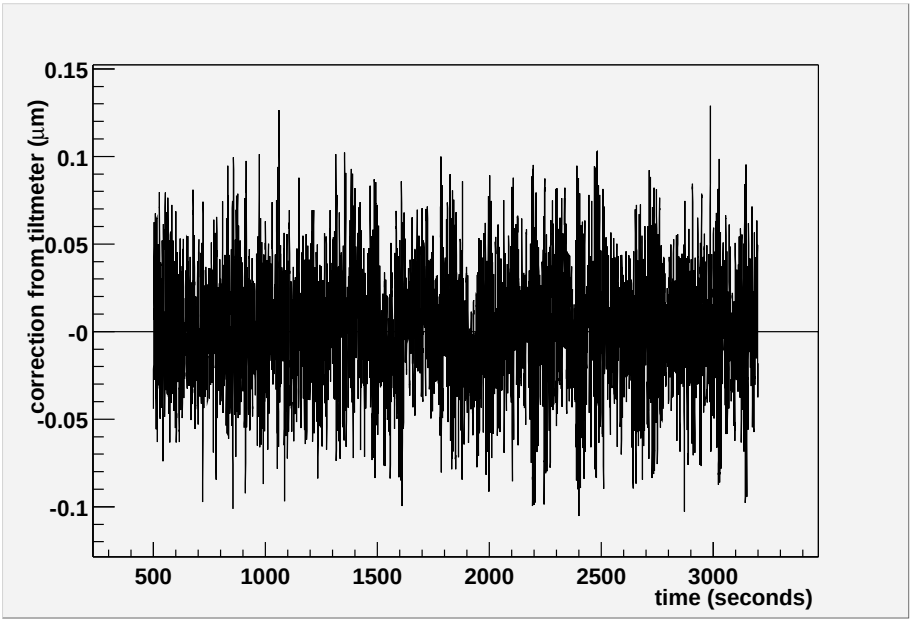
are obtained.

Coefficients should be $\simeq 1$ and of opposite sign.

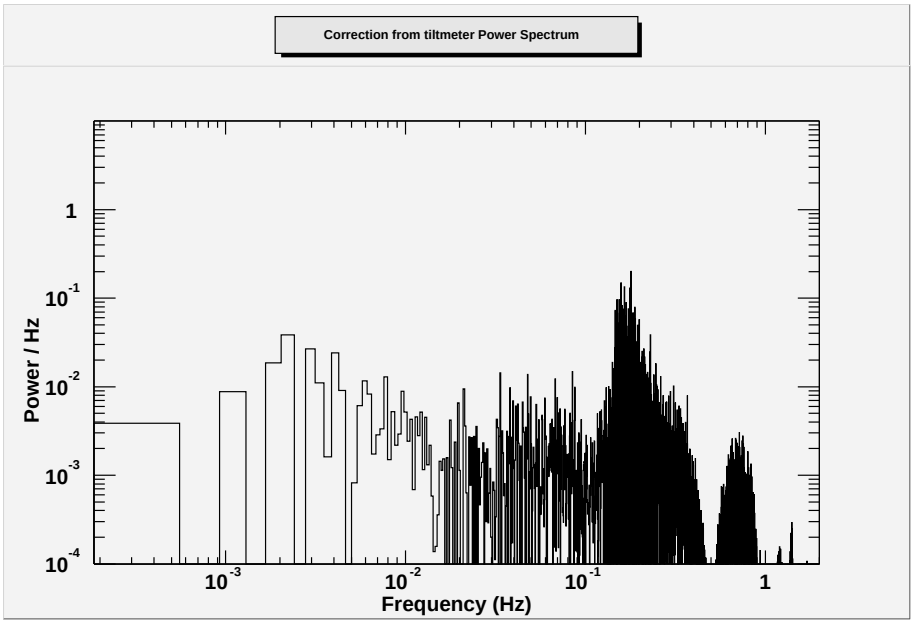
Overall, all corrections reduce the rms of error signal (after tidal corrections) only 4%.

On the micro-seismic peak (0.1 - 0.3 Hz) the reduction is approximately 30%.

Correction ($f_{lvea} * g * t_{lvea} + f_{mx} * g * t_{mx}$)

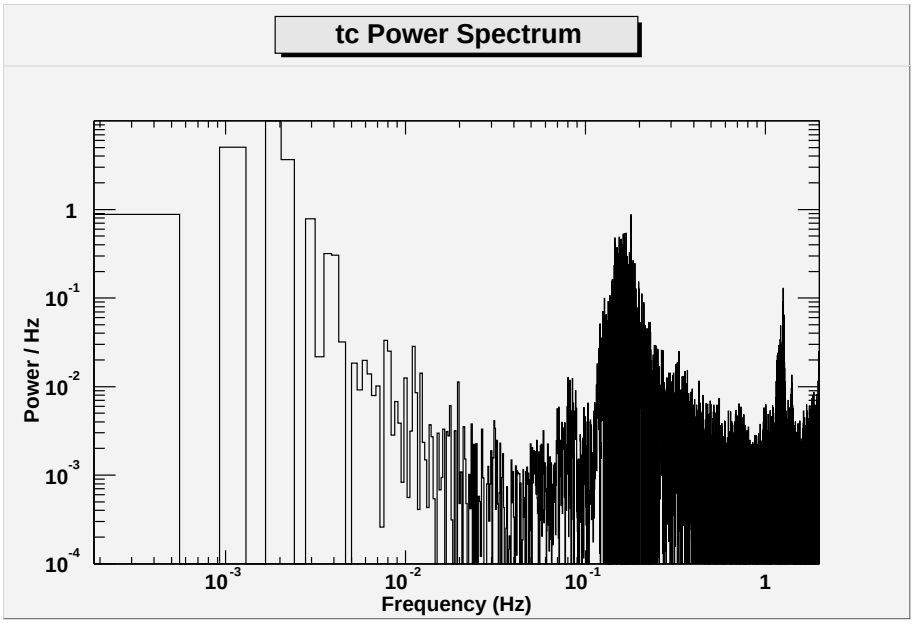


Power spectrum of fitted tilt correction:

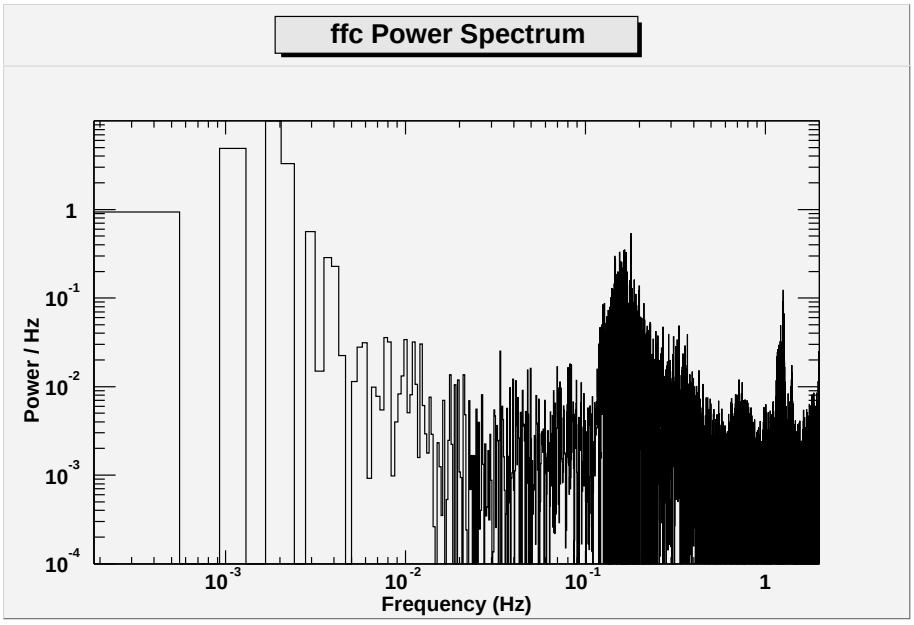


(Could be improved with a better filter)

Power spectrum after tide correction only



Power spectrum after tiltmeter micro-seismic correction:



Micro-seismic peak is somewhat reduced.

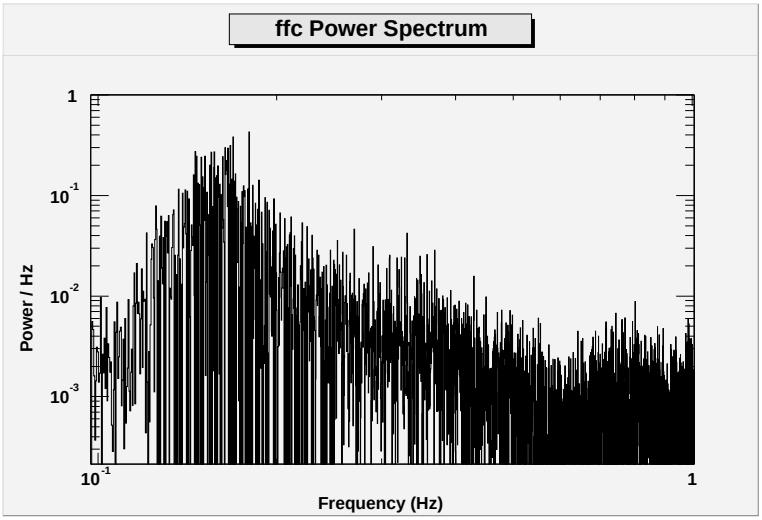
Equivalent results can be obtained from the seismometers if they are first differentiated to give acceleration.

The fitted coefficients are (up to a sign) almost identical:

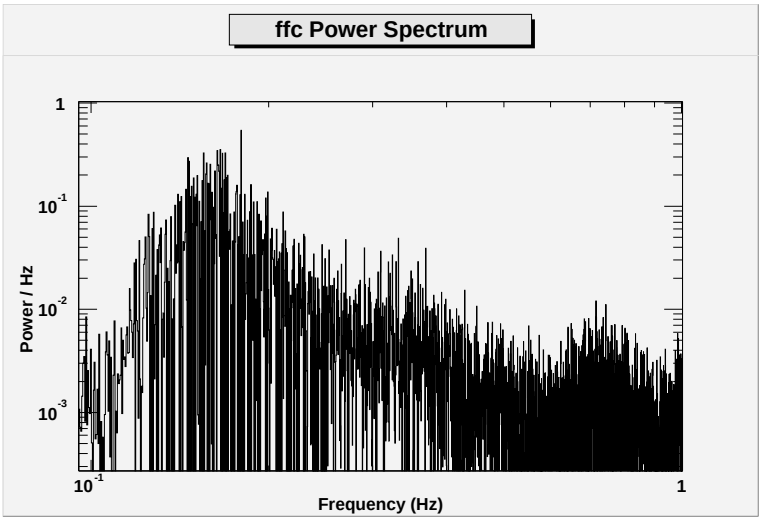
$$\begin{aligned} f_{lvea} &= 0.41 \pm 0.01 \ \mathrm{s}^2 \\ f_{mx} &= -0.20 \pm 0.01 \ \mathrm{s}^2 \end{aligned}$$

Power between 0.1 and 0.3 Hz reduced 35%.

Power of error signal corrected with the seismometers:



Power of error signal corrected with the tiltmeters:



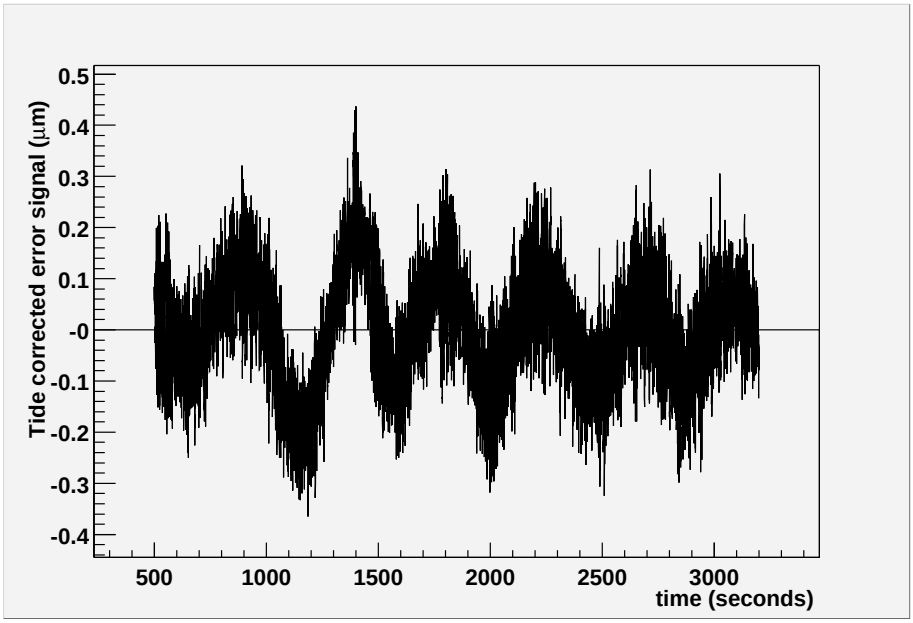
It is possible that the $\sim$ 500s oscillations in the error signal are due to actual tilts.

Filter the tiltmeters and accept the range 0.02 – 0.002 Hz.

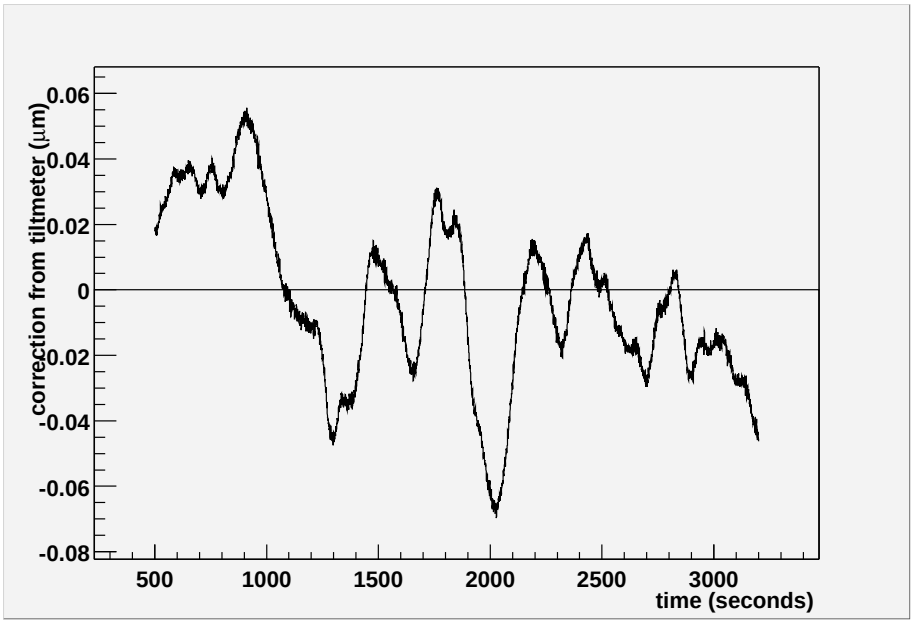
The resulting coefficients for the tilt corrections are

$$\begin{aligned} h_{lvea} &= 2.6 \pm 0.2 \text{ m} \\ h_{mx} &= 3.9 \pm 0.3 \text{ m} \end{aligned}$$

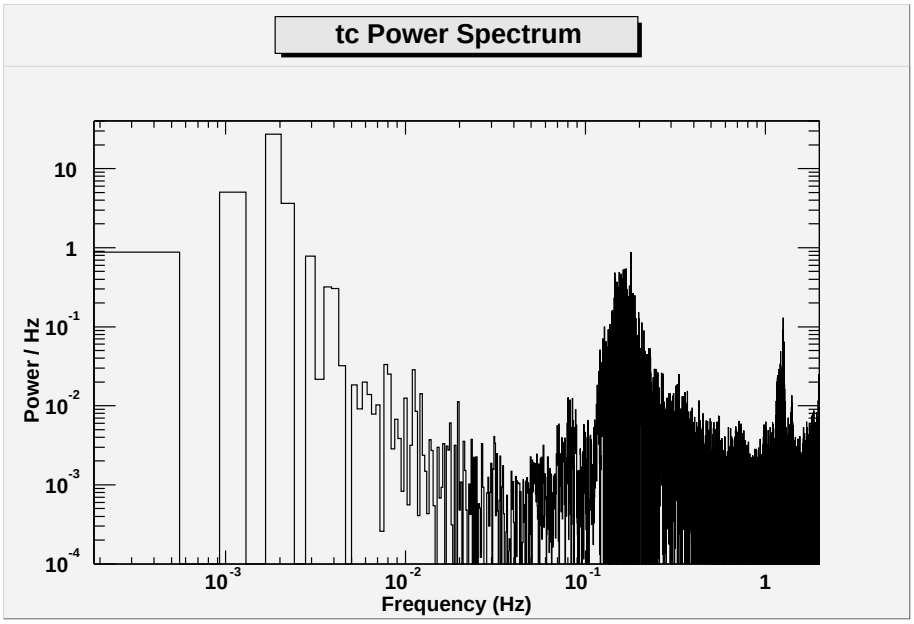
Tide corrected signal:



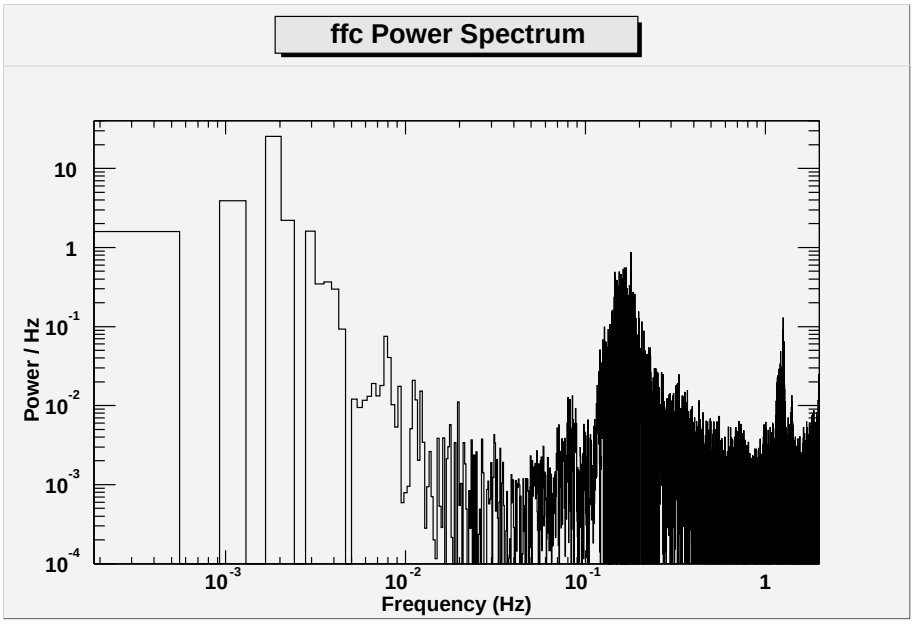
Correction ($h_{lvea} * t_{lvea} + h_{mx} * t_{mx}$):



Power spectrum after tide correction:



Power spectrum after low frequency tilt correction:



Conclusion:

- Effects of micro-seismic peak can be reduced 30% in a period with relative small seismic noise.

- Some evidence for effects of slower tilts on error signal, but correlations may be accidental or secondary.

Future Plans:

- Try to use better filters

- Study the long term behavior of tiltmeters

- Investigate removing tidal effects (input needed from Fred Raab)