Line Noise Investigation

Technical Report LIGO-T010018-00-D
Narrow Resonances in the E2 Data
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- Outline
  - Line Noise Investigation task
  - E2 data, line monitoring
  - Documentation
  - Lines observed in E2 data
  - Conclusion

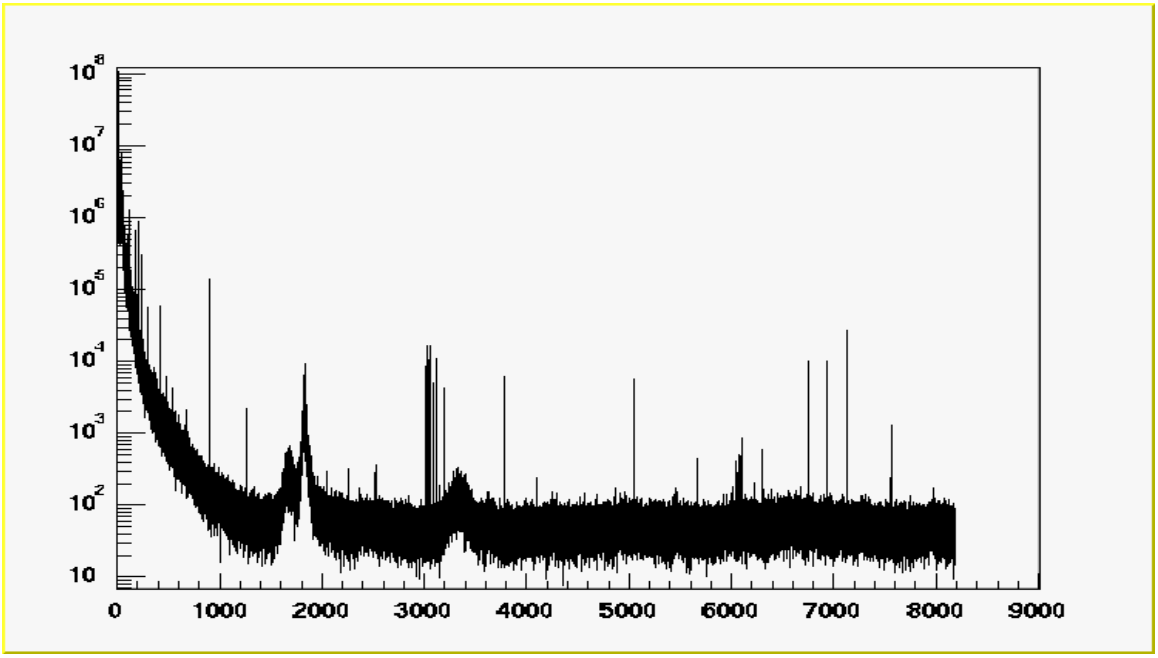
LIGO-G010126-00-Z

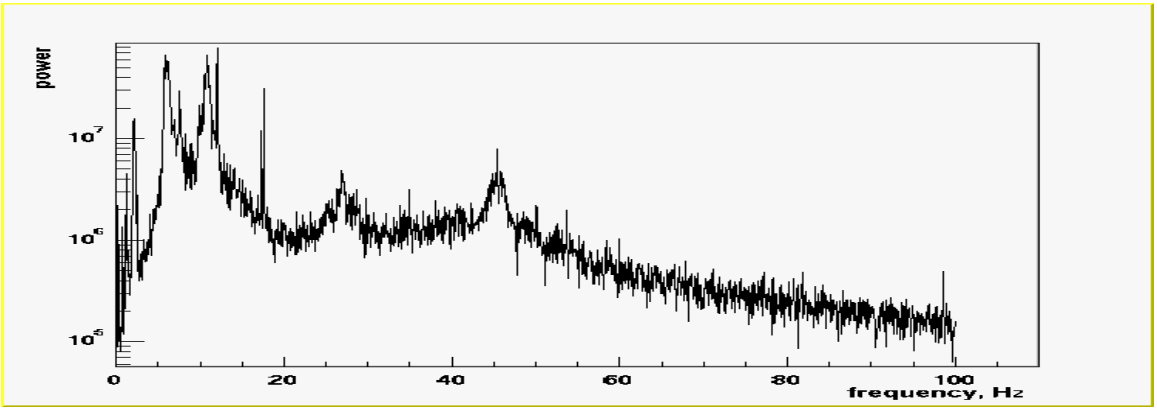
Line Noise Investigation

- Goal
  Characterization of line noise in the GW channel due to mechanical and environmental resonances, including measurement of line amplitude, frequency, width, etc.
- Data
  - ~80h of E2 data starting 11/9 at 9:17:47am (657796678)
  - full RDS, ~10% (~90GB) of data actually processed
- Line Monitoring
  - use the QMLR method (part of DMT)
  - ~40 lines monitored (0.7Hz – 7000Hz)
  - line trend data (10s-60s) ***f,a,phase,psd,snr,…..***
  - offline monitoring of LSC and IOO channels
  - online monitoring of calibration lines during the run
  - online monitoring of power with MultiVolt
- LNI documentation
  - LNI web page:
    www.phys.ufl.edu/LIGO/LINE/index.html
  - E2 run web page: directory with ~90 plots
  - LNI E2 run report: LIGO-T010018-00-D

LSC-AS_Q

- Mainly resonances in the LSC-AS_Q channel were studied. The interferometer noise was 4-5 orders of magnitude higher then nominal, what sometimes made it hard to detect resonances and do their detailed study (like phase analysis). Many expected mechanical resonances can't be even seen in the data.





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E2 Lines

F, HZ	W, Hz rms	A, a.e.	SNR	Source	System
0.729	0.014	1.42	1.8	BS,RM,ITM,ETM pendulum	LSC
0.793	0.007	4.67	12.6	SO(2K) pendulum	LSC
5.785 6.086	0.031 0.057	5.87 8.54	1.6 1.3	? ?	LSC, IOO
12.050	0.026	12.19	4.1	HAM stack	LSC, IOO
17.286 17.625	0.027 0.015	3.42 7.16	1.7 7.0	? ?	LSC, IOO(?)
34.943	0.035	2.02	1.3	Office area air handler	LSC, IOO
53.274 53.580	0.086 .0.031	0.86 23.4	0.6 9.9	HVAC system (?)	LSC, IOO
60.000 (V)	<0.01	3.75	5.4	Power lines	LSC,IOO,…
98.578 98.734	0.020 0.010	1.24 6.10	2.0 20.4	? ?	LSC, IOO
206.6 (V) 207.2 (V)	~0.05 <0.05	1.52 0.16	10.9 0.7	? ?	LSC
237.0 (V)	<0.05	0.84	5.7	?	LSC
xx1.25	-			ITMX calibration lines	LSC
xx1.75	-			ITMY calibration lines	LSC
xx2.25	-			ETMX calibration lines	LSC
xx2.75	-			ETMY calibration lines	LSC
1258.6 (V)	<0.1	0.07	4.9	?	LSC
3018, 3027 3034, 3040 3094, 3054 3094, 3114 3192 (V)	0.2-0.5			? frequency drift ~0.5Hz/day	LSC
3783	<0.05	0.2	14.0	4 resonances	LSC
5142, 6751.5, 6751.9, 7130, 7134, 6929 (V)	0.2-0.5			4 resonances	LSC
2048, 4096 6144	-			Sampling artifacts (1,2,3 harmonics)	LSC

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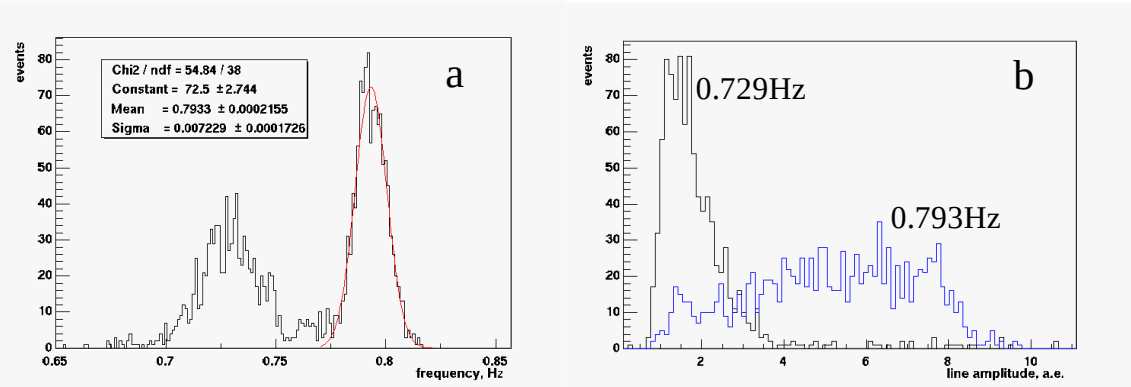
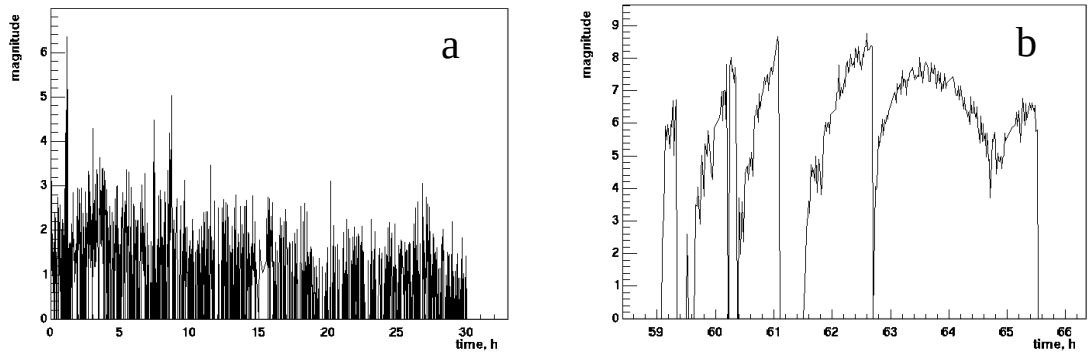
0.7-0.8Hz lines

- A group of resonances due to pendulum motion of mirrors (BS, RM, ITM, ETM) at 0.74-0.75Hz.
  - The LM can't resolve them - seen as a single line
- Another narrow line at 0.793Hz is probably due to the small optics (2K) pendulum pitch mode (0.79Hz as measured at LHO)



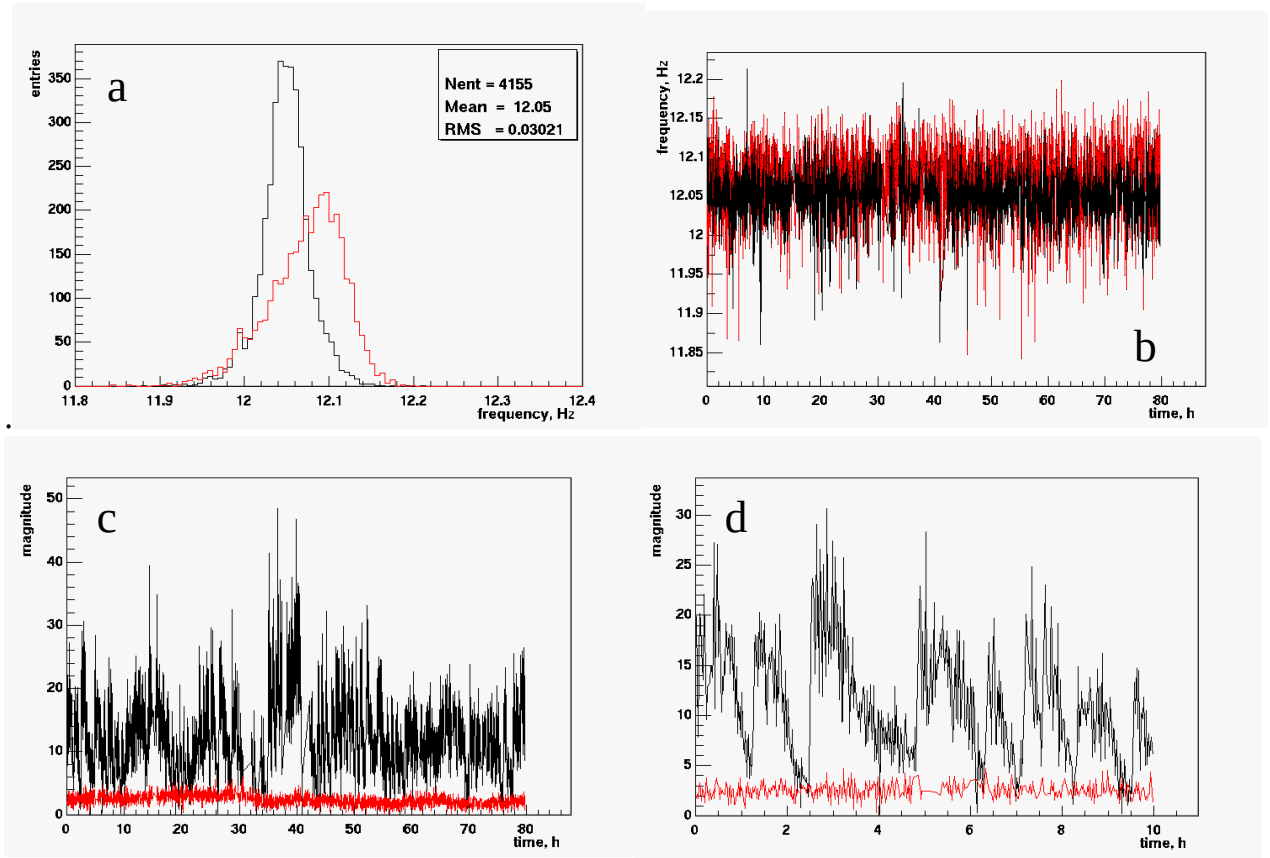
a-frequency histogram, b-amplitude distribution for 0.729Hz (black) and 0.793Hz (blue) lines.



Amplitude trend data for 0.729Hz (a) and 0.793Hz (b) lines.

12.05 Hz Line

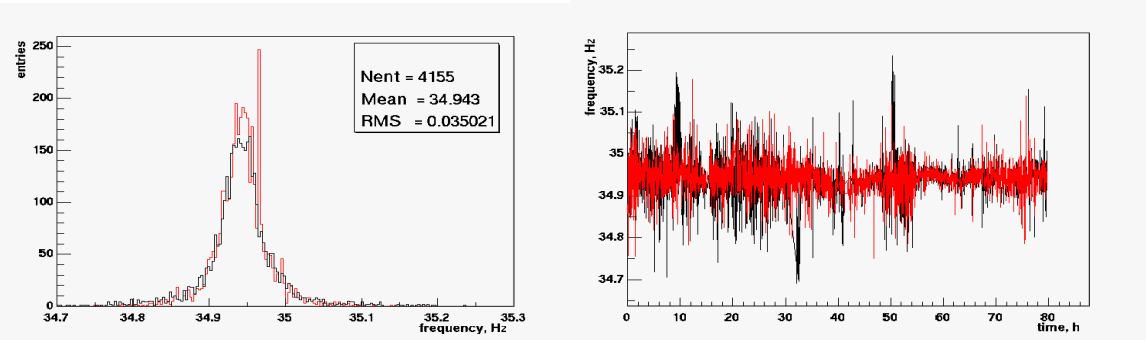
- observed both in LSC-AS_Q and IOO-MC_F channels. measured frequency: 12.05Hz and 12.07Hz respectively
- (?)corresponds to the HAM stack resonance (12.1 Hz).



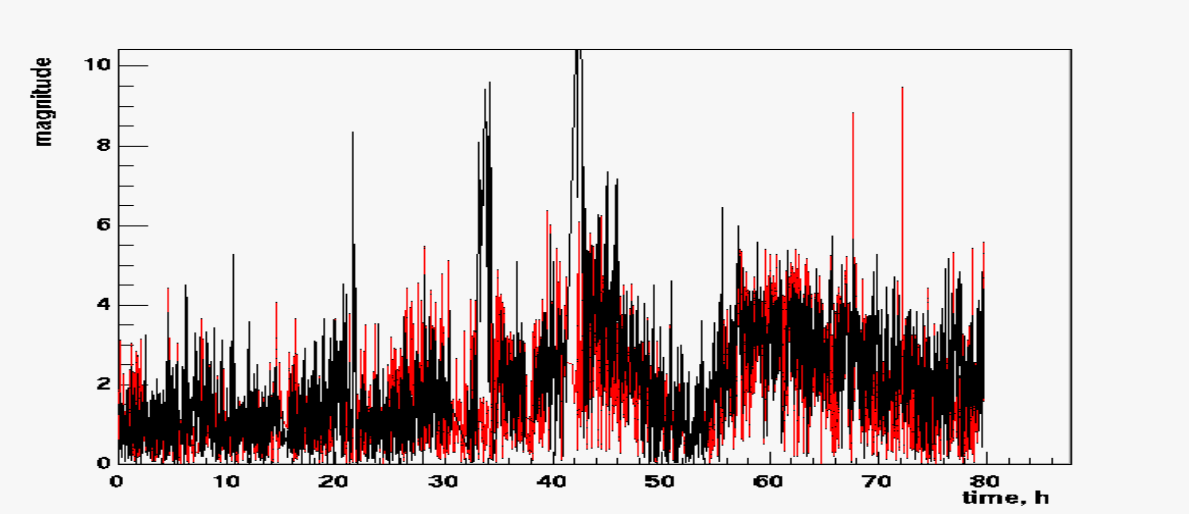
12.05 Hz line data for the LSC-AS_Q (black) and IOO-MC_F (red) channels. (a) – frequency histogram, (b) – frequency trend data, (c,d) – amplitude trend data.

35 Hz Line

- No mechanical resonances are expected at this frequency.
- Possibly it's an environmental line coming from the fan in office area air handler (expected ~35Hz).
- clearly seen in LSC-AS_Q and IOO-MC_F



Frequency histogram and trend data: black - LSC-AS_Q channel, red – IOO-MC_F channel.



Amplitude trend data: black - LSC-AS_Q channel, red – IOO-MC_F channel.

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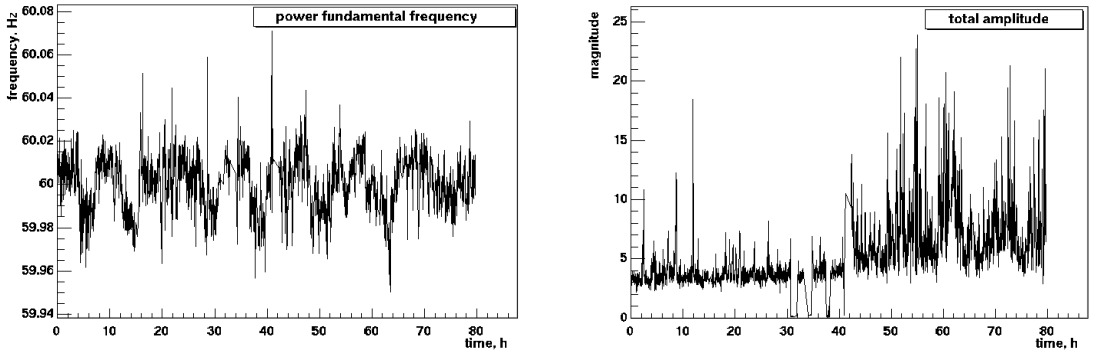
Power Lines

For the 16 kHz data channels there should be around 136 power lines. Actually only first 7 harmonics can be seen in the dark port channel.

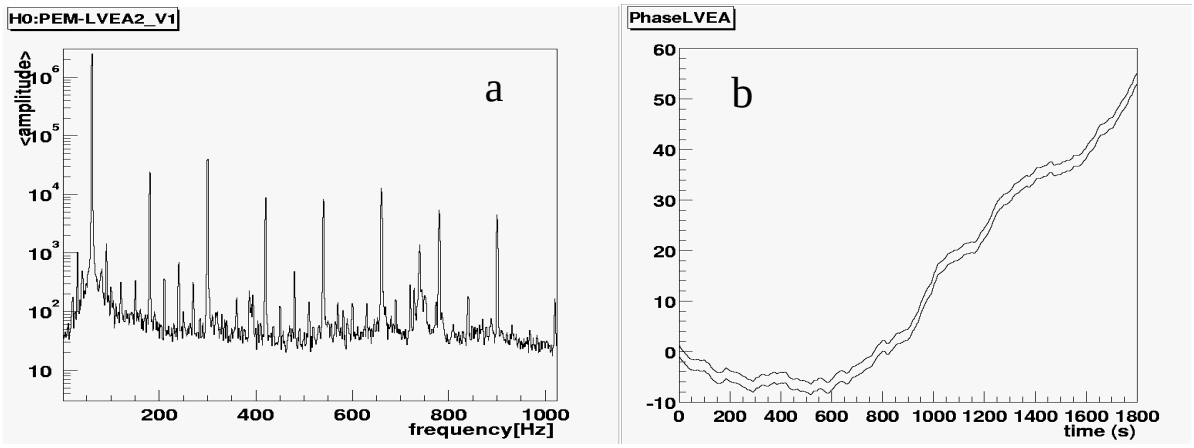
Relative intensity of the first 7 power lines

harmonic	1	2	3	4	5	6	7
intensity, %	33.6	37.8	16.8	8.6	1.3	0.4	1.3



Frequency and amplitude (first 7 harmonics) trend data for the power lines in the LSC-AS_Q channel.

Power monitors



(a) – power spectra, (b) – phase in the vertex and middle stations.

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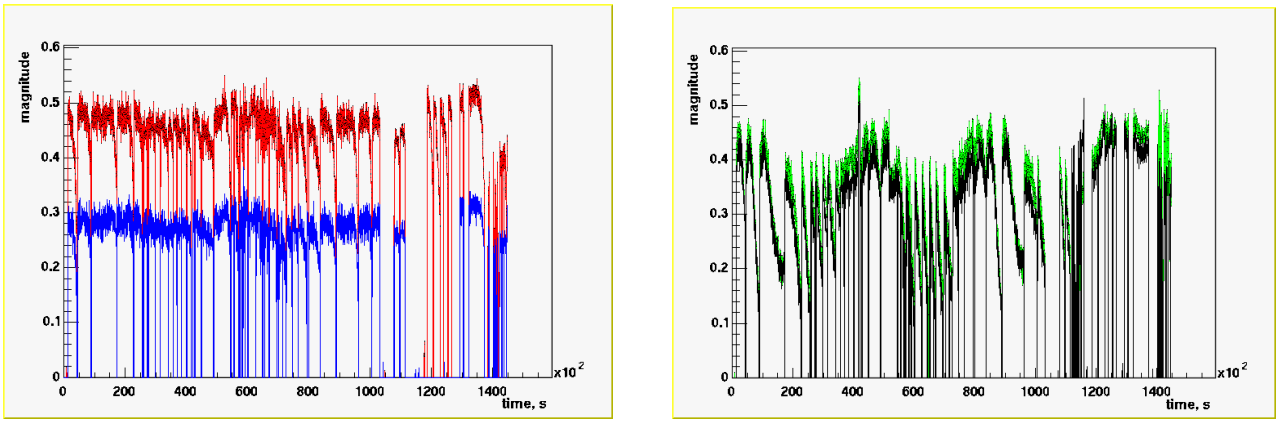
Calibration Lines

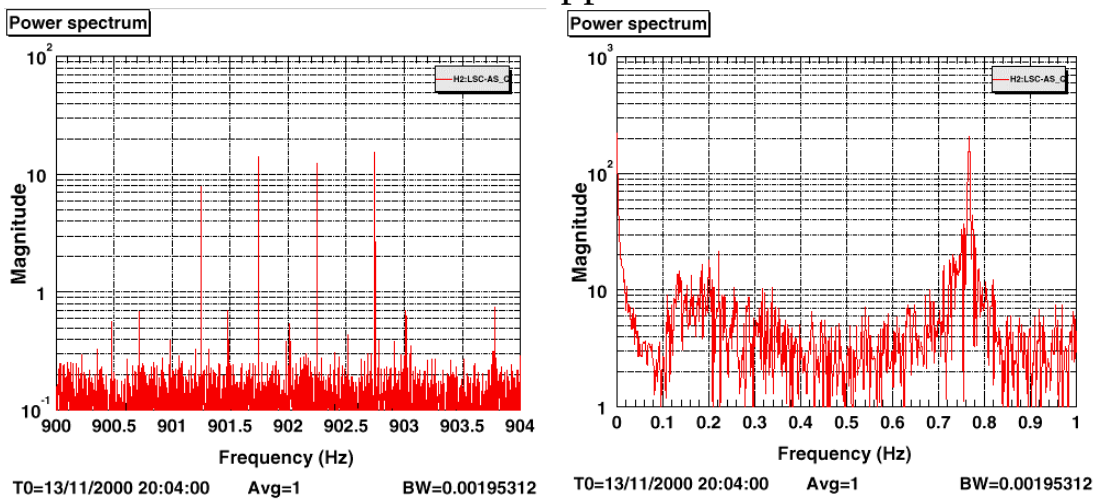
- 4 groups of lines: 31Hz, 71Hz, 271Hz, 901Hz
- 4 lines in each group separated by 0.5Hz



The 901-902 Hz calibration lines: (a) – X-arm calibration (blue – ITMX, red – ETMX), (b) – Y-arm calibration (black – ITMY, green – ETMY)

Non-linear effects associated with calibration lines

The X-arm sidebands appear at the 0.76 Hz offset



The modulation of the calibration lines with a pendulum oscillation.

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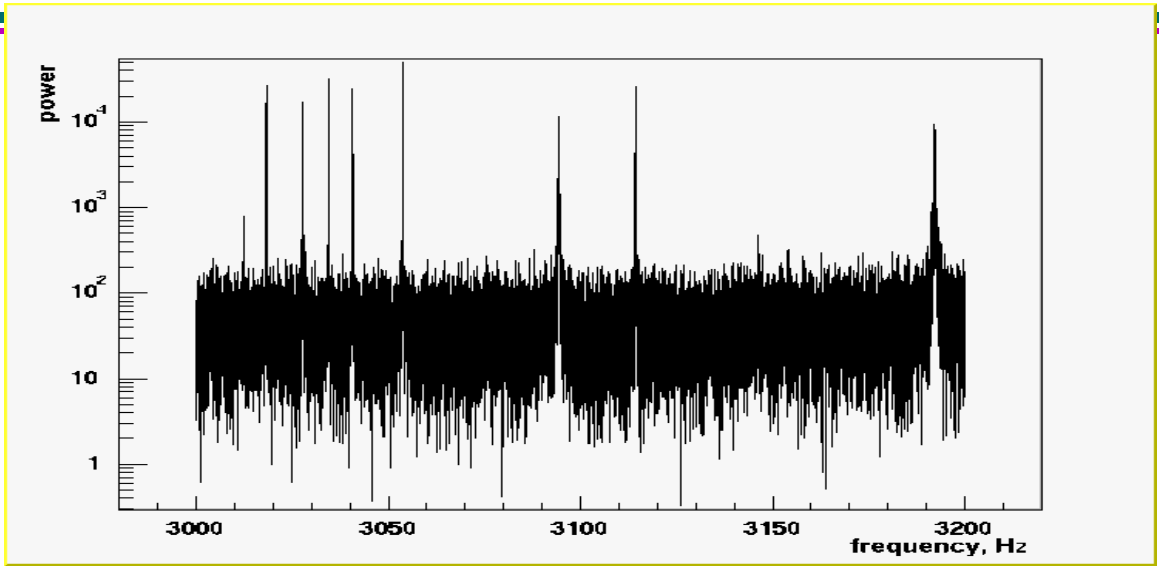
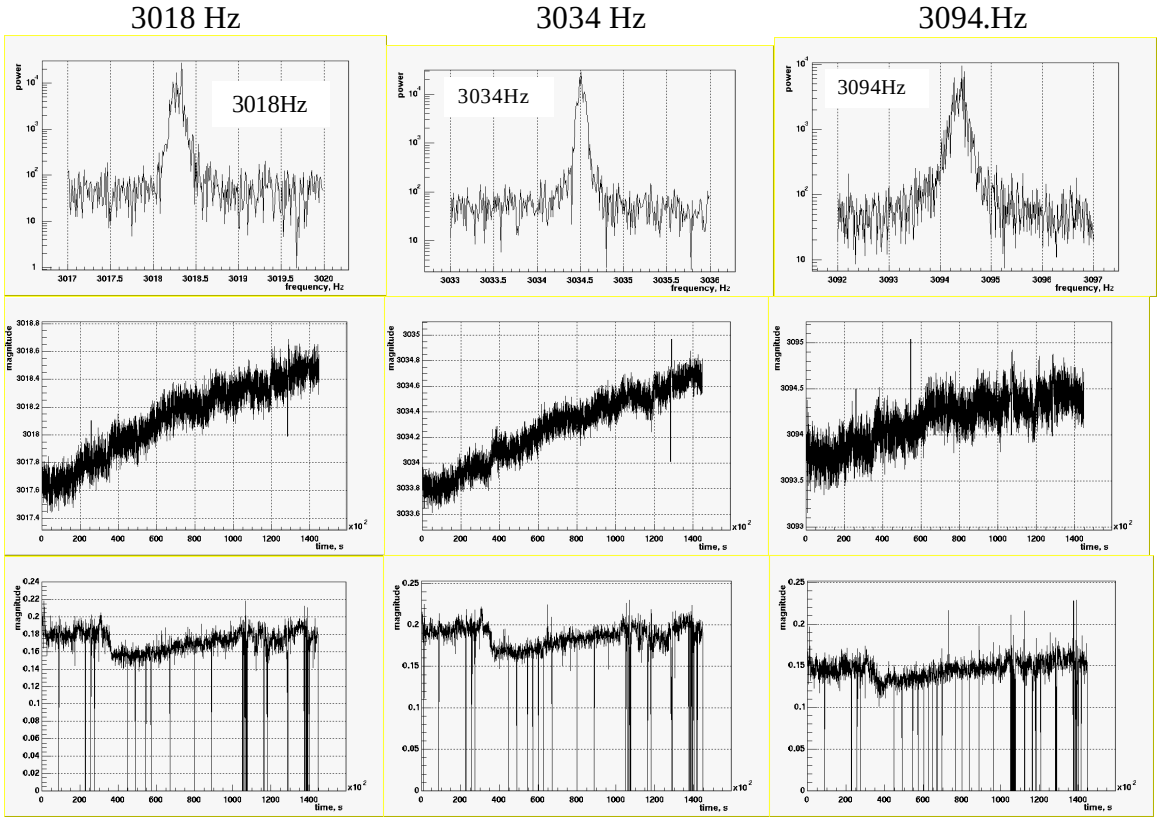
3783.1Hz-3883.5Hz lines



not seen in the IOO-MC_F channel / relatively wide (W~0.2-0.5Hz) / stable amplitude / slowly drifting frequency (~0.5 Hz/day) / highly correlated.



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Summary

- Narrow resonances have been studied and documented from data taken during the E2 run at LHO.
- While we have concentrated here on the LSC and IOO channels, similar results have been found in many other channels also.
- Using the Quasi-Monochromatic Line Monitor, we have recorded extensive trend data (more then 80 hours) showing frequency and amplitude time variability, frequency spread and possible confusion with other nearby lines.
- Overall, we have gathered extensive information about the line noise in the E2 run, which will serve as a first step towards confirmation of the source for the lines we discuss, and also towards an effort to deal with these lines, whether in the instrument itself, or in subsequent data.