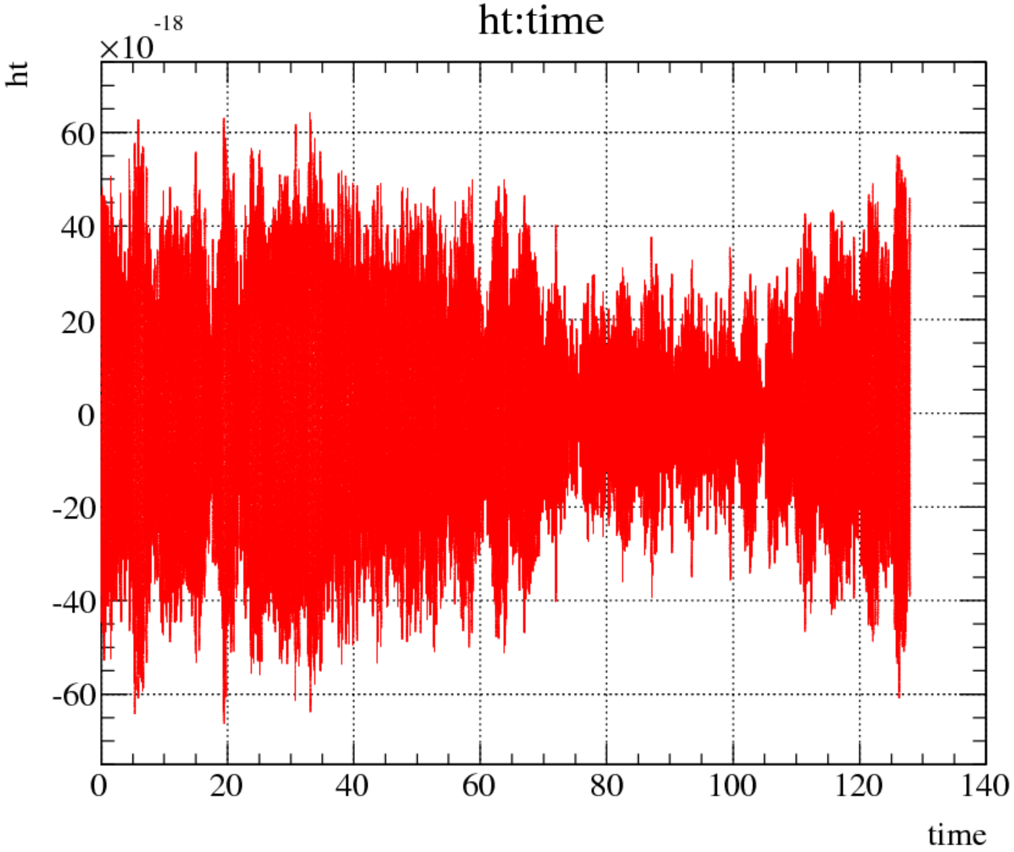
Line characterization

6 Oct. 2014

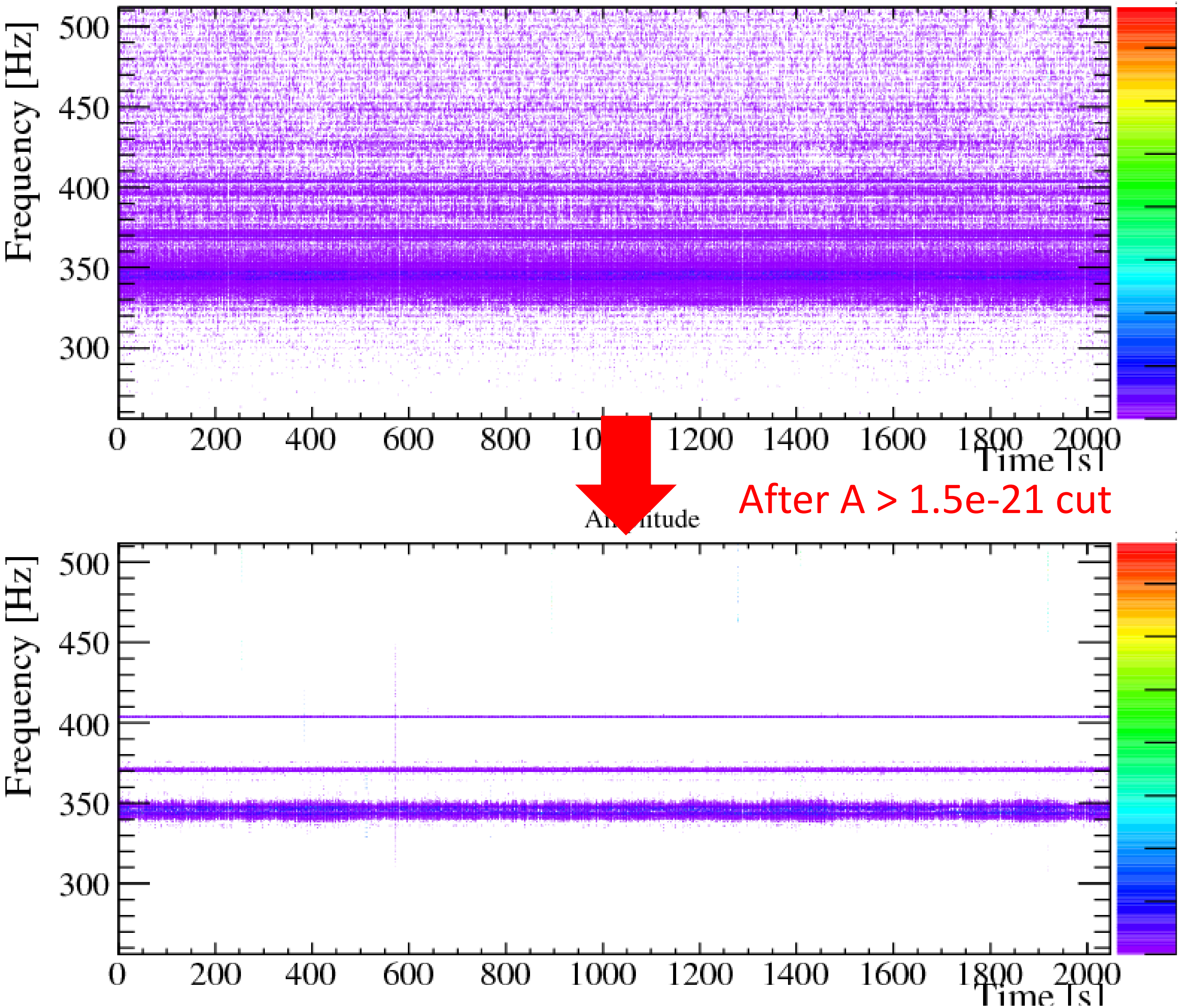
K. Ueno (Osaka Univ.)

S6 data (example)

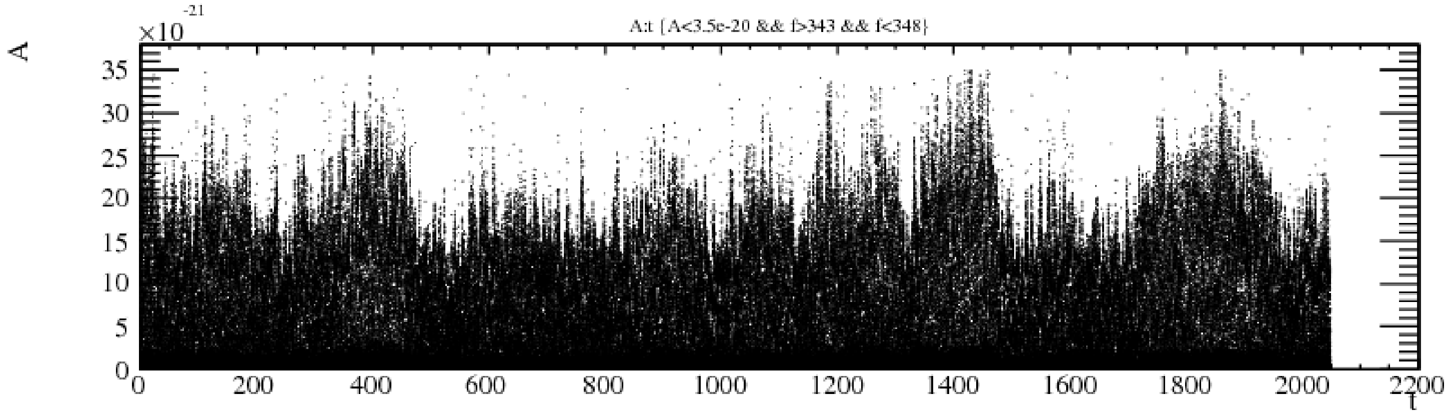
- I analyzed LIGO S6 data
  L-L1_LDAS_C02_L2-959200000-128.gwf
  - T = 128 s
  - fs = 16384 Hz



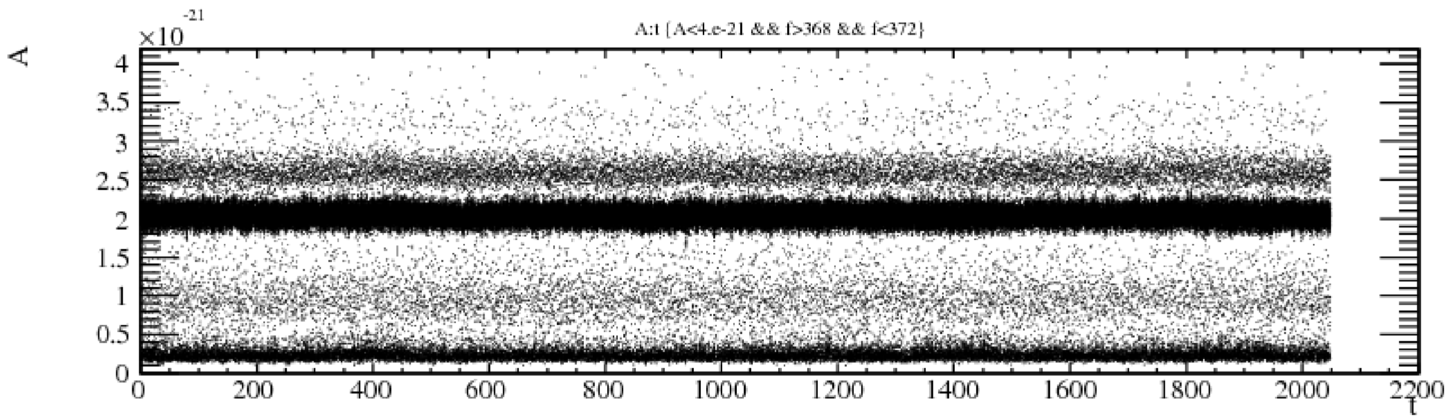
fs=1024Hz; frame=256; shift=16; #spectrum=20



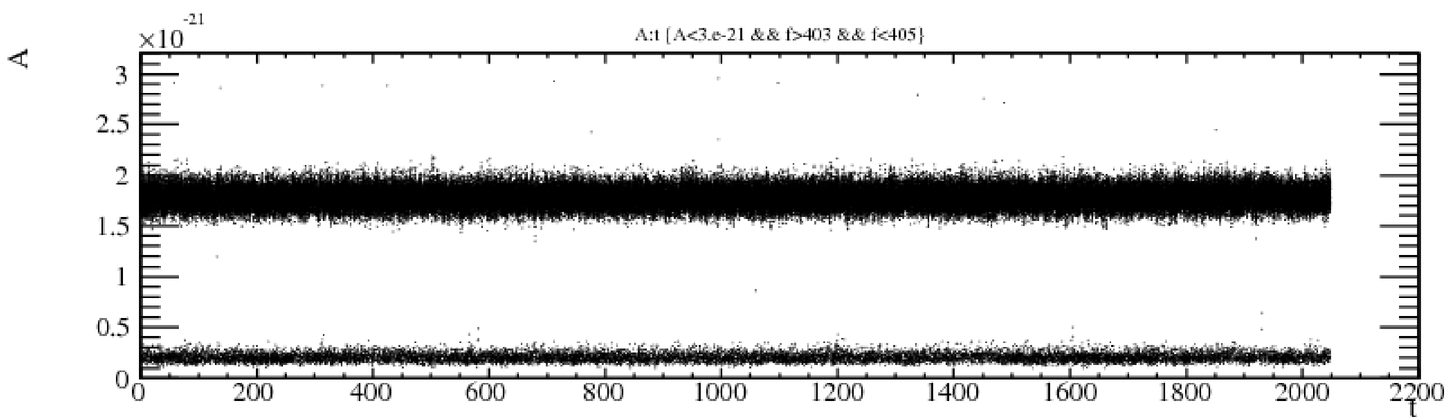
Time variation of amplitudes



~ 345 Hz

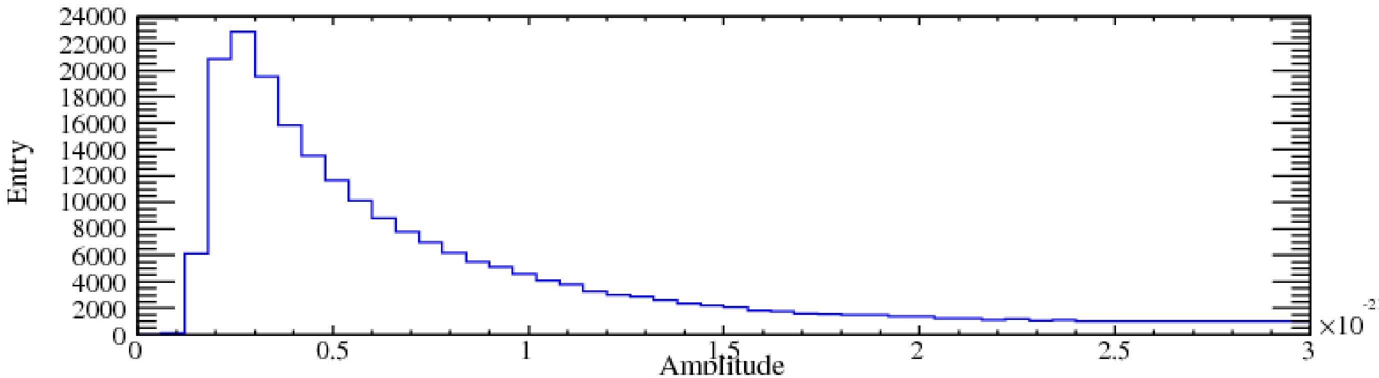


~370 Hz

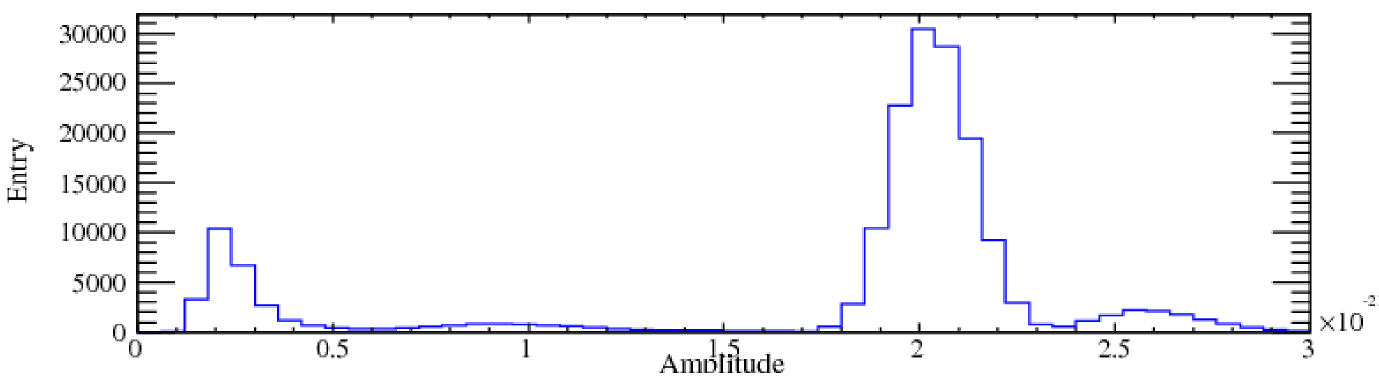


~403 Hz

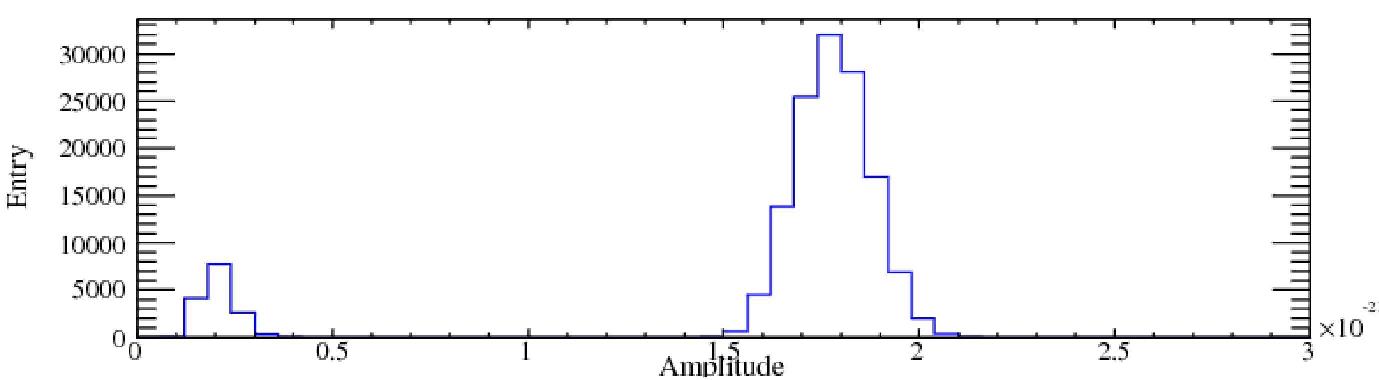
Amplitude distribution



~ 345 Hz

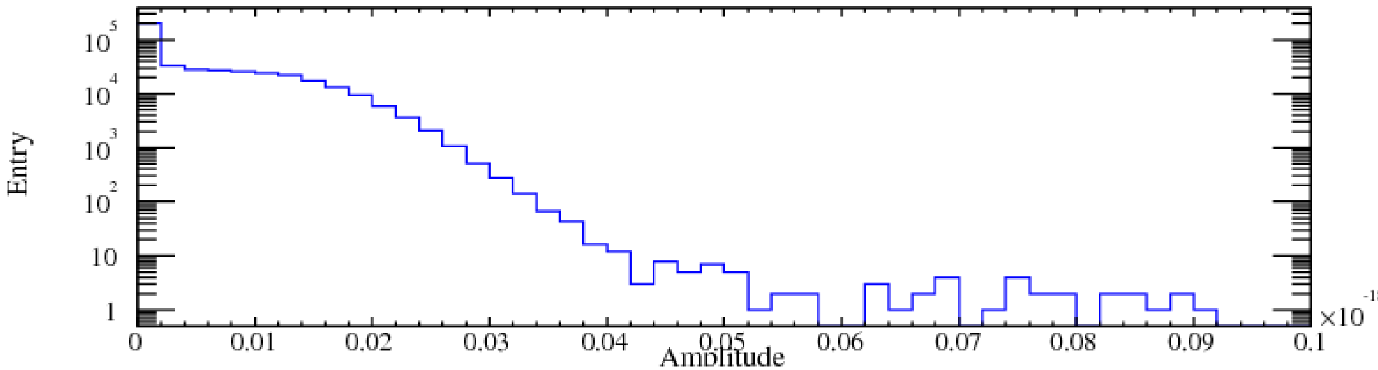


~370 Hz

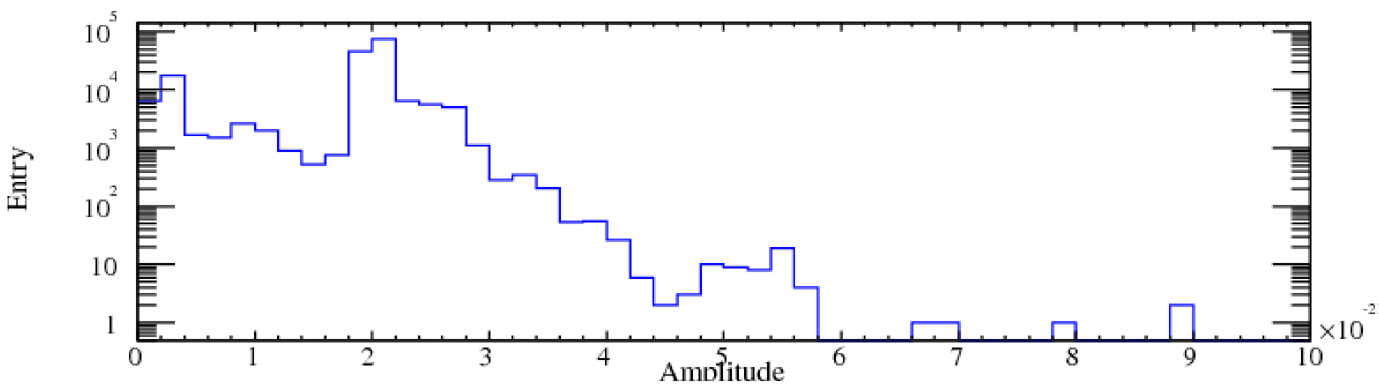


~403 Hz

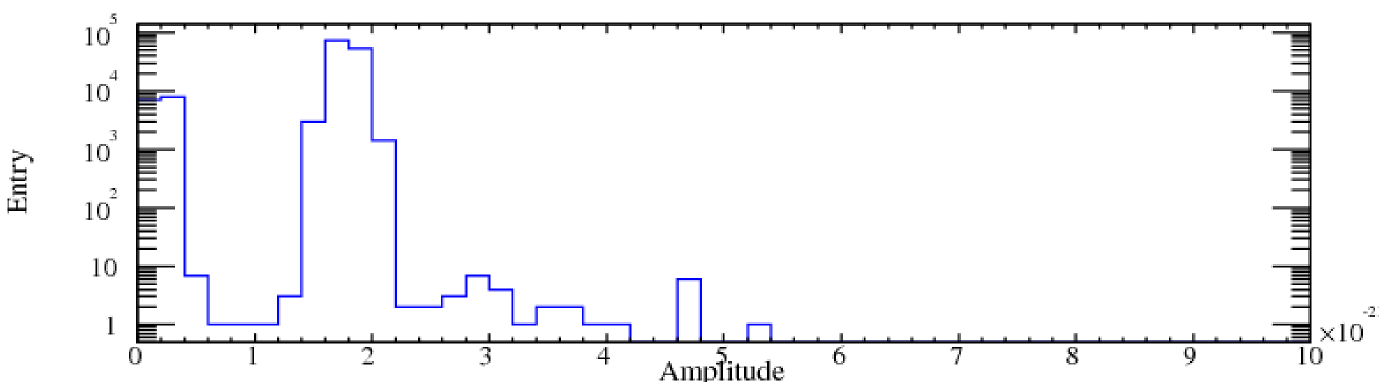
Amplitude distribution (logy)



~ 345 Hz



~370 Hz



~403 Hz

Backups

Non-Harmonic Analysis (NHA)

- NHA is a method to extract dominant frequency components in given time-series with high resolution, developed by a Toyama Univ. group which is led by Hirobayashi-san.

- The method itself is patent-protected and so not publicly available (even to the other KAGRA collaborators), but there are some papers which describe the outline of the method, especially,
  - “Noise reduction for periodic signals using high resolution frequency analysis” Yoshizawa et al., EURASIP Journal on Audio, Speech, and Music Processing 5, 2011

Basic Algorithm

1) FFT the given time series x(n) and find the frequency which gives the largest amplitude.

2) You somehow minimize the following cost function about A,f, and ϕ,

$$F(A, f, \varphi) = \frac{1}{N}\sum_{n=0}^{N-1}\left\{x(n) - A\cos\left(2\pi\frac{f}{f_s}n + \varphi\right)\right\}^2$$

starting from A and f estimated at 1). This is just a least square fit with a sinusoidal function.

3) Once the best-fit values of A,f, and ϕ are found, the waveform of converged spectrum is subtracted from x(n).

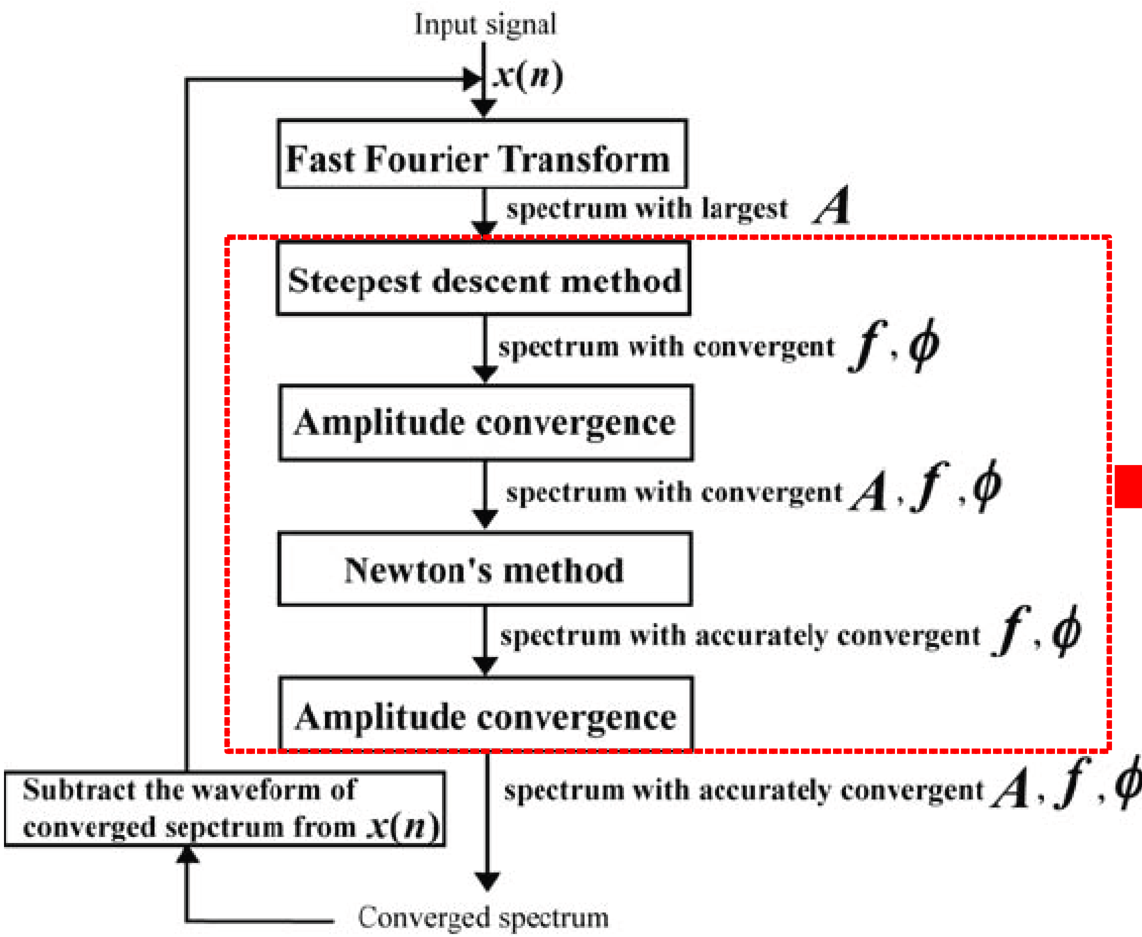
4) Repeat the procedure 1 〜 3 as many times as one would like.

Problems

- According to Hirobayashi-san, you need some specific environments such as MATLAB or GPGPU to execute their NHA code.
- In order to do data analysis ourselves efficiently, it's better to develop our own simple version of the code instead of using their real one.
- So I tried to implement this method from the scratch. But when I followed the paper faithfully, the solutions were found not to be stable and soon diverge.
- Instead of following the whole procedure written in the paper, I took another way to meet the same purpose. I'll refer to the new way (next slide) as "Iterative Least Square (ILS)" instead of NHA to avoid confusion.

Difference from NHA's paper

NHA paper



Iterative Least Square (ILS)

At one time with 3D Newton's method

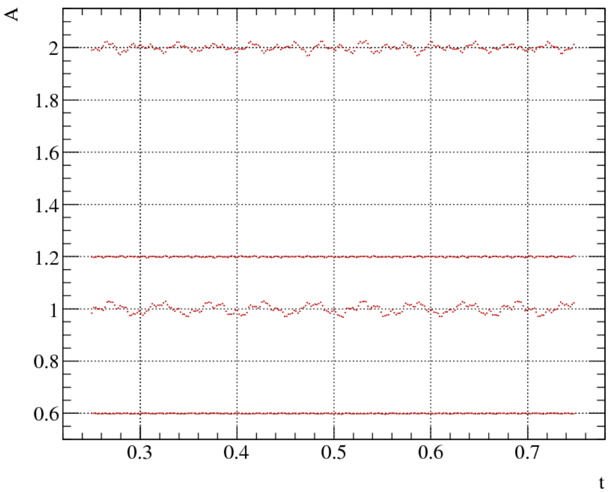
Test Example

- To test the performance of the ILS code, I artificially generated a signal time-series with some input parameters and tried to reconstruct them with ILS.
- The time-series is composed of four different signals, each of which has a constant amplitude and frequency.
- The sampling rate is 512 Hz, and the duration is set to 1 s.

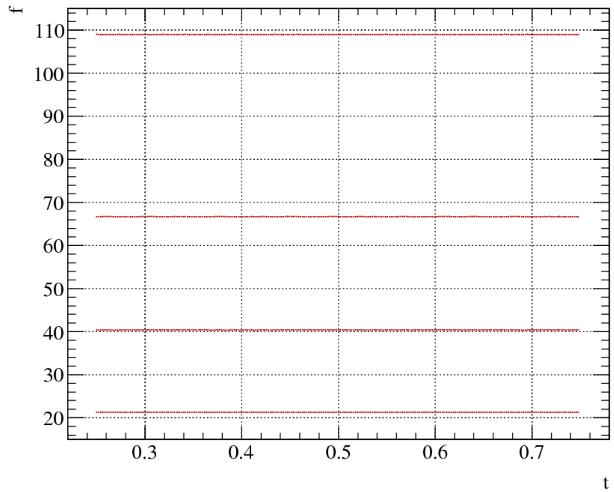
Amplitude	Frequency [Hz]	Initial phase [rad]
2.0	66.7	-0.15
1.2	109.0	0.46
1.0	40.4	2.40
0.6	21.3	0.10

Result (absolute)

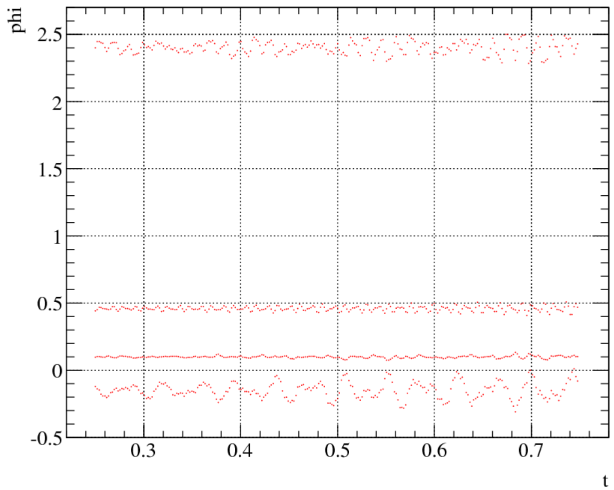
Amplitude



Frequency



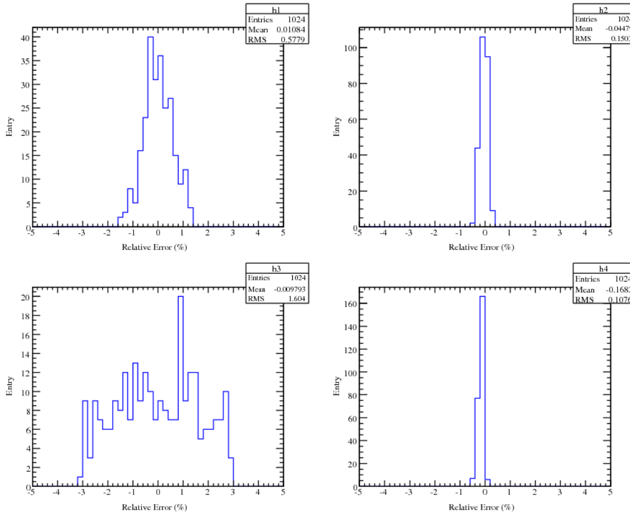
Initial phase



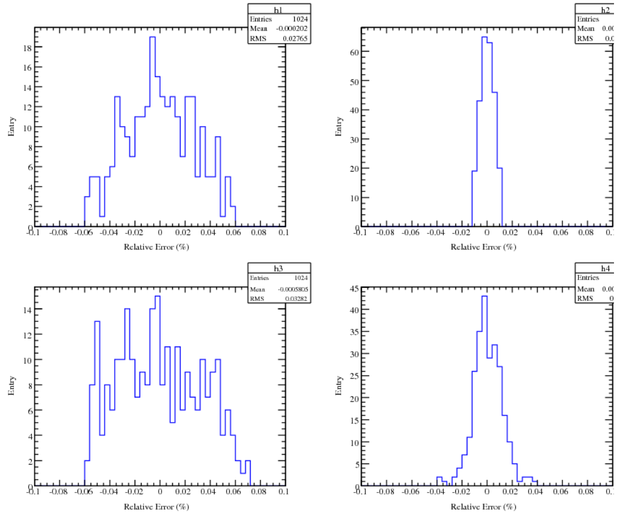
While frequencies were well reconstructed, some of the amplitudes were not, which are caused by signal-signal interference.
What is already clear: when there are multiple signals within the same duration, the minimum of the cost function does not always correspond to the true amplitude value, and the solution shift a little bit.

Result (resolution)

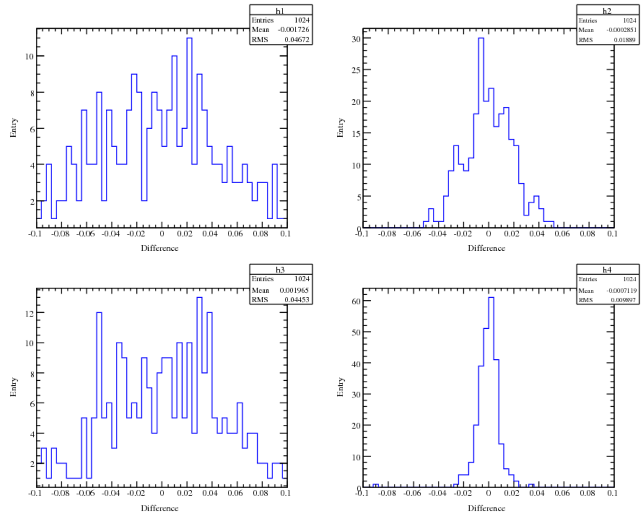
Amplitude



Frequency



Initial phase



Frequencies were reconstructed within 0.1%, while amplitudes 3%.