The knownpulsardemod DSO
August 2002 LSC Update

PULG Session 08/23/02

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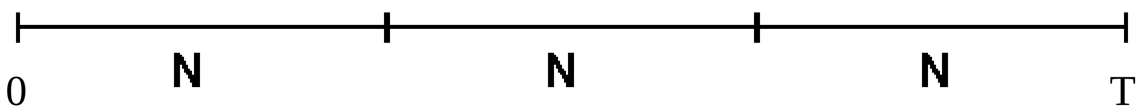
The knownpulsardemod DSO

- Runs under LDAS. Code is in LALWrapper CVS.
- Generates Short-time Fourier Transforms (SFTs).
- **NEW**: inputs SFTs, and ephemeris data from ilwd.
- **NEW**: wrote LALWRAPPERInitBarycenter to transfer ephemeris data from LDAS to LAL.
- Uses the LALDemod function to generate JKS F statistic for one set of source parameters.
- Writes to the SIGNAL_DPERIOD database table.
- **NEW**: also writes to the search summary and search summary variables tables; outputs F statistic in frame or ilwd format for a specified frequency band.

The JKS F Statistic

Jaranowski, Krolak, and Schutz gr-qc/9804014; Schutz & Papa gr-qc/9905018; Williams and Schutz gr-qc/9912029; Berukoff and Papa LAL Pulsar Package Documentation



$$F = \frac{4}{T}\frac{B|Y|^2 + A|Z|^2 - 2C\,\mathrm{Re}(YZ^*)}{D},$$

$$Y = \sum_{j=0}^{MN-1} x_j a_j e^{-i\Phi_{jb}}\Delta t, \qquad Z = \sum_{j=0}^{MN-1} x_j b_j e^{-i\Phi_{jb}}\Delta t,$$

$$A = (a \parallel a), \quad B = (b \parallel b), \quad C = (a \parallel b), \quad D = AB - C^2$$

$$\begin{pmatrix} a \\ b \end{pmatrix} = \begin{pmatrix} \cos 2\psi & \sin 2\psi \\ \sin 2\psi & \cos 2\psi \end{pmatrix}\begin{pmatrix} F_+ \\ F_\times \end{pmatrix}, \qquad (x \parallel y) = \frac{2}{T}\sum_{j=0}^{MN-1} x_j y_j \Delta t$$

$$Y = \sum_{\alpha=0}^{M-1} a_\alpha Q_\alpha \sum_{k=k^*-K}^{k^*+K} X_{\alpha k}^{SFT} P_{\alpha kb}\Delta t, \qquad Z = \sum_{\alpha=0}^{M-1} b_\alpha Q_\alpha \sum_{k=k^*-K}^{k^*+K} X_{\alpha k}^{SFT} P_{\alpha kb}\Delta t.$$

E7 Update

- Loop scripts drove knownpulsardemod to generated SFTs for L1, H1, and H2.
- Scripts are checked into MDC CVS.
- **NEW**: E7 SFTs data are available from LDAS using getsftdata.tclsh script. (Need ligotools LDAS job package and LDAS password.)
- **NEW**: LDAS can read SFT data very quickly (1 days worth of data in 1 Hz band in < 60 seconds.)
- **NEW**: knownpulsardemod test jobs that produce the JKS F statistic have been run on E7 data.

Goals before S1 (from last LSC conf.).

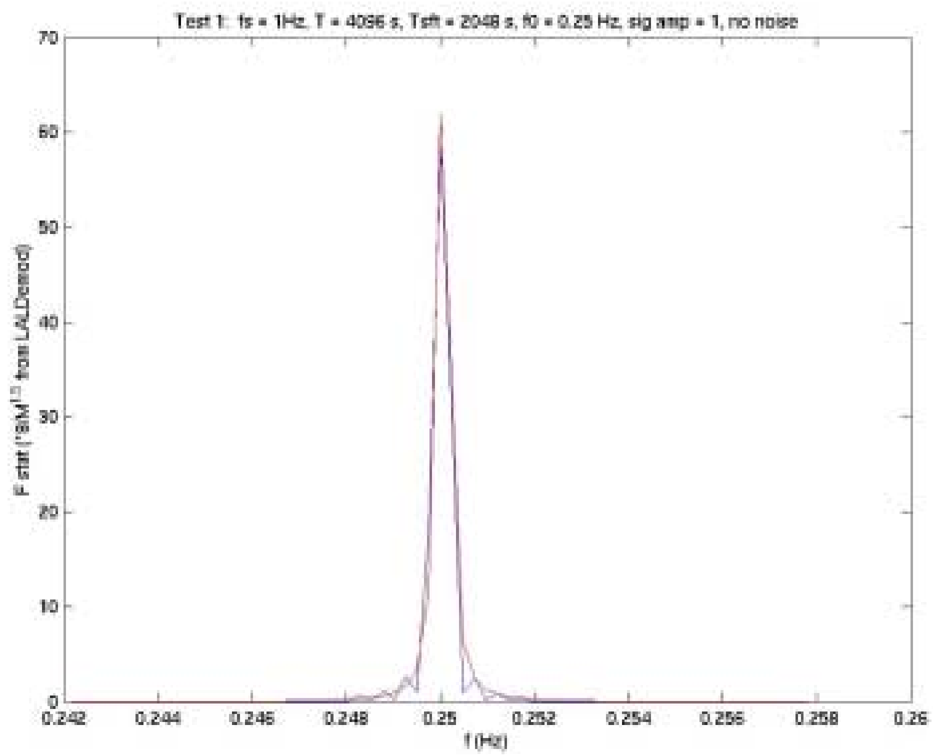
- Update knownpulsardemod DSO to work with latest LAL and LDAS code. **(DONE.)**
- Understand distribution of SNR and F statistic in Jaranowski, Krolak, and Schutz gr-qc/9804014. **(Understand the case of pure gaussian noise.)**
- Understand how to set upper limits. **(Have thought very briefly about this.)**
- Design and run knownpulardemod MDC tests for LALDemod. **(SURF Student Brian Cameron worked on LALapps test code.)**

Test Code Progress

- SURF student Brian Cameron wrote LAL-apps code to aid testing this summer.
- We worked on four basic tests:
  - Compared Brian’s code vs. LALDemod.
  - Generated synthetic data sets to study the distribution of the F statistic.
  - Studied: “Is F the best estimator?”
  - Studied effective of windowing and side lobes on SNR.
- Much more work is needed.

Simple Test of LALDemod

- Brian Cameron’s test code vs. LALDemod.



Distribution of the F Statistic.

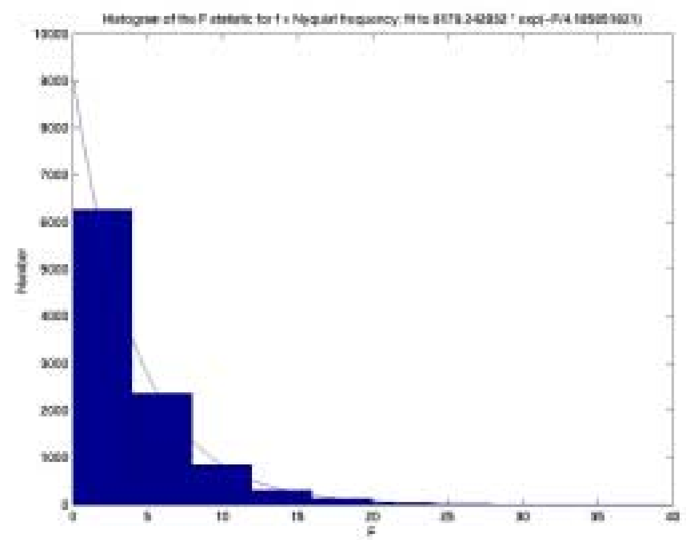
- Note that F depends on $a(t)\exp[i\Phi(t)]$ and $b(t)\exp[i\Phi(t)]$.
- Note that $a(t)$ and $b(t)$ are proportional to $\sin(2\pi f_r t)$ and $\cos(2\pi f_r t)$, where f_r is the frequency of the Earth's rotation.
- Thus F depends on amplitudes of $\sin(\Phi(t) \pm 2\pi f_r t)$ and $\cos(\Phi(t) \pm 2\pi f_r t)$.
- For white noise this corresponds to 4 gaussian distributed random amplitudes; F can be written as the sum of the squares of linear combinations of these and thus follows a chi-squared distribution for 4 degrees of freedom.

Special Case

- If $\Phi(t) = 2\pi f_c t$, where f_c is the Nyquist frequency, the F statistic comes from $f_c \pm f_r$ bins which are aliased to each other.
- For this case and white noise, F depends on only 2 independent gaussian distributed random variables, not 4. Thus F follows a chi-squared distribution for 2 degrees of freedom.

Special Case Nyquist Frequency, Distribution of F

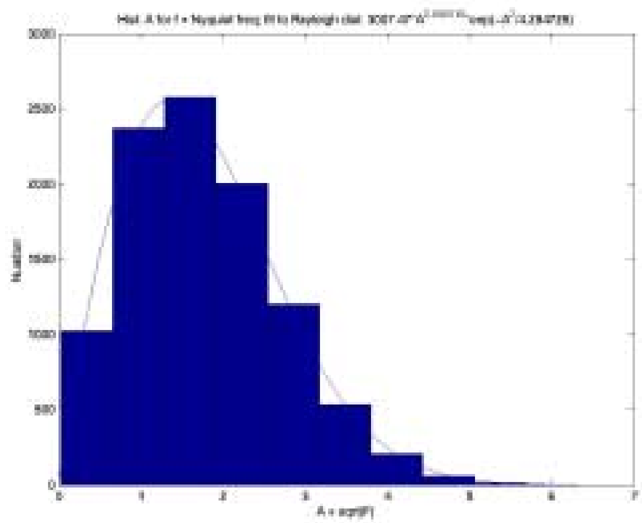
- For pure noise we get the usual chi-squared with 2 degrees of freedom: $\rho(F)\, dF = 1/2\sigma^2 \exp(-F/2\sigma^2) dF$



Courtesy Brian Cameron

Special Case Nyquist Frequency, Distribution of $A = \sqrt{F}$

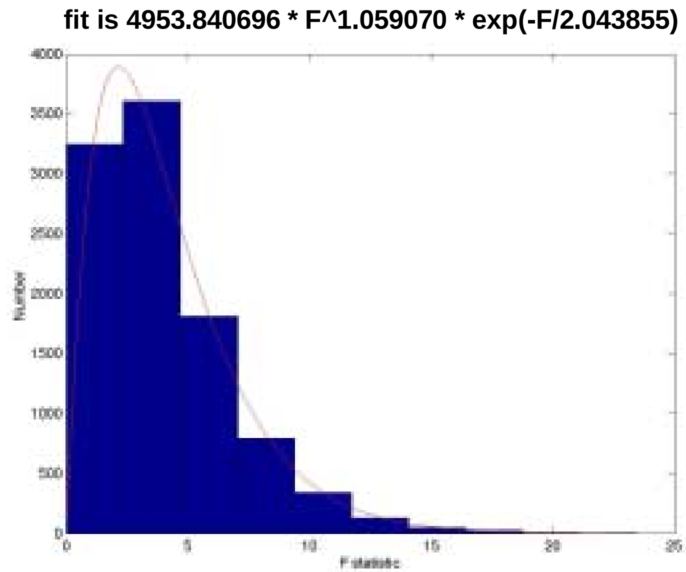
- For pure noise we get the usual Rayleigh distribution $\rho(A)\, dA = A/\sigma^2 \exp(-A^2/2\sigma^2)\, dA$



Courtesy Brian Cameron

General Case, Distribution of F

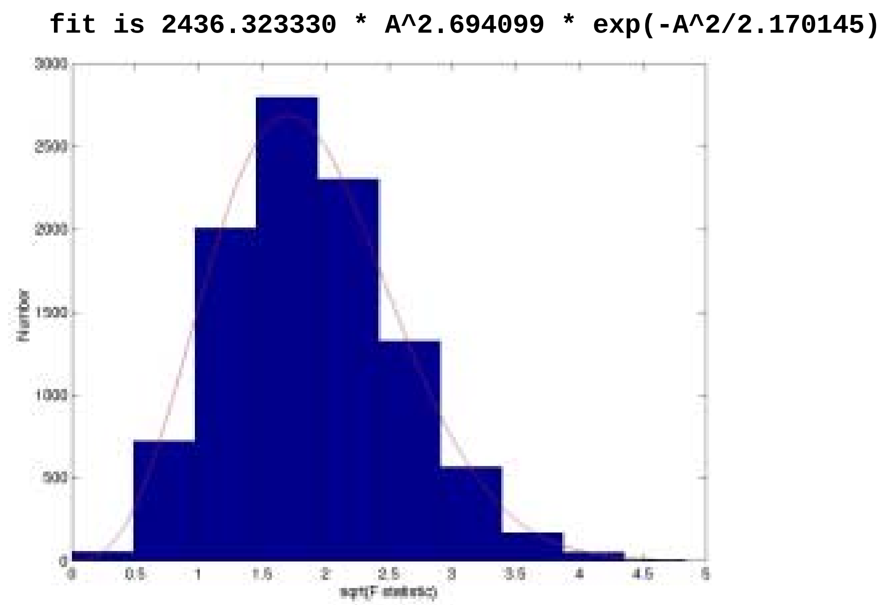
- For pure noise we get a chi-squared with 4 degrees of freedom: $\rho(F)\, dF = 1/4\sigma^4\, F \exp(-F/2\sigma^2)\, dF$, as predicted.



Courtesy Brian Cameron

General Case,
Distribution of $A = \sqrt{F}$

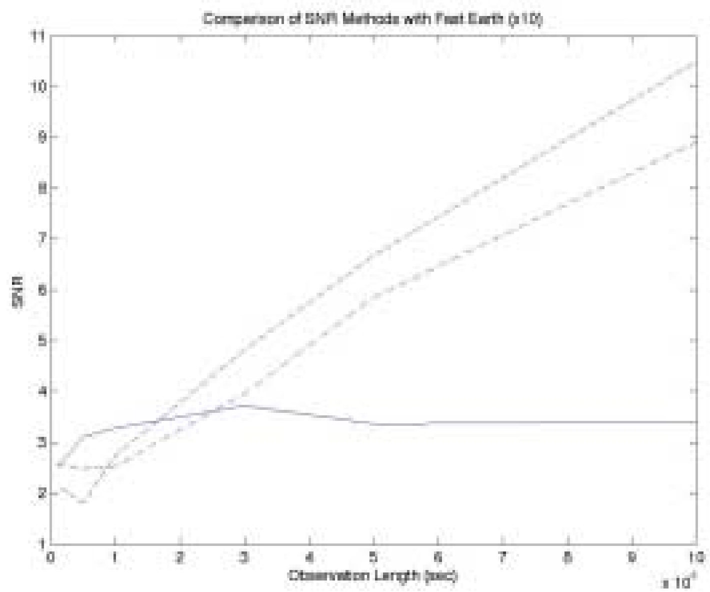
- For pure noise we get the expected distribution
  $\rho(A)\, dA = A^3/2\,\sigma^4 \exp(-A^2/2\sigma^2)\, dA$



Courtesy Brian Cameron

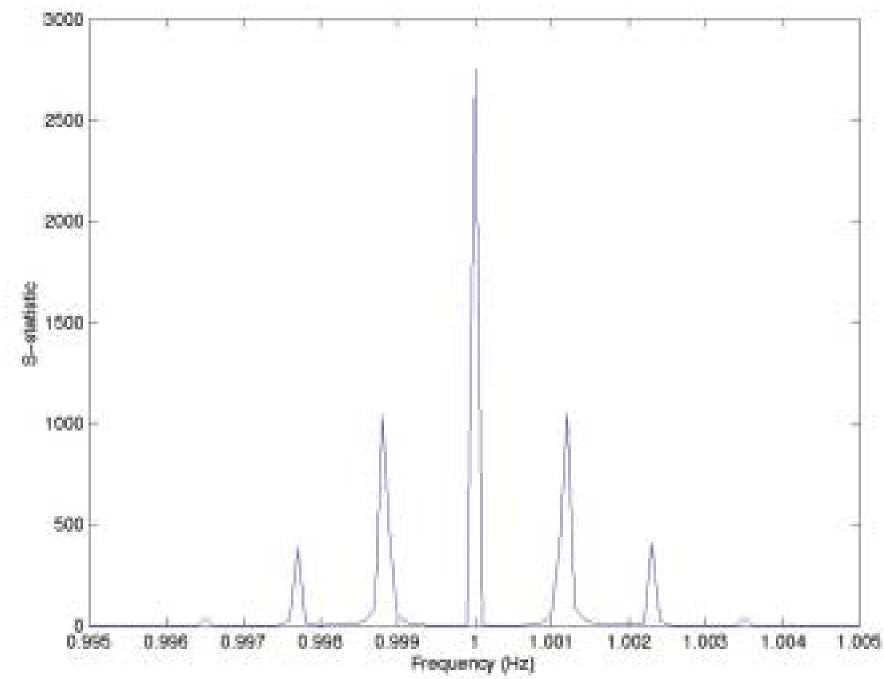
Is JKS F stat the best estimator?

- Should we track the amplitude and phase or just the phase?
- Generated signal at ¼ Nyquist frequency with large spindown and equiv of 10 days of data; SNR = max(A) with signal present divided by mean(A) when only noise is present.
- solid curve = no tracking, dot-dashed = track phase only, dotted = F stat tracks amp & phase = best. SNR ~ $\sqrt{T}$ for latter two, though this is not obvious from the graph.
- Differences are due to leakage into side lobes.



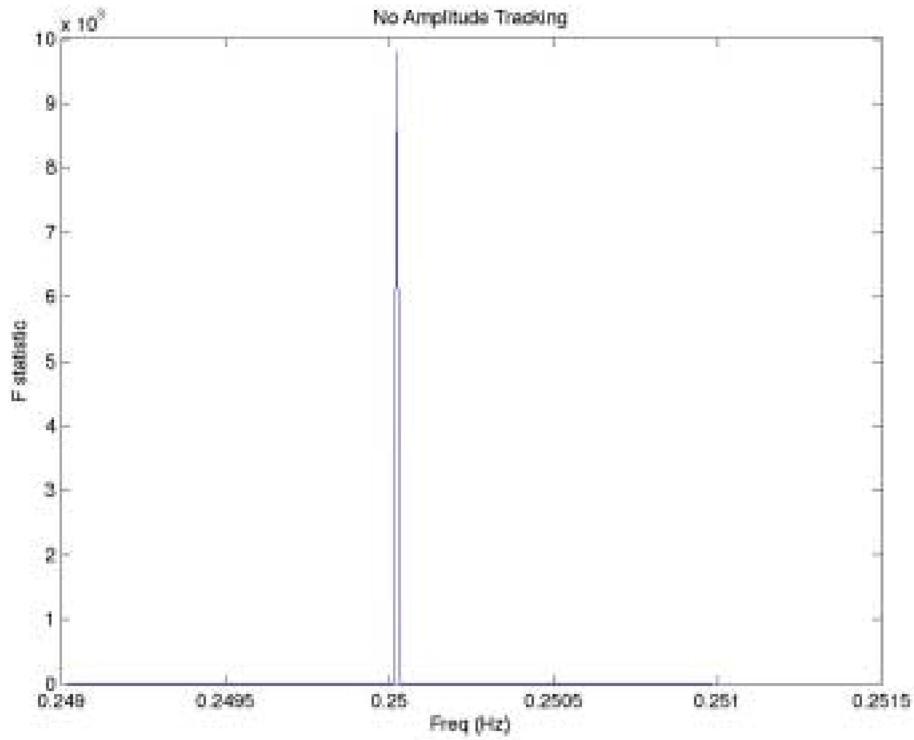
Courtesy Brian Cameron

Side lobes in JKS F Statistic



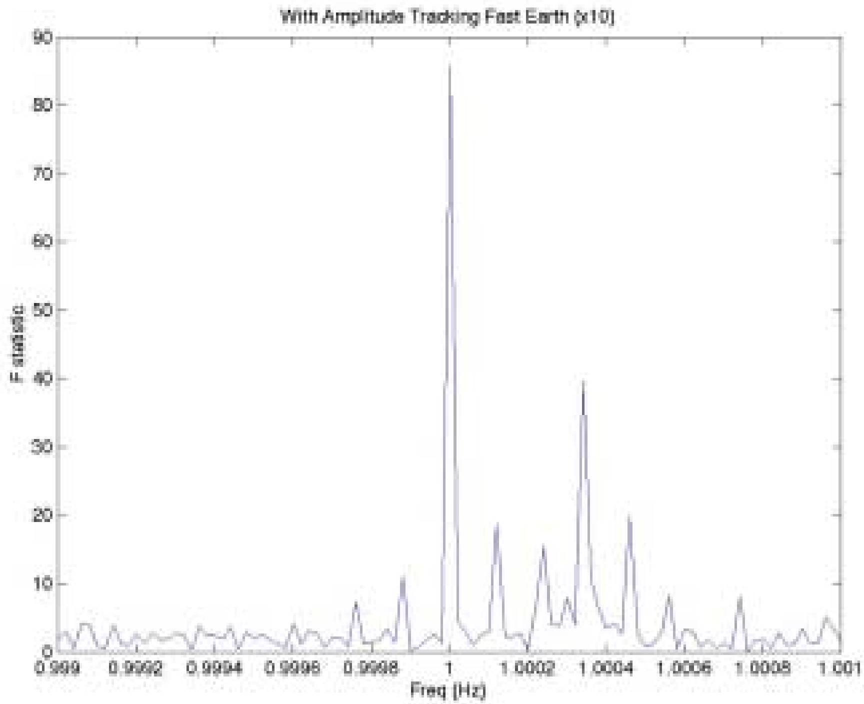
Courtesy Brian Cameron

Special case without amplitude tracking



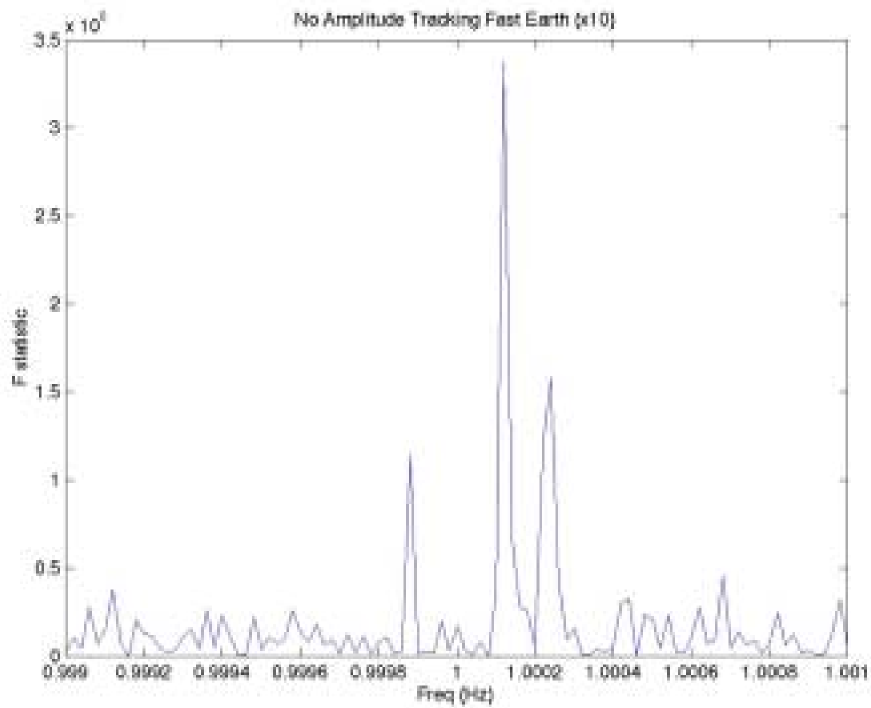
Courtesy Brian Cameron

General case with amplitude tracking = F statistic



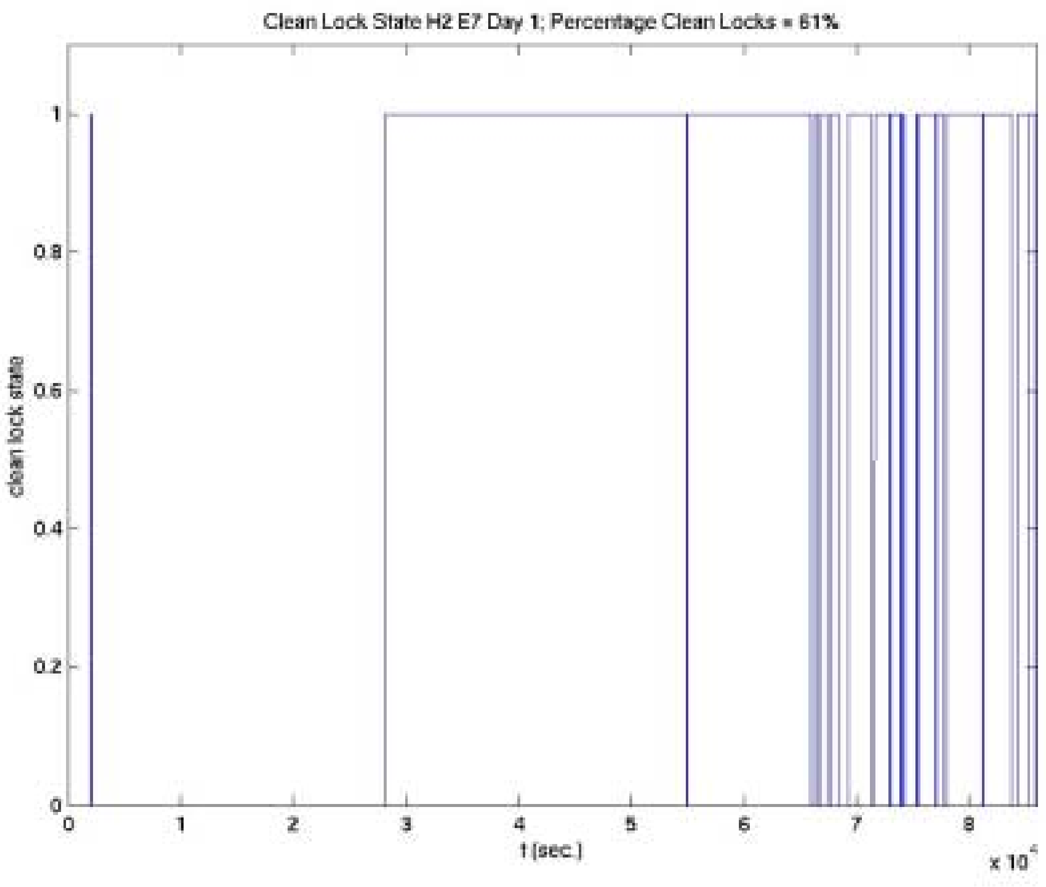
Courtesy Brian Cameron

General case without amplitude tracking

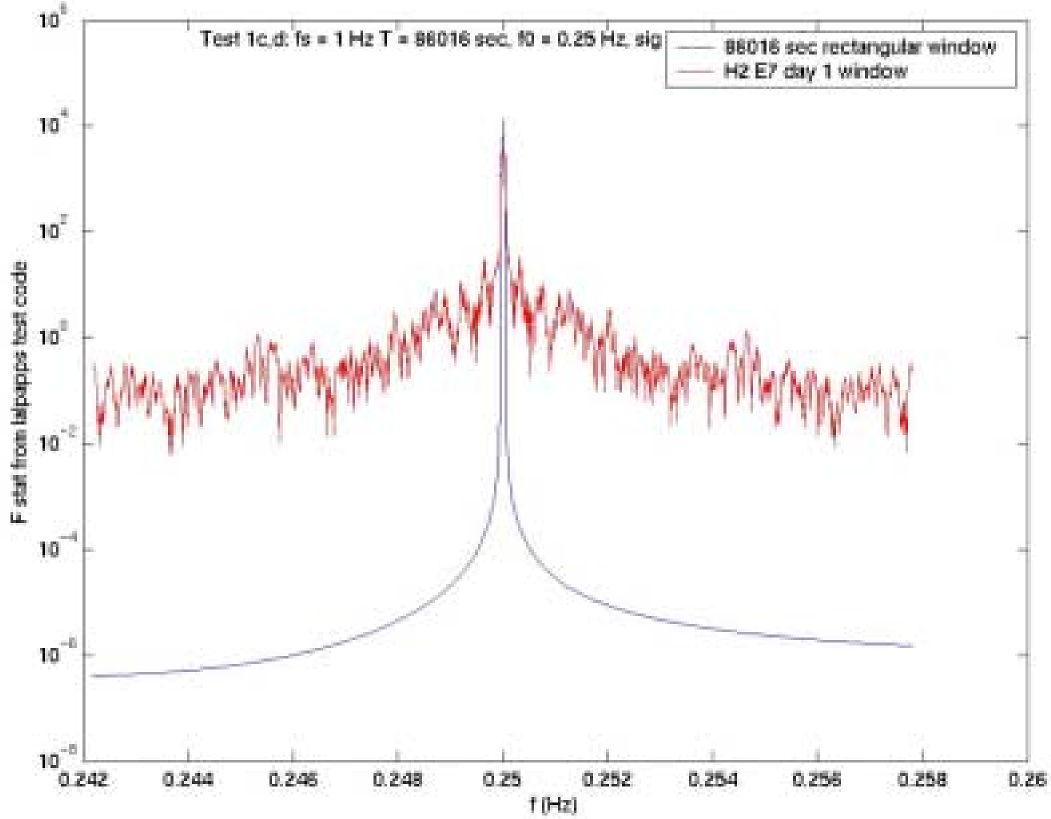


Courtesy Brian Cameron

Effective Windowing of Data

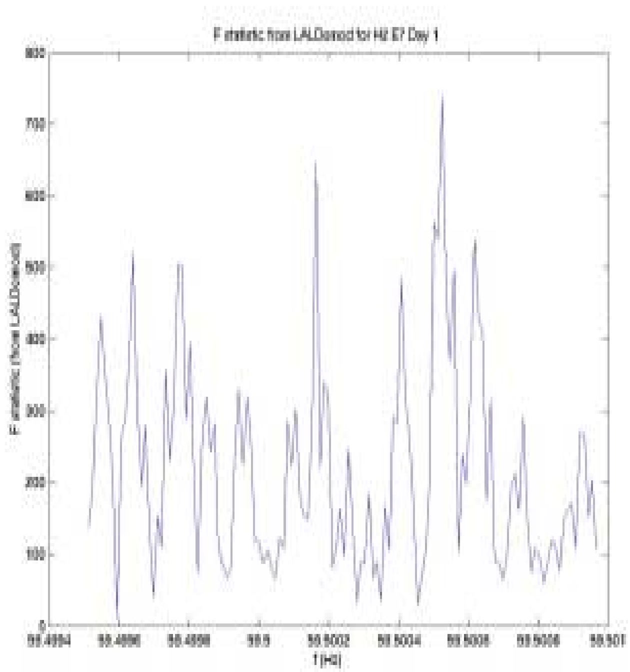


Leakage Due to Windowing



Sample Result from E7

- Produced by knownpulsardemod LDAS job in less than 2 minutes. Anyone with LDAS password can run jobs to get data like this.
- Warning: code is untested!



Data Quality and Dropout

- Clean locks are used to generate a quality channel. Poor quality data is “padded” (replaced) with the mean of the good quality data. The percent of the data padded is stored in the SFT history structure. **NEW: percent clean lock for S1 SFTs will be stored in search summary vars database table.**
- Data dropout code is not yet working. SFTs are missing for drop outs during E7. **SAME will be true for S1.**

knownpulsardemod MDC

- Held November 27-30 at LHO.
- In DCC: LIGO-T020014-00-W
- Primarly Tested SFT generation.
- MDC scripts and documentation are in UWM mdc CVS repository.
- **NEW**: need another MDC to test new code, before S1 data can be analyzed with confidence.
- Code needs to be debugged first.

Example Test

TEST 2a Correctness of SFT output

Purpose: Test that the SFTs output by the KPD DSO are indeed the DFT of the input data for input data with known results.

Tester: _______________. Date & Time: ___________. Tester Location: ____________.

Job Site: _________________________. Job Database: ____________________________.

Job Channel: ____________________. Job Log File: ______________________________.

Instructions: (See the "How to run the test scripts" section if you need help.)

Use RunJob.tclsh to run the jobs below, perform the task indicated, and record the results.

1. Impulse tests. These test run on KPDTEST-ImpulseN32I16-600000000-1.gwf, which contains 32 data points sampled at 32 Hz, with an impulse in the 16^{th} data point (index = 15).

. a. Run kpdImpulseTest.job. The output will be an xml file. Ftp the result to the KPD MDC output URL. Append test.2a.1a to the name. Check that the results agree with that in ASCII_ImpN32I16Output.txt.

LDAS Job #: Pass/Fail