Inspiral Waveform Consistency Tests

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The Standard $\chi^2$ Test

Divide template into $p$ parts, each expected (on average) to contribute equally to the total SNR, and calculate a $\chi^2$:

$$\chi^2(t) = p \sum_{l=1}^{p} \left| z_l(t) - z(t)/p \right|^2$$

$z$ and $z_l$ are complex numbers

LSC inspiral analysis group has used $p=8$ in the past, currently is using $p=14$
A Simulated Inspiral

$\chi^2$ vs SNR

Seconds from GPS Time 715504529.798096
The Loudest L1 Event in the S1 Analysis

\[ \chi^2 \]

\[ \text{SNR} \]
Why Do Garbage Events Survive the $\chi^2$ Test?

The $\chi^2$ test only uses a “slice” out of the time-freq plane.

SNR threshold is determined by noise averaged over job.

During a time interval with excess noise, the matched filter is likely to find some point in time with acceptable SNR & $\chi^2$. 
Garbage Events Near a Big Glitch

“Inaccurate” inspiral coalescence times are understood to arise from ringing of the template filter

$\chi^2$
Additional Waveform Consistency Tests

Look for excess noise just before the event time, using the matched filter output as a measure of noise in some way.

Count number of time samples above a threshold, or number of threshold crossings, over some time interval.

Threshold=6.5 seems good for weak events.
Allow for Large Signals

Use a threshold which depends on the peak SNR ($\rho$)

$$\text{threshold} = \sqrt{6.5^2 + \left(\frac{\rho}{6}\right)^2}$$
Evaluate Tests Using S1 Data

Modified filtering function in LAL to implement a few variations on these tests

(Chosen based on examining several of the loudest events)
Fixed vs. adjusted SNR threshold
A few different time windows

Re-ran the entire S1 inspiral analysis

Analyzed full data set with Caltech LDAS
Separate set of jobs with (software) injections, to calculate efficiency
Stored triggers, with extra information, in database
Studied effectiveness of the different test variations

Test which seemed to provide best discrimination: number of crossings over adjusted SNR threshold
Results for Simulated Signals

3 simulated events out of 2905 have 4 crossings
Results for Data

Cutting events with more than 4 crossings eliminates the loudest 13 events!
Summary and Plans

A test of this sort would have cleaned up the S1 data

Very clean – no inefficiency for signal!  (** But tuned on these events)
Reduced maximum SNR from 15.9 to 11.6
Rate limit would have improved from 170 to 140 per year per MWEG

Needs to be properly incorporated into LAL

Should probably develop a more robust way to deal with large signals

Needs to be re-tuned using S2 playground data

Hopefully, this will help the S2 analysis significantly

   Especially since we’ve had limited luck with auxiliary-channel vetoes