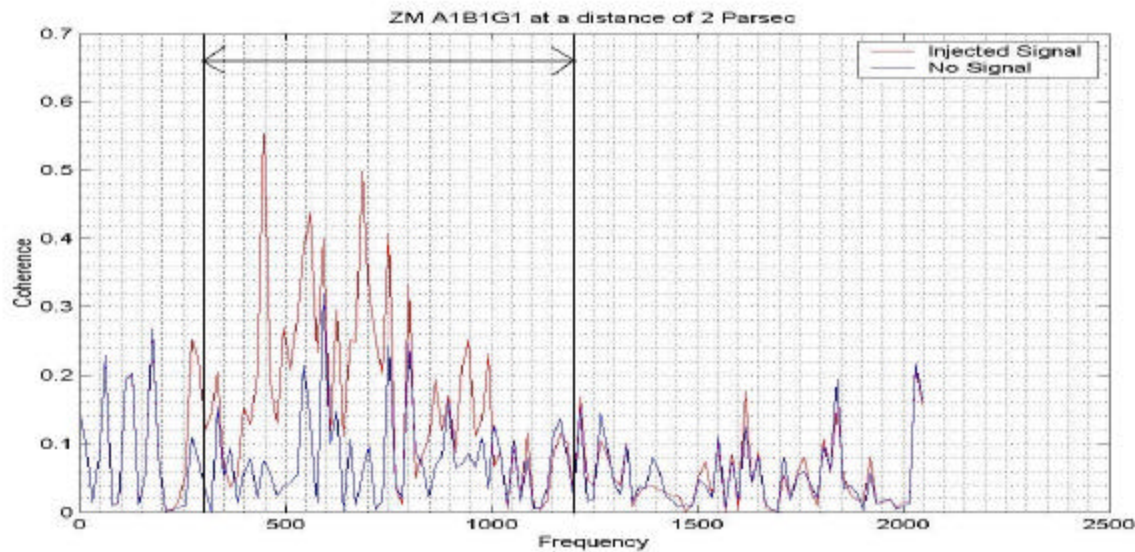




A Coherence Function Statistic to Identify Coincident Bursts

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Cross-correlation of coincident burst data

- After the search DSOs have identified data segments in which a burst is apparently present,
- *And* processing of the triggers identifies H2/L1 pairs which are coincident in time (to the level of resolution of the DSOs, eg, 1/8 second for tfclusters, ie, not as good as the required ± 10 msec),
- *And* trigger level consistency cuts are made (overlapping frequency band, consistent amplitudes, etc)
- We *still* may have to reduce the coincident fake rate.
- SO, go back to the raw data and require consistency:
- We seek a statistical measure which
 - » reduces false coincidences significantly while
 - » maintaining very high efficiency for even the faintest injected burst which triggers the DSOs
 - » And can provide a better estimate of the start-time coincidence
- We require this statistic to be robust even when
 - » the two IFOs have very different sensitivities as well as
 - » when there is a time delay of +/- 10 ms between the injected signals in the two IFOs.



Cross-correlation statistic

Let:

$X(t) = \Delta T$ seconds of data from H2

$Y(t) = \Delta T$ seconds of data from L1.

$CXY(f)$ = Coherence function between X , Y .

$$= \text{abs}(CSD(X, Y)^2) / (\text{PSD}(X) * \text{PSD}(Y))$$

(CSD = Cross Spectral Density, PSD = Power Spectral density)

Consider the statistic: **CCS** = Integral (CXY , $\{f_{\min}, f_{\max}\}$)

(or) since we are sampling the data at discrete time intervals, we use the following discrete analog of (*):

$$\text{CCS} = \sum CXY(f) * \Delta f \text{ (between } f_{\min} \text{ and } f_{\max})$$

In our analysis, we use the value of $\Delta T = 1$ second.

The statistic will depend upon the value of ΔT and this dependence needs to be explored.



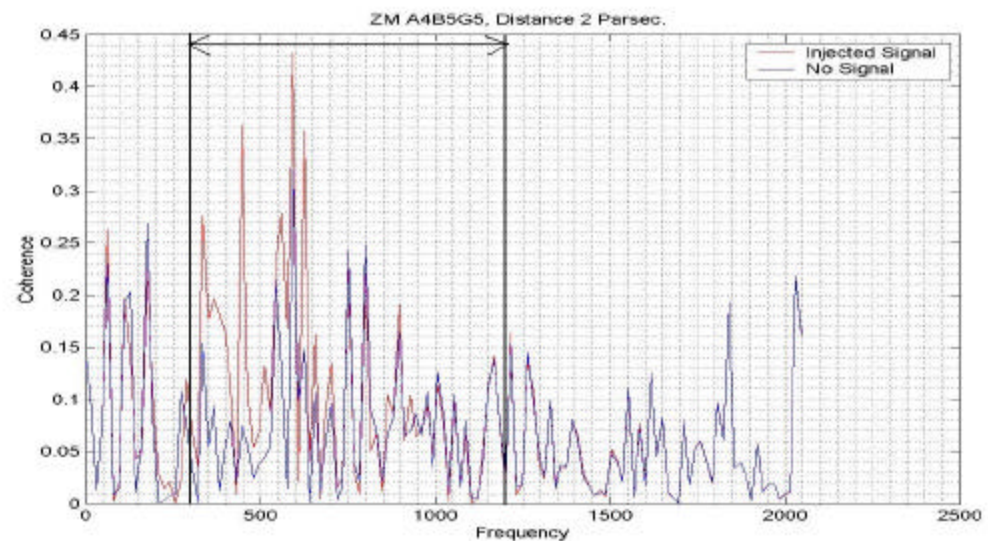
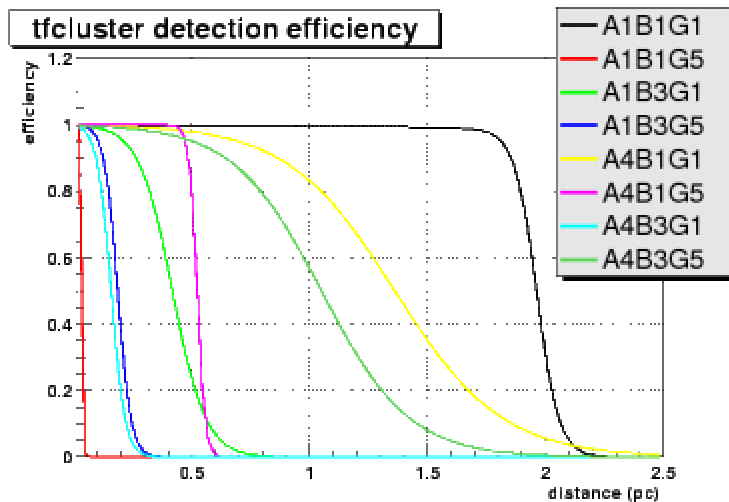
Evaluation of the CCS

- The idea behind this exercise is to determine the distribution of the CCS statistic before and after signal injection
- and thereby hope to find a value of the CCS statistic which can then be used as a test to identify coincident bursts.
- We would like this statistic to have a high efficiency of detection while maintaining a low fake rate.



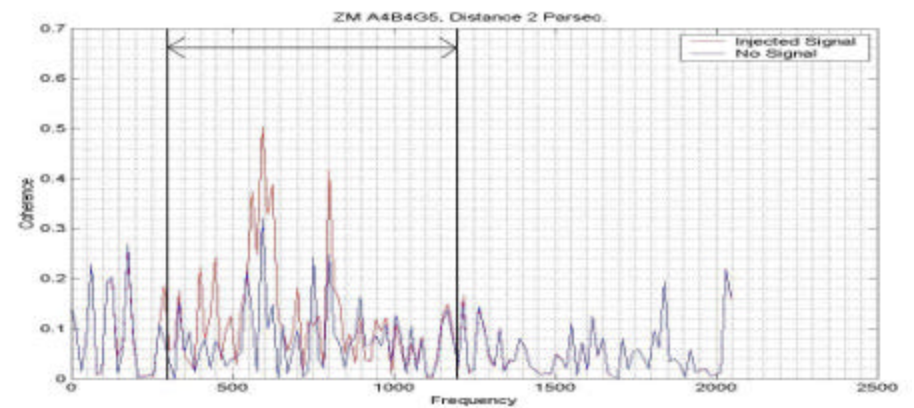
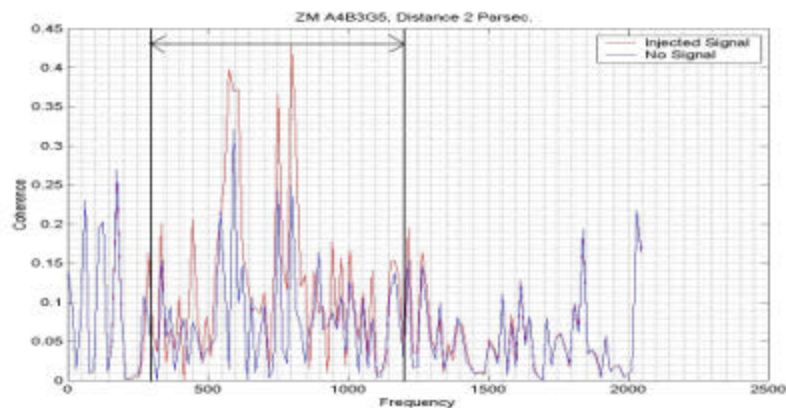
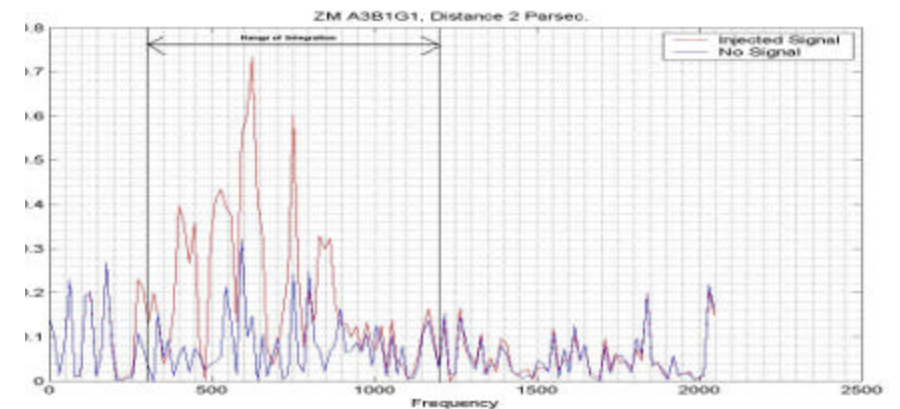
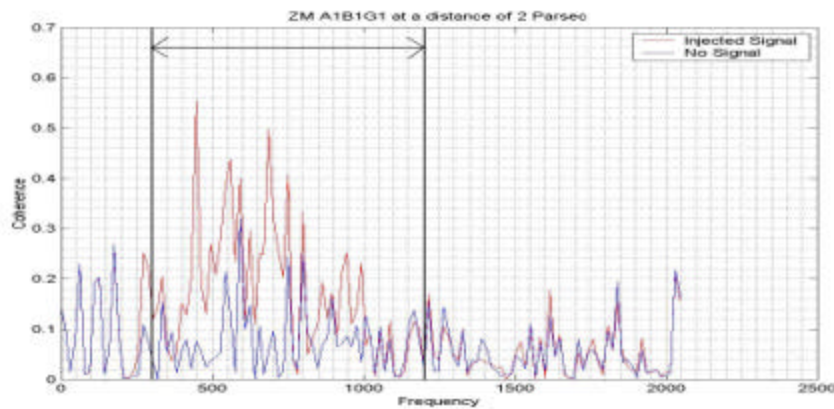
Determination of optimal values of f_{\min} and f_{\max}

- We are considering ZM waveforms at a distance of 2 parsec (limit of sensitivity during E7)
- To find the optimal range of values of f_{\min} and f_{\max} , we plot $CXY(f)$ for the case when there are no injected burst signals in H2, L1 and compare it with the case when we inject signals.





CCS for different ZM waveforms





Limits of integration

- From the above plots, it is clear that the region of interest lies between ~ 250 Hz – 1000 Hz.
- This is consistent with the fact that ZM supernovae have little power beyond 1000 Hz and the fact that LIGO has its peak sensitivity in this region.
- The plots also indicate that the CCS statistic would be of little use in detecting some weak waveforms (eg: A1B1G5).
- Details:
 - » The raw E7 data has been whitened and resampled to 4096 Hz
 - » The injected signals have been filtered through the calibrated transfer function (strain \rightarrow LSC-AS_Q counts), then whitened and resampled like the data.
 - » So far, we have been using 300-1000 Hz as our limits of integration.

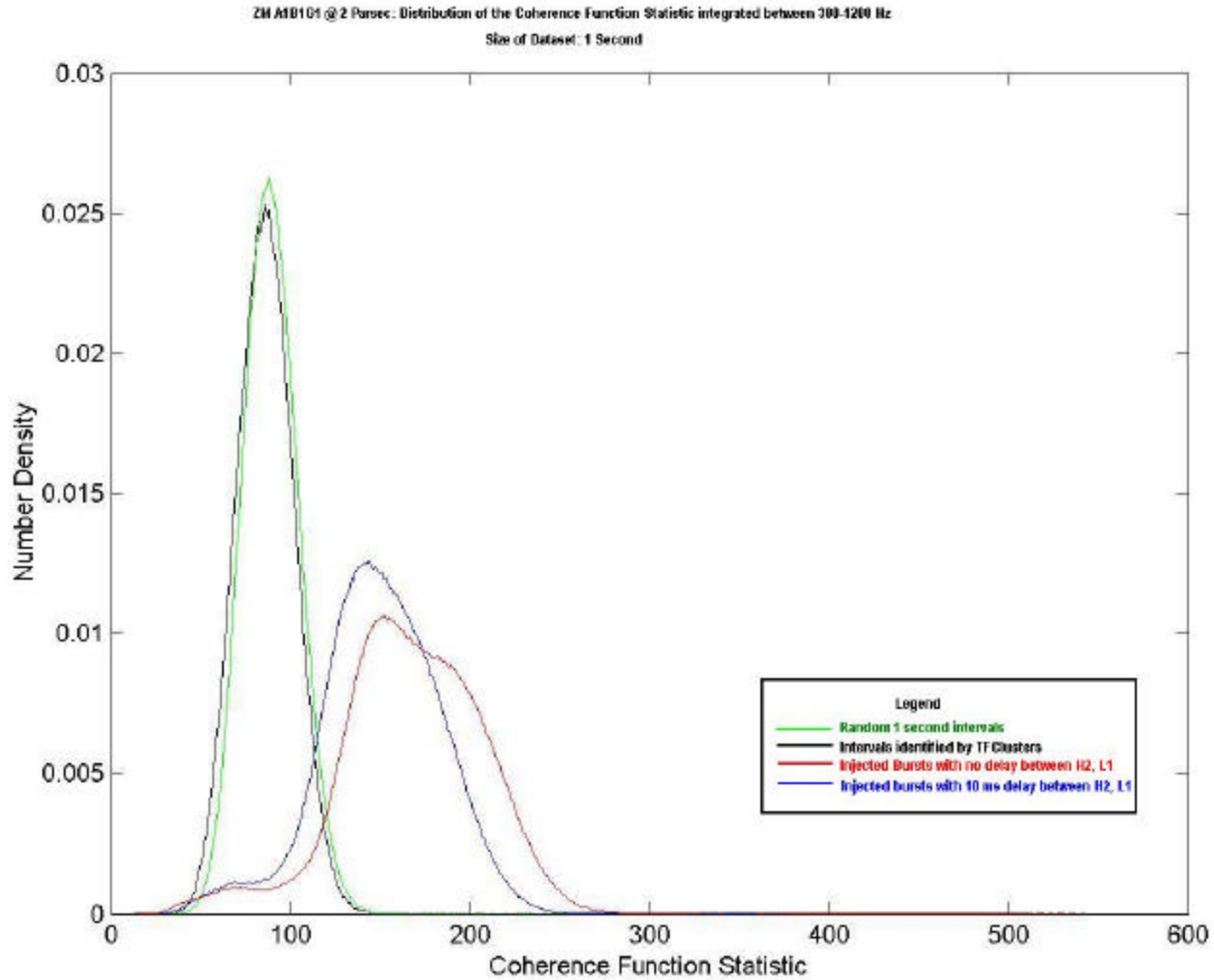


Procedure for evaluating CCS

- We take N ($N = 360$ in our case) seconds of data from L1 and H2.
- We break the N second dataset into $(N/\Delta T)$ intervals of length ΔT each ($\Delta T = 1$ second in our case).
- We then estimate the distribution of the CCS statistic on the raw data by forming $(N/\Delta T)^2$ coincidences between them and computing the CCS statistic between the ΔT second intervals thus generated.
- We histogram the results to arrive at the distribution of the CCS statistic on the raw data.
- Since the CCS statistic test will be used only on the data sections that trigger the DSOs, we perform the same analysis on the data sections between the times t and $t + \Delta T$ where t corresponds to the time identified by the DSO as the start time of the burst which triggered the DSO.
- We then inject ZM waveform signals in the $(N/\Delta T)$ intervals of length ΔT .
- The distribution of the CCS statistic after signal injection is similarly studied.
- We then inject the ZM waveform signals with a time delay of 10 ms (H2/L1 light travel time) between them and estimate the CCS statistic by the above method.



Summary of results



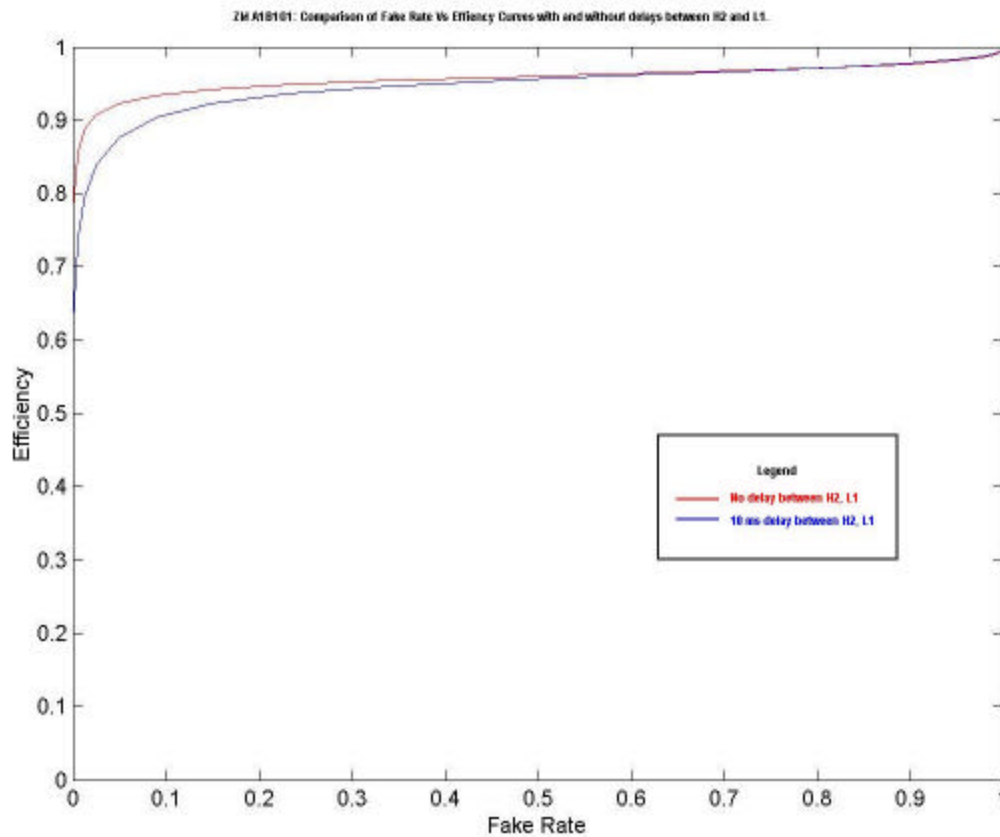


Observations

- the distribution of the CCS statistic on the data sections identified by the DSOs as containing bursts is very similar to the distribution of the CCS statistic on random ΔT seconds of data from L1 and H2.
- The peak of the CCS statistic distribution when the signal between H2, L1 is delayed by 10 ms is occurs at a slightly lower bin than the peak of the distribution when there is no delay.
- However, we can still produce an efficient value of the CCS statistic which maintains high rates of efficiency while minimizing the fake rate.



Cut on CCS. Efficiency vs fake rate reduction





Some things to be done

- Estimate the CCS between 250-1000 Hz. We expect the results to be better than the results obtained above (using 300-1000 Hz).
- Explore the dependence of the CCS on ΔT . Can we estimate ΔT to ± 10 msec or better?
- Explore other waveforms
- S1 data
- Automate, using LDAS (or DMT).