ALGORITHMS FOR THE DETECTION OF G.W. BURSTS

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We review the digital processing algorithms we have devised to estimate signal and noise parameters in a resonant g.w. detector. Signal is assumed as a broad band g.w. burst without spectral structures in the detector bandwidth, and a matched-adaptive Wiener filter is used to estimate its amplitude and arrival time up to μsec accuracy. Noise is modeled as an AR(4)MA(4) process and the 8 parameters are evaluated hourly to account for its slow non- stationarieties. A crucial point for the setup of the Wiener filter is the separation of gaussian noise from spurious excitations. We have also implemented likelihood testing of the Wiener filter performances which leads to a standard χ^2 test to discriminate candidate events from spurious ones.

A central issue of any g.w. search is the set up of data analysis procedures suitable to characterize and estimate noise sources of the detector as the extreme weakness of signals imposes their discrimination from noise at extremely low Signal to Noise Ratio (as low as SNR=3). In this communication, we present briefly the data analysis procedures for the production of candidate events, corresponding to impulsive mechanical excitation of the bar, devised for the AURIGA detector operating at the INFN National Laboratories of Legnaro, Italy. This detector starts the data taking with its final (ultracryogenic) experimental setup on June 1997. [1] The thorough study of its noise, by means of the data analysis, has been leading us to a better knowledge of the detector behavior and to a continuous upgrade of the data analysis itself. In fact, we succeed in the separation of time spans with almost gaussian noise from non-gaussian and/or strongly non-stationary ones.[2] This latter kind of noise can be further splitted into disturbances well delimited in time and with known origin (e.g. maintenance activities) and other more annoying disturbances arising from sources beyond our control. To get rid of these excess noise sources we have set up a vetoing procedure which removes the corresponding time intervals from the duty-cycle of the detector: i) the first level vetoes, set by the experimentalists, are lists of time intervals, with duration larger than 1 minute, where the detector is considered not operative due to maintenance activities or electronics malfunctioning; ii) the second level vetoes are automatically set by the on-line analysis after a test on the noise gaussianity and quasi- stationariety of chunks of filtered data. The algorithm which produces the second level vetoes basically consists in a variance estimate with the Chauvenet convergence method and a threshold on the Curtosis index. Core of the on-line data analysis is an adaptive Wiener-Kolmogorov linear filter, matched to a -like (i.e. millisecond duration) g.w. burst impinging on the detector.[3] The noise spectral density model needed to set up the Weiner filter is an AR(4)MA(4) process which works very well under the simplifying assumption that the noise is gaussian and stationary. To take into account slow drifts in the noise spectral density, which give rise to small variations of the 8 ARMA parameters, we have implemented a parameter tracking algorithm [3] which adjusts the relevant parameters until there is no residual correlation in the whitened data. This is enough to take care automatically of small corrections of the parameters and to keep the relative systematic error on SNR below 1%. Event search is a simple max-hold algorithm, which identifies the time and the amplitude of the local maxima of the filtered data within a time interval of about the reciprocal of the effective bandwidth of the system (i.e. ~ 1 second). The actual accuracy in the arrival time reconstruction of an impulsive event depends on its SNR and it is given approximately by $173\mu s/SNR$ for signals with $SNR > 20$.[4] A final goodness-of-the-fit check is performed for any candidate event by computing the residuals of the whitened data after subtracting the signal template with the estimated amplitude and time of arrival. We then apply a standard χ^2 test to reject spurious signal [5] by imposing a threshold on the reduced χ^2 of the candidate events. This threshold also guarantees a very small bias on the event amplitude estimate allowing a fair coincidence search with other g.w. detectors. While the behavior of Wiener filtering is well understood (theory and simulations with gaussian noise), validation of results in presence of a non-stationary system is still a great challenge, especially for the unbiased estimate of amplitudes and arrival times of candidate signals. To overcome these difficulties we set up an on-line Monte Carlo which adds to the acquired detector noise a large number of g.w. signals generated with the measured transfer function of the AURIGA detector. The Monte Carlo outputs are the effective probability distributions of the complete set of parameters describing impulsive g.w. signals i.e. SNR, χ^2, timing (phase and peak) errors. We are also able to estimate the (time dependent) efficiency of the AURIGA detector in recovering events above a given threshold on SNR. As an example we report here the results of the timing phase error estimate obtained superimposing 4×10^3 events with $SNR = 14$ to one month of AURIGA output. In the analysis we have excluded from the duty-cycle the first and second level vetoes. The resulting distribution $P(\varphi)$ has been fitted to the Normal probability density function: the parameters fitting procedure gives a standard deviation $\sigma_\varphi = (12.7 \pm 0.2)$ μsec with $\chi^2 = 0.9$ which is in good agreement with the theoretical prediction $\sigma_\varphi = 173/SNR = 12.4$ μsec.

References

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