An algorithm for determining the moment of occurrence of changes in the environment that are non-linear and / or non-Gaussian in nature

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POSTER

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OUTLINE

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ABSTRACT

Higher order statistical method, the fourth order cumulants, are used to remove Gaussian noise and increase SNR. Only those components of signal that are neither linear nor Gaussian are retained. These signal components usually carry information about the processes we want to analyze, such as explosions, earthquakes, meteorological phenomena, armed conflicts, nuclear tests and others. In addition, an algorithm has been developed that enables the beginning of some of the so-called processes to be determined very accurately on the basis of an individual signal, without a man in the loop. This time is commonly known as time of arrival, or ToA. If we use several spatially distributed sensors at the same time, it is possible to locate the place of occurrence of these phenomena by knowing only ToA at every spatially distributed sensor.

It should be noted that the usual cross-correlation methods are not used to determine ToA, because that implies significant data transfer from remote sensors to the CPU.

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INTRODUCTION

The fourth order cumulants are commonly used in applications for the Gaussian noise reduction of the signal and thus increase SNR.
Estimation of ToA of the wave front is resolved by algorithm supported by fourth order cumulant analysis. The ToA estimation algorithm consists of the following steps:

- ❑ De-noising of the signal is performed with the fourth order cumulant lags.
- ❑ Calculation of the variance function, $var_j(i)$, on subsets of data segment, which length is changing from 1 to N_{seg}, according following equation:

$$\mathrm{var}_j(i) = \frac{\sum_{i=1}^{i_{seg}} \left(x_j(i) - x_j\right)^2}{i_{seg\,j-1}} \begin{cases} j \in \left(1, j_{peaks}\right) \\ i_{seg} \in \left(1, N_{seg}\right) \end{cases}$$

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- Final estimate of ToA is done by analysis of the increase of *var* function.

De-noising of the signal by the fourth cumulant lags requires significant computing time, but another part of this process – estimation ToA is not time-consuming process. For instance, processor time of standard PC computer with relatively obsolete Intel Core 2 Duo, 2.93 GHz processor, in case when in signal, which length is 30 s and sampling rate 8333 Hz, and exist only one interesting event, is around 2-3 hundred milliseconds for ToA estimation.

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METHODS

Several techniques and methods have been developed for precise determination of the moment when some wave front approaches to the sensor. The most well known and most widely used are cross-correlation and beam-forming techniques and their variations. These methods and techniques are based on simultaneous measurements with several sensors placed on some mutual distances, so that the distance between them is of order few hundreds meters and even several kilometers. The downside of this way for determining ToA value is the need that all recorded signals at remote positions are transmitted to one place – CPU, where the data would be processed. The possibility of occurrence an error in data transfer is very probable, especially if this intensive data transfer is performed in conditions of interference and intentional interference (conditions in real war situations or similar).

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CTBTO
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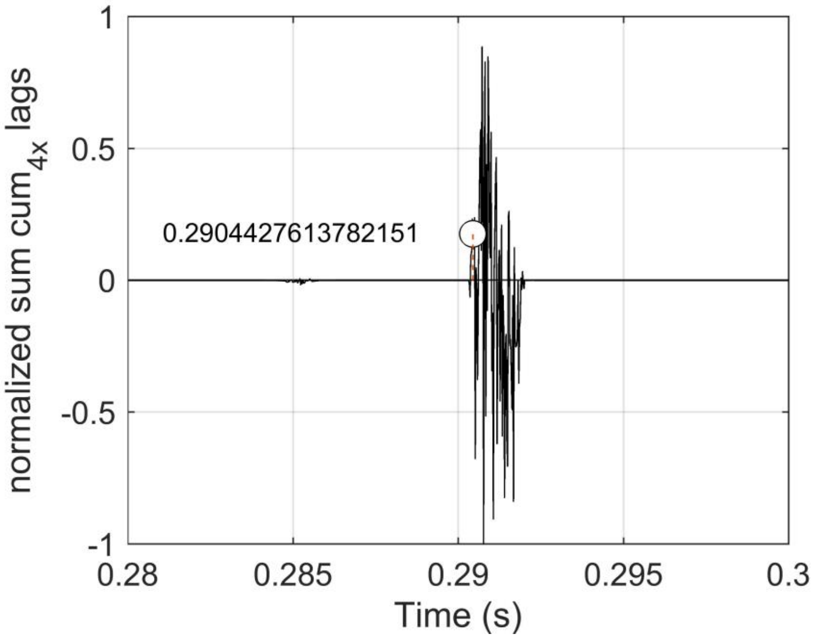
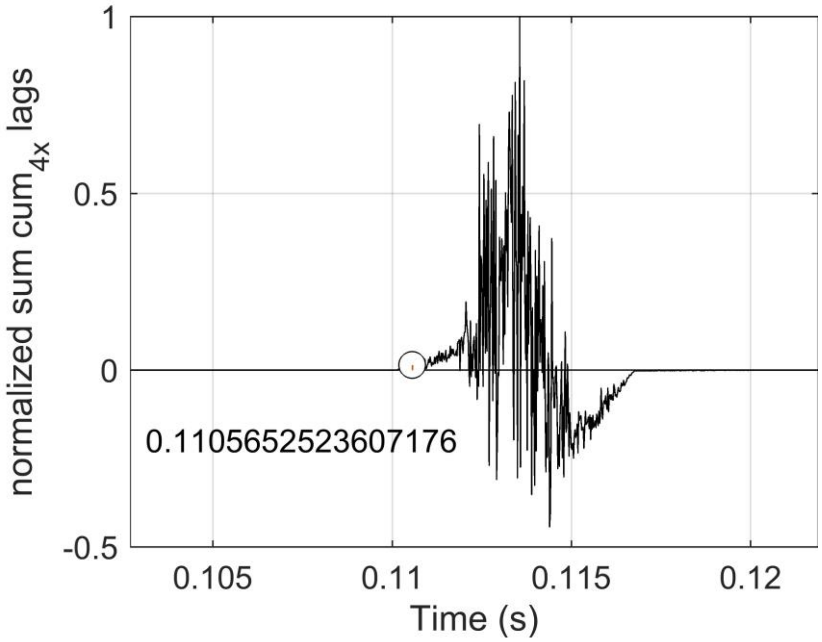
RESULTS



Smith-Wesson gun shot [1].



Depth charge explosion [1].

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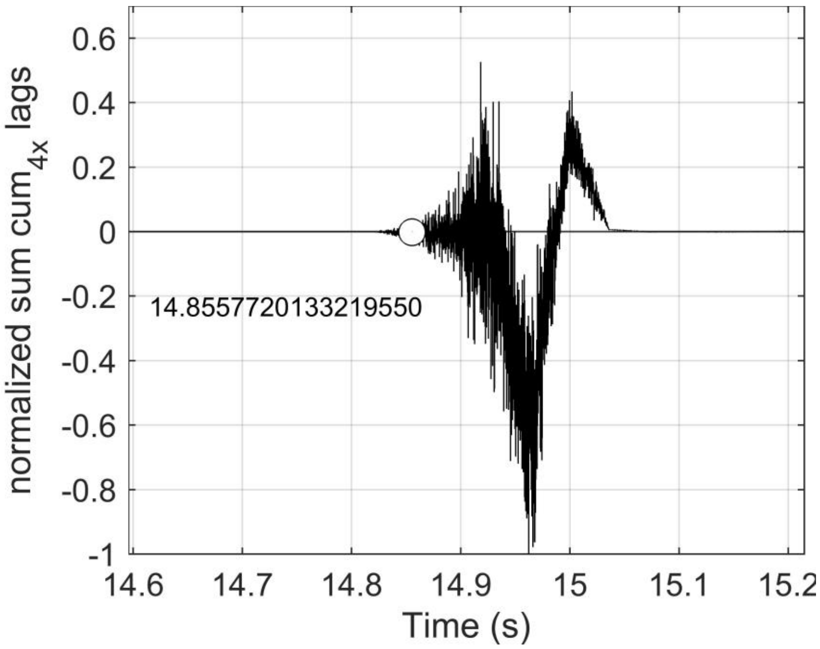
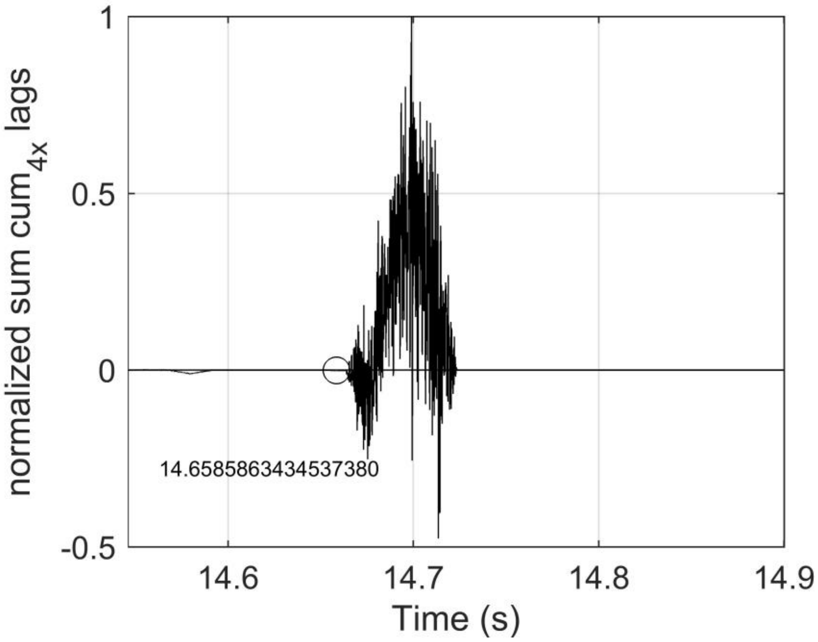


A shot from a gun [1].



A shot from a gun with silencer [1]

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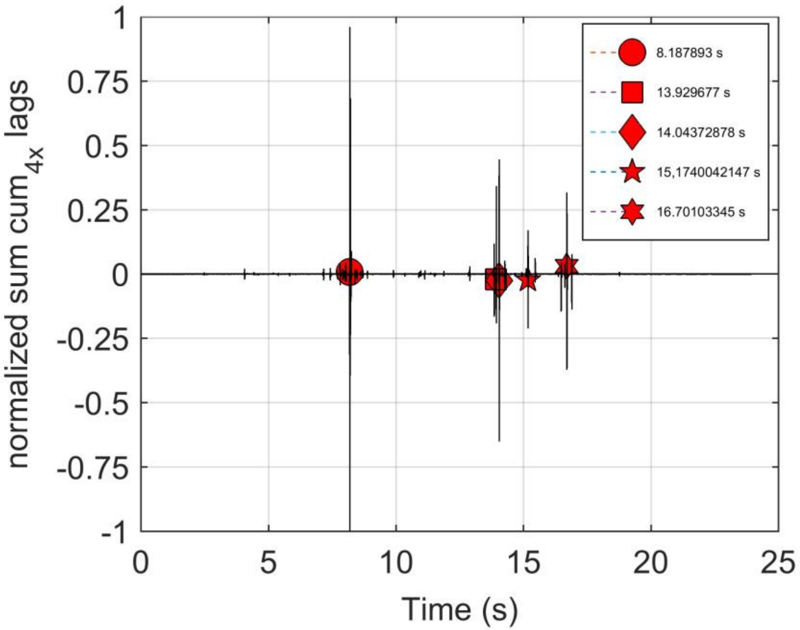
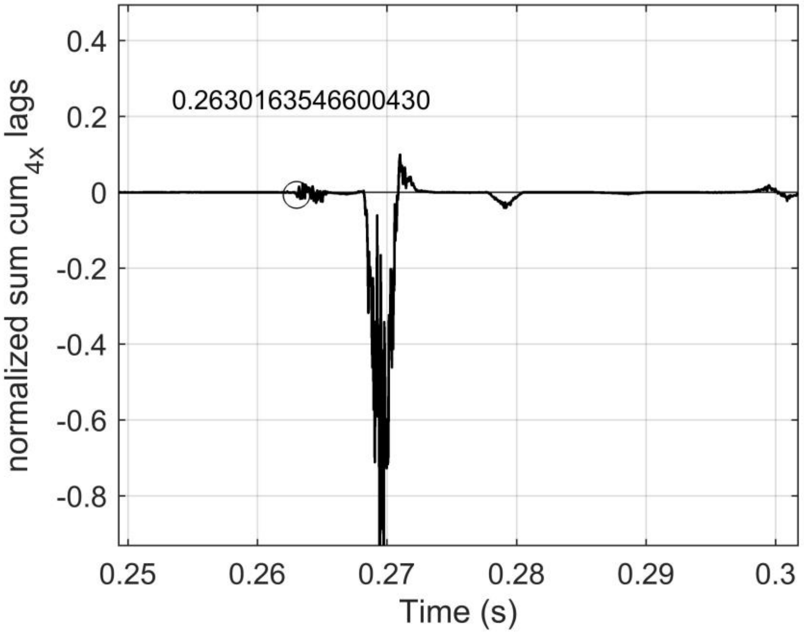


The earthquake seismic signals [1].



A sniper rifle shot. ToA of the shock wave is estimated [1].

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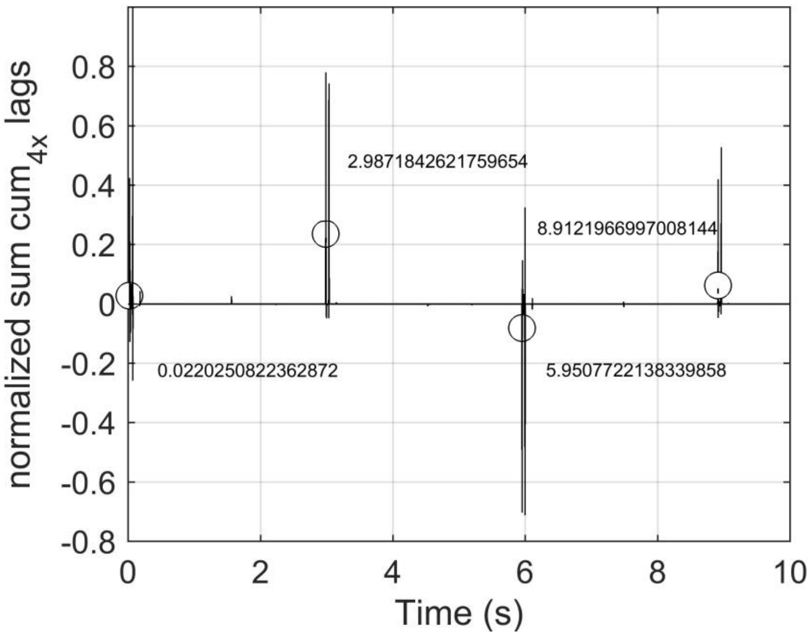
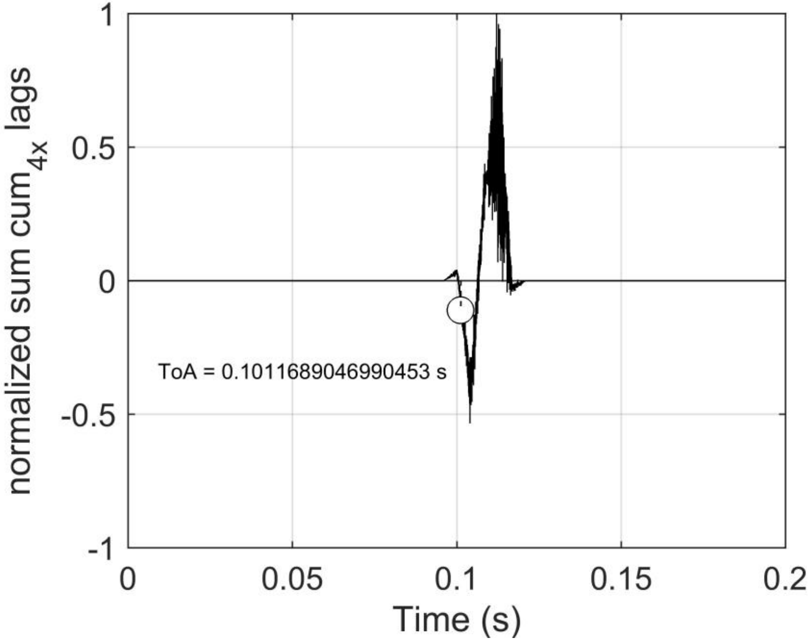


Sonar pings [1].



Grenade explosion [1].

[1] https://soundbible.com 19th May 2021.

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CONCLUSIONS

- In this work is presented an algorithm for estimationToA of the signals which originate from different sources: firing bullets from various infantry weapons, firing artillery projectiles and mines and other explosive devices on the ground and underwater, seismic phenomenon, and etc.
- The signal - to - noise ratio is improved with 4th order cumulants.
- Without the man in the loop is estimated ToA of the characteristic event.
- All of these results are achieved by analysis of a single sensor signal.
- In this way, the transfer of data from mutually distant sensors to the CPU was avoided in order to calculate ToA using cross-correlation analysis.