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INFORMATION AND COMPUTATION TECHNOLOGIES

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DENOISING OF GEOACOUSTIC EMISSION SIGNALS FROM NATURAL AND INDUSTRIAL NOISES USING SPARSE APPROXIMATION METHOD

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The paper suggests a method of denoising of geoacoustic emission signals from natural and industrial noises based on sparse approximation method. The method allowed the authors to clear geoacoustic emission pulses from spurious components.

Key words: sparse approximation, geoacoustic emission, matching pursuit, denoising

Introduction

Acoustic emissions in solid bodies are oscillations generated in the result of medium deformation in which the characteristics of pulse radiation depend on the properties of the occurring plastic processes [1]. It determines the interest to the investigation of emission phenomena to develop methods for acoustic diagnostics of mediums.

The acoustic emission of mesoscale range is generally called "geoacoustic emission"(GAE) specifying the frequency range or "mesoscale acoustic emission".

In case of moderate noises, when separate pulses are observed, GAE signals are easily distinguished at the background of noises of different nature due to their special form. However, sometimes it is difficult to determine pulses due to the presence of intensive noises of natural and industrial character. Thus, one of the subtasks of GAE signal analysis is the denoising of pulses from spurious components.

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MODEL OF GAE PULSE

In general case, the mathematical description of a GAE pulse $x(t)$ is the sum of noise $\varepsilon(t)$ and some function $s(t)$, the analytic expression of which is unknown:

$$x(t) = s(t) + \varepsilon(t), ||\varepsilon(t)|| < ||s(t)||.$$

Within the approach of sparse approximation (SA) the signal $x(t)$ can be represented in the form of a superposition of the finite (minimally possible) number of elementary functions $g_m(t)$, called atoms:

$$s(t) \approx \sum_{m=0}^{N-1} a_m g_m(t). \tag{1}$$

We should note that decomposition of (1) may include atoms, approximating signal spurious components such as spurious pulse inducing (SPI), noises and so on. Therefore, (1) can be represented as follows:

$$\begin{cases} x(t) = \sum\limits_{i=0}^{N_1-1} \alpha_i g_i(t) + \sum\limits_{j=0}^{N_2-1} \beta_j g_j(t) + R_N \\ \varepsilon(t) = \sum\limits_{j=0}^{N_2-1} \beta_j g_j(t), \\ N_1 + N_2 \to min, \end{cases} \tag{2}$$

where $g_i(t)$ are the atoms approximating the pulse, $g_j(t)$ are the atoms approximating SPI. N_1 value characterizes the complexity of pulse structure, N_2 is the pulse noisiness. The residual R_N determines the degree of correspondence of the decomposition to the real signal $x(t)$, and the following holds:

$$||\sum_{j=0}^{N_2-1} \beta_j g_j(t)|| < ||\sum_{i=0}^{N_1-1} \alpha_i g_i(t)||, ||R_N|| \ll \sum_{i=0}^{N_1-1} \alpha_i g_i(t).$$

i.e. a GAE pulse can approximately be represented in the form:

$$\begin{cases} s(t) \approx \sum\limits_{i=0}^{N_1-1} \alpha_i g_i(t) \\ N_1 \to min, \end{cases}$$

and the spurious component:

$$\varepsilon(t) = \sum_{j=0}^{N_2-1} \beta_j g_j(t).$$

As long as industrial noises of pulse nature affect the GAE signals the most, the denoising is illustrated on the example of clearing them from SPI.

METHOD OF GAE SIGNAL DENOISING

Fig. 1 shows time forms, SA, obtained by an adaptive algorithm of matching pursuit ($L_{ERR} = 5\%$) [2-5], and time-frequency presentations of signals with SPI noises.

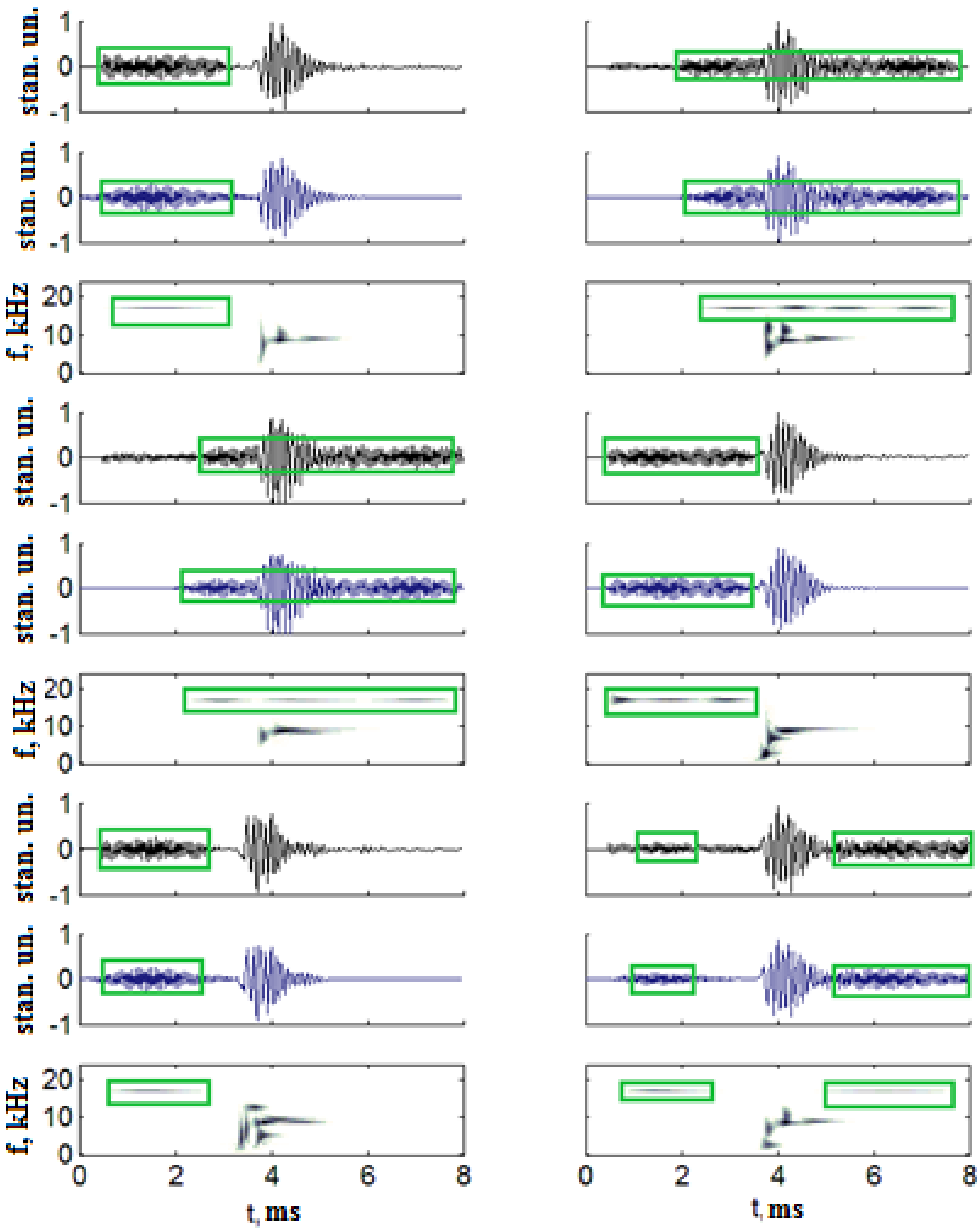

Fig. 1. SPI in GAE signals

SPI is marked by a green frame on the graphs. It is clear from the approximation graphs that SPI atoms are included into the decompositions.

To denoise the signals, it is necessary to remove the atoms describing the SPI from SA. For the chosen signals, the main difference of SPI from a "clear"signal is the carrier frequency value. SPI atom frequency is more than 15.2 kHz for the selected signals.

Fig. 2 illustrates the graphs of GAE signals minus SPI SA, SA and time-frequency representation of the signal "clear"component.

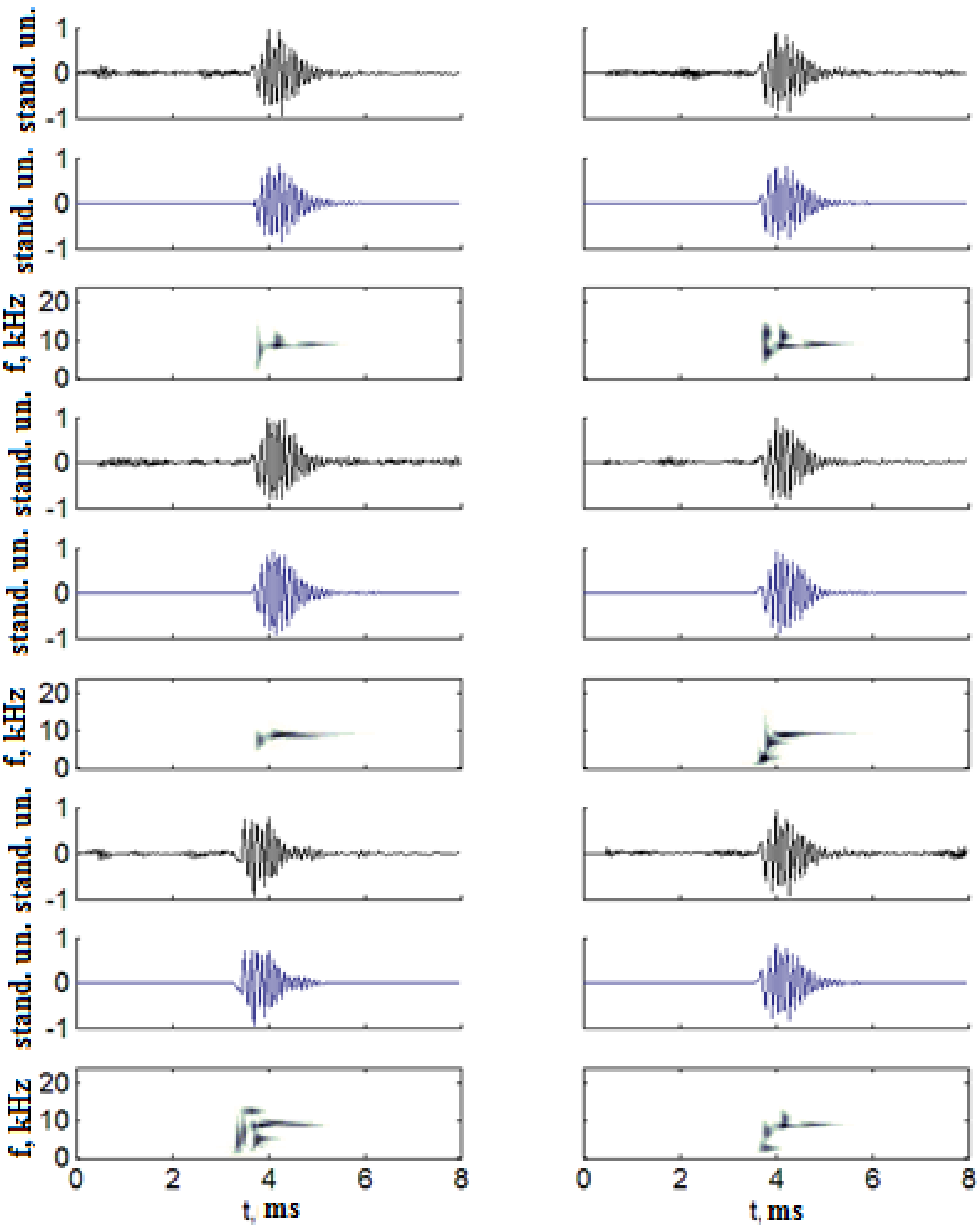

Fig. 2. GAE denoised signals

The process of denoising may be generalized for different types of noises. Fig. 3 shows a block-scheme of the algorithm for GAE signal denoising.

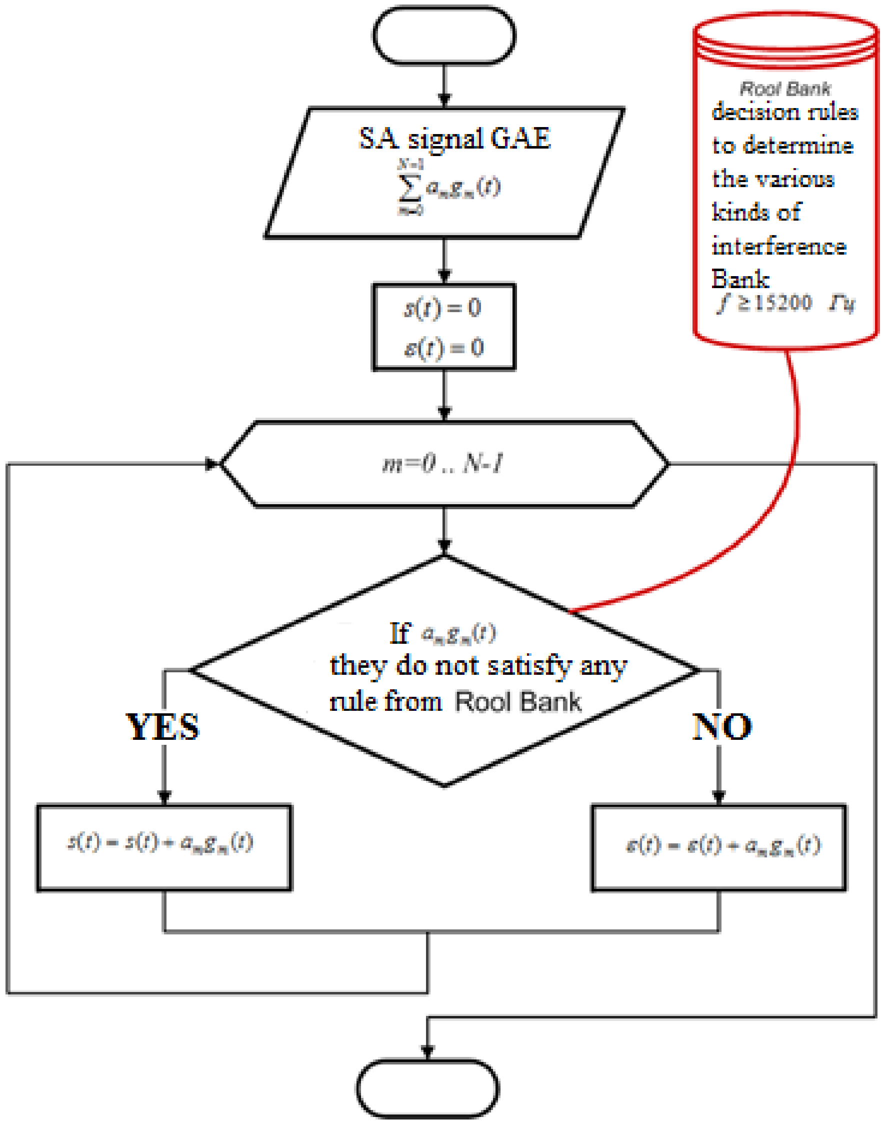

Fig. 3. Block-scheme of signal denoising on the basis of their SA

Conclusions

The advantages of the approach are the following:

1) departure from application of filters changing signal phase;

2) possibility of adaptive filtration, for example, elimination of noises having the same frequency with a "clear"signal. Other parameters but frequencies may be the criteria for selection. The decision rules may be formed for each kind of noises.

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