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THE THEORY OF ROBUST SYSTEM ANALYSIS OF SEISMIC SIGNALS

Abstract

For increasing the efficiency of the analysis of the seismic information a robust technology of system analysis is suggested. For this purpose a new robust technology forms and identifies the set of information signs of seismic signals. Robust algorithms on the base of which these sets are formed allow to consider the interferences of the seismic signals as a carrier of information. For this purpose sets of position-time and position-frequency parameters of interference and desired signal are also formed and used. These sets allow to analyze seismic oscillations which are higher than threshold level as well to analyze those that are on background level.

Introduction.

In the widely applied algorithms of signal processing the features of its formation are not taken into account sufficiently. Therefore in some cases the accuracy of determination of its spectral and correlation characteristics is not provided [1, 2, 3]. It is due to the fact that application of these algorithms supposes fulfillment of some condition [4], which hardly hold at practice. For this reason the errors which arise when we determine corresponding estimations leads to mistaken results and give makes some problems for the analysis of seismic signals. The possibility of using the interference as a carrier of information is not taken into a account.

As a result the information potential of the seismic signals is not used sufficiently. In the present paper the algorithms of formation of sets of robust information signs, which allow as much as possible, apply the information potential of seismic signals by the way of its system analysis is considered.

1. Analyses of errors of Fourier series coefficients estimations of estimations of seismic signals.

It is known [5, 6] that, total seismic signal $g(i\Delta t)$ forms from desired seismic signal $x(i\Delta t)$ and from interference $\varepsilon(i\Delta t)$, i.e. $g(i\Delta t)=x(i\Delta t)+\varepsilon(i\Delta t)$, and formulas of determination of values of coefficients a_n and b_n of Fourier series in this case have the form:

$$a_n=\frac{2}{N}\sum_{i=1}^{N}\left[\mathring{x}(i\Delta t)+\mathring{\varepsilon}(i\Delta t)\right]\cos n\omega(i\Delta t)=\frac{2}{N}\sum_{i=1}^{N^+}\left[\mathring{x}(i\Delta t)+\mathring{\varepsilon}(i\Delta t)\right]\cos n\omega(i\Delta t)+$$
$$+\frac{2}{N}\sum_{i=1}^{N^-}\left[\mathring{x}(i\Delta t)+\mathring{\varepsilon}(i\Delta t)\right]\cos n\omega(i\Delta t), \tag{1}$$

$$b_n = \frac{2}{N}\sum_{i=1}^{N}\left[\overset{\circ}{x}(i\Delta t)+\overset{\circ}{\varepsilon}(i\Delta t)\right]\sin n\omega(i\Delta t) = \frac{2}{N}\sum_{i=1}^{N^+}\left[\overset{\circ}{x}(i\Delta t)+\overset{\circ}{\varepsilon}(i\Delta t)\right]\sin n\omega(i\Delta t) + \\ + \frac{2}{N}\sum_{i=1}^{N^-}\left[\overset{\circ}{x}(i\Delta t)+\overset{\circ}{\varepsilon}(i\Delta t)\right]\sin n\omega(i\Delta t)\,, \quad (2)$$

where $\overset{\circ}{x}(i\Delta t)$ and $\overset{\circ}{\varepsilon}(i\Delta t)$ are centralized desired seismic signal and interference with mathematical expectation equal to zero, correspondingly, Δt is the step of discretezation; $i=1,...,N$ $\omega = 2\pi/T$; $n=1,2,...$.

At the practice the calculation of desired estimations of seismic signal with the help of formulas (1) and (2) gives great errors due to non-equality of the sum of positive N^+ and negative N^- errors of pair productions $\left[\overset{\circ}{x}(i\Delta t)+\overset{\circ}{\varepsilon}(i\Delta t)\right]\cos n\omega(i\Delta t)$ and $\left[\overset{\circ}{x}(i\Delta t)+\overset{\circ}{\varepsilon}(i\Delta t)\right]\sin \omega(i\Delta t)$ and its difference is error of obtained estimations [6]:

$$\lambda_{a_n} = \frac{2}{N}\sum_{i=1}^{N^+}\overset{\circ}{\varepsilon}(i\Delta t)\cos n\omega(i\Delta t) - \frac{2}{N}\sum_{i=1}^{N^-}\overset{\circ}{\varepsilon}(i\Delta t)\cos n\omega(i\Delta t)\,; \quad (3)$$

$$\lambda_{b_n} = \frac{2}{N}\sum_{i=1}^{N^+}\overset{\circ}{\varepsilon}(i\Delta t)\sin n\omega(i\Delta t) - \frac{2}{N}\sum_{i=1}^{N^-}\overset{\circ}{\varepsilon}(i\Delta t)\sin n\omega(i\Delta t)\,. \quad (4)$$

Therefore the results of spectral analysis of seismic signals in some cases are unsuitable.

The algorithms of correlation analysis of seismic signals also insufficiently considered the influence of interference on the result of processing the seismic signals.

2. The algorithms of determination of the estimations of dispersion of interference and robust estimations of Fourier series coefficients.

The carried out investigations [3, 4] have showed, that for robust analysis of real signals, at first, it is necessary to determine estimation of dispersion D_ε of interference $\varepsilon(i\Delta t)$. For this purpose we use the expression:

$$D_\varepsilon = \sigma^2(\varepsilon) \approx \frac{1}{N}\sum_{i=1}^{N}\left(\overset{\circ}{g}{}^2(i\Delta t) + \overset{\circ}{g}(i\Delta t)\overset{\circ}{g}((i+2)\Delta t) - 2\overset{\circ}{g}(i\Delta t)\overset{\circ}{g}((i+1)\Delta t)\right), \quad (5)$$

where $\overset{\circ}{g}(i\Delta t)$ is total centralized seismic signal, which consists of desired seismic signal $\varepsilon(i\Delta t)$ with mathematical expectation, approximately zero $m_\varepsilon \approx 0$; $i=\overline{1,N}$.

As the algorithms of spectral analyses in seismology are widely applied, and, taking into account, that above-mentioned shortages occures, it is obvious that there is the expedience of application of technology of robust spectral analysis, which is represented as aggregate of sequence of following procedures:

1) in realizing traditional algorithms in the process of calculation of sum $\sum_{i=1}^{N}\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)$ the mean value of productions $\Pi = \overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}$ and mean

values of positive $\Pi^{+}=\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{+}$ and negative $\Pi^{-}=\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{-}$ products, and also its quantities, i.e. N, N^{+} и N^{-} are determined;

2) the value of arithmetic mean with respect to relative error of samples of the seismic signals $\overline{\lambda}_{REL}$ determines by formula:

$$\overline{\lambda}_{REL}=\frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[\overset{\circ}{g}^{2}(i\Delta t)+\overset{\circ}{g}(i\Delta t)\overset{\circ}{g}((i+2)\Delta t)-2\overset{\circ}{g}(i\Delta t)\overset{\circ}{g}((i+1)\Delta t)\right]}}{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\overset{\circ}{g}^{2}(i\Delta t)}};\qquad (6)$$

3) conditions $N^{+}=N^{-}$ and $\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{+}=\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{-}$, are verified, and in case of validity it is recommended to use traditional algorithms;

4) for fulfillment of conditions $N^{+}\neq N^{-}$ and $\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{+}=$ $=\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{-}$, the formulas for determination of robust estimations a_n^R and b_n^R are applied in the form:

$$a_n^R=\frac{2}{N}\left\{\sum_{i=1}^{N}\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)-\left(N_{a_n}^{+}-N_{a_n}^{-}\right)\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}\right\},\qquad (7)$$

$$b_n^R=\frac{2}{N}\left\{\sum_{i=1}^{N}\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)-\left(N_{b_n}^{+}-N_{b_n}^{-}\right)\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)}\right\};\qquad (8)$$

5) for fulfillment of conditions $N^{+}>N^{-}$ and $\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{+-}$ $\neq\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}$, estimations a_n^R and b_n^R are determined by formulas:

$$a_n^R=\frac{2}{N}\left\{\sum_{i=1}^{N}\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)-\frac{1}{2}\left[N-\left(N_{a_n}^{+}-N_{a_n}^{-}\right)\right]\left[\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{+}-\right.\right.$$
$$\left.\left.-\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{-}\right]-\left(N_{a_n}^{+}-N_{a_n}^{-}\right)\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{+}\right\},\qquad (9)$$

$$b_n^R=\frac{2}{N}\left\{\sum_{i=1}^{N}\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)-\frac{1}{2}\left[N-\left(N_{b_n}^{+}-N_{b_n}^{-}\right)\right]\left[\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)}^{+}-\right.\right.$$
$$\left.\left.-\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)}^{-}\right]-\left(N_{b_n}^{+}-N_{b_n}^{-}\right)\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)}^{+}\right\};\qquad (10)$$

6) if $N^{+}<N^{-}$ and $\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{+}\neq\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{-}$ takes place, then estimations a_n^R and b_n^R are determined by expressions:

$$a_n^R=\frac{2}{N}\left\{\sum_{i=1}^{N}\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)-\frac{1}{2}\left[N-\left(N_{a_n}^{-}-N_{a_n}^{+}\right)\right]\left[\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{+}-\right.\right.$$
$$\left.\left.-\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{-}\right]-\left(N_{a_n}^{-}-N_{a_n}^{+}\right)\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{-}\right\}, \tag{11}$$

$$b_n^R=\frac{2}{N}\left\{\sum_{i=1}^{N}\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)-\frac{1}{2}\left[N-\left(N_{b_n}^{-}-N_{b_n}^{+}\right)\right]\left[\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)}^{+}-\right.\right.$$
$$\left.\left.-\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)}^{-}\right]-\left(N_{b_n}^{-}-N_{b_n}^{+}\right)\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)}^{-}\right\}; \tag{12}$$

7) for fulfillment of conditions $N^{+}=N^{-}$ and $\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{+}\neq$ $\neq\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{-}$, a_n^R and b_n^R are determined by formulas:

$$a_n^R=\frac{2}{N}\left\{\sum_{i=1}^{N}\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)-\frac{1}{2}N\left[\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega\omega(i\Delta t)}^{+}-\right.\right.$$
$$\left.\left.-\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)}^{-}\right]\right\}, \tag{13}$$

$$b_n^R=\frac{2}{N}\left\{\sum_{i=1}^{N}\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)-\frac{1}{2}N\left[\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)}^{+}-\right.\right.$$
$$\left.\left.--\overline{\lambda}_{REL}\overline{\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)}^{-}\right]\right\}; \tag{14}$$

8) the described procedure, except the second item, in determining robust estimations of coefficients of Fourier series for all cosinusoids and sinusoids is repeated. In formulas (7)-(14) the quantities of which subtracts from sums $\sum_{i=1}^{N}\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)$ and $\sum_{i=1}^{N}\overset{\circ}{g}(i\Delta t)\sin n\omega(i\Delta t)$ are represented as quantities of improvement of robustness $\lambda_{a_n}^R$ and $\lambda_{b_n}^R$ of coefficients a_n and b_n correspondingly. For example, in the formula (7) $\lambda_{a_n}^R=(N_{a_n}^{+}-N_{a_n}^{-})\overline{\lambda}_{REL}\,\overset{\circ}{g}(i\Delta t)\cos n\omega(i\Delta t)$ is the quantity of improvement of robustness of coefficient a_n.

Thus, determining the dispersion of interference D_ε, the robust estimations of coefficients of Fourier series a_n and b_n, and quantities of robustness $\lambda_{a_n}^R$ and $\lambda_{b_n}^R$, we achieve a possibility of formation of sets of corresponding information signs, which for analyses of seismic information can be used for raising the level of reliability of processing of results the seismic signals.

3. Robust technology of correlation analysis of seismic signals.

Taking into account, that above mentioned shortages of algorithms of spectral analyses take place determining another statistic characteristics, the robust technology of correlation analysis of seismic signals is showed below, which is represented as sequence of following actions:

1) by the help of formulas

$$R_{\overset{\circ}{g}\overset{\circ}{g}}(\mu)=\frac{1}{n}\sum_{i=1}^{n}\overset{\circ}{g}(i\Delta t)\overset{\circ}{g}((i+\mu)\Delta t), \tag{15}$$

$$R_{gg}(\mu)=\frac{1}{n}\sum_{i=1}^{n}g(i\Delta t)g((i+\mu)\Delta t) \tag{16}$$

the correlation function of centralized $\overset{\circ}{g}(i\Delta t)$ and non-centralized $g(i\Delta t)$ seismic signals is determined;

2) mean microerror $\langle\Delta\lambda(\mu=1)\rangle$ of one product $\overset{\circ}{g}(i\Delta t)\overset{\circ}{g}((i+1)\Delta t)$ is determined by formula:

$$\langle\Delta\lambda(\mu=1)\rangle=\left[1/n^{-}(\mu=1)\right]\lambda(\mu=1), \tag{17}$$

where $n^{-}(\mu=1)$ is quantity of products $\overset{\circ}{g}(i\Delta t)\overset{\circ}{g}((i+1)\Delta t)$ with negative sign, and $\lambda(\mu=1)$ is determined by formula:

$$\lambda(\mu=1)=\left|R_{gg}(\mu=1)-R_{\overset{\circ}{g}\overset{\circ}{g}}(\mu=1)\right|; \tag{18}$$

3) the quantity of improvement of robustness is determined with the help of expression:

$$\lambda^{Rr}_{\overset{\circ}{g}\overset{\circ}{g}}(\mu)\approx\left[n^{+}(\mu)-n^{-}(\mu)\right]\langle\Delta\lambda(\mu=1)\rangle, \tag{19}$$

where $n^{+}(\mu)$ and $n^{-}(\mu)$ are quantities of products $\overset{\circ}{g}(i\Delta t)\overset{\circ}{g}((i+1)\Delta t)$ correspondingly with positive and negative signs; n^{+} and n^{-} are quantities of positive and negative microerrors respectively;

4) by formula

$$R^{R}_{\overset{\circ}{g}\overset{\circ}{g}}(\mu)=\begin{cases}R_{\overset{\circ}{g}\overset{\circ}{g}}(\mu)-\left[\lambda^{R}_{\overset{\circ}{g}\overset{\circ}{g}}(\mu)+D_{\varepsilon}\right] & \text{for } \mu=0\\ R_{\overset{\circ}{g}\overset{\circ}{g}}(\mu)-\lambda^{R}_{\overset{\circ}{g}\overset{\circ}{g}}(\mu) & \text{for } \mu\neq 0\end{cases} \tag{20}$$

the result estimations of correlation functions of seismic signals are determined.

The determination of robust estimations of mutual correlation functions are realized in the same way [4].

4. Position-width-impulse method of analyses of seismic signals.

Carried out investigations has showed, that for whole application of information potential of seismic signals, we should analyze it in that period of time, when it take values more, than threshold value, as well in the period, when these values are less than threshold value, i.e. background. For this it is convenient to make analysis of seismic signals T_{kg}, F_{kg} and interference $T_{k\varepsilon}$, $F_{k\varepsilon}$ with application of methods by the following way [5]:

1) seismic signal $g(i\Delta t)$ is disintegrated into position-width-impulse signals (PWIS) $g_k(i\Delta t)$ with the help of following algorithm:

$$q_k(i\Delta t)=\begin{cases}1 \text{ for } g_{rem(k)}(i\Delta t)\geq \Delta g\cdot 2^k\ ,\\ 0 \text{ for } g_{rem(k)}(i\Delta t)< \Delta g\cdot 2^k\ ;\end{cases} \quad (21)$$

$$g_{rem(k)}(i\Delta t)=g_k(i\Delta t)-\left[q_{k+1}(i\Delta t)+q_{k+2}(i\Delta t)+\cdots+q_{(n-1)}(i\Delta t)\right], \quad (22)$$

where $g(i\Delta t)>2^n$; $g_{rem(n-1)}(i\Delta t)=g(i\Delta t)$; $n\geq\log\frac{g_{\max}}{\Delta g}$; $k=n-1,n-2,...,1,0$; Δg is step of quantification by level; Δt is step of discretezation.

2) position time T_k and position- frequent F_k parameters of PWIS for enough time period of observation are determined as mean values of zero and unit half-periods $g_k(i\Delta t)$ by formula:

$$<T_k>=<T_{k_1}>+<T_{k_0}>,\ F_k=\frac{1}{T_k}, \quad (23)$$

where $<T_{k_1}>=\frac{1}{\gamma}\sum_{j=1}^{\gamma}T_{k_{1j}}$, $<T_{k_0}>=\frac{1}{\gamma}\sum_{j=1}^{\gamma}T_{k_{0j}}$.

Here γ is quantity of unit and zero half-periods of PWIS for time of observation; j are order numbers of signals of PWIS q_k $^{\text{th}}$ position; $T_{k1_1},T_{k0_1},T_{k1_2},\ldots$ corresponds to time intervals, when condition $q_k(i\Delta t)=2^k(\Delta g=1)$; $T_{k0_1},T_{k0_{2t}},T_{k0_3},\ldots$ corresponds to the time intervals when condition $q_k(i\Delta t)=2^k(\Delta g=0)$.

3) position-time T_{kg} and position-frequent F_{kg} of parameters of PPDS $q_k(i\Delta t)$ of desired seismic signal are determined by the help of PPDS $q_k(i\Delta t)$, for which inequality $|q_k(i\Delta t)|>\sqrt{D_\varepsilon}$.

4) position-time and position-frequent $T_{k\varepsilon}$, $F_{k\varepsilon}$ parameters of noises of seismic signal are determined by the help of PWIS $q_k(i\Delta t)$, for which inequality $|q_k(i\Delta t)|<\sqrt{D_\varepsilon}$ holds.

By obtained values of T_{kg} and $T_{k\varepsilon}$, and also F_{kg} and $F_{k\varepsilon}$ of seismic signal and of interference, we form set of corresponding information signs.

5. Formation of sets of robust information signs of seismic signals.

It is obvious, that increasing of efficiency of application of information potential of seismic signals can be done with the help of system analysis of sets of above-mentioned information signs. Suppose, that on seismic active area with length 300 km and width 300 km, on abscess, as well as ordinate between equal spaces $S_1=S_2=...=S_9$, there are 9 seismic stations $C_1,C_2,...,C_9$ and its seismic signals processed with the help of telemetric system with application of considered algorithms (5-23).

In forming a sets of information signs dispersions W_D by obtained results of seismic information one can use the dispersions of seismic signals D_{g_c}, as well as dispersion of its noises D_{ε_c}, and also ratio of noise dispersion to seismic signal dispersion $\frac{D_{\varepsilon_c}}{D_{g_c}}$:

$$W_D^R = \begin{Bmatrix} D_{\varepsilon_{c1}}, D_{\varepsilon_{c2}}, \ldots, D_{\varepsilon_{c9}} \\ D_{g_{c1}}, D_{g_{c2}}, \ldots, D_{g_{c9}} \\ \frac{D_{\varepsilon_{c1}}}{D_{g_{c1}}}, \frac{D_{\varepsilon_{c2}}}{D_{g_{c2}}}, \ldots, \frac{D_{\varepsilon_{c9}}}{D_{g_{c9}}} \end{Bmatrix} \tag{24}$$

By the help of algorithms (7)-(14) according to robust estimations of coefficients of Fourier series of seismic signals the set of information signs is formed:

$$W_{ab}^R = \begin{Bmatrix} a_{11}^R b_{11}^R & a_{12}^R b_{12}^R & \cdots & a_{19}^R b_{19}^R \\ a_{21}^R b_{21}^R & a_{12}^R b_{12}^R & \cdots & a_{29}^R b_{29}^R \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1}^R b_{n1}^R & a_{n2}^R b_{n2}^R & \cdots & a_{n9}^R b_{n9}^R \end{Bmatrix}, \tag{25}$$

where $a_{11}^R b_{11}^R, a_{12}^R b_{12}^R, \ldots, a_{n1}^R b_{n1}^R, \ldots, a_{n9}^R b_{n9}^R$ are robust estimations of coefficients of Fourier series of 1st, 2nd,…, 9th seismic signals.

According to quantities of improving the robust λ_a^R and λ_b^R one can also form set:

$$W_{\lambda_{ab}^R}^R = \begin{Bmatrix} \lambda_{a11}^R \lambda_{b11}^R \ \lambda_{a12}^R \lambda_{b12}^R \ \ldots \ \lambda_{a19}^R \lambda_{b19}^R \\ \lambda_{a21}^R \lambda_{b11}^R \ \lambda_{a12}^R \lambda_{b22}^R \ \ldots \ \lambda_{a29}^R \lambda_{b29}^R \\ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \\ \lambda_{an1}^R \lambda_{bn1}^R \ \lambda_{an2}^R \lambda_{bn2}^R \ \ldots \ \lambda_{an9}^R \lambda_{bn9}^R \end{Bmatrix}. \tag{26}$$

According the result of estimations of mutual correlation functions of seismic signals by formulas (15)-(20), the set is formed:

$$W_R^R = \begin{Bmatrix} R_{12}^R R_{13}^R \ \ldots \ R_{19}^R \\ R_{21}^R R_{23}^R \ \ldots \ R_{29}^R \\ \ldots \ \ldots \ \ldots \ \ldots \\ R_{91}^R R_{92}^R \ \ldots \ R_{89}^R \end{Bmatrix}. \tag{27}$$

By obtained estimations of quantities of improvement of robust mutual correlation functions of seismic signals of different seismic stations another set of information signs is formed:

$$W_{\lambda_s^R}^R = \begin{Bmatrix} \lambda_{12}^R & \lambda_{13}^R & \ldots & \lambda_{19}^R \\ \lambda_{21}^R & \lambda_{23}^R & \ldots & \lambda_{29}^R \\ \ldots & \ldots & \ldots & \ldots \\ \lambda_{91}^R & \lambda_{92}^R & \ldots & \lambda_{89}^R \end{Bmatrix}. \tag{28}$$

Then the set from robust estimations of autocorrelation functions of seismic signals is formed:

$$W^R_{R_g} = \left\{R^R_{c1}, R^R_{c2}, R^R_{c3}, ..., R^R_{c9}\right\}. \qquad (29)$$

From obtained quantities of improvement of robust λ^R_g of autocorrelation functions of seismic signals, also the set can be formed:

$$W^R_{\lambda_{gg}} = \left\{\lambda^R_{c1}, \lambda^R_{c2}, ..., \lambda^R_{c9}\right\}. \qquad (30)$$

On the base of position-pulse-duration analysis of seismic signals (21)-(23) the position-time and position-frequent parameters of desired seismic signal T^C_{kg}, F^C_{kg} and its noises $T^C_{k\varepsilon}$, $F^C_{k\varepsilon}$ are determined, from values of which the corresponding sets of information signs is formed:

$$W_{T_{kg}F_{kg}} = \begin{Bmatrix} T^{C_1}_{kgq_o} F^{C_1}_{kgq_o} & T^{C_2}_{kgq_o} F^{C_2}_{kgq_o} & \dots & T^{C_9}_{kgq_o} F^{C_9}_{kgq_o} \\ \dots & \dots & \dots & \dots \\ T^{C_1}_{kgq_o} F^{C_1}_{kgq_o} & T^{C_2}_{kgq_o} F^{C_2}_{kgq_o} & \dots & T^{C_9}_{kgq_o} F^{C_9}_{kgq_o} \end{Bmatrix}, \qquad (31)$$

$$W_{T_{k\varepsilon}F_{k\varepsilon}} = \begin{Bmatrix} T^{C_1}_{k\varepsilon q_m} F^{C_1}_{k\varepsilon q_m} & T^{C_2}_{k\varepsilon q_m} F^{C_2}_{k\varepsilon q_m} & \dots & T^{C_9}_{k\varepsilon q_m} F^{C_9}_{k\varepsilon q_m} \\ \dots & \dots & \dots & \dots \\ T^{C_1}_{k\varepsilon q_m} F^{C_1}_{k\varepsilon q_m} & T^{C_2}_{k\varepsilon q_m} F^{C_2}_{k\varepsilon q_m} & \dots & T^{C_9}_{k\varepsilon q_m} F^{C_9}_{k\varepsilon q_m} \end{Bmatrix}. \qquad (32)$$

Moreover, from set (27) we can determine the set of time shifts W_τ between these signals in the form:

$$W_\tau = \begin{vmatrix} \tau_{12}\, \tau_{13} \dots \tau_{19} \\ \tau_{21}\, \tau_{23} \dots \tau_{29} \\ \vdots \ \vdots \ \vdots \ \vdots \\ \tau_{91}\, \tau_{92} \dots \tau_{89} \end{vmatrix}. \qquad (33)$$

Knowing the sets of quantities of distance $\{S_{12}, S_{13}, ..., S_{19}, ..., S_{89}\}$ between seismic receivers and set of time shifts between seismic signals W_τ, we can by formula $V_{ij} = \dfrac{S_{ij}}{\tau_{ij}}$ determine the set of velocities of distribution of seismic oscillations between seismic receivers in the form:

$$W_v = \begin{vmatrix} V_{12}\, V_{13} \dots & V_{19} \\ V_{21}\, V_{23} \dots & V_{29} \\ \vdots \quad \vdots \ \vdots & \vdots \\ V_{91}\, V_{92} \dots & V_{89} \end{vmatrix}. \qquad (34)$$

6. Coclusions.

Obtained robust sets of information signs (25)-(34) allow to make system analysis of seismic signals in the case, when seismic oscillations have the value more than threshold level, as well as in the case, when they are on the background level.

Due to this fact the possibility of efficient application of information potential of seismic oscillations, obtained from seismic receivers, appears.

For example, analyzing mentioned sets of information signs (24) we can conclude, that with increasing of seismic activity of controlled area, the estimations of quantities of dispersions of seismic signals, noises and its relations, will change. Moreover, these quantities depending on distance to epicentre will variates by different way.

Near epicentre the dispersions of seismic signals and its noises will be essensially different from the same estimations of seismic signals, obtained from stations, situated at the far distances.

Sets (27)-(28) and sets of autocorrelation functions of seismic signals (29), for example, have essentially big level of reliability of results of analysis of seismic signals after improving of robust estimations. At normal state of seismic actively the curves of functions $R^R_{c1}, R^R_{c2}, ..., R^R_{c9}$ will be the same. After raising the seismic activity they change by different ways. Moreover, autocorrelation functions of signals from seismic receivers near the epicentre with comparission to analogous estimations of signals of far seismic stations quickly falls down, but the last have much more maximal time and the process of changing by time is essentially less.

The sets (31) and (32) allow to obtain information about position-time and position-frequent parameters of seismic signals and its noises. It is easy to show, that even slightest seismic oscillations reflects at the first turn to the elements of set (32) [5].

By the help of the sets (33) and (34) we can obtain enough efficient information signs, which allow to determine velocity, direction and epicentre of seismic oscillations.

We suppose to use considered robust algorithms and formed on its base sets of information signs combining methods and algorithms, which usually are used by corresponding services of seismic stations. The banks of data's from the sets of information signs (24)-(34) of seismic information with application of accumulated materials are created for that, and they are regular supplemented by above-mentioned corresponding estimations of seismic signals. For intellectualization of system robust analysis of seismic information, these sets are used as knowledge base, and corresponding expert system are created. The procedure of analysis leads to the following. On the base of mentioned above algorithms we determine enumerate estimations and they consequently compares with elements of sets of knowledge base. As a result we obtain a few variants of solutions, which compares with each other, and using combination of its various combinations, identification and prediction of seismic oscillations. Are made the results of solutions by various methods and its combination are presented to specialists-seismologists.

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