IDENTIFICATION OF SEISMIC SIGNALS FROM UNDERGROUND NUCLEAR EXPLOSIONS AT DPRK TEST SITE



Task of Main center of special monitoring

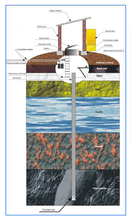
Monitoring of the nuclear tests and monitoring of the compliance of the international treaties for non-proliferation and ban of the nuclear weapon

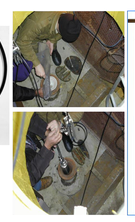
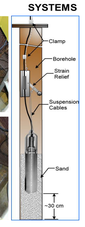
Monitoring of the earthquakes and geophysical phenomena on the territory of Ukraine and the Earth

Monitoring of the radiation environment

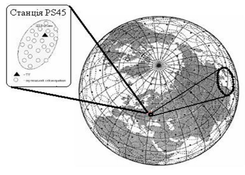
Експлуатація та обслуговування датчиків

GURALP SYSTEMS




Сейсмометр Guralp CMG-3ESPV



For the monitoring of certain areas of the globe located at teleseismic distances (Δ> 2000 km)relative to the observation sites, the most effective element of the seismic observations network of the MCSM is the Seismic Grouping System (SGS), which is included to the International Monitoring System as a PS45 seismic station.

The process of seismic signals identification from explosions at the DPRK test site includes two main stages:

1. Separating signals from explosive phenomena from the entire array of recorded seismic events occurring in the controlled area.

2. Identification of the registered seismic event as an UNE.

To solve the problem of identifying seismic signals from explosive events, a method is used that is based on differences in the amplitude of envelope signals from earthquakes and explosions as a function of frequency.

At the first stage of the implementation of this method, the normalized values of the amplitudes of the seismic envelope are calculated in the frequency range from 1 to 18 Hz:

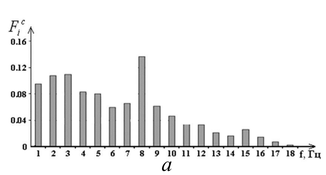
$$F_i = \frac{S_i}{\bar{S}},$$

F_i – the normalized value of the amplitude of the envelope of the wave fragment (signal or background) for the frequency i; S_i – amplitude of the envelope of the wave fragment (signal or background) for the frequency i:

$$S_i = \sum_{k=1}^{N} G_k,$$

N – duration of the signal (background) sample. Estimation of the total energy of the wave fragment (signal or background section) is as follows:

$$\bar{S} = \sum_{i=1}^{18} S_i,$$



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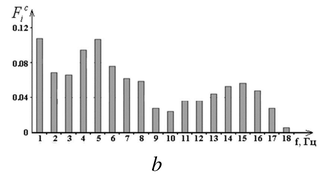


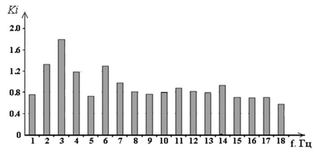
b

In order to take into account the background conditions in the area of the seismic station at the time of arrival of the seismic signal, the distribution of the amplitudes of the envelope of the wave fragment for the portion of the microseismic background preceding the seismic signal.

The next step is to determine the ratio of the amplitudes of the envelopes of seismic signals and background areas preceding them at the corresponding frequency :

$$K_i = \frac{F_i^c}{F_s^{\Phi}},$$

K_i - ratio of the amplitudes of envelopes of seismic signals and the background sections preceding them at a frequency i, F_i^c – normalized value of the envelope amplitude of a seismic signal at a frequency i; F_i^{Φ} – The normalized value of the envelope amplitude for the background section preceding the seismic signal at the frequency i.



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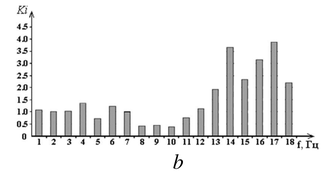


b

To obtain a numerical coefficient that unambiguously characterizes the nature of the seismic source, we find the sum of the values of K_i for frequencies i in the range 1 – 9 Hz (where the maximum values of K_i are concentrated for earthquakes) and for frequencies i in the range 10-18 Hz (where the maximum values of K_i are concentrated for explosions), after which we calculate their ratio K.

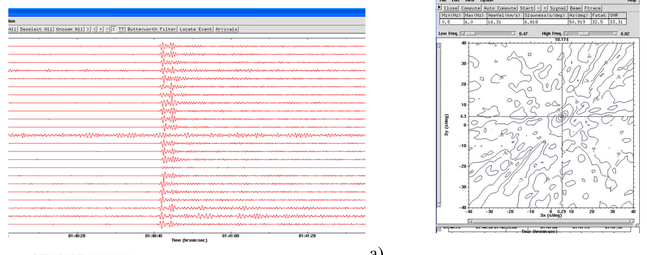
$$K = \frac{\sum_{i=10}^{18} K_i}{\sum_{i=1}^{9} K_i},$$

The decision on the nature of the source of the seismic disturbance is made on the following values: K > 1.05 - "explosion"; 0.95 < K < 1.05 - "uncertainty zone"; K < 0,95 - "earthquake".

Identification of the seismic signal from the UNE from the DPRK TS is performed by determining the degree of cross-correlation between the first arrivals of the registered seismic signal and the previously recorded signal from the UNE from the DPRK TS selected as the reference.

$$\hat{r}_{xy} = \frac{\hat{K}_{xy}}{\sqrt{\hat{D}_x \cdot \hat{D}_y}}$$

$\hat{K}_{xy}$– an estimate of the value of the correlation moment between the signals $x(t)$ and $y(t)$; $\hat{D}_x$, $\hat{D}_y$ – estimates of dispersion $x(t)$ and $y(t)$ respectively.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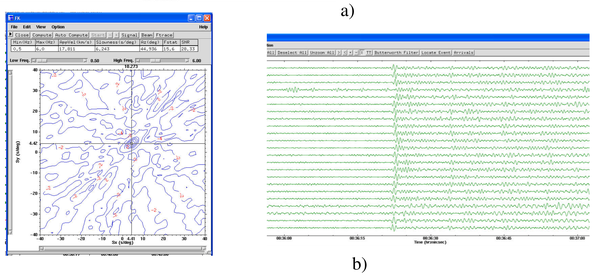
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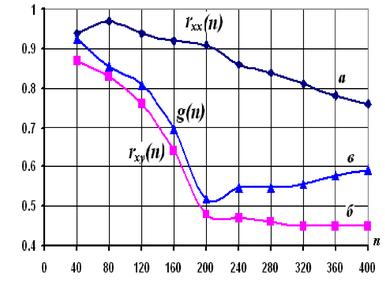
Determination of the duration of the seismic signal recording section for the implementation of the correlation schema for detecting the signal from the UNE from the DPRK TS is performed by searching for the minimum of the function of the ratio of the cross-correlation coefficients $g\ (n)$ for signals from UNEs and earthquakes.



$\hat{r}_{xx}(n)$ – cross-correlation coefficient between the reference signal and signals from DPRK TS UNE; $r_{xy}(n)$ – cross-correlation coefficient between reference signal and signals from earthquakes in region of Honshu Island.

As a reference, the signal from the UNE on 09.10.2006 was used. The cross-correlation coefficient $\hat{r}_{xx}(200)$ between the signals from DPRK TS UNE and the reference signal: 0.91 for the explosion on May 25, 2009, 0,96 for the explosion on February 12, 2013, 0.98 for the explosion on January 6, 2016 and 0,94 for the explosion on September 09, 2016.

The proposed procedures for the PS45 station allow to perform in near real-time as seismological monitoring of the DPRK TS location area as a identification of detected seismic signals.

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