STATISTICAL ASSESSMENT OF CHARACTERISTICS OF ACOUSTIC SIGNALS FROM LAND EXPLOSIONS

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ABSTRACT

The possibility of the estimation of ground explosions energy using infrasound monitoring data for 100-300 km distances is discussed. Infrasonic signals energy from ground explosions is estimated using different methods.

Keywords: infrasound, infrasonic signals sources, ground explosions

1. INTRODUCTION

To research dynamic processes and energy flows in the inner geospheres, the processes of energy redistribution and cause-effect relations in the system of interacting geospheres, as well as to study these disturbances are the task of high priority [1]. The atmospheric disturbances caused by natural sources and human activities result in different level energy flows in the geophysical environment [2, 3]. Powerful energy flows can cause the disturbance in geodynamic balance [4]. Powerful man-made and natural explosions in the atmosphere can be considered as the potential producers of such flows. In particular, the latter include the explosion of Chelyabinsk bolide, the energy release of which is (according to different estimates) from 247 to 638 kilotons in TNT equivalent [5].The energy sources related to human activity are the areas of industrial development of mineral resources and military ranges where explosive works are carried out. Such areas require special ecological attention and control.

2. EXPERIMENTAL

From March 2010 to the end of 2012 in Novosibirsk and Kemerovo regions the explosive works were carried out within the program of old ammunition utilization. The signals from ground explosions in Novosibirsk and Kemerovo regions were registered using the infrasound measuring setup of Tomsk state university. In paper [6, 7] the results of the signals study are presented. In this paper the amplitude-frequency characteristics of the infrasound signals generated by ground explosions are determined.

Using the triangulation method the directions of acoustic waves coming were determined. The directions indicated the location of explosive works. During the entire period of observation infrasound signals came from two directions. Most of the signals came from the directions coinciding with the direction from the military range in the village of Shilovo of Novosibirsk region. The second angular sector coincided with the direction from the military range in the town of Jurga in Kemerovo region. The distance from the Shilovo military range to the infrasound measuring setup in Tomsk is 254 km, the distance from Jurga military range is 96 km.

The aim of the study is to estimate the ground explosions energy for small distances (of the order of 100-300 km) propagation of infrasound signals.

In 2011 the infrasound measuring setup registered more than 1000 signals from the ground explosions. The most often registered values of the maximum amplitude of signals from peak to peak for an annual interval of time are made by 1,6 Pa (figure 1, a). The maximum amplitude of some signals from peak to peak reached 13, 5 Pa. The analysis of frequency of signals with the maximum amplitude from land explosions showed that the greatest number of signals were observed with frequencies about 0.1 Hz (figure 1, b).

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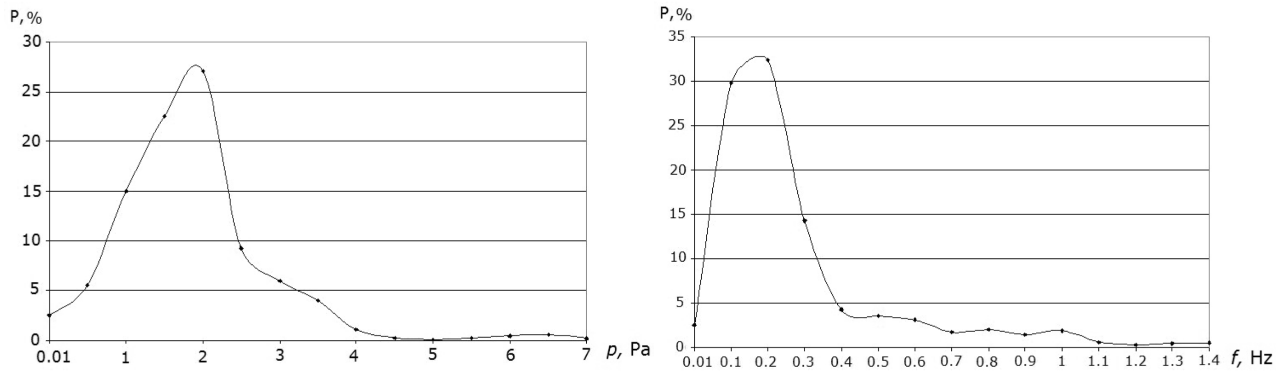
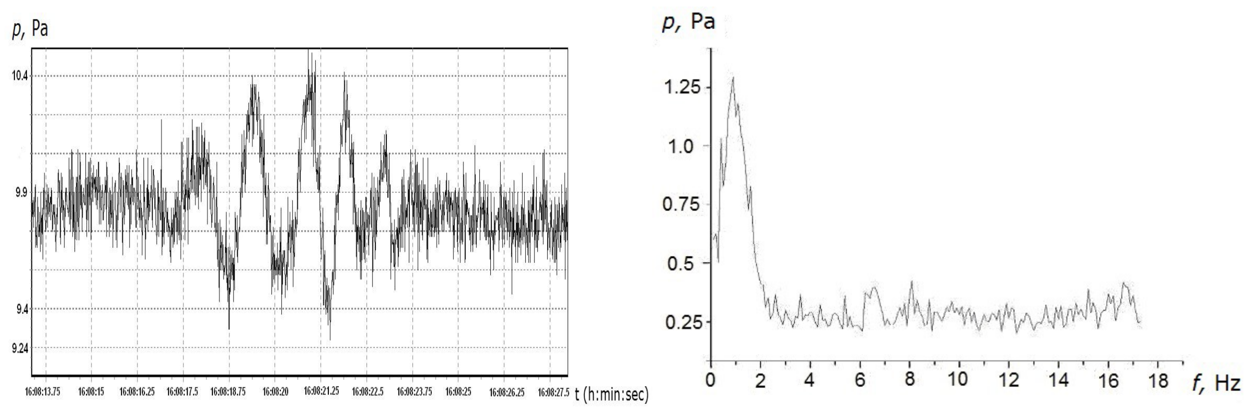


a) b)

Figure 1a. The maximum amplitudes distribution of infrasonic signals from explosions in 2011

Figure 1b. Frequencies distribution of infrasonic signals from explosions with the maximum amplitude in 2011

The temporal form for all registered signals has analog form. The signal represents the form of Zug consisting of several periods with gradually increasing and decreasing amplitude and with monotonously decreasing period (figure 1, a). The spectral analysis has showed the average range of these signals has the maximum at the frequency of 1 Hz (figure 2, b).



a) b)

Figure 2a. The temporal form of an infrasonic signal from land explosion

Figure 2b. Averaged range of infrasonic signals

Several research works have described some techniques of estimating the energy release of explosions [8]. The techniques can be divided into three groups. The first group includes the techniques in which the amplitude of a registered acoustic signal and the distance to a source are input parameters. The second group includes the techniques in which the frequency of registered signal with the maximum amplitude is an input parameter. The third group includes the techniques where the duration of a registered acoustic signal is an input parameter. It is shown above that the amplitude of registered signals at different epicentral distances depends on a wind velocity and direction at stratosphere and thermosphere altitudes, a direction to a registration point and weather conditions in a registration point. This leads to considerable variations of signal amplitudes for the source of the known power. Thus, if we apply the following ratio [8]:

$$\lg P = K + 0.33 \lg W - \lg R \tag{1}$$

where P is the pressure in Pa, W is the TNT equivalent in kT, R is the distance in km to a source (coefficient K has the value of 3.0 if to take into account that a wind direction at stratosphere altitude is perpendicular to the direction of infrasound signal propagation; K is 3.3 if a wind direction is longitudinal), that values of energy of the greatest number of signals from explosions have compounded from 0,01*10-2 кТ to 0,25*10-2 кТ (figure 3). According to the indirect data from media the amount of the destroyed ammunition in TNT equivalent is from от $5*10^{-4}$ кТ to $1,5*10^{-3}$ кТ. Undoubtedly, amplitude parameters of signals can't be the basis for the estimation techniques of explosive source energy. This is true for the third group of methods, since the duration of a registered signal depends on its amplitude parameters, to be exact, on the signal/noise parameter in a registration point.

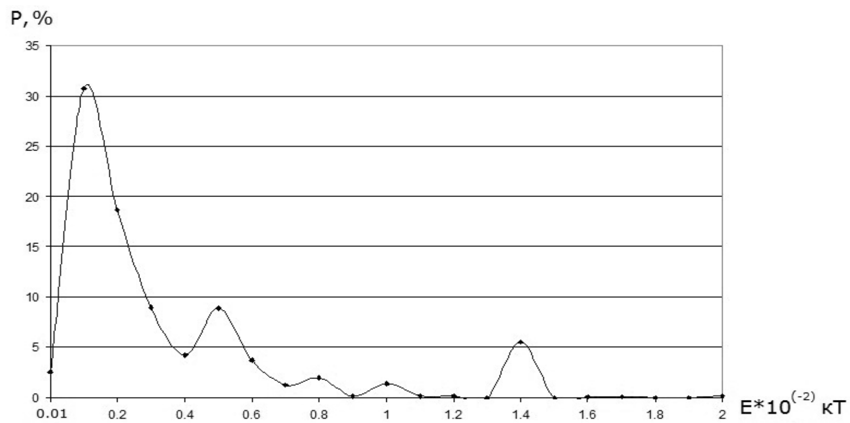


Figure 3. Values distribution of energy of the greatest number of signals from land explosions in 2011, have been calculated by estimation method inherently amplitude values of signals are used

To calculate the energy of explosive source let's use the following ratio [5]:

$$f = \frac{K_f}{2\pi \sqrt[3]{E}}, \qquad (2)$$

where E is TNT equivalent of an explosive source in kT; K_f is a proportionality coefficient, f is characteristic frequency of an acoustic signal. The coefficient K_f is considered to be equal to 1,6 at signals propagation in east-west direction. The coefficient K_f is considered to be equal to 1.2 at signals propagation in north-south direction.

Using formula (2) the infrasound signals from ground explosions were estimated. TNT equivalent of explosions was different in different months .In most cases in all months the explosion energy was equal to 0,01 *10-3кТ,.In some cases the explosion energy was 0,2*10-3кТ and 1,51*10-3кТ (figure 4). One can observe the agreement between the data on the amount of destroyed ammunition obtained by using this method and the data from media.

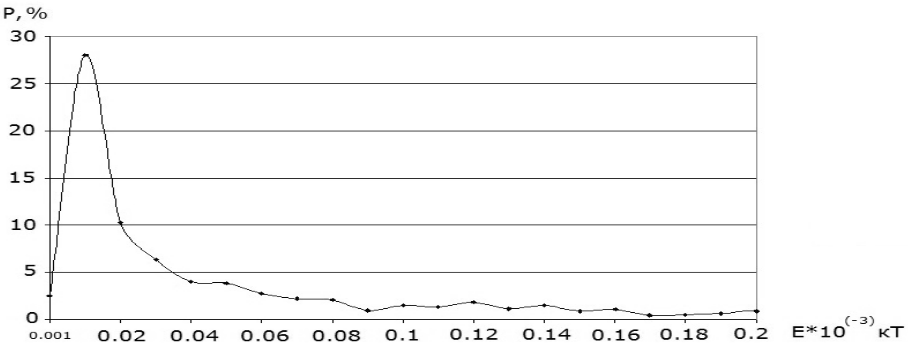
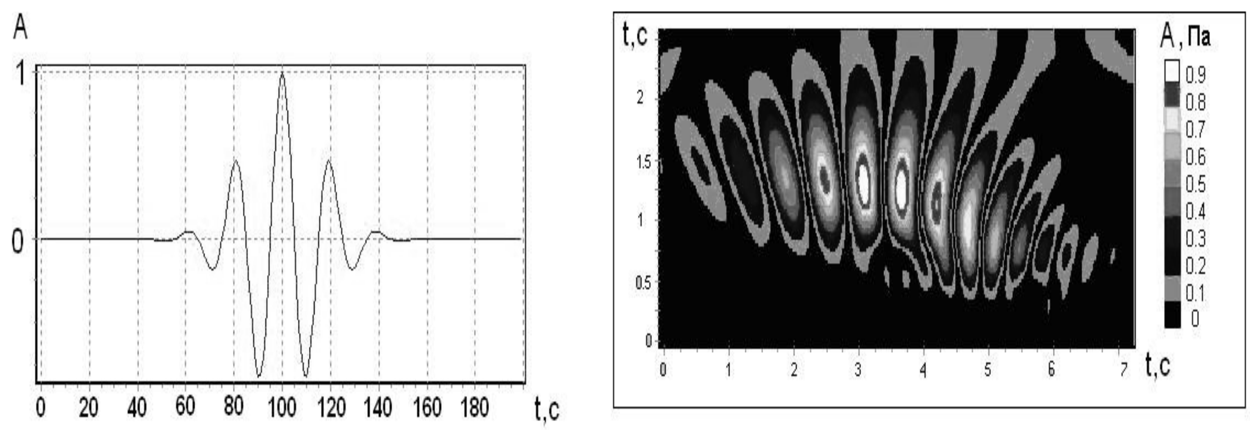


Figure 4. Values distribution of energy of the greatest number of signals from land explosions in 2011, have been calculated by estimation method inherently frequency characteristics of a signals are used

As mentioned above, to estimate the energy release of an explosive source, characteristic frequency of an acoustic signal obtained using Fourier transformation was used as an input parameter. However wavelet transformation showed the monotonic change of periods of the analyzed signals from explosions [6]. Figure 5b illustrates the typical image of wavelet transformation of impulse signals from explosion. Morley[9] function was used as the basic function of wavelet transformation, the image of which is similar to the form of the studied signals (Figure 5a).



a) b)

Figure 5a.The temporary image of the basic wavelet function (Morlet)

Figure 5b. The result of wavelet transformation of a signal.

3. CONCLUSION

As the result of the study it was found that:

1) Using wavelet transformation with basic Morlet function and analyzing signal structure enable to identify low frequency acoustic signals from ground explosions.
2) Using initial period of a signal for estimating energy release from explosions allows to estimate the energy of explosive source more accurately.
3) Is Numerically implemented an algorithm for determining the pulse energy source of the infrasound signal.

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