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NONSTATIONARY PROCESSES OF ACOUSTO-ELECTROMAGNETIC EMISSION OF THE LITHOSPHERE IN A SEISMIC ACTIVE REGION RESULTED FROM SURFACE AND BOREHOLE MEASUREMENTS

Nguyen Xuan Anh[1,5*], Uvarov V. N.[2], Lutsenko V. I.[3], Popov I. V.[3], Yiyang Luo[4]

[1]*Institute of Geophysics, VAST, Vietnam*
[2]*Institute of Cosmophysical Research and Radio Wave Propagation, Far East Division, Russian Academy of Sciences, Russia*
[3]*A.Ya. Usikov Institute of Radio Physics and Electronics of NAS of Ukraine (IRE NASU)*
[4]*N. E. Zhukovsky National Aerospace University (KHAI)*
[5]*Graduate University of Science and Technology, VAST, Vietnam*
[*]E-mail: nxuananh05@gmail.com

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ABSTRACT: The results of synchronous detection of the emission of various components of the electromagnetic and acoustic fields obtained under conditions of low industrial interference and a high level of microseismicity are investigated. To compensate electromagnetic radiation of lithospheric origin, a compensation method was used. The signal loop antenna, recording a mixture of signals of lithospheric and atmospheric-thunderstorm origins, was used as a magnetic core of a steel casing of the borehole. The compensating signal was recorded using an antenna, the receiving coil of which was identical to the coil of the signal antenna. The measurements were carried out in the seismically active region of Russia (the Kamchatka peninsula, the Paratun hydrothermal deposit) at the intersection of the sublatitudinal and submeridional fault zones. Methods for analyzing registration data of non-stationary processes are considered using the example of acoustic-electromagnetic emission of the lithosphere, the electromagnetic component of which is a component of the natural electromagnetic field of the Earth. Their characteristics are estimated and a statistical model is proposed that uses nested semi-Markov processes and finite atomic functions. Observations of geophysical electromagnetic fields, in addition to useful information about the emission processes, contain interference, mainly of technogenic origin. They are especially strong in downhole measurements when a well casing is used as the receiving antenna. These interferences significantly impede the allocation of useful information. The possibility of using bleaching filters to increase the contrast of observation of useful signals of lithospheric origin against their background is considered.

Keywords: Acousto-electromagnetic emission, non-stationary characteristics, lithosphere, seismically active region.

INTRODUCTION

Until now, the study of electromagnetic signals of lithospheric origin is one of the least developed problems. To a large extent, this is due to the need to isolate electromagnetic signals of lithospheric origin from the powerful masking background of the lightning, magnetospheric and technogenic radiation. The importance for studying of the statistical characteristics of this radiation is due to the fact that it reflects the geodynamic state of the lithosphere, which can be used, for example, in seismic forecasting and mineral exploration [1-3].

The statistical characteristics of electromagnetic and acoustic radiation of lithospheric origin were studied using the data of recording of the acoustic and electromagnetic radiation of the ELF-VLF range obtained in the seismically active zone of Kamchatka [1-5]. The measurements were carried out on the territory of the expedition center IKIR FEB RAS “Karymshina” that is located far from populated areas, at the intersection of regional fault zones within the Malko-Petropavlovsk zone of the transverse dislocation of the northwestern orientation, where the Paratun spreader zone passes. For reception, the magnetic frame antenna with an area of up to 10000 m^2 is used. It is located in mutually perpendicular planes, a quadrupole antenna and an acoustic receiver-a hydrophone in an artificial pond were used.

Conditions for the propagation of waves in the Earth's crust are improving with depth increasing. Therefore, to effectively study the wave fields of the lithosphere, it is necessary to obtain signals from the maximum possible depth. This is possible in mines (or wells), covering large areas and a variety of geological conditions.

A series of experiments was conducted with the arrangement of the coil of the magnetic antenna on the well casing, and the compensating antenna on the surface.

For this purpose, a natural experiment was set up at a borehole 74 on the Korkin Stream in the Paratunka River Basin (South Kamchatka). This well was drilled in 1968 to a depth of 649 m while studying the Paratunsky hydrothermal deposit in Kamchatka. The casing is made with a steel pipe of 168 mm in diameter with a depth of 195 m from the surface. The maximum water temperature of 56.8° C was registered at a depth of 620 m. The well is located in the zone of the sublatitudinal left-waved break at the intersection with the North-Western transform zone. Here the zone of the central planetary fault NNE is 20°, i.e. there is a zone of conjugation of faults (the zone of “opening” NE 50°, subparallel to the subduction zone of the Kurile-Kamchatka Trench).

The aim of the studies was to study spectra, emission distribution laws and intervals between them, both for various components of electromagnetic and acoustic emissions and both for surface and borehole measurements.

THE MAIN PART

Fig. 1 shows a fragment of 15 min. realization of synchronous recording of 3 channels and their energy spectra. It can be seen that the greatest density of emissions is observed in the channels of the latitudinal (3) and meridional (2) components of the magnetic field, in which radiation of atmospheric-thunderstorm origin dominates. It is somewhat smaller in the vertical component of the electric field. These three channels mainly contain information of atmospheric-thunderstorm and magnetospheric origin.

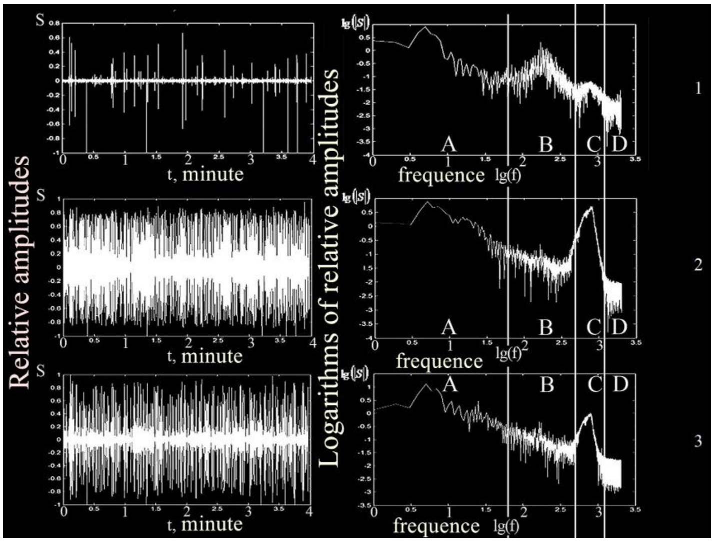
Their spectra clearly trace the increased radiation power due to the propagation of radiation from the world centers of equatorial thunderstorms and is identified on the spectrum as region C.

The emission density is significantly less in the channel of the vertical magnetic component - (1), in which the lithospheric radiation in the spectral region is clearly traced, which is indicated by the letter B. It can be seen that the atmospheric-thunderstorm radiation in this graph is smaller.

In the energy spectra, an increase in its density is observed in the frequency range 500 ... 1000 Hz, which is especially noticeable in the meridional (2) and latitudinal (3) channels of the magnetic component, as well as the channel of the vertical component of the electric field. The rate of decrease of the spectral density n while presenting the spectrum by fractal dependence is:

$$S(F) = S_0\left(1+\left|\frac{F}{\Delta F}\right|^n\right)^{-1} \qquad (1)$$

Where $1 \le n \le 2$, and ΔF is the half-width of the spectrum. However, such an assertion is valid if one process is responsible for the time series of observations, or if one process dominates. In our case, at each time the series of observations reflects several processes, and the competing ability of which varies with both frequency and time.



a) b)

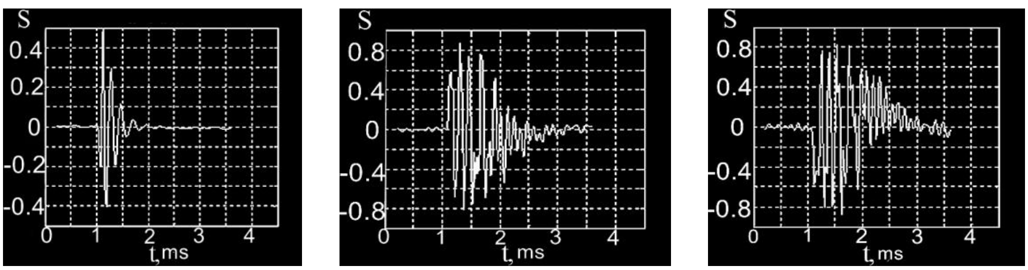
Fig. 1. Data recording in time (a) and their spectra (b) - of the electromagnetic emissions of lithospheric origin. The section of spectrum B is the manifestation of lithospheric radiation, section C is the region of the ionospheric channel; 1- (altitudinal), 2- (meridional), 3- (latitudinal) components of field

Fig. 2 shows the time recordings of the emission of the signal, and in fig. 3 their spectra are shown.

It can be seen on fig. 2 that the emissions are a nonstationary ultra-wideband process, for the description of which wavelets can be used, and their spectra substantially differ from the standard model of the Lorentz oscillator and their description can be constructed on Kravchenko's atomic functions [5].

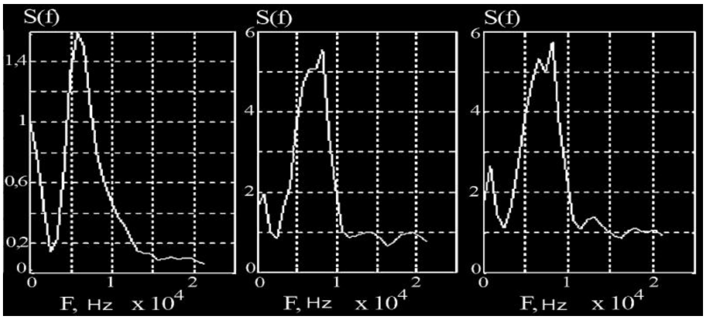
In borehole measurements, a significantly higher level is influenced by technogenic noise - fig. 4a. To suppress them, we used the optimal whitening algorithm, described in [6].

In this case, it is possible to significantly decrease the background noise and isolate the information components associated with lithospheric activity fig. 4c.



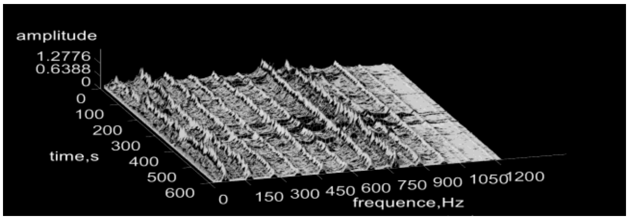
1 2 3

Fig. 2. Emissions on channels 1, 2 and 3

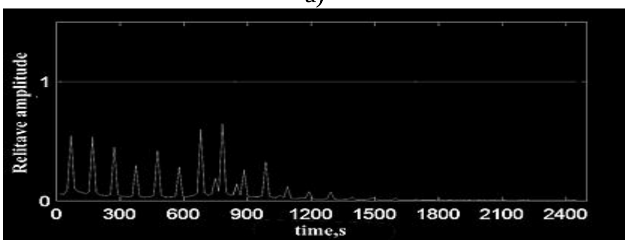


1 2 3

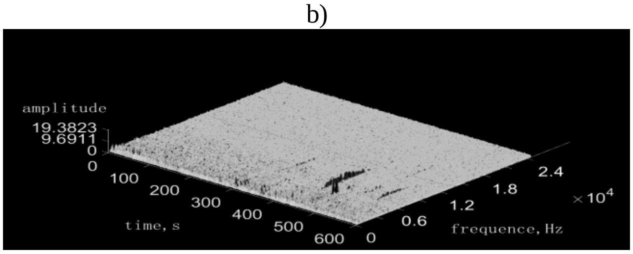
Fig. 3. Emission spectra for channels 1, 2 and 3



a)



b)



c)

Fig. 4. Spectrograms: initial (a) and after bleaching (c), frequency response of the bleaching filter (b)

Emissions in the downhole channel in the time domain after the bleaching operation is performed are shown in fig. 5a, and their spectrum in fig. 5b.

It can be seen that emission spectra of lithospheric origin, for both surface and borehole measurements are coincided.

To isolate radiation from lithospheric origin, it is expedient at the first stage to allocate emissions common to several channels of different polarizations. At the next stage, it is expedient to determine the direction of arrival associated with the need to find the source of ultra-wideband signals [7].

Signals that appear in both quadrupole and dipole channels are detected. Low-frequency radiations, like the manifested channels of the vertical magnetic component and quadrupole are most likely to have a lithospheric origin.

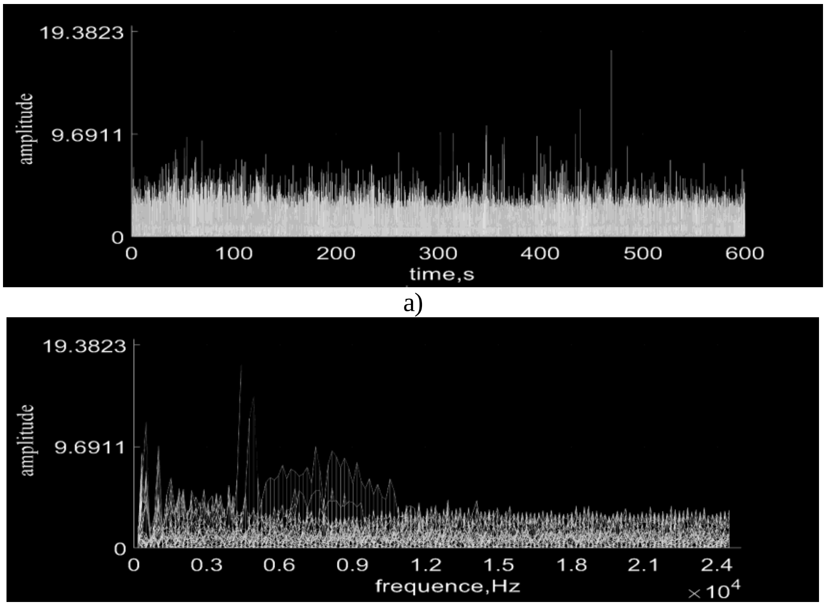


Fig. 5. Emissions of lithospheric radiation through the borehole channel after bleaching (a) and their spectra (b)

CONCLUSION

When the power density of the tectonic pulse flux exceeds the power threshold of the pulse dissipation in the rock, the motion acquires a turbulent character in space and a pulse in one time. The acousto-electromagnetic manifestations of the momentum flux dissipation also have the impulse character. Therefore, the nature of the manifestations reflects the nature of the tectonic impulse flow, makes it possible to assess the geodynamic situation and is used in forecasting earthquakes, studying the structure of subsoil for exploring and exploiting natural resources. Among the important characteristics for the tectonic flow manifestations, the pulse is the emission intensity and the mean interval between them, which can be used as an informative sign of the earthquake precursor.

To isolate closely spaced sources of the natural electromagnetic radiation from the powerful background to distant sources, a differential method is used that is physically reduced to use the quadrupole antenna which is not used in connection due to strong limitations on the range of propagation [3].

The application of this method in the seismically active zone of Kamchatka made it possible to detect the presence of previously unknown types of electromagnetic signals - electromagnetic manifestations of geoacoustic emission, manifested mainly in the vertical component of the natural electromagnetic field. The basic energy of radiation falls on a frequency band at about 50 ... 500 Hz, and the spectrum can be stable for tens of minutes, undergoing significant changes during the day. The laws of distribution of the emission durations and the intervals between them significantly differ from the standard exponential law. The average emission time for the quadrupole channel, the meridional and latitudinal channels of the magnetic component and the vertically polarized electric component is approximately 0.4 ... 0.6 ms, while that for the vertical component of the magnetic field and acoustic signal is 3 ... 6 ms. The largest average interval between the emissions along the acoustic channel is (~ 2.7 s) and longer than in the quadrupole channel (~ 0.3 ... 0.49 s) and the channel for vertical polarization of the magnetic field (~ 0.24 ... 0.78 s). Most impulses follow the meridional (mean period ~

0.07 ... 0.08 s), latitudinal (mean period ~ 0.09 ... 0.16 s) channels of the horizontal component of the magnetic field and the vertical component of the electric field (mean period ~ 0.09 ... 0.16 s). It is most likely that this type of pulsed radiation is associated with thunderstorm near-equatorial activity.

The proposed approach can be used to monitor geodynamic activity. Experimental characteristics of radiation can be used to create simulation models of electromagnetic emission processes of lithospheric origin.

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