ACOUSTO-ELECTROMAGNETIC INVESTIGATIONS OF AN ACOUSTICAL CHANNEL OF THE LITHOSPHERE-IONOSPHERE INTERACTION

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INTRODUCTION

Already for a long time a number of the known scientists (M. Hayakawa, Yu. Galperin, N. Blaunstein, M. Parrot etc) have put forward a hypothesis about existence of the acoustic channel of transfer of energy in the system "lithosphere-atmosphere-ionosphere" in the process the high-energy phenomena in the lithosphere and during its preparation. This hypothesis is confirmed by a number of researches. But in these researches an acoustic energy of earthquakes or research explosions was mainly used. High-power acoustic sources of such types are the weakly operated and ecologically dangerous. This report is devoted to experimental researches of the acoustic channel of lithosphere-ionosphere interaction by way of modification of the ionosphere by action of the ground-based acoustic excitation and of detection and analysis of the artificial acousto-ionospheric disturbances caused by this acoustic radiator. On the basis of these results the acousto-electromagnetic method of monitoring of the ionosphere has been developed. The method is intended for revealing of the acousto-ionospheric disturbances caused by action of ground-level infrasound.

INSTRUMENTATION AND METHODS

For full-scale experiments the following radio physical and acoustic equipment was being used: the ground-based operated parametric acoustic radiator; the highly-sensitive decameter radio telescope URAN-3 (10-30MHz, 256-element array antenna, effective area – 14000 m^2, registration of two linear polarizations); the short baseline decameter radio interferometer with movable receiving arm; and the special short-wave radio transmitters or broadcast stations. The following methods of electromagnetic sounding of the ionosphere were being used: radio astronomical method (RA method), method of inclined sounding of the ionosphere (IS method), and method of scattering on small-scale ionosphere inhomogeneities (SS method). In total more than two hundred experiments was carried out.

Distance between the acoustic radiator and radio telescope – 220 km. Parameters of acoustic excitation: frequency of acoustic waves - (10-30) Hz; the duration of one excitation session is equal 60s and total acoustic energy radiating during this period, is equal approximately $2\times\cdot10^6$J near the Earth surface. Initial conditions of experiments: for the IS method - operation frequency f_{op}=6.1 MHz<f_{MUF} (maximum usable frequency), elevation θ=62°, registration and measuring of an amplitude, Doppler frequency and time delays of the reflected ionosphere signals; for the SS method - operation frequency f_{op}=16.1MHz>$f_{MUF,}$ elevation θ=38.6°, registration and measuring of an amplitude, Doppler frequency and time delays of the scattered ionospheric signals; for the RA method - observations of cosmic radio sources, operation frequency f_{op}=25MHz; measuring of the correlation function in a regime of short base interferometry.

OBSERVATIONS AND DISCUSSION

There is the row of mechanisms of the lithosphere-ionosphere interaction at earthquakes [1, 2]. Some researchers [1] prove an acousto-gravitational mechanism of lithosphere-ionosphere interaction at the earthquakes. Other researches [2] assert that at the earthquakes, a nature of transfer of excitations to ionosphere is electromagnetic. One of approaches, which allow exploring nature of the lithosphere-atmosphere-ionosphere interaction, is based on experimental registration of time, through which the ionosphere response to the artificial ground-level acoustic excitation appears. On the basis of this parameter the electromagnetic responses of the atmosphere to the ground acoustic excitation can be divided into two classes: rapid responses and delayed responses.

Rapid responses appear after several tens of seconds. Their appearances one can explain by a hypothesis about acoustic excitation of the geo-electric contour (Fig. 1), resonance frequencies of which amount to ~500-1500 Hz [3]. The ground-level acoustic excitation can lead to change of a vertical current in the atmosphere and to excitation of the geo-electric contour. Geomagnetic responses in this case can appear greatly earlier than acoustic wave reaches the

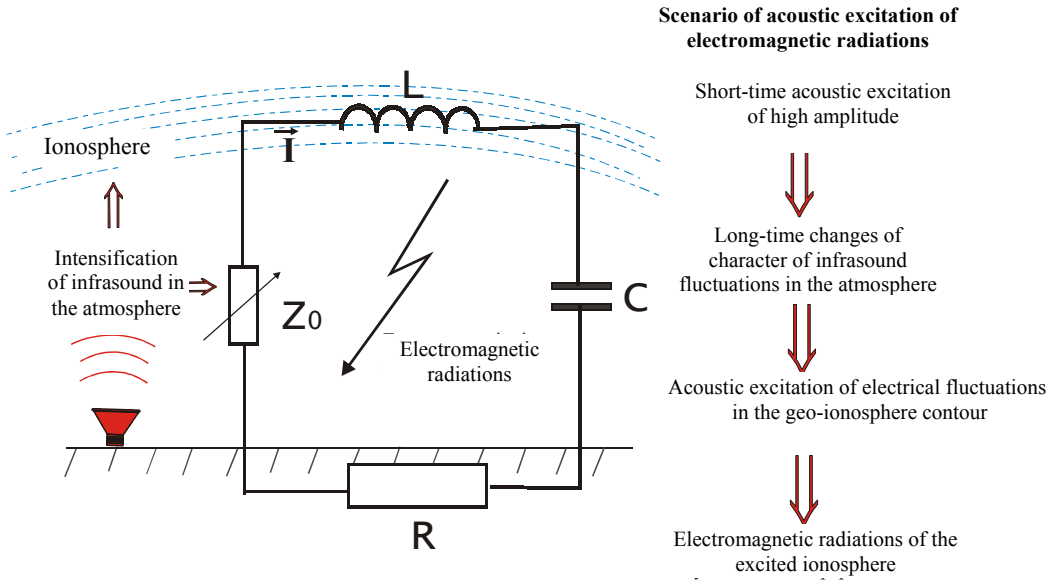

Fig. 1. A model of acousto-electromagnetic transformations in the system “lithosphere-atmosphere-ionosphere”.

Such a hypothesis can explain appearance of rapid responses. It’s necessary to note that rapid responses are observed rarely. In a series of 35 experiments carried out by authors, they have appeared only three times.

The delayed responses are being more often observed at the acoustic excitation of the atmosphere. For an example, typical changes of the energy of signals of geomagnetic variations in a range of 1-40 Hz at artificial acoustic excitation, which have been registered by authors, are represented in Fig. 2. Measuring of signals was conducted during one hour to acoustic excitation and one hour after one. Duration of electromagnetic responses of this type greatly exceeds a time of acoustic excitation. Probably they are the result of acoustic excitation of the atmosphere and action of this excitation to the ionosphere plasma.

Results of use of radio physical diagnostics of the ionosphere at the artificial ground-level acoustic excitation confirm that in addition to the electromagnetic channel the acoustical channel based on the direct propagation of the atmospheric infrasonic acoustic wave to ionosphere heights (though some scientists also deny such opportunity), also exists. As result, the modification of spatial distribution of components of the ionosphere plasma and excitation of the plasma waves is possible.

During the experiments three radio physical methods were being used for ionosphere diagnostics and detection of the artificial acousto-ionospheric disturbances (AID). The first method, namely RA-method, is based on the examination of decameter cosmic radio sources radiation propagated through the acoustically modificated ionosphere and registered by the radio telescope URAN-3. This method does not require of the use of a transmitting radio station. However, its failing is the limited measuring time, which is determined by the visibility time of radio objects (3C348, 3C274, etc). In the experiments the acoustic radiator and radio telescope URAN-3 were located on the same meridian on distance of 200 km.

Two types of the artificial AID have been observed and registered by the RA-method:
- Short-term increase of radiation intensity in the period of the possible passing of the LF acoustic wave excited by the acoustic radiator, through the ionosphere (in a time of 5,75±0,5 min after the beginning of acoustic excitation, that corresponds to time of vertical propagation of the LF acoustic wave on a height approximately 100 – 150 km).
- Appearance of the repeated ionosphere responses with a different delays in relation to beginning of the acoustic excitation, namely 20,66±2,24 min; 29,29±1,25 min; 41,7±2,27 min; 59,55±4,16 min. These responses may be caused by the plasma waves excited in the ionosphere. The high stability of these delays is observed in different days and for different space sources. Moreover, the ionosphere reaction correlates not only with the beginning time of the acoustic excitation, but also wits its form.

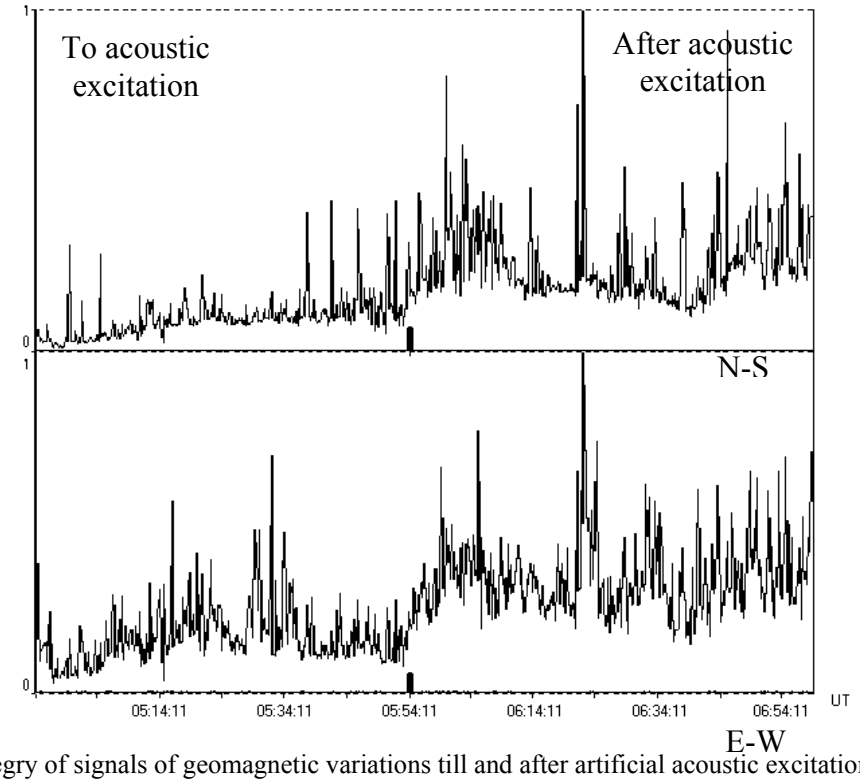

Fig. 2. Enegry of signals of geomagnetic variations till and after artificial acoustic excitation (1-40 Hz).

The second method, namely SS method, is one of the most informative methods for investigation of the ionosphere responses to the acoustic excitation. The scattered signal (both polarizations from each part of the URAN-3 antenna (Fig. 3)) was received from the ionosphere domain over the acoustic radiator. On all records two characteristic buckets are precisely allocated, first of which one can relate to the undisturbed ionosphere (before 16:31LT - beginning of the acoustic excitation), and second – to the disturbed one (about after 16:37 LT – wave spread time to the ionosphere).

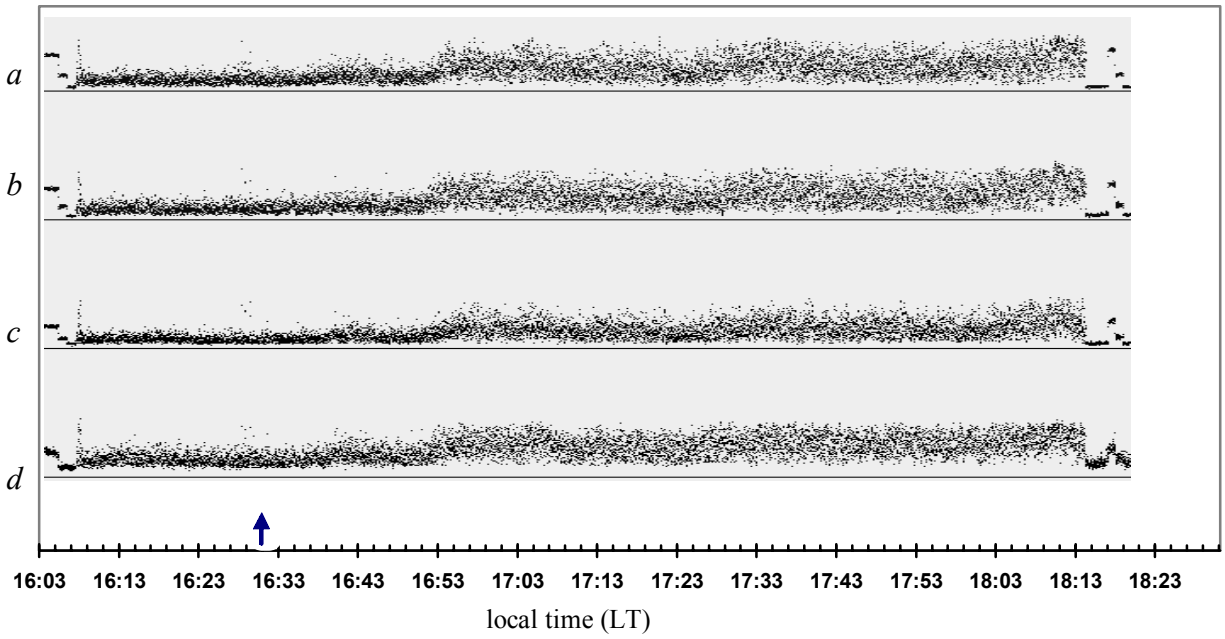

Fig. 3. Typical records of the scattered ionosphere signal from two parts of the antenna URAN-3 at ground-level acoustic excitation: (a, c) - polarization *A*; (b, d) – polarization *B*).

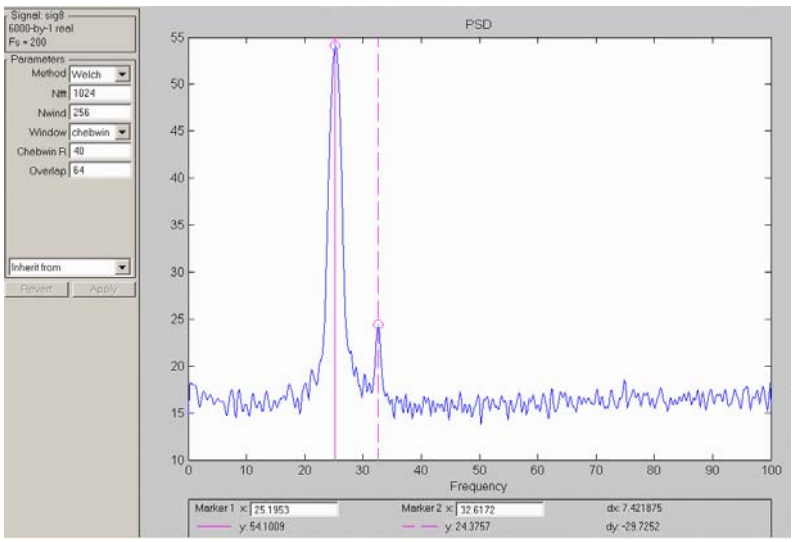

Fig. 4. – Power spectrum of the scattered ionosphere signal from the acoustically modified domain of the ionosphere (moment of passing of the acoustic wave through this domain – the Doppler shift is equal to 8 Hz).

One of the most informative parameters should be a Doppler shift in the registered scattered ionosphere signal, if it is caused by the motion of ionosphere heterogeneities under influence of the propagated acoustic wave. Fig. 4 demonstrates the occurrence of a Doppler shift (7Hz, by duration about 30 seconds) on the sixth minute after the acoustic excitation beginning, what corresponds to duration of the emitted acoustic impulse and to the spread time of the acoustic wave to the ionosphere. That is a serious argument for confirmation of a hypothesis on existence of the acoustic channel by transfer of energy in the system “lithosphere-atmosphere-ionosphere”.

On the basis of these results the acousto-electromagnetic method of the ionosphere monitoring have been proposed for study of the acoustical channel of the lithosphere-ionosphere interaction. Method includes: the permanent short wave adaptive electromagnetic sounding of the ionosphere by different radio physical methods; the periodical operated dosed acoustic excitation of the ionosphere for periodical determination of the current status of the ionosphere and forming of the standard response of the ionosphere to such artificial acoustic action; selection and identification on this basis of acousto-ionospheric disturbances of natural origin. Probably, such method will allow to detect the natural ionospheric precursors of the ground-level acoustic origin and, hence, to increase reliability of forecasting of earthquakes.

CONCLUSIONS

Results of the fulfilling of experiments on the acoustic modification of the atmosphere, including the ionosphere, with use of the ground-based operated acoustic radiator (of parametric type) and of the high sensitive decameter radio telescope URAN-3 (Ukraine) have confirmed validity of a hypothesis about the existence of different channels of energy transformation in the system " lithosphere-atmosphere-ionosphere" in the period of high-energy lithosphere events and of its preparation, including electromagnetic channel and acoustic channel. Investigations of the artificial acousto-ionospheric disturbances caused by action of this acoustic radiator and registered by the radio telescope URAN-3, experimentally proved possibility of the acoustic modification of the ionosphere by acoustical energy approximately $2\times\cdot10^{6}$J on the Earth surface.

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