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Self-oscillations in rocks, results of laboratory experiments

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Abstract
The method of generation of self-oscillations in rocks is developed here. Self-oscillations arise as a result of direct and inverse mechanoelectric transformations without an external generator. Laboratory experiments were executed with different samples. A relation between self-oscillation parameters from samples' humidity and direct electrical field applied to samples was detected.

Key words *self-oscillations – mechanoelectric self-oscillator – transformations – rocks*

1. Introduction

It is known that a geological medium which has large resources of energy is a complicated multiphase system in which transformations and interactions of geophysical fields of different origin proceed. There are experimentally detected parametrical, resonance, non-linear properties of rocks. A strong response to weak impacts was observed (Nikolaev and Vereschagina, 1991; Tarasov and Tarasova, 1995). The recently detected activation of seismic regime in seismoactive zones after powerful artificial electromagnetic pulses and geomagnetic storms (Tarasov *et al.*, 1999; Tarasov and Tarasova, 2002) should be especially noticed.

The investigation of relations between geophysical fields and the investigation of properties of the lithosphere, as a converter of energy, as well as the possibility to use this knowledge in practice have aroused increasing interest. This paper is dedicated to these problems.

2. Conditions of experiment

Figure 1 shows the skeleton diagram of a usual laboratory device for the investigation of mechanoelectric phenomena in rocks. The electric generator (1) is connected to the piezoelectric transducer (2), which generates acoustic signal in the sample (3). The energy of the acoustic oscillations is transformed in the sample into the energy of the electric oscillations. Electrodes (4) receive electric signals, which are amplified by the amplifier (5) and directed to the recorder (6).

The authors designed the device, the skeleton diagram of which is shown in fig. 2. The signal from the electrodes (3) is directed to the special electronic unit (4). From the output of the electronic unit the signal is directed to the input of the piezoelectric transducer (1).

The set-up of the components of the electronic unit allows for a positive feedback in a closed circuit and provides the conditions of stimulation of the self-oscillations.

The self-oscillations arise because of the mechanoelectric transformations in rock samples and the positive feedback and not because of an external forcing oscillator. The authors

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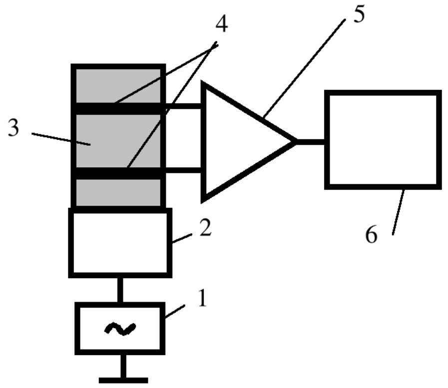

Fig. 1. The skeleton diagram of the laboratory device for the investigation of mechanoelectric phenomena in rocks: 1 – electric generator; 2 – piezoelectric transducer; 3 – sample; 4 – electrodes; 5 – amplifier; 6 – recorder.

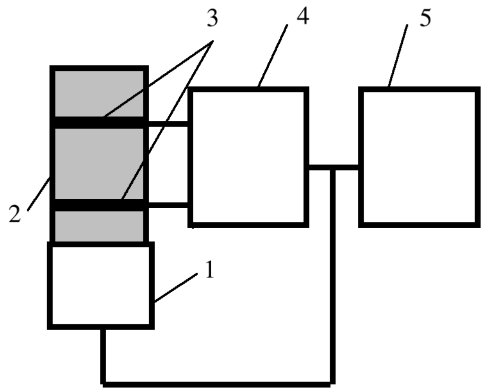

Fig. 2. The skeleton diagram of the laboratory device for the investigation of self-oscillations: 1 – piezoelectric transducer; 2 – sample; 3 – electrodes; 4 – electronic unit; 5 – recorder.

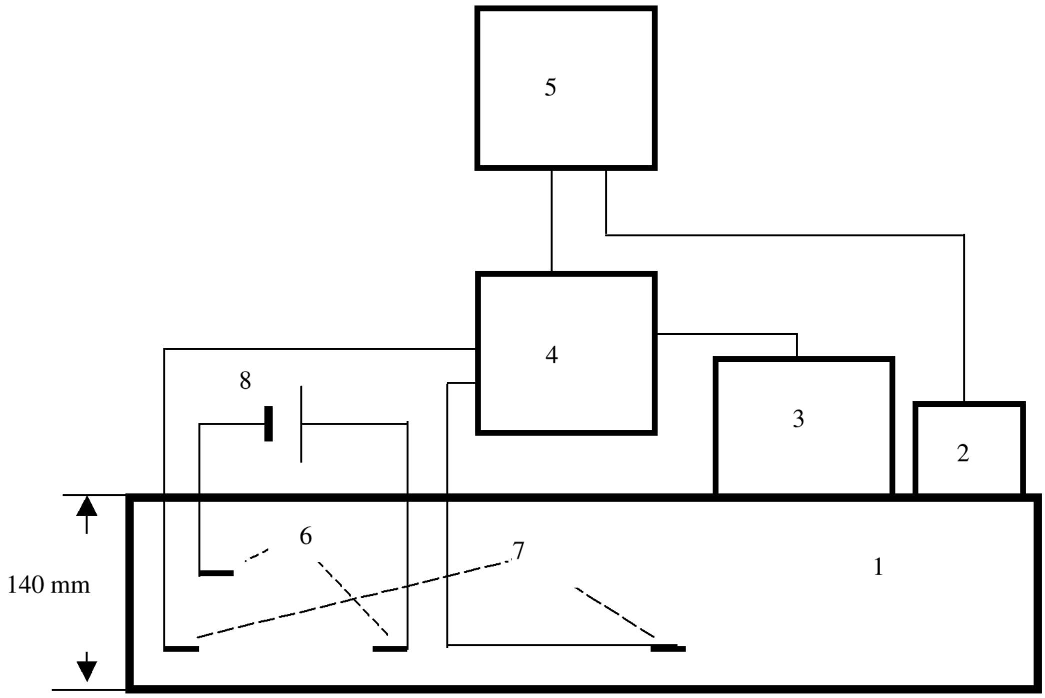

Fig. 3. The scheme of the self-oscillator (MSO) of the first type (*S-E*): 1 – sample (box with sand); 2 – measuring transducer; 3 – emitting piezoelectric transducer; 4 – electronic unit; 5 – recording device; 6 – additional electrodes; 7 – measuring electrodes; 8 – source of constant voltage.

have termed the device the Mechanoelectric Self-Oscillator (MSO).

Various materials were used as samples in the experiments: sand, clay, loam, concrete, bricks. In this paper, some results of the experiments with sand samples are presented.

The sample was made in the form of a plastic box (450 × 140 × 180 mm) filled with 19 kg of sand. A piezoelectric transducer was located on the sand surface. The resonant frequency of the transducer was 30 kHz. The system of electrodes was located inside the sample's body. Two types of mechanoelectric self-oscillators were investigated. In the self-oscillator of the first type (fig. 3) a transformation of acoustic oscillations (*S*) into electric oscillations (*E*) takes place. In the self-oscillator of the second type (fig. 4) a transformation of electric oscillations into acoustic oscillations takes place. The piezoelectric transducer (3) in the first device functions as an emitter. Measuring electrodes (7) are connected to the input of the electronic unit (4). The signal from the measuring electrodes is amplified by the electronic unit and is then directed to the input of the piezoelectric transducer. Additional electrodes (6) are connected to the constant voltage source (8).

The recording device (5) records two signals: the signal $U_E * K$ from the output of the preamplifier of the electronic unit (4) and the signal U_S from the output of the measuring piezoelectric transducer (2). U_E denotes a potential difference between the measuring electrodes (7), K denotes the amplification factor of the preamplifier. U_S corresponds to the displacement of the sample surface in the relative units.

The analog-digital converter L-761 of the «L-Card» Russian corporation (14 bits, signal processor AD-2184, Analog Devices Inc.) was utilized as the recording device.

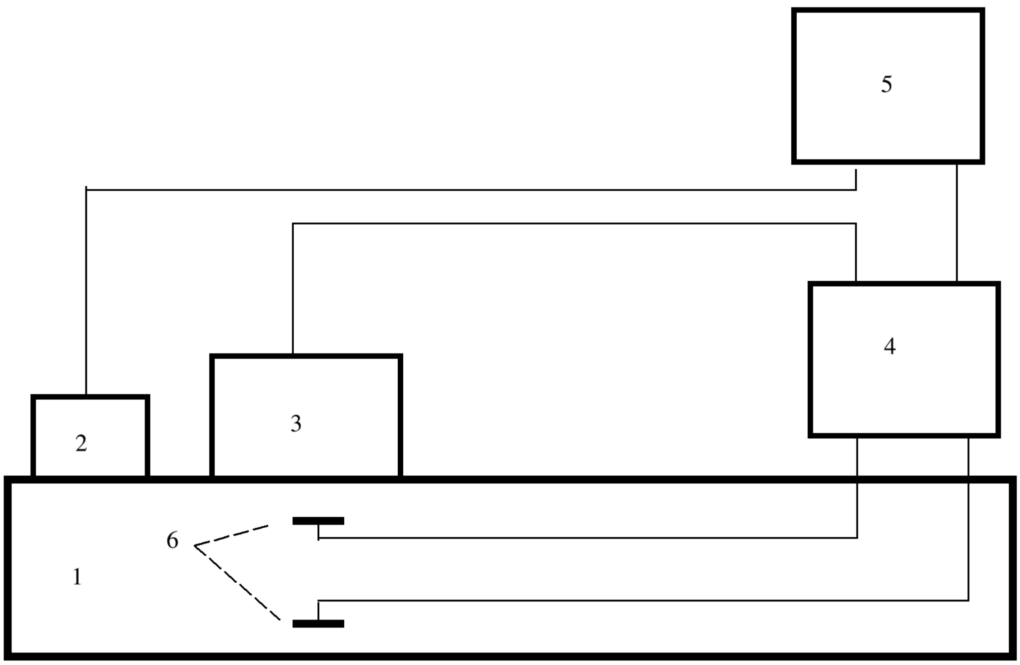

Fig. 4. The scheme of the self-oscillator (MSO) of the second type (*E-S*): 1 – sample (box with sand); 2 – measuring piezoelectric transducer; 3 – piezoelectric transducer-receiver; 4 – electronic unit; 5 – recording device; 6 – emitting electrodes.

The distinction between the first and the second devices (fig. 4) is that the piezoelectric transducer functions as the receiver of acoustic signals. The electric output of the piezoelectric transducer (3) is connected to the input of the electronic unit (4). The output of the electronic unit is connected to the emitting electrodes (6). U_E denotes the potential difference between the emitting electrodes (6).

3. Results of the experiments

1) The experimental results for the MSO of the first type (fig. 3, transformation *S-E*) are shown in figs. 5a,b, 6a,b, 7a,b and 8a,b. Electric and acoustic signals, generated in the sample during self-oscillations, are shown in figs. 5a, 6a, 7a and 8a. The corresponding spectra are shown in figs. 5b, 6b, 7b and 8b.

Figures 5a,b and 6a,b illustrate the relation between the parameters of self-oscillations and the value of the external direct electric field ***E***. Figure 5a,b: ***E*** = 0, fig. 6a,b: ***E*** = 9 v/cm.

Change in the phase shift between the signals U_S and U_E by almost 180° and change in the self-oscillations frequency by 680 Hz is caused by the influence of ***E***. It is possible to observe a small decrease of the oscillations amplitude and the *Q* factor, comparing figs. 5b and 6b.

Figures 7a,b and 8a,b show a relation between the parameters of self-oscillations and the sample humidity. Figure 7a,b corresponds to the room-dry sample; fig. 8a,b corresponds to the sample, whose humidity is increased by 3%. The phase shift between U_E and U_S is changed by several tens of degrees. The frequency of self-oscillations is changed by 290 Hz. The amplitude of oscillations is decreased to half the value of the room dry sample.

2) Results, obtained with the use of the MSO of the second type (fig. 4, transformation *E-S*) are shown in fig. 9a-d.

A self-oscillations mode was generated in the dry sample (fig. 9a). After that 100 ml of water was poured onto the surface of the sam-

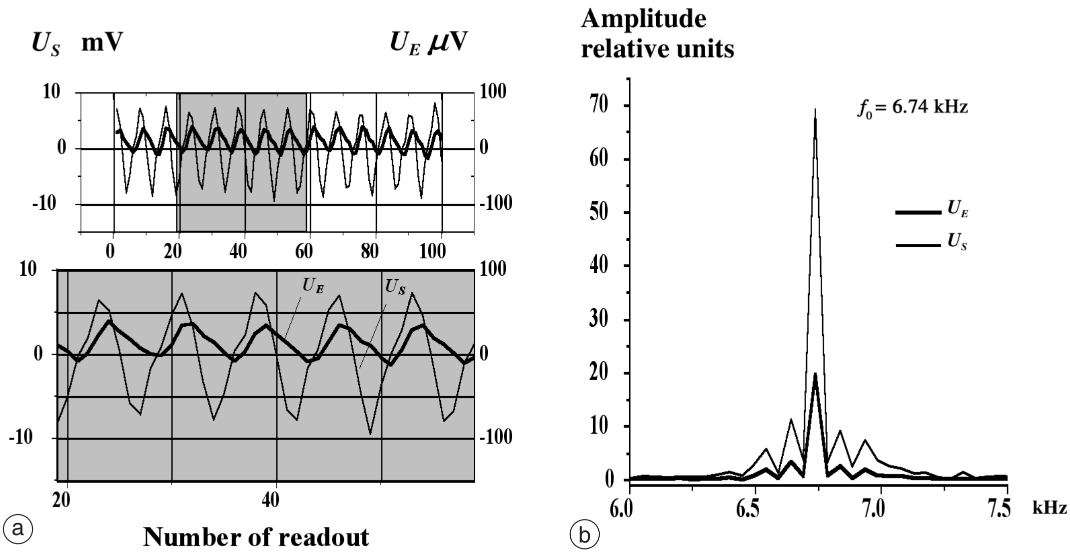

Fig. 5a,b. MSO of the first type (***E*** = 0): a) electric (U_E) and acoustic (U_S) signals; b) spectra of the signals U_E and U_S.

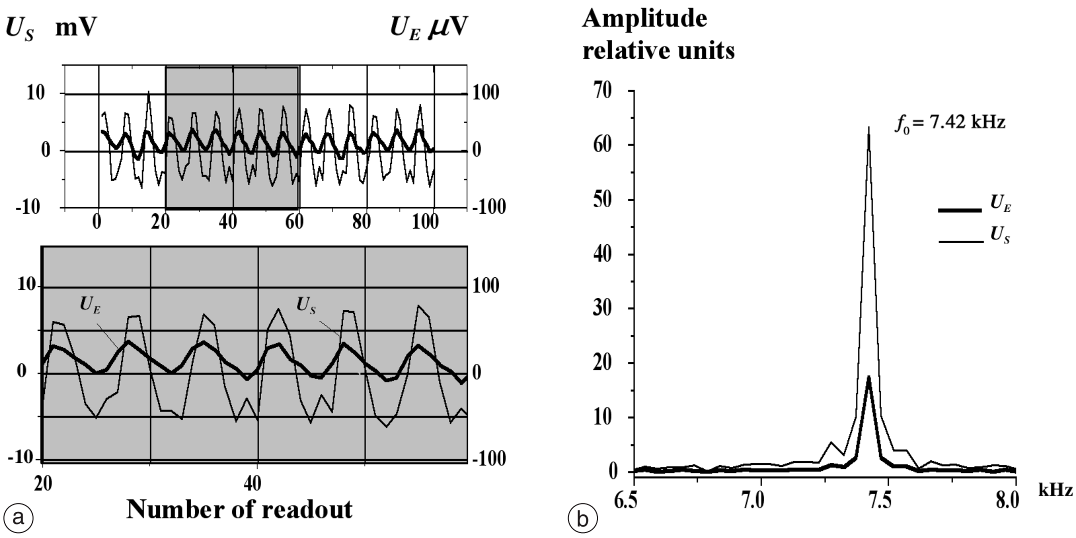

Fig. 6a,b. MSO of the first type (***E*** = 9 v/cm): a) electric (U_E) and acoustic (U_S) signals; b) spectra of the signals U_E and U_S.

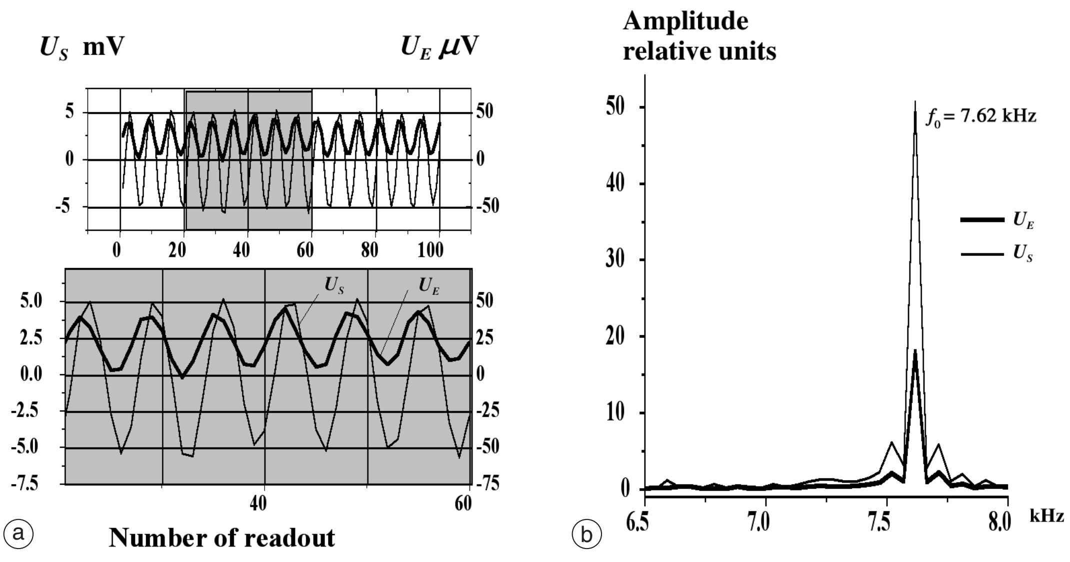

Fig. 7a,b. MSO of the first type, dry sample: a) electric (U_E) and acoustic (U_S) signals; b) spectra of the signals U_E and U_S.

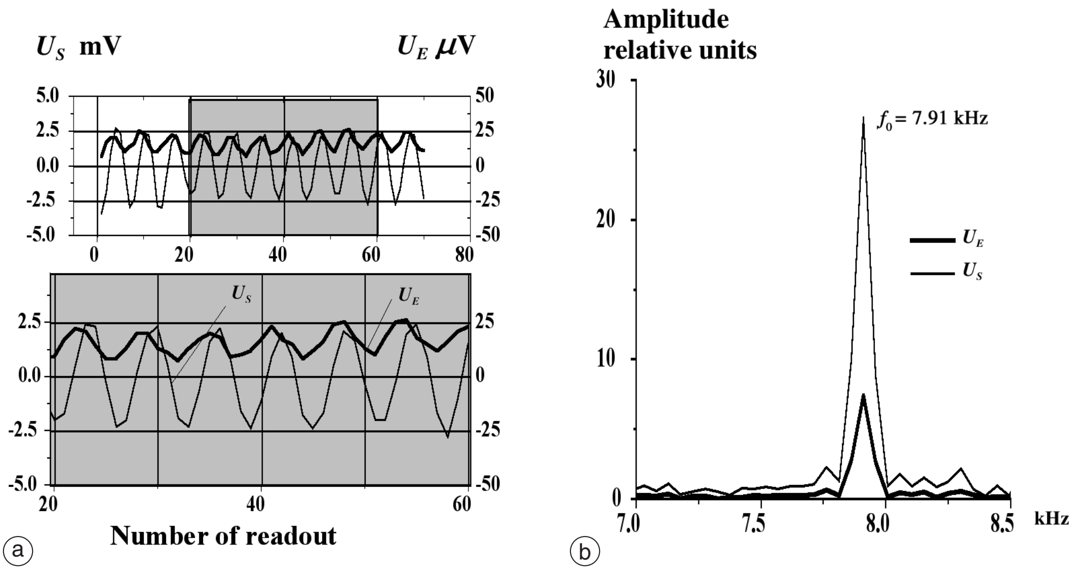

Fig. 8a,b. MSO of the first type, sample's humidity is increased by 3%: a) electric (U_E) and acoustic (U_S) signals; b) spectra of the signals U_E and U_S.

ple and three more measurements were taken (fig. 9b-d). All measurements were executed with 30-40 s intervals.

Comparison of the presented oscillograms traces the process disturbing the self-oscillations mode as a result of sample damping. Oscillations become unstable, and at the end of the experiment, the amplitudes of oscillations in both channels have decreased by approximately one order of magnitude.

4. Discussion

Only part of the obtained results are presented in the paper, other results are now being processed. The presented material allows the following conclusions.

1) Self-oscillations based on direct and inverse mechanoelectric transformations could be created in rocks. The sample of rock is the frequency defining element; frequency of self-oscillations, Q factor and amplitude are determined by the properties of the sample (object).

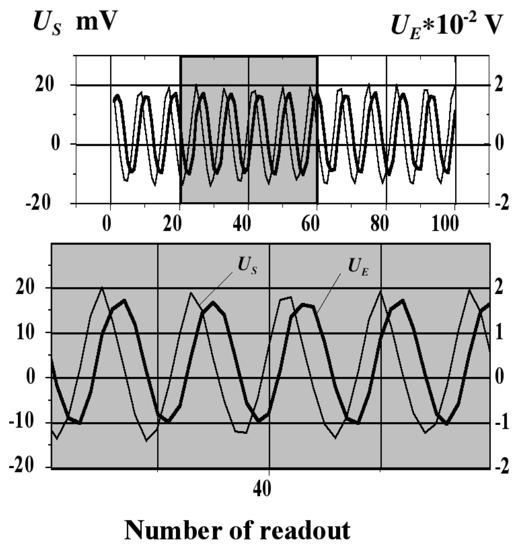

Fig. 9a. MSO of the second type. Change in self-oscillations after sample damping. Measurements were executed with 30-40 s intervals: dry sample, electric (U_E) and acoustic (U_S) signals.

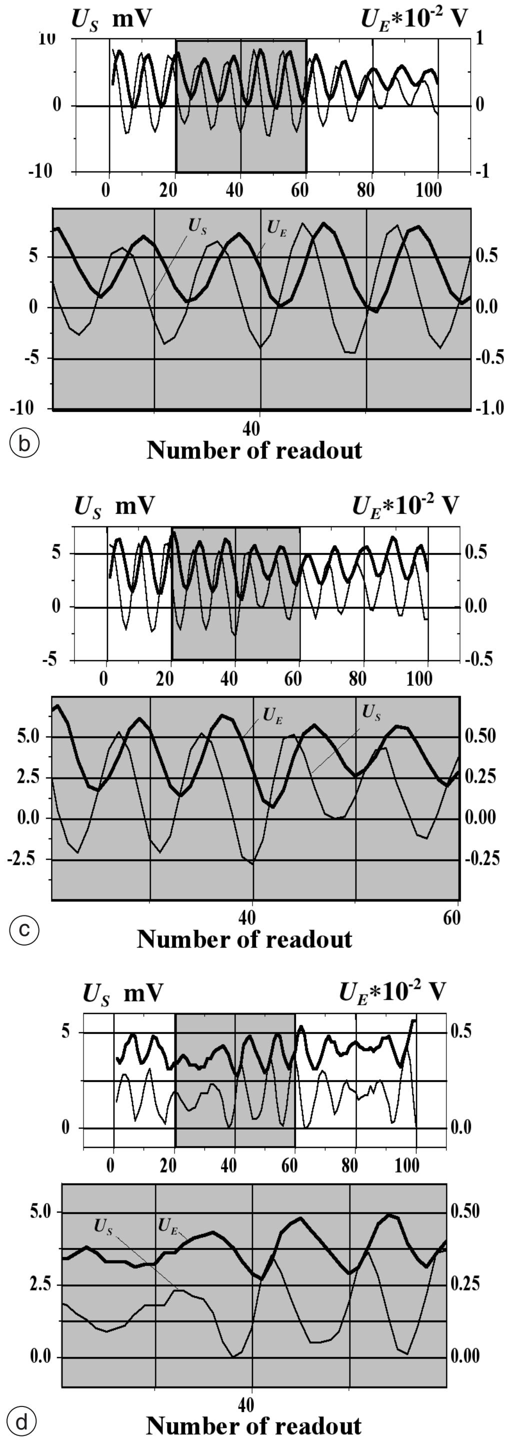

Fig. 9b-d. MSO of the second type. Change in self-oscillations after sample damping. Measurements were executed with 30-40 s intervals: damped sample, electric (U_E) and acoustic (U_S) signals.

External influence (direct electric field) also changes the parameters of self-oscillations. This result is indirectly confirmed by a relation between seismoelectric transformations and direct electric field, as was detected earlier (Cherniak, 1987).

2) A change in condition of the sample causes a change in phase shift between electric and acoustic signals in the sample.

3) Preliminary results show that mechanoelectric self-oscillators of the first and second type have different sensitivity to changes in condition of the samples.

5. Conclusions

Investigation of the self-oscillation processes in rocks in general, and processes based on mechanoelectric transformations in particular, are interesting from the point of view of both fundamental and applied science. There are some possible directions:

1) Development of new methods of rock investigation as mechanoelectrical transformer, as well as development of methods of investigation of different physical properties of rocks (material composition, humidity, fluid quality, porosity, anisotropy, etc.).

2) Development of a phenomenological model of the mechanism of earthquake initiation under impacts of different origin.

3) Natural modeling will open ways of development of new methods of control condition and purposeful influence on rocks and other objects.

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