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Physics

COMPUTER DETECTING AND PROCESSING OF THE SIGNALS OF A FLAT-COIL ABSOLUTE-POSITION SENSOR BASED SEISMIC DETECTOR

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A fast signal-processing system has been presented in this work for processing of frequency-shift signals obtained from the improved (by a flat pick-up coil based SFCO-method) seismic detector, capable to register also rapid vibrations (sharp shakings) of the Earth crust. It might be used also for detection and explanation of the nature of nuclear explosion and other types of blast explosions.

***Keywords*:** Single-layer Flat-Coil-Oscillator (SFCO), position sensor, seismic detector, fast signal-processing.

Introduction. According to the method used for detection of vibrations of Earth crust, modern seismic detectors can be classified within 2 main groups: inertial and strain meters [1]. Inertial seismometers measure ground motion relative to inertial reference (suspended inert mass), while strain-meters detect shift between two points of the ground. For improvement of much widely spread inertial seismometers a new absolute-position sensor is created in [2] and suggested to use as an additional for such type detectors, based on a single-layer flat-coil oscillator nanometer-shift resolution super broad-band technique [3]. Then the Russian (former USSR) SM-3 (CM-3) seismograph had been modernized with the use of a flat-coil stable-frequency such an oscillator, activated by a low power tunnel diode (a Single-layer Flat-Coil-Oscillator (SFCO) method [3–4]). The frequency of an oscillator serves as a measuring parameter in the modernized SM-3 seismograph, taken from such a flat-coil based additional sensor [5]. As is shown in [5], vibrations of the Earth crust result in the changes of the mutual distance between the flat coil (attached to the body of the seismograph) and metallic plate (attached to the inert mass of a suspended (hanging) pendulum) vibrating parallel to the coil face. This results in changes (modulation) of the tunnel diode oscillator frequency. Such improvement of the acting presently all over the world inertial seismographs may allow improving of the resolution by a factor of at least about 10–100 times – depending on the basic model (American models KS-1/KS-54000 and FBA-23, Europeans STS-1/STS-2 and GS-13, and the Russian SM-3, etc.). But the main advantage reached with the use of a flat-coil based new position sensor is its ability to reveal and detect slowly passing processes (such as quasi-static deformations, low-order free oscillations of

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Earth crust, precursor to earthquakes). That is because the single-layer flat-coil sensors are absolute position sensors, which may not one expect from the electromotive force (EMF) based traditional inertial seismic devices. That excludes detection of slow processes, because they are velocity sensors. However, even in modernized SM-3 seismic device [4] the frequency of a flat-coil oscillator is measured with the former USSR production Ch3-63 (Ч3-63) counter, with the maximal available registration detection time of about 0,1 sec. And that is the reason why, although after the said modernization the SM-3 device already may detect slowly passing processes, it may not still permit to detect the sharp shocks.

A fast signal-processing system has been elaborated and created in this work for processing of frequency-shift signals obtained from the improved (by a flat pick-up coil based SFCO-method) seismic detector, capable to register also sharp shakings of the Earth crust. It might be used also for detection and explanation of the nature of nuclear explosion and other types of blast explosions.

Results and discussion. According to the above, the frequency-shift of a single-layer flat-coil tunnel diode oscillator serves as an output signal for the modernized by the SFCO-method SM-3 seismograph. Otherwise, the harmonic oscillation frequency of the measuring oscillator is changed (modulated) according to the Earth crust vibration. Such types of phenomena in radiophysics and information transmission theory are known also as *frequency modulation* (FM) [6]. In other words, an instantaneous frequency $f_r(t)$ of the signal from seismometer (oscillator) is in a linear dependence from the value of instantaneous amplitude $a(t)$ of the Earth crust vibration according to the equation

$$f_r(t) = f_c + f_d \cdot a(t), \tag{1}$$

where $f_r(t)$ is the instantaneous frequency (*signal*) from the modernized SM-3 seismometer, f_c is the undisturbed (by the Earth's shock) steady frequency of the SFCO-oscillator, $a(t)$ is the instantaneous amplitude $a(t)$ of the Earth crust vibration, and f_d is the deepness of the modulation due to the Earth crust vibrations.

The main advantage of the FM-method is that the information to be transferred entirely sits in the oscillator frequency (correctly in its change). And therefore, even if the amplifiers cut the signal, and distort the amplitude information that in no way distorts the frequency information, minimizing the disturbing effect of amplifier environment.

One of main methods of implementation of frequency modulation/demodulation relates with the intersections through the zero (*zero crossing method*) [6]. The frequency of oscillations may be measured by study of the number of zero intersections. The signal under study (shown on Fig. 1 by crosses) is essentially amplified after passing through the amplifier (dashed lines on the Fig. 1), and then it is limited in amplitude by the amplifier (in the given case by a factor of about 1/10). As a result we have a rectangular wave (a fine bold line in Fig.1) with the frequency entirely corresponding to the initial wave's frequency. As was mentioned above, by limiting the amplitude of the signal we have no any distortion of the frequency signal, and so loss of information in FM-method. Then the rectangular FM-signal (square-wave signal) is connected to the pulse generator which creates short-pulse trains (bold lines in Fig.1) at every positive (*negative*) crossing of the zero (crossing of the horizontal axis). As a result we get pulse trains with a period $T_0 = 1/f_r(t)$, from which one may recover the transmitted frequency information by the simple equation below:

$$a(t) = \frac{1}{f_d}\left(\frac{1}{T_0} - f_c\right), \tag{2}$$

where f_c and f_d meanings are commented above.

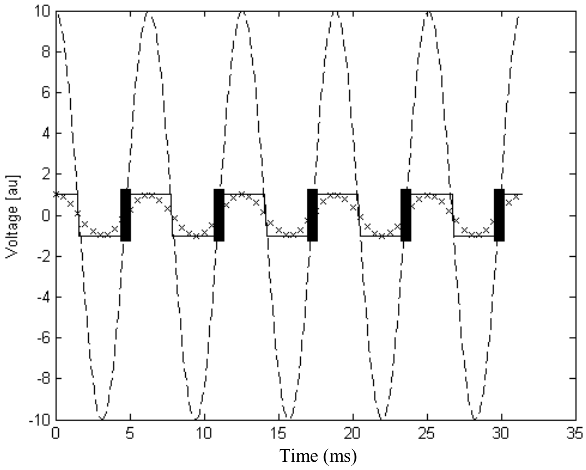

Fig. 1. Measured signal (crosses), amplified signal (dash line), limited square wave (thin lines), generated pulse train (bold lines).

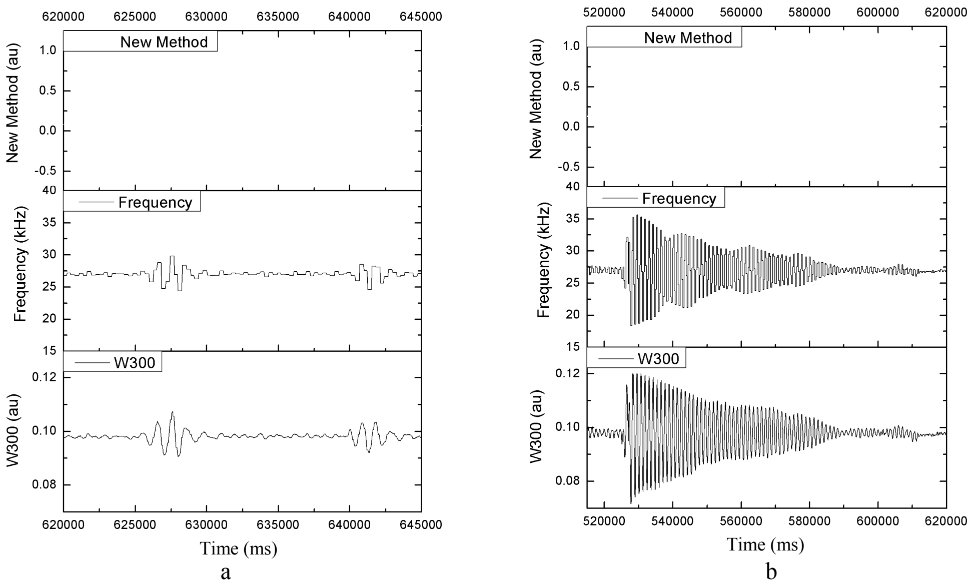

Fig. 2. Seismometer in action in different modes and by different measuring methods: a) impediment, b) free.

Such widely used method of frequency modulation/demodulation was used to recover the signals (information) from SFCO-method based modernized SM-3 seismometer. The computer processing and detecting of signals were done with National Instruments USB-DAQ 6251 (1,25 MSamples/sec.) data acquisition device in NI LabVIEW 8.5 environment. In Fig. 2 we bring frequency signals recovered by such a way. For comparison, on the same figure one may find also direct signals detected with the help of Russian (*former USSR*) Ch3-63 frequency meter, and with a W300 (Щ300) digital nano-voltmeter. As is seen our new approach entirely repeats direct measurements.

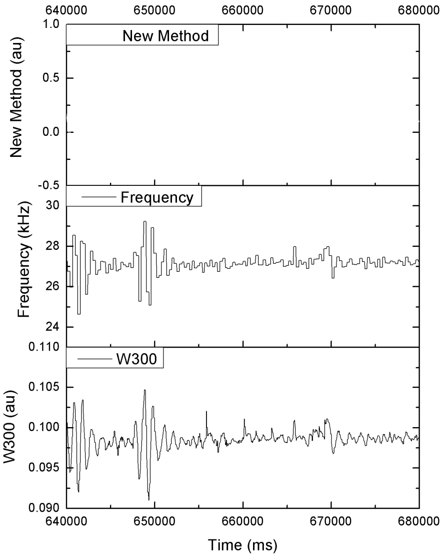

Fig. 3. Seismometer action in impediment mode with artificially generated rapid shakes.

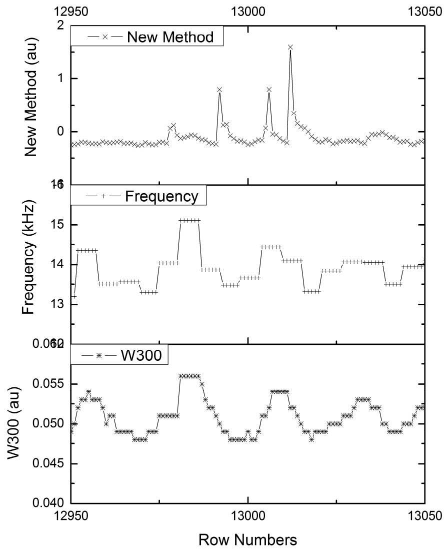

Fig. 4. Rapid shakes region in details.

Signals registered by the new method also presented in the next Fig. 3, but in this case against the specially created sharp shocks. As is seen from this figure, such sharp signals we were able to detected only by use of the new (fast processing) system. For more evidence, the region with sharp shakes are illustrated in the Fig. 4 with much more resolution.

Conclusions. As is seen from figures, main advantage of created fast processing system for Russian SM-3 inertial seismometers is that it enables to register rapid shakes. For example, it could give us possibility to explain mechanical shakes in earth crust vibrations. This fast processing method also can be used to study other fast processes like acoustic and ultrasonic waves.

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Գ. Հ. Կարապետյան

Հարթ կոճի հիման վրա գործող բացարձակ դիրքի տվիչով սեյսմիկ դետեկտորի ազդանշանների համակարգչային գրանցումն ու մշակումը

Աշխատանքում ներկայացված է հարթ կոճի տեխնիկայով (SFCO) կատարելագործված սեյսմիկ դետեկտորից ստացվող հաճախային (բնույթով թվային) ազդանշանների մշակման այնպիսի արագագործ համակարգ, որը կարողանում է գրանցել նաև երկրակեղևի կտրուկ ցնցումները: Այն կարող է կիրառվել նաև միջուկային և այլ տիպի պայթեցումների գրանցման ու դրանց բնույթի պարզաբանման նպատակներով:

Г.А. Карапетян.

Компьютерная регистрация и обработка сигналов, полученных от сейсмического детектора, основанного на сенсоре абсолютного положения с плоской катушкой

В работе представлена быстродействующая система обработки частотных (*цифровых*) сигналов, получаемых от сейсмического детектора, усовершенствованного техникой плоской катушки (SFCO), которая способна регистрировать также резкие толчки земной коры. Она может быть использована также для регистрации и выявления природы ядерных и других взрывов.