

OPTIMAL SEISMOMETERS FOR DIGITAL PC-BASED OBSERVATION SYSTEM

Fremd, V.M.

Schmidt Institute of Physics of the Earth, Russian Academy of Sciences, Moscow 123810, Russia.

A B S T R A C T

Two types of small size, high reliability, broadband three-component piezoelectric seismometers with common inert mass are proposed and elaborated. They provide seismic vibration recording in frequency range of 0.1-1000Hz with resolution about 15 nm at 1 Hz frequency and maximal acceleration 2g. Dynamic range of each type of seismometer is about 110 dB. Time of autonomous work without service is not less than 5 years. Instruments can be installed in bore-holes, sea-bottom stations and object body. They are optimal for use in local and regional networks and seismic monitoring systems.

ΙΔΑΝΙΚΑ ΣΕΙΣΜΟΜΕΤΡΑ ΓΙΑ ΨΗΦΙΑΚΑ ΣΥΣΤΗΜΑΤΑ ΠΑΡΑΤΗΡΗΣΗΣ ΒΑΣΙΣΜΕΝΑ ΣΕ PC

Fremd, V.M.

Π Ε Ρ Ι Λ Η Ψ Η

Προτείνονται και αναλύονται δύο τύποι πιεζοηλεκτρικών σεισμομέτρων τριών συνιστωσών με κοινή μάζα αδράνειας, μικρές διαστάσεις, υψηλή πιστότητα και ευρύ φάσμα συχνοτήτων. Τα σεισμομέτρα αυτά παρέχουν καταγραφές σεισμικών δονήσεων με συχνότητες 0.1-1000 Hz με ακρίβεια περίπου 15 nm στο 1 Hz και μέγιστη επιτάχυνση 2g. Η δυναμική απόκριση για κάθε τύπο σεισμομέτρου είναι περίπου 110 dB. Ο χρόνος αυτόνομης λειτουργίας χωρίς συντήρηση είναι πάνω από 5 χρόνια. Τα όργανα αυτά μπορούν να εγκατασταθούν σε πηγάδια γεωτρήσεων, υποθαλάσσιους σταθμούς, κλπ. Είναι ιδανικά για χρήση σε τοπικά και περιφερειακά δίκτυα και για συστήματα σεισμικής παρακολούθησης.

INTRODUCTION

The digital PC-based systems of seismic observations are widely used now. In these systems the signals from remote seismometers are transmitted to the central point equipped with universal PC for information recording, acquisition, processing and storage. Such third generation digital system provides necessary seismometric channels parameters, efficient data processing and good operation and financial characteristics. In the presence of accessible PC and telemetric devices the main problem is the optimal high-reliable seismometers working out.

DEMANDS OF SEISMOMETERS

In local and regional seismic observation systems vibrations with frequencies from 0.05 to 80-100Hz are necessary to record. In important objects seismic monitoring systems the high frequency increases up to 1kHz. The dynamic possibilities of channels have to provide minimal displacement about 10-15nm at 1Hz frequency for small and maximal acceleration about 2g for strong earthquakes recording.

The remote seismometers have to work practically without service. It might be as well to provide their using in boreholes and sea-bottom stations. Seriously attention be worthy the channels automatic calibration problem.

PIEZOELECTRIC SEISMOMETERS

The natural period of traditional pendulum seismometer mechanical system is usually longer than the maximal period of recorded vibration. As a result the rigidity of elastic suspension is relatively small and the dimensions and mass of pendulum are relatively big. Therefore, the pendulum systems of such seismometers are, as a rule, provided with the arresting and zero position control devices (Instruments, 1974).

At the same time as long ago, as 1915, B.B.Galitzin for the first time proposed piezoquartz seismometer (Galitzin, 1915). The principles and construction of piezoelectrical accelerometer are in detail described by Wood, (1921). But only after the field-effect transistor invention the first suitable and reliable piezoelectric seismometer came to be possible (Fremd, 1969).

In designing piezoelectric seismometers with volume-deformable piezoelements (Fremd, 1978), the basic mathematical formulas holding between the electric sensitivity S , the time constant τ , the eigen frequency f_0 and the capacitance c_0 of piezoelements of the seismometer's sensor are:

$$S = \frac{M a d}{C_0} \quad (1)$$

where M is the mass of the inertial element, a is the acting acceleration, d is the piezoelectric modulus of the used material;

$$\tau = R_{in} C_0 \quad (2)$$

where R_{in} is the input resistance of the circuit connected to the sensor;

$$f_0 = k \frac{\sqrt{E C_0}}{M} \quad (3)$$

where E is Young's modulus of the piezoelectric material, and k is a coefficient depending on electric properties of the piezoelectric material and on mechanical characteristics of the seismometer elements.

Formula (3) determines the frequency of natural oscillations of the system of the case, piezoelements, and inert mass for a construction in which the piezoelements, clamped between the case and inert mass, are simultaneously its elastic elements (fig.1).

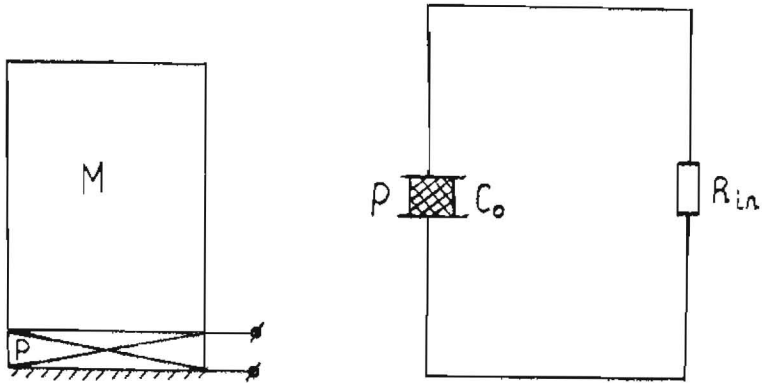


Fig.1. Diagram of mechanical (a) and electrical (b) schemes of piezoelectric seismometer. M- inertial mass, P- piezoelement.

The upper boundary of the range of recorded frequencies is usually chosen somewhat less than f_0 in the plateau section of the seismometer's frequency characteristic.

The lower boundary of the seismometer's frequency range is determined by the value of τ which in accordance with formula (2) is directly proportional to the piezoelement's capacitance c_0 . In turn, the sensor's electric sensitivity S (formula (1)) is inversely proportional to the capacitance c_0 .

Thus, in developing a piezoseismometer one has to seek a compromise between the values of S , τ , and f_0 , which determine the instrument's basic parameters: sensitivity and frequency range.

The important features of piezoseismometer are practically idea amplitude and phase frequency characteristics of high-frequency sensor with very small damping (fig.2).

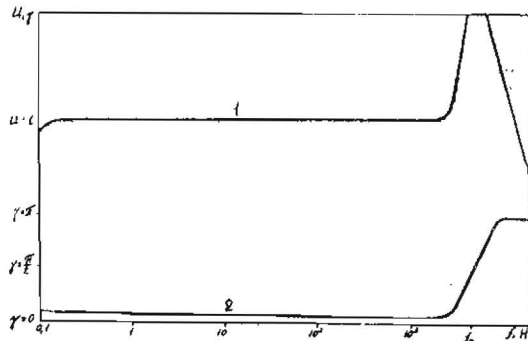


Fig.2. Schematic diagram of piezoseismometer amplitude (1) and phase (2) frequency characteristics.

Fig.3 shows in terms of visualized record (Fremd, 1984) the schematic diagram of the curves of maximal sensitivities of accelerographs (V_{0a}), velocity graphs (V_{0v}), and seismographs (V_0) for piezoseismometers with real accessible parameters. Also, fig.3 shows the schematic sensitivity curve of traditional galvanometric high-sensitive seismograph SKM-3 with so called standard characteristics (Instruments, 1974).

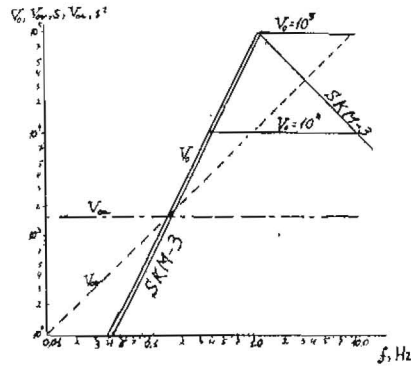


Fig.3. Schematic diagrams of channels with piezoseismometers maximal accessible sensitivity curves and high-sensitive seismograph SKM-3 magnifications curve.

Three-component piezoelectric accelerometer APT-1M with common cubic inert mass and field-effect tranzistors (fig.4) was specially designed in 1969 for strong-motion recording.

The sensitivity of APT-1M is 2.5 V/g, frequency range 0.15-1000 Hz, transverse component sensitivity about 3%. It has been produced by industry for about 20 years.

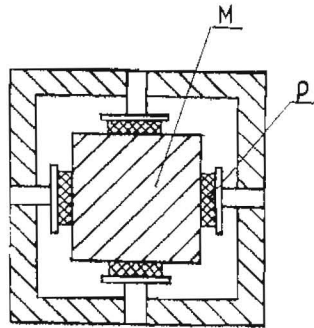


Fig.4. Schematic diagram of accelerometer APT-1M. M-inert mass, P-piezoelement.

Now in production are the new three-component piezoelectric TAF-family seismometers with common double-conic inert-mass (Fremd,1990). Schematic diagram of such construction is shown in fig.5.

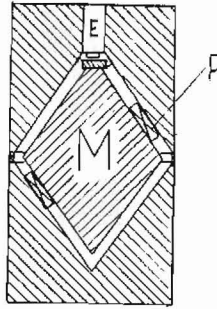


Fig.5. Schematic diagram of TAF-family piezoseismometer. M-inert mass, P-piezoelement, E-electromagnet of distant calibration device.

The three-component acceleromener TAF -head type of such seismometers- can be used for recording of seismic phenomena and in various field of science and technique to measure average levels of vibration, especially for strong earthquakes recording. Accelerometer consist of three-axial piezoelectric trasducer with common inert mass and three-channel preamplifier. Constructively instrument is made as a cylinder. The components sensitivity axes are mutually perpendicular and form angles $54^{\circ} 44'$ with the axis of the seismometer cylindrical case. Besides preamplifier electronics of accelerometer include generator for electromagnetic distant calibration device (see fig.5). Accelerometer TAF has the following main parameters:

Range	2g full scale;
Sensitivity	0.5 V.s ² /m;
Frequency range	0.2-1000 Hz (-3 dB);
Transverse sensitivity	4%;
Dynamic range	106 dB;
Power required	10 mA, 15V;
Operating temperature	-25 - +50°C;
Dimensions:	hight 120 mm;
	diameter 85 mm;
Weight	2.1 kg.

The second of now produced piezoseismometers is three-component velocimeter TPV. It has the similar as TAF construction and the following main parameters:

Resolution	15nm at 1 Hz frequency;
Sensitivity	6000 V.s/m;
Frequency range	02-100 Hz;
Dimensions:	hight 140 mm;
	diameter 150 mm;
Weight	12 kg.

The rest of parameters are the same as for TAF accelerometer.

It is very important that time of autonomous work for such seismometers is not less than 5 years without service. Piezoseismometers are useful in any position and can be installed in bore-holes, sea-bottom stations and in object body.

It is possible to increase the sensitivity of small diameter piezoseismometer by series mechanical and electrical connection of several identical so called seismometric modules (Fremd, 1991). In this case, the electric sensitivity of the compound seismometer should increase by n^2 , where n is the number of modules connected. It seems that three-component seismometric modules based on rigid, reliable piezoelectric sensors providing for flexible variation of parameters and characteristics of seismic arrays.

Because the frequency characteristics of digital seismometric channel strongly depend on seismometer parameters it is possible to form these characteristics inside seismometer, for example with the help of piezoseismometer built-in amplifier and filters choice.

SOME PRACTICAL RESULTS

Since 1991 up to day in Belgrade and Titograd seismic stations PC-based digital observation systems are operating (Fremd et al, 1992). These systems include channels with TAF accelerometers and PC AT 386 computer. They has detected about thousand local and regional earthquakes of magnitude from 1.8 to 5.7. Fig. 6 presents a typical example of record.

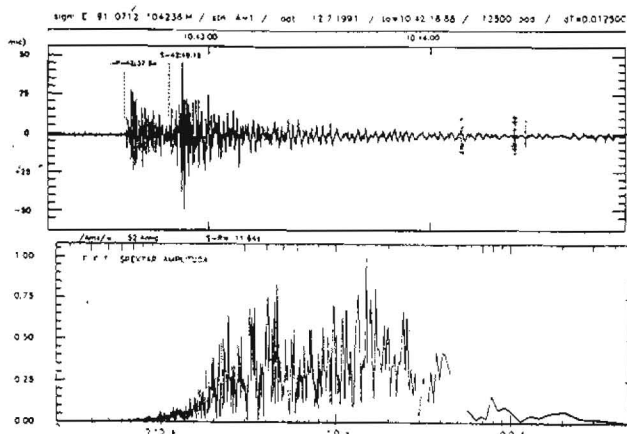


Fig.6. Record and spectrum of strong Temishoara earthquake 12.07.1991 on Belgrade station. $M=5.7$, epicentral distance about 500 km, the channel with TAF accelerometer.

Two years of systems operating confirm the physical and exploiting merits of piezoseismometers especially the high reliability of them.

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