Broadband molecular electronic seismometers

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ABSTRACT

The molecular electronic transfer seismometers offer an alternative to regular electromechanical devices way to record broadband seismic signals. The MET seismometers are compact in size, robust and easy to install. The operation principles of MET seismometers are described and experimental data related to performance comparison with regular electromechanical sensors are presented.

KEYWORDS: seismometers, broadband seismometers, seismology, instrumentation, molecular-electronic transfer.

INTRODUCTION

Spectacular advances in seismology in the last decades have been achieved, to a great extent, as a result of the tremendous progress in the instrumentation, particularly seismometers and data acquisition systems. The remarkable gains in seismometer characteristics have been based on the utilization of the state-of-the-art technologies in mechanical engineering, material science and especially electronics [1].

Expansion of the passband of a broadband seismometer to periods of 100 seconds and beyond imposes extremely strict requirements for mechanical design, material selection, and manufacturing. These inevitably lead to significant price increases. The high cost of manufacturing and the length of the manufacturing cycle often cause the manufacturers to initiate production only after receiving concrete orders which is the main reason for the long lead times.

Curiously, while the methods of signal conversion, conditioning, processing and recording have changed, the basic principle of the seismometer, a suspended solid inertial mass, had not changed since the Russian Prince Boris Golitsyn's instrument was invented in 1906.

The molecular electronic transfer (MET) seismometers [2], [3], [4] offer an alternative to regular electromechanical devices, providing high performance seismic data in compact size, robust, easy to install instruments. The operation principles of the MET seismometers are based on charge transfer variations due to electrolyte motion in the four-electrode electrochemical cell.

METHODS

A typical MET transducer cell contains anode and cathode electrodes separated by microporous dielectric spacers. The cell is filled with a highly concentrated iodine-based electrolytic solution, with a small dc-offset voltage applied between the electrodes. The physical principles of operation could be understood by analogy to an electronic vacuum tube. If, by some means, the grid could be made to move in response to an external mechanical acceleration (say, ground motion), the tube's current would be changed accordingly. The signal power would be amplified by many orders of magnitude at the expense of the anode power source. In a similar manner, an external acceleration along the sensor input axis causes the MET electrolyte to flow, changing the anode-cathode current. In this system, the electrolyte plays a dual role of the "grid" and the inertial mass. The resulting power gain eliminates the need for large inertial masses; the mass of the liquid electrolyte is just a few grams.

Many of the major advantages of an MET seismometer are attributable to the absence of moving or precision mechanical parts. These sensors are reliable and rugged; no arresters are required; they need no mass centering; and they can operate normally with installation tilts up to 15º. The operating temperature range goes down to -40° C and the power consumption is low.

Error! Reference source not found. shows a sketch of a basic MET cell. The transducer is enclosed in a channel 1 filled with an electrolyte 3. Microporous ceramic spacers 4 separate fine platinum mesh electrodes - cathodes 5 and anodes 6. A 300 mV dc-offset is applied between the anodes and cathodes. Thin platinum wires connect the electrodes to an external electronic circuit. The symmetrical geometry of the cell is important in ensuring its linear response over a wide range of accelerations. A standby electric current flows between the anode-cathode pairs and is processed by the adjacent electronic circuitry. An external motion causes a pressure difference ΔP across the transducer. The resultant flow of electrolyte entrains the charge carriers (ions and ionized molecules), raising their concentration on one set of electrodes and reducing it on the other set. This modifies the standby electric current as a function of the input mechanical motion. Efficiency of this energy conversion (i.e., the signal to noise ratio) and the transducer transfer function depend strongly on the cell configuration. Modern MET sensors have been based on the use of thoroughly elaborated theoretical foundations for the hydrodynamics, charge and mass transfer theory and extensive computer simulations of multiple cell geometries.

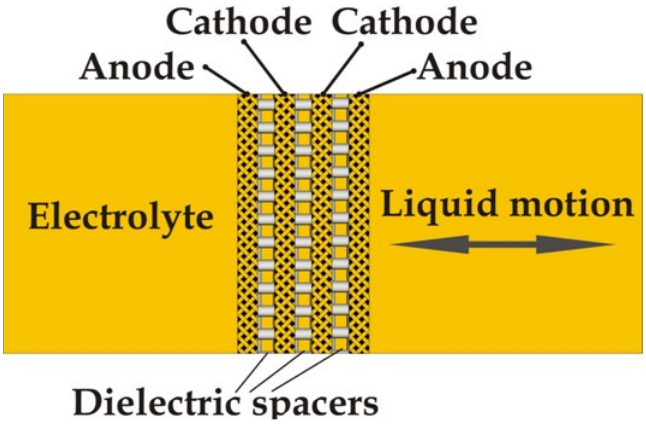

Figure 1. Molecular-electronic transfer cell.

RESULTS

An extensive comparison tests have been performed with the MET broadband seismometers in several seismological laboratories. Here we present some important results.

The comparison of CME-6211 120 sec seismometer with Trillium 120 has been performed in University of Patras. The authors thank Prof. E. Sokos for arranging the tests and providing the test data. The tests included direct comparison of the MET broadband seismometer output with the Trillium 120 broadband seismometer in teleseismic events recording and during quiet periods of time. Figure 2 presents a recordings and spectra of the event Mw 5.2 recorded on 12 February 2017 near the cost of Western Turkey. Poles and zeroes correction has been applied for both CME-6211 and Trillium 120 outputs.

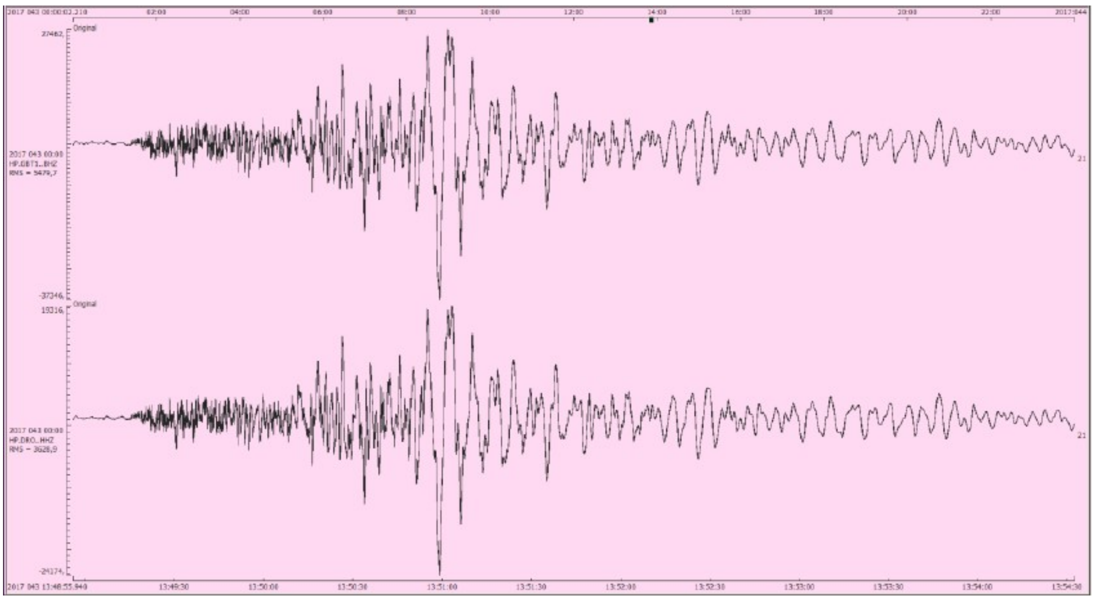

Figure 2. Teleseismic event Mw 5.2 near the cost of western Turkey, recorded by CME-6211 broadband seismometer (upper trace) and Trillium 120 (lower trace).

The comparison of the spectra for the same set of data are presented in Figure 3.

As it could be seen from the presented data, there is a great correlation between the data recorded by two different types of sensors.

Another tests were aimed to compare the self-noise of the sensors by recording the quiet time data and averaged over long time periods. The resulting PSDs together with NHNM and NLNM are presented in Figure 4. Due to the difference in the time periods when the recordings were performed and different processing software used, there is a difference in the resulting curves.

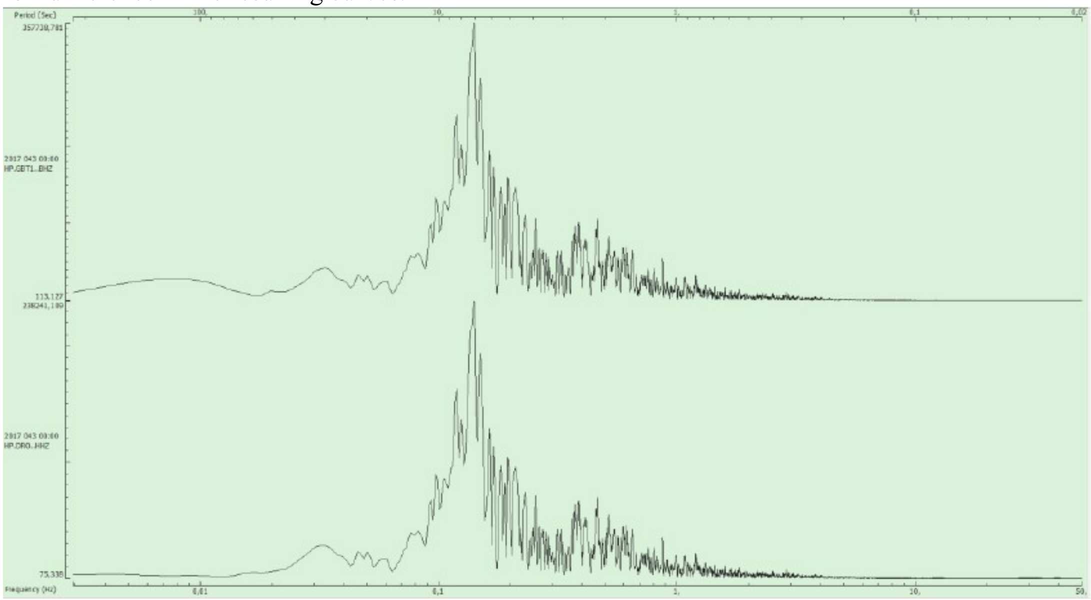

Figure 3. Spectra of the teleseismic event Mw 5.2 near cost of Western Turkey, recorded by CME-6211 broadband seismometer (upper trace) and Trillium 120 (lower trace).

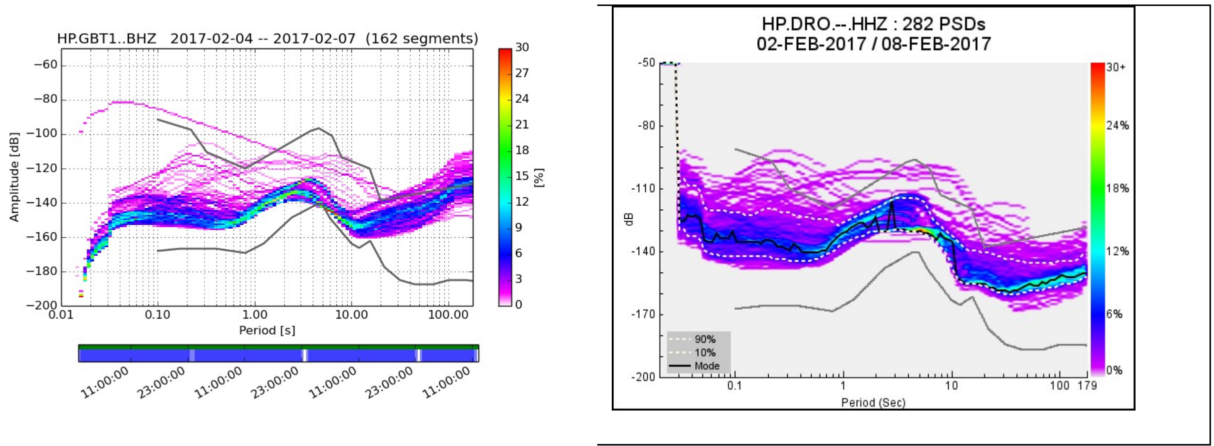

Figure 4. Comparison of the spectra recorded at quiet time period. Left – CME-6211 120 sec seismometer. Right – Trillium 120.

Nevertheless, the resulting curves display the equivalence of the data in major portion of the frequency range. Some difference could be found at very low frequencies <0.02 Hz where the Trillium 120 displays a little lower self-noise, although CME-6211 shows better noise at 2-10 Hz frequency range.

CONCLUSION

The molecular-electronic transfer technology offers an alternative approach to build broadband seismometers with the parameters compared to the best electromechanical sensors while keeping the lower cost, ruggedness and ability to operate in wide range of environmental conditions. This work was supported by the Russian Ministry of Science and Education, Project ID RFMEFI57817X0243.

REFERENCES

[1] G. Havskov, J., Alguacil, "Instrumentation in Earthquake Seismology," in *Instrumentation in Earthquake Seismology, Volume 22 of the series Modern Approaches in Geophysics*, New York, NY, USA: Springer-Verlag, 2010, pp. 11–76.
[2] V. Agafonov, A. Neeshpapa, and A. Shabalina, "Electrochemical Seismometers of Linear and Angular Motion," in *Encyclopedia of Earthquake Engineering SE - 403-1*, M. Beer, I. A. Kougioumtzoglou, E. Patelli, and I. S.-K. Au, Eds. Springer Berlin Heidelberg, 2015, pp. 944–961.
[3] W. T. He, D. Y. Chen, J. B. Wang, and Z. Y. Zhang, "MEMS based broadband electrochemical seismometer," *Opt. Precis. Eng.*, vol. 23, no. 2, pp. 444–451, 2015.

[4] H. Huang, B. Carande, R. Tang, J. Oiler, Z. Dmitriy, A. Vadim, and H. Yu, "Development of a micro seismometer based on molecular electronic transducer technology for planetary exploration," *Proc. IEEE Int. Conf. Micro Electro Mech. Syst.*, vol. 193512, pp. 629–632, 2013.