SEISMIC DETECTION UTILIZING A MINI SENSOR

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ABSTRACT

Over the last several decades seismometers' properties of long period, low noise, and high dynamic range consisted of mass and coil technology. From geophones to broadband seismometers, the period and noise was a function of mass size and weight. This by nature prevented the sensor from being designed to a miniature form factor. eentec has used its electrochemical technology quite successfully during the last 12 years, producing low cost, high performance seismometers. Through preliminary research it has been determined that our technology could be miniaturized to a three component, one-inch-cubed seismometer without compromising the sensors project specifications of passband, low noise, low power, and low cost. A first prototype was made and successfully tested that reduced the sensor element size from 2.5 inches to 7/8 of an inch. Current research efforts include analyzing these data and modeling every component of the seismometer smaller, then gradually building sub-assemblies, testing them at each stage, verifying against the models, and applying changes as needed to the various prototype sub-assemblies until they interact with each other to create a finalized, miniature seismometer. Such a unit would offer many advantages in packaging with recorders, transmission devices, or other sensors such as our rotational seismometer - especially in ocean bottom or deep sea applications.

OBJECTIVE

The objective of this research project is to develop the world's first mini seismometer. One that has the specifications of an industry standard seismometer. They include the following:

- miniature size – about 1 cubic inch
- power consumption should be below 100 mW for a basic analog sensor
- dynamic range - at least 120 dB
- high resolution in the required passband of 0.2 to 40Hz: below the USGS Low Earth Noise Model Extended passband from 0.07 to 50Hz will be evaluated. (e.g., approximately 0.5 ng/sqrt[Hz])
- the sensor must be capable of operation at any selected orientation of its axis of sensitivity

This project, if successful, would lead to the implementation of miniature, affordable, rugged, reliable, easily installed, high quality instruments, well suited for mass production.

RESEARCH ACCOMPLISHED

The research performed to date mainly involved computer analysis and modeling.

First was analysis of the Phase 1 data from the mini sensor pictured below. After analysis it was determined that the sensor self noise should be focused on first. A new devolvement of an improved noise model was required for further noise reduction. Based on our analyses we concluded that the complex transfer function of an electrochemical sensor is dependent on a number of parameters of mechanical and chemical nature:

$$S(\omega) \propto \frac{1}{1+i\omega\dfrac{d^2}{2D}} \times \frac{d\omega^2}{\omega^2 - \dfrac{k}{\rho LS} - i\omega\dfrac{R_h S}{\rho L}} \quad (1)$$

Where: i – imaginary unit; d – distance between electrodes; ρ – electrolyte density; L – height of the electrolyte column in the sensor; D – diffusion coefficient, S – effective area of the membrane, R_h – hydraulic impedance of the transducer cell, k – membrane rigidity, ω – angular velocity.

The first part of the sensor that may help in the noise reduction was the sensor element spacer thickness d. In our original electrochemical transducer element we used thicker spacers which deliver better performance at low periods up to 60 or 120 seconds. This was essential for the design of eentec broadband and long-period seismometers such as EP-300 and EP-105 as well as our latest rotational seismometer R-2. However such an approach is not applicable to the mini sensor since its passband is limited from medium to short periods from 0.2 to 40Hz.

It appeared from the above equation that reduction of the distance between electrodes would in fact increase the current gain at medium and high frequencies which allows reducing the noise in a smaller sensor. Frequency responses of an original sensor with 150um spacers and mini sensor with smaller spacers (company trade secret on dimensions) shown on Figure 3. See also Figure 4 below on the data acquired on the first small sensor and the mathematical graph showing the noise improvement. Three types of spacing material with different opening area and various R_h have been ordered and will undergo testing, determining if the model is correct. Projected noise improvement is about 10-12dB.

New designs of a miniature coil and magnet as well as Magnetic Hydro Dynamic (MHD) force-balanced feedback systems have been evaluated. No prototyping has occurred as yet, only modeling.

Electrolyte liquid for the seismometer is currently under investigation for optimal performance. Lithium-based electrolyte is prepared at various concentrations of active and indifferent ions for the extension of the temperature range of the mini sensor.

CONCLUSIONS AND RECOMMENDATIONS

From the theoretical and prototypes to date, it is very probable that we will complete the objective of this project.

Table 1. eentec SP400 vs Phase I mini sensor vs Phase II preliminary specs

PARAMETER	SP400	Proto I	Proto II
Operating principle	Proprietary Electrochemical Sensors; force-balanced	Proprietary Electrochemical Sensors;	Proprietary Electrochemical Sensors;
Output signals	2 horizontal, 1 vertical; velocity flat response	1 vertical; velocity flat response	2 horizontal, 1 vertical; velocity flat response
Dynamic Range	142 dB	122dB	132dB
Passband	0.067 – 50 Hz	0.2 – 40 Hz	0.07 – 50 Hz
Self-noise	-160dB	-158dB	-170dB
Generator constant	Standard: 2000 V/m/s; Optional: 350 – 20,000 V/m/s	8000 V/m/s;	Standard: 2000 V/m/s; Optional: 350 – 20,000 V/m/s
Maximum installation tilt	$\pm 10^{\circ}$	$\pm 10^{\circ}$	any
Temperature range	-12 to + 55 °C	-12 to + 55 °C	-12(-40) to + 55 °C
Dimensions	D214x220mm	25x25x25mm	25x25x25mm
Weight	~8kg	0.2kg	0.2kg
Power	10 – 15 Vdc; (Nominal 12Vdc); 30mA	10 – 15 Vdc; (Nominal 12Vdc); 10mA	10 – 15 Vdc; (Nominal 12Vdc); 3 mA

Figure 1. Progression of miniature sensor elements of a seismometer

Figure 2. Current prototype

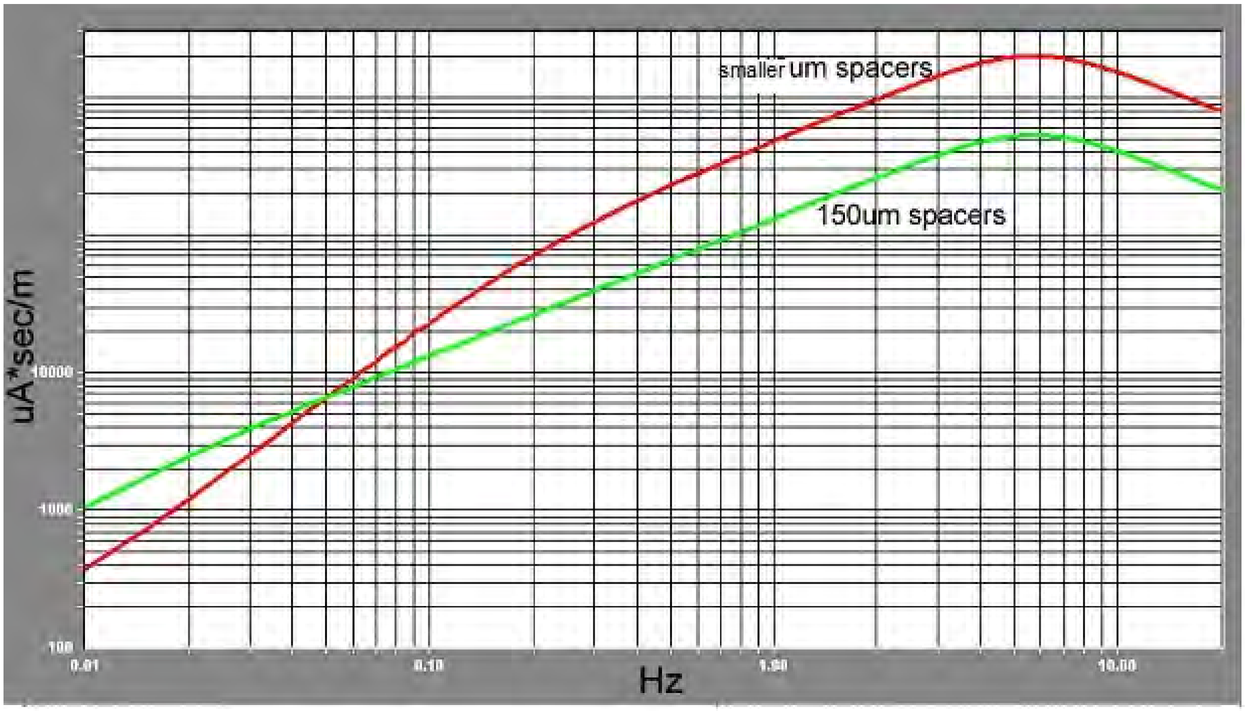

Figure 3. Frequency responses of an old and a new mini prototype

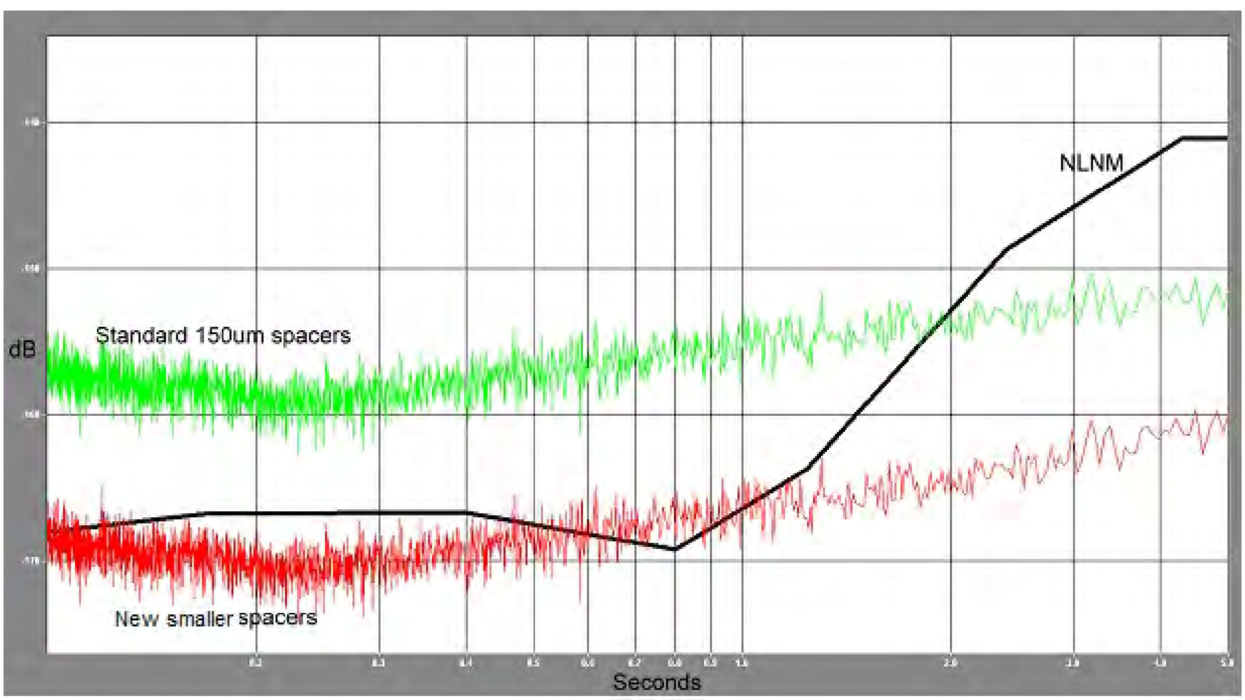

Figure 4. Test data using a smaller spacer