SmartSenseCom Introduces Next Generation Seismic Sensor Systems

Summary:

SmartSenseCom, Inc. (SSC) has introduced the next generation in seismic sensing technology. SSC's systems use a unique optical sensing approach originally developed by the U.S. Naval Research Laboratory to provide high-performance sensing in challenging operational environments. Different from MEMS or fiber-optic seismic sensor systems (including Distributed Acoustic Sensing [DAS]), SSC's seismic nodes use a simple, and inherently more robust, 100% passive, and EMI immune sensor and cabling system where the light from a LED source is modulated by the movement of a cantilever or spring-mass mechanism to detect vibrations. This approach to seismic sensing provides an order of magnitude improvement in sensitivity compared to geophones or DAS and exceptional low frequency resolution to fractional Hertz, greatly increasing the amount of high quality information available to operators. The only active electronic elements in the system—SSC's combined opto-electronics and data acquisition platform—can be placed up to 5 km away from the seismic nodes, providing much more flexibility in system design.

SmartSenseCom Seismic Node

Technology Overview

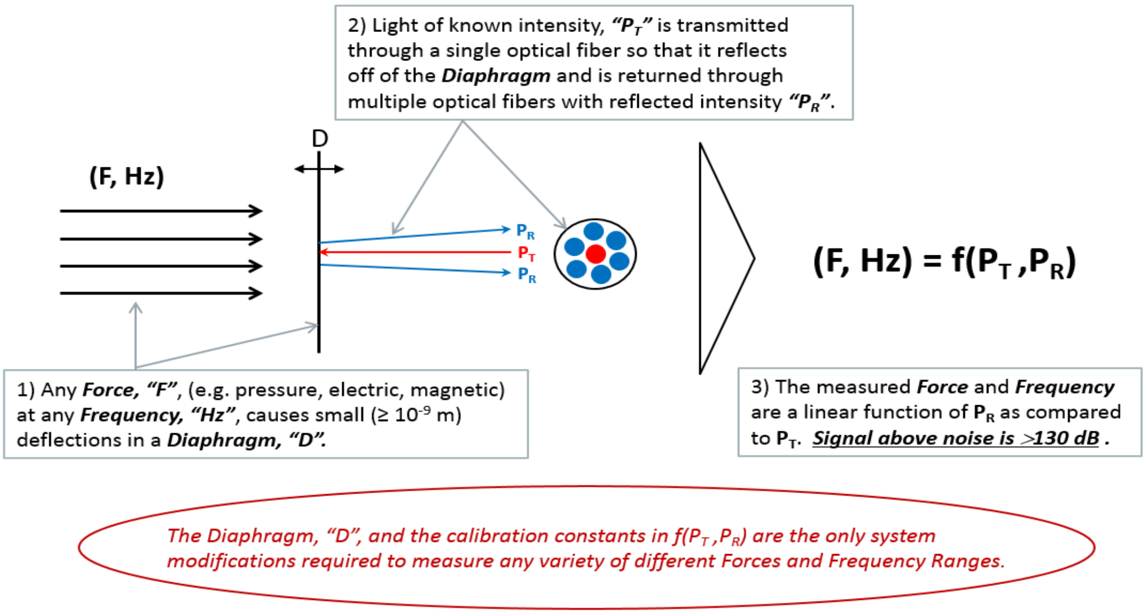


Figure 1 – Basic Principles of Intensity Modulated Optical Sensing

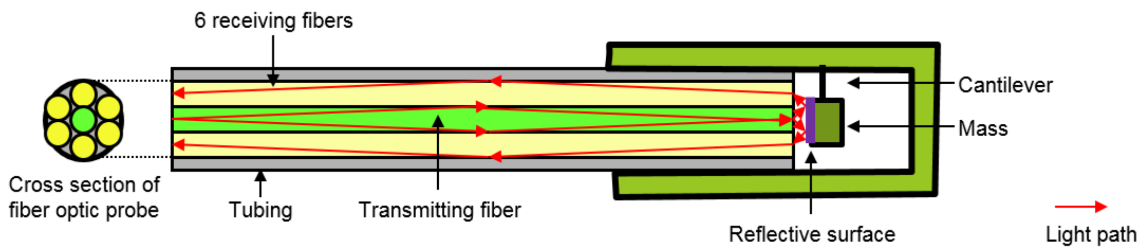
Basis of Technology

The SmartSenseCom (SSC) Atmospheric Acoustic, Vibration and Pressure Sensors are direct adaptations and derivative works of the intensity modulated optical micro-sensors developed by the U.S. Navy in the 1990s, building on the earlier work of the Navy in interferometry based optical sensing. Primary applications developed by the Navy were for hydrophone, temperature and strain measurement. The article in Attachment 1 [Bucaro et al, "Miniature, high performance, low-cost fiber optic microphone," 118 J. Acoust. Soc. Am. 1406-12, September 2005] provides an introduction to the sensor technology and how it measures displacement.

The basic design of SSC's sensors consists of an optical fiber probe separated from a reflective diaphragm by a small gap as illustrated in Figure 1. The fiber probe consists of seven fibers joined with epoxy. The center fiber transmits light from an LED-light source on to the diaphragm. Movement of the diaphragm linearly modulates the intensity of light collected in six receive fibers arranged around the center fiber in a hexagonal pattern. The current produced by photodiodes in the system's electronics contains a signal proportional to the force acting on the diaphragm.

SSC has extended the Navy's work to include development of optical accelerometers (vibration sensors) that comprise the sensing element of SSC's seismic nodes. The diaphragm in SSC's optical accelerometer design is a mass with a reflective service attached to a cantilever as illustrated in Figure 2.

Figure 2 – SSC optical accelerometer design



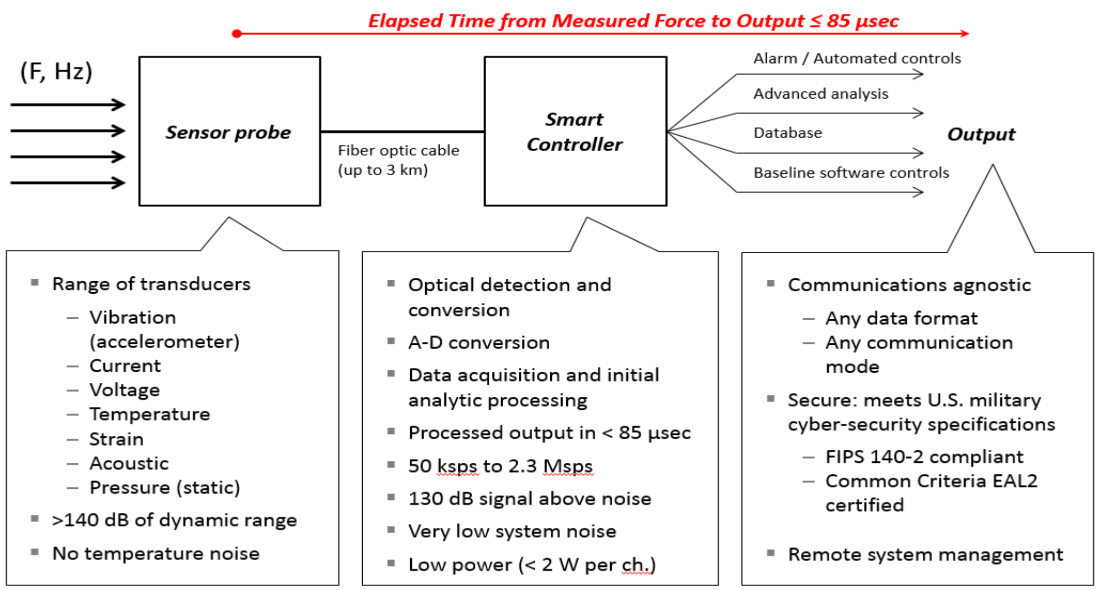
As the accelerometer vibrates, the cantilever bends due to the inertia of the mass, and the mass is displaced relative to the fiber optic probe. Acceleration is calculated based on the displacement of the mass and frequency of its vibration based on the following relationships:

$$A = \omega^2 x$$
$$\omega = 2\pi f$$

where A is acceleration, x is displacement, w is angular velocity, and f is frequency.

To take full advantage of the broad performance envelope of their optical sensors, SSC developed a proprietary electronics platform that consolidates electro-optics, analog-to-digital conversion, data acquisition and baseline signal processing into a single platform as outlined in Figure 5. The SSC platform delivers faster measurement, higher dynamic range, very low system noise, and improved power use efficiency compared to other commercially available systems.

Figure 3 – **SSC Optical Monitoring System Design**



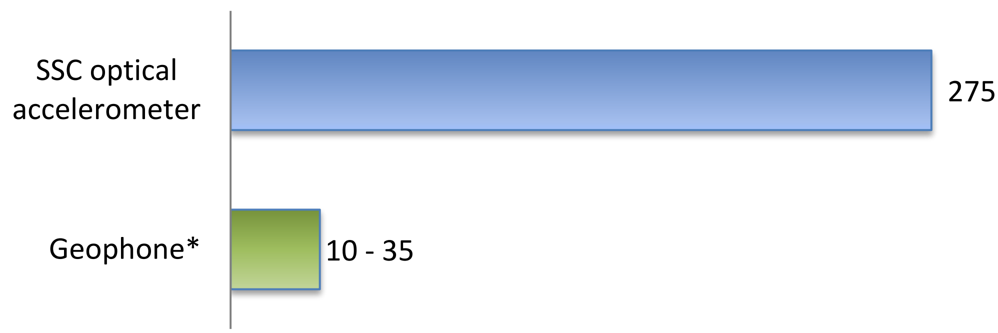
Equally important, the simple mechanical structure and passive design of the SSC platform is inherently more robust in the field. Compared to typical electromechanical systems, SSC sensor systems have a low power budget (less than 2 W per channel), provide size and weight savings, do not require recalibration, and are substantially more environmentally robust -- SSC sensor systems deliver nearly identical performance in the lab or in the field.

Advantages for Seismic Detection

SSC's technology platform provides a range of advantages for seismic sensing. Two advantages in particular—its high sensitivity and exceptional low frequency response—have unlocked the ability to passively detect, locate and classify the source of digging, vehicle, machinery, or other high interest activity with less than 1% error at distances of 275 meters or more.

High sensitivity for extended detection range. Laboratory calibration of SSC's optical accelerometers have demonstrated the ability to accurately measure displacements as small as $2.6 * 10^{-11}$ meters / $\sqrt{Hz}$ (at 30 Hz). This high sensitivity means that the sensors can detect the faint vibrations of digging related impulses from extended ranges. During field testing, SSC's accelerometers successfully detected a pickaxe striking the earth at a distance of 275 meters from the sensor. Data indicate that the sensors should be able to detect the same signal at a distance of at least 300 meters, however the test location did not allow a test at this distance. Moreover, these tests were accomplished in an outdoor environment. The sensors were placed in sand along a beach where high levels of background noise were present from the surf. This detection range is nearly an order of magnitude great than that typically achieved using a geophone as indicated in Figure 4.

Figure 4 – Detection range of digging related activity (meters)



Field test description

- High noise outdoor environment
- Sandy soil
- Test location limited to 275 meters – data indicates 300+ meter detection range

* Based on press research and feedback from program managers developing tunneling detection systems

Exceptional low frequency resolution to positively identify tunnel related activity. Geophones used for high resolution seismic measurement typically consist of a magnetic mass that moves within a wire coil when disturbed by a vibration. As the geophone vibrates, the movement of the mass within the coil creates an electrical signal. The low frequency limit, or corner frequency, of these devices is limited by the free period of the spring-mass system. The industry standard 10 Hz geophone typically sees a ~12 dB per octave reduction in amplitude response as frequency declines, limiting the ability of these devices to accurately measure frequencies below 2 to 5 Hz.

In contrast, recent field testing of SSC accelerometers demonstrated their exception low frequency response as illustrated in Figure 5. At least 7 dB of signal above noise was observed below 1 Hz in response to a test impulse generated at a distance of 275 meters from the sensor. The ability to resolve signals at these low frequencies allows the system to identify digging related impulses much more accurately by using the long wavelength emissions typically associated with these activities.

Figure 5 – Frequency response of SSC optical accelerometer during field testing