Marine Seismic Sensors

This document introduces the sensors used in marine seismic acquisition systems.

The primary sensors are the most critical element in a seismic acquisition system. Unless the geophones and hydrophones are well designed, the performance of the whole system can be compromised.

Towed arrays use large numbers of hydrophones to sample the pressure field across the array. Ocean bottom and land systems use multi-axis geophones to measure the seismic velocity vector. 4-component sensors, consisting of a 3-axis geophone and a hydrophone are used to measure the full seismic wave field. This consists of the primary wave (pressure) and the secondary wave (shear).

Hydrophones

Three types of hydrophone are currently used in seismic systems. The most common type uses a pair of lead zirconium titanate (PZT) plates bonded to a hermetically sealed chamber, which flexes with the changing pressure field. Flexing of a piezoelectric material causes the polarization of the crystal lattice to change, leading to a flow of charge, which can be detected as a voltage across a load.

Deep-water hydrophones use a solid piezoelectric cylinder, to resist crushing. These devices and are less sensitive and have a lower capacitance. High capacitance is desirable for driving long lines of wire and this type is normally used with pre-amplifiers at the sensor.

PVDF film hydrophones use many turns of piezoelectric film, wrapped on a ribbed cylinder. This type has a number of benefits. The pressure field is sampled over the whole surface of the cylinder, giving a good aperture, which is necessary to reduce turbulent boundary layer noise in some arrays that are not liquid-filled.

Geophones

The geophone uses a spring-mass system, operated at frequencies above its natural frequency. The modern seismic geophone is a remarkably effective device with a wide dynamic range and a flat response over the seismic band. At these frequencies, the proof mass, which is attached to the case by a spring, remains effectively stationary in inertial space, while the case moves relative to it. The seismic displacement is equal to the displacement of the case, relative to the proof mass. The case contains a pick-up coil and the proof mass is a samarium magnet. As the mass moves, electromagnetic induction causes a voltage across the coil. The output is proportional to the velocity of the case, relative to the mass. It is important that the case should well coupled to the seismic wave field and geophones for land use have spikes for insertion in the earth. Deployment of geophones on the seabed requires specialized techniques to ensure good coupling.

All-Optical Sensor Arrays

It is possible to build sensor arrays, whose components outside the instrument room consist essentially of glass fiber. Such systems have numerous potential advantages, including cost and size. For towed arrays, most of the high cost equipment is moved onto the ship, which reduces exposure to marine hazards. Lightweight arrays reduce fuel costs and increase operational flexibility.

All-optical arrays are particularly suitable for installation in oil wells, because glass fibre can withstand the high temperatures and pressures, encountered in oil wells.
The low cost of optical arrays makes it practical to deploy permanent seabed arrays for reservoir monitoring applications.

Two types of optical acquisition system are commonly used in geophysical applications. Both rely on a measurand; usually pressure, to modulate the optical path length by stretching a fiber. This can be used to shift the reflection wavelength of a fiber Bragg grating, fabricated in the fiber. When illuminated by broadband light, the reflection wavelength can be tracked by a spectrometer.

With interferometric systems, the path length change alters the path length in one arm of an interferometer. The other arm contains an optical frequency modulator. The paths are re-combined and interference takes place at the photo-detector, which gives a voltage output at the modulation frequency. Synchronous demodulation is used to extract the phase shift, which is proportional to the path length change.
Optical hydrophones are formed by winding many turns of low bend loss fiber on a complaint mandrel. The preferred operating band is 1550 nm, where 128 wavelengths are defined for telecommunication use. It is advantageous to use telecommunication components as the prices of components, such as tuneable lasers, are dropping rapidly.

Conclusion

A variety of sensors is now in use due mainly to the different operating environments. There is strong interest in finding new uses for optical sensors because of their low noise, and simplicity of the in-water sensors. However, the cost of the optical processing hardware must first be reduced for broader acceptance.