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Abstract

Monitoring of microseismic activity induced by hydraulic stimulation, carbon capture and storage, and geothermal injections is critical and often mandated by government agencies. Considering that optical fiber is becoming a common monitoring sensor with many applications (e.g., temperature monitoring, leak detection, fluid flow monitoring, microseismic monitoring, crosswell strain monitoring, production monitoring, etc.), we developed a fiber-optic-based (Distributed Acoustic Sensing or DAS) survey design tool for microseismic monitoring so to supplement current tools leveraging three-component (3C) sensors.

Key criteria for the survey design are the source, earth, noise, and response models. The source model encompasses the characteristics of generated events: location, energy, source mechanism, and radiation patterns. The earth model considers the efficiency of the seismic energy propagating from the source to the sensors. This relates to geological structures, velocities, and intrinsic attenuation of the formations the signal must pass through. The noise model is needed since when seismic energy radiating from the source reaches the receiver array, its detection depends on the signal strength compared to other signals (noise) at the array. Finally, the tool response model depends on the system. For an accelerometer, the response is particle acceleration; for a geophone, it is particle velocity; and for a DAS system, it is strain.

The signal of a geophone/accelerometer (3C or 1C) is well understood as it is mainly a function of the source's characteristics, the path from the source to the receiver, and the site function, which for downhole-located sensors is assimilated to coupling. The response of the geophone is particle velocity with limited bandwidth. DAS response is compounded with the apparent slowness at the cable because DAS measures strain. The gauge length could be another factor to consider for long gauge lengths. To be a true reflection of the monitored environment, the survey design must include the noise level, which is different between geophone-based and fiber optic-based systems. Finally, coupling is of critical importance in any survey design exercise. 3C geophones are often considered to be fully coupled to the formation (either directly or indirectly) as there are various means to achieve coupling via hydraulic arms, magnetic clamps, etc. Although a fiber optic cable can be clamped at specific depths, coupling is often aided by gravity (in a deviated and/or horizontal well) or by slacking in a vertical well; thus, understanding the coupling quality along the well trajectory is key.

The documented survey design scenarios illustrating the relative impact of the various elements from this study provide a procedure and guidelines for planning fiber optic microseismic acquisition.