Submarine Earthquake Event Recording While Wave Monitoring Using Submarine Optical Fiber Cable and DAS Technology

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Since 2011, the oil and gas industry has used distributed acoustic sensing (DAS) technology to meet the demands of pipeline monitoring and intrusion detection. The latest optical fiber sensing technology using differential phase data, called heterodyne distributed vibration sensing (hDVS), now enables DAS to record seismic signals, including vertical seismic profiling (VSP)¹. The potential of monitoring earthquake and tsunami in real time using the hDVS system by emulating natural earthquake data using cross-well VSP data and wave monitoring data was presented at JpGU-AGU 2017².

In September 2017, under the cooperation of Japan Agency for Marine-Earth Science and Technology (JAMSTEC), the proof experiments of earthquake monitoring using JAMSTEC-owned submarine optical fiber cable were carried out. Among the submarine optical fiber cables installed off the coast of Toyohashi, the authors chose a single-mode fiber with an optical length of approximately 17 km for this experiment. Continuous measurement of hDVS was conducted to measure background noise by connecting the Tier-3 hDVS system to the fiber. This paper presents the feasibility analysis of natural earthquake monitoring by an hDVS system with the passive recording mode.

The submarine optical fiber cable, which is owned by JAMSTEC and was installed off the coast of Toyohashi, was originally used as a cable for communication. This operation used an FC/PC-type connector, which can affect data because the reflection of the light pulse at the connector is large. For this reason, the field of fiber sensing avoids its use as much as possible. However, FC/PC is used in at least two places on the fiber cable, but one was exchanged with an FC/APC type to decrease reflection and improve data.

The background noise measurement was carried out continuously for approximately 14 hours from the evening of September 25 to the morning of September 26. Data indicated that wave movement was regularly recorded in the fiber from the coast to about 5 km, where the water depth is shallow. Examining the waveform measurement data confirmed that a natural earthquake event was captured at 11:54:55 UTC on September 25 [20:54:55 JST on September 25] and the subsequent data.

Referring to the hypocenter database provided by JMA for all detectable earthquake events in Japan, the following earthquake was identified as the possible candidate of the event observed in the continuously recorded data: September 25, 2017, at 20:54:49.7, at Latitude 34°53.3’N Longitude 138°31.8’E, 215-km depth, M3.9, epicenter location of Suruga Bay.

The natural seismic waves recorded at time are shown in Figure 1. The noise is conspicuous in the fiber farther than 8.1 km. The cause would be due to strong reflection in the FC/PC type connector and reflection at the end of the fiber. The continuous recording was performed with the following parameters: gauge length = 40 m; output spatial interval = 10 m; and output time interval = 2 ms. The recording length of one file was 30 s. The maximum fiber length that can be recorded using the Tier-3 hDVS system is 16.5 km; recording at total length of 17 km is not possible.
Observation showed that the P-wave arrived near the coastal area at 20:55:21 JST and the S-wave arrived at 20:55:44 JST, both on September 25. The submarine optical fiber cable is laid straight from the coastline toward the south, but both P-waves and S-waves arrived at the coastal part earlier by 0.4 s and 1.0 s respectively, compared with the offshore 16 km ahead. This indicates that the earthquake occurred slightly northward from the east-west direction with respect to the submarine optical fiber cable, supporting the conclusion that the epicenter was Suruga Bay.

The authors also referred continuous seismometer records by NIED Hi-net. Among the existing 21 monitoring stations in Aichi Prefecture, the Hi-net data at the Toyohashi site was compared with the recorded hDVS data and showed good matching. This record of the undersea earthquake monitored with the submarine optical fiber cable is the first case in the world using DAS technology as far as the authors recognize.

This project confirms that the hDVS system connected to a submarine optical fiber cable can be used to monitor natural earthquake events while monitoring waves.

Acknowledgements: JMA and NIRD data are used as a reference earthquake data for comparison.

References:

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