Potential of dense weather event observation using surface optical fiber cable and DAS technology

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Distributed acoustic sensing (DAS) technology is introduced in the oil and gas industry from around 2011 for monitoring pipelines and sensing intruders. In recent years, application of the latest optical fiber sensing technology using differential phase data called heterodyne distributed vibration sensing (hDVS) has made it possible to acquire the seismic data including the Vertical Seismic Profile (VSP)[1)]. Three-dimensional imaging can also be performed by a 3DVSP method[2)]. We have described the observation of natural earthquakes and waves, targeting the detection of tsunamis, using the hDVS device at recent JpGU and the seismological society of Japan (SSJ)[3)].

In September 2017, in cooperation with the Engineering Advancement Association of Japan (ENAA), we conducted a demonstration experiment of DAS technology including earthquake observation using optical fiber cable buried at depth of about 20 cm. Of the 400 m long optical fiber cables, 300 m was set back and forth in a 100 m long trench and the remaining 100 m was made to run along the ground surface, and then connected to a hDVS Tier-3 acquisition device. In other words, the optical fiber cable of about 50 m section that caused the ground to travel was under an environment susceptible to changes in weather. On the second day of the 4-day observation period, there was also a time zone in which rain fell and occasionally intense. Especially during the nighttime, continuous observation was carried out, so the fiber optic cable that crawled on the ground surface has not only accidental phenomena such as car traffic ground noise and natural earthquake, but also stationary phenomenon which seems to be the influence of rain fall was recorded. An example is shown in Fig 1.

This suggests that DAS technology using optical fiber as a vibration sensor may be used for weather observation. The hDVS/DAS records with GPS time stamp; the maximum observation length is depending on the type and state of fiber, but using low-loss single mode fiber a range of 40 km is achievable. If we can observe meteorological conditions over a range of tens of kilometers with a resolution of several tens of meters with a single device, we could issue more detailed warnings.

Installation of optical fiber for communication in Japan is often installed in the air such as utility pole and iron tower, except for the trunk communication network in the metropolitan area. Such optical fibers are directly influenced by rain and wind, however influence of noise sources generated on the surface such as vehicles, railways, factories, etc. is small. In other words, if you connect an hDVS/DAS device to an optical fiber on a transmission line called OPGW (optical fiber composite overhead ground wire), there is a possibility that weather network can be constructed in a short period of time. In the case of rain, when the rain is calm, the rate at which rain strikes the OPGW decreases, vibration or the dynamic strain of the optical fiber appears less, that is, the signal of hDVS/DAS is small. When the rain intensifies, the rate at which rain hits OPGW increases, vibration appears greatly, the signal of hDVS/DAS is large. So, it is possible to quantitatively observe local rainfall at intervals of several tens of meters. It would be possibly quantifying the size of rain drops as well as state of rain drops whether liquid or icy.

If rainfall and wind volume are large and change at the same time as a typhoon, it will be possible to take a method to separate each event. In the case of rain, raindrops collide with the fiber-optic cable, causing vibration, which is supposed to be more microscopic vibration and the frequency range of vibration is higher. On the other hand, in the case of wind, it seems that the frequency range is low due to macro vibration which affects the entire fiber optic cable between towers. When observing the ocean bottom earthquake using JAMSTEC owned submarine optical fiber cable, we observed the wave at the same time, but it is possible to separate two different events by changing the gauge length, which was presented at SSJ 2018[4]. Reprocessing the raw data for different gauge length is a capability that is unique to hDVS amongst the available DAS techniques. Real-time simultaneous observation of rainfall and wind will be possible by improving the hDVS system.

By connecting hDVS to underground, ocean floor, and terrestrial optical fiber networks, the possibility of constructing a comprehensive disaster prevention observation network of earthquakes, volcanoes, tsunamis, and observation of typhoons and Guerrilla rainstorm, has come to be seen.

Acknowledgements: We thank ENAA for permission to show recorded the hDVS data.

Keywords: DAS, hDVS, optical fiber, micro-scale meteorology, dense observation, typhoon