Development of acoustic signal processing unit for continuous observation of ocean bottom crustal deformation using marine GNSS buoy

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Observation for ocean bottom crustal deformation by global navigation satellite system (GNSS) /acoustic method is monitoring long-term changes in the position of transponder which is estimated from the travel time of acoustic signal between onboard transducer and transponder fixed on seafloor. Observation using vessel can be performed only several times a year and provides low temporal resolution for measurements. That is a problem for monitoring the time variation of fixing strength of plate boundary. It is expected that continuous observation helps to clarify the mechanisms of slow slip events, which take place along the plate interface, in more detailed.

We aim to realize continuous observation by using marine buoy. The Grant-in-Aid for Scientific Research (S) project "A challenge to develop GNSS buoy system for high-functional tsunami monitoring and continuous observation of ocean-bottom crustal movements" which has been started from 2016 utilizes the buoy off the coast of Ashizuri. It is equipped with GNSS (global navigation satellite system) antenna and receiver, acoustic ranging unit, and satellite communication unit. From buoy to ground station, the satellite communication unit transfers the results of acoustic ranging, and the position of buoy, which is estimated by precise point positioning. Our acoustic ranging system consists of acoustic ranging and signal processing devices which are connected with each other through USB cables. When the signal processing device receives the acoustic signal, it executes the correlation processing and outputs the messages including transmitted time and travel time to the satellite communication unit.

The accurate travel time can be obtained by correlation processing between replica and received acoustic signals. When the signal is reflected by sea surface, several peaks appear in the correlation coefficient. The result of observation using vessel shows that the correlation value peak of reflected signal was sometimes larger than that of direct signal. In this case, the peak position of direct signal exists former than the maximum peak position because a direct signal arrives primarily. That also suggests that the amplitude of received signal increases sharply at the timing of its arrival.

We propose detecting the arrival time of direct signal from two indexes: the value of correlation coefficient and the amplitude of received signal. By setting thresholds for these indexes, the correlation value peak of direct signal can be identified automatically and its correct travel time is obtained. Our proposed algorithm verifies three largest correlation peaks in an order from one with earliest arrival time and identifies one of them as that of a direct signal when the condition is satisfied. In order to determine the thresholds, we used the observation data obtained by using vessel off Ashizuri in June and September 2017. We firstly identified true peak position of direct signal by sight. To provide high recognition accuracy, we determined the condition for our research area: the correlation coefficient is more than 0.25 and signal-to-noise ratio is more than 5.0. The accuracy of identification is expected to be more than 99%.

Since the buoy employs the solar power generation system, there is a concern about the unstable power supply. Thus, we took measures to counter power failure by adding the functionality for automatic restart in power recovery to the signal processing device. We performed operational test for our acoustic ranging system in the pool in October 2017 before the construction on buoy. Both continuous measuring for one week and data transfer from signal processing device to satellite communication unit were successful. We' re planning to install the devices on buoy off Ashizuri this year and aiming for stable operation of a continuous observation.

Keywords: Ocean bottom crustal deformation, GPS/Acoustic method, Marine GNSS buoy