DOP-based accuracy evaluation of GNSS-A positioning on a drifting moored buoy quantified using sea trial observation data

*Misae Imano[1], Motoyuki Kido[2,3], Chie Honsho[3], Yusaku Ohta[3], Ryota Hino[3]

1. Graduate School of Science, Tohoku University, 2. nternational Research Institute for Disaster Science, Tohoku University, 3. Reserch Center for Prediction of Earthquakes and Volcanic Eruptions Graduate School of Science, Tohoku University

We have developed an offshore monitoring system of seafloor movement using a multi-purpose moored buoy, which realizes regular and on-demand GNSS-Acoustic (GNSS-A) measurements (Takahashi et al., 2014). The target accuracy of horizontal array position was set to 1 m, aiming to detect coseismic displacement accompanied with a huge earthquake (>M8). To endure the strong current around Japan, the system needs a slackly mooring technique for smaller tension (Ishihara et al., 2012) using a much longer tether line than the water depth. Because the moored buoy usually drifts by wind and current around a seafloor array, GNSS-A measurement is likely to be carried out far from the array center. However, the positioning accuracy significantly degrades when the observing point is positioned outside the array, due to a bad geometry between an observing point and transponders (Kido, 2007). Therefore, measurements using a moored buoy are generally carried out under worse conditions than those using a vessel. Our previous studies showed that the horizontal positioning accuracy (2 σ) with a single ranging was 46 cm when the buoy was inside the array, while it degraded to 97 cm when the buoy was outside the array, through a year-long sea trial near Nankai Trough (Imano et al., 2017; Kido et al., 2018). Besides the degradation depending on the distance from an observing point to the array center, we found a directivity of the positioning accuracy depending on the geometry between an observing point and seafloor transponders (Imano et al., 2018). In this study, we propose a method to evaluate the positioning accuracy at an arbitrary observing point based on the above characteristics of GNSS-A positioning using the system.

To interpret the accuracy degradation and directivity in relation to the position of observing points, we introduced Dilution of Precision (DOP: Langley, 1999) for GNSS-A positioning, which represents the degree of propagation of measurement errors to positioning errors. We firstly calculated EDOP/NDOP (the degree of error propagation to the EW/NS components of the array position) from the diagonal elements of the normal equation matrix of the observation equation of array positioning. Next, we computed error ellipses by diagonalizing the normal equation matrix because the nondiagonal elements were significantly large in many cases. The error ellipses clearly exhibit the feature that the estimation error of array positions was large in the direction from an observing point to the array center. Then, we converted the error ellipses to the positioning accuracy by multiplying the standard deviation of traveltime residuals when an array position was estimated using the data of all the 527 pings. The resulting positioning accuracy well explained the array position error and its dependency on the observing position found in the results of the sea trial.

The DOP analysis and its conversion into the positioning accuracy based on the actual observation data enable detailed assessment of the directional accuracy of GNSS-A positioning at arbitrary observing point, which is quite important in interpreting a realtime measurement of seafloor movement upon the occurrence of a huge earthquake. In this presentation, we will explain the above method and discuss its application to realtime GNSS-A positioning using the system assuming the occurrence of a huge earthquake.

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