Doctral Thesis
博士論文

Study on Ionosphere Delay Correction for Multi-GNSS Positioning
マルチ GNSS 測位のための電離圏遅延補正に関する研究

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Abstract

Ionosphere delay is the largest error factor for positioning using global navigation satellite system (GNSS), especially for single-frequency positioning. The electron density of ionosphere varies sometimes rapidly and locally due to the solar activity. The purpose of this work is to mitigate the ionospheric effect on single-frequency GNSS positioning. With the widespread of smartphones, the number of users of single-frequency positioning has been increasing explosively and its reliability is highly required. Therefore, this research can contribute to the reliable single-frequency GNSS positioning for huge number of users.

We proposed estimating the ionosphere delay in the process of the positioning calculation using single-frequency measurement with single epoch. The numerical evaluation conducted by measurements of American global positioning system (GPS) for selected five stations in Japan for both ionospheric quiet and stormy conditions during a period from 2013 to 2015. The correction effect on reducing the positioning error is higher than conventional correction method. However, it has an adverse effect on increasing the error rather than positioning without correction when the ionospheric effect on positioning is small.

The proposed ionosphere delay estimation method can be applied to not only GPS positioning but also multi-GNSS positioning, combining several satellite navigation systems. Currently, the operated satellite navigation systems are GPS, Russian GLONASS, European Galileo, Chinese BeiDou satellite system, Japanese quasi-zenith satellite system (QZSS), and Indian regional navigational satellite system (IRNSS). Using multi-GNSS positioning, the sufficient number of visible satellites is observable and the constellation is improved. Using selected satellite measurement which is suitable for positioning makes the positioning accuracy precisely, compared with using all visible satellites. In order to estimate the ionosphere delay more precisely for multi-GNSS positioning, we proposed the algorithm of selecting useful satellites by the residual ranging error of pseudorange measurement. From the performance evaluation conducted for GPS and Russian GLONASS positioning for ionospheric disturbed condition,

the satellite selection reduced the horizontal positioning error by maximum 20-60%. The ionosphere delay estimation with satellite selection reduced the error by maximum 60% at mid latitude region, compared with conventional one.