

# Observing ionosphere by GPS terrestrial network

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Satellite navigation systems, such as GPS, fundamentally compute user location using Doppler shift or propagation time of radio signals transmitted from satellites to user receiver, which would be delayed during passing ionosphere. While this effect is a major error source for positioning user location, it is possible to observe ionosphere using pre-surveyed GPS receivers as total electron content (TEC) along each signal path. One could know the spatial and/or temporal distribution of ionospheric total electron content with a lot of propagation delay measurements along each signal path observed by GPS receiver network.

Some studies on this methodology have reported the major problem is the appropriate estimation and removal of measurement error. There is well-known method for removal of integer ambiguities and cycle slips involved observation, but also, using dual frequency observation, hardware interfrequency biases of both satellites and receivers must be removed. A general algorithm for estimating bias-like error is Kalman filter approach assuming a mathematical model of ionosphere, usually single-layer thin-shell model. We compared some ionospheric models for this problem, and made it clear that thin-shell model is still valid but double- or triple-layer model is more preferable than single-layer assumption. Also, elevation mask angle applied to GPS observation data, which might be introduced to mitigate large measurement error due to low elevation angle, should be set less than values commonly used for this problem, for example, it should be 10-15 deg.

We used public data on May 28-29, 2003 observed by GEONET GPS network operated geographical survey institute of Japan for comparison of ionospheric models. Geomagnetic storm was observed at local night of May 29, and low-latitude aurora was reported in northernmost part of Japan. Estimated satellite interfrequency bias errors matched to group delay parameters of broadcast navigation message, although geomagnetic activity was high. Comparing estimated receiver interfrequency bias errors with the results with the other period data, it is shown that estimation process runs correctly. Processing with various ionospheric models showed that, (i) double- or triple-layer model is preferable than single-layer model; (ii) double layers are enough to estimate satellite bias correctly; (iii) ionospheric height assumed in the model should not be set high; (iv) Chapman model is a bit better than thin-shell model if ionospheric height is set properly; for the bias estimation processes. Double-layer model is better than triple-layer model in terms of resulted estimation accuracy due to a number of unknown parameters.

This report describes some methods for removing interfrequency biases involved in the measurement with dual frequency receivers which cause bias error into the TEC measurement, and evaluated ionospheric models via real data. Empirical models such as IRI are also valid for this evaluation. Considering of effects of ionospheric delays on satellite navigation systems, building up data during geomagnetic storms and evaluating integrity performance are essential.

[1] T. Sakai, et. al., Observing Ionosphere Total Electron Content by GPS Network, IEICE Technical Report, vol. 103, no. 531, pp. 13-18, SANE2003-87, Dec. 2003.