Precise Ionospheric Delay Estimation using the Local Taylor Series Expansion and the Multivariate Polynomial Regression Models for Single Frequency NavIC/IRNSS Receiver

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Navigation with Indian Constellation (NavIC) or the Indian Regional Navigation Satellite System (IRNSS) is an independent satellite based navigation system developed by the Indian Space Research Organization (ISRO). The advent of NavIC/IRNSS will be very helpful for navigation, particularly in the field of civil aviation sector. The NavIC/IRNSS is utilizing L5 and S band signals for navigation in the India. The System of seven satellites, NavIC/IRNSS will provide Special Positioning Service (SPS) and Precision Service (PS) towards the Indian subcontinent. In Positioning, Navigation, and Timing (PNT) application, measurement is affected by some intentional and unintentional sources of error like, Jammer, existing system having same operating frequency, satellite geometry, signal reception delays due to ionosphere and troposphere, multipath, Doppler effect due to relative motion, clock drift and receiver noise.

Here, the Ionospheric effect is consideredas a research work because the positional accuracy of the NavIC/IRNSS system is majorly affected by the ionosphere of low latitude equatorial Indian subcontinent, as the large Ionospheric gradient and intense irregularities are present in it. Hence, the future success of the NavIC/IRNSS system depends on the accuracy of the Ionospheric effects mitigation algorithm. In the course of seasonal activities, magnetic storms and daily activities, Total Electron Content (TEC) can be accurately estimated by the dual-frequency method, but the use of the single frequency regional model is difficult, therefore, some single frequency local models are essential to estimate Ionodelay accurately. Hence, the main objective is to study and analyze the position accuracy of the NavIC/IRNSS system after correcting Ionospheric effects using an efficient local single frequency model.

To estimate the Ionospheric delay (Ionodelay) precisely in local region more efficient, less complex, Taylor Series Expansion (TSE) and Multivariate Polynomial Regression (MPR) models based on single frequency are proposed for the NavIC/IRNSS system. By transmitting the Ionospheric information in the form of the coefficients (calculated using stationary dual frequency NavIC / IRNSS), it is possible to estimate the Ionodelay precisely for nearby (i.e. Ionospheric behavior does not change significantly) single frequency NavIC/IRNSS users. This proposed work concentrates to improve the positional accuracy of L5-band NavIC/IRNSS system. To achieve that, proposed models for Ionodelay, the Hopfield model for the Tropospheric delay mitigation and the Iterative Least Square (ILS) algorithm for position estimation is applied. The proposed MPR and TSE algorithm are verified by comparing the performance with dual-frequency NavIC / IRNSS receivers. Based on the geomagnetic index and data availability of the two NavIC/IRNSS receiver, quiet and disturbed days are selected for analysis.

For model validation, we considered two test setup, the TSE/MPR coefficients generation and Ionodelay estimation using (I) single receiver (II) two different receivers. In case (I), i.e. using one NavIC/IRNSS receiver, the TSE/MPR algorithm performance is

examined during the intense (D_{st}= -124, K_p= 8,A_p= 106) geomagnetic storm beginning from 08 September 2017 using the one week ofNavIC/IRNSS receiver data (3-9 September 2017) of the Indian equator (IIST Trivandrum) andfour EIA (SVNIT Surat, IIT Bombay, CBIT Hyderabad, IIT Gandhinagar) stations. The single-frequency local TSE/MPR and regional GIVE model performances are correlated with the reference dual-frequency model for verification.

In case (II), we define 10 km region as a local region and based on the data (quiet and disturb days) availability of two receivers (i.e. reference and rover) the performance of the local TSE and MPR models are examined. Based on the broadcast, the local model coefficients generated by the reference dual-frequency NavIC/IRNSS receiver of the SVNIT Surat station, the nearby (in the local < 10km area) rover single frequency NavIC/IRNSS receivers (at two locations) attempts to estimate the Ionodelay accurately. Further optimization in the positional accuracy is achieved by applying, the Hopfield model for the Tropospheric delay and Iterative Least Square (ILS) algorithm for position estimation. The local TSE and MPR algorithms are verified by comparing the performance in terms of 3 Dimensional DistanceRoot Mean Square (3DRMS), Circular Error Probability (CEP) and Spherical Error Probability(SEP) with the different single frequency (i.e global Klobuchar and regional GIVE model) and reference dual frequency model.

It is deduced from the analysis of both cases that single frequency TSE and MPR models performed nearly same (~0.8 meters of errors) as the reference dual frequency model and performed better compared to global Klobuchar and regional GIVE model for both the quiet and the stormy days. Moreover, the local TSE/MPR that generated the coefficients every 5 and 10 minutes have nearly performed in a similar way. Therefore, Ionospheric correction applied by the local TSE/MPR models cannot only improve the performance of the rover NavIC/IRNSS receivers in the local region, but will also reduce the computational cost of coefficients and the additional frequency if errors of up to 0.8 meters are tolerated. This verification can be further extended at various geographical locations for the different atmospheric condition considered as a future research work.