ESTIMATION OF LOW LATITUDE IONOSPHERIC TEC FROM DUAL FREQUENCY GPS OBSERVATIONS BY USING ADAPTIVE KALMAN FILTERING TECHNIQUE

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SUMMARY

The low latitude tropical ionosphere has been investigated by various researchers using Global Positioning System (GPS). Presently for many civil aviation applications the ionospheric modelling of the tropical region has gained importance, in particular for flight safety. Satellite Based Augmentation System (SBAS) is one of the most recent innovative applications of Global Positioning system (GPS) for civil aviation. India is on its way in developing SBAS for civil aviation to meet the requirements like availability, accuracy, integrity and continuity, which are critical for civil aviation safety, in particular for Precision Approach. Ionospheric corrections play vital role in all the above four requirements for precision approach. However, at the low latitude, the ionosphere over Indian subcontinent is quite different from that of the midlatitudes, further highly unstable. Hence the diurnal variation of TEC has to be modelled properly, which determines the signal delay range. Since the ionosphere is dispersive in nature, the dual frequency (L_1 = 1575.42 MHz and L_2 = 1227.60 MHz) GPS observations can be used to obtain Ionospheric Total Electron Content (TEC). Since TEC varies with local time and geomagnetic latitude, an Ionospheric Modeling Technique using spatial linear approximation of vertical TEC over receiver station has been implemented following Sardon et al. The effects of all the systematic errors due to the satellite plus the receiver (SPR) instrumental biases can reach upto several nanoseconds. (1 TEC is 10^{16} electrons/m^2, 1 ns = 2.86 TEC and 1 TEC = 0.16 m). Hence, to have an accurate estimation of ionospheric TEC, the instrumental biases must also be estimated. This paper describes a heuristic adaptive Kalman Filtering scheme developed to estimate the TEC, the constants in the linearisation scheme, as well as the above total instrumental biases.

The most general problem in state and parameter estimation technique consists of qualitatively modelling the system, measurement, process and measurement noise characteristics and to quantitatively estimate all the unknown parameters in the above by combining the information from the model output with the measurement data in some suitable optimal sense. The Kalman filter implementation is basically an optimization problem of dealing with the Cost Function J based on the difference between the model output and the measurement, called as the ‘innovation’, scaled by its covariance. The tuning of the above normalized Cost Function J to the number of measurement channels can be carried out by a batch or a sequential approach. In order to obtain the best possible results using the Kalman Filter approach, it is essential to provide appropriate values for the initial state, process and measurement noise covariances ($\mathbf{P_0}$, $\mathbf{Q}$ and $\mathbf{R}$) respectively, which in general may not be known. Generally the filter parameters are tuned manually without using the above cost function J! But the filter estimates can be highly sensitive to the above chosen statistics and thus these will have to be estimated carefully.

The general methodology of any filter estimation algorithm is to update the $\mathbf{X_0}$, $\mathbf{P_0}$, Θ, $\mathbf{R}$ and $\mathbf{Q}$ at a point, over a window, after a pass or after multiple passes by applying some corrections to them based on changes, iterations or sample statistics such that the numerical procedure does not diverge but converges to the best possible estimates based on the information contained in the data.

In the Adaptive Kalman Filter approach, a heuristic approach has been proposed by Myers and Tapley to estimate **R** and **Q**. Subsequently Gemson and Ananthasayanam showed that even $\mathbf{P_0}$ is equally important for parameter estimation problems. Further they showed that the inverse of the information matrix is a suitable choice to obtain $\mathbf{P_0}$ after a scouting filter pass through the data. Also they have shown that the data has to be iteratively processed for obtaining the convergence of the estimates for $\mathbf{P_0}$, **R** and **Q**. The tuning of the cost function J is carried out by simultaneously estimating the above statistics as well as the unknown parameters, which include the TEC and the instrumental bias. Using the above Adaptive Kalman Filtering technique, the vertical TEC values and SPR biases have been estimated over Bangalore, India.

REFERENCES

1. Sardon E, Rius A, and Zarraoa N, " Estimation of the transmitter and receiver differential biases and the ionospheric total electron content from Global Positioning System observations", Radio Science, Vol. 29, Number 3, pp. 577-586, May-June 1994.
2. Myers K.A and Tapley B.D., "Adaptive Sequential Estimation With Unknown Noise Statistics", IEEE Trans automatic Control, Vol. AC 21, pp 520-525, 1976.
3. Gemson R.M.O and Ananthasayanam M.R., "Importance of Initial State Covariance Matrix For The Parameters Estimation Using An Adaptive Extended Kalman Filter", Proc. AIAA Conference on Atmospheric Flight Mechanics, AIAA-98-4153, 1998.
4. Basu S, Su Basu, Groves K.M, Yeh H.-C, Su S.-Y, Rich F.J, Sultan P.J and Keskinen M.J, "Response of the Equatorial Ionosphere in the South Atlantic Region to the great magnetic storm of July 15, 2000", Geophysical Research Letters, Vol.28, pp 3577-3580, September 15, 2001.
5. Coco D.S, C.Coker, S.R.Dahlke and J.R.Clynch, "Variability of GPS satellite differential group delay biases", IEEE Trans. Aerospace. Electron. Syst., 27(6), 931-938,1991.