SCORE ALGORITHM FOR IMPROVING GPS ACCURACY IN LOW LATITUDE REGIONS

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1. ABSTRACT

GPS performance is limited by several sources of errors. Most of the errors are reasonably modelled. However, receiver pseudorange error did not receive much attention so far. Recently, it is proposed by Gregory Bishop (1994) an algorithm known as " Self Calibration Of pseudoRange Error (SCORE)" and used at mid latitude regions. In this paper we used this algorithm for receiver system calibration for low latitude regions. Our results are promising and shown marked improvement in GPS position accuracy even in low latitude regions.

2. INTRODUCTION

Global Positioning System (GPS) is a satellite based system used for navigation, position determination, and time transfer applications. The system consists of a 24-satellite constellation, plus associated ground-based monitoring and control facilities which is operated and maintained by the Department of Defence (DoD), USA. The satellites radiate precisely timed signals coded so that a receiver on or near the surface of the earth can determine both the transmission time delay (or equivalently, distance) from the satellite to the receiver and the precise satellite position. By simultaneously receiving such signals from at least four satellites, the receiver can determine its position and time. GPS provides two levels of service: a precise positioning service (PPS), available only to DoD, and other authorized users, and a standard positioning service (SPS), available free of service to civil users worldwide.

To implement International Civil Aviation Organization's Future Air Navigation Systems (FANS) concept, GPS is needed. High accuracy applications like aircraft's precision approach and landing system require close attention to the major error sources in GPS range measurements. These include selective availability, ionospheric delay, multipath from the receive antenna environment, differential group delay correction and receiver system errors. Receiver system errors originate in the pre-amplifier, antenna and may be in cabling connections whose performance is a function of temperature and aging. But limited attention has been given to calibrating the entire receiver system. In the Self Calibration Of pseudoRange Error (SCORE) the ionospheric delay property itself is used to calibrate the receiver system error [1]. This algorithm is used in this paper for analyzing the dual frequency GPS receiver data in India.

3. PROMINENT ADVANTAGES OF SCORE ALGORITHM

- SCORE technique does not require any dedicated channel to receive calibration signal
- In calibrating 1 or 2 TEC units we are seeking sub-nanosecond accuracies. SCORE technique is accurate to this level also. Where as hardware calibrator is not accurate to sub-nanosecond level.
- In a hardware calibrator, if the calibration of the system is done at the factory, then changing a component such as a pre-amplifier in the field could invalidate the calibration. SCORE technique is independent of all these system components.

- SCORE technique operates without using any test signal, assuming any model ionosphere, or applying data from an observing network.

4. SALIENT FEATURES OF SCORE ALGORITHM

The SCORE concept consists of self - consistency constraint on the receiver's own measurements of ionospheric delay to derive the sum of the receiver system and satellite pseudorange error for each satellite. The self consistency concept uses a "conjunction" occurring between two satellites, i.e. an event where both satellites arrive at the same moment at a point where their observed paths cross. It is well known in such an event the same ionospheric pseudorange error (TEC value) should be seen on each satellite. By adjustment of the assigned bias values for each satellite, SCORE algorithm minimizes the difference in vertical TEC derived from observations of two satellites for the same Ionospheric Pierce point Local Time (IPP LT) and latitude. By imposing this consistency between multiple pairs of satellites for many observations, a consistent set of corrections is obtained, yielding a reasonable representation of the vertical TEC profile. The average of these corrections becomes a system calibration parameter (SCP), which is used to calibrate receiver system and detect drift or changes. If absolute satellite errors are known then they may be subtracted from individual satellite "corrections" to obtain an absolute system calibration.

The mathematical quantity chosen to describe the equivalent vertical TEC difference for multiple observations is [3]:

$$E = \frac{1}{2}\sum_{\alpha}\sum_{i=1}^{I_\alpha} \sum_{\beta\neq\alpha} \sum_{j=1}^{J_\beta} W_{\alpha i,\beta j} \times (T_{\alpha i} - T_{\beta j})^2$$

for α_i = PRN α sample i

$W_{\alpha i,\beta j}$ = Weighting factor between samples αi and βj

$T_{\gamma k}$ = Calculated equivalent vertical TEC for sample γk, using the appropriate local zenith angle and satellite bias

$$T_{\gamma k} = (S_{\gamma k} - B_\gamma)\ \cos(\arcsin(\mu \cos\varepsilon_{\gamma k}))$$

for $S_{\gamma k}$ = Slant TEC for the data sample

B_γ = Combined receiver/satellite bias for PRN γ, in TEC units

$\varepsilon_{\gamma k}$ = Elevation angle for satellite sample, at observing site

μ = Altitude scale factor for coversion to IPP zenith angle $\mu = R_e/(R_e+H_{IPP})$

for R_e = Earth radius

H_{IPP} = Altitude of ionospheric pierce point which is defined as the point where the line-of-sight path from the user to a satellite intersects the layer in the ionosphere, 350 km above the surface of the earth.

A Gaussian function of local time and latitude differences was selected as an appropriate weighting factor

$$W_{ij} = \exp\left[-\frac{1}{2}\left[\frac{\theta_i - \theta_j}{\theta_o}\right]^2 - \frac{1}{2}\left[\frac{\lambda_i - \lambda_j}{\lambda_o}\right]^2\right]$$

for θ_k = LAT for sample k (degrees)

λ_k = Combined Modified Julian Day (MJD) and LT for sample k (day and fraction of day, λ = MJD + LT/24)

θ_0 = Reference latitude difference, for scaling (degrees)

λ_0 = Reference local time difference, for scaling (days)

5. RESULTS AND DISCUSSION

Using a dedicated RINEX dual frequency GPS receiver at National Geophysical Research Institute (NGRI), Hyderabad, Navigation and Observation data for several days were analyzed. The navigation data file consists of 38 parameters. But for the calculation of satellite position, elevation angle etc., only 23 parameters are used. Actually navigation data is available for every two hours. In between data is generated using standard formulae. Observation data file consists of C/A and P_2 pseudoranges and L_1 and L_2 phases for all the visible satellites. From this data file, ionospheric time delay and slant total electronic content (TEC) values for the satellites are estimated. From this information satellite position, elevation and azimuth angle of satellite, Local time (IPP LT), geomagnetic subionospheric point latitude (IPP latitude) and slant factor are estimated. Bancroft al gorithm [4] is used for the estimation of user position. By applying SCORE algorithm user position is recalculated.

Equivalent vertical TEC versus IPP LT and geomagnetic latitude are shown in Fig. 1 and Fig. 2 respectively for satellite vehicle (SV) 29. From Fig. 1 it is obvious that the TEC fluctuations are very much high during afternoon times. Fig. 2 shows VTEC versus geomagnetic latitude. The profile is an indication of the orbit of that particular satellite. That is why the SV travelled from 6^0 to 11^0 and then again to 0^0 latitude. Generally we expect high TEC values at low latitude regions. One of the reasons for having relatively high TEC at 8^0 than at 0^0 is that time difference. It is well known that TEC values reach the minimum during night time.

Table 1 shows the bias values for different selected pairs of satellites. The average of bias values, of all visible satellites will become the system calibration parameter (SCP), which is used to calibrate the receiver system. For correcting pseudoranges individual average bias values of satellites are used.

The position of NGRI in ECEF coordinate system due to actual survey, calculated using Bancroft algorithm and after the application of SCORE algorithm are presented in Table 2. Observed GPS receiver horizontal and vertical position accuracies are within 11 and 8 meters of the actual values.

Table 1. Bias values for different SV's in IPP latitude band of 7^o - 8^o

Satellite No.	Bias values in TECu	Duration Hr:Min:Sec
1 17	-0.125 6. 593	15:21:30 to 15:32:00
2 4	16.761 -7.785	06:02:30 to 06:32:00
3 29	17.08 11.24	16:15:30 to 16:34:30
21 25	16.161 4.532	18:14:00 to 18:36:30
23 24	1.4 -13.2	12:14:00 to 12:23:30

Table 2. User position before and after application of SCORE algorithm

ECEF coordinates (in Meters)	Actual NGRI Position	Calculated NGRI position using	
		Bancroft algorithm	SCORE algorithm
X	1208445.448	1208482.441	1208456.485
Y	5966807.378	5966749.047	5966794.214
Z	1897077.344	1897061.540	1897069.490

6. CONCLUSIONS

For a typical day all the necessary parameters required for estimating bias values for all visible satellites are calculated using data from a dual frequency receiver. It is concluded that the TEC values are very much high during afternoon times when compared to the night time values. Also it is shown that TEC values are a function of geomagnetic latitudes. Our initial results show that the position accuracy is improved by several meters due to SCORE algorithm even in low latitude regions such as India. SCORE can detect and separate receiver system, satellite and ionospheric changes and support correction for each. As the results are promising, SCORE algorithm may be considered for making Wide Area Augmentation System (WAAS) ionospheric corrections.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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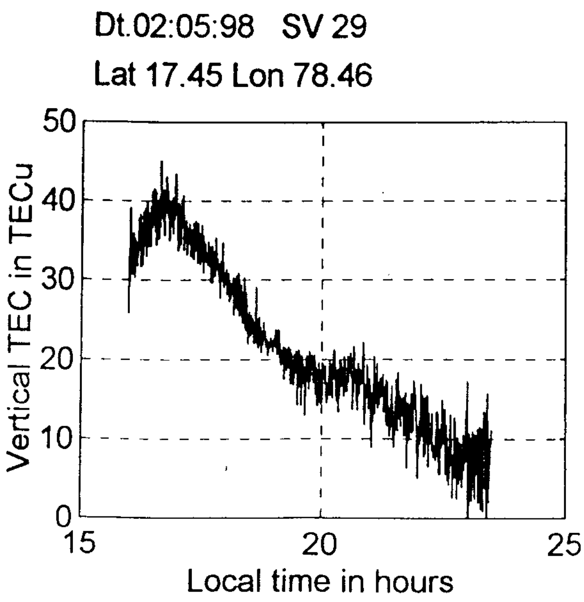

Fig.1 Local time vs VTEC

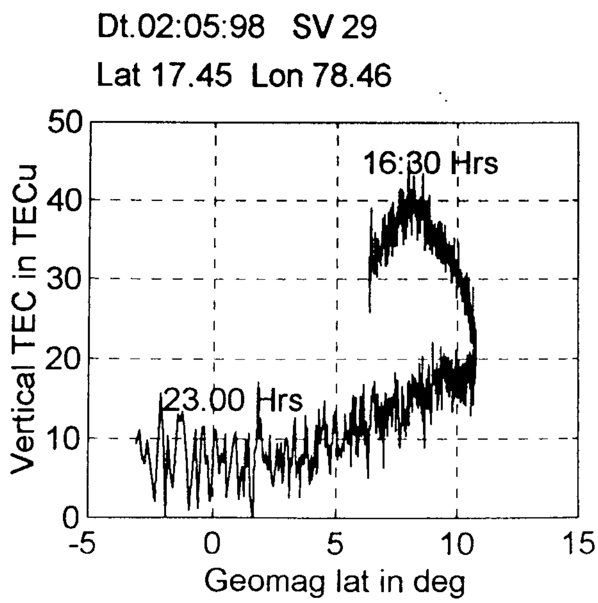

Fig.2 Geomag lat vs VTEC