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Precise GNSS Data Processing And Analysis For Single GNSS Station

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ABSTRACT

The Global Positioning System (GPS) is satellite-based navigation system providing positioning, timing and navigation (PTN) services worldwide. Accuracy of GPS can be affected by several sources of errors. Major error sources are errors are grouped on the basis of satellite errors, signal propagation errors and instrumental biases. Augmentation GPS system is necessary for achieving high positional accuracy. GPS aided Geo Agumented Navigation (GAGAN) positional accuracy can be achieved by proper estimation of error sources. In this paper, various GPS measurement errors are estimated by GNSS-Lab (gLAB) Tool suite. gLAB emerges as an ideal methodology for giving centimeter-level positioning utilizing current Global Navigation Satellite System(GNSS). The GPS data in RINEX format is considered for processing and analysis obtained from Mutli frequency GPS receiver located at KL University, vaddeswaram(16.44° N, 80.62° E), Guntur, India. GNSS parameters such as ionospheric delay, DOP, Positional errors are estimated by the kalman filter. The User Equivalent Range Error (UERE) is of order of few meters due to all sources of error .The outcome of this work would be useful to assessment of the error analysis.

Key Words: GNSS, gLAB software tool, Error Sources, UERE, KF

I.INTRODUCTION

GPS is developed for continuous and universal accessibility in navigation. GPS provides three dimensional position of user accurately, anywhere on the earth surface at every instant of time [1][2]. GPS errors can arise from inaccuracy of Pseudorange and carrier phase measurements in estimates of satellite position and clock corrections, ionospheric, tropospheric effects along the signal propogation path, and the reciver noise generated through signal -processing errors. The Propagation electromagnetic signals are affected due to the interaction free electrons in the region of the atmosphere. This affect is known as dispersive effect (frequency dependent), and can be eliminated in Dual-frequency receiver [3]. Ionospheric delays are larger at noon due to the higher illumination. Large positioning errors (mainly in vertical) appear when neglecting ionospheric corrections

II. ERRORS CORRECTION METHODS

Various errors sources can affect the Pseudorange and carrier phase measurements. These can be classified as

IONOSPHERIC TIME DELAY USING KLOBUCHAR MODEL

The Klobuchar model is based on the empirical approach in terms of accuracy and reduce the user complexity to keep minimum coefficients are broadcast by the satellite. This broadcast model is estimated to reduce the root mean square range measurements error due to ionospheric delay by about 50% [4]. At mid-latitudes and the remaining error in zenith delay can be up to 10m during the day. The range of the ionospheric shell is taken as 300-400Km. Assuming that there are no lateral electron gradients, we can get a simple and compact characterization of TEC along a signal path in terms of vertical TEC (TECV) and multiplier to account for the longer path length .The multiplier is called obliquity factor.

$$ION_{SLANT} = ION_{VERT}\, m(elev) \tag{1}$$

$$m(elev) = \left[1 - \left(\frac{R_E}{R_E + h}\cos(elev)\right)^2\right]^{-1/2} \tag{2}$$

$$ION_{VERT} = DC + A\cos\left[\frac{2\pi(t-\phi)}{p}\right] \tag{3}$$

$$ION_{VERT} = DC; if \left[\frac{2\pi(t-\phi)}{p}\right] > \frac{\pi}{2} \tag{4}$$

Where
DC=5ns,
ϕ =14(Phase offset)
T=Local Time

TROPOSPHERIC DELAY

The troposphere is the lower part of the earth's atmosphere. The troposphere approximately extends at a height of 9 km at the poles and 16 km from the equator.

The troposphere affects on the GPS signal by the neutral atoms and molecules [5]. The delay is caused by the troposphere and effects the code and carrier phase observations. Troposphere is non-dispersive medium and it doesn't depend on the GPS frequencies, and it doesn't figure out by dual frequency measurements. Though, several mathematical models can modeled the troposphere delay [6],[7],[8]. The tropospheric delay can be segregated based on dry and wet components, most of the delay caused by the dry component and constitutes about 90% and remaining can be caused by the wet component. Based on these mathematical models tropospheric delay can be estimate by the use of meteorological data including environment conditions and PRN elevation angle. The zenith tropospheric delay is the order 2 m [9]. Nominal dry and wet values are

$$T_{dry} = 2.3 \times \exp(-0.116 \times 10^{-3} \times H) \tag{5}$$

$$T_{wet} = 0.1$$

Where H height of the receiver

Simple Mapping is consider in the simple nominal modeling

$$M_{dry}(elev) = M_{wet}(elev) = M(elev) = \frac{1.001}{\sqrt{(0.002001 + \sin^2(elev))}} \tag{6}$$

The obliquity factor M (elev) is described in [8] and it is good for elevation angle over 5 degrees and the estimated part illustrated in the filter is

StdDev: 1.00, [Phi =1.00e+000, Q= 1.00e-004, P0= 2.50e-001]

Standard deviation can be treated as a weight for pseudorange measurements in the filter

$$W = \frac{1}{(stdDev)^2} \tag{7}$$

MULTIPATH ERROR

Multipath refers the signal reaching at the receiver via two or more paths due to the signal reflected from the objects and other structures. Normally, an antenna receives the reflected signal; in addition to the direct signal [10].Time instant of the signal reception delayed by the reflected signal. Multipath error significantly differ and affects pseudorange and carrier phase measurements. The GPS multipath techniques can be classified based on the Pre-receiver to Post-receiver signal processing techniques. To diminish the multipath error with Pre-receiver signal processing techniques incorporate high-quality antenna design and make use of RF-absorbing ground plane or choke-ring antennas [11].Receiver processing technologies have also been developed to mitigate the multipath effects[12].Multi path error in code measurements varies from $1-5$ m and carrier phase measurements varies from $1-5$ cm. Carrier phase measurements are used to smoothing the code phase measurements and also reduces effects of multipath.

USER EQUIVALENT RANGE ERROR

GPS accuracy can be affected by various errors sources and these errors arise from inaccuracies in estimates of satellite position and clock corrections, ionospheric, tropospheric effects along the signal propogation path, and the reciver noise generated through signal -processing errors. UERE is prominent model that represents the effect of all errors sources. It represents overall error sources affecting the pseudorange measurements [13]

$$\sigma_{UERE} = \sqrt{\sigma_{R1}^2 + \sigma_{R2}^2 + --- + \sigma_{Rn}^2} \quad (8)$$

Where
$\sigma_{R1}^2 + \sigma_{R2}^2 + --- + \sigma_{Rn}^2$ is the RMS of all GPS error sources
UERE=User Equivalent Range Error= RMS of all GPS errors suurces

DILUTION OF PRECISION

Satellite Geometry affected the accuracy of GPS system, these errors propagates in to the position domain by Dilution of Precision (DOP) factor depends on satellite geometry [14], the configuration of the satellite in view to a receiver at any given time can affect the accuracy of position determination. Lower DOP value yields smaller position error and the satellite geometry is good. Position accuracy and time bias errors of pseudorange errors differs with the different DOP parameters [10].The DOP parameters effect of satellite geometry based on the horizontal, Vertical, Geometric and Time components, Horizontal and vertical position accuracy component illustrated in term HDOP and VDO parameters [15] . Typically GDOP ranges from 2 to 4, HDOP ranges from 1 to 1.5 and VDOP ranges from 2 to 3 [16].Position accuracy can determine by the DOP factor in terms of two confidence levels 1σ and 2σ and the confidence level of 1σ and 2σ is 68.3% and 95.4% .Range error multiplied by twice of the appropriate dilution of precision factor [17].The user position accuracy is estimated using the formula

$$Position accuracy = DOP \times UERE \quad (9)$$

NORTH EAST UP POSITION ERROR

NEU co-ordinate system is a top centric horizontal co-ordinate system centered on an observer’s geographic location. The XY-plane represents horizontal plane with the X and Y axis pointing towards East and North and zenith pointing towards the Z-axis. NEU position error of the receiver achieved from the filter module. NEU error can be predictable by means of divergence among the prior Receiver Position and the filter assessment. Here we obtain the predictable error estimation. The prior position must be precise and yield the errors bias and horizontal diffusion

III. IMPORTANT STEPS for GNSS DATA PROCESSING USING gLAB TOOL

European space Agency (ESA) developed GNNS-Lab Tool suite (gLAB) for modeling and analyses the Global Navigation Satellite Systems (GNSS) observations at centimeter level (cm) with standalone point positioning (SPP) and pricise point positioning(PPP). To process and analyses GNSS observables gLAB requires the GNSS data in RINEX-3.00 or 2.0, SP3,ANTEX and SINEX .gLAB toll is quite flexible and able to simulate in two operating systems i.e. LINEX and Windows.

1) GUI consists of two main tabs Positioning and ANALYSIS TABS
2) In positioning tab interfaces with different processing options and this split into five different sections.
3) *INPUT module*: select the input RINEX observation and Navigation files , this file contains the GNSS measurements for a given station and file can be in RINEX format 2.11 or 3.0
4) *PREPROCESS module*: Preprocess module is to pre process the input data and provides all the configurations options to allows and changing the decimation rate, cycle-slip detection , elevation mask, and choosing particular PRNs for the processing
5) *MODEL module*: This module provides the modeling options to unable/disable the receiver measurements like, satellite clock offset correction, Ionospheric correction , Tropospheric correction , P1-P2 correction and P1-C1 correction.
6) *FILTER module*: We retrieve the parameter estimations to the given configuration options and to specify the required measurements to be estimated by using Kalman Filter (KF).
7) *OUTPUT module*: This module provides all the configuration options and data obtained from the FILTER.
8) In Analysis tab interfaces with different preconfigured plotting options for the Graphical details options and then configure into twelve different sections. NEU positioning error, Horizontal positioning error, Zenith Tropospheric Delay, Ionospheric combinations, Dilution Of Precision, Satellite skyplot, Carrier phase ambiguities estimations, Carrier phase ambiguities estimations, Measurement postfitx vs elevation and Orbits and Clock comparison.

IV.RESULTS AND ANALYSIS

GNSS-Lab Tool suite (gLAB) is used in estimating the various range error sources and RINEX and Broadcast files of the same day obtained by the Mutli frequency GPS receiver located at KL University, vaddeswaram(16.44° N, 80.62° E), Guntur, India is considered for processing and analysis. After estimating the error sources User Range Equivalent Range Error is calculated. For better position accuracy the range error multiplied by the DOP factor. In this paper 2σ level is consider for the appropriate DOP value;

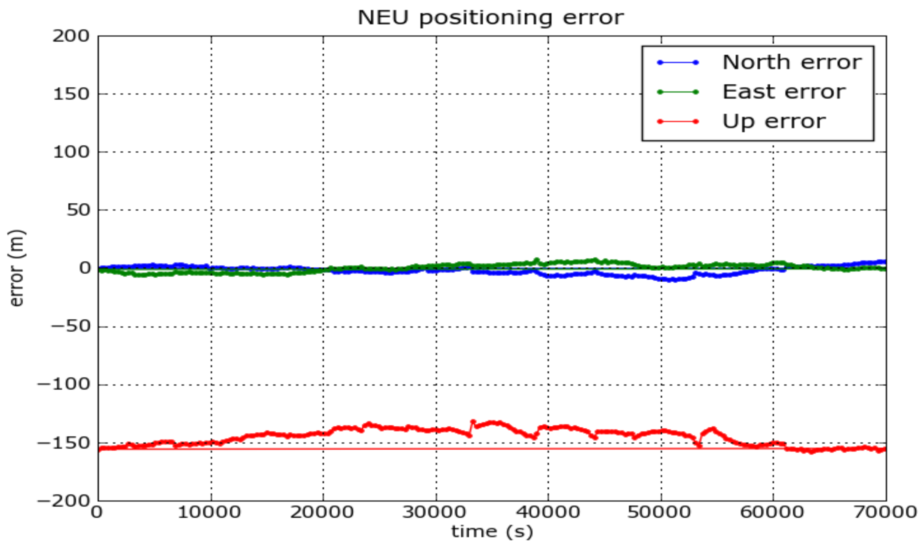

Fig.1: North East Up position Error

Fig1. Illustrate the NEU error achieved from filter module, this error can be predictable by means of divergence among the prior Receiver Position and the filter assessment. Here we obtain the predictable error estimation. The prior position must be precise and yield the errors bias and horizontal diffusion

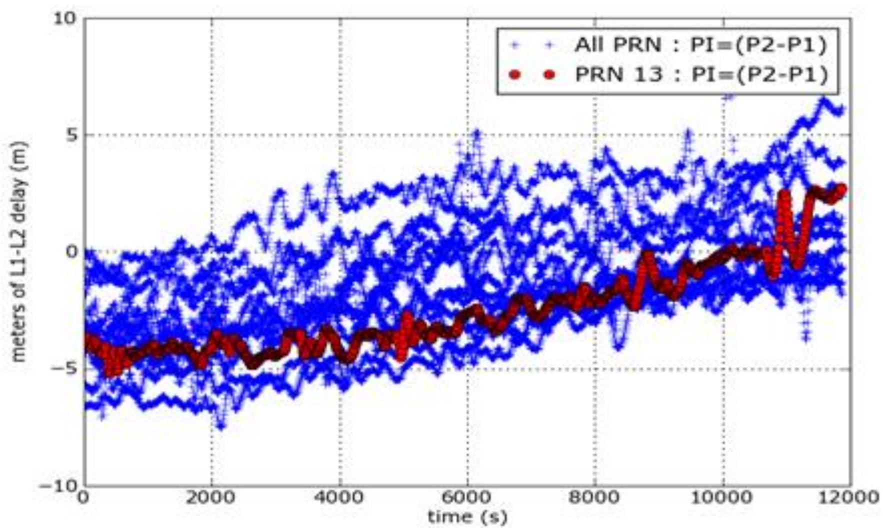

Fig2: Ionospheric Geometric combinations

Fig2. Illustrate the Ionospheric Geometry combinations free from the frequency-dependent effects and measurement noise and this combination is can be used to assessment the ionospheric electron content, observe cycle-slips in the carrier phase and also the antenna orbit as well

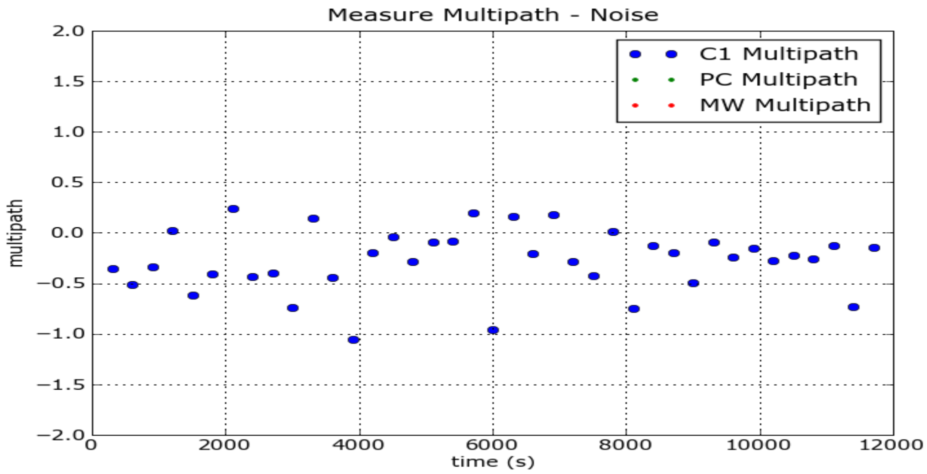

Fig3: Measurement Multi Path

Fig.3 illustrates the raw measurements of measurement multipath for c1 code measurement, Geometric-Free combination, Melbourne-Wubenna and the Graphic combination.

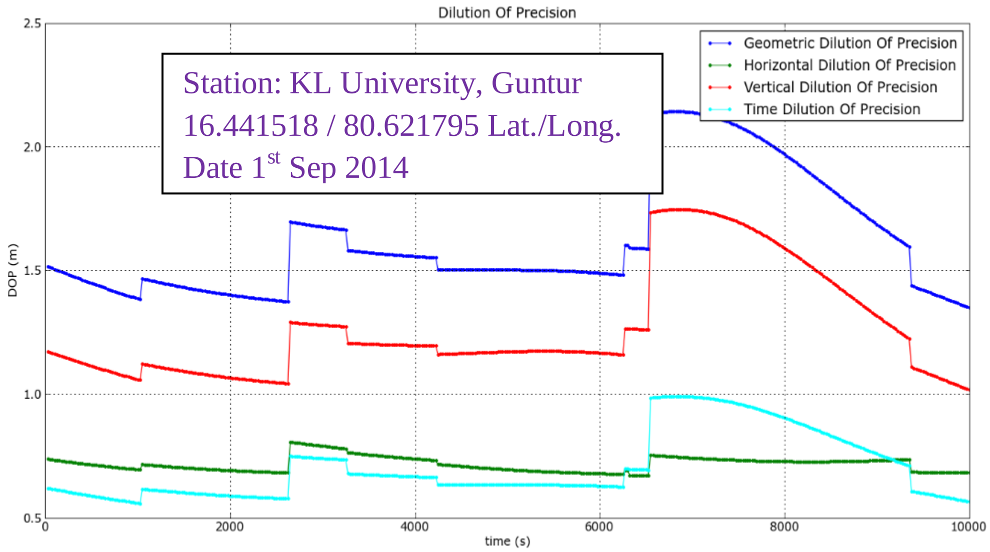

Fig4: Dilution of Precision

Fig.4 illustrates the various DOP computed on 1st sep 2104, from the figure the maximum GDOP value observed is 2.14 and this observed at 6200 sec of the GPS time, HDOP value observed is 0.8 and this observed at 6200 sec of the GPS time, VDOP value observed is 1.73 and this observed at 6200 sec of the GPS time and TDOP value observed is 1 and this observed at 6200 sec of the GPS time The maximum DOP value is obtained corresponds to the poor geometry of satellites at that particular epoch, The minimum DOP value is obtained corresponds to the good geometry of satellites at that particular epoch

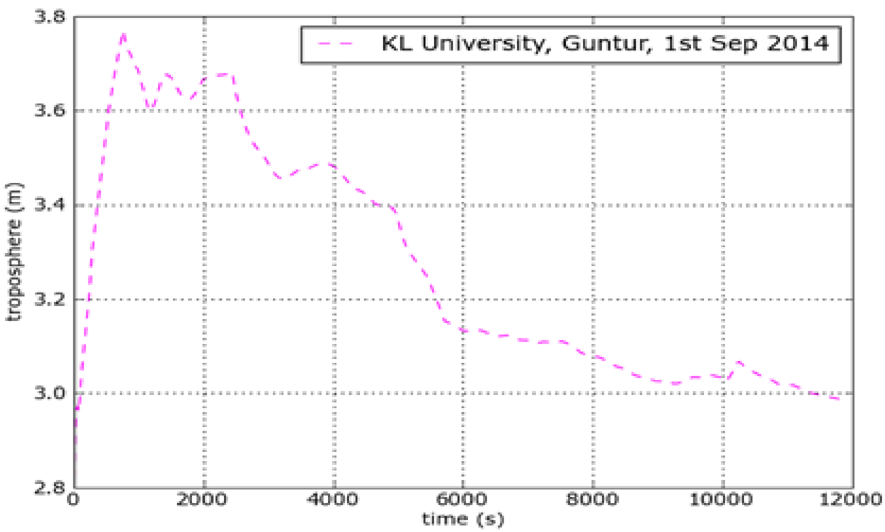

Fig.5: Zenith Tropospheric Delay

Fig.5 illustrates the Zenith Tropospheric Delay varies with a function of time, estimated part figure out in the filter section and the simple nominal part corrected in the modeling and this approach simplifies the model for vertical delays and it does not any surface meteorological data

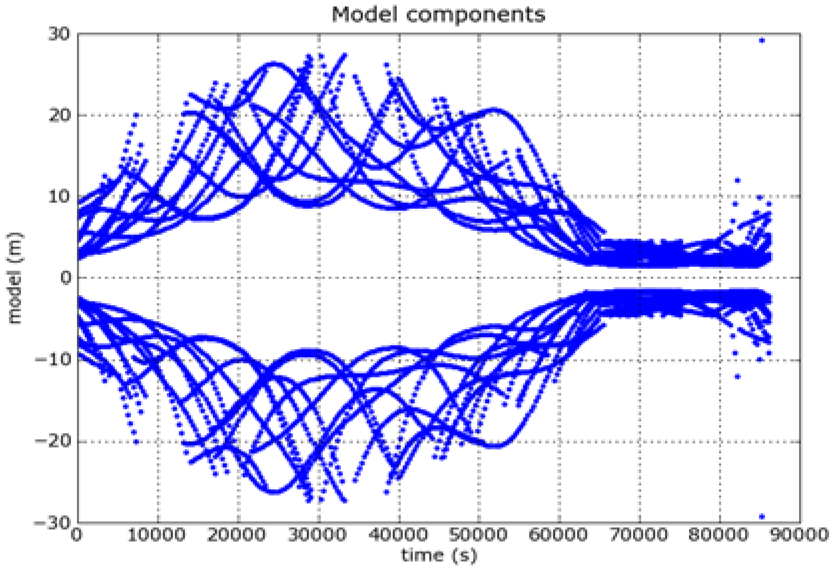

Fig.6: Model components

Fig6. Illustrates the Ionosphere delays code and advances carrier measurements and this model component is a function of time. This will be done using the data set and assess the worsening performance in the S/A on and S/A off scenarios. The impact on user domain accuracy of neglecting the different model terms in the GNSS positioning will be analyzed

Table: 1 GPS Error Budget Computation

Error Sources	RMS range error (m)
Ionospheric Delay	6.0
Tropospheric Delay	3.75
Multipath Error	0.3
UERE	7.07
Horizontal Position error (2σ) $(= 2 \times HDOP \times UERE)$	11.31
Geometric Position error (2σ) $(= 2 \times GDOP \times UERE)$	30.25
Vertical Position error (2σ) $(= 2 \times VDOP \times UERE)$	24.46
Time Position error (2σ) $(= 2 \times TDOP \times UERE)$	14.14

The rms range error can be obtained by the different error sources, UERE and the Dilution of Precision errors in meters. UERE is in the order of 7.07 due to ionospheric, tropospheric and multipath errors sources.

CONCLUSIONS:

Various sources errors can affect the code and carrier phase observations, for better position estimation based on the GPS observations. In this paper, various GPS measurement errors are estimated by GNSS-Lab (gLAB) Tool suite for improving the position accuracy. The rms range error can be obtained by the different error sources and the UERE is in the order of 7.07 due to ionospheric, tropospheric and multipath errors sources.

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