

Error Detection in 2D Orbit of GPS Satellites Using GPS Navigation Data File from GNSS Receiver

Ashok Singh Raj Purohit¹, Harshith Somanna PB¹, Anushree Shettigar¹,
Apoorva D¹, Dr. Dattathreya²

¹Department of Electronics and Communication, ²Senior Professor and Dean Planning,
AIET, Moodbidri, Mangalore

Corresponding Author: Ashok Singh Raj Purohit

ABSTRACT

This paper is to detect the error present in 2D orbits of the GPS satellites based on GPS navigation data file generated from GNSS receiver by comparing with the SP3 file by using MATLAB. The Receiver Independent Exchange Format (RINEX) File is used to extract the parameters from GPS navigation data file. The extracted parameters are used to find XYZ coordinates of GPS satellite and are plotted in 2 dimension by using MATLAB. The XYZ data extracted from SP3 file is plotted in 2 dimension and variance is found between XYZ coordinates extracted by SP3 file and GPS navigation data file in MATLAB.

Key words- GPS, GNSS receiver, SP3 file, RINEX File, MATLAB software.

I. INTRODUCTION

A satellite navigation system with global coverage is termed as Global Navigation Satellite System (GNSS). The GNSS system is used to find out geographic location of user anywhere in the world. This GNSS system include United States Global Positioning System (GPS), Russian Federation's Global Orbiting Navigation Satellite System (GLONASS), Europe's Galileo and many more. (Fritz J et al.) The GPS is a space based radio positioning system that provides 3 dimensional position, time and velocity information in any type of weather, anywhere on the Earth to users. (Ashok Singh Raj Purohit et al.)

The GPS satellite is operated by U.S. Department of Defense which consists of 32 satellites out of which 24 are visible at a time and aims at determining the user position, time and velocity accurately. The Space, Control and User segments are the different segments in GPS. (Ashok Singh Raj

Purohit et al.) The Space segment consists of a constellation of satellites transmitting radio signals to users. The Control segment consists of monitor stations and control stations that maintain satellites in proper orbits and rectify the satellites clocks. The User segments consist of GPS receiver equipment, which receives the signals from GPS satellites and uses to calculate position and time. (Paolo Dabove et al.)

The Standard Product 3 (SP3) is a precise ephemeris orbits in sp3 format. SP3 is an error free data file which is obtained by Scripps Orbit and Permanent Array Center (SOPAC). SOPAC provides several GPS satellite orbit files. (Sekath Varma et al.)

II. DETERMINATION OF PATH OF SATELLITE ORBIT

The GPS satellite path is obtained from GPS navigation data file. There are some parameters which are information source for evaluation or estimation of GPS

satellite position around the globe. These parameters are extracted from GPS navigation data file by comparing it with RINEX File. (Paolo Dabove et al.)

Some set of parameters (Ashok Singh Raj Purohit et al.) extracted from GPS navigation data file are then applied to the formulas and used to obtain XYZ coordinates by using MATLAB software. The set of mathematical equations or formulas used in determining satellite position (M.E. Awad et al.) are shown below.

The radius of elliptical orbit:

$$A = (\sqrt{a})^2 \quad (1)$$

Computed mean motion in rad/s:

$$n_0 = \frac{\mu}{A^3} \quad (2)$$

Time from ephemeris reference epoch evaluated in seconds (t is GPS system time):

$$t_k = t - t_{oe} \quad (3)$$

Corrected value of the mean motion:

$$n = n_0 + \Delta n \quad (4)$$

Mean anomaly evaluation:

$$M_k = M_0 + (n * t_k) \quad (5)$$

Kepler's equation for eccentricity:

$$M_k = E_k - e \sin E_k \quad (6)$$

The equation (6) is solved by iteration method by using Newton-Raphson method of iteration assuming $E_k = M_k$ as the initial condition.

$$\dot{E}_k = \frac{M_k}{(1 - e \cos E_k)} \quad (7)$$

Value of true anomaly from tan:

$$v_k = \tan^{-1} \left\{ \frac{\sin E_k \sqrt{1 - e^2}}{\cos E_k - e} \right\} \quad (8)$$

$$\dot{v}_k = \frac{\sin E_k E_k (1 + e \cos v_k)}{(1 - \cos E_k e) \sin v_k} \quad (9)$$

Argument of latitude:

$$\Phi_k = v_k + \omega \quad (10)$$

$$\dot{\Phi}_k = \dot{v}_k \quad (11)$$

Evaluation of the second harmonic correction to argument of latitude:

$$\partial u_k = C_{us} * \sin(2\phi_k) + C_{uc} * \cos(2\phi_k) \quad (12)$$

$$\partial \dot{u}_k = 2[C_{us} * \cos(2\phi_k) - C_{uc} * \sin(2\phi_k)] \dot{\phi}_k \quad (13)$$

Evaluation of the second harmonic correction to argument of radius:

$$\partial r_k = C_{rs} * \sin(2\phi_k) + C_{rc} * \cos(2\phi_k) \quad (14)$$

$$\partial \dot{r}_k = 2[C_{rs} * \cos(2\phi_k) - C_{rc} * \sin(2\phi_k)] \dot{\phi}_k \quad (15)$$

Evaluation of the second harmonic correction to argument of inclination:

$$\partial i_k = C_{is} * \sin(2\phi_k) + C_{ic} * \cos(2\phi_k) \quad (16)$$

$$\partial \dot{i}_k = 2[C_{is} * \cos(2\phi_k) - C_{ic} * \sin(2\phi_k)] \dot{\phi}_k \quad (17)$$

Corrected argument of latitude:

$$u_k = \phi_k + \partial u_k \quad (18)$$

$$\dot{u}_k = \dot{\phi}_k + \partial \dot{u}_k \quad (19)$$

Corrected argument of radius:

$$r_k = A(1 - e \cos E_k) + \partial r_k \quad (20)$$

$$\dot{r}_k = A e \sin E_k \dot{E}_k + \partial \dot{r}_k \quad (21)$$

Corrected argument of inclination:

$$i_k = i_0 + ((IDOT) * t_k) + \partial i_k \quad (22)$$

$$\dot{i}_k = IDOT + \partial \dot{i}_k \quad (23)$$

X satellite coordinate of orbital plane:

$$\dot{x}_k = r_k \cos u_k \quad (24)$$

$$\ddot{x}_k = (\dot{r}_k \cos u_k - r_k \sin u_k) \dot{u}_k \quad (25)$$

Y satellite coordinate of orbital plane:

$$\dot{y}_k = r_k \sin u_k \quad (26)$$

$$\ddot{y}_k = (\dot{r}_k \sin u_k + r_k \cos u_k) \dot{u}_k \quad (27)$$

Corrected longitude of ascending node:

$$\Omega_k = \Omega_0 + (\dot{\Omega} - \dot{\Omega}_e) t_k - \dot{\Omega}_e t_{oe} \quad (28)$$

$$\dot{\Omega}_k = \dot{\Omega} - \dot{\Omega}_e \quad (29)$$

X coordinate in ECEF Frame:

$$x_k = \dot{x}_k * \cos \Omega_k - \dot{y}_k * \sin \Omega_k \quad (30)$$

X coordinate in ECEF Frame:

$$y_k = \dot{x}_k * \sin \Omega_k + \dot{y}_k * \cos \Omega_k \quad (31)$$

X coordinate in ECEF Frame:

$$z_k = \dot{x}_k * \sin i_k \quad (32)$$

From the above set of equations we get XYZ coordinates of GPS satellite which depend on value of universal gravitational parameter of earth's rotation rate. According to WGS-84 model the values are:

$$\mu = 3.986005 \times 10^{14} \text{ m}^3/\text{s}^2 \quad (33)$$

$$\dot{\Omega}_e = 7.292115167 \times 10^{-5} \text{ rad/s} \quad (34)$$

The XYZ coordinates obtained with respect to ECEF (Earth Centered and Earth Fixed) coordinate system are then plotted in two dimension by using MATLAB tool.

III. VISUALIZATION OF SATELLITE ORBIT

The XYZ coordinates obtained in ECEF system by implementing the formulas in MATLAB and plotting the two dimensional plot with the help of MATLAB where y-axis represents data or value of GPS satellite and x-axis represents time at which GPS satellite was present or visible.

The below figure shows the two dimensional plot of XYZ coordinates of GPS satellites path from GPS navigation data file. (Ashok Singh Raj Purohit et al.)

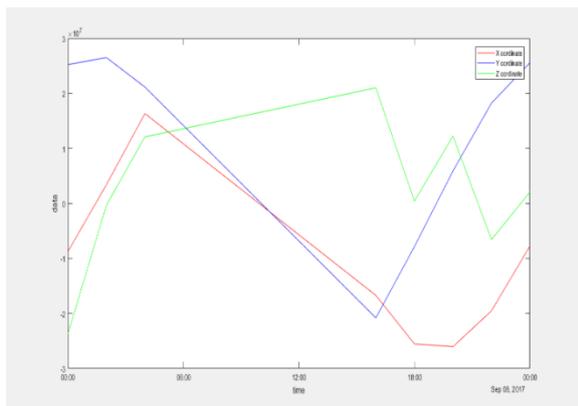


Figure 1. Visualization of path of GPS satellite from GPS navigation data file.

The above obtained 2D plot is interpolated to smooth curve and increase the number of samples along X axis which represents time. Initially there are 216 number of samples which are increased to 2880 samples by plotting satellite position for every 30 seconds by using MATLAB. The below figure represents interpolated path of XYZ coordinates of GPS satellite.

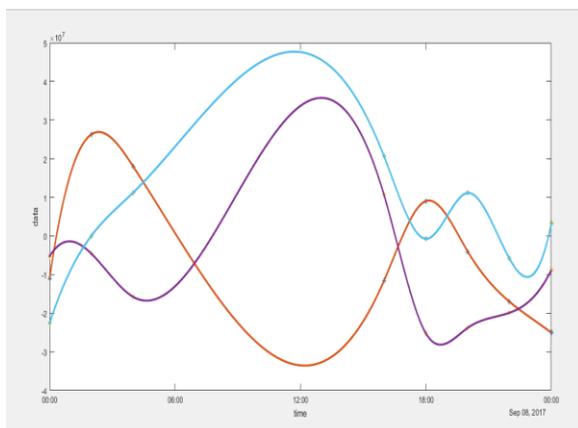


Figure 2. Interpolated path of GPS satellite.

This interpolated signal is then compared with the interpolated signal path of GPS satellite from SP3 file. The below figure shows the satellite path in 2D with XYZ coordinates extracted from SP3 file.

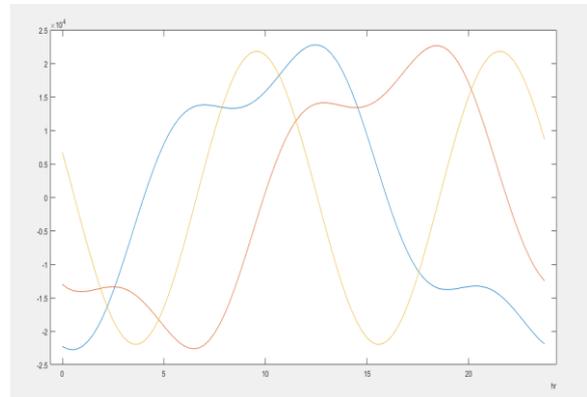


Figure 3. Visualization of satellite path of GPS satellite from SP3 file.

The above obtained plot of satellite path is interpolated by increasing the number of samples from 216 samples to 2880 samples so that a smooth curve can be obtained.

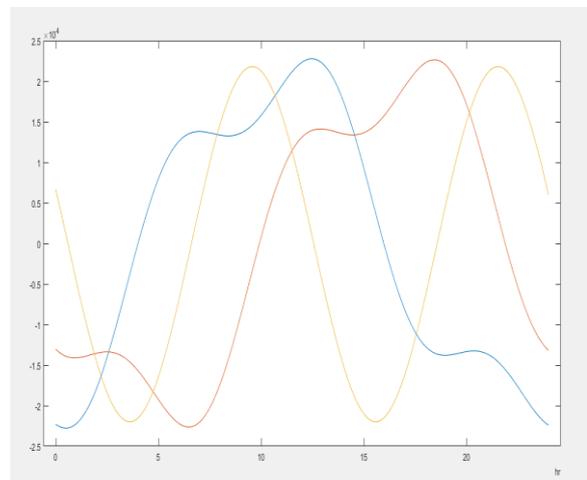


Figure 4. Interpolated signal of GPS satellite of SP3 file.

The interpolated signal plotted in 2D with XYZ coordinates of GPS navigation data file is compared with interpolated signal plotted with XYZ coordinates of GPS satellite from SP3 file to find the variance by taking difference between the plots and squaring the values. The below figure shows the error in GPS satellite signal of GPS navigation data file.

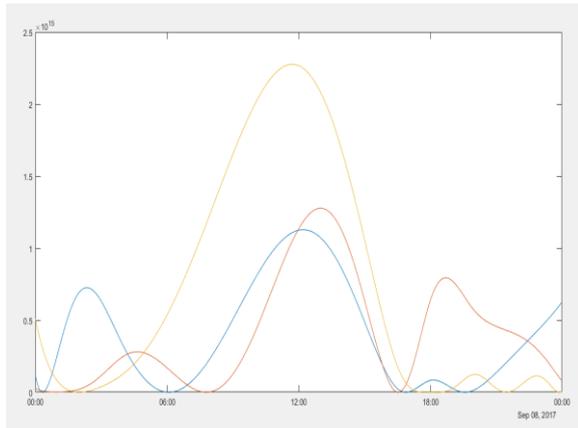


Figure 5. Variance in GPS satellite path.

The above figure indicates the amount of error present in satellite path plotted by using XYZ coordinates obtained from GPS navigation data file.

IV. CONCLUSION

The present work focuses on finding the amount of error present in GPS satellite path. Which is obtained by finding the difference in plot of XYZ coordinates obtained by implementing formulas using data extracted from RINEX file. Another plot of XYZ coordinates are obtained from SP3 file. In future the error can be minimized by using some filters. Kalman filter is one the filter that can be used to remove error in orbital path of GPS satellite obtained from GPS navigation data file.

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