In the Name of God

Total Electron Content (TEC) Estimation using Single-Frequency GPS Receiver

(A Case Study at Zanjan University)

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Abstract

- Global Positioning System (GPS) can provide us to study the effect of the ionosphere as the signals propagate from the satellites to GPS receivers. Efforts have been made to estimate the TEC using single frequency GPS pseudo range and carrier phase observations.

- In this study, we used GPS observations at the GPS site of Zanjan University made with single frequency receivers, according to a GPS single frequency broadcast model for estimation of TEC. Results have been compared with global TEC maps.

Introduction

- The ionospheric delay is still one of the largest sources of error that affects the positioning accuracy of any satellite positioning system. The ionospheric error is considered the major source of potential range delay for single frequency users after the Selective Availability(SA).
- Much effort has been made in establishing models for single frequency users to make this effect as small as possible. One of these models is broadcast Klobuchar model. Klobuchar model coefficients are in the satellite navigation message. Also the IGS (International GPS Service) products include global ionospheric maps in IONEX-format (IONosphere map EXchange format) which enable the computation of the ionospheric delay and TEC at any desired location and time.

Total Electron Content (TEC)

- The ionosphere is a region of ionized gases (free electron and ions). The parameter of the ionosphere that produces most of the effects on GPS signals is the total number of electrons, commonly called TEC
- TEC is determined as following equation:

$$TEC = \int N dl$$

- Where N is the local electron density, and the integration is along the signal path from the satellite to the receiver.

Klobuchar Model

- The entire vertical ionospheric refraction is approximated by klobuchar model and yields the vertical time delay for the GPS measurements.
- The evaluation of the klobuchar model may be performed by the following steps :

A) Computing the azimuth a and the zenith distance z of the satellite for epoch t_{UT}

B) Choosing a mean height of the ionosphere and computation the distance s between the observing site and the ionospheric point obtained from the triangle origin-observation site-IP.

C) Computing the coordinates φ_{IP}, λ_{IP} of the ionospheric point by means of the quantities a ,z,s.

D) Calculating φ_{IP}^{m} from below equation:

$$\sin\varphi_{IP}^{m} = \sin\varphi_{IP}\sin\varphi_{P} + \cos\varphi_{IP}\cos\varphi_{P}\cos(\lambda_{IP} - \lambda_{P})$$

E) Calculating A_2 and A_4 from below equations where the coefficients α_i, β_i ,i=1,…,4 are received via the satellite navigation message.

F) Computing the vertical delay ΔT_V^{Iono} by below equation

$$\Delta T_V^{Iono} = A_1 + A_2\cos\left(\frac{2\pi(t - A_3)}{A_4}\right)$$

where

$$A_1 = 5.10^{-9}s = 5ns$$

$$A_2 = \alpha_1 + \alpha_2\varphi_{IP}^{m} + \alpha_3\varphi_{IP}^{m\,2} + \alpha_4\varphi_{IP}^{m\,3}$$

$$A_3 = 14^h$$

$$A_4 = \beta_1 + \beta_2\varphi_{IP}^{m} + \beta_3\varphi_{IP}^{m\,2} + \beta_4\varphi_{IP}^{m\,3}$$

G) By calculating z' from below equation

$$\sin z' = \frac{R_E}{R_E + h_m} \sin z$$

(where R_E is the mean radius of the earth, h_m is a mean value for the height of ionosphere, z is the zenith distance at the observing site.)

and applying this equation

$$\Delta T^{Iono} = \frac{1}{\cos z'} \Delta T_V^{Iono}$$

the transition from the vertical delay to the delay along the wave path is achieved. The result is obtained as time delay in seconds which must be multiplied by the speed of light to get it as a change of range, then TEC is obtained by applying the below equation.

$$\Delta^{Iono} = \frac{1}{\cos(z')} \cdot \frac{40}{f^2} TEC$$

Data

- Global Positioning System TEC data were collected at 2 stations separated in latitude and longitude at Zanjan university by single frequency receivers. Klobuchar model and global TEC maps have been applied to estimation of TEC in those GPS stations for local time from 8:40 August 6 to 11:30 August 6 2006 and from 9:10 August 7 to 11:15 August 7 2006.

Table 1: Mean TEC from 8:40 August 6 to 11:30 August 6 2006

Klobuchar Model (TECU)	Global TEC Maps (TECU)
22.3	39.6

Table 2: Mean TEC from 9:10 August 7 to 11:15 August 7 2006

Klobuchar Model (TECU)	Global TEC Maps (TECU)
11.5	32.8

Results

Using the original Klobuchar model, 50%-60% of the ionosphere delay effects can be corrected generally at present. In order to improve the result, a new type of the model needs to be developed, which is more suitable for TEC correlation of regional and global area.

The TEC obtained from Klobuchar model with GPS broadcast coefficients were also compared with those derived by the global TEC maps. The difference between model and maps TEC varies with the location and local time.

The study has proved that the Klobuchar model has shortcomings regarding its low accuracy and less detailed description for the ionosphere's behaviour. Using the more coefficients in the Klobuchar model will give a better accuracy in computing the delay and TEC but it will still give a low-resolution description of the ionosphere performance.

Thanks to your attention.