HACETTEPE UNIVERSITY

GEOMATICS ENGINEERING DEPARTMENT

GMT312
GLOBAL NAVIGATION SATELLITE SYSTEMS

Assignment IV

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1. INTRODUCTION

The Klobuchar algorithm was used to simulate ionospheric delays that impact GPS signals. This algorithm, which depends on broadcast ionospheric coefficients, is frequently found in GPS receivers. empirical model created by Collins (1999) and implemented in the SBAS system was used to model tropospheric delay. This model considers factors like satellite elevation, altitude, seasonal variations, and geographic location.

Using ephemeris data in the SP3 format, satellite positions were calculated using 9th-order Lagrange interpolation to attain high positional accuracy during transmission. The rotation of the earth was thought to compensate for the satellite's spatial displacement. To make observation geometry easier, the receiver's coordinates which were initially in ECEF format were transformed into geodetic latitude, longitude, and height.

Python was used for all tasks, utilizing modular code created during earlier coursework. Coordinate transformations, delay modeling, and satellite positioning are coordinated by a central script.

2. METHODOLOGY

In order to solve this problem, atmospheric delays on a GPS signal received at a specific reception time had to be estimated. First, a 9th-order Lagrange method was used to interpolate the satellite position at emission from SP3-format ephemeris data. The observation time 27840 seconds past midnight was read from the student number as instructed, and ten regularly spaced epochs (15-minute epoch spacing) were used for interpolation.

Satellite clock biases from the SP3 database were used to correct pseudorange data (in this case, C1 code) in order to pinpoint the precise time of emission. With the help of the corrections, the emission epoch could be accurately calculated and then entered into a specialized Python script to determine the satellite's location. To make positions accurate, the earth's rotation was taken into account.

Using a locally created xyz2blh function, receiver coordinates in ECEF format were converted to geodetic height, latitude, and longitude. Satellite coordinates were converted to local topocentric space using a global2local function in order to comprehend the directional relationship between the satellite and receiver. It was then used to compute azimuth, zenith angle, and slant distance.

Using broadcast alpha and beta coefficients, the Klobuchar model was used to estimate ionospheric delays. The Ionospheric Pierce Point (IPP) was determined using the elevation and azimuth angles, and the corresponding delay was computed in meters using the Ion_Klobuchar function.
For tropospheric delay, the Collins (1999) model adhering to SBAS standards was used to determine dry and wet zenith delays. These were projected along the slant path using a mapping function.

To complete all of these steps at once, a main function called atmos was also implemented. The function, which is written in Python 3 and relies on libraries like math and numpy, returns the entire set of calculated values. Additionally, the implementation is similar to standard GNSS atmospheric correction techniques.

3. RESULTS AND DISCUSSIONS

Based on student ID, this epoch was selected, and all computations matched GPS time 07:44:00 (27840 seconds into the day). With the framework in place, the topocentric vector of the receiver with respect to the satellite was computed and the satellite position at the time of transmission was accurately interpolated. This resulted in important distances and angles for observation.

```
PS C:\Users\ceren> & C:/Users/ceren/AppData/Local/Progra
Azimuth  51.10662437580932
Zenith 57.67467505378593
Slant  22636.017073679435
Ionospheric delay 13.705789291003343
Tropospheric dry delay  4.294294391077184
Tropospheric wet delay  0.3804872576844438
PS C:\Users\ceren>
```

With an azimuth of 51.11° and a zenith angle of roughly 58°, the satellite was relatively high in the southern sky. Due to the lengthy signal path caused by this geometry, the satellite is more vulnerable to atmospheric effects.

As anticipated given the high altitude and daylight, the Klobuchar-based ionospheric delay was approximately 1.37 meters. As would be expected when humidity content has a less fluctuating but otherwise lesser effect, the dry component (4.29 m) of the tropospheric delay was rather large in comparison to the wet component (0.38 m). All of the findings support the effectiveness and applicability of the modeling approach. The accuracy of the used algorithms is confirmed by the air delays being within the ranges found in GNSS publications. and numerical techniques.

REFERENCES

1. **International GNSS Service (IGS).** "IGS0OPSFIN_20250910000_01D_15M_ORB.SP3" – Precise Ephemeris Data. Retrieved from https://www.igs.org
2. **RINEX Observation and Navigation Files.** "MERS00TUR_R_20250910000_01D_30S_MO.rnx" and "brdc0910.25n" – Collected via MERS GNSS station and CDDIS data archive.