AAE 575 Homework 5

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Problem 1:

There are two ways to find the Earth-Centered-Earth-Fixed (ECEF) coordinates for satellite position given the two files that were provided. The first method is to directly plot the X, Y, and Z coordinates that were provided in the IGS orbit position information in the igr11382.sp3 file that recorded the position of the orbit at certain time periods. The trajectory of the satellites can also be calculated using the ephemeris data that was provided during the same week in the ephemeris.dat file using the same points in time as the IGS orbits.

The first step was to extract the data from the .sp3 and .dat files which was the most complicated part of the assignment. To extract the .sp3 data, a function, read_sp3 and GPSweek were used to extract the data which gave the data in one structure and the column headers in the second structure. Once this is done, it is easy to access the data and headers from the structures. For the ephemeris data, the data was extracted by converting the .dat file into a table then reading the values. The values included the variable names for some reason in a cell array, so the cell was converted to a character array and extracted only the numerical values.

Once all of the data was extracted, the IGS satellite orbit data could be plotted immediately since the coordinates that were give were already in ECEF. This was plotted using either scatter3 or plot3 which plots 3D vectors.

For the ephemeris data, the ECEF coordinates were calculated using the algorithm on pages 106-107 of the IS-GPS 200M data sheet. This algorithm takes the data from the ephemeris file and creates the 3D coordinates by using Newtons and Kepler's equations of motion for a two-body system along with perturbations. The steps for this include finding the shape of the orbit with the ephemeris data which gives the semimajor axis and eccentricity, which the mean motion could be found as well using the definition for the value. The time series vector is found by taking the time steps from the IGS orbit data and subtracting the Time of Applicability from the ephemeris data. Next is to find the mean anomaly and from that, using Kepler's equation for time and an iterative algorithm, solve for the eccentric anomaly for each time step which can easily be converted into true anomaly. Once this is done, the argument of latitude can be found, but need to be corrected using the Second Harmonic Perturbations which make use of the latitude, radius, and inclination trigonometric amplitudes to corrected values for the latitude, radius, and inclination. Once this is done, x and y (within the orbital plane) can be found using polar coordinates and the longitude of the ascending node can also be calculated using the ephemeris data. Once this is done, a direction cosine matrix can be used to convert the x and y coordinates within the orbital plane to x, y, and z coordinates in the ECEF coordinate frame. Below, in figure 1, is the plot of the orbits in ECEF.

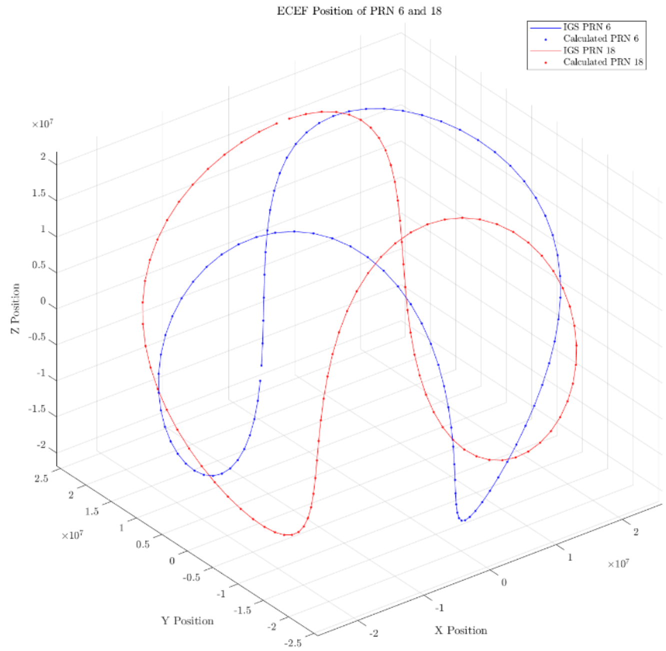

Figure 1 – PRN 6 and PRN 18 Orbits

Once the two sets of coordinate time series are found, the difference between the two can be found for each satellite (PRN) to get the error. The plots for these can be found in figures 2 and 3. The range of errors for are similar within ±200 meters for both PRN 6 and PRN 18, however when looking at the ±2 hour interval centered around the Time of Applicability, PRN 18 has a much lower range of error compared to PRN 6. This can be quantified by takin the root mean square between this time interval and comparing it which can be found the taking the square of the sum of the errors squared divided by the number of time steps. The time of applicability affects the error that is represented by the root mean square by change the window for the time interval that the root mean square is taken in. It can be seen in figures 2 and 3 that the information that is captured by the window is at the lowest error. The root mean square values for PRN 6 are 3.60597, 6.18754, and 3.59430 for the x, y, and z ECEF coordinates respectively. While the values for PRN 18 are as follows: 1.69815, 0.52498, and 1.76409 for the x, y, and z ECEF coordinates respectively. This confirms the previous discussion that PRN 18 has a lower error in the 4 hour window centered around the time of applicability for each PRN.

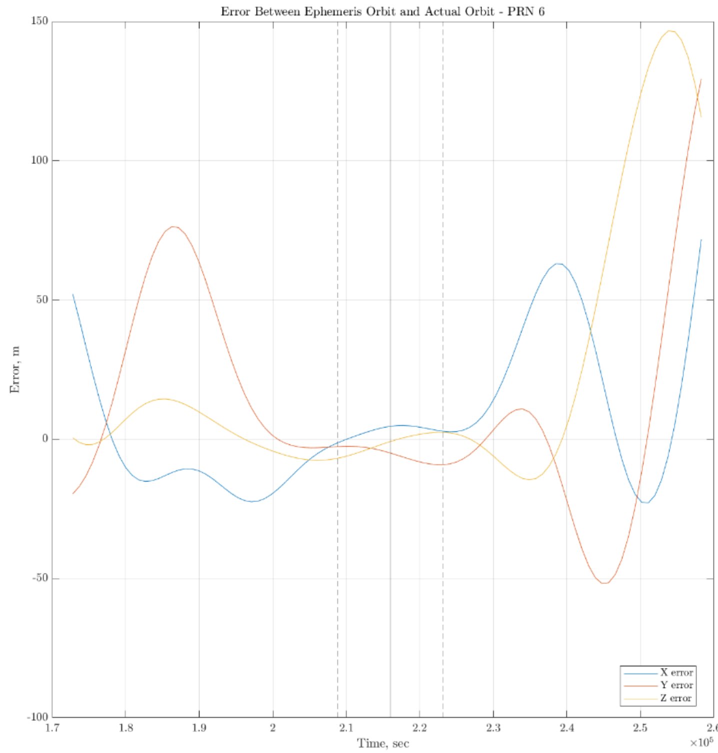

Figure 2 – Ephemeris and IGS Orbit Error (PRN 6)

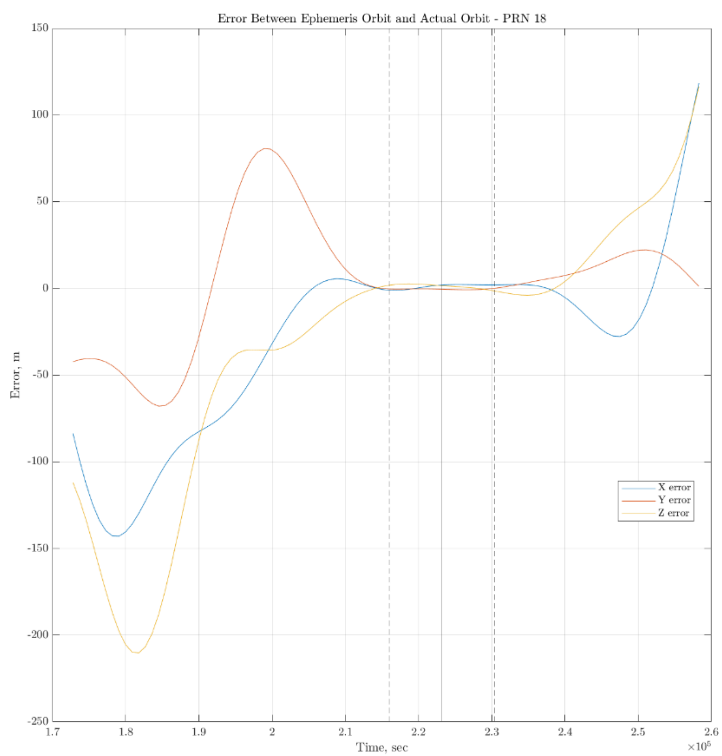

Figure 2 – Ephemeris and IGS Orbit Error (PRN 18)