Rectangular Display of Satellite Ground Tracks During Ground Site-to-Satellite Visibility

This ***Numerit*** computer program (`satplot5`) can be used to create a graphic display of satellite ground tracks on a rectangular map of the Earth. The ground track is plotted whenever a user-defined ground site has line-of-sight visibility with a user-defined satellite. The user can enforce an minimum elevation angle constraint or "mask" during the calculations. The software reads an ASCII data file named `gmapll.dat` to create geographic features on the display.

The topocentric elevation angle of a satellite relative to an observer or ground site on an oblate Earth is calculated from

$$E = \sin^{-1}\left(r_{z_{topo}}\right) \tag{1}$$

where the components of the topocentric position vector $\boldsymbol{r}_{topo}$ are determined from the following transformation matrix and the ECI position vector $\boldsymbol{r}_{eci}$ of the satellite:

$$\boldsymbol{r}_{topo} = [T]\boldsymbol{r}_{eci} = \begin{bmatrix} \sin f \cos q & \sin f \sin q & -\cos f \\ -\sin q & \cos q & 0 \\ \cos f \cos q & \cos f \sin q & \sin f \end{bmatrix} \boldsymbol{r}_{eci} \tag{2}$$

In this transformation f is the geodetic latitude of the ground site and q is the local sidereal time at the ground site.

The local sidereal time at a ground site is given by

$$q(t) = q_{g0} + w_e t + l_e \tag{3}$$

where q_{g0} is the Greenwich sidereal time at 0 hours universal time, w_e is the inertial rotation rate of the Earth, t is the elapsed time since 0 hours universal time and l_e is the east longitude of the ground site.

The ECI position vector used in this transformation is the position of the satellite relative to the observer or ground site. It is determined from the ECI position vectors of the observer $\boldsymbol{r}_{obs}$ and satellite $\boldsymbol{r}_{sat}$ according to

$$\boldsymbol{r}_{eci} = \boldsymbol{r}_{sat} - \boldsymbol{r}_{obs} \tag{4}$$

The scalar slant range from the observer to the satellite is computed from the components of this vector according to

$$p = \sqrt{x_{eci}^2 + y_{eci}^2 + z_{eci}^2} \tag{5}$$

The topocentric elevation angle is calculated from the *z* component of the topocentric unit position vector with this next expression

$$E = \sin^{-1}\left(r_{z_{topo}}\right) \tag{6}$$

Elevation is positive above the local horizontal or tangent plane at the observer's geographic location or ground site.

The software will interactively prompt you for the initial calendar date, universal time and classical orbital elements of the satellite. It will also ask you to input the geographic coordinates of the ground site. Finally, it will ask you to input a simulation duration in days and the graphics step size for plotting in minutes.

The following is a typical display created with this software. It illustrates the ground track of a low altitude Earth orbit (LEO). Each ground track data point is plotted at the graphics step size input by the user. The separation of the points is an indication of the speed of the satellite in its orbit. The number of data points in each pass is an approximate indication of the duration of the visibility. The ground site is marked with a small + symbol.

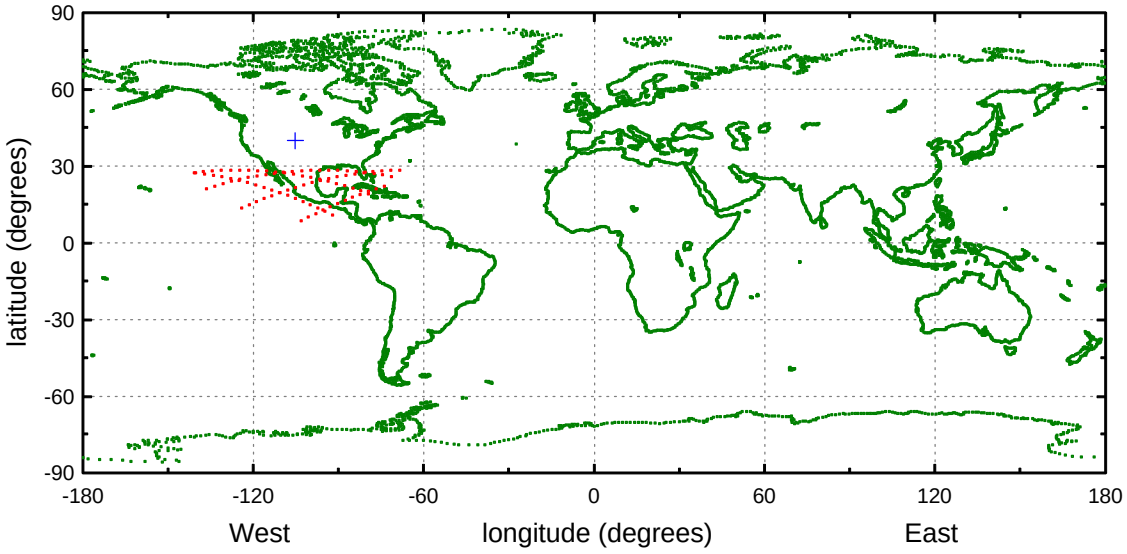

Figure 1. Rectangular View of Satellite Ground Track

You can zoom the plot by interactively changing both the physical size of the plot and the *x* and *y*-axis scales. Be sure to make the physical size compatible with the latitude and longitude scales. For example, the plot in Figure 1 covers 180 degrees in latitude and 360 degrees in longitude. The physical size of this plot is 6 inches wide and 3 inches high, a 2 to 1 scale. If you wanted to zoom in and plot from -180 to 0 degrees in longitude, you would make the physical width exactly equal to the physical height (a 1 to 1 scale), say 4

inches for both. You can also resize the plot by selecting and dragging the lower right corner of the frame.