Master of Geodesy and Geoinformation Science
TU Berlin

winter term 2021/22
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Introduction to Satellite Geodesy - Exercise

Assignment 5: Satellite orbits

Exercises

The orbits of six satellites are given in terms of their two line elements (attachment 1) in the Earth Centered Inertial (ECI) system. Use $GM_{\oplus} = 398600.44\ \mathrm{km^3\ s^{-2}}$ as geocentric gravitational constant.

1. Specify the orbital periods T of the satellites in UT1 to minute precision.
2. What semi major axis a, perigee and apogee heights (m precision) do the satellite orbits have?
3. Compute the position and velocity vectors of the satellites (attachment 1) during one day (t = start epoch, time increment 1 minute) in the ECI system. Plot the 3d-orbits together with a sphere of radius $R = 6371\ \mathrm{km}$ in the same figure. Plot the three velocity components and the magnitude of the velocity of each satellite each into an own figure.
4. Transform the ECI positions to the Earth Centered Earth Fixed (ECEF) system by considering the Earth phase of rotation in terms of $GMST$ only, i.e. neglecting precession, nutations, and polar motion. Plot the orbits in the ECEF system together with the Earth as a sphere of radius $R = 6371\ \mathrm{km}$ with coastlines or an Earth surface image projected on it.
5. Compute the ground tracks of the satellites and plot them on top of an Earth surface image or a coastline plot.
6. Compute the minima of the 3d-distance (to m precision) and of the zenith distance (to arc min precision) to an observer near Berlin (attachment 2) and the corresponding epochs (minute precision) of these events. Which satellite approaches the observer with the smallest 3d-distance and which satellite comes closest to the local zenith of the observer? Why do some of the satellites not approach Berlin or Berlin's zenith considerably?

Attachment

1. Two line elements of six Earth satellites (credits: Heavens Above)

Satellite name	i (deg)	Ω (deg)	e	ω (deg)	M (deg)	n (d^{-1})	t (date, time UT1)
ISS	51.7	19.1	0.00	17.6	10.4	15.50	2022-01-14, 04:49
Sentinel 1B	98.2	23.5	0.00	80.6	279.5	14.59	2022-01-13, 22:15
Molniya-1T	63.6	198.3	0.62	299.8	13.0	3.19	2022-01-12, 18:29
Galileo 9	55.7	266.4	0.00	14.0	346.1	1.71	2022-01-09, 02:07
Beidou IGSO 3	60.1	55.8	0.00	192.4	355.6	1.00	2022-01-13, 01:41
Meteosat 11	0.3	325.8	0.00	117.3	338.5	1.00	2022-01-13, 20:35

2. Cartesian coordinates of an observer near Berlin: $\boldsymbol{R_{Ber}} = \begin{pmatrix} 3782971.01 \\ 902152.49 \\ 5038375.59 \end{pmatrix}\ \mathrm{m}$

Due date
January 31, 2022