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HOW TO CALCULATE COORDINATES AND VELOCITY OF A SPACECRAFT USING GLONASS ALMANAC

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Research work sometimes requires knowledge about coordinates and velocity of a spacecraft. Data about coordinates and velocity of a spacecraft are needed to stabilize the spacecraft or to know its location, etc.

The goal of the research is computation of coordinates and velocity vector components at instant t_i (MT) of a day N_0 within a four-year period, and in absolute geocentric coordinate system $OX_aY_aZ_a$ (which origin and Z-axis coincide with origin and Z-axis of OXYZ system, the offset between the XOZ-plane and X_aOZ_a is equal to true sidereal time, and OY_a – axis completes the system as a right-handed one).

There are various ways of computing coordinates and velocity vector components. These computational methods use ephemerides or different GNSS data, or an almanac. In case you need more accurate estimates it is necessary to create the first method with using ephemerides and various GNSS data. When using this method it is necessary to start from an ephemeris and compute satellite positions at close time intervals (say 1 second) and derive velocity from here. Alternatively you can use Doppler estimates and integrate them. But this method needs data captured from a high-end receiver and complicated computation. In the present investigation a method which only involves an almanac is used.

The following describes the procedure for the computation of coordinates and velocity of a spacecraft. One procedure is to compute the position for the spacecraft for every second and compute the difference (*dx, dy, dz*) between two consecutive positions and divide by the time between the two epochs. Coordinates (1) and velocity vector components (2) at instant t_i in $OX_aY_aZ_a$ coordinate system can be computed as

$$\begin{aligned} X_{oi} &= r_i\left(\cos u_i \cdot \cos\Omega_i - \sin u_i \cdot \sin\Omega_i \cdot \cos i_i\right), \\ Y_{oi} &= r_i\left(\cos u_i \cdot \sin\Omega_i + \sin u_i \cdot \cos\Omega_i \cdot \cos i_i\right), \\ Z_i &= r_i \cdot \sin u_i \cdot \sin i_i; \end{aligned} \tag{1}$$

$$\begin{aligned} Vxo_i &= Vr_i\left(\cos u_i \cdot \cos\Omega_i - \sin u_i \cdot \sin\Omega_i \cdot \cos i_i\right) - Vu_i\left(\sin u_i \cdot \cos\Omega_i + \cos u_i \cdot \sin\Omega_i \cdot \cos i_i\right), \\ Vyo_i &= Vr_i\left(\cos u_i \cdot \sin\Omega_i + \sin u_i \cdot \cos\Omega_i \cdot \cos i_i\right) - Vu_i\left(\sin u_i \cdot \sin\Omega_i - \cos u_i \cdot \cos\Omega_i \cdot \cos i_i\right), \\ Vzo_i &= Vr_i \cdot \sin u_i \cdot \sin i_i + Vu_i \cdot \cos u_i \cdot \sin i_i. \end{aligned} \tag{2}$$

We cannot say that the method based on an almanac is better than other methods. In fact the opposite is valid: methods based on a combination of ephemeris and actual observations will be more accurate as the almanac is only a coarse approximation to an ephemeris. However, it is not always that we are interested in the most accurate method. In some cases we are interested in knowing the order of magnitude of the velocity components in an ECEF (Earth-Centered Earth-Fixed) system or in an inertial system. The procedure described in this research is one of the fastest and the most simple. This method yields results accurate to two-three significant digits and is therefore useful for rough calculations.