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DESIGNATION THE VELOCITY OF CESSNA 172 AIRCRAFT BASED ON GPS DATA IN FLIGHT TEST

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Abstract: *In recent years the GPS satellite receiver is a basic equipment of avionics onboard of aircraft. Especially, the GPS receiver is utilized for designation the component of PV (Position-Velocity) model of the aircraft in kinematic mode in air navigation. The mathematical scheme of recovery the velocity of aircraft in local frame ENU (East-North-Up) is presented in this article. As part of research works a values of velocity of motion of the aircraft were appointed and showed.*

Keywords: GPS, Velocity, ENU frame, Aircraft.

1. Introduction

The GPS receiver is usually placed on the board the platform of plane that allows to recovery the position of the aircraft in three-dimensional space. The typical accuracy of determine the position of the aircraft for GPS receiver is presented in ICAO instruction in Annex 10 (Grunwald et al., 2016). Set coordinates of the aircraft are related by the GPS receiver to the geocentric XYZ or the geodetic BLh frame or the local ENU frame (Wierzbicki et al., 2016). The GPS receiver built in into the navigational system of the aircraft also allows for determining the navigational parameters such as coordinates, velocity or attitude. Components of the vector speed are determined along each coordinate axis ENU and determine the relative rate of movement of platform.

Exploiting the technical infrastructure of the GPS receiver for determining navigational parameters of velocity of the platform of the aircraft is the aim of the study. In paper the relative velocity of motion of Cessna 172 plane were presented and described. The GPS data for research experiment are obtained from dual-frequency Topcon HiperPro receiver. The GPS receiver was installed onboard Cessna 172 plane at during the flight test on military aerodrome in Dęblin in 1st June of 2010. The article was divided into 3 sections and references were added at the end of this paper.

2. Methods and Results

The relative velocity of the flight of the aircraft was determined in the local ENU frame and is expressing the change of ENU coordinates in the determined interval of the time, according to equations:

$$V_E = \frac{\Delta E}{\Delta t} \tag{1}$$

$$V_N = \frac{\Delta N}{\Delta t} \tag{2}$$

$$V_U = \frac{\Delta U}{\Delta t} \tag{3}$$

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where V_E - velocity along to East (E) axis, V_N - velocity along to North (N) axis, V_U - velocity along to Up (U) axis, Δt - time interval.

The coordinates of aircraft in local frame ENU are designated using formula (Sanz Subirana et al., 2013):

$$\Delta E = -\sin L \cdot \Delta X + \cos L \cdot \Delta Y + 0 \cdot \Delta Z \quad (4)$$

$$\Delta N = -\cos L \cdot \sin B \cdot \Delta X - \sin L \cdot \sin B \cdot \Delta Y + \cos B \cdot \Delta Z \quad (5)$$

$$\Delta U = \cos L \cdot \cos B \cdot \Delta X + \sin L \cdot \cos B \cdot \Delta Y + \sin B \cdot \Delta Z \quad (6)$$

where *(E, N, U)* - the coordinate of aircraft position in navigational frame ENU, *(X, Z, Y)*- geocentric coordinates of aircraft, *(B, L)*- geodetic coordinates of aircraft, *B* - Latitude, *L* - Longitude.

The geocentric coordinates *(X, Z, Y)* are determinated based on navigation solution of user position in GPS system. In this paper, the geocentric coordinates of aircraft were designated using SPP (Single Point Positioning) method for C/A code observations. The GPS kinematic observations were collected by dual-frequency Topcon HiperPro receiver, which was located into pilot's cabin in Cessna 172 plane (Ćwiklak et al., 2010). The flight test was conducted close to military aerodrome in Dęblin in Poland at time of 1st June of 2010 (see Fig. 1). The flight trajectory of Cessna 172 plane was calculated into RTKLIB software in RTKPOST numerical module. The mathematical scheme of solution of SPP method in RTKPOST module is focused on least square estimation in stochastic model. The input data such as GPS observations and ephemeris parameters must be implemented in SPP method in RTKPOST module (Takasu, 2013). The final geocentric coordinates of aircraft can be also transformed using Helmert's formula into geodetic frame *(B, L)*. The results of trajectory in geodetic frame *(B, L)* are presented into Fig. 1. The geodetic coordinates *(B, L)* expressed the aircraft's position in global WGS-84 datum.

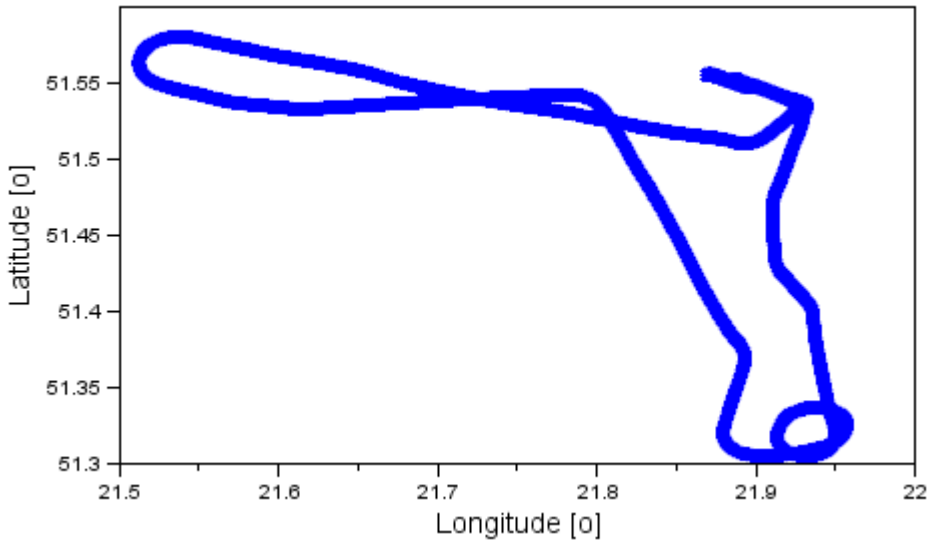

Fig. 1: The horizontal trajectory of flight of Cessna 172 plane.

Fig. 2 presents relative velocity of the flight of the Cessna 172 aircraft related to the local ENU frame. The value of the velocity along the E axis fluctuates -30.01 m/s to 31.35 m/s, in addition the average of absolute velocity is 11.85 m/s. One should be underline that the dispersion of results for the velocity along E and N axis is biggest of results presented in Fig. 2. The results of velocity parameter along the N axis are between -37.89 m/s and +31.07 m/s. The average of absolute value of V_N velocity equals 12.13 m/s, whereas the median for this parameter equals 6.92 m/s. The value of velocity for V_U parameter amounts between -5.14 m/s and 8.29 m/s. Moreover the average of absolute value of V_U parameter equals 0.52 m/s, whereas the median 0.29 m/s, accordingly. Additionally the V_U parameter has the smallest scattering of results in comparing to the V_E and V_N velocities. Moreover the results of V_E and V_N velocities are not exceeded the value of ±50 m/s.

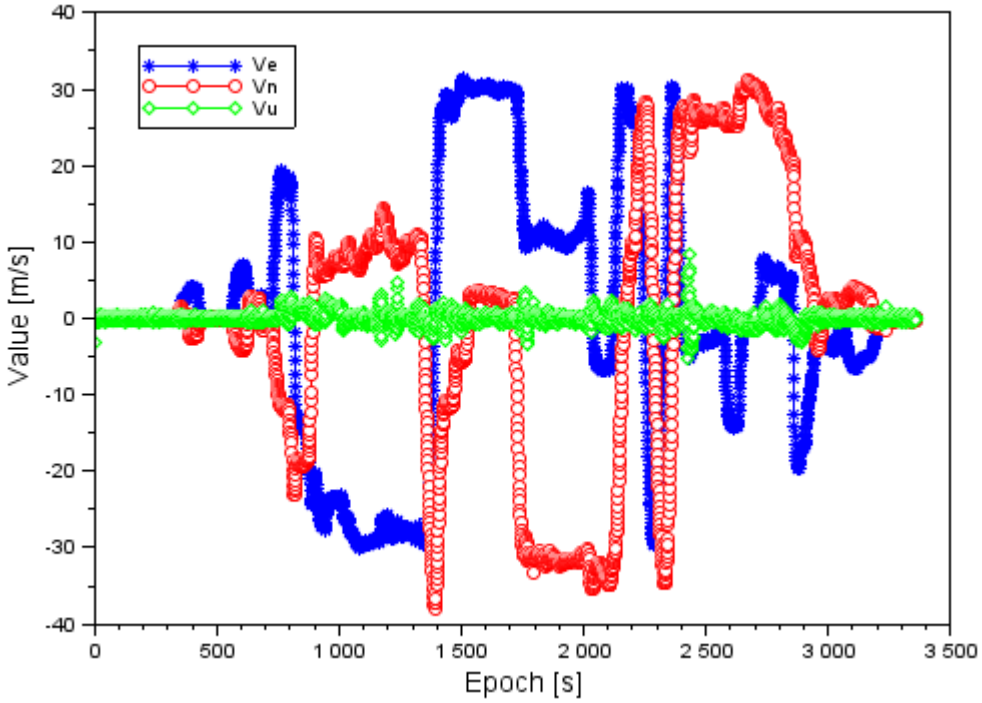

Fig. 2: The relative velocity of flight of Cessna 172 plane.

By identifying the velocity of the aircraft along each axis of the local ENU model, determination of the total velocity of flight of the Cessna 172 plane is possible, as below:

$$V_0 = \sqrt{V_E^2 + V_N^2 + V_U^2} \tag{7}$$

where V_0 - total velocity of aircraft.

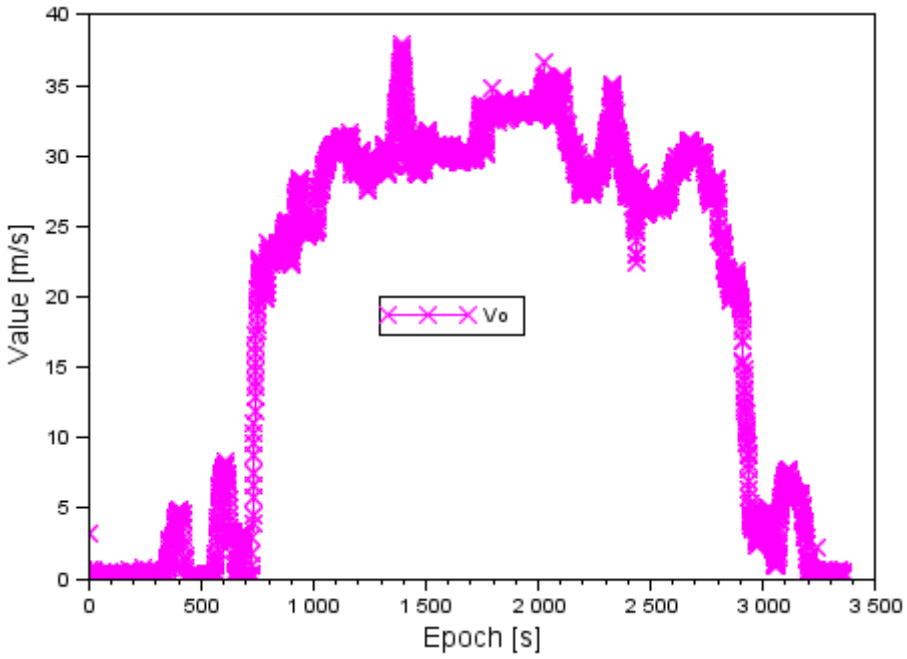

Fig. 3: The total velocity of flight of Cessna 172 plane.

Fig. 3 presents graph of the total velocity of the aircraft in the function of measured epoch. The average value of the velocity of an aircraft equals 19.57 m/s. It should be added that scattering of results for the parameter of the total movement speed of Cessna 172 plane equals between 0.02 m/s and 37.91 m/s. In addition median parameter for total velocity parameter equals 27.02 m/s. It is worthwhile to note that V_0 velocity parameter is less than 10 m/s for 34 % of obtained results and 72 % of results are less than 30 m/s, accordingly. In middle phase of flight, the total velocity can reach up to 38 m/s.

3. Conclusions

The practical application of the satellite GPS technique in the technology of aircraft, particularly in the aspect of the determination of position and velocity were presented in this article. In this paper, results of determination of coordinates the velocity in local frame ENU for the Cessna 172 aircraft were presented. The coordinates of the aircraft were expressed in the local frame ENU on the basis of the transformed method between geocentric, geodetic and local frame in GPS system. The nominal position of the aircraft was designated using GPS code observations for SPP positioning method in kinematic mode. Moreover the total velocity of motion of the Cessna 172 plane was also determined also in paper. The input data for research experiment was registered throught dual-frequency Topcon HiperPro receiver at during the flight experiment close to military aerodrome in Dęblin in Poland. The flight test was realized using Cessna 172 plane in day of 01.06.2010.

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