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GNSS TECHNOLOGY DETERMINATION OF FLYING MACHINE GUIDANCE PARAMETERS

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Abstract. *An algorithm of calculating the guidance parameters for GNSS aircraft landing technology was considered. The simulation and evaluation of calculation parameters error were performed as well.*

Keywords: flying machine; guidance parameters; guidance procedure; landing system; modeling; navigation system; trajectory.

1. Introduction

A global aero navigation plan in reference to CNS/ATM systems designates GNSS system as a key element of communication, navigation, surveillance systems and systems, which are connected with air traffic organization, as well as a basis the governments can improve the air navigation service. GNSS possesses the potential abilities to maintain all flight phases, providing continues global observation. It allows to exclude the need for plenty of ground-based and on-board systems, which were developed for special requirements at a definite flight stages. Nowadays precision approach procedures in accordance with first category together with corresponding GNSS equipment are authorized. The 2 and 3 categories requirements are being developing.

GNSS precision approach procedure is marked as GLS procedure approach. The GLS flight path is differently, not like by ILS. Data defining the flight path are transmitted onboard via digital data link as a data block FAS (final approach segment). Onboard equipment GNSS based on geometrical ratios calculates flight path parameters and designates homing characteristics similar to other approach systems, ILS for example.

Thus, it becomes evident that the further development and implementation of such systems are necessary to provide a higher level of safety.

2. Analysis of recent research and publications

Different working papers of International Civil Aviation Organization (ICAO) provide some guidelines and requirements relating to landing systems, including satellite landing system. However, it should be noted that in the literature, which is in the public domain, there is no data about algorithm for geometric calculation.

3. The goal of the article formulation

The task of this article is to develop a procedure for determining the parameters of guidance and to study precision characteristics of GLS information landing system without touching upon the problem of the integrity, continuity and operational readiness of service.

4. The main material

As a guidance parameters we can take values, which are defined during instrument landing using radio beacons (Agajanov et al. 1980). For lateral movement of the aircraft it is Z and ε_k - linear and angular deviation from the course beacon equisignal area (Fig. 1). For longitudinal movement of the aircraft it is H_k та ε_g - linear and angular deviation from the glide path (Fig. 2).

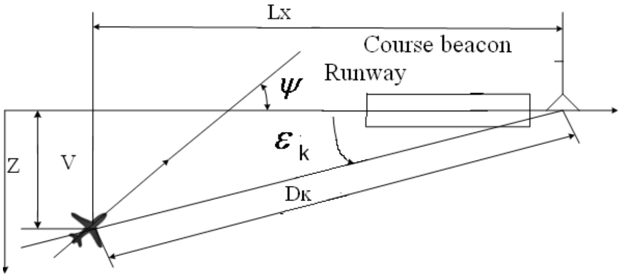

Figure. 1. Linear and angular deviation from the course beacon equisignal area:

D_k –a distance between the course beacon and projection of aircraft gravity center onto runway plane;

L_x – a distance between the intersection point of perpendicular from the aircraft center of gravity projection and runway axis to course beacon;

V – ground speed of the aircraft, projected to the runway plane;

ψ – yaw angle.

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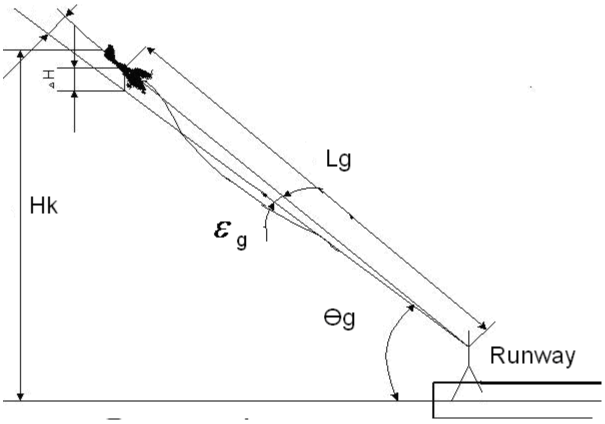

Figure. 2. Linear and angular deviation from the glide path:

θ_g – glide path angle;

H_k – a distance between projection of aircraft center of gravity to the vertical plane, which is held across the runway axis, and the horizontal plane;

L_g – a distance between projection of aircraft center of gravity to the vertical plane and glide beacon;

ΔH – excess of the projection of aircraft center of gravity to the vertical plane over the glide point in the vertical plane

From the GBAS (Ground Based Augmentation System) in the type 4 message data block FAS is transmitted onboard. To determine the trajectory of the final approach segment those data is transmitted (Fig. 3):

– Latitude θ_L, longitude λ_L and altitude h_L of landing threshold point L.

– The difference between the coordinates (latitude and longitude) of point F of the runway and the relevant parameters of the point L.

– Threshold crossing height while landing (TCH).

– Glide path angle (GPA).

– Course width KS.

– Offset Δ, which is the distance from the landing edge of the runway to point F.

Distance DL is also known.

Onboard GNSS equipment provides positioning in the PZ-90 and WGS-84 systems. It determines Cartesian coordinates TS (X_S, Y_S, Z_S) and spherical coordinates (θ_S, λ_S, h_S). Data from block FAS and onboard GNSS equipment allows to calculate the parameters for aircraft guidance using the algorithm, which block diagram is shown in Fig. 4.

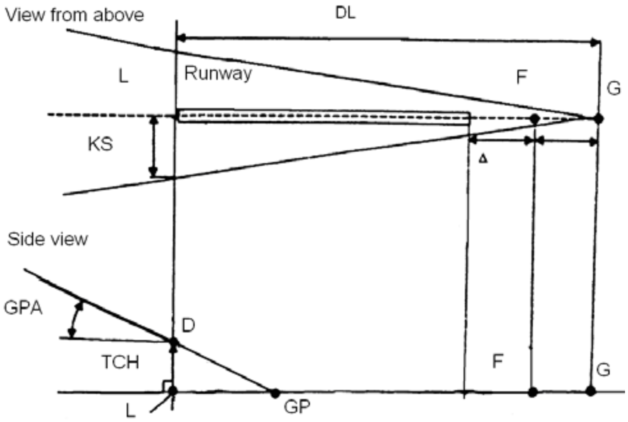

Figure. 3. The final approach step

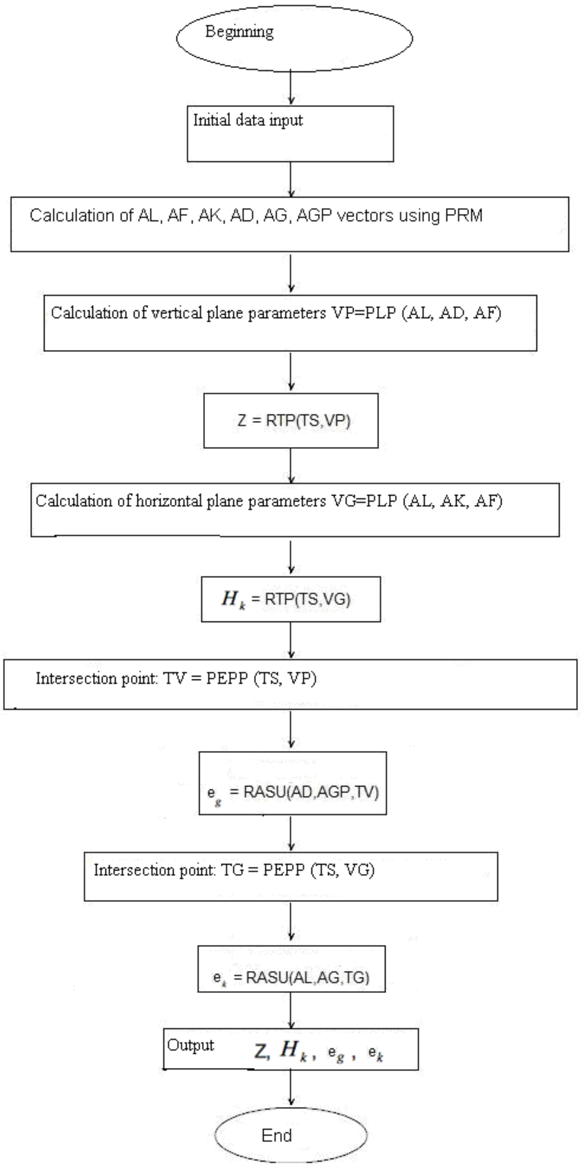

Figure. 4. Block diagram of the algorithm for calculating the guidance parameters.

The algorithm is implemented as a procedural features that are designed based on relations (SARPS):

– PRM – recalculation spherical coordinates to Cartesian;

– PLP – calculation of the general plane equation using coordinates of three points;

– RTP – calculation of the distance from point T and plane P;

– PEPP – calculation of the crossing point between the perpendicular, which is omitted from the point T, and plane P coordinates;

– RASU – calculation of the angle between two vectors in space.

The sequence of guidance parameters calculation is following:

– Using the procedure PRM we calculate coordinate vectors AL, AF, AK, AG, AD, AGP of points L, F, K, G, D, GP;

– Using vectors AL, AD, AF, the procedure PLP defines the parameters of the vertical plane equation;

– Using the vertical plane equation and the vector of aircraft coordinates TS, the procedure RTP determines the lateral deviation Z;

– Using coordinate vectors AL, AK. AF, we determine parameters of horizontal plane;

– Then we calculate deviation H_k from the horizontal plane;

– Then we define coordinates of the intersection point of the perpendicular from the point TS with the vertical plane using procedure PEPP;

– Using the procedure RASU we calculate lateral deviation ε_g;

– Then we define the coordinates of intersection point of the perpendicular from the point TS with the horizontal plane;

– Then we calculate lateral deviation ε_k;

– The next step is to output parameters Z, H_k, ε_g, ε_k.

A modeling was conducted for algorithm investigation.

Initial data of modeling:

Latitude θ_L = 50.4301972 deg;
Longitude λ_L = 30.42957516 deg;
Altitude of point L h_L = 200 m;
Course width KS = 140 m;
D = 3000 m;
GPA = 3 deg;
TCH= 50 m.

Coordinates of flying machine:
XS = XL -5000; YS = YL; ZS = ZL + 3000, where XL, YL, ZL – coordinates of point L;
Latitude $\theta_g = \theta_L$ – D/ 111110;
Longitude $\lambda_g = \lambda_L$;
Altitude $h_g = h_L$ of point G.
Latitude $\theta_{gp} = \theta_L$ – TCH/ (111110 *tg (GPA));
Longitude $\lambda_{gp} = \lambda_L$,
Altitude $h_{gp} = h_L$ of point GP.
Latitude $\theta_F = \theta_L$ – (D- 305)/111110;
Longitude $\lambda_F = \lambda_L$;
Altitude $h_F = h_L$ of point F.
Latitude $\theta_D = \theta_L$;
Longitude $\lambda_D = \lambda_L$;
Altitude $h_D = h_L$ + TCH of point D.

Simulations performed using MathCAD.

The meaning of modeling procedures was the following. For fixed values of aircraft coordinates were calculated values Z, H_k, ε_g, ε_k (using the program shown in Fig. 4).

In the series of realizations the random errors of coordinates calculations by onboard equipment were additively added to aircraft coordinates. The law of errors distribution – normal with parameters [0, sD].

There were calculated the guidance parameters for each realization and their deviations from the parameters, which were derived from faultless aircraft coordinates. When averaging over 1000 realizations were calculated mathematical expectations m Z, m H_k, m ε_g, m ε_k and rms values s Z, s H_k, s ε_g, s ε_k of the deviations. The results are shown in the Table. Units of measurement are meters and radians.

The data in Table shows that linear guidance parameters determination errors are directly proportional to the navigation determination errors. At the same time, navigation determination errors have almost no effect to the determination of angular parameters.

5. Conclusions

This research showed, that the proposed algorithm allows to calculate guidance parameters of the aircraft during approach and landing by GNSS technology. This model allows to determine the dependence of guidance parameters errors from the errors of coordinates calculation by onboard equipment.

Modeling results

sD	1	3	5	7	10
mZ	$< 10^{-2}$	$<10^{-2}$	-0,06	-0,08	- 0.1
m H_k	$< 10^{-2}$	0,04	- 0,03	- 0,05	- 0,17
m ε_g	$\sim 10^{-7}$	$\sim10^{-7}$	$\sim 10^{-6}$	$> 10^{-6}$	$> 10^{-6}$
m ε_k	$\sim10^{-7}$	10^{-6}	$\sim 10^{-6}$	$> 10^{-6}$	$> 10^{-6}$
sZ	1	3	5	7	~10
s H_k	1	3	5	7	~10
s ε_g	$\sim10^{-5}$	$\sim10^{-4}$	$>10^{-4}$	$>10^{-4}$	$>10^{-4}$
s ε_k	$\sim10^{-5}$	$\sim10^{-4}$	$>10^{-4}$	$>10^{-4}$	$>10^{-4}$

Simulation results showed, that differential mode of navigation definitions is necessary for categorized landing.

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Розглянуто алгоритм розрахунку параметрів наведення для посадки літального апарату за технологією GNSS. Проведено моделювання та оцінку похибок розрахунку параметрів.

Ключові слова: літальний апарат; моделювання; навігаційна система; параметри наведення; процедура наведення; система посадки; траєкторія.

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Рассмотрен алгоритм расчета параметров наведения для посадки летательного аппарата по технологии GNSS. Проведены моделирование и оценка погрешности вычисления параметров.

Ключевые слова: летательный аппарат; моделирование; навигационная система; параметры наведения; процедура наведения; система посадки; траектория.

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