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MOBILE MULTI-POSITION AIR-NAVIGATION-LANDING SYSTEM AND ITS PARAMETERS IN LANDING MODE

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Abstract

The structure of the navigation and landing system for light-weight aviation tasks, its operation principle, potential technical parameters, and the configuration of the airborne and ground-based equipment are proposed in the article. The operating modes of the system airborne equipment and its communication and interaction with standard aircraft instruments have been developed. Based on the tactics of using such system, the parameters of its frequency-code channels and the principles of its controlling are determined, which allow to identify the multi-position components of its ground-based equipment. The ways to improve system characteristics are proposed. An analysis of the aircraft location determination errors for a mobile two-position radio rangefinder ground-based inquiry-response system is carried out. The possibility of providing a categorized landing of light aircrafts in the signal field of such system is shown.

Keywords: navigation and landing system; aircraft; airborne radio rangefinder equipment; transponder beacons; retransmitter beacons; multi-positioning; regional airlines; landing approach; aircraft location

1. Introduction

There are landing fields, regional airlines aerodromes (RAL), aviation special purpose (ASP) and many aircrafts in our country, to solve their problems, it is not advisable to use existing stationary navigation and landing systems, such as ILS (Instrumental Landing System), MLS (Microwave Landing System), VOR/DME (Very High Frequency Omnidirection Range/Distance Measuring Equipment), as well as satellite navigation systems (SNS GPS and etc.). This is explain by the technical complexity and high cost in case of their installation on airdromes not equipped with standard landing equipment, as well as in territories not provided with the navigation field of the SNS.

Therefore, flights of the RAL aircraft are mainly carried out according to the rules of “visual driving” and are realized, in most cases, in areas with a low population density, above the terrain where difficult to maintain stationary ground equipment, on air routes with a low density of aircrafts flights, temporary landing fields or offshore platforms, for example, for agricultural or rescue operations, geological prospecting, oil production, etc.

At the same time, increasing flight efficiency requires implement in practice the navigation and landing system for the specifics operation conditions and the tasks of “small aviation”.

The ability of implementing such system is to expand the capabilities of the existing DME/N [1] and DME/P [2, 3] navigation rangefinder systems, as reliable means of near navigation and landing. This statement is based on the fact that there is a generation of precision DME/P rangefinders [4], in which the range of operating modes is expanded, the accuracy of range measurement is significantly increased, and connection with computing devices is simplified. The second fundamental factor is the further improvement of the characteristics of airborne computing devices, such as operation speed, memory size, weight and size characteristics and cost.

2. Analysis of research and publications

Current trends in the development of navigation and landing systems imply further compatibility of characteristics and maximum hardware, software and mathematical unification of airborne (AE) and ground equipment (GE) with existing, regulated by the International Civil Aviation Organization (ICAO), stationary systems of similar purpose serving the main-line aircraft, i.e. solving different types of problems with one configuration of equipment.

So, there are already prerequisites for solving the problems of navigation, landing and air traffic control by one complex of domestic equipment based on the modified DME/P equipment [3, 5-9]. Therefore, studies of ways to create a multifunctional navigation and landing system based on signal-forming and radio equipment, regulated by ICAO, principles of DME, for various modes of air navigation services for light aircraft and the tasks of RAL, ASP, etc. are important and actual.

3. Aim of the work

To continue the studies of earlier works [4, 6, 10, 11] and others, let's consider the justifications for the possibility of developing a mobile (portable) multi-position radio rangefinder inquiry-response system for providing navigation, approach and landing of light-engine aircrafts (MPLS).

The proposed MPLS consists of AE and GE [4], for the basis of the exchange of inquiry-response information between equipment standard signals are adopted, standardized by ICAO, the DME system [2]. This allows using AE and GE, as during the landing operations of aircraft in MPLS, and independently, including [12] – extended volumes of air navigation maintenance of VOR/DME systems.

4. Mobile multi-position radio rangefinder navigation-landing system MPLS and its application

The principle of operation of the MPLS in the landing mode is to measure on board the slant distances $D_{1,2,3}$ between the aircraft and each small-sized (portable) radio beacon (TP transponder and $RP_{1,2}$ retransmitters) with their known location on the ground, relative to runway (RW), and the subsequent calculation of aircraft location (AL) on its board, Fig. 1. Information is issued to the pilot in the analog form required for manual control of the aircraft, and/or digital for further processing in automatic control devices for flight modes [5].

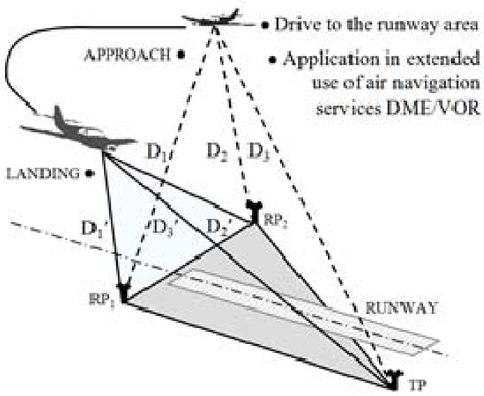

Fig. 1. The principle of MPLS operation

Parameters characterizing MPLS:

- the coverage area in the drive mode of the aircraft to the runway (at altitudes up to 6000 m) is 75 km in range and 360 degrees in azimuth, in flight (at altitudes above 6000 m) – 240 km (in accordance with ICAO documents, – DO 189);
- the accuracy of determining the AL in landing mode, in the standard sector, is sufficient for its implementation in category 1 (in accordance with ICAO documents – RNP (Required Navigation Performance) 0.02/40) [6, 10, 11];
- traffic capacity – up to 10 aircrafts;
- mass of AE – 2.5 kg, beacon-transponder and repeater (without antennas) – 3 kg and 2 kg;
- deployment time of the respondent beacon by 2 people – 30 minutes;
- the power supply of the responder beacon (repeater) is autonomous (or from the electrical supply network), power consumption is 30 W;
- the configuration of the AE MPLS include [5, 13], Fig. 2;
- aircraft standard equipment – a radio rangefinder DME/P (or a modified DME/PN), an airplane range indicator (RAI), an airplane azimuth indicator (AAI), a plank navigation device (PND), a bar altimeter BA (a radio altimeter RA);
- special equipment – control rack (RC), computing device (CD), paired device (PD).

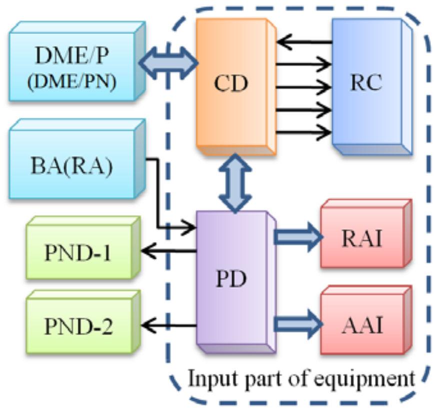

Fig. 2. Scheme electrical structural MPLS airborne equipment

In Fig. 2, the dashed line encircles the newly introduced, in addition to the standard, part of the MPLS AE [4, 13]. Range measurement and calculation of coordinate information are carried out in a CD connected to the control connector of the DME/P airborne unit [3] (with its software tuning to the frequency and time codes of the "leading" beacon and retransmitter beacons). Information about each measured range is output to the airborne computer with a 32-bit serial bipolar code. The operation of the CD is controlled by RC, and the displayed output information representing the coordinates of the aircraft is displayed on the word indicators.

5. Operating modes of the modified DME/PN radio rangefinder, its communication and interaction with standard airborne components of the MPLS

Operating modes:

(a). No radio link with DME transponder – redundancy mode. At the same time, "dashes" are displayed on the digital indicator board;

(b). Search for a synchronous transponder response. Indicated by "dashes" (no calculated data);

(c). Capture and tracking (measurement mode – data is ready).The board displays data of range, speed or time (on call);

(d). Control. On the board there is a sequential change of readings in accordance with the algorithm of the built-in control system BCS;

(e). Failure of the rangefinder. Indicated by a sharp decrease in the brightness of the digital display.

Information consumers on the range of DME/PN rangefinders correspond to RTM 1495-75 with a change 3. The speed of information output is 12...14.5 kHz. The address of the 32-bit data word of the rangefinder range 201_8 (BDC) or 202_8 (BC).

DME/PN interacts with the PB-85B radio altimeter. Altitude data in meters (word 224_8) is received in a serial code according to RTM 1495-75 with a change 3. If necessary, the problem of receiving altitude data in analog form by way of the relative resistance of the potentiometric output can be worked out.

Communication with the standard instrument of RAL aircraft PNP-72-2M (PNP-72-3M) is carried out in analogue form, in accordance with the instrument operating instructions OI ("sin/cos").

6. Identification of responder beacons and landing sites in the frequency range of the MPLS operation

According to the ICAO documents, 252 frequency-code channels (FCCh) in the frequency range 962÷1213 MHz with a step between the frequencies of adjacent channels of 1 MHz are allocated for the DME rangefinder system [1, 2]. Since the MPLS system must be compatible with the standard DME system, their FCChs must also match.

The tactics of the MPLS system usage allows us to make a number of simplifying assumptions regarding to the frequency mode of its operation:

1. Each responder beacon must operate on its own fixed FCCh. Frequency tuning or changing the time code of the responder beacon is not required.

2. The number of FCChs may be small (see Table). Their number should be determined by the necessity to recognize next aerodromes (landing fields), equipped with MPLS systems and located in their operation area.

3. Since the frequency range remains the same as approved by ICAO, the system frequency mode agreement with the State Committee for Radio Frequency SCRF is not required.

Table

Frequency code channels

Channel number		Frequency inquiry, MHz	Frequency response, MHz
MPLS	DME		
1	87	1111	1048
2	90	1114	1051
3	93	1117	1054
4	96	1120	1057
5	99	1123	1060
6	102	1126	1063
7	105	1129	1066
8	108	1132	1069
9	111	1135	1072

Based on these assumptions, as well as on the fact that it is sufficient to ensure recognition of three next landing fields of the RAL and the presence of three beacon transponders on each of them, it is advisable to use for MPLS, for example, the following 9 FCChs (see table.). In this case, the code interval between pulses in the inquiry mode on each of the FCChs is 36 μs, in the response mode – 30 μs.

As can be seen from the table, all the FCChs of the MPLS system [5] correspond to the table FCChs of the DME system [1, 2]. But the frequency spacing between next frequency channels of the MPLS is not 1, but at least 3 MHz, which makes it possible to reduce the noise immunity requirements of the receiving and transmitting devices of the transponder beacon.

A frequency spacing of 3 MHz also opens up a way to reduce the requirements on the spectrum shape of the pulse signal of the transponder beacon. Such signal currently used in the DME system. Therefore, it is way to increase the accuracy of fixing the time of the response signal arrival by increasing the steepness of its rising edge.

The last statement is explained by the fact that the envelope of the DME signal has an established shape of the $\cos^2$ type [2], which is caused, first of all, by the requirement of noise immunity of the DME system to the detriment, to some extent, of the steepness of the leading edge of the pulse, i.e. system accuracy.

The arrangement of next FCChs at 3 MHz can improve the noise immunity of the MPLS system and opens the way to increasing the accuracy of fixing the time of the response signal arrival of the beacon by using signals with the highest steepness of the leading edge of their envelope. The choice of a new form of response signals (quasi-complex signals with a rectangular envelope and biassymmetric spectrum located inside the DME frequency grid) was considered in [14]. They have, at equal duration and width of the spectrum with bell-shaped pulses, a significantly higher frequency resolution (due to the higher steepness of the spectrum from the "forbidden" side, to ensure electromagnetic compatibility, frequency band) and time (due to absolutely steep leading front), and hence the accuracy of determining the distance between the aircraft and the transponder beacon.

In this case the inquiry signals are standard, monofrequency with a bell-shaped envelope, radio pulses of airborne DME/P rangefinders, the beginning of such signal radiation is easily fixed with high precision in radio electronic circuits.

7. Control of MPLS FCChs choice

The FCCh of the airborne rangefinder DME/PN [1,2] of the MPLS system [5, 10] is set from the control and display panel CDP (RC) (Fig. 2). The display shows the DME/PN operating channel in the VOR frequencies paired with DME frequencies as recommended by ICAO.

Control of the FCChs combinations choice is made with RC of airborne equipment MPLS. The crew determines the program number of the FCChs installation in accordance with the flight mission. To do this, the RC provides a switch to 9 positions. Specific FCChs are recorded in the ROM CD with reference to the program number. In accordance with the FCChs installation program number, the CD generates control words on the DME/PN block with data about the block tuning frequency. The DME/PN unit is configured to operate with each beacon, and when a response signal is received, it outputs a digital "word" at its output with the corresponding measured distance to the beacon.

8. Detection of beacon transponders

Detection of a specific landing field can be done by a FCChs combination of three (four) transponder beacons. Of the nine FCChs of the MPLS system operation, at least three groups of completely independent frequencies can be distinguished. Therefore, three next landing fields can completely differ in the radiation frequency of the transponder beacons. Thus, frequencies combination is at the same time the "key" to detect a given landing field. In total, combinations of frequencies from 9 to 3 will be much larger.

If no response signals are received on the aircraft board when the system has a operating airborne and ground equipment, it means that the FCChs combination of ground beacons does not match the setting one for this aircraft, i.e. recognition did not happen.

9. Methodology for the systematic error estimation of the aircraft position determination during its landing approach in the MPLS

For a two-position mobile (minimum configuration of the MPLS [6]) rangefinder trajectory control system, we consider the errors of determining the AL when aircraft perform a landing approach according to the scheme characteristic for RAL [15] and presented in Fig. 3, where: MR_V, MR_h are aircraft maneuvering routes, respectively, in the vertical and horizontal planes; FDB, NDB – the far and near drive radio beacons, respectively; GPEP – the exit point of the aircraft on an inclined glide path; H_{gpe} – aircraft height at exit point to an inclined glide path; GPA – glide path angle; S is the distance of the components of the GE from the RW butt face.

This configuration is not mandatory; it is determined by the specific conditions for the placement of the GE components at the aerodromes of the RAL (terrain conditions, accessibility, electricity supply, etc.).

In this option, the characteristic of each individual configuration is set by the "a" value, which determines the distance from one of the GE components (for example, transponder – TP) to the axis RW. Distancing the first component of GE and another component of the GE (repeater – RP) – d_{01} from RW is not critical, although it is desirable that their arrangement be symmetrical.

The error analysis of the aircraft MPLS was carried out using the example of the AN-24 aircraft approaching at a speed of less than 300 km/h along a small rectangular route with the width of the pre-landing maneuvering zone, WPM = 7 km.

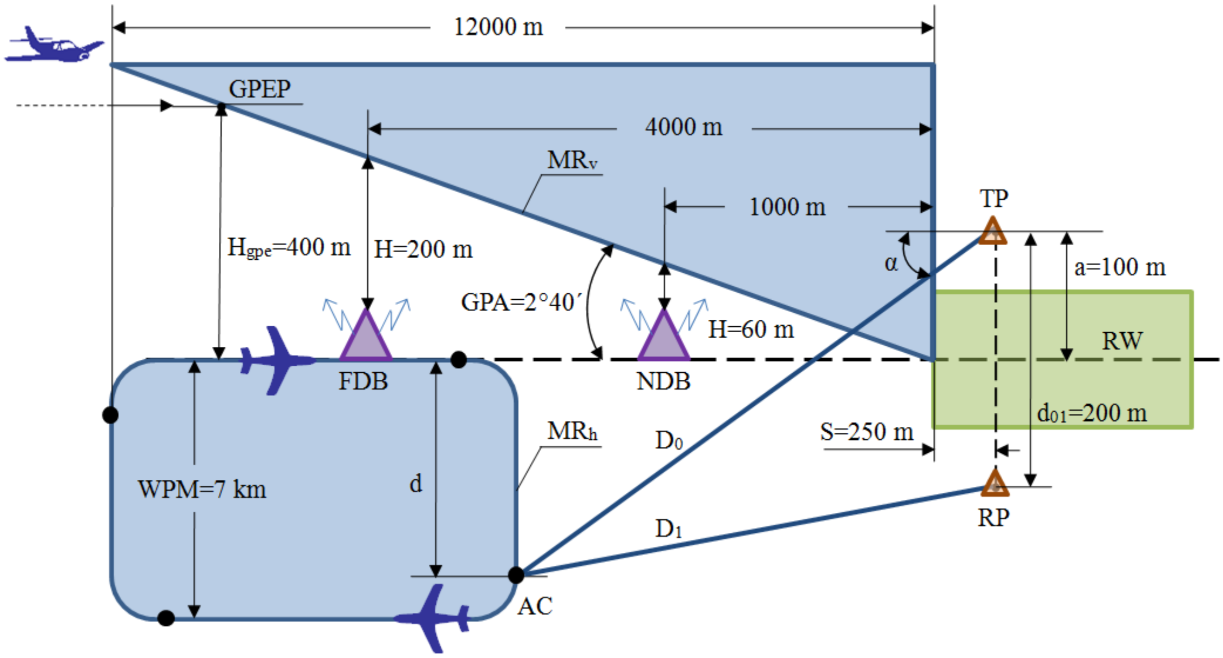

Fig. 3. The basic geometric correlation between the placement of beacons and runway to the estimation of errors in determining AL during its pre-landing maneuvering

To generate glide path control signals, data from the airborne barometric or radio altimeter are used [6].

The initial data for an example of aircraft landing are taken from [15]. Errors of determination the of the aircraft position are calculated at the points of turning. On the pre-landing straight line, the errors of deviations from the course and glide path lines are determined.

The obtained results can easily be generalized to the case of landing approach with a straight line and landing with WPM = 12 km.

When calculating the errors, it was assumed that the pre-landing maneuvers of the aircraft are carried out with a corresponding decrease in the flight height H, so that at any time interval the values of the inclined ranges (D_0, D_1), measured by the rangefinder, can be taken as horizontal ranges.

In a "planar" triangle the transponder-repeater-aircraft angle α can be determined from the expression:

$$\sin\alpha = \frac{(D_0^2 + d_{01}^2 - D_1^2)}{2d_{01}\cdot D_0}.$$

Putting $D_1 – D_0 = \Delta D$ and transforming, we have:

$$\sin\alpha = -\frac{\Delta D}{d_{01}}\left(1 + \frac{\Delta D}{2D_0}\right) + \frac{d_{01}}{2D_0}.$$

For aircraft deviation d from the center line of the runway, you can get:

$$d = -a + \frac{d_{01}}{2} - \frac{D_0\cdot\Delta D}{d_{01}} - \frac{(\Delta D)^2}{2d_{01}}.$$

With a symmetrical arrangement of the transponder and repeater relative to the runway:

$$a = \frac{d_{01}}{2} \text{ and } d = \frac{2D_0 + \Delta D}{2d_{01}}\cdot\Delta D,$$

where the deviation in the direction of the execution of turns is assigned a positive sign of the d value.

The error δ of the deviation d calculation can be defined as:

$$\delta_d = \frac{\delta(\Delta D)\cdot[\Delta D + D_0] + \delta(D_0)\cdot\Delta D}{d_{01}}.$$

When the line of the preset flight (LPF) coincides with the center line of the runway (flight on the pre-landing straight line), value ΔD is maintained equal to zero:

$$\delta_d = \frac{D_0}{d_{01}}\cdot\delta(\Delta D).$$

The system total error is determined by the measurement errors in AE, GE and the system errors.

10. Radio-technical components of the error of the AL determination in the MPLS

The main sources of measurement errors in the AE MPLS, operating with the DME signal format, both in the inquiry (airborne units DME/P, DME/N) and in the response (transponders, repeaters) modes, are [1-3, 13, 16, 17]:

- receiver (R) noises, distorting the leading edge of the bell-shaped envelope of the response pulses, causes a "vibration" in the time moment of pulses fixation [2, 13, 16];
- measurement resolution, determined by the frequency of the measuring quartz for DME/P [3] 20.7 MHz;
- inaccuracy of fixing the time position of the response pulses DME. Such accuracy is determined on the basis of the "0.5A" binding scheme (i.e., fixing at the level of 0.5 of the response radio pulse amplitude): distortion of the HF pulses envelope in the R during detection; the accuracy of determining the amplitude A; accuracy of the divider 1:2, providing a threshold of 0.5A. In the most unfavorable case, these components are summed up arithmetically;
- the delay instability in the R paths – operational: radio elements aging, fluctuations in the environment temperature, humidity, etc. It is determined, mainly, by the following reasons: the bandwidth goes away for all destabilizing factors; the instability of the response signals frequency and the heterodyne of the rangefinder transmitter;
- the pulses distortion in the receiver of the rangefinder (the leading edge cut of the response signal pulses) leads to an error due to the mismatch of the time 0.5A of the envelope of the HF pulses and 0.5A of the video pulse from the R output;
- "dead" time of the transponder. The measurement error, due to this cause the error, arises due to the arrival of nonsynchronous and chaotic response pulses in the tracking strobe of the measurement unit;
- the quartz instability in the range measuring unit is quite small ($<5\cdot10^{-6}$), so that the corresponding error component can be neglected.

GE MPLS contains receiving devices similar to AE, therefore their measurement errors can be taken equal.

Taking into account the accuracy characteristics of AE experimentally determined on prototype samples [4], we take for further calculations $\delta(D_0) = \pm 85$ m [3, 4]; for a system with DME/P pulses (its most unfavorable case), where D_0 is the range from aircraft to the GE MPLS.

The error $\delta(\Delta D)$ of the difference between two measurements D_1 and D_0 in the system [6] is very small, because the radiation time t_2 of the repeater signal is tightly connected with the radiation time t_1 of the transponder signal by a constant relation ($t_2 - t_1 = \text{const}$) using a special stabilization scheme. Herewith, the time t_2 does not depend on the distance tolerances between the GE components d_{01} and the oscillations of the signals delay in the repeater path. Besides that, when measuring a range difference ΔD by the range finder, constant measurement components are mutually subtracted. Based on the studies conducted in [6, 7], we accept $\delta(\Delta D) = \pm 3$ m.

11. Assessment of the system error of aircraft positioning during its approach on landing in the MPLS

Pre-landing maneuvering is performed according to the planks and the distance indicator D_0. The first turn begins 10 s after span of the FDB [15]. The turning start point can be determined by the distance D_0 with the error of the range indicator of the on-board device PND ($\delta_{d1} = \pm 0.5$ km for PND-72-1).

Beginning of the second turn can be defined as a point, remote from the runway axis by a distance d, equal to 4300 m ($D_0 \approx 4500$ m). Then the error of d determining is: $\delta_{d2} \le \pm 156$ m.

Airplane driving between the second and third turns is possible as a zero-driving by a course planks. Beginning of the third turn is determined in accordance with [15]:

$$D_0 = \sqrt{7000^2 + 9800^2} \approx 12000 \text{ m}.$$

When $d = \text{const} = 7000$ m, this algorithm can be implemented:

$$\Delta D = \sqrt{D_0^2 - 2 \cdot d_{01} \cdot d} - D_0 .$$

In this case maximum error of d determining ($D_0 \approx 12000$ m) is: $\delta_{d3} \approx \pm 230$ m.

Fourth turn begins at $d = 1800$ m (error $\delta_{d4} = \pm 180$ m).

Flight along the pre-landing straight line is carried out as zero-driving with an error δ_{d5}, linearly decreasing from ±180 m to ±15 m above the NDB.

With the expansion of the base between the MPLS GE components (d_{01}>200 m), the values of the d definition system error (δ) – are decreasing (Fig. 4).

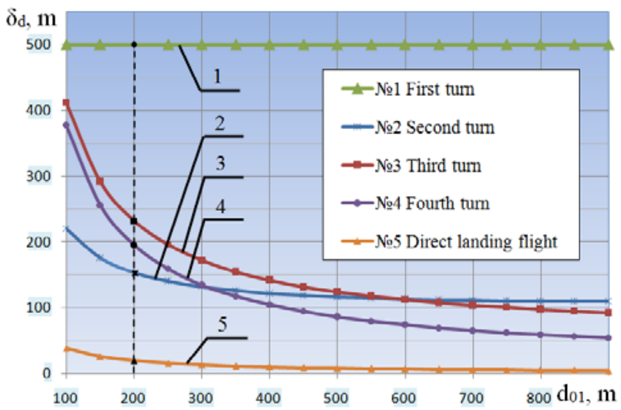

Fig. 4. Dependency graph of the error determining, by the MPLS system, the aircraft deviation from the center line of the runway at turns and on the aircraft direct flight trajectory δ_d versus the distance between its GE components d_{01}

The control of the aircraft trajectory in the vertical plane (of glide path) is also carried out as zero-driving by the planks of the PND device. Altitude data H is entered into the on-board rangefinder calculator from a radio altimeter (RA). The characteristic of the glide path GPA is entered from the on-board rangefinder control rack [6].

Calculated difference Δ_H of the heights, measured by the RA and calculated by the on-board DME rangefinder is: $\Delta_H = D_0 \cdot \sin(GPA) - H$.

From here, if we take the error $\delta_н$ of small heights RA ±6 % [1], the error $\delta(\Delta_H)$ of zero-driving along the glide path will be:

$$\delta(\Delta_H) = [\delta(D_0) + 0.06 \cdot D_0] \cdot \sin(GPA),$$

and it will be equal, at the point $H = 60$ m (for landing conditions in category I ICAO) with $GPA = 2.4$ degrees, $\delta(\Delta_H) = \pm 7.2$ m.

12. Conclusions

Early attempts of supporting the tasks of the RAL, came down to various variants of possible hardware AE and GE implementation. However, systemically, for the functions implementation of aircraft driving to the aerodrome zone, pre-landing maneuvering, approach and landing in automatic, semi-automatic and manual “devices driving”, the problem was not posed and was not solved.

The capabilities of rangefinding equipment, together with modern computing devices, have determined the prospect of creating a cheap and mobile system (MPLS) for the specified tasks. The ground equipment of such system should be small-sized, relatively inexpensive and operable in conditions of significant HF signals re-reflections. A fundamentally new element of the MPLS system is a repeater of the DME/P transponder signals. With regard to on-board equipment, all tasks are solved in the DME/P unit, which requires its minor modification. The construction of the control rack and indicators is determined by the light aircraft type. For the system operation, it was proposed to use a significantly smaller number of frequency channels (table) – nine fixed frequencies from among of standard DME frequencies with a difference of 3 MHz between them, which will lead to signals mutual influence decrease. It will be more effective, for the MPLS, to use, as the beacon and repeaters response signals, simple (monofrequency) signals with rectangular envelopes (but not with the standard DME bell-shaped envelope). This is explained by the fact, that the time interval between the AE emitted signal and the received one from the GE (therefore and the distance D, Fig. 1), is most clearly fixed by the front edge of such response radio pulses. Such measure can significantly increase the accuracy of the MPLS [14] range-measuring channel, in comparison with the standard DME channel accuracy. If the out-of-band emission level is found to be unacceptable with these measures, then it is possible to use a quasi-complex (frequency-modulated) [14] signals with a rectangular envelope and biasymmetrical (or single-band) spectrums, located inside the DME frequencies grid, as response GE radio pulses.

The flexibility of the MPLS information channels allows us to build a system configuration in various variants, taking into account a consumer requirements. In this case, it was shown, that a two-positional (multi-positional minimal configuration) radio-technical range-finding navigation and landing system allows for various [6, 10], including the typical pre-landing maneuvering configurations considered in the article, to implement the aircraft drive into the runway zone based on the range-finding measurements. Also, described system construction allows simultaneously servicing aircrafts, equipped with various (both new and old) modifications of DME equipment. Obtained results of maximum errors in determining, by the MPLS system, the aircraft deviation from the runway center line at the turns and on the direct aircraft flight trajectory, are conform to the aircraft navigation requirements and applicable to the aircraft driving conditions in the director (manual by devices) mode, and can also serve as initial data for control systems under automatical and semi-automatical aircraft flight modes. Optimization of spatio-temporal dimensions between ground-based system components (Fig. 4), is necessary both for achieve maximum effect by technical characteristics, and during equipment exploitation.

Generalizing the aforesaid, and also taking into account positive flight tests results of system, such as MPLS [18] type, it can be argued, that the installation of such systems on the RAL (ASP) aerodromes, instead of existing radio-technical systems RLS (radar landing system), BLE (blind landing equipment) and SDRS (separate drive radio station), will allow significantly reduce landing minimums for 3 and 4 classes aircrafts to the "60×800" and "80×1000" values [19]. This will become an important factor, influencing the increase in safety and regularity of flights on the RAL.

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Мобільна багатопозиційна аєронавігаційно-посадкова система та її параметри у режимі заходу на посадку

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У статті запропонована структура навігаційно-посадкової системи для задач легкомоторної авіації, її принцип функціонування, потенційні технічні параметри, склад бортової та наземної апаратури. Розроблені режими роботи бортового обладнання системи та його зв’язки і взаємодія зі стандартними приладами повітряних суден. На підставі тактики використання такої системи, визначені параметри її частотно-кодових каналів та принципи управління ними, що дозволяють ідентифікувати багатопозиційні компоненти її наземного обладнання. Позначені шляхи покращення характеристик системи. Проведено аналіз похибки визначення місцеположення повітряних суден для мобільної двухпозиційної радіодалекомірної запитно-відповідної системи наземного базування. Показана можливість забезпечення категорованої посадки легких літальних апаратів у полі сигналів такої системи.

Ключові слова: навігаційно-посадкова система; літальний апарат; бортове радіодалекомірне обладнання; маяки прийомо-відповідачі; ретранслятори; багатопозиційність; місцеві повітряні авіалінії; захід на посадку; місцеположення повітряного судна

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Мобильная многопозиционная аэронавигационно-посадочная система и ее параметры в режиме захода на посадку

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В статье предложена структура навигационно-посадочной системы для задач легкомоторной авиации, ее принцип функционирования, потенциальные технические параметры, состав бортовой и наземной аппаратуры. Разработаны режимы работы бортового оборудования системы и его связи и взаимодействие со стандартными приборами воздушных судов. На основании тактики использования такой системы, определены параметры ее частотно-кодовых каналов и принципы управления ими, позволяющие идентифицировать многопозиционные компоненты ее наземного оборудования. Обозначены пути улучшения характеристик системы. Проведен анализ погрешностей определения местоположения воздушных судов для мобильной двухпозиционной радиодальномерной запросно-ответной системы наземного базирования. Показана возможность обеспечения категорированной посадки легких летательных аппаратов в поле сигналов такой системы.

Ключевые слова: навигационно-посадочная система; летательный аппарат; бортовое радиодальномерное оборудование; маяки приемо-ответчики; ретрансляторы; многопозиционность; местные воздушные авиалинии; заход на посадку; местоположение воздушного судна

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