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Concept of monitoring complex of radio signal environment in the airdrome area

The concept of design of radio signal environment monitoring complex in the airdrome area is presented, which can ensure safety of landing using global navigation satellite system services. The structural scheme of the proposed complex and possible ways of performed tasks implementation are considered in a paper as well.

Introduction. The global navigation satellite system (GNSS) Landing System (GLS) implementation requires special attention to monitoring its characteristics. During GLS functioning there may arise anomalies in navigation equipment that cause a malfunction in the normal system functioning. The following factors may cause mentioned anomalies: the failure of navigation satellites or not enough quantity of visible ones to solve the navigation task onboard, poor geometry of navigation satellites, and radio interferences to GNSS signals in the GLS service area. Therefore, the question of creating a monitoring complex for the radio signal environment in the airport area is very relevant.

A number of works on monitoring of the interference environment and radio navigation field are known [1, 2, 3, 4], and conceptual approaches to monitoring the state of GNSS radio navigation fields has been considered in [5]. However, in these studies not enough attention is paid to the construction of monitoring reference points in the aerodrome area.

In this paper we consider the concept of constructing a complex for monitoring the radio signal environment in the aerodrome area, both from the point of view of the interference actions influence and the state of the radio navigation field on the provision of GLS service.

Concept of monitoring complex design. When developing the radio signal environment monitoring a complex in the aerodrome area, we assume it should perform the following task:

- detection of radio interference sources;
- initial definition of radio signals arrival directions;
- primary definition of frequencies and signal levels;
- signals identification;
- measurement of each identified narrow-band signal power and frequency band of noise-like interference;
- source direction determination for each identified signal;
- coordinates determination the of radiation sources;
- recalculation of energy indicators of interference signals relative to the aircraft approach and landing trajectories;
- estimation of radio navigational field availability at current moment of time;

- assessment of possibility of aircraft landing using GLS service at a given moment of time and prediction for the subsequent period.

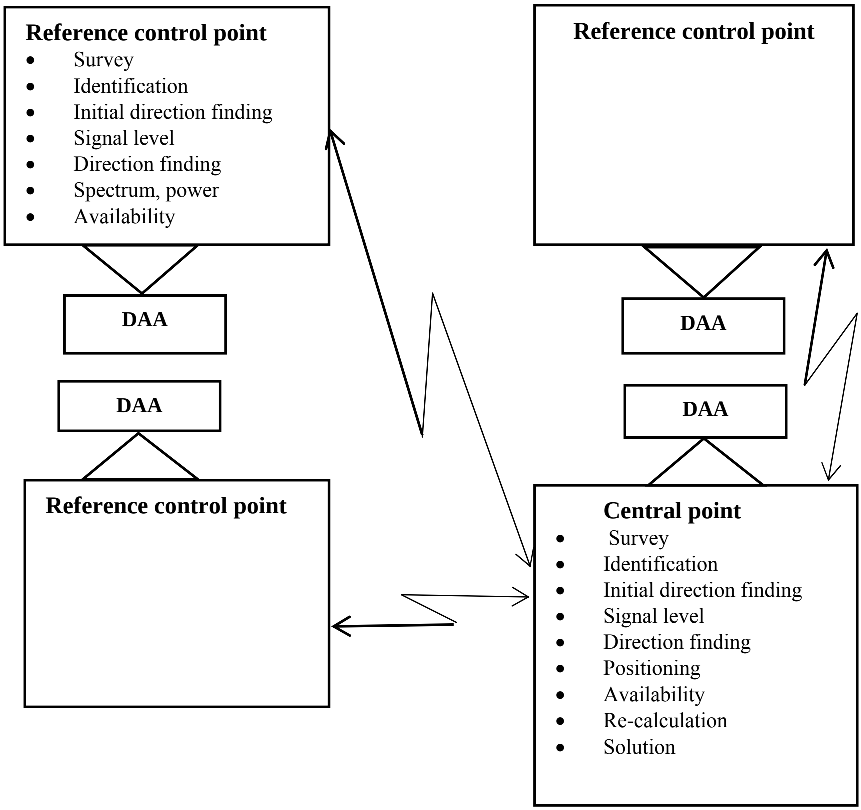

Fig.1. Generalized structural scheme of the complex

To implement these tasks, it is rational to use multi-position radio engineering systems, which allow more complete coverage of radio signals in the whole area around the airport runways, with appropriate location of positions, as compared with single-position ones using spatial coherence of radio signals. The second aspect of multiposition is the solution of the problem of determining the interference sources coordinates. One of the effective approaches implemented in such radio systems is usage of digital antenna arrays (DAAs) instead of single antennas, which has a number of advantages [6]. In our case, this is the possibility of targeting partial rays to individual interference sources or their spatially-focused groups and high flexibility in applying various signal processing techniques without loss of signal-to-noise ratio. The enlarged structural scheme of the complex is shown in Fig. 1.

The complex includes four spaced points, 3 of which are supporting the fourth central. It is possible to build a complex when the points are mobile. In any case, the coordinates of reference point are defined with high accuracy. Each item contains a DAA, a navigation receiver and digital radio communication facilities for exchanging data between points.

All 4 items simultaneously perform:

- detection of sources of radio emission;
- initial definition of directions of arrival of radio signals;
- primary definition of frequencies and signal levels;
- monitoring the coefficient of the geometry of the relative location of the navigation satellites and the point.

The work of reference points is synchronized in time with the central point. The central point uses the aggregated information from all points to identify signals and then send corresponding information back to those points. Using the spectro-analyzer, the power of each identified narrow-band signal or noise-like interference frequency band is measured at the corresponding point. Based on the measurement results of the spectrum analyzer, the central point issues a command to the reference points for determining the direction of those interference sources. On the basis of the obtained data from all the points at the central point, the coordinates of the interference sources are determined and the power levels are recalculated to the points of the flight path of the aircraft during landing. Taking into account the recalculated powers of the interference signals and the geometry of the relative location of the navigation satellites and the central point, the tasks of the availability of the radio navigational field at the current time for the selected points of the landing path are solved.

This allows us:

- to make a decision regarding the possibility of landing relying on GLS technology at a given moment of time;
- accumulate data for forecasting the possibility of landing using GLS technology for a subsequent period.

Special attention should be paid to the location of the reference control points of the monitoring complex, their location in the area of the aerodrome should not interfere with the procedure of aircraft landing. The antennas of navigation receivers of ground control points should receive all signals transmitted by the navigation satellites. The review of space is carried out due to the formation of partial rays of the DAA using a discrete Fourier transform. The detection can be carried out by the Neumann-Pearson criterion, taking into account the peculiarity of the approach to the choice of the probability of a false alarm value. After the signal is detected in space, the initial value of the direction of its arrival is determined to within half the width of the radiation pattern at the level of 0.7. This determines the size of the aperture of the DAA.

The analysis of the signal spectrum does not cause difficulties. It is not a trivial task to identify the signals detected by different reference control points. Aspects of its solution are considered, in particular, in [7, 8, 9]. In the first approximation, it can be carried out according to the frequency, level and initial values of the direction of arrival of the signal with subsequent refinement with more accurate direction finding.

Numerous methods of direction finding are known [10, 11]. The most promising one considering the DAA use is the correlation-interferometric method [12]. The measured phase differences between the DAA elements are correlated with the reference sets of phase differences on the same elements. The angles of arrival of the signal are determined by the maximum of the correlation relation. This method is proposed to be improved by using preliminary direction finding to build a set of reference sets of phase differences.

The main methods of passive location finding are the triangulation method and the difference-ranging method (DRM). DRM is the most known and applied method of determining the location of interference sources. It has high accuracy due to a small error in determining the input parameters - time delays [13]. Therefore, to determine the coordinates of the interference source, it is assumed that the DRM is used.

Aspects of monitoring the radio navigational field, in particular, its availability are considered in [14,15]. In a more narrow problem formulation, it is proposed to control the geometric factor when receiving signals by navigation receivers of the control reference points with a given time interval.

Conclusions. The proposed structure and principles represent a generalized concept for constructing a monitoring complex of both interference and radionavigation environment in the airodrome area to provide GLS services. The following task should be addressed in more detailed for successful mission of radio signal environment monitoring in the airdrome area:

- determination of complex components location in the airdrome area, taking into account the possibility of some elements relocation;
- the required degree of automation of the complex and control system for monitoring tasks;
- regulatory and legal framework for the monitoring complex implementation.

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