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Information Processing Algorithms in Aviation-Based Radioelectronic Surveillance Systems

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Abstract: **This article is dedicated to development of algorithms on information processing in aviation-based radioelectronic surveillance systems, aimed to solve problems of detection, location and identification of radiosignal-emitting sources.**

Key words: **radioelectronic surveillance system, the algorithm of information processing, detection, location, identification, radiosignal-emitting source**

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Contents

1. INTRODUCTION

Aviation-based radioelectronic surveillance systems (AB RESS), being passive systems, efficiently in a large spatial area provide the solution of tasks: detection, estimation of parameters of radio emission sources, including coordinates, and their recognition. In view of the dependence of the solutions of the listed problems, the highest efficiency of aviation electronic surveillance systems can be achieved with their joint optimal solution. However, in practice, due to the complexity of the synthesized joint optimal algorithms, which are difficult to implement even at the modern level of computing technology, they decompose and proceed to the construction of quasi-optimal algorithms. Decomposition is carried out according to the tasks being solved, allowing to increase both the efficiency of solving each of them and the efficiency of information processing in the AB RESS as a whole, while maintaining the main interdependence of solutions.

The structure of the information processing algorithm in AB RESS depends on the category of the source of radio emission. This paper deals with a source of radio emission of the primary category - a radio electronic device. In the case of such a source of radio emission, the information processing algorithm can be conventionally represented in the form of processing stages. At the first stage, information about the received signal of the radio emission source is processed. At the second stage - about the source of radio emission of the received signals.

The urgency of increasing the efficiency of information processing in AB RESS is due to the constant counteraction to them and the development of radio emission sources, the complication of the electronic situation in the observation area.

The work consists of three parts, each of which is respectively devoted to increasing the efficiency of signal detection, determination of coordinates and recognition of radio emission sources. They substantiate and describe the developed algorithms, and assess their effectiveness.

2 IMPROVING THE EFFICIENCY OF DETECTING SIGNALS FROM RADIO EMISSION SOURCES OF A KNOWN TYPE IN AB RESS

2.1 Characteristics of the detection of signals from sources of radio emission in AB RESS

Modern AB RESS are built on a multichannel principle to ensure the observation of radiosignal-emitting sources (RSES) in a wide frequency range [1]. In view of the fact that RSESs can emit radio signals in a wide range of possible values of their radio technical parameters (RTP), in particular, frequency and spectrum width, two cases of signal reception and detection are possible:

1. The bandwidth of the signal is greater than the bandwidth of the frequency channel.
2. The bandwidth of the signal is less than the bandwidth of the frequency channel.

In the first case, the broadband signal is fed to several frequency channels at once. In the REW aviation system, each channel receiving a given radio signal introduces its own distortions, which significantly complicate the solution of the signal detection problem due to the unevenness and differences in their amplitude-frequency characteristics (AFC). Reducing the level of these distortions due to the optimal construction of the onboard analog part of the RESS aviation system is not always possible due to its excessive complexity. Therefore, it is advisable to assign the task of signal processing to the on-board special computer in order to correct the distortions introduced by each channel of the RESS aviation system.

In the second case, several narrow-band signals can enter one frequency channel. An increase in the number of signals that are simultaneously within the bandwidth of the receiving path leads to the need to solve the problem of signal resolution, which, as a rule, is solved by means of frequency filtering.

At the same time, in contrast to radar systems, in which, on the basis of knowledge of the emitted signal, optimal methods of receiving reflected radio signals from objects and the underlying surface are used, in modern aviation RESS systems, due to the lack of such knowledge, non-optimal methods of receiving radio signals from RSES are used. However, the RESS aviation systems contain information about the received signals, which is used in solving the recognition problem and is contained in the catalog of types of radioactive sources. In it, each type is assigned a description in space of radio technical parameters, such as carrier frequency, pulse duration, spectrum width, and others. Based on these data, it seems possible to form matched filters with each type from the RSES catalog [2].

Obviously, not all RSES, and some are not fully represented in the catalog of types of RSES, especially during the period of active opposition of RSES to the RESS aviation systems. Therefore, the proposed method for increasing the efficiency of detecting signals of radiation sources should be considered as an addition to the existing methods. At the same time, in the course of a regular RESS, one should expect a decrease in the number of such RSESs and, consequently, an increase in the value of the proposed method in RESS aviation systems.

The consistent use of a correcting and matched filter with the type of RSES will increase the efficiency of detecting signals from these RSESs due to a significant increase in the signal-to-noise ratio at the detector input.

2.2 Methods for implementing filters

2.2.1 Implementation method of the equalization filter

The proposed method for the implementation of a correcting filter in digital form makes it possible to adjust its parameters individually for each channel of the receiving path. It is based on the determination of the values of the correcting filter on a finite set of frequency samples using the Parks-McClellen algorithm. They are calculated using the *firpm*(…) function in the MATLAB software package, which allows you to obtain filter coefficients with a finite impulse response.

Let the initial frequency response $\tilde{S}(n)$ of the receiving channel, obtained at $n = 1,2, ..., N$ frequency samples, be known, which distorts the received signal. Then the frequency response of the correcting filter that compensates for these distortions at each frequency point must satisfy the condition:

$$\frac{c_a}{\tilde{S}(n)} - \frac{\varepsilon_a}{\tilde{S}(n)} \le |\dot{K}_\kappa(n)| \le \frac{c_a}{\tilde{S}(n)} + \frac{\varepsilon_a}{\tilde{S}(n)}, \qquad (1)$$

where c_a – some coefficients to which the correction occurs; ε_a – permissible deviation of the frequency response from the values to which the correction occurs; $|\dot{K}_\kappa(n)|$ – AFC of the correcting filter.

As an example, **Fig. 1** shows the original normalized frequency response of the receiving channel approximated by line segments, where a solid line indicates its part in the used frequency band, and dashed lines - its part in unused frequency bands. For this frequency response of the receiving channel at $\varepsilon_a = 0.02$, in accordance with condition (1), the frequency response of the

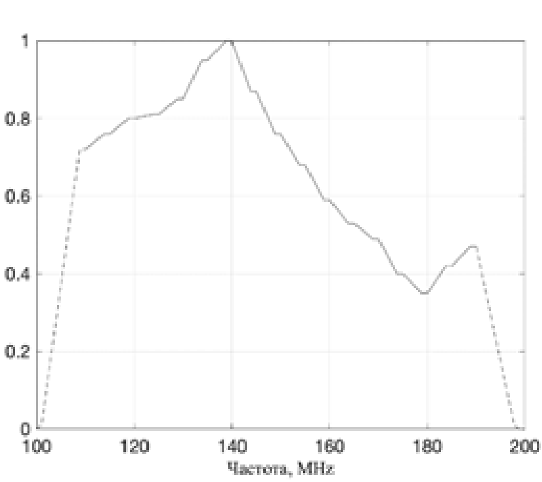

Fig. 1. *Initial normalized AFC of the receiving channel.*

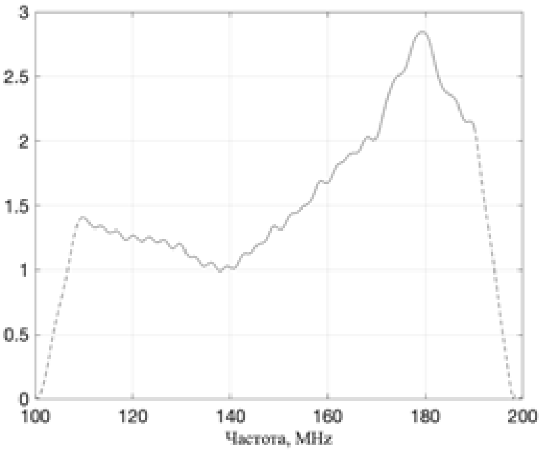

Fig. 2. *Frequency response of the correcting filter.*

correcting filter is determined, which is shown in **Fig. 2.**

The ideal, initial AFC of the receiving channel and the AFC of the receiving channel with a compensation filter are shown in **Fig. 3.** The root-mean-square deviation of the initial frequency response of the receiving channel from the ideal is $1.4\cdot10^{-1}$, and the standard deviation of the frequency response of the receiving channel, taking into account the compensation filter, from the ideal is $1.9\cdot10^{-4}$.

2.2.2 Implementation method of a filter matched to the type of RSES

The description of the types of RSESs in the space of radio technical parameters depends on the completeness and inaccuracy of a priori information about them. The specified description is determined by the alphabet of

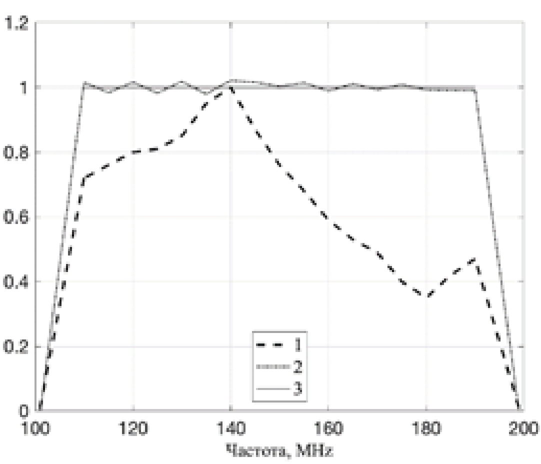

Fig. 3. *AFC: (1) - initial receiving channel; (2) - a receiving channel with a compensation filter; (3) - perfect.*

the features of the types and the density of the probability distribution of the values of the features for each type.

The method of implementing the filter, matched with the type of RSES, is reduced to the definition of the operator L of transition from the parametric description of the *s*-type RSES to the expression of the impulse response $h^{[s]}$ of the filter matched with it, where $s=\overline{1,N_B}$, N_b is the number of types in the catalog.

In the case of an unknown distribution law of RTP values, the description of the RSES types is, as a rule, specified in the known boundaries $\lambda^{[s]}_{\max}$, $\lambda^{[s]}_{\max}$ in the form of a multidimensional uniform probability density of RTP values. The composition of vectors $\lambda^{[s]}_{\max}$, $\lambda^{[s]}_{\max}$ of the catalog of types of RSES in the RESS:

$$\lambda^{[s]}_{\max}=[f^{[s]}_{0\max},\tau^{[s]}_{\max},T^{[s]}_{\max},\Delta F^{[s]}_{\max}]^T,$$
$$\lambda^{[s]}_{\min}=[f^{[s]}_{0\min},\tau^{[s]}_{\min},T^{[s]}_{\min},\Delta F^{[s]}_{\min}]^T.$$

Then the procedure for determining the impulse response of a filter matched to the type of RSES can be written in the form

$$h^{[s]}=\boldsymbol{L}\{\lambda^{[s]}_{\max},\lambda^{[s]}_{\min}\}.$$

The calculation of filters agreed with the types of RSES is performed once before the RESS. On the basis of the calculated coefficients in the digital processing unit, the corresponding digital filters are formed, which are used in the RESS process when detecting RSES signals [5].

If in the catalog of RSES types their description is limited by the carrier frequency and the signal spectrum width, then $\lambda^{[s]}_{\max}=[f^{[s]}_{0\max},\Delta F^{[s]}_{\max}]^T$, $\lambda^{[s]}_{\min}=[f^{[s]}_{0\min},\Delta F^{[s]}_{\min}]^T$. and the implementation of a filter consistent with the *s*-th type of RSES, is reduced to the formation of a band-pass digital filter. In this case, the operator L is the *firpm*(…) function of the MATLAB batch application, which calculates the coefficients of the desired filter with a finite impulse response. The values $(f_{0\max}+\Delta F_{\max})$ and

($f_{0\ min}$ – ΔF_{max}). are specified as the bandwidth frequencies in the calculation.

It should be expected that in the case of a description of the types of RSES by a large number of RTPs and the known law of their distribution, the calculation of filter coefficients matched with the type of RSES will become more complicated, and the signal-to-noise ratio at their output will increase.

2.3 Evaluation of the effectiveness of the proposed method for increasing the efficiency of detecting signals of RSES

Evaluation of the effectiveness of the proposed method for increasing the efficiency of detecting signals of RSES is based on comparing the efficiency of an autocorrelation detector of one receiving channel with and without the use of correcting and matched with the type of RSES filters.

Fig. 4 shows a diagram of an autocorrelation detector of one receiving channel using a correction filter Кк(n) and a filter Кс(n), matched with the s-type of RSES.

Efficiency assessment was carried out in the MATLAB programming environment.

The signal is generated in accordance with the following description of the RSES type:

[Pulse sequence, τ_{min} = 3 µs, τ_{max} = 5 µs, T_{min} = 10 µs, T_{max} = 15 µs, f_{0min} = 170 MHz, f_{0max} = 180 MHz, ΔF_{min} = 200 kHz, ΔF_{max} = 333 kHz].

The signal is in white Gaussian noise. The normalized frequency response of the receiver input circuits corresponds to the frequency response shown in Fig. 2.

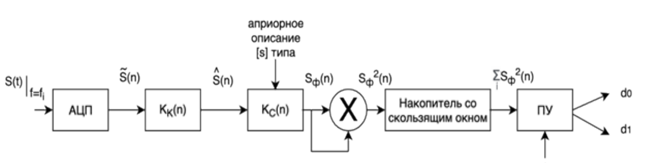

Fig. 4. *Schematic of an autocorrelation detector of one receiving channel.*

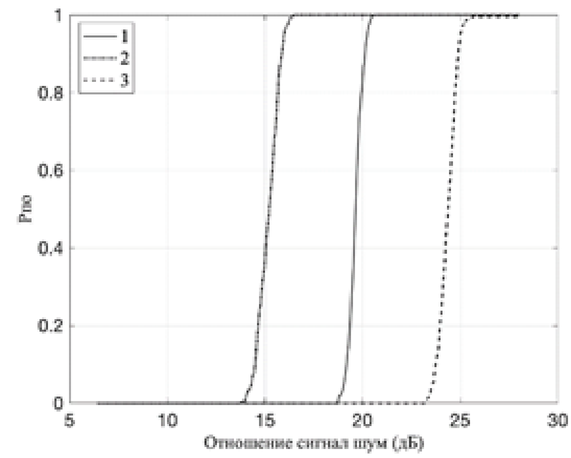

Fig. 5. *Dependence of the probability of correct signal detection on the signal-to-noise ratio: 1 - using only a correction filter; 2 - use of a correction filter and a filter matched to the type of RSES; 3 - without using a corrective filter and a filter matched to the type of RSES.*

The probabilistic characteristics of correct signal detection, presented in **Fig. 5**, are plotted for three cases:

1. Only a correction filter is used;
2. A correcting filter and a filter matched to the type of RSES are used;
3. Without the use of corrective and matched with the type of RSES filters.

It can be seen from the graphs that the combined use of correcting and type-matched RSES filters gives a gain in comparison with a receiver built without their use, in terms of the signal-to-noise ratio by 9 dB, which leads to an increase in the signal detection range by 2.8 times.

3. IMPROVING THE ACCURACY OF DETERMINING THE LOCATION OF IRI IN THE AVIATION ELECTRONIC SURVEILLANCE SYSTEM

3.1. Characteristics of determining the location of RSES in the aviation electronic surveillance system

In the RESS aviation systems, the coordinates of the RSES and the errors of their estimation are most often determined from the set of measured bearings. For this, a method based on the Kalman filter, the method of least squares of angle corrections, etc. are used. The general and necessary condition for the implementation of these methods is the assignment of an initial estimate of the coordinates of the RSES. The estimation result depends significantly on the accuracy of the initial estimate, especially with a small number of bearings. Due to the large error of the initial estimate of coordinates, in a number of cases, there is a "migration" of the estimate of the coordinates of the RSES during their further refinement. At the same time, the experience of using the RESS aviation systems has shown that a number of RSESs operate for a short time, which also leads to the need to determine their location based on a small number of bearings received.

The accuracy of the estimate is usually characterized [6] by the mean value of the squared error, which is equal to the sum of the variance of the estimate and the squared systematic error (bias) of the estimate. The expressions for calculating the variance D_λ of the estimate λ of the true coordinates of the RSES λ_0 are known. In modern aviation RESS systems, the systematic position determination error is not analyzed or eliminated, although the magnitude of this error, depending on the observation conditions, can be significant (up to several kilometers).

This part of the work is devoted to the analysis and elimination of the systematic error in determining the position of the radioactive sources in the AB RESS.

3.2. Analysis of the systematic error in determining the position of radioactive sources in the AB RESS

The systematic error in determining the location of the RSES can be defined as

$$\Delta = \mathbf{M}\{\lambda\} - \lambda_0,$$

where $\mathbf{M}\{\lambda\}$ is the mathematical expectation of the estimate, $\mathbf{M}\{\lambda\} = \int \lambda p(\lambda) d\lambda$; $p(\lambda)$ is the probability density of the estimate. For the case of a stationary local rectangular coordinate system OXY when the aircraft is flying along the abscissa axis $\lambda = [x,y]^T$, $\lambda_0 = [x_0,y_0]^T$, $\Delta = [\Delta x,\Delta y]^T$, where x, y – respectively, the abscissa and ordinate of estimating the location of a stationary ground-based RSES, x_0, y_0 are its true abscissa and ordinate, respectively, Δx, Δy is a systematic error in estimating the location of a stationary ground-based RSES on the abscissa and ordinate, respectively, t is the transposition sign. In the process of work, the expression for the probability density $p(x, y)$ of the initial estimate of coordinates was obtained [3] when it was formed from two bearings:

$$p(x,y) = \frac{\left|\frac{x_j - x_i}{y_0^3}\right| \exp\left\{\frac{-[arctg((x_0 - x_i)/y_0) - \alpha_i]^2 - [arctg((x_0 - x_j)/y_0) - \alpha_j]^2}{2\sigma^2}\right\}}{2\pi\sigma^2 \left[1 + \left(\frac{x_0 - x_i}{y_0}\right)^2\right]\left[1 + \left(\frac{x_0 - x_j}{y_0}\right)^2\right]},$$

where $(x_i, 0)$ and $(x_j, 0)$ are the coordinates of the aircraft, in which the initial and final bearings were measured, respectively; a_i and a_j – measurements of the initial and final bearings, respectively; σ – standard deviation (RMS) of bearing measurement.

Fig. 6 and **7** show, respectively, the projection of the normalized probability density $p(x, y)$ onto the OXY plane and the section of the probability density $p(x, y)$ by the plane perpendicular to the OX axis and passing through the point (0,0). In this case, the following are given: the true position of the RSES at the point (0; 100) km; the bearing was measured when the aircraft was at the points (–15; 0) km and (15; 0) km, which corresponds to the bearing base L = 30 km; RMS of bearing

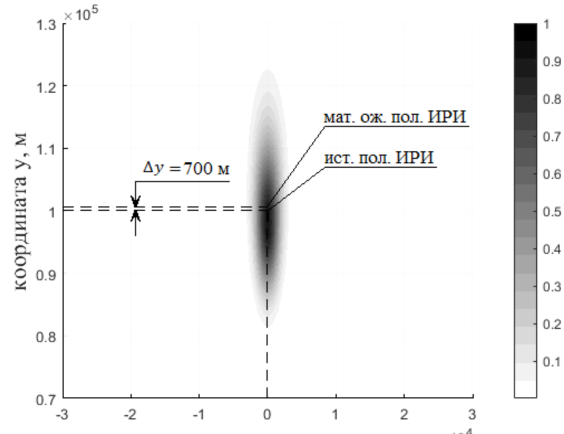

Fig. 6. *Projection of the probability density p(x, y) onto the OXY plane.*

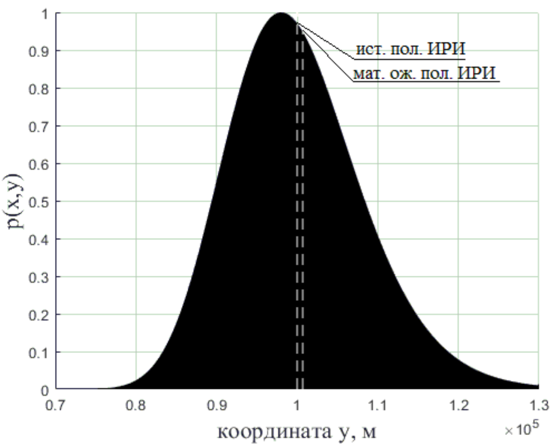

Fig. 7. *Section of the probability density p (x, y) by a plane perpendicular to the OX axis and passing through the point (0,0).*

measurement 1 degree. In Fig. 6, the value of the probability density is expressed in black and white gradient. From the analysis of the graphs it follows that the probability density distribution of the initial coordinates of the RSES $p(x, y)$ is unimodal and has a positive asymmetry. This type of probability density is confirmed experimentally when constructing a histogram. During the simulation, it was found that the probability density graph tends to a symmetric form when the angle between bearings tends to 109°.

Figs. 8, 9 show the graphs of the dependence of the systematic error Δy and Δx, respectively, of the initial estimate of the RSES on the distance D to the RSES. The range to

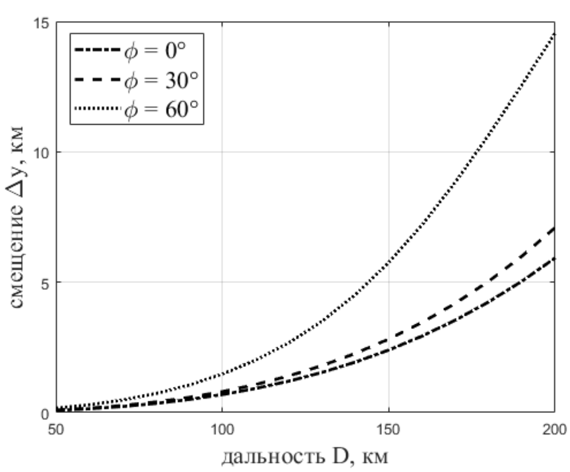

Fig. 8. *Dependence of the displacement Δy on the range D at σ = 1° and L = 30 km.*

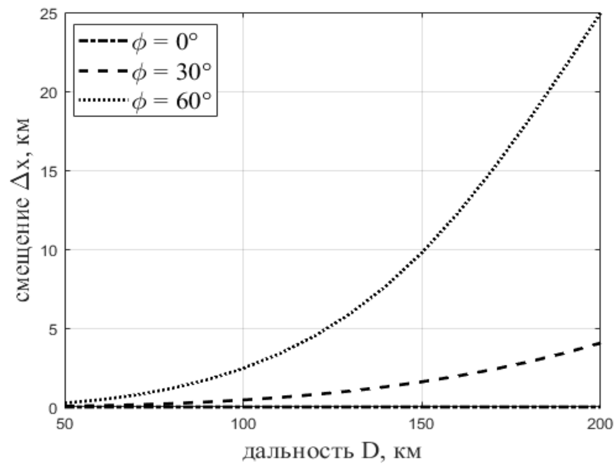

Fig. 9. *Dependence of the displacement Δx on the range D at σ = 1° and L = 30 km.*

the RSES is defined as the distance between the center of the DF base and the true location of the RSES. The plots were constructed with the RMS of the bearing measurement $\sigma = 1°$ and the bearing base L = 30 km. The angle ϕ between the perpendicular to the center of the bearing base and the direction to the RSES changes in the values of 0°, 30°, 60°. The range D to RSES varies from 50 km to 200 km. From the analysis of the graphs it follows that the systematic error increases nonlinearly with an increase in the range to the RSES, and with the RMS of measuring the bearing of the order of a degree at long ranges, it can be several kilometers.

3.3. Algorithm for eliminating the systematic error in determining the location of the RSES in AB RESS

Elimination of the systematic error in determining the position of the RSES is possible only under the known observation conditions and its true position. In practice, this information is obtained only after performing the RESSand analyzing the data. Since there is no way to obtain the location of the RSES without preliminary collection of information [7], the elimination of the systematic error is also possible only after the end of data acquisition. In view of the fact that it is not always possible to obtain an unbiased estimate of the position of the RSES with the help of the RESS, a method is needed that allows, on the basis of the obtained observation conditions for the estimation of the position of the RSES, to determine and eliminate the systematic estimation error.

As a result of the RESS, the following became known: the estimate $\hat{\lambda} = \{\hat{x}, \hat{y}\}$ of the coordinates of the RSES, hereinafter called the initial one; their estimation error $\hat{R}$; coordinates $\lambda_i = \{x_i, y_i\}$ of the aircraft at the moments of bearing measurements; bearing values $\{a_i\}$, where $i = 1,2, ..., N$, N - the number of measured bearings; RMS deviation of bearing measurement σ. It is required to eliminate the systematic error Δ in determining the position of the RSES with an acceptable accuracy Δ_{add}.

In the developed algorithm, the systematic error is eliminated by the successive approximation method based on the RESS simulation. Simulation of the RESS consists in repeated tests, where the coordinates of the RSES are estimated under known initial conditions and the measurement of the bearing with an error introduced by the random number sensor, as well as in the estimation of the statistical parameters of the coordinates. The block diagram of the algorithm is shown in **Fig. 10**. The algorithm can be conditionally divided into three stages: 1) determination of the number of tests for simulation of RESS 2) determination of the straight line, on which the position of the RSES is refined by the method of successive approximation; 3) cyclic refinement of the location of the RSES.

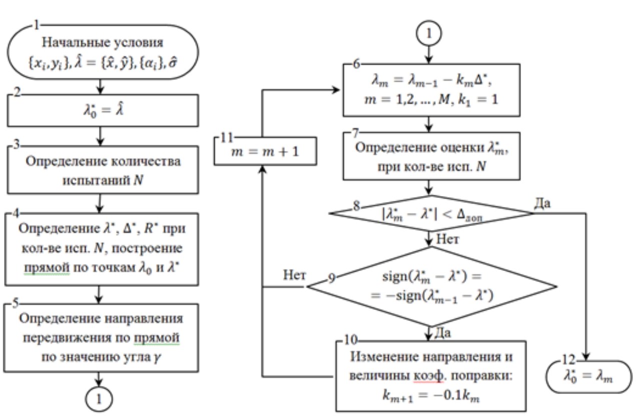

Fig. 10. *Algorithm block diagram.*

At the first stage of the algorithm, the location estimate $\hat{\lambda}$ is taken as the true position λ_0^*, and statistical simulation of the RESS is performed with a limited number of tests N_0. The standard deviation σ_{N0} of the obtained estimate λ_{N0}^* and the number of tests N, for which the standard deviation σ_N of the coordinate estimates $\lambda_m^* = \{x_m^*, y_m^*\}$, determined in the cyclic refinement of the true location of λ_m RSES at the m-th step of the cycle, will be, with a confidence level P, an order of magnitude less than the permissible deviation Δ_{add}. The number of tests N is determined from the inequality [4]

$$N \geq \left[\frac{t(P)}{0.1\Delta_{perm}}\right]^2 \sigma_{N0}^2,$$

where $t(P)$ is found from the equality $2\Phi(t) = P$, $\Phi(t)$ is the probability integral.

At the second stage of the algorithm, the statistical simulation of the RESS is repeated with the number of tests N and the estimate of coordinates λ^*, its systematic error Δ^* and the correlation matrix R^* are determined. A straight line is constructed passing through the points $\hat{\lambda}$ and $\hat{\lambda}^*$. The direction of movement along a straight line is determined by the value of the angle γ between the extreme bearings to the point λ_0^*.

At the third stage of the algorithm, a cycle of refinement of the coordinates of the RSES is performed by selection on a straight line by the method of successive approximation of coordinates $\lambda_m = \lambda_{m-1} - k\Delta^*$ at the m-th step of the cycle, where $m = 1,2, ..., M$, M is the number steps required to exit the loop, k is the bias correction factor. At each step, statistical simulation of the RESS is performed with the number of tests N, and an estimate of the coordinates λ_m^* is determined. If at the coordinates λ_m the condition $|\lambda_m^* - \lambda^*| < \Delta_{доп}$ is satisfied, then the true position $\lambda_0^* = \lambda_m$ of the RSES is determined with sufficient accuracy, otherwise a new iteration of the correction of coordinates λ_m begins, while changing the sign and magnitude of the correction in the case of "jumping over".

3.4. Evaluation of the efficiency of the algorithm for eliminating the systematic error in determining the position of the radioactive source in the aviation electronic surveillance system

The algorithm was tested on a PC using the MATLAB computing environment version R2019b. The performance of the PC was determined using the "bench (100)" function, which shows the averaged values of the execution time, among others, the "LU", "FFT" tests (operations with floating point numbers), respectively equal to 0.2174 s and 0, 1399 s.

The RESS simulation was carried out under the following initial conditions: the range D to the RSES varies from 50 to 200 km, the direction finding base is L = 30 km; 2 bearings measured symmetrically in one test; RMS of bearing measurement 1 degree; the number of tests for one iteration of the RSES coordinates correction is equal to $N = 10^7$. The execution time of one iteration was 160 s.

Fig. 11 shows the dynamics of changes in the deviation $\lambda_0^* - \lambda_0$ at D = 200 km, in **Fig. 12** – the graph of the dependence of the deviation of the initial and corrected estimates from the true position of the RSES on the distance D.

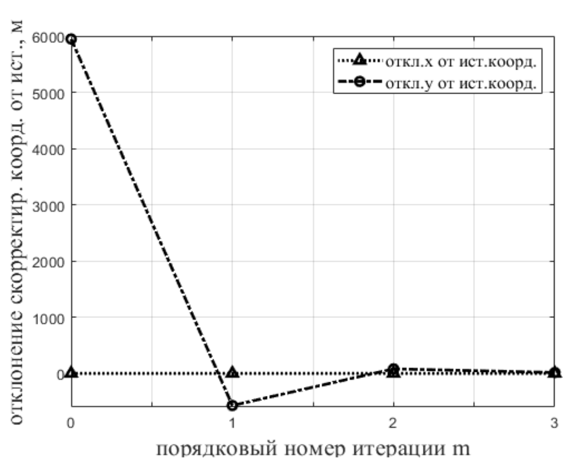

Fig. 11. *Dynamics of the deviation of the corrected coordinates of the RSES from the true ones at D = 200 km.*

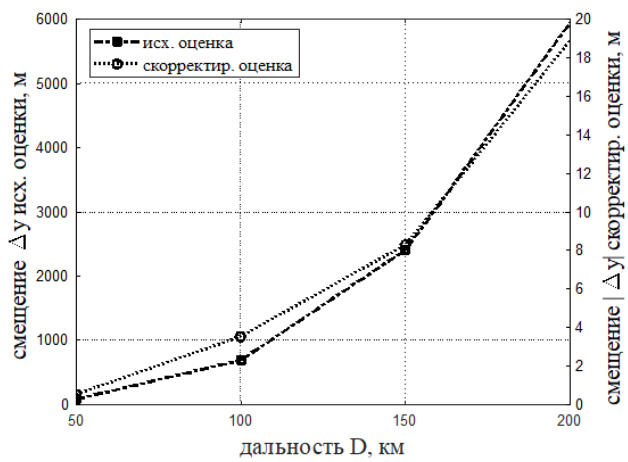

Fig. 12. *A graph of the dependence of the deviation of the initial and corrected estimates from the true position of the RSES on the range D.*

Analysis of the graphs shows that the systematic error decreases significantly already at the first iteration cycle of the algorithm, and further reduction is achieved after several subsequent iterations. At a distance of D = 200 km, the ordinate systematic error decreases from 6 km to 18 m; at smaller ranges, the result is significantly improved and amounts to a few meters. The systematic error along the abscissa in all cases does not exceed 1 m, which is insignificant within the framework of this problem. Thus, the developed algorithm provides effective elimination of the systematic error in estimating the position of the RSES.

4. IMPROVING THE EFFICIENCY OF RSES RECOGNITION

4.1 Characteristics of the solution to the problem of recognition of RSES

For the case of stationary sources of radio emission, the distance between which is greater than the root-mean-square error in determining their coordinates, the problems of detection and estimation can be solved with high reliability. However, the analysis of modern RSES showed that most of them change their location, the distance between them may be less than the mean square error in determining their coordinates, widespread use in the region of the same type of RSES, and the degree of overlap of possible values of parameters of different types is such that it will not allow solving the recognition problem definitely. At the same time, in the RESS aviation systems, as a rule, information about the RSES is received with significant frequency. All of the above factors significantly reduce the capabilities of the RESS aviation systems, not only in opening the RESS, and even more so in identifying and analyzing the changes that have occurred in the RESS area, accompanying the RESS and forming their radio technical portrait.

One of the ways to overcome these difficulties is to obtain from the received signals of the RSES, not only the values of radio technical parameters - identification signs already used in recognition, but also additional information. Additional information in the form of measured values, highlighted individual identifying signs, will increase the detail of recognition of radioactive sources up to a copy and, consequently, the effectiveness of their opening, tracking, identification and analysis of the changes that have occurred in the RESS area, clarification and addition of existing radio technical portraits of radioactive sources. This became possible due to the digital nature of information processing in modern aviation systems of the RESS, the intensive development of its algorithms and the corresponding element base.

However, the number of RSESs in the modern RESS area is so great that it is not possible to obtain additional information on all RSESs on a time scale close to real, due to the limited capabilities of the RESS aviation systems. A prerequisite for obtaining additional information about the RSES is the preservation of their received digitized signals for subsequent processing.

This part of the work is devoted to the preservation of the received RSES signal in a digitized form in the RESS aviation system.

4.2 Analysis of methods for storing the digitized signal of RSES in the RESS system

There are two known methods for storing the digitized signal of RSES in RESS systems.

The first method is the automatic saving of all digitized signals of the RSES. In view of the large number of RSESs and, accordingly, the signals received from them, this method places high demands on the RESS system in terms of the throughput of the channels for storing digitized signals, on the speed and volume of the memory device. In this regard, if a large number of digitized signals are transmitted over a radio channel, the secrecy of the operation and the noise immunity of the RESS system will decrease. At the same time, the experience of using RESS systems has shown that out of all the stored digitized signals, only a small part of them (less than 20%) can subsequently be claimed. The latter testifies to the inexpedient use of the computing resources of the RESS system in this method and the need to solve the problem of selecting the required digitized signals before storing them.

The second method is the automated saving of only the required digitized signals. This is achieved by changing the operator of the preset operating mode of the RESS system by adjusting it for frequency selection of the required signals and saving them in digital form. Due to the limited storage space of the RESS system, the recording time of a digitized signal may be shorter than its duration. As a result, the operations of recording the required signal by the operator are repeated many times, and in general a lot of time is spent on this. Therefore, this method is characterized by a low throughput for storing digitized signals.

The developed method implements the automatic storage of the required digitized signals from the RSES. It eliminates the disadvantages of the first method by selecting the required signals before storing them and the disadvantages of the second method by automatically performing this procedure. In this method, the possibilities of selection are significantly expanded by including additional selection conditions in it: by the type of RSES; by radio technical parameters, including frequency; at the location of the RSES; on the reliability of information about the received signals.

4.3 Algorithm for automatic saving of the required digitized signals of RSES

To automatically save the required digitized signals, tasks containing selection conditions are introduced into the RESS aviation system.

At the first stage of processing, after evaluating the radio technical parameters of the received signal, its belonging to the types of the radio emission source represented by the catalog of types can be determined. The assignment of the types of radiation sources, the digitized signals of which need to be stored, is considered as one of the ways of their selection in the space of radio technical parameters. Taking into account that not all interested RSESs or their signals, in particular new ones, are described in the catalog of types, another way of such selection is to determine whether the received signals belong to specified intervals of radio technical parameters.

At the second stage of processing, after assigning the received signal to one previously (at the previous step of observation) detected radio emission source, the coordinates of which have been determined, selection is carried out at the location of the RSES. For this, the areas of observation of the RSES are set, the signals of which must be stored in a digital form.

Since the information about the received signals significantly depends on the RESS conditions and has a probabilistic nature, in the process of its processing the parameters characterizing its reliability are estimated. To preserve reliable information in the developed algorithm, threshold values of these parameters are set: the reliability of the received signal, the probability of recognizing the type of RSES, the size of the largest semi-axis of the ellipse of the error in determining the coordinates of the RSES. Exceeding the preset threshold values is an additional way of selecting the received signals for recording them in digital form.

The developed algorithm for automatic storage of the required digitized signals of RSES is presented in the form of a block diagram in **Fig. 13.**

The input data of the algorithm is presented in Blocks 2-4. Block 2 – Data on the received signal, received on the *i*-th observation interval: number of the type of RSES; the probability of recognizing the type of RSES; RTP of the received signal; the value of the RTP reliability parameter; the decision on the belonging of the received signal to the RSES, the coordinates of which are determined. Block 3 – Data on RSES on the *i*-1 observation interval: coordinates of RSES: value of the parameter of reliability of coordinates of RSES Block 4 – Task data for saving digitized files: number of the specified type; type recognition probability threshold; specified RTP intervals; the threshold of

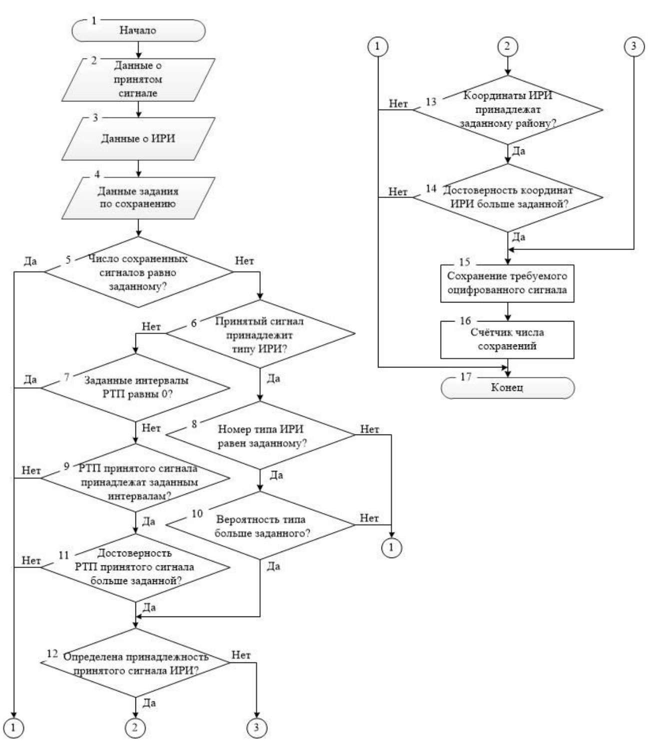

Fig. 13. *Block diagram of the algorithm for automatic storage of the required digitized signals of RSES.*

reliability of the parameters of the received signal; the given parameters of the observation area of the RSES; required number of stored digitized signals.

Checking the fulfillment of the selection conditions according to the task is represented by Blocks 5-14.

The completion of the task is achieved by executing, represented by Block 5, the equality of the number of previously stored digitized signals represented by Block 14 with a given number. It should be noted that when entering a task, the counter of the number of stored digitized signals is reset to zero.

Evaluation of the effectiveness of the developed algorithm showed that its implementation requires insignificant computing resources and will provide in modern aviation RESS systems automatic background storage of the received signals in digital form according to the task in a time scale close to real.

5. CONCLUSION

The analysis of solving the problems of detection, positioning and recognition of radioactive sources performed in this work substantiated the importance of the proposed methods for increasing their efficiency and determined the directions for the development of appropriate information processing algorithms in modern aviation RESS systems. The interdependence of the decisions made at each stage of information processing is used in the proposal for the use of correcting filters that are consistent with the type of RSES when detecting signals and saving them in digital form.

The performed modeling of the proposed methods and the developed algorithms for information processing confirmed their feasibility and increased efficiency in modern aviation RESS systems. The signal-to-noise ratio increases significantly in the receiving channels that use information about the types of radiation sources (in the example considered, the increase in the signal-to-noise ratio was 9 dB. With a permissible accuracy equal to 0.1 MSE, the systematic error in determining the position of the RSES is eliminated. Provides a background automatic saving of the received signals in a digital form according to the task in a time scale close to real in order to obtain additional information about RSES, their individual recognition, tracking, identification and analysis of the changes that have occurred in the RESS area.

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