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STATIC AND DYNAMIC ASSESSMENTS OF INFORMATION SIGNS IN RECOGNITION OF SOURCES AND OBJECTS OF OBSERVATION IN THE PROCESS OF RADIO MONITORING

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Background. The current state and problems of the surveillance and radio monitoring systems of Ukraine require fundamentally new approaches to increasing their efficiency and the level of informatization. At the same time, the informatization of the radio monitoring system should be understood as the process of implementation and application in various areas of their activity of methods and means of collecting, transmitting, processing, saving and using information in order to increase the effectiveness of conducting radio monitoring and meet the needs of national security based on the formation and use of information resources.

Objective. The purpose of the paper is to increase the effectiveness of radio monitoring by using the calculation of estimates of dynamic and static informational features when recognizing sources and objects of radio radiation and determining their phase (operational) state and level of possible danger.

Methods. Recognition is based on the method of least squares by calculating the degree of "similarity" (similarity coefficient) of the recognized object with objects whose classes are known. Both the researched and reference objects are presented as a set of values of informational features of various nature, some of which are unchanged over the entire period of observation, that is, static, while others change dynamically.

Results. The structure of the automated system of classification and recognition of surveillance objects and the recognition algorithm based on the calculation of static and dynamic information features and the similarity coefficient are proposed.

Conclusions. A distinctive feature of deciding whether an object or a source of information belongs to one or another class feature is the calculation of the degree of "similarity" (similarity coefficient) of the recognized object to objects whose classes are known. To eliminate recognition errors associated with a violation of the synchronicity of measurements of the values of dynamic informational features of reference objects and objects to be recognized, a calculation is required taking into account possible time shifts.

Keywords: *radio monitoring; method; information feature; recognition; classification; evaluation; algorithm; similarity coefficient.*

Introduction.

The current state and problems of the surveillance and radio monitoring systems of Ukraine require fundamentally new approaches to increasing their efficiency and the level of informatization. At the same time, the informatization of the radio monitoring system (RM) should be understood as an organized process of large-scale implementation and application in various areas of their activity in peacetime and wartime of methods and means of collecting, transmitting, processing, preserving and using information with the aim of increasing the effectiveness of conducting the RM and meeting the needs of the national security based on the formation and use of information resources [1].

Formulation of the problem

It is shown in [2] that one of the possible ways to solve the problems of increasing the efficiency of the monitoring system as a whole and radio-electronic surveillance as its component is the introduction of modern structural-systemic and signature technologies and methods of RM based on the ideology of intelligent systems (IS). That is, the modern RM system should be considered as an open automated system with elements of artificial intelligence.

It is known [3] that the use of IS technologies makes it possible to comprehensively solve the problems of recognition and classification of sources and objects of radio radiation (SORr) and determination of their phase (operational) state and level of possible danger. At the same time, in general, any IS consists of two interdependent subsystems: a subsystem for presenting formalized knowledge and a subsystem for choosing decision-making options.

The formalized knowledge representation subsystem contains many information elements - so-called information features (If). At the same time, each element must have a description of the structure, form, properties, functional connections and relationships between SORr. Along with this, by their nature, all Ifs can be conditionally divided into two main classes: static and dynamic, which are described both by quantitative characteristics and qualitatively at the verbal level (in the form of logical connections).

In [4], the main provisions of the approach to the calculation of estimates of dynamic and static Ifs in the recognition of DRVp are given. However, for its implementation, it is necessary to describe and explain in more detail the physical content of the main processes that occur during recognition with the calculation of If estimates, and to present the main procedures in the form of an appropriate algorithm. The specified circumstances determine the purpose and main content of the article.

Main part.

As it was shown above, the RM system can be represented by an open automated system, one of the main functions of which is the classification and recognition of SORr. This system (Fig. 1) consists of subsystems: representation of knowledge; calculation of IF estimates; decision support. At the same time, by classification we will understand the breakdown of the entire set of observation objects into non-intersecting classes, and by recognition - the assignment of the observation object to a specific class [5,6].

The recognition process is as follows. Apriori information is presented in the form of descriptions of known reference objects belonging to various established classes. The recognition algorithm compares the description of the recognized object with the reference descriptions of all objects and makes a decision about which class to attribute the observation object to. Recognition is based on the calculation of the degree of "similarity" (similarity coefficient) of the recognized object with objects whose classes are known. Both the studied and reference objects are represented as a set of IF values of different nature, some of which are constant over the entire observation period, that is, static, while others change dynamically.

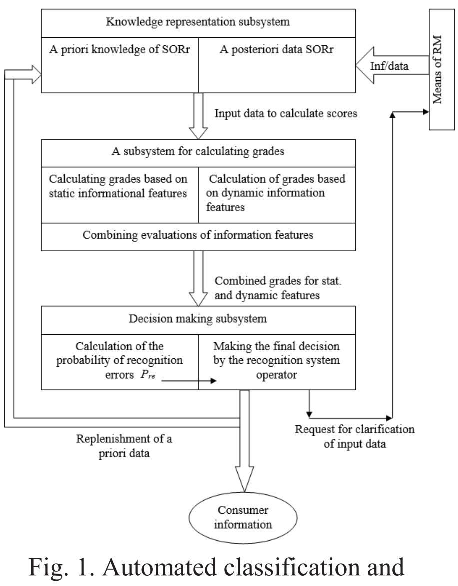

Fig. 1. Automated classification and recognition system SORr

The method of calculating estimates involves the separate calculation of static and dynamic IF estimates, followed by the formation of a general estimate based on them [7,8].

To calculate these estimates, it is necessary to carry out:

- formalization of input data;
- calculation of similarity coefficients by static IF;
- calculation of similarity coefficients by dynamic IF;
- calculation of the general assessment of the similarity of the studied and reference objects;
- calculation of the probability of a recognition error.

The listed procedures form the basis of the algorithm for calculating the estimates of the above-mentioned IFs.

The formalized knowledge representation subsystem, according to the generalized algorithm of the structural-systemic method [2], can be divided into two components: a priori knowledge about the structure, information features and functional connections between the SORr and a posteriori data coming from the means of observation. A posteriori data are presented in the form of aggregates of radio emission sources observed, as well as summaries of already classified and identified SORr. A priori knowledge about SORr and the connections between them are presented in the form of a set of information models of classes of observation objects.

The information model of the SORr class presentation considered in the article includes:

- class identifier;
- a set of IFs indicating that a specific object belongs to a given class;
- set of possible states of the object belonging to this class;
- a set of IFs that determine the state of the object at a given moment in time;
- information about the position of this object in the hierarchical structure of complex objects.

Each IF can take values from some fixed finite set of allowable values. Sets of admissible values of IF are also related to a priori knowledge about SORr. In the system of automated classification and recognition of SORr, the input data should be automatically checked for their belonging to a set of acceptable values.

According to the method of calculating dynamic and static IF estimates, the object of recognition is described by a multidimensional vector, the components of which are the values of the signs from the given alphabets. A set of k+1 elements {1,2,...,k,-} can be chosen as the alphabet of static IFs, where the numbers from 1 to k reflect the serial number of the IF value in the table of its permissible values, and a dash indicates the absence of information about this characteristic . The alphabet of dynamic features can be a set of points in the interval (a, b), in which the value of a given feature changes continuously, or a set {1,2,...,k,-}, if the value of the feature changes discretely.

A priori knowledge about the structure, IF and functional connections between SORr is expedient to present in the form of a set of tables (lists) of acceptable values for each IF and a set of descriptions of information models of classes of observation objects.To implement the method of calculating grades, the formal description of the information model of the class should include:

- class identifier;
- a set of reference values of static features, which is described by the vector X_{sf};
- a set of reference values of changes in dynamic characteristics, described by the matrix Y_{sf} of dimension $n \times m$, the rows of which represent a set of values of changes in each of n dynamic characteristics during m dimensions;
- a set of weight coefficients of static and dynamic features, which is described by vectors R_{sf} and R_{df}, which characterize the informativeness of each feature when making a decision in favor of a given class.

Taking into account that the reference matrices should most fully and accurately reflect the change in the parameters of the object of recognition, the values of changes in the features in the reference matrices should be represented with the maximum possible (from a practical point of view) sampling frequency.

A posteriori data on SORr are presented in the form of vectors of values of static features of recognition objects X_{sf} and matrices of values of dynamic features X_{df} (see Fig. 2).

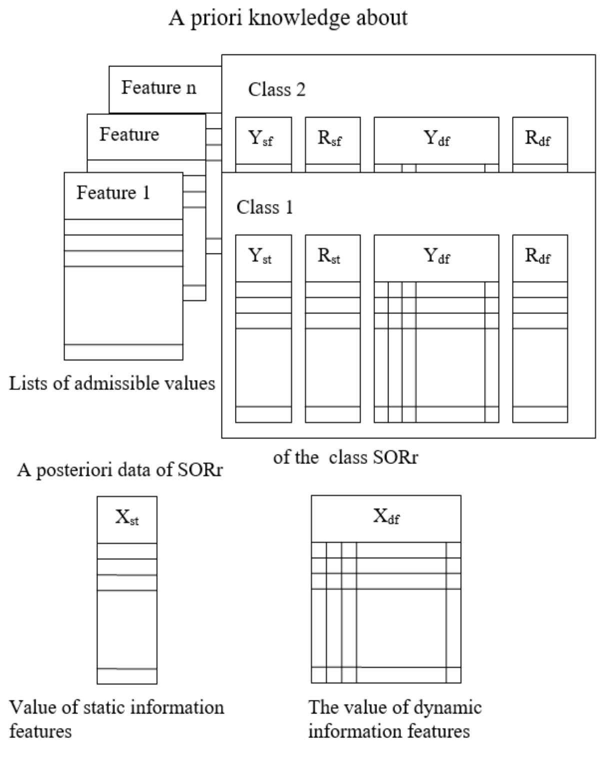

Fig. 2. Presentation of input data for recognition

The SORr recognition algorithm (Fig. 3) consists of the following procedures:

calculation of grades based on static characteristics;

calculation of grades based on dynamic characteristics;

combining estimates for static and dynamic features into a total estimate and calculating the probabilities with which the researched object of recognition can be attributed to each of the reference classes;

making a decision about recognition.

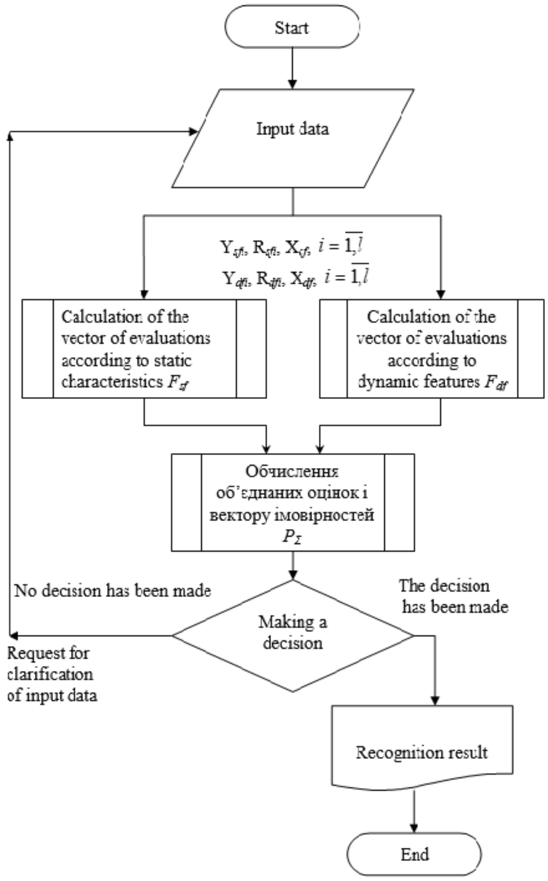

Fig. 3. Block diagram of the SORr recognition algorithm

Let's consider these procedures in more detail.

The values of the static IFs of the recognition object either coincide or do not coincide with the reference ones. Each such match must be included in the procedure for calculating the assessment on static features, taking into account the weight of the corresponding feature. For this, an auxiliary Boolean matrix A of dimension $l \times s$ is formed, which characterizes the coincidence or discrepancy of values s of static IOs with the corresponding values described in l information models of classes. The coefficients a_{ij} of matrix A take the following values:

$$a_{ij} = \begin{cases} 1, \text{if } x_j = y_{ij} \\ 0, \text{if } x_j \neq y_{ij} \end{cases}. \qquad (1)$$

After the formation of the matrix A, taking into account the weight of the IF r_{sfij} , the vector of estimates $F_{sf}=(f_{sf1},f_{sf2},...,f_{sfl})$ is calculated, in which

$$f_{sfi} = \frac{1}{s}\sum_{j=1}^{s} r_{sfij} \cdot a_{ij} . \qquad (2)$$

At the same time and independently of the calculation of static values, dynamic IF values are calculated. When calculating these estimates, it should be assumed that: l information models of classes of objects are described in the system of automated classification and recognition of SORr; the number of dynamic IFs is n; the dynamics of the change in IF values is described by m dimensions; a description of the dynamic IFs of the object under study is submitted to the input of the system in the form of a matrix Xdn of dimension $n \times q$.

Since in real conditions it is impossible to ensure the measurement of dynamic IF of recognition objects strictly at given moments of time, it is necessary to agree on the presentation formats of reference and real data to calculate estimates. Taking into account the fact that in practice the measurements are carried out irregularly, with a frequency no greater than the sampling frequency of the reference matrices, the number of measurements of the parameters of the recognition object q will always be no more than the number of m measurements in the reference matrices.

Also, due to the fact that the reference matrices describe not the absolute values of IF, but their changes (increases), the matching of input data consists in the formation of a matrix of changes (increases) in the values of information features Δ, where $\Delta_{ij}=x_{dfij}-x_{dfi,j-1}$, as well as in the oversampling of the matrix Δ to the frequency of measurements corresponding to the reference matrices Y_{dfi}.

To explain the physical content of the above, let's consider the simplest case under the following conditions:

- the input data presentation formats (information models of classes and object recognition) are agreed;
- only one of the information features of the SORr is dynamic and changes according to a periodic law with an a priori known repetition period T;
- measurement errors of IF values are distributed according to the normal law.

Let there be two reference models of SORr in the system of automated recognition and classification, the dynamics of which are shown in Fig. 4 in the form of graphic dependencies $y_1(t)$ and $y_2(t)$. The description of the recognition object is received at the input of the system in the form of a dependence x(t). The system performs a pairwise comparison of the recognition object x(t) and standards $y_1(t)$ and $y_2(t)$. When combining the graphs of the reference and real values ($z_1(t)$ and $z_2(t)$), it can be seen that the degree of similarity of the dynamics of the change in the values of the IF of the object of recognition and the reference descriptions is characterized by the size of the area of the obtained figures S_1 and S_2.

If we represent the sequence of discrete values of the functions $y_i(t)$ and $x(t)$ by their contours, then the calculation of the similarity coefficient k_i will be determined by the expression:

$$\frac{1}{k_i} = \int_{0}^{t_{\max}} \left| x(t) - y_i(t) \right| dt \; ; \; i = \overline{1,l} , \qquad (3)$$

where l - the number of information models of classes described in the system.

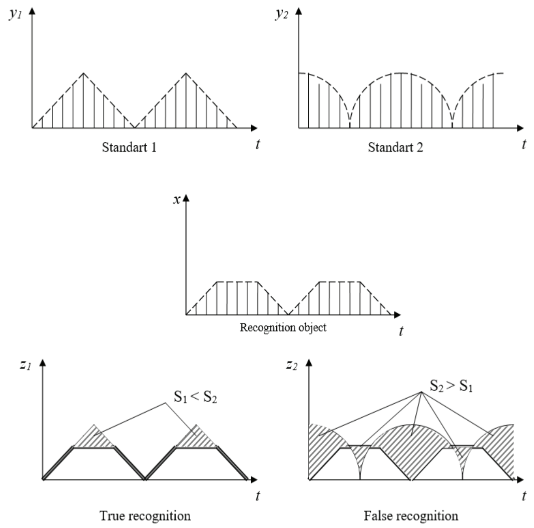

Fig. 4. The physical content of the similarity coefficient

Returning to the discrete values of the functions yi(t) and x(t), we obtain the formula for calculating the similarity coefficient as the sum of the distances between the real and reference values of a given IF. Since, according to the introduced restrictions, measurement errors obey the normal law, it is rational to use the least squares method to calculate the similarity coefficient ki between real and reference values, according to which:

$$k_i = \sum_{t=0}^{m} \frac{1}{\left(x(t) - y_i(t) \right)^2} , \quad i = \overline{1,l} \qquad (4)$$

where m - the number of measurements available for comparison;

$x(t)$, $y(t)$ - are, respectively, the real and reference values of the IF, which dynamically changes at the moment of time t.

In real conditions, a situation of violation of the synchronicity of the dynamics of the change in the values of the IF of the researched recognition object and the reference model is not excluded, which inevitably leads to recognition errors. To explain this situation, let's consider a special case. Let the input of the recognition system containing the reference descriptions $y_1(t)$ and $y_2(t)$ receive the description of the recognition object $x(t)$, which differs from the previously described case (see Fig. 4) in that the synchronicity of the dynamics of change the features of the object of recognition and the corresponding standard are violated and are T/2 (Fig. 5). When recognizing and calculating the areas S_1 and S_2, a situation arises when the object of recognition will be mistakenly assigned to the standard described by the dependence $y_2(t)$, because $S_1 > S_2$.

To eliminate such errors, it is necessary to carry out several comparisons when comparing with each of the standards, discretely changing the time shift by the amount of the number of measurements τ. The maximum value of the similarity coefficient for all shifts should be considered the result of this standard.

The similarity coefficient, taking into account time shifts, is calculated by the formula:

$$k_i = \max_{\tau=0,\tau_{\max}} \left(k_i'(\tau)\right), \qquad (5)$$

where

$$k_i'(\tau) = \sum_{t=0}^{m-\tau} \frac{1}{\left|x(t) - y_i(t+\tau)\right|^2} \qquad (6)$$

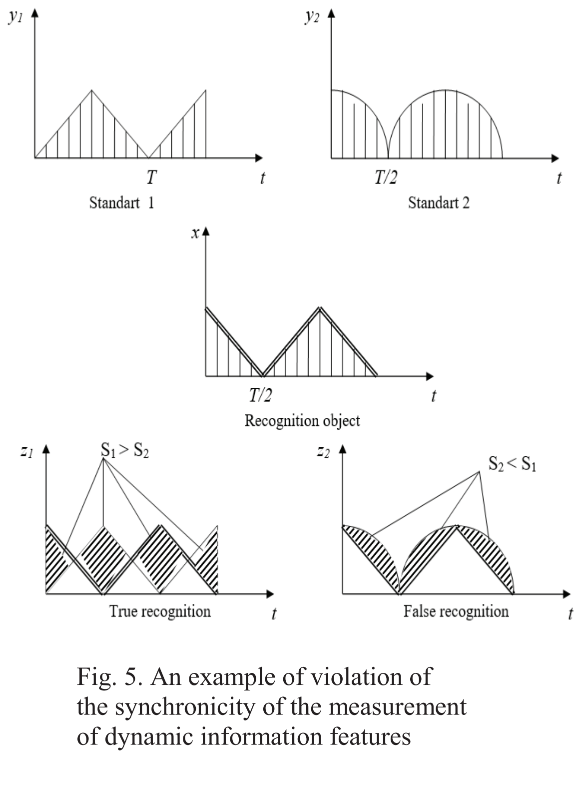

Fig. 5. An example of violation of the synchronicity of the measurement of dynamic information features

The number of measurements of the maximum possible delay τmax is calculated as half the period of the change in the values of the characteristic T at the sampling frequency F_d:

$$\tau_{\max} = \left[\frac{T \cdot F_d + 1}{2}\right]. \qquad (7)$$

Thus, the total evaluation of dynamic features according to the i-th standard is calculated according to the formula:

$$f_{dfi} = \frac{1}{n}\sum_{j=1}^{n} r_{dfij} \cdot k_{ij}\ , \qquad (8)$$

where n - the number of IFs by which the assessment is calculated;

$r_{\partial nij}$ - a weighting factor that characterizes the informativeness of the j-th feature when it is taken into account in favor of the i-th standard.

If n dynamic features (n>1) are described in the information models of SORr classes, then possible time shifts must be evaluated together, taking into account the weighting coefficients of the features. In these cases, the calculation of estimates is carried out as follows: using formulas (6), (8) a matrix of estimates Φ_{df} of dimension $l \times \tau_{\max}$ is formed according to all the information models of the classes described in the system and according to all possible time shifts. At the same time, the coefficients of the matrix Φ_{df} are calculated as:

$$\Phi_{dfij} = \frac{1}{n}\sum_{p=1}^{n} r_{dfjp} \cdot k_{ip}'(j). \qquad (9)$$

In this case, the total assessment based on dynamic features, taking into account time shifts, is calculated as the maximum element of the corresponding row of the matrix Φ_{df} according to the following expression:

$$f_{dfi} = \max_{j=0,\tau_{\max}} \left(\Phi_{dfij}\right). \qquad (10)$$

From the received values of total grades, a vector of grades $F_{df}=(f_{df1}, f_{df2}, \ldots, f_{dfl})$ is formed.

After normalizing the vectors

$F_{st}=(f_{st1}, f_{st2}, \ldots, f_{stl})$

and

$F_{df}=(f_{df1}, f_{df2}, \ldots, f_{dfl})$,

we will obtain the probability vectors

$P_{sf}=(p_{sf1}, p_{sf2}, \ldots, p_{sfl})$

and

$P_{df}=(p_{df1}, p_{df2}, \ldots, p_{dfl})$,

with which this object of recognition can be attributed to each of the l reference classes, where

$$p_{cmi} = \frac{f_{cmi}}{\sum_{j=1}^{l} f_{cmj}}\ , \qquad (11)$$

$$p_{dfi} = \frac{f_{dfi}}{\sum_{j=1}^{l} f_{dfj}}. \qquad (12)$$

Thus, the results of the calculation of estimates based on static and dynamic information features were obtained, which must be combined and form a vector of the total normalized estimate $P_\Sigma = (p_{\Sigma 1}, p_{\Sigma 2}, \ldots, p_{\Sigma l})$, in which

$$p_{\Sigma i} = \frac{p_{sfi} \cdot p_{dfi}}{\sum_{j=1}^{l} p_{sfj} \cdot p_{dfj}}. \qquad (13)$$

As a result, a vector of probabilities with which this object of recognition can be assigned to each of the l reference classes is formed.

The accuracy and adequacy of the obtained estimates depends on the number of static and dynamic IFs taken into account, as well as on the number of measurements (observations) of dynamic features.

Therefore, in order to make a final decision about whether an object belongs to a certain class, it is advisable to provide not only the value of the vector P_Σ , but also the value of the vectors P_{df} and P_{sf}, as well as information about the number of static and dynamic IF and the number of measurements (observations) of the recognition object. If the P_{df} and P_{sf} estimate differ significantly, the system operator makes the final decision based on the estimate made on the basis of a larger number of input data.

Conclusions

1. When solving the tasks of classification and recognition of SORr, it is advisable to use an automated classification and recognition system, which consists of a knowledge representation subsystem, a subsystem for calculating information feature estimates, and a decision support subsystem.
2. The process of making a decision on the recognition of SORr requires the availability of a priori knowledge and a posteriori data about SORr.
3. Making a decision about whether an object or a source of information belongs to one or another class is carried out according to the considered method of calculating grades. At the same time, its distinguishing feature is that the recognition is based on the calculation of the degree of "similarity" (similarity coefficient) of the recognized object with objects whose classes are known.
4. To eliminate recognition errors associated with a violation of the synchronicity of the measurements of the dynamic IF values of reference objects and objects to be recognized, it is necessary to calculate the estimates of dynamic features taking into account possible time shifts.

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Ільницький А.І., Цуканов О.Ф.

Статичні та динамічні оцінки інформаційних знаків при розпізнаванні джерел та об’єктів спостереження в процесі радіомоніторингу

Проблематика. Сучасний стан і проблематика систем спостереження і радіомоніторингу України вимагають принципово нових підходів до підвищення їх ефективності та рівня інформатизації. При цьому під інформатизацією системи радіомоніторингу слід розуміти процес впровадження та застосування в різних областях їхньої діяльності методів та засобів збору, передачі, обробки, збереження і використання інформації з метою підвищення ефективності ведення радіомоніторингу та задоволення потреб національної безпеки на основі формування і використання інформаційних ресурсів.

Мета досліджень. Підвищення ефективності радіомоніторингу шляхом використання обчислення оцінок динамічних і статичних інформаційних ознак при розпізнаванні джерел та об'єктів радіовипромінювання і визначення їх фазового (оперативного) стану та рівня можливої небезпеки.

Методика реалізації. Розпізнавання ґрунтується на методі найменших квадратів шляхом обчисленні ступеня «подібності» (коефіцієнта подоби) розпізнаваного об'єкта з об'єктами, приналежність яких класам відома. Як досліджуваний, так і еталонні об'єкти представляються у вигляді сукупності значень інформаційних ознак різної природи, одні з яких є незмінними на всьому періоді спостереження, тобто статичні, а інші динамічне змінюються.

Результати досліджень. Запропоновано структуру автоматизованої системи класифікації і розпізнавання об'єктів спостереження й алгоритм розпізнавання на базі обчислення статичних і динамічних інформаційних ознак та коефіцієнта подоби.

Висновки. Відмінною ознакою прийняття рішення про приналежність об'єкта або джерела інформації тому або іншому класові ознакою є обчислення ступеня «подібності» (коефіцієнта подоби) розпізнаваного об'єкта з об'єктами, приналежність яких класам відома. Для усунення похибок розпізнавання, пов'язаних з порушенням синхронності вимірів значень динамічних інформаційних ознак еталонних об'єктів і об'єктів, що підлягають розпізнаванню, необхідно обчислення з урахуванням можливих часових зсувів.

***Ключові слова**: радіомоніторинг; метод; інформаційна ознака; розпізнавання; класифікація; оцінка; алгоритм; коефіцієнт подоби.*