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## SIMPLIFIED METHOD OF QUALITY ANALYSIS FOR LARGE OBJECTS PERIMETER MONITORING RADIOTECHNICAL SYSTEMS

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**Abstract.** Proposed a method that allows us to simplify calculations for the quality analysis of the large objects perimeter monitoring radiotechnical systems through the use of formal parameters for the dependence between parameters of monitoring system and the conditions of usage.

**Keywords:** radiolocation control systems; perimeters protection control; electronic devices; quality control.

### Introduction

Given the current situation related to the various political and economic aspects of society, when there is a real danger of terrorism against both public and to commercial structures, the problem of security of various objects has become one of the most pressing. The need for its solution has caused the rapid development of technology in this field, the development of an extensive range of tools and security equipment, including the creation and modernization of methods of providing perimeter security facilities [1–3].

However, the protection of the perimeters of large facilities (airports, oil depots, power installations, etc.) that should have limited access requires the solution of other problems caused by the great extent of their perimeters with different conditions for using tools and security systems. The use of traditional mathematical methods for calculating the influence of various factors on the quality of such systems is challenging due to their multi-parameter nonlinear dependence. Therefore, it is appropriate to develop simplified methods of quality control for the RADIOTECHNICAL systems for large objects perimeters on the specific conditions of use.

### The problem statement

In this article we provide a generalization of results for improving the quality of *large objects perimeter monitoring radiotechnical systems* (LOPMRS), conducted over the last few years, and examines the practical suggestions for their use.

### Features of LOPMRS construction

When addressing the issue of security as a large object means some organizational and production structure, located in a large area (with different terrain, vegetation, levels of electromagnetic fields,

etc.), and containing structures and buildings, which united by a common perimeter. The example of such an object is shown on fig. 1. To prevent unauthorized access to the object along the inner side of its perimeter are typically equipped with *radiotechnical access control stations* (RACS), joined together into one security system. To localize the site of violation, as well as the possibility of compensating the influence of the environment on the performance on RACS, the entire security perimeter is divided into a number of sections named *control zones*. Within each of these areas is set one (or several) RACS, indicating the fact of the presence of the offender.

Technically LOPMRS is a telemetry system for collecting, processing and presentation of information about the space along the inner perimeter of the object under control.

In general, the block diagram of the LOPMRS can be like that shown in fig. 2.

In order to identify a person or group of people (offenders), trying to make unauthorized entry to an object in the RACS can use sensors of various types. Type of sensor is determined by the physical phenomena that form the basis of their action: the infrared radiation of a biological object, the reflection of electromagnetic waves in the optical and radio-frequency ranges, the scattering of acoustic and electromagnetic waves, the change of magnetic or electrostatic field, etc.

Accordingly, RACS classified as radio-beamed, radio-wave, infrared, optical, acoustic, ultrasonic, etc [1 – 4].

The effectiveness of any RACS will be different under different conditions of their use. That is why the solution to the problem of identification intruder perimeter of a large object has a number of features [4 – 6].

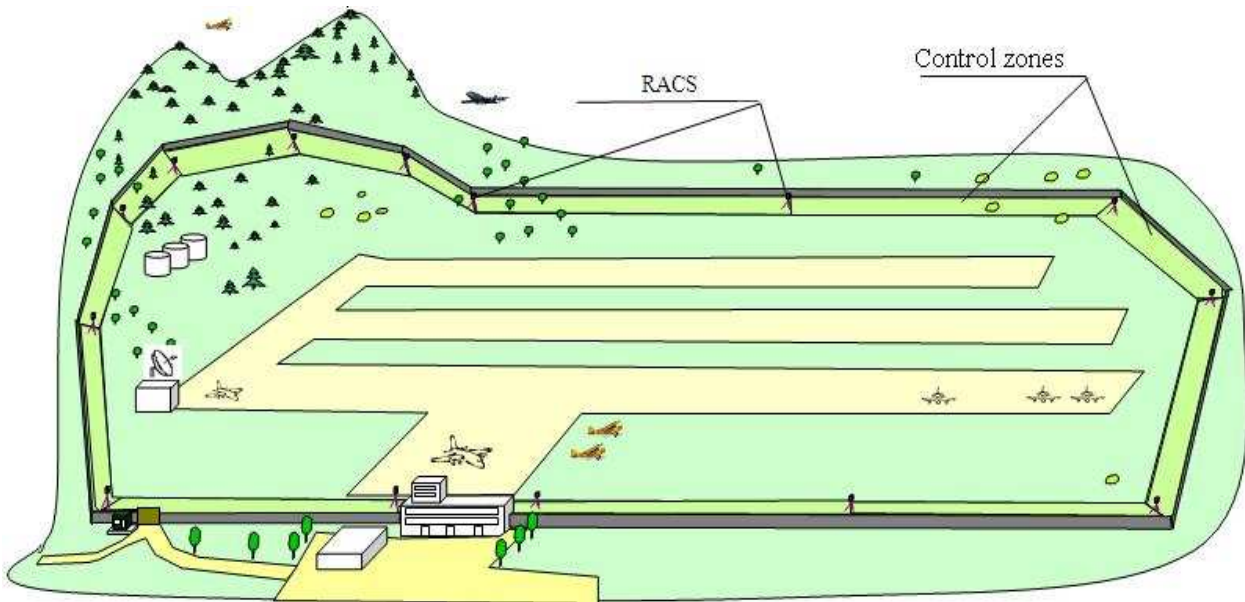


Fig. 1. Example of location of the radar system for the control of the perimeter of a large object

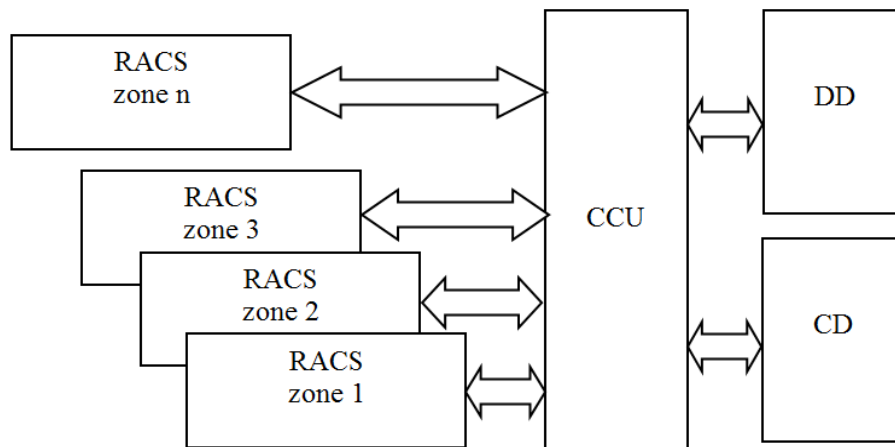


Fig. 2 Block diagram of the LOPMRS:

CCU – central control unit of the LOPMRS; DD – display device for system parameters visualization;  
CD – control device for warning and counteraction the violators

First of all, it is work in the near field (from a few to hundreds of meters), allowing to localize the site of violation on the protected perimeter of the object. In addition, it is necessary to form a narrow radiation pattern without side lobes, which reduces the likelihood of false positives and thus increase the effectiveness of the security system. As well important is the lack of dead zones near the reception and transmission antennas, due to the need to ensure continuity of the created field along the perimeter of the protected throughout the entire volume. In addition, there are some limitations on the power and frequency characteristics of the RACS, which are determined by their noise immunity, resistance to electronic countermeasures, as well as the possibility of exposure of personnel providing security facility.

The lower limit of sensitivity RACS receiving path is usually defined so as to allow selection of the interference of animals, birds and underlying vegetation. With the same purpose, often used adaptive processing of information received.

As was shown in [7; 8], the quality of the functioning of the RACS are strongly influenced not only the parameters of devices themselves, but also the conditions of their placement, as well as the surface roughness inside the control areas.

The efficiency of RACS essentially depends on a number of factors, conditions of use: geological (terrain type and chemical composition of the soil, water space, seismic activity), biological (plants, animals, birds, insects), climate (wind, dust, sand, rain, fog, solar radiation, temperature, storm events, seasonal events, etc.), electromagnetic fields and

radiation, acoustic, vibration, and light levels of radioactivity, etc.

Given that all these factors in a real object in general depend on the geographical coordinates for efficient LOPMRS feasible and promising is to use the technology and methods of *geoinformation systems* (GIS) [9; 10]. The GIS-based data processing is based on mapping the space images of the protected facility, with subsequent refinement for each control area on the perimeter of the object (fig. 3). With the location of the protected object, using a digital map of the area we can get information about the profile of the perimeter of the object, and the characteristics of each control zone. Further, having a model of geographic information on the specific area and information about the capabilities of the existing RACS, we could effectively solve the optimization problem (discrete choice of the RACS with the conditions of their use age) for each control zone guarding the perimeter [11; 12].

### Quality control of the LOPMRS

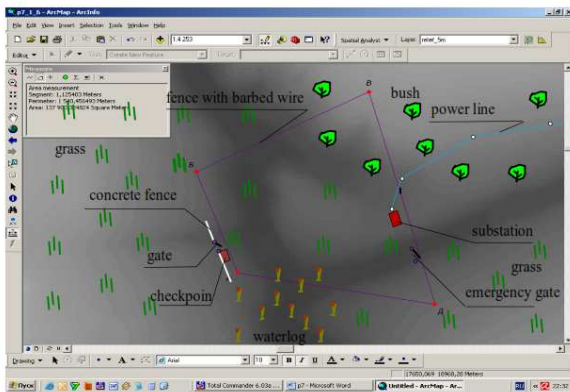
We call the quality of the LOPMRS the set of properties, resulting in their ability to perform specified functions under certain usage conditions; the

quality vector can be written as a function of two multi-parametric variables:

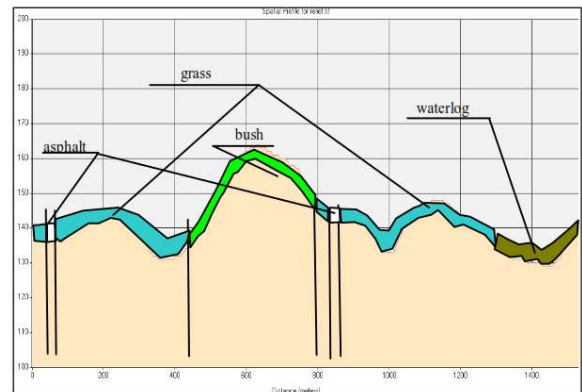
$$\vec{K} = f(\vec{T}_q, \vec{G}_\mu). \tag{1}$$

The variable  $\vec{T}_q$  defines dependence of the quality of a particular LOPMRS from the technological features of its creation. It depends on the principle of primary conversion of the physical parameters of the control object, the selected circuit solutions for components and assemblies of the LOPMRS, their technological performance, etc. Today, there are a number of methods for the evaluation of the quality of the technological content of radio systems, involving the use of computers [13; 14].

The second variable  $\vec{G}_\mu$  defines characteristics and usage conditions of the LOPMRS an gives the possibility to assess its impact on the quality of external destabilizing factors. The presence of this variable allows you to assess the quality of the system in a specific conditions.



a



b

Fig. 3. The use of GIS technology to build the perimeter of the object by coordinates (a) and his profile (b) on a digital terrain map

To create LOPMRS, optimal with respect to the specific application, it is expected to carry out a discrete selection of a particular set of variants of its construction  $\vec{M}_\mu$  if  $\mu = 1, 2, 3, \dots, m$ .

For the implementation of a discrete choice a comparative assessment of the system quality by the set of criteria should be made. It should be understood that each embodiment of the system has its own dependence on various factors, usage conditions  $P_j$  with  $j = 1, 2, 3, \dots, n$ . Considering each usage con-

dition each  $i$ -th quality criteria  $k_{i,j}$  with  $i = 1, 2, 3, \dots, q$  could be defined as

$$k_{i,j} = f(P_j), \tag{2}$$

for each case of the system  $\vec{M}_\mu$ .

The variable  $\vec{G}_\mu$  determined depending on the selected quality criteria as

$$\vec{G}_\mu = f(k_{i,j}), \tag{3}$$

However, given that the function  $k_{i,j}$  in the general case, are nonlinear the function  $\bar{G}_\mu$  is also nonlinear. Therefore, optimization of the LOPMRS according to usage conditions by physical measurement of the parameters of these factors is a challenging problem.

**The formalization of quality assessment of the LOPMRS**

To formalize the process of assessing the quality of LOPMRS we assume that there is  $m$  variants of the system are able to solve the task, and for all systems defined in the numerical form of the dependence of quality criteria  $k_{i,j}$  on the factors of usage conditions  $P_j$  (fig. 4). There are also defined a set of threshold values for each criterion of quality for all the usage factors, within which the system should operate.

Fig. 4, a and shows the dependency of quality criteria of the system from the first factor of usage conditions. It can be seen that the system satisfies the condition (8) for the first criterion in the range of the first factor of the usage conditions from  $P_{1 \min}$  to  $P_{1,2}$ , of second factor from  $P_{1 \min}$  to  $P_{1,3}$ , of 3<sup>rd</sup> from  $P_{1,1}$  to  $P_{1 \max}$ .

Fig. 4, b shows the dependence of the quality criteria of the same system from the second factor of usage conditions. The system is operable on the entire range of second factor of usage conditions from  $P_{2 \min}$  to  $P_{2 \max}$  for all criteria.

Fig. 4, c shows in the same system according to  $j$ -th factor of usage conditions. The system satisfies the condition (8) on the first criterion in the variation range of  $j$ -th factor of usage conditions from  $P_{j,1}$  to  $P_{j \max}$ , of second factor from  $P_{j,2}$  to  $P_{j \max}$ , of 3<sup>rd</sup> from  $P_{j \min}$  to  $P_{j \max}$ .

Generally it can be assumed that each case of the system for a specific control object depending on the construction features will have their own quality criteria depending on factors of usage conditions.

Obviously, to describe non-linear functions for functional  $k_{i,j}$  of the quality criteria for all  $m$  cases of the system design of all  $n$  factors of usage conditions is quite a challenging problem. Therefore, when creating RACS, to compare the quality of different systems, mainly used heuristic methods based on intuition and experience of the professional designers.

To simplify the process of assessing the quality we propose the technique of formalization of quality criteria [15; 16], based on the use of formal criteria as the ability of the system to provide the necessary technical and economic characteristics within certain ranges of changes in the factors of usage conditions  $\Delta P_j$ . This formalization is achieved by replacing the physical values of the factor  $P_j$  on the discrete values of this factor (fig. 5). Thus the formal quality criteria  $N_{\eta j}$  will be a numerical sequence of natural numbers from 1 to  $n$ .

To form the row the selected range  $\Delta P_j$  of the  $j$ -th factor of usage conditions of the system from the start value  $P_{\min}$  to the finish value  $P_{\max}$  is divided into several sub-ranges  $\Delta P_k$ , in each the real value of the factor  $P_j$  is denoted by  $\eta=1, 2, 3, \dots, n$ .

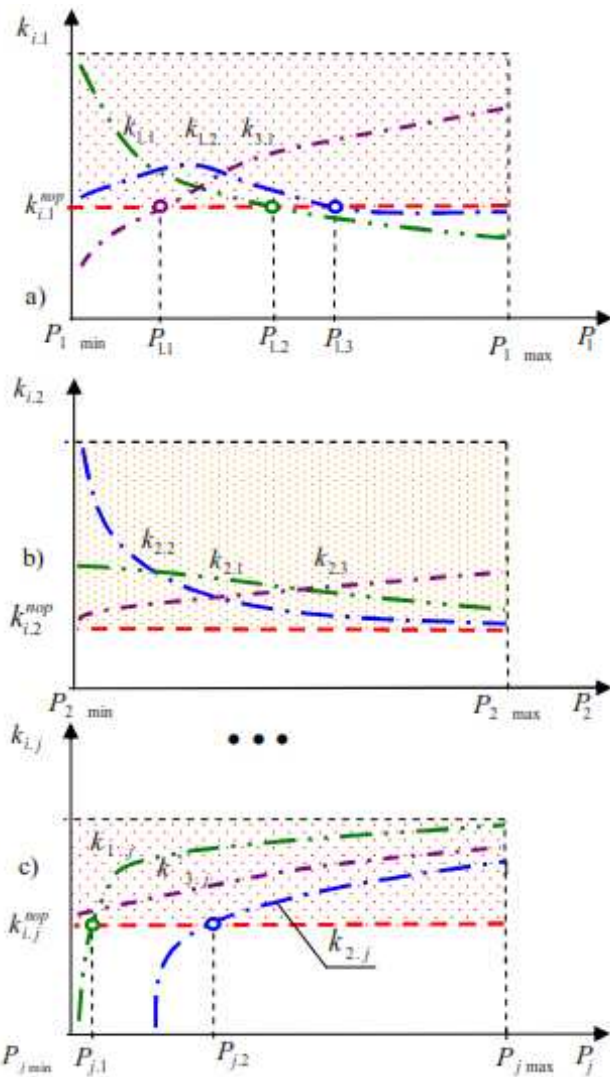


Fig. 4. The dependence of the quality criteria on the factors of usage conditions



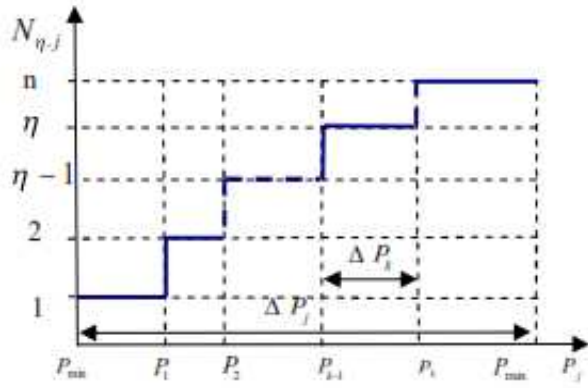


Fig. 5. The dependence of the formal quality criteria on the factors of usage conditions

Specific values of the formal quality criteria  $N_{\eta,j}$  for each  $\bar{M}_\mu$  are denoted by  $A_{\mu,j}$ , and are determined for each quality criteria as boundary values of the corresponding criteria for each discrete sub-range of the factor  $\Delta P_k$  range. The information about formal quality criteria for  $m$  cases of the system can be represented in table 1.

Table 1

Formal quality criteria of the LOPMRS

$N_{\eta,j}$	$N_{1,j}$	$N_{2,j}$	...	$N_{\eta,n}$
$M_\mu$				
1	$A_{1.1}$	$A_{1.2}$	...	$A_{1.n}$
2	$A_{2.1}$	$A_{2.2}$	...	$A_{2.n}$
3	$A_{3.1}$	$A_{3.2}$	...	$A_{3.n}$
...	...	...	...	...
$m$	$A_{m.1}$	$A_{m.2}$	...	$A_{m.n}$

Data from table 1 could be represented as matrix of the formal quality criteria:

$$\bar{A} = \{ A_{m,n} \} = \begin{Bmatrix} A_{1.1} & A_{1.2} & \dots & A_{1.n} \\ A_{2.1} & A_{2.2} & \dots & A_{2.n} \\ \dots & \dots & \dots & \dots \\ A_{m.1} & A_{m.2} & \dots & A_{m.n} \end{Bmatrix}. \quad (6)$$

Similarly, given a formalized performance defined in accordance with fig. 5 preset value of a range of factors usage conditions  $F_j = f(\Delta P_j)$ , to be met by the selected system (table 2):

Table 2

Formalized value ranges for usage condition of the LOPMRS

$F_j$	$F_1$	$F_2$	...	$F_n$
$\Delta P_j$	$B_1$	$B_2$	...	$B_n$

The data from table 2 could be represented as a matrix row of the formal quality criteria, which determines the real system usage conditions:

$$\bar{B} = \{ B_n \} = \{ B_1 B_2 \dots B_n \}. \quad (7)$$

As one can see the dimension of the row of the matrix (6) corresponds to the dimension of the row (7). Thus, based on [14], we could state that a sufficient condition for synthesis (discrete choice) of the LOPMRS is that every formal quality criteria of the chosen system is greater than corresponding formal quality criteria of the usage conditions  $\{A_{m,n}\} \geq \{B_n\}$ . Maximal efficiency of the system usage under given constraints  $E_{max}$  is obtained when corresponding values of the matrix elements  $\{A_{m,n}\}$  and  $\{B_n\}$  tends to each other  $\|\{A_{m,n}\} - \{B_n\}\|$ .

Thus, the objective function of optimal discrete choice of LOPMRS depending on the actual conditions is an expression that specifies the maximum efficiency of the system under given constraints on the parameters of the usage conditions factors:

$$\bar{\Phi} = \bar{E}_{max} = \begin{cases} \{A_{m,n}\} \geq \{B_n\}; \\ \|\{A_{m,n}\} - \{B_n\}\|, \end{cases} \quad (8)$$

$$\text{here } \begin{cases} P_{j \min} \leq P_j \leq P_{j \max}; \\ P_j = P'_j. \end{cases}$$

Determining the structure of the system with maximum efficiency is a solution of the LOPMRS optimization problem for specific application conditions.

**Conclusions**

The use of formal criteria for assessing the quality of LOPMRS greatly simplifies the process of carrying out a comparative analysis with multivariate discrete choice and performance optimization. This allows us to use known methods of mathematical analysis and automate the process of synthesis.

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**К. В. Колісник, А. В. Кіпенський, Є. І. Сокол. Спрощений метод аналізу якості радіолокаційних систем контролю периметрів великих об'єктів**

Запропоновано метод аналізу якості радіолокаційних систем контролю периметрів великих об'єктів, який використовує формалізовані показники, завдяки чому вдалося спростити розрахунки залежності параметрів засобів, що використовуються, від факторів умов застосування, та застосування звичайних методів математичного аналізу.

**Ключові слова:** радіолокаційні системи контролю, засоби контролю периметра, електронні пристрої, контроль якості.

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**К. В. Колесник, А. В. Кипенский, Е. И. Сокол. Упрощенный метод анализа качества радиолокационных систем контроля периметров крупных объектов**

Предложен метод анализа качества радиолокационных систем контроля периметров крупных объектов, основанный на использовании формализованных показателей, что позволяет упростить вычисления зависимостей параметров используемых средств от факторов условий их применения, и делает возможным использование методов математического анализа.

**Ключевые слова:** радиолокационные системы контроля, средства контроля периметра, электронные устройства, контроль качества.

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