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THEORETICAL BASIC CONCEPTS FOR FORMATION OF THE CRITERIA FOR MEASUREMENT SIGNALS SYNTHESIS OPTIMALITY FOR CONTROL OF COMPLEX RADIO ENGINEERING SYSTEMS TECHNICAL STATUS

In the article the theoretical basic concepts of the substantiation of the optimum measuring signals synthesis criteria for control of parameters of systems and elements of complex radio engineering systems (including unmanned and manned aircraft, samples of guided missile armament, radar stations, etc.) are proposed and studied. The analysis of known methods of controlling the technical state of complex radio engineering systems based on the investigation of their dynamic characteristics has been carried out. The results of such analysis allow achieving the goal – to substantiate the criteria for calculating the parameters of the optimal input measuring signal for controlling the technical state of complex radio engineering systems. It is shown that with a sufficiently small impedance of the input signal, practically all measuring signals are equivalent. Therefore, the task of selecting the parameters of an optimal measuring signal is relevant only for a rather large obstacle. The main criteria of optimization of parameters of incoming measurement signals, which include the maximum of the information index, the minimum of the mean square error, the maximum of sensitivity are considered. It is substantiated that the criteria considered are reduced to the one that is proposed to be used to find the parameters of the optimal input measurement signal used to control the technical state of systems and elements of complex radio systems at the exploitation stage.

Keywords*: the control radio engineering systems, the measurement signals, the criteria of optimization, the technical state.*

Formulation of the problem

The results of recent armed conflicts in the world (especially in Syria, Iraq and Libya in the course of the operations against the Islamic state) and the holding of the anti-terrorist operation in the east of Ukraine show an increase in the role of complex radio systems (RTS) in solving problems at tactical and operational tactical levels. In the article the term complex RTS is understood as complex examples of weapons and military equipment, including unmanned and manned aircraft, in conjunction with their ground control, navigation and guidance systems, samples of guided missile weapons with appropriate ground support systems, radar stations, etc., for the operation of which radio signals are used (radio waves for the transmission of information and energy).

In this case, for instance, unmanned aerial vehicles (UAVs) were used to carry out missions for misleading the enemy, intelligence and fire damage, that is, they were multifunctional (fig. 1) and were used to carry out the most dangerous for manned aviation missions.

However, the lack of an effective system of control and diagnostics of the UAVs technical state led to numerous "non-combat" losses of devices due to untimely detection of failures. Consequently, the scientific task of measuring the synthesis of signals for the control (determination) of the UAVs technical state during the operation phase in order to increase their reliability and combat capability is relevant.

Fig. 1. Auxiliary UAV equipment

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The purpose of the article is to substantiate the criteria for calculating the parameters of the optimal input measurement signal for controlling the technical status of complex radio engineering systems (based on the example of an unmanned aircraft) in the conditions of the additive Gaussian interference.

Analysis of recent research and publications

The basis of the UAVs technical state control is the study of their dynamic characteristics [1–8] using the generalized scheme shown in fig. 2. According to this scheme, the UAV input is influenced by the known measuring (testing or stimulating) signal $u(t)$, which is generated by the test signal generator G and has certain characteristics. Under the influence of the input measurement signal $u(t)$, an output signal $y(t)$ (feedback signal) or a certain form reaction depending on the form of the input signal and the parameters of the UAV [9–12] is generated at the output of the UAV. The input measurement signal $u(t)$ and the UAV output $y(t)$ signal are fed into the analyzer A, by which the parameters of the apparatus q_j, $j=\overline{1,N}$, are determined, where N is the number of control parameters of the UAV, or posteriori parameters, z_i, $i=\overline{1,M}$; M is the number of values of the i parameter obtained after the control of the UAV (a posteriori number of control parameters); those values allow to determine the technical state of the apparatus.

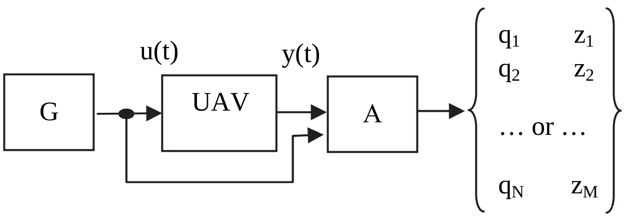

Fig. 2. Control structural diagram

Providing the control of the UAV technical status, methods and techniques of conducting control are of great importance [13–15]. Therefore, the synthesis of optimal input measurement signals for studying the dynamic characteristics of the UAVs by their technical conditions during their operation is an actual scientific problem.

Presenting main material

Consider UAV, the mathematical operator (functional) $F(\{u\})$ of which determines its response $y(t)$ at time t to the input measurement signal $u(t)$. The operator $F(\{u\})$ depends on the control parameters of the UAV q_j and in general can be nonlinear. Consequently, the reaction of the apparatus is a function of the parameters q_j and functional of the input measurement signal $u(t)$: $Y=y(t,\ q_j,\ \{u\})$. If there is an additive interference $\xi(t)$, the output signal of the device $x(t)$ will equal $x(t)=y(t)+\xi(t)$. Denote the nominal values of the parameters q_j through q_{jn}. At small deviations of the UAV q_j parameters from the nominal values, the signal of nonconformity at the output $\Delta x = x - x_n$ depending on the control time can be written as

$$\Delta x(t)=\sum_{j=1}^{N} d_j(t,\ \{u\})q_j+\xi(t), \tag{1}$$

where $d_j(t,\ \{u\})=\left.\frac{\partial \Delta y}{\partial q_j}\right|_{q_j=q_{jn}}$; $\Delta y = y - y_n$ the failure of the reaction (signal-response) of the UAV to the input measurement signal $u(t)$; y, y_n – reaction (signal-response) of the UAV and the nominal value of the reaction (signal-response) respectively.

Parameters of UAV control q_j (or parameter errors of the apparatus $\Delta q_j = q_j - q_{jn}$) are statistically dependent in the general case. But it must be borne in mind that the presence of dependent parameters leads to excessive control that is to reduction of the efficiency and the increase of economic costs. Therefore, when substantiating the control methods, we will assume that the control UAV parameters are stationary and uncorrelated with interference. According to this condition, we denote the correlation matrix of values Δq_j through $R_{qij} < \Delta q_i\ \Delta q_j >$, where the sign $<\ >$ means the mean value for the ensemble of quantities Δq_j. Since the matrix R_{qij} is positively definite ($\sum_{\substack{i=1,\ j=1 \\ i\neq j}}^{N} R_{qij}\xi_i\xi_j > 0$ for any $\xi_j \neq 0$) and symmetric ($R_{qij} = R_{qji}$), then by linear transformations we will proceed to new variables $\Delta q_j^{'}$ that will be statistically independent and their variances will be equal to one, that is $R'_{qij} < \Delta q'_i \; \Delta q'_j >= \delta_{ij}$, where δ_{ij} is Kronecker symbol [5]. Then we write the relation (1) for the independent variables $\Delta q'_j$ as

$$\Delta x(t) = \sum_{j=1}^{N} a_j(t, \{u\}) \Delta q'_j + \xi(t), \qquad (2)$$

where $a_j(t, \{u\}) = \left. \frac{\partial \Delta x}{\partial q'_j} \right|_{q'_j = q'_{jn}}$ are the independent control parameters of the UAV.

If necessary, with the help of the correlation (2) it is possible to return to the initial statistically dependent variables. The corroboration also applies to the variables q_j, which can also be considered statistically independent in subsequent calculations.

Often, the purpose of UAV control is to measure not the parameters q_j themselves, but some function from these parameters $Y = f(q_1, q_2, ..., q_N)$, that is, the determination of the technical state of the system by the generalized parameter. An example of such a function can be any value that determines the quantitative estimate of the stability of the apparatus. Denote the values whose values are to be obtained as a result of control (a posteriori value of the parameters), through z_i. Although the values of the parameters z_i (for M < N) carry less information about the system than the complete set of parameters z_i, in most cases, a successful selection of relatively small number of a posteriori parameters is considered sufficient for a relatively complete evaluation of the UAV quality, and, on the other hand, can greatly simplify its control. In the general case, the parameters z_i may coincide with q_j. Therefore, the completeness of UAV control depends on the number of parameters that are not subject to control, that is $Pa = M/N$. As a rule, when choosing the control parameters of a UAV it is necessary to seek conditions $Pa \to 1$ [6].

At small deviations Δq_j of the UAV parameters q_j from the nominal numbers q_{jn} values z_i are correlated with these parameters by linear dependence

$$z_i = \sum_{j=1}^{N} b_{ij} q_j \,, \qquad (3)$$

where, $i = \overline{1, M}$, $j = \overline{1, N}$, $M \le N$; b_{ij} are the elements of the coefficients matrix, which depends on the characteristics of the UAV.

Note that in the general case, the elements of the matrix b_{ij} may not have the inverse (this will necessarily be when $N \ne M$). The values z_i can be taken ort ho normal by random variables, $< z_i \; z_j >= \delta_{ij}$.

The purpose of UAV control is to determine the values z_i depending on the values of the parameters q_j (or non-compliance parameters $\Delta x(t)$). Since $\Delta x(t)$ is a functional of the input measurement signal $u(t)$, the values z_i will depend, on the one hand, on the method of control, and on the other hand, on the parameters of the measuring signal $u(t)$. Different criteria will lead to various optimal measurement signals $u_{opt}(t)$. This raises the question which of the criteria should be preferred. We note that with a sufficiently small interference, almost all measuring signals are equivalent, since in this case, as can be seen from (2), the knowledge of the functional $\Delta x(t)$ even at fixed moments of time makes it possible to determine accurately the values of the independent parameters $\Delta q'_j$, and, consequently, the quantities z_i. To do this, we need to solve the system of equations (2), which is written for different time points relative to the quantities $\Delta q'_j$. Therefore, the task of choosing the parameters of the optimal measurement signal of the UAV is relevant only for a rather large interference. In other words, the UAV measurement signal, which will be optimal for a large interference, will also be optimal for any interference value, because for a small interference, almost all of the UAV measurement signals are optimal in one or another way.

Consider the main criteria for optimizing the parameters of the UAV input measurement signals, which we shall refer to as the maximum of the information index, the minimum of the mean square error, the maximum of sensitivity, and substantiate that for large interference all of these criteria are reduced to one. This criterion can be accepted as universal for any interference.

Information index. Assume that the output signal of the UAV is measured at the time points $\{t_1, t_2, ..., t_m\}$, m is the number of moments of the time of parameter z_i measurement. To simplify further calculations, we will issue vector notation.

Let the vector Q denote the set of control parameters of the UAV: $Q = \{q_1, q_2, ..., q_N\}$; vector Z is a set of values: $Z = \{z_1, z_2, ..., z_M\}$, whose values are determined by the results of control of the UAV after the influence of the input measurement signal $u(t)$ on it; the vector ΔX is a set of values of the output UAV signal $\Delta x(t)$: $\Delta X = \{\Delta x(t_1), \Delta x(t_2), ..., \Delta x(t_m)\}$; respectively the vector of interference is

$\xi = \{\xi(t_1),\ \xi(t_2),\ ...,\ \xi(t_m)\}$. Then equations (2) and (3) are written as:

$$\Delta X = AQ + \xi; \quad (4)$$

$$Z = BQ, \quad (5)$$

where A is a matrix with elements $a_{kj} = a_j(t_k)$, $k = \overline{1, m}$; B is a matrix with elements b_{ij}, while, since $< z_i\ z_j >= \delta_{ij}$, matrix B satisfies the correlation

$$BB^T = E, \quad (6)$$

where B^T is the transposed matrix; E is a unit matrix.

In order to carry out arithmetic operations on matrices, we introduce vectors $\zeta = \{\Delta y(t_1),\ \Delta y(t_2),\ ...,\ \Delta y(t_m);\ z_1,\ z_2,\ ...,\ z_M\}$ and $\tilde{\xi} = \left\{\xi(t_1),\ \xi(t_2),\ ...,\ \xi(t_m);\ \underbrace{0,\ ...,\ 0}_{M}\right\}$ whose size is m + M and the matrix $C = \begin{pmatrix} A & 0 \\ 0 & B \end{pmatrix}$. Then from (4) and (5), we obtain $\zeta = CQ + \tilde{\xi}$, and the mutual information between the values ΔX and Z equals

$$I(\Delta X,\ Z) = \int_0^{m+M}\int_0^{m+M} p(\Delta X,\ Z)\log_2 \frac{p(\Delta X,\ Z)}{p(Z)p(\Delta X)} dZ d\Delta X = H(\Delta X) + H(Z) - H(\zeta),$$

where $p(\Delta X,\ Z)$ is the simultaneous probability of occurrence of quantities $\Delta X,\ Z$; $p(Z), p(\Delta X)$ is the probability of the appearance of quantities $Z,\ \Delta X$ respectively; $H(\Delta X),\ H(Z),\ H(\zeta)$ the entropy of the quantities $\Delta X,\ Z,\ \zeta$ respectively, which are determined by the formulas:

$$H(\Delta X) = -\int_0^{m+M} p(\Delta X)\log_2 p(\Delta X) d\Delta X;$$

$$H(Z) = -\int_0^{m+M} p(Z)\log_2 p(Z) dZ;$$

$$H(\zeta) = -\int_0^{m+M} p(\zeta)\log_2 p(\zeta) d\zeta,$$

where $p(\zeta)$ is the probability of appearance of the quantity ζ.

If the quantities Q are distributed according to the normal law, then the values $\Delta X,\ Z,\ \zeta$ according to (4–6) will also be distributed according to the normal law. Denote the correlation matrices of these quantities, respectively

$$(R_{\Delta X})_{ij} =< \Delta X_i\ \Delta X_j >;$$

$$(R_Z)_{ij} =< Z_i\ Z_j >;$$

$$(R_\zeta)_{ij} =< \zeta_i\ \zeta_j >.$$

If σ^2 is a dispersion of the interference, then these correlation matrices, taking into account (4–6), are written as:

$$R_{\Delta X} = AA^T + \sigma^2 E;$$

$$R_Z = BB^T = E;$$

$$R_\zeta = \begin{pmatrix} R_{\Delta X} & AB^T \\ BA^T & E \end{pmatrix}.$$

Using the well-known expressions for the entropy of a normal law [4], we obtain

$$I(\Delta X,\ Z) = \frac{1}{2}\log_2 \frac{\det R_{\Delta X}}{\det R_\zeta}.$$

Applying the Gauss formula for calculation $\det R_\zeta$, we obtain

$$\det R_\zeta = \det R_{\Delta X} \cdot \det\left(E - BA^T R_{\Delta X}^{-1} AB^T\right),$$

and finally for the function $I(\Delta X,\ Z)$, we have

$$I(\Delta X,\ Z) = -\frac{1}{2}\log_2 \det\left(E - BA^T R_{\Delta X}^{-1} AB^T\right). \quad (7)$$

For a beg interference

$$R_{\Delta X}^{-1} \approx \frac{E}{\sigma^2} + 0\left(\frac{1}{\sigma^4}\right), \quad (8)$$

so we obtain from (7):

$$I(\Delta X,\ Z) = -\frac{1}{2}\log_2\left[1 - \frac{1}{\sigma^2}Sp\left(BA^T AB^T\right)\right] \approx$$

$$\approx \frac{1}{2\sigma^2}Sp\left(BA^T AB^T\right) = \frac{1}{2\sigma^2}\sum_{k=1}^{m}\sum_{i=1}^{M}\left(\sum_{j=1}^{N} b_{ij}a_{kj}\right)^2.$$

Denote $F(\{u\}) = \sum_{k,i}\left(\sum_j b_{ij}a_{kj}(\{u\})\right)^2$. An information criterion for choosing an optimal measurement signal $u_{opt}(t)$, that is, a signal that allows you to obtain maximum information about the magnitudes z_i, reduces to the condition

$$F(\{u_{opt}\}) = \max_{\{u\}} F(\{u\}). \quad (9)$$

Indicator. Denote by means of ε the mean-square error (MSE) of the evaluation z_i^o of magnitude z_i:

$$\varepsilon = \sum_{i=1}^{M} < \left(z_i - z_i^o\right)^2 >.$$

As you know, the minimum value of the MSE evaluation z_i^o is provided if z_i^o is applied as posterior averaged value z_i,

$$z_i^o = \int_{k=1}^{m} z_{ik} p\left(Z \middle| \Delta X\right) dz ,$$

where $p\left(Z \middle| \Delta X\right) = p\left(Z, \Delta X\right) / p\left(\Delta X\right)$;

$$p\left(Z, \Delta X\right) \equiv p\left(\zeta\right) = \left(2\pi\right)^{-(m+M)/2} \left|\det R_{\zeta}\right|^{-1/2} \times$$

$$\times \exp\left[-\frac{1}{2}\left(\zeta R_{\zeta}^{-1} \zeta\right)\right];$$

$$p\left(\Delta X\right) = \left(2\pi\right)^{-m/2} \left|\det R_{\Delta X}\right|^{-1/2} \exp\left[-\frac{1}{2}\left(\Delta X R_{\Delta X}^{-1} \Delta X\right)\right].$$

After the calculations the value $\rho\left(Z \middle| \Delta X\right)$ we obtain

$$\varepsilon = \sum_{i=1}^{M} < \Delta z_i^2 > = \sum_{i=1}^{M} H_{ii} = M - Sp\left(BA^T R_{\Delta X}^{-1} AB^T\right).$$

We will determine the optimal signal $u_{opt}\left(t\right)$ of the UAV, which minimizes the MSE ε of the value z_i^o, from the condition

$$\varepsilon_{min}\left(\left\{u_{opt}\right\}\right) = \min_{\{u\}} \varepsilon\left(\left\{u_{opt}\right\}\right). \quad (10)$$

For a sufficiently big interference, taking into account (8), the formula (10), which determines the parameters of the optimal measurement signal $u_{opt}\left(t\right)$ of the UAV, takes the form

$$\varepsilon_{min}\left(\left\{u_{opt}\right\}\right) = M - \frac{1}{\sigma^2} \max_{\{u\}} Sp\left(BA^T AB^T\right), \quad (11)$$

which is equivalent to the correlation (9).

Indicator of sensitivity. Let us return to (2–3) and calculate the derivative of the value $\Delta y\left(t\right)$ in the direction of the normal to the hyper plane $z_i = const$, that is, the coefficient of sensitivity of the value $\Delta y\left(t\right)$ in relation to the change in magnitude z_i. In the coordinates $\left\{q_1, q_2, ..., q_N\right\}$ of the magnitudes $a_j\left(t\right)$ are the components of the gradient of the function $\Delta y\left(t\right)$: $\nabla\left[\Delta y\left(t\right)\right] = \left\{a_1\left(t\right), a_2\left(t\right), ..., a_N\left(t\right)\right\}$. According to (6), the values b_{ij} are the components of the unit vector of the normal to the hyper plane $z_i = const$: $n_i = \left\{b_{i1}, b_{i2}, ..., b_{iN}\right\}$. Therefore, the derivative function $\Delta y\left(t\right)$ in the direction of the normal n_i is equal to the scalar multiplication

$$\frac{\partial \Delta y}{\partial z_i} = \left[n_i \nabla\left(\Delta y\right)\right] = \sum_{j=1}^{N} b_{ij} a_j\left(t\right).$$

Denote this derivative through $B_i\left(t\right)$: $B_i\left(t\right) = \sum_{j=1}^{N} b_{ij} a_j\left(t\right)$.

We introduce the mean-square sensitivity, which is determined by all the results of measurements and by all values z_i by the formula.

$$S = \sum_{k=1}^{m} \sum_{i=1}^{M} B_i^2\left(t_k\right).$$

Then for the optimal input signal of the $u_{opt}\left(t\right)$ UAV, which provides the maximum value of the mean-square sensitivity, we write

$$S\left(\left\{u_{opt}\right\}\right) = \max_{\{u\}} S\left(\left\{u\right\}\right). \quad (12)$$

Conclusions

The analysis shows that the criteria for maximum information, of the minimum value of the mean square error and the maximum mean square sensitivity for a sufficiently big interference are reduced to a single criterion for determining the optimal input measurement signal $u_{opt}\left(t\right)$ of the UAV:

$$F\left(\left\{u_{opt}\right\}\right) = \max_{\{u\}} F\left(\left\{u\right\}\right) = \max_{\{u\}} \sum_{k=1}^{m} \sum_{i=1}^{M} B_i^2\left(t_k, \left\{u\right\}\right),$$

where $B_i\left(t_k, \left\{u\right\}\right) = \sum_{j=1}^{N} \frac{\partial z_i}{\partial q_j} \cdot \frac{\partial \Delta y}{\partial q_j} = \sum_{j=1}^{N} b_{ij} a_j\left(t_k, \left\{u\right\}\right)$.

Since, for a small obstacle, the measurement signal generating a non-singular matrix $a_j\left(t_k\right)$ is optimal (this condition is necessary for solving the system of equations (2) with $\xi \to 0$), then the signal obtained, for example, by the criterion of the maximum value of the information index (9), will be optimal. This allows applying criterion (9) to determine the parameters of the optimal UAV input signal for arbitrary interference.

Note that when continuously measuring the signal at the output of the UAV, the sum at all points t_k can be replaced by the integral over the control time. In this case, the functional $F\left(\left\{u\right\}\right)$ becomes functional

$$F_1\left(\left\{u\right\}\right) = \int_0^T \sum_{i=1}^{M} B_i^2\left(t, \left\{u\right\}\right) dt.$$

As shown above, provided that the matrix b_{ij} has an inverse (6), the equalities $B^T = B^{-1}$ and $B^T B = E$ are satisfied. At the same time $Sp\left(BA^T AB^T\right) = Sp\left(A^T A\right)$, and the functional F is a little simpler:

$$F = \sum_{k=1}^{m} \sum_{j=1}^{N} a_j^2\left(t_k, \left\{u\right\}\right).$$

On the other hand, it can be seen from (2) that the mean square value of the output signal of the UAV is equal to:

$$\sum_{k=1}^{m} < \left[\Delta x\left(t_k\right)\right]^2 > = \sum_{k=1}^{m}\sum_{j=1}^{N} a_j^2\left(t_k\right) + N\sigma^2,$$

that is, the functional F is the mean square value of the useful signal at the output of the apparatus. If the parameters z_i do not depend on all the parameters q_j (the matrix b_{ij} in this case will not have a reverse), then criterion (9) includes only the sensitivity coefficients of the parameters q_j influencing the magnitudes z_i, and the last part of the output signal, which depends on other random parameters q_j, actually is interference. Then criterion (9) maximizes only the useful (informational) part of the output signal.

Thus, in the article we have investigated the main criteria of optimization of measurement signals of measuring devices (generators, calibrators, control and control equipment, etc.), which are used for controlling the parameters of complex radio systems on the example of unmanned aerial vehicles during the operation phase. It is substantiated that in the presence of an additive Gaussian interference of sufficiently high level, the considered criteria are reduced to a single one. This criterion is proposed to be used to find the parameters of an optimal input measuring signal for controlling the technical state of unmanned aerial vehicles. The obtained results allow spreading the methodology of synthesis of the measuring signal to control the technical state of unmanned aerial vehicles on any sample of complex radio engineering systems.

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ТЕОРЕТИЧНІ ОСНОВИ ФОРМУВАННЯ КРИТЕРІЇВ ОПТИМАЛЬНОСТІ СИНТЕЗУ ВИМІРЮВАЛЬНИХ СИГНАЛІВ ДЛЯ КОНТРОЛЮ ТЕХНІЧНОГО СТАНУ СКЛАДНИХ РАДІОТЕХНІЧНИХ СИСТЕМ

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У статті запропоновані та досліджені теоретичні основи обґрунтування критеріїв синтезу оптимальних вимірювальних сигналів для контролю параметрів систем і елементів складних радіотехнічних систем (у тому числі безпілотних і пілотованих літальних апаратів, зразків керованого ракетного озброєння, радіолокаційних станцій тощо). Проведено аналіз відомих методів контролю технічного стану складних радіотехнічних систем, які ґрунтуються на дослідженні їх динамічних характеристик. Результати такого аналізу дозволяють досягти мети – обґрунтувати критерії для розрахунку параметрів оптимального вхідного вимірювального сигналу для контролю технічного стану складних радіотехнічних систем. Показано, що при достатньо малій перешкоді вхідного сигналу практично всі вимірювальні сигнали рівноцінні. Тому задача вибору параметрів оптимального вимірювального сигналу є актуальною тільки за досить великої перешкоди. Розглянуті основні критерії оптимізації параметрів вхідних вимірювальних сигналів, до яких віднесено максимум інформаційного показника, мінімум середньоквадратичної похибки, максимум чутливості. Обґрунтовано, що розглянуті критерії зводяться до єдиного, який пропонується використовувати для знаходження параметрів оптимального вхідного вимірювального сигналу, що застосовується для контролю технічного стану систем і елементів складних радіотехнічних систем на етапі експлуатації.

Ключові слова: *контроль радіотехнічних систем, вимірювальні сигнали, критерії оптимізації, технічний стан.*

ТЕОРЕТИЧЕСКИЕ ОСНОВЫ ФОРМИРОВАНИЯ КРИТЕРИЕВ ОПТИМАЛЬНОСТИ СИНТЕЗА ИЗМЕРИТЕЛЬНЫХ СИГНАЛОВ ДЛЯ КОНТРОЛЯ ТЕХНИЧЕСКОГО СОСТОЯНИЯ СЛОЖНЫХ РАДИОТЕХНИЧЕСКИХ СИСТЕМ

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В статье предложены и исследованы теоретические основы обоснования критериев синтеза оптимальных измерительных сигналов для контроля параметров систем и элементов сложных радиотехнических систем (в том числе беспилотных и пилотируемых летательных аппаратов, образцов управляемого ракетного вооружения, радиолокационных станций и тому подобное). Проведен анализ известных методов контроля технического состояния сложных радиотехнических систем, которые основываются на исследовании их динамических характеристик. Результаты такого анализа позволяют достичь цели – обосновать критерии для расчета параметров оптимального входного измерительного сигнала для контроля технического состояния сложных радиотехнических систем. Показано, что при достаточно малой помехе входного сигнала практически все измерительные сигналы равноценны. Поэтому задача выбора параметров оптимального измерительного сигнала является актуальной только при достаточно большом препятствии. Рассмотрены основные критерии оптимизации параметров входных измерительных сигналов, к которым отнесено максимум информационного показателя, минимум среднеквадратичной погрешности, максимум чувствительности. Обосновано, что рассмотренные критерии сводятся к единственному, который предлагается использовать для нахождения параметров оптимального входного измерительного сигнала, который применяется для контроля технического состояния систем и элементов сложных радиотехнических систем на этапе эксплуатации.

Ключевые слова: *контроль радиотехнических систем, измерительные сигналы, критерии оптимизации, техническое состояние.*