Diagnostics programs efficiency analysis in operation systems of radioelectronic equipment

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Abstract

Two variants of diagnostics programs of radioelectronic equipment in exploitation systems are considered. Analytical formulas for calculation of efficiency indexes in the absence and presence of first and second kind errors are given.

Keywords: radioelectronic equipment, diagnostic programs, data processing; maintenance

1 Introduction

There are many processes in operation systems of Radioelectronic Equipment (REE): technical diagnostics, maintenance, running repair, metrological assurance, monitoring, etc.

The process of defining the diagnostics object (DO) technical state is technical diagnostics. The DO technical state changes in case of its elements failures. Therefore technical diagnostics is actually the process of searching a failed DO element [1–7].

The methods of REE technical state diagnostics can be conditionally divided into two groups: statistical and analytical.

Statistical methods are based on application of statistical data of failures and damages in REE units and elements REE, collected and analyzed be forehand.

Analytical methods of REE diagnostics technical state can be conditionally divided into two subgroups. The methods of the first subgroup set the method of REE serviceability checking. The methods of the second subgroup determine the sequence of control-measuring operations fulfillment.

The first subgroup of methods contains: method of the intermediate measuring (with application of voltages charts, voltages drafts, resistances charts etc.); external observation; method of unit replacement, board under checking on consciously operating unit, board; comparison of operating unit signals, board and diagnosed unit of equipment; simulation of input signals; supply on the input of special test sets (signals); signature analysis, etc.

The second subgroup contains such methods: probability/time; half partition; on the basis of informative criterion; branches and limits; on the basis of the dynamic programming; random search; engineering and others.

The methods of REE fault-detection differ in the level of material resources consumption (time, cost, necessary control equipment), as well as in qualification of service personnel, etc. [4].

2 The main objective

Diagnostics programs analysis and the best options choose can be performed on the basis of efficiency indexes set. In the field of technical diagnostics the following basic efficiency indexes are used: D – probability of correct diagnostics; $m_1(t_d)$ – mean duration of diagnostics; $m_1(C_d)$ – mean cost of diagnostics; $m_1(Z_d)$ – mean labour intensity of diagnostics.

In general case indexes t_d, C_d, Z_d are random variables.

It is known that the most complete characteristic of a random variable is a probability density function (PDF). So the article discusses the problem of t_d PDF finding.

3 Basic part

In scientific and technical literature the procedure of DP development is named DP synthesis. For DP synthesis the methods of diagnostics are used.

Let's consider the examples of DP creation. Let DO – radio station transmission section, which is composed of such functional units: frequency synthesizer (master oscillator), modulator, power amplifier, aerial device and power supply block. Depth of diagnostics – to the level of functional unit. Let's constitute DM taking into account control points at DO (Figure 1). Parameters X_5 characterize the up – state of DO elements taking into account connections of elements with each other.

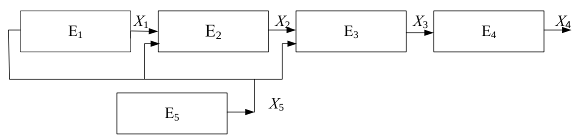

FIGURE 1 Diagnostic model of radiostation transmission section: element E_1 – frequency synthesizer (master oscillator); element E_2 – modulator; element E_3 – power amplifier; element E_4 – aerial device; element E_5 – power supply block

If in Figure 1 each DM element is considered separately, then parameters $\vec{X}_5$ will characterize the up-state of corresponding DM elements only. If it is impossible to break the connection between DM elements, then values of parameters $\vec{X}_5$ are determined taking into account interconnection of elements $E_1 - E_5$. Let's consider the last case. Let in the process of DO analysis necessary information about parameters $\vec{X}_5$ be obtained from the corresponding table.

For DM in Figure 1 we'll develop DP according to engineering approach. We'll use the method of the $\vec{X}_5$ parameters intermediate measuring. The order of parameters checking is following: at first we control a parameter X_5, then consequently – parameters X_1, X_2, X_3. We'll consider that in the process of $\vec{X}_5$ parameters control there are no errors in estimation of these parameters to preset requirements correspondence. Corresponding DP is shown in Figure 2.

In Figure 2 operations which correspond to RRP are also shown. These are operations of failed elements replacement and the whole REE up-state checking.

Thus, for DP and RRP realization it is necessary to fulfill 5 STO, which allow to REE up-state restore.

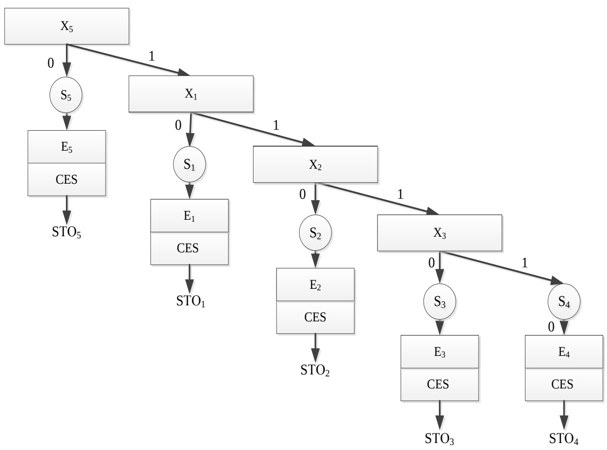

FIGURE 2 Diagnostic program and RRP with the use of engineering approach: RE – replacement of element; CPO – control of object up-state; STO – set of technological operations.

We will consider the example of DP development for DM (Figure 1), using simplified method on the basis of informative criterion. Following this criterion, for determination of $\vec{X}_5$ parameters control order it is necessary to calculate the preference function W at every step of control according to equation:

$$W_i = \min\left|\sum_{j=1}^{N}"0"_{ij} - \sum_{j=1}^{N}"1"_{ij}\right|,$$

where $\sum_{j=1}^{N}"0"_{ij}$ and $\sum_{j=1}^{N}"1"_{ij}$ – quantities of "0" and "1" in *i-th* row of table of DO states, N – quantities of DO states.

For this purpose we will conclude a table (matrix) of DO states. Rule of state table filling consists in following. If X_i parameter of model *i-th* element is out of tolerances limits (or it is absent), i.e. DO is in S_i state, then on crossing of X *i-th* row and S *i-th* column zero is written down. The output parameters of other elements depending on their functional connections with failed element can be within the limits of tolerance and are signed by "1" or out of tolerance – by "0". In this case DO is characterized by such states: S_1 – failure of E_1 element; S_2 – failure of E_2 element, S_3 – failure of E_3 element; S_4 – failure of E_4 element; S_5 – failure of E_5 element. Then output state table will look as it is shown on the chart of RRO technical state tables' analysis (Figure 3). For determination of the first DP parameter row of output table (Figure 3) is chosen with the minimum module of zeros and units difference quantities. If quantity of such rows is more than one, the choice is done arbitrarily. For rows X_1 and X_2 of output table we have $W_{1,2}$=1, for rows X_3 and X_5 – $W_{3,5}$=3, *and* for X_4 – W_4=5.

For definiteness X_2 parameter is chosen first for the control, although it would be possible to choose X_1 parameter. The result of X_2 value control is binary: X_2 parameter can be within the limits of tolerance (X_2=1) or out of tolerance (X_2=0). In this case the state table is decomposed on two tables. If on the first step X_2=1, the quantity of the possible DO states reduces to two (S_3 or S_4). For rows X_1, X_4, X_5 of corresponding table we have $W_{1,4,5}=2$, for a row X_3 – $W_3=0$. Therefore on the second step it is necessary to control X_3 parameter. If X_3=1, decision is made, that DO is in S_4 state, i.e. E_4 element failed. If X_3=0, decision is made, that DO is in S_3 state, i.e. E_3 element failed.

If on the second step X_2=0, the quantity of the possible DO states reduces to three (S_1, S_2, S_5). For rows X_3, X_4 of corresponding table we get $W_{3,4}$=3, for rows X_1, X_5 – W_1 and W_5=1. For definiteness on the second step X_5 parameter is chosen. If X_5=0, decision is made, that DO is in S_5 state, i.e. E_5 element failed. If X_5=1, another table which has two states is created (S_1 or S_2). For rows X_3, X_4 of this table $W_{3,4}=2$, for X_1 row – $W_1=0$. Therefore on the third step it is necessary to control X_1 parameter. If X_1=1, decision is made, that DO is in S_3 state, i.e. E_3 element failed. If X_1=0, decision is made, that DO is in S_1 state, i.e. E_1 element failed. Then RRP is created on the basis of DP. Taking into account the chart of state table analysis (Figure 3) corresponding DP and RRP are shown in Figure 4. These programs look like this, if errors are not revealed during $\vec{X}_5$ parameters control. If such conditions are not fulfilled, then the process of running repair is complicated – there is a necessity of additional technological operations realization on the search for those elements which indeed failed in RRO.

For DP checking it is recommended to model the situations of DO elements failure consistently, and depending on distribution of DO measuring parameters values, to execute further operations according to DP. If conditions of modeling and results of diagnostics coincide, then DP is developed correctly.

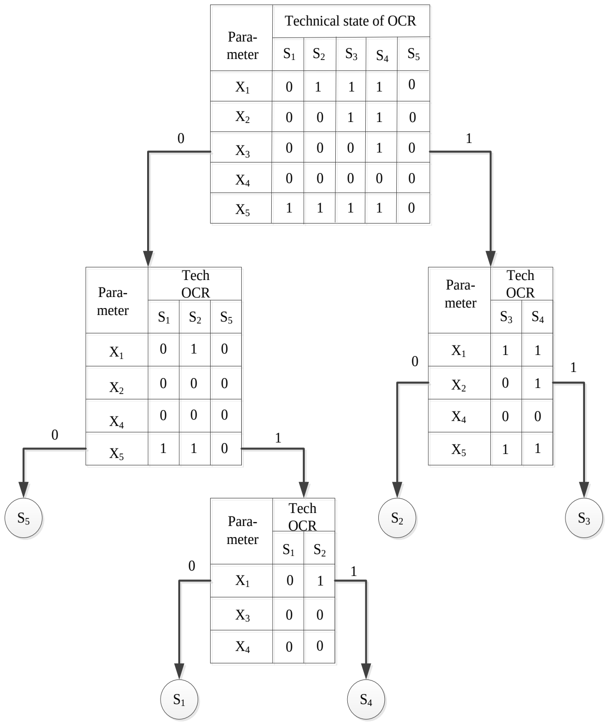

FIGURE 3 Chart of technical state analysis tables during RRO diagnostics according to informative criterion

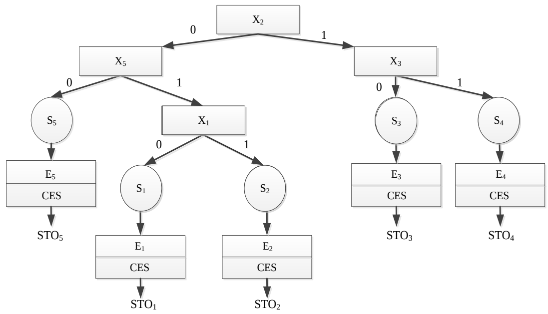

FIGURE 4 Diagnostic programs and RRP according to informative criterion

Every edge corresponds to conditional probabilities of transition from the initial state to a neighboring one, as well as other characteristics, for example, duration of technological operation, after which a change in DO technical state, material expenditures on technological operation etc. have taken place.

For drafting graphs it is possible to use corresponding DP or RRP, if they are supplemented with necessary data on resources consumption. In general case as many graphs are made, as there are elements in RRO. However, if there are no errors during DP control, then it is possible to apply one graph coinciding with DP or RRP image.

The graph of running repair process is built in accordance with the following general rules:

– after decision – making on the RRO functional element failure it is replaced with a serviceable one and the output control of the whole REE is executed;

– if the control testifies the REE up-state, the process of running repair is completed;

– if the RRO output control testifies the device faulty state, then regardless of whether there was replacement of RRO element, or not yet, successive replacement of RRO elements are done and obligatory output control of the whole RRO serviceability is fulfilled until RRO gets serviceable.

On the whole, application of these rules in case of control errors guarantees eventual duration of REE technical diagnostics and running repair process. Diagnostics or running repair graphs include sets of technological operations (STO).

This term determines a TO set, resulting in the search of the failed DM element or RRO serviceability restoration. To this set we refer the operations of DP control, replacement of failed RRO elements, and output control of RRO up-state after its repair. If there are no errors of DP control, the graph of RRO conditions, in the case of *i-th* REE element failure, will include one STO, stipulating restoration of REE serviceability after correct detection and replacement of the failed *i-th* element, by a serviceable one and positive control of the whole REE serviceability. Separate STO make a complete group of events.

Let's consider DP efficiency analysis. Each STO can be connected with corresponding material resources consumption – average aggregate time of *i-th* STO fulfillment, average aggregate labour intensity of *i-th* STO fulfillment, average aggregate costs of *i-th* STO fulfillment.

Conditional mean indexes of a certain DP efficiency during REE diagnostics, if there are no errors in the process of DP control, are determined as

$$m_1(t(STO_j / S_j)) = \sum_{i=1}^{l_j} t_{cij} \,,$$

$$m_1(Z(STO_j / S_j)) = \sum_{i=1}^{l_j} Z_{cij} \,,$$

$$m_1(C(STO_j / S_j)) = \sum_{i=1}^{l_j} C_{cij} \,,$$

where $m_1(t(STO_j / S_j))$ – conditional mathematical expectation of total duration of *j-th* STO fulfillment in case of *j-th* DO element failure; $m_1(Z(STO_j / S_j))$ – conditional mathematical expectation of *j-th* STO set aggregate labour intensity in the case of *j-th* DO element failure; $m_1(C(STO_j / S_j))$ – conditional mathematical expectation of *j-th* STO set aggregate costs in the case of *j-th* DO element failure; t_{cij} – mathematical expectation of *i-th* DP control duration in the case of the *j-th* REE DM element failure; Z_{cij} – mathematical expectation of *i-th* DP control labour intensity in the case of *j-th* DM element failure; C_{cij} – mathematical expectation of *i-th* DP control cost in the case of *j-th* DM element failure; *lj* – the quantity of the control operations of detecting *j-th* DO failed element; S_j – DO condition in the case of *j-th* DO element failure.

To determine absolute efficiency indexes it is necessary to fulfill another averaging operation:

$$m_1(t_d) = \sum_{j=1}^{N} m_1(t(STO_j / S_j))Q_j ,$$

$$m_1(Z_d) = \sum_{j=1}^{N} m_1(Z(STO_j / S_j))Q_j , \quad (1)$$

$$m_1(C_d) = \sum_{j=1}^{N} m_1(C(STO_j / S_j))Q_j ,$$

where $m_1(t_d)$ – mathematical expectation of one DO diagnostics duration; $m_1(C_d)$ – mathematical expectation of one DO diagnostics cost; $m_1(Z_d)$ – mathematical expectation of one DO diagnostics labour intensity; N – total quantity of DO elements; Q_j – probability of *j-th* DO element failure.

Using efficiency indexes $m_1(t_d)$, $m_1(C_d)$, $m_1(Z_d)$, according to Equation (1), it is possible to perform a comparative analysis of different DPs efficiency.

If there are no statistical data about DO or RRO elements reliability, probabilities of elements failures Q_i can be calculated by the known technology [1]. For this purpose the specification to the REE principle electric chart is used, a list and quantity of ERC contained in each DO or RRO element are determined. Assuming, that in terms the reliability theory ERC are connected in series, failures rate of *i-th* DM or RRO element can be calculated according to the Equation

$$\lambda_i = \sum_{j=1}^{K_i} n_{ij}\lambda_{ij} , \quad (2)$$

where K_i – quantity of ERC groups, of which the electric chart of *i-th* element is built (to ERC groups we may refer resistors, capacitors, chips etc.); n_{ij} – quantity of *j-th* group ERC, included in the principle chart of *i-th* element; λ_{ij} – average failure rate of *j-th* group ERC, included in the *i-th* DO or RRO element.

Failure rates are taken from reference tables [5], considering operation conditions as normal.

Calculating value of λ_i according to formula (2), failure probabilities of DO or RRO elements are determined, assuming, that only one element of the equipment can fail and elements failures are independent of each other:

$$Q_i = \frac{\lambda_i}{\sum_{j=1}^{N} \lambda_j} .$$

In case errors in DP state classification, both the REE diagnostics and running repair procedures are sharply complicated. There may be the situations of erroneous decisions as to DO or RRO condition that may result in excessive consumption of resources during REE diagnostics or running repair.

As for the running repair let's note that in case of any element failure RRO state graph will contain as many STOs as there are elements in RRO. In this case only one of all possible STOs will provide faithful detection of the faulty element, others will be characterized with additional consumption of resources due to erroneous replacement of RRO elements as a result errors of DP condition control. Analyzing RRP efficiency, it is necessary to make as many RRO state graphs, as there are elements in RRO. These graphs will help to define probabilities of STO performance correctly taking into account which element is faulty, and the probability of the first and second kind errors. According to the probabilities theory certain STO make a complete group of events.

Every STO during RRP can be connected with corresponding conditional consumption of material resources, such as conditional mathematical expectation of *i-th* STO aggregate time during maintenance and in case of the *j-th* RRO element failure $m_1(t(STO_i / S_j))$.

Then conventional average efficiency criteria are calculated as follows:

$$m_1(t_r / S_j) = \sum_{i=1}^{M_j} P(STO_i / S_j) m_1(t(STO_i / S_j)) ,$$

where $m_1(t_r / S_j)$ – conditional mathematical expectation value of time – taking for current repair with RRO *j-th* element faulty; M_j – the number of STO during RRO running repair due to its *j-th* element failure. STO quantity is equal to the quantity of RRO elements; $m_1(t(STO_i / S_j)$ - conditional mathematical expectation of the *i-th* STO total time during maintenance and in case of the *j-th* RRO element failure; $P(STO_i / S_j)$ - conditional probability of the *i-th* STO resulting from RRO *j-th* element failure.

To determine the RRO efficiency index unconditional value it is necessary to perform one more averaging operation:

$$m_1(t_r) = \sum_{j=1}^{N} m_1(t_r / S_j) P(S_j) ,$$

$$\sigma(t_r) = \left(\sum_{j=1}^{N} (m_1(t_r) - m_1(t_r / S_j))^2 P(S_j)\right)^{1/2} ,$$

$$P(S_j) = Q_j ,$$

where N – total RRO elements quantity; Q_j – RRO *j-th* element failure probability.

The Equation for determining correct diagnostics of DO average probability is the following:

$$m_1(D) = \sum_{j=1}^{N} D(S_j)Q_j \,,$$

where $D(S_j)$ – is conditional probability of DO correct diagnostics in the case of *j-th* element failure.

To determine $D(S_j)$ we may consider any of the RRO running repair graphs.

Consider the case, where α≠0, β≠0. Diagnostics program of a given object is divided into *n* conditional subprograms, where *n* – number of elements in DO. Each *i*-th subprogram will be based on the condition that the *i*-th element is refused in object. So the branches of the graph can be marked by errors of the first and second kind value.

Consider the example of DO, which includes four elements ($\mathrm{E}_1, \mathrm{E}_2, \mathrm{E}_3, \mathrm{E}_4$) connected in series (Figure 5).

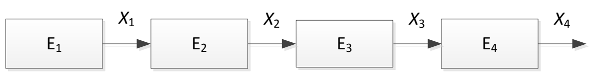

FIGURE 5 Example of DO

In Figure 5 X_i – information parameter (IP), which characterizes the work of corresponding of i -th DO element.

For this DO (Figure 5) will lead one of the four graphs for the case when first element failures (Figure 6).

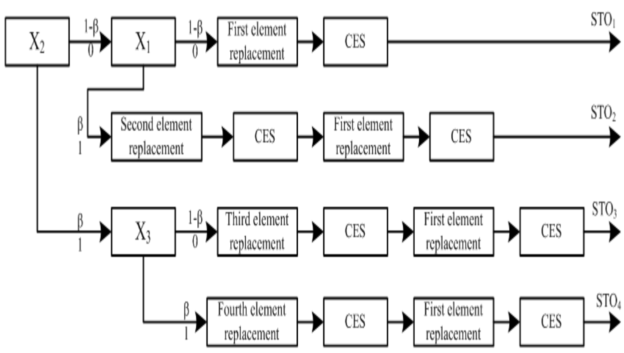

FIGURE 6 DO state graph in case of first element failure and the presence of control error

Each graph will contain three STO related to “false” element detection, and only one – with “true”. The number of operations, that are part of “false” element detection STO, will be determined by strategies, which are accepted in these cases. Among these strategies are: DR initially repetition, second signal control at output of elements with maximum failure probability.

Let’s use a strategy, in which during diagnostics the element with failure is replaced on objective functional. Then there is all DO control (this type of control hasn’t errors of the first and second kind). If as a result of final DO control is “failure”, the decision is taken about next fault DO element, starting from the first. Then again there is all DO control.

Analysis of Figure 6 shows that in the presence of errors of the first and second kind consumption of resources for diagnosis are increasing.

Consider the determination problem of probability density function of the time required to PD implementation $f(t_d)$ (in case, where α≠0, β≠0).

Consider the example, when DO first element objectively failures. Since the results of test operations are random, then certain STO will random too both in number and in duration. Probability of implementation certain operations $P(\mathrm{STO}_i / S_1)$ are conditional and form a complete group of events:

$$\sum_{i=1}^{4} P(\mathrm{STO}_i / S_1) = 1 \,,$$

where $P(\mathrm{STO}_i / S_1)$ – probability of the *i*-th STO implementation, if first element objectively failures .

Let’s the probabilities of first and second kind errors for all elements are equal: $\alpha = \alpha_i$, $\beta = \beta_i$.

Then

$$P(\mathrm{STO}_1 / S_1) = (1-\beta)^2,$$

$$P(\mathrm{STO}_2 / S_1) = \beta - \beta^2,$$

$$P(\mathrm{STO}_3 / S_1) = \beta^2,$$

$$P(\mathrm{STO}_4 / S_1) = \beta - \beta^2.$$

Suppose, that we know the conditional PDF of STO duration in the case of the first element failure $f(t_{\mathrm{STO}_i} / S_1)$. These conditional PDF satisfy the normalization condition, so

$$f(t_d / S_1) = P(\mathrm{STO}_1 / S_1) f(t_{\mathrm{STO}_1} / S_1) +$$
$$+P(\mathrm{STO}_2 / S_1) f(t_{\mathrm{STO}_2} / S_1) + P(\mathrm{STO}_3 / S_1) f(t_{\mathrm{STO}_3} / S_1) +$$
$$+P(\mathrm{STO}_4 / S_1) f(t_{\mathrm{STO}_4} / S_1).$$

According to the normalization condition:

$$\int_0^\infty f(t_d / S_1) dt_d = P(\mathrm{STO}_1 / S_1) \int_0^\infty f(t_{\mathrm{STO}_1} / S_1) dt_{\mathrm{STO}_1} + \ldots +$$
$$+ P(\mathrm{STO}_4 / S_1) \int_0^\infty f(t_{\mathrm{STO}_4} / S_1) dt_{\mathrm{STO}_4} = P(\mathrm{STO}_1 / S_1) +$$
$$+P(\mathrm{STO}_2 / S_1) + P(\mathrm{STO}_3 / S_1) + P(\mathrm{STO}_4 / S_1) = 1.$$

After defining all conditional PDF $f(t_d / S_i)$, we can determine unconditional PDF of PD:

$$f(t_d) = Q_1 f(t_d / S_1) + Q_2 f(t_d / S_2) + \\ + Q_3 f(t_d / S_3) + Q_4 f(t_d / S_4). \quad (3)$$

Unconditional PDF $f(t_d)$ will satisfy the normalization condition, i.e.:

$$\int_0^\infty f(t_d)dt_d = Q_1\int_0^\infty f(t_d/S_1)dt_d + Q_2\int_0^\infty f(t_d/S_2)dt_d +$$

$$+Q_3\int_0^\infty f(t_d/S_3)dt_d + Q_4\int_0^\infty f(t_d/S_4)dt_д =$$

$$= Q_1+Q_2+Q_3+Q_4 = 1.$$

These Equations for conditional and unconditional PDF can be generalized to the case when the DO consists of n elements. Thus the expression for STO duration PDF will depend on the number of elements in the object and PD type.

Let's consider the determination of moments for PDF, that represented by Equation (3). The expression for mathematical expectation:

$$m_1(t_d) = \int_0^\infty t_d f(t_d)dt_d = Q_1\int_0^\infty t_д f(t_d/S_1)dt_d +$$

$$+Q_2\int_0^\infty t_d f(t_d/S_2)dt_d + Q_3\int_0^\infty t_d f(t_d/S_3)dt_d + \quad (4)$$

$$+Q_4\int_0^\infty t_d f(t_d/S_4)dt_d = Q_1I_1+Q_2I_2+Q_3I_3+Q_4I_4.$$

In the Equation (4) the expression for I_i can be written as:

$$I_i = P(\mathrm{STO}_1/S_i)m_1(t_{\mathrm{STO}_1}/S_i) + P(\mathrm{STO}_2/S_i)m_1(t_{\mathrm{STO}_2}/S_i) +$$

$$+P(\mathrm{STO}_3/S_i)m_1(t_{\mathrm{STO}_3}/S_i) + P(\mathrm{STO}_4/S_i)m_1(t_{\mathrm{STO}_4}/S_i).$$

Equation (4) is a generalization of (2), when in the diagnostics errors of first and second kind are present.

The expression for the variance advisable to submit as follows:

$$\mu_2(t_d) = \int_0^\infty (t_d - m_1(t_d))^2 f(t_d)dt_d = m_2(t_d) - m_1^2(t_d).$$

In this case second initial moment $m_2(t_d)$ can be written as follows:

$$m_2(t_d) = \int_0^\infty t_d{}^2 f(t_д)dt_д = Q_1\int_0^\infty t_d{}^2 f(t_d/S_1)dt_д +$$

$$+Q_2\int_0^\infty t_d{}^2 f(t_d/S_2)dt_д + Q_3\int_0^\infty t_d{}^2 f(t_d/S_3)dt_д + \quad (6)$$

$$+Q_4\int_0^\infty t_d{}^2 f(t_d/S_4)dt_д = Q_1J_1+Q_2J_2+Q_3J_3+Q_4J_4.$$

In the Equation (6) the expression for J_i can be written as:

$$J_i = P(\mathrm{STO}_1/S_i)m_2(t_{\mathrm{STO}_1}/S_i) + P(\mathrm{STO}_2/S_i)m_2(t_{\mathrm{STO}_2}/S_i) +$$

$$+P(\mathrm{STO}_3/S_i)m_2(t_{\mathrm{STO}_3}/S_i) + P(\mathrm{STO}_4/S_i)m_2(t_{\mathrm{STO}_4}/S_i).$$

To assess the trustworthiness of that formulas statistical modeling was conducted using Monte-Carlo method for units, that shown in Figure 5.

Simulations carried out on condition that i-th STO duration PDF is Gaussian with following parameters: $m_1(t_{\mathrm{STO}_i}/S_i)$, $\mu_2(t_{\mathrm{STO}_i}/S_i)$, where ($i=\overline{1,4}$). Numerical values of the parameters of general block of data are listed in Table 1.

In addition, we assume that (if $i \neq j$):

1) $m_1(t_{\mathrm{STO}_i}/S_j) = m_1(t_{\mathrm{STO}_i}/S_i)+5$, if $i=1$ or $i=j+1$;

2) $m_1(t_{\mathrm{STO}_i}/S_j) = m_1(t_{\mathrm{STO}_i}/S_i)+10$, if $i=j+2$;

3) $m_1(t_{\mathrm{STO}_i}/S_j) = m_1(t_{\mathrm{STO}_i}/S_i)+15$, if $i=j-1$.

TABLE 1 Numerical values of the parameters of general block of data

Parameters of general block of data	Variant number				
	1	2	3	4	5
Q_1	0,4	0,25	0,1	0,2	0,1
Q_2	0,2	0,25	0,25	0,5	0,2
Q_3	0,1	0,25	0,4	0,15	0,3
Q_4	0,3	0,25	0,25	0,15	0,4
$m_1(t_{\mathrm{STO}_1}/S_1)$	50	50	50	50	50
$m_1(t_{\mathrm{STO}_2}/S_2)$	60	60	70	70	55
$m_1(t_{\mathrm{STO}_3}/S_3)$	75	70	80	90	75
$m_1(t_{\mathrm{STO}_4}/S_4)$	90	80	100	100	90
$\mu_2(t_{\mathrm{STO}_1}/S_i)$	25	25	49	49	36
$\mu_2(t_{\mathrm{STO}_2}/S_i)$	36	25	36	49	36
$\mu_2(t_{\mathrm{STO}_3}/S_i)$	25	25	36	25	49
$\mu_2(t_{\mathrm{STO}_4}/S_i)$	49	25	25	36	25
α	0,02	0,04	0,05	0,05	0,05
β	0,03	0,02	0,03	0,04	0,05

During the simulation was performed statistical estimation of mathematical expectation $m_1^*(t_d)$, variance $\mu_2^*(t_d)$, standard deviation $\sigma^*(t_d)$ and PDF of diagnostic duration $f^*(t_d)$. The simulation results in the form of point estimates of the parameters $m_1^*(t_d)$, $\mu_2^*(t_d)$, $\sigma^*(t_d)$, lower t_{dL} and upper t_{dU} limits of mathematical expectation $m_1^*(t_d)$ interval estimates and results of theoretical calculations of the parameters $m_1(t_d)$, $\mu_2(t_d)$, $\sigma(t_d)$ listed in Table 2. Interval estimates were calculated for a confidence probability $\gamma = 0{,}95$.

Graphics of diagnostics duration PDF for option number five of input data are shown in Figure 7. Comparison of theoretical calculations of diagnostics duration PDF in the absence ($f_1(t_d)$) and presence ($f_2(t_d)$) of first and second kind errors is shown in Figure 8.

TABLE 2 The simulation results

Variant number	Point estimates			Interval estimates	Calculation data		
	$m_1^*(t_d)$	$\mu_2^*(t_d)$	$\sigma^*(t_d)$	t_{dL} / t_{dU}	$m_1(t_d)$	$\mu_2(t_d)$	$\sigma(t_d)$
1	66,3	270	16,43	65,98/66,62	66,35	268,1	16,37
2	65	251	15,8	64,68/65,32	65	259	16,03
3	79,9	212,1	14,6	79,58/80,22	80,1	238,3	15,4
4	73	262,4	16,2	72,68/73,32	73,1	371	16,46
5	74,4	272	16,5	74,08/74,72	74,3	266,6	16,33

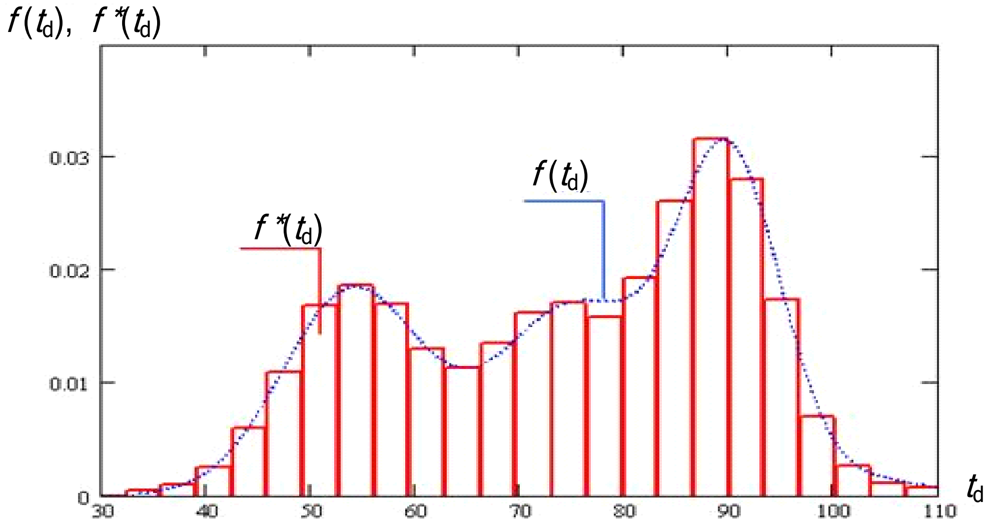

FIGURE 7 Results of theoretical calculations ($f(t_d)$) and statistical ($f^*(t_d)$) simulations to determine the diagnostics duration PDF (option input data – number 5)

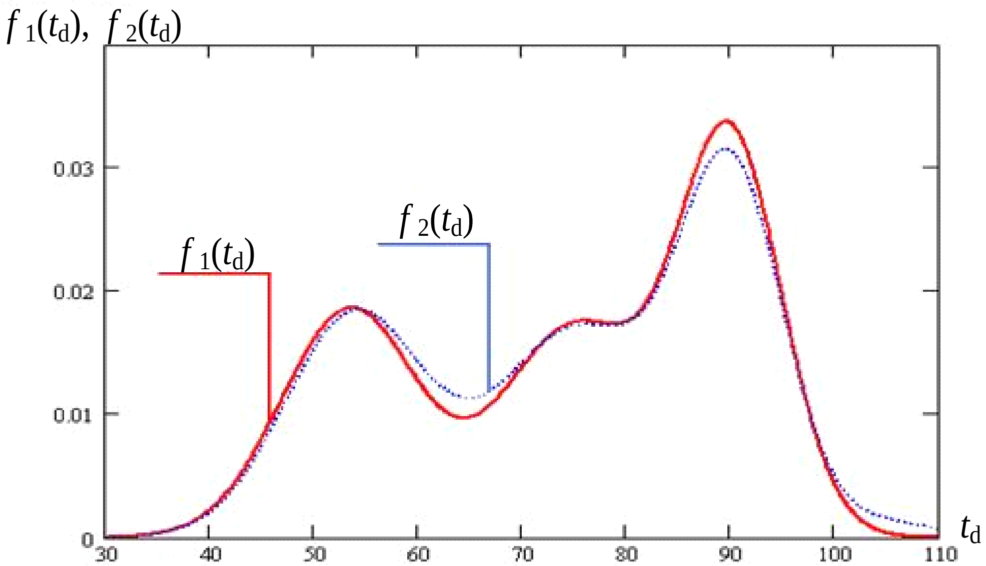

FIGURE 8 Comparison of theoretical calculations of diagnostics duration PDF in the absence ($f_1(t_d)$) and presence ($f_2(t_d)$) of first and second kind errors (option input data – number 5)

4 Conclusions

Problem of diagnostics duration PDF finding is considered in the article. This approach is adequate taking into account resources costs in the diagnostics process and running repairs.

Based on the comparison of the results of diagnostics process statistical modeling and theoretical calculations on the basis of the formulas can be concluded about the truthfulness of analytical formulas.

The results can be used for the design and modernization of Radioelectronic Equipment operation systems.

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