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Запропоновано метод синтезу, що базується на застосуванні інформаційних інваріантів, і виконано структурно-параметричний синтез діагностично-оздоровчого комплексу «Quanton». Проведена структурно-параметрична оптимізація комплексу по критерію продуктивності. Як інформаційні інваріанти використані повні (у межах прийнятої класифікації) множини шляхів отримання функціональних властивостей комплексу, фазових циклів життєвого циклу, структур технічних підсистем і способів управляння рівнями технізації, продуктивності та енергоефективності процесів. Множини шляхів отримання функціональних властивостей комплексу та фазових циклів життєвого циклу сформовані шляхом поелементного ускладнення відповідних атрибутів. Множина структур технічних підсистем, що відповідають певним рівням технізації функцій, визначена на основі періодичної системи технічних елементів. Повні множини можливих структурних рішень по способам управління продуктивністю та енергоефективністю процесів, отримані топологічним добутком множин видів об'єктів на види прийомів забезпечення потрібних властивостей чи якостей об'єктів. Для кожного структурно відмінного варіанту застосована типова процедура параметризації об'єктів та система залежностей задачі параметричної оптимізації дедуктивного типу. Система залежностей є конкретизованим випадком параметричних інформаційних інваріантів. Конкретизацію залежностей здійснено з використанням інформації про потрібні вихідні дані та цільові перетворення, що виникають у комплексі «Quanton», при взаємодії підсистем. Алгоритм пошуку гранично ефективного рішення є покроковим. Цим алгоритмом передбачається покрокове визначення оптимальних по продуктивності процесів значень параметрів в межах блокуючих контурів та послідуюче їх покращення по енергоефективності та якості. Внаслідок використання повних множин структур процесів, елементів та дискретно-континуальної процедури пошуку оптимального рішення досягнута комплексність оптимізації технічної інновації

Ключові слова: параметричний синтез, комплекс «Quanton», неінвазивна діагностика, спектральний метод, терапія високочастотна

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DEVELOPMENT OF THE METHOD OF STRUCTURAL AND PARAMETRIC SYNTHESIS OF THE QUANTON DIAGNOSTIC AND HEALTH COMPLEX

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1. Introduction

The Quanton diagnostic and health complex is a technical innovation designed to perform a triple function: non-invasive diagnostics of people, gaining information about the characteristics of the desired health normalizing effect on them and implementation of this effect. Non-invasive diagnostics combines spectral and binary methods. The spectral method with a certain level of reliability allows identifying organs that have deviations from the standards. The binary method, with its level of reliability, confirms or denies these results and, if confirmed, sets the necessary parameters of the normalizing electro-wave bioresonance effect.

The combination of these functions in one complex makes it promising for wide use. At the same time, to ensure its effective application not only in health care facilities, but also in everyday life, it is necessary to carry out optimization synthesis. The purpose of this task is to optimize the structure and parameters of the complex to obtain proper performance indicators: functionality, reliability of diagnostic results, efficiency of health effect and productivity. However, in the published patents [1, 2] methods of directed optimization structural-parametric synthesis of computer-integrated systems for combined performance of diagnostic and health functions are not described and not used in practice. This requires the creation of a special method of synthesis of such systems. General scientific bases for this purpose are created by works in the field of the theory of complex systems, theory of mechanisms and machines, theory of optimization.

The method can be based on the application of information invariants – typical structure models of processes and objects, their logical and mathematical models, which are unchanged during isochronous and higher time cycles of technical systems.

The solution of this issue will allow creating a complex with high performance in terms of functionality and efficiency.

2. Literature review and problem statement

The published patents [1, 2] describe electronic methods and means for diagnosing disorders of the functional and physiological state of people. Descriptions of approaches to research and mathematical modeling of diagnostic processes of metabolic imbalance [3], myocardial infarction [4], obesity [5], hypertension [6] are also available. The solutions given in these works allow creating diagnostic complexes to identify local disorders in the body, but do not give a holistic view of health. In addition, such complexes do not allow determining the methods and parameters of health effect on the body. On the basis of the method [7], it is possible to build the Quanton diagnostic and health complex with advanced functionality, but the patent does not describe the method of synthesis and optimization of such complex.

Many of the published papers detail the specific types of technical and technological systems and their elements for medical purposes. In particular, the paper [8] shows the need to take into account the human factor in the development of the human-machine interface. In [9], the method for optimizing closed-loop information processing to improve the efficiency of brain-computer interfaces based on visually evoked potentials is described. At the same time, the method of synthesis of the complexes required for this purpose is also not described in the mentioned papers.

The work [10] shows that probabilistic diagnostic decision support systems have the potential to accelerate the diagnosis of rare diseases offering differential diagnoses for physicians based on the introduction of the case and medical knowledge. However, this paper does not identify ways to ensure better performance and proper reliability of diagnostic systems. The proceedings of the symposium [11] present an interactive approach to computer-aided medical diagnostics. But ways to ensure higher performance are also not defined.

The study [12] substantiated the thesis of increasing interest in using microwave systems in modern medicine. However, this work, noting the relevance of applying new approaches to solving diagnostics problems and normalization of the functional and physiological state of people, does not give methods of creating integrated complexes for their solution. At the same time, many issues have been raised in the technical literature that provide a scientific basis for solving the basic problems associated with the creation of these complexes.

One of the most important elements of such complex systems is obtaining reliable diagnostic information about the condition of the human body by non-invasive means. In recent years, considerable interest of developers of diagnostic methods and devices has been paid to time-frequency or spectral analysis of the spectrum of signals of a biological object. This analysis has become a well-standardized tool for quantifying many clinical and physiological phenomena, as exemplified by [13, 14]. Much attention was also paid to the method of body impedance measurement. On the basis of impedance measurements, the method of binary identification of the biosystem state on the basis of electrodermal activity (EDA) or sympathetic skin response (SSR) is also developed [15]. But these works do not provide the method of structural-parametric optimization synthesis, which aims to improve the functionality and productivity of the Quanton complex.

A generalized approach to system engineering is outlined in [16]. The classical work [17], which proposes the system of elementary functions and version design method, allows extending the possibilities of synthesis. The monograph [18] presents theoretical principles and examples of application of the object-oriented approach to synthesis problems. In [19], the general system for solving modeling problems and using information bases is described. There are also publications showing the possibility of using the periodic system of technical elements [20] and general laws of technological development in the creation of technical innovations [21]. Possibilities of system management of productivity [22] and energy efficiency [23] of general technical complexes are described.

At the same time, in order to find extremely effective solutions when creating the Quanton diagnostic and health complex, it is necessary to have a sufficiently complete, functionally holistic method that would allow performing directed structural-parametric synthesis and optimization of this complex.

3. The aim and objectives of the study

The aim of the study is to develop a method and perform structural-parametric optimization synthesis of the Quanton diagnostic and health complex using structural information invariants. This will allow forming complete (within the accepted classifications) areas of structural and parametric solutions and provide the analytical design of the complex with extremely high productivity.

To achieve this aim, the following objectives were set:

– to develop a general algorithm of directed (non-analog) structural-parametric synthesis of the Quanton diagnostic and health complex;

– to determine the possibility of using general information invariants to form possible structural solutions of the complex;

– to formalize the problem of integrated structural-parametric optimization of the complex;

– to propose a method for finding the extremely effective parametric solution for structural variants of the complex;

– to evaluate the efficiency of the algorithm of integrated structural-parametric optimization with the option of technical audit by the increase of productivity levels of the diagnostics process and change of the optimality criterion.

4. Application of information invariants for structural-parametric optimization synthesis of the Quanton diagnostic and health complex

4. 1. Development of a general algorithm of directed (non-analog) synthesis of the complex

The extreme efficiency of the complex as a system can be achieved by integrated structural and parametric optimization. This involves finding complete sets of possible structural and parametric solutions, among which one optimal solution is determined by the optimality criterion. Applying the principle of informational subordination of synthesis stages, it is possible to use a general deductive approach (algorithm) to solve the specified problem with the following stages:

1. Generation of basic output data.
2. Setting constraints on the complex and its subsystems.
3. Formation of an overall set of structural decisions using the most common information invariants – ways of providing the required properties of the complex, structures of their phase cycles and possible levels of technicalization. Each level of technicalization corresponds to a typical structure – information invariant – of the periodic system of technical elements [20]. The overall structure is specified.
4. Each element of the general structures is parameterized, the deductive dependency system (complex information invariant) is used. The problem of optimization by the process performance criterion is formalized.
5. Optimization is performed, a solution is selected that meets the globally extreme value of the optimality criterion. Analytical technical audit of the feasibility of using sets of methods of controlling the performance, energy efficiency and quality of the system using profile information invariants – structures of the corresponding methods is carried out [22, 23].

Given the relatively small number of possible ways to ensure the desired properties of the complex, structural-parametric synthesis can be performed by linear search of variants, starting with the simplest one.

4. 2. Generation of basic output data

Solving the problem of synthesis of the complex involves the formation of lists of known attributes and those to be defined and their hierarchical levels.

According to the general system methodology for creating technical innovations [21] and features of the Quanton Complex, information on this can be presented as shown in Table 1.

Based on the data of Table 1, it is possible to define the main constraints on the complex and its subsystems.

Table 1

List of Quanton complex attributes

No.	Attribute name	Attribute definition level	Attribute value
1	Scope of application	Supersystem	Health care facilities, everyday life
2	Purpose	Supersystem	Performing diagnostic and health-improving functions
3	Functions (most common)	Supersystem	1. Spectral-wave diagnostics 2. Binary diagnostics 3. Resonance-wave recovery (normalization of functional and physiological state)
4	Principles	System and subsystems	*In diagnostics*: 1) determination of frequency spectrum deviations from the standard; 2) measurement of skin resistance in the body's response to the semantic influence of the information marker. *In recovery*: quantum resonance action by high-frequency electromagnetic waves
5	Processes	System and subsystems	System: serial, discrete-continuous Subsystems: parallel, discrete-continuous
6	Structures	System and subsystems	Defined when solving the synthesis problem
7	Parameters	System and subsystems	Defined when solving the synthesis problem

4. 3. Setting constraints on the complex and its subsystems

The optimality criterion is the process performance indicator. Limiting contours form parametric, functional and algorithmic constraints, which are valid in all stages of life cycle (LC), the main types of which are given in Table 2.

Table 2

Main types of constraints on the complex and its subsystems

No.	Types of constraints	Main content
1	Natural	Compliance of the complex and its subsystems with the laws of nature
2	Technical	Compliance with strength, reliability, accuracy and other constraints
3	Organizational	Providing organizational conditions for functions, their configuration, production and others
4	Temporal	Creation and functioning of the complex must take place at certain intervals
5	Ergonomic	The complex must meet the characteristics of the human body
6	Economic	Investment and cost of the complex must be limited
7	Environmental	The complex must be environmentally friendly

As organizational constraints, requirements are set to adapting the complex to the needs of each organism and possibility to have stationary and portable implementation.

5. Definition of common sets of structural solutions using information invariants

The structure of the complex is determined by its functions (Table 1), methods of their provision and levels of technicalization.

Methods to provide the required system properties include all stages of equipment life cycle (LC), combined into ranked clusters (gradually complicated). Fundamentally possible methods of providing the desired properties of the complex as a system can be those given in Table 3.

Table 3

Possible methods to provide the required properties of the complex

No.	Method and its designation	Phase cycle clusters – F_{cj}	Name
1	Using the system without reconfiguration – CT	$\mathbf{F \oplus U_f}$	Control
2	Using the system with reconfiguration – RC	$\mathbf{[(T \oplus U_t) \otimes (F \oplus U_f)] \oplus U_{tf}}$	Reconfiguration
3	Using the modernized system – MD	$\mathbf{[(A \oplus U_a) \otimes (D \oplus U_d) \otimes}$ $\mathbf{\otimes (L_b \oplus U_{lb}) \otimes (P \oplus U_i) \otimes}$ $\mathbf{\otimes (C \oplus U_c) \otimes (S \oplus U_s) \otimes}$ $\mathbf{\otimes (T \oplus U_t) \otimes (F \oplus U_f)] \oplus U_{lc}}$	Modernization
4	Using the newly created system of traditional form – TR	$\mathbf{(D \oplus U_d) \otimes (P \oplus U_i) \otimes}$ $\mathbf{\otimes (C \oplus U_c) \otimes (S \oplus U_s) \otimes}$ $\mathbf{\otimes (T \oplus U_t) \otimes (F \oplus U_f) \otimes}$ $\mathbf{\otimes (N \oplus U_n) \otimes (R \oplus U_r) \otimes}$ $\mathbf{\otimes (M \oplus U_m) \otimes (L \oplus U_l)] \oplus U_{lc}}$	Restructuring
5	Using the newly created system of innovative form – IB	$\mathbf{[(A \oplus U_a) \otimes (D \oplus U_d) \otimes}$ $\mathbf{\otimes (P \oplus U_i) \otimes (C \oplus U_c) \otimes}$ $\mathbf{\otimes (S \oplus U_s) \otimes (T \oplus U_t) \otimes}$ $\mathbf{\otimes (F \oplus U_f) \otimes (N \oplus U_n) \otimes}$ $\mathbf{\otimes (R \oplus U_r) \otimes (M \oplus U_m) \otimes}$ $\mathbf{\otimes (L \oplus U_l)] \oplus U_{lc}}$	Innovative building

Table 3 indicates the structural information invariants – typical phase cycles – LC components, on which the corresponding functions are implemented. The LC components include the following functions: intellectual activity (**A**) (synthesis of ideas, research, marketing); design and technological development of the object – design (**D**); production (**P**); certification (**C**); sales (**S**); tuning and training (**T**); functioning (**F**), repair (**R**); maintenance (**N**); modernization (**M**) and utilization (**L**). Index "b" means belonging to the old (former) system; $\mathbf{U_{ni}}$, $i \in \{A, D, P, C, S, T, F, R, N, M, L\}$, $\mathbf{U_{lc}}$ – control systems for phase subsystems implementing the phase cycles and **LC** as a whole. The sign ⊕ stands for parallel execution of actions (functions, cycles), and the sign ⊗ – consecutive.

Based on Table 1, a column matrix of phase cycle clusters is formed for each method:

$$M_{sh} = \begin{pmatrix} F_{c1} \\ F_{c2} \\ F_{c3} \\ F_{c4} \\ F_{c5} \end{pmatrix}, \qquad (1)$$

where F_{cj}, $j \in \{1, ..., 5\}$ are the phase cycle clusters for the methods CT, RC, MD, TR, and IB, respectively, listed in Table 3.

The structure of the phase cycles of the fifth method determines the most common typical structure of the LC:

$$LC = [(A \oplus U_a) \otimes (D \oplus U_d) \otimes (P \oplus U_i) \otimes (C \oplus U_c) \otimes \otimes (S \oplus U_s) \otimes (T \oplus U_t) \otimes (F \oplus U_f) \otimes (N \oplus U_n) \otimes \otimes (R \oplus U_r) \otimes (M \oplus U_m) \otimes (L \oplus U_l)] \oplus U_{lc}. \qquad (2)$$

Within each phase cycle, own technological processes, containing clusters of inherent operations are carried out. Since each technicalization level of functions corresponds to typical structures, at the 5th stage it is possible to formally determine sets of possible structures for each subsystem of the complex. Generation of a set of variants of the general structures of the complex as a whole is done by combining typical structures for each selected method and each phase cycle of the LC. This takes into account possible ways of combining functions in parallel and sequential implementation.

Their technicalization levels from the set of possible technical elements specified by the periodic system are to be determined [20]. It is possible to choose from the following levels of technicalization: manual – M, mechanized – H, automated – A, intellectual – I, intelligent – U, self-organizing – S, self-reproducing – R.

The levels of technicalization determine the amount of required material and energy information resource and level of optimality criterion. Therefore, these levels need to be optimized.

The controlled target phase cycle, required for the Quanton complex, whose structural invariant is given by the $\mathbf{F \oplus U_f}$ model (CT method), should implement the functions given in Table 1. However, the readjustment requirement also needs the implementation of the phase cycle inherent in the RC method with its $[(T \oplus U_t) \otimes (F \oplus U_f)] \oplus U_{tf.}$ At the same time, today there are no diagnostic and health complexes with the functions specified in Table 1. Because of this, there is one of three more difficult methods for synthesis: MD, TR, or IB.

Forming the general structure of the complex, it should be borne in mind that each function has a typical cluster (structural information invariant) – a triad chain, which, in addition, includes control and auxiliary functions [22]. On the basis of this, taking into account [7, 17], the structure of more specific than in Table 1, generalized functions performed by the Quanton diagnostic and health complex can be presented as shown in Fig. 1.

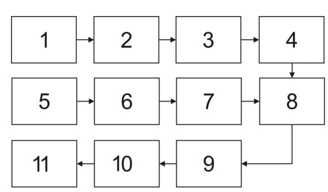


Fig. 1. Structure of generalized functions of the Quanton complex

Fig. 1 shows the generalized functions:

1 – creation of spectral-frequency information standard of the general functional and physiological state of the human body;

2 – spectral-frequency diagnostics of the general functional and physiological state of the person, determination of the real frequency spectrum of the human body;

3 – determination of the deviation from the spectral-frequency information standard, the values of which form a preliminary list of problem organs for which information markers are created;

4 – determination of the preliminary sequence of actions on problem organs;

5 – determination of the current electrical resistance between the determined points of the body, one of which must be bioactive;

6 – creation of an electrical standard of the general functional and physiological state of the person;

7 – creation (selection) of information markers for binary diagnostics of human organs and systems in accordance with the defined preliminary sequence of actions on the problem organs;

8 – sequential submission of request signals in accordance with the defined preliminary sequence of actions using information markers regarding the binary characteristics of systems and organs, values of frequency and time parameters and number of sessions of the required electromagnetic quantum-wave impact on the body;

9 – receiving responses on deviations of feedback signals from the information standard on the state of human systems and organs;

10 – formation of a refined list of systems and organs and the sequence of actions to restore the functional and physiological state of the person according to the results of body responses;

11 – restoration of the functional and physiological state of the person by periodic quantum-wave action on the body by electromagnetic fields with defined frequency and time characteristics and number of sessions, in accordance with the defined sequence of actions.

The generalized functions shown in Fig. 1 should be considered as basic functions $f_o^{(j)}$, each of them having its own preparatory functions $f_{no}^{(j)}$ and final functions $f_{go}^{(j)}$, as well as preparatory for the preparatory function $f_{nn}^{(j)}$. There are also the final function with respect to this function, that is $f_{g}^{(j)}$, the preparatory function for the final function – $f_{ng}^{(j)}$, as well as the final function for the final function – $f_{gg}^{(j)}$. The functions $f_i^{(j)}$ and $\in\{1, N\}$, where N=11 is the number of functions, at its upper hierarchical level j can have a complex structure. Complexity is caused not only by the need to have auxiliary and control functions, but also by the possibility to combine the functions in the following ways:

– sequential:

$$f_i^{(j+1)} = f_{i1}^{j} \oplus f_{i2}^{j}; \qquad (3)$$

– parallel:

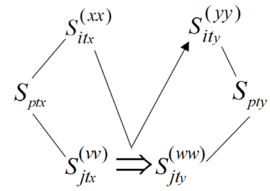
$$f_i^{(j+1)} = f_{i1}^{j} \otimes f_{i2}^{j}; \qquad (4)$$

– network:

$$f_i^{(j+1)} = f_1^{(j)} \Theta f_2^{(j)} \ldots \Theta f_n^{(j)},$$

$$\Theta \in \{\oplus, \otimes\}. \qquad (5)$$

For the transition from functional to elementary structures, it is advisable to use a universal modeling unit – information invariant, which reflects the target and forced transformations:



(6)

Here: $S_{\xi\, t_m}^{(kk)}$, $kk \in \{xx, yy, vv, ww\}$, $\xi \in \{i, j\}$ is the ξ-th system (subsystem) at time t_m, $m \in \{x, y\}$, whose state corresponds to the upper index (kk); S_p is the environment. The double horizontal arrow indicates the target transformation, and the single broken one indicates the forced transformation, which results from the change in the resource of the conversion system S_i when it affects the converted system S_j. Single sloping lines reflect the interaction of the system (subsystem) with the environment.

The model (6) reflects the general structure of the interacting systems (subsystems) over two phases: initial (indices of subsystems *xx* and *vv*) and final (indices of subsystems *yy* and *ww*). This model is obtained by matching the element of the function implementing it, taking into account their location in the environment, based on the general definition of the system.

The structures of subsystems can be specified on the basis of object classifications and their hierarchies [18].

Since the industry is currently producing modular designs that integrate multiple functions, depending on the optimality criterion and constraints, it is often advisable to use such objects. For example, there are diagnostic modules that comprehensively provide the implementation of the 3 functions indicated in Fig. 1 as 1, 2 and 3 with their control and auxiliary components.

Given this, one of the variants of the diagnostic and health complex may have a general structure, shown in Fig. 2.

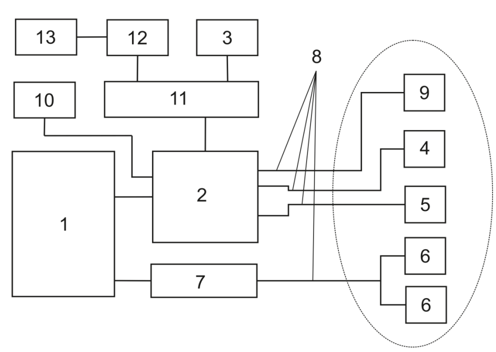


Fig. 2. Variant of the general structure of the Quanton complex

The complex includes:

1 – programming and computing unit with housing, memory and monitor;

2 – diagnostic and analytical module;

3 – set of electronic copies of information markers;

4 – passive electrode;

5 – probe electrode;

6 – conductive bracelets;

7 – generator capable of programming to different operating modes and frequencies of electrical sinusoidal pulses with a power source;

8 – switching devices.

The complex is additionally equipped with:

9 – capacitive sensor with a digital converter,

10 – generator of pulses, the shape of which is close to rectangular, connected to the diagnostic module 2 and the passive electrode 4 and the probe electrode 5. The complex also includes the unit 11 for rapid signal decomposition in the Fourier series and the unit 12 for comparing the obtained characteristics of the Fourier series with the standard (reference) characteristics in the unit 13.

The probe electrode 5 may have the manual (M) level of technicalization or be made as multi-contact, completed elastic fastener that allows obtaining the automated (A) level. To realize level A, a multiplexer is introduced to the complex, which provides sequential reading of signals from the electrodes. As a programming and computing unit 1, smartphone, tablet or laptop can be used, which allow an automated or partially intelligent technicalization level of the complex. Implementation of higher levels of technicalization requires special research and design work.

The complex operates as follows.

At the preparatory stage, spectral-frequency standards of the body, introduced into the memory of the programming and computing unit 1 with memory unit and monitor are created a priori, through statistical processing of the measurement results.

At the first operating stage of the complex, the real frequency spectrum of the human body and its deviation from the spectral-frequency standards are determined. To do this, an electric circuit is formed: passive electrode 4 – human body – programming and computing unit 1 with memory unit and monitor – capacitive sensor 9. This allows measuring the signals and performing spectral analysis thereof, passing through the unit 11 of rapid signal decomposition into the Fourier series. Next, characteristics of the spectral-frequency diagram are introduced in the unit 12 to compare the obtained characteristics of the Fourier series with the standard (reference) characteristics. According to the maximum values (for example, in decreasing order of their values) of deviations, the list of organs is determined, the functional and physiological state of which should be normalized.

In the second operating step, markers 3 are used for the determined list of organs and, using the organized electrical circuit, request signals regarding the binary characteristic (whether or not it is necessary to normalize) of their state are sent. For those biological structures that have given positive feedback on deviations of feedback signals from the information standard, markers are formed to determine the values of the frequency and time parameters and number of sessions of the required electromagnetic effect on the body. For this purpose, an electric circuit is formed: passive electrode 4 – diagnostic module 2 – probe electrode 5, passing electric current through it, answers are obtained by changing (increasing) the electrodermal activity. As information markers, content-ranked, deductively selected (so that the subsequent marker specifies the content of the previous one), biofield (mental), sound, or contact-text semantic structures can be used.

In the third stage, restoration of the functional and physiological state of the person is carried out by periodic quantum-wave action on the body by electromagnetic fields with defined frequency and time characteristics and number of sessions. Quantum-wave action on the body is carried out, passing the electric signal with the specified characteristics through the human body. The circuit includes conductive bracelets 6, programmed to the required operating modes and frequencies, generator 7 with a power source and switching devices 8. The generator electrically supplies a sinusoidal signal at frequencies within the upper half (more than 500 MHz) of megahertz and lower half (up to 100 GHz) of the gigahertz range.

Quantum-wave action on the human body is carried out by supplying a signal through the zones located on opposite (right and left) hands. Quantum-wave action must meet ergonomic constraints. This action, entering the field resonances with the biological structures that have deviations from the standards, changes their quantum energy characteristics. Since the body independently determines the characteristics of quantum-wave action, such influence is optimal and leads to the restoration of the functional and physiological state of the person.

Signals can be sent during sleep or any other activity (for example, in the workplace, in transport, etc.).

The procedure, starting from the third stage, is repeated for those biological structures that have deviated signals from the information standard, until the maximum approximation to the normative values is reached. However, the number of sessions is limited to 4 because of the inertia of biochemical reactions.

Therapy in the Quanton computer hardware and software complex is carried out in the mode of continuous adaptive action.

Deterministic electromagnetic radiation on the body (including in the area of biologically active points) affects it, correcting the spectra and healing both individual organs and the whole body.

When using information markers, the priorities of which are ranked by the values of deviations of the real frequency spectrum of the human body from spectral-frequency standards, quantum-wave action by electromagnetic fields gradually brings the organs closer to the normative state. Thus, part of the overall optimization procedure to maximize the productivity of the complex at the stage of diagnosis and operation is performed simultaneously.

In the Quanton complex, spectral and binary methods for obtaining information about the state of a biological object (human) are organized through two independent channels. Operations on these channels are performed sequentially, the results of the first one being a condition for the start of the second one. In order to minimize the possibility of errors in the diagnostics, both spectral and binary methods allow repetitions, which affects the overall productivity. Productivity is significantly affected by the level of technicalization of these processes. At the manual level of technicalization, the time spent on obtaining and processing information during diagnostics can be ten times higher than at the automated (computerized) level. Therefore, it is also necessary to optimize the complex by the criterion of process performance.

6. Parameterization of elements and formalized formulation of the parametric optimization problem

Parameterization of the elements of the resulting set of possible common structures must be performed for all attributes. For this purpose, clusters of geometric, electric, magnetic, strength, thermal, time, economic, environmental, ergonomic, physiological and other parameters are identified, which significantly influence the chosen optimality criterion and system restrictions. The need for identification and parameterization of attributes is specified by the tasks and conditions of synthesis, in particular, conditions for the use of modular structures and multifunctional components.

Level by level, starting from the hierarchically lowest, parametric optimization synthesis of subsystems using the given criterion and defined general constraints is carried out by specifying and solving the formally stated general problem on the basis of a universal system of dependencies [21].

$$W1(Z), W2(Z), \ldots, Wn(Z), \tag{7}$$

$$\begin{cases} \vec{w}(t,\vec{z}_k,\vec{u}_k) \Rightarrow \vec{w}(t)_{opt}, \\ u_k = \sum_{\xi}^{l} f_k\left(\delta_\xi u_{o\xi}^*\right), \\ \vec{z} = \Phi_c(t,\vec{y},\vec{u}), \\ u_o = \sum_{\eta}^{m} f_o\left(\delta_\eta u_{m\eta}^*\right), \\ u_n = \sum_{\tau}^{n} f\left(\delta_\tau u_\tau^*\right), \\ \delta_g(t) \in \{0,1\}, \\ g \in \{\xi,\eta,\tau\}, \\ Al_i^-\left(|S_\Sigma|,\vec{\Pi},t\right) \le Al_i\left(|S_\Sigma|,\vec{\Pi},t\right) \le Al_i^+\left(|S_\Sigma|,\vec{\Pi},t\right), \\ i \in \{1,l\}; \\ \Phi_j^-\left(|S_\Sigma|,\vec{\Pi},t\right) \le \Phi_j\left(|S_\Sigma|,\vec{\Pi},t\right) \le \Phi_j^+\left(|S_\Sigma|,\vec{\Pi},t\right), \\ j \in \{1,m\}; \\ \vec{\Pi}_{ijk}^- \le \vec{\Pi}_{ijk} \le \vec{\Pi}_{ijk}^+, \\ k \in \{1,n\}, \\ \vec{\Pi} \in \{\vec{x},\vec{y},\vec{z}\}. \end{cases} \tag{8}$$

where:

– W – vector – optimality criterion;

– t – time;

– $x_1, x_2, x_n; y_1, y_2, y_m, z_1, z_2, z_k, u_N, N \in \{k,o,n\}$ – parameters and control actions at the levels of the supersystem, system and subsystems, respectively;

– δ_g – sequences of control actions;

– sign Al means the algorithm of the procedure provided by the theory of deductive systems to determine the values of algorithmic constraints and tolerances;

– Φ, f_n – functional dependencies;

– $|S_\Sigma|$ – structure;

– Π – parameter vector;

– subscripts mean: k – supersystem; o – system; n – subsystem;

– i – level of hierarchy;

– j – number of functional restriction;

– p – relation to the parameter;

– opt – optimal value;

– superscripts "–" and "+" mean lower and upper tolerances, respectively.

Dependencies (7), (8) are an information invariant that reflects the general conditions and limitations of creation, structuring, functioning, possible development (modernization, restructuring), communication, control and transformation of the system. If specified, these dependencies allow solving the problem of complex optimization by the formalized method. In addition, a comprehensive analysis of the effectiveness of various system performance, energy efficiency and quality measures offered as an option in the course of technical audit can be conducted on their basis.

When setting and solving the problem of structural-parametric optimization of the Quanton complex by the performance criterion under constraints, including by reliability at the stage of operation, these dependencies can have the following form.

– optimality criterion:

$$t_g = t_{pfs} + t_s^n + kt_{pfb} + t_b^m + t_{re} \rightarrow \min; \tag{9}$$

– restriction:

$$\left(1 - q_s^n q_b^m\right) \ge [P_g];$$

$$n \ge 1; \tag{10}$$

$$4 \ge m \ge 1,$$

where t is time; subscripts pf indicate preparatory and final time; s, b, re is the ratio of the parameter to the operations of spectral and binary diagnostics and recovery, respectively; t_s, t_b is the main (machine) time of the specified operations; q_s, q_b are the error probabilities in spectral and binary diagnostics operations; $[P_g]$ is the general tolerance for the probability of obtaining the required information during diagnostics. The coefficient k and the exponents n and m denote the number of changes of measurement points and the number of repetitions of spectral and binary diagnostics operations. Number 4 is the maximum allowable number of measurement repetitions at one biologically active point.

In Fig. 3, the n–m coordinates show the limiting contour formed by constraints (10).

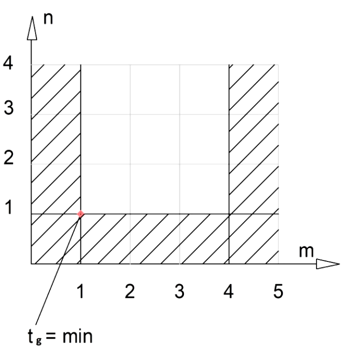


Fig. 3. Limiting contour formed by constraints (9)

The point corresponding to t_g=t min with sufficiently high accuracy of diagnostic operations is also noted, which ensures that constraints are satisfied (10).

7. Optimization and technical audit of the complex

It is advisable to perform the procedure of complex optimization, given the presence of multioperational structures, step by step, using discrete-continuous 3D models [24]. In the first stage, clusters of limiting contours are built, which form the areas of permissible parametric solutions for each of the sequential operations. This takes into account all types of constraints given in Table 2. In the second stage, for each of the possible methods and technicalization levels, the Pareto-optimal solution by the performance criterion is determined. In the third step, a globally efficient solution is determined within the complete set of clusters corresponding to the complete set of structural solutions by performing a comparison procedure for the optimality criterion. The fourth stage is system analytical technical audit by the energy efficiency criterion. In the fifth step, the synthesis is completed based on the comparison of quality indicators and selection of the best option.

Given the relatively small number of variables affecting the optimality criterion (8) and the additive nature of the component influence, the solution of the structural-parametric optimization problem can be found by search over the options. At the same time, it is advisable to use many typical ways of increasing the productivity of technical systems during the search [22].

In principle, in order to increase the efficiency of the process during the operation of the Quanton complex, it can be found that the reduction of the values of these variables can be achieved by:

– automation of preparatory work (reduction of t_{pfs}) when changing the technicalization level from P to A;

– increasing processor speed (reduction of t_s);

– minimization of the initial scope of work due to the preliminary selection of diagnostics objects according to the results of integrated evaluation of the body radiation spectrum (reduction of t_{pfb});

– improving the performance of preparatory work through the use of high-speed processor (reduction of t_{pfb});

– automation (change of technicalization level from P to A) of the search process and installation of contacts of the sensor head and information processing (reduction of t_{pfb});

– minimization of the time of supplying test signals (reduction of t_b);

– use of multi-contact head (reduction of k);

– increasing the accuracy of spectral and binary diagnostics (minimization of n and m);

– minimization of the duration of the main wave influence and the number of sessions due to independent selection by the body (reduction of t_{re}).

With the standard level of $[P_g]=0.99$ and real sufficiently wide values of $q_s=q_b=0.1$, condition (9) holds for $n=m=1$ ($P_g=1-0.1\cdot 0.1=0.99$). This provides optimization of the operating modes of the complex, which give it maximum productivity.

Reduction of each of the durations t_{pfs}, t_s, t_{pfb}, t_b and t_{re} will improve the parametric solution by the optimality criterion.

Practical implementation of this can be achieved by improving the design of the elements of the complex. The field simulation showed that providing automation of the binary diagnostics process with the use of a multi-channel head (multiplex sensor) will lead to a significant (from 30–40 min to 0.2 min) reduction of t_b. This will also allow for a minimum value of the coefficient k and eliminate the effect of the exponent m on t_f due to the small t_b. In general, achieving $t_s=t_b=0.1$ minutes will increase the productivity of the diagnostic process to (30–40)/0.2=150–200 times and for $t_{re}=60$ minutes will provide an increase of the optimality criterion by 1.5 times.

Further improvement of the complex by increasing its energy efficiency and quality can be carried out on the basis of technical audit. The algorithm of system technical audit can be based on the use of the general model of the target transformations arising in the interaction of the converting and converted systems according to the model (6). The audit determines the total energy consumption per unit of output and quality of the system. At the same time the expediency of using methods of ensuring high energy efficiency of the processes in each of the operations in the system of elements of the set of structures is defined. The selection criterion is assessment of the possibility of improving the performance indicators with the estimation the "cost-effect" ratio for each of the possible methods to improve the energy efficiency of the system. By the results of definition of this criterion, taking into account the available general restrictions, a decision is made on the option of modernization of technological subsystems. A complete (within the accepted classification) set of possible structural solutions for the main efficiency indicators is given in [23]. The matrix – the row r_{ij} of possible methods to improve energy the efficiency is as follows:

$$r_{ij}=\{E_l\times N,\ R_d\times N,\ C_b\times N,\ E_l\times h,\ R_d\times h,\ C_b\times h,\ E_l\times M_a,\ R_d\times M_a,\ C_b\times M_a,\ E_l\times A_a,\ R_d\times A_a,\ C_b\times A_a,\ E_l\times I_t,\ R_d\times I_t,\ C_b\times I_t,\ A_d\times N^*,\ I_n\times N^*,\ D_v\times N^*,\ A_d\times h^*,\ I_n\times h^*,\ D_v\times h^*,\ D_v\times M_a^*,\ I_n\times M_a^*,\ D_v\times M_a^*,\ D_v\times A_a^*,\ I_n\times A_a^*,\ D_v\times A_a^*,\ D_v\times I_t^*,\ I_n\times I_t^*,\ D_v\times I_t^*\}, \quad (11)$$

where r_{ij} is the set of functions, the duration of which affects energy consumption: M_a – main actions; A_a – auxiliary actions; I_t – idle time; a set of methods that allow reducing energy consumption, reducing the length of the cycle: E_l – elimination; R_d – reduction; C_b – combination; index * means a symmetric set of methods aimed at energy self-sufficiency of the system for the energy-giving functions: A_d – addition; I_n – increase; D_v – division.

With this set, it is possible to form a complete set M_{sh} of possible structural energy efficiency solutions for each possible method of system change:

$$M_{nsh}=M_{sh}\times r_{ij}^{\mathrm{T}}, \quad (12)$$

where the superscript "T" is the sign of transposition.

The feasibility of using each element of the set M_{nsh} is determined by comparison with the standard. Thus, the most energy-efficient pulse generator, diagnostic module, processor, multiplexer and other components are selected for the complex. The experience of applying this technical audit algorithm has shown the possibility to increase energy efficiency by more than 30 %. This is important in particular for the portable version of the complex.

To ensure the maximum quality of the complex, analysis of the accuracy of the frequency and reliability of the generator is carried out, which has a direct impact on the person. Among the possible options, a variant having an index not lower than the standard and better "cost-effect" ratio is chosen.

8. Discussion of the results of using information invariants for structural-parametric synthesis and optimization of the Quanton diagnostic and health complex

The developed method of directed (non-analog) structural-parametric synthesis of the Quanton diagnostic and health complex is based on the use of the proposed algorithm of searching for structural-parametric solutions in combination with general information invariants of technical innovations. The logic of the algorithm is based on the deductive approach and the principle of informational subordination of the stages of preparation and search of necessary solutions. Selection of information invariants is ensured in such a way as to obtain unspecified structures of functions and elements of the complex as a whole. This allowed solving the main problem of analytical design of the complex – non-analog determination of the set of possible variants of its ordered structures. The latter created the conditions for the formalized formulation of the problem of integrated structural-parametric optimization of the complex (dependencies (7) and (8), which are specified for the Quanton complex by dependencies (9) and (10), respectively). Ordering of information invariants in order of increasing complexity and the form of dependencies (9) and (10) became the basis for determining the method of searching for variants of structures and values of parameters that ensure extremely high productivity. Extremely high productivity is ensured by joint optimization of the structure and parameters of the complex, taking into account the completeness of their domains of existence. This is the main advantage of the method.

Taking into account the completeness of the domains of existence of structures and parameters and the possibility to perform synthesis without applying analogs are the fundamental difference of the proposed synthesis method from traditional heuristic and evolutionary ones. The direction of synthesis due to the ordering of information invariants distinguishes the proposed method from existing combinatorial methods.

An additional advantage of the proposed method is the ability to control the functionality, technicalization level and other indicators of the complex using appropriate invariants both in directed synthesis and in analytical audit.

The proposed algorithm of analytical technical audit takes into account the results of optimization by the productivity criterion and at the same time allows improving other indicators of the complex, in particular, energy efficiency and quality of the system.

The synthesized Quanton complex, due to biological feedback and binary identification of the biosystem state, enables the human body to independently determine the characteristics of quantum wave action, so its impact is optimal and leads to the restoration of the functional and physiological state of the person, increasing the adaptability and restoring self-regulation and self-regeneration mechanisms.

Quantum-wave action on the body can be carried out at home, during sleep, or be combined with any other activity (for example, in the workplace, in transport, etc.). In this case, the method increases its efficiency due to the consistent elimination of disharmonic processes, which have deviations from the normative characteristics, on the parameters, to which it responded and determined.

Since using the complex increases the amount of information obtained during diagnostics, the accuracy of diagnostics increases. For example, if the spectral-frequency method gives an error of 15 %, and the method at the body's request with the help of markers – at the level of 10 %, then the total error will be reduced to 0.15×0.10×100 %=1.5 %. Increase of the productivity of the complex is achieved by reducing time losses at the previous stage of selecting organs with deviations, since additional information is used in the overall diagnostics of the human body according to its spectral-frequency response.

The experience in using the proposed complex for more than 3,000 people at the manual level of binary diagnostics confirmed the achievement of the specified functionality and performance indicators.

The proposed general synthesis algorithm, used to determine structural and parametric solutions of the Quanton complex, is also suitable for solving the problems of complex optimization of other multioperational complexes. Constraints are that the dependencies (7), (8) are further refined for each other complex based on the use of the specified synthesis conditions. Additional research is required for the principles of choosing information invariants and conditions for the use of computer-aided design systems for synthesis.

9. Conclusions

1. The general algorithm of structural-parametric synthesis of the Quanton diagnostic and health complex is proposed, the novelty of which is to use information invariants, which allow forming complete areas of possible structural solutions and determining the set of general dependencies for parametric optimization.

2. As information invariants, sets of methods to obtain the functional properties of the complex, phase cycles of the life cycle, structures of technical subsystems and means to control the technicalization levels, productivity and energy efficiency of processes can be used.

3. Completeness of the domains of possible structural solutions, combined with the set of dependencies that bind the parameters, allows setting and solving the problem of a new level: integrated structural-parametric optimization of the complex.

4. The search for the extremely effective solution involves step-by-step determination of optimal parameter values within the limiting contours for each of the structural variants of the complex ranked by the level of complexity.

5. The use of the proposed optimization algorithm with the option of analytical technical audit allows increasing the productivity levels of the diagnostic process up to 150–200 times. In this case, the assessment of the level of the selected optimality-productivity criterion of the complex as a whole can increase 1.5 times. In addition, conditions are created to select an element base with higher energy efficiency, accuracy and reliability. This is a reserve for improving the operational properties of the complex.

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