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INNOVATION TECHNOLOGY FOR UPGRADING SPACE MONITORING STATIONS TO ADVANCED CIRCUITRY

Introduction. *Radar technologies have formed the foundation of outer space control systems in Ukraine, relying on radar stations.*

Problem Statement. *The domestic 5N86 radar has been in operation for an extended period, resulting in significant obsolescence of its elemental base. Many components have lost functionality and cannot be replaced. The elemental components used in the radar's design are either no longer produced by domestic manufacturers or have been manufactured using outdated technologies, rendering the system uncompetitive and unable to meet modern requirements.*

Purpose. *To justify possible approaches and methods for restoring the functionality of radio-electronic components with extended service lives.*

Materials and Methods. *The study has applied theoretical analysis, generalization, analogy methods, and estimated calculations based on device modeling theory.*

Results. *A technology for restoring the functionality of radio-electronic equipment has been developed by creating analogs of obsolete components. This approach has preserved structural and schematic consistency between the new sample and the prototype, eliminating the need for certain modules within the radar's hierarchical structure. By transitioning from outdated transistor circuitry to integrated designs using a functionally redundant elemental base, all target functions of 299 excluded modules have been implemented using 148 integrated microcircuits.*

Conclusions. *The proposed transition to advanced circuitry has enabled not only the preservation of functions in radio-electronic systems that had lost functionality but also elevated the radar to a higher operational level. This reengineering approach creates opportunities for both restoring outdated radar systems and developing advanced radar models that meet modern standards.*

Keywords: outer space control, reengineering, circuitry, modeling, module, cell.

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The development of new and improved samples of radio-electronic equipment (REE) always begins with an idea, which is later implemented in one form or another in a specific sample. It is difficult to determine the contribution of each participant to the creation of a new generation of REE, as the idea and its implementation are interdependent aspects of a unified process of creating a new sample. Even a good idea can fail with poor implementation, and conversely, a good implementation of a poor idea proves incapable of solving the problem. Therefore, it is crucial that the idea and its implementation belong to the same author, as there will always be executors of others' ideas, which may not always be correct.

Under the current military conflict in Ukraine, having accurate and timely data about the space environment, including the motion parameters of ballistic missiles and space objects, is crucial for victory. Solving the tasks of national defense requires the development and implementation of standardized procedures for space support operations (combat activities), with space situational awareness (SSA) being their fundamental functional domain [1, 2]. The task of continuously monitoring near-Earth space in all weather conditions is performed by long-range radar stations.

However, Ukraine's existing 5N86 radar stations designated for such purposes are technologically outdated, and achieving high-level tasks related to national security and defense with them is only possible after a significant modernization of the station's radio-electronic equipment.

The domestic 5N86 Dnipro (Hen House) radar is the primary tool for space control, making it extremely important to ensure its reliable and effective application for targeted purposes. The 5N86 radar belongs to the second generation of REE. Today, the groundwork laid during the creation of the first-generation radars is still being utilized, and new generations of radars are largely built on the foundations established in previous years. The current task is to develop a technology for restoring functionality and transitioning the first-generation REE hardware to new, modern circuitry structures that meet third-generation criteria while preserving the fundamental principles and classical circuitry solutions implemented in the radar.

Maintaining and adapting the primary target functions realized in the current radar to modern requirements significantly facilitates the resolution of issues related to creating new circuitry capable of ensuring high efficiency and qualitative characteristics of the hardware's target functions. The radio-electronic equipment of the existing radar has essentially exhausted its technical resources due to prolonged operational use [3].

The reliable operation of radar systems (RS) has clearly highlighted a critical issue, the resolution of which is highly relevant and significant in today's context. Modern global trends increasingly emphasize the importance of discovering new ways to enhance and improve existing systems and achieve new characteristics by developing and integrating innovative circuitry solutions into existing radio-electronic equipment (REE).

A distinctive feature of the current state of REE is that, while many samples in operation are not yet obsolete in design, they are based on outdated and physically exhausted elemental component bases (ECB). Most operational radar systems are considered "classical" models, possessing certain properties that meet not only present-day needs but also future requirements, owing to the foresight and design skill of their developers. These fundamental principles, formulated, substantiated, implemented, and proven over time, remain the cornerstone of future development and improvement. The long-standing functionality of the 5N86 Dnipro (Hen House) radar convincingly demonstrates its continued viability. Paradoxically, this "classical" effect of the technology, ensuring prolonged use, has also created the problem of maintaining and supporting the operability of existing products.

Thus, restoring the operability of REE under the conditions of discontinued production of both the equipment itself and the elemental components it relies on has become a pressing issue.

Until recently, modernization and repair were the primary methods of maintaining the technical condition of REE. However, repairing outdated weapon systems often involves retaining obsolete and unreliable equipment. As a method of maintenance, it merely replaces failed components, leaving the remaining elements with depleted resources, which cannot guarantee the reliability of repaired equipment [4, 5]. Furthermore, with the cessation of ECB production for existing circuitry, repairs as a restoration method have become infeasible, necessitating the exploration of alternative approaches to restore REE functionality.

The most suitable and contemporary solution is reengineering technology, which is rapidly replacing traditional approaches, especially when creating a high-quality replacement for high-tech products from scratch is nearly impossible. Designing a sophisticated product independently requires years of work and millions of dollars in investment. However, an alternative approach exists — one that is not as simple as changing suppliers but is also not as time-consuming as developing a new product from the ground up. This approach is reverse engineering, which entails analyzing an existing product and developing an equivalent based on this analysis that can be manufactured using domestic technological capabilities.

It is important to note that reengineering is not exclusive to economically underdeveloped countries. Even nations like China, with one of the most advanced economies, and European countries have successfully employed reverse engineering. For example, the Europeans transformed the American 6KAS radio tube into the “European” EL95, while the Americans created their own 6CA5 tube based on the European EL34.

A critical prerequisite for successful reverse engineering is the availability of an advanced domestic technological base, enabling the adaptation of new products to local manufacturing capabilities. Another essential condition is having a strong design school, including skilled designers and technologists, as the success and speed of reengineering depend significantly on specialists with expertise closely aligned to the project’s profile [6].

Reverse engineering is one of the fastest methods for restoring outdated equipment and achieving import substitution, presenting a viable opportunity to export domestically produced items at competitive prices. Pursuing a policy of purchasing imported ready-made products undermines the possibility of utilizing domestic developments, despite Ukraine’s reputation as a global innovator in the field of radio-electronic equipment (REE).

Currently, Ukraine lacks the methodological framework necessary to undertake essential reengineering transformations. There is no established methodology for evaluating the economic synergetic efficiency of such transformations, nor has a comprehensive analysis of the reengineering process been conducted. Additionally, the conceptual foundations for technological reengineering as a tool for achieving an innovation-driven breakthrough in Ukrainian machine-building remain undeveloped [7]. Today, the educational system predominantly produces users rather than engineers, even though “engineering” is the cornerstone of the term “reverse engineering,” with no mention of “consumer.” This gap may explain why users find importing equipment more accessible and comprehensible than engaging in reverse engineering.

The reengineering technology proposed in this study is innovative, as it addresses the challenges posed by discontinued production and the lack of elemental components used in the 5N86 radar system. Exploring new methods for restoring radio-electronic equipment is the only way to achieve positive outcomes under these circumstances. The suggested solution, which replaces outdated elemental bases with modern ones utilizing advanced circuitry while preserving existing structural frameworks, represents a novel approach in the design of complex technical systems.

The article presents key aspects of the work conducted in accordance with the Terms of Reference (TOR) approved by the National Academy of Sciences (NAS), the National Center for Control and Testing of Space Systems (NCCSS) under the State Space Agency, and the Ministry of Defense of Ukraine. These include:

- Identifying the structural and schematic features, as well as the construction and technological characteristics of the cells and modules of the 4PK control system in the 5N86 radar station.
- Establishing the list of functions and principles of operation for the existing cells and modules within the information reception unit in the 4PK-01 control cabinet.
- Performing simulation modeling of existing cells and modules on discontinued elemental bases.
- Justifying the applicability of reengineering technology to restore the functionality of cells and modules.
- Selecting new elemental bases for the existing structural and schematic designs.
- Conducting simulation modeling and developing models of cells using new elemental bases.
- Developing new circuit designs for constructing cells on updated elemental bases.
- Conducting test trials of the new cells, demonstrating their structural and functional interchangeability with the prototypes.
- Creating a complete set of design documents for manufacturing the new cells.
- Designing and manufacturing working prototypes of the newly developed cells and conducting experimental studies on their functionality.

The reengineering efforts in this study focused on 36 digital cells (2TY) and 299 modules (2TM) within the 4PK-14 control block of the 4PK-01 functional control system of the 5N86 "Dnepr" (Hen House) radar system for space monitoring and analysis. The selection of the 2TY digital cells and 2TM modules as reengineering targets was based on their role as primary structural elements, with 80% of the modules housed within the station's cells, blocks, and cabinets.

The selection criteria for reengineering objects emphasized functional completeness at the corresponding structural and hierarchical level of the radar system. The chosen modules and cells meet these criteria. The approach proposed in the study goes beyond refining existing technical, structural, and technological solutions. Instead, it aims for the complete rejection of outdated designs and the creation of fundamentally new solutions to ensure not only the restoration of non-functional components but also their operation at a qualitatively higher level.

The primary objective of the work is to identify a combination of components (modules, cells) and technologies that can reliably facilitate the creation of new components with the desired characteristics specified by the customer, minimizing associated risks. Achieving this objective requires more than the mere improvement of existing system-technical, design, and technological solutions. Instead, it calls for innovative approaches to ensure the development of high-performance, modern radar system components.

The need to reduce the variety of design types and unify them as a means of enhancing the manufacturability and efficiency of equipment production has highlighted the importance of investigating the potential for reusing structural elements, particularly the base-support structure (BSS).

Figure 1 illustrates the unified BSS of the existing 2TY cell.

Circuitry-wise, all cells and modules are implemented in discrete form on printed circuit boards. The electrical circuits are constructed using germanium semiconductors, resistors, and capacitors. A unified BSS is employed for all cells, with the connection of the boards to the block facilitated by a standardized connector.

It is worth noting that the circuit solutions utilized in the creation of the digital cells of the prototype are based on diode-transistor logic (DTL) elements operating in negative logic, unlike modern logic elements, which function in positive logic. The entire apparatus of the domestic 5N86 radar system is built on DTL.

Thus, for the independent development of new devices, it is critical to conduct research and identify innovative circuit and construction-technological principles for designing cells while ensuring

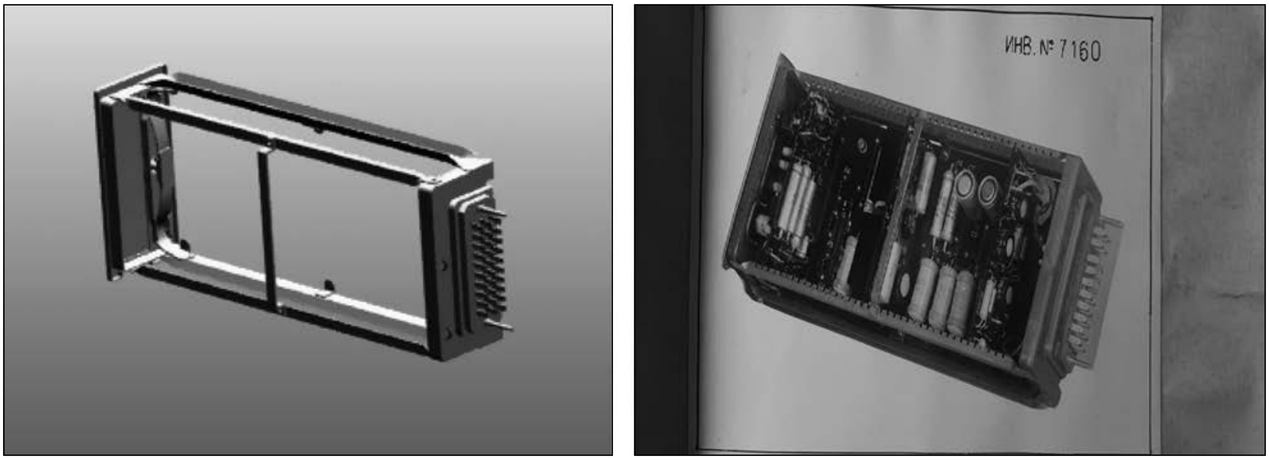

Fig. 1. General view of the existing base-support structure of the 2TY Cell

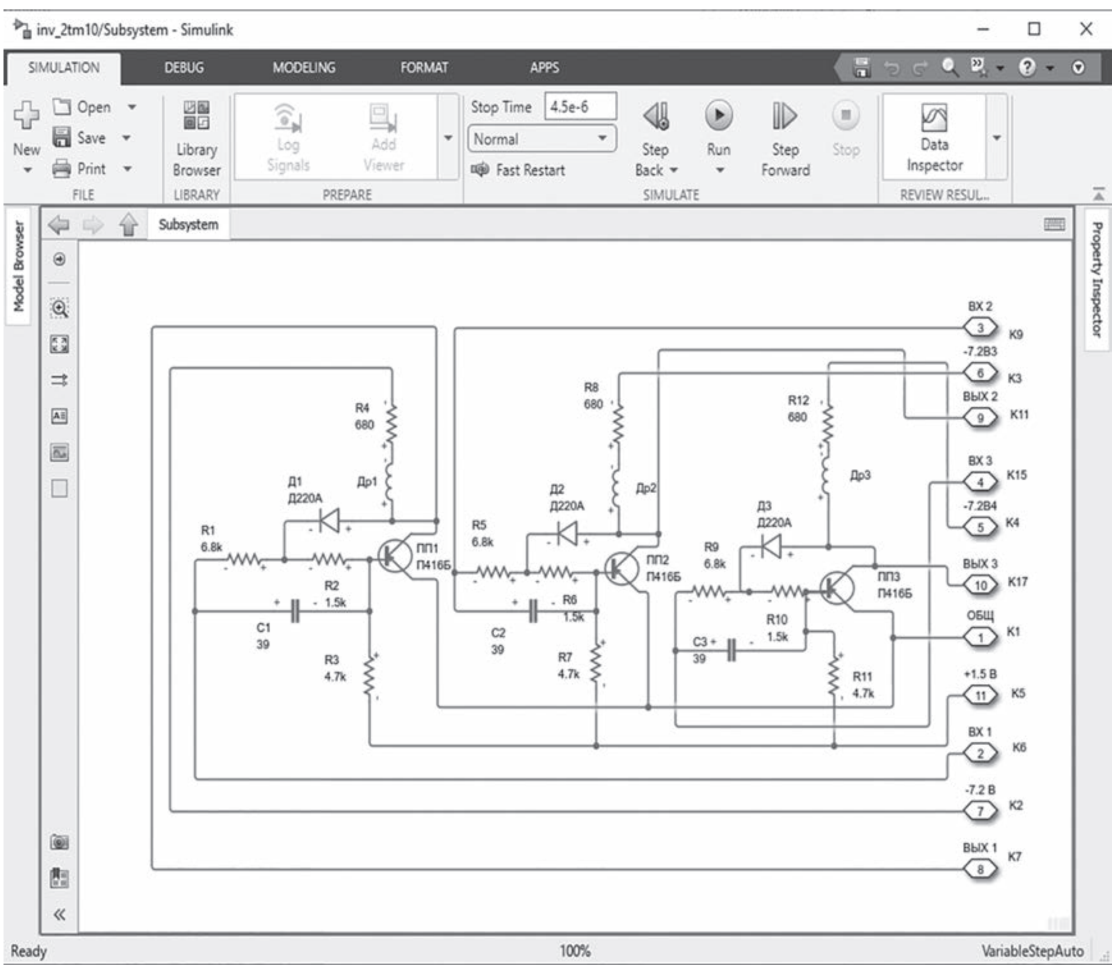

Fig. 2. Schematic Model of the 2TM-10 Inverter Module

full interchangeability of the new cells within the existing functionally complete equipment (FCE).

The first step in the reengineering of the selected objects — 2TM modules and 2TY cells (prototypes) — is to determine the operational principles and target functions of their circuit implementations through modeling. Circuit modeling is the most effective approach for studying the designed object during the formation stage of its schematic diagram due to its clarity, adaptability, and ease of adjustment.

During the modeling process, it is essential to create an electrical circuit model and testing models for the prototypes, obtaining results in the form of amplitude-time diagrams for the input and output signals of each cell and module. The modeling employs voltage, input, and output signal amplitude values specified in the design documentation for the respective modules and cells. The results and models derived from existing modules serve as the basis for modeling the 2TY cells. Figure 2 shows schematic model of the 2TM-10 inverter module designed for altering the polarity of pulse signals.

For each module, a testing model is developed within the Simulink/MATLAB environment. The results of testing the schematic model of the module are presented as time diagrams of the input and output signals in Fig. 3. All designations in the figure correspond to the current documentation.

The conclusion regarding the compliance of the developed module model with the requirements of the existing module was made through a comparative analysis of the test results of the module model against the parameters of the existing module.

The next step involves determining the operational principles and target functions of the schematic implementations of the existing 2TY cells through modeling in the Simulink/MATLAB environment. The schematic diagrams of the cells are constructed using discrete components from 2TM-type modules. The positional designations of the elements and contact numbering conform to the current documentation.

The test schematic for the 2TY-113 cell, designed for decoding binary three-digit codes and implemented using 2TM-49 and 2TM-10 modules, is shown in Fig. 4.

The third step is the development of ToR for designing the electrical circuits and constructing printed circuit boards (PCBs) for new cells. This step is based on information obtained during the modeling of existing modules and cells, as well as the results of test trials. Designing new electrical circuits is not feasible using the outdated existing component base (ECB) [8], as the primary operational and technical limitations and shortcomings of any electronic system are determined at the level of the ECB used.

The main task in reengineering the 2TY cells and 2TM modules is to select a new ECB to replace the components that are no longer in production. There are two possible approaches to address this issue: restoring the production of the outdated component base and replacing it with a more modern alternative.

However, using the first approach is both technically and economically inefficient and unjustified. The technical impracticality lies in the fact that the number of components in this case remains almost unchanged. Consequently, the operational characteristics of the products, including their reliability, also remain at the previous level. The technologies used in the development and production of the existing ECB are outdated, making their use by domestic manufacturers impractical due to the uncompetitiveness of the restored ECB.

The current level of semiconductor technology enables a qualitatively new implementation of previously created standard replacement elements using a new-generation component base. However, there is no universal methodology for selecting the optimal ECB for all scenarios. Therefore, choosing the ECB represents a critical scientific and practical task, the solution to which involves the development of fundamental technical and economic requirements for the new ECB.

The key feature of ECB selection in this context was that the decision was based on functio-

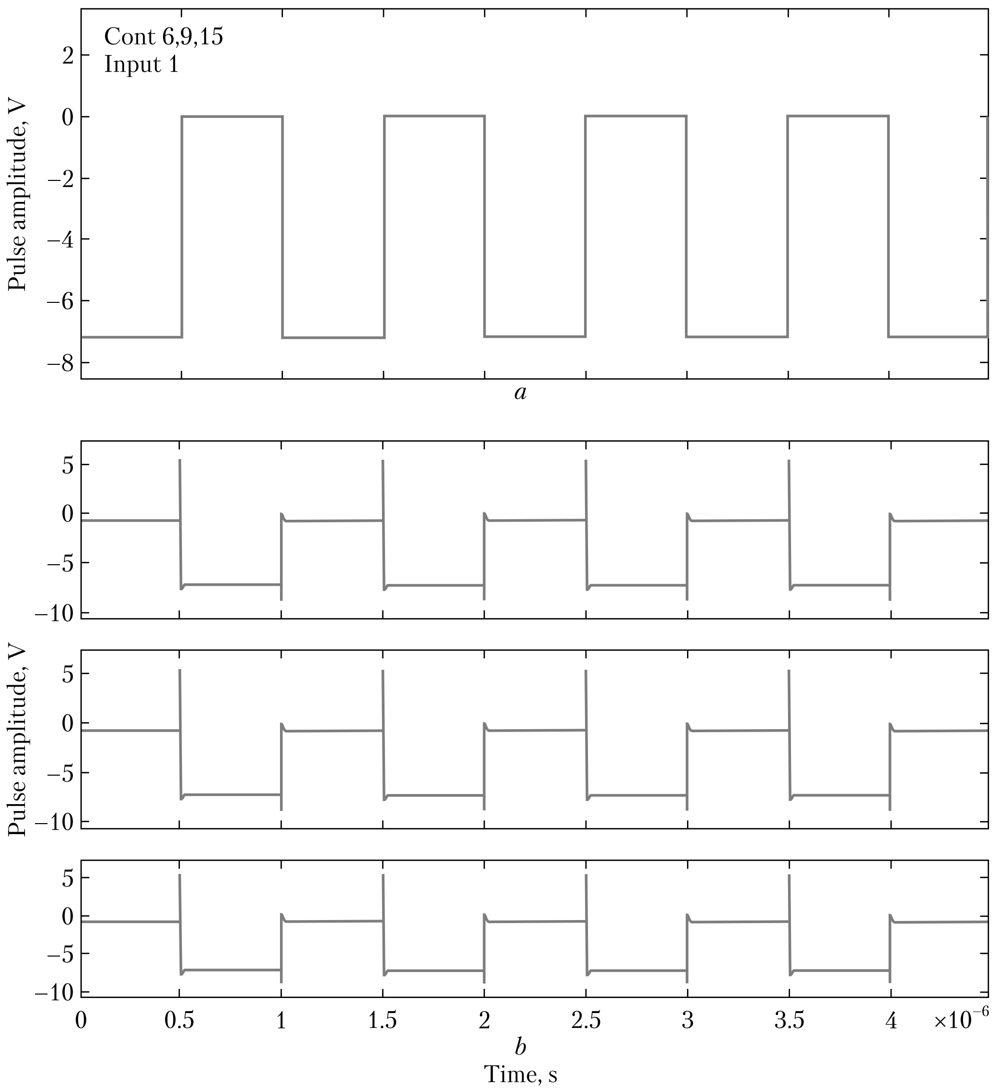

Fig. 3. Time diagrams of input (*a*) and output (*b*) signals

nal information obtained during the modeling of existing cells constructed using transistor-based discrete circuit technology.

The component base represents the foundational level of the structural-hierarchical division of a functionally complete device (FCD). Integrating all functional requirements at this foundational level (a single element) significantly influences the schematic and structural-technological design of both the new cells and the higher structural-hierarchical levels of the FCD.

Given the lack of a necessary domestic component base, the domestic developer urgently requires the supply of high-tech electronic component bases (ECB) from abroad. The Ukrainian market has long been saturated with imported electronic products. The selection of the nomenclature of foreign ECB manufacturers was made considering factors such as serial production scale, technological compatibility, functional completeness, full compliance with electrical parameters and application modes, as well as the availability for purchase and cost.

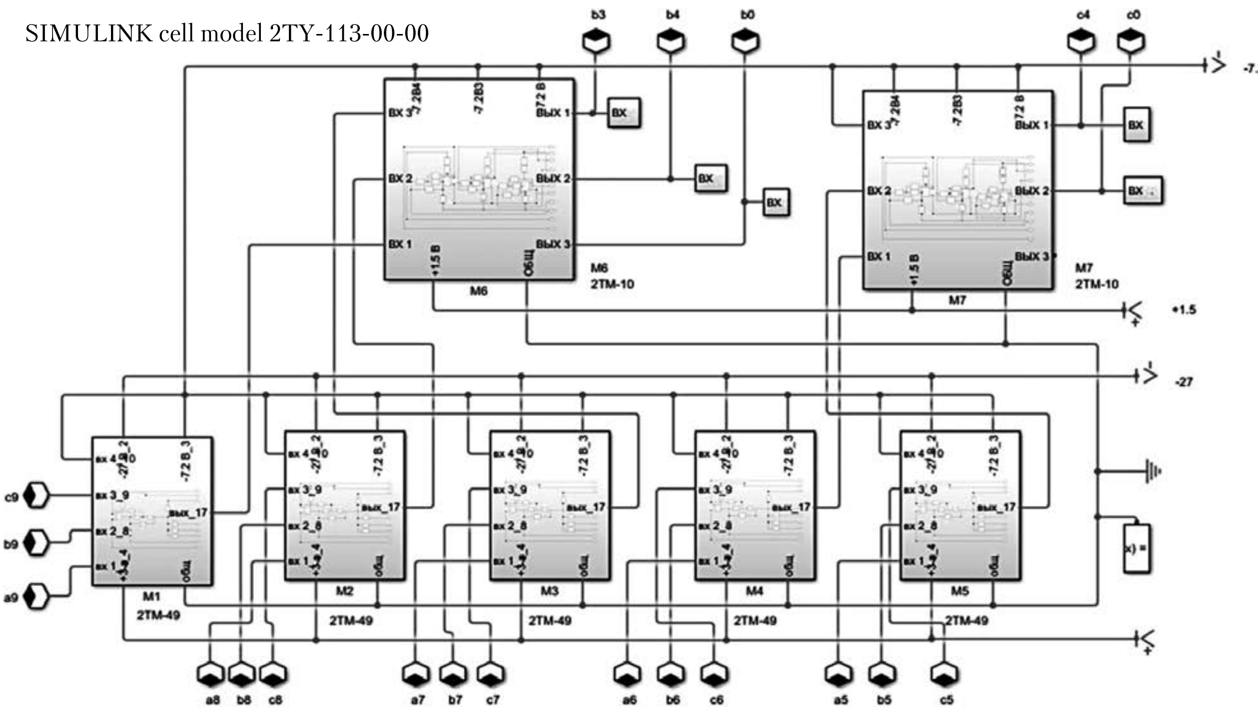

Fig. 4. Test Circuit for the 2TY-113 cell

One of the main criteria for selecting an ECB is the high reliability of the components, confirmed by years of operation. This is important because it is unrealistic to verify the published data on the actual reliability of modern microchips, transistors, etc., measured in FIT (Failure In Time). When selecting ECBs manufactured in the United States, it is necessary to consider that they are divided into quality classes: industrial (commercial/industry), military, and space-grade [9, 10].

Based on these established criteria, the well-known American company Texas Instruments (TI) [11] was chosen as the manufacturer for the new ECB. Specifically, taking into account the electrical modes and functions formed by the 2TY cells and 2TM modules, the widely used family of integrated circuits (ICs) from the 7400 series with transistor-transistor logic (TTL) was selected. The choice of specific ECB components must consider the input and output signal levels as well as the supply voltage of the respective cells.

The next criterion is speed. In the existing modules and cells, the maximum operating frequency is 2 MHz, while in the ICs from the CD4000 and SN7400 series, it is 8 MHz. An important criterion is the rise time of the pulse signals, which for the existing cells and modules is 0.1—0.6 μs. According to the technical data for the 4000 series, for logic elements working with pulse signals at a supply voltage of 10 V, ambient temperature of 25 °C, and a capacitive load of 50 pF, the typical rise time is 50 ns, with a maximum of 100 ns under the same conditions. For flip-flop circuits, the typical rise time is 30 ns.

All new 2TY cells have been developed within the framework of the ToR for the design of electrical circuits on a new component base, based on the initial data from the 2TY cell prototypes. The electrical schematic of the cell was developed in accordance with the ToR for the design of a new cell using the SN74HC02N IC. Figure 5 shows the electrical schematic of the 2TYn-113 (index *n* means new) cell.

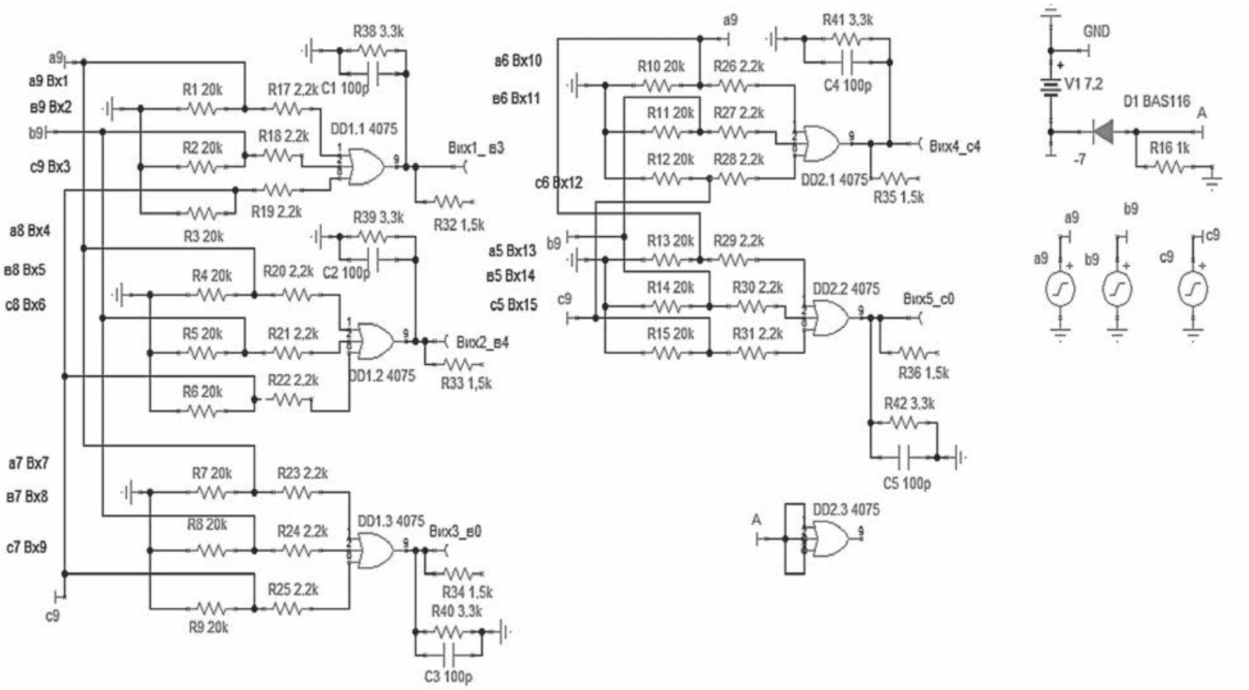

Fig. 5. Electrical diagram of the 2TYn-113 cell

The analysis of the test results for the 2TYn-113 cell showed that the obtained parameters fully match those of the prototype — the existing 2TY-113 cell.

Similarly, the development of other 2TYn cells using the new component base allowed for maintaining the intended purpose and all functions of the existing prototype 2TY cells, ensuring complete electrical and functional interchangeability between the old and new cells.

According to the Terms of Reference for design, after the development of electrical circuits, the design documentation for the 2TYn cells is created. The design of the printed circuit boards is done in P-CAD 2006. The basic supporting structure (BNC) of all 2TYn cells is also retained, using the same construction as the prototype 2TY cells. Maintaining the existing BNCs when creating the new cells helps reduce the time spent on designing the new generation of the structure and lowers manufacturing costs, as the BNC makes up to 30% of the total cost.

Retaining the circuit design and construction of the 2TYn cells, similar to the existing 2TY prototypes, ensures complete functional interchangeability of the new cells. The use of a new component base significantly simplified the circuit implementation, reducing the number of components used. This not only lowered power consumption but also improved the reliability of the cells.

Considering the financial capabilities and the possible levels of funding required to completely transition 2nd-generation radar systems to a new level, the decision should involve a step-by-step transition strategy.

The outcome of transitioning the cells to a new circuit design is the development of a complete set of operational documentation, including functional electrical diagrams (E2), schematic electrical diagrams (E3), a list of components (LE), and technical descriptions (TD). The total volume of operational documents developed for the new cells amounted to 112 pages in A4 format. The design documentation, which includes specifications, assembly drawings, and printed circuit board layouts for all cells, totaled 117 A4 pages. The technological documentation developed for replacing specific existing cells with new ones comprised 137 A4 pages.

Some results, reflected in prior publications [12—14], have been supplemented with new materials and have continued to contribute to ongoing research in this field. Comparative characteristics of the schematic solutions of the prototype and the new cells are presented in Table 1. As shown, the use of a new component base enabled the transition from discrete semiconductor circuitry based on germanium semiconductor technology to integrated circuitry utilizing TTL logic microchips.

The new circuitry for the 2TYn (new 2TY cells) allowed for the implementation of target functions more efficiently by excluding 299 modules from the hierarchical construction of the radar system (RLS). The solutions developed for the 2TYn cells operate with only one, significantly lower, voltage instead of the seven required by the prototypes. The use of a new generation of electronic component base (ECB) enabled simpler circuit implementations with fewer elements. For example, in the existing 2TM-50 module, the 2AND-NOT function is implemented using a two-channel coincidence circuit containing: 2 transistors (type P416) and 6 diodes (types D18, D9). In the electrical circuits of the 2TY-81 and 2TY-510 cells (comprising 5 and 8 modules of 2TM-50, respectively), the implementation required 10 and 16 transistors; 30 and 48 diodes, respectively. The new circuitry achieves the same function using only 3 and 2 components, respectively. The target functions previously implemented with 299 modules are now achieved with just 148 microchips. Additionally, the number of cells has been reduced due to the compact layout, with each 340 cm^2 board accommodating 2 to 6 microchips (each 4—16 cm^2).

The updated circuitry enables not only the elimination of modules but also a significant reduction in the number of cells. Moreover, the functional control system (4PC) on the new ECB is

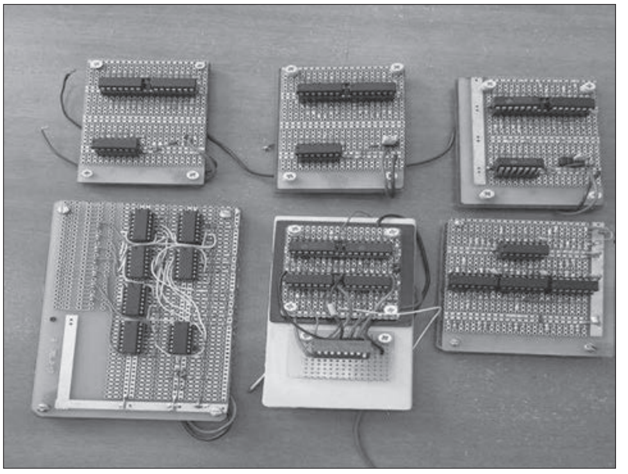

Fig. 6. Functional prototypes of the new cells

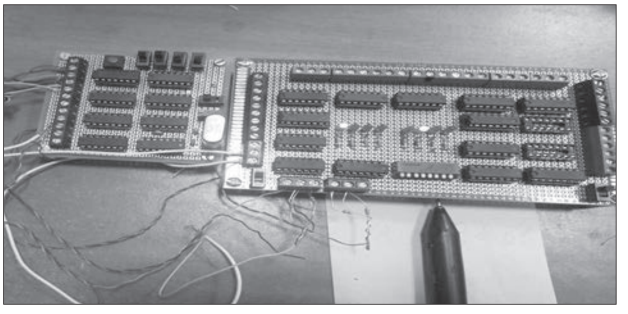

Fig. 7. Test equipment for verifying new logic cells

consolidated into a single cabinet, replacing the existing four.

To assess the conformity of 2TY (existing cells) and 2TYn (new cells), operational prototypes were manufactured and experimentally tested. The integrated circuitry of the new cells, developed based on the designed electrical circuits, ensures full functional interchangeability.

The general appearance of the functional prototypes of the new cells is shown in Fig. 6.

For the first time in domestic practice, a concept has been developed for transitioning from monofunctionality to multifunctionality in test equipment. The developed test equipment for verifying the new cells is shown in Fig. 7.

The testing of the new cells in the integrated circuit design not only confirmed the expected characteristics but also demonstrated that the obtained characteristics of the new cells are significantly better. Some comparative characteristics of the new cells and their prototypes are shown in Table 2.

As seen from Table, the integrated circuit design of the new cells addressed one of the key issues of large systems — the energy consumption. This was reduced from 200 W in the existing cells to 16 W in the new cells, and in some cases, even to 10 W. The testing of the new cells showed that the use of the new element base and circuit solutions resulted in an increase in the operating speed from 2 MHz to 8 MHz. The timing characteristics of the pulse signals used by the new cells allow for a significant improvement in the effectiveness and reliability of the required target functions. For example, the rise time of the pulse signals used to form the necessary target functions increased from 100—1000 ns in the existing cells to 8—10 ns in the new cells. The signal propagation delay in the electrical circuits of the cells was significantly reduced — from 50 ns in the existing cells to 6—10 ns in the new ones. Overall, the realization of the target functions is ensured with much better characteristics in the new cells.

Table 1. **Comparative Characteristics of Circuitry Solutions for Cells and Modules**

Cell	Prototype 2TY Discrete Circuitry		2TYn Integrated Circuitry	
	Module	Quantity	Quantity	
			Modules	Integrated circuit (IC)
81	2TM-50	5	0	3
113	2TM-49, 10	8	0	2
322	2TM-49	8	0	3
408	2TM-03, 42	10	0	4
676	2TM-35, 10	10	0	6
Total Modules		**299**	**Total ICs**	**148**

Table 2. **Comparative Characteristics of New Cells and Their Prototypes**

Parameters	Cell prototype 2TY	Cell 2 TYn
Power consumption, W	200	16 (10)
Speed, MHz	2	8
Rise time of pulse, ns	100—1000	8—10
Signal delay time, ns	50	6—10
Maximum operating temperature, °C	60	125 (150)

To assess the possibility of extending the life cycle of radio-electronic equipment with the new element base, circuit designs were developed using different types of integrated circuits. For example, the SD4000 series was used as an alternative to the SN 7400 series, and tests showed full compatibility, which reduces risks associated with the element base and provides a significant scientific and technical advance.

It should be noted that during the experimental testing of the cells made with the new element base, the temperature regime was maintained by natural air cooling, without the use of forced air cooling. Paradoxically, it was found, through the evaluation of thermal fields of the new cells using thermal imaging cameras and pyrometers, that the hottest area was the power supply circuits of the cells, not the cells themselves or their integrated circuits. At an ambient temperature of +23.2 °C, the temperature of the integrated circuits in all prototypes ranged from +24.4 °C to +25.3 °C.

Thus, as a result of the conducted simulation modeling and the development of module and cell models in the equipment of the existing radar system, new circuit solutions have been created for designing the new cells based on the new element base. Testing of the new cells demonstrated full structural and functional interchangeability with the prototype.

Therefore, the feasibility of using the innovative reengineering technology to restore the operability of radio-electronic equipment in the context of the discontinuation of both the equipment itself and its component base on which it was built has been substantiated.

Today, the role of the National Academy of Sciences (NAS) in addressing pressing issues as the main scientific organization of the country is clearly visible, and its efforts have been made in accordance with the priority research directions, as defined by the NAS of Ukraine. The developed technology will not only restore the functionality of outdated electronic systems but also serve as the foundation for creating the next generation of advanced electronic systems.

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ІННОВАЦІЙНА ТЕХНОЛОГІЯ ПЕРЕВЕДЕННЯ СТАНЦІЇ КОНТРОЛЮ КОСМІЧНОГО ПРОСТОРУ НА ПЕРСПЕКТИВНУ СХЕМОТЕХНІКУ

Вступ. Основою контролю космічного простору в Україні є радіолокаційні технології, що базуються на використанні радіолокаційних станцій (РЛС).

Проблематика. Елементна комплектуюча база, яка була застосована при проєктуванні РЛС, або зовсім не виробляється вітчизняними виробниками, або виробляється за застарілими технологіями, що робить її неконкурентною та нездатною забезпечити відповідність сучасним вимогам.

Мета. Обґрунтування можливих шляхів та способів відновлення працездатності складових радіоелектронного обладнання з тривалими термінами експлуатації.

Матеріали і методи. Застосовано метод теоретичного аналізу та узагальнення, методи аналогії, оціночні розрахунки теорії моделювання апаратів.

Результати. Розроблено технологію відновлення працездатності радіоелектронної апаратури шляхом створення аналогів застарілих складових радіоелектронного обладнання. Збереження конструктивно-схемної ідентичності нового зразка та прототипу, що лягло в основу нової технології, дозволило повністю виключити модуль як конструктивний елемент з ієрархічної схеми РЛС. Із застосуванням перспективної, функціонально надлишкової елементної бази здійснено переведення застарілої транзисторної схемотехніки на інтегральну, яка дозволяє реалізувати цільові функції меншою кількістю елементів. Так, усі цільові функції 299 модулів, виключених зі складу конструктивної ієрархії, реалізуються 148 інтегральними мікросхемами нових осередків.

Висновки. Переведення РЛС на перспективну схемотехніку дозволить забезпечити не тільки збереження функцій радіоелектронних виробів, що втратили працездатність, а й перевести РЛС на більш високий рівень функціонування. Пропонована технологія відновлення РЛС створює можливості не тільки для відновлення працездатності застарілих, а й для розробки перспективних зразків РЛС, що відповідають сучасним вимогам.

Ключові слова: контроль космічного простору, реінжиніринг, схемотехніка, модель, модуль, комірка.