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METHODS FOR IMPROVING THE DRG-05M DOSIMETER IN BRACHYTHERAPY

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ABSTRACT

Relevance: *The article discusses one of the ways to improve the DRG-05M dosimeter in brachytherapy by using new components and technologies in an improved scheme, which includes more accurate sensors, advanced signal processing techniques, efficient power cells, and other solutions. The application of such advanced components and technologies in the framework of DRG-05M dosimeter modernization is a new and original contribution to the field of dosimetry. The scientific novelty of the work is the improvement of the existing circuitry, namely, the improvement of the DRG-05M dosimeter's electrical circuitry based on the analysis of its shortcomings. It includes replacing components, optimizing circuit structure, eliminating noise and interference, and improving the stability and accuracy of measurements.*

The study aimed to *improve the DRG-05M dosimeter to provide more accurate and reliable radiation measurements in brachytherapy.*

Methods: *The paper analyses the existing components and their use in the electrical circuit to improve the measurement accuracy of the DRG-05M dosimeter, offers a new electrical circuit based on the collected data and requirements, considering the optimal location of components, their characteristics, performed calculations, and modeled circuit operation. We conducted this research within the PCF scientific program "Metrological support of dosimetric measurements in contact radiation therapy," IRN BR12967832.*

Results: *We have selected the components for improving the DRG-05M dosimeter: PMT, ADCs, indication unit, and power supply. The proposed changes to improve the DRG-05M dosimeter shall result in a very compact scintillation-type dosimeter. Its size and weight shall be reduced by at least 3 times; the accuracy and speed of measurement will increase, and the lifetime of the instrument shall improve.*

Conclusion: *Improvement of the dosimeter in brachytherapy is crucial to ensure the accuracy and reliability of measurement in treating cancer. Using components such as PMT, calibration source, battery charger, and microcontroller KR572PV5 can significantly improve the operation of the DRG-05M dosimeter and increase the accuracy of radiation dose measurement in brachytherapy.*

Keywords: *dosimeter, ADC, brachytherapy, radiation, electrical scheme.*

Introduction: The DRG-05M dosimeter is one of the most common dosimeters used in various fields related to radiation measurement. It is an indispensable tool in medical diagnostics and therapy involving ionizing radiation. It is used in brachytherapy and radiotherapy to measure the radiation that reaches the patient during a procedure. The DRG-05M dosimeter ensures accurate measurements and allows a controlled exposure, essential for patient safety and treatment efficacy. The DRG-05M dosimeter is also widely used in industrial and scientific research where radiation measurement is required. It is used in nuclear power engineering, scientific laboratories, and industries dealing with radioactive materials. It provides reliable dose measurements to ensure labor safety and control radiation risks. In emergencies related to radiation, the DRG-05M dosimeter is an integral tool for measuring exposure and assessing radiation risks. It allows for quick measuring of ambient radiation and taking appropriate measures to protect people and minimize radiation impact. The advantages of the DRG-05M dosimeter include reliability, wide measurement range, ease of use, and portability [1-4].

This research is relevant today because the accuracy and reliability of portable dosimeters remain an issue in radiation therapy and can negatively impact human health and the environment. Technological progress and the new components make it possible to improve dosimeters, making them more accurate, reliable, and easy to use.

This research has a high degree of novelty and originality in the following aspects:

– Improvement of the existing circuitry, namely, the DRG-05M dosimeter electric diagram based on its shortcoming analyses. This includes replacing components, optimizing circuit structure, eliminating noise and interference, and improving measurement stability and accuracy. Improving an existing device is practical and can increase its performance and efficiency.

– The use of new components and technologies; utilization of new components and technologies in the improved electric diagram. This includes more accurate sensors, advanced signal processing techniques, efficient batteries, and other solutions. Utilizing such advanced components and technologies to improve the DRG-05M dosimeter will be a new and original contribution to dosimetry.

– Experimental proof of the results: comparing the improved electric diagram with the original version of the DRG-05M dosimeter. This includes comparisons of accuracy, stability, and other measurement parameters.

This research presents a new approach to improving the electric diagram of the DRG-05M dosimeter used to measure the exposure and is an original contribution to dosimetry in brachytherapy and radiation safety.

The study aimed to improve the DRG-05M dosimeter to provide more accurate and reliable radiation measurements in brachytherapy.

Materials and methods: We used the following research methods:

– Analysis of the existing electric diagram of the device: a detailed analysis of the existing electric diagram of the DRG-05M dosimeter, identifying its main components, operating principles, and shortcomings that require improvement.

– Determining specific targets and requirements for an improved electric diagram, considering the shortcomings.

– Study of the new components and technologies: exploring advanced components and technologies that can be used in the improved electric diagram. This includes searching for new sensors, amplifiers, filters, analog-to-digital converters, and other elements that can increase the dosimeter performance.

– Designing a new electric diagram of the device: developing a new electric diagram based on the collected data and requirements, taking into account the optimal arrangement of components, choosing their characteristics, carrying out calculations, and modeling the circuit operation.

– Analysis of the results obtained and conclusions about the improvements achieved.

Results: DRG-05M dosimeter is a scintillation radiometer that consists of a scintillator, a photomultiplier tube (PMT), an analog-to-digital converter (ADC), a display unit, and a power supply unit for the entire circuit. We used a pulse amplitude-to-number converter as an ADC.

Figure 1 shows the operating principle of the selected dosimeter, DRG-05M. Scintillators convert radiation energy into light signals. External radiation, such as X-rays and gamma rays, reaches the scintillator. The energy resulting from the radiation impact on the scintillator material is transmitted to the substance particles. This energy excites atoms or molecules of the scintillator, which emit light in response [5]. The duration and brightness of light radiation depend on the absorbed gamma and X-ray photons. The higher the photon energy, the greater the intensity of the glow. The generated light radiation is recorded using the PMT. A polystyrene optical fiber is placed in front of the PMT to direct the emitted light to the PMT, which converts the light into an electrical signal. Accordingly, the signal level depends in direct proportion to the glow level. Afterwards, the electrical signal comes to the ADC and is processed by the ADC, converting it into a digital signal (pulses), the number of pulses depending on the signal level. Next, the display unit reads these pulses and displays information as digits.

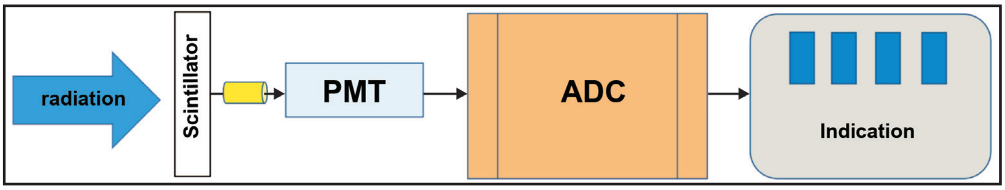


Figure 1 – Operating principle of the DRG-05M dosimeter

We selected the following components to improve the DRG-05M dosimeter: PMT, ADC, display unit, and power supply unit.

The PMT-31-1 sensor currently installed in the dosimeter consumes up to 1.5 kV, producing several volts as the signal measurement background and several millivolts of noise. Therefore, we selected a PMT H7826 series by HAMAMATSU (Japan). This PMT has better parameters than the current PMT-31-1 (higher sensitivity) and, most importantly, consumes 15 V voltage, much lower than the existing one.

We selected the KR572PV5 type microcontroller for ADC. This microcircuit can process and control signals in measuring devices. Due to its functionality, compactness, and low power consumption, it can be used in various measuring devices such as sensors, dosimeters, signal analyzers, and others where accurate signal processing and reliable measurement control are required.

Another reason to choose the KR572PV5 microcircuit was its built-in display unit. Figure 2 shows the KR572PV5 microcircuit block diagram and appearance. The block diagram incorporates an analog block, several decoders, and an impulse register. They can function as ADC, converting the digital signal into digital readings.

The power supply unit with a high-voltage module was replaced with a low-voltage power supply unit to increase sensitivity and increase the device's service life. The current PMT-31-1 required a voltage of about a thousand volts. With the new PMT, a voltage of 15 V will be sufficient. There are many options for power supply circuits on the Internet. We aimed to achieve 15 V instead of 1.5 kV voltage, sufficient for the selected components that consume a few microvolts of current.

Figure 3 shows a typical diagram of the converter connection with a liquid crystal indicator and the four elements that control the decimal points of the indicator. The device input voltage limits depend on the reference voltage U_{ref} and are determined by the ratio $U_{in.\,max}$=±1.999/U_{ref}. The current indicator readings should be expressed as a number equal to 1000 U_{in}/U_{ref}, but in practice, they are 0.1...0.2% lower. The measurement period at a clock frequency of 50 kHz is 320 ms. In other words, the device makes 3 measurements per second.

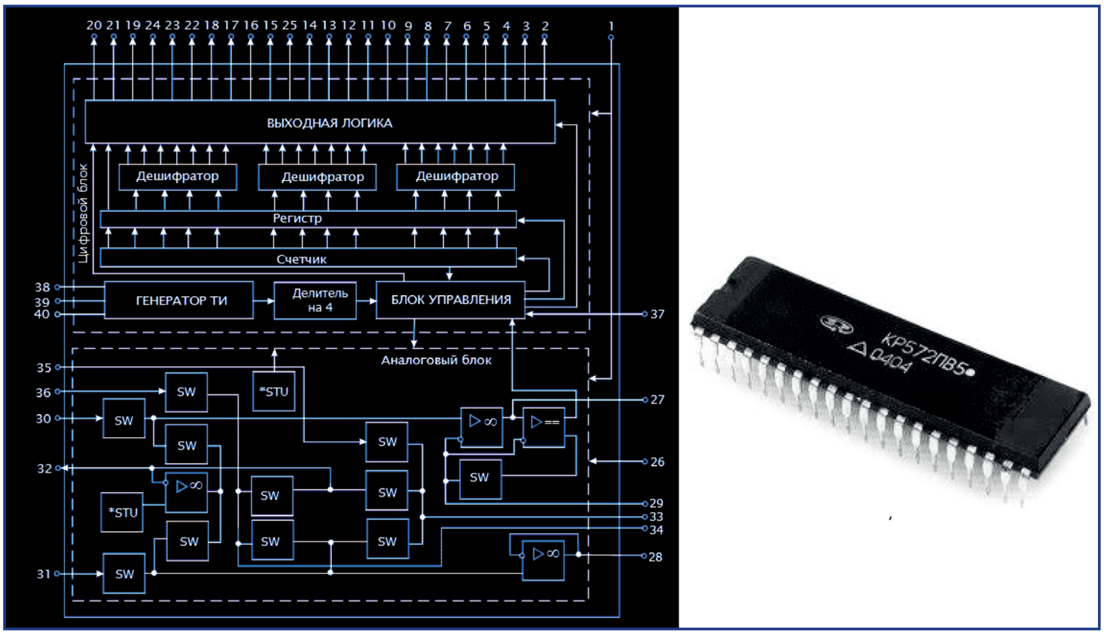
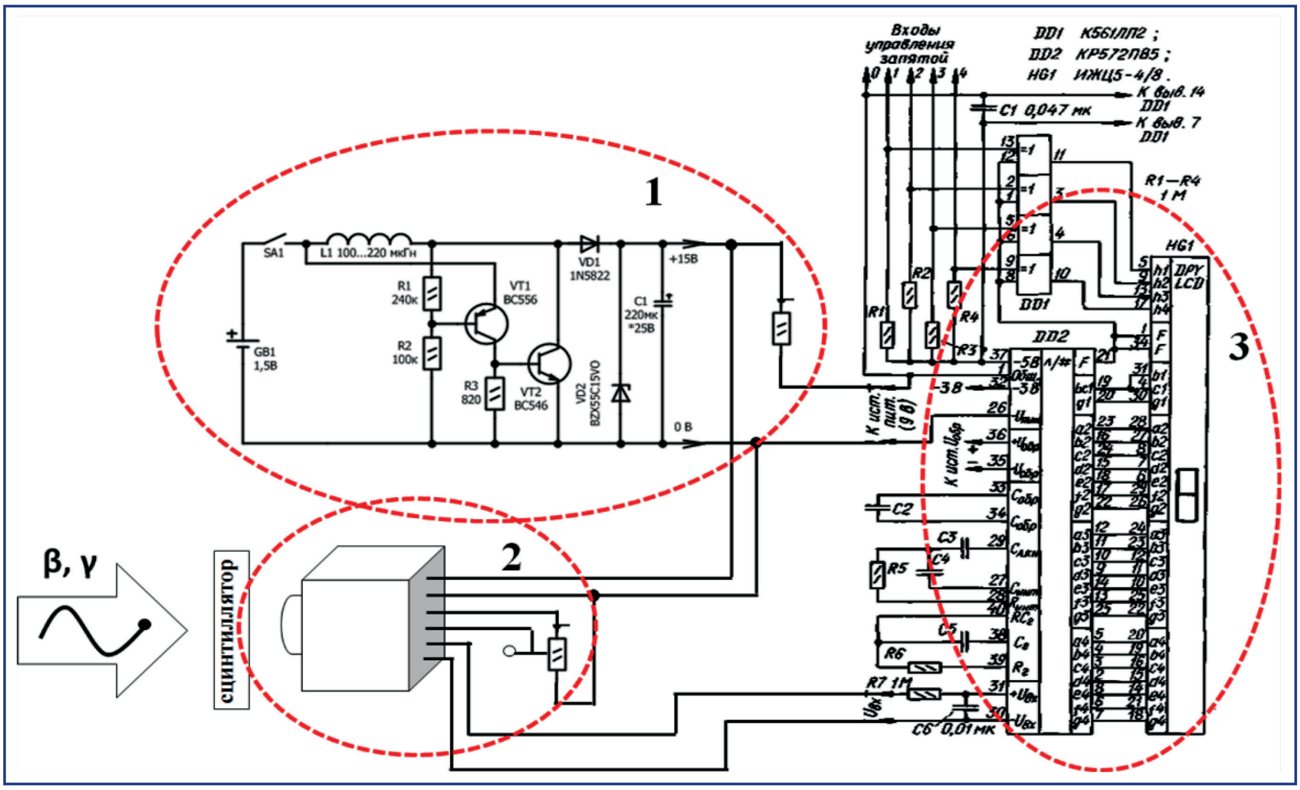


Figure 2 – The KR572PV5 microcircuit block diagram and appearance



1 – Power supply, 2 – PMT, 3 – ADC and indication
Figure 3 – Diagram of the improved DRG-05M dosimeter [6]

With all the suggested improvements to the DRG-05M dosimeter, we achieve a very compact scintillation-type dosimeter since the proposed components are twice smaller and perform better than the old ones. The size and weight of the device will be at least 3 times less while the accuracy, speed of measurements, and the device's service life shall increase.

Discussion: Improving the dosimeter used in brachytherapy is crucial to ensure the accuracy and reliability of measurements in treating oncological diseases. Components such as the new PMT, calibration source, battery charger, and KR572PV5 microcontroller can significantly improve the DRG-05M dosimeter operation and increase the accuracy of radiation dose measurement in brachytherapy.

We paid special attention to selecting and optimizing the circuit components. The proposed replacement of some circuit elements with more modern and accurate ones shall improve the overall performance of the dosimeter.

Conclusion: The research results presented in the paper demonstrate positive changes in the DRG-05M dosimeter operation after the following improvements:

1. The voltage consumed by the PMT dosimeter is 1.5 kV. We propose a 15 V PMT, which is two orders of magnitude lower than the current readings;

2. We suggest using a more modern ADC microcontroller than the one used in the existing dosimeter. The suggested microcontroller has higher characteristics that directly affects the measurement accuracy;

3. We suggest replacing the circuit power supply unit with a maximum 15 V supply. The power supply unit currently utilized in the dosimeter amplifies the voltage to 1.5 kV and produces noise of several volts.

The improved design with the original version of the dosimeter shows increased efficiency, reliability, and accuracy of dose measurements in brachytherapy.

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АНДАТПА

БРАХИТЕРАПИЯДА ДРГ-05М ДОЗИМЕТРІН ЖЕТІЛДІРУ ӘДІСТЕРІ

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Өзектілігі: *Мақалада жетілдірілген схемада жаңа компоненттер мен технологияларды қолдану арқылы брахитерапияда ДРГ-05М дозиметрін жетілдірудің бір әдісі қарастырылады. Ол дәлірек сенсорларды, сигналдарды өңдеудің озық әдістерін, тиімді қуат көздерін және басқа шешімдерді қамтиды. ДРГ-05М дозиметрін жаңарту аясында осындай озық компоненттер мен технологияларды қолдану дозиметрия саласына жаңа және ерекше үлес болып табылады. Жұмыстың ғылыми жаңалығы-қолданыстағы схеманы жетілдіру, атап айтқанда, оның кемшіліктерін талдау негізінде ДРГ-05М дозиметрінің электр схемасын жақсарту. Бұған компоненттерді ауыстыру, тізбек құрылымын оңтайландыру, Шу мен кедергілерді жою, өлшеудің тұрақтылығы мен дәлдігін жақсарту кіреді.*

Зерттеудің мақсаты *– брахитерапияда сәулеленуді дәлірек және сенімді өлшеуді қамтамасыз ету үшін ДРГ-05М дозиметрін жетілдіру.*

Әдістері: *Мақалада дозиметрдің ДРГ-05М өлшеу дәлдігін жақсарту үшін қолданыстағы компоненттерді талдау және оларды электр тізбегінде қолдану ұсынылған. Жаңа схеманы жобалау: жиналған мәліметтер мен талаптарға негізделген жаңа электр тізбегін жасаңыз. Компоненттердің оңтайлы орналасуын, олардың сипаттамаларын таңдауды, тізбектің жұмысын есептеуді және модельдеуді қарастырыңыз. Бұл ғылыми зерттеу ЖРН BR12967832 «Контактілі сәулелік терапияда дозиметриялық өлшемдерді метрологиялық қамтамасыз ету» БМҚ ғылыми бағдарламасын іске асыру шеңберінде жүргізілді.*

Нәтижелері: *Біз ДРГ-05М дозиметрін жақсарту үшін мынадай компоненттерді таңдадық: ФЭК, АЦТ, индикация блогы және сәйкесінше қуат көзі. ДРГ-05М дозиметрін жақсарту үшін ұсынылған барлық өзгерістерден кейін сцинтилляциялық типтегі шағын дозиметр алынады деп күтілуде. Мүмкін мөлшері мен салмағы кем дегенде 3 есе азаяды, сәйкесінше дәлдік пен жылдамдық өлшеу ұлғайту, сонымен қатар бұл құрылғының қызмет ету мерзіміне әсер етеді.*

Қорытынды: *Брахитерапияда дозиметрді жетілдіру онкологиялық ауруларды емдеуде өлшеудің дәлдігі мен сенімділігін қамтамасыз етуге бағытталған маңызды міндет болып табылады. Компоненттерді ФЭҚ, калибрлеу көзі, батареяларды зарядтағыш, КР572ПВ5 микроконтроллері ретінде пайдалану ДРГ-05М дозиметрінің жұмысын едәуір жақсартады және брахитерапиядағы сәулелену дозасын өлшеу дәлдігін арттырады.*

Түйінді сөздер: *дозиметр, АЦТ, брахитерапия, радиация, электр схемасы.*

АННОТАЦИЯ

СПОСОБЫ СОВЕРШЕНСТВОВАНИЯ ДРГ-05М ДОЗИМЕТРА В БРАХИТЕРАПИИ

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Актуальность: *В статье рассматривается один из способов совершенствования ДРГ-05М дозиметра в брахитерапии с помощью использования новых компонентов и технологий в усовершенствованной схеме, которая включает более точные датчики, передовые методы обработки сигналов, эффективные элементы питания и другие решения. Применение таких передовых компо-*

нентов и технологий в рамках модернизации дозиметра ДРГ-05М является новым и оригинальным вкладом в область дозиметрии. Научной новизной работы является усовершенствование существующей схемы, а именно, улучшения электрической схемы ДРГ-05М дозиметра на основе анализа его недостатков. Это включает замену компонентов, оптимизацию структуры схемы, устранение шумов и помех, а также улучшение стабильности и точности измерений.

***Цель исследования** – усовершенствование ДРГ-05М дозиметра для обеспечения более точных и надежных измерений радиации в брахитерапии.*

***Методы:** В статье представлен анализ существующих компонентов и использование их в электрической схеме для повышения точности измерения ДРГ-05М дозиметра. Предложена новая электрическая схема на основе собранных данных и требований, с учётос оптимального расположения компонентов, их характеристик, проведенных расчетов и смоделированной работы схемы. Данное научное исследование проведено в рамках реализации научной программы ПЦФ «Метрологическое обеспечение дозиметрических измерений в контактной лучевой терапии», ИРН BR12967832.*

***Результаты:** Научной группой были выбраны компоненты для усовершенствования ДРГ-05М дозиметра: фотоэлектронный умножитель (ФЭУ), аналогово-цифровой преобразователь (АЦП), блок индикации и блок питания. После всех предложенных изменений для усовершенствования ДРГ-05М дозиметра, ожидается получить очень компактный дозиметр сцинтилляционного типа. Габариты аппарата планируется уменьшить в 3 раза, точность и скорость измерения увеличить, а также это повлияет на срок службы эксплуатации прибора.*

***Заключение:** Совершенствование дозиметра в брахитерапии является важной задачей, направленной на обеспечение точности и надежности измерения в лечении онкологических заболеваний. Использование таких комплектующих как: ФЭУ, калибровочный источник, блок питания для зарядки батарей, микроконтроллер КР572ПВ5 могут существенно улучшить работу ДРГ-05М дозиметра и повысить точность измерения дозы в брахитерапии.*

***Ключевые слова:** дозиметр, аналогово-цифровой преобразователь (АЦП), брахитерапия, радиация, электрическая схема.*

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