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INSTRUMENT-MAKING AND INFORMATION-MEASURING SYSTEMS

ПРИЛАДОБУДУВАННЯ ТА ІНФОРМАЦІЙНО-ВИМІРЮВАЛЬНІ СИСТЕМИ

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PHOTOTHERAPY DEVICE WITH DETERMINATION OF ABSORBED ENERGY DOSE

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Summary. *The article deals with comprehensive analysis of the most common design of devices being used for human skin irradiation in phototherapy. The authors determined that their main drawback is the lack of the possibility of measuring of the absorbed light energy dose, and therefore, the inability to operationally forecast the treatment results. There was suggested the device and investigated the algorithm to transform the parameters of luminous flux that eliminate deficiencies. It facilitates determining of absorbed energy dose energy at irradiated areas of the patient's body during regulation of the calibration modes and measurement of irradiation signal parameters.*

Key words: *phototherapy device, luminous flux, power, irradiation signal, absorbed energy dose, commutation-modulation transformation.*

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It is known that role of light in metabolism of life forms is very important. The deficiency of this mechanism requires application of adjustable light sources for correction and regeneration of body functions as well as improvement of patients' general state [1]. Phototherapy is well-known and widely-used means of such improvement in practical medicine for treatment, prophylaxis and rehabilitation with the help of various wave-length luminous fluxes that influence on biologically active areas of human derma. Treatment of derma-helminthiasis, bronchopulmonary and orthopedic diseases, cancer, blood irradiation in photopheresis is an incomplete list of efficient application of phototherapy [2, 3].

An important thing during phototherapy procedures is setting of optimal parameters of irradiation: luminous flux power, exposition, wave length and irradiation dosage. Normally, the output power is set within mega W units, and efficiency of low-intensive phototherapy is maintained partially with an exposition [2]. Simultaneously, the biological effect depends upon absorbed dose of electromagnetic irradiation, which should be measured during manipulation procedures.

Analysis of the known research results. However, Korobov photon matrixes "Barve-Flex" [4] have no options to adjust the parameters of LEDs and control the irradiation and

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absorption level of luminous flux energy during manipulation procedures i.e. to assess the biological effect and forecast the phototherapy consequences.

The phototherapy device with LED matrix that is introduced in [5] assumed the regulation of irradiation parameters for certain LED groups, though it does not have the connection with irradiation object.

Another device [6] introduces more options as it has a couple of matrix panels and reverse connection due to setting of physiological parameters, though it can be very fast (e.g.: cardiac or respiration frequency), and sometimes with larger period (changes in cardiovascular and endocrine rates), which does not allow adjusting and forecasting of treatment efficiency.

Research objectives: elaboration and testing of phototherapy device and transformation of signals that would provide the measurement of intensity as well as control of absorbed energy during manipulation procedures with forecasting of time periods for the best treatment results.

Task setting. One has to examine the phototherapy devices and their algorithms of signal transformation for measurement of intensity as well as control of absorbed energy during manipulation procedures with forecasting of time periods for the best treatment results. Below, Figure 1 displays the developed functional scheme of phototherapy device, which accomplishes the given task.

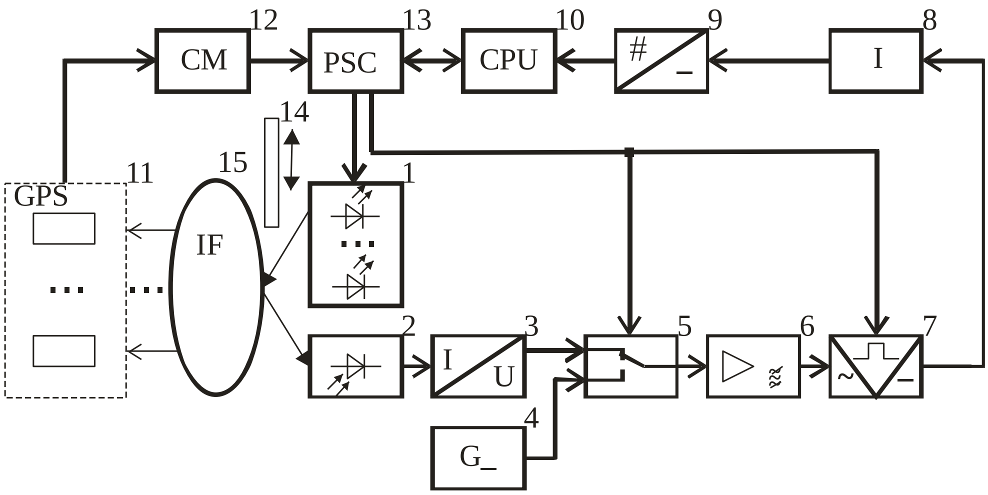

Figure 1. Functional scheme of phototherapy device
1 – LED matrix, 2 – sensor, 3 – converter current-voltage, 4 – generator of reference voltage, 5 – switcher, 6 – selective amplifier of switching frequency, 7 – synchronous detector, 8 – integrator, 9 – analog-to-digital converter, 10 – microcomputers, 11 – gauges of physiological state of the patient, 12 – communication module, 13 – power switching and controls, 14 – mirror 15 – irradiation facility

To convert the input signals the commutation-modulation method is used that increases considerably the sensitiveness of irradiation and provides the influence analysis even for irradiation signals of low intensity [7].

Phototherapy device works on stage-by-stage basis. The first stage assumes the matrix allocation on patient’s body. After this the mirror 14 is set between irradiation facility 15 and matrix and the irradiation with maximal intensity of luminous flux of LED matrix 1 is carried out simultaneously with calibration. Such mirror 14 allocation assumes that entire luminous flux of LED matrix 1 is reflected on luminous sensor 2 that provides precise current setting I_1 through it.

Simultaneously on output of converter “current-voltage” 3 the corresponding voltage rate is registered:

$$U_1 = I_1 R_N \,, \tag{1}$$

where I_1 – current via luminous sensor 2 at maximal intensity of luminous flux of LED matrix 1; R_N – input converter resistance 3.

Voltage U_1 is directed to the first input of the switcher 5. The voltage U_0 from generator of reference voltage 4 is directed to the second switcher 5.

This voltage value U_0 is selected from correlation:

$$U_0 = U_T = I_T R_N \,, \tag{2}$$

where I_T – dark current via LED sensor 2; U_T – the voltage being proportional to I_T .

The rectangular impulses, which provide the periodical switching of contacts in switcher 5 are delivered to input of switcher 5 from the second output of power switching and controls block 13 with Ω frequency.

The voltage (1) is created during the first commutation semi-period on the switcher 5 output, and, correspondingly, voltage (2) is created during the second commutation semi-period on the switcher 5 output.

As result of periodic switching at 5 from the sequence of impulses of voltages U_1 and U_0 the selective amplifier of switching frequency 6 selects and enhance the variable of voltage with amplitude that is defined with the formula:

$$U_2 = K_1 \frac{U_1 - U_0}{2} \,, \tag{3}$$

where K_1 – enhancement ratio of selective amplifier of switching frequency 6 for commutation frequency.

Alternating voltage after enhancement is rectified with synchronous detector 7, which is manipulated with commutation frequency voltage from switcher 5. The rectified voltage is accumulated in integrator 8 where low-frequency noises of converting and enhancing blocks are eliminated. On integrator 8 output there is direct variance voltage that is defined due to formula:

$$U_3 = \frac{K_1 K_2 K_3}{2} \left(U_1 - U_0\right), \tag{4}$$

where K_2 – rectification ratio of synchronous detector 7; K_3 – transmission ratio of integrator 8.

During consequent conversion in analog-to-digital converter 9 there formed a code that corresponds to maximal intensity of luminous flux of LED matrix 1:

$$N_1 = \alpha U_3 = \frac{S K_1 K_2 K_3}{2} \left(U_1 - U_0\right), \tag{5}$$

where α – aggregate ratio of conversion for measuring channel; S – scale ratio of analog-to-digital conversion.

Later this code (5) is stored in microcomputer memory 10. On the second stage the mirror is discarded and selected facility 15 is irradiated with given intensity.

During conversion on the first stage, there is formed a code on the output of analog-to-digital converter that corresponds to intensity of LED matrix 1 luminous flux, which is reflected from irradiation object 15:

$$N_2 = \alpha U_3' = \frac{SK_1K_2K_3}{2}\left(U_1' - U_0\right), \tag{6}$$

where U_1' – voltage stipulated with intensity of reflected from the object irradiation 15; U_3' – value of variance voltage, which corresponds to irradiation signal on the send stage.

The obtained code (6) is stored in microcomputer memory 10.

The difference between irradiation results on the first and second stages being stored in microcomputer 10 describes the absorbed by irradiation facility 15 part of luminous flux of LED matrix 1.

$$N_3 = N_1 - N_2 = \alpha\left(U_3 - U_3'\right). \tag{7}$$

The information about the capability of the studied derma section to absorb irradiation is stored in patient's e-card.

Research results. Thus, the suggested device provides the possibility to measure the luminous flux power and control its absorption rate during manipulation procedures i.e. assess the biological effect and forecast the irradiation results at the expense of elaborated irradiation algorithm. The important fact is that application of commutation-modulation conversion method due to [7] facilitates considerable increasing of analysis sensitiveness and processing of low-intensity signals of $10^{-6} – 10^{-10}$ .W.

Conclusions. The results of absorption capacity measurement for derma and biologically active areas treatment are stored in computer memory and can be consequently used for the next manipulation procedures that simplify considerably the treatment process. Besides, this parameter can be used as diagnostic one during the forthcoming manipulation procedures with stored changes. The suggested device simplifies the identification of parameters, improves its accuracy, provides the possibility to define the correlation between absorption rate and phototherapy efficiency.

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ПРИСТРІЙ ДЛЯ СВІТЛОТЕРАПІЇ З ВИЗНАЧЕННЯМ ДОЗИ ПОГЛИНУТОЇ ЕНЕРГІЇ

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Резюме. *Проаналізовано поширені конструкції пристроїв опромінювання шкіри людини різної складності, які використовуються для світлотерапії. Визначено, що їх основним недоліком є відсутність можливості вимірювання дози поглинутої енергії біооб'єктом, а відповідно, неможливість оперативного прогнозування результату лікування. Запропоновано пристрій та досліджено алгоритм перетворення параметрів світлового потоку, які усувають виявлений недолік. Це дозволяє оперативно визначати дозу поглинутої енергії опромінюваної ділянки тіла пацієнта при змінах вибраних режимів калібрування та вимірювання параметрів опромінюючого сигналу.*

Ключові слова: *пристрій для світлотерапії, світловий потік, потужність, опромінюючий сигнал, доза поглинутої енергії, комутаційно-модуляційне перетворення.*

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