- it is an universal algorithm of studies, that does not depend on the type of function that is approximated, amount of arguments and results of function;
- they consist with the adders collected on analog an component, that is increasing a fast-acting and exactness of implementation of operations;
- they give the wide field for the choice of parameters component (neurons).

3. ACM for modeling of neural network can be easily created on a modern element base.

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Андрусенко В., студ., Бех І., канд. .физ.-мат. наук, доц., Новак С., студ.
каф. радіотехніки та радіоелектронних систем, факультет радіофізики, електроніки та комп'ютерних систем,
Київський національний університет імені Тараса Шевченка

АНАЛОГОВА ОБЧИСЛЮВАЛЬНА МАШИНА (АОМ) ДЛЯ МОДЕЛЮВАННЯ НЕЙРОННИХ МЕРЕЖ (ЗАДАЧІ АПРОКСИМАЦІЇ МАТЕМАТИЧНИХ ФУНКЦІЙ)

За допомогою середовища моделювання NI Multisim реалізовано і досліджено аналогову обчислювальну машину, що моделює перцептрон Румельхарта, що на теперішній час є найбільш дослідженим. За допомогою отриманої АОМ було апроксимовано математичну функцію sin(x). Аналіз результатів апроксимації показав, що реалізована АОМ задовольняє поставленій задачі і відповідає встановленій точності моделювання функції.

Ключові слова: *нейронна мережа, перцептрон Румельхарта, апроксимація функції, аналогова обчислювальна машина.*

Андрусенко В., студ., Бех И., канд. физ.-мат. наук, доц., Новак С., студ.
каф. радиотехники и радиоэлектронных систем, факультет радиофизики, электроники та компьютерных систем,
Киевский национальный университет имени Тараса Шевченко

АНАЛОГОВАЯ ВЫЧИСЛИТЕЛЬНАЯ МАШИНА (АВМ) ДЛЯ МОДЕЛИРОВАНИЯ НЕЙРОННЫХ СЕТЕЙ (ЗАДАЧИ АПРОКСИМАЦИИ МАТЕМАТИЧЕСКИХ ФУНКЦИЙ)

С помощью среды моделирования NI Multisim реализовано и исследовано аналоговую вычислительную машину, моделирующую персептрон Румельхарта, который, в настоящее время, является наиболее исследованным. С помощью полученной АВМ была аппроксимирована математическая функция sin(x). Анализ результатов аппроксимации показал, что реализованная АВМ удовлетворяет поставленной задаче и соответствует установленной точности моделирования функции.

Ключевые слова: *нейронная сеть, персептрон Румельхарта, аппроксимация функции, аналоговая вычислительная машина.*

UDC 535.3

D. Babich, stud., N. Kuzkova, post grad. stud.,
O. Popenko, stud., A. Yakunov, Ph.D.
Taras Shevchenko National University of Kyiv, Physics Department

TEMPERATURE MEASUREMENT IN MICROWAVE-IRRADIATED SYSTEMS USING A TEMPERATURE-DEPENDENT FLUORESCENT DYE

Temperature sensitivity of the fluorescence intensity of the organic dyes solutions used for non-contact measurement of the electromagnetic millimeter wave absorption in water. By using two different dyes with opposite temperature effects, it was defined local temperature increase in the capillary that is placed inside a rectangular waveguide in which millimeter waves propagate. The application of this non-contact temperature sensing is a simple and novel method to detect temperature change in small biological objects.

Keywords: *:millimeter waves, non-contact temperature sensing, fluorescence, organic dyes, water, biomedical applications*

Introduction Biological effects of electromagnetic millimeter waves were observed in many experiments on various biological objects, starting from the bacteria to the whole human body as well as model systems in general [1]. Repeatedly noted that the nature of the microwaves on biological objects is different from the conventional thermal effect of electromagnetic waves of the other bands, and the physical nature of this phenomenon is still unclear.

One of the main problems, which complicates the construction of an adequate physical model, is the uncertainty of "non-thermal effect" definition, and the fact that in different experiments the power of millimeter waves, which have biological effects, differ by orders of magnitude [1]. For a correct measurement of absorbed radiation power and detecting possible heating as a result of irradiation, it is necessary to use special sensors, which can react to the absorption of millimeter waves in systems, close by their parameters to biological tissues.

It is considered that the use of low power (with output power up to 20 MW) millimeter waves generators does not result to significant heating of the irradiated matter. Calculations [4] provide an increase of temperature to 1ºC for different patterns of exposure, which should not cause essential biological effects. However, direct measurement of the temperature change in the area of irradiation is a challenging technical problem. High-sensitivity temperature sensors (thermocouples, thermistors, etc.) making perturbations in the investigated samples, affect the local temperature and heat transfer characteristics in a given place. Although less accurate, optical methods are more convenient for registration of temperature changes in small volumes [3].

The water in the millimeter wave range is characterized by a considerable absorption of electromagnetic waves. In particular, at a frequency of 50 GHz, corresponding to wavelengths in vacuum of 6 mm, the absorption coefficient is equal to 5.1 mm-1 [4]. Accordingly, the spatial temperature distribution in the irradiated samples containing water is very inhomogeneous. Electromagnetic millimeter waves heat the substances containing water in a thin surface layer with high temperature gradient, the numerical value of which can be estimated only by indirect methods. Therefore, existing methods for irradiation of biological objects are imperfect and metrological control tools are not reliable.

To determine temperature changes in water caused by the millimeter wave absorption we used an optical non-contact method, which is based on the existence of the fluorescence intensity dependence of temperature of organic dyes. It was measured the local temperature rise in the capillary, placed inside a rectangular waveguide, in which millimeter waves propagate. We have chosen two dyes with opposite temperature effects: Rhodamine 6G (R6G) and Rhodamine C (RC).

Methodology and experimental measurements Calibration of the fluorescence intensity of organic dyes aqueous solutions on temperature were carried out by means of diffraction spectrometer. Semiconductor laser emission with 406 nm wavelength and 60 mW output power was used as an excitation source. The samples were prepared from standard distilled water for medical purpose. The concentration of dyes (~ 0.4 g/liter) was chosen from the condition of maximum temperature sensitivity and temperature coefficients of approximate equality [3].

It was used a straight-through scheme for illumination and viewing [2]. The glass cuvette (3 mm pass length) with the dye solution was placed inside a large glass rectangular cell with water, which served as a water bath. Water temperature was maintained to within 0.2º.

The fluorescence spectra were measured at temperatures from 20 ºC to 40 ºC, over each 5 ºC (Fig.1). The intensity of fluorescence was normalized by the initial value, corresponded to the temperature of 20 ºC (Fig.2).

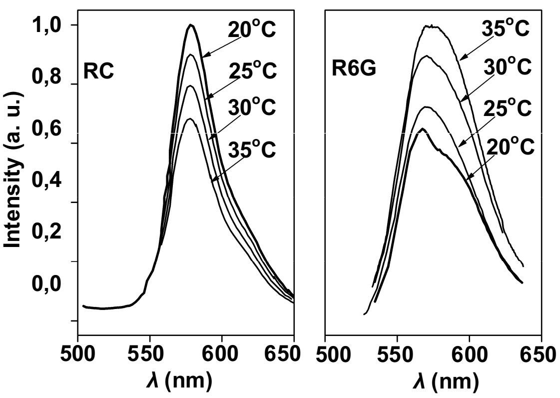

Fig.1. Fluorescence spectrum of Rhodamine 6G (R6G) and Rhodamine C (RC) at 5 ºC intervals from 20 to 35 ºC

Established, that in most cases, the temperature rise is making destructive contribution to the fluorescence yield [3]. With the growth of temperature, increases the frequency and energy of molecules collisions in solution as well as the amplitude of internal molecular vibrations, leading to an increase in non-radiative relaxation of the excited levels, and thus fluorescence quenching. Along with the temperature quenching of the dye solution are possible mechanisms that increase the overall yield of fluorescence with increasing temperature [3]. In particular, some organic molecules in aqueous solution tend to form associated complexes: dimers, trimers, etc., where fluorescence quantum yield is much lower than in the individual molecules. At sufficiently high concentrations, the fluorescence spectrum is formed as a superposition of the spectra of individual molecules and their associates. Some associates divided into separate molecules with increasing temperature that is accompanied by a relative increase in fluorescence intensity.

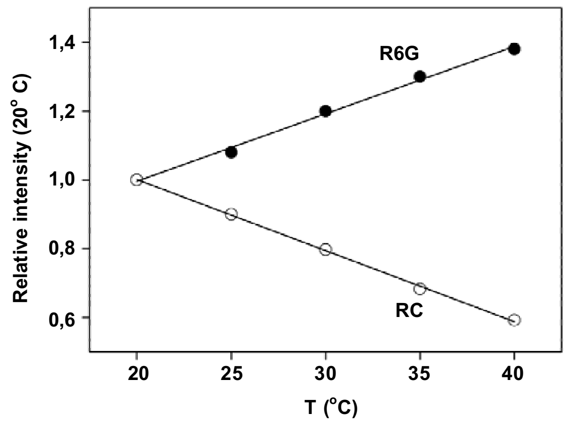

Fig.2. Temperature dependence of the relative fluorescence intensity of R6G and RC

Fig. 2 shows that the fluorescence temperature dependence of the RC solution corresponding to the first scenario, R6G – to the second, and in the range $20 \div 40°C$ intensities approximated by a linear function: $I(T)/I(20°C) = a + bT$, where b – temperature sensitivity coefficient. For given concentrations of solutions this parameter is equal $b_{R6G} = 0.019°C^{-1}$ and $b_{RC} = -0.021°C^{-1}$.

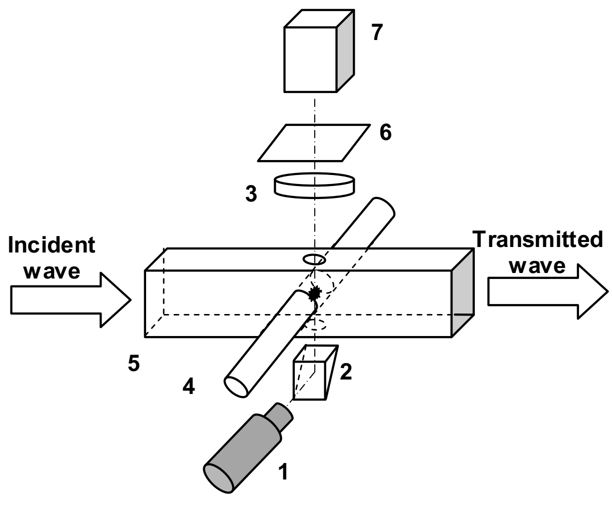

Fig.3. The measuring module is composed of laser (1), prism (2), focusing lens (3), glass capillary with a dye solution (4), waveguide (5), orange filter (6) and photo- detector (7)

Millimeter wave radiation from high frequency signal generator through polarizing attenuator was applied to the measuring module. Attenuator is included to prevent reflected power from damaging the amplifier. The measuring module (Fig. 3) consists of the segment of rectangular waveguide with a cross section 7.2 x 3.4 mm, inside which through the middle was inserted a glass capillary with an inner diameter of 0.5 mm. Focused laser beam excites fluorescence in filled capillary of dye solution.

For capillary with water in a rectangular waveguide area of maximum absorption of the electromagnetic millimeter wave corresponding to antinodes of electrical components and is concentrated in the central part of Δx ~ 1 mm [2]. Fluorescence signal from the central section was removed through a round hole made in the middle of the narrow waveguide wall opposite the capillary. The light stream focused by lens and passed through an orange filter to a photo-detector.

By using a thermal detector, the incident and transmitted radiation power was measured. The difference was equal to the power, absorbed in the sample. Previously in the range of 40–50 GHz was measured frequency dependence of the capillary absorption of water. At a frequency of 47.5 GHz it was observed a pronounced resonance maximum, typical for rectangular waveguide with dielectric cylinder of small diameter [2].

Further experiments were carried out at the frequency of resonance. Power absorbed into the capillary with a solution governed by polarization attenuator with attenuation coefficients 0, 1, 2, 3, 4 dB, which corresponded to an absolute absorbed power value of 20 mW, 15.8 mW, 12.5 mW, 10 mW, 7.9 mW respectively.

Duration of registration signal T ≈ 40 s was chosen from the condition significantly exceeded time of establishing of thermal equilibrium: T >> τ. Constant of relaxation was assessed by the expression τ ~ (Δx)2 / D, where D – coefficient of thermal conductivity of water, and for a given irradiation scheme was of the order of a few seconds.

Results and Analysis Fig. 4 shows the dynamics of R6G and PC fluorescence dyes for switched on and off microwave radiation with different capacities. The absorption of microwaves leads to fluorescence increasing for R6G solution and fluorescence quenching for RC. The gradual decrease in fluorescence intensity caused by photodestruction of organic dye molecules. By switching off temporarily laser emission, the initial level of fluorescence almost restored.

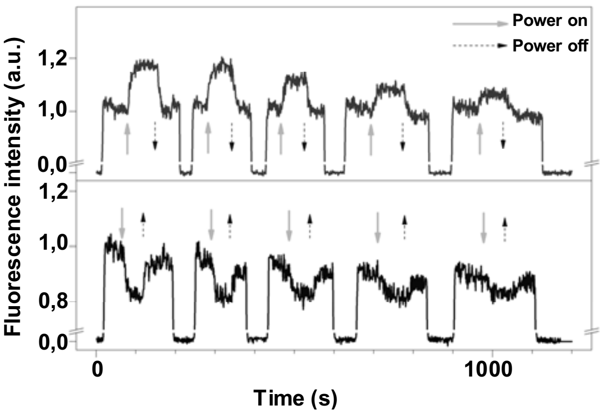

Fig. 4. Dynamics of the change in fluorescence intensity when millimeter wave radiation is turn on and turn off.
The voltage is switched off and the fluorescence returns to the base line before a different voltage is applied to the microheater. The two curves illustrate the repeatability of the fluorescence to achieve the same level for a given temperature

The dependence of the relative change in fluorescence intensity $|I - I_{20}| / I$ of the absorbed power in the capillary obtained from the experimental data (Fig. 5). In the first approximation it can be approximated by linear functions:

$y = 0.15 - 0.023x$ for R6G; $y = 0.14 - 0.024x$ for RC

Thus taking into account the calibration dependence (Fig. 2), it corresponds to a local temperature increase in the capillary absorbed at maximum power 20 mW: $\Delta T_1 = (7.7 \pm 0.4)°C$ for R6G and $\Delta T_2 = (7.4 \pm 0.4)°C$ for RC.

It could be seen that even a low-power microwave source, under certain conditions, cause significant heating of the sample, which can lead to significant biological effects. It should be noted that the special conditions of the experiment (placing the sample inside the waveguide, radiation at the resonant frequency) determine the maximum possible temperature response.

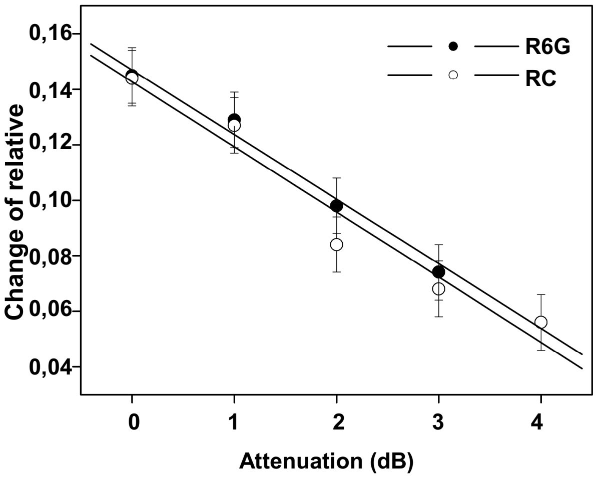

Fig. 5. Change of relative fluorescence intensity of the relaxation factor of attenuator

In most biophysical experiments with millimeter wave irradiation conditions of the samples, although not as severe, but carried out in the near zone of the waveguide. In the vicinity of the irradiated object there are standing waves that form parasitic resonances. The appearance of the local area temperature increase of a few degrees can cause thermal biological effects at low levels of total radiation power.

It is assumed [3,4] that with millimeter wave irradiation of dyes solutions possible additional non-thermal effect of millimeter waves on the spectral properties of solutions that is due to the change in the structure of water. During irradiation, pseudopolymer hydrogen bonding network undergoes deformation, rearrangement, and perhaps destruction. Restructuring of water under millimeter wave field causes structural changes in the molecular associates and promotes their decay.

In our study, we obtained the same value of the effective temperature for solutions with different scenarios of temperature behavior. This indicates on the absence of non-thermal effect of millimeter waves on water, at least in the conditions of sample irradiation inside the resonator at the resonant frequency.

Moreover, to the same conclusion leads comparison of dependency in Fig. 4. The equality of slope coefficients approximating lines indicates on the fact that probable non-thermal effect of millimeter waves on water under the given conditions can be neglected.

Conclusions. Optical non-contact method, which is based on the existence of the fluorescence intensity temperature dependence of the organic dyes used to determine changes in water temperature in the millimeter wave absorption.

Using two dyes with opposite effects, it was measured temperature heating an aqueous solution in the capillary, placed inside a rectangular waveguide.

Using even low-power sources of millimeter waves, the local increase in temperature of the sample can be several degrees. At the same time, the results indicate the absence of non-thermal effect of millimeter waves on the water.

The application of non-contact temperature sensing based on the temperature sensitivity of florescent dyes is a simple and novel method to detect temperature change in biological objects irradiated by millimeter waves.

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Бабіч Д., студ., Кузькова Н., асп., Попенко О., студ., Якунов А., канд. фіз.-мат. наук,
кафедра оптики, фізичний факультет
Київський національний університет імені Тараса Шевченка

ВИМІРЮВАННЯ ТЕМПЕРАТУРИ В СИТЕМІ ОПРОМІНЮВАНІЙ ЕЛЕКТРОМАГНІТНИМИ ХВИЛЯМИ МІЛІМЕТРОВОГО ДІАПАЗОНУ З ВИКОРИСТАННЯМ ТЕМПЕРАТУРОЗАЛЕЖНИХ ФЛУОРЕСЦЕНТНИХ ОРГАНІЧНИХ БАРВНИКІВ

Температурну чутливість флуоресценції розчинів органічних барвників використано для безконтактного вимірювання поглинання електромагнітних хвиль міліметрового діапазону у воді. За допомогою двох барвників з протилежними температурними ефектами визначено локальне підвищення температури в капілярі, розміщеному в середині прямокутного хвилеводу.

Застосування безконтактного температурного датчика є новим, простим методом визначення зміни температури малих біологічних об'єктів.
Ключові слова: *міліметрові хвилі, безконтактне вимірювання температури, флуоресценція, органічні барвники, вода, біомедичне застосування.*

Бабич Д., студ., Кузькова Н., асп., Попенко А., студ., Якунов А., канд. физ.-мат. наук,
кафедра оптики, физический факультет
Киевский национальный университет имени Тараса Шевченко

ИЗМЕРЕНИЯ ТЕМПЕРАТУРЫ В СИСТЕМЕ ОБЛУЧАЕМОЙ ЭЛЕКТРОМАГНИТНЫМИ ВОЛНАМИ МИЛЛИМЕТРОВОГО ДИАПАЗОНА С ИСПОЛЬЗОВАНИЕМ ТЕМПЕРАТУРОЗАВИСИМЫХ ФЛУОРЕСЦЕНТНЫХ ОРГАНИЧЕСКИХ КРАСИТЕЛЕЙ

Температурная чувствительность флуоресценции растворов органических красителей использована для бесконтактного измерения поглощения электромагнитных волн миллиметрового диапазона в воде. С помощью двух красителей с противоположными температурными эффектами определено локальное повышение температуры в капилляре, размещенном внутри прямоугольного волновода.

Применение бесконтактного температурного датчика является новым, простым методом определения изменения температуры малых биологических объектов.
Ключевые слова: *миллиметровые волны, бесконтактное измерение температуры, флуоресценция, органические красители, вода, биомедицинское применение*

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B. Bondar, Engineer-physicist, Clinical Hospital "Feofaniya",
Nuclear physics department, Taras Shevchenko National university of Kyiv
I. Mikhnytsky, Engineer-physicist, Ya. Kmetyuk,
Head of All-Ukrainian center for radiosurgery, Clinical Hospital "Feofaniya"

RADIATION SAFETY ASPECTS DURING 11-MEV MEDICAL CYCLOTRON OPERATION AND MAINTENANCE

The paper brings up the question of radiation safety aspects dealing with exploitation of cyclotron Eclipse RD (Siemens), that is used for positron-emission tomography with fluorodeoxyglucose (^{18}F-FDG). The main sources of radiation exposure and the efficiency of a cyclotron shielding were analyzed. The dose rates were measured from the activated details and wastes and the effective dose to personnel, performing operation and technical support of a cyclotron was estimated with the help of electronic personnel dosimeters EPD Mk2+ and thermoluminiscence dosimeters TLD Harshaw 100.
Keywords: *positron-emission tomography, fluorodeoxyglucose, cyclotron, radiation safety, effective dose.*

Introduction. Positron-emission tomography (PET) plays a crucial role in cancer diagnostics and can give information about the location of neoplasm and metastases, the intensity of metabolism and allows to estimate the efficiency of performed treatment [4]. PET requires radioactive tracers, and in this connection the low energy cyclotrons (up to 20 MeV) have found widespread applications in nuclear medicine for tracer production technologies [2]. The most commonly used PET radioisotopes (^{11}C, ^{13}N, ^{15}O, ^{18}F) can be produced through the proton induced reactions, such as (p,n) and (p,a). It is obvious, that the usage of cyclotrons leads to radiation exposure, caused by prompt radiation, produced tracer and induced activity. Moreover, in most cases cyclotron maintenance requires handling of radioactive components and wastes. Therefore special attention should be paid to the radiation safety aspects, providing additional shielding and dose control for personnel, who perform cyclotron operation and technical support. Besides, the analysis of the dose values enables to make a conclusion about the achieved radiation safety conditions and implementation of new safe measures, directed at a minimization of radiation exposure to personnel according to the ALARA principle.