TOMSK POLYTECHNIC UNIVERSITY
Томский политехнический университет

School School of Nuclear Science & Engineering
Field of training (specialty) 14.04.02 «Nuclear physics and technology»
Division Division for Nuclear-Fuel Cycle

MASTER'S GRADUATION THESIS

Topic of research work
Development of a spectrometer for use in medicine

UDC 539.1.075:621.384.8:615.478

Student

Group	Full name	Signature	Date
0AM9M	Mukanov Ernazar Bakytuly		

Scientific supervisor

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Aleinik A.N	PhD		

ADVISERS:

Section "Financial Management, Resource Efficiency and Resource Saving"

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Lubov Yu. Spicyna	PhD		

Section "Social Responsibility"

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Verigin D.A.	PhD		

ADMITTED TO DEFENSE:

Director of programme	Full name	Academic degree, academic rank	Signature	Date
Nuclear Medicine	Vera V. Verkhoturova	PhD		

Tomsk – 2021

LEARNING OUTCOMES

Expected learning outcomes

Learning outcome (LO)code	Learning outcome (a graduate should be ready)	Requirements of the FSES HE, criteria and / or interested parties
Professional competencies		
LO1	To apply deep mathematical, scientific, socio-economic and professional knowledge for conducting theoretical and experimental research in the field of the use of nuclear science and technology.	FSES HE Requirements (BPC-1,2, PC-3, UC-1,3), Criterion 5 RAEE (p 1.1) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
LO2	To demonstrate ability to define, formulate, and solve interdisciplinary engineering tasks in the nuclear field using professional knowledge and modern research methods.	FSES HE Requirements (PC-9,10,13,14,15, BPC-1,3), Criterion 5 RAEE (p 1.2) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
LO3	To plan and conduct analytical, simulation and experimental studies in complex and uncertain conditions using modern technologies, and to evaluate critically research results.	FSES HE Requirements (PC-1,13,22, UC-2, BPC-1), Criterion 5 RAEE (p 1.3) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the

		position of "medical physicist"
LO4	To use basic and special approaches, skills and methods for identification, analysis, and solution of technical problems in the field of nuclear science and technology.	FSES HE Requirements (PC-2,4,6,8, UC-2, BPC-1), Criterion 5 RAEE (p 1.4) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
LO5	To operate modern physical equipment and instruments, to master technological processes in the course of preparation for the production of new materials, instruments, installations, and systems.	FSES HE Requirements (PC-5,7,11,12, UC-2, BPC-1), Criterion 5 RAEE (p 1.4) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
LO6	To demonstrate ability to develop multioption schemes for achieving production goals with the effective use of available technical means and resources.	FSES HE Requirements (PC-16-21,23), Criterion 5 RAEE (p 1.5) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
Cultural competencies		
LO7	To demonstrate ability to use a creative approach to develop new ideas and methods for designing nuclear facilities, as well as to modernize and improve the	FSES HE Requirements (BPC-1,3, UC-3), Criterion 5 RAEE (p

	applied technologies of nuclear production.	2.4,2.5)
	Basic professional competencies	
LO8	To demonstrate skills of independent learning and readiness for continuous self-development within the whole period of professional activity.	FSES HE Requirements (UC-3, PC-1, BPC-1), Criterion 5 RAEE (p 2.6) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
LO9	To use a foreign language at a level that enables a graduate to function successfully in the international environment, to develop documentation, and to introduce the results of their professional activity.	FSES HE Requirements (PC-11,16,17, BPC-3), Criterion 5 RAEE (p 2.2) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"
LO10	To demonstrate independent thinking, to function efficiently in command-oriented tasks and to have a high level of productivity in the professional (sectoral), ethical and social environments, to lead professional teams, to set tasks, to assign responsibilities and bear liability for the results of work.	FSES HE Requirements (PC-18,23, UC-2), Criterion 5 RAEE (p 1.6,2.3) requirements of the Ministry of Health and Social Development of the Russian Federation under the unified skills guide for positions of managers, specialists and non-manual workers for the position of "medical physicist"

Министерство науки и высшего образования Российской Федерации
федеральное государственное автономное
образовательное учреждение высшего образования
«Национальный исследовательский Томский политехнический университет» (ТПУ)

School School of Nuclear Science & Engineering
Field of training (specialty) 14.04.02 Nuclear physics and technology
Division Division for Nuclear-Fuel Cycle

APPROVED BY:
Director of the programme
_____ _____Vera V. Verkhoturova
(Signature)   (Date)   (Full name)

ASSIGNMENT
for the Graduation Thesis completion

In the form:

Master's thesis

For a student:

Group	Full name
0AM9M	Mukanov Ernazar Bakytuly

Topic of research work:

Radiation dose optimization based on personalized numerical voxel models of exposure area

Approved by the order of the Director of School of Nuclear Science & Engineering (date, number):	

Deadline for completion of Master's Graduation Thesis:	06.06.2021

TERMS OF REFERENCE:

Initial data for research work: *(the name of the object of research or design; performance or load; mode of operation (continuous, periodic, cyclic, etc.); type of raw material or material of the product; requirements for the product, product or process; special requirements to the features of the operation of the object or product in terms of operational safety, environmental impact, energy costs; economic analysis, etc.)*	Development of a bio-impedance spectrometer for monitoring the state of tissues after radiation therapy sessions for patients with breast cancer.

List of the issues to be investigated, designed and developed *(analytical review of literary sources with the purpose to study global scientific and technological achievements in the target field, formulation of the research purpose, design, construction, determination of the procedure for research, design, and construction, discussion of the research work results, formulation of additional sections to be developed; conclusions).*	Performing a literature review of the research topic; Development of a bioimpedance spectrometer Perform diagnostics and study of its characteristics Measure phase angle in a patient with breast cancer.

Advisors to the sections of the Master's Graduation Thesis

(with indication of sections)

Section	Advisor
Financial Management, Resource Efficiency and Resource Saving	Lubov Yu. Spicyna
Social Responsibility	Verigin D.A.

Date of issuance of the assignment for Master's Graduation Thesis completion according to the schedule	

Assignment issued by a scientific supervisor / advisor:

Position	Full name	Academic degree, academic status	Signature	Date
Associate Professor	Aleinik A.N	PhD		

Assignment accepted for execution by a student:

Group	Full name	Signature	Date
0AM9M	Mukanov Ernazar Bakytuly		

School School of Nuclear Science & Engineering
Field of training (specialty) 14.04.02 Nuclear physics and technology
Level of education Master Degree Program
Division Division for Nuclear-Fuel Cycle
Period of completion 2018/2019 and 2019/2020 academic years

Form of presenting the work:

Master's Thesis

SCHEDULED ASSESSMENT CALENDAR

for the Master's Graduation Thesis completion

Deadline for completion of Master's Graduation Thesis:	11.06.2021

Assessment date	Title of section (module) / type of work (research)	Maximum score for the section (module)
02.02.2021	Drawing up and approving the terms of reference	10
02.03.2021	Selection and study of materials on the topic	10
11.03.2021	Choice of research area	15
26.04.2021	Conducting experiments	25
18.05.2021	Analysis and description of results	25
01.06.2021	Preparing for thesis defense	15

COMPILED BY:
Scientific supervisor

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Aleinik A.N	PhD		

AGREED BY:
Director of the programme

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Vera V. Verkhoturova	PhD		

TASK FOR SECTION

«FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY AND RESOURCE SAVING»

For a student:

Group	Full name
0AM9M	Mukanov Ernazar Bakytuly

School	School of Nuclear Science & Engineering	Division	Division for Nuclear-Fuel Cycle
Degree	Master Degree Program	Field of training/program	14.04.02 Nuclear physics and technology / Nuclear medicine

Input data to the section «Financial management, resource efficiency and resource saving»:	
1. Resource cost of scientific and technical research (STR): material and technical, energetic, financial and human	- Material costs 1761,4 rubles. - The main salary of the theme performers is 65428 rubles. - Costs of special equipment for scientific (experimental) work 2924.5 rubles. Overhead 16 1,1 rubles
2. Expenditure rates and expenditure standards for resources	Tariff for industrial electricity 5.8 per 1 kW • h - District coefficient of the city of Tomsk -1.3
3. Current tax system, tax rates, charges rates, discounting rates and interest rates	The amount of insurance premiums is 30% Reduced rate in Tomsk - 27 %
The list of subjects to study, design and develop:	
1. Assessment of commercial and innovative potential of STR	Competitive technical solutions evaluation map
2. Scheduling of STR management process: structure and timeline, budget, risk management	- SWOT analysis; - Planning of research work; - Development of a schedule for conducting scientific research (Gantt chart).
3. Determination of resource, financial, economic efficiency	The budget of scientific and technical research: calculation of material costs; calculation of the primary and secondary; salary performers topics; overhead costs; cost budgeting.
A list of graphic material *(with list of mandatory blueprints):*	
1. *"Portrait" of the consumer of the results of STR* 2. *Market segmentation* 3. *Evaluation of the competitiveness of technical solutions*	

4. *SWOT- analysis*
5. *Gantt chart and budget of scientific research*
6. *Assessment of resource, financial and economic efficiency of STR*
7. *Potential risks*

Date of issuance of the task for the section according to the schedule

The task was issued by adviser:

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor	Lubov Yu. Spicyna	PhD		

The task was accepted by the student:

Group	Full name	Signature	Date
0AM9M	Mukanov Ernazar Bakytuly		

Task for section
«Social responsibility»

To student:

group	Full name
0AM9M	Mukanov Ernazar Bakytuly

School	Nuclear Science and Engineering	Department	Nuclear fuel cycle
Degree	Master program	Specialization	Nuclear medicine (medical physics)

Title of master work:

Radiation dose optimization based on personalized numerical voxel models of exposure area

Initial data for section «Social Responsibility»:	
1. Information about object of investigation (matter, material, device, algorithm, procedure, workplace) and area of its application	Development of a bioimpedance spectrometer. Scope: Diagnostics of radiation therapy, and some other types of diseases.
List of items to be investigated and to be developed:	
1. Legal and organizational issues to provide safety: – Special (specific for operation of objects of investigation, designed workplace) legal rules of labor legislation; – Organizational activities for layout of workplace.	– Labour code of Russian Federation #197 from 30/12/2001 GOST 12.2.032-78 SSBT – Sanitary Rules 2.2.2/2.4.1340-03. Hygienic requirements for PC and work with it
2. Work Safety: 2.1. Analysis of identified harmful and dangerous factors 2.2. Justification of measures to reduce probability of harmful and dangerous factors	– Enhanced electromagnetic radiation level – Insufficient illumination of workplace – Excessive noise – Deviation of microclimate indicators – Electric shock
3. Ecological safety:	– Indicate impact of linear accelerator on hydrosphere, atmosphere and lithosphere – Indicate impact of high frequency radio waves generators on hydrosphere, atmosphere and lithosphere
4. Safety in emergency situations:	– Fire safety;

Assignment date for section according to schedule	

The task was issued by consultant:

Position	Full name	Scientific degree, rank	Signature	date
assistant professor	Verigin D.A.	Cand.of Sc.		

The task was accepted by the student:

Group	Full name	Signature	date
0AM9M	Mukanov Ernazar Bakytuly		

ABSTRACT

Master's Graduation work 114p., 31 fig., 25 tab., 25 sources.

Keywords: bioimpedance, cancer, radiation damages, phase angle, human tissue.

The object of research is a bio-impedance spectrometer for measuring physiological tissue changes after radiation therapy.

Aim of work is development of a bio-impedance spectrometer to determine the physiological status of living tissue after a cancer radiation therapy session with a diagnosis of breast cancer.

In the process of research were carried a device for bioimpedance spectrometry was developed.

As a result of the study the tests showed that the device allows you to measure bioimpedance in the frequency range from 10 Hz to 100 kHz. The efficacy of using the device in the diagnosis of tissues after radiation therapy sessions was also shown.

Cost effectiveness/significance the device is simple in construction and economical for production.

Application area: nuclear medicine, breast cancer.

Planned in the future using bio-impedance spectrometry can minimize side effects.

Contents

Introduction

There is now a need for a simple, non-invasive method for measuring body composition in a clinical setting. Most methods are either invasive, expensive, or not accurate enough because the underlying assumptions are not always feasible in the disease setting. Moreover, most methods cannot be used for repeated measurements, which are necessary to monitor changes in tissue composition. Measuring the electrical impedance of living tissue provides a set of parameters that can be used to simulate biological systems, and many studies have determined the relationship between electrical parameters and tissue structure or physiological phenomena. Measuring the impedance of living tissues in vivo presents certain difficulties. First of all, it depends on the fact that these parameters may differ from patient to patient. Living tissues are a heterogeneous material; however, to date, sufficient material has been accumulated to understand the conductive properties of tissues. Bioimpedance spectroscopy is a simple, non-invasive technique that can be reused. In this case, the body's resistance to alternating current is measured. Application of this method minimizes the risk of infection and can be used in monitor mode. An important property of biological tissues is the frequency dependence of conductivity. Since biological tissue is an accumulation of cells in a conductive fluid, its conductivity is primarily determined by the state of these two components. Electrical impedance consists of two components: active (ohmic) and reactive (capacitive) resistances. The first is the resistance of the intercellular space, while the second is the structure bounded by biological membranes - cells. The frequency range used for the study of biological objects covers frequencies from 1 kHz to 1.3 MHz. At low frequencies (less than 50 Hz), the electric current flows mainly through the intercellular fluid. As the frequency increases, tissue resistance decreases. This phenomenon is determined by the capacitive properties of cell membranes.

Electrical impedance spectroscopy (EIS) is increasingly used in medicine and other fields as a means of studying the properties of biological objects. Thus, the development of new diagnostic systems using bioimpedance multifrequency spectrometry is an urgent scientific and practical task.

To identify complications in the field of irradiation, it is necessary to develop an instrument that determines and gives the accuracy of the results, and using a bioimpedance spectrometer we can assess tissue damage during irradiation, may be important for evaluating the initial treatment in cases of tumor recurrence.

The aim of the work is the development of a bio-impedance spectrometer to diagnostics of the living tissue after a session of radiation therapy for cancer with a diagnosis of breast cancer.

To achieve the integrity of the following tasks:

1. Performing a literature review of the research topic

1. Development and manufacture of a bioimpedance spectrometer;

3. Development of software;

4. Measure phase angle in a patient with breast cancer

Chapter 1 Impedance of Biological Tissues

1.1 Impedance - basic concepts

The impedance of an element at a specific frequency is defined as the ratio between voltage and current for that frequency. In this case, there are two relationships between current and voltage: the first is the relationship between the amplitudes and the second is the relationship between the phases of current and voltage, that is, the delay between current and voltage. AC signals are represented by complex numbers that have a modulus and a phase. This representation allows you to simultaneously carry out calculations with the modulus of the value and its phase.

$$\text{Complex number: } c = a + jb \begin{cases} \text{Real part: } \mathrm{Re}(c) = a \\ \text{Imaginary part: } \mathrm{Im}(c) = b \end{cases} \quad (1)$$

$$\begin{cases} module: \, IcI = \sqrt{Re\{c\}^2 + Im\{c\}^2} \\ Phase: \, {\llcorner}c = \arctan(\dfrac{Im\{c\}}{Re\{c\}}) \end{cases} \quad (2)$$
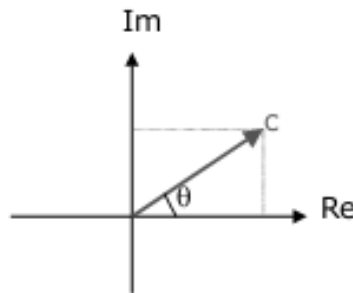
Figure 1 - Representation of numbers on the complex plane.

For a given frequency, both voltage and current are represented by amplitude and phase. Therefore, the electrical impedance is equal to the ratio of the amplitudes and the phase difference.

$$Z = \frac{V}{I} \text{ from this it follows } |Z| = \frac{|V|}{|I|}, \ \angle Z = \angle V - \angle I \ (3)$$

The real part of the impedance is called resistance, and the imaginary part is called reactance. The real part of Re (Z) causes power loss, and the imaginary part Im (Z) causes a delay between current and voltage. Resistance obeys Ohm's law, so its impedance is the ratio between the amplitudes of voltage and current.

$$Z = Re\ \{z\} = R = V\ /\ I \quad (4)$$

This expression is true for any combination of resistors as long as they can be combined into one resistance. For a capacitor, the current is proportional to the time derivative of the voltage, so Ohm's law is invalid. The capacitance impedance will be:

$$Z = -j\left(\frac{1}{2\pi fC}\right) \quad (5)$$

Thus, its impedance depends on the frequency and the phase is 90 °, that is, the capacitor is purely reactance. The resistance of the capacitor decreases for high frequencies, and increases for low frequencies.

Figure 2 shows a diagram for measuring the resistance of a human organ or any part of the body of O.
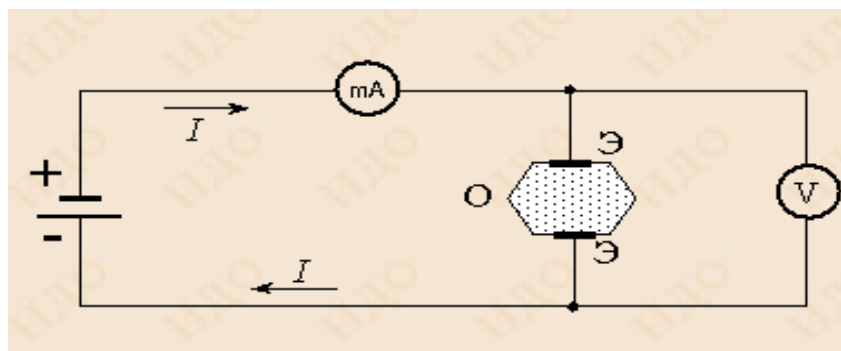
Figure 2 - Scheme for measuring organ resistance.

Where I is the current strength, U is the voltage between the electrodes. The true resistance of this area O due to the arising polarization of tissues and the appearance of additional charges on the electrodes is difficult to register. For these reasons, no direct current is used, alternating current is used instead. When an

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alternating current voltage is applied to the electrodes $U = U_0 \sin \omega t$, an alternating current flows in the circuit of the object under study O, changing according to the law $I = I_0 (\sin \omega t - \varphi_0)$. The value $Z = \dfrac{U_0}{I_0}$, there is resistance or can be called the impedance of the object and depends on the properties of the object itself, and on the frequency of the current. The cell membranes, as well as the interfaces between various tissues, are similar to a capacitor, so any part of the body has a more or less significant capacitance C. Capacitive resistance R_c decreases with an increase in the frequency of alternating current according to the law $R_c = \dfrac{1}{2\pi v C} = \dfrac{1}{\omega C}$.

1.2 Types of dispersions in biological tissues.

In a healthy body, the cell membrane consists of a non-conductive layer of lipids and protein molecules. Under the influence of alternating current, the structure of the cell membrane changes the reactive capacitance of the elements, which behave like a capacitor. Biologically, the cell membrane is a selective semipermeable barrier that separates the intracellular and extracellular spaces. It protects the interior of the cell, allowing the passage of certain substances for which it is permeable. The cell membrane maintains the osmotic pressure and the ion concentration gradient between the intracellular and extracellular spaces. This gradient creates a difference in electrical potential that is required for the cell to survive. Damage to the cell membrane, its functions, is lethal to the cell, as well as damage to the nucleus itself. It is extremely difficult to measure the electrical conductivity of biological systems at direct current due to the high degree of polarization of membranes and electrodes. At low frequencies of alternating current, most of the current flows through the intercellular spaces. With an increase in the frequency of the electric current, the reactance of the capacitance decreases, and the polarization phenomena decrease. The dependence of the resistance and capacitance of an object on frequency is called dispersion. In biological tissues,

three types of dispersions are observed - α, β and γ in the dependences of conductivity and permeability on frequency.
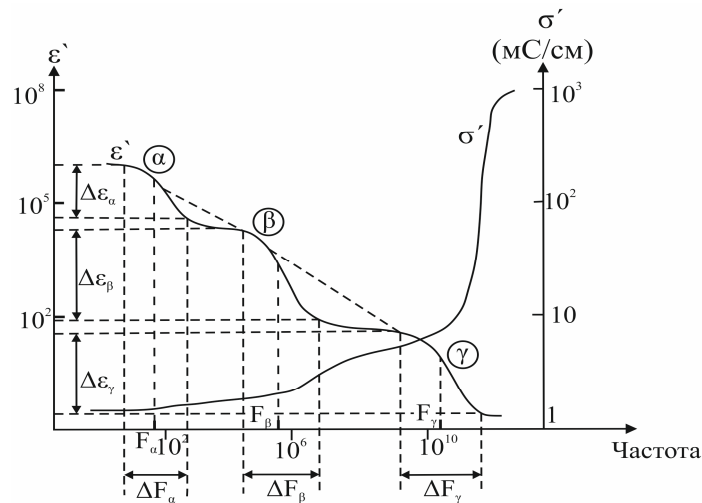
Figure 3 - Types of dispersions in biological tissues.

This relationship is referred to as variance. At relatively low frequencies <1 MHz, tissue conductivity is determined by the electrolyte conductivity of the intercellular fluid. Total conductivity depends on the volume of the intercellular space. In some cases, the so-called α-dispersion appears with an average frequency in the kilohertz range. It is assumed that this type of dispersion is mainly due to the interaction between ions bound on slightly charged surfaces and biological membranes. An additional contribution is made by the polarization of membrane proteins and lipids. At frequencies below the α-dispersion, the value of the relative dielectric constant rises sharply to 107.

In the frequency range 3 kHz - 1 GHz, β-dispersion is observed in biological materials with an average frequency of 100 kHz - 10 MHz. Its presence is explained by the interaction of intracellular and extracellular ions. At frequencies above β-dispersion, the impedance of cell membranes can be neglected. The applied voltage causes a current to flow through the extracellular space as well as through the intracellular space. The type of β-dispersion can be altered by side effects, for example, relaxation of amino acids or the presence of charge in intracellular organelles. At frequencies above 1 GHz, biological tissues

exhibit γ-dispersion, which is mainly determined by the relaxation of water molecules present in the tissues. In this frequency range, it is possible to study the hydration membranes along lipid membranes. The average frequency of 19 GHz is the relaxation frequency of free water. The frequency shift can be caused by the binding of proteins to water molecules. Hydrated proteins exhibit a wide range of frequencies from a few megahertz to GHz, reflecting the presence of charged macromolecules. In the most commonly used frequency range of 100 Hz to 10 MHz, the behavior of impedance is determined by β-dispersion. The cell is the basic unit of biological tissues, it consists of a phospholipid membrane, which separates its internal contents from the extracellular space. The extracellular space can be thought of as an electrolyte, where most of the ions are Na^+ and Cl^- ions. Therefore, the electrical properties of tissues depend on physical and chemical parameters that determine concentration or mobility. Temperature also plays an important role in ionic conductivity. The viscosity of the solution decreases with increasing temperature, while increasing the mobility of the ions and thus reducing the resistance. The pH in most tissues is in the 6-8 range, so the H^+ concentration is low and does not significantly contribute to conductivity. The concentration of ions inside the cell is comparable to that of the extracellular, only the main charge carriers are ions $K^+, HPO_4^{2-}, SO_4^{2-}$, proteins and organic acids. In addition, there are numerous structures inside the cell that have their own membrane. These membranes also have poor conductivity. Therefore, the impedance of the intracellular medium has capacitive properties.

The cell membrane is a double layer of lipids. It is about 7 nm thick, so water and lipid molecules can pass through it, but it poses a serious barrier to charged ions. Together with the extracellular and intracellular fluid, the membrane represents a capacitor with a capacity of approximately 1 μF / cm^2. Various proteins, transport organelles, as well as ion channels and pumps are built into the membrane, which play a major role in the activity of the cell.

1.2.1 Current flow during tissue ischemia

Some pathologies such as ischemia, infarction, or necrosis alter the content of the cell, which leads to a change in the impedance value. Figure 4 shows how ischemia affects impedance magnitude. During ischemia, there is a lack of oxygen in the cell, caused in some way, therefore, the cell experiences a deficit of energy and is not able to fully provide the ion channels and pumps with energy. Since water molecules easily penetrate the membrane, and the movement of ions in this case is limited, the inside of the cell contains more water than necessary. As a result, the cell increases in size, taking up more space in the extracellular space. Now the path for current in the extracellular space becomes limited and the resistance at low frequencies increases, indicating ischemia.
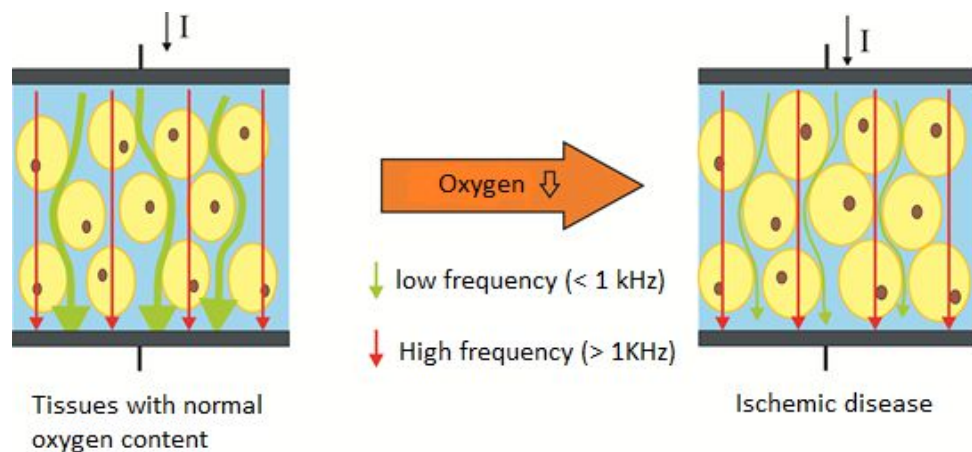
Figure 4 - Effect of ischemia on current flow.

Ischemia can be followed by necrosis, that is, a violation of the cell membrane and its death. Now the resistance at low frequencies begins to decrease, since the absence of a membrane allows current to flow in the extracellular space.

1.3 Equivalent cell layout

Figure 5 shows two equivalent circuits (RC), a circuit common in BIS and the numbers Z and Y are complex numbers. A frequently presented circuit in bioimpedance spectroscopy for liquid and solid materials. Any system of material-electrode in cell measurement has a geometric capacitance $C_g = C_\infty = C_1$ and parallel to it resistance $R_b = R_\infty = R_1$. Dielectric relaxation time constant $\tau_D = R_\infty C_\infty$. Typically, τ_D is the shortest time constant in a bioimpedance rectroscopy experiment. This is often so small, about $\tau_{D(-7)}$, that it has been applied for frequencies of large angles W_{max}. It should be noted, however, that lowering the temperature will often increase the volumetric arc value within the measurement range. As shown in Fig. 5 (b, e), the peak frequency of the semicircle W_p satisfies the condition $W_p \tau_D = 1$, only under the condition $W_{max} \tau_D \quad 1$ the full curve is almost obtained. Although, bulk resistance is not distributed, particularly for crystals, when it is actually distributed, the circuit response often results in a suppressed semicircle in the Z plane whose center lies below the real axis instead of a full circle centered on the real axis. From this distributed element, the frequency range for processes in the interval $W \quad \tau_D^{-1}$ was found. In the case of this distributed element, it is often found for processes with a $C_W \quad \tau_D^{-1}$ frequency range.
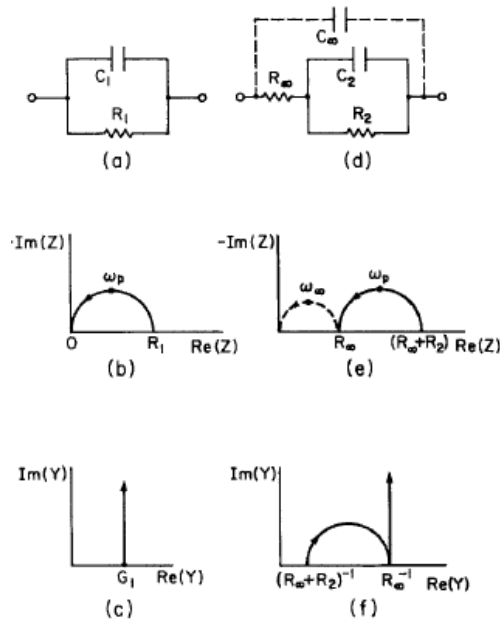
Figure 5 - RC circuit.

Figure 5, where a and d are RC circuit. B and f shows the resistance of the plane. Both c and f - arrows indicate direction with increasing frequency. Besides $R_1 = R_\infty$ and $C_1 = C_\infty$, there is often a parallel response of R_1, C_1 with heterogeneous electrode reactions. For such a case, we will set $R_1 = R_R$ and $C_1 = R_R$, where R_R is the reaction resistance and CR is the diffusion of the two-layer capacitance of the polarization region closer to the electrode in the simplest cases. The circuit shown in Figure 5 d. combines more possibilities when $R_2 = R_R$ and $C_2 = C_R$. The results shown in Figure 5 e and f correspond to $R_\infty = R_\infty$ $R_2 C_\infty$. It is also possible that the parallel RC connection may arise from specific absorption at the electrode, possibly associated with delayed process reactions. The response arising from in Fig. 5e is shown with dashed lines to remind that this often occurs in the easily observable high frequency region.

By chance, we will always assume that the capacitance and volume of the cell measurement wire are subtracted, (for example, using the results of a preliminary calibration of the system with empty cells or shorted ones) in such a

way that we will count with the response of only the material-electrode of the system.

Thus, we will always assume that the capacitance and volume of the cell measurement wire are subtracted, (for example, using the results of a preliminary calibration of the system with empty cells or shorted ones) in such a way that we will count with the response of only the material-electrode of the system. In the complex plane, the arrow shows the direction of increasing frequencies. $G_1 = R^{-1}_1$, $G_\infty = R^{-1}_\infty$, $G_2 = R^{-1}_2$. Since the results of impedance spectrometry usually include capacitance and less often inductance, it has become common to plot in a plane rather than a plane. Im (Z) and Re (Z) and planes Im (Z) and Re (Z), so most of the curves are in the first quadrant as shown in figure 1.3.1 b. This method is also equivalent to plotting rather than Z, so we can alternatively mark the ordinate Im (Z) instead of - Im (Z). Both choices will be used in the study. The conductivity of the parallel RC circuit from Figure 5a is the sum of the conductivity of the elements, thus

$$Y_a = G_1 + jwC_1,$$

6)

$$Z_a = Y_a^{-1} = \frac{R_1}{R_1 Y_a} = R_1[1 + jwR_1C_1]$$

7)

This result can be improved by multiplying by the numerator and denominator by $[1 - j\omega R_1 C_1]$, that is, the complex number is conjugate to $[1 + j\omega R_1 C_1]$. The response in Figure 5e is considered simple when the plot is plotted along the Y plane, as shown in Figure 5c.

1.4 Bioimpedance spectrometer analysis method.

Bioimpedance analysis at a single frequency, usually 50 kHz, is passed between surface electrodes placed on the arms and legs (Fig. 5). The electrodes are also used on other places, such as foot-to-foot or hand-to-hand electrodes. At a frequency of 50 kHz, strictly speaking, not the total suspended fluid is measured, but the resistance of the extracellular and extracellular fluid is measured. Single frequency bioimpedance analysis allows the estimation of fat-free mass and total suspended liquid, but cannot determine the difference between intracellular fluid. The results of bioimpedance analysis based on the theory of "mixing" and the empirical equation. Recent results have been obtained in healthy patients with robust biological gameostasis. Although single frequency bioimpedance analysis does not work under conditions of significantly altered hydration, it does not imply its use for obtaining FFM or TBW in healthy patients. The relative merit of the various equations must be discussed.
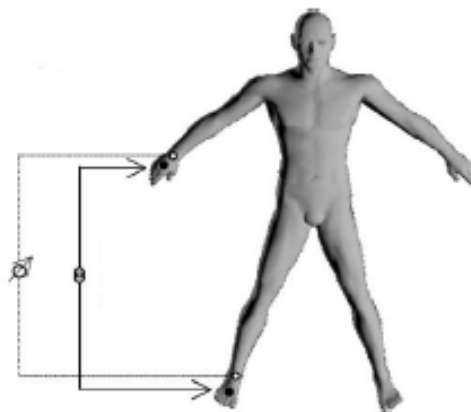
Figure 6 - Arrangement of electrodes on the arm and wrist and ankle of the legs for a tetrapolar sample.

1.5 Total body fluid, extracellular and intracellular fluids.

It has been found that current bioimpedance analysis methods (SF and MF-BIA) are not accurate enough to assess intracellular fluid under conditions of changing hydration. The equations that were developed for healthy populations are not valid for individuals with altered hydration. Data from hypo- and hyper-hydration studies suggest that electrolyte balance affects the measurement of bioimpedance analysis, regardless of fluid changes. Such effects are difficult to predict, as fluid and electrolyte changes will also affect the intra- to extracellular fluid ratio, which in turn affects resistance. ECW: intracellular fluid ratio, is a known factor to limit the applicability of the generated population bioimpedance analysis equations. In addition, bioimpedance analysis does not accurately assess intracellular and extracellular fluid when the fluid-containing cavity undergoes significant changes. Moreover, the average FFM body hydration changes with age. According to the work of Ellis.

At 50 kHz, single frequency bioimpedance analysis primarily reflects extracellular fluid, which represents a constant proportion of total body fluid under normal conditions. With an increase in extracellular fluid or the ratio of extracellular fluid to body fluid, it can mean edema or malnutrition. The MF-BIA appears to be sensitive to such changes, each if there is a slight change in the body weighed. On the other hand, parallel displacement, a single frequency bioimpedenasal analysis model appears to be sensitive to changes in intracellular fluid (or in whole body fluid), but unchanged in extracellular fluid. Thus, this model may be of limited use for assessing total body fluid or body fat when a state of abnormal hydration exists. Among the MF-BIA and BIS models, the 0 / ∞ parallel model is indicated to be more accurate and accurate for both intracellular and extracellular fluid measurements than single frequency bioimpedance analysis variables. According to Goodywak's work. The 0 / ∞ parallel model is found to accurately represent changes in intra and extracellular fluid make up Ringer's decision, proximally placed detector electrodes (elbow and knee). Scarf and others.

It was estimated that, as a result of this electrolyte change, the errors with the ratio to change in volume were large ($\leq 15\%$ for extracellular fluid and$> 20\%$ for intracellular fluid). They concluded that correcting the disrupted fluid model in order to change the resistance needed to obtain more accurate intracellular fluid data. If reliable data and a model of a destroyed fluid is included that considers heterogeneous tissues, then in this case the potential of the LSI can only be depleted. A valid model must ensure that changes in the extracellular fluid do not damage the intracellular fluid or vice versa. The standardization of the LSI method is the method under study. A meta-analysis developed by Martinol et al. Concluded that Single Frequency Bioimpedance Analysis and LSI significantly overestimated TBW in healthy individuals. MF-BIA is considered a more accurate method for determining TBW for healthy and obese individuals and for those with chronic kidney disease.

Chapter 2. Measuring Bioimpedance

2.1 Methods for measuring impedance

For bioimpedance measurements, noble metal or stainless steel electrodes are used. The distance between the potential electrodes is -2.5 mm, between the potential and current electrodes - 3 mm. This arrangement of the measuring electrodes allows you to register changes in the blood structure that occur in the interelectrode space due to the sedimentation and aggregation of erythrocytes during the measurement. When an electrode is applied to the skin surface, there is a certain electrical resistance at the electrode-skin junction. For a reliable recording of physiological signals, free from artifacts, it is necessary that the electrode has good (low resistance) contact with the skin. Since the top layer of the skin is largely composed of dead cells and there is always a certain amount of grease and dirt on it, the natural electrical resistance of the skin is high compared to the resistance of body fluids. Therefore, when placing the electrodes on the surface of the skin, the site to which the electrode will be applied is usually prepared or treated to lower the resistance.

To measure the impedance, a classical bridge circuit is used as shown in Fig. 7, this circuit consists of a constant resistance R_1, R_2, the measured impedance Z_m, a variable impedance Z_v, an active Rv and a reactive Xv. An alternating voltage generator is included in one of the diagonals of the bridge, and the second is a voltage meter.
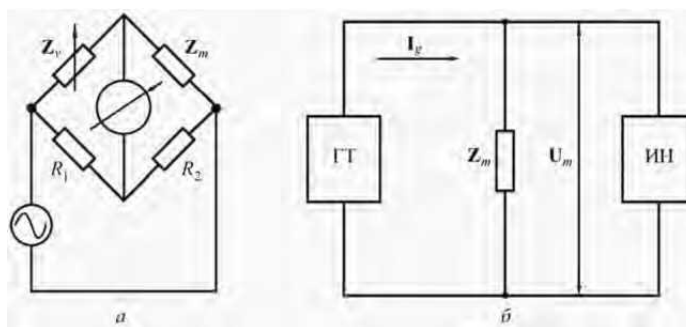
Figure 7 - Impedance measurement circuits: bridge (a), voltmeter method (b)

The Z_V components are adjusted so that the meter reads zero. When the bridge is balanced, the equality

$$\frac{Z_m}{Z_v} = \frac{R_2}{R_1}$$

8)

from which the active Rm and reactive Xm components of Zm are determined:

$$R_m = \frac{R_2}{R_1} R_v, \qquad X_m = \frac{R_2}{R_1} X_v$$

9)

Bridge meters provide high measurement accuracy, but since the process of adjusting Z_V even in the case of its automation takes a long time, they are not used in practical bioimpedance measurement.

The commonly used impedance measurement methods are based on Ohm's law, from which for the impedance modulus we obtain

$$Z_m = \frac{U_m}{I_g}$$

10)

where U_m is the measured voltage at the object. The GT current generator (Figure 8 b) maintains a given current Ig regardless of Z_m. The voltage meter IN is calibrated in resistance values to eliminate the need for calculations using formula (10).

To measure the complex impedance, use the circuit shown in Figure 8 a, where PD is a phase detector that forms a constant voltage proportional to the phase shift between the alternating voltage on the object and the generator current, AM is an amplitude detector, the constant voltage at the output of which is proportional to the modulus of impedance. In processing blocks. Sample 1, Sample 2 the voltage values from the detectors are converted into the values of the modulus and phase angle of the impedance, which can then be recalculated into the values of active and reactance values.

And also to measure the complex impedance, you can use the circuit shown in Figure 8 b. In the SD1 synchronous detector, the AC voltage from the object is multiplied by the AC voltage ui, in phase with the generator current, and in the SD2 synchronous detector, by the AC voltage U_q, delayed in phase with respect to the generator current by 90 ° (the so-called quadrature voltage). In this case, constant voltages are allocated at the outputs of SD1 and SD2, proportional, respectively, to the active and reactive components of the measured impedance.
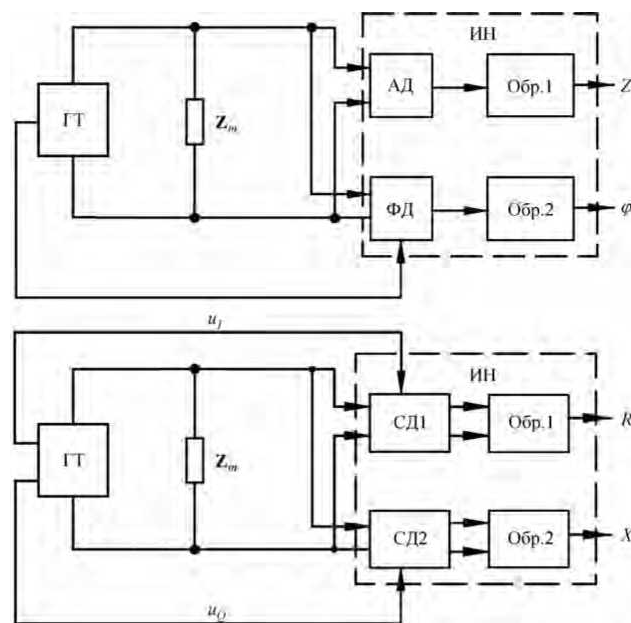
Figure 8 - Schemes for measuring the components of a complex impedance: using amplitude and phase detectors (a), using synchronous detectors (b)

The processing units convert these voltages into the values of the active and reactive resistances R_m and X_m, which can be converted into the modulus and phase angle of the impedance.

The circuits in Figure 8 allow measurements to be made at one frequency. In the case of multifrequency bioimpedance measurement, measurements at different frequencies are performed in turn. In this case, firstly, the duration of the procedure increases, and secondly, for different frequencies, results are obtained that relate to different times, which is unacceptable in some applications. One of

the ways to overcome these disadvantages is that an alternating current containing several harmonics is passed through the object [10]:

$$I = \sum_{k=1}^{K} I_{mk}\, e^{j\theta_k} e^{j\omega_k t} \qquad \text{11)}$$

$$I = \sum_{k=1}^{K} I_{mk}\, e^{j\theta_k} e^{j\omega_k t} \qquad \text{12)}$$

where I_{mk}, θ_k, ω_k are, respectively, the amplitude, initial phase and frequency of the k – th frequency component of the current, K is the number of these components. The voltage created by such a current at the impedance of the object has the form

$$U = \sum_{k=1}^{K} U_{mk}\, e^{j\psi_k} e^{j\omega_k t} \qquad \text{13)}$$

$$U = \sum_{k=1}^{K} U_{mk}\, e^{j\psi_k} e^{j\omega_k t} \qquad \text{14)}$$

The amplitude and phase of the k-th frequency component of the voltage are determined by the formulas $U_{mk} = I_{mk} Z(U_k)$, $U_k = U_k + U_k(I_k)$, where $Z(U_k)$ and $I_k(I_k)$ are the module and phase angle of the object impedance.

Further, the alternating voltage removed from the object can be applied in parallel to several voltage meters, each of which selects and measures one frequency component. A more promising method is based on the use of the discrete Fourier transform (DFT).

Let's introduce the concept of the complex amplitude of the k-th frequency component:

$$U_k = U_{mk}e^{j\omega_k t}$$

<div align="right">15)</div>

This value contains information about both the module and the phase angle of the impedance at the k-th frequency. To find the complex amplitudes, the alternating voltage is digitized and the DFT is performed

$$U_s = \sum_{n=0}^{N} u(n)e^{-j\frac{2\pi sn}{N}}$$

<div align="right">16)</div>

where u(n) are discrete values (readings) of voltage, N is the number of readings on the processed segment of alternating voltage. Complex amplitudes U_s correspond to frequencies 0, f_d / N, $2f_d / N$, ..., $(N-1)f_d / N$ where f_d - is the sampling frequency. The choice of the values of N and / d is carried out so that among these frequencies there are also the frequencies present in the current (7). The construction of bioimpedance analyzers according to this principle has been reported in a number of works.

The described probe current methods are widely used in *in vivo* measurements in the frequency ranges from 1 kHz to 1 MHz. For higher frequencies, other measurement methods are used. Investigation of the transmission of high-frequency electromagnetic waves through an object or reflection from an object is carried out up to frequencies of the order of 100 GHz. Transient analysis is also used when a voltage pulse is applied to an object (TimeDomainAnalysis). But all these methods are suitable mainly for *in-vitro* measurements.

2.2 Electrode-to-tissue contact.

The device measuring bioimpedance parameters interacts with the biological object through the electrodes. In the area of contact of the electrode with the tissue, rather complex physical and chemical processes occur that affect the measurement results. The main result of these processes is the change of charge

carriers that form an electric current. In wires and metal electrodes, the current is formed by electrons moving in the crystal lattice of the metal, and in tissue - by ions moving in the electrolyte solution. When the electrode contacts the electrolyte, an equilibrium potential difference is established between them, and a double electric layer is formed at the interface surface (Figure 9). In this case, the atoms of the electrode material can pass into the electrolyte, and the electrolyte ions can be deposited on the electrode surface. In the case of bioimpedance measurements, the dissolution of the electrode is unacceptable, therefore, electrodes made of silver, platinum and other inert metals are used, whose atoms only participate in the exchange of electrons with ions.
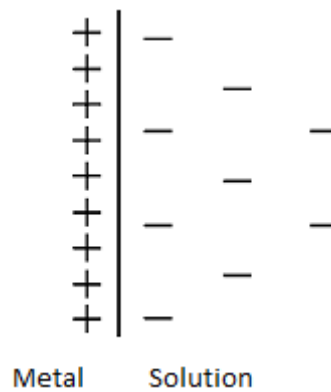
Figure 9 - Double electrical layer at the contact

When an electric current is passed through the contact, redox reactions occur directly at the electrode surface, ensuring the exchange of charge carriers. The magnitude of the potential difference between the electrode and the electrolyte changes in this case. This phenomenon is called electrode polarization. Polarization is undesirable because it requires additional voltage to be applied to the contact to allow current to flow.

Pure inert metal electrodes are characterized by significant polarization voltages. This is due to the fact that the atoms of the material of such electrodes are not directly involved in the reactions. To decrease the polarization, it is necessary that the ions of the atoms of the electrode material are present in the solution, and

the transition of ions occurs in any direction. The widely used $Ag / AgCl$ electrodes satisfy this requirement. An AgCl layer is formed on the surface of the silver electrode. Ions Cl^- are present in the tissue. Depending on the direction of the current, either an increase or a decrease in the thickness of the AgCl layer occurs. The polarization voltage is insignificant and, as a rule, does not exceed 10 mV.
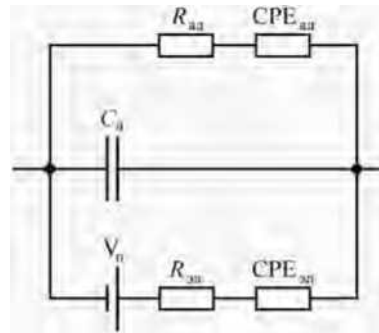
Figure 10 - Equivalent contact scheme.

The equivalent contact circuit (Figure 10) contains several parallel branches. One of them reflects the processes occurring during chemical reactions on the electrode. This branch includes a source of constant polarization voltage Vn and a circuit with a resistance Yael and a CPEEL element. The second branch contains the capacity of the double electric layer SD. Since this layer is very thin, the value of the capacitance turns out to be very significant - about 10 μF per 1 cm2 of the contact. The third branch reflects the adsorption of particles from the solution on the surface of the electrode. The scheme can be supplemented with branches corresponding to other processes. Due to the presence of a capacitive branch, the contact impedance modulus decreases with increasing frequency, so that at frequencies above 5 kHz, the influence of the contact on measurements is insignificant. But at lower frequencies, the polarization and impedance of the contact can make a significant contribution to the measurement error.

Special problems arise when applying electrodes to the skin surface. A thin (10-20 microns) stratum corneum in a dry state with direct current has a very high

resistivity, 104-105 Ohm · m. On alternating current, with increasing frequency, the resistivity gradually decreases to $\approx 10^2 Ohm \cdot m$ at 1 MHz. When the skin is hydrated, its resistance decreases. Sweat ducts also reduce resistance, but their effect is unstable.

The high impedance of the stratum corneum creates serious measurement difficulties. To overcome them, it is necessary, firstly, to cleanse the skin in the places where the electrodes are applied and, secondly, to apply a special gel or saline solution to the skin, which soak the stratum corneum and reduce its resistance. Also, special electrodes with micropoints are used, which penetrate through the stratum corneum and create contact with the well-conducting epidermis. Finally, the stratum corneum can be removed using abrasive materials.

The total contact impedance consists of the series-connected electrode-gel contact impedance, the gel impedance, and the stratum corneum impedance reduced by gel impregnation. The listed components have rather complex frequency dependences. In general, the contact impedance modulus decreases significantly with increasing frequency.

The voltage across the contact is described, generally speaking, by a non-linear function of the current density. Therefore, when a sinusoidal alternating current flows through the contact, the voltage on the contact may differ in shape from a sinusoid and contain higher harmonics. This effect is especially undesirable when measuring simultaneously at several frequencies, since it leads to the appearance of sum and difference frequencies. With increasing frequency, nonlinear distortions decrease, and the permissible current density increases. A platinum electrode at a frequency of 1 kHz ensures the absence of noticeable nonlinearity at a current density of up to 1 mA /cm2. When using electrodes with a small surface area, harmonic distortion can be significant.
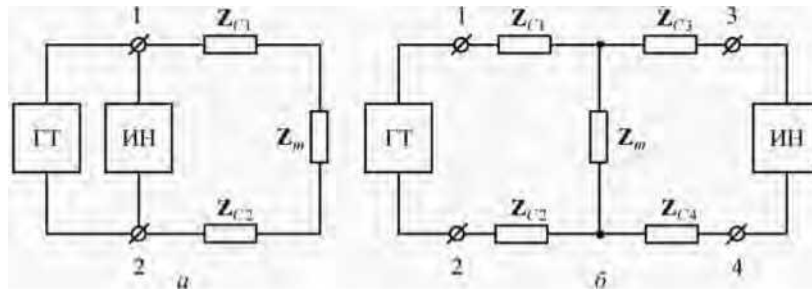
Figure 11 - Bipolar (a) and tetrapolar (b) measurement schemes.

Thus, contact impedances can have a significant effect on the bioimpedance measurement result. In a bipolar measurement scheme (Figure 11a), in which one pair of electrodes 1 and 2 is used both for supplying current and for removing voltage, the total impedance modulus is measured

$$Z_{sum} = Z_m + Z_{C1} + Z_{C2} \qquad (17)$$

where Z_{C1} and Z_{C2} are the impedances of contacts, the uncertainty and instability of which make it impossible to accurately determine the impedance of the object. In this regard, the field of application of the bipolar scheme is limited.

In the widely used tetrapolar circuit according to Figure 11b, current is injected into the object through current electrodes 1 and 2, and voltage is removed from measuring electrodes 3 and 4. If the input impedance of the voltage meter is significantly greater than the impedance module of the object, then the current through electrodes 3 and 4 and, therefore, the voltage drops across the impedances of contacts Z_{C3} and Z_{C4} will be negligible, and the voltage on the object itself will be measured.

2.2.1 Sources of error.

Measurement error is the difference between the measured value of a physical quantity and the true one. The true value of the impedance of a biological object is unknown, therefore, the errors of bioimpedance analyzers have to be estimated by measuring the equivalents of biological objects, as well as comparing the results of measurements of one and the same biological object obtained using devices of different types. Another possible source of information on errors is the

difference between the measured frequency characteristics of bioimpedance parameters from those predicted on the basis of proven theoretical models.

This section deals with instrumental and methodological errors in measuring the impedance of a biological object, due to the characteristics and parameters of the device and the measurement method. Errors in estimating the parameters of body composition are associated with errors in the measured values of active and reactive resistance, but also due to other reasons, primarily, inaccuracies in the models of bio-objects. These issues are analyzed in the next chapter.

Consider the impedance measurement process. The bioimpedance analyzer is pre-calibrated against a set of reference impedances. As a result, we obtain calibration functions of the form

$$U_d = F(Z_m, f, D)$$

18)

where Ud is the value of the analog or digital signal at the output of the voltage meter, Zm is the measured complex impedance, f is the frequency at which the calibration is performed, D is the measurement range. Such functions are generated for each measurement channel (R and X_C), each used frequency and each measurement range and are stored in the memory of the bioimpedance analyzer as a set of parameters or a table of values. When measuring the impedance of an object from the U_d value obtained from the detector using the calibration function, the measured Z_m values are calculated for the used frequency and the current measurement range.

Measurement errors by sources of occurrence are subdivided into methodical, instrumental, external and subjective.

Subjective errors are the result of operator errors. The high degree of automation of bioimpedance analyzers practically eliminates errors in reading the results and performing intermediate calculations. Potential errors are caused by

incorrect electrode placement. But the random errors that arise in this case are more correctly attributed not to the measurement of impedance, but to the method of assessing body composition, so they will be considered in the next chapter.

Instrumental errors are due to the characteristics of the equipment used. These errors arise for the following reasons:

• errors of reference impedances used for calibration;

• temperature and time instability of the generator current values and the parameters of the measuring path;

• errors of detectors associated with their nonlinearity and inertia;

• errors of analog-to-digital conversion and computation.

The influence of most of these factors in modern electrical measuring equipment can be reduced to a negligible level. Detector errors can be the most serious problem. But they, as a rule, are systematic and are taken into account during calibration. In general, with the modern level of the element base and circuitry, the instrumental error of the impedance meter is easily ensured within tenths of a percent.

External errors are the result of external causes in relation to the measuring device. These reasons, first of all, include changes in the characteristics of the environment: temperature, humidity, etc. In modern devices, the influence of these factors can also be reduced to acceptable limits.

Another type of external influence is electromagnetic fields emitted by other devices, for example, a computer included in the bioimpedance analyzer. The measurement results can eliminate errors when reading the results and performing intermediate calculations. Potential errors are caused by incorrect electrode placement. But the random errors that arise in this case are more correctly attributed not to the measurement of impedance, but to the method of assessing body composition, so they will be considered in the next chapter.

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Another type of external influence is electromagnetic fields emitted by other devices, for example, a computer included in the bioimpedance analyzer. The results of measurements can be influenced by signals from radio stations, for which the biological object is an antenna. These questions are still little researched. One of the ways to reduce the influence of external electromagnetic fields is the rational choice of frequencies at which measurements are performed.

Methodological errors arise due to incomplete accounting of the parameters of the equivalent circuit of the measuring circuit during the measurement. The fact is that when measuring bioimpedance, the values of some parameters of this circuit can differ significantly from the values that took place during the calibration. The analysis of this species inaccuracies are the focus of the remainder of this section.

2.2.2 Methods to reduce measurement errors.

Since the main cause of errors of the described types is parasitic capacitances, it is necessary to strive to minimize them. For this, various methods of capacitance compensation are used. This approach complicates the design of the cables connecting the device to the electrodes and has limited capabilities. It is difficult to compensate completely for the parasitic capacitance of the device, and the effect of the parasitic capacitance of the object cannot be reduced by this method.

Another approach proposed based on the correction of measurement results using information on the parameters of the equivalent circuit. If you have reliable information about the values of the parasitic capacitances and impedances of the contacts during the measurement, then according to the diagram in Figure 12, it is possible, based on the measured voltage Um, to calculate the object impedance Z_m. The methodology for implementing this approach includes two stages.

At the stage of instrument calibration, an assessment of its parasitic capacitances C_P and C_g is performed. In this case, such values of these capacitances are selected in order to obtain the minimum measurement error on the equivalents of an object with known impedances. The selected values of the parasitic capacitances of the device are saved together with its calibration characteristics in a file on the PC or the device memory. It also stores the impedance values that, when calibrated, simulated the impedances of the contacts.

During measurements on the object, the measurement results are corrected taking into account the real values of the impedances of the contacts and the parasitic capacitance of the object. These values are measured, fitted or entered based on a priori information or some indirect data. Below are examples of such a correction.

To correct methodological errors arising from changes in impedances Z_{C1} and Z_{C2}, it is necessary to measure these impedances. For this, the voltages

between electrodes 1-3 and 2-4 are measured (see Figure 12), according to which, using the calibration characteristics (12), the active and reactive components Z_{C1}, Z_{C2} are estimated. It can be seen from the equivalent circuit that the measured voltages will also be contributed by the voltage drop across the impedances Z_{C3}, Z_C. But, since only a small part of the current flows through these impedances, branching off from the main probe current flowing through Z_{C1}, Z_{C2}, their contribution will create a second-order correction of smallness. Taking this into account, all the necessary calculations can be performed according to a simplified equivalent circuit, in which there are no Z_{C3}, Z_{C4}, C_p, C'_p. Corrective corrections are obtained by comparing the modules and phases of the current flowing through the measured object during calibration and during measurement. The values of Z_{C1}, Z_{C2} required for calculations during calibration, as noted above, must be saved together with the calibration functions.

Checking the correction efficiency is carried out using the resistive-capacitive equivalents of the object. For example, when measuring an equivalent with the parameters R = 490 Ohm, X_C = 69 Ohm at a frequency of 50 kHz with the AVS-01 "Medass" bioimpedance analyzer, an increase in the resistances of the simulators Z_{C1} and Z_{C2} by 200 Ohms compared to the calibration conditions with the correction disabled leads to an error of the measured value XCna 3 - 4 Ohm. This gives an error in estimating the phase angle of the order of 0.5 °. When the correction is on, the X_q error does not exceed 0.1 Ohm. When measuring the bioimpedance of a person, the change in the measured phase angle when the correction is turned off can reach 1 ° or even more, depending on the electrodes used and the measured segment of the body. Obviously, this change is a measurement error.

Correction of the influence of changes in C_p, C_p, Z_{c3} and Z_{c4} on the results of measuring bioimpedance is complicated by the fact that it is not possible to directly measure these parameters. Therefore, it is necessary either to use some approximate estimates of their values, or to adjust the correction in such a way that

to achieve the correspondence of the frequency dependence of the measured impedance to the theoretical concepts. The second option is implemented in the software of the AVS-01 "Medass" bioimpedance analyzer. In this case, calculations are performed according to a simplified equivalent circuit, in which, in comparison with Fig. 12, there is no parasitic capacitance C_g, as a result of which the impedances Z_{c1} and Z_{c2} do not affect the measurement result.

Adjustment of the correction is carried out so as to obtain a hodograph that most closely matches the Cole model. Compliance control is carried out either visually by the shape of the hodograph, which should be an arc of a circle, or by the calculated and displayed value of the root-mean-square deviation of the approximation of the hodograph according to the Cole model from the measured and corrected bioimpedance values. The assumption about the correspondence of the impedance of the set of tissues of a living person to the Cole model is a hypothesis, the confirmation of which requires further research.

A typical view of the biosimple impedance hodograph, obtained when measured at 31 frequencies in the range from 5 to 500 kHz, is shown in Figure 17a. [10] The left part of the hodograph corresponding to high frequencies is shifted upward due to significant positive errors in measuring the reactive component at these frequencies. This effect has been noted in a number of works.
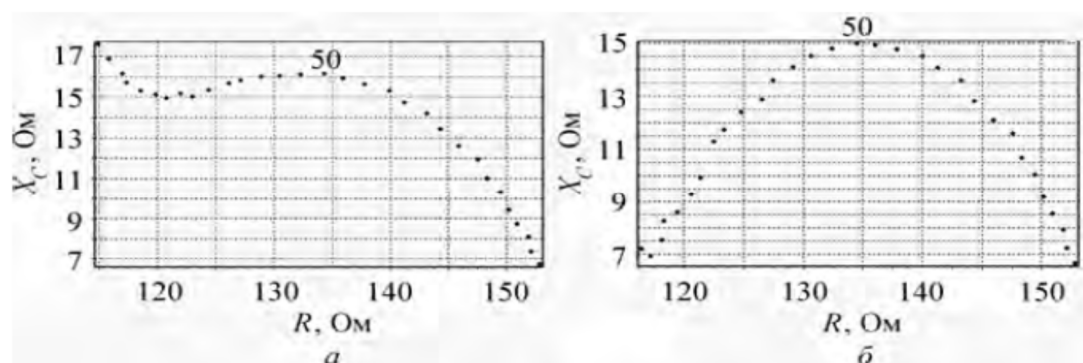
Figure 12 - Hodographs of bioimpedance before (a) and after (b) error correction.

When measuring according to the standard method according to the RN/RN scheme, to correct the hodograph shape, it is sufficient to introduce a correction by the value C'_p, since in this case the measuring electrodes are located directly at the boundaries of the measured part of the body and no body segments contribute to the impedances of the contacts Z_{C3} and Z_{C4}. As a rule, the correction of the hodograph shape (Figure 12b) is achieved when the capacitance C'_p is set to about 50 pF. In this case, the value of the measured phase angle at a frequency of 50 kHz decreases to 0,5°.

When measuring the impedances of body segments in 8-point and other schemes with the location of electrodes at the ends of the limbs, correction only by C'p turns out to be insufficient, since the body parts, through which the probing current does not flow, contribute to the impedances Z_{C3} and Z_{C4}. The resistance of these sections, together with the capacitances C_p and C'_p, must be taken into account when correcting. So, for the above-mentioned measurement of the left leg impedance according to the FN / LF scheme, the hodograph shape is corrected by setting C_p = 50 pF, Z_{C3} + Z_{C4} = 250 Ohm. It is this case that is shown in Figure 12b. Note that the value of 250 Ohm roughly corresponds to the sum of the resistances of the left arm and trunk. To perform correction in multi-segment programs, the measured impedances of the segments included in the circuit for measuring the impedance of this segment can be used as an estimate of Z_{C3} + Z_{C4}.

Thus, based on the analysis of the equivalent circuit of the measuring circuit, it is possible to largely correct the methodological errors of bioimpedance measurements. This makes it possible to increase the reliability of the obtained estimates of the composition of the body and various diagnostic parameters calculated from the values of the measured resistances.

Chapter 4 Financial management, resource efficiency and resource saving

The purpose of this section discusses the issues of competitiveness, resource efficiency and resource saving, as well as financial costs regarding the object of study of Master's thesis. Competitiveness analysis is carried out for this purpose. SWOT analysis helps to identify strengths, weaknesses, opportunities and threats associated with the project, and give an idea of working with them in each particular case. For the development of the project requires funds that go to the salaries of project participants and the necessary equipment, a complete list is given in the relevant section. The calculation of the resource efficiency indicator helps to make a final assessment of the technical decision on individual criteria and in general.

Achieving the goal is provided by solving the following problems:

• development of a common economic project idea, the formation of a project concept;

• organization of work on a research project;

• identification of possible alternatives for conducting research;

• research planning;

4.1 Potential consumers of research results

Radiation therapy, like any type of treatment, can be accompanied by both local (in the field of exposure to radiation on the tissue) as well as a common side effect. Side effects of radiotherapy are most often manifested in tissues and organs exposed to direct exposure to radiation.

It is necessary to determine the frequency and degree of radiation damage to normal tissues (skin, subcutaneous tissue, lungs) after complex treatment with fast neutrons of 6.3 MeV in patients with primary locally advanced breast cancer and with local relapses to us.

The work is aimed at assessing the possibility of using bioimpedance spectrometry for measuring tissue damage after radiation therapy.

In this work, the possibilities of using bioimpedance spectrometry for measuring tissue damage after radiation therapy. However, at this stage it is too early to talk about the commercial potential of this study. In this regard, the analysis of potential consumers has not been done. As you know, neutron irradiation leads to serious damage to biological tissues in the measurement, the phase angle versus frequency was used for irradiated tissues. Bioimpedance spectrometry is suitable for measuring tissue damage after radiation therapy for breast cancer. This device is compact, and it can be used in any oncology clinic after radiation therapy courses. The project is economically useful, since the construction of the device takes less cost.

4.2 Competitiveness analysis of technical solutions

In order to find sources of financing for the project, it is necessary, first, to determine the commercial value of the work. Analysis of competitive technical solutions in terms of resource efficiency and resource saving allows to evaluate the comparative effectiveness of scientific development. This analysis is advisable to carry out using an evaluation card.

First of all, it is necessary to analyze possible technical solutions and choose the best one based on the considered technical and economic criteria.

Evaluation map analysis presented in Table 2. The position of your research and competitors is evaluated for each indicator by you on a five-point scale, where 1 is the weakest position and 5 is the strongest. The weights of indicators determined by you in the amount should be 1. Analysis of competitive technical solutions is determined by the formula:

$$C = \sum P_i \cdot W_i, \tag{1}$$

$$C = \sum_{W_i \cdot} P_i,$$

C - the competitiveness of research or a competitor;

W_i – criterion weight;

P_i – point of i-th criteria.

You can use the following criteria for the model of expert evaluation:

- noise immunity;

- set of terminals relay protection;

- reliability of relay protection;

- smart interface quality;

- energy efficiency;

- ease of operation;

- ability to connect to PC;

- estimated lifetime;

- safety;

- etc.

Table 2 - *Evaluation card for comparison of competitive technical solutions*

Evaluation criteria *example*	Criterion weight	Points			Competitiveness Taking into account weight coefficients		
		P_f	P_{i1}	P_{i2}	C_f	C_{i1}	C_{i2}
1	2	3	4	5	6	7	8
Technical criteria for evaluating resource efficiency							
1. Ease of use (meets customer requirements)	0,15	5	5	4	0,75	0,6	0,65
2. Improving user productivity	0,13	5	5	5	0,65	0,65	0,67
3. Functional capacity	0,17	4	4	4	0,68	0,68	0,68
4. Easy operation	0,12	5	5	4	0,6	0,48	0,48
5. Safety	0,18	4	4	5	0,72	0,72	0,72
Economic criteria for performance evaluation							

1. Development cost	0,08	5	4	4	0,4	0,32	0,3
2. Market penetration rate	0,07	4	4	5	0,28	0,28	0,25
3. Expected lifecycle	0,1	4	4	4	0,4	0,4	0,4
Total	**1**	**36**	**35**	**35**	**4,48**	**4,13**	**4,15**

4.3 SWOT analysis

Complex analysis solution with the greatest competitiveness is carried out with the method of the SWOT analysis: Strengths, Weaknesses, Opportunities and Threats. The analysis has several stages.

The first stage consists of describing the strengths and weaknesses of the project, identifying opportunities and threats to the project that have emerged or may appear in its external environment.

1. **Strengths**. Strengths are the factors that characterize the competitive side of a research project. Strengths indicate that a project has a distinctive advantage or special resources that are special in terms of competition. In other words, strengths are the resources or capabilities available to the project management that can be effectively used to achieve the goals set. At the same time, it is important to consider the strengths both from the point of view of the project management and from the point of view of those who are still involved in it. It is recommended to ask the following questions:

• What technical advantages do you have over your competitors?

• What do your project participants do best?

• How close is your project to completion compared to your competitors?

2. **Weaknesses**. A weakness is a flaw, omission, or limitation of a research project that hinders the achievement of its goals. This is something that does not work well within the project or where it has insufficient capabilities or resources compared to competitors. To clarify the aspects you may be outperformed by your competitors, you should ask:

• What can be improved?

• What is being done wrong?

• What should I avoid?

3. **Opportunities**. Opportunities include any preferred situation in the present or future that occurs in the project environment, such as a trend, change, or perceived need that supports the demand for a result that allows the project management to improve their competitive position. You can simplify the formulation of project capabilities by answering the following questions:

• What opportunities do you see in the market? Search for free niches but remember that they do not remain free for long. The opportunity seen today may cease to exist in three months. Favorable opportunities may arise due to the following factors:

- changes in the technological sphere and in the market - both on a global and regional scale;

- changes in government policy regarding the industry where scientific research is conducted;

- changes in social standards, population profile, lifestyle, etc.

• What are the favorable market opportunities?

• What interesting trends have been noted?

• What needs and wishes do the buyer have, but are not met by competitors?

4. A **threat** is any undesirable situation, trend or change in the environmental conditions of a project that is destructive or threatening to its competitiveness in the present or future. The threat may be a barrier, restriction, or anything else that may cause problems, destruction, harm, or damage to the project. To identify project threats, we recommend answering the following questions:

• What trends do you see that could destroy your research project or make its results obsolete?

• What do competitors do?

• What are the obstacles facing your project (for example, changes in legislation, reduced budget financing of the project, delayed project financing, etc.)?

• Do the required specifications or standards change for the results of scientific research?

• Does the change in technology threaten the position of your project?

• Does the project management have problems with logistics?

It is recommended to present the results of the first stage of SWOT analysis in tabular form (Table 3).

Table 3 - *SWOT matrix*

	S1. Measurement stability S2. No complexity of processing results S3. The ability to attract consumers S4. The estimated market price of prototypes developed abroad to analyze impedance on other measurement methods is too high.	Weaknesses: W1. To reduce the error, large measurement statistics are needed. W2. The complexity of the design and design of models of the device for analysis of the electrical properties of materials . …
Opportunities: O1. The emergence of additional demand for a new product. O2. development of a device for measuring tissue damage O3. Collaboration with a number of new organizations.	1.The simplicity of obtaining and processing the results will enable us to increase the demand for our product. 2. Reliability and safety of the method will make it possible to establish cooperation with a number of new organizations.	1.Small measurement statistics lead to large measurement error
Threats: T1. High competition.	1.Demonstrate the simplicity of the device to customers and	1.Simplicity and accuracy of measurements give an

T2. Lack of funding from both the university and the states	focus on portability and low cost. 2. The analysis of materials provides an opportunity to enter the market.	advantage over competitors in the market. 2. Conclusion of financial agreements with external organizations by demonstrating possible device models.

The description of the strengths and weaknesses of the research project, its opportunities and threats should be based on the results of the analysis carried out in the previous sections of the master's thesis.

To improve the effectiveness of SWOT analysis, 5 to 10 points should be given in each area, which are considered as the most significant for scientific research.

The second stage consists of identifying the compatibility of the strengths and weaknesses of the project with the external environmental conditions. This compatibility or incompatibility should help to identify what strategic changes are needed. As part of this stage, it is necessary to construct an interactive matrix of the project. It helps to understand the various combinations of relationships between the areas of the SWOT matrix. It is possible to use this matrix as one of the bases for evaluating strategic choices. Each factor is marked "+" (meaning a strong match of strengths to capabilities), " - " (meaning a weak match), or " 0 "- if there is doubt about what to put " + "or" -". An example of an interactive project matrix is shown in Table 4.

Table 4

The interactive matrix of the project

Strengths					
Opportunities		S1	S2	S3	S4
	O1	+	+	+	-
	O2	+	+	+	0
	O3	+	+	+	+

4.4 Project Initiation

The initiation process group consists of processes that are performed to define a new project or a new phase of an existing one. As part of the initiation processes, the initial goals and content are determined, and the initial financial resources are recorded.

The internal and external stakeholders of the project that will interact and influence the overall outcome of the research project are identified. This information is fixed in the project Charter.

The project charter documents the business needs, the current understanding of the needs of the project customer, as well as the new product, service, etc. is the result that is planned to be created.

The charter of the scientific project of the master's work should have the following structure:

1. **The goals and results of the project**. In this section, you need to provide information about the project stakeholders, the hierarchy of project goals, and the criteria for achieving the goals.

Project stakeholders are persons or organizations that are actively involved in the project or whose interests may be affected both positively and negatively during

the execution or as a result of the completion of the project. They can be contractors, sponsors, the public, etc. Provide information on the project's stakeholders in Table 5.

Table 5

Stakeholders of the project

Project stakeholders	Stakeholder expectations
Russian oncology clinics and dispensaries	New innovative technique for measuring tissue changes after radiation therapy, easy to use and inexpensive.
Russian Cancer Research Institutes	Enhanced ability to determine the degree of exposure to radiation exposure for new research in this area.
Oncologists	Determination of the effects of radiation therapy on the irradiation area. Increased tumor control and, as a result, improved quality of treatment.
Oncological patients	Determination of the state of the area of radiation after radiation therapy

In Table 6, you need to provide information about the hierarchy of project goals and the criteria for achieving the goals. The project objectives should include resource efficiency and resource conservation goals.

Table 6

Purpose and results of the project

Purpose of project:	Show the possibility of using bioimpedance spectrometry to measure tissue damage after radiation therapy.
Expected results of the project:	Accurate assessment of the radiation response to the irradiated area. Assessment of changes in the electrical properties of tissues before and after radiation therapy. Reduction of complications after radiation therapy.
Criteria for acceptance of the project result:	Bioimpedance spectrometry device should have a compact form for ease of use to assess damaged tissue

	Data processing accuracy	
Requirements for the project result:	The results obtained must satisfy the acceptance criteria of the project result.	
	Research results must be accurate	
	If unsatisfactory results are obtained, additional studies should be carried out using other radiation sources.	
	The results of scientific research should be presented at one of the all-Russian / regional conferences and have a publication in one of the scientific journals.	

4.5 The organizational structure of the project.

At this stage of the work, the following issues need to be resolved: who will be included in the working group of this project, determine the role of each participant in this project, and also specify the functions performed by each of the participants and their labor costs in the project. This information should be presented in tabular form (Table 7)

Table 7

Working group of the project

№	Participant	Role in the project	Functions	Labor time, hours.
1	Aleinik. A.N. associate professor	Adviser project	Responsible for the implementation of the project within the specified resource limits, coordinates the activities of project participants.	216
2	Turgunova N.D. Nuclear physycist	Administrant project	Responsible for helping the master in the development of a device	68

			for bioimpedance spectrometer	
2	Mukanov E.B student	Administrat project	Writing a review of literary sources and technical literature. Carrying out experimental measurements and processing of the obtained data. Drawing up a report on research work.	564
TOTAL:				848

4.6 Project limitations

Project limitations are all factors that can be as a restriction on the degree of freedom of the project team members. Table 8 shows the main limitations of this work.

Table 8 – Project limitations

Factors	Limitations / Assumptions
3.1. Project's budget	357184,67 RUB
3.1.1. Source of financing	State financing
3.2. Project timeline:	03.02.2020 – 01.06.2020
3.2.1. Date of approval of plan of project	10.02.2020
3.2.2. Completion date	01.06.2020

4.7 Scientific research planning

The Graduate Qualification Study (GQR) is a work of a scientific nature related to scientific inquiry, research to obtain scientific generalizations, to find principles and ways of creating (modernizing) products, it includes:

1. fundamental research carried out with a view to enhancing scientific knowledge, phenomena and patterns of their development without regard to their specific practical application;

2. search research carried out with the purpose of finding ways to use the revealed phenomena and regularities in a concrete field of science and technology for creation of principally new products, materials and technologies;

3. applied research aimed at solving scientific problems, improvement of methods in order to obtain specific results used in experimental and design developments in the creation of scientific and technical.

4.7.1 Structure of work within the scientific research

Planning of the complex of proposed works is carried out in the following order:

– determination of the structure of works within the scientific research;

– definition of participants of each work;

– determination of the duration of work;

– construction of the schedule for scientific research.

To carry out scientific research, a working group is formed, which may include researchers and teachers, engineers, technicians, and laboratory technicians, the number of groups may vary. For each type of work to be carried out, an appropriate position for the executors shall be established. In this section, it is necessary to make a list of stages and works within the framework of scientific research, to make a distribution of performers by type of work. An approximate order of drawing up stages and works, distribution of performers by these types of work is shown in Table 7.

The table contains a list of the main stages of the study, the work performed in the study, and the distribution of roles of the work performers.

4.7.2 Development of a schedule for scientific research

During the performance of the thesis, for convenience and clarity, a ribbon schedule of scientific works is constructed in the form of a Gantt chart. The works on the topic are presented as long sections of time, characterized by the start and end dates of these works.

For the convenience of drawing a chart, the duration of each stage of work should be translated from working days to calendar days. To do this, you are should use the following formula:

$$T_{Ki} = T_{Pi} \ k_{cal} \ ;$$

where T_{Ki} – the duration of the i-th job in calendar days;

T_{Pi} – duration of the i-th job in working days;

k_{cal} – calendar factor.

Table 9 – List of stages, works and distribution of performers

Main steps	№	Content of work	Executioner's position
Development of technical specifications	1	The choice of research direction.	Supervisor, Consultant, Executor
Determination of research direction.	2	Drafting and approval of technical specifications.	Supervisor, Consultant, Executor
	3	Scheduling.	Supervisor, Consultant, Executor
Theoretical and experimental research	4	Review of literature and technical literature.	Executor
	5	Studying researches and applications of the voxel-based	Executor

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		analysis in other countries.	
	6	Creating code for voxel-based method calculation	Executor
Summary and assessment of results	7	Processing received data	Executor
	8	Data Analysis	Executor
Registration of qualifying work	9	Compilation of an explanatory note	Executor
	10	Preparing to defend a diploma thesis	Supervisor, Consultant, Executor

Labor costs in most cases form the bulk of the development cost, so an important point is the determination of the complexity of the work of each of the participants in the scientific research. The complexity of the implementation of scientific research is assessed expertly in man-days and is probabilistic in nature. depends on many difficult factors to consider. The following formula is used to determine the expected (average) labor intensity value:

$$t_{\exp i} = \frac{3t_{\min i} + 2t_{\max i}}{5},$$

where $t_{\exp i}$ – the expected complexity of the i-th work, person-day;

$t_{\min i}$ – the minimum possible complexity of the performance of a given i-th job (optimistic assessment: assuming the most favorable set of circumstances), person-day;

$t_{\max i}$ – the maximum possible complexity of a given i-th job (pessimistic assessment: assuming the most unfavorable set of circumstances), person-day.

Based on the expected complexity of the work, the duration of each work in working days T_{wd} is determined, taking into account the parallel work performed by several performers.

$$T_{wd} = \frac{t_{\exp i}}{N_i},$$

where T_{wd} – the duration of one work, working days;

$t_{\exp i}$ – the expected complexity of one job, person-days;

N_i – the number of performers performing simultaneously the same work at this stage, people.

In the course of this work, the number of people performing each of the work at each stage is equal to one.

The coefficient of calendar is determined by the following formula:

$$k_{cal} = \frac{T_{cal}}{T_{cal} - T_{weekend} - T_{hol}} = \frac{366}{366 - 52 - 14} = 1,22$$

where T_{cal} – calendar day amount per year;

$T_{weekend}$ – a number of days off per year;

T_{hol} – a number of holidays per year.

All calculated values are summarized in Table 10.

Table 10 – A project timeline in working days

№	Labour intensity			Participants	T_{Pi}	T_{Ki}
	t_{min}	t_{max}	t_{exp}			
1	3	7	4,6	Supervisor,	4,6	6
2	2	4	2,8	Supervisor, student	1,4	2
3	2	4	2,8	Supervisor, student	1,4	2
4	15	40	25	student	25	31
5	2	7	4	Consultant Student	2	2
6	20	45	30	Supervisor Student	15	18
7	5	15	9	Student	9,3	11
8	20	40	28	Supervisor	10	12,2

				Consultant Student		
9	21	35	26,6	Student	26,6	32
10	5	14	8,6	Supervisor Student	4,3	5
Total	95	211	141,4	-	75,6	120

№	Activities	Participants	T_c, days	Duration of the project											
				February			March			April			May		
				1	2	3	1	2	3	1	2	3	1	2	3
1	The choice of research direction.	Supervisor	6												
2	Drafting and approval of technical specifications.	Supervisor Student	2												
3	Related scheduling	Superviso r Student	2												
4	Review of literature and technical literature.	Student	3 1												

5	Experimental measureme	Supervisor Student	1 8														
6	Practical calculation	Supervisor Student	1 8														
7	Comparison of model results and experimental results.	Student	1 1														
8	Compilation and execution of calculations	Supervisor Consultant Student	1 1														
9	Drawing up an explanatory note.	Student	3 2														
10	Preparing for the defense.	Supervisor Student	5														

4.8 Scientific and technical research budget

When planning the budget of scientific research, it should be ensured that all types of planned expenditures necessary for its implementation are fully and reliably reflected. In the process of forming the budget, the planned costs are grouped according to the items presented in the table (Table 11).

Table 11-Grouping costs by articles

Work	Articles							
	Material costs	Costs of special equipment	Basic salary	Add. salary	Labor tax	Scientific and industrial business trips	Overhead	Total planned
1	1761,4	519000	169252	16925	45867		161,1	
2								
…								

4.9 Raw materials, components, purchased products and semi-finished goods (net of waste)

This article includes the costs of purchasing all types of materials, components and semi-finished products necessary to perform work on this topic. The amount of material assets required is determined according to the consumption rates.

The value of material costs is calculated according to the current price lists or contractual prices. The value of material costs includes transportation and procurement costs (3-5 % of the price). The same article includes the costs of documentation processing (office supplies, ranking of materials). The results for this article are entered in Table 12.

Table 12 - Raw materials, materials, components and purchased semi-finished goods

Name of position	Brand, size	Quantity (units, amount)	Price per unit (rub)	Sum (rub)
Laptop	Hewlett-Package	1	35900	35901
Soldering	Soldering	1	2000	2001

device	device			
			Total costs for materials	37902
			Total transportation and purchasing costs (3-5%)	
			Total costs per article, C_m	

Electricity costs are calculated by the formula:

$$C_{el} = T_{el} \cdot P \cdot F_{sum} = 2,45 \cdot 0,65 \cdot 636 = 1012,83 \text{ rub};$$

where T_{el} – tariff for industrial electricity (2,45 rubles per 1 kW·h);

P – equipment power is measured in kW;

F_{sum} – time of use of the equipment in hours (106 days of using by 6 hours).

4.10 Special equipment for scientific experiments

This article includes all the costs associated with the purchase of special equipment (instruments, control and measuring equipment, stands, devices and mechanisms) necessary for carrying out work on a specific topic. The cost of special equipment is determined according to the current price lists, and in some cases at the agreed price.

Table 16 - *Cost calculation for the article «Special equipment for scientific experiments»*

№	Name of equipment	Quantity, units	Price per unit, money (rub)	Total cost for position, money (rub)
1	Atmega16	1	150	150
2	Usb(Rs232)	1	510	510
3	AD5933	1	701,4	701,4
4	Resistors	30	8	240
5	Capacitor	16	5	80

When purchasing special equipment, it is necessary to include in the costs its delivery and installation in the amount of 15 % of its price. The cost of equipment used in the implementation of a specific scientific project and available in this scientific and technical organization is accounted in the form of depreciation charges. All calculations for the purchase of special equipment and equipment available in the organization, but used to perform a specific topic, are summarized in Table 16.

4.11 Basic salary

This article includes the basic salary of scientific and engineering workers, workers of model workshops and experimental production facilities directly involved in the performance of work on this topic. The amount of salary expenses is determined based on the labor intensity of the work performed and the current system of remuneration. The basic salary includes a bonus paid monthly from the salary fund (the amount is determined by the Regulations on Remuneration of Labor).

This point includes the basic salary of participants directly involved in the implementation of work on this research. The value of salary costs is determined based on the labor intensity of the work performed and the current salary system

The basic salary (S_b) is calculated according to the following formula:

$$S_b = S_a \cdot T_w , \qquad (5)$$

where S_b – basic salary per participant;

T_w – the duration of the work performed by the scientific and technical worker, working days;

S_a - the average daily salary of an participant, rub.

The average daily salary is calculated by the formula:

$$S_d = \frac{S_m \cdot M}{F_v} , \qquad (6)$$

где S_m – monthly salary of an participant, rub.;

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M – the number of months of work without leave during the year:

at holiday in 48 days, M = 11.2 months, 6 day per week;

F_v – valid annual fund of working time of scientific and technical personnel (251 days).

The valid annual fund of working time

Working time indicators	
Calendar number of days	365
The number of non-working days	
- weekend	52
- holidays	14
Loss of working time	
- vacation	48
- sick absence	
The valid annual fund of working time	251

Monthly salary is calculated by formula:

$$S_{month} = S_{base} \cdot (k_{premium} + k_{bonus}) \cdot k_{reg}, \qquad (7)$$

where S_{base} – base salary, rubles (the salary of an assistant professor, candidate of sciences is 35120 rubles);;

$k_{premium}$ – premium rate (0,3);

k_{bonus} – bonus rate (0,2-0,5);

k_{reg} – regional rate (1,3)

The basic salary of the Project leader is calculated on the basis of the mead-industry salary (usually, the head is from the TPU). The wage system assumes the following composition of wages:

Table 17 - Calculation of the basic salary

Performers	S_{base}, rubles	$k_{premium}$	k_{bonus}	k_{reg}	S_{month}, rub.	W_d, rub.	T_p, work days	W_{base}, rub.
Supervisor	35120	0,3	0,2-0,5	1,3	45 656	1 891	34,6	65428
Consultant	21760				28 288	1 172	11,3	13243
Student	17890				23257	963	94	90581
Total:								169252

4.12 Additional salary

This point includes the amount of payments stipulated by the legislation on labor, for example, payment of regular and additional holidays; payment of time associated with state and public duties; payment for work experience, etc.

Additional salaries are calculated on the basis of 10-15% of the base salary of workers:

$$W_{add} = k_{\text{extra}} \cdot W_{base}, \qquad (8)$$

where W_{add} – additional salary, rubles;

k_{extra} – additional salary coefficient (10%);

W_{base} – base salary, rubles.

Table 18 shows the form for calculating the basic and additional wages.

Table 18 - *Salary of scientific research project performers*

Salary	Supervisor	Consultant	Student
Basic salary	65428	13243	90581
Additional salary	6542	1324	9058
Total payments at	71970	14567	99639

article C_{sal}			

4.13 Social security pays (Labor tax)

Social security pays (so-called labor tax) to extra-budgetary funds are compulsory according to the norms established by the legislation of the Russian Federation to the state social insurance (SIF), pension fund (PF) and medical insurance (FCMIF) from the costs of workers.

Payment to extra-budgetary funds is determined of the formula:

$$P_{social} = k_b \cdot (W_{base} + W_{add}) \tag{9}$$

where k_b – coefficient of deductions for labor tax.

In accordance with the Federal law of July 24, 2009 No. 212-FL, the amount of insurance contributions is set at 30%. Institutions conducting educational and scientific activities have rate - 27.1%.

Table 20 - *Labor tax*

	Supervisor	Consultant	Student
Coefficient of deductions			
Salary, rubles	65428	13243	90581
Labor tax, rubles	6542	1324	9058
Extrabudgetary fund allocation rate	0,271		
Total:	45867		

4.14 Overhead costs

Overhead costs include other management and maintenance costs that can be allocated directly to the project. In addition, this includes expenses for the maintenance, operation and repair of equipment, production tools and equipment, buildings, structures, etc.

Overhead costs account from 30% to 90% of the amount of basic and additional salary of employees.

Overhead is calculated according to the formula:

$$C_{\text{ov}} = k_{ov} \cdot (W_{\text{base}} + W_{add})$$

9)

where   kov – overhead rate.

Table 21 - the cost of electricity

Name	Working hours	Power consumption, kW	Price per 1 kW, rub.	Electricity costs (S_{el}), rub.
1. TheratronEquinox 100 gamma therapeutic apparatus	20	10	5,8	1160
2.Cylindrical ionization chamber FC65-G	10	0,004		0,23
3.PC	10	0,004		0,23
Total:				**1160.46**

When performing the work, a laptop with an average power of 90 W (0.09 kW) was used.

Cost of energy spent on a laptop:

$C_{bl}1 = 5,8 \cdot 0,09 \cdot 294$ {49 working days*49)=153,47 rubles

Cost of energy spent on a soldering device with an average power of 40 W (0.04 kW):

$$C_{bl}S = 5,8 \cdot 0,04 \cdot 48 \text{ \{8 working days*6)=11,14 rubles}}$$

$$C_{bl} = C_{bl}1 + C_{bl}p = 153,47 + 11,4 = 161,61 \text{ rubles}$$

Denomination	Working hours	Power consumption, kW	Price per 1 kW, rub.	Electricity costs (S_{el}), rub.
1.Laptop	0,09	294	5,8	153,47
2.Cylindrical ionization chamber FC65-G	0,04	48		11,14
Total:				161,1

4.15 Determination of resource (resource-saving), financial, budgetary, social and economic efficiency of research

The effectiveness of a scientific resource-saving project includes social efficiency, economic and budgetary efficiency. Public efficiency indicators take into account the socio-economic consequences of the implementation of an investment project for society as a whole, including the direct results and costs of the project, as well as costs and benefits in related sectors of the economy, environmental, social and other non-economic effects.

The indicators of the economic efficiency of the project take into account the financial implications of its implementation for the enterprise implementing the project. In this case, the performance indicators of the project as a whole characterize from an economic point of view, technical, technological and organizational design solutions.

Budgetary efficiency is characterized by the participation of the state in the project in terms of expenditures and revenues of budgets of all levels.

In addition to the above types of efficiency, the resource effect can be distinguished (characterized by indicators reflecting the influence of innovation on

the volume of production and consumption of one or another type of resource), scientific and technical (evaluated by indicators of novelty and usefulness), etc.

4.16 Evaluation of the absolute effectiveness of the project

The project approach to the investment activity of the enterprise is based on the principle of cash flow. Its special feature is its predictive and long-term nature, so the applied approach to the analysis includes the time factor and the risk factor. To assess the overall economic efficiency of innovations, the following key indicators are recommended:

- net income;
- net discounted income;
- internal rate of return;
- need for additional funding;
- payback period;
- indexes of profitability of expenses and investments, etc.

Net income (i.e. Net Value, NV) is the accumulated effect (cash flow balance) for the billing period, where the summation extends to all the steps of the billing period. It is important to clearly distinguish between the final efficiency of the project and the costs of the enterprise before the date when the project begins to receive profit.

Another important indicator of the project's effectiveness is *net discounted income* (i.e. Net Present Value, NPV) - the accumulated discounted effect for the billing period. Discounting is the reduction of future income and expenses to the current moment, taking into account the current value of cash. The discount factor (Cd) is determined by the formula:

$$K_{\partial} = \frac{1}{(1+E)^t} \tag{10}$$

where

E is the discount rate for the period;

t - the serial number of the period from the beginning of the project implementation.

The discount rate (E) depends on the acceptable level of return on the invested capital. It can be equal to the yield on deposits, securities and other alternative areas of investment.

NV and NPV characterize the excess of total cash receipts over total costs for a project, respectively, without- and taking into account the inequality of costs and results related to different points in time. The difference between NV - NPV is often called the project discount.

For the project to be recognized as effective by the enterprise (investor), it is necessary for NPV of the project to be positive, and when comparing alternative projects, preference should be given to the project with a largest NPV.

Internal rate of return (i.e. IRR) characterizes the internal rate of return of an investment project. The internal rate of return is such a positive number of E_{intr}, at which, if the discount rate is equal to E_{intr}, the project's NPV turns to 0, for all large values it is negative, for all lower values, it is positive.

To assess the efficiency of an investment project, the value of IRR must be compared with the discount rate E. Investment projects with IRR> E have a positive NPV and therefore are effective. Projects with IRR <E have a negative NPV and are therefore ineffective.

IRR can also be used:

for the economic assessment of design solutions, if the acceptable values of IRR (depending on the area of application) are known for projects of this type;

to assess the degree of investment project stability by the difference between IRR - E;

to establish the discount rate E by the project participants according to the data on the internal rate of return of alternative directions of their own funds investment.

The *need for additional financing* (NAF) is the maximum value of the absolute value of the negative accumulated balance from investment and production (operating) activities. The NAF value shows the minimum volume of the external financing the project necessary to ensure its financial feasibility. Therefore, NAF is also called risk capital. It should be borne in mind that the real amount of required financing does not have to coincide with the NAF, and, as a rule, exceeds it due to the need to service the provided investments (for example, interest on a loan).

The degree of project stability in relation to possible changes in the implementation conditions can be characterized by indicators of break-even boundaries and limit values of such project parameters as production volumes, prices of manufactured products, limited resources used, etc. One of the most common indicators of this type is the *break-even point*.

The break-even level BP_t in the period t is the ratio of the real break-even sales (volume of production) to the planned index at this period. Break-even is the sales volume at which the net profit becomes equal to zero. When determining this index, it is assumed that the total current production costs can be divided into conditionally constant (not changing when the volume of production changes) and conditionally variable, changing in direct proportion to the volume of production.

The calculation of the break-even level in the period t (BP_t) is carried according to the formula:

$$BP_t = \frac{C_t - C_{vt} - DC_t}{V_t - C_{vt}} \tag{11}$$

where

V_t is the volume of production (sales) in the period t;

C_t - total operating costs of production (production costs including depreciation, taxes and other deductions attributed to both cost and financial results, except for income tax) in the period;

C_{vt} - a conditionally variable part of the total current production costs (including material costs, the cost of wages of the main workers, deductions to extra-budgetary funds, power electricity and other costs carried out in proportion to revenue);

DC_t - income from non-operating activities less expenses for these activities in the period.

Typically, a project is considered sustainable if, in the calculations for the project, the break-even level does not exceed 0.6 - 0.7 after the development of the design capacity. The proximity of the break-even level to 1 (100%), as a rule, indicates the insufficient resistance of the project to fluctuations in demand for goods in this period. Even satisfactory values of the break-even level do not guarantee the effectiveness of the project (positive NPV). At the same time, high values of the break-even level in certain periods cannot be considered as a sign of the unrealizability of the project (for example, at the stage of mastering commissioned capacities or during the overhaul of expensive high-performance equipment, they may exceed 100%).

To assess the social effectiveness of a research project, a master's student must identify the criteria of social effectiveness that are affected by the implementation of the research project and assess the degree of their influence.

4.17 Evaluation of the comparative efficiency of the scientific research project

Determination of efficiency is based on the calculation of the integral indicator of the efficiency of scientific research. Its finding is associated with the determination of two weighted averages: financial efficiency and resource efficiency.

An integral indicator of the financial efficiency of a scientific research is obtained in assessing the budget of costs of three (or more) variants of the implementation of a scientific research (see Table 5). For this, the largest integral indicator of the implementation of a technical problem is taken as the basis of the calculation (as the denominator), with which the financial values for all execution options are correlated.

Integral financial indicator is determined in the formula:

$$I_f^p = \frac{F_{pi}}{F_{max}},$$

где I_f^p – integral financial indicator of current project;

F_{pi} – price for i-th variant of execution;

F_{max} – maximum cost of execution of a research project (including analogs).

The resulting value of the integral financial indicator of development reflects the corresponding numerical increase in the budget of development costs in times (a value greater than one), or the corresponding numerical reduction in the cost of development in times (a value less than one, but higher than zero).

The integral indicator of the resource efficiency of the variants of the object of research can be defined as follows:

$$I_m^a = \sum_{i=1}^n a_i b_i^a, \qquad I_m^p = \sum_{i=1}^n a_i b_i^p, \qquad (13)$$

where

I_m^a is an integral indicator of resource efficiency of options;

a_i- the weight coefficient of the i-th parameter;

b_i^a, b_i^p. - the score of the i-th parameter for the analog and development, set by an expert method on the selected rating scale;

n - the number of comparison parameters.

It is recommended to calculate the integral resource efficiency indicator in the form of a table, an example of which is given below.

Table 22 - *Comparative evaluation of the characteristics of the project execution options*

Criteria	Parameter weighting factor	Analog 1 (Current project)	Analog 2
Promotes user productivity	0.1	5	4
Ease of use (meets customer requirements)	0.15	4	4
Immunity	0.15	4	5
Energy efficiency	0.20	4	3
Reliability	0.25	4	4
Material consumption	0.15	4	4
Total	1	4,1	3,95

I_{srp} 1= 5*0,1+4*0,15+4*0,15+4*0,2+4*0,25+5*0,05+4*0,01 = 4,1

I_{srp} 2= 4*0,1+4*0,15+5*0,15+3*0,2+4*0,25+2*0,05+4*0,1= 3,95

An integral efficiency indicator of the scientific research project (I_{fin}^p) and of the analog (I_{fin}^a) are determined according to the formula of the integral basis of the financial integral resource efficiency:

$$I_{fin}^p = \frac{I_m^p}{I_f^p}, \qquad I_{fin}^a = \frac{I_m^a}{I_f^a} \qquad \cdots \quad (14)$$

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Comparison of the integral indicator of the efficiency of the current project and analogs will determine the comparative efficiency the project. Comparative project efficiency:

$$E_{av} = \frac{I_{fin}{}^{p}}{I_{fin}{}^{a}} \qquad (15)$$

where

E_{av} is the comparative project efficiency;

$I_{fin}{}^{p}$ - integral indicator of project;

$I_{fin}{}^{a}$ - integral indicator of the analog.

Table 23 *Comparative project efficiency*

№	Indicator	Exe. 1	Exe. 2
1	Integrated Financial Development Indicator	0,49	1
2	Integrated Performance Indicator	8,37	3,95
3	Comparative Performance Options	2,12	1

Comparison of the values of integral indicators of efficiency allows master's students to choose a more effective solution to the technical problem in the master's thesis basing on financial and resource efficiency.

Conclusion

Thus, in this section was developed stages for design and create competitive development that meet the requirements in the field of resource efficiency and resource saving.

These stages include:

- development of a common economic project idea, formation of a project concept;

- organization of work on a research project;
- identification of possible research alternatives;
- research planning;
- assessing the commercial potential and prospects of scientific research from the standpoint of resource efficiency and resource saving;
- determination of resource (resource saving), financial, budget, social and economic efficiency of the project.

Chapter 5 Social responsibility

5.1 Introduction

Bioimpedance analysis (BIA) is a contact method for measuring the electrical conductivity of biological tissues, which makes it possible to assess a wide range of morphological and physiological parameters of the body. Bioimpedance analysis measures the active and reactive resistance of the human body and or its segments at various frequencies. Body composition characteristics such as fatty, cellular and musculoskeletal mass, volume and distribution of water in the body were calculated based on them. For bioimpedance measurement, an apparatus called a bioimpedance meter is used. This equipment was originally designed to assess tissue damage during irradiation. This will allow avoid unnecessary radiation therapy sessions. Today, bioimpedance analysis is successfully used by doctors of different specialties: nutritionists, endocrinologists, doctors of other areas. The technique provides the doctor with a large amount of valuable information, indicates the need for laboratory and functional studies, helps in determining treatment tactics.

5.2 Legal and organizational items in providing safety

Nowadays one of the main ways to radical improvement of all prophylactic work referred to reduce Total Incidents Rate and occupational morbidity is the widespread implementation of an integrated Occupational Safety and Health management system. That means combining isolated activities into a single system of targeted actions at all levels and stages of the production process.

Occupational safety is a system of legislative, socio-economic, organizational, technological, hygienic and therapeutic and prophylactic measures and tools that ensure the safety, preservation of health and human performance in the work process [1].

According to the Labor Code of the Russian Federation, every employee has the right:

- to have a workplace that meets Occupational safety requirements;

- to have a compulsory social insurance against accidents at manufacturing and occupational diseases;

- to receive reliable information from the employer, relevant government bodies and public organizations on conditions and Occupational safety at the workplace, about the existing risk of damage to health, as well as measures to protect against harmful and (or) hazardous factors;

- to refuse carrying out work in case of danger to his life and health due to violation of Occupational safety requirements;

- be provided with personal and collective protective equipment in compliance with Occupational safety requirements at the expense of the employer;

- for training in safe work methods and techniques at the expense of the employer;

- for personal participation or participation through their representatives in consideration of issues related to ensuring safe working conditions in his workplace, and in the investigation of the accident with him at work or occupational disease;

- for extraordinary medical examination in accordance with medical recommendations with preservation of his place of work (position) and secondary earnings during the passage of the specified medical examination;

- for warranties and compensation established in accordance with this Code, collective agreement, agreement, local regulatory an act, an employment contract, if he is engaged in work with harmful and (or) hazardous working conditions.

The labor code of the Russian Federation states that normal working hours may not exceed 40 hours per week. The employer must keep track of the time worked by each employee.

Rules for labor protection and safety measures are introduced in order to prevent accidents, ensure safe working conditions for workers and are mandatory for workers, managers, engineers and technicians.

5.3 Basic ergonomic requirements for the correct location and arrangement of researcher's workplace

The workplace when working with a PC should be at least 6 square meters. The legroom should correspond to the following parameters: the legroom height is at least 600 mm, the seat distance to the lower edge of the working surface is at least 150 mm, and the seat height is 420 mm. It is worth noting that the height of the table should depend on the growth of the operator.

The following requirements are also provided for the organization of the workplace of the PC user: The design of the working chair should ensure the maintenance of a rational working posture while working on the PC and allow the posture to be changed in order to reduce the static tension of the neck and shoulder muscles and back to prevent the development of fatigue.

The type of working chair should be selected taking into account the growth of the user, the nature and duration of work with the PC. The working chair should be lifting and swivel, adjustable in height and angle of inclination of the seat and back, as well as the distance of the back from the front edge of the seat, while the adjustment of each parameter should be independent, easy to carry out and have a secure fit.

5.4 Occupational safety

A dangerous factor or industrial hazard is a factor whose impact under certain conditions leads to trauma or other sudden, severe deterioration of health of the worker [1].

A harmful factor or industrial health hazard is a factor, the effect of which on a worker under certain conditions leads to a disease or a decrease in working capacity.

5.4.1 Analysis of harmful and dangerous factors that can create object of investigation

The object of research is a bioimpedance spectrometer for measuring physiological tissue changes after radiation therapy. The probe current source is the most important component of a bio-impedance spectrometer - accuracy, stability, reproducibility of measurement results, and the frequency and dynamic range of the entire device depend on its characteristics.

During measurements, direct current and current cannot be used. Low frequency, because at the point of contact of the electrode with the skin begin electrochemical reactions, and measurements become impossible. Moreover, direct currents of more than 100 μA can cause serious damage, while alternating current with a frequency of 10 ... 100 kHz and forceup to 5 mA does not cause any biological effect. The object of the study is "bioimpedance spectrometry to assess tissue damage after radiation therapy." the object of study cannot cause harmful and dangerous factors.

5.2.2. Analysis of harmful and dangerous factors that can arise at workplace during investigation

The working conditions in the workplace are characterized by the presence of hazardous and harmful factors, which are classified by groups of elements: physical, chemical, biological, psychophysiological. The main elements of the production process that form dangerous and harmful factors are presented in Table 24.

Table 24 - Possible hazardous and harmful factors

Factors (GOST12.0.003-2015)	Work stages			Legal documents
	Development	Manufacture	Exploitation	
1. Deviation of microclimate	+	+	+	Sanitary rules 2.2.2 /

indicators				2.4.1340–03. Sanitary and epidemiological rules and regulations "Hygienic requirements for personal electronic computers and work organization."
2. Excessive noise		+	+	
3.Increased level of electromagnetic radiation	+	+	+	
4.Insufficient illumination of the working area		+	+	Sanitary rules 2.2.1 / 2.1.1.1278–03. Hygienic requirements for natural, artificial and combined lighting of residential and public buildings.
				Sanitary rules 2.2.4 / 2.1.8.562–96. Noise at workplaces, in premises of residential, public buildings and in the construction area.
				Sanitary rules 2.2.4.548–96. Hygienic requirements for the microclimate of industrial premises.
5. Abnormally high voltage value in the circuit, the closure which may occur through the human body	+	+	+	Sanitary rules GOST 12.1.038-82 SSBT. Electrical safety. Maximum permissible levels of touch voltages and currents.

6. Increased levels of ionizing radiation	+	+	+	Sanitary Rules 2.6.1. 2523 -0 9. Radiation Safety Standards (NRB-99/2009).

The following factors effect on person working on a computer:

- physical:
  - o temperature and humidity;
  - o noise;
  - o static electricity;
  - o electromagnetic field of low purity;
  - o illumination;
  - o presence of radiation;
- psychophysiological:
  - o psychophysiological dangerous and harmful factors are divided into:
    - physical overload (static, dynamic)
    - mental stress (mental overstrain, monotony of work, emotional overload).

Deviation of microclimate indicators

The air of the working area (microclimate) is determined by the following parameters: temperature, relative humidity, air speed. The optimum and permissible values of the microclimate characteristics are established in accordance with [2] and are given in Table 25.

Table 25 - Optimal and permissible parameters of the microclimate

Period of the year	Temperature, ^{C}	Relative humidity,%	Speed of air movement, m/s
Cold and changing of seasons	23-25	40-60	0.1
Warm	23-25	40	0.1

5.3 Excessive noise

Noise and vibration worsen working conditions, have a harmful effect on the human body, namely, the organs of hearing and the whole body through the central nervous system. It result in weakened attention, deteriorated memory, decreased response, and increased number of errors in work. Noise can be generated by operating equipment, air conditioning units, daylight illuminating devices, as well as spread from the outside. When working on a PC, the noise level in the workplace should not exceed 50 dB.

5.4 Increased level of electromagnetic radiation

The screen and system blocks produce electromagnetic radiation. Its main part comes from the system unit and the video cable. According to [2], the intensity of the electromagnetic field at a distance of 50 cm around the screen along the electrical component should be no more than:

- in the frequency range 5 Hz - 2 kHz - 25 V / m;
- in the frequency range 2 kHz - 400 kHz - 2.5 V / m.

The magnetic flux density should be no more than:

- in the frequency range 5 Hz - 2 kHz - 250 nT;
- in the frequency range 2 kHz - 400 kHz - 25 nT.

5.5. Abnormally high voltage value in the circuit

Depending on the conditions in the room, the risk of electric shock to a person increases or decreases. Do not operate the electronic device in conditions of high humidity (relative air humidity exceeds 75% for a long time), high temperature (more than 35 ° C), the presence of conductive dust, conductive floors and the possibility of simultaneous contact with metal components connected to the ground and the metal casing of electrical equipment. The operator works with electrical devices: a computer (display, system unit, etc.) and peripheral devices. There is a risk of electric shock in the following cases:

with direct contact with current-carrying parts during computer repair;

when touched by non-live parts that are under voltage (in case of violation of insulation of current-carrying parts of the computer);

when touched with the floor, walls that are under voltage;

short-circuited in high-voltage units: power supply and display unit.

Upper limits for values of contact current and voltage

	Voltage, V	Current, mA
Alternate, 50 Hz	2	0.3
Alternate, 400 Hz	3	0.4
Direct	8	1.0

5.6 Ecological safety

5.6.1 Analysis of the impact of the research object on the environment

Most nuclear power plants release gaseous and liquid radiological effluents into the environment, which must be monitored. Civilians living within 80 km of a nuclear power plant typically receive about 0.1 μSv per year.

All reactors are required to have a containment building in according to international requirements. The walls of containment buildings are several feet thick and made of concrete and therefore can stop the release of any radiation emitted by the reactor into the environment

Large volumes of water are used during the process of nuclear power generation. The uranium fuel inside reactors undergoes induced nuclear fission which releases great amounts of energy that is used to heat water. The water turns into steam and rotates a turbine, creating electricity. Nuclear plants are built near bodies of water.

All possible impact of nuclear power plant on environment is greatly reduced in operating regime by many safety precautions means. The most danger of nuclear energy come because of different sorts of disaster.

During life cycle atomic power plant use nuclear fuel and produce electricity and nuclear waste. Spent nuclear fuel and waste are highly radioactive substances.

The special cask should be used to store these materials, due to their leak could poison environment.

Nuclear fuel consists from different isotopes with different half-life times. 97% of the waste produced in atomic power plant is classified as low- or intermediate-level waste (LLW or ILW). Low and intermediate level waste has been disposed of in near-surface storages for many years.

Other type of radioactive waste is classified as high-level waste (HLW). The amount of HLW produced (including used fuel when this is considered as waste) during nuclear production is small; a typical large reactor (1 GWe) produces about 25-30 tons of used fuel per year. High level waste has been disposed of in deep storages for many years

The radioactivity of nuclear waste naturally decays, and has a finite radiotoxic lifetime. Within a period of 1,000-10,000 years, the radioactivity of HLW decays to that of the originally mined ore.

The dangerous impact could be to hydrosphere and lithosphere due to leakage of waste in accidents. Therefore, international scientific collaboration is needed to develop safe storages for each types of radioactive waste.

Sources of ionizing radiation used in medicine could be divided into two groups: radioactive substances and radiation generators. The difference is that radiation generators like accelerators and x-ray tubes emit ionizing radiation only when they are turned on.

In ordinary work with necessary safety precautions, there are insignificant impact of using sources of ionizing radiation on environment. The immediate effect of ionizing radiation is ionization of air in room, but after a specified time the ionization disappears.

The danger of using radioactive materials could occur only in accidents with stealing and loosing these materials due to high toxicity.

The using of radio waves gives to industry great possibilities and finds a wide range of applications. The most known are communications. As energy of

radio waves is dissipated with distance effect of irradiation by radio waves was thoroughly study by scientist. There are a series of standards and legal notes to limit power of radio waves sources due harmful effect on biological tissues.

The impact on hydrosphere, atmosphere and lithosphere is a question to debate because of a small number of investigations in this field. Main impact could be only from powerful sources like radiolocation stations.

Mass production of plastic began only 60 years ago. During this time, its output increased 180 times. Recycling takes only 9% of the plastic. Another 12% is burned, and 79% goes to landfills and the environment.

As a result, there is pollution by debris of the lithosphere and hydrosphere. Due to the circulation of currents in the oceans, "garbage islands" are formed. At the same time, plastic not only drifts on the surface, but sinks to the bottom.

In addition to large plastic wastes, there are also wastes due to microplastics. According to international classification, any plastic particle less than 5 mm in length falls into this category. Microplastic is divided into primary and secondary. Primary is most often fibers added to synthetic clothing. When rubbing on a surface or washing, thousands of fibers are separated from it, "hanging" in the air or washed off into the sewer. The second most important source is particles of artificial rubber from tires, which each car leaves 20 grams per 100 km of track. In addition, cars erase markings from roads, which also contain plastic. Secondary microplastic is added to this - "large" debris, broken up into small pieces. As you know, plastic has decomposed for centuries. But it can quickly degrade to tiny parts, while maintaining its molecular structure.

The solutions to the plastic problem today are legislative restrictions on the use of plastic and disposable products, sorting and processing of waste. But they are still not effective solutions to the problem.

5.6.2 Analysis of the environmental impact of the research process

Process of investigation itself in the thesis do not have essential effect on environment. One of hazardous waste is fluorescent lamps. Mercury in fluorescent lamps is a hazardous substance and its improper disposal greatly poisons the environment.

Outdated devices goes to an enterprise that has the right to process wastes. It is possible to isolate precious metals with a purity in the range of 99.95–99.99% from computer components. A closed production cycle consists of the following stages: primary sorting of equipment; the allocation of precious, ferrous and non-ferrous metals and other materials; melting; refining and processing of metals. Thus, there is an effective disposal of computer devices.

5.6.3 Justification of environmental protection measures

Pollution reduction is possible due to the improvement of devices that produces electricity, the use of more economical and efficient technologies, the use of new methods for generating electricity and the introduction of modern methods and methods for cleaning and neutralizing industrial waste. In addition, this problem should be solved by efficient and economical use of electricity by consumers themselves. This is the use of more economical devices, as well as efficient regimes of these devices. This also includes compliance with production discipline in the framework of the proper use of electricity.

Simple conclusion is that it is necessary to strive to reduce energy consumption, to develop and implement systems with low energy consumption. In modern computers, modes with reduced power consumption during long-term idle are widely used.

5.7 Safety in emergency

5.7.1 Analysis of probable emergencies that may occur at the workplace during research

The fire is the most probable emergency in our life. Possible causes of fire:

- malfunction of current-carrying parts of installations;

- work with open electrical equipment;

- short circuits in the power supply;

- non-compliance with fire safety regulations;

- presence of combustible components: documents, doors, tables, cable insulation, etc.

Activities on fire prevention are divided into: organizational, technical, operational and regime.

5.7.2 Substantiation of measures for the prevention of emergencies and the development of procedures in case of emergencies

Organizational measures provide for correct operation of equipment, proper maintenance of buildings and territories, fire instruction for workers and employees, training of production personnel for fire safety rules, issuing instructions, posters, and the existence of an evacuation plan.

The technical measures include compliance with fire regulations, norms for the design of buildings, the installation of electrical wires and equipment, heating, ventilation, lighting, the correct placement of equipment.

The regime measures include the establishment of rules for the organization of work, and compliance with fire-fighting measures. To prevent fire from short circuits, overloads, etc., the following fire safety rules must be observed:

elimination of the formation of a flammable environment (sealing equipment, control of the air, working and emergency ventilation);

use in the construction and decoration of buildings of non-combustible or difficultly combustible materials;

the correct operation of the equipment (proper inclusion of equipment in the electrical supply network, monitoring of heating equipment);

correct maintenance of buildings and territories (exclusion of the source of ignition - prevention of spontaneous combustion of substances, restriction of fire works);

training of production personnel in fire safety rules;

the publication of instructions, posters, the existence of an evacuation plan;

compliance with fire regulations, norms in the design of buildings, in the organization of electrical wires and equipment, heating, ventilation, lighting;

the correct placement of equipment;

well-time preventive inspection, repair and testing of equipment.

In the case of an emergency, it is necessary to:

inform the management (duty officer);

call the Emergency Service or the Ministry of Emergency Situations - tel. 112;

take measures to eliminate the accident in accordance with the instructions.

Conclusion

In the course of the work done, a device for bio-impedance spectrometry was developed.The main parts of the device are an impedance convector based on the AD5933 microcircuit, a Howland current source and a microcontroller.

Before starting work, the device was tested for operability using an equivalent cell circuit. The measurement results of the circuit coincide with the theoretical data, which indicates the accuracy of the measurements by the device. Researchers have shown that the device allows measuring the impedance in the frequency range from 10 Hz to 100 kHz.

To assess changes in the electrical properties of tissues after irradiation, measurements were made in a patient with breast cancer. Existing data show that a lower phase angle means a decrease in cell integrity or cell death, and that a higher

phase angle implies the presence of a large number of intact cell membranes.

Measurement of the phase angle for diagnostic purposes has confirmed thatthis parameter has great prognostic value in various diseases.

The results of this work were presented at three conferences of the all-Russian and international level. Based on the obtained results three publications.

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