A RESEARCH STUDY OF THE DEPENDENCE OF BIOIMPEDANCE SPECTRUM OF BIOLOGICAL TISSUE ON DIFFERENT TEMPERATURE RANGES

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Introduction

One of the main issues in medicine is the difficulty to determine the boundaries and depth in applying cryotherapy. Individual characteristics of the tissue, different cooling rates and high temperature gradients during freezing cause troubles in accurately determining the freeze depth. Overexposure to cold can cause obstruction in the organ system, perforation and damage to healthy tissues. Insufficient influence intensity of the performed procedure can be ineffective and lead to development of both local complications in the form of inflammatory processes, and systemic complications such as postoperative thrombembolia and sepsis.

It is obvious that for exact determination of freezing depth it is necessary to use more advanced methods. One of the most accurate methods for determining the degree of tissue damage and cryonecrosis is to measure the active component of the tissue impedance [1]. Freezing water solutions in cells leads to sharp increase of electrical impedance, which is a reliable indicator of cryodestruction.

The practical application of this technology to control the quality of cryodestruction in the development and manufacture of medical equipment is hampered by the impossibility of a reasonable choice of parameters for bioelectrical impedance measurement equipment: the optimum frequency and strength of the probing current, the optimal design of the measuring electrodes when operating in a cryogenic surgical system.The presented work is devoted to the investigation of these issues and is oriented to the practical implementation of the technology of quality control of cryodestruction based on measurement of bioelectrical impedance in a wide frequency range of the probing current.

The aim of this work is the research the dependence of the bioimpedance spectrum of biological tissues on the temperature change from -18 to +30 degrees Celsius.

Description of the Laboratory Prototype

To solve this problem, we have developed a prototype device for carrying out impedance tomography. The electrical functional diagram of the electronic unit is proposed below.

The signal from the personal computer goes to the generator control system. The control system starts the DAC, which sends a probe current signal to the electrodes of the measuring chamber through the matching transformer. The signal passed through the object under investigation is amplified by passing through the amplifiers, and is digitized by the ADC. The digitized data is sent to the PC for further processing.

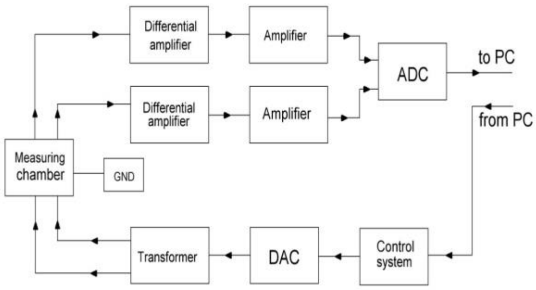

Figure 1 Structural diagram of the Prototype

The high-speed DAC acts as the probing pulse generator. The signals are recorded using a high-speed ADC E20-10 module with a low level of switching interference and a signal-to-noise ratio of 73 dB.

The measuring chamber is made in the form of a hollow cube. On the inner sides of the cube (Figure 2) there are probing and measuring silver electrodes.

Figure 2 Measuring chamber

The assembled laboratory prototype is shown in Figure 3.

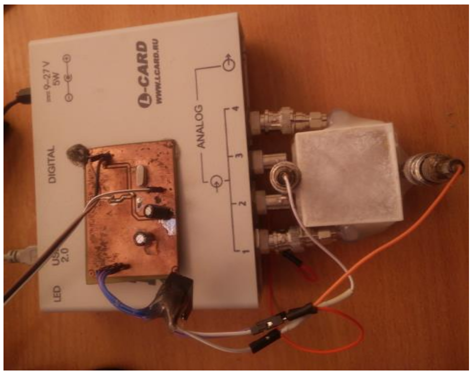

Figure 3 Appearance of the model for impedance tomography during the experiment

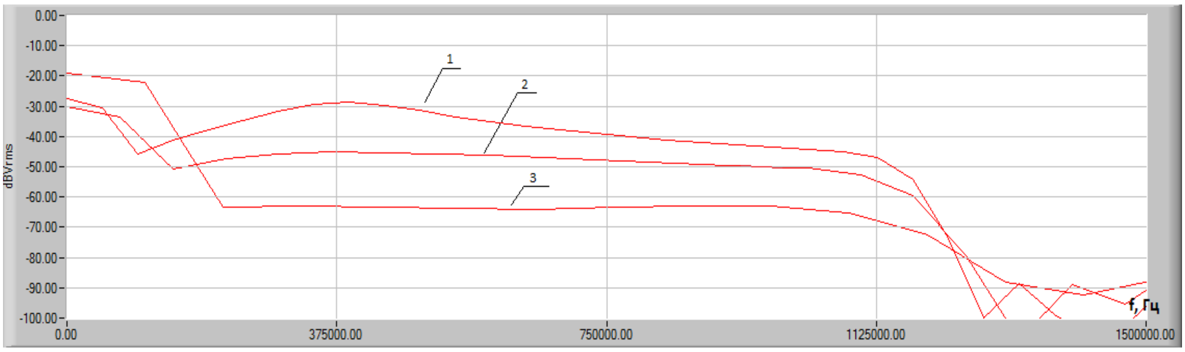

Figure 4 Bioimpedance spectrum of water with dissolved salts with temperature change. The current strength is 1 mA (amplitude value). The lines: 1 –18 °C below zero, 2 –7 °C below zero, 3 –4 °C above zero. The Y axis is the effective value of the voltage in the logarithmic scale of the measurement, the X axis is the frequency in Hz.

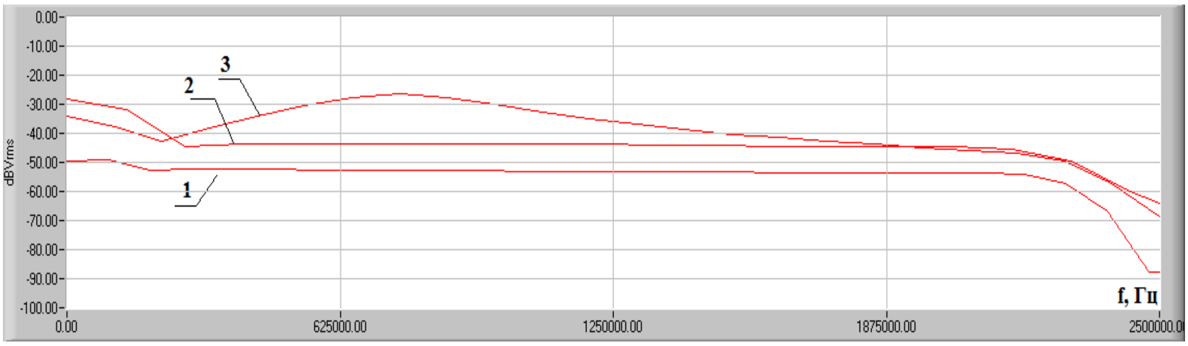

Figure.5 Bioimpedance spectrum of muscle tissue with temperature change. Current strength: 1 mA (amplitude value). Lines: 1 –16 °C above zero, 2 –4 °C below zero, 3 16 °C below zero. The Y axis is the effective value of the voltage in the logarithmic scale of the measurement, the X axis is the frequency in Hz.

Results

The developed prototype allowed to carry out experimental studies to analyze the spectrum of the probing signal in mineral water and muscle tissue at different temperatures.

Figures 4, 5 show the results of experiments carried out at different temperatures for the fluid (Figure 4) and muscle tissue (Figure 5).

Conclusion

As a result of the performed experimental studies, the dependencies of bioimpedance spectrum on the temperature of aqueous solutions of mineral salts and muscle tissue were obtained at the temperatures from -18 to +30 degrees Celsius. The obtained data show that as the freezing process progresses, the absolute value of the total electrical impedance of both the biological material and the aqueous solutions of the mineral salts increases. Under full deep freezing, a local increase in the electrical impedance in the frequency range of 375 – 750 kHz is observed for the aqueous solution of mineral salts, and that in the range from 625 to 1250 kHz for muscle material. Peak values are in the frequency of 375 kHz for the aqueous solution and in the frequency of 700 kHz for the muscle material. The obtained data allow to reliably determine the extent of biological material freezing by measuring the electrical impedance in the frequency range from 300 to 1300 kHz.

References

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