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SIMULATOR OF ELECTRICAL CHARACTERISTICS OF MUSCLE TISSUE

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Abstract. A simulator of electrical characteristics of muscle tissue with lumped parameters in a magnetic field was developed. Studies have been carried out to determine the parameters of elements with lumped parameters. According to the obtained data, it can be concluded that the response amplitude for the proposed simulators is directly proportional to the power of the magnetic signal. The most suitable for simulators of human muscle tissue is a scheme with concentrated parameters based on electrolytic capacitors.

Keywords: *simulator, magnetic field, biological tissue, magnetostimulator.*

Introduction

Devices and equipments, automated complexes for diagnostics systems, prevention and treatment of diseases are developed and used in medicine. Despite the dominance of medication, in recent years physiotherapeutic methods for changing of the human state are improved. The essence of this methods is to modify the chemical and ion interactions in human body. The main types of effects on a biological object include electric, magnetic and electromagnetic fields and radiation. Medical devices based on the use of these effects are characterized not only by high efficiency of application, but also by the prediction of possible consequences.

Transcranial magnetic stimulation (TMS) leads to excitation of electrical signals in the central and peripheral nervous system in an electrodeless manner [2]. Doctors face the problem of dosing and determining the level of induced electrical signal in human tissues. Thus, it is necessary to create a physical model of biological tissues.

Research methods

For successful application of a physical model of biological tissue, it is necessary to obtain similar electrical characteristics with a real biological sample when creating it. The amplitude of the induced signal in the biological sample was chosen as the measurement parameter.

The two-electrode method of electrical stimulation was used to measure the electrical characteristics of biological tissue (Figure 1).

The method of measuring the parameters of current induced in biological tissue by pulsed magnetic fields, depending on the magnetic pulse power and parameters of a biological sample was used in this work.

For measurements, there were used a magnetostimulator with a Neuro-MS/D inductor, a digital oscilloscope with a personal computer and muscle tissue with a system of electrodes. The muscle tissue similar to human was used as a biological sample (sample size 15×7×4 cm).

At this moment, various simulators of biological tissue have been developed in the world. Simulators of only physical parameters (based on ballistic gel) were created with a high service life [3, 4].

Water-containing simulators of electrical parameters created on the basis of impregnation of cotton fabric, knitwear, cellulose, felt with solutions of sodium and calcium salts, alcohol aqueous solutions, hydrogels have a short service life (several hours) [2].

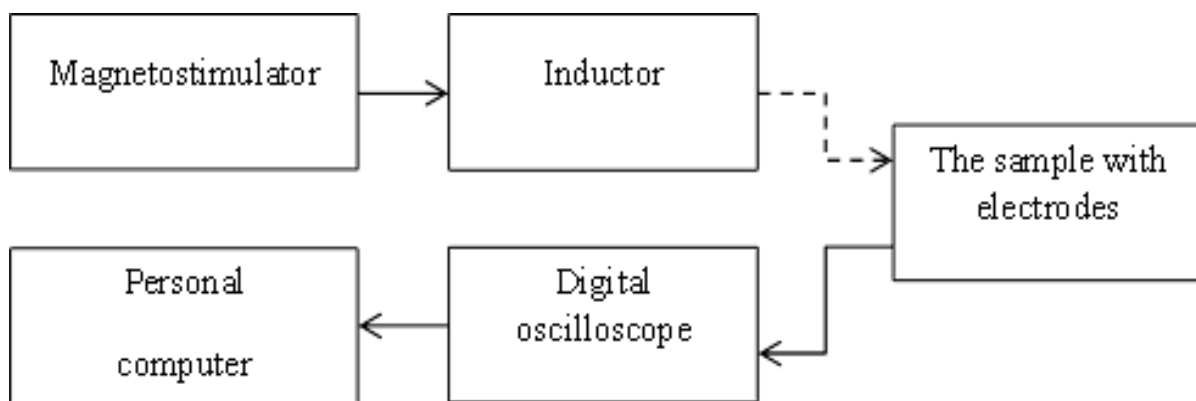


Figure 1. The structural combined scheme of installation for measurements of influence of a pulsed magnetic field on samples.

As a physical model of biological tissue, it is proposed to use a simulator of electrical characteristics with concentrated parameters in a magnetic field (Figure 2).

This model allows to achieve high performance on the service life of biological tissue simulators.

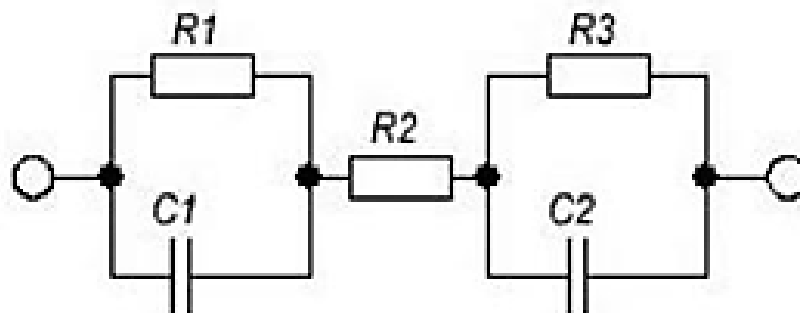


Figure 2. The simulator electrical scheme of biological tissue electrical characteristics with concentrated parameters in a magnetic field.

The aim of the research is to obtain simulators of biological tissues, the electrical characteristics of which will correspond to the electrical parameters of biological tissue.

Results and discussion

The parameters of components with concentrated parameters are selected. In the literature [5 - 8] the values of the parameters differ, so there were created three simulators samples of biological tissue electrical characteristics with concentrated parameters. This samples differ from each other by the type of components (electrolytic and ceramic capacitors) and their nominal value.

During the research, experiments were conducted with each of the developed simulators, as well as with a biological sample. In the Figure 3 there is presented an oscillogram of a typical signal induced by a pulsed magnetic field.

The amplitude of the induced signal was fixed. The values of the induced signal amplitude in muscle tissue and in the developed samples are presented in the table 1.

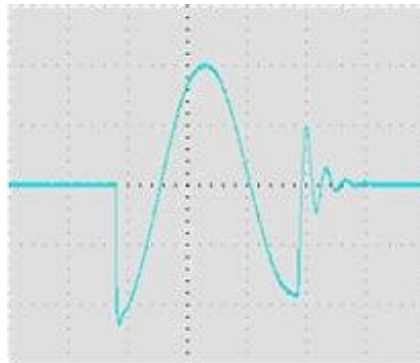


Figure 3. The shape of the signal induced by a pulsed magnetic field.

Table 1

The value of the induced signal amplitude in muscular tissue and in the developed samples of simulators

Pulse signal power, T	The amplitude of the voltage induced in muscle tissue, V	The amplitude of the voltage induced in the sample № 1, V	The amplitude of the voltage induced in the sample №2, V	The amplitude of the voltage induced in the sample № 3, V
1	63.4±0.5	57.4±0.5	53.5±0.5	49.5±0.5
0,95	63.4±0.5	55.4±0.5	51.5±0.5	45.5±0.5
0,9	59.4±0.5	51.5±0.5	47.5±0.5	45.5±0.5
0,85	55.4±0.5	49.5±0.5	45.5±0.5	43.6±0.5
0,8	53.5±0.5	47.5±0.5	43.6±0.5	41.6±0.5
0,75	49.5±0.5	43.6±0.5	39.6±0.5	39.6±0.5
0,7	45.5±0.5	41.6±0.5	37.6±0.5	37.6±0.5
0,65	43.6±0.5	39.6±0.5	35.6±0.5	35.6±0.5
0,6	37.2±0.5	37.6±0.5	31.7±0.5	31.7±0.5
0,55	34.3±0.5	31.3±0.5	29.3±0.5	29.7±0.5
0,5	31.3±0.5	28.7±0.5	26.9±0.5	24.8±0.5
0,45	28.1±0.5	25.7±0.5	24.4±0.5	22.6±0.5
0,4	25.7±0.5	23.0±0.5	21.4±0.5	20.2±0.5
0,35	22.6±0.5	20.4±0.5	19.6±0.5	17.4±0.5
0,3	19.6±0.5	17.4±0.5	16.6±0.5	15.1±0.5
0,25	16.6±0.5	14.5±0.5	14.3±0.5	13.1±0.5

Continuation Table 1

0,2	13.3±0.5	12.3±0.5	11.3±0.5	10.9±0.5
0,15	10.3±0.5	9.5±0.5	8.7±0.5	7.5±0.5
0,1	7.9±0.5	6.7±0.5	6.1±0.5	6.1±0.5
0,05	4.6±0.5	3.2±0.5	3.8±0.5	4.0±0.5

Comparing the data in the table, we obtained that the sample number 1 (with electrolytic capacitors) best mimics muscle the tissue. Differences in values are not more than 10 %. In the Figure 4 the dependence of the response amplitude in the biological muscle tissue sample and simulator No. 1 on the output signal power (% of the maximum value) is presented.

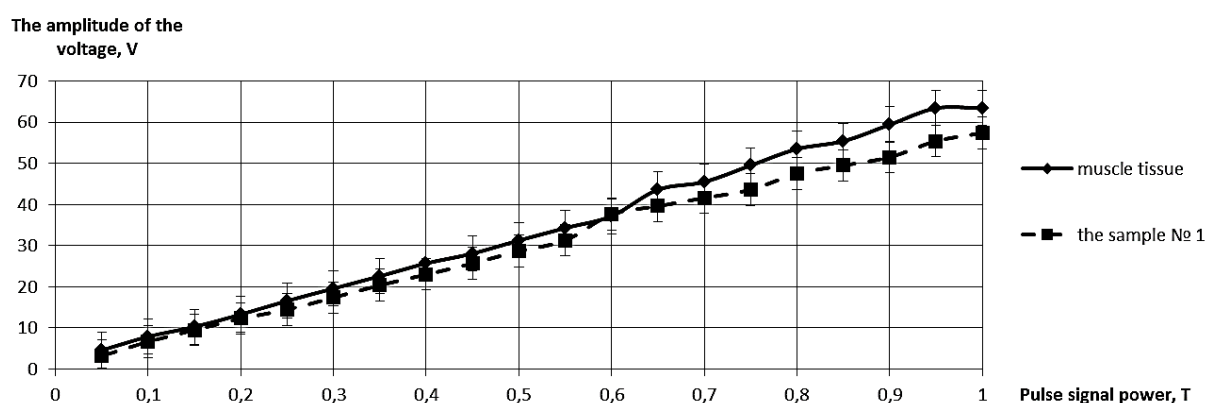


Figure 4. The dependence of the response amplitude in a biological sample of muscle tissue and simulator No. 1 on the output signal power.

Conclusion

According to the obtained data, it can be concluded that the response amplitude for the proposed simulators is directly proportional to the power of the magnetic signal. The most suitable for simulators of human muscle tissue is a scheme with concentrated parameters (Figure 2) based on electrolytic capacitors.

The developed simulators were introduced into the laboratory process at the Department of electronic engineering and technology of the educational institution "Belarusian state University of Informatics and Radioelectronics" in the course "Electronic medical devices, systems and complexes".

Reference

1. Al-Ademi, Ya.T.A. et al. *Vodosoderzhashchiye imitatory biologicheskikh tkaney dlya zashchity cheloveka ot elektromagnitnykh izlucheniye* [Water-containing imitators of biological tissues to protect humans from electromagnetic radiation]. Minsk: Bestprint, 2014.
2. Samuilov, I.V. *Modeli biologicheskikh tkaney dlya magnitoterapii* [Models of biological tissues for magnetotherapy]. In: *New Horizons - 2017: collection of materials of the Belarusian-Chinese Youth Innovation Forum*, Minsk, 2-3 november 2017. Minsk: BNTU, 2017, T. 2, pp. 23-25.
3. Filipchuk, O.V., Gurov, A.M. *Osobennosti primeneniya ballisticheskogo zhelatina kak imitatora biologicheskikh tkaney cheloveka* [Features of the use of ballistic gelatin as an imitator of human biological tissues]. In: *Theory and Practice of Ship Expertise and Criminalistics*, 2015, 15, pp. 367–373.
4. Karger, B. *Forensic ballistics*. In: *Forensic pathology reviews*, 2009, 5, pp. 139-172.
5. Volkenstein, M. V. *Molecular biophysics*. Elsevier, 2012.
6. Jackson, M. B. *Molecular and cellular biophysics*. Cambridge University Press, 2006.
7. Plutakhin, G.A., Koshchaev, A.G. *Biophysics: Textbook*. St. Petersburg: Doe, 2012.
8. Son, K.N., Rodin, V.I., Beslaneyev, E.V. *Biophysics*. - St. Petersburg: Doe, 2016.