INVESTIGATION ON SIMULTANEOUSLY INFLUENCE OF LOW FREQUENCY ELECTRICAL SIGNALS WITH AMPLITUDE MODULATION AND LOW FREQUENCY MAGNETIC FIELD ON CHARGED PARTICLES IN THE LIVE TISSUE

D. Tz. Dimitrov*, P. Decheva, M. Gavrilov*****

Technical University of Sofia, Bulgaria
**Faculty of Communication Technique and Technologies of Technical University-Sofia, ,Kl.Ohridsky 8, 1000 Sofia,Bulgaria*
***Faculty of Computer Sciences of Technical University-Sofia, ,Kl.Ohridsky 8, 1000 Sofia, Bulgaria*
****Department of Physiotherapy of Alexander's University Hospital-Sofia, "G.Sofiisky"40 Sofia, Bulgaria*

Abstract

There are experimental evidences that electric and magnetic field, used simultaneously, can aid nerve regeneration and peripheral circulation as well as blood vessels regeneration and soft tissue healing.

There is a better analgesic and antiphlogistic (anti-inflammatory) results when using both methods at the same time. So they are both used when healing arthritis, suppurative wounds and proceses.

In spite of that electrotherapy and magnetotherapy are widely used, there is not any program (these conclusion is made after some researches for that kind of program), used in practice, for visualization of their both influence of the humans. That is why the development of a software for that kind of visualization could contribute of more efficient use of those methods.

1. Introduction

Nowadays, electrotherapy and magnetotherapy are more and more used in the field of medicine[…].

Electrotherapy is often used[…] in cases of damaged peripheral nerves, but it is also worth much in cases of muscular atrophies after serious bone`s fractures, and some other diseases.

Magnetotherapy is a method that uses the effect of the magnetic fields for the purposes of medical treatment. It uses either constant or low-frequency magnetic field. One of the most popular applications of magnetic field is to assist fractured bone repairing and healing[….].

2. Main text

It is interesting to see the cases when one electrical and one magnetic signal have influenced on a charged particle. Both signals are constant or low-frequency, and they are independent at each other. Each of them can vary in different way within time.

The location of the vectors of intensity of the electric field $\vec{E}(x,y,z,t)$ and magnetic induction $\vec{B}(x,y,z,t)$, when both fields influence on the charged particle at the same time is shown on fig.1 in three-dimensional frame of reference XYZ.

For the very first moment it is accepted that the beginning of the frame of reference is exactly where the charged particle is situated. Moreover, but without lessen the size of the examinations, it is accepted that the axes of the tree-dimensional frame of reference have a direction so the vector of magnetic induction of the magnetic field $\vec{B}(x,y,z,t)$ coincide with the Z axis. The vector of intensity of the electric field $\vec{E}(x,y,z,t)$ could be situated in every place in the space. Gamma (γ) is the angle between $\vec{E}(x,y,z,t)$ and the Z axis, and beta (β) is the angle between the projection of $\vec{E}(x,y,z,t)$ in XOY and the X axis.

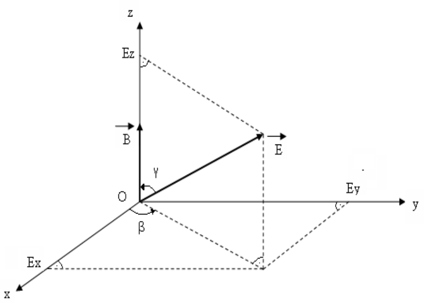


Fig. 1

The components of the vector $\vec{E}(x,y,z,t)$ on the X,Y,Z axes of the frame of reference are E_x, E_y, E_z. A differential equation about the movement of the charged particle could be written in correspondence of fig.1. Generally the differential equation is:

$$m\frac{d^2\vec{r}(t)}{dt^2} = q\vec{E}(x,y,z,t) + q[\frac{d\vec{r}(t)}{dt} x\vec{B}(x,y,z,t)] \tag{1}$$

Where:

m is the mass of the charged particle;

q is the electrical charge of the charged particle;

$\vec{r}$ is the tangential vector of the trajectory og movement of the charged particle.

According to fig.1 the components of the vector of intensity of the electric field of $\vec{E}(x,y,z,t)$ are:

$$\begin{aligned} E_x &= \left|\vec{E}(x,y,z,t)\right| \sin\gamma\cos\beta \\ E_y &= \left|\vec{E}(x,y,z,t)\right| \sin\gamma\sin\beta \\ E_z &= \left|\vec{E}(x,y,z,t)\right| \cos\gamma \end{aligned} \tag{2}$$

The equation (1) could be written for each of the axes X, Y, Z. As a result the equation (1) turns out into a system of differential equations.

$$\begin{aligned} & m\frac{d^2x(t)}{dt^2} = q[E(x,y,z,t)\sin\gamma\cos\beta + \\ & + B(x,y,z,t)\frac{dy(t)}{dt}] \\ & m\frac{d^2y(t)}{dt^2} = q[E(x,y,z,t)\sin\gamma\sin\beta + \\ & + B(x,y,z,t)\frac{dx(t)}{dt}] \\ & m\frac{d^2z(t)}{dt^2} = qE(x,y,z,t)\cos\gamma \end{aligned} \tag{3}$$

The system of differential equations (3) has been written for the general case when the electric and the magnetic fields are non homogeneous, and when they are changing slowly (with low-frequency) into the time. All manner of mathematical expressions describing space-temporal configuration of the external low-frequently electrical and magnetic signals could be used into these differential equations.

The mostly examined case is when the charged particle is placed into a homogeneous electrical and magnetic field.

It is interesting when there is more complicated signal that influence upon the charged particle, for example, when the "external" electrical signal is amplitude modulated. The algorithm for visualization the influence of the electrical and magnetic field over the human`s body is on the fig.2

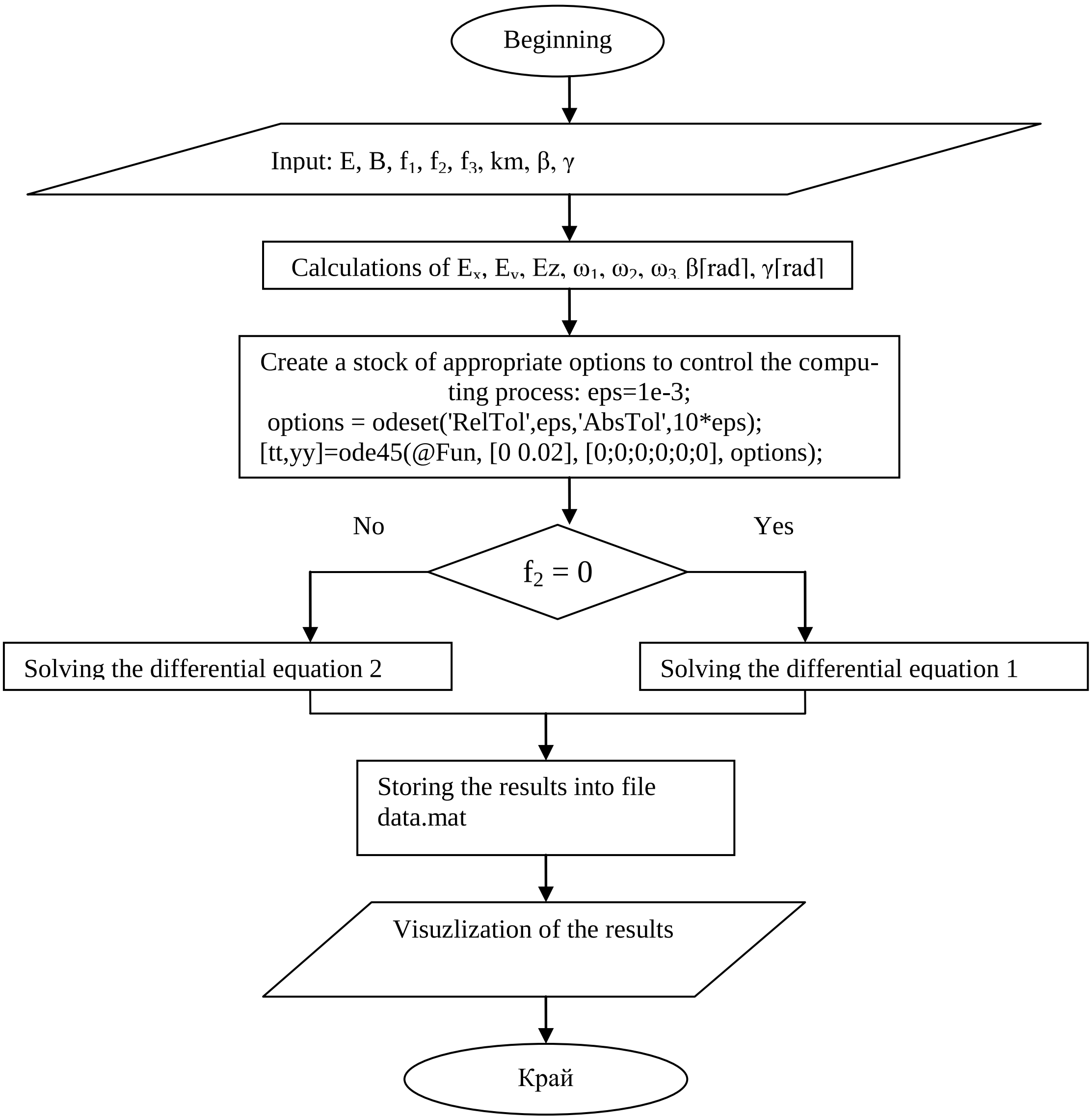


Fig. 2

Description of the algorithm

Input is an interface for entering data. After that into the "Calculation" block the input data has been used for calculating E_x, E_y, E_z, ω_1, ω_2, ω_3, β[rad], γ[rad]. The results of these calculations are necessary for the execution of the program. The next stage describes creating a stock of appropriate options to control the computing process. This one includes setting an appropriate accuracy of the calculations, choosing a solver that gives best results using the common data for the examined cases, setting initial values for solving the differential equations.

The next "Condition" block defines if the chosen electrical signal is harmonious or if it is amplitude modulated. If f2 = 0, it means that the signal is harmonious and the program continues with solving the differential equations 1. Otherwise the differential equations 2 would be solved. After that the results from the equations have been stored into a file, named data.mat. These results will be used later as an input data of another program that calculates and visualizes the amplitude-frequency spectrums of the signals.The last step is visualization of the results in two- and tree-dimensional graphics.

For the case when the charged particle is placed into homogeneous electrical and magnetic fields, the realized conditions are:

$$\vec{E}(t) = \vec{E}_m \cos\omega_1 t \wedge \vec{E}_m(x,y,z) = const$$
$$\vec{B}(t) = \vec{B}_m \cos\omega_1 t \wedge \vec{B}_m(x,y,z) = const \quad (4)$$
$$\beta = \gamma = 45^\circ$$

where:

$\vec{E}_m$ is the amplitude of the electrical intensity

ω_1 is the circular frequency of intensity of the electrical field;

B_m is the amplitude of the magnetic inductions;

ω_3 is the circular frequency of the magnetic field;

In that case the system of differential equations is:

$$m\frac{d^2x(t)}{dt^2} = q[E_m \sin\gamma\cos\beta\cos\omega_1 t + \frac{dy(t)}{dt}B_m\cos\omega_3 t] \quad (5)$$

$$m\frac{d^2y(t)}{dt^2} = q[E_m \sin\gamma\sin\beta\cos\omega_1 t + \frac{dx(t)}{dt}\cos\omega_3 t]$$

$$m\frac{d^2z(t)}{dt^2} = qE_m\cos\gamma\cos\omega_1 t$$

The solutions of the system are shown below in a graphic mode, and these solutions are calculated using concrete values of the parameters:

$$E_m = 200[V.m^{-1}]; \omega_1 = 2\pi 100[s^{-1}]$$
$$B_m = 30[mT], \omega_3 = 2\pi 50[s^{-1}]$$

The components of the trajectory of the movement of the charged particle are shown on fig.3 a, b and c. The trajectory of the movement of the charged particle in 3-D is shown on fig.3 d. It is obvious, from the system of differential equations, that the components of the “external” electrical signal take part in all of the equations of the system. . That is the reason that the electrical signal influences onto the components of the X, Y and Z axes of the trajectory and the speed of the charged particle.It is also obvious, that the components of the “external” magnetic signal take part only into the differential equations for the X and Y axes, so the magnetic signal influence onto the components of the trajectory and speed for X and Y axes only. The functions that describe the trajectory and speed over the Z component are periodic, and they are defined only by the function that describes the simple “internal” electrical harmonious signal**.**

Another interesting case is when the “external” electrical signal is amplitude modulated, and the magnetic signal is harmonious. In that circumstance, the conditions of influence from the “external” signals over the charged particle are:

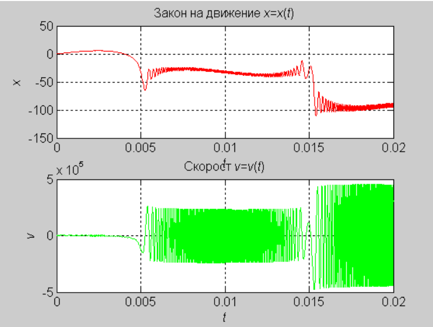
$$\vec{E}(t) = \vec{E}_m(1 + m\cos\omega_1 t)\cos\omega_2 t \wedge$$
$$\wedge \vec{E}_m(x,y,z) = const \wedge \vec{B}_m(x,y,z) = const \wedge$$
$$\wedge \vec{B}(t) = \vec{B}_m\cos\omega_3 t \wedge \beta = \gamma = 45^\circ \quad (6)$$

where:

$\vec{E}_m$ is the amplitude of the electrical intensity;

ω_1 is the circular frequency of intensity of the electrical field;

ω_2 is the circular frequency of the carrier signal when there is an amplitude modulations of the intensity of electrical field;



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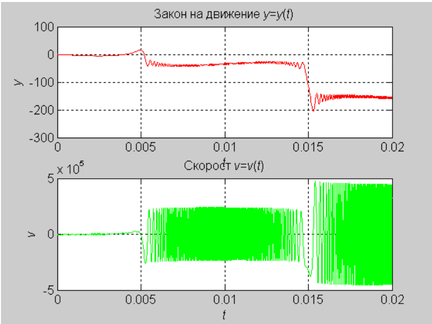

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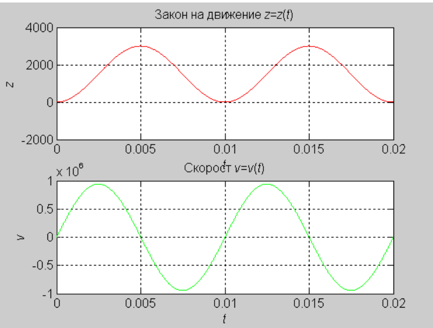

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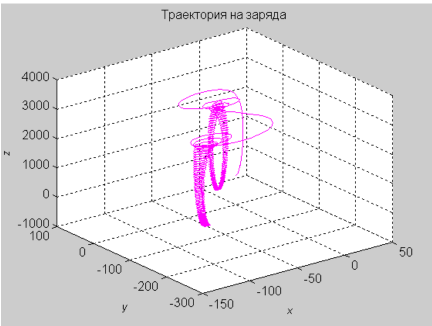


d)

Fig. 3

m is the coefficient of the amplitude modulation;

B_m is the amplitude of the magnetic inductions

ω_3 is the circular frequency of the magnetic field;

In that case the system of differential equations is:

$$m\frac{d^2x(t)}{dt^2}= \\ = q[E_m \sin\gamma \cos\beta(1+m\cos\omega_1 t)\cos\omega_2 t + \\ +\frac{dy(t)}{dt}B_m\cos\omega_3 t] \quad (7)$$

$$m\frac{d^2y(t)}{dt^2}= \\ = q[E_m \sin\gamma \sin\beta(1+m\cos\omega_1 t)\cos\omega_2 t + \\ +\frac{dx(t)}{dt}\cos\omega_3 t]$$

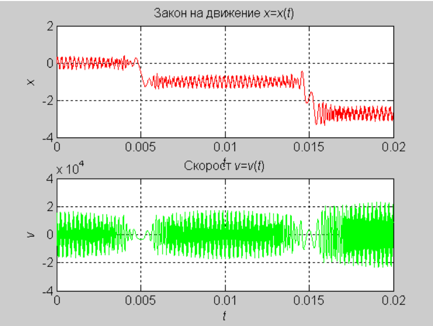
$$m\frac{d^2z(t)}{dt^2}= \\ = qE_m\cos\gamma(1+m\cos\omega_1 t)\cos\omega_2 t$$

The solutions of the system are shown below in a graphic mode, and these solutions are calculated using concrete values of the parameters:

$$E_m = 200[V.m^{-1}];\omega_1 = 2\pi 100[s^{-1}] \\ B_m = 30[mT],\omega_3 = 2\pi 50[s^{-1}] \\ \omega_2 = 2\pi 4000[s^{-1}], m = 1$$

The components of the trajectory of the movement of the charged particle are shown on fig.4 a, b and c. The trajectory of the movement of the charged particle in 3-D is shown on fig.4 d.

This case shows a very complicated process of amplitude modulation.



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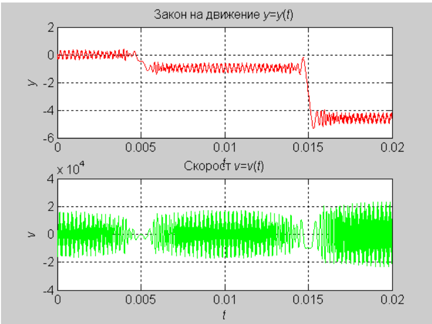

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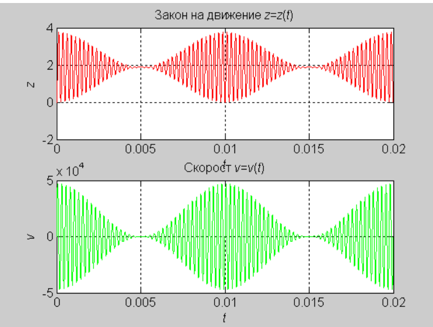

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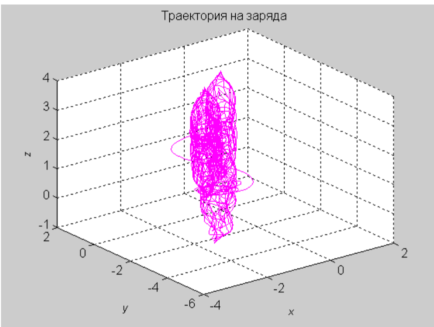
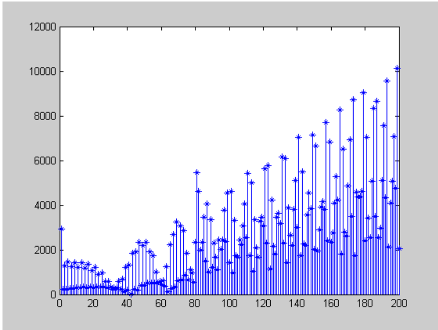


d)

Fig. 4

Spectral analysis

The results of the examination in the frequency area on the "internal" signals of the system, is shown below. The calculations of the amplitude-frequency spectrums are made by some computer methods.



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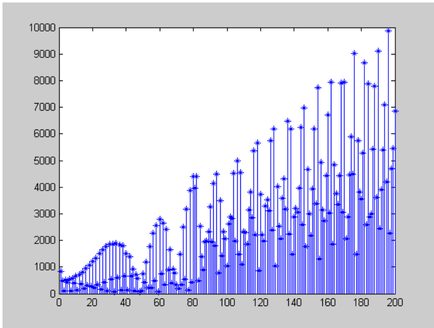

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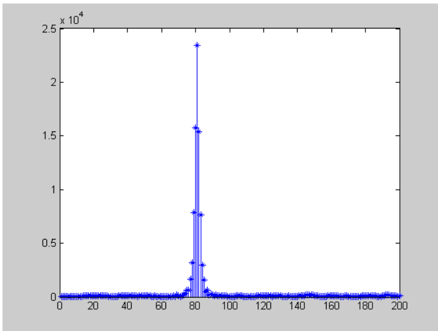

c)

Fig. 5

Most interesting amplitude-frequency spectrums are those, when the "external" electrical signal is amplitude modulated and magnetic signal is low frequency sinusoidal signal. In this case the amplitude-frequency spectrums of the reaction of the system are, according to X, Y and Z axes (fig.5a, b, c). It's clear that there are many new components in the frequency spectrum in the "internal" electric signals as results of influence of two low frequency "external" signals on the human body.

Conclusion

As result of the above investigation, a new method for therapy with simultaneously application of low frequency electrical and magnetic signals is obtained. This method has been checked in the Medical University of Sofia, Bulgaria and after its successful application, the method has been recommended in medical therapy.

References

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