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# Prospects of electrosleep therapy devices for long-distance drivers

**Key words:** encephalogram, biorhythms, correlation coefficients, impulse signals, electrosleep therapy devices, long-distance drivers

## Introduction

Uncompensated exhaustion is a fairly common problem for truck and bus drivers on international routes. In case of uncompensated exhaustion, the driver is unable to overcome the resulting attention violations with will effort, which increases the probability of errors and accidents. The last claim is confirmed by the increase in the number of incidents after 7 h and especially 10 h of work. To overcome this problem, it is necessary to stop and fall asleep for a short time. Recovery comes in about 10–15 min of relaxation. In order for the recovery to be as complete as possible within the specified short period of time, it is reasonable to use portable devices of electrosleep (transcranial) therapy (Fig. 1).

Electrosleep (other terms – cranial electrostimulation therapy, transcranial

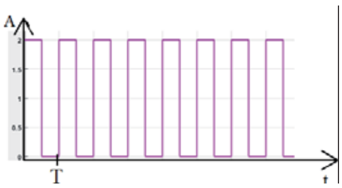
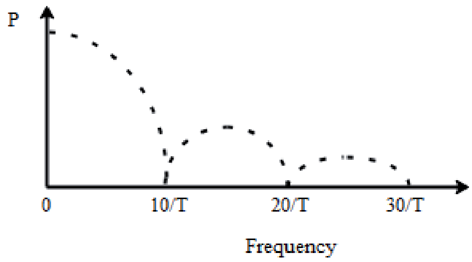
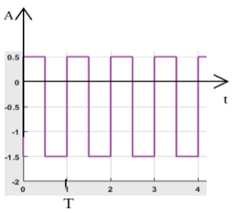
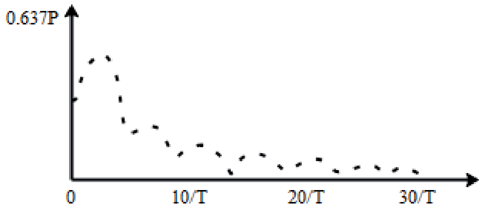
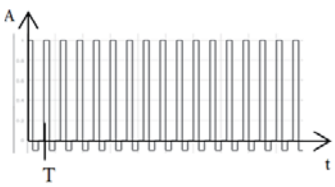
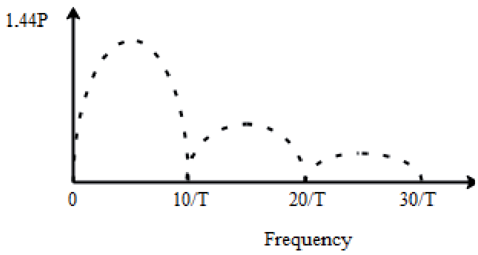

FIGURE 1. Portable device for electrosleep therapy (https://thebrainstimulator.net/wp-content/ /uploads/2016/11/tDCS-Brain-Stimulator-v3.jpg)

electrotherapy) is a general name for a group of methods aimed at inducing a similar state in a subject (Peterchev et al., 2012). The source of stimulation of the brain is weak impulse current, which causes sleep of varying depth and duration. Clinical studies have shown that the strongest impact is on pulses with a duration of approximately 0.3–0.5 ms and a frequency of repetition ranging from 0.5–2 to 80–100 Hz. Current levels are typically of 50–5 mA. More detailed information can be found on some websites, for example https://caputron.com/pages/best-tdcs-device or https://www.tdcs.com/best-tdcs-devices.

Pulse repetition rate is selected for each user individually, based on the functional state of the central nervous system, as well as the effect that is achieved at certain frequencies (Peterchev et al., 2012). The mechanism of pulsed currents influence is not completely studied (Shekelle et al., 2018).

Transcranial electrotherapy is considered to stimulate endorphin production and affect the hypothalamus, causing changes in neurohormonal regulatory mechanisms and reticular formation of the brain stem. The reticular formation is involved in many behavioral reactions

TABLE. Classes of devices and types of signals

| Class | Signal shape | Spectrum |
|---|---|---|
| IA |  |  |
| IIA |  |  |
| IIB |  |  |

and has a significant impact on body functioning and thought processes.

There are several classes of electrosleep therapy devices studied (Shekelle et al., 2018; Kernytskyy et al., 2020). They differ in electrode parameters (number, location and shape) and in signal shape features such as intensity and general shape, as well as pulse shape, amplitude, duration, polarity, repetition rate, and pulse series interval. Features of signal forms of different classes of electrosleep therapy devices are shown in the table.

In this regard, the development of methods for determining the parameters of the electrosleep signal, the action of which will be most effective, is an important task.

## Models and methods

The aim of this work was to determine correlation between human brain biorhythms and electrosleep device signal by calculating mutual correlation. For this purpose, the model in MATLAB Simulink environment was developed. The main elements of the model were an impulse generator, filters that were used to extract brain biorhythms from the common encephalogram, and a block for calculating correlation coefficients. The encephalogram was previously obtained and processed using the EEGLAB program (Guleyupoglu, Schestatsky & Fregni, 2015). ICA and ADJUST accessories were used for rejecting the artifact components (https://sccn.ucsd.edu/wiki/EEGLAB). According to the recommendations (http://xai-medica.com/neurocom/ica.htm), 4 (F4) lead was taken for delta and alpha rhythm separation, and 30 (O1) lead was taken for theta and beta rhythm separation according to the scheme “10–20”. The processed signals of the leads are shown in Figure 2.

## Analysis of simulation results

Subsequent model studies were conducted in several stages. First, the frequency dependencies of correlation coefficients for the signal of devices of classes IA and IIA were calculated. For this purpose, the frequency of the rectangular pulse generator was changed within 0.25–100 Hz, the pulse width was 20% of the period of repetition.

Figure 3 shows the graphs of correlation coefficient dependence on the frequency for a unipolar signal is common for delta, theta and alpha rhythms. The values of correlation coefficients are within 0.42–0.63 and reach the maximum values in the frequency range of

a b c

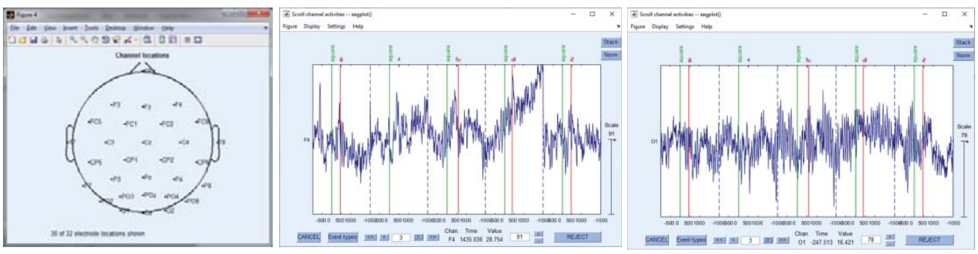


FIGURE 2. The processed signals of the leads: a – the leads placement; processed signals; b – signal F4; c – signal O1

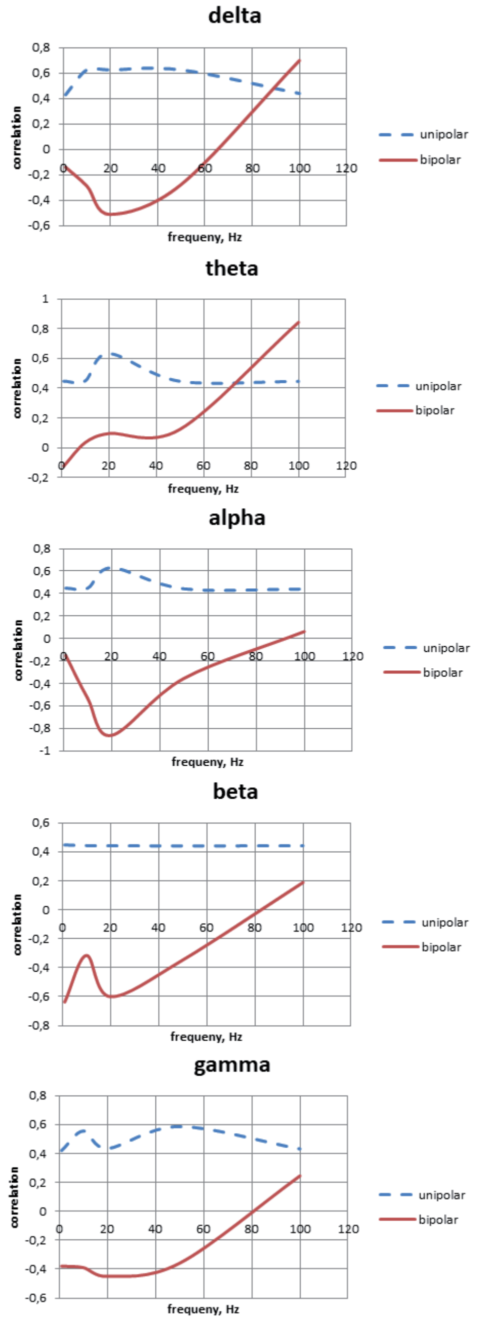



FIGURE 3. Dependence of the correlation coefficient on frequency

30–60 Hz. The values of correlation coefficients for beta and gamma rhythms are approximately within the same limits, but the dependence is monotonous. For a bipolar signal, the situation is significantly different. For theta rhythm at frequencies up to 20 Hz, the correlation coefficient is close enough to 0, and then gradually increases to 0.8 at 100 Hz. For all other rhythms, the correlation coefficient in the frequency range of 0.25–70 Hz is negative. The maximum modulus values are for the frequencies 15–25 Hz, and then they gradually decrease to almost zero values. At frequencies 80–100 Hz correlation coefficient changes its sign and then gradually increases to 0.2.

The next stage was the study of the correlation coefficient dependence on the pulse duration for cases of unipolar (Fig. 4a) and bipolar signal (Fig. 4b). The frequency of the oscillator was 1 Hz. On the diagrams it is visible, that for the delta rhythm this dependence in both cases has approximately the same character: the maximum on the modulus correlation coefficient corresponds to the pulse duration of 10%. It can also be argued that the polarity of the signal almost does not affect the general type of correlation coefficient dependencies for alpha and beta rhythms.

Finally, correlation coefficients for signals characteristic of class IIB devices have been calculated. In Figure 5 there are the families of graphs of correlation coefficients dependence on frequency for bipolar signals with the values of pulses of negative polarity (0.1–0.5) on the maximum amplitude of the signal. The graphs show that in the dependencies for delta and theta rhythms is not observed strongly pronounced minimums a b

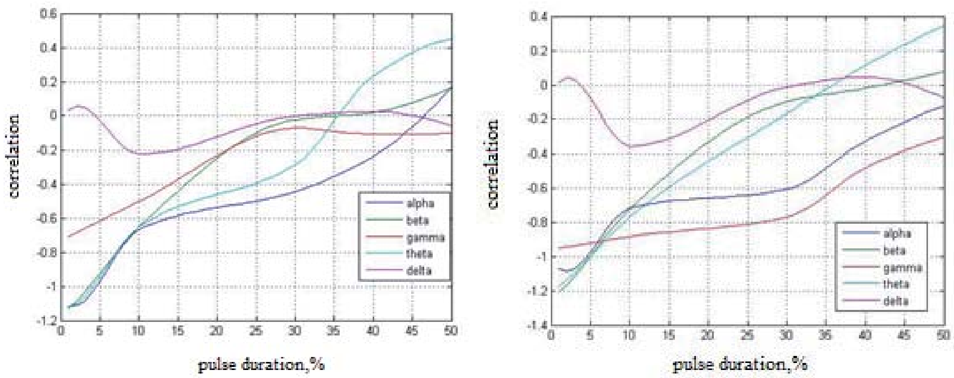



FIGURE 4. Dependencies of the correlation coefficient on the pulse duration from: a – unipolar signal; b – bipolar signal

and maximums. In the case of alpha rhythm the maximum is at 20 Hz. In beta and gamma rhythms there is a change in signs of correlation coefficients.

Figure 6 shows the graphs of correlation coefficients dependence on frequency for signals, consisting of the sequence of two pulses, the amplitude of the second pulse was (0.1–0.5) the amplitude of the first pulse. In general, the character of the graphs coincides with the graphs in Figure 5, but the values of correlation coefficients are higher.

Common to Figures 3, 5 and 6 is that the correlation coefficients reach their maximum modulus values in the frequency range of 15–25 Hz.

## Conclusions

The encephalogram was processed using the EEGLAB tool to remove artifacts. A model in the MATLAB Simulink environment was developed to evaluate the effect of the signal characteristics of electrosleep therapy devices on brain biorhythms, with the help of which correlation coefficients were calculated.

Impulse signals of different forms are investigated, in particular, the influence of repetition frequency, duration and polarity of impulses on the value of correlation coefficients is shown. It is shown that the strongest influence of the signal from electrosleep therapy devices on delta and alpha rhythms of the brain is observed. This is consistent with a study of encephalograms (Borges et al., 2020), which states that these rhythms are related to the resting state, while their stimulation promotes deep sleep and improves memory and attentiveness. In this regard, the introduction of electrosleep practices for long-distance drivers is promising, as it will contribute to improved driving safety. It is possible to increase the effectiveness of the stimulation signal by individual selection of amplitude characteristics.

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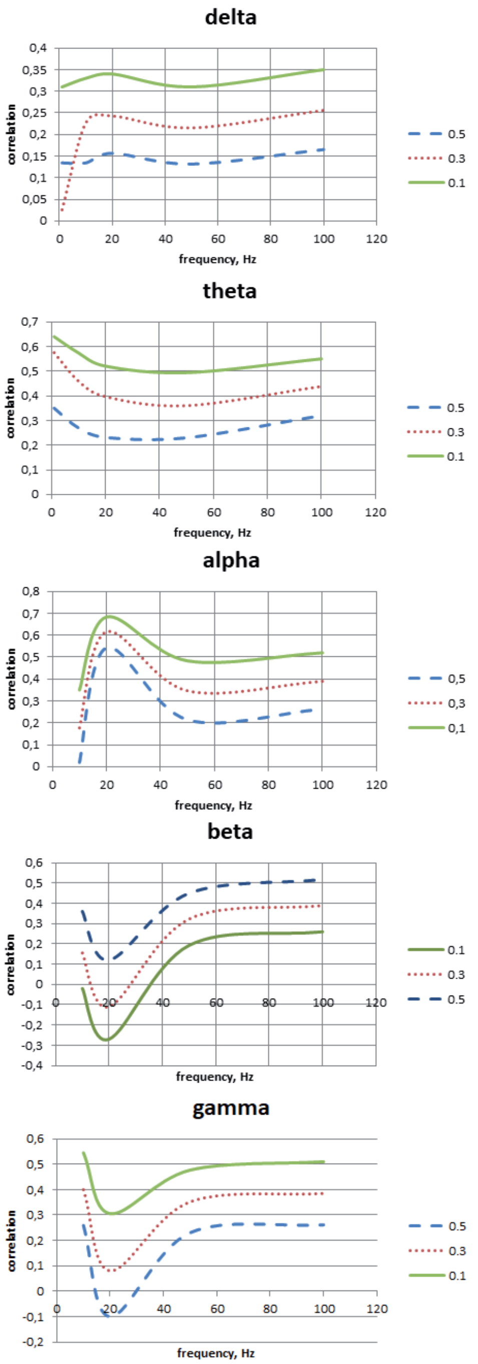


FIGURE 5. Dependencies of frequency correlation coefficients for bipolar signals of class IIB

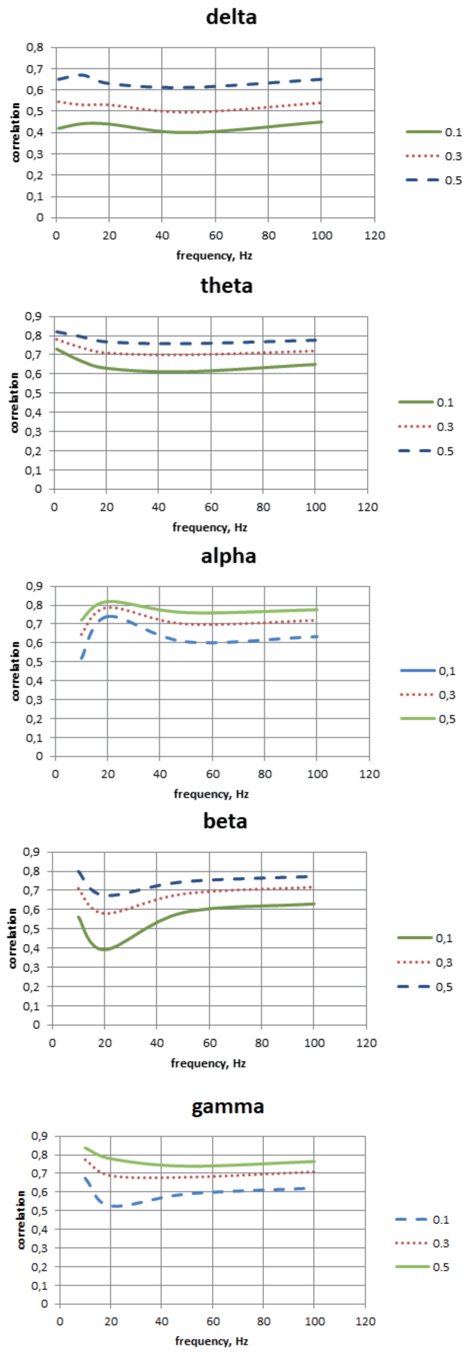


FIGURE 6. Dependencies of frequency correlation coefficients for signals consisting of a sequence of two pulses

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## Summary

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