On Some Possibilities of using Microwave Radiometry in the Analysis of Fluctuation Processes in Brain Tissue

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Abstract: The article presents pilot study of the fluctuation processes in the brain tissues. Experimental setup consists of the simultaneous record of microwave radiation in frequency range (3.4-4.2) GHz and heart rate variability signals. As the functional load the neuro-electrostimulation was used. The preliminary results have shown that the changes of the fluctuation process in brain tissues during the neuro-electrostimulation depends on the changes in the autonomic nervous system, as evaluated by heart rate variability analysis.

1 INTRODUCTION

Currently, all existing scientific ideas about the structure and principles of the human brain can be represented as follows (Nicholls, Martin, Wallace, & Fuchs, 2001).

The brain is a multilevel multifunctional central nervous system designed to receive, transmit, process and store information coming from organs, systems and the environment.

The main informational structural and functional units of the central nervous system are nerve cells (neurons) of the brain, which by connecting together using a large number of synapses form neuronal networks.

Morphofunctional systems of the brain based on neural networks provide functional cortical neurodynamic integration of various regions and brain formations of the brain (hemispheres, lobes, convolutions, etc.), which is manifested at the level of the whole brain by general bioelectric activity, oscillatory processes and magnetoencephalographic manifestations of the brain. Neurodynamic integration forms the neural network cognitive functions of the cerebral cortex.

As you gain new knowledge about the brain, paradoxical contradictions about its work appear. So in the works of A.S. Bryukhovetsky (Bryukhovetskiy, 2015) claims that the existing dogma that neural networks process information in the brain is erroneous. It has been hypothesized that the main structural element of information switching in the nervous tissue of the human brain is not a neuron, but information-commutative modules that form the vertical architecture of the nervous tissue of the human brain in the form of information lines and information channels, as well as a horizontal architecture in the form central, intermediate and peripheral information commutative. The information medium in the human brain may be the pia mater, and the system administrator and software carrier may be the arachnoid. The dimensions of the information field still require definition and refinement. Perhaps it is limited only by subarachnoid or subdural space.

Therefore, the study of the proposed phenomenon, primarily in the experiment by attracting new information-measuring methods, is undoubtedly relevant.

In this paper, we consider some of the possibilities of microwave radiothermography to solve this problem.

2 MATERIALS AND METHODS

Pilot studies of electromagnetic radiation in brain structures have been carried out, in which signals can be formed in accordance with the hypothesis of A.S. Bryukhovetsky. Five relatively healthy volunteer subjects took part in the studies. Before the experiment, each participant was informed about the progress of the experiment and agreed to participate in the experiment. During the study, microwave radiation (MR) and heart rate variability (HRV) signals were recorded.

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2.1 Experimental Setup

MR signals were recorded using an experimental MR8 radiometer. Radiometer Specifications:

- operating frequency range (3.4-4.2) GHz;
- passband of the low-pass filter 1 Hz;
- normalized fluctuation sensitivity of the radiometer 0.1 K.

The operating frequency range was chosen in order to be able to obtain information about the brightness temperature in the area of the soft and arachnoid meninges.

A radiometer with an antenna was located on the subject's head. The antenna was located in the area of the frontal lobe. The location corresponded to the F4 electrode in the international 10–20 EEG electrode placement system.

To provide protection against interference, the antenna was shielded with a metallic fabric. The experiments were carried out with the lights off. There were no mobile phones in the experiment room.

HRV signals were recorded using the corresponding recording channel of the Eencephalan-131-03 electroencephalograph-analyzer.

For neuro-electrostimulation, we used a device approved for use in Russia - the sympathetic nervous system activity corrector "SYMPATHOCOR-01"(Kublanov, 2008). One of the clinical effects of this device is to improve blood circulation in the vessels of the brain.

2.2 Timeline of the Experiment

The experiment consisted of five successive steps.

At the first stage (F), the participants sat calmly at rest without any functional load. The duration of the stage was 20 minutes.

At the second stage (S1), the participants were exposed to the "SYMPATHOCOR-01" device. The target of stimulation is the ganglia of the sympathetic nervous system. The duration of the stage was 5 minutes.

The third step (B) is a five-minute break, without any functional load.

At the fourth stage (S2), the participants were exposed to "SYMPATHOCOR-01" device. The target of stimulation is the ganglia of the sympathetic nervous system. The duration of the stage was 5 minutes.

The fifth stage (A) is the aftereffect. The duration of the stage was 10 minutes.

It is worth noting that neuro-electrostimulation causes interference on the ECG signal. Therefore, in the future, HRV signals in steps S1 and S2 were not analyzed.

2.3 Methods of Processing

Continuous wavelet analysis was chosen as the main processing method. The processing of biosignals was carried out in in-house software written in python. The main libraries used were the NumPy library for general mathematical transformations and the PyWT library for numerical computation of the continuous wavelet transform.

An eighth-order Gaussian wavelet was used as the basic wavelet. (Addison, 2005). For the HRV signal, the signal was preliminarily interpolated to a uniform time grid. Interpolation was carried out using the linear interpolation method. The grid pitch was 0.25 s.

For each biosignal, a wavelet analysis was performed in certain time-frequency windows. The following center frequencies of the spectral filters (0.03, 0.02, 0.01, 0.006, 0.005) Hz were selected for the MR signal. These frequencies correspond to fluctuations with periods of 30 s, 50 s, 100 s, 150 s, 200 s, respectively.

For the HRV signal, spectral analysis was performed in the ranges HF, LF, and VLF (Malik, 1996). In addition, two VLF subbands with central frequencies of 0.01 and 0.02 Hz, which are associated with a change in cognitive loads, were analyzed. (Togo, Kiyono, Struzik, & Yamamoto, 2006).

As a result of using the wavelet transform, wavelet spectrograms were obtained. An example of the obtained spectrograms for the MR signal and the HRV signal for one of the subjects is presented in Figures 1 and 2, respectively. Vertical black lines indicate the boundaries of the stages of the experiment.

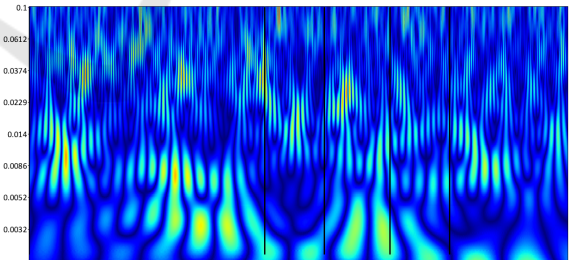

Figure 1: Wavelet-spectrogram of the MR signal.

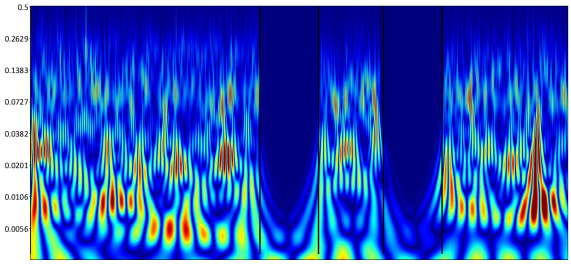

Figure 2: Wavelet-spectrogram of the HRV signal.

After obtaining wavelet spectrograms, the inverse wavelet transform was carried out in the frequency ranges of interest. Examples of signals after the inverse wavelet transform are shown in Figures 3 and 4, respectively.

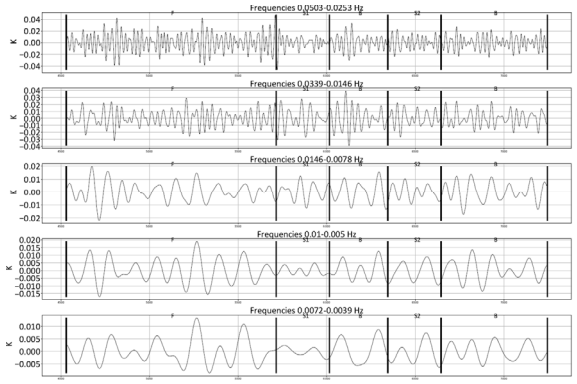

Figure 3: Inverse Wavelet-transform of the MR signal.

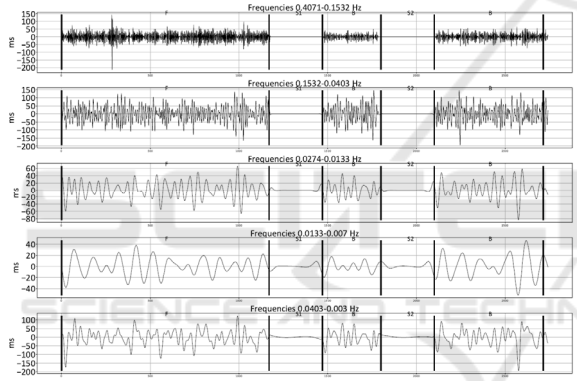

Figure 4: Inverse Wavelet-transform of the HRV signal.

3 RESULTS

To assess changes in the nature of fluctuations, a window estimate of the amplitude of the received signals was performed. For this, the standard deviation of the signals obtained as a result of applying the inverse wavelet transform was estimated. The width of the window in which the standard deviation was estimated was 60 seconds. At the same time, the window step was 30 seconds.

Tables 1 and 2 show the average values of the fluctuation amplitude estimates for the MR and HRV signals, respectively. In tables 1 and 2, column T denotes frequency windows (and their corresponding fluctuation periods).

In tables 1 and 2, bold marked significant changes in the amplitude of the fluctuations.

It should be noted that for different subjects' different changes in the nature of fluctuations of MR signals were observed depending on changes in the HRV signal.

Table 1: MR Spectral Powers (K).

		Stage of the Experiment				
	T	F	S1	B	S2	A
Subject 1	30	0.0068 ± 0.0022	0.0079 ± 0.0013	0.0097 ± 0.0047	0.0052 ± 0.0014	0.0063 ± 0.0015
	50	0.006 ± 0.0014	0.0072 ± 0.0012	0.0072 ± 0.0027	0.0047 ± 0.0007	0.0062 ± 0.0019
	100	0.003 ± 0.0011	0.0029 ± 0.0006	**0.0022 ± 0.0006**	0.0024 ± 0.0013	0.0025 ± 0.0008
	150	0.0021 ± 0.0009	0.0031 ± 0.0008	**0.0015 ± 0.0005**	0.003 ± 0.0004	0.0021 ± 0.001
	200	0.0013 ± 0.0006	0.0016 ± 0.0006	0.002 ± 0.0006	0.0017 ± 0.0003	0.0017 ± 0.0007
Subject 2	30	0.0068 ± 0.0027	0.0055 ± 0.0009	0.0078 ± 0.0024	0.0070± 0.0015	0.0075 ± 0.0019
	50	0.0064 ± 0.0017	0.0048 ± 0.0014	0.0052 ± 0.0032	0.0056 ± 0.0019	0.0062 ± 0.0012
	100	0.0032 ± 0.0013	0.0031 ± 0.0011	**0.0018 ± 0.0006**	0.0027 ± 0.0024	0.0032 ± 0.0017
	150	0.0027 ± 0.0011	0.0025 ± 0.0013	**0.0019 ± 0.0009**	0.0028 ± 0.0017	0.0029 ± 0.0015
	200	0.0018 ± 0.0007	0.0021 ± 0.0009	0.0014 ± 0.0009	0.0018 ± 0.0006	0.0020 ± 0.0009
Subject 3	30	0.0074 ± 0.0022	0.0049 ± 0.0011	0.0067 ± 0.0013	0.0083 ± 0.0027	0.0059 ± 0.0019
	50	0.0065 ± 0.0021	0.0046 ± 0.0008	0.0075 ± 0.0017	0.0057 ± 0.002	0.0059 ± 0.0022
	100	0.0034 ± 0.0013	0.0031 ± 0.0009	0.0029 ± 0.0015	0.0018 ± 0.0008	0.0024 ± 0.0007
	150	0.0025 ± 0.0019	0.0023 ± 0.0005	**0.0018 ± 0.0005**	**0.0013 ± 0.0007**	**0.0013 ± 0.0003**
	200	0.0017 ± 0.0012	0.0018 ± 0.0011	0.0017 ± 0.0009	0.0015 ± 0.0005	0.0009 ± 0.0004
Subject 4	30	0.0074 ± 0.0024	0.0054 ± 0.0033	0.0059 ± 0.0019	0.0053 ± 0.001	0.0054 ± 0.0012
	50	0.0054 ± 0.0018	**0.0063 ± 0.0021**	**0.0071 ± 0.0025**	0.0050 ± 0.0013	0.0053 ± 0.0014
	100	0.003 ± 0.0015	0.0027 ± 0.0009	0.0033 ± 0.001	0.0026 ± 0.0007	0.0031 ± 0.0011
	150	0.0031 ± 0.0014	**0.0011 ± 0.0003**	0.0026 ± 0.0009	0.0024 ± 0.0004	0.0028 ± 0.001
	200	0.0019 ± 0.001	**0.0006 ± 0.0003**	0.0018 ± 0.0007	0.0016 ± 0.0005	0.0014 ± 0.0004
Subject 5	30	0.0083 ± 0.0023	0.0082 ± 0.0024	0.0068 ± 0.0016	0.0071 ± 0.0021	0.0062 ± 0.0014
	50	0.0062 ± 0.0015	0.0058 ± 0.0014	0.0059 ± 0.0012	0.0046 ± 0.0013	0.0075 ± 0.0025
	100	0.0021 ± 0.001	0.002 ± 0.0004	0.0025 ± 0.0009	0.0023 ± 0.0006	0.0028 ± 0.001
	150	0.0013 ± 0.0007	**0.0026 ± 0.0006**	0.0018 ± 0.0014	0.0021 ± 0.0012	**0.0025 ± 0.0007**
	200	0.0013 ± 0.0005	**0.0022 ± 0.0005**	0.0018 ± 0.0009	0.0023 ± 0.0009	0.0014 ± 0.0006

Table 2: HRV Spectral Powers (ms).

		Stage of the Experiment				
	T	F	S1	B	S2	A
Subject 1	HF	8.5 ± 1.6	-	7.54 ± 0.69	-	8.26 ± 1.08
	LF	17.38 ± 6.38	-	15.57 ± 5.52	-	19.82 ± 6.14
	50	5.06 ± 2.43	-	4.8 ± 1.97	-	**7.72 ± 2.84**
	100	4.85 ± 1.75	-	**7.2 ± 2.6**	-	4.98 ± 2.25
	VLF	13.04 ± 5.15	-	13.85 ± 4.8	-	15.42 ± 4.3
Subject 2	HF	3.36 ± 0.65	-	3.2 ± 0.54	-	3.53 ± 0.38
	LF	4.03 ± 1.81	-	5.13 ± 2.25	-	5.75 ± 1.75
	50	1.86 ± 0.57	-	**3.04 ± 1.17**	-	**2.77 ± 1.25**
	100	1.35 ± 0.55	-	**2.88 ± 1.46**	-	**2.3 ± 0.84**
	VLF	4.31 ± 1.85	-	7.75 ± 4.2	-	6.87 ± 3.27
Subject 3	HF	5.03 ± 1.46	-	4.81 ± 0.55	-	**12.45 ± 10.47**
	LF	9.94 ± 4.49	-	**13.9 ± 4.86**	-	**22.46 ± 8.05**
	50	6.69 ± 3.39	-	6.03 ± 1.52	-	9.8 ± 4.13
	100	3.32 ± 1.31	-	2.7 ± 0.98	-	5.94 ± 2.63
	VLF	12.24 ± 6.7	-	11.68 ± 4.13	-	**18.85 ± 7.84**
Subject 4	HF	13.55 ± 1.82	-	**9.04 ± 1.1**	-	12.17 ± 1.7
	LF	25.55 ± 6.45	-	29.97 ± 6.33	-	26.44 ± 6.54
	50	10.57 ± 3.9	-	12.06 ± 2.47	-	12.22 ± 5.55
	100	6.74 ± 2.95	-	**4.37 ± 2.2**	-	8.43 ± 3.5
	VLF	22.64 ± 8.96	-	20.15 ± 6.66	-	24.03 ± 11.65
Subject 5	HF	2.63 ± 0.43	-	2.75 ± 0.43	-	2.95 ± 0.66
	LF	4.98 ± 1.34	-	4.48 ± 1.22	-	3.83 ± 1.04
	50	3.07 ± 1.15	-	2.68 ± 0.56	-	3.05 ± 1.44
	100	3.29 ± 1.42	-	**2.41 ± 1.17**	-	**1.07 ± 0.58**
	VLF	8.49 ± 3.2	-	6.69 ± 2.85	-	5.4 ± 2.35

So for the first subject, an increase in the amplitude of oscillations was noted with periods of 100 seconds during the break and with periods of 50 seconds during the aftereffect for the HRV signal. At the same time, significant changes were noted in the MR signal during the break for periods of fluctuations of 100 and 150 seconds.

For the third subject, a significant increase in fluctuations was observed in the LF range during the break and during the aftereffect. For the MR signal, a significant decrease in amplitude was noted for periods of fluctuations of 150 seconds after the break.

For the fourth subject, there was a significant decrease in fluctuations in the HF range and fluctuations with a period of 100 seconds during a break for the HRV signal. Moreover, in the MR signals, a decrease in amplitude was noted during the first stimulation for periods of fluctuations of 150 and 200 seconds. An increase in the amplitude of fluctuations with a period of 50 seconds was also noted during the first stimulation and interruption.

4 CONCLUSIONS

The article presents pilot study of the fluctuation processes in the brain tissues. Experimental setup consists of the simultaneous record of microwave radiation in frequency range (3.4-4.2) GHz and heart rate variability signals. As the functional load the neuro-electrostimulation was used. The preliminary results have shown that the changes of the fluctuation process in brain tissues during the neuro-electrostimulation depends on the changes in the autonomic nervous system, as evaluated by heart rate variability analysis.

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