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MATHEMATICAL MODEL OF THE 24-HOUR EEG SIGNAL OF PEOPLE WITH MANIFESTATIONS OF EPILEPSY FOR COMPUTER EEG SYSTEMS

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Epilepsy is one of the most common chronic diseases of the human brain, which manifests itself in the form of epileptic seizures.

In epilepsy of the focal type, pathological bioneuron activity is limited in certain areas of the brain, and in epilepsy of the generalized type, it is localized in all areas of the brain (Fig. 1).

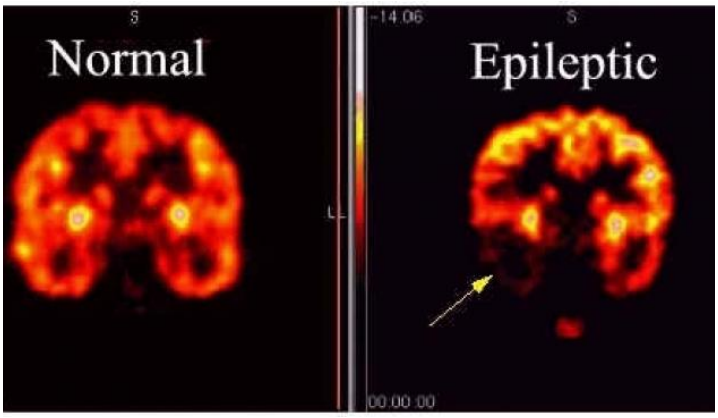

Figure 1. The state of the brain in a normal state and in epilepsy

One of the effective methods of detecting epileptic seizures in medical diagnostics is electroencephalography, which is based on the registration of brain biopotentials in the form of EEG signals using computer electroencephalographic systems [1, 2, 3].

A 24-hour study of human brain activity using the EEG method makes it possible to detect missed manifestations of epileptic seizures (duration and intensity), which in most cases can be missed. This method of medical and biomedical research within 24 hours is also relevant for various fields of medicine [5-9, 13-15].

Algorithmic software and methods of processing EEG signals [4, 10, 12] in computer electroencephalographic systems are implemented on mathematical models of EEG signals.

Known models of EEG signals (periodic process, almost periodic process, stationary random process) during 24 hours do not provide a constructive consideration of the interdependencies of the variation of the parameters of the studied signals, which occur in the time space before birth, during the manifestations and after the disappearance of the manifestations of epilepsy.

Therefore, the development of a new mathematical model of the EEG signal within 24 hours for computer electroencephalographic systems, which will provide the study of the interdependence of the variation of the parameters of the studied signal in time space for the detection of hidden manifestations of epilepsy in people, is an urgent task.

The structure of the realization of the EEG signal during the manifestation of epilepsy in different stages (periods) is characterized by the dominance of a certain type of signal oscillations of the frequency range $\left[f_1; f_2\right]$ against the background of other frequencies. The upper f_1 and lower f_2 limits of the frequency range vary depending on the type of epilepsy [Pedley T.A., Daly D.D., 1997; Kaibara M., Blume W.T., 1999]: Lennox-Gastaut syndrome (1.5-2 Hz), juvenile absence epilepsy (2-4 Hz), idiopathic generalized epilepsy (3-5 Hz) and others.

The real implementation of the EEG signal recorded over 24 hours is shown in Fig. 2 (the signal data is taken from the open database on the website http://www.physionet.org).

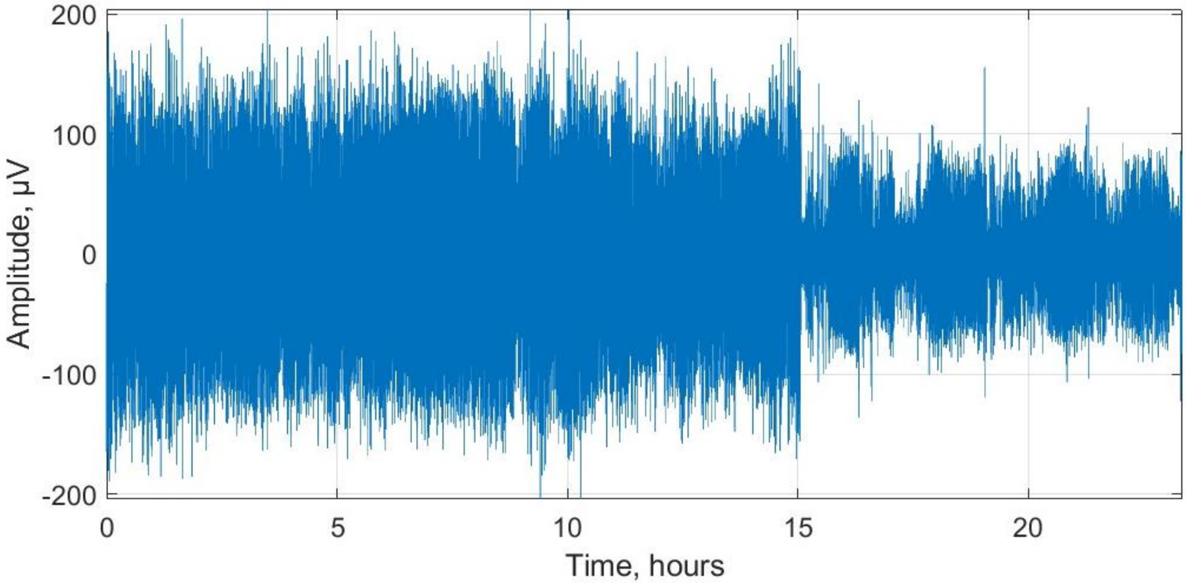

Figure 2. Real implementation of the EEG signal during 24 hours from the open database of the site http://www.physionet.org

Short-term fragments of the implementation of EEG signals determined by the visual method without cases of epilepsy and during the period of epilepsy in the form of epileptiform activity are shown in Fig. 3-4.

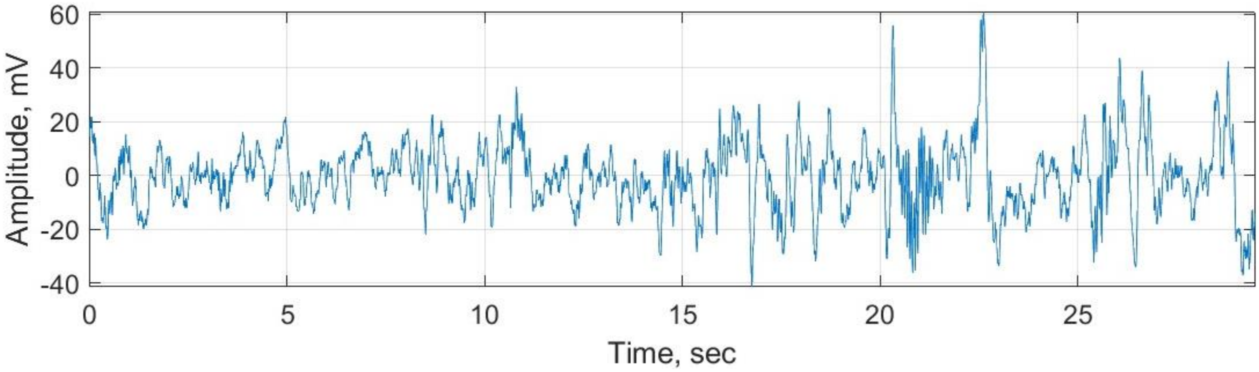

Figure 3. Short-term fragments of the realization of a real EEG signal without the manifestation of epileps

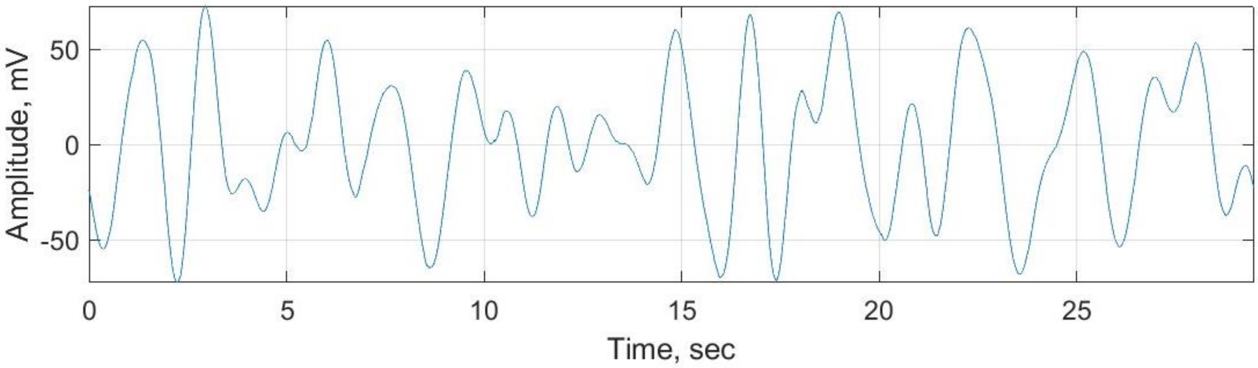

Figure 4. Short-term fragments of the realization of a real EEG signal with the manifestation of epilepsy

On the assumption that the EEG signal without epilepsy has the parameters and form of white noise, and during the period of manifestations of epilepsy it has special features of a set of harmonic components, the time structure of the EEG signal during 24 hours during the manifestation of epilepsy is shown in Fig. 5.

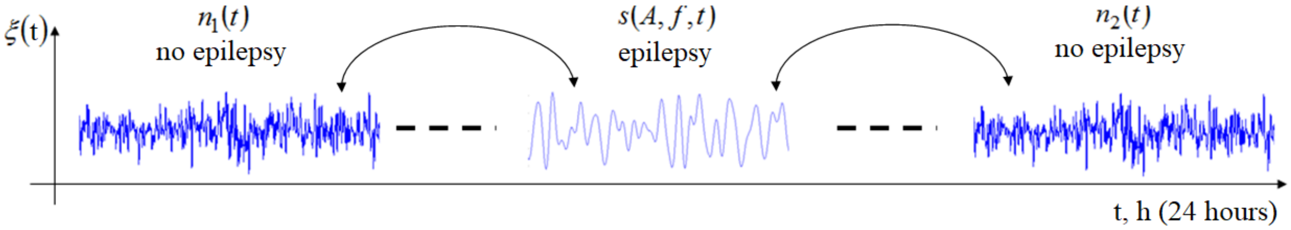

Figure 5. The temporal structure of the EEG signal during 24 hours during the manifestation of epilepsy

Taking into account such an assumption, the mathematical model of the EEG signal during 24 hours with time fragments of epilepsy is presented in the form of an additive mixture of harmonic (oscillating) functions with basic frequencies $f = [f_1; f_2]$ and a piecewise stochastic sequence of white noise (the area of temporal localization of the components of the model is stochastic):

$$\xi(t) = n_1(t) \cup s(A, f, t) \cup n_2(t) \ldots \cup s(A, f, t), \quad t \in \mathrm{R} \qquad (1)$$

where $n_1(t), n_2(t)$ – EEG signal in the form of white noise during the period without epilepsy;

$s(A, f, t)$ – EEG signal during the manifestation of epilepsy in the form of an additive mixture of harmonic components with frequencies in the range $f = [f_1; f_2]$ (in the case of manifestations of epilepsy, the implementation of the EEG signal is dominated by additive harmonic components of the signal with frequencies from f_1 Hz to f_2 Hz in the form of spike-like waves (epileptiform activity):

$$s(A, f, t) = \sum_{k=1}^{K} A_k \sin(2\pi f_k t), \qquad t \in \mathrm{R} \qquad (2)$$

where A_k – the value of the amplitudes of the harmonic components of the *k*-th functions (for all components *A*=1);

f_k – is the value of the base frequency of the *k*-th functions. The base frequency is the frequency of the harmonic function $s(A, f, t)$ (in the case of epilepsy, these frequencies are dominant against the background of other frequencies) (the frequency can be determined using the method given in the work [11]).

The duration of the components $n_1(t)$, $n_2(t)$ and $s(A, f, t)$ is variable and not predetermined.

The localization sequence of the harmonic components of the EEG signal in expression (2) is stochastic.

Since M times the number of time fragments with manifestations of epilepsy can be observed within 24 hours, expression (2) is presented in the form of a set:

$$\xi(t) = \bigcup_{m=1}^{M} \left(n_m(t) \cup \theta_m \cdot s_m(A, f, t)\right), \qquad t \in \mathrm{R} \qquad (3)$$

where $n_m(t)$ – *m*-time zone of the EEG signal in the form of white noise without epilepsy;

θ_m - an unknown parameter that can take two values ($\theta_m \in \{0,1\}$):

- θ_m =1 (the m-th time fragment of the EEG signal of the manifestation of epilepsy);
- θ_m =0 (*m*-th temporal fragment of the EEG signal in the absence of epilepsy).

The model of the EEG signal in the form of expression (3) reduces the problem of detecting the manifestation of epilepsy to the task of detecting the m-th temporal fragments of the EEG signal (the beginning and the end of the manifestation of epilepsy) on which the dominant harmonic components $\theta_m \cdot s_m(A, f, t)$ are localized at θ_m =1.

The model of the EEG signal in the form of a set of piecewise stochastic sequence of white noise (signal without epilepsy) and an additive mixture of harmonic functions of different frequencies (signal with epilepsy) makes it possible to develop algorithmic and software tools for processing the EEG signal during 24 hours in order to detect time points and intervals of epilepsy in humans.

References:

1. Liang S.F., Wang H.C., Chang W.L. (2010) Combination of EEG complexity and spectral analysis for epilepsy diagnosis and seizure detection. EURASIP Journal on Advances in Signal Processing, 853434. DOI: https://doi.org/10.1155/2010/853434

2. Smith S J M. (2005) EEG in the diagnosis, classification, and management of patients with epilepsy. J Neurol Neurosurg Psychiatry 2005;76(Suppl II):ii2–ii7. doi: 10.1136/jnnp.2005.069245.

3. Liman MNP, Al Sawaf A. Epilepsy EEG. 2023 May 1. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan. PMID: 32644338.

4. Khvostivskyy M.O., Pankiv I.M., Fuch O.V., Khvostivska L.V., Boyko R.R., Dunetc V.L., Kartashov V.V. Method and Algorithm of Electroencephalographic Signals Processing in Computer Medical Diagnostic Systems for Human Psychoemotional Indicators Detection. Visnyk NTUU KPI Seriia - Radiotekhnika Radioaparatobuduvannia, (91), pp. 63-71. DOI: 10.20535/RADAP.2023.91.63-71.

5. Hvostivska L., Oksukhivska H., Hvostivskyy M., Shadrina, H. (2019) Imitation Modeling of the Daily Pulse Signal for Long-Term Monitoring Systems [Імітаційне моделювання добового пульсового сигналу для задачі верифікації алгоритмів роботи систем довготривалого моніторингу]. Visnyk NTUU KPI Seriia - Radiotekhnika Radioaparatobuduvannia. 77 (Jun. 2019), 66-73. DOI:https://doi.org/10.20535/RADAP.2019.77.66-73.

6. Hvostivska L., Hvostivskyy M. Synthesis structure of information system of registration and processing of pulse signal [Синтез структури інформаційної системи реєстрації та обробки пульсового сигналу]. Scientific Bulletin of Chernivtsi University: Collection of Science. works. Physics. Electronics. Vol 4, Issue. 1. Chernivtsi: Chernivtsi National University, 2015. P. 83-89. ISSN 2227-8842

7. Khvostivskyi M.O. A mathematical model of macromechanism of forming of electroretinosignal is for the increase of authenticity of the oftalmodiagnostic systems [Математична модель макромеханізму формування електроретиносигналу для підвищення достовірності офтальмодіагностичних систем]: abstract of the dissertation for obtaining the scientific degree of candidate of technical sciences: 01.05.02. Ternopil, 2010. 20 p.

8. Palaniza Y.B. Shadrina H.M., Khvostivskiy M.O., Dediv L.Ye., Dozorska O.F. Main theoretical basis of biosignals modeling. Znanstvena misel in Slovenia: journal. Ljubljana. 2018. №16. Vol.1. pp. 39-44.

9. Mathematical and computer modeling of the electrocardiosignal in Holter monitoring systems [Математичне та комп’ютерне моделювання електрокардіосиґналів у системах голтерівського моніторинґу] / L.Ye. Dediv,

A.S. Sverstiuk, I.Yu. Dediv, M.O. Khvostivskyi, V.G. Dozorskyi, Ye.B. Yavorska. Lviv: "Magnolia-2006" Publishing House, 2021. 120 p.

10. Franchevska H.I., Khvostivsky M.O. (2019) Analysis of known methods of analysis of electroencephalosignal in epileptic seizures [Аналіз відомих методів аналізу електроенцефалосигналу при епілептичних нападах]. Actual problems of modern technologies: book of abstracts of the IV International scientific and technical conference of young researchers and students (Tern., 27-28 November 2019), vol. 1, pp. 157.

11. Hvostivska L.V., Osukhivska H.M., Hvostivskyy M.O., Shadrina H.M., Dediv I.Yu. Development of methods and algorithms for a stochastic biomedical signal period calculation in medical computer diagnostic systems [Розвиток методів та алгоритмів обчислення періоду стохастичних біомедичних сигналів для медичних комп’ютерно-діагностичних систем]. Visnyk NTUU KPI Seriia - Radiotekhnika Radioaparatobuduvannia, (79), pp. 78-84. doi: 10.20535/RADAP.2019.79.78-84.

12. Khvostivsky M.O., Khvostivska L.V., Boyko R.R. Development of mathematical support for computer systems for detecting epileptic manifestations in humans [Розвиток математичного забезпечення комп’ютерних систем виявлення епілептичних проявів у людини]. III International Scientific and Practical Conference "Information Systems and Technologies in Medicine" (ISM-2020): Coll. Science. Kharkiv Avenue: Nat. aerospace Univ. ME Zhukovsky "Kharkiv. aviation. Inst. ", 2020. pp.90-91.

13. Dragan Ya.P. Osukhivska H.M., Khvostivskyi M.O. Justification of the mathematical model of the electroretinographic signal in the form of a periodically correlated random process [Обґрунтування математичної моделі електроретинографічного сигналу у вигляді періодично корельованого випадкового процесу]. Computer printing technologies. - Lviv: Ukrainian Academy of Printing, 2007. Vol.18. pp.129-138.

14. Hvostivska L. (2016) Phase-time structure of the pulse wave as an indicator of stiffness of vessels [Фазово-часова структура пульсової хвилі як показник стану ригідності судини людини]. Materials of the XIX scientific conference of TNTU (Tern., 18-19 May 2016), pp. 126-127.

15. Khvostivskyi M.O., Khvostivska L.V. Development of mathematical models and methods of pulse signal analysis for computer systems for diagnosing the state of human vessels [Розвиток математичних моделей та методів аналізу пульсового сигналу для комп’ютерних систем діагностики стану судин людини]. II International Scientific and Practical Conference "Information Systems and Technologies in Medicine" (ISM-2019) [Text]: coll. of science pr. Kharkiv: National. aerospace University named after M. E. Zhukovsky "Kharkiv. aviation Institute of Technology", 2019. pp.61-63