ANALYSIS OF EPILEPTIC SIGNALS BASED ON DISCRETE HARTLEY TRANSFORM AND DISCRETE FOURIER TRANSFORM

A. Horiushkina and Y. Breslavets

Abstract— In this paper, the proposed approach to the problems of assessing the rhythms of the brain develops an analysis is made of the existing features of processing neurological signals. For the analysis of epileptic discharges, which are the focus of work, it is proposed to use orthogonal transformations. This was done on the basis of a reasoned model of epileptic discharges as a class of broadband pulse signals. The analysis of the main features of the discrete Fourier and Hartley transforms is presented as the main methods of signal processing in the case of epileptic seizures is carried out. The results of the analysis of the real, containing a fragment of the epileptic discharge of the EEG record obtained on the basis of the proposed approach are presented.

Keywords— *EEG signals, Dıscrete Fourier transform, Dıscrete Hartley transform, processing, simulation*

I. INTRODUCTION

THE problem of epilepsy is one of the most common neurological chronic diseases that affects a large number of people around the world. Statistics show that today the risks of sudden epilepsy are increase. Such cases often lead to premature death. Epilepsy is a sudden periodic disruption in the brain, associated with the hyper synchronization of electrical activity of neurons. A distinctive feature of epilepsy are repeated seizures-discharges. Attacks occur accidentally, disrupting the normal functioning of the brain in an unpredictable manner. Figure 1 shows an example of EEC record with an explicitly distinguishable [1-7]. Currently, the main means of neuroimaging used to detect epileptic discharges are EEG (electroencephalography), MEG (magnetic-encephalography), and more recently also MRI (magnetic resonance imaging).

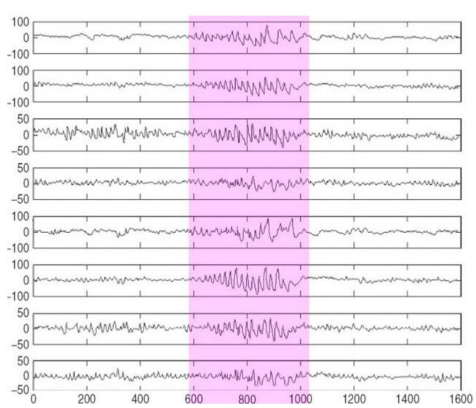

Fig. 1 EEC record with an explicitly distinguishable.

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However, the number of MRI machines is limited, they are expensive and scanning with them takes a long time. From MEG, on the other hand, due to sensitivity to the mobility of the patient, to other artifacts, it is difficult to obtain clear data, especially in moderate and severe cases. That is why, the EEG remains is a most useful and cost-effective method for studying epilepsy.

Researching's show, there are methods of processing signals that allow quickly and accurately process and transmit incoming information to the devices. Such representatives are the Dıscrete Fourier transform and the Dıscrete Hartley transform. Analysis of the literature shows that good results can be obtained with the aid of orthogonal transformations. Therefore, the issue of quality, informative signal processing in the case of epileptic seizures is topical [1-13].

II. METHODS OF PROCESSING EEG SIGNALS

In this article, for processing neurological signals, orthogonal transformations are taken as a basis. We will analyse the main transformations, namely, the Dıscrete Fourier transform and the Hartley discrete transformation [6].

A) THE DISCRETE FOURIER TRANSFORM (FFT) is one of the transforms widely used in digital signal processing algorithms, as well as in other areas related to the analysis of frequencies in a discrete signal. The discrete Fourier transform requires a discrete function as an input. Such functions are often created by sampling, namely sampling values from continuous functions.

Providing the analyse of some properties of the discrete Fourier transform

1. Linearity. If we take some linear combination of functions, then the Fourier transform of this combination will be the same linear combination of the Fourier images of these functions. This property allows you to reduce complex functions and their Fourier images to simpler ones.

2. Independence of the amplitude spectrum from the time shift of the signal. With moving of the function to the left or right along the x axis, only its phase spectrum will change.

3. Extension of the original function along the time axis (x) proportionally compresses its Fourier image on the frequency scale (w). The signal spectrum of finite duration is always infinitely wide and vice versa, the spectrum of finite width always corresponds to a signal of unlimited duration.

4. Convolution of functions which allow to reduce the convolution of functions to the pointwise multiplication of their Fourier transforms and vice versa - pointwise multiplication of functions to the convolution of their Fourier transforms.

5. Symmetry. In particular, it follows from this property that in the Fourier transform of a real-valued function, the amplitude spectrum is always an even function, and the phase spectrum is odd.

6."Energy" of the signal. It is meaningful only for signals of finite duration, the energy of which is finite, and indicates that the spectrum of such signals at infinity rapidly approaches zero. It is by virtue of this that properties on the spectra graphs are usually represented only by the "main" part of the signal, which carries the lion's share of energy - the rest of the graph simply tends to zero.

It is proved that if some periodic function with period 2T on interval [-*T*, *T*] satisfies the *Dirichlet* conditions (is continuous and has a finite number of extrema and points of discontinuity of the first kind), then it can be being represented as the sum of a Fourier series (expanded in a Fourier series):

$$f(x) = a_0 + \sum_{n=1}^{\infty}(a_n \cos\frac{n\pi x}{T} + b_n \sin\frac{n\pi x}{T}) \quad (1)$$

To determine the coefficients of the Fourier series, the following formulas:

$$a_n = \frac{1}{T}\int_{-T}^{T} f(x)\cos\frac{n\pi x}{T}dx$$
$$b_n = \frac{1}{T}\int_{-T}^{T} f(x)sin\frac{n\pi x}{T}dx \quad (2)$$

If the decomposable function is even ($f(-x) = f(x)$), then the Fourier series consists only of cosines, that is, all the coefficients of the signs are 0. If the decomposable function is odd ($f(-x) = -f(x)$), then the Fourier series consists only of sines, that is, all the coefficients of the cosines are 0. In general, the coefficients of sines and cosines are not equal to 0. Thus, any periodic function satisfying the *Dirichlet* conditions, can be expanded in a Fourier series, thereby representing it in the form of a sum of sines and cosines. The spectrum of a discrete periodic signal can be calculated at help of a discrete Fourier transform (DFT) [8].

To determine the amplitudes and phases of the frequency components of the signal, in discrete Fourier transform uses the basic functions of the sine and cosine. The spectrum of frequencies in a discrete Fourier transform is determined from amplitudes of sines and cosines, with repetition frequencies in the studied.

Discrete Fourier transform descrıbıng by formula:

$$X_k = \frac{1}{N}\sum_{i=0}^{N-1} x_n e^{-j\frac{2\pi ki}{N}} = = \frac{1}{N}\sum_{i=0}^{N-1} x_n\left[\cos\frac{2\pi ki}{N} - j\sin\frac{2\pi ki}{N}\right] \quad (3)$$

The sample is from 0 to N / 2 times, where N - is the number of sample elements. The Fourier transform decomposes a sampled signal from N counts on N / 2 + 1 sine and N / 2 + 1 cosine components.

B) THE DISCRETE HARTLEY TRANSFORM (DHT) is a kind of orthogonal trigonometric transformation. In many cases it can serve as a substitute for a transformed into a sequence *N* of real numbers H_0, H_1, ..., H_{N-1} by means of the Hartley transform according to the formula:

$$H_k = \frac{1}{N}\sum_{n=0}^{N-1} h_n cas\left(\frac{2\pi}{N}nk\right), k = 0,..., N-1 \quad (4)$$

From the figures 2, 3 can be seen that in the DFT there is no block of transition of the real part to the complex the area. This reduces the time spent on this transformation. For example, with the length of the input sequence of 10 counts. We have 10 operations of multiplication each operation is realistic for 10 cycles. Each cycle lasts for 2 seconds. For a given sequence length, we have a decrease in the time of the completed conversion for 2 sec. The time spent on processing DFT and on DFT differ.

The processing time of the DPC is 2 seconds faster than the DFT. As shown by the conducted studies with an increase in the volume of data, the time spent on data processing is also reduced in the case of DHT. Mechanism of epilepsy and the way of researching by methods of spectrum analysing.

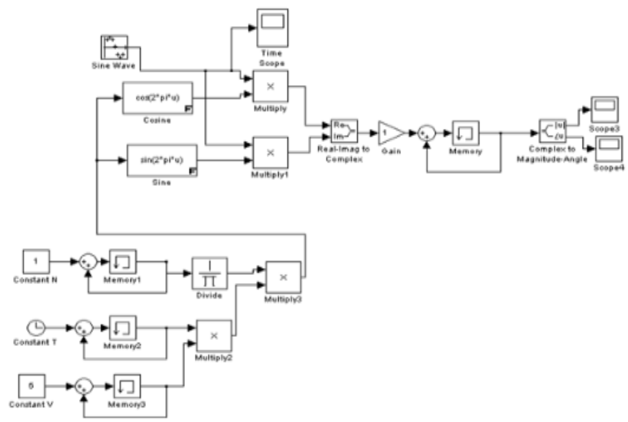

Fig. 2 – Structural scheme of discrete Fourier transform

In the Hartley definition for the transformation φ (ω), the coefficient $1/\sqrt{2\pi}$ was explicitly included to obtain a symmetric expression. Without this coefficient, then both integrals cannot simultaneously be correct. However, it should be considered inadvisable to maintain a pair of such specific coefficients, especially when performing numerical calculations. Was considered to change the function $\sqrt{2\pi}$ S (ω) instead of *S* (ω). As a result, the coefficient $1/\sqrt{2\pi}$ disappears in the definition of the direct Fourier transform, but in the formula of the inverse Fourier transform, the coefficient 1/2π became appears. Thus, intentionally sacrifice the symmetry of formulas. It is fair to say that this is an additional load for the memory, since it is necessary to remember which of the formulas contains the value 2π. One way to remember is that the coefficient 1 / 2π stands before the integral in which the differential d*ω* appears, which means the presence a quantity of the form ω/ 2π, that is, of the cyclic frequency *f* [8].

Epilepsy is a serious and fairly widespread disease of the brain.

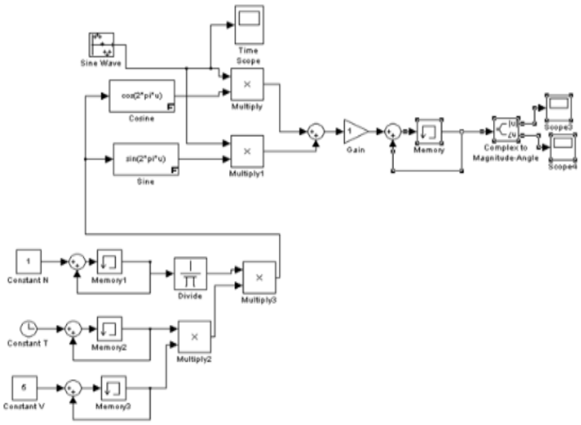

Fig. 3. Structural scheme of discrete Hartley transform

Typically, a qualitative description of the electrographic picture of discharges is given, features of the distribution of pathological activity along the areas of the cortex and other brain structures are determined, and some average quantitative estimates of epileptic seizures (mean duration of discharges, percent of time occupied by discharges and some others) are made. However, for differential diagnosis of different types of epilepsy, it is also useful to quantify the frequency-temporal organization of discharges and its dynamics for different types of epilepsy. Epilepsy is a chronic disease of the brain, characterized by repeated unprovoked attacks of motor, sensitive, vegetative, mental or psychic functions that occur due to excessive neuronal discharges [7-14].

One of the possible mechanisms for the development of epileptic form activity is due to the fact that cells generate bursts of impulses as a result of the potentiation of glutamatergic synaptic transmission and changes in calcium channel activity. The very synchronization of discharges, as is well known, is also found in normal, for example, in the generation of EEG rhythms.

Epilepsy is a chronic brain disorder characterized by repeated unprovoked attacks of motor, sensory, autonomic, mental or mental functions that occur due to excessive neuronal discharges. A common clinical sign in various forms of epilepsy is the occurrence in the brain of high-amplitude electrical discharges that are the result of simultaneous excitation of a large the number of neurons. Typically, a qualitative description of the electrographic picture of discharges is given, features of the distribution of pathological activity along the areas of the cortex and other brain structures are determined, and some average quantitative estimates of epileptic seizures (mean duration of discharges, percent of time occupied by discharges and some others) are made. However, for differential diagnosis of different types of epilepsy, it is also useful to quantify the frequency-temporal organization of discharges and its dynamics for different types of epilepsy [1-5].

One of the possible mechanisms for the development of epileptic form activity is due to the fact that cells generate bursts of impulses as a result of the potentiation of glutamatergic synaptic transmission and changes in calcium channel activity. The very synchronization of discharges is the norm, as in the generation of EEG rhythms.

There are many models for the study of epilepsy and all of them can be divided into several types - pharmacological, where a single administration of the substance provokes epileptic seizures; chemical handling, electric kindling, in which a chemical agent is used instead of a chemical agent electrostimulation by implanted electrodes; and various genetic models with some age limitations [9].

During the investigation and processing of the signal, a lot of useful information can be obtained from an analysis of its frequency characteristics. The Fourier transform (spectral analysis) represents a signal specified in the time domain in the form of an expansion in orthogonal basis functions (sines and cosines), thus allocating frequency components.

The initial data were taken when measuring the bioelectrical activity of the brain. The EEG was recorded in the laboratory. The data of the EEG signals were obtained and used in this work.

Spectral analysis is already classical methods of EEG processing. Fourier analysis allows us to judge the presence in this wave process of certain EEG rhythms and their individual expression.

Simulation of the source signals using orthogonal transformations.

For further research, signals were used that simulate the state of epileptic seizures and are also included in the mathematical simulacrum. The graphs of the original signal of the Hartley and Fourier transformations are mapped appropriately

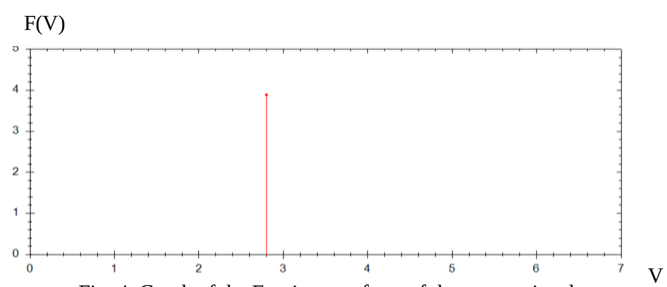

Fig. 4. Graph of the Fourier transform of the source signal

The results of the simulation were carried out in the Matlab system as well as with the help of the generated code of the C ++ program.

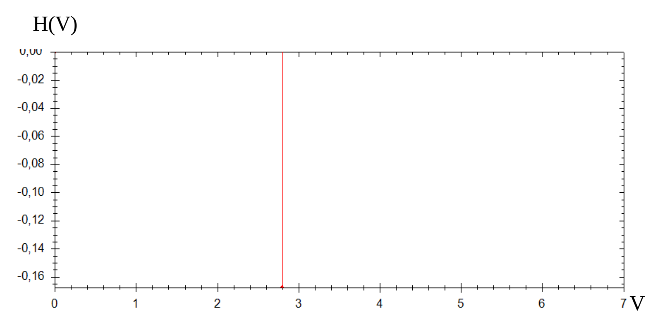

Fig. 5. Graph of the Dıscrete Hartley transform of the source signal

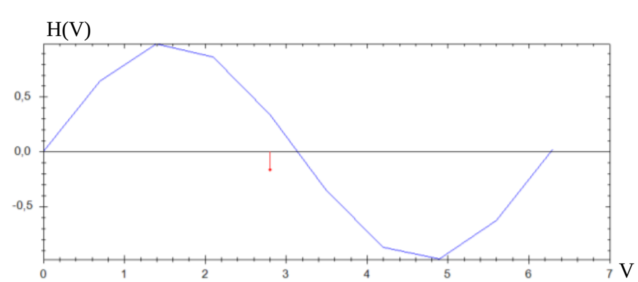

Fig. 6. Graph of the Dıscrete Hartley transform and the source signal

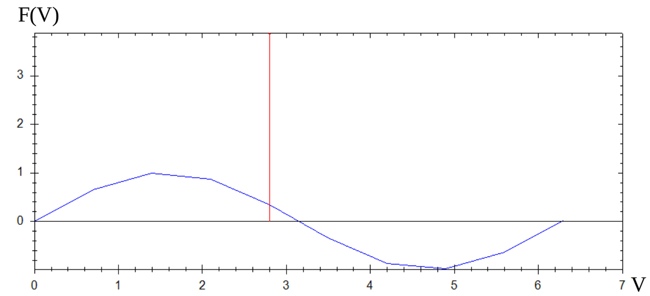

Fig. 7. Graph of the Discrete Fourier transform and source signal

The DFT vector has a physical meaning, namely, if the vector is a DFT signal, then the DFT decomposes it by frequency. Transformation Hartley does not have such a clear interpretation. Therefore, if the original data is valid, then the DHT may be larger effective than FFT. It is sometimes possible to transfer the DHT in the DFT. Avoid, and an example of such an approach is considered when multiplying long numbers [11-12].

III. CONCLUSIONS

At present, it has been established that epilepsy is not a single disease with various seizures, and is divided into separate forms – epileptic syndromes characterized by a stable relationship clinical, electrical and anatomical criterion, reaction on antiepileptic therapy and prognosis. Accordingly, the nature and severity of cognitive impairment varies with different forms of epilepsy. The aim of this work was a general study epileptic signs, mechanisms of their occurrence, the analysis of similar signals and spectral methods of their processing. The results of the research showed that discrete orthogonal transformations have good opportunities for qualitative processing of epileptic signals. In particular, two main transformations were compared, namely, the discrete Fourier transform and its analogue the discrete Hartley transformation.

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