This investigation may be useful for detection of hydrocarbon deposits by comparing the values of the input resistance of the medium layered over them, which has been calculated in the course of this research, with respect to the received practice, that may be useful in a real geological exploration.

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UDC 534.781

ANALYSIS OF FINE STRUCTURE VOWEL SOUND OF THE SPEECH SIGNAL USING WAVELET TRANSFORM

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The paper presents the comparative analysis of some mother wavelets and the investigation of the effect of varying of the frequency characteristics and the type of mother wavelet on the results of the wavelet analysis of stressed and unstressed isolated Russian language vowels of various speakers. The descriptiveness of wavelet representation of time-frequency domain of a signal is investigated on the basis of complex Morlet wavelet when changing the scale factors a u b.

A number of published works study the primary features of the speech signal: pitch frequency (a necessary criterion for determining the presence of speech in noise) and formants (the source of information not only about the speech signal, but also about the individual signs of the speaker). Known analysis methods of speech sounds are based on the spectral model of a stationary signal. However, in the speech signal the most informative features are changes of its time-frequency characteristics. To implement the analysis of both frequency and temporal characteristics of the signal it is necessary to use basic functions having properties of time-frequency localization - wavelets.

Effective methods of wavelet analysis of the fine structure of the speech signal were considered by L. Falek, A. Amrouche, L. Fergani, H. Teffahi, A. Djeradi, S. Rasskazova and others. In work [1] by V. Solov'ev, O. Rybal'skij, V. Zheleznyak, a three-dimensional Skeylogramm has been received on the basis of Morlet with the experimentally established constant parameter width of the wavelet. It represents a fragment of the phoneme "a" of the Russian language as a set of multifractal structures. However, the use of permanent settings for all wavelet transforms may significantly affect the interpretation of the results, because when you change the characteristics of the test signal you can obtain incomplete information of its fine structure. Thus, a more detailed analysis needs choosing the type of mother wavelet and its parameters. We repeated the experiment results with constant wavelet parameters for other stressed and unstressed isolated vowels of the Russian language of various speakers. And we further investigated the influence of the change of frequency characteristics and the type of mother wavelet on the results of wavelet analysis. We compared some mother wavelets and investigated descriptiveness of the wavelet representation of time-frequency domain of the signal when changing the scale factors a and b.

From the comparative analysis of known wavelet functions [2-4] (Gaussian type, "Mexican hat", Morlet and Meer) of the fine structure of the vowel sounds of the Russian language their time-frequency transformations are obtained [5]. These wavelets have a minimum of properties, which provide full opportunities in the technique of transformations, and have properties of time-frequency localization. Of all the investigated wavelet functions, complex Morlet wavelet has a narrower Fourier transform and more prolonged in the time domain (fig. 1). The presence of a dominant frequency allows varying selectivity of the complex Morlet wavelet in the frequency domain.

In the time domain complex Morlet wavelet is a complex exponent modulated by a Gaussian function. But in the frequency domain complex Morlet wavelet is shaped by Gaussian window with a central frequency f_0 and width B. Thus, the frequency range covered by the complex Morlet wavelet window is limited to an interval $\left[f_0 - B/2, f_0 + B/2 \right]$ (its bandwidth), where the largest part of its energy is concentrated. If you perform the Fourier transform of the complex Morlet wavelet, it is equal to zero for negative frequencies, which allows separating the amplitude and phasing components of signal. Complex Morlet wavelet has a close similarity to speech fragments (similar to the pulse components of no stationary signals) and has a better frequency localization among other bases, so it is the most informative in assessing the fine structure of speech signals.

Let's analyse how the shape of the mother wavelet affects the determination of the fine structure of the signal. From the speech signal recorded in normal conditions (pronounced by a male speaker sound "a" duration of 0.25 s and sampling frequency f_s – 11025 Hz) extract the fragment duration of 0.1 s, where main formants f_1, f_2 are located (fig. 2).

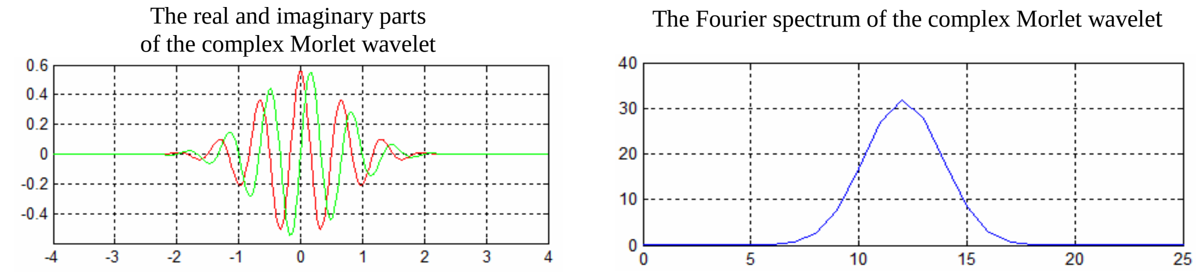


Fig. 1. Complex Morlet wavelet

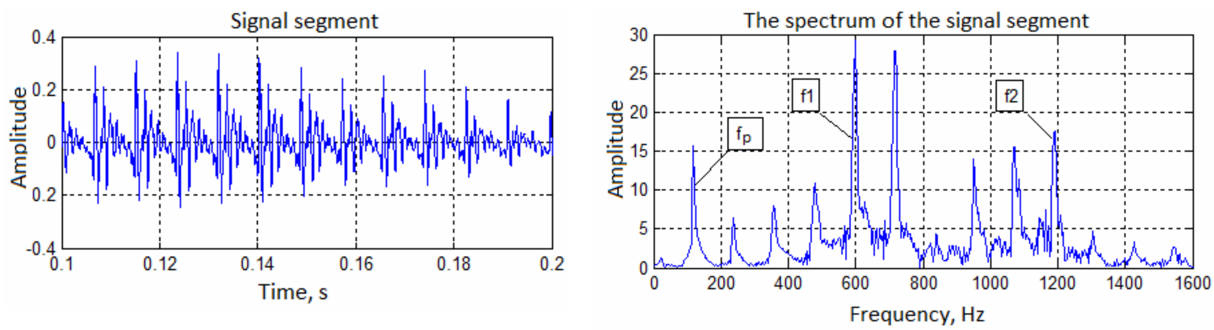


Fig. 2. The plot of the phoneme "a" in the range from 0.1 to 0.2 s

A fragment of vowel we represent as a time series with values of the function, following one another at regular time intervals Δt: $s_k = s(t_k)$, $t_k = \Delta t k$, $k = 0,1,...N-1$. Rationally set the interval of time window $\Delta t \le 20$*мс*, because in this range process can be considered as quasi-stationary. Assessment of the wavelet transform of this sequence is performed using wavelet function, and this function is computed on a set of argument values a_i and b_j, which are the scaling coefficients in frequency and time accordingly: $i = 0,1,..., N_a - 1$; $j = 0,1,..., N_b - 1$ [6]:

$$W_A(a,b) = \frac{1}{n(a,b)} \sum_{k=0}^{N-1} s_k \psi^* \left(\frac{t_k - b}{a} \right),$$

where $n(a,b) = \sum_{k=0}^{N-1} e^{-\frac{1}{B}\left(\frac{t_k - b}{a}\right)^2}$, $\psi(t) = \frac{1}{\sqrt{\pi B}} e^{\frac{-t^2}{B}} e^{i2\pi f_0 t}$ – complex Morlet wavelet.

Assessment of local energy spectrum is based on scalogramm [6]: $S(a_i, b_j) = \left| W_A(a_i, b_j) \right|^2$, which can be displayed in three-dimensional space coordinates (a,b,S) or as a topological map, depicting surface $S(a,b)$ in coordinates (a,b). A scalogramm of a plot of the phoneme "a" (fig. 2), representing large-scale distribution of the signal energy, wherein the time axis the shift value b of wavelet function is marked, the vertical axis – a scale a, is shown in fig. 3. The colour range clearly demonstrates dependence of intensity on changes of wavelet coefficients S. From fig. 3 follows that pitch harmonics remain stable throughout the time period, while the higher-order identified harmonics decay with time. Picture of wavelet spectrum clear reveals the presence of a sufficiently uniformly scaled periodicity, contained in the analysed dependencies, showing the presence of emerged frequency components that do not conform to the natural frequencies of the considered signal.

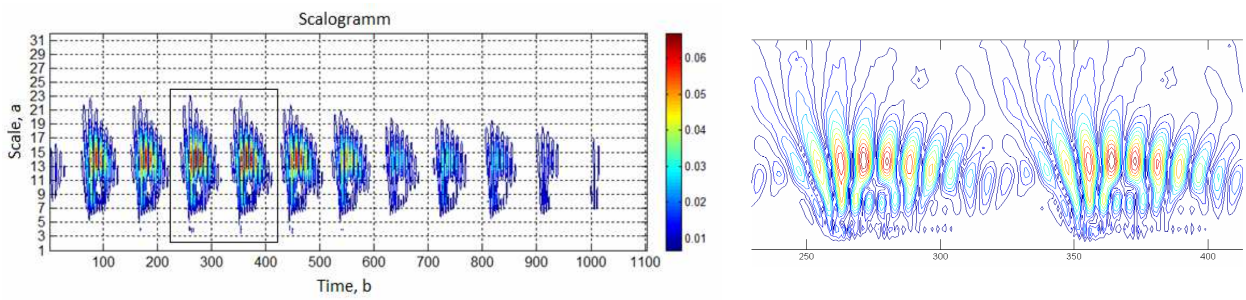


Fig. 3. Topological map phonemes "a"

You can cut off the influence of the contours, highlighting those points of scalogramm in which it has a maximum in the variables a and b, building a skeleton [6]:

$$S_c(a_i, b_j) = \begin{cases} S_{ij},\ if\ S_{i-1,j} < S_{i,j} > S_{i+1,j} \\ or\ S_{i,j-1} < S_{i,j} > S_{i,j+1} \\ 0,\ in\ other\ case. \end{cases}$$

Using scalogramm we can assess the global spectrum of energy and build skeylogramm:

$$G(a_i) = \frac{1}{N^*} \sum_j S(a_i, b_j),$$

where N^* – the number of points on which the averaging is carried out.

Time-frequency representation of the selected fragment of speech in the form of three-dimensional skeylogramm based on Morlet basis has a number of peculiarities, in particular, local maximums of wavelet transformation are informative to highlight the pitch frequency and the main formants due to the possibility of excluding resonance (false) formants. Skeylogramm analysis (fig. 4) shows that the location of the peaks on the time parameter corresponds strictly to local extremums of the amplitude of the sound wave in the time domain, which correspond to the amplitude bursts of the sound wave, given pitch frequency f_p (fig. 2).

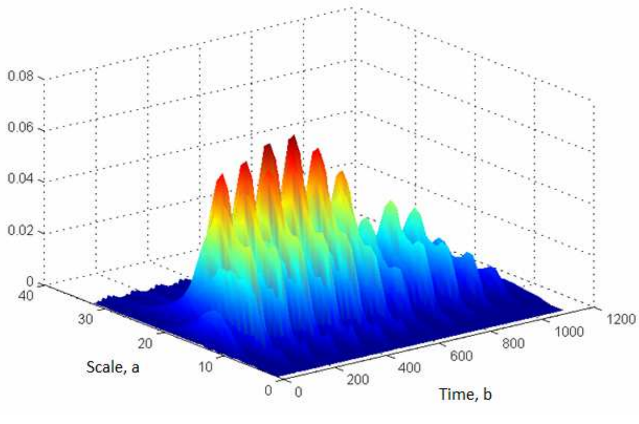
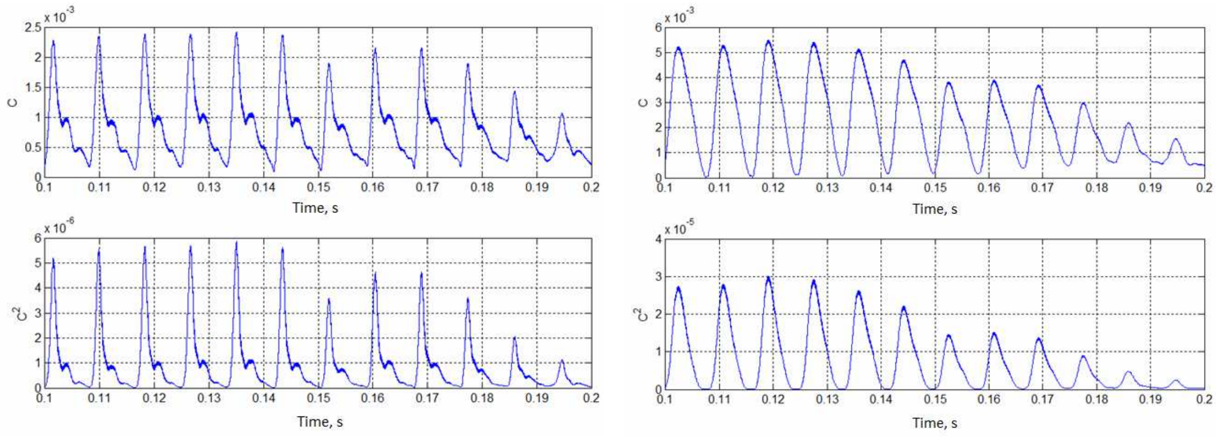


Fig. 4. Three-dimensional skeylogramm

In contrast to the Fourier transform, and applications of other wavelets, complex Morlet wavelet provides a higher level of "smoothness" skeylogramm. The shape of the normalized peaks is strictly individual at different voice characteristics.

On the example of a fragment of the phoneme "a" we demonstrate two-dimensional slices of the three-dimensional skeylogramm for different values of the parameters of the wavelet (fig. 5). On the basis of this analysis it is possible to obtain results for other phonemes vowel sounds of the Russian language.



a) parameters wavelet: B =1; f_0 =1.5 b) parameters wavelet: B =2; f_0 =0.5

Fig. 5. Two-dimensional slices of the three-dimensional skeylogramm

Thus, the application of wavelet transformation supplements signal characteristics obtained by the usual statistical methods (in particular spectral), as well as assesses the scaling parameter of signals. Our choice of the mother complex Morlet wavelet and the results of experimental research of parameters of vowel sounds, obtained by that wavelet transformations, allow managing the tuning of the wavelet to obtain a fine structure of the signal of a particular speaker in the real time. Additionally, you can use the wavelet transformations for clearing against harmful interference of measurement harmonic and chirp signals.

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FULL-DUPLEX NETWORK COMMUNICATION USING THE WEBSOCKET PROTOCOL

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The paper discusses current methods of full-duplex network communication and a powerful alternative called the WebSocket protocol. The protocol itself is described and compared to current solutions.

The modern world wide web as we know it at this point was established a while ago, including but not limited to technologies that are used as the basis of the web. The paradigm used for the Hypertext Transfer Protocol (HTTP) can be called as *Request-Response*. When a user goes to a web page he sends a *Request* to a web server. The web server sends a *Response* as a result of this interaction. Nothing is really happening until the user decides to navigate to the next destination page. The current web requires a lot more than this. Users want to load their content instantly and many web applications are based on the single page architecture, where content is updated on the single page, without the page reloading.

There are several techniques that allow this kind of interaction with a web content at this point. The most common one is so called *Long Polling*. When using this technique a client, which can be any HTTP client such as a web browser or any HTTP-based application, opens a HTTP connection to the web server using a request which keeps