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Determination of Center Frequency of the Signal on the Basis on Wavelet Transformation

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Abstract: In connection with the increased flow rate signals with short pulse duration to the methods of analysis used in modern means the automated radio monitoring are requirements to reduce the size of the analyzed sample. The research presents a method for determining the center frequency based on wavelet transform which allows to reduce the size of the sample signal. An example of phase-modulated radio signals provides a comparative analysis of the presented method and the method utilizing powering signal and spectrum analysis based on the fast Fourier transform.

Key words: Means the automated radio monitoring, the center frequency of the signal, fast fourier transform, continuous wavelet transform, Russia

INTRODUCTION

The research of tendencies of development of means of radio monitoring shows that the problem of increase in their efficiency became particularly important in recent years that is connected, first of all with increase in density of a flow of radio emissions in the working ranges of frequencies and growth of aprioristic uncertainty concerning their parameters (Kulbikayan, 2000). In particular in case of radio monitoring implementation often there is a task of detection and the analysis of signals of small duration to which radio-frequency pulses of signals treat with pseudorandom reorganization of operating frequency, the radio-frequency radiations corresponding to separate temporal slots of signals of the standards GSM, DECT, DMR and other similar radio-frequency pulses which in literature often call package signals in particular (Spazhakin and Tokarev, 2015). In this regard, the methods of determining the parameters of the signals used in modern means of Automated Radio Monitoring (ARM) are requirements to reduce the size of the analyzed sample. One of the primary tasks of the radio emission at the stage of analysis is to determine the center frequency of the signal.

To determine the center frequency in the Automated Workplace (AWP) are best suited methods and algorithms using digital processing to provide greater speed and accuracy with stable results (Rembovsky *et al*., 2006). These methods include methods for measuring the instantaneous frequency (Instantaneous Frequency Measurement (IFM), methods of using the Autocorrelation Function (ACF) and methods based on the FFT (Fast Fourier Transform-FFT).

The disadvantage of IFM methods is their inapplicability to signals with the single-sideband modulation (except a special case of modulation by harmonic oscillation) and to signals of COFDM (coded orthogonal frequency division multiplexing) that reduces universality of means of an automated workplace.

The methods of determination of center frequency using ACF assume high computing complexity. In (Jiang *et al*., 1999) researchers the valuation method of center frequency for signals with multi-level phase shift keying is offered. Together with a row of advantages (possibility of the analysis of the radio emission radiations which are transferred as in impulse and the continuous the modes stability of results in case of the low relation signal/noise, high accuracy of measurement) the provided method possesses such essential shortcoming as restriction of a class of analyzed radio emission radiations with signals with multi-level phase shift keying. The method of determination of center frequency offered by Sun and Feng (2010) represents preliminary estimate of frequency with use of ACF and its subsequent setup. Disadvantage of this method is costs of additional computing resources of not always justified setup of center frequency.

The main disadvantage of the methods based on FFT consists in need of large volume of selection. Brusin (2007) for the purpose of overcoming this shortcoming it is offered to use the sliding FFT option for a rough estimate of center frequency with its subsequent specification. However, this procedure owing to dichotomizing search considerably increases computing complexity of the appropriate algorithm.

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Brusin (2007) for increase in accuracy of assessment of center frequency of a signal it is offered to use wavelet-conversion. Use of wavelet-expansion of a signal, according to researchers will provide the accuracy of assessment of center frequency about 10% in case of a low signal-to-noise ratio.

Except provided there is a number of special methods and algorithms of determination of the central frequency of a signal (Wang *et al*., 2010; Li *et al*., 2001) which are oriented to the radio signals corresponding to certain technologies of transfer and use during the work in advance set templates of symbols or groups of symbols. However, these approaches aren't universal and can't independently be used in means of an automated workplace without essential decrease in their efficiency.

However, the offered algorithms don't allow with a necessary accuracy to estimate center frequency on small selections of a signal that hinders with the further analysis and automated identification of signals in particular with use of the approach provided in (Lapina and Lapin, 2015).

MATERIALS AND METHODS

The purpose of this operation is development of a method of determination of center frequency of a signal on the basis of the Continuous wavelet-Conversion (CVC). The method includes the following stages. Record of the digitized signal is analyzed, its spectrogram is built. The frequency band is selected and filtered, the data array for the further analysis is created.

This method doesn't require prior knowledge of a form of modulation of the taken signal. Implemented continuous wavelet transform on a wide range of values of the scaling parameter. Continuous wavelet transform is a convolution:

$$W(a,b_0) = \int_{-\infty}^{+\infty} f(t)\psi^*_{a,b_0}(t)dt$$

Analyzed the function f (t) and the two-parameter wavelet function $\psi_{a,b_0}(t)$ which is obtained from the mother wavelet $\Psi_0(t)$:

$$\psi_{a,b_0}(t) = \frac{1}{\sqrt{s}}\psi_0\left(\frac{b-b_0}{a}\right)$$

Where:

$\alpha \in R^+$ = The scaling parameter of the wavelet transform (further-scale)

$b_0 \in R$ = Shift parameter

The scaling parameter α inversely proportional to the frequency:

$$f = \frac{f_c}{a}$$

where, the coefficient of proportionality f_c is the central frequency of the wavelet. The choice of the mother wavelet was carried out based on the value of the central frequency and the computational complexity of the corresponding wavelet transform. The value of the central frequency of the wavelet determines the resolution of the wavelet transform. The computational complexity depends on the analytical form of the mother wavelet. The study selected Morlet wavelet which is a sine wave modulated by a Gaussian function and has the following form:

$$\psi_\omega(t) = e^{-t^2/2}\cos(\omega t)$$

where, ω parameter defines center frequency of the wavelet. This wavelet combines low computing complexity and the center frequency regulated by parameter ω.

The boundaries of the interval are set based on the condition that the center frequency is searched for on the interval (F_{min}, F_{max}) where Fmax is limited to half the sampling frequency. The corresponding minimum and maximum values of the scaling parameter is defined as:

$$a_{min} = \frac{F_d f_c}{2\pi F_{max}};\ a_{max} = \frac{F_d f_c}{2\pi F_{min}}$$

Where:

F_d = Sampling frequency

f_c = Center frequency of the wavelet

The increment of the scaling parameter is determined by Eq. 1:

$$\Delta a = \frac{a_{max} - a_{min}}{L} \quad (1)$$

where, L the number of values of the scaling parameter. Calculate the continuous wavelet transform on an interval (a_{min}, a_{max}) increments and displayed scalogram.

The automated analysis of distribution of energy of wavelet-coefficients and change of borders of an interval of change of the scaling parameter is carried out. As data of the analysis values of integrated distribution of energy on wavelet-transformation scales which are on Eq. 2 (Koronovsky and Hramov, 2003) are used:

$$E_i = E(a_i) = \int_{b_1}^{b_2} |W(a_i,b)|^2 db \quad (2)$$

Where:

E_i = The value of energy of wavelet-transformation corresponding to a_i scale

W (a_i, b) = Value of wavelet-transformation for the scaling ai parameter and parameter of shift of b, $a_i = a_{min} + i * \Delta a, i = 1,...,L$

Limits of integration and for a ratio (Eq. 2) are defined by the analyzed selection of a signal. The threshold of making decision on accessory of this scale to a new interval depends on average value of integrated distribution of energy:

$$E_{mean} = \frac{1}{L}\sum_{i=1}^{L} E_i$$

For each value range of center frequency of a wavelet of Morle the coefficient multiplier of a threshold of making decision on accessory of this scale to a new interval of change of the scaling parameter is set. In particular, for center frequency f_c the decision-making threshold for lower bound of a new interval is equal 0.3 E_{mean} for upper -0.8 E_{mean}. Normalizing coefficients of average integral distribution of energy are set proceeding from the analysis of a distribution function of energy of coefficients of wavelet-transformation on scales. Further, according to Eq. 1 is calculated new value increments scaling factor.

Implemented continuous wavelet transform with the changed in the previous step the boundaries of the range of values of the scaling parameter and display scalogram. According to Eq. 2 is calculated as the integral distribution of energy on the scale of the wavelet transform. There is in this sequence a maximum:

$$E_{max} = E(a_{max}) = \max_{a_{mi} \le a_i \le a_{max}}(E(a_i))$$

The corresponding scaling parameter determines center frequency by a equation:

$$F_{car} = \frac{f_c}{2\pi a_{max}} F_d$$

It is offered to evaluate an error of determination of center frequency through a difference of frequencies between the scale of wavelet-transform at which center frequency and to big adjacent is defined. This difference has an appearance:

$$\Delta F_{car} = \frac{f_c}{2\pi} F_d \frac{a_{n+1} - a_n}{a_n a_{n+1}} \quad (3)$$

Where:

f_c = The central frequency of the wavelet

F_d = Sampling frequency

a_n = Scale wavelet transform corresponding to the center frequency

a_{n+1} = Neighboring scale

Table 1: Absolute error of determination of center frequency (kHz) for phase modulated signals depending on the amount of analyzed selection of a signal

The sample size (kB)	Type of modulation		
	BPSK	QPSK	8 PSK
1	781.25	1562.5	3125
2	390.63	781.25	1562.5
4	195.31	390.63	781.25
8	97.65	195.31	390.63
16	48.83	97.65	195.31

The absolute error of determination of center frequency for Morle's wavelet depending on center frequency of a wavelet f_c and scale at which center frequency is defined with growth of center frequency is restricted to value 150 kHz, owing to proportional change of multipliers in Eq. 3.

The main requirement imposed to a method is the amount of analyzed selection of a signal. Values of absolute error of determination of center frequency for phase-modulated of radio emissions by means of the method using operation of involution of a signal in a level and the further analysis of a range by means of FFT for selections of a signal from 1-16 kb in size and types of modulation of BPSK (binary phase shift keying), QPSK (Quadrature Phase Shift Keying) and 8PSK (8 Phase Shift Keying) are given in Table.

Follows from the analysis of Table 1 that for each specific type of modulation the absolute error of determination of center frequency decreases with increase in the amount of analyzed selection of a signal. The absolute error of determination of center frequency for a method on the basis of the continuous wavelet-transformation depending on center frequency of the analyzing wavelet and scale of the wavelet-transformation corresponding to center frequency lies ranging from 150-280 kHz and doesn't depend on a type of modulation of an analyzed signal.

Dependence of accuracy of determination of center frequency on the amount of analyzed selection of a signal for a method on the basis of involution of a signal in a level and the analysis of its range by means of FFT for different types of modulation and for a method on the basis of CVC is given in a Fig. 1.

Follows from the provided diagrams that the method on the basis of the continuous wavelet-transformation provides more good results on the accuracy of

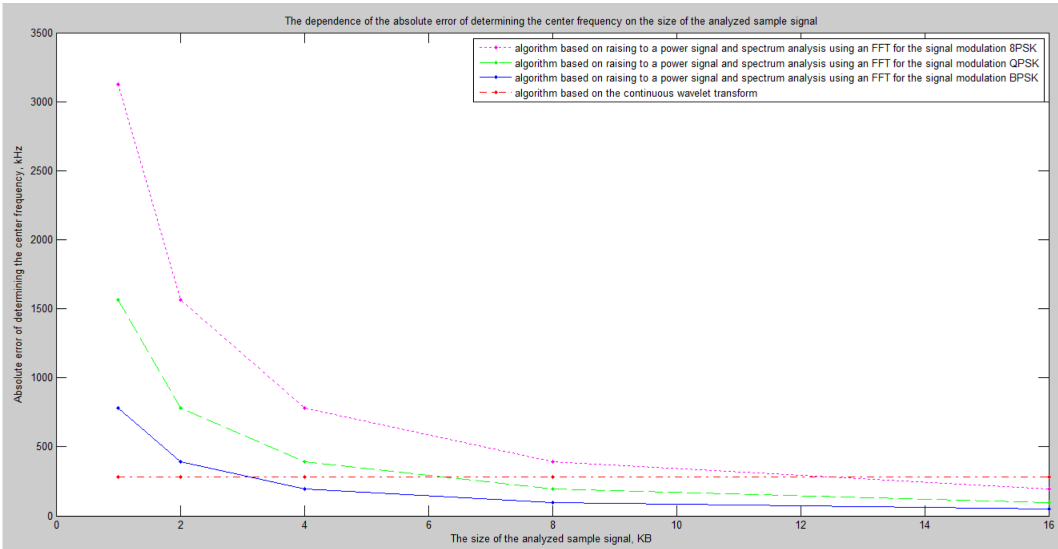

Fig. 1: The dependence of the absolute error of determining the center frequency on the size of the analyzed sample signal

assessment of center frequency for selections of signals to 2 kb (for signals with BPSK) to 4 kb (for signals with QPSK) and to 8 kb (for signals with 8 PSK).

CONCLUSION

Thus, the developed method for determining the center frequency based on the continuous wavelet-transform allows to determine the center frequency of small volumes of samples with a smaller absolute error signal than a method based on involution signal in a level and the analysis of a range by means of FFT. This method can find application by development of means of an automated workplace for determination of center frequency of signals of small duration.

REFERENCES

Brusin, E.A., 2007. Development and a research of methods of estimation of the bearing frequency of phase-modulated signals in coherent demodulators of satellite communication systems. Master's Thesis, Department of Technical Sciences.

Jiang, Y., W. Ting, F.B. Verahrami, R.L. Richmond and J.S. Baras, 1999. A carrier frequency estimation method of MPSK signals and its systolic VLSI implementation. Proceedings of the 33rd Annual Conference on Information Sciences and Systems, March 17-19, 1999, John Hopkins University, Baltimore, pp: 142-146.

Koronovsky, A.A. and A.E. Hramov, 2003. Continuous Wavelet Analysis and its Applications. Fizmatlit, Russia, Pages: 176.

Kulbikayan, B.H., 2000. Radio monitoring of an electromagnetic situation on the basis of rapid analysis with use of methods of spectral and correlative information processing. Master's Thesis, Department of Physical and Mathematical Sciences.

Lapina, T.I. and D.V. Lapin, 2015. Approach to automation of identification measurements of signals in telecommunication systems. Inform. Measur. Operat. Syst., 13: 63-67.

Li, J., G. Liu and G.B. Giannakis, 2001. Carrier frequency offset estimation for OFDM-based WLANs. IEEE Signal Proc. Lett., 8: 80-82.

Rembovsky, A.M., A.V. Ashikhmin and V.A. Kozmin, 2006. Radio Monitoring: Problems, Methods and Equipment. Springer, Moscow, Pages: 492.

Spazhakin, M.I. and A.B. Tokarev, 2015. Application of an algorithm of gertsel for bearing of package signals. Bulletin of the Voronezh State Technical University, T.11, No. 6, pp: 70-73.

Sun, X. and Q. Feng, 2010. A method of carrier frequency estimation based on spectral analysis of digital communication signal. Proceedings of the 3rd IEEE International Conference on Computer Science and Information Technology, July 9-11, 2010, China.

Wang, Q., C. Mehlfuhrer and M. Rupp, 2010. Carrier frequency synchronization in the downlink of 3GPP LTE. Proceedings of the IEEE 21st International Symposium on Personal Indoor and Mobile Radio Communications, September 26-30, 2010, IEEE.