ITMO. Scientific and technical herald of information technologies, mechanics and optics. - 2013. - № 3 (85). - p. 61 - 66

12. Grishentsev A.Yu., Korobeinikov A.G. An inverse problem of radio-frequency sounding of the ionosphere. // Journal of Radioelectronics. 2010. № 10. p. 6.
13. Grishentsev A.Yu., Korobeinikov A.G. Development of a model for the distribution of current densities during excitation of the ionosphere by high-frequency irradiation // Izvestiya Vysshikh Uchebnykh Zavedenii. Instrument making. 2010. P. 53. № 12. p. 41-47.

AN ANALYSIS OF SOME WAVELET FUNCTIONS IN TERMS OF BROADBAND SYSTEMS SYNTHESIS

Grishentcev A.U.[1], Korobeynikov A.G.[1], Velichko E.N. [2], Putintseva M.V.[2]
[1]ITMO University, St. Petersburg, Russia
[2] Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia
[1] E-mail: grishentcev@ya.ru

Abstract: This article deals with the issues of application of some wavelet functions for a wideband signal design on the basis of matrices of particular form of the autocorrelation function. The elements of such matrices are complex numbers with the module equal to one. The research objects are wavelet functions and wideband signals obtained on the basis of wavelet analysis. Numerous studies have displayed that rather explicit results of wideband signal design allow to receive following continuously differentiable wavelet functions: the b-spline wavelet, Morlet wavelet.

Keywords: wireless broadband connectivity, digital signal processing, wavelet functions.

Introduction

Methods and broadband radio communication systems in comparison with a set of modern technologies have a rather long history. The first receptions and transmissions were carried out for the wideband signals being of spark nature, and meet the criteria of the wideband signal TW>1, where T is a period, W is an emission frequency band (e.g., Popov lightning detector, Hertz spark-gap radio transmitter, Marconi transceivers and similar ones.) The subsequent development of a wireless communication, up to 1960s, was geared primarily towards narrowband signals. But unlikely, since the mid-twentieth century achieved technological capabilities and the radio communication theory allowed the implementation of the first spread-spectrum systems, mainly for the military radio communication and radio ranging use [1]. The development of outer space communication, as well as the necessity of rendering adequate transmitted data protection against the backdrop of the digital technologies developments and sustained growth of loading of an air fostered the proliferation of research and ubiquitous implementation of items of the spread-spectrum communication. Nowadays, the high-speed computing tools of signal processing (DSP digital signal processor) provide a significant potential for communication systems. The effective control of a spectrum with an equal signal drive distribution in time is a key concern of synthesis of the broadband signals (BS).

The effective control of a spectrum with an equal signal drive distribution in time is a key concern of synthesis of the broadband signals (BS).

The theoretical part of this study is devoted firstly to the exploration of the peculiarities of the spread-spectrum signal design on the basis of matrices with a particular form of an autocorrelation function using following continuously differentiable wavelet functions: b-spline wavelet, Morlet wavelet.

The main goal of the present work is to analyse the issue of a wideband signal design using wavelets on the basis of complex matrices with a particular form of an autocorrelation function (ACF). These groups of matrices were first considered by authors of this work [2–4]. ACF of such matrices has considerably larger size of the central element in comparison with side lobes. The distinctive feature of complex matrices and the ACF special form – value of complex elements. In this study [3] the possibility of division of complex-valued signals into imaginary and real components was shown by methods of digital processing on a receiving part. In research [5] the selection of the optimized shape of wavelet functions in the ACF

[6, 7] was made. We opted for the b-spline wavelet (bSW) and Morlet wavelet (MW).

Some analytical wavelet functions characteristics

Equation of a class of compactly supported normalized [8–10] b-spline wavelets is defined as:

$$\varphi_{\mathrm{bSW}}(t) = \sqrt{\frac{f_b}{\pi}}\left(\mathrm{sinc}(\frac{f_b t}{Q})\right)^Q e^{\mathrm{j}2\pi f_c t}, \tag{1}$$

where f_b is bSW frequency band; f_c is the center frequency of the bSW in Hz (i.e., the frequency corresponding to the spectral peak of the wavelet); Q is a damping ratio parameter of sinc-function ($Q = 1,2,3,\ldots$).

Spectrum of the bSW [5] within the interval $t \in [-T_{\mathrm{bSW}}/2, T_{\mathrm{bSW}}/2]$, differ substantially from spectrum within the interval $t \in [-\infty,\infty]$. It can be determined as:

$$\sqrt{\frac{f_b}{\pi}}\sqrt{\frac{1}{2\pi}}\int_{-\frac{T_{\mathrm{bSW}}}{2}}^{\frac{T_{\mathrm{bSW}}}{2}} \mathrm{sinc}(f_b t)\, e^{\mathrm{j}t(2\pi f_c t-\omega)} dt =$$

$$= \frac{1}{\pi\sqrt{2f_b}}\left(\int_0^{\frac{T_{\mathrm{bSW}}}{2}(f_b+2f_c\pi-\omega)} \frac{\sin(\mathrm{t})}{\mathrm{t}}\mathrm{dt} + \int_0^{\frac{T_{\mathrm{bSW}}}{2}(f_b-2f_c\pi+\omega)} \frac{\sin(\mathrm{t})}{\mathrm{t}}\mathrm{dt}\right). \tag{2}$$

Equation of a class of compactly supported normalized WM is defined as:

$$\varphi_{\mathrm{WM}}(t) = \sqrt[4]{\frac{2}{\pi f_b}}\, e^{\mathrm{j}2\pi f_c t - \frac{t^2}{f_b}}, \tag{3}$$

where f_b is WM frequency band in Hz; f_c is the center frequency of the WM in Hz.

Spectrum of the WM [5] in the bounded interval $t \in [-T_{\mathrm{WM}}/2, T_{\mathrm{WM}}/2]$ can be determined as:

$$\Upsilon_{\mathrm{WM}}(\mathrm{j}\omega) = F\{\varphi_{\mathrm{WM}}(t)\} = \sqrt[4]{\frac{2}{\pi f_b}}\sqrt{\frac{1}{2\pi}}\int_{-\frac{T_{\mathrm{WM}}}{2}}^{\frac{T_{\mathrm{WM}}}{2}}\left(e^{j2\pi f_c t - \frac{t^2}{f_b}}\right)e^{-j\omega t}dt = \\ = \mathrm{j}\sqrt[4]{\frac{f_b}{2\pi^3}}\,e^{-\frac{1}{4}f_b(\omega-2\pi f_c)^2}\left(\int_0^{\frac{2f_b f_c\pi-\mathrm{j}T_{\mathrm{WM}}-f_b\omega}{2\sqrt{f_b}}} e^{-t}dt - \int_0^{\frac{2f_b f_c\pi+\mathrm{j}T_{\mathrm{WM}}-f_b\omega}{2\sqrt{f_b}}} e^{-t}dt\right). \qquad (4)$$

The synthesis of the signaling messages

Firstly it is necessary to define the wavelet function $\varphi(t, f_{\mathrm{c}}(y))$ of time t, as superposition of functions $\varphi(t)$ (wavelet) and $f_{\mathrm{c}}(y)$ (function of carrier frequency). Then we can write the equation:

$$s(t) = \sum_{y=0}^{Y-1}\begin{pmatrix} Re\left[M[y][\left\lfloor\frac{t}{T_W}\right\rfloor]\right] Re[\varphi\left(f_c(y+1)(t-\frac{T_{\mathrm{W}}(1-2x)}{2}), f_c(y)\right)] \; + \\ +\mathrm{j}\cdot Im\left[M[y][\left\lfloor\frac{t}{T_{\mathrm{W}}}\right\rfloor]\right] Im[\varphi\left(f_c(y+1)(t-\frac{T_{\mathrm{W}}(1-2x)}{2}), f_c(y)\right)] \end{pmatrix}$$

Full signal duration $s(t)$ can be determined as: $T = XT_{\mathrm{w}}$, where X is the column dimension of matrix **M**; $[-T_{\mathrm{w}}/2, T_{\mathrm{w}}/2]$ is the interval of the wavelet function. As a synthesizing matrix, we use matrix MC_9 [2] with the size equal to 2×4:

$$\mathbf{M} = \begin{pmatrix} -\frac{\sqrt{2}}{2}+\mathrm{j}\frac{\sqrt{2}}{2} & 1 & \frac{\sqrt{2}}{2}+\mathrm{j}\frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2}-\mathrm{j}\frac{\sqrt{2}}{2} \\ -\frac{\sqrt{2}}{2}-\mathrm{j}\frac{\sqrt{2}}{2} & -\mathrm{j} & 1 & 0 \end{pmatrix},$$

e.g., synthesize signals using bSW, WB and SC, on the basis of matrix **M** (fig.1) either. Synthesis and signal analysis were carried out in the environment of MatLab [11].

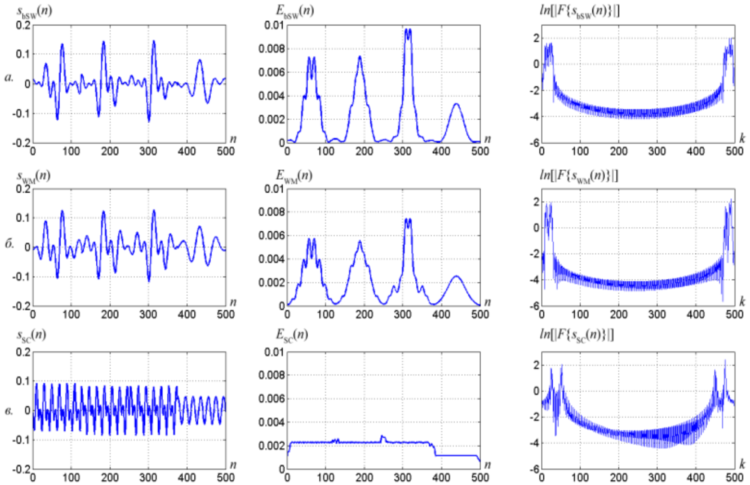

Fig.1. Comparison of signals, frequency content and averaged energy densities.

The first column of the first row (fig.1, *a*), contains signal message $s_{bSW}(n)$, obtained on the basis of bSW when $\frac{T_{bSW}}{2} = 2.85$, $f_b = 1$, $Q = 1$; the second column displays diagram $E_{bSW}(n)$ – averaged density of the energy distribution over n; in the third column it is reported that $\ln(|S_{bSW}(k)|) = \ln(F\{|s_{bSW}(n)|\})$. Similar charts were plotted for the signals synthesized on the basis of WM when $\frac{T_{WM}}{2} = 1.517$ and $f_b = 1$, (fig.1, *b*) (second line), as well as SC (fig.1, *c*) (third line), for the signal synthesized on the basis of matrix **M** using harmonic functions.

Figure (fig.1) analysis allows drawing following conclusions: when using wavelets (fig.1, lines a, b) high-frequency components of the signals decreasing more than threefold, in comparison with the signals, synthesized with the help of harmonic functions (fig.1, line c), it means that the application of wavelets redounds improvement of signal spectrum control. The best possible pattern of energy distribution enables to receive the signal, synthesized with the help of harmonic functions (fig.1, line c).

Conclusions

A larger time–frequency resource is required to provide equal peak signal-to-noise ratio, while transmitting signals that were synthesized with the help of wavelets and harmonic functions. It is noteworthy that the presence of ripple of energy distribution is not conducive to a signal identification, hidden in the airwave noise (subnoise signals). Thus, the application of wavelet functions for the organization of the hidden subnoise channels of a wireless communication is inexpedient. The wavelets for the synthesis of the broadband signals can find application in the systems in which concealing the fact of data transmission (steganography) is implemented not on the subnoise concealment, i.e. due to decrease of the signal level, but through other principles, including the use of a spatial time-frequency resource.

References

1. Noise-shaped signals in data-transmission systems. Edited by V. B. Pestryakova // M.: Sov. radio, 1973 – 424 p.
2. Grishentcev A.Yr., Korobeynikov A. G. Retrieval algorithm, some properties and application of complex-valued matrices for steganography and synthesis of the broadband signals // *Journal of Radio Electronics*. № 5, 2016. URL: http://jre.cplire.ru/jre/may16/11/text.pdf
3. Grishentcev A.Yr. On method of the separation in time of the autocorrelation of the harmonic components of wideband signals // *Journal of Radio Electronics*. № 9, 2016. URL: http://jre.cplire.ru/jre/sep16/2/text.pdf
4. Grishentcev A.Yr., Korobeynikov A. G., Velichko E. N., Nepomniashchaia E. K., Rosov S. V. Binary matrix synthesis for broadband communication signal shaping // Radiotechnics. 2015. № 9. P.: 51-58 T.
5. Grishentcev A.Yr., Korobeynikov A. G. Application of wavelets for broaband signals generation // Izv. vuzov. Priborostroenie. 2017. Vol. 60, № 8. P.: 712-720 T.
6. Grishentcev A.Yr., Korobeynikov A. G. On reduction of space dimension at digital signals correlation and convolution // Izv. vuzov. Priborostroenie. 2016. Vol. 59, № 3. P.: 211—218 T.

7. Dyatlov A. P., Kylbikayan B. H. Correlation processing of the broadband signals in the radiomonitoring automated complexes // M.: Gorachaya linya-Telecom, 2014. – 332 p.
8. Brayn V. O., Dolgyshin V. P., Loza V. N., Pampyha I. V. Research of possibilities and methods characteristics of abatement of noise during signal synthesis, based on wavelet technology // *Journal of Radio Electronics.* № 7, 2014. URL: http://jre.cplire.ru/win/jul14/6/abstract.html
9. Smolenintsev N. K. Wavelet analysis in MatLab // M.: DMK Press, 2010. – 448 p.
10. Bansai M., Sethi D. Denoising of speech and ecg signal by using wavelets // Lambert Academic Publishing, 2012. – 64 p.
11. MatLab, The MathWorks, Inc. URL: http://www.mathworks.com/

THE ARCHITECTURE PAYLOAD "S-AIS" FOR SERIES OF EXPERIMENTS

Malygin D.V., Popov E.N., NguyentanH.P.
Peter the Great St.Petersburg Polytechnic University, St. Petersburg, Russia
office@spbstu.ru

Abstract: The paper considers a technology of design and architecture of the onboard communication system "S-AIS" for a series of experiments on processing signals received from navigational equipment of ships.

Keywords: smal spacecraft, nanosatellite, picosatellite, platform, cubesat, onboard communication system, ais

In order to examine the message collision preventing method, based on Doppler filtering [2], in space-based AIS system, a series of space experiments is planned to be conducted on Cubesat-3U format satellite developed in the laboratory “Space communication technologies” of Peter the Great St. Petersburg Polytechnic University.

The equipment, needed for the experiments, contains the following components: spacecraft in Cubesat 3U form; on-board AIS