International Journal of Civil Engineering and Technology (IJCIET)
Volume 8, Issue 11, November 2017, pp. 652–657, Article ID: IJCIET_08_11_068
Available online at http://http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=8&IType=11
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

METHOD OF FORMING CHANNEL SIGNALS WITH ZERO ENERGY IN A GIVEN FREQUENCY RANGE OF FINAL DURATION

Evgeniy G. Zhilyakov, Sergey P. Belov, Andrei A. Chernomorets, Alexander S. Belov
Belgorod State University, 85, Pobeda Street, Belgorod, 308015, Russia

ABSTRACT

In this article problem of constructing broadband channel signals is considered in terms of usage of an orthogonal basis in the form of eigenvectors of sub-band matrices that must have a priori predetermined properties.

The increasing need for users to exchange information for different distances with a high quality of service, regardless of where they were located, led to the need to develop channel signals, the use of which in telecommunication systems would ensure high reliability of reception of transmitted information in conditions of various types of interference, including narrowband interference.

In this study, to improve the noise immunity of telecommunication systems it is proposed to use as a carrier of information a new class of broadband signals based on the use of eigenvectors of subband matrixes with small eigenvalues in which the distribution of parts of their energies in the frequency domain can adaptively change. The use of such signals, as shown by the results of the computational experiments, makes it possible to significantly increase the noise immunity of telecommunication systems in the conditions of spectrum-focused interference resulting from various phenomena, including the technogenic conditions of modern industrial cities, compared with the use for this purpose of known classes of broadband signals.

Key words: Channel signals with adaptive change in distribution of their energy fractions in the frequency range, Spectrum concentrated noise, Eigenvectors of the sub-band matrix.

Cite this Article: Evgeniy G. Zhilyakov, Sergey P. Belov, Andrei A. Chernomorets, Alexander S. Belov, Method of Forming Channel Signals with Zero Energy in a Given Frequency Range of Final Duration. *International Journal of Civil Engineering and Technology*, 8(11), 2017, pp. 652–657.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=8&IType=11

1. INTRODUCTION

1.1. Mathematical Basis of the Method

The method offered involves a new principle of forming channel signals based on the solution of a variational problem to minimize their energy in a given frequency domain of final duration [1, 2, 3]:

$$\|x\|^2 - P_r = x'(\mathbf{I} - \mathbf{A}_r) \cdot x = \max \tag{1}$$

where P_r – energy in a given frequency domain, the width of which equals to

$(\nu_{r+1} - \nu_r)$; $\mathbf{I} = diag(1,...,1)$ – identity matrix; $\|\vec{x}\|^2$ – total energy of the signal;

x – signal vector; x' – transposed signal vector; $\mathbf{A}_r = \{a_{ik}\}$- subband matrix corresponding to r- frequency domain with the elements of the following type:

$$a_{ik}^r = \begin{cases} \dfrac{\sin[\nu_r(i-k)] - \sin[\nu_{r-1}(i-k)]}{\pi(i-k)}, & i \neq k \\ \dfrac{\nu_r - \nu_{r-1}}{\pi}, & i = k \end{cases} \tag{2}$$

The following inequation is assumed here $0 \le \nu_r < \nu_{r+1} \le \pi$.

To form the channel signals, eigenvectors and $\mathbf{A}_r$ matrix eigenvalues must be calculated. To do this, it is reasonable to use the orthogonal basis consisting of a set of eigenvectors expressed by [4, 5, 6]: $Q = (q_j, q_{j+1},...,q_N)$, where $\vec{q}_J$ – eigenvectors of the subband matrix, λ_i – eigenvalues of eigenvectors $\vec{q}_J$ equal to $\lambda_k \approx \lambda_{k+1} \approx ... \approx \lambda_N \approx 0$, where $i = k,..,N$.

Thus, channel signals are formed as follows:

$$x = Q \cdot e, \tag{3}$$

where: $\vec{x}$ – channel signal formed; $\vec{e} = (e_1, e_2,...,e_J)$ – information vector; e_J – symbol transmitted.

It should be noted that the energy of a channel signal outside the given frequency domain is calculated from the following expression:

$$E_{out} = \sum_{i=1}^{J} e_i^2 (1 - \lambda_i) \tag{4}$$

Since subband vectors are orthogonal, the following equation must be used to restore the information vector:

$$e' = Q^T \cdot x \tag{5}$$

According to the expression (4) the method offered allows to form the channel signal x , with the minimum energy, and with values λ_i =0, with zero energy in a given frequency domain of final duration, which allows to minimize the influence of the spectrum concentrated noise when the frequency range of noise and domain coincide with minimum energy of the channel signal formed [7, 8].

According to the expression (3) signal formation allows to change the frequency domain where signal energy is minimum using eigenvectors for various subband matrix calculated according to expression (2). This fact allows to adapt to narrowband noise concentrated in various parts of the frequency range used to transmit data.

As noted above, when λ_i, is close to zero, the energy of the eigenvector almost completely concentrates outside the given frequency domain (Figure 1). Thus, concentration of narrowband noise in the frequency domain which does not contain energy components of the signal transmitted will not affect the accuracy of coherent reception of the signal formed on the basis of eigenvectors of the subband matrix.

2. SIMULATION EXPERIMENTS

To verify the theoretical results obtained, simulation experiments have been conducted which allowed to obtain quantitative assessments of distribution of the energy of channel signals (P), formed on the basis of subband vectors with eigenvalues close to zero. Figures 1-2 show how the energy spectrum of generated channel signals is distributed, and Figure 3 shows how the energy spectrum of broadband signals (BBS), obtained on the basis of M sequence, is distributed.

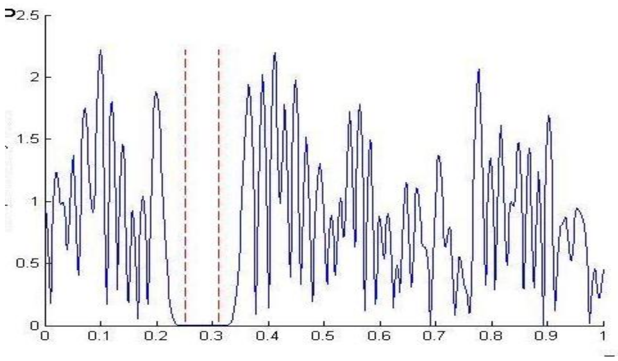

Figure 1 The energy spectrum of the channel signal formed on the basis of subband vector with the eigenvalue close to zero (zero energy in the range from 0.25π to 0.32π)

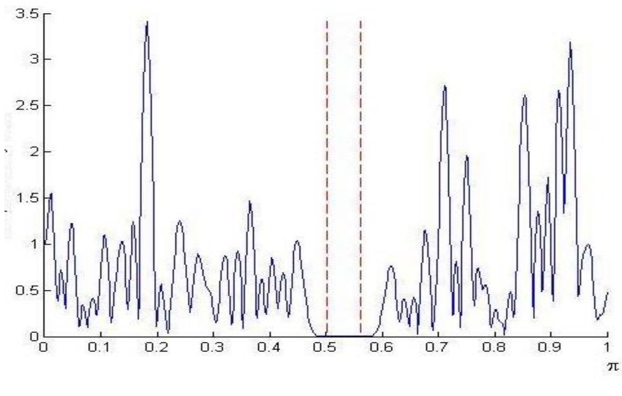

Figure 2 The energy spectrum of the channel signal formed on the basis of subband vector with the eigenvalue close to zero (zero energy in the range from 0.5π to 0.57π)

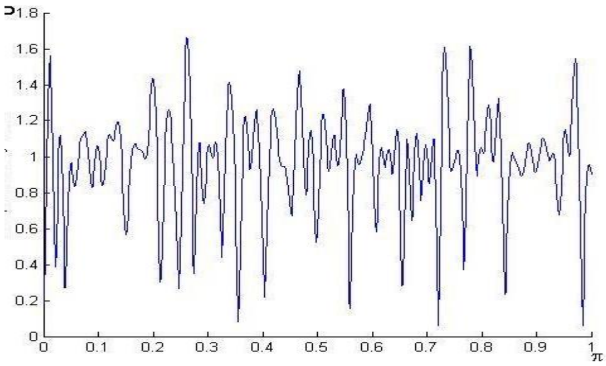

Figure 3 The energy spectrum of the BBS obtained on the basis of M sequence

To prove the efficiency of the method developed, we have estimated the probability of errors when receiving information sequences in conditions of narrowband noise, which is calculated by the following formula [9]:

$$P_{err} = 1 - F\left(\sqrt{\frac{E \cdot \chi(\tau, f)}{N_0}}\right) \qquad (6)$$

where $F(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z} e^{-y^2/2} dy$,

E – signal energy;

N_0 – single-sided noise spectral density;

$\chi(\tau, f) = \frac{\int_{-\infty}^{\infty} x(t) \cdot x(t+\tau) \cdot \exp(-j2\pi f t) dt}{\int_{-\infty}^{\infty} x(t) \cdot x(t) dt}$ – uncertainty function, when $f = 0$, is actually the autocorrelation function [9].

To determine the probability of errors, broadband signals have been simulated: using eigenvectors with small eigenvalues and BBS obtained on the basis of M sequence, as well as narrowband noise of various energies added to the signals. For the signals added to narrowband noise, the coefficient of correlation with the signal not affected by noise (reference signal of the receiving unit required for coherent correlation processing) is calculated. The obtained data were substituted in the formula (6). The results are shown in Table 1.

According to the results obtained for the BBS formed on the basis of M sequences, the increase in the narrowband noise energy results in the increase of probability of error when receiving a signal. The signal spectrum notching in the bandwidth of narrowband noise decreases the probability of error; however, in addition to error the signal is partially rejected, which results in worse noise immunity. In its turn, change in the probability of error when receiving a broadband signal using eigenvectors of the subband matrix is not more than $2 \cdot 10^{-6}$ up to -20 dB in the signal energy to noise energy ratio.

Table 1 The coefficient of correlation with the signal not affected by noise

Signal energy to noise energy ratio, dB		**20**	**12**	**6**	**2**	**-2**	**-6**	**-12**	**-20**
Probability of an error for a signal formed on the basis of eigenvectors	Frequency range of noise coincides with frequency domain	$6.91\cdot 10^{-6}$	$6.95\cdot 10^{-6}$	$6.86\cdot 10^{-6}$	$6.79\cdot 10^{-6}$	$6.69\cdot 10^{-6}$	$6.52\cdot 10^{-6}$	$6.11\cdot\cdot 10^{-6}$	$5.01\cdot 10^{-6}$
	Frequency range of noise does not coincide with frequency domain	$1.13\cdot 10^{-5}$	$1.05\cdot 10^{-5}$	$1.28\cdot 10^{-5}$	$1.48\cdot 10^{-5}$	$1.86\cdot 10^{-5}$	$2.68\cdot 10^{-5}$	$7.19\cdot 10^{-5}$	$1.5\cdot 10^{-3}$
Probability of an error for the BBS obtained on the basis of M sequence	Without spectrum notching	$9.17\cdot 10^{-6}$	$9.99\cdot 10^{-6}$	$1.15\cdot 10^{-5}$	$1.36\cdot 10^{-5}$	$1.77\cdot 10^{-5}$	$2.7\cdot 10^{-5}$	$8.42\cdot 10^{-5}$	$2.81\cdot 10^{-3}$
	With spectrum notching	$4.48\cdot 10^{-5}$	$4.5\cdot 10^{-5}$	$4.54\cdot 10^{-5}$	$4.59\cdot 10^{-5}$	$4.67\cdot 10^{-5}$	$4.8\cdot 10^{-5}$	$5.15\cdot 10^{-5}$	$6.41\cdot 10^{-5}$

3. CONCLUSIONS

Thus, according to the expression (3) formation of a channel signal allows to change the frequency domain, where the signal energy is minimal, through using eigenvectors with small eigenvalues for various subband matrix calculated according to expression (2). This fact allows to adapt to narrowband noise concentrated in different parts of the frequency range used to transmit information.

As noted above, when λ_i, is close to zero, the energy of the eigenvector almost completely concentrates outside the given frequency domain

(Figures 1-2), i.e. concentration of narrowband noise in the frequency domain, which does not contain energy components of the channel signal transmitted, will not affect the reception accuracy.

The simulation results and calculations for the probability of errors have shown that the signal with eigenvectors of the subband matrix with small eigenvalues is more resistant to the effect of spectrum concentrated noise. Besides, energy distribution in the frequency domain of the signal offered might be changed depending on the interference environment.

These signal properties in total allow to confidently state that their application will allow to improve the quality of data transmission in communication systems with broadband signals when they are affected by narrowband noise.

ACKNOWLEDGEMENTS

The research was conducted under the State assignment of Belgorod State National Research University, project code #8.2201.2017/4.6.

REFERENCES

[1] Zhilyakov, E.G., Belov, S.P. and Prokhorenko, E.I. Metody obrabotki rechevykh dannykh v informatsionno – telekommunikatsionnykh sistemakh na osnove chastotnykh predstavleniy. Monografiya [Methods of Processing Voice Data in Information and Telecommunication Systems on the Basis of Frequency-Domain Representations. Monograph]. Belgorod : Izdatel'stvo BelGU, 2007.

[2] Rektoris, K. Variatsionnye metody v matematicheskoy fizike i tekhnike [Variational Methods in Mathematical Physics and Engineering]. Moscow : Mir, 1995.

[3] Gantmakher, F.R. Teoriya matrits [Theory of Matrixes]. Moscow : Nauka, 1967.

[4] Zhilyakov, E.G., Belov S.P. and Ursol, D.V. About the Best Orthogonal Basis for Generation of the Channel Signals. *International Journal of Applied Engineering Research*, **9(22)**, 2014, pp. 12121-12126.

[5] Khurgin, Ya.I. and Yakovlev, V.P. Finitnye funktsii v fizike i tekhnike [Finite Functions in Physics and Technics]. Moscow : Nauka, 1971.

[6] Franks, L.E. Teoriya signalov [Signal Theory]. Moscow : Sovetskoe Radio, 1974.

[7] Marple, S.L.-Jr. Tsifrovoy spektral'nyy analiz i ego prilozheniya [Digital Spectral Analysis with Applications]. Moscow : Mir, 1990.

[8] Widrow, B. and Stearns, S.D. Adaptivnaya obrabotka signalov [Adaptive Processing of Signals]. Moscow : Radio i svyaz', 1989.

[9] Viterbi, E.D. Printsipy kogerentnoy svyazi. Monografiya [Principles of Coherent Communication. Monograph]. Moscow : Sovetskoe Radio, 1970.

[10] Arpan Deyasi and Swapan Bhattacharyya, Numerical Computation Of Eigenenergy And Transmission Coefficient Of Symmetric Quantum Double Barrier Structure With Variable Effective Mass In Presence Of Electric Field. International Journal of Electronics and Communication Engineering & Technology (IJECET), 2(1), 2011, pp. 24–34.

[11] Prof. B.S PATIL and Prof. A.R YARDI, Real Time Face Recognition System Using Eigen Faces. International Journal of Electronics and Communication Engineering & Technology (IJECET), 4(2), 2013, pp. 72–79.