№16/2018

Znanstvena misel journal

The journal is registered and published in Slovenia.

ISSN 3124-1123

VOL.1

The frequency of publication – 12 times per year.

Journal is published in Slovenian, English, Polish, Russian, Ukrainian.

The format of the journal is A4, coated paper, matte laminated cover.

All articles are reviewed

Edition of journal does not carry responsibility for the materials published in a journal.

Sending the article to the editorial the author confirms it's uniqueness and takes full responsibility for possible consequences for breaking copyright laws

Free access to the electronic version of journal

Znanstvena misel journal

Slovenska cesta 8, 1000 Ljubljana, Slovenia

Email: info@znanstvena-journal.com

Website: www.znanstvena-journal.com

CONTENT

TECHNICAL SCIENCES

MAIN THEORETICAL BASIS OF BIOSIGNALS MODELING

Palaniza Y.B.,
Ternopil Ivan Puluj National Technical University, Ternopil, Ukraine;
Department Assistant
Shadrina H.M.,
Ternopil Ivan Puluj National Technical University, Ternopil, Ukraine;
Ph.D.
Khvostivskiy M.O.,
Ternopil Ivan Puluj National Technical University, Ternopil, Ukraine;
Ph.D.
Dediv L.Ye.,
Ternopil Ivan Puluj National Technical University, Ternopil, Ukraine;
Ph.D.
Dozorska O.F.
Ternopil Ivan Puluj National Technical University, Ternopil, Ukraine;
post graduate student

Abstract

The phonocardiosignal (PCS) synchronously registered with electrocardiosignal simulation model was developed in this work using the methods as: the real signal envelope calculation, the real PCS signal approximation using the piecewise, bandpass filtration for "frequency-filling vector" and band-limited white noise calculation. The software in the MATLAB environment for the PCS simulation as the means of heart pathology detection algorithms verification in cardiac diagnostic systems was developed.

Keywords: biosignal, cardiosignal, phonocardiogram, mathematical model, simulation model, verification, algorithms for heart pathology detecting, MATLAB.

Problem formulation. According to statistics, one of the first position among the causes of people morbidity and mortality in the world are heart deseases. The non-invasive methods development for the cardiovascular system (CVS) researches which enables to obtain objective information about the heart work (Sokolov VV, Wenink A.C .; Anderson R.H.). The phonocardiosignal proper analysis by computer-aided diagnostic systems allows to reveal the CVS functional changes and choose a preventive measures method carrying out, and, to prevent disease development by appropriate treatment and screening in the case of pathological disorders detection. The phonocardiosignal analysis method effectiveness depends on an adequate mathematical model availability and based on it developed simulation model as the means of the CVS pathology detecting algorithms verification. The simulation model makes it possible to represents in its structure a priori data according to real signal characteristic.

Recent researches analysis. There are a number of phonocardiogram recording and analyzing diagnostic systems. The data processing algorithms in these systems based on a phonocardiosignal mathematical model. Today, there are two approaches to the phonocardiosignals mathematical models development in particular deterministic (Kebot and Dodge (1925), Mannheimer (1941), G.I. Casirsky (1957)) and stochastic (Metin Akay (Houston), G. M. Osukhivska (1997)).

According to CVS known models structures analysis it was founded that they do not allow the experimental signal form reproducing, including medical-morphological parameters structure which are important indicators during the CVS state diagnosing procedure in medical practice.

Aims. The research aim is phonocardiosignal simulation for the task of the heart pathologies detecting algorithms verification. Goal achieving requires a number of tasks solving: based on the FCS simulation model as PCSP [1,2] for the experimental signals form reproduction for the task of heart pathology detecting algorithms correct verification in the cardio diagnostic systems.

Research results. As PCS`s nature is non-stationary [2-5] and adequate to it mathematical representation is in the form of PCSP [2,3], therefore the simulation model expression is:

$$\xi(t)=\sum_{k}^{N_k}\left(\begin{cases}\tilde{\xi}_k\left(E(s_{nk},A_{nk}+\psi_A,T_{nk},v_{nk},t_n)\cdot(w\cdot wn(T_{nk-o\cdot T_{n-1k}})\otimes h(f_{nkl}+\psi_{f_{nkl}},f_{nkh}+\psi_{f_{nkh}}))\right), & t\in[T_{k-1},T_k)\\ 0, & t\notin[T_{k-1},T_k)\end{cases}\right)$$

де: $\tilde{\xi}_k$ – k-realization of PCS;

N_k – number of PCS realizations;

M_k – number of PCS intervals at k - realization;

$$E(s_{nk}, A_{nk}, \psi_A, T_{nk}, v_{nk}, t_n) = \begin{cases} \dfrac{A_{nk}}{1+\left(\dfrac{0.5\cdot T_{nk}}{t_n}\right)^{v_{nk}\cdot 10}} + \psi_A,\ s_{nk} > 0 \\ \dfrac{2\cdot A_{nk}}{1-\cdot\left(\dfrac{0.5\cdot T_{nk}}{t_n}\right)^{v_{nk}\cdot 10}} + \psi_A,\ s_{nk} < 0 \end{cases}$$

s_{nk} – approximate function slope rising/falling marker of n-intervals at k-realization;

A_{nk} – amplitude of n-interval at k-realization;

T_{nk} – length of n-interval at k-realization;

v_{nk} –rising/falling speed of n-interval at k-realization;

t_n – certainty range of n-interval;

w – Blackman window;

wn – white noise;

o – overlap factor of n-interval with length T_{nk} k- realization relatively $n-1$- interval with length T_{n-1k} k-realization;

$h(f_{nkl}+\psi_{f_{nkl}}, f_{nkh}+\psi_{f_{nkh}})$ – the FIR-filter core frequency bandwidth with lower f_{nl} and upper f_{nh} bandwidth limits;

$\psi_{A_{nk}}(M(A_{nk}), D(A_{nk}))$,

$f_{nkl}(M(fi_{nkl}), D(fi_{nkl}))$ і

$f_{nkh}(M(fi_{nkh}), D(fi_{nkh}))$ – random variables for amplitudes of lower and upper bandpass filter bandwidth limits of n-interval at k-realization with Gaussian distribution, mathematical expectations $M\{A\} = M(fi_{nkl}) = M(fi_{nkh}) = 0$ and dispersions $D(fi_{nkl})$, $D(fi_{nkh})$.

$k \in Z, n \in Z$ – the set of real numbers.

The development of software performed using Matlab environment, which combines a large number of high-level abstraction tools and allows to simplify this stage and time-to-market period reducing.

Based on the expression above, a of the phonocardiogram simulation program block diagram (Fig. 1) was developed:

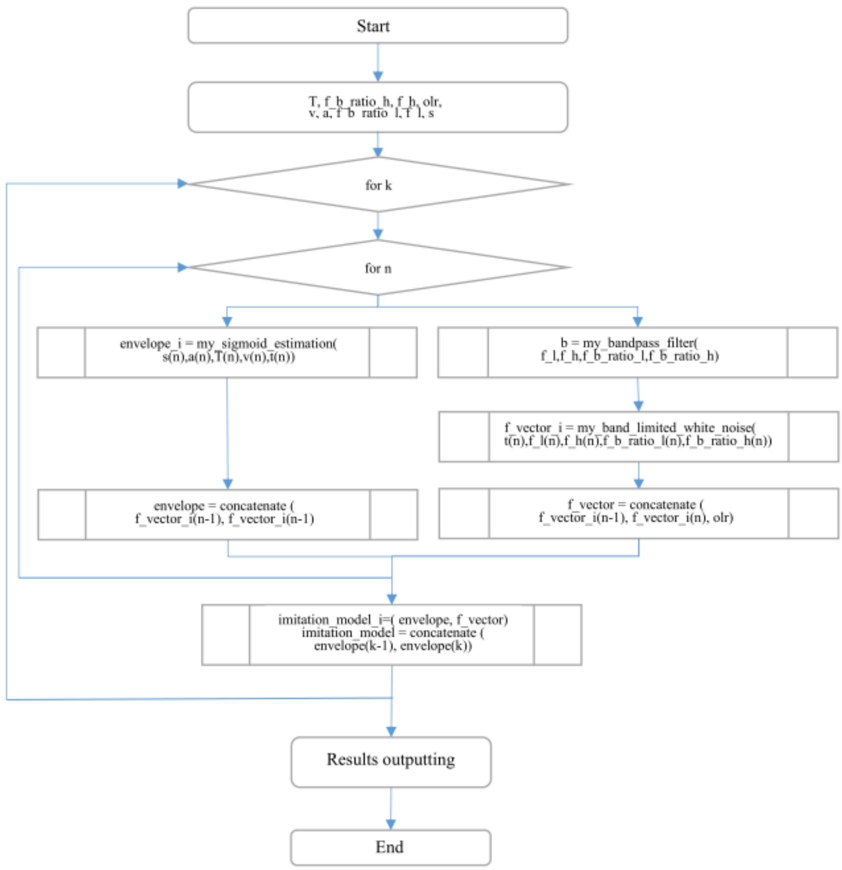

Fig. 1. Послідовність операцій реалізації імітаційної моделі ФКС

The program includes the following steps:

– data initialization:

s_{nk} – approximate function slope rising/falling marker of n-intervals at k-realization;

A_{nk} – amplitude of n-interval at k-realization;

T_{nk} – length of n-interval at k-realization;

v_{nk} –rising/falling speed of n-interval at k-realization;

t_n – certainty range of n-interval;

o – overlap factor of n-interval with length T_{nk} k- realization relatively $n-1$- interval with length T_{n-1k} k-realization;

f_{nl} – lower bandwidth limit;

f_{nh} – upper bandwidth limit;

$f_{b\,ratiol}$ – front slope rising factor of bandpass filter;

$f_{b\,ratioh}$ – back slope falling factor of bandpass filter;

–input parameters, initial software objects and functions setting;

– recursion by entering into the loop the number of iterations of which depends n-interval at k-realization number.

– dividing the algorithm into two branches to execute it in parallel mode and/or using a video card resources if there are more than one processor core in the system.

– next step of the algorithm first branch is the conjugation function calculation in n-interval at k-realization.

– next step of the algorithm first branch is the conjugation functions concatenation into envelope vector in n-interval at k-realization.

– next step of the algorithm second branch is bandpass filter synthesis (his b-poles calculation).

– band-limited white noise n-interval calculation.

– band-limited white noise weighed with the Blackman window concatenation with overlapping in n-interval calculation.

– both branches convergence into one algorithm calculation stream to envelope and frequency-filling vectors multiplicative mixture generation.

– saving the calculation results and outputting the results in a user-friendly graphical form.

– clearing the working space, bringing the environment to its default state, checking checksums and exit from the code execution environment.

To illustrate the results of the program algorithm, consider one realization of real PCS (Fig. 1).

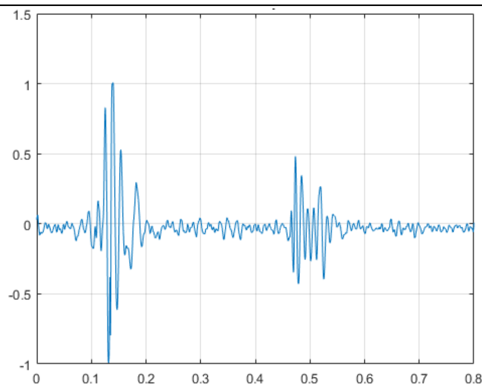

Fig. 1. Real phonocardiosignal (abscissa axis – time (s); ordinate amplitude (normalized to unity))

The envelope calculation by passing PCS through the Gilbert phase-inverter, amplitude-frequency characteristic (AFC) of it depicted in Fig. 3.

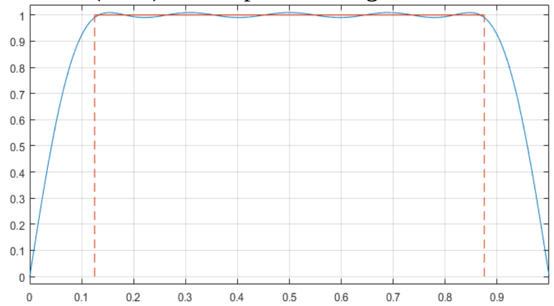

Fig. 2. AFC of Gilbert phase-inverter (abscissa axis – normalized frequency ([0 1]); ordinate amplitude (normalized to unity)). The ideal AFC depicts by dotted line

Calculated PCS envelope is shown in Fig. 3:

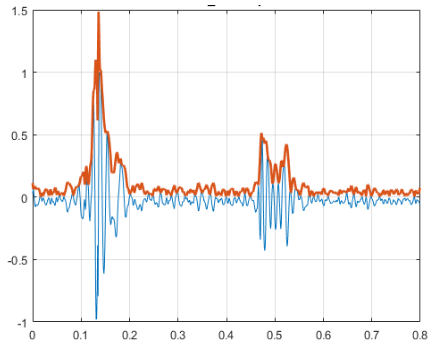

Fig. 3. Real PCS end envelope (thickened curve) (abscissa axis – time (s); ordinate amplitude (relative))

For a frequency-filling and an envelope vectors creating, the real PCS is conventionally divided into morphological intervals according to medical practice. At each of the intervals the envelope generating is performed using the as a sigmoid-form conjugation function. Its modified expression allows to the amplitude, the existence interval and the slope characteristics define flexibly using only one corresponding separate variable.

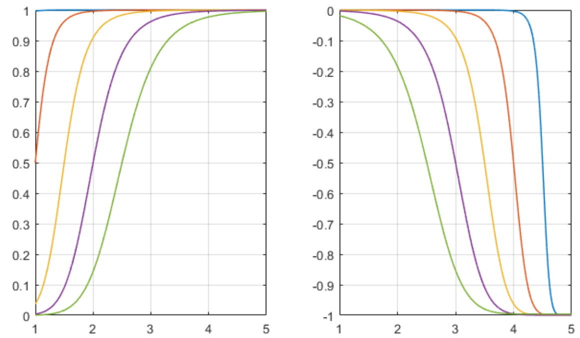

Fig. 4. Conjugation functions for piecewise approximated PCS envelope generated according to specified variable values $s_{nk}>0$, T_{nk} *= [1:5],* t_n *=5(left side) and* $s_{nk}<0$, T_{nk} *= [1:5],* t_n *=5(right side) (abscissa axis – time (s); ordinate amplitude (relative)).*

At each of the morphological intervals, frequency-filling vector is generated by passing a white noise through a bandpass filter, the AFC of which, for example, is depicted in Fig. 5.

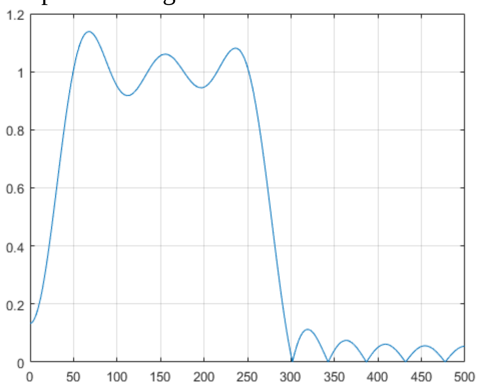

Fig. 5. The bandpass filter structure according to f_{nl} *=0,* f_{nh} *=300 (abscissa axis – frequency (Hz); ordinate – amplitude (normalized to the gain ratio k=1))*

The generated bandwidth noise amplitude and phase spectra are shown in Fig. 6.

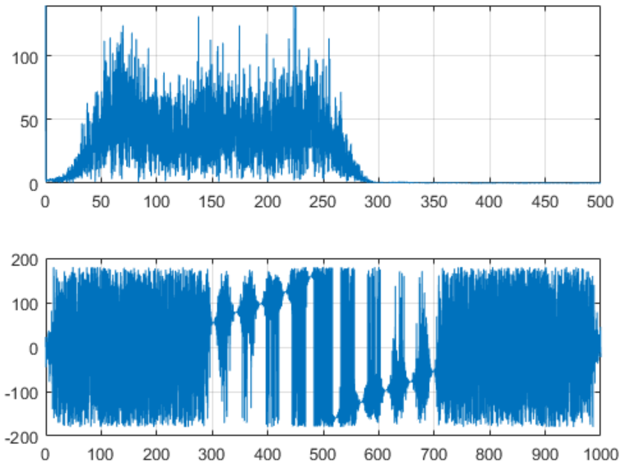

Рис. 6. Amplitude (top) and phase (bottom) spectra of the calculated band-limited white noise according to f_{nl} *=0,* f_{nh} *=300 (abscissa axis – frequency (Hz); ordinate – (top) amplitude (relative)) and (bottom) phase angle (Degree)*

As a result of the real FCS processing and the envelope calculation, it was performed its piecewise approximation using the sigmoid-form function and calculated the corresponding frequency-filling single-amplitude vector in accordance with the physiological data (Fig. 7).

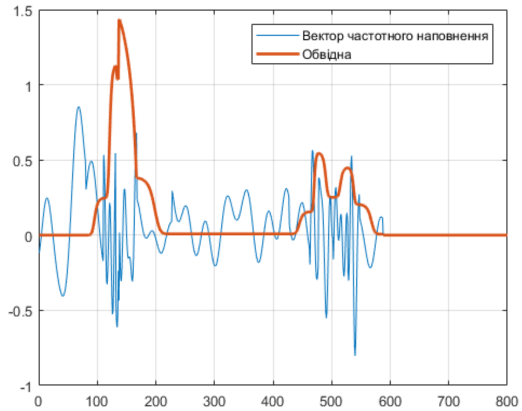

Fig. 7. Frequency-filling vector of PCS (thin curve), approximated envelope fo PCS (thickened curve), (abscissa axis – time (s); ordinate amplitude (relative)

The result of one PCS-realization simulation is shown in Fig. 8.

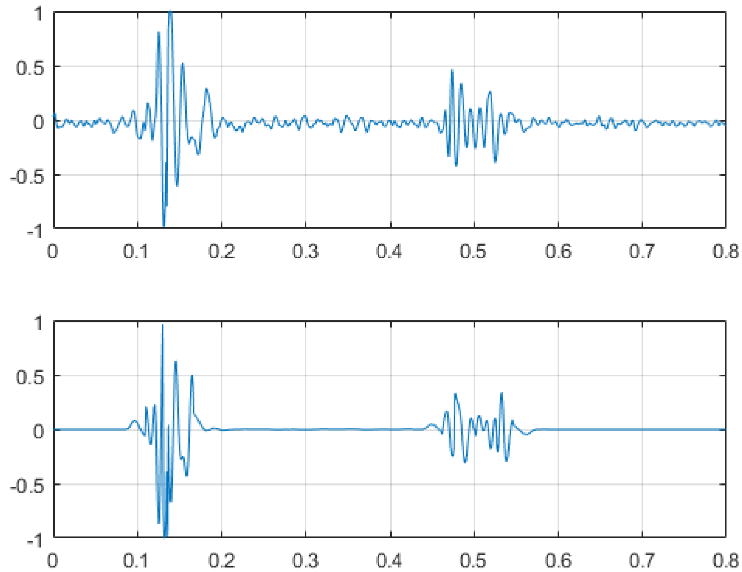

Fig. 8. Real PCS (top) and simulated PCS (bottom), (abscissa axis – time (s); ordinate – amplitude (normalized))

The result of PCS simulation is shown in Fig.9:

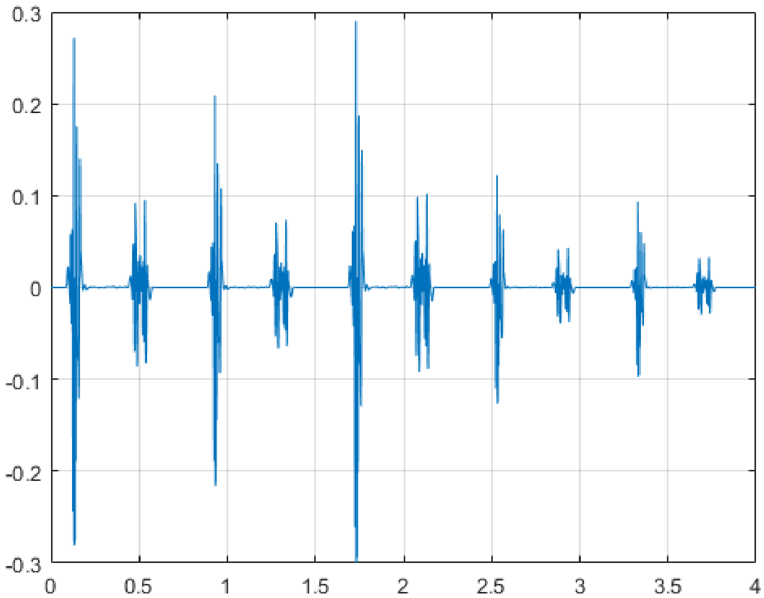

Fig. 9. Simulated PCS (5 realizations), (abscissa axis – time (s); ordinate – amplitude (normalized))

The real and simulated PCS Fourier spectrograms and are shown in Fig. 10.

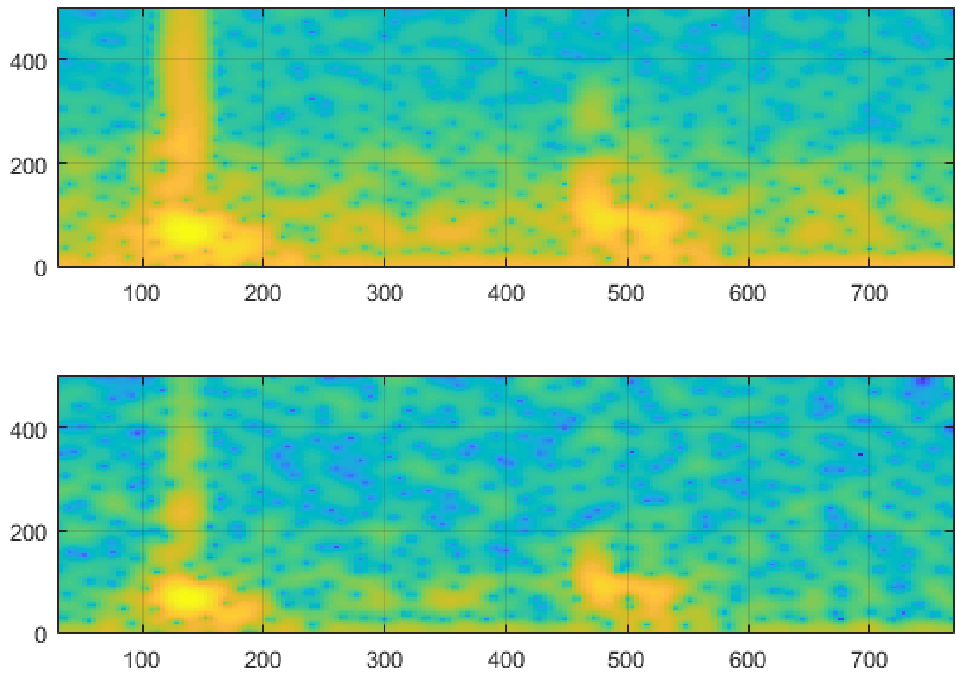

Fig. 10. Fourier spectrograms for real PCS (top) and simulated PCS (bottom), (abscissa axis – time (s); ordinate – frequency (Hz))

For the obtained results accuracy evaluation the mean-square similarity criterion (for discrete data) was applied:

$$\varepsilon^2 \approx \frac{1}{N_1 N_2} \sum_{n_1=0}^{N_1-1} \sum_{n_2=0}^{N_2-1} [f(n_1,n_2) - g(n_1,n_2)]^2 , \qquad (2)$$

where: $f(n_1,n_2)$ i $g(n_1,n_2)$ – images-matrices described by models of homogeneous random fields; n_1, n_2 – 2-dimensional image element index; N_1, N_2 – image dimensions.

The result of the standard-quadratic criterion calculation is equal to 0.15, which indicates a high degree similarity level. Thus, an objective assessment indicates the adequacy of the simulation model to the real signal.

Conclusions. The phonocardiosignal simulation model as piecewise approximated additive-multiplicative mixture of the piecewise conjugated sigmoid-form vector and the frequency-filling vector of the band-limited white noise generated by zero-phase-shifting filtration methods which enabled the procedure of high-precision signal simulation according to experimental signals was developed at first time.

References

1. Dragan Y. Power theory of linear models of stochastic signals: - Lviv, Center for Strategic Studies of eco-bio-technical systems, 1997. - XVI + 333c.

2. Palaniza Y.B. Modern approaches to the phonocardiosignal processing and its mathematical model in the periodically correlated random process form / Y.B. Palaniza // Bulletin of the Khmelnytsky National University. Technical sciences - 2016. - Issue. 2 (235). - pp. 90-93.

3. Dragan Y.P. Description of tone cardiosignals using the model of periodically correlated processes / Y.P. Dragan G.M. Osukhivskaya // Problems of Management and Informatics - 1999.

4. Dragan Ya.P. MODEL OF THE TEST SIGNAL NOISE IN CHANNELS WITH DIGITAL SIGNAL PROCESSING. / Dragan Ya.P., Yavorskii B.I. // Radioelectronics and Communications Systems (English translation of Izvestiya Vysshikh Uchebnykh Z. , 1986 — vol. 29, no. 9. — 17-21 — ISSN 00337870.

5. Dragan Ya.P. Information ability specificity of periodically correlated and related random processes as rhythmic stochastic models / Dragan Ya.P., Sikora L.S., Yavorskij B.I. // Problemy Upravleniya I Informatiki (Avtomatika). , 1997 — no. 6. — 96-109 — ISSN 05722691.

VOL.1

№16/2018

Znanstvena misel journal

The journal is registered and published in Slovenia.

ISSN 3124-1123

The frequency of publication – 12 times per year.

Journal is published in Slovenian, English, Polish, Russian, Ukrainian.

The format of the journal is A4, coated paper, matte laminated cover.

All articles are reviewed

Edition of journal does not carry responsibility for the materials published in a journal.

Sending the article to the editorial the author confirms it's uniqueness and takes full responsibility for possible consequences for breaking copyright laws

Free access to the electronic version of journal

Znanstvena misel journal

Slovenska cesta 8, 1000 Ljubljana, Slovenia

Email: info@znanstvena-journal.com

Website: www.znanstvena-journal.com