

UDC 621.391 (045)

DOI:

<sup>1</sup>O. Lavrynenko,  
<sup>2</sup>G. Konakhovych,  
<sup>3</sup>D. Bakhtiiarov

## COMPRESSION ALGORITHM OF VOICE CONTROL COMMANDS OF UAV BASED ON WAVELET TRANSFORM

<sup>1,2,3</sup>Telecommunication Systems and Networks Department, Educational & Research Institute of Air Navigation, National Aviation University, Kyiv, Ukraine

E-mail: <sup>1</sup>oleksandr.lavrynenko@gmail.com, ORCID ID: <sup>1</sup><http://orcid.org/0000-0002-7738-161X>

**Abstract**—It is proposed to use developed digital speech signal compression algorithm based on wavelet transform in the unmanned aerial vehicle voice control system. It is implemented the estimation of compression data ratio and bit rate depending on the parameters of the correlation coefficient, the signal / noise ratio, peak signal / noise ratio and root-mean square error, which is the main criterion of performance of speech quality. The results of experimental studies suggest the feasibility of further practical application of the proposed digital speech signal compression algorithm based on wavelet transform in voice control systems unmanned aerial vehicle.

**Index Terms**—Compression algorithm; wavelet transform; voice control; unmanned aerial vehicle; compression ratio; correlation coefficient; bit rate.

### I. INTRODUCTION

In voice control systems unmanned aerial vehicle (UAV) there is a problem of speech redundancy. One of the main problem of the speech signal compression algorithm is the methods of optimal reduction of redundancy of voice data and optimization of its parameters with the parameters of the UAV control system. The solution of the problem will allow to increase the capacity of linear paths and channels in the conditions of specified criterions of communication UAV quality. The reduction of redundancy of voice data, while maintaining the required quality of speech perception allows to transmit the data at lower speeds, thereby increasing the channel UAV capacity.

### II. PROBLEM STATEMENT

1) **Need** to develop a digital speech signal compression algorithm based on wavelet transform (WT) using entropy arithmetic coding and optimization of its parameters with the parameters of the UAV control system, which allows to achieve desired results in the enhancement of data compression while maintaining the intelligibility of speech, which in its turn will transmit speech data at low speeds and decreasing the flow of transmitted information, thereby increasing the bandwidth of existing linear paths and channels UAV.

2) **Need** to prove experimentally and substantiate the usefulness of using digital speech signal compression algorithm based on WT in voice control systems UAV.

The objectives of the experimental studies:

a) to develop and research the proposed digital speech signal compression algorithm based on WT in the software package Matlab;

b) to calculate the bit rate (BR), the compression ratio (CR), the correlation coefficient (CC), the signal / noise ratio (SNR), peak signal / noise ratio (PSNR) and root-mean square error (RMSE) of experimental example of the speech up and after the application of the compression algorithm;

c) to carry out a comparative evaluation of the CR, CC, SNR and PSNR depending on BR;

d) to carry out a comparative evaluation of the CR, CC, SNR and PSNR depending on CR.

The developed digital speech signal compression algorithm based on WT providing optimal solutions of the relevant tasks such as digital speech data compression, the maximum speech signal quality at a certain level of compression, the possibility of the release of some bandwidth of the communication channel for the transmission of digital data (commands), security of transmitted speech data, the possibility to implement the algorithm microprocessor with low productivity to reduce the cost of the developed device.

Developed and researched digital speech signal compression algorithm based on WT using entropy arithmetic coding provides a reduction in volume of digital speech data with together with speech intelligibility and thereby increases the bandwidth of the communication channel. The results of experimental studies suggest the feasibility of further practical application of the proposed digital speech signal compression algorithm based on wavelet transform into different models of vocoding devices.

### III. COMPRESSION ALGORITHM OF VOICE CONTROL COMMAND OF UAV BASED ON WAVELET TRANSFORM

The article presents the developed digital speech signal compression algorithm based on WT using entropy arithmetic coding (Fig. 1). In the research as an input digital speech compression algorithm is

used male voice recording with a sampling rate of 8 kHz and the quantization bit depth of 8 bits per sample, which corresponds to the basic digital channels of the telephone network – 64 Kbit/s. The main task of speech signal compression is to reduce the flow of data transmitted over the digital communication channel with a slight deterioration of the restored-term speech at the receiving end.

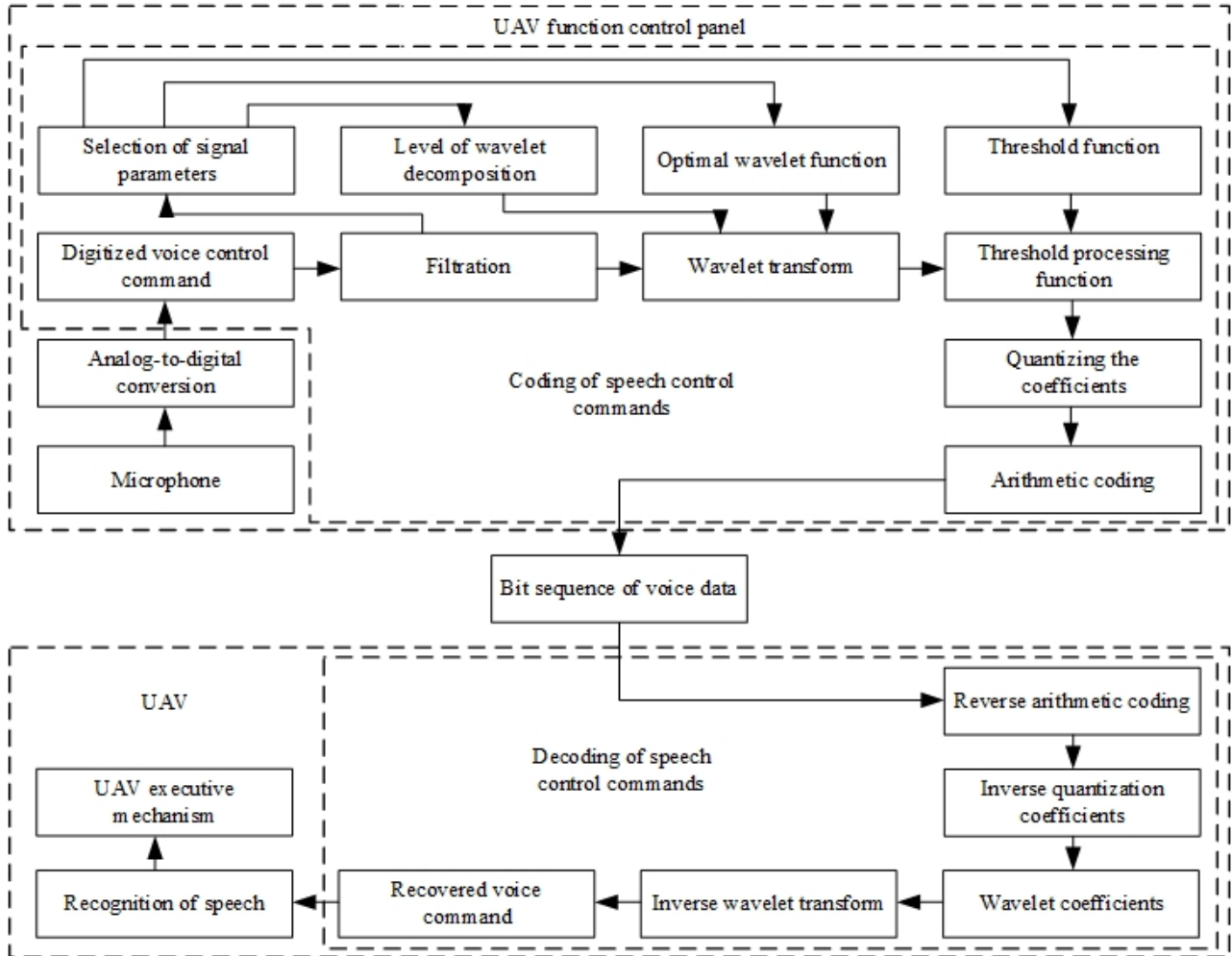


Fig. 1. Compression Algorithm of Voice Control Command of UAV based on Wavelet Transform

In Speech signal compression according to the developed algorithm takes place in several phases. In the first phase for noise reduction and normalization of frequency spectrum of digital speech signal is supplied to 2nd order Butterworth low pass filter, where  $n=5$  with  $a$  bandwidth 300...3400 Hz, which is represented as a row vector  $b$  and  $a$ , having a length  $2n+1$  and the polynomial coefficients of numerator and denominator of transmitting function descending powers of  $z$ :

$$H(z) = \frac{B(z)}{A(z)} = \frac{b(1) + b(2)z^{-1} + \dots + b(n+1)z^{-n}}{1 + a(2)z^{-1} + \dots + a(n+1)z^{-n}}$$

Butterworth filter cutoff frequency is the frequency at which transmission coefficient module is  $\sqrt{1/2}$ . Figure 2 shows diagram of frequency-response characteristic (FRC), phase-frequency response (PFC), impulse response (IR) of synthesized 10th order Butterworth filter with a bandwidth 300...3400 Hz. In the second phase compression algorithm normalized after filtration speech signal after filtering comes on the discrete wavelet transform (DWT) block [1]. Since the speech signal is a non-stationary random process, then to process it was proposed to use DWT the input of which receives the digital samples of the speech signal, and the output generated wavelet coefficients (WC) [1].

Based on an earlier experimental study as a mother wavelet function is appropriate to use the Daubechies wavelet of order 12.

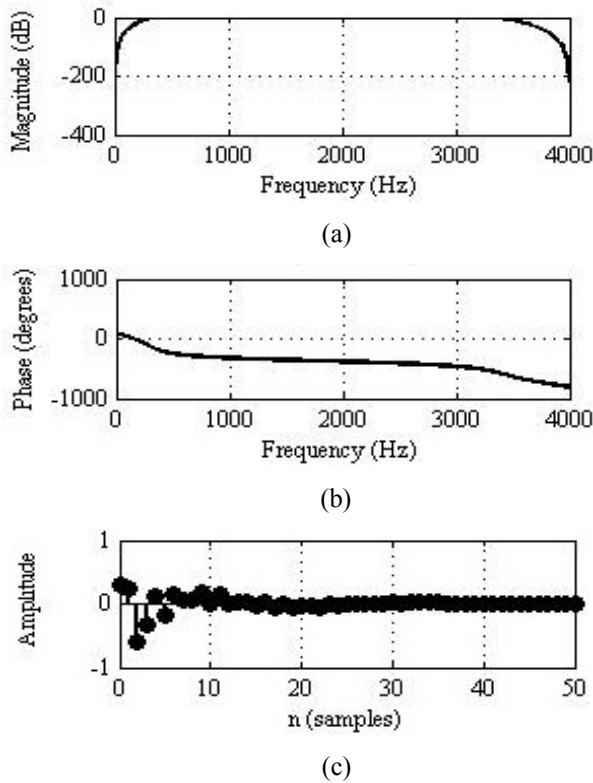


Fig. 2. (a) – FRC, (b) – PFC, (c) – IR of synthesized 10th order Butterworth filter with a bandwidth 300...3400 Hz

Calculation of the order  $N$  Daubechies scaling filter comes to finding the roots of a polynomial of degree  $4N$  (Fig. 3), whose coefficients

$$a(k) = \frac{\prod_{l=-N+1}^N \left(\frac{1}{2} - l\right)}{\prod_{l=-N+1}^N (k-l)},$$

$$k = 1, \dots, N,$$

for all  $k \neq l$  form sets

$$\{a(N) \ 0 \ a(N-1) \ 0 \ \dots \ 0 \ a(1) \ 1 \ a(1) \ 0 \ a(2) \ 0 \ \dots \ 0 \ a(N)\}$$

In the third phase WC after DWT come on the thresholding block. The main property of DWT is that the converted signal is represented by a large number of redundant WC, which, after thresholding are reset WC resets via a given threshold function, WC low or equal to that will be equal to zero, and the rest will remain unchanged.

Wavelet coefficient with an absolute value close to zero only contain a small part of the signal energy. Wavelet coefficient resetting results in negligible energy losses. This property makes DWT attractive for compressing voice data [2].

The Figure 4 shows a threshold function for processing the WC speech signal, where  $x$  – the value of the WC before the threshold,  $y$  – the value of WC after threshold,  $\Theta$  – threshold. Threshold enhancement will increase the degree of redundancy reduction, but at the same time will decrease speech intelligibility. Lowering the threshold to reduce the loss of informational WC, but also reduces the effectiveness of signal compression [3].

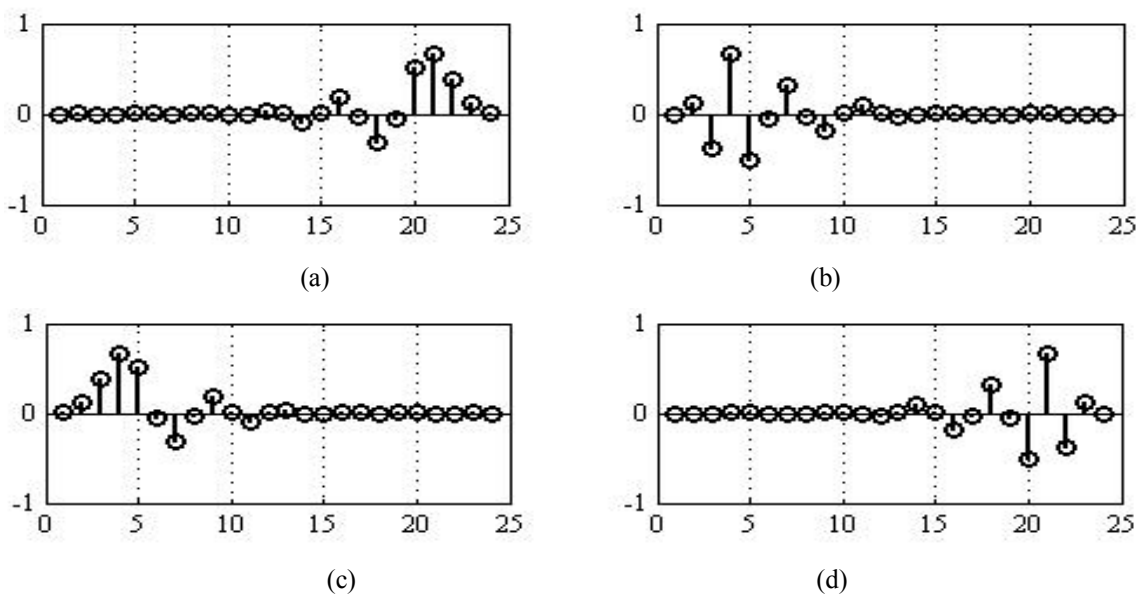


Fig. 3. Orthogonal Daubechies filter of order 12: (a) is the decomposition low-pass filter; (b) is the decomposition high-pass filter; (c) is the reconstruction low-pass filter; (d) is the reconstruction high-pass filter

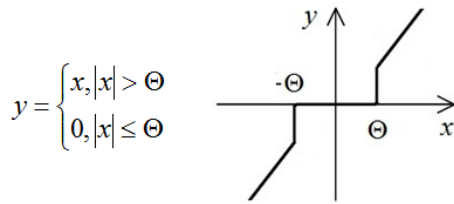


Fig. 4. The threshold function

In the fourth phase of the WC compression algorithm after thresholding is introduced as 8-bit integers. This format is also used for the data transmission. Since detail and approximation of WC are real numbers, then before you performing of speech compression by the arithmetic coding, it is necessary to convert the WC which passed threshold in a numerical range corresponding to the selected format. Otherwise, the WC compression flow will be bigger than speech signal flow.

This operation can be performed using the quantization. Thus arises the quantization error, which introduces additional distortion in the transmitted speech signal. In the fifth phase of the of compression algorithm, the quantized WC encoded by the by arithmetic coding, whereby in the output the compressed bit sequence of speech signal data is generated.

A distinctive feature of the arithmetic coding from well-known coding methods is that neither the encoder or decoder does not store all possible set of code words. Instead, in the transmission of a particular sequence  $x$  the code word  $c(x)$  is calculated only for predetermined sequence  $x$ . Encoding rules are known to the decoder, and it restores  $x$  by  $c(x)$ , not having a full list of code words [4].

#### IV. RESULTS

In the article the digital speech signal compression algorithm based on WT using entropy arithmetic coding was developed, and modeling in software package MATLAB, in particular, it was carried out evaluating the CR data and BR in dependence on the parameters of CC, the SNR, and PSNR and RMSE, which is the main criterion of performance of speech quality.

The first experiment (Table I) was conducted according to the criteria as BR at the output of speech compression algorithm, depending on which values were changed CR, CC, SNR, PSNR, RMSE, thereby giving an objective assessment of speech intelligibility and the level of compression speech data during operation of the algorithm at the given BR.

TABLE I DEPENDENCE RELATION CR, CC, SNR, PSNR, RMSE ON BR

BR (Kbit/s) output	BR (Kbit/s) input	CR	CC	SNR (dB)	PSNR (dB)	RMSE
8	64	8	0.9614	11.2124	34.0639	0.2750
9	64	7.1	0.9701	12.3023	35.1537	0.2426
10	64	6.4	0.9770	13.4187	36.2744	0.2133
11	64	5.8	0.9822	14.5125	37.3640	0.1881
12	64	5.3	0.9861	15.5819	38.4334	0.1663
13	64	4.9	0.9891	16.6320	39.4835	0.1474

The second experiment (Table II) was conducted according to the criteria as CR of speech data at the output of digital speech signals compression algorithm, depending on which values were changed BR,

CC, SNR, PSNR, RMSE, thereby giving an objective assessment of speech intelligibility and speech data transmission speed operation of the compression algorithm at the given BR

TABLE II DEPENDENCE RELATION BR, CC, SNR, PSNR, RMSE ON CR

CR	BR (Kbit/s) output	BR (Kbit/s) input	CC	SNR (dB)	PSNR (dB)	RMSE
4	16	64	0.9949	19.9081	42.7596	0.1011
5	12.8	64	0.9885	16.4126	39.2641	0.1511
6	10.6	64	0.9806	14.1443	36.9958	0.1962
7	9.1	64	0.9710	12.4302	35.2817	0.2390
8	8	64	0.9613	11.2008	34.0523	0.2754
9	7.1	64	0.9390	9.2728	32.1243	0.3438

The results of the experiment show that the optimal solution on criteria of the ratio of the speech quality on the level of compression will be proposed speech signal compression algorithm with BR = 9 (9.1) Kbit / s, that allows you to save sufficient CR =

7 (7.1), wherein the main index of criteria of speech quality CC = 0.9701 (0.9710), SNR = 12.3023 (12.4302) dB, PSNR = 35.1537 (35.2817) dB and RMSE = 0.2426 (0.2390) give high results in the conditions of given parameters of BR and CR.

## V. CONCLUSIONS

The article presents a developed digital speech signal compression algorithm based on WT using entropy arithmetic coding was developed, and modeling in software package Matlab.

The usefulness of using digital speech signal compression algorithm based on WT into different models of vocoding devices experimentally proved and substantiated.

The comparative evaluation of the CC, SNR, PSNR and RMSE depending on BR and CR was carried out.

On the basis of the results of the study (Table I and II) you can demonstrably see, at what speed, with what degree of compression algorithm works with the appropriate quality criteria. The optimal solution in terms of intelligibility at a reasonably good compression will be proposed speech signal compression algorithm with BR = 9 (9.1) Kbit/s, that gives the result CR = 7 (7.1), wherein the main index of criteria of speech quality CC = 0.9701 (0.9710), SNR = 12.3023 (12.4302) dB, PSNR = 35.1537 (35.2817) dB and RMSE = 0.2426 (0.2390)

give high results in the conditions of given parameters of BR and CR.

## REFERENCES

- [1] O. Lavrynenko, G. Konakhovych, and D. Bakhtiiarov, "Method of Voice Control Functions of the UAV," *Methods and Systems of Navigation and Motion Control (MSNMC), IEEE 4th International Conference*, 2016, pp. 47–50.
- [2] D. Bakhtiiarov, G. Konakhovych, and O. Lavrynenko, "Protected System of Radio Control of Unmanned Aerial Vehicle," *Methods and Systems of Navigation and Motion Control (MSNMC), IEEE 4th International Conference*, 2016, pp. 196–199.
- [3] G. F. Konakhovych, O. Y. Lavrynenko, V. V. Antonov, and D. I. Bakhtiiarov, "A digital speech signal compression algorithm based on wavelet transform," *Electronics and control systems*, vol. 48, no. 2, pp. 30–36, 2016.
- [4] L. F. Sanchez, H. Abaunza, and P. Castillo, "Safe navigation control for a quadcopter using user's arm commands," *Unmanned Aircraft Systems (ICUAS) 2017 International Conference*, 2017, pp. 981–988.

Received October 27, 2017

**Lavrynenko Oleksandr.** Post-graduate student.

Telecommunication Systems and Networks Department, Educational & Research Institute of Air Navigation, National Aviation University, Kyiv, Ukraine.

Education: National Aviation University, Kyiv, Ukraine, (2014).

Research area: speech recognition, digital signal processing, information security.

Publications: more than 15.

E-mail: [1oleksandrlavrynenko@gmail.com](mailto:1oleksandrlavrynenko@gmail.com), ORCID ID: [1http://orcid.org/0000-0002-7738-161X](http://orcid.org/0000-0002-7738-161X)

**Konakhovych Georgy.** Doctor of Engineering Science. Professor.

Telecommunication Systems and Networks Department, Educational & Research Institute of Air Navigation, National Aviation University, Kyiv, Ukraine.

Education: National Aviation University, Kyiv, Ukraine, (1968).

Research area: information security systems, telecommunication systems.

Publications: more than 100.

E-mail: [oleksandrlavrynenko@gmail.com](mailto:oleksandrlavrynenko@gmail.com)

**Bakhtiiarov Denis.** Post-graduate student.

Telecommunication Systems and Networks Department, Educational & Research Institute of Air Navigation, National Aviation University, Kyiv, Ukraine.

Education: National Aviation University, Kyiv, Ukraine, (2013).

Research area: information security systems, telecommunication systems.

Publications: more than 15.

E-mail: [oleksandrlavrynenko@gmail.com](mailto:oleksandrlavrynenko@gmail.com)

**О. Ю. Лавриненко, Г. Ф. Коначович, Д. І. Бахтіяров.** Алгоритм стиснення голосових команд керування БПЛА на основі вейвлет-перетворення

Запропоновано використовувати розроблений алгоритм стиснення цифрових мовних сигналів на основі вейвлет-перетворення в системі голосового керування безпілотного літального апарата. Здійснено оцінювання коефіцієнта стиснення даних і швидкості передачі бітів в залежності від параметрів коефіцієнта кореляції, відношення сигнал / шум, пікового відношення сигнал / шум і середньоквадратичної помилки, які виступають головними показниками критерію якості мови. Отримані результати експериментального дослідження дозволяють зробити висновок про доцільність подальшого практичного застосування запропонованого алгоритму стиснення цифрових мовних сигналів на основі вейвлет-перетворення в системах голосового керування безпілотного літального апарата.

**Ключові слова:** алгоритми стиснення; вейвлет-перетворення; голосове управління; безпілотний літальний апарат; коефіцієнт стиснення; коефіцієнт кореляції; швидкість передачі бітів.

**Лавриненко Олександр Юрійович.** Аспірант.

Кафедра телекомунікаційних систем, Навчально-науковий інститут аеронавігації, Національний авіаційний університет, Київ, Україна.

Освіта: Національний авіаційний університет, Київ, Україна, (2014).

Напрямок наукової діяльності: розпізнавання мови, цифрова обробка сигналів, захист інформації.

Кількість публікацій: більше 15.

E-mail: [oleksandrlavrynenko@gmail.com](mailto:oleksandrlavrynenko@gmail.com), ORCID ID: <http://orcid.org/0000-0002-7738-161X>

**Конахович Георгій Філімонович.** Доктор технічних наук. Професор.

Кафедра телекомунікаційних систем, Навчально-науковий інститут аеронавігації, Національний авіаційний університет, Київ, Україна.

Освіта: Національний Авіаційний Університет, Київ, Україна (1968).

Напрямок наукової діяльності: системи захисту інформації, телекомунікаційні системи.

Кількість публікацій: більше 100.

E-mail: [oleksandrlavrynenko@gmail.com](mailto:oleksandrlavrynenko@gmail.com)

**Бахтіяров Денис Ілшатович.** Аспірант.

Кафедра телекомунікаційних систем, Навчально-науковий інститут аеронавігації, Національний авіаційний університет, Київ, Україна.

Освіта: Національний Авіаційний Університет, Київ, Україна (2013).

Напрямок наукової діяльності: системи захисту інформації, телекомунікаційні системи.

Кількість публікацій: більше 15.

E-mail: [oleksandrlavrynenko@gmail.com](mailto:oleksandrlavrynenko@gmail.com)

**А. Ю. Лавриненко, Г. Ф. Конахович, Д. И. Бахтияров.** Алгоритм сжатия голосовых команд управления БПЛА на основе вейвлет-преобразования

Предлагается использовать разработанный алгоритм сжатия цифрового речевого сигнала, основанный на вейвлет-преобразовании в системе голосового управления беспилотного летательного аппарата. Осуществлено оценивание коэффициента сжатия данных и скорости передачи битов в зависимости от параметров коэффициента корреляции, отношения сигнал / шум, пикового отношения сигнал / шум и среднеквадратичной ошибки, которые выступают главными показателями критерия качества речи. Полученные результаты экспериментального исследования позволяют сделать вывод о целесообразности дальнейшего практического применения предложенного алгоритма сжатия цифровых речевых сигналов на основе вейвлет-преобразования в системах голосового управления беспилотного летательного аппарата.

**Ключевые слова:** алгоритмы сжатия; вейвлет-преобразование; голосовое управление; беспилотный летательный аппарат; коэффициент сжатия; коэффициент корреляции; скорость передачи битов.

**Лавриненко Александр Юрьевич.** Аспірант.

Кафедра телекоммуникационных систем, Учебно-научный институт аэронавигации, Национальный авиационный университет, Киев, Украина.

Образование: Национальный Авиационный Университет, Киев, Украина (2014).

Направление научной деятельности: распознавания речи, цифровая обработка сигналов, защита информации.

Количество публикаций: более 15.

E-mail: [oleksandrlavrynenko@gmail.com](mailto:oleksandrlavrynenko@gmail.com), ORCID ID: <http://orcid.org/0000-0002-7738-161X>

**Конахович Георгий Філімонович.** Доктор технических наук. Професор.

Кафедра телекоммуникационных систем, Учебно-научный институт аэронавигации, Национальный авиационный университет, Киев, Украина.

Образование: Национальный Авиационный Университет, Киев, Украина (1968).

Направление научной деятельности: системы защиты информации, телекоммуникационные системы.

Количество публикаций: более 100.

E-mail: [oleksandrlavrynenko@gmail.com](mailto:oleksandrlavrynenko@gmail.com)

**Бахтияров Денис Илшатович.** Аспірант.

Кафедра телекоммуникационных систем, Учебно-научный институт аэронавигации, Национальный авиационный университет, Киев, Украина.

Образование: Национальный Авиационный Университет, Киев, Украина (2013).

Направление научной деятельности: системы защиты информации, телекоммуникационные системы.

Количество публикаций: более 15.

E-mail: [oleksandrlavrynenko@gmail.com](mailto:oleksandrlavrynenko@gmail.com)