AP19679505 Research and development of algorithms of multithreshold decoding of convolutional codes and their hardware-software implementation for high-speed radio channels with fades - p.m. Sailau kyzy Zh.

The relevance of the research is related to the implementation of the tasks of the state programme "Digital Kazakhstan", the Law of the Republic of Kazakhstan "On National Security" and the State Concept of Cyber Security "Cyber Shield of Kazakhstan" to ensure information security of information and communication infrastructure, maintenance and development of an effective system of protection of information resources and communication infrastructure. The development of the national radio communication system is an important component of national and information security, as it ensures interconnection between the services of special government agencies, the Armed Forces, law enforcement agencies, emergency medical services, fire and search and rescue teams.

Currently, high-speed reliable radio communication systems are realised using orthogonal frequency division channel multiplexing technology, which provides the required spectral efficiency and high data capacity. But in broadband wireless communication over long distances, many errors occur, which leads to the need to also use direct error correction techniques. The idea of the project is to develop and hardware-software implementation of efficient error correction schemes for use in radio communication networks with fading, as well as in the presence of Doppler shift and intersymbol interference.

The project purpose is to research and develop methods and means of error correction providing operation near channel capacity when used in fast-changing digital radio communication systems together with multiplexing technologies with orthogonal frequency division of channels and multiposition modulation, space-time coding and precoding.

Expected and achieved results:
Achieved results for the reporting period:
1. The works on studying the specifics of digital radio systems of information transmission for mobile radio communication systems in the presence of fading, radio modems, radio systems of receiving video, audio information are carried out, the requirements used in the choice of methods of noise-resistant coding by the criterion of maximum value of EVC, speed, complexity of software and hardware implementation of encoders and decoders are determined.

The basic principles of LDPC coder implementation are investigated. Software and hardware implementation of encoding and decoding with hard decision algorithms with bit inversion on the basis of mathematical models and algorithms have been realised. According to the simulation results the effect of error correction of LDPC codes using Tanner graph for radio channels was analysed.

According to the results of these experiments published one publication -1 (one) article in the proceedings of the VIII International Scientific Conference "Informatics and Applied Mathematics" (26 - 27 October 2023, Kazakhstan, Almaty).

2. The analysis of susceptibility of self-orthogonal codes to propagation of errors with use of multivariate derivative functions of probability, and with application of graph Tanner code; the received results are used at construction and a choice of codes for application in multithreshold decoders at a noise level, less than carrying capacity of a radio channel only on some tenths dB.

The method of decrease in influence of decoding error propagation influence is offered, based on construction of self-orthogonal codes with small degree of crossing of sets of control errors for various information symbols. The original programme of simulation of convolutional coders with manual and automatic correction of code parameters, introduction of errors in a communication channel and optimization of parameters of iterative threshold decoding was used. Simulation results have shown that optimisation of threshold values and weight coefficients for all threshold elements reduces the effect of error propagation and efficiency of error correction.

The research results are accepted for publication in the 7th International Symposium on Innovative Approaches in Smart Technologies (23-25 November 2023, Turkey, Istanbul).

3. Investigations of efficiency of algorithms of multithreshold decoding of convolutional codes for communication channels with fading are carried out. Modification of the scheme of error correction at the expense of optimisation of parameters of work of multithreshold decoder (MTD), new algorithms of work of separate functional nodes of decoder, and also schemes of cascading, which constituent element are multithreshold decoders is offered and proved.

The algorithm of optimisation of parameters of multithreshold decoding of symbolic self-orthogonal codes which allows to reduce in several times number of variants of an enumeration at minimisation of function of decoding and to reduce probability of error of decoding more than on 2 orders is offered.

The new cascade coding scheme consisting of two MTD with variation of coding parameters in the Gaussian channel is investigated. The probabilities of decoding error probability in the effective region of the multithreshold decoder and the speed of software implementation of these concatenation schemes are estimated.

On results of the given experiments one publication -1 (one), in the domestic edition recommended by Committee on quality assurance in the sphere of science and higher education of the Ministry of science and higher education of the Republic of Kazakhstan is published.

4. Theoretical and simulation modelling of MTD application in digital radio systems using multiplexing with orthogonal frequency division of channels and multiposition modulation is carried out. Theoretical estimations and experimental characteristics of MTD for convolutional codes in the form of dependence of decoding error probability on noise level in radio channels in the presence of fading are received. Experimental characteristics of optimised MTD for convolutional codes in radio channels in the presence of inter-symbol interference are investigated.

According to the results of these experiments one publication -1 (one) article in the proceedings (XXVI International Conference "Digital Signal Processing and Its Applications - DSPA-2024" (26-30 March 2024, Moscow, Russia) pp.33-38.

5. Methods of MTD application in systems with several transmitting and several receiving antennas, methods of radio channel estimation using MTD are developed. Methods of MTD application in systems with several transmitting and several receiving antennas are investigated. Experimental characteristics of the multithreshold decoder for convolutional codes in the form of dependence of decoding error probability on the noise level in radio channels in the presence of fading are implemented.

By results of the given experiments the certificate on entering of data in the state register of copyrights on the program for computer and one publication is received: the Certificate on entering of data in the state register of the rights protected by copyright [1]46161 from "21" May 2024.

1 article in the materials (XVI Saginov Readings. Integration of education, science and production (13-14 June 2024, Karaganda, Kazakhstan).

6. Joint iterative demodulation/decoding methods are developed to improve the energy efficiency of digital radio data transmission systems with MTD.

A paper has been prepared based on the results of the research and is under review in a domestic publication recommended by SHEQAC.

Expected results

7. To develop software versions of multithreshold decoders for radio communication systems possessing high speed at the expense of parallelisation of process of calculations on the basis of the open standard of parallel programming of heterogeneous systems OpenCL.

8. To investigate possibilities of realisation of high-speed multithreshold decoders as an embedded system on programmable logic integrated circuits (PLIC) on the basis of use of OpenCL compiler for reconfigurable systems.

9. To prepare test programs, test methods and experimentally investigate performance parameters of technical implementation (software and hardware) of optimised MTD methods for radio communication systems.

10. Prepare software and design documentation of the developed software and hardware solutions, applications for patents and/or state registration certificates for software products, training manual for implementation of the project results in the educational process.
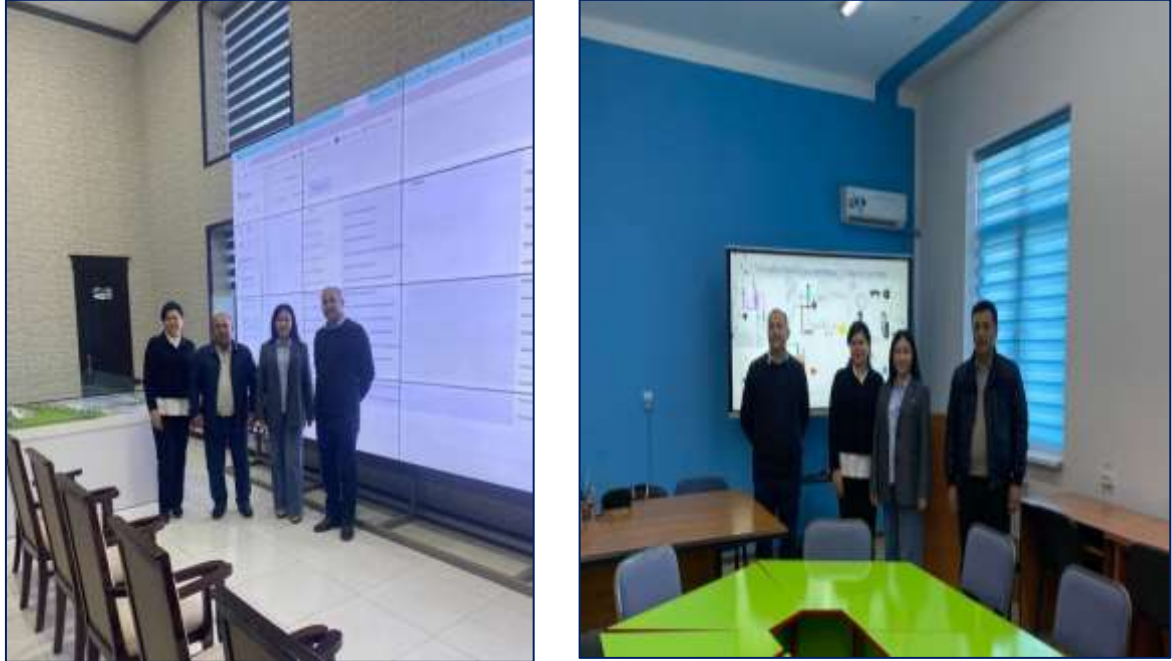
Figure 1 - Discussing opportunities for developing collaborative research with colleagues at Bukhara Institute of Engineering and Technology, Bukhara, Uzbekistan, 2023.
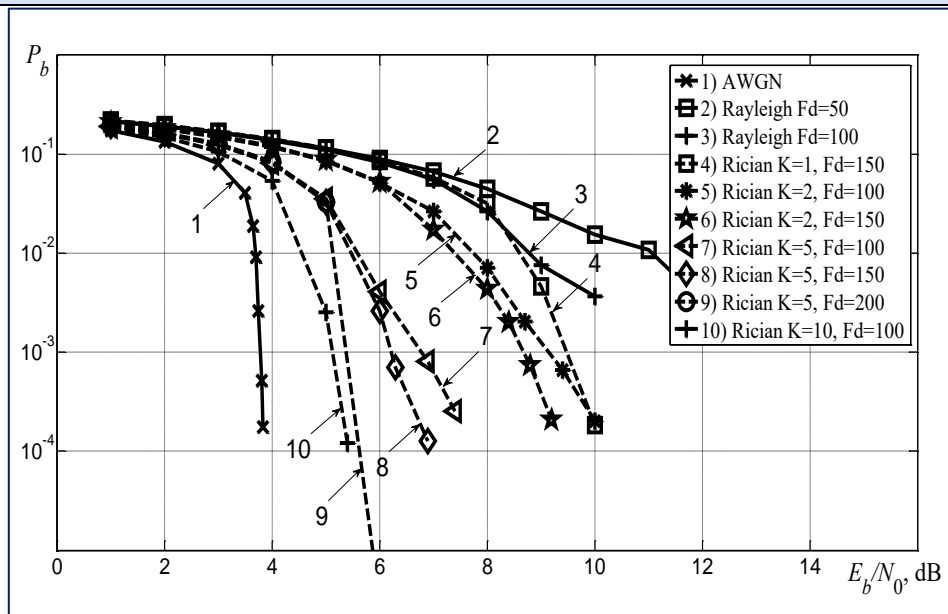
Figure 2 - MTD characteristics in a channel with fades
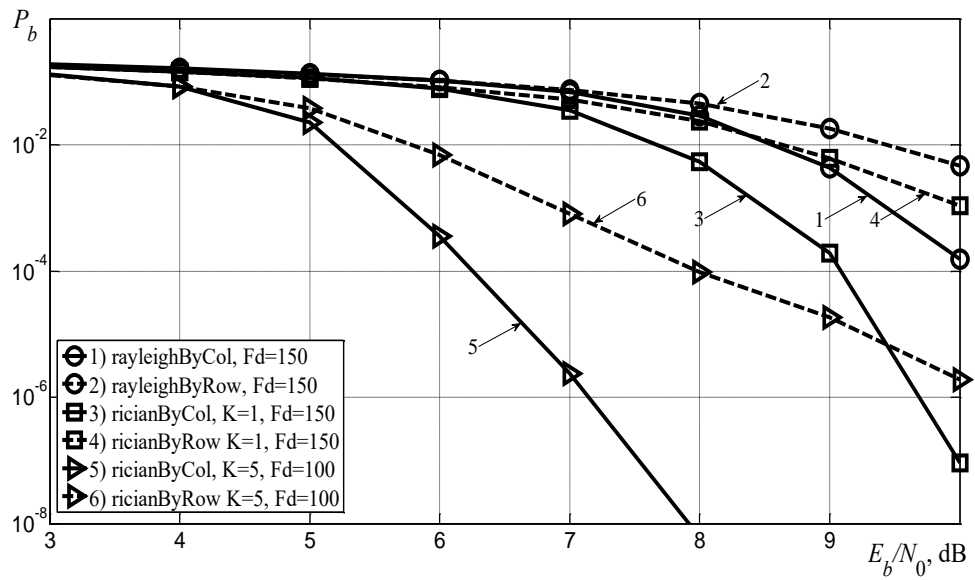
Figure 3 - MTD characteristics in a fading channel with serial and parallel bit transmission

Figure 4 - XXVI International Conference "Digital Signal Processing and Its Applications - DSPA-2024") 26-30 March 2024, Moscow, Russia.

Figure 5 - Project Manager Sailau kyzy Zh., Gennady Vladimirovich Ovechkin, Doctor of Technical Sciences, Professor of the Department of "Computational and Applied Mathematics" Ryazan State Radio-Technical University	Figure 6 - Project Manager Sailau kyzy J. with the staff of the Centre for International Communications of Ryazan State Radio-Technical University

List of publications

1. Sailau kyzy Zh. Tızbektı kodtardyñ köp şektı dekodtau parametrlerın oñtaïlandyru algoritmın äzırleu// Proceedings of the University. – 2023. – No. 3(92). – P. 474–480. https:// DOI 10.52209/1609-1825_2023_3_474
http://tu.kstu.kz/publication/publication/download/634

2. Sailau kyzy Zh., Satybaldina D., Amanov A.N., Jakina M.M. Radioarnalar üşın tanner grafyn qoldanu arqyly LDPC kodtarynyñ qatelerdı tüzetu äserın taldau // International Scientific Conference "Informatics and Applied Mathematics") 26-27 October 2023, Kazakhstan, Almaty. P.274-280. https://conf.iict.kz/wp-content/uploads/2023/10/collection_CSAM_VIII_2023_1.pdf

3. Zhuldyz Sailau қyzy, Dina Satybaldina, Gulmira Danenova, Makhabbat Kokkoz, Nurlan Tashatov, Design of Majority Decoded Codes and Decoding Algorithm Based on Error Propagation Analysis//7th International Symposium on Innovative Approaches in Smart Technologies (23-25 qaraşa 2023 j., Türkia, Stambul).
http://www.isassymposium.org/isas2023/ISAS2023_Symposium_Information.pdf

4. Sailaukyzy Zh., Hasenova Z.T., Zhakina M.M., Amanov A.N., "Construction of simulation model of digital radio data transmission system with noise-resistant coding //(XXVI International Conference "Digital Signal Processing and Its Applications - DSPA-2024" (26-30 nauzyz 2024, Moscow, Russia) p.33-38. http://dspa-conf.org/storage/Proceedings/DSPA2024_RNTORES_proceedings.pdf

5. Sailauqyzy Zh., Qūtjan S.D., Quanyş A.Q., "AAGŞ kanaldary üşın Rid-Solomon kodynyñ jüzege asyru prinsipterın zertteu"// Q.İ. Satpaevtyñ 125 jyldyğyna arnalğan, "Qazaqstan-2050" Strategiasyn jüzege asyrudağy jastar ğylymynyñ ülesı" atty Respublikalyq studenttık ğylymi konferensiasy (11-12 säuır 2024 j., Qazaqstan, Qarağandy). https://www.kstu.kz/wp-content/uploads/2024/06/SBORNIK-Stud.Konf.-1-CHAST_.pdf

6. Sailau kyzy Zh., İbragimov U.M., Şuğa tözımdı kodtardy qoldanu arqyly radioarnany bağalau ädısterı men kriterilerı//Halyqaralyq ğylymi-täjıribelık konferensia "XVI Sağynov oqulary. Bılım, ğylym jäne öndırıs integrasiasy" (13-14 mausym 2024 j., Qazaqstan, Qarağandy). https://www.kstu.kz/wp-content/uploads/2024/07/2-chast.pdf

7. Certificate of inclusion of information in the state register of copyrighted computer software No. 46161 dated 21 May 2024.https://drive.google.com/file/d/1_ct5ugaIEN98MwONUfWZhyuN7gFpN8DQ/view?usp=sharing

Research team
1. Sailau kyzy Zhuldyz - Project Manager, PhD, Acting Associate Professor NPJSC Abylkas Saginov Karaganda Technical University, Department of ITS.
ORCID: 0000-0001-7605-7634;
Scopus Author ID: 57440117200
2. Danenova Gulmira Tulendievna - Senior Researcher, Candidate of Technical Sciences, Associate Professor NPJSC Abylkas Saginov Karaganda Technical University, Department of ITS
Hirsch Index-1;
ORCID: 0000-0003-3301-7282;
Scopus Author ID: 57140638000.
3. Khasenova Zarina Toleubekovna - Senior Researcher, PhD, Dean of the School of Computer Science D. Serikbayev East Kazakhstan technical university.
Hirş İndeksı =2 (Scopus);
Hirsch Index=1 (WoS);
Scopus Author ID = 57205141835
4. Kokkoz Makhabbat Meiramkyzy - Senior Researcher, Candidate of Pedagogical Sciences, Associate Professor NPJSC Abylkas Saginov Karaganda Technical University, Department of ITS.
Hirsch Index-3;
Researcher ID: P-6669-2017;
Scopus Author ID: 56646533000;
ORCID: 0000-0002-6232-1868
5. Satybaldina Dina Zhagyparovna - Senior Researcher, Candidate of Physical and Mathematical Sciences, Associate Professor, Department of Information Security L.N. Gumilev Eurasian National University.
ResearcherID: P-1120-2014;
Scopus Author ID: 57193740669;
ORCID: 0000-0003-0291-4685.
6. Tashatov Nurlan Narkenovich- Researcher, Candidate of Physical and Mathematical Sciences, Associate Professor, Department of Information Security L.N. Gumilev Eurasian National University.
ResearcherID: P-1134-2014;
Scopus Author ID: 55946377700;
ORCID: 0000-0002-3271-2163.
7. Egamberdiev Eldor Ulugbekovich - Researcher, Director of "Adal Damu" LLP
ResearcherID: К-5417-2013;
ORCID: 0000-0001-5289-6580;
Scopus Author ID: 57196402736.
8. Madina Maulenkyzy Zhakina - junior researcher, master student of gr. VTM-23-1 Abylkas Saginov Karaganda Technical University, ITS department.
9. Amanov Aydos Nurlanovich- Junior Researcher, Master student of gr. VTM-23-1 Abylkas Saginov Karaganda Technical University, ITS department.

Information for potential users
The implementation of this project on the creation of error correction tools for radio channels supports the development of new generation wireless networks and the application of

methods for building adaptive telecommunication systems that allow to ensure high reliability of message transmission in radio channels with variable parameters.

Scope:

Applicability and/or commercializability of the obtained scientific results - the expected scientific results can be used for modernisation of equipment of radio communication systems of organisations providing national security and defence of the Republic of Kazakhstan, increase of reliability of information transmission.

Information update date: 05.07.2024