

## ABSTRACT AND REFERENCES

## INFORMATION AND CONTROLLING SYSTEMS

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**IMPROVING THE MODEL OF DECISION MAKING ABOUT ABNORMAL NETWORK STATE USING A POSITIONING SYSTEM (p. 6-11)****Ivan Antipov**Kharkiv National University of Radio Electronics,  
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We have proposed to supplement the model of decision making about abnormal states of a wireless network under conditions of uncertainty by another attribute – the location of wireless mobile and stationary devices in a controlled network.

The method of trilateration, based on the measurement of signal strength at three points, is considered. This method has a high accuracy of determining the location of a wireless device, provided that the most accurate model of radio waves propagation is constructed. However, given the specificity of radio waves propagation inside the premise, it is rather difficult to build such a model for them. Therefore, it is proposed to use the method of radio fingerprints. This method is based on the construction of radio maps for each of the three access points, which indicates the signal level from a typical wireless device located at a certain number of reference points. We have also considered the possibility of the combined application of two methods, which will make it possible to determine the location of a wireless device even when it is outside the radio map.

Experimental studies were carried out, including the creation of radio maps for a room of area 70 m<sup>2</sup> with 26 reference points. We employed three identical routers and a smartphone. During the experiment, it turned out that, depending on the orientation of the mobile device (in fact, its antenna), the measured power changes, so the radio maps were constructed based on average power for six different positions of the mobile device. It is shown that the level of the signal is almost independent of the door and window position in the room.

This analysis of the principles of organizing various types of attacks on wireless networks has revealed that accounting for the position makes it possible to detect attacks of the types “man in the middle” and “false access point” that were not identified by the base model. In addition, the improved model allows determining the source of interference at the “muting” attack.

**Keywords:** signal strength, trilateration, radio fingerprints method, radio map, location of wireless subscriber.

**References**

1. Vsesvitnie doslidzhennia ekonomichnykh zlochyniv ta shakhrastva 2018 roku: rezultaty opytuvannia ukrainskykh orhanizatsiyi. PwC. Available at: <https://www.pwc.com/ua/uk/survey/2018/pwc-gecs-2018-ukr.pdf>
2. Kotov, V. D., Vasil'ev, V. I. (2012). Current state of network intrusion detection. *Vestnik Ufimskogo gosudarstvennogo aviacionnogo tekhnicheskogo universiteta*, 16 (3 (48)), 198–204.
3. Los', A. B., Danielyan, Yu. Yu. (2014). Sravnitel'nyy analiz sistem obnaruzheniya vtorzheniy, predstavlenykh na otechestvennom rynke. *Vestnik Moskovskogo finansovo-yuridicheskogo universiteta*, 3, 181–187.
4. Antipov, I. E., Yashchenko, T. A., Nasif, N. T. (2011). Primenenie nechetkoy logiki dlya povysheniya bezopasnosti besprovodnyh setey na baze tekhnologii Wi-Fi. *Radiotekhnika*, 165, 103–106.
5. Markin, D. O. (2015). Issledovanie effektivnosti algoritmov opredeleniya mestopolozheniya mobil'nyh ustroystv vnutri pomeshcheniya. *Vestnik RGRTU*, 54, 32–39.
6. The Cisco Hyperlocation Module: Best of Interop Awards Finalist. Cisco Blogs. Available at: <https://blogs.cisco.com/wireless/the-cisco-hyperlocation-module-best-of-interop-awards-finalist>
7. Yurkin, D. V., Nikitin, V. N. (2014). Intrusion detection systems in IEEE 802.11 local wireless networks. *Informacionno-upravlyayushchie sistemy*, 2, 44–49.
8. Niculescu, D., Nath, B. (2003). Ad hoc positioning system (APS) using AOA. *IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies (IEEE Cat. No.03CH37428)*. doi: <https://doi.org/10.1109/infocom.2003.1209196>
9. Shirman, Ya. D., Golikov, V. N., Busygin, I. N., Kostin, G. A., Manzhos, V. N., Minervin, N. N. et. al. (1970). *Teoreticheskie osnovy radiolokacii*. Moscow: Sovetskoe radio, 560.
10. Youssef, M., Youssef, A., Rieger, C., Shankar, U., Agrawala, A. (2006). PinPoint: An asynchronous time-based location determination system. *Proceedings of the 4th international conference on Mobile systems, applications and services – MobiSys 2006*, 165–176. doi: <https://doi.org/10.1145/1134680.1134698>
11. Cong, L., Zhuang, W. (2002). Hybrid TDOA/AOA mobile user location for wideband CDMA cellular systems. *IEEE Transactions on Wireless Communications*, 1 (3), 439–447. doi: <https://doi.org/10.1109/twc.2002.800542>
12. Bargshady, N., Garza, G., Pahlavan, K. (2016). Precise Tracking of Things via Hybrid 3-D Fingerprint Database and Kernel Method Particle Filter. *IEEE Sensors Journal*, 16 (24), 8963–8971. doi: <https://doi.org/10.1109/jsen.2016.2616758>
13. Atia, M. M., Noureldin, A., Korenberg, M. J. (2012). Dynamic Propagation Modeling for Mobile Users' Position and Heading Estimation in Wireless Local Area Networks. *IEEE Wireless Communications Letters*, 1 (2), 101–104. doi: <https://doi.org/10.1109/wcl.2012.020612.110279>
14. ITU-R P.1238-9 – Propagation data and prediction methods for the planning of indoor radio communication systems and the radio local area networks in the frequency range 300 MHz to 100 GHz (2017). Geneva: ITU-R Recommendations.
15. Zymbler, M. L., Miniakhmetov, R. M., Rogov, A. A. (2013). The survey of indoor positioning algorithms for mobile devices. *Bulletin of the South Ural State University. Series «Computational Mathematics and Software Engineering»*, 2 (2), 83–96. doi: <https://doi.org/10.14529/cmse130207>

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## DEVELOPMENT OF PROCEDURES FOR DETERMINING THE PARAMETERS OF AN AIRCRAFT SERVO ACTUATOR (p. 11-18)

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Main trends in the use of electro-hydraulic actuators and requirements to parameters were discussed. Necessity of using automatic methods for testing an electro-hydraulic actuator together with the standard hardware of the electronic control unit was substantiated. The procedures for testing the control loop of an electro-hydraulic actuator set forth in this study make it possible to eliminate effects of mutual influence of dynamic and static characteristics of the actuator and hardware of the electronic control unit. Procedures for automatic identification of the actuator model and procedures for automatic determination of main parameters and characteristics of the actuator such as zero shift, dead space, amplitude-frequency, phase-frequency and speed characteristics have been proposed. When introducing the proposed procedures, the problem of processing high-speed characteristics of the actuator having high noisiness associated with the pulse nature of the derivative of the discrete signal of the actuator position (12 bits) was solved. In order to avoid introduction of errors in the waveform, in addition to standard digital filtering methods, it was proposed to approximate the noisy actuator characteristic by means of the Bezier curve. A procedure was proposed to record hysteresis of the speed characteristic by means of a cycle of continuous change of speed of movement of the output link of the actuator during the working stroke. The method for automatic identification of a simplified actuator model can significantly reduce labor costs in processing of experimental data. The parameters of the actuator model obtained for various deviations in parameters and various actuator operating conditions (external factors) can improve quality of synthesis of control algorithms.

**Keywords:** electro-hydraulic actuator, speed characteristic, dead space, amplitude-frequency characteristic, phase-frequency characteristic.

### References

- Erofeev, E. V. (2016). Sistema rulevnyh privodov i energeticheskii kompleks perspektivnyh samoletov transportnoy kategorii. Elektrifikatsiya letatel'nykh apparatov. Tr. nauch.-tekhn. konf. Moskva: ID Akad. Zhukovskogo, 178–187.
- Ogol'tsov, I., Samsonovich, S., Selivanov, A., Alekseenkov, A. (2014). New developments of electrically powered electrohydraulic and electromechanical actuators for the more electric aircraft. 29th Congress of the International Council of the Aeronautical Sciences. Saint Petersburg.
- Barnett, S. A., Lammers, Z., Razidlo, B., Leland, Q., DelMar, J. (2012). Test Set-up for Electromechanical Actuation Systems for Aircraft Flight Control. SAE Technical Paper Series. doi: <https://doi.org/10.4271/2012-01-2203>
- R50-109-89. Rekomendatsii. Nadezhnost' v tekhnike. Obe-spechenie nadezhnosti izdeliy. Obshchie trebovaniya (1989). Moscow.
- Actuators: Aircraft Flight Controls, Power Operated, Hydraulic, General Specification For. ARP 1281. SAE. doi: <https://doi.org/10.4271/arp1281>
- Cantero, E. D., Andreatza, W., Bravin, E., Sosa, A. (2014). Acceptance test for the linear motion actuator for the scanning slit of the hie-isolde short diagnostic boxes. European organization for nuclear research. CERN-ACC-NOTE-2014-0099. HIE-ISOLDE-PROJECT-Note-0036. Geneva.
- Gilson, E., Kopp, J. D., Manzanares D. (2014). Moog next generation control and actuation. R3ASC. Toulouse, 43–54.
- Chan, C.-H., Liu, G. (2004). Actuator hysteresis identification and compensation using an adaptive search space based genetic algorithm. Proceedings of the 2004 American Control Conference. doi: <https://doi.org/10.23919/acc.2004.1384775>
- Balaban, E., Bansal, P., Stoelting, P., Saxena, A., Goebel, K. F., Curran, S. (2009). A diagnostic approach for electro-mechanical actuators in aerospace systems. 2009 IEEE Aerospace Conference. doi: <https://doi.org/10.1109/aero.2009.4839661>
- Narasiman, S., Roychoudhury, I., Balaban, E., Saxena, A. (2010). Combining model-based and feature-driven diagnosis approaches – a case study on electromechanical actuators. 21st International workshop on principles of diagnosis.
- Langjord, H., Kaasa, G.-O., Johansen, T. A. Nonlinear observer and parameter estimation for electropneumatic clutch actuator. Available at: <http://folk.ntnu.no/torarnj/Nolcosver2.pdf>
- Desborough, L., Miller, R. (2001). Increasing customer value of industrial control performance monitoring -honeywell's experience. Chemical Process Control, 172–192.
- Choudhury, A. S., Shah, S. L., Thornhill, N. F. (2008). Diagnosis of Process Nonlinearities and Valve Stiction. Data Driven Approaches. Springer, 286. doi: <https://doi.org/10.1007/978-3-540-79224-6>
- Liang, L., Jiannan, L., Wan, H. (2014). Parameter estimation for linear control valve with hysteresis. Submitted to IEEE transactions on automation science and engineering. Available at: <https://arxiv.org/pdf/1605.00347.pdf>
- Shi, W. Electro-Hydraulic Servo-Valve and Motion and Control Loading of Full Flight Simulator. Available at: [https://digital.library.ryerson.ca/islandora/object/RULA%3A2203/datastream/OBJ/download/Electro-Hydraulic\\_Servo-Valve\\_and\\_Motion\\_and\\_Control>Loading\\_of\\_Full\\_Flight\\_Simulator.pdf](https://digital.library.ryerson.ca/islandora/object/RULA%3A2203/datastream/OBJ/download/Electro-Hydraulic_Servo-Valve_and_Motion_and_Control>Loading_of_Full_Flight_Simulator.pdf)
- Xu, Y. (2013). Modelling and control of a high performance electro-hydraulic test bench. INSA de Lyon.
- Michel, R. A simple method to determine control valve performance and its impacts on control loop performance. Available at: <http://www.topcontrol.com/fichiers/en/controlvalveperformance.pdf>
- Galinaitis, W. S., Joseph, D. S., Rogers, R. C. (2001). Parameter Identification for Preisach Models of Hysteresis. ASME Design Engineering Technical Conferences. Pittsburgh.
- Abbasov, M. E. (2014). Metody optimizatsii. Sankt-Peterburg.
- Grigor'eva, K. V. (2007). Metody resheniya zadachi minimizatsii kvadratichnoy funktsii. Sankt-Peterburg.
- Armstrong, B., Wit, C. C. (1995). Friction Modeling and Compensation. The Control Handbook. CRC Press.
- Kononykhin, E. A., Yepifanov, S. V. (2016). Backfitting of servovalve characteristics using unit level dynamic models. Aviacionno-kosmicheskaya tekhnika i tekhnologiya, 6, 48–54.

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**TESTING OF MEASUREMENT INSTRUMENT SOFTWARE WITH THE PURPOSE OF CONFORMITY ASSESSMENT (p. 19-26)**

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The analysis of the regulatory framework for testing measuring instruments (MI) software at the national level to determine its suitability for carrying out conformity assessment was conducted. Comparison of the general requirements of national normative documents and documents of international and regional organizations of legal metrology OIML and WELMEC was conducted. In particular, regarding the suitability of software for application and protection against unauthorized interference. It is found that the current national standard contains only general requirements for software protection and does not determine the methodology of software testing. This is important because the MIs, which are intended for use in the field of regulated metrology, must undergo a procedure for conformity assessment with the requirements of the technical regulations.

The main differences were identified and the necessary elements were established to achieve the presumption of conformity of the software with essential requirements of the technical regulations during conformity assessment of the MI. Requirements of normative documents concerning suitability for application and protection against unauthorized interference are identified. In order to specify requirements for software and to ensure compliance with the requirements of the software test method, the need for additional use of the requirements of the OIML D 31 and WELMEC 7.2 documents was established. The need to revise the current national standard for MI software testing was proved. The algorithm of testing of the MI software for conformity assessment was established and studied. The algorithm takes into account the requirements of international standards for the software life cycle and the quality system when developing the software. This will take into account all the elements necessary to achieve the presumption of conformity of software with the essential requirements of technical regulations.

**Keywords:** software, measuring instruments, testing, conformity assessment, technical regulations.

**References**

- OIML D 31:2008. General Requirements for Software Controlled Measuring Instruments. OIML (2008). Paris, 53.
- COOMET R/LM/10:2004. COOMET Recommendation: Software for Measuring Instruments: General Technical Specifications (2004). COOMET, 10.
- WELMEC 7.1. Informative Document: Development of Software Requirements. Available at: [http://www.welmec.org/fileadmin/user\\_files/publications/WG\\_07/7-1\\_FRPO.pdf](http://www.welmec.org/fileadmin/user_files/publications/WG_07/7-1_FRPO.pdf)
- WELMEC 7.2. Software Guide (Measuring Instruments Directive 2004/22/EC). Available at: [http://www.welmec.org/fileadmin/user\\_files/publications/WG\\_07/Guide\\_7.2\\_2015\\_\\_Software.pdf](http://www.welmec.org/fileadmin/user_files/publications/WG_07/Guide_7.2_2015__Software.pdf)
- WELMEC 2.3. Guide for Examining Software (Non-automatic Weighing Instruments). Available at: [http://www.welmec.org/fileadmin/user\\_files/publications/2-3.pdf](http://www.welmec.org/fileadmin/user_files/publications/2-3.pdf)
- Directive 2014/32/EU on the harmonisation of the laws of the Member States relating to the making available on the market of measurement instrument (recast) (2004). Official Journal of the European Union, L96/149. Available at: <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0032>
- Velychko, O. N. (2007). Normative base for certification of measurement provision software. *Measurement Techniques*, 50 (4), 364–371. doi: <https://doi.org/10.1007/s11018-007-0076-5>
- Velychko, O., Gordiyenko, T. (2010). The implementation of general international guides and standards on regional level in the field of metrology. *Journal of Physics: Conference Series*, 238, 012044. doi: <https://doi.org/10.1088/1742-6596/238/1/012044>
- Velychko, O. N. (2009). Basic tests, stages, and features in monitoring measuring instrument software. *Measurement Techniques*, 52 (6), 566–571. doi: <https://doi.org/10.1007/s11018-009-9308-1>
- Velychko, O. (2008). Using of Validated Software for Uncertainty Analyses Tools in Accredited Laboratories. *Key Engineering Materials*, 381-382, 599–602. doi: <https://doi.org/10.4028/www.scientific.net/kem.381-382.599>
- Velychko, O., Gordiyenko, T., Hrabovskiy, O. (2018). Testing of measurement instrument software on the national level. *Eastern-European Journal of Enterprise Technologies*, 2 (9 (92)), 13–20. doi: <https://doi.org/10.15587/1729-4061.2018.125994>
- Peters, D., Grottker, U., Thiel, F., Peter, M., Seifert, J.-P. (2014). Achieving Software Security for Measuring Instruments under Legal Control. *Position Papers of the 2014 Federated Conference on Computer Science and Information Systems*, 3, 123–130. doi: <https://doi.org/10.15439/2014f460>
- Esche, M., Thiel, F. (2015). Software Risk Assessment for Measuring Instruments in Legal Metrology. *Proceedings of the 2015 Federated Conference on Computer Science and Information Systems*, 5, 1113–1123. doi: <https://doi.org/10.15439/2015f127>
- Sadiq, M., Rahmani, M. K. I., Ahmad, M. W., Jung, S. (2010). Software risk assessment and evaluation process (SRAEP) using model based approach. *2010 International Conference on Networking and Information Technology*. doi: <https://doi.org/10.1109/icnit.2010.5508535>
- Boccardo, D. R., dos Santos, L. C. G., da Costa Carmo, L. F. R., Dezan, M. H., Machado, R. C. S., de Aguiar Portugal, S. (2010). Software evaluation of smart meters within a Legal Metrology perspective: A Brazilian case. *2010 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT Europe)*. doi: <https://doi.org/10.1109/isgteurope.2010.5638881>

16. Peters, D., Peter, M., Seifert, J.-P., Thiel, F. (2015). A Secure System Architecture for Measuring Instruments in Legal Metrology. *Computers*, 4 (2), 61–86. doi: <https://doi.org/10.3390/computers4020061>
17. Thiel, F., Hartmann, V., Grottker, U., Richter, D. (2014). IT Security standards and legal metrology – Transfer and Validation. *EPJ Web of Conferences*, 77, 00001. doi: <https://doi.org/10.1051/epjconf/20147700001>
18. Jacobson, J. (2006). Validation of software in measuring instruments. *Computer Standards & Interfaces*, 28 (3), 277–285. doi: <https://doi.org/10.1016/j.csi.2005.07.006>
19. Thiel, F., Grottker, U., Richter, D. (2011). The challenge for legal metrology of operating systems embedded in measuring instruments. *OIML Bull.*, 52 (1), 5–14.
20. DSTU 7363:2013. Prohramne zabezpechennia zasobiv vymiriuvальноi tekhniki. Zahalni tekhnichni vymohy (2013). Kyiv: Minekonomrosvytku Ukrainy, 11.
21. ISO/IEC 27005:2018. Information technology. Security techniques. Information security risk management (2018). International Organization for Standardization, 56.
22. ISO/IEC/IEEE 12207:2017. Systems and software engineering. Software life cycle processes (2017). International Organization for Standardization, 145.
23. ISO/IEC/IEEE 90003:2018. Software engineering. Guidelines for the application of ISO 9001:2008 to computer software (2018). International Organization for Standardization, 69.

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#### **DEVELOPMENT OF NIEDERREITER HYBRID CRYPTOCODE STRUCTURE ON FLAWED CODES**

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The use of the Niederreiter modified crypto-code structure (MCCS) with additional initialization vectors (with many invalid positional vectors of the error vector and multiple positions of shortening the error vector) requires an increase in the speed of cryptographic transformation of the system as a whole. For this purpose, it is proposed to use flawed codes. Flawed codes allow you to increase the speed of code transformations by reducing the power of the field while damaging the plaintext and reducing the amount of data transferred by damaging the ciphertext. This approach allows the construction of hybrid crypto-code structures based on the synthesis of Niederreiter modified crypto-code structures on modified (shortened or extended) codes on elliptic curves with damaging procedures. A significant difference from classical hybrid (complex) cryptosystems is the use of asymmetric cryptosystems to ensure data security with fast crypto-transformation procedures (generation and decoding of a codogram). The paper discusses methods for constructing flawed codes and approaches for using the Niederreiter hybrid crypto-code structure on modified elliptic codes. Practical algorithms are proposed for using the MV2 damage mechanism in the Niederreiter crypto-code structure on modified elliptic codes, which makes it possible to implement a hybrid crypto-code structure. The results of a comparative assessment of energy consumption for the formation of an information package with various methods of damage, which determined the choice of damage method in practical algorithms. The conducted studies confirm the competitive efficiency of the proposed cryptosystem in Internet technologies and mobile networks, ensuring practical implementation on modern platforms and the necessary cryptographic strength under post-quantum cryptography.

**Keywords:** flawed codes, Niederreiter hybrid crypto-code structure, modified elliptic codes, multichannel cryptography.

#### **References**

1. Androshchuk, H. O. (2017). Kiberbezpeka: tendentsiyi v sviti ta Ukraini. Kiberbezpeka ta intelektualna vlasnist: problemy pravovoho zabezpechennia: materialy Mizhnarodnoi naukovo-praktychnoi konferentsiyi. Kyiv: Vyd-vo «Politekhnika», 30–36.
2. Grishchuk, R. V., Danik, Yu. G.; Danik Yu. G. (Ed.) (2016). *Osnovy kiberbezopasnosti*. Zhitomir: ZHNAEU, 636.
3. Ivanchenko, I. S., Khoroshko, V. O., Khokhlachova, Yu. Ye., Chyrkov, D. V.; Khoroshko, V. O. (Ed.) (2013). *Zabezpechennia informatsiynoi bekhpeky derzhavy*. Kyiv: PVP “Zadruha”, 170.
4. Baranov, O. A. (2014). Pro tлумachennia ta vyznachennia poniattia «kiberbezpeka». *Pravova informatyka*, 2, 54–62.

5. Babych, Ye. Yu. (2016). Zabezpechennia kiberbezpeky v Ukraini. Aktualni zadachi ta dosiahnennia u haluzi kiberbezpeky: materialy Vseukrainskoi naukovopraktychnoi konferentsiyi. Kropyvnytskyi: KNTU, 77–78.
6. Leonenko, G. P., Yudin, A. Yu. (2013). Problemy obespecheniya informacionnoy bezopasnosti sistem kriticheski vazhnoy informacionnoy infrastruktury Ukrainy. *Information Technology and Security*, 1 (3), 44–48.
7. Yevseiev, S., Koc, G. P., Korol', O. G. (2015). Analysis of the legal framework for the information security management system of the NSMEP. *Eastern-European Journal of Enterprise Technologies*, 5 (3 (77)), 48–59. doi: <https://doi.org/10.15587/1729-4061.2015.51468>
8. Yevseiev S. (2017). Ispol'zovanie ushcherbnyh kodov v kriptokodovyh sistemah. *Systemy obrobky informatsiyi*, 5 (151), 109–121. doi: <https://doi.org/10.30748/soi.2017.151.15>
9. Kuchuk, N., Mozhaiev, O., Mozhaiev, M., Kuchuk, H. (2017). Method for calculating of R-learning traffic peakedness. 2017 4th International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S&T). doi: <https://doi.org/10.1109/infocommst.2017.8246416>
10. Kuchuk, G., Kharchenko, V., Kovalenko, A., Ruchkov, E. (2016). Approaches to selection of combinatorial algorithm for optimization in network traffic control of safety-critical systems. 2016 IEEE East-West Design & Test Symposium (EWDTS). doi: <https://doi.org/10.1109/ewdts.2016.7807655>
11. Mozhaiev, O., Kuchuk, H., Kuchuk, N., Mozhaiev, M., Lohvynenko, M. (2017). Multiservice network security metric. 2017 2nd International Conference on Advanced Information and Communication Technologies (AICT). doi: <https://doi.org/10.1109/aiact.2017.8020083>
12. Chen, L., Jordan, S., Liu, Y.-K., Moody, D., Peralta, R., Perlner, R., Smith-Tone, D. (2016). Report on Post-Quantum Cryptography. NIST. doi: <https://doi.org/10.6028/nist.ir.8105>
13. Dinh, H., Moore, C., Russell, A. (2011). McEliece and Niederreiter Cryptosystems that Resist Quantum Fourier Sampling Attacks. *Lecture Notes in Computer Science*, 761–779. doi: [https://doi.org/10.1007/978-3-642-22792-9\\_43](https://doi.org/10.1007/978-3-642-22792-9_43)
14. Sidel'nikov, V. M. (2008). *Teoriya kodirovaniya*. Moscow: FIZMATLIT, 324.
15. Yevseiev, S., Tsyhanenko, O., Ivanchenko, S., Alekseyev, V., Verheles, D., Volkov, S. et. al. (2018). Practical implementation of the Niederreiter modified cryptocode system on truncated elliptic codes. *Eastern-European Journal of Enterprise Technologies*, 6 (4 (96)), 24–31. doi: <https://doi.org/10.15587/1729-4061.2018.150903>
16. Cho, J. Y., Griesser, H., Rafique, D. (2017). A McEliece-Based Key Exchange Protocol for Optical Communication Systems. *Lecture Notes in Electrical Engineering*, 109–123. doi: [https://doi.org/10.1007/978-3-319-59265-7\\_8](https://doi.org/10.1007/978-3-319-59265-7_8)
17. Yevseiev, S., Rzaev, K., Korol, O., Imanova, Z. (2016). Development of mceliece modified asymmetric crypto-code system on elliptic truncated codes. *Eastern-European Journal of Enterprise Technologies*, 4 (9 (82)), 18–26. doi: <https://doi.org/10.15587/1729-4061.2016.75250>
18. Yevseiev, S., Tsyhanenko, O. (2018). Development of asymmetrical crypto-coded construction of niderraiter on modified codes. *Systemy obrobky informatsiyi*, 2 (153), 127–135. doi: <https://doi.org/10.30748/soi.2018.153.16>
19. Dudykevych, V. B., Kuznetsov, O. O., Tomashevskiy, B. P. (2010). Krypto-kodovyi zakhyst informatsiyi z nedvykovym rivno vahovym koduvanniam. *Suchasnyi zakhyst informatsiyi*, 2, 14–23.
20. Dudykevych, V. B., Kuznetsov, O. O., Tomashevskiy, B. P. (2010). Metod nedvykovoho rivnovahovoho koduvannia. *Suchasnyi zakhyst informatsiyi*, 3, 57–68.
21. De Vries, S. Achieving 128-bit Security against Quantum Attacks in OpenVPN. Available at: <https://internetscriptieprijs.nl/wp-content/uploads/2017/04/1-Simon-de-Vries-UT.pdf>
22. Baldi, M., Bianchi, M., Chiaraluce, F., Rosenthal, J., Schipani, D. Enhanced public key security for the McEliece cryptosystem. arXiv.org. Available at: <https://arxiv.org/abs/1108.2462>
23. Yevseiev, S., Rzaev, Kh., Tsyhanenko, A. (2016). Analysis of the software implementation of the direct and inverse transform in non-binary equilibrium coding method. *Journal of Information Security*, 22 (2), 196–203.
24. Niederreiter, H. (1986). Knapsack-type cryptosystems and algebraic coding theory. *Problems of Control and Information Theory*, 15 (2), 159–166.
25. Mishchenko, V. A., Vilanskiy, Yu. V. (2007). Ushcherbnye teksty i mnogokanal'naya kriptografiya. Minsk: Enciklopediks, 292.
26. Mishchenko, V. A., Vilanskiy, Yu. V., Lepin, V. V. (2006). Kriptograficheskiy algoritm MV 2. Minsk, 177.
27. Rukhin, A., Sota, J., Nechvatal, J., Smid, M., Barker, E., Leigh, S. et. al. (2000). A statistical test suite for random and pseudorandom number generators for cryptographic applications. NIST. doi: <https://doi.org/10.6028/nist.sp.800-22>
28. Berlekemp, E. R. (1971). *Algebraicheskaya teoriya kodirovaniya*. Moscow: Mir, 480.
29. Kasami, T., Tokura, N., Iwadari, E., Inagaki, Ya. (1978). *Teoriya kodirovaniya*. Moscow: Mir, 576.
30. Kuznecov, A. A., Korolev, R. V., Tomashevskiy, B. P. (2010). Ocenka stoykosti kriptokodovyh sredstv zashchity informacii k atakam zloumyshlennika. *Systemy upravlinnia, navihatsii ta zviazku*, 2 (14), 114–117.
31. Naumenko, N. I., Stasev, Yu. V., Kuznetsov, O. O. (2005). *Teoretychni osnovy ta metody pobudovy alhebraichnykh blokovykh kodiv*. Kharkiv: KhUPS, 267.
32. Yevseiev, S. P., Ostapov, S., Bilodid, I. (2017). Research of the properties of hybrid crypto-code constructions. *Ukrainian Information Security Research Journal*, 19 (4), 278–290. doi: <https://doi.org/10.18372/2410-7840.19.12206>

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**THE DEVELOPMENT OF METHODS FOR DETERMINING VIBRATION STOCHASTIC FIELDS OF TECHNOLOGICAL COMPLEXES (p. 38-47)**

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The force effects occurring in technological complexes have been studied on the basis of the analysis of technical diagnostics system.

Due to the distinction between deterministic and random force effects, there have been proposed various methods to distinguish the vibration of informational diagnostic characteristics in order to ensure prompt and reliable detection of the rapidly developing defects. Reliable diagnostics will make it possible to switch from a system of scheduled preventive repairs to the organization of repairs for the current state, with a decrease in the cost of repairing and rebuilding the units of technological complexes by early detection of the defects emerging in the assembly components.

On the basis of analyzing the process of propagation of vibroacoustic waves caused by the power action, there has been developed a mathematical model for the emergence and propagation of elastic waves in sophisticated technological complexes from the places of their origin to the point of observation. There have been suggested kinematic schemes for propagation of low-frequency vibrations, vibrosignals from the brush-collector unit, as well as waves from the inner ring of the bearing. This makes possible to substantiate a mathematical model of the occurrence and propagation of vibroacoustic waves in the parts and units of technological complexes from various sources of vibration.

The comparative analysis of the research findings on the real vibration fields and the results of numerical modeling confirms the adequacy of the model to the real process. The article presents the graphs of the temporal realization of signals in the model, the spectra of the realized signals, as well as their autocorrelation functions reflecting the main characteristics of the signals at the measurement point. The findings can be used to diagnose and reduce the cost of repair and restoration of the units in sophisticated technological complexes by early detection of the defects emerging in the assembly parts.

**Keywords:** vibration signal, stochastic, rolling bearings, vibration fields, vibroacoustic waves, shock pulse.

## References

- Marchenko, N. B., Nechyporuk, V. V., Nechyporuk, O. P., Pepa, Yu. V. (2014). *Metody otsiniuvannya tochnosti informatsiyno-vymiriuvalnykh system diahnostryky*. Kyiv: Vyd-vo PVP «Zadruha», 200.
- Marchenko, N. B., Nechiporuk, E. P. (2012). *Prichyny vznikoventiya i klassifikatsiya otkazov v tekhnicheskikh sistemah*. Suchasnyi zakhyst informatsiyi, 4, 84–87.
- Marchenko, N. B., Nechyporuk, O. P., Vakhil, A. A., Shukalo, V. V. (2014). *Metody obrobky vibrodiahnostychnoi informatsiyi ta pobudova na yikh osnovi system operatyvnoi diahnostryky elektrotekhnichnoho obladnannia*. The Caucasus Economical and social analysis journal of southern Caucasus, 3, 25–29.
- Ge, M., Wang, J., Ren, X. (2017). *Fault Diagnosis of Rolling Bearings Based on EWT and KDEC*. Entropy, 19 (12), 633. doi: <https://doi.org/10.3390/e19120633>
- Kumar, M. S., Prabhu, B. S. (2000). *Rotating Machinery Predictive Maintenance Through Expert System*. International Journal of Rotating Machinery, 6 (5), 363–373. doi: <https://doi.org/10.1155/s1023621x00000348>
- Xu, X., Han, Q., Chu, F. (2018). *Review of Electromagnetic Vibration in Electrical Machines*. Energies, 11 (7), 1779. doi: <https://doi.org/10.3390/en11071779>
- Wang, F., Liu, X., Liu, C., Li, H., Han, Q. (2018). *Remaining Useful Life Prediction Method of Rolling Bearings Based on Pchip-EEMD-GM(1,1) Model*. Shock and Vibration, 2018, 1–10. doi: <https://doi.org/10.1155/2018/3013684>
- Abuthakeer, S. S., Mohanram, P. V., Mohankumar, G. (2011). *The Effect of Spindle Vibration on Surface Roughness of Workpiece in Dry Turning Using Ann*. International Journal of Lean Thinking, 2 (2), 42–58.
- Li, Y., Wang, L., Guan, J. (2017). *A Spectrum Detection Approach for Bearing Fault Signal Based on Spectral Kurtosis*. Shock and Vibration, 2017, 1–9. doi: <https://doi.org/10.1155/2017/6106103>
- Ly, Y., Zhang, Y., Yi, C. (2018). *Optimized Adaptive Local Iterative Filtering Algorithm Based on Permutation Entropy for Rolling Bearing Fault Diagnosis*. Entropy, 20 (12), 920. doi: <https://doi.org/10.3390/e20120920>
- Zhitomerskiy, V. K. (1966). *Mekhanicheskie kolebaniya i praktika ih ustraneniya*. Moscow: Mashinostroenie, 175.
- Tihonov, V. I. (1982). *Statisticheskaya radiotekhnika*. Moscow: Radio i svyaz', 624.
- Korn, G., Korn, T. (1977). *Spravochnik po matematike dlya nauchnykh rabotnikov i inzhenerov*. Moscow: Nauka, 456.
- Gioev, Z. T., Golov, Yu. V. et. al. (2007). *Sposoby vydeleniya iz sobstvennoy korpusnoy vibratsii dvigatelya skrytoy periodicheskoy sostavlyayushchey – defekta*. Elektrovozostroyeniye, 38, 308–319.
- Vol'dek, A. I. (2008). *Elektricheskie mashiny. Vvedenie v elektromekhaniku*. Mashiny postoyannogo toka i transformatory. Sankt-Peterburg: Piter, 320.

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## COMPREHENSIVE APPROACH TO MODELING DYNAMIC PROCESSES IN THE SYSTEM OF UNDERGROUND RAIL ELECTRIC TRACTION (p. 48-57)

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An analysis of tasks on improving energy efficiency of electric traction systems reveals the need for the introduction of new technologies, namely modern rolling stock with a traction asynchronous electric drive, as well as traction substations, based on new technolo-

gies. To solve this class of problems, we have defined the need for an integrated simulation model of the electric traction system that would ensure a sufficient level of its reliability.

This work reports details of algorithms for calculating the parameters in order to develop a simulation model of the integrated electric traction system of an underground rail system, which consists of electricity supply subsystems, electric drive of rolling stock, and mechanical part of the traction transmission.

In the programming environment Matlab/Simulink, based on the known, actual and refined, estimation parameters, we developed a simulation model of the system of traction electric supply to an underground rail with a two-way power to two tracks. We have constructed a simulation model of the modern traction electric drive of the underground rail cars with a vector system to control an asynchronous electric drive and a uni-mass mechanical part, capable of taking into consideration the impact of the coefficient of adhesion.

We have compared results from the imitational simulation of dynamic processes with oscillograms for the actual operation modes of an underground rail system, which confirmed the adequacy of the model to the examined object. The correspondence between results obtained from simulation is confirmed by the oscillograms from analysis of voltage and current of the contact network, as well as by characteristics of the traction and braking modes of rolling stock.

We have simulated processes of work of the power supply system, a nonstationary regime at deterioration of adhesion conditions, and a recuperative braking mode with energy transferred to other trains.

Using the developed model of the integrated system of electric traction would contribute to a more detailed study into the mutual influence of elements in the electric traction system. That would make it possible to improve the efficiency of making technical decisions related to meeting safety requirements, preventing the disruptions of normal operation, and bringing down operating costs.

**Keywords:** imitation simulation, underground rail system, traction power supply, electric train, traction induction electric drive.

## References

- Basov, H. H., Yatsko, S. I. (2005). Rozvytok elektrychnoho motorvahonnoho rukhomoho skladu. Ch. 2. Kharkiv: «Apeks+», 248.
- Yatsko, S., Karpenko, N., Vashchenko, Y., Panchenko, V. (2017). Development of equipment for distribution devices power traction electric supply. Part I. Collected scientific works of Ukrainian State University of Railway Transport, 172, 37–48. doi: <https://doi.org/10.18664/1994-7852.172.2017.116689>
- Liubarskyi, B., Petrenko, A., Shaida, V., Maslii, A. (2017). Analysis of optimal operating modes of the induction traction drives for establishing a control algorithm over a semiconductor transducer. Eastern-European Journal of Enterprise Technologies, 4 (8 (88)), 65–72. doi: <https://doi.org/10.15587/1729-4061.2017.109179>
- Liubarskyi, B., Petrenko, O., Iakunin, D., Dubinina, O. (2017). Optimization of thermal modes and cooling systems of the induction traction engines of trams. Eastern-European Journal of Enterprise Technologies, 3 (9 (87)), 59–67. doi: <https://doi.org/10.15587/1729-4061.2017.102236>
- Su, S., Tang, T., Wang, Y. (2016). Evaluation of Strategies to Reducing Traction Energy Consumption of Metro Systems Using an Optimal Train Control Simulation Model. Energies, 9 (2), 105. doi: <https://doi.org/10.3390/en9020105>
- Sulym, A. (2015). On the question of a reasonability of capacitive storages use in the metro. Elektromekhanichni i enerhozberihaiuchi systemy, 1 (29), 94–100.
- Yu, L., He, J. H., Hu, J., Bo, Z. Q., Li, M. X., Yip, T., Klimek, A. (2010). Accurate track modeling for fault current on DC railways based on MATLAB/Simulink. IEEE PES General Meeting. doi: <https://doi.org/10.1109/pes.2010.5590135>
- Panchenko, V. V. (2013). Dynamic properties of system «rectifier with buck converter – load». Eastern-European Journal of Enterprise Technologies, 4 (8 (64)), 14–17. Available at: <http://journals.uran.ua/eejet/article/view/16445/13927>
- Sablin, O. I. (2014). Study of the efficiency of the electric energy recovery process in the subway. Eastern-European Journal of Enterprise Technologies, 6 (8 (72)), 9–13. doi: <https://doi.org/10.15587/1729-4061.2014.30483>
- Gao, Z., Fang, J., Zhang, Y., Jiang, L., Sun, D., Guo, W. (2015). Control of urban rail transit equipped with ground-based supercapacitor for energy saving and reduction of power peak demand. International Journal of Electrical Power & Energy Systems, 67, 439–447. doi: <https://doi.org/10.1016/j.ijepes.2014.11.019>
- Tian, Z., Hillmansen, S., Roberts, C., Weston, P., Chen, L., Zhao, N. et. al. (2014). Modeling and simulation of DC rail traction systems for energy saving. 17th International IEEE Conference on Intelligent Transportation Systems (ITSC). doi: <https://doi.org/10.1109/itsc.2014.6958067>
- Du, F., He, J. H., Yu, L., Li, M. X., Bo, Z. Q., Klimek, A. (2010). Modeling and Simulation of Metro DC Traction System with Different Motor Driven Trains. 2010 Asia-Pacific Power and Energy Engineering Conference. doi: <https://doi.org/10.1109/appeec.2010.5448372>
- Verhille, J. N., Bouscayrol, A., Barre, P. J., Hautier, J. P. (2006). Model validation of the whole traction system of an automatic subway. 2006 IEEE Vehicle Power and Propulsion Conference. doi: <https://doi.org/10.1109/vppc.2006.364346>
- Ferrari, A., Fantechi, A., Magnani, G., Grasso, D., Tempestini, M. (2013). The Metrò Rio case study. Science of Computer Programming, 78 (7), 828–842. doi: <https://doi.org/10.1016/j.scico.2012.04.003>
- Mayet, C., Horrein, L., Bouscayrol, A., Delarue, P., Verhille, J.-N., Chattot, E., Lemaire-Semail, B. (2014). Comparison of Different Models and Simulation Approaches for the Energetic Study of a Subway. IEEE Transactions on Vehicular Technology, 63 (2), 556–565. doi: <https://doi.org/10.1109/tvt.2013.2280727>
- Buriakovskiy, S., Babaiev, M., Liubarskyi, B., Maslii, A., Karpenko, N., Pomazan, D. et. al. (2018). Quality assessment of control over the traction valve-inductor drive of a hybrid diesel locomotive. Eastern-European Journal of Enterprise Technologies, 1 (2 (91)), 68–75. doi: <https://doi.org/10.15587/1729-4061.2018.122422>
- Mayet, C., Delarue, P., Bouscayrol, A., Chattot, E., Verhille, J.-N. (2014). Dynamic Model and Causal Description of a Traction Power Substation Based on 6-Pulse Diode Rectifier. 2014 IEEE Vehicle Power and Propulsion Conference (VPPC). doi: <https://doi.org/10.1109/vppc.2014.7007054>
- 7036.000.000 RE. Vagony metropolitena modeley 81-7036 i 81-7037. Rukovodstvo po ekspluatatsii (2016). Kremenchug, 115.
- Zhao, X., Liu, H., Zhang, J., Zhang, H. (2013). Simulation of Field Oriented Control in Induction Motor Drive System. TELKOMNIKA Indonesian Journal of Electrical Engineering, 11 (12). doi: <https://doi.org/10.11591/telkomnika.v11i12.3674>

20. METRO KIEV. General specification for electric equipment (2009). Warszawa, 51.
21. Retune the Drive Parameters. Available at: <https://www.mathworks.com/help/physmod/sps/powersys/ug/advanced-users-retune-the-drive-parameters.html>
22. Sytnik, B. T., Yac'ko, S. I., Bryksin, V. A., Mihaylenko, V. S., Uskov, Yu. P. (2012). Adaptivnoe upravlenie v diskretnykh sistemakh vysokogo poriyadka s zapazdyvaniem. Chast' 3. Sintez adaptivnogo chastotno-impul'snogo PI-regulyatora s optimizatsiey parametrov nastroyki na osnove kriteriya garantirovannoy stepeni ustoychivosti. Collected scientific works of Ukrainian State University of Railway Transport, 128, 182–192.

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**DEVELOPMENT OF THE ALGORITHM OF VIDEO IMAGE ADAPTATION TO SPECTRAL POWER DISTRIBUTION OF ILLUMINANTS (p. 58-67)**

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Proposals for further progress of video technologies, issues that need to be resolved to implement this progress and possible ways to implement them in real devices of special and general application are made. It is proposed to supplement the conventional model of the video path with a color perception model and an adaptive model of the spectral power distribution of the illuminant. Attention is paid to the end devices of the video path, which may introduce unacceptable changes in the transmitted video information, namely color. The schemes of the algorithm of adaptation to the spectral power distribution of the illuminant are presented. The possibility of universal use of the proposed algorithm in video transmission systems is considered. The algorithm of video image adaptation to the spectral power distribution of illuminants based on the selection of reference spectral power distributions with the given color coordinates is proposed. The algorithm of allocation of the spectral power distribution of the illuminant from the overall image scene is presented. Metrological support to assess the influence of the illuminant on the quality of color rendering is proposed. It is proposed to use spectral color distributions, the set of which is presented in the paper, as optical test images for testing the color rendering quality. Comparative characteristics with existing sets of spectral power distributions are presented and it is shown that they are not enough to implement the proposed algorithm. The simulation results prove the necessity and advantages of using the proposed algorithm. The image after the application of the algorithm is such if it was observed in sunlight, regardless of what type of lighting was used during shooting or observation. In addition, the presented algorithm allows adaptation to the spectral power distribution of various illuminants, such as incandescent lamps, fluorescent, LED, signal flares, and the like.

**Keywords:** spectrum, adaptation, color rendering, color perception, assessment, metrology, video applications, video communication, CAM16.

**References**

1. Recommendation ITU-R BT.709-6. Parameter values for the HDTV standards for production and international programme exchange (2015). Geneva, 19.
2. Recommendation ITU-R BT.2020-2. Parameter values for the HDTV standards for production and international programme exchange (2015). Geneva, 8.
3. Recommendation ITU-R BT.2100. Image parameter values for high dynamic range television for use in production and international programme exchange (2018). Geneva, 16.
4. ITU-R Television colorimetry elements (2017). Geneva, 78.
5. CIE Technical Report: Colorimetry (2004). Geneva, 19.
6. Pyliavskiy, V. (2014). An evaluations of color reproduction distortion in high definition television path with use of color bar signals. *Izvestiya Vysshikh Uchebnykh Zavedenii Rossii. Radioelektronika*, 3, 26–32.
7. Phuangsuwan, C., Ikeda, M. (2017). Chromatic adaptation to illumination investigated with adapting and adapted color. *Color Research & Application*, 42 (5), 571–579. doi: <https://doi.org/10.1002/col.22117>
8. Gofaizen, O., Pyliavskiy, V., Osharovska, O., Patlayenko, M. (2017). Adaptation to observation conditions in television systems by means of signal correction. 2017 4th International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S&T). doi: <https://doi.org/10.1109/infocommst.2017.8246413>
9. Pyliavskiy, V., Gofaizen, O., Siden, S., Vakarchuk, A. (2018). Use color appearance model for video applications. 2018 14th International Conference on Advanced Trends in Radioelectronics, Telecommunications and Computer Engineering (TCSET). doi: <https://doi.org/10.1109/tcset.2018.8336419>
10. Li, C., Li, Z., Wang, Z., Xu, Y., Luo, M. R., Cui, G. et. al. (2017). Comprehensive color solutions: CAM16, CAT16, and CAM16-UCS. *Color Research & Application*, 42 (6), 703–718. doi: <https://doi.org/10.1002/col.22131>
11. Li, C., Xu, Y., Wang, Z., Luo, M. R., Cui, G., Melgosa, M. et. al. (2018). Comparing two-step and one-step chromatic adaptation transforms using the CAT16 model. *Color Research & Application*, 43 (5), 633–642. doi: <https://doi.org/10.1002/col.22226>
12. Xu, L., Zhao, B., Luo, M. R. (2018). Colour gamut mapping between small and large colour gamuts: Part I gamut compression. *Optics Express*, 26 (9), 11481. doi: <https://doi.org/10.1364/oe.26.011481>
13. Xu, L., Zhao, B., Luo, M. R. (2018). Color gamut mapping between small and large color gamuts: part II gamut extension. *Optics Express*, 26 (13), 17335. doi: <https://doi.org/10.1364/oe.26.017335>
14. Zhao, B., Xu, L., Luo, M. R., Safdar, M. (2018). Evaluation of Gamut Mapping Algorithms in different Uniform Colour Spaces. 2018 Colour and Visual Computing Symposium (CVCS). doi: <https://doi.org/10.1109/cvcs.2018.8496580>
15. Khanh, T. Q., Bodrogi, P., Vinh, T. Q. (2017). Color Quality of Semiconductor and Conventional Light Sources. Wiley, 370. doi: <https://doi.org/10.1002/9783527803453>
16. Gofaizen, O. V., Pilyavskii, V. (2012). Digital television systems colour gamut. *Digital Technologies*, 11, 47–70.
17. Bukov, R. M. (1988). The quality of color television images. *Radio and Communication*.
18. Luo, M. R., Cui, G., Li, C. (2006). Uniform colour spaces based on CIECAM02 colour appearance model. *Color Research & Application*, 31 (4), 320–330. doi: <https://doi.org/10.1002/col.20227>
19. Pilyavskiy, V. V. (2014). On the selection of test material for colorimetry assesment of a quality of ultra high definition TV video path. *Modern problems of radio engineering and telecommunications*.



20. ISO/TR 16066:2003. Graphic technology – Standard object colour spectra database for colour reproduction evaluation (SOCS) (2003). Geneva: ISO, 46.
21. Floral Reflectance Database. Available at: <http://reflectance.co.uk/>
22. Gofaizen, O. V., Pilyavskiy, V. V. (2013). Construction of equidistant grid in uniform color space, uniformly filling color gamut transmitted and reproduced by television systems. *Digital Technologies*, 14, 62–80.

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**DESIGNING ADAPTIVE PID CONTROLLER NON-SENSITIVE TO CHANGES IN AERODYNAMIC CHARACTERISTICS OF AN UNMANNED AERIAL VEHICLE (p. 68-75)**

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The method of implementing an adaptive PID controller using a reference model of an unmanned aerial vehicle is presented. The unmanned aerial vehicle has a nonlinear characteristic and high sensitivity to external influences. The operation of a standard controller in a nonlinear model in the event of disturbing influences does not meet the specified quality criteria. Problems that affect the flight time of the unmanned aerial vehicle are represented by variations in aerodynamic coefficients in the known ranges. Herewith, aerodynamic parameters change, and the system becomes unstable. To eliminate unwanted deviations, an adaptive PID controller loop is introduced into the aerial vehicle control system. Using the reference model of the control object, the adaptation comparator provides the necessary PID controller settings. The introduction of such a correction control signal allows countering various failures and disturbances that lead to uncontrolled control. It was found that this method of control of the unmanned aerial vehicle is very effective, since the obtained result is closer to the experimental one. The study of failures was carried out through the observation of changes in aerodynamic coefficients. The study of changes in aerodynamic coefficients allows failure-free determination of the nominal values of the object coefficients. Such an approach to modeling the unmanned aerial vehicle also makes it possible to solve the economic side of the problem – to conduct experiments in the ANSYS-CFX aerodynamic application without costs for restoring vehicles and structures lost as a result of experimental testing.

**Keywords:** adaptive PID, reference adaptive control model (RACM), aerodynamic coefficients, uncertain model.

**References**

1. Francois, B., Hassan, N., Ouladsine, M. (2008). Diagnostic et tolérances aux défauts: application à un drone. Université Paul Cézanne.
2. Randalw, B., Timothy, W. M. (2012). *Small Unmanned Aircraft. Theory and Practice*. Princeton University Press. doi: <https://doi.org/10.1515/9781400840601>
3. Boudiba, O. (2017). Models of small-sized aircraft as an object of study for functionally stable control. *Open Information and Computer Integrated Technologies*, 78, 136–144.
4. Zhezhera, I., Ouissam, B., Firsov, S. (2017). Development of a functionally sustainable system of orientation of a free battle fighting unit. *Eastern-European Journal of Enterprise Technologies*, 6 (9 (90)), 22–29. doi: <https://doi.org/10.15587/1729-4061.2017.118640>
5. Boudiba, O. (2018). Robust control of unmanned aerial vehicle at the speeds uncertainty. *Open Information and Computer Integrated Technologies*, 81, 4–11.
6. Firsov, S. N., Fomichov, K. F., Boudiba, U., Zhezhera, I. V. (2016). Functional sustainable management of angular motion of the small-sized aircraft. *Systemy ozbroiennia i viyskova tekhnika*, 3, 33–37.
7. Goverde, R. M. P. (1996). *Civil Aircraft Autopilot Design Using Robust Control*. Delft University of Technology, 35–44.
8. *Robust Control Design with MATLAB®* (2005). Springer. doi: <https://doi.org/10.1007/b135806>
9. Tao, J., Liang, W., Sun, Q.-L., Luo, S.-Z., Chen, Z.-Q., Tan, P.-L., He, Y.-P. (2017). Modeling and Control of a Powered Parafoil in Wind and Rain Environments. *IEEE Transactions on Aerospace and Electronic Systems*, 53 (4), 1642–1659. doi: <https://doi.org/10.1109/taes.2017.2667838>
10. *Aérodynamique Et Mécanique Du*. Vol. 2. Du B.I.A au C.A.E.A. (2013). Académie de Toulouse.
11. Pranai, K., Maitree, T., Vittaya, T., Arjin, N., Pisit, B. (2011). Design Mrac Pid Control For Fan And Plate Process. *SICE Annual Conference*. Tokyo, 2945–2946.
12. Parks, P. (1966). Liapunov redesign of model reference adaptive control systems. *IEEE Transactions on Automatic Control*, 11 (3), 362–367. doi: <https://doi.org/10.1109/tac.1966.1098361>
13. Simple Adaptive Control Example. Available at: <https://www.mathworks.com/matlabcentral/fileexchange/44416-simple-adaptive-control-example>
14. Oblak, B. (2011). Introduction à la Théorie Classique de la Portance. *vesion du printemps*. Available at: [http://homepages.ulb.ac.be/~boblak/Miscellaneous/Oblak\\_Airfoil.pdf](http://homepages.ulb.ac.be/~boblak/Miscellaneous/Oblak_Airfoil.pdf)
15. zcan, A. E. (2008). *Autopilot And Guidance For Anti-Tank Imaging Infrared Guided Missiles*. Available at: <https://etd.lib.metu.edu.tr/upload/12610111/index.pdf>