

Optimization of the Probability of Transmission of Flight Data in the Response Channel of Secondary Radar Systems

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Abstract—In the work presented it is shown that the use of time-domain codes and positional codes as request signals and response signals, as well as the implementation aircraft transponder based on the principles of an open single-channel queuing system with failures lead to a significant decrease in both the noise immunity of the information systems under consideration when deliberate correlated interference operates in the request channel, and to a decrease in information security. The approach is based on the analysis of both information request signals and response signals, as well as the principles of constructing secondary radar systems in general and an aircraft transponder in particular. It is also shown that with the optimal choice of the transmission probability of flight data from air objects and the number of channels for processing received flight data, depending on the possible number of air objects located at the same azimuth, it is possible to optimize the probability of transmission of flight data in the response channel of secondary radar systems.

Keywords—airspace control systems (ACS), air traffic control (ATC), secondary surveillance radar (SSR), identification friend or foe (IFF), request signal (RS), answer signal (AS).

REFERENCES

- [1] S. Dubet, "Aeronautical information and meteorological data-link services," *2007 IEEE/AIAA 26th Digital Avionics Systems Conference*, 2007, pp. 4.B.1-1-4.B.1-9, doi: 10.1109/DASC.2007.4391902.
- [2] . Liu, Y. Cheng, Y. F. Hu, P. Pillai and V. Esposito, "Air-ground service integration for future aeronautical communication using SOA," *2011 Integrated Communications, Navigation, and Surveillance Conference Proceedings*, 2011, pp. H4-1-H4-10, doi: 10.1109/ICNSURV.2011.5935287.
- [3] [1]A. Neal, J. Flach, M. Mooij, S. Lehmann, S. Stankovic and S. Hasenbosch, "Envisaging the Future Air Traffic Management System", *The International Journal of Aviation Psychology*, vol. 21, no. 1, pp. 16-34, 2011. doi: 10.1080/10508414.2011.537557.
- [4] A. Maliarenko, *Sistemy radiolokacii dlia upravleniya vozduzhnym dvizheniem i gosudarstvennogo radiolokacionnogo opoznavania* [Radiolocation systems for air traffic control and state-monitored radar-based identification]. Kharkov: KhUPS, 2007
- [5] M. Stevens, *Secondary surveillance radar*. Boston, Mass.: Artech House, 1988.
- [6] I. Svyd, I. Obod, O. Maltsev and A. Hlushchenko, "Secondary Surveillance Radar Response Channel Information Security Improvement Method," *2020 IEEE 11th International Conference on Dependable Systems, Services and Technologies (DESSERT)*, 2020, pp. 341-345, doi: 10.1109/DESSERT50317.2020.9125018.
- [7] I. Svyd, I. Obod, O. Maltsev, I. Shtykh, G. Zavolodko and G. Maistrenko, "Model and Method for Request Signals Processing of Secondary Surveillance Radar," *2019 IEEE 15th International Conference on the Experience of Designing and Application of CAD Systems (CADSM)*, 2019, pp. 1-4, doi: 10.1109/CADSM.2019.8779347.
- [8] G. Jiang, Y. Fan and H. Yuan, "Assessing the Capacity of Air Traffic Control Secondary Surveillance Radar System," *2019 Cross Strait Quad-Regional Radio Science and Wireless Technology Conference (CSQRWC)*, 2019, pp. 1-3, doi: 10.1109/CSQRWC.2019.8799146
- [9] T. Schuck, B. Shoemaker and J. Willey, "Identification friend-or-foe (IFF) sensor uncertainties, ambiguities, deception and their application to the multi-source fusion process," *Proceedings of the IEEE 2000 National Aerospace and Electronics Conference. NAECON 2000. Engineering Tomorrow (Cat. No.00CH37093)*, 2000, pp. 85-94, doi: 10.1109/NAECON.2000.894896.
- [10] O. Strelnytskyi, I. Svyd, I. Obod, O. Maltsev, O. Voloshchuk and G. Zavolodko, "Assessment Reliability of Data in the Identification Friend or Foe Systems," *2019 IEEE 39th International Conference on Electronics and Nanotechnology (ELNANO)*, 2019, pp. 728-731, doi: 10.1109/ELNANO.2019.8783397.
- [11] I. Obod, I. Svyd, O. Maltsev and B. Bakumenko, "Comparative Analysis of Noise Immunity Systems Identification Friend or Foe,"

- 2020 *IEEE 40th International Conference on Electronics and Nanotechnology (ELNANO)*, 2020, pp. 751-756, doi: 10.1109/ELNANO50318.2020.9088856.
- [12] C. Reck, M. S. Reuther, U. Berold and L. Schmidt, "Spatial filtering and equalization for SSR signal detection in a multipath environment," *2011 German Microwave Conference*, Darmstadt, pp. 1-4, 2011.
- [13] V. Semenets, I. Svyd, I. Obod, O. Maltsev and M. Tkach, "Quality Assessment of Measuring the Coordinates of Airborne Objects with a Secondary Surveillance Radar", *Data-Centric Business and Applications*, pp. 105-125, 2021. doi: 10.1007/978-3-030-71892-3_5.
- [14] M. Skulysh, O. Romanov, L. Globa and I. Husyeva, "Managing the Process of Servicing Hybrid Telecommunications Services. Quality Control and Interaction Procedure of Service Subsystems", *Advances in Soft and Hard Computing*, pp. 244-256, 2018. doi: 10.1007/978-3-030-03314-9_22.
- [15] I. Svyd, I. Obod, G. Zavalodko and O. Maltsev, "Interference immunity of aircraft responders in secondary surveillance radars," *2018 14th International Conference on Advanced Trends in Radioelectronics, Telecommunications and Computer Engineering (TCSET)*, 2018, pp. 1174-1178, doi: 10.1109/TCSET.2018.8336404.
- [16] X. Du, K. Liao and X. Shen, "Secondary Radar Signal Processing Based on Deep Residual Separable Neural Network," *2020 IEEE International Conference on Power, Intelligent Computing and Systems (ICPICS)*, 2020, pp. 12-16, doi: 10.1109/ICPICS50287.2020.9202372.
- [17] I. Obod, "Integrated Coordinate-and-Time Support for the Address Inquiry in the Secondary Radar Systems", *Telecommunications and Radio Engineering*, vol. 53, no. 3, pp. 54-56, 1999. doi: 10.1615/telecomradeng.v53.i3.100
- [18] I. Svyd, I. Obod, O. Maltsev, O. Vorgul, G. Zavalodko and A. Goriushkina, "Noise Immunity of Data Transfer Channels in Cooperative Observation Systems: Comparative Analysis," *2018 International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S&T)*, 2018, pp. 509-512, doi: 10.1109/INFOCOMMST.2018.8632019.
- [19] Á. Parra-Cerrada, V. González-Posadas, J. L. Jiménez-Martín, Á. Blanco-del-Campo, W. Hernandez and C. Calderón-Córdova, "Low-Cost Measurement for a Secondary Mode S Radar Transmitter," in *IEEE Transactions on Instrumentation and Measurement*, vol. 64, no. 12, pp. 3217-3225, Dec. 2015, doi: 10.1109/TIM.2015.2450357.
- [20] J. Tol, P. van Genderen and L. P. Ligthart, "Improvement of the SSR mode S data link using a distributed ground system," *Proceedings of International Radar Conference*, 1996, pp. 519-522, doi: 10.1109/ICR.1996.574518.
- [21] O. Romanov and V. Mankivskiy, "Optimal Traffic Distribution Based on the Sectoral Model of Loading Network Elements," *2019 IEEE International Scientific-Practical Conference Problems of Infocommunications, Science and Technology (PIC S&T)*, 2019, pp. 683-688, doi: 10.1109/PICST47496.2019.9061296.
- [22] I. Svyd, I. Obod and O. Maltsev, "Interference Immunity Assessment Identification Friend or Foe Systems", *Data-Centric Business and Applications*, pp. 287-306, 2021. doi: 10.1007/978-3-030-71892-3_12.
- [23] I. Obod, I. Svyd, O. Maltsev, O. Vorgul, G. Maistrenko and G. Zavalodko, "Optimization of the Quality of Information Support for Consumers of Cooperative Surveillance Systems", *Data-Centric Business and Applications*, pp. 133-155, 2020. doi: 10.1007/978-3-030-43070-2_8.
- [24] I. Svyd, I. Obod, O. Maltsev, T. Tkachova and G. Zavalodko, "Optimal Request Signals Detection in Cooperative Surveillance Systems," *2019 IEEE 2nd Ukraine Conference on Electrical and Computer Engineering (UKRCON)*, 2019, pp. 1-5, doi: 10.1109/UKRCON.2019.8879840.
- [25] J. Ye, R. Shi, F. Liang, Y. Li and H. Lin, "Research and Simulation Analysis on Research on Secondary Radar Signal Coverage," *2021 IEEE 5th Advanced Information Technology, Electronic and Automation Control Conference (IAEAC)*, 2021, pp. 2308-2311, doi: 10.1109/IAEAC50856.2021.9390640.
- [26] I. Svyd, I. Obod, O. Maltsev, O. Strelnytskyi, O. Zubkov and G. Zavalodko, "Method of Increasing the Identification Friend or Foe Systems Information Security," *2019 3rd International Conference on Advanced Information and Communications Technologies (AICT)*, 2019, pp. 434-438, doi: 10.1109/AICT.2019.8847853.
- [27] O. Romanov, M. Nesterenko and V. Mankivskiy, "The Method of Redistributing Traffic in Mobile Network", *Data-Centric Business and Applications*, pp. 159-182, 2021. doi: 10.1007/978-3-030-71892-3_7.
- [28] L. Globa, M. Skulysh, O. Romanov and M. Nesterenko, "Quality Control for Mobile Communication Management Services in Hybrid Environment", *Lecture Notes in Electrical Engineering*, pp. 76-100, 2019. doi: 10.1007/978-3-030-16770-7_4.
- [29] I. Svyd, I. Obod, O. Maltsev, G. Zavalodko, G. Maistrenko and L. Saikivska, "Method of Enhancing Information Security of Requesting Cooperative Surveillance Systems," *2019 IEEE International Scientific-Practical Conference Problems of Infocommunications, Science and Technology (PIC S&T)*, 2019, pp. 732-736, doi: 10.1109/PICST47496.2019.9061366.
- [30] I. Obod, I. Svyd, O. Maltsev, O. Vorgul, G. Maistrenko and G. Zavalodko, "Optimization of Data Transfer in Cooperative Surveillance Systems," *2018 International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S&T)*, 2018, pp. 539-542, doi: 10.1109/INFOCOMMST.2018.8632134.
- [31] I. Svyd, I. Obod, O. Maltsev, T. Tkachova and G. Zavalodko, "Improving Noise Immunity in Identification Friend or Foe Systems," *2019 IEEE 2nd Ukraine Conference on Electrical and Computer Engineering (UKRCON)*, 2019, pp. 73-77, doi: 10.1109/UKRCON.2019.8879812.
- [32] T. Otsuyama, J. Naganawa, J. Honda and H. Miyazaki, "Measuring Signal Environment in the Aircraft Surveillance Frequency by Flight Experiments," *2018 International Symposium on Electromagnetic Compatibility (EMC EUROPE)*, 2018, pp. 44-47, doi: 10.1109/EMCEurope.2018.8485178.
- [33] O. Romanov, M. Nesterenko, L. Veres and Y. Hordashnyk, "IMS: Model and calculation method of telecommunication network's capacity," *2017 International Conference on Information and Telecommunication Technologies and Radio Electronics (UkrMiCo)*, 2017, pp. 1-5, doi: 10.1109/UkrMiCo.2017.8095412.
- [34] V. Semenets and T. Stytcenko, "Analysis of Electromagnetic Environment and Modeling of Spurious Radiation Sources", *Telecommunications and Radio Engineering*, vol. 75, no. 15, pp. 1385-1396, 2016. Available: 10.1615/telecomradeng.v75.i15.70.
- [35] L. Vlasenko, A. Rutkas, V. Semenets and A. Chikriy, "On the Optimal Impulse Control in Descriptor Systems", *Journal of Automation and Information Sciences*, vol. 51, no. 5, pp. 1-15, 2019. Available: 10.1615/jautomatinfscien.v51.i5.10.
- [36] L. Vlasenko, A. Rutkas, V. Semenets and A. Chikrii, "Stochastic Optimal Control of a Descriptor System", *Cybernetics and Systems Analysis*, vol. 56, no. 2, pp. 204-212, 2020. Available: 10.1007/s10559-020-00236-7.
- [37] V. Lysak, H. Kawaguchi and I. Sukhoivanov, "Gain spectra and saturation power of asymmetrical multiple quantum well semiconductor optical amplifiers", *IEEE Proceedings - Optoelectronics*, vol. 152, no. 2, p. 131, 2005. Available: 10.1049/ip-opt:20045021.
- [38] Sirenko, K. Y., and Y. K. Sirenko. "Exact "Absorbing" Conditions in Initial-Boundary Value Problems in the Theory of Open Waveguide Resonators." *Computational Mathematics and Mathematical Physics*, vol. 45, no. 3, 2005, pp. 490-506.
- [39] I. Obod, I. Svyd, O. Vorgul, O. Maltsev, O. Datsenko and N. Boiko, "Optimization of Data Processing Structure for Multi-Position Radar Surveillance Systems," *2021 IEEE 3rd Ukraine Conference on Electrical and Computer Engineering (UKRCON)*, 2021, pp. 133-137, doi: 10.1109/UKRCON53503.2021.9575286.
- [40] I. Svyd, I. Obod, O. Maltsev, V. Andrusovich, B. Bakumenko and O. Vorgul, "Optimal Measurement of Signal Data Parameters of Requesting Radar Systems," *2021 IEEE 3rd Ukraine Conference on Electrical and Computer Engineering (UKRCON)*, 2021, pp. 138-141, doi: 10.1109/UKRCON53503.2021.9575235.
- [41] I. Obod, I. Svyd, G. Zavalodko, O. Maltsev, B. Bakumenko and V. Chumak, "Assessing SSR Relative Data Capacity," *2021 IEEE 3rd Ukraine Conference on Electrical and Computer Engineering (UKRCON)*, 2021, pp. 142-146, doi: 10.1109/UKRCON53503.2021.9575971.