The Effect of Masking Interference on the Quality of Request Signal Detection in Aircraft Responders of the Identification Friend or Foe Systems

Ivan Obod
Dept. of Microprocessor Technologies and Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
ivan.obod@nure.ua

Iryna Svyd
Dept. of Microprocessor Technologies and Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
iryna.svyd@nure.ua

Oleksandr Maltsev
Dept. of Microprocessor Technologies and Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
aleksandr.maltsev@nure.ua

Sviatoslav Starokozhev
Dept. of Microprocessor Technologies and Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
sviatoslav.starokozhev@nure.ua

https://ieeexplore.ieee.org/document/9467955

DOI: 10.1109/PICST51311.2020.9467955

***Abstract*—The principle of building a network of survey IFF systems, the principle of servicing request signals in an aircraft responder, as well as the presence of a significant number of information facilities operating in the frequency range of IFF systems predetermined the presence of significant flows of intra-system and intentional correlated and uncorrelated interference of significant intensity both in the request channel and response channel. The use of primitive time-domain and positional codes as request signals predetermined the low noise immunity of IFF systems when exposed to masking interference in the request channel due to the need to expand the receiver bandwidth significantly higher than the bandwidth of the request signals used. The paper evaluates the influence of masking interference on the quality of detection of request signals in aircraft responders. It is shown that the expansion of the bandwidth of the receiver of the aircraft responder leads to additional losses in the signal-to-noise ratio, as a consequence to a decrease in the noise immunity of the considered information systems.**

Keywords—identification friend or foe (IFF); air object (AO); aircraft transponders (AT); request signal (RS); masking interference (MI).

REFERENCES

[1] B. Stevens, F. Lewis and E. Johnson, *Aircraft Control and Simulation: Dynamics, Controls Design, and Autonomous*. John Wiley & Sons, 2016.

[2] M. Thomas and H. Buchanan, "The Need for Battle Managers in the Tactical Air Control System", *Air Power Journal*, 1987.

[3] P. Lynn, *Radar Systems*. Boston: Springer, 1987, doi: https://doi.org/10.1007/978-1-4613-1579-7

[4] A. Farina and F. Studer, *Digital processing of radar information*. Moscow, Russia: Radio i svyaz, 1993. (In Russian).

[5] M. Stevens, *Secondary surveillance radar*. Boston, Mass.: Artech House, 1988.

[6] E. Kim and K. Sivits, "Blended secondary surveillance radar solutions to improve air traffic surveillance", *Aerospace Science and Technology*, vol. 45, pp. 203-208, 2015, doi: https://doi.org/10.1016/j.ast.2015.05.018.

[7] J. Gao, J. Zou and N. Guo, "A Secondary Surveillance Radar Data Analysis Technique Based on Geometrical Method", *Lecture Notes in Electrical Engineering*, pp. 707-715, 2019, doi: https://doi.org/10.1007/978-981-13-6508-9_85.

[8] A. Fahmy and K. Moustafa, "A Survey of IFF Systems", *The International Conference on Electrical Engineering*, vol. 5, no. 5, pp. 1-11, 2006, doi: https://doi.org/10.21608/iceeng.2006.33679.

[9] M. Garcia, J. Hoffman, J. Rowley and D. Stone, "Test for Success: Next Generation Aircraft Identification System RF Simulation," *2007 Integrated Communications, Navigation and Surveillance Conference*, Herndon, VA, 2007, pp. 1-10, doi: https://doi.org/10.1109/ICNSURV.2007.384161.

[10] I. Svyd, I. Obod, G. Zavolodko and O. Maltsev, "Interference immunity of aircraft responders in secondary surveillance radars," *2018 14th International Conference on Advanced Trends in Radioelecrtronics, Telecommunications and Computer Engineering (TCSET)*, Slavske, 2018, pp. 1174-1178, doi: https://doi.org/10.1109/TCSET.2018.8336404.

[11] V. Lebedev, A. Lenshin, N. Tikhomirov. "Efficiency of Suppression of Radar Systems with an Active Code Response by Intentional Interference", *Bulletin of the Voronezh Institute of the Ministry of Internal Affairs of Russia*, № 4, pp. 114-121, 2015.

[12] S. Zhironkin, S. Bliznyuk and A. Kuchin, "Jamming Resistance of the Inbound Channel of an Identification System with Broadband Signals and Error Control Codes in the Conditions of Pulse Noise and Intra-System Jamming", *Journal of Siberian Federal University. Engineering & Technologies*, pp. 673-682, 2019, doi: https://doi.org/10.17516/1999-494x-0166.

[13] 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), Kyiv, Ukraine, 2019, pp. 728-731, doi: https://doi.org/10.1109/ELNANO.2019.8783397.

[14] J. Pollack and P. Ranganathan, "Aviation Navigation Systems Security: ADS-B, GPS, IFF", in *International Conference on Security & Management*, *SAM'18*, International Conference on Security & Management, SAM'18, Las Vegas, Nevada, USA, 2018, pp. 129-135.

[15] I. Svyd, I. Obod, O. Maltsev, T. Tkachova and G. Zavolodko, "Improving Noise Immunity in Identification Friend or Foe Systems", *2019 IEEE 2nd Ukraine Conference on Electrical and Computer Engineering (UKRCON)*, Lviv, Ukraine, 2019, pp. 73-77, doi: https://doi.org/10.1109/UKRCON.2019.8879812.

[16] I. Svyd, I. Obod, O. Maltsev, O. Strelnytskyi, O. Zubkov and G. Zavolodko, "Method of Increasing the Identification Friend or Foe Systems Information Security," *2019 3rd International Conference on Advanced Information and Communications Technologies (AICT)*, Lviv, Ukraine, 2019, pp. 434-438, doi: https://doi.org/10.1109/AIACT.2019.8847853.

[17] M. Siergiejczyk, K. Krzykowska and A. Rosiński, "Reliability Assessment of Cooperation and Replacement of Surveillance Systems in Air Traffic", *Proceedings of the Ninth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX. June 30 – July 4, 2014, Brunów, Poland*, pp. 403-411, 2014, doi: https://doi.org/10.1007/978-3-319-07013-1_39.

[18] I. Svyd, I. Obod, O. Maltsev, O. Vorgul, G. Zavolodko 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)*, Kharkiv, Ukraine, 2018, pp. 509-512, doi: https://doi.org/10.1109/INFOCOMMST.2018.8632019.

[19] I. Obod, I. Svyd, O. Maltsev, G. Maistrenko, O. Zubkov and G. Zavolodko, "Bandwidth Assessment of Cooperative Surveillance Systems," *2019 3rd International Conference on Advanced Information and Communications Technologies (AICT)*, Lviv, Ukraine, 2019, pp. 1-6, doi: https://doi.org/10.1109/AIACT.2019.8847742.

[20] I. Obod, I. Svyd, O. Maltsev, O. Vorgul, G. Maistrenko and G. Zavolodko, "Optimization of Data Transfer in Cooperative Surveillance Systems," *2018 International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S&T)*, Kharkiv, Ukraine, 2018, pp. 539-542, doi: https://doi.org/10.1109/INFOCOMMST.2018.8632134.

[21] I. Svyd, I. Obod, O. Maltsev, T. Tkachova and G. Zavolodko, "Optimal Request Signals Detection in Cooperative Surveillance Systems," *2019 IEEE 2nd Ukraine Conference on Electrical and Computer Engineering (UKRCON)*, Lviv, Ukraine, 2019, pp. 1-5, doi: https://doi.org/10.1109/UKRCON.2019.8879840.

[22] R. Wiley, *ELINT*. Norwood: Artech House, 2006.

[23] C. Reck, U. Berold, J. Weinzierl, and L. P. Schmidt, "Direction of arrival estimation from secondary surveillance radar signals in presence of hardware imperfections", in *Proceedings of the 5th European Radar Conference*, pp. 252-255, October 2008.

[24] N. Petrochilos, G. Galati and E. Piracci, "Secondary Surveillance Radar: Sparsity-based sources separation in a real environment," *2008 Tyrrhenian International Workshop on Digital Communications - Enhanced Surveillance of Aircraft and Vehicles*, Capri, 2008, pp. 1-5. doi: https://doi.org/10.1109/TIWDC.2008.4649029.

[25] I. Globus. *Binary coding in asynchronous systems*. Moscow, Russia: Svyaz, 1972. (In Russian).

[26] M. Yarlykov and M. Chernyakov, *Optimization of asynchronous address radio communication systems*. Moscow: Svyaz', 1979.

[27] A. Lenshin and V. Lebedev, "Characteristics of the spoofing resistant signal receiver in radar systems with active response", *Radio and telecommunication systems*, vol. 1, pp. 31-38, 2017.

[28] A. Belov, S. Kozlov, A. Korobkov and S. Chabdarov, "Multi-signal extraction of address flows in asynchronous impulse radio-systems", *Bulletin of Kazan State Technical University. A.N. Tupolev*, vol. 4, no. 74, pp. 164-171, 2018. (In Russian).

[29] I. Tsikin and E. Poklonskaya, "Secondary surveillance radar signals processing at the remote analysis station", *SPbSPU Journal. Computer Science. Telecommunication and Control Systems*, Volume 10, Issue 2, pp. 58-74, 2017. (In Russian).

[30] A. Doerry, "Comments on radar interference sources and mitigation techniques", *Radar Sensor Technology XIX; and Active and Passive Signatures VI*, 2015. doi: 10.1117/12.2075743.

[31] I. Svyd, I. Obod, O. Maltsev, I. Shtykh and G. Zavolodko, "Model and Method for Detecting Request Signals in Identification Friend or Foe Systems," *2019 IEEE 15th International Conference on the Experience of Designing and Application of CAD Systems (CADSM)*, Polyana, Ukraine, 2019, pp. 1-4, doi: 10.1109/CADSM.2019.8779322.

[32] 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)*, Polyana, Ukraine, 2019, pp. 1-4, doi: https://doi.org/10.1109/CADSM.2019.8779347.

[33] R. Jain, F. Templin and K.-S. Yin, "Analysis of L-Band Digital Aeronautical Communication Systems: L-DACS1 and L-DACS2", *2011 Aerospace Conference*, 2011. doi: 10.1109/aero.2011.5747378.

[34] X. Li and J. Du, "Performance optimization algorithm of radar signal processing system", *Cluster Computing*, vol. 20, no. 1, pp. 359-370, 2016, doi: https://doi.org/10.1007/s10586-016-0710-6.

[35] E. Piracci, G. Galati, N. Petrochilos and F. Fiori, "1090 MHz channel capacity improvement in the air traffic control context", *International Journal of Microwave and Wireless Technologies*, vol. 1, no. 3, pp. 193-199, 2009, doi: https://doi.org/10.1017/s1759078709000191.

[36] Y. Chen, S. Lo, P. Enge and S. Jan, "Evaluation & comparison of ranging using Universal Access Transceiver (UAT) and 1090 MHz Mode S Extended Squitter (Mode S ES)", *2014 IEEE/ION Position, Location and Navigation Symposium - PLANS 2014*, 2014, doi: https://doi.org/10.1109/plans.2014.6851456.

[37] M. Leonardi and M. Maisano, "Backward Compatible Physical Layer Protocol Evolution for ADS-B Message Authentication," in *IEEE Aerospace and Electronic Systems Magazine*, vol. 35, no. 5, pp. 16-26, 1 May 2020, doi: https://doi.org/10.1109/MAES.2020.2983621.

[38] A. Lenshin and A. Nagalin, "Protection indicators of information processes in indentification systems under jamming conditions", Telecommunications, vol. 10, pp. 30-34, 2015. (In Russian).

[39] A. Lenshin and V. Lebedev, "Comprehensive methodology for assessing the effectiveness of the functioning of radar systems with an active response", *Dynamics of complex systems - XXI century*, vol. 2, pp. 60-64, 2017. (In Russian).

[40] A. Bestugin, A. Eshenko, A. Filin, A. Plyasovskikh, A. Shatrakov and Y. Shatrakov, *Air Traffic Control Automated Systems*. Singapore: Springer Singapore, 2020.

[41] A. Lenshin, N. Tikhomirov and V. Lebedev, "Efficiency of suppressing radar with an active response by masking and imitating interference", *XX International Scientific and Technical Conference "Radiolocation, navigation, communication"*, Voronezh, 2014, pp. 1323-1331. (In Russian).

[42] A. Lenshin and V. Lebedev, "Mathematical model definition of the spread spectrum jamming effect on the identification system", *Radio and telecommunication systems*, vol. 2, pp. 13-19, 2014.

[43] I. Obod, I. Svyd, O. Maltsev, O. Vorgul, G. Maistrenko and G. Zavolodko, "Optimization of the Quality of Information Support for Consumers of Cooperative Surveillance Systems", In: Radivilova T., Ageyev D., Kryvinska N. (eds) *Data-Centric Business and Applications. Lecture Notes on Data Engineering and Communications Technologies*, vol 48. Springer, Cham, pp. 133-155, 2020, doi: https://doi.org/10.1007/978-3-030-43070-2_8.

[44] I. Obod, I. Svyd, O. Maltsev, G. Zavolodko, D. Pavlova and G. Maistrenko, "Fusion the Coordinate Data of Airborne Objects in the Networks of Surveillance Radar Observation Systems", In: Radivilova T., Ageyev D., Kryvinska N. (eds) *Data-Centric Business and Applications. Lecture Notes on Data Engineering and Communications Technologies*, vol 48. Springer, Cham, pp. 731-746, 2020, doi: https://doi.org/10.1007/978-3-030-43070-2_31.

[45] J. Veselý and P. Pouč, "The Secondary Surveillance Radar Parameters Extraction by Using of SIF/IFF Responses Analysis", *Advances in Military Technology*, vol. 4, no. 1, pp. 41-47, 2009.

[46] P. Poornima, B. Roja Reddy and B. G. Anantha Murthy, "Design and Simulation of Two-Chain Monopulse Receiver for IFF Radar Application," *2018 3rd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology*

(RTEICT), Bangalore, India, 2018, pp. 1114-1118, doi: https://doi.org/10.1109/RTEICT42901.2018.9012646.

[47] I. Svyd, I. Obod, O. Maltsev, I. Shtykh, G. Maistrenko and G. Zavolodko, "Comparative Quality Analysis of the Air Objects Detection by the Secondary Surveillance Radar," *2019 IEEE 39th International Conference on Electronics and Nanotechnology (ELNANO)*, Kyiv, Ukraine, 2019, pp. 724-727, doi: https://doi.org/10.1109/ELNANO.2019.8783539.

[48] I. Obod, I. Svyd, O. Maltsev and B. Bakumenko, "Spatial Methods for Increasing the Bandwidth of a Mobile Information Network," *2020 IEEE 15th International Conference on Advanced Trends in Radioelectronics, Telecommunications and Computer Engineering (TCSET)*, Lviv-Slavske, Ukraine, 2020, pp. 50-54, doi: https://doi.org/10.1109/TCSET49122.2020.235388.

[49] I. Svyd, O. Maltsev, I. Obod and G. Zavolodko, "Fusion Method of Primary Surveillance Radar Data and IFF systems Data," *2020 IEEE 11th International Conference on Dependable Systems, Services and Technologies (DESSERT)*, Kyiv, Ukraine, 2020, pp. 336-340, doi: https://doi.org/10.1109/DESSERT50317.2020.9125040.

[50] 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)*, Kyiv, Ukraine, 2020, pp. 751-756, doi: https://doi.org/10.1109/ELNANO50318.2020.9088856.

[51] S. Tkachenko, "Information processing algorithm in direct identification subsystem taking into account spatial density of identifiable objects", *Telecommunications*, vol. 1, pp. 2-7, 2016. (In Russian).

[52] S. Tkachenko, A. Avramov and S. Ivanov, "Principles of additional selection of a request signal by angular coordinates in a radar system with an active response", *Proceedings of Voronezh State University*, vol. 11, no. 6, pp. 104-107, 2010. (In Russian).

[53] O. Peker and D. Akdur, "A Method for Elimination of False IFF Target Reports by Using ISLS and RSLS Techniques," *2019 Signal Processing Symposium (SPSympo)*, Krakow, Poland, 2019, pp. 315-318, doi: https://doi.org/10.1109/SPS.2019.8881951.

[54] Z. Cao and L. Chen, "Security in application layer of radar sensor networks: detect friends or foe", *Security Comm. Networks*, vol. 8, pp. 2712–2722, 2015, doi: https://doi.org/10.1002/sec.572.

[55] D. Wang, Q. Bao, Z. Niu and Z. Chen, "Weak target detection algorithm for non-cooperative bistatic radar," IET International Radar Conference 2015, Hangzhou, 2015, pp. 1-5, doi: https://doi.org/10.1049/cp.2015.1124.

[56] Y. Guo, J. Yang and C. Guan, "A Mode 5 signal detection method based on phase and amplitude correlation," *2013 Ninth International Conference on Natural Computation (ICNC)*, Shenyang, 2013, pp. 1219-1223, doi: https://doi.org/10.1109/ICNC.2013.6818164.