POZNAN UNIVERSITY OF TECHNOLOGY

BULLETIN 2024

Institute of Radiocommunications

Dear Readers,

I am honored and pleased to present this bulletin to guide you through recent research, development, and educational activities at the Institute of Radiocommunications.

The Institute of Radiocommunications is an organizational unit of the Faculty of Computing and Telecommunications of the Poznan University of Technology, with its activities focused on scientific research, higher education, and research supervision in wireless communications. The Institute was established in 2020 and organizationally transformed from the Chair of Wireless Communication, Faculty of Electronics and Telecommunication. It has a modern scientific infrastructure, specialized laboratories, and experienced staff. It cooperates with businesses and implements research and development projects funded by the industry, national agencies, and the European Commission. Research results are published in prestigious scientific books and journals and are subject to license agreements and patents. Students and doctorate candidates are also involved in scientific research and projects, pursuing their bachelor-, master- and doctoral degrees under the supervision of the Institute's scientific staff. The Institute cooperates with universities and research-and-development centers from Europe, Asia, Africa, and North America, and its employees are members and leaders of important organizations in the area of radio communication.

I encourage you, dear Readers, to learn about our thematic research areas and infrastructure, recent achievements, projects, and publications, as well as our academic educational activities and potential. We are open to cooperation and scientific exchange with you and your institution as prospective research and scholarly exchange partners.

I also take the opportunity to invite you to the conferences our Institute is organizing this and next year: the National Conference on Radiocommunications and Teleinformatics (KRiT 2024) on September 11-13, 2024, and the European Conference on Networks and Communications (EuCNC), supported by the European Commission, planned to be held at Poznan University of Technology in 2025.

Professor Hanna Bogucka, PhD
Director of the Institute of Radiocommunications

Poznan, May 2024

Advanced methods and techniques for identifying and counteracting cyber attacks on the 5G access network and applications

Professor Krzysztof Wesołowski talks about research on 5G system cybersecurity

Changes in the concept and design of mobile networks during the development of fifth-generation (5G) systems pose new, serious security challenges. Among other novelties, a new type of network has appeared, i.e. private networks. In 5G systems, the hardware layer is separated from the software layer and network virtualization has been introduced. The 5G network also needs to support a large number of different types of devices, from devices generating and receiving traffic of advanced multimedia streams at very high data rates, to traffic at low speeds generated by a huge number of terminals operating in the Internet of Things (IoT) mode, and implement various types of spectrum access. The concept of creating network slicing, the use of protocols known from the World Wide Web, and the concept of "Edge Computing" are just some of the technologies that, while increasing the capabilities of the 5G network, can also cause security threats. The 3GPP organization includes these aspects as part of the next-generation system standard, proposing security solutions such as: unified access-agnostic authentication, access network security mechanisms between the remote and central unit (Radio Access Network security for Distant Units—Central Unit split), service-based architecture, etc. However, these general system security mechanisms have been so far tested to a limited extent.

In the Institute of Radiocommunications, the project entitled "Advanced methods and techniques for identifying and counteracting cyber attacks on the 5G access network and applications" (5gSTAR) has been conducted since 2021. The Institute is one of the partners of the consortium led by the Military Communication Institute, the State Research Institute. The third partner is the Grandmetric company located in Poznan. The project is funded by the National Center for Research and Development.

5GSTAR
CYBERSECURITY

The main goal of the project is to develop methods and techniques for identifying and counteracting new advanced attacks on access infrastructure and 5G applications. The implementation of the 5gSTAR system aims at direct and positive contribution to increasing the level of security in the cyberspace of the Republic of Poland. In particular, the project focuses on 5G application scenarios requiring very low delays and/or very high reliability (Ultra Reliable Low-Latency Communications—URLLC), i.e. those that fit into modern Industry 4.0 installations. The project will develop elements of detection (probe, honeypot) and attack prevention (application firewall, firewall, security policy), as well as a security monitoring application enabling risk assessment and reporting. The developed system enables integration with client systems, offering protection of ICT infrastructure, threat detection, protection of privacy, confidentiality, integrity, and availability. This consequently allows for the implementation of secure ICT products and services in cyberspace, especially in the area of operation of key service operators. The project is interdisciplinary, focusing on both attacks observed in layers 1-3 and 4-7 of the ISO/OSI model. Methods of analyzing large data sets (collected from sensors placed at various points in the network), statistical analysis algorithms, and artificial intelligence (Machine Learning) are used. The sensors planned for development (probe, honeypot) use novel and innovative algorithms that constitute a significant contribution to the development of knowledge in the field of 5G network security. The monitoring application uses a cognitive approach, presenting the most important information in a transparent way that allows one to quickly learn about the status of the system and take appropriate actions.

Besides the research related to higher layers of the 5G system, some research has also been performed on counteracting intentional jamming, i.e. attack in the physical layer. A new jamming detection algorithm has been proposed and the algorithm of separation of useful signal from jamming one has been analyzed.

"We believe that the development and maturity of future radio communication technologies will be possible only if we resolve the cybersecurity concerns. Our team contributes to building advanced defense methods, ready to be applied in 5G and 6G systems. This is a source of our professional satisfaction", says Professor Krzysztof Wesołowski, the leader of the 5gSTAR team in the Institute of Radiocommunications.

News and recent achievements

30.11.2023

At the end of November, despite the unfavourable weather and with some delay, our first satellite antenna was finally installed in Kąkolewo campus. Engineers from ORBIT company, the antenna manufacturer, together with collegues from TESPOL company, the system supplier, implemented this complicated operation smoothly and without any disturbances.

It took two days to assemble the radome and the antenna reflector on the ground, while on the third day the components were moved to the top of the tower using a crane and fastened safely. During day 4 the antenna system was calibrated and tested, and finally we were trained by the specialist from ORBIT in system maintenance. We plan to do the final testing, including communication with a satellite, when all works inside the technical room are finished and the communication equipment is installed and configured.

We encourage you to watch a short video showing this interesting operation.

SCAN ME

6.10.2023

On October 6, 2023, the Institute of Management and Information Systems at the Faculty of Management Engineering of the Poznań University of Technology and the Entrepreneurial Women's Club in Poznań organized the 1st Women's Science and Business Forum combined with the 4th edition of the Women's Entrepreneurial Day. The focus of that year's event was on the aspects of combining science with business and to support the scientific and business development of women and men. Organizers and guests emphasized the role of broadening horizons, strengthening research capacity and contributing to an innovative, competitive and prosperous European society.

Prof. Hanna Bogucka took part in that event as a panelist of the session "Know-how — science and technology in practice".

22.09.2023

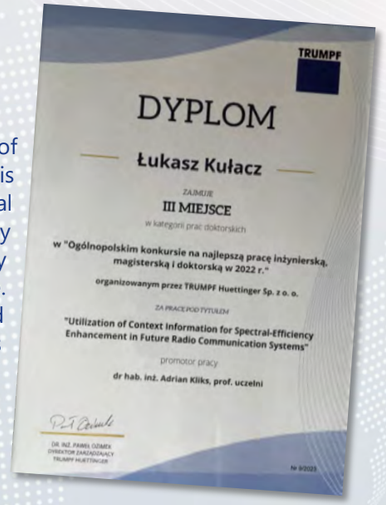
During the Conference of Radiocommunication and Teleinformatics (KRiT) held on September 20-22, 2023, in Krakow, the Foundation for the Support of the Development of Radiocommunication and Multimedia Technologies awards were presented to the winners of the competition for the best article by a young author. A distinction in this competition was awarded to **Marcin Hoffmann, M.Sc.,** for the paper entitled "Evaluation of a User-Centric Massive MIMO Network". The awardee is an employee and doctoral student of the Institute of Radiocommunications. Congratulations!

20.09.2023

The 21st edition of the national competition for the best doctoral thesis in the field of radiocommunication and multimedia techniques, organized by the Foundation for the Support of the Development of Radiocommunication and Multimedia Technologies, has ended. This year, the first prize went to **Dr. Bartosz Bossy** for the dissertation entitled "Energy-Efficient Resource Allocation in OFDM Systems with Computational Awareness." The supervisor of the thesis defended on June 27, 2022, was Prof. Hanna Bogucka. An honorable distinction in the competition also went to an employee of our Institute, **Dr. Łukasz Kułacz** for the dissertation entitled "Utilization of context information for spectral-efficiency enhancement in future radio communication systems". The supervisor of the thesis defended on December 13, 2022, was Prof. Adrian Kliks. The award ceremony took place on September 20, 2023, in Krakow, during the opening session of the Radiocommunications and Teleinformatics Conference, KRiT 2023.

20.09.2023

With great satisfaction, we noticed the announced results of the 1st edition of the "National competition for the best engineering, master's and doctoral thesis in 2022". Doctoral thesis entitled: "Utilization of Context Information for Spectral -Efficiency Enhancement in Future Radio Communication Systems", written by **Łukasz Kułacz** under the supervision of Prof. Adrian Kliks, was qualified by the Competition Jury to the group of the highest rated and took third place. 141 works were submitted to the competition, including 55 master's theses and 24 doctoral theses. By decision of the Competition Jury, three financial awards and two equivalent financial distinctions were awarded in each category of the competition. The awards ceremony took place on June 20, 2023 in the Small Hall of the Warsaw University of Technology.



1.07.2023

Prof. Cynthia Hood from the Illinois Institute of Technology (Illinois Tech) in Chicago, USA, has finished her scientific internship at the Institute of Radiocommunications as part of a Fulbright scholarship. Scientific interests of prof. Hood focus on network and systems management, wireless networks, adaptive systems, and innovation in education. During her six-month stay, she was cooperating with the team of our institute towards the use of artificial intelligence methods in the management of the electromagnetic spectrum. Welcome to the Institute of Radiocommunications!

26.04.2023

With great satisfaction, we noticed the announced results of the 19th edition of the competition "Award of the City of Poznań for an outstanding doctoral thesis" and "Award of the City of Poznań for an outstanding master's thesis". Master's thesis entitled: "Optimization of the location of base stations on unmanned aerial platforms from the perspective of using radio resources", written by **Mr. Piotr Jaworski** under the supervision of Prof. Adrian Kliks, was qualified by the Competition Jury to the group of the highest rated and won a distinction. 79 works were submitted to the competition, including 37 master's theses and 42 doctoral theses. By decision of the Competition Jury, three equivalent financial awards and four equivalent financial distinctions were awarded in the category of doctoral theses, and three equivalent financial awards and three equivalent financial distinctions in the category of master's theses. The award ceremony took place on April 26, 2023 in the White Room of the Poznań City Hall.

15.03.2023

We are happy to announce that our satellite ground station, located at Piotrowo campus, is now fully tested and operational. It can be used for communications with Low Earth Orbit (LEO) satellites, using amateur VHF/UHF bands. The station is equipped with two high-gain Yagi-Uda antennas, powered by ICOM IC-9700 transceiver. For signal reception SDR receivers (FanCube Dongle & USRP B210) are used. The antennas are installed on rotators which can track the fast moving objects on the sky. A parabolic tracking antenna with 3m diameter and the septum feed operating in C-band is also installed in the ground station. It will be used in a high-throughput transmission system developed in our Institute in cooperation with Kyiv Polytechnic Institute and SatRev company.

9.09.2022

During the National Conference on Radiocommunication, Broadcasting and Television (KKRRiT) held on 7-9 September, 2022 in Warsaw, the Awards of the Foundation for the Development of Radiocommunication and Multimedia Techniques were presented to the winners of the competition for the best article by a young author. The first prize was awarded to **Małgorzata Wasilewska, MSc**, for the article on "Intelligent Prediction of Spectrum Occupancy that Includes Fading Effect Influence". The second prize in this competition went to **Cezary Adamczyk, MSc**, for the article on "Detection of Decision Conflicts in Intelligent Radio Controllers in Open Radio Access Networks". In turn, **Salim Janji, MSc**, received a distinction for his paper entitled "Procedure for the Deployment of FSO Mobile Forwarding Relays Powered by RES". All laureates are our Ph.D. students at the Institute of Radiocommunications.

7.09.2022

During the National Conference on Radiocommunication, Broadcasting and Television (KKRRiT) held on 7-9 September in Warsaw, the Awards of the Association of Telecommunications Engineers (SIT) were given to the winners of the national competition for the best diploma thesis (bachelor's or master's) in telecommunications. Our student, **Adam Samorzewski, MSc.** received the First Prize of SIT for the best master thesis. The title of the thesis was: "Sustainable management of radio resources in wireless systems with energy-autonomous nodes", and the supervisor was **Prof. Adrian Kliks** from the Institute of Radiocommunications. In turn, the distinctions in this competition went to: **Maciej Nikiforuk, MSc.** for his master thesis entitled "Foliage Attenuation at 28 GHz Centre Frequency" and **Damian Piotrowski, MSc.**, for his master thesis entitled "Predictive modelling of electromagnetic field by using machine-learning methods". The supervisor of the distinguished works was **Dr. Krzysztof Cichoń** from the Institute of Radiocommunications.


OGÓLNOPOLSKI KONKURS STOWARZYSZENIA
INŻYNIERÓW TELEKOMUNIKACJI - X edycja
NA NAJLEPSZĄ PRACĘ DYPLOMOWĄ Z ZAKRESU TELEKOMUNIKACJI

SIT

NAGRODA
za pracę magisterską pt.

„Zarządzanie zasobami radiowymi w systemach bezprzewodowych z autonomicznymi energetycznie węzłami"

dla

mgra inż. Adama Samorzewskiego

obronioną w 2022r. na
Wydziale Informatyki i Telekomunikacji
Politechniki Poznańskiej
Promotor pracy: dr hab inż. Adrian Kliks, prof. PP
Warszawa, 15 sierpnia 2022r.

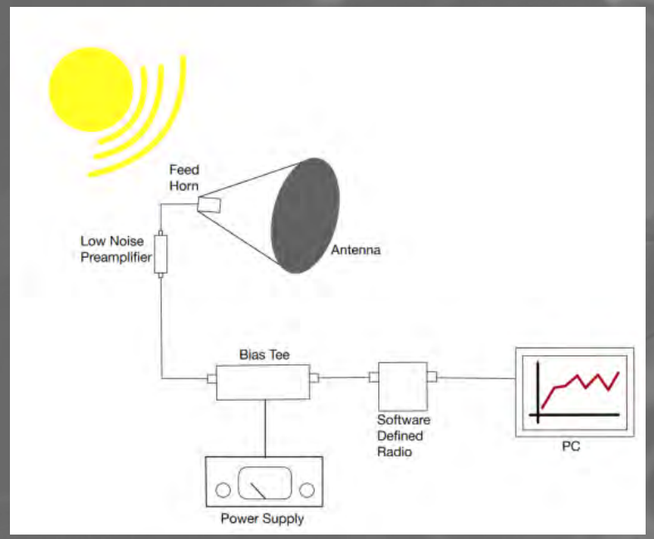
Andrzej Dulka
Prezes Zarządu Głównego SIT

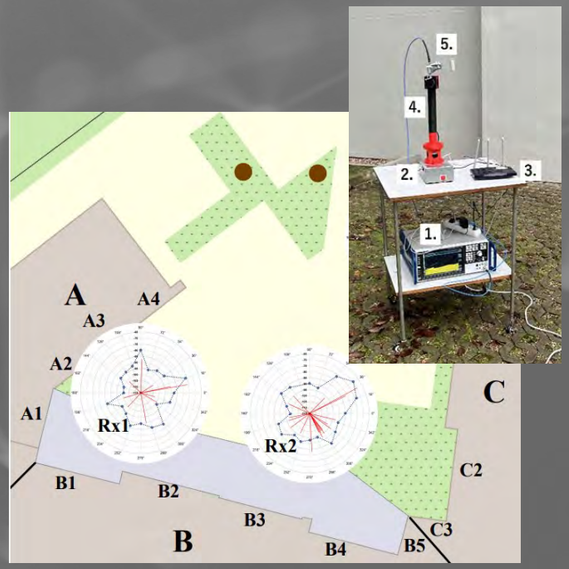
Mirosław Stando
Sekretarz Generalny

SPEKTRUM — Students' Scientific Club — news and achievements

In March 2024, two projects proposed by Spektrum SSC, were accepted for further founding. The first one involves building a radio telescope and its necessary infrastructure, including a programmable component to acquire and analyze the received signal. It is aimed at observing the Sun by capturing electromagnetic waves to monitor solar activity. The signal acquired form antenna will be transmitted via a fiber optic cable to a software-defined radio receiver, offering flexible adjustments of radio frequency parameters. This system will utilize Python-developed software for signal analysis and data visualization. The project's potential expansions include increasing the observable spectrum, remote system control, and creating a neural network for detecting cosmic anomalies.

The second project "Spectrum Communications" is designed to enhance students' networking skills by setting up an autonomous system (AS) node for global internet traffic exchange within the Spektrum SSC. Students will access two independent traffic exchange nodes, facilitating advanced configuration testing and will gain practical experience in configuring real-world internet infrastructure components.



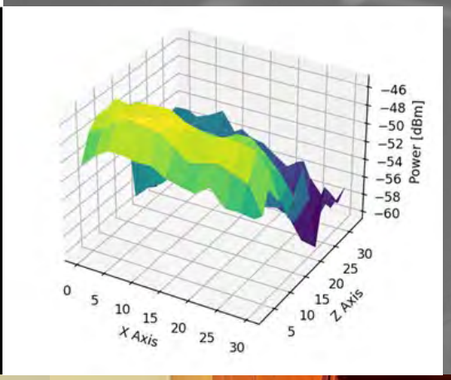


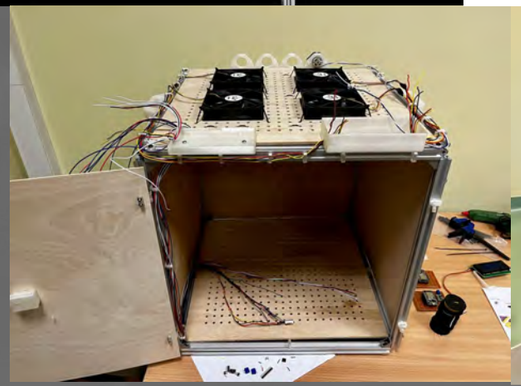
The I-ASPEES-5G grant project, carried out by Spektrum SSC, focused on developing an automated system for spatial radio frequency measurements. The main goal of this project was to create a rotating head that allows precise control of the direction of the antenna for measurements in the 18-30 GHz frequency range used in 5G networks. Measuring equipment from Rohde & Schwarz was used, whose operation is synchronized with the rotation of the antenna by the system. The building at 3 Polanka Street was selected for testing, and the results are consistent with digital simulations, confirming that the system is working properly and will be useful for future propagation measurements.

At the recent Hobby Fair held at the Poznań International Fair on November 18th and 19th, 2023, Spektrum SSC stood as the lone representative of the Faculty of Computer Science and Telecommunications, showcasing projects from the Poznań University of Technology. Our booth attracted the attention of both young attendees and their parents. During the event, we presented the IASPEES-5G project, featuring a cone antenna and TEM line. Engaging with enthusiasts facilitated the exchange of knowledge and experiences. The event emerged as an exceptional platform for science promotion and an intriguing meeting spot for enthusiasts across various domains.

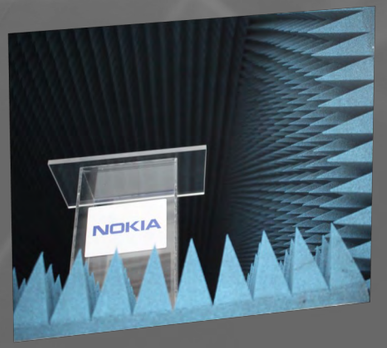
The Spektrum SSC is implementing the project entitled "Study of the influence of the electromagnetic field on plant development". The goal of the project is to build a set of stands enabling the subjecting of selected, small plants to the influence of a homogeneous electromagnetic field in the VHF and UHF frequency range.

Measurements in the TEM cell have become a key element enabling the development of the project. The exemplary result of measurements for 150 MHz frequency is plotted in figure. This graphical representation makes it easier to understand the behavior of the TEM cell during wave propagation, contributing to the greater utility and efficiency of further research.





We visited Nokia's laboratories in Wrocław on 30th of November 2023 r. Courtesy of the Finnish corporation, we were able to see, among other things, the unechoic chamber, which is used for over-the-air (OTA) measurements. In addition to the tour itself, the company's employees told us about the projects they are currently working on and their internship programs.



On May 20, 2023, the nationwide action "Night of Museums" was held in Poznań, attended by representatives of Spektrum SSC.

In the Zamek Cultural Center, the Poznań University of Technology prepared stands and a series of lectures devoted to space. As part of this event, members of the Spectrum SSC — Aleksandra Słomczewska and Nikoloz Glonti — gave a popular science lecture on communication in space. In addition, throughout the event, they were available at the stand where visitors could come and hear, among others, about the cooperation between the Kiev University of Technology and the Poznań University of Technology for the development and construction of a nanosatellite intended for Earth observation missions.

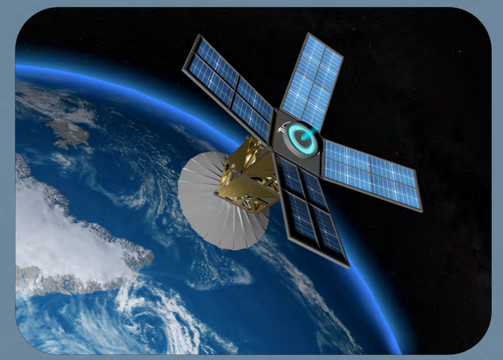
Research thematic areas

Cellular networks

The Institute pursues research on contemporary and future radio access networks, in particular on the fourth-, fifth- and sixth-generation cellular systems (4G, 5G and 6G). It concerns new physical-, data-link control-, medium-access control-, and network-layer techniques for achieving key performance indicators (KPI) stated for 4G, 5G and 6G. New solutions, including non-orthogonal multiple access (NOMA) using diverse power allocation, and space-division multiple access (SDMA) using adaptive antennas, are investigated. Moreover, effective algorithms for radio-resource management in cells of various types, and for interference coordination in pico- and femto-cells are also the subjects of research.

An important direction of research is efficient duplex transmission in relay links, as well as flexible selection of relaying nodes for quality-of-service improvement in cellular networks. The investigated topic related to specific challenging applications is ultra-reliable low latency communication (URLLC), one of the main segments of 5G systems.

Satellite communications

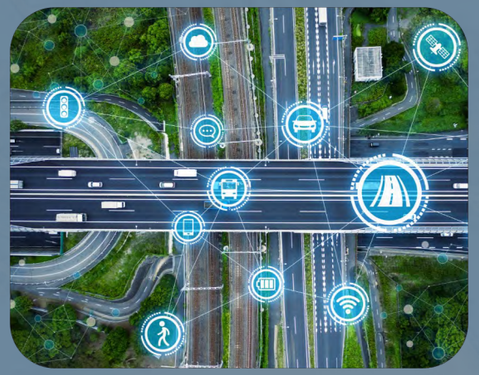


The increasing popularity of nanosatellites, e.g. in Cubesat form factor, requires new types of radio links delivering high-throughput and high-reliability communications for downloading the data from satellite payload. Research in the area of satellite communications focuses on baseband/physical layer, as well as data-link-layer algorithms and protocols which can be used for the development of cheap communication modules implemented using the Software Defined Radio (SDR) technique. In particular, energy-efficient modulation types are investigated, having in mind the limited power available onboard the satellite. Due to the tight radio link budget, advanced synchronization and channel coding schemes are considered as well. Machine learning based algorithms for optimum transmission parameters selection is another field of interests. The selected solutions are implemented using the Software Defined Radio technique, based on off-the-shelf SDR platforms and general-purpose processors, as well as dedicated hardware including FPGA chips and integrated transceivers.

Cognitive radio systems

Research in the area of cognitive radio technologies includes theoretical studies and experimental trials on the acquisition of context information related to the radio environment, machine learning methods for the improvement of the quality of this information, as well as the principles of signal transmission in radio communication networks using it. In particular, the research focuses on autonomous and cooperative sensing and spectrum sharing policies based on either centralized or distributed coordination of dynamic spectrum access. Radio Environment Maps (REMs) are being investigated for their use in cognitive radio systems for the reduction of interference between systems utilizing a range of the radio frequency band. Moreover, physical-layer algorithms are being investigated that increase the spectral efficiency of systems with frequency-neighboring signal spectra.

V2X Communication Systems



Communication between vehicles and vehicles and infrastructure (V2X) which is one of the significant topics of 5G development, is a subject of investigations in the Institute. Part of the research was performed in the framework of cooperation with Nokia Solutions and Networks. The research team investigated traffic safety, meant as the minimization of vehicle collision probability, in the case of vehicle platoons (convoys) when a wireless communication system (e.g., IEEE 802.11p) is applied within a moving platoon. The team considered vehicle control algorithms ensuring reliability and string stability from the system theory point of view. The next research topic is lengthening the vehicle platoon by applying so-called virtual communication leaders. Subsequent research topics are related to radio resource management algorithms aiming at the minimization of packet collision probability by applying Mode 3 and 4 LTE system specialized in V2X communications. Recent investigations focus on databases and edge intelligence to support dynamic spectrum access for vehicle platooning.

Unmanned Aerial Vehicle Communications

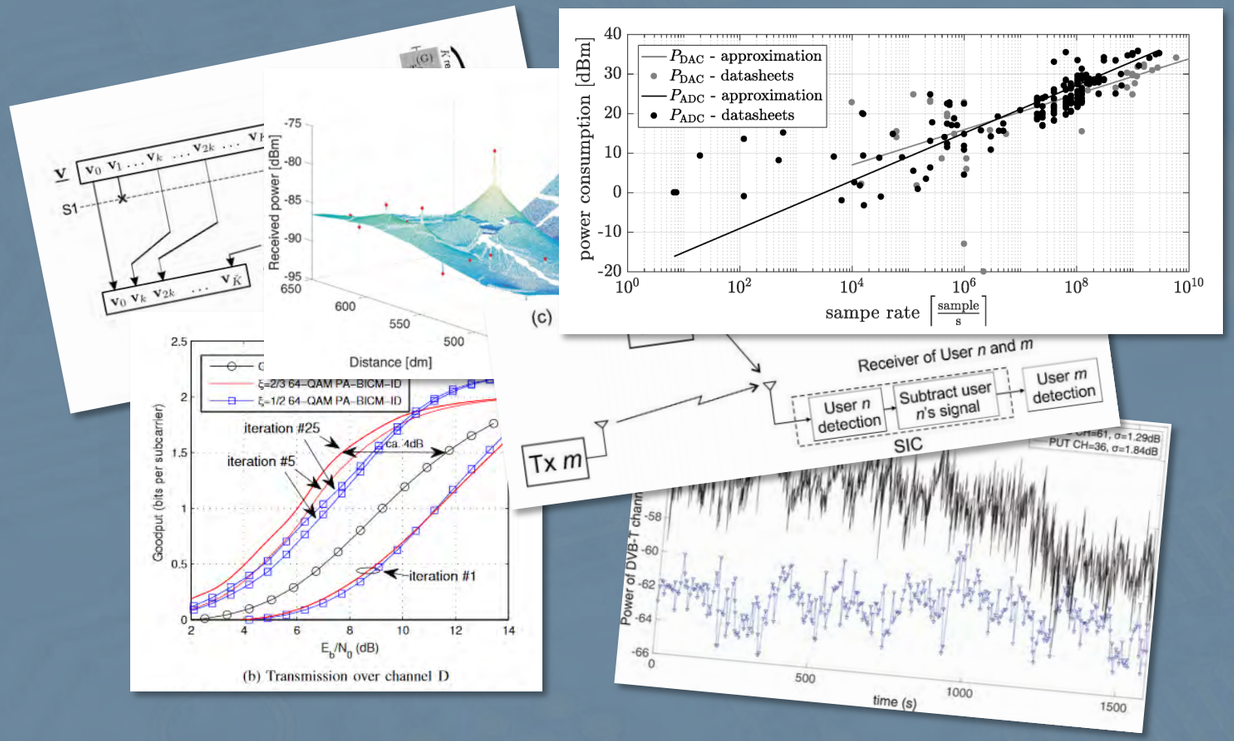
Research related to communication with unmanned aerial vehicles (UAV) concentrate on air to ground radio channel modeling for both long-range (LOS/NLOS) and medium-range (LOS) UAV communication systems, physical layer solutions for control and telemetry radio links with high reliability and high-speed data links, as well as energy-efficient solutions for UAV communications. Original synchronization, modulation/demodulation and channel coding/decoding methods and algorithms are developed and investigated for the physical layer of UAV communication systems. The selected solutions are implemented using the Software Defined Radio (SDR) technique.

Green communications

An important area of research in the Institute are the so-called green communications, which encompass techniques aiming at high energy efficiency in the next-generation communication and computing networks. These techniques are designed to minimize the energy per successfully transmitted and processed information unit (bit), whereas all network segments are analyzed, *i.e.*, end-user equipment, wireless part (radio access network), wireline part (core network, Internet, long-distance optical links) and data centers implementing computational tasks. Optimization of these separate segments is considered, as well as joint optimization of the tasks transmission, offloading and computing in the network of various configurations based on edge-, cloud- and fog computing. Moreover, brain-inspired energy-efficient communication networking is a key topic of research in the Institute.

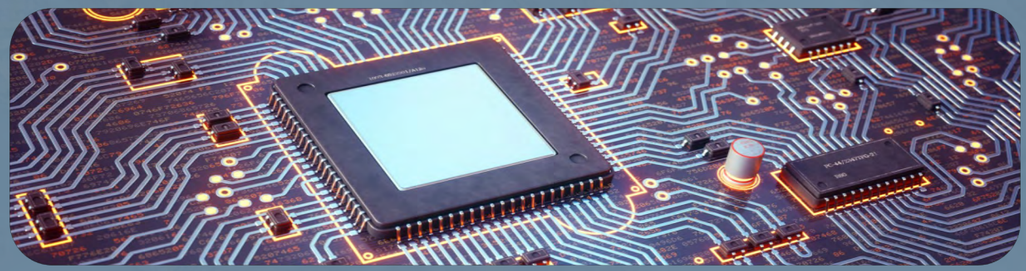
Physical-Layer Algorithms

The Institute pursues research on physical layer algorithms in modern mobile radiocommunication systems. They are connected with multitone modulation using orthogonal (OFDM) and non-orthogonal subcarriers (FBMC) and non-contiguous, fragmented spectrum bands. Research work is directed towards the minimization of the out-of-band emission, reduction of non-linear distortions, reliable reception of signals and synchronization algorithms. Another field of studies encompasses channel coding using various types of error correction codes, namely, convolutional codes, turbo codes, selected types of LDPC codes and polar codes with several decoding algorithms. Moreover, bit-interleaved coded modulation with iterative decoding is investigated. Applications and improvements of transmission and reception diversity techniques are also being explored, in particular Multiple-Input, Multiple-Output (MIMO) and massive MIMO (M-MIMO) technologies, and beamforming algorithms in antenna matrices.



VLSI Testing

Beginning with the introduction of commercial manufacturing of integrated circuits, electronic testing has a history of almost 60 years, and its importance cannot be overestimated. The unprecedented proliferation of digital devices in telematics, medicine, defense systems, or transportation, clearly underlines the extreme significance of their test quality. Failure to find defective circuits that constitute the heart of many life-critical or mission-critical mechanisms may lead to severe consequences. The goal of our group is to create new methods to allow the development of computer-aided tools supporting automated test generation, test data compression, built-in self-test, and design for testability. The corresponding research results are presented in prestigious publications and numerous US patents. Furthermore, several solutions have been commercialized, primarily by our industrial partner Mentor, A Siemens Business, with the introduction of award-winning VLSI test technologies, often the first solutions of this kind on the market.



Cybersecurity of radio networks

Research in cybersecurity focuses on methods of detection and mitigation of attacks launched via the radio interface and new methods of data encryption, authentication, and security monitoring. Algorithms for detecting anomalies in radiocommunication traffic are being developed using artificial intelligence (AI) methods, particularly machine learning (ML), and strategies for eliminating their effects. Methods are also being developed to detect and counteract attacks on the AI algorithms used in radio networks. The research also includes lightweight encryption and authentication algorithms characterized by low complexity and low energy consumption.

Laboratories and infrastructure

Wireless Local and Personal Area Network Laboratory

In this laboratory, ambitious and exciting research projects in the field of wireless communications are realized. They include advanced MIMO technologies, communications with Unmanned Aerial Vehicles (UAVs) and practical implementation of software-defined platforms. There are 12 work stations in the lab. Various WLAN devices are used, mainly, access points, access routers, bridges, controllers, and network adapters. Besides wireless devices, numerous elements of the structural networks are also used. Moreover, the lab is featured with a specialist spectrum analyzer, as well as advanced software tools designed for the analysis of traffic inside WLANs.

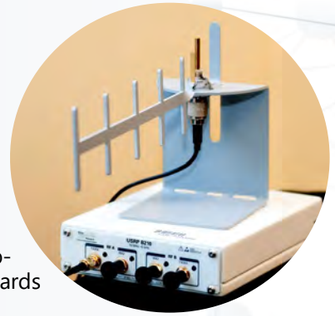
Advanced Wireless Communications Research Laboratory

In this laboratory, ambitious and exciting research projects in the field of wireless communications are realized. They include advanced MIMO technologies, communications with Unmanned Aerial Vehicles (UAVs) and practical implementation of software-defined platforms. There are evaluation boards PicoZed SDR (ADRV9361), Xilinx ZC702/706 modules with AD9361 transceivers, six MIMO transceivers supported by FPGA platforms. There are also six computationally powerful PCs, with specialist software tools, such as MATLAB/Simulink by Mathworks, FPGA Vivado by Xilinx, as well as software delivered by Mentor Graphics for the simulation and verification of FPGAs.

Mobile Terminal Programming Laboratory

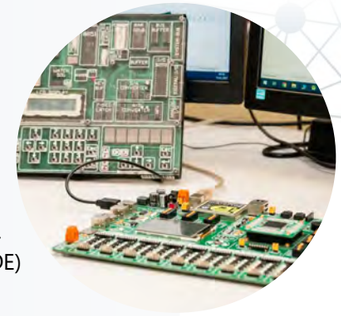
Programming skills and well-established knowledge on testing of mobile applications (i.e., apps devoted for smartphones, smartwatches, tablets, etc.) are among the most desired abilities of prospective ICT workers. The lab on programing mobile terminals is prepared to instruct students on two most popular operating systems – Android and iOS. It is featured with 16 PCs with MS Windows 10, mostly with two screens, beamer with wireless connection, as well as 7 Apple MiniMacs with the newest operating system and XCode environment.

Mobile Radiocommunications and Cognitive Radio Laboratory



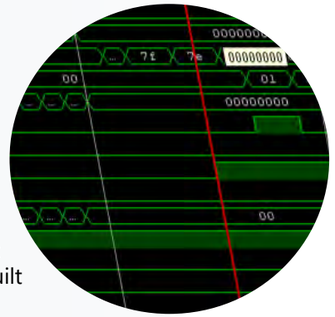
This laboratory is of mixed nature: both didactic and research. It involves practical exercises in various fields, such as: basic features of wireless signal propagation, cellular networks of all generations (2G-6G), radio measurements, software-defined and cognitive radio, as well as cellular network design. The laboratory is also equipped with highly advanced measurement devices, such as, signal generators (Rohde&Schwarz, Tektronix, Philips), spectrum and signal analyzers (Rohde&Schwarz, Agilent, Anritsu), radiocommunication testers (Rohde&Schwarz), digital oscilloscopes (Agilent, Tektronix). There are also software defined radio modules, mainly USRP N200, N210, USRP 1, and USRP B210, as well as evaluation boards with digital signal processors by Texas Instruments.

Microprocessor Programming Laboratory



A well-equipped laboratory introduces the fundamentals of creating and testing software for microcontrollers of different kinds. There are 16 separate workplaces featured with PCs operated by MS Windows 10 (in most cases, equipped with two screens), and two development kits: one devoted to the 8051 microprocessor, and one to the TI ARM Cortex M4. In particular, there are 16 boards called Didactic Microprocessor Kits DSM-51, and 16 boards „EasyMxPRO™v7 for STELLARIS® ARM®" with the M4C123GH6PGE microcontroller. For programming, dedicated Integrated Development Environment (IDE) is used, called Code Composer Studio.

Digital Circuits & VLSI Testing Laboratories



The digital circuits laboratory is a computer-based lab, featured with software useful to design, analyse and simulate the performance of digital circuits, of either combinational or sequential type. The VLSI test laboratory was founded based on industrial grade design automation tools provided by Mentor, a Siemens Business. This software comprises several best-in-class EDA solutions, used to generate, simulate, and apply production test patterns for digital circuits and systems. During classes, students learn how to automate the process of test generation, fault simulation, test point insertion, and fault diagnosis. Furthermore, they are taught basics of modern HDL design for testability (using Verilog), test compression, and built-in self-test.

Software Engineering Laboratory

The software engineering laboratory is a comprehensive learning center, providing students with the opportunity to learn key skills in programming, algorithm design, and working with web technologies and ICT networks. It includes an air-conditioned room equipped with 18 PCs connected to the Internet, allowing hands-on learning in a comfortable environment. Each of the 18 PCs is installed with the MS Windows 10 and Linux Ubuntu operating systems, allowing students to choose the platform that suits their preferences or the requirements of the task at hand.

High-performance computer claster

The computer cluster consists of 39 AMD processors with clock rate ranging from 3.0 to 4.0 GHz, total core number is equal to 316 and total RAM installed exceeds 400 GB. Such a configuration allows for independent usage of the each of available cores. The computing cluster itself is operated by Linux-based CentOS, whereas the management of cluster cores and processes is performed by means of Perceus and SLURM software, respectively. Sequential and parallel computations are allowed. Such flexibility allows for efficient cluster use in various research and teaching tasks in the field of wireless communications.

Teaching offer

The teaching offer of the Institute of Radiocommunications includes courses (lectures, classes, laboratory classes, projects and seminars) in wireless communications on three levels: elementary, advanced and expert. Theoretical knowledge on radio communication technologies and wireless networks is supplemented with practical experience obtained during laboratory and project tasks.

The B.Sc. and M.Sc. programs in Electronics and Telecommunications are offered both in Polish and English (specialization in Information and Communication Technologies), while programs in Teleinformatics is currently offered just in Polish. Please, refer to our website for detailed programs and offered courses.

In the first-cycle (BSc Eng.) studies, our students have the opportunity to become familiar with the fundamentals of digital transmission systems, radiocommunications, cell networks (2G-5G), WLANs (in the IEEE 802.11 standard – WiFi) and WPANs (in the Bluetooth standard). Moreover, they obtain practical knowledge on high-level language programming and developing applications for mobile devices (e.g. smartphones, tablets) with Android and iOS. In second-cycle (MSc) studies, students learn about advanced mobile and satellite communication systems, sensor networks, solutions for the Internet-of-Things, programmable and cognitive radio technologies, advanced coding techniques, principles of cell network design, space communications and vehicle-to-vehicle communication systems (also between autonomous vehicles). Students have many opportunities to team up and participate in research and development projects dealing with modern mobile radio technologies.

Projects (2020–2024)

International projects

- **PASSIONATE** (https://passionate.webs.tsc.uc3m.es) – Physics-based wireless AI providing scalability and efficiency" – international project no. CHIST-ERA-22-WAI-04 within the CHIST-ERA program, funded by National Science Centre based on agreement no. 2023/05/Y/ST7/00002 (2023-2026)
- **COST CA20120** (https://interactca20120.org) – Intelligence-Enabling Radio Communications for Seamless Inclusive Interactions (INTERACT), EU Horizon 2020 Programme project (COST action) (2021-2025)
- **FAUST** – Fog Communication, Computing And Control for SUStainable Future of ICT, project no. PL-TW/V/3/2018 for Polish-Taiwanese joint research funded by National Centre for Research and Development (2018-2021)
- **CERTAIN** – Cognitive Engine for Radio environmenT Awareness In Networks of the future, DAINA (DAINA 1) project no. 2017/27/L/ST7/03166 for Polish-Lithuanian research cooperation funded by National Science Centre (2018-2021)

National projects

- *Utilization of the Machine Learning and Radio Environment Maps for Management of User-Centric Massive MIMO Network*, PRELUDIUM (PRELUDIUM 21) project no. 2022/45/N/ST7/01930, funded by National Science Centre (2023-2026)
- *Context-information aware usage of intelligent antenna matrices and holography for wireless signal transmissions*, OPUS (OPUS 22) project no. 2021/43/B/ST7/01365 funded by National Science Centre (2022-2026)
- *Cross-layer design of ultra spectrally- and energy-efficient 6G system aware of radio front-end nonlinearity*, OPUS (OPUS 21) project no 2021/41/B/ST7/00136 funded by National Science Centre (2022-2025)
- *Fresh and Green Cellular IoT Edge Computing Networks* PRELUDIUM (PRELUDIUM 20) project no. 2021/41/N/ST7/03941, funded by National Science Centre (2022-2024)
- *Radio spectrum occupancy detection using federated machine learning*, PRELUDIUM (PRELUDIUM 20) project no. 2021/41/N/ST7/01298 funded by National Science Centre (2022-2023).
- *Advanced methods and techniques for identification and counteracting cyber attacks on 5G access network and applications* (5gSTAR), project no. CYBERSECIDENT/487845/IV/NCBR/2021 funded within the 4th CyberSecIdent programme - Cybersecurity and e-Identity by National Centre for Research and Development (2021-2024)
- *Universal nanosatellite platform for research, experimental and commercial type hosted payload missions*, POIR.01.01.01-00-1211/19 project funded by National Centre for Research and Development (2020-2023)
- *Utilization of rich context information for wireless communications in vehicle platooning*, OPUS (OPUS 15) project no. 2018/29/B/ST7/01241 funded by National Science Centre (2019-2022)
- *Brain-Inspired Massive Radio Communication Networks – BioNets*, OPUS (OPUS 12) project no. 2016/23/B/ST7/03937 funded by National Science Centre (2017-2020)

Industry-funded research

The Institute's researchers cooperate with national and international companies, implementing projects and research framework agreements with Mentor, A Siemens Business (formerly Mentor Graphics Corporation) in Wilsonville, OR, USA, Nokia Wrocław R&D in Poland, Huawei Technologies Sweden AB, Fairspectrum in Helsinki, Finland, Military Aviation Plant no. 2 in Bydgoszcz, Poland, and others.

Dissertations (2020–2024)

Doctoral dissertations

Saif Sabeeh
Radio resource management for C-V2X communication systems (2023)
Promoter: Krzysztof Wesołowski, co-promoter: Paweł Sroka

Mohammed Jasim Obaid Khafaji
The Use of Evolutionary Algorithms in the Next-Generation Wireless Systems (2023)
Promoter: Maciej Krasicki

Łukasz Kułacz
Utilization of Context Information for Spectral-Efficiency Enhancement in Future Radio Communication systems (2022)
Promoter: Adrian Kliks

Bartosz Bossy
Energy-Efficient Resource Allocation in OFDM Systems With Computational Awareness (2022)
Promoter: Hanna Bogucka, co-promoter: Paweł Kryszkiewicz

Sylwester Milewski
Hypercompression of test data (2022)
Promoter: Jerzy Tyszer

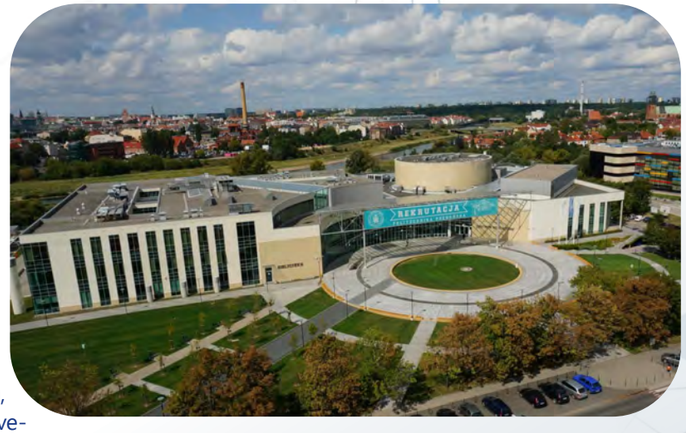
Hind Salim Ghazi
Non-Orthogonal Multiple Access with Successive Interference Cancellation and its Applications (2021)
Promoter: Krzysztof Wesołowski

Anna Maria Łukowa
Coordinated Radio Resource Management in 5G Systems with Time Division Duplex (2020)
Promoter: Krzysztof Wesołowski

Habilitation dissertation

Paweł Kryszkiewicz
New Methods of Increasing the Spectral and Energy Efficiency of Wireless Systems
Doctor Habilitus in Engineering and Technical Sciences,
Discipline: Technical Computer Science and Telecommunications (2022)

Conferences & events (2023–2024)



The National Conference on Radiocommunications and Teleinformatics
Poznan, Sept. 11-13, 2024

The National Conference on Radiocommunications and Teleinformatics (KRiT 2024), the main Polish conference in the above-mentioned fields, will be held on September 11-13, 2024 at the Poznan University of Technology. The organizers of the conference are the Institute of Radiocommunications and the Institute of Teleinformatic Networks of the Poznan University of Technology and the Association of Telecommunications Engineers (SIT).

The conference is the successor to two well-known annual events having a long tradition: the National Symposium on Telecommunications and Teleinformatics (KSTiT) and the National Conference on Radiocommunication, Radio Broadcasting and Television (KKRRiT). The Radiocommunication and Teleinformatics Conference, following the example of its predecessors, as well as KRiT 2023, which took place in Krakow in September 2023, creates excellent conditions for establishing new contacts between representatives of the world of science and business, because its participants are industry entrepreneurs, research workers of universities and research institutes, as well as PhD students and students.

Lecture on **"Integrated Sensing and Communications with Full Duplex MIMO and Reconfigurable Metasurfaces"** by **Prof. George Alexandropoulos**

On November 16, 2023, during the Institute of Radiocommunication seminar and the meeting of the Polish Chapter of IEEE Communications Society, Professor George Alexandropoulos from the National and Kapodistrian University of Athens in Greece gave a lecture on "Integrated Sensing and Communications with Full Duplex MIMO and Reconfigurable Metasurfaces".

Professor George Alexandropoulos is an IEEE Communications Society Distinguished Lecturer and the world expert in MIMO technique and Intelligent Reflecting Surfaces.

The lecture was of great interest to students, PhD students, researchers, and engineers in Poland and abroad.

Lecture by Prof. Lajos Hanzo entitled **"The Evolution of Quantum Key Distribution Networks: On The Road To The Quinternet"**

On October 26, 2023, during the Institute of Radiocommunication seminar and the meeting of the Polish Chapter of IEEE Communications Society, Professor Lajos Hanzo from the University of Southampton in Great Britain gave a lecture on "The Evolution Of Quantum Key Distribution Networks: On The Road To The Qinternet".

Lajos Hanzo FREng, FIEEE, FIET, EURASIP Fellow, received his 5-year Master's degree in electronics from the Technical University of Budapest in 1976, his doctorate in 1983, and his Doctor of Sciences (DSc) degree in 2004. During his career in telecommunications, he has held various research and academic posts in Hungary, Germany, and the UK. Since 1986 he has been with the School of ECS, University of Southampton, UK, where he holds the Chair in Telecommunications. He published 2000+ research contributions at IEEE Xplore.

COST INTERACT 6th Technical Meeting

Poznan, September 12-14, 2023

On September 12-14, 2023, the 6th technical meeting of the COST CA20120 INTERACT was held at the Poznań University of Technology, organized by the Institute of Radiocommunications PUT. During the event, meetings of working groups were held, the considerations of which concerned "Intelligence-Enabling Radio Communications for Seamless Inclusive Interactions". During three days, 3 plenary lectures and 38 technical papers were delivered, prepared by scientists from all over Europe.

Wireless World Research Forum

Poznan, March 28-30, 2023

On March 28-30, 2023, the Institute of Radiocommunications hosted the 49th meeting of Wireless World Research Forum under the theme “Towards sustainable and automated communications”. WWRF is a unique forum which brings together the wireless community to tackle key research challenges.

Selected publications (2020–2024)

Journal papers

- M. Hoffmann, S. Janji, A. Samorzewski, Ł. Kułacz , C. Adamczyk, M. Dryjański, P. Kryszkiewicz, A. Kliks , H. Bogucka, „Open RAN xApps Design and Evaluation: Lessons Learnt and Identified Challenges", *IEEE Journal on Selected Areas in Communications*, 2024, vol. 42, no. 2, pp. 473-486
- M. Krasicki, „Labeling-Based Recipient Identification with Low-Order Modulation", *Electronics*, 2024, vol. 13, no. 2, pp. 425-1-425-23
- C. Adamczyk, A. Kliks, „Conflict Mitigation Framework and Conflict Detection in O-RAN Near-RT RIC", *IEEE Communications Magazine*, 2023, vol. 61, no. 12, pp. 199-205
- H. Bogucka, B. Kopras, F. Idzikowski, B. Bossy, P. Kryszkiewicz, „Green Time-Critical Fog Communication and Computing", *IEEE Communications Magazine*, 2023, vol. 61, no. 12, pp. 40-45
- M. Wasilewska, H. Bogucka, H. V. Poor, „Secure Federated Learning for Cognitive Radio Sensing", *IEEE Communications Magazine*, 2023, vol. 61, no. 3, pp. 68-73
- H. Bogucka, B. Kopras, „Uberization of telecom networks for cost-efficient communication and computing", *IEEE Communications Magazine*, 2023, vol. 61, no. 7, pp. 74-80
- R. Krenz, P. Sroka, M. Sybis, I. Zainutdinov, K. Wesołowski, „A Low-Cost High-Throughput C-Band Communication System for CubeSats", *Electronics*, 2023, vol. 12, no. 20, pp. 4374-1-4374-18
- M. Wachowiak, P. Kryszkiewicz, „Clipping noise cancellation receiver for the downlink of massive MIMO OFDM system", *IEEE Transactions on Communications*, 2023, vol. 71, no. 10, pp. 6061-6073
- K. S. Gill, P. Kryszkiewicz, P. Sroka, A. Kliks, A. M. Wyglinski, „Memory Enabled Bumblebee-based Dynamic Spectrum Access for Platooning Environments", IEEE Transactions on Vehicular Technology, 2023, vol. 72, no. 5, pp. 5612-5627
- P. Kryszkiewicz, P. Sroka, M. Sybis, A. Kliks, „Path Loss and Shadowing Modeling for Vehicle-to-Vehicle Communications in Terrestrial TV Band". *IEEE Transactions on Antennas and Propagation*, 2023, vol. 71, no. 1, pp. 984-998
- J. Rajski, M. Trawka, J. Tyszer, B. Włodarczak, „A Lightweight True Random Number Generator for Root of Trust Applications", *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, 2023, vol. 42, no. 9, pp. 2815-2825
- S. Eggersglüß, S. Milewski, J. Rajski, J. Tyszer, „A new static compaction of deterministic test sets", *IEEE Transactions on Very Large Scale Integration (VLSI) Systems*, 2023, vol. 31, no. 4, pp. 411-420
- M. Krasicki, „BICM-ID Labeling-Based Recipient Identification in a Heterogeneous Network", *Sensors*, 2023, vol. 23, no. 7, pp. 3605-1-3605-11
- S. Sabeeh,, K. Wesołowski, „Congestion Control in Autonomous Resource Selection of Cellular-V2X", *IEEE Access*, 2023, vol. 11, pp. 7450-7460
- B. Kopras, B. Bossy, F. Idzikowski, P. Kryszkiewicz, H. Bogucka, "Task Allocation for Energy Optimization in Fog Computing Networks with Latency Constraints", *IEEE Transactions on Communications*, 2022, vol. 70, no. 12, pp. 8229-8243
- S. Janji, A. Samorzewski, M. Wasilewska, A. Kliks, "On the Placement and Sustainability of Drone FSO Backhaul Relays", *IEEE Wireless Communications Letters*, Aug. 2022, vol. 11, no. 8, pp. 1723-1727
- B. Kaczmarek, G. Mrugalski, N. Mukherjee, A. Pogiel, J. Rajski, Ł. Rybak, J. Tyszer, "LBIST for Automotive ICs with Enhanced Test Generation", *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, July 2022, vol. 41, no. 7, pp. 2290-2300
- P. Kryszkiewicz, C. Canfield, S. Bhada, A. M. Wyglinski, "A Systems Approach for Solving Inter-Policy Gaps in Dynamic Spectrum Access-Based Wireless Rural Broadband Networks", *IEEE Access*, March 2022, vol. 10, pp. 25165-25174
- B. Bossy, P. Kryszkiewicz, H. Bogucka, "Energy-Efficient OFDM Radio Resource Allocation Optimization With Computational Awareness: A Survey", *IEEE Access*, Sept. 2022, vol. 10, pp. 94100-94132
- E. Peltonen, et. al. (incl. P. Sroka), "The Many Faces of Edge Intelligence", *IEEE Access*, Sept. 2022, vol. 10, pp. 104769-104782
- J. Mongay Batalla, M. Mohsin, C. X. Mavromoustakis, K. Wesołowski, G. Mastorakis, K. Krzykowska-Piotrowska, "On Deploying the Internet of Energy with 5G Open RAN Technology Including Beamforming Mechanism", *Energies*, 2022, vol. 15, no. 7, pp. 2429-1 - 2429-19
- P. Sroka, E. Ström, T. Svensson, A. Kliks, "Autonomous Controller-Aware Scheduling of Intra-Platoon V2V Communications", *Sensors*, 2023, vol. 23, no. 1, pp. 60-1-60-21
- S. Sabeeh, K. Wesołowski, P. Sroka, "C-V2X Centralized Resource Allocation with Spectrum Re-Partitioning in Highway Scenario", *Electronics*, 2022, vol. 11, no. 2, pp. 279-1-279-20
- Ł. Kułacz, A. Kliks, "Dynamic Spectrum Allocation Using Multi-Source Context Information in OpenRAN Networks", *Sensors*, 2022, vol. 22, no. 9, pp. 3515-1-3515-11
- M. Wasilewska, H. Bogucka, A. Kliks, "Federated Learning for 5G Radio Spectrum Sensing", *Sensors*, 2022, vol. 22, no. 1, pp. 1-15
- M. J. Khafaji, M.Krasicki, "Uni-Cycle Genetic Algorithm as an Adaptation Engine for Wireless Channel Equalizers", *Electronics*, 2022, vol. 11, no. 2, pp. 171-1-171-11
- A. Chaoub, M. Giordani, B. Lall, V. Bhatia, A. Kliks, L. Mendes, K. Rabie, H. Saarnisaari, A. Singhal, N. Zhang, S. Dixit, M. Zorzi, "6G for Bridging the Digital Divide: Wireless Connectivity to Remote Areas", *IEEE Wireless Communications*, Feb. 2022, vol. 29, no. 1, pp. 160-168
- M. Hoffmann, P. Kryszkiewicz, A. Kliks, "Frequency Selection for Platoon Communications in Secondary Spectrum Using Radio Environment Maps", *IEEE Transactions on Intelligent Transportation Systems*, March 2022, vol. 23, no. 3, pp. 2637-2650
- M. Wasilewska, A. Kliks, H. Bogucka, K. Cichoń, J. Ruseckas, G. Molis, A. Mackutė-Varoneckienė, T. Krilavičius, "Artificial Intelligence for Radio Communication Context-Awareness", *IEEE Access*, 2021, vol. 9, pp. 144820-144856
- M. Hoffmann, P. Kryszkiewicz, "Reinforcement Learning for Energy-Efficient 5G Massive MIMO: Intelligent Antenna Switching", *IEEE Access*, 2021, vol. 9, pp. 130329-130339
- M. Dryjański, Ł. Kułacz, A. Kliks, "Toward Modular and Flexible Open RAN Implementations in 6G Networks: Traffic Steering Use Case and O-RAN xApps", *Sensors*, 2021, vol. 21, no. 24, pp. 8173-1-8173-14
- M. J. Khafaji, M. Krasicki, "Uni-Cycle Genetic Algorithm to Improve the Adaptive Equalizer Performance", *IEEE Communications Letters*, 2021, vol. 25, issue. 11, pp. 3609-3613
- Y. Liu, S. Milewski, G. Mrugalski, N. Mukherje, J. Rajski, J. Tyszer, B. Włodarczak, "X-Tolerant Compactor maXpress for In-System Test Applications with Observation Scan", *IEEE Transactions on Very Large Scale Integration (VLSI) Systems*, 2021, vol. 29, no. 8, pp. 1553-1566
- J. Tyszer, W.-T. Cheng, S. Milewski, G. Mrugalski, J. Rajski, M. Trawka, "Autonomous Scan Patterns for Laser Voltage Imaging", *IEEE Transactions on Emerging Topics in Computing*, 2021, vol. 9, no. 2, pp. 680-691
- M. Hoffmann, P. Kryszkiewicz, A. Kliks, "Increasing Energy Efficiency of Massive-MIMO Network via Base Stations switching using Reinforcement Learning and Radio Environment Map", *Computer Communications*, 2021, vol. 169, pp. 232-242
- H. Salim Ghazi, K. Wesołowski, "Application of an Interference Cancellation Detector in a Two-Way Relaying System with Physical Network Coding", *Electronics*, 2021, vol. 10, no. 11, s. 1294-1-1294-17
- N. Mukherjee, D. Tille, M. Sapati, Y. Liu, J. Mayer, S. Milewski, E. Moghaddam, J. Rajski, J. Solecki, J. Tyszer, "Time and Area Optimized Testing of Automotive ICs", *IEEE Transactions on Very Large Scale Integration (VLSI) Systems*, 2021, vol. 29, no. 1, s. 76-88
- Ł. Kułacz, A. Kliks, "Brain-Inspired Data Transmission in Dense Wireless Network", *Sensors*, No. 21(2), 576, pp. 1-20
- Ł. Kułacz, A. Kliks, P. Kryszkiewicz, B. Bossy, „Dynamic Transmit Profile Selection in Dense Wireless Networks, *Sensors*, 2021, vol. 21, no. 1, pp. 134(1) – 134(14)
- P. Kryszkiewicz, A. Kliks, Ł. Kułacz, B. Bossy, "Stochastic Power Consumption Model of Wireless Transceivers", *Sensors*, 2020, vol. 20, no. 17, pp. 4704-1-4704-12
- Y. Huang, S. Milewski, J. Rajski, J. Tyszer, C. Wang, "Low Cost Hypercompression of Test Data", *IEEE Transactions on Computer Aided Design of Integrated Circuits and Systems*, 2020, vol. 39, no. 10, pp. 2964-2975
- Y. Liu, N. Mukherjee, J. Rajski, S. M. Reddy, J. Tyszer, "Deterministic Stellar BIST for Automotive ICs", *IEEE Transactions on Computer Aided Design of Integrated Circuits and Systems*, 2020, vol. 39, no. 8, pp. 1699-1710
- M. Dryjański, A. Kliks, "A Hierarchical and Modular Radio Resource Management Architecture for 5G and Beyond", *IEEE Communications Magazine*, 2020, vol. 58, no. 7, pp. 28-34
- B. Bossy, P. Kryszkiewicz, H. Bogucka, „Energy Efficient Wireless Relay Networks with Computational Awareness", *IEEE Transactions on Communications*, Vol. 68, No. 2, Feb. 2020, pp. 825 - 840
- B. Bossy, P. Kryszkiewicz, H. Bogucka, "Flexible, Brain-Inspired Communication in Massive Wireless Networks", *Sensors*, 2020, vol. 20, no. 6, pp. 1-14

Papers in conference proceedings

- C. Adamczyk, A. Kliks, „Detection and mitigation of indirect conflicts between xApps in Open Radio Access Networks", IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), May 20, 2023, Hoboken, USA
- M. Hoffmann, P. Kryszkiewicz, „Signaling Storm Detection in IoT Network based on the Open RAN Architecture", IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), May 20, 2023, Hoboken, USA
- K. Wesołowski, „A Simple Algorithm for Jamming Detection in OFDM Systems", IEEE 97th Vehicular Technology Conference (VTC2023-Spring), June 20-23, 2023, Florence, Italy
- M. Wasilewska„ H. Bogucka, „Deep learning for Improved Spectrum Occupancy Prediction with Fading Estimation in 5G Radio," IEEE International Conference on Communications (ICC), May 28– June 1, 2023, Rome, Italy, pp. 4609-4614
- J. Rajski, M. Trawka, J. Tyszer (WIiT), B. Włodarczak, „Hybrid Ring Generators for In-System Test Applications," IEEE European Test Symposium (ETS), May 22-26, 2023, Venice, Italy
- P. Sroka, A. Kliks, "Distributed Learning for Vehicular Dynamic Spectrum Access in Autonomous Driving", IEEE International Conference on Pervasive Computing and Communications, PerCom Workshops 2022, March 21-25, 2022, Pisa, Italy, pp. 605-610
- K. Cichoń, M. Nikiforuk, "A Comparative Study of Vegetation Attenuation at Millimeter Waves Bandwidth", 30th International Conference on Software, Telecommunications and Computer Networks, SoftCOM 2022, Split, Croatia, Sept. 22-24, 2022, pp. 1-6
- C. Adamczyk, A. Samorzewski, M. Grzyb, A. Kliks, "Cloud-based Spectrum Access Control System for Dense IoT Networks", 30th International Conference on Software, Telecommunications and Computer Networks, SoftCOM 2022, Split, Croatia, Sept. 22-24, 2022, pp. 1-6
- M. Hoffmann, P. Kryszkiewicz, "Radio Environment Map and Deep Q-Learning for 5G Dynamic Point Blanking", 30th International Conference on Software, Telecommunications and Computer Networks, SoftCOM 2022, Split, Croatia, Sept. 22-24, 2022, pp. 1-3
- M. Hoffmann, P. Kryszkiewicz, "Similarity Measures for Location-Dependent MMIMO, 5G Base Stations On/Off Switching Using Radio Environment Map", IEEE 22nd International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM) 2021, June 7-11, 2021, Pisa, Italy, virtual conference, pp. 286-291
- P. Sroka, A. Kliks, M. Sybis, P. Kryszkiewicz, "Dynamic Power and Frequency Allocation Scheme for Autonomous Platooning", IEEE 93rd Vehicular Technology Conference (VTC2021-Spring), April 25-28, 2021, Helsinki, Finland, virtual conference, pp. 1-6
- S. Sabeeh, K. Wesołowski, "Resource Re-Selection with Adaptive Modulation and Collision Detection in LTE V2X Mode 4", IEEE 32nd Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), Sept. 13-16, 2021, Helsinki, Finland, virtual conference, pp. 1005-1010
- B. Grzelak, M. Keim, A. Pogiel, J. Rajski, J. Tyszer, "Convolutional Compaction-Based MRAM Fault Diagnosis", IEEE European Test Symposium (ETS) 2021, May 24-28, 2021, Bruges, Belgium
- K. Lenarska, K. Wesołowski, M. Sybis, "Application of Virtual Leaders in Long Vehicle Platoons Operating with Cooperative Adaptive Cruise Control Using IEEE 802.11p Transmission", IEEE International Symposium on "A World of Wireless, Mobile and Multimedia Networks" (WoWMoM) 2020, Aug. 31-Sept. 03, 2020, Cork, Ireland
- M. Hoffmann, A. Kliks, P. Kryszkiewicz, G. P. Koudouridis, "A Reinforcement Learning Approach for Base Station On/Off Switching in Heterogeneous M-MIMO Networks", IEEE International Symposium on "A World of Wireless, Mobile and Multimedia Networks" (WoWMoM) 2020, Aug. 31-Sept. 03, 2020, Cork, Ireland
- S. Sabeeh, K. Wesołowski, "C-V2X Mode 4 Resource Allocation in High Mobility Vehicle Communication", IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2020), Aug. 31-Sept. 03, 2020, London, United Kingdom
- P. Kryszkiewicz, "Neuron-Inspired Communications for Energy Efficient Internet of Things Networks", IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom 2020), March 23-27, 2020, Austin, TX, USA
- B. Kaczmarek, G. Mrugalski, N. Mukherjee, J. Rajski, Ł. Rybak, J. Tyszer, "Test Sequence-Optimized BIST for Automotive Applications", IEEE European Test Symposium (ETS 2020), May 25-29, 2020, Tallinn, Estonia
- M. Krasicki, "Labeling-Based Recipient Identification for BICM-ID in 64-QAM case", 16th IEEE International Conference on Wireless Communications & Mobile Computing (IWCMC 2020), June 15-19, 2020, Limassol, Cyprus

Books and book chapters

M. Wasilewska, H. Bogucka, A. Kliks, "Spectrum Sensing and Prediction for 5G Radio" 13th EAI International Wireless Internet Conference, EAI WiCON 2020, 11-12 Dec. 2020, [in] **Big Data Technologies and Applications**, Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering series [ed. Zeng Deze et.al.], Springer, Cham, 2021, vol. 371.

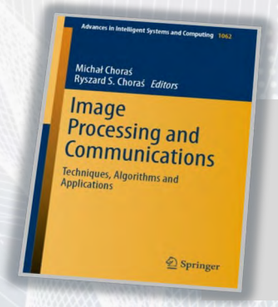
ISBN: 978-3-030-72801-4, pp. 176-194

K. Cichoń, A. Kliks "Efficient Clustering Schemes Towards Information Collection", [In:] G. Caso, L. De Nardis, L. Gavrilovska (eds) **Cognitive Radio-Oriented Wireless Networks**. CrownCom 2020. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol. 374. Springer, Cham, 2021.

ISBN: 978-3-030-73422-0, pp. 45-58

P. Kryszkiewicz, M. Sybis, P. Sroka, A. Kliks, "Distance Estimation for Database-assisted Autonomous Platooning", [In:] G. Caso, L. De Nardis, L. Gavrilovska (eds) **Cognitive Radio-Oriented Wireless Networks**. CrownCom 2020. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 374. Springer, Cham, 2021.

ISBN: 978-3-030-73422-0, pp. 91-101



M. Sybis, P. Sroka, A. Kliks, P. Kryszkiewicz, "V2X Communications for Platooning: Impact of Sensor Inaccuracy" [in] **Image Processing and Communications: Techniques, Algorithms and Applications** (ed. Michał Choraś, Ryszard S. Choraś), Springer, 2020.

ISBN 978-3-030-31254-1

A. Kliks, P. Kryszkiewicz, C.F. Bader, D. Triantafyllopoulou, C.E. Caicedo, S. Aydin, N. Dimitriou, M. Sybis (Eds.), ***Cognitive Radio-Oriented Wireless Networks, 14th EAI International Conference, CrownCom 2019***, Poznan, Poland, June 11–12, 2019, Proceedings, Springer 2019, 410 Pages.

ISBN 978-3-030-25748-4, 410 Pages

Contact

Institute of Radiocommunications
Poznan University of Technology
3 Polanka Str., 61-131 Poznań, Poland
e-mail: office_cr@put.poznan.pl
Phone: +48 61 665 3930
Fax: +48 61 665 3823

ir.put.poznan.pl

Our location