Signal Processing Symposium

SPSympo – 2023

Abstract Book

September 26 – 28, 2023

Karpacz, Poland

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Photo on the front page:

the conference venue Sandra Resort and Spa, Karpacz

(photo posted with the permission of the resort's owner)

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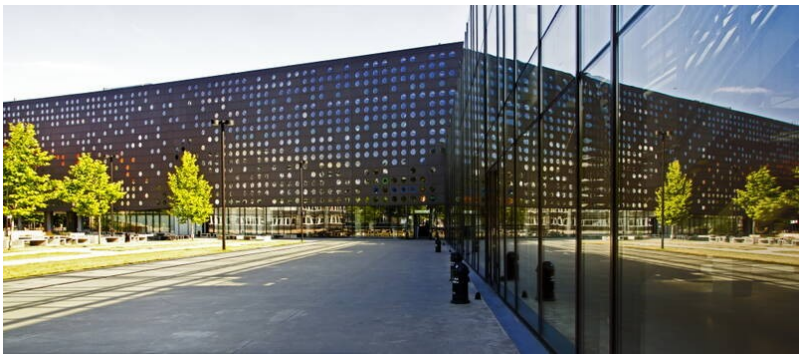
Welcome to SPSympo 2023



One of many modern industrial style buildings of the Wroclaw University of Science and Technology, Poland.

Dear Colleagues, The **Signal Processing Symposium** is a biannual international conference that brings **students**, **researchers**, **and scientists** representing a broad spectrum of computer science and radioelectronics disciplines to present their latest findings and to discuss new trends shaping future research directions in science and technology. After 20 years since its first edition in 2003, SPSympo has become a well-established and an excellent forum for active participation in workshops, lectures, and scientific discussions in technical and evening sessions. **SPSympo-2023** will be held alongside the **LXIX Open Seminar on Acoustics (OSA)**. We strongly believe that this cooperation will create new grounds for broadening our scientific horizons, developing new relationships, and altogether offering the prospect of novel synergies in our future research. Both conferences will touch on similar issues, i.e. signal/sound/image acquisition, processing, transmission, and analysis, in a broad range of applications covering remote sensing systems, IoT, telemedicine, medical diagnosis, treatment, and rehabilitation, robotics, human-system interaction, environment monitoring, space technologies, and various fields related to acoustics. In brief, the allied SPSympo and OSA create a unique opportunity to look at the field of signal processing from two different perspectives. On behalf of the Technical Program Committee, we cordially invite you to the Signal Processing Symposium 2023!

prof. Piotr Samczyński and *prof. Ryszard Makowski* – SPSympo-2023 Chairman

Piotr Samczyński and Ryszard Makowski – SPSympo-2023 Chairman

Signal Processing Symposium

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Acknowledgements

Six scientists from two Ukrainian universities, National Technical University of Ukraine in Kyiv and Lviv Polytechnic National University, which are associated partners of the ENHANCE Alliance, attend the SPSympo-2023 conference thanks to the financial support from the Polish National Agency for Academic Exchange (NAWA).

20th Anniversary of the IEEE Signal Processing Society Poland Chapter

Dear Colleagues

In 2023, we celebrate the 20th anniversary of the Poland Chapter of the IEEE Signal Processing Society. The festivities for the Chapter's 20th anniversary will take place on September 25, 2023, in Karpacz near Wrocław, Poland, coinciding with the start of the Signal Processing Symposium (SPSympo) 2023, one of our flagship conferences.

The idea of establishing the Poland Chapter of the IEEE Signal Processing Society was conceived in 2002 during discussions within the management of the Polish Section of IEEE. The preparatory work was led by Prof. Krzysztof Kulpa from Warsaw University of Technology, and officially, the Chapter was founded on May 13, 2003, with over 70 members at that time. Just eleven days later, on May 24, 2003, the Chapter organized its inaugural international conference – the Signal Processing Symposium 2003, in Wilga near Warsaw, Poland.

The first elections for the Chapter authorities took place in 2004, and for the subsequent term, Prof. Krzysztof Kulpa served as the Chapter's head. During his tenure, the Signal Processing Symposium began to be organized biennially. SPSympo 2005 in Wilga gathered over 150 participants from 10 countries, and a similar number of people participated in subsequent editions of the conference. Alongside conference organization, the Chapter hosted seminars and extended invitations to scientists from Poland and abroad to present tutorials.

In the following term (2006-2007), Prof. Mirosław Świercz from Bialystok University of Technology assumed the Chapter's leadership. The Chapter's membership remained stable at approximately 70 individuals. Notably, employees from subsequent academic institutions actively participated in the Chapter's activities. During this term, the next edition of SPSympo took place in Jachranka near Warsaw, Poland.

The next Chair of the Chapter was (2008-2016), Prof. Adam Dąbrowski from Poznan University of Technology. Prof. Dąbrowski is the founder of another flagship conference of the Chapter, SPA – Signal Processing Algorithms, Architectures, Arrangements, and Applications. This conference originated from the IEEE Signal Processing Workshop (IEEE SP) organized by Prof. Dąbrowski since 1993. The 26th SPA Conference is scheduled to be held in 2023.

In the subsequent term (2017-2019), Prof. Piotr Samczyński from Warsaw University of Technology served as the Chair of the Chapter. During this period, the Chapter actively engaged in various promotional activities aimed at popularizing the field of signal processing within Polish research centers, as well as initiatives targeting high school students and college students. The Chapter provided support for the organization of international scientific conferences held in Poland, including the 20th Polish Conference on Biocybernetics and

Biomedical Engineering (2017), the SPSympo (2017 and 2019), and the SPA conferences (2017-2019). Notably, in 2018, Chapter members participated for the first time in the Science Picnic held at the National Stadium in Warsaw, organized by Polish Radio and the Copernicus Science Center. This initiative involved the collaboration of three prominent scientific institutions: Warsaw University of Technology, AGH University of Science and Technology, and Lodz University of Technology. In recognition of the collective efforts of the entire Management Board, the Poland Chapter of the IEEE Signal Processing Society received the prestigious 2018 Chapter Certificate of Merit award from the IEEE Signal Processing Society in 2019.

The succeeding Chair of the Chapter (2019-2023) was Prof. Piotr Augustyniak from AGH University of Science and Technology. He continued the tradition of inviting outstanding lecturers (IEEE Distinguished Lecturers) but introduced a novel approach – a 'lecture tour' consisting of a series of lectures held in various Polish cities. By announcing these talks collectively, interested individuals could visit their chosen city at the appropriate time. Prof. Augustyniak also proposed new promotional activities targeting high school and college students. The primary aim of this promotion was to raise awareness about the significant role signal processing plays in various aspects of modern life. This initiative engaged schoolchildren, who often approach mathematics with hesitation, as they discovered the exciting applications of signal processing. Some even expressed interest in contributing to the shaping of the 'digital world' of the future. During Prof. Augustyniak's tenure, a dedicated YouTube channel called 'Amplitude' was established, presenting videos on signal processing. This knowledge became accessible without time or geographical limitations. Another collaborative effort was the competition for video presentations of diploma theses related to signal processing, with the inaugural edition announced in the summer of 2022.

Since March 2023, I have had the honor and pleasure of serving as the Chair of the Chapter, endeavoring to uphold the traditions, activities, and projects initiated by my esteemed predecessors. Presently, the Chapter has over 80 members, comprising scientists, Ph.D. students, and engineers, and maintains a presence in all major technical universities across Poland.

On behalf of the Board of the Poland Chapter of the IEEE Signal Processing Society, I would like to extend an invitation to all participants of the Signal Processing Symposium 2023 to join us in celebrating the 20th anniversary of our Chapter.

Prof. Konrad Jędrzejewski, Karpacz, Poland, September 2023

prof. Konrad Jędrzejewski

Chair of the Poland Chapter of the IEEE Signal Processing Society

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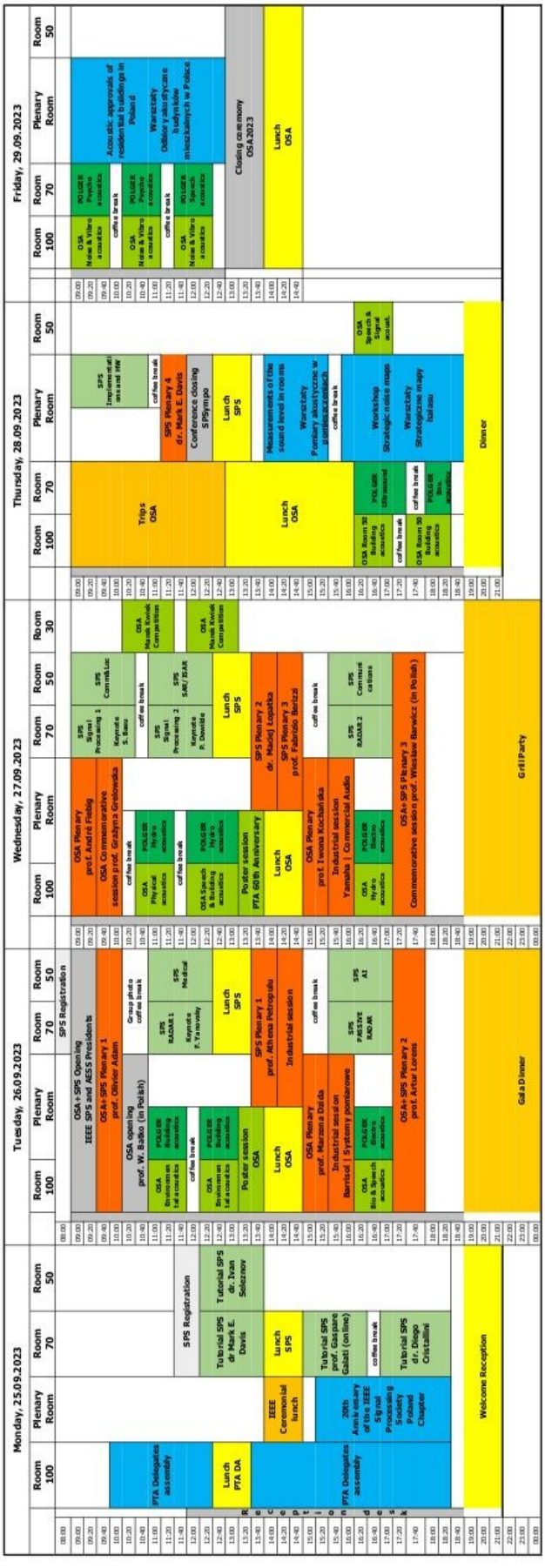
Signal Processing Symposium

Joint Programme OSA2023 and SPSympo2023



Keynote Speeches

Keynote Speech Session *OSA + SPS Plenary 1*

Analysis of Underwater Soundscapes

Prof. Olivier Adam – Sorbonne Université, France

Dr Olivier ADAM is Professor at the Sorbonne University, Paris, France. Specialist in bioacoustics, he studies cetacean species to describe their populations and societies. He is currently working on the study of mother-calf interactions in humpback whales, on the analysis of surface social behaviours in sperm whales and on the description of underwater soundscapes. He is the author and co-author of more than 60 scientific papers. He was the curator of the Baleinopolis exhibition at the Palais of Porte Dorée in Paris (https://youtu.be/gRbQR77TrRM) and of the photo exhibition "L'Océan c'est Vivant" at the Cité internationale in Paris and on the Seine river bank. He is the co-organiser of international conferences, including the DCLDE (https://www.soest.hawaii.edu/ore/dclde/), and the Humpback Whale World Congress (https://www.hwwc.mg). He was the carrier of 3 webinars, on ocean noise pollution (https://oceanambassadors.co.uk/shush-noise-in-the-ocean-sorbonne-university), on the blue economy (https://oceanambassadors.co.uk/blueco-can-the-economy-of-the-oceans-really-be-sustainable), and on the ethics (https://oceanambassadors.co.uk/ethics-for-ocean).

Keynote talk description

Analysis of underwater soundscapes aims to detect and classify acoustic events in 3 main categories: sounds from the environment (geophony), from the living non-human species (biophony), from human activities (anthrophony). One of the objectives is to describe how the anthropic sounds impacts the marine ecosystem. Analysis focused on specific acoustic features including the types of sound, acoustic intensities, bandwidth, duration of the sound exposition. To answer these questions, recent studies were done on the cetacean species to evaluate the level of these effects, from behavior changes to beaching. Since 2007, thresholds were suggested to avoid temporary and permanent threshold shifts for 3 categories of cetaceans: "low frequency cetaceans" including the mysticeti species, "high frequency cetaceans" including almost all the odontoceti species, and "very high frequency cetaceans" including the small odontoceti species like the porpoises, the vaquitas. In our team, we focused on the manual and automatic annotation of the large dataset of acoustic recordings in order to use this information to train convolutional neural network (CNN). We built a platform to simplify this processing. Results show that after a short training session, non-expert annotators can be involved to identify specific underwater sounds, and they obtained close results than from expert annotators. Thus, citizen science seems to be a complementary option to increase the number of annotated datasets. The next step is to test different structures of CNN to optimize the classification of sounds from a catalogue including sounds emitted by few cetaceans species and sounds from the large commercial ships. This work will contribute to mitigate the underwater noise pollution.

Keynote Speech Session *SPS Plenary 1*

Integrated Communication-Sensing Wireless Systems

Prof. Athina Petropulu – Rutgers University, USA

Athina P. Petropulu is Distinguished Professor at the Electrical and Computer Engineering (ECE) Department at Rutgers, having served as chair of the department during 2010-2016. Prior to joining Rutgers she was a Professor of ECE at Drexel University (1992-2010). She held Visiting Scholar appointments at SUPELEC, Universite' Paris Sud, Princeton University and University of Southern California. Dr. Petropulu's research interests span the area of statistical signal processing, wireless communications, signal processing in networking, physical layer security, and radar signal processing. Her research has been funded by various government industry sponsors including the National Science Foundation (NSF), the Office of Naval research, the US Army, the National Institute of Health, the Whitaker Foundation, Lockheed Martin and Raytheon. Dr. Petropulu is Fellow of IEEE and the American Association for the Advancement of Science (AAAS), and recipient of the 1995 Presidential Faculty Fellow Award given by NSF and the White House. She is 2022-2023 President of the IEEE Signal Processing Society (SPS). She has served as Editor-in-Chief of the IEEE Transactions on Signal Processing (2009-2011) and IEEE Signal Processing Society Vice President-Conferences (2006-2008). She was General Chair of 2020 and 2021 IEEE SPS PROGRESS Workshops, General Co-Chair of the 2018 IEEE International Workshop on Signal Processing Advances in Wireless Communications (SPAWC), Kalamata Greece, and General Chair of the 2005 International Conference on Acoustics Speech and Signal Processing (ICASSP-05), Philadelphia PA. She was Distinguished Lecturer for the Signal Processing Society for 2017-2018, and is currently Distinguished Lecturer for the IEEE Aerospace & Electronics Systems Society. She is recipient of the 2012 IEEE Signal Processing Society Meritorious Service Award, and co-recipient of the 2005 IEEE Signal Processing Magazine Best Paper Award, the 2020 IEEE Signal Processing Society Young Author Best Paper Award (B. Li), the 2021 IEEE Signal Processing Society Young Author Best Paper Award (F. Liu), the 2021 Barry Carlton Best Paper Award by IEEE Aerospace and Electronic Systems Society, and the 2022 IEEE Sensor Array and Multichannel Signal Processing Workshop Best Student paper Award (Y. Li) and the 2023 Stephen O. Rice Prize Best Paper Award by the IEEE Communications Society.

Keynote talk description

Dual-function radar-communication (DFRC) systems are integrated sensing-communication systems that use the same waveform for simultaneously probing the surroundings and communicating with other equipment. DFRC systems offer high spectral, hardware and power efficiency, and as such are prime candidates for 6G wireless systems, such as autonomous driving vehicles, unmanned aerial vehicles, surveillance, search and rescue, and advanced manufacturing where networked robots are involved in the manufacturing process. Before the DFRC promise is realized, several issues need to be addressed.

One of those issues is security. By embedding communication information in the probing waveform, DFRC systems are vulnerable to eavesdropping by the targets. In this talk we will present a novel physical layer security (PLS) system design for optimizing the communication secrecy rate while maintaining sufficient power in the target echoes to ensure high target sensing performance. We will also present a novel Directional Modulation (DM) approach for achieving PLS, via which, the DFRC system is designed to deliver the signal intact to the legitimate destination and scrambled in all other directions. We will examine the possibility of the target/eavesdropper defying the proposed security measures and investigate additional protection measures.

Keynote Speech Session *OSA + SPS Plenary 2*

Cochlear Implant – an electronic prosthesis of a sensory organ

Dr. Artur Lorens – Institute of Physiology and Pathology of Hearing, Warsaw, Poland

Artur Lorens Ph.D. Eng., head of the Department of Auditory Implant and Perception of World hearing Center of the Institute of Physiology and Pathology of Hearing, Warsaw, Poland. Scientific experience in the field of auditory implants, psychoacoustics and auditory perception modeling. Scientist in charge of the HearingTreat Marie Curie EU project (2006-2010). Member of the Polish Scientific Association of the Hearing and Communication Disorders Member of the American Auditory Society, International Society of Audiology, European Society for Artificial Organs, European Academy of Otology&Neurootology.

Keynote Speech Session *SPS Plenary 3*

New signal processing challenges in Defence applications

Prof. Fabrizio Berizzi (University of Pisa | EDA, Italy)

Fabrizio Berizzi was born in Piombino (Italy) on 25-th of November 1965. He is a full professor at the University of Pisa currently suspended since May 2018 to be a temporary agent of the European Defence Agency (EDA) with the role of Project Officer of Electro-Optical Sensors Technologies. He has been an IEEE senior member since 2006. He has been the Italian Academic national member of the NATO SET panel member from April 2014 to April 2018. He has been the head of the Radar Laboratory of the University of Pisa (Italy) for 15 years and the Director of the Radar and Surveillance System (RaSS) laboratory of the CNIT (National Inter-university consortium for Telecommunication) in Italy for 3 years. His main research interests are in the field of radar system design and signal processing and specifically in radar imaging (SAR/ISAR/InSAR,3D imaging), polarimetric, passive, Over the Horizon, multichannel/multistatic, cognitive radars, image enhancement and processing technique, EO counter (counter) measure systems and active imaging. He is the author of more than 100 papers in prestigious international journals and co-authors of 5 books.

Keynote Speech Session *SPS Plenary 2*

Deep Tech Europe – European Innovation Council: focus on emerging digital technologies

Dr. Maciej Łopatka

Maciej Lopatka is a Policy Adviser for research and innovation at the European Innovation Council and SME Executive Agency (EISMEA) established by the European Commission to support development of breakthrough technologies and game changing innovations. He worked for the European Commission's Research Executive Agency as Project Officer and Joint Research Centre as Scientific Officer, NATO Undersea Research Centre as Research Assistant, Grenoble Institute of Technology as post-doctoral researcher and for a high-tech SME as Research Engineer. He holds dual-award Ph.D. degree in Engineering Sciences from Wroclaw University of Technology (WUT, Poland) and University of Paris-Est Creteil (UPEC, France). He holds also M.Sc. degree in Telecommunications (WUT) and M.Sc. degree in Biomedical Engineering (UPEC). He has more than 15 years of experience in research and is author, co-author and reviewer of numerous scientific publications. He was Erasmus scholar, French government grantee and received few excellence awards. His professional interests focus on scientific research and knowledge for policy, technology foresight, strategic and business intelligence. He speaks fluently Polish (mother tongue), English, French and Italian and studies Spanish. His passions are running, cycling, skiing, music, books and photography.

Keynote talk description

The European Innovation Council (EIC) is a flagship initiative of the European Commission with a budget of over EUR 10 bn under the Horizon Europe Programme (2021 – 2027). The EIC aims to back the most ambitious and visionary ideas of thousands of research teams and startups from across Europe. The programme supports all stages of the innovation chain from high-risk interdisciplinary research ideas through proof of concept and technology transfer to financing and scale up of high-potential startups and SMEs. The EIC provides funds and business acceleration services for any technologies and innovations that cut across scientific, technological, sectoral and application fields or represent novel combinations of these (bottom-up). This is complemented by a 'challenge driven' approach (top-down) supporting EU policy priorities and strategic goals such as transitioning to a green, digital and healthy society including associated strategies such as Chips Act, RePowerEU, New Industrial Strategy and the European Health Union. The presentation will include some insights into the current EIC portfolio of funded R&I projects (with examples ranging from lab to market), show impact of the programme delivered so far and expose some considerations for the future. The main focus will be given to emerging digital technologies that have been identified by the EIC as having strategic importance for the EU.

Keynote Speech Session *SPS Plenary 4*

A Technical Confluence Of UWB Radar and Communications In A Congested RF Environment

Dr. Mark E. Davis – Senior Independent Consultant, USA

Mark E Davis has over 50 years' experience in Radar technology and systems development. He has held senior management positions in the Defense Advanced Research Projects Agency (DARPA), Air Force Research Laboratory, and General Electric Aerospace. At DARPA, he was the program manager on both the foliage penetration (FOPEN) radar advanced development program and the GeoSAR foliage penetration mapping radar. Dr Davis wrote the text: "Foliage Penetration Radar – Detection and Characterization of Objects Under Trees", published by Scitech Raleigh NC in March 2011. A new text on Ultra-Wide Band Surveillance Radar has been published by IET in January 2021, which serves as the reference text for this tutorial. His education includes a PhD in Physics from The Ohio State University, and Bachelor and Masters Degrees in Electrical Engineering from Syracuse University. He is a Life Fellow of both the IEEE and Military Sensing Symposia. And, he has held positions as IEEE Aerospace Electronics Systems Society President Elect, past member of the AESS Board of Governors, VP Conferences, and past-Chair the Radar Systems Panel. He is the 2011 recipient of the AESS Warren D White Award for Excellence in Radar Engineering, and the 2018 IEEE Dennis J. Pickard Medal for Radar Technologies and Applications.

Keynote talk description

Modern Ultra-Wide Band (UWB) RF systems require bandwidth to achieve channel use for communication, and fine spatial and Doppler resolution for radar. These capabilities require extensive testing to meet significant standards for both personal communications and radar sensing systems.

There has been a significant change since 2005 in the spectrum compliance process. This was based on major advances in the communications and radar system technology, as well as shifting from analogue to digital transmitters in both RF modes.

The recent development in cognitive control of both radar and communications provides an opportunity for reducing the possibility of spectrum interference. The main elements of this technology is the development of orthogonal waveforms that provide a moderate prevention of co-channel interference, the ability to sense the spectrum around a transmitter to determine regions of the spectrum, not being used (white spaces) and the recent development of machine learning that can greatly enable the performance for radar resolution and communications lower bit error rates.

The Plenary talk will provide a brief summary of the issues, and posit development plans for future radar research and development.

Keynote Speech Session *Signal Processing 1, Room 50*

Algebraic considerations for M-D stochastic realization

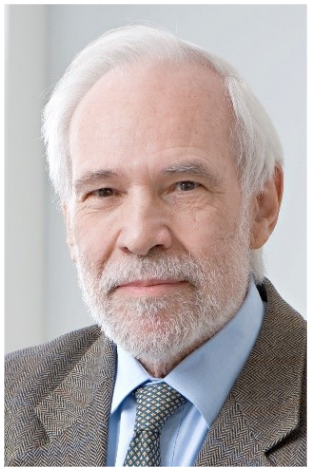
Dr. Sankar Basu

Sankar Basu is a program Director at the US National Science Foundation. He is a Fellow of the IEEE, and a Fellow of the American Association for the Advancement of Science. He received a PhD from the University of Pittsburgh, served on the faculty of Stevens Institute of Technology, was a visiting senior scientist Naval Underwater Systems Center, CT. He visited the Ruhr University, Bochum, Germany as an Alexander von Humboldt Fellow, the MIT Laboratory for Information and Decision Systems (LIDS) and served as a Research Staff Member at the IBM T. J. Watson Research Center. During 2012 he was a science advisor to the US Embassy in Berlin, Germany. His interests are in Signal and Systems Theory, and Computing Hardware design. Author of over one hundred publications including coediting two special volumes on Wavelets and Filter Banks, and a book Advances in Learning Theory: Methods, Models, and Applications, he also holds 10 US Patents. He served in editorial boards of many professional journals, including as the Editor-in-Chief. He was the founding general chair of the 1st IEEE Int. Conf. on Multimedia & Expo, and a co-organizer of the NATO Advanced Study Institute on Statistical Learning and Applications Katholieke University, Belgium.

Keynote Speech Session *Signal Processing 2, Room 50*

An interesting new problem in stochastic modeling

Prof. Patrick Dewilde, *Honorable Professor, Wroclaw University of Science and Technology (Poland)*



Patrick Dewilde (EE `66 KULeuven, Belgian Lic. Math. `68 and PhD `70 Stanford University) has been a professor in electrical engineering at the Technical University of Delft for 31 years, director of the Delft Institute for Micro-electronics DIMES for ten years, chairman of the Technology Foundation STW (a major Dutch research funding agency) for eight years and director of the Institute of Advanced Study of the TU Munich for five years. His research, published in the international scientific literature and some books, has focused on mathematical issues related to the design, control and operations of dynamical systems in general and in particular circuits and systems for signal processing. He is an IEEE Fellow since 1981, an elected member of the Dutch Royal Academy of Arts and Science, has been elevated to the rank of Knight of the Dutch Lion and is presently a honorary professor both at the Technische Universität München and the Technical University of Wroclaw.

Keynote talk description

This talk addresses the modeling of a non-Gaussian stochastic process based on a fully ordered sequence of measurement of moments or correlations. To do so, it uses recent results in the parametrization of all the

moment generating functions that interpolate the given or measured correlation data. While the parametrization problem appears to be adequately solved, the crucial numerical determination of the resulting cumulative probability function (cpf) or probability density function (pdf) appears to be a new interesting but unsolved problem, even in the single variable case. The talk introduces the problem and its background, hoping to provide motivation for further research.

Keynote Speech Session *SPS Radar 1, Room 50*

Peculiarities and experience of W-band cloud radar calibration

Prof. Felix Yanovsky – National Aviation University, Kyiv, Ukraine

Felix J. Yanovsky (IEEE M'94–SM'96–F'08–LF'20) graduated (with Honors) from the National Aviation University (NAU), Kyiv, Ukraine. He got his PhD degree in Radar & Radio Navigation, DSc degree (habilitation) in Aviation Meteorology, and the one more DSc in Radar & Radio Navigation in 1979, 1992, and 1993 respectively. He is currently a Senior Researcher in the Delft University of Technology, Geoscience and Remote Sensing department and (remotely) the Professor of Electronics, Robotics, Monitoring and IoT Technologies (ERMIT) Department in NAU. He was visiting professor and/or scientist in different Universitates in the Netherlands, USA, Germany, Jordan, Republic of Korea, China, Poland, India, and Kenya. He promoted 16 PhD & DSc holders and hundreds of M.S. and Engineers. He was the Chair of IEEE Ukraine Section (2016-2022), founder and Chairman of the Microwaves, Radar and Remote Sensing Symposium (MRRS). Research activity in electronics, IT, radar, remote sensing, signal processing. He took part in numerous projects in Ukraine, the Netherlands, and Republic of Korea. He has numerous awards and International Grants. Author of 12 books (CRC, Springer, Momentum Press, Elsevier, Tekhnika, NAU), more than 500 papers, and 42 invention patents.

Keynote talk description

This talk is devoted to discussing peculiarities of W-band cloud radar calibration. After brief overview on meteorological radar calibration for quantitative information obtaining, we will focus on problems and their possible solutions in respect to mm-wave radar calibration. Experimental part of the talk is based on multi-instrument measurements in rain provided during several years in the Cabauw experimental site are used for comparison of 94 GHz radar data with non-radar droplet size distribution measurements, provided by laser disdrometers. Specialized Matlab software tool developed for such processing complex data and radar calibration will be demonstrated.

Tutorials

Tutorial Session *Monday 25.09.2023, 12.20 pm – 2.00 pm*

Exploring Scaling Analysis: A Pathway to Understand Complexity in Natural Phenomena

Dr. Ivan Seleznov- Graduate School of Engineering Science Osaka University, Japan

Dr. Ivan Seleznov is a Post-doc researcher at the Department of Mechanical Science and Bioengineering at Osaka University in Japan, where he conducts cutting-edge research in the field of biomedical signals. In addition to his academic work, Ivan is also the Chief Technology Officer of Flora, a startup focused on using data analysis to enhance female well-being and improve working conditions for women. His research has focused on the interpretation of electroencephalograms during cognitive workload and emotions, fractal analysis of electroencephalograms, human stabilograms, heart rate, and the development of new techniques in 2D scaling analysis. These contributions have received recognition in several peer-reviewed journals and conference proceedings.

Tutorial description

In this tutorial, attendees will learn about scaling analysis (fractal analysis) – an innovative technique for analyzing complex signals in various natural phenomena. These complex signals have been shown to be the result of non-linear, non-equilibrium, and non-stationary processes, but traditional analytical tools and techniques often assume the stationarity and linearity of data. Conventional methods, such as analysis of means, standard deviations, and histogram features, are not enough to capture the hidden dynamics and information contained in such signals. The fractal analysis provides a way to uncover the underlying complexity of signals and extract valuable insights for researchers. It focuses on the self-similar patterns that exist within complex signals and use mathematical models to describe the scaling behavior of these patterns over different scales of observation. In this tutorial, attendees will learn the theory behind scaling analysis, as well as the tools and techniques used to perform such analysis. This will include a focus on the mathematical models used to describe scaling behaviour, the use of scaling exponents to quantify complexity, and the comparison of scaling and fractal analysis to traditional methods. During the tutorial, we will also demonstrate practical applications of scaling analysis, emphasizing the usage of the analysis of seismic time series as well as human centre-of-pressure time series. By the end of the tutorial, attendees will have a solid understanding of the principles of scaling and fractal analysis and will be able to apply these techniques to their own data and research.

Tutorial Session *Monday 25.09.2023, 12.20 pm – 2.00 pm*

UWB Surveillance Radar

Dr. Mark E. Davis – Senior Independent Consultant, USA

Mark E. Davis has over 50 years' experience in Radar technology and systems development. He has held senior management positions in the Defense Advanced Research Projects Agency (DARPA), Air Force Research Laboratory, and General Electric Aerospace. At DARPA, he was the program manager on both the foliage penetration (FOPEN) radar advanced development program and the GeoSAR foliage penetration mapping radar. Dr Davis wrote the text: "Foliage Penetration Radar – Detection and Characterization of Objects Under Trees", published by Scitech Raleigh NC in March 2011. A new text on Ultra-Wide Band Surveillance Radar has been published by IET in January 2021, which serves as the reference text for this tutorial. His education includes a PhD in Physics from The Ohio State University, and Bachelor and Masters Degrees in Electrical Engineering from Syracuse University. He is a Life Fellow of both the IEEE and Military Sensing Symposia. And, he has held positions as IEEE Aerospace Electronics Systems Society President Elect, past member of the AESS Board of Governors, VP Conferences, and past-Chair the Radar Systems Panel. He is the 2011 recipient of the AESS Warren D White Award for Excellence in Radar Engineering, and the 2018 IEEE Dennis J. Pickard Medal for Radar Technologies and Applications.

Tutorial description

Ultra Wide Band Surveillance Radar is an emerging technology for detecting and characterizing targets and cultural features for military and geosciences applications. It is essential to have fine range and cross-range resolution to characterize objects near and under severe clutter. This Lecture is divided into five parts.

- **The Early History of Battlefield Surveillance Radar:** Battlefield surveillance from manned and unmanned aircraft, along with early experiments in fixed and moving target detection and foliage penetration are covered.
- **UWB Phased Array Antenna:** Wideband waveforms place a significant demand on the ESA design to maintain gain and sidelobe characteristics. Design of ESA systems with time delay steering and digital beamforming will be illustrated.
- **UWB Synthetic Aperture Radar (SAR):** A brief description of key UWB surveillance SAR systems will be provided, along with illustrations of the SAR image and fixed object detection capability. Interferometric SAR with multiple channels have provided terrain height measurements and improved detection of moving target detection with UWB waveforms.
- **UWB Ground Moving Target Indication:** Space Time Adaptive Processing (STAP) has been used for over 20 years for detecting and tracking moving targets in clutter. As the resolution is improved for target characterization, the limits of STAP are tested. This section will discuss an approach for increasing the bandwidth and maintaining geolocation accuracy with Along Track Interferometry.

- **New research in Multi-mode Ultra-Wideband Radar**, The last section of the lecture will illustrate new technologies that have promise for future multimode operation: simultaneous SAR and GMTI in a multichannel radar.

Tutorial Session (online) *Monday 25.09.2023, 3.0 pm – 4.40 pm*

Noise Radar Technology: Yesterday, Today and Tomorrow

Prof. Gaspare Galati – Tor Vergata University, Italy

Gaspare GALATI received the Dr. Ing. Degree (Laurea) in Nuclear Engineering in 1970. From 1970 until 1986, he was with the company Selenia S.p.A. where he was involved in radar systems analysis and design and, from 1984 to 1986, headed the System Analysis Group. From March 1986, he was associate professor at the Tor Vergata University of Rome; from November 1996 to 2017, he is full professor of Radar Theory and Techniques at the Tor Vergata University. In 2017 he has been designated Honorary Professor by the Ministry of Education. His main interests are in Radar theory and techniques, Detection and estimation, Noise Radar, Navigation and Air Traffic Management. He is author/co-author of about 300 papers, 20 patents and 10 books on those topics.

More info on: https://eln.uniroma2.it/ricerca/laboratori-di-ricerca/radar-and-navigation/

Tutorial description

In spite of the centennial age of radar, this technology is facing continuous progress. This tutorial considers two significant, or promised, advancements in the radar field, namely Noise Radar Technology (NRT) and Quantum Radar (QR). Rationale, present status, ongoing research and future perspectives are discussed, not forgetting some critical and controversial elements.

Tutorial Session *Monday 25.09.2023, 5.00 pm – 6.40 pm*

Novel potentials enabled by satellite-based passive radars

Dr. Diego Cristallini – Fraunhofer FHR, Wachtberg, Germany

Dr. Diego Cristallini is Head of the Passive Radar Group at Fraunhofer FHR. He graduated cum laude in Telecommunication Engineering in May 2006 and received the Ph.D. degree in Radar Remote Sensing in April 2010 both from the University of Rome “La Sapienza”. From December 2009 to February 2015 he has been with the Array-based Radar Imaging Department of the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR in Wachtberg, Germany. Since March 2015, Diego is leading the Team on Passive Covert Radar in the Passive Radar and Anti-Jamming Techniques Department of Fraunhofer FHR, Germany. From March to June 2020, he has been visiting scientist at Defence Science and Technology (DST) Group in Edinburgh, South Australia. Dr. Cristallini serves as voluntary Reviewer for a number of international technical journals, and he is active in the scientific community serving as TPC for several international conferences related to radar. He is also a regular lecturer at the Fraunhofer International Summer School on Radar and SAR. Dr. Cristallini is co-chair of the NATO-SET 242 group on “PCL on moving platforms” and he has been lecturing for the NATO LS-243 “Passive Radar Technology”. Dr. Cristallini received the Best Paper Award at EUSAR 2014, co-authored the Best Poster Award at EUSAR 2018.

Tutorial description

Passive radar has now become an established technology. Among current active field of research it is worth mentioning the capability to perform imaging as well as the capability of detection of small objects such as drones. Satellite Illuminators of Opportunity (IOs) such as Digital Video Broadcast – Satellite (DVB-S) as well as the exploitation of emerging broadband communication satellite constellations (e.g. Starlink or OneWeb) offer interesting characteristics to perform these two tasks. In fact, they offer relatively wide signal bandwidths for passive radars (up to 2 GHz), they operate at high carrier frequencies (namely in Ku-Band), and these so-called megaconstellations with global and continuous coverage are planned to be composed of hundreds or thousands of satellites deployed at low Earth orbits (LEO), thus offering continuous and synoptic illumination on wide and also remote areas. In particular, while the wide signal bandwidth enables high range resolutions, the high operating frequency significantly increases the system sensibility against Doppler (and micro-Doppler) modulations with respect to other conventional passive radar IOs at lower frequencies. Both these aspects offer extremely appealing characteristics for detection and imaging. Finally, preliminary experimental measurements will be presented. All of these analyses will provide an overview of the great potential capabilities achievable by using these novel satellite constellations as illuminators of opportunity, trying also to promote further research and developments in this field that will open up new and advanced passive radar applications.

Industrial Session

Industrial Session *Tuesday 26.09.2023, 2.20 pm – 3.00 pm*

Democratising radars: from drone wars to space-based imaging

Dr. Maciej Klemm – Advanced Protection System S.A., Gdynia, Poland

Dr. Maciej Klemm holds a PhD in electromagnetic and microwave engineering from the Swiss Federal Institute of Technology Zurich in Switzerland. He previously obtained his master's degree in microwave and antenna engineering at his home university - Gdańsk University of Technology. He is a former lecturer with over 15 years of experience, as a scientist he worked primarily in Great Britain, including: as Associate Professor at the Department of Electrical and Electronics at the University of Bristol. He has many years of experience in the commercialization of scientific research, and is the author of over 70 scientific publications, including several breakthroughs in the field of electromagnetic and nano antennas. - Winner of the Best Young British Scientific Engineer competition awarded by Tony Blair, Prime Minister of Great Britain, in 2007. - Also awarded by the Engineering and Physical Science Research Council (EPSRC).

About Company

Advanced Protection Systems SA, based in Gdynia, Poland, develops the pioneering **FIELDctrl 3D MIMO radars** and the **SKYctrl anti-drone system** to effectively detect, classify, track and neutralise UAVs. With a task force of more than a hundred technology, military and business experts, as well as scientists, engineers and developers, Advanced Protection Systems produces high-quality and exceptionally effective anti-drone systems that have achieved a comparative advantage over competitors' solutions. The company develops, manufactures and implements every component of the technology in-house: from the integrated circuits, electronics and mechatronics to the software and final implementation. Advanced Protection Systems' radar technologies protect key locations worldwide, both military and civilian. **The Ukrainian Armed Forces** using the **SKYctrl system** confirm its effectiveness: 'So far, this is the best system I and other units have seen and experienced. (...) Its range corresponds to the specification and is even greater, depending on the flight altitude of the BSP. It even sees birds, but does not neutralise them because it automatically distinguishes them from the drones.'

SPSympo 2023 - Conference Agenda

Monday 25.09.2023

12.20 pm – 2.00 pm	Location - Room 50, TUT-I.S.: Tutorial - Ivan Seleznov, Chair – Ł. Maślikowski	Location - Room 70, TUT-MED: Tutorial – Mark E. Davis, Chair – P. Samczyński
2.00 pm – 3.00 pm	Lunch break	
3.00 pm – 4.40 pm	Location - Room 70, TUT-SPS-G.G.: Tutorial Online - Gaspare Galati, Chair - Jacek Misiurewicz	
3.00 pm – 6.40 pm	Location – Plenary Room, IEEE, Chair – K. Jędrzejewski and B. Szlachetko	
4.40 pm – 5.00 pm	Coffee break	
5.00 pm – 6.40 pm	Location - Room 70, TUT-SPS-D.C.: Tutorial - Diego Cristallini, Chair - Mateusz Malanowski	

Tuesday 26.09.2023

9.00 am – 9.30 am	SPSympo Opening, Chair - Krzysztof Kulpa, Chair - Piotr Jerzy Samczyński and Agnieszka Wielgus, Ryszard Makowski, Jan Zarzycki	
9.40 am – 10.20 am	OSA & SPS Plenary 1 - Olivier Adam, Chair - Piotr Jerzy Samczyński, Chair - Agnieszka Wielgus and prof. Krzysztof Kulpa, Przemysław Plaskota	
10.20 am – 11.00 am	Coffee break	
11.00 am – 12.40 pm	Location - Room 50, SPS-Medical: Medical signals processing, Chair – Athina Petropulu, Chair – Z. Świętach	Location – Room 70, SPS-Radar1: Radar 1, Chair – Mark Edward Davis, Chair – Łukasz Maśliowski
12.40 pm – 1.40 pm	Lunch break	
1.40 pm – 2.20 pm	SPS Plenary 1 - Athina Petropulu, Chair – J. Misiurewicz and K. Jędrzejewski	
2.20 pm – 3.00 pm	Industrial Session, Democratising radars: from drone wars to space-based imaging, Maciej Klemm, Advanced Protection Systems SA, Gdynia, Poland	
3.00 pm – 3.40 pm	Coffee break	
3.40 pm – 5.20 pm	Location - Room 50, SPS - AI/ANN: Artificial Intelligence, Artificial Neural Networks, Chair – Ivan Seleznov, Chair – Zbigniew Świętach	Location: Room 70, SPS - PassiveRadar: Passive radar, Chair - Diego Cristallini, Chair - Mateusz Malanowski
6.00 pm – 6.40 pm	OSA & SPS Plenary 2 - Artur Lorens, Chair - Agnieszka Katarzyna Wielgus, Chair – Przemysław Plaskota	

Wednesday 27.09.2023

9.00 am – 10.40 am	Location - Room 50, SPS-CommLoc: Communications and Localization, Chair - Patrick Dewilde, Chair - Urszula Libal	Location - Room 70, SPS-SigProc1: Signal Processing 1, Chair - Ewa Świercz, Chair - Sankar Basu
10.40 am – 11.00 am	Coffee break	
11.00 am – 12.40 pm	Location - Room 50, SAR/ISAR: SAR/ISAR, Chair - Fabrizio Berizzi, Chair - Marcin Bączyk	Location - Room 70, SPS-SigProc2: Signal Processing 2, Chair - Damian Gromek, Chair - Olivier Adam
12.40 pm – 1.40 pm	Lunch break	
1.40 am – 2.20 pm	SPS Plenary 2 - Maciej Łopatka, Chair - Agnieszka Katarzyna Wielgus, Chair - Mateusz Malanowski	
2.20 pm – 3.00 pm	SPS Plenary 3 - Fabrizio Berizzi, Chair - Agnieszka Katarzyna Wielgus, Chair - Mateusz Malanowski	
3.00 pm – 3.20 pm	Coffee break	
3.40 pm – 5.00 pm	Location - Room 50, SPS-Comm: Communications, Chair – Tomasz P. Zieliński, Chair – Urszula Libal	Location - Room 70, SPS-Radar 2: Radar 2, Chair – Maciej Janusz Łopatka, Chair – Karol Abratkiewicz
5.00 pm – 5.40 pm	OSA & SPS-Plenary 3 – Commemorative Session prof. Wiesław Barwicz, Chair – Przemysław Plaskota	

Thursday 28.09.2023

9.00 am – 11.00 am	Location – Plenary Room, SPS-ImpAndHW: Implementations and hardware, Chair – Istvan Balajti, Chair - Jacek Misiurewicz
11.00 am – 11.40 am	Coffee break
11.40 am – 12.20 pm	SPS Plenary 4 - Mark E. Davis, Chair - Felix Yanovsky, Chair - Bogusław Szlachetko
12.20 pm – 1.00 pm	SPS-Closing: Closing Session, Chair - Piotr Jerzy Samczyński, Chair - Agnieszka Katarzyna Wielgus and prof. Krzysztof Kulpa, Przemysław Plaskota
1.00 pm – 2.20 pm	Lunch break

SPSympo 2023 – Abstracts

Tuesday 26.09.2023, 11.00 am – 12.40 pm, Plenary Room, SPS-Radar 1.

Session Chairs: **Mark Edward Davis and Łukasz Maślikowski**

1) Near Field Phase Correction for Cascaded Radar

Kang Liu[1], Xiangcheng Zhu[2], Yu Cao[2], Qiyang Ge[2], Yuanhui Zhang[2]

[1]Einstein E-Tech GmbH, Germany; [2]China Jiliang University, China

The cascaded radar imaging system consists of four 79GHz Radar chips, each has 3Tx and 4Rx. Sparse Uniform Linear Array (ULA) configurations of 16 microstrip patch antennas are arranged in azimuth and 4 element of Minimum Redundancy Array (MRA) is considered for elevation. A sparse 86-by-7 Uniform Planar Array (UPA) for measuring three-dimensional (3D) high angular resolution is achieved by using Multiple-In Multiple-Out (MIMO). Calibration and near field applications become very challenge topics for these kinds of radar system with very large aperture. This paper presents an algorithm of near field phase correction for cascaded radar imaging. The phase errors among MIMO virtual channels are modeled and compensated. Near field radar imaging is generated by beamforming approach, where the results are compared with and without using the optimized phase correction algorithm. The complexity and performance of the proposed near field correction algorithm are analyzed and evaluated by simulated data and real scene test.

2) Analysis of the impact of aircraft maneuvers and atmospheric conditions on the quality of clutter suppression in Space-Time Adaptive Processing

Błażej Ślesicki[1], Anna Ślesicka[1], Adam Kawalec[2], Małgorzata Żmigrodzka[1]

[1]Lotnicza Akademia Wojskowa, Poland; [2]Wojskowa Akademia Techniczna, Poland

Space-time adaptive processing (STAP) of signal is a modern signal processing technique applied to radar systems. The STAP technique is used for the detection of objects moving on the ground through a airborne radar. STAP is designed to filter out echoes from interference sources and preserve the signal coming from the object of interest. The article presents the problem of the influence of aircraft maneuverability and, at the same time, the influence of atmospheric conditions on the quality of clutter filtering in the received echo signal using STAP. The paper presents a model of STAP signal processing for the aforementioned phenomena, while simulations performed confirmed the existence of the analyzed problems.

Tuesday 26.09.2023, 11.00 am – 12.40 pm, Room 30, SPS Medical.

Session Chairs: **Athina Petropulu and Zbigniew Świętach**

1) Applicaton of Bluetooth Low Energy 5 Technology in Wireless 12-Lead ECG Signal Transmission

Bartosz Nowak, Konrad Jędrzejewski, Warsaw University of Technology, Poland

The paper presents the results of experimental studies on the use of Bluetooth Low Energy 5 technology for wireless, real-time transmission of 12-lead electrocardiogram (ECG) recordings on mobile devices. To conduct

the experiments, a dedicated wireless ECG measurement system was developed using the evaluation boards: ADS1298RECGFE-PDK with ADS1298 chip for biomedical signal acquisition and nRF5340DK with nRF5340 System-on-Chip that employs BLE 5. The developed hardware and software enabled research on the practical measurement of the maximum achievable throughput of the wireless BLE-based channel and determination of the ECG sampling rate for which raw 12-lead ECG data can be transmitted wirelessly without losses under the assumed conditions.

2) Comparison of Effectiveness of Heart Rate Variability Indices in Differentiation of Atrial Fibrillation from Sinus Rhythm

Szymon Buś[1], Konrad Jędrzejewski[1], Przemysław Guzik[2]

[1]Warsaw University of Technology, Poland; [2]Poznan University of Medical Sciences, Poland

Recently, various heart rate variability (HRV) indices have been used to differentiate normal sinus rhythm (SR) from atrial fibrillation (AF). This study compared the effectiveness of different HRV indices for detecting AF using in 64,910 ECG segments of 60-second electrocardiograms (ECGs). Exactly 34081 SR and 33331 AF 60-second ECGs were analyzed. Based on the receiver operating characteristic analysis results and Youden's approach, we identified optimal cutoff values of HRV indices. Next, these HRV cutoffs were compared for their diagnostic properties using several classification measures, including sensitivity, specificity, and accuracy. The groups that demonstrated the most effective diagnostic properties were pRRx (percentage of differences between successive RR intervals greater than or equal to x ms), and pRRx% (percentage of relative RR interval differences greater than or equal to x%). The best area under curve (0.972), accuracy (95.3%) and diagnostic odds ratio (483) were found for pRR4%. This study highlights the potential of these HRV indices in detecting AF and could have significant implications for clinical practice.

3) Burnout-specific changes in brain activity (under way to Exhaustion)

Dmytro Harmatiuk[2], Sergii Tukaiev[1,3], Anton Popov[2], Mykola Makarchuk[3]

[1]Università della Svizzera italiana, Lugano, Switzerland; [2]Igor Sikorsky Kyiv Polytechnic Institute, Kyiv, Ukraine; [3]Taras Shevchenko National University of Kyiv, Kyiv, Ukraine

Burnout syndrome is one of the forms of chronic occupation stress. There is no single view on the nature and structure of emotional burnout. Boyko's psychological construct of Emotional Burnout (EB) defines Syndrome as a mechanism of psychological defense in the form of complete or partial excluding of emotions in response to traumatic influences and includes three key stages: Anxiety Tension, Resistance, and Exhaustion. The neurophysiological mechanisms of emotional burnout remain insufficiently studied. Establishing burnout-specific changes in brain activity is necessary to understand the phenomenon of burnout and distinguish it from other emotional mental disorders. Defining the EEG markers of burnout was our aim. 752 volunteers, first-fifth year students from the Taras Shevchenko National University of Kyiv aged 18 to 26 years participated in this study. EEG was recorded during the resting state (3 min, closed eyes condition) monopolarly using EEG 23-channel system Neurocom. To establish EEG correlates of emotional burnout during rest state we used a special software written in Python 3.6 to implement Power Spectral Density calculation, the interhemispheric and intrahemispheric average coherence and Detrended Fluctuation Analysis (DFA). We analyzed separate artifact-free EEG segments in all frequency bands from 0.2 to 45 Hz. Psychological testing was performed before the registration of EEG. To determine the formation of emotional burnout Boyko's

"Syndrome of emotional burnout" Inventory was used. The Exhaustion phase of emotional burnout was formed in 79 participants, and it was under development in 213 participants. In background EEG activity during the development of the Exhaustion phase of emotional burnoutvariations in EEG spatial synchronization were observed in low- and high-frequency EEG componentsand includes the formation of two separate networks of functional connections: interhemispheric prefrontal, anterior frontal, and frontal links (alpha and gamma low bands) and parietal-occipital links (alpha and gamma high bands). DFA describes the long-term temporal correlations in the cortex, which are involved in different aspects of brain functioning. We detected a high resting state DFA scaling exponent values (up to 0.90-0,95) under exhaustion development in the alpha 1 (left temporal, parietal area), alpha 2 (right frontal area), alpha3 (posterior regions). Obtained values of DFA exponent and average coherence suggest the exhaustion formation is accompanied by the changes in visual and verbal processing, emotional processes (discretion and analysis).

4) Beneficial effects of transcutaneous auricular vagus nerve stimulation on the emotional state and cognitive functioning: a pilot study

Sergii Tukaiev[1,2], Oleksandr Pravda[2], Sergiy Danylov[3], Viktor Komarenko[3], Nickolai Vysokov[4], Dauren Toleukhanov[4], Anna Tarasenko[4], Kristina Mashtalerchuk[2], Viktoriia Kravchenko[2], Mykola Makarchuk[2], João Miguel Alves Ferreira[5]

[1]Università della Svizzera italiana, Lugano, Switzerland; [2]Taras Shevchenko National University of Kyiv, Kyiv, Ukraine; [3]Beehiveor Academy and R&D Labs, Kyiv, Ukraine; [4]BrainPatch Ltd, Dublin, Ireland; [5]Universidade de Coimbra, Coimbra, Portugal

Vagus nerve stimulation as a modern effective method of neuromodulation produces therapeutic effects for the treatment of psychiatric disorders, neuralgia, heart failure, and others. Auricular vagus nerve stimulation reduces anxiety, alleviates stress and emotional burnout, and improves cognitive function. The objectives of the current study was to evaluate the effects of the non transcutaneous auricular vagus nerve stimulation (taVNS) and sham stimulation (SHAM) on emotional state, emotional burnout and and reveal a causal relation between taVNS and a related cognitive function. 6 right-handed male volunteers aged 18-22 years (Mage= 18.00) participated in taVNS study. 5 right-handed male volunteers aged 18-22 years (Mage= 18.00) participated in SHAM study. We used the combination of pleasant meditative classical music and a slow bi-polar wave (0.1-0.2 Hz) of electrical non-invasive transcutaneous auricular vagus nerve stimulation for 5 minutes. The set of 4 VNS was performed at intervals of 3 days. EEG was registered during the rest state before and after of taVNS (3 min, closed eyes condition). To measure the severity of emotional burnout in students, we used the 22-item Maslach Burnout Inventory (MBI). To determine the development of short-term memory we used 2 computer subtests. taVNS attenuated emotional burnout (the depersonalization and reduction of personal achievements). The results of the test indicate the improving effect of the set of VNS on short-term memory. Changes in the psychoemotional state of the respondents were accompanied increasing in the ratio of beta /alpha rhythms, the theta-Fz/alpha-Pz ratio that reflects an enhancement of the activation level, the amount of brain resources involved in processing the perceived information. The observed increase in the power of the alpha rhythm may relate to improving of mental process and internally oriented attention in creative activities. A higher left frontal activity under the cognitive test points to a positive emotional attitude toward the task. The detected focus of beta, gamma, and theta activities in the vertex (Cz) reflected the effect of taVNS on learning at the level of the sensorimotor cortex. Activation of the right dorsolateral prefrontal cortex reflects the taVNS effect on the attention processes. The increase in the theta activity in the left occipital cortex indicated the involvement of the visual cortex. The obtained data suggests that the taVNS have a

prolonged beneficial effects of emotional state and stimulating effect on the brain processes, enhancement of the cognitive process.

5) Spectral and topographic analysis of reaching movement regulation mechanism

Anton Vavreshchuk[2], Anton Popov[2], Igor Zyma[3], Valeriya Gritsenko[4], Sergii Tukaiev[1,3]

[1]Università della Svizzera italiana, Lugano, Switzerland; [2]Igor Sikorsky Kyiv Polytechnic Institute, Kyiv, Ukraine; [3]Taras Shevchenko National University of Kyiv, Kyiv, Ukraine; [4]West Virginia University, Morgantown, USA

Movement is the result of the implementation of brain's processes controlling the performance of the limbs and providing the integration of complex sensory information. It is unclear whether different neural mechanisms are involved in the temporal processing of movement initiation and termination. A study of the encoding of temporal information for the initiation and termination of arm movements using event-related potentials (ERPs) found that activity in the premotor area was significantly lower before initiation and cessation of arm movements in response to time-predicted compared to unpredictable stimuli. The aim of this study was to detect the sequence of brain processes during movement and to determine the topological characteristics of movement regulation mechanisms. To establish EEG correlates of voluntary movement we analysed the entire period of performance of an external (motor) task that was divided into several successive stages: interstimulus interval, the appearance of the goal and the beginning of movement towards it, implementation of movement towards the goal, achievement of the goal, its disappearance as a signal to move back, backward movement to the starting position and stopping the movement. EEG analysis allowed identifying the informational and nodal points of movement formation. We supposed that differences in the EEG curves of brain activity are reflecting the specifics of right/left-hand movement, adjustment-correction of movements for the right hand and a weaker one for the left. The movements of the right hand are more automated and less prone to downward control (from the frontal cortex, associative and sensorimotor areas). It should be stressed that the energy consumption in the case of left-hand movement should be large for right-handed subjects.

Tuesday 26.09.2023, 3.40 pm – 5.20 pm, Room 50, SPS Passive Radar.

Session Chairs: **Diego Cristallini and Mateusz Malanowski**

1) Passive Bistatic Radar for space target detection using the GRAVES radar as an illuminator

Kacper Jan Piekutowski, Piotr Samczyński, Warsaw University of Technology, Poland

The main goal of this work was to develop a demonstration passive radar system for observing objects at low Earth orbit with use of French radar GRAVES (from French Grand Réseau Adapté à la Veille Spatiale). With use of relatively inexpensive setup (Yagi antenna and simple SDR (Software Defined Radio) an attempt was made to receive signals reflected from International Space Station. Additional analysis was performed with aid of MATLAB environment and its Satellite Communications Toolbox to confirm detection. Two methods were examined and applied to received and recorded signals: matched filtering and ACCF (Adjacent Cross-Correlation Function). They were used to improving reception capabilities and deducing additional information about received pulses, with mixed results.

2) Multi Tx and Multi Rx Passive Radar Demonstrator with Limited Number of Receiving Channels

Elżbieta Kałamajska, Marcin Bączyk, Łukasz Maślikowski, Warsaw University of Technology, Poland

In this paper, the method of utilizing laboratory equipment for passive wideband measurements was presented. The problem of a limited number of receiving channels is addressed and a solution based on offline processing is proposed. This paper develops the topic such as signal synchronization, receiver - transmitter distance differences compression and signal channelisation The proposed method is verified by applying a signal processing chain for detecting and tracking targets. The performance of obtained tracks is analyzed.

3) Polynomial-Based Detector for Passive Radar Operating in The DVB-T Band

Marek Ciesielski, Warsaw University of Technology, Poland

The paper presents an alternative solution for target detection in a DVB-T passive radar. A method of modelling the crossambiguity function using a two-dimensional polynomial was proposed and tested in simulations and measurements.

4) Multilook processing scheme in DVB-T based Passive SAR applications

Pedro Gomez-del-Hoyo, Piotr Samczynski, Damian Gromek, Warsaw University of Technology, Poland

In this paper, digital video broadcasting (DVB-T) transmitters are considered for passive SAR imaging of ground scenarios. A multilook processing scheme is proposed to reduce image noise, to improve the interpretation of the radar image and to make possible the correct detection and area delimitation of scattering targets in the radar scene. A measurement campaign was carried out to analyse and validate the proposed processing scheme. A DVB-T based passive radar was mounted in an EADS CASA C-295M aircraft to generate the synthetic aperture of the receiver. The acquired data was processed under different passive imaging configurations to analyse the radar image quality improvement of multilook processing scheme. Results show the reduction of image noise and the high increase of targets boundaries identification that can be used as a starting point for carrying on further passive SAR scattering characteristics analysis.

Tuesday 26.09.2023, 3.40 pm – 5.20 pm, Room 30 SPS AI/ANN

SPS Artificial Intelligence, Artificial Neural Networks.

Session Chairs: **Ivan Seleznov and Zbigniew Świętach**

1) Complexity reduction of ANN model for CU size selection in HEVC

Mateusz Henryk Lorkiewicz[1], Olgierd Stankiewicz[1], Marek Domański[1], Hsueh-Ming Hang[2], Wen-Hsiao Peng[2]

[1]Poznan University of Technology, Poland; [2]National Chiao Tung University, Taiwan

In HEVC, compression is performed in Coding Units (CUs) being pixel blocks of a size adaptively chosen according to the content. Flexible selection of CUs size is done via hierarchical partitioning. A large number of partitioning schemes are available and an efficient choice among them is crucial for the implementation of high-performance, energy-efficient encoders. In this paper we consider ANN model as a suitable solution in terms of performance-quality-time trade-off. The paper describe an new version of ANN architecture for

Division Matrix estimation, such as in [1], which enables usage of smaller model in terms of number of weights and required computational resources. Proposed solution increases efficiency of the training process and allows usage of lesser amount of convolution filters in network layers what makes the model more efficient. This gain is attained while sustaining encoding performance comparable to solutions known from literature.

2) Influence of Feature Scaling and Number of Training Sessions on EEG Spectral-based Person Verification with Artificial Neural Networks

Renata Plucińska[1], Konrad Jędrzejewski[1], Urszula Malinowska[2], Jacek Rogala[2]

[1]Institute of Electronic Systems, Faculty of Electronics and Information Technology, Warsaw University of Technology, 00-665 Warsaw, Poland; [2]Institute of Experimental Physics, Faculty of Physics, University of Warsaw, 02-093 Warsaw, Poland

Research on using EEG as a biometric began over 20 years ago. However, compared to more traditional modalities like fingerprints, EEG is still relatively novel. Further studies on larger databases are necessary to properly verify proposed methods, accounting for temporary fluctuations in the EEG signal. The paper focuses on the impact of methods of feature scaling on the efficiency of EEG spectral-based person verification using artificial neural networks. For our research, we used signals collected from 29 individuals, with 20 recording sessions each performed on different days. Having such a database, the influence of a number of training sessions on the verification results was also investigated. We tested various methods for scaling estimates of power spectral density coefficients and obtained the best results after converting them to the decibel scale.

3) Algorithm and Processor Architecture for the Implementation of the Minimum Filtering Technique in Complex-valued CNNs

Aleksandr Cariow, Janusz Papliński, West Pomeranian University of Technology, Poland

In this paper, we present a resource-efficient algorithmic solution regarding the fully parallel hardware implementation of the basic filtering operation performed in the complex-valued convolutional neural networks (CNNs). In fact, this basic operation computes the inner products of adjacent complex-valued vectors formed by a sliding time window from the current data stream with the impulse response vector of a 3- tap finite impulse response (FIR) filter. We adapt Winograd's minimal filtering algorithm for a case of the complex-valued data and applied it to develop a fully parallel hardware oriented algorithm for implementing basic filtering operations in complex-valued CNNs. We also additionally apply the well-known Gauss's trick for multiplying complex numbers, which replaces 4 multiplications and 2 real additions with real 3 multiplications and 3 real additions. A general view of the architecture of the processor unit for the implementation of this operation is also given. A fully parallel hardware implementation of the proposed processor unit provides 50% savings in the number of embedded multipliers compared to a fully parallel hardware implementation of the naive calculation method.

4) Detecting Drones at an Entrance to a Bee Hive Based on Audio Signals and Autoencoder Neural Networks

Urszula Libal, Paweł Biernacki, Wroclaw University of Science and Technology, Poland

Detecting a large number of drones at the entrance of a beehive in the late Spring, may be one of the signs of swarming, since the peak of a drone number is correlated with the overcrowded hive. Swarming is a natural method of reproduction observed in honey bees when half of the bee colony leaves their hive with an old queen. This is a potentially dangerous situation, as the queen and the part of the colony may escape. To prevent this, we propose an early swarming detection system based on the behaviour of drones near the hive entrance. The system analyzes sound signals recorded at the entrance of the hive by an autoencoder neural network to detect drones. Simulations using real signals have shown that it is possible to effectively detect drones based on audio signals only. The achieved detection accuracy makes it possible to create an effective alarm system for beekeepers.

Wednesday 27.09.2023, 9.00 am – 10.40 am, Room 50, SPS Signal Proc. 1.

Session Chairs: **Ewa Świercz and Sankar Basu**

1) Development of HFB with the use of 2'nd order pass-band filters

Zbigniew Świętach, Bogusław Szlachetko, Wroclaw University of Science and Technology, Poland

Systems using hybrid filter banks (HFB) are an attractive solution, but so far they have not been used in practice. This is related to the complication of the analogue part, which creates an analysis filter bank (AFB). Striving to meet the conditions of perfect reconstruction in the entire operating band of the HFB structure forces the need to develop AFB with the use of higher-order analogue filters and additionally special phase shifters. As a result, the analogue part reaches a degree of complexity that significantly hinders hardware implementation. Moreover, the repeatability and stability of the HFB structure become hard to reach. The article analyses the possibility of using simple 2'nd order analogue filters without any additional elements. The presented theoretical analysis of the issue indicated that there is such a possibility. In this case, however, one should agree to put additional guard bands at the beginning and the end of the HFB system band of interest.

2) Multiple Scanning Order in Fast Depth Estimation Algorithm

Hubert Zabinski[1,2], Krzysztof Wegner[1], Olgierd Stankiewicz[2]

[1]Mucha sp. z o.o,; [2]Poznan University of Technology

Fast algorithms for stereoscopic depth estimation typically employ a processing of the input images in a Single Scanning Order (SSO). In this paper we present a novel approach which employs processing in Multiple Scanning Orders (MSO), which are then merged together into a final depth map. We demonstrate the advantages of the proposal on the example of fast depth estimation technique, adaptable both for mobile platforms and FPGA. We show that application of the proposal leads to considerable quality improvement at the acceptable complexity cost

3) A branch and bound scheme for near-field broadband beamforming problem

Agnieszka Katarzyna Wielgus, Bogusław Szlachetko, Wroclaw University of Science and Technology, Poland

In beamforming one of the main issue is to determine a microphone configuration, i.e. the microphone number and their position. In practice, a big microphone arrays can be used and they can be adjusted to the given

environment through the thinning approach: only a part of microphones is active and take part in beamforming. The problem of choosing a set of active microphones is a nonlinear and non-convex NP- hard optimization problem. It means that there does not exist a polynomial-time algorithm that solves this problem optimally. To solve such a problem exact methods (e.g. exhaustive search) or heuristics can be used. However, for this problem, during an exhaustive search 2^n possible solutions have to be checked. Such computational complexity makes it impossible to be used for real-life applications. On the other hand, heuristic approaches can provide a good quality solutions, however we do not know if it is an optimal one or we do not know how far the provided solution is from the optimal one. The recently proposed solution methods are based on metaheuristics and on Taguchi method. In this paper we provide and examine an exact algorithm based on branch and bound approach. In branch and bound solution set is divided into smaller subsets and some of them are excluded from further consideration, since we know, they do not contain an optimal solution. This method significantly reduces computation time.

Wednesday 27.09.2023, 9.00 am – 10.40 am, Room 30, SPS CommLoc.

Session Chairs: **Patrick Dewilde and Urszula Libal**

1) 5G NR Based Passive Radar-on-Demand Using Channel Impulse Response Estimate

Tomasz P. Zieliński, Marek Wypich, AGH University of Science and Technology, Poland

In order to recover transmitted bits most receivers have to estimate the channel impulse or frequency response and equalize the channel influence. In multi-path fading channels with Doppler effect the samples of channel impulse response (CIR) oscillates with Doppler frequencies. It is shown in the paper that CIR estimates calculated by means of 5G NR waveform inside the 5G NR receiver can be used for remote sensing purposes, e.g. finding distances and velocities of object/vehicles moving in the receiver neighborhood. It is shown in the paper that appropriately configured standard Channel State Information (CSI) Reference Signal (RS), used in 5G, allows such environment sensing. In order to increase radar functionality some OFDM symbols in 5G frames can be entirely or partly used as additional pilots, i.e. object illuminators. This gives possibility of creating a completely new 5G NR utilization, which can be called a radar-on-demand (RoD). In the paper results from simulational testing of this idea are presented for different pilot configurations and different frequency estimation methods.

2) Two-Stage Overlapping Algorithm for Signal Doppler Frequency Location Method

Rafał Szczepanik, Jan M. Kelner

Military University of Technology, Faculty of Electronics, Institute of Communications Systems, Poland

Localization techniques of radio emitters are widely used in civil and military applications. In civilian systems, the positioning of user equipment in mobile networks is one of the basic functionalities on which many modern telecommunications services are based. In military systems, the location of radio emitters is one of the main tasks performed by reconnaissance and electronic warfare systems. For these latter, the signal Doppler frequency (SDF) method was developed. SDF allows the emitter localization by a single sensor. In this method, the radio signal processing technique is based on an overlapping algorithm, which was introduced two years ago. In this paper, we present a novel two-stage overlapping algorithm, which relates to the

processing of IQ radio signal samples and then to a data vector with determined Doppler frequency shift values. The proposed solution ensures greater accuracy in positioning the emitter using the SDF.

3) Frequency Stability Evaluation of SDR Platforms Concerning their Use in Doppler-based Location Method

Kacper Bednarz, Jarosław Wojtuń, Jan M. Kelner

Military University of Technology, Faculty of Electronics, Institute of Communications Systems, Poland

Signal Doppler frequency (SDF) is one of the methods for locating radio emitters, which is based on the Doppler effect. In this case, the SDF accuracy is closely related to the accuracy of determining the Doppler frequency shift. Therefore, ensuring high frequency stability of the software-defined radio (SDR) platform, which is used int the location sensor, plays an important role. In this paper, we explore several widely-available SDR platforms that could use in that sensor. Based on the accuracy of instantaneous frequency measurement over time, we evaluate the frequency stability parameter of each SDR platform. We conduct tests as a function of time for various environmental conditions.

4) Autonomous mobile system for detecting and jamming cellular network signals using a software defined radio integrated into a UAV platform

Paweł Skokowski, Jan Dułowicz, Military University of Technology, Poland

The article presents a built-up model of a system for detecting and jamming radio communication in 2G / 3G / 4G / 5G cellular systems installed on an Unmanned Aerial Vehicle (UAV). The proposed approach was built according to a modular concept to increase its reliability, ease of changing individual components, possible quick technological upgrade, and accessible porting equipment to various mobile platforms. All used elements are the Commercial Off The Shelf (COTS) type. The used platform is a UAV that provides several advantages for the proposed solution, such as very high mobility, remote work, and the possibility of autonomous flight. All components have been integrated, and the developed proprietary application is used to define the mission's parameters and illustrate the current electromagnetic environment situation for the monitored frequency band of cellular systems. The proposed system can be included in the military operational and reconnaissance solutions category. After a short introduction and justification of the work undertaken, the developed concept, components of the proposed system, and then the solution implementation was presented. The research was conducted for the selected test scenario, which was used to develop conclusions and plan further work to develop a jammer operating in a smart manner

5) Close-Distance Optical Flow Fusion Using EKF for Multirotor UAV Position Estimation

Jędrzej Benedykt Szczepaniak, Bogusław Szlachetko, Politechnika Wrocławska, Poland

This paper proposes the use of close-distance optical flow measurements to enhance Extended Kalman Filter (EKF) position and velocity estimation accuracy of Unmanned Aerial Vehicle (UAV) with the use of existing infrastructure in a GPS-denied environment. The scenario assumed in this project involves a UAV navigating through a mine shaft with a central steel cable that passes through the shaft's centre. The UAV has a special design with a hole in the centre allowing it to fly up and down while maintaining the central cable in its geometric centre. The UAV is equipped with a camera facing parallel to the cable at a close and constant

distance. By utilizing optical flow algorithms, we can estimate the UAV's vertical velocity. Using the EKF filter, we aim to integrate these velocity measurements with existing measurements from the Inertial Measurement Unit (IMU), magnetometer, and barometer, to improve the accuracy of the UAV's vertical velocity and height measurements.

Wednesday 27.09.2023, 11.00 am – 12.40 pm, Room 50, SPS Signal Proc. 2.

Session Chairs: **Damian Gromek and Olivier Adam**

1) An interesting new problem in stochastic modeling (Keynote Speech)

Patrick Dewilde, TUM, Belgium

This presentation addresses the modeling of a non-Gaussian stochastic process based on a fully ordered sequence of measurement of moments or correlations. To do so, it uses recent results in the parametrization of all the moment generating functions that interpolate the given or measured correlation data. While the parametrization problem appears to be adequately solved, the crucial numerical determination of the resulting cumulative probability function (cpf) or probability density function (pdf) appears to be a new interesting but unsolved problem, even in the single variable case. The talk introduces the problem and its background, hoping to provide motivation for further research.

2) RANSAC as a Method for Reliable Line Identification for Efficient Estimation of the Instantaneous Frequency Rate

Ewa Świercz, Dariusz Jańczak, Krzysztof Konopko, Bialystok University of Technology, Poland

The random sample consensus (RANSAC) is applied as an effective approach for parameter estimation in case of presence of outliers. The CPF-RANSAC estimator is proposed and evaluated on signals embedded in high noise. Cubic phase function (CPF) is the distribution used for an efficient estimation of instantaneous frequency rate (IFR) for non-stationary signals with polynomial phase of the third order, called cubic phase (CP) signals. The most popular polynomial phase signals (PPS) are signals with the polynomial phase of the second order i.e., signals with linear frequency modulation (LFM). In real environment LFM signals are frequently distorted by additional third order component, what results in CP signals. Such signals appear as a line on the Time-Instantaneous Frequency Rate (T-IFR) plane, the parameters of which depend on the phase parameters of the signal. Thus, the problem under consideration concerns line estimation in a T-IFR plane. The IFR estimates are obtained by searching maximum of the CPF representation. Then the hbox{CPF-RANSAC} strategy randomly selects a subset of data samples obtained from the CPF distribution of signals and uses them to estimate parameters of line. Optimal fitting to the line is obtained by selection of points based on the maximum likelihood (ML) estimation.

3) Low-complexity algorithms for trinion-based digital signal processing

Aleksandr Cariow, West Pomeranian University of Technology, Poland

This paper continues a series of publications devoted to low-complexity digital signal processing (DSP) algorithms using hypercomplex number systems. As in the previous cases, we are talking about three basic

digital signal processing operations: the operation of multiplying two hypercomplex numbers, the operation of the dot product of two hypercomplex-valued vectors, and the operation of multiplying a hypercomplex number by a set of several other hypercomplex numbers. However, unlike the previous cases, the new algorithms use trinions as the underlying hypercomplex number system. To reduce the computational complexity of these operations, it is proposed to use the fast circular convolution algorithm, well known in digital signal processing. Using this algorithm reduces the number of multiplications and additions of real numbers required to perform calculations. Thus, the use of the proposed algorithms will speed up calculations in DSP applications using trinions.

4) Reducing the impact of fundamental frequency on the HFCC parameters of the speech signal

Stanisław Marek Gmyrek, Robert Hossa, Ryszard Makowski

Wroclaw University of Science and Technology, Poland

The voiced parts of the speech signal are shaped by glottal pulse excitation, the vocal tract, and the speaker's lips. Semantic information contained in speech is shaped mainly by the vocal tract. Unfortunately, the quasiperiodicity of the glottal excitation, in the case of HFCC parametrization, is one of the factors affecting the significant scatter of the feature vector values by introducing ripples into the amplitude spectrum. This paper proposes a method to reduce the effect of the quasiperiodicity of the excitation on the feature vector. For this purpose, blind deconvolution was used to determine the vocal tract transfer function estimator and the corrective function of the amplitude spectrum. Then, based on the obtained HFCC parameters, statistical models of individual Polish speech phonemes were developed in the form of mixtures of Gaussian distributions, and the influence of the correction on the quality of classification of speech frames containing Polish vowels was investigated.

Wednesday 27.09.2023, 11.00 am – 12.40 pm, Room 30, SPS SAR/ISAR.

Session Chairs: **Fabrizio Berizzi and Marcin Bączyk**

1) High Resolution FMCW SAR Imaging Based on Compressive Sensing Framework

SREELAKSHMI SOWJANYA LANKA[1], NAGARAJU L[2], KISHORE KUMAR PULI[3]

[1]National Institute of Technology Andhra Pradesh, India; [2]National Institute of Technology Andhra Pradesh, India; [3]National Institute of Technology Andhra Pradesh, India

In this paper, we introduce a new Compressive Sensing (CS) based synthetic aperture radar (SAR) imaging algorithm which provides a high-resolution. Imaging a target or scene is one of the most important applications of Synthetic Aperture Radar. Conventional imaging algorithms sometimes produce higher sidelobe levels in the resultant image which further need to be suppressed to get finer resolutions and these algorithms require high storage capacity to generate High-resolution images. In this scenario, we propose a Frequency Modulated continuous wave (FMCW) radar which is the better choice in SAR imaging technology due to its hardware simplicity and low cost. Initially, the FMCW SAR imaging problem is defined as a CS problem and imaged using the OMP algorithm. Here, conventional Back projection, and OMP algorithms were compared in terms of image quality. Later introduced a Modified OMP algorithm (M-OMP) for SAR imaging to get highly

focused target images to achieve good resolution. From the results, it is observed that the proposed algorithm is showing clearer target images with good resolution than the conventional imaging methods.

2) Usage of ray tracing technique for ISAR Simulations

Michał Jan Bartoszewski, Warsaw University of Technology, Poland

This paper describes the results of ISAR simulations using the ray tracing technique. This technique allows for a more accurate portrayal of reality by computer simulations. Due to its computational complexity, it is not often used because of very long simulation times. Usage of this technique allows for precise calculations of target surfaces visible by the transmitter and receiver. This paper will show differences between ISAR simulations taken without a ray tracing module, with a ray tracing module, and real-life measurements.

3) Range and height estimation methods for ISAR imaging

Jakub Jerzy Sobolewski, Warsaw University of Technology, Poland

This paper presents a technique for uncooperative target range and height estimation, using a method adopted from SAR imaging called PGA (Phase Gradient Algorithm) for range estimation and a method proposed by the author for target height estimation. Simulation and real data examples are presented. The goal of this article is to suggest the future possibilities of very accurate trajectory estimation.

4) Anomaly Detection using Variational Autoencoder in SAR Images

Sandhi Wangiyana, Warsaw University of Technology, Poland

Monitoring large areas to detect unexpected changes is beneficial in disaster response preparations, particularly when using a persistent information source such as Synthetic Aperture Radar (SAR) images. However, the complexity of radar images makes it difficult to select features that differentiate relevant and irrelevant changes. In this research, a Variational Autoencoder (VAE) was trained in a self-supervised way to learn meaningful representations of the multitemporal SAR dataset. The embeddings from adjacent timeframes were then compared using a distance function to quantify the degree of change. The distance in the latent space highlights relevant and irrelevant changes better than the distance in the data space using direct pixel values.

Wednesday 27.09.2023, 3.20 pm – 5.00 pm, Room 50, SPS Radar 2.

Session Chairs: **Maciej Janusz Lopatka and Karol Abratkiewicz**

1) Keystone Transform in Low PRF FMCW Radars

Marcin Bączyk, Warsaw University of Technology, Poland

The article presents a modification of the algorithm for determining the cross-ambiguity function based on the Keystone transformation. The applied change allows for the correct focusing of fast targets with low pulse repetition frequency. The presented algorithm was developed in particular processing Frequency Modulated Continuous Wave signals, where the pulse repetition frequency is limited due to the radar's maximum range.

2) Impact of pulse width parameter on the bias of the CRLB model in MIMO radar

Neda Rojhani[1], Marco Passafiume[2]

[1]University of Calgary; [2]Radar and Surveillance System (RaSS) Laboratory, CNIT,Pisa

This paper deals with the effect of pulse width parameter on Cram´er-Rao Lower Bounds (CRLB) model reliability for a widely distributed pulsed signal MIMO radar. When a model is incorrectly defined, it leads to an increase in CRLB estimation, yielding it useless as an instrument for defining system design parameters. The purpose of this study is to provide a theoretical description of such model biasing effect, particularly when dealing with a moving target, as well as to introduce practical conditions on the pulse width parameter to reduce the latter and overcome reliability reduction. The simulation results validate the theoretical description while also demonstrating the effectiveness of proposed conditions to reduce the bias effect.

3) Comparison of pulse compression algorithm implementations on various hardware platforms

Mateusz Dróżka, PIT-RADWAR, Poland

This paper presents the preparation and results of the comparison of two implementation methods for matched filtering (pulse compression) algorithm for air defense radar. First method uses the General Purpose computing on Graphics Processing Unit (GPGPU) technique in the form of the NVIDIA CUDA platform. The second method is based on computing with Intel's Central Processing Unit (CPU) and Advanced Vector Extension (AVX) instructions. Both ways have your own advantages and disadvantages and the purpose is to determine the possibilities of two implementation approaches.

Wednesday 27.09.2023, 3.20 pm – 5.00 pm, Room 30, SPS Communiations.

Session Chairs: **Tomasz P. Zieliński and Urszula Libal**

1) Impact of Uplink Traffic on 5G-based Passive Radar

Radosław Maksymiuk, Karol Abratkiewicz, Piotr Samczyński, Warsaw University of Technology, Poland

Several pioneering works present experimental results of 5G-based passive radars. In those works, the illumination source is a signal transmitted by the 5G base station (simulated and real-life). Therefore the uplink (UL) signal (transmitted from user equipment to the base station with a time division duplex (TDD)) was considered a source of interference and was cut to achieve successful target detection. This work presents an in-depth analysis of the impact of the uplink signal on the performance of the 5G-based passive radar. The study shows that in most scenarios, the implications of uplink traffic are insignificant, which is a valuable conclusion considering the real-time implementation of the 5G-based passive radar. It is shown that skipping the step of uplink cancelation in the TDD 5G network-based passive radar results in significant computational complexity reduction. The simulations were carried out under various conditions, including the different instantaneous amounts of resources allocated in both directions of wireless network traffic and the distance from the radar receiver to the base station and the user equipment. The experimental validation (using the real-life 5G signals) of the conducted research proved the simulation results.

2) Channel Estimation and Equalization in OTFS Transmission System with Random-Padding

Pavel Karpovich[1,2], Tomasz Zielinski[1]

[1]AGH University of science and technology, Poland; [2]Nokia Solutions and Networks

Since high Doppler frequency shifts destroy sub-carrier orthogonality of the Orthogonal Frequency Division Multiplexing (OFDM), which is typically used in multi-carrier communication, its application is very difficult in high mobility scenarios due to occurring problems with channel estimation and equalization. For this reason the Orthogonal Time Frequency Space (OTFS) modulation has been developed recently for data transmission in a mobile Rayleigh fading channel with strong Doppler effect. In contrary to OFDM, for the OTFS channel estimation and equalization in such case is still possible although not straightforward. In this work this issue is deeper analyzed in the context of OTFS communication systems with random padding, recently introduced by us, which can be jointly used as passive radar. Influence of different parameters of the pro-posed channel estimation procedure as well as several channel equalization approaches, e.g. 1-tap, maximum-ratio combining (MRC), linear minimum mean square error (LMMSE) and some others, upon the achievable transmission bit error rate (BER) is investigated via simulation for 3GPP extended vehicular A model (EVA) and high-speed train (HST) channels

3) Correlational Analysis in QoS Parameter Assessment for 5G Emerging Networks in Poland

Dariusz Zmysłowski, Jan M. Kelner

Military University of Technology, Faculty of Electronics, Institute of Communications Systems, Poland

In this paper, we present a preliminary correlation analysis of quality of service (QoS) metrics for the upcoming fifth-generation (5G) network. This assessment was made based on drive-test measurements carried out in an urban environment for all four operators operating in Poland. The measurements were made by a professional company that assesses the quality and availability of mobile services. Our analysis is based on a Pearson correlation coefficient (PCC), which illustrates the similarities degree between two metrics. Typically, the PCC values for the two selected QoS parameters are small, i.e., the parameters are not linearly correlated. Therefore, in further analysis, we look at the distribution of parameters to indicate a non-linear relationship between them.

4) Algorithm for Determining Propagation Attenuation Maps based on Truncated Terrain Profiles

Michał Kryk, Krzysztof Malon, Jan M. Kelner

Military University of Technology, Faculty of Electronics, Institute of Communications Systems, Poland

Radio environment maps (REMs) are used to manage radio networks, e.g., mobile ad-hoc networks (MANETs). In this case, network nodes typically use software-defined and cognitive radio technologies. In previous works, we proposed an algorithm for creating the propagation attenuation map (PAM) based on the parabolic equation method (PEM). PEM allows determining the attenuation distribution along the selected terrain profile, which is taken from the digital terrain elevation data (DTED) for a specific transmitter location. PAM as an REM element is used to assess the radio ranges of individual MANET nodes. The developed PAM algorithm is based on terrain profiles determined radially from the transmitter position. This approach resulted

in a high density of terrain profile points near the transmitter and simultaneously multiple attenuation determinations for the same terrain points. Therefore, in this paper, we propose modifications to the PAM algorithm based on truncated terrain profiles. This approach reduces the time of performed calculations and PAM determination.

5) Direct Sequence Spread Spectrum-based Radio Steganography

Mateusz Wróbel, Zbigniew Piotrowski, Jan M. Kelner

Military University of Technology, Faculty of Electronics, Institute of Communications Systems, Poland

Direct sequence spread spectrum (DSSS) is a spread-spectrum modulation technique primarily used to reduce overall signal interference. DSSS is one of the so-called secondary modulation techniques, which makes the transmitted signal wider in bandwidth than the information bandwidth. On the other hand, this technique allows the transmitted information signal to be hidden in the noise. Thus, DSSS signals are classified as low probability of intercept/low probability of detection (LPI/LPD). DSSS modulation is also used in data hiding for both radio and audio signals. In this case, the DSSS-based steganography algorithms used various information-hiding mechanisms, e.g., modulation parameter modification. In the novel solution proposed in this paper, we use DSSS with variable processing gain to keying additional-information. In this case, the hidden message is transmitted in a switching order of spreading sequences taken from a dictionary known only to the notified parties.

Thursday 28.09.2023, 9.00 am – 11.00 am, Room 50, SPS ImpAndHW.

Session Chairs: **István Balajti and Jacek Misiurewicz**

1) Stability of Clock Frequency Offset Measurements and Synchronization in UWB devices

Josef Krška, Václav Navrátil, Czech Technical University in Prague, Czech Republic

UWB positioning combines time measurements from several devices to estimate the position of a target device. These measurements, however, are expressed in the device's own timescale that is derived from its free running clock source, generally a~crystal oscillator. The timescales are inherently offset and with different and time-variant drift, both of which have to be compensated during the estimation. With the coherent IR-UWB chips it is possible to measure the drift either directly (Carrier Frequency Offset) or indirectly with timestamps. This work provides the stability analysis of such measurements as well as the characterization of the noise that affects them. From the results the usability of drift measurement methods for synchronization and positioning is inferred.

2) Removal of Training Signals in Synchronized Multi-Channel PCL Receiver

Gustaw Mazurek, Warsaw University of Technology, Poland

In this paper we describe a method to remove the training sequences from the recorded signals and validate it on a real signals acquired during APART-GAS field trials in Poland in 2019. We show that after filtering out the training sequences, the useful components coming from a DAB illuminator remain untouched by the proposed

method. This allows us to perform successful PCL detection also on the modified parts of the signal which have so far been disturbed by the training sequences.

3) Evaluation of X-band Up/Down Converter Design for Pulse Radar Application

Krzysztof Stasiak, Piotr Krysik, Grzegorz Pietrzykowski, Jakub Julczyk, Łukasz Maślikowski

Warsaw University of Technology, Poland

This paper presents the evaluation of the X-band frequency converter design for the pulse radar system based on the Radio Frequency System-on-Chip (RFSoC) module. Two hardware implementations are being compared - Commercial-Off-The-Shelf (COTS) and the solution based on a dedicated Printed-Circuit-Board (PCB). The advantages and disadvantages of both approaches are shown in terms of achievable parameter ranges, mechanical properties, fields of application, and scalability. A general comparison of the UDC performance is analyzed. The developed hardware has been validated within the real-life radar system in a laboratory; thus, the signal processing results are also covered.

4) Positioning and orientation of a virtual robotic arm based on real sensor data in the LabVIEW environment focused on the forward and inverse kinematic analysis of motion

Gyula Korsoveczki, János Huszenicza, István Balajti, University of Debrecen, Hungary

The paper analyzes the motion of a six-degree-of-freedom (6 DoF) simulated robotic arm using an analog accelerometer (GY-61) sensor, and then evaluates the forward and inverse kinematic possibilities of the robotic arm. The model of the robotic arm was developed in a 3D design program, while the values of the accelerometer sensor were read by a NI USB-6001 data acquisition card. NI LabVIEW software (LVS) realizes a connection between the data acquisition card and the modeling program. LVS uses three modules: NI DAQmx, LabVIEW SoftMotion and LabVIEW MathScript. Ni DAQmx is a driver that recognizes and manages the data acquisition card. The SoftMotion module establishes communication between LabVIEW and the 3D designer program. The MathScript module performs kinematic calculations and enables text programming with the same syntax as Matlab. The calculated results record positions of the robot and evaluate the measured results.

5) Quarter car suspension state space model and full state feedback control for Real-Time Processing

Károly Árpád Kis, Gyula Korsoveczki, Kornél Sarvajcz, Péter Korondi, István Balajti

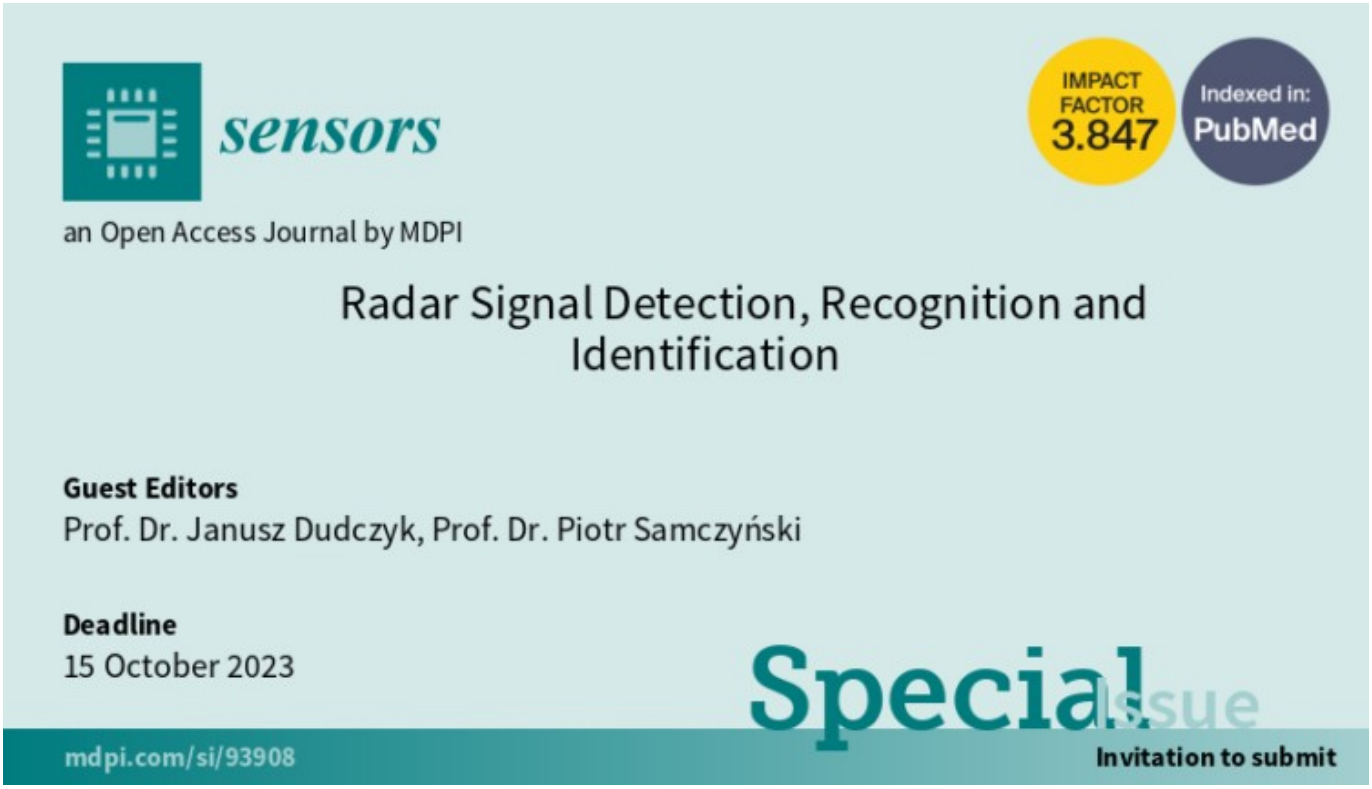
University of Debrecen, Hungary

This paper presents the examination of the suspension of a quarter car model from the point of view of observability and controllability. The modeling of an active suspension with full state feedback control and the design of a state observer is planned to be used for real-time processing of the university's self-driven vehicles under development.

The SPSympo 2023 Publications - Special Issue

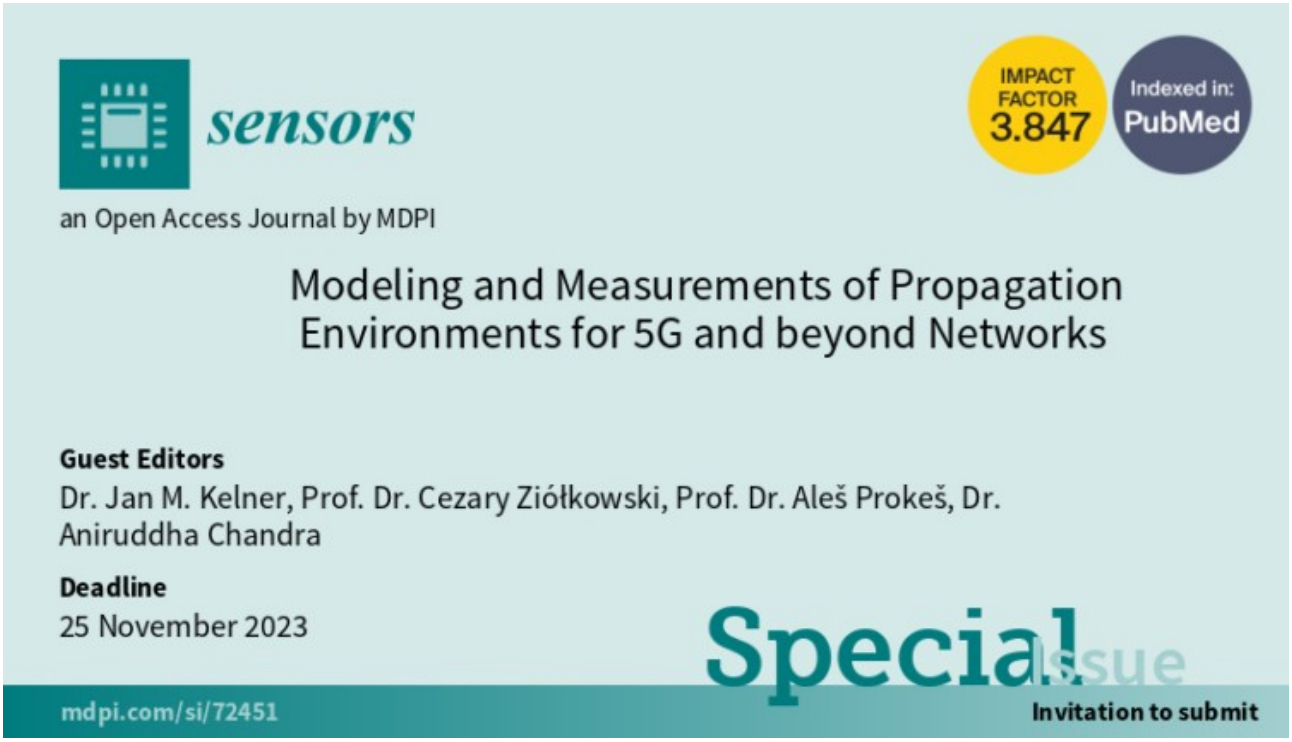
Selected papers will be recommended for publication in the Special Issue on Radar Signal Detection, Recognition and Identification, Special Issue on Recent Advancements in Radar Imaging and Sensing Technology II, or Special Issue on Modeling and Measurements of Propagation Environments for 5G and beyond Networks in Sensors MDPI Journal (**IF 3.847**).

Radar Signal Detection, Recognition and Identification



Recent Advancements in Radar Imaging and Sensing Technology II

Modeling and Measurements of Propagation Environments for 5G and beyond Networks



Signal Processing Symposium

SPSympo 2025

To the next Signal Processing Symposium we would like to invite you to Warsaw, Poland, in May/June 2025.