JOHANNES KEPLER UNIVERSITY LINZ

ISP

2013-2018 FIVE-YEAR ANNIVERSARY REPORT

Institute of Signal Processing

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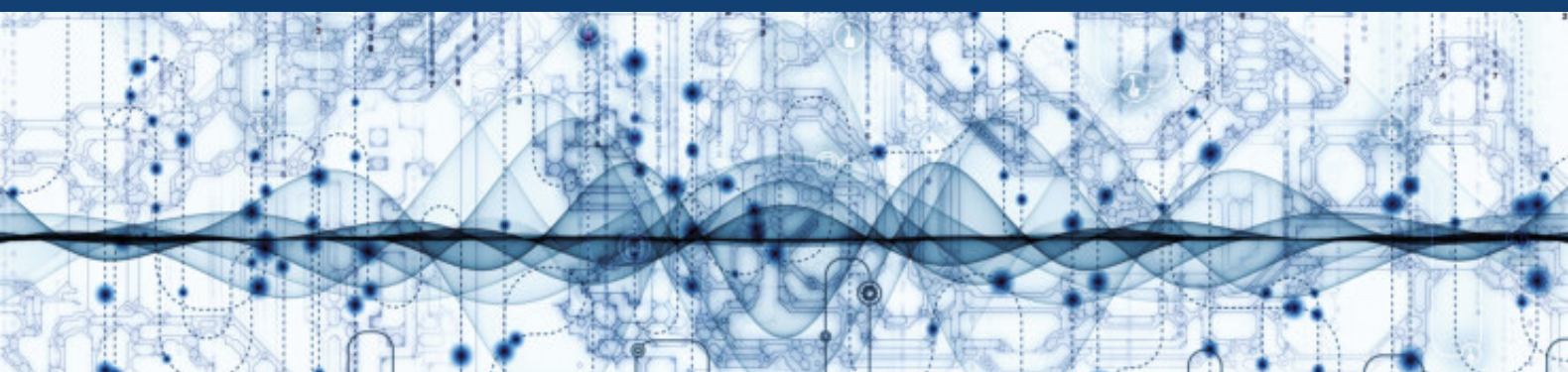

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Institute of Signal Processing

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Foreword

The Institute of Signal Processing (ISP), representing one chair of the Computer Science Department, was founded in September 2013 to further strengthen the Johannes Kepler University (JKU) Linz in the field of electronics and information engineering. We are located in the JKU Science Park in Linz, Austria, which provides an excellent working environment and a perfect atmosphere for creativity and development.

Since the institute's foundation many things have happened. The institute grew from originally 4 to 17 employees, and if we additionally count the external Ph.D. students then the ISP even has 22 members. Furthermore, we have become quite international: current and former research staff members come from Austria, Bosnia and Herzegovina, Cuba, Czech Republic, Germany, Greece, Guatemala, Hungary, India, Pakistan, and Serbia. Our research portfolio includes both fundamental science and applied research. In 2018 the annual third-party volume was around € 600.000.-, and the annual number of publications reached 25 journal and conference articles. Within the reporting period research staff members received several highly renowned awards for their project achievements or publications.

In teaching we are involved in the study programs *Electronics and Information Technology, Mechatronics,* and *Computer Science* at both Bachelor and Master level. From 2019 on we will also be engaged in the planned study programs *Artificial Intelligence* and *Medical Engineering.*

Let me say a few words about our area of expertise called signal processing. Our worldwide largest professional association, the IEEE signal processing society, gives the following explanation on its homepage: *"The technology we use, and even rely on, in our everyday lives – computers, radios, video, cell phones – is enabled by signal processing, a branch of electrical engineering that models and analyzes data representations of physical events. Signal processing is at the heart of our modern world, powering today's entertainment and tomorrow's technology. It's at the intersection of biotechnology and social interactions. It enhances our ability to communicate and share information. Signal processing is the science behind our digital lives."* In fact, signal processing is the enabler technology for many of today's electronic applications, but it is mostly invisible to the user.

At the ISP, on the one hand we develop fundamental signal processing algorithms further, and on the other hand we apply signal processing algorithms to a variety of different modern applications, the latter in close co-operation with industry partners. One of the nice things about our research discipline is that we come in contact with many different application fields ranging from communications, radar, biomedical signal processing, acoustics to ultrasound engineering, just to name a few. This is also reflected in the manifold research projects conducted at the ISP, which will be briefly presented in this report.

This brochure gives an overview of the ISP. We report on our research activities, highlight our teaching portfolio, and we review our scientific, promotion and social activities.

I would like to thank everybody who makes our institute what it is. Enjoy this report!

Mario Huemer,
Professor and Head of Institute

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The Institute at a Glance

Our research and teaching activities focus on the algorithmic-, architectural- and hardware-oriented aspects of signal processing systems. Application areas are information and communication systems, particularly radio frequency and baseband integrated circuits, bio- and sensor-signal processing as well as automotive applications.

We started our research activities with the fundamental research project *Unique Word OFDM,* which is on modern wireless waveform design, and was transferred from my former employer, the Alpen-Adria University Klagenfurt, to the ISP. The project was funded by the Austrian Science Fund (FWF), and conducted in co-operation with the University of Erlangen-Nuremberg (Prof. Huber). Further fundamental research topics have been established in the fields of estimation theory, on sparsity aware signal processing, and on biomedical signal processing, the latter in co-operation with the Kepler University Hospital. We also continued the successful co-operation with Infineon Villach/ Munich, which originally started during my time in Carinthia. In this co-operation we work on battery and power management for electronic applications as well as on signal processing concepts for acoustic and ultrasound applications. Soon we also strengthened the co-operation with DICE Linz GmbH, an Infineon subsidiary, in the field of automotive radar. A major milestone was the establishment of the *Christian Doppler Laboratory for Digitally Assisted RF Transceivers for Future Mobile Communications* in January 2017, which we operate together with the Institute for Communications Engineering and RF-Systems. The CD lab is co-headed by Prof. Andreas Springer and me, our industrial partner is DMCE GmbH, an Intel subsidiary. The lab is dedicated to research on digital signal processing methods for radio frequency (RF) transceivers. The ISP is also a partner of the Linz Center of Mechatronics (LCM) in the K2 center *Symbiotic Mechatronics*. Within the K2 center we co-operate with GE Healthcare on ultrasound medical devices, and with Primetals on acoustic predictive maintenance. In a strategic basic research project we work on sparsity aware signal processing. A number of smaller projects with regional industry and research institutions complement our research activities.

Currently we are laying the foundation stone for another strategic co-operation with the recently founded Silicon Austria Labs (SAL). Together with neighboring JKU institutes and SAL we are planning to establish the joint lab *embedded Signal Processing and Machine Learning – eSPML,* and together with the Alpen-Adria University Klagenfurt and the Graz University of Technology we are planning to establish a joint doctoral program, which will be mainly financed by SAL.

The third party funding in the ISP's first five years of existence came from funding agencies like the Christian Doppler Research Association, the Austrian Research Promotion Agency (FFG), the Austrian Science Fund (FWF), the European Commission, and from industry. Our list of industry partners currently comprises DMCE (an Intel subsidiary), Infineon, DICE (an Infineon subsidiary), Intel, GE Healthcare, Primetals, and voestalpine. Furthermore, we co-operate/co-operated with the following research institutions and universities: Alpen-Adria University (AAU) Klagenfurt, Carinthian Tech Research AG (CTR), Kepler Universitätsklinikum (KUK),

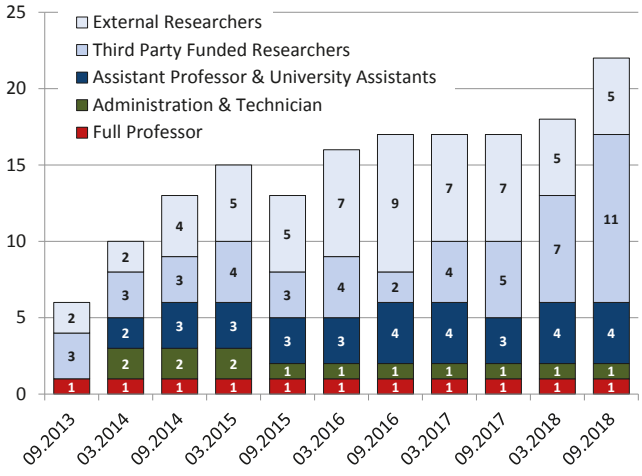
Linz Center of Mechatronics (LCM), Pontifical Catholic University of Rio de Janeiro, Research Center for Non Destructive Testing GmbH (RECENDT), Silicon Austria Labs (SAL), Software Competence Center Hagenberg (SCCH), Technical University Ilmenau, University of Applied Sciences of Upper Austria, University of Erlangen-Nuremberg.

The research results are frequently also integrated into our lectures and labs. Furthermore, we offer our students the possibility to contribute to our basic and applied research projects in the form of bachelor and master theses or by doing an internship. We believe, that the theory discussed in the lectures together with the incorporation of real world applications is a strong asset of the ISP and its neighboring Computer Science and Mechatronics institutes at JKU. Our own teaching activities in basic and advanced signal processing are continuously complemented by renowned guest lecturers and professors.

Our mission is to create the future with excellent achievements in research and teaching, in an international and welcoming atmosphere.

Personnel Development

I gladly remember Monday, September 2, 2013, when Christian Hofbauer, Ram Sunil Kanumalli and I met at the newly founded Institute of Signal Processing. The offices were already furnished, but nobody was personally welcoming us there. This was a quite unusual but exciting situation. However, we immediately received our JKU IDs, and the computers with running software had already arrived in the early morning hours. One of our first actions was to screen the applications for the secretary position, and we prepared the advertisements for the university assistant employments. Five years later, in December 2018, the ISP has the remarkable number of 17 employees, 5 external Ph.D. students, and 5 student assistants. Currently, the ISP members represent seven different nations.



The graph above shows the personnel development of the ISP since its foundation in September 2013. The institute has 5.5 assigned so-called permanent staff positions financed by the university's global budget: 1 full professor, 1 assistant professor, 1 postdoc university assistant, 1 predoc university assistant, 0.5 secretariat positions, 1 technician. Currently, the technician position is temporarily re-dedicated to a predoc university assistant position. Furthermore, the institute employs 11 researchers by third party funds (1 senior postdoc, 1 postdoc, and 9 Ph.D. students).

The competence of our team shows strong multidisciplinarity, our researchers hold degrees in Electrical Engineering, Electronics and Information Technology, Information Technology, Telematics, Mechatronics, Telecommunications Engineering, Electrical and Computer Engineering, Computer Science, Mathematics, Hardware Software Design, Network Engineering, and Medical Engineering.

And there is one thing we are particularly proud of: though we are decidedly a quite technical research group we have the remarkable number of four female staff members (corresponding to 24%), which is pretty good in engineering sciences.

JOHANNES KEPLER UNIVERSITY LINZ

The Institute at a Glance

Technical Infrastructure

The Institute of Signal Processing owns a laboratory incorporating the basic infrastructure needed for the development and verification of prototype hardware. A pool of servers, workstations and software tools completes our infrastructure.

Signal Processing Lab

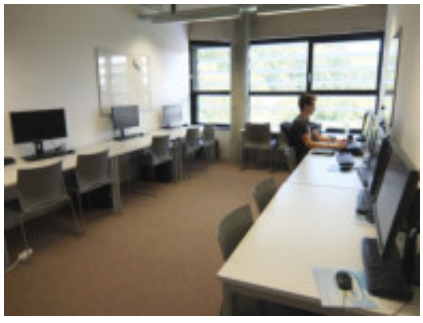
The signal processing lab contains basic voltage/current sources/sinks, and oscilloscopes with low (1GHz), medium (4GHz) and high (13GHz) bandwidth. Furthermore, it offers two vector signal generators (12GHz) and a vector signal analyzer (26GHz). For debugging of digital circuits a logic analyzer (up to 666MHz and 34 channels) is available. Various high-performance FPGA boards for prototyping are also present. Recently the ISP purchased a board plotter for PCB design.
Besides this equipment the institute also owns a 32 channel in/out low noise audio interface with two 16 channel loudspeaker amplifiers for audio applications, and a high-performance and high-accuracy biosignal amplifier and acquisition/processing system that allows investigation of brain-, heart- and muscle-activity, eye movements, respiration, galvanic skin response and many other physiological and physical parameters.

Students Lab

The usage of the students lab is twofold. First, we utilize it for teaching our lab courses. Second, we give our bachelor and master students free access to the room to have a silent place at the campus for the purpose of studying or writing their bachelor and master theses. There are a total of nine workstations available with MATLAB® and programs for FPGA simulation and programming installed on the PCs. Additionally, the students have access to oscilloscopes and signal generators.

Server Infrastructure

For complex computations and intensive simulations the server infrastructure comprises four Lenovo Think Station beasts. One of these beasts has an Intel Xeon 3.1GHz ten core processor and 128GB of RAM. For additional speed up a CUDA-enabled NVIDIA GeForce GTX TITAN X is available. Each of the other three PCs has an Intel Xeon 2.6GHz processor with 2x12 cores, 512GB of RAM and a CUDA-enabled NVIDIA Quadro K620 graphic card. All servers are accessed via remote desktop connection and utilize a hard disk space of 1TB each.



People

Permanent Staff

Head of Institute

Mario Huemer

Research and teaching staff member since 01.09.2013

Mario Huemer was born in Wels, Austria, in 1970. He received the Dipl.-Ing. degree in Mechatronics and the Dr.techn. degree from the Johannes Kepler University (JKU) Linz, Austria, in 1996 and 1999, respectively. The early stages of his professional career were JKU Linz (1997-2000, university assistant), DICE Linz, an Infineon subsidiary (2000-2002, project manager), University of Applied Sciences of Upper Austria (2002-2004, lecturer), and University of Erlangen-Nuremberg, Germany (2004-2007, associate professor). In 2007 Mario Huemer moved to Klagenfurt, Austria, to establish the Chair of Embedded Systems and Signal Processing at Klagenfurt University as a full professor. From 2012 to 2013 he served as dean of the Faculty of Technical Sciences. Since September 2013 he is head of the newly founded Institute of Signal Processing at the JKU Linz. Furthermore, since 2017 he is co-head of the Christian Doppler Laboratory for "Digitally Assisted RF Transceivers for Future Mobile Communications." Mario Huemer published more than 230 papers in journals and conference proceedings. In 2000 he received the dissertation awards of the German ITG and the Austrian GIT societies, in 2010 the Austrian Cardinal Innitzer award in natural sciences, and in 2016 the German ITG award. He is member of the IEEE, VDE/ITG, and ÖVE.

Assistant Professor

Michael Lunglmayr

Research and teaching staff member since 01.09.2014

Michael Lunglmayr was born in Linz in 1981. He received his Ph.D. from the University of Erlangen-Nuremberg in 2009. In March 2009, he joined the Embedded Systems and Signal Processing Group at the Alpen-Adria University Klagenfurt as a postdoc, and in September 2014 he joined the Institute of Signal Processing, Johannes Kepler University Linz, where he became an assistant professor in 2016. His current research interests are in algorithms for real-time signal processing - especially for estimation and optimization - their theory and implementation in digital hard- and software.

People

Administration

Birgit Bauer

Member since 01.10.2013

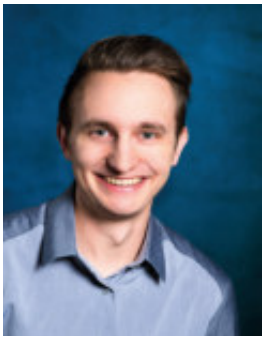
Birgit finished business school at Linz/Rudigierstraße in 1991. After working at several companies and attending some classes at BFI and WIFI like SAP, Italian language or computer classes, in 2010 she decided to do her A-Levels and succeeded in 2011. In October 2013 Birgit started as secretary at the Institute of Signal Processing.

University Assistants

Péter Kovács

Postdoctoral research and teaching staff member since 01.03.2018

Péter Kovács obtained his M.Sc. degree in Computer Science from the Eötvös Loránd University in 2010. He then started his Ph.D. work on transformation methods in signal processing at the Eötvös Loránd University. In 2012, he began his academic career as an assistant lecturer at the Department of Numerical Analysis of the Eötvös Loránd University. After earning his Ph.D. degree in 2016, he was promoted to assistant professor. Since March 2018 he is a postdoc researcher at the Institute of Signal Processing, Johannes Kepler University Linz. His current research interests are related to adaptive signal representations, sparse estimation of ECG signals, optimization, analysis and implementation of numerical algorithms.



Carl Böck

Research and teaching staff member since 01.11.2015

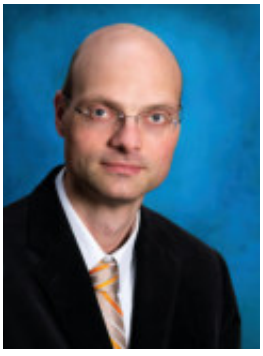
Carl Böck was born in Vorderweißenbach, Austria, in 1989. He received his Dipl.-Ing. degree in Telematics from Graz University of Technology in January 2016. During his academic education he studied for one year in Bozeman, Montana. In his master studies Carl Böck specialized in “Computational Intelligence” as well as in “Medical Informatics, Bioinformatics and Neuroinformatics”. He wrote his master thesis “ECG Signal Analysis based on the Wavelet Transform” in co-operation with the general hospital of Linz. Since November 2015 Carl Böck is a university assistant at the Institute of Signal Processing, Johannes Kepler University Linz. His research interests include adaptive signal representations of ECG and EEG signals for medical decision support.

Andreas Gaich

Research and teaching staff member since 15.11.2015

Andreas Gaich was born in Deutschlandsberg, Austria, in 1985. He studied Electrical/ Audio Engineering at the Graz University of Technology and received his B.Sc. degree in 2011. In the master studies he focused on speech signal processing at the Signal Processing and Speech Communication Laboratory (SPSC) at the Graz University of Technology and finished it in 2015. Since November 2015, he is a university assistant at the Institute of Signal Processing, Johannes Kepler University Linz. There he is working towards his Ph.D. in co-operation with Infineon Technologies Austria AG in Villach. His research activities focus on acoustic beamforming.

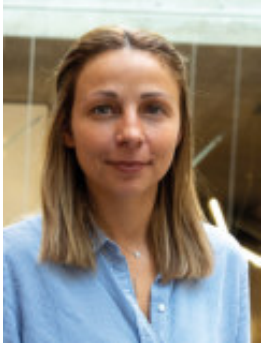
Third Party Funded Researchers



Eugen Pfann

Senior postdoctoral research staff member since 15.02.2017

Eugen Pfann received the Dipl.-Ing. degree in Information Engineering from the Vienna University of Technology, Austria, in 1994. In 2003 he was awarded a Ph.D. degree from the University of Strathclyde, Glasgow, UK, for his work on Sigma Delta adaptive LMS filters. In 2002 he joined the University of Strathclyde as research fellow. From 2007 until 2009 he was affiliated with Steepest Ascent Ltd., Glasgow, UK, as DSP consultant. From 2009 to 2017 he was working at DMCE GmbH (Intel Linz), Austria. He then joined the Institute of Signal Processing, Johannes Kepler University Linz, as a senior postdoc researcher. His current research interests are sensor array processing, acoustic beamforming, gesture recognition and real time DSP algorithms for next generation mobile communications devices.

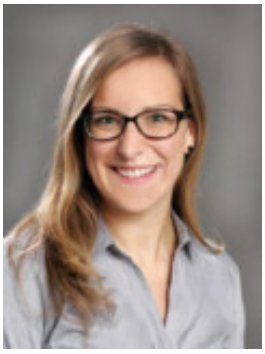


Kyriaki Kostoglou

Postdoctoral research staff member since 01.05.2018

Kyriaki Kostoglou received her diploma degree in Electrical and Computer Engineering from Aristotle University of Thessaloniki (AUTH), Greece (2010) and her M.Sc. degree in Computer Engineering from University of Cyprus (UCY), Cyprus (2012). In 2017, she completed her Ph.D. studies and received her Ph.D. degree from the Department of Electrical and Computer Engineering, McGill University, Canada. The topic of her Ph.D. thesis was the identification of multiple-input time-varying systems and binary response systems for biomedical applications. Since May 2018 Kyriaki Kostoglou is a postdoc researcher at the Institute of Signal Processing, Johannes Kepler University Linz. Her current research interests include system identification in medical ultrasound imaging.

People



Christina Auer

Research staff member since 01.09.2017

Christina Auer was born in Linz, Austria, in 1987. From 2005 till 2012 she studied Applied Mathematics at the Johannes Kepler University Linz. The topic of her master thesis, that she partly wrote at the UCLA, was image denoising. After graduation, she joined the Linz Center of Mechatronics (LCM GmbH) where she was working in the R&D, especially with Kalman filtering for localization. Since September 2017, she is a researcher at the Institute of Signal Processing, Johannes Kepler University Linz. Now she is working towards her Ph.D. in co-operation with DMCE GmbH (Intel Linz) as a member of the CD laboratory for Digitally Assisted RF Transceivers for Future Mobile Communications. Her research activities focus on self-interference cancellation using kernel adaptive filtering.

Yuneisy García Guzmán

Research staff member since 01.05.2018

Yuneisy Esthela García Guzmán was born in Cuba in 1991. She received her diploma degree in Electrical and Electronics Engineering from José Antonio Echeverría Higher Polytechnic Institute (CUJAE), Cuba (2014). In 2018, she completed her master studies and received her Master of Science degree from the Department of Electrical Engineering, Pontifical Catholic University of Rio de Janeiro, Brazil. The topic of her master thesis was “Compressed Sensing Algorithms for Direction of Arrival Estimation”. In 2018, she joined the Institute of Signal Processing, Johannes Kepler University Linz. Her current research interests include compressed sensing and sparsity aware signal processing.

Andreas Gebhard

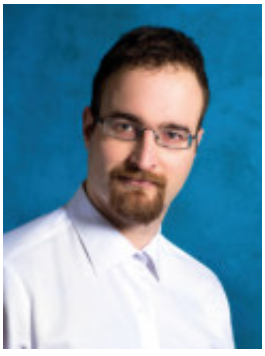
Research staff member since 01.12.2014

Andreas Gebhard was born in Bregenz, Austria, in 1982. He received his Dipl.-Ing. degree in Electrical Engineering from Graz University of Technology in October 2011. In his master studies he specialized in ‘Control and Automation’. He wrote his diploma thesis in the field of nonlinear control techniques. After graduation, he joined the Linz Center of Mechatronics (LCM GmbH) where he was working in the R&D of mechatronic systems. Since December 2014, he is a researcher at the Institute of Signal Processing, Johannes Kepler University Linz, where he is working towards his Ph.D. His research activities focus on the mitigation of RF impairments for LTE and LTE-A RF transceiver systems using adaptive and statistical signal processing techniques.

Daniel Lagler

Research staff member since 01.05.2018

Daniel Lagler was born in Gmunden, Austria, in 1987. He received his M.Sc. degree in Computer Science from the TU Munich, Germany, in 2012. Afterwards, he started a career as a software engineer at TomTec Imaging Systems in Unterschleißheim, Germany, developing medical 2D/3D/4D ultrasound analysis and review applications. From 2014 to 2018, he worked at GE Healthcare in Zipf. There, he focused on the design, development and optimization of image and signal processing algorithms for ultrasound systems specialized in gynecology and obstetrics. Since 2018, he is a researcher at the Institute of Signal Processing, Johannes Kepler University Linz, working towards his Ph.D. in the field of ultrasound signal processing for localization and object detection in co-operation with Infineon Technologies.



Jovan Markovic

Research staff member since 01.01.2018

Jovan Markovic was born in Belgrade, Serbia, in 1984. From 2007 to 2014 he studied at the Vienna University of Technology where he obtained the B.Sc. degree in Electrical Engineering and Information Technology and the M.Sc. degree in Telecommunications in 2012 and 2014, respectively. In May 2013 he joined the company Danube Mobile Communications Engineering (DMCE) in Linz where he still works as an R&D engineer. In November 2014 he joined the Institute of Signal Processing, Johannes Kepler University Linz, as an external Ph.D. student. Since January 2018 he is a part-time member of the Institute of Signal Processing. His current research activities focus on signal processing techniques in digital transmitters for cellular applications.

Christian Motz

Research staff member since 01.01.2017

Christian Motz was born in Vöcklabruck, Austria, in 1990. From 2010 to 2015 he studied at the University of Applied Sciences of Upper Austria in Hagenberg where he obtained his M.Sc. degree in Embedded Systems Design. He wrote his master thesis in co-operation with the Software Competence Center Hagenberg GmbH in the field of pattern matching dealing with the efficient implementation of Weyl's Discrepancy Measure for 2D image data. Since January 2017 Christian Motz is a researcher at the Institute of Signal Processing, Johannes Kepler University Linz, where he is working towards his Ph.D. in co-operation with DMCE GmbH (Intel Linz). His research focuses on receiver interference cancellation by means of adaptive signal processing methods.

People

Thomas Paireder

Research staff member since 15.01.2018

Thomas Paireder was born in Melk, Austria, in 1992. From 2012 to 2018 he studied at the Johannes Kepler University Linz where he obtained his Bachelor degree in Information Electronics and his Master degree in Electronics and Information Technology in 2016 and 2018, respectively. He wrote his master thesis in co-operation with the RECENDT GmbH in the field of signal processing. In his thesis he implemented a real-time processing system for Laser-ultrasonic signals. Since January 2018, he is a researcher at the Institute of Signal Processing, Johannes Kepler University Linz, where he is working towards his Ph.D. in co-operation with the DMCE GmbH (Intel Linz), focusing his research on receiver interference cancellation by means of adaptive signal processing methods.

Oliver Ploder

Research staff member since 01.09.2018

Oliver Ploder was born in Graz, Austria, in 1992. From 2012 to 2016 he studied at the Johannes Kepler University Linz where he obtained his B.Sc. degree in Information Electronics. He received his M.Sc. degree in Telecommunication Engineering with a focus on Wireless Communications from the Universitat Politècnica de Catalunya (BarcelonaTech) in 2018. His master thesis was written on the topic of “Secure State Estimation in Cyber Physical Systems (CPS)”. Since September 2018, he is a researcher at the Institute of Signal Processing, Johannes Kepler University Linz, where he is working towards his Ph.D. in co-operation with the DMCE GmbH (Intel Linz), focusing his research on receiver interference cancellation for LTE and LTE-A RF transceiver systems by means of machine learning.

Christoph Preissl

Research staff member since 01.01.2018

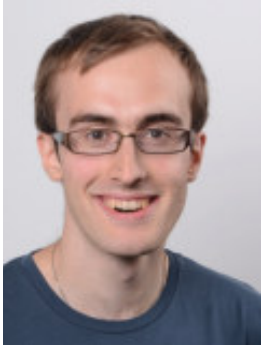
Christoph Preissl was born in Linz, Austria, in 1987. From 2007 to 2013 he studied at the JKU Linz, where he obtained his M.Sc. degree in Industrial Mathematics in 2013. He wrote his Master thesis in co-operation with MathConsult GmbH in the field of Inverse Problems. His thesis deals with Adaptive Optics (AO). In December 2014 he joined the company DMCE GmbH (Intel Linz) where he is currently working as an R&D student and he also joined the Institute of Signal Processing, Johannes Kepler University Linz, as an external Ph.D. student. His research activities focus on digital phase-locked loops, digital-to-time converters and digitally intensive transceiver architectures for cellular applications. Since January 2018 he is a member of the ISP.

External Ph.D. Students

Michael Gerstmair

External Ph.D. student since 01.07.2016

Michael Gerstmair was born in Linz, Austria, in 1986. He received the B.Sc. degree in Telematics from Graz University of Technology in 2013. In 2016 he received his M.Sc. degree in Information Electronics from the Johannes Kepler University Linz. He wrote his master thesis at the Institute of Signal Processing in co-operation with GE Healthcare Austria GmbH & Co OG. Since July 2016, he is employed at DICE GmbH & Co KG working towards his Ph.D. as an external researcher at the Institute of Signal Processing, Johannes Kepler University Linz. His research activities focus on the investigation of RF impairments in highly integrated radar front ends as well as the development of digital signal processing algorithms for automotive radar sensors to estimate position and velocity of surrounding objects.



Adnan Husakovic

External Ph.D. student since 01.01.2018

Adnan Husakovic was born in Doboj, Bosnia and Herzegovina, in 1991. He received his Dipl.-Ing. degree in Mechatronics in 2017, specializing in the domain of automotive control and systems optimization. His master thesis dealt with identification methods based on modal testing in hydraulic applications. Since 2011 he is working for Primetals Technologies, and in September 2017 he established a co-operation with the Institute of Signal Processing, Johannes Kepler University Linz, where he is working towards his Ph.D. in co-operation with LCM Linz and Primetals Technologies. His research activities focus on acoustic condition monitoring and machine learning in the domain of steel- and ironmaking.

Marc Kanzian

External Ph.D. student since 01.01.2016

Marc Kanzian was born in Villach, Austria, in 1989. From 2010 to 2013 he studied Network Engineering at the Carinthia University of Applied Sciences (CUAS) in Klagenfurt. After receiving his B.Sc. degree in 2013, Mr. Kanzian started his master studies in Communications Engineering, also at the CUAS in Klagenfurt. For his master thesis he worked at Infineon Technologies Austria in Villach on an optimized dither generation scheme for Sigma-Delta modulators. In July 2015, he finished his master studies. Since January 2016 he is employed at Infineon Technologies Austria in Villach working towards his Ph.D. as an external researcher at the Institute of Signal Processing, JKU Linz. His current research activities focus on the field of digital control and system identification for multiphase DC-DC converters.

People

Alexander Klinkan

External Ph.D. student since 01.04.2017

Alexander Klinkan was born in Linz, Austria, in 1985. In 2012 he received the Dipl.-Ing. degree in Mechatronics from the Johannes Kepler University Linz with specialization on Integrated Circuit (IC) design for FPGAs and ASICs. In 2011 he joined DMCE GmbH (Intel Linz) for writing his diploma thesis with the title "High-Level Synthesis of DSP Blocks". In 2012 he started a full-time employment at DMCE working in the field of Sampling Rate Converters (SRCs). Since January 2017 he has been working towards his Ph.D. in co-operation with the Institute of Signal Processing, Johannes Kepler University Linz. His research activities focus on interpolation algorithms and implementation architectures of SRCs in polar transmitters.

Christoph Mahringer

External Ph.D. student since 01.09.2014

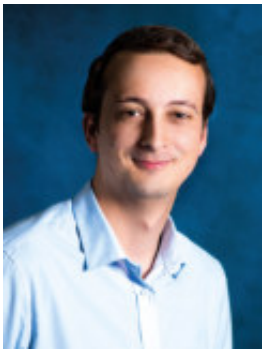
Christoph Mahringer was born in Linz, Austria, in 1982. He studied Medical Engineering at the University of Applied Sciences Upper Austria and received his diploma degree in 2007. Since September 2010 he has worked for the biomedical technology department at the General Hospital in Linz. In 2013 he received his M.Sc. degree in health studies from the University of Applied Sciences for Health Professions Upper Austria. In 2014 a co-operation between the Institute of Signal Processing, the department for operational intensive care and anesthesia as well as the department for neurology and psychiatry, both at the Kepler University Hospital, was established which raised the opportunity of a Ph.D. research on the analysis of biomedical signals and their use for disease detection.

Former Staff Members

Florian Bemsel

Technician from 01.03.2014 to 30.04.2015

Florian Bemsel studied Hardware/Software Systems Engineering at the University of Applied Sciences of Upper Austria, where he received his Dipl.-Ing. (FH) degree in 2007. He conducted his internship and his diploma thesis at the research institute IMEC in Belgium. After holding positions at Fronius International, Brunel Communications, and Robert Bosch GmbH, he joined the Institute of Signal Processing, Johannes Kepler University Linz, in March 2014. Since May 2015, Florian Bemsel is with Pilz GmbH & Co. KG.



Andreas Berger

Research staff member from 01.09.2013 to 30.06.2016

Andreas Berger studied Information Technology at the Alpen-Adria University (AAU) Klagenfurt, Austria, with main focus on embedded systems, signal processing and control systems. In 2013 he finished his master studies, and started as a researcher at the Embedded Systems and Signal Processing Group at AAU. In September 2013, he joined the Institute of Signal Processing, Johannes Kepler University Linz, working towards his Ph.D. in co-operation with Infineon Technologies Austria. The research focus of his Ph.D. project was the optimization of wireless power transfer and power management systems for mobile devices. In 2016, he joined Infineon Technologies Austria, where he is working as a concept engineer in the field of power and battery management systems.

Christian Hofbauer

Research and teaching staff member from 01.09.2013 to 31.08.2015

Christian Hofbauer was born in St. Peter am Wimberg, Austria, in 1982. From 2002 to 2006, he studied Hardware/Software Systems Engineering at the University of Applied Sciences of Upper Austria. He received his Dipl.-Ing. (FH) degree in 2006. He conducted his internship and his diploma thesis at the research institute IMEC in Belgium. From September 2007 to August 2013, he was a researcher at the Embedded Systems and Signal Processing Group at the Alpen-Adria University (AAU) Klagenfurt. In September 2013, he joined the Institute of Signal Processing, Johannes Kepler University Linz, where he continued and finalized his Ph.D. thesis on the Unique Word OFDM transmission concept. Since October 2015, Christian Hofbauer is a researcher at the Linz Center of Mechatronics (LCM).

Ram Sunil Kanumalli

Research staff member from 01.09.2013 to 31.01.2016

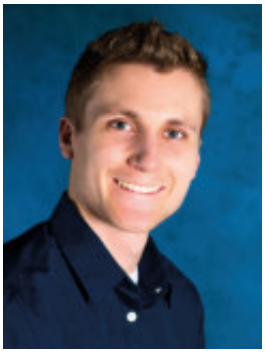
Ram Sunil Kanumalli was born in India in 1989. He received the Dipl.-Ing. (M.Sc.) degree in Information Technology in 2012 from the Alpen-Adria University (AAU) Klagenfurt, Austria, where he specialized in embedded communications and signal processing. He then started as a Ph.D. researcher at the Institute of Networked and Embedded Systems in Klagenfurt, and joined the Institute of Signal Processing, Johannes Kepler University Linz, in September 2013. Since 2016, he is working with Intel Linz, Austria. His research activities focus on digital and mixed-signal based interference cancellation techniques in the presence of various imperfections for the next generation of wireless transceiver systems.

People

Oliver Lang

Research and teaching staff member from 01.02.2014 to 28.02.2018

Oliver Lang was born in Schärding, Austria, in 1987. From 2007 to 2014 he studied Electrical Engineering (B.Sc.) and Microelectronics (M.Sc.) at the Vienna University of Technology, Austria. He wrote his master thesis in co-operation with Agilent Measurement Technologies GmbH in the field of scanning microwave microscopy. From 2014 to 2018, he was a university assistant at the Institute of Signal Processing, Johannes Kepler University Linz, where he received his Ph.D. in 2018. In his Ph.D. project entitled "Knowledge-Aided Methods in Estimation Theory and Adaptive Filtering" he developed several novel estimators and adaptive filters for particular application scenarios. Since 2018, he has been working at DICE GmbH in Linz, which is a subsidiary company of Infineon.



Alexander Melzer

Research and teaching staff member from 01.03.2014 to 30.06.2017

Alexander Melzer was born in Voitsberg, Austria, in 1988. He received the Dipl.-Ing. degree in Telematics from the Graz University of Technology, Austria, in 2012. From 2013 to 2014, he held a position at Maxim Integrated Products GmbH Austria. In 2014, he joined the Institute of Signal Processing, Johannes Kepler University Linz, as a university assistant, where he received his Ph.D. in 2017. In his Ph.D. project, which was conducted in co-operation with DICE GmbH & Co KG, novel concepts for the cancellation of the so-called short-range leakage in automotive radar applications have been proposed. Since 2018, he has been working as concept engineer at Infineon Technologies in Graz.

Alexander Onic

Research staff member from 14.10.2013 to 20.12.2013

Alexander Onic is product architect for next generation 77GHz automotive radar MMICs at Infineon Technologies / DICE Danube Integrated Circuit Engineering in Linz, Austria. He received the Dipl.-Ing. degree in electrical engineering from the University of Erlangen-Nuremberg in 2007 and the Ph.D. degree from the Alpen-Adria University Klagenfurt in 2013. Alexander is certified as ISO 26262 Functional Safety Engineer by TUEV SUED. His research interests in sensor technologies for autonomous driving, as well as signal processing, communications engineering and estimation theory are consequently supplemented by the research co-operation with the Johannes Kepler University Linz on mixed signal processing topics.

Stefan Trampitsch
External Ph.D. student from 01.04.2013 to 31.12.2016

Stefan Trampitsch was born in St. Veit an der Glan, Austria, in 1986. From 2007 to 2010 he studied Systems Engineering at the Carinthia University of Applied Sciences in Villach. After receiving his B.Sc. degree in 2010, he started his master studies in Information and Communications Engineering at the Alpen-Adria University of Klagenfurt. In April 2013 he finished his master studies and joined the Intel Mobile Communications group in Villach working towards his Ph.D. as an external researcher at the Institute of Signal Processing, Johannes Kepler University Linz. His current research activities focus on modeling and digital pre-distortion of capacitive radio frequency digital-to-analog converter (RF-DAC).

Student Assistants

Stefan Baumgartner
Since 01.10.2018
Bachelor student in Electronics and Information Technology (ELIT)

Christoph Dutzler
From 01.10.2016 to 31.01.2018
Bachelor student in ELIT

Christian Egger
From 07.03.2016 to 06.07.2016
Bachelor student in Mechatronics

Martin Friedl
From 07.03.2016 to 06.07.2016
Master student in Mechatronics

Michael Gerstmair
From 01.07.2014 to 28.02.2015
Master student in ELIT

Bernhard Gschwandtner
Since 01.06.2018
Bachelor student in ELIT

David Hackl
From 01.03.2017 to 30.06.2018
Master student in ELIT

Simon Hehenberger
From 01.03.2017 to 30.06.2017
Master student in ELIT

Bernhard Hiptmair
From 01.10.2015 to 31.05.2018
Master student in Mechatronics

Harald Holzmann
From 01.07.2014 to 30.04.2015
Master student in Web Engineering

Thomas Jedinger
From 01.02.2017 to 31.07.2017
Master student in Mechatronics

Jürgen Josef
From 01.10.2013 to 31.01.2014
Master student in Mechatronics

Oliver Ploder
From 01.11.2015 to 31.08.2016
Bachelor student in ELIT

Ondrej Pospichal
Since 01.10.2018
Brno University of Technology, Czech Republic

Lukas Rienessl
Since 13.08.2018
Bachelor student in ELIT

Fisnik Sulejmani
From 01.03.2018 to 30.06.2018
Master student in Mechatronics

Matthias Wagner
Since 01.10.2017
Master student in Mechatronics

JOHANNES KEPLER UNIVERSITY LINZ

Teaching

The Institute of Signal Processing offers courses mainly for the study programs Electronics and Information Technology, Mechatronics, and Computer Science at both Bachelor and Master level. Almost all lectures are accompanied by exercise classes or labs in which the theoretical content is applied to practical examples.

Bachelor and Master Courses offered by the ISP

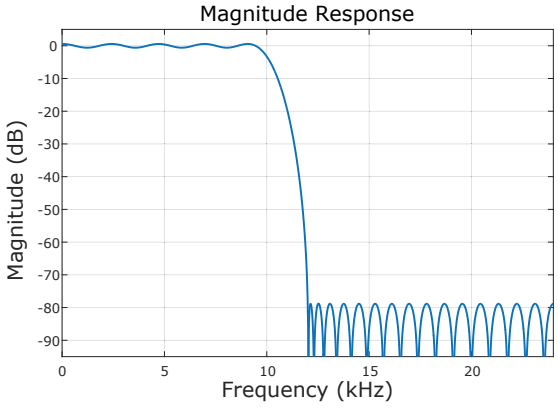
Course		Title	Lecture	Hrs	Exercise/Lab	Hrs
Bachelor		Digital Signal Processing	Huemer, Lunglmayr	2	Böck, Gaich	1
		Discrete-Time Signals and Systems	Huemer	2	Böck, Gaich	1
		Information Engineering	Huemer, Lunglmayr	2	-----	
	Master	Signal Processing Architectures	Lunglmayr	2	Lunglmayr, Motz	3
		Optimal and Adaptive Signal Processing Systems	Huemer, Lunglmayr	2	Kovács	1
		Special Topics in Signal Processing	Guest Lecturers	2	-----	

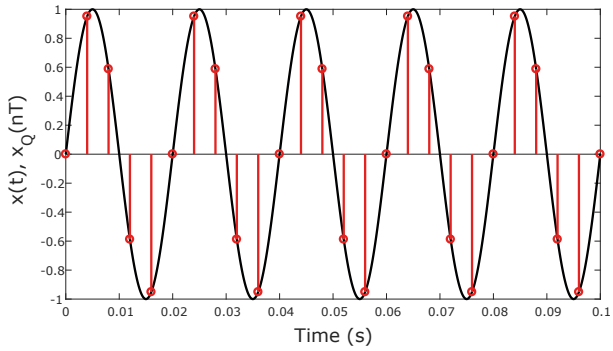
Digital Signal Processing

Digital signal processing nowadays is present in almost every consumer electronics device, vehicle, industrial machinery, et cetera. This lecture provides an introduction of the field of digital signal processing. Besides fundamental methods and algorithms, basic skills in MATLAB® are acquired by the attendees. Biweekly assignments accompany the lecture.

The lecture starts with a general introduction defining the term signal processing and illustrating various applications. Subsequently, fundamental topics of signal processing, i.e. frequency representation of analog and digital signals, sampling, reconstruction, the sampling theorem, and correlation are discussed in detail. The remaining parts of the lecture deal with time-discrete systems and their representations, and with the design of digital filters.

The lecture mainly targets Computer Science students in the fifth semester. Combined with the exercise classes in which MATLAB® is frequently used the students should develop a good understanding of fundamental signal processing methods for further usage in their studies.





Discrete-Time Signals and Systems

Discrete-time signals and linear time-invariant systems, their representations and mathematical treatment are the main topics of this lecture. The audience, mainly Electronics and Information Engineering students in their third semester, learns in detail how to work with discrete-time signals and systems in the time and frequency domain by discussing the topics listed below. Additionally, the students consolidate their knowledge by exercises in MATLAB®.

- Discrete-time signals
- Discrete-time linear systems
- Sampling theorem and signal reconstruction
- Discrete Fourier transform and fast Fourier transform.
- z-Transform
- Digital filters
- State space representations of dynamic systems
- Vector- matrix representations of discrete-time signals and systems

Teaching

Information Engineering

This lecture, specifically designed for Mechatronics students in their fourth semester, provides the basics of information processing systems. The lecture consists of three parts: information preprocessing, information extraction, and information transmission. These main parts deal with the following subtopics:

Information preprocessing – analog and digital preprocessing of signals

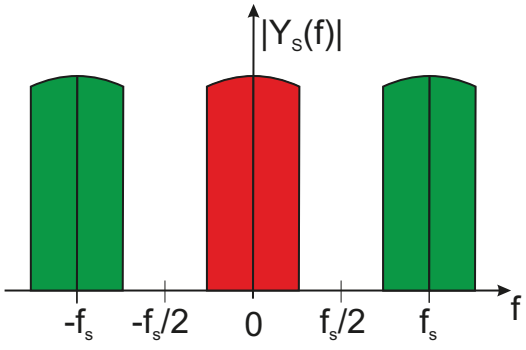
- Sampling theorem
- Analog filters
- Digital filters

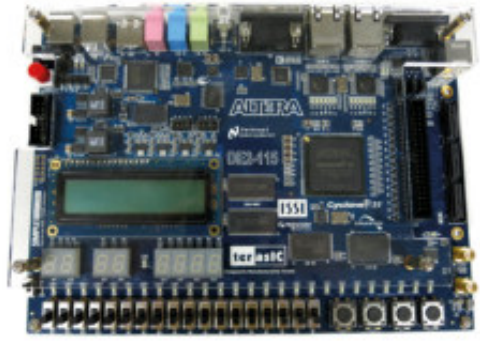
Extraction of signal information under additive noise disturbances

- Basics of estimation theory
- Least squares estimation
- Practical applications

Digital information transmission

- Baseband data transmission
- Equivalent complex baseband representation of bandpass signals
- Digital modulation principles





Signal Processing Architectures

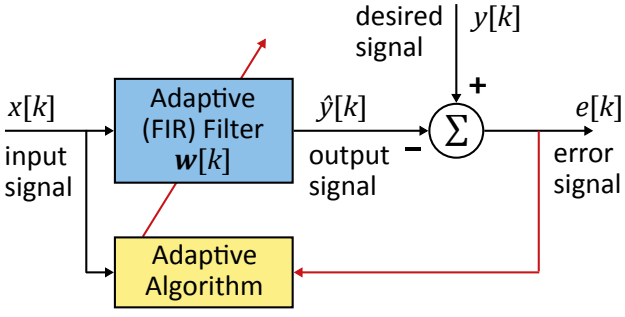
This lecture is recommended for experienced Bachelor as well as for Master students. It focuses on signal processing hardware and implementations. The audience learns about the variety of hardware platforms, efficient algorithms, implementation aspects and pitfalls. In the lab course the students implement signal processing algorithms on an FPGA under constant supervision. Specifically, the following topics are discussed within this lecture:

- Review of basic digital signal processing algorithms
- DSP arithmetic
- DSP hardware: DSPs, FPGAs and ASICs
- CORDIC-algorithm: theory, architectures and applications
- Fixed point effects in digital filtering
- Low cost digital filters
- Multirate signal processing
- Sigma-delta modulation and oversampling ADCs
- Numerically controlled oscillators

Optimal and Adaptive Signal Processing Systems

Statistical and adaptive signal processing algorithms have a vast application range in electronic systems designed to transmit, receive, store or extract information. These systems include communications, radar, speech and image processing, biomedical signal processing, control systems, and many others. The lecture particularly targets Master students in Electronics and Information Engineering as well as in Mechatronics. The presented theory is applied to many real world application examples. The accompanying exercise classes focus on the implementation of the developed concepts and algorithms in MATLAB®. In detail, this lecture focuses on the following topics:

- Basics of estimation theory
- Optimum filters
  - Wiener filters
  - Least squares filters
- Adaptive filters
  - Least mean squares (LMS)
  - Recursive least squares (RLS)
- Kalman filter
  - Kalman filter for linear systems
  - Extended Kalman filter for non-linear systems



Guest Lectures held at External Institutions

Digitale Signalverarbeitung

Univ.-Prof. Dr. Mario Huemer,
Assist.-Prof. Dr. Michael Lunglmayr

The lecture was held at the Alpen-Adria University Klagenfurt in the style of a block seminar during the summer semester 2015.
The content was closely related to the course „Discrete-Time Signals and Systems."

Teaching

Special Topics in Signal Processing (Guest Lectures)

Information Theory, SS 2015

Prof. Dr. Johannes Huber, University of Erlangen-Nuremberg

In this lecture, Prof. Huber gave an introduction to the basic terms and concepts of information theory, that are information, entropy, mutual information, information transmission, data compression, coding, and related topics.

Contents: Fundamentals of Information Theory, Source Coding, Characterization of Transmission Channels, Channel Capacity, Information Theory for Continuously Distributed Random Variables, Signal Distortions.

CHANNEL CODING WITH PROF. HUBER

Channel Coding, SS 2016

Prof. Dr. Johannes Huber, University of Erlangen-Nuremberg

This lecture covered the fundamentals and applications of channel coding in digital communications, and provided insight into current research activities in this field.

Contents: Fundamentals of Block Coding, Linear Block Codes, Linear Cyclic Codes, BCH und RS Codes, Convolutional Codes, Turbo Codes, Principles and Limits for Information Combining, LDPC-Codes, Polar Codes, Coded Modulation.

Adaptive and Array Signal Processing, WS 2016/17

Prof. Dr. Rodrigo de Lamare, Pontifical Catholic University of Rio de Janeiro

Prof. de Lamare gave an overview of array signal processing for communications and radar with a focus on beamforming and direction of arrival estimation.

Contents: Fundamentals of Array Processing, Array Configurations, Discrete Time Models, Optimum and Robust MVDR Beamforming, Adaptive Beamforming, Direction of Arrival Estimation.

Multirate Digital Signal Processing, SS 2018

Prof. Dr. Dietmar Wenzel, Rhode & Schwarz GmbH, TU Munich

Sampling rate conversion is a key factor, especially when it comes to the coupling of digital systems or to the compression of data. In this lecture, students learned the underlying theory and background, to design sampling rate converters, to employ various implementation forms, and to understand the economical aspects of different architectures. Examples for implementations of multirate signal processing architectures were given for audio, video and mobile communications.

Research

The Institute of Signal Processing focuses on the algorithmic-, architectural- and hardware-oriented aspects of signal processing systems. Application areas are information and communication systems, particularly radio frequency and baseband integrated circuits, bio- and sensor-signal processing as well as automotive applications. Our research portfolio includes both fundamental science and applied research. Several projects are conducted in co-operation with academic and industrial partners.

Academic Partners

- Alpen-Adria University (AAU) Klagenfurt, Austria
- Carinthian Tech Research AG (CTR), Villach, Austria
- Kepler Universitätsklinikum (KUK), Linz, Austria
- Linz Center of Mechatronics GmbH (LCM), Austria
- Pontifical Catholic University of Rio de Janeiro, Brazil
- Research Center for Non Destructive Testing GmbH (RECENDT), Linz, Austria
- Silicon Austria Labs (SAL)
- Software Competence Center Hagenberg (SCCH)
- Technical University Ilmenau, Germany
- University of Applied Sciences of Upper Austria
- University of Erlangen-Nuremberg, Germany

Industrial Partners

- Danube Integrated Circuit Engineering GmbH & Co KG (DICE), Infineon Linz, Austria
- Danube Mobile Communications Engineering GmbH & Co KG (DMCE), Intel Linz, Austria
- GE Healthcare, Zipf, Austria
- Infineon Technologies Austria AG, Villach
- Infineon Technologies AG, Munich, Germany
- Intel Austria GmbH, Villach
- Primetals Technologies Austria GmbH, Linz
- voestalpine AG, Linz, Austria

Silense

Funding

- CDG (Christian Doppler Research Association), since 2017
- EU Horizon 2020 programme, since 2017
- FFG (Austrian Research Promotion Agency), since 2013
- FWF (Austrian Research Fund), 2013-2016
- Industrial partners, since 2013

Christian Doppler Forschungsgesellschaft

FFG Promoting Innovation.

FWF Der Wissenschaftsfonds.

JOHANNES KEPLER UNIVERSITY LINZ

Research

On the following pages we give an overview about the research at the ISP. We start with the absolute highlights, that are the Ph.D. examinations and our doctorate graduates. In the reporting period five researchers that started their project during Mario Huemer's time in Klagenfurt conducted their doctoral exams at the Alpen-Adria University Klagenfurt, and two Ph.D. exams already took place at JKU. Like in Klagenfurt, we will establish the old tradition, that the researchers of the institute build a doctor cap for the graduates.

The subsequent sections will be dedicated to our research projects. At the ISP, on the one hand we develop fundamental signal processing algorithms further, and on the other hand we apply signal processing algorithms to a variety of different modern applications, the latter in close co-operation with industry partners. One of the nice things about our research discipline is that we come in contact with many different application fields, which is also reflected in the manifold research projects conducted at the ISP.

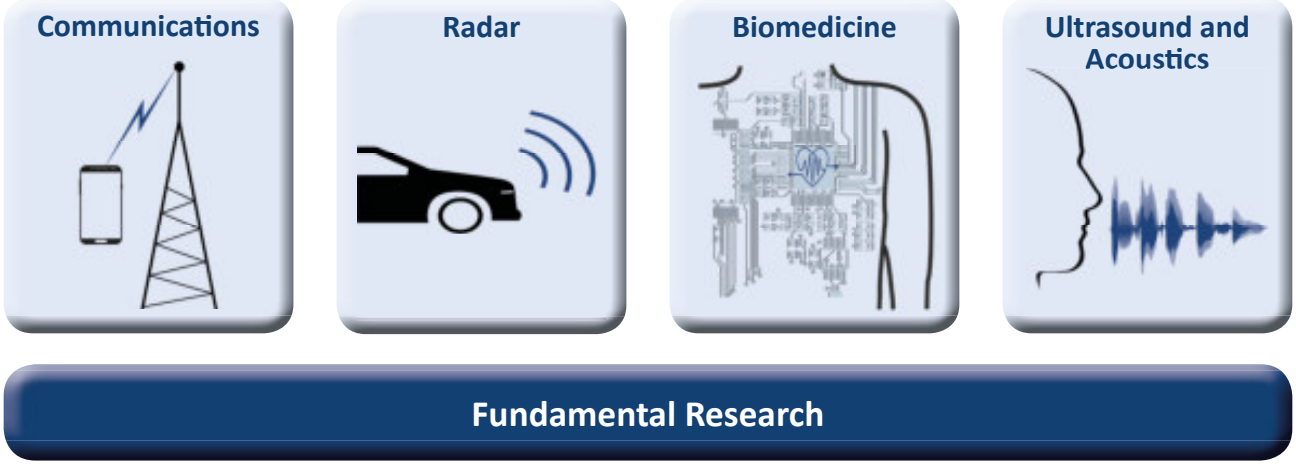
In our project overview we group related projects together. We start with the more application oriented projects in the fields:

- **Signal processing for communications,**
- **Signal processing for automotive radar transceivers,**
- **Biomedical signal processing,**
- **Ultrasound and acoustic signal processing,**
- **Battery and power management,**

followed by purely fundamental research projects:

- **Low complexity iterative signal processing methods,**
- **Sparsity aware signal processing,**
- **Knowledge-aided methods in estimation theory and adaptive filtering.**

The project overview is then followed by our list of publications, patents, and talks, we present our appointments and activities for the scientific community and for the JKU, and proudly report about our received awards.



Completed Ph.D. Theses

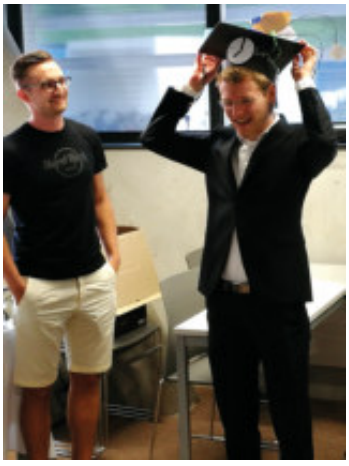
Johannes Kepler University Linz

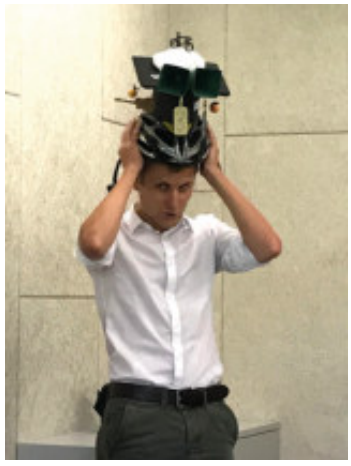
- **Oliver Lang:** *Knowledge-Aided Methods in Estimation Theory and Adaptive Filtering.* Institute of Signal Processing, May 2, 2018.
- **Alexander Melzer:** *Short-Range Leakage Cancellation in FMCW Radar Transceiver MMICs.* Institute of Signal Processing, June 21, 2017.

OLIVER LANG DURING HIS PH.D. DEFENSE

Alpen-Adria University Klagenfurt

- **Venkata Satya Rajendra Prasad Pathuri Bhuvana:** *Robust and Efficient Techniques for Multi-Sensor Information Filtering.* Institute of Networked and Embedded Systems, Nov. 16, 2017.
- **Christian Hofbauer:** *Design and Analysis of Unique Word OFDM.* Institute of Networked and Embedded Systems, June 22, 2016.
- **Matteo Agostinelli:** *Nonlinear Control for Integrated DC-DC Converters.* Institute of Networked and Embedded Systems, Dec. 18, 2015.
- **Christoph Unterrieder:** *Design, Modeling and Implementation of a Battery Management Fuel Gauge IC.* Institute of Networked and Embedded Systems, Nov. 2, 2015.
- **Alexander Onic:** *Receiver Concepts for Unique Word OFDM.* Institute of Networked and Embedded Systems, Dec. 13, 2013.





DIY DOCTOR CAPS - AN ISP TRADITION
(LEFT TO RIGHT) OLIVER LANG, ALEXANDER MELZER, CHRISTIAN HOFBAUER

Research Projects

Communications Engineering

CD Lab for Digitally Assisted RF Transceivers for Future Mobile Communications

Project Facts

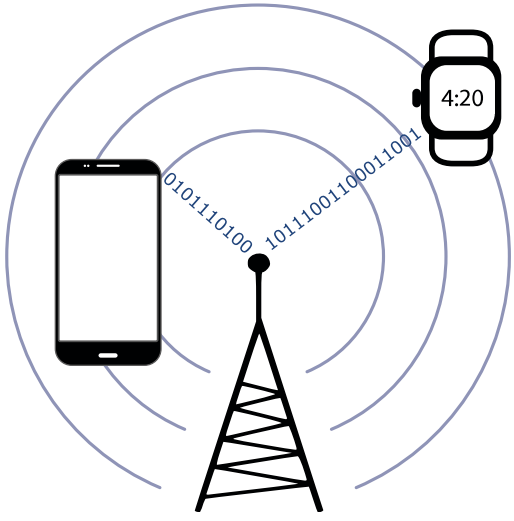
- **Funding:** CDG, DMCE (Intel Linz)
- **Partners:** DMCE (Intel Linz)
- **Duration:** Jan. 2017 - Dec. 2023

Research Focus

- **Receiver Interference Cancellation**
- **Energy Efficient Digitally Assisted Transmitter Architectures**
- **All-Digital Phase-Locked Loops**

Overview

In January 2017, the Institute of Signal Processing and the Institute for Communications Engineering and RF-Systems established the *Christian Doppler (CD) Laboratory for Digitally Assisted RF Transceivers for Future Mobile Communications* in co-operation with DMCE Linz, an Intel subsidiary. The lab has a total duration of seven years and an overall budget of € 4.700.000.-. The CD laboratory is dedicated to basic and applied research on digital signal processing (DSP) methods for radio frequency (RF) transceivers. With current Complementary Metal-Oxide-Semiconductor (CMOS) technology, DSP methods are perfectly suited to compensate analog imperfections appearing in RF circuits, to introduce advanced signal processing methods not feasible with analog circuits, and to benefit from technology scaling in terms of computing performance, power consumption and chip area.



Heads of the CD Lab

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RF transceivers in current commercial products already make use of DSP. The continuously increasing requirements for mobile devices, e.g. from the 4th generation (4G) mobile communications standard “Long Term Evolution” (LTE) and the currently implemented 5G standard, will strongly increase this

CD Lab for Digitally Assisted RF Transceivers for Future Mobile Communications

Andreas Springer and Mario Huemer

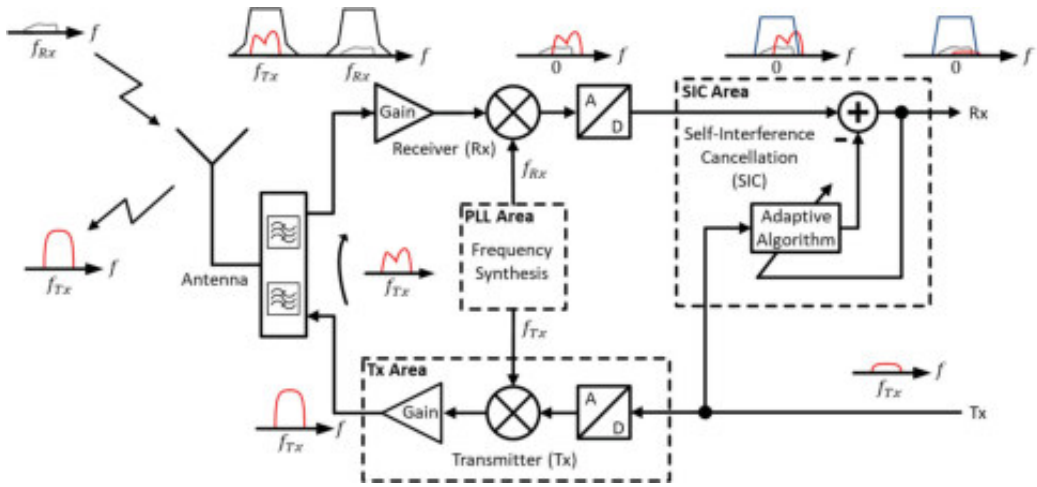
need in future developments. A common result of these requirements is both a significant rise in complexity of the transceiver architectures and a substantially increasing number of possibilities for self-interference. In the CD laboratory we tackle these issues by making use of DSP and focus our research in three areas:

- **Area 1: Receiver (RX) Interference Cancellation:** We develop methods to identify and cancel interference in the receivers by digital or mixed signal concepts.
- **Area 2: Energy Efficient Digitally Assisted Transmitter (TX) Architectures:** Digitally assisted transmitter architectures need to be explored to accommodate channel bandwidths well beyond 20 MHz for high data rate applications.
- **Area 3: All-Digital Phase-Locked Loops:** Improved all-digital phase-locked loops (ADPLLs) are required, e.g. to reduce the number of digitally controlled oscillators in a transceiver chip. Furthermore, the reduction of the power consumption of ADPLLs is targeted to enable low-cost RF transceivers for Internet of Things devices.

While each of these three strands of research has its own specifics, complexity and interference issues are linking them together and make them to some extent depend on each other. Furthermore, system-level time- and frequency domain modeling and statistical signal processing methods are common research methods applied across the different topics.

Outcomes of our CD-laboratory are DSP algorithms, architectures, methods, and in selected cases prototype implementations for RX, TX and ADPLL which allow the realization of RF transceivers fulfilling the increasing requirements on user experience like data rate and seamless connectivity while reducing chip area, power consumption and design complexity.

The block diagram below depicts a typical RF transceiver and visualizes the three research areas addressed above. Area 1 is handled by the ISP, area 2 is executed in co-operation of both institutes, and area 3 is conducted by Prof. Springer's institute. In the following the three areas are described briefly.



JOHANNES KEPLER UNIVERSITY LINZ

Research Projects

Receiver Interference Cancellation

One of the main reasons for receiver desensitization in frequency-division duplex (FDD) transceivers is the limited isolation between the transmitter(s) and the receiver(s). The resulting transmitter leakage into the receiver paths can be identified as the root cause of several receiver interferences. With the introduction of carrier aggregation to support higher data rates the number of severe transmitter induced interference problems has even reached a new dimension, and the challenges will further exacerbate in 5G and beyond RF transceivers.

In this area mathematical models of the different types of interferences are developed, and fully digital as well as mixed signal based interference cancellation methods are investigated. We develop adaptive and flexible architectures and aim to relax the requirements on the analog components. Also complexity considerations play a crucial role, since the algorithms have to run in real-time on battery powered mobile communication devices. Especially for nonlinear problems it is not always straightforward to derive a perfectly accurate mathematical model, therefore we currently, in parallel to model based approaches, also investigate data based machine learning concepts for self-interference cancellation.

The main focus of our investigations in this area is on the cancellation of TX induced self-interference, but concepts to mitigate other types of interferences (such as, e.g., WiFi blockers) are also investigated.

ISP Research Team

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Transmitter Architectures

Area 2 has its focus on signal processing concepts for digitally assisted transmit architectures. The aim of this area is to investigate and optimize novel architectures based on radio frequency digital-to-analog converters (RF-DACs) which are used to replace traditional mixers in the transmit path. Basically, we can distinguish between two topologies, the IQ-RF-DAC and the polar-RF-DAC, each

with its own advantages and disadvantages. We furthermore explore new architectures, which try to combine the advantages of both concepts. The goal is to enable the efficient use of RF-DACs for LTE and 5G waveforms. Since these standards have stringent requirements on spectral purity, we particularly investigate digital pre-distortion methods to linearize the transmitters.

ISP Research Team

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Frequency Synthesis

Area 3 focuses on the advancement of ADPLLs as a major building block in RF transceivers. Research is conducted to improve spectral purity, frequency coverage, and settling time of ADPLLs. For polar transmitter architectures the target is to improve the modulation bandwidth of the ADPLL to cover the increasing bandwidths appearing in LTE carrier aggregation modes and in 5G. For low-power Internet of Things (IoT) applications the power consumption of ADPLLs needs to be reduced significantly.

Selected Publications

[1] Gebhard A., Lang O., Lunglmayr M., Motz C., Kanumalli R. S., Auer C., Paireder T., Wagner M., Pretl, H., Huemer M., "A Robust Nonlinear RLS Type Adaptive Filter for Second-Order-Intermodulation Distortion Cancellation in FDD LTE and 5G Direct Conversion Transceivers," *accepted for publication in the IEEE Transactions on Microwave Theory and Techniques.*

[2] Sadjina S., Kanumalli R. S., Gebhard A., Dufrene K., Huemer M., Pretl H., "A Mixed-Signal Circuit Technique for Cancellation of Interferers Modulated by LO Phase-Noise in 4G/5G CA Transceivers," in *IEEE Transactions on Circuits and Systems I: Regular Papers,* vol. 65, no. 11, pp. 3745-3755, Nov. 2018.

[3] Klinkan A., Pfann E., Huemer M., "A Novel Interpolation Method for Polar Signals in Radio Frequency Transmitters," in *IEEE Transactions on Circuits and Systems II: Express Briefs,* vol. 65, no. 5, pp. 692-696, May 2018.

[4] Kanumalli R. S., Buckel T., Preissl C., Preyler P., Gebhard A., Motz C., Markovic J., Hamidovic D., Hager E., Pretl H., Springer A., Huemer M., "Digitally-Intensive Transceivers for Future Mobile Communications - Emerging Trends and Challenges," in *e&i Elektrotechnik und Informationstechnik (Austrian Journal of Electrical and Information Engineering),* vol. 135, no. 1, pp. 30-39, Jan. 2018.

[5] Trampitsch S., Markovic J., Oßmann P., Fritzin J., Zaleski J., Mayer C., Fulde M., Pretl H., Springer A., Huemer M., "A Nonlinear Switched State-Space Model for Capacitive RF DACs," in *IEEE Transactions on Circuits and Systems I: Regular Papers,* vol. 64, no. 6, pp. 1342-1353, June 2017.

Research Projects

Communications Engineering, Fundamental Research

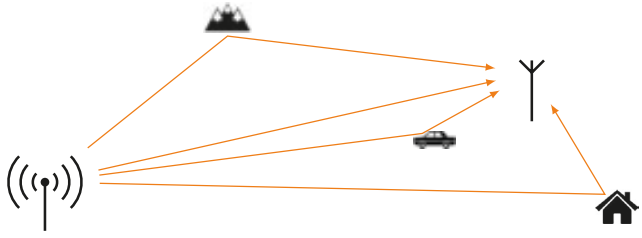
Unique Word OFDM

Ph.D. Project Facts

- **Funding:** FWF
- **Partners:** University of Erlangen-Nuremberg
- **Duration:** Sept. 2013 - Apr. 2016

Research Focus

- **Waveform Design for Future Wireless Communications**
- **Data Estimation**



Overview

Orthogonal Frequency Division Multiplexing (OFDM) is currently the dominating digital transmission technique in most of the modern broadband wireless and wired communication systems. One of the drawbacks of classical OFDM is that up to 20% of the transmit energy is wasted for so called guard intervals (GIs), which are placed between successive OFDM symbols to cope with the effects of multipath propagation. These guard intervals are typically built by random, data dependent sequences. In Unique Word OFDM (UW-OFDM), which has been developed by the involved project partners, the guard interval is built of a deterministic - the so-called unique word. This sequence provides the same advantages as the usual cyclic prefix GI (diagonalization of the channel matrix, prevention of intersymbol interference), but can additionally be designed to optimally meet synchronization and estimation tasks. Furthermore, most importantly, and different to almost all block based signaling

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Unique Word OFDM

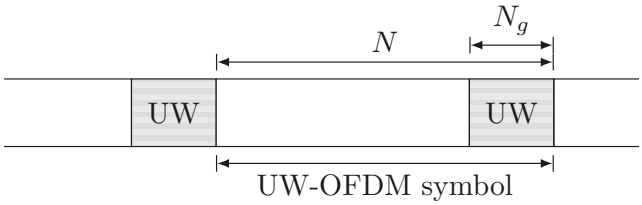
Christian Hofbauer, Alexander Onic and Mario Huemer

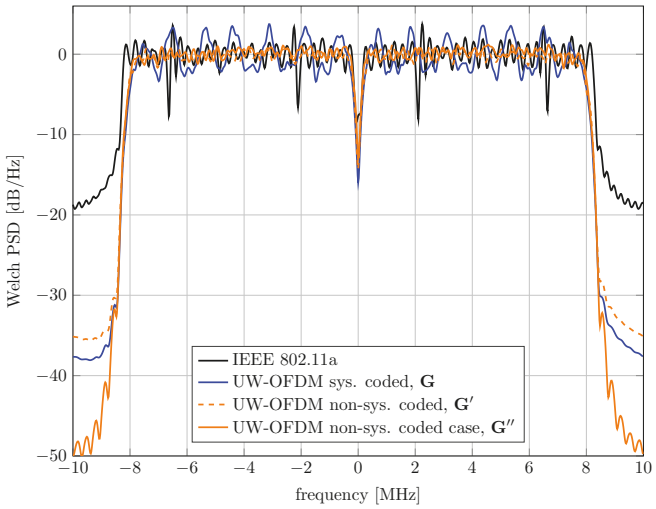
schemes it entails the introduction of a certain redundancy in the frequency domain. This redundancy can be exploited beneficially to enhance range, reliability, capacity or battery lifespan. In this sense, UW-OFDM transforms the usually disregarded guard interval into a multi purpose sequence, thus tackling the well-known inefficiency problem of guard intervals in current communication systems. Moreover, adapting the UW and therefore the GI length to different channel conditions will not impact the DFT length and thus keeps relevant processing chain structures untouched. Hence, UW-OFDM allows supporting a wide range of communication scenarios while ensuring high efficiency.

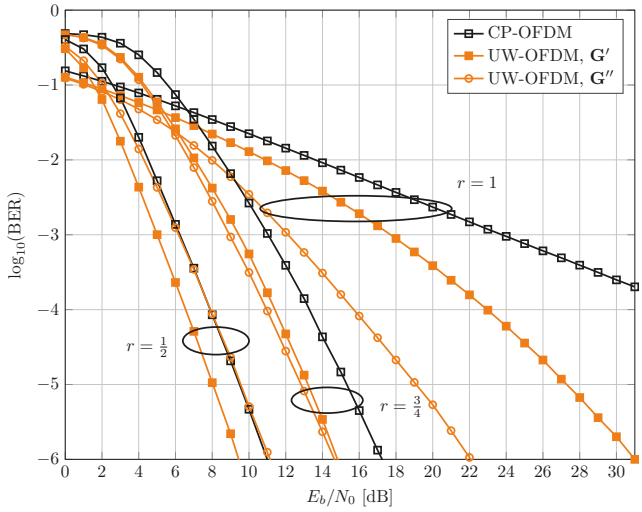
Selected Publications

[1] Onic A., Huemer M., "Noise Interpolation for Unique Word OFDM," in *IEEE Signal Processing Letters*, vol. 21, no. 7, pp. 814-818, July 2014.

[2] Huemer M., Hofbauer C., Onic A., Huber J., "Design and analysis of UW-OFDM signals," in *International Journal of Electronics and Communications (AEÜ)*, vol. 68, no. 10, pp. 958-968, Oct. 2014.







JOHANNES KEPLER UNIVERSITY LINZ

Research Projects

Radar Signal Processing

Short-Range Leakage Cancellation in Automotive Radar Systems

Ph.D. Project Facts

- **Funding:** FFG (COMET Research Programme), DICE Linz
- **Partners:** DICE Linz, LCM Linz
- **Duration:** Mar. 2014 - June 2017

Research Focus

- **Radar Signal Processing and Analysis**
- **Leakage Cancellation, Statistical Signal Processing**
- **Hardware Prototyping with Real-Time Signal Processing on FPGA**

Overview

Today's cars are equipped with radar sensors, which provide precise information about the distance, speed and angle to surrounding objects on the road. This information is essential for modern driver assistance systems such as adaptive cruise control or brake assistance systems. Further, it enables future autonomous driving features. Most importantly, however, the accuracy and range of the radar sensors are critical for the safety of the car occupants as well as other daily road users. This is of particular significance since around 90 percent of all rear-end collisions with personal injuries occur due to human mistakes. Assuming all cars on the road to be equipped with emergency brake systems, up to 72 percent of these collisions could be prevented.

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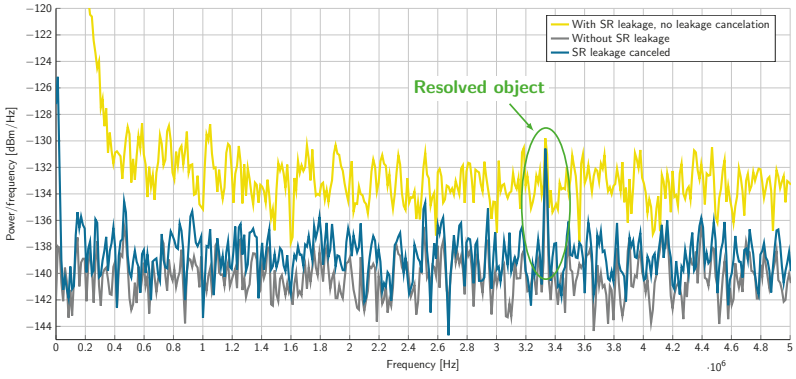
Short-Range Leakage Cancellation in Automotive Radar Systems

Alexander Melzer and Mario Huemer

For reasons of car appearance as well as protection of the device itself, the radar sensors are often mounted right behind the bumper. This, however, causes unwanted signal reflections from such. Particularly, the reflections yield so-called short-range (SR) leakage, which superimposes reflections of true objects that have to be detected most precisely. Together with disturbances inherently present in the radar transmit signal, the bumper reflections limit the achievable sensitivity and accuracy of the radar sensor severely. As a consequence, driver assistance systems may react delayed in critical situations.

In this Ph.D. project, novel concepts that aim to cancel the SR leakage in the automotive application have been proposed. These are the first known solutions of their kind that can be implemented holistically within an integrated circuit (IC) operating at 77 GHz. The tight design constraints regarding implementation in the IC are circumvented by employing sophisticated statistical signal processing. Simulation as well as measurement results from the developed hardware prototype show that the sensitivity can be more than doubled by applying the proposed concepts.



Selected Publications

[1] Melzer A., Starzer F., Jäger H., Huemer M., "Real-Time Mitigation of Short-Range Leakage in Automotive FMCW Radar Transceivers," in *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 64, no. 7, pp. 847-851, July 2017.

[2] Melzer A., Onic A., Huemer M., "Online Phase Noise Estimation in FMCW Radar Transceivers Using an Artificial On-Chip Target," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 64, no. 12, pp. 4789-4800, Dec. 2016.

[3] Melzer A., Onic A., Starzer F., Huemer M., "Short-Range Leakage Cancelation in FMCW Radar Transceivers Using an Artificial On-Chip Target," in *IEEE Journal of Selected Topics in Signal Processing*, vol. 9, no. 8, pp. 1650-1660, Dec. 2015.

Research Projects

Radar Signal Processing

Phase Noise Monitoring in Automotive Radar Sensors

Ph.D. Project Facts

- **Funding:** DICE Linz (an Infineon subsidiary)
- **Partners:** DICE Linz
- **Duration:** July 2016 - Dec. 2019

Research Focus

- **RF-Impairments in Radar MMICs**
- **Phase Noise Monitoring Functions**
- **Radar Signal Processing**

Overview

Since the first radar system was successfully tested by Christian Hülsmeyer in 1904, radar sensors were used to determine the range, angle and velocity of objects in many different applications. Due to its unique property of being not effected by adverse lighting and weather conditions it is considered a key technology for modern vehicle safety and comfort systems. Together with ultrasound sensors, lidars, and cameras, frequency modulated continuous wave (FMCW) radar systems form the backbone of advanced driver assistant systems (ADASs) as well as autonomous driving (AD). Since ADASs directly influence the vehicle dynamics, new regulating functional safety (FuSa) requirements, such as the ISO 26262 standard, were introduced. Fulfilling this standard requires not only intensive verification and testing of the product functionality, but also monitoring of safety relevant parameters during operation in order to protect the road users.

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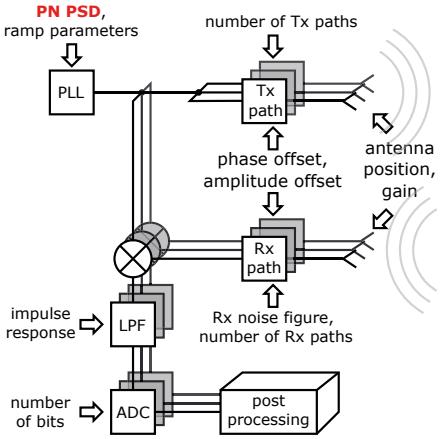
Phase Noise Monitoring in Automotive Radar Sensors

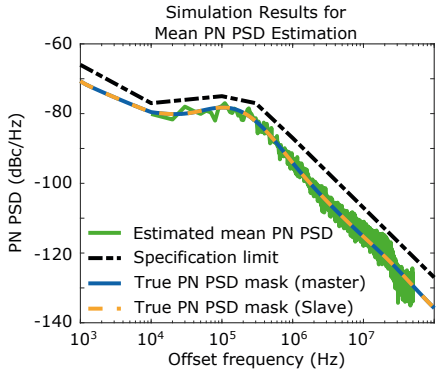
Michael Gerstmair and Mario Huemer

The aim of this Ph.D. project is to investigate the impact of selected RF impairments on the radar measurement and further develop monitoring functions for safety relevant parameters using sophisticated signal processing algorithms.

One of the most limiting impairments of an FMCW radar system in terms of range precision and detection sensitivity is the phase noise (PN) contained in the transmit signal. To fully understand the influence of PN on the radar measurement, a fast and accurate PN simulation environment, including state-of-the-art radar signal processing algorithms for signal evaluation, was implemented [1]. The simulator directly calculates the baseband signal and thereby omits computationally expensive RF rates. This results in very fast simulations, since the baseband bandwidths are typically in the low MHz range.

The thereby acquired knowledge was used to develop a PN monitoring function for high resolution radar sensors [2]. These high resolution radar systems are able to precisely locate and identify objects in their field of view. To provide the therefore required number of transmit and receive channels, multiple radar MMICs are connected, i.e. cascaded. The developed monitoring function estimates the mean PN power spectral density (PSD) of two radar MMICs during operation. This estimation result can subsequently be used to detect if the MMICs generate PN out of specification. Different to most of the existing work, this method uses an application relevant FMCW signal instead of a continuous wave signal. Since PN monitoring functions are indispensable in terms of FuSa for ADAS and future AD, the method was patented, and further publications are in progress.





Selected Publications

[1] Gerstmair M., Melzer A., Onic A., Huemer M., "Phase Noise Power Spectral Density Estimation in Cascaded Automotive Radar Transceiver MMICs," in *Proceedings of the ASILOMAR Conference on Signals, Systems, and Computers*, 4 pages, Oct. 2018, Pacific Grove, CA, USA.

[2] Gerstmair M., Melzer A., Onic A., Stuhlberger R., Huemer M., "Highly Efficient Environment for FMCW Radar Phase Noise Simulations in IF Domain," in *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 65, no. 5, pp. 582-586, May 2018.

Research Projects

Biomedical Signal Processing

ECG Signal Analysis

Ph.D. Project Facts

- **Partners:** Kepler Universitätsklinikum (KUK)
- **Duration:** Apr. 2016 - Mar. 2020

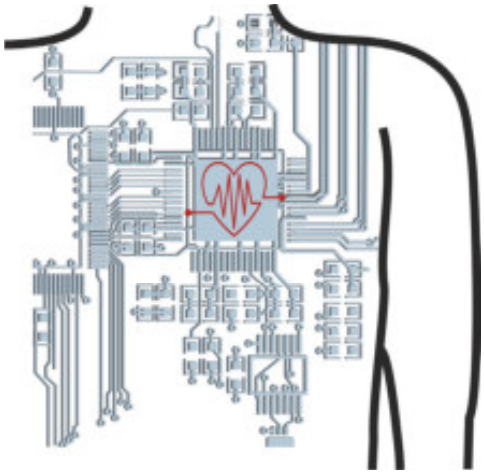
Research Focus

- **Biomedical Signal Processing**
- **Time-Frequency Analysis and Signal Representation**
- **Decision Support in Critical Care**

Overview

Current investigations focus on the electrocardiogram (ECG) which is a well-established and easy to obtain physiological signal of remarkable diagnostic power. It provides a wide spectrum of information regarding a patient's condition. However, the clinically relevant information is often transient or masked by noise and therefore hard – if not even impossible – for the human observer to detect and interpret. In general, consistent interpretation of ECG phenomena is a difficult task due to inter-patient and inter-observer variability. This research aims to develop analysis tools that provide reliable parameters and predictors for distinct diseases, thereby supporting practicing clinicians in their daily business.

The electrocardiogram (ECG) is one of the most used biomedical signals for diagnosing cardiovascular diseases. As shown in the figure below, it reflects the internal or external influences onto our cardiovascular system, as e.g. mental stress, medication, or



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ECG Signal Analysis
Carl Böck, Péter Kovács and Mario Huemer

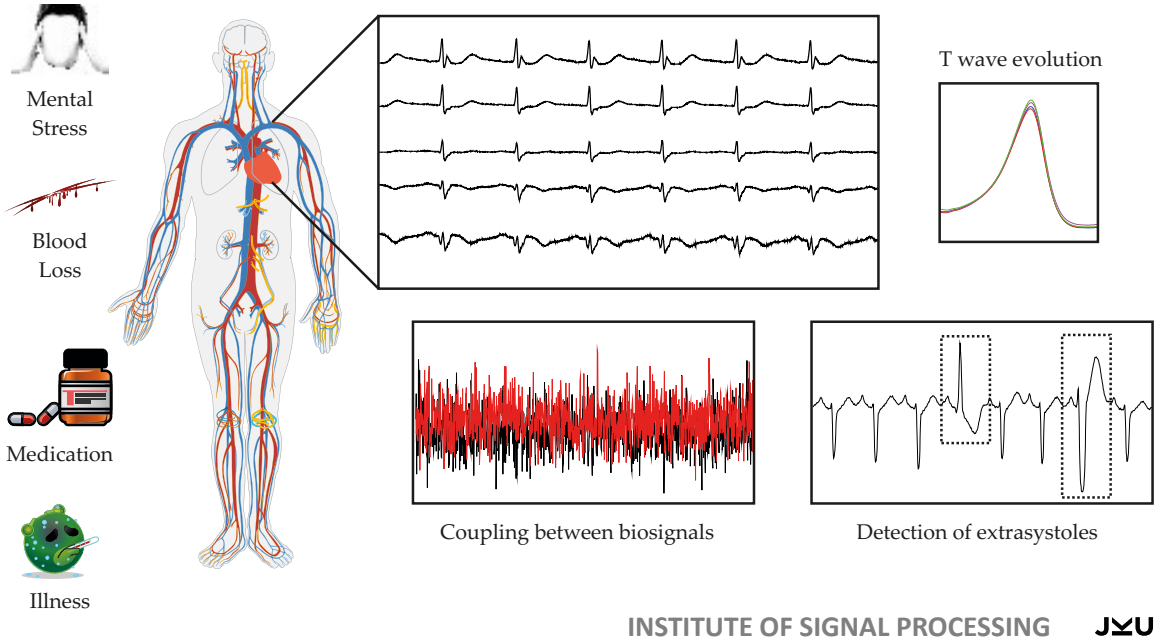
illness. Diagnoses for specific diseases are usually based on clinically established parameters, such as unnatural changes in the heart rate, disturbances in the heart rhythm, or obvious changes of the ECGs' morphology. Although these parameters are, due to their simplicity and interpretability, extremely useful for physicians, they do not provide information about subtle changes of the underlying ECG. A subtle change in the ECGs' morphology however, could be a crucial indicator for a specific pathology and could therefore support physicians in the diagnosis procedure.

This Ph.D. project focuses on the extraction and visual representation of hidden information in the ECG. Unfortunately, this information is not only superimposed by well-known noise sources, such as baseline wander, muscle noise, etc., but also by physiological noise, introduced, for example, by a changing respiratory rate. Consequently, such influences have to be eliminated before extracting the diagnostic information. Considering this, the long-term variability and changes of the ECG morphology are analyzed and evaluated in terms of their medical usefulness. For that reason we use specific signal transformations in order to represent the crucial information in a low-dimensional space. Particular attention is paid on the interpretability of the extracted information, such that physicians are supported but not replaced in decision-making.

Selected Publications

[1] Kovács P., Böck C., Dozsa T., Meier J., Huemer M., "Waveform Modeling by Adaptive Weighted Hermite Functions," *accepted for publication in the Proceedings of the IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP 2019)*, May 2019, Brighton, Great Britain.

[2] Kovács P., Böck C., Meier J., Huemer M., "ECG Segmentation Using Adaptive Hermite Functions," in *Proceedings of the ASILOMAR Conference on Signals, Systems, and Computers*, pp. 1476-1480, Oct. 2017, Pacific Grove, CA, USA.



Research Projects

Biomedical Signal Processing

Medical Ultrasound Imaging

Project Facts

- **Funding:** FFG (COMET Research Programme), GE Healthcare
- **Partners:** LCM Linz, GE Healthcare
- **Duration:** May 2018 - Dec. 2021

Research Focus

- **Artifact Suppression for Medical Ultrasound Imaging**
- **Time-Varying System Identification**
- **Data-Driven Modeling**

Overview

The real-time nature of medical ultrasound, combined with the ease of use, the low cost and the portability of its equipment renders ultrasound imaging an indispensable tool for both diagnostic and guided applications. Ultrasound has the ability to penetrate deep into soft tissues maintaining a good spatial resolution. Despite the great advances in ultrasound imaging technology, there is still space for improvement in terms of image resolution enhancement. This research focuses on the algorithmic development of signal processing and system identification techniques that tackle the unwanted effects of noise originating either from the body itself or the ultrasound system, providing higher quality images with enhanced diagnostic value.

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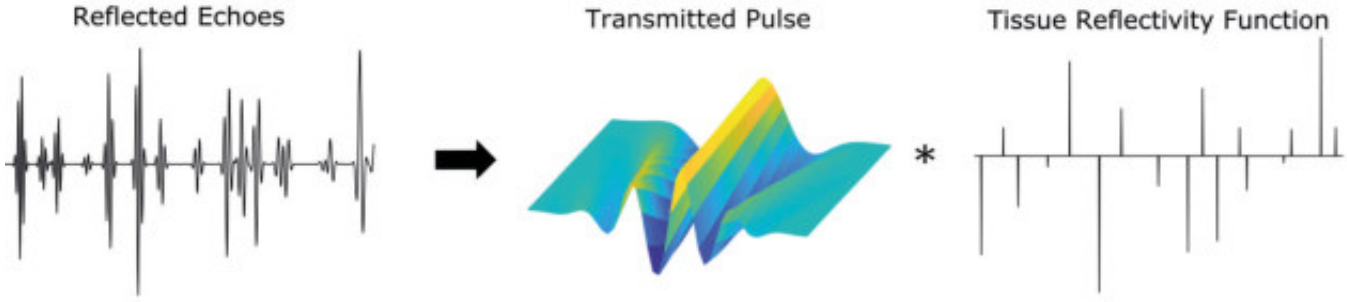
Medical Ultrasound Imaging

Kyriaki Kostoglou and Carl Böck

Medical ultrasound is a noninvasive imaging technique that uses high-frequency sound waves to create real-time images of the human body. The procedure involves an ultrasonic transducer that transmits short acoustic pulses and records the echoes that are reflected back from internal structures of targeted body regions. These echoes are then used to generate fine images of the underlying anatomy.

The interaction between the acoustic pulse generated by the transducer and the scanned human tissue introduces a particular type of blurring to the output image (as shown in the figure below), reducing both contrast and resolution. The removal of the pulse from the ultrasound image is not an easy task since tissue heterogeneity induces pulse-shape distortions. Furthermore, image quality is degraded by the presence of noise that arises either from the electronics of the detection system or the large variations in the acoustic properties of the body. One such example is reverberation noise, i.e. echoes that are reflected back and forth several times before they reach the transducer.

The main goal of this research is the development of compensation strategies that reduce the impact of acoustic and anatomic artifacts, allowing proper image interpretation. Specifically, we focus on eliminating the blurring effect of the transmitted pulse on the obtained images. To this end, we have developed data-driven algorithms that can accurately model the transmitted pulse and track changes in its shape down through the tissue. By removing the distorted pulse from the ultrasound image, we achieve improved contrast and image resolution. Compared to other techniques, the aforementioned data-driven methodology is fully automated and requires no prior knowledge of the underlying system characteristics. Regarding the suppression of noise artifacts, originating either from the body or the ultrasound system, we combine adaptive filtering methods and time-varying system identification techniques taking into account the exact position and the shape of the artifacts, as well as prior information about the anatomy.



Ultrasound imaging can be described as a system identification problem. The echoes that are reflected back to the transducer can be modeled as the convolution between the distorted transmitted pulse and the tissue reflectivity function (i.e. the strength of the acoustic reflectors and scatterers in the tissue as a function of their spatial coordinates). The convolution with the pulse has a blurring effect on reflectivity, and usually closely spaced reflectors are not easily distinguished.

Research Projects

Ultrasound and Acoustic Signal Processing

Ultrasound Gesture Recognition

Project Facts

- **Funding:** EU (ECSEL project), FFG
- **Partners:** Infineon Villach, Infineon Munich, LCM Linz
- **Duration:** May 2017 - Apr. 2020

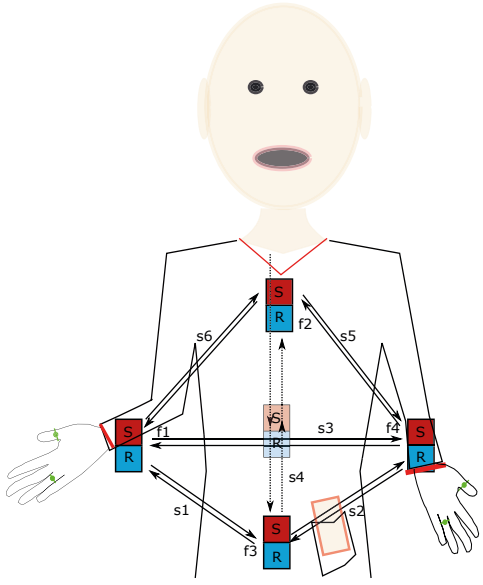
Research Focus

- **Ultrasound Localization**
- **Machine Learning**
- **Array Signal Processing**
- **Gesture Tracking**

Overview

With the advance of ultrasound transducer technology reducing sensor size, cost and power consumption while increasing bandwidth ultrasound based designs become a viable alternative in a range of new application areas.

To promote research and explore different use cases of ultrasound technology is one of the main aspirations of the European Horizon 2020 project “Silense”. In this context, applications for the automotive market, indoor navigation and smart home environment, to name a few, are investigated. As part of the Silense consortium our research focus lies on the realization of a wearable gesture recognition system.



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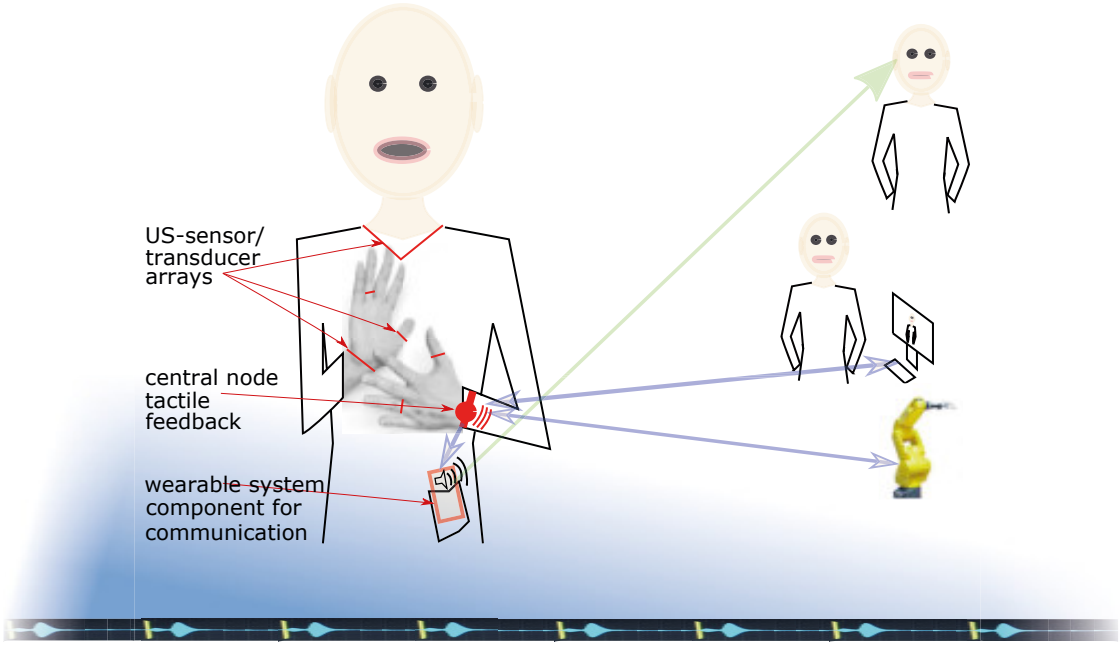
Ultrasound Gesture Recognition
Eugen Pfann and Daniel Lagler

The applications of wearable gesture recognition systems are manifold and some realizations of such ultrasound systems are on the market today already - for example in the gaming industry as human-machine interface control gadgets. This research takes the existing capabilities one step further, mainly in terms of accuracy and speed of measurements and the number of transducer nodes deployed in order to increase the space of coverage.

This will open new possibilities in a variety of use cases. In this project we target three application areas, namely, sign language interpretation, control of industrial robots and physio-therapeutic training aids to assist an accurate reproduction of the training exercises as instructed by the therapist.

The figure below depicts an ultrasound gesture recognition system. It consists of a number of small nodes attached to wearable items such as rings, a necklace, a belt buckle or wrist bands. These nodes perform measurements on their relative location and motion and, pass the acquired information to a central unit.

The main focus in this project is to devise the signal processing algorithms to provide exact location and motion measurements and to extract the required information from the raw data. This includes array signal processing, sensor signal fusion and motion tracking. Appropriate features are extracted from the recorded data and serve as input for machine learning algorithms in order to yield information on the executed gestures.



Research Projects

Ultrasound and Acoustic Signal Processing

Airborne Ultrasound in Home Environments

Ph.D. Project Facts

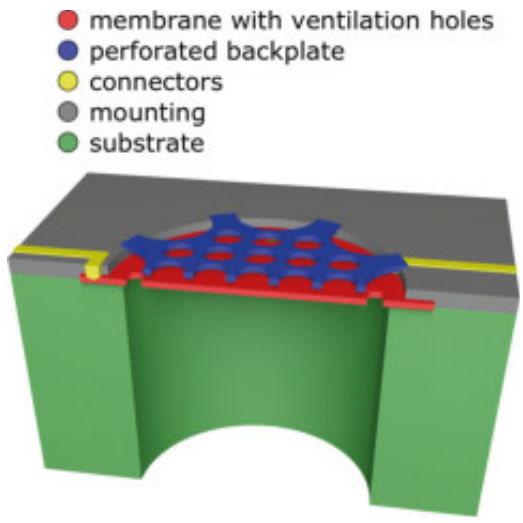
- **Funding:** Infineon Villach
- **Partners:** Infineon Villach, Infineon Munich
- **Duration:** May 2018 - Apr. 2021

Research Focus

- **Echo-Localization**
- **Beamforming**
- **Object Detection**
- **Gesture Recognition**

Overview

The advances in microelectromechanical systems (MEMS) manufacturing enables the production of small and low-cost capacitive micromachined ultrasound transducers (CMUTs). In contrast to piezoelectric ultrasound transducers, which exploit the piezoelectric effect of certain materials in order to convert a voltage into an ultrasound wave and vice versa, capacitive ultrasound transducers consist of a parallel plate capacitor containing a fixed backplate and a flexible membrane. Applying an alternating voltage between the membrane and the backplate, the electrostatic forces cause a vibration of the membrane and generate an ultrasonic pulse. Due to the reversibility of the process, this effect may be also used for measuring incident ultrasound signals.



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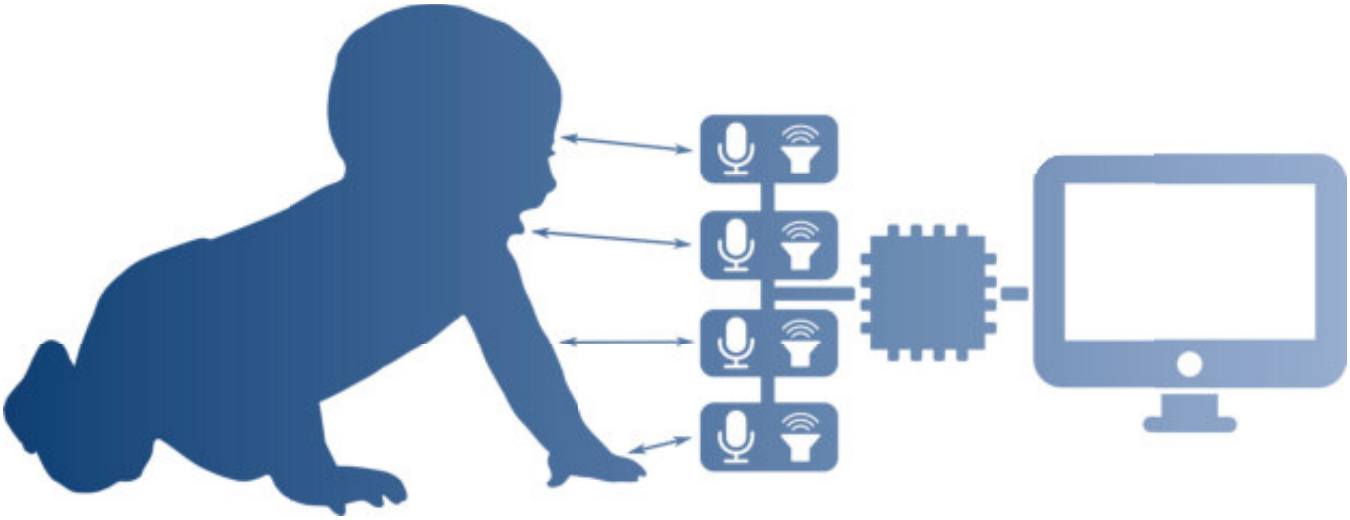
Airborne Ultrasound in Home Environments

Daniel Lagler, Eugen Pfann and Mario Huemer

As a result of a significant decrease in manufacturing costs during the last few years, the application of capacitive ultrasound technology is facilitated in smart home applications, where low cost and lean design are crucial. In this joint project with Infineon Technologies AG, we implement systems composed of small arrays of CMUTs and investigate them in terms of spatial and temporal resolution, range, required hardware and energy consumption. Basic measurements with the MEMS transducers and acoustic simulations of several array geometries provide insights into the possibilities and limits of certain array layouts. Additionally, the influence of temperature, wind, atmospheric humidity and other influencing factors on the speed of sound, attenuation and reflectance are analyzed in order to avoid incorrect assumptions of certain input parameters and for the development of robust algorithms.

A second focus in this Ph.D. project is the development of signal and image processing algorithms with respect to dedicated tasks in smart home environments. This includes in particular the development and improvement of object and person detection algorithms, people counting or gesture recognition. In addition to classical signal and image processing approaches, segmentation and pattern recognition techniques and also machine learning approaches are investigated.



Research Projects

Ultrasound and Acoustic Signal Processing

Photoacoustic and thermographic non-destructive testing

Project Facts

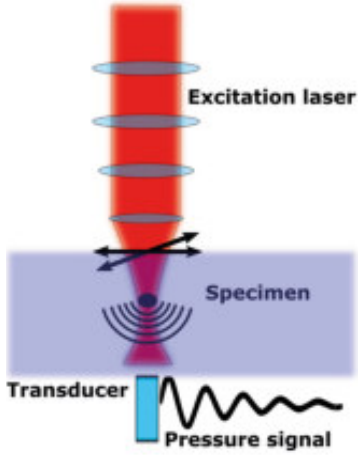
- **Funding:** RECENDT GmbH, JR Center for Thermal NDE of Composites
- **Partners:** RECENDT GmbH, JR Center for Thermal NDE of Composites
- **Duration:** May 2018 - Dec. 2018

Research Focus

- **Photoacoustic and Thermographic Imaging**
- **State Space Models and Analysis**
- **Optimization and Regularization Methods**

Overview

Analysis of structural imperfections of materials, spare parts, or components of a system is very important in order to prevent malfunctioning devices. For economic reasons, these investigations should be carried out in a non-destructive way. For instance, ultrasonic testing is a widely used technique, which is based on ultrasound wave propagation in the specimen to be tested. In this case, ultrasound waves pass through the material and are reflected by the defects. The echo pulses can be measured on the surface of the specimen, which are used to localize the defects in question. The research project focuses on photoacoustic and thermographic imaging, in which multiple 1D surface measurements are combined to reconstruct the original pressure or heat distribution in the cross section of the sample. Medical imaging is another possible application, where abnormalities of the biological tissue should be detected.



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Photoacoustic and thermographic non-destructive testing

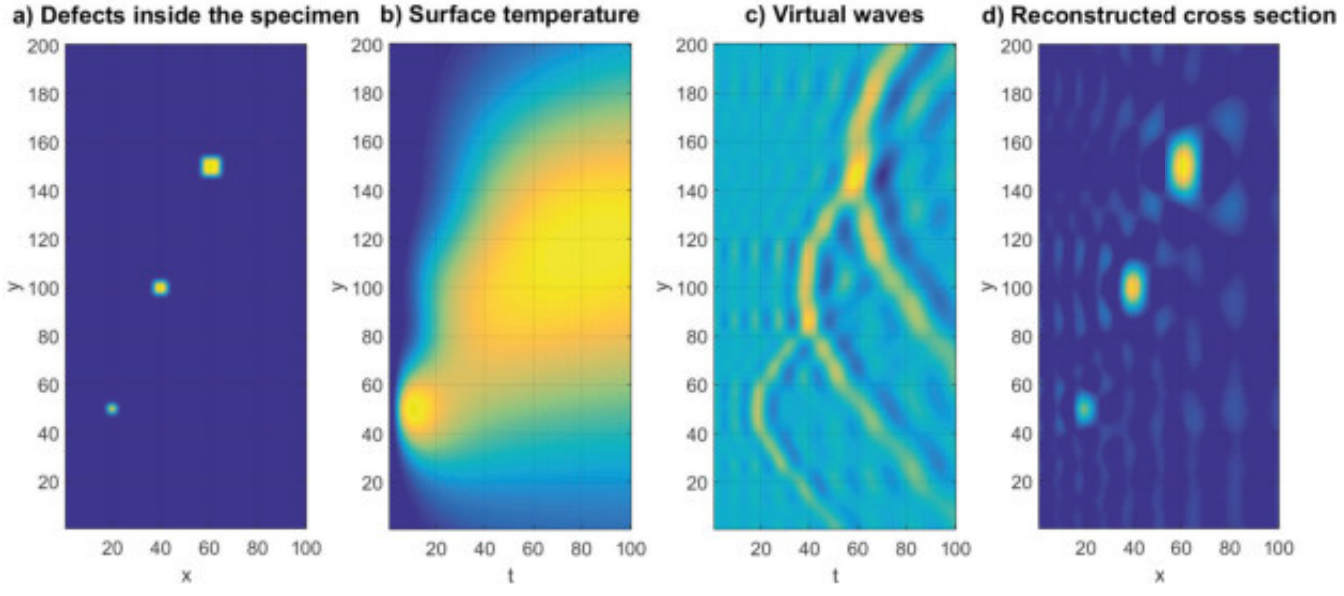
Péter Kovács, Michael Lunglmayr, Christian Motz, Oliver Lang and Mario Huemer

Photoacoustic imaging, also called optoacoustic or thermoacoustic imaging, is based on the generation of ultrasound following a temperature rise after illumination of light absorbing structures within a (semi)transparent and turbid material, such as a biological tissue. It provides optical images with specific absorption contrast. In photoacoustic tomography the temporal evolution of the acoustic pressure field is sampled using an array of ultrasound detectors placed on or outside the tissue surface or by moving a single detector across the detection surface. Images of the optical absorption within the tissue are then reconstructed by solving an inverse source problem. The main goal of this research is to improve the reconstruction accuracy by using state space models and optimization of the excitation laser signals. In order to deal with the ill-posedness of the problem, regularization methods can be applied incorporating additional conditions such as non-negativity and sparsity.

In case of thermographic imaging the specimen is heated, then the corresponding temperature evolution is measured on the sample surface. Compared to ultrasonic testing, the physical phenomena for thermography is quite different, which is described by the heat diffusion equation. However, the original problem can be reformulated in such a way that ultrasound imaging techniques are applicable. The figure below demonstrates each step of this transformation, which is again an ill-posed inverse problem causing artifacts in the reconstructed image, see, for example, figure d). In this project, we are focusing on regularization techniques in order to improve the reconstruction accuracy.

Selected Publications

[1] Lang O., Kovács P., Motz C., Huemer M., Berer T., Burgholzer P., "A Linear State Space Model for Photoacoustic Imaging in an Acoustic Attenuating Media," in *Inverse Problems*, vol. 35, no. 1, 29 pages, Jan. 2019.



Research Projects

Ultrasound and Acoustic Signal Processing

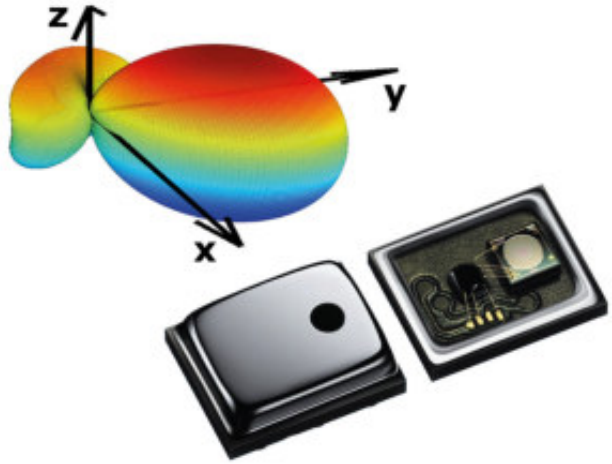
Acoustic Beamforming and Event Detection

Ph.D. Project Facts

- **Funding:** Infineon Villach
- **Partners:** Infineon Villach, Infineon Munich
- **Duration:** Nov. 2015 - Oct. 2019

Research Focus

- **Microphone Array Processing**
- **Speech Enhancement**
- **Noise Reduction**
- **Acoustic Event Detection**



Acoustic Beamforming

For humans, voice is the most natural way of communicating with each other. For this reason the desire of interacting with computers by voice was always present over the past 50 years. The performance capability of modern computers combined with recent advances in the development of artificial intelligence made it possible for devices to perceive voice commands. Cloud-based voice assistants, currently available on the market, are an emerging technology that enables the control of electrical household devices, gathering information from the Internet and setting up all kind of reminders. These interfaces utilize microphones that capture the spoken commands and transfer them into the cloud for further processing. As it can be seen in the picture on the next page, in a real environment there are many challenges to be overcome to receive a clean voice signal that can be interpreted by the device. For example, reflections (1), back-

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Acoustic Beamforming and Event Detection
Andreas Gaich, Eugen Pfann und Mario Huemer

ground noise (2), and acoustic echos (3,4) overlap with the desired voice signal and as a consequence degrade the word recognition rate.

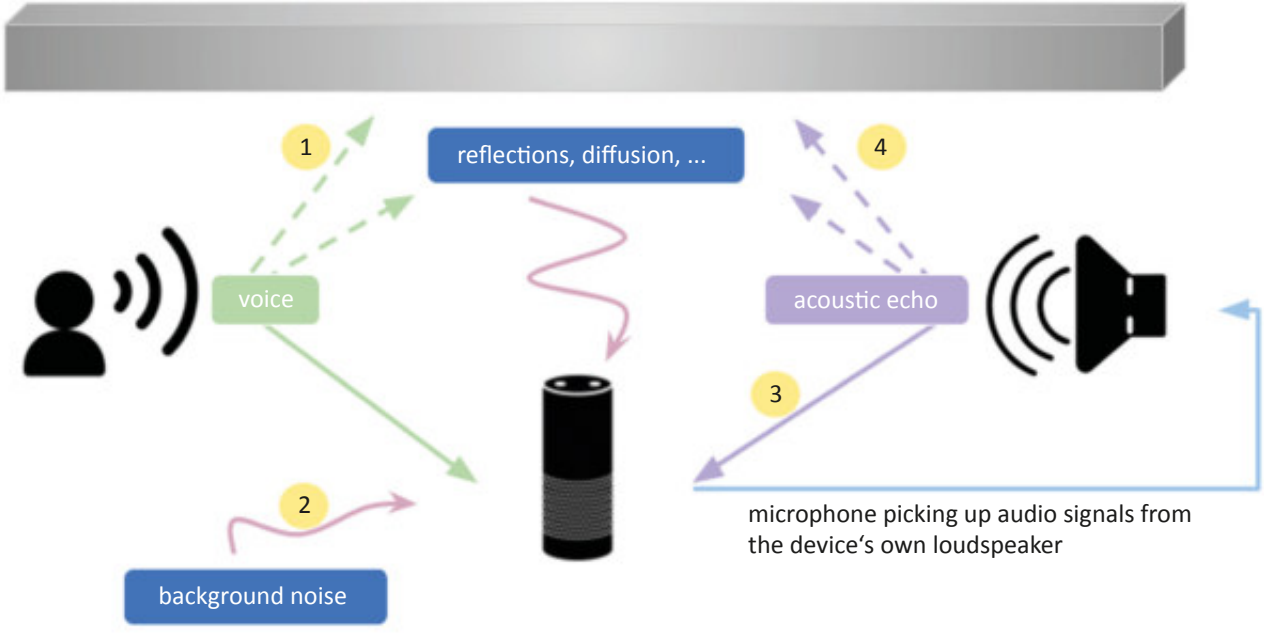
Therefore microphone arrays can be used to enhance the speech quality and suppress ambient noise. Microphone arrays utilize the spatial information of the sound sources and focus on the direction of the desired source while suppressing sources from other directions. This is called beamforming.

In this Ph.D. project we develop model based as well as deep learning based beamforming algorithms for voice assistance applications and investigate the influence of microphone and array imperfections, such as microphone self noise, complex frequency response mismatch between microphones in the array, and microphone displacement, on the performance of these algorithms.

Acoustic Event Detection

Sound capturing devices become increasingly ubiquitous in different kind of environments ranging from homes and offices to car interiors and on mobile phones. Combining ease of installation and decreasing costs the main purpose of these devices is typically the recording and processing of speech. However, at the same time these devices can be utilized to scan the environment in order to detect events which have a particular acoustic signature. For example, this could be a home appliance break down, a water leak, an intrusion scenario or a person or object falling to the ground.

Machine learning algorithms are applied in this project for acoustic event detection. A main focus lies on an increase of algorithm reliability, as depending on the type of event a false alarm can have similar negative consequences as a non-detected event.



Research Projects

Ultrasound and Acoustic Signal Processing

Acoustic based Predictive Maintenance

Ph.D. Project Facts

- **Funding:** FFG (COMET Research Programme), Primetals Technologies
- **Partners:** LCM Linz, Primetals Technologies
- **Duration:** Jan. 2018 - Dec. 2021

Research Focus

- **Acoustic Signal Processing and Analysis**
- **Time-Frequency Analysis and Signal Representation**
- **Pattern Classification**
- **Machine- & Deep Learning**

Overview

The detection of faulty conditions in steel plants by characterization of the emitted sound is a versatile tool with usually small installation effort.

Furthermore, the question from where the erroneous sound is emitted is an interesting research topic with wide application possibilities, as it directly allows not only the detection but also the immediate localization of potential problems. The advantages of acoustic condition monitoring with localization features range from condition-based maintenance to early diagnosis of unexpected behavior of the plant and thus to an improvement of the economic efficiency.

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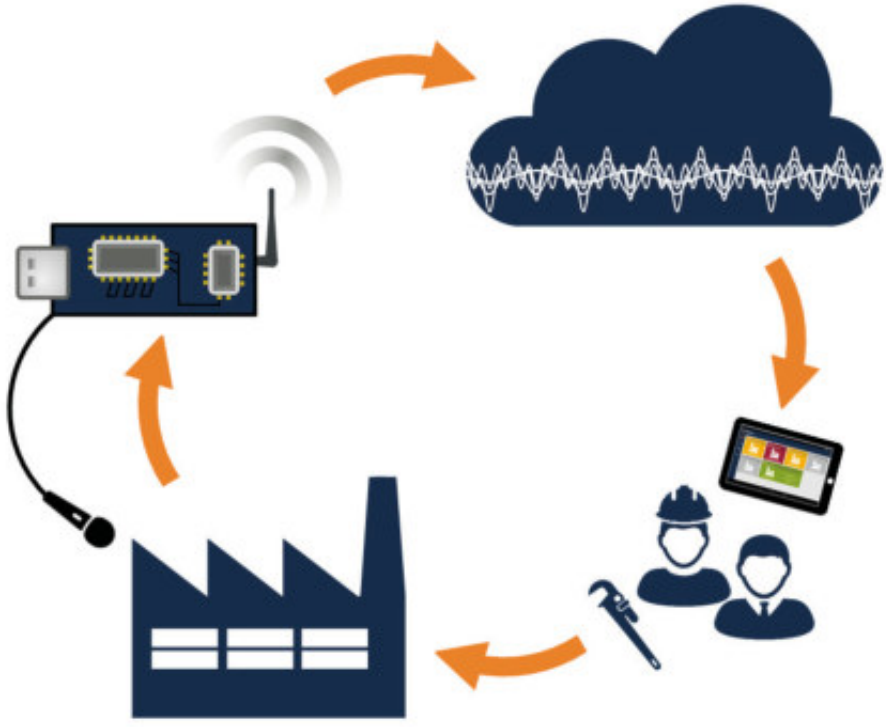
Acoustic based Predictive Maintenance
Adnan Husakovic, Eugen Pfann, Andreas Gaich and Mario Huemer

Causal relation models describing the interdependencies and connections between process variables may also help to perform supervision and quality control in various systems. These will be especially considered in those ones where no quality criteria are measured/supervised over time, i.e. where no direct predictive mappings can be established. Such models, which may be built from high-dimensional and/or transformed system identification cycles might be used for residual signal analysis: significant deviations may provide an indication for upcoming problems either at a late or even at an early stage.

This Ph.D. project focuses on patterns of sound signals in the time-frequency domain in combination with machine and deep learning based classification or regression methods. Appropriate feature extraction, sliding-window and frequency analysis techniques of the audio signals will help to prepare an adequate compact representation of the signals and to reduce the dimensionality of the learning problems and the models.

Selected Publications

[1] Husakovic A., Pfann E., Huemer M.: "Robust Machine Learning Based Acoustic Classification of a Material Transport Process," in *Proceedings of the 14th Symposium on Neural Networks and Applications (NEUREL 2018)*, 4 pages, Nov. 2018, Belgrade, Serbia.



Research Projects

Battery and Power Management

Highly Efficient Wireless Power Transfer

Ph.D. Project Facts

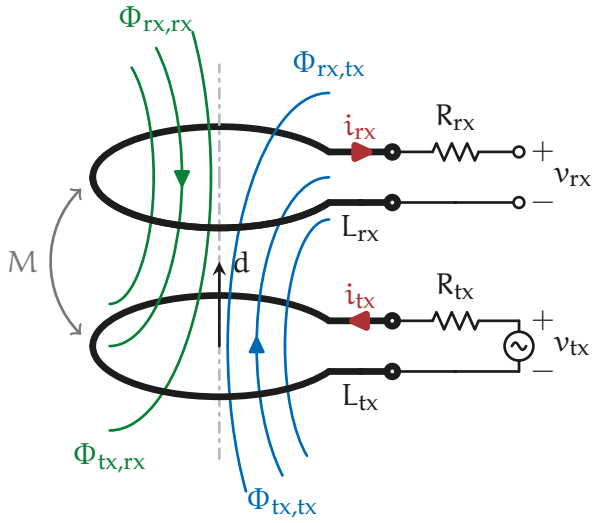
- **Funding:** Infineon Villach
- **Partners:** Infineon Villach
- **Duration:** Sept. 2013 - June 2016

Research Focus

- **System Modeling**
- **Control Techniques**
- **Optimization Concepts**

Overview

The increasing demand on battery-powered electronic devices fosters the need for innovative solutions for the power and battery management of these systems. It is a common situation that the battery of our smartphone runs low quite fast and we have to recharge it several times a day. This comes from the fact that today's batteries often constitute the bottleneck in the design of mobile devices. Wireless power transfer is an emerging technology which allows engineers to completely "cut the wire" and create a remarkable new user experience. Since the battery of our smartphone is constantly recharged whenever the device is placed on the wireless charger that could be seamlessly integrated in a piece of furniture, e.g. an office desk, we do not even recognize that the phone is recharged.



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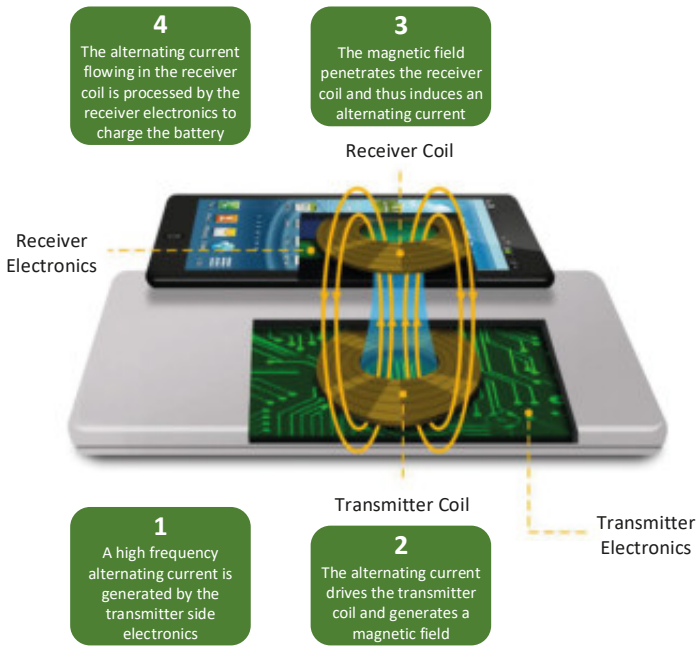
Highly Efficient Wireless Power Transfer

Andreas Berger and Mario Huemer

A typical wireless power transfer system, as shown in the figure below, consists of a transmitter, generating a magnetic field, and a receiver, utilizing the transmitted energy to charge e.g. the battery of a smartphone. The achievable efficiency depends on physical quantities, i.e. the distance and alignment between the coils, and the utilized electrical power processing. To improve the system performance a sophisticated control algorithm has been developed, which is able to increase the power transfer efficiency by modulating the phase-shift and the output voltage amplitude of the active rectifier in the receiver. Additionally, the developed control approach enables increases in the amount of extractable output power and consequently the possible operation distance between transmitter and receiver by a substantial amount.

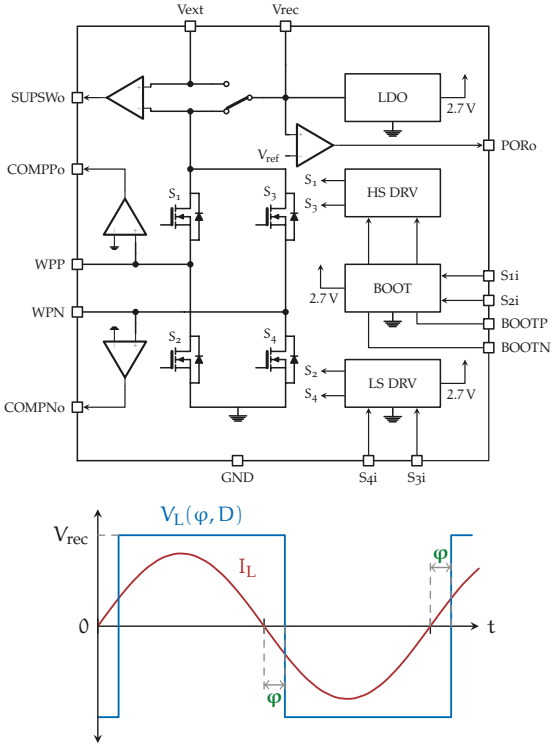
The research focus of this Ph.D. project is the modelling, control and optimization of wireless power transfer systems in the low to medium power range up to 15W, which is perfectly suited for charging devices like smartphones and tablet computers.



Selected Publications

[1] Berger A., Agostinelli M., Sandner C., Vesti S., Huemer M., "High Efficient Integrated Power Receiver for a Qi Compliant Wireless Power Transfer System," in *Proceedings of the IEEE Wireless Power Transfer Conference (WPTC 2016)*, 4 pages, May 2016, Aveiro, Portugal.

[2] Berger A., Agostinelli M., Vesti S., Oliver J., Cobos J., Huemer M., "A Wireless Charging System Applying Phase-Shift and Amplitude Control to Maximize Efficiency and Extractable Power," in *IEEE Transactions on Power Electronics*, vol. 30, no. 11, pp. 6338-6348, Nov. 2015.



Research Projects

Battery and Power Management

Advanced Control and System Identification Techniques for Multi-Phase DC-DC Converters

Ph.D. Project Facts

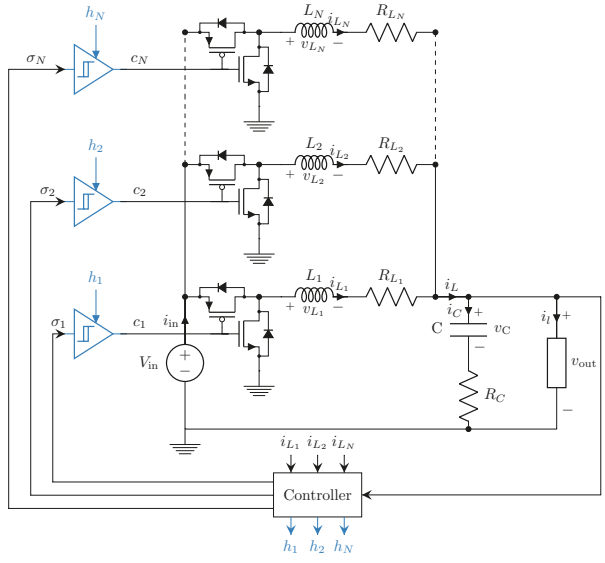
- **Funding:** Infineon Villach
- **Partners:** Infineon Villach
- **Duration:** Jan. 2016 - Dec. 2018

Research Focus

- **System Modeling**
- **Control Techniques**
- **System Identification Concepts**

Overview

The increasing amount of required functionality in today's electronic devices demands for more advanced power supply concepts. A possible solution to increase the performance and efficiency of DC-DC converters is to use multi-phase topologies. These converters employ multiple parallel power stages, hence sharing the total load current. In order to provide a regulated output voltage and equal sharing of the total current, a control concept is an essential part of such a converter. Furthermore, the importance of online system identification (SI) in power electronics is ever increasing. It enables the tracking of variable system parameters, which in turn can be used for online controller tuning.



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Advanced Control and System Identification Techniques for Multi-Phase DC-DC Converters

Marc Kanzian and Mario Huemer

In this project, a novel digital constant frequency sliding mode control (SMC) law for interleaved multi-phase DC-DC converters is developed. Both constant switching frequency and interleaving are achieved by dynamically adjusting the hysteresis band of the comparators that generate the control signals. The proposed interleaving method neither imposes constraints on the number of required phases to obtain a specific output voltage nor uses a quasi-SMC law as other implementations for interleaved converters typically do. The suggested control concept accomplishes an accurate output voltage regulation and an improved dynamic performance in comparison with quasi-SMC.

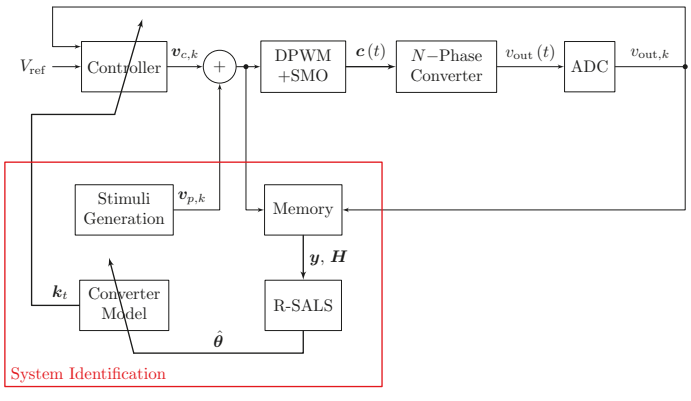
In order to detect the employed converter configuration, a state-space-based SI approach utilizing the step-adaptive approximate least squares estimation algorithm is proposed. The presented method accurately provides the parameters of the converter's state-space model while simultaneously featuring a fast convergence rate and low computational complexity.

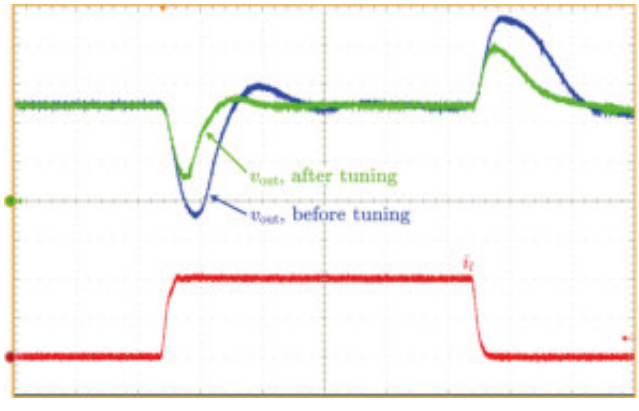
In comparison with state-of-the-art parametric SI methods, the number of required multiplications is more than halved, while accuracy is improved. Consequently, the estimated converter model is utilized to automatically tune the controller. This results in an improved converter performance in terms of overshoots, undershoots, and settling times.

Selected Publications

[1] Kanzian M., Gietler H., Unterrieder C., Agostinelli M., Lunglmayr M., Huemer M., "Low-Complexity State-Space-Based System Identification and Controller Auto-Tuning Method for Multi-Phase DC-DC Converters," in *IEEE Transactions on Industry Applications (Early Access)*, 11 pages, Oct. 2018.

[2] Kanzian M., Agostinelli M., Huemer M., "Sliding Mode Control with Inductor Current Observer for Interleaved DC-DC Converters," in *Proceedings of the IEEE Workshop on Control and Modeling for Power Electronics (COMPEL 2017)*, 7 pages, July 2017, Stanford, CA, USA.





Research Projects

Fundamental Research

Low Complexity Iterative Signal Processing Methods

Project Facts

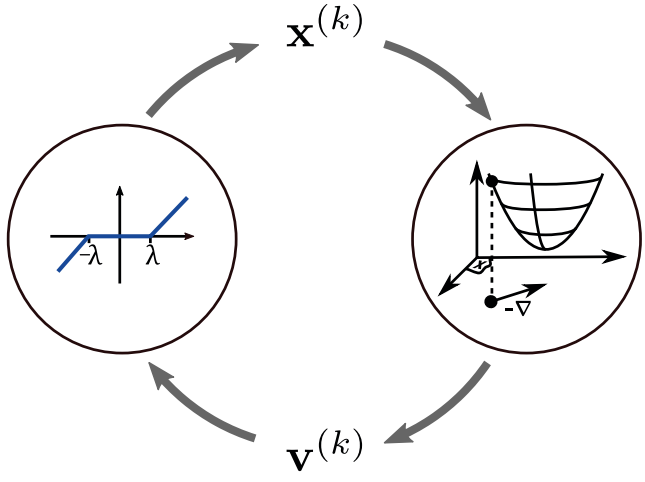
- **Duration:** since Jan. 2015, ongoing

Research Focus

- **Estimation Algorithms**
- **Low Complexity Algorithms**
- **Efficient Hardware Architectures**

Overview

The goal of this project is to develop low complexity iterative signal processing methods, mainly for estimation. The focus lies on developing low complexity algorithms for hardware implementation, as well as formulating the theoretical framework behind such algorithms. An efficient implementation starts with the design of an algorithm itself. Considering a future hardware implementation of an algorithm already during its design phase offers a large potential to reduce the complexity of a signal processing system. For this reason, this project covers the theoretical aspects of efficient algorithms as well as implementation specific details of a hardware realization. The project considers traditional l_2-norm estimation as well as combined l_1/l_2-norm approaches for sparse estimation.



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Low Complexity Iterative Signal Processing Methods
Michael Lunglmayr

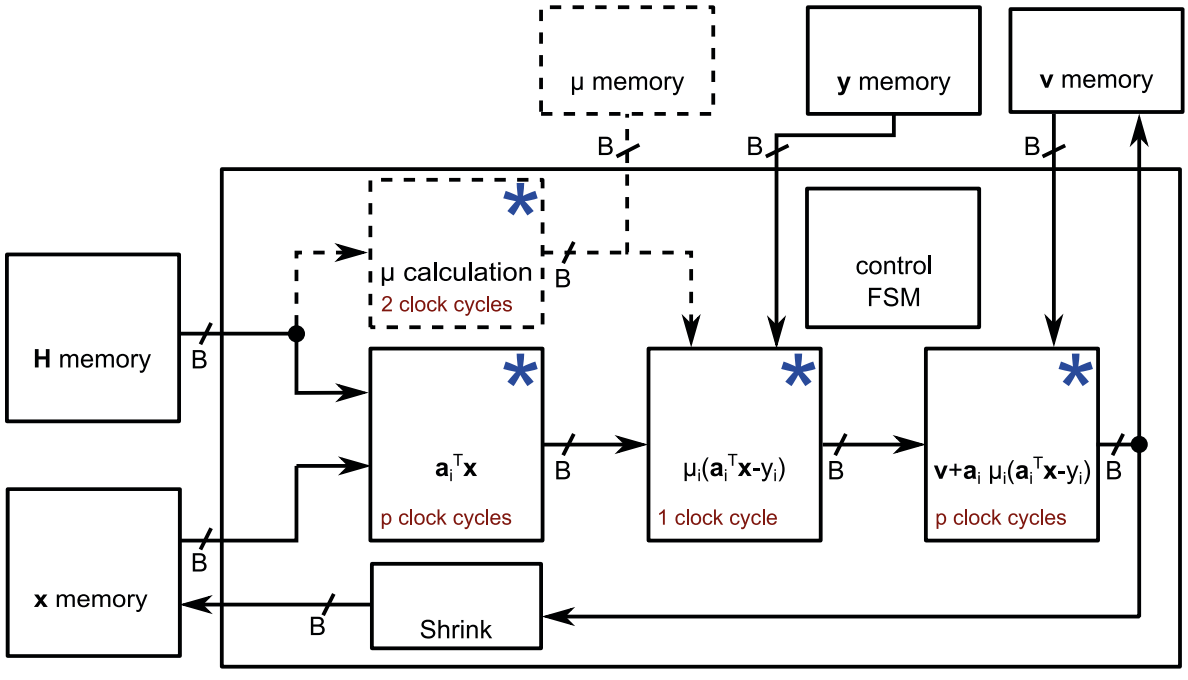
Because estimation algorithms are typically used in applications with noisy measurements, estimation results are naturally afflicted with errors. Due to these inevitable errors, approximate algorithms are often used in this field, allowing for a trade-off between precision and computational complexity. In this project, we especially investigate iterative algorithms, due to their typically fine granularity for tuning complexity as well as approximation error.

For designing low complexity iterative signal processing methods in digital hardware, not only the computational complexity, traditionally measured in multiply-and-accumulate (MAC) operations, has to be considered. For an implementation in digital hardware also memory access operations and memory organization, as well as the organization and placement of operational building blocks has to be considered. Furthermore, alternative implementation concepts such as stochastic computing are investigated within the scope of this project.

Selected Publications

[1] Lunglmayr M., Huemer M., "Sparsity-Enabled Step Width Adaption for Linearized Bregman based Algorithms," in *Proceedings of the 21st IEEE Statistical Signal Processing Workshop (SSP 2018)*, pp. 608-612, June 2018, Freiburg, Germany.

[2] Lunglmayr M., Hiptmair B., Huemer M., "Scaled Linearized Bregman Iterations for Fixed Point Implementation," in *Proceedings of the IEEE International Symposium on Circuits and Systems (ISCAS 2017)*, 4 pages, May 2017, Baltimore, MD, USA.



Research Projects

Fundamental Research

Sparsity Aware Signal Processing

Ph.D. Project Facts

- **Funding:** FFG (COMET Research Programme)
- **Partners:** LCM Linz
- **Duration:** May 2018 - Dec. 2021

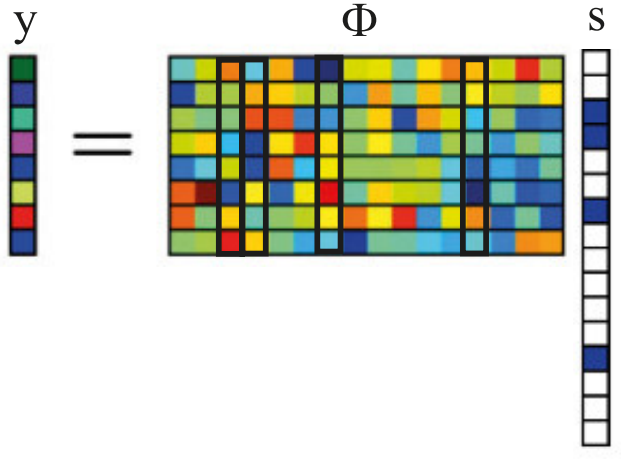
Research Focus

- **Estimation Algorithms**
- **Sparse Recovery Algorithms**
- **Efficient Hardware Architectures**

Overview

Sparse signal processing is a rapidly growing field that has attracted considerable attention in the scientific community in the last years, especially in the field of compressed sensing.

Compressed Sensing (CS) is a signal processing technique for efficiently acquiring and reconstructing sparse signals. A signal is considered sparse if most of its information is contained within a few non-zero samples. Consequently, a signal reconstruction algorithm has to find a sparse vector that best represents the measured signal. Many algorithms to solve this problem are based on l1-norm optimization. However, for a real-time implementation exactly solving an l1-norm optimization problem is typically too complex to be implemented. Alternatively, approximate algorithms can be used instead. Such algorithms typically do not only have less computational complexity, but often also



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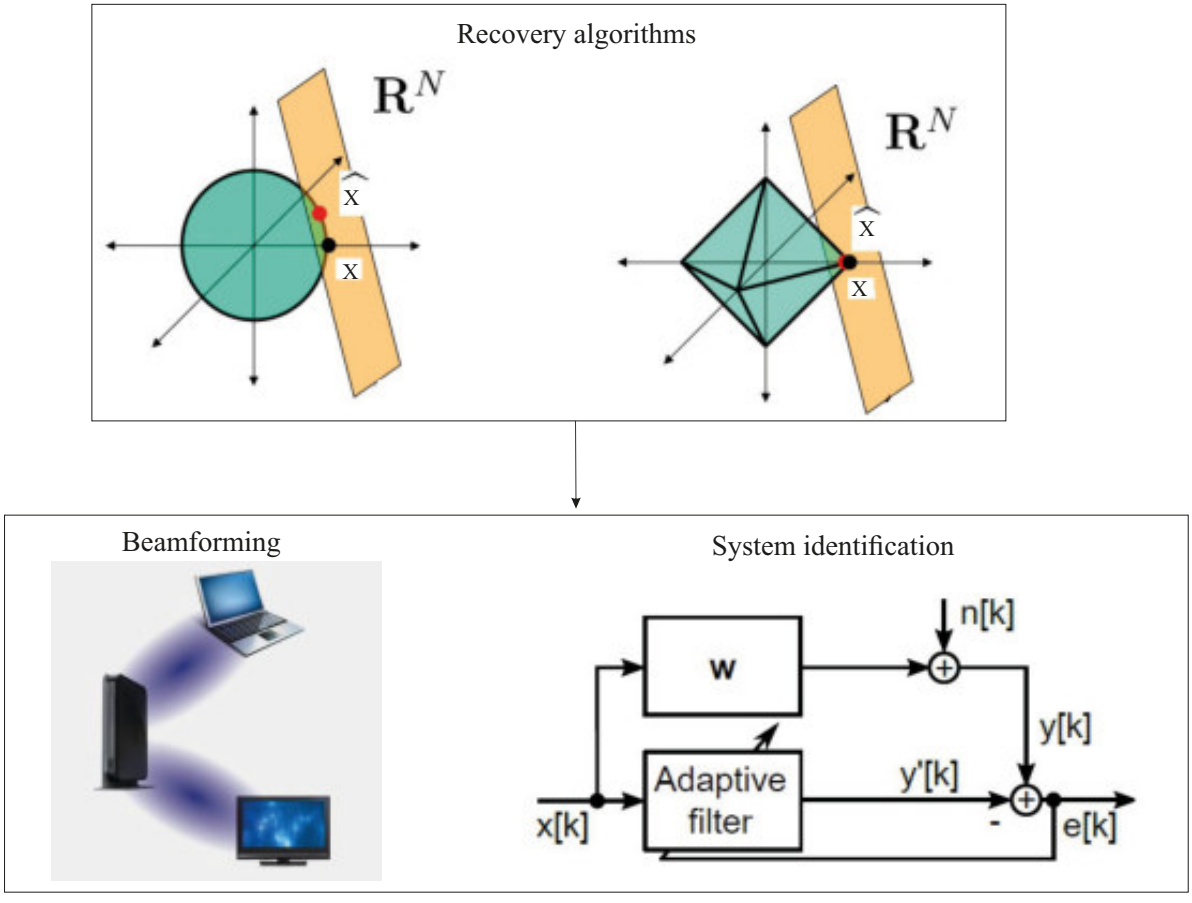
Sparsity Aware Signal Processing
Yuneisy E. Garcia, Michael Lunglmayr and Mario Huemer

require less memory access operations and less precision for number representation and arithmetic operations.

The main goal of this Ph.D. project is to design and implement efficient novel reconstruction algorithms allowing for a reasonable performance/complexity trade-off. Potential candidates are iterative or approximate algorithms that often achieve low complexity. We will particularly focus on compressed sensing and sparsity-aware algorithms for system identification, parameter estimation, beamforming or direction finding. Our aim is to develop efficient algorithm designs and architectures for selected use-cases by considering the implementation in digital hardware during the algorithm development phase.



Research Projects

Fundamental Research

Knowledge-Aided Methods in Estimation Theory and Adaptive Filtering

Ph.D. Project Facts

- **Duration:** Mar. 2014 - Feb. 2018

Research Focus

- **Knowledge-Aided Classical Estimators**
- **Component-Wise Conditionally Unbiased Bayesian Estimators**
- **Knowledge-Aided Adaptive Filters**

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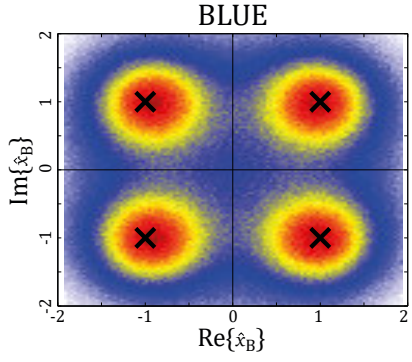
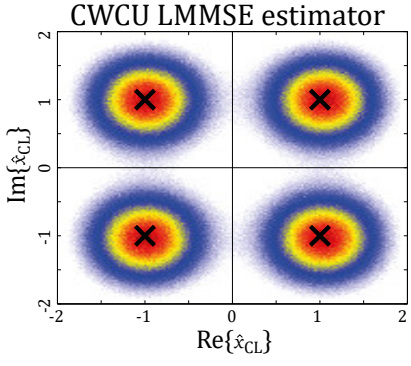
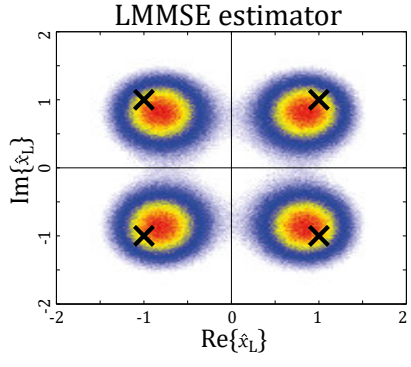
Overview

Estimation theory is a key enabler in many of today's electronic products, devices, and industrial equipment. It provides the basis for efficient data estimation in communication systems, accurate characterization of systems based on measurements, estimation of parameters, signals and spectra, signal tracking, or noise cancellation, to name just a few.







Knowledge-Aided Methods in Estimation Theory and Adaptive Filtering

Oliver Lang and Mario Huemer

Due to the ever-increasing complexity and the more demanding applications of modern electronic systems, optimal or near-to-optimal performance of estimation methods is often required. To achieve such an optimal performance, every available information about the underlying system model should be incorporated by the estimators.

Ultimately, additional model knowledge is present in many applications. Possible examples of additional model knowledge as well as their optimal incorporation into the estimation process were investigated within the scope of the Ph.D. dissertation conducted at the ISP from 2014 to 2018 by Oliver Lang.

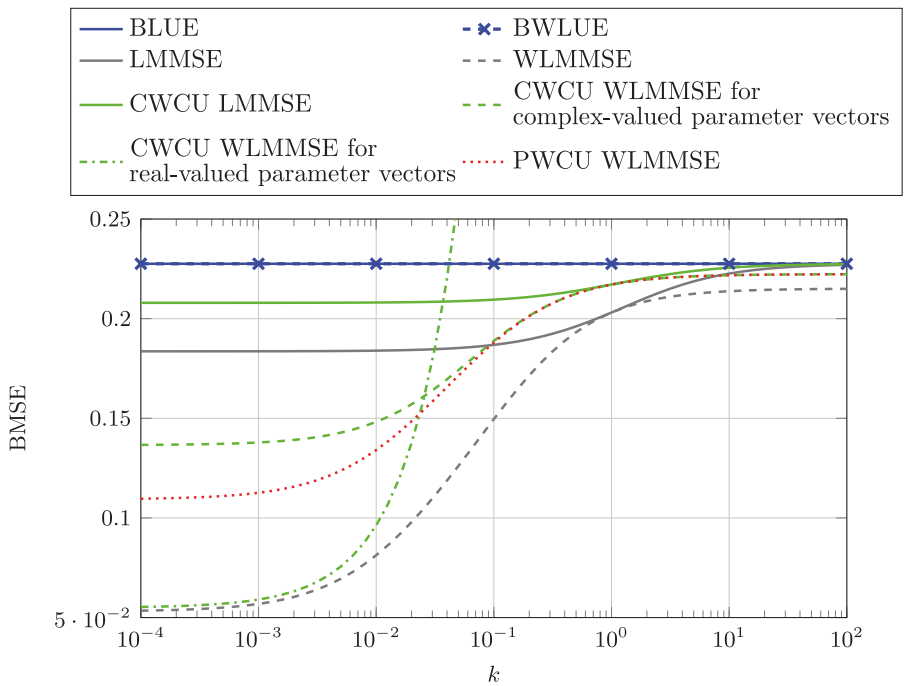
In his dissertation, novel classical estimation concepts as well as interesting advances in Bayesian estimation were analyzed in-depth.

Finally, novel adaptive filters were developed, also allowing the incorporation of additional model knowledge. All concepts are derived analytically, and the properties of the estimators and filters are studied in great detail. Furthermore, a number of application examples are given, and numerical Monte Carlo simulations are used to test the algorithms.

Selected Publications

[1] Lang O., Elvira V., Huemer M., "Estimation of Real Valued Impulse Responses based on Noisy Magnitude and Phase Measurements," in *Proceedings of the ASILOMAR Conference on Signals, Systems, and Computers*, pp. 772-777, Oct. 2017, CA, USA.

[2] Huemer M., Lang O., Hofbauer C., "Component-Wise Conditionally Unbiased Widely Linear MMSE Estimation," in *Elsevier Signal Processing*, vol. 133, pp. 227-239, Apr. 2017.



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Publications

ISP Fingerprint

	2018	2017	2016	2015	2014	2013
Publications	26	22	14	13	10	5
Presentations	18	20	24	10	4	3
Research Projects	11	12	14	10	8	5
Scientific Community Services	12	6	6	12	9	4
Granted Patents	2	3	2	0	1	0

Journal Articles

2018

• Buckel T., Preyler P., Klinkan A., Hamidovic D., Preissl C., Mayer T., Tertinek S., Brandstätter S., Wicpalek C., Springer A., Weigel R., "A Novel Digital-Intensive Hybrid Polar-I/Q RF Transmitter Architecture," in *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 65, no. 12, pp. 4390-4403, Dec. 2018.

• Sadjina S., Kanumalli R., Gebhard A., Dufrene K., Huemer M., Pretl H., "A Mixed-Signal Circuit Technique for Cancellation of Interferers Modulated by LO Phase-Noise in 4G/5G CA Transceivers," in *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 65, no. 11, pp. 3060-3073, Nov. 2018.

• Elmaghraby A., Kanumalli R., Schelmbauer W., Mayer A., Herzinger S., Schwartz D., Huemer M., Weigel R., "A Mixed-Signal Technique for TX-Induced Modulated Spur Cancellation in LTE-CA Receivers," in *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 65, no. 9, pp. 3060-3073, Sept. 2018.

• Gu J., de Lamare R., Huemer M., "Buffer-Aided Physical-Layer Network Coding With Optimal Linear Code Designs for Cooperative Networks," in *IEEE Transactions on Communications*, vol. 66, no. 6, pp. 2560-2575, June 2018.

• Klinkan A., Pfann E., Huemer M., "A Novel Interpolation Method for Polar Signals in Radio Frequency Transmitters," in *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 65, no. 5, pp. 692-696, May 2018.

• Gerstmair M., Melzer A., Onic A., Stuhlberger R., Huemer M., "Highly Efficient Environment for FMCW Radar Phase Noise Simulations in IF Domain," in *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 65, no. 5, pp. 582-586, May 2018.

• Cheema S., Wolf M., Huemer M., Haardt M., "Unique Word DMT Schemes using Real-Valued

Journal Articles

Constellations for IM/DD Optical Systems," in *IEEE Photonics Technology Letters*, vol. 30, no. 10, pp. 935-938, May 2018.

• Pathuri Bhuvana V., Preissl C., Tonello A., Huemer M., "Multi-Sensor Information Filtering with Information based Sensor Selection and Outlier Rejection," in *IEEE Sensors Journal*, vol. 18, no. 6, pp. 2442-2452, Mar. 2018.

• Kanzian M., Gietler H., Agostinelli M., Priewasser R., Huemer M., "Comparative study of digital control schemes for interleaved multi-phase buck converters," in *e&i Elektrotechnik und Informationstechnik*, vol. 135, no. 1, pp. 54-60, Jan./Feb. 2018.

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Granted Patents

Harmonic Suppressing Local Oscillator Signal Generation

Publication number: US 9,935,722 B2
Year: 2018 **Region:** United States
Owner: Intel IP Corporation, Santa Clara, CA, USA
Inventors: Andreas Gebhard, Silvester Sadjina, Krzysztof Dufrene, Stefan Tertinek

Radar Transceiver with Phase Noise Cancellation

Publication number: DE 10 2016 120 185 B4
Year: 2018 **Region:** Germany
Owner: Infineon Technologies AG
Inventors: Mario Huemer, Alexander Onic, Rainer Stuhlberger, Alexander Melzer

Pulse Generation using Digital-to-Time Converter

Publication number: US 9,755,872 B1
Year: 2017 **Region:** United States
Owner: Intel IP Corporation, Santa Clara, CA, USA
Inventors: Stefan Tertinek, Andreas Gebhard, Silvester Sadjina, Krzysztof Dufrene

Radar Device with Phase Noise Estimation

Publication number: DE 10 2015 120 733 B4
Year: 2017 **Region:** Germany
Owner: Infineon Technologies AG
Inventors: Alexander Melzer, Mario Huemer, Alexander Onic, Florian Starzer, Rainer Stuhlberger

Simplified Adaptive Filter Algorithm for the Cancellation of TX-Induced Even Order Intermodulation Products

Publication number: CN 102611651 B
Year: 2017 **Region:** China
Owner: Infineon Technologies AG
Inventors: Christian Lederer, Mario Huemer, Stefan Herzinger, Gernot Hueber, Burkhard Neurauter, Alexander Mayer

RADAR DEMONSTRATOR

Control Architectures for RF Transceivers

Publication number: US 9,325,352 B2
Year: 2016 **Region:** United States
Owner: Intel Mobile Communications GmbH, Neubiberg, Germany
Inventors: Siegfried Brandstätter, Burkhard Neurauter, Mario Huemer, Werner Hein, Wandad Guscheh, Manuel Jung, Gunther Kraut, Thomas Pühringer, Friedrich Seebacher, Andreas Voggeneder, Michael Wekerle, Dietmar Wenzel

Radar Device with Noise Cancellation

Publication number: DE 10 2015 100 804 B4
Year: 2016 **Region:** Germany
Owner: Infineon Technologies AG
Inventors: Mario Huemer, Rainer Stuhlberger, Alexander Onic, Florian Starzer, Alexander Melzer

OFDM Transmission and Reception

Publication number: EP 2 566 121 B1
Year: 2014 **Region:** Europe
Owner: Lakeside Labs GmbH, Klagenfurt, Austria
Inventors: Mario Huemer, Christian Hofbauer, Johannes B. Huber

ISP in the Press

Seite 18 OBERÖSTERREICH Montag, 6. November 2017

Wirtschaft
Oberösterreich

Alexander Melzer (l.), der in Linz studierte, trägt mit seiner Lösung dazu bei, Autofahren sicherer zu machen.

Entwicklung der Signalverarbeitungs-Profis erhielt zuletzt Innovationspreis

Linzer machen Autos schlauer

Eine Stoßstange hat Alexander Melzer ins Labor gebracht, den Prototyp aufgebaut, um dann seine Lösung für Radarsensoren vorzustellen. Am Institut für Signalverarbeitung an der Linzer Kepler-Uni entstand eine Technik, die Autofahren sicherer machen kann. Zuletzt gab's dafür den Landespreis für Innovation.

Seit vier Jahren gibt es das Institut für Signalverarbeitung, kurz ISP, in Linz. Mittlerweile arbeiten dort 17 Mitarbeiter unter der Leitung von Uni-Professor Mario Huemer, der das Vertrauen von Mikroelektronik-Spezialist Infineon erhielt, um Radarsensoren mit zusätzlichem Know-how auszustatten.

Bislang sind in Pkw zwischen einem und zwei solcher Sensoren in der Stoßstange verbaut. „In der Zukunft werden es wohl acht sein", weiß Alexander Melzer, der an der Linzer Kepler-Uni das Projekt mit Huemer vorangetrieben hat.

Die Ausgangssituation sah so aus: Sensoren, die heute Infos für Einparkhilfen, Geschwindigkeits- und Abstands-Regler sowie Bremsassistenten liefern, übermitteln immer wieder ungenaue Ergebnisse, weil ein Teil der Signale von der Stoßstange zurückprallt und so kein sauberer Wert da ist. „Die Sensoren werden bewusst hinter der Stoßstange verbaut, damit Linse und Antennen nicht verschmutzen", weiß Huemer. Melzer entwickelte nun ein System für Sensoren, das die Störungen durch die Stoßstange wieder herausrechnet.

Drei Jahre Arbeit stecken in der Lösung, eine Zeit mit viel Simulations- und Rechenarbeit. „Wir sind mit dem gesamten mathematischen Methodenapparat drauf losgegangen", erzählt Huemer.

Das System denkt mit, kann sich selbst einstellen. So wird der Sensor in verschiedenen Automodellen einsatzbereit. B. Kneidinger

Huemer (l.) zeigt am Messgerät (o.) den Fortschritt.

Foto: Audi AG, Harald Dostal (4)

"KRONENZEITUNG"

NEWSPAPER ARTICLE FROM NOVEMBER 6, 2017 WITH AN INTERVIEW OF MARIO HUEMER AND ALEXANDER MELZER ON RADAR SIGNAL PROCESSING IN AUTOMOTIVE APPLICATIONS

Nächste **Mobilfunk-Generation**

Bestmögliche Empfangsqualität bei minimalem Energieverbrauch plus drastisch erhöhte Datentransferrate: Forscher der Johannes Kepler Universität Linz (JKU) wollen gemeinsam mit dem Mobilfunk-Unternehmen DMCE neue Standards für künftige Handygenerationen setzen. Am 16. März 2017 wurde ein entsprechendes „Christian Doppler (CD) Labor für digital unterstützte Hochfrequenz-Transceiver in zukünftigen mobilen Kommunikationssystemen" eröffnet.

Im Vollausbau werden in dem bis 2023 laufenden CD-Labor zwölf wissenschaftliche Mitarbeiter unter der Federführung der Institutsleiter für Signalverarbeitung Univ.-Prof. DI Dr. Mario Huemer und Univ.-Prof. DI Dr. Andreas Springer, Institut für Nachrichtentechnik und Hochfrequenzsysteme, an den neuartigen Signalverarbeitungsmethoden forschen. Die hier erarbeiteten Konzepte und Algorithmen sollen den Energieverbrauch künftiger Mobilfunkchips deutlich senken, die Empfangsqualität optimieren und die Anforderungen an die hochkomplexen analogen Schaltungsblöcke reduzieren. Darüber hinaus sollen die Ergebnisse dieses CD-Labors wertvolle Beiträge für die Entwicklung der fünften Mobilfunkgeneration liefern.

Wirtschaft kooperiert mit Wissenschaft

Mit der steigenden Nutzung mobiler Kommunikationsgeräte wie Smartphones als multifunktionale Werkzeuge für den Alltag sind die technischen Anforderungen an die Geräte massiv gestiegen. Das wirkt sich auch unmittelbar auf die Chips in den Geräten aus. Entsprechend groß ist daher das Interesse der Industrie weltweit, durch effizientere Schaltungen und Methoden der digitalen Signalverarbeitung bessere Leistungsfähigkeit bei geringerem Energieverbrauch zu ermöglichen. 4,7 Mio Euro an Forschungsgeldern werden in die nächste Mobilfunk-Generation gesteckt. Das CD-Labor wird jeweils zur Hälfte vom Unternehmenspartner DMCE (Danube Mobile Communications Engineering GmbH & Co KG) und der öffentlichen Hand finanziert, wichtigster öffentlicher Fördergeber ist das Bundesministerium für Wissenschaft, Forschung und Wirtschaft (BMWFW).

■ **www.jku.at**

"Zukünftige Mobilfunksysteme werden nicht nur Handys und Tablets umfassen, sondern auch Automobile, Maschinen und viele Geräte, die wir ständig im Alltag nutzen. Die Arbeiten unseres CD-Labors werden helfen, maßgeschneiderte Funkchips für alle diese verschiedenen Anwendungen zu entwerfen.

Univ.-Prof. DI Dr. Andreas Springer, Institutsleiter für Nachrichtentechnik und Hochfrequenzsysteme an der JKU Linz

"Hochfrequenz-Sender und -Empfänger in unseren Smartphones nutzen bereits heute digitale Signalverarbeitung, um eine gute Verbindungsqualität und hohe Datenraten zu ermöglichen. Dieser Trend wird sich massiv verstärken und unsere Forschungsarbeiten werden hier wesentliche Beiträge leisten.

Univ.-Prof. DI Dr. Mario Huemer, Institutsleiter für Signalverarbeitung an der JKU

12 x-technik WANTED 1/Mai 2017

"WANTED - X-TECHNIK"

MAGAZINE ARTICLE FROM MAI 2017 ON THE CD LAB FOR DIGITALLY ASSISTED RF TRANSCEIVERS FOR FUTURE MOBILE COMMUNICATIONS

JOHANNES KEPLER UNIVERSITY LINZ

Talks and Poster Presentations

Talks and Poster Presentations

The ISP researchers presented their conference papers at the corresponding conferences in form of oral or poster presentations. Additionally, the following presentations were given:

Talks

2018

- **Böck C.:** *Cardiorespiratory couplings: Investigating the respiration influence onto the ECG.* 4. Kepler Science Day, Linz, Austria, Nov. 29, 2018.
- **Auer C., Gebhard A.:** *All Digital Interference Cancellation Architectures for RF Transceivers.* Evaluation of the Christian Doppler Laboratory for Digitally Assisted RF Transceivers for Future Mobile Communications, Linz, Austria, Nov. 9, 2018.
- **Motz C., Paireder T.:** *Laboratory Demonstration: Cancellation of Tx Harmonics in RF Transceivers.* Evaluation of the Christian Doppler Laboratory for Digitally Assisted RF Transceivers for Future Mobile Communications, Linz, Austria, Nov. 9, 2018.
- **Huemer M., Springer A.:** *Presentation of the Christian Doppler Laboratory for Digitally Assisted RF Transceivers for Future Mobile Communications.* Evaluation of the Christian Doppler Laboratory for Digitally Assisted RF Transceivers for Future Mobile Communications, Linz, Austria, Nov. 9, 2018.
- **Huemer M.:** *Industry-Related PhD Research: Benefits and Expectations from the University Point of View.* Keynote Speech at the Uniday 2018, organized within the framework of the PhD Excellence Network of Infineon Austria, Villach, Nov. 8, 2018.
- **Huemer M.:** *Digitally Assisted RF Transceivers for Future Mobile Communications.* Invited talk at Brandenburgische Technische Universität Cottbus - Senftenberg, Cottbus, Germany, Oct. 11, 2018.
- **Auer C.:** *Self-Interference Cancellation in LTE/5G FDD Carrier Aggregation Transceivers using Adaptive Filtering.* Presentation at the 6th ARGE HFT Workshop 2018, Seefeld, Austria, Sept. 6, 2018.
- **Huemer M.:** *Forschung am Institut für Signalverarbeitung.* Invited talk at voestalpine AG, Linz, Austria, May 16, 2018.

2017

- **Böck C.:** *Langzeit-Variabilität der EKG Morphologie.* 3. Kepler Science Day, Linz, Austria, Nov. 22, 2017.
- **Huemer M.:** *Capacitive-DAC based Transmitter Architectures: Modeling and Digital Pre-Processing.* Invited talk at IMS/RFIC Workshop WMB: Digital-Intensive Wireless Transmitters for 4G/5G Broadband Mobile Communications, Honolulu, HI, USA, June 5, 2017.
- **Melzer A.:** *Real-Time Mitigation of Short-Range Leakage in Automotive FMCW Radar Transceivers.* Presentation of the TCAS II paper vol. 64, no. 7, pp. 847-851 at the IEEE International Symposium on Circuits and Systems (ISCAS 2017), Baltimore, MD, USA, May 30, 2017.
- **Huemer M., Springer A.:** Vorstellung des *CD Labors für digital unterstützte Hochfrequenz-Transceiver in zukünftigen mobilen Kommunikationssystemen.* Eröffnungsfeier des CD-Labors für digital unterstützte Hochfrequenz-Transceiver in zukünftigen mobilen Kommunikationssystemen, Linz, Austria, Mar. 16, 2017.
- **Lunglmayr M.:** *From Heart Rate Variability to Autonomic Nervous System - Poincaré plot vs. Spectral Analysis.* Presentation at the International Conference on Computer Aided Systems Theory (EUROCAST 2017), Las Palmas de Gran Canaria, Spain, Feb. 23, 2017.

Talks

2016

- **Böck C.:** *Detektion geringfügiger Veränderungen im EKG bei Volumengabe.* 2. Kepler Science Day, Linz, Austria, Nov. 9, 2016.
- **Gebhard A.:** *Adaptive Self-Interference Cancelation in LTE-A Carrier Aggregation FDD Direct-Conversion Transceivers.* 62. Fachgruppentreffen der ITG Fachgruppe "Algorithmen für die Signalverarbeitung," Linz, Austria, Oct. 14, 2016.
- **Melzer A.:** *Short-Range Leakage Cancelation in FMCW Radar Transceivers.* 62. Fachgruppentreffen der ITG Fachgruppe "Algorithmen für die Signalverarbeitung," Linz, Austria, Oct. 14, 2016.
- **Huemer M.:** *Novel Low Complexity and High Performance IMD2 Cancelation Algorithm.* Invited talk at Intel Phoenix, USA, Sept. 28, 2016.
- **Huemer M.:** *The Unique Word OFDM Transmission Technique.* Invited talk at International Workshop on Communications and Signal Processing (SAM-IWCSP 2016), Rio de Janeiro, Brazil, July 14, 2016.
- **Huemer M.:** *Algorithmen und Anwendungen der Signalverarbeitung.* Invited talk at GE Healthcare, Zipf, Austria, May 18, 2016.
- **Gebhard A.:** *Self-Interference Cancelation in LTE Carrier Aggregation Transceivers.* Presentation at DMCE/Intel Linz PhD Day, Linz, Austria, May 11, 2016.
- **Huemer M.:** *Digital Interference Cancellation in LTE FDD RF-Transceivers.* Invited talk at Pontifical Catholic University of Rio de Janeiro, Brazil, Apr. 4, 2016.
- **Huemer M.:** *Unique Word OFDM (UW-OFDM): An Overview.* Invited talk at Pontifical Catholic University of Rio de Janeiro, Brazil, Apr. 4, 2016.
- **Huemer M.:** *Short-Range Leakage Cancelation in FMCW Radar Transceivers Using an Artificial On-Chip Target.* Presentation at ITG-Fachgruppentreffen „Algorithmen für die Signalverarbeitung," Ulm, Germany, Mar. 11, 2016.

2015

- **Huemer M.:** *Signalverarbeitung - meist verborgen, aber allgegenwärtig.* Invited talk at Primetals Technologies Austria GmbH, Linz, Oct. 15, 2015.
- **Melzer A.:** *Short-Range Leakage Cancelation in FMCW Radar Using an Artificial On-Chip Target.* Presentation at the U.R.S.I. Kleinheubacher Tagung 2015, Miltenberg, Germany, Sept. 29, 2015.

2014

- **Melzer A.:** *Short-Range Leakage Cancellation in FMCW Radar Transceivers.* Invited talk at 2nd Workshop of the Radio Frequency Engineering Working Group of the Austrian Research Association, Vienna, Austria, Oct. 23, 2014.

2013

- **Huemer M.:** *Unique Word Prefix OFDM (UW-OFDM): An Overview.* IFIP TC7 Conference 2013 on System Modelling and Optimization, Klagenfurt, Austria, Sept. 10, 2013.

JOHANNES KEPLER UNIVERSITY LINZ

Talks and Poster Presentations

Poster Presentations

2018

- **Lagler D.:** *Analysis and Application of Capacitive Micromachined Ultrasound Transducer (CMUT) Arrays in Smart Home Environments.* Campeon Innovation Week 2018, Infineon, Munich, Germany, Oct. 24, 2018.
- **Gaich A.:** *Mask-based beamforming with deep neural networks.* Campeon Innovation Week 2018, Infineon, Munich, Germany, Oct. 24, 2018.
- **Motz C.:** *Low Complexity Second-Order Intermodulation Distortion Cancellation Algorithm for LTE-A RF Transceivers.* Microelectronic Systems Symposium (MESS 2018), Vienna, Austria, Apr. 12, 2018.

2017

- **Gaich A.:** *Cerebro - MultiMicBoard - A hardware setup for evaluation and development of speech enhancement algorithms.* Campeon Innovation Week 2017, Infineon, Munich, Germany, Oct. 26, 2017.
- **Gaich A.:** *Influence of MEMS Microphones Imperfections on the Performance of First-Order Adaptive Differential Microphone Arrays.* Infineon Innovation Days 2017, Villach, Austria, Apr. 25, 2017

RADAR DEMONSTRATION AT THE SHOW-AND-TELL SESSION, ICASSP 2016, SHANGHAI

- **Kanzian M.:** *Advanced Control Techniques for Multi-Phase DC/DC Converters.* Infineon Innovation Days 2017, Villach, Austria, Apr. 25, 2017.
- **Melzer A.:** *Short-Range Leakage Cancelation and Phase Noise Estimation in FMCW Radar Transceiver MMICs.* Infineon Innovation Days 2017, Villach, Austria, Apr. 25, 2017.

2016

- **Gaich A.:** *Influence of MEMS Microphones Imperfections on the Performance of First-Order Adaptive Differential Microphone Arrays.* Campeon Innovation Week 2016, Infineon, Munich, Germany, Oct. 27, 2016.
- **Gerstmair M.:** *Automotive Radar System Simulator.* Campeon Innovation Week 2016, Infineon, Munich, Germany, Oct. 27, 2016.
- **Kanzian M.:** *Advanced Control Techniques for Multi-Phase DC/DC Converters for Automotive Microcontroller Applications.* Campeon Innovation Week 2016, Infineon, Munich, Germany, Oct. 27, 2016.
- **Melzer A.:** *Short-Range Leakage Cancelation and Phase Noise Estimation in FMCW Radar Transceiver MMICs Using an Artificial On-Chip Target.* Campeon Innovation Week 2016, Infineon, Munich, Germany, Oct. 27, 2016.
- **Gebhard A.:** *Modulated Spurs in LTE-A Carrier Aggregation Transceivers.* Microelectronic Systems Symposium (MESS 2016), Vienna, Austria, Apr. 28, 2016.
- **Melzer A.:** *Real-Time Short-Range Leakage Cancelation in FMCW Radar Transceivers.* Show and Tell session at the 41st IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP 2016), Shanghai, China, Mar. 23, 2016.,"

Scientific Appointments and Community Services

Evaluation of doctoral theses

Mario Huemer served as an evaluator and examiner of the following doctoral theses:

- **Matej Kloc:** *Adaptive Echtzeit-Drahtloskommunikation für den Test von Automobilsystemen.* Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, Sept. 11, 2018.
- **Alexander Traub:** *Ultraschall-Übertragungssystem mit mehreren Trägerfrequenzen für unsynchronisierte Lokalisierungssysteme.* Albert-Ludwigs-Universität Freiburg im Breisgau, Germany, June 13, 2018.
- **Sher Ali Cheema:** *Advanced Signal Processing Concepts for Multi-Dimensional Communication Systems.* Technical University of Ilmenau, Germany, Apr. 23, 2018.
- **Christian Blümm:** *Maximizing OFDM Performance through Real Time Adaptivity*. Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, Oct. 25, 2016.
- **Ahmed Elmaghraby:** *Transmitter Leakage Cancellation in Cellular Handset Receivers.* Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, Oct. 21, 2015.
- **Mohamed Abolfadl Ibrahim:** *The Polar Transmitter: Analysis and Algorithms.* Universität Stuttgart, Germany, Oct. 20, 2015.
- **Markus Kaiser:** *Range-Doppler-Analyse von FMCW-Sekundärradar-basierten Lokalisierungssystemen.* Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, Sept. 29, 2014.
- **Michael Wiehl:** *Effiziente und robuste Funkübertragung von Messdaten in einem Magnetresonanztomographen.* Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, Sept. 01, 2014.
- **Alexander Hartmann:** *Microcontroller-compatible Stabilization and Signal Processing of TDLS Gas Sensor Systems for ISM Applications.* Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, March 31, 2014.

Mario Huemer served as an evaluator of the following doctoral thesis:

- **Adnan Qamar Kiayani:** *Modeling and Digital Mitigation of Transmitter Imperfections in Radio Communication Systems.* Tampere University of Technology, July, 2015.

Program Committee Memberships

Mario Huemer

- Technical Area Chair for "Communications Systems" of the 2018 Asilomar Conference of Signals, Systems, and Computers, Pacific Grove, USA, 2018.
- Organization of the Special Session "Sparsity in Estimation" at the IEEE Statistical Signal Processing Workshop (SSP 2018), Freiburg, Germany, 2018.
- Organization of the Workshop "Applications of Signal Processing Technology" at EUROCAST 2017, Las Palmas, Gran Canaria, Spain, 2017.
- Organization of the Workshop "Signals and Systems in Electronics" at EUROCAST 2015, Las Palmas, Gran Canaria, Spain, 2015.
- Technical Program Committee Member of the Austrian Workshop on Microelectronics (Austrochip), 2014-2018.
- Technical Program Committee Member of the International Telecommunications Symposium (ITS 2014), Sao Paulo, Brazil, 2014.

Scientific Appointments and Community Services

JOHANNES KEPLER UNIVERSITY LINZ

• Organization of the Minisymposium "Unique word OFDM" at the IFIP TC7 Conference on System Modeling an Optimization, Klagenfurt, Austria, 2013.

Michael Lunglmayr

• Organization of the Special Session "Sparsity in Estimation" at the IEEE Statistical Signal Processing Workshop (SSP 2018), Freiburg, Germany, 2018

• Organization of the Workshop "Applications of Signal Processing Technology" at EUROCAST 2017, Las Palmas, Gran Canaria, Spain, 2017

• Organization of the Workshop "Signals and Systems in Electronics" at EUROCAST 2015, Las Palmas, Gran Canaria, Spain, 2015

Conference Board Membership

• **Mario Huemer** was Conference Board Member-at-Large of the "IEEE Signal Processing Society," 01.01.2015 - 31.12.2016

MARIO HUEMER GIVING A TALK AT THE PH.D. EXCELLENCE PROGRAM DAY, INFINEON VILLACH

Editorial Board Memberships

• **Mario Huemer** is Associate Editor (AE) for the "IEEE Signal Processing Letters," 05.05.2017-30.4.2019

• **Mario Huemer** was member of the Editorial Board of the "AEÜ - International Journal of Electronics and Communications," 01.01.2009 - 31.07.2015

Research Visits

• **Michael Lunglmayr** was on research visit at the University of Passau, Germany, 01.10.2018 - 21.12.2018

• **Mario Huemer** was on research visit at the Pontifical Catholic University of Rio de Janeiro, Brazil, 31.03.2016 - 07.04.2016

Reviewing Activities

The members of the ISP were involved in review and evaluation activities for international journals and conference papers, as well as for the following institutions:

- University of Erlangen-Nuremberg, External reviewer in an appointment procedure, 2018
- German Society of Information Technology (ITG), ITG-Fellow-Award, 2017
- Austrian Federal Ministry of Science Research and Economy, 2016
- Austrian Academy of Sciences, 2015
- European Commission in the FET-Open Call, 2014
- Freiburg Institute for Advanced Studies, 2014
- German Research Foundation (DFG), 2013, 2014
- Austrian Research Association (ÖFG), 2013

Appointments and Responsibilities at the JKU

Mario Huemer

- Member of a habilitation committee, 2018-2019
- Member of two habilitation committees, 2017-2018
- Member of the selection committee for an endowed professorship in *"Cyber Physical Systems in Engineering and Production,"* 2017
- Member of the study commission "*Electronics and Information Technology,"* since October 2016
- Chairman of the appointment committee for a full professorship in *"Integrated Circuits and Systems Design,"* 2014-2015
- Member of the appointment committee for a full professorship in *"Energy Efficient Analog Circuits and Systems,"* 2014-2015
- Member of the faculty conference of the Faculty of Engineering and Natural Science, since September 2013
- Head of the Institute of Signal Processing, since September 2013

Awards

Best Diploma Graduates Award Austria 2018

Thomas Paireder was awarded the honorary prize of the Austrian Minister of Education, Science and Research 2018 for his extraordinary educational performance. This award, which is endowed with € 3.000.- prize money, is assigned to the best graduates of Austrian universities in the particular year. It was handed over by Minister Dr. Heinz Faßmann on November 12, 2017, in the "Aula der Wissenschaften" in Vienna.

Houska Award Nomination 2017

The Houska Award is the largest private Austrian award for industry-oriented research, and yearly honors outstanding projects. In 2017 Alexander Melzer and Mario Huemer were nominated among the five best out of the total of 27 contributions in the category “University Research” with the project “Short-Range Leakage Cancellation in FMCW Radar Transceiver MMICs Using an Artificial On-Chip Target”. The nomination took place in a two-step procedure by an advisory board and an expert jury. The project team received the award certificate on May 4, 2017, at a beautiful ceremony in Vienna. In addition, the ISP got € 10.000.- in prize money.

Landespreis für Innovation OÖ 2017

Alexander Melzer and Mario Huemer received the Upper Austrian Innovation Award (Landespreis für Innovation OÖ) in the category “Research Institutions” for the project “Short-Range Leakage Cancellation in FMCW Radar Transceiver MMICs Using an Artificial On-Chip Target”. The award honors innovative projects that prove to be beneficial to society. The awarding took place at the ORF regional studio of Upper Austria.

Infineon Austria Innovation Award 2017 - Category "Ph.D."

Infineon Austria yearly honors outstanding Ph.D. theses with the Innovation Award. Among several nominees from all over Austria, Alexander Melzer convinced the expert jury and was awarded for the best and most innovative PhD thesis in 2017. The award ceremony took place at the Infineon Austria headquarter in Villach on April 24, 2017. It was endowed with € 2.500.- prize money.

ITG Award of the VDE 2016

The German ITG award of the VDE yearly honors three to four outstanding scientific publications in the field of information technology. In 2016 Alexander Melzer and Mario were awarded with this renowned prize for the contribution:

A. Melzer, A. Onic, F. Starzer, and M. Huemer, "Short-Range Leakage Cancelation in FMCW Radar Transceivers Using an Artificial On-Chip Target," in *IEEE Journal of Selected Topics in Signal Processing,* vol. 9, no. 8, pp. 1650-1660, Dec. 2015.

The award, endowed with € 3.000.-, was handed over during a festive event in Berlin on November 29, 2016.

Johann Puch Automotive Awards 2016

The contribution of Alexander Melzer and Mario Huemer entitled "Mitigation of Bumper Reflections for Increased Range and Accuracy in Automotive Radar Systems" was awarded with the third price of the Johann Puch Automotive Awards 2016, endowed with € 2.000.- prize money. The award was received on September 15, 2016 at the "automotive.2017-conference" in Bad Radkersburg, Austria.

U.R.S.I. Young Scientist Award 2015

Alexander Melzer received the Young Scientist Award of Excellence at the U.R.S.I. Kleinheubacher Conference 2015 in Miltenberg, Germany. The award was endowed with € 1200.-.

Houska Award Nomination 2014

In 2014, the ISP was nominated and rewarded with € 10.000.- for the project "Efficient and accurate estimation of internal cell parameters in battery management fuel gauge chips," which was a co-operation between the JKU (M. Huemer), the Alpen-Adria University Klagenfurt (C. Unterrieder) and Infineon Technologies, Villach. The technology was also granted for patent and integrated in the latest Infineon's battery management chip.

Events

Inaugural Lecture

F.L.T.R.: FRANZ WINKLER, MARIO HUEMER, WERNER BAUMGARTNER, RICHARD HAGELAUER

On January 20, 2014, Mario Huemer and his colleague Werner Baumgartner from the Institute of Biomedical Mechatronics gave their inaugural lectures. The festive event was opened by allocutions given by then rector Prof. Dr. Richard Hagelauer and by then dean Prof. Dr. Franz Winkler. Afterwards Werner Baumgartner gave an inspiring talk about what scientists can learn from particular animals when developing novel methods and concepts in medical engineering. Finally, Mario Huemer explained the term signal processing with descriptive examples, gave an overview of the history and achievements of the discipline, and highlighted the current research activities of the ISP.

Meeting of the ITG-Fachgruppe "Algorithmen für die Signalverarbeitung"

The 62nd meeting of the ITG-Fachgruppe "Algorithmen für die Signalverarbeitung" was jointly organized by the Institute of Signal Processing and the Institute for Communications Engineering and RF-Systems, and took place at the JKU campus on October 14, 2016.
The group is made up of experts in signal processing from universities and industry all over Germany, Austria and Switzerland, and meets twice a year for the purpose of knowledge exchange.

The meeting traditionally started on Thursday evening with a pleasant get together for dinner at the restaurant "Josef - Das Stadtbräu."

On the next morning Prof. Dr. Bin Yang, who is the chairman of the group, opened the meeting and handed over to Andreas Springer and Mario Huemer to introduce their institutes to the community.

The rest of the day was mostly covered by presentations of selected research topics of both institutes. Talks were given by Bernhard Etzlinger (NTHFS), Andreas Gebhard (ISP), Werner Haselmayr (NTHFS), Christian Hofbauer (ISP/LCM), Alexander Melzer (ISP) and Thomas Wagner (NTHFS).

In the afternoon the group visited the laboratory,

where Alexander Melzer gave a live demonstration of his radar prototype to the topic of “Short-Range Leakage Cancellation in FMCW Radar Transceivers.”

The meeting ended with an interesting talk of Prof. Bin Yang about deep learning. In his presentation he introduced the audience to the fundamentals of deep learning and showed some impressive results out of his own research projects.

MACHINE AND DEEP LEARNING IS AN EMERGING TOPIC IN THE SIGNAL PROCESSING COMMUNITY

Opening Ceremony of the Christian Doppler Laboratory

The Christian Doppler (CD) Laboratory was officially opened with a great opening ceremony on March 16, 2017. The CD Laboratory is led by Andreas Springer and Mario Huemer and focuses on future mobile communications transceiver chips.

The Christian Doppler Laboratory for Digitally Assisted RF Transceivers for Future Mobile Communications is dedicated to research on digital signal processing (DSP) methods for radio frequency (RF) transceivers. Half of the funding comes from the industrial partner DMCE (Danube Mobile Communications Engineering GmbH & Co KG), an Intel subsidiary, and the other half comes in part from the Austrian Federal Ministry of Science, Research and Economy and in part from the National Foundation for Research, Technology and Development. Until 2023, up to 12 researchers can be continuously employed to develop novel signal processing concepts and algorithms with the goal to optimize the transmission and reception quality of mobile devices, while keeping the overall power consumption at a minimum.

At the opening ceremony Andreas Springer and Mario Huemer highlighted the challenges that arise for future RF transceiver chips with the 5th generation mobile standard (5G), and gave an overview about the planned research activities in the lab.

F.L.T.R.: MARIO HUEMER, MEINHARD LUKAS, THOMAS STELZER, ANDREAS SPRINGER, MARKUS SCHUTTI, REINHART KÖGERLER

Events

In their speeches, JKU rector Univ.-Prof. Dr. Meinhard Lukas, then vice governor of Upper Austria Mag. Thomas Stelzer and Dr. Markus Schutti from DMCE Linz emphasized the potential of the CD Lab and noticed that this center of excellence is a distinguished addition to the JKU and a highly important contribution to further strengthen the research and business location of Upper Austria!

Prof. Johannes B. Huber from the University of Erlangen-Nuremberg completed the evening with an informative and exhilarating talk on the subject "Eine gute Theorie ist das Praktischste, was es gibt!"

Finally, all guests were invited to join the get together at a delicious buffet. A band offered the appropriate musical entertainment.

CD LAB TEAM AT THE TIME OF THE OPENING CEREMONY

Evaluation of the Christian Doppler Laboratory

On November 9, 2018, the two-year evaluation of our CD lab took place. Before this, we submitted a detailed report describing our achievements and future plans. During the evaluation day an overview, a number of technical presentations as well as a lab demo were given. The evaluation committee came to a very positive conclusion, such that in December we received the official decision of the Christian Doppler Research Association, that our lab is approved for the next three-year period. We'd like to thank all the researchers that contributed to the report, to the evaluation day program and to the very positive result!

PRESENTATION OF SILVESTER SADJINA AS PART OF THE CD LAB EVALUATION

ISP Institute Retreats

Every year around the end of September the staff of the ISP comes together for the institute retreat. All researchers working at the institute and all external Ph.D. students doing their research in co-operation with industry meet at a place outside the university campus to spend three days together. This year's retreat took place at the Bioseminarhof Windhör in Saxen, Austria, near the Danube river.

The intention of the retreat is twofold. First, a major goal is to reflect the preceding year and to give an outlook of the upcoming year, to discuss institute internal affairs, and to get an idea and understanding of the problems colleagues are working on. Every Ph.D. student is encouraged to present his or her topic in the form of an oral or poster presentation which is the basis for further discussions. Second, the retreat stands for a social get-together, to learn more about the colleagues apart from working environment. The agenda of the retreat tries to cover the scientific and administrative demands as well as team-building and social interests.

One afternoon of the retreat is reserved for the team-building event which had been very diversified over the last five years. Hiking along the Danube, asphalt curling, building a Da Vinci bridge, barbecue in the evening, all of these activities were a lot of fun.

Events

Cooking Event

As the Institute of Signal Processing has grown from three employees at the start in September 2013 up to the impressive number of 22 (including the external Ph.D. researchers) at the very moment, teambuilding is an absolute must.

Therefore, in 2014 we started with our annual cooking event with a yearly growing number of participants. And, whilst for the first few years we did some really high-class cooking, in 2017 and 2018 we focused on BBQ also due to limited kitchen space.

This year we had a special agenda highlight – the bonfire talks – which were highly enjoyed by everyone, and as hunger always returns, we then had roasted bread and sausages on a spit.

Christmas Party

When we started in September 2013 Christmas was already close – especially for having a proper location to party, but with only eight staff members it was small but nice at pizzeria Monte Verde.

Our Christmas parties follow a strict agenda: first a visit at Christkindlmarkt, then some train the brain, and finally: Christmas dinner.

In 2015 for example, we visited AEC and found some surprising signal processing there.

The 2017 Christmas event started with hot punch, of course, and then we tried – and managed – to "Escape the room," and finally had some perfectly prepared dinner at "Fischerhäusl" in Linz/Urfahr.

Social Events

Swing Golf

You don‘t have to be a professional golfer with expensive equipment to have the possibility to play golf in Linz.

This experience was made on June 14, 2018 by nine members of the ISP that visited the Swing Golf course in Linz/Urfahr for a funny evening. Swing golf is played like golf on eighteen holes, but you only use one single golf club, and the balls are a little bit bigger and softer than the original ones.

After a short introduction to the rules and the handling of the golf club we in turn more or less successfully hit the ball towards the hole. With little practice, at the end of that day at least a few of us have managed to hit the ball more than 50 meters. Because it was getting dark, we stopped the game after five holes, but we will return to determine the ISP Swing Golf champion.

Ski Day

On February 3, 2018 a small group of four winter sports enthusiasts organized the first “ISP Ski Day.”

The trip started early in the morning towards Hinterstoder, a small but mighty ski resort in Upper Austria. Tough the sun was not shining the group enjoyed perfect snow conditions. The fresh powder made the day to an absolute highlight on and also off the slopes. After a very athletic day they finally sat together for a cup of tea where the decision to repeat this event next year was made.

JOHANNES KEPLER UNIVERSITY LINZ

Promotion Activities

Besides our research activities we are also organizing and participating in events to increase the visibility of our institute and the study programs "Electronics and Information Technology," "Computer Science" and "Mechatronics." Our motivation is to increase the interest in technical sciences, and of course for digital signal processing.

2018

- 05.12.2018: Besuch einer 4. Klasse AHS; Vorstellung der Tätigkeiten eines Forschers am ISP; Andreas Gaich, Michael Gerstmair
- Juli 2018: Betreuung Maturaprojekt der HTL Traun; Carl Böck
- 16.07.2018: "Leben für Joe"; Workshop für die Kinderuni; Michael Lunglmayr, Christian Motz
- 04.05.2018: YS Workshop der ELIT; Andreas Gaich
- 13.04.2018: "Was können Autos von Fledermäusen lernen"; Vortrag im Schloss Starhemberg, Eferding; Mario Huemer
- 13.04.2018: Lange Nacht der Forschung; Mitorganisator und Experimentierstand zu Themen der Signalverarbeitung; Christina Auer, Carl Böck, Andreas Gaich, Michael Gerstmair, Michael Lunglmayr, Thomas Paireder, Eugen Pfann
- 23.03.2018: YS Workshop der Informatik; Andreas Gaich
- 19.03.2018: Institutspräsentation im Zuge der JKU IEEE Tech Rally; Carl Böck, Michael Gerstmair
- 26-28.02.2018: Vorstellungen bei Traumberuf Technik der ELIT & Informatik; Michael Gerstmair, Christian Motz
- 12.02.2018: Vorstellung beim FIT-Infotag; Michael Gerstmair

2017

- 15.12.2017: Besuch einer 4. Klasse AHS; Vorstellung der Tätigkeiten eines Forschers am ISP; Andreas Gaich
- 20.-22.09.2017: Standbetreuung auf der Studieninformationsmesse; Carl Böck, Andreas Gaich
- August 2017: Betreuung Maturaprojekt der HTL Saalfelden; Andreas Gaich
- 10.07.2017: "Leben für Joe"; Workshop für die Kinderuni; Michael Lunglmayr, Christian Motz
- 31.03.2017: YS Workshop der ELIT; Michael Lunglmayr
- 16.03.2017: "Erhöhung der Reichweite von hochintegrierten KFZ-Radar-Abstandssensoren"; Vortrag am Softwarepark Hagenberg; Alexander Melzer
- 27.02.-01.03.2017: Vorstellungen bei Traumberuf Technik der ELIT & Informatik; Christian Motz
- 17.02.2017: Vorstellung beim FIT-Infotag; Alexander Melzer

2016

- 28.11.2016: "Current Topics in Signal Processing"; Vortrag an der HTL Steyr; Alexander Melzer
- 23.11.2016: "Einblick in die Forschung an der JKU"; Vortrag für den MKV Enns; Carl Böck, Alexander Melzer
- 21.-23.09.2016: Standbetreuung auf der Studieninformationsmesse; Carl Böck, Andreas Gaich, Oliver Lang, Alexander Melzer
- Aug. 2016: Betreuung eines Ferialpraktikanten; Oliver Lang, Michael Lunglmayr
- 19.07.2016: "Batmans kleine Helfer"; Workshop für die Kinderuni; Andreas Gebhard, Alexander Melzer, Birgit Bauer

Talks, Presentations and Workshops

• 09.05.2016: “Warum benötigt die Fledermaus keinen Notbrems-Assistenten?”; Vortrag im Kepler Salon; Mario Huemer

• 29.04.2016: YS Workshop der ELIT; Michael Lunglmayr

• 22.04.2016: Lange Nacht der Forschung; Mitorganisator und Experimentierstand zu Themen der Signalverarbeitung; Carl Böck, Andreas Gaich, Michael Lunglmayr, Christoph Mahringer

• 23.02.2016: Vorstellungen bei Traumberuf Technik der ELIT; Oliver Lang, Michael Lunglmayr

• 08.02.2016: Vorstellung beim FIT-Infotag; Michael Lunglmayr

• 01.02.2016: Institutspräsentation und Vorstellung ausgewählter Forschungsthemen beim Lions Club Linz City; Carl Böck, Mario Huemer, Alexander Melzer

2015

• Mai 2015: YS Workshop der ELIT; Christian Hofbauer

• 25.02.2015: Organisator von Traumberuf Technik der ELIT, Oliver Lang, Alexander Melzer

• 20.01.2015: Science Slam Wettbewerbsteilnahme im Posthof Linz; Michael Lunglmayr

2014

• 12.11.2014: Schüler Workshop im Rahmen des “Invent a Chip” Wettbewerbes; Florian Bemsel

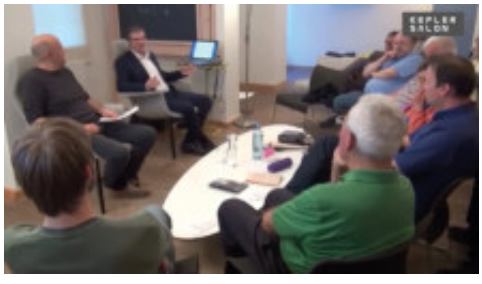
• 17.09.2014: Standbetreuung auf der Studieninformationsmesse; Oliver Lang, Michael Lunglmayr, Alexander Melzer

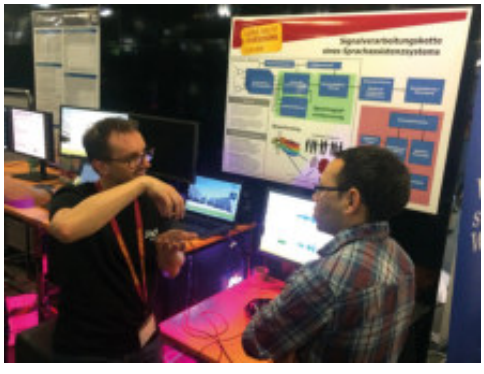
• 04.04.2014: Lange Nacht der Forschung; Experimentierstand zu Themen der Signalverarbeitung; Christian Hofbauer, Oliver Lang, Alexander Melzer

• Apr. 2014: YS Workshop; Christian Hofbauer

2013

• Sept. 2013: Präsentation des Studiengangs Informatik auf der Hausmesse; Christian Hofbauer





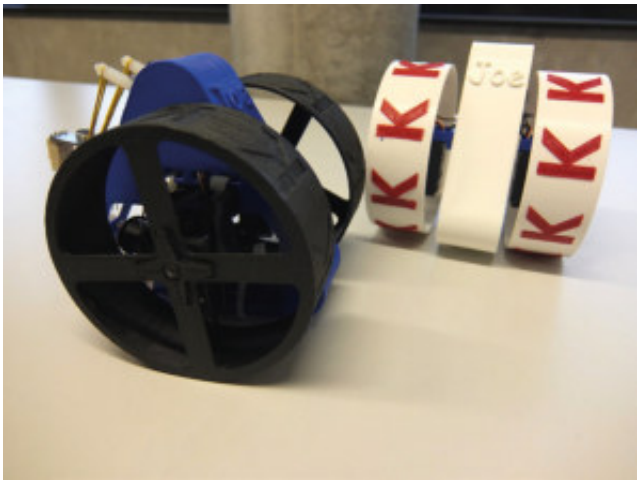
ISP MEMBERS AT PROMOTION ACTIVITIES: (TOP-LEFT) MARIO HUEMER, KEPLER SALON 2016; (BOTTOM-LEFT) ANDREAS GAICH, LANGE NACHT DER FORSCHUNG 2018; (MIDDLE) MICHAEL LUNGLMAYR, KINDERUNI 2018; (RIGHT) ANDREAS GEBHARD AND ALEXANDER MELZER, KINDERUNI 2016

Promotion Activities

For promotion purposes, the ISP has a couple of demonstrators available. The aim is to bring signal processing closer to young people in a playful way. Together with researchers from the ISP in workshops kids are given the opportunity to implement simple signal processing algorithms on these demonstrators. Three demonstrators "Cordula", "Joe" and the "Audi Q2 Model Car" are presented on the next two pages.

Cordula

Cordula is a stuffed animal bat equipped with two microphones placed at the front of her cool sunglasses and a loudspeaker placed inside her belly. Like an echo sounder she is able to measure distances in her line of sight by sending out an acoustic chirp and measuring the time delay of the reflected signal at the microphones. A beamformer is implemented to suppress undesired reflections from other directions. Cordula is also able to determine the direction of a speaker and turns towards the speaker if he or she calls her name. The direction of arrival estimation is done by measuring the time delay between the two microphones, and the accuracy can be further enhanced with signal processing.



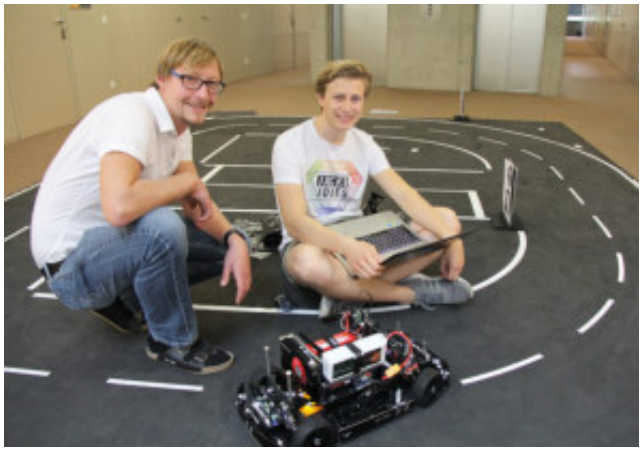
Joe

Joe was specially developed for the „Kinderuni" and is a robotic vehicle that in its first version can be controlled by a PC via cable communication to drive forward, backward, left and right. In workshops the participants learn how to program the small microprocessor that processes the command signals and controls the motors of the wheels. The second generation of Joe utilizes a microphone module that enables Joe to be clap controlled. Therefore, features have to be extracted out of the audio signal to be able to reliably classify the clap signals in a noisy environment. Joe will be further developed in collaboration with the Institute of Polymer Product Engineering of the JKU.

Demonstrators

Audi Q2 Model Car

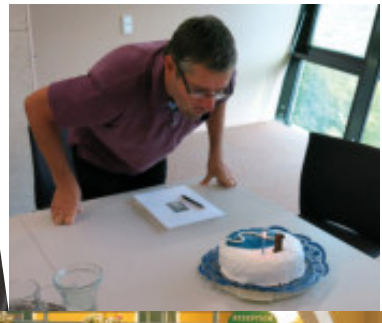
The Audi Q2 model car was developed by Audi specifically for the “Audi Autonomous Driving Cup” and is a 1:8 scale replica of its original version. The car is equipped with wheel speed sensors, motion tracking sensors, ultrasonic sensors, and cameras. The implemented digital image processing algorithms allow the car to drive on a miniaturized roadway autonomously. Further, the car is equipped with an Infineon radar sensor in order to enable the development of radar based advanced driver assistance systems like adaptive cruise control or autonomous emergency breaking.



MICHAEL GERSTMAIR (LEFT) AND LUKAS RIENESSL TESTING LANE DETECTION ALGORITHMS ON THE TEST PARCOUR

JOHANNES KEPLER
UNIVERSITY LINZ

Photos



JOHANNES KEPLER UNIVERSITY LINZ

ISP
INSTITUTE OF SIGNAL PROCESSING

The Institute of Signal Processing (ISP) of the Johannes Kepler University Linz focuses on the algorithmic-, architectural- and hardware-oriented aspects of signal processing systems. Application areas are information and communication systems, particularly radio frequency and baseband integrated circuits, bio- and sensor-signal processing as well as automotive applications. Our research portfolio includes fundamental science and applied research, both in close co-operation with academic and industrial partners.

In teaching we are involved in the Bachelor and Master programs “Electronics and Information Technology,” “Computer Science” and “Mechatronics.”

Established in the JKU Science Park in September 2013, the institute currently employs 17 people.