

# **ADWICE**

Advanced Wireless Technologies for Clever Engineering

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## ADWICE Introduction

With its teaming 2020 effort, the EU is offering a new programme that allows two universities to join forces and offer a new research and innovation potential for an existing research centre to foster the industry in Moravia but also international companies outside the Czech Republic. The SIX Centre founded in 2010 is an excellent starting point for such an endeavour.

The Brno University of Technology with its excellent laboratory equipment and support of the Czech government to maintain this on one hand, and the Technische Universität Wien on the other, with its international visible expertise and high reputation, are excellent partners to succeed in shaping a reformed SIX Centre with high international visibility and strong impact on industry. With the ADWICE project, we are able to stimulate innovations jointly with companies and even prepare for far-ahead visionary research quests that will be the driving future motor for the industry in Moravia.

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## Description of SIX Research Centre

Brno University of Technology (BUT) was established in 1899 as the Austrian Emperor and Hungarian King Franz Joseph I signed a decree to lay the foundation of a Czech technical university in Brno – the first Czech higher education institution in Moravia. At the time of opening, the university had four professors and forty-seven students. In the course of more than 110 years it has matured into an internationally recognized institution offering a cutting-edge education based on the latest scientific and professional knowledge delivered from eight faculties and the Institute of Forensic Engineering covering a broad spectrum of fields ranging from technical and scientific disciplines through economics to the arts. Electrotechnical disciplines were first taught at the university in 1905. Currently, they are covered by the Faculty of Electrical Engineering and Communication (FEEC) with around 4,000 students altogether.

The Research Centre of Sensor, Information and Communication Systems (SIX) was established in 2010 as a joint initiative of FEEC departments to support the innovation potential of companies which actively exploit communication, information and sensor technologies in different areas of life. Supporting the quality of life of the aging population (sensing life functions and wireless transmission of information), reducing the danger of terroristic attacks (sensing marks of dangerous substances and wireless warning), controlling traffic by using the concept of an intelligent highway (mutual communication among cars and stationary units) or using the analysis of speech signals for a timely diagnosis of nervous diseases can be given as examples.

The SIX Research Centre exploits the background of the university to obtain new knowledge and to create novel solutions by its own fundamental research. New knowledge is subsequently applied to novel products and novel services of partner companies. The SIX Research Centre performs technological research to be applied in communication, information and sensor systems in a near future. Hence, the motto of the SIX Research Centre:

*The Sixth Sense for Communication Systems of the Future.*

2014 was the first year of full operation of the Centre without direct financial support from public sources. In comparison with 2013 the number of full-time jobs increased from 70 to 110, the number of trained Master graduates from 43 to 135 and Ph.D. graduates from 14 to 23. In 2014, the income from research contracts increased by 38% compared to 2013. The growth of the Centre needs to be accompanied by excellence – the main outcome of the ADWICE project.



## Description of TU Wien

Technische Universität Wien (TU Wien), founded on 6 November 1815 as the k.k. Polytechnisches Institut (Imperial Royal Polytechnic Institute), is celebrating its 200th anniversary in 2015. The roots of the institution are the military and commercial-technical vocational schools that have existed across Europe since the beginning of the 18th century. These schools were founded to address the growing need in public administration, the military, and economics for skilled workers with an educational background in technology and the natural sciences.

Today, TU Wien is a modern research university. More than 4,500 employees work, research, and teach at Austria's largest institution for research and education in the natural sciences and engineering.

A prerequisite for the continued success of TU Wien's further development in the strenuous fields of research, teaching, and innovation is a research environment that equally encourages high quality fundamental and application-oriented research.

The TU Wien's Faculty of Electrical Engineering and Information Technology is located at the Gusshausstrasse in Vienna. The faculty committed to the highest quality in research and teaching and to fostering a working environment that promotes the best possible creative achievements, thereby offering employees an attractive environment in which they can unfurl their individual abilities. The faculty pursues the vision of ranking among the frontrunners of comparable university faculties. It is among the leading research institutions worldwide in selected fields.

The faculty's professional competence primarily focuses on the following fields of electrical engineering and information technology:

- Photonics
- Micro- and Nanoelectronics
- Telecommunications
- Systems and Control Engineering
- Energy Technology and Energy Systems

Today the faculty hosts about 500 employees. Every year, more than 400 students start the bachelor programme and about 100 select one of our five master programmes.





# MAIN SERVICES

## Services Offered by ADWICE Team

The SIX Research Centre already offers a multitude of services for companies:

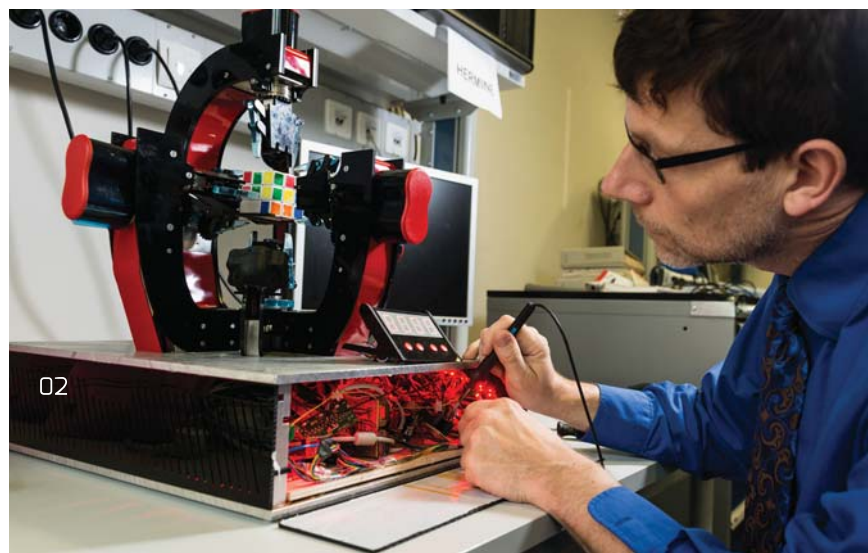
- Micro- and Nanoelectronics
- Industry lectures (visions of the future)
- IT colloquium
- Trade shows
- Organization of workshops
- Support on international visibility
- Radar on new technologies
- High quality modern lab equipment
- Networking

Through Adwice we will be able to offer more services for companies:

- IPR support
- Company relations
- English speaking/writing/editing
- Research proposal writing
- EU programming scout
- EU admin expertise
- Web presentation and PR
- Find the best funding opportunity for your project



- 01 VoIP testbed: Stress and validation testing of Softswitches
- 02 A robot to solve Rubik's Cube puzzle in around 5 seconds



## How to Get Funding

A bright idea itself is not enough for success. Time, effort and skills are needed to convert an idea into a concept, solution or even product. We are well aware that none of these building blocks comes for free and they get even more demanding for visionary ideas requiring long term research.

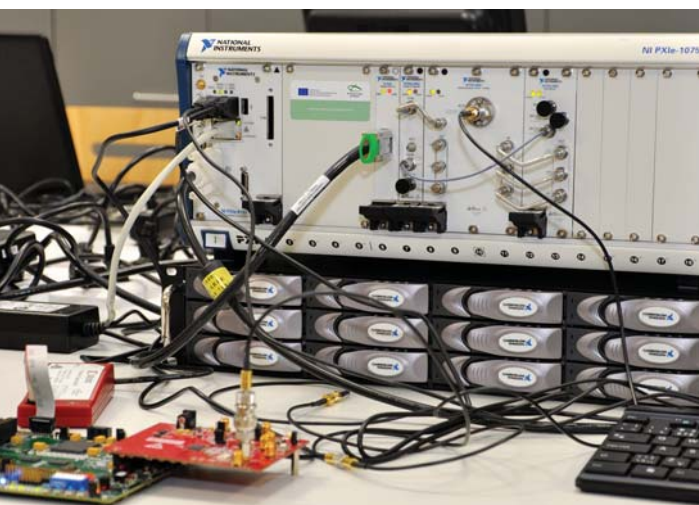
Fortunately, schemes exist to reduce the amount of money needed to invest in research from private sources, be it co-funded collaborative projects, innovation voucher initiatives or funded grant projects supported by national or international foundations.

In addition, the SIX Research Centre has prepared its own co-funding scheme, supporting visionary research ideas through financial contribution of the Centre itself. Get involved in our membership system to qualify for such co-financing!

Whether it is a TACR application or the find of the right EU consortium, a city innovation check or finding your way through the jungle of EU regulations, we will recommend a suitable national or international funding scheme for you. Contact us, tell us your needs and we will create a financially feasible solution.

- 01 Real-time measurements of a FPGA-based software defined radio transmitter
- 02 Preparation of nanoparticles for sensor applications in an inert atmosphere glovebox

01



02



## Smart Sensor Systems

The trend in the evolution of future sensor systems is directed to ultra low-power integrated devices with wireless and energy harvesting capability. It is clear that any technical solution is challenging especially given the wide range of related topics. Advanced chemical sensors and biosensors, sensors of physical quantities, on-chip energy storage, special integrated circuit systems with auto-diagnostic properties, and enhanced metrology methods are the main research domain in the research group. All functionalities of the sensor systems are developed to be integrated using nano- and microtechnologies because the size of each individual component is the most decisive parameter when targeting a highly-integrated and compact module design. The aims include as well wearable technology development which enables sensors systems to be easily integrated to clothes or placed directly on epidermis.



### Projects & Cooperation (selected)

A piezoelectric MEMS sensor based on resonant operation principles was developed in co-operation with AC<sup>2</sup>T Research to enable measurement of physical parameters like viscosity and density of liquid lubricants.

Strong cooperation with the company CSRC (Czech Space Research Center) which is engaged in aerospace design. Contribution and collaboration on the Gradiometer project with CSRC and presently on other interesting projects provided by ESA (European Space Agency).

*Nanoelectronics for Mobile AAL Systems (MAS)* - consortial ENIAC project focused on developing AAL systems for Point of Care, no. 120228. Funding institution: European Union. Funding program: ENIAC-2009.



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### Publication record (selected)

KUCERA, M., WISTRELA, E., PFUSTERSCHMIED, G., RUIZ-DIEZ, V., SÁNCHEZ-ROJAS, J. L., SCHALKO, J., BITTNER, A., SCHMID, U. Characterisation of higher orders of the roof tile-shaped out-of-plane vibrational modes in aluminum-nitride-actuated self-sensing micro-resonators in liquids. *Applied Physics Letters*, Aug. 2015, vol. 107, no. 5, 053506. DOI: 10.1063/1.4928429

SEDLÁK, P., ŠIKULA, J., MAJZNER, J., VRŇATA, M., FITL, P., KOPECKÝ, D., VYSLOUŽIL, F., HANDEL, P. Adsorption-desorption noise in QCM gas sensors. *Sensors and Actuators B: Chemical*, 2012, vol. 166-167, p. 264-268. DOI: 10.1016/j.snb.2012.02.058



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### Patents (selected)

NEUŽIL, P., HUBÁLEK, J. Miniature bolometer membrane with increased absorption. Reg. number 28484, 2015.

HUBÁLEK, J. Deposition method of chip microelectrodes distributed on a board using chemical solutions and apparatus for making the same. Reg. number 305166, 2015.

SÁNCHEZ-ROJAS, J. L., DÖRR, N., BITTNER, A., KUCERA, M., SCHMID, U. MEMS-sensor zur Detektion von Umgebungsparametern. WO 2014086884A1, 2015.



BECKER, T., KLUGE, M., SCHNEIDER, M., BITTNER, A., SCHMID, U. Apparatus and method for acquiring mechanical loads on thrust elements. EP 2585792 B1, US 8677830 B2, 2014.

## Successful cooperation with industry (selected)

*Energy harvesting for autonomous wireless sensor nodes in aircrafts.* A thermoelectric energy harvesting module was developed in cooperation with Airbus group to power structural health sensor nodes on an airplane using a phase changing material as storage for thermal energy to provide sufficient energy output.

*TES, EGU – HV laboratory.* The partial discharges (PD) diagnostic sensor system was developed within the collaboration and is utilized for real field diagnostics in the nuclear power plant Dukovany. The PD diagnostic sensor system received the main award at the Amper 2015 exhibition as the most beneficial exhibit.

## High-tech devices (selected)

The laboratory infrastructure for micromachined sensors and microsystems technology that has been built over many years represents a value of approximately 5 Mio. Euro and is a solid base for future research work. The laboratories comprise approx. 250 m<sup>2</sup> clean room area.

The Wireless Body Area Network (WBAN) coordinator is a mobile device used for ZigBee network managing for biomedical applications (personal medicine and activity monitoring). The coordinator creates and manages network and establishes connection to other (mainly sensor) devices located on the measured patient's body.

- 01 Clean room area
- 02 Wearable platform WBAN (results of project MAS)
- 03 Partial discharges diagnostic sensor system in the nuclear power plant Dukovany



# Networked Signal Processing

In today's information-based societies, millions of individuals and devices are connected wirelessly. Networked sensors acquire measurements relevant to fields such as automation, healthcare, transportation, energy distribution, surveillance, remote sensing, and robotics. The Signal Processing Group develops advanced methods for processing and interpreting sensor data and for converting the information gained into pertinent actions. In doing so, it addresses challenges posed by "big data" scenarios, the upcoming Internet of Things, and the ubiquitous proliferation of sensor devices in current and future sensor-communication-actuator networks. The focus of the Signal Processing Group is on the analysis of data streams, the semantic understanding of audio, image, and video signals, and distributed cognition and control problems in agent networks.



## Projects & Cooperation (selected)

With the cooperation of a local ICT software company, we developed a method for intelligent optimization and control of business processes. This method was tested and deployed within the environment of one of the key logistics companies operating in Central Europe. The developed method was based on artificial intelligence using genetic programming and saved up to 40 % of time and resources when deployed.

*EU/FP6/IST project MASCOT (Multiple Access Space-Time Coding Testbed).* Partners: Forschungszentrum Telekommunikation Wien (FTW), Nokia, Fraunhofer Institute for Communications/Heinrich Hertz Institute, Politecnico di Torino, ETH Zurich, Universitat Pompeu Fabra. Project goal: Development and VHDL implementation of transceiver techniques for multiuser MIMO communication systems. Project duration: 2006–2008.



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## Publication record (selected)

DROTÁR, P., MEKYSKA, J., REKTOROVÁ, I., MASAROVÁ, L., SMÉKAL, Z., FAÚNDEZ ZANUY, M. Decision support framework for Parkinson's disease based on novel handwriting markers. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, May 2015, vol. 23, no. 3, p. 508–516. DOI: 10.1109/TNSRE.2014.235999

HLINKA, O., HLAWATSCH, F., DJURIC, P. M. Distributed particle filtering in agent networks: A survey, classification, and comparison. *IEEE Signal Processing Magazine*, Jan. 2013, vol. 30, no. 1, p. 61–81. DOI: 10.1109/MSP.2012.2219652



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## Patents (selected)

FEICHTINGER, H. G., GROECHENIG, K. H., HAMPEJS, M., HLAWATSCH, F., HRYCAK, T., MATZ, G., KLOTZ, A., TAUBOECK, G. Method of equalizing a multicarrier signal for intercarrier interference. AT511343 (A5) – 2012-11-15.

ARTES, H., HLAWATSCH, F. Method and device for blindly equalizing signals transmitted over time-variant transmission channels. AU2324502 (A) – 2002-05-27.

## Successful cooperation with industry (selected)

*Prototype for intrusion detection of a large scale monitored area, OPTOKON, a.s.* The company deals with supplying special equipment for the military and security companies. The aim of the project was to develop a distributed sensor system suitable, for example, for border, object or area surveillance, as well as for monitoring pipelines, or monitoring other sources of mechanical vibrations. The total range of the system should be up to 100 km with a resolution of 100 m. A multi-purpose surveillance system, using standard telecommunication optical fibers as a distributed sensor, was developed. The whole system is located only on one side of the optical fiber. By using existing telecommunication optical paths it is possible to monitor and detect events around the optical fiber.

The advantages of the proposed solution include the ability to recognize various events. This very flexible system detects a wide spectrum of events (e.g. movement of vehicles, aircrafts or walking intruders) and can be connected to already built information and monitoring systems according to customer requirements.

## High-tech devices (selected)

*GPU supercomputer.* Special computer equipped with massively parallel devices of more than 9000 computing units and a fast bus. With the GPU supercomputer it is possible to accelerate machine learning tasks and simulations up to 720 times.

*3D printer.* A 3D inkjet printer that is able to create photo-realistic color 3D prints: three-dimensional solid high-resolution objects with a color texture (4-channel CMYK). This enables rapid prototyping in fields such as architecture, consumer product design, digital manufacturing, and fine art production, provides a better understanding of virtual objects, e.g. in medicine.

## Events we co-organized (selected)

*The 7th International Congress on Ultra Modern Telecommunications and Control Systems (ICUMT 2015).* ICUMT is an IEEE (R8 + CS Section SP/CAS/COM Joint Chapter) technically co-sponsored (approved) annual international congress providing an open forum for researchers, engineers, network planners and service providers. The congress targeted on newly emerging algorithms, systems, standards, services, and applications, bringing together leading international players in telecommunications, control systems, automation and robotics.

*International Conference on Telecommunications and Signal Processing (TSP).* In cooperation with the IEEE Czechoslovakia Section SP/CAS/COM Joint Chapter, the TSP 2015 Conference is organized by eight European universities from the Czech Republic, Hungary, Turkey, Poland, Slovak Republic, and Slovenia for academics, researchers, and developers.

01 GPU supercomputer

02 3D printer Zprinter 650

01

02





## Smart Transport

The demand for transport of people and goods is continuously increasing. To make transport safer, more efficient and cleaner, various traffic telematics services are currently under development. Such intelligent transport systems (ITS) services require dependable vehicular communications (DVC) providing robust connectivity at moderate data rates. DVC includes vehicle-to-infrastructure (V2I), vehicle-to-vehicle (V2V), wireless-intra-vehicle (WIV), as well as infrastructure-to-infrastructure (I2I) communication scenarios. We aim at the reliable transmission of small data packets with a hard delivery deadline. Achieving this goal will enable sensor data fusion among road users and the roadside infrastructure. Our aim is to enable cooperative ITS by DVC.

Our research activities in this area include radio propagation channel measurements and modeling and novel PHY transceiver algorithms development. We focus on WIV and V2V for on-board sensor networks, vehicle localization and tracking, as well as radio frequency and free space optical I2I communication. Dependability will be achieved by exploiting innovative diversity mechanisms in the (unreliable) propagation channel, jointly in the spatial-, polarization-, and frequency-domains, leaving out the delay-domain. Our research activities will include channel analysis, new algorithms development and PHY layer design.



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### Projects & Cooperation (selected)

The main output of the project *Multi-channel digitizer with the company ERA* is developing a new radiolocation system based on passive coherent locations using a highly specialized and precise digitizer and advanced DSP and data streaming functionalities implemented in FPGA.

The Christian Doppler Laboratory *Wireless technologies for sustainable mobility* at TU Wien was established during 2009. Research focuses on dependable vehicular connectivity (DVC), radio-frequency identification (RFID) tags, and vehicular 5G. Annual research volume is around 600kEUR. Corporate research partners are Kapsch TrafficCom, BMW, Infineon Technologies, NXP, A1, Kathrein, and PIDSO.



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### Publication record (selected)

BLUMENSTEIN, J., MARŠÁLEK, R., FEDRA, Z., PROKEŠ, A., MECKLENBRÄUKER, C. Channel estimation method for OFDM in low SNR based on two-dimensional spreading. *Wireless Personal Communications*, Sep. 2014, vol. 78, no. 1, p. 715–728. DOI: 10.1007/s11277-014-1779-y

BERNADÓ, L., ZEMEN, T., TUFVESSON, F., MOLISCH, A. F., MECKLENBRÄUKER, F. Delay and Doppler spreads of non-stationary vehicular channels for safety relevant scenarios. *IEEE Transactions on Vehicular Technology*, Jan. 2014, vol. 63, no. 1, p. 82–93, DOI:10.1109/TVT.2013.2271956



### Patents (selected)

PETRŽELA, J.; GÖTTTHANS, T. Electronically tuned oscillators with fractal circuit elements. Reg. number 304655, 2014.



NEWTON, E., RANDALL, D., MECKLENBRÄUKER, F., ÖTTL, M., MENZEL, C., BENZ, M., KLEIN, A., SITTE, A., ULRICH, T., KÖHN, R. KRAUSE, J., TRAYNARD, J.-M., MITJANA, E. Communications method and system for transmitting data of several combined services via physical channels which are used in common. EP 1135892 A2, 2008.

## Successful cooperation with industry (selected)

*CISC Semiconductor GmbH.* The company provides solutions for RFID measurement tools to support the industry with compliance and performance testing. The market need for fast and highly precise measurement instruments at lower cost had to be addressed by developing a new HW platform.

For the development of the new product a universal software-defined radio platform was selected, which provides the possibility to implement major functions in software instead of hardware. This helped to significantly reduce the price of the final product. The possibility to extend the product's capabilities with new functions by updating the firmware instead of replacing the hardware led to improved flexibility. A prototype of a UHF RFID tag tester has been implemented, which covered the design of hardware, software and firmware. Evaluating the accuracy of the new test instrument was carried out at RF labs of the SIX Research Centre. The company successfully introduced the product on the market. The cooperation between CISC and SIX in this area is ongoing.

## High-tech devices (selected)

*6 GHz vector signal generator R&S SMU 200A* with real-time generation of 2x2 MIMO, 40 fading paths and 200 MHz bandwidth.

*13.5 GHz real-time spectrum analyzer R&S FSVR13* with vector signal analysis option.

*Anechoic chamber (ETS Lindgren)* with near-field scanner (NSI) for antenna characterization and emission measurements (800 MHz – 40 GHz). The shielded anechoic chamber occupies a volume of 5 m x 5 m x 5 m and its outside-to-inside isolation is better than 85 dB for frequencies up to 100 GHz. The useable volume for RF measurements is approx. 1 m x 1 m x 1 m. The nearfield scanner is based on a spherical geometry with 2-axis positioner. Antennas-under-test can be characterized accurately from 800 MHz up to 40 GHz. Absolute gain measurements can be carried out with  $\pm 0.5$  dB accuracy.

*20 GHz four-port vector network analyzer Agilent E5071C-TDR* with built-in Enhanced Time Domain Analysis option.

01 Anechoic chamber for antenna characterization and device emission measurements

02 Setup for UWB intra-car channel sounding in time domain



# High Mobility Communications

The society of tomorrow is a mobile society that highly relies on high data rate internet access. Wireless cellular systems either dedicated to rooms via antenna distribution systems or designed for high mobility users are a crucial necessity for such a society.

We are ready to address research questions related, e.g., to efficient dynamic coordination of heterogeneous networks to support large numbers of mobile users, and to propose perspective physical layer technologies for 5G and beyond systems including D2D communication. We are able to evaluate the performance of the adopted solutions through computer simulations or real-world measurements.



## Projects & Cooperation (selected)

*EU project CORTIF (CATRENE): Coexistence of radiofrequency transmission in the future.* Partners: Airbus Defence & Space, IMEC, IMT, NXP Netherlands, Technicolor, Technolution, TU Eindhoven, Universitat Politecnica de Catalunya, XLIM - University of Limoges CNRS. The goal of this project is to assure the future use of the radio spectrum by multiple applications without detrimental mutual interference. The orientation of the group is mainly the coexistence between broadcasting services, WLANs and WPANs in terms of measurements, modeling and algorithms.

National project *Quality of experience aspects of broadcast and broadband multimedia services*, in the frame of COST Action IC1003. Partners (selected): University of Würzburg, VTT, Czech Technical University in Prague. The goals were to analyze and model the prospective methods for coding and transmission of image and video content with the main focus on the impact on the perceived quality.

*EU project LOLA: Achieving low-latency in wireless communications.* Partners: Eurecom (France), Linköping University (Sweden), AT4 wireless (Spain), THALES Communications SA (TCF, France), ERICSSON D.O.O. (Serbia), MTS (Serbia). TU Wien participated as a work package leader in the area of Traffic Generation and Modeling.



## Publication record (selected)

HANZO, L., HAAS, H., IMRE, S., O'BRIEN, D., RUPP, M., GYONGYOSI, L. Wireless myths, realities and futures: From 3G/4G to optical and quantum wireless. *Proceedings of the IEEE*, May 2012, vol. 100, p. 1853–1888. DOI: 10.1109/JPROC.2012.2189788

POLÁK, L., KLOZAR, L., KALLER, O., ŠEBESTA, J., SLANINA, M., KRATOCHVÍL, T. Study of coexistence between indoor LTE femtocell and outdoor-to-indoor DVB-T2-lite reception in a shared frequency band. *EURASIP Journal on Wireless Communications and Networking*, 2015, 2015(114), 14 p. DOI: 10.1186/s13638-015-0338-x



## Patents (selected)

KRUPKA, M., MORAVEC, J., PACHMÁŇ, J., ŠELEŠOVSKÝ, J., MARŠÁLEK, R., ŠEBESTA, V., PROKEŠ, A. Method of measuring and evaluating characteristic of explosion-generated sequential optical signals. Patent no. 305407, granted.



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## Successful cooperation with industry (selected)

*Testing of 3G mobile networks in the Czech Republic. T-Mobile Czech Republic, a.s.* A goal of the project was to measure the basic parameters of 3G mobile networks in the Czech Republic. Indicators such as downlink/uplink throughput, latency or reference web page download time were observed. The measurement campaign took place in February 2011 during working hours on randomly selected places in 21 main cities all around the Czech Republic. A statistical evaluation was also a part of the project. The outputs of the project helped to get information about the quality of network coverage and real performance delivered to mobile internet connection users.

## High-tech devices (selected)

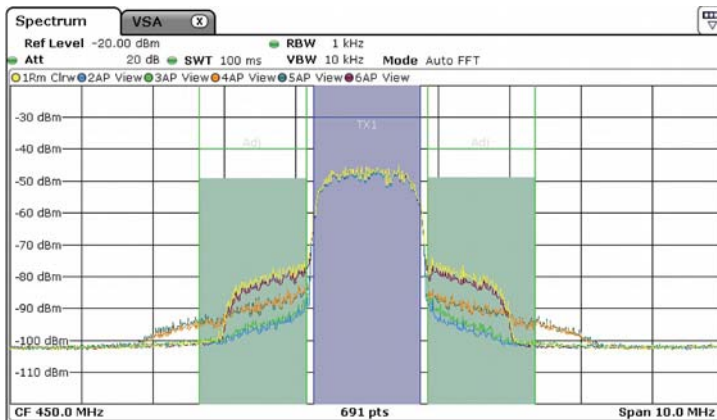
A Wireless Communication Laboratory equipped with specialized instruments such as Rohde & Schwarz Radio Network Analyzer TSMQ with ROMES software - a tool for monitoring mobile network standards, field test measurements and performance evaluation, or a spectrum and vector signal analyzer FSQ8 for the frequency range 20 Hz - 8 GHz with options covering recent digital communication standards including 3GPP LTE.

A Digital Broadcasting Laboratory comprising of broadcast test systems for digital audio/multimedia broadcasting DAB/DMB and terrestrial and mobile digital video broadcasting DVB-T/H (Rohde & Schwarz SFU).

## Events we co-organized (selected)

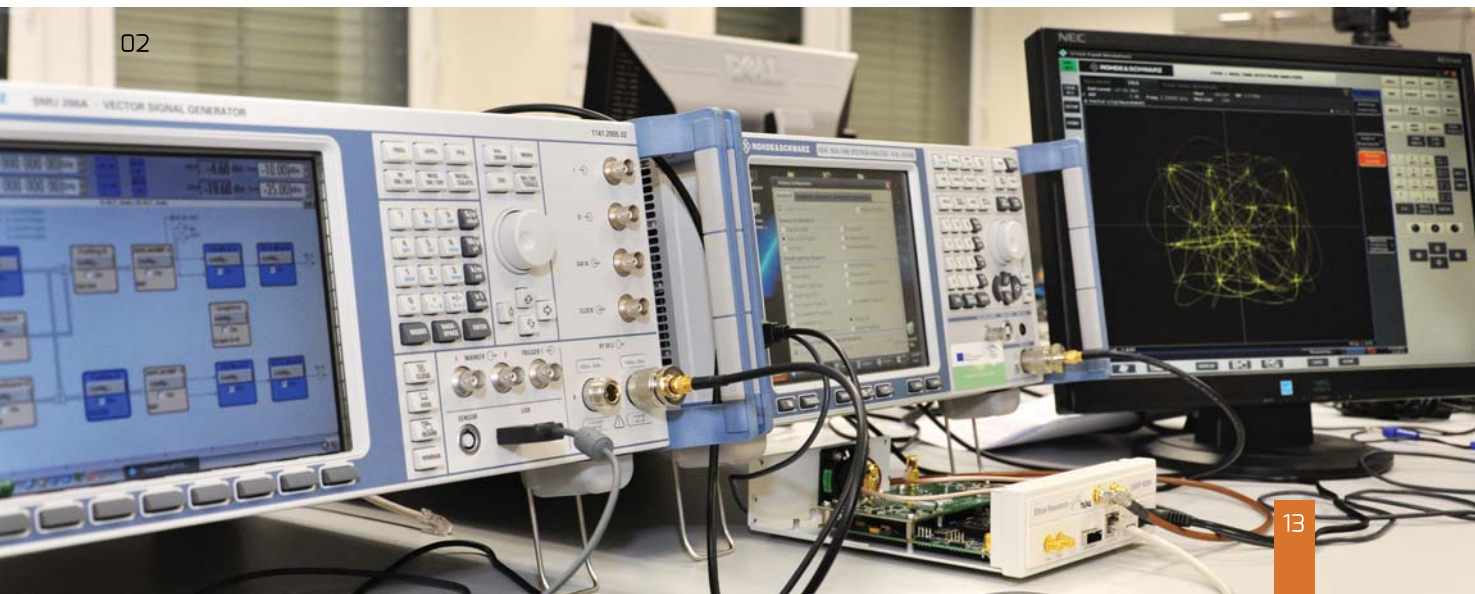
International seminar with guest speakers Harri Holma (CTO Nokia), Erik Dahlman (CTO Ericsson).

01



- 01 Spectra of communication device with in-built digital power amplifier linearization (in cooperation with RACOM s.r.o.)
- 02 Evaluation of communication systems' physical layer

02





# Advanced Cybersecurity

The Advanced Cybersecurity group is focused on the methods and technologies for the protection against cyber attacks. The group is composed of teams from both universities involved in the project, namely Prof. Tanja Zseby's team (TUW) and Dr. Jan Hajný's team (BUT). Security of cyber-physical systems, an area where both teams are already very active, is the core of the joint research plan. In future research, the group will focus on particular aspects of cyber-physical security, i.e. cryptography for resource-restricted devices, machine learning for anomaly detection and side-channel attacks and stress testing of heterogeneous networks. In addition, the group will serve other working groups in their particular needs.



## Projects & Cooperation (selected)

Project *LTE-assisted WiFi-direct* was completed on a live 3GPP LTE deployment at Brno University of Technology, Czech Republic. This unique trial united partners from Tampere Univ. of Technology, Brno Univ. of Technology, and Intel Labs US.

Project *Application of modern cryptographical methods to increase communication security in telematics systems* with the company Honeywell. The main outcome is the design and implementation of cryptographic protection for smart house installations.

Project *RASSA- Referenzarchitektur für sichere Smart Grids in Österreich*, (funded by FFG). The project develops a reference architecture for secure smart grids in Austria. Several major stakeholders (vendors, operators) for smart grid technologies are involved.



## Publication record (selected)

HAJNÝ, J., MALINA, L., DZURENDA, P. Privacy-PAC: Privacy-enhanced physical access control. In *Proceedings of the 13th Workshop on Privacy in the Electronic Society WPES '14*. Pre-conference workshop of the 21st ACM Conference on Computer and Communications Security. Scottsdale (Arizona, USA), Nov. 2014, p. 93-96. DOI: 10.1145/2665943.2665969

IGLESIAS VAZQUEZ, F., ZSEBY, T. Analysis of network traffic features for anomaly detection. *Machine Learning*, 2014, 26 p. DOI: 10.1007/s10994-014-5473-9

ZSEBY, T., IGLESIAS VAZQUEZ, F., KING, A., CLAFFY, K. Teaching network security with IP darkspace data, *IEEE Transactions on Education*, 2015, 7 p. DOI 10.1109/TE.2015.2417512



## Successful cooperation with industry (selected)

Stress testing and security evaluation of a network infrastructure. Problem: The bank has updated its IT infrastructure recently, including its firewalls and network filters. The bank wanted to 1) find the true performance limits of the newly purchased security devices and 2) to verify that the devices are fully functional in case a massive attack comes.



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Solution: The high-speed traffic generator Spirent Avalanche 3100B was connected to the infrastructure of the bank. The testing device was configured to generate legitimate traffic (HTTP(S) requests) and analyze the behavior of the infrastructure. The load was gradually increased from Kbps to Gbps. Malicious traffic, namely various DDoS attacks, were mixed into the legitimate traffic to evaluate the operability of network filters. The complete test was running in a live infrastructure and network administrators had the right to stop the test immediately.

Results: The performance limits of the firewalls and network filters were found. The behavior of the infrastructure under extreme load was analyzed. The functionality of security devices was evaluated and devices not performing as promised by vendors were identified. The main bottleneck of the infrastructure (a particular filter with specific HTTPS deep packet inspection feature activated) was identified.

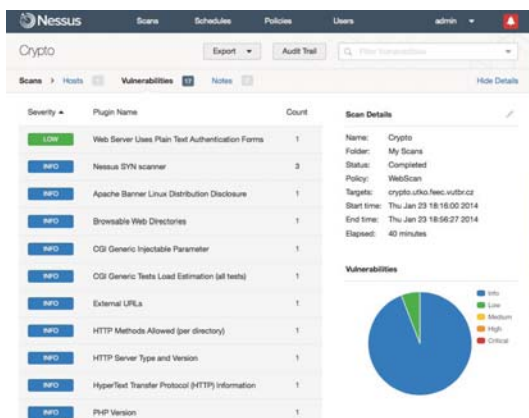
## High-tech devices (selected)

*Spirent Avalanche 3100B.* A device capable of performance and security testing of network infrastructures and services. Extreme traffic of up to 20 Gbps can be generated by the device to evaluate the scalability and behavior of the infrastructure or service in non-standard conditions.

*LTE Infrastructure.* The unique experimental LTE-A network is deployed within the SIX Research Centre. This complex communication system consists of RAN, EPC and IMS components as well and so supports most of the functionality expected of LTE Release 10 standard. The deployed cellular base stations support frequency bands of 700 MHz, 1800 MHz and 2600 MHz with a bandwidth of 5 MHz.

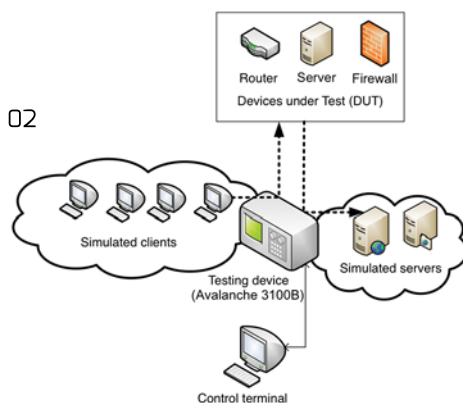
*Data Storage and Computing Cluster.* The TUW network security lab contains data storage and a computing cluster for network traffic analysis and anomaly detection methods. The infrastructure will also be used to collect and analyze sensor data from the microgrid lab (FUSE testbed) that is currently established at TU Wien.

01



- 01 Network vulnerability scanners
- 02 Testing of network infrastructure
- 03 Spirent Avalanche 3100B

03



# Advanced Antennas and Circuits

The electromagnetic interface is a key-aspect of modern wireless systems. It encompasses all that connects the digital domain to the received and transmitted EM-waves. Research of the Advanced Antennas and Circuits Group is focused on three main areas: "communication", "identification", and "sensing", and covers everything from antennas, circuit/system design, to related signal processing. Emphasis is put on the integration of modules to their surroundings, on adaptive and reconfigurable solutions, and their implementation by advanced and non-conventional technologies. The two research teams from TU Wien and BUT perfectly complement each other in those topics: Whether the goal is a novel antenna or a complete RF system design, the teams have the required know-how up to frequencies in the millimeter wave range.



## Projects & Cooperation (selected)

*UHF RFID ranging concepts which can be used with unmodified EPC Gen2 tags.* Investigations were based on a patent from TU Wien. The concepts constituted of RF system design/simulations, signal processing, a real-time FPGA-based demonstrator, and the development of custom silicon for a UHF tag with enhanced ranging capabilities. The project was carried out with several industrial partners including a major UHF tag manufacturer.

*Switched mode RF power amplifiers with high efficiency.* The research included novel design methodology for digitally driven amplifiers, PWM noise shaping, signal processing for 1-bit systems, nonlinear characterization and linearization of systems with quantized input signals.



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## Publication record (selected)

ARTHABER, H., FASETH, T., GALLER, F. Spread-spectrum based ranging of passive UHF EPC RFID tags. *IEEE Communications Letters*, vol. PP, no. 99, 4 p. DOI: 10.1109/LCOMM.2015.2469664.

PUSKELY, J., POKORNÝ, M., LÁČÍK, J., RAIDA, Z. Wearable disc-like antenna for body centric communications at 61 GHz. *IEEE Antennas and Wireless Propagation Letters*, 2015, vol. 14, p. 1490–1493. ISSN: 1536-1225. DOI: 10.1109/LAWP.2014.2367812



## Patents (selected)

ARTHABER, H., PSAIER, S. Method for access control. EP 12450043.0-2211, granted. Use of capacitive coupling for keyless entry systems.

ARTHABER, H. Method and system for localizing objects. AT511750 B1, granted. A spread-spectrum based ranging method for off-the-shelf UHF RFID tags.

ARTHABER, H. Method and apparatus for measuring signal phase shifts. AT497607 T, granted. A low complexity method for estimating phase difference between broadband modulated signals.

RAIDA, Z., ČÁP, A., POLÍVKA, M. Multi-band patch antenna. Patent no. 299752, granted. An original method for creating multiband planar antennas by etching notches into the antenna element.



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## Successful cooperation with industry (selected)

*High-power transmit antennas for DVB-H and DVB-T.* TESLA Holding succeeded in winning a tender for constructing DVB-H and DVB-T networks in Poland. For this network, modular antennas designed for analog broadcasting had to be redesigned to meet requirements of digital standards. The BUT team created numerical models of high-power transmit antennas and optimized the design from the viewpoint of electrical parameters, mechanical properties, reliability, and robustness. Optimized numerical models were used for tolerance and sensitivity analyses resulting in manufacturing documentation. The designed antennas were introduced to series production and were installed in Poland.

*Implementation of an ultra-linear L-band OFDM transmitter for airborne applications with high peak power (250 W).* The work was performed with Frequentis AG (Austria), a major player in air traffic safety, within the scope of the European SESAR joint undertaking. It covered the entire RF/mixed-signal/FPGA co-design, the development of the digital-predistortion based linearization concept, and the implementation of a final prototype.

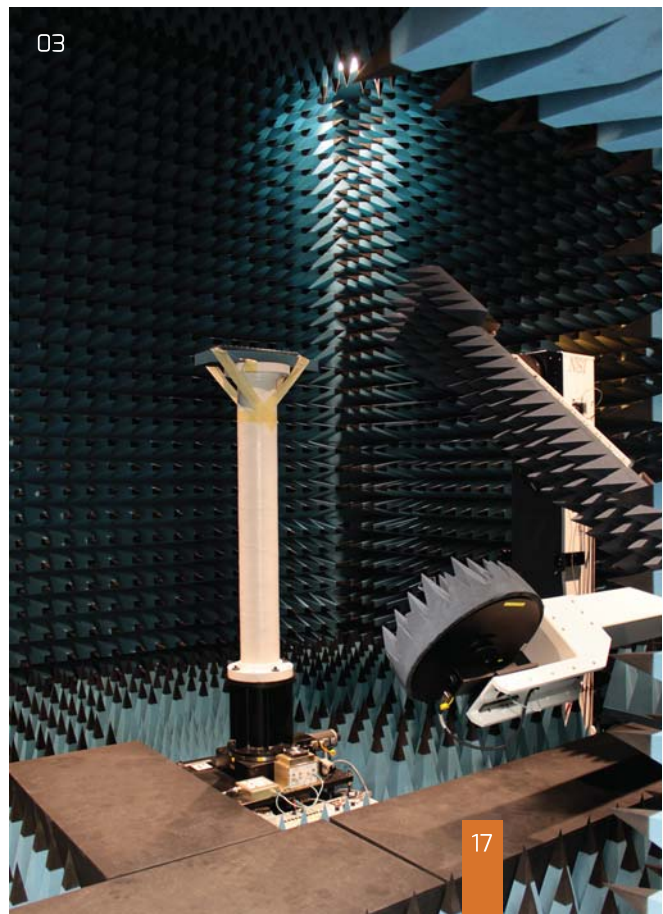
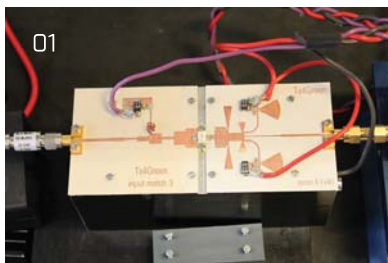


## High-tech devices (selected)

*Harmonic load-pull setup Maury ATS.* Performing load-pull-measurements is often the key in dealing with nonlinear effects in active devices. The state-of-the-art 18 GHz high power Maury system is extended with in-house developed active loads and harmonic loads.

*Network analyzers Keysight PNA-X and R&S ZVA.* Linear and non-linear analysis up to 110 GHz and 50 GHz, resp., for the measurement of circuits, systems, and antennas. Pulse modulation capabilities and fast CW-measurements up to 70 GHz enable analysis of time-variant effects.

*Spherical antenna measurement systems NSI 700S-30 and NSI 700S-90E.* The scanners, both installed in anechoic chambers, are able to measure radiation properties of antennas and systems. In total, the frequency range is from 800 MHz up to 40 GHz in the near-field, and up to 110 GHz in the far-field.



- 01 Switched mode RF power amplifiers
- 02 L-band OFDM transmitter
- 03 Antenna measurement system

## Awareness in Cyber-Physical Systems

Awareness, consisting of self-monitoring, situation awareness, and attention, is a key enabler for efficient cyber-physical systems. Attention is instrumental in balancing the competing tasks of data collection, processing and responses under tight resource constraints because it assigns priorities to tasks and goals. These priorities dynamically change depending on the situation. Thus, situation awareness assesses the observations and gives significance to data, attention directs scarce system resources to the most important tasks and, by means of self-awareness, the overall system performance is monitored in a dynamically changing environment. Our main research goals in the context of cost constrained cyber-physical systems include the key aspects of awareness, their efficient realization, on-line learning techniques, and group awareness.



### Projects & Cooperation (selected)

*ICTT4RobustGrid – ICT requirements for operation of advanced and robust smart grids.* Multi-agent systems (MAS) are able to cope with complex tasks in highly diverse fields. One of their applications is smart grids (intelligent power distribution systems), as their increasing complexity demands innovative and efficient control systems. The ICT4RobustGrid analyzes existing structures and identifies requirements for MAS. The project's goal is to compile a research roadmap in order to prepare for the transition from currently dominating centralized to future decentralized control.

*SIRIUS – Solid state outdoor lighting with intelligent management for increasing energy efficiency.* Lighting systems in public space make up a significant portion of municipal power consumption. The project's goal is to develop, integrate, and evaluate a control mode for the intelligent, adaptive control of streetlights. By combining sensor data for the detection of road users and environmental influences, adapted lighting strategies can be developed.



### Publication record (selected)

DUTT, N., JANTSCH, A., SARMA, S. Towards smart embedded systems: A self-aware system-on-chip perspective. *ACM Transactions on Embedded Computing Systems*, Special Issue on Innovative Design Methods for Smart Embedded Systems, 2015.

PREDEN, J.-S., TAMMEMÄE, K., JANTSCH, A., LEIER, M., RIID, A., CALIS, E. The benefits of awareness and attention in fog and mist computing. *IEEE Computer*, Special Issue on Self-Aware/Expressive Computing Systems, July 2015, vol. 48, no. 7, p. 37–45. DOI: 10.1109/MC.2015.207

ŠTŮSEK, M., HOŠEK, J., KOVÁČ, D., MAŠEK, P., ČÍKA, P., MAŠEK, J., KRÖPFL, F. Performance analysis of the OSGi-based IoT frameworks on restricted devices as enablers for connected-home. In *Proceedings of the 7th International Congress on Ultra Modern Telecommunications and Control Systems ICUMT 2015*. Brno (Czech Republic), 2015, p. 211–216.



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## **Successful cooperation with industry** (selected)

*On-chip network performance analysis.* Intel research requested proposals for methods to analyze throughput, delay and congestion behaviors for on-chip communication networks with 10-20% accuracy. A. Jantsch and his team, then at KTH in Stockholm, proposed an analysis method based on Network Calculus for analyzing worst case behavior based on our earlier work. To model the microarchitecture of the on-chip communication at the cycle accurate level of detail, as required, we adopted the xMAS formalism developed at Intel Research Labs in Moscow. Detailed Network Calculus models for the xMAS elementary components buffers, switches, delays, merge elements, muxes, and flow control have been developed and verified. Various on-chip communication architectures for wormhole switching, virtual channels, deterministic and adaptive routing have been studied based on the xMAS models and Network Calculus. Finally, the analysis techniques for worst case delay, throughput and buffer utilization have been implemented in a tool based on xMAS modeling.

## **High-tech devices** (selected)

*Wafer Prober PM8 Probe System* from Sues MicroTec Systems GmbH.

*Climatic chamber Vötsch VC3 7018* serves for performing evaluation of devices under test exposed to thermal and humidity effects.

*Phoenix X-ray Micromex DXR-HD.* Suitable for disclosing soldering defects on printed circuit boards, can also be used for defect detection inspection in mechanical components.

## **Events we co-organized** (selected)

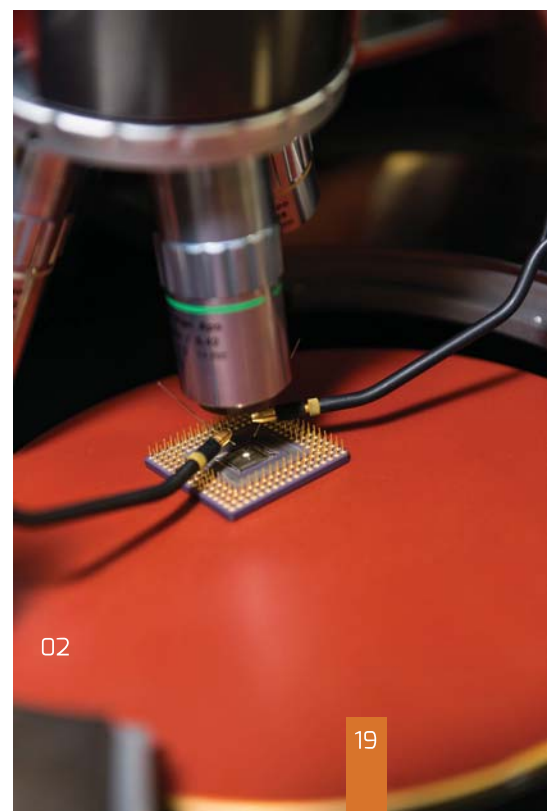
*iPack Annual Conference of the iPack Excellence Center in 2012*, with over 70 participants, half from industry.

*iPack Annual Conference of the iPack Excellence Center in 2013*, with over 100 participants, half from industry.

*CODES+ISSS 2004*, IEEE Conference on HW/SW Codesign and System Synthesis in Stockholm.

01 Phoenix X-ray Micromex DXR-HD

02 Analysis of highly integrated circuits



# INTERNATIONAL VISIBILITY

## International Collaboration

### **University of Castilla-La Mancha, Spain**

Long standing successful co-operation on the topic of piezoelectric MEMS resonator devices by combining modeling and simulation expertise with hardware design, manufacturing and characterization.

### **Imperial College, London, UK**

In this co-operation, novel approaches to energy harvester designs based on thermoelectric energy generation are investigated.

### **Gdansk University of Technology, Poland**

Mutual collaboration on fluctuation phenomena in chemical gas sensors within the Czech-Polish project 7AMB13PL032 and further projects have been applied.

### **Massachusetts Institute of Technology (MIT), USA**

In cooperation with a team from MIT, we took part in joint research of image processing methods for EM slices being used to train machine learning algorithms for the purpose of automatic segmentation of neural structures.

### **Austrian Academy of Sciences, Acoustics Research Institute, Austria**

Based on two bilateral projects, we cooperate with this institution in the field of signal processing, namely in developing audio restoration algorithms such as signal declipping and completing missing signal parts. We also participate in developing an open-source Large Time-Frequency Analysis Toolbox.

### **Austrian Institute of Technology (AIT), Austria**

Cooperation in the field of intra-car channel measurement and modeling and localization in UWB and millimeter wave band.

### **Graz University of Technology, Institute of Microwave and Photonic Engineering, Austria**

Cooperation in the field of free space optics channel modeling and atmospheric effects characterization.

### **University of Cantabria, Systems and Automation Engineering Department, Spain**

Cooperation in the area of fully photonic optical communications and medical investigation.

### **Université Paris-Est, ESIEE Paris, France**

More than ten years-lasting cooperation in the field of power amplifier linearization techniques and transceiver algorithm design, joint supervision of several PhD thesis (doctorat en cotutelle).

### **University of Würzburg, Germany**

Long-term cooperation with the University of Würzburg first aimed at optimizing video transmission in mobile networks, later evolved into research in the area of quality of experience for HTTP adaptive streaming.

### **Ulm University, Germany**

Recently started cooperation in the domain of cognitive radio algorithms design and implementations.

### **Johann Wolfgang Goethe-Universität Frankfurt, Germany**

Cooperation in the field of digital identity protection and cryptographic privacy-enhancing technologies.

### **Universitat Rovira i Virgili, Spain**

Cooperation in the field of cryptologic protocol design, in particular the development of lightweight cryptosystems for low-performance devices, such as smart cards, sensors and microcontrollers.

### **University of California, San Diego (UCSD), USA**

Cooperation in the field of network data analysis and secure smart grid communication.

### **Polytechnic University of Catalonia, Spain**

The cooperation is focused on the development of methodology for the design of filtering antennas (filtennas) composed from a patch array, substrate integrated resonators, and substrate integrated feeders.

### **Holon Institute of Technology, Israel**

At present, we are preparing a research project focused on the development of intelligent textile materials to be used as a wireless feed and wireless communicator with sensors of vital functions. Partner companies in the project plan to use the intelligent textile as a cover for mattresses in hospital beds.

### **University of California, Irvine (UCI), USA**

Cooperation on researching SoC platforms for self-aware cyber-physical systems, based on CPSoC, which has been developed at UCI.

### **Tallinn University of Technology, Laboratory of Proactive Technologies, Estonia**

Cooperation on study awareness in sensor networks for medical and surveillance applications.

### **Tampere University of Technology, W.I.N.T.E.R. Group, Finland**

Cooperation on network assisted D2D communication with possible deployment in sensor networks.

and more ...

## Industrial Partners

### **Infineon Technologies AG, Germany**

Development of advanced and robust materials for MEMS and power electronics.

### **AVX Czech Republic s.r.o, Czech Republic**

Project on new protective coating of capacitors.

### **Honeywell Czech Republic, Automation and Control Solutions**

The Honeywell ACS department offers products and solutions for the control of thermal heating and technological processes for automation equipment. The Signal Processing Working Group collaborates in the evaluation of noise but only for certain components of industrial products, according to current standards. Cooperation on the design and implementation of cryptographic protocols for data encryption and authentication.

### **RapidMiner Inc., USA**

The company Rapid-I offers software, problem solutions and services in the area of predictive analysis, data mining and text mining. The company focuses on intelligent automated analysis of large data corpuses, i.e. for a large amount of structured data such as databases and unstructured data such as texts.

### **Webnode AG, Czech Republic**

One of key software products of Webnode, the internationally active company from Brno, provides cheap web hosting services together with tools for quick and easy creation of free websites, visited by more than 60 million users every month. Other products of Webnode company include artificial intelligence for business process optimization and automation of text processing.

### **ERA a.s., Czech Republic**

Long term cooperation in the domain including the development of supporting blocks for a new radiolocation system based on passive coherent location.

### **TESLA a.s., Czech Republic**

Long term cooperation focused on radio communications and special communications equipment design. A development of a dedicated aggregation algorithm and hardware for dual radio links belongs to last conjoint projects.

### **CISC Semiconductor GmbH, Austria**

The aim of long term cooperation is design and realization of UHF RFID devices based on a new universal software-defined radio platform.

### **Airbus Group**

Cooperation on energy harvesting for autonomous wireless sensor nodes in aircrafts.



### **RACOM, s.r.o., Czech Republic**

Cooperation in the field of advanced signal processing methods and physical layer design for new generations of communication systems under NLOS conditions.

### **A1-Telecom, Austria**

Long standing theoretical as well as experimental research on 3rd, 4th and 5th generation cellular networks.

### **Kathrein Werke, Germany**

Many years of collaboration in front-ends, experimental work and indoor distribution for cellular networks.

### **E.ON, Czech Republic**

Cooperation on the analysis and evaluation of smart metering technologies with special focus on PLC (Power Line Communication).

### **INVEA-TECH a.s., Czech Republic**

Cooperation on the design and implementation of encryption systems for high speed (up to 100 Gbps) network cards based on FPGA (Field Programmable Gate Array) circuits.

### **Frequentis AG, Austria**

Research on transceivers and algorithms for the upcoming LDACS-1 communication standard within the European SESAR joint initiative. Currently, joint analog/digital demodulator concepts for high interference scenarios are being investigated.

### **AT&S Austria Technologie & Systemtechnik AG, Austria**

Development of methods for the characterization of high speed printed circuit boards. A strong focus is put on studying the material's and production process's influence on losses up to 110 GHz.

### **Volkswagen AG, Germany**

Previously, cooperation was focused on the development of antenna concepts for Car2Car communication, and antennas for positioning and data fusion algorithms. Now, we are cooperating in developing the methodology for in-car electromagnetic field modeling.

### **Telekom Austria Group, Austria**

Development of Smart Multi-Purpose Home Gateway (SyMPHOnY), which merges detection and forwards the alarm systems' events. The technology behind may be raised in any smart home or industry building.

### **SEWIO Networks s.r.o., Czech Republic**

Cooperation in IoT, D2D communication, online learning techniques, and developing algorithms for indoor localization.

and more ...

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