







# Damir Rakhimov

## Research and Development in Wireless/DSP

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### SUMMARY

I am a researcher with 10+ years of R&D experience and a focus on signal processing/machine learning for wireless communications. I have strong knowledge in (multi) linear algebra and probability theory. I am interested in research/development tasks on the intersection between theory and practice and involving solutions to various challenges. My work background includes experience in measurements/testing, programming microcontrollers/FPGAs, developing wireless systems prototypes, and organizing work processes.

### TECHNICAL SKILLS

- **Languages:** Python, C++, System Verilog, VHDL, Matlab, LabView
- **Frameworks:** Matlab/GNU Octave, QuaDRiGa, GNU Radio, USRP, LabView/RFSA/RFSG/LV-FPGA, Python, NumPy, Pandas, PyTorch, Scikit-Learn, OpenCV, OpenCL, CUDA
- **Technologies:** MIMO-OFDM, mmWave, Machine Learning, FPGA, SDR
- **Methods:** Channel Estimation, Beamforming, Adaptive Array Signal Processing, Statistical Processing, Linear Algebra, Multidimensional Processing, Robust Methods, Numerical Optimization

### PROFESSIONAL EXPERIENCE

#### CRL | TU-Ilmenau | Ilmenau, Germany

*A leading German public research university located in Thuringia, central Germany*

##### Senior Researcher in Wireless & DSP

Apr '22 – Present

- Research / Development of new mmWave algorithms for CE and BF
- Computer simulations and tests / Preparation of research reports
- Preparation of research proposals / Contacts with industrial partners

##### Research Assistant / MSCSP Program Manager

Aug '18 – Apr '22

- Teaching / Student assistance / Study program administration / Admission
- Research on CE for mmWaves / Preparation of research reports / Literature review
- Software testbed development and programming / Computer simulations

#### RTS | KNRTU-KAI | Kazan, Tatarstan

*One of the largest technical universities in Russia, with over 110,000 alumni*

##### Lead Engineer / Research Assistant

Sep '13 – Aug '18

- Research in the field of wireless communications and transmission systems
- Prototyping of wireless systems / FPGA development
- Preparation of scientific/technical documentation and reports

##### Automation Engineer

Jan '10 – Aug '13

- Software development for automated testing stands
- Development of algorithms for digital signal processing

### EDUCATION

#### Doctor Engineer (PhD)

Jan '19 – Present

CRL | TU-Ilmenau | Ilmenau, Germany

- **Thesis:** Advanced Tensor-based Signal Processing Techniques for Channel Estimation at mmWave and sub-THz frequencies
- **Advisor:** Univ. – Prof. Dr. Martin Haardt

#### Master of Science in Communications and Signal Processing (with Honor, GPA: 5.0/5.0)

Sep '11 – Jun '13

RTS | KNRTU-KAI | Kazan, Tatarstan

- **Thesis:** Software-Hardware Testbed for Research and Development of Time- and Frequency Synchronization Methods for OFDM
- **Advisor:** Prof. Dr. Adel F. Nadeev

#### Bachelor of Science in Info-communication Systems and Networks (with Honor, GPA: 5.0/5.0)

Sep '07 – Jun '11

RTS | KNRTU-KAI | Kazan, Tatarstan

- **Thesis:** Development of software for an automated system for antenna measurements
- **Advisor:** Prof. Dr. Adel F. Nadeev

## WORK / RESEARCH INTERESTS

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- MIMO-OFDM Wireless Communications / Adaptive Array Signal Processing / Beamforming / Channel Estimation
- Statistical Methods / Machine Learning / Artificial Intelligence / Autonomous Systems
- Real-Time Signal Processing / SoC / ASIC / FPGA / GPU / TPU
- Linear Algebra / Multidimensional (Tensor) Processing / Optimization Methods and Algorithms

## PROJECTS

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### CRL | TU-Ilmenau | Ilmenau, Germany

#### Reconfigurable Intelligent Surfaces and Holographic Beamforming for Non-Terrestrial Networks

Jan '22 – Aug '23

- **Role:** Senior Team Member
- **Duties:** Software architecture design, task decomposition, design of detection/estimation algorithms, performance verification via numerical simulations, and negotiations with industrial partners.

The project investigated the application of the new emerging technology of reconfigurable intelligent surfaces (RISs) and holographic beamforming to improve the performance of satellite communication networks. During the project, the analysis of achievable data rates for a communication system assisted by a RIS under impairments constraints such as thermal deformations and low-resolution phase shifters.

#### Advanced Hybrid Analog-Digital Massive MIMO Techniques for Millimeter Wave Wireless Systems

Apr '19 – Dec '21

- **Role:** Senior Team Member
- **Duties:** Software architecture design, design of detection/estimation algorithms and performance verification via numerical simulations/analytical derivations.

This project aimed to design advanced massive hybrid analog-digital mMIMO techniques and the required channel acquisition schemes to improve the performance of future broadband mmWave wireless communication systems in the 28 GHz band using multiple antennas.

### RTS | KNRTU-KAI | Kazan, Tatarstan

#### Design and hardware verification of pattern distortion compensation algorithms for multi-beam antenna systems

Jan '17 – Dec '17

- **Role:** Lead Team Member
- **Duties:** Architecture design, task decomposition, team management, negotiations with industrial partners, implementation of algorithms in hardware, software design, system performance evaluation, and hardware verification.

The project's goal was to develop algorithms and a testbed to compensate for the impairments of a satellite antenna system with multiple beams. Perturbation of the antenna reflector is considered the main source of the impairments. As a result of the project, a digital pattern distortion compensation algorithm was proposed based on the pilot signals. Performance verified via measurement as the NI testbed.

#### Research and development of a prototype of the video processing unit of the adaptive front-light control system

Jan '16 – Feb '17

- **Role:** Lead Team Member
- **Duties:** Architecture design, task decomposition, team management, negotiations with industrial partners, algorithms design and verification, hardware implementation, and system performance evaluation.

The project aimed to design a processing chain for object detection and control of an adaptive-front light system (AFS, part of ADAS). During the project, an AFS prototype was developed and tested on the dataset for various road conditions. Additional evaluation of system performance and the importance of detection features was carried out.

#### Development of waveguide mode converter for radio direction finder and test equipment to it.

Mar '15 – Nov '15

- **Role:** Senior Team Member
- **Duties:** System modeling, software development to control test equipment for direction finder, designing of system structure, performance verification of measuring/estimation algorithms.

The goal of the project was to design a testbed for a radio direction finder in the K-band and evaluate the performance of its key parameters. The measurement platform was built on the equipment from NI. The software was designed in LabView. The complex could measure complete radio direction finder response over angles, store signals in real-time to RAID, and extract quality parameters from the measured data.

#### Development of a digital processing module for a prototype of a beacon transponder

Sep '13 – Jan '14

- **Role:** Senior Team Member
- **Duties:** Algorithms design/verification, hardware implementation, and system performance evaluation.

In this work, a prototype of a technological beacon transponder for an air traffic control radar beacon system (ATC RBS) was developed. The prototype consisted of National Instruments equipment and the Altera FPGA development board. The technological beacon transponder is test equipment for secondary surveillance radars (air traffic control radar beacon system) that is used for equipment verification at civil airports. Within the project, the receive algorithm was developed and tested by NI equipment; later, it was transferred to the Altera FPGA development board.

#### Research and development of a prototype for an OFDM-based communication system

Jan '12 – Dec '12

- **Role:** Team Member
- **Duties:** System modeling, development of software for a USRP testbed, algorithms design/verification

The goal of the project was the investigation of the OFDM technology. Particular focus was placed on analyzing the time- and frequency-synchronization algorithms. During the project, I created the architecture for the transceiver design and developed the corresponding algorithms for signal processing. Further, the performance was analyzed at the NI-SDR testbed with physical signals.

#### Development of software for an automated system for antenna measurements

Apr '11 – Oct '11

- **Role:** Team Member
- **Duties:** Development of software for measurement devices, software for measurement data processing, and software for data visualization.

The project aimed to build the control software for an automatic antenna measurement system. The corresponding measurement system was built on the vector network analyzer from National Instrument equipment. The control systems facilitated the measurements of antenna parameters, such as diagram pattern, matching coefficient, polarization, etc. All software was developed in the graphical programming environment Labview within the project.

## LANGUAGE ABILITIES

- **English:** Full professional proficiency - Oral (C2), Reading (C2), Writing (C1)
- **German:** Limited working proficiency - Oral (B2), Reading (B1), Writing (A2)
- **Russian:** Native language
- **Tatar:** Native language

## MAIN PUBLICATIONS

### Journal Papers

- **D. Rakhimov**, and M. Haardt, "Analytical performance assessment of 2-D Tensor ESPRIT in terms of physical parameters," *IEEE Open Journal of Signal Processing*, vol. 5, pp. 122-131, 2023
- J. Zhang, **D. Rakhimov**, M. Haardt, "Gridless channel estimation for hybrid mmWave MIMO systems via Tensor-ESPRIT algorithms in DFT beamspace", *IEEE Journal of Selected Topics in Signal Processing*, vol. 15 (3), pp. 816-831, 2022

### Conference Papers

- G. C. Nwalozie, **D. Rakhimov**, and M. Haardt, "Robust near-field beamforming for millimeter wave communication systems with aperture perturbation," in *Proc. 49<sup>th</sup> IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP 2024)*, Seoul, Korea, pp. 1-5, Apr. 2024
- **D. Rakhimov**, and M. Haardt, "Analytical performance assessment of 1-D ESPRIT in DFT beamspace," in *Proc. 57<sup>th</sup> Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, USA, pp. 1-7, 2023
- G. C. Nwalozie, **D. Rakhimov**, and M. Haardt, "Near-field Beamforming for MU-MIMO Millimeter Wave Communication System," in *Proc. 31<sup>st</sup> European Signal Processing Conference (EUSIPCO 2023)*, Helsinki, Finland, pp. 1-5, Sep. 2023
- **D. Rakhimov**, B. Peng, E. Jorswieck, M. Haardt, "Robust Reflective Beamforming for Non-Terrestrial Networks under Thermal Deformations," in *Proc. 48<sup>th</sup> IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP 2023)*, Rhodes Island, Greece, pp. 1-5, Jun. 2023
- **D. Rakhimov**, M. Haardt, "Equivalence of aperture reduction in element space and constrained combination of DFT beams in beamspace," in *Proc. 48<sup>th</sup> IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP 2023)*, Rhodes Island, Greece, pp. 1-5, Jun. 2023
- **D. Rakhimov**, A. Rakhimov, A. Nadeev, M. Haardt, "Tensor Formulation of the Cramer-Rao Lower Bound for Beamspace Channel Estimation in mmWave MIMO-OFDM", in *Proc. 25<sup>th</sup> International ITG Workshop on Smart Antennas (WSA 2021)*, Nice, France, pp. 1-5, 2021
- **D. Rakhimov**, S. P. Deram, B. Sokal, K. Naskovska, A. L. F. de Almeida, and M. Haardt, "Iterative tensor receiver for MIMO-GFDM systems," in *Proc. 11<sup>th</sup> IEEE Sensor Array and Multichannel Signal Processing Workshop (SAM 2020)*, virtual, pp. 1-5, Jun. 2020
- **D. Rakhimov**, J. Zhang, A. de Almeida, A. Nadeev, M. Haardt, "Channel Estimation for Hybrid Multi-Carrier mmWave MIMO Systems Using 3-D Unitary Tensor-ESPRIT in DFT beamspace", in *Proc. 53<sup>rd</sup> Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, USA, pp. 447-451, 2019

## TEACHING EXPERIENCE

### CRL | TU-Ilmenau | Ilmenau, Germany

- Mobile Communications (Summer Semester)** Apr '19 – Mar '22
- Wireless Channels, Bello Function, OFDM, MIMO, Spatial Multiplexing, Diversity, MU-MIMO
- Adaptive and Array Signal Processing (Winter Semester)** Oct '18 – Jun '22
- Wiener Filter, SD, LMS, RLS, LCMV, MVDR, MUSIC, ESPRIT, Tensors, HOSVD, CPD
- Communications Engineering (Winter Semester)** Oct '18 – Mar '22
- Correlation Theory, DFT, DTFT, Modulations, Matched Filter, OFDM, Statistical Analysis
- MIMO Wireless Communications (Summer Semester)** Feb '15 – Feb '22
- Linear Algebra, MIMO, Capacity, Spatial Multiplexing, Diversity, MRT, DET OSTBC, MU-MIMO

### RTS | KNRTU-KAI | Kazan, Tatarstan

- Linear Algebra (Winter Semester)** Sep '17 – Mar '18
- Determinant, Gauss method, Subspaces, EVD, SVD, Tensors
- Applied Information Technologies (Winter Semester, Summer Semester)** Sep '17 – Mar '18
- MATLAB, Python, SDR, USRP, RTL-SDR
- Statistical Methods in Communications (Summer Semester)** Feb '15 – Mar '18
- AWGN, Detector, Interference, Mixture Models, EM, Kalman Filter
- Theory of Optimal Signal Processing (Winter Semester)** Sep '14 – Mar '18
- Probability, Decision Criteria, Detection, AWGN

## VOLUNTEERING EXPERIENCE

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### Reviewer for Journals

Sep '21 – Present

- ▶ IEEE Journal of Selected Topics in Signal Processing
- ▶ IEEE Transactions on Vehicular Technology
- ▶ IEEE Transactions on Signal Processing
- ▶ IEEE Transactions on Communications
- ▶ IEEE Open Journal of Signal Processing
- ▶ IEEE Wireless Communications Letters
- ▶ IEEE Signal Processing Letters
- ▶ Journal of Electrical and Computer Engineering
- ▶ Signal Processing (EURASIP)

### Reviewer for Conferences

Mar '22 – Present

- ▶ IEEE ICC 2024
- ▶ IEEE ICASSP 2024
- ▶ IEEE ICC 2023
- ▶ IEEE ICASSP 2023
- ▶ IEEE GlobeCom 2023
- ▶ EUSIPCO 2023
- ▶ IEEE ICC 2022

### Organizer of open seminars on FPGAs

Sep '14 – May '18

- ▶ RTS | KNRTU-KAI | Kazan, Tatarstan

I was organizing open weekly seminars on developing electronic devices and algorithms with FPGAs (field-programmable gate arrays). The main goal was to teach and learn how to design real-time algorithms for software-defined radios. As a result of this activity, one book on the work with FPGAs was written, and a new study course was introduced at the Department of Radioelectronics and Telecommunication Systems.

### Organizer of an engineering bureau for students

Sep '10 – Aug '13

- ▶ RTS | KNRTU-KAI | Kazan, Tatarstan

I co-founded a student design bureau at the Institute of Radioelectronics and Telecommunications. The main focus was to work with children and students on learning the basics of radio electronics and programming. The main activity of the bureau was the development of microsatellites for the CANSAT competition. The bureau also provided controlled access to modern equipment and facilities to interested people and hobbyists.

## MEMBERSHIPS

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### Member of the Institute of Electrical and Electronics Engineers

Mar '19 – Present

- ▶ Professional International Association for Science and Technology.

### Member of the IEEE Signal Processing Society

Mar '19 – Present

- ▶ The oldest IEEE professional society for signal processing scientists and professionals since 1948.

### Member of the IEEE Communications Society

Mar '19 – Present

- ▶ International organization for engineering professionals in communications technology and information networking.

## REFERENCES

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### Univ. Prof. Dr.-Ing. Martin Haardt

- ▶ Communications Research Laboratory, TU-Ilmenau, Germany

[martin.haardt@tu-ilmenau.de](mailto:martin.haardt@tu-ilmenau.de)

### Prof. Dr.-Ing. Eduard A. Jorswieck

- ▶ Institute for Communications Technology, TU-Braunschweig, Germany

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### Prof. Dr.-Ing. Adel F. Nadeev

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