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Editorial
Implementation Aspects and Testbeds for MIMO Systems

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The *MIMO* (multiple-input multiple-output) systems have emerged as a key technology for wireless local area networks (WLANs), wireless metropolitan area networks (WMANs), and cellular mobile communication systems (3G, 4G) because they promise greater coverage, higher data rates, and improved link robustness by adding a *spatial* dimension to the time, the frequency, and the code dimensions. Recent progress in standardization and in first MIMO prototype chipsets has forced manufacturers worldwide to pay more attention to MIMO implementation aspects. Moreover, MIMO testbeds have become more and more attractive to universities and to research institutes as has been observed in the past few years. The aim of this special issue is to reflect the current state-of-the-art MIMO testbeds and to examine the several MIMO implementation challenges for current and for future wireless communication standards.

We classified the accepted thirteen submissions into four major categories: (1) hardware-oriented prototypes, (2) flexible testbeds, (3) analog issues, and (4) fast algorithms.

Hardware-oriented prototypes

In the first paper, Guo et al. present an efficient circulant approximation-based MIMO equalizer architecture for the CDMA downlink, reducing the direct matrix inverse (DMI) to some FFT operations. Further parallel and pipelined VLSI architectures with Hermitian optimization and reduced-state FFT reduce the complexity even more. A comparative study of both the conjugate-gradient and the DMI algorithms shows very promising performance/complexity tradeoff. VLSI design space in terms of area/time efficiency is explored extensively for layered parallelism and pipelining with a Catapult C high-level synthesis methodology. In the next paper, Dowle et al. describe the development of the STAR (space-time array research) platform, an FPGA-based research unit operating at 2.45 GHz and capable of having a maximum of twelve 20 MHz bandwidth channels of real-time, space-time, and MIMO processing. The design method starts with Matlab/Octave. With manual refinement steps, VHDL code for FPGAs is obtained and verified via ModelSim with the original design. Various pitfalls associated with the implementation of MIMO algorithms in real time are highlighted, and finally the development requirements are given to aid comparison with traditional DSP development. The paper by Goud et al. describes a portable 4×4 MIMO test-bed operating in an ISM band around 900 MHz. Details of channel measurements and capacity analysis of unusual indoor and outdoor locations obtained with the test-bed are also included. The next paper by Haustein et al. presents a reconfigurable hardware test-bed suitable for real-time mobile communication with multiple antennas. Supported are four transmit and five receive antennas operating at 5.2 GHz with a maximum bandwidth of 100 MHz. Efficient implementation of MIMO signal processing using FPGAs and DSPs is described. An experimental verification of several real-time MIMO transmission schemes at high data rates in a typical office scenario is presented, and results on the achieved BER and throughput performance are given. Spectral efficiencies of more than 20 bps/Hz and a throughput of more than 150 Mbps was shown with a single-carrier transmission. The experimental results clearly show the feasibility of real-time high-data-rate MIMO techniques with state-of-the-art hardware and that more sophisticated baseband signal processing will be an essential part of future communication systems.

Weijers et al. propose a systematic way from a transmission-system model, as often underlying a Matlab simulation, to a real-time prototype realized on a predefined hardware platform, avoiding inconsistencies of adhoc procedures. The suggested design flow is partly manual, but always systematic and assisted by tools suitable for the individual steps.

Flexible testbeds

The next five papers of the issue cover flexible testbeds, where the flexibility is usually achieved by higher-level programming languages. Xiang et al. describe a 4×4 MIMO-OFDM test-bed mainly based on laboratory test equipment and offline processing. Channel measurements and antenna selection techniques are presented. The paper also assesses the degradation due to carrier frequency offset and imperfect channel estimation. The next paper by Borkowski et al. presents a real-time MIMO test-bed for both single-carrier and OFDM transmission. A specific SIMD processor implemented on FPGAs is described, as well as the specific analog hardware at 10 GHz that is supported by offline and online calibration. The influence of polarization on the channel capacity is also addressed. In the paper by Caban et al., the focus is on the comfortable use of a flexible DSP/FPGA and RF hardware setup. Real-time tests with four transmit and receive channels each are possible at a data rate of 2.45 GHz. All pre- and postprocessing is done within Matlab, while the real-time requirements are fulfilled by burst-data transmission through the hardware. Multiuser abilities are also provided. In the contribution by Samuelsson et al., a test-bed for spatial multiplexing is proposed that relies on off-the-shelf radio hardware only. A comparison of SISO with MIMO reveals that even with rather low-cost hardware the remarkable spectral efficiency improvement and the associated multiplexing gain of MIMO can be demonstrated. The paper by Fàbregas et al. presents the complete design methodology of a MIMO-OFDM test-bed for WLAN applications. The design steps include a characterization of the indoor MIMO channel and the specific baseband and RF hardware at 5 GHz. The mapping and validation of the algorithms using Matlab, C++, and VHDL is detailed, and measurements are described.

Analog issues

The contribution by Liu et al. addresses a specific problem in the popular transmit-antenna diversity scheme termed "transmit MRC." While symmetries are usually assumed for the up- and downlink channels as well as between the antennas, in reality mismatches are found. A novel statistical analysis provides a deeper understanding and especially leads to a novel calibration scheme, which is finally implemented on a real-time prototyping platform. The paper by Piechocki et al. presents an extension of analogue turbo decoder concepts to MIMO detection. The first analogue implementation results show reductions of a few orders of magnitude in the number of required transistors, consumed energy, and the same order of improvement in processing speed. LDPC is used as a test case for the analysis.

Fast algorithms

Safar et al. propose an efficient detection of space-frequency block codes by means of the sphere decoding technique formulated in the complex domain. Three approaches are detailed: one approach is modulation independent, whereas the two others are specific for QAM and QPSK, respectively. The complexity analysis of these techniques is assessed.

ACKNOWLEDGMENTS

We thank the authors, the reviewers, the publisher, and the Editor-in-Chief for their efforts. We also hope that this special issue will stimulate subsequent contributions on MIMO testbeds so as to widely spread the required technical knowledge and to validate in further detail the realistic performance gain of multiantenna systems.

Thomas Kaiser
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Thomas Kaiser received a Diploma degree from the Ruhr-University Bochum in 1991, and a Ph.D. degree in 1995 and a German Habilitation degree in 2000, both from Gerhard-Mercator-University Duisburg and in electrical engineering. From 1995 to 1996, he spent a research leave at the University of Southern California, Los Angeles, which was grant-aided by the German Academic Exchange Service. From April 2000 to March 2001, he was the Head of the Department of Communication Systems at Gerhard-Mercator-University Duisburg and from April 2001 to March 2002, he was the Head of the Department of Wireless Chips & Systems (WCS) at Fraunhofer Institute of Microelectronic Circuits and Systems. Now he is the Coleader of the Smart Antenna Research Team (SmART) at the University of Duisburg-Essen. In summer 2005, he joined Stanford's Smart Antenna Research Group (SARG) as a Visiting Professor. He has published more than 80 papers in international journals and at conferences, and he is the coeditor of the three forthcoming books: *UWB Communication Systems—A Comprehensive Overview*, *Smart Antennas—State of the Art* (both to appear in the EURASIP book series), and *UWB Communications* (to be published by Wiley). He is the founder of PLANET MIMO Ltd. and belongs to the Editorial Board of EURASIP Journal of Applied Signal Processing and to the advisory board of a European multiantenna project. He is the founding Editor-in-Chief of the upcoming IEEE Signal Processing Society e-letter. He is involved in several national and international projects, and has chaired and cochaired a number of special sessions on multiantenna implementation issues. Beside this special issue in hand, he is also a Guest Editor of the EURASIP special issues on "Advances in Smart Antennas," "UWB State of the Art," and "Wireless Location Technologies and Applications." His current research interest focuses on applied signal processing with emphasis on multiantenna systems, especially its applicability to ultra-wideband systems, and on implementation issues.

André Bourdoux received the M.S. degree in electrical engineering (specialization in microelectronics) in 1982 from the Université Catholique de Louvain-la-Neuve, Belgium. He is coordinating the research on multiantenna communications in the Wireless Research Group at IMEC. His current interests span the areas of wireless communications theory, signal processing, and transceiver architectures with a special emphasis on broadband and multiantenna systems. Before joining IMEC, his research activities were in the field of algorithms and RF architectures for coherent and high-resolution radar systems. He is the author and coauthor of several conference and journal papers and of 2 patents applications in the field of SDMA and MIMO transmission. He is a coeditor of the book *Smart Antennas—State of the Art* to be published in the EURASIP Book Series on Signal Processing and Communications.

Markus Rupp received his Dipl.-Ing. degree in 1988 from the University of Saarbruecken, Germany, and his Dr.-Ing. degree in 1993 from the Technische Universität Darmstadt, Germany. He is presently a Full Professor of digital signal processing in mobile communications at the Technical University of Vienna. He is an Associate Editor of IEEE Transactions on Signal Processing, of JASP EURASIP Journal of Applied Signal Processing, of JES EURASIP Journal on Embedded Systems, and is elected AdCom Member of EURASIP. He authored and coauthored more than 180 papers and patents on adaptive filtering, wireless communications, and rapid prototyping.

Ulrich Heute was born in 1944 in Magdeburg, went to school till 1964, and studied electrical engineering at Stuttgart Technical University from 1965 to 1970; he received the Dipl.-Ing. degree in 1970. At Friedrich-Alexander University, Erlangen, he did research on digital filters, spectral analysis, and speech processing; he received the Ph.D. degree in 1975 and the Habilitation degree in 1982, and was a Senior Engineer until 1987. He became a Professor for digital signal processing at Ruhr-University Bochum in 1987, and has been a Professor for circuit and system theory at Christian-Albrechts University, Kiel, since 1993. He was a Guest Researcher at Georgia Institute of Technology in 1979 and at the University of California/Santa Barbara in 1990, 1991, and 1997 (some months each). His research interests include digital signal processing, filters and filter banks, spectral analysis, and speech-signal processing (combined source and channel coding, enhancement, modeling, and quality assessment). He is a Member of the IEEE (SM), EURASIP (Secretary 1988–1994, President 1994–1998), ITG, DEGA, and ASA.

EURASIP JOURNAL ON APPLIED SIGNAL PROCESSING

Special Issue on

Advanced Signal Processing and Computational Intelligence Techniques for Power Line Communications

Call for Papers

In recent years, increased demand for fast Internet access and new multimedia services, the development of new and feasible signal processing techniques associated with faster and low-cost digital signal processors, as well as the deregulation of the telecommunications market have placed major emphasis on the value of investigating hostile media, such as powerline (PL) channels for high-rate data transmissions.

Nowadays, some companies are offering powerline communications (PLC) modems with mean and peak bit-rates around 100 Mbps and 200 Mbps, respectively. However, advanced broadband powerline communications (BPLC) modems will surpass this performance. For accomplishing it, some special schemes or solutions for coping with the following issues should be addressed: (i) considerable differences between powerline network topologies; (ii) hostile properties of PL channels, such as attenuation proportional to high frequencies and long distances, high-power impulse noise occurrences, time-varying behavior, and strong inter-symbol interference (ISI) effects; (iv) electromagnetic compatibility with other well-established communication systems working in the same spectrum, (v) climatic conditions in different parts of the world; (vii) reliability and QoS guarantee for video and voice transmissions; and (vi) different demands and needs from developed, developing, and poor countries.

These issues can lead to exciting research frontiers with very promising results if signal processing, digital communication, and computational intelligence techniques are effectively and efficiently combined.

The goal of this special issue is to introduce signal processing, digital communication, and computational intelligence tools either individually or in combined form for advancing reliable and powerful future generations of powerline communication solutions that can be suited with for applications in developed, developing, and poor countries.

Topics of interest include (but are not limited to)

- Multicarrier, spread spectrum, and single carrier techniques
- Channel modeling
- Channel coding and equalization techniques
- Multiuser detection and multiple access techniques
- Synchronization techniques
- Impulse noise cancellation techniques
- FPGA, ASIC, and DSP implementation issues of PLC modems
- Error resilience, error concealment, and Joint source-channel design methods for video transmission through PL channels

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EURASIP JOURNAL ON APPLIED SIGNAL PROCESSING

Special Issue on

Numerical Linear Algebra in Signal Processing Applications

Call for Papers

The cross-fertilization between numerical linear algebra and digital signal processing has been very fruitful in the last decades. The interaction between them has been growing, leading to many new algorithms.

Numerical linear algebra tools, such as eigenvalue and singular value decomposition and their higher-extension, least squares, total least squares, recursive least squares, regularization, orthogonality, and projections, are the kernels of powerful and numerically robust algorithms.

The goal of this special issue is to present new efficient and reliable numerical linear algebra tools for signal processing applications. Areas and topics of interest for this special issue include (but are not limited to):

- Singular value and eigenvalue decompositions, including applications.
- Fourier, Toeplitz, Cauchy, Vandermonde and semi-separable matrices, including special algorithms and architectures.
- Recursive least squares in digital signal processing.
- Updating and downdating techniques in linear algebra and signal processing.
- Stability and sensitivity analysis of special recursive least-squares problems.
- Numerical linear algebra in:
  - Biomedical signal processing applications.
  - Adaptive filters.
  - Remote sensing.
  - Acoustic echo cancellation.
  - Blind signal separation and multiuser detection.
  - Multidimensional harmonic retrieval and direction-of-arrival estimation.
  - Applications in wireless communications.
  - Applications in pattern analysis and statistical modeling.
  - Sensor array processing.

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EURASIP JOURNAL ON APPLIED SIGNAL PROCESSING

Special Issue on
Human-Activity Analysis in Multimedia Data

Call for Papers

Many important applications of multimedia revolve around the detection of humans and the interpretation of human behavior, for example, surveillance and intrusion detection, automatic analysis of sports videos, broadcasts, movies, ambient assisted living applications, video conferencing applications, and so forth. Success in this task requires the integration of various data modalities including video, audio, and associated text, and a host of methods from the field of machine learning. Additionally, the computational efficiency of the resulting algorithms is critical since the amount of data to be processed in videos is typically large and real-time systems are required for practical implementations.

Recently, there have been several special issues on the human detection and human-activity analysis in video. The emphasis has been on the use of video data only. This special issue is concerned with contributions that rely on the use of multimedia information, that is, audio, video, and, if available, the associated text information.

Papers on the following and related topics are solicited:

- Video characterization, classification, and semantic annotation using both audio and video, and text (if available).
- Video indexing and retrieval using multimedia information.
- Segmentation of broadcast and sport videos based on audio and video.
- Detection of speaker turns and speaker clustering in broadcast video.
- Separation of speech and music/jingles in broadcast videos by taking advantage of multimedia information.
- Video conferencing applications taking advantage of both audio and video.
- Human mood detection, and classification of interactivity in duplexed multimedia signals as in conversations.
- Human computer interaction, ubiquitous computing using multimedia.
- Intelligent audio-video surveillance and other security-related applications.

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EURASIP JOURNAL ON APPLIED SIGNAL PROCESSING

Special Issue on

Advanced Signal Processing and Pattern Recognition Methods for Biometrics

Call for Papers

Biometric identification has established itself as a very important research area primarily due to the pronounced need for more reliable and secure authentication architectures in several civilian and commercial applications. The recent integration of biometrics in large-scale authentication systems such as border control operations has further underscored the importance of conducting systematic research in biometrics. Despite the tremendous progress made over the past few years, biometric systems still have to reckon with a number of problems, which illustrate the importance of developing new biometric processing algorithms as well as the consideration of novel data acquisition techniques. Undoubtedly, the simultaneous use of several biometrics would improve the accuracy of an identification system. For example the use of palmprints can boost the performance of hand geometry systems. Therefore, the development of biometric fusion schemes is an important area of study. Topics related to the correlation between biometric traits, diversity measures for comparing multiple algorithms, incorporation of multiple quality measures, and so forth need to be studied in more detail in the context of multibiometrics systems. Issues related to the individuality of traits and the scalability of biometric systems also require further research. The possibility of using biometric information to generate cryptographic keys is also an emerging area of study. Thus, there is a definite need for advanced signal processing, computer vision, and pattern recognition techniques to bring the current biometric systems to maturity and allow for their large-scale deployment.

This special issue aims to focus on emerging biometric technologies and comprehensively cover their system, processing, and application aspects. Submitted articles must not have been previously published and must not be currently submitted for publication elsewhere. Topics of interest include, but are not limited to, the following:

- Fusion of biometrics
- Analysis of facial/iris/palm/fingerprint/hand images
- Unobtrusive capturing and extraction of biometric information from images/video
- Biometric identification systems based on face/iris/palm/fingerprint/voice/gait/signature
- Emerging biometrics: ear, teeth, ground reaction force, ECG, retina, skin, DNA
- Biometric systems based on 3D information
- User-specific parameterization
- Biometric individuality
- Biometric cryptosystems
- Quality measure of biometrics data
- Sensor interoperability
- Performance evaluation and statistical analysis

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EURASIP JOURNAL ON BIOINFORMATICS AND SYSTEMS BIOLOGY

Special Issue on
Information Theoretic Methods for Bioinformatics

Call for Papers

Information theoretic methods for modeling are at the center of the current efforts to interpret bioinformatics data. The high pace at which new technologies are developed for collecting genomic and proteomic data requires a sustained effort to provide powerful methods for modeling the data acquired. Recent advances in universal modeling and minimum description length techniques have been shown to be well suited for modeling and analyzing such data. This special issue calls for contributions to modeling of data arising in bioinformatics and systems biology by information theoretic means. Submissions should address theoretical developments, computational aspects, or specific applications. Suitable topics for this special issue include but are not limited to:

- Normalized maximum-likelihood (NML) universal models
- Minimum description length (MDL) techniques
- Microarray data modeling
- Denoising of genomic data
- Pattern recognition
- Data compression-based modeling

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