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Tutorial Track 3: Cognitive Radio Systems

Flexible Transceivers Based on Time-Frequency Representation Theory

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Short Tutorial Description

The emergence of ever new standards for wireless access and networking fuels the trend towards multimode devices. Since the assembling of tailored solutions for single standards into hybrid devices has clear limitations, there is an increasing demand for multi-purpose transceiver processors which can cope with today's predominant and even potential future air interfaces in a uniform fashion. On the physical layer the challenge is to deal with the various signal formats such as single-carrier (SC), multi-carrier (MC), and spread-spectrum (SS) signals.

The traditional approach for multimode devices is to have separated chains for each mode. The chains could be implemented in hardware (HW) or in software (SW) as in software defined radios (SDRs) or as a mixture. Another route is a parameterized transceiver. It contains only one chain with parameterized blocks so that the parameters are selected according to the mode. Therefore, it is a uniform receiver architecture. Traditionally, SC signals are received in the time domain and MC signals in the frequency domain. However, SC signals may equally well be received using frequency domain signal processing. Therefore, frequency domain signal processing or, more generally, time-frequency (TF) signal processing (SP) is a tool for parameterized transceivers. The potential benefits of parameterized transceivers are power and silicon area saving, fast switching time between modes, shorter design cycle, etc.

Potential benefits of TF SP or, in particular, the Gabor transform or, equally, the short time Fourier transform (STFT) based processing include its capability to model double-spread channels as single tap TF sub-channels. This is an extension of orthogonal frequency-division multiplexing (OFDM), where fading channels are divided into single tap sub-channels in frequency domain.

This tutorial provides insight into TF SP based flexible transceivers in the baseband level introducing fundamental ideas of TF SP, its possible advantages and flexible transceiver chains based on it. In addition, special topics like TF SP based channel modelling, channel estimation and synchronization are addressed. The proposed receiver is compared to a conventional time domain UMTS receiver in terms of simulations in additive white Gaussian noise as well as in fading multipath channels. Finally, an implementation of the proposed transceiver into a flexible HW platform is discussed.

Speakers are researchers from URANUS IST-27960 project (UNIVERSAL RADIO-LINK PLATFORM FOR EFFICIENT USER-CENTRIC ACCESS**)**, www.ist-uranus.org. See the TOC for the names and further details.

Schedule

Theory part: Dr. Harri Saarnisaari, CWC

- Introduction
- Time-Frequency Processing at the Transceiver
  - Basics of Time-Frequency Analysis
  - Signal Expansion and Demodulation in Time-Frequency Domain
  - Doubly-Dispersive Channel Modelling
  - Efficient Implementations
  - Two-Dimensional Channel Estimation Methods
  - Symbol Synchronization
  - Application to UMTS and Simulation Results

Implementation part: Prof. Peter Jung and M.Sci (EE) Alex Viessmann, University of Duisburg-Essen

- Demonstration and Implementation Issues
  - Implementation of URANUS TRX into a Flexible Hardware Platform
    - Design strategy,
    - Realization of HW/SW blocks,
    - Integration,
    - HW/SW structure,
    - Complexity evaluation,
  - Video Demonstration

Speakers' Biographies

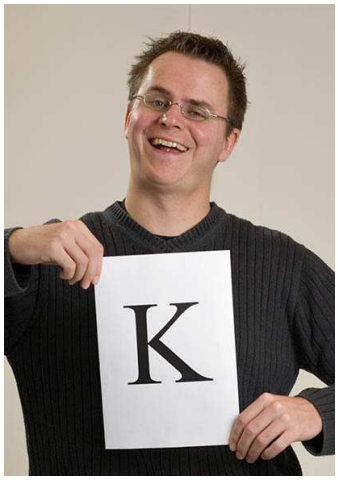
Dr. Harri Saarnisaari

Harri Saarnisaari received M.Sc in physics from University of Kuopio in 1993 and Ph.D EE in telecommunications from University of Oulu. Since 1994 he has been working in Telecommunications laboratory or Centre for Wireless Communications (CWC) in University of Oulu. Currently he is a senior research scientist and holds a senior assistant position. He was involved as one of the principal designers to the seven years Finnish software defined radio (SDR) project, wherein highly capable tactical communication and navigation waveforms were developed for Finnish defense forces and implemented into a SDR platform. His research interests are in signal processing for communications, especially frequency domain receiver design, synchronization, parameter estimation, interference cancellation, antenna array processing, network synchronization and location and positioning techniques.

Prof. Peter Jung

Peter Jung received the diploma (M.Sc. equiv.) in physics from University of Kaiserslautern, Germany, in 1990, and the Dr.-Ing. (Ph.D.EE equiv.) and Dr.-Ing. habil. (D.Sc.EE equiv.), both in electrical engineering with focus on microelectronics and communications technology, from University of Kaiserslautern in 1993 and 1996, respectively. In 1996, he became private educator (equiv. to reader) at University of Kaiserslautern and in 1998 also at Technical University of Dresden, Germany. From March 1998 till May 2000 he was with Siemens AG, Bereich Halbleiter, now Infineon Technologies, as Director of Cellular Innovation and later Senior Director of Concept Engineering Wireless Baseband. In June 2000, he became Chaired Professor for Communication Technologies (KommunikationsTechnik) at the Gerhard-Mercator-University Duisburg. In 1995, he was co-recipient of the best paper award at the ITG-Fachtagung Mobile Kommunikation, Ulm, Germany, and in 1997, he was co-recipient of the Johann-Philipp-Reis-Award for his work on multicarrier CDMA mobile radio systems. Professor Jung served as chairman of the Fakultätentag für Elektrotechnik und Informationstechnik (FTEI) e.V., and member of the board of VDE/VDI-GMM. He was a member of the editorial board of IEEE Transactions on Wireless Communications and has been a member of the editorial boards of the Springer Journal of Wireless Personal Communications and of the Hindawi Research Letters in Communications. His areas of interest include wireless communication technology, software defined radio, and system-on-a-chip integration of communication systems.

M.Sc. (EE) Alex Viessmann



Alexander Viessmann was born in Krefeld, Germany in 1978 and began his studies in electrical engineering in 1999 at the former Gerhard-Mercator-University of Duisburg and pursued his studies in the field of microelectronics. Alexander Viessmann obtained the diploma degree in electrical engineering (M.Sc. EE equivalent) in 2005 from the department of electrical engineering at the university of Duisburg-Essen, Duisburg, Germany. He joined the RF division of Atmel and the Chair of Communication Technologies at Duisburg-Essen University in 2005. He is working towards his Ph.D. in the field of innovative reconfigurable wireless communication technologies. Further research interests are oscillator and PLL design. Mr. Viessmann received the Siemens Communications Academic Award for his diploma thesis in the field of oscillator design in 2005 and the Texas Instruments Excellence in Signal Processing Award in 2006. In addition, Mr. Viessmann is co-recipient of the Gerotron EEEfCOM innovation award, category universities, 2006.