

**Title:** Software Defined Radios: Technological solutions and challenges  
Paving the way towards cognitive radios

**Duration:** Half Day (3 hours)

**Speakers:** Dr. Antoine Dejonghe, Dr. Liesbet Van der Perre

**Affiliation:** Wireless Group, IMEC, Belgium

**Rational: the overall objective of the tutorial:**

*The wish and need for Software Defined Radios*

We see an increasing need for functional flexibility in radio systems. Indeed, the variety of wireless standards is very large, and can be expected to still grow in the future. Also, the scalability within newly defined standards, with 3GPP-LTE as a crucial example, is enhancing, in order to better service dynamics in wireless applications and propagation conditions.

In combination with the huge costs related to system-on-chip (SoC) design (newer design technology nodes urge high-volume, multi-purpose and preferably widely programmable devices that can be easily updated even after deployment in the field), we see the implementation of wireless standards on reconfigurable radio platforms as the only viable option in the coming years.

*Technological solutions and challenges: making flexibility rhyme with low power*

An effective solution to implement reconfigurable radio systems consists in the combination of SDR-based programmable digital baseband engines and reconfigurable analog front-end circuits.

For the reconfigurable digital baseband engine, one has to carefully trade-off flexibility and energy efficiency: flexibility should only be introduced where its impact on the total average power is sufficiently low or where it offers a broad range of control options that can be exploited effectively later in the control step (targeted flexibility).

For the reconfigurable analog front-end, architectures and circuits should be designed for a broad range of requirements in carrier frequency, channel bandwidth and noise performance with minimal penalty in power consumption, while also offering energy scalability.

A major challenge is to enable low energy reconfigurable radio implementations, suited for handheld multimedia terminals and competitive with fixed hardware implementations. To make such terminals a reality, a two-step approach is advocated. First, effective energy scalability is enabled in the design of the radio baseband and front-end. Secondly, the scalability is exploited to achieve low power operation by a cross-layer controller that follows at run-time the dynamics in the application requirements and propagation conditions.

*Paving the way towards cognitive radios*

Future communication systems will have to seamlessly and opportunistically integrate multiple radio technologies and heterogeneous wireless access networks, to offer context-dependent ubiquitous connectivity and content access. The growing demand for large data rates reveals an increasing spectrum scarcity. New paradigms for efficiently exploiting the spectrum are clearly needed in this context. A continuously growing role for smart/adaptive spectrum-agile radios exploiting the capabilities of reconfigurable radio architectures is to be expected. Pushed to the limit, this leads to the disruptive concept of cognitive radio (CR). Such a CR is defined as a radio that can autonomously change its transmission parameters based on interaction with the complex environment (radio scene, application and user requirements) in which it operates.

The spectrum data-mining and agile air interface requirements of such cognitive radios also claim for SDR-based implementations. These CR systems can in fact be thought of as extensions of the concepts introduced above, i.e., a reconfigurable radio coupled with a now "cognitive" adaptive control that can sense, adapt and learn. The need to detect and/or generate virtually any kind of waveform in any band pushes, on the other end, the specification of the underlying reconfigurable radio to the limit.

## **Outline: a brief structure of the tutorial:**

- Introducing the wireless and technology scene: the wish and need for SDRs (~20min)

*An overview of current and emerging wireless standards, as drivers for SDR solution will be given. The technological scaling enabling and urging flexible devices will be illustrated.*

- SDR Baseband platforms: opportunism to combine flexibility and low energy (~40min)

*This part will give an overview of SDR baseband solutions. Special focus will be on the heterogeneous MPSoC approach optimized for scalability and low energy, and attention is paid to the optimization of a domain-specific, high-performance processor.*

- SDR front-end solutions: generating elastic waves (~40min)

*Radio front-end building blocks need to be designed to offer flexibility in carrier frequency, channel bandwidth, noise performance, etc. without a significant power penalty.*

- Cross layer optimization: exploit flexibility for low energy (~40min)

*It will be shown how flexibility can be exploited for low power, through a cross-layer controller. Moreover, use cases will be presented showing the impressive gains that can be achieved.*

- Towards Cognitive Radios: saving on spectral resources (~40min)

*The increasing need to efficiently exploit the spectrum will be pointed out in this context. The concept of cognitive radio will then be introduced. We will preview on how SDR-based implementations and cross-layer control are crucial to realize cognitive radios, and explain the specific features that will need to be added.*

## **Intended audience:**

The target audience is researchers, system engineers, and designers active in wireless communications, with interest in reconfigurable radio solutions, and cross-layer optimization.

### **Biography of the speaker(s):**

The speakers have expertise in wireless communications, and Software Defined Radios specifically. They have authored and co-authored over 200 published papers in the field of wireless communications. These papers include high impact publications on the specific topic of Software defined Radio:

- Keynote speech at SIPS 2005, L. Van der Perre, 'SDRs for wireless terminals flexibility for low power, or not.'
- Solicited paper for ISSCC 2007, 'Architectures and Circuits for Software Defined Radios: scaling and scalability for low cost and low energy', L. Van der Perre et Al.
- To appear in Signal processing Magazine May 2007, special issue on Special issue on Resource-Constrained Signal Processing, Communications, and Networking, A. Dejonghe et Al. "Green Reconfigurable Radio Systems: Creating and Managing Flexibility to Overcome battery and Spectrum Scarcity"
- Keynote at 'Wireless Reconfigurable Terminals', April 2006, Rome, 'Digital baseband solutions for SDR terminals: Flexibility for low power, or not', L. Van der Perre et Al.
- Invited paper DATE 2007 Algorithm-Architecture co-design for SDRs
- Invited paper at SDR forum 2007: B. Bougard, L. Van der Perre, et Al. 'A low power signal detection and pre-synchronization engine for energy-aware Software Defined Radio', published in SDR Forum 2007, November 2007, Orlando, USA
- Invited paper WIC Midwintermeeting, January 2005, 'Flexible radios: making flexibility rhyme with low cost and low power', L. Van der Perre et Al.

Previous tutorials:

- Smart Antennas, IST Mobile Summit 2004, Lyon, 20 attendees
- Software Defined Radios: DATE 2007, Nice, number of attendees to be finalized (expected ~50)
- Software Defined Radios: Needs and opportunities, Technological solutions and challenges: Crowncom 2006, ~20 attendees
- Flexible Radio workshop: NEWCOM Project D, Leuven, ~50 attendees.

### **Antoine Dejonghe**

Antoine Dejonghe received the M. Sc. Degree in Electrical Engineering (summa cum laude) and the Ph.D. Degree from the Université Catholique de Louvain (UCL), Louvain-la-Neuve, Belgium, in 2000 and 2004, respectively. He was with the Communications and Remote Sensing Laboratory of UCL from 2000 to 2004, as a Research Fellow of the Belgian National Fund for Scientific Research (FNRS). Since 2004, he is Senior Research Engineer in the Wireless Research Group of the Inter-university Microelectronics Center (IMEC), Leuven, Belgium.

His previous work focused on the design of digital communication systems with an emphasis on iterative detection and decoding schemes. He is currently leading research activities towards the design of energy-aware cross-layer control of software-defined radio systems. He is also focusing on the extension of these

concepts to cognitive radio systems. Antoine Dejonghe is an author and co-author of over 50 scientific publications.

**Liesbet Van der Perre**

Liesbet Van der Perre received the M.Sc. degree in Electrical Engineering from the K.U.Leuven, Belgium, in 1992. The research for her thesis was completed at the Ecole Nationale Supérieure de Telecommunications in Paris. She graduated summa cum laude with a PhD in electrical engineering from the same university in 1997. Liesbet earned an award from IBM in 1986, and she received a study-visit scholarship for study in the United States from the Fina Maecenas Foundation.

Her work in the past focused on radio propagation modelling, system design and digital modems for high-speed wireless communications. She was a system architect in

IMEC's OFDM ASICs development, which was nominated as one of the IEEE International Solid State Circuit Conference's (ISSCC's) 'Best of 50 Years' papers. Consequently, she was the project leader for IMEC's low power Turbo codec. Currently, she is the scientific director of wireless research group in IMEC's, comprising teams of researchers in the fields of digital baseband solutions, RF front-ends, cross-layer optimization, and ultra low power radios. She's the project leader for the digital baseband Software Defined Radio, and a public speaking coach for IMEC staff. Also, she was a part-time professor at the University of Antwerp, Belgium, till 2004. She's an author and co-author of over 150 scientific publications published in conference proceedings, journals, and books. She is a member of the expert group of the 'eMobility' technology platform, which created a proposal for a 'Strategic Research Agenda' for the 7FP.