

**WSH (RFIC) Sunday 08:00 – 12:00 BCEC Room 152**  
**System-Level Design and Implementation of Gb/s 60GHz Radios**  
**Half-day workshop reviewed by RFIC.**

**Organizer(s):**

Alberto Valdes Garcia, IBM Research, Yorktown Heights, NY, USA.  
Su-Khiong Yong, Samsung Electronics, San Jose, CA, USA.

In recent years, the design of active and passive mm-wave components in general, and in the 60GHz band in particular, has become a center of gravity for academic and industrial research. The time has come to move beyond circuit components and fulfill the motivation for the development of this technology: the deployment of commercial solutions capable of delivering Gb/s wireless links in a variety of applications. A successful Gb/s 60GHz radio module is the result of holistic design. These contemporary systems push the boundary not only of RF design, but also of DSP techniques, and communication systems. This workshop brings to IMS-RFIC 2009 the experts leading the standards, design and system integration for 60GHz commercial solutions. The physical layer design and specifications for key applications, such as high-definition video and fast download, are covered considering both single-carrier and OFDM modulations. The pros and cons of each signaling scheme for different usage scenarios are analyzed. The impact of RF circuit non-idealities in these systems is also addressed. Full system implementation examples, including radio and baseband, are presented and illustrated with 60GHz end-to-end systems and link experiments. One of the specific challenges and opportunities of 60GHz is the directionality of the transmitted energy that can be enhanced and steered through the use of beamforming. While different RF implementations of phased-arrays are available in contemporary literature, the impact of beamforming on a high data rate communication system is less understood. This workshop will cover this crucial aspect from a system viewpoint. All of the presentations will address how these important aspects of 60GHz systems are addressed by the emerging standards such as the IEEE 802.15.3c 60GHz standard.

**Speakers:**

1. Alberto Valdes-Garcia, IBM Research, USA

“Introduction and Overview of 60GHz Standardization”

2. Yasunao Katayama, IBM Tokyo Research Laboratory. Japan

“End-to-end 60GHz Single-Carrier System Implementation and Link Experiments”

In this talk, we will go over details of single-carrier system designs and their end-to-end demonstrations with 60GHz SiGe radio and FPBA-based baseband system. We will show and compare various design points with different modulation schemes, demodulation as well as timing-recovery schemes, and various choices of error correction codes. We will also share with the audience valuable lessons learned through demonstration system implementations and link experiments, in particular focussing on those associated with Gbps wireless systems. Finally, we will discuss opportunities and challenges in extending

single-carrier systems for higher data rates and/or NLOS channel environments, considering appropriate beam forming technology and advanced equalization schemes that can improve and compensate channel response characteristics.

3. Su-Khiong Yong, Samsung Electronics, USA  
“OFDM System Design for 60GHz High-Definition Video Applications”

This talk presents a comprehensive introduction to the emerging 60 GHz orthogonal frequency division multiplexing (OFDM) wireless technology to enable uncompressed high definition video streaming. First, we present the motivations of using OFDM by highlighting its pros and cons, and the differences compare to 60 GHz OFDM system at lower carrier frequencies. The design criteria that relate both the system and channel parameters in order to arrive at the OFDM system timing parameters are discussed. We also explain how these parameters result into radio specifications such as spectral mask, EVM and minimum receiver sensitivity level. The baseband architecture of the OFDM system to support multi-gigabits transmission is then presented. In particular, we discuss the use of two unequal error protection (UEP) techniques at baseband, namely UEP coding and UEP mapping to support uncompressed high definition video streaming.

4. Chang-Soon Choi, IHP Microelectronics GmbH, Germany  
“60-GHz SiGe BiCMOS Radio and OFDM Baseband Implementation for Gbps WLAN Applications”

This presentation describes fully developed 60-GHz OFDM hardware demonstrators and outlines design considerations for future implementation. We first present the 60 GHz SiGe RF front-ends which have been optimized with primary emphasis on low phase-noise PLLs and high power amplifiers (HPA) to support OFDM transmission. The influences of hardware imperfections including HPA nonlinearity and PLL phase-noise on OFDM baseband transmission are to be discussed. We also show the baseband OFDM hardware processor realized with high-speed FPGA board and its demonstration in 60-GHz wireless links. The remainder of this presentation will focus on the design approaches and challenges of next-generation 60-GHz OFDM demonstrators targeting future Gbps wireless LAN applications which will be envisioned by IEEE 802.11 VHT (Very High Throughput) standard activities. New OFDM baseband architectures and 60-GHz RF transceivers supporting beamforming technologies will be key points to be discussed.

5. André Bourdoux, IMEC, Belgium  
“Beamforming at 60GHz: Challenges and Solutions”

Analog BeamForming (ABF) with one scalar weight per antenna is an attractive technique for high rate, low-cost, lowpower communication with multiple antennas. However, the design of the corresponding joint transmit and receive (Tx/Rx) ABF optimization algorithms is still challenging in the case of multipath channels due to this

constraint of only one scalar weight per antenna. We analytically derive the optimal Tx/Rx scalar weights that maximize the Signal to Noise Ratio at the input of an equalizer. We propose a near optimal solution to compute the dis-entangled weights. We show that the required Channel State Information (CSI) for ABF weights computation is the inner product between all MIMO channel impulse response pairs (not necessarily the full MIMO-multipath channel matrix). Taking the channel length into account, a training-based estimation strategy of this CSI is also proposed. Finally, we also describe how the protocol of the IEEE802.15.3c standard will support beamforming.