Guest Editorial
Realizing Gbps Wireless Personal Area Networks

THERE is increasing interest to push wireless data rates beyond a Giga-bit-per-second (Gbps) in order to more rapidly access data on personal devices, as well as potentially replace all the cables going into a device, including the video cable. One means of achieving this is through the use of wireless personal area networks (WPANs) which take advantage of short separation distances (typically less than 10 meters), wide bandwidths on the order of 100's of MHz to several GHz, and advanced signal process techniques including MIMO, advanced FEC, and higher-order modulation techniques. However, further research is needed for achieving Gbps rates in low-cost and low-power devices, ranging from low power RF and high-speed digital circuits to potentially new network architectures.

The goal of this special JSAC issue is to bring together the state-of-the-art, across multiple disciplines, for achieving Gbps WPAN capability. In particular, in this issue, we include papers ranging from MIMO-OFDM systems in a narrowband channel, to UWB systems leveraging GHz available bandwidth, to systems operating at 60 GHz and even optical wireless systems. In addition, we include papers which cover detailed implementations of circuits to MAC layer protocols to overall systems design. We hope the breadth of topics will help educate and foster new ideas.

NARROWBAND SYSTEMS: The paper "Probabilistically Bounded Soft Sphere Detection for MIMO-OFDM Receivers: Algorithm and System Architecture" by P. Radosavljevic et al. is the only paper in this journal focused on achieving Gbps data rates using the existing narrowband channels. In particular, the use of MIMO to achieve spatial multiplexing and advanced FEC techniques to enhance performance is studied. The authors present information on a hardware prototype of the system and evaluate the complexity and level of parallel processing needed to implement such a scheme and achieve throughputs on the order of a Gbps.

UWB SYSTEMS: The paper "Pulse Antenna Permutation and Pulse Antenna Modulation: Two Novel Diversity Schemes for Achieving Very High Data-Rates with Unipolar MIMO-UWB Communications" by Abou-Rjeily, proposes space-time block codes for MIMO-UWB systems, with particular emphasis upon Impulse-Radio Time-Hopping approaches. Unipolar transmission and transmitter diversity is considered to minimize RF circuit complexity. A comprehensive analysis is considered, based upon indoor channel models, to understand the impact upon inter-pulse interference and inter-symbol interference.

In the early research work on high speed UWB, much of the system development focused on impulse radio systems. In recent years, most development shifted to OFDM because of its inherent ability to manage multipath effectively. In a closer look at how impulse radio could be used for gigabit speeds, the paper by Agudelo et al., "A Novel Correlation Adaptive Receiver Structure for High Speed Transmissions in Ultra Wide Band Systems with Realistic Channel Estimation," explores rake structures and techniques that would boost impulse radios into higher speeds than previously explored.

60 GHZ: The majority of the papers presented in this journal are in the area of 60 GHz wireless systems, since there is significant industry and academic focus on the use of the 60 GHz spectrum for Gbps wireless systems, including WPAN as well as WLAN usage. We include topics including circuit and device implementations, MAC layer protocols, WPAN systems, WLAN systems, and new usages in vehicles.

60 GHZ IMPLEMENTATIONS: The paper "60 GHz Single-Chip CMOS Digital Radios and Phased Array Solutions for Gaming and Connectivity" by Pinel et al. summarizes the implementation of Gbps integrated low-power CMOS radio with embedded signal processing for 60-GHz wireless applications, including gaming, TDD and FDD short range wireless, and radar applications. The authors explore the application of injection locking of local oscillators to a master oscillator for power savings, and compare various integrated circuit developments in the field.

The paper "Iterative Receiver Employing Phase Noise Compensation and Channel Estimation for Millimeter-Wave OFDM Systems" by S. Suyama et al. addresses an important challenge for 60 GHz systems, namely dealing with the relatively large phase noise that exists when trying to implement high-frequency systems in low-cost CMOS. The authors propose a low-complexity decision-directed phase noise compensation scheme which is demonstrated to enable high-order modulation (64-QAM) in order to achieve Gbps rates.

The paper "On-Chip Integrated Antenna Structures in CMOS for 60 GHz WPAN Systems" by Gutierrez et al. presents several on-chip antenna structures for 60GHz WPAN applications. Typical CMOS process parameters are considered to design and tradeoff antenna structures and possible design rules. Implemented designs include dipole, Yagi, rhombic and loop structures.

60 GHZ MAC PROTOCOLS: Although one of the challenges of 60 GHz systems is the severe attenuation experienced when operating at such high frequencies, this can be turned into an advantage when trying to reuse the spectrum in a small area. The paper "Virtual Time-Slot Allocation Scheme for Throughput Enhancement in a Millimeter-Wave Multi-Gbps WPAN System" by C-S Sum et al. proposes a method for coordinating time-slot allocations based upon measured interference in order to allow non-interfering devices to occupy the

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same time-slots in an area in order to enhance the aggregate throughput of the system.

The paper "Beam Codebook Based Beamforming Protocol for Multi-Gbps Millimeter-Wave WPAN Systems" by Wang et al. explores the use of a MAC layer beamforming protocol following the guidelines of the IEEE 802.15.3c criteria for millimeter-wave 60-GHz wireless personal area networks (60GHz WPANs). The authors consider simple beam codebooks such that each element in a phased antenna array only has four phase shifts (0, 90, 180, 270) and no amplitude adjustment. The authors show a large reduction of beamforming setup time is possible using their proposed technique as opposed to brute force searching.

The paper "Blockage and Directivity in 60GHz Wireless Personal Area Networks: From Cross-Layer Model to Multihop MAC Design" by Singh et al. presents a cross-layer modeling approach for 60GHz networks which accounts for the problems of directionality and blockage which distinguish such networks from lower carrier frequencies. The paper investigates the concept of a low overhead MAC design which can support multihop relaying with adaptive directional beam antennas.

Since it's envisioned that 60 GHz WPAN systems will be carrying many different kinds of data and multi-media traffic, it's important to support different kinds of access methods, namely TDMA for high quality-of-service links, as well as CSMA/CA for rapid access to the channel for data or control information. The paper "Throughput Analysis and Improvements of Hybrid Multiple Access in IEEE 802.15.3c mmWave-WPAN" by C. Pyo et al. studies the current IEEE 802.15.3c standard which includes a hybrid MAC capability, and evaluates a method for optimizing the throughput of the system by reducing the collisions in the CSMA/CA time-slots using a private channel release time. This feature is shown to help significantly increase the available throughput of the IEEE 802.15.3c network.

60 GHZ WPAN SYSTEMS: Clearly, the use of smart antenna technology is critical for 60 GHz in order to overcome the severe path loss experienced as such high frequencies. However, this must be balanced with relatively low-cost implementations which are required for consumer electronic and mobile devices. The paper "Hybrid Beam-Forming and Beam-Switching for OFDM Based Wireless Personal Area Networks" by S. Yoon et al. attempts to create a compromise between performance and computational complexity by evaluating a hybrid beam-forming and beam-switching algorithm for WPAN systems.

The paper "Error Performance and Throughput Evaluation of a Multi-Gbps Millimeter-Wave WPAN System in the Presence of Adjacent and Co-Channel Interference" by Sum et al. shows the system performance of Multi-Gbps mm-wave WPAN system and is based upon the IEEE 802.15.3c standard proposal. The authors investigate the impact of adjacent and co-channel interference for both line-of-sight and non-line-of-sight multipath environments. The paper also reviews a variety of design parameters and the corresponding impact upon link performance in the presence of varying channel characteristics.

The paper "Analysis on Spatial Reuse and Interference in 60-GHz Wireless Networks" by Park et al. evaluates the potential for spatial reuse and the degree of interference in 60 GHz indoor wireless communication systems. Simulations are made in indoor environments by varying parameters affecting the spatial reuse and aggregate data rates. The results show that there is high potential of spatial reuse and also there are considerable cases in which interference mitigation mechanisms are needed to improve spatial capacity of 60 GHz systems.

The paper "Relay with Deflection Routing for Effective Throughput Improvement in Gbps Millimeter-Wave WPAN System" by Lan et al. analyzes the effective throughput of mmWave WPAN employing a decode and forward relay, taking the impact of concurrency into consideration, and models the maximization of effective throughput as an integer programming problem. To solve this problem, the simulated performances of two sub-optimal routing algorithms are evaluated and compared with conventional multi-hop schemes. The first one is "best fit deflection routing" (BFDR), and the second one "random fit deflection routing (RFDR)". The conditions to achieve better throughput performance than traditional relay schemes are derived.

A classic debate in just about any wireless system design often revolves around whether to use OFDM or single carrier modulation. In the paper by Kato et al., "Single Carrier Transmission for Multi-Gigabit 60 GHz WPAN Systems," the authors explore the relative merits of single carrier modulation for relatively short range 60GHz communications, with a usage model that focuses on a lower complexity, lower power solution than could be realized using an OFDM scheme and possible phased array beamforming.

60 GHZ WLANS: The paper "Emperical Capacity of mmWave WLANs" by Yiu et al. calculates the empirical capacity of 60GHz Wireless LAN that adopts Spatial Time Division Multiple Access exploiting smart antenna arrays. It is shown that the system achieves over 9 Gbps capacity using 400MHz bandwidth by employing linear arrays with an appropriate beam nulling technique.

The paper "Experimental Investigations of 60 GHz WLAN Systems in Office Environment" by Maltsev et al. presents wideband 60 GHz propagation measurements in an office environment. The authors show that the line-of-sight component and the first- and second-order reflections contain most of the received signal power, and provide a statistical cluster model for the measured channel impulse response. The authors also show that a high degree of cross polar discrimination (XPD) exists at 60 GHz as compared to 2 and 5 GHz, thus indicating that signal depolarization may significantly degrade the performance of 60 GHz indoor wireless communication systems.

60 GHZ VEHICLE AREA NETWORK: The paper "A Sixty GHz Vehicle Area Network for Multimedia Communications" by Sawada et al. presents RF propagation measurements made inside a vehicle at millimeter wave frequencies, with the intended application of intra-car wireless multi-media connectivity. The work focuses on measurement techniques and impulse response modeling of the propagation channel inside a car, and finds that propagation delay spreads are typically less than 7 ns.

OPTICAL WIRELESS: Finally, our last paper "Performance Evaluation of 2.5 and 5 Gbit/s Optical Wireless Systems Employing a Two Dimensional Adaptive Beam Clustering Method and Imaging Diversity Detection" by Alsaadi et al. presents simulation results of infra-red (IR) communication systems capable of overcoming Non Line-of-Sight (NLOS) propagation issues through the use of electrical beamforming and receiver combining. Several permutations of link scenarios involving steering algorithms and room positioning are simulated. The authors introduce several adaptive algorithms and optical receiver combining techniques which are shown to achieve high overall SNR for IR link data rates up to 2.5 and 5 Gbps.

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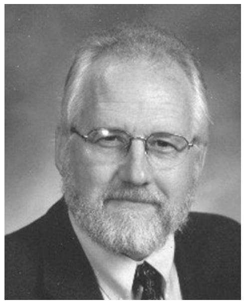
Jeff Foerster joined Intel in August 2000 as a Wireless Researcher in Hillsboro, Oregon, and is currently a Principal Engineer in the Wireless Communications and Architecture Lab. He leads a research team focused on future short- and medium-range wireless technologies, which has included Ultra-wideband (UWB) technology and related regulations, 60 GHz system design, wireless displays, and wireless video services. He chaired the channel modeling sub-committee for the IEEE 802.15.SG3a study group focusing on UWB channel models to be used for evaluating future UWB based proposals which has been widely used in the industry and academia, and chaired the regulatory group within WiMedia. Jeff was Vice Chair of the Technical Program Committee of the ICUWB'07 conference and has served on the Technical Program Committee for the ICC WCS, GlobeComm, WCNC, and UWBST conferences. Jeff has published 15 IEEE papers including journals, magazine, and conferences, has been an invited panelist at several conferences, was lead author of a book chapter on UWB, and has contributed to several international regulatory bodies including CEPT TG3 and ITU TG1/8. Prior to joining Intel, he worked on Broadband Wireless Access (BWA) systems and standards, and was technical editor of the IEEE 802.16 standard for a short time. He received his B.S., M.S., and Ph.D. degrees from the University of California, San Diego, where his thesis focused on adaptive interference suppression and coding techniques for CDMA systems.



Jim Lansford is Chief Technology Officer of Alereon; he has almost 30 years of experience in communications system analysis and design as well as digital signal processing. In addition to developing advanced technologies and architectures for future UWB systems, including Alereon's CogniPHY™ technology, he is heavily involved in a number of standards, trade group and regulatory activities. Dr. Lansford is formerly Co-chair of IEEE802.15.3a, the High Rate WPAN Task Group, and was also formerly the chair of 802.19 (Wireless Coexistence Technical Advisory Group) within IEEE 802. He was a significant contributor to 802.15.2 and 802.11g. In addition to his technical activities, he is involved in business development activities with strategic partners and key customers. Prior to Alereon, Dr. Lansford was VP of Business Development and CTO of Mobilian Corporation, where he promoted Mobilian's multi-standard radio technology, which included advanced interference management techniques. Prior to Mobilian, Dr. Lansford was a Wireless System Architect with Intel Corporation, and was the Co-Chairman of the Technical Committee for the HomeRF Industry Working Group, a wireless technology industry consortium of over 100 companies. In addition to his experience with Alereon and two previous start-ups, he has served on the teaching and/or research faculty of Georgia Tech, the University of Colorado – Colorado Springs, and Oklahoma State University. He has published numerous articles in journals and other publications, and holds several patents. He is currently a Visiting Associate Professor of Electrical Engineering at Texas State University in San Marcos, TX.

Dr. Lansford is also an ABET Program Evaluator, a Senior Member of the IEEE, and a certified IEEE Wireless Communication Professional (IEEE WCET Certification).

Dr. Lansford received his Ph.D. in Electrical Engineering from Oklahoma State University in 1988, his M.S. in Electrical Engineering from the Georgia Institute of Technology in 1982, and his B.S. in Electrical Engineering, with highest honors, from Auburn University in 1980.

Joy Laskar received his B.S. degree (Computer Engineering with Math/Physics Minors, summa cum laude) from Clemson University and his M.S. and Ph.D. degrees in Electrical Engineering from the University of Illinois at Urbana-Champaign. Prior to joining Georgia Tech in 1995, Dr. Laskar was a visiting professor at the University of

Illinois at Urbana-Champaign and an assistant professor at the University of Hawaii at Manoa. At Georgia Tech he holds the Schlumberger Chair in Microelectronics in the School of Electrical and Computer Engineering. He is also Founder and Director of the Georgia Electronic Design Center, and he heads a research group of 50 members and has graduated 36 Ph.D. students since 1995. He has authored or co-authored more than 500 papers, several book chapters and three books (with another book in development). He has given numerous invited talks, and he has more than 40 patents issued or pending. Dr. Laskar and his research team have founded four companies to date: an advanced WLAN IC Company: RF Solutions, which is now part of Anadgics (Nasdaq: Anad), a next-generation analog CMOS IC Company, Quellan, which is developing collaborative signal-processing solutions for the enterprise, video, storage and wireless markets and two more companies which are part of Georgia Tech's Venture lab process. Dr. Laskar was elected IEEE Fellow in 2005 and served as General Chairman of the IEEE International Microwave Symposium 2008. He currently serves as an elected member of the IEEE MTT-S Administrative Committee, Chair of the IEEE MTT-S Education Committee, and Vice-Chair of the IEEE MTT-S Executive Committee.

Dr. Laskar's honors include the Army Research Office's Young Investigator Award in 1995, the National Science Foundation's CAREER Award in 1996, NSF Packaging Research Center Faculty of the Year in 1997, and co-recipient of the IEEE Rappaport Award (Best IEEE Electron Devices Society Journal Paper) in 1999. He was faculty advisor for the 2000 IEEE MTT IMS Best Student Paper award, was Georgia Tech, Faculty Graduate Student Mentor of the year in 2001, received a 2002 IBM Faculty Award, and the 2003 Clemson University College of Engineering Outstanding Young Alumni Award. He was the 2003 recipient of the Outstanding Young Engineer award of the Microwave Theory and Techniques Society and was named an IEEE Fellow in 2005. For the 2004-2006 term, Dr. Laskar served as an IEEE Distinguished Microwave Lecturer and currently is an IEEE EDS Distinguished Lecturer. He received Georgia Tech's "Outstanding Faculty Research Author" award in 2007 and ECE's Distinguished Mentor Award in 2008.

Theodore S. Rappaport is the William and Bettye Nowlin Chair in Engineering at the University of Texas at Austin and is the founding director of the Wireless Networking and Communications Group (WNCG) at the university's Austin campus, a center he founded in 2002. Prior to joining UT Austin, he was on the electrical and computer engineering faculty of Virginia Tech where he founded the Mobile and Portable Radio Research Group (MPRG), one of the world's first university research and teaching centers dedicated to the wireless communications field. Prof. Rappaport has been a pioneer in the fields of radio wave propagation, wireless communication system design, and 60 GHz millimeter wave communications, and his work has influenced many international wireless standard bodies. Rappaport has served on the Technology Advisory Council of the Federal Communications Commission (FCC) and has conducted research for NSF, DoD, and dozens of global wireless communications companies throughout his career. He is one of the world's most highly cited authors in the wireless field, having authored or co-authored over 200 technical papers, over 100 US and international patents, and several best-selling books. In 2006, Rappaport was elected to serve on the Board of Governors of the IEEE Communications Society (ComSoc), and was elected to the Board of Governors of the IEEE Vehicular Technology Society (VTS) in 2008. In 1999, his pioneering work on site-specific RF propagation and system design received the IEEE Communications Society Stephen O. Rice Prize Paper Award. In 1989, he founded TSR Technologies, Inc., a cellular radio/PCS software radio manufacturer that he sold in 1993 to what is now CommScope, Inc (NYSE: CTV). In 1995, he founded Wireless Valley Communications Inc., a site-specific wireless network design and management firm that he sold in 2005 to Motorola, Inc. (NYSE: MOT). Rappaport has testified before the US Congress, has served as an international consultant for the ITU, has consulted for over 30 major telecommunications firms, and works on many national committees pertaining to communications research and technology policy. He is a highly sought-after consultant and technical expert, and serves on boards of several high-tech companies. As a faculty member, Rappaport has advised over 100 students who continue to accomplish great things in the communications, electromagnetics and circuits fields throughout industry, academia, and government. When he is not teaching or doing research with students, he enjoys long-distance running, amateur radio (N9NB), singing, and traveling. He received B.S., M.S., and Ph.D. degrees in electrical engineering from Purdue University in 1982, 1984, and 1987, respectively, and is Outstanding Electrical Engineering Alumnus from that school.

Shuzo Kato received his Ph. D degree in electrical and communications engineering from Tohoku University, Sendai Japan in 1977. From 1977 to 1995, he worked at NTT (Nippon Telegraph and Telephone) Research Laboratories in Japan, specializing personal and satellite communications systems R&D. These include core technology developments for TDMA equipment, modems, and forward error correction schemes in addition to ASIC implementations of PHS (Personal Handy Phone) handsets and many satellite communication terminals. He has managed to develop 39 kinds of ASICs so far without re-spins including the world first TDMA chip set in 1986, the world fastest Viterbi decoder chip in 1987 and 1993, lowest power consumption ADPCM codec in 1994, best receiver sensitivity and the world first 2 V operating CMOS SOC PHS baseband chip in 1994 and many others. He founded Pacific Communications Research Corp.

focusing on ASIC, SW and system design for PCS In 1995, at the same time he served as Senior Executive Vice President, and later as President of Uniden Corporation. From January 1999 to July 2001, he served as Executive Vice President, Mitsubishi Wireless Communications Inc (MWCI) in USA, as well as President, Mobile Communications Technology Center of MWCI in San Diego, CA responsible for mobile phone technology development up to real/sellable and high yield cell phones with all certificates (FCC, CTIA and inter-operability). From 2002 to 2005, he served as Executive Vice President of Teradyne Japan responsible for P/L, Engineering, Production and Global Marketing as well as President and CEO of Omni Wireless Inc., in California, USA.

He currently is Professor, Research Institute of Electrical Communications, Tohoku University, Japan, Program Coordinator, Ubiquitous Mobile Communications at NICT (National Institute of Information and Communications Technology) working on wireless communications systems R&D focusing on millimeter wave communications systems. He has been serving as Vice-chair of IEEE802.15.3c Task Group working on millimeter wave systems standardization and Chair of COMPA (Consortium of Millimeter Wave Systems Practical Applications) promoting millimeter wave systems globally. He has published over 200 technical papers, held over 75 patents (including a patent which became DOD (Department of Defense, USA) standard in 1998), co-founded International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC). He is a Fellow of the IEEE and IEICE Japan and served as an Editor of IEEE Transaction on Communications, Chairman of Satellite and Space Communications Committee, COMSOC IEEE, a Board Member of IEICE Japan.