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*Special Issue of European Transactions on Telecommunications on 'Next Generation Wireless and Mobile Communications'**

Guest Editorial

Despite the promises of more feature-rich, highly interactive and high bit-rate multi-media services of third generation (3G) systems for the end-users and increased revenues for the operators, the research community has perceived the limitations of these systems in terms of user throughput and cost of operation and consequently has started to work towards next generation (NG) systems that are also being addressed as beyond third generation (B3G) or fourth generation (4G) systems. NG systems, which encompass B3G, 4G systems, and so on, are expected to allow subscribers to transparently access broadband multimedia services via multiple wireless and wireline access networks as if they are connected via broadband modems to the Internet.

The NG mobile networks are expected to be introduced according to the roadmap shown in Figure 1 and are being developed according to the general guidelines and rough specifications of various organisations worldwide:

- The *Wireless World Research Forum* has published its Books of Vision in 2000 and 2004 to outline technologies suited to introduce NG systems and the roadmap for their introduction.
- The *European Union* is continuously updating its *Information Society Technology (IST)* Framework Program started in the early 90s and is funding to a large amount research projects in the domains of broadband access, mobile technologies and services. Examples of these are WINNER, Ambient Networks, E2R and Smart Mobile Life that cooperate under the Wireless World Initiative.
- *ITU-R* approved the Recommendation M.1645 as the baseline for all activities towards the preparation of the World Radio Conference 2007 (WRC-2007) for the potential identification of new spectrum for mobile and wireless communication.
- *3GPP* initiated end of 2004 a study item on the further evolution of 3G systems with the major requirements on the radio interface of peak data rates up to about 100 Mbps with very low latency. The requirements are much more ambitions than the ITU-R requirements on systems beyond 3G.
- In *Japan*, the *mobile IT Forum* (mITF) was established in 2001 to realise future mobile communications systems and services such as the 4G system and mobile commerce services. mITF published roadmaps towards 4G in 2001 and 2004. The *National Institute of Communication Technology (NiCT)*, a public research organisation, is running the *New Generation Mobile Network Project* that is developing technologies for B3G systems. *NTT DoCoMo* has developed a system proposal for systems beyond 3G and a demonstrator.
- In *Korea*, the *Next Generation Mobile Committee—NGMC* is developing guidelines of 4G services, 4G spectrum, technologies and is coordinating 4G technology-related activities in Korea. ETRI of Korea is driving a national program on wideband mobile communications (Wireless Broadband—WiBro) to be deployed during the year 2006.
- *China* government launched the national research project Future Technologies for Universal Radio Environment (FuTURE) in the framework program 863 in the area of mobile communications for the time frame of the 10th 5-year-plan 2001–2005. The project phase 2 is planned up to 2010 aiming to achieve international leadership in mobile communications. The FuTURE project has focused on the development of radio transmission technologies, which satisfies the future needs for the time frame 2005–2010.
- In the *United States*, the IEEE, a globally operating organisation with its headquarters in the US, has developed standards for wireless local area networks and is now expanding that work to drive the development of future systems with extended capabilities. These alternative radio standards including activities on interworking and the support of mobility management may have an impact on 3G and its enhancements as well as NG

*Selected papers from 11th European Wireless Conference 2005, Nicosia, Cyprus.

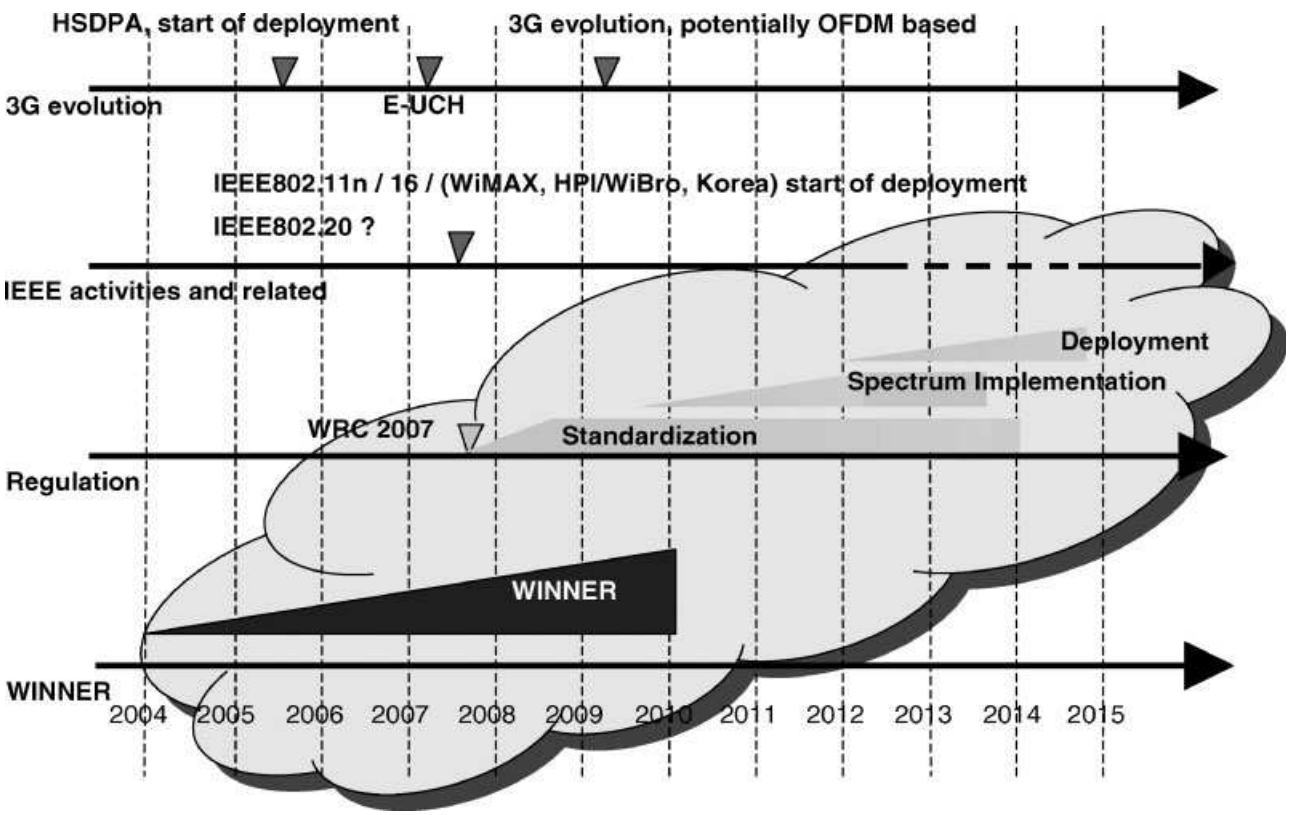

Figure 1. Roadmap according to the planning of 3GPP, IEEE, ITU-R and IST-WINNER (Source: WINNER).

systems. Another major player in North America is the *Defense Advanced Research Project Agency (DARPA)*. The DARPA neXt Generation (XG) communications program is developing the technology to allow multiple users to share use of the spectrum through adaptive mechanisms.

The *wireless IT sector* is specifying radio interface systems on the lower layers in the IEEE Project 802. In addition, industry standards and proprietary solutions are developed for special applications. All these standards are focusing on parts of the system. Their integration in existing networks is not yet solved. From a capabilities point of view these systems do not fulfil the requirements on systems beyond 3G with respect to supported throughput, latency, mobility and flexibility.

NG systems, according to Figure 1, will be shaped by emerging standards for wireless access from mobile terminals, like '3G evolution' and IEEE 802 wireless systems evolution, for example 802.11n ('a quarter Gigabit WLAN'), 802.16e ('mobile WiMax', cf. WiBro), 802.16j (Mobile Multihop Relaying, MMR), 802.20 (Mobile Broadband Wireless Access MBWA), and 802.21 (for handover and interoperability between heterogeneous network types including both 802 and non 802 networks). The Figure also shows the ITU-R regulation activities represented by WRC-2007 that is expected to specify new bands where NG systems will operate. In view of IST-WINNER, in 2012 the spectrum implementation will start permitting deployment of NG systems from 2014 on.

Main characteristics of NG systems are seamless use of a multitude of existent and forthcoming access network types by mobile terminals, and not a replacement of predecessor systems by a new design. Evolution towards NG mobile networks is already taking place through the interworking of 3G cellular systems such as UMTS/HSDPA, cdma2000 and GSM/EDGE with other broadband wireless access technologies such as WiFi hotspots and the forthcoming WiMax metropolitan networks to provide mobile users with anytime anywhere access to broadband multimedia services over the Internet, as shown in Figure 2.

The NG mobile networks will also be shaped by emerging standards for wireless access from mobile terminals, for example IEEE 802.20, and for integration of heteroge-

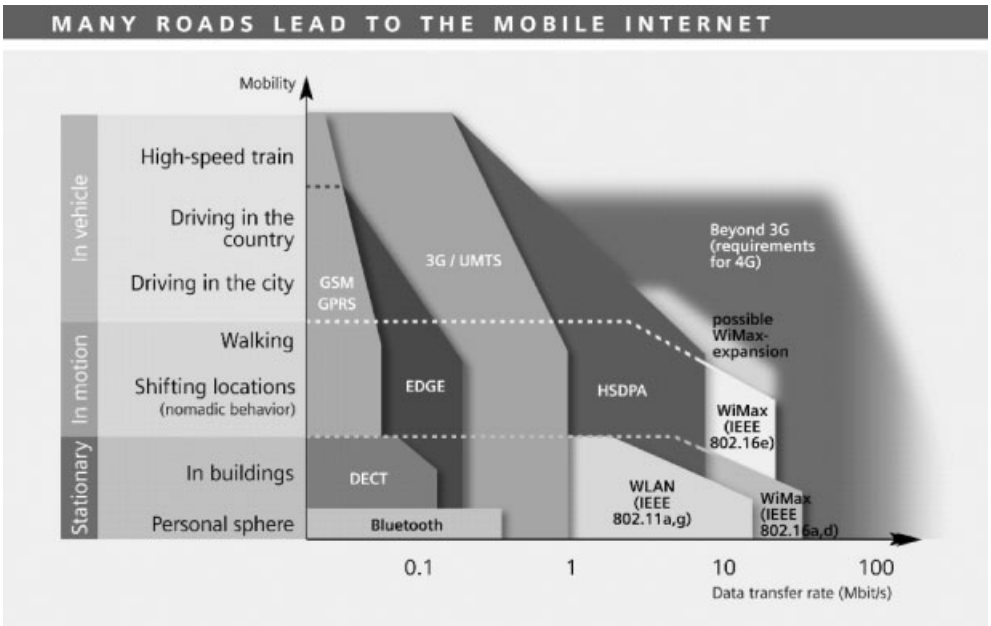

Figure 2. Mobility versus multiplexing user data rate of various mobile and wireless systems (Source: Siemens 2005).

neous wireless access networks, for example IEEE 802.21 that will establish interworking of IEEE wireless and wireline systems and any other mobile systems. This type of interworking may result in a converged global network and will provide many technical challenges.

Owing to the heterogeneity in the wireless access techniques and the requirements of multimedia and VoIP services, QoS provisioning and enforcement in the future generation mobile networks will become a demanding issue for the wireless access equipment vendors, networks service providers and customers.

Multi-carrier-based transmission and spatial multiplexing will be the dominating transmission technologies of future broadband networks. Cross-layer protocol engineering along with application-oriented signalling, and creation of new services will be required for efficient network resource utilisation and to bring profitability to the service providers.

The *11th European Wireless Conference 2005* in Cyprus has provided a technical forum for the dissemination of new results in this exciting research area. It has covered key aspects of NG mobile networks, particularly transmission techniques, architectures, protocols, mobility management, radio resource control protocols and signalling platforms to coordinate heterogeneous wireless access networks and integrate them into a common core network.

The topics mentioned above have been part of the 11th European Wireless Conference and, accordingly, this Special Issue presents a set of high-quality selected papers representing upgraded versions of original papers from EW 2005 that have passed another review round by the Guest Editors. The ten selected articles are grouped into four domains.

1. INTERFERENCE AVOIDANCE AND MIMO SYSTEMS EVALUATION

The paper 'Inter-Cell Coordination in Wireless Data Networks' by Thomas Bonald, Sem Borst, Alexandre Proutiere presents a systematic analytical treatment to calculate the gain of interference avoidance through inter-cell scheduling in TDMA-based radio networks. The performances Figure given have been derived based on an analytic model and evaluated based on linear programming. The capacity is considered as the main parameter and it is proven that for symmetric networks with small cell radii the gain in capacity by interference avoidance is between 33 and 50%, depending on the cell configureuration. To be able to analytically solve the problem, the assumptions made are fairly restrictive, with attention given only to two-cell and symmetric networks. It remains open to apply this approach to more general cases, where based on some comments made by the authors heuristic approaches might be required.

In 'Evalutation of MIMO Systems with Respect to Front-End Imperfections' the author(s): Christoph Degen, Olivier Koch, Wilhelm Keusgen, Bernhard Rembold deviatates from the main stream of modelling MIMO systems. Performance investigation of MIMO systems is commonly performed based on an ideal MIMO system model that is setting out from perfect overall system calibration, amplifier linearity and negligible phase noise. In contrast, this paper focuses on these issues and investigates on the impact of specific system imperfections. In particular, the commonly known MIMO system model of a single carrier frequency-domain equalisation/predistortion system is extended to consider transceiver calibration errors, phase noise and amplifier nonlinearities. For MIMO equalisation at either the transmitter or receiver site, the effect of these MIMO system imperfections are investigated by means of analysis and simulation, wherein zero-forcing and minimum-mean-square-error/Wiener joint detection/predistortion is considered. Among others, in particular the result that noise may compensate for interference that is caused by calibration errors and phase noise is remarkable.

2. MODULATION, CODING AND EQUALISATION

In the paper 'Signalling Overhead for ASBA in an MC-CDMA System by Y. Zhang, E. Costa, M. Lott, the authors study the signalling overhead of a dynamic subband allocation scheme, named Adaptive Sub-Band Allocation (ASBA), in an MC-CDMA system. The OFDM system channel estimation is performed aiming at an especially low overhead. The examples presented are being studied by semi-analysis and simulation and can be taken as representative for a large range of speed of movement. The use of OFDMA and CDMA is combined in order to provide high flexibility for synchronised downlink transmission in future 4G mobile systems. This flexibility can be exploited by allocating different subsets of users to different sets of sub-carriers, based on the channel state information (CSI), so as to achieve a considerable throughput increase. In this paper, the authors extend the analysis of a previous paper on ASBA, where ideal knowledge of CSI was assumed, by considering the actually measured CSI, and by taking into account the overhead introduced by CSI feedback carried into uplink pilots. To this aim, a channel estimation scheme is selected, as a good compromise of different considered schemes, and a simulation analysis is carried out to investigate the trade-off between the frequency with which channel estimation is updated and the corresponding overhead, as a function of user mobility and modulation schemes. Thanks to this analysis, the authors are able to derive an approximate formula for the optimum CSI updating period, which proves to be effective in achieving a higher throughput when ASBA is implemented, as opposite to fixed user and channel allocation.

In 'The Turbo-Fountain' by Hrvoje Jenkac, Joachim Hagenauer, Timo Mayer, the authors study the application of the principle of fountain coding to deliver reliable broadcast with asynchronous data access in a wireless environment. The broadcast service constraints are first described and the goal of error-free transmission with asynchronous access is then set. The fountain code concept seems to be an attractive solution to reach that goal. Fountain codes have already been proposed and optimised for erasure channels. To adapt the fountain coding concept to wireless channels, the authors introduce the turbo fountain codes. Two structures are proposed and according to simulations, the parallel turbo fountain seems more efficient. The simulation context is highly detailed and is taken as realistic as possible.

The idea is extended to joint source coding and simulation results show the structure efficiency and open improvement perspectives for the future. Authors give theoretical bounds that enable to appreciate the structure performance.

The paper is such written that a reader not familiar with fountain coding or turbo codes is given enough information to understand the concept. It is both educational and of high scientific level and interest.

G. Dietl and W. Utschick propose in their paper 'MMSE Turbo Equalization for Real-Valued Symbols' an MMSE turbo equaliser for BPSK. Since symbols are real, the MMSE criteria consider only the real part of the output equaliser in the optimisation process. So, the transfer function of the equaliser is modified in consequence. This approach is pragmatic, often known but at my knowledge never published in the turbo equalisation context. Although theoretically expensive, the transfer function of the equalisers with *a priori* information for BPSK is derived as the major contribution of the paper. Comparison between classical MMSE optimisation and the proposed method (widely linear detection) are given. Picinbono et al. have shown in 1995 that the MSE estimation of real data in complex Gaussian noise is not optimally performed by Wiener filtering but requires the use of a Widely Linear (WL) Wiener filtering. This paper investigates this estimator (which uses a linear form of the observation and its conjugate) for turbo equalisation. It shows that, WL

filtering improves the receiver quality with respect to the classical Wiener equaliser when BPSK symbols are used.

The paper by Gerd Richter, Martin Bossert, Elena Costa and Martin Weckerle 'On Time-Varying Cyclic Delay Diversity' introduces an elegant diversity technique for OFDM-based transmission systems. CCD substantially improves the performance but introduces no additional complexity at the receiver making this technique particularly attractive. For OFDMA systems with many users, where each user is allocated only a subset of the sub-carriers, CDD cannot provide full diversity for one user. Time varying CDD increases the diversity by using multiple transmit antennas leading to lower BER and FER under OFDMA transmission.

3. MAC PROTOCOLS AND COGNITIVE RADIO FOR IEEE 802.11 WLANS

The paper 'Comparison of Modified Dual Queue and EDCA for VoIP over IEEE 802.11 WLAN' by J. Yu and S. Choi provides the performance evaluations of VoIP service based on IEEE 802.11 DCF, IEEE 802.11e and the proposed modified dual queue (MDQ) solution based on event driven simulation. Delay, throughput and jitter performances have been studied and compared for different channel access methods and their enhancements together with sufficient simulation results. A MDQ approach based on the legacy DCF is proposed for improving the QoS of VoIP service in 802.11 WLAN. It is shown to what extent, by means of a software upgrade only, the performance of currently deployed 802.11 WLAN devices can be improved to come close to that of the next generation 802.11e WLANs. Although it is demonstrated that the performance of the forthcoming EDCA is superior to that of MDQ in all scenarios, characterised by different amount of background TCP sessions in parallel to the VoIP sessions, it is highlighted that MDQ provides acceptable Figures in most scenarios, thus allowing for supporting, at an acceptable cost, new real time services in currently deployed hot spots systems.

The next two papers focus on *cognitive radio*, as a means for flexible spectrum usage through dynamic assignment of unused radio resources in licensed spectrum, without interfering with the (possible) operation of licensed radios.

The paper 'Spectrum Sharing with Value-Orientation for Cognitive Radio', by S. Mangold, L. Berlemann and S. Nandagopalan introduces a sociological approach to cognitive radio operation, which is modelled by a 'contemporary society', a concept drawn from social science. Thanks to this modelling, the authors are able to characterise current approaches and propose a new one that is based on social awareness, according to which each radio does not only pursues its own interests, but also, partially, the interests of the other radio devices. This new concept is exemplified by means of a sample radio system that is based on CSMA/CA.

On the other hand, the paper 'Spectrum Load Smoothing: Distributed Quality-of-Service Support for Cognitive Radios in Open Spectrum' by L. Berlemann, S. Mangold, G. R. Hiertz and B. Walke, focuses more specifically on MAC protocols for cognitive radios, taking the forthcoming IEEE 802.11e as a reference, and discussing what modifications would be needed, in both centrally controlled (HCCA) and contention-based (EDCA) channel access, so as to implement spectrum sharing in an effective way. In both cases, it is proposed the usage of an algorithm, named Spectrum Load Smoothing (SLS), in order to coordinate allocations of shared spectrum. The authors compare by simulation, in a scenario with different coexisting quality of service (QoS) oriented Basic Service Sets (QBSS), the performance of three different cases: legacy, modified HCCA and modified EDCA. The analysis shows that HCCA and EDCA with SLS both outperform the legacy case. Simulation analysis is then extended to evaluate the capability of SLS to support QoS.

4. RADIO NETWORK PLANNING

In 'Radio Propagation in Frequency Selective Buildings' by M. Raspopoulos, F. A. Chaudry, S. Stavrou the authors propose the deployment of frequency selective surfaces (FSS) in indoor wireless environments and investigate their effect on radio wave propagation. Simulations have been performed at two frequencies in order to verify the frequency selectivity of FSS. This technology can be used to either isolate coverage in some indoor areas by increasing the attenuation or to passively amplify the reflected waves to channel the signal into well defined areas where an improved coverage is required. In the course of experimentation, the authors demonstrate a possible $\sim$20 dB improvement over the non-FSS case and discover that improved restriction occurs if ceiling and floor FSS are removed.

The Guest Editors are thankful to the following colleagues that have provided significant help in reviewing the papers: Karine Amis, Marc Chenu, Claudio Cicconetti, Maxime Colas, Michael Einhaus, Shujia Gong, Alban Goupil, Emmanuel Jaffrot, Christophe Laot, Christopher St. Jean, Yunpeng Zang.

We sincerely hope that you, the reader, will enjoy studying this Special Issue.

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GUEST EDITORS' BIOGRAPHIES

Bernhard H. Walke is running the Chair for Communication Networks (ComNets) at RWTH Aachen University, Germany, where about 30 researchers work on topics like air-interface design, development of tools for stochastic event driven simulation and analytical performance evaluation of services and protocols of XG wireless systems. Most of this work continuously has been funded from 3rd parties' grants. He is the author of the book 'Mobile Radio Networks—Networking, Protocols and Traffic Performance' and of the book UMTS—The Fundamentals and the forthcoming 2006 book 'IEEE 802 Wireless LAN/PAN/MAN Systems: Standards, Models and Traffic Performance'. He has been a board member of ITG/VDE and is Senior Member of IEEE. He has served as Programme Committee and Steering Committee Chairman of various conferences like the European Wireless (EW) conference that he co-founded. In 2005, he was the Scientific Chair of IEEE-PIMRC 2005, Berlin. His group has substantially contributed to the development of standards like ETSI/GPRS, ETSI/BRAN HiperLAN2, CEN TC 278 DSRC (electronic fee collection), IEEE 802.11e, 802.16 and 802.15.3. From 2001–2003 he was an elected Chair of Working Group 4 (New Technologies) of the Wireless World Research Forum. Prior to joining academia, he worked for 18 years in various industry positions at AEG Telefunken (now EADS AG). He holds a Dr. (1975) degree in information engineering from University of Stuttgart, Germany.

Bijan Jabbari is a Professor of Electrical Engineering at George Mason University, Fairfax, VA, and an affiliated faculty with ENST Paris, France. He is a coeditor of recent books on Multi-access, Mobility and Teletraffic (Kluwer Publishing, Volume I, IV, V, and VI). He is the International Division Editor for Wireless Communications of the Journal of Communications and Networks, the Editor for Wireless Multiple Access for the IEEE Transactions on Communications, and was on the editorial board of Proceedings of the IEEE. He is the past chairman of the IEEE Communications Society technical committee on Communications Switching and Routing. He is a recipient of the IEEE Millennium Medal in 2000 and the Washington DC Metropolitan Area Engineer of the Year Award, in 2003. He continues research on multi-access communications and high performance networking. He received the PhD degree from Stanford University in electrical engineering.

Enzo Mingozzi (e.mingozzi@iet.unipi.it) has been an Associate Professor at the Faculty of Engineering of the University of Pisa, Italy, since January 2005. He received a Laurea (cum laude) degree and a PhD in Computer Systems Engineering in 1995 and 2000, respectively, from the University of Pisa. His research activities span several areas, including design and performance evaluation of multiple access protocols for wireless networks, QoS provisioning and service integration in IP networks. He has been involved in several national (FIRB, PRIN) and international (Eurescom, IST) projects, as well as research projects supported by private industries (Telecom Italia Lab, Nokia). He actively took part in the standardisation process of HIPERLAN/2 and HIPERACCESS networks, in the framework of the ETSI project Broadband Radio Access Networks (BRAN). He has served in the Technical Program Committee of several international conferences. He served as the Tutorial Chair on the European Wireless 2002 (EW2002) Conference Committee, and guest-edited a special issue of the Wireless Networks journal on selected papers from EW2002.

Alain Sibille graduated from Ecole Polytechnique (Paris, 1977), from ENST (Paris, 1979), and obtained the PhD and habilitation degree (HDR, University of Paris 7) in 1985. He was first employed by France Telecom from 1979 to 1992,

where he conducted basic research on quantum semiconductor devices for ultra high frequencies and micro/opto- electronic applications. He then moved to Ecole Nationale Supérieure de Techniques Avancées (ENSTA) where he is now in charge of the Electronics and Computer Engineering department. His present personal scientific interests lie in ultra wide band communications, and in the interactions between antennas, channel and signal processing. Alain Sibille has authored or co-authored about 100 refereed publications and communications, and has been actively involved within these areas in several European and French research projects. He particularly contributed within a French delegation in the COST 273 four years cooperation action 'Towards mobile broadband multimedia networks', which ended in June 2005.