Editorial

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The past few years have been marked by a worldwide standardization activity for third-generation (3G) wireless systems, which are intended to deliver high data rates and are expected to handle multimedia applications in addition to voice. The key multiple-access technique that has been chosen for 3G wireless systems is CDMA.

The performance of 3G wireless systems might not be sufficient to meet the needs of future high-performance multimedia applications such as full-motion video and teleconferencing. Hence, there will be a need for systems that extend the capabilities of 3G wireless systems, sometimes referred to as fourth-generation (4G) wireless systems, whatever they might be. It is likely that these wireless systems will retain a CDMA component, but compared to 3G wireless systems, the changed operating conditions will present a new set of challenges in the development of CDMA detection techniques.

The aim of this special issue is to cover present research in the development of improved CDMA detection techniques for future wireless systems. Following the review process, thirteen papers have been selected for this issue. They can be classified into four broad categories: detection techniques for downlink CDMA, detection techniques for uplink CDMA, synchronization for CDMA, and combinations of CDMA with OFDMA.

In most CDMA systems, the downlink constitutes the bottleneck, since this is the link that has to enable the highest data rates. However, since the data streams corresponding to the different users can be organized in a synchronous manner and all these streams travel through the same channel from the viewpoint of a specific terminal, the receiver design can be kept rather simple. In a flat-fading channel, one generally applies a code-matched filter at the receiver, which is optimal if the different users are assigned orthogonal codes. However, this limits the maximum number of users to a value given by the spreading factor. To overcome this problem, one may consider two sets of orthogonal codes and assign one set of users to one set of codes and the other set of users to the other set of codes. This doubles the maximal number of users and does not increase too much the amount of multiuser interference (MUI) at the output of the code-matched filter. In the first paper, Vanhaverbeke and Moeneclaey go one step further and exploit the additional degree of freedom that one set of orthogonal codes should not be aligned with the other set of orthogonal codes. This allows them to reduce the MUI by up to 50% compared to the case where the two sets of codes are aligned. If a downlink CDMA system suffers from frequency-selective fading, the code-matched filter generally performs poorly since the code orthogonality is destroyed by the channel.

In that case, one generally applies a chip-level equalizer before the code-matched filter to equalize the channel and restore the code orthogonality. The chip-level equalizer that is often adopted is the MMSE FIR equalizer. In the second paper by Nguyen et al., on the other hand, an attractive alternative is presented, namely a Kalman-filter (KF) equalizer, which can take into account nonstationarity arising from a time-varying channel or a scrambling code for instance. Two KF versions are discussed. Both of them outperform the popular MMSE FIR equalizer.

In the uplink of a CDMA system, the users are generally asynchronous and their data streams travel through different channels when arriving at the base station. This complicates the receiver design considerably compared to the downlink receiver design. While for the downlink, single-user detectors are sufficient, that is, receivers that only require the code and the channel of the desired user to detect a specific user's data stream, the uplink generally requires multiuser detectors, that is, receivers that need the codes and the channels of all active users to detect a specific user's data stream. Note that it is possible to use a single-user receiver also for the uplink, but it will generally perform poorly, especially for high user loads. The optimal multiuser detector has been introduced by Verdu in 1986. However, due to its large computational complexity, linear multiuser detectors have been presented as interesting alternatives. Other popular multiuser detectors are the parallel interference cancellation (PIC) multiuser detector and the Kalman-filter (KF) multiuser detector. In the third paper by Morosi et al., a turbo version of a PIC multiuser detector for turbo-coded CDMA is proposed, whereas in the fourth paper by Sayadi and Marcos, a KF multiuser detector for CDMA in impulsive noise is presented. To decrease the complexity and improve the performance of multiuser detectors, it is often important to know how many users are active at any time and who they are. In the fifth paper, Haghighat and Soleymani propose a MUSIC approach to deal with this problem, which turns out to provide a reliable performance. Finally, in the sixth paper by Del Re et al., it is shown that under certain circumstances, existing single-user and multiuser detectors for uplink CDMA systems can be improved by exploiting the fact that a user can be in either one of two states: a talk state or a silent state.

Synchronization plays an important role in CDMA systems, especially for the uplink. In this issue, a couple of papers are devoted to timing estimation for uplink CDMA systems. In the seventh paper by Liu and Li, a novel training-based near-far-resistant timing estimation algorithm is proposed. It is based on the earlier developed large-sample maximum-likelihood (LSML) algorithm and is referred to as the modified LSML algorithm. However, in contrast to the LSML algorithm, which needs to perform a multidimensional search, the MLSML algorithm provides a closed-form solution. Next to training-based timing estimation, it is also possible to estimate the code timing in a blind fashion using for instance MUSIC. In the eighth paper by Hu, a new blind timing estimation algorithm is proposed,

which is outperformed by MUSIC only at low SNR, while having a linear complexity instead of a cubic complexity, like MUSIC. Synchronization is also important for mobile positioning. Estimating the delay of the first arriving path allows one to determine the distance between the mobile and the base station. However, the use of a bandlimited pulse shape decreases the accuracy of this delay estimate. In the ninth paper, Hamila et al. introduce a novel delay estimation process that reduces the effect of the bandlimited pulse shape.

While CDMA is capable of collecting the multipath diversity but suffers from MUI, orthogonal frequency-division multiple access (OFDMA) completely eliminates the MUI but can not collect the multipath diversity and therefore suffers from frequency selectivity. To capitalize on the advantages of both CDMA and OFDMA, combinations of CDMA and OFDMA have been developed. Depending on the way they are combined, we can distinguish between multicarrier CDMA (MC-CDMA), multicarrier direct-sequence CDMA (MC-DS-CDMA), and multitone CDMA (MT-CDMA). The next four papers deal with some of these combinations. In the tenth paper, Hou and Dubey derive an exact closed-form BER expression for downlink MC-CDMA systems applying a matched filter at the receiver. Previously derived BER expressions are based on certain assumptions which are not guaranteed in practice. In the eleventh paper by Tan et al., optimal power control for uplink multicode MC-CDMA systems applying successive interference cancellation (SIC) at the receiver is derived. Note that a multicode CDMA system is actually a multirate CDMA system, where each user can be assigned multiple codes, depending on the data rate this user requests. Since a major drawback of any combination of CDMA and OFDMA is its sensitivity to frequency synchronization errors and nonlinear distortions from the power amplifier, the twelfth paper by Rugini and Banelli examines the effect of these impairments on the performance of downlink MC-DS-CDMA systems applying a matched filter at the receiver. Finally, in the thirteenth and last paper by Giannakis et al., a generalized MC-CDMA (GMC-CDMA) system is proposed, which truly combines all the advantages of CDMA and OFDMA: it collects the multipath diversity and completely eliminates MUI. It is shown how all previously proposed combinations of CDMA and OFDMA (MC-CDMA, MC-DS-CDMA, and MT-CDMA), as well as the conventional DS-CDMA system can be viewed as special cases of GMC-CDMA. In addition, frequency reallocation procedures for underloaded GMC-CDMA systems are presented to increase the performance.

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Geert Leus was born in Leuven, Belgium, in 1973. He received the Electrical Engineering degree and the Ph.D. degree in applied sciences from the Katholieke Universiteit Leuven, Belgium, in June 1996 and May 2000, respectively. He has been a Research Assistant and a Postdoctoral Fellow of the Fund for Scientific Research-Flanders, Belgium, from October 1996 till September 2003. During that period, Geert Leus was affiliated with the Electrical Engineering Department, Katholieke Universiteit Leuven, Belgium. Currently, Geert Leus is an Assistant Professor in the Faculty of Electrical Engineering, Mathematics and Computer Science, Delft University of Technology, The Netherlands. During the summer of 1998, he visited Stanford University, and from March 2001 till May 2002, he was a Visiting Researcher and Lecturer at the University of Minnesota. His research interests are in the area of signal processing for communications. Geert Leus received a 2002 IEEE Signal Processing Society Young Author Best Paper Award. He is a Member of the IEEE Signal Processing for Communications Technical Committee, and an Associate Editor for the IEEE Transactions on Wireless Communications, the IEEE Signal Processing Letters, and the EURASIP Journal on Applied Signal Processing.

Philippe Loubaton was born in 1958 in Villers Semeuse, France. He received the M.S. and the Ph.D. degrees from École Nationale Supérieure des Télécommunications, Paris, France, in 1981 and 1988, respectively. From 1982 to 1986, he was a member of the technical staff of Thomson-CSF/RGS, where he worked in digital communications. From 1986 to 1988, he worked with the Institut National des Télécommunications as an Assistant Professor of electrical engineering. In 1988, he joined the École Nationale Supérieure des Télécommunications, Paris, France, working in the Signal Processing Department. Since 1995, he has been a Professor of electrical engineering at Marne-la-Vallée University, Champs-sur-Marne, France. After some works on two-parameter stationary stochastic processes, his present research interests are in statistical signal processing, and digital communications with a special emphasis on blind equalization, multiuser communication systems and multicarrier modulations, and performance analysis of large communication systems. Dr. Loubaton served as an Associate Editor for the IEEE Transactions on Signal Processing (1999–2001) and for the IEEE Communications Letters (2001–2003). He was a Member of the IEEE Signal Processing for Communications Technical Committee (1998–2004), and is currently an Associate Editor for IEEE Transactions on Signal Processing.

Dirk Slock received an Engineering degree from the University of Gent, Belgium, in 1982. In 1984, he was awarded a Fulbright scholarship for Stanford University, USA, where he received the M.S. degree in electrical engineering, M.S. degree in statistics, and the Ph.D. degree in electrical engineering in 1986, 1989, and 1989, respectively. While at Stanford, he developed new fast recursive least-squares (RLS) algorithms for adaptive filtering. From 1989 till 1991, he was a member of the research staff at the Philips Research Laboratory, Belgium. In 1991, he joined the Eurécom Institute where he is now a Professor. At Eurécom, he teaches statistical signal processing and signal processing techniques for wireless and wireline communications.

His research interests include DSP for mobile communications (antenna arrays for (semiblind) equalization/interference cancellation and spatial division multiple access, space-time processing and coding, channel estimation) and adaptation techniques for audio processing. More recently he is focusing on receiver design and downlink antenna-array processing for third-generation systems, introducing spatial multiplexing in existing wireless systems, fading channel modeling and estimation, and OFDM systems. In 2000, he cofounded SigTone, a startup developing music signal processing products. He is also active as a Consultant on xDSL and DVB-T systems. He received one best journal paper award from the IEEE-SP and one from EURASIP in 1992. He is the coauthor of two IEEE Globecom98 Best Student Paper Awards. He was an Associate Editor for the IEEE-SP Transactions from 1994 till 1996. He is an Editor for the EURASIP Journal on Applied Signal Processing, for which he also guest edited two special issues.

Michael D. Zoltowski was born in Philadelphia, Pa, on August 12, 1960. He received both the B.S. and M.S. degrees in electrical engineering with highest honors from Drexel University in 1983 and the Ph.D. degree in systems engineering from the University of Pennsylvania in 1986. In Fall 1986, he joined the faculty of Purdue University where he currently holds the position of Professor of electrical and computer engineering. Dr. Zoltowski is a Fellow of IEEE. He is also the recipient of the 2002 Technical Achievement Award from the IEEE Signal Processing Society. He is also a corecipient of the IEEE Communications Society 2001 Leonard G. Abraham Prize Paper Award in the field of communications systems. He is the recipient of the IEEE Signal Processing Society's 1991 Paper Award, "The Fred Ellersick MILCOM Award for Best Paper in the Unclassified Technical Program" at the 1998 IEEE Military Communications (MILCOM 1998) Conference, and a Best Paper Award at the IEEE International Symposium on Spread Spectrum Techniques and Applications (ISSSTA 2000). From 1998 to 2001, he was a Member-at-Large of the Board of Governors and Secretary of the IEEE Signal Processing Society. He is currently the Area Editor in charge of feature articles for the IEEE Signal Processing Magazine. He has served as an Associate Editor for both the IEEE Signal Processing Transactions and the IEEE Communications Letters.