MULTI-CARRIER SPREAD-SPECTRUM
Multi-Carrier Spread-Spectrum
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KHALED FAZEL
Marconi Communications GmbH,
Backnang, Germany

and

STEFAN KAISER
DoCoMo Communications Laboratories Europe GmbH,
Germany

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*Invited paper*
The field of multi-carrier and spread spectrum communications has become an important research topic with increasing number of research activities [1]. Especially in the last two years, beside deep system analysis of various multiple access schemes, new standardization activities in the framework of beyond 3G (B3G) concepts have been initiated. Multi-carrier transmission is considered to be a potential candidate to fulfill the requirements of the next generation system. The two important requirements of B3G/4G can be summarized as: i) much higher data rate for cellular mobile radio and ii) a unique physical layer specification for indoor/hot spot and outdoor/cellular applications, including fixed wireless access (FWA) schemes. The activities within the 3GPP and WiMAX fora are examples of such trends (see Fig. 1).

Figure 1  Beyond 3G: Worldwide Standardization Activities
The WiMAX (Worldwide Interoperability for Microwave Access [2]) vision is to provide broadband wireless access with its primary goal to promote IEEE 802.16a-e and ETSI-BRAN standards through interoperability testing and certification. In the first step the broadband access to the so-called last mile applications with fixed positioned terminals is envisaged. Further steps will cover portability and in long term even mobility. Note that OFDM/OFMA techniques with multiple antennas will play an important role to cover the non line-of-sight reception conditions.

Meanwhile, in order to fulfil the long term strategy of 3GPP (third generation partnership project) with the targets [3]

- increased peak data rates (100/50 Mbps DL/UL),
- scalable and increased user throughput,
- improved spectrum efficiency (e.g., DL up to 5 bit/s/Hz),
- improved latency (user plan: below 10 ms),
- scaleable bandwidth (from 1.5 MHz up to 20 MHz),
- reduced CAPEX and OPEX ,
- compatibility with earlier releases and with other systems and
- optimised for low mobile speed but supporting high mobile speed,

multi-carrier transmission is considered to be a potential candidate for the physical layer.

Adaptivity and trade-off between coverage, data rate and mobility with unique air interface architecture will be the key features for the success of next generation wireless systems. Fixed receivers with short coverage distance (pico cells) and ideal channel condition shall be able to receive the highest data rate, whereas subscribers with high mobility conditions and large coverage area (macro cells) shall be able to receive the necessary data rate to establish the required communication link.

**Multi-carrier and spread-spectrum** systems with their generic air interface and adaptive technologies will be considered as potential candidate to fulfill the above mentioned requirements of B3G/4G systems [1].

**SCOPE OF THIS ISSUE**

The aim of this issue, consisting of six parts, is to edit the ensemble of contributions presented during the three days of the 5th International Workshop on Multi-Carrier Spread-Spectrum (MC-SS 2005), held from September 14-16, 2005 in Oberpfaffenhofen, Germany.

The first part is devoted to **general issues** of MC-SS. First, Higuchi *et al.* give an overview on the 1 Gpbs transmission experiences at NTT DoCoMo with space diversity effects in MIMO channels. Their concept to achieve a tradeoff between data rate and coverage is based on using variable spreading in frequency and time domain.
Akthman and Hanzo analyze the performance of near-maximum-likelihood detection in multiple-antenna-aided multi-carrier systems that allow a high reduction of the system complexity. The idea of superposition of information as it was proposed by T. Cover for broadcast channel to offer a higher channel capacity is treated by Bossert with a new scope of application, which is the downlink of a cellular system. Here, the superposition of information is performed by using multi-level coding. The notion of adaptivity in MC-CDMA systems is studied by Cosovic and Kaiser. The estimation of the parameters needed for interference cancellation in a power-controlled MC-CDMA downlink transmission is analyzed by Morelli et al. Guenach and Steendam evaluate the performance and parameter optimization of MC-CDMA systems. An efficient low-complexity algorithm of OFDM inter-channel interference is proposed by Chang. A performance comparison of multi-carrier systems in the presence of jamming and fading is done by Matolak et al. Finally, a detailed comparison of CDMA in the context of OFDM and SC/FDE is performed by Witschnig et al.

The second part of this issue is devoted to cellular aspects. The impact of intercell interference in a downlink of MC-CDMA systems is presented by Doukopoulos and Legouable. Quantification of the impact of the physical layer based on the downlink capacity of a multi-cellular environment is performed by Mourad et al. Strategies for the management of the radio resource for an MC-CDMA system over correlated fading channels is presented by Plass and Dammann. The analysis of the throughput of heterogeneous multi-cell multi-user MIMO-OFDM systems is done by Mielczarek and Krzymien. Finally, a performance analysis of a real HF radio link based on spread-spectrum multi-carrier multiple access (SS-MC-MA) modem is done by Santana-Sosa et al.

The spreading and detection aspects are discussed in the third part of this issue. First, Weitkemper et al. analyze the performance of a successive iterative interference cancellation algorithm for a single carrier spread spectrum system. A bandwidth and power efficient digital transmission scheme using sets of orthogonal codes is presented by Teich et al. A simplified realization of a pseudo-orthogonal carrier interferometry OFDM by FFT algorithm is proposed by Anwar et al. The performance of a CDM-OFDMA system exploiting the uniqueness of rotated spreading is given by Raulefs et al. Tamura et al. analyze the detection of pre-coded OFDM by symbol recovering on degraded carriers. A semi-blind multiuser detection algorithm in a zero padded OFDM-CDMA scheme is proposed by Boloix-Tortosa et al. At the end of this section a study on adaptive successive detection algorithm using the M algorithm based on ML criterion for downlink MC-CDMA systems is proposed by Morishige et al.

The fourth part is devoted to channel estimation. Mazzoni et al. present an uplink channel estimation for MC-CDMA systems with timing offsets. An iterative channel estimation algorithm for MIMO MC-CDMA systems is proposed by Sand et al. The performance investigation of an improved channel estimation algorithm exploiting the long term channel properties is done by Weber et al. Space-frequency coding and signal processing for downlink MIMO MC-CDMA is analyzed by Lee et al. Cariou and Helard present a superimposed pilot-based channel estimation algorithm for
MIMO OFDM code division multiplexing uplink systems. Finally, Bader and Gonzales propose a location adjustment algorithm of pilot symbols in time and frequency in OFDM systems based on the channel variability parameters.

The fifth part assembles all issues related to **MIMO and adaptivity** techniques. A receiver architecture for closed-loop spatial multiplexing applied in a B3G system is presented by Malik and Yew. The performance of a MIMO-OFDM transmission scheme employing sub-carrier phase hopping is analyzed by Suyama et al. A multi-carrier SDMA system with reduced intra-user cross-correlations is studied by Dawod et al. In relation to adaptivity, the paper by Ohkawa and Kohno discusses the effect of adaptive modulation and forward error correction coding on multi-band OFDM-MIMO systems. Near optimal performance for high data rate MIMO MC-CDMA schemes is presented by Bouvet and Helard. The STBC-TCM for MC-CDMA systems with SOVA-based decoding and soft-interference cancellation method is proposed by Paredes Hernandez and Garcia Otero. An algorithm for an adaptive assignment of subcarriers and spreading codes for throughput maximization in a multi-user MC-SS system is presented by Pfletschner and Bader. Crussiere et al. present a new loading algorithm for adaptive SS-MC-MA systems over power line channels. The system performance is compared with DMT. An investigation of an optimal solution for multiuser sub-carrier allocation in OFDMA systems is done by Peng et al. In a similar way an optimal solution to adapt sub-carrier-and-bit allocation in multi-class multiuser OFDM systems is presented by Zhou et al. A dynamic and scalable bandwidth allocation algorithm for beyond 3G CDMA systems is proposed by Fong et al. Elliott et al. analyze the performance of an effective SINR mapping for an MC-CDMA system. Finally, a combination of hybrid ARQ and iterative multi-user detection for OFDMA-CDM is presented by Arkhipov et al.

The last part of this book is devoted to **system performance and implementation aspects**. A detailed comparative performance analysis of CDM-OFDMA and MC-CDMA systems is presented by Zhang and Lindner. The performance of a multi-user transmit power control algorithm for multi-carrier modulation systems in a quasi-synchronous uplink channel is analysed by Fujii et al. Wicpalek et al. present the compensation of IQ imbalance in a single carrier system with frequency domain equalization. The implementation aspects of an uplink MC-CDMA multi-user detector are presented by Happonen et al. The analytical performance of a frequency offset multi-user multi-array system is studied by Renoul et al. The effects of subcarrier interleaving on low density parity check coding is studied by Lee et al. Regarding combating the effect of non-linearity, Sezginer and Sari analyse one-shot and iterative symbol predistortion techniques for peak-to-average power reduction (PAPR) in OFDM systems. On a similar topic, Rave et al. present an iterative correction and decoding scheme for OFDM transmission systems affected by clipping. The reduction of PAPR in MC-CDMA signals by selected mapping with interleavers is presented by Saito et al. An iterative nonlinear channel compensation algorithm in MC-CDMA systems is analysed by Lottici and Giannetti. To gain more channel bandwidth in a crowded spectrum allocation, Cosovic and Janardhanam propose a technique for sidelobe suppression in an OFDM system. Blind phase noise estimation in OFDM systems by sequential Monte Carlo method is presented by Panayirci et al. A
sensitivity comparison of multi-carrier and spread spectrum systems to phase noise is finally analyzed by Garnier *et al.*

In conclusion, we would like to thank all the authors who have contributed to this issue and all those in general who responded enthusiastically to the call. We hope that this edited book may serve to promote further research in this area and with that can contribute to the success of the next generation wireless technology.

**REFERENCES**

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