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Editorial

Smart Antennas for Next Generation Wireless Systems

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The adoption of multiple antenna techniques in future wireless systems is expected to have a significant impact on the efficient use of the spectrum, the minimisation of the cost of establishing new wireless networks, the enhancement of the quality of service, and the realisation of reconfigurable, robust, and transparent operation across multitechnology wireless networks. Although a considerable amount of research effort has been dedicated to the investigation of MIMO systems performance, results, conclusions, and ideas on the critical implementation aspects of smart antennas in future wireless systems remain fragmental.

The objective of this special issue is to address these critical aspects and present the most recent developments in the areas of antenna array design, implementation, measurements, and MIMO channel modelling, robust signal processing for multiple antenna systems and interference-aware system level optimisation.

In the area of *antenna array design*, the paper by T. Cooper et al. presents a tower-top smart antenna calibration scheme, designed for high-reliability tower-top operation and based upon an array of coupled reference elements which sense the array's output. The theoretical limits of the accuracy of this calibration approach are assessed and the expected performance is evaluated by means of initial prototyping of a precision coupler circuit for a 2×2 array.

The design of uniform rectangular arrays for MIMO communication systems with strong line-of-sight components is studied in the paper by F. Bøhagen et al., based on an orthogonality requirement inspired by the mutual information. Because the line-of-sight channel is more sensitive to antenna geometry and orientation, a new geometrical model is proposed in this paper that includes the transmit and receive orientation through a reference coordinate system, along with a spherical wave propagation model to provide more accurate propagation predictions for the line-of-sight channel. It is shown that the separation distance between antennas can be optimized in several cases and that these configurations are robust in Ricean channels with different K-factors.

The paper by M. Mowlér et al. considers estimation of the mutual coupling matrix for an adaptive antenna array from calibration measurements. This paper explicitly incorporates the lack of information about the phase centre and the element factor of the array by including them in an iterative joint optimization. In particular, the element factor of the array is approximated through a basis expansion—the coefficients of the expansion are estimated by the algorithm. Analysis, simulations, and experimental results demonstrate the efficacy of the proposed estimator.

Diversity characterisation of two-antenna systems for UMTS terminals by means of measurements performed concurrently with the help of a reverberation chamber and a Wheeler Cap setup is addressed in the paper by A. Diallo et al. It is shown that even if the envelope correlation coefficients of these systems are very low, having antennas with high isolation improves the total efficiency by increasing the effective diversity gain.

In the paper by S. Savazzi et al., the authors address the design problem of linear antenna array optimization to enhance the overall throughput of an interference-limited system. They focus on the design of linear antenna arrays with nonuniform spacing between antenna array elements, which explicitly takes into account the cellular layout and the propagation model, and show the potential gains with respect to the conventional half wavelength systems. For such purposes two optimisation criteria are considered: one based on the minimization of the average interference power at the output of a conventional beamformer, for which a closed-form solution is derived and from which the justification for unequal spacings is inferred; a second targets the maximization of the ergodic capacity and resorts to numerical results.

Addressing the *robust MIMO signal processing* aspect, the paper by P. Theofilakos and A. Kanatas considers the use of subarrays as a way to improve performance in MIMO communication systems. In this approach, each radio frequency chain is coupled to the antenna through a beamforming vector on a subarray of antenna elements. Bounds on capacity for Rayleigh fading channels highlight the benefits of subarray formation while low-complexity algorithms for grouping antennas into subarrays illustrate how to realize this concept in practical systems.

The paper by I. Cosovic and G. Auer presents an analytical framework for the assessment of the pilot grid for MIMO-OFDM in terms of overhead and power allocation. The optimum pilot grid is identified based on the criterion of the capacity for OFDM operating in time-variant frequency selective channels. A semianalytical procedure is also proposed to maximize the capacity with respect to the considered estimator for realizable and suboptimal estimation schemes.

The paper by A. Del Coso and C. Ibars analyses a point-to-point multiple relay Gaussian channel that uses a decode-and-forward relaying strategy under a half duplex constraint. It derives the instantaneous achievable rate under perfect CSI assumption and obtains the relay selection algorithm and power allocation strategy within the two consecutive time slots that maximises the achievable rate. Furthermore the study provides upper and lower bounds on the ergodic achievable rate, and derives the asymptotic behaviour in terms of the number of relays, showing that for any random distribution of relays the ergodic capacity of the multiple relay channel under AWGN grows asymptotically with the logarithm of the Lambert function of the total number of relays.

In the paper by A. Ikhlef and D. Le Guennec, the problem of signal detection in MIMO systems is addressed focusing on blind reduced complexity schemes. In particular, the authors propose the use of blind source separation techniques, which avoid the use of training sequences, for blind recovery of QAM and PSK signals in MIMO channels. The proposed low-complexity algorithm is a simplified version of the CMA algorithm that operates over a single signal dimension, that is, either on the real or imaginary part and of which convergence is also proved in the paper.

In the area of *system level optimisation*, the paper by C. Sun et al. considers the application of switched directional beams at the transmitter and receiver of a MIMO communication link. The beams provide a capacity gain by focusing on different dominant wave clusters in the environment; switching between beams gives additional diversity benefits. Electronically steerable parasitic array radiators are suggested as a means to implement the beamforming in the RF. Performance is particularly enhanced at low SNRs compared to a conventional MIMO system that requires an RF chain for each antenna.

In the paper by N. Jalden et al., the inter- and intrasite correlation properties of shadow fading and power-weighted angular spread at both the mobile station and the base station are studied, for different interbase station distances, utilizing narrow band multisite MIMO measurements in the 1800 MHz band.

A. M. Kuzminskiy and H. R. Karimi show in their paper the potential increase in throughput when multiantenna interference cancellation techniques are considered to complement the multiple access control protocol. The work evaluates the gains that multiantenna interference cancellation schemes provide in the context of WLAN systems which implement the CSMA/CA MAC protocol.

Transmit diversity techniques and the resulting gains at the cell border in a cellular MC-CDMA environment using smart base stations are addressed in the paper by S. Plass et al. Cellular cyclic delay diversity (C-CDD) and cellular Alamouti technique (CAT) are proposed, that improves the performance at the cell borders by enhancing macrodiversity and reducing the overall intercell interference.

The paper by B. Bougard et al. investigates the transceiver energy efficiency of multiantenna broadband transmission schemes and evaluates such transceiver power consumption for an adaptive system. In particular, the paper evaluates the tradeoff between the net throughput at the MAC layer versus the average power consumption, that an adaptive system switching between a space-division multiplexing, space-time coding or single antenna transmission achieves. Authors provide a model that aims to capture channel state information in a compact way, and from which a simple policy-based adaptation scheme can be implemented.

In the last paper, W. Sheng and S. D. Blostein formulate the problem of admission control for a CDMA beamforming system as a cross-layer design problem. In the proposed framework, the parameters of a truncated automatic retransmission algorithm and a packet level admission control policy are jointly optimized to maximize throughput subject to quality-of-service requirements. Numerical examples show that throughput can be increased substantially in the low packet error rate regime.

The theme of this special session was inspired by the joint research collaboration in the area of smart antennas within the ACE project, a Network of Excellence under the FP6 European Commission's Information Society Technologies Initiative. The objective of this issue is to share some insight and encourage more research on the critical implementation aspects for the adoption of smart antennas in future wireless systems.

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