ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 5, Issue 10, October 2016

To study and comparison of various Beamforming techniques for Multiuser MIMO-OFDM system

1. Shivani Saxena, PG student, MIT Ujjain(m.p)
2. Prof.Mohit Pant, Asst Prof., MIT Ujjain(m.p)

Abstract—This paper consists three techniques of beamforming for MIMO systems base on iterative finding of transmit and receive beamformers.In the first case the transmit beamformers are set (known) and the receive beamformers are calculated. It works by projecting the Tx beamformers into a null space of appropriate channels. This eliminates one interference term for each user. The basic idea is to optimize SNR ratio taking into account the orthogonality so as to reduce interference. In the next case we simultaneously optimize the Tx and Rx beamformers from constrained SNR maximization. It uses the results from the previous case. The third case is also for joint optimization of Tx–Rx beamformers but combines constrained SNR and signal to-interference-plus-noise ratio maximization. The minimum number of antennas required is derived as part of the formulation. A precoder is used for extracting multipath diversity.At last; the required feedback rates are derived and compared to existing beamforming methods. Using the standardized statistical channel model for IEEE 802.11n, our imulations demonstrate faster beamforming, improved error performance, and the ability to extract multipath diversity which is not possible in the leastsquare approach.

Index Terms—wireless communications,SNR interference channel, beamforming, optimization, MIMO-OFDM, multipath diversity.

I. INTRODUCTION

The term “beamforming” is used to denote an array processing technique for estimating one or more desired signals. The output provided by each antenna element is weighted according to a certain criterion in order to distinguish the spatial properties of a signal of interest from noise and interference. The name beamforming

comes from the early forms of antenna arrays that were used to generate pencil beams, so as to receive signals from a specific direction and attenuate signals incoming from other directions. From this primary meaning related to propagation environments characterized by a low angular spread, beamforming has been extended to rich scattering scenarios and, at present, this term is used to denote the antenna processing techniques operating both in low and high-rank channels. . As a further clarification of the context, some recent works refer to interference suppression operations as precoder matrices and interference alignment (IA), e.g., [7], but in this paper, the signal processing operations are referring to beamforming as a vector operator. Therefore, we have considered only single stream thansmission of data. The relationship between this work and other representative examples of single-stream transmission beamforming works is summarized as follows. In [8] and [9], the SINR optimization was treated for a specific user which has multiple transmit and receive antennas, while the other user—as one interferer—has single transmit and receive antennas; whereas in this paper, all users have multiple transmit and receive antennas. The joint transmit beamformer (Tx-BF) and receive beamformer (Rx-BF) design for minimum SINR maximization in a MIMO interference channel system has been proven to be a strongly NP-hard problem [10]. Recently, a joint leakage interference (LI) minimization and maximization of the individual signal powers (SPs) and SINRs was reported [11] using an optimization approach with a fixed point method. The numerical results revealed that the joint LI-SP-SINR problem has superior performance compared to the max–min SINR problem, but with much less computational complexity. The minimum number of required antennas for each user with respect to the number of users for the joint LI-SP-SINR problem has not been addressed to date, but new results are presented in this paper. Various objective (cost) functions have been presented in interference channel systems, and the optimization criteria have included, for example, beamforming design for mean-squared error (MSE) minimization [12], weighted sum rate maximization [7], and maximization of the sum signal power across the network divided by the sum interference power [13]. For the MSE minimization in [12], the problem led to an iterated second-order cone programming routine. For the weighted sum rate maximization of [7], the constrained problem was converted to an unconstrained problem and solved by a gradient descent algorithm. Finally, the problem addressed in [13], i.e., the sum signal power divided by sum interference power, was simplified by using an alternating maximization method. It is clear that there are several different approaches to the beamforming problem. The ultimate metric is a practicable digital communications performance, but it is not yet possible to optimize this directly. Instead, the optimization of some analogue channel performance functions is followed by a calculation of some aspect of the associated communications performance—usually an information-theoretic capacity or throughput rate, along with some error performance. Along these lines, this paper presents three new beamforming design cases. First, a constrained SNR maximization is sought in which the Tx-BFs for all the users are acquired by deploying the null-space of an appropriate channels matrix (described below). This null-space assignment for Tx-BFs eliminates one term of interference at each receiver. The remaining interference terms at each receiver can be eliminated by means of orthogonal vectors. The Rx-BF of each user, in this case, has a closedform solution if its norm is one. The second case is joint Tx–Rx beamformer design for constrained SNR maximization where only the Rx-BF at each receiver terminal nulls out all the interference. This problem leads to a multi-objective optimization which can be solved iteratively because it has guaranteed convergence. The third case is joint constrained SNR and SINR maximization. This problem has a solution because its corresponding vector field is nonexpansive.

II SYSTEM MODEL, PROBLEMS FORMULATIONS AND THEIR SOLUTIONS

The communications situation as it relates to the model is summarized as follows. There are *K* pairs of multi-antenna terminals which are striving to share simultaneously the spectrum in time and space. The channel is modeled as 1) a tapped delay line (*L* + 1 taps) according to the IEEE 802.11n propagation model or 2) a single-tap flat fading channel with a perfect spatial correlation matrix. The first channel model justifies both the MIMO-OFDM configuration and deploying the multi-path precoder in this paper. The second channel model is used only to compare the performance of the existing methods with our three proposed designs.

The K user all have N_t transmit antennas and N_r receive antennas, and all users utilize each of the P subchannels. The formulation in this section assumes K ≥ 3; the case for K = 2 is special and is discussed separately below. Referring to Fig. 1, the transmit beamformers for the ith user at the pth subcarrier are written $v_i(p) \in C^{N_t \times 1}$, and similarly, the receive beamformers are $u_i(p) \in C^{N_r \times 1}$ for $i \in \{1, \ldots, K\}$ and $p \in \{0, \ldots, P-1\}$. In Fig. 1, the MUX block stacks P samples of s_i is the input symbol stream of user i. Define $\tilde{s}_i \overset{\Delta}{=} \Phi\, [s_i(0) \ldots s_i(P-1)]^T$, then the output of the transmit beamformer is $v_i(p)\, \tilde{s}_i(p)$ where $\|v_i(p)\| = 1$and $\tilde{s}_i(p)$ is the pth element of vector $\tilde{s}_i$. The user' data symbols are assumed to be mutually independent. For simplicity, assume $\Phi = I_{P \times P}$ for now. So in this case, $\tilde{s}(p) = s_i(p)$. Later on, we consider an optimal Φ matrix to extract multi-path diversity.

The frequency selective channel from the μth transmit antenna of the ith transmitting user to the vth receive antenna of the rth receiving user is denoted by the delay-time function $h^{r,i}_{v\mu}(l)$ where $v \in \{1, \ldots, N_r\}$, $\mu \in \{1, \ldots, N_t\}]$ and $r \in \{1, \ldots, K\}$, and $l \leq L + 1$ indexes the delay-time bin. The channel is considered unchanging for one OFDM symbol and independent between OFDM symbols. Assuming perfect OFDM symbol timing synchronization, then after removal of the cyclic prefix with length $L_{CP} \geq L$ and after FFT, the received signal vector for the ith user can be written:

$$y_i(p) = H_{i,i}(p) v_i(p) s_i(p) + \sum_{i' \neq i}^{K} H_{i,i'}(p)\, v_{i'}(p)\, s_{i'}(p) + n_i(p) \qquad (1)$$

In (l), the channel at subcarrier p is $H_{r,i}(p) \in C^{N_r \times N_t}$. The (v, μ) entry of it is defined as $[H_{r,i}(p)]_{v,\mu} \overset{\Delta}{=} H^{r,i}_{v\mu}(p)$, where

$$H^{r,i}_{v\mu}(p) := \sum_{i=0}^{L} h^{r,i}_{v\mu}(l)_e^{-2\pi lp/P}$$

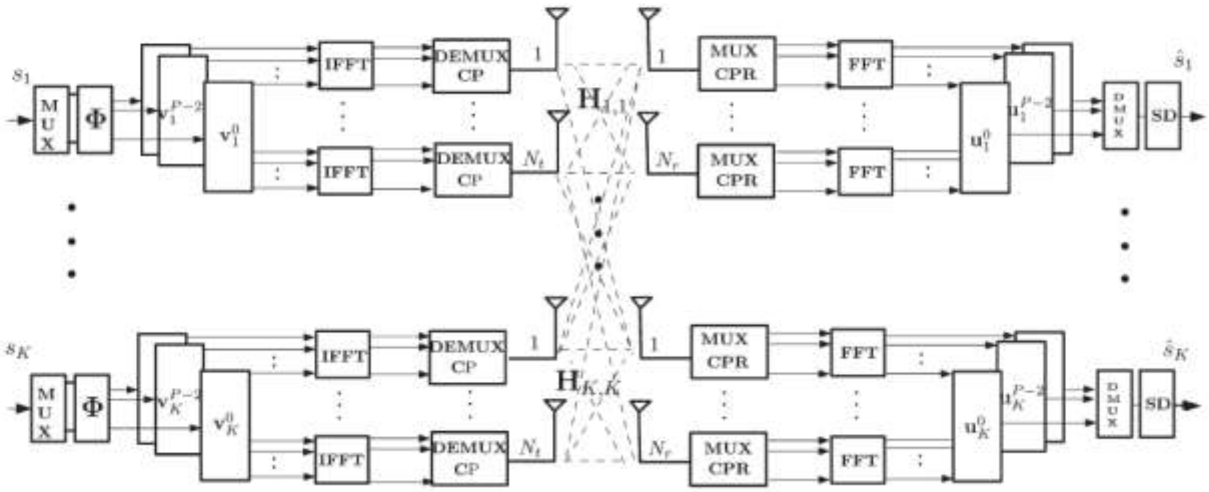
From the kronecker model, $H^{r,i}_l = \left(R^r_l\right)^{1/2} G_l \left(R^i_l\right)^{T/2}$ is the lth channel tap matrix where $h^{r,i}_{v\mu}(l) = \left\lfloor H^{r,i}_l \right\rfloor_{v,\mu}$ and $G_l \in C^{N_r \times N_t}$ is a complex matrix with zero-mean and unit-variance Gaussian estries. The R^r_l and R^i_l are the receive and transmit spatial correlation matrix, respectively. $\left\lfloor R^r_l \right\rfloor_{v,\mu} = 1$ for v = μ and $\left\lfloor R^r_l \right\rfloor_{v,u} = p^{r,l}_{v,\mu}$ for v ≠ μ represents the complex correlation coefficients between the vth and μth receiving antennas. For a special type of uniform linear antenna array, the correlation of the fading between two antennas spaced $d_{v,\mu}$ apart can be modeled by

ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 5, Issue 10, October 2016

$p^{r,l}_{v,\mu} = R^{l}{}_{XX}(D) + jR^{l}{}_{XY}(D)$ [17], where D = $2\pi d_{v,\mu}/\lambda$ and:

$$R^{l}_{XX}(D) = \int_{-\pi}^{\pi} \cos(D \sin(\phi))\, f^{l}(\phi)\, d\phi \quad (2)$$

$$R^{l}_{XY}(D) = \int_{-\pi}^{\pi} \sin(D \sin(\phi))\, f^{l}(\phi)\, d\phi \quad (3)$$



Algorithm-I

OPTIMAL RX-BFS FOR CONSTRAINED SNR MAXIMIZATION WHEN THE TX-BFS ARE KNOWN

In this section, the Tx-BFs are found from the null space of an appropriate set of channels, and then the optimal Rx-BFs are sought. For K ∈ {2 (n + 1) : n ∈ N}, where N denotes positive integers, the beamformer v_i is obtained by

$$v_i = N(H_{K+1-i,\,i}) \quad (4)$$

Where
$$N(A) \overset{\Delta}{=} \{x \mid Ax = 0, \|x\| = 1\} \quad (5)$$

is an orthonormal basis for the null space of A. For K ∈ {2n + 1 : n∈ N}, the v_i can be found by

$$v_i = \begin{cases} N(H_{K+1-i,\,i}) & \text{if } K+1-i < i \\ N(H_{K,\,i}) & \text{if } K+1-i = i \\ N(H_{K-i,\,i}) & \text{if } K+1-i > i \end{cases} \quad (10)$$

Note that from (4) or (5), $H_{1,K} v_K = 0$. The next step is to determine u_i such that it maximizes the signal-to-noise ratio (SNR) of the ith user (i.e., after the Rx - BF) while suppressing the K - 2 remaining interference terms. This optimization problem is denoted P for first receiver as an example, and the rest of receivers' beamformer designs follow by the same methodology. For simplicity, E $\{|s_i|^2\} = \sigma_s^2$ and E $\{n_i n_i^H\} = \sigma_n^2$ I. The problem is expressed

P :

$$\max_{u_1 \in C^{N_r} \backslash 0} \frac{u_1^H H_{1,1} v_1 v_1^H H_{1,1}^H u_1}{u_1^H u_i}$$

$$\text{S.t.} \begin{cases} u_i^H H_{1,2} v_2 = 0 \\ u_1^H H_{1,3} v_3 = 0 \\ u_1^H H_{1,K-1} v_{K-1} = 0 \end{cases}$$

So P is a constrained SNR maximization formulation where maximization over a quasi-convex object function with affine constraints is sought [19]. The maximizing of the ratio of quadratic forms is a known problem with an eigen solution. But here the difference is that the P has constraints force the interference, for the first user as an example, to be eliminated. To solve P, its Lagrangian function is needed:

$$L(x,\lambda) = -\frac{x^H Q x}{x^H x} - \sum_{i=1}^{K-2} \lambda_i x^H q_i ;$$

(6)

Algorithm-II

JOINT RX-BF AND TX-BF FOR CONSTRAINED SNR MAXIMIZATION

In the previous section, the optimal closed-form Rx-BFs were obtained by (4) while the Tx-BFs are the null space of channels as expressed by (4) or (5) according to an even or odd number of users, respectively. In this section, joint Tx-BF and Rx-BF are designed for the constrained SNR maximization problem by using the extended alternating optimization (EAO) algorithm for a multi-objective optimization.

Consider the following optimization problem :

$$\min_{x \in \Omega_J} J(x) = J_1(x_1, \ldots, x_K) + \ldots + J_K(x_1, \ldots, x_K) \quad (7)$$

Where $x = |x_1, \ldots, x_K|^T$ and Ω_J is the feasible set. Generally solving such a nonlinear constrained optimization problem is difficult. However, if firstly for each objective function, i.e., J_i, i = 1, …, K, there is a quniqu global minimizer with respect to x_i for fixed $x_1, \ldots, x_{i-1}, x_i + 1, \ldots x_K$, then EAQ approximates the difficult problem's solution by simultaneous solving of the following K problems:

$$\min_{x_i \in \Omega_i} J_i(x_1, \ldots x_{i-1}, x_i, x_{i+1}, \ldots, x_K)$$

(8)

Where $\Omega_1 \times \ldots \times \Omega_K = \Omega_J$.

Now it can be assumed that the optimal solution of (27) can be represented as :

$x_i = l_i(x_1, \ldots, x_{i-1}, x_{i+1}, \ldots, x_K)$

i = 1, …, K (9)

Where l_i is a nonlinear function with following property :

$\forall x_i \in \Omega_i$, $J_i(x_1, \ldots x_{i-1}, x_i, x_{i+1}, \ldots, x_K)$

$\geq J_i(x_1, \ldots x_{i-1}, x_i, x_{i+L}, \ldots, x_K)|x_i = l_i(x_1, \ldots, x_{i-1}, x_{i+1, \ldots,} x_K)$ (10)

Secondly, if for some a, $\|l_i\| \leq a$ for $\|col\{x_1, \ldots x_{i-1}, x_{i+1}, \ldots, x_K\}\| \leq a$ (where the col operator concatenates vectors), then there is a Nash equilibrium (NE) for K sub-problems (games), see Appendix C. Finally, NE for these K games can be approximated iteratively by :

$$x_i^{(n+1)} = l_i\left(x_1^{(n+1)}, \cdots, x_{i-1}^{(n+1)}, x_{i+1}^{(n)}, \cdots, x_K^{(n)}\right)$$

(11)

In the rest of the paper, N is the fixed number of iterations after which the $\left\{x_i^{(N)}\right\}_{i=1}^{K}$ is the approximation for $\left\{x_i^*\right\}_{i=1}^{K}$.

Algorithm-III

TX-BF AND RX-BF DESIGN FOR JOINT CONSTRAINED SNR MAXIMIZATION AND SINR MAXIMIZATION

In the previous section, each Rx-BF null its interference and then this solution is inserted to the constrained SNR objective function which yields the Tx beamformer. In this section, multiobjective optimization by the fixed point method is applied. Instead of G, which is optimization w.r.t. v_1 and u_1, define the problem G_1 as :

$$G_1 : \max_{v_1 \in C^{N_t}} v_1^H H_{1,1}^H u_1 u_1^H H_{1,1} v_1$$

$$\text{s.t.} \quad (34) \quad \begin{cases} v_1^H H_{2,1}^H u_2 = 0 \\ v_1^H H_{3,1}^H u_3 = 0 \\ \vdots \\ v_1^H H_{K,1}^H u_K = 0 \\ v_1^H v_1 \leq 1. \end{cases}$$

This problem is maximization w.r.t. v_1 only. (In an alternative notation, we are seeking a Nash equilibrium point for two games.)

$v_1 = \gamma\,[N(D)]_1 + \delta\,[N(D)]_2$

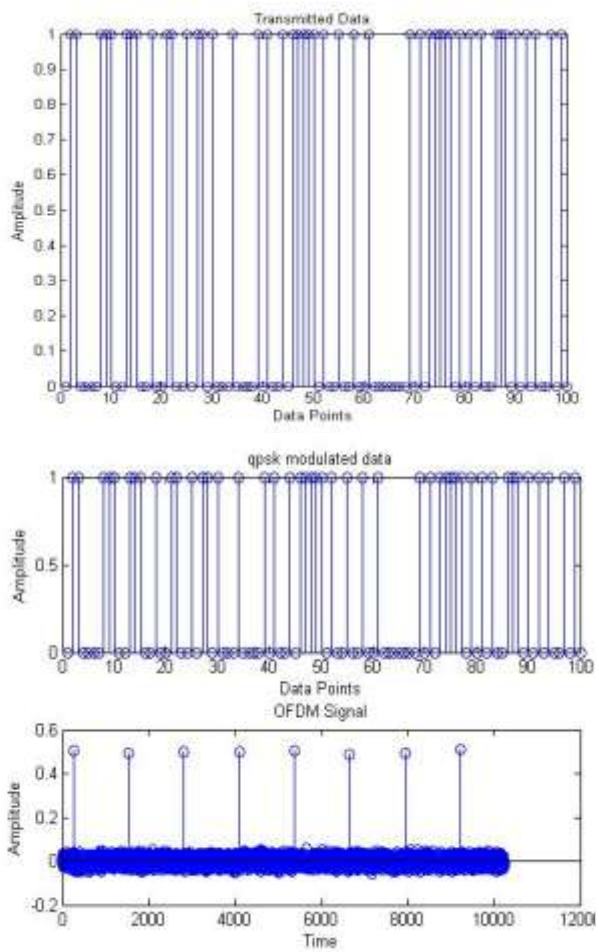
(35)

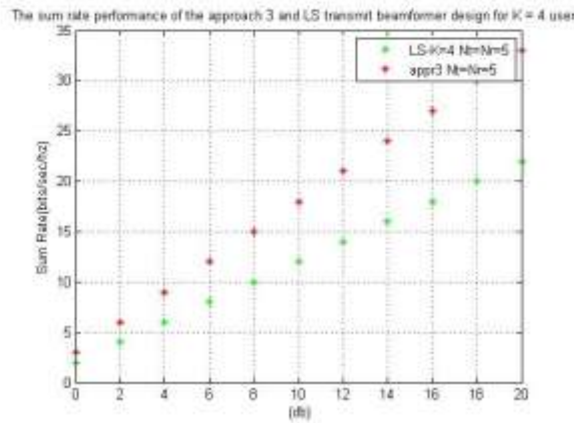
RESULTS

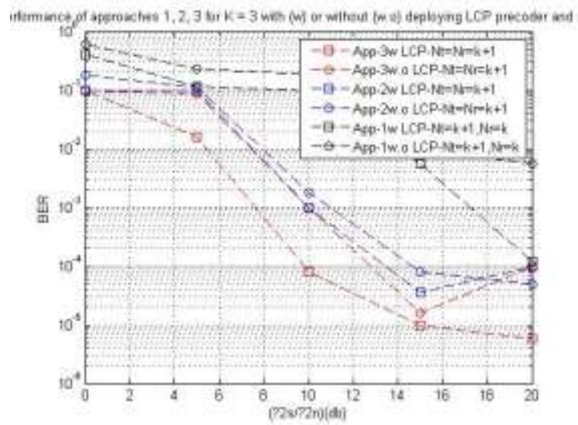
In this section numerical experiments are described for validating the analysis. The simulation parameters are summarized in Table IV. For simplicity, all the users use QPSK in the evaluation of BER performance. As discussed in the Introduction, digital communications performance is a tricky aspect of link optimization and using a single modulation cannot create high capacity (efficiency) over a range of average SNRs. (Rayleigh channels, for example, have a very large range of average SNRs.) Similarly, there is no channel coding. Strictly, the digital communications behavior should be optimized, but

this is not yet possible in general as discussed. Nevertheless, optimizing
with the analogue objective functions, and then applying a fixed communications configuration allows a fair performance comparison between the differently optimized beamformers. The IEEE 802.11n standard characterizes MIMO channels forWireless Local Area Networks (WLAN). The IEEE 802.11n channel models [16] are designed for indoor WLAN for bandwidths of up to 100 MHz, at frequencies of 2 and 5 GHz. The channel models comprise a set of 6 profiles, labeled A to F (one tap for model A, and 9 to 18 taps for models B-F), which cover the scenarios of flat fading, residential, residential/small office, typical office, large office, and large space (indoors and outdoors).

.







CONCLUSION

In this paper three beamforming techniques have been analyzed and implemented for MIMO systems.With a unit norm for the transmit and receive beamformers, the algorithms comprise iterative procedures with closed-form steps, allowing a fast solution. Because no derivative or Lagrangian multiplier is needed, the computational complexity is less than existing beamforming methods. It is shown that the third algorithm—joint constrained SNR and SINR maximization—outperforms the least-square beamforming design, c.f. (43), with a much lower computational time. For quasi-realistic channels (exponential power delay profile, Kronecker antenna correlations, as in the IEEE 802.11n channel model), the second algorithm may be better than the third algorithm and also it requires less feedback. The first algorithm is the simplest in terms of complexity. It has the lowest feedback rate. But it has worse performance compared to the other two algorithms and some existing designs. A lower feedback rate than existing beamforming methods is a feature of the first two algorithms, when the same number of antennas is considered. It is known that the LCP matrix improves the error performance in strongly idealized channels (uniform power delay profile), and here our simulations demonstrate that for the more realistic IEEE 802.11n channel models, the addition of the LCP matrix (prior to the Tx beamformer) still improves the error performance. The simplicity of the presented algorithms comes at the price of one more antenna element at each terminal, compared to existing methods. The results of this paper can also be viewed as some quantification of the trade-offs of between algorithmic simplicity, a minimum number of antennas, feedback rate, and the capability of extracting multipath diversity, in beamforming for the MIMO-OFDM interference channel.

REFERENCES

[1] S. Peters and R. Heath, "Cooperative algorithms for MIMO interference channels," *IEEE Trans. Veh. Technol.*, vol. 60, no. 1, pp. 206–218, Jan. 2011.

[2] M. Schubert and H. Boche, "Solution of the multiuser downlink beamforming problem with individual SINR constraints," *IEEE Trans. Veh. Technol.*, vol. 53, no. 1, pp. 18–28, Jan. 2004.

[3] M. Schubert and H. Boche, "Iterative multiuser uplink and downlink beamforming under SINR constraints," *IEEE Trans. Signal Process.*, vol. 53, no. 7, pp. 2324–2334, Jul. 2005.

[4] M. Codreanu, A. Tolli, M. Juntti, and M. Latva-aho, "Joint design of Tx–Rx beamformers in MIMO downlink channel," *IEEE Trans. Signal Process.*, vol. 55, no. 9, pp. 4639–4655, Sep. 2007.

[5] G. Zheng, K.-K.Wong, and T.-S. Ng, "Throughput maximization in linear multiuser MIMO-OFDM downlink systems," *IEEE Trans. Veh. Technol.*, vol. 57, no. 3, pp. 1993–1998, May 2008.

[6] A. Bourdoux and N. Khaled, "Joint TX–RX optimisation for MIMOSDMA based on a null-space constraint," in *Proc. IEEE VTC Fall*, 2002, vol. 1, pp. 171–174.

[7] H. Sung, S.-H. Park, K.-J. Lee, and I. Lee, "Linear precoder designs for K-user interference channels," *IEEE Trans. Wireless Commun.*, vol. 9, no. 1, pp. 291–301, Jan. 2010.

[8] K.-K. Wong, R.-K. Cheng, K. Letaief, and R. Murch, "Adaptive antennas at the mobile and base stations in an OFDM/TDMA system," *IEEE Trans. Commun.*, vol. 49, no. 1, pp. 195–206, Jan. 2001.

[9] A. Pollok, W. Cowley, and N. Letzepis, "Symbol-wise beamforming for MIMO-OFDM transceivers in the presence of co-channel interference and spatial correlation," *IEEE Trans. Wireless Commun.*, vol. 8, no. 12, pp. 5755–5760, Dec. 2009.

[10] Y.-F. Liu, Y.-H. Dai, and Z.-Q. Luo, "Max–min fairness linear transceiver design for a multi-user MIMO interference channel," in *Proc. IEEE ICC*, Jun. 2011, pp. 1–5.

[11] M. Toutounchian and R. Vaughan, "SINR-based transceiver design in the K-user MIMO interference channel using multi-objective optimization," in *Proc. IEEE 78th VTC Fall*, Sep. 2013, pp. 1–5.

[12] H. Shen, B. Li, M. Tao, and X.Wang, "MSE-based transceiver designs for the MIMO interference channel," *IEEE Trans. Wireless Commun.*, vol. 9, no. 11, pp. 3480–3489, Nov. 2010.

[13] O. El Ayach, S. Peters, and R. Heath, "The feasibility of interference alignment over measured MIMO-OFDM channels," *IEEE Trans. Veh. Technol.*, vol. 59, no. 9, pp. 4309–4321, Nov. 2010.