Volume 5, Issue 5, May 2015 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Dynamic Robust Hybrid Optimal Data Send MIMO by using EHDM Algorithm

T.Varsha*, Bullarao.D, Nageswara Rao Putta
Department of Computer Science,
SITS, JNTUA, Andhra Pradesh, India

Abstract— I introduce a multi-stage hybrid optimization approach to linear encoder design in multiuser MIMO systems and propose two efficient MIMO algorithms that also incorporate robustness against channel estimation errors. The first one called Dynamic maximization robust (DMR) encoding employs a multistage optimization process and achieves exceptional transforming performance at low complexity in various multiuser scenarios. The second algorithm known as enhanced HDM (EHDM) precoding adopts a three-stage optimization strategy and provides better performance than DMR in certain full spatial multiplexing scenarios where multiple data streams are transmitted to each of the simultaneous users.

Keywords— Multiuser MIMO, hybrid precoding, diversity, spatial multiplexing, uplink-downlink duality.

I. INTRODUCTION

Multiuser MIMO (MU-MIMO) constitutes an integral part of the fourth generation (4G) mobile technologies and beyond due to its great potential for increasing the system capacity of cellular networks. The downlink transmission problem in MUMIMO systems involves mitigating the multiuser interference (MUI) using some linear or nonlinear pre coding scheme at the base station (BS) and optimizing the downlink transmit power allocation for each user subject to an average total power constraint. Linear MU-MIMO transmission schemes can be broadly classified according to the optimization criteria used and may have certain advantages as well as limitations depending on the adopted algorithm.

Channel inversion (zero-forcing (ZF) pre coding) and regularized channel inversion [2], [3], [4], [5] (minimum mean square error (MMSE) pre coding) are the simplest linear pre coding schemes for the multiuser downlink. These schemes only support single-antenna user equipment (UEs), resulting in a vector channel for each user can significantly improve the performance of MU-MIMO systems in terms of the bit-error rate (BER) as well as the achievable sum-rates. For example, the authors in [2] distinguish between areas with line of sight connection to an interfering base station and thus high interference and areas with minimal or no interference due to large shadowing effects of buildings in the Manhattan scenario. The areas are defined on a purely geometrical basis, taking neither reflections ,diffraction nor other spatial effects into account. On the other hand, other schemes assume that the interference is so large that more resources than necessary are spent. For instance, in [3], a two-hop cell with four relay nodes (RNs) is investigated. On the first hop, the base station (BS) transmits the data to four RNs. Therefore, the use of multiple UE antennas can potentially take the performance of MU-MIMO systems to a much higher level, provided favorable propagation conditions exist. All precoding techniques can be classified by the amount of the MUI they allow (as zero or non-zero MUI techniques) and linearity (as linear and non-linear techniques). Linear precoding techniques require no overhead to provide the mobile the demodulation information and are less computationally expensive than non-linear. However, non-linear techniques can provide much higher capacity.

Block diagonalization (BD) is a linear pre-coding technique for the downlink of MU MIMO systems [1]. It decomposes a MU MIMO downlink channel into multiple parallel independent single-user MIMO downlink channels. The signal of each user is pre-processed at the transmitter using a modulation matrix that lies in the null space of all other users' channel matrices. Thereby, the MUI in the system is efficiently set to zero. BD can be used with any other previously defined single-user MIMO technique [2], as the different users do not interfere with each other. BD is attractive if the users are equipped with more than one antenna. However, the zero MUI constraint can lead to a significant capacity loss when the users' subspaces significantly overlap. Another technique also proposed in [1], named successive optimization (SO), addresses the power minimization and the near-far problem and it can yield better results in some situations but its performance depends on the power allocation and the order in which the users' signals are preprocessed. The zero MUI constraint is relaxed and a certain amount of interference is allowed.

Tomlinson-Harashima precoding is a non-linear pre-coding technique developed for single-input, single-output (SISO) multipath channels. Recently it has been also proposed for the equalization of MUI in MIMO systems [3], where it performs spatial pre-equalization instead of temporal, for ISI channels. Minimum mean-square-error (MMSE) precoding in combination with THP is proposed in [4]. MMSE balances the MUI in order to reduce the performance loss while the THP is used to eliminate the part of the MUI and improves the diversity. However, for two closely spaced antennas, as in the case when the user is equipped with multiple antennas, the inter-stream interference mitigation still causes some performance loss. This paper is organized as follows. In Section 2, we describe the MU downlink channel.

In Section 3, we describe the precoding techniques that will be compared and in Section 4, we present the results of the simulations. A short summary follows in the Section 5.

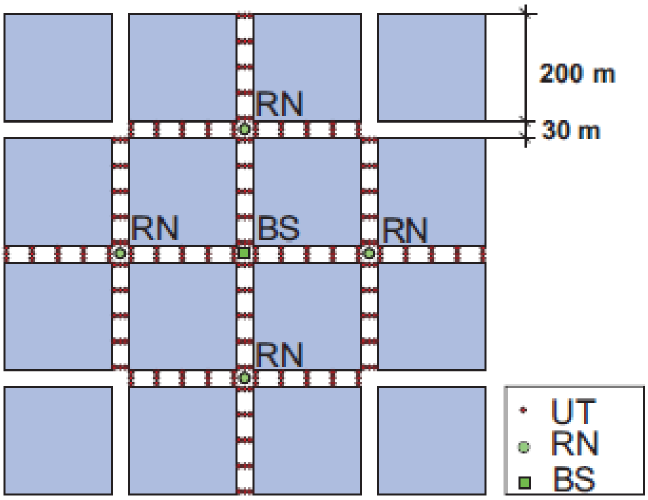

Fig. 1. The investigated Manhattan scenario. The red dots indicate the possible positions of the user terminals (UTs).

Displaying with the light green circles and there are under the rooftop and there are placed in the street crossings. They are equipped with 8 directional antennas, which are arranged in four uniforms liner arrays, one for every street. The user terminals (UTs) possess two antennas each. To obtain a realistic insight into the impact of multi-user interference in such a scenario, Each realization represents an independent operating condition and is characterized by 16 users located randomly on the grid of red dots shown in Fig. 1.

Simple linear techniques like channel inversion and regularized channel inversion [1]–[4] are applicable if each user equipment (UE) utilizes a single receive antenna though the performance is generally much lower than that of nonlinear techniques based on dirty paper coding [4], [5]. However, linear MU-MIMO downlink techniques that allow the use of multiple receive antennas at the UE are of particular interest since they can provide higher diversity gain using single-stream transmission or alternatively, multi-stream transmission can be employed to obtain spatial multiplexing gain for the users. Block diagonalization (BD) [6], successive minimum mean square error (SMMSE) [7] and regularized block diagonalization (RBD) [8] are examples of low-complexity precoding techniques for multi-antenna UEs which provide closed-form expressions for the precoding matrices. However, this advantage comes at the cost of lower performance.

Several linear transmission schemes based on iterative processing at the BS have also been proposed in literature (e.g., [8]–[15]). Such schemes are capable of achieving higher performance gains at the expense of significantly increased complexity. Total-MMSE (T-MMSE) [12], the direct optimization scheme of [14], and modified TMMSE (MT-MMSE) [15] are joint transmit -receive optimization techniques based on minimization of the sum of the mean square errors (MSEs) for all simultaneous users. MT-MMSE uses a modified total MMSE criterion resulting in better performance. In [11] and [13], the uplink/downlink duality is exploited to obtain a convex objective function which converges to the exact MMSE solution. Iterative RBD (IRBD) [8] is another interesting iterative scheme which allows the unused row subspace of a user's channel to be utilized for other users' transmissions by iteratively performing RBD. Even though IRBD is generally outperformed by T-MMSE, MT-MMSE and the duality-based schemes, it is much simpler to implement and still provides good performance.

In this paper, we present a new hybrid iterative MU-MIMO downlink transmission scheme referred to as hybrid diversity maximization (HDM). HDM combines a simple iterative modified RBD (IMRBD) scheme and the minimum sum-MSE criterion of [12] and [14] to minimize the average bit-error rate (BER) while maintaining reasonably low system complexity. We analyze the proposed HDM scheme by using single-stream transmission for each multi-antenna UE in order to maximize the diversity gain.

The paper is organized as follows: In Section II, we describe the system model for MU-MIMO downlink transmission. Section III presents a detailed description of the proposed downlink transmission scheme. The simulation results, comparing the performance of the proposed scheme with other techniques, are presented in Section IV. Section V finally concludes the paper.

This paper solves the most general problem in this area, eliminating most of the constraints placed on this problem in previous works. We jointly optimize the power allocation and transmit and receive filters for both problems of minimizing transmit power with QoS constraints and for minimizing SMSE with a total transmit power constraint for the MIMO case. The system model under consideration allows for an arbitrary number of transmit antennas and an arbitrary number of receive antennas at each user. Each user, in turn, may receive multiple data streams. In this regard, this paper generalizes previously known algorithms for the MISO case incorporating joint transmit/receive processing. The only limitations are resolvability constraints due to the linear precoding/decoding used. Unlike in [11], our proposed power minimization algorithm does not diverge in some scenarios. This allows for an examination of feasibility of a set of target SINRs.

II. MULTI-USER MIMO DOWNLINK AND UPLINK SYSTEM

The next generation of wireless mobile communication systems requires the reliable transmission of high-rate data under various types of channels and scenarios. Current wireless mobile, data, and fixed access communication systems are converging into a data (all IP) oriented wireless networks with high spectral efficiency. Future wireless communication systems should be flexible and adaptive to various scenarios and Quality-of-Service (QoS) requirements. The system should be robust to the influence of fading, interference, and hardware imperfections.

The very high data rates that are required for future wireless systems in reasonably large areas do not appear to be feasible with the conventional techniques and architectures. Frequency bands that are envisioned for future wireless communication systems are well above 2 GHz. The radio propagation in these bands is significantly more vulnerable to non-line-of sight (NLOS) conditions, which is typical in modern urban communications. The efficient design of wireless systems will require the use of multiple antennas, advanced adaptive modulation and coding schemes, relaying nodes, cooperative networks and users, and cross-layer design.

The goal of reaching high data rates is particularly challenging for systems that are power, bandwidth, and complexity limited. However, another domain can be exploited to significantly increase channel capacity: the use of multiple transmit and receive antennas. Pioneering work by Winters [1], Telatar [2], and Foschini [3] ignited much interest in this area by predicting remarkable spectral efficiencies for wireless systems with multiple antennas when the channel exhibits rich scattering and the channel state information (CSI) can be accurately tracked. This initial promise of exceptional spectral efficiency resulted in an explosion of research activities to characterize the theoretical and practical issues associated with multiple-input multiple-output (MIMO) channels and to extend these concepts to multi-user systems. The main question from both a theoretical and practical standpoint is whether the enormous initially predicted capacity gains can be obtained in a more realistic operating scenarios and what specific gains result from adding more antennas and overhead or computational power to obtain CSI at the transmitter and receiver.

The large spectral efficiencies associated with MIMO channels are based on the premise that a rich scattering environment provides independent transmission paths for each transmit receive antenna pair. Therefore, for single-user (SU) systems, a transmission and reception strategy that exploits this structure achieves capacity on approximately min(MT,MR) separate channels, where MT is the number of transmit antennas and MR is the number of receive antennas. Thus, capacity scales linearly with min(MT,MR) relative to a system with just one transmit and one receive antenna. The capacity increase requires a scattering environment such that the matrix of channel gains between each transmit and receive antenna pair has full rank and independent entries and that perfect estimates of these gains are available at the transmitter and receiver.

Space-time coding (STC) [4], [5], and spatial multiplexing (SMUX) [3], [6], provide full diversity and achieve high data rates over MIMO channels, respectively. Spatial mul tiplexing involves transmitting independent streams of data across multiple antennas to maximize throughput, whereas space-time coding maps input symbol streams across space and time for diversity and coding gain at a given data rate. Neither scheme requires CSI at the transmitter. However, to achieve the maximum information rate and/or the diversity and array gain afforded by increased computational complexity, appropriate precoding and modulation techniques are necessary.

Generalized designs of a jointly optimum linear precoder and decoder for a SU MIMO system, using a mean-squared error (MSE) criterion are presented in [7] and [8]. The framework presented in these papers is general and addresses several optimization criteria like minimum MSE (MMSE), minimum bit error rate (BER) and maximum information rate. It is assumed that the channel is known at the receiver as well as at the transmitter. CSI can be acquired at the transmitter either by using feedback from the receiver or by using the reciprocity principle when the transmitter and receiver operate in time division duplex (TDD) so that the time-invariant MIMO channel transfer function is the same in both ways. The optimum precoder and decoder diagonalize the MIMO channel into eigen subchannels. The different solutions targeting different optimization criteria are obtained by using different power allocation schemes over these subchannels. For example, the optimum linear precoder and decoder that maximize the information rate, decouple the MIMO channel into eigen subchannels and allocate power to these subchannels according to the water-pouring policy [7], [9].

An important research topic is the study of multi-user (MU) MIMO systems. Such systems have the potential to combine the high capacity achievable with MIMO processing with the benefits of space division multiple access (SDMA). In the MU MIMO scenario, a base station (BS) or an access point (AP) is equipped with multiple antennas and it is simultaneously communicating with a group of users. Each of these users is also equipped with multiple antennas. Motivated by the need for cheap mobiles with low power consumption, we focus on systems where the complex signal processing is performed at the BS/AP. The BS/AP will use the CSI available at the transmitter to allow these users to share the same channel and mitigate or completely eliminate multi-user interference (MUI) in an ideal case.

In a MU scenario, capacity becomes a K-dimensional region defining the set of all rate vectors (R1,...,RK) simultaneously achievable by all K users. Two MU MIMO scenarios can be distinguished. In the first scenario, multiple non-cooperative terminals are transmitting to a single receiver. This scenario is often referred to as the MU MIMO uplink (UL) channel. In the information theory it is known as the MIMO multiple access channel (MAC). The scenario, in which a single terminal is transmitting to multiple non cooperative receivers is referred to as MU MIMO downlink channel or broadcast channel (BC). MU MIMO downlink system is depicted in Figure 1.1 and MU MIMO uplink system is depicted in Figure 1.2. The capacity region of a general MIMO MAC was obtained in [2], [10]. It has been shown that a linear detection with successive interference cancellation (SIC) provides the maximum sum rate capacity of a MU MAC system. However, the capacity of a MIMO BC is an open problem due to the lack of a general theory on non-degraded broadcast channels. In pioneering work by Caire and Shamai [11], a set of achievable rates for the MIMO BC was obtained by applying Costa's "dirty-paper" coding (DPC) technique at the transmitter [12]. In [12], Costa proved the surprising result that the capacity of the channel, when the non-causal additive Gaussian interference is perfectly known at the transmitter, is the same as if the interference was not present. It was also shown in[11]

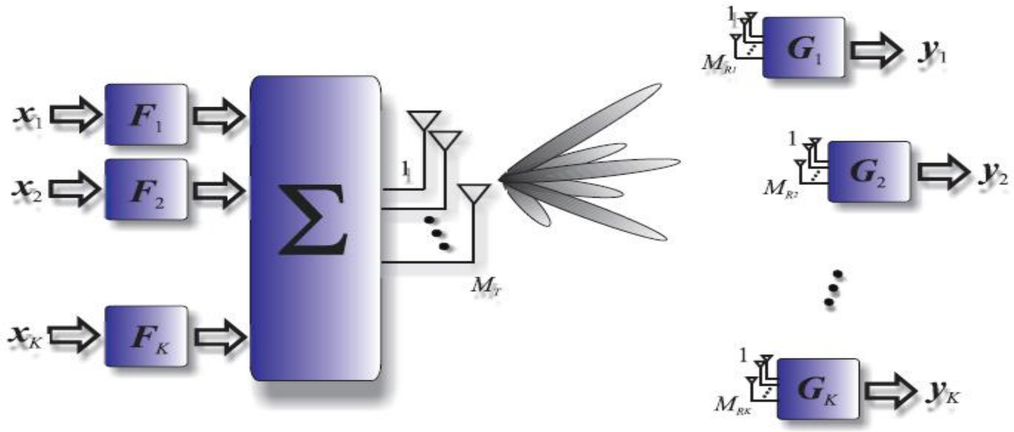

Figure 2.1: Block diagram of multi-user MIMO downlink system.

that the sum rate MIMO BC capacity equals the maximum sum rate DPC achievable region by demonstrating that the achievable rate meets the Sato upper bound [13]. DPC is a technique that allows non-causally known interference to be "pre-subtracted" at the transmitter. In [14], [15] it was shown that the achievable region of the MIMO BC obtained using DPC is equal to the capacity region of the MIMO MAC using uplink downlink duality. This allows us to substitute the non-convex problem of finding the DPC rate region with the dual MAC problem where the rates are convex functions of the correlation matrices.

DPC can achieve the maximum sum rate of the system and provide the maximum diversity order [16], [17]. However, these techniques require the use of a complex sphere decoder or an approximate closest-point solution, which makes them hard to implement in practice, especially when the number of users is large [17]. Tomlinson-Harashima precod ing (THP) was first developed for single-input single-output (SISO) multipath channels, where it was used to overcome the error propagation problem of decision feedback filter ing, [18], [19]. In [20] it is proposed for the equalization of MUI in MIMO systems. In [21] the authors propose the use of THP in combination with MMSE filtering. In [21] successive interference cancellation is performed at the transmitter, whereas the receiver still performs linear filtering. In [22], both feedforward and feedback filters are deployed at the transmitter which results in a significant reduction of the computational load at the receiver side. Although DPCs outperform THP, THP is much less computationally demanding and thus more attractive for practical implementation.Linear MU MIMO processing techniques are less computationally demanding than DPCs, and they can use either instantaneous channel knowledge or long-term statistics of

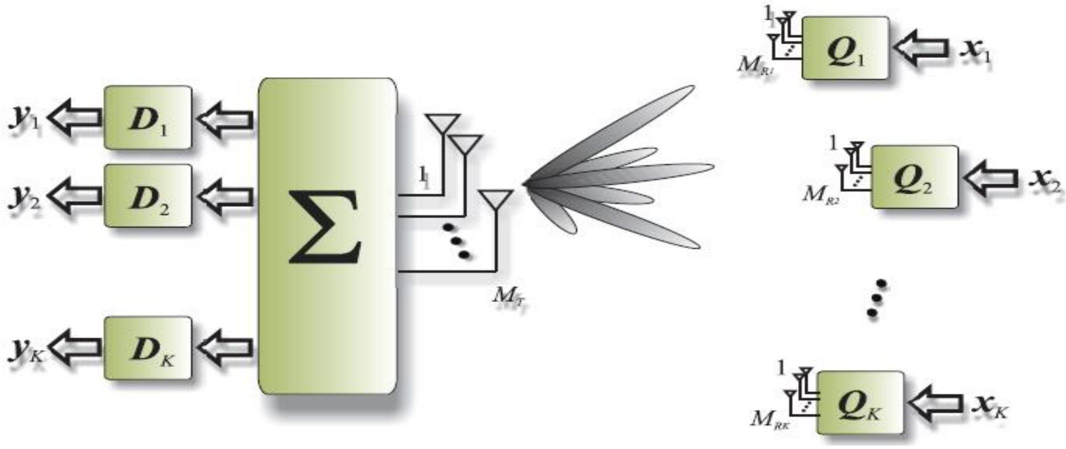

Figure 2.2: Block diagram of multi-user MIMO uplink system.

the channel to perform precoding or decoding. In general, linear MU MIMO processing techniques cannot provide the maximum sum rate capacity, but there are some cases where this is possible and where the MUI is set to a minimum by choosing semi-orthogonal users for simultaneous transmission using SDMA [23]. In this thesis it will be empirically shown that linear processing techniques reach the sum-rate capacity of the BC channel also when the total number of antennas at the user terminals is equal to or greater than the number of antennas at the base station. Non-linear MU MIMO processing techniques require the instantaneous knowledge of the channel transfer function at the BS. On the other hand, linear MU MIMO processing techniques can be used with various degrees of channel state information. Thus, linear techniques are more flexible and more favorable for practical implementation than non-linear techniques

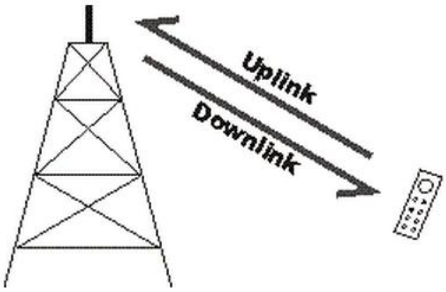

Figure 2.3: Block diagram of multi-user MIMO downlink and uplink system

III. EXPERIMENTAL RESULTS

Macroscopic fading is caused by shadowing effects of buildings or natural features and is determined by the local mean of the fast fading signal. Microscopic fading corresponds to rapid fluctuations of the received signal in time, frequency, and space and is caused by the signal scattering off objects between the transmitter and the receiver. The effective path loss follows an inverse n^{th} power law. In real environments the path loss exponent varies from 2.5 to 6 and is also a function of the terrain and foliage.

In a multipath environment, several time-shifted and scaled versions of the transmitted signal arrive at the receiver, which cause frequency selective fading. The maximum spread of path delays is called time delay spread Ґmax. The root-mean-squared (RMS) delay spread of the channel $^{\delta}$, is defined as [9]

$$\sigma_\tau = \sqrt{\frac{\int_0^{\tau_{max}} (\tau - \bar{\tau})^2 \, \mathrm{PDP}(\tau)\, d\tau}{\int_0^{\tau_{max}} \mathrm{PDP}(\tau)\, d\tau}}$$

where PDP(_) is the power delay profile of the channel, i.e. the average power as a function of delay, and

$$\bar{\tau} = \frac{\int_0^{\tau_{max}} \tau \mathrm{PDP}(\tau)\, d\tau}{\int_0^{\tau_{max}} \mathrm{PDP}(\tau)\, d\tau}$$

Frequency selective fading is characterized by the coherence bandwidth BC which is inversely proportional to the RMS delay spread and is a measure of a channel's frequency selectivity. When the coherence bandwidth is comparable or less than the signal bandwidth, the channel is said to be frequency selective.

The comparison of the DPC sum rate capacity bound of the BC and the previously introduced very simple (VS) BC sum rate capacity bound is shown in Figures 3.1 and 3.2. The first VS BC sum rate capacity bound is obtained using the equation which corresponds to the capacity of the MU MIMO channel where all users are orthogonal in space. However, the influence of MUI which is neglected is too big and as a result this bound is too loose. The other option is to substitute the precoding matrices Qk obtained by maximizing in the expression for dual MAC . As it can be seen from Figure 3.1, in case of low MUI, i.e., when the total number of antennas at the user terminals is less or equal to the number of antennas at the base station, the second approximate VS bound, when the interference between the users is also taken into account when calculating the system capacity, is the same as the DPC bound. In case of high MUI, i.e., when the number of antennas at the user terminals is greater than the number of antennas at the base station, the approximate VS BC sum rate capacity bound is very close to the DPC bound and at high SNRs it matches the DPC bound. The antenna configuration of the system in Figures 3.1 and 3.2 is: at the base station we have 6 antennas, and there are three users in the system. In the first figure all users are equipped with 2 antennas and in the second figure all users are equipped with 4 antennas each.

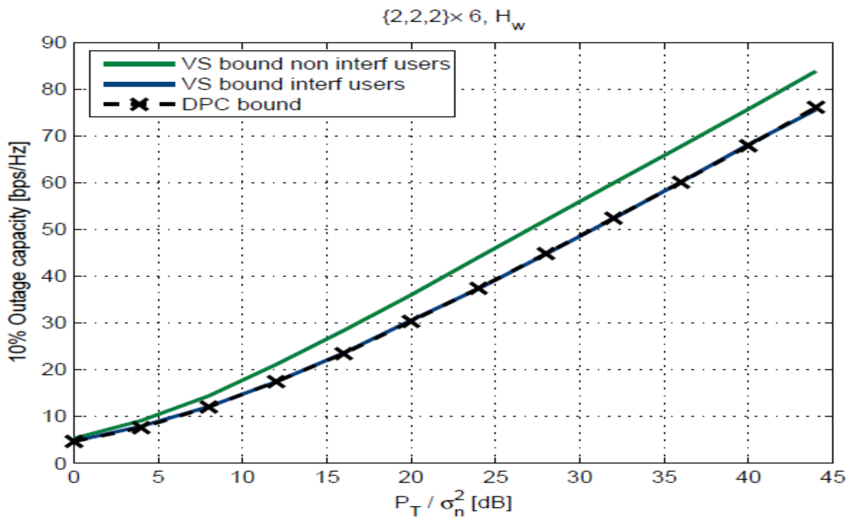

Figure 3.1: Broadcast channel upper bounds. 10 % Outage capacity. MR ≤ MT case

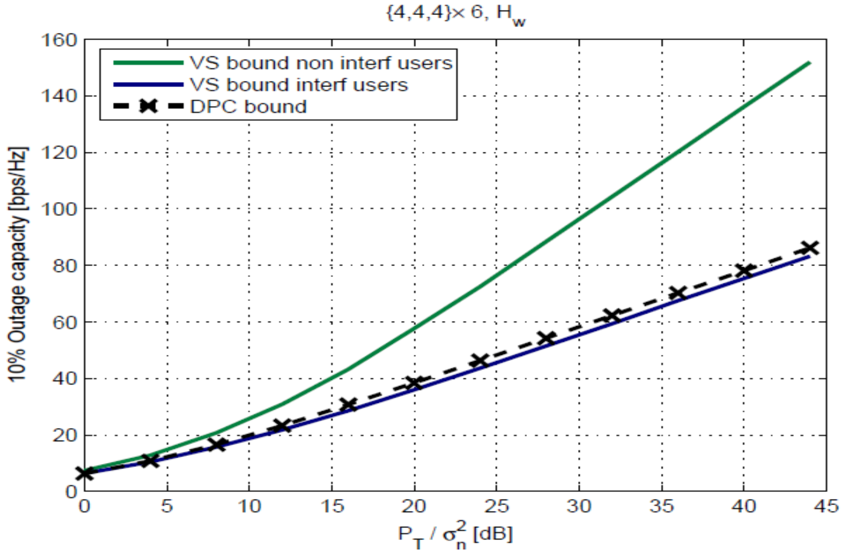

Figure 3.2: Broadcast channel upper bounds. 10 % Outage capacity. MR > MT case.

IV. CONCLUSION

We have proposed two robust linear transmission schemes for the multiuser MIMO downlink, namely HDMR and EHDM. Both schemes are based on the hybrid optimization concept where multiple optimization stages are used to com-pute the final Tx encoders. The dual-stage HDMR algorithm exhibits fast convergence and is particularly effective in single-stream as well as multi stream transmission scenarios with fewer transmitted data streams than the number of channel seigenmodes and/or a sufficiently large number of UE antennas providing extra diversity gain. HDMR achieves high performance in such scenarios at much lower complexity than other iterative algorithms, rendering it well-suited to practical implementation. The three-stage EHDM algorithm outperforms HDMR in multi stream transmission scenarios with full spatial multiplexing and a minimal set of Rx antennas at each UE, though at the cost of relatively higher com-plexity. Both schemes incorporate robustness against channel estimation errors and generally achieve lower BERs compared to non-robust techniques in the aforementioned full spatial multiplexing scenarios.

REFERENCES

[1] G. Cinis and J. Cioffi, "A multi-user precoding scheme achiev-ing crosstalk cancellation with application to DSL systems," in Proc. Asilomar Conf. on Signals, Systems, and Computers, November 2000, vol. 2, pp. 1627–1637.

[2] V. Stankovic and M. Haardt, "Multi-user MIMO downlink pre-coding for users with multiple antennas," in Proc. Of the 12-th Meeting of the Wireless World Research Forum (WWRF), Toronto, Canada, November 2004.

[3] T. Haustein, A. Forck, H. Gäbler, C. V. Helmolt, V. Jungnickel, and U. Krüger, "Implementation of adaptive channel inversion in a real-time MIMO system," in Proc. 2004 IEEE Int. Symp. Pers., Indoor Mobile Radio Commun., pp. 2524–2528.

[4] K. K. Wong, R. D. Murch, and K. B. Letaief, "A joint-channel diagonalization for multiuser MIMO antenna systems," IEEE Trans. Wireless Commun., vol. 2, no. 4, pp. 773–786, July 2003.

[5] J. Zhang, Y. Wu, S. Zhou, and J. Wang, "Joint linear transmitter and receiver design for the downlink of multiuser MIMO systems," IEEE Commun. Lett., vol. 9, no. 11, pp. 991–993, Nov. 2005.

[6] J. Joung and Y. H. Lee, "Regularized channel diagonalization for multiuser MIMO downlink using a modified MMSE criterion," IEEE Trans. Signal Process., vol. 55, no. 4, pp. 1573–1579, Apr. 2007.

[7] A. Mezghani, M. Joham, R. Hunger, and W. Utschick, "Transceiver design for multi-user MIMO systems," in Proc. ITG/IEEE Workshop on Smart Antennas (WSA 2006), Ulm, Germany, Mar. 2006.

[8] Q. H. Spencer and M. Haardt, "Capacity and downlink transmission algorithms for a multi-user MIMO channel," in Proc. 2002 Asilomar Conf. Signals, Syst., Comput., pp. 1384–1388.

[9] V. Stankovic, "Multi-user MIMO wireless communications," Ph.D. dissertation, Ilmenau University of Technology, Ilmenau, Germany, Nov. 2006.

[10] F. Khalid and J. Speidel, "Hybrid diversity maximization precoding for the multiuser MIMO downlink," in Proc. 2011 IEEE Int. Conf. Commun., pp. 1–5.

[11] F. Khalid, "Hybrid precoding for multiuser multiple-input multiple-output mobile communications," Ph.D. dissertation, University of Stuttgart, Stuttgart, Germany, Sep. 2012.

[12] T. Haustein, C. V. Helmolt, E. Jorswieck, V. Jungnickel, and V. Pohl, "Performance of MIMO systems with channel inversion," in Proc. 2002 IEEE VTC — Spring, pp. 35–39.

