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Interference Mitigation in MIMO Systems by Subset Antenna Transmission

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Abstract- In this paper we proposed an adaptive power allocation scheme for MIMO systems by using subset antenna transmission (SAT) techniques to increase the spectral efficiency in the presence of co-channel interference (CCI). These techniques out performs all-antenna transmission scheme by achieving low BLER even in higher modulation order. This scheme uses the phenomena of unbalanced eigen modes in channel matrices often observed in the presence of high-power interference or noise. We also infer that the capacity loss is reduced by allocating transmit power equally on a selected subset of transmit antennas.

Keywords- Channel State Information, Subset Antenna Transmission, Co-Channel Interference, Block Error Rate, Signal-to-Noise Ratio, Signal-to-Interference Ratio, Intersymbol Interference, Multiple Input Multiple Output.

1. INTRODUCTION

The impairments from CCI and ISI have been major obstacles to reliable communication in long-range cellular networks and in short-range wireless local- and personal-area networks. Linear filtering, equalization, and diversity combining techniques have been traditional means to combat the impairments in separate or joint fashions. Also, the interference cancelling techniques designed for decoding of multiple single-user signals have been applied in decoding of spatially multiplexed data streams in MIMO systems. However, the impairments from high-power CCI and ISI in time-varying channels still impose severe constraints in the design of practical interference resilient receivers [2, 3, 4].

INTERFERENCE MITIGATION IN MIMO SYSTEMS BY SUBSET ANTENNA TRANSMISSION

The capacity of a multiple-input multiple-output (MIMO) system depends on the number of transmit/receive antennas, the correlation between the channel coefficients of individual paths, and the method for allocating the power over the transmit antennas [5]. If channel state information (CSI) is available at the transmitter, power allocation by a water-filling algorithm is known to optimize capacity for AWGN channels. Likewise, if CSI is not available, equal power distribution is optimum for AWGN channels. However, if co-channel interference (CCI) is present, these techniques no longer optimize capacity.

(1.1) Channel capacity with equivalent channel matrix

The system under consideration has a single-user link of interest affected by CCI from another user. The user of interest and interfering user have M transmit and N receive antennas, respectively. In a at faded MIMO system, the received signal vector Yn*1 is

$$\begin{aligned} \mathbf{y} &= \sqrt{P_T}\mathbf{H}\mathbf{s} + \sqrt{P_I}\mathbf{H}_I\mathbf{s}_I + \mathbf{w} \\ &= \mathbf{H}\mathbf{s} + \mathbf{n} \end{aligned}$$

(1.2) Condition number

The condition number of matrix A is defined as

$$\kappa(\mathbf{A}) = \rho(\mathbf{A})\rho(\mathbf{A}^{-1}) = |\lambda_{max}(\mathbf{A})/\lambda_{min}(\mathbf{A})|$$

where $\rho(\mathbf{A}) \equiv \max\{|\lambda| : \lambda$ is an eigen value of Ag is the spectral radius of a matrix A. Condition number often used to measure the invertibility of a matrix, i.e., a matrix having a larger condition number is more likely to be singular than one having a smaller condition number. A large condition number generally indicates the presence of a dominant eigen mode in a given matrix as well. Figure 30 shows the probability density function (pdf) of the condition number with different signal-to-interference ratio (SIR), PT =PI , conditions at a signal-to-noise ratio (SNR) PT =_2 of 30 dB. Each pdf is obtained from 10,000 independent channel realizations.

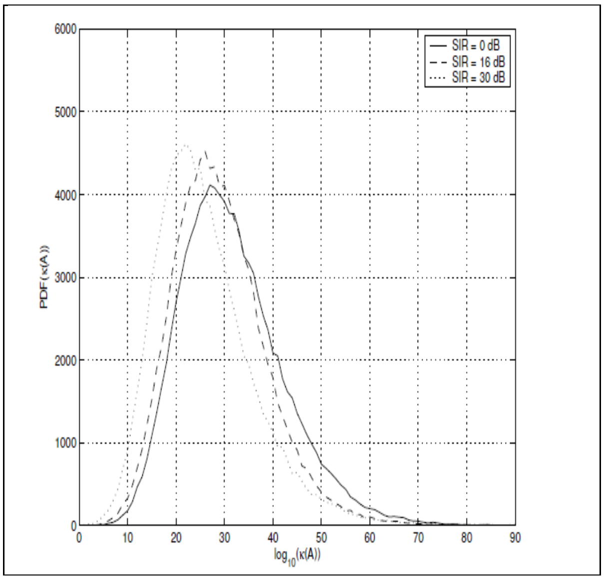

Figure 1

2. EFFECTIVE EIGENMODES

The dominance of the largest eigen mode in the low SIR regime is intensified by the nature of the water-filling algorithm. Elimination of all but the few largest eigen modes in the low SNR regime has been observed previously and is apparent in Figure as well. In Figure, ill-conditioned (large k (A)) channel matrix pour most of the power into the small deepest buckets (eigen modes) as the transmit power reduces from PH to PL. However, the channel matrix A is well-conditioned (small k (A)), and most of the eigen modes are carrying information with corresponding allocated transmit power even with reduced total power level .

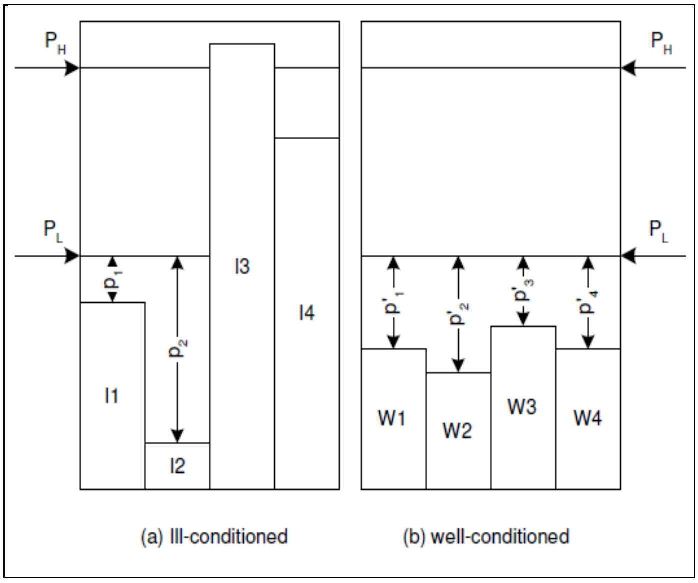

Figure 2

Let us denote the number of effective eigen modes η as

$$\eta = E\{\#\text{ of eigenmodes } \lambda_i \text{where } p_i \neq 0 \mid \gamma\}.$$

The capacity of a MIMO system employing the equal-power distribution scheme over M transmit antennas is

$$\begin{aligned} C_M &= \log_2 \det\left(\frac{P_T}{M}\hat{\mathbf{H}}\hat{\mathbf{H}}^H + \mathbf{I}\right) \\ &= \sum_{i=1}^{M} \log_2\left(\frac{P_T}{M}\lambda_i + 1\right) \end{aligned}$$

3. SUBSET ANTENNA SELECTION

The selection of the antenna subset is an important factor that changes the capacity of the proposed power allocation technique with SAT. The size of subset antenna set, ^M , can be specified by determining the average number of effective eigen modes through computer simulation. Without loss of generality, we assume that only the CSI of the desired signal is available at the transmitter and receiver in the presence of unknown CCI. With this condition, we employed norm-based and cross correlation-based antenna selection criteria computed from the CSI of the desired signal in the computer simulations for their simplicity and practicality.

(3.1) Maximum Modulus

This norm-based techniques chooses ^M antennas having the largest modulus of the channel coefficient vector, Mi, for transmission, where

$$\mathcal{M}_i = \sqrt{\sum_{j=1}^{N} h_{ij} h_{ij}^H}, \quad 1 \le i \le M$$

where hij is the channel coefficient from ith transmit to jth receive antenna.

(3.2) Minimum cross-correlation:-

$$\mathcal{R}_{ij} = \sum_{k=1}^{N} h_{ik} h_{jk}^H, \qquad i \neq j.$$

(3.3) Random Selection

A randomly selected M^ antenna subset can be a last resort for the worst case, where even the CSI of desired signal may not available at the transmitter.
SAT antenna selection criteria and corresponding capacities :-

	Ant. Sel.	Capacity
EP1R	1 Random	$\log_2 \det(P_T \hat{\mathbf{H}}_{r1} \hat{\mathbf{H}}_{r1}^H + \mathbf{I}_N)$
EP1M	1 Max $\mathcal{M}_i$	$\log_2 \det(P_T \hat{\mathbf{H}}_{m1} \hat{\mathbf{H}}_{m1}^H + \mathbf{I}_N)$
EP2R	2 Random	$\log_2 \det(\frac{P_T}{M} \hat{\mathbf{H}}_{r2} \hat{\mathbf{H}}_{r2}^H + \mathbf{I}_N)$
EP2M	2 Max $\mathcal{M}_i s$	$\log_2 \det(\frac{P_T}{M} \hat{\mathbf{H}}_{m2} \hat{\mathbf{H}}_{m2}^H + \mathbf{I}_N)$
EP2C	2 Min $\mathcal{R}_i s$	$\log_2 \det(\frac{P_T}{M} \hat{\mathbf{H}}_{c2} \hat{\mathbf{H}}_{c2}^H + \mathbf{I}_N)$
EP4	All 4	$\log_2 \det(\frac{P_T}{M} \mathbf{H} \mathbf{H}^H + \mathbf{I}_N)$

Table 1

The subset selection criteria and their capacity is listed in the above table.

4. SAT IN V-BLAST TYPE RECEIVER

(4.1) V-Blast Architecture

To achieve the higher capacity predicted by previous studies using MIMO schemes, the architectures known as vertically layered BLAST (D/V-BLAST) are proposed. The data stream is demultiplexed into M substreams, and fed into a transmitter antenna in M*N V-BLAST MIMO systems.

The encoding process is a simple bits-to-simple mapping, and all substreams are mapped independently. The total transmit power is equally divided into M transmitters. The channel matrix H is assumed to remain constant, i.e., quasi-stationary, during the transmission of a whole data block.

(4.2) Decoding process of V-blast

The detection process of the V-BLAST scheme estimates the transmitted symbols given received signal vector **y** and channel matrix **H** in

Y=Hs + n.

For the SAT scheme, the M^ elements of the transmitted symbol vectors are assumed to be uncorrelated. The channel matrix is assumed to be known to the receiver , and to be full rank. The decision process involves linear nulling and estimated symbol cancellation.

5. RESULTS

The performance of the proposed SAT method is evaluated by computer simulations. The simulations use 10000 channel realizations for each SIR and SNR condition. For SAT scheme realizations, a 4×4 MIMO system is considered. Based on the number of effective eigen modes in low SIR conditions, the number of antennas used in the SAT method is fixed to one-half of total number of antennas, $\hat{M} = M/2 = 2.$

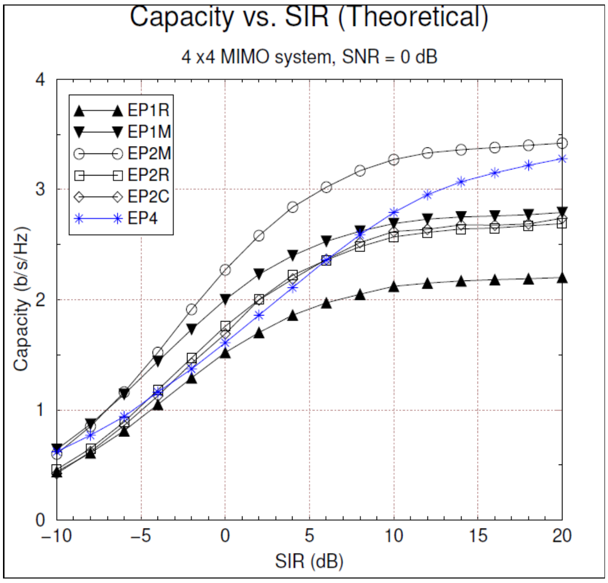

Figure 3

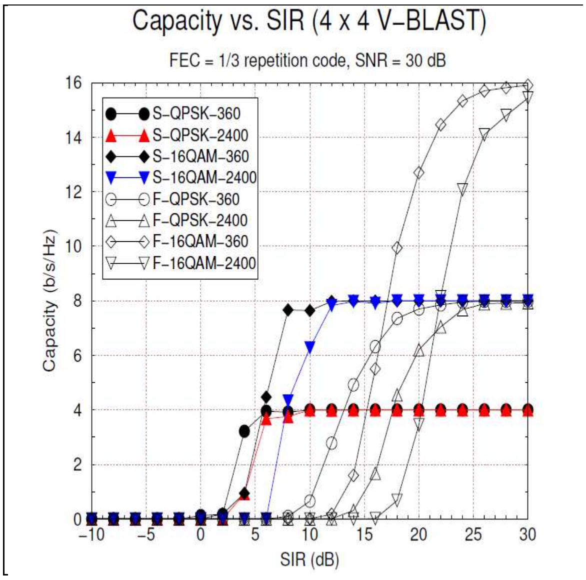

Figure 4

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