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Multi-Input Multi-Output Fading Channel Equalization with Constellation Selection and Space-Time Precoders

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Abstract

We consider multiplexing systems in correlated multiple-input multiple-output (MIMO) fading channels with equal power allocated to each transmit antenna. Under several constraints, the number and subset of transmit antennas together with the transmit symbol constellations are determined assuming knowledge of the channel correlation matrices. The maximum outage data rate of the SCR receiver is seen to be close to the outage channel capacity. Identification of the channel matrix is of main concern in wireless multiple input multiple output (MIMO) systems. To maximize the SNR, the best way to utilize a MIMO system is to communicate on the top singular vectors of the channel matrix. In this paper we addresses t several issues and the problem of channel tracking and equalization for multi-input multi-output (MIMO) time-varying frequency-selective channels. These channels model the effects of inter-symbol interference (ISI), co-channel interference (CCI), and noise. Via singular value decomposition (SVD) analysis, the precoder is used to be shown to outperform the orthogonal frequency division multiplexing (OFDM) precoder in bit-error-rate (BER), transmission rate, and receiver implementation.

Keywords

MIMO, SCR, BER, OFDM

1. Introduction

In today's scenario MIMO is very useful with the is an especially attractive research topic for future scheduling scheme designs and their applications.Multiple-input multiple-output (MIMO) systems offer much larger channel capacity over traditional single-input single-output (SISO) system. Recently, many transmit beam forming Algorithms have been developed to exploit the high capacity in the MIMO systems [1] [2] [3] [4] [5]. Furthermore, in MIMO systems, after selecting the group of users with the currently maximum combination of OFDM system. Exploiting the flexibility of MIMO systems in order to have high data rates feasible rates determined by a packet scheduler in each time-slot, we need to assign them to the transmitter's antennas in such a way that we can achieve the maximum throughput in the system. Diversity techniques such as space-time coding have received a great deal of attention due to their ability to provide higher spectral efficiency than conventional single-input single-output (SISO) systems [6]. When applying these techniques in a frequency-selective channel, a space-time equalizer is required at the receiver to compensate for the inter symbol interference (ISI).

The transmitter/receiver diversities in multiple-input multiple output (MIMO) channels will play a key role in future high-rate wireless communication. In a practical environment, the impairment introduced by multipath propagation and limited bandwidth can cause severe receiver performance degradation. Intersymbol interference (ISI) has become a very critical problem in high-speed telecommunication systems, such as terrestrial television broadcasting and cellular mobile communication systems.

It is thus critical that one designs a channel estimator that takes into account the channel correlation and is capable of providing good identification performance. However, such an estimator often requires information of channel correlation, which is to be obtained by on-line measurement, is susceptible to environment variation and measurement error. We propose a model-based channel estimation analysis with different aspects and scheme that can do without knowledge of second-order.

We also discuss antenna assignment scheme, referred to as max deviation delete (MDD), for the downlink of a MIMO cellular system based on spatial multiplexing, which exploits multiple antennas to achieve a diversity effect from multiple users. Multiple inputs multiple output (MIMO) systems are capable of delivering large increases in capacity through utilization of parallel communication channels [7], [8], [9]. MIMO systems now constitute a major research area in telecommunications. It is also considered to be one of the technologies that have a chance to resolve the bottlenecks of traffic capacity in the forthcoming broadband wireless Internet access networks which is Universal Mobile Telephone Services (UMTS) and beyond.

Antenna selection has also been proposed for enhanced performance in correlated fading [10], [11].

Assuming that the number of RF chains is less than the number of antennas, the antenna selections algorithms choose the optimum subset of transmit and receive antennas based on minimum error rate. The size of the active subsets of transmit and receive antennas is fixed by the number of RF chains. Per-antenna rate control with equal power allocation is applied to uncorrelated fading channels in [12], where it is shown that per-antenna rate control at the fading rate nearly achieves capacity. However, adaptation at the fading rate may be difficult to achieve in practice due to inaccuracies in channel estimates and feedback delays.

The remaining of this paper is organized as follows. We discuss MIMO in Section 2. In Section 3 we discuss about SCR. The evolution and recent scenario in section 4.In section 5 we discuss about model analysis. The conclusions and future directions are given in Section 6. Finally references are given.

2. MIMO

In radio, multiple-input and multiple-output, or MIMO is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology. Note that the terms input and output refer to the radio channel carrying the signal, not to the devices having antennas.

MIMO can be sub-divided into three main categories, precoding, spatial multiplexing or SM, and diversity coding. Precoding is multi-stream beam forming, in the narrowest definition. In more general terms, it is considered to be all spatial processing that occurs at the transmitter. In (single-layer) beam forming, the same signal is emitted from each of the transmit antennas with appropriate phase (and sometimes gain) weighting such that the signal power is maximized at the receiver input. The benefits of beam forming are to increase the received signal gain, by making signals emitted from different antennas add up constructively, and to reduce the multipath fading effect.

Spatial multiplexing requires MIMO antenna configuration. In spatial multiplexing, a high rate signal is split into multiple lower rate streams and each stream is transmitted from a different transmit antenna in the same frequency channel. If these signals arrive at the receiver antenna array with sufficiently different spatial signatures, the receiver can separate these streams into (almost) parallel channels. Spatial multiplexing is a very powerful technique for increasing channel capacity at higher signal-to-noise ratios (SNR). The maximum number of spatial streams is limited by the lesser in the number of antennas at the transmitter or receiver. Spatial multiplexing can be used with or without transmit channel knowledge. Spatial multiplexing can also be used for simultaneous transmission to multiple receivers, known as space-division multiple accesses. By scheduling receivers with different spatial signatures, good separability can be assured.

Diversity Coding techniques are used when there is no channel knowledge at the transmitter. In diversity methods, a single stream (unlike multiple streams in spatial multiplexing) is transmitted, but the signal is coded using techniques called space-time coding. The signal is emitted from each of the transmit antennas with full or near orthogonal coding. Diversity coding exploits the independent fading in the multiple antenna links to enhance signal diversity. Because there is no channel knowledge, there is no beam forming or array gain from diversity coding. Spatial multiplexing can also be combined with precoding when the channel is known at the transmitter or combined with diversity coding when decoding reliability is in trade-off.

Multiple-input and multiple-output (antennas), or MIMO, refers to the use of multiple antennas both at the transmitter and receiver to improve the performance of radio communication systems which is shown in fig 1.

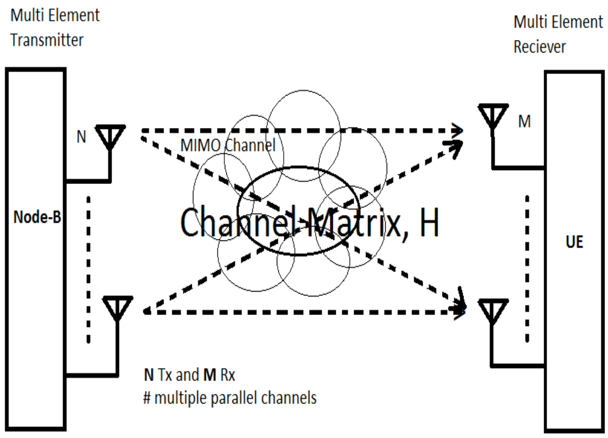

Fig 1: MIMO Transmitter

In MIMO systems, a transmitter sends multiple streams by multiple transmit antennas. The transmit streams go through a matrix channel which consists of multiple paths between multiple transmit antennas at the transmitter and multiple receive antennas at the receiver. Then, the receiver gets the received signal vectors by the multiple receive antennas and decodes the received signal vectors into the original information. Here is a MIMO system model

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{n}$$

Where y and x are the receive and transmit vectors, respectively. In addition, H and n are the channel matrix and the noise vector, respectively.

The average capacity of a MIMO system is as follows:

$$C = E[\max_{\mathbf{Q}} \log_2(\mathbf{I} + \mathbf{H}\mathbf{Q}\mathbf{H}^H)]$$

This is a min (N_t, N_r) time larger than that of a SISO system.

3. SCR

Signal-to-noise ratio (often abbreviated SNR or S/N) is a measure used in science and engineering to quantify how much a signal has been corrupted by noise. It is defined as the ratio of signal power to the noise power corrupting the signal. A ratio higher than 1:1 indicates more signal than noise. While SNR is commonly quoted for electrical signals, it can be applied to any form of signal (such as isotope levels in an ice core or biochemical signaling between cells). In less technical terms, signal-to-noise ratio compares the level of a desired signal (such as music) to the level of background noise. The higher the ratio, the less obtrusive the background noise is. "Signal-to-noise ratio" is sometimes used informally to refer to the ratio of useful information to false or irrelevant data in a conversation or exchange.

Signal to clipping noise ratio (SCR) and active-set methods are two existing methods for peak-to-average power ratio (PAPR) reduction based on tone reservation.
The ideal clipper is defined as

$$clip_A(x_k) = \begin{cases} x_k, & |x_k| \le A \\ A \cdot e^{j\arg\{x_k\}}, & |x_k| > A \end{cases}$$

The clipping noise power is defined as

$$\| \mathbf{x} - clip_A(\mathbf{x}) \|_2^2 = \sum_{n=0}^{N-1} (\mathbf{x} - clip_A(\mathbf{x}))^2 .$$

And the SCR will be

$$SCR = \frac{\| \mathbf{x} \|_2^2}{\| \mathbf{x} - clip_A(\mathbf{x}) \|_2^2} .$$

If we include the Peak Reduction Tones (PRT) to these equations, then the transmitted sequence can be replaced by x+c, where c = Qˆ Cˆ . So the corresponding SCR is

$$SCR = \frac{\| \mathbf{x} \|_2^2}{\| \mathbf{x} + \hat{\mathbf{c}} - clip_A(\mathbf{x} + \hat{\mathbf{c}}) \|_2^2} .$$

To maximize SCR, we just need to minimize the denominator of, since the nominator is the signal sequence we can't control. This optimization problem is also convex (quadratic program) with respect to the unknown's ˆC. It can be optimized exactly using standard software but with high computational complexity.

4. Evolution and Recent Scenario

In 2002, Christos Komninakis et al. [13] proposed about a low-order autoregressive model approximates the MIMO channel variation and facilitates tracking via a Kalman filter. Hard decisions to aid Kalman tracking come from a MIMO finite-length minimum-mean-squared-error decision-feedback equalizer (MMSE-DFE), which performs the equalization task. Since the optimum DFE for a wide range of channels produces decisions with a delay 0, the Kalman filter tracks the channel with a delay. A channel prediction module bridges the time gap between the channel estimates produced by the Kalman filter and those needed for the DFE adaptation. Their proposed algorithm offers good tracking behavior for multiuser fading ISI channels at the expense of higher complexity than conventional adaptive algorithms.

In 2003, Ravi Narasimhan [14] analysis on spatial multiplexing systems in correlated multiple-input multiple-output (MIMO) fading channels with equal power allocated to each transmit antenna. Under this constraint, the number and subset of transmit antennas together with the transmit symbol constellations are determined assuming knowledge of the channel correlation matrices. They first consider a fixed data rate system and vary the number of transmit antennas and constellation such that the minimum margin in the signalto- noise ratio (SNR) is maximized for linear and Vertical Bell Laboratories Layered Space-Time (V-BLAST) receivers. They also derive transmit antenna and constellation selection criteria for a successive interference cancellation receiver (SCR) with a fixed detection order and a variable number of bits transmitted on each sub stream. They compared with a system using all available antennas, performance results show significant gains using a subset of transmit antennas, even for independent fading channels.

In 2004, Tobias Dahl et al. [15] proposed about a new approach for direct blind identification of the main independent singular modes, without estimating the channel matrix itself. The right and left singular vectors with maximum corresponding singular values are determined using payload data and are continuously updated while at the same time being used for communication. The feasibility of the approach is demonstrated by simulating the performance over a noisy, fading time-varying channel.

In 2005, Nihar Jindal et al. [16] compare the capacity of dirty-paper coding (DPC) to that of time-division multiple access (TDMA) or a multiple-antenna (multiple input multiple-output (MIMO)) Gaussian broadcast channel (BC). They find that the sum-rate capacity (achievable using DPC) of the multiple-antenna BC is at most min ( ) times the largest single-user capacity (i.e., the TDMA sum-rate) in the system, where is the number of transmit antennas and is the number of receivers. This result is independent of the number of receive antennas and the channel gain matrix, and is valid at all signal-to-noise ratios (SNRs).

In 2006, Masoomeh Torabzadeh and Yusheng Ji [17] proposed about nature of independent time-varying channels across different users in a multi-user wireless system provides multi-user diversity. In addition, multiple antennas that spatially separate the signals from different users can be used to provide multiple access gain. Combining fair scheduling and efficient antenna assignment, we can achieve the goal of fairness and maximum capacity.

In 2010, Qihui Liang et al. [18] proposed about the computational complexities of two methods which are analyzed and simulation is done for comparing their PAPR-reducing performance. The simulation results show that active-set method requires less computational complexity than that of SCR method while they achieve similar PAPR reduction performance.

5. Model Analysis

We can consider a MIMO with p and q transmitters and receivers respectively the output sequence with input j and output I is

$$x_i(k) = \sum_{j=1}^{p} \sum_{l=0}^{d} h_{ij}(l) s_j(k-l)$$

Where d denotes the max ISI degree. The Z-transformation is

$$\mathbf{H}(D)\mathbf{s}(D) = \mathbf{x}(D)$$

We design the model with the above MIMO and the linear SNR consideration with the active antenna transceiver is given by

$$\gamma_{\min} = \frac{\mathrm{SNR}_{\min}}{\Gamma\left(2^{\frac{b_T}{M_T}} - 1\right)}.$$

A lower bound for is obtained in the following for the analysis of outage rate. The average value of the lower bound is used to select the active transmit antennas and constellations for a fixed data rate. We now obtain a lower bound for using the following lower bound for SNR.

The substream bit allocations and number of transmit antennas for SCR detection with fixed detection order. Let $b_i, i = 1, \ldots, M_T$, denote the spectral efficiencies allocated to each of the active transmit antennas. The optimization problem can be stated as follows:

$$\max_{(M_T, M_R, p, q, b_i): \sum_{i=1}^{M_T} b_i = b_T} \; \min_{i \in \{1, \ldots, M_T\}} \gamma_i$$

Where

$$\gamma_i = \frac{\mathrm{SNR}_i}{\Gamma(2^{b_i} - 1)}$$

This shows good transmission rates in different simulation situations.

6. Conclusion

Signal to clipping noise ratio (SCR) and active-set methods are two existing methods for peak-to-average power ratio (PAPR) reduction based on OFDM is good in several situations.

To maximize the SNR, the best way to utilize a MIMO system is to communicate on the top singular vectors of the channel matrix. In this paper we addresses t several issues and the problem of channel tracking and equalization for multi-input multi-output (MIMO) time-varying frequency-selective channels. These channels model the effects of inter-symbol interference (ISI), co-channel interference (CCI), and noise. Via singular value decomposition (SVD) analysis, the precoder is used to be shown to outperform the orthogonal frequency division multiplexing (OFDM) precoder in bit-error-rate (BER), transmission rate, and receiver implementation. In this paper we also analyze several aspects with their advantages and disadvantages.

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