Eigen Value Decomposition with Per Antenna Power Constraint for MIMO-OFDM Systems

A.Suban, S.Mohammed Salman Fariz, S.Sathiyanathan and S.Pradeep Kannan

Abstract **- In this paper we propose eigenvalue decomposition (EVD) algorithm for MIMO-OFDM systems. MIMO consists of multiple transmit and receive antennas to increase the capacity of the channel. OFDM-encoding digital data in combination with MIMO systems is also considered. Eigen Value Decomposition is the factorization of a channel matrix in a canonical form, whereby the matrix is represented in terms of its eigen values and eigen vectors which enables to perform optimal linear precoding. Hence SNR is improved. This work mainly aims at reducing the high peak powers using Per-Antenna Power technique. Sum power connstraint is also considered and MATLAB simulation for both per antenna power constraint and sum power constraint has been done. Finally it has been proved that per antenna power constraint is better than sum power constraint.**

Index terms- eigenvalue decomposition (EVD), multiple- input multiple- output (MIMO), orthogonal frequency division multiplexing (OFDM), per antenna power constraint.

I. INTRODUCTION

The need for high throughput wireless transmission continues to grow. In MIMO-OFDM systems the multiple antennas at both transmitter and receiver make multiple transceivers. In the past decade, a great deal of research has been directed toward the development of optimal transmission schemes for the MIMO BC [1-6]. These systems are encountered in the wireless environment where multiple TX/RX antennas are used to increase Data-rate and mitigate channel fades through the use of spatial multiplexing and TX/RX diversity respectively [7]. The MIMO approach also finds application in wire-line environments like digital subscriber line (DSL) where it can be used to enable crosstalk cancellation [8]. Literatures [9] have shown that OFDM systems with transmit power allocation can achieve better system throughput[9]. While in physical implementation of OFDM system, the maximum transmit power is limited by the linearity of power amplifier, otherwise distortion will be introduced [10]. In modern MIMO-OFDM communication systems with high-throughput requirement, such as IEEE 802.11n, the time interval of sending the preceding matrix to the transmitter is specified [11] For channels known at both the transmitter and the receiver, the capacity can be obtained by performing singular value decomposition of the channel and water-filling power allocation on the channel eigenvalues [12]. The optimal input covariance matrix shows that its eigenvectors are not the same as the channel right singular vectors as in the case of sum power constraint [13]. For the Gaussian broadcast channel (GBC), the sum capacity and the capacity-achieving precoder are known under the total power constraint (TPC) across all transmit antennas [14].Applying a power constraint to the total power of all TXs provides an extra degree of freedom in power allocation. This allows power to be redistributed from TXs which have poor channels to TXs whose channels have low attenuation[15]. In paper , a novel method is obtained by putting a constraint on the average power of a single antenna. However, the limitation of average power cannot guarantee the limitation of instantaneous signal power, and it will introduce serious signal distortion which is not taken into consideration in [16] therefore these methods can't be applied to a wideband system. In many transmission operations of practical interest, each antenna has its own power amplifier and is operated under the per-antenna power constraint (PAPC).[17]. In [18], the problem of a multi-user downlink channel is considered with a per-antenna power constraint. With PPC BF can achieve performance close to that obtained with total-power-constraint-based BF, even for a small number of feedback bits.[19].. The capacity of a constant MIMO channel with per-antenna constraint is still an open problem[20]. The paper is organized as follows.MIMO SYSTEMS are described in section II and the concept of OFDM is detailed in section III. The details of the operation of the proposed EVD algorithm are presented in Section IV. Results are presented in the following sections respectively.

A.Suban is working as Assistant professor, S.Mohammed Salman Fariz, S.Sathiyanathan and S.Pradeep Kannan are UG final year students Department of ECE, Velammal college of engineering and technology, Madurai-625009, Emails: subanece@gmail.com, salmanfarizs@gmail.com, ssathiyanathanece@gmail.com,pkpeepdeep05@gmail.com.

II. MIMO SYSTEMS

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 technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (WI-Fi), 4G,3GPP Long Term Evolution, WiMAX and HSPA+. In MIMO systems, a transmitter sends multiple streams by multiple transmit antennas. The transmit streams go through a matrix channel which consists of all $N_t N_r$

paths between the N_t transmit antennas at the transmitter and N_r 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. A narrowband flat fading MIMO system is modelled as

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

Where $\mathbf{y}$ [1×n]and $\mathbf{x}$[1×n] are the receive and transmit vectors, respectively, and H [n×n]and $\mathbf{n}$[1×n] are the channel matrix and the noise factor, respectively.

Spatial multiplexing techniques make the receivers very complex, and therefore they are typically combined with Orthogonal frequency-division multiplexing (OFDM) or with Orthogonal Frequency Division Multiple Access (OFDMA) modulation, where the problems created by a multi-path channel are handled efficiently. The IEEE 802.16e standard incorporates MIMO-OFDMA. The IEEE 802.11n standard, released in October 2009, recommends MIMO-OFDM.MIMO is also planned to be used in Mobile radio telephone standards such as recent 3GPP and 3GPP2. In 3GPP, High-Speed Packet Access plus (HSPA+) and Long Term Evolution (LTE) standards take MIMO into account. Moreover, to fully support cellular environments, MIMO research consortia including IST-MASCOT propose to develop advanced MIMO techniques, e.g., multi-user MIMO (MU-MIMO).

III.ORTHGONAL FREQUENCY DIVISION MULTIPLEXING

Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, DSL broadband internet access, wireless networks, and 4G mobile communications. The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate intersymbol interference (ISI) and utilize echoes and time-spreading (on analogue TV these are visible as ghosting and blurring, respectively) to achieve a diversity gain, i.e. a signal-to-noise ratio improvement. In OFDM based wide area broadcasting, receivers can benefit from receiving signals from several spatially dispersed transmitters simultaneously, since transmitters will only destructively interfere with each other on a limited number of sub-carriers, whereas in general they will actually reinforce coverage over a wide area. This is very beneficial in many countries, as it permits the operation of national single-frequency networks (SFN), where many transmitters send the same signal simultaneously over the same channel frequency. SFNs utilize the available spectrum more effectively than conventional multi-frequency broadcast networks (MFN), where program content is replicated on different carrier frequencies. SFNs also result in a diversity gain in receivers situated midway between the transmitters. The coverage area is increased and the outage probability decreased in comparison to an MFN, due to increased received signal strength averaged over all sub-carriers.

IV.EIGEN VALUE DECOMPOSITION

Eigenvectors and eigenvalues are numbers and vectors associated to square matrices, and together they provide the agent-decomposition of a matrix which analyzes the structure of this matrix. Even though the eigen-decomposition does not exist for all square matrices, it has a particularly simple expression for a class of matrices often used in multivariate analysis such as correlation, covariance, or cross-product matrices. The eigen-decomposition of this type of matrices is important in statistics because it is used to find the maximum (or minimum) of functions involving these matrices. Eigenvectors and eigenvalues are also referred to as characteristic vectors and latent roots or characteristic equation. The set of eigenvalues of a matrix is also called its spectrum. Alternatively Eigendecomposition is the factorization of a matrix into a canonical form, whereby the matrix is represented in terms of its eigenvalues and eigenvectors. Only diagonalizable matrices can be factored in this way.

Notations and Definitions:
There are several ways to define eigenvectors and eigenvalues,
The most common approach defines an eigenvector of the matrix **A** as vector **u** that satisfies the following equation:

$$Au = \lambda u$$

When rewritten, the equation becomes:

$$(A - \lambda I)u = 0$$

Where **λ** is a scalar called the eigenvalue associated to the eigenvector.

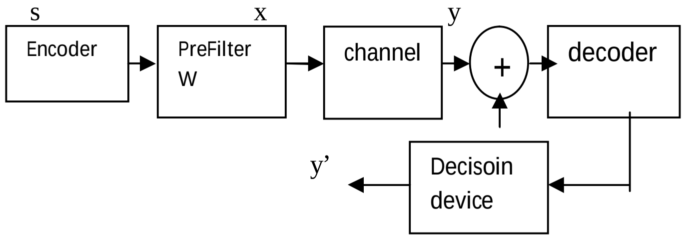


Fig 1 *Block diagranm of Conventional MRT technnique*

In the above technique the data is fist encoded and passed though the prefilter to remove the noiseThen its passed through channel and decoded.Finally output is received from the decision device.

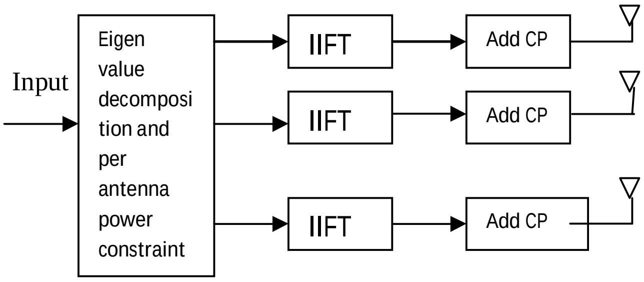


Fig 2 *Block diagram of transmitter model*

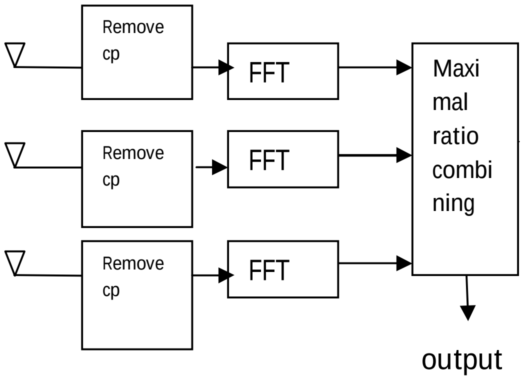


Fig 3 *Block diagram of receiver model*

In the transmitter side the channel is decomposed using eigen value decomposition and per antenn power technique is also used then inverse fourier transform is carried out then cyclic prefix is added and passed through the receiver.

In the receiver side the cyclic prefix is first removed from the channel and the fast fourier transform is carried out and maximal ratio combining is done, finally the output is received at the receiver.

V. POWER CONSTRAINTS

Consider a multiple-input multiple output (MIMO) channel with n transmit and m receive antennas. The channel between each transmit-receive pair is a complex, multiplicative factor *hij*. Denote the channel coefficient matrix as **H** of size $m\times n$, and the transmit signal vector as $x=[x_1...x_N]^T$. Then the received signal vector of length m can be written as

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

where $\boldsymbol{z} \sim \boldsymbol{CN}(\boldsymbol{0}, \boldsymbol{I})$ is a vector of additive white circularly complex Gaussian noise. Here we have normalized the noise power at all receivers, which can be done by absorbing the actual noise power into the transmit power constraint. Assume the channel H [n×n] is known at both the transmitter and receiver. The capacity of the MIMO channel depends on the power constraint on the input signal vector x.In all cases, because of the Gaussian noise and known channel at the receiver, the optimal input signal is Gaussian with zero mean.

Let $Q = E\left[XX^{+}\right]$be the covariance of the Gaussian input, then the achievable transmission rate is

$$r = \log\det\left(I_m + HQH \pm\right)$$

The remaining question is to establish the optimal Q that maximizes this rate according to the **CSIT** condition and a given power constraint.

Often the MIMO capacity is studied with sum power constraint across all antennas. In this paper, we consider a more realistic per-antenna power constraint. For comparison, we also include the case of independent multiple-access power constraint. We elaborate on each power constraint below.

1) *Sum power constraint*: With sum power constraint, the total transmit power from all nantennas isP, but this power can be shared or allocated arbitrarily among the transmit antennas. This constraint translates to a condition on the input covariance as

$$tr(Q) \le P$$

This constraint allows complete cooperation among the transmit antennas.

2) *Per-antenna power constraint:* Here each antenna also has a separate transmit power budget of P_i (I =1, ..., n) but can fully cooperate with each other. Such a channel can model a physically centralized MIMO system, in which the per-antenna power comes from the realistic individual constraint of each transmit RF chain. The channel can also model a distributed (but cooperative) MIMO system, in which each transmit antenna belongs to a sensor or an ad hoc node distributed in a network and thus cannot share power. The per-antenna constraint is equivalent to having the input covariance

Matrix Q with fixed diagonal values $Q_{ii} = P_i$. Denote $e_i = [0...1...0]^T$ as a vector with the i^{th} element equal to 1and the rest is0. Then the per-antenna power constraint $Q_{ii} \le P_i$ can be written as

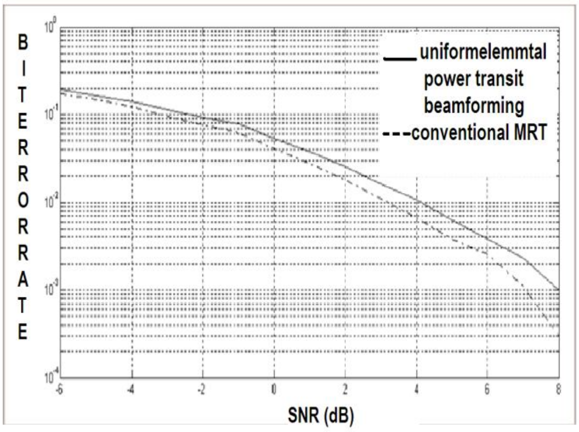
$$e_i^T Q e_i \le P_i, i = 1...n$$

This constraint is a set of linear constraints on Q. It should be stressed that a constraint on the diagonal values of Q is not the same as a constraint on the eigenvalues of Q.

VI. RESULTS AND DISCUSSIONS:

The proposed algorithm is coded using Matlab. Perfect channel knowledge is assumed to be available at the transmitter.Channel is a frequency flat Rayleigh channel model.Quadrature Pulse Shift Keying (QPSK) modulation is used for the transmitted symbol.

Simulation and inference:



The transmit beamforming design under uniform elemental power constraint performance is better than the conventional Maximum Ratio Transmission (MRT). Uniform elemental power constraint case has a higher signal-to-noise ratio (SNR) with a low bit error rate (BER) compared to the conventional MRT approach case. The cyclic algorithm has low computational complexity.

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First Author

A. Suban, received B.E in the department of Electronics and Communication Engineering from Anna university, Chennai and M.E in the discipline of Wireless Technology from Thiagarajar College of Engineering, Madurai in 2011.
He is currently working as Assistant Professor in the Department of Electronics and Communication Engineering, Velammal College of Engineering and Technology, Madurai-625009, Tamil Nadu, India. His area of interest in Signal processing mainly focused on MIMO techniques with beamforming, OFDM and power control techniques.

Second Author

S.Mohammed Salman Fariz , pursuing Bachelor of engineering in Velammal College of Engineering and Technology, Madurai-625009. His area of interst is signal processing.

Third Author

S.Sathiyanathan, pursuing Bachelor of engineering in Velammal College of Engineering and Technology, Madurai-625009. His area of interst is signal processing.

Fourth Author

S.Pradeep Kannan , pursuing Bachelor of engineering in Velammal College of Engineering and Technology, Madurai-625009. His area of interst is signal processing.