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Performance Analysis, MIMO, Rician Fading Channel

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PERFORMANCE ANALYSIS AND EVALUATION OF MASSIVE MIMO SYSTEM

Abstract

This article examines the performance of massive MIMO uplink system over Rician fading channel. The performance is estimated regarding spectral efficiency versus number of base station antennas utilizing three plans of linear detection, maximum-ratio-combining (MRC), zero forcing receiver (ZF), and minimum mean-square error receiver (MMSE). The simulation results reveal that the spectral efficiency increments altogether with expanding the quantity of base station antennas. Additionally, the spectral efficiency with MMSE is superior to that with ZF, and the last is superior to that with MRC. Furthermore, the spectral efficiency diminishes with expanding the fading parameter.

1. INTRODUCTON

Multiple Input Multiple Output (MIMO) innovation is a point-to-point communication links with different antennas at both the transmitter and receiver. The utilization of various antennas at both transmitter and receiver give an enhancements for data rate, in light of the fact that the more antennas, the more autonomous data streams can be conveyed; an enhancements for unwavering quality, on the grounds that the more antennas, the more possible ways that the radio signal can spread over, and an enhancements for energy efficiency, on the grounds that the base station can center its emitted energy into the spatial bearings where it realizes that the terminals are found (Marzetta, 2010).

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An upgraded type of point-to-point MIMO innovation is multiuser MIMO (MU-MIMO) which empowers different autonomous radio terminals to get to a system improving the communication abilities of every individual terminal. MU-MIMO varies from point-to-point MIMO in two regards: first, the terminals are ideally isolated by numerous wavelengths, and second, the terminals can't team up among themselves, either to transmit or to receive data (Ngo, 2012; Ngo, Larsson & Marzetta, 2013).

These days, MU-MIMO systems are utilized in new generation wireless innovations, because of that wireless innovation improvement is continuous, the quantities of users and applications increment quickly. At that point, wireless communications require the high data rate and connection dependability simultaneously. Thusly, MU-MIMO upgrades need to think about 1) giving the high data rate and connection unwavering quality, 2) bolster all users in a similar time and frequency asset, and 3) utilizing low power utilization. Practically speaking, the interuser interference has a solid effect when more users access to the wireless connection. Convoluted transmission techniques, for example, interference cancellation ought to be utilized to keep up a given wanted nature of administration. Because of these problems, MU-MIMO with exceptionally enormous antenna arrays (known as massive MIMO) is proposed. With a massive MU-MIMO system, we mean a hundred of antennas or all the more serving many users. The channel vectors are about orthogonal, and afterward the interuser interference is diminished significantly. In this way, the users can be served with high data rate all the while (Yang & Marzetta, 2013; Pakdeejit, 2013).

2. SYSTEM MODEL

The model of massive MIMO system investigated here comprises of uplink system model, channel model (Rician fading channel), and linear detection plans. These three sections are examined in subtleties in the following sections.

2.1. Uplink system model

A solitary cell uplink system is deemed here, where there are K mobile users and one base station (BS). Every user has one transmit antenna, and the BS has M receive antennas apparatuses as appeared in Fig. 1. The received signal at the BS is (Pakdeejit, 2013; Lu, et al., 2014):

$$y = \sqrt{p_u}\sum_{k=1}^{K} h_k x_k + n \tag{1}$$

$$y = \sqrt{p_u} H x + n \tag{2}$$

Where $\sqrt{p_u}x_k$ is the transmitted signal from the kth user (the median power transmitted by every user is p_u), $h_k \in \mathbb{C}^{M\times 1}$is the channel vector between the kth user and the BS, $n \in \mathbb{C}^{M\times 1}$ is the additive noise vector, $H \triangleq [h_1 \quad \dots \quad h_K]$ is channel matrix given underneath, and $x \triangleq [x_1 \quad \dots \quad x_K]^T$. It is expected that the components of h_k and n are (independent identically distribution) i.i.d. Gaussian distributed with zero mean and unit variance (Lu, et al., 2014).

$$H = \begin{bmatrix} h_{11} & h_{12} & \dots & h_{1K} \\ h_{21} & h_{22} & \dots & h_{2K} \\ \vdots & \vdots & \ddots & \vdots \\ h_{M1} & h_{M2} & \dots & h_{MK} \end{bmatrix} \tag{3}$$

The BS will coherently distinguish the signals transmitted from K users by utilizing the received signal vector y together with information on the channel state data (CSI). This CSI must be assessed. The channel gauge can be acquired from uplink training.

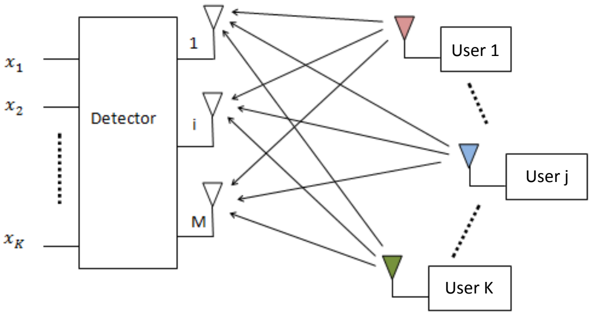

Fig. 1. Massive MIMO uplink system model (Lu L. et al., 2014)

It is expected that the channel remains steady over T symbol duration. During every coherence interval, there are two phases (see Fig. 2). In the first phase, a section τ of the coherence interval is utilized for uplink training to evaluate the channel of every user. In the second phase, all K users at the same time transmit their data to the BS. The BS at that point identifies the transmitted signals utilizing the direct gauges obtained in the first phase.

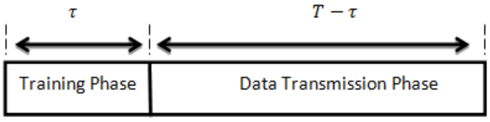

Fig. 2. Uplink transmission protocol (Lu, et al., 2014)

2.2. Rician fading channel

A likelihood density capacity of the signal received in the line-of-sight (LOS) condition follows the Rician conveyance. In the LOS condition where there exists a solid way which is not dependent upon any misfortune because of reflection, diffraction, and scattering, the amplitude of the received signal can be distinct as $X = a + W1 \ + jW2$ where a represents the LOS part, while, $W1$ and $W2$ are the i.i.d. Gaussian random variables with a zero mean and variance of σ^2 as in the non-LOS condition. It has been realized that X is the Rician random variable. At that point, the channel coefficient of Rician fading channel is given by (Ciuonzo, Rossi & Dey, 2015):

$$h_{Rician} = a + c + jd \tag{4}$$

Where $a = \sqrt{\frac{\mathcal{K}}{\mathcal{K}+1}}$, $c \sim \mathcal{N}\left(0, \frac{1}{2(\mathcal{K}+1)}\right)$, $d \sim \mathcal{N}\left(0, \frac{1}{2(\mathcal{K}+1)}\right)$, and $\mathcal{K}$ is the ratio of the power in the LOS part to the power in the other (non-LOS) multipath parts. The fading parameter $\mathcal{K}$ which is typically given in is a proportion of the seriousness of the fading, a little $\mathcal{K}$ suggests extreme fading, while, an enormous $\mathcal{K}$ infers milder fading.

2.3. Linear detection

To get ideal performance, the maximum likelihood (ML) multiuser discovery can be utilized by the BS to identify all signals transmitted from k user, expecting that the BS has impeccable CSI information. The multifaceted nature of ML is high, so the BS can utilize linear detection plans to minimize the decoding complexity. Nonetheless, these plans have lower detection unwavering quality contrasted and ML detection, however when the quantity of BS antennas is huge, linear detectors are about ideal. Three plans of linear detection are considered, maximum-ratio combining (MRC), zero-forcing receiver (ZF), and minimum mean-square error receiver (MMSE) as portrayed beneath (Ciuonzo, Rossi & Dey, 2015).

2.3.1. Maximum-Ratio Combining (MRC)

With MRC, the BS maximizes the received signal-to-noise ratio (SNR) of each stream, neglecting the effect of multiuser interference. Accordingly, to recognize the transmitted signal from the *k*-th user, the received signal *y* is multiplied by the conjugate-transpose of the channel vector *h_k*, as follows (Fatema, et al., 2018):

$$\tilde{y}_k = {h_k}^H y = \sqrt{p_u} \| h_k \|^2 x_k + \sqrt{p_u} \sum_{i \neq k}^{K} {h_k}^H h_i x_i + {h_k}^H n \tag{5}$$

The received signal-to-interference-plus-noise ratio (SINR) of the *k*-th stream for MRC is given by:

$$SINR_{mrc,k} = \frac{p_u \|h_k\|^4}{p_u \sum_{i\neq k}^{K} \left|{h_k}^H h_i\right|^2 + \|h_k\|^2} \tag{6}$$

The achievable rate of *k*-th user with MRC is given by

$$R_k{}^{MRC} = log_2\left(1 + \frac{p_u \|h_k\|^4}{p_u \sum_{i\neq k}^{K} \left|{h_k}^H h_i\right|^2 + \|h_k\|^2}\right) \tag{7}$$

Hence the spectral efficiency with MRC is given by

$$R^{MRC} = K * R_k{}^{MRC} = K * log_2\left(1 + \frac{p_u \|h_k\|^4}{p_u \sum_{i\neq k}^{K} \left|{h_k}^H h_i\right|^2 + \|h_k\|^2}\right) \tag{8}$$

MRC is a very simple signal handling since the BS just increases the received vector with the conjugate-transpose of the channel matrix *H*, and afterward identifies each stream independently. All the more critically, MRC can be executed in a distributed way. Also, MRC can accomplish a he same array gain as in the case of a single-user system at minimum SNR, however MRC performs ineffectively in interference restricted situations since it disregards the effect of multiuser interference.

2.3.2. Zero-Forcing Receiver (ZF)

Rather than MRC, zero-forcing collectors (ZF) consider the interuser interference; however disregard the effect of noise. With ZF, the multiuser interference is totally nulled out by anticipating each stream onto the orthogonal space of the interuser interference. All the more accurately, the received vector is multiplied by the pseudo-reverse of the channel matrix *H* as (Fatema, et al., 2018; Chopra, et al., 2018):

$$\tilde{y} = (H^H H)^{-1} H^H y = \sqrt{p_u}x + (H^H H)^{-1} H^H n \tag{8}$$

The received SINR of the *k*-th stream is given by:

$$SINR_{zf,k} = \frac{p_u}{[(H^H H)^{-1}]_{kk}} \tag{9}$$

The achievable rate of *k*-th user with ZF is given by

$$R_k{}^{ZF} = log_2\left(1 + \frac{p_u}{[(H^H H)^{-1}]_{kk}}\right) \tag{10}$$

Hence the spectral efficiency with ZF is given by

$$R^{ZF} = K * R_k{}^{ZF} = K * log_2\left(1 + \frac{p_u}{[(H^H H)^{-1}]_{kk}}\right) \tag{11}$$

ZF is a basic signal preparing and functions admirably in interference constrained situations, however since ZF ignores the effect of noise; it works ineffectively under noise restricted situations. Compared with MRC, ZF has a higher execution multifaceted nature because of the calculation of the pseudo-converse of the channel gain matrix.

2.3.3. Minimum Mean-Square Error Receiver (MMSE)

It is realized that the MMSE receiver expands the received SINR. Consequently, among the MMSE, ZF, and MRC receivers, MMSE is the best; the received SINR for the MMSE receiver is given by (Fatema, et al., 2018; Chopra, et al., 2018):

$$SINR_{mmse,k} = p_u {h_k}^H \left(p_u \sum_{i\neq k}^{K} h_i {h_i}^H + I_M\right)^{-1} h_k \tag{12}$$

The achievable rate of k-th user with MMSE is given by:

$$R_k{}^{MMSE} = log_2\left(1 + p_u {h_k}^H \left(p_u \sum_{i\neq k}^{K} h_i {h_i}^H + I_M\right)^{-1} h_k\right) \tag{13}$$

Hence the spectral efficiency with MMSE is given by:

$$R^{MMSE} = K * R_k{}^{MMSE} = K * log_2\left(1 + p_u {h_k}^H \left(p_u \sum_{i\neq k}^{K} h_i {h_i}^H + I_M\right)^{-1} h_k\right) \tag{14}$$

Where $\boldsymbol{I_M}$ is the identity matrix of size M.

3. SIMULATION RESULTS

A progression of PC simulation tests are done to consider the system performance. The performance is estimated by drawing the spectral efficiency versus the number of BS antennas using MRC, ZF, and MMSE. The quantity of users is picked to be $K = 2$ and $K = 0$ dB & -40 dB. Moreover, the SNR is set at 0 dB. Fig. 3 and Fig. 4 demonstrate that the spectral efficiency increments as the quantity of BS antennas increments for $K = 0$ dB & -40 dB respectively. Additionally, the spectral efficiency with MMES is superior to that with ZF, and the last is superior to that with MRC for $K = 0$ dB & -40 dB. Besides, by comparing between Fig. 3 and Fig. 4, it can reasoned that the spectral efficiency for $K = -40$ dB is superior to the spectral efficiency for $K = 0$ dB.

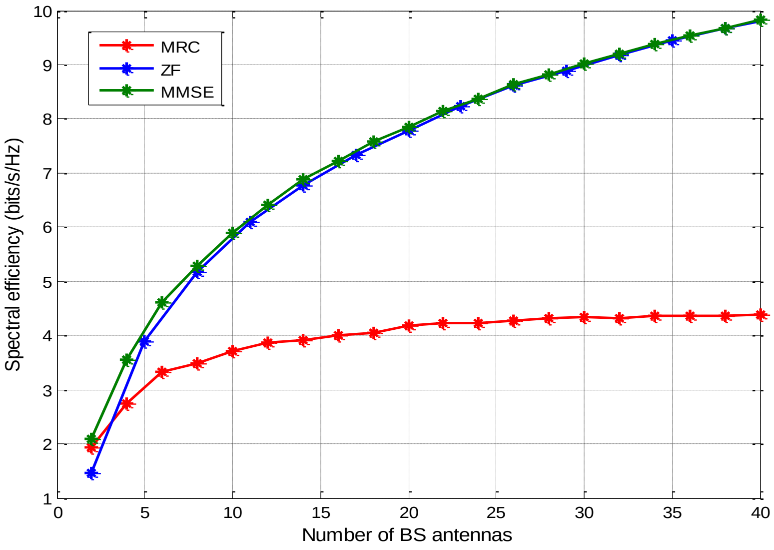

Fig. 3. The spectral efficiency versus the number of BS antennas for MRC, ZF, MMSE and $\mathcal{K}$ = 0 dB

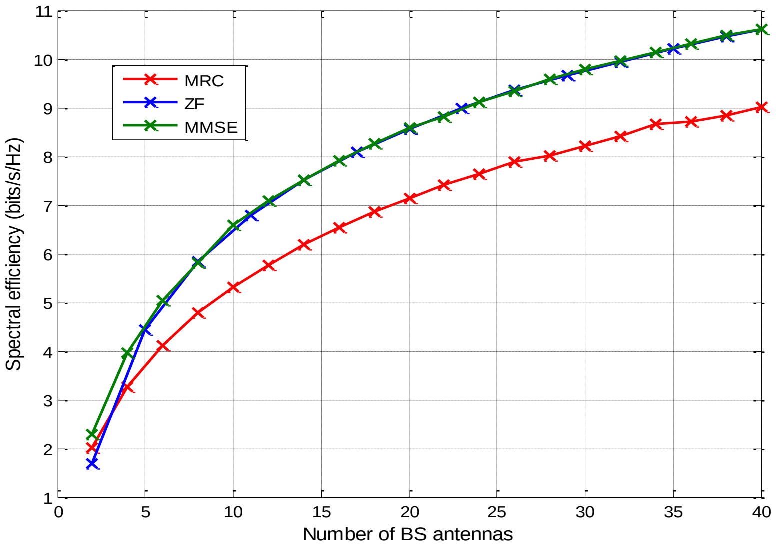

Fig. 4. The spectral efficiency versus the number of BS antennas for MRC, ZF, MMSE and $\mathcal{K}$ = -40 dB

4. CONCLUSION

The performance of massive MIMO uplink system was estimated over Rician fading channel, utilizing MRC, ZF, and MMSE linear detection plans. The outcomes reveal that the performance improved altogether with expanding the quantity of BS antennas for various estimations of K. Additionally, the performance with MMSE is superior to that with ZF and the last is superior to that with MRC for various estimations of K. Moreover, as K expands, the spectral efficiency diminishes.

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