Tight Bounds on SINR with ZFBF and Feedback

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***Abstract*— the concept of Multiple Input Multiple Output (MIMO) is an advanced one in the field of wireless communications. The main objective behind the MIMO is providing high data rates to multiple users at a time. MIMO also aims to provide maximum channel gain, high degree of multiplexing, robust data rate and multi user diversity etc. however all these are effectively achieved by using the Channel State Information at Transmitter (CSIT). CSIT is the feedback information of the channel from the end users to the transmitter. Therefore multiple users are sending back the information at a same time, which causes the interference among the entire feedback channels and effectively degrades the SINR (Signal to Interference plus Noise Ratio). Therefore to address this problem we provide a systematic approach to derive bounds on the SINR to avoid the problem of interference, by assuming transmitter using zero forcing beam forming, and all the users are assumed to be orthogonal to each other.**

***Key words*- MIMO, Broadcast channels, and array signal processing, feedback communication, co channel interference, diversity methods.**

I. INTRODUCTION

MIMO is an advanced communication system by employing an arrays of antennas at both transmitter and receiver side. The concept of Multiple Input Multiple Output is a promising technique for significant increase in channel capacity, spectrum efficiency, maximum channel gain and degree of multiplexing and diversity etc. Therefore ever increasing demand for all the above mentioned factors the concept of MIMO becomes as most important concept in the field of wireless communications. Channel State Information (CSI) available at both transmitter and receiver are one of the most important factors, which greatly influences the capacity MIMO system. The receiver can measures the channel state information using the pilot signals which are embedded within the information or data symbols while transmitting from transmitter. There are several scenarios are available based on the available CSI at transmitter as follows:

- In the case of frequency duplexed systems, the uplink channel and downlink channels are differentiated in terms frequency. Therefore both the channels are considered as individual unique channel and thus the channel state information must be sent back using round trip delays or feedback.
- In the case of time-duplexed systems, the uplink and downlink channels are reciprocal to each other as long as the fading process time complete, i.e. the coherence time exceeds the duplex time then, the transmitter have to access the reliable CSI at low and moderate levels of mobility.
- Whereas for high degree of mobility, even for time-duplexed systems also the Channel State Information becomes outdated.

However for high data rate communications in wireless communication with several multiple antenna arrays, the CSIT (Channel State Information at the Transmitter) is very critical factor. CSIT is a most favourable factor for achieving high degree of diversity and allowing the entire system to serve multiple users at a time.

In this paper we propose a systematic method for improving the efficiency of antenna systems by limiting the channel state information at transmitter with two bounds. Here we considered a MISO (Multiple-Input-Single-Output) broadcast channels and assume that Zero Forcing Beam Forming (ZFBF) is performed at Base Station (BS) to provide parallel transmission to multiple users.

Remaining of this paper is arranged as: section II derives a complete architecture for considered system with channel data information and channel quality information. Section III analyses the complete process if bound of SINR and finally section IV provides the simulation results and analysis of proposed method.

II. System Model

Consider a MISO communication system with one base station consisting of $\mathbf{N_t}$ transmitting antennas and one receiving antenna. Below figure shows a simple block diagram of two antenna MISO system.

Assume that broadcast MISO channels are used to communicate *'K'* user's terminals, which consists of a single individual antenna. The base station performs two important tasks, one is beam forming and another one is scheduling. For performing the first one we considered the concept of block and flat fading and similarly the scheduling process is depend on the channel state feedback information from users through error free channel.

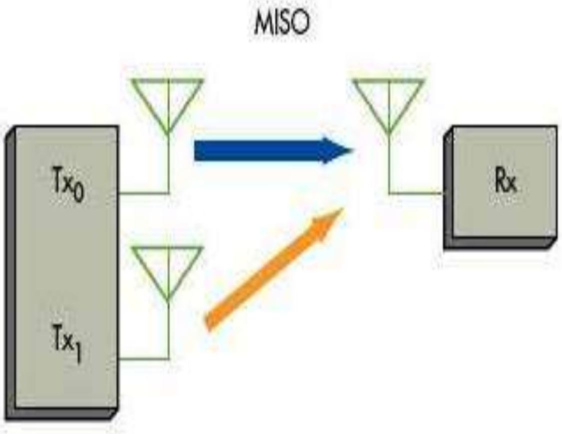

Fig 1: A simple two antenna MISO antenna system

The important consideration here is that the perfect information of the all the channels are available at all the receivers.
While in the process of transmission, each k[th] scheduled user receives data symbol as

$$\mathbf{y_k} = \sqrt{\rho}\mathbf{w}_k^{\mathbf{H}}\mathbf{h_k x_k} + \sqrt{\rho}\sum_{\mathbf{j=1,j\neq k}}^{\mathbf{M}} \mathbf{w_j^H h_k x_j} + \mathbf{n_k}$$

…………………(1)

Where $\mathbf{h_k}$ is defined as the channel vector matrix of the k^{th} user with the degree of $\mathbf{N_t \times 1}$, $\mathbf{w_k}$ is known as beam forming vector, $\mathbf{x_k}$ is the transmitted symbol for the k^{th} user from BS, and $\mathbf{n_k}$ is additive white noise.
As expressed in equation 1, after every reception of information symbol every user has to send feedback information of their corresponding channel to the Base Station (BS). However for efficient communication process we categorize the feedback information from all the *'K'* users as CQI (Channel Quality Information) and CDI (Channel Direction Information). The channel Quality Information is particularly related to the quality of SINR (signal-to-interference-plus-noise ratio) for scheduling of the information blocks and high data rate allocation. Therefore

The CQI is comprises in the terms of SINR, and from equation 1 the CQI is defined as

$$\gamma_\mathbf{k} = \frac{\rho\left|\mathbf{w_k^H h_k}\right|^2}{\sigma^2 + \rho\sum_{\mathbf{j=1,j\neq k}}^{\mathbf{M}}\left|\mathbf{w_j^H h_k}\right|^2}$$

…………………….. (2)

For enabling the simultaneous transmissions and performing the zero forcing beam forming base station widely uses the Channel Directional Information.

In the next context, we propose a method to find out a lower bound on the SINR that may be computed at the user terminal. Then, we propose a correction factor, applied by the BS after determining the beam forming vectors that improves the bound.

III. Lower Bounds on the SINR

In this section we derive a lower bound on SINR by considering all the system considerations in previous section. After effective communication has done among the transmission antennas and receiving antennas the estimated instantaneous SINR is defined as

$$\gamma_k = \frac{\rho\|\mathbf{h}_k\|^2\left|\mathbf{a}_k\mathbf{w}_k^H\hat{\mathbf{h}}_k + \bar{\mathbf{a}}_k\mathbf{w}_k^H\mathbf{e}_k\right|^2}{\sigma^2 + \rho\|\mathbf{h}_k\|^2\sum_{j=1,j\neq k}^{M}\left|\bar{\mathbf{a}}_k\mathbf{w}_j^H\mathbf{e}_k\right|^2}$$

………………………….. (3)

Where $\hat{\mathbf{h}}_k$ is known as normalized channel vector of transmission antenna array, $\mathbf{e}_k$ is a unit vector orthogonal to $\hat{\mathbf{h}}_k$, $\mathbf{a}_k$ is defined as the projection of $\hat{\mathbf{h}}_k$ onto the quantized CDI $\hat{\mathbf{h}}_k$, and $\bar{\mathbf{a}}_k$ is the projection of $\tilde{\mathbf{h}}_k$ onto $\mathbf{e}_k$.
Therefore now we have o find the bounds for 3.

A. At User Terminal:

By considering the available information from the user terminals we have to derive a lower bound which is very tight. And by considering several communication lemmas we derive the lower tight bound on SINR as:
Consider that *'M'* antennas are arranged to transmit with equal power by using CQI and ZFBF.

Therefore for all individual scheduled users the SINR γ_k is defined as $\gamma_{\mathbf{LB_k}}$

$$\gamma_{\mathbf{LB_k}} = \frac{\frac{\mathbf{P}}{\mathbf{M}}\|\mathbf{h}_k\|^2\left(\alpha_k\mathbf{B} - \bar{\alpha}_k\bar{\mathbf{B}}\right)^2}{\sigma^2 + \frac{\mathbf{P}}{\mathbf{M}}\|\mathbf{h}_k\|^2\bar{\alpha}_k^{\,2}\left(\mathbf{1} + (\mathbf{M}-\mathbf{2})\varepsilon_\omega\right)}$$

……………… (4)

B. At Base Station

Since it is not possible to perform accurate quantization we may not expect exact bound on SINR. Therefore we proposed an adjusted bound.
Therefore we propose an adjusted bound by multiplying $\gamma_{\mathbf{LB_k}}$ By a constant χ, so that $\hat{\gamma}_k = \chi\gamma_{\mathbf{LB_k}}$ .whereas χ is defined as

$$\chi \leq \mathbf{f}(\alpha_k, \beta_k, \mathbf{B}) \equiv \frac{(\alpha_k \beta_k - \bar{\alpha}_k \bar{\beta}_k)^2}{(\alpha_k \mathbf{B} - \bar{\alpha}_k \bar{\mathbf{B}})^2} \quad \text{…..……….. (5)}$$

Therefore with this adjustment, the bound approaches the true SINR as the accuracy of quantization increases.

IV. Results and Analysis

For the process of simulation we considered system with three transmit antennas, 100 users with individual antenna and a signal-to- noise ratio of $P/\sigma^2 = 20\text{dB}$. And we assumed that the feedback information of CDI is quantized accurately.

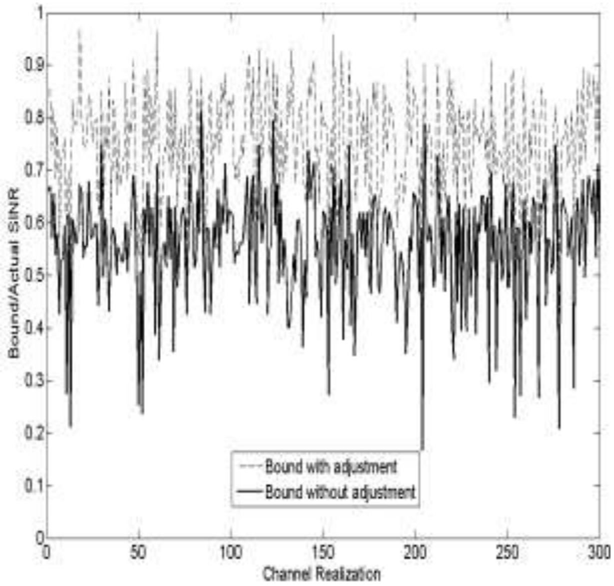

Fig 2: simulation results for Ratio between the bounds and the actual SINR

Above figure 2 represents the comparison of proposed deriver bounds with actual SINR of user. As from the observation of simulation results we find that the proposed bound are never crosses the actual SINR of best scheduled user. It means that the proposed bounds are able to provide high degree of multiplexing gain and diversity which are very important for multiple antenna considerations.

Figure 3 represents the resulting sum rates. From the above simulation we observe that the linear decrease will happen with the linear increment in number of antennas. Here whenever the critical dimensions are present in the channel vector then the number of bits is restricted to a constant. However from the above simulation results it is clear that our proposed bounds on SINR is an efficient method to achieve high data rates without any intermediate interferences and providing high data rates.

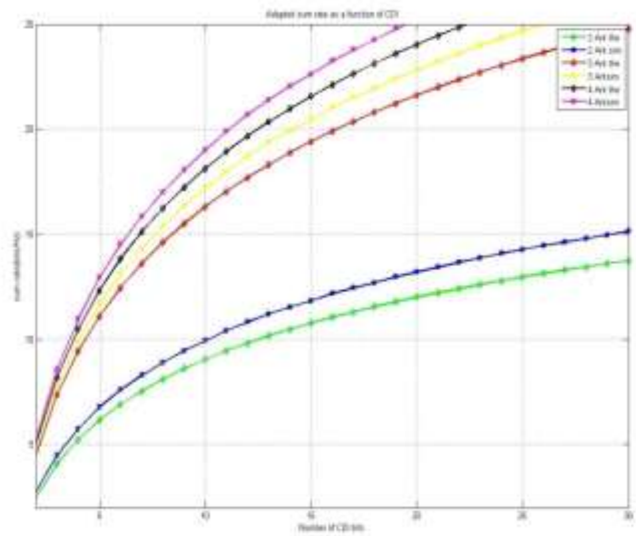

Fig.3: Simulation results for N_t =2, 3 and 4 transmit antennas.

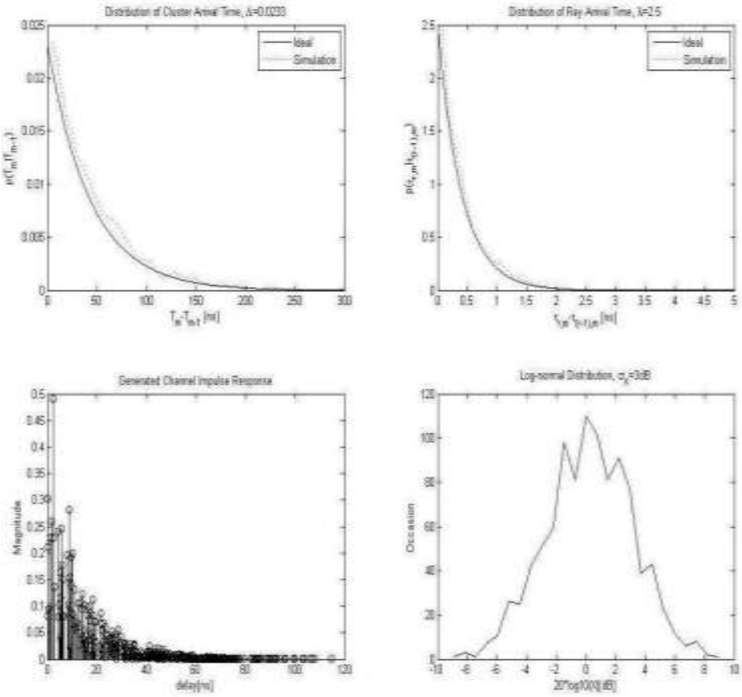

Fig 4: Distribution of arrival times

Figure 4(a) and (b) shows the distribution of cluster arrival times and ray arrival times resp. including simulation results to be compared with the analytical ones where m^{th} cluster arrival time T_m& r^{th} ray arrival time $\mathcal{J}_{r,m}$ in m^{th}cluster are generated in such a way that each of them as an exponential distribution resp.

Fig 4(c) shows channel impulse response of S-V channel power distribution obtained by simulating 1,000 channels from which it is clear channel power follows log-normal distribution.

CONCLUSION

Using this paper we solve the problem of interference in wireless communications by effectively adjusting the tight bounds on SINR. More specifically we proposed a systematic method for improving the efficiency of antenna systems by limiting the channel state information at transmitter with two bounds. Here we considered a MISO (Multiple-Input-Single-Output) broadcast channels and assume that Zero Forcing Beam Forming (ZFBF) is performed at Base Station (BS) to provide parallel transmission to multiple users.

REFERENCES

[1] D. Tse and P. Viswanath, *Fundamentals of Wireless Communications*, 1st edition. Cambridge University Press, 2005.

[2] T. Yoo, N. Jindal, and A. Goldsmith, “Multi-antenna downlink channels with limited feedback and user selection,” *IEEE J. Sel. Areas Commun.* vol. 25, pp. 1478–1491, Sep. 2007.

[3] M. Kountouris, R. de Francisco, D. Gesbert, D. Slock, and T. Sälzer,“Efficient metrics for scheduling in MIMO broadcast channels with limited feedback,” in *Proc. 2007 IEEE Int. Conf. Acoustics, Speech Signal Process.*, vol. 3, pp. III-109–III-112.

[4] M. Trivellato and F. B. F. Tosato, “User selection schemes for MIMO broadcast channels with limited feedback,” in *Proc. 2007 IEEE Veh. Technol. Conf. – Spring*, pp. 2089–2093.

[5] F. G. Fernandes, R. R. Lopes, and D. Zanatta Filho, “Zero-outage
Strategy for multi-antenna broadcast channels with limited feedback,” in *Proc. 2008 IEEE Workshop Signal Process. Advances Wireless Commun.*

[6] N. Jindal, “Antenna combining for the MIMO downlink channel,” *IEEE Trans. Wireless Commun.*, vol. 7, no. 10, pp. 3834–3844, Oct. 2008.

[7] T. Yoo and A. Goldsmith, “Sum-rate optimal multi-antenna downlink beam forming strategy based on clique search,” in *Proc. 2005 IEEE Global Telecomm. Conf.*, vol. 3.

[8] D. J. Love, R. W. Heath Jr., and T. Strohmer, “Grassmannian beam forming for multiple-input multiple-output wireless systems,” *IEEE Trans. Inf. Theory*, vol. 49, no. 10, pp. 2735–2747, Oct. 2003.

[9] R. Horn and C. Johnson, *Matrix Analysis*, 1st edition. Cambridge University Press, 1985.

BIO DATA

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