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# Block Diagonalization Precoding for Multiuser –MIMO Downlink Channel

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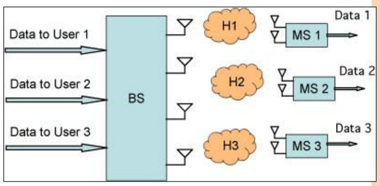
**Graphical abstract**




**Abstract**

The transmission of data in broadcast channel is not a straightforward process; on the receiver side, there could be difficulties in coordinating signal detection. In this paper, the use of Block Diagonalization (BD) to mitigate the inter-user interferences for this work will be investigated. This paper will probe the bit error rate (BER) performances of BD within various parameters number of antennas, $N_M$ and the number of users, K. Computer simulation, matrix laboratory (MATLAB) tools will be utilised and the result of simulation will be shown through demonstrating uses by more users and lesser antennas, which is better than having more antennas with fewer users in the BD precoding method.

*Keywords*: Block Diagonalization(BD), precoding ,Multiuser-MIMO(MU-MIMO).



## 1.0 INTRODUCTION

In the communication system, interferences are one of the obstructions between the antenna and the receiver. When waveform signals are obstructed, the signals will become scattered and this affects the optimum performance of network coverage in the single input single output (SISO). This will lead to problems such as fading, cutting off of services and intermittent, therefore number of errors will increase and the speed of data transmissions will be reduced.

For this reason, the multiple input, multiple output (MIMO) has been introduced to eliminates multipath and mitigate the interferences to the minimum level. The MIMO technology is used in the latest generation of mobile communication systems such as in Worldwide Interoperability for Microwave Access (WiMAX) system, Long-Term Evolution (LTE) system, as well as in the orthogonal frequency division multiplexing (OFDM) system. MIMO can achieve a diversity gain and degree of freedom by spatial multiplexing to improve data rate in the systems [1]. Recently, a majority of applications, particularly in cellular telephony and wireless LAN have been deployed in single base environments while sending data stream simultaneously to many users.

Therefore, multiuser-multiple input multiple output (MU-MIMO) is introduced to enhance communication capabilities. The multiple users will exploit the system's capacity to its maximum and enable access to the same channel simultaneously; using the spatial degrees of freedom offered by MIMO and combined with space division multiple accesses (SDMA) in MU-MIMO. Besides that, MU-MIMO also offers great potential to gain higher capacity, increased diversity and suppress the interferences. In cellular communication system, two scenarios have to be considered; (i) uplink and (ii) downlink channel:

Uplink channel, also known as a Multiple Access Channel (MAC) is when users transmit to base station (BS) over the same channel and for downlink, also known as broadcast channel (BC) occurs when BS is transmitting signal to a bunch of users, as shown in figure 1 below. This requires processing in the form of precoding and SDMA based downlink scheduling user. At first, the transmitter has to acknowledge channel state information at the transmitter (CSIT) to enable throughput improvement over the SU-MIMO when the transmitted antenna is bigger than the received antenna (nT> nR).

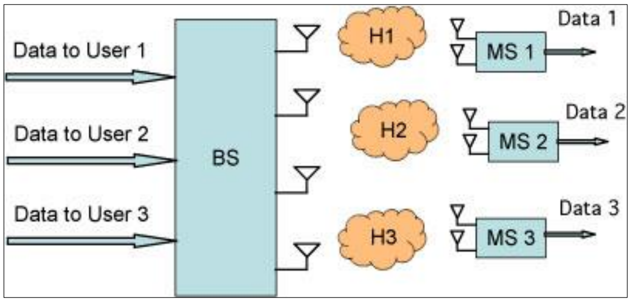



**Figure 1** An illustration of Multiuser-MIMO of downlink. Base station is transmitting to group of users simultaneously.

Communication wireless technology evolves in a very fast pace. In recent years, MU-MIMO has become a famous topic, especially on the downlink channel, which is also known as BC. Single base station (BS), transmits data stream to be decoded by each user simultaneously in a multiple users channel. Thus, MU-MIMO potentially has a high gain sum capacity and diversity with free spatial degree [8]. Similarly, as explained in [1] and [10], spatial degree of freedom in MU-MIMO can be exploited to enhance system capacity by simultaneously sharing scheduling spatial channels. Despite the advantages of MU-MIMO, having multiple users with multiple antennas can cause the system to not only suffer from noise and inter-antenna interferences, but also inter-user interferences [10]. Interferences are often becoming an issue in the propagation of transmission channel. Hence, MIMO is created to mitigate the multipath interferences due to the obstructions where waveforms are scattered before reaching their destination. Evolving from single user – Multiple input multiple output (SU-MIMO) systems to MU-MIMO, interferences in transmission has gained attention among researchers due to the fact that networks will encounter inter-antenna interferences in its own signal and other user interferences in MU-MIMO . In addition, other user interferences will take place when the data streams from BS are transmitted simultaneously to multiple antennas and other users intend to receive signal from other users.

The authors in [8] stated that BS is required in interferences cancellation, caused by the coordination signal detection, considering several precoding methods as stated in [3],[10] and [8] . Meanwhile, paper [2] proposed the use of multiuser detection (MUD) to mitigate interferences, despite the challenges in applying it at mobile stations (MS) of the downlink channels although the uplink BS has already been used. Therefore, several precoding techniques were introduced in broadcast channel (BC) to suppress or mitigate interferences. DPC precoding techniques are well known techniques which have the ability to pre-cancel interferences at BS using CSI In addition ,it was also proven that it is capable to gain sum capacity in paper [5] and [4] but unfortunately ,as mentioned in [3],[10],and [4] ,DPC is not suitable to be implemented in practical system, due to high computational complexity involved in DPC.

Therefore, BD precoding was chosen and this paper discusses how BD performances will help to mitigate interferences since data transmission is not straight forward. Coordinated signal detection or precoding method at receiver side for BC is need. Recently, BD was discussed among researchers in papers [3],[4],[5],[6],[7],[8],[9], due to the level of complexity in BD precoding is not as complex if compared to others precoding techniques; precoding is used in multi-antenna wireless communication systems to support multi stream transmissions by the generalization of beamforming. However, the objective of this study will study BD performances in different parameters of the antenna,NM and user,*K* by assuming complete CSIT at BS.

Even though DPC can achieve the sum capacity level in MU-MIMO, it has high computational complexity level if compared to BD [5] . Meanwhile, CI method is a linear precoding similar to BD but with a lower level of complexity. However, CI has issues with interferences cancellation since it considers all signals other than the target signal as interferences and will cancel it. This may work in SU-MIMO, but in MU-MIMO, the performance worsens because of the inter-antenna interferences in its own signal. Other user interferences, which mitigate both signal and noise enhancement become more severe from the perspective of the target users. In this case, BD is the most suitable method since BD will only cancel out interferences from other users and inter antenna interferences will be mitigated by other detection methods.

This paper will present the result of the simulations about the differences parameter between (i) variable of users and (ii) variable of antenna in term of bit error rate (BER) and signal to noise ratio (SNR) in limitation using only the QPSK mapper.

## 2.0 MU-MIMO WITH BD SYSTEM MODEL

Each mobile station (MS) is assumed to be equipped with $N_M$ and $N_{\mathbf{B}}$ antennas respectively and *K* is considered as an independent user in MU-MIMO. Where $\mathbf{x} \in \mathbb{C}\mathbf{N_B} \times \mathbf{1}$,is transmitting signal from BS and $\mathbf{y_u} \in \mathbb{C}\mathbf{N_M} \times \mathbf{1}$,is a received signal at $\mathbf{U^{th}}$ user, u = 1,2,…,*K* . If channel gain between BS and u th user is represented by $\mathbf{H_u^{DL}} \in \mathbb{C}\mathbf{N_M} \times \mathbf{N_B}$.In downlink channel, received signal is expressed as:

$$\mathbf{y_u} = \mathbf{H_u^{DL}}\mathbf{x} + \mathbf{z_u}, \text{ u=1, 2, 3 . . . K} \quad (1)$$

and $\mathbf{z_u} \in \mathbb{C}\mathbf{N}^{\mathbf{M\,x\,1}}$ is an additive noise. So overall system is represented by this single vector:

$$\underbrace{\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ \cdot \\ \cdot \\ \cdot \\ y_K \end{bmatrix}}_{y_{BC}} = \underbrace{\begin{bmatrix} H_1^{DL} \\ H_2^{DL} \\ H_3^{DL} \\ \cdot \\ \cdot \\ \cdot \\ H_K^{DL} \end{bmatrix} x +}_{H_{DL}} \underbrace{\begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ \cdot \\ \cdot \\ \cdot \\ z_K \end{bmatrix}}_{z}$$

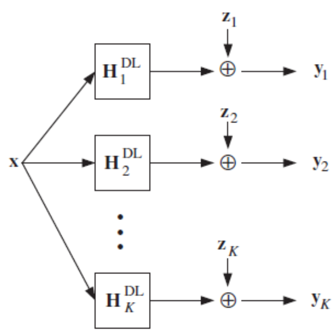



**Figure 2** Downlink channel model for MU-MIMO systems.

BD is chosen as a suitable method for precoding technique in MU-MIMO because BD has the least complexity if compared to other precoding [9].If $\mathbf{N_{M,u}}$ is assumed as the number of antennas for $\mathbf{U^{th}}$ user, u = 1,2...*K* . For $\mathbf{U^{th}}$ user signal,$\mathbf{x_u} \in \mathbb{C}\mathbf{N_M, u} \times \mathbf{1}$, and the received signal , $\mathbf{y_u} \in \mathbb{C}\mathbf{N_M, u} \times \mathbf{1}$is given as:

$$\mathbf{y_u} = \mathbf{H_u^{DL}} \sum_{\mathbf{k=1}}^{\mathbf{K}} \mathbf{W_k}\,\tilde{\mathbf{x}}_\mathbf{k} + \mathbf{z_u}$$

(2)

$$\mathbf{y_u} = \mathbf{H_u^{DL} W_u \tilde{x}_u} + \sum_{\mathbf{k=1,k\neq u}}^{\mathbf{K}} \mathbf{H_u^{DL} W_k}\,\tilde{\mathbf{x}}_\mathbf{k} + \mathbf{z_u}$$

Where $\mathbf{W_u} \in \mathbb{C}\mathbf{N_B} \times \mathbf{N_{M,u}}$ is the precoding matrix for $\mathbf{U^{th}}$ user, $\mathbf{H_u^{DL}} \in \mathbb{C}\mathbf{N_M} \times \mathbf{N_B}$ is the channel matrix between BS and the $\mathbf{U^{th}}$ user and and $z_u$ is the noise vector, considering the received signals for the fourth user case (i.e., *K* = 4),

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} H_1^{DL} & H_1^{DL} & H_1^{DL} & H_1^{DL} \\ H_2^{DL} & H_2^{DL} & H_2^{DL} & H_2^{DL} \\ H_3^{DL} & H_3^{DL} & H_3^{DL} & H_3^{DL} \\ H_4^{DL} & H_4^{DL} & H_4^{DL} & H_4^{DL} \end{bmatrix} \begin{bmatrix} W_1 \tilde{x}_1 \\ W_2 \tilde{x}_2 \\ W_3 \tilde{x}_3 \\ W_4 \tilde{x}_4 \end{bmatrix} + \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \end{bmatrix} \qquad (3)$$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} H_1^{DL} W_1 & H_1^{DL} W_2 & H_1^{DL} W_3 & H_1^{DL} W_4 \\ H_2^{DL} W_1 & H_2^{DL} W_2 & H_2^{DL} W_3 & H_2^{DL} W_4 \\ H_3^{DL} W_1 & H_3^{DL} W_2 & H_3^{DL} W_3 & H_3^{DL} W_4 \\ H_4^{DL} W_1 & H_4^{DL} W_2 & H_4^{DL} W_3 & H_4^{DL} W_4 \end{bmatrix} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \tilde{x}_3 \\ \tilde{x}_4 \end{bmatrix} + \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \end{bmatrix}$$

Where $\mathbf{H_4^{DL} W_4}$ effective channel matrix for *u*=1, 2, 3, 4 user receiver and 4th user transmit signal.

$$\mathbf{H_u^{DL} W_{k=N_{M,u}} \times N_{M,u}, \forall\, u \neq k} \qquad (4)$$

Where $\mathbf{0_{N_{M,4}-N_{M,4}}}$ is zero matrix and can be block diagonalized $\mathbf{W_u} \in \mathbb{C}\mathbf{N_B} \times \mathbf{N_{M,u}}$ must be unitary, u = 1, 2..,*K*, Therefore ,the equation below indicates interferences free transmission.

$$\mathbf{y_{u=H_u^{DL} W_u \tilde{x}_{u+} z_u}}\ ,\ u=1,2\ ,\ \ldots, K\ . \qquad (5)$$

$\tilde{\mathbf{x}}_\mathbf{u}$ can be estimated by other signal detection methods .The precoder matrix$\mathbf{W_u} \in \mathbb{C}\mathbf{N_B} \times \mathbf{N_{M,u}}$ must be designed to lie in the null space of $\tilde{\mathbf{H}}_\mathbf{u}^\mathbf{DL}$ as equation 5 below;

$$\tilde{\mathbf{H}}_\mathbf{u}^\mathbf{DL} \mathbf{W_u} = \mathbf{0_{N_{M,total}-N_{M,u}}}\ ,\ u = 1,2..,K \qquad (6)$$

The received signal for *K* = 4 is expressed as;

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} H_1^{DL} W_1 & 0 & 0 & 0 \\ 0 & H_2^{DL} W_2 & 0 & 0 \\ 0 & 0 & H_3^{DL} W_3 & 0 \\ 0 & 0 & 0 & H_4^{DL} W_4 \end{bmatrix} \qquad (7)$$

Where, zero matrices are appropriate dimensions. Then singular value decomposition can be expressed as;

$$\tilde{\mathbf{H}}_\mathbf{u}^\mathbf{DL} = \mathbf{U_u} \tilde{\Lambda}_\mathbf{u} \left[\tilde{\mathbf{V}}_\mathbf{u}^\mathbf{non-zero} \tilde{\mathbf{V}}_\mathbf{u}^\mathbf{zero}\right]^\mathbf{H} \qquad (8)$$

Where $\tilde{\mathbf{V}}_\mathbf{u}^\mathbf{non-zero} \in \mathbf{C}^{(\mathbf{N_{m,total}-N_{M,u}})\times \mathbf{N_B}}$ and $\tilde{\mathbf{V}}_\mathbf{u}^\mathbf{zero} \in \mathbf{C}^{\mathbf{N_{m,u}} \times \mathbf{N_B}}$ are composed of right singular vector to non zero singular values and zero singular values, respectively. Multiply with $\tilde{H}_u^{DL}$ with $\tilde{V}_u^{zero}$ as equation 9,

$$\tilde{\mathbf{H}}_\mathbf{u}^\mathbf{DL} \tilde{\mathbf{V}}_\mathbf{u}^\mathbf{zero} = \tilde{\mathbf{U}}_\mathbf{u} \left[\tilde{\Lambda}_\mathbf{u}^\mathbf{non-zero}\ \mathbf{0}\right] \begin{bmatrix} \left(\tilde{\mathbf{V}}_\mathbf{u}^\mathbf{non-zero}\right)^\mathbf{H} \\ \left(\tilde{\mathbf{V}}_\mathbf{u}^\mathbf{zero}\right)^\mathbf{H} \end{bmatrix} \tilde{\mathbf{V}}_\mathbf{u}^\mathbf{zero} =$$

$$\tilde{\mathbf{U}}_\mathbf{u} \tilde{\Lambda}_\mathbf{u}^\mathbf{non-zero} \left(\tilde{\mathbf{V}}_\mathbf{u}^\mathbf{non-zero}\right)^\mathbf{H} \tilde{\mathbf{V}}_\mathbf{u}^\mathbf{zero}$$
$$= \tilde{\mathbf{U}}_\mathbf{u} \tilde{\Lambda}_\mathbf{u}^\mathbf{non-zero}\, 0$$
$$= \mathbf{0} \qquad (9)$$

Lets us take example as;$N_B$ = 6*K* = 2, $N_{M,1}$ = $N_{M,2}$ = 3

$$\tilde{\mathbf{H}}_\mathbf{1}^\mathbf{DL} = \mathbf{U_1} \tilde{\Lambda}_\mathbf{1} \left[\tilde{\mathbf{V}}_\mathbf{1}^\mathbf{non-zero} \tilde{\mathbf{V}}_\mathbf{1}^\mathbf{zero}\right]^\mathbf{H}$$
$$\tilde{\mathbf{H}}_\mathbf{2}^\mathbf{DL} = \mathbf{U_2} \tilde{\Lambda}_\mathbf{2} \left[\tilde{\mathbf{V}}_\mathbf{2}^\mathbf{non-zero} \tilde{\mathbf{V}}_\mathbf{2}^\mathbf{zero}\right]^\mathbf{H}$$
$$\tilde{H}_3^{DL} = U_3 \tilde{\Lambda}_3 [\tilde{V}_3^{non-zero} \tilde{V}_3^{zero}]^H$$

$$[\tilde{u}_{11} \quad \tilde{u}_{12} \quad \tilde{u}_{13}] \begin{bmatrix} \tilde{\lambda}_{11} & 0 & 0 & 0 & 0 & 0 \\ 0 & \tilde{\lambda}_{12} & 0 & 0 & 0 & 0 \\ 0 & 0 & \tilde{\lambda}_{13} & 0 & 0 & 0 \end{bmatrix} [\tilde{v}_{11} \quad \tilde{v}_{12} \quad \tilde{v}_{13} \quad \tilde{v}_{14} \quad \tilde{v}_{15} \quad \tilde{v}_{16}] \qquad (10)$$

$$[\tilde{u}_{21} \quad \tilde{u}_{22} \quad \tilde{u}_{23}] \begin{bmatrix} \tilde{\lambda}_{21} & 0 & 0 & 0 & 0 & 0 \\ 0 & \tilde{\lambda}_{22} & 0 & 0 & 0 & 0 \\ 0 & 0 & \tilde{\lambda}_{23} & 0 & 0 & 0 \end{bmatrix} [\tilde{v}_{21} \quad \tilde{v}_{22} \quad \tilde{v}_{23} \quad \tilde{v}_{24} \quad \tilde{v}_{25} \quad \tilde{v}_{26}] \qquad (11)$$

$$[\tilde{u}_{31} \quad \tilde{u}_{32} \quad \tilde{u}_{33}]\begin{bmatrix} \tilde{\Sigma}_{31} & 0 & 0 & 0 & 0 & 0 \\ 0 & \tilde{\Sigma}_{32} & 0 & 0 & 0 & 0 \\ 0 & 0 & \tilde{\Sigma}_{33} & 0 & 0 & 0 \end{bmatrix}[\tilde{v}_{31} \quad \tilde{v}_{32} \quad \tilde{v}_{33} \quad \tilde{v}_{34} \quad \tilde{v}_{35} \quad \tilde{v}_{36}] \qquad (12)$$

From equation (10),(11),(12) the following precoding matrices were obtained $\mathbf{W_u} \in \mathbb{C}^{6\times3}$ ,u = 1, 2, 3 :

$$\mathbf{W_1} = \tilde{\mathbf{V}}_1^{\mathbf{zero}} = [\tilde{v}_{14} \quad \tilde{v}_{15} \quad \tilde{v}_{16}] \qquad (13)$$
$$\mathbf{W_2} = \tilde{\mathbf{V}}_2^{\mathbf{zero}} = [\tilde{v}_{24} \quad \tilde{v}_{25} \quad \tilde{v}_{26}] \qquad (14)$$
$$\mathbf{W_3} = \tilde{\mathbf{V}}_3^{\mathbf{zero}} = [\tilde{v}_{34} \quad \tilde{v}_{35} \quad \tilde{v}_{36}] \qquad (15)$$

Which construct the following transmitted signal, $\in \mathbb{C}^{6\times1}$ ,

$$\mathbf{x} = \mathbf{W_1}\,\tilde{\mathbf{x}}_1 + \mathbf{W_2}\,\tilde{\mathbf{x}}_2 + \mathbf{W_3}\,\tilde{\mathbf{x}}_3 \qquad (16)$$

Where $\tilde{\mathbf{x}}_\mathbf{u} \in \mathbb{C}^{3\times1}$ is the $\mathbf{U}^{\mathbf{th}}$ user signal, u = 1,2,3 .Then the received signal of the first user is given as ;

$$\mathbf{y_1} = \mathbf{H}_1^{\mathbf{DL}}\,\mathbf{x} + \mathbf{z_1}$$
$$= \mathbf{H}_1^{\mathbf{DL}}\,(\mathbf{W_1}\,\tilde{\mathbf{x}}_1 + \mathbf{W_2}\,\tilde{\mathbf{x}}_2 + \mathbf{W_3}\,\tilde{\mathbf{x}}_3) + \mathbf{z_1}$$
$$= \mathbf{H}_2^{\mathbf{DL}}\left(\tilde{\mathbf{V}}_1^{\mathbf{zero}}\tilde{\mathbf{x}}_1 + \tilde{\mathbf{V}}_2^{\mathbf{zero}}\tilde{\mathbf{x}}_2 + \tilde{\mathbf{V}}_3^{\mathbf{zero}}\tilde{\mathbf{x}}_3\right) + \mathbf{z_1}$$
$$= \mathbf{H}_3^{\mathbf{DL}}\left(\tilde{\mathbf{V}}_1^{\mathbf{zero}}\tilde{\mathbf{x}}_1 + \tilde{\mathbf{V}}_2^{\mathbf{zero}}\tilde{\mathbf{x}}_2 + \tilde{\mathbf{V}}_3^{\mathbf{zero}}\tilde{\mathbf{x}}_3\right) + \mathbf{z_1}$$
$$= \mathbf{H}_3^{\mathbf{DL}}\,\tilde{\mathbf{V}}_1^{\mathbf{zero}}\tilde{\mathbf{x}}_1 + \mathbf{z_1}$$
$$= \mathbf{H}_2^{\mathbf{DL}}\,\tilde{\mathbf{V}}_1^{\mathbf{zero}}\tilde{\mathbf{x}}_1 + \mathbf{z_1}$$
$$= \mathbf{H}_1^{\mathbf{DL}}\,\tilde{\mathbf{V}}_1^{\mathbf{zero}}\tilde{\mathbf{x}}_1 + \mathbf{z_1} \qquad (17)$$

From equation (16), we have used the fact that $\mathbf{H}_1^{\mathbf{DL}} = \mathbf{H}_2^{\mathbf{DL}} = \mathbf{H}_3^{\mathbf{DL}}$ .We can see that the received signal is composed of the desired signal only.

## 3.0 RESULT AND DISCUSSION

For this study, MATLAB simulation results were derived to explain the effects of BER and signal noise ratio in the decibel (SNRdB) for BD performances. This simulation results were effective when varying different antennas and users respectively. On the other hand, the effects of inter antenna interferences were mitigated by applying several techniques as discussed in [9], [3]. This paper discusses user interferences and comparing BER system performances in different parameters.

In the process of precoding, BD method was used to cancel interferences from other users. This paper focuses on mitigating user interferences , but, does not discuss in details inter-antenna interferences.Therefore, results in the figure 4, 6, and 7 was simulated using Zero forcing (ZF) detection method to eliminate inter antenna interferences. Beside the ZF method, any other advanced signal detection method was also be used to improve BER performances such as the minimum mean square error (MMSE) signal detection or ordered successive interference (OSIC) signal detection as well as other methods.

### 3.1 BER Performance Of MU-MIMO With BD With Fixed Number Of Received Antenna, $N_M$ .

Figure 3(a) illustrates the antenna configuration for *K*=2, $N_M$ =2 and figure 3(b) shows the antenna configuration for *K*=3, $N_M$ =2. It can be concluded from the demonstrated figure, that when the number of users increased, more interference will present in the communication system.

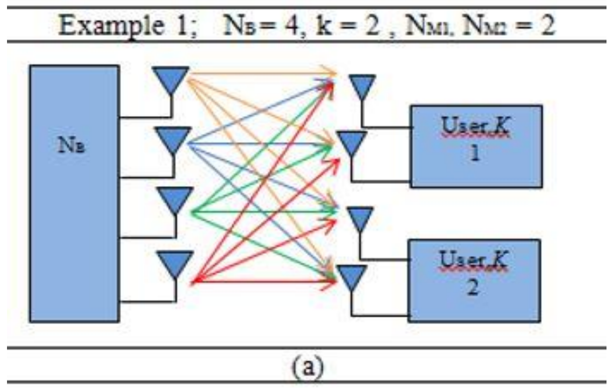



**Figure 3(a)** Antenna configuration for K=2, $N_M$ =2

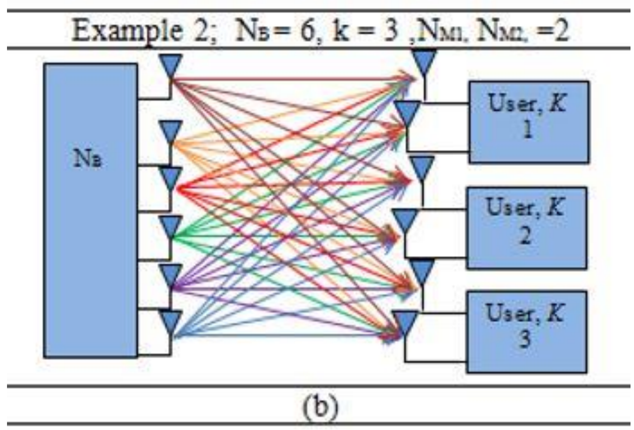



**Figure 3(b)** Antenna configuration for K=3, $N_M$ =2

Figure 4 shows the effect of varying number of users (*K*=2,3,4,5) with fixed number of received antenna ( $N_M$ =2) on the system BER.

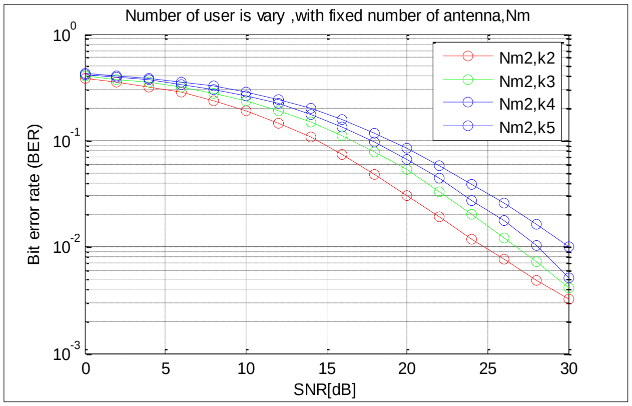



**Figure 4** BER performance of BD method for an example Number of user,*K* vary with fixed number of antenna , $N_M$

Table 1 shows BER gets higher proportional with number of user,*K*. Hence, the performance of BD is better with less number of user,*K* .

**Table 1** Number of antenna, $N_M$ is fixed with vary number of user, *K* at SNRdB 20

| Number of antenna transmitter, $N_B$ | Number of antenna receiver $N_M$ | Number of user,*K* | BER (at 20dB) |
|---|---|---|---|
| 4 | 2 | 2 | 0.03075 |
| 6 | 2 | 3 | 0.05296 |
| 8 | 2 | 4 | 0.06675 |
| 10 | 2 | 5 | 0.08468 |

### 3.2 BER Performance of MU-MIMO with BD with Fixed Number Of Received Antenna, *K*.

Figure 5(a) illustrates the antenna configuration for *K*=3, $N_M$ =2 and figure 5(b) shows the antenna configuration for *K*=3, $N_M$ =3.When the number of received antenna increased, more interferences presences in inter-antenna systems is observed.

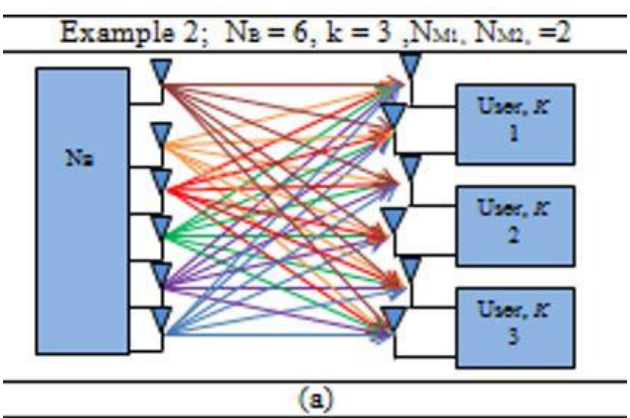



**Figure 5 (a)** Antenna configuration for K=3, $N_M$ =2

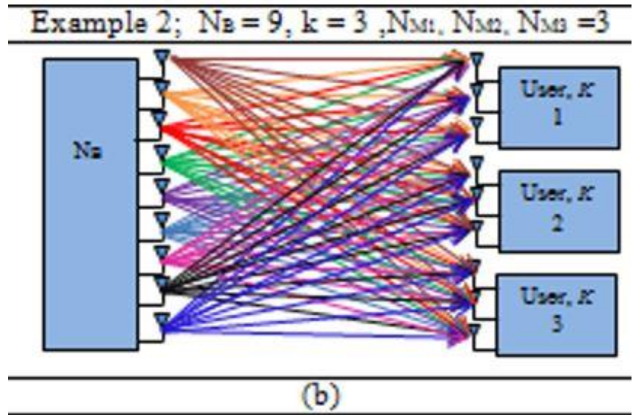



**Figure 5(b)** Antenna configuration for K=3, $N_M$ =3

Figure 6 illustrates the number of antenna, NM varies from ( $N_M$ =2,3,4,5) and the observed effect numbers of antenna, $N_M$ on BER performance. Number of users is fixed with three user (*K*=3) each to differentiate performances as shown in table 2.

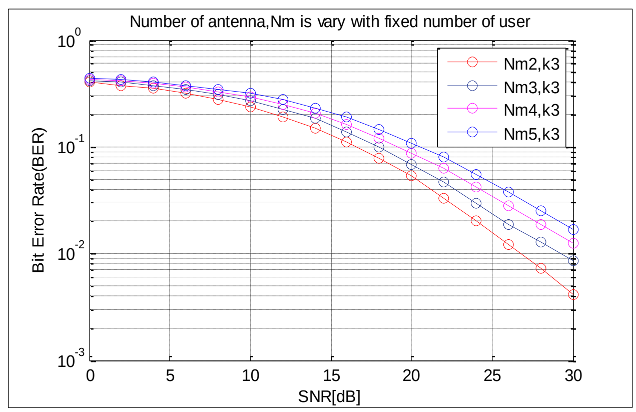



**Figure 6** BER performance of BD method for an example number of user, K is fixed with vary number of antenna, $N_M$

SNR is inversely related to BER, hence, the higher the SNR, BER will become lower. Since there is a varying number of antenna, the graph represents performance of ZF precoding instead of BD; ZF is a linear precoding for multiuser transmission scheme but it mitigates only interferences among different antenna. Table 2 presents BER performances at 20dB and shows BER is better with fewer number of antennas.

**Table 2** Number of antenna, $N_M$ is vary with fixed number of user,*K* at SNRdB 20

| Number of antenna transmitter, $N_B$ | Number of antenna receiver , $N_M$ | Number of user ,*K* | BER (at 20dB) |
|---|---|---|---|
| 6 | 2 | 3 | 0.05296 |
| 9 | 3 | 3 | 0.06839 |
| 12 | 4 | 3 | 0.08796 |
| 15 | 5 | 3 | 0.1092 |

### 3.3 *BER* Performance of MU-MIMO with BD With Fixed Total Transmit Antenna, $N_B$.

Result in figure 7 show fixed base transmitter, $N_B$ is 6, but the numbers of of antenna receivers, $N_M$ are varied and user , *K* as shown in table 3 below.
The total number of transmitter antenna is calculated by NB = *K* × $N_M$ .In this case, *K* × $N_M$ is 6

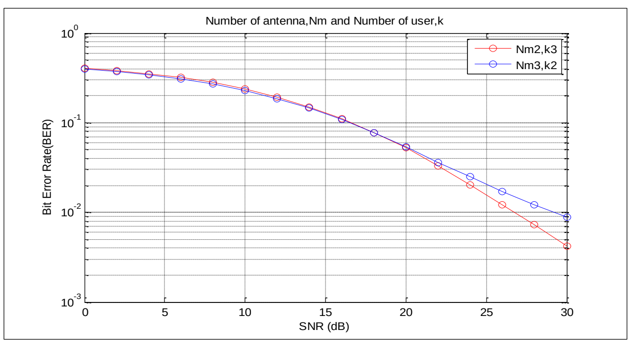



**Figure 7** BER performances of BD methods for varying user and receiver at SNRdB 20.

**Table 3** Compare number of antenna, $N_M$ and number of user,K

| Number of antenna transmitter , $N_B$ | Number of antenna receiver , $N_M$ | Number of user ,*K* | BER (at 20dB) | BER (at 22dB) |
|---|---|---|---|---|
| 6 | 2 | 3 | 0.05387 | 0.03304 |
| 6 | 3 | 2 | 0.05387 | 0.03567 |

Figure 7 and table 3 show that at a higher SNR ( > 20dB ),when $N_M$ is 2 and *K* is 3, the result is better when compared with when NM is 3 and *K* is 2 ( $N_M$ =2 &*K*=3 > $N_M$ =3 &*K*=2 ). This shows that having more users with fewer antennas is better than having more antennas for fewer users. However, at low SNR (< 20dB), result for both is comparable as shown in the table above.

## 5.0 CONCLUSIONS

Our communications system improves in parallel with the advancement of technology. Interferences will become more severe as more users and more antennas take place in the system. Therefore, even though BD precoding has the ability to mitigate interferences, some improvements need to be done to tackle this issue. From this paper, it can be observed that having more users with fewer antennas is better than having more antennas for fewer users.

Future researches should study how to combine the BD precoding with other methods to mitigate both inter-user interferences and inter-antenna interferences with low complexity level.

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## References

[1] GesbertD., KountourisM., JrR. W. H., ChaeC.-B. and SälzerT. 2007. From Single User to Multiuser Communications: Shifting the MIMO Paradigm. *IEEE Signal Process. Mag*. 1–29.
[2] Gelal E., Pelechrinis K., BroustisI., KrishnamurhtyS. V., Mohammed S., Chockalingama. and KaserasS. 2010. On the impact of MIMO Diversity On Higher Layer Performance. *Proc. - Int. Conf. Distrib. Comput. Syst*. 4: 764–773.
[3] KhanM. H., ChoK. M., LeeM. and ChungJ.-G. 2014. A Simple Block Diagonal Precoding For Multi-User MIMO Broadcast Channels, *EURASIP J. Wirel. Commun. Netw*. (1): 95.
[4] SpencerQ. H., SystemsD. C., PeelC. B., FederalS. and Swindlehursta L. 2004. An Introduction to the Multi-User MIMO Downlink. *Commun. Mag. IEEE*. 42(10): 60–67.
[5] ZuK., de Lamare R. and Haardt M. 2013. Generalized Design Of Low-Complexity Block Diagonalization Type Precoding Algorithms For Multiuser MIMO Systems. 61(10): 4232–4242.
[6] ChoY. S., Kim J., YangW. Y. and Kang C. G. 2010. MIMO-OFDM Wireless Communications with MATLAB®. Chichester, UK: *John Wiley & Sons, Ltd*.
[7] Khan M. H., ChoK. M., LeeM. and ChungJ.-G. 2014. A Simple Block Diagonal Precoding For Multi-User MIMO Broadcast Channels, *EURASIP J. Wirel. Commun. Netw*. 2014(1): 95.
[8] Shen Z., ChenR., AndrewsJ., HeathR. and EvansB. 2006. Sum Capacity of Multiuser MIMO Broadcast Channels with Block Diagonalization, *2006 IEEE Int. Symp. Inf. Theory*. 1: 886–890.
[9] Wang F. 2011. Performance of Block Diagonalization Scheme for Downlink Multiuser MIMO System with Estimated Channel State Information. *Int'l J. Commun. Netw. Syst. Sci*. 4(2): 82–87.
[10] Shen Z., Chen R., Andrews J. G., Heath R. W. and EvansB. L.. 2006. Sum Capacity Of Multiuser MIMO Broadcast Channels With Block Diagonalization. *IEEE Int. Symp. Inf. Theory - Proc*. 1: 886–89