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PERFORMANCE EVALUATION OF TRANSMISSION FOR MULTIUSER MIMO BROADCAST CHANNEL

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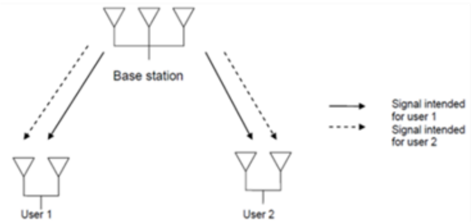

Abstract

Multiple Input Multiple Output (MIMO) system has been brought a great improvement in spectral efficiency and the system capacity by serving multiple users simultaneously. The mathematical model of downlink Multi-user MIMO system and its capacity has been presented as well as different precoded transmission schemes. It is to implementing the downlink MU-MIMO system, such as channel inversion (CI), block diagonalization (BD), dirty paper coding (DPC) and tomlinsonharashimaprecoding (THP). It is because, in wireless and mobile communication system has been requires a reliable transmission of high data rates under various channel type different scenarios and reduce MU interference in the system. These compares the method of transmission for broadcast channel (BC) and propose the best one method that outperforms existing technique with percentage improvement from the worst performance.

Keywords: Multiuser MIMO; Bit Error Rate (BER); multiuser interference; Broadcast Channel (BC)

1.0 INTRODUCTION

In the past few years, MIMO systems have drawn a lot of attention due to achieve high throughput in wireless communication system. To significantly increase system performance as well as capacity, antenna systems which employ multiple antennas at both the base station (BS) and mobile station (MS), operating in space time, have been proposed and demonstrated [1]. For no bandwidth expansion or increase in transmitted power is required is the most important advantage of using multiple antennas or space diversity for capacity and performance improvement. To be classified as multi user MIMO BC and multi user MIMO multiple access channel (MAC), the research on MIMO systems have been extended to multiuser MIMO systems. This focused only on multi user MIMO BC because the main difficulty in BC is that the desired signal is affected by other userssignals. The , CI, BD, DPC and THP methods are used to cancel interference due to other users and give the performance comparison of both methods in terms of BER [8].

2.0 SYSTEM MODEL

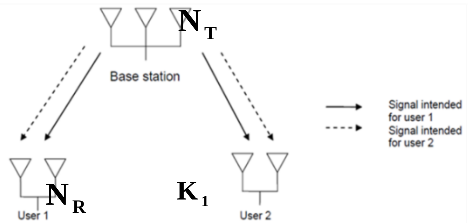

Figure 1 An illustration of a multi-user MIMO downlink. Each user often receives data intended for other users

The downlink channel, where the base station is simultaneously transmitting to a group of users, is illustrated in Fig. 1. In the situation depicted, the base attempts to transmit over the same channel to two users, but there is some inter-user interference for user 1 generated by the signal transmitted to user 2 and vice versa. With the aid of multi user detection (MUD), it may be possible for a given user to overcome the multiple access interference (MAI), but such techniques are often too costly for use at the receivers. Ideally, we would like to mitigate the MAI at the transmitter by intelligently designing the transmitted signal. If CSI is available at the transmitter, it is aware of what interference is being created for user 2 by the signal it is transmitting to user 1 and vice versa. This inter-user interference can be mitigated by intelligent beam forming or the use of dirty paper codes. Such techniques will be discussed later.

3.0 MATHEMATICAL MODEL FOR MULTIUSER MIMO SYSTEM

The downlink channel shows in equation 1 and also known as a BC. Where **x** is the transmit signal from the BS and $\mathbf{y_u}$ is the received signal at the $\mathbf{u^{th}}$ user, u = 1, 2… **K**. Let $\mathbf{H_u^{DL}}$ represents the channel gain between BS and the $\mathbf{u^{th}}$ user. Where additive zero mean circular symmetric complex gaussian (ZMCSCG) noise is the $\mathbf{z_u}$ at the $\mathbf{u^{th}}$ user where this noise is the random vector. All user signals by a single vector have been representing and the overall system can be represented as [5].

$$\begin{bmatrix} y_1 \\ y_2 \\ . \\ . \\ y_K \end{bmatrix} = \begin{bmatrix} H_1^{DL} \\ H_2^{DL} \\ . \\ . \\ H_K^{DL} \end{bmatrix} x + \begin{bmatrix} z_1 \\ z_2 \\ . \\ . \\ z_K \end{bmatrix} \tag{1}$$

4.0 TRANSMISSION MODEL FOR BROADCAST CHANNEL

The coordinated signal detection on the receiver side is the main difficulty in data transmission in BC because it is not straightforward and thus interference cancellation at BS is required. In this investigate, four different transmission method has been consider.

4.1 Channel Inversion (Ci)

The received signal of the $\mathbf{u^{th}}$ user can expressed as

$$\mathbf{y_u} = \mathbf{H_u^{DL}} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ . \\ . \\ \tilde{x}_K \end{bmatrix} + \mathbf{z_u}, \mathbf{u} = \mathbf{1,2,3,....,K} \tag{2}$$

$$\begin{bmatrix} y_1 \\ y_2 \\ . \\ . \\ y_K \end{bmatrix} = \begin{bmatrix} H_1^{DL} \\ H_2^{DL} \\ . \\ . \\ H_K^{DL} \end{bmatrix} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ . \\ . \\ \tilde{x}_K \end{bmatrix} + \begin{bmatrix} z_1 \\ z_2 \\ . \\ . \\ z_K \end{bmatrix} \tag{3}$$

Equation (3) shows that a scalar at the received signal at each user terminal. Interferences due to other signals cannot be canceled since each user is equipped with a single antenna. Instead, precoding techniques such as channel inversion and regularized channel inversion can be considered. Zero Forcing (ZF) pre-equalization is the same processing as the CI but the only difference is that H in equation (5) is replaced with $\mathbf{H^{DL}}$. [3], [4].

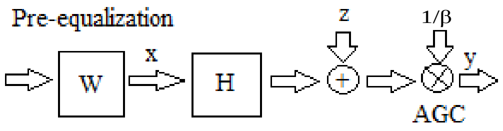

Figure 2 Pre-equalization process [6]

The pre-equalization also can be represented by a pre-equalizer weight matrix **W** and thus, the preceded symbol vector **X** can be expressed as

$$\mathbf{X} = \mathbf{W}\tilde{\mathbf{x}} \tag{4}$$

The original symbol vector for transmission is $\tilde{\mathbf{X}}$. In case where the ZF equalization is employed, the corresponding weight matrix (assuming that the channel matrix is square) is given as [6]

$$\mathbf{W_{ZF}} = \boldsymbol{\beta}\mathbf{H}^{-1} \tag{5}$$

Where $\boldsymbol{\beta}$ is a constant to meet the total transmitted power constraint after pre-equalization and it is given as [6]

$$\boldsymbol{\beta} = \sqrt{\frac{\mathbf{n_T}}{\mathbf{Tr}\left(\mathbf{H}^{-1}\left(\mathbf{H}^{-1}\right)^{\mathbf{H}}\right)}} \tag{6}$$

The received signal must be divided by **β** via automatic gain control (AGC) at the receiver to compensate for the effect of amplification by a factor of **β** at the transmitter. The received signal **y** is given by [4].

$$\begin{aligned}\mathbf{y} &= \frac{1}{\beta}(\mathbf{H}\mathbf{W}_{ZF}\tilde{\mathbf{x}} + \mathbf{z}) \\ &= \frac{1}{\beta}(\mathbf{H}\beta\mathbf{H}^{-1}\tilde{\mathbf{x}} + \mathbf{z}) \\ &= \tilde{\mathbf{x}} + \frac{1}{\beta}\mathbf{z}\end{aligned} \tag{7}$$

4.1.1 Regularized Channel Inversion (Rci)

Other than ZF pre-equalization, minimum mean square error (MMSE) pre-equalization can also be used. In this case, the weight matrix is given as

$$\begin{aligned}\mathbf{W}_{MMSE} &= \beta \times \mathbf{arg_W minE}\{||\beta^{-1}(\mathbf{HW}\tilde{\mathbf{x}} + \mathbf{z}) - \tilde{\mathbf{x}}||^2\} \\ &= \beta \times \mathbf{H}^H(\mathbf{HH}^H + \frac{\sigma_Z^2}{\sigma_X^2}\mathbf{I})^{-1}\end{aligned} \tag{8}$$

whereW is the original symbol vector for transmission.

To meet the total transmitted power constraint, the constant β has been used again. It is calculated by equation (8), but now, replace H^{-1} with $H^H (HH^H + \sigma^2 z/\sigma^2 z\ I)^{-1}$. The pre-equalization scheme on the transmitter side has been observed that outperforms the receiver-side equalization. It's attributed to the fact that the receiver-side equalization suffers from noise enhancement in the course of equalization.

4.2 Block Diagonalization (Bd)

This considers a downlink scenario, where the base station broadcasts information to K mobile users. Each selected mobile user has been considered receives multiple data streams. The base station employs $\mathbf{N_T}$ transmit antennas $\mathbf{k}^{\mathbf{th}}$ mobile user is equipped with $\mathbf{N_R}$ receiving antennas. The downlink complex channel matrix between the BS and the $\mathbf{k}^{\mathbf{th}}$ mobile terminal is denoted by $\mathbf{H_k} \in \mathbf{C}^{M_k \times N_t}$. Let $\mathbf{N_{M,u}}$ denote the number of antennas for the $\mathbf{u}^{\mathbf{th}}$ user, u = 1, 2… k. for the $\mathbf{u}^{\mathbf{th}}$ user signal $\tilde{\mathbf{x}}_u \in \mathbf{C}^{N_{M,u} \times 1}$, the received signal $\mathbf{y}_u \in \mathbf{C}^{N_{M,u} \times 1}$ is given as bellow:

$$\begin{aligned}\mathbf{y_u} &= \mathbf{H_U^{DL}}\sum_{\mathbf{k=1}}^{\mathbf{K}}\mathbf{W_k}\tilde{\mathbf{x}}_\mathbf{k} + \mathbf{z_u} \\ &= \mathbf{H_U^{DL}W_U}\tilde{\mathbf{x}}_\mathbf{U} + \sum_{\mathbf{k=1,k\neq U}}^{\mathbf{K}}\mathbf{H_U^{DL}W_k}\tilde{\mathbf{x}}_\mathbf{k} + \mathbf{z}_u\end{aligned} \tag{9}$$

$\mathbf{H_U^{DL}} \in \mathbf{C}^{N_{M,u} \times N_B}$ is the channel matrix between BS and the justify $\mathbf{U}^{\mathbf{th}}$ user.

$\mathbf{W_U} \in \mathbf{C}^{N_{M,u} \times N_{M,u}}$ Is the precoding matrix for the $\mathbf{U}^{\mathbf{th}}$ user, and $\mathbf{Z_U}$ is the noise vector.

$$\begin{aligned}\mathbf{y_1} &= \mathbf{H_1^{DL}x} + \mathbf{Z_1} \\ &= \mathbf{H_1^{DL}}\tilde{\mathbf{V}}_\mathbf{1}^{\mathbf{zero}}\tilde{\mathbf{x}}_\mathbf{1} + \mathbf{Z_1}\end{aligned} \tag{10}$$

In derivation equation (10), the fact that $\mathbf{H_1^{DL}} = \tilde{\mathbf{H}}_\mathbf{2}^{\mathbf{DL}}$ and $\mathbf{H_2^{DL}} = \mathbf{H_1^{DL}}$ have been used. From equation (10), composed that, the received signal is the desired signal only, the receive signal of the second user has been found in a similar way [6].

4.3 Dirty Paper Coding (Dpc)

DPC is a method of precoding the data. The effect of the interference can be canceled subject to some interference that is known to the transmitter [7]. In the course of precoding the $\mathbf{k}^{\mathbf{th}}$ user signal, the interference due to the first up to (k-1) th user signals has been canceled. The received signal is given as [6].

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} H_1^{DL} \\ H_2^{DL} \\ H_3^{DL} \end{bmatrix}\begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \tilde{x}_3 \end{bmatrix} + \begin{bmatrix} z_1 \\ z_2 \\ z_3 \end{bmatrix} \tag{11}$$

The Channel matrix $\mathbf{H^{DL}}$ can be LQ-decomposed as.

$$\mathbf{H_U^{DL}} = \begin{bmatrix} l_{11} & 0 & 0 \\ l_{21} & l_{22} & 0 \\ l_{31} & l_{32} & l_{33} \end{bmatrix}\begin{bmatrix} q_1 \\ q_2 \\ q_3 \end{bmatrix} = \mathbf{LQ} \tag{12}$$

whereL is identity matrix and Q is vector

Let $\mathbf{x} = [x_1 x_2 x_3]^T$ denote a precoded signal or $\tilde{\mathbf{x}} = [\tilde{x}_1 \tilde{x}_2 \tilde{x}_3]^T$. The effect of Q is eliminated through the channel by transmitting $\mathbf{Q^H x}$. The received signal is.

$$\begin{aligned}\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} &= \begin{bmatrix} H_1^{DL} \\ H_2^{DL} \\ H_3^{DL} \end{bmatrix}\mathbf{Q^H x} + \begin{bmatrix} z_1 \\ z_2 \\ z_3 \end{bmatrix} \\ \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} &= \begin{bmatrix} l_{11} & 0 & 0 \\ l_{21} & l_{22} & 0 \\ l_{31} & l_{32} & {}_{33} \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} z_1 \\ z_2 \\ z_3 \end{bmatrix}\end{aligned} \tag{13}$$

From the equation (13) the received signal for the first user is given by.

$$\mathbf{y}_1 = \mathbf{l}_{11}\mathbf{x}_1 + \mathbf{z}_1 \tag{14}$$

The equation for interference free for first user is [6].

$$\mathbf{x}_1 = \tilde{\mathbf{x}}_1 \tag{15}$$

By the same process equations for second, third and fourth users are as follows.

$$\mathbf{x}_2 = \tilde{\mathbf{x}}_2 - \frac{\mathbf{l}_{21}}{\mathbf{l}_{22}}\tilde{\mathbf{x}}_1 \tag{16}$$

$$\mathbf{x}_3 = \tilde{\mathbf{x}}_3 - \frac{\mathbf{l}_{31}}{\mathbf{l}_{33}}\mathbf{x}_1 - \frac{\mathbf{l}_{32}}{\mathbf{l}_{33}}\mathbf{x}_2 \tag{17}$$

For the interference-free data transmission, the following condition needs to be met.

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ -\dfrac{l_{21}}{l_{22}} & 1 & 0 \\ -\dfrac{l_{31}}{l_{32}} + \dfrac{l_{32}}{l_{33}}\dfrac{l_{31}}{l_{32}} & \dfrac{l_{32}}{l_{33}} & 1 \end{bmatrix} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \tilde{x}_3 \end{bmatrix} \tag{18}$$

This matrix expresses the (DPC). Finally the equation of received signal is.

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} l_{11} & 0 & 0 \\ 0 & l_{22} & 0 \\ 0 & 0 & l_{33} \end{bmatrix} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \tilde{x}_3 \end{bmatrix} + \begin{bmatrix} z_1 \\ z_2 \\ z_3 \end{bmatrix} \tag{19}$$

It is obvious that the precoding matrix in DPC is a scaled inverse matrix of the lower triangular matrix which is obtained from the channel gain matrix, and the interference-free detection can be made for each user.

4.4 Tomlinson Harashima Precoding (Thp)

The symmetric modulo operation for M-ary QAM modulated symbols has been discuss in order to address THP for the multiuser MIMO system, which is an extension of equation (20) to the two-dimensional case.

The real and imaginary parts of a symbols has been bounded by [-A, A], with A=$\sqrt{M}$ in M-ary QAM with a square constellation. The symmetric modulo is defined as below.

$$\mathbf{x} = \mathbf{mod}_A(\mathbf{c}) \underline{\underline{\Delta}} \mathbf{c} - \mathbf{2A}[(\mathbf{c} + \mathbf{A})/\mathbf{2A}] \tag{20}$$

$$\mathbf{mod}_A(\mathbf{x}) = \mathbf{x} - \mathbf{2A}[(\mathbf{x} + \mathbf{A} + \mathbf{jA})/\mathbf{2A}] \tag{21}$$

As a method to find integer values and modulo operation can be interrupted. Then modulo operation in equation (21) can be express as equation (22).

$$\mathbf{mod}_A(\mathbf{x}) = \mathbf{x} + \mathbf{2A.m} + \mathbf{j2A.n} \tag{22}$$

The modulation operation by referring to equation (16), (17) and (18) above, THP data symbols are represented as [6].

$$\begin{aligned} \mathbf{x}_1^{TH} &= \mathbf{mod}_A(\tilde{\mathbf{x}}_1) = \tilde{\mathbf{x}}_1 \\ \mathbf{x}_2^{TH} &= \mathbf{mod}_A\left(\tilde{\mathbf{x}}_2 - \frac{\mathbf{i}_{21}}{\mathbf{i}_{22}}\mathbf{x}_2^{TH}\right) \\ \mathbf{x}_3^{TH} &= \mathbf{mod}_A\left(\tilde{\mathbf{x}}_3 - \frac{\mathbf{i}_{31}}{\mathbf{i}_{33}}\mathbf{x}_1^{TH} - \frac{\mathbf{i}_{32}}{\mathbf{i}_{33}}\mathbf{x}_2^{TH}\right) \end{aligned} \tag{23}$$

5.0 RESULTS AND DISCUSSION

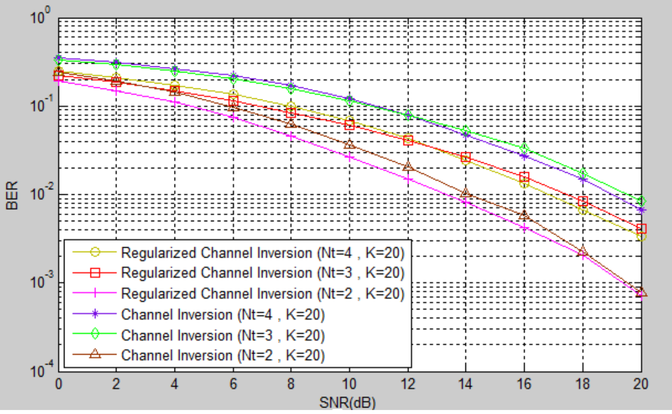

Figure 3 BER performance of two CI methods.

Table 1 Reading two method CI

METHODS	N_T	K	BER	SNR(dB)
	4	20	$1X10^{-1}$	8dB
RCI	3	20	$1X10^{-1}$	6.9dB
	2	20	$1X10^{-1}$	4.5dB
	4	20	$1X10^{-1}$	11dB
CI	3	20	$1X10^{-1}$	10.8dB
	2	20	$1X10^{-1}$	5.8dB

Figure 3 displays the BER performance of CI and RCI. Two situations are included, in where the numbers of users denote as K is fixed to 20, while the number of transmit antenna is varied. The criterion has been come from the equation (6). As can be observe, the percentage of improvement from the worst performance between CI and RCI with different number of transmit antennas have been investigated. The analysis that outcome from the RCI coding shown that the three number of transmit antenna percentage is 13% at BER 1X10^{-1}, and for two number of transmit antenna percentage is 43% at BER 1X10^{-1}. The suitable number of antenna with less interference is two number of transmit antenna. The analysis outcome from the CI coding shows that when the number of transmit antenna as three, the percentage is 1.8% at BER 1X10^{-1}. Nextas two number of transmit antenna, the percentage is 47%at BER 1X10^{-1}. By comparing two different coding technique with two number of transmit antenna, the result obtain that RCI technique can produce the better performance with 22% improvement and can reduce interference in the system.

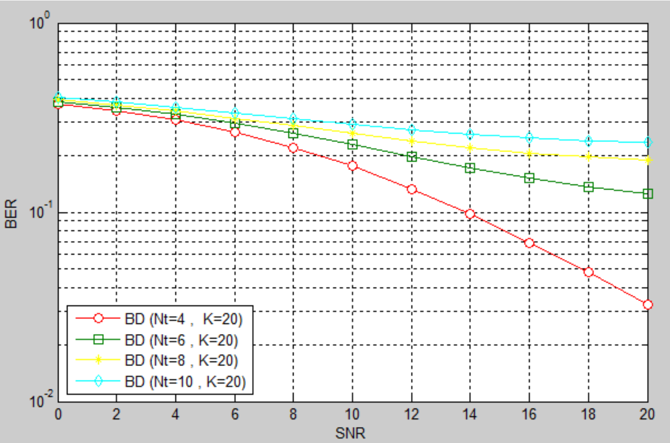

Figure 4 BER performance of BD method using ZF detection at the receiver.

Table 2 Reading for BD

METHOD	N_T	K	BER	SNR (dB)
BD	4	20	3X10^{-1}	4dB
	6	20	3X10^{-1}	5.6dB
	8	20	3X10^{-1}	6.9dB
	10	20	3X10^{-1}	9dB

The BER performance of BD method using ZF detection at the receiver investigated, in where the number of transmit antenna is varied while the number of users is fixed to 20. The percentage of improvement from the worst performance with difference numbers of transmit antenna has been investigated. 23% at BER 3X10^{-1} is the percentage that outcome for the number of transmit antennas as eight. It follow by 38% at BER 3X10^{-1} for the number of transmit antenna as six and 55% at BER 3X10^{-1} for number of transmit antenna as four. It can be seen in Figure 4 that BD can produce the better performance with decrease the number of transmit antenna and can reduce the interference in the system.

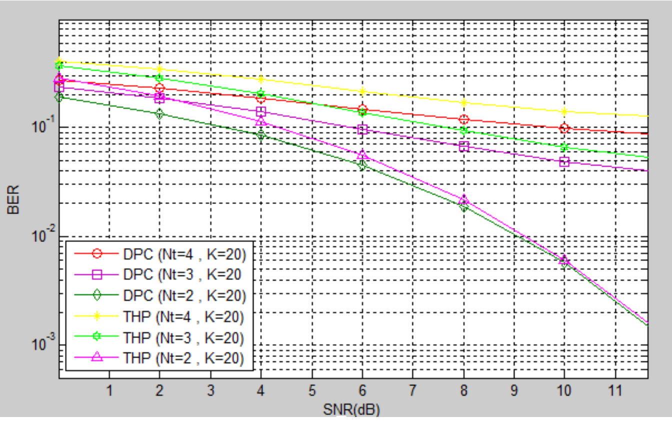

Figure 5 BER performance: DPC vs. THP.

Table 3 Reading for DPC and THP

METHODS	N_T	K	BER	SNR (dB)
DPC	4	20	2X10^{-1}	3.4dB
	3	20	2X10^{-1}	1.5dB
	2	20	2X10^{-1}	0dB
THP	4	20	2X10^{-1}	6.5dB
	3	20	2X10^{-1}	4.2dB
	2	20	2X10^{-1}	1.9dB

The BER curve DPC or THP for number of transmit antenna is varied and K number of users are fixed to 20 as depicted in Figure 5. The criterion comes from equation (16), (17), and (18) for DPC and (23) for THP. From the table 3, the percentage of improvement from the worst performance can be obtained with do the comparison between DPC and THP. The analysis outcome from the THP coding shows that when the number of transmit antenna as three, the percentage improvement is 35% at BER 2X10^{-1} and the percentage improvement for number of transmit antenna as two is 70% at BER 2X10^{-1}. The suitable number of antenna with less interference is two number of transmit antenna. The next analysis that outcome from the DPC coding shown that the three number of transmit antenna percentage is 55%at BER 2X10^{-1} and for two number of transmit antenna percentage is 100% at BER 2X10^{-1}. The suitable number of antenna with less interference is two number of transmit antenna. By comparing two different coding technique with two number of transmit antenna, the result obtain that DPC technique can produce the better performance with 30% improvement and can reduce interference in the system.

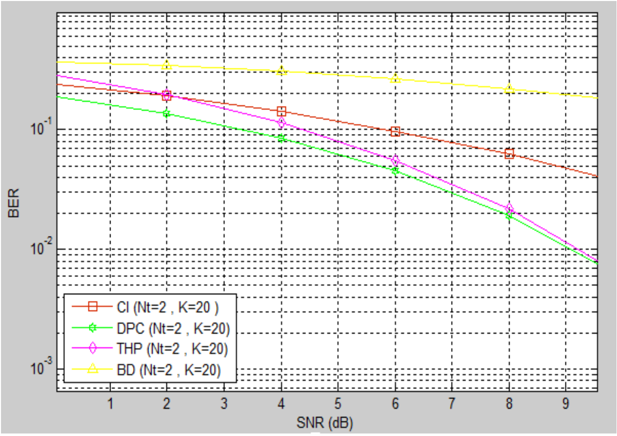

Figure 5 Comparison between all transmission methods for broadcast channel

Table 4 Reading for method BC

METHODS	N_T	K	BER	SNR (dB)
BD	2	20	2X10^{-1}	8.9dB
THP	2	20	2X10^{-1}	1.9dB
CI	2	20	2X10^{-1}	1.7dB
DPC	2	20	2X10^{-1}	0dB

In Figure 5, The BER performance of different transmission methods for BC has been compared. A multiuser MIMO downlink system considers with number of transmit antenna are two at the BS and 20 numbers of user. It can be seen that the percentage of improvement from the worst performance with BD, following with THP as much as 78% at BER 2X10^{-1}, next is CI with 80% at BER 2X10^{-1} and DPC as much as 100% at BER 2X10^{-1}. By comparing four different coding technique, the result obtain that DPC technique can produce the best performance and can reduce interference in the system

6.0 CONCLUSION

In this paper, the different method of BC downlink system and also different coding have been investigate to find the best one method that outperform existing technique. As can be observe, DPC seen very effective in canceling multi-user interference for multiuser MIMO downlink. Compared with some method of delivery for the broadcast channel, the proposed method greatly reduces the complexity at the same time enhancing overall system performance. In order to achieve the maximum diversity order system, the number of coding technique must be increase.

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