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Performance of Relay Assisted STBC Coded MIMO Wireless Downlink Communication

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ABSTRACT

In this paper, performance of relay assisted wireless downlink communication is investigated in the presence of rayleigh fading where source (base station) is equipped with multiple transmit antennas, relay is equipped with multiple transmit and receive antennas, and destination (mobile handset) has single receive antenna. Data are modulated by QPSK or 16 QAM or 64 QAM modulator at basestation; then modulated symbols are encoded by STBC encoder and finally, encoded symbols are split into n streams which are simultaneously transmitted using n transmit antennas of base station. Relay receives the rayleigh fading effected signal using multiple receive antennas, combines and decodes the received signal using maximum likelihood decoder; then re-encodes the symbols using STBC, and re-transmits the re-encoded symbols using n transmit antennas of relay. It is observed that relay assisted system having with different combination of transmit and receive antennas at relay provides 11-13 dB gain compared to direct link at 10^{-5}.

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1. INTRODUCTION

Communication from basestation to handset is called downlink communication. It is desired to install multiple transmit and multiple receive antennas at basestation as well as handset to boost the data rate and achieve better transmission quality. Unfortunately it is not possible to install many antennas onto a small mobile hand set due to size, complexity, power or other constraints. To overcome this problem, one would consider the concept of relaying which provide power efficient solution to achieve spatial diversity in wireless fading channels [1–3].

There are mainly two types of relays: Amplify and Forward (AF) and Decode and Forward (DF). AF simply amplifies the incoming signal and forwards it to the destination without any attempt to decode it. AF relay is easy to implement but can not achieve high performance gain. On the other hand, DF decodes the incoming signal, re-encodes it, and then retransmits it to the destination. Although the complexity of DF is high but can obtain high performance gain [4]. So we have used DF to show the performance of our system.

On the other hand, there are mainly two types of transmission techniques for multiple input and multiple output (MIMO) system. One is transmit diversity in which different duplicates of the same transmission sequence are transmitted through different transmission antennas. One of the typical transmit diversity technique is Space Time Block Coding (STBC) [5-8]. The other one is transmitting multiplexing in which different transmission sequences are transmitted through different transmission antennas. The typical transmitting multiplexing technique is Bell Labs Layered Space-Time (BLAST) [9-12]. In this paper we have used STBC to show the performance of our system.

Relay assisted wireless communication has been widely studied [5-36]. [13-15] show the performance of relay using amplifying and forwarding. [16,17] show the performance of relay having difference time slot to transmit information. [18-22] show the performance of relay having single antenna at source, relay and destination. [23-25] show the performance of relay having single antenna at source and destination but multiple antennas at relay. [26-31] show the performance of relay having multiple antennas at source, relay and destination. Our previous papers investigate the performance of relay for uplink wireless communication [32-34]. This paper investigates the performance of relay for downlink wireless communication where source is equipped with multiple transmit antennas, relay is equipped with multiple transmit and receive antennas and destination is equipped with single transmit antenna.

2. SYSTEM MODEL

It is considered that the source (basestation) is equipped with multiple transmitte antennas and relay is equipped with multiple transmit antennas and multiple receive antennas and destination (handset) is equipped with single receiving antenna. Data are modulated by a QPSK or 16 QAM or 64 QAM modulator before transmitting as shown in Fig.1. The encoding and decoding techniques of the system are discussed in detail below:

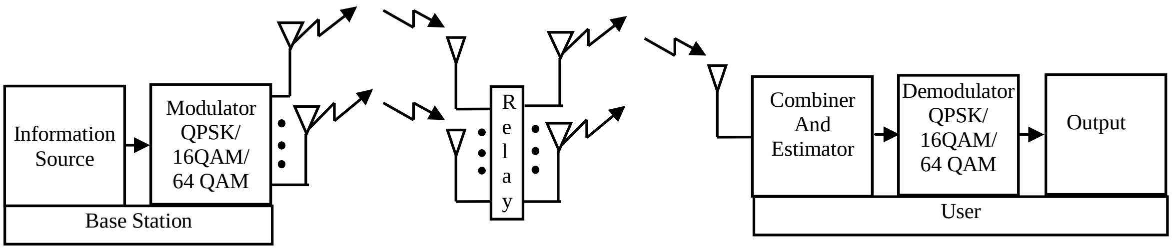

Figure 1. System Block diagram

2.1. Encoding at basestation

The modulated symbols are encoded using Space Time Block Coding (STBC) according to number of transmit antennas. Suppose we have two or four transmit antennas at the basestation; so modulated symbols are encoded according to table I or table II for two and four transmit antennas respectively [38, 39]:

Table 1. The encoding and transmission sequence for two transmit antennas of basestation

Time slot	Antenna-I	Antenna-II
Time slot-I	s_1	s_2
Time slot-II	$-s_2^*$	s_1^*

Table 2. The encoding and transmission sequence for four transmit antennas of basestation

Time slot	Antenna			
	Antenna-I	Antenna-II	Antenna-III	Antenna-IV
Time slot-I	s_1	s_2	$\frac{s_3}{\sqrt{2}}$	$\frac{s_3}{\sqrt{2}}$
Time slot-II	$-s_2^*$	s_1^*	$\frac{s_3}{\sqrt{2}}$	$-\frac{s_3}{\sqrt{2}}$
Time slot-III	$\frac{s_3^*}{\sqrt{2}}$	$\frac{s_3^*}{\sqrt{2}}$	$\frac{-s_1 - s_1^* + s_2 - s_2^*}{2}$	$\frac{-s_1 - s_2^* + s_1 - s_1^*}{2}$
Time slot-IV	$\frac{s_3^*}{\sqrt{2}}$	$-\frac{s_3^*}{\sqrt{2}}$	$\frac{s_2 + s_2^* + s_1 - s_1^*}{2}$	$\frac{s_1 + s_1^* + s_2 - s_2^*}{2}$

2.2. Received Signal at Relay

If the signals s_t^i , i =1, 2, ... n are transmitted simultaneously at each time slot t using n transmit antennas of base station, then the signal received at antenna j of relay can be written as:

$$r_t^j = \sum_{i=1}^{n} p_{i,j}^{SR} h_{i,j} s_t^i + n_t^j \tag{1}$$

where r_t^j is the received symbol on the j^{th} receiver antenna of relay at time slot t

$p_{i,j}^{SR}$ is path loss from transmit antenna i of source to receive antenna j of relay and $p_{i,j}^{SR} \alpha \frac{1}{d_{SR}^2}$

$h_{i,j}$ is the path gain from transmit antenna i to receive antenna j . The path gains are modeled as samples of independent complex Gaussian random variables with variance 0.5 per real dimension. The wireless channel is assumed to be quasi-static so that the path gains are constant over a frame of length l and vary from one frame to another.

s is the transmitted symbol at time slot t and

n_t^j is the noise on j^{th} receive antenna at time slot t . It is assumed that the noise on each receive antenna at each time slot is independent from the noise on the other receive antennas.

It is considered that $H_{ij} = p_{i,j} h_{i,j}$, then (1) can be rewrite as:

$$r_t^j = \sum_{i=1}^{n} H_{i,j} s_t^i + n_t^j \tag{2}$$

2.3. Decodingl at relay

For detecting symbols s_1 and s_2 of two transmit antennas, (3) and (4) decision metrics have been used:

$$\left| \left[\sum_{j=1}^{m} \left(r_1^j H_{1,j}^* + \left(r_2^j\right)^* H_{2,j} \right) \right] - s_1 \right|^2 + \left(-1 + \sum_{j=1}^{m} \sum_{i=1}^{2} \left| H_{i,j} \right|^2 \right) \left| s_1 \right|^2 \tag{3}$$

$$\left| \left[\sum_{j=1}^{m} \left(r_1^j H_{2,j}^* - \left(r_2^j\right)^* H_{1,j} \right) \right] - s_2 \right|^2 + \left(-1 + \sum_{j=1}^{m} \sum_{i=1}^{2} \left| H_{i,j} \right|^2 \right) \left| s_2 \right|^2 \tag{4}$$

The detected symbols of two tansmit antennas are denoted as $\hat{s}_1$ and $\hat{s}_2$.

For detecting symbols s_1 , s_2 and s_3 of four transmit antennas, (5), (6) and (7) decision metrics have been used :

$$\left| \left[\sum_{j=1}^{m} \left(r_1^j H_{1,j}^* + \left(r_2^j\right)^* H_{2,j} + \frac{(r_4^j - r_3^j)\left(H_{3,j}^* - H_{4,j}^*\right)}{2} - \frac{(r_3^j + r_4^j)^* \left(H_{3,j} - H_{4,j}\right)}{2} \right) \right] - s_1 \right|^2 + \left(-1 + \sum_{j=1}^{m} \sum_{i=1}^{4} \left| H_{i,j} \right|^2 \right) \left| s_1 \right|^2 \tag{5}$$

$$\left|\left[\sum_{j=1}^{m}\left(r_1^j H_{2,j}^* - \left(r_2^j\right)^* H_{1,j} + \frac{(r_4^j + r_3^j)\left(H_{3,j}^* - H_{4,j}^*\right)}{2} + \frac{(-r_3^j + r_4^j)^*\left(H_{3,j} - H_{4,j}\right)}{2}\right)\right] - s_2\right|^2 + \left(-1 + \sum_{j=1}^{m}\sum_{i=1}^{4}\left|H_{i,j}\right|^2\right)\left|s_2\right|^2 \quad (6)$$

$$\left|\left[\sum_{j=1}^{m}\left(\frac{\left(r_1^j + r_2^j\right)H_{3,j}^*}{\sqrt{2}} + \frac{\left(r_1^j - r_2^j\right)^* H_{4,j}^*}{\sqrt{2}} + \frac{\left(r_3^j\right)^*\left(H_{1,j} + H_{2,j}\right)}{\sqrt{2}} + \frac{\left(r_4^j\right)^*\left(H_{1,j} - H_{2,j}\right)}{\sqrt{2}}\right)\right] - s_3\right|^2 + \left(-1 + \sum_{j=1}^{m}\sum_{i=1}^{4}\left|H_{i,j}\right|^2\right)\left|s_3\right|^2 \quad (7)$$

The detected symbols of three tansmit antennas are denoted as $\hat{s}_1$, $\hat{s}_2$ and $\hat{s}_3$.

2.4. Re-encoding at relay:

STBC encoder of relay encodes the decoded symbols $\hat{s}_1$, $\hat{s}_2$ and $\hat{s}_3$ according to the Table III and IV for two and four transmit antennas respectively and then at each time slot t, signals $\hat{s}_t^i$, i =1, 2, … n are re-transmitted simultaneously using n transmit antennas of relay.

Table 3. The encoding and transmission sequence for two transmit antennas of relay

	Antenna-I	**Antenna-II**
Time slot-I	$\hat{s}_1$	$\hat{s}_2$
Time slot-II	$-\hat{s}_2^*$	$\hat{s}_1^*$

Table 4. The encoding and transmission sequence for two transmit antennas of relay

Time slot	Antenna			
	Antenna-I	Antenna-II	Antenna-III	Antenna-IV
Time slot-I	$\hat{s}_1$	$\hat{s}_2$	$\frac{\hat{s}_3}{\sqrt{2}}$	$\frac{\hat{s}_3}{\sqrt{2}}$
Time slot-II	$-\hat{s}_2^*$	$\hat{s}_1^*$	$\frac{\hat{s}_3}{\sqrt{2}}$	$-\frac{\hat{s}_3}{\sqrt{2}}$
Time slot-III	$\frac{\hat{s}_3^*}{\sqrt{2}}$	$\frac{\hat{s}_3^*}{\sqrt{2}}$	$\frac{-\hat{s}_1 - \hat{s}_1^* + \hat{s}_2 - \hat{s}_2^*}{2}$	$\frac{-\hat{s}_1 - \hat{s}_2^* + \hat{s}_1 - \hat{s}_1^*}{2}$
Time slot-IV	$\frac{s_3^*}{\sqrt{2}}$	$-\frac{s_3^*}{\sqrt{2}}$	$\frac{\hat{s}_2 + \hat{s}_2^* + \hat{s}_1 - \hat{s}_1^*}{2}$	$\frac{\hat{s}_1 + \hat{s}_1^* + \hat{s}_2 - \hat{s}_2^*}{2}$

2.5. Received signal at destination:

At time *t* the signal y_t , received at destination, is given by

$$y_t = \sum_{i=1}^{n} P_i^{RD} a_i \hat{s}_t^i + \eta_t \tag{8}$$

where y_t is the received symbol at destination at time t.

p_i^{RD} is path loss from transmit antenna i of relay to receive antenna and $d_{i,j} \alpha \frac{1}{d_{RD}^2}$

a_i is the channel from transmit antenna *i* to receive antenna *j*.

$\hat{s}_t^i$ is the transmitted symbol from transmit antenna *i* at each time slot *t*.

η_t is the noise on receive antenna at time *t* .

It is considered that $A_i = P_i^{RD} a_i$, then (8) can be rewrite as:

$$y_t = \sum_{i=1}^{n} A_i \hat{s}_t^i + \eta_t \tag{9}$$

2.5. Decodingl at Destination

The combiner combines received signals of destination which are then sent to the maximum likelihood detector. For detecting symbols $\hat{s}_1$ and $\hat{s}_2$ of two transmit antennas, (10) and (11) decision metrics have been used.

$$\begin{aligned} &\left| \left[\left(y_1 A_1^* + (y_2)^* A_2 \right) \right] - \hat{s}_1 \right|^2 \\ &+ \left(-1 + \sum_{i=1}^{2} |A_i|^2 \right) |\hat{s}_1|^2 \end{aligned} \tag{10}$$

$$\begin{aligned} &\left| \left[\left(y_1 A_2^* - (y_2)^* A_1 \right) \right] - \hat{s}_2 \right|^2 \\ &+ \left(-1 + \sum_{i=1}^{2} |A_i|^2 \right) |\hat{s}_2|^2 \end{aligned} \tag{11}$$

For detecting symbols $\hat{s}_1$, $\hat{s}_2$ and $\hat{s}_3$ (12),(13) and (14) decision metrics have been used.

$$\begin{aligned} &\left| \left[\left(y_1 A_1^* + (y_2)^* A_2 + \frac{(y_4 - y_3)(A_3^* - A_4^*)}{2} \right. \right. \right. \\ &\left. \left. \left. - \frac{(y_3 + y_4)^* (A_3 - A_4)}{2} \right) \right] - \hat{s}1_1 \right|^2 \\ &+ \left(-1 + \sum_{i=1}^{4} |A_{i,j}|^2 \right) |\hat{s}_1|^2 \end{aligned} \tag{12}$$

$$\left|\left[\left(y_1^j A_2^* - \left(y_2\right)^* A_1 + \frac{(y_4+y_3)\left(A_3^* - A_4^*\right)}{2} + \frac{(-y_3+y_4)^*\left(A_3 - A_4\right)}{2}\right)\right] - \hat{s}_2\right|^2 + \left(-1+\sum_{i=1}^{4}\left|A_i\right|^2\right)\left|\hat{s}_2\right|^2 \tag{13}$$

$$\left|\left[\left(\frac{\left(y_1+y_2\right)A_3^*}{\sqrt{2}} + \frac{\left(y_1-y_2\right)^* A_4^*}{\sqrt{2}} + \frac{\left(y_3\right)^*\left(A_1+A_2\right)}{\sqrt{2}} + \frac{\left(y_4\right)^*\left(A_1-A_2\right)}{\sqrt{2}}\right)\right] - \hat{s}_3\right|^2 + \left(-1+\sum_{i=1}^{4}\left|A_i\right|^2\right)\left|\hat{s}_3\right|^2 \tag{14}$$

The detected symbols are demodulated by a QPSK or 16 QAM or 64 QAM demodulator to get the output.

3. Simulation Results

In this section, computer simulation is carried out to show the BER performance of the proposed system. The results are evaluated for several combinations of Tx and Rx antennas with and without relay. 64 QAM is used for simulation. It is considered that relay is placed at the middle of source and destination. We used two terms in fig.3-fig .7: Direct Link (DL) and Via Relay Link (VRL). DL means that information pass from source to destination without relay. On the other hand, VRL means that information pass from source to relay and then from relay to destination as shown in fig. 2.

Fig. 3 shows the performance of DL and VRL where basestation has 2 Tx, relay has 2 Tx and 2 Rx and handset has 1 Rx. it is observed that VRL provides 13 dB coding gain compared to DL at 10^{-5}.

Fig. 4 shows the performance of DL and VRL where basestation has 2 Tx, relay has 2 Tx and 4 Rx and handset has 1 Rx. it is observed that VRL provides 11 dB coding gain compared to DL at 10^{-5}.

Fig. 5 shows the performance of DL and VRL where basestation has 4 Tx, relay has 4 Tx and 2 Rx and handset has 1 R_x. it is observed that VRL provides 11 dB coding gain compared to DL at 10^{-5}.

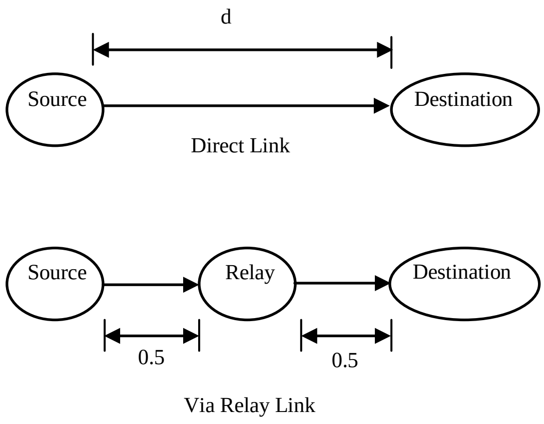

Fig. 2. Direct Link and Via Relay Link

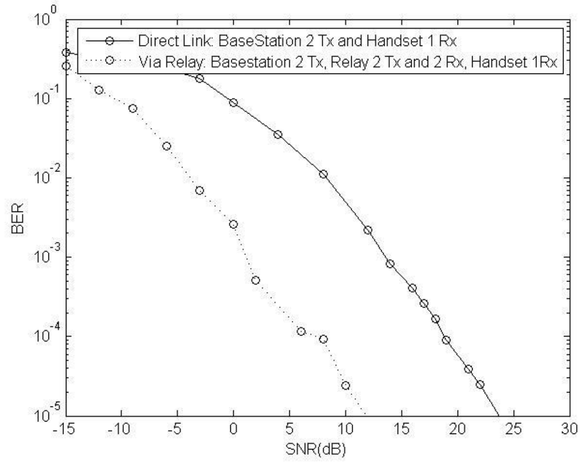

Fig. 3. BER performance comparision of wireless downlink communicationa for direct line with $2T_x$ & $1R_x$ and relay with $2T_x$ & $2R_x$

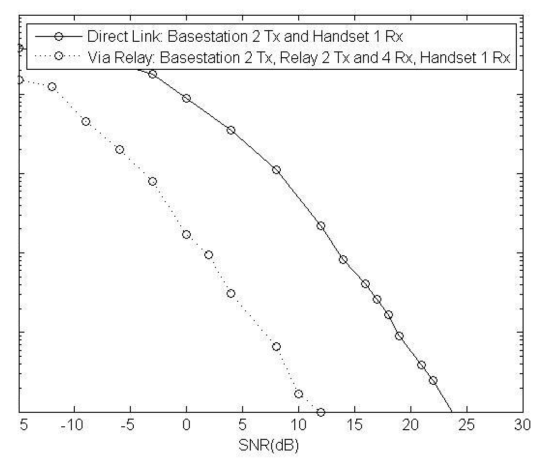

Fig. 4. BER performance comparision of wireless downlink communicationa for direct line with $2T_x$ & $1R_x$ and relay with $2T_x$ & $4R_x$

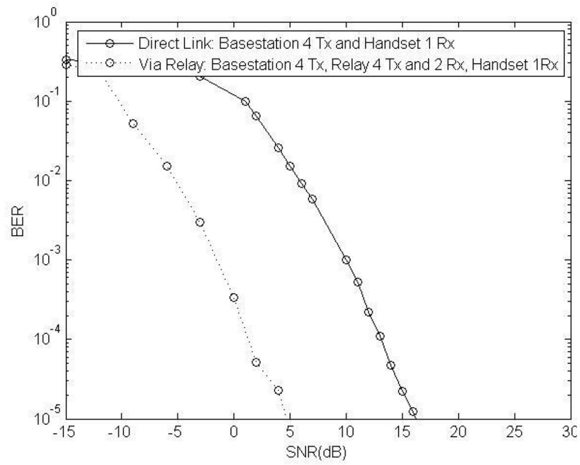

Fig. 5. BER performance comparision of wireless uplink communicationa for direct line with $4T_x$ & $1R_x$ and relay with $4T_x$ & $2R_x$

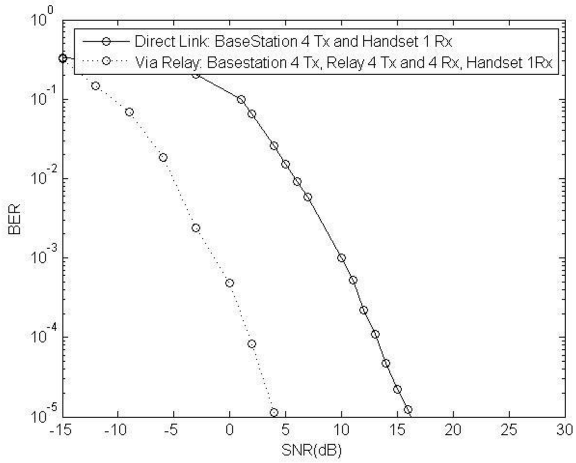

Fig. 6. BER performance comparision of wireless uplink communicationa for direct line with $4T_x$ & $1R_x$ and relay with $4T_x$ & $4R_x$

Fig. 6 shows the performance of DL and VRL where basestation has 4 T_x, relay has 4 T_x and 4 R_x and handset has 1 R_x. it is observed that VRL provides 12 dB coding gain compared to DL at 10^{-5}.

4. Conclusion

From the simulations results, it is observed that relay assisted downlink wireless communication makes a significant difference over direct downlink wireless communication. It is possible to get 11 - 13 dB gain by placing relay between source and destination at 10^{-5}.

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BIOGRAPHY OF AUTHOR

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