Improvement of Communication System over Multipath Channels using Time Reversal Division Multiple Access Technique

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***Abstract*-- In broad-band communications, wide range of frequencies are available allowing more information to be transmitted in a given amount of time.The multi-path effect makes high speed broad-band communication a challenging task due to the severe inter-symbol interference (ISI).To resolve this problem, multicarrier modulations are needed at the receiver to alleviate the ISI. A novel concept of time-reversal division multiple access (TRDMA) has been introduced as a wireless channel access method based on its high-resolution spatial focusing effect. Time reversal signal processing is a technique for focusing waves. This paper aims to develop a multi-user downlink system with both the single-input single-output (SISO)antenna scheme and with multiple-input single-output (MISO) antenna scheme and the system (MISO) performance are investigated in terms of its effective signal-to-interference-plus-noise ratio (SINR), the achievable sum rate and the achievable rates with outage.**

***Index Terms*— Time reversal, TRM, spatial focusing,temporal focusing.**

I. INTRODUCTION

Communication is the process of transmission of information from one point to another through a guided or unguided medium. In the present world, wireless communication system has got many applications such as GPS units, wireless computer networks, keyboards and headsets, cordless telephones, etc[8]. All the advancements in this field are to achieve two important goals namely reliability and efficiency.

Time reversal signal processing is a technique for focusing waves. Time Reversal Mirror focus waves using time reversal method. TRM transmits a plane wave towards the target and is reflected offit. The reflected wave returns to TRM as if the target has emitted a weak signal. TRM reverses and retransmits the signal as usual and a more focused wave propagates towards the target. As process is repeated, waves become more and more focused on target. In time reversal signal processing, one need not know any details about the channel. The step of sending the wave through the channel effectively measures it and retransmission step uses this data to focus the wave. Thus we only need to know that the channel is reciprocal.The single-user TR wirelesscommunications consist of two phases: the recording phase and the transmission phase. When transceiver T wants to transmit information to transceiver R, transceiver R first sends an impulse that propagates through a scattering multi-path environment and the multi-path signals are received and recorded by transceiver T; then, transceiver Rtransmits the time-reversed waves back through the communication link to transceiver R. The TR waves can retrace the incoming paths, ending up with a “spiky” signal-power spatial distribution focused only at the intended location, commonly referredto as spatial focusing effect,by utilizing channel reciprocity[2]-[4]. Also, from a signal processing point of view, in single-user communications, TR essentiallytreats the multi-pathas a matched filter computing machine for the intended receiver, and concentrates the energy of the signal in the time domain, which is referred to as temporal focusing effect.[9]-[11].

A.Objectives

The main objective of this project is to structure a multi-user downlink system for future energy-efficient low-complexity broadband wireless communications. Several major developments have been proposed and considered in the proposed TRDMA multi-user communication system. Namely:

(i) Introduce TRDMA multi-user downlink system with single transmit antennae (SISO case).
(ii) Introduce TRDMA multi-user downlink system with multiple transmit antennae (MISO case).
(iii) Evaluate SINR, achievable sum rate and achievable rate with outage for MISO TRDMA system.

III.SYSTEM ARCHITECTURE

The multi-path effect makes high speed broadband communications a very challenging task due to the severe Inter Symbol Interference (ISI). Earlier access methods do not ensure secure communications. By concentrating energy in both the spatial and temporal domains, TR transmission technique provides low-complexity energy-efficient communication**.** The main goal of this work is to structure a multi-user downlink system for future low complexity secure broad band wireless communication.

A. Block diagram of the system

Figure 3.1.1 and 3.1.2 provides a block diagram representation for the entire transmission and reception system. Three scenarios are presented: simulation of SISO TRDMA multiuser downlink system, simulation of MISO TRDMA multiuser downlink system and evaluation of SINR (signal to interference plus noise ratio), achievable sum rate and outage rate for MISO case. BER rate performances of both the system are evaluated. Block diagram of SISO TRDMA is shown in figure 3.1.1 and MISO TRDMA is shown in figure 3.1.2.

In this work, a multiuser downlink system over multipath randomchannel are considered and proposed the concept of TRDMA as a wireless channel access method by taking advantage of the high-resolution spatial focusing effect. Time reversal wireless communication has two phases: recording phase and transmission phase [5].

a. Recording phase

In the TRDMA multiuser downlink system, there are multiple users receiving independent messages from the base station(BS). TRM shown in the figure.3.1.1 and 3.1.2 is a device that can record and time-reverse the received waveform, which are then used to modulate the time-reversed waveform with input signal by convolving them together in the later transmission phase. During the recoding phase, initially the multiple users transmit an impulse signal to the base station. The TRMs at the BS record the channel responseof each link and store the time-reversed and conjugated version of each channel response for the following transmission phase. The waveform recorded by the TRM reflects the true channel impulse response[1].

b. Transmission phase

After the channel recording phase, the system starts the transmission phase. In the transmission phase, the required input sequences are fed into the TRM which is then convolved with the time reversed CIR stored at the base station. The outputs of TRM bank are added together, and transmitted into wireless channels.. The signal received at user will be the convolution of transmitted signal and channel impulse response. The receiver performs a one-tap gain adjustment to the received signal in orderto recover the original signal. To maintain low complexity at receivers, MISO case is being considered where the BS is equipped with multiple antennas together with multiple users equipping single antennas each. The block diagram of MISO TRDMA system is shown in the figure.3.1.2.

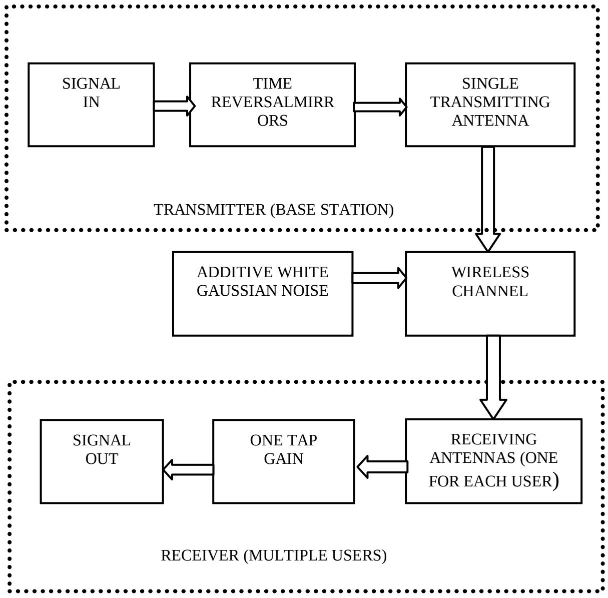

Figure.3.1.1. SISO TRDMA multiuser downlink system

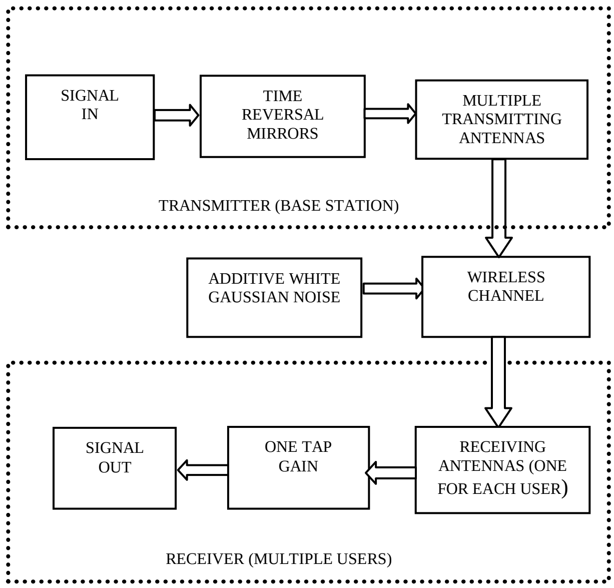

Figure.3.1.2 MISO TRDMA multiuser downlink system

c. Time reversal mirror

Time Reversal Signal Processing is a technique for focusing waves. A Time Reversal Mirror is an electronic mirror placed at the base station, which can focus waves using the time reversal method [4][10]. Initially, TRM transmits a plane wave toward the target and is reflected off it. The wave returns back to the TRM, as if the target has emitted a weak signal. The TRM reverses and retransmits the signal as usual, and a more focused wave propagates toward the target.

B. Effective SINR

The effective SINR[6] at each for MISO case are investigated. The average effective SINR at user i can be defined as the ratio of the average signal power to the average interference-and-noise power, i.e.

$$\mathrm{SINR(i)} = \frac{E[P_{SIG}(i)]}{E[P_{ISI}(i)]+E[P_{IUI}(i)]+\sigma^2} \quad (3.1)$$

where; $P_{SIG}(i) = \left|\sum_{m=1}^{M_T}(h_i^m * g_i^m)[L]\right|^2$ is the signal power

$P_{ISI}(i) = \sum_{l=0}^{(2L-2)/D}\left|\sum_{m=1}^{M_T}(h_i^m * g_i^m)[Dl]\right|^2$ is the power associated with inter-symbolinterference

$P_{IUI}(i) = \sum_{\substack{j=1 \\ j\neq i}}^{N}\sum_{l=0}^{(2L-2)/D}\left|\sum_{m=1}^{M_T}(h_i^m * g_j^m)[Dl]\right|^2$ is the power associated with inter-user interference

σ^2= background noise

D = rate back off factor (ratio of sampling rate to

baud rate)

L = length of the channel

h_i^m =channel impulse response

g_i^m =time reversed channel impulse response

C. Achievable sum rate

The transmission rate or achievable sum rate measures the total amount of information that can be effectively delivered during transmission. The achievable sum rate for N users is a good indication of the long-term performance and can be calculated by;

$$R = \frac{\eta}{D}\sum_{i=1}^{N}\log(1 + \mathrm{SINR(i)}) \quad (3.2)$$

Where η = discount factor that describes the portion

of transmission phase

D. Achievable rate with outage

The outage rate can be defined as the [3][7], bits sent over random channels to be decoded with some probability of errors namely the outage probability. If the achievable rate of user i is less than the given transmission rate R, the system is said to be at outage. Outage probability can be calculated as;

$$P_{out} = P_r\left\{\frac{1}{N*D}\sum_{i=1}^{N}\log(1 + \mathrm{SINR(i)}) < R\right\} (3.3)$$

where P_{out} = outage probability

N = number of users

R= Achievable Rate

IV. SIMULATION TOOLS

In this project, MATLAB R2011a version is used.The simulation parameters used are listed in table 4.1.

Table 4.1 Simulation parameters

Modulation	BPSK
No: of Transmitting antennas	2,6
No: of Receiving antennas	1 for each user
Data length	400
Transmission modes	Spatial Multiplexing

V. RESULTS AND DISCUSSION

As a part of this project, the bit error rate performance of TRDMA multiuser downlink system with both single and multiple transmit antennas was simulated. Also the effective SINR, achievable sum rate and outage rate for MISO case was also simulated.

A.Bit error rate for SISO case

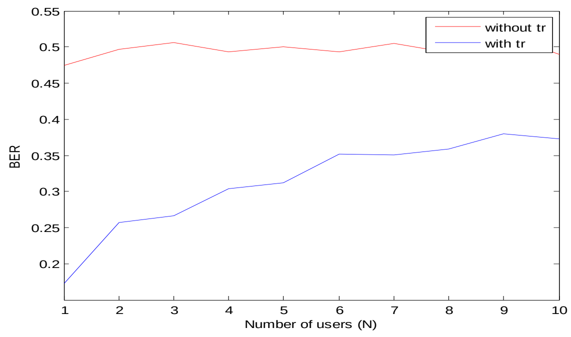

Figure.5.1 Bit Error Rate for SISO case

Figure.5.1 shows that the BER of data with time reversal is less than the data without time reversal.

B. Bit error rate for MISO case

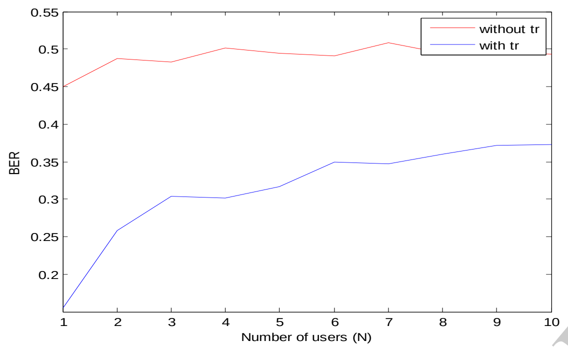

Figure.5.2 Bit Error Rate for MISO case

Figure.5.2 shows that the BER of data with time reversal is less than the data without time reversal.

C. SINR vs SNR for MISO case (MT as a parameter)

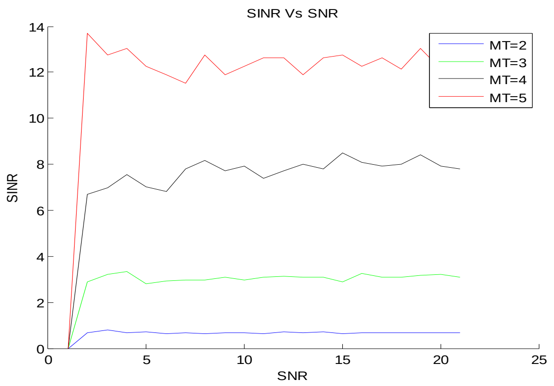

Figure.5.3 SINR vs SNR with MT (number of multiple antennas) as parameter

As MT (number of multiple antennas) increases, SINR also increases, since signal strength increases with increase in number of antennas.

D. Achievable sum rate for MISO

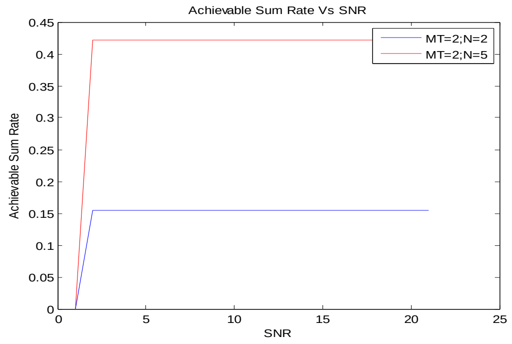

Figure.5.4 Achievable sum rate vs SNR

Figure.5.4 shows Achievable sum rate vs SNR for MISO case keeping number of transmitting antennas a constant and varying the number of users (N). As the number of users increases, achievable sum rate increases.

E. Outage rate for MISO

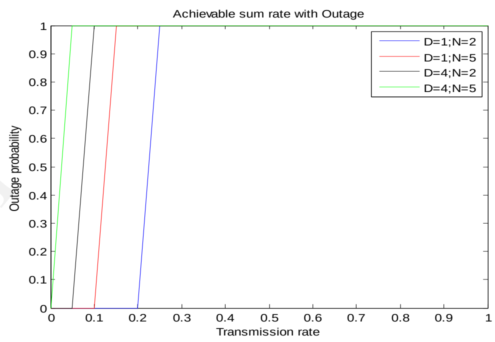

Figure.5.5 Achievable rate with Outage

Figure.5.5 shows Outage probability vs transmission rate. A larger N reduces the individual achievable rate with same outage probability due to severe inter-user interference. A larger D also results in reduced individual achievable rate of the user as it lowers the symbol rate of the transmitter.

VI. CONCLUSION

TRDMA is a novel wireless channel access method which uses the advantage of the high-resolution spatial focusing effect of time-reversal structure. In this work, simulation of TRDMA multiuser downlink system with both single and multiple transmit antennas (SISO and MISO case) was performed. The effective SINR, achievable sum rate and achievable rate with outage probability for MISO case was also simulated. The simulation results confirm that the BER performance of time reversed data is less than the data without time reversal, the effective SINR increases with increase in number of multiple antennas and achievable sum rate increases with number of users. The simulation results also confirmed that the probability of a system that moves to outage occurs rapidly with increase in number of users and rate back-off factor.

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