Analysis of Spatial Multiplexing in MIMO Systems

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***Abstract*—**Multiple-input-multiple-output (MIMO) systems use multiple antennas at both the transmitter and the receiver. Under multipath environments with independent multipath fading between each transmitter and receiver pair, MIMO wireless communication systems achieve significant capacity gains over the convention wireless communication systems that use single antenna. This has led to MIMO being regarded as one of the promising emerging wireless technologies. This project deals with the MIMO base spatial multiplexing techniques that provide high link gains. It is proposed to study, analyze and simulate these techniques. The simulation results will allow us to compare different spatial multiplexing schemes.

***Index Terms*—**MIMO, Spatial Multiplexing, Fading.

I. INTRODUCTION

A. MIMO

Wireless Communication is having fastest growing period due to its technology permitting widespread deployment [6]. In Wireless Communication, it can be observed that Multiple-Input Multiple-Output Technique is emerging as a new technology. MIMO technology has proved as very effective method for the efficient usage of large bandwidth [5]. In this system, simultaneously the signals are transmitted through by different transmitter antennas to different receiver antennas resulting spectral efficiency [7].

B. SPATIAL MULTIPLEXING

This scheme makes full use of the rich scattering wireless channel which allows the receiver side antennas to detect the signals transmitted by the transmitter antennas which means that this simultaneous use of multiple antennas in rich scattering environment.

This environment results the same frequency band to provide a linear increase in capacity gain in the number of antennas [1][3].

It is observed that spatial multiplexing differ from space-time coding method. Hence, a new method named space-time correlation has been introduced among transmitted signals to improve information protection and increase diversity gain [11].

A basic spatial multiplexing schema is as shown below.

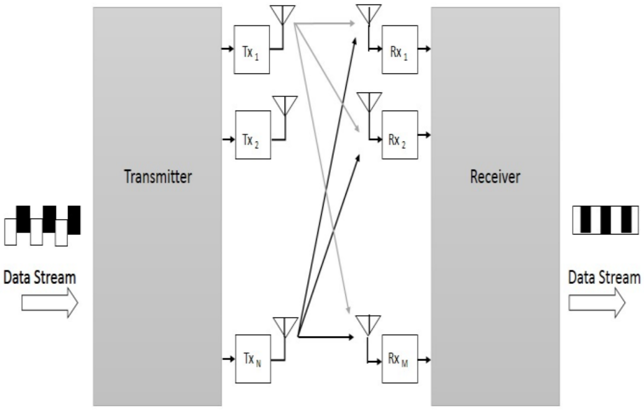


Fig. 1. Basic Spatial Multiplexing Scheme with N transmitter and M receiver antennas

II. RECEIVER DESIGN FOR SPATIAL MUTIPLEXING SYSTEM

N_T is the lower rate stream which is demultiplexed by the transmitted data stream in spatial multiplexing system. N_T transmitter antennas simultaneously transmit each demultiplexed substream after coding and modulation processing. All the substreams signals lies in the same frequency band. At the receiver side, superposition of the transmitted signals is observed by each antenna after which it is separated into constituent data streams, and get multiplexed to recover the original data stream. Spatial multiplexing receivers are usually divided into three classes; the maximum likelihood receiver, the linear receiver and the successive interference cancellation receiver [2][4].

A. Maximum Likelihood (ML) Receiver

Theoretically, this algorithm is the optimum method for recovering the transmitted signal at the receiver side. Mainly comparison of the received signals with all possible transmitted signal vector is performed by this receiver which is further modified by channel matrix H and the transmit symbol vector x is estimated as per the Maximum Likelihood Principle, as shown [1]

$$\hat{x} = arg_{X_k \epsilon \{x_1,\dots,x_{N_T}\}} \min ||r - Hx_k||^2$$

Here,$\hat{\boldsymbol{x}}$ denotes estimated symbol vector. All possible vector constellations are searched by this ML receiver for the most probable transmitted signal vector. Due to exponentially increased complexity it becomes very difficult to use ML receiver in regular practice.

B. Zero Factor (ZF) Receiver

It is a simple linear receiver. A straight matrix inversion method is used by this type of receiver.

If it is assumed that H (channel matrix) is invertible, with which a transmitted data symbol vector can be calculated.

$$\hat{x} = (H^{*}H)^{-1}Hx = H^{+}x$$

Here,$^{+}$ represents the pseudo-inverse. Inverse exist only in the case if H has independent columns.

It can be observed that how ZF receiver can separate the co-channel signals.

C. Minimum Mean-Square Error (MMSE) Reciever

This is also one of the linear detection algorithm. Matrix **D** is chosen estimate a random vector **x** on the basis of observation **y**. This minimizes the Mean Square Error

$$\varepsilon^{2} = E[(x-\hat{x})^{*}(x-\hat{x})] = (x-Dy)^{*}(x-Dy)$$

The solution of the linear MMSE is given by

$$\hat{x} = D.r = (\frac{1}{SNR}I_{N_R} + H^{H}H)^{-1}H^{H}.r$$

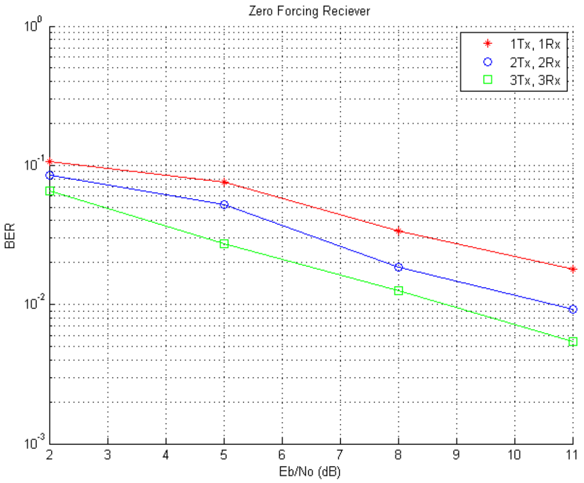
Here, the superscript H denotes the complex conjugate transpose. Where the ZF receiver perfectly separates the co-channel signals at the cost of noise enhancement, the MMSE receiver can minimize the overall error. This error mainly caused by noise and interference between the co-channel signals.

D. Successive Interference Cancellation(SIC) Reciever

The SIC receiver is called just as V-BLAST receiver. This is an attractive alternative to ZF and MMSE receivers.

III. SIMULATION RESULTS

The average bit error rate (BER) is simulated with $E_b/\ N_0$ for various configurations of antenna. Several spatial multiplexing schemes on Rayleigh fading channels are simulated so as to compare the difference of performances [3].



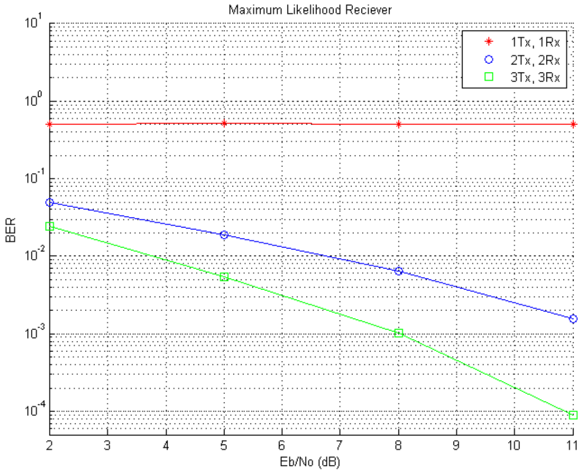


Fig. 2. Bit Error Rate (BER) comparison for various antenna configurations over spatial multiplexing scheme by using Maximum Likelihood (ML) receiver technique

Fig. 3. Bit Error Rate (BER) comparison for various antenna configurations over spatial multiplexing scheme by using Zero Forcing (ZF) receiver technique

It can be seen that the BER performance increases by introducing an extra transmit and an extra receive antenna.

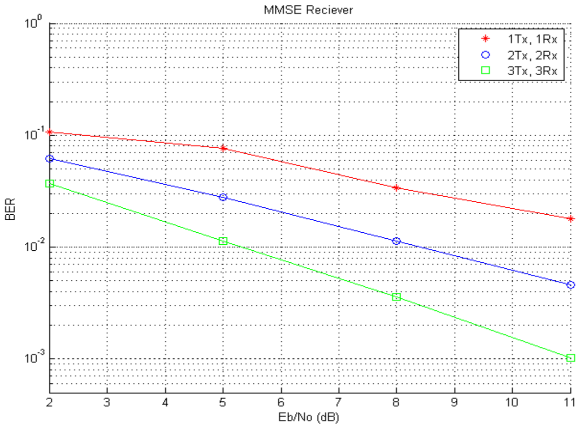


Fig. 4.Bit Error Rate (BER) comparison for various antenna configurations over spatial multiplexing scheme by using Minimum Mean Square Error (MMSE) receiver technique

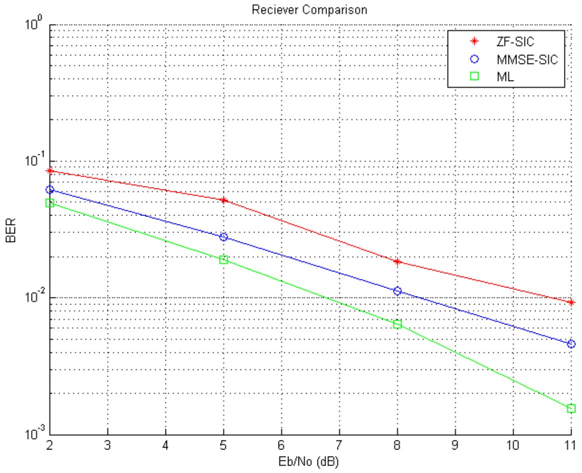


Fig. 5. Comparison of ML, ZF and MMSE receivers with BER vs. E_b/N_0 for 2 Tx 3 Rx antenna configuration over spatial multiplexing scheme

IV. CONCLUSION

The theoretical background for MIMO wireless communication system is investigated. In this paper, a simulation study has presented to show the capability for MIMO systems. By simulating each receiver concept, the performance of spatial multiplexing schemes has been studied. From the simulation results, it can be clearly observed that the MIMO systems offer convincing gains in performance as compare to traditional wireless communication systems [9][10]. The results shows clear impact that can be poised to play a significant role for next generation communication systems and standards such as mobile communication.

V. REFERENCES

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