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Simulation and Performance Evaluation of Spatial Diversity in MISO System

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ABSTRACT*:* We simulated a developed generic fading model that allowed for the study of the Multiple Input Single Output (MISO) based on the alteration of the receive antennas and the correlation between them. The MISO model was developed and simulated in MATLAB/SIMULINK where multiple (2, 3, 4 and 5) transmitters were used to transmit information over the channel while single receiver was employed for reception. The received information was then compared with what was transmitted in order to obtain the Bit Error Rates (BER) against each Signal-to Noise Ratio (SNR). A single Input Single Output model was also developed to serve as the ground truth. The results of the simulations indicated that BER reduced as number of transmitters (TX) increased. Over the same conditions, the best BER for the SISO model was 0.10 while for SIMO model with RX = 2, 3, 4 and 5 were respectively 0.09, 0.03, 0.00 and 0.01.

KEYWORDS: Multiple Input Single Output, single Input Single Output, Antenna, Bit Error Rate.

I. INTRODUCTION

There is a demand for fast and reliable wireless communications due to the numerous advantages it has over its wired counterpart. Small scale fading, mainly due to multipath, affects the wireless channel and deteriorates the quality of signal in unpredictable ways due to the changing and varying nature of the environment. This occurs when radio waves from the transmitting antenna reach the receiving antenna by more than one path through reflection or diffraction by different interacting objects in the environment. Each of these paths has different attenuation and time delay in addition to the possibility of some phase shift due to reflections. It affects transmission at the receiver side when a basic receiver adds up the different multi path components (MPCs) due to its failure to differentiate between them causing interference which can either be constructive or destructive, depending on the phases of the MPCs.

Multipath fading is a small-scale phenomenon but the level of attenuation of the signal changes substantially if the position of the receiver or the transmitter is varied by about half a wavelength. Large scale fading on the other hand is caused when obstacles attenuate the amplitude of the components that propagates along the direct connection between the communicating devices. This effect occurs gradually rather than instantaneous; the mobile station (MS) has to move over a large distance to fall into the dark zone. Both large and small-scale fading lead to low reception quality when the received signal amplitude is low leading to bad speech (in voice telephony), high BER and low data rate (data transmission) and obviously leading to connection termination if the quality remains too low for a long period.

Countering this effect is not possible by mere increase in Signal-to-Noise Ratio (SNR)(Molisch, 2005), since the BER in Rayleigh fading channels only decreases linearly with SNR increase. It is impracticable to therefore use this method in combating Rayleigh Fading. Changing the channel characteristics, by using Diversity, is a sure way of ensuring that

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the SNR has a higher probability of being high. It has been shown that spatial diversity is an attractive solution of improving system capacity and performance by increasing SNR.

Spatial Diversity has been used in multiple studies in improving the error rate performance of channels. The Bit Error Rate performance of Free Space Optical (FSO) links with spatial diversity (with M transmit and N receive apertures) was investigated over lognormal atmospheric turbulence fading channels. The authors demonstrated that for FSO links the effect of diversity manifests itself as a decrease of the channel variance. They also noted that it was important to resourcefully separate between apertures and to achieve diversity gains from multiple transmitter/receiver, it was critical to strictly co-align. Diversity ensures that the same information arrives at the receiver (RX) on channels that are statistically independent. MISO is a spatial diversity technique with ***M*** TXs separated in space and a single receiver (RX).

This work looked at Multiple Input Single Outputs (SIMO) technique in realizing the diversity gain. For the purpose of this work - and of major concern – we will deal with fading and particularly small and large scale fading. The contributions of this paper are summarized below.

i. Investigating the performance of Multiple Input Single Output form of diversity in improving the BER in wireless communication and thus combating small scale fading.
ii. Creation of various models to look at the various antenna configurations at the TX and the performance of each configuration. Here the number of antennas are varied at the TX.
iii. The performance of the system after varying the correlation between the antenna elements are also looked at.

II. SYSTEM MODEL AND ASSUMPTIONS

Simulations were carried out in Simulink (MATLAB software) package from the Mathworks. Simulink has an edge as the simulations are interactive and parameters can be changed with the results immediately seen. It is integrated with Matlab and can thus import from and/or export to the Matlab workspace. It uses block sets and toolboxes thereby making it user friendly. It can also be integrated with many simulation environments and hence there is no special requirement on the simulator. It can be easily analysed.

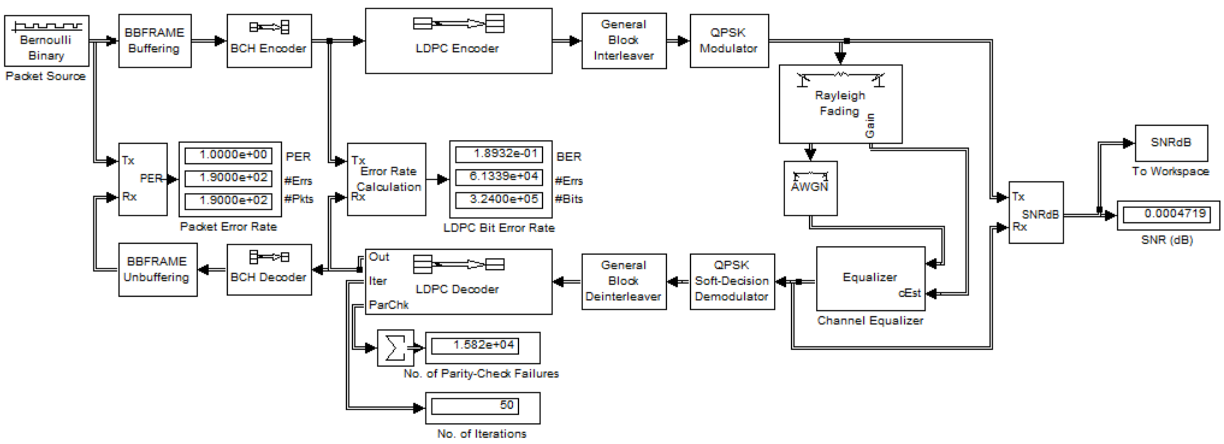

Figure 1: SISO model block diagram

Figure 1 is a block diagram of an initial simulation that was developed to determine the bit error rate performance of the receiver over a single input, single output (1Tx, 1RX) channel. This served as the benchmark for developing the proposed model.

The MISO system was developed where Low Density Parity check Codes (LDPC) was used for channel coding. A fading channel and an Adaptive White Gaussian Noise are added along the channel between the transmitters and receiver.

The number of transmitters, TX was **M** (M = 2, 3, 4, 5), while that of the receiver, RX was 1. In order to measure and analyse the performance of generic MISO systems, based on Bit Error Rate (BER) and Signal to Noise Ratio (SNR), an algorithm was developed where M can be varied. In each of the instances of the M variation, the number of iterations for the LDPC code was 100. The SNR were also varied from -5 to 5 incrementing by unity. For every receiver variation at a given SNR, the BER was recorded.

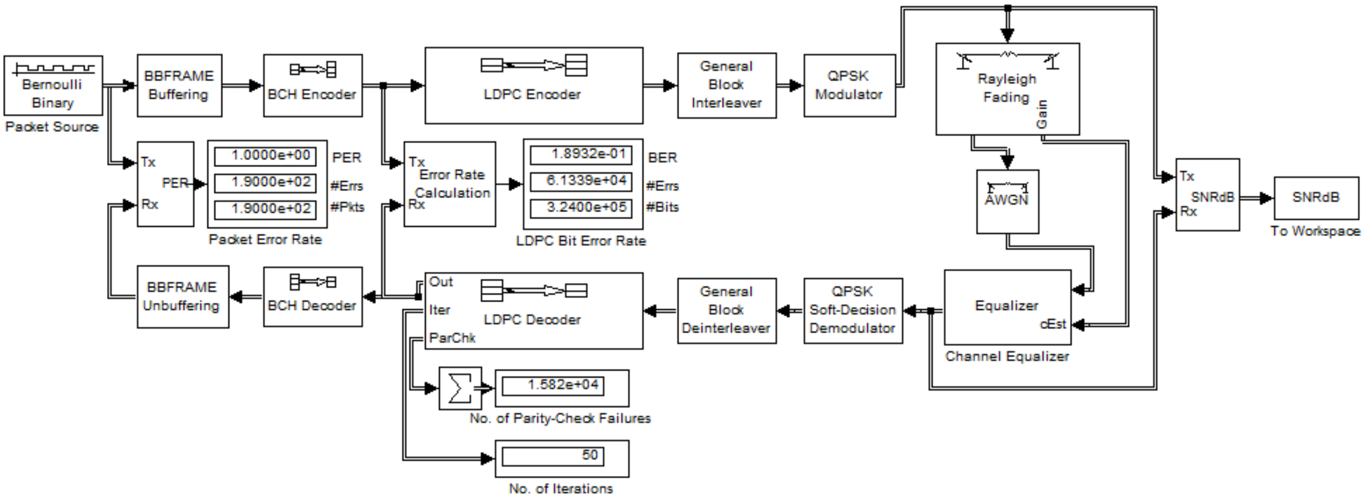

Figure 2: MISO model block diagram

A block diagram of the MISO model is shown in Figure 2 while the description of the block sets are as follows:

A. Information Source

The information source for the simulation is the Bernoulli Binary Generator block. It generates a random data of frame size 1504 message bits at 3.1662×10^{-5} sampling time which is buffered and fed to the BCH encoder as the input, K (32208) bits.

B. BCH (Source) Encoder

The BCH encoder is used as the source coder and gets its input from the output of the Bernoulli Generator which is first buffered. The purpose for buffering is to meet the criteria of the BCH encoder which specifies that:

$$\log_2(N+1) = M \quad (1)$$

Where $3 \leq M \leq 16$ and $N = 2^M - 1$

M is determined by considering the LDPC encoder input requirement (32400 bits) which is derived from the output of the BCH encoder. Using equation 8, M is approximated to 15. The BCH encoder encodes the input frame message using an (N,K i.e. 32400,32208). The BCH decoder at the receive side decodes the message.

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C. LDPC (Channel) Encoder and General Block Interleaver

The output of the BCH encoder is fed to the LDPC encoder for channel coding. The LDPC encoder encodes a message using a binary low-density parity-check code. The code is specified by the parity-check matrix. The block length of the LDPC codes is 64800 which is processed in one unit of time in the simulation. The LDPC decoding uses the hard decision for its decision type to decode the transmitted message. The general block interleaver which gets its input from the output of the LDPC encoder, rearranges the elements of its input vector without repeating or omitting any elements. Its output is then modulated using the M-PSK.

D. Modulator

The message data from the General Block Interleaver is modulated using the M-ary Phase Shift Keying (M-PSK) provided by the Quasi-PSK (Q-PSK) since M = 4. The value of M also specifies the size of the PSK constellation. Since M=4, the 4-PSK constellation is thus used in the simulations. The output frame length of this block is 32400 as every two input bits produce a symbol. The decoder block decodes signals it receives using the approximate log-likelihood decision type.

E. Orthogonal Space Time Block Coding (OSTBC) Encoder

The information symbols from the 4-PSK encoder is encoded by the orthogonal space time block code block using the Alamouti code for 1 transmit antenna for the SIMO simulations. The corresponding outputs of the blocks are 32400x1 for N_t at rate equals 1. The entries on the column of the output of this block correspond to the data transmitted over one antenna.

The OSTBC combiner block takes the receive signals from the receive antenna and combines them with the Channel State Information (CSI) to get an estimate of the transmitted symbols and then outputs them and fed to the 4_PSK decoder. It is assumed that the CSI is perfectly known at the receive side for this simulation.

F. The Channels

Fading Channels: Here, a subsystem is employed to implement an m x n fading channel. Where for MISO $n > 1$ and $m = 1$. The Multipath Rayleigh Fading Channel (MRFC) block is used to simulate the flat Rayleigh fading subsystem from the transmit side to the receive side antennas.

The initial seed parameters of the MRFC blocks are set to different values in order to have independent fading sub-channels.

Receiver Noise: The Adaptive White Gaussian Noise (AWGN) channel block which adds white Gaussian noise is used. The Mode parameter is set to Signal to Noise Ratio (SNR) and Energy bit to Noise spectral density ratio E_b / N_o for each simulation.

G. Bit Error Rate (BER)

The main goal of the simulation is to determine the BER performance of the system and compare with other models with varying parameters – i.e. diversity and SNR. To calculate the BER, the BER calculator compares the received (decoded) bits with the corresponding transmitted (encoded) bit by X-ORing the two corresponding signals. If an error is detected, it updates the BER as the simulation is being carried out. The BER calculation subsystem has a three-element vector containing the BER, number of observed errors and the number of bits processed which is saved as MATLAB workspace variable BER.

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III. RESULTS

This section represents the results of the simulations starting with the benchmark model (SISO) and then SIMO with RX = 2, 3, 4 and 5. As highlighted, the iteration for the LDPC was 100 while the SNR was varied from -5 to 5, with unity increment. The results are plotted on a log scale for clarity and ease of analysis since the SNR is in decibels.

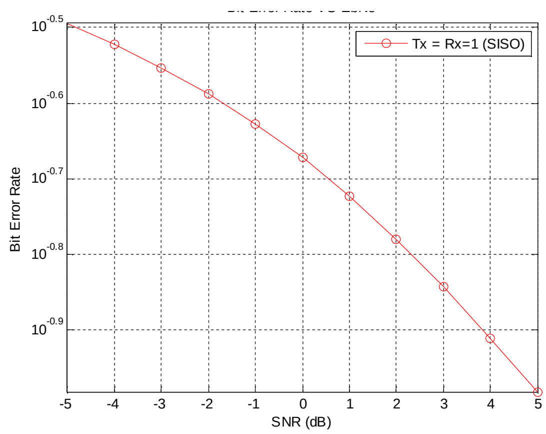

Figure 3: BER performance for SISO model (1 Receiver and 1 Transmitter)

Figure 3 shows the BER vs SNR for the SISO channel. The BER reduces from 0.32 to 0.10, almost linearly as the SNR increased. In this case it was obvious that the only factor responsible for the BER improvement was the corresponding improvement of the SNR.

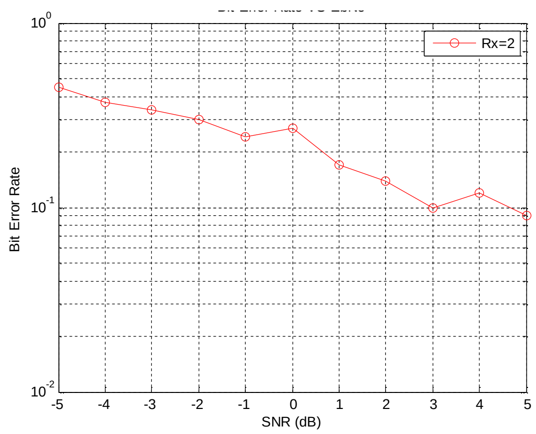

Figure 4: BER performance for SIMO model with 2 Transmitters

Figure 4 shows the performance of the MISO model with 2 transmitters. The BER at SNR = -5 was 0.45 and at 5 was 0.09. This improvement was however not linear. For instance at SNR = -1 dB, the BER was 0.24 while at SNR = 0 dB, it was 0.27. This indicated that for the model and at those instances, the BER was better at SNR = -1 dB which is unlike

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the graph pattern showing marked improvement with each SNR increment. The slope of the BER improvement was about -0.036.

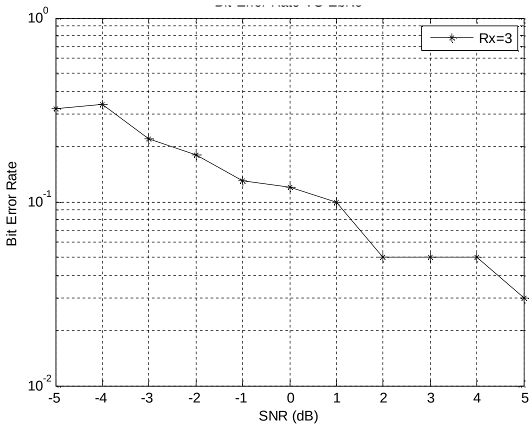

Figure 5: BER performance for SIMO model with 3 Transmitters

Figure 5 represents the MISO model for 3 transmitters where the BER were 0.32 and 0.03 at SNR = -5 and 5 respectively. There was a steady improvement of the BER especially at SNR = 2 dB and thereafter remained constant till at 5 dB.

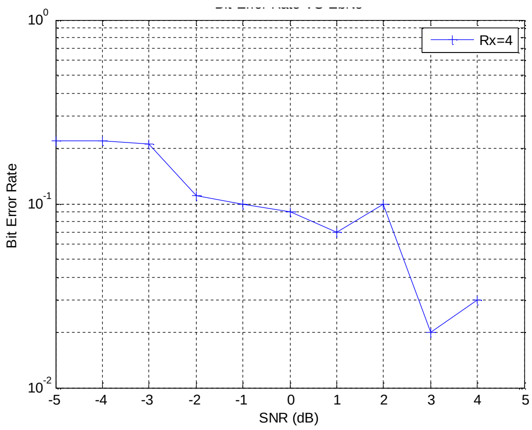

Figure 6: BER performance for SIMO model with 4 Transmitters

In Figure 6, the simulation for the MISO model with 4 transmitters indicated that the BERs at SNR = -5 and 5 dB were respectively 0.22 and 0.00. This means that at 5 dB all the information were received without any errors. Although at 3 dB and 4 dB the BERs were respectively 0.03 and 0.02 showing a spike in error which did not impede the error free reception at 5 dB from being achieved.

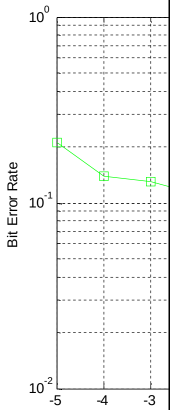

Figure 7: BER perfor[redacted]

When the TX = 5, the BERs at SNR = -5 and 5 d[redacted] 2 and 4 dB were respectively 0 (zero) indicating t[redacted]

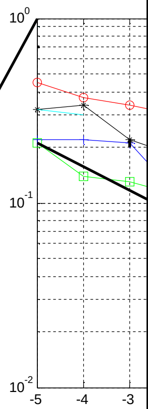

Figure 8: BER performa[redacted]

Figure 8 shows the performance comparison of a[redacted] performance with TX = 2, was the worst among [redacted] SISO model was the worst. Interestingly, at -4 d[redacted] TX = 3. Besides these, the MISO model's BERs [redacted] to this were at 2 dB where the BER for TX = 4 w[redacted] was better than that for TX = 5. Another observat[redacted] TX = 5 where spikes were observed at odd SNR. [redacted]

A MISO model with TX = 2, 3, 4 and 5 and RX [redacted] model with TX = RX = 1. The model indicate[redacted] Although some spikes in BER were observed, t[redacted] transmitters increased.

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Starting at -5 dB to 5 dB, the BER for SISO model reduced from 0.32 to 0.10 while for MISO model with TX = 2 it was 0.45 to 0.09 and for TX = 3 the reduction was from 0.32 to 0.03. When TX = 4, the BER over the same range reduced from 0.22 to 0.00 while it was 0.21 to 0.01 for TX =5.

It can be deduced that for the developed model, the BER reduced as number of transmitters are incremented from 2 - 5 over the same given conditions. The BER at TX = 3 can be said to be sufficient for both voice and data.

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