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Impact Of Noise Cancellation Scheme On Performance Enhancement Of MIMO-OFDM Wireless Communication System

Md. Johirul Islam[1]
[1]Lecturer,Dept. of Computer Science and Engineering, Varendra University,
Rajshahi, Bangladesh
Email: johirul@vu.edu.bd

Rajibul Hasan[2]
[2]Dept. of Information and Communication Engineering,
University of Rajshahi,
Rajshahi, Bangladesh
Email: russelice08@gmail.com

***Abstract*—Multiple Input Multiple Output (MIMO) Multiple Input Multiple Output (MIMO) systems offer a considerable enhancement of data throughput and link range without requirement of additional bandwidth or transmit power under implementation of multiple antennas both at transmitter and receiver. In view of improving performance of MIMO wireless communication system, noise and interference reduction play a vital role in effective transmission of data in various forms such as audio, video, text, image etc.**
In this research paper, a comprehensive study has been made on implementation of various noise and interference reduction techniques for performance improvement of a simulated MIMO-OFDM wireless communication system.

From the study, it has been ratified and explored that a significant noise and interference reduction is observed in case of implementing LMS scheme with Zero Forcing (ZF) channel equalization/signal detection technique.

Keywords—MIMO-OFDM, LMS Algorithm, Signal Detection, System Model, Simulation Parameters, Simulation, Performance Evaluation

I. INTRODUCTION

The next generation wireless communication systems will deal with high-speed internet access, high quality multimedia streams, and mobile computing as well as data transmissions at higher data rates than ever before for mobile stationery users. The quick expanding demands for services with high data rates,high quality, and high mobility, are driving recent developments in communication technologies for broadband wireless communications.

MIMO-OFDM is the basis for most advanced wireless local area network (Wireless LAN) and mobile broadband network standards because it attains the extreme spectral efficiency and, therefore, provides the highest capacity and data throughput. In 1996 Greg Raleigh invented MIMO when he showed that different data streams could be transmitted at the same time on the same frequency by taking advantage of the fact that signals transmitted through space bounce off objects (such as the ground) and take multiple paths to the receiver. That is, by using multiple antennas and preceding the data, different data streams could be sent over different paths. Raleigh suggested and later proved that the processing required by MIMO at higher speeds would be most manageable using OFDM modulation, because OFDM converts a high-speed data channel into a number of parallel, lower-speed channels. Hence MIMO OFDM provides the 'all in one package" by providing the speed, range and reliability simultaneously [1].

II. MIMO-OFDM

Nortel defines the OFDM-MIMO combination as "With OFDM, a single channel within a spectrum band can be divided into multiple, smaller sub-signals that transmit information simultaneously without interference. Because MIMO technology is able to link together many smaller antennas to work as one, it can receive and send these OFDM's multiple sub-signals in a way that allows the bandwidth to be substantially increased to each user as required"

OFDM is the technique used to mitigate the multipath propagation problem and MIMO is used for the efficient usage of spectral bandwidth thus combining these techniques results in wireless system that has best spectral coverage, reliable transmission in highly obstructive environment, and data rates in 100's of megabits.

MIMO caters the spatial diversity whereas OFDM can use either FDD or TDD multiplex technique. In the spatial domain, MIMO provides greater capacity. In the time domain, the modulation method OFDM simplifies the equalization process by eliminating the inter symbol interference (ISI). With the combination of MIMO and OFDM, greater channel capacities could be realized with robustness to channel impairments like ISI through cyclic prefix (CP) and multipath fading through adaptive bit loading.

OFDM creates the slow time varying channel streams and MIMO has capacity of transmitting the signals over multiple channels by use of an array of antennas thus the combination of OFDM & MIMO can generate extremely beneficial results. OFDM signals are greatly affected by the presence of objects, while on the other hand the MIMO takes its advantage from multipath propagation. So the concept is to generate the OFDM signals and subject to MIMO antennas.

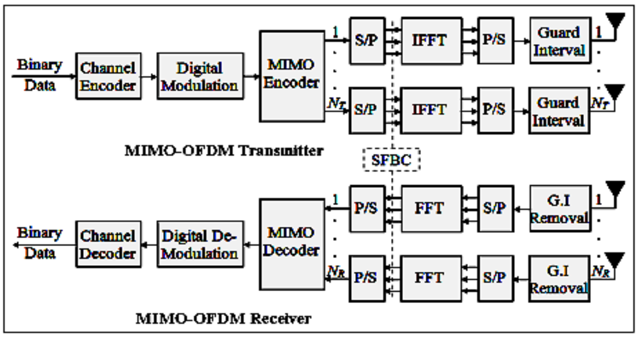

Fig.1. MIMO-OFDM Transmitter and Receiver System Block Diagram [2].

III. LMS ALGORITHM

Digital filter is the basic building block of Digital Signal Processing systems. Finite Impulse Response (FIR) is preferred when compared to Infinite Impulse Response (IIR), because of its properties like guaranteed stability, linear phase and low response, but with expense of large number of arithmetic operations are involved. In communication systems channel noise and Inter Symbol Interference (ISI) degrades the performance of communication system. To reduce this problem adaptive equalizers are used to shape the signals at the receivers. Least Mean Square technique is the one of the adaptive techniques. The figure below shows an adaptive noise cancellation scheme.

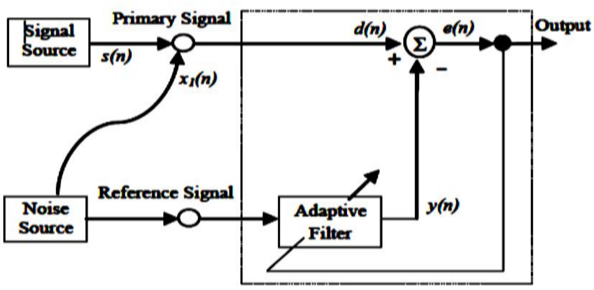

Fig.2. Adaptive Noise cancellation [3]

The LMS algorithm is a search algorithm in which a simplification of the gradient vector computation is made possible by appropriately modifying the objective function [3]. The LMS algorithm, as well as others related to it, is widely used in various applications of adaptive filtering due to its computational simplicity. The convergence speed of the LMS is shown to be dependent on the eigenvalue spread of the input signal correlation matrix [4],[5]. The LMS algorithm is by far the most widely used algorithm in adaptive filtering for several reasons. The main features that attracted the use of the LMS algorithm are low computational complexity, proof of convergence in stationary environment, unbiased convergence in the mean to the Wiener solution, and stable behavior when implemented with finite-precision arithmetic.

Let x(n) and d(n) represent the reference input and the desired output signal, respectively, to the adaptive filter. Let L denote the total number of filter coefficients. Define the L x 1 coefficient vector H (n) and the input vector X (n) as

$H(n) = [h_0(n), h_1(n) ... h_{L-1}(n)]\ T$ ……………......….(1)

$X(n) = [x(n), x(n-1) ... x(n-L+1)]\ T$ ……………......(2)

The LMS is described as

$e(n) = d(n) - HT(n)\ X(n)$ ………………………….......(3)

$H(n+1) = H(n) + \mu_s X(n)\ e(n)$ …………………......(4)

In practice, (4) may be replaced with

$$H(n+1) = H(n) + \frac{\mu}{X^{\wedge}T\ (n)} X(n)e(n) \quad ....(5)$$

Where the positive step-size μ is bounded by 2, σ is a small positive number and r(0) is the estimated autocorrelation function value of x(n) for lag 0.

IV. SIGNAL DETECTION

There are numerous detection techniques available with combination of linear and nonlinear detectors. The most common detection techniques are ZF, MMSE detection technique.

A. *Zero Forcing (ZF) Detection*

The basic Zero force equalizer of 2x2 MIMO channel can be modelled by taking received signal y_1 during first slot at receiver antenna as:

$y_1 = h_{1,1}x_1 + h_{1,2}\ x_2 + n_1$

$= [h_{1,1}\ h_{1,2}][x_1\ x_2] + n_1$…………………...................….(6)

The received signal y_2 at the second slot receiver antenna is:

$y_2 = h_{2,1}\ x_1 + h_{2,2}\ x_2 + n_2$

$= [h_{2,1}\ \ h_{2,2}][x_1\ x_2] + n_2$………….....................….(7)

Where i=1, 2 in $\mathbf{x}_i$ is the transmitted symbol and i =1, 2 in $\mathbf{h}_{i,j}$ is correlated matrix of fading channel, with j represented transmitted antenna and i represented receiver antenna, is the noise of first and second receiver antenna. The ZF equalizer is given by:

$W_{ZF} = (H^H)^{-1} H^H$ ………………….…….....................(8)

Where W_{ZF} is equalization matrix and H is a channel matrix. Assuming $M_R \geq M_T$ and H has full rank, the result of ZF equalization before quantization is written as:

$y_{ZF} = (H^H)^{-1} H^H y$ ……………………………………......(9)

B. Minimum Mean Square Estimator (MMSE)

Minimum mean square error equalizer minimizes the mean –square error between the output of the equalizer and the transmitted symbol, which is a stochastic gradient algorithm with low complexity. Most of the finite tap equalizers are designed to minimize the mean square error performance metric but MMSE directly minimizes the bit error rate. The channel model for MMSE is same as ZF [6], [7]. The MMSE equalization is

$W_{MMSE} = \arg_G^{min} \mathbf{E}_{x,n} [||x-x^\wedge||^2]$ ....(10)

Where is W_{MMSE} equalization matrix, H channel correlated matrix and n is channel noise

$y_{MMSE} = H^H (HH^H + n_0 I_n)^{-1} y$ …………………………(11)

V. SYSTEM MODEL

Impact of noise cancellation scheme on performance enhancement of MIMO-OFDM system simulation model to be implemented has been discussed thoroughly and all related assumptions have been stated clearly and justified. The implemented model needs to be realistic as possible in order to get reliable results. It is to be mentioned here that the real communication systems are very much complicated and due to unavailability of the algorithms to simulate the performance evaluation of their various sections, generally, simulations are made on the basis of some assumptions to simplify the communication systems concerned.

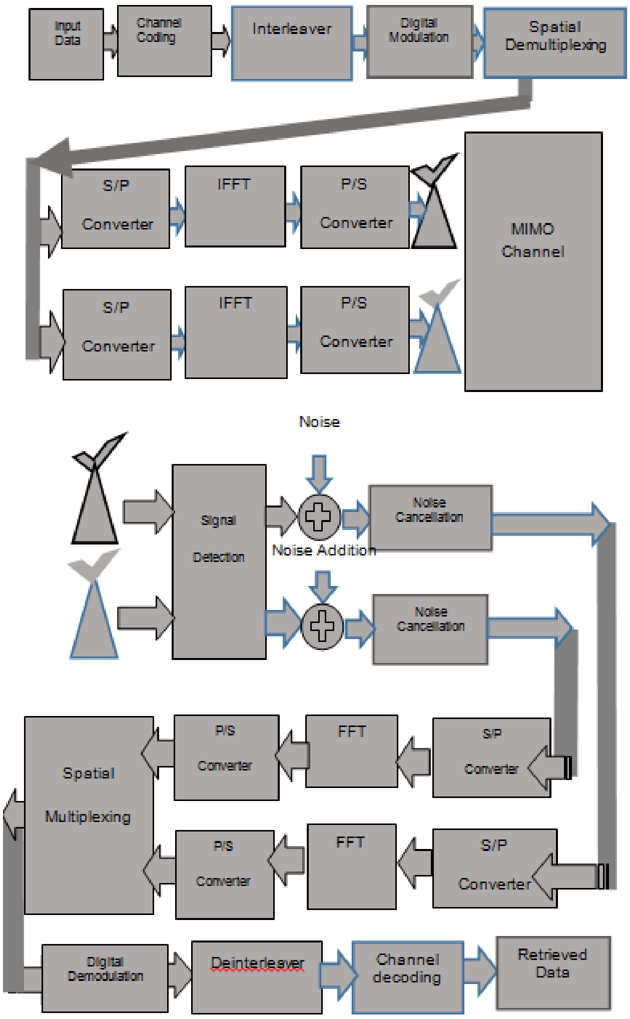

Fig.3. Noise Cancellation Scheme on MIMO-OFDM Wireless Communication System

Simulation Parameters

In an attempt to use realistic and typical values the following parameters were used

Parameter	Parameter Values
No. of bits used for synthetic data	2*1024
SNR	-5 to 5 db.
Modulation and De-modulation	4QAM,QPSK,BPSK
Equalization Technique	Zero Forcing(ZF), Minimum Mean Square Estimator(MMSE)
FEC code	Convolution code
Wireless channel	AWGN and Rayleigh channel

VI. SIMULATION

For simulation purpose, we have used SNR value -5db to 5db as default value. To perform

Forward Error Coding (FEC) we have used Convolutional Coding along with equalization techniques i.e., Zero forcing (ZF) and Minimum Mean Square Estimator (MMSE) equalizer. Basically we have performed our simulation in Additive White Gaussian Noise (AWGN) Channel and Rayleigh Fading Channel with input as synthetics data bits. We have collected real channel coefficient of Rayleigh fading channel to perform our simulation as Rayleigh fading channel is treated as the worst channel condition in considering channel fading in wireless communication.

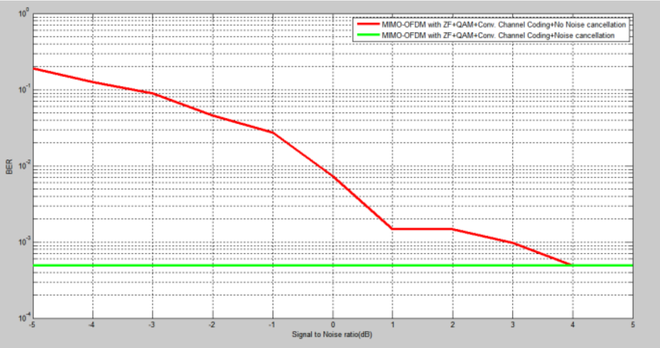

Fig.4. BER vs. SNR of MIMO-OFDM with and without Adaptive Noise Cancellation Scheme implementing with convolutional Channel Coding, QAM modulation scheme and Zero Forcing Equalization over AWGN channel and Rayleigh Fading Channel

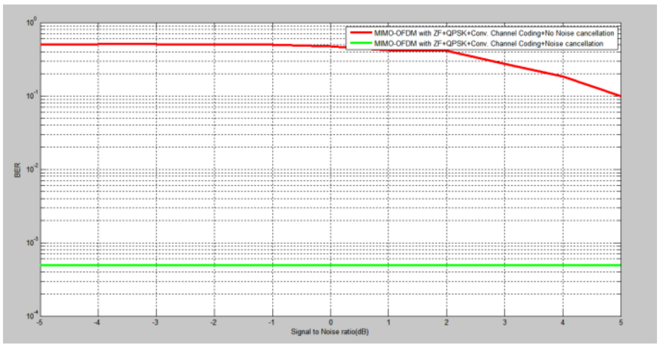

Fig.5. BER vs. SNR of MIMO-OFDM with and without Adaptive Noise Cancellation Scheme implementing with convolutional Channel Coding, QPSK modulation scheme and Zero Forcing Equalization over AWGN channel and Rayleigh Fading Channel

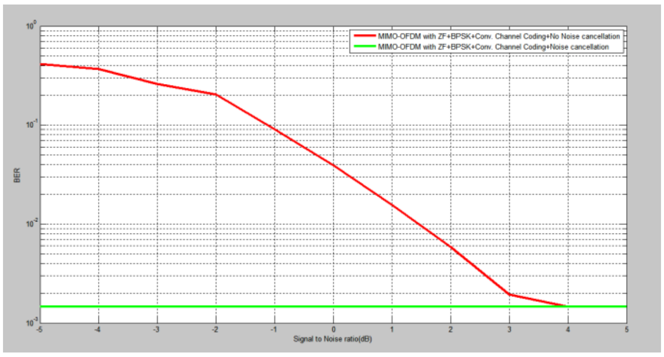

Fig.6. BER vs. SNR of MIMO-OFDM with and without Adaptive Noise Cancellation Scheme implementing with convolutional Channel Coding, BPSK modulation scheme and Zero Forcing Equalization over AWGN channel and Rayleigh Fading Channel

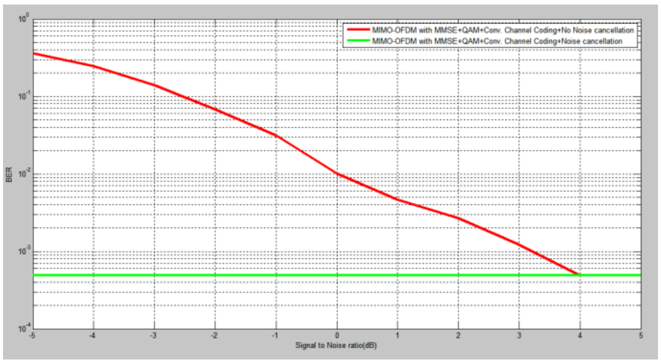

Fig. 7. BER vs. SNR of MIMO-OFDM with and without Adaptive Noise Cancellation Scheme implementing with convolutional Channel Coding, QAM modulation scheme and Minimum Mean Square Estimator (MMSE) over AWGN channel and Rayleigh Fading Channel

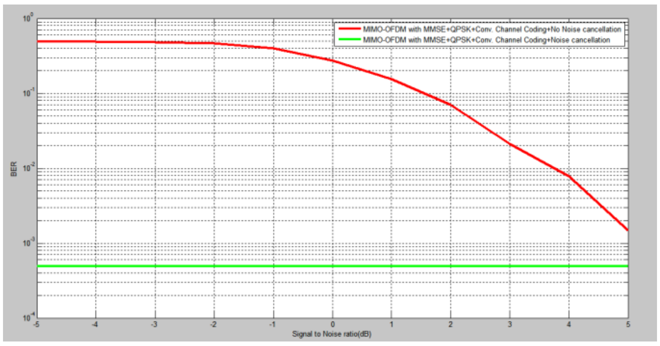

Fig.8. BER vs. SNR of MIMO-OFDM with and without Adaptive Noise Cancellation Scheme implementing with convolutional Channel Coding, QPSK modulation scheme and Minimum Mean Square Estimator (MMSE) over AWGN channel and Rayleigh Fading Channel

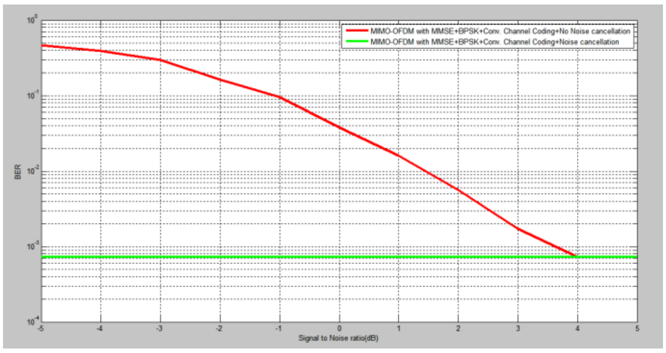

Fig.9. BER vs. SNR of MIMO-OFDM with and without Adaptive Noise Cancellation Scheme implementing with convolutional Channel Coding, BPSK modulation scheme and Minimum Mean Square Estimator (MMSE) over AWGN channel and Rayleigh Fading Channel

VII. PERFORMANCE EVALUATION

From Simulation we have found excellent Data for Bit Error Rate (BER) analysis with increasing Signal to Noise Ratio (SNR) value containing -5dB to 5dB. We know SNR= -5dB means Noise power is greater than Signal power by 5dB and SNR= 0dB means Noise power and Signal power is identical. In same fashion SNR= 5dB means Signal power is greater than Noise power by 5dB.

We have calculated total BER with increasing SNR for every condition such as ZF with QAM, MMSE with QAM, ZF with BPSK, MMSE with BPSK, ZF with QPSK and MMSE with QPSK where Convolutional coding is used as a common channel coding.

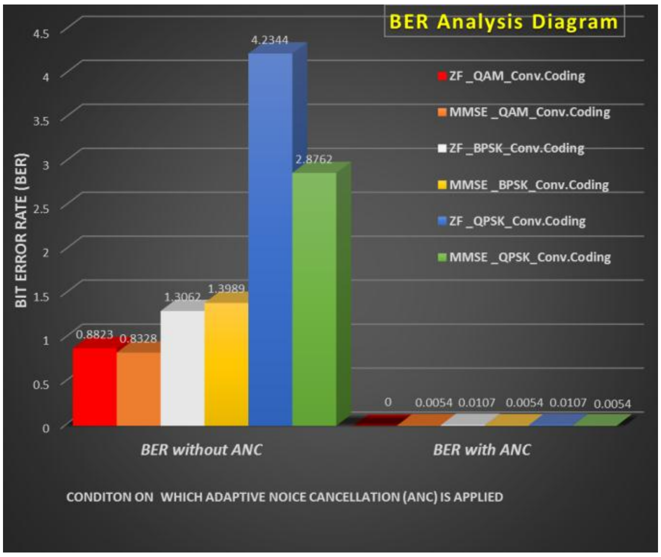

Fig. 10. BER Analysis Diagram in Different Condition When SNR = -5dB to 5dB

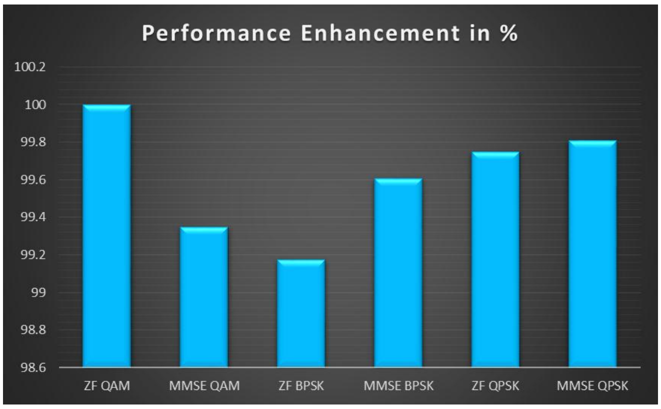

Fig.11. *Performance Enhancement Diagram in Different Condition when SNR = -5dB to 5dB*

From Fig.11 it can be conclude that if we implement LMS based noise cancellation scheme in MIMO-OFDM containing ZF as an equalization technique, QAM as a modulation technique and Convolutional Channel coding, we will get 100 percent noise free signal. In other case we will also get almost 100 percent noise free signal but best performance will be found in earlier.

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