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Performance Evaluation of Different Adaptive Beamforming techniques for MIMO-OFDM System

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ABSTRACT

In wireless communication, the receiver side BER strongly affected by channels noise, interference, distortion, synchronization error and wireless multipath fading channels, Multiple-input and multiple-output(MIMO) and Orthogonal frequency-division multiplexing (OFDM) system is the use of multiple antennas at both the end in wireless communication to improve BER performance. In this new information high data rate and strong reliability features are becoming the dominant factor for a successful deployment of commercial networks. The specifically, Multiple Input Multiple Output (MIMO) beam-forming is helpful in cancelling such interference since it can spatially suppress some of the multipath. We propose an ICI eliminating beam forming scheme employing a per-tone processing approach, an with moderate computational complexity.The results has been shown in the paper for the simulation in various conditions.

Keywords: OFDM, MIMO, Beamforming, LMS, RLS, STBC, QAM, AWGN, etc.

INTRODUCTION

Wireless communication is one of the most vivacious areas in the communication field now a day. Although the development in this area was started way back in 1960s, but a lot of research is done in this area in last decade. The reason for this is due to a variety of factors discussed below:

• The demand is seem-less connectivity has risen manifolds, mainly due to cellular telephony but expected to be soon eclipsed by wireless data applications.

• The sophisticated signal processing algorithms can be implemented with the advent of VLSI technology. Due to the success of 2G wireless standards especially CDMA it has been shown that communication ideas can be implemented in practice. The research push in the past decade has led to a much better-off set of perspectives and tools on how to communicate over wireless channels, and scenario is still very much in the emerging stages. There are two fundamental aspects of wireless communication that make the problem demanding and motivating as compared to wire line communication.
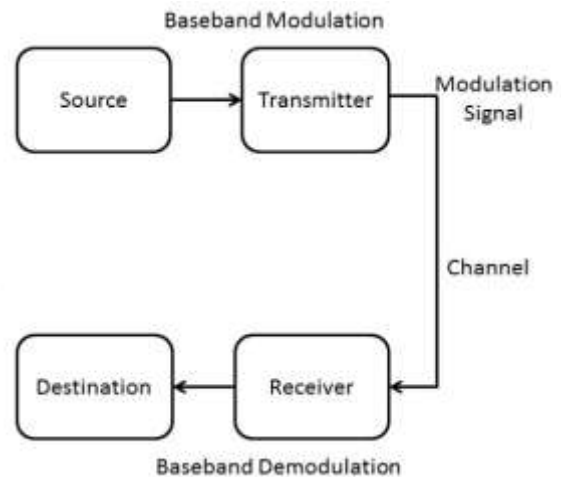

Fig:1. Wireless communication system.

OFDMA SYSTEM MODEL

Orthogonal Frequency Division Multiplexing (OFDM) has been successfully applied to a wide variety of digital communication applications over the past several years. The orthogonal frequency division multiplexing (OFDM) principle was adopted as a physical layer for many important communication systems such as asymmetric digital

subscriber loop (ADSL), Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB), high-definition television (HDTV), wireless local area network (WLAN) and the fourth generation of mobile cellular, the theory, algorithms, and implementation techniques of OFDM are topics of high interest.

The baseband OFDM signal at output of the equation (1) IFFT given as:

$$X_n = \left(\frac{1}{\sqrt{N}}\sum_{l=0}^{N-1} X_{l} e^{j\frac{2\pi}{N}ni}\right) \qquad (1)$$

At the receiver, the received OFDM signal is mixed with local oscillator signal, and with the frequency offset deviated from Δf the carrier frequency of the received signal. the received signal is given by:

$$\hat{x}_n = (X_n \otimes h_n)e^{j\frac{2\pi}{N}n\Delta fT} + z_n$$
$$\hat{X}_k = \sum_{l=0}^{N-1} X_1 H_1 Y_{1-k} + Z_k \qquad (2)$$

$$= X_k H_k U_0 + \sum_{l=0,l\neq k}^{N-1} X_1 H_1 Y_{1-k} + Z_k \qquad (3)$$

The first term of equation (3) is a desired transmitted data symbol X_k. In the second term of represents the ICI from the undesired data symbols on other subcarriers in OFDM symbol H_k is the channel frequency response and Z_k denotes the frequency domain of z_n. The term Y_{1-k} is the coefficient of FFT (IFFT), by:

$$Y_{1-k} = \frac{1}{\sqrt{N}}\sum_{l=0}^{N-1} e^{j\frac{2\pi}{N}n(l-k+\Delta fT)} \qquad (4)$$
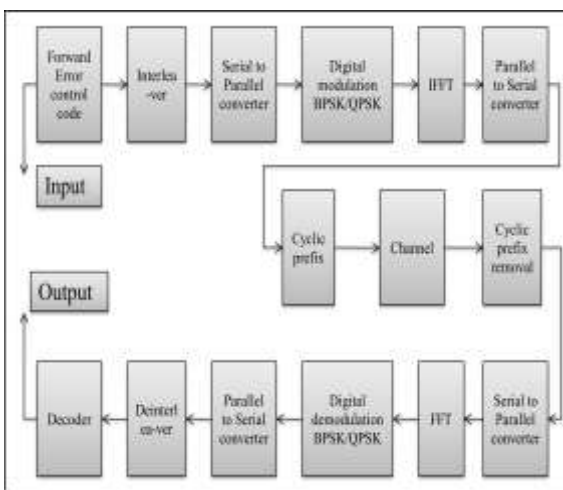

Fig: 2. Basic OFDM Block Diagram.

In the above figure we can see the block diagram of the basis OFDM system; now in the following subsection. The source coding entails the efficient representation of information sources. For both discrete and continuous sources, the correlations between samples are exploited to produce an efficient representation of the information. The aim of source coding is either to improve the SNR for a given bit rate or to reduce the bit rate for a given the SNR. An obvious benefit of the latter is a reduction in the necessary system resource of bandwidth and/or energy per bit to transmit the information.

MIMO SYSTEM

Multiple-Input-Multiple-Output (MIMO) communication techniques have been an important area of focus for 4th generation wireless systems. This is mainly because of their potentials for high capacity, increased diversity, or interference. The MIMO is an acronym that stands for Multiple Input Multiple Output. In the MIMO system and antenna technology that is used both in the transmitter and the receiver for wireless radio communication. The MIMO technology has attracted attention in wireless communications because it offers significant increases in data throughput and link range without additional bandwidth or transmission power. The have achieves this by higher spectral efficiency (more bits per second per hertz of bandwidth) and link reliability or diversity. Because of the properties, MIMO is an important part of modern wireless communication such as IEEE8002.16
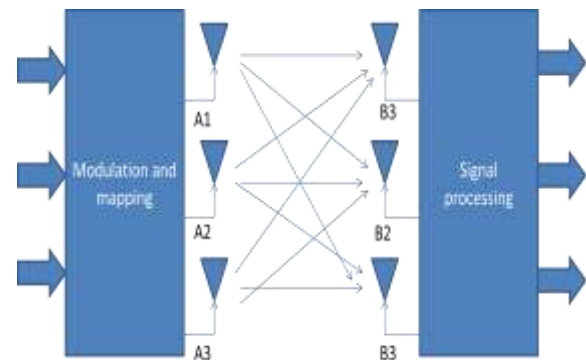

Fig: 3. MIMO system with nT transmitters and nR receivers

In radio communications MIMO means multiple antennas both on transmitter and receiver side of a specific radio link system. The case of spatial multiplexing different data symbols are transmitted on the radio link by different antennas on the same frequency within the same time interval. In Multipath propagation is assumed in order to ensure the correct operation of spatial multiplexing modle, since MIMO

is performing better in terms of channel capacity in a rich scatter multipath environment than in case of environment.

MIMO–OFDM SYSTEM MODEL

In this section a model is given for multiuser MIMO–OFDM radio transmission illustrated with its block scheme and optimization potentials are summarized. To start with, a brief summary follows about the three, in our point of view essential scheme:

OFDM modulation generates several sub channels (or subcarriers) on orthogonal frequencies, which allows realizing parallel communication on the carriers without the need of guard frequency bands. Broadband data is multiplexed onto the carriers, resulting in traffic with low data rate on them. The OFDM scheme provides a Transmission structure which can easily in terms of computational complexity be made resistant against multipath fading effects.
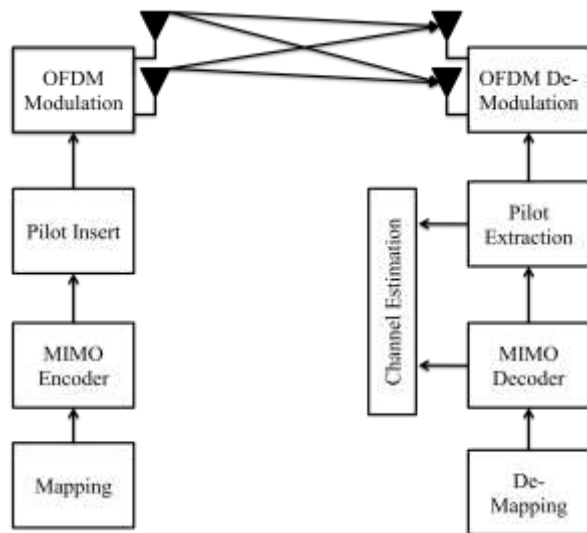

Fig: 4. MIMO-OFDMA System model

MIMO–OFDMA is a combination of downlink MIMO transmission and OFDM based multiple accesses. In the Multiple-Input Multiple-Output (MIMO) communication System exploits the degrees of freedom introduced by multiple transmitted and received antenna to offer high spectral efficiency. In narrow band channels, when channels state information is available at the transmitter and instantaneous adaptation is possible, the capacity achieving distribution is found by using the well known water filling algorithm.

BEAMFORMING

Beam forming techniques are designed to transmit or receive the signal to/from the preferred directions, where multiple antennas are used to shape the overall antenna beam in a certain way in order to maximize antenna gain in target direction or to suppress target dominant interference .The main goal of beam forming is to increase received signal power and, subsequently, to improve coverage.

For the beam forming a high antenna correlation caused by small inter antenna distance is beneficial in order to provide array gain. In this case the channels between different transmit antennas and receiver are highly correlated meaning having the same fading. And these channels differ only in the phase component.
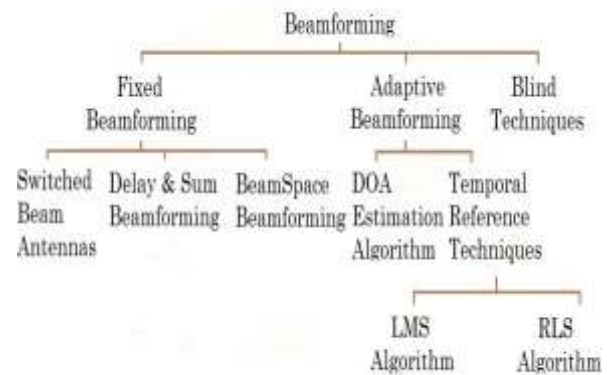

Fig: 5. Beamforming Techniques

LMS algorithm *Because of its simplicity and robustness method, the LMS algorithm has become one of the most popular adaptive signal processing techniques adopted in many applications including antenna array Beamforming systems. The LMS algorithm is a popular solution used in beamforming technique. This algorithm is easy to implement with low computation and performs pretty well. The basic LMS algorithm is expressed as follow.*

$$w(n + 1) = w(n) + 2\mu x(n)e(n) \qquad (5)$$

The reference signal d(t) generated at the receiver is usually assumed to have similar statistical properties as the transmitted signal.

For the purpose of simulation, we will simply assume that the reference signal is identical to the incoming signal. The error signal e (n) = d (n) − y (n) is fed into the weight updating algorithm. For determining the weights is based on minimizing the mean squared

error (MSE) between the beam former output and the reference signal:

$$E(e^2) = E(d^2) - 2w^H r - w^H R_{xx} w \qquad (6)$$

Where Rxx is the autocorrelation matrix of the received signal x and r = E[dx] is the cross-correlation between the reference signal and the received signals. Mean squared error surface is a quadratic function of w and is minimized by setting its gradient with respect to w to zero.

$$\Delta w[E(e^2)] = 2r + 2R_{xx}w + 0 \qquad (7)$$

$$w_{opt} = R_{xx}^{-1} r$$

The LMS algorithm is a stochastic gradient optimization algorithm that converges to this solution. It is based on a traditional optimization technique called the Method of Steepest Descent (MSD). The weight vector is made to evolve in the direction of the negative gradient which points towards the minimum.

$$w(n+1) = w(n) + \frac{\mu}{2}\{-\nabla w[[E(e^2(n))]] \qquad (8)$$

$$R_{xx}(n0 = x(n)x^H(n) \qquad (9)$$

$$r(n) = d(n)x(n) \qquad (10)$$

The gives us a simple expression for weight updating

$$w(n+1) = w(n) + 2\mu x(n)e(n) \qquad (11)$$

The LMS algorithm is initiated with an arbitrary value W (0) for the weight vector at n=0. The successive of the weight vector eventually leads to the minimum value of the mean squared error.

Recursive Least Square (RLS) Algorithm*The SMI technique has several drawbacks. In even though the SMI method is faster than the LMS algorithm method, the computational burden and potential singularities can cause problems. However we can recursively calculate the required correlation matrix and the required correlation vector.*

$$R_{xx}(k) = \sum_{i=1}^{k} x(i)x^H(i) \qquad (12)$$
$$r(k) = \sum_{i=1}^{k} d^*(i)x(i) \qquad (13)$$

Where k, is the block length and last time sample k and $R_{xx}(k), r(k)$ is the correlation estimates ending at time sample k. Both summations Equations use rectangular windows, thus they are equally consider all previous time samples.

$$\widehat{R}_{xx}(k) = \sum_{i=1}^{k} \alpha^{k-i} x(i)x^H(i) \qquad (14)$$

$$\hat{r}(k) = \sum_{i=1}^{k} \alpha^{k-i} d^*(i)x(i) \qquad (15)$$

Where α is the forgetting factor. The forgetting factor is also sometimes referred to as the exponential weighting factor. In α is a positive constant such that .When also indicates infinite memory. In break up the summation in Equations into two terms,the summation for values up to i = k −1 and last term i=k.

$$\widehat{R}(k) = \alpha \sum_{i=1}^{k-1} \alpha^{k-1-i} x(i)x^H(i) + x(k)x^H(k) \quad (16)$$

The RLS algorithm does not require any matrix inversion computations as the inverse correlation matrix is computed directly. It is almost ten times faster compared to LMS. In the requires reference signal and correlation matrix information.

RESULTS AND DISCUSSION
System description

The system description for the simulation is given in fig 5. The input data are transmitted through the MIMO-OFDM system with beamforming.
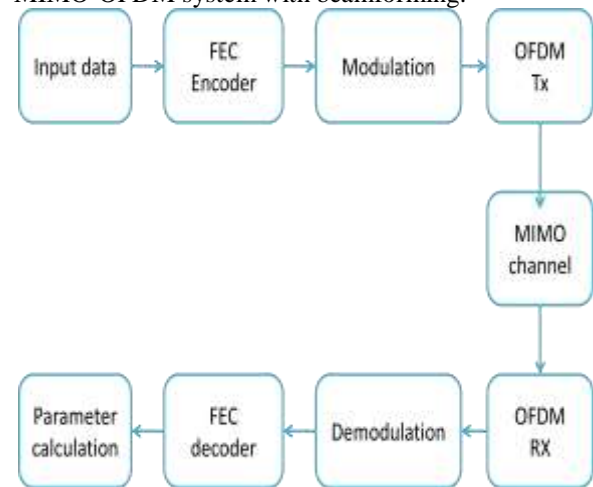

Fig: 5.System block diagram

The BER performance graphs for the simulated MIMO-OFDM with the implementation of communication channel coding under QAM, BPSK, and QPSK digital modulation schemes over AWGN channel, Rayleigh and Rician multipath fading channels. in using beamformig method for example RLS, LMS, N-LMS algorithm method.

The performance of MIMO-OFDM system with beamforming method are generated bit error ratio with respect to EbNo in shown fig. 6

PARAMETERS:

•BPSK- at BER level 10-2SNR Level:

No Beam forming- 17

LMS- 4

N-LMS- 7

RLS- 5

•QPSK- at BER level 10-2 SNR Level:

No Beam forming- -

LMS- 22

N-LMS- 16

RLS- 12

•QAM- at BER level 10-2 SNR Level:

No Beam forming- -

LMS- -

N-LMS- -

RLS- 11

•LMS – at BER level 10-2 SNR Level:

BPSK- 4

QPSK- 22

QAM- -

•N-LMS – at BER level 10-2 SNR Level:

BPSK- 7

QPSK--

QAM--

COLOUR SCHEME:
•BPSK, QPSK and QAM:
Blue – No Beamforming
Red – RLS Algo
Green – LMS
Magenta – N-LMS

•Lms, nlms,rls and no beamforming:
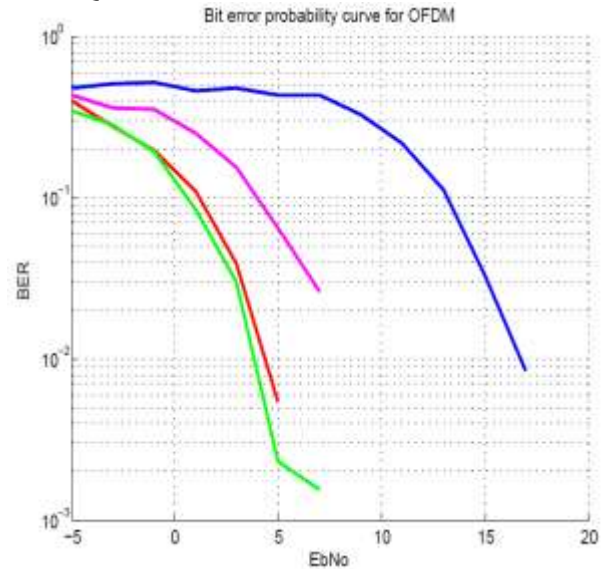Red – BPSK
Green – QPSK
Blue – QAM

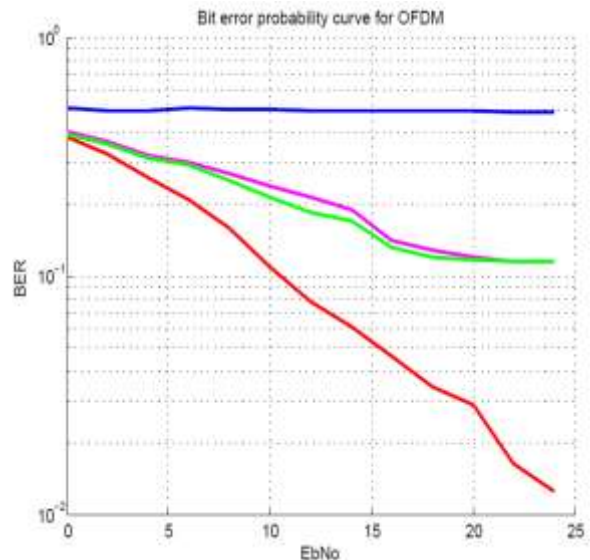*Fig: 6. the performance of OFDM for Bit error ratio vs EbNo*

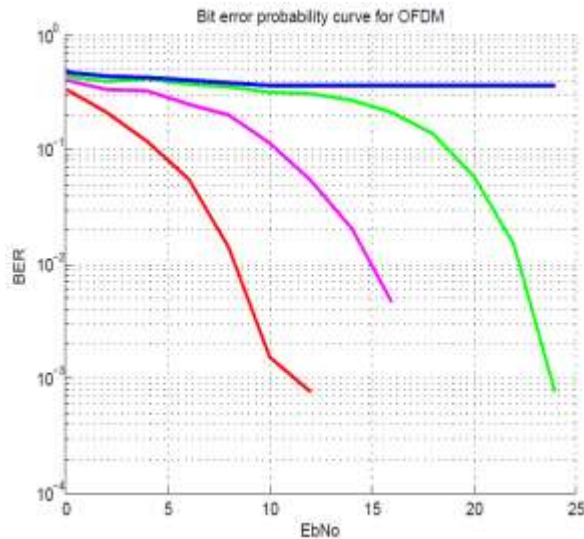*Fig: 7. the performance of OFDM for Bit error ratio vs EbNo*

Fig: 8. the performance of OFDM for Bit error ratio vs EbNo

CONCLUSION

In this work, performance comparison of communication based MIMO-OFDM system is given with and without using adaptive beamforming. In this paper, LMS (Least Mean Square), NLMS, and RLS (Recursive Least Square) adaptive beamforming algorithms are implemented in matlab. The proposed scheme has been verified in AWGN channel, Rayleigh Fading channel and Rician Fading channel. It has been observed that BER performance of the system is improved with adaptive beamforming.The adaptive beamforming improves the system performance greatly using BPSK modulation compared to the QPSK modulation.Many times QPSK and BPSK performs in similar manner especially during non stationary environment. It is found that with increase of modulation order the capacity enhancement is compare to SNR and BER etc.

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