



BER Performance Comparison of MIMO OFDM with Channel Equalizers

Amol Kumbhare*
Department of
Electronics and Communication
MITM,RGPV, India

Smita Jolania
Department of
Electronics and Communication
KITE,RTU, India

DR Rajesh Bodade
Department of
Electronics and Communication
MCTE Mahoo Indore, India

Abstract— MIMO-OFDM technology is a combination of multiple-input multiple-output (MIMO) antenna technology with orthogonal frequency division multiplexing (OFDM). This technique has shown its importance to support high data rate and high performance in different channel conditions. Space time block coding scheme for MIMO system has drawn much attention in wireless technologies just because of its decoding simplicity. In this paper we present performance comparison of space time block coding with different equalizer techniques Zero Forcing Equalizer, minimum mean square error, maximum likelihood sequence estimation. The BER performance, spectral efficiency and capacity are the prime parameter to evaluate the performance of any communication system. The performance comparisons is shown in result section.

Keywords: OFDM, STBC, ZF, MMSE, MLSE, BER etc.

I. INTRODUCTION

Digital communication using Multiple-Input Multiple-Output (MIMO) technique is one of the most significant technical breakthroughs in wireless communication system. MIMO systems are simply defined as the systems containing multiple transmitter antennas and multiple receiver antennas. Communication theories show that MIMO systems can provide a potentially very high capacity that, in many cases, grows approximately linear with the number of antennas. Recently, MIMO systems have already been implemented in wireless communication systems, especially in wireless LANs (Local Area Networks) due to higher transmission frequency 2.4 GHz. The core idea under the MIMO systems is the ability to overcome the effect of multi-path propagation, which is typically an obstacle in conventional wireless communication, into a benefit for users. The main feature of MIMO systems is the antenna diversity based on *space-time* processing. Space-Time Codes (STCs) are the codes designed for the use in MIMO systems. In STCs, signals are coded in both temporal and spatial domains. Among different types of STCs, Orthogonal Space-Time Block Codes (OSTBCs) possess a number of advantages over other types of STCs.

MIMO-OFDM technology is a combination of multiple-input multiple-output (MIMO) wireless technology with orthogonal frequency division multiplexing (OFDM) that has been recognized as important technique in the field of wireless communication system .Space time block coding scheme for MIMO system has drawn much attention in wireless technologies just because of its decoding simplicity.

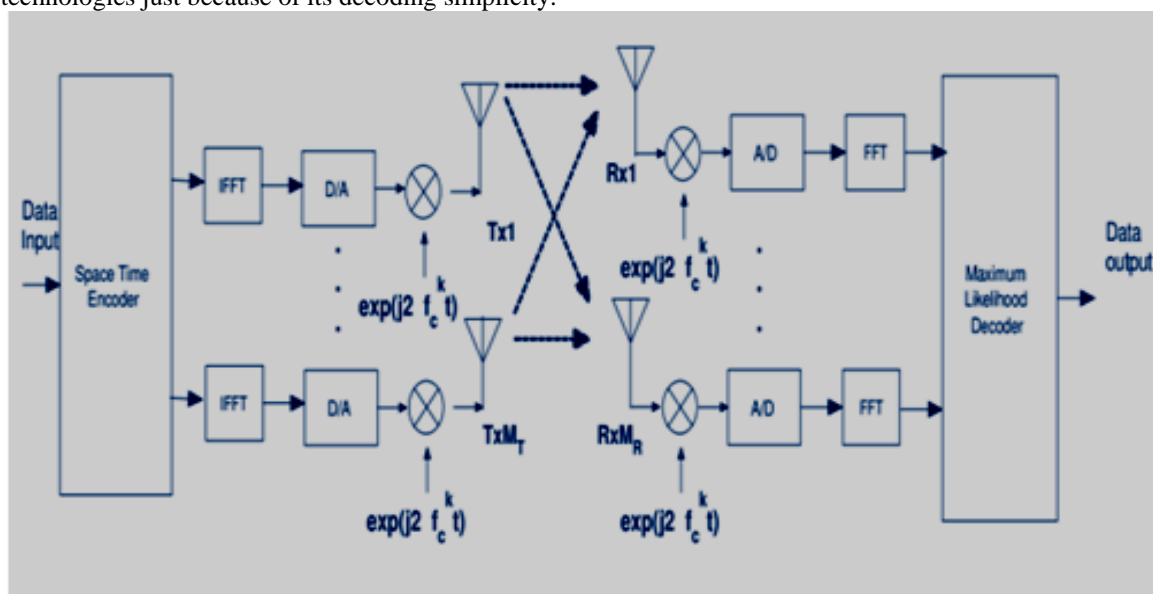


Fig 1 MIMO-OFDM

II. OFDM

OFDM is similar to FDM but much more spectrally efficient by spacing the sub channel much more spectrally efficient by spacing much closer together. This is done by finding frequencies that are orthogonal, which means that are perpendicular in a mathematical sense, allowing the spectrum of each sub-channel to overlap another without Interfering with it. In the effect of this is seen as the required bandwidth is greatly reduced by removing guard bands and allowing signals to overlap .In order to demodulate the signal ,a discrete Fourier transform (DFT) is needed .Fast Fourier transform (FFT) chips are commercially available making this a relatively easy operation .

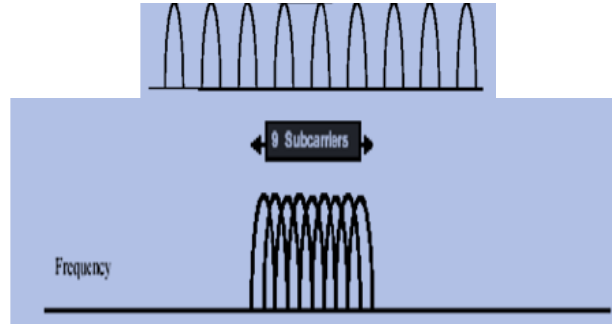


Fig 2 Carrier distribution in FDM and OFDM scheme

The ISI is significantly low in the OFDM system due to orthogonal property. But the BER performance is poor compare to CDMA system . The MIMO technique is useful with OFDM for BER performance improvement.

III. STBC MIMO TECHNIQUE

A complex orthogonal space-time block code for MIMO technique was developed by Alamouti [20]. This technique uses two transmitting antenna. In the Alamouti encoder, two consecutive symbols x_1 and x_2 are encoded with the following space-time codeword matrix as follows:

$$X = \begin{bmatrix} x_1 & -x_2^* \\ x_2 & x_1^* \end{bmatrix} \quad (1)$$

Alamouti encoded signal is transmitted from the two transmit antennas over two symbol periods. During the first symbol period at $t+T$, two symbols x_1 and x_2 are simultaneously transmitted from the two transmit antennas. During the second symbol period $t= 2T$, these symbols are transmitted again, where $-x_2^*$ is transmitted from the first transmit antenna and x_1^* transmitted from the second transmit antenna. For Maximum Likelihood signal detection of Alamouti's space-time coding scheme, we assume that two channels gains $h_1(t)$ and $h_2(t)$ remain constant over two consecutive symbol periods such that

$$h_1(t)=h_1(t+T)=h_1=|h_1|e^{j\theta_1} \quad (2)$$

$$h_2(t)=h_2(t+T)=h_2=|h_2|e^{j\theta_2} \quad (3)$$

Where $|h_1|$ and $e^{j\theta_1}$ denote the amplitude gain and phase rotation over the two symbol periods. At the receiver the received signals y_1 and y_2 at time t and $t+T_s$ can be given as

$$y_1=h_1x_1+h_2x_2+z_1 \quad (4)$$

$$y_2=h_1x_2^* + h_2x_1^* + z_2 \quad (5)$$

where z_1 and z_2 are the additive noise at time t and $t+T_s$, respectively. In this paper we have proposed Alamouti's space time block code for two transmit antenna and more than one receive antenna case.

IV. CHANNEL EQUALIZERS

Equalization is a process which applies the FIR filter that provides an approximate inverse of channel frequency response on the received signal. This process enhances the performance of communication against the ISI and ICI. There are various type of equalizer are used in the communication some of given as following,

1) Zero Forcing Equalizer

Zero Forcing Equalizer is a linear equalization algorithm used in communication systems, which inverts the frequency response of the channel. This equalizer was first proposed by Robert Lucky. The Zero-Forcing Equalizer applies the inverse of the channel to the received signal, to restore the signal before the channel. The name Zero Forcing corresponds to bringing down the ISI to zero in a noise free case. This will be useful when ISI is significant compared to noise. For a channel with frequency response $F(f)$ the zero forcing equalizer $C(f)$ is constructed such that $C(f) = 1 / F(f)$. Thus the combination of channel and equalizer gives a flat frequency response and linear phase $F(f)C(f) = 1$. If the channel response for a particular channel is $H(s)$ then the input signal is multiplied by the reciprocal of this. This is intended to remove the effect of channel from the received signal, in particular the Intersymbol Interference (ISI). For simplicity let us consider a 2x2 MIMO channel, the channel is modeled as,

The received signal on the first receive antenna is,

$$y_1 = h_{1,1}x_1 + h_{1,2}x_2 + n_1 = [h_{1,1} \ h_{1,2}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1 \quad (6)$$

The received signal on the Second receive antenna is,

$$y_2 = h_{2,1}x_1 + h_{2,2}x_2 + n_2 = [h_{2,1} \ h_{2,2}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_2 \quad (7)$$

Where y_1, y_2 are the received symbol on the first and second antenna respectively, $h_{1,1}$ is the channel from 1st transmit antenna to 1st receive antenna, $h_{1,2}$ is the channel from 2nd transmit antenna to 1st receive antenna, $h_{2,1}$ is the channel from 1st transmit antenna to 2nd receive antenna, $h_{2,2}$ is the channel from 2nd transmit antenna to 2nd receive antenna, x_1, x_2 are the transmitted symbols and n_1, n_2 are the noise on 1st and 2nd receive antennas.

The equation can be represented in matrix notation as follows:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \quad (8)$$

Equivalently,

$$y = H \cdot x + n \quad (9)$$

To solve for x , we need to find a matrix W which satisfies $WH = I$. The Zero Forcing (ZF) detector for meeting this constraint is given by,

$$W = (HH^H)^{-1} H^H \quad (10)$$

Where W - Equalization Matrix and H - Channel Matrix, This matrix is known as the Pseudo inverse for a general $m \times n$ matrix where

$$HH^H = \begin{pmatrix} h_{1,1}^* & h_{2,1}^* \\ h_{1,2}^* & h_{2,2}^* \end{pmatrix} \begin{pmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{pmatrix} \quad (11)$$

$$= \begin{bmatrix} |h_{1,1}|^2 + |h_{2,1}|^2 & h_{1,1}^* h_{1,2} + h_{2,1}^* h_{2,2} \\ h_{1,2}^* h_{1,1} + h_{2,2}^* h_{2,1} & |h_{1,2}|^2 + |h_{2,2}|^2 \end{bmatrix} \quad (12)$$

Note that the off diagonal elements in the matrix HH^H are not zero, because the off diagonal elements are non zero in values. Zero forcing equalizer tries to null out the interfering terms when performing the equalization, i.e. when solving for x_1 the interference from x_2 is tried to be nulled and vice versa. While doing so, there can be an amplification of noise. Hence the Zero forcing equalizer is not the best possible equalizer. However, it is simple and reasonably easy to implement.

2) MMSE Equalization

A minimum mean square error (MMSE) estimator describes the approach which minimizes the mean square error (MSE), which is a common measure of estimator quality. The main feature of MMSE equalizer is that it does not usually eliminate ISI completely but, minimizes the total power of the noise and ISI components in the output. Let x be an unknown random variable, and let y be a known random variable. An estimator $\hat{x}(y)$ is any function of the measurement y , and its mean square error is given by.

$$MSE = E \{ (\hat{x} - x)^2 \}, \quad (13)$$

where the expectation is taken over both x and y .

The MMSE estimator is then defined as the estimator achieving minimal MSE. In many cases, it is not possible to determine a closed form for the MMSE estimator. In these cases, one possibility is to seek the technique minimizing the MSE within a particular class, such as the class of linear estimators. The linear MMSE estimator is the estimator achieving minimum MSE among all estimators of the form $AY + b$. If the measurement Y is a random vector, A is a matrix and b is a vector. Let us now try to understand the math for extracting the two symbols which interfered with each other. In the first time slot, the received signal on the first receive antenna is,

$$y_1 = h_{1,1}x_1 + h_{1,2}x_2 + n_1 = [h_{1,1} \ h_{1,2}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1 \quad (14)$$

The received signal on the second receive antenna is

$$y_2 = h_{2,1}x_1 + h_{2,2}x_2 + n_2 = [h_{2,1} \ h_{2,2}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_2 \quad (15)$$

Where

y_1, y_2 are the received symbol on the first and second antenna respectively,
 $h_{1,1}$ is the channel from 1st transmit antenna to 1st receive antenna,
 $h_{1,2}$ is the channel from 2nd transmit antenna to 1st receive antenna,
 $h_{2,1}$ is the channel from 1st transmit antenna to 2nd receive antenna,
 $h_{2,2}$ is the channel from 2nd transmit antenna to 2nd receive antenna,
 x_1, x_2 are the transmitted symbols and
 n_1, n_2 are the noise on 1st and 2nd receive antennas.

Equivalently,

$$y = H.x + n \quad (16)$$

The Minimum Mean Square Error (MMSE) approach tries to find a coefficient W which Minimizes the

$$E\{[Wy-x][Wy-x]^H\} \quad (17)$$

Criterion,

Where W - Equalization Matrix

H - Channel Matrix and

n - Channel noise

y - Received signal.

To solve for x , we need to find a matrix W which satisfies $WH = I$. The Minimum Mean Square

Error (MMSE) detector for meeting this constraint is given by,

$$W = [H^H H + \text{NoI}]^{-1} H^H \quad (18)$$

3) MLSE Equalizer

For a single carrier communication systems transmitting N complex symbols $\mathbf{s} = \{s_1, s_2, \dots, s_N\}T$, chosen from an alphabet D , through a multipath channel with impulse response $\mathbf{h} = \{h_0, h_1, \dots, h_{L-1}\}$ of length L , the symbol received on the k^{th} instant is described by

$$r_k = \sum_{j=0}^{L-1} h_j s_{k-j} + n_k \quad (19)$$

where n_k is the k^{th} zero-mean, σ^2 variance, Gaussian noise sample. To find the most likely transmitted sequence s , the cost function

$$L = \sum_{k=1}^N |r_k - \sum_{j=0}^{L-1} h_j s_{k-j}|^2 \quad (20)$$

needs to be minimized. The MLSE equalizer based on the Viterbi Algorithm (VA) [2] minimizes (2) optimally by using a trellis, with computational complexity linear in N and exponential in L [1]. The proposed iterative MLSE equalizer also minimizes the cost (2), with computational complexity quadratic in N but approximately independent from L , enabling it to perform near-optimal MLSE equalization in systems with extremely long CIR lengths with very low computational cost.

V. RESULT

The MIMO OFDM system with different equalizer performance has been given below based on the study given in reference section[4]. The 1 no. graph 1x1, 2 no. graph 2x1 and 3rd graph is showing 2x2 systems for MMSE code. The different equalizer performance are shown in the figure below .

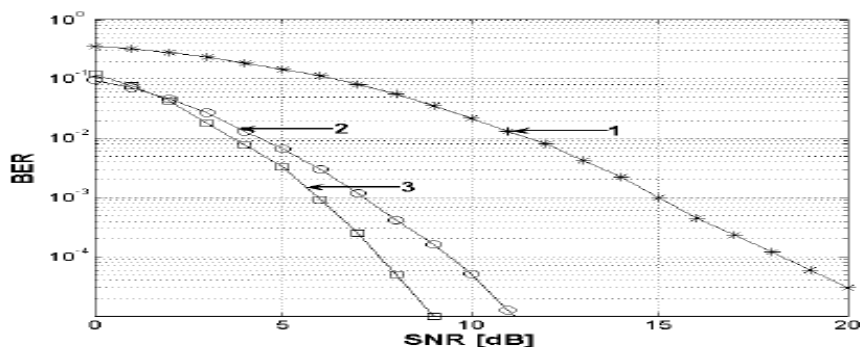


Fig 3. BER PERFORMANCE OF MIMO-OFDM

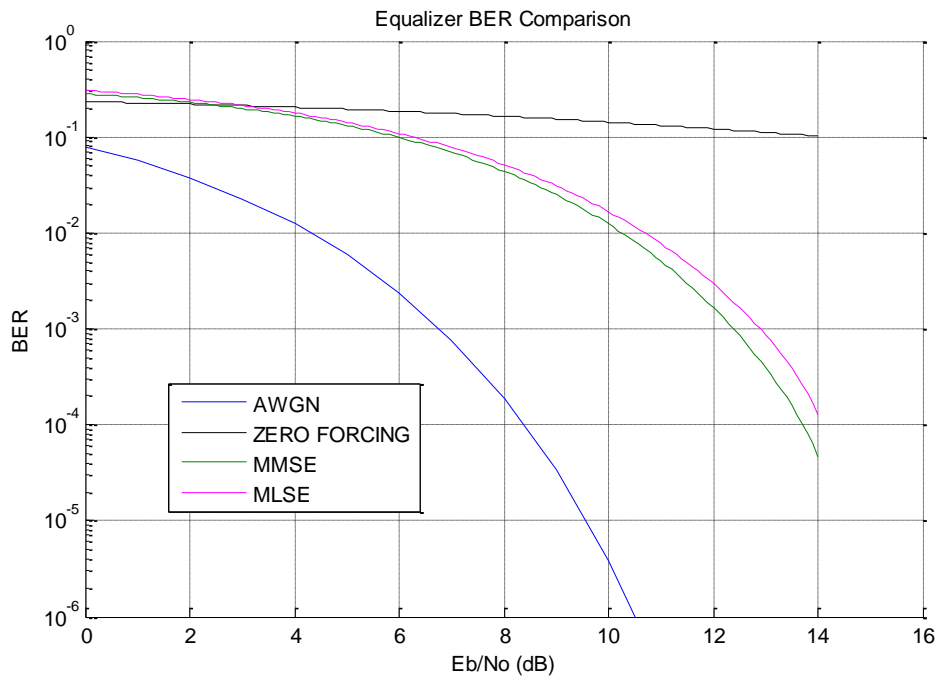


Fig 4. BER PERFORMANCE OF DIFFERENT EQUILIZER

VI. CONCLUSION

The different equalizer may be use in the equalizations of channel depending on the known channel state or estimated channel state. The combination of zero forcing with maximum likely hood sequence or combination of MMSE and MLSE is given an additional advantage in equalization. The zero forcing equalizer improves the performance over channel response and BER performance is further improved by finding maximum likelihood sequence. The BER performance will perform better.

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