MMSE Algorithm Based MIMO Transmission Scheme

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***ABSTRACT*:** *This paper presents a Multiple-Input Multiple-Output (MIMO) transmission scheme that combines the spatial modulation (SM) with MIMO spatial multiplexing technique. The SM uses N_A number of active antennas to transmit the same symbol, the proposed MIMO model uses the N_A number of active antennas to transmit different symbols at the same time to increases the spectral efficiency of the system. A Zero-Forcing based equalizer is used at the receiver to jointly estimate the transmitted symbols as well as the index of active antennas combination. The zero-forcing based detection scheme suffers from a higher complexity and Inter channel Interference (ICI) with less probability of error (BER). For solving the problem in this paper a MMSE based detection scheme is used which improve the BER (bit error probability). The performance of MMSE based detection scheme is evaluated in an uncorrelated flat Rayleigh fading channel and compared with the Zero-forcing based spatial modulation and MMSE Detector.*

Keywords-,*AWGN(Additive white Gaussian noise) ,Rayleigh fading channel, Antenna Combination Binary phase shift keying (BPSK), Bit error rate (BER), Inter-symbol interference (ISI), Minimum mean square error (MMSE), MIMO System, Spatial Modulation, Spatial Multiplexing, Zero Forcing (ZF).*

1. INTRODUCTION

The need for high data rate and high spectral efficiency for the MIMO scheme are the key elements that drive research in future Wireless communication systems. Spatial Modulation was first proposed by Mesleh et al.. Paper [1] presents a MIMO transmission scheme based on the GSM (generalized spatial modulation) combined with the spatial multiplexing. Unlike the GSM which transmits the same symbol over the active antennas, the proposed scheme uses N_A antennas out of N_T to transmit N_A different symbols simultaneously, where $N_A < N_T$. The scheme exploits the index of Active antennas combinations instead of antenna index to convey information bits. As results more information bits can be sent by the scheme, i.e., increased spectral efficiency. In paper [2] to deal with the constraint of the existing method, a modified detection algorithm based on Normalized maximum ratio combination (NMRC) was proposed, which can be used in unconstrained channel. Analysis and simulation results show that NMRC detection can work efficiently with very low complexity. In[3] In this paper, a new transmission approach, called spatial modulation, that entirely avoids ICI(inter channel interference) and requires no synchronization between the transmitting antennas while maintaining high spectral efficiency is presented by using a novel transmit antenna number detection algorithm called iterative-maximum ratio combining (i-MRC) is presented. The results are compared to ideal V-BLAST (Vertical-Bell Lab Layered Space-Time)[3] and to MRC. Spatial modulation outperforms MRC. The (bit-error-rate) BER performance and the achieved spectral efficiency is comparable to V-BLAST. In paper (4)this paper is mainly focused on the concept of SM to design the multiple-antenna wireless system and to get transmit-diversity gain, given by the Space-Time Block Codes (STBCs) technology.

At the receiver end, a Sub-optimal detector (Zero-forcing) [1] is used to estimate the transmitted symbols and the index of active antennas combination. This detector suffers from a high computational complexity Inter channel Interferences (ICI). To solve this problem, This Paper present a New MMSE detector based on the ZF detector And ML (Maximum Likelihood Detection).

After going through the various effective Algorithms are known from the literature, such as maximum likelihood, NMRC ,i-MRC and zero forcing algorithms. The result from the proposed Algorithms (MMSE) in this paper work is better as compare to the other existing algorithms which are being shown in the experimental result section-5 of this paper. The performance improvement of this algorithm over Sub-optimal(zero forcing) SM and by increasing the modulation order, it makes a choice for high data rate transmission for LTE-Advanced.

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2. MIMO MODEL WITH MMSE ALGORITHM

In this paper MIMO model is used for solving the problem in a communication environment like scattering, reflection etc.where it is used four antenna at the transmitting end and four at the receiving end.

In this model different-2 detection algorithm like maximum likelihood, zero-forcing (based on maximum likelihood), and MMSE can be used at the receiving end to get the original signal back. In this paper MMSE (proposed algorithm) is used because it gives the minimum BER (bit error rate) than zero-forcing.

2.1 BASIC MODEL

This paper considers a MIMO communication model with T_R transmitting antennas and N_R receives antennas as shown in Fig. 1.In this model b is a input sequence of independent random bits i.e. transmitted through a MIMO channel. The transmitter combined the incoming bits, b, into blocks of $\log_2(Nc{*}M^{NA})$ bits. The first $\log_2(Nc)$ bits are used to select the index of combination of active antennas, and the remaining $N_A\log_2(M)$ bits are mapped into a complex signal constellation vector $s = [S_1\ S_2\ .\ .\ .\ S_{NA}\ ]^T$ to be transmitted over the N_A active antennas, where $S_k(k = 1, . . . ,N_A)$ is selected from an BPSK signal points .

At the receiver end, the received samples can be expressed as

$$y = H_X + n \qquad (1)$$

Where $y = [Y_{1,}\ Y_2\ldots Y_{N_R}]^T$ is the N_R x 1 received samples vector, and $n = [n_l\ldots\ n_{N_R}]^T$ is the N_R x 1 additive noise vector, H is the N_R x N_T channel matrix between transmit antennas and receive antennas, and is given by:

$$H = \begin{bmatrix} h_{1,1}h_{1,2} & \cdots & h_{1,N_T} \\ \vdots & \ddots & \vdots \\ h_{N_R,1}h_{N_R,2} & \cdots & h_{N_R,N_T} \end{bmatrix} \qquad (2)$$

The Proposed MMSE based transmission scheme forms a sequence of independent random bits into blocks. At the transmitter end each block contains 10g2 (Nc M^{NA}) bits, where M is the modulation order and Nc is the number of combinations. The first 10g2(N_C) bits are used to select the N_A number of active antennas combination from the available combinations, and the next $\log_2(M^{NA})$ bits are modulated using a M -PSK and transmitted by the active antennas that is selected from transmitting antennas .

At the Transmitter end in this paper consider a system with $N_T = 4$, $N_A = 1$, and M = 2 (BPSK) [1].

In mapping procedure the system can convey Three bits in each time slots. Suppose that a block of Three bits, [0 1 0], is to be transmitted. In this case, the symbols -1 and 1 will be transmitted on antennas 2, respectively.

In Table I, illustrate a special example of the mapping of the proposed scheme for $N_T = 4$, $N_A = 1$ and M = 2.

At the receiving stage in this paper present a proposed algorithm that is MMSE algorithm instead of Zero-forcing algorithm because MMSE algorithm gives better Spectral efficiency and less ICI (inter-channel interference) and less error probability than Zero Forcing Algorithm

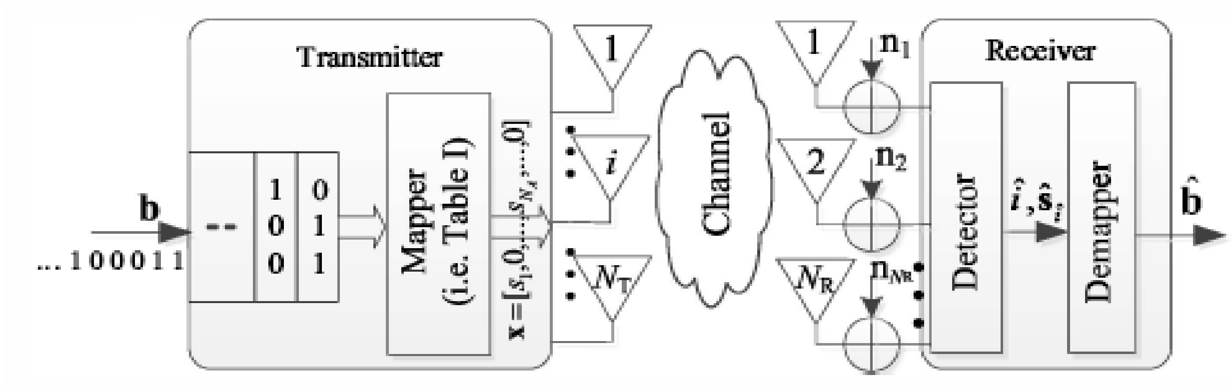

Fig.1 Block Diagram of MIMO model with MMSE Detection Algorithm [1]

Table.1 Proposed Mapping at the transmitter end $N_T = 4$, $N_R = 4$, $N_A = 1$

Block Input	Active Antenna	Transmit Vector
[0 0 0]	1	[1 0 0 0]
[0 0 1]	1	[-1 0 0 0]
[0 1 0]	2	[0 1 0 0]
[0 1 1]	2	[0 -1 0 0]
[1 0 0]	3	[0 0 1 0]
[1 0 1]	3	[0 0 -1 0]
[1 1 0]	4	[0 0 0 1]
[1 1 1]	4	[0 0 0 -1]

3.2. MIMO ALGORITHMS

3.2.1. Optimal Detector (Maximum likelihood)

Since the channel inputs are assumed equally likely, the optimal detector is based on the ML principle. The receiver uses maximum likelihood (ML) detector to estimate the combination index, and transmit symbol vector.

3.2.2. Suboptimal Detector (Zero-Forcing Detector)

Zero Forcing Equalizer is a linear equalization algorithm used in communication systems, which inverts the frequency response of the channel.

A suboptimal detector is used to reduce the complexity of the optimal detector. The suboptimal detector is based on the zero forcing (ZF) and the ML detectors, where the ZF detector is first applied on each possible channels matrix between the transmit antennas combination and all the receive antennas. Unlike the ML detector which searches overall possible symbol vectors and Nc channel matrices, the proposed detector uses ML function to search only over the vectors that obtained.

The sub-optimal detector has a complexity of $(4N_RN_A\text{-}N_A\text{+}N_R\text{+}P)N_C$ where P is the complexity of pseudo-inverse. Psudo-invers matrix H† is given as:

$$H^{\dagger} = (H^HH)H^H \tag{3}$$

In this Equation the proposed algorithm (MMSE) is applied in this paper.

3.2.3. Proposed Algorithm (MMSE Algorithm)

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 (inter symbol interference) completely but, minimizes the total power of the noise and ISI components in the output.

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Algorithm 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 x^ (y) is any function of the measurement y, and its mean square error is given by:

$$MSE = E\{(x\hat{} - x_2)\} \tag{4}$$

where the expectation is taken over both x and y.

The MMSE detector is then defined as the detector achieving minimal MSE. 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:

$$y_1 = h_{1,1}X_1 + h_{1,2}X_2 + n_1 = (h_{1,1}\ h_{1,2})\begin{pmatrix} X_1 \\ X_2 \end{pmatrix} \tag{5}$$

The received signal on the second receive antenna is:

$$y_2 = h_{2,1}X_1 + h_{2,2}X_2 + n_2 = (h_{2,1}\ h_{2,2})\begin{pmatrix} X_1 \\ X_2 \end{pmatrix} \tag{6}$$

Where,

y_1, y_2 are the received symbol on the first and second antenna respectively,

h_{11} is the channel from 1st transmit antenna to 1st receive antenna,

h_{12} is the channel from 2nd transmit antenna to 1st receive antenna,

$h_{21}$is the channel from 1st transmit antenna to 2nd receive antenna,

$h_{22}$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:

$$\begin{pmatrix} Y_1 \\ Y_2 \end{pmatrix} = \begin{pmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{pmatrix}\begin{pmatrix} X_1 \\ X_2 \end{pmatrix} + \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} \tag{7}$$

Equivalently:

$$y = H_X + n \tag{8}$$

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

$$E\{[w_{y-x}][W_{y-x}]^H\} \quad (9)$$

Criterion,
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:

$$W = [(H^H H + N_o I)^{-1} H^H] \quad (10)$$

This matrix is known as the pseudo inverse for a general m x n matrix.

3.3. COMBINATION OF ACTIVE ANTENNA DESIGN

The MMSE based detection scheme uses the index of active antenna combination to convey information bits. In this paper uses a proposed algorithm to design a table of active antennas combination. Consider a MIMO system with N_T and N_R transmit and receive antennas, respectively, and only N_A antennas are active during transmission, where $N_A \leq N_T$ so that, the total number of possible combinations can be calculated as C[1], is:

$$C = \binom{N_T}{N_A} = \frac{N_A!}{N_A!(N_T - N_A)!} \quad (11)$$

The MMSE based transmission scheme uses only Nc combinations out of the total possible combinations, C, where Nc[1]

$$Nc = [C]_2^k \quad (12)$$

Where k is an integer number. For example, assume MIMO system with Four transmit antennas, $N_T = 4$, and only one antenna is active during transmission, $N_A=1$ .Thus, the number of combinations that are used in the proposed scheme is Nc = 4 Therefore, the number of bits that is send by the combination index is $\log_2(4) = 2$ bits.

The spectral efficiency (no. of bits per symbol) can be calculated as:-

$$\eta_{SM} = \log_2(N_C) + \log_2(M) \ [1] \quad (13)$$

$$\eta_{new} = \log_2(N_C) + N_A \log_2(M)[1] \quad (14)$$

So the number of bits that are send through the Spatial modulation scheme is 3bps/Hz. If Number active antenna increases the Spectral efficiency of MMSE based detection Scheme is improved than

2. EXPERIMENTAL RESULTS

This section provides simulation results for the MMSE based transmission scheme, and compares these results with the Zero-Forcing algorithm. .In this paper uses an uncorre1ated Rayleigh fading channel and the channel is perfectly known to the receiver. The M-PSK modulation scheme is used with M=2 the scheme become BPSK.

In Fig.2 plot the BER performance of the 3 bps/Hz spectral efficiency for the BPSK modulation scheme with $N_A = 1$, the zero-forcing and the MMSE Detection algorithm. MMSE detector performs the best result than Zero forcing Detector, and provides SNR gain of about 7dB and 8dB over the zero-forcing based SM and at BER of 0.0037, respectively. The performance of this scheme is decreased when zero-forcing detection is used. The zero-forcing detection algorithm gives worse performance at high SNR, so the MMSE Detection algorithm is used to perform best at high SNR.If number of Active Antenna increases the SM Scheme gives much better results.

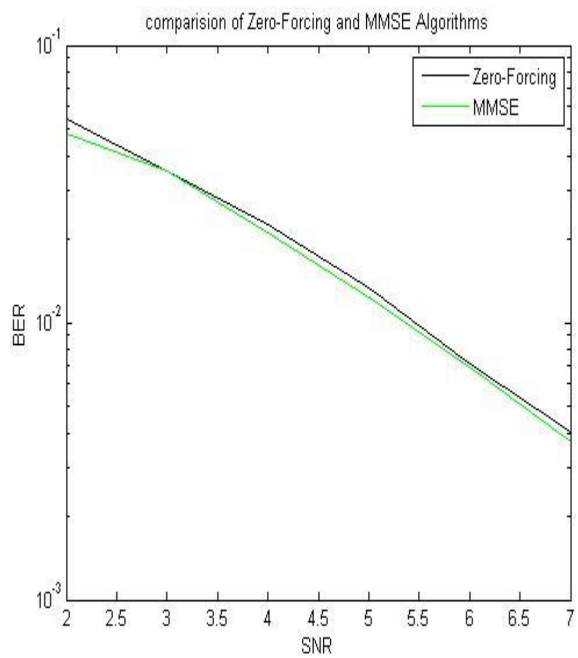
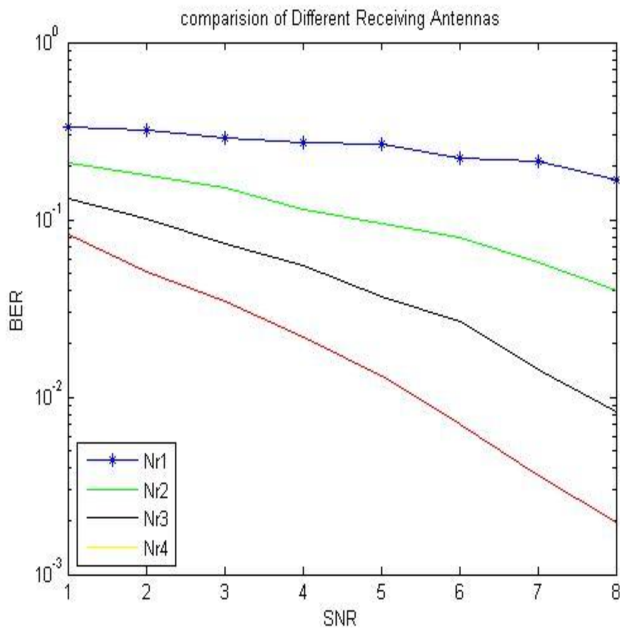


Fig.2 BER Performance for a Zero-Forcing and MMSE algorithm (proposed)

In Fig.3 plot the BER performance for the BPSK scheme with Nr=1, Nr=2, Nr=3, Nr=4 receiving Antennas by using the MMSE Detection Algorithm. In this MIMO model the results are shows that increasing the receiving antenna at the receiver it improves the BER as shown in fig.3



Antenna

3. CONCLUSION

This paper presents MIMO Transmission scheme based on MMSE detection algorithm for higher spectral efficiency and minimum BER. In this scheme uses the index of the active antennas combination to transmit information bits. After that it uses different antennas to transmit different symbols at the same time during one symbol interval. The combination of active antennas is a subset of a larger set of active antenna combinations. At the receiver, if the zero-forcing detection is used to estimate the transmitted symbols and the index of active antennas combination. This detector suffers from a higher receiver complexity and Inter channel Interferences (ICI). For solving this problem a MMSE detection algorithm (proposed algorithm) is used that is based on the ZF detector and ML (Maximum Likelihood Detection) algorithm.

The results shows that proposed scheme uses MMSE detection gives the best results than zero-forcing detection algorithm, the detection with zero-forcing suffer from higher computational complexity. While the MMSE detector performance is best at high spectral efficiency with very low complexity and less number of transmit antennas. So, the performance is increased with the MMSE detection scheme compares to zero-forcing detection algorithm and by increasing the modulation order,making it a good choice for high data rate transmission for LTE-Advanced.

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