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Performance Enhancement of Adaptive DFE Detector for MIMO System

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ABSTRACT: In this paper; we study detection techniques in Multiple Input Multiple Output (MIMO) spatial multiplexing system. This paper includes techniques like Maximum likelihood (ML), Minimum Mean Square Estimation (MMSE), and Adaptive Decision Feedback Equalizer (DFE) algorithm. The adaptive DFE detection achieves the optimal performances with reduced complexity using 4QAM modulation. The simulation result of adaptive DFE decoder shows the Bit error rate (BER) decreases as increase in the signal-to-noise ratio (SNR) as compared to the ML and MMSE equalization.

Keywords*:* MIMO, Spatial Multiplexing, Detection technique, Maximum likelihood detection, minimum Mean Square estimation, Adaptive DFE.

I. INTRODUCTION

MIMO systems are defined as point-to-point communication links with multiple antennas at the both side of transmitter and receiver. The use of multiple antennas at both side clearly provide enhanced performance over diversity systems. In recent research it is observed that MIMO can significantly increase the data rates of systems without increasing the transmit power or bandwidth [1]. MIMO system uses the spatial diversity to increase data rate and spectral efficiency [2]; MIMO channels provide a number of advantages over Single Input Single Output (SISO) channels such as the array gain, the diversity gain, and the multiplexing gain. MIMO can yield significantly improve reliability of link and increase data rate without using additional bandwidth. The unique characteristic of MIMO channels is multiplexing gain. Spatial multiplexing is a transmission technique in MIMO wireless communication to transmit independent and separately encoded data signals called streams, from each of the multiple transmits antennas. Thus, spatial multiplexing is powerful technique which increases channel capacity at higher SNR values [3-5]. There are numerous detection techniques in MIMO wireless communication such as Maximum Likelihood detection (ML); Minimum Mean Square Error Equalizer (MMSE), Adaptive Decision Feedback Equalizer (DFE).

In this paper, we propose a simple ML detection, MMSE and Adaptive DFE technique using 4-QAM modulation and results are compared.
The simulation result of Adaptive DFE algorithms shows significant improvement in performance and BER compared to the ML and MMSE equalization. The main advantage of the proposed approach is significant performance improvements of detections while maintaining the low computational complexities.

II. SYSTEM MODEL

Figure1 shows the block diagram MIMO detection technique. Detection is technique of extracting original signal from received signal. Maximum likelihood; MMSE equalizer; and Adaptive DFE, is used in proposed system. In MIMO high data rate is achieved by the mean of spatial multiplexing technique, in which Independent stream of information is transmitted in parallel over the different transmitting antenna [6]. Here, we consider a MIMO flat fading channel with M_T transmitting antennas, M_R receiving antennas and $M_R \geq M_T$. In MIMO spatial multiplexing system m^{th} information symbol d_m is transmitted directly on m^{th} transmit antenna. At a given instant of time this gives a baseband model with

$$r = H\,d + w \qquad \ldots(1)$$

The $M_T \times 1$ transmit vector $d = (d_1\ d_2\ \ldots.\ d_{MT})^T$, The channel matrix H is $M_R \times M_T$.

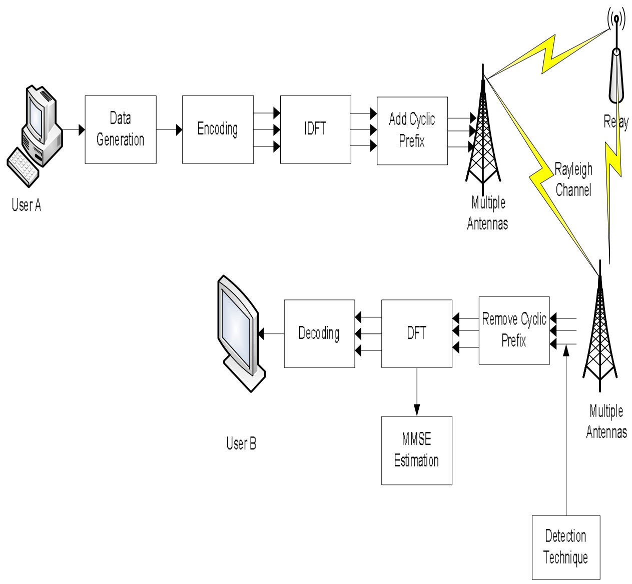

Fig. 1. Block Diagram of MIMO Detection technique.

The $M_R \times 1$ received vector r = (r_1 r_2 …. r_{MT}) ^{T} , and $M_R \times 1$ noise vector w = (w_1 w_2 …. w_{MR}) ^{T}. The (n, m)th entry of H, $H_{n,m}$ = $(H)_{n,m}$ is complex valued fading coefficient between the *n*th receive antenna and *m*th transmit antenna.

The d_m is data symbol drawn from a complex valued symbol alphabet *A* and are assumed to be zero-mean and independent with unit variance. The w_m is noise component is assumed to be circularly symmetric complex Gaussian with σ_w^2 variance. At the receiver channel H is assumed to be perfectly known [6].

The maximum possible diversity in a MIMO spatial multiplexing system is given by the number of receive antenna M_R. Maximum diversity is available if $H_{n,m}$ channel coefficients are independent, because each information symbol d_m is transmitted over M_R independent scalar fading channels $H_{n,m}$, $n = 1,…, M_R$ [6] . The larger M_R, smaller is the probability that all channels fade simultaneously and thus the data detection reliability can be improved. If available diversity is M_R, the symbol error rate of Maximum likelihood detector decays like SNR^{-M_R} in the high regime [7].

A. Maximum Likelihood Detection

Maximum likelihood is optimal detection in the sense of minimum error probability and it fully exploits the available diversity. From system model (1) the maximum likelihood detection can be given by

$$d_{ML} = \arg\min_{d\in D}\{ \| r - Hd \|^2\}. \qquad (2)$$

Here, $\mathcal{D} = \mathcal{A}^{MT}$ denotes the set of possible transmitted data vectors d. The cardinality of $|\mathcal{D}| = |\mathcal{A}^{MT}|$ and thus grows exponentially with M_T. ML detection corresponds to a nonconvex optimization problem because $\mathcal{D}$ is not a convex set [8] [9]. The maximum likelihood receiver tries to $\hat{\mathcal{X}}$ which minimizes,

$$J = |y - H\hat{\mathcal{X}}|^2 \qquad (3)$$

$$\left[\begin{pmatrix}y_1\\ y_2\end{pmatrix} - \begin{pmatrix}h_{1,1} & h_{1,2}\\ h_{2,1} & h_{2,2}\end{pmatrix}\begin{pmatrix}\hat{x}_1\\ \hat{x}_2\end{pmatrix}\right]^2 \qquad (4)$$

The simulation of maximum likelihood detection include mainly finding the minimum among the possible all the transmit symbol based on the
Minimum chose the estimate of transmit symbol and repeat for multiple values of E_b/N_0[10].

B. MMSE Equalizer

MMSE equalizer is used to minimize the mean square error E ($\|Gr - d\|^2$), where G is equalization matrix and E (•) denotes the expectation of the random variable [2].

Let X is an unknown random variable, and Y is a known random variable. An estimator $\hat{X}(Y)$ is any function of the measurement Y, and its MSE is given by [11].

$$MSE = E\{(\hat{X} - X)^2\} \qquad (5)$$

The MMSE detection is used to reduce the noise by using the minimum mean square error equalizer matrix [2]. Here we assume that the symbol vectors x are uncorrelated random with zero mean and covariance matrix σ^2_xI is covariance matrix with identity matrix I, and the noise vector w is independent and identically distributed complex noise with zero mean and covariance matrix σ^2_wI.

$$G_{MMSE} = (H^H H + (\sigma^2_w/\sigma^2_x)I)^{-1} H^H \qquad (6)$$

The MMSE equalizer does not fully eliminate the Inter Symbol Interference (ISI), but it minimizes the total noise power and ISI in output.

C. Adaptive Decision Feedback Equalizer

Adaptive DFE is improves the performance of DFE. This eliminates Inter Symbol interference (ISI) by using the pervious detector on the current received symbol [12].

To describe the adaptive DFE structure, suppose ($a_1,a_2,\ldots a_N$) are block of symbol and ($r_1, r_2,\ldots r_N$) are block of received symbol respectively. The received block is given to adaptive DFE operator, and the output of Adaptive DFE block id denoted by ($R_1, R_2\ldots R_N$). The equalizer multiplies this output block with feed forward coefficient ($F_1, F_2,\ldots F_N$) the resulting block is given to inverse DFT, it gives the output block ($y_1, y_2,\ldots y_N$) on which the threshold detector bases its first decision for transmitted signal block.

After the first decision made by the receiver, the decision block is fed to feedback filter with coefficient ($B_1, B_2,\ldots B_N$) and an adaptive DFE is implemented at K^{th} iteration

$$y_n = \sum_{n-1}^{N} F_n^{(k)} R_n + \sum_{n-1}^{N} B_n^{(k)} A_n^{(k-1)} \; n = 1,2..N$$

Where $F_n^{(k)}$ and $B_n^{(k)}$ coefficients sets of feedback and feed forward filter.

III. RESULT AND DISCUSSION

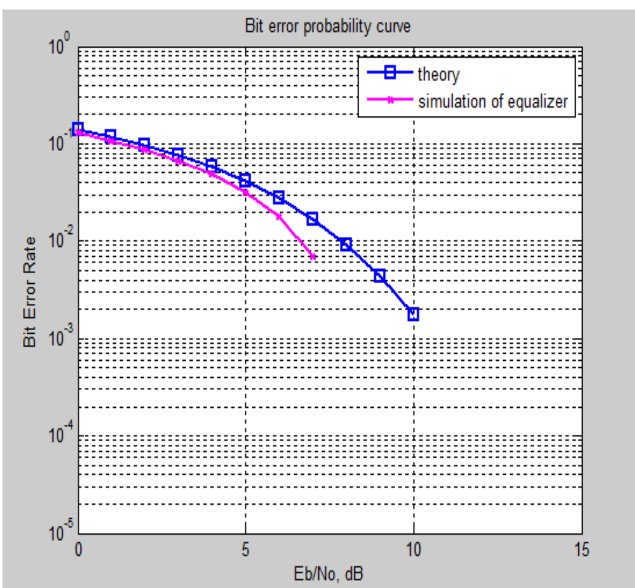

Fig. 2. BER plot of 2x2 MIMO Equalization.

Above Fig 2 and fig 3 shows the BER performance for 2x2 MIMO Rayleigh channel using Equalization and adaptive DFE respectively. The simulation result of both equalizers shows that Bit error rate (BER) decreases with the increase in signal to noise ratio (SNR). Fig 2, the graph shows BER 10^{-2} the SNR value is ~ 7dB. Fig 3, the graph BER 10^{-2} the SNR value is ~ 6dB.

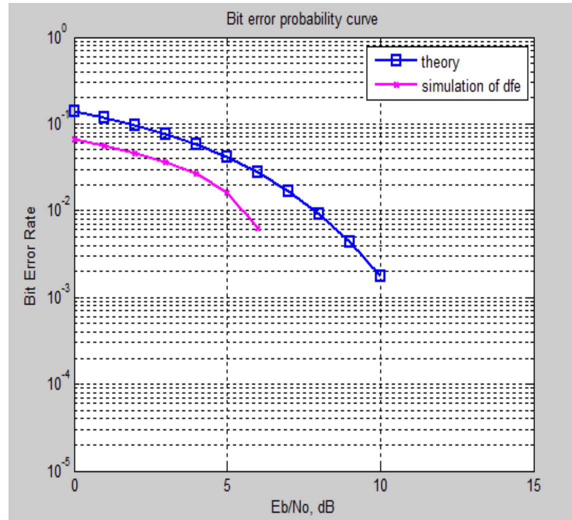

Fig. 3. BER plot of 2x2 MIMO Adaptive DFE.

IV. CONCLUSION

We develop the ML, MMSE and Adaptive DFE detection techniques for MIMO system, and performance are analyzed BER Vs SNR. Finally we compare the performance of equalization technique and Adaptive DFE detection technique as shown in graph BER decreases with the increase in the SNR value. The adaptive DFE gives the better compared to the equalization detection technique.

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