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Reduction in Bit Error Rate from Various Equalization Techniques for MIMO Technology

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Abstract*-The effect of fading and interference effects can be combated with equalizer for a MIMO system. MIMO systems exploit the multipath propagation in rich scattering environment using multiple transmit and receive antennas to increase the capacity of a link. The matrix channel plays a pivotal role in the throughput of a MIMO link since the modulation, data rate, power allocation and antenna weights are dependent on the channel gain. In this case independent, identically distributed (i.i.d.) Rayleigh fading MIMO channel with m-transmit and n-receive antennas has been taken, the diversity order is almost same i.e. m x n for ZF, MRC and MMSE-filtering-based decoding. The error probability analysis also yields a design criterion for optimizing transmitt power allocations. This paper analyses the performance of MMSE, ZF equalizer and MRC based receiver for MIMO wireless channel .The BER characteristics for the various transmitting and receiving antennas simulated in MATLAB tool box and many advantages and disadvantages the system is described. The simulation is carried out in signal processing lab, which shows that the MRC equalizer based receiver is a good choice for removing some ISI and minimizes the total noise power. The results show that the BER decreases as the m x n antenna configurations is increased.

***Index Terms* -Equalizer, Bit error rate, Signal to noise ratio (Eb/N0), transmitting antenna, receiving antenna**

I. INTRODUCTION

Wireless communication technology has shown that when multiple antennas at both transmitter and receiver are employed it provides the possibility of higher data rates compared to single antenna systems [1] [2]. In the never-ending search for increased capacity in a wireless communication channel it has been shown that by using MIMO (Multiple Input Multiple Output) system architecture it is possible to increase that capacity substantially. Usually fading is considered as a problem in wireless communication but MIMO channels uses the fading to increase the capacity. MIMO systems transmits different signals from each transmit element so that the receiving antenna array receives a superposition of all the transmitted signals.

All signals are transmitted from all elements once and the receiver solves a linear equation system to demodulate the message. Since the MIMO system architecture uses the independent fading between different antenna-elements perhaps it could be possible to increase the independent fading by using some sort of mixer in the channel so that the channel doesn't get stuck in a stat of low diversity gain. There will be some experiments made with a retro directive antenna that should work as a mixer. In this paper, different equalization approach called **Minimum Mean Square Error (MMSE), ZF (Zero Forcing)** equalization has been discussed. The channel as a flat fading Rayleigh multipath channel and the modulation as BPSK has been taken.

II. 2×2 MIMO CHANNEL

In a 2×2 MIMO channel, input data symbols can be transmitted in sequence, for example $\{x_1,x_2,x_3,x_4,x_5,x_6 \ldots.. x_n\}$ Symbols can be grouped in a pair of two. In the first time slot, x_1 and x_2 can be send from the first and the second antenna. In second time slot, x_3 and x_4 can be send from the first and the second antenna, and x_5 and x_6 in the third time slot and so on. As two symbols are in a group and sending them in one time slot, there is a need of $n/2$ time slots to complete the transmission so data rate is doubled**.** This forms the simple explanation of a probable MIMO transmission scheme with 2 transmit antennas and 2 receive antennas.

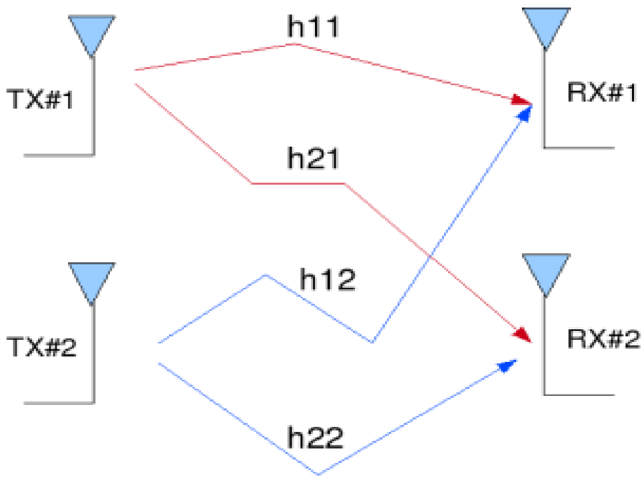

Fig.1 Transmit 2 Receive (2×2) MIMO channel

The received symbols after transmission of symbols in first time slots can be given as
The received [4] symbol on first receive antenna is,

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

The received signal on the second receive antenna is,

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

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

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$h_{1,1}$ 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 is the noise on 1st, 2nd receive antennas.
Above equation can be written as
y = H_x + n
here
Y is the received symbol
H is the channel matrix
X the transmitted symbol matrix
N is the noise matrix

III. MMSE EQUALIZER

In MIMO wireless communication, an equalizer is employed which is a network that makes an attempt to recover a signal that has suffers with an Inter symbol Interference(ISI) and proves the BER characteristics and maintains a good SNR. A Minimum Mean Square Error (MMSE) estimator is a method in which it minimizes the mean square error (MSE), which is a common measure of estimator quality. Minimum mean-square error equalizer, which does not usually eliminate ISI completely but instead, minimizes the total power of the noise and ISI components in the output. The MMSE estimator is then defined as the estimator achieving minimal MSE. Generally, it very difficult 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.

IV. MINIMUM MEAN SQUARE ERROR (MMSE) EQUALIZER FOR 2×2 MIMO CHANNEL

The Minimum Mean Square Error **(**MMSE**)** approach minimizes the mean square error given by E

E$\left\{[W_x - x][W_y - y]^H\right\}$ and coefficient W minimizes the MSE

W = $[H^H H + N_0 I]^{-1} H^H$

Where W - Equalization Matrix

I is the Identity matrixN_0 is the number of symbols

V. ZERO FORCING EQUALIZER

Zero Forcing Equalizer refers to a form of linear equalization algorithm used in communication systems which inverts the frequency response of the channel. This form of 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. It has many useful applications. For example, it is studied heavily for IEEE 802.11n (MIMO) where knowing the channel allows recovery of the two or more streams which will be received on top of each other on each antenna. The name Zero Forcing corresponds to bringing down the inter symbol interference (ISI) to zero in a noise free case. This will be useful when ISI is significant compared to noise. When comparing to the equation in Zero Forcing equalizer apart from the term $N_0 I$ both the equations are comparable. Infact, when the noise term is zero, the MMSE equalizer reduces to Zero Forcing equalizer. For a channel with frequency response F(f) the zero forcing equalizer C(f) is constructed by 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. In reality, zero-forcing equalization is not a better equalization technique because channel impulse response has finite length. Another reason is, at some frequencies the received signal may be weak. To compensate, the magnitude of the zero-forcing filter ("gain") grows very large. As a consequence, any noise added after the channel gets boosted by a large factor and destroys the overall signal-to-noise ratio. Furthermore, the channel may have zeroes in its frequency response that cannot be inverted at all. (Gain * 0 still equals 0). Numerical [3] results show that ZF is indeed asymptotically optimal and has a fairly good performance for relatively small number of users as well, but suffers from performance degradation under imperfect transmitter channel knowledge.

VI. MAXIMAL-RATIO COMBINING

Various techniques are known to combine the signals from multiple diversity branches. In Maximum Ratio combining each signal branch is multiplied by a weight factor that is proportional to the signal amplitude. That is, branches with strong signal are further amplified, while weak signals are attenuated. In telecommunications, maximal-ratio combining is a method of diversity combining in which the signals from each channel are added together and the gain of each channel is made proportional to the RMS value of signal and inversely proportional to the mean square noise level in that channel. Different proportionality constants are used for each channel. It is also known as ratio-squared combining and predetection combining. Maximal-ratio-combining is the optimum combiner for independent AWGN channels. Matthew R. McKay et.al.[3] proposed multiple-input multiple-output (MIMO) transmit beamforming systems with maximum ratio combining (MRC) receivers. He also proved that MIMO-MRC achieves the maximum available spatial diversity order, spatial correlation.

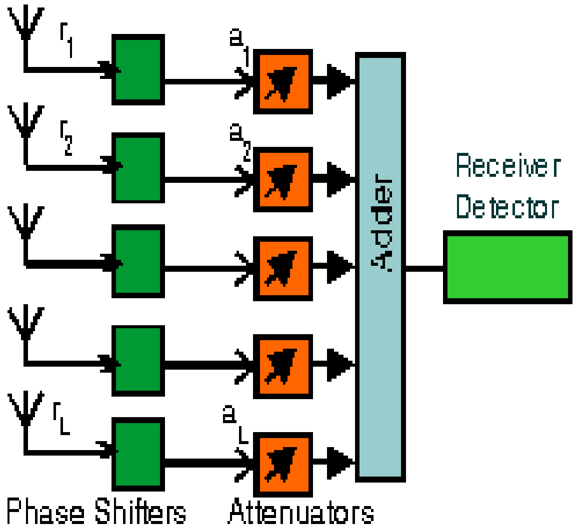

Fig. 2 L-branch antenna diversity receiver (L = 5).

With MRC, the attenuation/amplification factor is proportional to the signal amplitude $a_i = r_i$ for each channel i.

VII. FLOW CHART FOR APPROACH

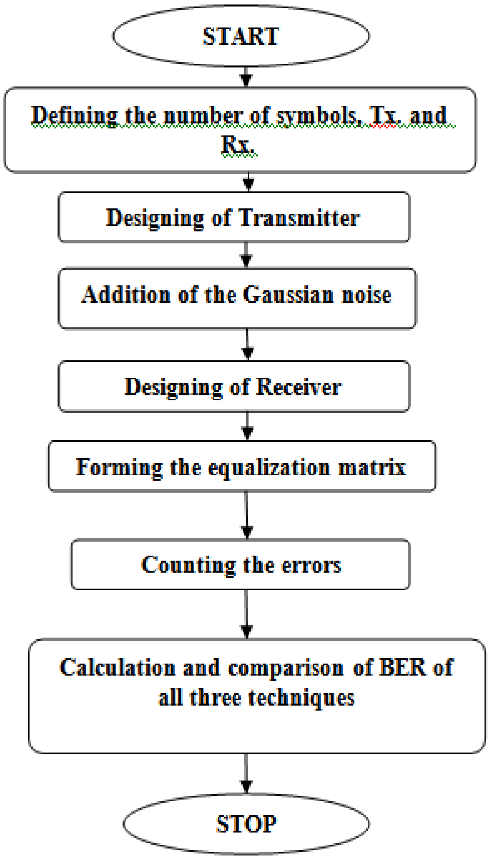

Fig. 3 Flow chart for the Modelling of MMSE

VIII. RESULT AND CONCLUSION

The simulations were carried out at signal processing lab .Now let us consider the simulation analysis of MMSE equalizer for 2 x n antenna configurations which means keeping the transmitter antenna as two and vary the number of antennas in the receiver side. From the figure window shown in figure no. 6, it's evident that the BER decreases as the receiver antenna increases for all of the equalizers. For a better clarity the data from the figure window is taken and plotted in the form of bar chart as shown in figure no 7. Also, comparison has been done between three mentioned techniques. This can be done by comparing BER of three techniques for 2 x 2 equalizers as shown in figure no. 4. Comparative Bar graph of BER for three 2 x 2 equalizer is given in figure no. 5.

This is a simulation study on the performance analysis of m x n Equalizer based MMSE, ZF and MRC receiver for MIMO wireless channel. BER got from ZF, MRC and MMSE are respectively 0.1464, 0.0581and 0.0925. So, it is very clear from the results that MRC is the best Equalization method for MIMO system. Also, a more balanced linear equalizer is the Minimum mean square error equalizer, which however is not eliminate ISI completely but instead minimizes the total power of the noise and ISI components in the output. From the simulation results it is evident that the BER decreases as the number of receiving antenna increases with respect to number of transmitting antenna in all the three equalizer based MIMO receiver.

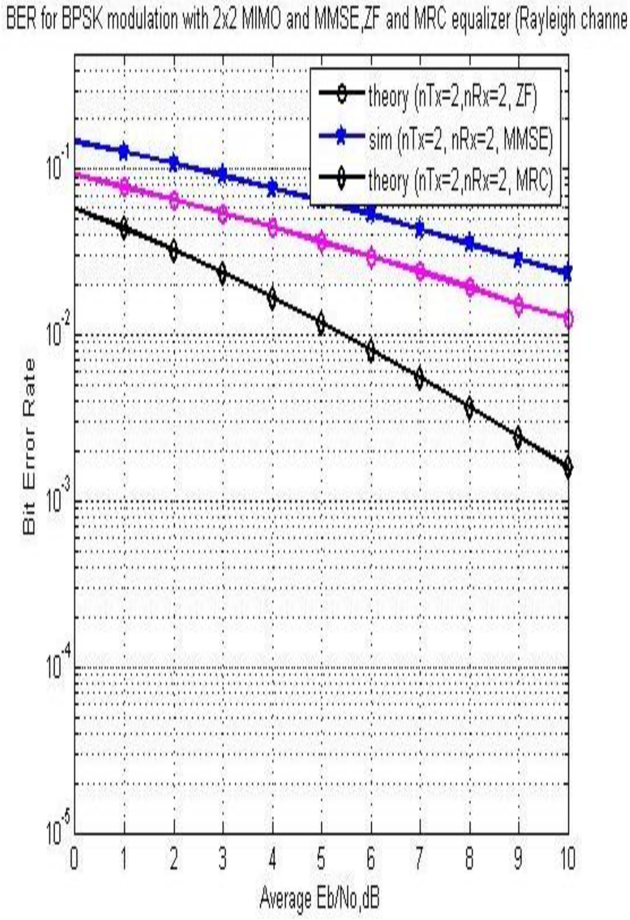

Fig. 4 comparison between BER of MMSE, MRC and ZF for BPSK modulation in 2x2 MIMO

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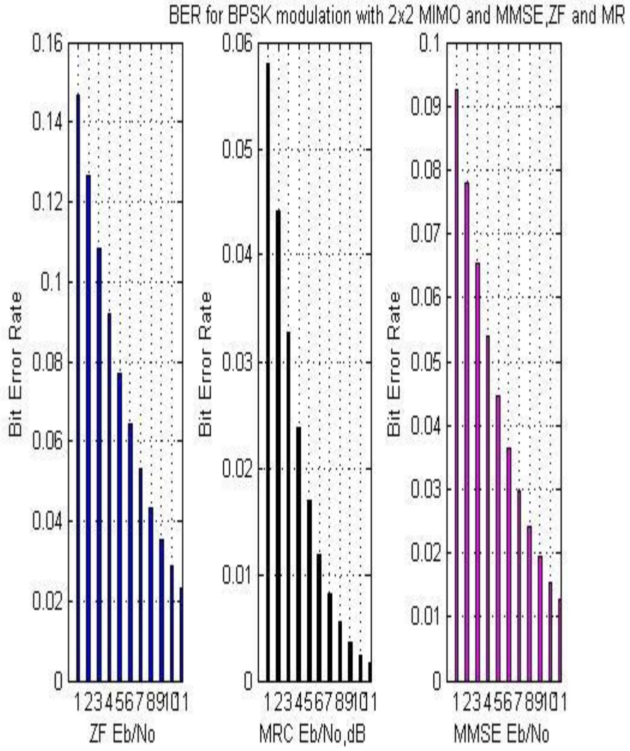

Fig. 5 Bar Graph for comparison between BER of MMSE, MRC and ZF for BPSK modulation in 2x2 MIMO

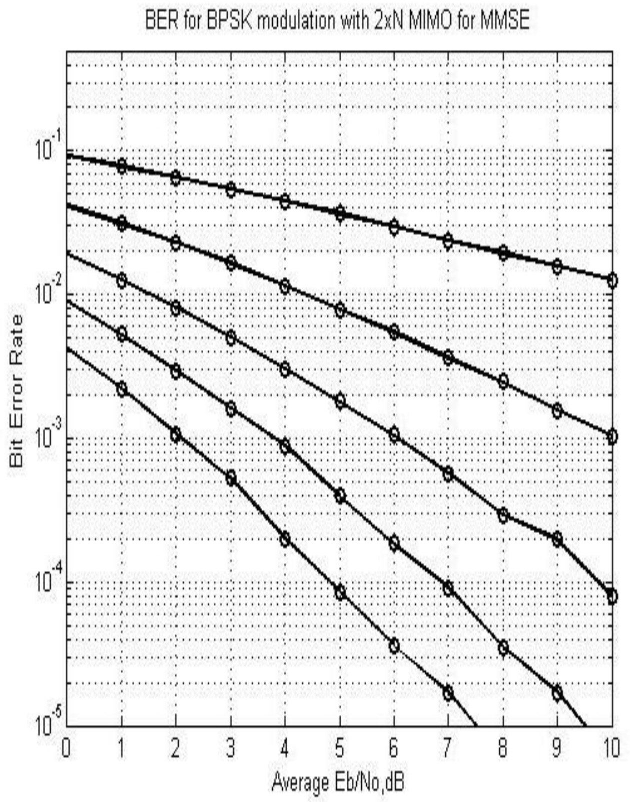

Fig. 6 comparison between BER for different number of Receivers in 2xN MIMO

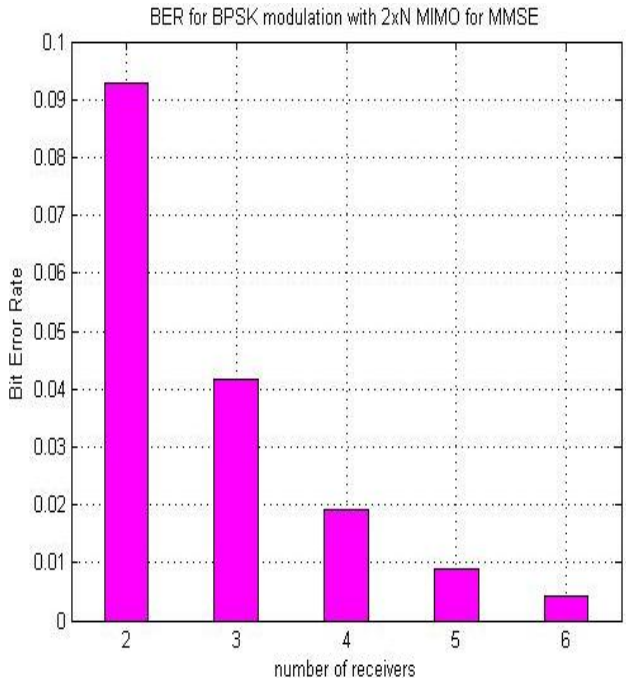

Fig.7 bar graph for the comparison between BER for different number of Receivers in 2xN MIMO

REFERENCES

1. H. Zhang, H. Dai, Q. Zhou, and B. L. Hughes, 2006 On the "diversity-multiplexing tradeoff for ordered SIC receivers over MIMO channels," IEEE International Conference on Communications (ICC), Istanbul, Turkey.
2. K. Cho and D. Yoon, 2002 , On the general BER expression of one and two-dimensional amplitude modulations," IEEE Transactions on Communications, vol. 50.
3. Matthew R. McKay, Alex J. Grant, and Iain B. Collings, "Performance Analysis of MIMO-MRC in Double-Correlated Rayleigh Environments" IEEE Transactions on Communications (Submitted November 2005) .
4. N. Sathish Kumar, Dr. K. R. Shankar Kumar "Performance Analysis of M*N Equalizer based Minimum Mean Square Error (MMSE) Receiver for MIMO Wireless Channel" International Journal of Computer Applications (0975 – 8887) Volume 16– No.7, February 2011.
5. D. Tse and P. Viswanath, 2005 Fundamentals of Wireless Communications. Cambridge Press. 1074-1080
6. N. Jindal, 2005 High SNR analysis of MIMO broadcast channels," *Proc.* IEEE Int. Symp. Information Theory, Adelaide,Australia.
7. X. Zhang and S. Kung, 2003, Capacity analysis for parallel and sequential MIMO equalizers," IEEE Transactions on Signal Processing, vol. 51. 2989-3003
8. B. Hassibi, 2000, A fast square-root implementation for BLAST," Thirty-Fourth Asilomar Conf. Signals, Systems and Computers. 1255-1259
9. N. Prasad and M. K.Varanasi, 2004, Outage capacities of space-time architecture," Information Theory Workshop, SanAntonio, Texas. 24-29
10. M. Varanasi, 1995, Group detection for synchronous Gaussian code-division multiple-access channels," IEEE Transactions on Information Theory, vol. 41. pp. 1083-1096.

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