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OPTIMIZATION OF MIMO SYSTEM USING SIC-MMSE IN ADDITIVE WHITE GAUSSIAN NOISE RAYLEIGH FADING CHANNELS

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ABSTRACT
Multiple-Input Multiple-Output(MIMO) technology is one of the most promising wireless technologies that can efficiently boost the data transmission rate, improve on system coverage and enhance the link liability. The performance of MIMO system can be improved by using multiple antennas at transmitter and receiver side to provide spatial diversity. The use of multiple antennas at both transmitter and receiver side can considerably increase the channel throughput which makes it irresistible for high data rate wireless applications. In this paper, the effects of the number of transmit and receiver's antennas on the performance of MIMO system over AWGN and Rayleigh fading channels with MMSE receiver were analyzed. This paper also analyzed the effect of inter-symbol interference in MIMO.Channel estimation scheme was developed called the Successive Interference Cancellation Minimum Mean Square Error (SIC-MMSE) based on bit error rate using Mat-lab software. The results show an improvement to the MMSE scheme. As a result of reduction in the amplified noise of MMSE scheme, SIC-MMSE was formed with an improvement of threepercentage (3%).

Keywords: MIMO, Additive White Gaussian Noise, Minimum Mean Square Error, Successive Interference Cancellation.

I. INRTODUCTION

Efficient communication system is a major backbone to the growth and development of any society or nation at large. With the increase in wireless technological development, there is need for innovative approach designed to integrate features such as high data rates, highqualityof service delivery and multimedia in the existing communication network. In wireless systems, radio signals are corrupted due to channel fading, distortion, dispersion, inter-symbol interference and noise. In order to combat these channel effects, modern systems employ various techniques including multiple-antenna transceivers using spatial diversity[1]. Initially, multi-antenna systems were proposed only for point-to-point communication but have now extended to point to multi point communication. Multiple-Input Multiple-Output from multiple transmitters and multiplereceivers' antenna can reduce the effects of multipath propagation fading and noise in the channel[2]. MIMO signals are transmitted from different antennas at the transmitter using the same frequency and multiplexed in space. Received signal in MIMO system is usually distorted by multipath propagation fading, in order to recover the original transmitted signal correctly, channel effect must be compensated for and repaired at receivers' side. Various channel estimation schemes are employed in order to mitigate the physical effects of the medium present. Hence MIMO systems utilize space multiplex by using array of antennas for enhancing the efficiency of the wireless signals at particular utilized bandwidth [3]. MIMO technology is being used and proposed in the near future for many modern wireless systems in many different ways to combat effects ofmultipath propagation fading, noise and to improve system performance on the basis of receiving signals. Basically, these techniques transmit different data streams on different transmit antennas simultaneously. By designing an appropriate processing architecture to handle these parallel streams of data, the data rate and/or the Signal-to-Noise Ratio (SNR) performance can be increased [4].The performance of MIMO channel is optimize by using different channel estimation scheme such as, Minimum mean square error (MMSE), Successive Interference Cancellation Minimum Mean Square Error (SIC-MMSE) [5].

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II. SYSTEM MODELLING

Channel estimation is an important technique especially in mobile wireless network systems where the wireless channel changes over time, usually caused by transmitter and/or receiver being in motion at vehicular speed. Mobile wireless communication is adversely affected by the multipath interference resulting from reflections from surroundings, such as hills, buildings and other obstacles. In order to provide reliability and high data rates at the receiver, the system needs an accurate estimate of the time-varying channel [6]

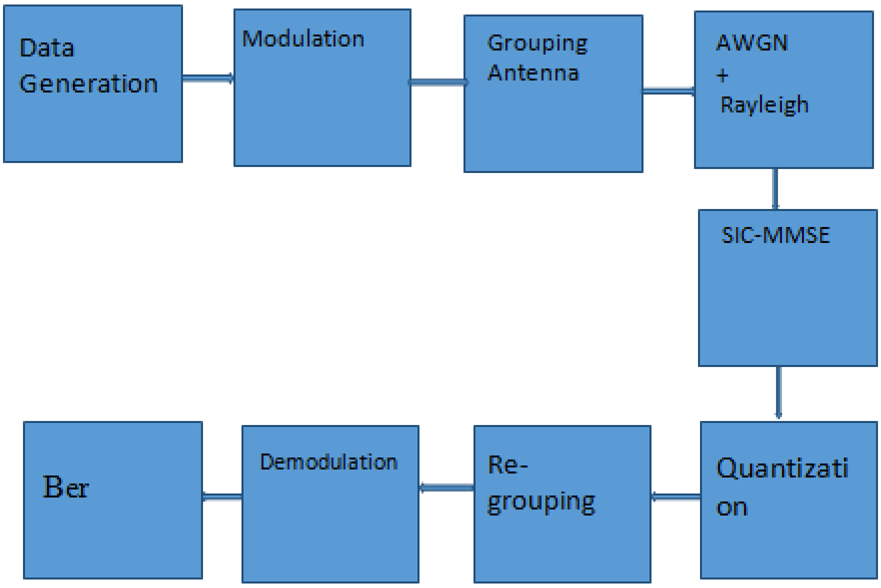

Figure 1: Block diagram of channel estimation SIC Minimum Mean Square Error

1.1 Minimum mean square error channel estimation

The Minimum Mean Square Error algorithm which tries to obtain the Mean Square Error (MSE) is a common measure of estimator quality. The main feature of MMSE equalizer is that it does not usually eliminate ISI completely but, tries to provide a tradeoff between ISI mitigation and noise enhancement by minimizing the total power of the noise and ISI components in the output. This type of channel estimation equalizer uses the squared error as performance measurement. The receiver filter is designed to fulfill the minimum mean square error criterion. The main objective of this method is to minimize the error between target signal and output obtained by filter. The computation for this method is as follows, If transmitted symbol is represented by $x_1$andx_2, andh_{11} represent the channel from first transmitter to first receiver,h_{12} represent the channel from second transmitter to first receiver, h_{21} represent the channel from first transmitter to second receiver and h_{22} represent the channel from second transmitter to second receiver and n_1,n_2 represent noise on first and second receiver then the received symbol on first receiver is given by;

$MSE = E\{(X\text{-}X\hat{})^2\text{-} X^{\hat{}})^2\}$ (1)

Mathematical Modeling of Channel estimation MMSE Equalization Matrix

To extract the two symbols which interfere with each other in the case 2 × 2 MIMO configuration, the received signal on the first received antenna is given by;

$y_1 = h_{11}x_1 + h_{12}x_2 + n_1$(2)

The received signal on the second receive antenna is:

$y_2 = h_{21}x_1 + h_{22}x_2 + n_2$(3)

It is clear from this equation that ifh_{11}, h_{12}, h_{21}, h_{22} and y_1, y_2 is known then it is easier for the receiver to compute the x_1 and x_2.

Now if we rewrite the above equation then

$y = Hx + n$(4)

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Now, MMSE algorithm computes the coefficient of matrix W which minimize the condition
$E\{[wy - x][wy - x]\wedge H(5)$

Solving above equation gives
$W = (H^H \mathrm{H} + N_o I)^{-1} H^H (6)$

From the above equation it is clear that this equation is different from the equation of zero forcing equalizer by the term $N_o I$If we put $N_o I = 0$ in this equation then MMSE equalizer becomes zero forcing equalizer. This method can be extended to multiple transceiver antenna configurations.

III. SUCCESSIVE INTERFERENCE CANCELLATION USING OPTIMAL ORDERING

In the previous successive interference cancellation method, estimation symbol is chosen arbitrarily and then its effect is subtracted from received symbol $y_1\ and y_2$. A better result can be obtained if we choose estimated symbol whose influence is more than other symbol. For this first of all the power of both the symbol is computed at the receivers and then the symbol having higher power is chosen for subtraction process.

The power of transmitted symbol x_1 is given by

$$P_{x1} = |h_{11}|^2 + |h_{21}|^2 (7)$$

Similarly the power of transmitted symbol x_2 is given by

$$P_{x2} = |h_{12}|^2 + |h_{22}|^2 \qquad (8)$$

If$P_{x1} > P_{x2}$, then the receiver decides to remove the effect of $\hat{x}_1$ from the received vector $y_1$and y_2 $\hat{x}_2$. Else if $P_{x1} \leq P_{x2}$ then the receiver decide to subtract the effect of $\hat{x}_2$from the received vector y_1 and y_2, and then re-estimate $\hat{x}_1$

$$\binom{r1}{r2} = \begin{pmatrix} y1 - & h11x1 \\ y2 - & h12x1 \end{pmatrix} = \begin{pmatrix} h12x1 & +n1 \\ h22x1 & +n2 \end{pmatrix} (9)$$

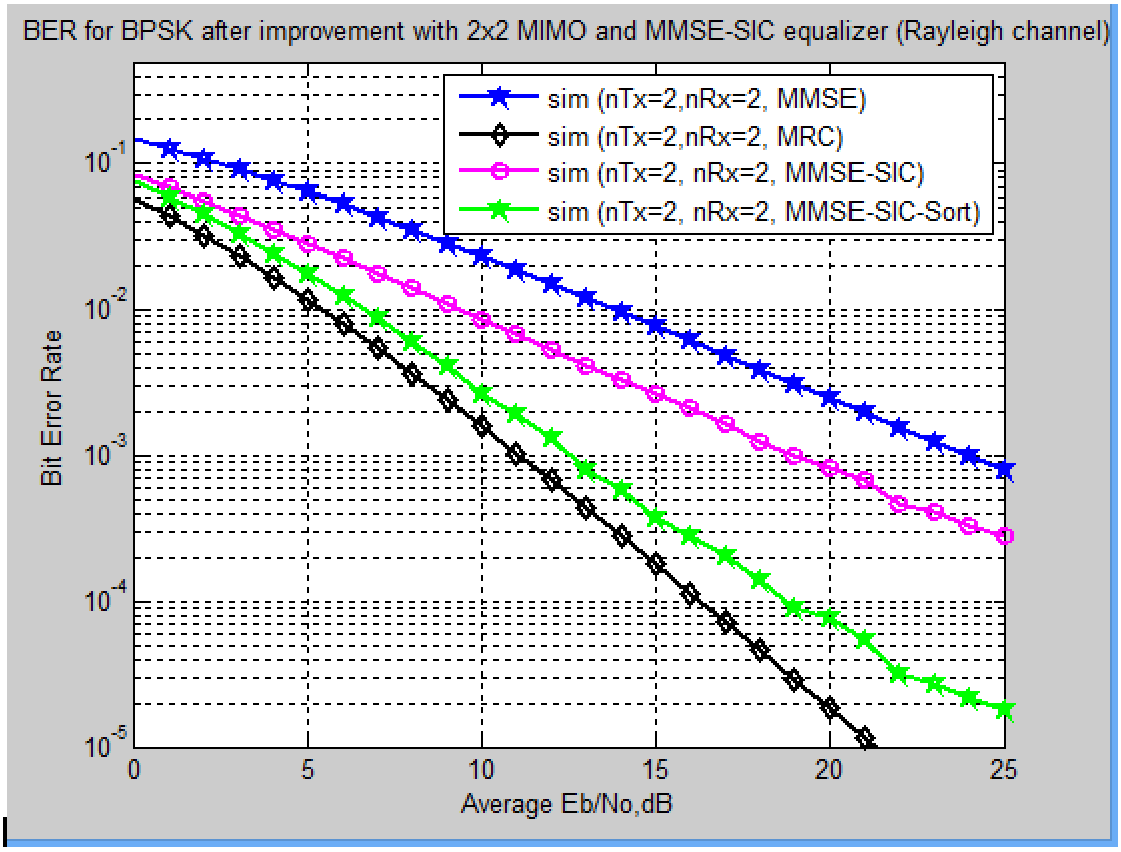
$$\binom{r1}{r2} = \binom{h_{12}}{h_{22}} x_2 + \binom{n_1}{n_2} \qquad (10)$$

Once the effect of either $\hat{x}_1$ or $\hat{x}_2$ is removed the new channel estimation becomes optimally equalizer called the maximum combining ratio.By applying maximum ratio combining (MRC), the equalized symbol is given by

$$x_2 = \frac{h^h r}{h^h h} (11)$$

IV. RESULTS & DISCUSSIONS

Simulation Results of Minimum Mean Square Error Successive Interference cancellation using Minimum Mean Square Channel estimation techniques discussed are obtained and given below. This scheme is studied for 2×2 MIMO and $2 \times N$ MIMO systems for Rayleigh fading channel under AWGN. The modulation schemes used is Binary Phase Shift Keying. $BER Vs E_b$is plotted as shown below. Simulation results show that SIC- MMSE and SIC MMSE SORT scheme performs better than Just Minimum Mean Square Error Scheme in 2×2 MIMO system. Also the qualities of the signal received increase as the number of receiving antenna increases.



Figure; 2.0 plot of BER for MIMO* 2×2 *with (SIC) MMSE equalization

The figure shows that the BER for SIC-MMSE in MIMO system is lower than that of the MMSE using the same number of transmitting and receiving antenna; at BER of $10^{-3} E_b/N_o$of MMSE SIC is given as $18dB$ and also the E_b/N_o of MMSE-SIC-SORT is $13dB$, that of MMSE at $10^{-3}$is$24dB$ at that bench mark..At random point of$15dB$ using multiple antennas, that is

Tx= 2, Rx=2, BER for MMSE SIC = 0.003, BER for MRC= 0.0002:

$$\% \, of BERimprovement = \frac{MMSESIC(BER) - MRC(BER) \times 100}{MMSESIC(BER)} \tag{12}$$

$$\% \, of BERimprovement = \frac{(0.003 - 0.0002) \times 100}{0.003}$$

$$= \frac{(0.0028) \times 100}{0.003} = 93.33\%$$

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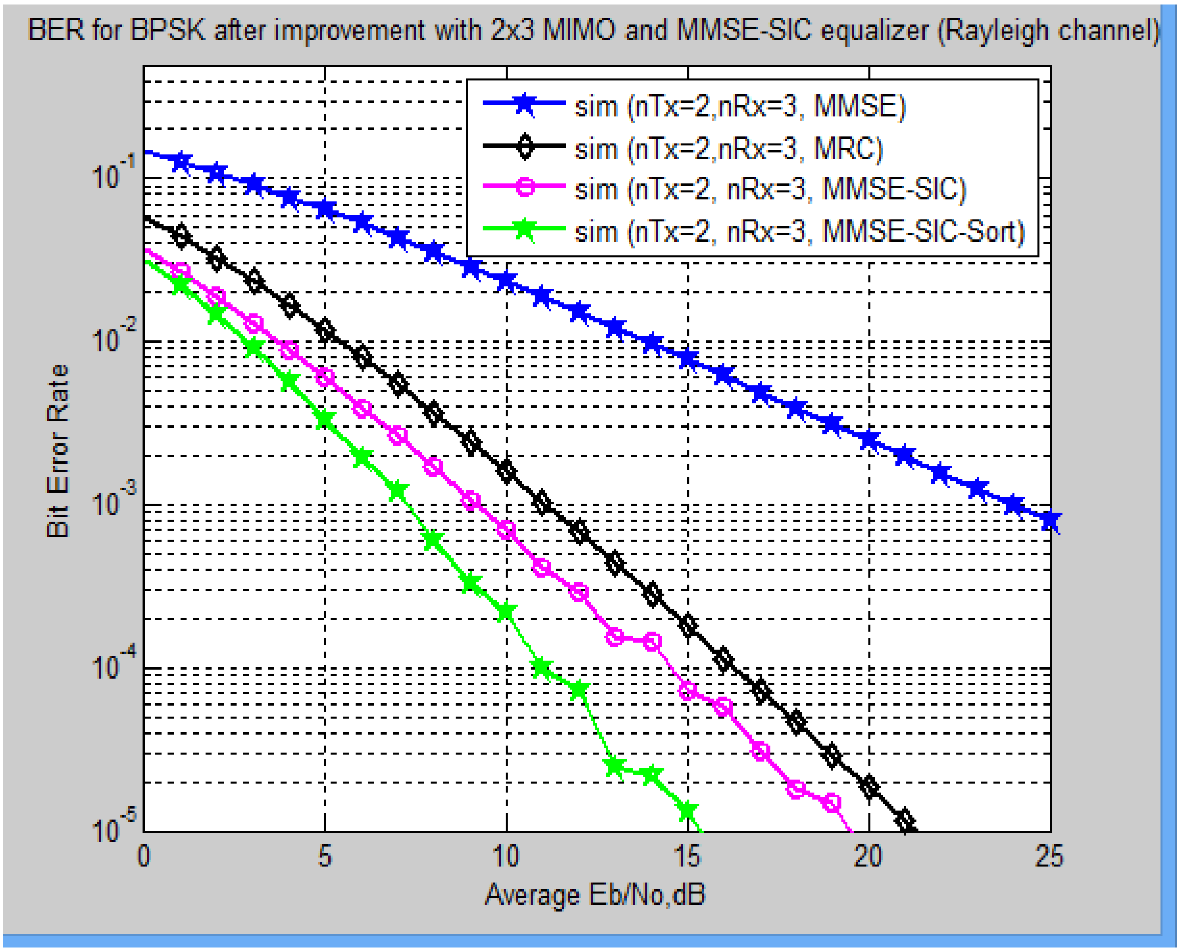


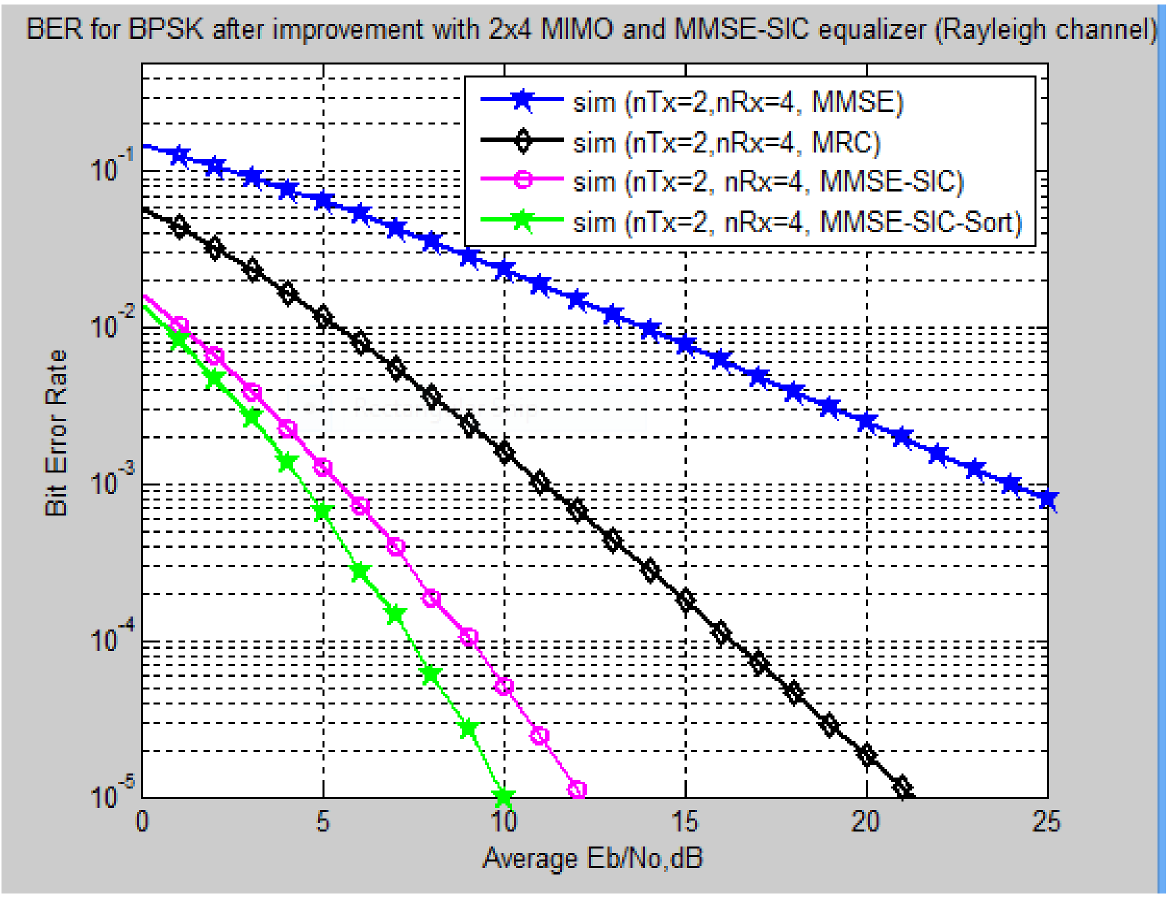
Figure;* 3.0 *plot of BER for MIMO* 2 × 3 *with (SIC) MMSE equalization

From the figure above at BER of 10^{-3} for the SIC-MMSE is $9dB$; at the reference point of voice data which is 10^{-3} the Eb/No of MMSE-SIC-SORT is $7dB$. Also the receive antenna increase from 2-to-3, this show an improvement in the quality of signal at the receiver sides. This improvement is indicated by reduction in E_b/N_o. At a random point of $15dB$ using multiple antennas, that is Tx= 2, Rx=3, BER for MRC= 0.0002, BER for MMSE SIC = 0.00001,

$$\mathbf{\% \ of \ BER \ improvement} = \frac{\mathbf{MRC(BER) - MMSE \ SIC \ (BER) \times 100}}{\mathbf{MRC(BER)}}$$

$$\mathbf{\% \ oF \ BER \ improvement} = \frac{\mathbf{(0.0002 - 0.00001) \times 100}}{\mathbf{0.0002}}$$

$$= \frac{\mathbf{(0.00019) \times 100}}{\mathbf{0.0002}} = \mathbf{95\%}$$



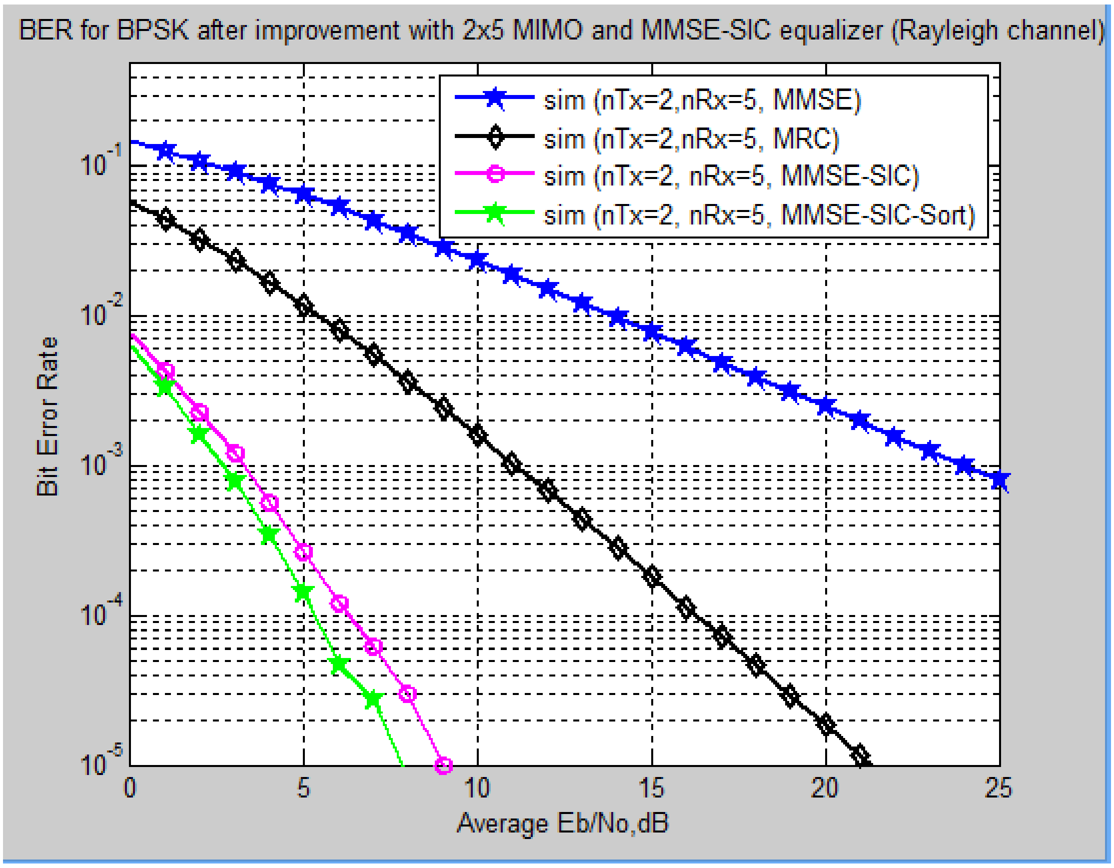
Figure;4.0 plot of BER for MIMO2 × 4 with SIC-MMSE equalization

The figure shows the BER and the E_b/N_o when the number of the transmitting antenna is 2, and the receiving is increase from 2-to-4. At a BER point of 10^{-3} the E_b/N_0 for MMSE-SIC is $\mathbf{55dB}$, which indicate an improvement in the signal quality as result of reduction in BER.At a random point of 10dB using multiple antennas, that is Tx= 2, Rx=4, BER for MRC= 0.002, BER for MMSE SIC = 0.00005,

$$\%\ \boldsymbol{of\ BER\ improvement} = \frac{\boldsymbol{MRC(BER) - MMSE\ SIC(BER) \times 100}}{\boldsymbol{MRC(BER)}} \quad (\mathbf{14})$$

$$\%\ \boldsymbol{of\ BER\ improvement} = \frac{\mathbf{(0.002 - 0.00005) \times 100}}{\mathbf{0.002}}$$

$$= \frac{\mathbf{(0.00195) \times 100}}{\mathbf{0.002}} = \mathbf{97.5\%}$$



Figure;* 5.0 *plot of BER for MIMO 2×5 with SIC-MMSE equalization

The figure shows, the BER verse$\boldsymbol{E_b/N_o}$ when the number of the transmitting antenna is 2, and the receiving antenna is increase from 2-to-5. At BER of 10^{-3}which the reference point for voice data transmission, $\boldsymbol{E_b/N_o}$is $\boldsymbol{3.5dB}$, which indicate an improvement in the signal quality as result of reduction in BER.
At 10dB using multiple antennas, that is Tx= 2, Rx=5, BER for MRC=0.01, BER for MMSE SIC = 0.0002,

$$\%\ \boldsymbol{of\ BER\ improvement} = \frac{\boldsymbol{MRC(BER) - MMSE\ SIC(BER) \times 100}}{\boldsymbol{MRC(BER)}} \qquad (\mathbf{15})$$

$$\%\ \boldsymbol{OF\ BER\ omprovement} = \frac{\mathbf{(0.01 - 0.0002) \times 100}}{\mathbf{0.01}} = \mathbf{98\%}$$

As a result of reduction in the noise content of MMSE MIMO system, to form SIC MMSE there is an improvement in the BER by3% of bit error rate, which increases from 95% to 98%.

V. CONCLUSION

In this paper, Successive Interference Cancellation has been introduced into a linear channel estimation algorithm MMSE and a reduction in the BER has been achieved, this is an improvement to the performance of the wireless system. Also, For MIMO system, increase in the number of receiver antenna above the transmitter antenna result into error reduction in the transmitted signal and improvement in the system performance since the degraded signal are compensated for at the receiver.Based on the Simulationresults, the successive interference cancellation algorithm is an improvement to the linear estimator MMSE

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