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Performance Evaluation of V-BLAST MIMO System Using Rayleigh & Rician Channels

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Abstract

Wireless communication system employs the application of multiple antennas at both transmitter and receiver to improve data rates through multiplexing techniques. In this paper, we studied the BER performance of Vertical Bell Labs Layered Space Time Architecture (V-BLAST) spatial Multiplexing Technique with various equalisation techniques like Maximum Likelihood (ML), Minimum Mean Square Error (MMSE), Zero Forcing (ZF), Zero Forcing Successive Interference Cancellation (ZF-SIC)by M-PSK modulation techniques in Rayleigh flat fading and Rician channel. We will compare different detection techniques for different modulation techniques and concluded that ML-VBLAST using BPSK under Rayleigh flat fading channel gives best results. The ML equaliser outperforms the ZF, ZF-SIC and MMSE equaliser, however its complexity increases exponentially as the modulation order increases. Also, MIMO systems with large constellations are less efficient compared to small constellation The performance of 1024- PSK under Rician channel is the worst

Keywords: MIMO, BER, SNR, PSK, QAM, ZF, MMSE, SIC, V-BLAST, ML

Introduction

Multiple antennas at both the transmitter and receiver leads to diversity and beamforming, thereby increasing the capacity of system indirectly and improving SNR. Spatial multiplexing directly improves the capacity by transmitting multiple data streams.

MIMO Channel Model

Consider a 2×2 MIMO channel with two transmit and two receive antennas. For two transmit antennas, we group the symbols into groups of two. In the first time slot, $x_1 x_2$ send from the first and second antenna. In second time slot $x_3 x_4$ send from the first and second antenna and so on.

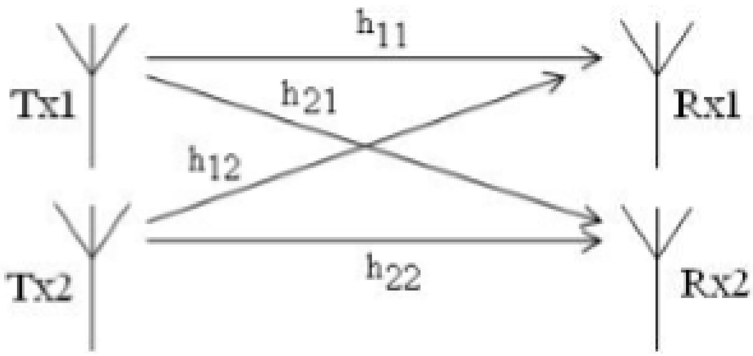

Fig.1 2 X 2 MIMO configuration

In the first time slot, the received signal on the first receiver antenna is,

$$y_1 = h_{11}x_1 + h_{12}x_2 + n_1 = [h_{11}\ h_{12}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1 \quad (1)$$

The received signal on the second receiver antenna is:

$$y_2 = h_{21}x_1 + h_{22}x_2 + n_1 = [h_{21}\ h_{22}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_2 \quad (2)$$

The above equation can be represented in matrix formation as follows:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \quad (3)$$

MIMO detectors

- *Zero Forcing Equalizer (ZF).* Zero Forcing Equalizer is a linear equalization algorithm used in communication systems, which inverts the frequency response of the channel.
- *Minimum Mean Square Error Equalizer (MMSE).*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. MMSE equalizer does not eliminate ISI completely but, minimizes the total power of the noise and ISI components in the output.
- *Zero Forcing With Successive Interference Cancellation (ZF-SIC).* Successive interference cancellation (SIC) is based on subtraction of interference of already detected elements from received signal vector.
- *Maximum Likelihood Detector (ML).*Maximum Likelihood detection is a method that performs Maximum Likelihood search over all possible transmitted symbol vectors.

Simulation results

In this section results are shown in terms of Bit Error Rate (BER) with respect to variation in SNR for 2X2 MIMO V-BLAST system using M-PSK modulation techniques and compared for various equalisation algorithms under Rayleigh and Rician channels.

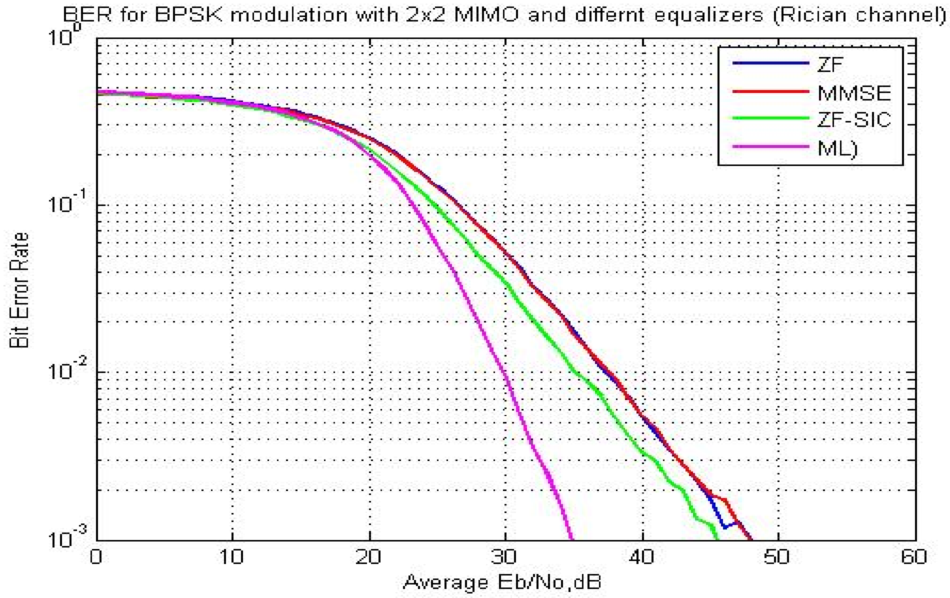

Fig2. BPSK modulation under Rician channel

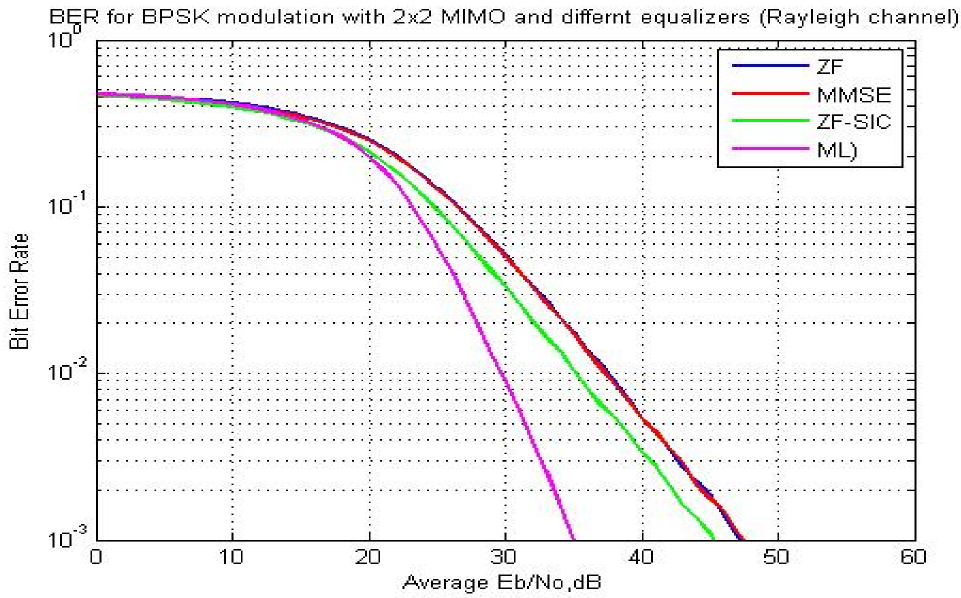

Fig.3 BPSK modulation under Rayleigh channel

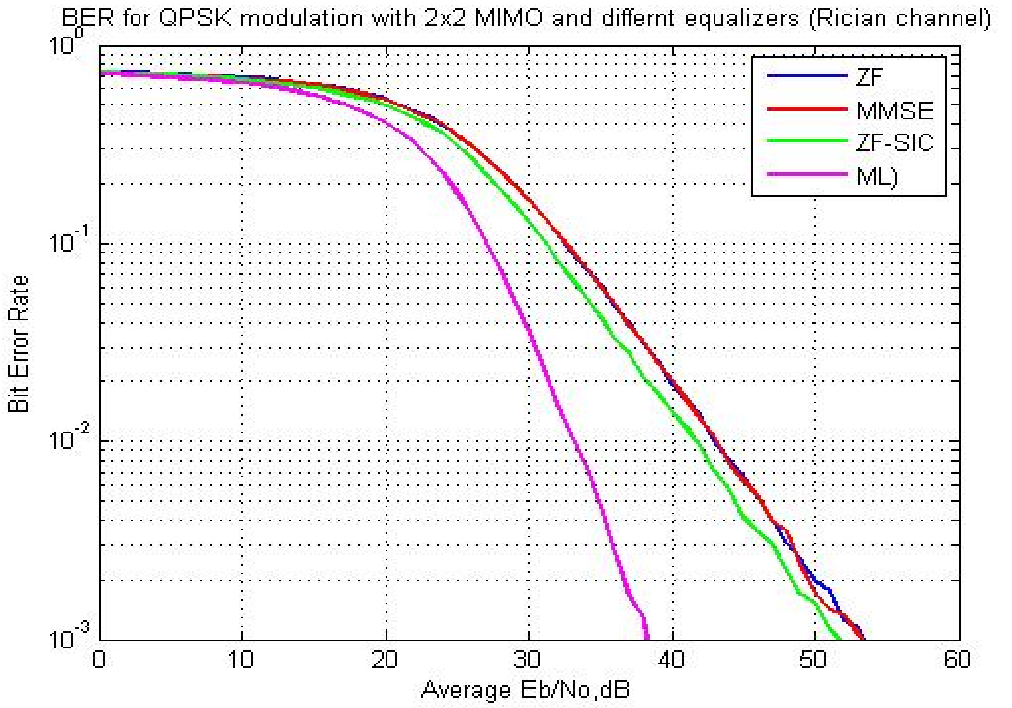

Fig.5 QPSK modulation under Rician channel

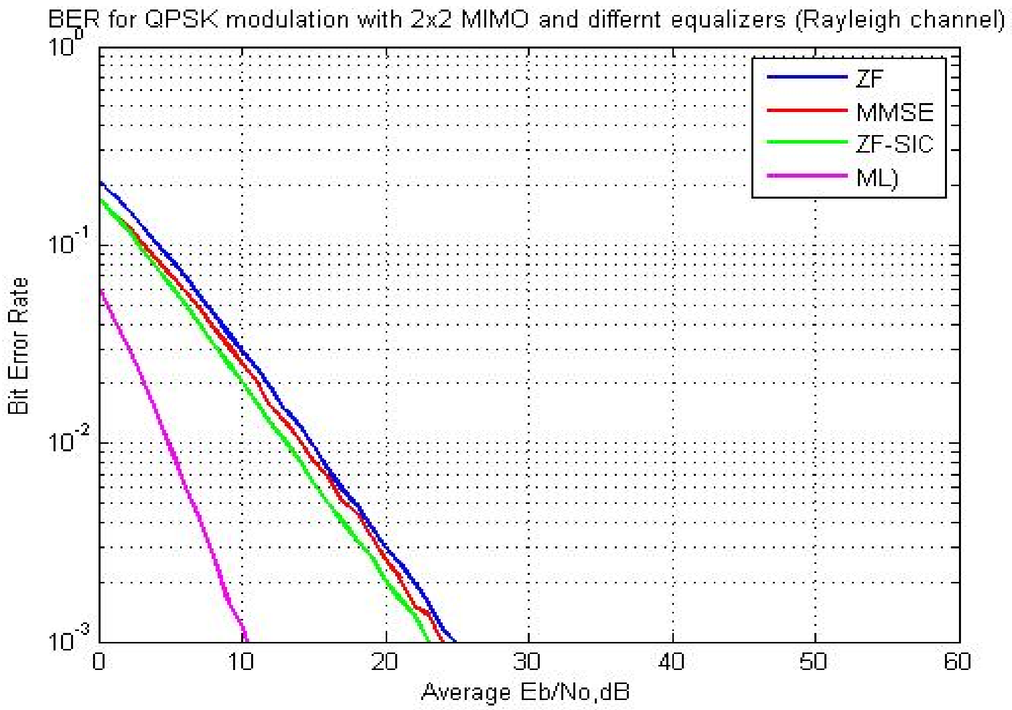

Fig.6 QPSK modulation under Rayleigh channel

Table 1. BER for BPSK and QPSK modulation

Modulation technique	ML	ZF-SIC	MMSE	ZF
BPSK in Rician (at 30dB)	0.0092	0.0337	0.0510	0.0516
BPSK in Rayleigh (at 10dB)	0.0088	0.0327	0.0498	0.0507
QPSK in Rician (at 30dB)	0.0351	0.1268	0.1646	0.1661
QPSK in Rayleigh (at 10dB)	0.0011	0.0199	0.0249	0.0287

Here it is seen that BER for ML equaliser is less than all other equalisers. SO ML equaliser is best amongst the equaliser. Also, the performance of BPSK is better as compared to QPSK modulation.

As the order of modulation increases, the complexity of ML equaliser increases exponentially. So at modulation level of 16-PSK and above we will compare the graphs for only ZF-SIC, MMSE and ZF equaliser.

Table 2. BER for Rician at 50dB SNR

Modulation	ZF-SIC	MMSE	ZF
16-PSK	0.0208	0.0282	0.0286
64-PSK	0.2711	0.3128	0.3133
256-PSK	0.7785	0.7960	0.7963
1024-PSK	0.9435	0.9479	0.9487

Table3. BER for Rayleigh at 30dB SNR

Modulation	ZF-SIC	MMSE	ZF
16-PSK	0.6489	0.6730	0.6737
64-PSK	0.9089	0.9162	0.9169
256-PSK	0.9778	0.9790	0.9795
1024-PSK	0.8945	0.9030	0.9037

Each figure shows 3 subplots corresponding to ZF-SIC, MMSE, ZF equalisation techniques for a 16-PSK, 64-PSK, 256-PSK and 1024-PSK modulation technique in Rician channel.

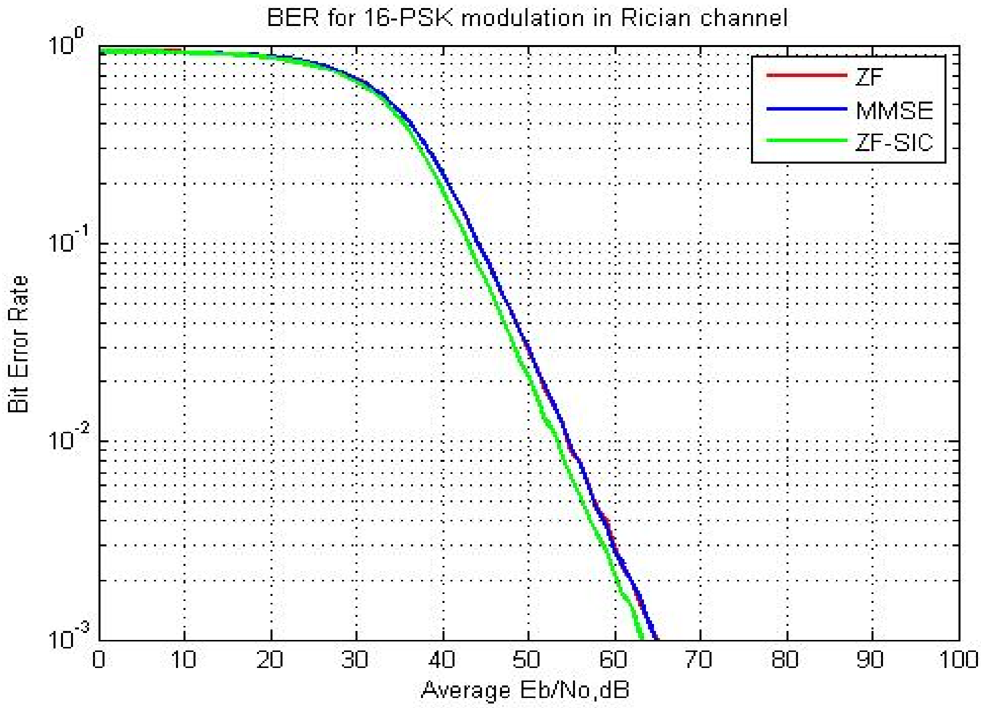

Fig6. 16-PSK modulation in Rician channel

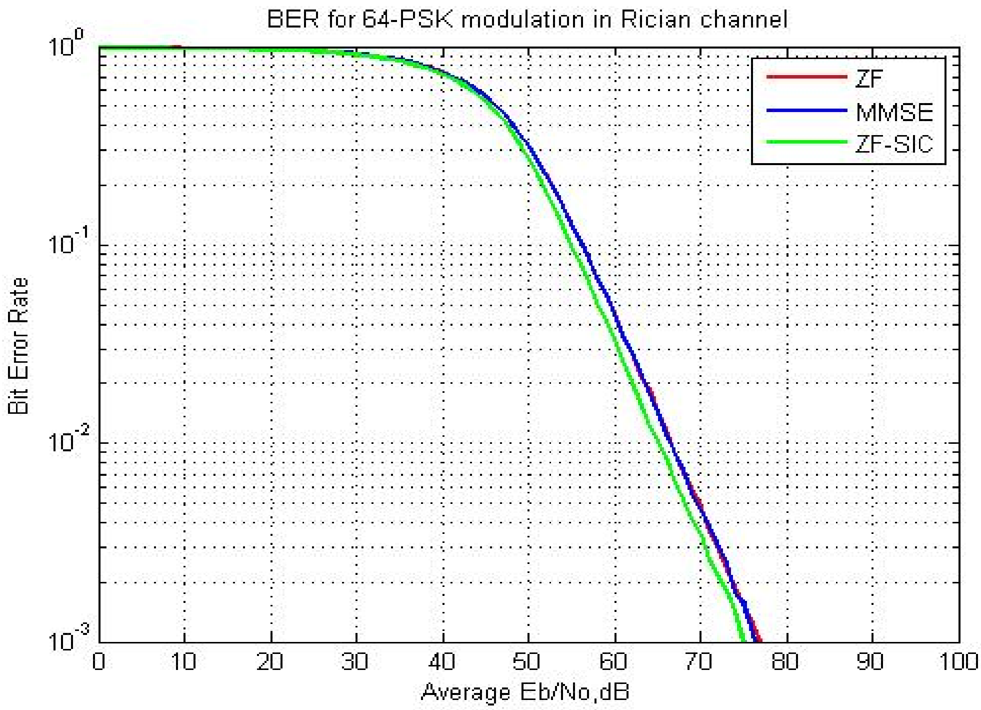

Fig7. 64-PSK modulation in Rician channel

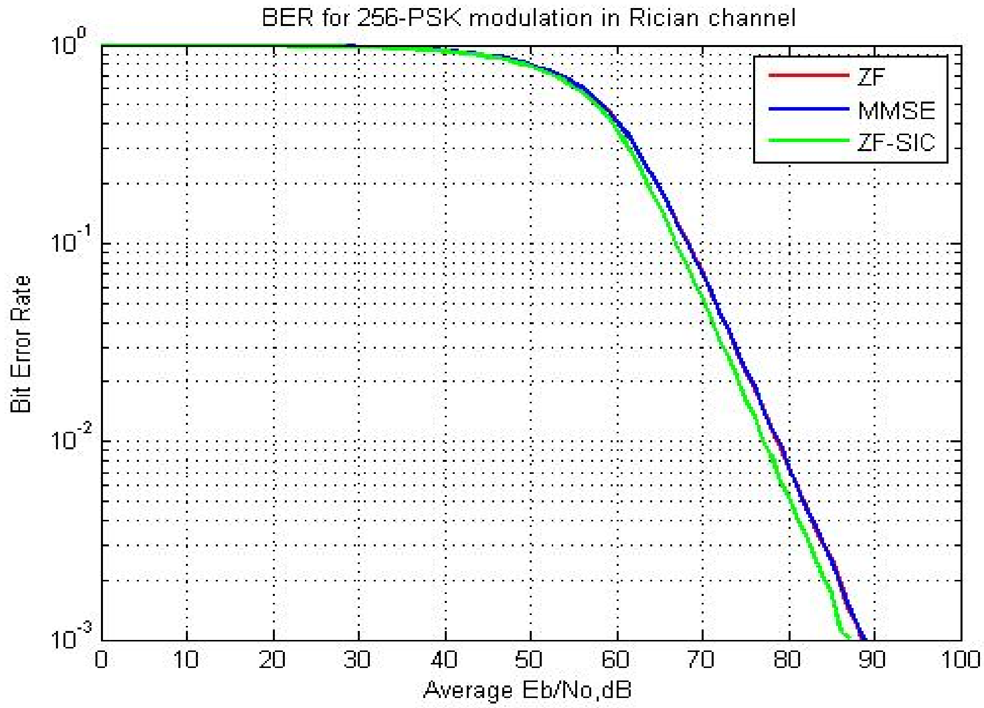

Fig8. 256-PSK modulation in Rician channel

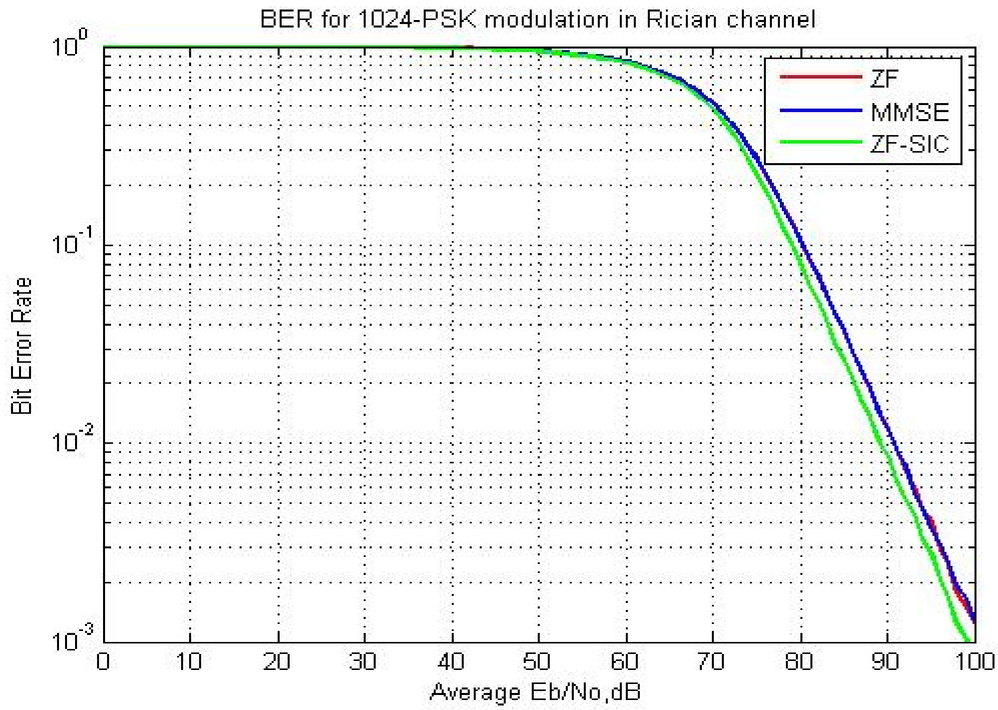

Fig9. 1024-PSK modulation in Rician channel

Each figure shows 3 subplots corresponding to ZF-SIC, MMSE, ZF equalisation techniques for a given modulation technique in Rician channel.

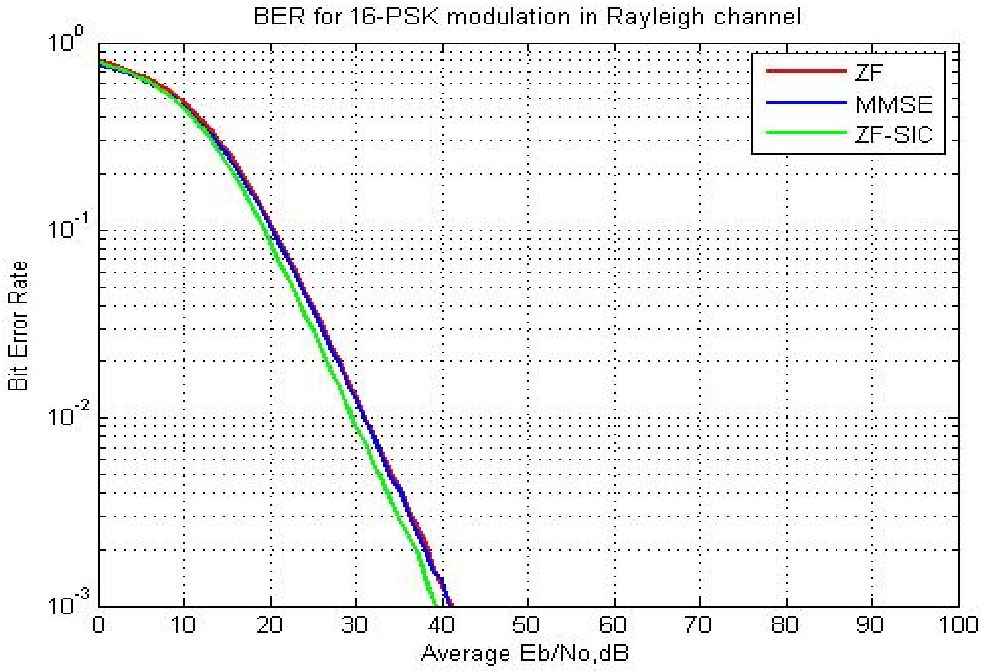

Fig10. 16PSK modulation in Rayleigh channel

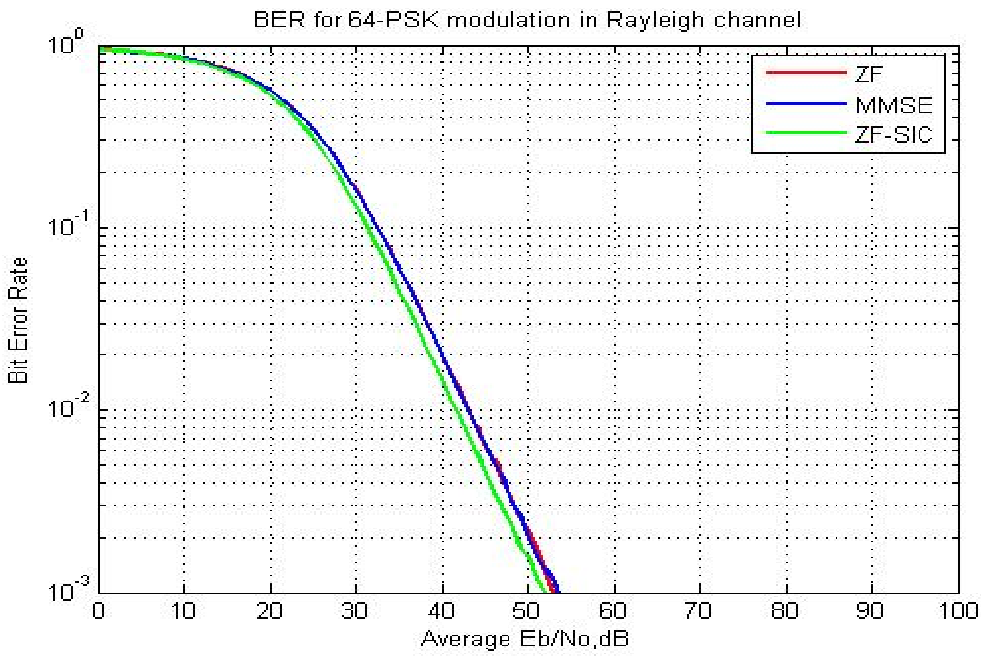

Fig11. 64PSK modulation in Rayleigh channel

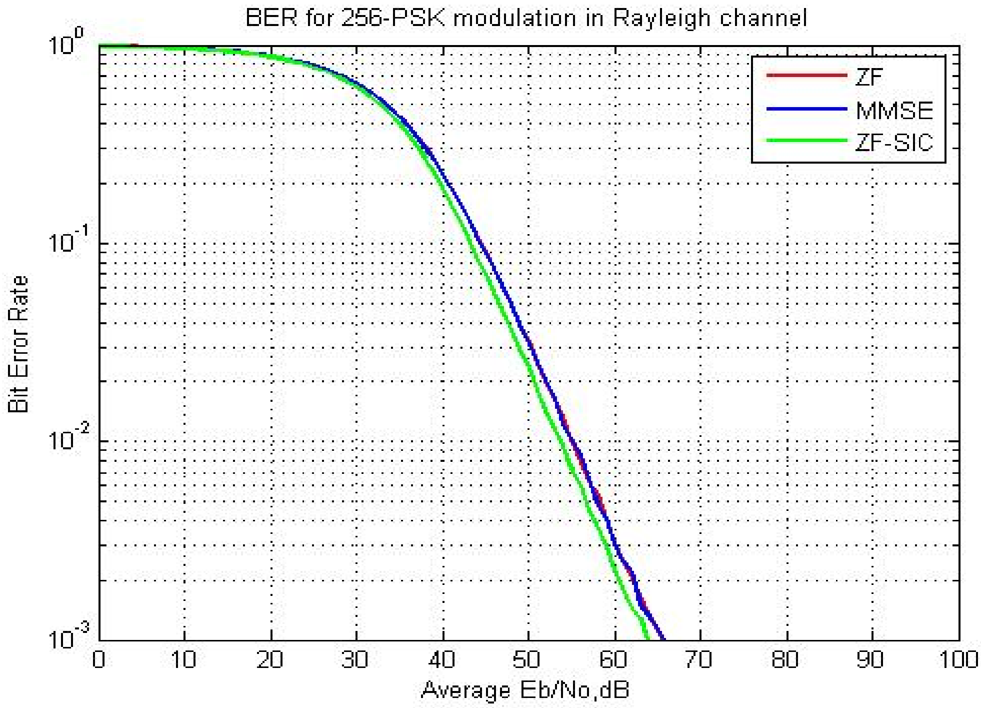

Fig12. 256PSK modulation in Rayleigh channel

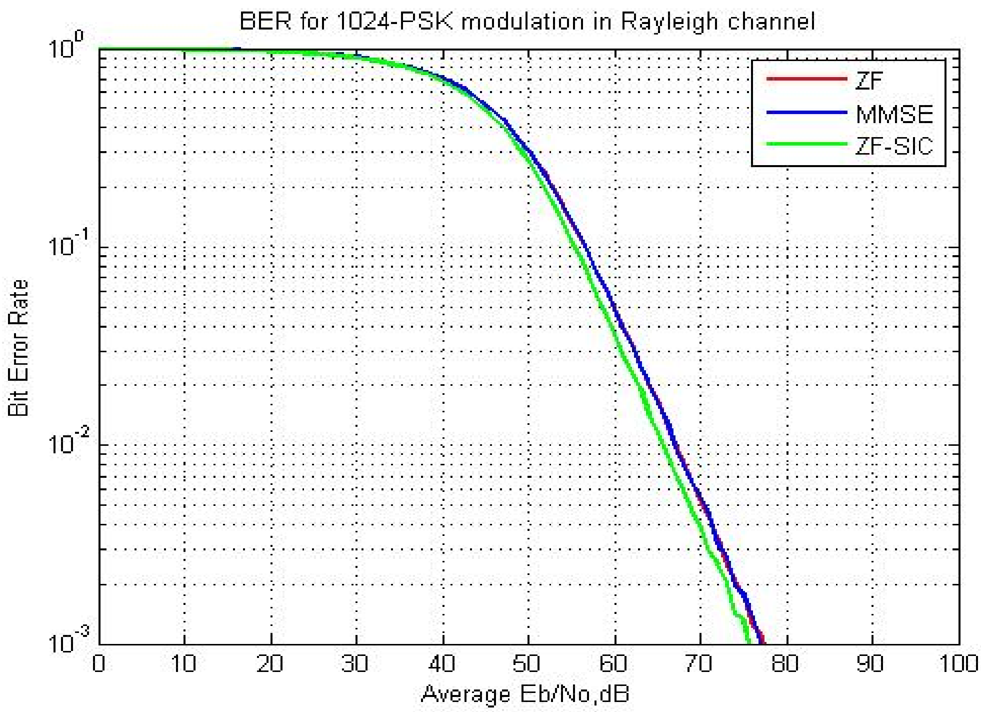

Fig13. 1024 PSK modulation in Rayleigh channel

Conclusion

Various equalisation techniques are used to mitigate ISI which is due to multipath fading. BER analysis is done using various equalisers in Rician and Rayleigh fading MIMO channel. We concluded that ZF, MMSE perform worse than other methods while requiring a lower complexity. The ML equaliser outperforms the ZF, ZF-SIC and MMSE equaliser, however its complexity increases exponentially as the modulation order increases. Also, MIMO systems with large constellations are less efficient compared to small constellation. Finally, we concluded that MIMO system with BPSK modulation and ML equaliser over Rayleigh fading channel is optimum compared to choice of other modulation schemes and equalisers considered. And the worst performance is shown by 1024-PSK in Rician channel.

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