Performance Evaluation of Different Equalization Techniques for DPSK in Wireless Communication

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Abstract- Due to the distortive character of the propagation environment and High bit data rate transmission over wireless channel makes the channel response extend over more than one symbol period transmitted data symbols will spread out in time and will interfere with each other, a phenomenon called Inter Symbol Interference (ISI). This is undesirable and makes the recovery of signal difficult. Equalization is method which is commonly employed to fight with ISI. In this paper different equalizer has been analyzed and compared for 2x2 MIMO channel.

Keywords- *DPSK, MIMO, interference, MMSE, Zero forcing AWGN, Rayleigh*

I. INTRODUCTION

The emergence of internet and mobile technology has enabled us to share video, text, voice and all other information in all over the world. Introduction of wireless and 3G mobile technology has made it possible to transfer the data at very high speed while keeping the high quality of the data intact. To achieve high quality data at very high data rate is a big challenge. These problems can be minimized by applying Orthogonal Frequency division Multiplexing technology. Unlike wired media, in wireless media, signal reach the receiver from different path and hence lead to the inter symbol interference. This inter symbol interference phenomenon causes the increased bit error rate [1].

Generally in designing the communication system, it is assumed that the AWGN Channel or non dispersive channel passes all the frequency which is practically not possible. It is very important to make some refinement in simple non-dispersive channel model to represent the practical channel which is given by

$$r(t) = u(t) \otimes h_c(t) + n(t)$$

Where u(t) represents the signal to be transmitted, h_c (t) represents the channel response and n(t) represents AWGN whose PSD (Power spectral density) is given by $N_0/2$. From this it is clear that the dispersive nature or characteristics of channel is modeled with the help of linear filter $h_c(t)$.

For any band-limited or dispersive channel, the impulse response of the channel resembles the impulse response of ideal low pass filter. Due to this the transmitted signal is smeared in time and hence spread the symbols length causing the overlapping of adjacent symbols. The interference caused by this phenomenon is known as inter-symbol interference (ISI). This phenomenon is undesirable in communication system and increased the bit error rate (BER) and hence need to be resolved correctly. This problem of ISI can be overcome by either designing the band-limited pulses otherwise known as nyquist pulses for transmission or by filtering the received signal to suppress the effect of ISI introduced by the impulse response of the channel. The process of mitigating the effect of ISI by using appropriate filtering operation is known as equalization process [2].This paper presents a performance evaluation of some of the equalization techniques like zero forcing, zero forcing with successive interference cancelling (ZF-SIC), MMSE, ZF-SIC with optimal ordering, Maximum likelihood (ML) equalizer, MMSE-SIC with optimal ordering 2x2 MIMO system under Rayleigh fading and noisy channel.

Differential Phase-Shift Keying (DPSK)

Differential phase shift keying (DPSK) is a common form of phase modulation that conveys data by changing the phase of the carrier wave. in differentially encoded BPSK a binary '1' may be transmitted by adding 180° to the current phase and a binary '0' by adding 0° to the current phase. Another variant of DPSK is Symmetric Differential Phase Shift keying, SDPSK, where encoding would be +90° for a '1' and -90° for a '0'.In differentially encoded QPSK (DQPSK), the phase-shifts are 0°, 90°, 180°, -90° corresponding to data '00', '01', '11', '10'. This kind of encoding may be demodulated in the same way as for non-differential PSK but the phase ambiguities can be ignored. Thus, each received symbol is demodulated to one of the M points in the constellation and a comparator then computes the difference in phase between this received signal and the preceding one. Fig 1.6 shows the block diagram of DPSK.

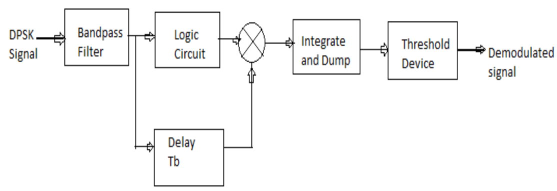

Fig.1:1 Block Diagram of DPSK

II. CHANNEL MODEL

AWGN (additive white Gaussian Noise) is model of channel which produces only white Gaussian noise (having Gaussian distribution) whose spectral density is constant. This channel model does not introduce frequency selectivity, fading dispersion and interference phenomenon. This channel model is sufficient enough to analyze the effect of Gaussian noise coming from various natural sources [3] with the simple mathematical model. Fading is the phenomenon of introducing distortion in carrier modulated signal in some propagation medium [4]. The main reason of fading phenomenon in wireless media is multipath propagation which results in transmitting signal's reaching the receiver by two or more path. These different paths introduce constructive and destructive interference in the signal causing phase shifting of the signal. Rayleigh fading is one of the types of fading which occurs due to the multipath reception. It can be simulated with the help of statistical model for analyzing the effect of propagation environment on a signal [3].

Channel model having the characteristics of multipath environment can be simulated. The impulse response of 3-tap multipath channel model with spacing T is shown below-

$$h[k] = [h_1\ h_2\ h_3]$$

a)

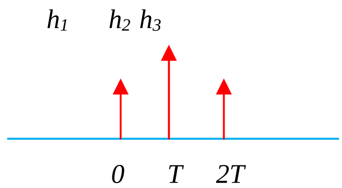

Fig.2: Impulse Response of multipath Channel

Apart from experiencing multipath effect, the transmitted signal is also affected by AWGN (Absolute Gaussian noise) noise n. This noise is represented by Gaussian function given

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

by

Here the μ represents the mean of distribution and σ is variance.
With the known channel response h(k) and noise n, the signal received at the receiver is given by $y(k)= x(k)\otimes h(k)+n$

Here the $\otimes$ represents the convolution operation [5].

III. EQUALIZER

Equalization is the process of mitigating the ISI effect by decreasing the error probability which occurs in the communication system when no ISI suppression method is applied. But since the suppression of ISI tends to enhance the noise power therefore the optimum balance between noise power enhancement and suppression of ISI need to catered [4].

Adaptive equalization[7][8]

An adaptive equalizer is a type of digital filter or equalization filter which is designed in such a way that it automatically adapts itself to the time varying properties of communication channel. This technique is frequently used to mitigate the distortion produced by multipath effect.

Zero Forcing Equalizer [9][10]

Proposed by Robert lucky, zero forcing method of equalization is a linear equalization method which restores the transmitted signal by inverting the frequency response of the channel. The name zero forcing comes from the fact that it is able to reduce the ISI to zero value in case of noise free environment. This method is useful for the channel where the ISI is more pronounced than the noise.

MMSE Equalizer [11]

This type of equalizer uses the squared error as performance measurement [11]. The receiver filter is designed to fulfill the minimum mean square error criterion. Main objective of this method is to minimize the error between target signal and output obtained by filter.

Zero Forcing with Successive Interference cancellation (ZF-SIC) Equalizer [12]

In this method, first of all the zero forcing equalizer find the estimated symbol x_1 and x_2 then one of the estimated symbol is subtracted from received symbol to compute the equalized symbol by applying maximum ration combining(MRC)[36].

Successive Interference Cancellation using optimal ordering Equalizer [13]

In the previous successive interference cancellation method, estimation symbol is chosen arbitrarily and then its effect is subtracted from received symbol y1 and y2. 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.

MMSE SIC with optimal ordering [14]

The same concept of successive interference with optimal ordering can also be applied to the MMSE equalizer and the resultant equalizer is known as MMSE SIC with optimal equalizer.

ML (Maximum Likelihood) Equalizer

Let x represent the signal matrix, H represent the channel response and n represent the noise then the signal obtained at the receiver is given by

$$y = Hx + n$$

IV. METHODOLOGY

In order to analyze how different techniques of equalization perform in MIMO having noisy and rayleigh channel characteristics, a simulation program is designed for all the six method in MATLAB environment.

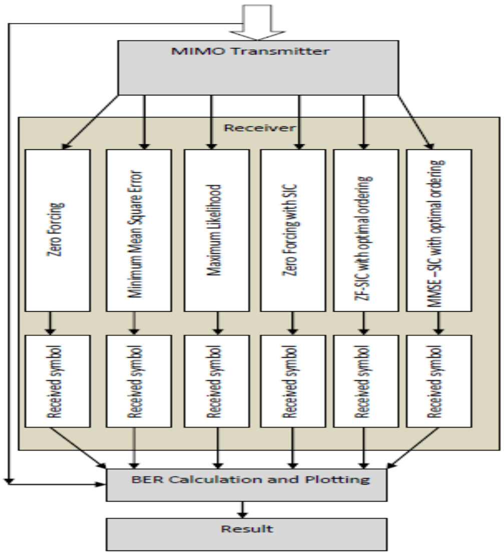

Fig.3: Flow Diagram of Methodology

V. EXPERIMENTAL RESULTS

Here is the performance of all the six equalizer for DPSK in 2x2 MIMO systems.

5.1 BER FOR ZF EQUALIZER

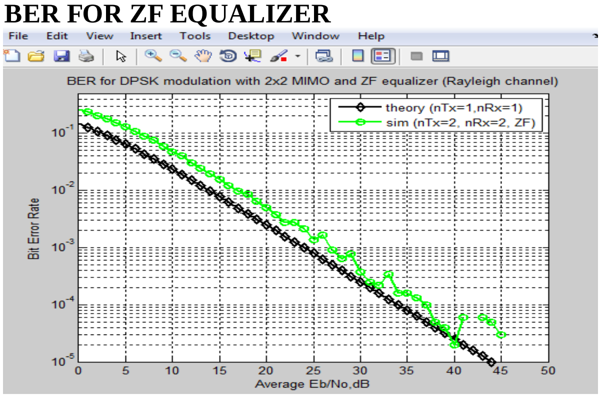

Fig.4: BER for ZF Equalizer for DPSK

Table 5.1 Theoretical and Simulated BER table for ZF equalizer (DPSK Modulation)

Eb/ No In dB	Theoretical BER fornTx=1,nRx=1	Theoretical BER for nTx=1,nRx=1(MRC)	Simulated BER fornTx=2,nRx =2(ZF)
0	0.146447	0.058058	0.25864
10	0.023269	0.001599	0.04769
20	0.002481	0.00000000184	0.00479
30	0.00025	0.00000000187	0.00048
40	0.000025	0.00000000187	0.00004

Fig5.1and table5.1 shows the BER performance for DPSK modulation for 2x2 MIMO system using ZF equalizer in Rayleigh channel. Black lines show the theoretically ideal value for BER. Green line shows the simulation result. From the graph we can see that ZF equalizer shows much improvement in SNR. Table shows that as per SNR increases the value of BER decreases for ZF equalizer.

5.2 BER FOR ZF-SIC EQUALIZER

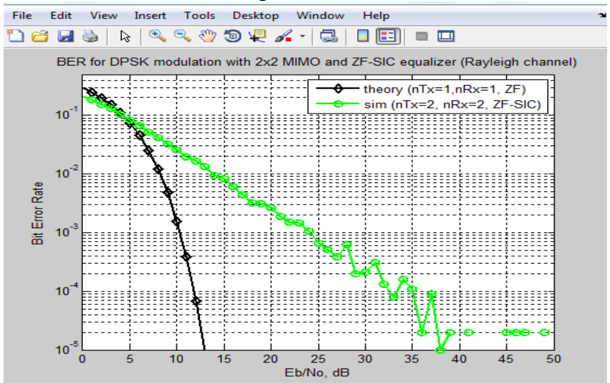

Fig.5: BER for ZF-SIC Equalizer for DPSK

Table 5.2 Theoretical and Simulated BER table for ZF-SIC with (DPSK Modulation)

Eb/No In dB	Theoretical BER for nTx=1,nRx=1	Theoretical BER for nTx=1,nRx=1(MRC)	Simulated BER for nTx=2,nRx=2(ZF-SIC)
0	0.146447	0.058058	0.211333
10	0.023269	0.001599	0.025598
20	0.002481	0.00000000184	0.002416
30	0.00025	0.00000000187	0.000227
40	0.000025	0.00000000187	0.000009

The fig 5.2 and table5.2 shows the BER performance for DPSK modulation for 2x2 MIMO system using ZF–SIC equalizer in Rayleigh channel. Green line shows the simulation result. The result of ZF-SIC is shown in figure 5.8 it can depicts that much improvement is achieved by ZF equalizer as compared to ZF-SIC. Table also shows the result for ZF-SIC Equalizer.

5.3 BER FOR MMSE EQUALIZER

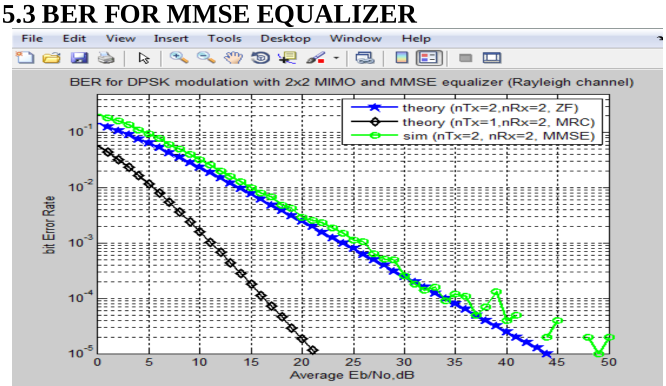

Fig.6: BER for MMSE Equalizer for DPSK

Table 5.3 Theoretical and Simulated BER table for MMSE equalizer (DPSK Modulation)

Eb/No In dB	Theoretical BER for nTx=1,nRx=1	Theoretical BER for nTx=1,nRx=1(MRC)	Simulated BER for nTx=2,nRx=2(MMSE)
0	0.146447	0.058058	0.212862
10	0.023269	0.001599	0.032661
20	0.002481	0.00000000184	0.003266
30	0.00025	0.00000000187	0.000355
40	0.000025	0.00000000187	0.000036

The fig and table 5.3 shows the BER performance for DPSK modulation for 2x2 MIMO system using MMSE equalizer in Rayleigh channel. Green line shows the simulation result. The result of MMSE is shown in figure 5.3; it can depict that much improvement is achieved by ZF and ZF-SIC equalizer as compared to MMSE equalizer. Table also shows the result for ZF-SIC Equalizer.

5.4 BER FOR ZF-SIC OPTIMAL ORDER EQUALIZER

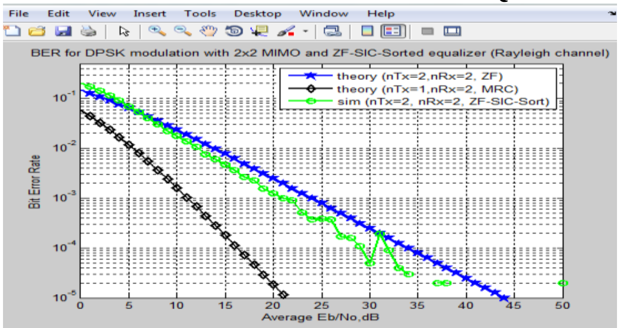

Fig.7: BER For ZF-SIC OPTIMAL ORDER Equalizer for DPSK

Table 5.4 Theoretical and Simulated BER table for ZF-SIC Equalizer (DPSK Modulation)

Eb/No In dB	Theoretical BER for nTx=1,nRx=1	Theoretical BER for nTx=1,nRx=1(MRC)	Simulated BER for nTx=2,nRx=2 (ZF-SIC)
0	0.146447	0.058058	0.211333
10	0.023269	0.001599	0.025598
20	0.002481	0.00000000184	0.002416
30	0.00025	0.00000000187	0.000227
40	0.000025	0.00000000187	0.000009

The fig and table 5.4 shows the BER performance for DPSK modulation for 2x2 MIMO system using ZF–SIC OPTIMAL ORDER equalizer in Rayleigh channel. Green line shows the simulation result. The result of ZF-SIC is shown in figure 5.4 it can depict that the result is approx similar to ZF-SIC.

5.5 BER FOR MMSE-SIC OPTIMAL ORDER EQUALIZER

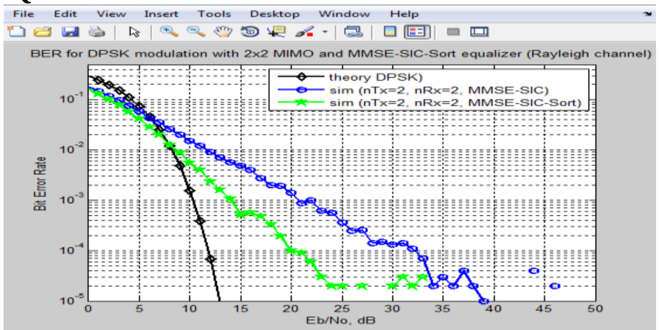

Fig.8: BER For MMSE-SIC OPTIMAL ORDER Equalizer for DPSK

Table 5.5 Theoretical and Simulated BER table for MMSE with optimal order equalizer

Eb/No In dB	Theoretical BER for nTx=1,nRx=1	Theoretical BER for nTx=1,nRx=1(MRC	Simulated BER of MMSE-SIC for nTx=2,nRx=2
0	0.146447	0.058058	0.17474
10	0.023269	0.001599	0.01633
20	0.002481	0.00000000184	0.0012
40	0.000025	0.00000000187	0

The fig 5.5 and table5.5 shows the BER performance for DPSK modulation for 2x2 MIMO system using MMSE–SIC equalizer in Rayleigh channel. Green line shows the simulation result. The result of MMSE-SIC is shown in figure 5.5 it can depicts that much improvement is achieved by MMSE-SIC equalizer as compared to ZF-SIC and MMSE equalizer.. Table also shows the result for MMSE-SIC Equalizer.

5.6 BER FOR ML EQUALIZER

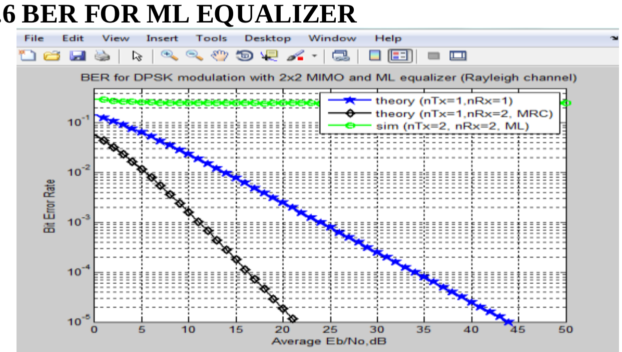

Fig.9: BER for ML Equalizer for DPSK

Table 5.6 Theoretical and Simulated BER table for ML equalizer (DPSK Modulation)

Eb/No In dB	Theoretical BER for nTx=1,nRx=1	Theoretical BER for nTx=1,nRx=1(MRC)	Simulated BER for nTx=2,nRx=2 (ML)
0	0.146447	0.058058	0.30361

10	0.023269	0.001599	0.25065
20	0.002481	0.00000000184	0.24985
30	0.00025	0.00000000187	0.24977
40	0.000025	0.00000000187	0.24997

The fig 5.6 and table5.6 shows the BER performance for DPSK modulation for 2x2 MIMO system using BER for ML Equalizer in Rayleigh channel. Green line shows the simulation result. From the fig and table we can conclude that ML Equalizer shows the worst result among these above mentioned equalizer in term of cancelling the interference to optimum level.

From comparing all the six equalizer for DPSK modulation the result for ZF Equalizer is best among these above mentioned equalizer in terms of cancelling the interference to optimum level.

VI. CONCLUSION

To achieve higher data rate and least BER is the demand of wireless system design. Equalization techniques play very important role for designing such system. In this paper performance comparison of different key equalization techniques has been carried out under the fading and noisy environment to find out the appropriate equalizer for 2x2 MIMO systems. From the result obtained it is evident that zero forcing equalizer shows better performance if noise is zero and shows degradation under fading environment.

The performance of ZF-SIC, MMSE, and ZF-SIC with optimal ordering, MMSE-SIC with optimal ordering and ML equalizer are in increasing order. From the results it can be concluded that the ZF equalizer is best among these above mentioned equalizer in term of cancelling the interference to optimum level.

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