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Simulation on Effect of Doppler shift in Fading Channel and Imperfect Channel Estimation for OFDM in Wireless Communication

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ABSTRACT

In wireless communication system the transmitted signal is distorted by the various phenomenon that is intrinsic to the structure and contents of the wireless channel. Among these fading and interference has been the dominant sources of Distortion and degradation of performance. Fading can be defined as the fluctuation in amplitude phase and multipath delays over very short travels distance or the very short time duration. To increase high data rate in wireless communication Multiple-Input Multiple-Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) techniques have been considered best as they have high-frequency spectrum efficiency. In this study the performance of fading channel on the wireless communication is studied, simulated and compared for Maximum Likelihood (ML) receivers in different modulation structure in the presence of Gaussian Channel estimation error based on different Doppler shift. The second part of this study is to analyze the performance degradation due to channel estimation error, fading noise, and interference between users for several fading channels in multiple users multiple antennas with different performance measures.

Keywords: MIMO, OFDM, Maximum Likelihood, Doppler Shift

I. INTRODUCTION

Wireless communication has been one of the most active areas of technology development which has experienced massive growth and commercial success in the recent years. Each system in wireless communication should transmit digital signals in the physical channels which can cause fading. Due to random and time variant in nature simulation of wireless channels accurately has become an important field of study for the design and performance evaluation of wireless communication systems and components [1]. Radio waves propagate from a transmitting antenna, and travel through free space undergoing absorption, reflection, refraction, diffraction and scattering. They are greatly affected by different physical structures such as buildings, bridges, hills, tress, ground terrain, the atmosphere, and the obstacles in their path, like etc [2]. These multiple physical phenomena are responsible for most of the characteristic features of the received signal with random attenuations and delays. This type of fading affects the signals transmitted through wireless channels and causes the short-term signal variations [5]. In order to ignore the large scale path loss effects, small scale fading or simply fading is used. This results in describing the rapid fluctuations of the Amplitudes, Phases of a radio signal. However the constraint is that it must be justified over a short period of time or travel distance. In the other way round, the multipath waves are the fading which are been caused due to interceptions between 2 or more transmitted signal which arrive at the receiver at slightly different times. The resulting waves are cumulated at the receiver end to give a resulting signal which can

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vary widely in amplitude and phase, depending on the distribution of the intensity and relative propagation time of the waves and the bandwidth of the transmitted signal. This is due to Doppler shift [4]. The Doppler shift will be positive if the mobile is moving towards the direction of the arrival of the wave whereas it will be negative if the mobile is moving away from the direction of arrival of the wave. Depending on how rapidly the transmitted baseband signal changes as compared to the rate of change of the channel, a channel may also be classified either as a fast fading or slow fading channel [4]. When the channel impulse response changes rapidly within the symbol it is known as fast fading and when it changes at a rate much slower than the transmitted baseband signal then it is slow fading.

(A) Doppler shift

If the distance between the observer and the source is increasing, the frequency apparently decreases, whereas the frequency increases if the distance between the observer and the source is decreasing. This relationship is called **Doppler Effect** (or **Doppler Shift**) [5].The Doppler Effect cause the received frequency of a source (how it is perceived when it gets to its destination) to differ from the transmitting frequency. For a vehicle moving in a straight line Doppler frequency shift (f_d) depends on the relative velocity between the transmitter and the vehicle (v), the frequency (or wavelength) of the transmitter (λ), and the direction of the vehicle with the receiving signal (θ).

$$f_d = \frac{2\pi}{\lambda} \| v \| \cos(\theta(t)) \tag{1}$$

The difference between the maximum and minimum values of f_d is called Doppler spread which can causes fading in wireless communication [4].

The coherence time of the channel is related to with as described Doppler spread of the channel. When a user (or reflectors in its environment) is moving, the user's velocity causes a shift in the frequency of the signal transmitted along each signal path. When the user is moving at a constant velocity v_0 along a path, v be the signal velocity, vs be the source velocity, and f be the emitted frequency, then the frequency of the detected (observed) signal (f') is given by

$$f' = \left(\frac{v \pm vo}{v \pm vs} \right) f \tag{2}$$

The Doppler shifts depends upon function of

1. Signals and signals with different traveling paths;
2. Different rate of change of change in phase and
3. Direction of motion

Channels with a large Doppler have signal components changing independently. Since fading depends on whether signal components add constructively or destructively, such channels can have a very short coherence time. Coherence time can be defined as

$$Tc \approx \sqrt{\frac{9}{16\pi fm^2}} = \frac{0.423}{fm} \tag{3}$$

If the symbol period of the baseband signal (reciprocal of the baseband signal bandwidth) is greater than the coherence time, then the signal will distort, since channel will change during the transmission of the signal. Coherence time definition implies that two signals arriving with a time separation greater than T_C are affected differently by the channel. There has been great interest in the structure of optimum receivers for digital detection signals transmitted over fading in the presence of additive white Gaussian noise (AWGN) for last decades [7]. To detect transmitted symbols, we have considered two types of receiver, coherent and non- coherent.

(B) Fading

Multipath propagation mainly due to reflection, diffraction, scattering, atmospheric condition and the lack of direct line of sight cause fading, which results in the loss or distortion of the signal in the receiving side. Fading is one consequence of transmitting a signal through a time – varying multi-path channel is to confront at the receiver with a signal fading (amplitude variation in the received signal). Hence not only the propagation delays but also the random impulse responses of the channel will provoke some attenuation and time spread of the signal transmitted. Symbol duration, bandwidth and channel parameters are some of the factors that decide the type of the fading channel.

Fading can be divided into different types.

a) *Due to effect of multipath*: The loss of signal power or strength due to the signal attenuation and the distance between transmitter and receiver cause fading. Interference between multipath waves which arrive at the receiver at a slightly different time can cause fluctuation in the amplitude and phase of the received signal.

b) Due to the effect of Doppler spread: Fading mainly depends on the channel coherence time. If the channel coherence time is larger than the symbol period or delay constraint of the channel slow fading occurs and hence the channel remains approximately static over a symbol or multiple symbols. Slow fading is usually expected with low Doppler spread values; i.e. with slower moving obstacles and receiver/ transmitter. If the channel coherence time is small then fast fading occurs and hence the channel changes over the one period. The velocity of the mobile (or velocity of objects in the channel,) and the baseband signaling determines whether a signal undergoes slow fading or fast fading.

c) OFDM Technology: To mitigate the cited effect a narrowband channel is needed, but for high data rates a broadband channel is needed.

The aim is that the new symbol duration of each subcarrier is larger than the maximum delay of the channel, T > Tmax.An OFDM signal is a sum of subcarriers that are individually modulated by using phase shift keying (PSK) or Quadrature Amplitude Modulation (QAM). The symbol can be written as:

$$s(t) = \mathrm{Re}\left\{ \sum_{i=-\frac{N_s}{2}}^{\frac{N_s}{2}-1} d_{i\frac{N_s}{2}} \exp\left(j2\pi(f_c - \frac{i+0.5}{T} \right)(t - t_s) \right\},$$

$$s(t) = 0,\ t < t_s \ and\ t > t_s = T \qquad (4)$$

where:

N_S is the number of subcarriers

T is the symbol duration

f_c is the carrier frequency

In order to create the OFDM symbol a serial to parallel block is used to convert N serial data symbols into N parallel data symbols. Then each parallel data symbol is modulated with different orthogonal frequency subcarriers and added to an OFDM symbol, [18]. After conversion of the symbol from serial to parallel symbols are inserted with different technique between the data symbol. Pilot bits are randomly generated and inserted between data bits. Finally, OFDM symbols with pilots are transmitted over the multipath channel [8][15][18].

d) Channel Estimation: Assuming that inter-symbol interference is dropped by the guard interval [24], we write output Y (k) as:

$$Y = Xh + nY \tag{5}$$

Where Y is the received vector, X is a matrix containing the transmitted signal points on its diagonal, h is a channel attenuation vector and n is a vector of i complex zero mean. In the following the Linear Minimum Mean Square Error (LMMSE) and Least Square (LS) estimate in detail is described. It's assumed that the received OFDM symbol contains data known to the estimator - either training data or receiver decisions.

e) Maximum Likelihood: Maximum likelihood (ML) is optimal decoding method that compares the received signal and possible transmitted signal. As the transmitted signal is modified by channel matrix, we need to estimate transmit symbol by using maximum likelihood detection algorithm [9].

$$\hat{x} = \arg\ x_k \in \{x1, x2, \ldots\ldots, x_N\} \min \| r - H_{xk} \| \tag{6}$$

$\|r\text{-}H_{xk}\|$ is ML metric which achieve maximum performance when transmitted vectors are equally likely [9][10], where r is the received signal and H is the channel matrix.

II. PERFORMANCE METRICS

Performance analysis of wireless system requires the averaging of performance metrics over these fading models. The main performance metrics are the Signal to Noise Ratio (SNR) and Bit Error Ratio(BER) Energy per bit to noise power spectral density ratio.

(A) Signal to Noise Ratio (SNR)

SNR is the ratio of the received signal strength over the noise strength in the frequency range of the operation. It is measured in decibels and represented as [6]

$$SNR = \log\left(\frac{Signal\ Power}{Noise\ power}\right) db \tag{7}$$

(B) Average Bit Error Ratio (BER)

BER can be calculated by the number of bits received as per the equation above. In digital transmission the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise interference distortion or bit synchronization errors [6].

It is given by

$$BER = \frac{Bits\ in\ error}{Total\ bits\ received} \tag{8}$$

The analytical BER expression for BPSK signal in Additive white Gaussian noise (AWGN), Rayleigh and Rician channels are respectively given by[16],

$$Pb = 1/2\left(1 - \sqrt{\frac{\frac{Eb}{No}}{1 + \frac{Eb}{No}}}\right) \ for\ Rayleigh \tag{9}$$

$$P_{b=\frac{1}{2}} erfc\left(\sqrt{\frac{E_b}{N_o}}\right) \;\; for \;\; AWGN \tag{10}$$

$$P_{b=\frac{1}{2}} erfc\left[\sqrt{\frac{K\left({Eb}/{N_O}\right)}{K+{Eb}/{N_O}}}\right] \text{ for Rician} \tag{11}$$

Where k= m/2σ^2

$$\sigma = \frac{1}{2*(k+1)} \tag{12}$$

$$m = \sqrt{\frac{k}{(k+1)}} \tag{13}$$

where erfc is the error function, Eb is the energy in one bit, and N_0 is the noise power spectral density (noise power in a 1Hz bandwidth).

Also the BER expressions for M-ary QAM signaling in AWGN and Rayleigh channels are [15][16] as

$$Pe = \frac{2(M-1)}{M\log_2 M} Q\left(\sqrt{\frac{6Eb}{N_o}\cdot\frac{\log_2 M}{M^2-1}}\right) \text{ for AWGN} \tag{14}$$

$$Pe = \frac{(M-1)}{M\log_2 M}\left(1-\sqrt{\frac{3\gamma\log_2 M/(M^2-1)}{3\gamma\log_2 M/(M^2-1)+1}}\right) \text{ for Rayleigh} \tag{15}$$

Where, γ and M denote E_b/N_0 *(Energy per bit to Noise power spectral density ratio*) and the modulation order, respectively.

II. SIMULATION RESULT

(A) Simulation Parameters

Parameters	*Specification*
FFT Size	64
Number of carrier in OFDM	52
Channel	RAYLEIGH, RICIAN
Signal constellation	QPSK
Doppler shift	5 Hz- 1000Hz

(B) Description of simulation process

Figure 1 shows the block diagram of the general procedure of the simulation process. In this system the random binary input is modulated with the QPSK technique. The modulated data is converted from serial to parallel converter to convert the serial data to parallel data symbols with the insertion of Pilot bit. These parallel data streams are then modulated with different carrier frequencies and added to create an OFDM

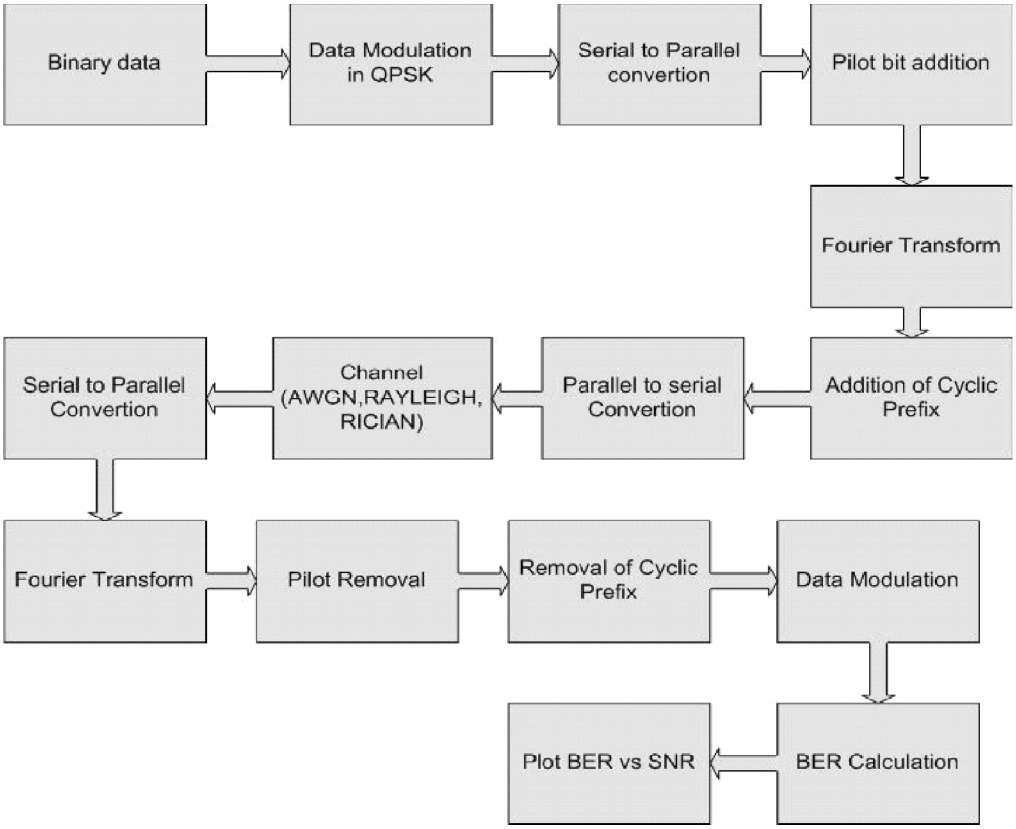

Figure 1: Block Diagram of simulation process

symbols using Inverse Fast Fourier Transform (IFFT).Then it is added with cyclic prefix to preserve the orthogonality of the subcarriers. These signals are then passed through the different channel serially. In the receiver side the received signal, after the removal of the pilot symbol and the cyclic prefix are done, demodulation and equalization is done. It is then compared with the original transmitted signal and is compared with different performance measures.

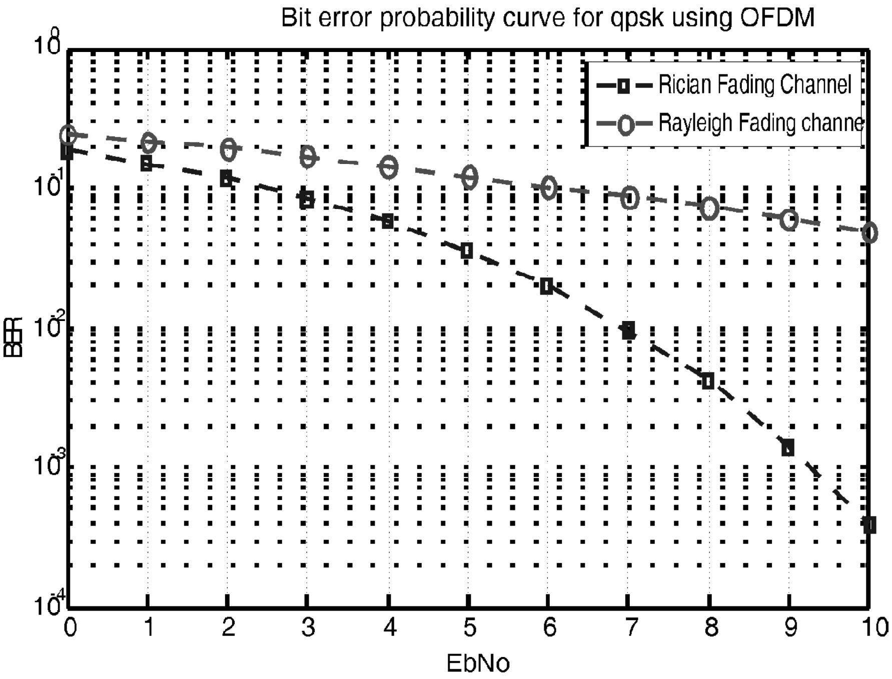

Figure 2: Simulation Plot for OPSK using QFDM Modulation technique under different channel for Doppler shift

(C) Comparison between Rayleigh and Rician Channel

Table 1
Comparison between the Rayleigh and Rician channel for different Doppler shift frequency for the same SNR=10db

Doppler shift(Hz)	*SNR(dB)*	*BER(Rayleigh Channel)*	*BER(Rician Channel)*
10	10	0.04957	0.04699
50	10	0.0659	0.05494
100	10	0.08089	0.06574
300	10	0.1033	0.08769
500	10	0.1119	0.09698
1000	10	0.1147	0.1021

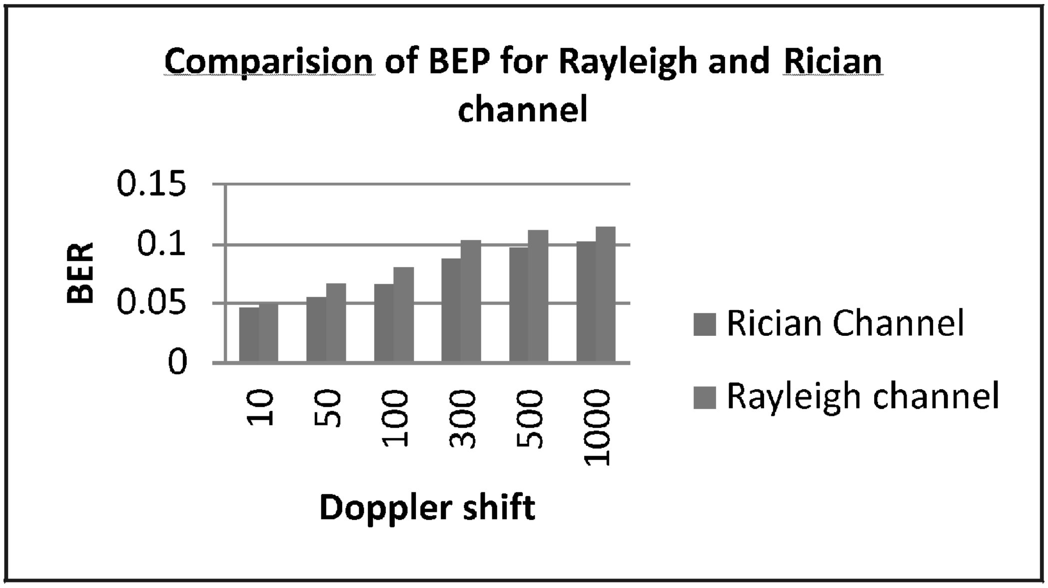

Figure 3: Chart for comparison of BEP for different channel due to different Doppler shift

Figure 2 shows the variation of bit error rate for OPSK using QFDM Modulation technique for different frequency of Doppler shifts in Rayleigh and Rician Channel. From the table 1 and the simulated data we can see that the BER increases with the increase in the Doppler shift for different frequency range in Rayleigh and Rician channel models in different carrier phase shift of QPSK. Also, we can see that the BER is slightly higher in Rayleigh channel as compared to the Rician channel. This shows that the effect of Doppler shift will have equal effect regarding the type of channel but is less as compared to the Rayleigh channel and with the increase in the Doppler shift the effect becomes more significant in the Rayleigh channel than in Rician channel.

(D) Simulation Parameters for ML Detection for BPSK modulation

Parameters	*Specification*
MIMO	2*2,
SISO	1*1
Channel	AWGN,RAYLEIGH
Modulation	BPSK

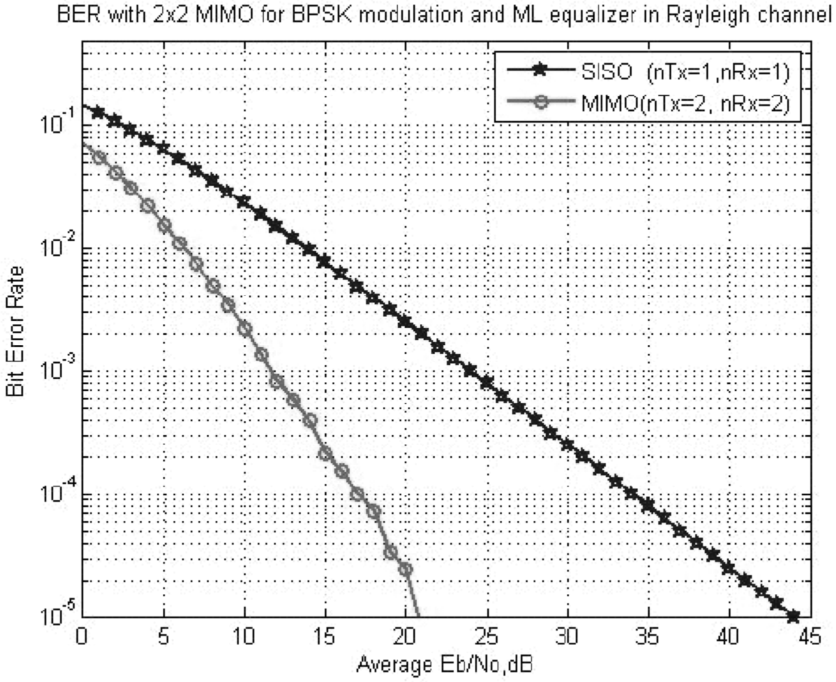

Figure 4: E_b/N_o Plot with ML estimation (2*2)

The above simulation graph shows that the BER for MIMO with BPSK modulation is less as compared to the SISO for the same E_B/N_0. That is the noise that is added in the channel affects SISO channel more than the MIMO channel. The ML receiver used as a receiver detects more signals in the receiver in the MIMO channel by MLSE than in SISO channel.

IV. CONCLUSION

From the simulation results, it can be observed that the increase in the Doppler shift in the different channel models for OFDM signal increases the BER rate for the constant SNR, whereas the BER decreases with the increase in SNR for the same Doppler Shift. Also Due to the Doppler fading caused by the Doppler shift, it can be observed that the signal at the receiver side varies. In low Doppler shift, the BER vary less for Rayleigh and Rician channel but with the increase in Doppler shift the Rician channel have less BER as compared with the Rayleigh channel with the presence of a dominant LOS component. Also the effect of noise is more in SISO than in MIMO and is less in 16 QAM modulations than AWGN channel with the presence of Gaussian noise in the channel while detecting through ML detector. The result can be further analyze in different other channel models such as in Nakagami-m channel models, Weibull, Beckmann channel models with different modulation technique and different coding techniques, such as 64- QAM modulation techniques .

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