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PERFORMANCE IMPROVEMENT OF MIMO OFDM SYSTEMS THROUGH CHANNEL ESTIMATION

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ABSTRACT

A brief overview of MIMO-OFDM system design has been discussed and its key techniques are introduced. It also focuses on OFDM-based air interface, spatial channel modelling, transceiver design, channel estimation and minimizing the BER ratio by modifying the Maximum Likelihood function through channel estimation.

KEYWORDS

OFDM, MIMO, Channel Estimation, Maximum Likelihood, Frequency Offset.

1. INTRODUCTION

Orthogonal frequency-division multiplexing (OFDM) is a well known method for high-data-rate wireless transmission. OFDM may be combined with multiple antennas at both the access point and mobile terminal to increase diversity gain and enhance system capacity on a time-varying multipath fading channel, resulting in a multiple-input multiple-output OFDM system. It converts a frequency-selective channel into a parallel collection of frequency flat sub channels, which makes the receiver simple [1]. Multiple antennas can be used at the transmitter and receiver, now widely termed as a MIMO system[2].

Recently OFDM was selected as the high performance local area network transmission technique. A method to reduce the ISI is to increase the number of subcarriers by reducing the bandwidth of each sub channel while keeping the total bandwidth constant [3]. The ISI can instead be eliminated by adding a guard interval at the cost of power loss and bandwidth expansion [4]. These OFDM systems have been employed in military applications since 1967's, [5,6]. Simplified model implementations were studied by Peled [7] in 1980.Most recent advances in OFDM transmission were presented in the impressive state of art collection of works edited by Fazel and Fettweis [8]. Recent research efforts have focused on solving a set of inherent difficulties regarding OFDM, namely peak-to-mean power ratio, time and frequency synchronization, and on mitigating the effects of the frequency selective fading channels.

Channel estimation and equalization is an essential problem in OFDM system design. Basic task of equalizer is to compensate the influences of the channel. This compensation requires, however an estimate of the channel response. Often the channel frequency response or impulse response is derived from training sequence or pilot symbols, but it is also possible to use non-pilot aided approaches like blind equalizer algorithms [9,10]. Channel estimation is one of the fundamental issue of OFDM system design, without which, non coherent detection has to be utilized, which incurs performance loss of almost 3-4dB compared to coherent detection [11]. A

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popular class of coherent demodulation for a wide class of digital modulation schemes has been proposed by Mohr and Lodge [12], and is known as Pilot Symbol Assisted Modulation, PSAM. The main idea of PSAM channel estimation is to multiplex known data streams with unknown data. Channel estimation using superimposed pilot sequences [13] is also a completely new area, idea for using superimposed pilot sequences have been proposed by various authors for different applications [14]. In [15], superimposed pilot sequences are used for time and frequency synchronization.

Use of the pilot symbols for channel estimation is basically an overhead of the system, and it is desirable to keep the number of pilot symbols to a minimum. In [16], Julia proposed a very good approach for OFDM symbol synchronization in which synchronization is achieved simply by using pilot carriers already inserted for channel estimation, so no extra burden is added in the system for the correction of frequency offsets. Similarly in [17], it has been shown that the number of pilot symbols for a desired bit error rate and Doppler frequency is highly dependent on the pilot patterns used, so by choosing a suitable pilot pattern we can reduce the number of pilot symbols, but still retaining the same performance. Most common pilot patterns used in literature are block and comb pilot arrangements. Comb patterns perform much better than block patterns in fast varying environments [18,19].

2. SYSTEM MODEL

Orthogonal Frequency Division Multiplexing is one of the most promising physical layer technologies for high data rate wireless communications due to its robustness to frequency selective fading, high spectral efficiency, and low computational complexity [14]. OFDM can be used in conjunction with a Multiple-Input Multiple-Output transceiver to increase the diversity gain or the system capacity by exploiting spatial domain. Because the OFDM system effectively provides numerous parallel narrowband channels, MIMO-OFDM is considered a key technology in emerging high-data rate systems such as 4G, IEEE 802.16, and IEEE 802.11n. MIMO communication uses multiple antennas at both the transmitter and receiver as shown in figure 1 to exploit the spatial domain for spatial multiplexing or spatial diversity. Spatial multiplexing has been generally used to increase the capacity of a MIMO link by transmitting independent data streams in the same time slot and frequency band simultaneously from each transmit antenna, and differentiating multiple data streams at the receiver using channel information about each propagation path. In contrast to spatial multiplexing, the purpose of spatial diversity is to increase the diversity order of a MIMO link to mitigate fading by coding a signal across space and time so that a receiver could receive the replicas of the signal and combine those received signals constructively to achieve a diversity gain.

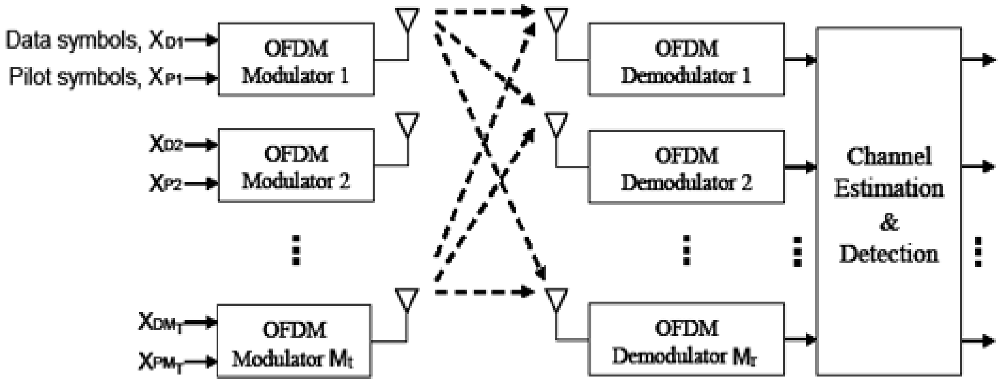

Figure 1. Typical MIMO-OFDM architecture.

3. ANALYSIS OF CHANNEL ESTIMATION

In order to allow channel estimation at the receiver, many standards provide that some of the transmitted cells $Xn(u)$ are pilot cells known to the receiver. All other cells are used for data transmissions and are denoted as data cells. Pilots may be arranged in various patterns, meant to ease both interpolation of channel estimate on data carriers and tracking of channel variation in time.

Channel Estimation for OFDM uplink has time variant multipath fading, multi access interference and inter symbol interference which constitute major impairments. However, to date, most research on OFDM channel estimation has focused on the more tractable pilot-assisted techniques. Channel estimation is a crucial part of a multi user receiver. The least squares algorithm suffers from slow convergence with increasing load. The derivation of an improved channel estimator based on the linear minimum mean square error criterion, which also takes into account the variances in the estimated data symbol. Calling this random variable R, it will have a probability density function

$$p_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega},\ r \geq 0 \qquad (1)$$

where $\Omega = E(R^2)$

For Rayleigh fading with a vertical receive antenna with equal sensitivity in all directions, this has been shown to be:

$$S(\vartheta) = \frac{1}{\pi f_d \sqrt{1-\left(\frac{\vartheta}{f_d}\right){}^\wedge 2}} \qquad (2)$$

where ν is the frequency shift relative to the carrier frequency. This equation is only valid for values of ν between $\pm f_d$; the spectrum is zero outside this range.

The digital source is usually protected by channel coding and interleaved against fading phenomenon, after which the binary signal is modulated and transmitted over multipath fading channel. Additive noise is added and the sum signal is received. Due to the multipath channel there is some inter symbol interference in the received signal. Therefore a signal detector needs to know channel impulse response characteristics to ensure successful equalization. After detection the signal is deinterleaved and channel decoded to extract the original message.

Input Signal to Time Domain is given by

$$x(n)=IDFT\{X(k)\} \qquad (3)$$

where $n=0,1,2,\ldots,N-1$

Guard Interval has been given by

$$x_f(n) = \begin{cases} x(N+n), & n = -N_g, -N_g+1, \ldots, -1 \\ x(n), & n = 0,1,\ldots, N-1 \end{cases} \qquad (4)$$

The received signal is given by

$$y_f = x_f(n) \otimes h(n) + w(n) \qquad (5)$$

Where h(n) is the channel impulse response and w(n) is the white Gaussian noise.

Guard removal is denoted by

$$y(n) = y_f(n) \quad n = 0,1,\ldots,N-1 \qquad (6)$$

Output Signal from Frequency Domain is given by

$$\begin{aligned} &Y(k) = DFT\{y(n)\} \\ &k = 0,1,2,\ldots,N-1 \end{aligned} \qquad (7)$$

Output Signal consists of Transmitted signal, Intersymbol Interference and white Gaussian noise and can be denoted as

$$\begin{gathered} Y(k) = X(k)H(k) + I(k) + W(k) \\ k = 0,1,\ldots,N-1 \end{gathered} \qquad (8)$$

Finally Estimated Channel Response or System Response can be written as

$$X_e(k) = \frac{Y(k)}{H_e(k)} \quad k = 0,1,\ldots,N-1 \qquad (9)$$

3.1. Maximum Likelihood for Channel Estimation

Digital signal is transmitted over a fading multipath channel, after which the signal has memory of symbols. Thermal noise is generated at the receiver and it is modelled by additive white Gaussian noise, which is sampled at the symbol rate. The demodulation problem here is to detect the transmitted bits from the received signal. Besides the received signal the detector needs also the channel estimates which are provided by a specific channel estimator device.

To assist the joint detection operation the joint channel estimator provides channel estimates. Optimum method for the joint data detection and channel estimation is the ML approach.
For an asynchronous channel, the complexity of this kind of estimator depends exponentially on both the number of users and transmitted symbols because only one transmitted symbol and optimization approach cannot be used anymore. The complexity demands can be reduced by using dynamic forward/backward programming methods like Viterbi algorithm. The computation of the general criterion function results in too heavy calculations. Therefore the iterative methods could be also utilized. The search procedures could be based on the steepest descent, the gauss method. The steepest descent has the simplest form and the Newton method is the most complicated one because it requires the computation of the second derivative. The update rule based on the Newton's solution for the minimization problem can be expressed at the i^{th} iteration.

The realizable receiver structure can be achieved by assuming that some of the parameters are known in advance or are approximated. In this section it is assumed that the tentative data decision have been got for example from training sequence and delays are known for channel estimation.

4. NUMERICAL RESULTS

The Numerical Results has been found out in three phases.

4.1. Phase 1

Table 1. OFDM Generation using PSK Modulation

Parameter	**Specification**
No. of Data Points	100000
Signal Constellation	4 point PSK
FFT Size	8
Channel	AWGN channel
Data Rate of OFDM Signal	1Mbps

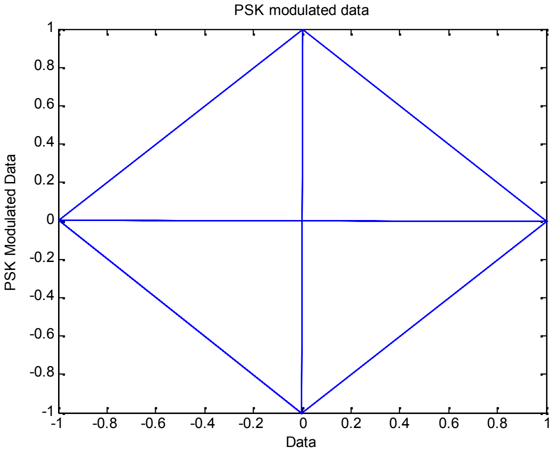

Figure 2. PSK Modulated Data

A sequence of random binary information signal is generated, then the binary signal is modulated using PSK modulation. At last OFDM signal is generated using the PSK modulated signal and transmitted through the AWGN channel. At the receiver side, OFDM signal is received, then demodulated and error is observed.

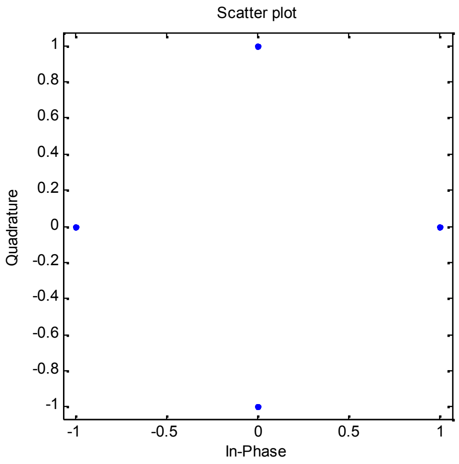

Figure 3. Scatter Plot

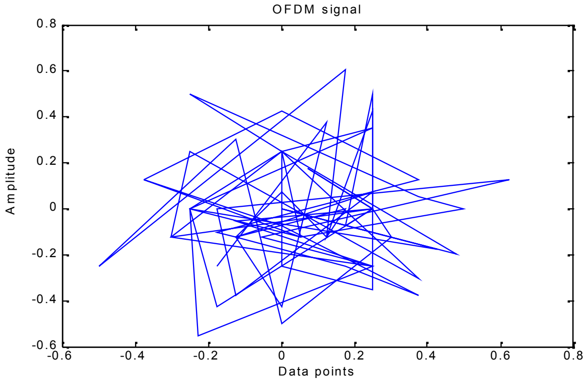

Figure 4. OFDM Signal

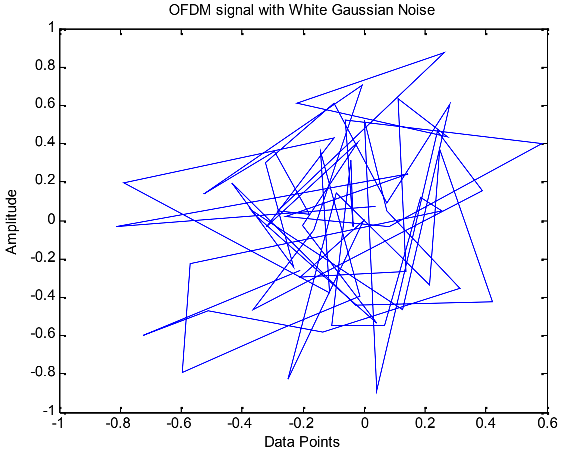

Figure 5. OFDM Signal with White Gaussian Noise

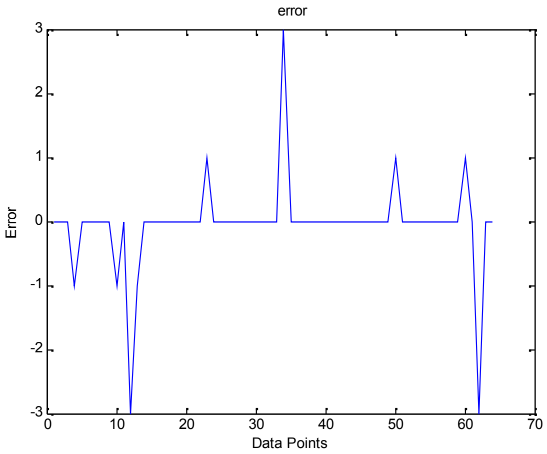

Figure 6. Error Observed

4.2. Phase 2

Table 2. BER For MIMO With ML RECEIVER Using BPSK Modulation.

Parameter	**Specification**
No. of Data Points	100000
Signal Constellation	BPSK
Channel	Rayleigh channel
Receiver Structure	Maximum Likelihood Receiver

A sequence of random binary signal is generated, modulated using BPSK modulation and transmitted through Rayleigh Channel using two antennas. At the receiver, Maximum likelihood receiver is used to receive the signal then BER Vs. EB/N0 has been calculated for MIMO system with Maximum Likelihood Receiver using BPSK Modulation system through Rayleigh Channel.

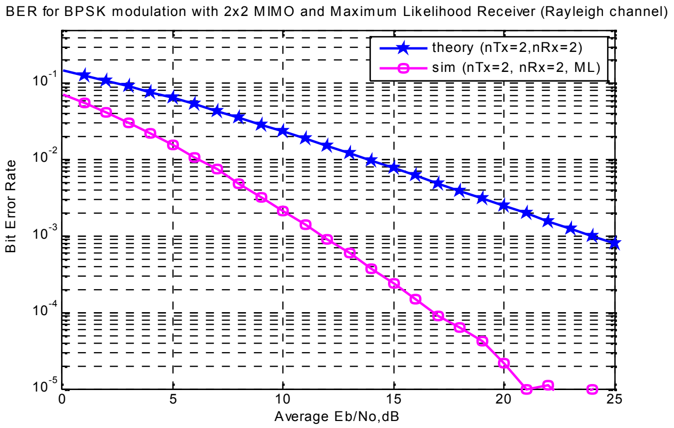

Figure 7. BER for BPSK Modulation with 2x2 MIMO and Maximum Likelihood Receiver (Rayleigh Channel)

4.3 Phase 3

Table 3. BER For MIMO OFDM Systems Using Channel Estimation

Parameter	**Specification**
Number of Carriers	128
FFT Size	64
Pilot Ratio	1/16
Guard Length	16
Guard Type	Cyclic Extension
Data Rate of OFDM signal	1Mbps
Signal Constellation	QPSK
Channel	Rayleigh Channel
FFT Sampling Rate	20MHz
Receiver Structure	Maximum Likelihood Receiver

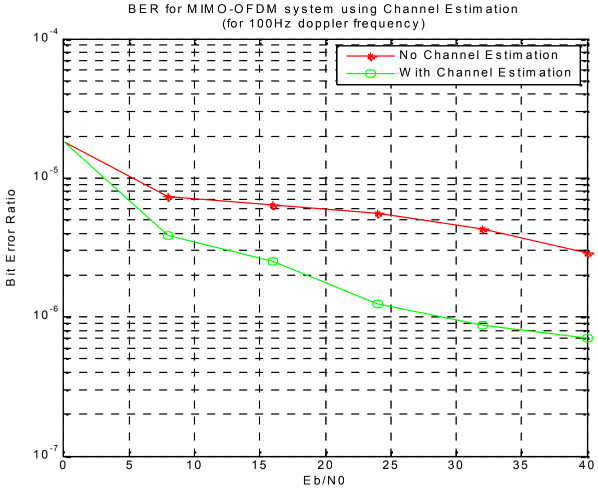

Figure 8. BER for MIMO-OFDM System using Channel Estimation for Doppler frequency 100Hz

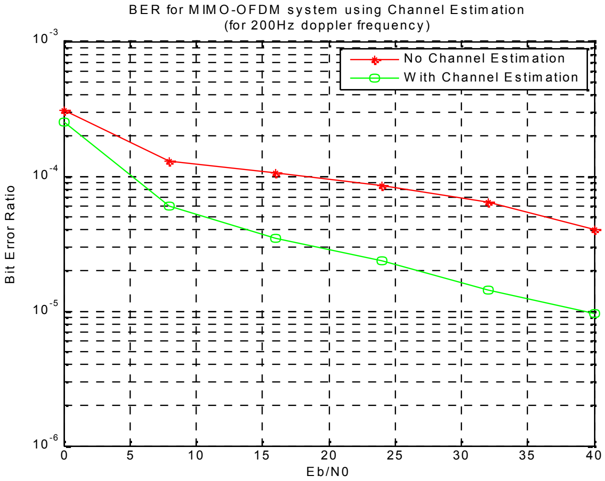

Figure 9. BER for MIMO-OFDM System using Channel Estimation for Doppler frequency 200Hz

Here a sequence of random binary signal has been generated, then modulated using QPSK modulation, and transmitted through Rayleigh Channel using two antennas. At the receiver side, Maximum Likelihood receiver is used to receive the signal and BER Vs. EB/N0 has been Calculated for MIMO OFDM system with Maximum Likelihood Receiver using QPSK Modulation system through Rayleigh Channel.

5. CONCLUSION

The MIMO-OFDM system performance has been analysed by Channel estimation using linear block codes. To determine the system performance the BER is calculated for the OFDM signal, using maximum likelihood receiver implemented with maximum likelihood equalizer in the channel estimation. It has been observed that the BER performance is better for the 2×2 MIMO OFDM system with channel estimation rather than the same without channel estimation.

Hence the proposed algorithm can be considered for improving the system performance and simulation results conclude that by decreasing the Doppler frequency shift, there is an enhancement in the error performance.

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