Investigate of Training Based Channel Estimation for a MIMO-OFDM System Over Different Modulation Technique

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***Abstract*— Orthogonal Frequency Division Multiplexing (OFDM) in communications systems combine with Multiple-Input Multiple-Output (MIMO) can improve capacity and achieve high data rate. In OFDM communications systems, the system performance will be cause to interference inter-symbol (ISI). Therefore, the pilot arrangement which is the training sequence based channel estimation are used and applied at Least Square Channel Estimation (LSE) to eliminate the ISI; accurate channel state information (CSI) is required at the receiver to improvement the performance. Thus, the objective of this paper is to investigation of Training Based Channel Estimation for MIMO-OFDM system in communication system to reduce inter-symbol interference (ISI) in order to estimates the channel information. To analyze the performance, the different digital modulation schemes such as 4-PSK, 16-PSK, 4-QAM and 16-QAM, and different number of pilot are done. The simulation results presented by using Software MATLAB Programming and have been evaluated in term of signal-to-noise ratio, SNR versus bit error rate, BER. It has been concluded, if BER is low, means achieves in estimate error and enhance the performance of MIMO-OFDM system in communication system.**

***Keywords*— Training based channel estimation; MIMO; OFDM System; Digital Modulation; Channel Estimation.**

I. INTRODUCTION

OFDM stands for orthogonal frequency division multiplexing is the popular method for high data rate wireless communication system. OFDM is sometimes also called multi-carrier or discrete multi-tone modulation. In this new era of technology, to becoming dominant factors for the successful commercial exploitation the network by achieves the high data rate and its spectral efficiency achieved by spectrum overlapping through the adoption of fast Fourier transform (FFT) and inverse fast Fourier transform (IFFT) in the implementation [1]. The combination of with antenna arrays at the transmitter and receiver provide OFDM to enhance the system capacity on time-variant and frequency-selective channels, resulting in a multiple-input multiple-output (MIMO) configuration and to avoid Inter Symbol Interference (ISI). Basically, these techniques which is MIMO-OFDM are 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 [2]

This paper proposes the channel estimation technique in MIMO-OFDM wireless communication system that uses this property to obtain the channel state information and the different digital modulation such as BPSK, QPSK and QAM. The major challenge faced in MIMO-OFDM system is how to obtain the channel state information accurately and promptly for coherent detection of information symbols [3]. There are many channel estimation technique in MIMO-OFDM system such as training based technique, blind technique and semi-blind technique. The technique that uses in this project to obtain the channel state information is through the training based channel estimation. The performance of channel estimator depends on the training symbol structure and the type of channel estimation. The training based method channel estimation can be performed by either block type pilot or by comb pilot. The block type pilot where pilot tones are inserted into all frequency bins within periodic intervals of OFDM blocks and the comb pilots where pilot tones are inserted into each OFDM symbol with a specific period of frequency bins [3]. Hence, investigate the training symbol structure on block type that corresponding channel estimation technique for MIMO-OFDM wireless communication systems and different number of the pilot symbol are represented to compare the performance.

II. MIMO-OFDM SYSTEM

OFDM system is a modulation technique that it modulates data on the subcarriers of the same distance. The information is modulated onto the sub-carrier by varying the amplitude, phase or both. The Inverse Fast Fourier Transform (IFFT) are used and each of subcarrier combine together to produce time-domain waveform to be transmitted. The frequency responses of each of the sub-carriers are overlapping and orthogonal to obtained a high spectral efficiency. This orthogonal prevent interference between sub-carriers and maintained even if the signal through multiple channels by introducing a cyclic prefix or sometimes called guard interval which prevents the Inter-symbol Interference (ISI) in the carrier. Therefore, OFDM is needed for wireless communication system. In addition, the MIMO are suited with OFDM to achieve a high system capacity for wireless communication system. MIMO system is suffer from the ISI which to improve for the poor BER performance to achieved high efficient spectral efficiency and get high system capacity. MIMO is multiple antennas are used at the both side which are used at transmitter and receiver. The received signal is received either directly or by reflected signals in MIMO system. MIMO system is combining with the OFDM. The multipath propagation usually occurs and causes the MIMO channels to be frequency selective at real situation. As shown as Figure 1 is a MIMO-OFDM System.

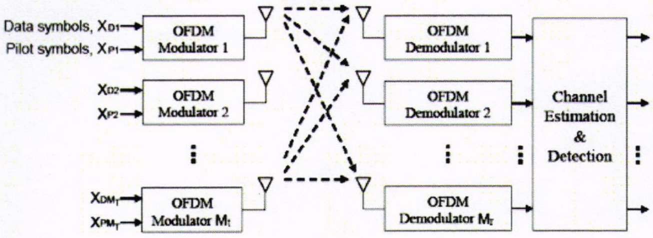

Figure 1: MIMO-OFDM System

III. SYSTEM MODEL

Figure 2 shows the block diagram of MIMO-OFDM system from transmitter to receiver. The total number subcarrier is N. In OFDM, the band is divide into N narrow subcarrier transmit at symbol for each sub-channel. This allows to be used in a spectral overlapped manner that enables the maximum use of the available bandwidth. The selected of orthogonal sub-carrier that allows the spectrum of each sub-carrier to avoided Inter symbol-interference (ISI) because have a null at the other sub-carrier frequencies. The Inverse Fast Fourier Transform (IFFT) was easily implemented the digital modulation by an orthogonal sub-carrier. The cause ISI from multipath spread of the channel and can be eliminate by added a guard interval to the transmitted signal.

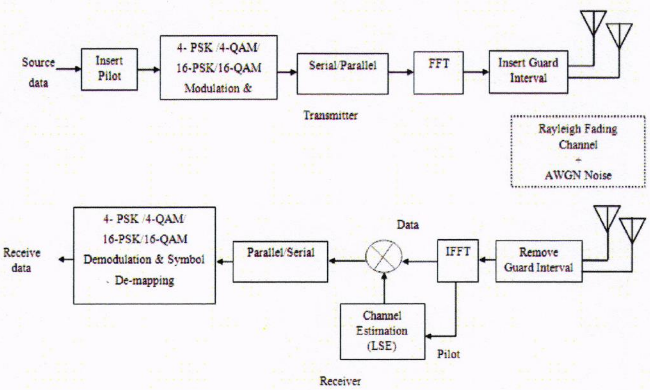

Figure 2: Block Diagram of MIMO-OFDM System.

Firstly, the data stream or signal information are inserting with pilot. Pilot are insert in MIMO-OFDM system for easy detect because it's ensure that they do not interfere with one another and can be used to provide a reliable estimate. After the pilot are insert, according to the modulation technique are used. The signal information is grouped and mapped according to the modulation in "signal mapped". This paper considers of various modulation techniques such as 4-PSK, 16-PSK, 4-QAM and 16-QAM. Each branch performed serial-to-parallel conversion with width equal to the number of subcarriers. To apply the Fast Fourier Transform (FFT) after the parallel symbol are modulated onto subcarrier. The reason of convert into parallel in transmission because to support the high data rate. At transmitter as though they are in the time-domain and this symbol is used as input to FFT block that leads to signal into the frequency domain. Then through into insert the guard interval to make the system robust to multipath propagation or eliminate interference between OFDM symbols. All this are the transmitter process and after finish the process at transmitter, the process at receiver is beginner. Since the channel noise is assumed to be additive white Gaussian noise (AWGN) and is applied to the transmitted signal. There is corrupted by AWGN at a particular signal to noise ratio on the serially transmitted data. This model allows for the signal-to-noise ratio, SNR variation. The chances of the bits being corrupted decreases as the SNR value increases. The Channel model is applied to the noise-corrupted transmitted signal. The Rayleigh fading channel model is the one of the standard channel and use for this project.

At the receiver, the signal information was passed through OFDM demodulators which first remove the guard interval before data is sent to Inverse Fast Fourier Transform (IFFT). After IFFT, the channel will estimate by using training structure technique that applied at Least Square channel estimate. In order, it can provide reliability and high data rate at receiver for MIMO-OFDM systems hence to obtain channel state information, CSI. In MIMO-OFDM systems, channel state information (CSI) is essential at the receiver in order to coherently detect the received signal. After channel estimation done, the guard interval is removed and data is converted to a parallel stream for the input to IFFT block which converts back frequency domain signal to time domain signal. Then, the information data is obtained back in "signal de-mapped" block. The demodulator performs the demodulation function by different demodulation techniques such as 4-PSK, 16-PSK, 4-QAM and 16-QAM. Finally, it will give the desired output at the end of this process.

IV. CHANNEL ESTIMATION

Channel estimation is the most important in the MIMO-OFDM wireless communication system. Channel estimation is the process described the effects of the physical medium on input sequence. It is an important and necessary function for wireless communication systems. The multipath interferences resulting from reflection from surrounding such as building, hills and others that related that affected to the wireless communication system. MIMO-OFDM system is suitable for channel estimation. The system needs an accurate estimate of time-varying or with minimum delay to provide high data rate and reliability at the receiver. In this paper, investigate the training based channel estimation to estimate channel and focused on block type arrangement.

A. Training Based Channel Estimation

In training based channel estimation algorithms, training symbol or pilot tones that are known to the receiver are multiplexed along with the data stream for channel estimation [4]. The reason inserted of pilot for channel estimation and coherent detection at receiver side. Moreover, to estimate the channel by develop knowledge of transmitted pilot symbol. In all of the subcarriers of an OFDM block are inserted of pilot tones for block type channel estimation with a specific period in time. This type of pilot arrangement shows in Figure 3 called block type channel estimation.

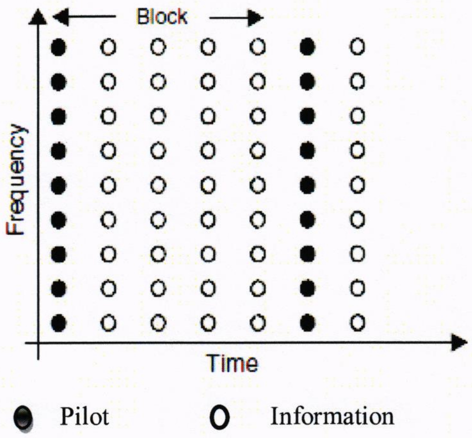

Figure 3: Block Type

B. Least Square Channel Estimation

In block type based channel estimation, OFDM channel estimation symbols are transmitted periodically, in which all sub-carriers are used as pilots [5]. There will be no channel estimation error since the pilots are sent at all carriers if the channel is constant during the block. The block type arrangement can be applied at Least Square channel estimation (LSE). LSE is a well known method and widely use for estimation in MIMO-OFDM system. To estimate the channel conditions are specified by $\overline{H}$ or $\bar{g}$. Given the pilot signals specified by matrix $\underline{X}$ or vector $\overline{X}$ and y is the vector of output signal is after OFDM demodulation or received signals. The receiver uses the estimated channel conditions to decode the received data inside the block until the next pilot symbol arrives. The LS estimator minimizes the parameter $(\bar{Y} - \underline{X}\overline{H})^H(\bar{Y} - \underline{X}\overline{H})$, where $(.)^H$means the conjugate transpose operation. The LS estimate is represented by:

$$hLs = \underline{X}^{-1}y = [(X_k/Y_k)]^T \; (k = 0, \ldots, N-1) \quad (1)$$

The X is the diagonal matrix of pilot and N specified as the number of pilot in one of OFDM symbol. The $h\hat{}$ is the impulse response of the pilots of one OFDM symbol, and W is the AWGN channel noise. If there is no ISI, the signal received is written as:

$$y = XF\,h\hat{} + W \quad (2)$$

$$h_{LS} = X^{-1}y$$
$$where \quad X = diag\,\{x_0, x_1, \cdots x_{N-1}\}$$
$$y = \begin{bmatrix} y_0 \\ \vdots \\ y_{N-1} \end{bmatrix} \quad (3)$$

Also F is the Fourier transfer matrix as below,

$$F = \begin{bmatrix} W_N^{00} & \cdots & W_N^{0(N-1)} \\ \vdots & \ddots & \vdots \\ W_N^{(N-1)0} & \cdots & W_N^{(N-1)(N-1)} \end{bmatrix} \quad \text{and}$$

$$W_N^{nk} = \frac{1}{N} e^{-j2\pi \frac{n}{N}k} \quad (4)$$

To use Least Square method for channel estimation, usually put that observation equation into a matrix form. The LS channel estimation is calculated with very low complexity. So, we choose LSE rather than other method like MSE channel estimation for the simplicity of implementation.

C. PSK and QAM Digital Modulation

Commonly, in digital wireless communication systems includes constant amplitude modulation and non-constant amplitude modulation for M-array digital modulation methods. A typical example of two modulation methods are M-array phase shift keying (M-PSK) and quadrature amplitude modulation (QAM) [6].

The Phase Shift Keying (PSK) is one of the modulation techniques that used in wireless communication system. The phase of the carrier is altered in accordance with the input binary coded information in PSK modulation. There are many types in PSK modulation such as BPSK, 8-PSK, 16-PSK, QPSK, DPSK. But, this project performed in 4-PSK, 16-PSK, and 4-QAM and 16-QAM modulation technique. The QPSK is a 4-ary PSK signal and also known as quaternary PSK. Figure 4 below shows the modulated waveform of PSK.

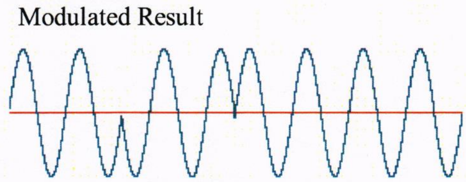

Figure 4: Digital Phase Shift Keying (PSK).

With four phases, QPSK helps to encode two bits per symbol; with gray coding so that the bit error rate (BER) can be minimized-sometimes it is misperceived as twice the BER of BPSK [5]. The Quadrature Amplitude Modulation (QAM) are also widely use for the modulation technique in MIMO-OFDM system. The QAM changes the amplitude of two sinusoidal carriers depend on the digital sequence that must be transmitted. The two carriers being out of phase of $+\pi/2$, this amplitude modulation called Quadrature. The number of amplitude phase combination could be infinite, but a practical limit is reached when the difference between adjacent combinations becomes too small to be detected reliably in the presence of noise and distortion. Error rates of higher-order QAM systems such as this degrade more rapidly than QPSK as noise or interference is introduced. A measure of this degradation would be a higher bit error rate (BER).

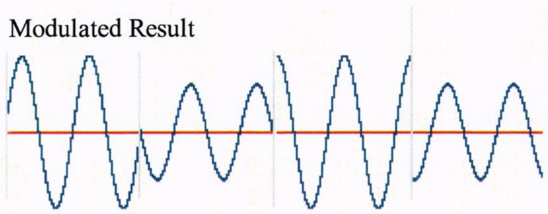

Figure 5: Digital Quadrature Amplitude Modulation (QAM).

V. SIMULATION RESULTS

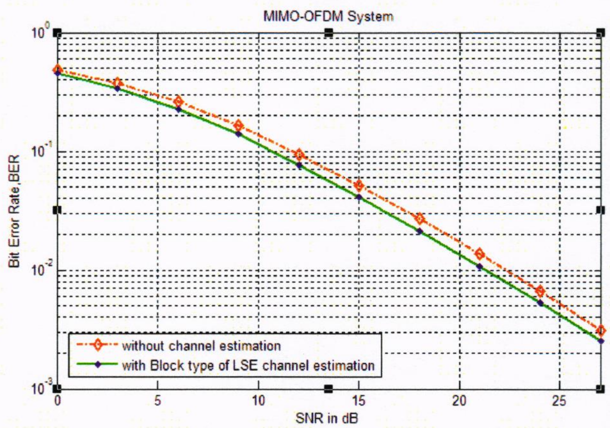

Figure 6: Comparison without channel estimation and with channel estimation.

Figure 6 shows the simulation BER versus SNR comparison of without block type at Least Square Channel Estimation (LSE) and with block type at Least Square Channel Estimation (LSE). For block type pilot arrangement consider an OFDM system with N=256 subcarriers and the channel length, L=16. The spacing between pilots is taken as 8. So the numbers of pilots are 32 for with channel estimation. It can observe that, when without channel estimation the BER will increase compare with the channel estimation the BER is less. So, when low of BER, it get better performance because has low noise. The block type of Least Square Channel Estimation (LSE), channel impulse response is estimated by algorithm of block type of Least Square Channel Estimation (LSE) as analyzed in Chapter 2. So the receiver of system could get accurate received signal. As have the low bit error rate, BER, means achieve more accurate channel estimation at the cost of less transmitted data.

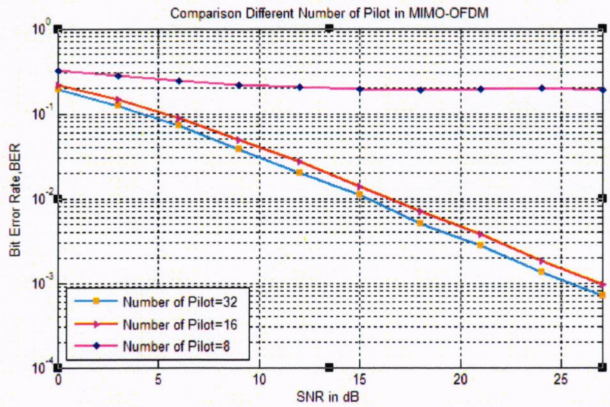

Figure 7: BER LSE of Block Type under Different Number of Pilot

Figure 7 shows the simulation BER versus SNR comparison of block type at Least Square Channel Estimation with different number of pilot. It can be observed that the number pilot of 32 shows the less of BER than number pilot of 16. But the number pilot of 8 has worse BER performance. Pilot are insert in MIMO-OFDM system for easy detect because it's ensures that they do not interfere with one another and can be used to provide a reliable estimate. Moreover, pilots are used for synchronization and channel estimation purpose that can be eliminated the interference inter-symbol (ISI) which is a distortion at signal. So, more pilots are inserted, and more efficiently to estimate the channel and obtain low bit error rate to get better performance.

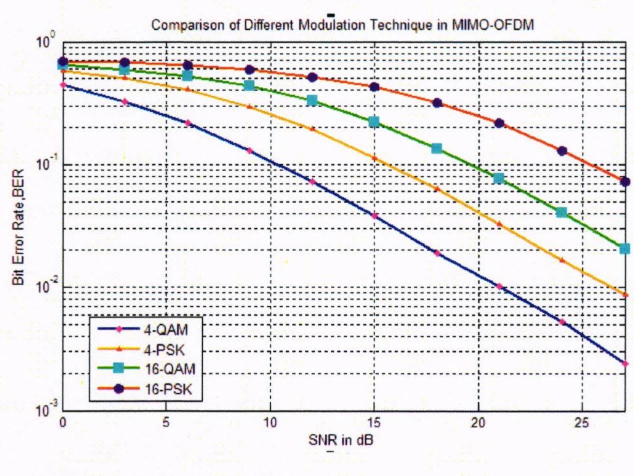

Figure 8: BER LSE of Block Type under Different Digital Modulation

Figure 8 shows the simulation BER versus SNR performance of block type under different Digital Modulation at Least Square Channel Estimation (LSE) with different number of pilot (SNR versus BER). For block type pilot arrangement consider an OFDM system with N=256 subcarriers and the channel length, L=16. It can be observed that 4-QAM achieve low bit rate compare to 16-QAM. Similarly to 4-PSK also achieve low bit rate as compare to 16-PSK. More high order modulation, more point of constellation it is possible to transmit. However point is close together and they are therefore more susceptible to noise and data error this results in a higher bit error rate (BER) [13].

Consequently, the noise immunity of QAM is very high, best for high data rate and low error probablity then PSK but depends the M-order of the modulation technique . In order, M-order QAM modulation is better than M-order PSK modulation because QAM is combinations of amplitude and phase are employed to achieve higher data rates.

VI. CONCLUSION

In this paper, the most important is channel estimation and training based channel estimation was investigated to estimate the channel accurately and less the noise. The modulation techniques and number of pilot are also important to design a MIMO-OFDM System. Different numbers of pilot are simulated for their effect on the performance of training based channel estimation in MIMO-OFDM System. The performance comparison of different modulation technique is also are done and compare their performance. The pilots are used for channel estimation purpose. Hence, when increased the number of pilot it can estimate channel efficiently to obtain low bit error rate. The performance comparison of different modulation techniques are obtained, as increase the M-order of the any modulation technique, the advantage will be in form of high data rate but at cost of degraded performance and more susceptible to noise. Through all this simulation, important choose the number of pilot, modulation technique and training based channel estimation to achieve good performance in MIMO-OFDM System.

VII. FUTURE WORK

Future work will include more channel estimation techniques such as channel estimation based on the blind and semi-blind channel estimation technique to test which is the best.

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