Channel Estimation for Wireless Communication

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Abstract – Proper knowledge about the system is prerequisite in any wired/wireless communication. Channel is either assumed or modeled or estimated in time domain/frequency domain. Frequency domain pilot aimed channel estimation techniques are either Least Square Error (LSE) based or Minimum Mean Square Error (MMSE) based. Least square based techniques are computationally less complex. Frequency domain channel estimation technique employ known symbols called pilots at known position in the Orthogonal Frequency Division Multiplexing (OFDM) symbol grid these pilots are arranged in a regular manner as comb-type, block-type, 2D - grid type.

Key Words: LSE, MMSE, OFDM, SNR, BER.

1. INTRODUCTION

In wired communication there is a physical connection between Transmitter and Receiver. Where as in wireless communication, the channel is "FREE SPACE". The signal that is transmitted at the transmitter propagates in the free space where there will be many obstacles. So we need to know about the Channel State Information (CSI). As the demand for high data rate communication has been increasing rapidly, it is required to overcome the problems associated with high speed communications. As the transmission signal passes through the channel it gets effect by many degradations, such as noise attenuation, multipath, interference, time variation, nonlinearities. Time variant channel estimation is one such crucial technique used to improve the performance of the modern wireless system with Doppler shift and multipath spread.

1.1 OFDM System description

Considering an OFDM system, with the input bit stream multiplexed into N symbol streams, each with symbol period T, and each symbol stream is used to modulate parallel, synchronous sub-carrier [1]. The sub-carriers are spaced by 1 in frequency, thus they are orthogonal over the interval (0,Ts). First, a serial-to-parallel (S/P) converter groups the stream of input bits from the source encoder into group of $\log_2 M$ bits, where M is the alphabet of size of the digital modulation scheme employed on each sub-carrier. A total of N such symbols, X_m, are created. Then, the N symbols are mapped to bins of an Inverse Fast Fourier Transform (IFFT). These IFFT bins correspond to the orthogonal sub-carriers in the OFDM symbol. Therefore, the OFDM symbol can be expressed as

$$x(n) = \frac{1}{N}\sum_{m=0}^{N-1} X_m e^{\frac{j2\pi nm}{N}} \qquad (1)$$

Where the X_m is the baseband symbols on each sub-carrier, N is the no. of sub-carriers mapping the input stream into groups of $\log_2 m$ where m is the size of each symbol. At the receiver end, the discrete signal is demodulated using an N-point Fast Fourier Transform (FFT) operation. The demodulated symbol stream is given by:

$$Y(m) = \sum_{m=0}^{N-1} y(n) e^{\frac{-j2\pi nm}{N}} + W(m) \qquad (2)$$

Where, W(m) corresponds to the FFT of the samples of w(n), which is the Additive White Gaussian Noise (AWGN) introduced in the channel.

1.2 Baseband of OFDM Transceiver system

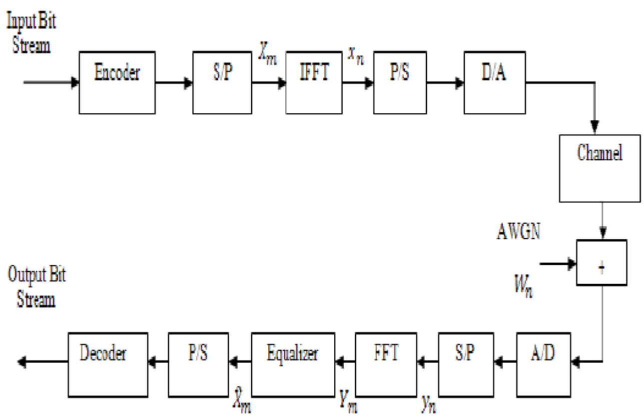

Fig1: Baseband of OFDM Transceiver system

2. CHANNEL ESTIMATION TECHNIQUES

In wireless communication system [2], the channel estimation plays an important role. There are different types of channel estimation techniques such as Pilot, Blind and Semi-blind. In this paper a Pilot or Training based technique is proposed. Pilot based approaches are widely used to estimate channel properties and correct the received signal. Different Pilot based schemes as Block type, Comb type and Lattice type pilot allocations [3].

In Block type pilot scheme, OFDM symbols with pilots at all subscribers are transmitted periodically for channel estimation. Using these pilots, a time-domain interpolation is performed to estimate the channel along the time axis. Let S_t denote the period of pilot symbols in time. As the coherence time is given in an inverse form of the Doppler Frequency $f_{doppler}$ in the channel. The pilot symbol period must satisfy the following inequality:

$$S_t \leq \frac{1}{f_{doppler}}$$

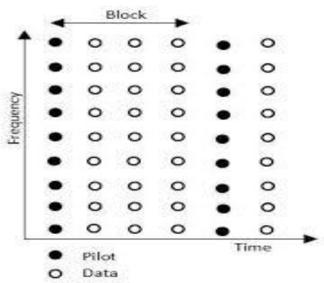

Fig 2 : Block Type Pilot allocation scheme

In Comb type pilot scheme, the idea behind the comb type pilot allocation scheme is similar to the block type scheme except that it combats the time variations of the channel between OFDM symbols in comb type of pilot arrangement every OFDM symbol has (N_p) pilot tones which are periodically inserted into the input signal (X) with pilot subcarrier spacing (S_f). A frequency domain interpolation along the frequency axis is performed using the pilot to estimate the channel.

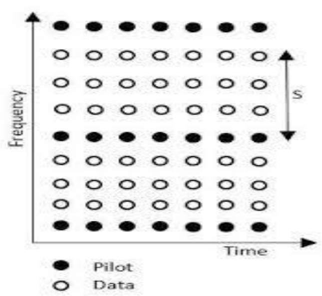

Fig 3 : Comb Type Pilot allocation scheme

In Lattice type of pilot arrangement, pilots are inserted along both the time and frequency axes for channel estimation. In order to keep track of the frequency selective and time varying channel characteristics, the pilot subcarrier spacing (S_f) must be less than the coherence time. The pilot symbols arrangement must satisfy the following inequality:

$$S_t \leq \frac{1}{f_d} \text{ and } S_f \leq \frac{1}{\sigma_{max}}$$

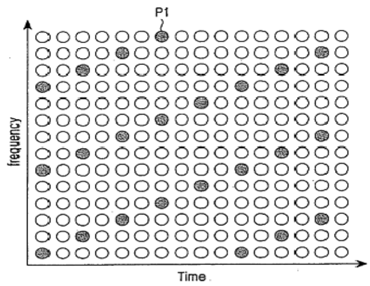

Fig 4: Lattice Type Pilot allocation scheme

2.1 Relationship between SNR and BER:

The number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization error is called Bit Error Rate (BER).

BER=Error/Total Number of Bits.

The Signal to Noise Ratio (SNR) is defined as ratio of signal power to the noise power.

$SNR=(P_{signal} / P_{noise})$

The relationship between SNR and BER is given as

BER=Q (1/σ)
BER=Q (SQRT (SNR))

Where,

Q(x)=0.5* erfc (x/sqrt(2))

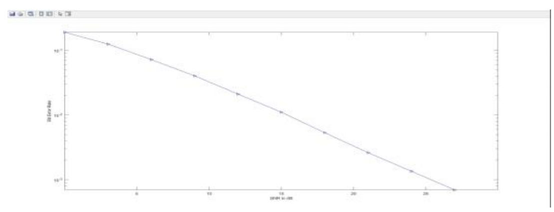

Fig 5: SNR vs BER for Wireless Channel Estimation

2.2 LSE and LMMSE

Channel can be estimated in time domain or frequency domain. In frequency domain two algorithms are proposed Least Square Error (LSE) and Linear Minimum Mean Square Error (LMMSE). LSE [5] algorithm is relatively easy to implement due to its less complexity and it also does not require any channel apriority probability. The MMSE estimator employ, the second- order statistics f the channel conditions to reduce the [6] Mean Square Error (MSE). To achieve better performance LMMSE is proposed. LMMSE is optimum in minimising Mean Square Error (MSE) as it uses addition information of operating SNR and the channel statistics. But it complexity is higher due to channel correlation and the matrix inversion. There can be compromise of complexity and performance by taking the effect of the channel taps and Channel Impulse Response (CIR) samples. By assuming the impulse response of finite length, these two algorithms can be modified having less complexity. In mobile wireless links the channel statistics are not known, in these cases it is robust to consider the uniform Power Delay Profile (PDP), which also reduced by regularizing the Eigen values of the matrix being inverted or by down-sampling the channel vector.

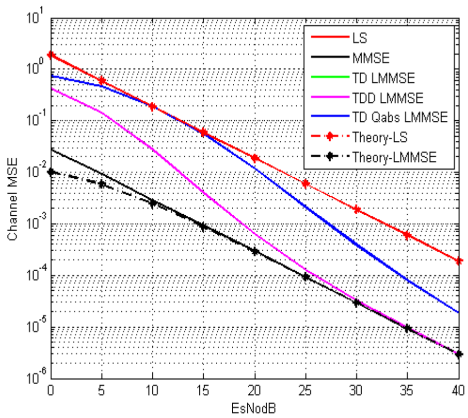

Fig -6: Channel MSE vs EsNodB for channel estimation

3. CONCLUSION

In this project we studied about how the signal is propagating in the channel. To retrieve the Channel State Information (CSI), the Pilot channel estimation technique is used. Here we calculate the Bit Error Rate (BER) and Signal to Noise Ratio (SNR) using Least Square Error (LSE) and Minimum Mean Square Error (MMSE). For any communication system low bit error rate is acceptable, so from the above results LMMSE has low bit error rate. The relation between Signal to Noise Ratio (SNR) and Bit Error Rate (BER) are inversely proportional to each other.

REFERENCES

[1] R. E. Ziemer, R. L. Peterson, Introduction to Digital Communication, 2nd Edition, Prentice Hall, 2002.

[2] Rakshit Govil, "Different Types of channel Estimation Techniques Used in MIMO-OFDM for Effective Communication Systes", International Journal of Engineering Reasearch & Technology(IJRET)ISSN: 2278-0181 Vol. 7 Issue 07, July-2018.

[3] Anil Kumar Patnayak "Channel Estimation in OFDM System".

[4] K. Elissa, "Title of paper if known," unpublished.

[5] Saqib Saleem, "Optimization of LSE and LMMSE Channel Estimation Algorithms based on CIR Samples and Channel Taps".

[6] Akash Kumar Shrivas "A Comparative Analysis of LS and MMSE Channel Estimation Techniques for MIMO-OFDM System", International Journal for Innovation Research in Science & Technlogy (IJIRST), ISSN: 2349-6010 Volume 1, Issue 8 Jan 2015.

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