An Enhanced Channel Estimation Technique For OFDM System: A Review

Rakesh Dwivedi[1] , Prof. Swatantra Tiwari[2]

[1]M-Tech Research Scholar, [2]Research Guide

Deptt. of Electronics & Communication, RIT, Rewa

Abstract - OFDM is becoming a very popular multi-carrier modulation technique for transmission of signals over wireless channels. It converts a frequency-selective fading channel into a collection of parallel flat fading subchannels, which greatly simplifies the structure of the receiver. The available bandwidth is utilized very efficiently in OFDM systems without causing the ICI (inter-carrier interference). By combining multiple low-data-rate subcarriers, OFDM systems can provide a composite high-data-rate with long symbol duration. That helps to eliminate the ISI (inter-symbol interference), which often occurs along with signals of a short symbol duration in a multipath channel. In this work various efficient pilot based channel estimation schemes for OFDM systems has compared and investigated. The channel estimation can be performed by either inserting pilot tones into all subcarriers of OFDM symbols with a specific period or inserting pilot tones into each OFDM symbol. In this present study, two major types of pilot arrangement such as block- type and comb-type pilot have been focused employing Least Square Error (LSE) and Minimum Mean Square Error (MMSE) channel estimators. The pilot signal estimation is based on LSE and MMSE criteria, together with channel interpolation using linear interpolation and spline cubic interpolation.

Keywords- OFDM, Pilot based channel estimation, Least Square Error.

I. INTRODUCTION

Over the past two decades, the rapid development of wireless communication technology has brought great convenience to people's lives and work. In the 21st century, wireless communication technologies, especially mobile communication technology, presents unprecedented development. The goal of next generation of mobile wireless communication system is to achieve ubiquitous, high-quality, high-speed mobile multimedia transmission. To achieve this goal, various new technologies are constantly being applied to mobile communication systems. Academia and industry have reached a consensus that OFDM is one of the most promising core technologies in new generation of wireless mobile communication system.

The OFDM technology is widely used in two types of working environments, i.e., a wired environment and a wireless environment. When used to transmit signals through wires like twisted wire pairs and coaxial cables, it is usually called as DMT (digital multi-tone). For instance, DMT is the core technology for all the xDSL (digital subscriber lines) systems which provide high-speed data service via existing telephone networks. However, in a wireless environment such as radio broadcasting system and WLAN (wireless local area network), it is referred to as OFDM. Since we aim at performance enhancement for wireless communication systems, we use the term OFDM throughout this research work. Furthermore, we only use the term MIMO-OFDM while explicitly addressing the OFDM systems combined with multiple antennas at both ends of a wireless link.

OFDM is a multi-carrier modulation scheme that encodes data onto a Radio Frequency (RF) signal. Unlike conventional single carrier modulation schemes such as AM/FM (amplitude or frequency modulation)that send only one signal at a time using one radio frequency, OFDM sends multiple high speed signals concurrently on specially computed, orthogonal carrier frequencies. The result is much more efficient use of bandwidth as well as robust communications during noise and other interferences.

OFDM is modulation method known for its capability to mitigate multipath. In OFDM the high speed data stream is divided into R narrowband data streams, R corresponding to the subcarriers or subchannels i.e. one OFDM symbol consists of R symbols modulated by Quadrature Amplitude Modulation (QAM) or Phase Shift Keying (PSK). As a result the symbol duration is R times longer than in a single carrier system with the same symbol rate. The symbol duration is made even longer by adding a cyclic prefix to each symbol. As long as the cyclic prefix is longer than the channel delay spread, OFDM offers Inter Symbol Interference (ISI) free transmission.

II. OFDM SYSTEM MODEL

In the current and future mobile communications systems, data transmission at high bit rates is essential for many services such as video, high quality audio and mobile integrated service digital network. When the data is transmitted at high bit rates, over mobile radio channels, the channel impulse response can extend over many symbol periods, which leads to Inter-symbol interference (ISI). Orthogonal Frequency Division Multiplexing (OFDM) is one of the promising candidate to mitigate the ISI. In an OFDM signal the bandwidth is divided into many narrow sub-channels which are transmitted in parallel. Each sub-channel is typically chosen narrow enough to eliminate the effect of delay spread. By combining OFDM with CDMA dispersive- fading limitations of the cellular mobile radio environment can be overcome and the effects of co-channel interference can be reduced.

Orthogonal Frequency Division Multiplexing (OFDM) has proven to be a modulation technique well suited for high data rates on time dispersive channels.

There are some specific requirements when designing wireless OFDM systems, for example, how to choose the bandwidth of the sub-channels used for transmission and how to achieve reliable synchronization. The latter is especially important in packet- based systems since synchronization has to be achieved within a few symbols. In order to achieve good performance the receiver has to know the impact of the channel. The problem is how to extract this information in an efficient way. Conventionally, known symbols are multiplexed into the data sequence in order to estimate the channel. From these symbols, all channel attenuations are estimated with an interpolation filter.

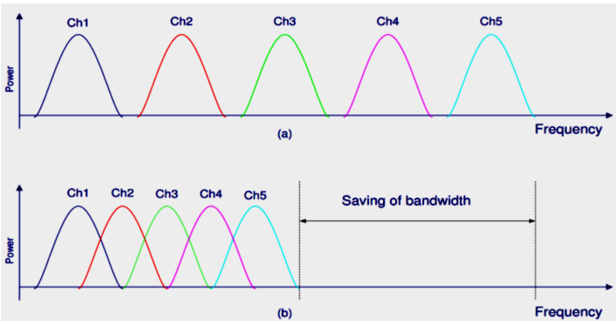

Figure 2.1 Comparison between conventional FDM and OFDM.

The principle of OFDM is to divide a single high-data-rate stream into a number of lower rate streams that are transmitted simultaneously over some narrower subchannels. Hence it is not only a modulation (frequency modulation) technique, but also a multiplexing (frequency-division multiplexing) technique. Before we mathematically describe the transmitter-channel-receiver structure of OFDM systems, a couple of graphical intuitions will make it much easier to understand how OFDM works. OFDM starts with the "O", i.e., orthogonal. That orthogonality differs OFDM from conventional FDM (frequency-division multiplexing) and is the source where all the advantages of OFDM come from. The difference between OFDM and conventional FDM is illustrated in Figure 2.1 It can be seen from Figure 2.1, in order to implement the conventional parallel data transmission by FDM, a guard band must be introduced between the different carriers to eliminate the interchannel interference. This leads to an inefficient use of the rare and expensive spectrum resource.

A. OFDM Principles

In order to achieve efficient information transmission, M-ary digital modulation could be used to transmit data symbols. Compared with the binary digital modulation, a M-ary symbol can carry log2 M bits of information, whereas a binary symbol can only carry one bit of information. Commonly, M-ary digital modulation methods used in digital communication systems includes constant amplitude modulation and non-constant amplitude modulation. A typical example of two modulation methods are M-ary phase shift keying (MPSK) and quadrature amplitude modulation (QAM). Let me take quadrature phase shift keying (QPSK) for an example to introduce MPSK.

QPSK uses four points on the constellation diagram, equispaced around a circle. With four phases, QPSK can encode two bits per symbol, as shown in Figure 2.2, with Gray coding to minimize the bit error rate (BER) sometimes misperceived as twice the BER of binary phase shift keying (BPSK).

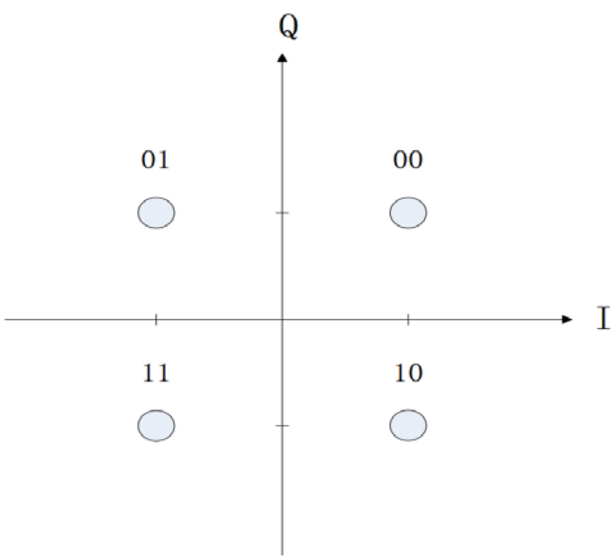

Figure 2.2 Constellation of QPSK.

Because amplitude of MPSK modulation is kept constant, so to get circular constellation map. If the phase and amplitude of signal modulated can be changed, it can get QAM method with non-constant amplitude.

B. Pilot-Based Channel Estimation

Compared to non-coherent detection, coherent detection can achieve a higher data rate and a better performance at the price of acquiring accurate channel estimates. Thus, the channel estimates become necessary. Due to the orthogonality between subcarriers in OFDM systems, different pilot allocation schemes can be adopted.

- Block Type Pilot Allocation

The block type pilot allocation is to insert pilots periodically into all subcarriers in the frequency domain, so the channel frequency response for each subcarrier can be estimated.

- Comb-Type Pilot Allocation

The idea behind the comb-type pilot allocation is similar to the block type except that it combats the time variations of the channels between OFDM symbols. The pilots are inserted in several particular subcarriers across all the time.

- Lattice-Type Pilot Allocation

Compared to the above allocation schemes, the pilots are scattered over the time and the frequency domain to keep track of the frequency selectivity and time variation of the channels.

III. RELATED WORK

C. Rezgui and K. Grayaa,[1] In this work, propose a novel method for channel estimation based on adaptive pilot spacing using low complexity with least-square (LS) channel estimation. Many channel estimation method uses LS or MMSE (Minimum Mean Square Error) channel estimator. The MMSE channel estimation technique suffers from a high computational complexity with an order of O(N - P3) operations ((N - P) represents the total number pilot in one OFDM symbol) due to an inversion matrix operation. However LS presents low complexity. MMSE have good results in low SNR (Signal to Noise Ratio), but with high SNR, LS estimator is more efficient. So, we are interested in LS estimator with adaptive pilot arrangement in order to have a minimal complexity and better results for low and high SNR. MATLAB Monte-Carlo simulations are used to evaluate the performance of the proposed estimator.

A. Mohamed, O. Onireti, M. Imran, A. Imrany and R. Tafazolli,[1] Most of the wireless systems such as the long term evolution (LTE) adopt a pilot symbol-aided channel estimation approach for data detection purposes. In this technique, some of the transmission resources are allocated to common pilot signals which constitute a significant overhead in current standards. This can be traced to the worst-case design approach adopted in these systems where the pilot spacing is chosen based on extreme condition assumptions. This suggests extending the set of the parameters that can be adaptively adjusted to include the pilot density. In this research work, propose an adaptive pilot pattern scheme that depends on estimating the channel correlation. A new system architecture with a logical separation between control and data planes is considered and orthogonal frequency division multiplexing (OFDM) is chosen as the access technique. Simulation results show that the proposed scheme can provide a significant saving of the LTE pilot overhead with a marginal performance penalty.

M. A. Youssefi and J. El Abbadi,[3] This research work presents a new approach to achieve optimal training sequences (OTS) in terms of minimizing the mean-square channel estimation error for spectrally efficient MIMO OFDM systems. It is shown that the OTS are equi-powered, equi-spaced and position orthogonal. However, in special cases we can find that required conditions to achieve optimal pilot design are not satisfied, this means the optimum pilot is unachievable. In this research work, an algorithm is proposed to achieve suboptimum pilot design under time varying channels. To offer high throughput gains, we propose an adaptive pilot scheme in order to optimally use pilot tones over time varying channels.

K. Wang, H. Shen, W. Wu and Z. Ding,[4] This work proposes a novel linear programming approach for the joint detection and decoding of LDPC-based space-time (ST) coded signals in multi-antenna orthogonal frequency division multiplexing (OFDM) systems. While traditional receivers typically decouple the detection and decoding processes as two disjunctive blocks or require iterative turbo exchange of extrinsic information between the soft detector and decoder, we formulate a joint linear program (LP) by exploiting the constraints imposed on the data symbols, training symbols, noise subspace as well as channel code. In consideration of the vast amount of LDPC parity check inequalities, we further present an adaptive procedure to significantly reduce the complexity of the joint LP receiver. Our LP-based receivers outperform existing receivers with substantial performance gains. Moreover, the proposed joint LP receiver demonstrates strong robustness when pilot symbols are sparsely arranged on subcarriers.

E. V. Zorita and M. Stojanovic,[5] In this research work, Alamouti space-frequency block coding, applied over the carriers of an orthogonal frequency-division multiplexing (OFDM) system, is considered for obtaining transmit diversity in an underwater acoustic channel. This technique relies on the assumptions that there is sufficient spatial diversity between the channels of the two transmitters, and that each channel changes slowly over the carriers, thus satisfying the basic Alamouti coherence requirement and allowing simple data detection. We propose an adaptive channel estimation method based on Doppler prediction and time smoothing, whose decision-directed operation allows for reduction in the pilot overhead. System performance is demonstrated using real data transmitted in the 10-15-kHz acoustic band from a vehicle moving at 0.5-2 m/s and received over a shallow-water channel, using quadrature phase-shift keying (QPSK) and a varying number of carriers ranging from 64 to 1024. Results demonstrate an average mean squared error gain of about 2 dB as compared to the single-transmitter case and an order of magnitude decrease in the bit error rate when the number of carriers is chosen optimally.

M. Karami, A. Olfat and N. C. Beaulieu,[6] The optimization of pilot symbol parameters can improve the spectral efficiency of adaptive modulation for orthogonal frequency division multiplexing (OFDM) systems, since pilot symbols impose an overhead on the system consuming power and bandwidth. An optimal pilot symbol assisted adaptive modulation (PSAAM) scheme for OFDM systems is proposed that maximizes spectral efficiency by adapting the power and constellation size of each subcarrier based on employing imperfect channel state information (CSI) at the transmitter. The pilot symbol power and spacing is also optimized in this scheme. A suboptimum scheme that decreases computational complexity without perceivable loss in performance is also presented. The optimality of minimum mean square error (MMSE) channel prediction for OFDM systems expressed in terms of a lower bound on spectral efficiency is approached. It is proved that the rectangular pilot pattern with equi-spaced and equal power pilot tones achieves the minimum MSE of the channel prediction in addition to having the advantage of simplifying PSAAM design. Numerical results show the importance of optimal pilot parameter adjustment for rapidly fading channels.

S. Phrompichai,[7] A suboptimal adaptive semiblind receiver is proposed for 3GPP LTE downlink MIMO-OFDM systems. The receiver directly detects data using frequency diversity of code division multiplexing technique and updating tap-weight vector exploits the contribution of information from pilot signal and data signal on the resource block mapping. The complex frequency-domain space-frequency received shift sub-resource block signal sequence matrix is formulated to take the diversity from MIMO-OFDM scheme and combats the effect of inter-carrier-interference. Numerical results show that performance of proposed adaptive semiblind receiver outperforms adaptive pilot-based receiver in term of BER over ITU MIMO Pedestrian A and Vehicular A in fast time varying frequency-selective fading channel models.

IV. PROBLEM STATEMENT

One problem is that only an intermediate solution can be first obtained by solving the LS estimation problem. It means that the intermediate solution is still a function of the unknown target location. Extra constraints are needed to get the final target estimation. Though such a constraint exists, solving the quadratic equation may end up with nonexistence of a real positive root. Another problem is that it is unclear how the measurement noise variance affects the estimation accuracy. Intuitively, a small variance is always preferred. In our proposed algorithm, the constrained LS-type optimization problem is solved by using Lagrange multiplier. And it is pointed out that the noise variance is closely related to the equivalent SNR.

V. CONCLUSION

Pilot-based channel estimation of OFDM systems and relevant work has discussed in detail. Focus has been placed on different pilot based methods. The research work first introduces the OFDM wireless communication technology, history, basic principles, advantages, disadvantages and application prospects. Then, the wireless multipath channel effect on the OFDM system is analyzed theoretically. After that, the focus on pilot-based channel estimation of OFDM is discussed. CP is used for eliminating the ISI and avoids the equalizer in time domain. But in frequency domain, equalizer is necessary for channel estimation to reduce the ICI.

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