MIMO-OFDM Communication System: Channel Estimation and Wireless Location

Kajal¹, Ms Bhawna²

¹ M.TECH Final year Student, Dept. of ECE, R.N College of Engineering, Gohana Road, Rohtak, Haryana
² HOD, Dept. of ECE, R.N College of Engineering, Gohana Road, Rohtak, Haryana.

ABSTRACT

In this new information age, high data rate and strong reliability features our wire-less communication systems and is becoming the dominant factor for a successful deployment of commercial networks. MIMO-OFDM (multiple input multiple output-orthogonal frequency division multiplexing), a new wireless broadband technology, has gained great popularity for its capability of high rate transmission and its robustness against multi-path fading and other channel impairments. A major challenge to MIMO-OFDM systems is how to obtain the channel state information accurately and promptly for coherent detection of information symbols and channel synchronization.

Keywords: MSE, MIMO, OFDM

1. INTRODUCTION

The advances and developments in the technique field have partially helped to realize our dreams on fast and reliable communicating any time are expecting to have more experience in this wireless world such as wireless Internet surfing and interactive multimedia messaging so on. One natural question is: how can we put high-rate data streams over radio links to satisfy our needs? New wireless broadband access techniques are anticipated to answer this question. For example, the coming 3G (third generation) cellular technology can provide us with up to 2Mbps (bits per second) data service. But that still does not meet the data rate required by multimedia media communications like HDTV (high-definition television) and video conference. Recently MIMO-OFDM systems have gained considerable attentions from the leading industry companies and the active academic community. A collection of problems including channel measurements and modeling, channel estimation, synchronization, IQ (in phase-quadrature) imbalance and PAPR (peak-to-average power ratio) have been widely studied by researchers. Clearly all the performance improvement and capacity increase are based on accurate channel state information. Channel estimation plays a significant role for MIMO-OFDM systems. The maturing of MIMO-OFDM technology will lead it to a much wider variety of applications.

2. OFDM SYSTEM MODEL

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 thesis. 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.

The history of OFDM can all the way date back to the mid 1960s, when Chang published a paper on the synthesis of band limited orthogonal signals for multichannel data transmission. He presented a new principle of transmitting signals simultaneously over a bandlimited channel without ICI and ISI. Right after Chang's publication of his paper, Saltzburg demonstrated the performance of the efficient parallel data transmission systems in 1967, where he concluded that the strategy of designing an efficient parallel system should concentrate on reducing crosstalk between adjacent channels than on perfecting the individual channels themselves. His conclusion has been proven far-sighted today in the digital baseband signal processing to battle the ICI. Through the development of OFDM
technology, there are two remarkable tributions to OFDM which transform the original analog multicarrier system today’s digitally implemented OFDM.

**Fig. 1** Block diagram of MIMO-OFDM scheme with coherent detection and channel Estimation

The use of DFT (discrete Fourier transform) to perform baseband modulation and demodulation was the first milestone when Wein-stein and Ebert published their paper in 1971. Their method eliminated the banks of subcarrier oscillators and coherent demodulators required by frequency-division multiplexing and hence reduced the cost of OFDM system. In We-instein's paper they used a guard interval between consecutive symbols and the raised-cosine windowing in the time-domain to combat the ISI and the ICI. But their system could not keep perfect orthogonality between subcarriers over a time dispersive channel. This problem was first tackled by Peled and Ruiz in 1980 with the introduction of CP (cyclic prefix) or cyclic extension. They creatively filled the empty guard interval with a cyclic extension of the OFDM symbol. If the length of CP is longer than the impulse response of the channel, the ISI can be eliminated completely.

Furthermore, this effectively simulates a channel performing cyclic convolution which implies orthogonality between subcarriers over a time dispersive channel. Though this introduces an energy loss proportional to the length of CP when the CP part in the received signal is removed, the zero ICI generally pays the loss. And it is the second major contribution to OFDM systems. With OFDM systems getting more popular applications, the requirements for a better performance is becoming higher. Hence more research efforts are poured into the investigation of OFDM systems. Pulse shaping at an interference point view, is beneficial for OFDM systems since the spectrum of an OFDM signal can be shaped to be more well-localized in frequency; Synchronization in time domain and in frequency domain renders OFDM systems robust against timing errors, phase noise, sampling frequency errors and carrier frequency offsets; For coherent detection, channel estimation provides accurate channel state information to enhance performance of OFDM systems; Various effective techniques are exploited to reduce the relatively high such as clipping and peak windowing.

### 3. MIMO-OFDM CHANNEL ESTIMATION

With the ever increasing number of wireless subscribers and their seemingly greedy" demands for high-data-rate services, radio spectrum becomes an extremely rare and invaluable resource for all the countries in the world efficient use of radio spectrum requires that modulated carriers be placed as close as possible without causing any ICI and be capable of carrying as many bits as possible. Optimally, the bandwidth of each carrier would be adjacent to its neighbors, so there would be no wasted bands. In practice, a guard band must be placed between neighboring carriers to provide a guard space where a shaping filter can attenuate a neighboring carrier's signal. These guard bands are waste of spectrum. In order to transmit high-rate data, short symbol periods must be used. The symbol period $T_{sym}$ is the inverse of the baseband data rate $R$ ($R = 1/T_{sym}$), so as $R$ increases, $T_{sym}$ must decrease.

In a multipath environment, however, a shorter symbol period leads to an increased degree of ISI, and thus performance loss. OFDM addresses both of the two problems with it unique modulation and multiplexing technique. OFDM divides the high-rate stream into parallel lower rate data and hence prolongs the symbol duration, thus
helping to eliminate ISI. It also allows the bandwidth of subcarriers to overlap without ICI as long as the modulated carriers are orthogonal. OFDM therefore is considered as a good candidate modulation technique for broadband access in a very dispersive environments. However, relying solely on OFDM technology to improve the spectral efficiency gives us only a partial solution. At the end of 1990s, seminal work by Foshini and Gans and, independently, by Telatar showed that there is another alternative to accomplish high-data-rate over wireless channels: the use of multiple antennas at the both ends of the wireless link, often referred to as MA (multiple antenna) or MIMO in the literature.

The MIMO technique does not require any bandwidth expansions or any extra transmission power. Therefore, it provides a promising means to increase the spectral efficiency of a system. In his paper about the capacity of multi-antenna Gaussian channels Telatar showed that given a wireless system employing $N_t$ TX (transmit) antennas and $N_r$ RX (receive) antennas, the maximum data rate at which error-free transmission over a fading channel is theoretically possible is proportional to the minimum of $N_t$ and $N_r$ (provided that the $N_tN_r$ transmission paths between the TX and RX antennas are statistically independent).

Now let’s come back to the previous question: what can be done in order to enhance the data rate of a wireless communication systems? The combination of MIMO systems with OFDM technology provides a promising candidate for next generation and mobile wireless systems. In practice for coherent detection, however, accurate channel state information in terms of channel impulse response (CIR) or channel frequency response (CFR) is critical to guarantee the diversity gains and the projected increase in data rate.

The channel state information can be obtained through two types of methods. One is called blind channel estimation which explores the statistical in-formation of the channel and certain properties of the transmitted signals. The other is called training-based channel estimation, which is based on the training data sent at the transmitter and known a priori at the receiver. Though the former has its advantage in that it has no overhead loss, it is only applicable to slowly time-varying channels due to its need for a long data record. Our work in this thesis focuses on the training-based channel estimation method, since we aim at mobile wireless applications where the channels are fast time-varying. The conventional training-based method is used to estimate the channel by sending first a sequence of OFDM symbols, so-called preamble which is composed of known training symbols. Then the channel state information is estimated based on the received signals corresponding to the known training OFDM symbols prior to any data transmission in a packet.

The channel is hence assumed to be constant before the next sequence of training OFDM symbols. A drastic performance degradation then arises if applied to fast time-varying channels. optimal pilot-tone selection and placement were presented to aid channel estimation of single-input/single-output (SISO) systems. To use a set of pilot-tones within each OFDM block, not a sequence of training blocks ahead of a data packet to estimate the time-varying channel is the idea behind our work. However direct generalization of the channel estimation algorithm in to MIMO-OFDM systems involves the inversion of a high-dimension matrix due to the increased number of transmit and receive antennas, and thus entails high complexity and makes it infeasible for wireless communications over highly mobile channels. This becomes a bottleneck for applications to broadband wireless communications. To design a low-complexity channel estimator with comparable accuracy is the goal of this paper.

The bottleneck problem of complexity for channel estimation in MIMO-OFDM systems has been studied by two different approaches. The first one shortens the sequence of training symbols to the length of the MIMO channel, as described in leading to orthogonal structure for preamble design. Its drawback lies in the increase of the overhead due to the extra training OFDM blocks. However its construction of the pilot-tones is not explicit in terms of space-time codes (STC). We are motivated by both approaches in searching for new pilot-tone design. Our contribution in this chapter is the unification of the known results of in that the simplified channel estimation algorithm is generalized to explicit orthogonal space-frequency codes (SFC) that inherit the same computational advantage as while eliminating their respective drawbacks.

In addition, the drastic performance degradation occurred in is avoided by our pilot-tone design since the channel is estimated at each block. In fact we have formulated the channel estimation problem in frequency domain, and the CFR is parameterized by the pilot-tones in a convenient form for design of SFC. As a result a unitary matrix, composed of pilot-tones from each transmit antenna, can be readily constructed. It is interesting to observe that the LS algorithm based on SFC in this paper is parallel to that for conventional OFDM systems with single transmit/receive antenna. The use of multiple transmit/receive antennas offers more design freedom that provides further improvements on estimation performance.
4. OFDM-BASED WIRELESS LOCATION for PERFORMANCE

WiMax is an acronym for Worldwide Interpretability for Microwave Access. It is not only a technical term indicating a new wireless broadband technology, but also referred to as a series of new products working on this network. The real WiMax-based wireless gears do not come to the market yet. But people are already very familiar with the WiFi-based products such as notebook wireless cards and wireless routers from Linksys, D-Link and Belkin, while they are checking their emails or surfing on Internet wirelessly on campus or at airports, hotels, bookstores and coffee shops. WiFi stands for Wireless Fidelity and it is the first available technology for WLAN and wireless home networking. However it is constrained by its limited coverage of about 50-100 meters and relatively low data rate. Different from WiFi, WiMax is another new broadband wireless access technology that provides very high data throughput over long distance in a point-to-multipoint and line of sight (LOS) or non-line of sight (NLOS) environments. In terms of the coverage, WiMax can provide seamless wireless services up to 20 or 30 miles away from the base station. It also has an IEEE name 802.16-2004. It is this IEEE standard that defines the specifics of air interface of WiMax.

CONCLUSION

This paper addresses the problem of channel estimation of MIMO-OFDM systems. It starts from the matrix representation of the signal model of MIMO-OFDM systems, which clearly describes the relation of signals in frequency domain and time domain and expressing operations like adding CP and removing CP as matrix product. From the resulting MIMO-OFDM signal model, a pilot tone based channel estimation is proposed to estimate the fast time-varying and frequency-selective fading channel via the least-squares method. The least-squares is selected for the purpose of low complexity, though some other methods such as MMSE and ML may produce better estimation performance. To further reduce the computa-tional complexity, the pilot tone matrix is designed as a unitary matrix to save the computation of the matrix inversion in the standard LS solution. The pilot tone matrix is designed in a simple way that Nt disjoint pilot tone sets are placed at one.

REFERENCES