A Review on Channel Estimation in Wireless MIMO-OFDM Systems

Rupmala Barde[1], Prof. Sudesh Gupta[2]

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

Department of Electronics and Communication Engineering, TIT-S, Bhopal

Abstract-Telecommunications relay on the contribution of a wide range of advancements to fulfill the needs of enormous information clients. The blast in innovation which introduced the data age has turned into the reason for characterizing power in the cutting edge world. No advanced economy can flourish without a necessary data innovation and telecommunications framework. The great advancement of portable wireless systems and the capability of wire-less interactive media communications increment the traffic in the system and the requirement for open radio range. The quantity of new wireless applications increments and some current applications are extending. This need requires guidelines and licenses which is the situation now a days. Wireless communication systems are managed by permitting the radio Spectrum.

Keywords- MIMO-OFDM channel estimation, Sparse channel estimation.

I. INTRODUCTION

The advancement of multicarrier orthogonal frequency division multiplexing (OFDM) technology with multiple-input multiple-output (MIMO) MIMO) systems stand as promising technologies to address bottlenecks in the traffic capacity of current and future high data rate wireless communications systems like long- term evolution (LTE), Wi-Fi, and worldwide interoperability for microwave access (WiMAX). MIMO systems use multiple antennas at both the transmitter and receiver to create additional sub-channels in the spatial domain. Parallel channels are established over the same time and frequency. Therefore, higher capacity and reliability can be achieved without the need for increased transmission power or additional bandwidth. OFDM converts a frequency selective channel into a parallel set of frequency flat channels by splitting the available spectrum into a number of overlapping but orthogonal narrowband subcarriers.

Recently, the extension of MIMO systems to accommodate multiple users (multi- user MIMO) has been a major matter of interest. It is mainly motivated by the necessity to identify the network capacity improvements resulting from the employment of MIMO arrangements. In multi-user MIMO-OFDM, wireless broadband services with higher spectral efficiency can be enabled by employing multiple antennas at an access point (AP) to serve mobile stations (MS) equipped with a single antenna or multiple antennas.

The multiple paths in a channel represent the effect of multiple wave fronts. The channel is said to be time-varying, when the transmitter or the receiver is mobile or the channel is rapidly changing due to environmental conditions. Identifying the information about the channel is important in order to recover the transmitted signal at the receiver under these channel conditions. This phenomenon is referred to as channel estimation. The removal of channel effects is referred to as equalization. Channel tracking performs an important task to track a time-varying channel even after the initial channel estimation. The motivation of the study presented in this Study is to develop channel tracking algorithm that can suit the novel SDMA based multi-user MIMO-OFDM communication system.

To realize effective channel estimation in OFDM system, the characteristics of both the wireless channel and OFDM system are fundamental. In this study, we firstly focus on the effect of channel propagation, then, OFDM system model including its mathematical description is presented. After that, classical channel estimation methods are discussed. Finally, simulation comparisons are given for classical channel estimation methods for both the rich multipath and sparse multipath channels.

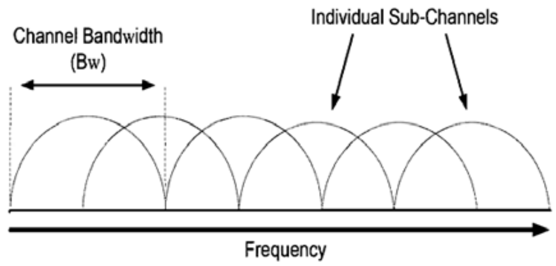

Fig. 1 OFDM Frequency Spectrum.

Wireless radio channels present huge challenge for modern high-speed and reliable communication since they are not only vulnerable to interferences and noise, but also they are highly affected by impediments, Doppler Shift (Moving Environment) and changing communication environment dynamics. The transmitted radio signals are likely to be diffracted, scattered, reflected and attenuated during their transmission, therefore, when the radio signals reach the receiver, they may have different transmission paths and random phases, furthermore their power is attenuated.

The earlier works on MIMO systems were focused mostly on basic spatial diversity and later the MIMO system was used to limit the degradation caused by multipath propagation. The multipath propagation has been the advantage turning the additional signal paths which has been considered as additional channels to carry additional data.

One of the core ideas behind MIMO wireless systems is space-time signal processing, in which time (the natural dimension of digital communication data) is complemented with the spatial dimension inherent in the use of multiple spatially distributed antennas, i.e. the use of multiple antennas located at different points. Accordingly, MIMO wireless systems can be viewed as a logical extension to the smart antennas that have been used for many years to improve wireless.

It is found that between a transmitter and a receiver; the signal can take many paths. Additionally by moving the antennas even for a small distance, the paths used will change. The variety of paths available occurs as a of the number of objects that appear to the side or even in the direct path between the transmitter and receiver.

During the transmission, there are different scales of fading. Roughly, the fading of wireless channel propagation can be classified into large scale fading, which is generally used to characterize the intensity of the transmitted signal over comparatively long transmitter-receiver (T-R) separation distance with several hundreds or thousands meters and small scale fading, which is usually employed to characterize the transmitted signal intensity over several wavelengths. For large scale fading, the main contributors are path loss and shadowing. While for small scale fading, the main contributor is multipath fading. In the following, the characteristics of both large scale fading and small scale fading of wireless channel are presented.

Sparse Channel Estimation

Channel estimation methods are crucial to realize effective sparse channel recovery. Generally, channel estimation can be classified into two categories, frequency domain channel estimation and time domain channel estimation.

Frequency domain least squares (LS) and minimum square error (MMSE) are two major classical frequency domain channel estimation methods. Generally, frequency domain MMSE method can achieve better channel estimation performance than frequency LS method, but frequency domain MMSE method requires the prior knowledge of channel statistics and noise variance. Moreover, it has an increased computational complexity. Comparatively, the complexity of frequency domain LS is low and it is popular to combine LS method with different interpolation algorithms to realize effective channel estimation. For example, linear interpolation, second-order interpolation, low pass interpolation etc are commonly used types. Among them, linear interpolation with lowest computational cost is the most classical one, but its performance relies on comparatively high percentage of pilots and it is vulnerable to noise, especially when the channel is sparse.

II. MIMO OFDM

Consider a MIMO-OFDM system with transmit and receive antennas. The transmitter and receiver are shown in Fig. 3.1 (a) and (b) respectively. Each OFDM symbol will have K subcarriers. The data to be transmitted is first modulated using M- PSK or M-QAM modulator. Then mapped symbols are grouped into groups of K symbols each to be transmitted on different antennas. The grouped symbols are coded and overlaid on K subcarriers depending upon the type of MIMO-OFDM system. The IFFT is applied to each group, and CP is added. The length of the CP is chosen to be greater than channel length L.

(a) Transmitter

(b) Receiver

Figure: 3.1 OFDM-MIMO Model.

At the receiver, each antenna will receive signals from all the transmitting antennas through multipath with noise that will be assumed to be AWGN. The receiver first removes CP from the signal and then applies FFT. The symbols are then decoded using a suitable decoder and given to the demodulator to recover transmitted binary data.

Channel Estimation

Channel estimation is the process of characterizing or analyzing the effect of the physical medium on the input sequence. The basic channel block diagram of channel estimation procedure is shown in Figure 3.2. The primary importance of channel estimation is that it allows the receiver to take into account the effect of channel on the transmitted signal, secondly channel estimation is essential for removing ISI, noise rejection techniques etc. In wideband mobile communications systems, a dynamic estimation of the channel is essential before the demodulation of OFDM signals because the radio channel is time-varying and frequency selective.

There are two main types of channel estimation methods, namely blind methods and training sequence methods. In blind methods, mathematical or statistical properties of transmitted data are used. This makes the method extremely computationally intensive and thus hard to implement on real time systems. In training sequence methods or non-blind methods, the transmitted data and training sequences known to the receiver are embedded into the frame and sent through the channel.

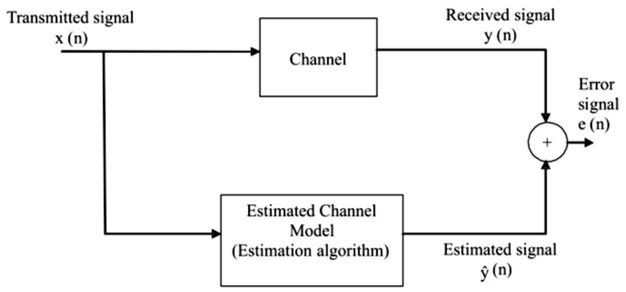

Figure: 3.2 Estimated Channel Model.

Generally, the length of the training sequence is twice or thrice the order of the channel and it is computationally simple compared to blind methods. One of the popular methods is to make use of the training bits known to the receiver. The transmitter periodically, inserts the symbol from which the receiver derives its amplitude and phase reference. Although training sequence method is much less computationally intensive than the blind methods, the channel bandwidth is not put into effective use by the transmission of training sequences.

Another channel estimation method is called semi-blind method. The semi-blind methods use information from both training sequence and statistical properties of the transmitted signal, which makes them more robust than the blind methods while they still require less training compared to the non-blind methods.

It is preferable to estimate the channel before converting the received signal to time domain so as to reduce or eliminate the risk of compounded error. Therefore in this project, frequency domain channel estimator is designed and simulated.

In OFDM system, data are modulated on frequency domain sub-channels and scaled by different sub-channel frequency response coefficients after passing through the multipath channel. For coherent detection, these sub-channel frequency responses must be estimated. This estimation is usually done using training symbols which are embedded in the symbol. In this Study pilots are used for channel estimation.

The transmission at high data rates in a wireless channel gives rise to Inter-Symbol Interference (ISI) which in distortion in transmitted signal. A complex receiver structure is required to combat ISI. Orthogonal Frequency Division Multiplexing (OFDM) is a simple solution to this problem. OFDM transmits data simultaneously on multiple carriers, which are orthogonal to each other. Thus, a high data rate stream is converted into a number of small data rate streams and transmitted simultaneously on different subcarriers.

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.

Two important technologies for energy-and-bandwidth-efficient wireless communications that have been developed over the past couple of decades are OFDM and MIMO. OFDM is known to effectively mitigate the inter-symbol interference caused by the frequency selective fading channel. Multiple-Input Multiple-Output (MIMO) systems provide spatial diversity, leading to significant gains in the capacity of the time-varying wireless channel. To reap the advantages of the above two systems, MIMO-OFDM systems have emerged as the clear choice in nearly all wireless standards.

III. LITERATURE SURVEY

Sr. no.	*Title*	*Author*	*Year*	*Approach*
1	Channel Estimation in MIMO–OFDM Systems Based on a New Adaptive Greedy Algorithm	Y. Huang, Y. He, Q. Luo, L. Shi and Y. Wu	2019	This letter proposes a new adaptive matching pursuit (NAMP) algorithm and the evaluation prototype based on the LTE-Advanced wireless channel model.
2	BEM-Based Channel Estimation and Interpolation Methods for Doubly-Selective OFDM Channel	Y. Liao et al	2018	a modified Lagrange interpolation method is also proposed in this paper which could segment the interpolation interval and find the mean value of the interpolation.
3	Structured compressed sensing-based time-frequency joint channel estimation for MIMO-OFDM systems	Y. Fan, H. Li, S. Song, W. Kong and W. Zhang	2018	This paper proposes a time-frequency joint channel estimation method based on structured compression sensing (SCS) for multi-input and multi-output orthogonal frequency division multiplexing (MIMO-OFDM) system.
4	Low-Rank Channel Estimation for MIMO MB-OFDM UWB System Over Spatially Correlated Channel,	M. Hajjaj, W. Chainbi and R. Bouallegue	2016	In this letter, we derive a low-complexity channel estimation scheme for multiple-input multiple-output multiband orthogonal frequency division multiplexing ultra wideband (MIMO MB-OFDM UWB) system over spatially correlated channel.
5	Robust MIMO-OFDM design for CMMB systems based on LMMSE channel estimation	F. Hu, Y. Wang and L. Jin	2015	In particular, a low-complexity effective strategy for transmission scheme based on parallel SFBC design is realized, while the data rate is the same as the traditional SFBC system.
6	Channel estimation for MIMO-OFDM systems	S. Manzoor, A. S. Bamuhaisoon and A. N. Alifa	2015	Channel estimation is a very important process in the operation of MIMO-OFDM systems, as it is vital for accurately estimating the Channel Impulse Response (CIR) of the channel under various conditions.
7	A convex optimization based sparse channel estimation algorithm for two-way relay networks	Ping Deng and Hongguang Xu	2011	In this paper, a new convex optimization based sparse channel estimation algorithm for two way relay networks is proposed. The theoretical analysis and simulation results show the validity of this algorithm.

Y. Huang, Y. He, Q. Luo, L. Shi and Y. Wu [1] Channel estimation methods based on compressed sensing can be used to effectively obtain channel state information of MIMO-OFDM systems. This letter proposes a new adaptive matching pursuit (NAMP) algorithm and the evaluation prototype based on the LTE-Advanced wireless channel model. First, NAMP does not need the priori-knowledge of the sparsity level. Second, the fixed step size is determined in order to improve the efficiency of signal reconstruction. Third, a singular entropy order determination mechanism is employed to prevent the less relevant atoms from being introduced. Finally, simulation results are discussed in detail, which demonstrate that the proposed method results in lower computational complexity, and especially achieves more stable performance.

Y. Liao et al [2] In high-speed environments, the time and frequency selective (doubly-selective) channel which introduces the inter-carrier interference (ICI) into OFDM system is a big challenge for receiver design. The cost of computation complexity for eliminating ICI is very high with traditional channel estimation methods. For decreasing the complexity of doubly-selective channel estimation, the base expansion model (BEM) which could eliminate ICI is adopted in this paper to reduce space complexity. At the same time, some classical interpolation algorithms based on BEM are presented, including spline interpolation, Sinc interpolation, cubic B-spline interpolation and Lagrange interpolation. In order to further improve the accuracy of channel interpolation, a modified Lagrange interpolation method is also proposed in this paper which could segment the interpolation interval and find the mean value of the interpolation.

Finally, the complexity and the performance in all aspects including estimation accuracy, bit error rate (BER) and robustness of above interpolation methods are compared and analyzed by simulation with MATLAB.

Y. Fan, H. Li, S. Song, W. Kong and W. Zhang [3] This paper proposes a time-frequency joint channel estimation method based on structured compression sensing (SCS) for multi-input and multi-output orthogonal frequency division multiplexing (MIMO-OFDM) system, which is different from traditional channel estimation scheme. In the proposed method, the received time-domain training sequences (TSs) without interference cancellation are exploited to obtain the coarse MIMO channel estimation of the path delays. By utilizing structured compression sensing method, furthermore a priori information-assisted adaptive structured subspace pursuit (PA-ASSP) algorithm which adopts a small amount of frequency domain orthogonal pilots is proposed to reconstruct the channel impulse response (CIR) of the MIMO channel so that the accurate channel gains is obtained. The simulation results show that the proposed scheme can more accurately estimate the channel with fewer pilots, and its performance is closer to the least squares (LS) algorithm.

M. Hajjaj, W. Chainbi and R. Bouallegue [4] In this letter, we derive a low-complexity channel estimation scheme for multiple-input multiple-output multiband orthogonal frequency division multiplexing ultrawideband (MIMO MB-OFDM UWB) system over spatially correlated channel. More precisely, we drive a linear minimum mean-squared-error (LMMSE) channel estimation algorithm. Then, an optimal low-rank LMMSE channel estimation method based on low-rank approximation is deduced from the LMMSE one. Through simulation results, we show that the proposed LMMSE channel estimator provides significant performance gain over least square (LS) one. We also show that the low-rank LMMSE channel estimator reduces significantly the computational complexity while maintaining comparable performance with LMMSE one for low signal-to-noise ratio (SNR) and minor performance degradation for high SNR.

F. Hu, Y. Wang and L. Jin [5] Employing MIMO-OFDM architecture in the next generation of CMMB systems offers the potential to obtain higher spectral efficiency as well as diversity gain. In particular, a low-complexity effective strategy for transmission scheme based on parallel SFBC design is realized, while the data rate is the same as the traditional SFBC system. At the receiver, the time-frequency joint LMMSE wiener filtering channel estimation is proposed to accurately track the MIMO channel variation, whereby time-domain synchronizing signal is used for path delays estimation, while the MIMO path gains are acquired by the differential pilots without interference cancellation. Finally, the simulation results demonstrate the performance advantages of the proposed robust design.

S. Manzoor, A. S. Bamuhaisoon and A. N. Alifa [6] Channel estimation is a very important process in the operation of MIMO-OFDM systems, as it is vital for accurately estimating the Channel Impulse Response (CIR) of the channel under various conditions. As such, it is useful to have a Matlab®/ Simulink to model the behavior of the channel estimation process in a MIMO-OFDM system, in order to study the error rate of the system under different modulation and SNR conditions. As one of the most common transmitter diversity schemes used in MIMO-OFDM systems is Alamouti's Space Time Block Code (STBC), a Simulink model is developed for performing channel estimation, assuming that the STBC is used. The model will then generate graphs of error rates vs SNR for different modulation schemes. The results show great improvement in Bit Error Rate (BER) by utilizing a Reed-Solomon Forward Error Correction code (RS-FEC) method.

Ping Deng and Hongguang Xu [7] Two-way relay network is a new type of modern communication. In this network two terminals can simultaneously transmit and receive information, realize high data rate transmission over the wireless frequency-selective fading channel. Under the assumption of coherent detection, the fading channel coefficients need to be firstly estimated and then used in the detection process of data information. However, conventional linear estimation techniques usually neglect the sparsity of multipath channels. To enhance the accuracy of multipath channel estimation, in this paper, a new convex optimization based sparse channel estimation algorithm for two way relay networks is proposed. The theoretical analysis and simulation results show the validity of this algorithm.

IV. PROBLEM IDENTIFICATION

OFDM has been known as a suitable candidate to be used in CR systems because of its flexibility and spectral efficiency, but the estimation in OFDM is a challenging issue. MIMO has been known as a technique in improving the wireless system performance by exploiting the channel spatial diversity, but integrating MIMO with OFDM is a challenging task because the pilot pattern design becomes more complex. Enhancing system capacity and estimation performance from previous work on combination of virtual pilot concept and Hexagonal pilot pattern in SISO OFDM by exploring the spatial diversity of the channel by the application of MIMO. Simplifying the filtering process and saving energy by utilize virtual pilots within the pilot patterns in the MIMO system.

V. CONCLUSION

Over the years, several fundamental works based on OFDM or similar multicarrier approaches have been published. However, implementation limitations delayed its practical application. The study of the fast Fourier transform and the introduction of digital signal processing techniques in modem design made the use of OFDM practical in a wide variety of applications. The use of multiple antenna technique has gained overwhelming interest throughout the last decade. The idea of using multiple antenna configuration instead of a single one has proven to be successful in enhancing data transfer rate,coverage, security and overall the performance of radio networks.

REFERENCES

[1] Y. Huang, Y. He, Q. Luo, L. Shi and Y. Wu, "Channel Estimation in MIMO–OFDM Systems Based on a New Adaptive Greedy Algorithm," in IEEE Wireless Communications Letters, vol. 8, no. 1, pp. 29-32, Feb. 2019.

[2] Y. Liao et al., "BEM-Based Channel Estimation and Interpolation Methods for Doubly-Selective OFDM Channel," 2018 IEEE International Conference on Smart Internet of Things (SmartIoT), Xi'an, 2018, pp. 70-75.

[3] Y. Fan, H. Li, S. Song, W. Kong and W. Zhang, "Structured compressed sensing-based time-frequency joint channel estimation for MIMO-OFDM systems," 2018 13th IEEE Conference on Industrial Electronics and Applications (ICIEA), Wuhan, 2018, pp. 2006-2010.

[4] M. Hajjaj, W. Chainbi and R. Bouallegue, "Low-Rank Channel Estimation for MIMO MB-OFDM UWB System Over Spatially Correlated Channel," in IEEE Wireless Communications Letters, vol. 5, no. 1, pp. 48-51, Feb. 2016.

[5] F. Hu, Y. Wang and L. Jin, "Robust MIMO-OFDM design for CMMB systems based on LMMSE channel estimation," 2015 IEEE 5th International Conference on Electronics Information and Emergency Communication, Beijing, 2015, pp. 59-62.

[6] S. Manzoor, A. S. Bamuhaisoon and A. N. Alifa, "Channel estimation for MIMO-OFDM systems," 2015 5th National Symposium on Information Technology: Towards New Smart World (NSITNSW), Riyadh, 2015, pp. 1-7.

[7] Ping Deng and Hongguang Xu, "A convex optimization based sparse channel estimation algorithm for two-way relay networks," 2011 International Conference on Multimedia Technology, Hangzhou, 2011, pp. 4748-4751.