Review of Channel estimation approaches in MIMO-LTE Networks

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***Abstract*—** MIMO-OFDM is the establishment for most exceptional wireless local area network (wireless LAN) and versatile broadband network gauges since it accomplishes the greatest spectral efficiency and, along these lines, conveys the most noteworthy limit and data throughput. Multiple information, multiple output-orthogonal frequency division multiplexing (MIMO-OFDM) is the prevailing air interface for 4G and 5G broadband wireless correspondences. In this paper MIMO-OFDM and channel estimation is reviewed.

***Keywords*—** *MIMO-OFDM, Channel estimation,Block-Type Pilot Channel Estimation, Comb-Type Pilot Channel Estimation,Throughput.*

I. INTRODUCTION

Multiple input, multiple output-orthogonal frequency division multiplexing (MIMO-OFDM) is the dominant air interface for 4G and 5G broadband wireless communications. It combines multiple input, multiple output (MIMO) technology, which multiplies capacity by transmitting different signals over multiple antennas, and orthogonal frequency-division multiplexing (OFDM), which divides a radio channel into a large number of closely spaced sub channels to provide more reliable communications at high speeds. Research conducted during the mid-1990s showed that while MIMO can be used with other popular air interfaces such as Time Division Multiple Access (TDMA) and code division multiple access (CDMA), the combination of MIMO and OFDM is most practical at higher data rates. MIMO-OFDM is the foundation for most advanced wireless local area network (wireless LAN) and mobile broadband network standards because it achieves the greatest spectral efficiency and, therefore, delivers the highest capacity and data throughput. Greg Raleigh invented MIMO in 1996 when he showed that different data streams could be transmitted at the same time on the same frequency by taking advantage of the fact that signals transmitted through space bounce off objects (such as the ground) and take multiple paths to the receiver. That is, by using multiple antennas and pre-coding the data, different data streams could be sent over different paths. Raleigh suggested and later proved that the processing required by MIMO at higher speeds would be most manageable using OFDM modulation, because OFDM converts a high-speed data channel into a number of parallel, lower-speed channels [1].

A. Channel Estimation

Complex channel estimation (i.e., estimation of channel gain, which includes phase and amplitude) performed for each individual RAKE fingers is required for coherent detection (Maximal Ratio Combining). Complex channel estimation is performed with the assistance of known transmitted pilot symbols. The accuracy of the channel estimation is crucial for RAKE receiver performance, and it depends on the pilot channel energy, the channel estimation algorithms, and the environment conditions. In particular, mobile speed is required for a variety of channel estimation algorithms [2].

B. Types of Channel Estimation

Block-Type Pilot Channel Estimation:

Under the assumption that the interferences are completely eliminated. As a result, the fading channel of the OFDM system can be viewed as a 2D lattice in a time-frequency plane, which is sampled at pilot positions and the channel characteristics between pilots are estimated by interpolation. The art in designing channel estimators is to solve this problem with a good trade-off between complexity and performance. It is thus performed by inserting pilot tones into certain subcarriers of each OFDM symbol, where the interpolation is needed to estimate the conditions of data subcarriers [3].

Comb-Type Pilot Channel Estimation:

Comb type pilot-based channel estimation is suitable for fast-fading channel where the channel condition changes between adjacent OFDM symbols. T In comb type channel estimation, after extracting the pilot signals from the received signal, the channel transfer function is estimated from the received pilot signals and the known pilot signals. The channel responses of data subcarriers can be estimated with the interpolation of the neighbouring pilot channel responses. Comb type pilot-based channel estimation can be based on least square (LS), minimum mean square error (MMSE) or least mean square (LMS) method. Here only MMSE channel estimator is employed for the estimation of channel at pilot subcarriers because of its superior performance as compared to LS estimator. Pilot signal estimation and channel interpolation algorithms are discussed in the following subsections [4].

II. LITERATURE REVIEW

Zhen Gao et.al. [5] This letter proposes a parametric sparse multiple input multiple output (MIMO)-OFDM channel estimation scheme based on the finite rate of innovation (FRI) theory, whereby super-resolution estimates of path delays with arbitrary values can be achieved. Meanwhile, both the spatial and temporal correlations of wireless MIMO channels are exploited to improve the accuracy of the channel estimation. For outdoor communication scenarios, where wireless channels are sparse in nature, path delays of different transmit-receive antenna pairs share a common sparse pattern due to the spatial correlation of MIMO channels. Meanwhile, the channel sparse pattern is nearly unchanged during several adjacent OFDM symbols due to the temporal correlation of MIMO channels. By simultaneously exploiting those MIMO channel characteristics, the proposed scheme performs better than existing state-of-the-art schemes.

Feng Wan et.al. [6] In this paper, a semiblind algorithm is presented for the estimation of sparse multiple-input–multiple-output orthogonal frequency-division multiplexing (MIMO-OFDM) channels. An analysis of the second-order statistics of the signal that was received through a sparse MIMO channel is first conducted, showing that the correlation matrices of the received signal can be expressed in terms of the most significant taps (MSTs) of the sparse channel. This relationship is used to derive a blind constraint for the effective channel vector that corresponds to the MST position. The blind constraint is then combined with the training-based least square criterion to develop a semi blind approach for the estimation of MSTs of the sparse channel. A signal perturbation analysis of the proposed approach is conducted, showing that the new semi blind solution is not subject to the signal perturbation error when the sparse channel is a decimated version of a full finite impulse response channel.

Eric Pierre Simon et.al. [7] In this paper, a novel pilot-aided algorithm is developed for multiple-input–multiple-output (MIMO) orthogonal frequency-division-multiplexing (OFDM) systems operating in a fast time-varying environment. The algorithm has been designed to work with both the parametric L-path channel model (with known path delays) and the equivalent discrete-time channel model to jointly estimate the multipath Rayleigh channel complex amplitude (CA) and the carrier frequency offset (CFO). Each CA time variation within one OFDM symbol is approximated by a basis expansion model representation. An autoregressive model is built for the parameters to be estimated. The algorithm performs estimation using extended Kalman filtering. The channel matrix is thus easily computed, and the data symbol is estimated without inter carrier interference (ICI) when the channel matrix is QR decomposed.

P. Sridhar et.al. [8] In MIMO-LTE-A Networks, maximum-likelihood receiver structure can suppress more than a single interfering layer if there are only two antennas in terminal receiver. Also, the channel state should be estimated for correctly recovering the transmitted information. Hence in this paper, proposed to design a Channel Quality Estimation with Parallel Inter Carrier

Interference (ICI) cancellation technique for MIMO-LTE-A networks. Initially the maximum-likelihood detection – interference suppression (MLD-IS) scheme is applied to suppress the interfering links. Then in ICI cancellation process, a parallel interference cancellation (PIC) method and decision statistical combining (DSC) are utilized to cancel the ICI and improve data symbol detection. The channel state is estimated by means of Linear Minimum Mean Square Error (LMMSE) method based on the Channel Quality Indicator (CQI) and Pre-coding Matrix Indicator (PMI) feedbacks.

Chenhao Qi et.al.[9] Due to multipath delay spread and relatively high sampling rate in OFDM systems, the channel estimation is formulated as a sparse recovery problem, where a hybrid compressed sensing algorithm as subspace orthogonal matching pursuit (SOMP) is proposed. SOMP first identifies the channel sparsity and then iteratively refines the sparse recovery result, which essentially combines the advantages of orthogonal matching pursuit (OMP) and subspace pursuit (SP). Since SOMP still belongs to greedy algorithms, its computational complexity is in the same order as OMP. With frequency orthogonal random pilot placement, the technique is also extend to MIMO OFDM systems.

Bor-Sen Chen et.al. [10] Channel estimation is an important issue for wireless communication systems. A channel estimation scheme using a Takagi-Sugeno (T-S) fuzzy-based Kalman filter under the time varying velocity of the mobile station in a multiple-input multiple-output orthogonal frequency-division multiplexing (MIMO-OFDM) system is proposed in this paper. The fuzzy technique is used to interpolate several linear models to approximate the nonlinear estimation system. A MIMO system with the orthogonal space-time block coding (OSTBC) scheme is considered, where the radio channel is modeled as an autoregressive (AR) random process. The parameters of the AR process and the channel gain are simultaneously estimated by the proposed method. One-step-ahead prediction can be obtained during this estimation procedure. This is useful for the decision-directed channel-tracking design, particularly in the fast-fading channel. Furthermore, the robust minimum mean-square error (MMSE) equalization design can be achieved by considering the channel prediction error to improve the performance of symbol detection.

Po-Lin Chiu et.al.[11] This paper presents a modified interpolation-based QR decomposition algorithm for the grouped-ordering multipleinput multiple-output (MIMO) orthogonal frequency division multiplexing (OFDM) systems. Based on the original research that integrates the calculations of the frequency-domain channel estimation and the QR decomposition for the MIMO-OFDM system, this study proposes a modified algorithm that possesses a scalable property to save the power consumption for interpolation-based QR decomposition in the variable-rank MIMO scheme. Furthermore, also develop the general equations and a timing scheduling method for the hardware design of the proposed QR decomposition processor for the higher-dimension MIMO system. Based on the proposed algorithm, a configurable interpolation-based QR decomposition and channel estimation processor was designed and implemented using a 90-nm one-poly nine-metal CMOS technology. The processor supports 2 2, 2 4 and 4 4 QR-based MIMO detection for the 3GPP-LTE MIMO-OFDM system and achieves the throughput of 35.16 MQRD/s at its maximum clock rate 140.65 MHz.

Wenbo Ding et.al.[12] This letter proposes a time-frequency joint sparse channel estimation for multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) systems under the framework of structured compressive sensing (CS). The proposed scheme firstly relies on a pseudo random preamble which is identical for all transmit antennas to acquire the partial common support by utilizing the sparse common support property of the MIMO channels. And then a very small amount of frequency domain orthogonal pilots are used for the accurate channel recovery. Simulation results show that the proposed scheme demonstrates better performance and higher spectral efficiency than the conventional MIMO-OFDM schemes. Moreover, the obtained partial common support can be further utilized to reduce the complexity of the CS algorithm as well as improve the signal recovery probability under low signal to noise ratio conditions.

Jin-Goog Kim et.al.[13] proposed a method of obtaining the autocorrelation matrix to improve the performance of the subspace-based channel estimation method. By exploiting the circulant property of the received signal, the proposed method reduces the number of received blocks required to satisfy the persistency of excitation (POE) criterion for the input and decreases the residual error which affects the accuracy of the noise subspace. To verify the proposed method, we derive the analytical method for evaluating the POE criterion for the input. In simulation results, we demonstrate the efficiency of the proposed method.

Nina Wang et. al. [14] Multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) is the promising technology for next generation communication systems due to high throughput. Due to the coherent receiving and demodulation at the receiver, accurate channel state information (CSI) is indispensable. Conventional rich assumption–based channel estimators have been proposed at the cost of enough training resource which leads to extra spectrum waste. However, physical measurements have verified that the wireless channels tend to exhibit sparse structure in high-dimensional space, e.g., delay spread, Doppler spread and space spread. Some sparse channel estimation methods for the MIMO-OFDM have been proposed. These estimation methods utilize either greedy algorithm or convex optimization. In this paper, a novel sparse channel estimation method is proposed using sparse cognitive matching pursuit (SCMP) algorithm. Compared to other compressive algorithms in the state of art, the major innovation of the SCMP sparse channel estimation method (SCMP-SCE) is the ability of obtaining the accurate CSI without prior information of sparsity.

Author Name	Year	Technology Used	Description
Zhen Gao et.al.	2014	Super-resolution sparse MIMO-OFDM channel estimation	This letter proposes a parametric sparse multiple input multiple output (MIMO)-OFDM channel estimation scheme based on the finite rate of innovation (FRI) theory, whereby super-resolution estimates of path delays with arbitrary values can be achieved. Meanwhile, both the spatial and temporal correlations of wireless MIMO channels are exploited to improve the accuracy of the channel estimation. For outdoor communication scenarios, where wireless channels are sparse in nature, path delays of different transmit-receive antenna pairs share a common sparse pattern due to the spatial correlation of MIMO channels. Meanwhile, the channel sparse pattern is nearly unchanged during several adjacent OFDM symbols due to the temporal correlation of MIMO channels.
Feng Wan et.al.	2011	Semiblind sparse channel estimation	In this paper, a semiblind algorithm is presented for the estimation of sparse multiple-input–multiple-output orthogonal frequency-division multiplexing (MIMO-OFDM) channels. An analysis of the second-order statistics of the signal that was received through a sparse MIMO channel is first conducted, showing that the correlation matrices of the received signal can be expressed in terms of the most significant taps (MSTs) of the sparse channel. This relationship is used to derive a blind constraint for the effective channel vector that corresponds to the MST position. The blind constraint is then combined with the training-based least square criterion to develop a semi blind approach for the estimation of MSTs of the sparse channel.
Eric Pierre Simon et.al.	2011	Joint carrier frequency offset and fast time-varying channel estimation	In this paper, a novel pilot-aided algorithm is developed for multiple-input–multiple-output (MIMO) orthogonal frequency-division-multiplexing (OFDM) systems operating in a fast time-varying environment. The algorithm has been designed to work with both the parametric L-path channel model (with known path delays) and the equivalent discrete-time channel model to jointly estimate the multipath Rayleigh channel complex amplitude (CA) and the carrier frequency offset (CFO). Each CA time

			variation within one OFDM symbol is approximated by a basis expansion model representation. An autoregressive model is built for the parameters to be estimated. The algorithm performs estimation using extended Kalman filtering. The channel matrix is thus easily computed, and the data symbol is estimated without inter carrier interference (ICI) when the channel matrix is QR decomposed.
P. Sridhar et.al.	2016	Interference cancellation and channel estimation	In MIMO-LTE-A Networks, maximum-likelihood receiver structure can suppress more than a single interfering layer if there are only two antennas in terminal receiver. Also, the channel state should be estimated for correctly recovering the transmitted information. Hence in this paper, proposed to design a Channel Quality Estimation with Parallel Inter Carrier Interference (ICI) cancellation technique for MIMO-LTE-A networks. Initially the maximum-likelihood detection – interference suppression (MLD-IS) scheme is applied to suppress the interfering links. Then in ICI cancellation process, a parallel interference cancellation (PIC) method and decision statistical combining (DSC) are utilized to cancel the ICI and improve data symbol detection.
Chenhao Qi et.al.	2011	A hybrid compressed sensing algorithm	Due to multipath delay spread and relatively high sampling rate in OFDM systems, the channel estimation is formulated as a sparse recovery problem, where a hybrid compressed sensing algorithm as subspace orthogonal matching pursuit (SOMP) is proposed. SOMP first identifies the channel sparsity and then iteratively refines the sparse recovery result, which essentially combines the advantages of orthogonal matching pursuit (OMP) and subspace pursuit (SP). Since SOMP still belongs to greedy algorithms, its computational complexity is in the same order as OMP.
			With frequency orthogonal random pilot placement, the technique is also extend to MIMO OFDM systems.
Bor-Sen Chen et.al.	2012	Robust fast time-varying multipath fading channel estimation and equalization	Channel estimation is an important issue for wireless communication systems. A channel estimation scheme using a Takagi-Sugeno (T-S) fuzzy-based Kalman filter under the time varying velocity of the mobile station in a multiple-input multiple-output orthogonal frequency-division multiplexing (MIMO-OFDM) system is proposed in this paper. The fuzzy technique is used to interpolate several linear models to approximate the nonlinear estimation system. A MIMO system with the orthogonal space-time block coding (OSTBC) scheme is considered, where the radio channel is modeled as an autoregressive (AR) random process. The parameters of the AR process and the channel gain are simultaneously estimated by the proposed method. One-step-ahead prediction can be obtained during this estimation procedure. This is useful for the decision-directed channel-tracking design, particularly in the fast-fading channel.
Po-Lin Chiu et.al.	2011	Interpolation-based QR decomposition and channel estimation processor	This paper presents a modified interpolation-based QR decomposition algorithm for the grouped-ordering multiple input multiple-output (MIMO) orthogonal frequency division multiplexing (OFDM) systems. Based on the original research that integrates the calculations of the frequency-domain channel estimation and the QR decomposition for the MIMO-OFDM system, this study proposes a modified algorithm that possesses a scalable property to save the power consumption for interpolation-based QR decomposition in the variable-rank MIMO scheme.
Wenbo Ding et.al.	2015	Time–frequency joint sparse channel estimation	This letter proposes a time-frequency joint sparse channel estimation for multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) systems

			under the framework of structured compressive sensing (CS). The proposed scheme firstly relies on a pseudo random preamble which is identical for all transmit antennas to acquire the partial common support by utilizing the sparse common support property of the MIMO channels. And then a very small amount of frequency domain orthogonal pilots are used for the accurate channel recovery. Simulation results show that the proposed scheme demonstrates better performance and higher spectral efficiency than the conventional MIMO-OFDM schemes.
Jin-Goog Kim et.al.	2012	Subspace-based channel estimation	proposed a method of obtaining the autocorrelation matrix to improve the performance of the subspace-based channel estimation method. By exploiting the circulant property of the received signal, the proposed method reduces the number of received blocks required to satisfy the persistency of excitation (POE) criterion for the input and decreases the residual error which affects the accuracy of the noise subspace. To verify the proposed method, we derive the analytical method for evaluating the POE criterion for the input. In simulation results, it demonstrate the efficiency of the proposed method.
Nina Wang et. al.	2011	A novel sparse channel estimation method	In this paper, a novel sparse channel estimation method is proposed using sparse cognitive matching pursuit (SCMP) algorithm. Compared to other compressive algorithms in the state of art, the major innovation of the SCMP sparse channel estimation method (SCMP-SCE) is the ability of obtaining the accurate CSI without prior information of sparsity.

III. CONCLUSION

It consolidates multiple information, multiple output (MIMO) technology, which increases limit by transmitting distinctive flags over multiple receiving wires, and orthogonal frequency-division multiplexing (OFDM), which isolates a radio channel into an extensive number of firmly separated sub-channels to give more dependable correspondences at high speeds. In this paper MIMO-OFDM and channel estimation is reviewed.

IV. REFERENCES

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