Extensive Review on Time-Frequency Joint Channel Estimation for MIMO-OFDM Systems

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Abstract-The development of orthogonal frequency division multiplexing (OFDM) has enables excellence method for accomplishing high-speed data transmission with high bandwidth effectiveness in frequency-selective multipath fading channels. The requirement of channel state information is the fundamental problem with coherent OFDM systems. For coherent location of the information symbols, the channel gain of each sub-carrier is required. This problem is additionally complicated when time-varying of the channel fading and the correlation between the sub-channels due to Doppler frequencies. With compressed sensing, the sampling rate can possibly be reduced. A compressed sensing approach utilized, the receiver comprises of a various analog correlators that process the received signal by anticipating the received signal utilizing random(or pseudo random) vectors. In this examination presented an extensive review on time-frequency joint channel estimation for MIMO-OFDM framework.

Keywords- Wireless Communication, Channel Estimation, OFDM, MIMO-OFDM, Time-Frequency Joint Channel Estimation.

I. INTRODUCTION

For OFDM systems utilizing coherent demodulation, perfect channel estimation is critical in terms of low BER performance. Unlike for systems with a single-transmit antenna, the channel estimation process for OFDM systems with multiple transmit antennas is complex. Orthogonal Frequency Division Multiplexing (OFDM) originated from the need of efficient communications through frequency-selective fading channels. A channel is frequency- selective if the frequency response of the channel changes significantly within the band of the transmitted signal. While, a constant frequency response is called flat fading. Fig.1.1 (a), (b) exemplifies the frequency-selective and flat fading channels. Digitally modulated signals going through a frequency-selective channel will be distorted, resulting in inter-symbol-interference (ISI). To mitigate the ISI, a complex equalizer is usually needed to make the frequency response of the channel flat within the bandwidth of interest; or the symbol duration must be long enough so that the ISI-affected portion of a symbol can be negligible. From the frequency-domain viewpoint, the latter approach means to transmit a narrow-band signal within whose bandwidth the channel can be well considered to be flat fading, as shown in Fig. 1.1 (d). This fact gives the idea that one can transmit several low-rate data streams, each at a different carrier frequency through the channel in parallel, and each data stream is ISI-free and only a simple one-tap equalizer is need to compensate the flat fading. This idea is illustrated in Fig. 1.2. That is actually the idea of Frequency Division Multiplexing (FDM).

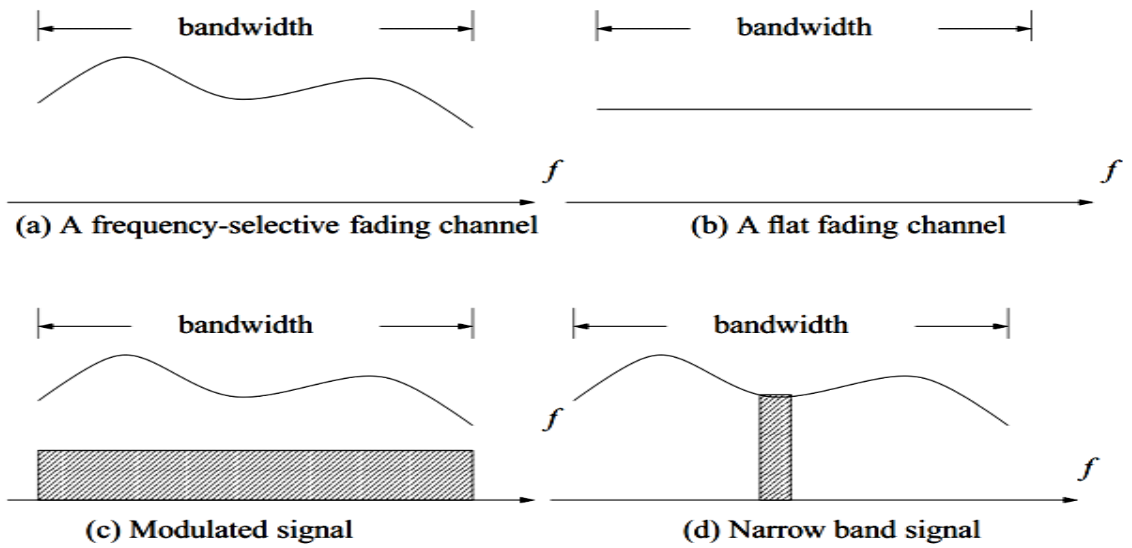

Fig. 1.1 Signals transmitted through frequency-selective channels.

However, this multi-carrier transmission scheme may suffer inter-carrier interference (ICI), i.e., the signals of neighboring carriers may interfere each other. To avoid the ICI, guarding bands are employed in FDM to separate different sub-carriers. This results in a waste of the spectrum. OFDM follows the very similar multi-carrier modulation strategy. However, it employs the orthogonality among sub-carriers to eliminate the ICI without the need of the guarding bands.

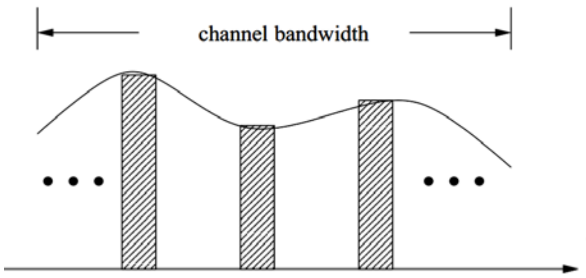

Fig. 1.2 Multi-carrier modulation scheme

II. MIMO OFDM

The spectrum of OFDM is shown in Fig. 2.1. From the figure It has been seen that those subcarriers are overlapping. Transmitting in parallel increases the symbol duration for the lower rate parallel subcarriers. This reduces the relative amount of dispersion in time caused by multipath delay spread. To save bandwidth in an OFDM signal, the carriers are arranged in a way that the sidebands of the individual carriers overlap as shown in Fig. 2.2 and the signals are still received without adjacent carrier interference. To achieve this, the carriers need to be mathematically orthogonal. The word orthogonal means that the frequencies of the carriers in the system have a precise mathematical relationship. Thus the carriers need to be linearly independent. This linear independence can be realized only if the carrier spacing is a multiple of 1/Ts, where Ts is the symbol period. The signal obtained from the OFDM demodulator will be integrated over a symbol period to recover the transmitted data. This integration will be zero for the other subcarriers if the frequencies of those subcarriers (in time domain) have an integer number of cycles in the symbol period T. OFDM is the most appropriate candidate to be used for the future communication techniques such as cognitive radio or smart radio. This is because in OFDM, individual subcarriers can be deactivated (subcarriers are fed with zeros) depending on the availability of the channel. It supports data rates which fulfill the needs of communication today with sufficient robustness of the radio channel. OFDM can handle multipath propagation efficiently and it is robust against frequency selective fading or narrow band interference, because only a certain number of the subcarriers could be affected. Affected subcarriers can be repaired using error correcting codes. The performance of the OFDM link is determined by the average received power rather than the power of the weakest carrier.

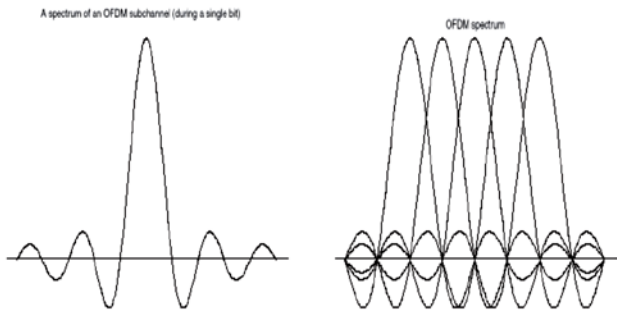

Fig.2.1 OFDM spectrum, one subcarrier (left) and five subcarriers (right).

For mobile communications, the channel tap coefficients are random variables. In case the wireless channel varies very slowly, the tap coefficients remain constant for each frame of data. For Rayleigh fading channels, the channel tap coefficients are modeled as complex Gaussian random variables which have zero mean. The different channel taps are assumed to be independent. The average channel gains for different paths are determined from the power Delay profile of the wireless channel. If the MIMO-OFDM system has N_c subcarriers and the fading coefficients are spatially uncorrelated and that the fading coefficients remain constant during one OFDM symbol. Then the transmitted signal over M antennas can be represented by a matrix X_{OFDM} with dimensions $N_{cx}M$. A symbol transmitted at subcarrier n on transmit antenna i is $x_i(n)$.

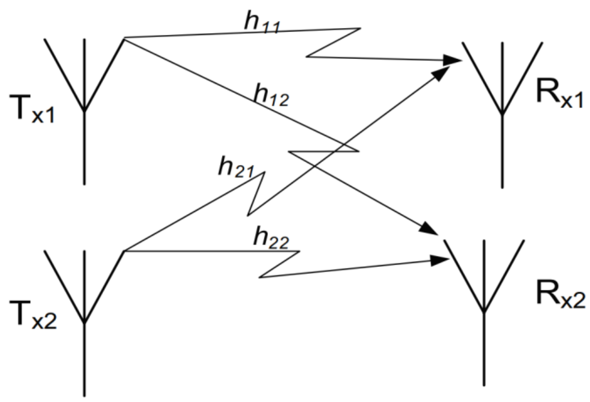

Fig.2.2 MIMO System Model.

III. LITERATURE REVIEW

SR. NO.	TITLE	AUTHORS	YEAR	APPROACH
1	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	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 has reported in this work
2	Beam-Blocked Channel Estimation for FDD Massive MIMO With Compressed Feedback	W. Huang, Y. Huang, W. Xu and L. Yang	2017	A compressive channel estimation scheme for FDD massive MIMO systems, has reported where the beam-blocked sparsity of massive MIMO channels in beamspace is leveraged
3	Performance comparison of massive MIMO and conventional MIMO using channel parameters	M. Pappa, C. Ramesh and M. N. Kumar	2017	This work concentrate on estimating the channel parameters for conventional MIMO and massive MIMO based on training-based and blind channel estimation techniques wherein the performance of both is compared
4	Selective detection with adaptive channel estimation for MIMO OFDM	M. Kashoob and Y. Zakharov	2016	This work investigate the performance of a new selective detection algorithm that is a modification
5	Joint channel and phase noise estimation in MIMO-OFDM systems	I. M. Ngebani, I. Zibani, E. Matlotse, K. Tsamaase and J. M. Chuma	2016	In this work the problem of joint channel and phase noise estimation in a system with multiple transmit and receive antennas where each antenna is equipped with its own independent oscillator is tackled
6	Enhanced channel estimation for Spatial Multiplexing MIMO-OFDM system	G. R. Patil and V. K. Kokate	2015	In this work an enhanced channel estimation for Spatial Multiplexing (SM) Multiple Input Multiple Output (MIMO) Orthogonal Frequency Division Multiplexing (OFDM) system has reported
7	Investigation of blind and pilot based channel estimation performances in MIMO-OFDM system	S. Ü. Ercan and Ç. Kurnaz	2015	MIMO-OFDM channel estimation performance is investigated by using two different frequency selective channels for a blind algorithm based on independent component analysis (ICA) and comb type pilot based algorithm in this work
8	MIMO-OFDM channel estimation using distributed compressed sensing,	B. L. Priyanka, K. Rajeswari and S. J. Thiruvengadam	2014	In this work a method of sparse channel estimation using compressed sensing for MIMO-OFDM system has reported

Y. Fan, H. Li, S. Song, W. Kong and W. Zhang, [1] This work 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.

W. Huang, Y. Huang, W. Xu and L. Yang, [2] to fully exploit both multiplexing gain and array gain of massive multiple-input-multipleoutput (MIMO), the channel state information must be obtained accurately at transmitter side (CSIT). However, conventional channel estimation solutions are not suitable for frequency-division duplexing (FDD) multiuser massive MIMO because of overwhelming pilot and feedback overhead. To reduce the pilot and feedback overhead of channel estimation in FDD systems, a compressive channel estimation scheme for FDD massive MIMO systems is reported this work, where the beam-blocked sparsity of massive MIMO channels in beamspace is leveraged. Particularly, first a beam-blocked compressive channel estimation scheme has reported, which can reduce the overhead for downlink training. Then, an optimal block orthogonal matching pursuit algorithm at the BS is proposed to acquire reliable CSIT from the limited number of pilots. Furthermore, an efficient algorithm for channel matrix recovery from separately quantized amplitude and phase of received signals is developed to efficiently decrease feedback load. Simulation results demonstrate that our proposed scheme outperforms conventional solutions.

M. Pappa, C. Ramesh and M. N. Kumar, [3] Multiple-input multiple-output (MIMO) technology is becoming mature in wireless communication systems. It has led to third and fourth generation wireless systems, which has been providing good range, reliability and higher data rates. For the increased demand of much higher data rates, coverage, spectral efficiency, capacity and reduced latency, the evolution of the next generation i.e., the fifth generation technology is necessary. Massive MIMO technology is one of the most promising solutions for the above-mentioned challenge. In massive MIMO, the base station is incorporated with hundreds to thousands of antenna array wherein the degrees of freedom can be exploited and the energy can be efficiently used due to the fact that the extra antennas at the base station helps focus the energy into the smaller regions of space. To reap the benefits provided by the extra antennas, the channel information is necessary which makes it possible to have a reliable communication. Therefore, to acquire the channel knowledge, channel state information is required at the base station and estimating the channel parameters plays an important role. In this work, concentrate on estimating the channel parameters for conventional MIMO and massive MIMO based on training-based and blind channel estimation techniques wherein the performance of both is compared.

M. Kashoob and Y. Zakharov, [4] in this work, investigate the performance of a new selective detection algorithm that is a modification of that proposed in [1]. The channel estimation used is based on adaptive model-based regularization in Multi Input Multi Output (MIMO) OFDM systems. The Basis Expansion Model (BEM) approach is employed for channel estimation. For the adaptive regularization, regularization matrices are computed for a set of uniform power delay profiles. The generalized cross-validation method is then used to select a best matrix from the prcomputed set. The performance of the detector implementing the channel estimation with adaptive regularization with the performance of the detector is compared using the Linear Minimum Mean Square Error (LMMSE) channel estimation.

I. M. Ngebani, I. Zibani, E. Matlotse, K. Tsamaase and J. M. Chuma [5] The combination of MIMO techniques with OFDM, MIMO-OFDM, is a promising way of achieving high spectral efficiency in wireless communication systems. However, the performance of MIMO-ODFM systems is highly degraded by RF impairments such as phase noise. Similar to the SISO case, phase noise in MIMO-OFDM systems results in a common phase error (CPE) and inters carrier interference (ICI). In this work the problem of joint channel and phase noise estimation in a system with multiple transmits and receives antennas where each antenna is equipped with its own independent oscillator is tackled. The technique employed makes use of a novel placement of pilot carriers in the preamble and data portion of the MIMO-OFDM frame. Numerical results using a 16 and 64-QAM modulation scheme are provided to illustrate the effectiveness of the proposed scheme for MIMO-OFDM systems.

G. R. Patil and V. K. Kokate [6] this work presents, enhanced channel estimation for Spatial Multiplexing (SM) Multiple Input Multiple Output (MIMO) Orthogonal Frequency Division Multiplexing (OFDM) system. Initial estimate of the channel is obtained using pilot assisted Least Square (LS) channel estimation using frequency domain approach. Recovered symbols are used to further enhance the channel estimate through time domain approach. The performance of the proposed estimator is demonstrated using computer simulations which are carried out under different channel conditions. S. Ü. Ercan and Ç. Kurnaz [7] In order to decrease wireless channel's destructive effects and increase system performance in multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) system, channel state information (CSI) is required. CSI is obtained by using pilot based; blind and semi-blind channel estimation algorithms. Though blind algorithm has low system performance is preferred owing to its high bandwidth efficiency. In this study, MIMO-OFDM channel estimation performance is investigated by using two different frequency selective channels for a blind algorithm based on independent component analysis (ICA) and comb type pilot based algorithm. It is seen from the results that MIMO-OFDM channel estimation performance changes according to channels frequency selectivity's, and pilot based algorithm is not always given best results.

B. L. Priyanka, K. Rajeswari and S. J. Thiruvengadam [8] this work proposes a method of sparse channel estimation using compressed sensing for MIMO-OFDM system. The channel estimation is formulated as a sparse recovery problem because of the maximum delay spread in the high data rate OFDM communication systems. The proposed Distributed Compressed Sensing (DCS) algorithm for channel estimation in MIMO-OFDM system exploits the join sparsity of the MIMO channel. It takes less number of iterations in solving the channel estimation problem and runs much faster than the existing Compressive Sampling Matching Pursuit (CoSaMP). Simulation results demonstrate the validity of the algorithm. For the MIMO channels of unknown sparse degrees, the proposed DCS algorithm gives good channel estimation performance with less number of subcarriers reducing the complexity of the system.

IV. PROBLEM STATEMENT

Modern digital RF (radio frequency) communication systems are able to operate very close to theoretical performance limits. This fact has enabled everyday technologies, such as cellular telephony and digital television, as well as more exotic applications such as secure military communications and deep-space links with robotic probes. However, many of these systems depend on coherent detection, which requires that the phase of the received signal to be known. In practice, a wireless receiver will not have prior knowledge of the phase of the received RF signal; therefore the receiver must derive the phase of the signal from careful measurement of the signal’s parameters. The process of estimating and compensating for the phase is called carrier synchronization or carrier recovery. 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 [1]. The efficiency and robustness is always a challenge for MIMO channel estimation scheme to be optimized in terms of BER and MSE.

V. CONCLUSION

In this examination an extensive review on Time-Frequency joint channel estimation for MIMO-OFDM systems has reported. Multipath and fading are two important issues in radio communication systems which have to be well understood in order to design a reliable and efficient communication system. Channel estimation methods also show some difference between systems with a single-transmit antenna and systems with transmitter diversity. While the complexity of the estimators is low for systems with a single-transmit antenna, the estimators for systems with multiple transmitters are very complex. This high complexity stems from the fact that signals transmitted from multiple antennas interfere with each other at the receivers. The channel estimation in OFDM is a challenging task. To solve this challenge by designing different pilot pattern to estimate the wireless channel is required. A way for enhancing the spectrum utilization efficiency is by improving the bitrate or BER of the wireless system.

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