A Survey on Time-Frequency Joint Channel Estimation for MIMO-OFDM Systems

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Abstract-Wireless communications systems have advanced significantly in the past years and played an extremely important role in our society. The demand for communications among people is increasing exponentially, requiring more connectivity, more services, and higher quality. Wireless communication is the transfer of information without the use of wires, allowing the user the freedom to be mobile. Apart from user satisfaction, there is a very legitimate justification of wireless connectivity from the service provider's point of view. There are many areas in the world that are still inaccessible to land line systems due to their remoteness or because of intervening inhospitable terrain. In addition, the economic point of view has also helped in the success of wireless communications. The requirement for high rate information administrations is developing, particularly as sight and sound applications picking up prevalence as they require higher information rate with nature of administration.

Keywords-MIMO Systems, channel estimation, Compression sensing.

I. INTRODUCTION

Orthogonal Frequency Division multiplexing (OFDM), the multi-carrier modulation (MCM) technique, has been seen to be very effective for communication over channels with frequency selective fading. It is very difficult to handle frequency selective fading in conventional communication receivers as the design of the receiver becomes hugely complex. OFDM technique efficiently utilizes the available channel bandwidth by dividing the channel into low bandwidth continuous channels. Instead mitigating frequency selective fading as a whole, OFDM mitigates the problem by converting the entire frequency selective fading channel into number of narrow bandwidth flat fading channels. Flat fading makes the receiver easier to combat channel tracking and Inter Symbol Interference (ISI) by employing simple equalization schemes.

Spread spectrum modulation has been the basis for majority of proprietary communication and broadcasting technology including wireless local Area Networks (WLANs), Zig Bee, Ultra Wide Band (UWB) and others. Through the use of frequency hopping and direct sequence, these WLANs provide data rates from 1 to 11 Mbps. Regardless of these relatively high data rates, there has been an increasing demand of higher data rate for wireless broadband Local Area Networks (LANs) and Metropolitan Area Networks (MANs). Because of relatively inefficient use of bandwidth, spread spectrum systems did not satisfy the even higher data rates that multimedia applications required. In addition, multimedia applications operating outdoors or within industrial environments require a wireless network capable of operating more effectively in "RF hostile" areas. Consideration of more efficient and robust OFDM technology became a viable option for high data rate multimedia implementations. OFDM sometimes referred to as multi-carrier or discrete multi-tone modulation, utilizes multiple sub-carriers to transport information from one user to another.

OFDM is a form of signal modulation that divides a high data rate modulating stream to many slowly modulated narrowband close-spaced sub-carriers. In this way narrowband sub-channels, carried by close-spaced sub-carrier, becomes less sensitive to frequency selective fading. In some respects, OFDM is similar to conventional frequency-division multiplexing (FDM). The difference lies in the process in which individual sub-carriers are modulated and demodulated. Priority is also given to minimize the interference and crosstalk among the channels and symbols comprising the data stream. Generally all channels are handled together and individual channels are never handled separately.

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.

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. A possible way of performing channel estimation is illustrated in Fig.

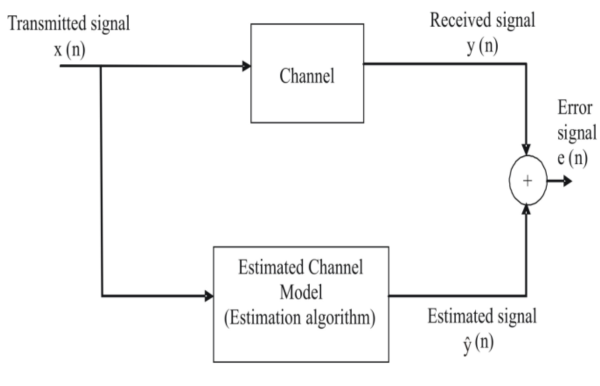

Figure: Estimated Channel Model.

Structured Compressed Sensing

Compressed sensing (CS) is an emerging field that has attracted considerable research interest in the signal processing community. Since its introduction only several years ago, thousands of papers have appeared in this area, and hundreds of conferences, workshops, and special sessions have been dedicated to this growing research field.

Due to the vast interest in this topic, there exist several excellent review articles on the basics of CS. These articles focused on the first CS efforts: the use of standard discrete-to-discrete measurement architectures using matrices of randomized nature, where no structure beyond sparsity is assumed on the signal or in its representation.

II. MIMO-OFDM

An immense amount of research interest has recently been concentrated on the modulation techniques that exhibit a high potential to satisfy the challenging requirements such as high data rates, imposed by the rapidly evolving wireless communications applications including wireless multimedia, wireless Internet access, and future-generation mobile communication systems. OFDM is a promising digital modulation scheme to simplify the equalization in frequency selective channels and provide simpler. As detailed in the previous section, MIMO communications technology, can achieve significant increases in the channel capacity. Therefore, the combination of OFDM with MIMO communications.

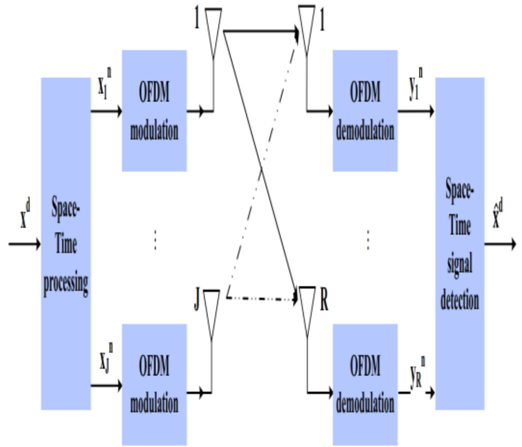

Figure MIMO OFDM System.

Which is MIMO-OFDM systems, can realize high-performance transmissions. Although, multi-path propagation causes frequency selectivity in broadband wireless channels, most MIMO systems are used for channels with flat fading. Therefore, the MIMO-OFDM technique has initially been proposed to use OFDM to alleviate ISI in MIMO systems and found to be a propitious selection for high data rate wireless broadband communications.

The capability of OFDM systems to cope with highly time-variant wireless channel characteristics explains the rapid employment of OFDM systems in the latest wireless communications systems. However, as stated in, systems knowledge pertaining to the channel conditions encountered is crucial in achieving high capacity and the realizable integrity of communication systems. Therefore, the provision of an accurate and efficient channel estimation approach is a critical feature in accomplishing high performance wireless system.

Joint Channel Estimation

In the communication between terminals in either point-to-point or multi-user scenarios, channel estimation is a crucial task since the reliable detection of data is based on the knowledge of channel state information (CSI). In practice, this task is accomplished by sending from the transmitters a training sequence before the actual data to probe the channel, and then estimating the channel parameters at the receivers. Consider the problem of estimation of a frequency-selective time-invariant channel of length N between a transmitter X and a receiver Y , in a single-carrier system.

Channel estimation for purposes of equalization is a long standing problem in signal processing. Wireless propagations are characterized by sparse channels that are channels whose time domain impulse response consists of a large number of negligible time intervals. This study examines the use of compressed sensing, an emerging theory for sparse signals, in the estimation of highly sparse channels.

III. LITERATURE SURVEY

S. No.	Title	Author	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	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
2	Field of experts: Optimal structured Bayesian compressed sensing	X. Lan and K. Barner	2017	In this paper, author propose an optimal structured Bayesian Compressed Sensing (BCS) reconstruction framework. Constructed to capture signal structure precisely, this framework employs Field of Experts (FoE) to fuse Hidden Markov Random Fields with Gaussian Scale Mixtures as prior distributions.
3	The design of a dual-structured measurement matrix in compressed sensing	J. Qiao and X. Zhang	2016	This paper constructs a new dual-structured measurement matrix-unit array + random matrix, by combining the advantages of the random measurement matrices with high recovery probability and the structured measurement matrices of low storage.
4	Compressed Sensing Remote Sensing Image Reconstruction Based on Wavelet Tree and Nonlocal Total Variation	W. Hao, M. Han and W. Hao	2016	In this paper for solving the compressed sensing remote sensing image reconstruction. Experiments show the well performance of our model in reconstruction accuracy compared to other methods.
5	Time–Frequency Joint Sparse Channel Estimation for MIMO-OFDM Systems	W. Ding, F. Yang, W. Dai and J. Song	2015	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).
6	Tensor Space-Time-Frequency Coding With Semi-Blind Receivers for MIMO Wireless Communication Systems	G. Favier and A. L. F. de Almeida	2014	In this paper, author first introduce two new classes of constrained tensor models that author call generalized PARATUCK- (N1, N) and Tucker- (N1, N) models. A new tensor space-time-frequency (TSTF) coding structure is then proposed for MIMO OFDM-CDMA wireless communication systems
7	Spectrally Efficient Time-Frequency Training OFDM for Mobile Large-Scale MIMO System	L. Dai, Z. Wang and Z. Yang	2013	In this paper, author propose the time-frequency training OFDM (TFT-OFDM) transmission scheme for large-scale MIMO systems, where each TFT-OFDM symbol without cyclic prefix adopts the time-domain training sequence (TS) and the frequency-domain orthogonal grouped pilots as the time-frequency training information.

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

X. Lan and K. Barner [2] Exploiting signal structure can improve Compressed Sensing reconstruction performance. In this paper, we propose an optimal structured Bayesian Compressed Sensing (BCS) reconstruction framework. Constructed to capture signal structure precisely, this framework employs Field of Experts (FoE) to fuse Hidden Markov Random Fields with Gaussian Scale Mixtures as prior distributions. This approach optimizes the parameters of FoE by minimizing KL-divergence via Contrastive Divergence learning method. An analytical posterior inference via auxiliary-variable Gibbs sampler is then constituted to reconstruct the signal. Simulations show that this proposed method, named Optimal Structured BCS based on FoE (OS-BCS-FoE), outperforms previous CS recovery methods used for image restoration applications.

J. Qiao and X. Zhang [3] The design of measurement matrices is one of the key contents of the compressed sensing (CS) theory. This paper constructs a new dual-structured measurement matrix-unit array + random matrix, by combining the advantages of the random measurement matrices with high recovery probability and the structured measurement matrices of low storage. The experiments show that the reconstruction errors can be gotten lower through using the measurement matrix designed than those of the simple application of the random measurement matrix. Then a method of sub-frame overlapping is proposed for reconstructing the entire signal, which can remove large errors caused by unit array in the measurement matrix, and ensure the stability of the whole signal reconstruction. Simulation results demonstrate that the signal to noise ratio (SNR) is increased significantly and the reconstruction performance of signal is improved remarkably.

W. Hao, M. Han and W. Hao [4] Compressed sensing reconstructs data using much less sampling data, generally as O(K+Klogn), compared to Nyquist theory. K is the sparsity of data and n is the length of data. Furthermore, according to the basic principle of structured sparsity theory, for a standard K-sparse data, the measurements need for reconstructing original data can be further reduced from O(K+Klogn) to O(K+logn). The wavelet coefficients have tree structure and can be used in compressed sensing. The nonlocal total variance (NLTV) is highly effective in sharping image edges and preserving fine details. It also performs well in getting rid of the block effects caused by total variance (TV). Consequently, a new model based on NLTV and wavelet tree is proposed in this paper for solving the compressed sensing remote sensing image reconstruction. Experiments show the well performance of our model in reconstruction accuracy compared to other methods.

W. Ding, F. Yang, W. Dai and J. Song [5] 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 first relies on a pseudorandom 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. 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 and improve the signal recovery probability under low signal-to-noise-ratio conditions.

G. Favier and A. L. F. de Almeida [6] In this paper, we first introduce two new classes of constrained tensor models that we call generalized PARATUCK- (N1, N) and Tucker- (N1, N) models. A new tensor space-time-frequency (TSTF) coding structure is then proposed for MIMO OFDM-CDMA wireless communication systems. Two semi-blind receivers relying on the new generalized PARATUCK model are derived for solving the problem of joint channel and symbol estimation. One is iterative and based on a two-step alternating least squares (ALS) algorithm. The other one is a closed-form and low-complexity solution which consists of the Kronecker product least squares (KPLS) estimation of the symbol matrix and a matrix unfolding of the channel tensor. Uniqueness of the underlying tensor model is discussed and system design requirements are derived for applicability of the ALS and KPLS receivers. We also show that the so-called TSTF system can be viewed as an extension of three existing tensor-based ST/TST/STF coding systems that are described in a unified framework. Computer simulation results illustrate the good performance of the TSTF system which outperforms the considered existing tensor-based systems both in terms of symbol estimation quality and allocation flexibility.

L. Dai, Z. Wang and Z. Yang [7] Large-scale orthogonal frequency division multiplexing (OFDM) multiple-input multiple-output (MIMO) is a promising candidate to achieve the spectral efficiency up to several tens of bps/Hz for future wireless communications. One key challenge to realize practical large-scale OFDM MIMO systems is high-dimensional channel estimation in mobile multipath channels. In this paper, we propose the time-frequency training OFDM (TFT-OFDM) transmission scheme for large-scale MIMO systems, where each TFT-OFDM symbol without cyclic prefix adopts the time-domain training sequence (TS) and the frequency-domain orthogonal grouped pilots as the time-frequency training information. At the receiver, the corresponding time-frequency joint channel estimation method is proposed to accurately track the channel variation, whereby the received time-domain TS is used for path delays estimation without interference cancellation, while the path gains are acquired by the frequency-domain pilots. The channel property that path delays vary much slower than path gains is further exploited to improve the estimation performance, and the sparse nature of wireless channel is utilized to acquire the path gains by very few pilots. We also derive the theoretical Cramer-Rao lower bound (CRLB) of the proposed channel estimator. Compared with conventional large-scale OFDM MIMO systems, the proposed TFT-OFDM MIMO scheme achieves higher spectral efficiency as well as the coded bit error rate performance close to the ergodic channel capacity in mobile environments.

IV. PROBLEM IDENTIFICATION

In wireless communication condition, the primary issue is to battle channel estimation. Multipath is a wonder that happens because of the entry of the transmitted signal through various ways. The signal touches base at the recipient through various points, with various time delays and distinctive frequency shifts. Channel estimation algorithms enable the beneficiary to surmise the motivation reaction of the channel. This information of the channel's conduct is well-used in present day radio communications. adaptive channel equalizers use channel evaluations to defeat the impacts of entomb symbol obstruction. Decent variety procedures use the channel gauge to actualize a coordinated channel with the end goal that the collector is ideally coordinated to the gotten signal rather than the transmitted one. Greatest probability finders use channel estimates to limit the error likelihood.

V. CONCLUSION

Wireless communication systems are picking up fame particularly as for cell phones and wireless information devices in light of their convenience and portability. At first, wireless systems was for the most part planned and created to help voice. Along these lines, new wireless systems must be planned considering the requirement for information and sight and sound administrations. One of the well known wireless systems is wireless neighborhood (WLANs) which interconnects the PCs and other handheld gadgets in short range, normally in an office space.

Data is one of the fundamental qualities of our cutting edge and fast creating world. There is no uncertainty that the data insurgency quickens the pace of life of conventional individuals and logical research in different fields. Every day, we utilize tremendous measure of data, including sound, pictures, and content information, etc. Among every one of these information, an extensive sum is transmitted by different sorts of wireless communication systems.

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