Channel Estimation based on Compressive Sensing in OFDM Systems under Severely Fading Channels

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***Abstract*— Orthogonal Frequency Division Multiplexing (OFDM) is a digital multicarrier transmission technique which is based on Frequency division Multiplexing. Several multimedia standards uses Time Frequency Training (TFT) OFDM systems as the key modulation technique. This paper introduces a high accurate low complexity compressive sensing (CS) based channel estimation namely Auxiliary information based Subspace Pursuit in TFT-OFDM systems. ASP based channel estimation in TFT-OFDM system is based on two steps. Firstly by using time domain training sequence (TS) path delay can be estimated. Then secondly by using a small amount of frequency domain pilots inserted into the OFDM data block channel can be perfectly estimated. Furthermore, the auxiliary information obtained in the first step is used to reduce complexity. Simulation results shows that proposed ASP algorithm has better performance than existing algorithm in both static and dynamic scenarios.**

Keywords- Channel estimation(CE), compressive sensing(CS), Orthogonal frequency division multiplexing, time frequency training OFDM.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is an emerging technology for high data rates. OFDM is a particular form of multi-carrier transmission technique and is suited for frequency selective channels and high data rates.. In an OFDM scheme, a large number of orthogonal, narrowband subcarriers are transmitted in parallel, divide the available transmission bandwidth [1]. Orthogonal frequency division multiplexing is widely used in high speed broad band wireless communications. Several digital multimedia standards such as Digital video broadcasting standard(DVBT2) and Chinese digital terrestrial multimedia broadcasting (DTMB) standard uses OFDM as the key modulation technique. In TDS-OFDM a time-domain training sequence (TS) is inserted between the successive OFDM data block in order to eliminate the inter-block interference (IBI) caused by multipath channels [2]. TDS-OFDM has superior performance in terms of fast synchronization and channel estimation (CE) and also it achieves a high spectral efficiency.

The main drawback of time-domain synchronous (TDS) OFDM is that the training sequence and OFDM data block will cause mutual interference to each other. Under severely fading channel it is very difficult to remove inter-block interference. To solve this problem time-frequency training (TFT) OFDM [3] system can be used. In TFT-OFDM system both time domain training sequence and frequency domain pilots can be used for channel estimation. This paper proposes a compressive sensing based channel estimation namely Auxiliary information based Subspace Pursuit (ASP) algorithm in TFT-OFDM system under severely fading channels. Unlike the conventional scheme of TDS-OFDM where the IBI caused by the preceding OFDM data block to the current TS has to be cancelled completely, it is not necessary to remove such interference in the proposed scheme because training sequence is used here only for path delay estimation. Also path delay that is estimated by using training sequence is used as auxiliary information for perfect channel estimation.

II. RELATED WORK

Orthogonal frequency division multiplexing is widely used in wireless communications. In time domain synchronous OFDM cyclic prefix (CP) is replaced by training sequence usually pseudo-noise sequence. However there is a mutual interference between training sequence (TS) and OFDM data block. In order to avoid mutual interference an iterative cancellation algorithm can be used in TDS-OFDM [4]. This iterative cancellation algorithm effectively reduces interference. However this algorithm results in performance degradation under severely fading channels.

Dual pseudo noise sequence OFDM (DPN-OFDM) is a scheme [5] which is used to reduce performance degradation in severely fading channels and for effective channel estimation. In DPN-OFDM scheme an extra PN sequence is inserted to prevent the second PN sequence from being contaminated by the preceding OFDM data block. In this way, the DPN-OFDM scheme removes the complex iterative interference cancellation and improves the CE performance. However its main disadvantage is that it reduces spectral efficiency. The PN sequence length in TDS-OFDM system is designed to be longer than the maximum CIR length in order to ensure reliable system performance. However, the spectral efficiency of DPN-OFDM scheme is reduced by doubled the length of PN sequence.

In order to solve the problem of spectral efficiency compressive sensing (CS) is used in TDS-OFDM systems. The existing system uses CS based channel estimation namely Priori information aided iterative hard threshold (PIAIHT) [9] algorithm. PIAIHT based channel estimation is based on two steps. An overlap-add method of the time domain training sequence is used to obtain the coarse estimate of channel. Then secondly by using this prior information channel can be accurately estimated without spectral efficiency loss. Since it is an iterative based algorithm it requires more number of training sequences which will results in performance degradation under severely fading channels. Due to this reason Auxiliary information based Subspace Pursuit (ASP) algorithm is proposed for channel estimation in TFT-OFDM systems.

III. SYSTEM MODEL

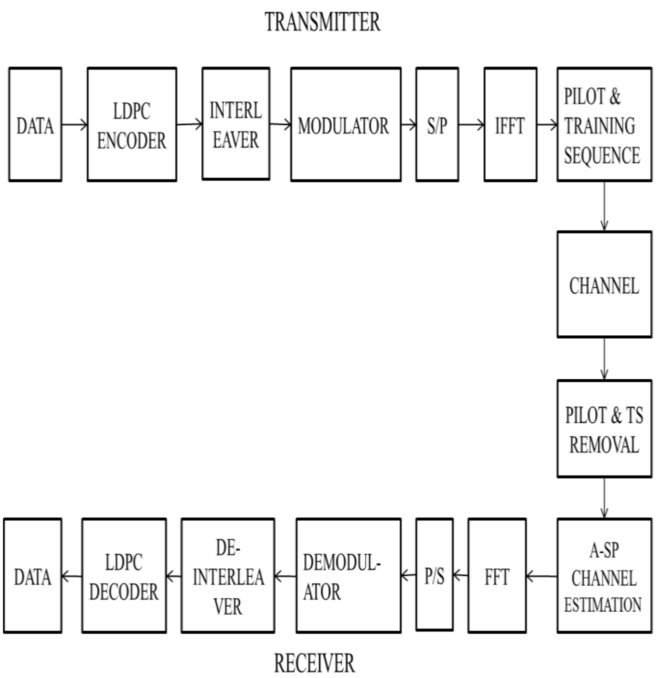

Fig.1: Block diagram of the system model

The block diagram of the proposed system model is shown in the fig.1. In the proposed system model the input symbols are firstly encoded by using Low Density Parity (LDPC) encoder. LDPC codes are single error correcting codes. It has capability to detect two errors and can correct single error. After encoding the input symbols the resulting encoded data are interleaved in order to avoid random or burst errors. The major advantage of inter leaver are it doesn't change the throughput or data rate. It has low computational power. After passing through the inter-leaver the data symbols are modulated by using 16 QAM. In 16 QAM number of sub-carriers is 64. The main advantage of using QAM is that as degree increases bit error rate decreases. Now the incoming data symbols are converted into parallel data by passing through Serial to parallel converter and by performing ifft operation the parallel symbols are converted into frequency domain. Now frequency domain pilots and time domain training sequences are inserted. This constitutes the transmitter section. Now it is passed through the channel. In the receiver side firstly pilots and training sequence has to be removed. Then the channel is estimated by using ASP algorithm based channel estimation scheme. This is the main step in the proposed system model. Now the data symbols are converted into time domain by performing fft operation. By passing through parallel to serial converter the parallel time domain data symbols are converted to serial data. After de inter leaving the received data symbols are finally decoded by using Low Density Parity (LDPC) decoder.

IV. ASP BASED CHANNEL ESTIMATION

The proposed CS based channel estimation method firstly utilizes the PN based correlation in the time-domain to obtain the auxiliary channel information. Then the frequency domain pilots are used for exact CIR estimation. The procedure for this method can be divided into four steps: 1) PN based path delay estimation, 2) Cyclicity reconstruction of the OFDM block and 3) Exact estimation using ASP 4) Maximum likelihood estimation

1) *PN based path delay estimation*

In this step the received PN sequence d is directly correlated with input PN sequence c to acquire coarse channel estimate.

$$h^{i} = \frac{1}{M} c \otimes d \qquad (1)$$

Although the coarse path delay estimation is not accurate due to the existence of inter block interference (IBI), the good autocorrelation property of the PN sequence ensures that the auxiliary channel information is necessary for ASP algorithm. Since the path gain obtained in equation (1) is small it is neglected and considers only the path delays. Therefore path delay set is,

$$T_0 = \left\| h^{i} \right\| \qquad (2)$$

Then the channel sparsity level is S is,

$$S = S_0 + \gamma = \left\| T_0 \right\| + \gamma \qquad (3)$$

where S_o is the initial channel sparsity level.

2) *Reconstruction of the OFDM block*

The reconstruction of the OFDM block is achieved by firstly adding the received PN sequence and the received OFDM symbol. Then subtracting the input PN sequence from the result obtained in the first step. In this way each OFDM block can be reconstructed and hence pilots can be extracted.

In this step the IBI caused by the PN sequence is obtained by computing the linear convolution between the input sequence and the estimated CIR obtained in the preceding OFDM data block. In the received PN contains not only the useful part but also it contains useless part which is the IBI region which should be removed before estimation in the current OFDM block.

3) Exact estimation using ASP

After step 2 the pilots can be extracted from the OFDM block after cyclic reconstruction for final accurate channel estimation. Compared to the existing PIAIHT algorithm the proposed ASP algorithm differs in the following three aspects.

i) Initial configuration

In ASP algorithm unlike existing PIAIHT algorithm initial parameter is taken as path delay which is the auxiliary information available in the proposed algorithm.

ii) Significant entry identification

Unlike existing PIAIHT algorithm where the S most significant entries in the observation matrix Φ are identified in each iterations, here the S_0 most significant entries unchanged and identify the next $S-S_0$ in ASP hence computational complexity can be reduced.

iii) Iterations

Since in the proposed algorithm initial sparsity level is fixed number of iterations is reduced.

4) Maximum likelihood estimation

The accurate path gain can be estimated finally by using maximum likelihood estimation.

V. SIMULATION RESULTS

In this section we compare the performance of proposed ASP scheme with existing PIAIHT scheme and DPN-OFDM scheme under several broadcasting channels. The OFDM block length is 4096. The modulation scheme used in both static and dynamic channel is 16QAM. Here adopted the ITU-VB channel and China digital television set 8th channel model (CDT-8) channel in the simulation, where both static and dynamic mobile scenarios were investigated. The simulation was carried using MATLAB R2013a tool.

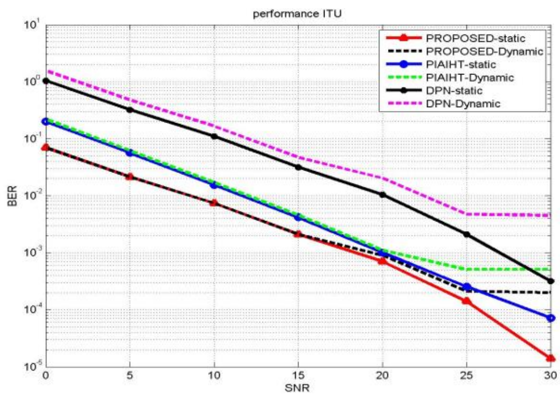

Fig.2: BER performance comparison of proposed ASP scheme with existing scheme and DPN-OFDM scheme in ITU-VB channel.

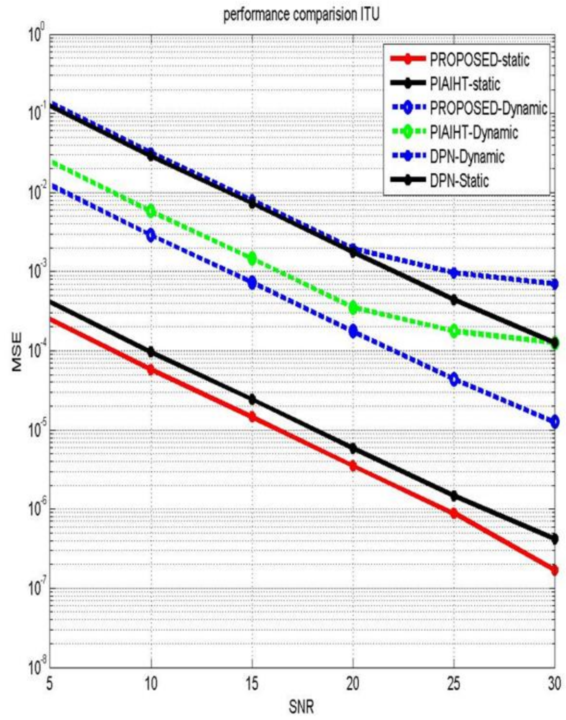

Fig.3: MSE performance comparison of proposed ASP scheme with existing scheme and DPN-OFDM scheme in ITU-VB channel.

The fig.2: represents BER performance comparison of proposed scheme with existing scheme and DPN-OFDM scheme. Here compares the performance of proposed scheme with existing scheme and also considers static and dynamic mobile scenarios.

Static mobile scenario means channel is static so that parameter variation is less than dynamic scenario. In fig.2: proposed Asp scheme has better performance because in both static and dynamic cases as compared to previous scheme, proposed scheme has lower Bit Error Rate.

The fig.3: represents MSE performance comparison of proposed scheme with existing scheme and DPN-OFDM scheme in ITU-VB channel. Here also MSE performance is better for proposed scheme in static condition. Also when consider only dynamic scenario MSE is lower for proposed ASP scheme than existing scheme and DPN-OFDM scheme. Hence proposed scheme has better performance comparison than existing and DPN-OFDM scheme. As a conclusion the proposed scheme has better performance because in static as well as dynamic cases MSE is low when SNR increases.

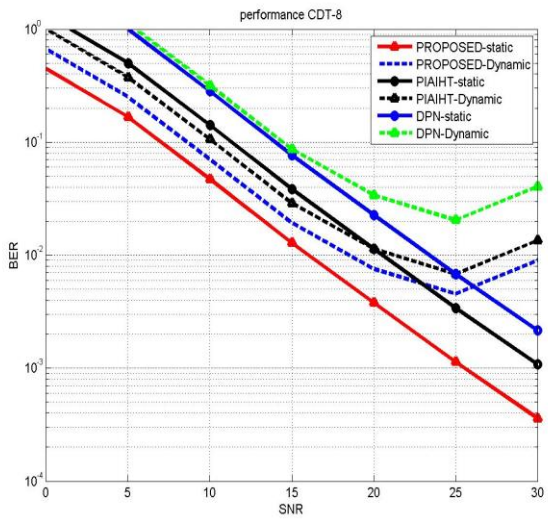

Fig.4: BER performance comparison of proposed scheme with existing scheme and DPN-OFDM scheme in CDT-8 channel.

The fig.4: represents BER performance comparison of proposed scheme with existing scheme and DPN_OFDM scheme in CDT-8 channel. Here also consider both static and dynamic scenarios. When SNR is low BER is high for both proposed ASP scheme and existing PIA-IHT scheme. But when snr increases ber decreases for both schemes. When consider dynamic and static cases of proposed scheme, static scenario has lower BER compared with dynamic scenario. Hence proposed scheme under static scenario has better performance.

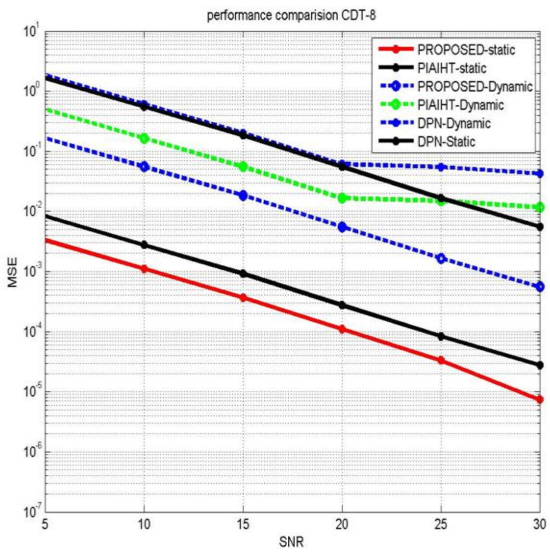

Fig.5: MSE performance comparison of proposed ASP scheme with existing scheme and DPN-OFDM scheme in CDT-8 channel.

The fig.5: represents MSE performance comparison of proposed scheme with existing scheme and DPN-OFDM scheme in CDT-8 channel. Here performance is better for proposed scheme than existing and DPN-OFDM scheme because MSE is lower. Also static case has less MSE than dynamic cases because parameter variation is less in static scenario as compared to dynamic scenario.

VI. CONCLUSION

A low complexity, high accurate channel estimation scheme known as Auxiliary information based Subspace Pursuit algorithm is introduced here. ASP channel estimation is used here for accurate channel estimation in TFT-OFDM system. Moreover the proposed system uses LDPC codes for channel error detection and correction. Simulation results shows that the proposed channel estimation scheme has good performance in both static and dynamic mobile scenarios. The MSE performance of this method outperforms the conventional schemes. The main advantages of this scheme are the proposed scheme uses only a small amount of frequency domain pilots for exact channel estimation and also it requires less number of iteration.

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