International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 08 | Aug -2017 www.irjet.net p-ISSN: 2395-0072

Compressive Sensing based adaptive channel estimation for TDS-OFDM system using sparsity level of channel

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Abstract - *In this paper, Time Domain Synchronous Orthogonal Frequency Division Multiplexing (TDS-OFDM) transmission system is proposed as an alternative approach to the traditional CP-OFDM technology as it provides significant improvement in spectral efficiency since no additional pilots are required and it achieves faster synchronization. This paper introduces the compressive sensing (CS) method which depends on sparsity level of the channel. By using CS based TDS-OFDM it can support higher order modulation and avoid performance loss over fast fading channels. Initially, the sparsity estimation is utilized to detect actual sparsity level of wireless channel, which is detected by using the restricted isometric principle. If the channel is sparse enough then the priori aided subspace pursuit algorithm is used which should meet the CS model else the improved iterative method is used. Finally the accurate channel is estimated. Simulation results determine that the proposed system achieves better MSE performance and robustness compared with traditional CS based methods.*

***Key Words:* Time domain synchronous OFDM (TDS-OFDM), Compressive sensing(CS),sparsity, subspace pursuit (SP)**

1. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is mainly categorized into three types of transmission schemes[1] : cyclic prefix OFDM (CP-OFDM), zero padding OFDM (ZP-OFDM), and time domain synchronous OFDM (TDS-OFDM). In traditional OFDM, a cyclic prefix (CP) is inserted as the guard interval between nearby OFDM symbols. CPOFDM and ZP-OFDM require many numbers of pilots, but this can be saved in TDS-OFDM. Thus, TDS-OFDM has higher spectral efficiency than CP-OFDM and ZP-OFDM. Also this TDS-OFDM has fast and reliable synchronization compared to the others. This can also used in digital television terrestrial broadcasting (DTTB) standard called the digital terrestrial multimedia broadcasting (DTMB). Digital terrestrial television broadcasting (DTTB) currently attracts a significant amount of attention in television services, as it provides for fasterand more reliable transmission than conventional analog television services. Digital Television Terrestrial Multimedia Broadcasting (DTMB) is the TV standard for mobile and fixed terminals used in china.

Most wireless communications and wireless broadcasting implementations use CPOFDM, which can be considered as the "classic" version of OFDM with the lowest complexity. In recent years TDS-OFDM has been introduced, especially for TV broadcasting. DTMB can implement in both single and multicarrier modulation with a distinct structure called time domain synchronous OFDM. This standard is based on time-domain synchronous OFDM (TDS-OFDM),where the level of the M-QAM modulation can either be 4, 16, 32, or 64.DTMB claim this standard that it has faster and more accurate channel tracking than the DVB-T standard does due to its use of TDSOFDM.

Compressive sensing (CS) is based on the sparsity level of the channel in which priori information is exceedingly important which is directly related to the estimation accuracy. The major aim is to reconstruct the signal. In this paper we find out the sparsity level of the channel which is not always satisfied with CS models [3]. To combine the theoretical CS model and the complex practical channel, we obtain the sparsity level of the channel into account and propose the performance analysis of sparsity level of channel based CS methods [2]. Firstly, a sparsity detection method is proposed to detect the real sparsity level of the channel. Then, we check whether the sparsity level meets the theoretical model, if it meets the CS method we propose the priori aided subspace pursuit (PA-SP) algorithm to reconstruct the sparse channel. Besides, by using the PA-SP algorithm for channel estimation it could acquire lower complexity and higher accuracy than other methods. Otherwise, when the channel is not sparse, we adopt improved iterative algorithm in which the sparsity level is used to identify the significant taps in the reconstructed channel. Finally, the proposed channel estimation scheme has improved accuracy and robustness compared with traditional CS based methods.

2. TDS-OFDM

OFDM is a very popular and very important modulation technology that is widely used in wireless communication and broadcasting systems. A cyclic prefix is inserted at the beginning of each OFDM symbol before transmission and removed before demodulation. The length of the cyclic prefix is greater than or equal to that of the channel impulse response to eliminate the inter-symbol interference. The three type of OFDM are shown in Fig .1

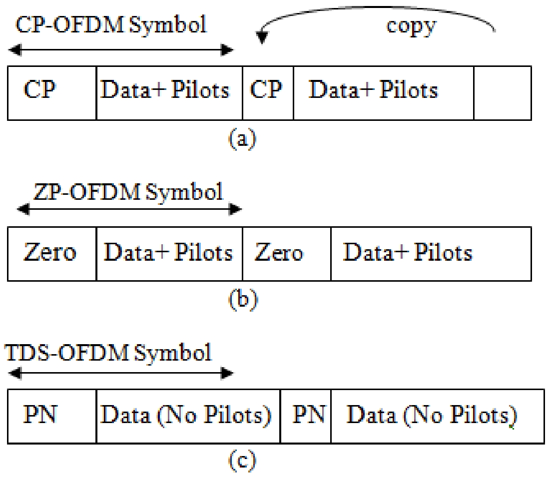

Fig-1. (a) CP-OFDM (b) ZP-OFDM (c) TDS-OFDM

The TDS-OFDM technique can attain fast signal capture and robust synchronization.The special feature of this technique is that a PN sequence with good autocorrelation

property inserted between consecutive information symbols. A TDS-OFDM system model that consist of PN sequence and an OFDM data block that is shown in Fig.1c

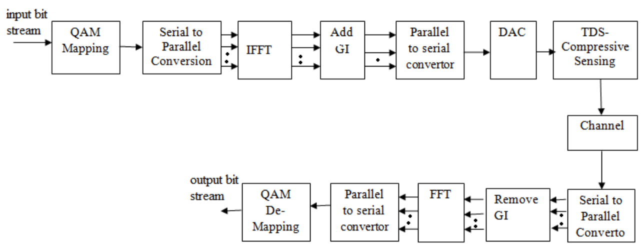

Fig-2. TDS-OFDM compressive sensing

Improvements at the demodulation stage were recently obtained with an OFDM variant, which is based on a newly proposed time-division synchronization OFDM (TDSOFDM)scheme, in which the PN sequence is used. The PN sequence can furthermore be used as a training sequence (TS) for synchronization and channel estimation. The major benefit of this scheme is removal of frequency domains pilots. Therefore TDSOFDM has been choosing as the key technology of the international digital television terrestrial broadcasting (DTTB) standard. TDS-OFDM contain interference from earlier OFDM block, which exists in IBI-free region. The new compressive sensing (CS) theory, which is fundamentally different from the classical Shannon-Nyquist sampling theorem, has the ability to solve the problems of TDS-OFDM. After the modulation and interleaving data converted to time domain, then the PN sequence is added. At the receiver section channel estimation is done and all the reverse process that are done in the transmitter are done, that is removal of PN sequence, FFT, and de-interleaving, is also done here.

3. COMPRESSIVE SENSING

Compressive sensing (CS) has been introduced to efficiently reconstruct sparse signals. The methodology of CS has been applied in coding, information theory, statistical signal processing. Based on this methodology, CS can be employed to take advantage of the inherent sparsity of wireless channels. This is significant because fewer pilot tones to estimate the channel impulse response results in more subcarriers for data transmission CS based TDS- OFDM By using CS based method, it can support higher order modulation. In this paper, the compressive sensing (CS) theory is adopted to solve those problems of TDS-OFDM, but it heavily relies on the sparsity level of the channel. The impulse response can be modeled as,

$$h_n = \sum_{k=0}^{k-1} \beta_k \, \delta[n-\tau_k],\ 0 \le n \le K\text{-}1 \qquad (1)$$

is the nth entry of the CIR vector.Let A be the path delay set and B be the path gain set and they can be modeled as,

$$A = \{\tau_0, \tau_1, \ldots, \tau_{K-1}\}, \qquad (2)$$

$$B = \{\beta_0, \beta_1, \ldots, \beta_{K-1}\} \qquad (3)$$

The PN sequence length is designed to K-1 combat the worst case of fading channels in TDS-OFDM system. This indicates that even though the received PN sequence is contaminated by the previous OFDM data block, there exists an IBI-free region $r = [r_0, r_1, \ldots, r_{G-1}]^{\cdot}$ of small size $G = M - L + 1$ at the receiver end of PN sequence[3]:

$$r = \Phi h + n \qquad (4)$$

where $n = [w_0, w_1, \ldots, w_{G-1}]^T$ denotes the additive white Gaussian noise (AWGN), and

$$\Phi = \begin{bmatrix} c_{L-1} & c_{L-2} & \cdots & c_0 \\ c_L & c_{L-1} & \cdots & c_1 \\ \vdots & \vdots & \ddots & \vdots \\ c_{M-1} & c_{M-2} & \cdots & c_{M-L} \end{bmatrix}_{G \times L} \qquad (5)$$

where Φ denotes the Toeplitz matrix of size G*Ldetermined by the PN sequences.

The restricted isometry principle less (RIPless) condition for stable recovery [4], should satisfy the sparsity level of channel (K)

$$K \le G/4\Delta \qquad (6)$$

where Δ indicates the parameter $C_0(\log(L/G)+1)$ with C_0 as an constant value, which is equal to 1. If we want to adopt the CS algorithm, the channel of sparsity level should satisfy the RIPless condition.

4. METHOD FOR ESTIMATING THE CHANNEL

From the Fig. 3, sparsity detection is generally used to roughly estimate the channel and detect the noise. Initially we make use of a sparsity detection to identify the actual channel sparsity level. Then we check whether the sparsity level meets the CS model or not, i.e., $K \leq G/(4\Delta)$. When the wireless channel is sparse enough, the proposed PA-SP algorithm is used. Otherwise, when the channel is not sparse, we adopt improved iterative algorithm. Finally, the accurate channel is estimated.

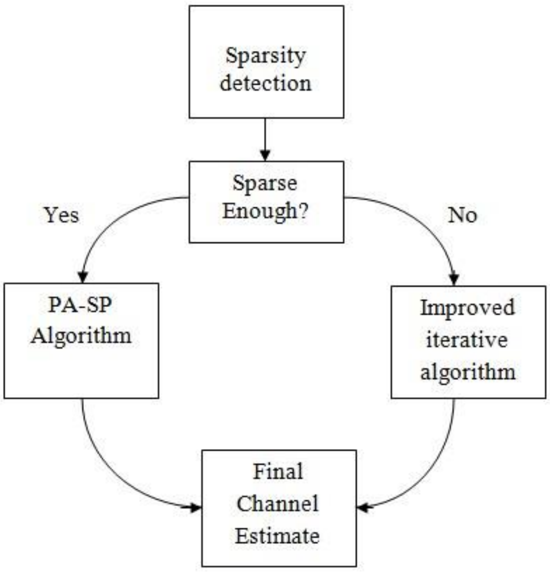

Fig-3. Structure for adaptive channel estimation

4.1 PA-SP Based Channel Estimation

In contrast with the traditional SP algorithm [6], we can find that they follow similar procedure, but they are distinct in the features described below:

1) Initialization: We estimate the initial subspace as the sparsity detection result $\widehat{D}$ instead of the largest K magnitude entries in the vector $\Phi^{*}z$.Thus the initialization not only estimates the real subspace well, but also doesn't require any computation.

2)Halting condition: The delay set $\widehat{D}$ is used to quit the iteration instead of residual z_r, which keep unchanged when the algorithm acquires the highest correlation subspace.

3) Number of iteration: Compared to previous iteration number log(K), the proposed scheme only requires K_0 iterations, so the complexity is reduced.

The channel estimation for the proposed PA-SP algorithm has lower complexity and high accuracy, since the channel sparsity level K and the initial subspace D are known in the prior.

4.2 Improved Iterative Channel Estimation

The improved iterative algorithm is utilized when the sparsity level does not satisfy the CS model. The main concept of this method is that we choose the strongest K values in the channel estimation result regarded as real taps and weaken the rest as noise to enhance the estimation accuracy.At lth iteration, we can obtain the channel estimate result as

$$\hat{h}^{(l)}=h+n^{(l)} \qquad (7)$$

where h is the actual channel and $n^{(l)}$ is the noise in lth iteration. The accuracy of this method is better when compared to the traditional counterparts.

5. RESULTS AND DISCUSSION

The results obtained by using the proposed algorithm is for reconstructing the signal using compressive sensing method.

A.PA-SP ALGORITHM

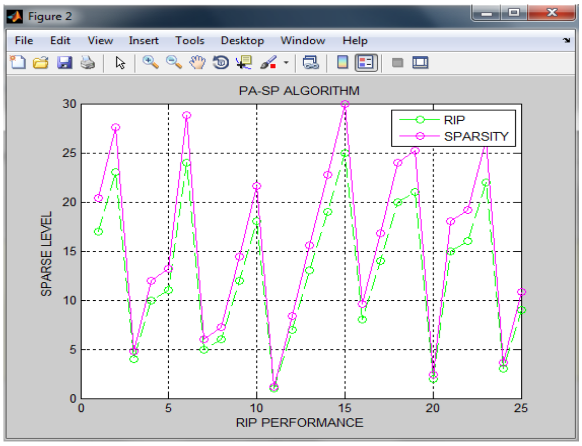

Fig-4.PA-SP Algorithm

The PA-SP algorithm is used when the channel sparsity is met with the restricted isometry property condition. Here the RIP condition is met. From the fig.4, if RIP exceeds the sparsity level then the improved iterative algorithm is used.If RIP condition is met, the channel strength is low so the PA-SP algorithm is implemented.

B.MSE PERFORMANCE COMPARISON

The MSE performance is analyzed for the CP-OFDM and the TDS-OFDM system. When RIP condition is met with CS method, then the TDS-OFDM is 1dB better than the CP-OFDM. When the RIP condition is not met with the CS method, then the TDS-OFDM is 2dB better than CP-OFDM.MSE performance is analyzed after the RIP condition is met.

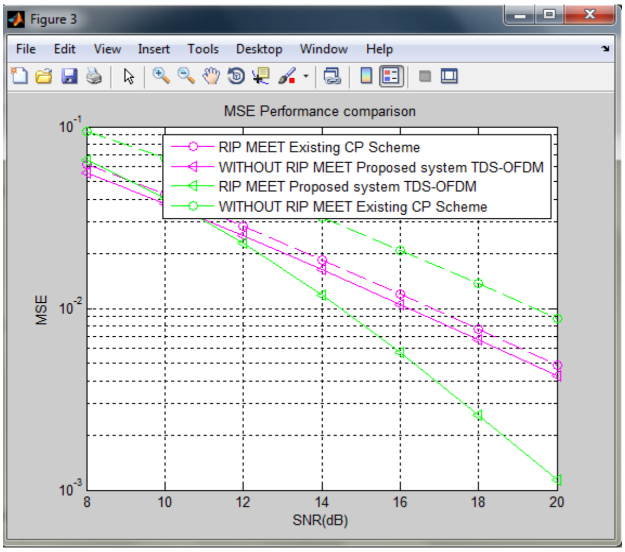

Fig-5.MSE performance Comparison

C.PN SEQUENCE WITH OVERLAPPING DATA

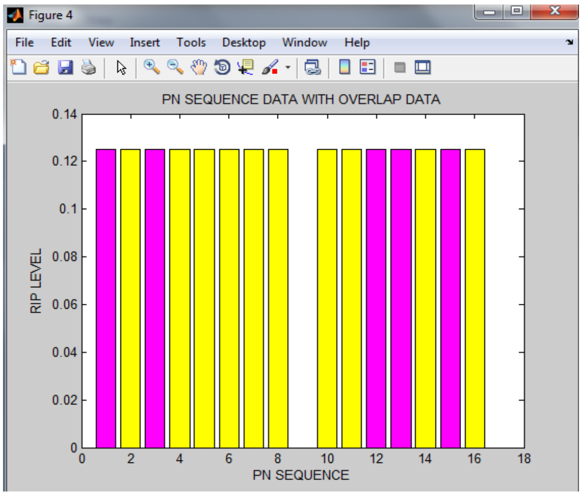

Fig- 6. PN sequence with overlapping data

D.IMPROVED SIGNAL

The improved iterative algorithm is used when the sparsity level does not meet the CS method. This method reconstructs the PN sequence through overlapping and non-overlapping data and performs channel estimation in iterative manner. Based on the PN sequence and RIP level, the improved signal is estimated.

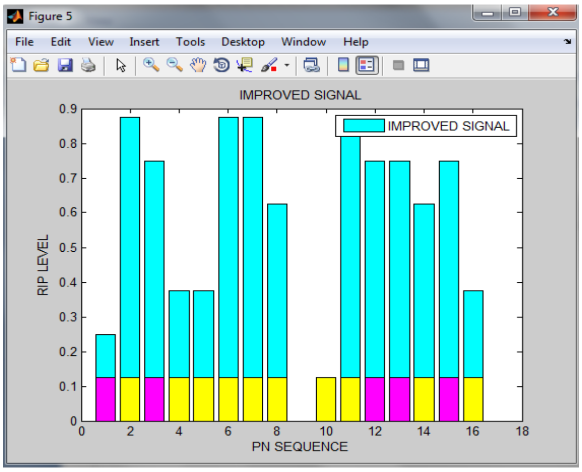

Fig-7. Improved signal

6. CONCLUSION

In this paper, we have aimed to reconstruct the weaker signal by using CS method, which rely on channel sparsity. Besides, by using the PA-SP algorithm for channel estimation it could acquire lower complexity and higher accuracy than other methods. The results of simulation show that the proposed scheme achieves improved MSE performance than the traditional CS based methods. For future work, we plan to adapt the optimal maximum likelihood algorithm and show the capacity maximization by using water filling algorithm

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