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CS Based Channel Estimation for OFDM Systems under Long Delay Channels Using MATLAB

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ABSTRACT
Orthogonal frequency division multiplexing (OFDM) is a technique which are used in the next-generation wireless communication. Channel estimation in the OFDM technique is one of the big challenges, ever since high-resolution channel estimation can significantly improve the equalization at the receiver and consequently enhance the communication performances. Channel computation using superimposed pilot sequences is also a fully new area, idea for using superimposed pilot sequences has been proposed by various authors for different applications. *In this paper, we are introduced a high accurate, low complexity compressive sensing (CS) based channel estimation namely Auxiliary information based Subspace Pursuit (ASP) in TFT-OFDM systems. ASP based channel estimation in TFT-OFDM system is based on two steps.* First is, by exploiting the signal structure of recently proposed TDM-OFDM scheme, the supporting channel information is obtained. Second is, we propose the supporting information based subspace pursuit (SP) algorithm to use a very small amount of frequency domain pilots embedded in the OFDM block used for the exact channel estimation. Moreover, the obtained auxiliary channel information is adopted to reduce the complexity of the conventional SP algorithm. Simulation results demonstrate a important reduction of the number of pilots relative to least-squares channel estimation and supporting high-order modulations like 256 QAM.

Keywords: Compressed Sensing (CS), QAM, Signal to Noise Ratio (SNR), Subspace Pursuit (SP), TDM-OFDM

I. INTRODUCTION

OFDM is a signalling technique which has been applied broadly in the wireless communication systems by reason of its ability to maintain the effective transmission and the efficient bandwidth utilization which are in the presence of several channel losses and one of them is a frequency discerning fading. In the OFDM system, channel estimation is important to obtain the channel state information (CSI), for reducing the bit error speed and to achieve the distortion of a smaller amount of output data. There are different methods which are used for channel estimation for example: with or without a requirement of parametric models, blind or pilot based methods, frequency and/or time domain analysis and adaptive or non-adaptive techniques. The recently introduced principle and methodology of compressed sensing (CS) allows the efficient rebuilding of sparse signals from very limited number of measurements (samples) [1, 2]. CS has gained a rapid-increasing the interest in the applied mathematics. In this, we apply Compressed Sensing to pilot-based channel estimation in the highly moveable environments. In Conventional methods , channels estimation is not capable to use the inherent scarcity of transmission channel which is by the reason of the sparse distribution of scatters in space. As we will demonstrate, CS provides a constructive way for exploiting this lack in order to less the number of pilots and, hence, increases spectral efficiency. After conducting an wide survey, it was found that the worked done in the referred paper uses 128 QAM technique for data transmission and used SP algorithm in compressed sensing for channel estimation. So it's proposed that in order to achieve a better data rate A-SP algorithms alongwith 256 QAM technique can be used. In referred paper [8] Ding represented the output at signal speed of 60 km/hr, which can be pushed up to 123 km/hr by using the proposed algorithms.

System model

In CS-OFDM, the modulated symbols are processed block-by-block. Assume that there are N=LM modulated symbols in one block. It is different from conventional OFDM, CS-OFDM further divides the length N block into Vector Block (serial to parallel buffer), where each Vector Block has size M. Instead of doing IFFT of size N as in conventional OFDM, CS-OFDM does component wise vector IFFT of size over the Vector Blocks. The IFFT size is reduced from N to L by M times. This IFFT size reduction also reduces the peak to average power ratio (PAPR). It has the merit of Low PAPR and Cost reduction for transceiver architecture.

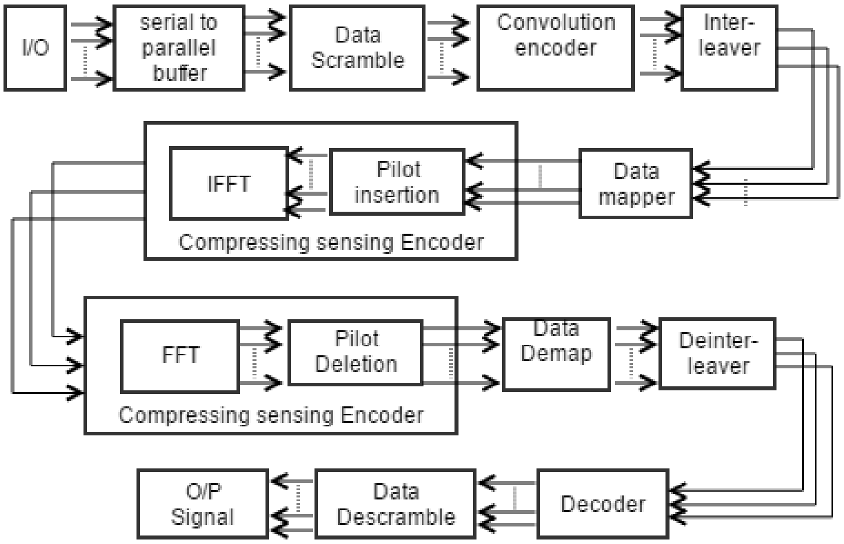

Figure 1 Block diagram of system model

Signal characteristics

An OFDM signal consists of N orthogonal subcarriers modulated by N parallel data streams. Each of the baseband subcarriers is in the form of

$\emptyset_k(t) = e^{j2\pi f_k t}$ …….(1)

Where f_k is the frequency of the k^{th} subcarrier.

One baseband OFDM symbol (without a cyclic prefix) multiplexes N modulated subcarriers:

$s(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x_k \, x\emptyset_k(t) \qquad 0 < tN < T$

……..(2)

Where X_k is the kth complex data symbol (typically taken from a PSK or QAM symbol constellation) and NT is the length of the OFDM symbol. The subcarrier frequencies f_k are equally spaced.

$f_k = \frac{k}{NT}$ …… (3)

The signal (2) separates data symbols in frequency by overlapping subcarriers thus using the available spectrum in an efficient way.

The OFDM equation (2) could typically be received by using a bank of matched filters. T-spaced sampling of the in-phase and quadrature components of the OFDM symbol yields by ignoring channel impairments such as additive noise or dispersion.

$s(nT) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x_k e^{j2\pi\frac{nk}{N}}$ …… (4)

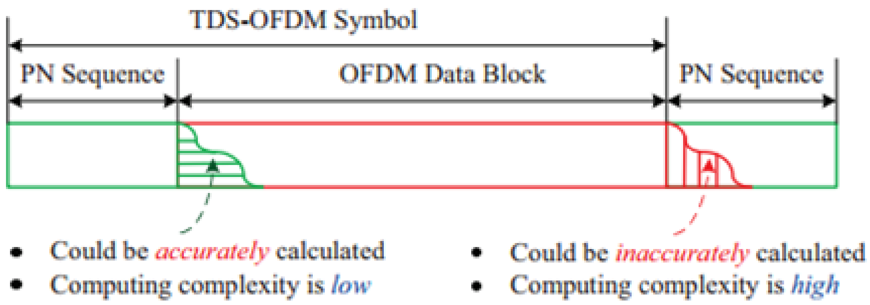

Figure **2** Distinct features of the IBIs in TDS-OFDM

The cyclic prefix, illustrated in Figure 2, works as follows. Between consecutive OFDM symbols a guard period is inserted that contains a cyclic extension of the OFDM signal. Which is the inverse discrete Fourier transform (IDFT) of the constellation symbols Xk. According to the sampled data is demodulated with a DFT. The DFT, usually implemented with an FFT, actually realizes a sampled matched-filter receiver in systems without a cyclic prefix.

$s(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x_k \, e^{j2\pi f_k t} \qquad -\Delta < t < NT$

….(5)

The signal then passes through a channel, modelled by a finite-length impulse response limited to the interval. If the length of the cyclic prefix delta is chosen such that

$$r(t) = s(t) * h(t) = \frac{1}{\sqrt{N}} H_k x_k e^{j2\pi f_k t} \quad \text{……(6)}$$
$$0 < t \leq NT$$

Where$H_k = \int_0^{\Delta_h} h(\tau) e^{-j2\pi f_k \tau} d\tau$ …..(7)

The Fourier transform of h(t) is evaluated at the frequency f_k. In this interval, the received signal is similar to the original signal except the $H_k X_{k\ w}$ which modulates the kth subcarrier instead of Xk. By using this way, the cyclic prefix preserves the orthogonality of the subcarriers.

Equation (6) suggests that the OFDM signal can be demodulated by taking an FFT of the sampled data over the interval [0;NT], ignoring the received signal before and after 0<t<=NT. The received data (disregarding additive noise) are

$y_k = H_k x_k$, k=0, …..N-1 …..(8)

The received data in Equation (8) can be recovered with N parallel one-tap equalizers. This simple channel equalization motivates the use of a cyclic prefix and often the use of OFDM itself. Since we ignore the signal within the cyclic prefix this prefix also acts as the above mentioned silent guard interval. It prevents ISI between successive OFDM symbols.

The use of a cyclic prefix in the transmitted signal has the disadvantage of requiring more transmit energy. The loss of transmit energy or loss of signal-to-noise ratio (SNR) due to the cyclic prefix is

$$\epsilon_{loss} = \frac{NT}{NT+\Delta} \quad \text{…..(9)}$$

This is also a measure of the bit rate reduction required by a cyclic prefix.

II. METHODOLOGY

We propose a CS-based CE method with the auxiliary information based SP (A-SP) algorithm. the proposed CS-based CE method firstly utilizes the PN-based correlation in the time domain to obtain the auxiliary channel information and then the frequency-domain pilots are used for the final exact CIR estimation based on CS. The specific procedure of this method can be divided into three steps:

1. PN-based coarse path delay estimation,
2. Cyclicity reconstruction of the OFDM block,
3. Exact CIR estimation using A-SP.

Step 1: PN-Based Coarse Path Delay Estimation
Based on the good auto-correlation property of the PN sequence, the received PN sequence $\mathbf{d}^i$ is directly correlated with the locally known PN sequence **c** to acquire the coarse channel estimate h^{-i} as

$$h^{-i} = \frac{1}{M} \otimes d^i = h^i + v \quad \text{......(10)}$$

Where v denotes the AWGN as well as the effect of interference caused by the preceding OFDM block.

The path gains in h^{-i} are discarded directly, and only the path delays of the most significant taps (partial path delays) are retained in the initial coarse path delay set

$$T_0 = \left\{ l : \left\| h_l^{-i} \right\|_2 \geq p_{th} \right\}_{l=0}^{L-1} \quad \text{……(11)}$$

Where p_{th} is the power threshold configured

Then, the channel sparsity level S can be approximated by

$$S = S_0 + a = \|T_0\|_0 + a \quad \text{…….(12)}$$

Where $S_0 = \|T_0\|_0$ denotes the initial channel sparsity level, and a is a number used to combat the interference effect.

Step 2: Cyclicity Reconstruction of the OFDM Block is achieved by firstly subtracting the IBI caused by the PN sequence from the received OFDM block, then adding the received PN sequence and finally subtracting the first part of linear convolution outputs between the PN sequence and channel .In this step, the IBI caused by the PN sequence is obtained by computing the linear convolution between the local PN sequence and the estimated CIR obtained in the preceding symbols. Under the slow time-varying channels, which can be assumed in many wireless broadcasting systems, the estimated CIR obtained in the preceding symbol can be used for the IBI removal in the current symbol. In fact, the received PN sequence contains not only the useful part which is the IBI caused by the OFDM block, but also the useless part that is the linear convolution between the PN sequence and channel. Hence, the useless part should be removed after the received PN sequence is added to achieve the cyclicity reconstruction.

Step 3: Exact CIR Estimation Using A-SP - The pilots can be extracted from the OFDM block after cyclicity reconstruction for the final accurate CE. Based on the basic idea of classical SP algorithm, we propose the A-SP algorithm, whereby the auxiliary channel information obtained in *Step 1* is exploited to improve the CE performance and lower the computational complexity. The proposed A-SP algorithm is described by pseudo code as shown in below.

Algorithm(Auxiliary information based SP)
Inputs:
1. Initial coarse path delay set T_0 , channel sparsity level S, Initial channel sparsity level S_0.
2. Noise measurement $m \triangleq y^{-i}|r$
3. Observation matrix $\Phi \triangleq diag(x^{-i}|r)F_L^{\Gamma}$

Output:
1. $T^0 \leftarrow T_0$; (Initial configuration)
2. $r \leftarrow m - \Phi_{T^0}\Phi^*_{T^0}m$; (Initial residual)
3. $k \leftarrow 0$; (Initial iteration flag)
4. while $k < S - S_0$ do
5. $k \leftarrow k + 1$; (update iteration flag)
6. $p \leftarrow \Phi^H r$; (Generate target CIR proxy)
7. $\check{T}^k \leftarrow \check{T}^{k-1} \cup \sup(p_{S-S_0})$; (Significant entry identification)
8. $q \leftarrow \Phi^*_{\check{T}^k}m$; (least square signal estimation)
9. $T^k \leftarrow \sup(q_S)$;(select most significant entries)
10. $r \leftarrow y - \Phi_{T^k}\Phi^*_{T^k}m$; (Update residual)
11. end while
12. Actual path delay acquisition: $T \leftarrow T^k$;

III. RESULT ANALYSYS

Here, we compare the performance of proposed ASP scheme with existing TDS-OFDM scheme and DPN-OFDM scheme under the ITU-VB channel. The simulation was carried using MATLAB tool.

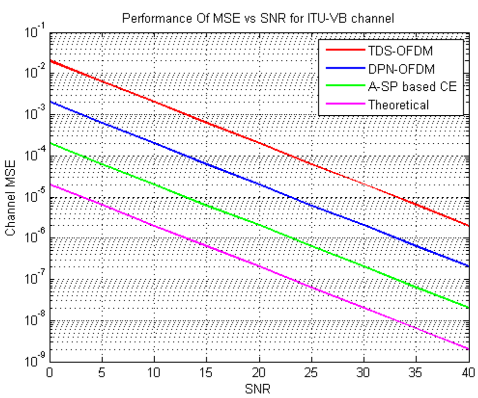

Figure 3 MSE performance comparison of proposed scheme with existing schemes in ITU-VB channel.

The figure 3 represents MSE performance comparison of proposed scheme with existing TDS-OFDM and DPN-OFDM schemes in ITU-VB channel. Hence proposed scheme has better performance comparison than existing schemes.

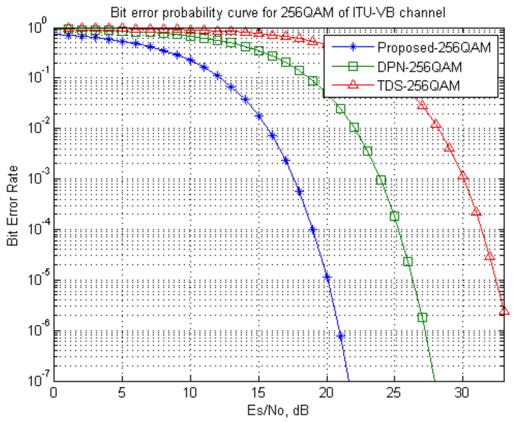

Figure 4 BER performance comparison of proposed ASP scheme with existing schemes in ITU-VB channel.

The figure 4 represents BER performance comparison of proposed scheme with existing TDS-OFDM and DPN-OFDM schemes. In the proposed A-SP scheme has better performance and has lower Bit Error Rate.

IV. CONCLUSION

1. We have proposed a channel estimation technique based on the newly introduced principle of compressed sensing. Our results demonstrate that Compressed Sensing makes it possible to exploit the "delay doppler sparsity" of wireless channels for a reduction of the number of pilots required for channel estimation within multicarrier systems. The MSE performance of this method outperforms to the conventional schemes and is close to the CRLB by simultaneously exploiting the time-domain PN sequence and frequency-domain pilots. Simulation results show that the proposed scheme has a good BER performance and can work the 256 QAM, especially when the maximum channel delay spread is fairly close to or even larger than the GI length.
2. By using the auxiliary channel information, the proposed A-SP algorithm has lower complexity than the conventional SP algorithm.

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