Performance of Joint Time-Frequency TDS-OFDM System under Relaigh Channel

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Abstract— To transmit Videos, Images etc. over wireless channels, spectrally efficient technique needs to be developed as the spectrum available is a limited resource. Time Domain Synchronous OFDM (TDS-OFDM) is a technique that is spectrally more efficient than other OFDM techniques. But performance of TDS-OFDM is poor in fast fading channels. In this paper, time-frequency structure is proposed. Each symbol consists of time domain one sample shifted training sequence (TS) as guard interval and frequency domain pilots inserted within the data block .This structure improves performance of TDS-OFDM over fast fading channels maintaining the spectral efficiency. The path delay estimation is carried out using time domain training sequence and path gain estimation is done using frequency domain pilots. Channel estimation can be performed using very few numbers of pilots. Hence spectral efficiency is maintained. Also as channel estimation is carried out using pilots present in data block, inter symbol interference is also negligible compared to normal TDS-OFDM.

Key words: Channel Estimation, Cyclic Prefix (CP), Fast fading channels, Pilots, Time Domain Synchronous Orthogonal Frequency Division Multiplexing (TDS-OFDM), Training Sequence

I. INTRODUCTION

Vehicular communications is widely used technology which allows users to communicate at higher speeds and without any interruptions in ongoing communication. Orthogonal Frequency Division Multiplexing (OFDM) is a widely used technique in wireless communications because of its robustness to highly frequency selective fading channels. OFDM technique allows more number of users to communicate simultaneously without interference and being digital; it is immune to channel noise. OFDM is basically a block based transmission system in which two adjacent data blocks are separated by guard interval to avoid inter-block interference. Based on technique to separate the two data blocks, OFDM is categorized into different types: Zero padding OFDM (ZP-OFDM), Cyclic prefix OFDM (CP-OFDM) and time Domain Synchronous OFDM (TDS-OFDM) [1]. The standard CP-OFDM scheme is widely adopted by most of the current communications standards, e.g., IEEE 802.11g/n/ac, 802.16e/m, 802.11p. It utilizes the CP to eliminate the inter-block-interference (IBI) as well as inter-carrier-interference (ICI) [2]. All zeros are used instead of CP in ZP-OFDM to tackle the channel null problem [2]. Based on the concept of joint time-frequency processing, TDS-OFDM uses the known pseudorandom noise (PN) sequence as the guard interval and the training sequence (TS) for synchronization and channel estimation. Large number of frequency-domain pilots used in CP-OFDM and ZP-OFDM can be saved. Thus, TDS-OFDM has higher spectral efficiency as compared to ZP-OFDM and CP-OFDM. Additionally, fast and reliable synchronization can be also achieved. TDS-OFDM is the key technology for digital television terrestrial broadcasting (DTTB) standard called digital terrestrial multimedia/television broadcasting (DTMB).

TS and the OFDM data block causes mutual interferences to each other, thus iterative interference cancellation has to be used to achieve reliable time-domain channel estimation and frequency-domain data detection in TDS-OFDM systems. This causes two major problems of TDS-OFDM: First, in low-speed vehicular channels, it is very difficult to completely remove the residual interference when the channel delay spread is large. Hence it is difficult to support high-order modulations like 256QAM ; Second, due to the mutual condition of accurate channel estimation and reliable data detection, the performance degradation of data detection deteriorates the channel estimation accuracy, and vice versa, so performance loss is unavoidable over fast fading channels.

The Time domain synchronous OFDM (TDS-OFDM) is the widely used technique for digital television/terrestrial multimedia broadcasting. The TDS-OFDM replaces cyclic prefix in Cyclic Prefix OFDM (CP-OFDM) by a known pseudo noise (PN) as the guard interval between two successive data symbols. This PN sequence can be used as the training sequence (TS) for both channel estimation and synchronization at the receiver side. Because of this large number of pilots are saved.

TDS-OFDM has higher spectral efficiency than the other techniques used to separate the data symbols in OFDM. However the main drawback of TDS-OFDM is that inter block interference (IBI) is more between TS and OFDM block. Thus an iterative interference cancellation algorithm has to be adapted for channel CE and channel equalization, but which has higher complexity. This will degrade the whole systems BER performance and also becomes difficult to support higher order modulation.

Some alternative solutions are proposed to solve this problem. One of those solutions is dual-PN padded OFDM (DPN-OFDM), where PN sequence is duplicated twice to make PN sequence immune to IBI. Hence the second PN sequence can be directly used for CE. This avoids iterative interference cancellation algorithm which has high complexity. But spectral efficiency is reduced because of DPN. Compressive Sensing (CS) technique is proposed to solve the problem of TDS-OFDM and DPN i.e. to support higher order modulations and spectral efficiency loss.

Equalization is a method used for recovery of distorted signal when it is transmitted through the channel, received by convolution process and observed in Additive

Noise. Process of recovery of signal that is convolved with impulse response of channel is known as the Equalization.

II. TDS-OFDM SIGNAL STRUCTURE

The performance of TDS-OFDM is poor over fast fading channels. To improve this performance, joint time frequency channel estimation method is proposed. The proposed TDS-OFDM signal is different from convenient TDS-OFDM in following aspects: 1) Time domain guard interval and 2) frequency domain grouped pilots. Time domain training sequence one sample shifted training sequence is used for path delay estimation and frequency domain grouped pilots are used for path gain estimation. Channel estimation can be performed using very few pilots. Hence spectral efficiency is maintained and also performance is improved in fast fading channels.

Fig.1 shows the signal structure of joint Time-Frequency TDS-OFDM system.

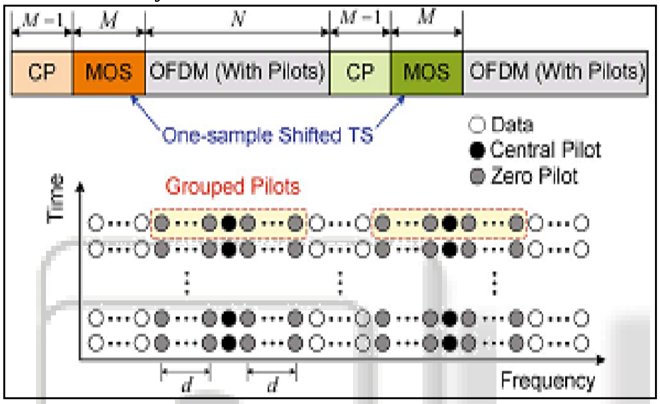

Fig. 1: Joint Time-Frequency signal structure for TDS-OFDM [1]

In the signal structure shown in Fig.1, each i^{th} symbol consist of OFDM data block $x = [x_{i,0}, x_{i,1}, \ldots, x_i, x_{i,N-1}]^T$ of length N. Guard interval is the time domain TS $C = [c_{i,0}, c_{i,1}, \ldots, c_i, c_{i,M-1}]^T$ of length M. Time domain OFDM data block is represented by $X_i = F_N^H X_i$ where X_i denotes FFT of x_i. The TS of $i + 1^{th}$ symbol generated by cyclically shifting TS c_i. Hence non constant TS is used for channel estimation.

Instead of using PN sequence with non-ideal autocorrelation property, MOS is used.

$$c_{i,n} - b(n_1)\exp\left(\frac{2\pi}{\sqrt{M}} m n_0 n_1\right), \qquad (2.1)$$

where $0 \le n_0 \le \sqrt{M} - 1, 0 \le n_1 \le \sqrt{M} - 1$.

In proposed signal structure, pilots are scattered in signal bandwidth. One non-zero central pilot is located in the middle and 2d zero pilots are present around this zero pilot. Zero pilots are used to improve the performance over ICI.

III. JOINT CHANNEL ESTIMATION

Chanel estimation is carried out for channel equalization at the receiver. Effect of channel is nullified using channel equalization at the receiver end. In conventional TDS-OFDM, both path gain and path delay are estimated using time domain TS. In proposed technique, path gain is estimated with the help of pilots and path delay is estimated using time domain TS.

A. Path Delay Estimation Using TS

TS (i.e. used as guard interval) is IBI immune because CP used in it. Path delay estimation is done by circular convolution of local sequence and received TS.

$$\hat{h}_i = \frac{1}{M} c_i^{(s)} \otimes d_i = \frac{1}{M} c_i^{(s)} \otimes \left(c_i^{(s)} \otimes h_i + v_i\right) \quad (3.1)$$

Where $c_i^{(s)}$ is the rearranged vector based on c_i, v_i denotes the channel AWGN vector whose every element has zero mean and variance of σ^2 and h_i denotes channel impulse response during TS.

B. Path Gain Estimation Using Frequency Domain Pilots

Path gain estimation is carried out using frequency domain pilots that are present in the OFDM data block. Path gain over fast fading channels is given by Q-order Taylor series expansion.

$$h_{i,n,l} = \sum b_{i,n,v} \gamma_{i,l,v} + \varepsilon_{i,n,l} \qquad (3.2)$$

Where b_n denotes basis function, $\gamma_{i,l} = [\gamma_{i,l,0}, \gamma_{i,l,1}, \ldots, \gamma_{i,l,Q}]$ with the entry $\gamma_{i,l,v}$ being the v^{th} polynomial coefficient and $\varepsilon_{i,n,l}$ represents the approximation error. Approximation order Q depends on maximum Doppler spread of the channel. For fast fading channels Q=1 ensures good approximation performance.

IV. SIMULATION RESULTS AND CONCLUSION

The simulation of joint Time-Frequency TDS-OFDM system is carried out using MATLAB 2013a. In the simulation, 16 QAM is assumed and FFT size is 2048. The cyclic prefix length used is 16 bits. Simulation is carried out for 500 OFDM Symbols.

The simulation results carried out after simulation is shown in fig. 2.

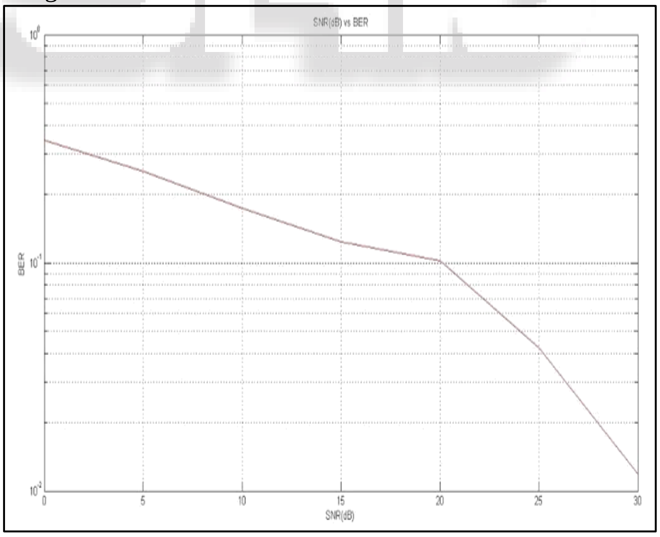

Fig. 2: BER vs SNR (dB) Plot

Simulation result is the plot of BER for different values of SNR(dB). From the plot obtained, it is clear that value of BER decreases as the value of SNR(dB) increases.

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REFERENCES

[1] L. Dai, Z. Wang, J. Wang, and Z. Yang, "Joint Time-Frequency Channel estimation for Time Domain Synchronous OFDM Systems," IEEE Trans. Broadcast. , vol. 59, no. 1, pp. 168-173, March 2013.
[2] B. Muquet, Z. Wang, G. Giannakis, M. De Courville, P. Duhamel," Cyclic prefixing or zero padding for wireless multicarrier transmissions?", IEEE Trans. Commun., vol.50, no.12, pp. 2136-2148, Dec 2002.
[3] Dai, Z. Wang, and Z. Yang, "Time-frequency training OFDM with high spectral efficiency and reliable performance in hisgh speed environments," IEEE Journal on Selected Areas in Communication, vol. 30, no. 4, pp. 695-707, May 2012
[4] LJ. Wang, Z. Yang, C. Pan, and J. Song, "Iterative padding subtraction of the PN sequence for the TDS-OFDM over broadcast channels," IEEE Transactions on Consumer Electronics, vol. 51, no. 11, pp. 1148–1152, Nov. 2005.
[5] Z. Tang, R. Cannizzaro, G. Leus, P. Banelli, " Pilot assisted time-varying channel estimation for OFDM systems," IEEE Trans. Signal Process., vol. 55, no. 5, pp. 2226-2238, May 2007.
[6] L. Dai, Z.Wang, J. Wang, Z. Yang, " Joint channel estimation and time-frequency synchronization for uplink TDS-OFDMA systems", IEEE Trans. Consum. Electronic., vol. 56, no. 2, pp. 494-500, May 2010.
[7] Linglong Dai, Zhaocheng Wang, and Zhixing Yang, "Spectrally efficient Time-Frequency training OFDM for mobile large-scale MIMO systems," IEEE Journal on Selected Areas in Communications, vol. 31, no. 2, February 2013.
[8] Jingon Joung, Chin Keong Ho and Sumei Sun, "Spectral Efficiency and Energy Efficiency of OFDM Systems: Impact of power Amplifiers and Countermeasures," IEEE Journal on Selected Areas in
[9] Istdeo Singh and K. Giridhar, "Enhancement in Spectral Efficiency using Transmit-side Channel Shortener for MISO-OFDM Systems", IEEE Signal Processing Letters, vol. 21,no.6,pp. 712-716,June 2014.
[10] C. yen Ong, J. Song, C. Pan and Y. Li "Technology and standards of digital television terrestrial multimedia broadcasting", IEEE commun. Mag., vol. 48, no. 5, pp.119-127, May 2010.
[11] J. Huang, S. Zhou, C. Berger, and P. Willett, "Progressive inter-carrier interference equalization for OFDM transmission over time-varying underwater acoustic channels," IEEE Journal Select. Topics Signal Process.,vol. 5, no. 8, pp. 1524–1536, Dec. 2011.