Analysis of Compressed Sending Time-Frequency Training OFDM for Improved Performance of the System

Sudha Kushwaha, Sourabh Pandey

Abstract- Orthogonal frequency division multiplexing is widely recognized as the one important technology in broadband wireless communication systems. In wireless communication orthogonal frequency division multiplexing render higher spectral efficiency as well as enhanced performance over fast fading channel. The time domain synchronous orthogonal frequency division multiplexing also offers enhanced spectral efficiency compared to cyclic prefix orthogonal frequency division multiplexing. But interference cancellation problem degrades performance loss in high speed communication channel. The compressed sending based channel estimation increases the spectral efficiency by using time delay and reducing number of pilot symbols. This paper proposes a new scheme called compressed sending time frequency training orthogonal frequency division multiplexing. This scheme uses training information in time and frequency domain. The simulation shows that the proposed scheme outperforms TFT orthogonal frequency division multiplexing, cyclic prefix orthogonal frequency division multiplexing and TDS orthogonal frequency division multiplexing in high speed mobile environments.

Keywords-Wireless, Frequency, Channel, Multiplexing, Pilot, Training

I. INTRODUCTION

The orthogonal frequency division multiplexing is a special type of multicarrier modulation where a single data stream is sent over a number of lower rate subcarriers. Orthogonal frequency division multiplexing can be thought as a modulation technique. One important reasons of using orthogonal frequency division multiplexing is to strengthen the robustness against frequency selective fading and narrowband interference. In single carrier system interference can cause the entire link to fail also a few percentage of subcarriers can be affected. Error correction coding can then be used to correct the few erroneous subcarriers. Due to the robustness to the frequency selective multipath channel and the low complexity of the frequency domain equalizer, orthogonal frequency division multiplexing has been seen as one of important technique for the next generation broadband wireless communication systems. There are three types of orthogonal frequency division multiplexing: cyclic prefix orthogonal frequency division multiplexing, zero padding orthogonal frequency division multiplexing and time domain synchronous orthogonal frequency division multiplexing.

The broadly used cyclic prefix orthogonal frequency division multiplexing scheme utilizes the cyclic prefix orthogonal frequency to eliminate the inter block interference as well as the inter carrier interference. With cyclic prefix orthogonal frequency division multiplexing and zero padding orthogonal frequency division multiplexing schemes some dedicated frequency domain pilots are required for synchronization and channel estimation. To solve this problem training sequence such as the pseudorandom noise sequence instead of the cyclic prefix is used as the guard interval in the TDS orthogonal frequency division multiplexing scheme. As the training sequence is known to the receiver, it can be also used for synchronization and channel estimation also. The training sequence serving as the cyclic postfix is not independent of the orthogonal frequency division multiplexing block like that in TDS orthogonal frequency division multiplexing but is generated by the redundant frequency domain comb type pilots within the orthogonal frequency division multiplexing symbol. In this way the inter block interference from the training sequence can be avoided. The cyclic postfix orthogonal frequency division multiplexing scheme does not resolve the problem of the interference from the orthogonal frequency division multiplexing data block. The iterative interference cancellation is required for channel estimation and orthogonal frequency division multiplexing equalization process. Thus the equivalent signal to noise ratio at the receiver will be reduced if the identical transmitted signal power is permitted. The signal to noise loss can be minutely reduced by changing the positions of the redundant pilots in the frequency domain but the effect is not as required. The most effective solution to the interference problem of TDS orthogonal frequency division multiplexing is to duplicate the training sequence twice resulting in the dual pseudorandom noise orthogonal frequency division multiplexing scheme. The second received pseudorandom noise sequence immune from the interference caused by the preceding orthogonal frequency division multiplexing data block can be directly used for channel estimation and the interference cancellation. In this way the iterative interference cancellation algorithm can be avoided leading to the reduced complexity and improved performance over fast fading channels. The spectral efficiency of the dual pseudorandom noise orthogonal frequency division multiplexing solution is remarkably decreased by the doubled length of the training sequence. The principle and methodology of compressed sensing allows the efficient reconstruction of sparse signals from a very limited number of measurements. Compressed sensing has gained a fast growing interest in applied

Revised Version Manuscript Received on April 09, 2016.

Sudha Kushwaha, Research Scholar, Acropolis Institute of Technology and Research, Bhopal (Madhya Pradesh). India.

Prof. Sourabh Pandey, Acropolis Institute of Technology and Research, Bhopal (Madhya Pradesh). India.

mathematics and signal processing. Orthogonal frequency division multiplexing has progressed much and being used for various communication applications such as digital audio broadcasting and digital video broadcasting. It has also been adopted as the physical layer modulation scheme for wireless networking standards such as Hiperlan2 and IEEE 802.11a.The orthogonal frequency division multiplexing overcome the problem of dispersive channels. There are still some problems which need to be addressed such as time and frequency synchronization, frequency selective fading, and the Peak to average power ratio. A multicarrier system is basically a number of information bearing carriers transmitted in parallel. Multicarrier systems in wireless applications are less susceptible to channel induced distortions than single carrier systems at corresponding data rates. Orthogonal frequency division multiplexing is being primarily deployed in the wireless environment. In wireless channel the electromagnetic signals travel through medium may fraught with disruptive and warping effects. The transmitted signal does not only have a direct path to the receiver. The signal is reflected of buildings and mountains and other obstacles so that multiple delayed copies of the same transmitted signal arrive at the receiver affecting other symbols. These causes inter symbol interference which degrades the bit error rate. The longer the delay of the paths the greater will be the inter symbol interference. A measure of the delay is given by the root mean square delay spread which is a measure of the delay experienced by a single pulse. The data rate in a single carrier system can be increased by shortening the symbol time of the transmitted pulses but they will be even more affected by the root mean square delay spread and require more complex equalization in the receiver. This phenomenon has make use of multicarrier techniques where the transmitted bandwidth is divided into many narrow band channels which are then transmitted in parallel. Each subcarrier is modulated at a sufficiently low data rate so that it is not affected by the delay spread.

II. RELATED WORK

D. Linglong, Z.Wang and Z.Yang, et al [1] describes the, orthogonal frequency division multiplexing is widely recognized as the key technology for the next generation broadband wireless communication systems. The time domain synchronous OFDM has higher spectral efficiency than the standard cyclic prefix OFDM but suffers from severe performance loss over high speed mobile channels since the required iterative interference cancellation between the training sequence and the OFDM data block. The redundant grouped pilots only occupy about 3% of the total subcarriers, thus TFT OFDM still has much higher spectral efficiency than CP OFDM by about 8.5% in typical applications. Simulation results also demonstrate that TFT OFDM outperforms CP OFDM and TDS OFDM in high speed mobile environments. Adachi and E. Kudoh, et al[2] explained the most important technical challenge for the realization of 4G mobile networks is twofold: to overcome the highly frequency selective fading channel and to significantly reduce the transmit power from mobile terminals. It has been shown that the application of frequency-domain equalization can take advantage of channel frequency selectivity and improve the transmission performance of single carrier as well as multicarrier signal transmissions. Either SC or MC can be used for the downlink to achieve almost the same bit error rate performance. X. Yuan, Q. Guo, X. Wang, and L. Ping et al [3] described the evolution analysis of low cost iterative equalization in coded linear systems with cyclic prefixes. Muquet, Z. Wang, G. Giannakis, M. De Courville, and P. Duhamel et al[4] states that, the Zero padding of multicarrier transmissions has recently been proposed as an appealing alternative to the traditional cyclic prefix orthogonal frequency division multiplexing to ensure symbol recovery regardless of the channel zero locations. In [5] the digital television terrestrial multimedia broadcasting standard was ratified on August 18, 2006, and is the mandatory digital television terrestrial broadcasting standard in China. DTMB defines the signal frame structure, the coding and modulation schemes, and adopts time domain synchronous orthogonal frequency division multiplexing technology using pseudo random sequence as both the guard interval of the OFDM block and the training symbol. It can deliver fast system synchronization, accurate channel estimation, high spectrum efficiency, and excellent single frequency network performance. X. Wang, P. Ho, and Y. Wu,et al [6] define the channel estimation scheme using a new jammed pilot detection algorithm for orthogonal frequency-division multiplexing systems under narrow band jamming .signal to jamming ratio The jammed pilot subcarrier can be detected and excised by using the proposed algorithm after least squares estimation. The average mean square error on one OFDM symbol both under a jammed and a removed pilot subcarrier are derived analytically. J. Wang, Z. Yang, C. Pan, and J. Song et al [7] defined In contrast to the classical cyclic prefix OFDM, the time domain synchronous OFDM employs a known pseudo noise sequence as guard interval. Conventional channel estimation methods for TDS OFDM are based on the exploitation of the PN sequence and consequently suffer from inter symbol interference. J. Song, Z. Yang, L. Yang, K. Gong, C. Pan, J. Wang, and Y. Wu et al[8] performs that the Digital Terrestrial Television Broadcasting is a member of our daily life routine, and nonetheless, according to new users necessities in the fields of communications and leisure, new challenges are coming up. Moreover the current standard is not able to satisfy all the potential requirements. For that reason first of all a review of the current Standard has been performed. [10][11][12] Studies on the synchronization and channel estimation in cyclic postfix based OFDM system. M. Huemer, C. Hofbauer, and J. Huber et al [13] studies the Unique word prefix in SC/FDE. J. Fu, J. Wang, J. Song, C. Pan, and Z. Yang et al [15] explain the Time domain synchronous orthogonal frequency division multiplexing modulation scheme can improve the spectrum efficiency over the traditional cyclic prefix OFDM technology at the cost of computational efforts due to the iterative padding subtraction at the receiver to mitigate the inter symbol interference caused by the multipath propagation. It also outperforms IPS method under the time varying fading channel in terms of symbol error rate and maximum Doppler frequency verified by the computer simulation. L. Bomer and M. Antweileretal [16] states that the Perfect sequences and arrays have periodic auto correlation functions whose out of phase values are zero. Time discrete N phase sequences and arrays have complex elements of magnitude one, and one of (2π/N) n, 0 ⩽n <N, different phase values.Existenceconditions and construction methodsfor perfectNphase sequences and arrays with a small alphabet of possible phase values are introduced. [20] X. Wang, H. Li, and H. Lin, explain recent development in cognitive radio communications brings significant technical challenges in the design of adaptive and robust transmission techniques in hostile communication environments due to the dynamic channel transitions and strong co-channel interference. [21] W. Song and J. Lim, described the Time varying channels will degrade the performance of orthogonal frequency division multiplexing due to the inter channel interference. Authors proposes the channel estimation for multiple input multiple output OFDM with time varying channels based on the grouped and equi- spaced pilot tones. Authors approximate the time varying channels to the polynomials. In [22] W. Jeon, K. Chang, and Y. Cho, state that the loss of sub channel or thogonality due to time variant multipath channels in orthogonal frequencydivision multiplexing systems leads to inter channel interference which increases the error floor in proportion to the Doppler frequency. A simple frequency domain equalization technique which can compensate for the effect of ICI in a multipath fading channel is proposed. In this technique the equalization of the received OFDM signal is achieved by using the assumption that the channel impulse response varies in a linear fashion during a block period and by compensating for the ICI terms that significantly affect the bit error rate performance. [23] P. Schniter, described the orthogonal frequency division multiplexing systems may experience significant inter carrier interference when used in time and frequency selective, or doubly selective channels. In such cases the classical symbol estimation schemes, e.g., minimum mean squared error (MMSE) and zero forcing estimation require matrix inversion that is prohibitively complex for large symbol lengths. An analysis of the ICI generation mechanism leads us to propose a novel two stage equalizer whose complexity is linear in the OFDM symbol length. The first stage applies optimal linear preprocessing to restrict ICI support, and the second stage uses iterative MMSE estimation to estimate finite alphabet frequency domain symbols. Simulation results indicate that equalizer has significant performance and complexity advantages over the classical linear MMSE estimator in doubly selective channels.

In [24] V. Namboodiri, H. Liu, and P. Spasojevi, explain Turbo equalization schemes based on minimum mean square error criteria available in the literature are computationally involved as they require some form of matrix inversion. Authors propose a low complexity turbo equalization scheme with successive interference cancellation for the equalization of doubly dispersive channels for orthogonal frequency division multiplexing based receiver systems where the matrix inversion is eliminated completely. Numerical simulation results show that TE SIC performs better than other schemes of comparable computation complexity at signal to noise ratios of practical interest. [25] X. Wang, Y. Wu, J. Chou nard, and H. Wu, described a new multicarrier system, termed multi symbol encapsulated orthogonal frequency division multiplexing, in which one cyclic prefix is used for multiple OFDM symbols.

The original motivation for the MSE-OFDM proposal is to reduce the redundancy due to the CP in static channel environments. The authors then found that an alternative implementation of the system can be used to improve the robustness to frequency offset and reduce the peak to average power ratio. A new preamble and the corresponding frequency offset and channel estimation techniques are studied for the MSE OFDM system. Using the proposed MSE OFDM preamble the joint maximum likelihood estimation of the frequency offset and the channel impulse response is investigated. Possible ways to reduce the joint estimation complexity, including exploitation of the preamble structure, approximation of the joint ML estimator, and fast Fourier transform pruning are discussed. The performance of the proposed MSEOFDM systems and channel estimators are analyzed and verified through numerical simulations.

III. SIMULATION RESULT AND DISCUSSION

Simulations were carried out to investigate the performance of the proposed TFT orthogonal frequency division multiplexing transmission scheme. The signal bandwidth was 7.56 MHz at the central radio frequency of 770 MHz and the subcarrier spacing was 2 kHz. The modulation scheme 64QAM was adopted. Other system parameters were consistent specified as $N = 3780$, $M = 420$, $N_{group} = 40$, $Q = 1$, $d = 1$, $S = 20$, $J_0 = 3$.we adopted the powerful low density parity check code with the block length of 64, 8000 bits and code rate of 2/3 as specified by the standard for reliable system performance. The maximum Doppler spread of 20 Hz and 100 Hz were considered which corresponded to the relative receiver velocity of 28 km/h and 140 km/h at 770 MHz respectively. In the result evaluation we assumed M equally spaced combo type pilots. The classical iterative algorithm is used for TDS orthogonal frequency division multiplexing. Figure 4 compares the coded bit error rate performance of the conventional cycle prefix orthogonal frequency division multiplexing, TDS orthogonal frequency division multiplexing and cyclic postfix orthogonal frequency division multiplexing schemes with the proposed TFT orthogonal frequency division multiplexing over the AWGN channel. We find that TFT orthogonal frequency division multiplexing and TDS orthogonal frequency division multiplexing have very close BER performance and they have the SNR gain of 0.18 dB compared with cycle prefix orthogonal frequency division multiplexing and improved cycle prefix orthogonal frequency division multiplexing. The reason is that the equivalent SNR at the receiver is reduced by the large amount of pilot with boosted power in cycle prefix orthogonal frequency division multiplexing and improved cycle prefix orthogonal frequency division multiplexing. Figure1and Figure2 compares the coded BER performance of TFT orthogonal frequency division multiplexing with cycle prefix orthogonal frequency division multiplexing, TDS orthogonal frequency division multiplexing and DPN orthogonal frequency division multiplexing over the Vehicular B channel with the receiver velocity of 28 km/h. The performance of cycle prefix orthogonal frequency division multiplexing is between that of TDS orthogonal frequency division multiplexing and DPN orthogonal frequency division multiplexing while the proposed TFT orthogonal frequency division multiplexing scheme has superior BER performance to those three conventional orthogonal frequency division multiplexing transmission schemes. For example, when the BER equals to 10^{-4}, TFT orthogonal frequency division multiplexing outperforms DPN orthogonal frequency division multiplexing, cycle prefix orthogonal frequency division multiplexing and TDS orthogonal frequency division multiplexing by the SNR gain of 0.95 dB, 1.15 dB and 2.40 dB, respectively. Compared with DPN orthogonal frequency division multiplexing, cycle prefix orthogonal frequency division multiplexing and TDS orthogonal frequency division multiplexing the SNR gain achieved by TFT orthogonal frequency division multiplexing is increased to be about 1.15 dB, 2.25 dB and 4.40 dB respectively. Compared with cycle prefix orthogonal frequency division multiplexing and DPN orthogonal frequency division multiplexing, TFT orthogonal frequency division multiplexing achieves the performance improvement because the proposed joint channel estimation can accurately track the channel variation and inter carrier interference is removed before the frequency domain equalization. Again reducing some pilot and performed the BER analysis with SNR as shown in Figure 3 and Figure 4.

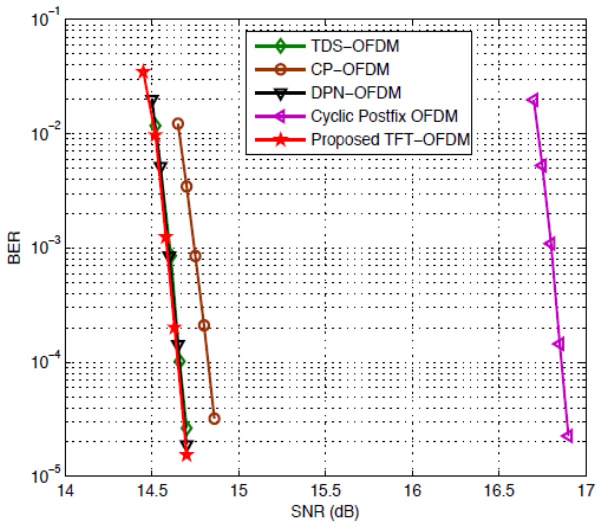

Figure 1: BER performance comparison between the proposed TFT OFDM scheme and the traditional schemes over the AWGN channel

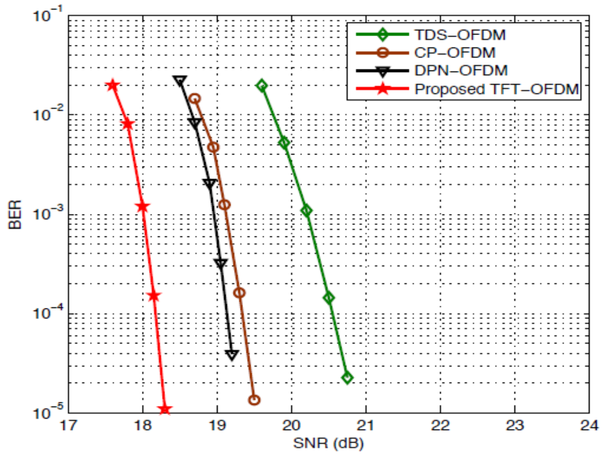

Figure 2: BER performance comparison between the proposed TFT-OFDM scheme and three traditional schemes over the Vehicular B channel with the receiver velocity of 28 km/h.

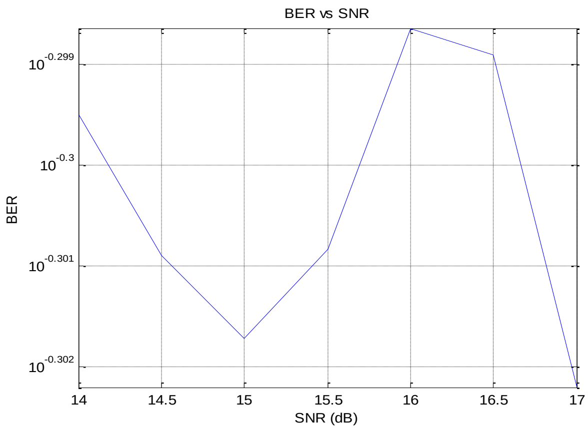

Figure 3: BER performance proposed new TFT OFDM scheme.

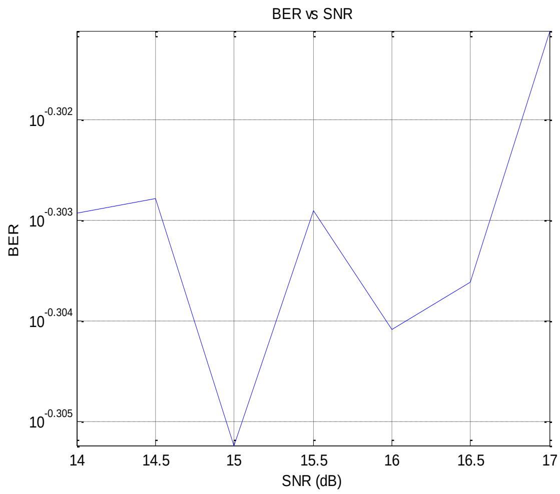

Figure 4: BER performance proposed new TFT OFDM scheme.

IV. CONCLUSION AND FUTURE WORK

This paper present a novel scheme based on orthogonal frequency division multiplexing called TFT orthogonal frequency division multiplexing where the training information exists in both time and frequency domains. The corresponding time frequency channel estimation uses the time domain training sequence without interference cancellation to calculate the channel path delays and the channel path coefficients are gained by using the pilot groups scattered within the orthogonal frequency division multiplexing symbol. Also the variation of the fast fading channels within every TFT orthogonal frequency division multiplexing symbol can be well tracked. The iterative inter carrier interference removal method also aids in system performance improvement. The grouped pilots in TFT orthogonal frequency division multiplexing occupy less than 3% of the signal bandwidth. Thus high spectral efficiency as well as good performance is achieved over fast varying channel. This higher spectral efficiency and enhanced system performance proves this scheme a promising technique for high speed mobile environment in wireless communication system. The signal bandwidth can be improved by varying number of pilots in frequency variable.

REFERENCES

1. D. linglong, Z.Wang and Z.Yang , "Time-Frequency Training OFDM with High Spectral Efficiency and Reliable Performance in High Speed Environments" IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, VOL. 30, NO. 4,pp-695-707, MAY 2012.
2. F. Adachi and E. Kudoh, "New direction of broadband wireless technology," Wireless. Communication Mob. Com., vol. 7, no. 8, pp. 969–983, Oct. 2007.
3. X. Yuan, Q. Guo, X. Wang, and L. Ping, "Evolution analysis of low cost iterative equalization in coded linear systems with cyclic prefixes," IEEE J. Sel. Areas Communication, vol. 26, no. 2, pp. 301–310, Feb. 2008.
4. B. Muquet, Z. Wang, G. Giannakis, M. De Courville, and P. Duhamel, "Cyclic prefixing or zero padding for wireless multicarrier transmissions?" IEEE Trans. Communication, vol. 50, no. 12, pp. 2136–2148, Dec. 2002.
5. C. yen Ong, J. Song, C. Pan, and Y. Li, "Technology and standards of digital television terrestrial multimedia broadcasting," IEEE Communication Mag., vol. 48, no. 5, pp. 119–127, May 2010.
6. Wang, P. Ho, and Y. Wu, "Robust channel estimation and ISI cancellation for OFDM systems with suppressed features," IEEE J. Sel. Areas Communication, vol. 23, no. 5, pp. 963–972, May 2005. On Computers, 61, 2012, pp. 1507-1520.
7. J. Wang, Z. Yang, C. Pan, and J. Song, "Iterative padding subtraction of the PN sequence for the TDS-OFDM over broadcast channels," IEEE Trans. Consume. Electron, vol. 51, no. 11, pp. 1148–1152, Nov. 2005.
8. J. Song, Z. Yang, L. Yang, K. Gong, C. Pan, J. Wang, and Y. Wu, "Technical review on Chinese digital terrestrial television broadcasting standard and measurements on some working modes," IEEE Trans. Broadcast., vol. 53, no. 1, pp. 1–7, Feb. 2007.
9. Framing Structure, Channel Coding and Modulation for Digital Television Terrestrial Broadcasting System. Chinese National Standard, GB 20600-2006, Aug. 2006.
10. J. Kim, S. Lee, and J. Seo, "Synchronization and channel estimation in cyclic postfix based OFDM system," in Proc. IEEE 63rd Vehicular Technology Conference (VTC'06-Spring), Melbourne, Vic, May 2006, pp. 2028–2032.
11. Synchronization and channel estimation in cyclic postfix based OFDM system," IEICE Trans. Communication., vol. E90-B, no. 3, pp. 485– 490, Mar. 2007.
12. S. Tang, K. Peng, K. Gong, and Z. Yang, "Channel estimation for cyclic post fixed OFDM," in Proc. International Conference on Communications, Circuits and Systems (ICCCAS'08), Fujian, China, May 2008, pp. 246–249.
13. M. Huemer, C. Hofbauer, and J. Huber, "Unique word prefix in SC/FDE and OFDM: A comparison," in Proc. IEEE Global Telecommunications Conference (GLOBECOM'10), Miami, USA, Dec. 2010, pp. 1321– 1326.
14. Onic and M. Huemer, "Direct vs. two-step approach for unique word generation in UW-OFDM," in Proc. the 15th International OFDM Workshop (InOWo'10), Los Alamitos, CA, Sep. 2010, pp. 145–149.
15. J. Fu, J. Wang, J. Song, C. Pan, and Z. Yang, "A simplified equalization method for dual PN-sequence padding TDS-OFDM systems," IEEE Trans. Broadcast., vol. 54, no. 4, pp. 825–830, Dec. 2008.
16. L. Bomer and M. Antweiler, "Perfect N-phase sequences and arrays," IEEE J. Sel. Areas Communication., vol. 10, no. 4, pp. 782–789, May 1992.
17. A. V. Oppenheim, R. Schafer, and J. Buck, Discrete-Time Signal Processing, 4th ed. NJ, USA: Prentice Hall, 2010.
18. L. Dai, Z. Wang, C. Pan, and S. Chen, "Positioning in Chinese digital television network using TDS-OFDM signals," in Proc. IEEE International Conference on Communications (ICC'11), Kyoto, Japan, Jun. 2011, pp. 1–5.
19. Frame Structure, Channel Coding and Modulation for a Second Generation Digital Terrestrial Television Broadcasting System (DVB-T2). ETSI Standard, EN 302 755, V1.1.1, Sep. 2009.
20. X. Wang, H. Li, and H. Lin, "A new adaptive OFDM system with pre-coded cyclic prefix for dynamic cognitive radio communications," IEEE J. Sel. Areas Communication, vol. 29, no. 2, pp. 431–442, Feb. 2011.
21. W. Song and J. Lim, "Channel estimation and signal detection for MIMO-OFDM with time varying channels," IEEE Communication. Lett., vol. 10, no. 7, pp. 540–542, Jul. 2006.
22. W. Jeon, K. Chang, and Y. Cho, "An equalization technique for orthogonal frequency division multiplexing systems in time variant multipath channels," IEEE Trans. Communication, vol. 47, no. 1, pp. 27–32, Jan. 1999.
23. P. Schniter, "Low complexity equalization of OFDM in doubly selective channels," IEEE Trans. Signal Process., vol. 52, no. 4, pp. 100–1011, Apr. 2004.
24. Namboodiri, H. Liu, and P. Spasojevi`c, "Low complexity turbo equalization for mobile OFDM systems with application to DVB-H," in Proc. IEEE Global Telecommunications Conference (GLOBECOM'10), Miami, USA, Dec. 2010, pp. 1328–1333.
25. X. Wang, Y. Wu, J. Chouinard, and H. Wu, "On the design and performance analysis of multi symbol encapsulated OFDM systems," IEEE Trans. Veh. Technol., vol. 55, no. 3, pp. 990–1002, May 2006.