Reduction in PAPR-BER of MIMO System using Hybrid Companding and DCT Technique

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Abstract—One of the major drawback of OFDM system is relatively high Peak-to-Average Power Ratio (PAPR), which tends to reduce the power efficiency of the Radio Frequency Amplifier. In order to minimize the PAPR ratio this thesis focuses on PAPR reduction techniques. Extensive investigation of different PAPR reduction techniques has been made. Based on the survey it is found Selective Mapping (SLM) is the most widely used PAPR reduction technique. It is distortion less, efficient, offers better BER performance and can be implemented for any number of sub-carriers. One of the disadvantage is high computational complexity. In this paper hybrid discrete cosine transform (DCT) and companding, for two antennas MIMO-OFDM system, is proposed which can achieve better PAPR performance at much less bit error rate (BER). Simulation results show that the proposed approach can reduce BER and achieve a better PAPR reduction compared to previous technique.

Keywords— PTS, DCT, COMPANDING, MIMO-OFDM, PAPR, BER

I. INTRODUCTION

The rapid growth of the wireless communication market is expected to continue in the future, as the demand for all types of wireless services is increasing. New generations of wireless mobile radio systems aim to provide flexible data rates and a wide variety of applications to the mobile users while serving as many users as possible. As more and more devices go wireless, future technologies will face spectral crowding, and coexistence of wireless devices will be a major issue. Therefore, considering the limited bandwidth availability, accommodating the demand for higher capacity and data rates is a challenging task, requiring innovative technologies that can coexist with devices operating at various frequency bands. Recent wireless applications demands for high data rate. However the symbol duration reduces with increase in data rate, system using single carrier modulation suffer from severe inter symbol interference caused by dispersive fading channel there by requires more complex equalization. A very complex receiver structure is needed which makes use of computationally expensive equalization and channel estimation algorithms to correctly estimate the channel, so that the estimations can be used with the received data to recover the originally transmitted data. Orthogonal Frequency Division Multiplexing (OFDM) can drastically simplify the equalization problem by turning the frequency-selective channel into a flat channel. A simple one-tap equalizer is needed to estimate the channel and recover the data [1]. OFDM is a special form of multi carrier transmission technique, it divides the entire frequency selective fading channel into many narrow band flat fading sub channels in which high bit rate data are transmitted in parallel and do not undergo Inter Symbol Interference (ISI) due to the long symbol duration [2]. Therefore OFDM Modulation is considered as key Technology and adopted in Digital Audio Broadcasting (DAB), terrestrial TV in Europe , Wireless local area network (WLAN), Multimedia Mobile Access Communication (MMAC) [3-4], Wimax and LTE.

The transmit signals in an OFDM system can have high peak values in the time domain since many sub-carrier components are added via an IFFT operation. Therefore, OFDM systems are known to have a high PAPR, compared with single carrier systems [5]. In fact, the high PAPR is one of the most detrimental aspects in the OFDM system, as it decreases the Signal-to-Quantization Noise Ratio (SQNR) of Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC) while degrading the efficiency of the power amplifier in the transmitter [6].

II. MIMO-OFDM SYSTEM

Multiple antenna techniques can be used to increase diversity of wireless systems in order to increase the cell range, data rate through spatial multiplexing, and reduce interference from other users. Multiple-antenna techniques include MIMO diversity and MIMO spatial multiplexing. OFDM can transform such a frequency-selective MIMO channel into a set of parallel frequency-flat MIMO channels to decrease receiver complexity. MIMO diversity is a space-time modulation technique in which the core idea is to send dependent streams of data from each transmit antenna [6]. The combination of OFDM and MIMO systems [7] can achieve a lower error rate and enable high capacity of wireless communication system by flexibly exploiting diversity gain and the spatial multiplexing gain. The space time coding method aims to improve the system’s performance by exploiting the multiple antennas for diversity gain. It increases the network throughput by selecting quality signal paths such that high data rates can be achieved. This method is particularly attractive as it does not require channel knowledge in the transmitter. The resulting diversity gain improves the reliability of fading wireless links and hence improves the quality of the transmission. It is notable that the space time coding [8] method does not increase the capacity linearly with the number of transmit/receive elements used. However, it maximizes the wireless range and coverage by improving the quality of the transmission.

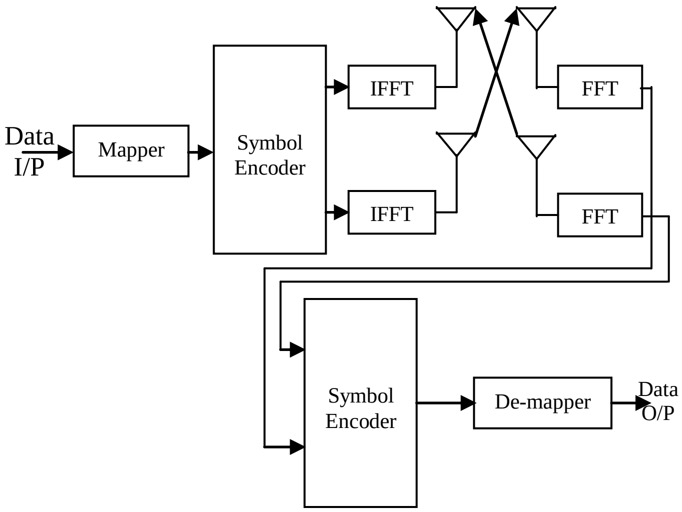

Figure 1: MIMO-OFDM system model

The received signal at j[th] antenna can be expressed as

$$R_j[n.k] = \sum H_{ij}[n,k]\, X_i\, [n,k] + W[n,k] \quad (1)$$

Where H is the channel matrix, X is the input signal and W is noise with zero mean and variance. Also b_i [n,k] represents the data block i^{th} transmit antenna, n^{th} time slot and k^{th} sub channel index of OFDM. Here i and j denoted the transmitting antennas index and receiving antenna index respectively.

The MIMO-OFDM system model [10] with NR receives antennas and NT transmits antennas can be given as:

$$\begin{bmatrix} Z_1 \\ Z_2 \\ \vdots \\ Z_N \end{bmatrix} = \begin{bmatrix} H_{1,1} & H_{1,2} & \cdots & H_{1,NT} \\ H_{2,1} & H_{2,2} & \cdots & H_{2,,NT} \\ \vdots & \vdots & \ddots & \vdots \\ H_{NR,1} & H_{NR,2} & \cdots & H_{NR,NT} \end{bmatrix} \begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_{NT} \end{bmatrix} + \begin{bmatrix} M_1 \\ M_2 \\ \vdots \\ M_{NT} \end{bmatrix} \quad (2)$$

Where, Z represents O/P data vector, H denotes Channel matrix, A denotes I/P data vector and M represents Noise vector. The wireless channel used is AWGN channel. After receiving the signal the CP is removed then the pilots are also removed from main signal received. After this the signal that is in time domain can be again converted to frequency domain by taking FFT of the received signal.

The sequence on each of the OFDM block is then provided to channel estimation block where the received pilots altered by channel are compared with the original sent pilots. Channel estimation block consists of the algorithms that are applied to estimate the channel.

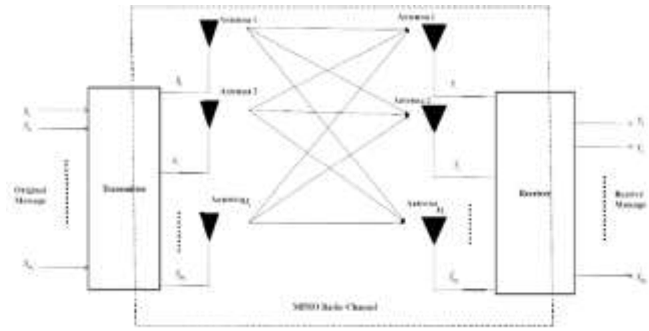

Figure 2: Block diagram of MIMO-OFDM system

A MIMO system takes advantage of the spatial diversity that is obtained by spatially separated antennas in a dense multipath scattering environment. MIMO system may be implemented in different ways to obtain either diversity gain to combat signal fading or to obtain capacity gain. MIMO can be easily realized through Space Time Coding (STC) such as Space Time Block Codes (STBC) and Space Time Trellis Codes (STTC) which transmits multiple copies of data stream across number of antennas. The space-time-frequency coded OFDM system is used to achieve maximum diversity. It provides increased spectral efficiency and is effective in handling the frequency selective fading nature of the wireless channel [9].

III. PTS SCHEMES

In the SISO-PTS scheme, the original data sequence in the frequency domain is partitioned into M disjoint, equal length sub blocks Xv (v = 1, 2... M) as follows [11].

$$X = \sum_{v=1}^{M} X_v \quad (3)$$

By multiplying some weighting coefficients to all the subcarriers in every subblock, we can get the new frequency sequence.

$$X' = \sum_{v=1}^{M} b_v X_v \quad (4)$$

Finally, at each transmitting antenna, there are (V-1) sub blocks to be optimized, and the candidate sequence with the lowest PAPR is individually selected for transmitting. Assume that there are W allowed phase weighting factors. To achieve the optimal weighting factors for each transmitting antenna, combinations should be checked in order to obtain the minimum PAPR [12].

In, the idea of alternate optimization is introduced, and it can be also applied to PTS in multiple antennas OFDM systems, denoted as alternate PTS. Different from ordinary PTS, phase weighting factors are needed only for half of the sub blocks in A-PTS. That is to say, starting from the first sub block, every alternate sub block is kept unchanged and phase weighting factors are optimized only for the rest of the sub blocks, which leads to the reduction of computational complexity. In this way, the computational complexity is greatly reduced at the expense of PAPR performance degradation [11]. Employed spatial sub block circular permutation for A-PTS scheme to increase the number of candidate sequences which improves the PAPR performance further.

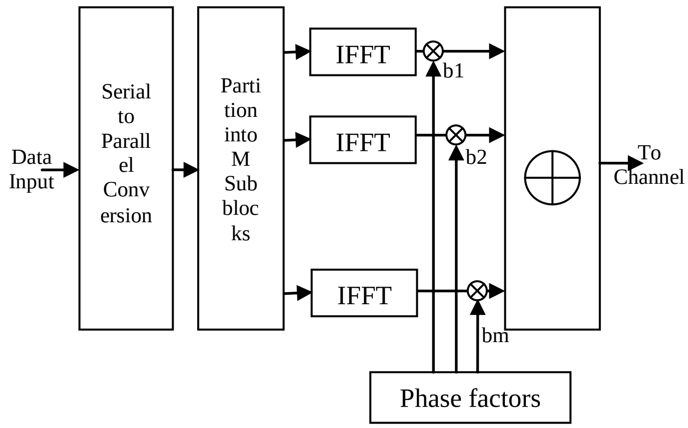

Figure 3: Block Diagram of PTS Scheme

Next, the conversion of the optimum weighting coefficient is discussed. In order to maintain the conjugate and symmetric relations between the two antennas after scrambling sequence methods, we should convert the optimum weighting coefficient a(opt) at antenna 1 into that of antenna 2 denoted as b(opt) by the inverse conjugate and symmetric transformation. For example, when the optimum weighting coefficient a (opt) is [1, 1, j, -j], the optimum weighting coefficient for antennas 2 is b (opt) = [1, 1, -j, j]. The PTS scheme can be also applied to the MIMO-OFDM system with more transmits antennas.

Based on advance PTS, an approach to solve the contradiction between the PAPR performance and computational complexity in STBC MIMO-OFDM system is proposed. Let us consider a STBC MIMO-OFDM system that employs Alamouti scheme. The coding matrix is:

$$G = \begin{pmatrix} x_1 & -x_2^* \\ x_2 & x_1^* \end{pmatrix} \quad (5)$$

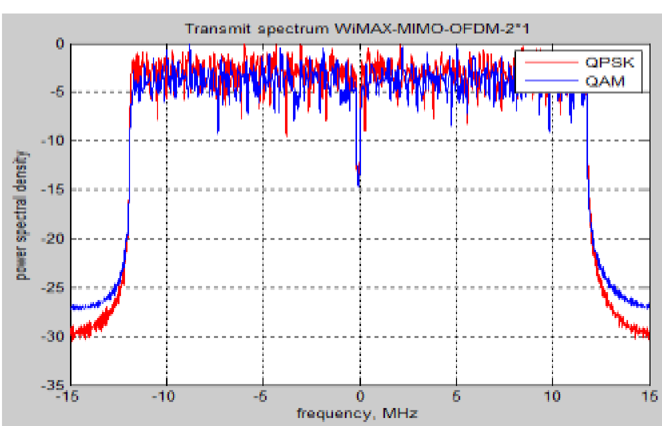

Figure 4: Power Spectral Density of MIMO-OFDM 4×4 System

Simulation experiments are conducted to evaluate the transmit spectrum, bit error rate (BER), peak average to peak ratio (PAPR) reduction performance of the MIMO-OFDM scheme using PTS technique. In addition, it is assumed that the data are QPSK, 16-QAM modulated and are transmitted using 256 FFT.

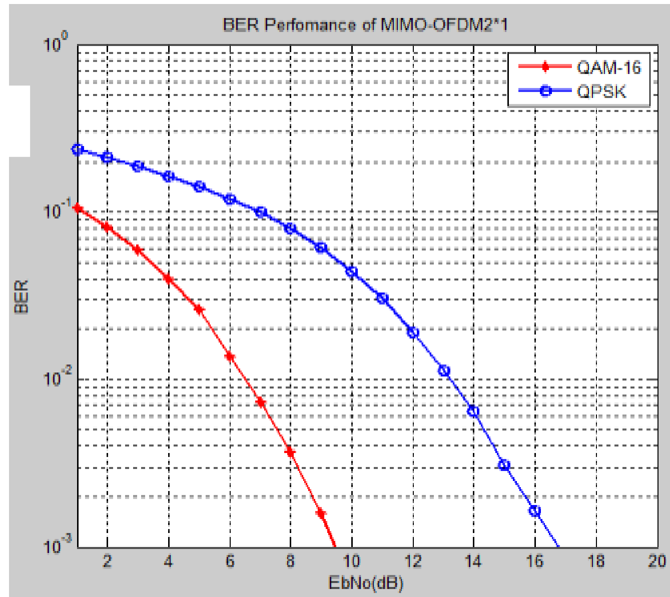

Figure 5: BER Performance of MIMO-OFDM 4×4 System

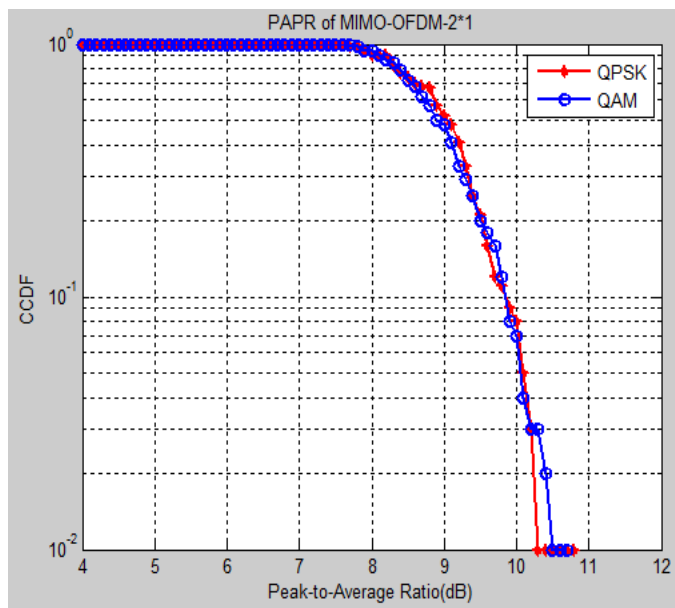

Figure 6: PAPR Performance of MIMO-OFDM 4×4 System

IV. PROPOSED METHODLOGY

We have proposed a wavelet based MIMO-OFDM system for the reduction of PAPR, which effectively reduces the PAPR on rational selection of phase values.

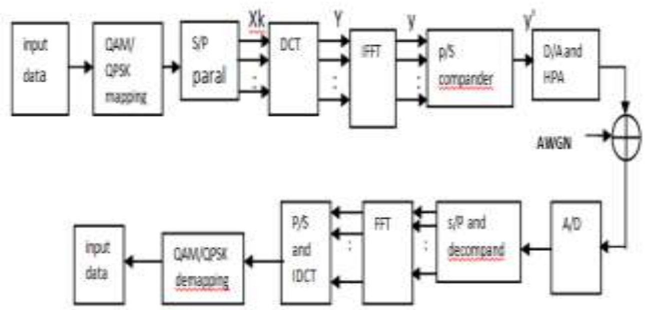

Figure 7: Flow Char of Proposed Methodology

First the original input signal is modulated with BPSK, QPSK, QAM-16 and PTS technique had been applied, where the phase values are generated using optimized algorithm. This helps to minimize the PAPR of the input signal. Then discrete wavelet transform is applied and has been followed by DCT which is applied transmitted through AWGN channel. At the receiver, the inversion of transmitter will be done.

Figure 6 shows the enhanced transmitter block diagram of the presented work. In this research work conventional OFDM is followed by the WPT and DCT for PAPR reduction and vice versa is also simulated. Both transmitter and receiver are simulated in order to calculate the BER.

VI. SIMULATION RESULT

The CCDF is generally used to evaluate the performance of PAPR reduction on MIMO-OFDM system (IEEE 802.16e) signals for a statistical pair of view. The CCDF is defined as the probability that the PAPR as in equation and $PAPR_0$ as shown in the following:

$$PAPR\{Y\} = \arg \underbrace{\max}_{k=1,2,3,\ldots\ldots N_T} (PAPR\{Y_k\})$$

Where Y_k , $k = 1.2.3.......N_T$ represents the time-domain transmitted signal of the k-th antenna

$$CCDF(PAPR_0) = \Pr(PAPR\{Y\} > \{PAPR_0\})$$

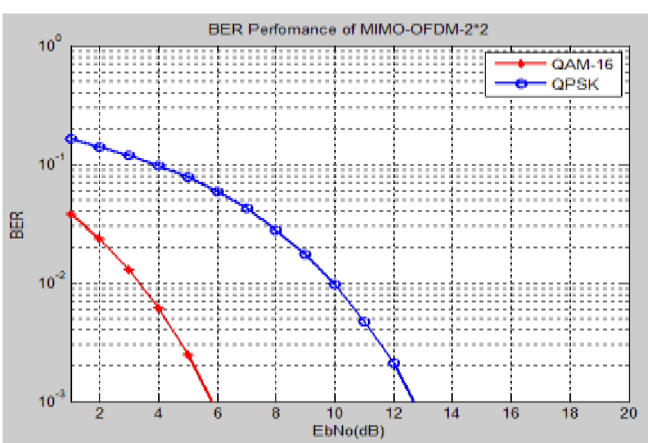

Figure 8: BER Performance of MIMO-OFDM 2×2 System

Figure 8 shows the graphical illustration of the performance of MIMO-OFDM 2×2 System using hybrid DCT with companding technique discussed in this research work in term of bit error rate (BER). From the above graphical representation it can be inferred that the proposed algorithm gives the best performance for QAM-16 modulation technique.

Figure 9 shows the graphical illustration of the performance of MIMO-OFDM 2×2 System discussed in this research work in term of peak signal to noise ratio (PAPR). From the above graphical representation it can be inferred that the proposed hybrid DCT with companding technique based MIMO-OFDM algorithm gives the best performance for QAM-16 modulation technique.

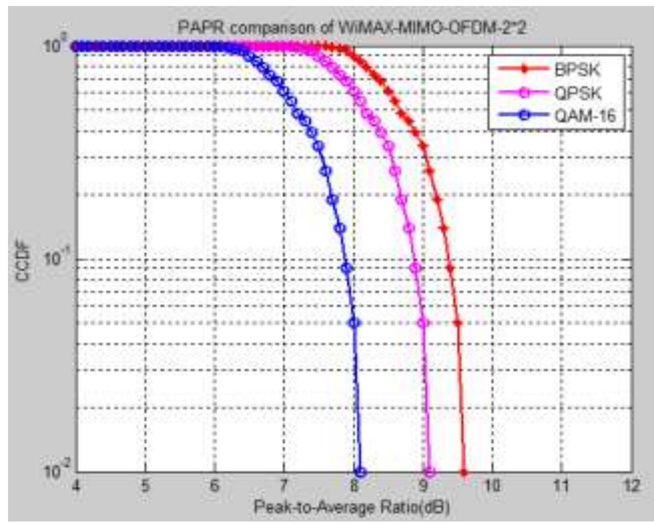

Figure 9: PAPR Performance of MIMO-OFDM 2×2 System

VII. CONCLUSION

Another approach to control the high PAPR is to use FEC coding across subcarriers and select such codewords which minimise the PAPR and also effectively improve the error rate performance. This will reduce the inherent redundancy; however, it should be exploited for error correcting. Moreover, the achievable code rate decreases with increasing code length. In order to maintain a reasonable rate, several shorter length codes can be used to encode a large number of OFDM sub channels. In this paper, a method is proposed for minimization of PAPR in MIMO-OFDM systems using PTS method. The PTS is concatenated with DCT and DWT signal processing algorithm to improve the efficiency and reduction of peak power of the MIMO-OFDM system. Because of autocorrelation of DCT the average power will be reduced.

REFRENCES

[1] Ebubekir Memisoglu, Ahmet Enes Duranay and Hüseyin Arslan, "Numerology Scheduling for PAPR Reduction in Mixed Numerologies", IEEE Wireless Communications Letters, Vol. 10, No. 6, June 2021.

[2] H. Chen, J. Hua, J. Wen, K. Zhou, J. Li, D. Wang, and X. You, ''Uplink interference analysis of F-OFDM systems

under non-ideal synchronization,'' IEEE Trans. Veh. Technol., vol. 69, no. 12, pp. 15500–15517, Dec. 2020.

[3] S. Rajasekaran, M. Vameghestahbanati, M. Farsi, H. Yanikomeroglu, and H. Saeedi, ''Resource allocation-based PAPR analysis in uplink SCMA-OFDM systems,'' IEEE Access, vol. 7, pp. 162803–162817, 2019.

[4] Z. Zhou, L. Wang, and C. Hu, ''Low-complexity PTS scheme for improving PAPR performance of OFDM systems,'' IEEE Access, vol. 7, pp. 131986–131994, 2019.

[5] W. Hu, ''SLM-based ACO-OFDM VLC system with low-complexity minimum amplitude difference decoder,'' Electron. Lett, vol. 54, no. 3, pp. 141–146, 2018.

[6] Y. Hori and H. Ochiai, ''A new uplink multiple access based on OFDM with low PAPR, low latency, and high reliability,'' IEEE Trans. Commun., vol. 66, no. 5, pp. 1996–2008, May 2018.

[7] Ashna Kakkar, Sai Nitesh Garsha,Ojasvi Jain and Kritika, "Improvisation in BER and PAPR by using hybrid reduction techniques in MIMO-OFDM employing channel estimation techniques", 7th International Advance Computing Conference, IEEE 2017.

[8] Ho-Lung Hung, Yung-Fa Huang, Ching-Chuan and Rung-Ching Chen, "Performance of PTS-Based Firefly Algorithm Scheme for PAPR Reduction in SFBC MIMO-OFDM Communication Systems", International Symposium on Computer, Consumer and Control, IEEE 2016.

[9] P. Kothai and R. Prabhu M.E., "PAPR Reduction in MIMO OFDM Using Adaptive SLM Scheme", International Journal for Research in Applied Science & Engineering Technology (IJRASET), Vol. 03, No. 05, pp. 729-735, May 2015.

[10] Muhammet Nuri Seyman, Necmi Taspmar, "Channel estimation based on neural network in space time block coded MIMO-OFDM system", Digital Signal Processing, Vol. 23, No.1, pp. 275-280, Jan. 2013.

[11] P. Mukunthan and, P Dananjayan," PAPR Reduction based on a Modified PTS with Interleaving and Pulse Shaping method for STBC MIMO-OFDM System", IEEE ICCCNT'12 , 26th _28th July 2012, Coimbatore, India.

[12] L. Yang, K. K. Soo, S. li, and Y. M. SU, "PAPR Reduction Using Low Complexity PTS to Construct of OFDM Signals Without Side Information", IEEE Transactions on Broadcasting, Vol. 57, No. 2, pp. 4532-4539, June 2011.

[13] Anushree Neogi and Abhijit Mitra "MAP Estimation of CFO and STO for a Convolutionally Coded OFDM System" National Conference on Communications (NCC), pp. 01-05, IEEE 2011.

[14] Chin-Liang Wang and Shun-Sheng Wang and Hsiao-Ling Chang, "A Low-Complexity SLM Based PAPR Reduction Scheme for SFBC MIMO-OFDM Systems", 978-1-61284-254-7/11 IEEE 2011.

[15] Li, M., Wang, X. and Guo, L.W. "The Research on the Performance of Iterative KALMAN Channel Estimation in MIMO-OFDM System", Journal of Hebei University of Science and Technology, Vol. 31, No.6, pp. 550-552, Dec. 2010.