Review of Single Carrier/Multi Carrier OFDM Performance Enhancement Techniques

Ms.Harshada Dilip Sawant, Prof. Mr. G.B. Lohiya

Abstract— **The traditional Orthogonal Frequency Division Multiplexing (OFDM) has its number of advantages such as robustness against frequency selective fading, high data rate transmission, bandwidth efficiency, etc. But the major problems with multi carrier OFDM is high peak to average power ratio and high sensitivity to carrier frequency offset (CFO).**

The aim of this paper is to study techniques to enhance the performance of multi carrier/ single carrier OFDM. The study shows that the problem of high PAPR in OFDM can be reduce by using SCOFDM (Single Carrier Orthogonal Frequency Division multiplexing) which is combination of traditional single carrier technique and OFDM. But performance of SCOFDM degrades due to ICI in high mobility environment and this can be improved by using various ICI reduction techniques such as windowing, self-cancelation, MKM, etc. While improving the ICI, performance degradation may occur due to increase in PAPR. This paper also discusses various PAPR reduction techniques such as clipping and filtering, pulse shaping, adaptive filter, etc.

The literature review shows that MKM (Magnitude Keyed Modulation) is simplest method to reduce the ICI in high mobility environment for SCOFDM but MKM causes high PAPR. The increased PAPR due to MKM can be reducing by using PAPR reduction techniques such as Clipping and Filtering.

Index Terms— SCOFDM, OFDM, ICI, PAPR

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has several advantages over traditional single carrier technique such as bandwidth efficiency, spectral efficiency better than FDM (frequency division multiplexing), high data rate transmission, etc. Due to these advantages it has been considered as a strong candidate for next generation wireless communication systems, but it suffers from the problem of high PAPR and sensitivity to Doppler and frequency offset. The high PAPR affect the Power amplifier if OFDM is used for uplink because mostly user equipment's are battery operated. SCOFDM is combination of traditional single carrier technique and multi carrier OFDM. Compared to traditional OFDM, Single Carrier OFDM (SC-OFDM) has demonstrated excellent bit error rate (BER) performance, as well as low peak to average power ratio (PAPR). Similar to other multi-carrier transmission technologies, SC-OFDM suffers significant performance degradation resulting from intercarrier interference (ICI) in high mobility environments. Different ICI mitigation techniques are proposed in the past years for OFDM as well as SCOFDM.

Manuscript received March, 2015.

Ms.Harshada Dilip Sawant.*,Electronics and Telecommunication, University of Mumbai/DMCE, Navi Mumbai,,India*

Prof. Mr. G. B. Lohiya*, Electronics and Telecommunication, University of Mumbai/ DMCE, Navi Mumbai, India,*

II. SINGLE CARRIER ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (SCOFDM)

To minimize the PAPR issue a solution has been proposed, called Single carrier OFDM (SC-OFDM). The name SCOFDM is misleading as DFT-S-OFDM (Discrete Fourier Transform spread OFDM).The name DFT-S-OFDM better represents the process, but SCOFDM is used as marketing name [15]. DFT-S-OFDM technique is also known as a Single Carrier Frequency Division Multiple Access (SCFDMA). SCOFDM is a combination of traditional single carrier technique and traditional OFDM.

Single Carrier OFDM (SC-OFDM) combine benefits of multi-carrier trans- mission with single carrier transmission. The transmitter and receiver block diagram for SCOFDM system is shown in Fig 1.

The block diagram of SCOFDM shows that modulated input data is transformed into time domain by using DFT (Discrete Fourier Transform). Then symbol mapping is done. After that IDFT (Inverse Discrete Fourier Transform) block map it to block of subcarriers. The processed data is transmitted to the receiver through channel; the reverse procedure of transmitter is performed at the receiver.

Single carrier OFDM has advantages such as excellent bit error rate (BER) performance as well as low peak to average power ratio (PAPR) as compared to multi carrier Orthogonal frequency Division Multiplexing (OFDM) [3].

ISSN: 2278 – 909X

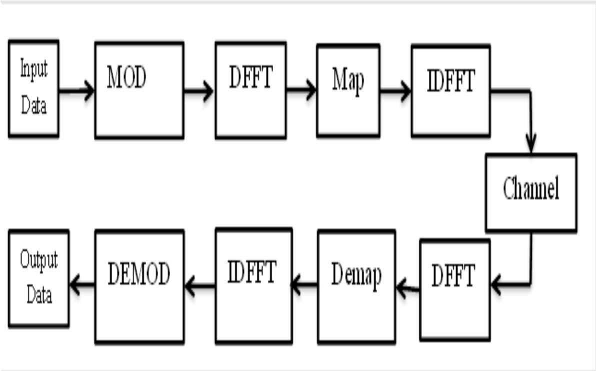

Fig. 1 Block diagram of SCOFDM transmitter and Receiver

III. ICI Reduction techniques

A. Interference Cancellation Technique

This technique is used by many people for OFDM as well as SCOFDM mentioned in [4, 5, 6, 7, and 14]. These techniques reduce or eliminate the ICI, reduce sensitivity to frequency shifts. But these ICI cancellation or self-cancellation techniques are having disadvantages such as additional multiplication, complexity, etc.

B. Windowing or Window Shaping Technique

Windowing or window shaping techniques are mentioned in [2, 8]. The window shaping technique for OFDM radio-over fiber system [2] increase the resistance to residual CFO to about eight times. Also improved the sampling frequency offset but this improvement was done at the power penalty of 2dB. While in Edge windowing technique side lobe suppression was achieved while maintaining the spectral efficiency.

C. CP-OQAM-OFDM Based SC-FDMA

Wenjin Wang et.al. proposed CP-OQAM-OFDM Based SC-FDMA: Adjustable User Bandwidth and Space-Time Coding [17]. To combat both inter-symbol- interference and multiple access interference in frequency- selective fading channels, a joint linear minimum mean square error frequency domain equalization using prior information with low complexity was developed. Subsequently, they constructed space-time codes for the proposed SC-FDMA. Advantage of this method is that it combats Inter symbol interference (ISI) and Multi access interference (MAI) with less complexity.

D. Magnitude Keyed Modulation

Xue Li et. al. proposed an ICI immune SCOFDM via Magnitude Keyed Modulation (MKM) for high speed aerial vehicle communication [1]. As in this paper they used SCOFDM it will provide excellent BER performance and low PAPR. Magnitude Keyed Modulation technique provide ICI immunity without increasing the complexity of system. In this method they used the magnitude to carry digital symbols. Another advantage of this method is provides ICI immunity without reducing the data rate. Small disadvantage is that PAPR will increase in small amount as compared to SCOFDM with QPSK since magnitude varies for different symbol in time domain. However SCOFDM with MKM has much lower PAPR than OFDM system with either PSK or MKM.

IV. PAPR Reduction techniques

A. PAPR Reduction Scheme for SC-OFDM with Frequency Domain Multiplexed Pilots

Fumihiro Hasegawa et.al proposed A Novel PAPR Reduction Scheme for SC-OFDM with Frequency Domain Multiplexed Pilots [9]. In this paper a novel data-pilot multiplexing scheme with reduced peak to average power ratio (PAPR) was introduced for single carrier (SC)-orthogonal frequency division multiplexing (OFDM) systems. In this scheme, phases of SC- OFDM symbols were rotated adaptively such that PAPR is reduced and circular shifts are introduced in the time domain (TD). The advantages of this technique are it reduces PAPR and provide superior Bit error rate (BER).

B. Peak Power Reduction of SC-FDMA Signals Based on Trellis Shaping

Taewoo Lee et.al proposed Peak Power Reduction of SC-FDMA Signals Based on Trellis Shaping [18]. They proposed, by a novel modification the peak power reduction technique based on the trellis shaping developed for conventional single-carrier modulation, they demonstrated that significant PAPR reduction can be achieved for SC-FDMA signals. This technique mitigates the increase of PAPR.

C. Clipping and Filtering Technique

This method was proposed in [10, 16]. Using clipping processing causes both in-band distortion and out-of-band distortion but this can be reduce by using filtering after clipping. This technique provides PAPR reduction by simple way. Here clipping expand the signal spectrum but it was reduced by using the filtering technique. Filtering decreases the spectrum growth.

D. PAPR Reduction in Coded SC-FDMA Systems via Introducing Few Bit Errors

Jinwei Ji et.al. proposed PAPR Reduction in Coded SC-FDMA Systems via Introducing Few Bit Errors [11].They proposed a simple and flexible peak-to-average power ratio (PAPR) reduction scheme for coded single carrier frequency division multiple access (SC-FDMA) signals in the uplink of the Long Term Evolution (LTE). The proposed scheme was based on the introduction of few bit errors to modify the few complex modulated symbols of each data SC-FDMA symbol in a sub-frame, which cause peaks of the output signal samples to be larger than a predetermined threshold value. Advantages of this method are it is simple, flexible and avoid

ISSN: 2278 – 909X

excess Bandwidth (BW). This method can be used for higher order modulation.

E. Pulse shaping filters

The above mentioned technique was proposed in [12] by Ishu, Naresh Kumar. This technique reduces PAPR by using pulse shaping filters such as Raised cosine Filter (RC) and Rooted Raised Cosine Filter (RRC).

F. Adaptive Digital filter

Aping Yao et. al proposed Peak-To-Average Power Reduction of OFDM Signals Using Adaptive Digital Filter [13]. Authors proposed a novel method to reduce the PAPR of the OFDM signals. The presented method adaptively filters the modulated data (M-PSK and QAM) to obtain OFDM symbols with a minimized PAPR. With optimally selected digital filter coefficients, the PAPR of the OFDM symbols can be minimized. The PAPR reduction of OFDM signals varies with the order of the digital filter. In a receiver, the modulated data may be recovered by a reversed procedure. Simulation results in this paper demonstrated that this method was more superior to the PCR method for the PAPR reduction.

V. Conclusion

For high mobility environment ICI is one of the major issues. As per the literature review, Magnitude Keyed Modulation provides ICI immunity to single carrier OFDM system without increasing the complexity of the system. Single carrier OFDM has low PAPR as compared to conventional OFDM but while reducing the ICI by using MKM, PAPR increases as compared to SCOFDM with MPSK modulation. This increased PAPR can be reduced by using the PAPR reduction techniques. Clipping and filtering technique is the simple way to reduce PAPR. If it is possible to reduce increased PAPR in SCOFDM via MKM then this method will be convenient for High speed aerial vehicle communication.

Acknowledgment

Author Ms. Harshada Dilip Sawant thanks Prof. G. B. Lohiya, Asst. Prof. DMCE, Airoli, Navi Mumbai for guiding her throughout her work.

REFERENCES

[1] Xue Li, Steven Hong, Vasu D. Chakravarthy, Michael Temple, Zhiqiang Wu, “Intercarrier Interference Immune Single Carrier OFDM via Magnitude-Keyed Modulation for High Speed Aerial Vehicle Communication”, *IEEE Transactions On Communications*, Vol. 61, No. 2, February 2013

[2] Li Tao, Jianjun Yu, Junwen Zhang, Yufeng Shao, and Nan Chi, “Reduction of Intercarrier Interference Based on Window Shaping in OFDM RoF Systems”, *IEEE Photonics Technology Letters*, Vol. 25, No. 9, May 1, 2013

[3] Hideo Kohayash, Tadayuki Fukuharal, Hao Yuant, and Yoshio Takeuchi, “Proposal of Single Carrier OFDM Technique with Adaptive Modulation Method”, in *Proc. 2003 IEEE Veh. Technol. Conf. – Spring*, vol. 3, pp. 1915–1919.

[4] S.-M. Tseng, Y.-C. Kuo, and Y.-T. Hsu, “Turbo ICI cancellation and LDPC decoding for OFDM systems,” in *Adv. Technol. Commun.*, pp. 405–408, Oct. 2008

[5] Y. Zhao and S.-G. Haggman, “Intercarrier interference self-cancellation scheme for OFDM mobile communication systems,” *IEEE Trans. Commun.*, vol. 49, pp. 1185–1191, July 2001.

[6] A. Seyedi and G. Saulnier, “General ICI self-cancellation scheme for OFDM systems,” *IEEE Trans. Veh. Technol.*, vol. 54, pp. 198–210, Jan.2005.

[7] X. Li, R. Zhou, V. Chakravarthy, S. Hong, and Z. Wu, “Total intercarrier interference cancellation for OFDM mobile communication systems,” in *Proc. 2010 IEEE Consumer Commun. Netw. Conf.*, pp. 1–5.

[8] Alphan Sahin, Huseyin Arslan, “Edge Windowing for OFDM Based Systems”, *IEEE Communications Letters*, Vol. 15, No. 11, November 2011

[9] Fumihiro Hasegawa, Akihiro Okazaki, Hiroshi Kubo, Damien Castelain, and David Mottier, “A Novel PAPR Reduction Scheme for SC-OFDM with Frequency Domain Multiplexed Pilots”, *IEEE Communications Letters*, Vol. 16, No. 9, September 2012

[10] Prafulla. D. Gawande, Sirddharth. A. Ladhake, “PAPR Performance Of Ofdm System By Using Clipping And Filtering Method”, *International Journal of Advances in Engineering & Technology*, Vol. 6, Issue 2, pp. 789-794, May 2013,

[11] Jinwei Ji, Guangliang Ren, Huining Zhang, “PAPR Reduction in Coded SC-FDMA Systems via Introducing Few Bit Errors”, *IEEE Communications Letters*, Vol. 18, No. 7, July 2014

[12] Ishu,Naresh Kumar, “PAPR Reduction in Wavelet based SCFDMA using Pulse Shaping Filters for LTE Uplink Transmission”, *International Journal of Applied Engineering Research*, Volume 9, Number 20 (2014) pp. 6481-6492

[13] Aping Yao, Yi Zheng, “Peak-To-Average Power Reduction Of OFDM Signals Using Adaptive Digital Filter”, *IEEE* ICASSP, pp. 305-308, 2006

[14] Meng Ma, Xiaojing Huang, Y. Jay Guo, “An Interference Self-Cancellation Technique for SC-FDMA Systems”, *IEEE Communications Letters*, Vol. 14, No. 6, June 2010

[15] Leonhard Korowajczuk, *LTE, WiMAX and WLAN Network Design, Optimization and Performance Analysis*, John Willey & Sons,2011

[16] Luqing Wang and Chintha Tellambura, “A Simplified Clipping and Filtering Technique for PAR Reduction in OFDM Systems”, *IEEE Signal Processing Letters*, Vol. 12, No. 6, pp.453-456 June 2005

[17] Wenjin Wang, Xiqi Gao, Fu-Chun Zheng, Wen Zhong, “CP-OQAM-OFDM Based SC-FDMA: Adjustable User Bandwidth and Space-Time Coding”, *IEEE Transactions On Wireless Communications*, Vol. 12, No. 9, pp.4506-4517, September 2013

[18] Taewoo Lee, Hideki Ochiai, “Peak Power Reduction

ISSN: 2278 – 909X

of SC-FDMA Signals Based on Trellis Shaping", *Globocom 2012 symposium on selected areas*,3268-3273

Ms. Harshada Dilip Sawant received her B. E. degree in Electronics and Telecommunication from University of Mumbai and pursuing M.E. from Datta Meghe College of Engg., Airoli, Navi Mumbai, University of Mumbai. Her area of interest is wireless communication.

Prof. Mr. G. B. Lohiya completed his M.E in Electronics Engineering from Shri Guru Gobind Singhji Institute of Engineering and Tech. Nanded .He is currently an Asst. Professor in Datta Meghe College of Engg., Airoli, Navi Mumbai, University of Mumbai, India. His current research interest includes embedded systems and networks.

ISSN: 2278 – 909X