A Review of Pre-Coding Based System to Reduce PAPR in OFDMA

Iqra Sattar[1], Muhammad Shahid[2] and Mohsin Khan[3]
[1,3]Department of Computer Science, University of Lahore (Sargodha Campus)
[2]Department of Electrical Engineering, Pakistan Institute of Engineering and Applied Sciences
[1]iqrasatar@gmail.com, [2]shahidbhutta@gmail.com, [3]mohsin_btn@yahoo.com

***Abstract*– OFDMA is promising technique for new high speed wireless data networks. It provides high speed data transfer with high spectral efficiency and noise immunity for in band and out band spectrum. Multiple slow speed data streams can be transmitted simultaneously. But the main problem associated with this type of networks is PAPR. PAPR occurs due to limited linear operation of high frequency power amplifier. This drawback is so severe that all the advantages of OFDMA become unattractive. However this problem can be overcome by pre-coding technique that is presented in this paper and the fruits of OFDMA can be enjoyed.**

***Keywords*– Walsh-Hadamard Transform (WHT), Discrete Hartley Transformation (DHT), Zadoff-Chu Transformation (ZCT), Discrete Fourier Transformation (DFT) and Bit Error Rate (BER)**

I. INTRODUCTION

OFDMA is found to be very efficient in Digital Television Broad casting (DTB), Digital Audio broadcasting (DAB) & Digital Video Broad casting (DVB). Multiple slow speed data streams are transmitted simultaneously using a single high speed carrier. The slow speed data streams are modulated using orthogonal carriers which improve the bandwidth utilization. The orthogonal carriers have inherited property of noise immunity for in band and out of band spectrum. OFDMA is becoming the most popular technique for wireless data transmission due to its advantages. It offers the considerable high data rate transmission, high spectral efficiency, immunity to the frequency selective fading channels multipath delay spread tolerance and high power efficiency [1]. Most of the high speed wireless communication standards have adopted OFDM e.g., IEEE 802.11, IEEE 802.16, IEEE 802.20, European Telecommunication Standards Institute, BRAN (Broadcast Radio Access Networks) committee [2], [3].

OFDMA can fulfill the ever growing needs of high speed wireless transmission. OFDMA is a type of OFDM in which the high speed data stream is split into several low speed data streams. Each data stream is assigned a subcarrier and every subcarrier is orthogonal to other which minimizes the inter-carrier-interference (ICI). It provides the simple solution with less computational complexity and hardware requirements [4]-[9]. Due to its fascination and attractive advantages, it is becoming very popular now-a-days [10]-[12].

The inherited features of OFDMA such as noise immunity, low multipath fading and simplicity on hardware implementation by using only FFT techniques make it ideal fulfill the needs of high speed wireless communication. Impulse noise immunity eliminates the need of equalizer [13].

In OFDMA, the data streams are mapped and modulated with subcarriers. These subcarriers are transmitted in parallel which significantly increases the bandwidth and the inter symbol interference remains minimum due to inherit property of OFDMA [30], [31].

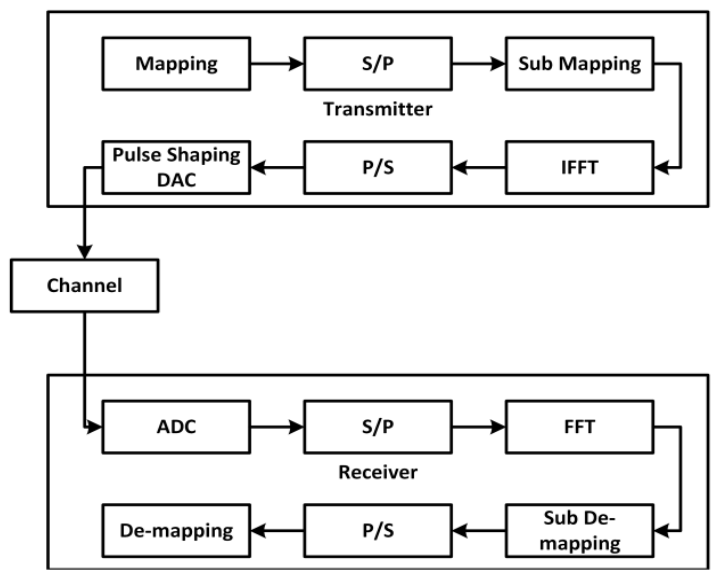

Fig. 1. Localized OFDMA

The symbol duration is transmitted to provide framing for the receiver to detect symbol and to retrieve the data correctly [32].

There is one major drawback and that is PAPR of transmitting signal. If the peak is limited due to some constraint then the average power will also be constrained relatively because of constant power modulation technique and in the consequence of this, the range of multicarrier transmission will be reduced. The transmit amplifier must operate in a linear region to avoid out-of-band radiation and intermodulation of subcarriers. Since the power conversion is poor, it reduces the battery life in portable devices. Due to this major drawback of PAPR, multicarrier transmission (OFDMA) is not suitable for portable devices [13].

Due to high PAPR, the complexity of analog to digital and digital to analog converters increases significantly and it also affects the efficiency of high power RF amplifier [14].

Due to nonlinear operation of high frequency power amplifier also results on high BER which is undesired in a reliable data transmission [13].

II. LITERATURE REVIEW

In the literature, a number of techniques like Amplitude Clipping and Filtering [15]-[17], Partial Transmit Sequence [18]-[20] and Selected Mapping technique [21]-[23] have been introduced to reduce PAPR but all of them have some drawbacks as well.

Usually the techniques of reducing PAPR disturb the wave shape of signal that results in inter-carrier-interference, out of band noise, increase in BER and most of them reduce PAPR at the expense of bandwidth. On the other hand, the coding techniques do not affect the signal rather they transform or code the data using different algorithm to minimize PAPR. These algorithms increase the computational complexity and demand more time for more complex algorithms which is undesirable for high speed communication. This problem with coding techniques can be overcome by using pre-coding techniques.

III. PRE-CODING TECHNIQUES

In pre-coding techniques, the data is transformed or coded before transmission that saves time and ensure high speed transmission. The block diagram of Pre-coded localized OFDMA is shown in Fig. 2.

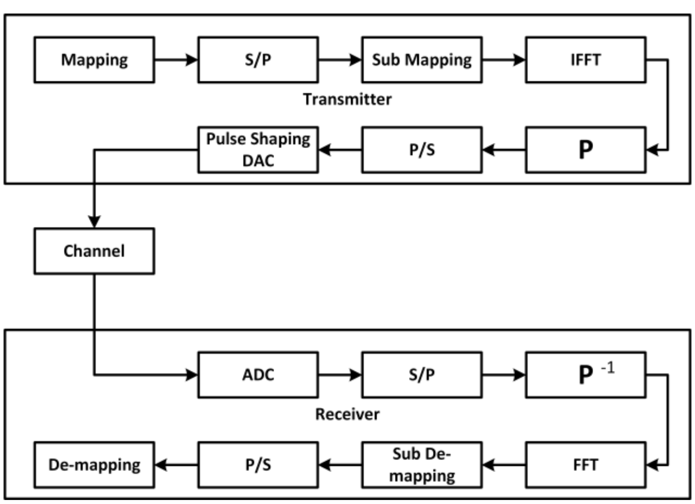

Fig. 2. Pre-coded Localized OFDMA

The pre-coding part is shown with block "P" in the Fig. 2. The pre-coding is usually done after IFFT on the transmitter side and inverse pre-coding is done before FFT on receiver side. The pre-coding and inverse pre-coding cancel the effect of each other and provides a mechanism to reduce PAPR by reshaping the data. The Pre-coding technique can be any algorithm that helps to reduce PAPR. The pre-coding techniques like WHT, DHT, ZCT and DFT are briefly discussed below:

A) Walsh-Hadamard Transform (WHT)

This is the simplest and linear transformation that is applied as butterfly structure of FFT. WHT does not increase the complexity of the system. Mathematically, WHT [24] can be expressed as:

$$H_1 = [1]$$

$$H_2 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

$$H_2 = \frac{1}{\sqrt{2N}}\begin{bmatrix} H_N & H_N \\ H_N & H_N^{-1} \end{bmatrix}$$

Where H_N^{-1} is the binary complement of H_N.

Although this technique helps to reduce PAPR but it is not as efficient as the later techniques which are described below:

B) Discrete Hartley Transformation (DHT)

The DHT is also a linear transformation of data. In DHT, N real numbers $x_0, x_1, \dots, x_{N-1}$ are transformed into N real numbers $H_0, H_1, \dots, H_{N-1}$. According to [25], the N-point DHT can be defined as follows:

$$H_k = \sum_{n=0}^{N-1} x_n \left[\cos\left(\frac{2\pi nk}{N}\right) + \sin\left(\frac{2\pi nk}{N}\right)\right]$$

The pre-coding based matrix A can be constructed as follows:

$$A = \begin{bmatrix} a_{00} & a_{01} & \cdots & a_{0(L-1)} \\ a_{10} & a_{11} & \cdots & a_{1(L-1)} \\ \vdots & \vdots & \ddots & \vdots \\ a_{(L-1)0} & a_{(L-1)1} & \cdots & a_{(L-1)(L-1)} \end{bmatrix}$$

A is pre-coding matrix of size $L \times L$ shown in above equation, m and l are integers from 0 to $L-1$. The DHT is also invertible transform which allows us to recover x_n from H_k and inverse can be obtained by simply multiplying DHT of H_k by $\frac{1}{N}$.

C) Zadoff-Chu Transformation (ZCT)

The Zadoff-chu (ZC) sequences have optimum correlation properties with ideal periodic autocorrelation and constant magnitude. According to [26], [27] ZC sequences of length L can be defined as:

$$a_n = \begin{cases} e^{\frac{j2\pi r}{L}\left(\frac{k^2}{2}+qk\right)}, & for\ L\ even \\ e^{\frac{j2\pi r}{L}\left(\frac{k(k+1)}{2}+qk\right)}, & for\ L\ odd \end{cases}$$

Where $k = 0,1,2,\cdots,L-1$, q is any integer and r is any integer relatively prime to L. The By reshaping the Zadoff-chu sequence by $k = mL + l$, the ZC transformation matrix (ZCMT) for $N = L \times L$ can be written as:

$$A = \begin{bmatrix} a_{00} & a_{01} & \cdots & a_{0(L-1)} \\ a_{10} & a_{11} & \cdots & a_{1(L-1)} \\ \vdots & \vdots & \ddots & \vdots \\ a_{(L-1)0} & a_{(L-1)1} & \cdots & a_{(L-1)(L-1)} \end{bmatrix}$$

Here m is the row variable and l the column variable. In other words, the L^2 point long ZC sequence fills the kernel of the matrix transform row-wise.

ZCMT is applied to the uplink signal and in the simulation; it is found that the ZCMT reduces PAPR significantly as compared to conventional WHT pre-coding based technique. This technique is independent of the nature of input signal and also it can offer substantial gain in fading multipath channels due to frequency variation in communication channels.

D) Discrete Fourier Transform (DFT)

In DFT pre-coding technique, the size of pre-coder is same as it is of IFFT used to combine separate signals and the resultant signal need only a single carrier because DFT and IDFT cancel each other [28], [29]. In this way, the system becomes just like a single-carrier system but its PAPR is improved. The Pre-coding matrix P of dimension $N \times N$ is used before the IFFT to reduce the PAPR. The pre-coding matrix P can be written as:

$$P = \begin{bmatrix} p_{00} & p_{01} & \cdots & p_{0(L-1)} \\ p_{10} & p_{11} & \cdots & p_{1(L-1)} \\ \vdots & \vdots & \ddots & \vdots \\ p_{(L-1)0} & p_{(L-1)1} & \cdots & p_{(L-1)(L-1)} \end{bmatrix}$$

The signal with N subcarriers can be written as complex base band OFDM as follows:

$$x(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} P.X_k.e^{-j2\pi k\Delta f t} \quad ,0 \le t \le NT$$

The vector signal with N subcarriers modulated OFDM can be written as:

$$x_N = IFFT\{P.X_N\}$$

The PAPR of OFDM signal can be written as:

$$PAPR = \frac{\max|x(t)|^2}{E[|x(t)|^2]}$$

The DFT and IDFT sequence of length N can be written as:

$$X(k) = \sum_{n=0}^{N-1} x(n).e^{-j2\pi nk} \quad ,k = 0,1,\cdots,N-1$$

$$x(n) = \frac{1}{N}\sum_{k=0}^{N-1} X(k).e^{j2\pi nk} \quad ,k = 0,1,\cdots,N-1$$

Where, $p_{mn} = e^{-\frac{j2\pi mn}{N}}$, m and n are integers from 0 to $N-1$.

This technique is better than the clipping and clipping, filtering pre-coding and ZCT techniques in reducing the PAPR of OFDM signal. Also the BER is improved as well.

IV. CONCLUSION

The traditional techniques are not so efficient in reducing PAPR. Most of them reduce PAPR at the expense of Bandwidth and high BER. Coding techniques does provide the solution to reduce PAPR but they increase the computational complexity and high BER. Therefore, a pre-coding must be employed to achieve better results. By reviewing all the above briefly discussed pre-coding techniques, it is concluded that the DFT is best and effective technique to reduce PAPR of OFDM signal. DFT technique does not require any special hardware to implement and it has less computational complexity as compared to the other techniques. However, the DFT converts the multicarrier transmission to single carrier which is its drawback.

V. FUTURE WORK

A new pre-coding based technique will be proposed to reduce PAPR. The proposed techniques will have the similar results as DFT in reducing the PAPR as well as it will also facilitate the multicarrier transmission instead of single carrier.

REFERENCES

[1] I. Baig and V. Jeoti, "DCT Precoded SLM Technique for PAPR Reduction in OFDM Systems", the 3rd International Conference on Intelligent and Advanced Systems (ICIAS2010) June.2010, Kuala Lumpur, Malaysia.

[2] JAE HONG LEE SEUNG HEE HAN, "An Overview of Peak-To-Average Power Ratio Reduction Techniques for Multicarrier Transmission," IEEE Wireless Communications, pp. 56-65, April 2005.

[3] Yiyan Wu Tao Jiang, "An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals," IEEE Transactions on Broadcasting, VOL. 54, NO. 2, JUNE 2008, vol. 54, no. 2, pp. 257-268, June 2008.

[4] R. W. Chang, "Synthesis of Band-Limited Orthogonal Signals for Multichannel Data Transmission", Bell Sys. Tech. J., Vol. 46, No. 12, Dec. 1966, pp. 1775–96.

[5] B. R. Saltzberg, "Performance of an Efficient Parallel Data Transmission System," IEEE Trans. Commun., Vol. 15, No. 6, Dec. 1967, pp. 805–11.

[6] R. W. Chang and R. A. Gibby, "A Theoretical Study of Performance of an Orthogonal Multiplexing Data Transmission Scheme," IEEE Trans. Commun., vol. 16, no. 4, Aug. 1968, pp. 529–40.

[7] S. B. Weinstein and P. M. Ebert, "Data Transmission by Frequency-Division Multiplexing Using the Discrete Fourier Transform," IEEE Trans. Commun., vol. 19, no. 5, Oct. 1971, pp. 628–34.

[8] L. J. Cimini, Jr., "Analysis and Simulation of a Digital Mobile Channel using Orthogonal Frequency Division Multiplexing," IEEE Trans. Commun., vol. 33, No. 7, July, 1985, pp. 665–75.

[9] J. A. C. Bingham, "Multicarrier Modulation for Data Transmission: An Idea Whose Time Has Come," IEEE Commun. Mag., vol. 28, no. 5, May 1990, pp. 5–14.

[10] M. Alard and R. Lasalle,"Principles of Modulation and Channel Coding for Digital Broadcasting for Mobile Receivers", EBU Rev., vol. 224, Aug. 1987, pp. 47–69.

[11] U. Reimers, "Digital Video Broadcasting," IEEE Commun. Mag., vol. 36, no. 10, June 1998, pp. 104–410.

[12] B. R. Saltzberg, "Comparison of Single-Carrier and Multitone Digital Modulation for ADSL Applications", IEEE Commun. Mag., vol. 36, no. 11, Nov. 1998, pp. 114–21.

[13] Seung Hee Han, Jae Hong Lee, "An Overview of P Eak-To-Average Power Ratio Reduction Techniques for Multicarrier Transmission", IEEE Wireless Communications, April 2005.

[14] WANG, H. CHEN, B, "Asymptotic Distributions and Peak Power Analysis for Uplink OFDMA Signals", IEEE International Conference on Acoustics, Speech, and Signal Processing, vol. 4, pp. IV, May 2004.

[15] R. O'Neill and L. B. Lopes, "Envelope Variations and Spectral Splatter in Clipped Multicarrier Signals," Proc. IEEE PIMRC '95, Toronto, Canada, Sept. 1995, pp. 71–75.

[16] X. Li and L. J. Cimini, Jr., "Effect of Clipping and Filtering on the Performance of OFDM," IEEE Commun. Lett., vol. 2, no. 5, May 1998, pp. 131–33.

[17] J. Armstrong, "Peak-to-Average Power Reduction for OFDM by Repeated Clipping and Frequency Domain Filtering," Elect. Lett., vol. 38, no. 8, Feb. 2002, pp. 246–47.

[18] S. H. Müller and J. B. Huber, "OFDM with Reduced Peak–to–Average Power Ratio by Optimum Combination of Partial Transmit Sequences," Elect. Lett., vol. 33, no. 5, Feb. 1997, pp. 368–69.

[19] S. H. Müller and J. B. Huber, "A Novel Peak Power Reduction Scheme for OFDM," Proc. IEEE PIMRC '97, Helsinki, Finland, Sept. 1997, pp. 1090–94.

[20] A. D. S. Jayalath and C. Tellambura, "Adaptive PTS Approach for Reduction of Peak-to-Average Power Ratio of OFDM Signal," Elect. Lett., vol. 36, no. 14, July 2000, pp. 1226–28.

[21] S. H. Müller and J. B. Huber, "A Comparison of Peak Power Reduction Schemes for OFDM," Proc. IEEE GLOBECOM '97, Phoenix, AZ, Nov. 1997, pp. 1-5.

[22] R. W. Bäuml, R. F. H. Fisher, and J. B. Huber, "Reducing the Peak-to-Average Power Ratio of Multicarrier Modulation by Selected Mapping," Elect. Lett., vol. 32, no. 22, Oct. 1996, pp. 2056–57.

[23] H. Breiling, S. H. Müller–Weinfurtner and J. B. Huber,"SLM Peak-Power Reduction without Explicit Side Information", IEEE Commun. Lett., vol. 5, no. 6, June 2001, pp. 239–41.

[24] N. Ahmed and K.R. Rao, "Orthogonal transforms for digital signal processing," Berlin: Springer Verlag, 1975.

[25] Bracewell, R.N., "Discrete Hartley transform", Journal of the Optical Society of America, 73(12), (1983), 1832-1835.

[26] CHU, D. C.: "Poly-phase Codes with Good Periodic Correlation Properties", IEEE Trans. Inform. Theory, vol. IT–18, pp. 531–532, July 1972.

[27] POPOVIC, B. M.: "Spreading Sequences for Multi-Carrier CDMA Systems", In IEE Colloquium CDMA Techniques and Applications for Third Generation Mobile Systems, London, pp. 8/1–8/6, May 19, 1997.

[28] Mohamed A. Aboul-Dahab, Esam A., A. A. Hagras, and Ahmad A. Elhaseeb, "PAPR Reduction Based on DFT Precoding for OFDM Signals", International Journal of Future Computer and Communication, Vol. 2, No. 4, August 2013, pp.325-328.

[29] D. Galda, H. Rohling, "A Low Complexity Transmitter Structure for OFDM-FDMA Uplink Systems", IEEEVTC'02, vol. 4, 2002, pp. 1737–1741.

[30] Jr L. J. Cimini, "Analysis and simulation of a digital mobile channel using orthogonal frequency division multiplexing," IEEE Trans. Communication, vol. COM-33, no. 7, pp. 665-675, July 1985.

[31] Y. G. Li and G. Stüber, "Orthogonal Frequency Division Multiplexing for Wireless Communications," Boston, MA: Springer-Verlag, January 2006.

[32] Chenyang Yang,Gang Wu, Shaoqian Li, and Geoffrey Ye Li Taewon Hwang, "OFDM and Its Wireless Applications: A Survey", IEEE TRANSACTIONSON VEHICULAR TECHNOLOGY, vol. 58, NO. 4, pp. 1673-1694, May 2009.