A Novel Combined Method for PAPR Reduction and BER Enhancement in OFDM

Veena Gopinath[1], Sudhi Sudharman[2]

[1]Student, Mahatma Gandhi University, Sree Buddha College of Engineering For Women, Elavumthitta,, Pathanamthitta, India

[2]Assistant Professor, Mahatma Gandhi University, Sree Buddha College of Engineering for Women, Elavumthitta, Pathanamthitta, India

Abstract: ***Orthogonal Frequency Division Multiplexing (OFDM) being a multi-carrier transmission, is one of the most superior technologies in wireless communication. In this paper, a brief overview of an OFDM system is explained. High Peak-to-Average Power Ratio (PAPR) is the major issue associated with an OFDM system, so a novel Partial Transmit Sequence (PTS) technique is proposed for PAPR reduction. The data rate of a typical OFDM communication system is also derived provided bandwidth is assumed to be of 5 kHz. It is obvious from the simulation results that PTS is the better method for PAPR reduction and BER enhancement in comparison with clipping and weighted OFDM.***

Keywords: BER, OFDM, PAPR, PTS, SNR**.**

1. Introduction

The method of encoding digital data on multiple carrier frequencies is termed as OFDM. Because the spectra of the sub-carriers overlap, high spectral efficiency can be obtained in OFDM by selecting a special set of orthogonal carrier frequencies [1]. Besides its advantages, high peak in the OFDM signal at the transmitter is the main issue and the problem is called Peak to Average Power Ratio (PAPR). PAPR can be reduced by so many techniques such as clipping, weighted OFDM, selected mapping, partial transmit sequence and so on. However, there is a trade-off between the PAPR reduction and BER. Considering this trade-off, PTS technique (explained in section III) is proved to be the best for PAPR reduction [2] – [6], [8] – [9].

In the 1960's, the OFDM technique was used in high frequency military systems such as KINEPLEX, ANDEFT and KATHRYN. For example, the variable rate data modem in KATHRYN was built for the high frequency band. It used up to 34 parallel low-rate phase-modulated channels with a spacing of 82 Hz. In the 1980's, OFDM was studied for high speed modems, digital mobile communications and high density recording. In the 1990's, OFDM was exploited for wideband data communications over mobile radio FM channels, high bit rate digital subscriber lines, asymmetric digital subscriber lines, very high speed digital subscriber lines, digital audio broadcasting and high definition television terrestrial broadcasting. Nowadays, OFDM technology has wide applications in wireless communications as IEEE 802.11, IEEE 802.16, 4G mobile communication and so on. The purpose of the paper is to show how PTS alleviates PAPR thereby providing high data rate. And the simulation results indicate PTS is the best technique for PAPR reduction as well as for better BER reduction [7] – [9], [10].

Section II describes an OFDM system. PAPR, being the major drawback, a novel methodology called PTS is introduced in section III. Section IV deals with the analysis of data rate followed by simulation results and conclusion in section V and section VI respectively.

2. OFDM System

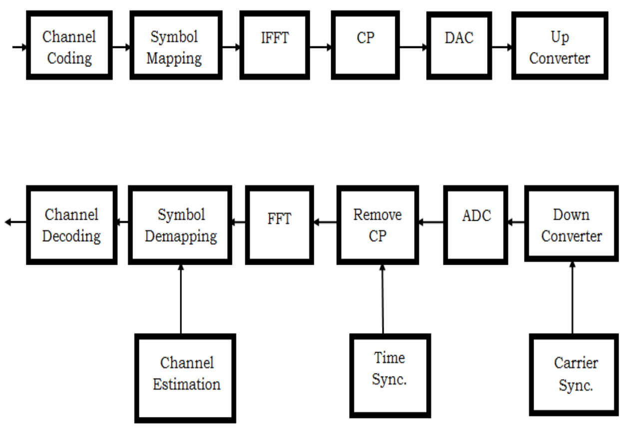

Figure 1: Block Diagram of an OFDM System

The OFDM data source is converted to time domain using IFFT. Channel coding and symbol mapping are done on the data symbol prior to IFFT for the purpose of reducing BER and PAPR respectively. Each of the N channel bits appears at a different frequency if the IFFT output signals are transmitted sequentially. When IFFT is employed, the subcarriers spacing is selected such that at the frequency where the received signal is evaluated, all other signals would be zero. The resultant time domain signal is then added with Cyclic Prefix (CP) to eliminate Inter Symbol Interference (ISI) that makes communication less reliable. CP indicates the symbol prefixing with a repetition of the end. For instance, suppose the data is x(0), x(1), x(2), x(3), x(4), x(5) and x(6). Adding CP implies that the last portions, say, x(4), x(5) and x(6) are copied to the beginning of the original data so that distortions like ISI would affect only the copied parts, thereby recovering the original data (by removing CP at the receiver). This is illustrated in Figure 2. The time domain signal added with CP is then fed to Digital to Analog

Converter (DAC) which converts the digital data to analog form in order for up conversion. In the up converter, the data is converted from low frequency to high frequency for transmission.

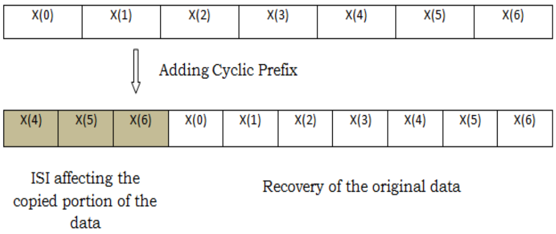

Figure 2: Concept of Cyclic Prefix

At the receiver, the exact inverse operation is performed. The high frequency data is converted to corresponding low frequency using down converter. The down converted analog data is then transformed to digital form using Analog to Digital Converter (ADC). The CP added at the transmitter section is removed at the receiver and is fed to FFT for conversion from time domain to frequency domain. The FFT output is then fed to symbol de-mapping which de-maps the symbols and the original data transmitted can be recovered now after decoding. Channel Estimation is done at the receiver to maximize the transmission rate. Both the transmitted and received signals should exhibit similar properties such as frequency and phase, so carrier synchronization is performed. Time synchronization is employed at the CP removal block for transmission without much delay. Synchronization consists of two tasks:

- Appropriate parameter estimation (frequency offset, time offset, phase offset).
- Based on the estimate, actual offset correction.

As the number of N-point IFFT increases, the number of subcarriers would be high at the transmitter and causes high peaks in the OFDM signal that leads to high Peak-to-Average Power Ratio (PAPR) thereby causing signal distortion and poor system performance. So a novel methodology called Partial Transmit Sequence (PTS) technique is discussed in the following section to alleviate PAPR.

3. PTS Methodology for PAPR Reduction

The input data **X** is partitioned into smaller M disjoint sub-blocks, which are represented by the vector $\mathbf{X}_m$, where m = 1, 2, . . . M, such that

$$\mathbf{X} = \sum_{m=1}^{M} X_m \quad (1)$$

As per assumption, each sub-block contains a set of sub-carriers having same size. These partitioned sub-blocks are then converted to time domain using N-point IFFT. Since IFFT is a linear transformation, the time domain representation of the block is given by,

$$\mathbf{x} = \text{IFFT}\,\{\textstyle\sum_{m=1}^{M} X_m\} = \sum_{m=1}^{M} IFFT\,\{X_m\} = \sum_{m=1}^{M} x_m \quad (2)$$

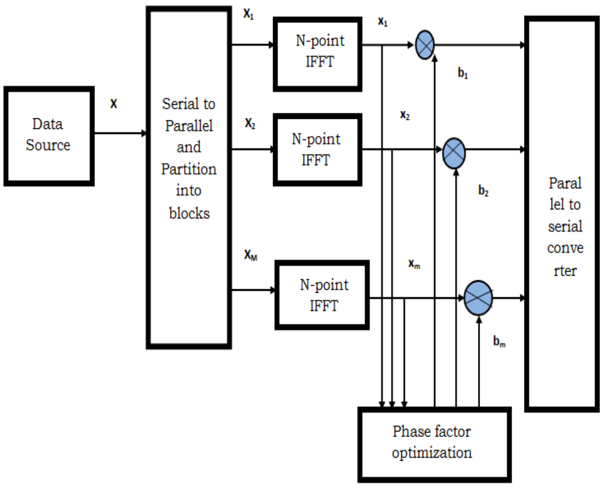

Figure 3: PTS Scheme for PAPR Reduction

The resultant time domain sequences are then combined with complex phase factors $\mathbf{b} = [b_1\ b_2\ .\ .\ .\ b_m]^T$ for PAPR minimization. Thus the PAPR reduction can be performed by the weighted combination of M sub-blocks. After combination, the signal in time domain is given by,

$$\mathbf{x}'(\mathbf{b}) = \sum_{m=1}^{M} b_m\, x_m \quad (3)$$

The allowable phase factors are $b_m = e^{j\emptyset_m}\ x_m$, where $\emptyset_m$ can be chosen freely within [0, 2π). For simplicity, equation (3) can be written as,

$$\mathbf{x}'(\emptyset) = \sum_{m=1}^{M} e^{j\emptyset_m}\, x_m \quad (4)$$

where $\emptyset = [\emptyset_1\ \emptyset_2\ .\ .\ .\ \emptyset_M]^T$. The objective of the PTS scheme is to design an optimal phase factor for the sub-block set that minimizes the PAPR. The minimum PAPR with the PTS technique is related to the problem

$$\text{minimize max } |\mathbf{x}'(\emptyset)|$$
$$\text{subject to}$$
$$0 \le \emptyset_m < 2\pi,\ m = 1, 2, \ldots, M.$$

PTS requires side information to be sent to the receiver to inform it of the phase rotation used so the data can be decoded. PTS is flexible as the number of blocks and phase rotations can be increased providing more alternative transmit signals to choose from.

4. Data Rate Analysis

The designed OFDM system for instance possesses 5 kHz bandwidth such that the whole 5 kHz bandwidth is divided into 80 sub-carriers.

Band width = Number of sub-carriers X sub-carrier frequency spacing, Δf.

$$\Delta f = \frac{5\ kHz}{80} = 62.5\ \text{Hz}.$$

Out of 80 sub-carriers, there exist one null sub-carrier for direct current and 9 sub-carriers for guard band. Hence there are only (60 – 10 =) 50 data sub-carriers. Thus, the real data bandwidth is 50 X 62.5 = 3.125 kHz.

FFT/IFFT period, $T = \frac{1}{f} = \frac{1}{62.5\ Hz} = 16$ ms.

CP duration = a quarter of FFT/IFFT period $= \frac{1}{4}$ X 16 ms = 4 ms.

Number of CP points = $\frac{64}{4\ ms}$ =16.
OFDM symbol duration = 20 ms.
No. of OFDM samples in time domain = 80.
In addition to CP, a cyclic postfix with 0.5 ms and two data points is utilized for the windowing operation. The roll-off factor of raised cosine window is 0.025. The frame structure of OFDM system is shown in Figure 4.

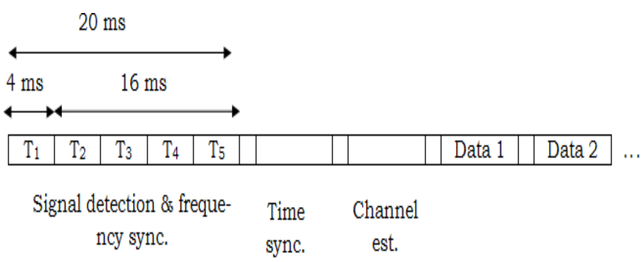

Figure 4: Frame Structure of OFDM System

The frame is divided into 10 time slots with each slot containing 5 OFDM symbols. Figure 4 shows a single slot. In this slot, there are 5 OFDM symbols. The 3 OFDM symbols together form a frame head, where the first OFDM symbol consists of 5 repetition sequences with a period of 4 ms. The frame head function consists of detecting signal, estimation of the channel and synchronizing time/frequency. Since each slot duration is 100 ms (20 ms X 5), the period of a frame is 1 s (10 X 100 ms). Also, there are 50 OFDM data symbols in a frame. Now, the data rate expression can be obtained as

$$R_{data} = \frac{R_{code}\ X\ N_{modu}\ X\ N_{datasymb}\ X\ N_{subc}}{T_{frame}}$$

$$= \frac{{}^{3}/_{4}\ X\ 16\ X\ 50\ X\ 10}{1\ s} = 6\ \text{kb/s}.$$

where R_{code} = channel coding code rate(For convolutional code, R_{code} = ${}^{3}/_{4}$.

N_{modu} = Level of modulation (here 16 QAM).
If 64 QAM is employed, R_{data} would be 24 kb/s.

$N_{datasymb}$ = Number of data symbols in a frame.
N_{subc} = Number of data sub-carriers.
T_{frame} = Duration of a frame.

As the bandwidth and level of modulation increases, data rate would also increase.

5. Simulation Results

In Figure 5, it can be viewed that PTS achieves SNR of 20 at a very low BER of less than 0.05. On the other hand, weighted OFDM obtains the same SNR but at a BER of above 0.1, and clipping provides the same SNR value at a high BER of above 0.2. Similarly, in the graph shown in Figure 6, it has been observed that unprocessed data has higher PAPR and is near to 12 dB. Clipped data, on the other hand, can provide PAPR of around 11.5 dB which is less than unprocessed signal. However, the data with weighted OFDM gives PAPR of 9.5 dB. PTS technique provides much better performance than the other three, i.e., it can exhibit less PAPR of 6.99 dB. Thus, the simulated results proved that PAPR reduction using Partial Transmit Sequence (PTS) achieves higher PAPR reduction and enhanced BER performance than weighted OFDM and clipping methods.

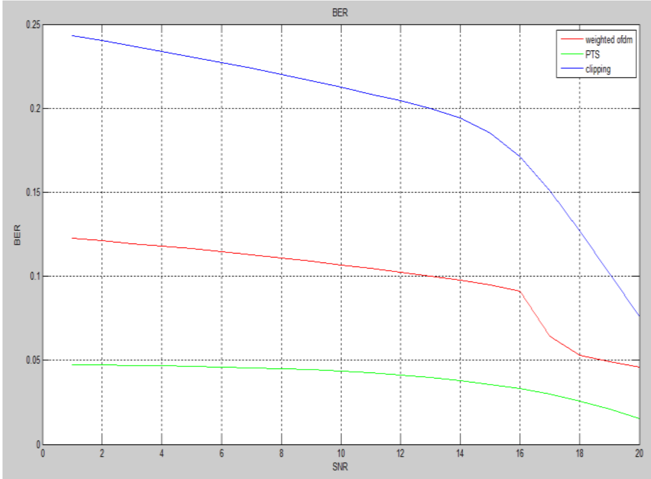

Figure 5: BER comparison of PTS scheme with clipping and weighted OFDM methods.

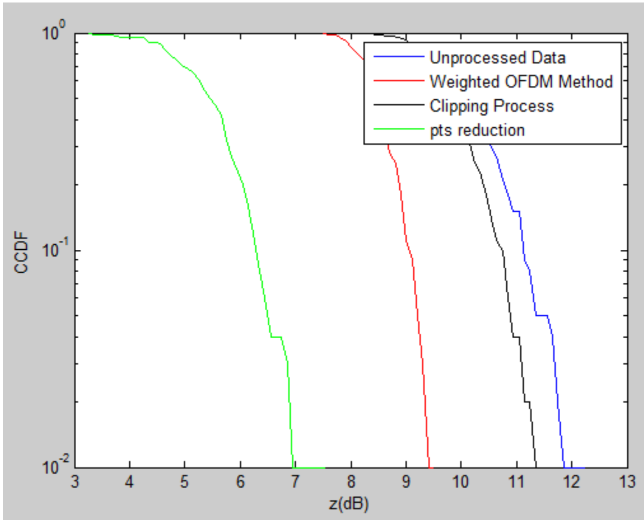

Figure 6: PAPR Reduction Comparison of PTS technique with weighted OFDM, unprocessed data and clipping processes.

6. Conclusion

The use of OFDM has increased greatly in the last 10 years. It has been used for modem/ADSL application where it coexists with phone line. The main issue associated with OFDM systems is that when the input sequences are highly correlated, a very high PAPR can be exhibited by the composite transmit signal. In this paper, a PAPR reduction scheme called PTS technique has been projected to remove PAPR in the OFDM signal. Simulations were conducted and it shows that PTS provides better reduction in PAPR and an enhanced BER performance (low BER and high SNR). Thus the paper has explored the role of OFDM in wireless communication by keeping a trade-off between PAPR and BER.

7. Acknowledgement

The author would like to thank her family, especially her parents, for their constant support and inspiration.

References

[1] Zhenyu Zhang, Fanxin Zeng, Lijia Ge, Shaorong Chen, Bo Yang, Guixin Xuan, "Design and Implementation of Novel HF OFDM Communication Systems" in 14th IEEE International Conference on Communication Technology (ICCT), pp. 1088-1092, November 2012.
[2] Jung – Chieh Chen, "Partial Transmit Sequences for Peak-to-Average Power Ratio Reduction of OFDM Signals with the Cross-Entropy Method" in IEEE Signal Processing Letters, vol. 16, no. 6, June 2009.
[3] A.D.S. Jayalath and C. Tellambura, "Reducing the Peak-to-Average Power Ratio of Orthogonal Frequency Division Multiplexing Signal through bit or symbol interleaving", in Electronics Letters, vol. 36, no. 13, June 2000.
[4] Er. Ankita and Anand Nayyar, "Review of various PTS (Partial Transmit Sequence) techniques of PAPR (Peak to Average Power Ratio) reduction in MIMO-OFDM", in International Journal of Innovative Technology and Exploring Engineering (IJITEE), vol. 2, issue 4, March 2013.
[5] Arun Gangwar and Manushree Bhardwaj, "An Ooverview: Peak to Average Power Ratio in OFDM system and its Effect", in International Journal of Communication and Computer Technologies (IJCCT), vol. 01, no. 2, issue 02, September 2012.
[6] S. H. Muller and J. B. Huber, "OFDM with reduced peak-to-average power ratio by optimum combination of partial transmit sequences", in Electronics Letters, vol. 33, no. 5, February 1997.
[7] Manushree Bhardwaj, Arun Gangwar and Devendra Soni, "A Review on OFDM: Concept, Scope & its Applications", in IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE), pp. 07-11, vol. 1, issue 1, May-June 2012.
[8] Vahid Tarokh and Hamid Jafarkhani, "On the Computation and Reduction of the Peak-to-Average Power Ratio in Multicarrier Communications", in IEEE Transactions on Communications, vol. 48, no. 1, January 2000.
[9] Chang Eon Shin, Kyung Soo Rim and Youngok Kim, "A weighted OFDM Signal Scheme for Peak-to-Average Power Rratio Reduction of OFDM Signals", in IEEE Transactions on Vehicular Technology, vol. 62, no.3, March 2013.
[10] R. Prasad, "OFDM for Wireless Communications Systems" (Arch House, Boston, London, 2004).
[11] Y. Li and Gordon L. Stuber, "Orthogonal Frequency Division Multiplexing for Wireless Communications" (Springer, New York, USA, 2006).

Author Profile

Veena Gopinath received her B.Tech degree from Kerala University in 2013 and is currently pursuing M.Tech degree from Mahatma Gandhi University. She has presented 3 National Conferences held in Kerala and 1 International Conference (IEEE) held in Tamil Nadu respectively. On Optical OFDM in wireless communication, she has published one paper in IEEE xplore digital library and another paper in National Conference on Emerging Trends in Engineering & Technology (NCETET '14) 2014, IJERT conference proceeding, vol. 3, issue 08 respectively. Recently, she has published her work related to PAPR reduction technique in International Journal of Advanced Research in Electronics & Communication Engineering (IJARECE), vol. 4, issue 7, July 2015. Her areas of research include wireless communication, multicarrier transmission and OFDM.