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COMPARATIVE STUDY OF PEAK TO AVERAGE POWER RATIO REDUCTION TECHNIQUES IN AN OFDM SYSTEM

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ABSTRACT

Orthogonal frequency division multiplexing (OFDM) is an emerging technology in wireless communication system. It is a multi-carrier transmission and suggested for 4G network. It has advantages like efficient deal with multi-path propagation, robust against ICI and efficient use of bandwidth. But major disadvantage in the OFDM system is peak to average power ratio (PAPR), which reduces efficiency of the HPA used at transmitter and increase complexity of analogue to digital converter (ADC) and digital to analogue converter (DAC). Different techniques have been proposed for reduction of PAPR like clipping and filtering, coding scheme, SLM (selective mapping), PTS (partial transmit sequence) and precoding techniques but none of them give acceptable results. In this paper, PAPR reduction techniques have been discussed. Their working efficiency against PAPR, advantages and disadvantages will also be discussed. Peak to average power ratio is the ratio of square of maximum power of signal to square of average power of signal. Different techniques give different results but precoding technique show very good results in PAPR reduction process. Hybrid technique also gives acceptable results with very low complexity in PAPR reduction.

Keywords: *High power amplifiers, peak to average power ratio, partial transmit sequence, selective mapping, inter carrier interference.*

1. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is an effective technique that is used in wireless communication system's multicarrier transmission. It is preferably used because of its robustness against frequency selective fading, efficient use of bandwidth and easy implementation at receiver [1-2]. It has lower complexity as compared to single carrier transmission system, high spectral efficiency, less inter carrier interference (ICI) and inter symbol interference (ISI). It also eliminates the demand of equalizers. It is considered as a suitable technique that is used in Digital Audio Broadcasting (DAB), and Terrestrial Digital Video Broadcasting (DVB-T).The OFDM modulation accomplished by IFFT that enables the use of sub carriers.

There are many advantages of OFDM beside some disadvantages including sensitivity of transmitter blocks such as analogue to digital converter (ADC), digital to analogue converter (ADC), and high power amplifiers (HPA) which play important role in whole OFDM system performance process. Due to which, HPA works in saturation region. The challenging disadvantage in OFDM system is Peak to Average Power Ratio (PAPR) that causes reduction of efficiency of whole system. This is due to addition of singles with similar phase causing production of large peaks that is N time of average power. So, OFDM system having high PAPR requires an expensive transmitter. This expensive transmitter causes high power amplifier (HPA) to work in high linear region. If it does not maintain high linear region range, then will cause of channel interference which reduces the whole system's performance [3-5].For reduction of PAPR in OFDM system, a large number of techniques have been proposed that give better results in PAPR reduction process. So, it is necessary to overcome this OFDM system's problem by exploring PAPR and PAPR reduction techniques.

2. OFDM BASICS AND PAPR

An OFDM signal is collection of number subcarriers. The bandwidth of the OFDM system is portioned into a number of sub carriers and then converted into parallel form. After converting it in parallel form, it is mapped. Then, this mapped data is sent to an IFFT block where its transformation takes place. Cyclic prefix is inserted in the data block after implementation of IFFT block and again converted into serial form. Digital to Analogue converter is applied on coming data and transmitted through channel. At receiver, the same process but inverse to that implemented in transmitter block is applied [6-7]. An OFDM system is shown in Figure 1.

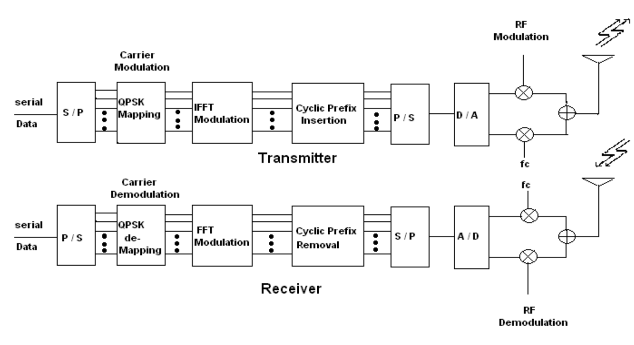

Fig 1: Block diagram of OFDM System with architecture of Transmitter and Receiver

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Let us, we take a collection of data sequence, i.e. $X = X_1, X_2, X_3 \ldots\ldots, X_n$ transmitted as an OFDM symbol, the OFDM signal having N number of subcarriers represented as;

$$X_u = \frac{1}{\sqrt{N}} \sum_{m=0}^{k-1} X_m e^{j2\pi \frac{u}{N} m}$$

$$\therefore\ u = 0,1,2,3, \ldots\ldots, k-1.$$

All symbols that are sent to receiver are orthogonal to each other. In OFDM system, two signals will be orthogonal if their integral product is equal to zero. The orthagonality of carriers is shown in Figure2.

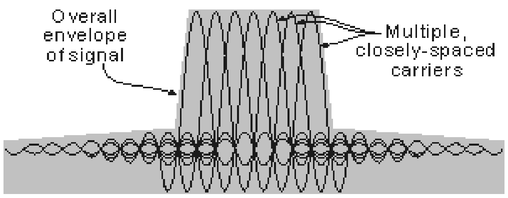

Fig 2: Orthagonality principle between subcarriers in an OFDM system [35]

The PAPR in OFDM signal is

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

This is the proportion of square of maximum power of signal and square of average power of signal. It can be written as;

$$PAPR(x) = 10log_{10}\left[\frac{max|x(t)|^2}{E[|x(t))|^2]}\right]$$

$E[|x(t))|^2]$= probability expectation of signal, X (t) = base band signal.

Complementary cumulative distribution function (CCDF) is used to find working of PAPR in the signal. It analyzes the power peaks of signal. Mathematically, it can be explained as;

$$P\ (PAPR > C) = 1 - P\ (PAPR \leq C)$$

It shows that probability of PAPR of signal is exceeded than the clip level C.

$$= 1 - F(C)^N = 1 - (1 - exp(-C))^N$$

C is called the clipping level.

3. CRITERIA

As discussed above, many techniques are used for PAPR reduction, but no one give acceptable results. The criterion of PAPR reduction in OFDM is defined. To reduce PAPR at an acceptable level, following factor must be considered for an OFDM system.

3.1. High Capability to Reduce PAPR

The capability to reduce PAPR is the basic factor of PAPR reduction criteria. If a technique reduces PAPR largely, it is considered a good technique in this regard. It also has some harmful factors including in bond radiations and out of band radiation in selection of a technique.

3.2. Low Average Power

If a technique reduces PAPR, it should also reduce average power of signal and should maintain it in an acceptable region. If average power is increased and crosses an acceptable level, a large linear region is required in High Power Amplifier (HPA) due to which BER degradation takes place.

3.3. Decreasing intricacy (Low Complexity)

The technique, used for PAPR reduction in an OFDM system, should has lower intricacy. In other words, there should be low complexity in an OFDM system. In time and hardware implementation, complexity should be low.

3.4. Minimum Bandwidth Expansion

Bandwidth is based upon the data rate. If there is higher data rate, more bandwidth is required for the system. But in some techniques (such as PTS and SLM), side information is sent to receiver for synchronization with transmitting data. This side information causes the expansion of bandwidth. But few techniques are used that cause expansion in bandwidth due to code rate production. So, there should be no increase in bandwidth because it will degrade performance of the system. Due to use of channel coding, data rate is increased that causes of expansion in bandwidth.

3.5. Minimum BER Performance Degradation

The basic propose of using techniques, that reduce PAPR is, to increase performance of the OFDM System. It also includes BER. There should also be minimum BER in system than original OFDM system. Side information is sent to the receiver for synchronization with transmitting data. If errors occur in this information, it may cause increase in BER that may affect the whole data. So BER performance degraded.

3.6. Minimum Additional Power Required

Any wireless system has a great dependency upon power efficiency. If any technique that is used for PAPR reduction need more power, causes BER performance degradation, when the original signal is recovered at receiver.

3.7. Better Spectral Efficiency

If a technique used for PAPR reduction, causes the destruction of OFDM system's main features i.e. immunity to multipath fading and ICI, is not considered good. So, spectral efficiency should maintain by PAPR reduction techniques.

3.8. Other Factors

Some non-linear devices that are used in the system, should consider important when, we apply PAPR reduction technique, i.e. DAC, ADC and HPA. These are all memory-less and non-linear devices. The PAPR reduction techniques avoid non-linear distortion produced due to these devices.

4. LITERATURE REVIEW

In literature, many techniques have been proposed for reduction of PAPR. The selection of techniques for PAPR reduction alters by examining requirement of system which depends on spectral efficiency, increment in BER, computational complexity, data rate loss, and signal transmit

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power at receiver end which are taken in to account before adopting a PAPR reduction technique. Different techniques give different results in PAPR reduction having different level of success and implementation. These techniques have been categorized into three major groups shown in table 1.

1. Signal Distortion Technique
2. Scrambling Technique
3. Precoding Technique

Table 1. PAPR reduction Techniques

Signal Distortion techniques	Scrambling techniques	Precoding techniques
Clipping and Filtration technique	Block Coding Technique	Discrete Cosine Transform
Peak Windowing	Tone Reservation	Discrete sine Transform
	Tone Injection	Discrete Hartley Transform
	SLM and PTS technique	

4.1. Signal Distortion Techniques

4.1.1. Clipping and Filtration Technique

Clipping technique is most easy and basic PAPR reduction modality in which high peaks above threshold level are clipped leading to PAPR reduction. But it causes in band radiation and out band radiation. The interference in channel takes place due to out band radiation. So, filtering process is used that removes out band radiation problem but causes the growth of peaks. So, repeated process of clipping and filtration is applied to get better results in PPAR reduction process [8-10].

This technique helps to decrease PAPR problem without expansion in spectrum of signal. In case of OFDM signal with sampling, the clipping technique is applied with correction and for this; each signal is oversampled with a factor of four. This technique is more useful for PSK scheme [11-12].

4.1.2. Peak Windowing

Peak windowing technique is like clipping technique in which self-interference is introduced and BER is increased causing increase in out band radiation. We apply window of different types such as hamming window and Gaussian shaped window to the OFDM signal. The convolution of windows and original OFDM signal takes place. When the amplitude of OFDM signal overshoots the threshold level then window function terminate peak amplitude resulting a lustrous signal. The used window should be narrow enough because long window affects signal samples. This technique performed better than clipping and filtration technique in PAPR reduction process [12-13].

4.2. Scrambling techniques

The basic principle of these techniques is to scramble the OFDM signal with phase sequences and then choose OFDM signal having lowest PAPR. These techniques reduce PAPR to some extent but the disadvantage of these techniques is need of side information that should also be sent to the receiver for synchronization.

4.2.1. Block Coding Technique

This is widely used technique for PAPR reduction in which different coding blocks or code words are used and data word is mapped onto code word resulting removal of those bits of data from authorized sequence that cause high PAPR. When we select code words, the things that should be considered are M-ary phase modulation, coding rate, encoding and decoding rate. The main thing that should be considered is error detection and its correction or error decoding [14-15].This technique is useful only for that multicarrier system that has few numbers of subcarriers. In practical multicarrier system, advantage of block coding for PAPR reduction is limited.

4.2.2. Tone Reservation

This is an efficient technique for PAPR reduction in which transmitter reserves tone (subcarriers) for PAPR reduction of OFDM signals. The main objective of this technique is to add time domain signal with original time domain signal to minimize PAPR. Different carriers are used in tone reservation. In OFDM System, subcarriers are reserved at transmitter side and they carry no data. They only perform function of PAPR reduction. The data is changed after application of tone reservation process and returns a new modulated signal with low PAPR [16-17].Figure 3 shows process of tone reservation.

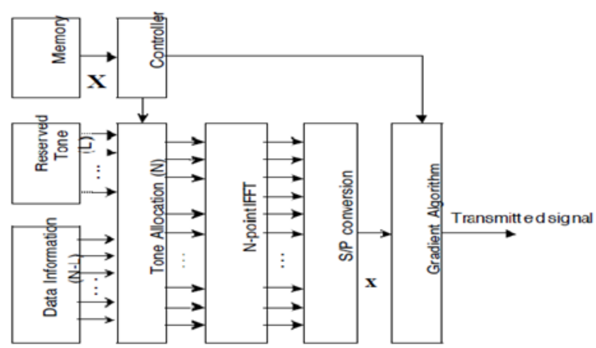

Fig 3: OFDM Transmitter architecture using Tone Reservation

4.2.3. Tone Injection

The main idea of tone injection is to boost the constellations cyclically. So, same data points correspond to collective constellation points. This process is the injection of tone having specific frequency and phase in symbol that correlate to replacing native constellations with one of these identical constellation points. First thing is to copy the original constellation points to alternative points. So, all constellation points are mapped and extra-points freedom is easily used to reduce PAPR. It is popularly used because of newly applying

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points into basic constellation points for new points, for larger constellation points.

Tone injection (TI) is more arguable than TR. In TR, injected signals carry frequency band like information carrying signals while in TI technique, alternative constellation points carry higher energy and higher computational difficulty [18-20].

4.2.4. SLM and PTS Techniques

In SLM, separate phase rotations are applied to subcarriers, while in PTS, all subcarriers are combined in phase optimization block.SLM is an efficient PAPR reduction technique that depends on phase rotation. SLM-OFDM system is given in Figure 4. A dissimilar phase sequence is multiplied with each data block of the OFDM system giving the changed data blocks.

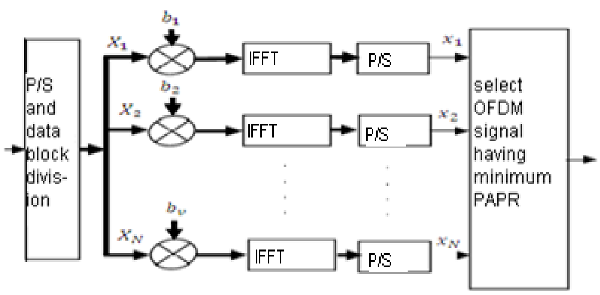

Fig 4: Block diagram of Selective Mapping (SLM) [21]

Similarly in PTS, the phase sequence is multiplied with each data block and produce data block having different PAPR. The data block having minimum PAPR is selected [21-22], as shown in Figure 5.

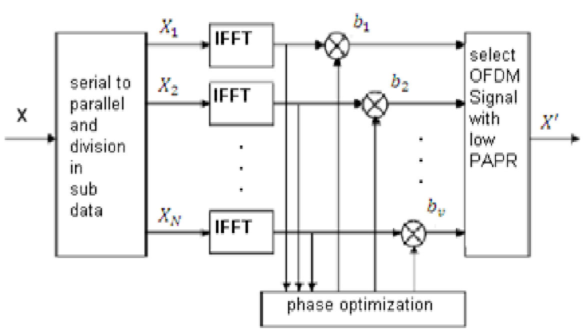

Fig 5: Block diagram of Partial Transmit Sequence (PTS) [21]

The mathematical representation of both techniques is given as below;

Let us, the data blocks are $X = [X_1, X_2, X_3, \ldots \ldots, X_N]$ and phase factors sequence is as

$b = [b_1, b_2, b_3, \ldots \ldots, b_v]$. The obtained OFDM signal is as;

$$X(r) = [X_1 b_1, X_2 b_2, X_3 b_3, \ldots \ldots, X_N b_v]$$

$$X_n^v = X(t).\, b_v$$

$\therefore\ v = 1,2,3, \ldots \ldots, V$ *and*

$$X(t) = \frac{1}{\sqrt{N}} \sum_{n=1}^{N} X_n e^{j2\pi\Delta f t}$$

So it becomes as;

$$x_n^{(v)} = \frac{1}{\sqrt{N}} \sum_{n=1}^{N} X_n^v e^{j2\pi\Delta f t}$$

$$\therefore v = 0,1,2,3, \ldots \ldots, V - 1.$$

Among all data blocks, minimum PAPR carrying block is selected and transmitted. The phase sequence must be sent as side information to recover data; reverse order of transmitter takes place at receiver.

During SLM implementation, v IFFT operations are performed for each block and the needed side information bit is $[\log_2^v]$. The design of phase factors play an important role in reduction of PAPR. For reduction of difficulty and to minimize the number of bits as side information, different additions in SLM proposed previously [23]. Without transmission of side information, a SLM technique is also proposed in a previous article [24].

Both techniques are important in PAPR reduction process. In PTS, breaking up of input data in sub-blocks takes place. So, some complexity is reduced to some extent on applying IFFT operation. It is more useful then SLM, if it reduces the computational complexity. So, PTS performance is good as compared to SLM in PAPR reduction. But PTS needs more bits as side information as compared to SLM [25].

4.3. Precoding techniques

Precoding techniques consist of different types of precoding transform matrix including DCT, DST, and DHT. In precoding techniques, the precoding matrix is applied to the constellation symbols of signal to reduce PAPR. These techniques are better as compared to all mentioned above. The major advantage of these techniques is no need of side information. Recently, these precoding techniques are combined with scrambling techniques for PAPR reduction showing better results than other techniques. The Precoding based OFDM system shown in Figure 6.

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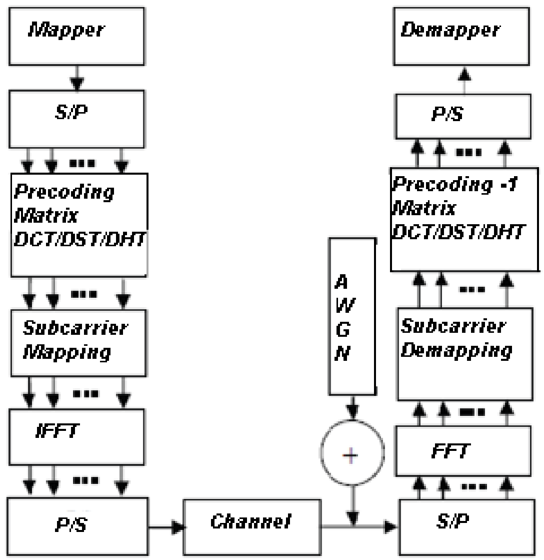

Fig 6: Block diagram of Precoding based OFDM System in which Precoding matrix including DCT, DST or DHT is applied on constellation symbols before IFFT implementation. [34]

4.3.1. DCT Transform

Discrete Cosine Transform (DCT) causes decorrelation of data. When decorrelation process has been performed, an encoding process is carried out by transform coefficients without losing compression efficiency. The DCT performs function of packing of energy in low frequency regions. So, few high frequency content can also be removed without decrement in quality. The DCT is defined as;

$$M(u) = \beta(u) \sum_{n=0}^{N-1} x(n) \cos\left[\frac{\pi(2n+1)u}{2N}\right] \quad \dots\dots (1)$$

$$Where\ u = 0,1,2,3, \dots\dots\dots, U-1$$

$$and \quad N = 0,1,2,3, \dots\dots\dots, n-1.$$

And its inverse is as

$$x(n) = \sum_{u=0}^{N-1} \beta(u) M(u) cos\left[\frac{\pi(2n+1)u}{2N}\right] \quad \dots\dots (2)$$

$$Where\ x = 0,1,2,3, \dots\dots\dots, X-1$$

$$and \quad N = 0,1,2,3 \dots\dots\dots., n-1.$$

In both equations β(u) is defined as

$$\beta(u) = \begin{cases} \sqrt{\frac{1}{N}} & for\ u = 0 \\ \sqrt{\frac{2}{N}} & for\ u \neq 0 \end{cases}$$

DCT transform matrix is applied on constellation symbols of OFDM signal and the baseband modulated signal is converted to parallel form from, serial form in DCT-OFDM system.

Discrete cosine transform is defined as in matrix form as below;

$$M = \begin{pmatrix} m_{00} & m_{01} \dots & m_{0(n-1)} \\ m_{10} & m_{11} \dots. & m_{1(n-1)} \\ \vdots & \vdots \quad \ddots & \vdots \\ m_{(n-1)0} & m_{(n-1)1} \dots & m_{(n-1)(n-1)} \end{pmatrix}$$

DCT precoding matrix is given below:

$M = m_{m,N}$

Let's we have a complex vector of size N is as;

$$X = X_0, X_1, X_2, \dots\dots, X_{N-1}$$

The DCT precoding matrix applied to this complex vector. After applying DCT, we get $Y = MX$

Where M is precoding matrix of size $n \times n$ and can be written as;

$$Y' = \sum_{N=0}^{n-1} m_{n,N} X_N$$

Where nth row and nth column of precoding matrix [26-27].The DCT -OFDM signal is as;

$$X_u = \frac{1}{\sqrt{N}} \sum_{m=0}^{k-1} Y' e^{j2\pi \frac{u}{N} m} \therefore u = 0,1,2, \dots, N-1.$$

It is illustrated in Figure 6.

4.3.2. DST Transform

Discrete Sine Transform is a Fourier related transform having real matrix. It has resemblance with imaginary parts of DFT but it operates on real valued data with odd symmetry. Its process of application is same as performed in DCT transform. The DCT and DST are inverse to each other at some extent having boundary conditions related varied DCT and DST varieties. Every element of DST should have equal magnitude and DST matrix should be non-singular. It is defined as below:

$$X_q = \frac{2}{N+1} \sum_{b=0}^{N-1} x_b sin\left[\frac{\pi}{N}\left(b + \frac{1}{2}\right)(q+1)\right] \therefore q = 0,1,2, \dots\dots, N-1.$$

Its inverse is as;

$$x_b = \frac{2}{N+1} \sum_{q=0}^{N-1} X_q sin\left[\frac{\pi}{N}\left(b + \frac{1}{2}\right)(q+1)\right] \therefore b = 0,1,2,3, \dots\dots, N-1.$$

[28-29]. Discrete sine transform matrix of order equal to symbols number of signal is applied to constellation symbols before IFFT implantation causing PAPR reduction because of reduction of autocorrelation that create large peaks. For DST based OFDM system's figure, please see Figure 6.

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4.3.3. DHT Transform

Discrete Hartley Transform is also similar to Fourier transform. DHT is a fast algorithm proposed in 1983. Its main point is to obtain real outputs from real inputs, without participation of complex numbers. It is defined as;

$$H_b = \sum_{k=0}^{N-1} x_k \left[cos\left(\frac{2\pi}{N}bk\right) + sin\left(\frac{2\pi}{N}bk\right)\right]$$

Where $b = 0,1,2,3, \ldots\ldots, B-1$. As we know that,

$$cos(b) + sin(b) = cas(b)$$

So, $$H_b = \sum_{k=0}^{N-1} x_k cas\left(\frac{2\pi}{N}bk\right)$$

Its inverse can be obtained just multiplying H_b by $\frac{1}{N}$.Discrete Hartley Transform based OFDM system for PAPR reduction has been discussed in [30-32]. Same process of PAPR reduction is performed as performed in DCT and DST based OFDM systems. Discrete Hartley Transform matrix form can be as,

$$A= \begin{pmatrix} b_{00} & b_{01} \cdots & b_{0(q-1)} \\ b_{10} & b_{11} \ldots. & b_{1(q-1)} \\ \vdots & \vdots \quad \ddots & \vdots \\ b_{(q-1)0} & b_{(q-1)1} \cdots & b_{(q-1)(q-1)} \end{pmatrix}$$

The DHT precoding matrix is as;

$$A=b_{m,n}$$

Modulated baseband data in complex vector is as;

$$X= [X_1, X_2, X_3, X_4, \ldots\ldots, X_{N-1}]$$

The resultant of DHT precoding matrix A and modulated complex vector X is;

$$D=AX$$

$$D=\sum_{n=0}^{N-1} b_{m,n}X_n \qquad \text{m=0, 1, 2, 3… N-1.}$$

Finally, we can write the DHT based OFDM system as;

$$D_n = \frac{1}{\sqrt{N}}\sum_{m=0}^{N-1} D.e^{j2\pi\frac{n}{N}m}$$

Where n=0, 1, 2, 3…N-1.For its illustration, please consult Figure 6.

Hybrid techniques have also been proposed that give efficient results, having less computational complexity and no need of side information in PAPR reduction process. e.g. hybrid based SLM technique. In conventional SLM technique, we require side information and also have computational complexity in PAPR reduction process. While in hybrid based SLM technique having low complexity and no side information and give very good result in PAPR reduction [33].The comparison between different PAPR reduction techniques using different parameters is shown in table 2.

Table 2: Comparison of properties of PAPR techniques

PAPR Reduction Technique	Minimize Distortion	Complexity	Data loss	Data Rate Reduction	Power increase	Operations needed at transmitter (**TX**) and receiver(**RX**)
Clipping and Filtration	NO	NO	NO	NO	NO	**TX:** Clipping **RX:** none
Tone Reservation	YES	YES	YES	YES	YES	**TX:** reservation of unused subcarriers **RX:** None
Tone Injection	YES	YES	YES	NO	YES	**TX:** Alternative encoding **RX:** none
Selective Mapping	YES	YES	YES	YES	NO	**TX:** N times IFFT operations **RX:** side information, inverse SLM

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Partial Transmit Sequence	YES	YES	YES	YES	NO	**TX:** N times IFFT operations **RX:** side information, inverse PTS
Precoding technique	YES	NO	NO	NO	NO	**TX:** Precoding matrix **RX:** inverse precoding matrix

5. CONCLUSION

Orthogonal frequency division multiplexing is a most popular and an efficient modulation technique in wireless system. It has high spectral efficiency and robust against ISI. But the main disadvantage is PAPR that degrades efficiency of the system. When the input of system has high correlation, PAPR becomes high. This paper deals with expert opinion on different techniques to reduce PAPR and their problems in the system. These problems include BER performance degradation, data rate loss, bandwidth expansion, in bond or out of bond radiations, low spectral efficiency and other computational complexities. The PTS and SLM techniques show good performance in PAPR reduction but problem is the need of required side information that are used to recover the original signal at receiver causing complexity. Precoding technique's performance is very good as compared to other techniques because they need no side information and also cause low complexity. Hybrid techniques also show very good performance in PAPR reduction.

6. SIMULATION AND RESULTS:

Figures 7, 8 and 9 show the CCDF comparisons of PAPR of conventional OFDM system, SLM-OFDM system and DCT-SLM based OFDM system using different system parameters that have shown in table 3.

Table 3: System parameters used in simulation process.

System Parameters	Assumptions
OFDM symbols	10,000
number of sub bands	64
oversampling factor	4
OFDM symbol Candidates	16,32,64
Size of FFT	128
Modulation	QPSK

Precoding based OFDM system has lowest PAPR.

Using matlab, the simulation results that obtained, shown in table 4.

Table 4: Comparison of simulation results.

System type	PAPR of OFDM system using 16 symbol candidate	PAPR of OFDM system using 32 symbol candidate	PAPR of OFDM system using 64 symbol candidate
Conventional OFDM	11.3 db	11.2 db	11.2 db
SLM based OFDM	7.3 db	6.8 db	6.5 db
DCT-SLM based OFDM	6.8 db	6.5 db	6.2 db

Their CCDF comparison has shown in figures 8, 9 and 10.

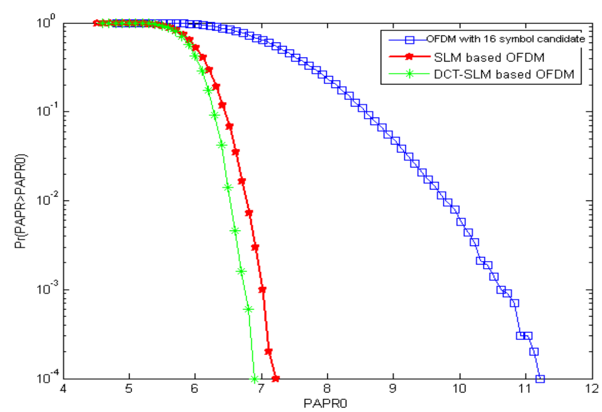

Fig 7: Comparison of CCDF of PAPR performance of OFDM with 16 symbol candidates, SLM based OFDM and DCT-SLM based OFDM using QPSK modulation. DST-SLM based OFDM system has low PAPR as compared to OFDM system and SLM based OFDM system.

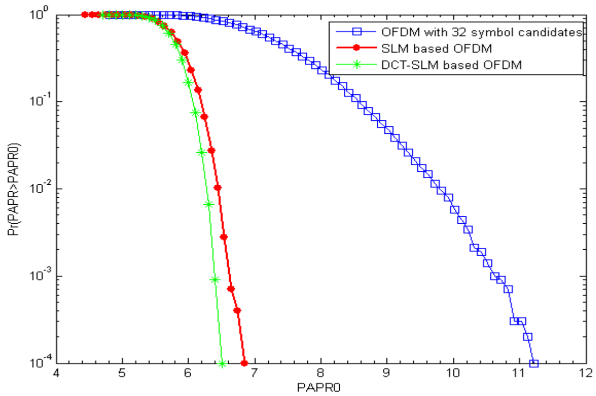

Fig 8: Comparison of CCDF of PAPR performance of OFDM with 32 symbol candidates, SLM based OFDM and DCT-SLM based OFDM using QPSK modulation. DST-SLM based OFDM system has low PAPR as compared to OFDM system and SLM based OFDM system.

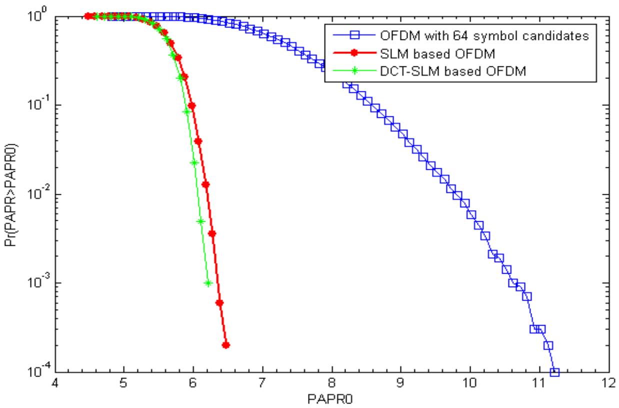

Fig 9: Comparison of CCDF of PAPR performance of OFDM with 64 symbol candidates, SLM based OFDM and DCT-SLM based OFDM using QPSK modulation. DST-SLM based OFDM system has low PAPR as compared to OFDM system and SLM based OFDM system.

FUTURE RECOMMENDATION

In future, precoding techniques could be combined with PTS having block configuration and also contemplating some clipping derivatives for PAPR reduction at an acceptable level and to make OFDM system efficient. Precoding techniques using Discrete Wavelet Transform (DWT) may also be implemented for PAPR reduction.

REFERENCES

[1] Han, S.H., and Lee, J. H. 2004."PAPR reduction of OFDM signals using a reduced complexity PTS technique." Signal Processing Letters, IEEE, vol.11, no.11: pp.887-890. DOI: 10.1109/LSP.2004.833490

[2] Jiang, T., Yang, Y., & Song, Y. H. 2005."Exponential companding technique for PAPR reduction in OFDM systems." Broadcasting, IEEE Transactions vol. 51, no. 2: pp. 244-248. DOI: 10.1109/TBC.2005.847626

[3] Han, S. H., & Lee, J. H. 2005."An overview of peak-to-average power ratio reduction techniques for multicarrier transmission." Wireless Communications, IEEE vol. 12, no. 2: pp. 56-65. DOI: 10.1109/MWC.2005.1421929

[4] Jiang, T., & Zhu, G. 2005."Complement block coding for reduction in peak-to-average power ratio of OFDM signals." Communications Magazine, IEEE vol. 43, no. 9: pp. S17-S22. DOI: 10.1109/MCOM.2005.1509967

[5] Jiang, T., & Wu, Y. 2008. "An overview: peak-to-average power ratio reduction techniques for OFDM signals." IEEE Transactions on broadcasting, vol. 54, no.2: pp. 257-268. DOI: 10.1109/TBC.2008.915770

[6] Jiang, Y. (2010)."New companding transform for PAPR reduction in OFDM." Communications Letters, IEEE,vol.14, no.4: PP. 282-284. DOI: 10.1109/LCOMM.2010.04.092030

[7] Baig, I., & Jeoti, V.2010."PAPR reduction in OFDM systems: Zadoff-Chu matrix transform based pre/post-coding techniques." In Computational Intelligence, Communication Systems and Networks (CICSyN), 2010 Second International Conference Liverpool: IEEE on 28-30 July 2010: pp. 373-377.

[8] Armstrong, J.2002."Peak-to-average power reduction for OFDM by repeated clipping and frequency domain filtering." Electronics letters,vol.38, no. 5:pp 246-247.DOI: 10.1049/el:20020175

[9] Ochiai, H., & Imai, H. 2002."Performance analysis of deliberately clipped OFDM signals." Communications, IEEE Transactions,vol.50, no.1: pp. 89-101.DOI: 10.1109/26.975762

[10] Van Nee, R., & de Wild, A. 1998."Reducing the peak-to-average power ratio of OFDM." In Vehicular Technology Conference VTC 98. 48th Ottawa, Ont: IEEE on 18-21 May 1998: pp. 2072-2076.

[11] Bhatnagar, S., Beakta, S., &Manchanda, R. 2010 . "Comparative analysis of the techniques for reducing PAPR in OFDM". In Computational Technologies in Electrical and Electronics Engineering (SIBIRCON), 2010 IEEE Region 8 International Conference Listvyanka: IEEE on 11-15 July 2010: pp. 233-238.

[12] Jiang, T., Xiang, W., Richardson, P. C., Guo, J., & Zhu, G. 2007. "PAPR reduction of OFDM signals using partial transmit sequences with low computational complexity". Broadcasting, IEEE Transactions, vol.53, no.3: pp. 719-724. DOI: 10.1109/TBC.2007.899345

[13] Chen, G., Ansari, R., & Yao, Y. 2009. "Improved peak windowing for PAPR reduction in OFDM." In Vehicular Technology Conference, Barcelona: IEEE 2009. VTC Spring 2009. IEEE 69th: pp. 1-5. DOI: 10.1109/VETECS.2009.5073593

[14] Yang, K., & Chang, S. I. 2003."Peak-to-average power control in OFDM using standard arrays of linear block codes." Communications Letters, IEEE, vol.7, no.4: pp.174-176. DOI: 10.1109/LCOMM.2003.811204

[15] Sathananthan, K., &Tellambura, C. 2002. "Coding to reduce both PAR and PICR of an OFDM signal." Communications Letters, IEEE, vol. 6, no.8: pp. 316-318. DOI: 10.1109/LCOMM.2002.802065

[16] Li, H., Jiang, T., & Zhou, Y.2011. "An improved tone reservation scheme with fast convergence for PAPR reduction in OFDM systems." Broadcasting, IEEE Transactions, vol.57, no.4: pp. 902-906. DOI: 10.1109/TBC.2011.2169622

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[17] Wang, L., &Tellambura, C. 2008."Analysis of clipping noise and tone-reservation algorithms for peak reduction in OFDM systems." Vehicular Technology, IEEE Transactions, vol. 57, no.3: pp. 1675-1694. DOI: 10.1109/TVT.2007.907282

[18] Hou, J., Tellambura, C., &Ge, J. 2013."Clipping noise-based tone injection for PAPR reduction in OFDM systems." In Communications (ICC), 2013 IEEE International Conference Budapest: IEEE on 9-13 June 2013: pp. 5759-5763.

[19] Lim, D. W., Heo, S. J., & No, J. S. 2009."An overview of peak-to-average power ratio reduction schemes for OFDM signals." Communications and Networks, Journal, vol. 11, no.3: pp. 229-239. DOI: 10.1109/JCN.2009.6391327

[20] Han, S. H., Cioffi, J. M., & Lee, J. H. 2006. "Tone injection with hexagonal constellation for peak-to-average power ratio reduction in OFDM." Communications Letters, IEEE,vol.10, no.9: pp. 646-648. DOI: 10.1109/LCOMM.2006.1714532

[21] Baig, I., &Jeoti, V.2010. "DCT precoded SLM technique for PAPR reduction in OFDM systems." In Intelligent and Advanced Systems (ICIAS), International Conference Kuala Lumpur, Malaysia: IEEE on 15-17 June 2010:pp. 1-6.

[22] Heo, S. J., Noh, H. S., No, J. S., & Shin, D. J.2007. "A modified SLM scheme with low complexity for PAPR reduction of OFDM systems." In Personal, Indoor and Mobile Radio Communications, 2007. PIMRC 2007. IEEE 18th International Symposium Athens: IEEE on 3-7 Sept. 2007: pp. 1-5.

[23] Müller, S. H., & Huber, J. B. 1997. OFDM with reduced peak-to-average power ratio by optimum combination of partial transmit sequences. Electronics letters, vol.33, no.5:pp. 368-369. DOI: 10.1049/el:19970266

[24] Breiling, M., Müller-Weinfurtner, S. H., & Huber, J. B. 2000. "Peak-power reduction in OFDM without explicit side information." In 5th International OFDM-Workshop Hamburg, Germany on September,2000: pp. 28.1-28.4.

[25] Guan, L., Jiang, T., Qu, D., & Zhou, Y. 2010. "Joint channel estimation and PTS to reduce peak-to-average-power radio in OFDM systems without side information." Signal Processing Letters, IEEE, vol. 17, no.10: pp.883-886. DOI: 10.1109/LSP.2010.2066562

[26] Tan, P., & Beaulieu, N. C. 2006. "A comparison of DCT-based OFDM and DFT-based OFDM in frequency offset and fading channels." Communications, IEEE Transactions, vol. 54, no.11: pp. 2113-2125. DOI: 10.1109/TCOMM.2006.884852

[27] Tan, P., & Beaulieu, N. C.2005. "An improved DCT-based OFDM data transmission scheme." In Personal, Indoor and Mobile Radio Communications, 2005. PIMRC 2005. IEEE 16th International Symposium Berlin: IEEE on 11-14 Sept. 2005: pp.745-749.

[28] Kumar, A. A., & Makur, A. 2010. "Improved coding-theoretic and subspace-based decoding algorithms for a wider class of DCT and DST codes." Signal Processing, IEEE Transactions, vol. 58, no.2: pp. 695-708. DOI: 10.1109/TSP.2009.2031727

[29] Baig, I., Jeoti, V., Ikram, A. A., & Ayaz, M. 2014. "PAPR reduction in mobile WiMAX: a novel DST precoding based random interleaved OFDMA uplink system." Wireless networks, vol. 20, no. 5: pp. 1213-1222. DOI: 10.1007/s11276-013-0671-0

[30] Ouyang, X., J. Jin, G. Jin, and Z. Wang. 2012. "Low complexity discrete Hartley transform precoded OFDM for peak power reduction." Electronics letters, 48(2): 90-91. DOI: 10.1049/el.2011.3283

[31] Ouyang, X., J. Jin, G. Jin, and Li, P. 2015. "Low Complexity Discrete Hartley Transform Precoded OFDM System over Frequency Selective Fading Channel." ETRI Journal.Vol.37, no.1: PP.32-42. http://dx.doi.org/10.4218/etrij.15.0114.0513

[32] Pérez-Cruz, F., Rodrigues, M. R., & Verdú, S. 2010. " MIMO Gaussian channels with arbitrary inputs: Optimal precoding and power allocation. Information Theory", IEEE Transactions, vol.56, no.3: PP.1070-1084. DOI: 10.1109/TIT.2009.2039045

[33] Yue, G, and Wang, X. 2006."A hybrid PAPR reduction scheme for coded OFDM." Wireless Communications, IEEE Transactions, vol. 5, no. 10: PP. 2712-2722. DOI: 10.1109/TWC.2006.04136

[34] KHAN, M., IQBAL, S., & ASGHAR, W. 2014. A Review Paper On: The Papr Analysis of Orthogonal Frequency Division Multiplexing (OFDM). International journal. Vol.4, no.1:DOI : 10.5121/ijmnct.2014.4101

[35] Speth, Michael, and Meik Dörpinghaus. 1999. "OFDM receivers for broadband-transmission." Link: http://www. ert. rwth-aachen. de/Projekte/Theo/OFDM/ www_ ofdm. Html (1999).

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