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A REVIEW ON PEAK-TO-AVERAGE POWER RATIOREDUCTION TECHNIQUES FOR OFDM SIGNALS

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ABSTRACT

OFDM is one among the most potential candidate currently used in modern digital transmission. It's a special form of multi carrier transmission where a single data stream is transmitted over a number of other lower data rate subcarriers. One of the most challenging and most talked about issue in ODFM is high PAPR (Peak to Average Power Ratio). In this paper, we have done review and analysis of different existing PAPR reduction techniques for OFDM System based on various parameters like bandwidth expansion, performance, spectral spillage and computational complexity.

KEYWORDS: Survey, OFDM (Orthogonal Frequency Division Multiplexing), PAPR (Peak to Average Power Ratio), HPA (High Power Amplifier), Review Paper.

INTRODUCTION

OFDM is multicarrier multiplexing access Technique for Transmitting Large data over Radio waves. Next mobile Generation system is expected to provide high data rate to meet the requirement for future multimedia application. Minimum data rate required for the 4G System is 10-20Mbps & at least 2Mbps in moving vehicles. And modulation technique adopted by 4G mobile system is OFDM. One of the major problems observed in OFDM system is **PAPR** (Peak to Average Power Ratio). This PAPR must be Reduce for efficient transmission. Different techniques can be used for reduce PAPR in OFDM system.

A large peak-to-average power ratio (PAPR) would cause the power amplifier used in an OFDM system to be driven in the saturation region, thus leading to signal distortion. The classical remedy for this PAPR problem is to use a linear amplifier with a large dynamic range. This solution, however, imposes a stringent requirement on the analog devices in both the transmitter and receiver, and therefore, increases the cost of the system.

Traditional single carrier modulation techniques can achieve only limited data rates due to the restrictions imposed by the multipath effect of wireless channel and the receiver complexity. High data-rate is desirable in many recent wireless multimedia applications **[1]**. However, as the data-rate in communication system increases, the symbol duration gets reduced. Therefore, the communication systems using single carrier modulation suffer from severe **Intersymbol interference** (ISI) caused by dispersive channel impulse response, thereby needing a complex equalization mechanism. Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multicarrier modulation scheme, which divides the entire frequency selective fading channel into many orthogonal narrow band flat fading sub channels. In OFDM system high-bit-rate data stream is transmitted in parallel over a number of lower data rate subcarriers and do not undergo ISI due to the long symbol duration**[2]**.

General structure of OFDM

The basic principle of OFDM is to split a high rate input data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. Because the transmission rate is slower in parallel subcarriers, a frequency selective channel appears to be flat to each subcarrier. ISI is eliminated almost completely by adding a guard interval at the beginning of each OFDM symbol. However, instead of using an empty guard time, this interval is filled with a cyclically extended version of the OFDM symbol. This method is used to avoid ICI.

OFDM is a special case of Multicarrier Modulation (**MCM**). In MCM, input data stream is divided into lower rate substreams, and these sub streams are used to modulate several subcarriers. In general, the spacing between these subcarriers is large enough such that individual spectrum of subcarriers do not overlap. Therefore the receiver uses a bandpass filter tuned to that subcarrier frequency in order to demodulate the signal. In OFDM, subcarrier spacing is kept at minimum, while still preserving the time domain orthogonality between subcarriers, even though the individual frequency spectrum may overlap.

A typical OFDM transmission system is shown in **Fig. 1**. At the transmitting end, first of all, input binary serial data stream is first processed by channel encoder, constellation mapping and serial to parallel (**S/P**) conversion. A single signal is divided into N parallel routes after N-point inverse fast Fourier transform (**IFFT**). Each orthogonal sub-carrier is modulated by one of the N data routes independently. By definition the N processed points constitute one OFDM symbol.

Next, convert modulated parallel data to serial sequence and then copy the last L samples of one symbol to the front as cyclic prefix (**CP**). At last, arrive at transmitter after process of digital to analog (**D/A**) conversion and radio frequency (RF) modulation. To recover the information in OFDM system, reception process is converse and self-explanatory. At the receiving end, digital down conversion is carried out, demodulate receiving signals.At last, demodulated signals are fed into an analog to digital (**A/D**) converter, sample output and take timing estimation to find initial position of OFDM symbol. The CP added in transmission process is removed and N-Points fast Fourier transform (**FFT**) transformation will be conducted on the left sample points to recover the data in frequency domain. The output of baseband demodulation is passed to a channel decoder, which eventually recover the original data.

Major advantages of OFDM systems

- **Saving of Bandwidth,** the OFDM system is more bandwidth efficient in comparison to Frequency Division Multiplexing (FDM, in FDM technique numerous distinct carriers are spaced apart without overlapping where in OFDM system the sub-carrier overlap each other due to orthogonality features. Due to overlapping of sub-carriers the usage of bandwidth reduced drastically and also reduced the guard bands for the separation of sub-carriers.
- **Easy to implement modulation and demodulation,** the challenging problem in a MCM system is to implement bank of modulators at the transmitter side and demodulators at the receiver side. The concept of “Data transmission” can be efficiently implemented using IFFT and FFT instead of bank of modulators at the transmitter side and demodulators at the receiver side respectively.
- **Easy Equalization,** In OFDM system, wideband channel is divided into flat fading sub-channels, it reduces the equalization complexity in the receiver.
- **Susceptible to frequency selective fading,** due to capability of parallel transmission (each sub-carrier has narrow bandwidth to overall bandwidth of signal) OFDM is highly susceptible to frequency selective fading. OFDM converts a frequency selective fading channel into several flat fading channels.
- **Protection against Intersymbol interference,** the extended symbol time (due to lower data rate) makes the signal less susceptible to affect the channel such as multipath propagation which introduces Inter Symbol Interference (ISI). The use of cyclic prefix between consecutive OFDM symbols makes it immune to ISI. Also, it is less sensitive to sample timing offsets than single carrier system.

OFDM Signal Characteristics

For an OFDM system with N sub-carriers, the high-speed binary serial input stream is denoted as $\{ai\}$.After serial to parallel (S/P) conversion and constellation mapping, a new parallel signal sequence $\{d0, d1, \ldots\ldots di \ldots\ldots dN-1\}$is obtained, di is a discrete complex valued signal **[3]**. Here, $di \in \{\pm 1\}$ when BPSK mapping is adopted. When QPSK mapping is used, $di \in \{\pm 1, \pm i\}$. Each element of parallel signal sequence is supplied to N orthogonal sub-carriers $\{e^{j2\pi f0t}, e^{j2\pi f1t} \ldots e^{j2\pi fN-1t}\}$ for modulation, respectively. Finally, modulated signals are added together to form an OFDM symbol. Use of discrete Fourier transform simplifies the OFDM system structure. The complex envelope of the transmitted OFDM signals can be written as

$$x(t) = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} X_K e^{j2\pi f_k t}, \; 0 \le t \le NT \qquad \ldots \textbf{(1)}$$

Signals with large N become Gaussian distributed with Probability Density Function (PDF) is given by [4].

$$P_r\{x(t)\} = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{[x(t)]^2}{2\sigma^2}} \qquad \ldots \textbf{(2)}$$

Where σ is the variance of $x(t)$.

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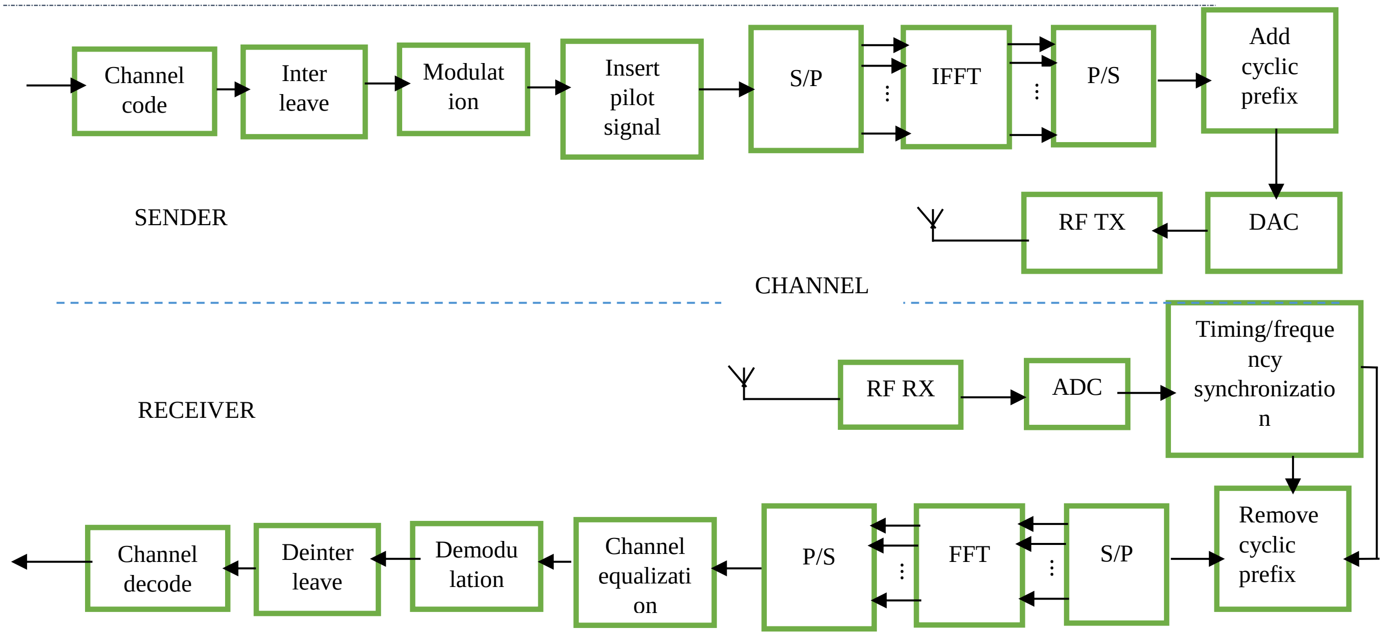

Fig. 1: Basic structure of OFDM system

Definition of PAPR

For a complex base band signal, $s(t) = s_I(t) + s_Q(t)$, PAPR would be defined as,

$$PAPR\ \{s(t)\} = \frac{\max_t |s(t)|^2}{\lim_{T\to\infty}\frac{1}{T}\int_0^T |s(t)|^2}. \qquad \textbf{... (3)}$$

When the same signal $s(t)$ is transposed over Radio Frequency (RF) signal with $f_0 = \frac{\omega_0}{2\pi}$being the carrier frequency the PAPR would be defined as,

$$PAPR\ \{s(t)\} = \frac{\max_t |R_e(s(t)e^{j\omega_0 t})|^2}{\lim_{T\to\infty}\frac{1}{T}\int_0^T |R_e(s(t)e^{j\omega_0 t})|^2 dt}. \qquad \textbf{... (4)}$$

The relation between base band signal PAPR, $PAPR_{BB}$, and RF signal PAPR, $PAPR_{RF}$,

$$PAPR_{RF}dB \approx PAPR_{BB}dB + 3dB. \qquad \textbf{... (5)}$$

As it could be seen that PAPR exhibits the variations in the peak of the signal with respect to its mean power and consequently its dynamic range.

Major problems of OFDM system

Despite of several advantages, the OFDM systems also have some major problems like-

- **High Peak to Average Power Ratio (PAPR) of transmitted Signal**-Presence of a large number of subcarriers with varying amplitude results in a high peak to average power ratio (PAPR) of the system with large dynamic range, which in turn effects on the efficiency of the RF amplifier.
- **Synchronization (timing and frequency) at the Receiver**-Symbol Timing Offset (STO) and Carrier Frequency Offset (CFO) effects on the performance of OFDM system. Correct timing between FFT and IFFT is required at the receiver side. OFDM system is highly sensitive to Doppler shifts which affect the carrier frequency offset, resulting in ICI.

The PAPR reduction technique should be chosen with awareness according to various system requirements.

TABLE 1: Comparison of PAPR Reduction Techniques

Reduction Technique	**Parameters**			**Operation required at Transmitter (TX)/ Receiver (RX)**
	Decrease distortion	Power raise	Defeat data rate	

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Clipping and Filtering	No	No	No	TX: Clipping RX: None
Selective Mapping (SLM)	Yes	No	Yes	TX: M times IDFTs operation RX: Side information extraction, inverse SLM
Block Coding	Yes	No	Yes	TX: Coding or table searching RX: Decoding or table searching
Partial Transmit Sequence(PTS)	Yes	No	Yes	TX: V times IDFTs operation RX: Side information extraction, inverse PTS
Interleaving	Yes	No	Yes	TX: D times IDFTs operation, D-1 times interleaving RX: Side information extraction, de-interleaving
Tone Reservation(TR)	Yes	Yes	Yes	
Tone Injection(TI)	Yes	Yes	No	

REVIEW OF RELATED WORK

Joint ICI Cancellation and PAPR Reduction in OFDM systems without side information[5]. In this paper, researchers have proposed the mathematical analysis of PAPR performance for ICI self-cancellation, new ICI self-cancellation and ICI conjugate cancellation schemes. It demands the requirement of PAPR reduction because PAPR performance of these schemes are either very nearer to or poorer than the OFDM signal. Here in this paper, researchers has introduced a multipoint partial transmit scheme (PTS), which progress the PAPR performance the PAPR performance of ICI canellation scheme.

An SDP approach for PAPR reduction in OFDM using partial transmit sequence [6]. The Partial transmit sequence algorithm has been broadly used to lessening the influence of peak to average power ratio in OFDM system. The important phase in PTS is the practice of a finite set of phase factor "bv" to rotate the data or information signal before transmission to decrease the effect of PAPR. In this paper, researchers propose a semi definite programming which discoveries the optimal set of phase rotation factors recycled in the PTS technique.

Reduction of PAPR in OFDM system by intelligently applying both PTS and SLM algorithm [7] In OFDM system PAPR is the key problem. Selective mapping and partial transmit sequence (PTS) existing scheme are effective but on the other hand it is very hard to gadget due to the high complication. The characteristic algorithm in this research area are the multi-time clipping algorithm SLM algorithm, PTS algorithm and golay complement sequence algorithm. In this paper, researcher found that both SLM and PTS algorithm have good performance in dropping the PAPR than the golay complement sequence algorithm than the clipping algorithm. Thus a new PAPR reduction algorithm is offered, by using both PTS and SLM algorithm, which tries lessen the PAPR problem.

Partial Transmit Sequence for PAPR reduction of OFDM signal with Stochastic Optimization technique [8]. A high PAPR is a major drawback in orthogonal frequency division method. The conventional PTS technique is very effective in PAPR reduction in OFDM, but the complexity is more in practical. To diminish the complexity still improving the PAPR statistics. So in this paper, researchers has presented a stochastic optimization technique to lessen the PAPR of an OFDM system.

Peak to average power ratio reduction using adaptive digital filter [9]. OFDM is a promising technique in contrast to the multipath fading channel for wireless communication. In this paper researchers propose a method to condense the PAPR effect of the OFDM signal. Here adaptive digital filters are used to lessen the consequence of PAPR.

Comparative study of PAPR reduction technique in OFDM[10]. OFDM suffers the PAPR problem and that is a major problem of multicarrier transmission system. The PAPR is the ratio of maximum power of a sample in a given OFDM transmit symbol to the average power of that OFDM symbol. PAPR occurs the different subcarriers are out of phase with each other. This paper represent different PAPR reduction technique and accomplish the comparison of difficult techniques.

$Arunjeeva, L. Arunmozhi, S.$ [11] presented their work "A novel complexity PAPR reduction scheme for MIMO-OFDM systems" IEEE Conference in which they have used a number of peak-to-average power ratio (PAPR) reduction techniques have been proposed for (MIMO-OFDM) systems; however, most of them involve very high computational complexity and are not applicable to MIMO-OFDM systems with space frequency block coding (SFBC). A novel complexity PAPR reduction scheme for SFBCMIMO-OFDM systems is proposed.

$Wei\ Xuefeng$ [12] presented their work "A new algorithm for reduction of peak-to-average power ratio in MIMO-OFDM system" IEEE Conference in which they have used the copy theory based mixed on the traditional SLM scheme, this paper proposes a new kind of mimo-ofdm system reduces the SLM PAPR algorithm and presents the corresponding policy results. According to the simulation results, we can see this improved technique not only keeps the former probability scheme's advantages, but also further reduces the probability of high PAPR value.

$Wang, L., Liu, J.$ [13] presented their work "Cooperative PTS for PAPR reduction in MIMO-OFDM" IET JOURNALS & MAGAZINES Partial transmit sequence (PTS) provides attractive peak-to-average power ratio (PAPR) reduction performance in OFDM or MIMO-OFDM. However, it leads to prohibitively large computational complexity. A cooperative PTS (co-PTS) is proposed. In co-PTS, alternate optimization and spatial sub-block circular permutation are employed. Simulation results show that co-PTS can reduce computational complexity dramatically and achieve better PAPR reduction performance compared to ordinary PTS.

$Umeda, S. Suyama, S. Suzuki, H. Fukawa,$[14] presented their work "PAPR Reduction Method for Block Diagonalization in Multiuser MIMO-OFDM Systems" IEEE Conference This paper proposes BD transmission selected mapping (BD-SLM) that can reduce PAPR while maintaining the BD effect. BD-SLM performs the phase shift to modulation signals of all users before the linear precoding. From several phase sequences, it selects a phase sequence that minimizes the peak of the time-domain signals at all transmit antennas. Computer simulations demonstrate that BD-SLM can drastically reduce PAPR in 16 × 4 MIMO-OFDM with four users, and that it can alleviate the performance degradation even when the power amplifier causes nonlinear distortion.

Biao Yan; Hui Zhang; Yinxia Yang; Qian Hu; Mengdong Qiu [15] presented their work "An improved algorithm for peak-to-average power ratio reduction in MIMO-OFDM systems" IEEE Conference in which they have used Sub-block Successive Transform (SST) algorithm is an effective method to reduce the PAPR of the MIMO-OFDM signals, and can fully utilize the degrees of freedom in space domain to overcome the shortage of Successive Suboptimal Cross-Antenna Rotation and Inversion (SS-CARI) algorithm. However, the degrees of freedom in frequency domain are not considered in SST algorithm.

For this problem, an improved SST (ISST) algorithm is proposed, in which, not only Sub-blocks are permuted in the same way as SST algorithm in space domain, but also sub-blocks on the same antenna are successively rotated in frequency domain. So it can fully use the degrees of freedom in both space domain and frequency domain. Simulation results indicate that the effect of PAPR reduction of presented method is obviously better than that of SST algorithm.

TABLE 2: Summary of Literature Review

Year	Author	Title	Approach	Result

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2012 [11]	Arunjeeva, L. Arunmozhi, S	A novel complexity PAPR reduction scheme for MIMO-OFDM systems	SFBCMIMO-OFDM systems Used	Reduce PAPR in MIMO-OFDM
2011 [12]	Wei Xuefeng	A new algorithm for reduction of peak-to-average power ratio in MIMO-OFDM system	Copy theory based mixed on the traditional SLM scheme	Reduces the probability of high PAPR value
2011 [13]	Wang, L., Liu, J.	Cooperative PTS for PAPR reduction in MIMO-OFDM	Cooperative PTS (co-PTS) Method	Achieve better PAPR reduction performance
2010 [14]	Umeda, S. Suyama, S. Suzuki, H. Fukawa, K.	PAPR Reduction Method for Block Diagonalization in Multiuser MIMO-OFDM Systems	BD transmission selected mapping (BD-SLM)	Reduce PAPR in 16 × 4 MIMO-OFDM with four users
2009 [15]	Biao Yan; Hui Zhang; Yinxia Yang; Qian Hu; Mengdong Qiu	An improved algorithm for peak-to-average power ratio reduction in MIMO-OFDM systems	Sub-block Successive Transform (SST) algorithm	Reduce the PAPR of the MIMO-OFDM signals

Research in[16], Pankaj Gupta proposed Performance Analysis of Peak to Average Power Ratio Reduction Techniques in OFDM System. In this paper, different PAPR reduction techniques are analyzed and compared with standard OFDM [17]. In [18],*Shilpa Jaswal* proposed Comparative analysis of SLM and Iterative Flipping PAPR Reduction Techniques. In this paper we have discussed different PAPR reduction techniques and compared Selective Mapping and Iterative Flipping with each other [19]. [20] Kamal Singh proposed Comparative Analysis of PTS and Iterative Flipping Scheme for Reduction of PAPR in OFDMA Networks. In this paper partial transmit sequences (PTS) and iterative flipping schemes are discussed to reduce PAPR and compared with original scheme (without PAPR reduction scheme) [21].

[22] Byung Moo Lee proposed An Enhanced Iterative Flipping PTS Technique for PAPR Reduction of OFDM Signals. In this chapter, we propose an enhanced version of the iterative flipping algorithm to reduce the performance gap between the iterative flipping algorithm and the ordinary PTS technique. In the proposed algorithm, there is an adjustable parameter to allow a performance/ complexity trade-off [23].

CONCLUSION

OFDM seems to be an attractive technique for wireless communication because of its channel robustness and spectrum efficiency. But the major drawback in OFDM systems is that the composite transmit signal sometimes exhibit a very high PAPR as the input signal are highly correlated. This paper presents a review of various PAPR reduction techniques.In this paper it is aimed to investigation some of the techniques which are used to reduce the high PAPR of the system. We have taken and reviewed various techniques to reduce PAPR, all of them have potential to provide considerable reduction in PAPR, but at the cost of BER performance degradation, loss in data rate, increase in power of the transmitted signal, computational complexity, etc. Adding to this combination of these techniques can be used to obtain some more PAPR reduction.The MIMO technique with PAPR reduction technique can be perform further better with optimization of communication parameter & may be a future technique for OFDM based system. This review gives an opportunity to explore the area of research for betterment of OFDM based system.

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