A Survey on Various PAPR Reduction Techniques in OFDM Communication Systems

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Abstract - *One of the emerging technologies in the field of communications is wireless technology. It provides efficient data transmission and a growing concept for 4G and 5G communications. The concept of OFDM system states that it is a form of multi-carrier modulation. The OFDM system suffers from the drawback of high PAPR i.e. Peak to average Power Ratio. Numerous Techniques such as SLM, PTS, Tone Reservation, Clipping and filtering etc. have been discussed in this review paper which are used to reduce the PAPR effect in OFDM systems.Different parameters such as distortion Rate, data rate, power raise etc. are analyzed with the study of different PAPR reduction techniques.*

KeyWords: *OFDM, PTS, SLM, BER, PAPR, PSK, QAM,CDF.*

1.INTRODUCTION TO OFDM SYSTEMS

In the present scenario, the demand for high speed data transmission has increased with accelerated growth in the field of wireless technology. Wireless communication has seen sudden rise in its development as a large number of wireless devices are being innovated day by day for efficient transmission. These wireless devices have access to internet, the transmission of data faces distortion and hence the distortion factor is reduced.

The basic principle of OFDM systems is that it is a form of multi-carrier modulation. It is a type of signal modulation that provides a high data rate modulating stream placing them onto many slowly modulated space carriers[10] which are orthogonal to each other. The main advantages of using OFDM Scheme is that it provides high spectral efficiency[14],increased system efficiency for reliable transmission ,improves bandwidth efficiency. It can handle multipath interference and ISI i.e. Intersymbol Interference. Recently studied data depicts that there are several limitations which are being suffered by the OFDM Systems .One of the major drawback is that OFDM systems exhibit High PAPR i.e. Peak to Average Power ratio[9]. Several techniques such as SLM(Selective Mapping)[3],PTS(Partial Transmit Sequence)[8],[11],Tone Reservation, clipping and filtering[7],Companding[5],etc are being discussed in this paper which are used for minimizing the effect of PAPR i.e. Peak to Average Power Ratio. The OFDM communication systems finds it's applications in Digital television and audio broadcasting, DSL Internet access, wireless networks and 4G mobile communications[13].

The assembling of this Review paper is done as follows:- Section 1 gives us the introduction to OFDM Systems. Section 2 explains the concept of PAPR in OFDM Signal. Section 3 gives the classification of PAPR Reduction Techniques. Section 4 explains numerous PAPR Reduction Techniques. Section 5 mentions the overall analysis of the mentioned PAPR Reduction Techniques on various parameters. Section 6 depicts the conclusion part.

2. PAPR IN OFDM SIGNAL

In OFDM System Model, it can be noted that the input transmit signals are modulated first using either PSK or QAM i.e. Phase Shift Keying or Quadrature Amplitude Modulation and then undergo IFFT (Inverse Fast Fourier Transform)operation at the transmitter end. The orthogonal sub-carriers are produced at the transmitter side[11].These transmitted signals can have high peak values in time domain and these high peak values are referred to as high Peak To Average Power Ratio, in OFDM Systems as compared with Single carrier systems. The high PAPR is a result of summation of sinc waves and non-constant envelope. The deleterious effect of High PAPR is that it decreases the Signal to Quantization Noise Ratio of ADC and DAC's, while lowering the performance of power amplifier.Therefore,RF power amplifiers needs to be operated in very large linear region,Elseways the signal peaks will get entered into non-linear region and will cause distortion. So there are number of PAPR reduction techniques. The efficiency of any PAPR Reduction Technique is measured through Cumulative Distribution, i.e.(CDF).

PAPR of a signal is represented by:-

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

Where E[.] depicts Expectation operator[14].

3.CLASSIFICATION OF PAPR REDUCTION TECHNIQUES:-

Signal Scrambling Techniques	Signal Distortion Techniques
1. Selective Mapping (SLM)	1. Clipping and Filtering
2. Partial Transmit Sequence	2. Peak windowing
3. Tone Reservation	3. Peak Reduction Carrier
4. Tone Injection	4. Companding
5. Interleaving	

Table 1:-Various PAPR reduction Techniques.

4. VARIOUS PAPR REDUCTION TECHNIQUES

The explanation of the above mentioned PAPR Reduction techniques is given in this section.

4.1 SIGNAL SCRAMBLING TECHNIQUES

4.1.1 Selective Mapping (SLM):-

The paper that fabricated the "Selective Mapping Technique" first was penned down by Bamul,Fischer and Huber in 1996.[3]SLM is one of the favorable Reduction techniques as it does not introduces distortion and yields effective PAPR Reduction in OFDM System. In this technique the Input data blocks are multiplied by each of the phase sequences to generate alternative input symbol sequences. Each of the alternative I/P data sequence is processed further under IFFT Operation and then the signal with lowest PAPR is selected for Transmission[11]. Selected Mapping Technique is a technique which is used to lessen the PAPR effect which is observed in OFDM Systems. It is a kind of Phase Rotation Method..The SII(side information index) should be transmitted to allow recovery of data block at the receiver side.

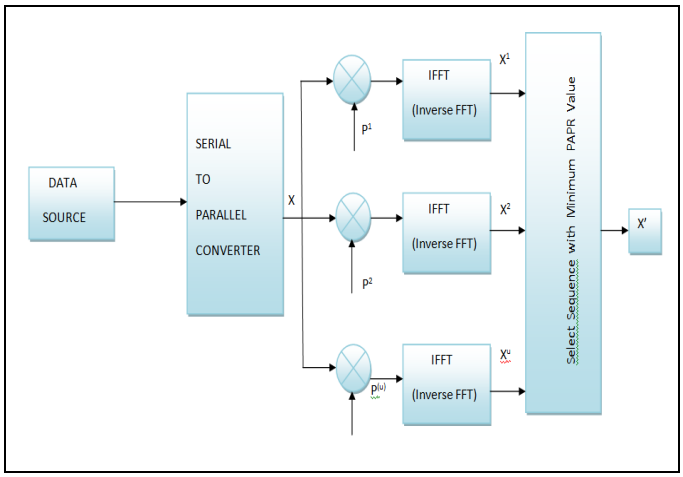

Figure -1:- The Block Diagram of SLM Scheme

Using Selected Mapping technique (SLM), input data is portioned into sub data blocks given below of length N, and is converted into the parallel data stream using serial to parallel converter. When the data is parallel converted then OFDM data block is multiplied element by element with phase sequence given as

$$P^u = [P^1, P^2, P^3, \ldots P^U] \quad \ldots(i)$$

Where u= [0, 1, 2....U], to make OFDM data blocks to be phase rotated. Therefore X (u) expressed as,

$$X^{(u)} = [x_0^{(u)}, x_1^{(u)}, \ldots\ldots\ldots x_{N-1}^{(u)}]^T$$

$$= [P_0^{(u)} x_0, P_1^{(u)} X_1, \ldots\ldots\ldots P_{N-1}^{(u)} X_{N-1}]^T$$

$$= P^{(u)} x \quad \ldots..(ii)$$

After data blocks are phase rotated, the rotated OFDM data blocks represents similar information which are unmodified OFDM data blocks, provided with known phase sequence. Now frequency domain signal is converted into the time domain X (u), by the help of IFFT. The fundamental idea that lies in this technique, it helps to select the signal with lowest PAPR value from independent phase sequences that have same information at the transmitter end.

4.1.2 Partial Transmit Sequence(PTS):-

The PTS (Partial Transmit Sequence)technique is popularly used technique for PAPR reduction and the concept of PTS Scheme can be clearly understood by its bock diagram. The concept of this PAPR reduction technique is addition of Phase Rotation to develop a candidate signal and to select one signal with low PAPR[8].The statistics of a multi carrier signal gets enhanced by using this technique.

Due to multicarrier propogation,the high value of PAPR affects the system capacity . So there is a need to reduce the high value of PAPR .For this, an approach named PTS (Partial Transmit Sequence) is discussed in this section which reduces the PAPR to a certain extent.

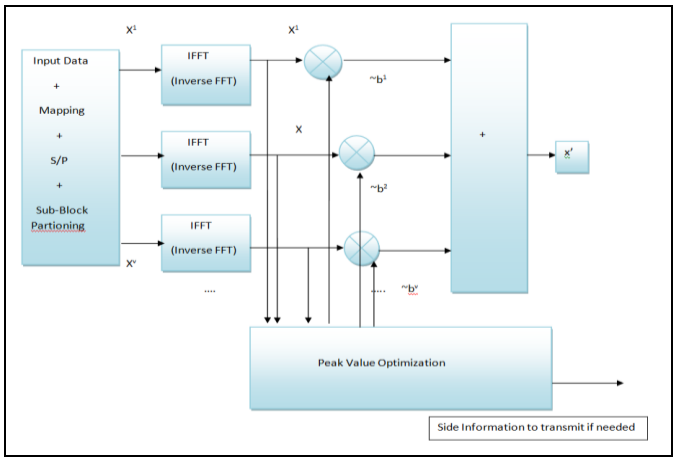

Figure 2: Block Diagram of PTS Scheme.

The vital idea that lies behind this PTS scheme is to divide the original OFDM sequence into several sequences and each sequence is multiplied by distinct weights until the best result is achieved. The PTS block Diagram shows that the input data block of N symbols is portioned into disjoint sub blocks and then the signal is further transmitted[10]. The portioning of sub-blocks is one another factor which should be taken into consideration as it also affects the PAPR reduction performance. The three ways of sub block portioning schemes are adjacent, interleaved and pseudo-random portioning[12].The PTS scheme is complex in nature and it also adds SII (Side Information Index) as that in SLM scheme.

4.1.3 Tone Reservation:-

A Tone Reservation Technique partitions N sub carriers i.e. small number of tones into data tones and peak reduction tones.(PRT's).The central idea behind this Tone Reservation scheme is that small set of tones are created for PAPR Reduction. It can be referred to as a accurate technique. This method is used to minimize the High peak values. It is based on adding a data block and time-domain signal. At the transmitter, the calculation of time domain signal can be done. The values for PAPR reduction in tone reservation approach depends on some factors such as number of reserved tones, amount of complexity and allowed power on reserved tones[9].This technique shows that by reserving even a small fraction of tones leads to large reduction in PAPR value.. The benefits of Tone Reservation method can be coined to be less complex in nature. No additional information is required to be operated at the receiver side. In this method , no side information is required at the receiver end.

4.1.4 Tone Injection:-

The Tone Injection approach was penned down by Muller, S.H., Huber, J.B [4].The basis of the tone injection scheme is general additive method which provides desired PAPR reduction. By the implementation of the additive method on the multicarrier signal, the PAPR reduction is achieved without any data rate loss. A set of equivalent constellation points is being used by this Tone Injection approach for original constellation points to minimize the effect of PAPR. The demerits of Tone Injection scheme is that this approach requires additional side information for decoding the signal at the receiver side and cause extra IFFT operation which results in complex circuitry.

4.1.5 Interleaving Technique:-

A technique which uses a set of Interleavers for PAPR reduction is called Interleaving technique.in this scheme,the upraised value of PAPR is reduced by using set of interleavers but not by using the set of Phase sequences as in PTS and SLM technique. A long correlation pattern is broken down to reduce the elevated values of correlated data structures[9].By the use of this Interleaving technique,we can obtain higher code rate without expansion in bandwidth as compared to conventional OFDM systems,without increase in number of sub-carriers. This interleaving technique gets slightly complex in nature and it gets moderately complex to compute using this technique.Interleavers are used to produce permuted data blocks from the same data block. The PAPR of (K-1) permuted data blocks and that of the original data block with the lowest PAPR is then chosen for transmission. For recovery of original data block,the receiver must be knowing which interleaver is used at the transmitter end.therefore,the number of required 'side information' bits is log2K . This normal Interleaving technique is illustrated below :

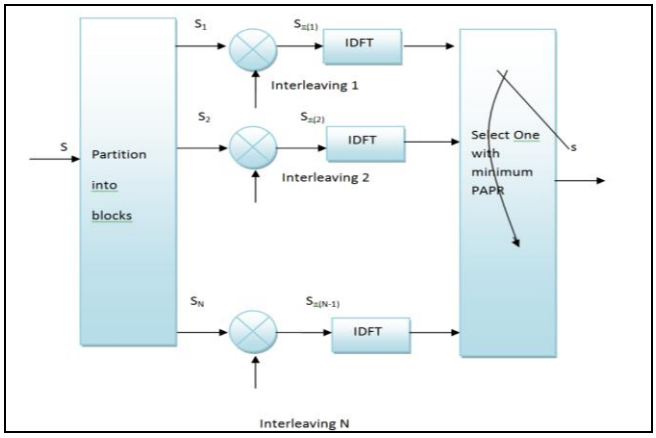

Figure 3:-Block Diagram of Interleaving technique

Thus, interleaving and de-interleaving can be done simply. The amount of PAPR reduction depends on the number of Interleavers and the design of the Interleavers.

4.2 SIGNAL DISTORTION TECHNIQUES

4.2.1 Clipping and Filtering Technique:-

The clipping and filtering technique for PAPR reduction is one of the simplest techniques and is being mostly used for getting reduced value of PAPR.The functioning of clipping and filtering technique is clear from its name itself i.e. it clips the part of the signals which are not allowed to enter the specified region. The operation of clipping and filtering technique can be understood by using the HPA (High Power Amplifier) with saturation region below the signal span will automatically cause the signal to be clipped.For amplitude clipping, that is

$$C(x) = \begin{cases} x, & x \le A \\ A, & x > A \end{cases}$$

Generally, clipping is performed at the transmitter. However, the receiver need to estimate the clipping that has occurred and to compensate the received OFDM symbol accordingly. Typically ,at most one clipping occurs per OFDM symbol, and thus the receiver has to estimate two parameters: location and size of the clip.However, it is difficult to get these information. Therefore, clipping method introduces both in band distortion and out of band radiation into OFDM signals, which degrades the system performance including BER and spectral efficiency. Filtering can reduce out of band radiation after clipping although it can not reduce in-band distortion. However, clipping may cause some peak regrowth so that the signal after clipping and filtering will exceed the clipping level at some points. To reduce peak regrowth, a repeated clipping-and-filtering operation can be used to obtain a desirable PAPR at a cost of computational complexity increase. As improved clipping methods, peak windowing schemes attempt to minimize the out of band radiation by using narrowband windows such as Gaussian window to attenuate peak signals[7].

4.2.2 Peak Reduction Carrier :-

This technique was proposed by Tan and Wassell,[1]and this technique demonstrates that it is used to reduce the elevated value of PAPR by using data bearing Peak Reduction Carrier in OFDM systems.this technique is associated with the use of higher order modulation scheme to represent a lower order modulation symbol[2],[9].The phase shift keying modulation schemes is suited for Peak Reduction Carrier as in this envelope of all the sub-carriers are the same.The implementation of Quadrature Amplitude Modulation Scheme will result in serious BER (Bit Error Rate) degradation. When the higher order modulation schemes are used by this technique to represent lower order modulation scheme data then,there is increased probability of error and hence the overall BER performance gets degraded.

5.OVERALL ANALYSIS OF VARIOUS PAPR REDUCTION TECHNIQUES

S.No	PAPR Reduction Technique	Parameters
1.	*Selective Mapping Technique*	*It decreases distortion.* *There is no Power raise in SLM technique.* *Selects the signal with lowest PAPR value for transmission.*
2.	*Partial Transmit Sequence*	*This technique helps in reducing distortion.* *No power raise .* *It is complex in nature.*
3.	*Tone Reservation*	*Reduces distortion effect.* *Power gets raised in this technique.* *It is less complex in nature.*
4.	*Tone Injection*	*It reduces distortion effect.* *Power raise is observed in this technique.* *PAPR reduction is observed without data rate loss.*

5.	*Clipping &Filtering*	▪ *It introduces distortion.* ▪ *No Power Raise .* ▪ *It is one of the simplest technique to apply.*

6. CONCLUSION

OFDM (Orthogonal Frequency Division Multiplexing) is a form of multi-carrier modulation technique. Wireless Communication is emerging technology in the present times and OFDM systems are in use because of its advantages such as providing High Spectral Efficiency, Increased Bandwidth Power and its robustness against multipath Interference.. But the OFDM System suffers from the drawback of high values of PAPR i.e. Peak to Average Power Ratio. In this Review paper, several techniques for PAPR Reduction are being reviewed and discussed. The techniques are classified into two categories. 1. Signal Scrambling Techniques 2. Signal Distortion Techniques. Numerous techniques such as SLM,PTS,Tone Reservation, Tone Injection, Interleaving, Clipping and filtering and Companding techniques are being discussed in this review paper. The analysis of PAPR Reduction Techniques on various Parameters is done. It has been studied that different PAPR Reduction techniques are able to reduce the PAPR effect, but there is no specific technique for PAPR Reduction which can reduce this effect for multi-carrier transmission. It is concluded that the PAPR Reduction Technique should be selected as per the system requirements.

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