INTRODUCTION TO PAPR REDUCTION TECHNIQUES IN OFDM SIGNALS

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ABSTRACT

Orthogonal frequency division multiplexing (OFDM) has been adopted as a standard for various high data rate wireless communication systems due to the spectral bandwidth efficiency, robustness to frequency selective fading channels, etc. However, implementation of the OFDM system entails several difficulties. One major disadvantage of OFDM is that the time domain OFDM signal which is a sum of several sinusoids leads to high peak to average power ratio (PAPR). There are many methods for reducing the PAPR with an ultimate goal of reducing the PAPR as much as possible. Number of techniques has been proposed in the literature for reducing the PAPR in OFDM systems.

Key words: OFDM, PAPR, Signal scrambling

I INTRODUCTION

Recently, orthogonal frequency division multiplexing (OFDM) has been regarded as one of the core technologies for various communication systems. Especially, OFDM has been adopted as a standard for various wireless communication systems such as wireless local area networks, wireless metropolitan area networks, digital audio broadcasting, and digital video broadcasting .It is widely known that OFDM is an attractive technique for achieving high data transmission rate in wireless communication systems and it is robust to the frequency selective fading channels. However, an OFDM signal can have a high peak -to-average power ratio (PAPR) at the transmitter, which causes signal distortion such as in-band distortion and out-of band radiation due to the nonlinearity of the high power amplifier(HPA) and a worse bit error rate (BER). In general , HPA requires a large back off from the peak power to reduce the distortion caused by the nonlinearity of HPA and this gives rise to a low power efficiency, which is a significant burden, especially in mobile terminals. This causes clipping of the OFDM signal by the High power amplifier (HPA) and in the HPA output producing nonlinearity. This non-linearity distortion will result in band distortion and out-of-band radiation. The in-band distortion causes system performance degradation and the out-of-band radiation causes adjacent channel interference (ACI) that affects systems working in neighbor band. Hence the OFDM signal may have In band and Out-of-band distortion which degradation of Bit-error-rate (BER) performance. One solution is to use a linear power amplifier with large dynamic range. However, most promising solution to reduce PAPR by using through PAPR reduction techniques such as SLM and PTS.

II ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING(OFDM)

OFDM Short for ***O**rthogonal **F**requency **D**ivision **M**ultiplexing*, an FDM modulation technique for transmitting large amounts of digital data over a radio wave. OFDM works by splitting the radio signal into multiple smaller sub-signals that are then transmitted simultaneously at different frequencies to the receiver. OFDM reduces the amount of crosstalk in signal transmissions. 802.11a WLAN, 802.16 and Wi -MAX technologies use OFDM. It is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication , whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, DSL broadband internet access, wireless networks, and 4G mobile communications The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions (for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath) without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate inter-symbol interference (ISI) and utilize echoes and time-spreading (on analogue TV these are visible as ghosting and blurring, respectively) to achieve a diversity gain, i.e. a signal-to-noise ratio improvement. This mechanism also facilitates the design of single frequency networks (SFNs), where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system.

2.1 Orthogonality

In OFDM, the sub-carrier frequencies are chosen so that the sub-carriers are orthogonal to each other, meaning that cross-talk between the sub-channels is eliminated and inter-carrier guard bands are not required as shown in OFDM spectrum.

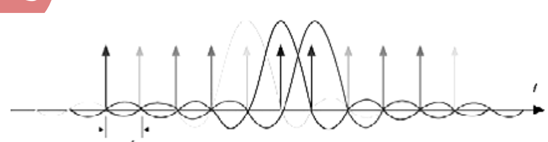

Fig 1: OFDM spectrum

This greatly simplifies the design of both the transmitter and the receiver; unlike conventional FDM, a separate filter for each sub channel is not required.

2.2 OFDM Transceiver Model

To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the orthogonality of the carriers. For this reason, OFDM is generated by firstly choosing the spectrum required based on the input data, and modulation scheme used. Each carrier to be produced is assigned same data to transmit. The required amplitude and phase of them are calculated based on the modulation scheme. The required spectrum is then converted back to its time domain signal using an Inverse Fourier Transform (IFT). In most applications, an Inverse Fast Fourier Transform (IFFT) is used. The IFFT performs the transformation very efficiently and provides a simple way of ensuring the carrier signals produced are orthogonal.

The Fast Fourier Transform (FFT) transforms a cyclic time domain signal into its equivalent frequency spectrum. This is done by finding the equivalent waveform, generated by a sum of orthogonal sinusoidal components. The amplitude and phase of the sinusoidal components represent the frequency spectrum of the time domain signal. The IFFT performs the reverse process, transforming a spectrum (amplitude and phase of each component) into a time domain signal. An IFFT converts a number of complex data points, of length that is a power of 2, into the time domain signal of the same number of points. Each data point in frequency spectrum used for an FFT or IFFT is called a bin. The orthogonal carrier required for the OFDM signal can be easily generated by setting the amplitude and phase of each frequency bin, thus performing the IFFT.

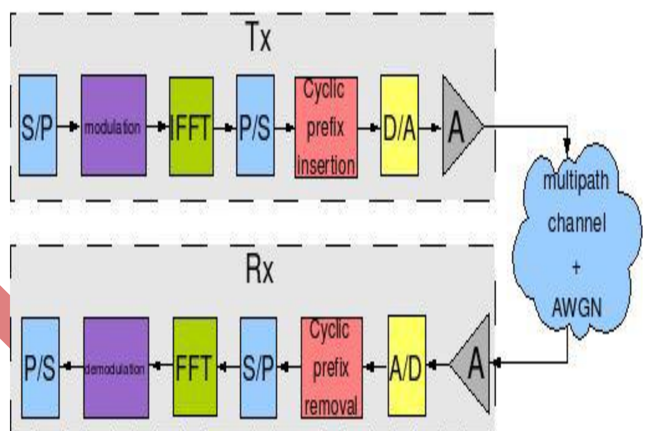

Fig 2: OFDM transceiver model

Figure above shows the configuration for a basic OFDM Transmitter and Receiver. The signal generated is at base band and so to generate an RF signal, the signal must be filtered and mixed to the desired transmission frequency.

III PROBLEM OF PEAK TO AVERAGE POWER RATIO(PAPR)

High Peak-to-Average Power Ratio (PAPR) has been recognized as one of the major practical problem in OFDM signal. High PAPR results from the nature of the modulation itself where multiple subcarriers / sinusoids are added together to form the signal to be transmitted. When N sinusoids add, the peak magnitude would have a value of N,

where the average might be quite low due to the destructive interference between the sinusoids. High PAPR signals are usually undesirable for it usually strains the analog circuitry. High PAPR signals would require a large range of dynamic linearity from the analog circuits which usually results in expensive devices and high power consumption with lower efficiency (for e.g. power amplifier has to operate with larger back-off to maintain linearity).
In OFDM system, some input sequences would result in higher PAPR than others. For example, an input sequence that requires all such carriers to transmit their maximum amplitudes would certainly result in a high output PAPR. Thus by limiting the possible input sequences to a smallest sub set, it should be possible to obtain output signals with a guaranteed low output PAPR.

3.1 PAPR

Theoretically, large peaks in OFDM system can be expressed as Peak-to-Average Power Ratio, or referred to as PAPR, in some literatures, also written as PAR. It is usually defined as,

$$PAPR = \frac{P_{Peak}}{P_{Average}} = 10\log_{10}\frac{\max[|x_n|^2}{E[|x_n|^2}$$

Where P_{Peak} denotes peak value , $P_{Average}$ means average output power. E denotes the expected value, x_n represents the transmitted OFDM signals which are obtained by taking IFFT operation on modulated input symbols. Mathematical, x_n is expressed as:

$$x_n = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k\, W_N^{nk}$$

For an OFDM system with N sub-carriers, the peak power of received signals is N times the average power when phase values are the same. The PAPR of baseband signal will reach its theoretical maximum at (dB) = 10log 10. For example, for a 16 sub-carriers system, the maximum PAPR is 12 dB. Nevertheless, this is only a theoretical hypothesis. In reality the probability of reaching this maximum is very low.

3.2 Various PAPR Reduction Techniques

Numerous schemes have been developed to reduce the PAPR of OFDM signals, which is one of the major drawbacks in multicarrier systems. In this section, we investigate the conventional PAPR reduction schemes using some examples and discuss related optimization problems as well as the advantages and disadvantages in terms of the PAPR reduction capability, computational complexity, BER degradation, power increase, etc. These techniques are divided into two groups. These are signal scrambling techniques and signal distortion techniques. The figure shown below shows all the schemes used for PAPR reduction. Signal scrambling techniques are all variations on how to scramble the codes to decrease the PAPR. Coding techniques can be used for signal scrambling. Golay complementary sequences, Shapiro-Rud in sequences, M sequences, Barker codes can be used efficiently to reduce the PAPR. However with the increase in the number of carriers the overhead associated with exhaustive search of the best code would increase exponentially. More practical solutions of the signal scrambling techniques are block coding, Selective Level Mapping (SLM) and Partial Transmit Sequences (PTS). Signal scrambling techniques with side information reduces the effective throughput since they introduce redundancy.

The signal distortion techniques introduce both In band and Out-of-band interference and complexity to the system. The signal distortion techniques reduce high peaks directly by distorting the signal prior to amplification. Clipping the OFDM signal before amplification is a simple method to limit PAPR.

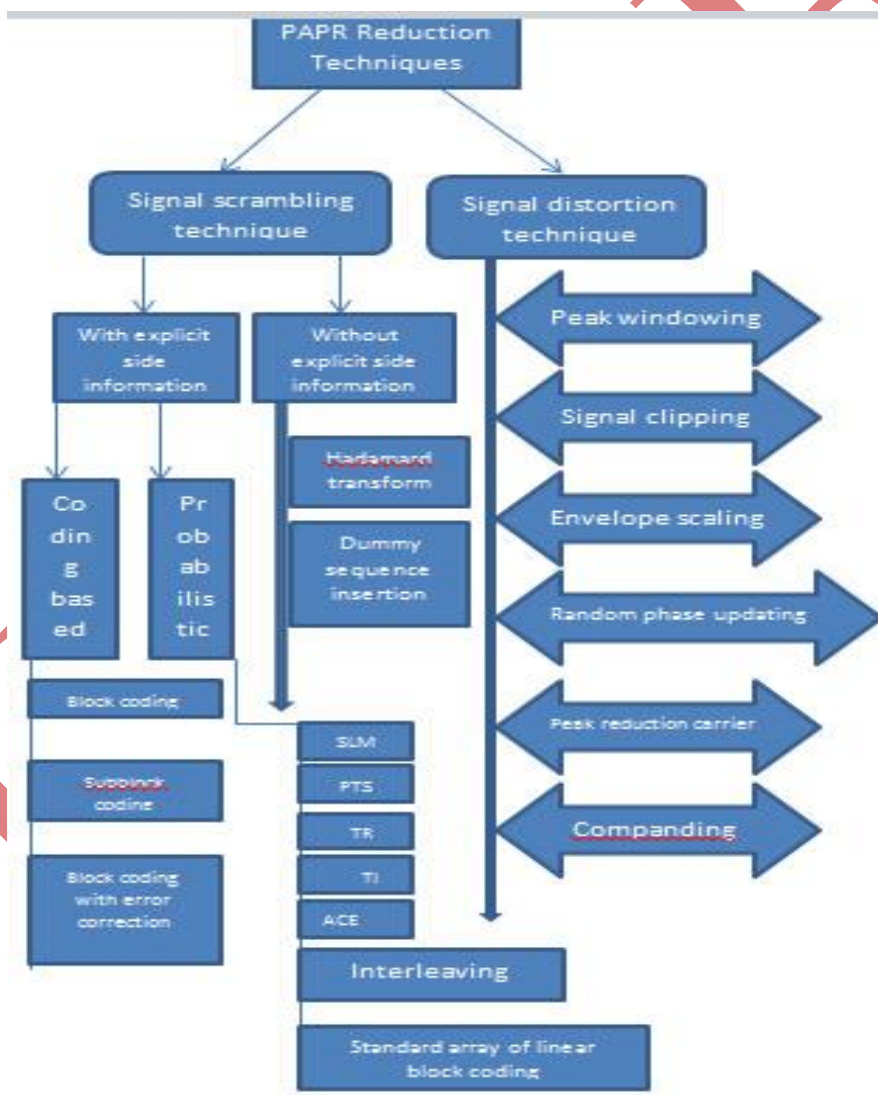

Fig 3: PAPR Reduction Technique

However clipping may cause large out-of band (OOB) and in-band interference, which results in the system performance degradation. More practical solutions are peak windowing, peak cancellation, Peak power suppression, weighted multicarrier transmission, companding etc. Basic requirement of practical PAPR reduction techniques include the compatibility with the family of existing modulation schemes, high spectral efficiency and low complexity.

IV SIGNAL SCRAMBLING TECHNIQUES

4.1 Block Coding Techniques

The main idea behind this scheme is that PAPR can be reduced by block coding the Data such that set of permissible code words does not contain those which result in excessive peak envelope powers (PEPs). There are three stages in the development of the block coding technique. The first stage is the selection of suitable sets of code words for any number of carriers, any M-ary phase modulation scheme, and any coding rate. The second stage is the selection of the sets of code words that enable efficient implementation of the encoding /decoding. The third stage is the selection of sets of code words that also offer error deduction and correction potential. There are a number of approaches to the selection of the sets of code words. The most trivial brute force approach is sequential searching of the PEP for all possible code words for a given length of a given number of carriers. This is simple and appropriate for short codes because it requires excessive computation. Most sophisticated searching techniques such as natural algorithms can be used for the selection of longer code words. The encoding and decoding, with sets of code\ words selected from searches, can be performed with a look up table or using combinatorial logic exploiting the mathematical structure of the codes.

4.2 Sub Block Coding Techniques

The proposed scheme for reducing the PAPR of OFDM has low complexity and is found that more than 3dB reduction in PAPR can be achieved when the code rate is ¾. The introduction of Sub-block coding (SBC) is based on the observation that all ¾ rate systematically coded block codes with the last bit as an odd parity checking bit demonstrate lowest peak envelope power. This coding scheme is termed as systematic odd parity checking coding (SOPC). It is found that both SOPC and block coding schemes are not effective in terms of PAPR reduction when the frame size is large, however, large PAPR reduction can still be obtained if the long information sequence is divided in to several sub-blocks, and each sub-block encoded with SOPC. There are many possible locations, where the odd parity checking bits can be inserted into each frame to reduce PAPR. Redundant bit location optimized sub-block coding (RBLO-SBC) optimizes these locations for further reduction of PAPR. Combination optimized sub-block coding scheme (COSBC) optimizes the combination of the coded sub-blocks, where two coding schemes instead of one is used to encode the same information source.

4.3 Block Coding Scheme With Error Correction

In block coding approach, the PAPR of the OFDM symbol can be reduced by selecting only those code words with small PAPR. The main idea of the scheme proposed in this paper is that well designed block codes can not only reduce the PAPR, but also provide error correction capability. In the transmitter of the system, a k bit data block (e.g. say 4-bit data) is encoded by a (n, k) block code with a generator matrix G, followed by the phase rotator vector b to yield the encoded output x = a. G + b (mod 2)

To obtain the proper generator matrix and phase rotator vector that ensure the minimum PAPR for the OFDM system, check all the 2_n codes and select only 2_kcodes that achieve the minimum PAPR. Then the generator matrix G and the phase rotator vector b g are generated which are utilized to provide mapping between these symbol combination and the input data vector a. In the receiver system, the converse functions of the transmitter are performed. The parity check matrix H is obtained from the generator matrix G, with an exception that the effect of the phase rotator vector b is eliminated before calculations of syndromes. This method provides error correction capability and can improve the overall system performance.

4.4 Selected Mapping (SLM)

In Conventional SLM (C-SLM) method, OFDM signal is first converted from serial to parallel by means of serial-to-parallel converter. The parallel OFDM signal is then multiplied by several phase sequences that are created offline and stored in a matrix. A copy of the OFDM signal is multiplied with a random vector of phase sequence matrix. For each sub block IFFT is performed and its PAPR is calculated to look for the minimum one. The OFDM signal having minimum PAPR is then selected and be transmitted. The main drawbacks of this technique are the high complexity due to the high number of sub blocks and the need to send side information which result in data rate and transmission efficiency degradation, respectively. In Fig. 1, the number of candidate signal or sub blocks is given by *U*, hence *log2U* number of bits is required to be sent as side information. The other drawback of this method is that by increasing *U*, higher number of IFFT blocks are required which increase the complexity significantly. Hence, a method with low complexity and high PAPR performance is required.

4.5 Partial Transmit Sequence (PTS)

The main idea behind the scheme, is that, the data block is partitioned into non-overlapping sub blocks and each sub block is rotated with a statistically independent rotation factor. The rotation factor, which generates the time domain data with the lowest peak amplitude, is also transmitted to the receiver as side information. PTS is also probabilistic scheme of reducing PAPR. PTS scheme can be interpreted as a structurally modified case of SLM scheme and, it is found that the PTS schemes performs better than SLM schemes. When differential modulation is used in each sub block, no side information needs to be transmitted to the receiver.

4.6 Standard Arrays Of Linear Block Codes:

In this scheme, a signal with minimum PAPR from U distinct signals is chosen as the transmit signal, where U distinct signals are constructed by scrambling a code word with the properly selected co-set leaders. Because the co-set leaders are used only for scrambling, no side information is required to be transmitted and the received signals can be easily decoded by syndrome decoding. The key idea is to use the standard array of block codes for reduction of the PAPR in OFDM system, not for error correction. This is possible by choosing a vector that yields low (possibly minimum) PAPR in each co-set as its co-set leader, instead of a minimum weight vector. This scheme is a modified version of SLM, in which the transmit signal is selected as a signal with minimum PAPR from differently scrambled signal of the information by a number of random sequences. It is found that the proposed scheme has slightly better performance in PAPR reduction than the SLM method. The most important aspect of the scheme is that it achieves better performance than SLM without transmitting any side information.

4.7 Interleaving

This scheme proposes a data randomization technique for the reduction of the PAPR of the OFDM system. The scheme also proposes an adaptive technique to reduce the complexity of the scheme. The key idea in adaptive interleaving is to establish an early terminating threshold i.e. the search is terminated as soon as the PAPR value reaches below the threshold, rather than searching all the interleaved sequences. The low threshold will force the adaptive interleaving (AIL) to search for all the interleaved sequences, whereas for the large threshold value, AIL will search only a fraction of the interleaved sequences. The most important aspect of this method is that it is less complex than the PTS method but achieves comparable results. The scheme does not provide the guaranteed PAPR reduction and for the worst case PAPR value of N. Therefore, higher order error correction method should be used in addition to this scheme.

4.8 Hadamard Transform

The scheme focuses on the relationship between correlation properties of OFDM input sequence and PAPR probability. The proposed Hadamard transform based scheme reduces the occurrence of the high peaks comparing the original OFDM system. It is found that the PAPR can be reduced to about 2dB in 16 QAM OFDM system without any power increaseand side information and little increase in system complexity. The idea to use the Hadamard transform is to reduce the autocorrelation of the input sequence to reduce the peak to average power problem and it requires no side information to be transmitted to the receiver.

4.9 Dummy Sequence Insertion

In this method, dummy sequence is added into the input data for the PAPR reduction before IFFT stage. Complementary sequence, correlation sequence, and other specific sequence may be used as the dummy sequence that does not work as the side information unlike the PTS and SLM methods. So there is no BER degradation due to side information error. PAPR threshold technique is combined into this DSI method. If the PAPR of IFFT output is lower than a certain prescribed PAPR threshold level, the IFFT output data is transmitted. Otherwise, dummy sequence is inserted to lower the PAPR. The block code based schemes for PAPR reduction suffers from the overhead of large side information to be transmitted to the receiver. In the proposed scheme dummy variables are inserted in the transmitted data for the reduction of PAPR of the OFDM signal. The receiver can simply discard the dummy data sequence, as it is does not contain any information. BER performance of the DSI scheme is independent of the error in the dummy data sequence. The DSI method demonstrates improved BER performance as compared to the conventional PTS and has higher transmission efficiency for PAPR reduction than the conventional block coding. DSI method using complimentary sequence is better than the other methods.

4.10 Tone Reservation

In this method, the basic idea is to reserve a small set of tones for PAPR reduction. The problem of computing the values for these reserved tones that minimize the PAPR can be formulated as a convex problem and can be solved exactly. The amount of PAPR reduction depends on the numbers of reserved tones, their location with in the frequency vector, and the amount of complexity. This method describes an additive method for reducing PAPR in multi-carrier transmission, and shows that reserving a small fraction of tones leads to large reductions in PAPR ever with simple algorithm at the transmitter, and with no additional complexity at the receiver. When the number of tones N is small, the set of tones reserved for PAPR reduction may represent a non-negligible fraction of the available bandwidth and can result in a reduction in data rate. TR method has the advantages of being less complex, no special receiver operation, and no need for side information. Tone reservation is based on adding a data block dependent time signal to the original multicarrier signal to reduce its peaks. This time domain signal can be easily computed at the transmitter and stripped off at the receiver.

4.11 Tone Injection

This is an additive method, which achieves PAPR Reduction of multicarrier signals with no data rate loss. The basic idea is to increase the constellation size so that each of the points in the original basic constellation can be mapped into several equivalent points in the expanded constellation, Since each information unit can be mapped into one of several equivalent constellation points, these extra degrees of freedom can be exploited for PAPR reduction. The method is called Tone Injection, as substituting the points in the basic constellation for the new points in the larger constellation is equivalent to injecting a tone of the appropriate phase and frequency in the multi-carrier symbol.

4.12 Active Constellation

In the active constellation extension technique, some of the outer signal constellation points in the data block are dynamically extended towards the outer side of the original constellation such that the PAPR of the data block is reduced. The main idea of this scheme is easily explained in the case of a multicarrier signal with QPSK modulation in each sub-carrier. In each sub-carrier there are four possible constellation points that lie in each quadrant in the complex plane and are equidistant from the real and imaginary axes. Assuming white Gaussian noise, the maximum likelihood decision region are the four quadrants bounded by the axes, thus, a received data symbol is absorbed. Any point that is farther from the decision boundaries than the normal constellation point (Proper quadrant) will offer increased margin which guarantees a lower BER. The Active Constellation Extension (ACE) idea can be applied to other constellation as well such as QAM and MPSK constellation, because the data points that lie on the outer boundaries of the constellation have room for increased margin without degrading the error probability for other data symbols. This scheme simultaneously decreases the BER slightly while substantially reducing the peak magnitude of the data block. Further more there is no loss in data rate and no side information is required. However these modification may increase the transmit signal power for the data block and usefulness of the scheme is restricted to a modulation with a large constellation side.

V SIGNAL DISTORTION TECHNIQUES

5.1 Clipping & Filtering

In this approach, the amplitude peaks are corrected (or signal is modified) in such a way that a given amplitude threshold of the signal is not exceeded after the correction. The OFDM signal is corrected by adding it with a corrective function k(t). This correction limits the signal s(t) to A0 at positions of tn of amplitude peaks. This method produces no out-of-band interference and causes interference of the OFDM signal with minimal power. If the OFDM signal is not oversampled, then the correction scheme is identical with clipping and each correction of an amplitude peak causes interference on each sub carrier and the power of the correcting function is distributed evenly to all sub carriers. To apply this correcting scheme, the signal s(t) is oversampled by a factor of four and normalized so that the signal power is one. Then the signal is corrected with k(t). For the correction the amplitude threshold A0 is set according to the input bakeoff. After the correction, the signal is limited to the amplitude A0 in order to take into account the limitation of amplitude peaks which may have remained. The signal can be corrected by multiplicative Gaussian function or additive sinc function. The interesting part of the scheme is that it can be used for any number of subcarriers and it does not need any redundancy. The PAPR is reduced at the cost of small increase in the total in band distortion.

5.2 Peak Windowing

Clipping is one example of a PAPR reduction technique creating self interference. Peak Windowing technique provides better PAPR reduction with better spectral properties than clipping. Peak windowing can achieve PAPR around 4dB for an arbitrary subcarriers, at the cost of slight increase in BER and out-of-band (OOB) interference. In windowing technique a large signal peak is multiplied with a certain window, such as Gaussian shaped window, cosine, Kaiser and Hamming window. Since the OFDM signal is multiplied with several of these windows, the resulting spectrum is a convolution of the original OFDM spectrum with the spectrum of the applied window. Ideally the window should be as narrow band as possible, on the other hand the window should not be too long in the time domain because that implies that many signal samples are affected increasing the BER. With windowing method, PAPR can be reduced down to about 4dB, independent of the number of sub carriers. The loss of SNR caused by the signal distortion is limited to about 0.3dB. A back off relative to maximum output power of about 5.5dB is required in order to keep undesired spectra distortion at least 30dB below the in-band spectral density.

5.3 Envelope Scaling

The main idea behind the scheme is that the envelopes of all the subcarriers input, with PSK modulation, are equal. The envelope of the input in some subcarriers can be scaled to obtain the minimum PAPR at the output of IFFT. The final input that gives the lowest PAPR will be sent to the system. The input sequences has the same phase information as the original one but the envelopes are different. So the receiver can decode the received sequence without any side information. The main idea behind the scheme is that the envelope of the input in some subcarriers is scaled to obtain the minimum PAPR at the output of the IFFT. The scheme seems only suitable to PSK schemes, where all the envelope of all subcarriers input are equal. When the OFDM system implements the QAM modulation scheme, the carrier envelope scaling will result in the serious BER degradation. To limit the BER degradation, amount of the side information would also be excessive when the number of subcarriers is large.

5.4 Random Phase Updating

In the random phase updating algorithm, a random phases generated and assigned for each carrier. The random phase update is continued till the peak value of the OFDM signal is below the threshold. The threshold can be dynamic and the number of iterations for the random phase update is limited. After each phase update, the PAPR is calculated and the iteration is continued till the minimum threshold level is achieved or the maximum number of iterations has been reached. The random phase increments distribution can be\ considered uniform or Gaussian. The phase shifts have to be known at the transmitter and the receiver. In this scheme, the BER performance won't degrade only if the receiver knows all the phase changes. This implies a large amount of side information. The efficiency of the algorithm is mainly related to the selected threshold level and\ consequently number of iterations and not the number of carriers. The algorithm can be improved using the quantization and grouping of phases, and with dynamic threshold.

5.5 Peak Reduction Carrier

The scheme proposes the use of the data bearing peak reduction carriers (PRCs) to reduce the effective PAPR in the OFDM system. The technique involves the use of a higher order modulation scheme to represent a lower order modulation symbol. This allows the amplitude and phase of the PRCs to lie within the constellation region representing the data symbol to be transmitted. For example, to use a PRC that employs a 16 PSK constellation to carry QPSK data symbol, the 16 phases of the 16 PSK constellations are divided into four regions to represent the four different values of the QPSK symbol. This technique uses the higher order modulation schemes for representing lower order modulation scheme data. This will incur the penalty of an increased probability of error, thus worsening the overall BER performance. So there exists a tradeoff between PAPR reduction and BER performance when selecting the constellation of the PRCs.

5.6 Companding

The paper, by Wang et.al, proposes a simple and effective companding technique to reduce the PAPR of OFDM signal. The OFDM signal can be assumed Gaussian distributed, and the large OFDM signal occurs infrequently. So the companding technique can be used to improve OFDM transmission performance. _-law companding technique is used to compand the OFDM signal before it is converted into analog waveform. The OFDM signal, after taking IFFT, is companded and quantized. After D/A conversion, the signal is transmitted through the channel. At the receiver end then the received signal is first converted into digital form and expanded. Companding is highly used in speech processing where high peaks occur infrequently. OFDM signal also exhibit similar characteristic where high peaks occur infrequently. Companding technique improves the quantization resolution of small signals at the price of the reduction of the resolution of large signals, since small signals occur more frequently than large ones. Due to companding, the quantization error for large signals is significantly large which degrades the BER performance of the system. So the companding technique improves the PAPR in expense of BER performance of the system.

IV OVERALL COMPARISON OF ALL THE TECHNIQUES

Here we will compare all the scheme to get a conclusion which one best among all .

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

V CONCLUSION

Orthogonal frequency division multiplexing is a form of multi carrier modulation technique with high spectral efficiency, robustness to channel fading, immunity to impulse interference, uniform average spectral density apacity of handling very strong echoes and less non linear distortion. It is recently being used for both wireless and wired high rate digital data communications. Despite of its many advantages, OFDM has two main drawbacks Viz: high peak to average power ratio (PAPR) and frequency offset. High PAPR causes saturation in power amplifiers, leading to inter modulation products among the sub carriers and disturbing out of band energy. Therefore, it is desirable to reduce the PAPR. Several techniques have been proposed such as clipping, windowing, coding, pulse shaping, tone reservation, tone injection, companding etc. But most of these techniques are unable to achieve simultaneously a large reduction in PAPR with low complexity, with low coding overhead, without performance degradation and without Transmitter and Receiver symbol handshake. Basic requirement of practical PAPR reduction techniques include the compatibility with the family of existing modulation schemes, high spectral efficiency and low complexity. There are many factors to be considered before a specific PAPR reduction technique is chosen. These factors include PAPR reduction capacity, Power increase in transmit signal, BER increase at the receiver, loss in data rate, computational complexity increase and so on. No specific PAPR reduction technique is the best solution for all multi carrier transmission. Rather the PAPR reduction technique should be carefully chosen according to various system requirements.

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