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PAPR Reduction of OFDM Signals Using SLM

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Abstract :

It is well known that the orthogonal frequency division multiplexing (OFDM) is a promising technique for getting high data rate in multi path fading environment. Hence the advance technologies like LTE and WIMAX use this as its physical layer. The well-known disadvantage of OFDM is its high peak to average power ratio (PAPR). The PAPR reduction using Selected mapping (SLM) technique is being analyzed here. With this PAPR reduction technique it requires to send extra Side Information (SI) index along with the transmitted OFDM signal and error in detecting these extra bits at the receiver leads to data rate loss. Without sending this SI index the detection of this thing will also be possible following the sub-optimal algorithm at receiver. This paper analyses the PAPR reduction performance using complimentary cumulative distribution function (CCDF) plot and the probability of SI detection error performance as per the criteria.

I. INTRODUCTION

The demand of high data rate services has been increasing very rapidly and there is no slowdown in sight. We know that the data transmission includes both wired and wireless medium. Often, these services require very reliable data transmission over very harsh environment. Most of these transmission systems experience much degradation such as large attenuation, noise, multipath, interference, time variance, nonlinearities and must meet the finite constraints like power limitation and cost factor. One physical layer technique that has gained a lot of popularities due to its robustness in dealing with these impairments is multi-carrier modulation technique. In multi-carrier modulation, the most commonly used technique is Orthogonal Frequency Division Multiplexing (OFDM); it has recently become very popular in wireless communication.

Unfortunately the major drawback of OFDM transmission is its large envelope fluctuation which is quantified as Peak to Average Power Ratio (PAPR). Since power amplifier is used at the transmitter, so as to operate it in a perfectly linear region the operating power must lie below the available power. For reduction of this PAPR lot of algorithms have been developed. All of the techniques have some sort of advantages and disadvantages. Clipping and Filtering is one of the basic technique in which some part of transmitted signal undergoes into distortion. Also the Coding scheme reduces the data rate which is undesirable. If we consider Tone Reservation (TR) technique it also allows the data rate loss with more probable of increasing power.

Again the techniques like Tone Injection (TI) and the Active Constellation Extension (ACE) having a criterion of increasing power will be undesirable in case of power constraint environment. If we go for the Partial Transmit Sequence (PTS) and Selected Mapping (SLM) technique, the PTS technique has more complexity than that of SLM technique. This Selected Mapping is one of the promising techniques due to its simplicity for implementation which introduces no distortion in the transmitted signal. It is known as the classical SLM technique. This technique has one of the disadvantage of sending the extra Side Information (SI) index along with the transmitted OFDM signa,which can be avoided using a special technique. The concentration of this thesis work is specially upon the Selected Mapping technique. Here the three important analysis of this technique has been done. Out of them one is, how to avoid the transmission of extra information along with the OFDM signal . Another one important analysis of this technique is how to reduce the computational complexity. Also one important analysis is to be done about the mutual independence between the alternative phase vectors used in this technique. One technique also being proposed which has an advantage of reducing the PAPR and simultaneously reducing the computational complexity in comparison to that of the Classical SLM. In addition to this the proposed technique also avoids the sending of extra SI index.

II. PEAK TO AVERAGE POWER RATIO

It is defined as the ratio between the maximum power and the average power for the envelope of a baseband complex signal $\tilde{x}(t)$ i.e.

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

Also we can write this PAPR equation for the complex passband signal $x(t)$ as

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

III. SLM TECHNIQUE

This is an effective and distortion less technique used for the PAPR reduction in OFDM. The name of this technique indicates that one sequence has to be selected out of a number of sequences. According to the concept of discrete time OFDM transmission we should make a data block considering N number of symbols from the constellation plot, where N is the number of subcarriers to be used. Then using that data block U number of independent candidate vectors are to be generated with the multiplication of independent phase vectors. Let us consider X is the data block with X(k) as the mapped sub symbol(i.e. the symbol from the constellation). Where k = {0, 1, 2, ...N − 1}. Let the u^{th} phase vector is denoted as $B^{(u)}$,where u = {1, 2, ...U}. The u^{th} candidate vector that is generated by the multiplication of data block with the phase vector is denoted as $X^{(u)}$. So we can write the equation to get the k^{th} element of u^{th} candidate vector as

$$X^{(u)}(k) = X(k)\, B^{(u)}(k)$$

Then by doing IFFT operation to each candidate vector we will obtain U number of alternative OFDM signals, so the nth symbol of u^{th} alternative OFDM signal can be written mathematically as

$$x^{(u)}(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X^{(u)}(k)\, e^{j\left(\frac{2\pi nk}{N}\right)}$$

So out of the U number of alternative OFDM signals the signal having minimum PAPR is to be selected for transmission. Let that selected OFDM signal is denoted as $x^{(\tilde{u})}(k)$. This selected mapping(SLM) technique is known as the classical SLM . The block diagram for this technique is shown in Fig1.

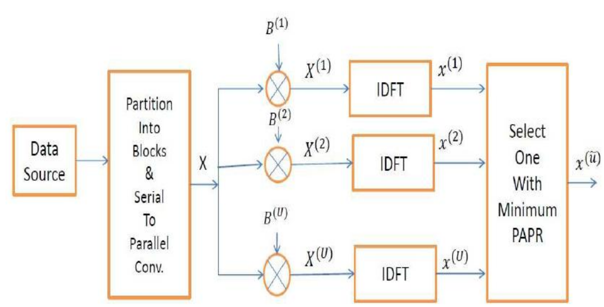

Fig1.BlockDiagram of SLM

So in this technique for generation of alternative OFDM symbols the independent phase vectors has to generate. We get from the equation 2.6, the k^{th} value of u^{th} phase vector is denoted as $B^{(u)}$ (k) and can be found by

$$B^{(u)}(k) = e^{j\emptyset^{(u)}(k)}$$

Where $\emptyset\ (k)$ is the random phase value. we get that $X^{(u)}(k)$ be a phase rotated version of X (k). we came to know that two phase vectors $B^{(m)}$ and $B^{(l)}$ is dependent if any joint cumulant between them is nonzero. So thecondition of mutual independence between $b^{(m)}(n)$ and $b^{(l)}(n)$ is given as

$$E\left[e^{j\emptyset}\right] = 0$$

To make satisfy the above condition $\emptyset$ should be uniformly distributed in [0, 2π). According to this selection criteria of $\emptyset$ the variation of the PAPR reduction performance will be shown in the next subsection. The Fig1. provides description about the transmitter side of the SLM technique. This selected OFDM signal at transmitter side has to be detected at the receiver. So the receiver must have the information about the perfect phase phase vector that has been multiplied to generate that selected OFDM signal. Hence to fulfill the requirement of the receiver some side information(SI) has to be transmitted along with the selected OFDM signal.This SI index is generally transmitted as a set of ⌈log2 U⌉ bits.

For the efficient transmission of these extra bits channel coding technique should be required. If any SI index cannot be detected perfectly then that total recovered transmitted block will be in error. So we should follow a new SLM technique which avoids the sending of SI index.

IV. MODIFIED SLM TECHNIQUE

The modification can be made with designing the phase sequence. According to the classical SLM technique $\left|B^{(u)}(k)\right| = 1$. With following the new SLM technique a modified scheme can be considered for the construction of phase sequences. In this modified phase sequence at some points out of $n \in \{0,1, \dots \dots \dots N-1\}$it is requied to put $B^{(u)}(k) = Ce^{j\emptyset^{(u)}(k)}$. Here C is the extension factor with satisfying the condition C>1. With following this concept of designing the phase sequence the perfect detection of SI index at the receiver becomes easy. This detection can be done using suboptimal algorithm. According to the concept of sub-optimal algorithm out of M number of phase sequences one sequence is being selected which satisfies the minimum energy difference between transmitted signal and received signal. This selected phase sequence should be the perfect sequence that gives the information about transmitted data block. There may be some probability of error with detecting the perfect phase sequence which is being analyzed here as the probability of SI index error with respect to different values of C. Also the analysis of bit error rate erformance being done for considering a fixed value of C.

V. SIMULATION RESULTS

In this paper we assume the transmission channel as a quasi-static frequency selective Rayleigh fading with equal power taps. We also assume the use of nonlinear solid state power amplifier (SSPA) at the transmitter output. The parameters are used are given as follows:

N= Used data subcarriers={70,360,720}

The modulation schemes to be used for the simulation work are QPSK. During the calculation of PAPR for the different data subcarriers we have to consider the over sampling factor. As the actual data transmission is in Analog form but we are analyzing here in digital form. So to get perfect PAPR the oversampling factor is to be considered.

A. PAPR USING CCDF

As discussed above the analysis of the performance of PAPR reduction is very easy through the CCDF. This performance using the classical SLM technique is shown in Fig2.

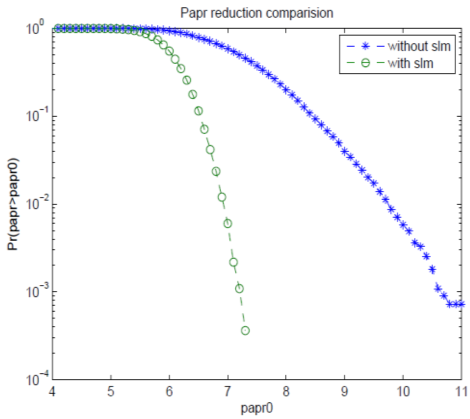

Fig2: PAPR comparison for classical slm

If we consider all the candidate vectors in a matrix form then without following the oversampling concept the dimension of that matrix will be U × N and with following the oversampling concept the dimension becomes U × V N. Here the number of subcarriers used to be N = 128 and the oversampling factor V = 4. So this figure 2.2 describes the performance criteria of the classical SLM technique on the basis of PAPR reduction performance.

B. PAPR Reduction Performance

Fig3 shows the complementary cumulative distribution function (CCDF) for the PAPR reduction obtained by using modified SLM technique for QPSK modulation. Here the value f extension factor is taken as C=1.2 and the used subcarriers as N={70,360,720}. The increased value of subcarriers leads to increase in the PAPR value. With increasing the valueof N the IFFT size increases which leads to more number of additions and multiplications and that leads to high PAPR.

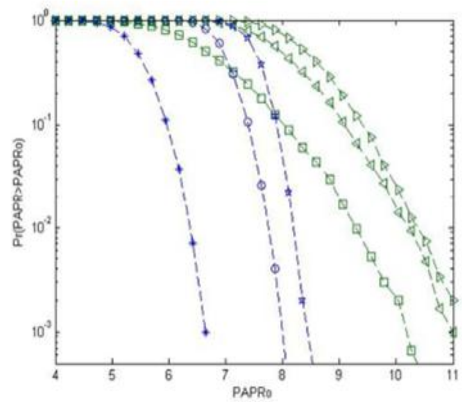

Fig3. CCDF for the PAPR obtained using modified SLM for different data subcarriers.

CONCLUSION

Our aim is to get high data rate simultaneously with a long range of communication. So by using the physical layer as OFDM we will get high data rate with reduced PAPR using new SLM technique. Our research work is performed by considering OFDM scheme based on QPSK modulation and this technique performs well for the large number of subcarriers. In fact the probability of SI detection error performs well with increasing the value of extension factor C and/or the number of subcarriers.

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