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Comparative study between Selection Mapping Technique (SLM) and Partial Transmission Sequence (PTS) for PAPR reduction in OFDM signals

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Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is a very attractive technique for high-data-rate transmission in wireless and wired applications. 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). Number of techniques has been proposed in the literature for reducing the PAPR in OFDM systems. In this paper two techniques proposed for reducing the PAPR are Selected Mapping (SLM) and Partial Transmit Sequence (PTS). The reduction of peak to average transmit power ratio of multicarrier modulation systems, called selected mapping, which is appropriate for a wide range of applications. Significant gains can be achieved by selected mapping where as complexity remains quite moderate. The partial transmit sequences (PTS) scheme achieves an excellent peak-to-average power ratio (PAPR) reduction performance of orthogonal frequency division multiplexing (OFDM) signals at the cost of exhaustively searching all possible rotation phase combinations, resulting in high computational complexity. The simulation results show that the performance of SML and PTS and compare between them.

Keywords: CCDF, DAB, DAV, FFT, IFFT I/Q, ISI, OFDM, PAPR, PTS, SLM.

I. INTRODUCTION

OFDM (Orthogonal Frequency Division Multiplexing) is a multicarrier modulation that is implemented in many recent wireless applications due to its ability to combat impulsive noise and multipath effects and make better use of the system available bandwidth. It has been adopted for the European Digital Audio Broadcasting (DAB) [1] and Digital Video Terrestrial Broadcasting (DVB) standards, it has been proposed for UMTS (Universal Mobile Telecommunication Systems) [2] and it has just been standardized for new wireless LAN generations (HIPERLAN: High Performance Radio LAN. OFDM offer high spectral efficiency, immune to the multipath delay, low inter-symbol interference (ISI), immunity to frequency selective fading and high power efficiency. Due to these merits OFDM is chosen as high data rate communication systems such as Digital Video Broadcasting (DVB) and based mobile worldwide interoperability for microwave access (mobile Wi-MAX)[3]. The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. These subcarriers are overlapped with each other. Because the symbol duration increases for lower rate parallel subcarriers, the relative amount of dispersion in time caused by multipath delay spread is decreased. Inter-symbol interference (ISI) is eliminated almost completely by introducing a guard time in every OFDM symbol[4].

The entire data stream of OFDM is divided into different blocks of N symbols each. Each block is multiplied with U different phase factors to generate U modified blocks before giving to IFFT block. Each modified block is given to different IFFT block to generate OFDM symbols. PAPR is calculated for each modified block and select the block which is having minimum PAPR ratio. This technique can reduce PAPR considerably. But this technique will increase circuit complexity since it contains several IFFT calculations. In SLM method, firstly M statistically independent sequences which represent the same information are generated and then the resulting M

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statistically independent data blocks $S_m = [S_{m,0}, S_{m,1} .. S_{m,N-1}]^T$, M= 1,2,.....M are then forwarded into IFFT operation simultaneously. Finally, at the receiving end, OFDM symbols $X_m = [x_1, x_2 ....x_N]^T$ in discrete time domain are acquired and then the PAPR of M vectors are calculated separately. Eventually, the sequences x_d with the smallest PAPR will be elected for final serial transmission [5]. In PTS technique, an input data block of N symbols is partitioned into disjoint sub blocks. The subcarriers in each sub block are multiplied by a phase factor .The phase factors are selected such that the PAPR of the sub blocks is minimized. Optimization techniques used to select the phase factors in order to achieve the above objective. Each of the sub blocks having the minimum PAPR and hence the combined signal of the different sub blocks is having the minimized PAPR[6].

In this paper we have investigate the performance of Selection Mapping Technique (SLM) and Partial Transmission Sequence (PTS) for PAPR reduction and compare between them.

II. OFDM SYSTEMS

OFDM is a multiplexing technique that subdivides the bandwidth into multiple frequency sub-carriers. In an OFDM system, the input data stream is divided into several parallel sub-streams of reduced data rate (thus increased symbol duration) and each sub-stream is modulated and transmitted on a separate orthogonal sub-carrier. The increased symbol duration improves the robustness of OFDM to delay spread. 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 [7]. This greatly simplifies the design of both the transmitter and the receiver. However OFDM requires very accurate frequency synchronization between the receiver and the transmitter; with frequency deviation the sub-carriers will no longer be orthogonal, causing *Inter-Carrier Interference* (ICI) [8].

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 multi-path) 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. By converting a single high frequency carrier to several sub-carriers, OFDM enhances the ability to cope with frequency selective fading effects and narrow bandwidth interference. The orthogonal property also greatly simplifies the design of both transmitter and receiver. A receiver can detect every sub-carrier data, which commonly is done via Fast Fourier Transform (FFT). Therefore a separate filter for each sub channel is not required. However, in practice, the sub-carriers are modulated in different amplitude and phase [9].

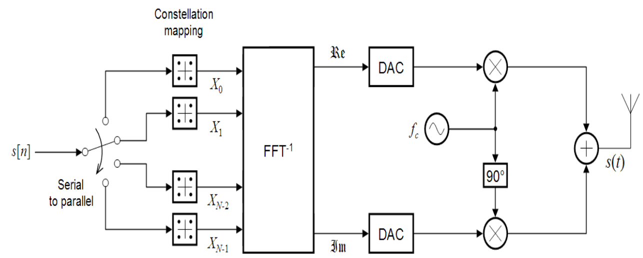

Figure 1: Block diagram of a OFDM system

An OFDM transmitter can be implemented by using inverse fast Fourier transform (IFFT) and the output of IFFT block is a time domain signal. The output of IFFT(OFDM signals) have an inherent difficulty that it may exhibit a very high peaks since it is generated by the addition of several independently modulated signal. The power of these large peaks will be very high compared to the average power of the signal. Hence peak to average power ratio is very high which is considered as the major disadvantage of the OFDM technique. These large peaks cause saturation in power amplifiers which is placed at the front end of the transmitter and leads to nonlinear distortions [6].

The OFDM system suffers from different drawbacks. Since the OFDM signal is a combination of several modulated sub carriers, the signal may have large peak power, which makes the Peak-to-Average Power Ratio (PAPR) also large. High PAPR results in reduction of efficiency of the Power Amplifier. The OFDM transmission exploits the strict orthogonality of each sub carrier, which makes OFDM sensitive to frequency offsets and phase noise. The basic modulation algorithms and other adaptive modulation techniques also increase the complexity of computations. In the modern OFDM transceiver, the RF electronic devices have several different impairments known as "dirty RF". The impairments that have major impacts on the system performance are: Nonlinear high power amplifier, Phase noise, PAPR Problem and In-phase and Quadrature (I/Q) imbalances [10-11].

III. PAPR OF OFDM SIGNAL

In OFDM systems, a fixed number of successive input data samples are modulated first (e.g. PSK or QAM), and then jointly correlated together using IFFT at the transmitter side. IFFT is used to produce orthogonal data subcarriers. Mathematically, IFFT combines all the input signals (superposition process) to produce each element (signal) of the output OFDM symbol [3]. The time domain complex baseband OFDM signal can be represented as

$$X_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\pi kn/N}, N=0,1,2,3,..,N-1 \quad (1)$$

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Where x_n is the *n*-th signal component in OFDM output symbol, X_k is the *k*-th data modulated symbol in OFDM frequency domain, and *N* is the number of subcarriers.
The PAPR (in dB) of the transmitted OFDM signal can be defined as [2]:

$$PAPR=\frac{\max[|x(t)|^2]}{E[|x|^2]}, \qquad 0\leq t\leq T \qquad (2)$$

Where $E[\cdot]$ is the expected value operator. The theoretical maximum of the PAPR for *N* number of subcarriers is as follows:

$$PAPR_{max}=10\log(N)dB \qquad (3)$$

PAPR is a random variable, because it is a function of the input data and the input data are random variable. Therefore PAPR can be calculated by using level crossing rate theorem that calculates the average number of times that the envelope of a signal crosses a given level. Knowing the amplitude distribution of the OFDM output signals, it is easy to compute the probability that the instantaneous amplitude will be above a given threshold and the same goes for power[12],[13]. This is performed by calculating the complementary cumulative distribution function (CCDF) for different PAPR values as follows:

$$CCDF=Pr(PAPR>PAPR_0) \qquad (4)$$

IV. PAPR REDUCTION TECHNIQUES

Researchers have been proposed several PAPR reduction techniques. These techniques are divided into two groups. There are signal scrambling techniques and signal distortion techniques. Block coding techniques selected mapping (SLM) [16], partial transmit sequence (PTS) [15] etc are signal scrambling techniques. Signal distortion techniques are peak windowing, envelope scaling, peak reduction carrier , clipping and filtering.

V. Selection Mapping Technique (SLM):

The SLM technique was first described by Bauml *et al.* [17]. In the SLM, the input data sequences are multiplied by each of the phase sequences to generate alternative input symbol sequences. Each of these alternative input data sequences is made the IFFT operation, and then the one with the lowest PAPR is selected for transmission [18].
The CCDF of the original signal sequence PAPR above threshold $PAPR_0$ is written as $Pr(PAPR>PAPR_0)$. Thus for K statistical independent signal waveforms, CCDF can be written as $[Pr(PAPR>PAPR_0)]^R$. So the probability of PAPR exceed the same threshold. The probability of PAPR larger than a threshold Z can be written as

$$P(PAPR<Z)=F(Z)^N=(1-\exp(Z))^N \qquad (5)$$

Assuming that M-OFDM symbols carry the same information and that they are statistically independent of each other. In this case, the probability of PAPR greater than Z is equals to the product of each independent probability. This process can be written as

$$P\{PAPR_{low}>Z\}=(P\{PAPR>Z\})^M=((1-\exp(-Z))^N)^M \qquad (6)$$

In selection mapping method, firstly M statistically independent sequences which represent the same information are generated, and next, the resulting M statistically independent data blocks $S_m=[S_{m,o},S_{m,1},\ldots.S_{m,N-1}]^T$ for m=1,2,...,M are then forwarded into IFFT operation simultaneously. $X_m=[x_1,x_2,\ldots.x_N]^T$ in discrete time-domain are acquired and then the PAPR of these M vectors are calculated separately. Eventually, the sequences x_d with the smallest PAPR is selected for final serial transmission. Fig-2 shows the basic block diagram of selection mapping technique for suppressing the high PAPR.

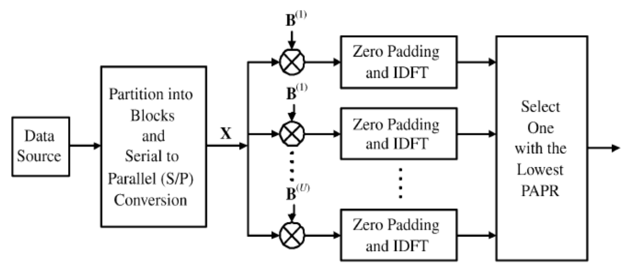

Figure 2. The Block Diagram of Selected Mapping Technique

VI. PARTIAL TRANSMITS SEQUENCE (PTS)

Partial Transmit Sequence (PTS) algorithm is a technique for improving the statistics of a multicarrier signal. The basic idea of partial transmit sequences algorithm is to divide the original OFDM sequence into several sub-sequences and for each sub-sequences multiplied by different weights until an optimum value is chosen.

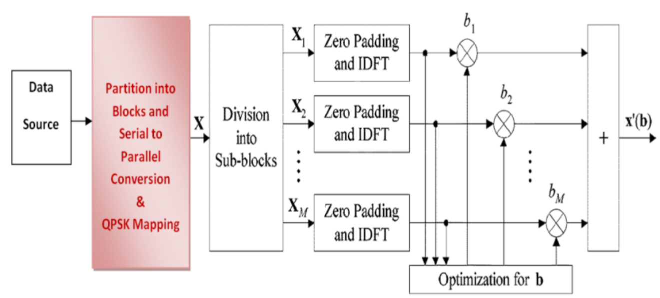

Figure 3: The Block diagram of PTS Technique

The Block diagram of conventional PTS is shown in Fig.3. The basic principles of practical partial transmit sequence (PTS) is as follows. First of all, we use vector data X to define the symbols. Second, divided this vector into M

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groups, denoted by { X_m, m=1, 2… M}. Then the M group summed up as follows [12-15]:

$$X(\acute{b}) = \sum_{m=1}^{M} b_m X_m \qquad (7)$$

Where, {b_m , m=1, 2… M} is the weighted coefficient, so that, $b_m = e^{j\varphi m}$, φ_m=[0,2π] which are considered auxiliary information. Then we adopt IDFT (Inverse Discrete Fourier Transform) to $X(\acute{b})$, so we obtain $X(\acute{b})$=IDFT{$X(\acute{b})$}. Referred to the IDFT instruction, we use of M separate IDFT given as follows:

$$X(\acute{b}) = \sum_{m=1}^{M} b_m .\mathrm{IDFT}\{X_M\} = \sum_{m=1}^{M} b_m X_m \qquad (8)$$

Choose appropriate weighted-coefficients {b_m=1,2… ,M} corresponding to minimum PAPR of sequence X (b) described as follows :

$$\{b_1, b_2, , b_m\} = \underset{\{b_1, b_2, \ldots, b_m\}}{argmin} \left(max_{1 \le n \le N} \left| \sum_{m=1}^{M} b_m . X_m \right|\right)^2 (9)$$

Where, argument (.) represents the sentence condition which makes the function to achieve the minimum value. Thus we use M-1 IDFT to search the optimized weight coefficients { b_m} and to achieve the purpose of reducing the PAPR value in OFDM system [19].

VII. SIMULATION AND RESULTS

The complementary cumulative distribution function (CCDF) of the PAPR is the most commonly used performance measures for PAPR reduction techniques. In SML, instead of applying reference data symbols for synchronization and channel estimation only, carefully selected codeword's can be transmitted on the pilot subcarriers caring additional information about the selected vector mask for PAPR minimization. Thus, no additional side information is needed to be sent to the receiver in order to recover OFDM data blocks.

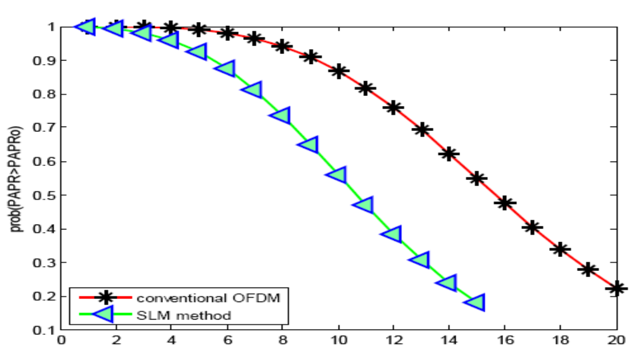

Figure 4: PAPR of the OFDM signal with and without SLM technique

Now discussed the simulation result for PTS technique, there are varying parameters which impact the PAPR reduction performance these are: The number of sub-blocks, which influences the complexity strongly, the number of possible phase value, which impacts the complexity and the sub-block partition schemes.

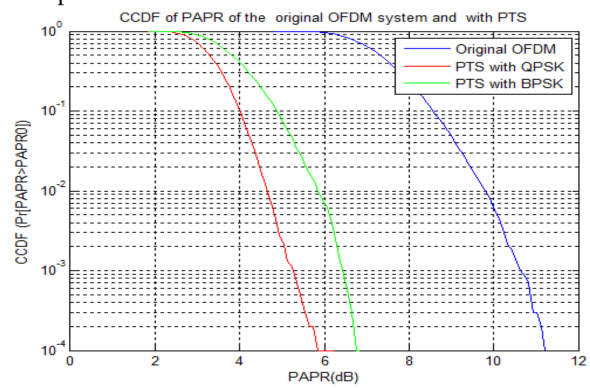

Figure 5. PAPR reduction of PTS Scheme with BPSK and QPSK modulation

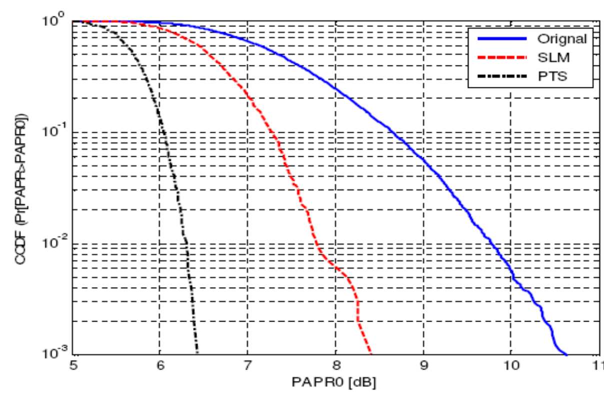

Figure 6: Performance compared for SLM and PTS methods.

CONCLUSIONS

OFDM has been seen as the core technique of the future communication systems because it has many advantages. On the other hand, the OFDM system suffers from different drawbacks. High PAPR results in reduction of efficiency of the Power Amplifier. In this paper proposed PAPR reduction techniques are Selection Mapping Technique (SLM) and Partial Transmission Sequence (PTS). Although SLM and PTS are important probabilistic schemes for PAPR reduction, SLM can produce independent multiple frequency domain OFDM signals, whereas the alternative OFDM signals generated by PTS are independent. PTS divides the frequency vector into some sub-blocks before applying the phase transformation. Therefore some of the complexity of several full IFFT operations can be avoided in PTS, so it is more advantageous than SLM if amount of computational complexity is limited. It is clear that PTS method is special case of SLM method. For PTS method, the number of rotation factors may be limited in certain range. The two typical signal scrambling techniques, SLM and PTS are

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investigated to reduce PAPR, all of which have the potential to provide substantial reduction in PAPR. PTS method performs better than SLM method in reducing PAPR.

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BIOGRAPHIES

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