A Review on Various Technique of PAPR Reduction for OFDM Communication System

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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). This paper provides a review of various technique of PAPR reduction for OFDM communication system.

Keywords - OFDM(orthogonal frequency division multiplexing), PAPR(peak to average power ratio), SLM(selected mapping), PTS(partial transmit sequence), CCDF(complementary cumulative distribution function).

1. INTRODUCTION

The reduction of peak to average transmit power ratio of multicarrier modulation systems, called selected mapping[1], 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.

2. LITRETURE REVIEW

[1]In 2001,Selected mapping (SLM) peak-power reduction is distortion less as it selects the actual transmit signal from a set of alternative signals, which all represent the same information. The specific signal generation information needs to be transmitted and carefully protected against bit errors. Here, we propose an extension of SLM, which employs scrambling and refrains from the use of explicit side information in the receiver. Some additional complexity and nearly vanishing redundancy is introduced to achieve markedly improved transmit signal statistics. Even though SLM is applicable with any modulation, we concentrate on orthogonal frequency-division multiplexing (OFDM) in this letter.

[2] In 2014, This paper investigates the use of a pilot signal in reducing the electrical peak-to-average power ratio (PAPR) of an orthogonal frequency division multiplexing (OFDM) intensity modulated optical wireless communication system. The phase of the pilot signal is chosen based on the selected mapping (SLM) algorithm while themaximum likelihood criterion is used to estimate the pilot signal at the receiver. Bit error rate (BER) performance of the pilot-assisted optical OFDM system is identical to that of the basic optical OFDM (with no pilot and no PAPR reduction technique implemented) at the desired BER of less than 10^{-3} needed to establish a reliable communication link. The pilot-assisted PAPR reduction technique results in higher reduction in PAPR for high order ($M > 4$) constellations than the classical SLM. With respect to a basic OFDM system, with no pilot and no PAPR reduction technique implemented, a pilot-assisted M-QAM optical OFDM system is capable of reducing the electrical PAPR by over about 2.5 dB at a modest complementary cumulative distribution function (CCDF) point of 10^{-4} for$M = 64$. Greater reductions in PAPR are possible at lower values of CCDF with no degradation to the system's error performance. Clipping the time domain signal at both ends mildly (at 25 times the signal variance level) results in a PAPR reduction of about 6.3 dB at the same CCDF of 10^{-4} but with an error floor of about 3×10^{-5} . Although it is possible to attain any desired level of electrical PAPR reduction with signal clipping, this will be at a cost of deterioration in the systems's bit error performance.

[3]In 2002,Orthogonal frequency division multiplexing (OFDM) is sensitive to the carrier frequency offset (CFO).We introduce the peak interference-to-carrier ratio

(PICR) to measure the resulting intercarrier interference (ICI). This paper shows that PICR can be reduced by selected mapping (SLM) and partial transmit sequence (PTS) approaches. These schemes are analyzed theoretically and their performances are evaluated by simulation.

[4]In 2005,Selected mapping (SLM) and partial transmit sequence (PTS) are well-known techniques for peak-power reduction in orthogonal frequency-division multiplexing (OFDM). We derive a simplified maximum likelihood (ML) decoder for SLM and PTS that operates without side information. This decoder exploits the fact that the modulation symbols belong to a given constellation and that the multiple signals generated by the PTS or SLM processes are widely different in a Hamming distance sense. Pair wise error probability (PEP) analysis suggests how SLM and PTS vectors should be chosen. The decoder performs well over additive white Gaussian noise (AWGN) channels, fading channels, and amplifier nonlinearities.

[5]In 2006,Orthogonal Frequency Division Multiplexing (OFDM) is a spectrally efficient multicarrier modulation technique for high speed data transmission over multipath fading channels. However, the price paid for the high spectral efficiency is low power efficiency. OFDM signals suffer from high peak-to-average power ratios (PARs) which lead to power inefficiency in the RF portion of the transmitter. Selected mapping (SLM) is a promising technique to reduce the PAR of an OFDM signal and is distortion less. In this paper, we propose a novel technique which links the index of the phase rotation sequence in SLM to the location of the pilot tones that are used to estimate the channel. Each pilot tone location - phase sequence selection can lead to a different PAR value for the time-domain OFDM signal, and the signal with the lowest PAR value is transmitted. Our proposed method is “blind” in the sense that the optimum pilot tone location - phase sequence index is not transmitted as side information. We describe a novel technique to blindly detect the optimum index at the receiver. PAR reduction performance as well as BER performance of the proposed method in frequency selective fading channels are investigated.

[6]In 2006,One of the major drawbacks of orthogonal frequency division multiplexing (OFDM) is the high peak-to-average power ratio (PAPR) of the transmitted OFDM signal. Partial transmit sequence (PTS) technique can improve the PAPR statistics of an OFDM signal. However optimum PTS (OPTS) technique requires an exhaustive search over all combinations of allowed phase factors, the search complexity increases exponentially with the number of sub-blocks. By combining sub-optimal PTS with a preset threshold, a novel reduced complexity PTS (RC-PTS) technique is presented to decrease the computational complexity. Numerical results show that the proposed approach can achieve better performance with lower computational complexity when compared to that of other PTS approaches.

[7]In 2008, One of the challenging issues for Orthogonal Frequency Division Multiplexing (OFDM) system is its high Peak-to-Average Power Ratio (PAPR). In this paper, we review and analysis different OFDM PAPR reduction techniques, based on computational complexity, bandwidth expansion, spectral spillage and performance. We also discuss some methods of PAPR reduction for multiuser OFDM broadband communication systems.

[8]In 2009,Selected mapping (SLM) is a technique used to reduce the peak-to-average power ratio (PAPR) in orthogonal frequency-division multiplexing (OFDM) systems. SLM requires the transmission of several side information bits for each data block, which results in some data rate loss. These bits must generally be channel-encoded because they are particularly critical to the error performance of the system. This increases the system complexity and transmission delay, and decreases the data rate even further. In this paper, we propose a novel SLM method for which no side information needs to be sent. By considering the example of several OFDM systems using either QPSK or 16-QAM modulation, we show that the proposed method performs very well both in terms of PAPR reduction and bit error rate at the receiver output provided that the number of subcarriers is large enough.

[9]In 2009,This letter considers the use of the partial transmit sequence (PTS) technique to reduce the peak-to-average power ratio (PAPR) of an orthogonal frequency division multiplexing (OFDM) signal. The conventional PTS technique can provide good PAPR reduction performance for OFDM signals; however, it requires an exhaustive search over all combinations of allowed phase factors, resulting in high complexity. In order to reduce the complexity while still improving the PAPR statistics of an OFDM signal, a new method using the Cross-Entropy (CE) method is proposed to reduce both the PAPR and the computational load. In the proposed CE method, we first define a score or fitness function based on the corresponding PAPR reduction performance. The score function is then translated into a stochastic approximation problem which can be solved effectively. The simulation results show that the performance

of the proposed CE method provides almost the same PAPR reduction as that of the conventional exhaustive search algorithm while maintaining low complexity.

[10]In 2013, 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.

[11]In 2013,The main drawback of OFDM system is the high Peak to Average Power Ratio (PAPR) of the transmitted signals. Partial transmit sequence scheme is a promising algorithm to reduce the peak-to-average power ratio (PAPR) in orthogonal frequency division multiplexing (OFDM). The Partial Transmit Sequence (PTS) consist of several inverse fast Fourier transform (IFFT) operations and complicated calculations to obtain optimum phase sequence which results in increasing the computational complexity of PTS. A phase sequence applied to the PTS Scheme reduces its complexity but at the expense of slight degradation in PAPR reduction. In this paper, for further reduction of PAPR the peak clipping of the OFDM signal is introduced along with the PTS with new phase sequence scheme. Since clipping is one of the simplest techniques of PAPR reduction, it does not increase the complexity of the system much and a better PAPR reduction is obtained with the combined effect of clipping and PTS with New Phase Sequence. But the clipping technique introduce some distortion in the signal, however peak clipping of signal below a particular threshold can maintain the BER in the tolerable range. The clipping threshold selected will be different for different OFDM systems.

[12]In 2013,OFDM systems have the inherent problem of a high peak to average power ratio (PAPR). OFDM Suffers as the no of Subcarriers operating in the large dynamic range operates in the non-linear region of amplifier due to OFDM suffer the PAPR problem Application of high power amplifiers results in increased component cost. In general, there has been a trade-off between PAPR reduction and computational complexity in partial transmits sequence (PTS) OFDM. The complexity reduction of PTS PAPR reduction scheme in OFDM systems by reducing the complexity of the IFFT architecture is investigated in this paper. In the IFFT architecture of PTS OFDM scheme, there are a lot of additions and multiplications with zero, which are obviously unnecessary. We can efficiently reduce the computational complexity without changing the resulting signal or degrading the performance of PAPR reduction by eliminating the additions and multiplications with zero from the architecture. In this paper PTS SUB-BLOCKS PAPR reduction techniques have been proposed and analyzed.

[13]In 2014,Orthogonal frequency division multiplexing (OFDM) is a type of multicarrier modulation technique in which entire bandwidth is divided into large number of small sub-carriers and each subcarrier is transmitted parallel to achieve higher data rates. It is used in various applications like Digital audio broadcasting (DAB), Digital video broadcasting (DVB) & wireless LAN. OFDM is a attractive modulation scheme with strongly efficient in bandwidth usage, immunity against multipath fading environment. It has less ICI and ISI and provides better spectral efficiency. Although it has various advantages but still certain disadvantages are: high Peak to average Power ratio, high bit error ratio (BER) & synchronization problem. This paper will focus on various PAPR reduction techniques and conclude with comparison between various techniques.

[14]In 2014,A power amplifier (PA) for a femto-cell base station should be highly efficient and small. The efficiency for amplification of a high peak-to-average power ratio (PAPR) signal is improved by designing an asymmetric Doherty power amplifier(DPA). From the simulation result for a long-term evolution (LTE) signal with 7.2-dB PAPR, the DPA delivers the highest efficiency with 1:1.4 cell size ratio for the carrier and peaking PAs. A small size is achieved by designing the DPA using a GaN monolithic microwave integrated circuit process. For broadband operation, we employ a new circuit topology to alleviate the

bandwidth limiting factors of the DPA such as a quarter-wavelength transformer, phase compensation network, and offset line. With the design concept, an asymmetric broadband DPA is implemented using a TriQuint 3MI 0.25-m GaN-HEMT MMIC process. Across 2.1–2.7 GHz, the implemented PA deliver a drain efficiency of over 49%, a gain of over 12.6 dB, and adjacent channel leakage ratio of below 45 dBc at an average power of over 33.1 dBm for the LTE signal. This fully integrated circuit has a chip-size of 2.65 mm× 1.9 mm.

3. PAPR PROBLEM IN OFDM

PAPR stands for Peak to average power ratio. It is defined as the formula of "ratio of Peak to average power’’[8].

$$PAPR_{dB} = 10 \log \left(\frac{\max[x(t)x*(t)]}{[x(t)x*(t)]} \right)$$

Where ()* corresponds to the conjugate operator.
PAPR is a measure of a Multicarrier signal. As OFDM signal consists of a number of independently modulated symbols. The sum of independently ratio (PAPR).

4. VARIOUS PEAK-TO-AVERAGE-POWER RATIO REDUCTION (PAPR) TECHNIQUES

The electrical PAPR of a single symbol OFDM signal oversampled L-times in the time domain[6].

$$PARR \triangleq \frac{\max_{0 \le n \le NL-1} |x(n)|^2}{E[|x(n)|^2]}$$

Where E [.] denotes the statistical expectation. Any reductions in PAPR are normally illustrated using a PAPR complementary cumulative distribution function (CCDF). The CCDF of the PAPR is defined as the probability, and it is the most frequently used measure for describing PAPR reduction.

5. DISCRIBING PAPR REDUCTION TECHNIQUES

A. Pilot-Assisted OFDM Technique for PAPR Reduction

An OFDM frame is firstly defined as a cluster of U data carrying symbols and a pilot symbol show Fig 1. each of the (U + 1)-symbols in the OFDM frame comprises of N_{sub} active subcarriers. The data carrying symbols are represented as $X^u(k)$, u = 1, 2. . . U while the pilot symbol, with amplitude $A_p(k)$ and phase $\theta_p(k)$, is represented as [12]

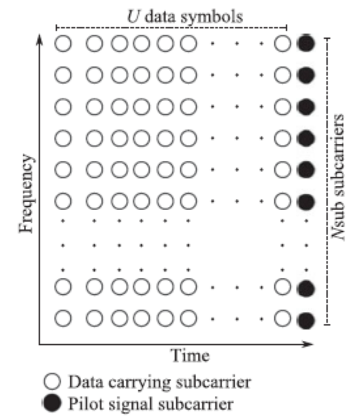

Fig.1. An illustration of the pilot-assisted OFDM signal frame.

$$X_p(k) = X^{U+1}(k) = A_p(k)e^{j\theta_p}(k)$$

where k = 0, 1, . . .,$N_{sub} - 1$.
The proposed pilot-assisted OFDM technique for PAPR reduction begins with modification of the OFDM signal as follows. For a given subcarrier k, the phase of each data entry $X^u(k)$, u = 1, 2, . . . , U; k = 0, 1, . . .,$N_{sub} - 1$, is rotated by $\theta_p(k)$ while the amplitude is scaled by a factor $A_p(k)$. The resulting signal is denoted as $\tilde{x}^u(k)$. That is,

$$\tilde{x}^u(k) = x^u(k) \times A_p e^{j\theta p(k)}$$

In principle, $\theta_p(k)$ could take on any value between 0 and 2π. To make suitable for $\tilde{x}^u(k)$ intensity modulation of the optical source as highlighted, Hermitian symmetry is invoked on it to obtain $\tilde{x}^u_H$ This is then followed by an IFFT operation and the DAC to obtain the discrete and continous time domain signals $\tilde{x}(n)$ and $\tilde{x}(t)$ respectively.
The reduction in PAPR is achieved by choosing a pilot phase sequence $\theta_p(k)$ that avoids coherent addition of the subcarriers as much as possible. The process of achieving this is summarized as follows:
1) Generate R different iterations of the pilot sequence,

$$X^r_p, r = 1, 2, . . . ,R;$$

2) Each X^r_p comprises of a randomly generated phase sequence,

$$\theta_p(k), k = 0, 1, . . .,N_{sub} - 1;$$

3) evaluate the $PAPR^r$ value of each iteration of X^r_p;4) Choose the desired pilot as the sequence $X_p = X^{\tilde{r}}_p$ that gives the minimum PAPR of all the R different iterations. That is,

$$\tilde{r} = \arg\min_{1 \le r \le R} (PARR^r)$$

$$\tilde{r} = \operatorname{argmin}_{1 \le r \le R} \left[\frac{\max_{0 \le n \le (U+1)(NL-1)} |\tilde{x}^{r}(n)|^2}{E[|\tilde{x}^{r}(n)|^2]} \right]$$

In order to preserve the electrical power of the data signals, it is desirable to constrain the pilot signal amplitude A_p to unity. Moreover, to maintain the original constellation of the input symbol sequence and for case of pilot signal recovery, the phase angle in every pilot phase sequence is constrained to either 0 or π. This results in $X_p(k) \in \{\pm 1\}$, for $k = 0, 1, . . , N_{sub} - 1$.

Although the R pilot sequences here are generated randomly with a uniform distribution. Any other phase sequence sets that make the data symbols appear statistically independent as much as possible will suffice. The random phase sequence set however gives the most PAPR reduction.

With U = 1, the pilot phase sequence selection process just described is analogous to the classic SLM algorithm with the SI contained in the pilot. It should however be noted that, unlike the classical SLM, using a cluster of U >1 data carrying symbols guarantees significant PAPR reductions across a wide range of signal constellations and the receiver does not need to know the exact amount of phase-rotation on each subcarrier. Also the pilot sequence used for PAPR reduction could simultaneously be used for channel estimation. It should equally be mentioned that embedding a pilot symbol.

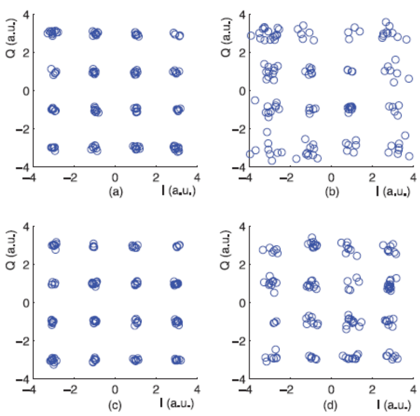

Fig.2. Constellation diagrams of 16-QAM optical OFDM with L = 4, U =5, and Nsub = 127 active subcarriers at an SNR of 22 dB. (a) Basic OFDM without PAPR reduction, (b) pilot assisted OFDM technique, symbol estimation based on, (c) pilot assisted OFDM technique with ML pilot symbol estimation based on and (d) clipped OFDM with $C_{cl} = C_{cu} = 40$.

B. Pilot Signal Estimation at the Receiver

The received signal, in the frequency domain, is given by

$$Y^{u}(K) = H(K) \times \widetilde{X^{u}}(k) + N(k);$$

u = 1, 2, . . . , U + 1

Where H(k) is the channel's frequency response for the kth subcarrier and *N*(k) is the corresponding additive white Gaussian noise with zero mean and variance σ^2 . A basic recovery of the transmitted data symbols could be performed by dividing every data element in $Y^u(k)$ by the received pilot signal $Y^{U+1}(k)$. This will result in an estimate $\hat{x}^u(k)$ of the transmitted data symbol as

$$\hat{X}^{u}(k) = \frac{Y^{u}(k)}{Y^{U+1}(k)}; \quad u = 1, 2, \ldots, U.$$

The received pilot signal $Y^{U+1}(k) = H(k)\tilde{A}_P(k)e^{j\tilde{\theta}_P}(k)$ where $\tilde{A}_p(k)$ and $\tilde{\theta}_p(k)$ are the noise corrupted pilot signal amplitude and phase, respectively. We will introduce data recovery errors due to the presence of noise on both the received pilot and data carrying symbols. An illustration of this effect on the received data constellation diagram is shown in Fig.2(b).at an electrical SNR of 22 dB. A similar diagram for the basic OFDM system with no PAPR reduction is shown in Fig.2(a). for comparison. The electrical SNR in this case is defined as

$$SNR = \frac{(KR\beta)^2 E[|\tilde{x}(n)|^2]}{\pi^2}$$

Where R is the PD's responsivity.

To improve on the data recovery, the pilot signal has to be correctly estimated in the presence of noise. To achieve this, we use the ML estimation technique. An estimate $\theta_p(k)$ of the pilot signal's phase is taken as the angle θ_i, i = 1, 2 (where $\theta_1 = 0$ and $\theta_2 = \pi$) that has the minimum Euclidean distance from $\tilde{\theta}_p(k)$. That is,

$$\widetilde{\theta_p}(k) = \arg\min_{1<i<2} [\tilde{\theta}p(k) - \theta_i)^2]$$

The estimated pilot signal then becomes $\hat{x}_P(k) = e^{j\theta p(k)}$. This ML criterion for estimating the pilot signal's phase is thus equivalent to the condition given as

$$\hat{X}_p(k) = \begin{cases} +1, & \text{if } \cos(\tilde{\theta}_p(k)) \ge 0 \\ -1, & \text{otherwise.} \end{cases}$$

An estimate of the transmitted data symbol is therefore obtained as

$$\hat{X}^{u}(k) = \frac{Y^{u}(k)}{\hat{X}_p(k)}; \quad u = 1, 2, \ldots, U.$$

In addition to maintaining the pilot signal amplitude as unity, the ML condition will correct for all pilot phase noise that falls within the range −π/2 to π/2. A sample received data constellation diagram that is based on is shown in Fig.2(c) at an SNR of 22 dB. When this figure is compared with Fig.2(b), the ML pilot estimation technique's significant improvement in data recovery becomes very obvious. Henceforth, the ML pilot signal estimation technique shall be assumed unless otherwise stated. Moreover, this decoder is quite simple requiring only 2Nsub | .|2 operations to solve the ML criterion.

C. PAPR Reduction by Clipping

Signal clipping as a means of PAPR reduction is the most commonly used and the simplest technique to implement optical OFDM system. The signal clipping takes place at the transmitter in the time domain prior to the DAC stage. The signal could be clipped at lower and/or upper levels. The lower and upper clipping levels, represented as £cl and £cu respectively, will be expressed in terms of the signal variance $\sigma^2_{x^u}$,where $x^u = IFFT(X^u{}_H)$; u = 1, 2, . . . , U

$$\epsilon_{cl} = -C_{cl}\,\sigma^2_{x^u}$$
$$\epsilon_{cl} = C_{cu}\,\sigma^2_{x^u} \qquad (13)$$

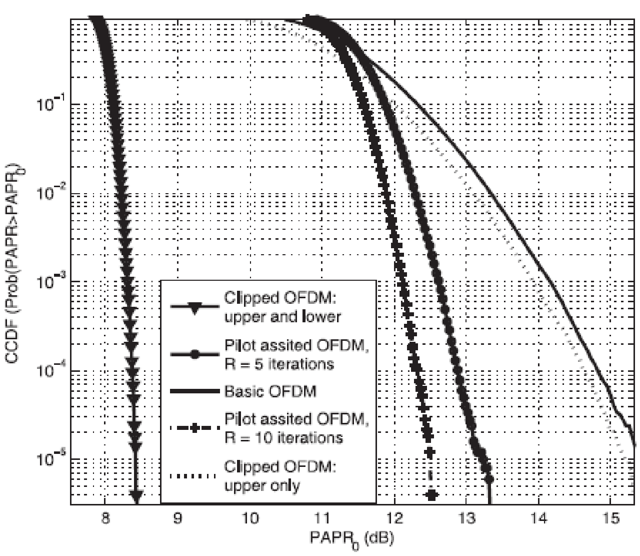

Fig.3. The PAPR CCDF plot for clipped and pilot assisted optical OFDM using 64-QAM, L= 4, U= 5 data carrying symbols and N_{sub}= 127 active subcarriers, $c_{cl} = c_{cu} = 25$

C_{cl} and C_{cu} are unit-less coefficients that determine the severity of the clipping at lower and upper levels respectively. The higher the values of C_{cl} and C_{cu} , the smaller the amount of clipping and vice versa. The clipping operation thus result in the following clipped-OFDM signal $x_c(n)$

$$x_c(n) = \begin{cases} x^u(n), & if\ \epsilon_{cl} \le x^n(n) \le \epsilon_{cu} \\ \epsilon_{cu}, & if\ x^u(n) > \epsilon_{cu} \\ \epsilon_{cl}, & if\ x^u(n) < \epsilon_{cl}\,. \end{cases}$$

The required dc bias for the clipped-OFDM now becomes x_{dc} = min $[x_c(n)]$. An illustration of the impact of a very mild signal clipping ($C_{cl} = C_{cu}$ = 40) on the received data constellation diagram is shown in Fig.2(d). Comparing this constellation diagram with that of the basic OFDM shown in Fig 2(a), clearly shows the effect of clipping induced signal distortion.

5. CONCLUSION

OFDM has been seen as the core technique of the future communication system 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 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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