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PAPR Reduction For Power Optimization In OFDM

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Abstract:
Optimizing the energy consumption of cellular networks is one of the booming challenges the industrialists and academics are facing. In the present energy crisis, it is high time to consider the reduction of energy consumption as it affects the operational and environmental expenditures. One of major problems in OFDM is high peak to average power ratio (PAPR), which makes system performance very sensitive to distortion introduced by nonlinear devices such as power amplifiers (PAs). The basic solution to this problem is to use a linear amplifier or to back-off the operating point into the linear region of the nonlinear HPA. However, power efficiency of HPA becomes very low so that this large back off is not desirable. Another method to avoid the nonlinear distortion is a linearization technique, which is good for the single carrier signal with just 3 dB PAPR. However, this linearization is not enough for the OFDM signal of multi-carrier system as large back-off is still required. There have been many studies on the PAPR reduction methods such as block coding method, clipping method, phase control method, partial transmit sequence (PTS) method and selective mapping (SLM) method. In PTS, the lowest PAPR signal is produced by optimally phase combining of the signal sub blocks.

Key words: *PAPR, PTS, OFDM*

1.PAPR Reduction

Orthogonal frequency division multiplexing (OFDM) is regarded widely as the key underlying air interface technology for wireless systems such as WI-MAX, 3GPP long-term evolution (LTE), and 3GPP2 ultra-mobile broadband (UMB). Due to the inherent nature of these technologies, OFDM signals have high peak-to-average power ratio (PAR) that adversely affects the efficiency of power amplifiers (PAs) used in wireless base stations.

A number of techniques have been proposed to reduce the PAPR of multicarrier modulation schemes. They are broadly categorized into two: deterministic and probabilistic techniques Deterministic methods limit the crest factor of the OFDM signals below a threshold level [2]. Clipping and block coding belong to this category. Probabilistic methods statistically improve the character of the crest factor distribution of the OFDM signals without signal distortion. Tone Reservation (TR), Selected mapping (SLM) and partial transmit sequence (PTS) are included in this category [4]. The various approaches are quite different from each other and impose different constraints.

Crest factor reduction (CFR) is one of the techniques for reducing the peak-to-average ratio (PAR) of an orthogonal frequency division multiplexing (OFDM) waveform. An OFDM signal is made up in the frequency domain as a set of orthogonal carriers that are each modulated by a constellation symbol. The main disadvantage of OFDM modulation is that the time domain representation approximates a Gaussian distribution and therefore exhibits large envelope variations. Power amplifiers usually only have a limited linear region, making it necessary to back off the amplifier so that the transmit signal has never driven the amplifier into the non-linear region, which causes spectral re-growth and inefficient amplifier power. By reducing the PAR of the input signal, you can achieve greater power efficiency from the amplifier or use a less expensive power amplifier with a more limited linear region.

2.PTS (Partial Transmit Sequence)

One of the classical and most popular techniques is known as partial transmit sequences (PTS). In PTS, non-overlapping subsets of OFDM subcarriers are formed, rotated independently, and combined again. Since the signal representations corresponding to different rotations exhibit different PARs, selecting the representation with the minimum PAR leads to PAR reduction. PTS is known to achieve a high performance and redundancy utilization, but implementation problems arise from (i) a relatively high computational complexity for searching the optimum sequence of rotation factors and (ii) the need to transmit side information (SI) about the selected sequence to the receiver to undo the rotation of OFDM subcarriers.

In PTS, data symbols in X are partitioned in to M disjoint sub blocks $X^{(i)}$, where $1 \leq i \leq M$, such that

$X = \sum X^{(i)}$; $1 \leq i \leq M$

Three partitioning strategies namely Adjacent, Interleaved and Random have been proposed. We apply the Random Partitioning strategy, which typically yields the best PAPR reduction performance.

The sub blocks $X^{(i)}$ are transformed in to M time-domain partial transmit sequences.

$x^{(i)} = IFFT(X^{(i)})$; $1 \leq i \leq M$

These sequences are independently rotated by some phase factors,

$b_i \approx \exp(j*\Phi_i)$; $1 \leq i \leq M$

These are then combined to produce the time-domain OFDM signal,

$x = \sum b_i * x^{(i)}$; $1 \leq i \leq M$

Assuming that Φ_i and thus b_i can attain W different values with $b_i = 0$, there are W^M alternative representations of an OFDM symbol. These representations correspond to all possible vectors

b= $[b_2....b_M]$

PTS selects a vector b_i such that the PAPR of the corresponding transmit sequence "x" is the lowest among all examined sequences. Figure 1 shows the block representation of the PTS algorithm which is been explained above.

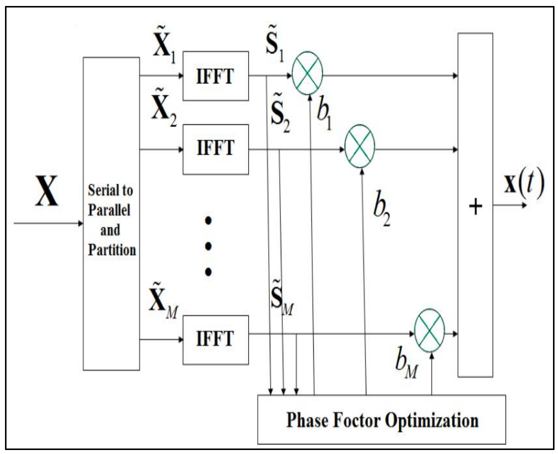

Figure 1: Partial Transmit Sequence (PTS) Algorithm

3.OFDM Generation

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 [8]. Each carrier to be produced is assigned some data to transmit. The required amplitude and phase of the carrier is then calculated based on the modulation scheme (typically differential BPSK, QPSK, or QAM). The required spectrum is then converted back to its time domain signal using an Inverse Fourier Transform. 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 carriers required for the OFDM signal can be easily generated by setting the amplitude and phase of each frequency bin, then performing the IFFT. Since each bin of an IFFT corresponds to the amplitude and phase of a set of orthogonal sinusoids, the reverse process guarantees that the carriers generated are orthogonal.

4.Simulation Results

In order to reduce the high PAPR, we perform PTS algorithm. Figure 2 shows the OFDM signal. Figures 3,4,5,6 shows the partitioning of signal, after serial to parallel conversion. Figure 7 shows the PAPR comparison of with and without PTS algorithm. The red colour corresponds to output of PTS, while blue colour is that of without PTS. Y-axis denotes the complementary cumulative distribution function while X-axis denotes the PAPR ratio. A CCDF shows how much time the signal spends at or above a given power level. The power level is expressed in dB relative to the average power. We can see that there has been a reduction of 5 dB in the PAPR, when the CCDF function is 10^{-2}.

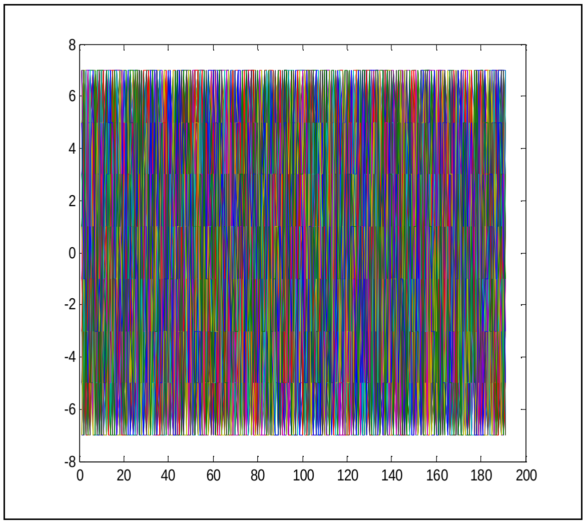

Figure 2: OFDM Signal

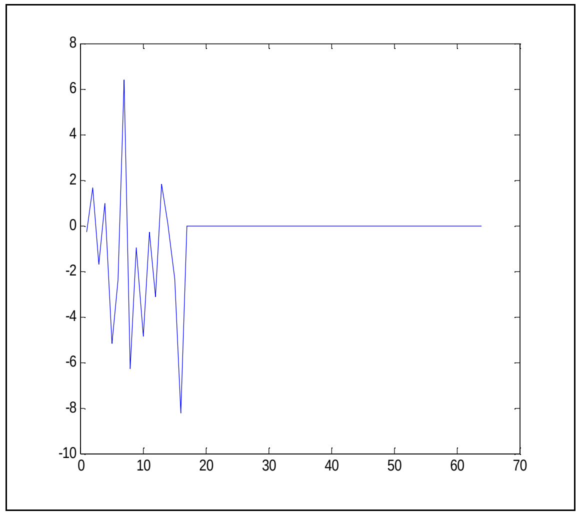

Figure 3: Partitioning In To Segments: First Segment

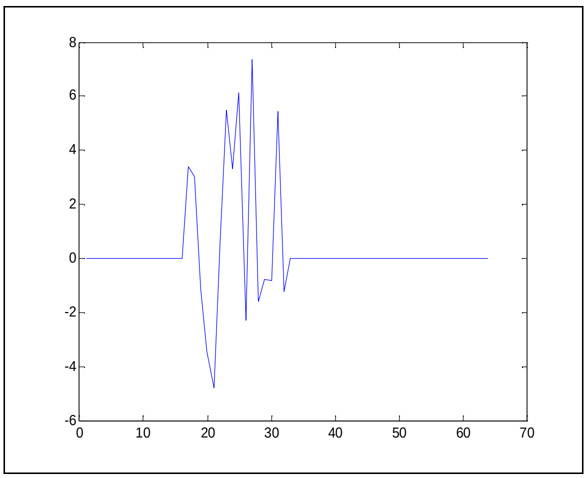

Figure 4: Partitioning In To Segments: Second Segment

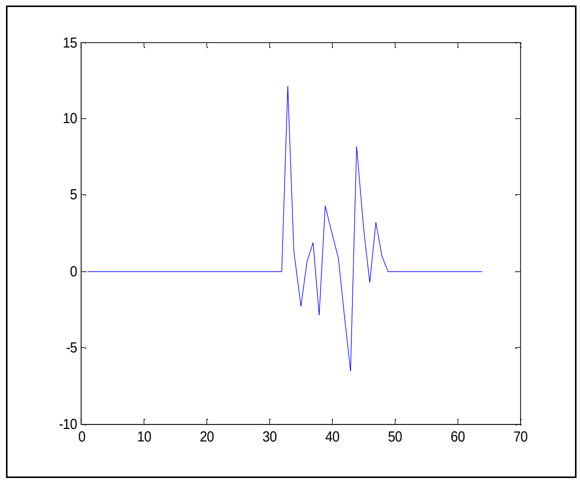

Figure 5 Partitioning In To Segments: Third Segment

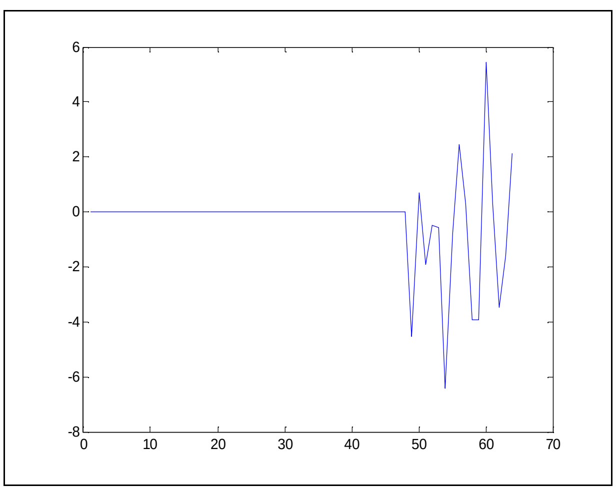

Figure 6: Partitioning In To Segments: Fourth Segment

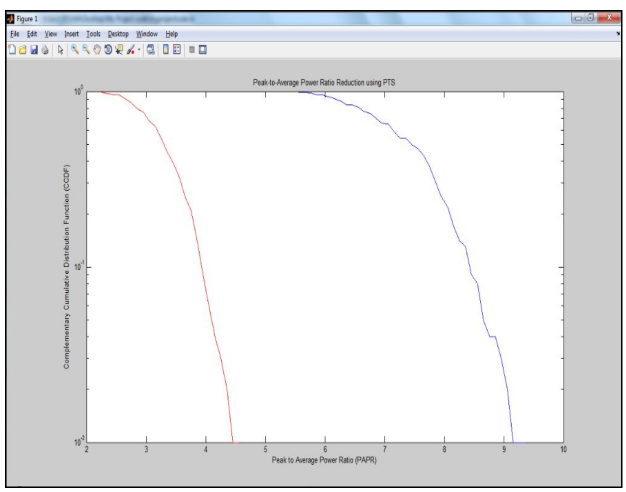

Figure 7: PAPR Comparison Of With And Without PTS

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