REDUCTION OF PEAK - TO - AVERAGE POWER RATIO FOR OFDM SIGNALS

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Abstract: In this paper, a peak-to-average-ratio (PAPR) reduction scheme based on a weighted orthogonal frequency-division multiplexing (OFDM) signal is presented to reduce the PAPR without distortion in removing the weight at the receiver side. In the proposed scheme, a weight is imposed on each discrete OFDM signal via certain kind of a band limited signal, and an OFDM signal formed with the weighted discrete data is then considered before a high power amplifier (HPA), whereas the original signal can be recovered completely at the receiver side. Meanwhile, the time duration needed to transmit the weighted OFDM signal is the same as the time duration for the original OFDM signal. The effectiveness of the proposed scheme is evaluated with computer simulations. According to numerical results, the PAPR of the weighted OFDM signal is smaller than that of the clipping and filtering (C&F) method. Here, the proposed method is simpler than the C&F method.

Keywords: Convolution, Orthogonal Frequency-Division Multiplexing (OFDM), Peak-to-Average-Power Ratio PAPR), weighted data.

1. INTRODUCTION

Orthogonal frequency-division multiplexing (OFDM) is a transmission technique that modulates multiple carriers simultaneously. Although their spectra overlap, the transmitted multiple carriers can be demodulated orthogonally, provided that correct time windowing is used at the receiver. Since the OFDM-based system has high spectral efficiency and is robust against inter symbol interference and frequency-selective fading channels, it has been widely chosen for European digital audio/video broadcasting and wireless local/metropolitan area network standards, and now, it is used in most broadband wireless communication systems. However, one of the major problems of OFDM-based systems is the high peak-to-average-power ratio (PAPR) of a transmitted signal, which causes a distortion of a signal at the nonlinear high-power amplifier (HPA) of a transmitter. Thus, the power efficiency of the HPA is seriously limited to avoid nonlinear distortion; otherwise, the high PAPR results in significant performance degradation. Because of the practical importance of this problem, a number of algorithms for reducing the high PAPR have been developed, such as clipping and filtering (C&F), coding, adaptive symbol selection, such as selected mapping; partial transmit sequence and interleaving, tone reservation/injection, active signal constellation extension ,companding .

In this paper, a PAPR reduction scheme based on a weighted OFDM signal is presented to reduce the PAPR without distortion in removing the weight at the receiver side. This method is motivated by a circular convolution process, i.e., the modulated OFDM signal is convoluted with a certain kind of signal Φ for smoothing the peak of the OFDM signal before the HPA. Here, we choose the signal Φ to satisfy that the Fourier transform ϕ of Φ has no zero on the real line. The convoluted signal can be written as a simple weighted OFDM signal. When the discrete data $\{a_k\}_{k=0}^{N\ 1}$ is given, we consider weighted data $\{a\ k\}^{N1}$ and form an OFDM signal with this weighted discrete data. Then, this weighted OFDM signal is the same as the given convoluted signal. Since weight ϕ is non-uniform, the bit-error-rate (BER) performance could be degraded. In practice, to improve the BER performance, we modify the weight by adding a suitable positive constant to the original weight. The PAPR of the weighted OFDM signal with the modified weight is smaller than that of the C&F method.

The effectiveness of the proposed scheme is evaluated with computer simulations. In this weighted OFDM method with modified weight, the time duration needed to transmit the weighted OFDM signal is the same as the time duration for the original OFDM signal. Moreover, the original discrete data can be recovered completely at the receiver side with additional 2N complex multiplications of computational complexity without extra cost in transmission.

In this paper, the weighted OFDM system and also the condition for a function to be a weight function are presented. A mathematical reason for the merit of the weighted OFDM system derived from a circular convolution system is also presented. The rest of this paper is organized as follows. In Section II, the considered system is briefly described. In Section III, the weighted OFDM signal motivated by the convolution method is provided. In Section IV, the effectiveness of the proposed scheme is evaluated with simulation results.

2. SYSYTEM MODEL

Orthogonal multicarrier modulation is an efficient method of data transmission over channels with relatively simple implementation based on the inverse fast Fourier transform (IFFT). The simplified block diagram for an OFDM system with the convolution scheme is shown in Fig.1. and the weighted scheme is shown in Fig. 2. As described in Fig. 1, the modulated data stream is carried on the multi carriers by the IFFT, and the convolution block reduces the PAPR of signal, which is corresponding to the weight block of the proposed scheme, as shown in Fig.2. In the following block, the cyclic prefix is added before the HPA

For a discrete data $\{a_k\}_{k=0}^{N-1}$, multi carrier modulated signal $x_N(t)$ on [0,NT] is represented by

$$x_n\ t\ = \frac{1}{N} \sum_{k=o}^{N-1} a_{k} e^{\frac{j2\pi kt}{NT}} \quad (1)$$

Where N is number of subcarriers, T is the original symbol period, Δf □ $1/NT$ and $f_k = k\Delta f$, k = 0,1,...N- 1. The PAPR of $x_N(t)$ is given by

$$PAPR\ x_n\ = \frac{max_{0\le t\le NT}|x_n\ t\ |^2}{E(|x_n(t)|^2} \quad 2$$

Where E (.) denotes expectation operator

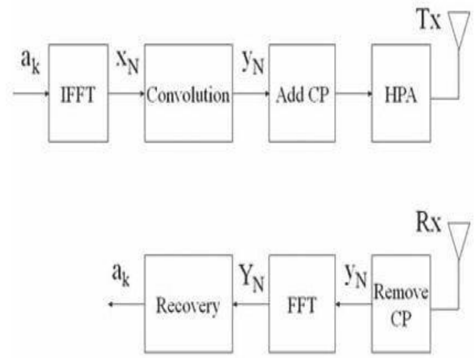

Figure 1: Conventional OFDM scheme

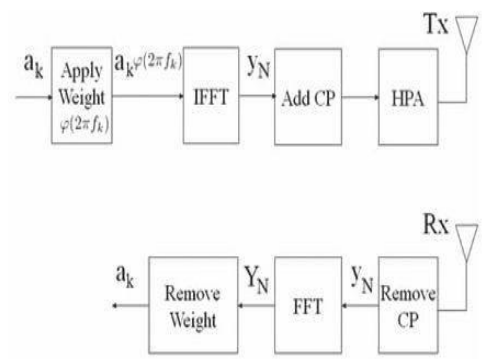

Figure 2: Weighted OFDM scheme

3. WEIGHTED OFDM SYSTEM

Here, in the weighted OFDM signal, where the weight is derived from a suitable band limited signal having no zero on the real line. This method is motivated by a convolution method

The Fourier Transform of $f(t)$ is given by

$$F\ f\ t\ = F\ \omega\ = \int f\ t\ e^{-j\omega t}dt \quad 3$$

If the integral exists. Then Inverse Fourier Transform is defined by

$$F^{-1}\ F\ \omega\ = f\ t\ = \frac{1}{2\pi}\int F\ \omega\ e^{j\omega t}d\omega \quad 4$$

Then

$$F^{-1}\ F\ \omega\ = f\ t \quad (5)$$

When f and $F[\ f\ ]$ are integrable and

$$f\ t\ = f\ -t \quad 6$$

Consider signal Ψ as

$$\Psi(t) = \frac{1-\sin c\,(t)}{\pi^2 t^2} \quad (7)$$

Where

$$\sin c(t) = \begin{cases} 1, & t = 0 \\ \sin \pi t, & t \neq 0 \end{cases}$$

Consider the circular convoluted signal as

$$y_n(t) = \frac{1}{2\pi} xn(t)^{*}\Psi(t)$$

$$y_n(t) = \frac{1}{2\pi}\int_{-\pi}^{\pi} x_n(t-\tau)\,\Psi(\tau)\,d\tau \quad (8)$$

Taking the Fourier transform in (8),

$$F[y_n(t)] = \frac{1}{2\pi} F[x_n(t)]\,F[\Psi(t)]$$

$$F[y_n(t)] = F[x_n(t)]\,\varphi \quad (9)$$

The convoluted signal in (8) can be expressed as the following weighted OFDM signal

$$y_n(t) = \frac{1}{N}\sum_{k=0}^{N-1} a_k \varphi(2\pi f_k)\, e^{2\pi f_k t}, 0 \le t \le NT \quad (10)$$

4. SIMULATION RESULTS

The performance of this proposed scheme is analyzed through the simulations. In the simulations, 10^3 Binary Phase Shift Keying (BPSK) modulated OFDM symbols were randomly generated.

Fig. 3 shows the CCDFs of the C&F method for N = 128.

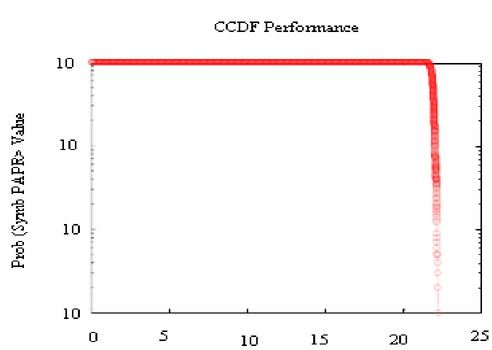

Figure 3: CCDFs of the C&F method

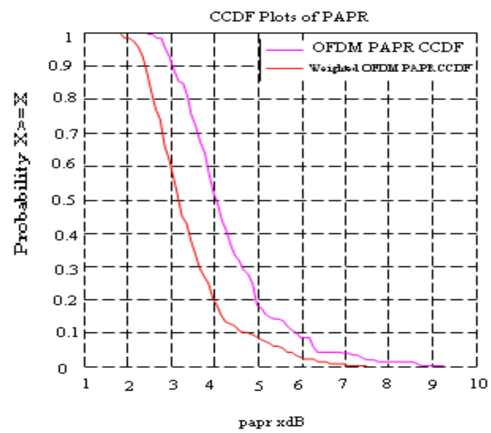

Figure 4: CCDFs of the Conventional OFDM & Weighted OFDM methods

Figure 4: shows the CCDFs of the Conventional OFDM & Weighted OFDM method for N = 128. It can be seen from figures 3 & 4 that the PAPR is considerably reduced in Weighted OFDM scheme compared to Clipping & Filtering method and Conventional OFDM method.

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