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Research Article

Performance Analysis of Weighted OFDM

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Abstract

This work presents the performance analysis of Weighted Orthogonal Frequency Division Multiplexing (W-OFDM). OFDM has emerged as one of the most widely used multi-carrier nodulation techniques in broadband wireless communication. In which mutually orthogonal sub-carriers are employed to modulate binary data streams. It has efficient bandwidth usage along with high data rates. But one of the major challenges that OFDM suffers from is high value of Peak to Average Power Ratio (PAPR). To reduce PAPR, W-OFDM is an enhancement or variant of traditional OFDM that incorporates a weighting function to improve the performance of the system. Weighted OFDM scheme has gained a lot of attention because it will not affect the BER performance adversely. In this paper PAPR of weighted orthogonal frequency division multiplexing scheme for different modulation techniques is analysed. Results show that weighted OFDM preforms better than the conventional OFDM in terms of PAPR.

Keywords: *OFDM, W-OFDM, Sub-carrier, PAPR, BER*

1. Introduction

The requirement of high data rate and high spectral efficiency is increasing day by day. So, the multicarrier modulation is one of the solutions to meet these requirements. The most common technique of multicarrier modulation is Orthogonal Frequency Division Multiplexing (OFDM), which is widely used in wireless communication. It is a key modulation technique used in modern communication systems, including wireless broadband, Wi-Fi, 4G and beyond. OFDM enables high spectral efficiency, robustness against multipath fading, and the ability to handle high data rates [1-2]. However, OFDM also comes with challenges such as Peak-to-Average Power Ratio (PAPR), Inter-Symbol Interference (ISI), hardware complexity, and synchronization issues. Synchronization is crucial in OFDM systems because even slight timing or frequency mismatches can lead to inter-symbol interference and Inter-Carrier Interference (ICI). Several synchronization techniques have been proposed such as frequency synchronization and time synchronization. Time synchronization ensures that the receiver knows when to start receiving the signal. It is crucial to avoid timing misalignments, which can lead to ISI. The cyclic prefix in OFDM can be used to synchronize the timing between the transmitter and receiver.

Advanced algorithms like Maximum Likelihood Estimation (MLE) and Least-Squares (LS) methods have also been proposed to improve time synchronization accuracy. Frequency synchronization ensures that the receiver can compensate for any frequency offset between the transmitter and receiver caused by Doppler shift or oscillator mismatch. Known pilot signals or reference signals can be used to estimate and correct the frequency offset. However, in blind frequency synchronization techniques pilot signals are not required [2-4].

The other challenge in OFDM is high Peak to Average Power Ratio (PAPR), which is major disadvantage of OFDM. High PAPR in OFDM results the power amplifier in saturation thus having distortion due to in-band and out-of-band radiation. There are so many techniques to reduce PAPR like clipping & filtering, selective mapping, partial transmit sequence, tone reservation and many more techniques [3].

Clipping is one of the simplest and most widely used techniques for reducing PAPR. It involves clipping the signal to a predetermined threshold value. It effectively reduces PAPR, but introduces distortion, which can degrade the signal quality [5]. Selective Mapping (SLM) is a probabilistic technique where multiple candidate signal sequences are generated from the original data sequence by multiplying the data with different phase sequences. The sequence with the lowest PAPR is then selected for transmission. But it requires the transmission of side information to the receiver to inform it of the selected sequence and its

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computational complexity increases with the number of phase sequences [4,6]. Variants of SLM, such as partial SLM and multi-block SLM, have been proposed to reduce the side information overhead and computational complexity. PTS is a technique that divides the data block into several sub-blocks, and each sub-block is multiplied by a phase factor. The phase factors are optimized to minimize the overall PAPR of the transmitted signal. The PAPR can be reduced significantly and no out-of-band distortion is introduced. But it has high computational complexity due to the need for an exhaustive search for optimal phase factors and requires the transmission of phase information as side information [4,7-8].

Tone reservation works by reserving a set of tones (subcarriers) in the OFDM spectrum to be used for PAPR reduction. These tones are designed to cancel out high PAPR signals. This technique is effective in reducing PAPR without distortion and no need for side information transmission. However, a portion of the spectrum is reserved for PAPR reduction, which reduces data throughput. Researchers have investigated adaptive tone reservation schemes, where the number and selection of reserved tones are adjusted based on the PAPR of the signal [3-4].

In this paper performance of Weighted Orthogonal Frequency Division Multiplexing (W-OFDM) is analysed. The primary motivation behind W-OFDM is to optimize certain system parameters such as PAPR, spectral efficiency, or interference management, by applying weights to different subcarriers or data symbols [9]. This approach can provide significant benefits in various wireless communication scenarios, including 4G.

The rest of the paper is organized as follows: Section II describes Weighted OFDM System Model. Simulation results are shown in section III and paper is concluded in section IV.

2. Weighted OFDM system model

W-OFDM is an enhancement or variant of traditional OFDM that incorporates a weighting function to improve the performance of the system. In traditional OFDM, the data symbols are mapped onto subcarriers, and all subcarriers are treated equally in terms of their importance and power levels. However, in W-OFDM, a weighting factor is applied to each subcarrier or set of subcarriers to achieve specific system goals such as improving signal quality, minimizing interference, and reducing PAPR. Block diagram of W-OFDM is shown in Fig-1. W-OFDM transmitter is to take the input data and map it onto a set of frequency subcarriers. The data can be encoded using different modulation schemes, such as QAM (Quadrature Amplitude Modulation) or PSK (Phase Shift Keying). The input data, typically in the form of bits, is first converted into symbols using a modulation technique (e.g., QAM, PSK). Each symbol is mapped to a specific subcarrier, according to the modulation scheme used. A set of weighting factors or functions is applied to the subcarriers or symbols, typically aiming to adjust the power allocation or modify the signal characteristics based on the desired performance metric. The weighted signal in the frequency domain can be represented as:

$$S_k = w_k \cdot X_k \quad (1)$$

Where, S_k is the weighted signal on subcarrier k, X_k is the original data symbol assigned to subcarrier k and w_k is the weighting factor applied to subcarrier k. The weighted data is then transformed into the time domain using the Inverse Fast Fourier Transform (IFFT), just like traditional OFDM. The IFFT produces the time-domain signal $s(t)$, which is the W-OFDM transmitted signal.

$$s(t) = IFFT\,\{S_0, S_1, \ldots, S_{N-1}\} \quad (2)$$

where N is the number of subcarriers. To combat the effects of multipath fading and delay spread in wireless communication, a *Cyclic Prefix* (*CP*) is added to the time-domain signal before transmission. The cyclic prefix is appended to the front of the *IFFT* output. The signal is then transmitted over the communication channel, where the weighting factors help manage interference, optimize power distribution, or reduce PAPR.

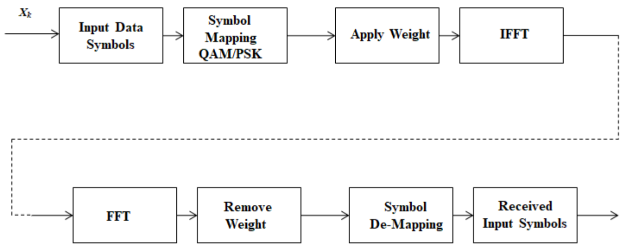

Fig-1. Block diagram of Weighted OFDM System

At receiver side, the received signal, $r(t)$, is a combination of the transmitted signal $s(t)$ and noise which is given as

$$r(t) = s(t) + n(t) \quad (3)$$

Where, $n(t)$ is the Gaussian noise introduced by the communication channel. The receiver needs to convert the received time-domain signal into the frequency domain by using the Fast Fourier Transform (FFT). The signal at the receiver can be represented as

$$R_k = S_k + N_k \quad (4)$$

Where, R_k is the frequency domain representation of the received signal, S_k is the frequency domain representation of the transmitted signal and N_k is the noise and distortion in the frequency domain. The receiver must reverse the weighting to recover the original data. To recover the transmitted data, the receiver must normalize the received signal by dividing by the weights w_k. This operation compensates for the effect of the weighting applied during transmission. Once the weightings have been compensated, the receiver performs demodulation QAM/PSK to recover the transmitted data symbols.

3. Simulation results

In this paper W-OFDM system is simulated using MATLAB and results are compare with OFDM system. For simulation number of subcarriers are taken as 256 and cyclic prefix is ¼.

Fig-2, shows the comparison of PAPR of transmitted signal for W-OFDM system and OFDM system for 16-QAM modulation technique. Result shows that the PAPR of W-OFDM system is less than the PAPR of the OFDM system.

In Fig-3 the comparison of PAPR of transmitted signal for W-OFDM system and OFDM system for 16-PSK modulation technique is shown. From result it has been observed that the PAPR of W-OFDM system is less than the PAPR of the OFDM system.

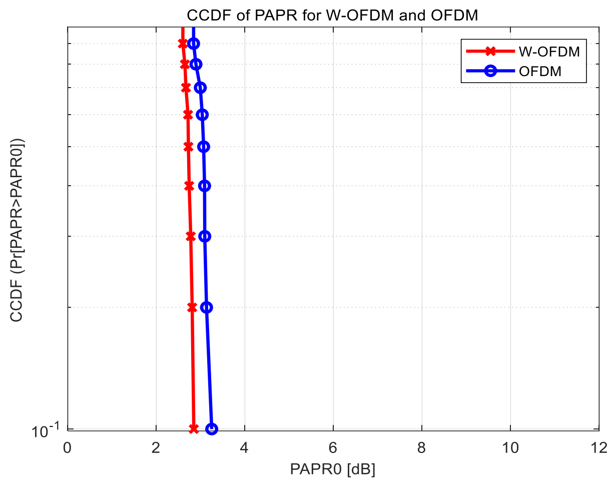

Fig. 2. PAPR of W-OFDM and OFDM with 16-QAM modulation techniques

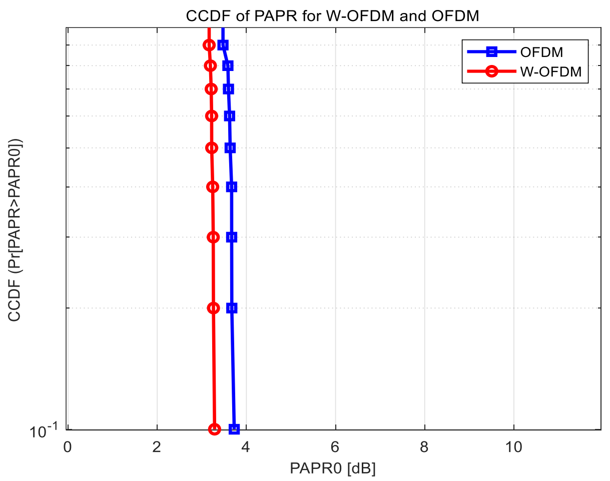

Fig. 3. PAPR of W-OFDM and OFDM with 16-PSK modulation techniques

Conclusion

This paper investigates weighted OFDM system for achieving low PAPR over various modulation techniques. The results show that W-OFDM reduces PAPR in comparison with OFDM system. From the results it is noted that PAPR is improved with W-OFDM technique with QAM modulation technique than the OFDM system with QAM modulation technique. Similarly, a comparison of PAPR of W-OFDM system with PSK modulation technique and OFDM system with PSK modulation technique is made for AWGN channel. PAPR performance for W-OFDM system is better than the OFDM system.

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