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Weighted OFDM for PAPR Reduction

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***Abstract*— Orthogonal Frequency Division Multiplexing (OFDM) is the most emerging technology of this era. In high speed wireless communications, OFDM has become the popular modulation technique and is advantageous over other technologies. Distortions like ISI can be completely and effectively mitigated in OFDM as the carriers are orthogonal. The high Peak-to-Average Power Ratio (PAPR) is the only obstacle in OFDM which causes signal distortion and BER performance degradation. A weighted OFDM methodology is described for PAPR reduction without removing weight at the receiver section. The time duration to transmit the weighted OFDM signal is same as the time duration to transmit the original OFDM signal. The simulation results show that weighted OFDM technique provides enhanced system performance than the clipping method.**

***Index Terms*— BER, OFDM, PAPR, Weighted OFDM.**

I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is used in many high data rate wireless systems. Since the overall channel in OFDM is divided into multiple narrowband signals, it is more resistant to frequency selective fading than single carrier systems. It also makes efficient use of the available spectrum and the channel equalization in OFDM is much simpler.

The entire link failure happens due to a single fade or interference in a single-carrier system but only a small percent of the sub-carriers will be affected in case of a multi-carrier system, and one of the main reason to use OFDM is its high robustness against narrowband interference. The first person to suggest OFDM for wireless communications was Climini in 1985. The advancements in the DSP hardware in the early 1990s made OFDM a realistic option for wireless systems. In OFDM, the information is split into N parallel streams and are transmitted by modulating N distinct carriers. The pecularity of OFDM is the orthogonality of sub-carriers.

The main drawback of OFDM is its Peak-to-Average Power Ratio (PAPR) due to a noise like amplitude variation and a high dyanamic range in the OFDM signal. These high peaks can be alleviated by techniques like clipping, weighted OFDM method, Selected Mapping and so on, out of which clipping is the simplest method but it leads to signal distortion.

Section II explains the causes and criteria to select methods for PAPR reduction. The proposed method called weighted OFDM, to reduce PAPR, is described in section III, followed by simulation results and conclusion in section IV and section V respectively.

II. PEAK TO AVERAGE POWER RATIO

The signal distortion at the nonlinear high power amplifier of the transmitter occurs due to the high PAPR of the transmitted signal. The main idea to reduce PAPR is to improve the Bit Error Rate (BER) performance of an OFDM signal. PAPR arises due to the occurrence of out-of-phase of the different sub-carriers in a multi-carrier system. The peak value of the system can be very high as compared to the average of the whole system when there are a huge number of independently modulated sub-carriers in an OFDM system. The spiky power spectrum at the IFFT output results in high PAPR.

Because of high PAPR, RF amplifiers need to be operated in a very large linear region, leading to complexity of the desired system. Several techniques such as clipping, peak windowing, coding and so on have been developed for PAPR reduction. However, these methods fail to achieve PAPR reduction with low complexity and without performance degradation. The criteria for selecting a method to reduce PAPR include

- Average power should be low.
- Bandwidth expansion is not needed.
- Implementation complexity should be small..
- No need of additional power.
- Bit Error Rate (BER) should be negligible/low.

Techniques for PAPR reduction may vary according to system requirement and is dependent on factors namely, data rate loss, computation complexity, spectral efficiency etc. Many techniques have been suggested to reduce PAPR with different levels of complexity and are categorized into two groups called signal scrambling and signal distortion techniques. Selected mapping, partial transmit sequence and tone injection/rejection comes under signal scrambling technique whereas clipping & filtering, peak windowing and envelope scaling comes under signal distortion technique.

III. WEIGHTED OFDM METHODOLOGY

A weighted OFDM signal is provided and the method is motivated by circular convolution method so that PAPR of the convoluted signal can be reduced. Later, the simulation results tell us that weighted OFDM signal can provide much BER performance than that of normal clipping method. In clipping method, whenever the OFDM signal exceeds the predefined threshold level, that portion of the signal level will be clipped. The clipping method is not generally used since it causes signal distortion, low bit rate, high bit error and performance degradation of the system.

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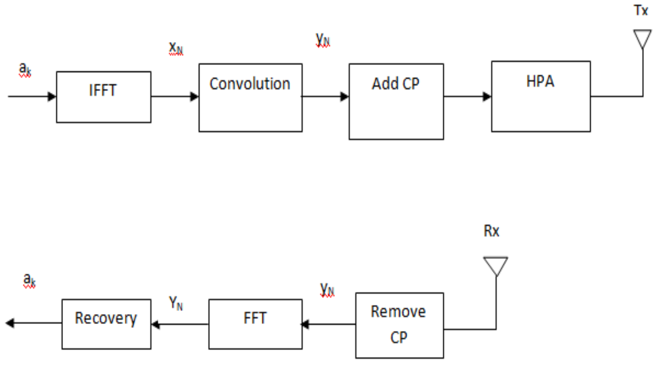

Fig. 1: Block diagram of an OFDM system with convolution scheme

As shown in Fig. 1, the circular convoluted signal can be represented as

$$y_N(t) = \frac{1}{2\pi}[x_N * \emptyset(t)] = \frac{1}{2\pi}\int_{-\pi}^{\pi} x_N(t-\epsilon)\,\emptyset(\epsilon)\,d\epsilon \quad (1)$$

where x_N is the multi-carrier modulated signal and can be written as

$$x_N(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} a_k\, e^{j2\pi f_k t} \quad (2)$$

where a_k is the discrete data for k = 0, 1, . . . , N – 1, N is the number of sub-carriers and $\emptyset$ is a suitable bandlimited signal. Taking Fourier Transform of (1) yields

$$F[y_N] = \frac{1}{2\pi} F[x_N]\, F[\emptyset] = F[x_N]\,\varphi \quad (3)$$

$$F[x_N](\epsilon) = \frac{2\pi}{\sqrt{N}}\sum_{k=0}^{N-1} a_k\, \delta(\epsilon - 2\pi f_k) \quad (4)$$

The discrete data a_k can be recovered from (4) as follows:

$$a_k = \frac{\sqrt{N}\, F[x_N](2\pi f_k)}{2\pi\varphi(2\pi f_k)} \quad (5)$$

However, the discrete data obtained in (5) has high PAPR due to the presence of large number of sub-carriers at the IFFT output of the transmitter section. Thus, weighted OFDM methodology is implemented as shown in Fig. 2.

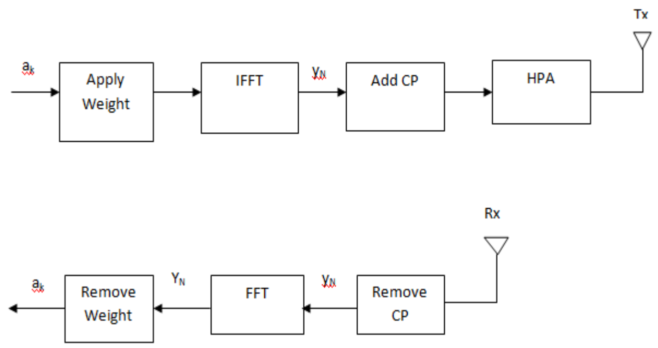

Fig. 2: Block diagram of an OFDM system with weighting scheme

In case of weighted OFDM technique, (1) can be written as:

$$\int_{-\pi}^{\pi} e^{j2\pi f_k(t-\epsilon)}\,\emptyset(\epsilon)\,d\epsilon = 2\pi\, y_N(t) \quad (6)$$

$y_N(t)$ in weighted OFDM signal can be expressed as:

$$y_N(t) = e^{j2\pi f_k t}\,\varphi(2\pi f_k) \quad (7)$$

Thus (6) becomes,

$$\int_{-\pi}^{\pi} e^{j2\pi f_k(t-\epsilon)}\,\emptyset(\epsilon)\,d\epsilon = 2\pi\varphi(2\pi f_k)\, e^{j2\pi f_k t} \quad (8)$$

$$y_N(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} a_k\, e^{j2\pi f_k t}\,\varphi(2\pi f_k) \quad (9)$$

for $0 \le t \le NT$.

IV. SIMULATION RESULTS

On comparison with weighted OFDM method with unprocessed data, weighted OFDM has better BER performance. It has been shown in Fig. 3 that as the old system achieves SNR of 20 at a BER of about 0.35, the weighted OFDM method can achieve the same SNR at a low BER of about less than 0.2. Similarly, it is obvious from Fig. 4 that PAPR of weighted OFDM is 8.55 dB which is far better than that of unprocessed data, which is having PAPR of around 11.2 dB. PAPR is plotted as a function of Complementary Cumulative Distribution Function (CCDF).

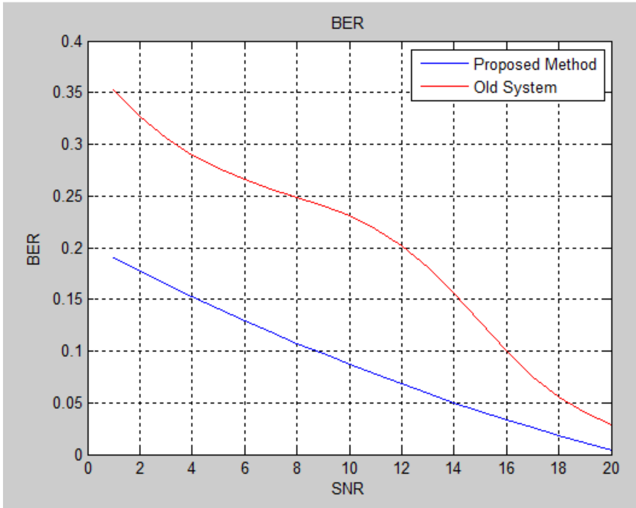

Fig. 3: Comparison of BER performance of weighted OFDM method with that of clipping method

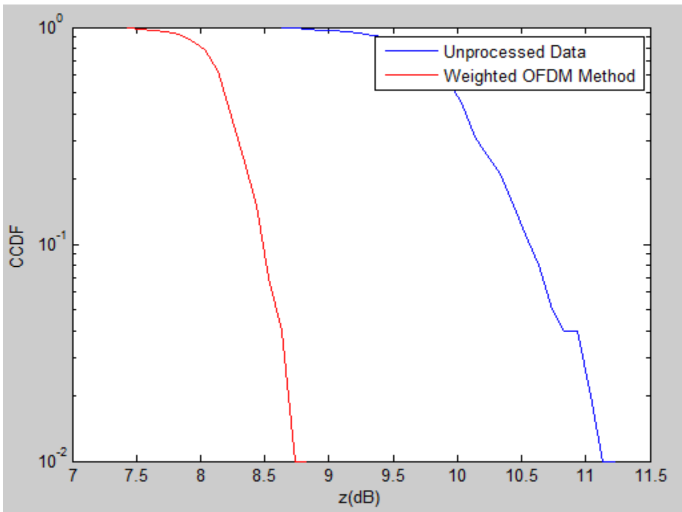

Fig. 4: Comparison of PAPR in weighted OFDM with Unprocessed data.

V. CONCLUSION

OFDM is a new modulation scheme that can transfer large amount of data which existing techniques cannot support. In order to meet high data rate demand in communications in both wired and wireless environments, OFDM is the suitable digital transmission method and has been deployed in digital audio/video broadcasting in Europe, as well as in the asymmetric digital subscriber line high data rate wired links. In this paper, the basic idea behind OFDM has been discussed. PAPR, being the serious limitation in OFDM signal, can be eliminated by a suitable technique called weighted OFDM method that has also been explained. Finally, the simulation results proved that weighted OFDM methodology provides better BER performance than the normal convolution method.

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