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Advanced OFDM System

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Abstract: Digital multimedia applications create an ever increasing demand for broadband communication systems. The technical requirements for related products are very high, but it is desired that the solutions must be cheap to implement, feasible or lead to sub optimal results. Orthogonal Frequency Division Multiplexing (OFDM) is a method that allows transmitting high data rates over extremely hostile channels at a comparatively low complexity than the traditional single carrier techniques.

Keywords: OFDM, PAPR, Commpanding, Windowing

I. INTRODUCTION

International Standards for OFDM have been specified by IEEE 802.11, IEEE 802.16, IEEE 802.20, European Telecommunications Standards Institute (ETSI) and Broadcast Radio Access Network (BRAN) committees. OFDM is a multicarrier modulation where information data is divided into many parallel sub-channels of narrow bandwidth that are transmitted simultaneously over a number of subcarriers. The data rate of each sub-channel is much less than the total data rate.

In despite of its advantages, there is a serious problem, PAPR. This problem comes from the nature of the modulation itself, where multiple sub-carriers/sinusoids are added together to form the signal to be transmitted. In this topic, proposed scheme will be presented to reduce the PAPR by using the companding and windowing methods.

II. LITERATURE SURVEY

There are several developed techniques to reduce the PAPR in OFDM systems [7, 12] such as Clipping [7], Companding [4, 6, 15] , Partial Transmit Sequence (PTS) [3,5,12], Selected Mapping (SLM) [7,12] and Coding [10]. The clipping technique is the simplest one that can be used in OFDM systems, but it causes additional clipping noise, which degrades the system performance. An alternative technique to mitigate the PAPR problem is based on signal transformations. This technique involves a signal transformation prior to amplification, then an inverse transformation at the receiver prior to demodulation. Trigonometric transforms were suggested as alternatives for the FFT to reduce the PAPR. The authors concluded that OFDM systems with trigonometric transforms provide higher PAPR reduction than the standard FFT based system. However, they modified the OFDM symbols before transmission using the PTS. Their results reveal that without PTS, the distribution of PAPR is the same for that conventional one such that the reduction depends on PTS, which makes redundancy in the system.

The SPIHT is used for image transmission over the OFDM system in several research works [11] because the SPIHT has a good rate-distortion performance for still images. In the, with comparatively low complexity and it is scalable or completely embeddable.

Yan Sun [16] proposed A Joint Channel Estimation and Unequal Error Protection Scheme for Image Transmission in Wireless OFDM Systems. This orthogonal frequency division multiplexing (OFDM) modulation, adopted by the digital video broadcasting (DVB-T) standard, has been recognized for its good performance for high data rate wireless communications. Therefore, the study of the robust transmission of multimedia data over OFDM systems has attracted extensive research interests. In the past, channel estimation, which is an important aspect in OFDM systems, has not been exploited for multimedia transmission. When using the block training based channel estimation, OFDM data blocks experience unequal decoding error rate due to the imprecision of channel estimation. We use this property to provide unequal error protection (UEP) for transmission of SPIHT coded images. Compared with the systems using pilot training channel estimation schemes, which are recommended in the DVB-T standard, the proposed scheme improves the PSNR of reconstructed images by up to 2 dB.

Gusmao, Rui [17] proposed an On Frequency Domain Equalization and Diversity Combining for Broadband Wireless Communications. This is concerned with the use of frequency-domain equalization (FDE) and space diversity within block transmission schemes for broadband wireless communications. The expected performance with both multicarrier (MC) and single-carrier (SC) modulations is emphasized, when a cyclic prefix, long enough to cope with the maximum relative channel delay, is appended to each transmitted block. A set of numerical results is presented and discussed, with the help of appropriate, analytical performance bounds which are conditional on a given channel realization. These bounds are used to explain the performance advantage of the SC/FDE option, the benefits of space diversity, and the impact of the criterion for computing the FDE parameters.

Chih-Yuan Yang [18] proposed a LDPC Coded OFDM Modulation for High Spectral Efficiency Transmission.

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This paper investigates efficient low-density parity-check (LDPC) coded orthogonal frequency division multiplexing (OFDM) modulation schemes for fixed wireless application. We use partially LDPC coded with double gray code labeling technique and Reed-Solomon code with LDPC Coded Modulation (RS-LCM) to achieve better performance than the conventional LDPC bit-interleaved coded modulation (BICM) scheme. RS-LCM scheme outperforms BICM scheme by 0.4 dB at a BER of 10^{-5}.

Sashuang Wang [19] proposed a Progressive Image Transmission over Wavelet Packet Based OFDM. A new scheme for progressive image transmission over wavelet packet based orthogonal frequency division multiplexing (WP-OFDM) system is proposed. First, the BER performances of WP-OFDM systems with different Daubechies wavelet as orthogonal basis functions in multipath fading channel are investigated. The results show that there are error floors in the BER curves, so an equalization method is applied to eliminate the error floor. Then in the WP-OFDM system with the equalization method, a joint source channel coding (JSCC) method is introduced to give image encoder output bit streams with different perception importance unequal error protection. Simulation results confirm the effectiveness of our proposed image transmission scheme.

Rushdi [20] proposed a PAPR reduction in Trigonometric Based OFDM System. A key building block in any OFDM transceiver is the Fast Fourier Transform (FFT) and its inverse. A number of researchers have recently proposed the use of the discrete cosine transform (DCT) and the discrete sine transform (DST), and their inverses as alternative modulating/demodulating bases to improve the BER performance of OFDM schemes while maintaining a low implementation cost. In this paper, we consider the open problem of reducing the peak-to-average power ratio (PAPR) in OFDM systems that deploy these trigonometric transforms. In specific, we show that similar to the FFT case, the complex envelope of a band limited DCT/DST-OFDM signal has a chi-square distribution with one degree of freedom and hence converges weakly to a Gaussian random process as the number of sub-carriers becomes large. Using this result, we then derive closed form expressions for the complementary cumulative distribution functions (CCDF) of each system and show that OFDM systems with trigonometric transforms provide higher PAPR reduction than the standard FFT-based system. Simulation results that compare the CCDFs of the different transforms using the partial transmit sequences (PTS) technique confirm our theoretical findings. Tao Jiang [7] proposed An Overview of Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals. One of the challenging issues for Orthogonal Frequency Division Multiplexing (OFDM) system is its high Peak-to-Average Power Ratio (PAPR). In review and analysis different OFDM PAPR reduction techniques, based on computational complexity, bandwidth expansion, spectral spillage and performance and also some methods of PAPR reduction for multiuser OFDM broadband communication systems.

III. OFDM STRUCTURE

A multicarrier communication system with orthogonal sub-carriers is called Orthogonal Frequency Division Multiplexing (OFDM) system. The word "orthogonal" indicates that there is a precise mathematical relationship between the frequencies of the carriers in the system. The basic principle of OFDM is to split a high-data-rate sequence into a number of low-rate sequences that are transmitted simultaneously over a number of subcarriers.

OFDM is suitable for high-speed communication. It reduces the effect of ISI and multipath by breaking the signal into many narrow bandwidth carriers. This results in a low symbol rate reducing the amount of ISI. In addition to this, a guard period is added to the start of each symbol, removing the effects of ISI for multipath signals delayed less than the guard period.

As communication systems increase their information transfer speed, the time for each transmission necessarily becomes shorter. Since the delay time caused by multipath remains constant, ISI becomes a limitation in high-data-rate communication. OFDM avoids this problem by sending many low speed transmissions simultaneously. For example, the figure below shows two ways to transmit the same four pieces of binary data.

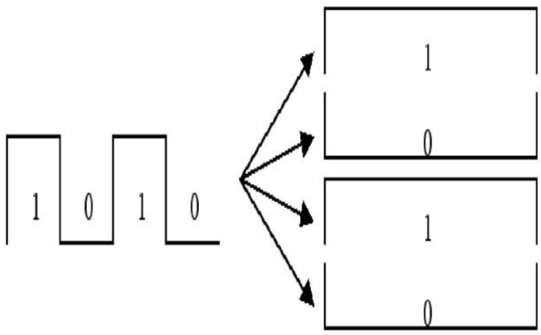

Fig. 1. OFDM transmission

Suppose that this transmission takes four seconds. Then, each piece of data in the left picture has duration of one second. On the other hand, OFDM would send the four pieces simultaneously as shown on the right. In this case, each piece of data has duration of four seconds. This longer duration leads to fewer problems with ISI. Another reason to consider OFDM is low-complexity for high-speed systems as compared to traditional single carrier techniques.

In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-channels or sub-carriers, transmitted in parallel, divide the available transmission bandwidth. The separation of the sub-carriers is theoretically minimal such that there is a very compact spectral utilization.

But the question arises…why we use a multi-carrier system. There are 2 main reasons: During transmission, data may be lost in one or two sub-carriers, but in a multi-carrier system, we do not lose the whole stream. It helps to combat frequency-selective channel fading.

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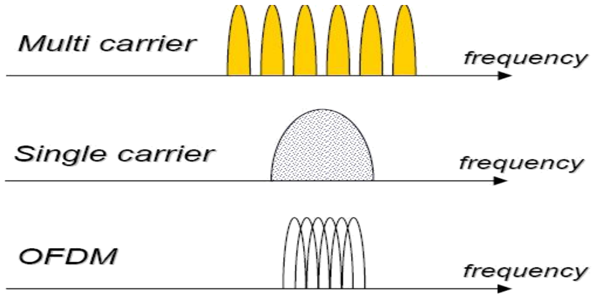

Fig. 2. OFDM signal

IV. PEAK-TO-AVERAGE POWER RATIO (PAPR)

The main disadvantage of OFDM is high peak-to-average power ratio (PAPR). A high peak to average power ratio causes saturation in power amplifiers, leading to inter modulation products among the sub carriers and disturbing out of band energy. Therefore, it is desirable to reduce the PAPR.

By definition we have,

$$PAPR = \frac{\text{Peak Amplitude of the Signal}}{\text{Average value of the Signal}}$$

An OFDM signal consists of a number of independent sub carriers, which can give a large peak-to-average power ratio (PAPR) when added coherently. When N signals are added with the same phase, they produce a peak power that is N times the average power. As a result, linear behavior of the system over a large dynamic range is needed and the efficiency of the output amplifier is reduced. The average power must be kept low in order to prevent the transmitter amplifier saturation.

$$PAPR = \frac{|x(t)|^2}{P_{avg}}$$

Where, x(t) - Peak Amplitude of the Signal,
Pavg - Average value of the Signal

The Peak-To-Average Power Ratio (PAPR) is currently viewed as an important implementation issue in the communication systems. Specifically, for wireless cellular systems, the price of the mobile unit is required to remain low. This means that a limited PAPR can be supported. Orthogonal Frequency Division Multiplexing (OFDM) and Single Carrier (SC) are the prominent candidates for the next generation of wireless communications physical layer standards. PAPR was considered extensively for OFDM and much attention was given to the issue by academy and industry. This shows that PAPR should be considered for SC just as well. PAPR as a function of bandwidth efficiency for OFDM and SC modulation techniques is considered. It is shown that high PAPR for both types of modulation technique appears as a result of high bandwidth efficiency demand, regardless of the modulation technique used.

V. TECHNIQUES TO REDUCE HIGH PAPR

A. Companding

In companding method, compression is used in the transmitter and expansion in the receiver. By considering the approximate distribution of the OFDM amplitudes, we compress the dynamic range with a memory-less transformation at the transmitter and expand the amplitude level at the receiver. This transformation essentially changes the probability distribution of the amplitude of OFDM signal and achieves the PAPR reduction by both enlarging the small amplitudes and compressing large signals. The power is adaptively allocated for each sub-carrier according to the distribution in each block.

The compander consists of compressor and expander. The compressor is a simple logarithm computation. The reverse computation of a compressor is called an expander. In this scheme, the compression at the transmitter end is used after the IFFT process and expansion at the receiver end is used prior to FFT process.

B. Windowing

A different approach to reduce the PAPR is to multiply large signal peak with a Gaussian shaped window or any other window with good spectral properties. Since the OFDM signal is multiplied with several of these windows the resulting spectrum is a convolution of the original OFDM spectrum with the spectrum of the applied window. So, ideally the window should be as narrow band as possible. On the other hand, the window should not be too long in the time domain, because that implies that many signal samples are affected, which increases the bit error ratio. Examples of suitable window functions are the Cosine, Kaiser and Hamming window. Peak windowing technique offers reasonably good reduction in PAPR achieved independent from number of sub-carriers, at the cost of a slight increase in BER and out of band radiation. Windowing parameters, window width and attenuation factor should be selected such a way that it will reduce the PAPR. However, it is difficult to find a relationship between windowing parameters and PAPR since the PAPR is random. Generally, the window width should be small in order to avoid distorting many sample values and the attenuation factor should be selected by considering PAPR reduction and signal distortion. Further, it is necessary to relate OFDM parameters with peak windowing.

OFDM signal is multiplied by the window function when the signal peak exceeds the clipping level. Unlike the clipping, the OFDM signal within the windowing width is modified. This results in a smoothed OFDM signal.

The PAPR reduction is achieved at the cost of degrading the bit error rate performance (BER) and out of band radiation. PPR cannot be reduced beyond a certain limit by removing peaks, as the average value of the OFDM signal also decreases, which in turn increases the PAPR. Peak windowing method concerns only removing the peak values, which have low probability of occurrence.

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OFDM signal exhibits some low values, we will call it "bottoms" with low probability of occurrence, like peaks. By increasing these bottoms above certain level, the average value of OFDM signal can be shifted up. This results in PAPR reduction. This is like inverted windowing.

Peak Windowing distorts the OFDM signal causing inband distortion and out of band radiation. Inband distortion causes to BER performance degradation. When clipping ratio is increased the BER performance is better, but, the reduction in PAPR is not much. When clipping ratio is low, the amount of peaks removed is high. Thus, signal has been distorted very much and BER performance degrades.

VI. PROPOSED SYSTEM

A. OFDM Transmitter

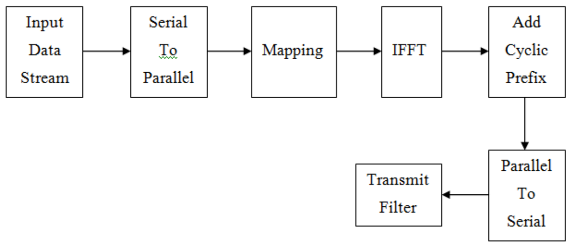

Fig. 3. OFDM transmitter

OFDM transmitters generate both the carrier and the data signal simultaneously. The specific process of digital signal generation used in OFDM is based on the series of mathematical computations known as an Inverse Fourier Transform and the process results in the formation of a complex modulated waveform at the output of the transmitter. The incoming serial data is first converted from serial to parallel and grouped into x bits each to form a complex number. The complex numbers are modulated in a baseband fashion by the IFFT and converted back to serial data for transmission. A guard interval is inserted between symbols to avoid inter-symbol interference (ISI) caused by multipath distortion. The discrete symbols are converted to analog and low pass filtered for RF up-conversion.

B. OFDM Receiver

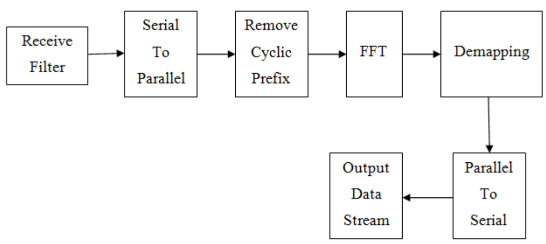

Fig. 4. OFDM receiver

The receiver performs the reverse operation of the transmitter, mixing the RF signal to baseband for processing, then using a Fast Fourier Transform (FFT) to analyze the signal in the frequency domain. The amplitude and phase of the subcarriers is then picked out and converted back to digital data.

The IFFT and the FFT are complementary function and the most appropriate term depends on whether the signal is being received or generated. In cases where the signal is independent of this distinction, then the term FFT and IFFT is used.

VII. EFFECT OF AWGN ON OFDM

Noise exists in all communications systems operating over an analog physical channel, such as radio. The main sources are thermal background noise, electrical noise in the receiver amplifiers and inter-cellular interference. In addition to this, noise can also be generated internally to the communications system as a result of Inter-Symbol Interference (ISI), Inter-Carrier Interference (ICI) and Inter-Modulation Distortion (IMD). These sources of noise decrease the Signal to Noise Ratio (SNR), ultimately limiting the spectral efficiency of the system. Most types of noise present in radio communication systems can be modeled accurately using Additive White Gaussian Noise (AWGN). This noise has a uniform spectral density making it white and a Gaussian distribution in amplitude also referred to as a normal distribution or bell curve.

OFDM signals have a flat spectral density and a Gaussian amplitude distribution provided that the number of carriers is large. Because of this, the inter-cellular interference from other OFDM systems has AWGN properties. For the same reason ICI, ISI, and IMD also have AWGN properties for OFDM signals.

VIII. CONCLUSION

The OFDM system can play an important role in wireless communication. It is necessary to reduce the PAPR in OFDM system because it can decrease the performance of the communication. Our research shows that there exist a big potential to reduce the PAPR of OFDM system by using companding and windowing method. This OFDM system may bring a revolution to wireless communication because it can reduce the PAPR with high precision.

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