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Study on Reduction of PAPR of OFDM Signals

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Abstract: In this paper, we have presented a report on peak to average power ratio (PAPR) reduction based on a weighted OFDM signal scheme. This method is proposed to reduce the PAPR, without distortion of the original signal while removing the weights at the receiver side. In the proposed scheme, a weight is allocated on each discrete signal via a certain kind of a band pass signal through mixture, and an OFDM signal formed with the weighted discrete data is then considered before a high power amplifier where as the original signal can be recovered at the receiver side. Meanwhile the time duration needed to transmit weighted signal is the same as the time duration for the original OFDM signal. The effectiveness of the proposed scheme is evaluated with computer simulations.

Keywords: PAPR (Peak-to-Average Power Ratio), OFDM, SLM, FFT (fast Fourier transform).

I. INTRODUCTION

These Modern wireless communication systems are aimed at providing extremely high-speed data transmission to support high speed Internet, high quality multimedia and high definition streaming videos, where orthogonal frequency division multiplexing (OFDM), a multicarrier transmission technique, has emerged as key technology to achieve high data rates and to increase system's reliability in harsh wireless channels. OFDM has been widely adopted in many wireless and wire line communication standards such as Third Generation Partnership Project (3GPP), Long-Term Evolution Advanced (LTEA), Wireless Local Area Networks (WLANs, IEEE 802.11a and IEEE 802.11g), Worldwide Interoperability for Microwave Access (WiMAX, IEEE 802.16), digital audio broadcasting (DAB), digital video broadcasting (DVB), European HIPERLAN/2, and digital subscriber line (DSL). OFDM divides the data into several parallel and orthogonal streams or sub channels (called subcarriers) and each subcarrier (basically a sinusoidal signal) has constant amplitude, but when summing the subcarriers, the resulting OFDM signal fluctuates over a large range. For N subcarriers, the peak power can theoretically be N times larger than the average power.

The ratio between the peak power and the average power is referred to as peak-to-average power ratio (PAPR). The high PAPR requires transmitter's power amplifier with a large linear range capable of accommodating the signal, but practically power amplifier has a limited linear region beyond which it saturates to a maximum output level. Thus, such efficient schemes need to be investigated that can reduce the occurrence of large signal peaks at the input of the power amplifier in order to minimize the detrimental effects of nonlinear distortions without sacrificing the power efficiency. A number of approaches have been proposed in the literature to solve the PAPR problem, such as clipping and filtering, companding, tone reservation, tone injection, partial transmit sequences, selective mapping, constellation shaping, and coding based schemes. Major techniques with their pros and cons are summarized as follows. Clipping and filtering is considered as the simplest PAPR reduction technique, which limits the peak envelope of the input signal to a predetermined level,

Otherwise passes the signal without change. Filtering the clipped signal helps to reduce out-of-band distortion but leads peak power regrowth. Various techniques to mitigate the harmful effects of clipping and filtering have been proposed but unable to maintain the error performance.
Compounding transforms has low computational complexity and simple implementation but it comes with the price of increased error rate. In selective mapping (SLM) technique, a set of adequate different OFDM symbols is generated, all representing the same information as the original OFDM symbol, then transmitted the one with the lowest PAPR. Information about the selected symbol is transmitted to the receiver as side information which reduces the data rate. Another disadvantage of SLM is high computational complexity due to the symbol selection process. In the partial transmit sequence (PTS) technique, an input data block of length N is partitioned into a number of disjoint sub-blocks and then weighted by a phase factor, which is selected to minimize the PAPR of the combined signal. PTS technique has similar disadvantages as that of SLM technique. In tone injection (TI) technique, the constellation size is increased so that each of the points in the original basic constellation is mapped into several other points in the expanded constellation, which helps to reduce PAPR but with increased power and complexity. In tone reservation (TR) technique, a subset of tones is reserved which carries no information data.
Orthogonal frequency division multiplexing (OFDM) is emerging technology for 4th generation (4G) cellular networks. OFDM is a parallel transmission scheme which splits high data rate serial data stream into low-rate sub

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stream; each one is modulated on a separate SC. OFDM is one of the many multicarrier modulation techniques, which provides high spectral efficiency, low implementation complexity, less vulnerability to echoes and non – linear distortion. Due to these advantages of the OFDM system, it is vastly used in various communication systems. But the major problem one faces while implementing this system is the high peak – to – average power ratio of this system.

A large PAPR increases the complexity of the analog-to-digital and digital-to-analog converter and reduces the efficiency of the radio frequency power amplifier. Regulatory and application constraints can be implemented to reduce the peak transmitted power which in turn reduces the range of multi carrier transmission. This leads to the prevention of spectral growth and the transmitter power amplifier is no longer confined to linear region in which it should operate. This has a harmful effect on the battery lifetime. Thus in communication system, it is observed that all the potential benefits of multi carrier transmission can be out - weighed by a high PAPR value. .

Many PAPR reduction schemes based on different techniques, such as clipping and filtering, window shaping, block coding, partial transmit sequence (PTS) technique, and selective mapping (SLM) technique, phase optimization, tone reservation and injection and constellation techniques have been discussed in literature. Specifically, constellation scheme can reduce PAPR more effectively than the clipping approach to the original signals.

Today, the data communications are more various. Each communication needs a high data rate and an efficient bandwidth use. For the air media, this higher data rates should be balanced with the system ability to cope with multipath fading. This need can be fulfil with the existence of Orthogonal Frequency Division Multiplexing (OFDM) technique. OFDM can handle multipath fading and use a bandwidth efficiently. OFDM is efficient in bandwidth use because its signal is orthogonal.

In OFDM technique, a bandwidth is divided into some channel, each is called sub-channel. Each sub-channel is independent each other and has one-carrier. In the time domain, OFDM signals are a superposition of its sub channels. Typically, each sub channel uses QAM modulation. The superposition of these sub channels makes the occurrence of PAPR phenomenon in the OFDM. The PAPR phenomenon is not applicable for the receiver amplifier.

OFDM signals have a strong relation with the chosen modulation mode. This paper will see how the 4-QAM and 16-QAM modulation mode affect the PAPR value. In addition, it will include the effect of the sub channels in producing PAPR value.

II. LITERATURE SURVEY

It is usually assumed that data–networks are a 20th Century phenomenon. Evidence of efforts to build data communications systems, however, can be found throughout history. Before the electrical telegraph was introduced, many countries in Europe already had fully operational nationwide data–networks in place. We briefly recount the long history of pre–electric communication methods and devices.

Modern data communications techniques rely on many concepts and ideas that all seem to have evolved in a relatively short span of time. When, in the mid 19th Century, the electrical Telegraph was introduced, a system of message relaying and encoding had to be developed virtually on the spot. Or so it seems.

It is clear that all these methods are limited in their possible uses: they are all relatively crude broadcast methods that cannot but give a small set of pre–defined messages. It would be interesting to see, therefore, what historical record there is of methods and techniques that make point–to–point signalling of arbitrary messages possible. For this, a number of enabling techniques had to be developed first.

These include:
- Methods for relaying messages point to point, instead of broadcasting them.
- Methods for encoding arbitrary information, e.g. in an alphabet, or in a vocabulary that has been optimized for a particular type of signalling.

Assuming that we have some type of rudimentary signalling link, the problem of controlling that link itself also has to be solved. To be able to do this at all, one has to be able to make the distinction between control information and message data, even when both types of signals travel on the same link. Furthermore, explicit control procedures have to be formulated and agreed upon between the senders and receivers of a data link. It is interesting to see when we can find the first evidence of explicit:
- Distinctions being made between control information and message data, and
- Methods being developed for error control, flow control, and rate control.

III.PAPR IN OFDM

OFDM is a powerful modulation technique being used in many new and emerging broadband communication systems.

–Advantages:
Robustness against frequency selective fading and time dispersion. Transmission rates close to capacity can be achieved. Low computational complexity implementation.

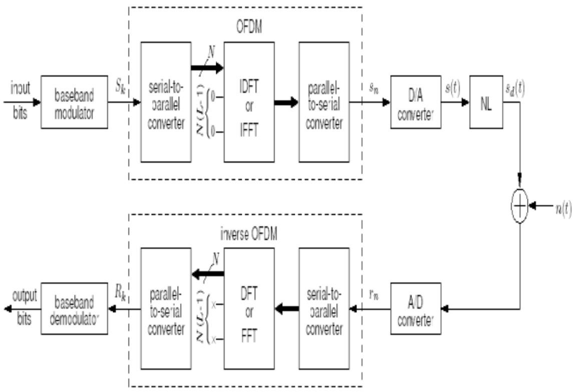
–Drawbacks:
Sensitivity to frequency offset. Sensitivity to nonlinear amplification. Compensation techniques for nonlinear effects, Linearization (digital predistortion).Peak-to-average power ratio (PAPR) reduction. Post-processing.

- PAPR-reduction techniques:

– Varying PAPR-reduction capabilities, power, bandwidth and complexity requirements.
– The performance of a system employing these techniques has not been fully analyzed
– PAPR is a very well known measure of the envelope fluctuations of a MC signal
– Used as figure of merit.
– The problem of reducing the envelope fluctuations has turned to reducing PAPR.
– In this paper we present a quantitative study of PAPR and NL distortion
– simulate an OFDM-system employing some of these techniques

Motivation: evaluate the performance improvement capabilities of PAPR-reducing methods.

Orthogonal Frequency Division Multiplexing



An OFDM signal can be expressed as

$$s_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} S_k e^{j2\pi kn/N}$$

Peak-to-average power ratio
Let be the m-th OFDM symbol, then its PAPR is defined as
The CCDF of the PAPR of a non-oversampled OFDM signal is

$$\mathrm{PAPR}_m = \frac{\left\| \mathbf{s}^{(m)} \right\|_\infty^2}{E\left[\left\| \mathbf{s}^{(m)} \right\|^2 \right] / N}$$

$$\Pr\left(\gamma > \gamma_0\right) = 1 - \left(1 - e^{-\gamma_0}\right)^N$$

CCDF of PAPR increases with the number of subcarriers in the OFDM system. It is widely believed that the more subcarriers are used in a OFDM system, the worse the distortion caused by the nonlinearity will be. In-band and out-of-band distortion If N is large enough, the OFDM signal can be approximated as a complex Gaussian distributed random variable. Thus its envelope is Rayleigh distributed in decibels

PAPR is mathematically defined as:

$$PAPR = 10log_{10} \frac{\max\left[|x(t)|^2\right]}{\frac{1}{T}\int_0^T |x(t)|^2 dt}$$

Reduction Techniques
Two categories of the PAPR reduction methods can be classified: the first kind is distortion less and the second one is distorted. The distortion less methods will not distort the original OFDM waveform. However, these methods have to transmit the additional side information (SI) along with the OFDM signal.
Hence, the distortion less methods has the disadvantage of reducing the system throughput. On the contrary, the distorted methods will not reduce the throughput. However, they are nonlinear and suffer the bit error rate (BER) degradation of the system.

Signal Scrambling Techniques
- Block Coding Techniques
- Block Coding Scheme with Error Correction
- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS)
- Interleaving Technique
- Tone Reservation (TR)
- Tone Injection (TI)

Signal Distortion Techniques
- Peak Windowing
- Envelope Scaling
- Peak Reduction Carrier, Clipping and Filtering

IV. WEIGHTED OFDM SYSTEM WITH MODIFIED WEIGHT

The demerit of the weighted OFDM signal is the degradation of BER performance since the weight ϕ is nonuniform. To overcome this let us consider the modified weight with a positive constant α as follows:

$$\varphi_\alpha(x) = \varphi(x) + \alpha / \log N$$

Where α is a shift parameter, and logN is obtained by experiment. Then,ϕ=ϕ0. In the weighted OFDM signal in (11), we replace weight ϕ with ϕα for a suitable positive constant to get the weighted OFDM signal, i.e.,

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

as a transmitted signal instead ofxNin (1).n system (13), weightϕα(2πfk)is imposed on the discrete dataak, k=0,...,N−1, and we form an OFDM signal with the weighted discrete data{akϕα(2πfk)} N−1 k=0 to get weighted OFDM signal zN.

We transmit weighted OFDM signalzNfor the same time duration [0,NT]as the original OFDM signal.

We note that weightϕis positive on the real line; therefore, the modified weight ϕαis positive on the real line. Since ϕα(2πfk)=0for
anyk=0,...,N−1, the discrete data{ak} N−1 k=0
The PAPR of weighted OFDM is given by can be completely recovered.

$$\mathrm{PAPR}(z_N) = \frac{\max_{0\le t\le NT} |z_N(t)|^2}{E\left(|z_N(t)|^2\right)}$$

We note that a sufficient condition for a signal˜ ϕto be a proper weight is that˜ ϕ(2πfk)=0foranyk=0,...,N−1. We expect that the performance of the weighted OFDM system corresponding to ˜ ϕ depends on the smoothness of the Fourier transform of˜ ϕ.

V. SIMULATION RESULTS USING MATLAB

The performance of this proposed scheme is analysed through the simulations. In the simulations, 10 3 quadratic-phase-shift-keying (QPSK)-modulated OFDM symbols were randomly generated. Fig. 2 shows the CCDFs of the C&F method and the proposed method for N=128,256,512. The proposed method is simulated with a fixed shift parameter alpha=0.03, and several C&Fs are simulated with various clipping ratios CR=0.8, 1.2, 1.6, respectively.

As shown in the figure, the proposed scheme can reduce the PAPR around 3 dB for N=128 and 2 dB for N=512, respectively, at the 1% of the CCDF, compared with the C&F scheme. Note that the PAPR of the original OFDM signal exceeds 14.8 dB for N=128 and 16 dB for N=512, respectively. In Figs. 2 and 3, since the results induced by quadratic-amplitude modulation mapping are almost the same as those induced by QPSK mapping, here, we provide only the results induced by QPSK mapping.

Fig. 3 compares the C&F method with the proposed method for CCDFs and BER performance over the additive White Gaussian noise channel together. As shown in the figure, the BER performance and the CCDF of the proposed method with α=0.15 are superior to those of the C&F method for CR=0.8,1.2,1.6 when N=128 is fixed.

Output Waveforms:

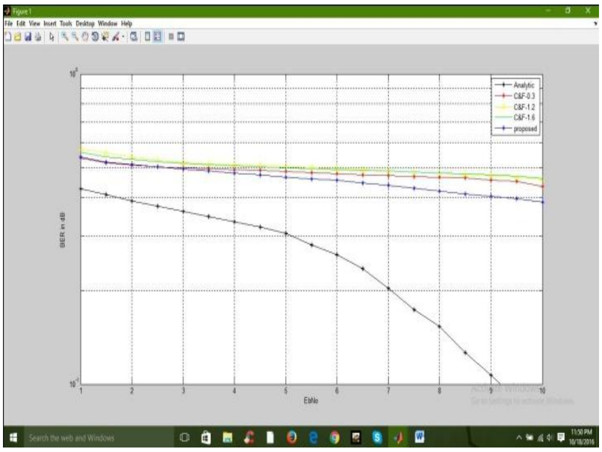

Fig :1

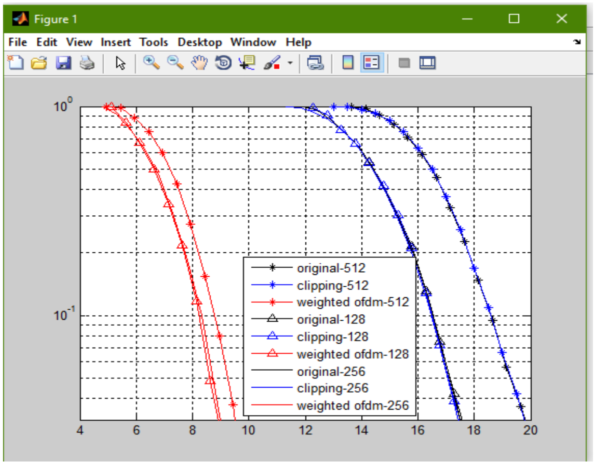

Fig :2

VI. CONCLUSION

A PAPR reduction scheme based on a weighted OFDM signal has been proposed to reduce the PAPR without data distortion in removing the weight at the receiver side in the mathematical view. To reduce the peak of the OFDM signal, a band limited signalϕ, which is not zero on the set{2πfk} N−1 k=0, is introduced, and we form weight ϕα=ϕ+α/logN for a suitable positive constant α.

We consider a weighted discrete data to form a weighted OFDM signal, which is defined on the same time interval as the original OFDM signal, before the HPA, where the weights are imposed by using signalϕ. It is shown that the PAPR of this weighted OFDM method is smaller than that of the C&F method, and the BER performance is improved compared with the C&F method. The schemes for reducing the peak-to-average-power-ratio are seen, few schemes also help in reducing the bit error rate though not to the required extent. The weighted OFDM scheme helps in achieving the goal of obtaining lesser peak-to-average-power-ratio as well as bit error rate. Yet to achieve the ideal case new methods are to be found which reduces the bit error rate and peak-to-average-power-ratio.

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BIOGRAPHIES

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