Analysis of OFDM BER and PAPR using TURBO CODE

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Abstract
The principles of Orthogonal Frequency Division Multiplexing (OFDM) modulation have been in existence for several decades. However in recent years the attention towards OFDM has grown rapidly in the field of wireless and wired communication systems because of its advantages. The main problem of OFDM is high Peak to average power ratio (PAPR) which affects the performance and efficiency of high power amplifier used in radio system. In this paper we review and analysis different PAPR reduction techniques. We also describe the comparision between OFDM BER using turbo code and PAPR reduction with different modulation technique using turbo code . In end we made conclusion that turbo code using qpsk technique is better to reduce PAPR and for BER turbo code with half rate is better.

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing which is one of multi-carrier modulation techniques offers a considerable high spectral efficiency, multipath delay spread tolerance, immunity to the frequency selective fading channels and power efficiency [1], [2]. As a result, OFDM has been chosen for high data rate communications and has been widely deployed in many wireless communication standards such as Digital Video Broadcasting (DVB) and based mobile worldwide.
Due to the large number of subcarriers, OFDM systems have a large dynamic signal range with a very high PAPR. As a result, the OFDM signal will be clipped when passed through a non linear power amplifier at the transmitter end. Clipping degrades the bit-error-rate (BER) performance and causes spectral spreading [3], [4]. One way to solve this problem is to force the amplifier to work in its linear region. Unfortunately, such a solution is not power efficient. Power efficiency is necessary in wireless communication as it provides adequate area coverage, saves power consumption, and allows small-size terminals. It is, therefore, important to aim at a power efficient operation of the power amplifier with low back-off values and try to prevent the occurrence of signal clipping. This can be done through some manipulations of the OFDM signal before transmission.
Therefore, it is important and necessary to research on the characteristics of the PAPR including its distribution and reduction in OFDM systems. To achieve the above objective, several proposals have been suggested and studied in the literature including clipping [4]–[5], Tone Reservation (TR) and Tone Injection(TI) [6], constellation shaping [7], Partial Transmission Sequence (PTS) and Selective Mapping (SLM)[8]–[9] and other techniques such as pre-scrambles proposed in [10]. These schemes can mainly be categorized into signal scrambling techniques, such as block codes and PTS etc., and signal distortion techniques such as clipping.
In this paper, firstly we investigate the distribution of PAPR based on the characteristics of the OFDM signals. Then, we analyze five typical techniques of PAPR reduction and in the end we compare all the technique on the basic of different characteristics.

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2. DEFINATION OF PAPR

1) Continuous-time PAPR
In general, the PAPR of OFDM signal x (t) is defined as the ratio between the maximum instantaneous power and its average power

$$PAPR\left[x(t)\right] = \frac{\max_{0 \le t \le NT}\left[x(t)^{2} \right]}{P_{av}}$$

Where Pav is the average power of x (t) and it can be computed in the frequency domain because Inverse Fast Fourier Transform (IFFT) is a (scaled) unitary transformation [11].

2) Discrete-time PAPR
The PAPR of the discrete time sequences typically determines the complexity of the digital circuitry in terms of the number of bits necessary to achieve a desired signal to quantization noise for both the digital operation and the DAC.

To better approximate the PAPR of continuous-time OFDM signals, the OFDM signals samples are obtained by L times oversampling. L-times oversampled time-domain samples are LN samples are L (n-1). Therefore, the oversampled IFFT output can be expressed as

$$x[n] \triangleq \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j\frac{2\pi nk}{LN}}, \quad 0 \le n \le LN-1$$

The PAPR is defined as the ratio between the maximum power occurring in OFDM symbol to the average power of the same OFDM symbol

$$PAPR = \frac{max|x(t)|^2}{E[|x(t)|^2]}$$

Where *E* [.] denotes expectation.

Unfortunately, OFDM has the drawback of a potentially high peak to average power ratio (PAPR). Since a multicarrier signal consists of a number of independent modulated subcarriers that can cause a large PAPR when the subcarriers are added up coherently. When the OFDM signal with high PAPR passes through a non-linear device, (power amplifier working in the saturation region), the signal will suffer significant non-linear distortion. This non-linear distortion will result in in-band distortion and out-of-band radiation. The in-band distortion causes system performance degradation and the out-of-band radiation causes adjacent channel interference (ACI) that affects system working in the neighbor bands. To lessen the signal distortion, it requires a linear power amplifier with large dynamic range. However, this linear power amplifier has poor efficiency and is so expensive [11].

3. MOTIVATION OF PAPR REDUCTION

1) Nonlinear Characteristics of HPA:-Most radio systems employ the HPA in the transmitter to obtain sufficient transmission power. For the proposed of achieving the maximum output power efficiency, the HPA is usually operated at or near the saturation region. Moreover, the nonlinear characteristic of the HPA is very sensitive to the variation in signal amplitudes. However, the variation of OFDM signal amplitudes is very wide with high PAPR. Therefore, HPA will introduce inter-modulation between the different subcarriers and introduce additional interference into the systems due to high PAPR of OFDM signals. This additional interference leads to an increase in BER. In order to lessen the signal distortion and keep a low BER, it requires a linear work in its linear amplifier region with a large dynamic range. However, this linear amplifier has poor efficiency and is so expensive. Power efficiency is very necessary in wireless communication as it provides adequate area coverage, saves power consumption and allows small size terminals etc. Hence, a better solution is to try to prevent the occurrence of such interference by reducing the PAPR of the transmitted signal with some manipulations of the OFDM signal itself [8], [11].

2).Power saving: - When a HPA have a high dynamic range, it exhibits poor power efficiency. It has been shown that PAPR reduction can significantly save the power, in which the net power saving is directly proportional to the desired average output power and it is highly dependent upon the clipping probability level.
Suppose that an ideal linear model for HPA, where linear amplification is achieved up to the saturation point, and thus we
obtain

$$\eta = \frac{0.5}{\text{PAPR}}$$

Where ή is the HPA efficiency and it is defined as ή = Pout, av/Pdc where Pout, av is the average of the output power and Pdc is the constant amount of power regardless of the input power.
To illustrate the power inefficiency of a HPA in terms of the PAPR, we give an example of OFDM signals with 256 subcarriers. In order to guarantee that probability of the clipped OFDM frames is less than 0.01%, we need to apply an input back off (IBO) equivalent to the PAPR i.e PAPR= 14.02 (25.235) and thus the efficiency of HPA becomes ή =1.98%. Therefore, so low efficiency is a strong motivation to reduce the PAPR in OFDM systems.

4. VARIOUS STEPS FOR FINDING PAPR

In this we described the flow chat for finding the value of PAPR [22] [23]. The various processes are describes as.

1.) First of all consider transmited OFDM signal which will be received by dividing a carrier modulated signal into many signal.

2.) Then find a maximum value or peak of transmitted OFDM signal.

3.) After that we will find out the mean value of transmitted of OFDM signal.

4.) After that we will use above defined formula and find out the value of PAPR

4.1 PAPR REDUCTION TECHNIQUES IN OFDM

In this section, we mainly discuss some typical techniques for
PAPR reduction in OFDM systems or to solve the above issues

1.) Clipping and Filtering: - The simplest and most widely used technique of PAPR reduction is to basically clip the parts of the signals that are outside the allowed region [12]. For example, using HPA with saturation level below the signal span will automatically cause the signal to be clipped. For amplitude clipping, that is

$$C(x) = \begin{cases} x, & x \le A \\ A, & x > A \end{cases}$$

Where A is preset clipping level and it is a positive real number

Generally, clipping is performed at the transmitter. However,

The receiver need to estimate the clipping that has occurred and

to compensate the received OFDM symbol accordingly. Typically, at most one clipping occurs per OFDM symbol, and thus the receiver has to estimate two parameters: location and size of the clip. However, it is difficult to get this information. Therefore, clipping method introduces both in band distortion and out of band radiation into OFDM signals, which degrades the system performance including BER and spectral efficiency.

Filtering can reduce out of band radiation after clipping although it can not reduce in-band distortion. However, clipping may cause some peak regrowth so that the signal after clipping and filtering will exceed the clipping level at some points. To reduce peak regrowth, a repeated clipping-and-filtering operation can be used to obtain a desirable PAPR at a cost of computational complexity increase. As improved clipping methods, peak windowing schemes attempt to minimize the out of band radiation by using narrowband windows such as Gaussian window to attenuate peak signal.

2). Pilot Tones and Unused Carriers: - OFDM-based applications, not all subcarriers are used to transmit the information data. Some subcarriers are set to zero to prevent out-of-band radiation. For example, in an IEEE802.11a system, 64 tones are employed, in which 48 tones are data carriers, 4 carriers are pilot tones and the remaining 12 tones have a value of zero and are unused. Since these unused tones do not affect the original data carriers, they can be used to reduce the PAPR without increasing the BER or a reduction in data through-put.

Although this results in a slight broadening of the original spectrum, it is possible for the spectrum to remain well inside the spectrum mask defined in the standards. Wang et al. [13-14] proposed a PAPR reduction technique through use of the unused tones in IEEE 802.11a.

This technique can be viewed as extension of PAPR reduction technique using clipping and filtering. The filtering technique is designed to alleviate out-of-band distortion but cannot correct

inband distortion. In this technique involves clipping but uses the unused carriers and phase information of the pilot tones to reduce the PAPR. It is an iterative process which converges quickly

The clipped time domain signal *c* is then converted back into the frequency domain using an FFT. The zeros in *m* of the outermost unused (free) sub-carriers are replaced with their corresponding clipped values in the frequency domain. The phase of the pilots in the frequency domain can be changed to the corresponding clipped phase in the frequency domain, while the amplitude is restored to a value of 1. All of the remaining values in the frequency domain are restored to their original value before clipping. The new transmit signal is generated after an IFFT.

Scaling algorithm:- Initially the scale factor αi at the first iteration is set to1. For αi+1 this is increased to β. if this causes a further decrease in PAPR at αi+2 the value of β increased, if not the new scale factor becomes β-§. This process continues until an optimum scale factor is found. Values of β and § were found empirically

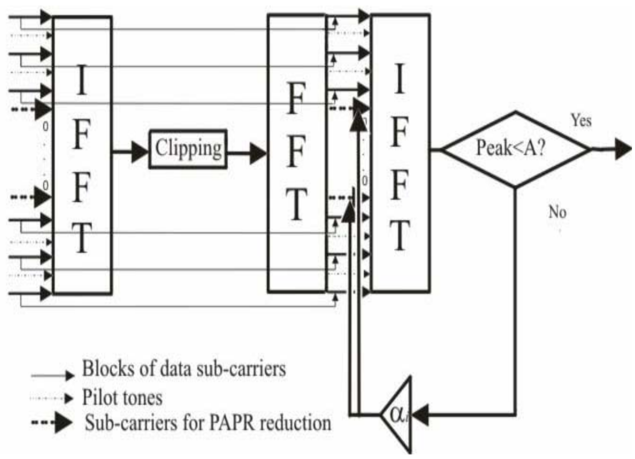

Figure1:- scaling algorithm

It can significantly reduce high peaks in the OFDM systems but introduces very low out-of-band distortion. It also has a lower BER than clipping and windowing due to no interference to the original data carriers before transmission [15].

3.) Coding technique:- The parity bits added in the block codes will correct a limited number of bit errors in each codeword. When the bit errors are closely clustered we say that the errors occur in bursts.

Convolution Coding:- Convolution codes are referred to as continuous codes as they operate on a certain number of bits continuously. Interleaving has mitigating properties for fading channels and works well in conjunction with these two types of coding. Convolution codes are commonly specified by three parameters; (n,k,m). where n = number of output bits,k = number of input bits, m = number of memory registers. The quantity *k/n* called the code rate is a measure of the efficiency of the code. Commonly *k* and n parameters range from 1 to 8, *m* from 2 to 10 and the code rate from 1/8 to 7/8 except for deep space applications where code rates as low as 1/100 or even longer have been employed .Often the manufacturers of convolution code chips specify the code by parameters (*n*,*k*,L). In above these L is called the constraint length of the code and is defined by Constraint Length, L = k (m-1) .The constraint length L represents the number of bits in the encoder memory that affect the generation of the *n* output bits. The constraint length L is also referred to by the capital letter K, which can be confusing with the lower case *k*, which represents the number of input bits. In some books K is defined as equal to product of the k and *m*.

4) *turbo code:-* Turbo codes were first presented at the International Conference on Communications in 1993. Until then, it was widely believed that to achieve near Shannon's bound performance, one would need to implement a decoder with infinite complexity or close. Parallel concatenated codes, as they are also known, can be implemented by using either block codes (PCBC) or convolution codes (PCCC). PCCC resulted from the combination of three ideas that were known to all in the coding community. The transforming of commonly used non-systematic convolution codes into systematic convolution codes. An iterative decoding algorithm centered on the last two concepts would refine its output with each pass, thus resembling the turbo engine used in airplanes. Hence, the name Turbo was used to refer to the process.

Turbo encoder:- Convolution encoding results from passing the information to be encrypted through a linear shift register. The encoder shown here is non systematic because no version of the uncoded input is part of the output. Convolution encoder can be represented by their generator polynomials. For the encoder below, g (1) = [111] and g (2) = [101].

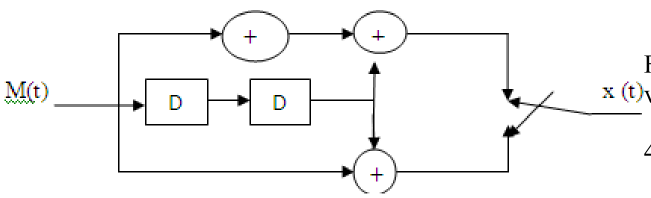

Figure2:- constraint length k=2 convolution encoder

4.2 Results

In this we are going to implement each block individually at transmitter side or at receiver side to produce accurate result.Here we compare the results of OFDM BER implemented by using turbo code .

Turbo code:- In this we show the graph between E_b/N_0 and BER for OFDM using turbo encoder and decoder at transmitter side and receiver side. In this same coding rate half is used and same generating polynomial. This shows that the value of BER will be reduced at value of E_b/N_0 9dB while for convolution it will be equal to 16 dB. So Turbo code is better technique to implement an OFDM system when coding rate is ½ when low error is required.

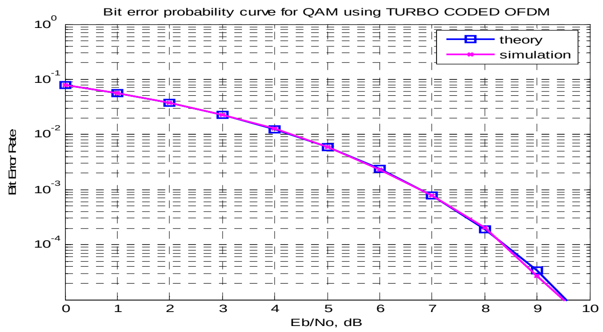

Figure4:-BER v/s SNR for Turbo codes

c) *PAPR (Peak to average power ratio):-* The graph below shows the value of PAPR for two modulation scheme using turbocode.

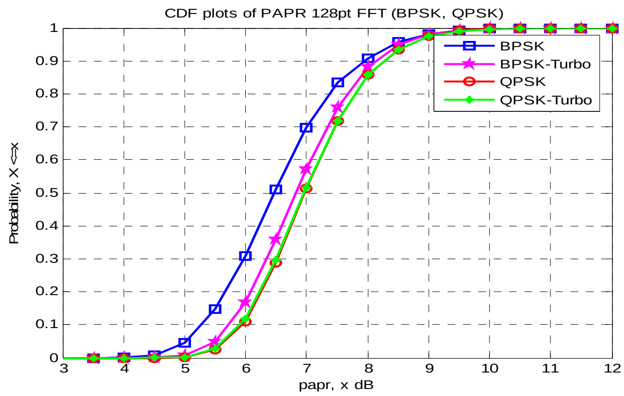

Figure 5:-PAPR with or without using Turbo codes for various modulation

4.3 Application of OFDM

OFDM has been chosen for several current and future communications systems all over the world. It is well suited for systems in which the channel characteristics make it difficult to maintain adequate communications link performance. Recently, OFDM has also been adopted into several European wireless communications applications such as the digital audio broadcast (DAB) and terrestrial digital video broadcast (DVB-T) systems.

1)Digital Broadcasting:-Standardized in 1995, Digital Audio Broadcasting (DAB) was the first standard to use OFDM. DAB uses a single frequency network, but the efficient handling of multi path delay spread results in improved CD quality sound, new data services, and higher spectrum efficiency. A broadcasting industry group also created digital Video Broadcasting (DVB) in 1993. DVB produced a set of specifications for the delivery of digital television over cable, DSL and satellite. Terrestrial network, Digital Terrestrial Television Broadcasting (DTTB), was standardized DTTB utilizes OFDM in up to 2,000 and 8,000 sub-carrier modes.

2)Terrestrial Digital Video Broadcasting:-A pan-broadcasting-industry group created Digital Video Broadcasting (DVB) in 1993. DVB produced a set of specifications for the delivery of digital television over cable, DSL and satellite. In 1997 the terrestrial network, Digital Terrestrial Television Broadcasting (DTTB) was standardized. DTTB utilizes OFDM in the 2,000 and 8,000 sub carrier modes.

3) IEEE 802.11a/HiperLAN2 and MMAC Wireless LAN:- OFDM in the new 5GHz band is comprised of 802.11a, HiperLAN2, and WLAN standards. In July 1998, IEEE selected OFDM as the basis for the new 802.11a 5GHz standard in the U.S. targeting a range of data rates up to 54 Mbps. In Europe, ETSI BRAN is now working on three extensions for OFDM in the Hiper LAN standard: (i) HiperLAN2, a wireless indoor LAN with a QOS provision; (ii) Hiper Link, a wireless indoor backbone; and (iii) Hiper Access, an outdoor, fixed wireless network providing access to a wired infrastructure

5. CONCLUSIONS

OFDM is a very attractive technique for wireless communications due to its high data rate, spectrum efficiency and channel robustness. One of the serious drawbacks of in OFDM systems is very high PAPR because a multicarrier signal consists of a number of independent modulated sub carriers. when the input sequences are highly correlated. In this paper,we described four typical techniques to reduce PAPR have been analyzed, all of which have the potential to provide substantial reduction in PAPR at the cost of loss in data rate, transmit signal power increase, BER performance degradation, computational complexity increase, and so on. Since turbocode are better in case of BER and provide low PAPR.

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