PAPR PERFORMANCE OF OFDM SYSTEM BY USING CLIPPING AND FILTERING METHOD

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ABSTRACT

Multicarrier schemes are supported to high data rate. Orthogonal Frequency Division Multiplexing (OFDM) and Filtered Multi-Tone (FMT) are two techniques of multicarrier schemes. OFDM is an attractive air-interface for next-generation wireless network without complex equalizer. OFDM is designed such a way that it sends data over hundreds of parallel carrier which increases data rate. OFDM scheme is suffer by inter-symbol interference (ISI) problem and peak-to-average power ratio (PAPR). An OFDM signal consists of a number of independently modulated carriers, which can give a large peak-to-average power ratio when added up coherently. When N signals are added with the same phase, they produce a peak power that is N times the average power. For this example, the peak power is 16 times the average value. The peak power is defined as the power of a sine wave with amplitude equal to the maximum envelope value. Hence, an unmodulated carrier has a PAP ratio of 0 dB. An alternative measure of the envelope variation of a signal is the Crest factor, which is defined as the maximum signal value divided by the RMS signal value. For an unmodulated carrier, the Crest factor is 3 dB. This 3-dB difference between the PAPR and Crest factor also holds for other signals, provided that the center frequency is large in comparison with the signal bandwidth. A large PAP ratio brings disadvantages like an increased complexity of the analog-to-digital (A/D) and digital-to-analog (D/A) converters and a reduced efficiency of the RF power amplifier.
To reduce the PAPR, many techniques have been proposed, such as clipping, coding, partial transmit sequence (PTS), selected mapping (SLM), interleaving, hadamard transforms and other techniques etc. Among those PAPR reduction methods, the simplest method is to use the clipping method. However, using clipping processing causes both in-band distortion and out-of-band distortion but this can be reduce by using filtering after clipping. This paper focus is on the clipping and filtering technique to reduce PAPR of OFDM system. Using simulation results the analyzing effect of clipping and filtering technique to reduce the PAPR.

KEYWORDS: *OFDM, FFT, IFFT, PAPR, PTS, CR*

I. INTRODUCTION

To meet the needs of 4th generation (4G) systems, the 3rd Generation Partnership Project has proposed the Long Term Evolution (LTE) specification. Amendment released by 3GPP basically made on physical layer and MAC layer of 3rd generation specifically in the modulation and multiple access schemes. In 3rd generation, IEEE 802.16 standard implements the OFDM for uplink and downlink [1,2]. In next generation, LTE (Long Term Evolution) used Orthogonal Frequency Division Multiplexing (OFDM) for its downlink and Single-Carrier Frequency-Division Multiple Access (SC-FDMA) for its uplink. Therefore in this generation, OFDM becomes a main multicarrier scheme for communication system. OFDM has emerged as a promising air interface technique. In Context of wired environments, OFDM techniques are also known as Discrete Multi Tone (DMT) transmissions and are employed in the American National Standards Institute's (ANSI) ADSL, HDSL and VDSL [16].However, any multicarrier signal with a large number of sub channels is hampered by PAPR. When passed through a nonlinear device, such as a high power amplifier, the signal may suffer significant spectral spreading and in-band distortion. The conventional solutions to this problem are to use a linear amplifier or to back off the operating point of a nonlinear amplifier; both approaches resulting in a significant power efficiency penalty. Moreover, the low data rate on the subcarriers mitigates the effect of the multipath. Advantage of OFDM system is that it can be implemented fast Fourier transform which makes it faster and efficient.

Unfortunately, due to high PAPR result, degraded the system performance by reducing the efficiency of the high power amplifier and also limits the dynamic range of Analog-to-Digital (A/D) and Digital-to-Analog (D/A) converters. These negative effects may compensate all the potential benefits of OFDM transmission system. In individual sub channels, the amplitude of the transmitted OFDM signal generally suffers from high peak-to-average power ratio (PAPR). This fact complicates implementation of the analog radio frequency (RF) frontend. When the PAPR is high, the digital-to-analog converter (DAC) and power amplifier (PA) of the transmitter require high dynamic ranges to avoid amplitude clipping. Such high dynamic range increases complexity, reduces efficiency, and increases cost of the components. On the other hand, if the dynamic range is too low, there would be substantial amount of signal distortion which in turn will raise the amount of bit error rate (BER). Furthermore, the distortion would cause unwanted out-of-band radiation. Several Scrambling, coding technique and signal distortion techniques have been proposed to overcome PAPR problem [6, 7, 8].

This paper is organized as follows: in section II, we describe the basic of PAPR. In section III, amplitude clipping and Filtering PAPR reduction techniques is analyzed. In section IV, we simulated and compare the clipping method with the different level of clip and filtering level. Finally, conclusions and future scope are made in section V according to simulation results and section VI respectively.

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

In general, even linear amplifier imposes a nonlinear distortion on their outputs due to their saturation characteristics. Figure 1 shows the input-output characteristics of high power amplifier. Due to the aforementioned saturation characteristic of the amplifier, the maximum possible output is limited when the corresponding input power is max. As illustrated in Figure 1, the input power must be backed off so as to operate in the linear region. Therefore, the nonlinear region can be described by IBO (Input Back-Off) or OBO (Output Back-Off) [1, 9, 10].

$$IBO = 10log_{10}\frac{P_{in}^{max}}{P_{in}} \quad \text{-------- 1}$$

$$OBO = 10log_{10}\frac{P_{out}^{max}}{P_{out}} \quad \text{-------- 2}$$

Note that the nonlinear characteristic of HPA (High Power Amplifier), excited by a large input, causes the out-of-band radiation that affects signals in adjacent bands, and in-band distortions that result in rotation, attenuation, and offset on the received signal [1].

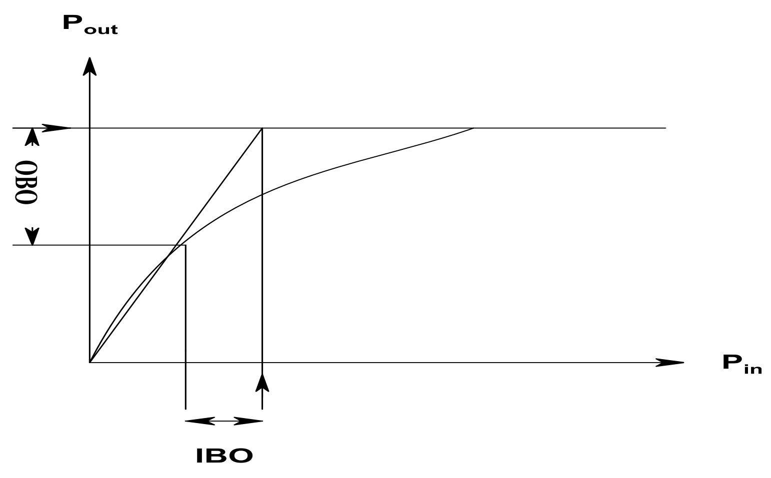

Fig. 1 Input output characteristic of an HPA

Consider a baseband PAM signal for a complex data sequence$\{a[n]\}$:

$$\tilde{s}(t) = \sum_k a[n]g(t - kT_s) \quad \text{----------} \; 3$$

Where is a transmit pulse for each symbol and is the symbol duration. PAM transmitter for Equation 3, in which the output of the pass band quadrature modulator is represented as

$$s(t) = \sqrt{2}\, R_e\{\tilde{s}_I(t) + j\tilde{s}_Q(t)e^{j2\pi f_c t}\} \quad \text{------------} \; 4$$

Where $\tilde{s}_I(t)$ and $\tilde{s}_Q(t)$ denote the in-phase and quadrature components of the complex base band PAM signal respectively.

PAPR (Peak to Average Power Ratio)

The success behind the implementation of OFDM system is that, it is more robust to multipath induced Inter Symbol Interferences (ISI) and has high spectral efficiency [11,12,17]. Despite these advantages, OFDM has some disadvantages that need to be addressed for its successful implementation. A major disadvantage of OFDM is that it generates signals with large amplitude variation which is known as Peak to Average Power Ratio (PAPR). The Peak to Average power Ratio can be simply defined as the ratio between the average signal power and the maximum or minimum signal. As we know that basic cause of a high PAPR in the OFDM signal is the Gaussian signal distribution which arises due to the large number of sub channels and their linear combination due to the IFFT operation. Now we will look at the mathematical definition of PAPR. Mathematically, the PAPR of complex pass band signal is given in equation 5.

$$PAPR\{\tilde{s}(t)\} = \frac{max\,\left|Re\left(\tilde{s}(t)e^{j2\pi t f_c}\right)\right|^2}{E\left\{\left|Re\left(\tilde{s}(t)e^{j2\pi t f_c}\right)\right|^2\right\}} = \frac{max|s(t)|^2}{E\{|s(t)|^2\}} \quad \text{---------} \; 5$$

The above power characteristics can also be described in terms of their magnitudes (not power) by defining the crest factor (CF) as

Pass-band Condition:

$$CR = \sqrt{PAPR} \quad \text{-----------------} \; 6$$

CDF: However, it is difficult to derive the exact CDF for the oversampled signals and therefore, the following simplified CDF will be used:

$$f_z(z) \approx \left(1 - e^{-Z^2}\right)^{\alpha N} \quad \text{------------------------} \; 7$$

III. CLIPPING AND FILTERING

A high PAPR brings disadvantages like increased complexity of the ADC and DAC and also reduced efficiency of radio frequency (RF) power amplifier. One of the simple and effective PAPR reduction techniques is clipping, which cancels the signal components that exceed some unchanging amplitude called clip level. In Clipping, the amplitudes of the input signal are clipped to a predetermined value. However, clipping yields distortion power, which called clipping noise, and expands the transmitted signal spectrum, which causes interfering. Clipping and filtering technique is effective in removing components of the expanded spectrum. Although filtering can decrease the spectrum growth, filtering after clipping can reduce the out-of-band radiation, but may also cause some peak re-growth, which the peak signal exceeds in the clip level [13,14].

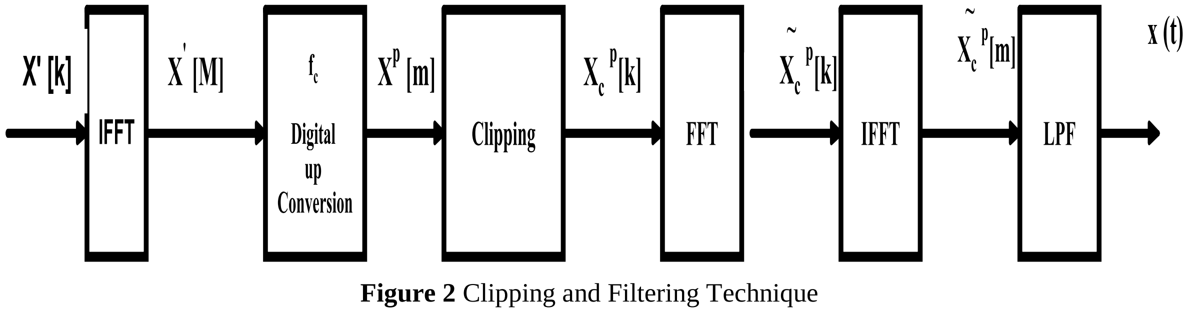

Figure 2 Clipping and Filtering Technique

The technique of iterative clipping and filtering reduces the PAPR without spectrum expansion. However, the iterative signal takes long time and it will increase the computational complexity of an OFDM transmitter. But without performing interpolation before clipping causes it out-of-band. To avoid out-of-band, signal should be clipped after interpolation. However, this causes significant peak re-growth. So, it can use iterative clipping and frequency domain filtering to avoid peak re-growth [4]. In the system used, serial to parallel converter converts serial input data having different frequency component which are base band modulated symbols and apply interpolation to these symbols by zero padding in the middle of input data. Then clipping operation is performed to cut high peak amplitudes and frequency domain filtering is used to reduce the out of band signal, but caused peak re-growth [4,17]. This consists of two FFT operations. Forward FFT transforms the clipped signal back to discrete frequency domain. The in-band discrete components are passed unchanged to inputs of second IFFT while out of band components are null. Clipping introduces in band distortion and out-of-band signals, which can be controlled by proper filtering [13].

$$x_c^p[m] = \begin{cases} x^p[m] & if\ |x^p[m]| < A \\ \frac{x^p[m]}{|x^p[m]|} \cdot A & Otherwise \end{cases} \quad \text{---------------} \; 8$$

Where, A is the pre-specified clipping level. Note that Equation (8) can be applied to both baseband complex-valued signals and pass band real-valued signals be applied only to the passband signals. Let us define the clipping ratio (CR) as the clipping level normalized by the RMS value s of OFDM signal, such that

$$CR = \frac{A}{\sigma} \quad \text{---------------} \; 9$$

IV. SIMULATION PARAMETER AND RESULT

The values of parameters used in the QPSK/OFDM system for analyzing the performance of clipping and filtering technique are as fallows. Bandwidth= 1MHz, fs = 8 MHz, carrier frequency= 2MHz, FFT size = 128, CP= 32 and clipping ratio = 1.2. Figure 3 shows the impulse response and frequency response of the finite-duration impulse response (FIR) BPF used in the simulation where the sampling frequency fs = 8 MHz, the stop band and pass band edge frequency vectors are [1.4, 2.6][MHz] and [1.5, 2.5] [MHz], respectively, and the number of taps is set to 104 such that the stop band attenuation is about 40dB.

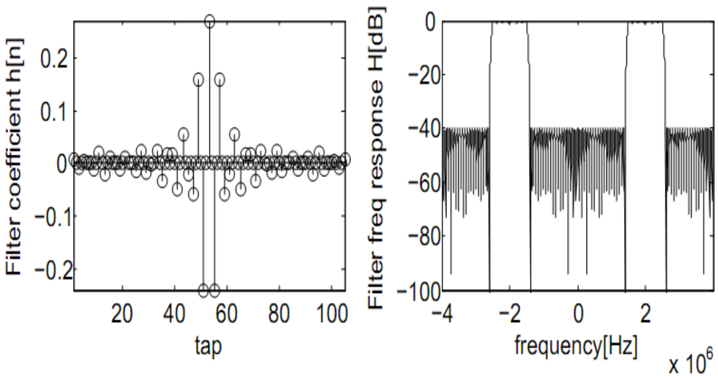

Figure 3 Characteristics of pass band FIR filter

Figure 4 shows the results for clipping and filtering of OFDM signals with the parameter values listed above. Figures show the histograms as probability density functions (PDFs) and power spectra of the oversampled baseband OFDM signal$x'[m]$, the corresponding pass band signal$x^p[m]$, the pass band clipped signal$x_c^p[m]$, and its filtered signal $\tilde{x}_c^p[m]$.

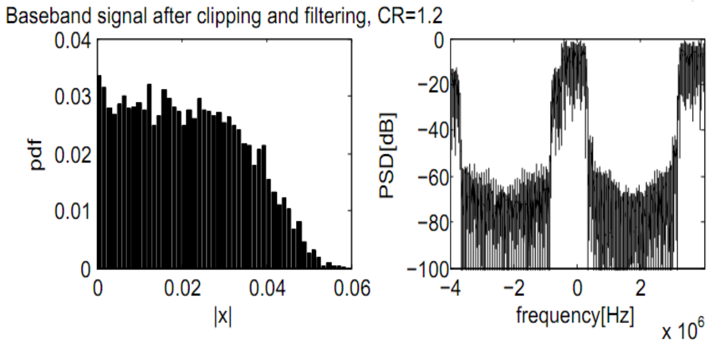

Figure 4 Power spectrum of Baseband and PDF of pass band signal

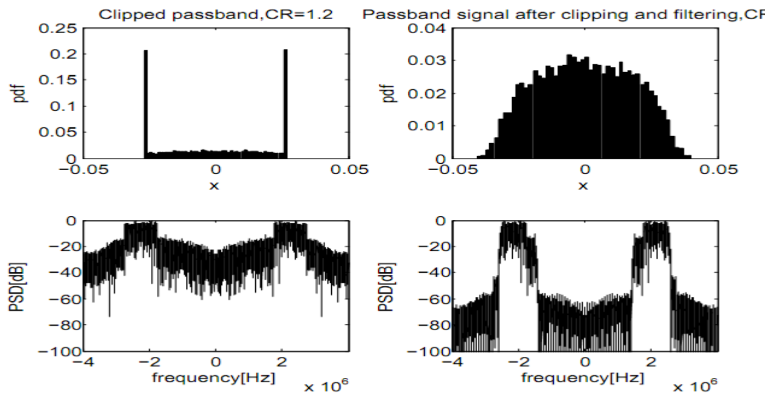

Figure 5 PDF and Power Spectrum of Clipped and Filtered signal

It can be seen from Figure 5 that the OFDM signal approximately follows a Gaussian distribution. Meanwhile, the amplitude of the clipped signal is distributed below the clipping level. The filtered signal shows its peak value beyond the clipping level. It can also be seen that the out-of-band spectrum increases after clipping, but decreases again after filtering.

V. CONCLUSION

In this paper clipping and filtering method of reduction of PAPR is analyzed and its effects are considered. There are several techniques to handle PAPR problem. The clipping is simple method with minimal computing complexity. We reduce PAPR by just clipping the excessive peaks. The pass band signal has a PAPR in OFDM, so after clipping the PAPR considerably reduce. PPAR further reduce by using filtering. This clipping and filtering provides good PAPR reduction and increase signal noise immunity.

VI. FUTURE SCOPE

An OFDM signal consists of a number of independently modulated subcarriers, which can give a large peak to average ratio when added up coherently. This produces the distortion in channel. Mostly non-linear amplitude clipping algorithm was used to reduce the PAPR of OFDM systems. Amplitude clipping resulted in out-of-Band spectrum spillage. Also the BER and PER performance was degraded by the implementation of the amplitude clipping algorithms. There are several clipping techniques where each of the techniques tries to minimize the out-of-band radiation, the BER and PER. An alternative direction is use to coding of the incoming bit-stream such that the resulting IFFT output had a lower PAPR. Lot of researched is done on code for reducing PAPR, such as convolution code, Gloay code, LDPC code, M-sequence (Maximum Length) codes and partial M-sequence codes. All these codes are designed for low order modulation systems. Not much literature is found on techniques to reduce the PAPR for higher order modulated OFDM systems with very large number of sub-carriers. Adaptive scheme may be develop using concatenated coding are being thought of which shall be integrated with OFDM to minimize the burst error and PAPR.

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