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Effect of Clipping Ratio on Bit Error Rate Performance of Clipped and Filtered OFDM Signal

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Abstract

Wireless communications is regarded as the most important development with wide range of applications. Advances and development in this field aim for fast and reliable communication. Orthogonal frequency division multiplexing signal provides high spectral efficiency and ease of implementation. But it suffers from high peak to average power ratio. This paper presents the effect of clipping ratio on bit error rate performance for a clipping and filtering technique, which is widely used to reduce high peak to average power ratio.

Keywords: Bit error rate, CCDF, Clipping, Ortho frequency division multiplexing, Peak to average power ratio

Introduction

Ortho frequency division multiplexing (OFDM) is an extension of frequency division multiplexing (FDM) [1]. FDM divides the available bandwidth into many narrow sub bands and uses a large number of parallel narrow band subcarriers. The use of orthogonal subcarriers allows the subcarriers spectra to overlap. Due to orthogonality it is possible to recover the individual subcarriers signals despite the overlapping spectra and thus there is no need of guard intervals as required in FDM [2]. Orthogonal subcarriers usage also helps to decrease the implementation complexity of both transmitter and receiver.

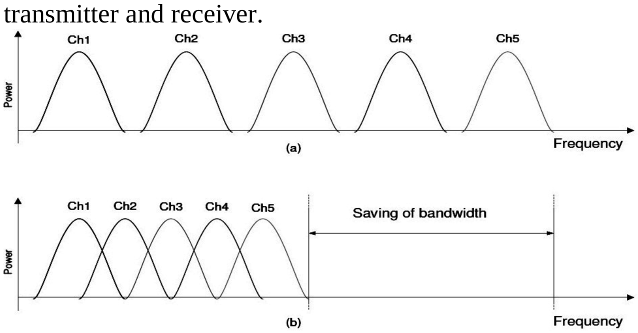


Fig.1. Comparison of FDM and OFDM

The available bandwidth is utilized very efficiently in OFDM systems without causing the ICI (inter-carrier interference). By combining multiple low-data-rate sub-carriers, OFDM systems can provide a composite high-data-rate with a long symbol duration. OFDM system has advantages of high spectral efficiency, Simple implementation by Fast Fourier transform (FFT), Low receiver complexity, robust ability for high data rate transmission over multipath fading channel, high flexibility in terms of link adaptation, low complexity multiple access schemes such as orthogonal frequency multiple access (OFDMA).But it suffers from relatively higher peak to average power ratio. High PAPR is serious problem arising for an OFDM system [3-7]. If the signal comprises the sum of N sinusoids each of maximum amplitude A, then it is possible that at some point all sinusoids will be added with the maximum amplitudes and the amplitude of resulting signal at this point will be NA. These large peaks disturb out of band energy and therefore increase in-band noise and can cause the saturation in power amplifiers, leading to increasing Bit error rate (BER) when the signal has to go through the amplifier non-linearity. Therefore, it is desirable to reduce the PAPR. PAPR can be defined mathematically as:

$$PAPR = \frac{\max_{t\in[0,T]} |s(t)|^2}{E\{|s(t)|^2\}} \qquad (1)$$

Where s (t) is the modulated OFDM signal and E {} is the expected value or average value. For large values of N assuming that s (t) is the sum of N sinusoids it is possible to apply the central limit theorem to s (t). In accordance with central limit theorem the real and imaginary part of s (t) have the Gaussian distribution. In accordance with central limit theorem the real and imaginary part of $s(t)$ have the Gaussian distribution. That means the amplitude of the OFDM signal has a Rayleigh distribution with zero mean and a variance of Nv, where v is the variance of one subcarrier. Then the cumulative distribution function (CDF) for the PAPR per OFDM symbol is given by:

$$\Pr\{PAPR\rangle\gamma\} = 1-(1-e^{\gamma})^N \qquad (2)$$

The expression (2) confirms that large peaks occur quite rarely. However, even rare large peaks can distort signal significantly. Clipping and filtering is widely used to suppress high PAPR [10-11]. In this paper bit error rate (BER) performance of clipping and filtering technique has been investigated.

Clipping and Filtering

In PAPR reduction schemes clipping, being considered the simplest, limits the maximum of transmit signal to a pre-specified level. Clipping ha disadvantages of BER performance degradation which occurs because of the in-band signal distortion caused by Clipping and Out-of-band radiation is caused by clipping imposing out-of-band interference signals to adjacent channels. The out-of-band signals caused by clipping can be reduced by filtering it may affect high-frequency components of in-band signal (aliasing) when the clipping is performed with the nyquist sampling rate in the discrete-time domain. But if clipping is performed for the sufficiently-oversampled OFDM signals (e.g., $L \geq 4$) in the discrete-time domain before a low-pass filter (LPF) and the signal passes through a band-pass filter (BPF), the BER performance will be less degraded [12]. **Peak re-growth** is the problem faced by the system when filtering the clipped signal is used to reduce out-of-band radiation. The signal after filtering operation may exceed the clipping level specified for the clipping operation [36]. PAPR reduction scheme using clipping and filtering is shown in Figure 2 where L is the oversampling factor and N is the number of subcarriers. In this scheme, the L-times oversampled discrete-time signal $x'[m]$ is generated from the IFFT ($X'[k]$ with $N \cdot (L-1)$ zero-padding in the frequency domain) and is then modulated with carrier frequency f_c to yield a pass band signal $x^p[m]$. Let $x_c^p[m]$ denote the clipped version of $x^p[m]$, which is expressed as:

$$x_c^p[m] = \begin{cases} -A & x^p[m] \leq -A \\ x^p[m] & |x^p[m]| < A \\ A & x^p[m] \geq A \end{cases} \qquad (3)$$

Or

$$x_c^p[m] = \begin{cases} x^p[m] & \text{if } |x^p[m]| < A \\ \dfrac{x^p[m]}{|x^p[m]|} \cdot \mathrm{A} & \text{otherwise} \end{cases}$$

(4)

where A is the pre-specified clipping level. Note that Equation (4) can be applied to both baseband complex-valued signals and passband real-valued signals, while Equation (3) can 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

$$CR = \frac{A}{\sigma} \qquad (5)$$

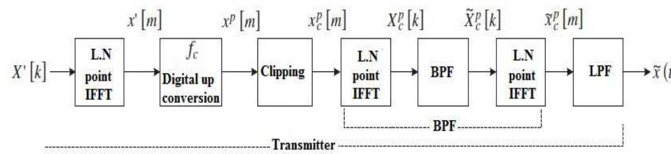
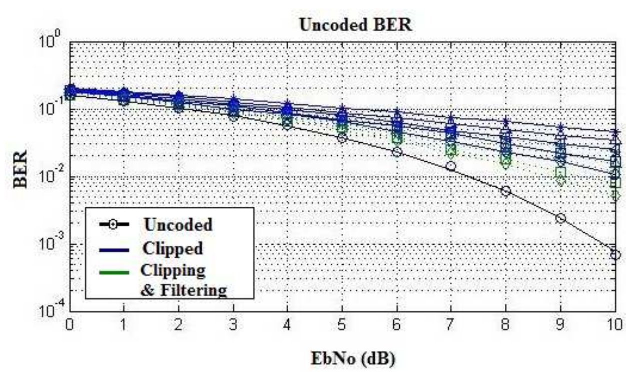


Fig. 2 Block diagram of a PAPR reduction scheme using clipping and filtering

Simulation Results

Crest factor being the square root of PAPR facilitates in determining the PAPR distribution. The BER performance is shown in Fig 3.



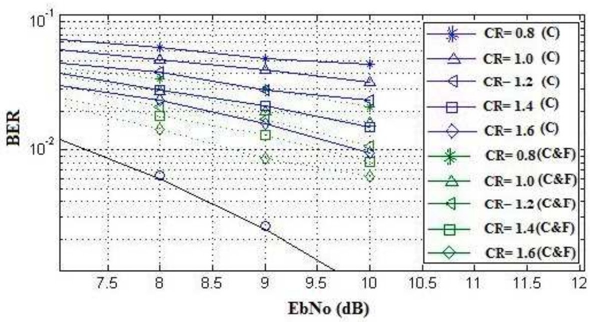


Fig 3 BER Performance of OFDM signal

From the analysis of the PAPR results presented above it can be concluded that the PAPR of the OFDM signal decreases significantly after clipping. To avoid out of band radiations caused by clipping, filtering is done, which increases the PAPR. The BER performance becomes worse as the clipping ratio decreases.

Conclusion

Due to its high spectral efficiency, OFDM is becoming popular choice these days. But OFDM suffers from high PAPR. High PAPR can be reduced using clipping and filtering. Simulation results show that as the clipping ratio increases, BER performance of OFDM signal degrades.

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