2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

A study of the peak-windowing performance considering the impact of the window width

Ali CHEAITO and Yves LOUET
IETR / CentraleSupélec, Campus de Rennes, Av. de la Boulaie, Cesson-Sévigne, France

Résumé

The peak windowing is one of the simpliest and most effective Peak-to-Average Power Ratio (PAPR) reduction techniques. In this study the effect of the used window width is discussed in terms of the signal quality-metrics, i.e., the Error Vector Magnitude (EVM), the Adjacent Chanel Power Ratio (ACPR) as well as the PAPR reduction gain. Based on our results, very good compromises between all these criteria could be achieved with respect to the standards requirements.

1 Introduction

Peak-to-Average Power Ratio (PAPR) remains a serious problem in several communication systems using multicarrier modulation technique. Amplifying a signal with a high PAPR value close to the saturation zone of the Power Amplifier (PA) results in strong nonlinear distortions and dramatical degradation of the Bit Error Rate (BER). On the other, large amount of power back-off results in a significant penalty in terms of the PA power efficiency. As a result PAPR reduction is a straightforward way to deal with with the fluctuation of the time domain signal, and then to achieve better trade-off between the PA linearity and power efficiency.

Many PAPR reduction techniques have been proposed to address this problem [1]. Among those techniques the peak windowing method [2], [3], found its way into practical implementation as it does not require any transmission of side information nor modification of the receiver structure. Moreover, it does not cause any peak regrowth and maintain a good spectral characteristic compared to the clipping method with comparable complexity [2].

Built on the idea of smooth attenuation of peaks to avoid sharp corners caused by direct clipping, peak windowing uses weighted window function instead of hard clipper function. Several window functions can be adopted such as Hamming, Kaiser or Gaussian window. In practice, each peak is processed by a window function weighted by the amount of the peak above the clipping level and the overall window function is the superposition of the sequence of all peak window functions. In literature, several studies have investigated the weight of the window function in order to overcome some drawbacks of the peak windowing technique. One example of these drawbacks is the consecutive peaks problem : when consecutive peaks cluster together, neighboring peak window functions will unfortunately overlap leading to over-attenuation.

Nevertheless, to our best knowledge, no study has investigated the impact of the width of the window function on the technique performance. In this paper we will investigate the Error Vector Magnitude (EVM) and the Adjacent Chanel Power Ratio (ACPR) performence as well as the effectiveness of the PAPR reduction of the peak windowing technique as a function of the width of the used window function.

2 The impact of the window width on peak-windowing performance

The basic idea of peak windowing is to multiply the envelop of the signal, denoted by $x(t)$, by a weighting function $b(t)$. Thus, the envelope of signal after peak windowing, $\tilde{x}(t)$, is expressed as

$$\tilde{x}(t) = x(t).b(t). \tag{1}$$

In this study, the Gaussian pulse shape is considered because it is optimally concentrated both in time and frequency domain. Therefore, the weighted function given by $b(t)$ is composed of a sum of Gaussian pulses as

$$b(t) = 1 - \sum_{n=-\infty}^{\infty} a_n.w(t-t_n). \tag{2}$$

Note that t_n is the position of a local maximum of the envelop, $x(t)$, and a_n denotes the attenuation constant. $w(t)$ is the Gaussian window function given by

$$w(t) = e^{-\gamma t^2} \tag{3}$$

where γ controls the width of the window.

In the literature, the width of the used window is usually fixed to ensure a good spectral characteristics. Then, the optimization of the technique are usually based on this fixed width. Although the width of the used function directly impacts the signal spectrum, it has also a strong effect on the in-band error of the signal as well as on the PAPR reduction gain.

For example, the use of a broad pulse, results in a narrow band weighting function. Therefore, the out of band distortions are mitigated in this case. But simultaneously, the envelope is changed even more what results in higher EVM values. On the other hand, the use of a narrow pulse leads to a large band weighting function. Thus, the EVM will decrease as the envelope distortions are less with narrow width pulse. However, this will generate an adjacent channel spectral regrowth as the band of the window is larger which will lead to a degradation of the ACPR.

Even though these concepts appear intuitive, they hide very interesting trade-off between EVM, ACPR and the PAPR reduction gain that should be well investigated. To the best of our knowledge, no study has investigated the impact of the width of the used window on the peak windowing performance.

3 Simulation Results

Simulations are used to clarify the effect of the window width on the peak windowing performance. The simulated system employs an OFDM signal with 1024 subcarriers using 16 QAM. The mean PAPR of the signal before peak windowing is 9.4 dB. We fixed the threshold, $\frac{A^2}{P}$, at 6.5 dB. Note that A is the amplitude threshold and P is the signal average power. Fig. 1, 2, 3 represent the ACPR, the EVM, and the mean PAPR as a function of γ, respectively.

As expected, we remark that when γ increases, the ACPR increases while the EVM decreases. On the other hand, we can notice that the maximum PAPR reduction gain is obtained when γ =13. In the literature, the typical used value of γ is equal or less to 5 which guaranties a good spectral characteristics. However, standards generally let a degree of freedom by providing a spectral mask limit. Therefore, the values of γ that are greater than 5 could be acceptable for some given standards. Thus, we can imagine different scenarios for different γ values. For example, if the ACPR of -30.6 dB falls below the spectrum mask (for a given standard), we can choose a γ value of 13. Even if the ACPR value will increase by 0.5 dB, in this way we will decrease the EVM from 6.5% to 4%, and we will decrease the PAPR of the signal from 7.1 dB to 6.83 dB.

Thus, based on these curves we conclude that we can improve the performance of the peak windowing by optimizing the PAPR reduction gain with respect to the EVM and ACPR requirements. As a result, a smart solution for future implementations would be to control the peak windowing parameters (i.e., the threshold and the window width) in a flexible way to meet a various EVM and ACPR target values related to different qualities of service.

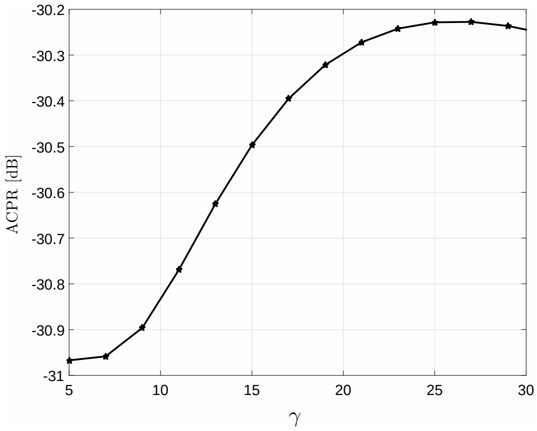

FIGURE 1. The ACPR as a function of γ.

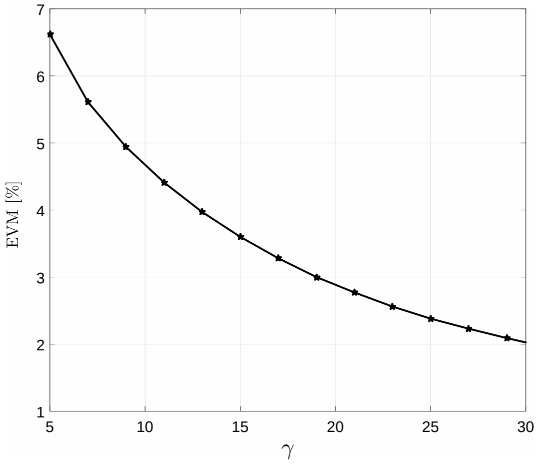

FIGURE 2. The EVM as a function of γ.

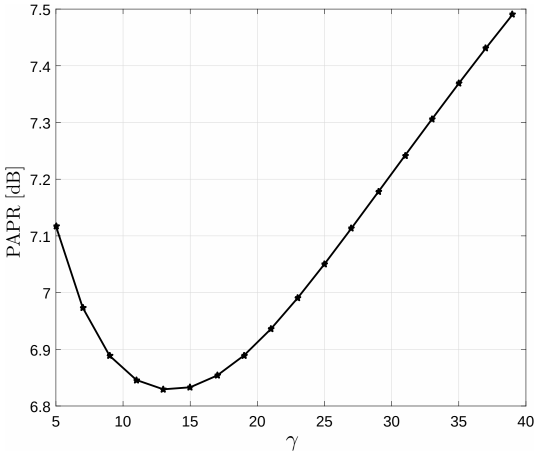

FIGURE 3. The PAPR reduction gain as a function of γ.

4 Conclusion

The impact of the width of the window function on the peak windowing performance is studied in terms of the signal quality-metrics, i.e., the EVM, the ACPR as well as the PAPR reduction gain. Based on this study, we conclude that the width of the window function should be wisely chosen in order to maximize the PAPR reduction gain while respecting the standards requirements in terms of EVM and ACPR.

Références

[1] S. H. Han and J. H. Lee, "An overview of peak-to-average power ratio reduction techniques for multi-carrier transmission," *IEEE Wireless Communications*, vol. 12, no. 2, pp. 56–65, April 2005.

[2] M. Pauli and P. Kuchenbecker, "On the reduction of the out-of-band radiation of ofdm-signals," in *1998 IEEE International Conference on Communications, ICC 98. Conference Record.*, vol. 3, Jun 1998, pp. 1304–1308.

[3] R. V. Nee and A. de Wild, "Reducing the peak-to-average power ratio of ofdm," in *Vehicular Technology Conference, VTC 98. 48th IEEE*, vol. 3, May 1998.