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EXPLOITING LDPC CODES FOR IMPROVING THE PERFORMANCE OF CLIPPED-OFDM SYSTEM

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique that becomes the best choice in wireless high-data-rate transmission. The drawbacks of OFDM are high Peak-to-Average Power Ratio (PAPR) and sensitivity to frequency offset. High PAPR decreases the amplifier's efficiency. The simplest PAPR reduction method is clipping, but it gives in-band and out-of-band distortion that degrades the performance of the system. There are various types of clipping, such as classical clipping, deep clipping, and smooth clipping. This paper analyses the use of low-density parity-check (LDPC) codes as an error correction coding (ECC) for those various types of clipping. The simulation results show that classical clipping gives the best performance in PAPR reduction and error probability.

Keywords: Classical Clipping; Deep Clipping; LDPC Codes; OFDM; PAPR; Smooth Clipping

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM), as a multicarrier transmission, has become popular both in wireless and wired communication. In wired communication, it is known as Discrete Multitone Transmission (DMT). OFDM is a modulation scheme for high data rate transmission in a dispersive delay condition (Molisch, 2011). The data is transmitted in parallel using orthogonal sub-carriers. Thus, it yields the overlapping spectrum (Pun et al., 2007).

One of the drawbacks in OFDM system is high peak-to-average power ratio (PAPR) (Juwono & Gunawan, 2009). It happens because of superposition of the in-phase signals. High PAPR causes inefficiency in the amplifier. In many low-cost applications, high PAPR reduces the potential advantages.

Clipping is the simplest PAPR reduction technique. There are many research papers about clipping. In (Langlais et al., 2011), low density parity check (LDPC) as error correction coding (ECC) is used to compensate the bit error rate (BER) because of classical clipping. In (Soriano & Marciano, 2006), performance of various types of clipping, i.e. classical, heavy-side, deep, and smooth clipping, are compared and analyzed.

This paper compares and analyzes the performances of OFDM system by implementing LDPC codes to the three types of clipping, namely classical clipping (CC), deep clipping (DC), and smooth clipping (SC). We do not compare the heavy-side clipping because it gives the worst performance. The rest of this paper is organized as follows. Section II discusses the OFDM and PAPR theory, as well as clipping and LDPC review. The system model used in this research appears in Section III. The simulation results and the analysis are given in section IV while section V concludes the performances of LDPC codes in various types of clipping.

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2. OVERVIEW OF OFDM, PAPR, CLIPPING, AND LDPC CODES

2.1 OFDM and PAPR

OFDM signal in discrete form can be expressed as

$$x[n] = \sum_{n=0}^{N_{sc}-1} X[k] e^{\frac{j2\pi kn}{N_{sc}}} \quad (1)$$

where $X[k]$ is the modulated signal and N_{sc} is the number of sub-carriers. Observation of Eq. (1) leads us to simplify the notation by using N-point IFFT to yield the OFDM signals. By using IFFT, the complexity of the transmitter can be reduced.

The PAPR can be defined as the ratio between maximum power and average power in one OFDM symbol. It denotes as

$$PAPR = \frac{\max|s[k]|^2}{E\{|s[k]|^2\}} \quad (2)$$

where $E\{\bullet\}$ is the expectation of random signal. The PAPR is usually analyzed by using statistical parameters, namely the complementary cumulative density function (CCDF). CCDF shows the probability that PAPR exceeds a certain level.

2.2 Clipping

Clipping means to cut the signal's amplitude exceeding a certain level. This is the simplest method for reducing the PAPR. It, however, causes in-band and out-of-band distortion and therefore degrades the BER and increases the out-of-band emission respectively.

As stated before, this paper only discusses three types of clipping: classical, deep, and smooth. The formula for each type of clipping is given by

Classical clipping

$$f(r) = \begin{cases} r, & r \le A \\ A, & r > A \end{cases} \quad (3)$$

Deep clipping

$$f(r) = \begin{cases} r, & r \le A \\ A - p(r-A), & A < r \le \frac{1+p}{p} A \\ 0, & r > \frac{1+p}{p} A \end{cases} \quad (4)$$

Smooth clipping

$$f(r) = \begin{cases} r - \frac{1}{b} r^3, & r \le 1.5A \\ A, & r > 1.5A \end{cases} \quad (5)$$

where A is clipping level, p is depth factor, and $b = 27A^2/4$. Another parameter that characterizes the clipping performance is clipping ratio that is given by $CR = A/\sigma$, where σ is the rms level of the OFDM signal.

The transfer functions of the three types of clipping are shown in Figure 1.

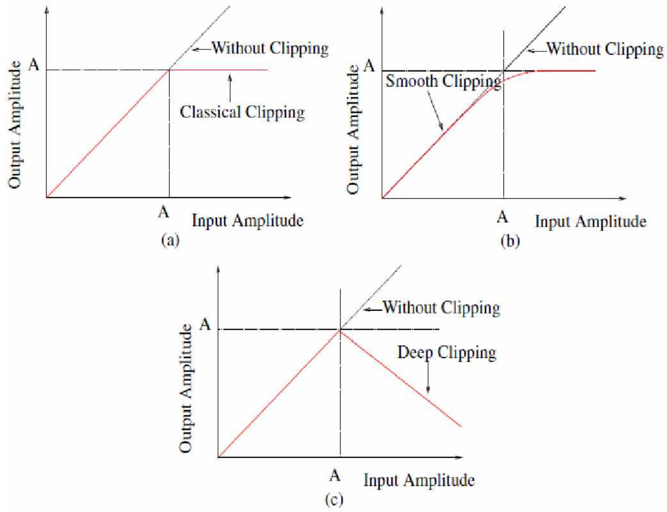

Figure 1 Clipping transfer functions: (a) classical clipping, (b) deep clipping, (c) smooth clipping (Guel & Palicot, 2009)

2.3 LDPC Codes

LDPC codes are linear codes with an iterative decoding algorithm. It was proposed by Gallager in 1962 and almost forgotten for about 30 years. Today, LDPC becomes popular because of its performance that is close to Shannon's limit.

The (N, K) LDPC codes have parity check matrix **H** sized M x N, where K = N – M and R = K/N. All the rows of the parity check matrix must be linearly independent. In this paper, the generation of **H** uses Log Sum Product Algorithm (Log-SPA) (MacKay, 1997).

3. METHODOLOGY

The block diagram used in this paper appears in Figure 2. The input bit is first encoded by using LDPC encoder. The encoded data will be mapped by using QPSK. Then, they will be form into parallel and processed by IFFT block before added cyclic prefix. Afterwards, the process of clipping will be applied. Clipping is usually followed by filtering to suppress the out-of-band emission. At the receiver, the reverse processes are applied, including the soft decision demapping and LDPC encoding.

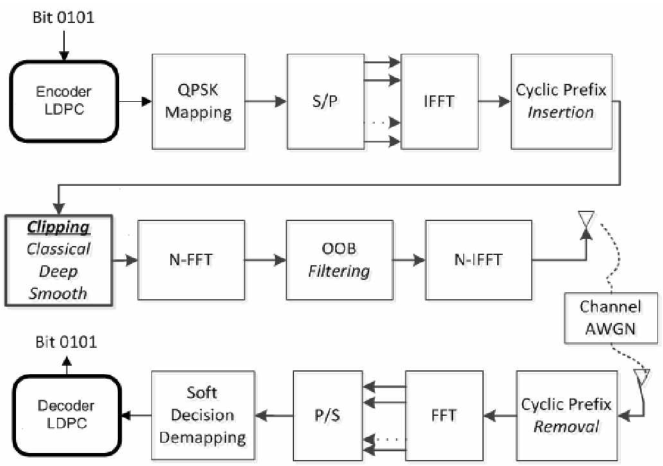

Figure 2 System model

4. NUMERICAL RESULTS AND ANALYSIS

The values of the parameters used in this simulation are shown in Table 1. We will analyze the performance of the system by looking through the CCDF, power spectral density (PSD), and bit error rate (BER). PSD is used to analyze the out-of-band (OOB) emission.

Tabel 1 Simulation Parameters and Their Values

Parameters	Values
nIFFT	256
Oversampling	4
Bit number	640,000
Channel	AWGN
Modulation	QPSK
Cyclic prefix length	25% (Pradabpet, et. al., 2008)
Deep factor (p)	0.6 (Kimura, et. al., 2008)
Clipping ratio	1.4 (Li & Cimini, 1998)
LDPC decoder	Log-Sum-Product
Maximum iteration	10
Code rate	1/2

Figure 3 shows the PSD comparison between the original OFDM system and OFDM systems with three types of clipping. It shows that the lowest and the highest OOB emission are for CC and SC respectively. The difference is approximately 5 dB.

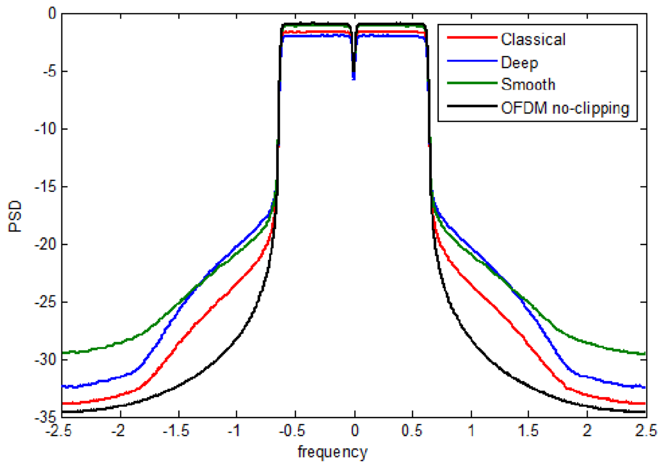

Figure 3 PSD comparison

Figure 4 shows the CCDF for system without clipping, and systems with CC, DS, and SC without LDPC codes. It shows that DC yields the biggest PAPR reduction, about 4 dB, followed by CC and SC for about 3dB and 1 dB respectively. The use of LDPC codes does not affect the PAPR as shown in Figure 5.

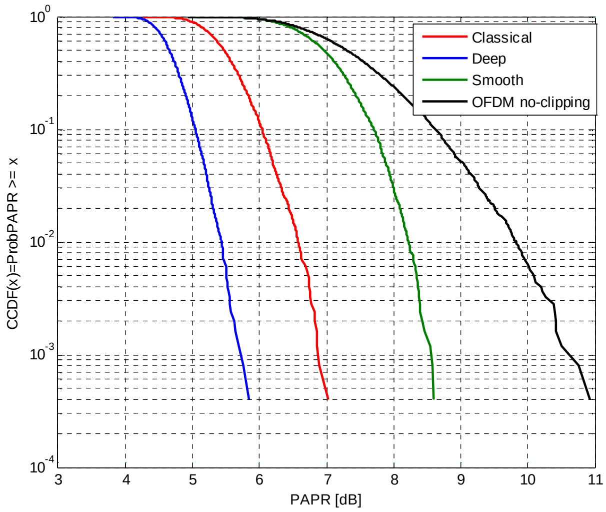

Figure 4 CCDF comparison, system without LDPC codes

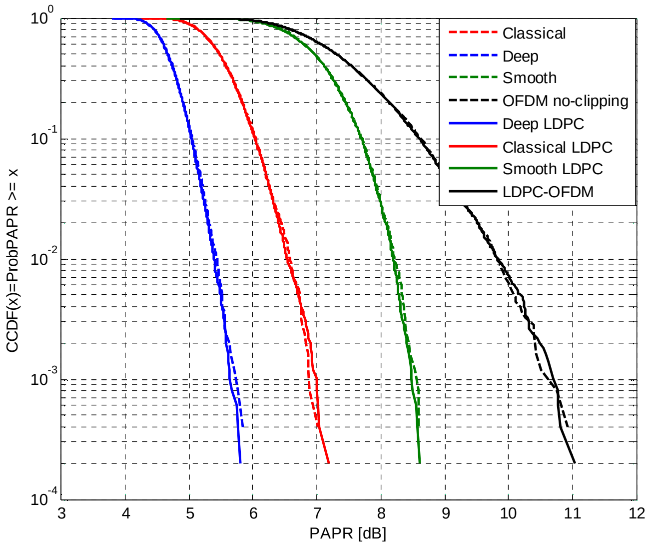

Figure 5 CCDF comparison, system with LDPC codes

The BER for OFDM system, both with and without LDPC codes, using CC, DC, and SC appears in Figure 6. It is obvious that clipping degrades the BER. The level of degradation, however, is different for each type of clipping. The system with CC and SC yield nearly the same BER. But, when LDPC codes are applied, system with SC yields better BER than one with CC. Overall, the implementation of LDPC codes improves the BER performance of the system, although clipping process means the system performance is worse than the one without clipping.

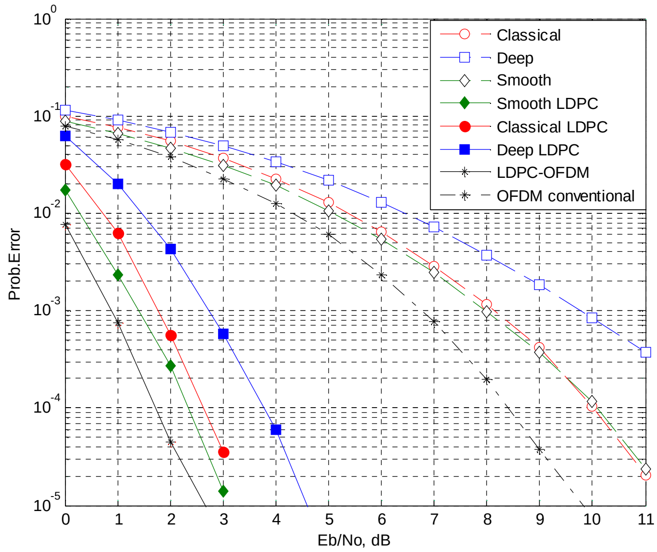

Figure 6 BER performance for CC, DC, and SC with and without LDPC

5. CONCLUSION

This paper compares the effects of implementing LDPC codes as ECC to three types of coding. Generally, there is a trade-off among the performance levels. For example, DC yields the biggest PAPR reduction, but it has the worst BER. The results show that implementation of LDPC codes does not affect the PAPR and it highly improves the BER performance by at least 6 dB.

6. REFERENCES

Armstrong, J. 2002. Peak-to-Average Power Reduction for OFDM by Repeated Clipping and Frequency Domain Filtering, IEEE Electronic Letters.

Guel, D., & Palicot, J. 2009. Analysis and Comparison of Clipping Techniques for OFDM Peak-to-Average Power Ratio Reduction, 16th International Conference on Digital Signal Processing.

Juwono, F. H. and Gunawan, D. 2009. PAPR Reduction Using Huffman Coding Combined with Clipping and Filtering for OFDM Transmitter, CITISIA.

Kimura, S., Nakamura, T., Saito, M., and Okada, M., (2008), PAR Reduction for OFDM Signals Based on Deep Clipping, In 3rd International Symposium on Communications, Control, and Signal Processing.

Langlais, C., Haddad, S., Louet, Y., and Mazouz, N. 2011. Clipping Noise Mitigation with Capacity Approaching FEC Codes for PAPR Reduction of OFDM Signals, 8th International Workshop on Multi-Carrier Systems & Solutions (MC-SS).

Li, X. and Cimini, L. J. 1998. Effects of Clipping and Filtering on the Performance of OFDM, IEEE Communication Letters, Vol. 2, No. 5, pp. 131 – 133.

MacKay, D. J. C. 1997. Good Error-Correcting Codes Based on Very Sparse Matrices, IEEE International Symposium on Information Theory.

Molisch, A. F. 2011. *Wireless Communications*, 2nd ed., John Wiley & Sons.

Pradabpet, C., Eupree, K., Chivapreecha, S., Dejhan, K. 2008. A New PAPR Reduction Technique for OFDM-WLAN in 802.11a Systems, Ninth ACIS International Conference on Software Enginering, Artificial Intelligence, Networking, and Parallel/Distributed Computing.

Pun, M. O., Morelli, M., and Kuo, C. C. J. 2007. Multi-Carrier Techniques for Broadband Wireless Communications: A Signal Processing Perspective, Imperial College Press.

Soriano, R. D., & Marciano, J. S. 2006. The Effect of Signal Distortion Techniques for PAPR Reduction on the BER Performance of LDPC and Turbo Coded OFDM System, TENCON 2006.