Turbo Equalization with Cancelation of Nonlinear Distortion for CP-Assisted and Zero-Padded MC-CDM Schemes

Rui Dinis, *Member, IEEE*, Paulo Silva, and Teresa Araújo

***Abstract*—In this paper, we consider MC-CDM schemes (MultiCarrier Code Division Multiplexing) where clipping techniques are employed to reduce the envelope fluctuations of the transmitted signals. Both CP-assisted (Cyclic Prefix) and ZP (Zero-Padded) MC-CDM schemes are studied. We develop frequency-domain turbo equalizers combined with an iterative estimation and cancelation of nonlinear distortion effects, with relatively low complexity since they allow FFT-based (Fast Fourier Transform), frequency-domain implementations.**

Our performance results show that the proposed receivers allow significant performance improvements at low and moderate SNR (Signal-to-Noise Ratio), even when strongly nonlinear transmitters are employed. The receiver for ZP MC-CDM is of special interest for systems where the duration of the channel impulse response is not a small fraction of the duration of the MC-CDM blocks, being suitable to MC-CDM systems with very large blocks (hundreds or even thousands of subcarriers), since they do not require the inversion nor the multiplication of large matrixes.

***Index Terms*—MC-CDM, zero-padded MC-CDM, turbo equalization, nonlinear distortion.**

I. Introduction

MC-CDM schemes (Multicarrier Coded Division Multiplexing) [1] combine an OFDM modulation (Orthogonal Frequency Division Multiplexing) [2] with coded division multiplexing, typically employing orthogonal spreading codes. However, since the transmission over time-dispersive channels destroys the orthogonality between spreading codes, an FDE (Frequency-Domain Equalizer) is required before the despreading operation (as with MC-CDMA schemes [3]), usually optimized under an MMSE criterion (Minimum Mean-Squared Error). It was shown in [4] that the performance of MC-CDMA can be significantly improved if the linear FDE is replaced by an IB-DFE (Iterative Block Decision Feedback Equalizer) [5]. These techniques can also be employed with MC-CDM schemes[1].

As with conventional OFDM schemes, typically a CP (Cyclic Prefix) is inserted before each MC-CDM burst. This CP, which allows low-complexity FFT-based (Fast Fourier Transform) receiver implementations, should be longer than the maximum CIR length (Channel Impulse Response). The CP leads to a decrease on the power efficiency of the modulation, due to the "useless" power spent on the CP. For this reasons, the length of the CP should be a small fraction of the length of the blocks. Typically the adopted CP length is an upperbound on the expected CIR length, which can be much higher than the true CIR length. In this case, ZP schemes (Zero Padded) can be a good alternative to CP-assisted schemes [6]. ZP schemes have better performance than CP-assisted schemes, but we need to employ complex receiver structures, involving the inversion and/or the multiplication of matrixes whose dimensions grow with the block length [7], which are not suitable when large blocks are employed. The receiver complexity with overlap-and-add techniques, is similar to the one of conventional CP-assisted schemes, but the performance is also identical [7]. A promising detection technique for ZP schemes is to employ an FDE operating on an extended version of the received block [8].

As with other multicarrier schemes, MC-CDM signals have strong envelope fluctuations and high PMEPR values (Peak-to-Mean Envelope Power Ratio), making them very prone to nonlinear effects. A promising approach to reduce the PMEPR of the transmitted signals while maintaining the spectral occupation of conventional schemes is to employ clipping techniques, combined with frequency-domain filtering [9], [10]. However, the nonlinear distortion effects can be severe when a low-PMEPR transmission is intended [9], [10]. To improve the performances, we can employ receivers where nonlinear distortion effects are iteratively estimated and compensated [11], [12].

In this paper, we consider MC-CDM schemes employing clipping techniques. Both CP-assisted MC-CDM and ZP MC-CDM schemes are considered. To improve the performances at low and moderate SNRs we consider the use of turbo equalization schemes, where the equalization and channel decoding operations are repeated iteratively, sharing information between them [13], [14]. We develop frequency-domain turbo equalizers for both CP-assisted and ZP MC-CDM schemes which combine an iterative estimation and cancelation of nonlinear distortion effects. The proposed turbo receivers have relatively low complexity, since they allow FFT-based, frequency-domain implementations.

Paper approved by N. Benvenuto, the Editor for Modulation and Detection of the IEEE Communications Society. Manuscript received September 25, 2007; revised March 17, 2008 and July 7, 2008.

R. Dinis is with the Instituto de Telecomunicações, Lisbon, Portugal, and also with the Faculdade de Ciências e Tecnologia, Univ. Nova de Lisboa, Caparica, Portugal (e-mail: rdinis@fct.unl.pt).

P. Silva is with the Instituto de Telecomunicações, Lisbon, Portugal, and also with the Instituto Superior de Engenharia, Univ. do Algarve, Faro, Portugal (e-mail: psilva@ualg.pt).

T. Araújo is with Instituto Superior de Engenharia do Porto, Portugal. (e-mail: taraujo@isep.ipp.pt).

This work was partially supported by Fundação para a Ciência e Tecnologia (pluriannual funding, U-BOAT project PTDC/EEA-TEL/67066/2006 and FCT/POCI 2010 research grants SFRH/BD/24520/2005 and SFRH/BD/29682/2006).

Digital Object Identifier 10.1109/TCOMM.2009.08.070485

[1]The main difference between MC-CDMA and MC-CDM schemes is that the later all spreading codes are intended to a given user.