Loading Techniques for OFDM Systems with Nonlinear Distortion Effects

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***Abstract*—In this paper we study the impact of nonlinear distortion effects on adaptive OFDM (Orthogonal Frequency Division Multiplexing) systems. An analytical statistical characterization of the transmitted signals is included which is obtained taking advantage of the Gaussian-like nature of the OFDM signals when the number of subcarriers is high. This statistical characterization is used to evaluate loading algorithms in the presence of strong nonlinear distortion effects and to redefine loading algorithms taking into account nonlinear distortion issues[1].**

I. Introduction

Multicarrier modulation (MCM) is the method of choice for the next generations of wireless standards [1]. It has been investigated as an effective technique for high data rate communications over multipath channels due to its robustness to intersymbol interference (ISI) and it has been used in a wide range of applications, e.g., asymmetric digital subscriber line (ADSL) [2], wireless local area network (WLAN) systems [3] and digital broadcasting systems [4], [5]. The principle of MCM is to split a high data rate information stream into a number of parallel streams with lower data rate and transmit them simultaneously. Its primary advantage over other data transmission schemes is this ability to transform a frequency-selective fading channel into a collection of approximately-flat subchannels, which yields simpler designs of the transceivers. In OFDM systems, a special form of MCM popular these days, we transmit parallel streams on a number of overlapping but orthogonal subchannels, allowing high spectral efficiency [6], [7]. In this case, the implementation of the transceivers is made using a pair of DFT/IDFT blocks. Another advantage of MCM is its ability to adapt the subcarrier operating parameters to the communications channel, thereby enhancing the overall performance of the system.

Although several subcarrier parameters are available for adjustment, one of the most popular choices is subcarrier signal constellation size. The process of adjusting this parameter, called adaptive bit loading, involves an algorithm that adjusts the number of bits per subcarrier (and corresponding constellation size) according to the channel conditions, i.e. the transmitted number of bits is not equal across all subcarriers [8], [9], [10], [11]. Another parameter that can be adjusted is the energy attributed to each subcarrier. It can be chosen according to the number of bits and channel attenuation on a particular subcarrier. Consequently, adaptive bit loading has the potential to achieve data transmissions that are very spectrally efficient.

With OFDM and other MCM schemes, the transmitted signals have large envelope fluctuations and high PMEPR (Peak-to-Mean Envelope Power Ratio), leading to amplification difficulties. For this reason, several techniques have been proposed to reduce the envelope fluctuations of OFDM signals, namely employing clipping and filtering techniques (see [12] and references within).

In this work we present an analytical approach for evaluating the impact of nonlinear distortion effects inherent to the signal processing techniques for reducing the PMEPR of the transmitted signals on OFDM signals. For this purpose, the statistical characterization of the signals along the transmission chain is obtained, taking advantage of the Gaussian-like nature of the OFDM signals when the number of subcarriers is high. This characterization is then used for an analytical performance evaluation and to define enhanced loading algorithms, taking into account nonlinear distortion effects.

This paper is organized as follows: Sec. II presents the nonlinear distortion effects on OFDM signals considered in this paper. The statistical characterization of the transmitted signals is made in Sec. III and Sec. IV presents the loading techniques. A set of performance results is presented in Sec. V. Finally, Sec. VI is concerned with the conclusions of this paper.

II. Nonlinear Signal Processing for OFDM Signals

In this section we consider nonlinear signal processing schemes which operate on a sampled version of the OFDM signal. The basic transmitter structure considered in this section is depicted in Fig. 1. This structure is similar to the clipping and filtering techniques proposed in [12] for reducing the PMEPR of the transmitted OFDM signals while maintaining the spectral efficiency of conventional OFDM schemes. Each of the N frequency-domain symbols to be

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