AN EFFICIENT SPECTRAL SHAPING METHOD FOR OFDM SYSTEMS USING CORRELATED INTERPOLATION OF SYMBOLS

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***Abstract*— The generation of suitable *orthogonal frequency division multiplexing* (OFDM) signals on the grounds of fully digital signal processing is considered. The main objective is to obtain a discrete-time signal with adequate allocation of power emissions in both, in-band portion (i.e., the allocated band for communication) and out-of-band portion (i.e., the band allocated to adjacent channels) of the spectrum. The proposed method prevents the transmitter from using traditional filtering techniques, to keep under control power emissions in the system. In addition, the adaptability feature of our proposal makes its implementation attractive within *cognitive radio* (CR) and *software defined radio* (SDR) OFDM-based systems. Our spectral shaping approach is based on an optimum interpolation, obtained from the combination of an *inverse fast Fourier transform* (IFFT) and a spectral precoding operation, both of them transparent from the perspective of a conventional (legacy) OFDM receiver.**

***Keywords*— Correlated interpolation, IFFT, double-length, OFDM, N-continuous, symbol merging, spectral precoding, spectral shaping.**

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is an attractive modulation technique that is not only widely used in current commercial systems (e.g., xDSL, DVB, WiFi, and WiMAX), but it also represents the selected candidate to be implemented in the air interface of future high-speed mobile communications standards (i.e., LTE and LTE-Advanced). The available spectrum in an OFDM transmission is occupied by orthogonal subcarriers, which are utilized to convey parallel data streams across non-interfering portions of the channel. The use of OFDM allows to exploit effectively both, the frequency- and time- domain dimensions of a (slowly varying) frequency selective fading channel, as it admits simple single-tap equalization using a *cyclic prefix* (CP) (Hwang *et al.*, 2009). Another important property is the possibility of implementing the required transmit signal processing operations completely in the digital domain, using the well-known and efficient *fast Fourier transform* (FFT) algorithm. Nevertheless, the implementation of OFDM in practice comes with many challenges. For example, high levels of out-of-band power emissions may be generated in transmission (due to discontinuities in the time-domain OFDM signal) if no corrective measures are taken. Trying to alleviate this problem, in this paper we focus on the use of a novel interpolation method that we named *correlated interpolation* (CI), as a simple way to achieve a suitable spectrum shape of the output signal in a practical system implementation.

An OFDM signal is a sequence of OFDM symbols, each one consisting of a collection of modulated orthogonal subcarriers. Since the amplitudes and phases of the subcarriers are often statistically independent, OFDM symbols are considered independent as well. Due to this phenomenon, the concatenation of OFDM symbols introduces discontinuities in the corresponding time-domain signal, or equivalently, high levels of out-of-band power emissions are generated. The simplest solution to this problem consists in using filtering techniques that limit this undesired power leakage out-of-band; nevertheless, the main drawback of such an approach is a reduction in the effectiveness of the CP that is introduced (van de Beek and Berggren, 2009a). Mahmoud and Arslan (2008) proposed an interesting alternative to control this problem, which is basically based on implementing adaptive symbol transitions when generating the OFDM signal. However, the main drawback in this case is the necessity to update the transmitter signal processing on a per-symbol basis, increasing as a consequence the complexity of the system (i.e., its implementation requirements).

This work focus on the generation of OFDM signals that comply with common quality requirements specified by emission masks, such as the ones that are presented in LTE specifications (3GPP 36.211, 2012). In other words, we address the generation of an over-sampled digital signal that improves the spectral allocation of power in both, in-band and out-of-band regions. The key idea behind our proposal is based on correlating two OFDM symbols in frequency-domain, to obtain a continuous behavior in time-domain by means of the CI. This is obtained using an *inverse discrete Fourier transform* (IDFT) representation with double length, when compared to the one that is used in conventional OFDM transmissions. At that time, the concatenation points in the resulting sequence of OFDM symbols will show a continuous behavior in half of the original merging points (that correspond to the whole OFDM transmission). A preliminary version of this merging concept was previously presented in Lizarraga *et al*. (2011a).

A spectral precoding technique is additionally introduced in this paper, with the ultimate goal of guaranteeing a continuous time-domain behavior in the remaining