Design and Performance Evaluation of a Multiuser OFDM System Based on Differential Quadrature Chaos-Shift-Keying Spread Spectrum

ABSTRACT

This paper aims to propose a multiuser OFDM system with non-coherent differential quadrature chaos-shift-keying (OFDM-DQCSK) modulation. The proposed system is based on direct sequence spread spectrum where chaotic codes replace conventional spreading sequences. Orthogonal sets of chaotic spreading codes can be generated. The proposed system uses duplicated reference subcarriers that are private and non-shared. At the receiver, these reference subcarriers are used for the differential non-coherent de-spreading. Neither complex channel estimators nor carrier synchronization is required for demodulation. The chaotic reference signals are averaged at the receiver so that the additive white gaussian noise (AWGN) on the reference signal is averaged to a negligible value. A simulation of the bit error rate performance is performed in the presence of AWGN, multipath Rayleigh flat-fading channels and multiple access interference (MAI). In conclusion, the proposed non-coherent system achieves a remarkable improvement due to the usage of the Reference Averaging Technique.

Keywords: Chaotic codes; spread spectrum; OFDM; differential chaos shift keying; AWGN averaging.

I. INTRODUCTION

The direct sequence spread spectrum (DS-SS) system supports multiple access communication among different users. It can combat multipath fading interference in the presence of a frequency selective channel. However, the performance of this system is limited by the inter-chip interference and the multiple access interference (MAI) [1]. The inter-chip interference is considerably reduced by combining OFDM with the DS-SS system. As a result, the hybrid system becomes more resistant to multipath interference in frequency selective channels [2].

Chaotic codes are non-periodic random like sequences and can give orthogonal sets of spreading codes. A comprehensive comparison between chaotic and conventional PN codes is made in [3] and [4]. The comparison shows that chaotic spreading codes are a strong competitor for the conventional spreading codes and outperform conventional spreading sequences in terms of ease of generation and flexibility in choosing the length of the sequence [5], [6]. Chaotic signals are suitable for spread-spectrum modulation because of their wideband characteristics, sharp autocorrelation property, and low cross-correlation values among each other. The chaotic sequence generator is very sensitive to initial condition values. Theoretically, this allows the generation of an infinite number of uncorrelated chaotic sequences even if they are from the same chaotic map generator [5].

In [7], an OFDM system with DCSK modulation is proposed, which uses Fast Fourier Transform (FFT) algorithm rather than employing a bank of filters. In [8], the author improves the system in [7] to support multiple access communication and analyses the BER performance of a multi-user transmission in AWGN and multipath Rayleigh fading channels.

A. Contributions

It is observed in the system proposed in [8] that, in a non-coherent differential modulation scheme, correlating the data symbols with a noisy reference deteriorates the BER performance to a large extent when compared with the coherent performance. It is contributed to this work that, if AWGN noise samples and multipath fading channel coefficients that corrupt the reference subcarrier are minimized or averaged, the non-coherent scheme can achieve a significant improvement without complex channel estimators. Therefore, in the proposed (OFDM-DQCSK) system, more reference subcarriers replicas are transmitted to be averaged at the receiver side so that the AWGN samples are averaged to a value almost zero according to the Strong Law of Large Numbers discussed in section II.D. The multipath channel coefficients are also averaged to their mean value as well. As a result, the BER performance of the proposed system is improved remarkably.

In the previous work presented in [8], binary modulation with DCSK spread spectrum is used. However, in this work, QPSK is used instead of binary modulation. In this way, the energy efficiency is increased because the reference code transmitted on the reference subcarrier is used to reference two bits instead of one. As a result, the BER performance is significantly improved more than the BER performance of the system in [8].