Chaotic sequences in MC-CDMA Systems

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Abstract—The chaotic sequences in MC-CDMA Systems are presented in this paper. Performance evaluation and comparison of multi-carrier code division multiple access system model for different spreading sequences with chaotic sequences at the presence of Saleh and Rapp model of high power amplifier (HPA) is investigated. The simulation results in Matlab are presented here.

Keywords—MC-CDMA, Saleh model, Rapp model, Chaotic sequences

I. INTRODUCTION

Sequences derived from chaotic phenomena are actively being considered for spread-spectrum communications [10]. In recent years there has been an increasing amount of interest in chaotic sequences in CDMA systems. MC/DS CDMA is described in [11]. Comparison of chaotic sequences and another type of pseudorandom sequences in CDMA systems is described in [13], [14], [15]. This paper is deal with chaotic sequences in MC CDMA systems. Chaos is a deterministic, random-like process found in non-linear dynamical system, which is non-periodical, non-converging and bounded. Moreover, it has a very sensitive dependence upon its initial condition and parameters. The generation of orthogonal sequences is utmost importance in MC-CDMA systems, in order to increase the spectrum efficiency in multirate communications systems. In CDMA, sets of non-correlated sequences with good autocorrelation and crosscorrelation properties are required in order to provide low interference between users [12].

Section II. described MC-CDMA system model, section III. deal with nonlinear models, section IV. described chaotic sequences versus another type of pseudorandom sequences in MC-CDMA systems.

II. MC-CDMA SYSTEM MODEL

In MC-CDMA, instead of applying spreading sequences, in the time domain, we can apply them in the frequency domain, mapping a different chip of a spreading sequence to an individual Orthogonal Frequency Division Multiple Access (OFDM) subcarrier. Hence each of OFDM subcarrier has a data rate identical to the original input data rate and the multicarrier system absorbs the increased rate due to spreading in wider frequency band.

In MC-CDMA transmitter, the information bits to be transmitted by a particular user, are firstly base-band modulated (QAM, PSK) into some modulation symbols and then are spreaded by using a specific spreaded sequence $c_m$. In the case of MC-CDMA, as the spreading codes Walsh codes, Gold codes, Zadoff-Chu codes, Golay codes and Chaotic sequence codes can be used. The spreaded symbols are modulated by multi-carrier modulation implemented by IFFT (Inverse Fast Fourier Transform) operation. The IFFT after parallel-to-serial conversion represents the input signal of a HPA (High Power Amplifier), (see Fig. 1). The receiver consists of serial-to parallel converter, FFT (Fast Fourier Transform), BMF (receiver-Bank of Matched Filters), block of linear or non-linear transformation (labelled as T) and a decision device. Here, the operation of a single-user receiver known as BMF consists of a set of simple matched filters (correlators). In order to extend BMF into a multi-user receiver, the T-transformation block is included in the receiver structure [3]. In this paper, the linear MMSE-MUD [4] as well as nonlinear MSF-MUD for MC-CDMA [5], [6] are considered. The T-transformation block in MMSE-MUD is represented by multi-channel linear Wiener filter. In the case of MSF-MUD, the T-transformation block is represented by a complex valued-multichannel nonlinear microstatistic filter (C-M-CMF). C-M-CMF is the minimum mean-square error estimator based on the estimation of desired signals by using a linear combination of vector elements obtained by threshold decomposition of filter input signals [5], [2].

The main benefit of combining OFDM with DS-spread is that it is possible to prevent the obliteration of certain subcarriers by deep frequency domain fades [1].

A block diagram of the simplified baseband model of MC-CDMA transmitter is given in Fig. 1 [2].

The basic structure of receivers considered in this paper is sketched in Fig. 2.

III. NONLINEAR MODELS

There are two major types of power amplifiers used in communications systems:
The measure of effects due to nonlinear HPA could be decreased by the selection of relatively high value of IBO.
B. Nonlinear MC-CDMA System – Saleh Model

For the specification of the Saleh model of HPA, the parameters $k_G = 2$, $\chi_0 = \chi = 1$ and $k_\Phi = \pi/3$ have been chosen.

The Saleh nonlinearity type has very destructive effect on QAM modulation (Fig. 5) [9]. The number of 100 000 input bits, the number of 3 users and the modulation type of 16-QAM or 8-PSK was used for simulation. In the Fig. 5, the signal constellations at the outputs of 16-QAM mapper and BMF for Eb/No = 12 dB are given.

C. Nonlinear MC-CDMA System – Rapp Model

For the specification of the Rapp model of HPA, its parameters have been set to $k_G = O_{sat} = 1$ and $s = 3$.

The number of 100 000 input bits, the number of 3 users and the modulation type of 16-QAM and 8-PSK was used in simulation. In the Fig. 7 the signal constellation at the outputs of 16-QAM mapper and BMF for Eb/No = 12 dB are given.

In the Fig. 8, the BER vs. Eb/No for MC-CDMA transmission system for different spreading sequences and 8-PSK is given. The AWGN channel model, 9 users and IBO = 2 dB was used in this simulation. It can be seen from Fig. 8, that the best performance can be provided when we used Golay sequences in combination with MSF-MUD, MMSE-MUD or BMF. When we used the chaotic sequences, MSF-MUD and MMSE-MUD have the same performance, receiver BMF is not available. The worse performance has the Zadoff-Chu sequences.

V. CONCLUSION

In this paper, the performance of MC-CDMA transmission system for two different models of HPA (Saleh and Rapp model), the different spreading sequences and receiver types is investigated. It has been found that Saleh model of HPA introduces much higher nonlinear distortion and causes more significant degradation of MC-CDMA transmission system performance than that of Rapp model. The best performance we can obtained when we used the Golay sequences in combination with MSF-MUD or MMSE-MUD. Chaotic sequences have similar performance like Golay sequences.

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Fig. 6 BER vs. Eb/No for MC-CDMA transmission system for different spreading sequences (8-PSK modulation, Saleh model, IBO = 2 dB)

Fig. 7 Original symbol constellation at the output of the 16-QAM – Rapp model

REFERENCES


