Chapter 25

A New Approach to BSOFDM:
Parallel Concatenated Spreading Matrices OFDM

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1. ABSTRACT

This chapter discusses a new concept for Block Spread OFDM called Parallel Concatenated Spreading matrices OFDM (PCSM-OFDM) which was first presented in (Raad, I. and Huang, X. 2007). While BSOFDM improved the overall BER performance on OFDM in frequency selective channels, this new approach further improves the BER of BSOFDM by over 3dB gain. This uses coding gain to achieve this and is similar in concept to the well known error correction codes Turbo Codes. This is done by copying the data at the transmitter n times in parallel and multiplexing.

2. INTRODUCTION

In today's world, it has become extremely important to continue to develop wireless communications to maintain continued economic growth. This is only achievable by ensuring that businesses and their customers have the best possible communications available. It is very important to remember that many businesses have invested large amounts of capital into the existing communication systems and as such it is not possible to deploy new systems. Therefore, to achieve better use of existing solutions and make use of the existing bandwidth becomes the priority.

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A number of wireless solutions for modulating symbols across frequency selective channels exist. One of these solutions is called Orthogonal Frequency Division Multiplexing (OFDM).

OFDM is a method used to implement mutually orthogonal signals and this is done by setting up multiple carriers at a suitable frequency separation and modulating each symbol stream separately (Kamilo, F. 1995). By increasing the number of carriers the data rate per carrier can be reduced for a given transmission. The symbol streams do not interfere with each other because of the carriers being mutually orthogonal. It is possible to mitigate fading through suitable interleaving and coding. One method of ensuring the signals are independent of each other is to select the frequency separation between each signal in a manner which will achieve orthogonality over a symbol interval.

While OFDM will combat the effect of multipath transmission, other methods need to be utilized to mitigate the effect of fading. One way of achieving this is called Diversity Transmission. Diversity transmission can be used to reduce or remove the effect of fading by the transmitted signal power being "split between two or more sub channels that fade independently of each other, then the degradation will most likely not be severe in all sub channels for a given binary digit" (Rappaport, T. S. 2002). Then when all the outputs of these sub channels are recombined in the proper way the performance achieved will be better than the single transmission. There are a number of ways to achieve this diversity and the main methods include "transmission over spatially different times (space diversity), at different paths (time diversity) or with different carrier frequencies (frequency diversity)" (Rappaport, T. S. 2002).

Block Spread OFDM (BSOFDM), also known as pre-coded OFDM, has been used to achieve frequency diversity and has shown significant improvement over conventional OFDM in frequency selective channels. This is done by dividing the N subcarriers into M sized blocks and spreading them by multiplying these blocks with spreading codes such as the Hadamard matrix.

This chapter introduces Parallel Concatenated Spreading Matrices which further improves the BSOFDM by employing coding gain.

This chapter is organized as follows. A detailed literature review is provided to discuss methods which are used in this kind of system. This begins with the discussion of OFDM which is followed by a comparison of OFDMA, CDMA and TDMA based on studies already available. In the same section a brief discussion about diversity is presented since Block Spread OFDM employs frequency diversity. The method and examples of how frequency diversity is used is presented next and gives examples of two different spreading matrices used widely in industry standards. These are the Hadamard and the Rotated Hadamard matrices.

Block Spread OFDM is discussed in detail in section 2.5. In Section 3 and 4, the Parallel Concatenated Spreading Matrices OFDM (PCSM-OFDM) is presented in detail and discussed. The comparison between OFDM, BSOFDM and PCSM-OFDM is presented and analyzed. The scalable version of PCSM-OFDM – higher order PCSM-OFDM, is presented and discussed in Section 5. The concluding remarks and future recommendations are given in Sections 6 and 7.

2.1 Orthogonal Frequency Division Multiplexing (OFDM)

OFDM is currently used in high speed DSL modems over copper based telephone access lines. Since this work is primarily a contribution to the wireless communications then it is important to discuss where this modulation scheme is used in this field. OFDM has been standardized as part of the IEEE802:11a and IEEE802:11g for a high bit rate 54Mbps data transmission over wireless LANs (WLANs) (Schwartz, M. 2005).

In today's world there is an increased need for higher bit rate and higher bandwidth data transmission over radio based communication systems. It has been established in (Schwartz, M. 2005) that as the transmission bandwidth increases, frequency selective fading and other signal distortions occur. One of the major signal distortions that do occur in digital transmission is inter-symbol interference.

OFDM, by dividing the signal transmission spectrum into narrow segments and transmitting signals in parallel over each of these segments, mitigates this effect. If the bandwidth of each of these frequency spectrum segments is narrow enough, flat or non-frequency-selective fading will be encountered and the signal transmitted over each segment will be received non-distorted.