COMPARISON OF WAVELET PACKETS IN MULTI-CARRIER CDMA COMMUNICATION

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ABSTRACT

This article introduces using wavelet packet transform instead Fourier transform in multi-carrier communication. Articles form this field devote mostly with Haar or Daubeschies mother wavelet. In this article different types of mother wavelet have been used and compared in flat Rayleigh channel.

1 INTRODUCTION

Next generation communication systems require high-bit-rate transmission to keep promise of high quality communication. To employ multi-carrier techniques on multi-path fading environment can help to perform it. Multi-carrier CDMA (Code Division Multiple Access) communication is a combination of multi-carrier modulation scheme and CDMA concept. The principle of multi-carrier is to convert a serial high-rate data stream onto multiple parallel low-rate sub-streams. Each sub-stream is modulated on another sub-carrier. Since the symbol rate on each sub-carrier is much less than the initial serial data symbol rate, the effects of delay spread, i.e., ISI, significantly decrease, reducing the complexity of the equalizer. OFDM (Orthogonal Frequency Division Multiplex) is a low-complex technique to efficiently modulate multiple sub-carriers by using digital signal processing [7].

The multi-carrier CDMA schemes can be categorized mainly into two groups. One spreads the user symbols in the frequency domain (e.g. MC-CDMA), the other spreads user symbols in the time domain (e.g. MC-DS-CDMA) [2], [7].

Instead Fourier transform (FT) in multi-carrier communication we have another possibility in wavelet transform(WT), which offers some better properties. The first ideas of using wavelet transform in communication were made in multidimensional signalling techniques. [4] introduces WPM (Wavelet Packet Modulation), which employs the basis function from an arbitrary of a dyadic tree structured filter bank as orthogonal pulse shapes for conventional quadrature amplitude modulation (QAM) symbols.

However this article deals with employing wavelet packet transform WPT instead of FT because WP have good properties that make them a candidate for user signature waveforms in a CDMA communication system [2]. Wavelet packet waveforms have the property of localization in both frequency and time domains. Utilizing the time domain localization property of wavelet packet waveforms, a multi-carrier CDMA system based on wavelet packets can be designed to achieve both frequency and time domain diversity. In [2] these properties are employed for RAKE fingers (path strength) computing. The used system is based on MC-DS-CDMA. There is a need of one RAKE combiner for each sub-carrier in an ordinary MC-DS-CDMA system, the complexity of the receiver depends highly on the number of sub-carriers and limits the number of frequency bins. In the wavelet packet based multi-carrier CDMA system only one time domain RAKE combiner is needed in the detector, because the wavelet packet transform is used to combine signals from all sub-carriers prior to the time domain RAKE combiner [5].

Another advantage is introduces in [8]. According to proposals of the IEEE 802.16.3, the PHY layer overhead for wavelet-based OFDM (DWT-OFDM) is less than that of DFT-OFDM.

2 MC-DS-CDMA

The MC-DS-CDMA transmitter spreads the original data stream over different sub-carriers using a given spreading code in the time domain. Input serial data stream ***d*** is divided to parallel blocks, which length equals number of sub-carriers (*Nc*). In each sub-carrier DS-CDMA is applied with the user specific spreading code $\boldsymbol{c}^{(k)}$ with spreading factor (*SF*), which hasn't to be equal to number of sub-carriers (*Nc*). Each column vector from matrix:

$$\boldsymbol{S}^{(k)} = \boldsymbol{d}^{(k)}\boldsymbol{c}^{(k)} \tag{1}$$

where $\boldsymbol{d}^{(k)}$ is column vector with length *Nc*,

$\boldsymbol{c}^{(k)}$ is row vector with length *SF*.

is fed to IDFT (Inverse Discrete Fourier Transform).

MC-DS-CDMA receiver comprises inverse OFDM (with DFT) and single-user or multi-user detector [7]. Single-user detector which consists of equalizer, despreader and quantizer has been used in simulation.

3 WAVELET BASED MULTI-CARRIER COMMUNICATION

Wavelet transforms can be thought of as a generalized Fourier Transform while allowing design of a communication system with certain specific properties. In that respect it is similar to discrete multiplexing (DMT) and OFDM with certain additional benefits that can be designed by carefully selecting the orthonormal basis functions [3] [8].

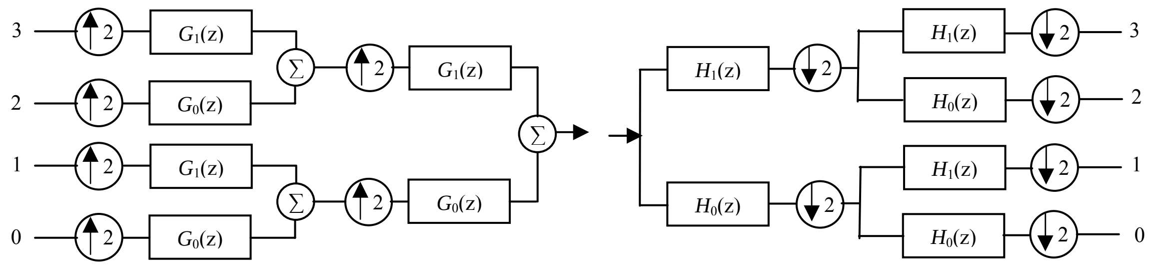

Fig. 1: *Reconstruction (left), decomposition (right) full tree*

Discrete Wavelet Packet transform (DWPT) is a variant of Discrete Wavelet transform (DWT), when decomposition and reconstruction is realized by full tree(fig. 2)

G_1,G_0 is reconstruction high pass respectively low pass filter and H_1, H_0 is decomposition high pass respectively low pass filter. Up arrow and down arrow denote upsampling and downsampling. Impulse responses of filters are generated from wavelet mother functions (Haar, Daubechies, Coiflet, Beykin etc.).

Input data stream $\boldsymbol{d}$ is spread with the user specific spreading code $\boldsymbol{c}^{(k)}$ with spreading factor (*SF*) in the same meaning as above in MC-DS-CDMA. While input to IDWPT (Inverse DWPT) is a whole matrix $\boldsymbol{S}^{(k)}$

$$\boldsymbol{S}^{(k)} = \boldsymbol{d}^{(k)}\boldsymbol{c}^{(k)} \tag{2}$$

where $\boldsymbol{c}^{(k)}$ is row vector with length *SF*, $\boldsymbol{d}^{(k)}$ is column vector with length *Nc*.

Circular convolution has been used instead classic convolution.

4 CHANNEL MODEL

Rayleigh distribution is derived from two zero-mean statistically independent normally distributed random variables μ_1, μ_2, each having a variance σ_0^2, according to $\zeta = \sqrt{\mu_1^2 + \mu_2^2}$. The probability density function [6]

$$p_\zeta(x) = \frac{x}{\sigma_0^2} e^{-\frac{x^2}{2\sigma_0^2}}, \ x \geq 0 \tag{3}$$

Flat Rayleigh channel with Jakes power spectral density is used in simulation. The frequency range of the Jakes power spectral density is limited to the range $|f| \leq f_{\max}$, $f_{\max}$ denotes the maximum Doppler frequency due to the motion of the receiver or transmitter. Generation of two coloured Gaussian random processes is based on a superposition of finite number of harmonic function according Rice method. Monte Carlo Method (MCM) has been employed for computation of the model parameters (Doppler coefficients, discrete Doppler frequencies and Doppler phases) [6].

5 SIMULATION RESULTS AND DISCUSSION

Simulation was done in Matlab. At first data are generated for each user. These data are bipolar (1 or -1) and the probability of ones is the same as probability of minus ones. Complex-valued data are input of MC-DS-CDMA or discrete wavelet packet based MC-DS-CDMA transmitter. Number of sub-carriers is 16 in both systems, spreading factor SF of Walsh code has been chosen 16. Time duration of chip is 0.8 microseconds and Doppler frequency is 370 Hz, we assume 2GHz carrying frequency. Imperfect equalization is assumed, based on MRC (Maximum Ratio Combining)[7] and signals from different users are not symbol synchronized, only chip synchronized.

Simulation results (fig. 2) show better BER performance for wavelets Symlet, Vaidynathan, Beykin and Coiflet. Multi-carrier system based on Daubechies wavelet has worse BER performance than previous wavelet packet however better BER compared with MC-DS-CDMA communication. Only receiver based on Battle wavelet packets reached worse BER performance than MC-DS-CDMA system. It's suitable to remark, that wavelet based multi-carrier communication doesn't increase length of signal after wavelet based modulation.

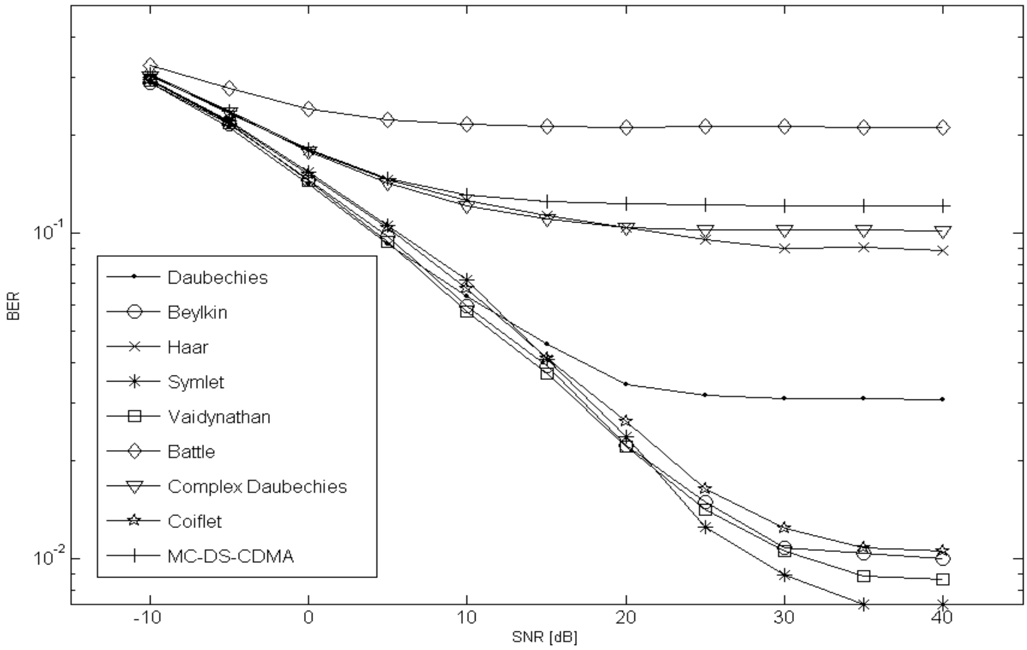

Fig. 2: *BER performance of MC-DS-CDMA and wavelet based MC-DS-CDMA*

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