

Performance analysis of DWPT- MC-CDMA system

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ABSTRACT

Multicarrier code division multiple access (MC-CDMA) system is the promising technique for future wireless multimedia communication. MC-CDMA system is the combination of both orthogonal frequency division multiplexing (OFDM) and code division multiple access (CDMA). In MC-CDMA system, each user's information is transmitted with unique code over the N number of subcarriers. DWPT-MC-CDMA system uses wavelet basis instead of DFT basis to deal with the problem of inter-channel interference (ICI) and spectral bandwidth efficiency. The theoretical analysis shows that wavelet has lower side lobe components and higher bandwidth efficiency. In this paper, the simulation gives lower ICI and better bit error rate performance and throughput in wavelet MC-CDMA system than the other system.

Keywords: CDMA, OFDM, MC-CDMA, Wavelet packet, QMF, DWPT

I. INTRODUCTION

Code Division Multiple Access (CDMA) is a multiplexing technique, where a number of users simultaneously and synchronously access a channel by modulating and spread their information-bearing signals with pre-assigned signature sequences, it has been considered to be a candidate to support multimedia services in mobile radio communications, because it has its own capabilities to cope with asynchronous nature of multimedia data traffic, to provide higher capacity over conventional access techniques such as time-division multiple access (TDMA) and frequency-division multiple access (FDMA), and to combat to hostile channel frequency selectivity. On the other hand, the multicarrier modulation scheme, often called orthogonal frequency division multiplexing (OFDM), has drawn a lot of attention in the field of radio communications. This is mainly because of the need to transmit high data rate in a mobile environment which makes a highly hostile radio channel. OFDM systems have advantages such as robustness against multipath and impulse noise [13]. However, the problem of frequency offset, is considered one of the main drawbacks of MC-CDMA systems, resulting from Doppler's shift which introduced signal distortion and power loss. MC-CDMA schemes are categorized mainly into two groups. One spreads the original data stream using a given spreading code, and then modulates a different sub carrier in each chip and other spreads the serial-to-parallel converted data streams using a given spreading code, and then modulates a different sub carrier with each of the data stream similar to a normal DS-SS-CDMA scheme [15].

Due to the relationship between circular and linear convolutions in discrete Fourier transform, multicarrier is one of the modulation techniques which can cope frequency selective fading for its advantage in frequency diversity, MC-CDMA with its frequency diversity is an attractive modulation scheme for multiuser high data rate wireless communication system [4], [5]. In OFDM and MC-CDMA system, sub channel decomposition cannot be achieved without adding guard band or cyclic prefix, where a copy of the end part of the data symbol block is transmitted. This method needs transmitting extra guard interval signals that introduces overhead and thus leads to spectral inefficiency and performance degradation [10]. Replacing the Fourier based exponential carriers of MC-CDMA with wavelet based lower side lobe component [1]. The wavelet packets multicarrier multicode code division multiple access system uses WPs as subcarrier instead of sinusoidal one. This system output forms the system which uses sinusoidal signals as subcarriers because

(1) WPs have much lower side lobes with negligible side lobe energy leakage compared to sinusoidal carriers that will reduce the problem of intercarrier interference and multiple access interference.

(2) WPs are naturally orthogonal and well localize in both time and frequency domain, which relaxes the requirement of frequency or time guard between different user signals [16].

There are two levels of orthogonality, i.e. along subband axis and user axis. The problems of the detection to retrieve the data symbol are: first, how to combine the signal scattered in all subbands to exploit the frequency diversity. Second, how to mitigate the multiple access interference signal. Therefore we propose an approach where the detection is performed on both axis using minimum mean squared error algorithm in subband axis and user axis. The first one is called MMSE combiner to exploit the frequency diversity available in MC-CDMA signal. The second is called MMSE multiuser detection [2]. The adaptive implementation of MMSE multiuser detection has also been discussed in this paper.

It would be remarkable if we can get the superiorities of DWPT-MC-CDMA system and implement it in software defined radio for cellular systems. The transceiver then can be reconfigured and reprogrammed easily just by software. There is a possibility to combine *Walsh-Hadamard* transform (for spreading) and wavelet transform (for multicarrier modulation) in one block so that it reduces the complexity in implementation.

The aim of this paper is to compare the performance of MC-CDMA system with and without wavelet. This paper compares the bit error rate (BER) performance and throughput value of MC-CDMA system with and without wavelet.

II. WAVELET PACKET AND SYSTEM MODEL

As a generalization of wavelets, wavelet packets were introduced first for data analysis and compression [18]. They are functions well localized in both time and frequency domains. The construction of a wavelet packet basis starts from a pair of quadrature mirror filters (QMF), g_1 and g_0 , satisfying the following conditions,

$$\sum_{n=-\infty}^{\infty} g_1(n) = 2$$

$$\sum_{n=-\infty}^{\infty} g_1(n) g_1(n-2k) = 2\delta(k)$$

$$g_0(n) = (-1)^n g_1(L-n-1)$$

The sequence of functions $\varphi_n(x)$, called wavelet packets, are recursively defined by the QMF $g_1(n)$ and $g_0(n)$ as

$$\varphi_{2n}(x) = \sum_{k \in \mathbb{Z}} g_1(k) \varphi_n(2x-k)$$

$$\varphi_{2n+1}(x) = \sum_{k \in \mathbb{Z}} g_0(k) \varphi_n(2x-k)$$

The first two functions of this sequence $\varphi_0(x)$ and $\varphi_1(x)$ are exactly the scaling function and its corresponding wavelet function from a *Multiresolution Analysis (MRA)*. Since the two functions $\varphi_{2n}(x)$ and $\varphi_{2n+1}(x)$ are generated from the same function $\varphi_n(x)$, they are called the “children” functions of the “parent” $\varphi_n(x)$. Wavelet packets have the following orthogonality properties

$$(\varphi_n(x-j), \varphi_n(x-k)) = \delta(j-k)$$

$$(\varphi_{2n}(x-j), \varphi_{2n+1}(x-k)) = 0$$

The above equation indicates that each individual wavelet packet is orthogonal to its nonzero integral shifted version and any pair of “children” wavelet packets coming from the same “parent” function is orthogonal at all nonzero integral shifts. Two operators, also known as filtering down sampling processes using the QMF $g_1(n)$ and $g_0(n)$, are defined as

$$G_1\{x\}(2n) = \sum_{k \in \mathbb{Z}} x(k) g_1(k-2n)$$

$$G_0\{x\}(2n) = \sum_{k \in \mathbb{Z}} x(k) g_0(k-2n)$$

These two operators can be used to decompose (analyze) any discrete function $x(n)$. In each step the resulting two coefficient vectors have a length half of the input vector so that the total data length remains unchanged. The process can continue and stop at any desired step. For the deepest decomposition the output coefficient vectors become scalars. This decomposition process is called Discrete Wavelet Packet Transform (DWPT) [9]. The DWPT transform is orthogonal and the original signal $x(n)$ can be recovered from the coefficients by the inverse transform, which is defined as a series of up sampling-filtering processes using the reversed filters $g_1(-n)$ and $g_0(-n)$. It can also be constructed using the Inverse DWPT (IDWPT) [8] and it is defined as,

$$G_1^{-1}\{x\}(n) = \sum_{k \in \mathbb{Z}} x(k) g_1(n-2k)$$

$$G_0^{-1}\{x\}(n) = \sum_{k \in \mathbb{Z}} x(k) g_0(n-2k)$$

The process of constructing a wavelet packet function set can be more clearly seen through the wavelet packet construction tree shown in Fig.1. Each wavelet packet function is constructed by starting from a leaf of this binary tree with an impulse $\delta(n)$, going up node by node until reaching the root of the tree. The operator from one node to an upper layer node is one of the above operators G_1^{-1} and G_0^{-1} depending on the left/right direction. The set of functions constructed starting with all possible shifts of the impulse $\delta(n)$, from all the leafs of an admissible tree form a complete orthonormal function set for the space spanned by the scaling function $\phi_0(x)$ and its shifts, i.e., a wavelet packet basis. A large number of wavelet packet bases are available to be chosen from by different pruning of the binary wavelet packet tree for a given maximum level L .

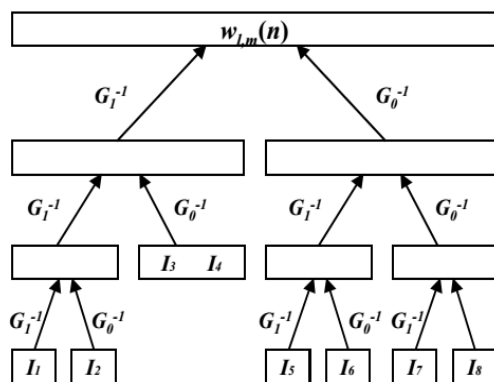


Fig.1 Wavelet packet construction tree

Wavelet packets have the following remarkable features that make them useful in communications [11], [12]:

A. Flexibility- To decompose a discrete signal with length N , there exist as many as $2^{N/2}$ to $2^{5N/8}$ wavelet packet bases, by different pruning of the binary wavelet construction tree. This feature provides great flexibility for the use of wavelet packets in communications. A pruning configuration that best matches the communication channel characteristics can be chosen and adaptively modified to follow the varying communication channels in practice.

B. Time and frequency localization- Wavelet packets are well localized in both time and frequency domains. This feature, together with the orthogonality, relaxes the requirement of frequency/time guard between different user signals because the orthogonality is maintained for overlapped (in both time and frequency domains) wavelet packets. This is also an advantage of using wavelet packets to model many communication channels that are characterized by not only frequency selectivity but also time variation.

C. Orthonormal basis- An orthonormal and complete wavelet packet set, i.e., an orthonormal basis set can be constructed efficiently. This provides perfect spreading codes that have zero cross-correlations, thereby eliminating multiple access interference in the absence of synchronization error.

D. Multirateability - An orthonormal wavelet packet basis generated from a certain configuration of a wavelet packet tree divides the frequency axis into (overlapped) bands of various sizes. The functions in the basis occupy different intervals in the time domain. This feature naturally enables multirate communications.

E. Low complexity- A discrete signal can be decomposed into a wavelet packet basis with fast filter bank algorithms whose complexity is in the order of $N \log 2N$. Therefore, wavelet packet based methods have the advantage of low computation complexity.

III. DWPT-MC-CDMA SYSTEMS

The system model for discrete wavelet packet transform multicarrier code division multiple access (DWPT-MC-CDMA) system is shown in Fig.2.

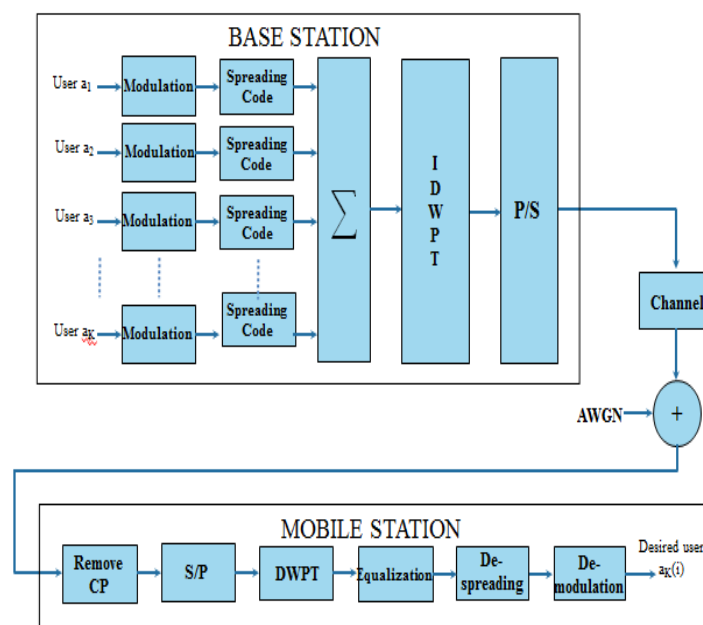


Fig.2 System model for DWPT-MC-CDMA system

In DWPT-MC-CDMA transmitter, K number of input signals gets modulated with its carrier frequency. Then the modulated signals get spreaded and get correlated. Then these signals are fed to IDWPT and then to parallel to serial convertor. Then these serial data signals are fed to channel with the AWGN.

In DWPT-MC-CDMA receiver, the cyclic prefix is removed from transmitted signal. Then these signals are fed to the serial to parallel convertor and to the DWPT. Then these signals are despreaded after equalization to get the received output signal.

In DWPT-MC-CDMA transmitter as illustrated in Fig.3, the transmitted signal for the user is the following real signal in continuous form:

$$s_k(t) = \sum_{i=-\infty}^{\infty} \sum_{m=1}^{M-1} a_k[i] c_{k,m} f_m(t - iMT_b)$$

where represents the waveform and modulator filter of subchannel. This filter acts for waveform and subcarrier simultaneously and should be bi-orthogonal [3],[19]. In discrete waveform it is written as

$$\sum_n g_i(n) f_j(Ml - n) = \delta(l) \delta(i - j)$$

where are the synthesis filters in the transmitter and are the analysis filters in the receiver, $i=0,1, \dots, M-1$. These two set of filters can be seen as matched filter process.

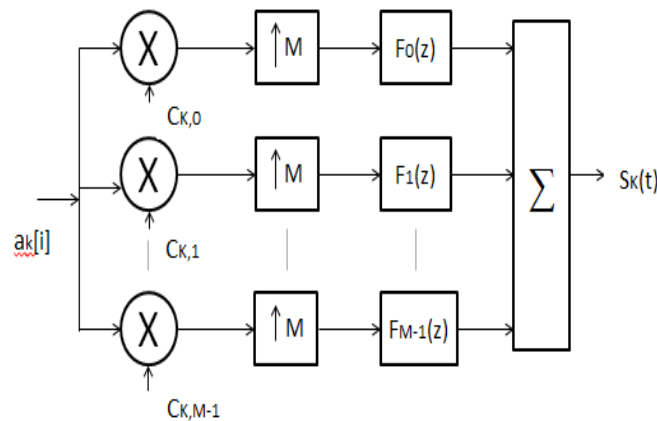


Fig.3 The model of DWPT- MC-CDMA transmitter

If there are K active users, then the received signal in complex analytic representation is

$$r(t) = \sum_{k=0}^{K-1} \sum_{i=-\infty}^{\infty} \sum_{m=0}^{M-1} h_m a_k[i] c_{k,m} f_m(t - iMT_b - L_m T_b) + z(t)$$

The model of DWPT-MC-CDMA receiver is illustrated in Fig.4.

The decision variable for 0^{th} user and i^{th} symbol is given by,

$$d_0[i] = a_0[i] \sum_{m=0}^{M-1} \alpha_m h_m + \sum_{k=1}^{K-1} a_k[i] \sum_{m=0}^{M-1} \alpha_m h_m c_{0,m} c_{k,m} dt + \eta \quad \text{where,}$$

$$\eta = \sum_{m=0}^{M-1} \alpha_m \frac{1}{T_b} \int_{iT_b}^{(i+\nu)T_b} g_m(t) z(iMT_b - t) dt$$

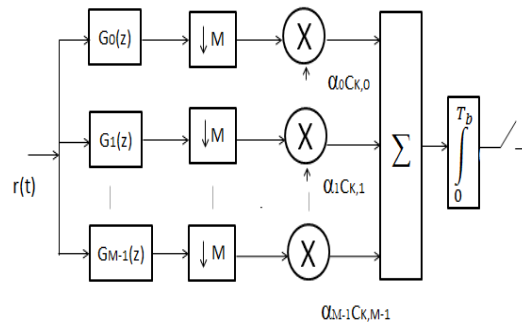


Fig.4 The model of DWPT-MC-CDMA receiver

As can be seen from equations, if synchronization and delay estimation are perfect, both systems give almost the same bit error rate performance for the same noise level. The imperfect of those processes will give different result for Fourier based and wavelet based systems. The wavelet based is expected to give better result because the averaging process in calculation of the decision variable is done both in frequency domain (by summation of all sub channels m) and time domain (by integration over v or summation over N).

IV.RESULTSAND DISCUSSION

The Bit Error Rate vs SNR performance of the MC-CDMA system is analysed using without and with wavelet in a Rayleigh fading channel.

The number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors. The bit error probability is the expectation value of the BER. If the medium between the transmitter and receiver is good and the signal to noise ratio is high, then the bit error rate will be very small possibly insignificant and having no noticeable effect on the overall system. However if noise can be detected, then there is chance that the bit error rate will need to be considered. The main reasons for the degradation of a data corresponding bit error rate are noise and changes in the propagation path [6], [7].

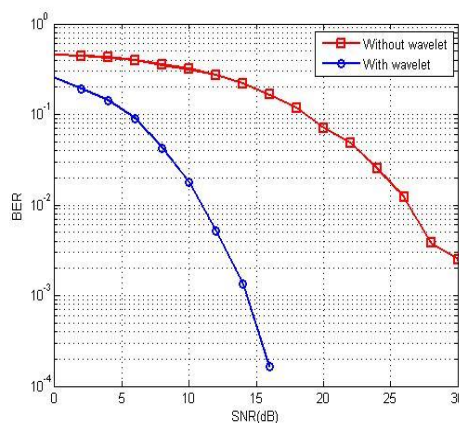


Fig.5 BER vs SNR for without and with wavelet in MC-CDMA

As with mobile environment signal fading occurs that results in degradation of the performance of the system. Fig.5 compares the BER performance for without and with wavelet in MC-CDMA system. The bit error rate (BER) performance of MC-CDMA system with wavelet is low when compared to the bit error rate (BER) performance of MC-CDMA system without wavelet. The signal to noise ratio (SNR) for MC-CDMA system with wavelet is less when compared to the signal to noise ratio (SNR) without wavelet. Fig.5 shows that bit error rate (BER) performance of MC-CDMA system with wavelet is better than the bit error rate (BER) performance of MC-CDMA system without wavelet.

Throughput is affected by the channel environment such as the distance between the transmitter and the receiver, the fading state of the channel, and the noise and interference characteristics. It is also influenced by the choice of design parameters, modulation, power level, multiple access scheme and many others. As we discussed earlier by using wavelet MC-CDMA interferences is reduced when comparing with conventional MC-CDMA. As result we can able to achieve higher throughput using DWPT-MC-CDMA system.

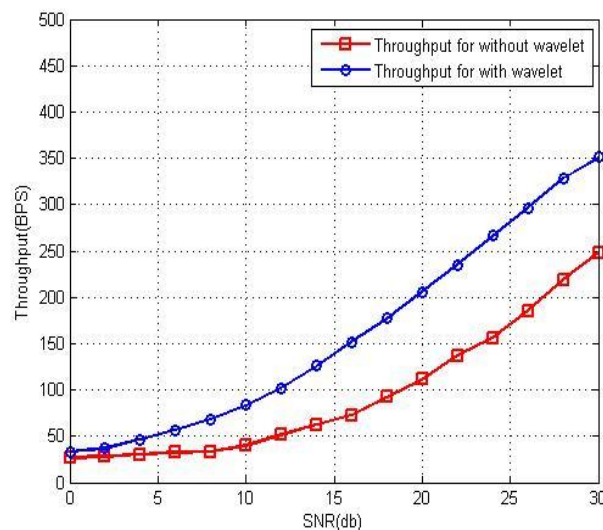


Fig.6 Throughput Vs SNR For Without and With Wavelet in MC-CDMA System.

Fig.6 compares the throughput value for with and without wavelet in MC-CDMA system. Throughput value with wavelet in MC-CDMA system is high when compared with the throughput value of MC-CDMA system without wavelet. Throughput value of MC-CDMA system with wavelet is 350(bps) and the throughput value of MC-CDMA system without wavelet is 250(bps). This shows that MC-CDMA system with wavelet gives better performance than the MC-CDMA system without wavelet.

V. CONCLUSION

Multi-carrier communication is commonly employed to combat channel distortion and improves the spectral efficiency. The basic idea of the scheme entails the division of the available spectrum into subbands of relatively narrow bandwidth such that the subchannels are nearly distortionless. The combination of multi-carrier

modulation and CDMA into multi-carrier MC- CDMA appears to be very attractive in mobile communications because it meets the challenges for next generation systems which are high data rate (wideband) system, robust against multipath fading and multiple access interference, higher spectral efficiency and network capacity. Traditionally the multi-carrier modulation is implemented using discrete Fourier transform (DFT) basis. The theoretical analysis and the simulation have been done and shown that the proposed system (DWPT-MC-CDMA system) has superior performance in term of bit error rate (BER), throughput value.

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