International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 5, July - 2012

Dynamic Spreading Code Allocation Strategy for A Downlink MC-CDMA System

Sudha Chandrika
Research Scholar J.N.T.U Hyderabad

Dr.V.D.Mytri
Princiapl, SIT Gulbarga

Abstract

The MC-CDMA (Multi-Carrier Code Division Multiple Access) transmission is a promising solution for the physical layer of future broadband wireless communication systems which will have to support multimedia services. By combining OFDM (Orthogonal Frequency Division Multiplexing) and CDMA, we obtain a high speed transmission capability in multipath environments and large multiple access capacity. Unlike CDMA, MCCDMA performs the spreading operation in the frequency domain, mapping each chip of the user spreading code on one subcarrier, and thus introduces frequency diversity. However when the MC-CDMA signal propagates through a frequency selective fading channel, the code orthogonality is destroyed and the resulting MAI limits the system performance. Several approaches have been proposed to mitigate MAI and to improve signal detection. The conventional single-user detection techniques, applying per subcarrier equalization as in OFDM systems and then correlation with the code of the desired user, offer poor performance. Indeed, by channel inversion, ZF (Zero Forcing) can eliminate MAI but in return-noise amplified on deeply faded subcarriers. The other techniques including MRC (Maximum Ratio Combining), EGC (Equal Gain Combining) and MMSE (Minimum Mean Square Error) cannot restore the orthogonality of codes and lead to residual MAI. Therefore more advanced methods such as MUD (Multi-User Detection) have been developed.

In this paper, we investigate the impact of Walsh-Hadamard spreading code allocation on the performance of a downlink MC-CDMA system in a time varying frequency selective channel. The analysis shows that this impact is important on the multiple access interference and the inter-carrier interference power levels. We propose a code allocation strategy that minimizes the global interference power and significantly improves the performance of the MC-CDMA system.

Keywords- *Multi-Carrier CDMA, Walsh-Hadamard codes, code allocation strategy, frequency selective fading, time varying channel*

1. Introduction

Multi Carrier Code Division Multiple Access (MC-CDMA) is a relatively new concept. Its development aimed at improved performance over multipath links. Multi-carrier CDMA is a digital modulation technique where a single data symbol is transmitted at multiple narrowband subcarriers with each subcarrier encoded with a phase offset of 0 or based on a spreading code [1]. The narrowband subcarriers are generated using BPSK modulated signals, each at different frequencies which at baseband are at multiples of a harmonic frequency. The Walsh-Hadamard codes are widely used and retained here for spreading in downlink because of their orthogonality properties [3]. Consequently, the subcarriers are orthogonal to each other at baseband, and the component at each subcarrier may be filtered out by modulating the received signal with the frequency corresponding to the particular subcarrier of interest and integrating over a symbol duration [9]

2. MC-CDMA SYSTEM DESCRIPTION

2.1 *MC-CDMA transmitter model*

Figure.1 depicts the block diagram of the MC-CDMA transmitter of a user u. Each data symbol x_u of duration Tx is spread by the spreading code $\{c_k^u, k=0 \ldots L-1\}$ assigned to the user u including L chips, each of duration $Tc=Tx/L$. The components of the resulting spread sequence are then transmitted in parallel on $N=L$ orthogonal subcarriers using the OFDM modulator. For a downlink transmission, the system is synchronous, so orthogonal Walsh-Hadamard codes are used for spreading[3]. This technique performs the spreading operation in the frequency domain since each chip is sent on one subcarrier, and introduces frequency diversity because each symbol is transmitted through all the subcarriers.

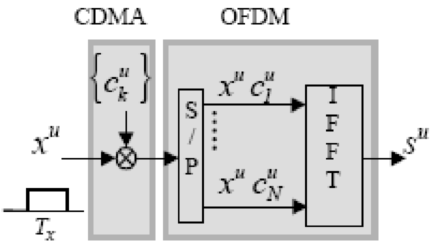

Figure 1. MC-CDMA transmitter

2.2. Channel model

We consider a time-varying channel with correlated Rayleigh fading envelopes. This channel is assumed to be frequency selective over the total system bandwidth but the narrowband signal which is transmitted through each subcarrier experiences a flat fading. The channel frequency response at the sampling time *nT* on the subcarrier *k* can then be written as *Hn,k=Xn,k+ iYn,k.*, where *Xn,k* and *Yn,k* are two zero-mean Gaussian random variables with a variance *σ2/2*. Their correlation functions in time and frequency are given by [4]:

$$E[X_{n,k}\,X_{n'k'}] = E\,[Y_{n,k}Y_{n'k'}]$$

$$= \frac{\sigma^2 J_0(2\pi F_d(n-n')T)}{2(1+(2\pi(k-k')\Delta f\sigma_c))^2)} \quad (1)$$

$$E\left|X_{n,k}Y_{n'k'}\right| = -E\left|Y_{n,k}\,X_{n',k'}\right|$$

$$= -2\pi(kk')\Delta f\,\sigma_\tau E\left|X_{n,k}X_{n',k'}\right|$$

where J_0 is the zero*th*-order Bessel function of the first kind, *Fd* is the maximum Doppler frequency, *Δf* is the subcarrier spacing and σ_τ is the channel delay spread. To obtain the frequency channel coefficients *Hn,k*, Gaussian random variables with these correlation properties are generated according the algorithm described in [4]. The spectral correlation is reproduced by applying a coloring matrix on *N* uncorrelated Gaussian random variables and the time correlation is reproduced via a Doppler filter as proposed by Young [5]. The *Np* paths $h_{n,l}$ ($0 \le l \le Np$-1) of the time varying channel impulse response are then obtained by IFFT.

2.3. MC-CDMA receiver model

The MC-CDMA receiver of a user *u* is represented on figure 2. It includes a basic OFDM demodulator with FFT operation and one tap equalizer per subcarrier followed by a CDMA correlator.

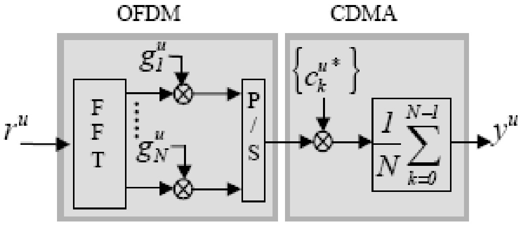

Figure 2. MC-CDMA Receiver

At the output of the FFT, the signal obtained on the subcarrier *k* resulting from the contribution of the *Nu* active users can be written as:

$$y_k = \beta_{k,k}\sum_{u=0}^{N_u-1} x^u c_k^u + \sum_{m=0,m\neq k}^{N-1}\beta_{k,m}\sum_{u=0}^{N_u-1} x^u c_k^u + n_k \quad (2)$$

where the three terms respectively correspond to the signal on the desired subcarrier, the inter-carrier interference (ICI) due to channel time variations, and the additive white Gaussian noise. $\beta_{k,m}$ can be viewed as a channel leakage between two subcarriers *k* and *m* and is defined as:

$$\beta_{k.m} = \sum_{l=0}^{N_p-1} H_l^{(k-m)}\, e^{-j2\pi lm/N} \quad (3)$$

It represents the FFT of $H_l^{(k-m)}$ which is proportional to the FFT of the *lth* time varying channel path $h_{n,l}$:

$$H_l^{(k-m)} = \frac{1}{N}\sum_{n=0}^{N-1} h_{n,l}\, e^{-j2\pi x(k-m)/N} \quad (4)$$

We can note that if the channel is time invariant, $\beta_{k,m}=0$ if $k \neq m$ so there is no ICI and $\beta_{k,k}$ simply corresponds to the channel coefficient on the subcarrier *k*. For equalization, we consider a single-user detection technique based on MMSE (Minimum Mean Square Error)because it offers a good tradeoff between complexity and BER performance [6]. The equalization coefficient on the subcarrier *k* is expressed as:

$$g_k = \frac{\beta^*_{k,k}}{\left|\beta_{k,k}\right|^2+\frac{1}{\gamma_k}} \qquad (5)$$

Where γ_k is the signal to noise ratio on the subcarrier *k*. This technique enables the restoration of code orthogonality for high values of $|\beta_{k,k}|$ and avoids an excessive amplification of noise for low values of $|\beta_{k,k}|$.

3. Block Diagram

3.1. MC-CDMA transmitter

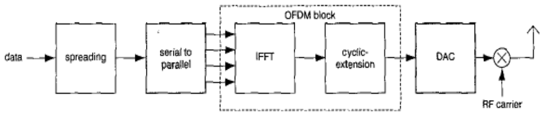

Figure 3.1Block diagram of MC-CDMA transmitter

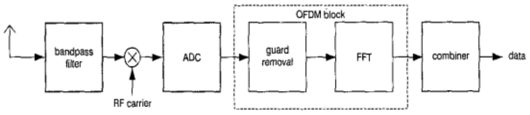

Figure 3.2 Block diagram of MC-CDMA receiver

In MC-CDMA systems, the signal is spread and then converted into a parallel data stream, which is then transmitted over multiple carriers. If the spreading factor is equal to the number of carriers then this system modulates the carriers with same data bit, but with a phase shift on each carrier with determined by the spreading code (Fig.(3.1)).

This multicarrier modulation can be efficiently implemented using an inverse FFT [11].

To overcome the effect of inter symbol interference this baseband signal is cyclically extended by more than the channel delay spread to allow the transmission of an interference-free symbol [11].

By using a guard interval, the receiver selects the portion of the signal that is free from inter symbol interference (Fig(3.2)). This is processed by an FFT block to demodulate the multiple carriers.

4. Spreading Code Allocation Algorithm

All the Walsh-Hadamard spreading codes of length *N* can be numbered from 0 to *N-1*. We denote Ω = {*0,…,N-1*} the set of these code numbers and Ω*Nu* = {*z0,…,zNu-1*} a subset of *Nu* codes numbers that can be assigned to the *Nu* active users. To determine the subset of codes minimizing the interference power, we use the following cost function *f*(Ω*Nu*) defined as in [8] by:

$$f(\Omega_{N_u}) = max_{z_k \in \Omega_{Nu}}[P^{z_k}]$$

where P^{zk} is the total interference power, including MAI and ICI power, affecting the code numbered z_k:

$$P^{z_k} = \sum_{i=0,i\neq k}^{N_u-1} P_{MAI}^{z_k,z_l} + P_{ICI}^{z_k,z_l}$$

To accelerate the search for the optimal subset of codes, the algorithm consists in recursively creating *N* possible subsets of *Nu* codes and in choosing the one which minimizes the cost function. To build the *N* subsets, a code number is initialized at the first iteration and then at each iteration, we pick the user code which presents the minimal mutual interference power with the selected codes in the previous iterations. The suboptimal code allocation algorithm is the following:

for n = 0 to N-1

The number of the first code is initialized:

$$Z_0 = n$$

$$ICI_{iu} = a_u x_{iu} + \sum_{l=1}^{L+P-1} S_u[l] S_u^*[l] - a_u x_{iu}$$

$$ISI_{iu} = a_u \sum_{n=-i,n\neq i}^{N-i} x_{iu} \cdot \sum_{l=1}^{L+P-1} S_{uu}[l]\, S_{uu}^*[l+nl]$$

$$MAI_{iu} = \sum_{n=-i}^{N-i} \sum_{k=1,k\neq u}^{k} a_k\, x_{ik} \cdot \sum_{l=1}^{L+P-1} S_{ku}[l] S_{uu}^*[l+n]$$

$$= \sum_{n=1}^{N} \sum_{k=1,k\neq u}^{k} a_k\, x_{i,k} \rho k_{un}$$

$$S_{ku}[l] = \sum_{p=1}^{P} c_k[l-p+1] \cdot h_u[p]$$

for k =1 to N_u*-1*

The number of the *kth* code is chosen to minimize the maximum mutual interference power with the previously selected codes $Z_{0\ldots\ldots\ldots}Z_{k-1}$

$$Z_k = argmin_{z_i \in \Omega, z_i \neq z_0 \ldots\ldots z_{k-1}}[max_{z_j = z_0 \ldots\ldots z_{k-1}}[P^{z_i z_j}]]$$

A possible subset of *Nu* codes is obtained:

$$\Omega_n = \{z_0, \ldots\ldots \ldots z_{N_u-1}\}$$

The optimal subset is selected among the *N* possible code subsets to minimize the cost function:

$$\Omega_{N_u}^{opt} = \arg min_{\Omega_{n,n=0\ldots\ldots N-1}}[f(\Omega_n)]$$

5. System Description

Consider the downlink transmission of a synchronous CDMA system of *K* users under frequency selective fading, where the channels' path delays are assumed to be an integer number of the chip period. All codes and channels are assumed to have normalized energy of one and length of *L* and *P* chips, respectively. The data frame is *N* symbols long. *Tb* and *Tc* are the symbol and chip periods, respectively. The received signal at the *u−th* MU can be expressed as:

$$r_u\,(\mathrm{t}) = \sum_{i=1}^{N} \sum_{k=1}^{k} \sum_{p=1}^{p} a_k\ x_k(i)c_k(\mathrm{t}\text{-}\mathrm{i}T_b\text{-}\mathrm{p}T_c)h_{pu}(\mathrm{i}) + n_u\,(t)$$

where *xk*(*i*), *ak*, *ck* are the *k−th* user's PSK modulated data symbol for the *i − th* symbol period, amplitude and code, *hpu*(*i*) and *nu*(*t*) are the *u − th* MU's channel *p − th* tap coefficient and AWGN noise corrupting the signal of interest. The output of the Rake receiver of the *u − th* user can be expressed as [10]:

$$d_{iu} = \sum_{P=1}^{P} \int_{iT_b+PT_c}^{(i+1)T_b\ +pT_c} r_u\,(\mathrm{t})\ h_{pu}^{*}\ (i)c_u^{*}(\mathrm{t}\text{-}\mathrm{i}T_b\text{-}\mathrm{P}T_c)\mathrm{dt}$$

$$= a_u x_{iu} + ICI_{iu} + ISI_{iu} + MAI_{iu} + \eta_{iu}$$

Here x_{iu} is a compact representation of the desired (u − th) user's signal for the i − th period of interest, ICI_{iu} is the Inter Chip Interference between adjacent chips, ISI_{iu} is the Inter Symbol Interference caused by adjacent symbols, MAI_{iu} is the cumulative MAI caused by the interfering K − 1 users and η_{iu} is the noise component at the Rake output. If a discrete time representation is adopted by sampling the signals at the chip rate with rectangular pulses then Tb, Tc can be omitted and the above terms can be defined as:
Where *hu*[*p*] is the discrete time representation of *hpu*(*i*) and

$$\rho k_{un} = \sum_{l=1}^{L+P-1} S_{ku}[\mathrm{l}]\ S_{uu}^{*}[l+nL] \qquad (6)$$

is the cross-correlation of the users multipart-corrupted signature waveforms (*sku*) in (6). Evidently, even if orthogonal codes are used the resulting cross correlation of the codes viewed at the receiver is non-zero due to the channel distortion. For reasons of simplicity, in the following we adopt a bit wise approach but expansion to block wise processing as in [4] is straightforward. The index *n* in of (7) can consequently be dropped. Furthermore, it should be clarified that, as in the majority of conventional precoding schemes (e.g. in [1,4]), the knowledge of the channel response for all receivers is required at the base station (BS) for the proposed precoding. This can be made available by channel estimation at the transmitter in the time division duplex (TDD) transmission mode [5], which is assumed in this paper. It can be seen in (2) that given the channel state information (CSI) and data knowledge readily available at the BS the decision variables at the receiver can be pre-estimated. By selecting the appropriate code allocation for transmission at each symbol period the factors can be influenced and hence the distribution of the *diu* values in (2) for all users can be improved to offer enhanced reliability in the detection.

6. Performance Evaluation

We investigated the impact of spreading code allocation on the performance of a downlink MC-CDMA system in a time varying frequency selective channel. The analysis shows that this impact is important on the multiple access interference and the inter-carrier interference power levels. We proposed a code allocation strategy that minimizes the global interference power and significantly improves the performance of the MC-CDMA system.

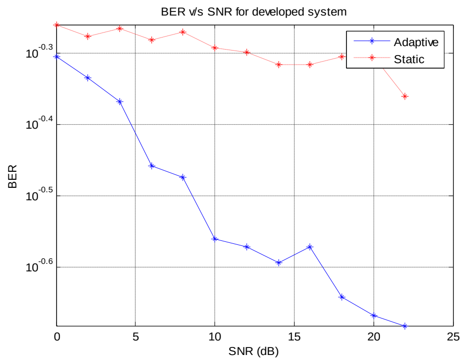

Figure 5. BER vs SNR for developed system(LHL)

The above graphs show BER vs. SNR. The x-axis indicates SNR and y-axis indicates BER. The dotted line indicates the bit error rate of fixed codes. The continuous lines indicate the bit error rate of adaptive codes.

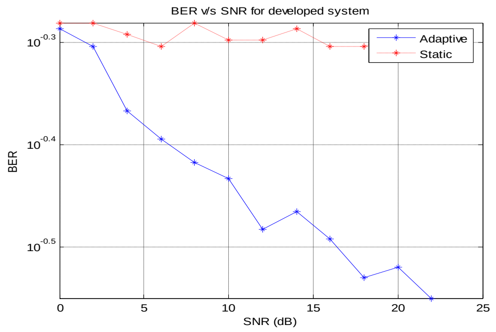

Figure 6 BER vs SNR for developed system(LHH)

It is observed that with the adaptive allocation of the coding sequence, the system performance with respect to estimation accuracy is improved. The bit error rate is very much reduced if adaptive codes are used rather than a fixed code.

7. CONCLUSION

As the current wireless communication system has moved towards digital modulation, CDMA have emerged as one of the best suited communication standard in current scenario. Due to its multiple advantages CDMA is most preferred architecture for current and future generation communication system. The major advantage of CDMA based communication system is its ability towards noise rejection due to pseudo noise spreading sequence. Due to the dynamicity observed in wireless channel. This property is minimizing in current CDMA system, with the variation in channel effects the codes are not varying, which was mainly focused in this paper work.

A symbol to symbol adaptive code allocation is developed for the current CDMA architecture, It is observed that with the adaptive allocation of the coding sequence the system performance with respect to estimation accuracy is improved .The effect of estimation accuracy is also effective with respect to the offered load for the communication system. In this work an evaluation to BER at variable noise level is evaluated for CDMA based spread spectrum communication system, and compared with the conventional fixed code allocation method under variable offered load and the performance were observed improved over the conventional approach.

This work focus on the adaptive allocation of code for CDMA based communication system the work could be enhanced for further performance. Enhancement with the incorporation of resource allocation strategies for the improvement of estimation accuracy in CDMA system. Further works can be carried out to evaluate the effect of timing jitter in a MC CDMA system in the presence of fading, To evaluate the performance of MC CDMA system with Rake receiver to overcome the effect of fading, to evaluate the performance improvement with forward error correction coding like convolution coding and Turbo coding etc.

References

[1] S. Hara, R. Prasad, “Overview of multicarrier CDMA”, *IEEE Communications Magazine*, vol. 35, pp. 126-133, Dec. 1997.

[2] N. Yee, J.P. Linnartz, G. Fettweis, “Multi-carrier CDMA in indoor wireless radio networks”, *IEEE PIMRC’93*, pp. 109-113, Sept. 1993.

[3] B.M. Popovic, “Spreading sequences for multicarrier CDMA systems”, *IEEE Transactions on Communications*, vol. 47, pp. 918- 926, June 1999.

[4] L.C. Tran, T.A. Wysocki, J. Sebbery, A. Mertins, “A generalized algorithm for the generation of correlated Rayleigh fading envelopes in radio channels”, *IEEE IPDPS’05*, April 2005.

[5] D.J. Young, N.C. Beaulieu, “The generation of correlated rayleigh random variates by inverse discrete Fourier transform”, *IEEE Transactions on Communications*, vol. 48, pp. 1114-1127, July 2000.

[6] J.Y. Beaudais, J.F. Hélard, J. Citerne, “Comparaison des performances de différentes techniques de détection appliquées à un signal AMRC à porteuses multiples dans un canal de Rayleigh”, *GRETSI'99*, pp. 737-740, Sept. 1999.

[7] D. Mottier, D. Castelain, “A spreading sequence allocation procedure for MC-CDMA transmission systems" *IEEE VTC Fall’00*, pp. 1270-1275, Sept. 2000.

[8] A.M. Mourad, A. Gueguen, R. Pyndiah, “Impact of the spreading sequences on the performance of forward link MC-CDMA systems”, *IEEE ISSSTA’04,* pp. 683-687, Sept. 2004

[9] J. G. Proakis, Digital Communications, Mc-Graw Hill, 2nd ed., 1991.

[10] ***S .*** Kondo and L. B. Milstein, "Performance of Multicarrier DS CDMA Systems," */E€€* Trans. Commun., vol. 44, no. 2, Feb. 1996, pp. 238-46.

[11] ***S.*** Kaiser, “Multi-Carrier CDMA Radio Systems – Analysis and Optimization of Detection, Decoding, and Channel Estimation”, ***PhD. Thesis,*** VDI-Verlag, Fortschxittberichte VDI, Series **10,** No. **531, 1998.**

[12] T. S. Rappaport, “Wireless Communications Principles and Practice”, Pearson Education, Inc., 2004.