Multi-carrier CDMA

Communications System Design

<< Literature Survey>>

Dong-Ming Chuang andYucong Gu

EE382C Spring 1998

Abstract: The Multi-carrier CDMA system is a novel 3rd generation mobile communication system. In this project we will use C language to design a Multi-carrier CDMA communication system in Ptolemy system.

I. Introduction

Recently, there has been considerable interest in applying direct sequence spread spectrum (SS) techniques to multiple access communications. This is partly due to its multiple access capability, robustness against fading, and anti-interference capability. 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 mobile environment which makes a highly hostile radio channel. To Combat the problem, the OFDM seems to be a solution.

The combination of OFDM and CDMA for mobile radio transmission has been proposed by several authors [1-6] such as “Multicarrier (MC-) CDMA”, “Multicarrier DS-CDMA”, “Mutilating (MT-) CDMA”. These signals can be easily transmitted and received using the fast Fourier transform (FFT) without increasing the transmitter and receiver complexities, and have the attractive feature of high spectral efficiency due to minimally densely subcarrier spacing.

The combination of OFDM and CDMA is anticipated a good approach to the 3rd generation mobile communication system where users will get access to an array of voice, data, and video communication services anywhere in the world at any time. All these date rates with different qualities of services will be variable and the data rate will be up to 2 Mbit/s for HDTV etc. Also the request for accessing the system will be very intensive.

II. Comparison of three types of Multi-carrier CDMA schemes

Table 1 shows the system features comparison. The required bandwidths of MC-CDMA and MC DS-CDMA are the same as wide as that DS-CDMA, and the MT-CDMA schemes has almost the twice bandwidth as the DS-CDMA scheme. For the detection methods, a lot of strategies have been proposed for down-link channel of MC-CDMA. But, the down-link detection strategies for MT- CDMA and MC DS-CDMA haven't proposed yet. From these comparisons, it seems that the MC-CDMA scheme is better than other schemes.

TABLE 1.

Access scheme	DS-CDMA	MC-CDMA	MC DS-CDMA	MT-CDMA
No. of subcarriers	1	N	N	N
Processing Gain	G	G	G	G*N
Symbol duration	T	T*N/G	T*N	T*N
Required Bandwidth	G/T	G/T*(N+1)/N	G/T*(N+1)/N	(2G*N)+N1)/T/N

III. MC-CDMA Transmitter

The MC-CDMA transmitter for a single user is shown in Figure 1. The binary data $a_m(k)$ are first multiplied by the pseudo noise (PN) binary sequence $s_m(i)$ that is called spreading code. The bit duration T of the data is much longer than the PN sequence chip duration T_c. Normally $N = \frac{T}{T_c}$ may be equal to 32, 64, 128 or higher. After the necessary encoding, the sequence that corresponds to one data bit is modulated in the band of N modulators. A very efficient way of realizing such a modulation scheme is the Inverse Fast Fourier Transform (IFFT). The distance between subcarriers is equal to the chip rate or its multiple. This modulation is called OFDM (Orthogonal Frequency Division Multiplex). The the circular prefix or guard time should be introduced for each symbol in order to combat the transients and the inter symbol interference caused by the channel and filters in the system. The circular prefix consists of $\mu - 1$ repeated samples from the IFFT output where μ is the length of the channel impulse response or the delay spread measured in samples. At the output of IFFT the pulse shaping filter followed by a modulator which shifts the whole spectrum to the desirable frequency band can be applied. Another solution is to apply the offset IFFT that eliminates the necessity of the above mentioned frequency shift.

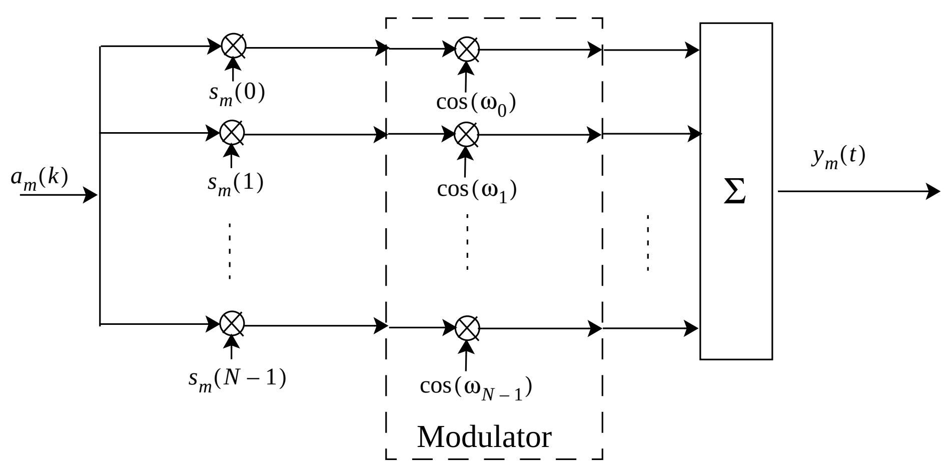


Fig. 1 Realization of MC-CDMA transmitter of a single user

In MC-CDMA system, sub-carrier frequencies are usually chosen to be orthogonal to each other, i.e., sub-carrier frequencies satisfy the following condition:

$$\int \cos(\omega_i t)\cos(\omega_j t))dt = 0, \ for((i \neq j))$$

where Tc is the chip duration; ω_i and ω_j are the i-th and j-th carrier frequencies. The sepectrum of MC-CDMA signal is shown in Figure. 2

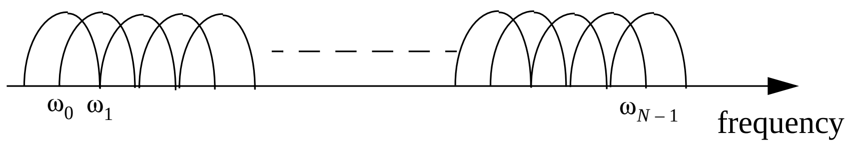
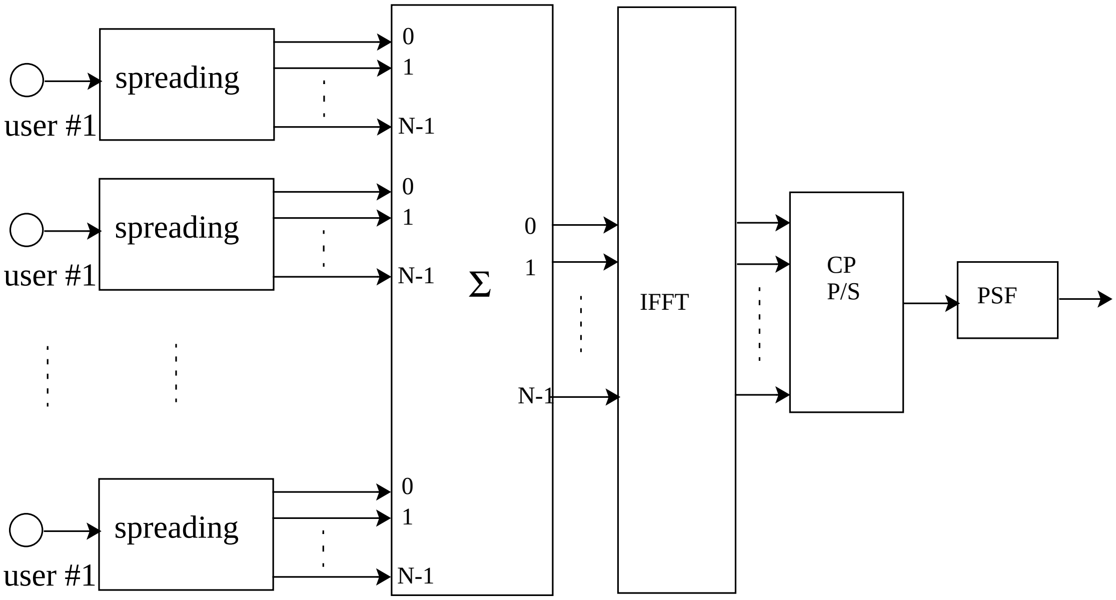


Fig. 2 Spectrum of MC-CDMA signal

The MC-CDMA transmitter for the base station is presented in Figure 3. After spreading chips the users' unique PN sequences are added. The result of this summation is a composite sequence. Multi-carrier modulation is achieved by applying IFFT to this summarized signal. Every chip in this composite sequence corresponds to one frequency bin. The circular prefix is attached to every block of N samples. Finally, the signal is filtered in a pulse shaping filter. In the case described above every chip occupies one frequency bin, however it not necessarily has to be so. If a user has the lower bit rate he can use the moreappropriate (smaller) number of frequency bins. The remaining bins can be utilized by other users.



CP- circular prefix

P/S -parallel to serial conversion

PSF-pulse shaping filter

Fig. 3 MC-CDMA transmitter for a base station

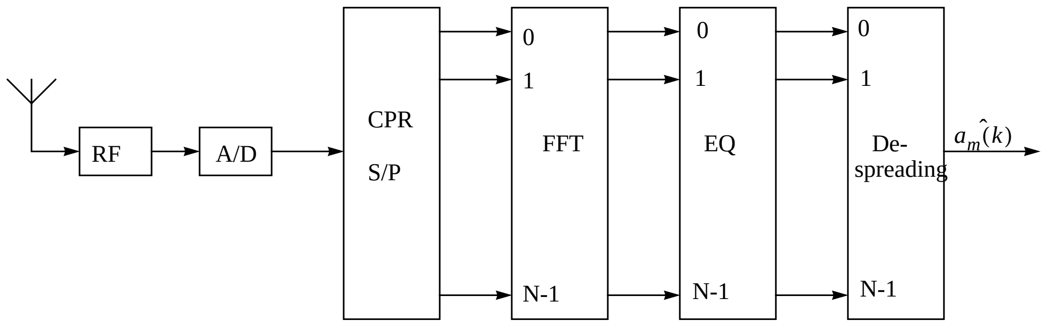
The IFFT order has to be at least as high as the highest number of chips per bit for a single user. Moreover, IFFT order should be high enough to ensure that the over head cased by the circular prefix was possibly small:

$$N \gg \mu - 1 \quad (1)$$

There is also the upper limit for the block length N at the IFFT output. It will be decided by MC-CDMA receiver.

IV. MC-CDMA receiver

The basic structure of the MC-CDMA mobile station receiver is presented in Figure 4. The receiver of the base station consists of the same blocks as those in Figure 4, however



RF: receive filter;
CPR: circular prefix removing;
EQ means equalization

Fig 4 MC-CDMA receiver for a mobile station

after output of FFT are fed to x branches (one branch for each user). A N equalizer and despreading block are applied in every branch to equalize the user's individual channel and multiply the received signal by the user's unique PN code.

The equalization usually uses adaptive equalizer or adaptive discrete matched filter (ADMF) at the receiver input. Its coefficients are calculated adaptively according to the adequate algorithm. For the correct operation of the applied adaptive filter we assume the channel characteristic remains unchange during the duration of the block of N samples. The changes of channel characteristics depend primarily on the vehicle's speed. Thus, the duration of a single block must be much smaller than the inverse of the maximum Doppler frequency. Hence, the upper limit for the IFFT order applied in the transmitter is specified by Equation (2).

$$N \ll \frac{f_c}{f_D} \quad (2)$$

where f_c is the chip rate and f_D is the maximum Doppler frequency.

The problems of the signal reception for the mobile station receiver and for the base station receiver are different. It is clear that the channel equalization for the downlink is much easier than that for the uplink. The mobile receiver is to estimate only one channel from a certain portion of the received signal. On the other hand, the uplink has to estimate many channels from the equivalent portion of the signal. Another problem of the signal reception in uplink transmission case is that the signals coming from the different users are not synchronized in time. In the receiver the possibility of the synchronization loss in frequency has to be taken into account as well. The signal coming from each user suffers from the loss of orthogonality of the subband signals because the interchannel interference (ICI) presents in the transmission channel. Obviously, ICI for every user may have different range and should be cancelled separately. Thus, the problem of channel estimation for the uplink in MC-CDMA system is rather complex.

V. Future Work

We will implement MC-CDMA system (Receiver and transmitter) in Ptolemy by using C language.

VI. Reference

[1] V.M. Dasilva and E.S. Sousa, “Performance of Orthogonal CDMA Codes for Quasi-Synchronous Communication Systems”, IEEE Selected Areas in Communication, 1994, v12, n.5, pp.842-852.

[2] S. Kondo and L.B. Milstein, “Performance of Multi-carrier DS CDMA Systems”, IEEE Trans. on Communication, Vol. 44, n.2 Feb. 1996, pp.238-246

[3] E. SOurour and M. Nakagwa, “Performance of Orthogonal Multi-carrier CDMA in a Multi-path Fading Channel”, IEEE Trans on Communication, Vol. 44, n3. Mar. 1996, pp.356-367.

[4]N. Yee, J-P. Linnartz and G. Fettweis, “Multi-carrier CDMA in indoor Wirless Radio Networks”, Proc. of IEEE PIMRC’93, Japan, Sep. 1993, pp.109-113.

[5] L. Vandendorpe, “Multi-tone Direct Sequence CDMA System in an indoor Wireless Environment”, Proc. of IEEE First Symposium of Communications and Vehicular Technoloy, Oct. 1993, pp.4.1.1-4.1.8.

[6] Hanna Bogucka, ”Transmission and Reception of the Multi-carrier CDMA Signals in the 3rd Generation Mobile Communication Ssytem”, IEEE International Conference on Personal Wireless Communications, Feb 1996, pp.319-322