MULTICARRIER TECHNIQUES: OWSS AND MC-CDMA

Ing. Tomáš KAŠPAREC, Doctoral Degreee Programme (1)
Dept. of Radio Electronics, FEEC, BUT
E-mail: xkaspa07@stud.feec.vutbr.cz

Supervised by: Prof. Vladimír Šebesta

ABSTRACT

This article deals with comparing of two multicarrier systems in AWGN channel. Comparative parameter is BER (Bit Error Rate). MC-CDMA (Multicarrier Code Division Multiple Access) uses orthogonality of cosine functions. While OWSS (Orthogonal wavelet spread spectrum) utilizes so called OWSS pulses. These techniques change frequency selective fading channel into more flat fading channels. Multicarrier techniques are proposed to next generation of mobile communications, e.g. 4th generation.

1 INTRODUCTION

Multicarrier CDMA (Code Division Multiple Access) communication is a combination of multicarrier modulation scheme and CDMA concept. Multicarrier communication (MC) schemes divide fast data stream into more streams, which are not so fast. Each the data stream modulates other subcarrier. Subcarriers should be orthogonal. Complex exponentials are good subcarriers for example. The purpose to use multicarrier transmission is to extend the symbol duration so that a frequency selective fading channel is divided into a number of flat fading channels, because subcarriers have much narrower bandwidths. CDMA is a multiple access technic using some properties of spreading sequences for separation different users.

Three types of multiple access schemes based on a combination of code division and multicarrier techniques were proposed, such as “multicarrier (MC-) CDMA,” “multicarrier DS-CDMA,” and “multitone (MT-) CDMA” [1]. Those three techniques use the cosine waveforms as subcarriers. Further MC systems are known which use another shape of subcarriers. In [2] a new signaling system is proposed which using a new class of signaling pulses. Called OWSS (Orthogonal Wavelet Spread Spectrum), they are generated through a combination of OWDM (Orthogonal Wavelength-Division Multiplexing) and spread-spectrum concepts. It is known techniques with wavelet packet transformation [3,4].

This article reviews the multicarrier CDMA schemes, specially MC-CDMA scheme and a little modified OWSS concept. In this paper a downlink wireless communication AWGN channel is assumed, in which the signals from different users are assumed synchronized. The article shows their properties in AWGN channel. In the following, MC-CDMA scheme is introduced. Next section is devoted OWSS signaling system. Systems simulation results are given in the last section.

2 MC-CDMA

The multicarrier CDMA schemes can be categorized mainly into two groups. One spreads the user symbols in the frequency domain, the other spreads user symbol in the time domain. The MC-CDMA transmitter spreads the original data stream over different subcarriers using a given spreading code in the frequency domain. A fraction of the user symbol corresponding to a chip of the spreading code is transmitted through a different subcarrier. In this article only downlink channel is considered. We do not pay attention to the auto-correlation characteristic of the spreading code. So we can use the spreading code, which is orthogonal. The Walsh-Hadamard codes are used [4].

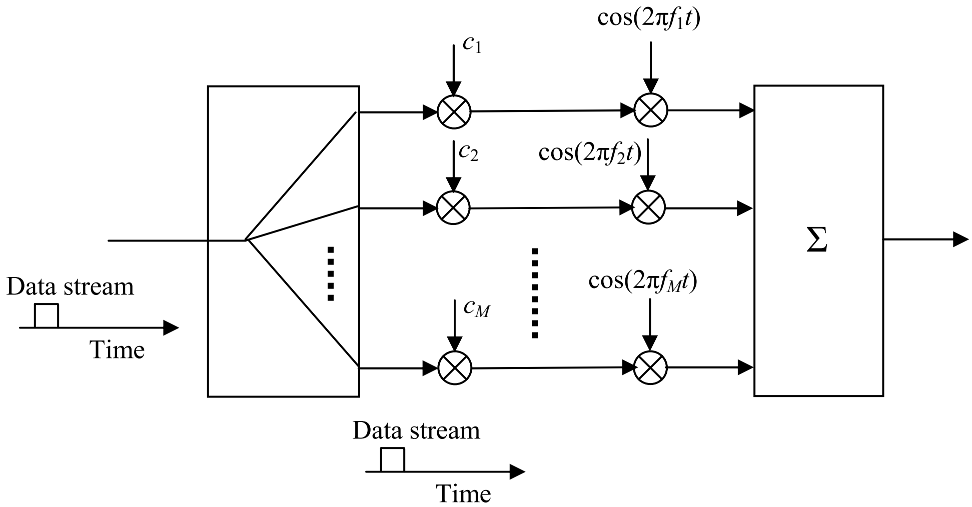

Fig. 1: *MC-CDMA transmitter scheme.*

Figure 1 shows the MC-CDMA transmitter scheme, where M denotes the number of subcarrier and $\boldsymbol{c} = [c_1\ c_2\ ...\ c_M]$ is a spreading Walsh-Hadamard code with processing gain M. Then we consider processing gain and number of subcarriers are the same.

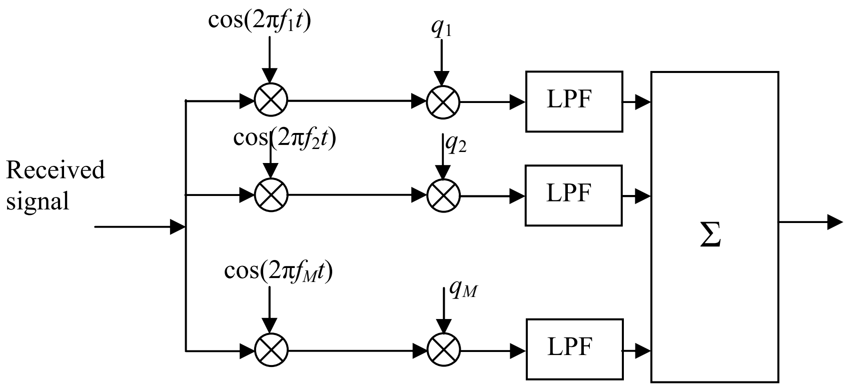

Fig. 2: *MC-CDMA receiver.*

Figure 2 shows the MC-CDMA receiver, where after the serial-to-parallel conversion, the m-th subcarrier is multiplied by the gain q_m to combine the received signal energy scattered in the frequency domain. The decision variable is given by equation (1).

$$D^j = \sum_{m=1}^{M} q_m \sum_{j=1}^{J} z_m^j a^j c_m^j + n_m \qquad (1)$$

Where, $y_m = \sum_{j=1}^{J} z_m^j a^j c_m^j + n_m$ and n_m are the complex baseband component of the received signal after down-conversion with subcarrier frequency synchronization and the complex additive Gaussian noise at the m-th subcarrier, respectively, z_m^j and a^j are the complex envelope of the m-th subcarrier and the transmitted symbol for the j-th user, respectively, and J is the number of active users. If we use ORC (Orthogonality Restoring Combining) then the gain is $q_m^j = c_m^j z_m^* |z_m|^2$. Other detection strategies are in [1].

3 OWSS

OWSS is a proposed signaling system for 100-150 MB/s wireless LANs. OWSS pulses are generated through a combination of orthogonal wavelength-division multiplexing and spread-spectrum concepts. The system offers several advantages including robustness to frequency-selective fading, effective equalization due, in part, in to the wide spectrum and wide time-support of the pulses used, high data rate [2]. The concept uses the pulses $\varphi_m(t)$, $m = 0, 1, ..., M-1$ from an orthonormal set over certain interval of time instead cosine functions in MC-CDMA. Then output signal over time T is

$$s_0(t) = \sum_{m=0}^{M-1} a_m \varphi_m(t), \qquad (2)$$

where M is the number of various pulses in orthonormal set, and the length of pulses is $T = MT_S$, where T_S is the basic symbol interval. Each basis pulse $\varphi_m(t)$ serves to create a "virtual" channel over which the symbol a_m is carried. A supersymbol is vector of symbol $\boldsymbol{A} = [a_0\ a_1\ ...\ a_{M-1}]^T$. The basic sets are generated from wavelets. All OWDM basis functions can be generated through the process of scaling or shifts from a single function, called the mother wavelet. And it is reason why they are indexed by two indices, one signifying scale, the other shift. Thus, if $\psi(t)$ is the mother wavelet, the basis functions are of the form:

$$\psi_{m,n} = 2^{-m/2}\psi(2^{-m}t - n), \qquad (3)$$

where m is scale index and n shift index, both indexes are integer.

The orthonomal basis sets are generated through a tree structure. To illustrate, let us define $g_0 = [2^{-1/2}\ 2^{-1/2}]$ and $g_1 = [2^{-1/2}\ -2^{-1/2}]$, g_0 is a scaling function and g_1 constitutes the well-known Haar wavelet. Then we show in fig. 3 two full trees, which can generate basis function over support intervals of 2 and 4, respectively.

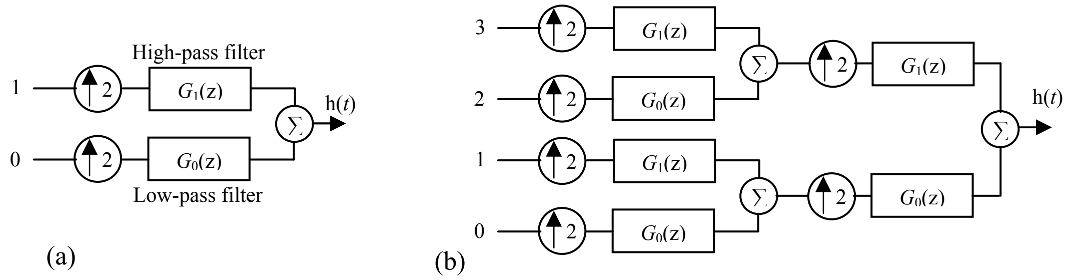

Fig. 3: *Synthesis tree, (a) one-stage,(b) two-stages.*

In the fig. 3 there are circles, with up arrow, which denote upsampling device, and the digit 2 signifies that the upsampling ratio is two. G_0(z) and G_1(z) is transfer function of low-pass filter and high-pass filter, respectively. They are gained by z-transform of g_0 and g_1. In each of the two cases shown in this figure, a member of the basis set is generated by applying a unit pulse at any one, and only one, input node while all other nodes receive a zero input. The transmitted signal for the *i*th user is

$$s^{(i)}(t) = \sum_n a_n^{(i)} \sum_{m=0}^{M-1} c_m^{(i)} \varphi_m (t - nT) \tag{4}$$

where a_n is data symbol, $\boldsymbol{c}^{(i)} = [c1\ c2\ ...\ c_M]$ is spreading code for the i-th user. Spreading codes are Walsh-Hadamard codes, because these codes are orthogonal (see section 2). In [2] are proposed receiver techniques based on DFE (Decision Feedback Equalizer) and possibility combination of OWSS and STC (Space-Time Coding).

4 SIMULATION

Simulation was done in Matlab. Parameters of simulation are in table (1). 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. Data are input of OWSS or MC-CDMA transmitter, where data are sampled and modulated. AWGN (Additive White Gaussian Noise) is added to output from transmitter, Matlab function *awgn* is used. In this simulation we consider downlink channel, and good chip synchronization. Output of channel is filtered by low-pass filter. RRC (Root Raised Cosine) filter is used. The parameters of filter are: bandwidth is $M\Delta f$, in this case bandwidth is 8, roll-off factor is 0.5. In receiver the averaging on symbol duration is consider instead of low-pass filtering (see fig.2 block LPF). The simulation outputs are two graphs, which both show comparing of OWSS and MC-CDMA fig.4. On the left picture there is BER performance as function of SNR (Signal to Noise Ration) in dB and on the right one there is dependence BER on number of user.

	OWSS	MC-CDMA
The data symbol duration	$T_c = 1$	$T_c = 1$
Number of subcarriers	$M = 8$	$M = 8$
Symbol duration at subcarrier	$T_s = MT_c$	$T_s = MT_c$
Processing gain (length of code)	M	M
Sample period	$T_{vz} = 0.0125$	$T_{vz} = 0.0125$
Subcarrier separation	$\Delta f = 1/ T_c$	
Wavelet		haar
Length of data vector	20 000	20 000

Tab. 1: *Simulation parameters*

5 SIMULATION RESULT AND DISCUSSION

Simulation results may be seen on the fig. 4. The picture on the left side gives comparison of BER performance between OWSS based on wavelet and MC-CDMA. System OWSS has better BER performance than MC-CDMA. The similar situation shows the picture on the right side, OWSS has better performance than MC-CDMA.

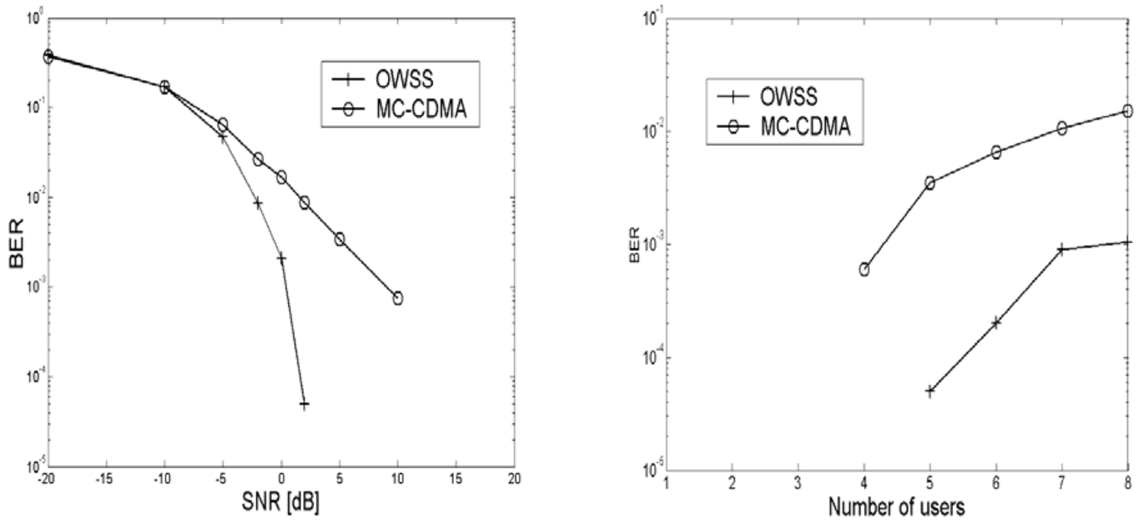

Fig. 4: *Simulation result, BER performance*

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