Simulation of Multi-Carrier CDMA system for future wireless systems

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Abstract *In this paper, new multiple access schemes based on the combination of Code Division Multiple Access (CDMA) and Multicarrier modulation (also known as OFDM (Orthogonal Frequency division Multiplexing)) are reviewed. Some of the main systems proposed to date are identified and the advantages of such systems discussed. A description of a simulation platform developed to analyse the performance of such systems is included, together with some illustrative outputs.*

1 Introduction

The next generation of mobile communication systems (also known as third generation or 3G systems) will be able to provide a whole variety of voice, data and video services to the user. 3G system will operate in the 2 GHz region and provide data rates of up to 2Mbps. The application wish list for 3G systems ranges from viewing sports highlights and movie trailers using a mobile videophone, to internet access and remote connection to the company computer network.

Beyond this, future generations of wireless systems (sometimes referred to as 4G systems) will provide even higher data rates and greater flexibility. This will necessitate the use a transmission scheme which can accommodate very high data rate transmission over the hostile wireless channel.

Much research has been done on the use of wideband-CDMA for such systems. The main advantages of CDMA are well known, however, its capacity is limited by the other users interference[1]. In addition, CDMA systems:
* are difficult to implement because they have a complex receiver structure and
* do not provide good spectral efficiency

It has been suggested in the literature that a combination of CDMA with a multi-carrier modulation scheme may help ameliorate the limitations indicated and this is considered here. In section 2 the general concept of CDMA systems combined with multi-carrier modulation is described and the advantages of such systems considered. Section-3 describes a simulation platform developed to analyse the performance of such systems and presents some illustrative output waveforms. Finally, section 4 provides brief concluding remarks and indications of ongoing studies.

2 Background

Multiple access schemes based on a combination of CDMA and Multi-carrier modulation were first proposed at PIMRC in 1993[4]. The combination of the two schemes can be done in a number of ways. In this section we first describe the principles of multi-carrier modulation technique and then go on to describe multi-carrier CDMA.

2.1 Multi-Carrier Modulation

In a multi-carrier modulation scheme the available bandwidth, B, is divided into N subchannels which are spaced B/N apart. Each subchannel is modulated by an orthogonal subcarrier so that the spectrum of each subchannel mutually overlaps[3].

The input data stream is divided into N parallel data streams by using a serial-to-parallel (S/P) converter. The parallel data streams are then modulated by N orthogonal subcarriers and summed before transmission. To maintain the orthogonality of the subcarriers (which can be lost due to multipath effects) and to eliminate the effects of Inter symbol interference (ISI) (due to multipath) a guard period is added to each symbol after the summation.

If the guard period is greater then the maximum delay spread of the system and the S/P converted symbol duration is smaller then the coherence time of the system then the transfer function of each subchannel is quassi-constant in time and frequency[3].

Key benefits of Multicarrier modulation include:

- As the duration of the symbol at the output of the S/P converter is N times that at the input, the effect of ISI caused due to multipath is reduced.
- Mutual overlapping of the subcarriers provides optimum spectral efficiency.
- High frequency diversity is obtained due to the fact that the transfer functions of the subchannels are quassi-constant in time and frequency. This provides greater capacity.

A major practical advantage of multi-carrier modulation is that it can be implemented using an FFTs.

2.2 Multi-Carrier CDMA

In a multi-carrier CDMA system, the individual users data is first spread using the high rate spreading code and then put through a multi-carrier modulator. The multi-carrier CDMA schemes proposed to date can be categorised into two groups[4]: One spreads the original data stream using a given spreading code, and then modulates a different subcarrier with each chip (Fig-1a). The other spreads the S/P converted datastreams using a given spreading code, and then modulates a different subcarrier with each data stream(Fig-1b). The first arrangement is sometimes referred to as spreading in the frequency domain and the second as spreading in the time domain. The first scheme is generally known as MC-CDMA (multi-carrier CDMA) and the second scheme is known as MC-DS-CDMA (Multicarrier Direct sequence CDMA).

It has been suggested in the literature[4] that an MC-CDMA scheme is a more efficient form of transmission scheme. This is because in an MC-CDMA receiver, the received signal is combined, in a sense, in the frequency domain, therefore the receiver can always use all the received signal energy scattered in the frequency domain.

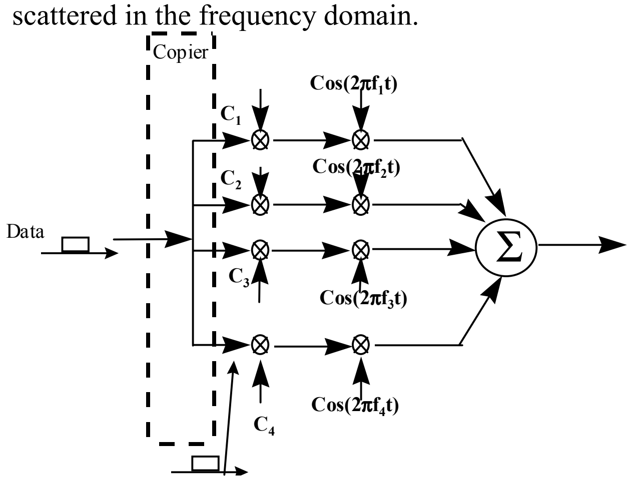

Fig-1a: Spreading in Frequency Domain

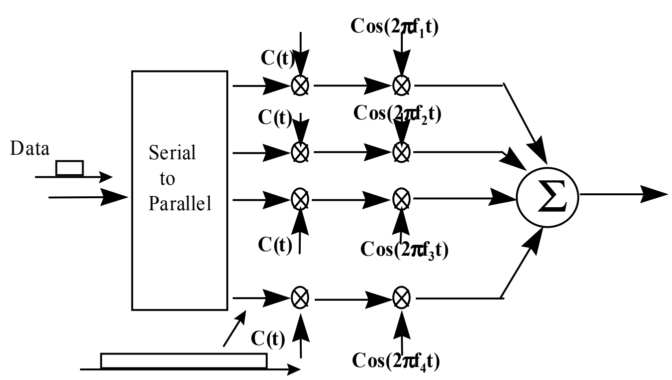

Fig-1b: Spreading in Time Domain

3 Simulation Platform

A simulation platform has been developed using matlab to model the downlink of the mobile radio system. A transmission scheme as illustrated in Fig-2 is under investigation. Section 3.1 describes the transmitter model and section 3.2 describes the receiver model. The platform is based on the MC-CDMA scheme described in section 2.2. This scheme is being investigated because of its apparent advantages. Table-1 lists the values of the main system parameters adapted for this study. The parameter values used are similar to those used for HIPERLAN-2 [6] and IEEE 802.11a.

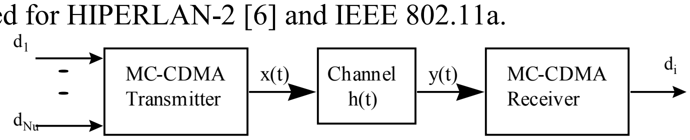

Fig-2: Transmission model for the downlink of a mobile radio communications system

3.1 Transmitter Model

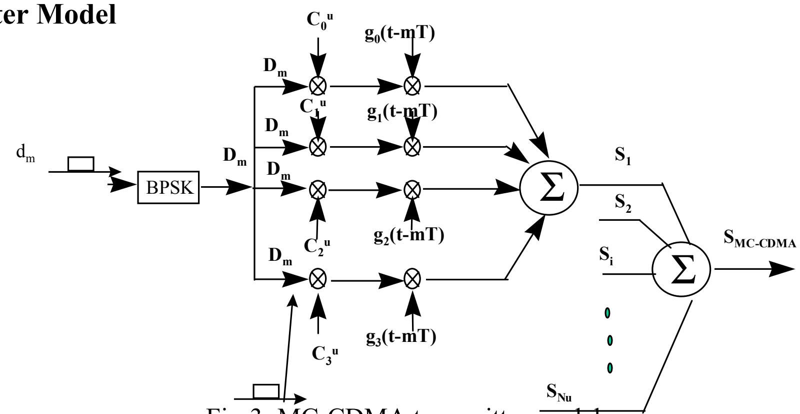

Fig-3: MC-CDMA transmitter model

In a MC-CDMA transmitter, each user data is first modulated using BPSK modulation. The BPSK modulated signal is then serial to parallel converted (The length of the serial to parallel convertor is equal to the max number of users in the system - N). Each branch of the S/P converter output is multiplied by a chip of the walsh code (length N) and then mapped onto N subcarriers. (Each user is assigned a unique code.) The output of each branch is summed and a guard period is then added.

The transmitted waveform is given by,

$$S_{mc-cdma}(t) = \sum_{u=1}^{N_u} S_u$$

$$S_u = \sum_{m=-\infty}^{\infty} \sum_{n=0}^{N-1} D_m c_n^u g_n(t-mT) e^{j2\pi f_c t}$$

$$g_n(t) = e^{j2\pi n(t-T_{cp})/(T-T_{cp})} \text{ t } [0, T]$$

$N=N_{max}$=Number of Subcarriers
T_{cp}=Guard Period

N_u=Number of Active users
$T=T_{useful}+T_{cp}$

3.2 Receiver Model

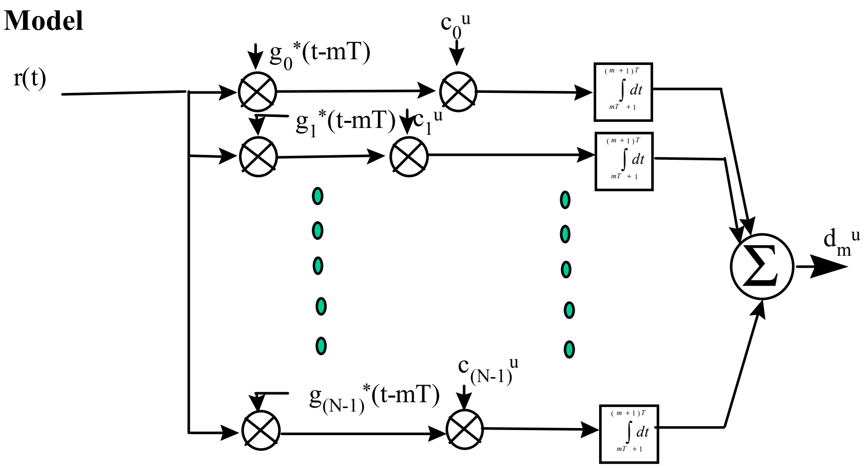

Fig-4: MC-CDMA receiver model for user *u*

The received signal is first demultiplexed by multiplying the input signal by the complex conjugate of the subcarriers. The output is then integrate over the symbol duration to recover the symbol value. The output from each of the integrators is then parallel to serial converted and multiplied by the spreading code to recover the original user data.

The recovered user data for user *u* is given by,

$$D_m^u = \sum_{n=0}^{N-1} \int_{mT+T_{cp}}^{(m+1)T} r(t) c_n^u g_n^*(t-mT)$$

r(t)= received baseband signal

The simulation parameters adapted for the study are listed below.

Parameter	Value
Carrier Frequency, f_c	5GHz
Processing Gain, G	64
Spreading Code	Walsh Hadamard
Modulation	BPSK
No of Subcarriers, N	64
Useful symbol interval, T_{useful}	399.2 μs
Subcarrier spacing, Δf	312.5 KHz
Guard Period, T_{cp}	800 ns

Table-1: Simulation Parameters

3.3 Illustrative Outputs

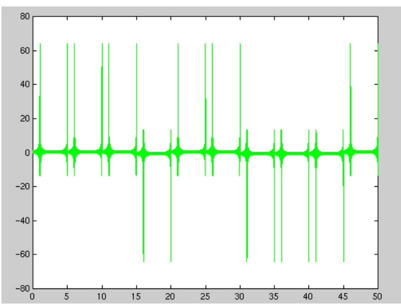

Fig-5a: MC-CDMA System – 1user

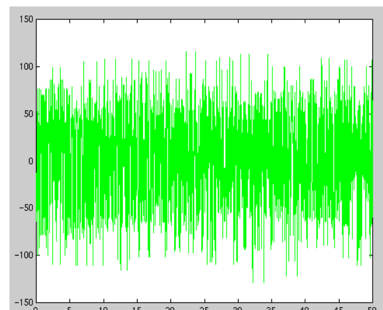

Fig-5b: MC-CDMA System – 64 user

4 Concluding Remarks

This paper has reviewed new multiple access scheme based on a combination of CDMA and multi-carrier modulation. It has provided a brief description of multi-carrier modulation. The general concept of multi-carrier CDMA has also been explained. A simulation platform developed to analyse the performance of MC-CDMA has been described and some illustrative outputs presented. This will provide a flexible tool with which to study the performance of MC-CDMA systems in different channel conditions with different parameter values. Ongoing work is particularly focused on investigation of future broadband systems such as HIPERLAN and MBS.

References

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