Design and Performance of Code Division Multiple Access Physical Layer Transceivers in Flat and Selective Fading Channels

Aktham Hasan Ali

Abstract— Code Division Multiple Access (CDMA) is the technology used in all third generation cellular communications networks, and it is a promising candidate for the definition of fourth generation standards. The wireless mobile channel is typically frequency-selective causing interference among the users in one CDMA cell. In this work, CDMA Transceivers block has been studied widely, and an analysis of proposed model based on Orthogonal frequency-division multiplexing OFDM based Fourier transform on in Flat and Selective Fading Channels

Keywords: CDMA, OFDM, IFFT, FFT, Flat Fading, Selective Fading, Channels

I. INTRODUCTION

Digital wireless communication system, like cellular systems and wireless LANs, along with devices such as small laptop computers, PDAs and mobile phones, have enabled the development of wireless networking as that now mobile users expect to be able to use the same multimedia applications as fixed users. Code division multiple access (CDMA) is a channel access method used by a variety of digital radio communication technologies. CDMA is an example of multiple accesses, which is where several transmitters can send information simultaneously over a single communication channel. This allows a number of users to share a band of frequencies. To permit this to be achieved without undue interference between the users, CDMA employs spread-spectrum technology and a special coding scheme. CDMA is used as the access a technique in many mobile phone standards like CDMA One, CDMA2000 (the 3G evolution of CDMA One), and WCDMA (the 3G standard used by GSM carriers), which are often referred to as simply CDMA. The technology of code division multiple access channels has long been known. In the USSR, the first work devoted to this subject was published in 1935 by Professor Dmitriy V. Ageev.[1] It was shown that through the use of linear methods, there are three types of signal separation: frequency, time and compensatory. The technology of CDMA was used in 1957, when the young military radio engineer Leonid Kupriyanovich in Moscow, made an experimental model of a wearable automatic mobile phone, called LK-1 by him, with a base station. LK-1 has a weight of 3 kg, 20–30 km operating distance, and 20–30 hours of battery life. The base station, as described by the author, could serve several customers.

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In 1958, Kupriyanovich made the new experimental "pocket" model of mobile phone. This phone weighed 0.5 kg. To serve more customers, Kupriyanovich proposed the device, named by him as correllator.[4][5] In 1958, the USSR also started the development of the "Altai" national civil mobile phone service for cars, based on the Soviet MRT-1327 standard, the phone system weighed 11 kg it was placed in the trunk of the vehicles of high-ranking officials and used a standard handset in the passenger compartment. The main developers of the Altai system were VNIIS (Voronezh Science Research Institute of Communications) and GSPI (State Specialized Project Institute). In 1963 this service started in Moscow and in 1970 Altai service was used in 30 USSR cities. Short for Code-Division Multiple Access, a digital cellular technology that uses spread-spectrum techniques. Unlike competing systems, such as GSM, that use **TDMA**, CDMA does not assign a specific frequency to each user. Instead, every channel uses the full available spectrum. Individual conversations are encoded with a pseudo-random digital sequence. CDMA consistently provides better capacity for voice and data communications than other commercial mobile technologies, allowing more subscribers to connect at any given time, and it is the common platform on which 3G technologies are built. CDMA is a military technology first used during World War II by English allies to foil German attempts at jamming transmissions. The allies decided to transmit over several frequencies, instead of one, making it difficult for the Germans to pick up the complete signal. Because Qualcomm created communications chips for CDMA technology, it was privy to the classified information. Once the information became public, Qualcomm claimed patents on the technology and became the first to commercialize it. Multicarrier CDMA schemes can be broadly categorized into two groups. The first type spreads the original data stream using a spreading code and then modulates different carriers with each chip, i.e., spreading the chips in the frequency domain. This is usually referred to as MC-CDMA and is the technique of interest to us[2, 3]. The second type spreads the serial to parallel converted streams using a spreading code and then modulates different carriers with each data stream, i.e., spreading in the time domain [4, 5]. Again there are two schemes reported in this spreading in time domain approach based on the subcarrier frequency separation. Denoting the bit duration as T and the chip duration as T , then the subcarrier spacing in one system is 1/T and the other is 1/Tb. The former is called the Multicarrier DS-CDMA (MC-DS-CDMA) and the latter is called the Multi-tone CDMA (MT-CDMA). The performance of these two schemes has been studied for an uplink channel in [2, 6] . Hara [7] has shown that MC-CDMA

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outperforms MC-DS-CDMA and MT-CDMA in terms of downlink BER performance. MC-CDMA is thus an attractive technique for the downlink.. In 1993 Persson et al.[8], proposed MC-CDMA, mainly due to the OFDM modem's ability to reduce ISI, combination of orthogonal frequency division multiplexing and code division multiple access (CDMA) has been subject to intensive research lately and called multi-carrier CDMA or MC-CDMA [9, 10]. An MMSE receiver was analyzed for MC-CDMA transmission over a mobile channel with Doppler effect in [11],[12, 13] . Its performance was shown to be better than uncoded OFDM.

II. The Simulation Block Diagram

The block diagram of MC-CDMA transmitter is shown in Figure 2. The input data stream is spread using the spreading sequence which could be a Walsh-Hadamard code or a PN sequence. The resultant chips after spreading the symbols are modulated into different subcarriers using the IFFT operator. The end few symbols are appended at the beginning of the frame to act as the cyclic prefix. The cyclic prefix maintains Orthogonality between the subcarriers in a multipath channel. The receiver first removes the cyclic prefix and then performs an FFT operation of the received symbols and brings them back to the frequency domain .then dispreading and decoding of the chips in frequency domain are performed.

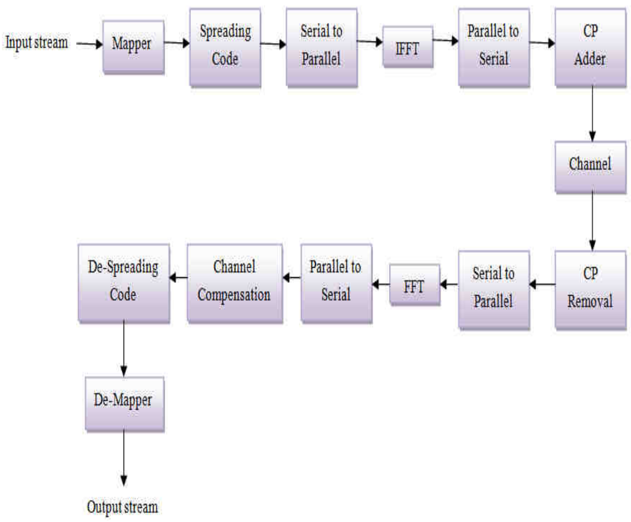

Figure 1: Block Digram of MC-CDMA Transceivers Based Fourier Transform

III. Simulation Results of the Proposed Design:

The BER performance of MC-CDMA Transceivers Model is simulated in this section, the performance of this model will be studied under different channel characteristics, like delay spread, path gain of the reflected path and the Doppler frequency which make the interference rejection problem more difficult. , in this paper the Walsh-Hadamard (code 20) has been used with 32 bits of zeros are added. A simulation of the two systems has been made using MathWorks TM in the MATLAB® R20013a software package. And the BER performance of the two systems will be considered in different channel models which are AWGN, and AWGN+ frequency selective fading channel, with a bit rate of 5 Mbps and 64 subcarriers are used in this simulation. Table. 1 shows the parameters of the system used in the simulation.

Table.1: Simulation Parameters

Modulation Types	QPSK
Bandwidth	5 MHz.
Number of FFT points	64
Walsh-Hadamard Code	Walsh-Hadamard, 32 bit
Cylices Prefix	26 Symbol
Bit Rate	5 Mbps
Channel model	Flat Fading + AWGN
	Frequency Selective Fading +AWGN

IV. Performance of the Proposed MC-CDMA OFDM Two-User

In this part the spreading consists of multiplying the input data by a pseudo-random or pseudo-noise (PN) sequence, the bit rate of which is much higher than the data bit rate. This increases the data rate while adding redundancy to the system. The ratio of the sequence bit rate to the data rate is known as the spreading factor. When the signal is received, the spreading is removed from the desired signal by multiplying it by the similar PN sequence that is accurately synchronized to the transmitted PN signal. When such a despreading operation is applied to the interferer's signals, perfectly there is no more contribution to the user of interest's signal level. This is achieved in CDMA systems by assigning each user/transmitter distinct codes that have low cross-correlation properties, like the perfect orthogonal codes or any one of the PN, sequences. The next sections highlight the dissimilar sequences, their properties, and the transmission and receiving environments in which they yield attractive performance. In Figures 2, 3, 4 and 5 Two-User comparison. a two-user data transmission system with the two data streams being separately spread by dissimilar orthogonal codes.

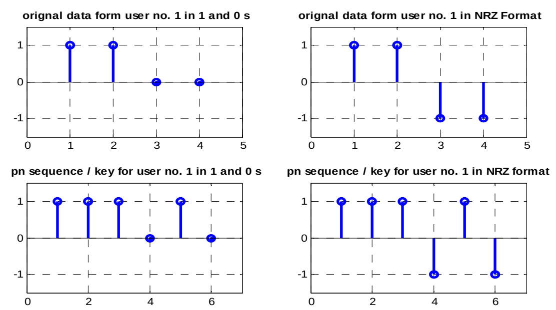

Figure 2: Explain the original data and pn sequence/key for user 1

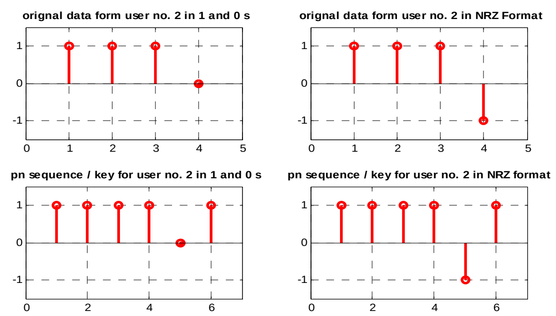

Figure 3: Explain the original data and pn sequence/key for user 2

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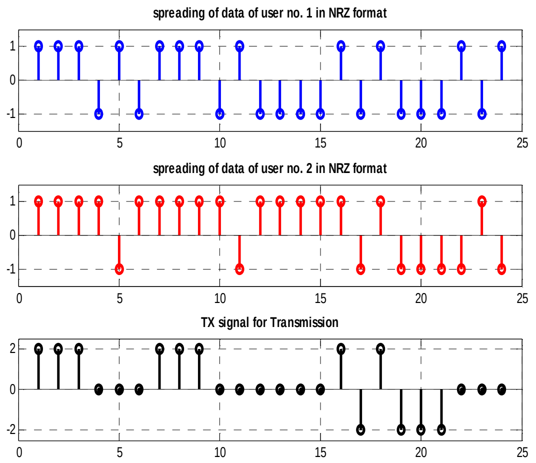

Figure 4: Explain Spreading of Data of user 1, 2 and TX Signal for Transmission

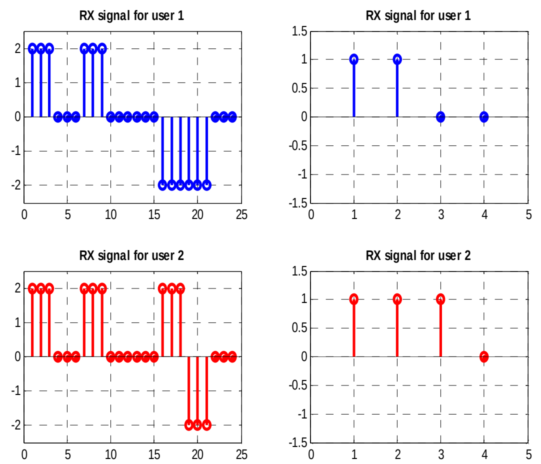

Figure 5: Explain RX Signal for user 1and 2

V. PERFORMANCE OF THE PROPOSED MC-CDMA OFDM IN AWGN CHANNEL

In this part, the channel here is modeled as an Additive White Gaussian Noise, from Figure.2, it is found that the proposed system OFDM MC-CDMA OFDM does worked with SNR= 23.5dB at BER=10^{-3}

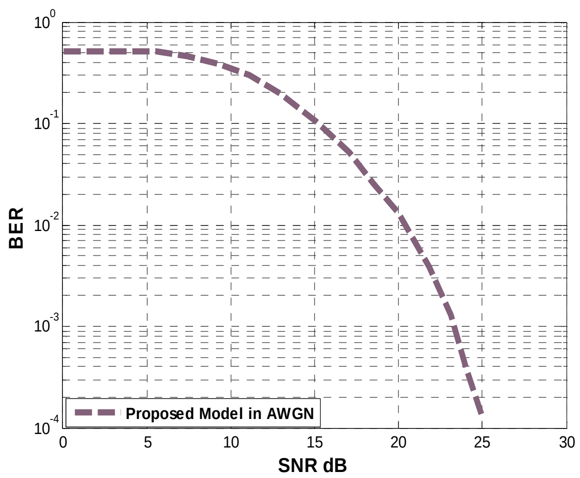

Figure 2: BER Performance of Proposed Model in AWGN

VI. PERFORMANCE OF THE PROPOSED MC-CDMA OFDM IN FLAT FADING CHANNEL

In this kind of channel, the signal will be affected by the flat fading in addition to AWGN; in this case all the frequency components in the signal will be affected by a constant attenuation and linear phase distortion of the channel, which has been chosen to have a Rayleigh's distribution. A Doppler frequency of 10 Hz is used in this simulation. From Figiure.3, it can be seen that for BER= 10^{-3} the SNR required for OFDM MC-CDMA is about 25dB, choice Doppler Shifts are used, the values taken are 100Hz, 500Hz and the BER vs. SNR are given in the two Figure.4 and Figure.5 below 32 dB and 44 dB respectively.

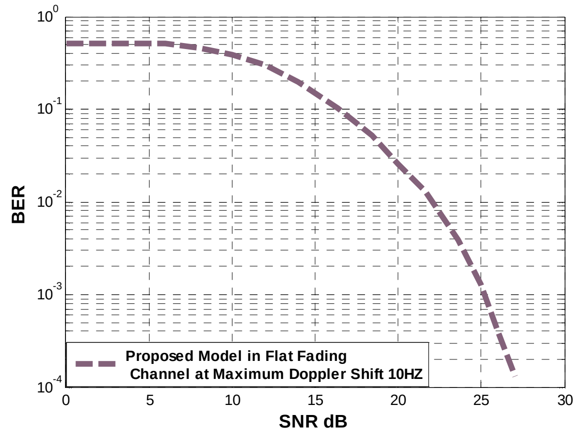

Figure 3: BER Performance of Proposed Model in Flat Fading Channel at Maximum Doppler Shift 10HZ

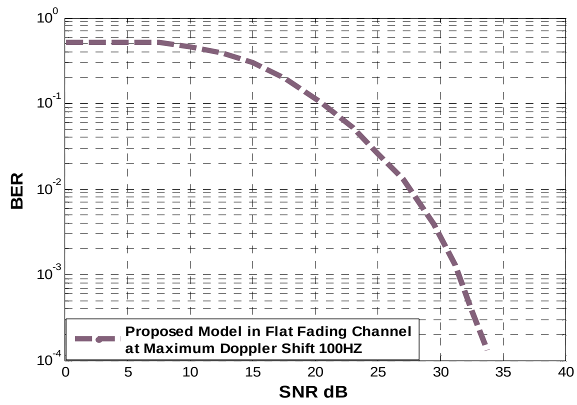

Figure 4: BER Performance of Proposed Model in Flat Fading Channel at Maximum Doppler Shift 100HZ

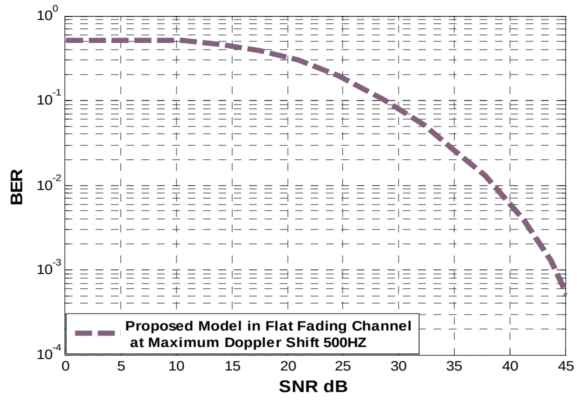

Figure 5: BER Performance of Proposed Model in Flat Fading Channel at Maximum Doppler Shift 500HZ

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VII. PERFORMANCE OF THE PROPOSED MC-CDMA OFDM IN SELECTIVE FADING CHANNEL

In this part, the channel model is assumed to be selective fading channel, where the parameters of the channel in this case corresponding to multipaths where two paths are selected the LOS and second path the LOS path having Average Path Gain equal 0dB and Path Delay 0, where the second path has Average Path Gain -8dB and path Delay one sample as shown in Figiure.6 at Maximum Doppler shift 10Hz it is obvious from this Figure, that BER performance of for OFDM MC-CDMA .The OFDM MC-CDMA has BER performance of 10^{-3}about 27.5dB .following that, the three systems are tested on other different parameter by changing first the Maximum Doppler Shift, setting the parameter to 100Hz and then to 500Hz, the values are shown in Figure.7 and Figure.8 for Doppler Shift parameter test, at 100Hz has BER performance of 10^{-3}about 38dB and at 500 Hz has poor BER performance at 10^{-3} .

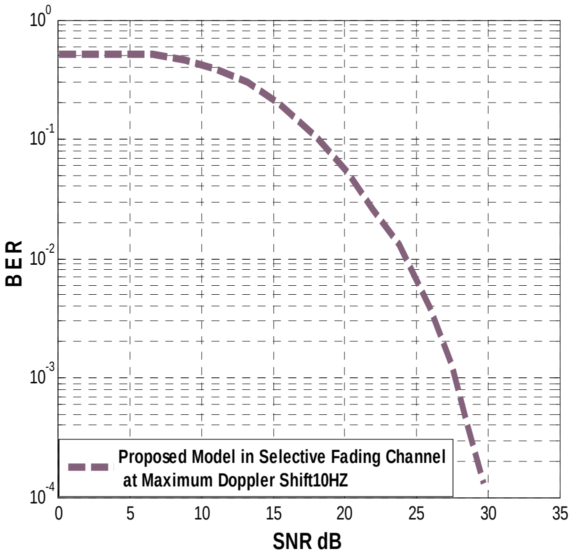

Figure 6: BER Performance of Proposed Model in Selective Fading Channel at Maximum Doppler Shift10HZ

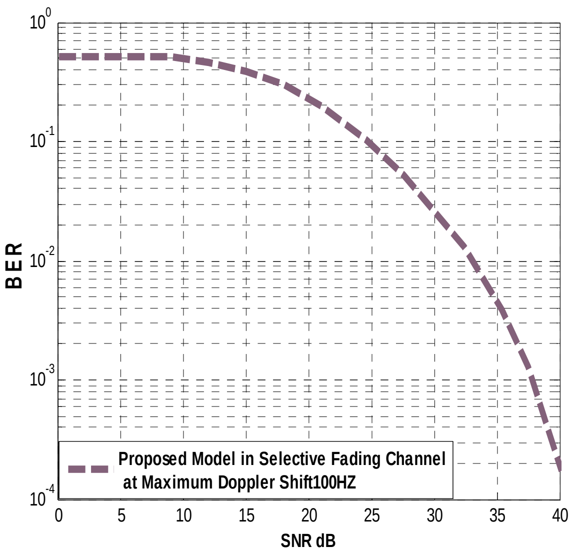

Figure 7: BER Performance of Proposed Model in Selective Fading Channel at Maximum Doppler Shift100HZ

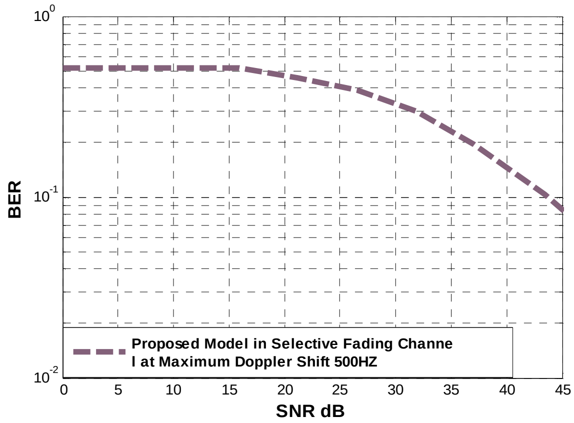

Figure 8: BER Performance of Proposed Model in Selective Fading Channel at Maximum Doppler Shift 500HZ

VIII. CONCLUSION

In this paper, we proposed the baseband transceiver architecture of a downlink MC-CDMA communication system. At first, a set of MC-CDMA system specifications suited for 3G WCDMA environments was designed. Based on the specifications, a transmitter with subcarrier data scrambling was introduced. Then we designed and integrated all necessary modules in a baseband MC-CDMA receiver, including a symbol boundary detector, a carrier frequency recovery loop, a timing frequency recovery loop, a channel estimator, and a combining and dispreading block. In the receiver, two novel techniques that enhanced the system performance, joint carrier/timing frequency error estimation and frequency-domain interpolation-based channel estimation, were implemented. Simulation results showed that the scrambling in the transmitter and the two new receiver algorithms greatly improved the MC-CDMA system performance. The simulation results also showed that the maximum aggregate uncoded data rates that can be transmitted reliably in mobile/stationary multipath fading channels were 5.4/10.8Mbps, respectively. As a result, the proposed MCCDMA baseband transceiver algorithm/architecture can play an important role in future high-data-rate downlink communications over mobile multipath fading channels.

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