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Modelling and Simulation of Multicarrier Code Division Multiple Access (CDMA) System using RAKE receiver

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ABSTRACT

In this paper, simulation model of multicarrier code division multiple access (MC-CDMA) system employing spreading code with RAKE receiver is analyzed. This paper is concerned in particular such a system and its performance under frequency-selective Rayleigh fading channel with various delays profiles. The bit error probabilities under varying multipath diversity orders use maximum ratio combining (MRC) RAKE reception to mitigate frequency-selective fading. The performance is also evaluated taking into account various numbers of parameter sets such as lengths of PN codes and number of fingers in a RAKE receiver, etc. The bit error rate (BER) of this system is analysed by using mat lab software.

Keywords: multicarrier, CDMA, spreading code, fading, maximum ratio combining, RAKE

INTRODUCTION

Mobile communications are rapidly becoming more and more necessary for everyday activities. The improvement in the capacity of mobile communication is due to the use of multiple access techniques where many subscribers can share the same channel for transmission. Multiple access techniques are Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). In FDMA, the bandwidth is divided into number of channels and distributed among users and in TDMA, the entire bandwidth is available to the user but only for a finite period of time. In these multiple access techniques, Code Division Multiple Access (CDMA) is becoming a popular technology for cellular communications [1].

Code Division Multiple Access (CDMA) is a multiplexing technique where number of users simultaneously and asynchronously accesses a channel by modulating and spread their information signals with spreading sequences. Unlike other multiple access techniques such as FDMA and TDMA are limited in frequency band and time duration respectively. Therefore, it has its own capabilities to cope with asynchronous nature of multimedia data traffic to provide higher capacity over conventional access techniques and to combat the hostile channel frequency selectivity [2].CDMA uses spread spectrum technology in which the modulated information is transmitted in a bandwidth considerably greater than the frequency bandwidthcontaining the original information and Direct sequence (DS) and frequency hopping (FH) CDMA are also types of CDMA system.

On the other hand, the multicarrier modulation scheme called orthogonal frequency division multiplexing (OFDM) has a lot of attention in the field of radio communications because of the need to transmit high data rate in mobile environment which makes a highly hostile radio channel [1]. Thus, OFDM looks like a solution to combat this problem.

There are three types of new multiple access schemes based on a combination of CDMA and OFDM techniques. They are multicarrier (MC) CDMA, multicarrier DS-CDMA and multi-tone (MT) CDMA. MC-CDMA technique has been considered as an effective solution to improve bandwidth efficiency and robustness in mitigating frequency-selective fading and it has a great potential to implement future mobile communications [3]. In multicarrier system, the signal can be easily transmitted and received using the fast Fourier transform (FFT) device without increasing the transmitter and receiver complexities.

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The paper is organized as follows. Section II and III explain about multicarrier CDMA system and RAKE receiver respectively. Section IV describes simulation model of the system and its subsystem and section V shows the results of the system. Section VI discusses and concludes about the system.

MULTICARRIER CDMA SYSTEM

Multicarrier (MC) CDMA technique has been considered as an effective solution to improve bandwidth efficiency and robustness in mitigating frequency-selective fading and it has a great potential to implement future mobile communications beyond the third generation (3G) [3]. Multicarrier (MC) CDMA system is a combination of CDMA scheme and orthogonal frequency division multiplexing (OFDM) signaling and spreading in frequency domain. Therefore, the parameters of OFDM become the basic parameters of MC-CDMA. The multicarrier CDMA scheme is categorized mainly into two groups. One spreads the original data stream using a given spreading code and then modulates a different subcarrier with each chip and other spreads the serial-to-parallel converted data streams using a given spreading code and then modulates a different subcarrier with each of the data stream [2].

The MC-CDMA transmitter configuration for the j^{th} user is shown in figure 1. In this figure, the main difference is that the MC-CDMA scheme transmits the same symbol in parallel through several subcarriers, whereas the OFDM scheme transmitsdifferent symbols. $Cj(t) = [c1^j , c2^j ,......, c^j_{GMC}]$ is the spreading code of the j^{th} user in frequency domain, G_{MC} denotes the processing gain, sometimes called the spreading factor [4]. The input data stream is multiplied by the spreading code of length G_{MC}. Each chip of the code modulates one subcarrier. The number of subcarriers is $N = G_{MC}$. All the data corresponding to the total number of subcarriers are modulated in baseband by an IFFT and converted back into serial data. Then, a cyclic prefix is inserted between the symbols to combat the inter-symbol interference (ISI) and the inter-carrier interference (ICI) caused by multipath fading. Finally, the signal is digital to analog converted and up converted for transmission.

In MC-CDMA transmission, it is essential to have frequency non-selective fading over each subcarrier. Therefore, if the original data rate is high enough to become subject to frequency selective fading, the input data have to be serial to parallel converted into P parallel data sequences $[a^j_1, a^j_2,.......,a^j_p]$ and each serial to parallel output is multiplied with spreading code of length G_{MC} subcarrier [4]. Thus, all $N = P \times G_{MC}$ subcarriers are also modulated in baseband by IFFT.

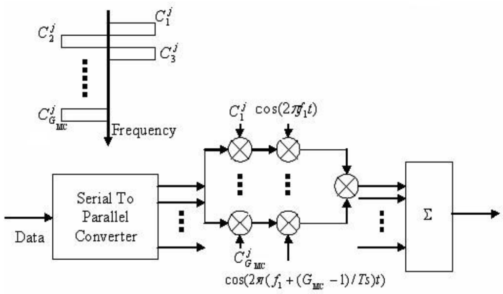

Figure1. *MC-CDMA transmitter*

MC-CDMA RAKE RECEIVER

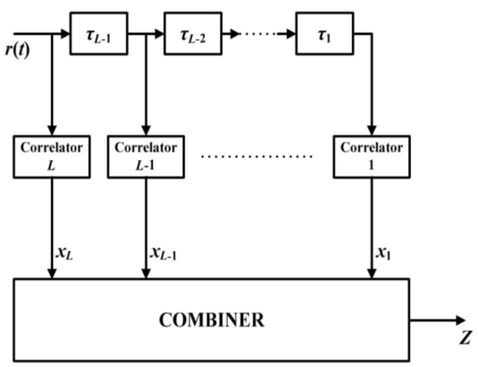

Figure2. *RAKE receiver*

The RAKE receiver consists of multiple fingers also called correlators in which the received signal is multiplied by time shifted versions of a locally generated code sequence with one finger for each path, with assumption that the time delay of each multipath component is determined. Each single RAKE finger is an independent receiver for the signal from a specific path which correlates with spreading code. The finger outputs are combined coherently by RAKE combiner, using some combining techniquesto improve the received signal quality. There are several types of space combining techniques that can be generally performed depending on the amount of channel state information (CSI) available at the receiver [4]: selection combining (SC), equal gain combining (EGC) and maximum ratio combining (MRC). EGC involvesco-phasing of the useful signal in all branches and summing them while MRC output presents a weighted sum of co-phased signals from all branches, requiring all of the amount of CSI [5]. Unlike previous, SC technique processes only one of the branches with the highest signal to noise ratio (SNR). The channel parameters are assumed known in the despreading and demodulation process although in practice the impulse response of the channel is typically estimated using pilot symbols or pilot channel.

SIMULATION MODEL OF THE SYSTEM

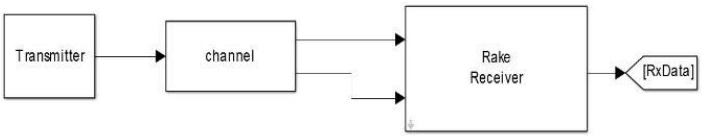

Figure3. *Overall Simulation Model of the system*

The simulation model consists of three subsystems: the transmitter, the channel and the receiver. The short presentation of these subsystems as follows:

Transmitter Model

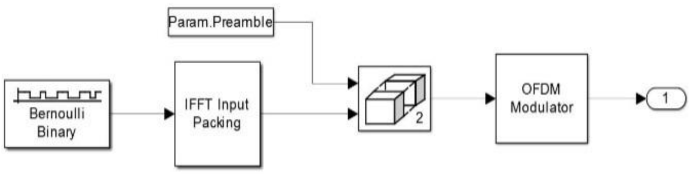

Figure4. *MC-CDMA Transmitter Model*

In the transmitter model, the input data from Bernoulli binary generator is converted firstly into parallel data stream and each parallel data stream is spread with spreading code that is PN sequence and the spreading data is modulated by QPSK modulator in IFFT input packing block. The modulated output is concatenated with preamble that is like a pilot signal. Finally, this data is fed to OFDM modulator to add guard bands and cyclic prefix and then transmitted through the channel.

Channel Model

This system is considered in the urban area and then the transmitted signal can occur as multipath fading signals because of many obstacles and they cannot be line of sight signals. The transmission is corrupted by noise in reality. For this reason multipath Rayleigh fading and Additive White Gaussian Noise (AWGN) channel are used in this system. AWGN is a good model for the physical reality as long as the thermal noise at the receiver is the only source of disturbance.

RAKE Finger Model

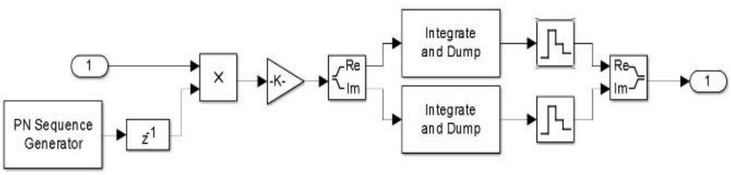

Figure5. *RAKE finger Model*

Figure 4 shows the structure of a finger that despreads the received signal by correlating it with the desired user's delayed PN sequence. The correlation is performed in the 'Integrate and Dump' block that integrates over T_b the product of the code sequence with the received signal.

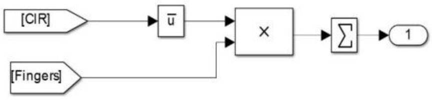

Figure6. *Maximum Ratio Combining*

In the receiver model, maximum ratio combining (MRC) is used. MRC is that the output symbols from different fingers are multiplied with complex conjugate of the channel impulse response which is obtained from the propagation of a unit impulse in the channel and the result of the multiplication is summed together into combined symbol.

SIMULATION RESULTS

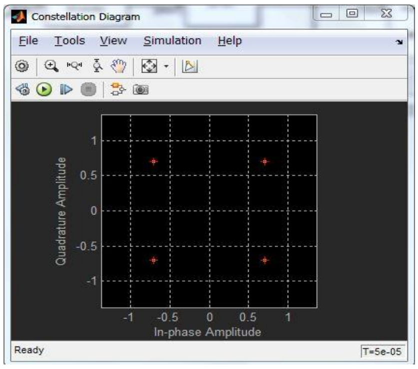

Figure7. *Before the signal is transmitted through the channel*

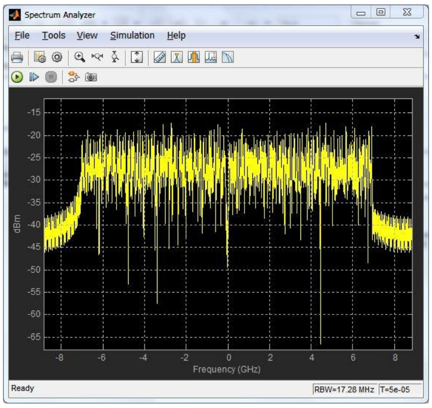

Figure8. *Before the signal is transmitted through the channel*

Figure 7 and 8show the constellation diagram of signal and the spectrum analyzer result of signal before channel respectively. As the signal is not transmitted through the channel, the transmitted power spectrum is fairly uniform and the symbol points on the constellation diagram are not scattered. This mean that the signal has less inter-symbol interference (ISI). Then, this signal is transmitted through the channel and the results are shown as follows.

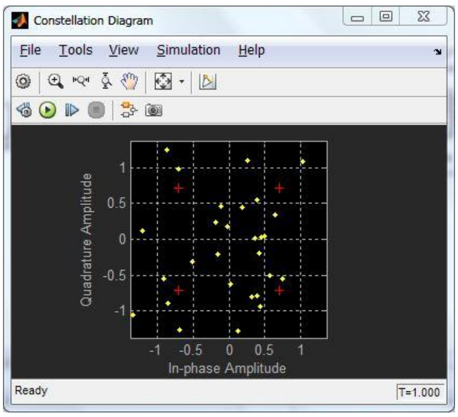

Figure 9: After the signal is transmitted through the channel

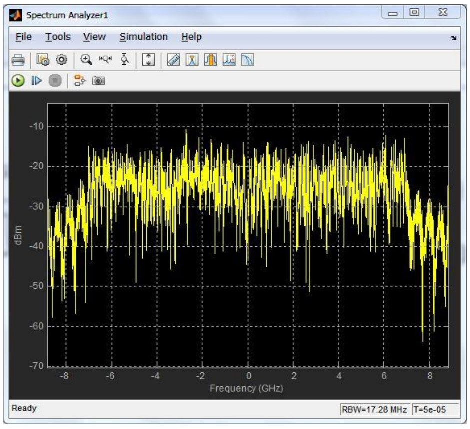

Figure10. *After the signal is transmitted through the channel*

In Figure 9, the symbol points on the constellation diagram are scattered and the received power spectrum from the spectrum analyzer has deepvariation in figure 10. As a result, the signal has inter-symbol interference (ISI).

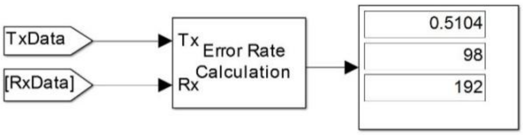

Figure11. *BER result of the system*

For this reasons, the output of bit error rate (BER) of the system is high. The result has shown in figure 11.

DISCUSSION AND CONCLUSION

BER results of other research papers are at least 10^{-4} and in these papers, BER results are tested by changing the spreading code length. In [4], DS-CDMA system uses RAKE receiver to minimize BER more than conventional systems and this system shows the BER results that are approximately 10^{-3} by varying multiple paths of RAKE receiver and then BER comparison of with and with RAKE receiver in which BER is approximately 10^{-4}. [5] shows BER results by using different spreading codes: the orthogonal codes (Walsh-Hadamard), pseudo-random (PN) sequences and Kasami sequences in which BER results are approximately 10^{-3}, 10^{-2} and 10^{-4} respectively. In [6], BER result of MC-CDMA is approximately 10^{-5} by using QPSK modulation and AWGN channel.In this paper, the RAKE receiver is used for multicarrier CDMA system rather than using conventional CDMA system. Although this receiver is used in this system to mitigate these effects, this system cannot reduce these effects so far and BER of the system is 0.5104. Due to this result, the parameters of the system will be changed to minimize these effects.

Therefore, the important parameters of the system are spreading code or spreading code length, modulation method, IFFT length, multiple paths, the numbers of RAKE finger (correlators) and combination method. In some research papers, BER is related to the spreading code and code length and the longer the code length, the less the BER. In this system, BER can be decreased by changing the spreading code or code length to obtain better result.

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