BER Simulation for WCDMA System in Multipath Fading Channel

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Abstract

The goal for the third generation (3G) of mobile communications system is to seamlessly integrate a wide variety of communication services. One of the most promising approaches to 3G is to combine a Wideband Code Division Multiple Access (WCDMA) air interface with the fixed network of Global System for Mobile communications (GSM). In this paper we investigate the bit error rate (BER) of a WCDMA system at both uplink and downlink for different channel conditions at a multiuser environment. Simple rake diversity combining is employed at the receiver. Performance improvement due to error correction coding scheme is also shown.

1 WCDMA: Air Interface for 3G

Third generation cellular systems are being designed to support wideband services like high speed Internet access, video and high quality image transmission with the same quality as the fixed networks. Research efforts have been underway for more than a decade to introduce multimedia capabilities into mobile communications. Different standard agencies and governing bodies are trying to integrate a wide variety of proposals for third generation cellular systems. One of the most promising approaches to 3G is to combine a Wideband CDMA (WCDMA) air interface with the fixed network of GSM. Several proposal supporting WCDMA were submitted to the International Telecommunication Union (ITU) and its International Mobile Telecommunications for the year 2000 (IMT2000) initiative for 3G. All these schemes try to take advantage of the WCDMA radio techniques without ignoring the numerous advantages of the already existing GSM networks. The standard that has emerged is based on ETSI's Universal Mobile Telecommunication System (UMTS) and is commonly known as UMTS Terrestrial Radio Access (UTRA) [1].

The access scheme for UTRA is Direct Sequence Code Division Multiple Access (DS-CDMA). The information is spread over a band of approximately 5 MHz. This wide bandwidth has given rise to the name *Wideband* CDMA or WCDMA. There are two different modes namely: Frequency Division Duplex (FDD) Time Division Duplex (TDD). Since different regions have different frequency allocation schemes, the capability to operate in either FDD or TDD mode allows for efficient utilization of the available spectrum. *We investigated a WCDMA system operating in the FDD mode. So all the system description here holds for the FDD mode only.*

2 WCDMA Physical Layer:

This section provides a layer 1 (also termed as physical layer) description of the radio access network of a WCDMA system operating in the FDD mode.

2.1 Physical Channel Structure

WCDMA defines two dedicated physical channels in both links: Dedicated Physical Data Channel (DPDCH) to carry dedicated data generated at layer 2 and above and Dedicated Physical Control Channel (DPCCH) to carry layer 1 control information. Each connection is allocated one DPCCH and zero, one or several DPDCHs. In addition, there are common physical channels defined as: Primary and secondary Common Control Physical Channels (CCPCH) Synchronization Channels (SCH) for cell search, Physical Random Access Channel (PRACH).

2.2 Spreading and Modulation

In the uplink the data modulation of both the DPDCH and the DPCCH is Binary Phase Shift Keying (BPSK). The spreading modulation used in the uplink is dual channel QPSK. Figure 1 shows the spreading and modulation for an uplink user. The uplink user has a DPDCH and a DPCCH. The channelization codes used for spreading are known as Orthogonal Variable Spreading Factor (OVSF) codes. The spreading factor for the control channel is always set at the highest value, which is 256. This improves the noise immunity at the control channel by taking advantage of the highest possible processing gain. The complex scrambling code is a unique signature of the mobile station (MS).

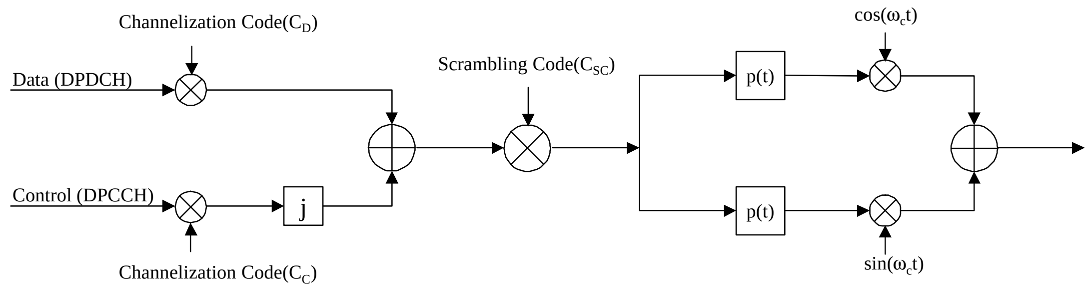


Figure 1: Uplink Spreading and Modulation

Quaternary Phase Shift Keying (QPSK) is applied for data modulation in the downlink. The data in the I and Q branches are spread to the chip rate by the same channelization code. The channelization code is the same OVSF codes mentioned above. This spread signal is then scrambled by a cell specific scrambling code. Figure 2 shows the spreading and modulation for a downlink user. The downlink user has a DPDCH and a DPCCH. Additional DPDCHs are QPSK modulated and spread with different channelization codes.

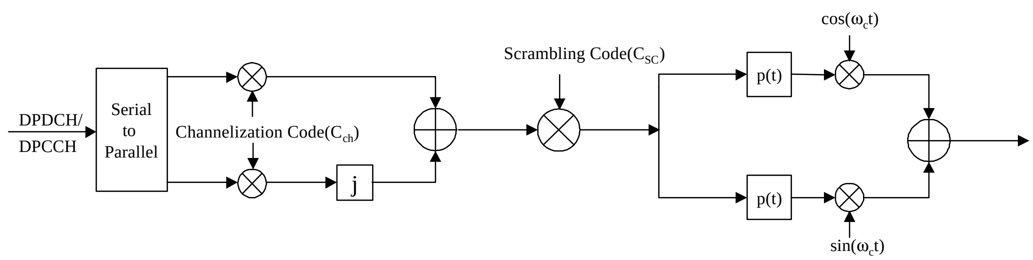


Figure 2: Downlink Spreading and Modulation

OVSF codes can be explained using the code tree shown in the next figure. The subscript here gives the spreading factor and the argument within the parenthesis provides the code number for that particular spreading factor.

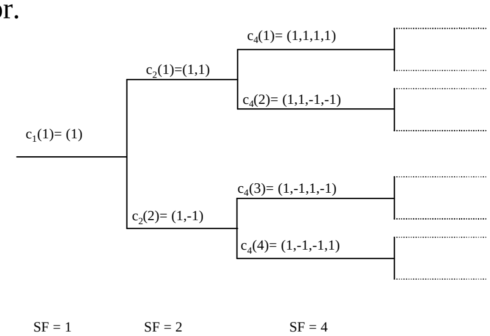


Figure 3: Code-tree for Generation of OVSF Codes

Each level in the code tree defines spreading codes of length SF, corresponding to a particular spreading factor of SF. The number of codes for a particular spreading factor is equal to the spreading factor itself. All the codes of the same level constitute a set and they are orthogonal to each other. Any two codes of different levels are orthogonal to each other as long as one of them is not the mother of the other code [2]. For example the codes $c_{16}(2)$,$c_8(1)$ and $c_4(1)$ are all mother codes of $c_{32}(3)$ and hence are not orthogonal to $c_{32}(32)$. Thus all the codes within the code tree can not be used simultaneously by a mobile station. A code can be used by an MS if and only if no other code on the path from the specific code to the root of the tree or in the sub-tree below the specific code is used by the same MS [3]. Similar restrictions apply for the downlink.

Uplink Scrambling codes help maintain separation among different mobile stations. Either short or long scrambling codes can be used in the uplink. Short scrambling codes are recommended for base stations equipped with advanced receivers employing multiuser detection or interference cancellation. Since we employed a simple rake receiver, we used long scrambling codes in the simulator. The downlink scrambling codes maintain separation among cells/base stations. References [3] and [4] provides detailed description of the scrambling codes.

2.3 Channel Coding

WCDMA systems have provision for both Convolutional Coding and Turbo Coding for error correction. For standard services that require BER up to 10^{-3} convolutional coding is to be applied. The constraint length for the proposed convolutional coding schemes is 9. For services that require BER from 10^{-3} to 10^{-6}, turbo coding is required. Reference [5] provides a detailed description of the error correction coding schemes along with rate matching, interleaving and transport channel mapping. We will apply a rate 1/3, constraint length 9 convolutional coding scheme to an uplink 9.6 kbps voice service and show the BER improvement as a result of coding gain.

3 Simulation Description

This section describes the simulation methodology to evaluate the Bit Error Rate (BER) at the uplink and the downlink of a Wideband CDMA (WCDMA) system.

Data is transmitted in a frame by frame basis over a time varying multipath channel. Each frame is 10 ms long. Reference [6] provides a detailed description of the frame structure. The channels used are linear time variant filters. We have a number of independently Rayleigh faded components on the sampling instants. Two different types of multipath channel were employed in the simulation namely Indoor channel and Vehicular A Outdoor channel. The multipath profiles of the channels shown in the following tables are taken from [6]

Table 2a Indoor Channel Power Delay Profile

Relative Delay	Avg. Power
0	0
50	-3
110	-10
170	-18
290	-26
310	-32

Table 2b Vehicular A Outdoor Channel Power Delay Profile

Relative Delay	Avg. Power
0	0
310	-1
710	-9
1090	-10
1730	-15
2510	-20

3.1

All the delays in the tables are measured at nano-secs and the power is shown in dB scale. The vehicular A channel has a mobile speed of 120 Km per hour associated with it where as the indoor channel correspond to a pedestrian walking speed of 5 Km per hour. So we have a relatively slow fading environment.

Receiver design incorporates rake diversity combining. We assume that the receiver has a perfect channel estimate to perform maximal ratio combining (MRC). Additive White Gaussian Noise

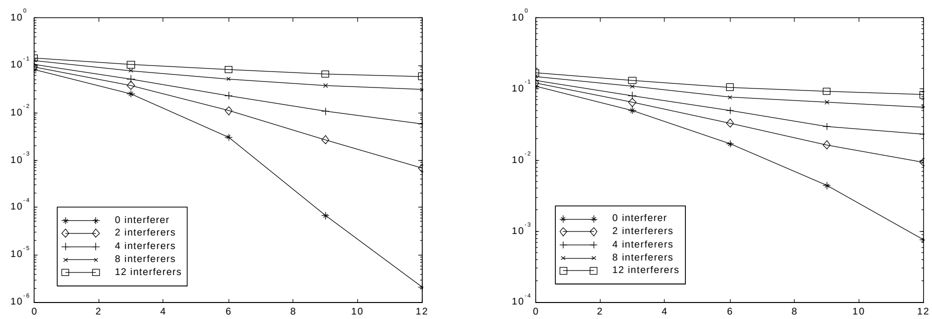
(AWGN) is added at the front end of the rake receiver. Multiple Access Interference (MAI) is generated in a structured way rather than treating it as AWGN. MAI is implemented by generating the signals for a number of interfering MS within the system. Each interfering user has its own control channel and one data application. The MAI is asynchronous in the uplink whereas it is synchronous in the downlink. No antenna diversity technique was considered for the basic simulation. However we will show an example of performance improvement with error correction coding.

4 Simulation Results:

The simulation results are presented in this section. We find that

- Orthogonality among channels is preserved better at the downlink.
- The system is interference limited at both the links for higher number of users.
- As the system load approaches 50%, the performance for the system without coding becomes unacceptable.

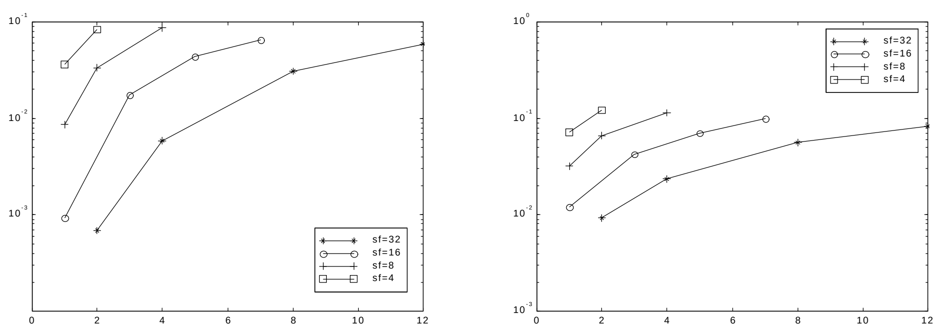
We also implemented a rate 1/3 constraint length 9 convolutional coding for an uplink voice application that has a data rate of 9.6 kbps. A Viterbi soft decision decoder was used at the receiver. The convolutional coding was found to provide with a gain of 4.7 dB.



(a) Indoor Channel (b) Vehicular A Outdoor Channel

Figure 4: BER vs E_b/N_0 at the Uplink

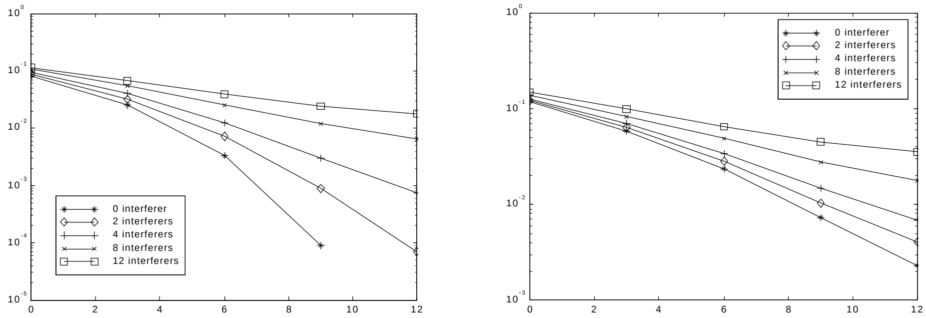
(The Spreading Factor of the User is 32.The Number of Interferers Vary from 0 to 12)



(a) Indoor Channel (b) Vehicular A Outdoor Channel

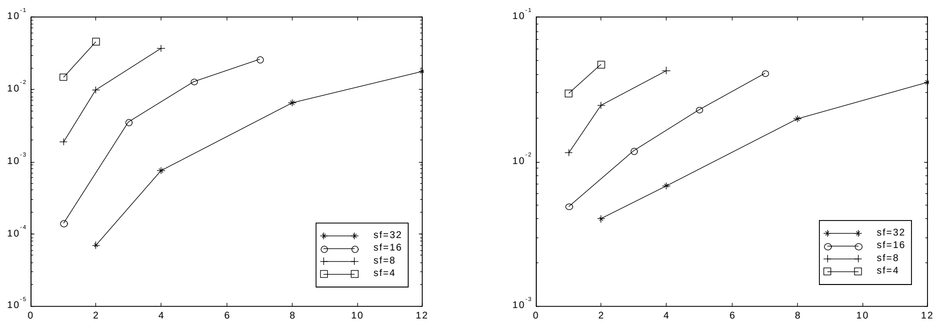
Figure 5: BER vs Interferers at the Uplink

(E_b/N_0 is 12 dB)



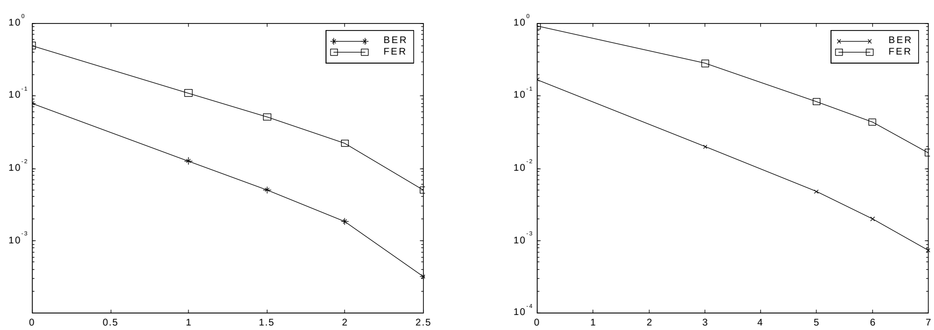
a) Indoor Channel (b) Vehicular A Outdoor Channel

Figure 6: BER vs E_b/N_0 at the Downlink
(The Spreading Factor of the User is 32.The Number of Interferers Vary from 0 to 12)



(a) Indoor Channel (b) Vehicular A Outdoor Channel

Figure 7: BER vs Interferers at the Downlink
(E_b/N_0 is 12 dB)



(a) Indoor Channel (b) Vehicular A Outdoor Channel

Figure 8: Uplink Performance for 9.6 kbps Voice Service
(Constraint Length 9, Rate 1/3 Convolutional Coding is used.)

Reference:

[1] Malcom W. Oliphant, " The Mobile Phone Meets the Internet," *IEEE Spectrum*, pp. 20-28, August 1999.

[2] Esmael H. Dinan and Bijan Jabbari, "Spreading Codes for Direct Sequence CDMA and Wideband CDMA Cellular Networks," *IEEE Communications Magazine*, vol. 36, pp. 48-54, September 1998.

[3] Third Generation Partnership Project Technical Specification Group Radio Access Network Working Group 1," Spreading and Modulation," TS 25.213 V2.1.2 (1999-4).

[4] Fakhrul Alam and Brian D. Woerner, *Simulation of Third Generation CDMA Systems*. Masters Thesis, Virginia Tech, Blacksburg, VA, September 1995.

[5] Third Generation Partnership Project Technical Specification Group Radio Access Network Working Group 1, " Multiplexing and Channel Coding (FDD)," TS 25.212 V2.0.1 (1999-08).

[6] Third Generation Partnership Project Technical Specification Group Radio Access Network Working Group 1, " Physical Channels and Mapping of Transport Channels onto Physical Channels (FDD)," TS 25.211 V2.2.1 (1999-08).

[7] Alpha Concept Group, "Wideband Direct Sequence CDMA (WCDMA) Evaluation Document (3.0)," Tdoc SMG 905/97, December 15-19, 1997, Madrid, Spain.