Performance Evaluation of WCDMA for UMTS in the Presence of Multiple Access Interference

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다중접속 간섭 환경에서 UMTS WCDMA 시스템의 성능분석

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Abstract

Wideband code division multiple access (WCDMA) is the most widely adopted third generation air interface. The physical layer of the air interface is the main discussion topic during standardization processes. This paper aims to investigate the performance of uplink WCDMA over many conceivable transmission scenarios in realistic operating conditions. The focus of the study is placed on the performance under frequency selective fading channel conditions with multiple access interference (MAI) in mixed services environments. For the investigation, a simulator has been developed and it encompasses a variety of WCDMA air interface features. The results show that the performance is greatly affected by MAI and is further aggravated with the presence of frequency selective fading, thereby necessitating a suitable compensation measure.

요 약

광대역 코드분할다중 접속은 가장 광범위하게 채택되고 있는 3세대 무선접속이다. 무선접속의 물리계층은 표준화 과정에서 주요 토의 주제이다. 본 논문은 실제적인 환경에서 많은 고려 가능한 전송 시나리오상에서 상향 WCDMA 성능을 조사하는 것이 목적이다. 본 논문의 초점은 주파수 선택적 페이딩 채널조건에서 다중 접속 간섭 및 혼합 서비스 환경 경우의 성능분석에 있다. 본 조사를 위해 시뮬레이터를 개발하였으며 다양한 WCDMA의 무선접속 특징을 포함하고 있다. 시뮬레이션 결과에 의하면 성능은 다중접속 간섭에 의해 크게 영향을 받으며 또한 주파수 선택적 페이딩 조건에 의해 성능열화 현상을 초래하게 되어 적절한 보상기술 적용이 요구된다.

I. Introduction

The demand for multimedia services has prompted an introduction of a third generation mobile radio system, which provides the high bit rate services and thus enables the transmission of high quality images and video as well as access to the web with high data rates. The realization of a third generation mobie radio system is called Universal Mobile Telecommunication System (UMTS). UMTS is designed to provide highly personalized and user-friendly mobile access to future information society. Moreover, it represents a substantial advance over existing mobile systems in many aspects. Wideband Code Division Multiple Access (WCDMA) is the most widely adopted air interface within UMTS [1]. WCDMA provides flexibility to users, network operators and service developers and embodies many new and different concepts and technologies. This paper considers the performance of WCDMA under frequency selective fading with multiple access interference in propagation environments where a cell is loaded with mixed data rates.

II. WCDMA Features

The WCDMA (UTRA FDD) phyical layer offers a high level of flexibility to accommodate future services. The main feature of WCDMA is summarized in Table 1. Prior to the discussion of WCDMA further, it is worthwhile to review the main differences between IS-95 and WCDMA. Both WCDMA and IS-95 utilize direct sequence CDMA. The higher chip rate of 3.84 Mcps adopted in WCDMA gives more multipath diversity than the chip rate of 1.2288 Mcps, especially in small urban cells. Note that the enhanced diversity gain provides performance improvement and good coverage. The high chip rate also gives a higher trunking gain. WCDMA offers fast closed-loop power control in both uplink and downlink, while IS-95 uses fast power control only in uplink. WCDMA uses asynchronous base stations where no synchronization from GPS is needed. In addition, WCDMA uses inter-frequency handoffs in order to maximize the use of several carriers per base station.

Table 1. Summary of WCDMA features

Multiple access	Wideband DS-CDMA
Duplex scheme	FDD
Chip rate	4.096 Mcps (8.192/16.348 Mcps)
Carrier spacing	4.4-5.0 MHz (200 kHz)

The data transmission at the transmitter is made over the air with transport channels, which are mapped in the physical layer to different physical channels. The physical layer is required to support variable bit rate (VBR) transport channels to offer bandwidth on demand services, and to be able to multiplex several services to one connection. The phsical channels are listed in Table 2.

Table 2. Physical channels

channel	Names	Roles
dedicated physical channels	DPDCH (physcial data)	carry dedicated data
	DPCCH (physical control)	carry control information
common physical channels	CCPCH (common control)	downlink common channels
	SCH (synchronization)	cell search
	PRACH (physical random access)	random access channel

1. UplinK Transmission

In the uplink transmission, DPDCH and DPCCH channels are I/Q multiplexed as shown in Fig. 1. DPCCH carries pilot bits, transmit power control bit (TPC) commands and an optional transport format indicator (TFI). If more than one DPDCH channel is needed by a particular user, multi-code transmission is required. The DPDCH and DPCCH channels are each multipled by different binary valued channelisation codes, which are orthogonal variable spreading factor (OVSF) codes generated by the code generation tree [1-3].

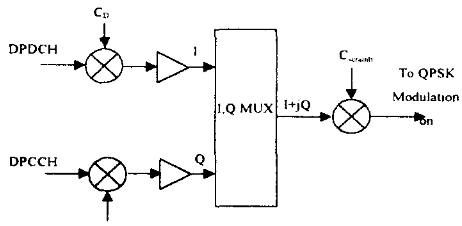

Fig.1 Uplink spreading and modulation

The chip rate is 4.096 Mcps for all users and physical channel types. Therefore, the symbol rate for a particular user's physical channel is determined by the spreading factor used. The spreading factor varies from 4 to 256. There is no requirement to coordinate the allocation of channelisation codes between mobile stations, because a second stage of signal spreading using a scrambling code is employed. The uplink scrambling code can be either short or long. The short scrmabling code is a complex code built of two 256-chip long extended codes from the very large Kasami set of length 255, while the long code is a 40 960-chip segment of a Gold code of length $2^{41}-1$.

2. UMTS Channel Models

The link performance of mobile radio systems is affected by channel impairments. Of the channel parameters affecting the performance, the effect of channel time delay is necessary to be considered in the system level performance evaluation. UMTS provides a number of channel models for different propagation environments : indoor, outdoor to indoor/ pedestrian and vehicular models [3]. As an example, Fig.2 shows the channel model for vehicular environment A.

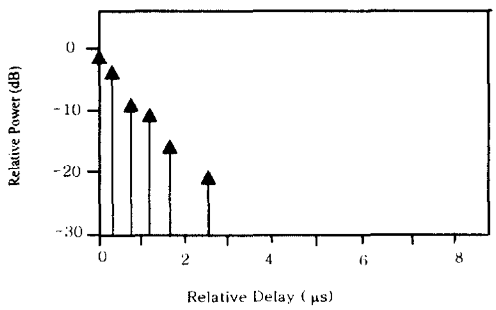

Fig.2 Channel model of Vehicular A

It is known that channel delay often represented by delay spread produces irreducible bit error rate (IBER) and it needs to be rigorously analyzed before the system is deployed. The analysis of channel model and its relevant wideband parameters are well documented in the literature [4].

III. Simulations and Discussions

In order to efficiently perform the link level evaluation of BER performance of WCDMA, a simulator has been developed with full conformance to WCDMA specifications. A transmission frame consists of multiple slots. The key modules rely on frame and slot based processing for both the reception and transmission functions. First, in the transmitter, the frame based processing consists of frame encoding and interleaving. A single transmit antenna is used in the simulation. The in-phase and quadrature components of the transmitted signal are multiplied by a random segment of pre-generated fading channel complex envelope. The resulting signals are then added with AWGN. Since the present study considers multiple access interference (MAI), the signals from a number of multiple users are received at the same time.

For each user, the physical channel data consist of an information sequence with control information. The length of the information sequence and the encoding rate determine the number of binary symbols to be transmitted on the I and Q branches of the modulator. That is, the users with higher information rates will have lower spreading gains. In addition to specifying the processing gain, frame interleaver size of the convolution and turbo encoding and decoding are also determined by the information data rate.

In the receiver, basically the reverse operation is performed. That is, the signal is first processed by a chip match filter and then a rake receiver is used. In the present simulation, a delayed-reference signal type of rake receiver is implemented [5]. The present simulator does not model intercell interference and narrowband interference within the channel. Perfect receiver synchronization is assumed. The excess delay of each multipath component is assumed to be known at the receiver. The performance evaluation has been conducted for the uplink WCDMA transmission in a number of simulation scenario, based on different channel propagations, SNR, the number of multiple access users, etc. The simulation parameters are as follows: a carrier frequency of 2GHz, 3-finger rake receiver and perfect power control. Different mobile speeds were employed for the UMTS propagation environments. In order to compare the BER performance, the convolutional encoder whose constraint length is 9 was not employed except for the mixed service environments. Fig. 3 shows the BER performance of UMTS indoor propagation environments. The mobile speed employed is 5km/h. All users are assumed to transmit the data at the rate of 128 kbps with a spreading factor of 32. The delay spread for this channel model is found to be 0.035 μs. The performance of a single user scenario is better than 10^{-3} at the SNR value of

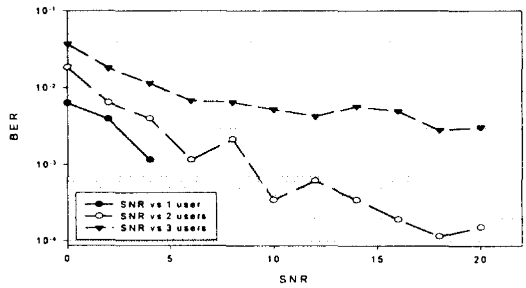

Fig.3 BER performance of Indoor

4dB, whereas the performance degrades when 2 or 3 users are present. In case of UMTS outdoor-to-indoor/pedestrian model with the same mobile speed as the indoor model, the performance becomes worse due to both the presence of increased channel time delay and MAI as shown in Fig.4.

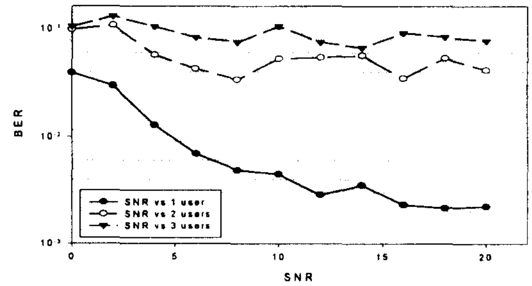

Fig.4 BER performance of Outdoor-to-Indoor/Ped

Therefore, it is necessary to employ a measure to compensate MAI, such as, for example, an interference cancellation technique. Fig.5 shows the performance of the UMTS vehicular model with the mobile speed increased to 50 km/h. It can be seen that the performance exhibits a slight improvement in comparison to the previous two conditions, although the delay spread is increased to 4 μs.

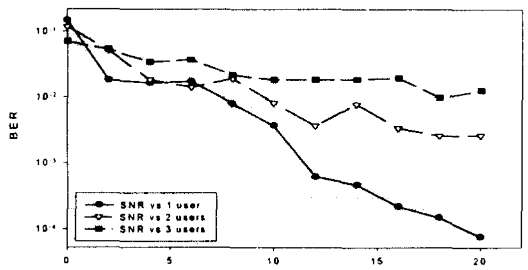

Fig.5 BER performance of Vehicular

This is due to the fact that the effect of path diversity in the receiver exists. The investigation has been further conducted for transmission scenarios where users with different data rates exist together. For the present study, the data rates of 128kbps, 256kbps and 1024 kbps with the corresponding spreading factors of 32, 16 and 4 were considered, respectively. Fig.6 shows the

BER performance for the indoor model with 5 users in a cell. The percentages of data traffic load in a cell are 50%, 30% and 20% for 128kbps, 256kbps and 1024kbps users, respectively.

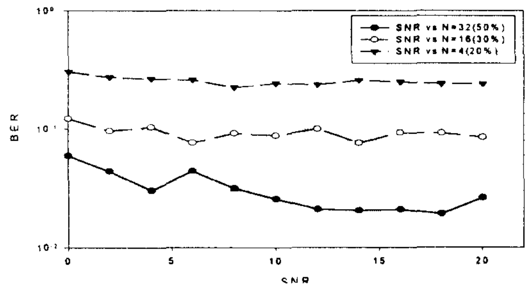

Fig.6 BER performance of Indoor (mixed)

The performance becomes unacceptable as all the users suffer from severe MAI and relatively lower spreading gains. In order to improve the performance, the convolutional encoder specified in WCDMA air interface specifications [3] is employed and the BER performance is shown in Fig.7. The performance except for the case of 1024 kbps users is greatly improved. This phenomenon can also be observed with UMTS outdoor-to-indoor/pedestrian channel model as shown in Fig.8.

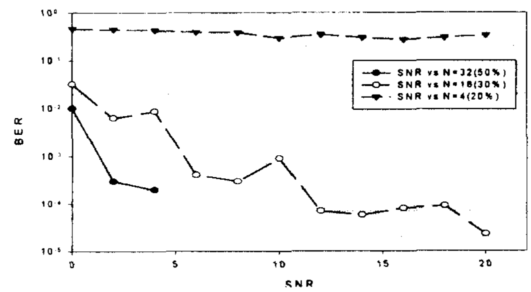

Fig.7 BER performance of indoor (mixed, CC)

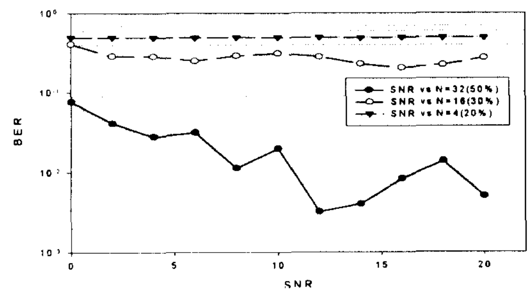

Fig.8 BER performance of Outdoor-to-indoor/ped (mixed, CC)

With the vehicular channel model submitted, however, the performance for the 256 kbps and 1024 kbps users is greatly improved as shown in Fig.9. It can be noted that comparing with the performance of mixed service environments without convolutional encoding (see Fig.5), the performance with the highest spreading gain (N=32, 128kbps) is greatly improved. This is due to high spreading gain combined with significant error correction capability through convolutional coding whose constraint length is 9.

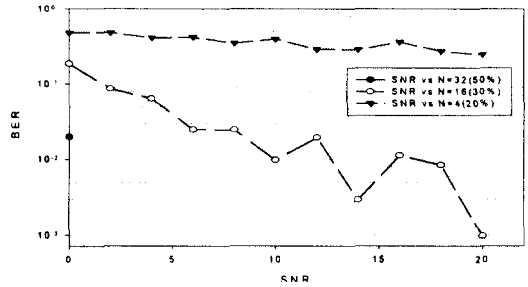

Fig.9 BER performance of Vehicular (mixed, CC)

IV. Conclusions

The investigation of WCDMA performance has been conducted in realistic propagation environments where MAI with different data rates are present, in addition to channel delay often represented by delay spread. It is found that for the various channel models specified in UMTS specifications, the performance variation is sensitive to the amount of MAI and at some cases, the performance exhibits IBER due to the effect of channel delay. Therefore, it is necessary to utilize a number of techniques to compensate the effect of MAI, e.g. interference cancellation schemes. Presently, the work to enhance the link quality using various receiver techniques is underway.

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