WCDMA Simulator Engine for 3G Wireless Network

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Abstract

Wideband Code Division Multiple Access (WCDMA) is one of the air interface techniques proposed for the third generation (3G) mobile communication system. WCDMA was selected because it fulfills the IMT-2000 requirements for higher data rate transmission, support of multimedia capabilities and other flexible services due to its variable bit rates and larger bandwidth, improved capacity and coverage, efficient power control and support for advanced and improved detector structures. Performance evaluation of 3G wireless network through simulation plays an important role in the design and implementation of the actual system, aiding the wireless system designer by providing them the necessary performance conformance statistics prior to implementation. In accordance with this goal, a simulator engine was developed entirely on a MATLAB platform to emulate the behaviour of the WCDMA air interface for both the uplink and downlink in a real world fading mobile environment. This paper discuss the development of the simulator along with a brief description of its functionalities and user interface. The WCDMA air interface mode focused in this paper is in accordance to the 3GPPs frequency division duplex (FDD) mode and restricted to the physical layer description. Performance results for the selected cases for the downlink, uplink, varying mobile velocity and sampling rates are also provided.

Keyword : **Downlink, RAKE, Uplink, WCDMA.**

1. INTRODUCTION

Excessive standardization work was carried out by the ITU in the design and development of the third generation radio standards under the International Mobile Telecommunications

- 2000 (IMT-2000) banner. To enable a successful deployment of the 3G system, two components have been identified and given due importance namely the adaptive antenna array (AAA), which forms the building block for smart antennas and WCDMA radio transmission technology (RTT). The standardization work for 3G was later carried out by the Third Generation Partnership Project (3GPP) group formed by the European Telecommunications Standard Insitute (ETSI) from Europe and Association of Radio Industry and Business (ARIB) from Japan, under the guidelines prepared by the IMT-2000, with WCDMA chosen as the preferred radio transmission technology in both countries [1-3].

The standardization process was frozen in mid 2002 to be followed next by the implementation phase [4]. The 3G wireless network is required to be far more superior in terms of services rendered and efficiency related to the radio spectrum allocation. The system requirements as underlined by ETSI / IMT-2000 must be able to support flexible services consisting voice, data and multimedia capabilities with data rates from 144 kbps in a vehicular environment, 384 kbps at pedestrian speeds, and upto 2 Mbps in a low or indoor mobility environment. 3G is expected to provide quality of speech comparable to wire-line services, higher capacity, symmetrical and asymmetrical data transmission, packet and circuit switching as well as global roaming capabilities to subscribers [5]. To note, the most important aspect of the 3G system is to complement the existing second generation infrastructure through backward compatibility with a long term goal of replacing them [2].

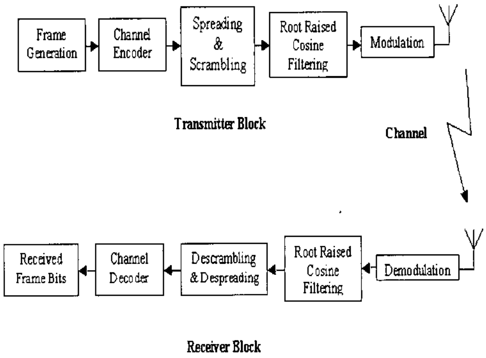
This paper presents a structured method for a comprehensive study on WCDMA air interface analysis and the performance evaluation of 3G wireless network through the development of a simulator aimed specifically for wireless system design and research purposes. Earlier works from Mobile Portable Research Group (MPRG) of Virginia Polytechnic Institute and the Rohde & Schwarz have dealt with the development of WCDMA simulator for both educational and research purposes [6-7]. Rohde & Schwarz 3G simulator was built on a different platform, while the MPRGs 3G simulator (WCDMA simTM) was developed on a MATLAB platform. The Rohde & Schwarzs simulator provides a dynamic menu for the evaluation of the WCDMA signal to the end user. The user selectable menu enables the signal properties to be viewed and evaluated in due course of simulation. On the other hand, WCDMAsim TM provides user with a simple selectable menu which produces the end results for bit error rate (BER) statistics as well as additional information regarding error clusters in the data sequence [6].

In this work, a WCDMA simulator was developed on a MATLAB version 5.3 platform to simulate the system at both uplink and downlink by extending further the work started in [8] to incorporate additional channel models and receiver structure algorithms such as equal gain combining (EGC) for RAKE. The simulator also allows user to view the WCDMA signal transformation and fading characteristics of the propagation channel through the simulator menu options. The WCDMA performance is evaluated using the BER statistics against the signal to noise ratio (Eb/N0) and number of interferers.

Section 2 of this paper explains the WCDMA air interface, Section 3 describes the simulator development and features, and Section 4 provide simulation results for selected cases of downlink, uplink, different mobile speeds and sampling rates. Finally, Section 5 conclude this paper with discussions on the developed simulator and suggestions for future work.

2. WCDMA AIR INTERFACE

WCDMA air interface exists in three different modes namely the direct sequence WCDMA using frequency division duplex (WCDMA-FDD) for paired bands, multi-carrier WCDMA (MC-WCDMA) and time division duplex WCDMA (WCDMA-TDD) for unpaired bands. The WCDMA air interface by UMTS utilizes the WCDMA- FDD direct sequence mode together with the hybrid of the other available modes [1]. This mode is also referred to as UMTS terrestrial radio access (UTRA FDD). A generic block diagram of the WCDMA air interface is given in Fig. 1. Table 1 listed the physical layer of WCDMA air interface based on the 3GPP wideband CDMA specifications [1].



[Fig. 1] Generic Block Diagram of WCDMA Air Interface

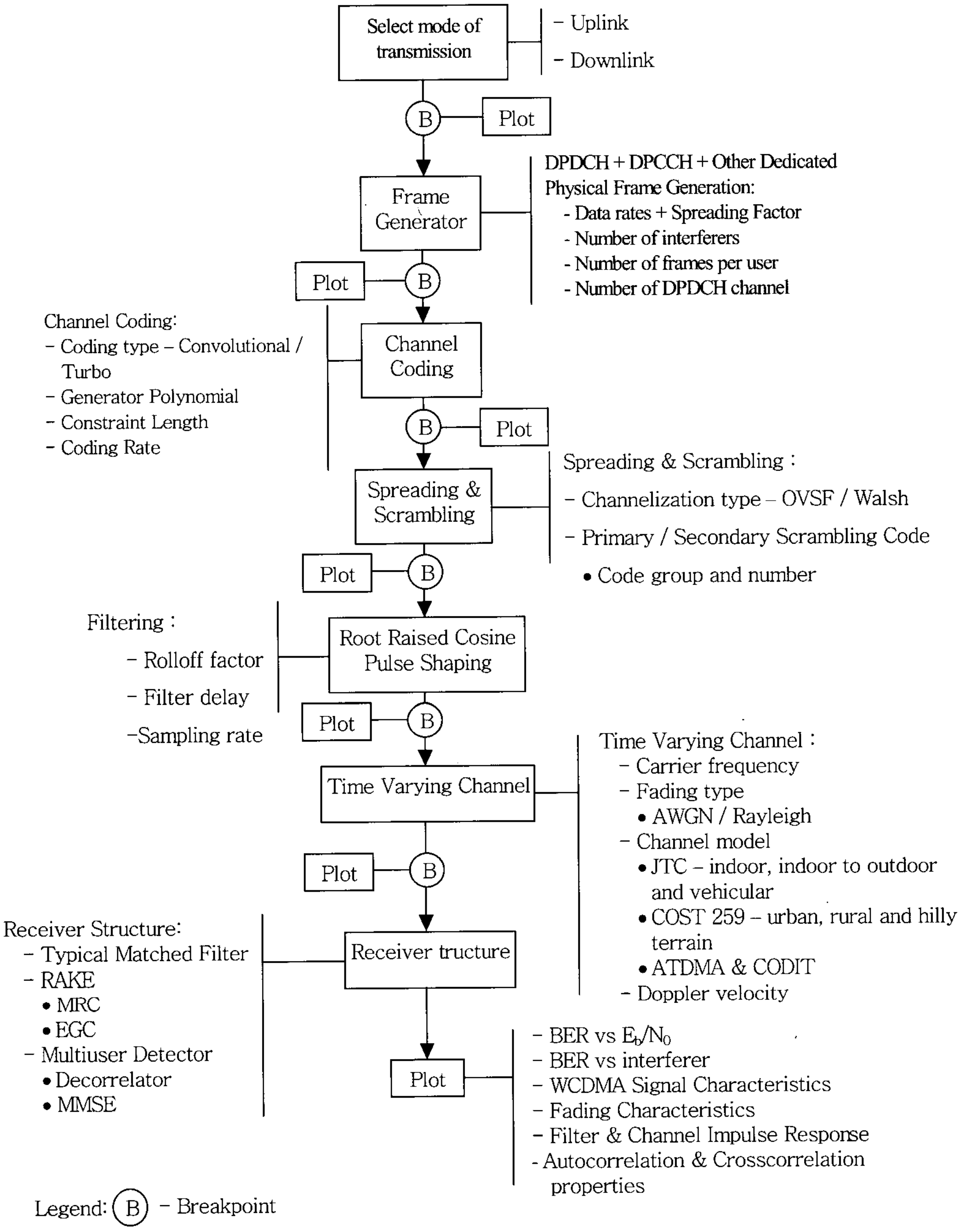
3. WCDMA SIMULATOR DESCRIPTION AND FEATURES

The WCDMA simulator engine is developed according to the 3GPP specifications and is restricted to the physical layer of the WCDMA FDD mode. The simulator incorporates both the uplink and the downlink. It forms an essential tool for assessing the performance of the WCDMA air interface for 3G wireless network through simulation. This is so because the performance of the 3G air interface needs to be evaluated prior to implementation by assessing the systems performance in varying system parameters and in various channel conditions.

[Table 1] WCDMA Air Interface Specifications [1].

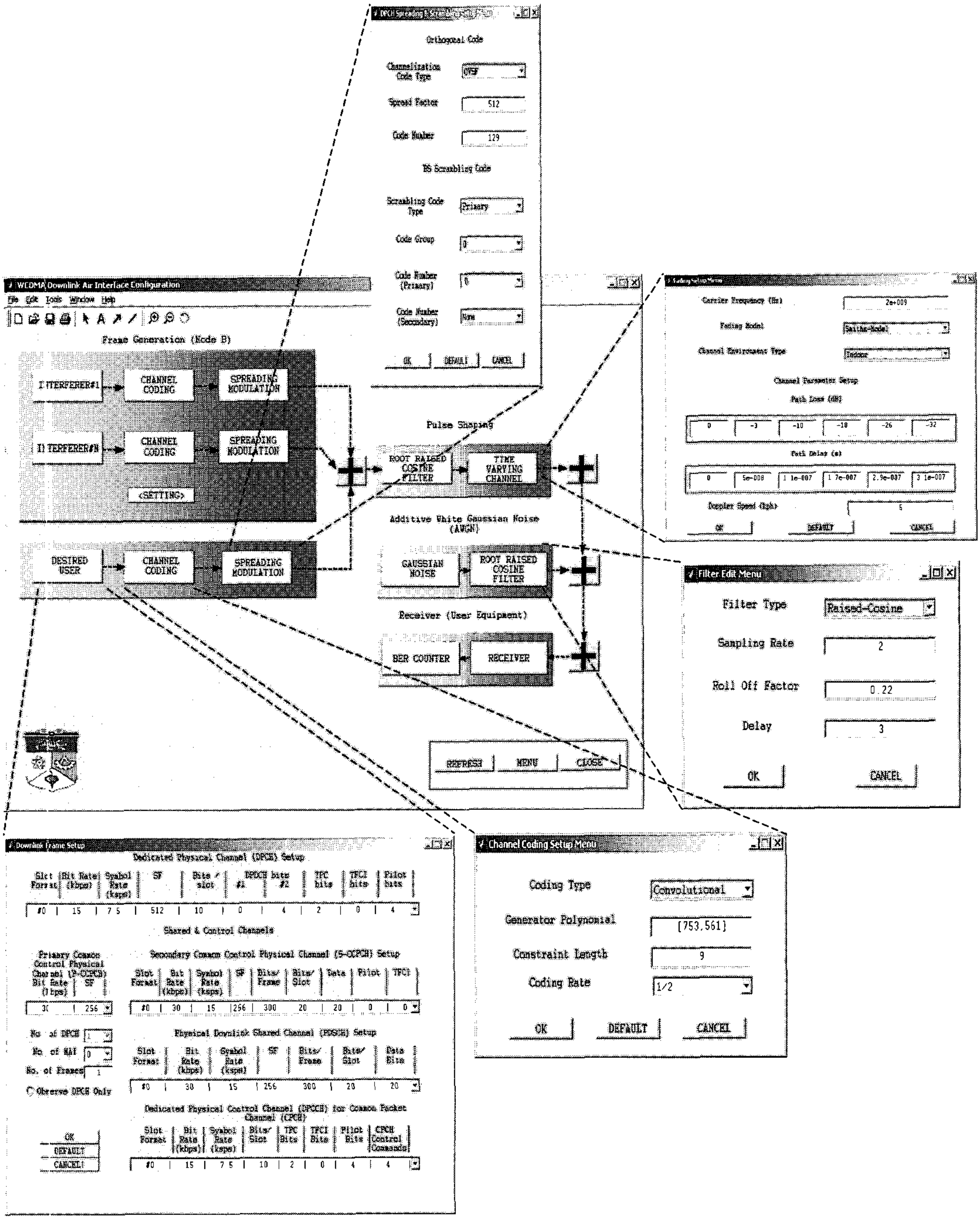
Channel bandwidth	5 MHz
Downlink RF channel structure	Direct spread
Chip rate	3.84 Mcps
Frame length	10 ms
Carrier spacing	4.2 MHz to 5.4 MHz (200 kHz raster)
Baseband filter	Root raised cosine (roll off factor 0.22)
Data modulation	QPSK (Downlink), BPSK (Uplink)
Spreading modulation	Balanced QPSK (Downlink), Dual-channel QPSK (Uplink); Complex spreading circuit
Coherent detection	User dedicated time multiplexed pilot (downlink and uplink); No common pilot in downlink
Channel multiplexing in downlink	Data and control channels time multiplexed
Channel multiplexing in uplink	Control and pilot channel time multiplexed, I & Q multiplexing for data and control channel
Multirate	Variable spreading and multicode
Channel coding	Convolutional (rate = 1/2, 1/3, constraint length = 9). Turbo
Spreading factor	4 - 256 (Uplink), 4 - 512 (Downlink)
Power control	Open and fast closed loop (1.5 kHz)
Spreading (Downlink)	OVSF sequences for channel separation, Gold sequences of length 2^{18}-1 for cell and user separation (truncated 10 ms period)
Spreading (Uplink)	OVSF sequences, Gold sequences of length 2^{25}-1 (truncated to 10 ms period) or alternatively short scrambling code of 256-chip period for user separation (different time shifts in I & Q channel)
Base station synchronization	Asynchronous

The output response of the simulator is the bit error rate (BER) against signal to noise ratio (Eb/N0) for varying number of interferers, data rates, spread factors, sampling rate and vehicular speeds. User is able to select the existing dedicated channel options for the WCDMA frame generation at the generator block. Channel encoding option is also enabled with either rate 1/2 or rate 1/3 convolutional encoding.



[Fig. 2] User Selectable Parameters at Simulator Menu

The simulator is presented in graphical user interface (GUI) to provide a friendly platfrom for the user. A menu is provided to enables user to select the system parameters and view the WCDMA signal transformation at each block (to help user to better understand the WCDMA system) or as a complete system.



Orthogonal Code

Channelization Code Type: OVSF

Spread Factor: 512

Code Number: 129

BS Scrambling Code

Scrambling Code Type: Primary

Code Group: 0

Code Number (Primary): 0

Code Number (Secondary): None

Carrier Frequency (Hz): 2e+009

Fading Model: Saitha-Model

Channel Environment Type: Indoor

Channel Parameter Setup

Path Loss (dB)

0	-3	-10	-18	-26	-32

Path Delay (s)

0	5e-008	1.1e-007	1.7e-007	2.9e-007	3.1e-007

Doppler Speed (kph): 5

Filter Type: Raised-Cosine

Sampling Rate: 2

Roll Off Factor: 0.22

Delay: 3

Coding Type: Convolutional

Generator Polynomial: [753,561]

Constraint Length: 9

Coding Rate: 1/2

Dedicated Physical Channel (DPCH) Setup

Slot Format	Bit Rate (kbps)	Symbol Rate (ksps)	SF	Bits / slot	DPDCH bits #1	DPDCH bits #2	TPC bits	TFCI bits	Pilot bits
#0	15	7.5	512	10	0	4	2	0	4

Shared & Control Channels

Primary Common Control Physical Channel (P-CCPCH)

Bit Rate (kbps)	SF
30	256

Secondary Common Control Physical Channel (S-CCPCH) Setup

Slot Format	Bit Rate (kbps)	Symbol Rate (ksps)	SF	Bits/ Frame	Bits/ Slot	Data	Pilot	TFCI
#0	30	15	256	300	20	20	0	0

No of DPCH: 1

No. of MAI: 0

No. of Frames: 1

○ Observe DPCH Only

Physical Downlink Shared Channel (PDSCH) Setup

Slot Format	Bit Rate (kbps)	Symbol Rate (ksps)	SF	Bits/ Frame	Bits/ Slot	Data Bits
#0	30	15	256	300	20	20

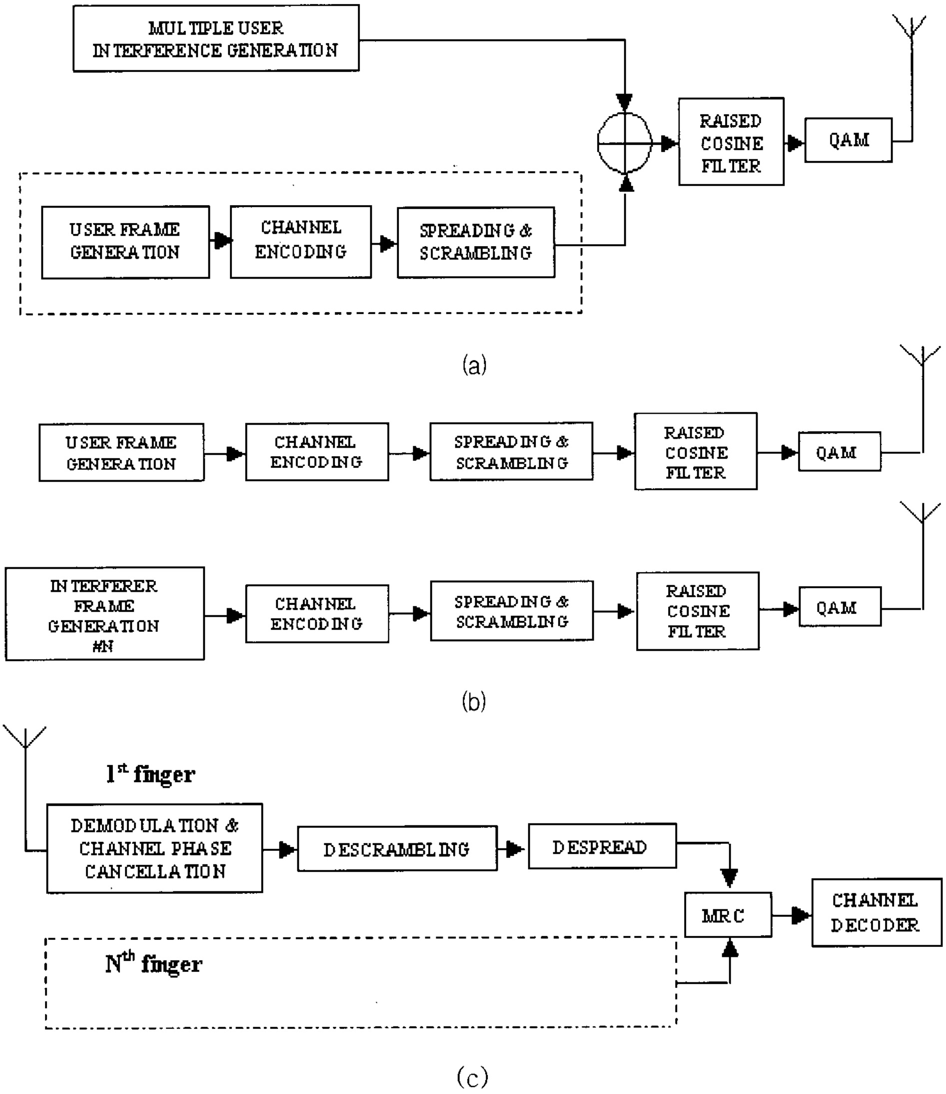
Dedicated Physical Control Channel (DPCCH) for Common Packet Channel (CPCH)

Slot Format	Bit Rate (kbps)	Symbol Rate (ksps)	Bits/ Slot	TPC Bits	TFCI Bits	Pilot Bits	CPCH Control Commands
#0	15	7.5	10	2	0	4	4

[Fig. 3] WCDMA Simulator User Interface for Downlink Case

The WCDMA simulator incorporate the joint technical committee (JTC) power delay profile for the indoor, indoor to outdoor and vehicular channel similar to [8]. It also supports other channel models such as ATDMA, CODIT, and COST 259 channel model for typical urban, rural area and hilly terrains not supported in [6].

COST 259 channel model is the UMTS extension of GSMs COST 207 channel model to overcome the limitations caused by the latter [9]. The simulator also has the capability to support different RAKE combining algorithms such as maximal ratio combining (MRC) and equal gain combining (EGC) as well as the conventional matched filter detector.



[Fig. 4] (a) Downlink Transmitter (b) Uplink Transmitter and (c) Receiver Block Diagram

[Fig. 2] shows the user selectable menu of the simulator. The user can select the desired parameter and receiver/transmitter options through the GUI menu. [Fig. 3] shows the GUI for the downlink case.

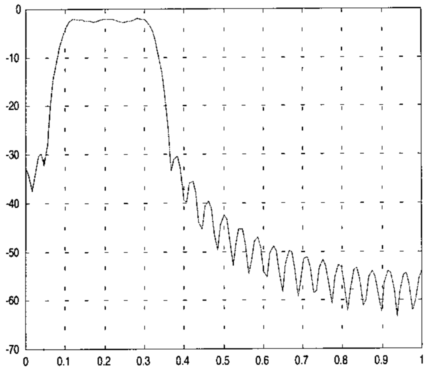
[Fig. 4] shows the block diagram of the transmitter and receiver, where the transmitter downlink and uplink block are shown in [Fig. 4](a) and [Fig. 4](b) respectively. The difference between uplink and downlink can be seen in the generation of radio frame referring to the dedicated data and control channel inclusive of other dedicated channels, spreading and modulation, scrambling code generation, and in the structured method of injecting multiple user interferers into the system.

At the downlink part (Fig. 4(a)), each users radio frame is generated and spread to the chip rate using different OVSF codes, this is to ensures the orthogonality between user signals. Prior to scrambling, all the user signals are summed assuming perfect time synchronization between the signals. Then, the baseband signal is sent for pulse shaping and subsequently followed by quadrature amplitude modulation (QAM) prior to transmission. The transmitted signal is distorted by passing it through a small scale fading propagation medium and the received signal at the receiver front end is further corrupted by adding additive white gaussian noise (AWGN). The multiple paths of the arriving signal is tapped and passed through a RAKE receiver where the signal is demodulated and fed through a phase canceller with an assumption of perfect channel estimation to counter the effects of fading. Then, the signal is descrambled, despread and later followed by maximal ratio combining (MRC) to obtain the original data.

The uplink (Fig. 4(b)) differs in the sense that each user is not synchronized to each other. The radio frame of each user is spread to the chip rate and later scrambled with an unique scrambling code specific only to that particular user. Next, the scrambled signal is filtered and applied with QAM modulation. Each users modulated signal is transmitted separately through the propagation medium and only adds up at the receiver front end. Similar to the downlink, the received signal is further corrupted with AWGN noise prior to demodulation. The unsynchronized received signal of each user is corrected by adjusting to its transmission time offset prior to demodulation. Later, the demodulated signal is passed through the RAKE and subsequently descrambled, despread and MRC combined to obtain the transmitted data.

4. SIMULATOR OUTPUTS

In this section, selected case simulation results of the WCDMA air interface produced by the simulator are presented.



[Fig. 5] WCDMA Spectrum

Fig. 5 displays the spectrum of the WCDMA signal output generated by the simulator. The characteristic of the signal could be also viewed in different fading environments and channel models. This capability ensures a better understanding of the evaluated system by the user. Fig. 6 presents the impulse responses of the channels, the system is evaluated at downlink for indoor, indoor to outdoor and vehicular channel according to the joint technical committee (JTC) power delay profile with maximum number of taps limited to six.

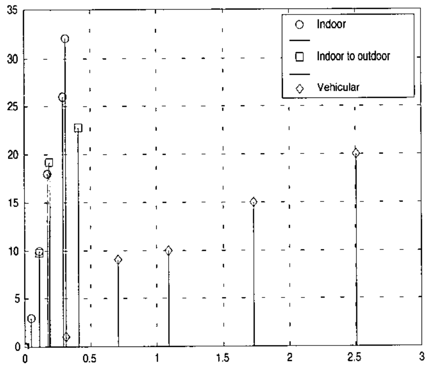
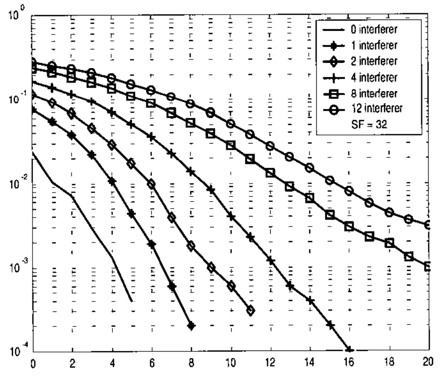


Fig. 6. (a) Indoor (b) Indoor To Outdoor and (c) Vehicular Channel Impulse Response for the JTC Power Delay Profile

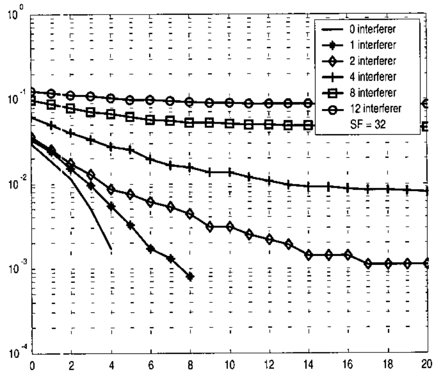
[Fig. 7] and Fig. 8 respectively show the WCDMA downlink and uplink performance in a 5km/h indoor Rayleigh fading environment for varying number of interferers. The system has a data rate of 120 ksps corresponding to a spread factor of 32 with a sampling rate of 8. RAKE fingers with MRC combining is used at the receiver front end. Fig. 9 shows the effect of mobile velocity on the system performance in various channel environments for the downlink case with the number of interferers set to 4. Fig. 10 displays the performance improvement obtained by increasing sampling rate for a single user environment in a downlink environment. Perfect power control and channel estimation is assumed for all the cases without channel encoding. These results have been thoroughly evaluated and compared with results from [5],[8] and in other references from the open literatures.

Case 1: Downlink



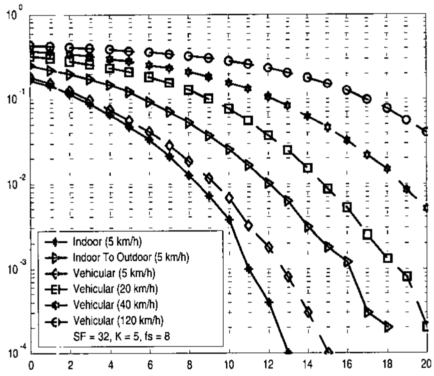
[Fig. 7] BER vs Eb/N0 at WCDMA Downlink for 5 km/h Indoor at 120 ksps with Sampling Rate of 8

Case 2: Uplink



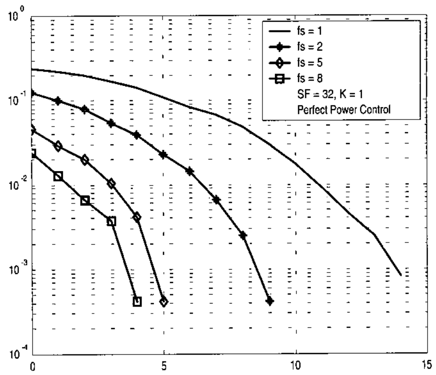
[Fig. 8] BER vs Eb/N0 at WCDMA Uplink for 5 km/h Indoor at 120 ksps with Sampling Rate of 8

Case 3: Different Mobile Velocity



[Fig. 9] BER vs Eb/N0 at WCDMA Downlink for Varying Mobile Velocity at 120 ksps with 5 Users and Sampling Rate of 8

Case 4 : Different Sampling Rates



[Fig. 10] BER vs Eb/N0at WCDMA Downlink for Different Sampling Rates in a 5 km/h Indoor Single User Environment of Data Rate 120 ksps

5. CONCLUSIONS AND DISCUSSIONS

In this paper, the development of the WCDMA simulator for both the uplink and downlink on a MATLAB Ver.5.3 platform is presented. The simulator is presented in GUI menu to provide a user friendly environments and applications. User is able to select the desired system configuration at selectable menus at the simulator blocks, this enables the user to view the WCDMA signal transformation and the channel characteristics involved in the simulation.

The simulator provides user with the reliable performance statistics for the WCDMA air interface in the form of BER against Eb/N0 for varying number of interferers, data rates, spread factors, sampling rates, and vehicular speeds. The user is also able to select different receiver structures such as conventional matched filter and RAKE receiver (employing MRC and EGC algorithms) from the simulator. Additional channel models such as COST 259, ATDMA and CODIT are also supported by the simulator.

The simulator only supports the 3GPPs direct sequence WCDMA FDD mode and is limited to the physical layer of the air interface. Moreover, it is only capable of evaluating a single base station with multiple number of users within a single cell scenario. Small scale propagation path loss have been given due importance here and in earlier works due to severe fading effects it has upon the radio signal. Therefore, effects of large scale propagation loss is excluded in this work.

The simulator could be improved further by implementing multiuser detector algorithms, MIMO capabilities, handover algorithms, power control schemes and large scale propagation effects. This simulator serves to enrich the currently available simulation tools and hardware by providing a cheaper alternative for the investigation of the 3G WCDMA air interface performance.

ACKNOWLEDGEMENT

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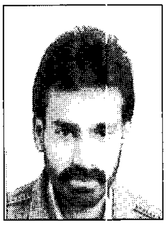
Biography



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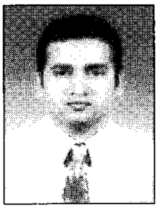

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