WCDMA Design Handbook

Developed out of a successful professional engineering course, this practical handbook provides a comprehensive explanation of the Wideband CDMA (Code Division Multiple Access) air interface of third-generation UMTS cellular systems. The book addresses all aspects of the design of the WCDMA radio interface from the lower layers to the upper layers of the protocol architecture. The book considers each of the layers in turn, to build a complete understanding of the design and operation of the WCDMA radio interface including the physical layer, RF and baseband processing, MAC, RLC, PDCP/BMP, Non-Access Stratum and RRC. An ideal course book and reference for professional engineers, undergraduate and graduate students.

Andrew Richardson has many years of experience in digital communication systems, having worked for Philips, Nokia and Simoco on both second- and third-generation mobile phone systems. Since 1999 he has run his own consultancy, Imagicom Ltd, offering design and training services in telecommunication systems technology.

WCDMA
Design Handbook

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To my wife and family, Alex, Beth, Emma and Evie,
and also to my parents Peter and Marea.

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Preface

The *WCDMA Design Handbook* addresses the subject of wideband code division multiple access (WCDMA) as defined by the Third Generation Partnership Project (3GPP) and provides a detailed review of the architecture and the operation of the system. In particular, the focus of the book is the radio interface, from the physical layer through to the upper layers of the non-access stratum. This text either offers a complete 'end-to-end' explanation of the system operation, or alternatively allows the reader to focus on any aspects of the system which are of specific interest and relevance. For this reason, the material is presented in a modular fashion, with the overlap and interlinking of the chapters kept to a minimum to allow the chapters to be as self-standing as possible in order to facilitate a 'pick and mix' approach to the book where required.

The structure of the book is intended to provide a solid introduction to the basic principles for the operation of the complete system and then to focus on the specific details in each of the relevant chapters. The major principles for the operation of the WCDMA system are considered throughout the different chapters, including the use of codes and multiplexing in the physical layer, the procedures for transport format combination control in layer 2 and the radio interface control procedures either within the radio resource control (RRC) protocol in the access stratum, or within the mobility management and service management protocols in the non-access stratum. One of the key methods of examining the system is the use of examples to demonstrate the operation of specific procedures or processes.

At the lower layers, the book focuses on the FDD mode of the WCDMA system. The use of the TDD mode is considered to a greater degree as the higher layer protocols are considered. The emphasis is on the first release of the WCDMA specifications (Release 99).

Written for a professional audience, the book is relevant to practising engineers and managers, and graduate and undergraduate students. Like most texts at this level, it is beneficial for the reader to have had some previous exposure to cellular radio systems such as GSM. It is assumed that the reader is comfortable with the technical nature of the information in this technical book.

The book can be considered as being in four parts. Part 1 comprises Chapters 1–3 and is a general introduction; Part 2, Chapters 4–7, covers mainly the physical layer; Part 3, Chapters 8–12, covers layers 2 and 3 in the access stratum; and Part 4, Chapters 13 and 14, covers the non-access stratum protocols. The reading of these four parts will depend upon the specific interests of the reader. For RF, DSP, ASIC and hardware engineers Parts 1 and 2 are recommended. For protocol designers/software designers and protocol test engineers who are focussing on the operation of the access stratum of the WCDMA system, Parts 1 and 3 are the most appropriate. Both protocol designers/ software designers and protocol test engineers concentrating on the operation of the non-access stratum of the WCDMA system should read Parts 1 and 4. Finally, for an interested reader, or for a graduate or undergraduate course, the chapters can be taken in order. The book closely follows the 3GPP specifications; for completeness the relevant specifications are outlined in the Appendix.

The *WCDMA Design Handbook* is based on the experience and knowledge gained over a 20-year period by the author. The detail has been honed during the process of presenting the material in the form of a number of training courses on WCDMA, from layer 1 through to the non-access stratum. It is the first in what is planned to be a series of books by the author following the development of the UMTS and wireless cellular market place, with an emphasis on a detailed understanding of the design and operation of the technology. Dr Richardson is a director of the established training and consultancy company Imagicom Ltd (www.imagicom.co.uk), which specialises in delivering regular advanced level technical training courses, the material for which is constantly updated and presented both via a range of scheduled public courses usually held in Cambridge UK and to major players in the telecommunications industry on an in-house basis.

Acknowledgements

I would like to give special thanks to my wife Alex for her enduring support over the many hours that it has taken to bring this volume from conception into existence; without her this book could not exist. I love her deeply.

Abbreviations

2G	second generation
3G	third generation
3G-MSC/VLR	third generation mobile switching centre/visitor location register
3GPP	3rd Generation Partnership Project
3G-SGSN	third generation serving GPRS support node
AC	access class
ACK	acknowledgement
ACLR	adjacent channel leakage ratio
ACS	adjacent channel selectivity
ADC	analogue to digital converter
ADF	application dedicated files
AGC	automatic gain control
AI	acquisition indicator
AICH	acquisition indication channel
AID	application identifier
AK	anonymity key
AM	acknowledged mode
AMD	acknowledged mode data
AMF	authentication and key management field
AMR	adaptive multirate
AP	access preamble
APN	access point name
ARQ	automatic repeat request
AS	access stratum
ASC	access service class
ASIC	application specific integrated circuit
ATM	asynchronous transfer mode
ATT	AICH transmission timing
ATT	attach flag
AUTN	authentication token
AV	authentication vector

AWGN	additive white Gaussian noise
BBF	baseband filter
BC	broadcast control
BCCH	broadcast control channel
BCD	binary coded decimal
BCFE	broadcast channel functional entity
BCH	broadcast channel
BER	bit error rate
BGCF	breakout gateway control function
BLER	block error rate
BMC	broadcast and multicast control protocol
BO	buffer occupancy
BPF	band pass filter
BPSK	binary phase shift keyed
BS	base station
BSC	base station controller
BSS	base station system
BTS	base transceiver station
C/I	carrier to interference ratio
C/T	control/traffic
CA	channel assignment
CAI	channel assignment indicator
CAMEL	customised application for mobile network enhanced logic
CBC	cell broadcast centre
CBS	cell broadcast service
CC	call control
CCC	CPCH control channel
CCCH	common control channel
CCDF	complementary cumulative distribution function
CCTrCH	coded composite transport channel
CD	collision detection
CD/CA-ICH	collision detection/channel assignment indicator channel
CDMA	code division multiple access
CFN	connection frame number
CID	context identifier
CK	cipher key
CKSN	cipher key sequence number
CLI	calling line identification
CLIR	calling line identification restriction
CM	connection management
CN	core network

CP	control protocol
CPBCCH	compact packet BCCH
CPCH	common packet channel
CPICH	common pilot channel
CRC	cyclic redundancy check
CRNC	controlling radio network controller
c-RNTI	cell radio network temporary identifier
CS	circuit switched
CSCF	call session control function
CSICH	CPCH status indication channel
CTCH	common traffic channel
CTFC	calculated transport format combination
CTS	cordless telephony system
CW	continuous wave
D/C	data/control
DAC	digital to analogue converter
DC	dedicated control
DCCH	dedicated control channel
DCF	digital channel filter
DCFE	dedicated control functional entity
DCH	dedicated transport channel
DCS1800	digital cellular network at 1800MHz
DC-SAP	dedicated control SAP
DECT	digital enhanced cordless telecommunications
DF	dedicated files
DPCCH	dedicated physical control channel
DPCH	dedicated physical channel
DPDCH	dedicated physical data channel
DRAC	dynamic resource allocation control
DRNC	drift radio network controller
DRNS	drift radio network subsystem
DRX	discontinuous reception
DSCH	downlink shared transport channel
DSP	digital signal processor
DTCH	dedicated traffic channel
DTX	discontinuous transmission
EDGE	enhanced data rates for GSM evolution
EF	elementary file
EGC	efficient Golay correlator
EIR	equipment identity register
e-MLPP	enhanced multilevel precedence and preemption

EMS	extended message service
EOT	end of transmission
EPC	estimated PDU counter
ETSI	European Telecommunications Standards Institute
EVM	error vector magnitude
FACH	forward access channel
FBI	feedback mode indicator
FCT	frame count transmitted
FDD	frequency division duplex
FDMA	frequency division multiple access
FER	frame error rate
FFT	fast Fourier transform
FHT	fast Hadamard transform
FIR	finite impulse response
G3	Group 3
GC	general control
GERAN	GSM/EDGE radio access network
GGSN	gateway GPRS support node
GMM	GPRS mobility management
GMMAS-SAP	GPRS mobility management SAP
GMSC	gateway mobile switching centre
GPRS	general packet radio service
GSM	global system for mobile communications
GSMS	GPRS short message service
GTP	GPRS tunnelling protocol
HC	header compression
HCS	hierarchical cell structures
HE/AuC	home environment/authentication centre
HFN	hyper frame number
HLR	home location register
HPLMN	home PLMN
HPSK	hybrid PSK
HSDPA	high speed downlink packet access
HSS	home subscriber server
HTTP	hypertext transfer protocol
I-CSCF	interrogating call session control function
IE	information element
IK	integrity key
IMEI	international mobile equipment identity
IMS	internet protocol multimedia subsystem
IMSI	international mobile subscriber identity

IMT2000	International Mobile Telecommunications 2000
IP	internet protocol
IPDL	idle period on the downlink
ISDN	integrated services digital network
ITU	International Telecommunication Union
KSI	key set identifier
LA	location area
LAC	location area code
LAI	location area identifier
LAPP	log *a-posteriori* probability
LAU	location area update
LI	length indicator
LLC	logical link control
LLR	log likelihood ratio
LNA	low noise amplifier
LO	local oscillator
LR	location registration
LSB	least significant bit
MAC	message authentication code
MAC	medium access control
MAC-b	MAC – broadcast
MAC-c/sh	MAC – common or shared
MAC-d	MAC – dedicated
MAC-hs	MAC – high speed
MAP	maximum a-posteriori probability
MASF	minimum available spreading factor
MCC	mobile country code
ME	mobile equipment
MF	master file
MGCF	media gateway control function
MGW	media gateway
MIB	master information block
MLSE	maximum likelihood sequence estimation
MM	mobility management
MN	mobile network
MNC	mobile network code
MO	mobile originated
MRC	maximum ratio combining
MRF	media resource function
MRFC	media resource function controller
MRFP	media resource function processor

MRW	move receive window
MS	mobile station
MSB	most significant bit
MSC	mobile switching centre
MSE	mean square error
MSIN	mobile subscriber identifier number
MT	mobile terminated
MUX	multiplex
NACK	negative acknowledgement
NAS	non-access stratum
NSAPI	network service access point identifier
NW	network
OCQPSK	orthogonal complex QPSK
OSI	open systems interconnection
OTDOA	observed time difference of arrival
OVSF	orthogonal variable spreading factor
PCCC	parallel concatenated convolutional code
PCCH	paging control channel
PCCPCH	primary common control physical channel
PCDE	peak code domain error
PCF	policy control function
PCH	paging channel
PCPCH	physical common packet channel
P-CPICH	primary common pilot channel
PCs	personal communication system
P-CSCF	proxy call session control function
PD	protocol discriminator
PDC	personal digital cellular
PDCP	packet data convergence protocol
PDN	packet data network
PDP	packet data protocol
PDSCH	physical downlink shared channel
PDU	protocol data unit
PI	paging indicator
PICH	paging indication channel
PID	packet identifier
PIN	personal identification number
PLMN	public land mobile network
PMM	PS mobility management
PN	pseudo-noise
PNFE	paging and notification functional entity

PRA	PCPCH resource availability
PRACH	physical random access channel
PS	packet switched
PSC	primary synchronisation code
P-SCH	primary synchronisation channel
PSK	phase shift keying
PSTN	public switched telephone network
PTM	point to multipoint
P-TMSI	packet temporary mobile subscriber identity
PTP	point to point
QoS	quality of service
QPSK	quadrature phase shift keying
R4	Release 4
R5	Release 5
R6	Release 6
R99	Release 99
RA	routing area
RAB	radio access bearer
RABM	radio access bearer manager
RAC	radio access capability
RACH	random access channel
RAI	routing area identifier
RAT	radio access technology
RAU	routing area update
RB	radio bearer
RES	response
RL	radio link
RLC	radio link control
RLS	radio link set
RLS	recursive least squares
RM	rate match
RNC	radio network controller
RNS	radio network subsystem
RNTI	radio network temporary identifier
ROHC	robust header compression
RPLMN	registered PLMN
RRC	radio resource control
RRC	root raised cosine
RR-SAP	radio resource SAP
RSCP	receive signal code power

RTT	round trip time
S/P	serial to parallel
SAP	service access point
SCCPCH	secondary common control physical channel
SCH	synchronisation channel
S-CPICH	secondary common pilot channel
SCR	source controlled rate
S-CSCF	serving call session control function
SDP	session description protocol
SDU	service data unit
SF	spreading factor
SFN	system frame number
SGSN	serving GPRS support node
SHCCH	shared channel control channel
SI	status indicator
SI	stream identifier
SIB	system information block
SIBn	system information broadcast type n ($n = 1, \ldots, 18$)
SID	silence descriptor
SIP	session initiation protocol
SIR	signal to interference ratio
SISO	soft in soft out
SLF	subscription location function
SM	session management
SMC-CS	short message control – circuit switched
SMC-GP	short message control – GPRS protocol
SM-RL	short message relay layer
SMS	short message service
SMSMM	SMS mobility management
SM-TL	short message transfer layer
SNR	signal to noise ratio
SOVA	soft output Viterbi algorithm
SQN	sequence number
SRB	signalling radio bearer
SRNS	serving radio network subsystem
s-RNTI	serving radio network temporary identifier
SS	supplementary service
S-SCH	secondary synchronisation channel
SSDT	site selection diversity transmission
STTD	space time transmit diversity

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SUFI	super fields
TACS	total access communications system
TAF	terminal adaptation function
TCP	transmission control protocol
TCTF	target channel type field
TCTV	traffic channel transport volume
TDD	time division duplex
TDMA	time division multiple access
TE	terminal equipment
TF	transport format
TFC	transport format combination
TFCI	transport format combination indicator
TFCS	transport format combination set
TFS	transport format selection
TFT	traffic flow template
TG8/1	Task Group 8/1
TGMP	transmission gap sequence measurement purpose
TI	transaction identifier
TIA	Telecommunications Industry Association
TM	transparent mode
TMD	transport mode data
TMSI	temporary mobile subscriber identity
ToS	type of service
TPC	transmit power control
TTI	transmission time interval
TVM	traffic volume measurement
Tx	transmit
UARFCN	UTRA absolute radio frequency channel number
UDP	user datagram protocol
UE	user equipment
UICC	universal integrated circuit card
UM	unacknowledged mode
UMTS	Universal Mobile Telecommunications System C304
URA	UTRAN registration area
URL	uniform resource locator
u-RNTI	UTRAN radio network temporary identifier
US	update status
USAT	USIM application toolkit
USCH	uplink shared channel
USIM	universal subscriber identity module
UTRAN	UMTS terrestrial radio access network

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VAD	voice activity detection
VCAM	versatile channel assignment mode
VGCS	voice group call service
VLR	visitor location register
WCDMA	wideband code division multiple access
XMAC	expected message suthentication code
XRES	expected response