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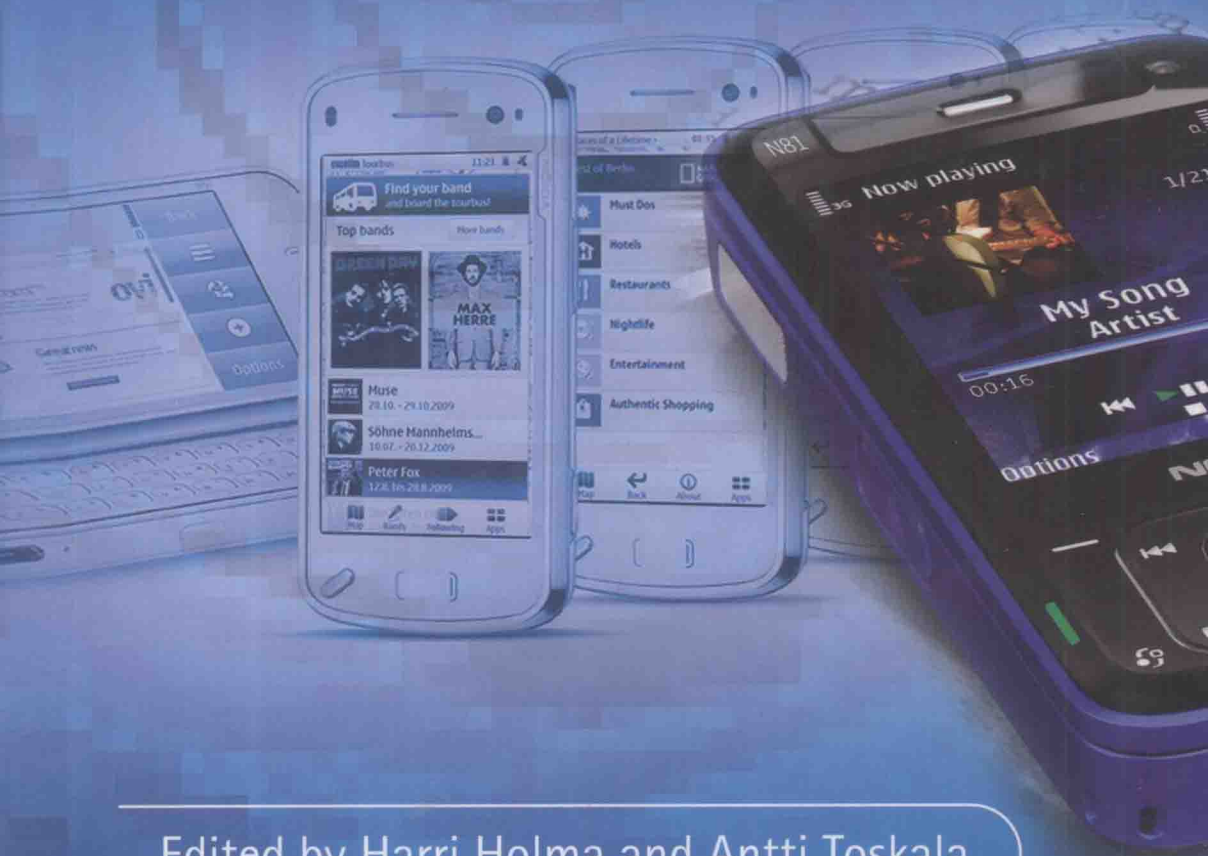
WCDMA FOR UMTS

- HSPA EVOLUTION AND LTE

Fifth Edition



Edited by Harri Holma and Antti Toskala

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Nokia Siemens Networks, Finland

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WCDMA FOR UMTS

Preface

Second generation telecommunication systems, such as GSM, enabled voice traffic to go wireless: the number of mobile phones exceeds the number of landline phones and the mobile phone penetration is approaching 100% in several markets. The data handling capabilities of second generation systems are limited, however, and third generation systems are needed to provide the high bit rate services that enable high quality images and video to be transmitted and received, and to provide access to the web with higher data rates. These third generation mobile communication systems are referred to in this book as UMTS (Universal Mobile Telecommunication System). WCDMA (Wideband Code Division Multiple Access) and its evolution HSPA (High Speed Packet Access) is the main third generation air interface globally. During the publication of the 5th edition, the number of WCDMA/HSPA subscribers has exceeded 500 million. It is expected that the 1 billion landmark will be passed in less than two years. There are over 300 commercial HSPA networks globally supporting peak data rates up to 42 Mbps. HSPA has grown to be the preferred radio network for providing wireless broadband access, for supporting an increasing number of smart phones and for offering high capacity and high quality voice service in an efficient way. This book gives a detailed description of the WCDMA/HSPA air interface and its utilization. The contents are summarized in Figure 1.

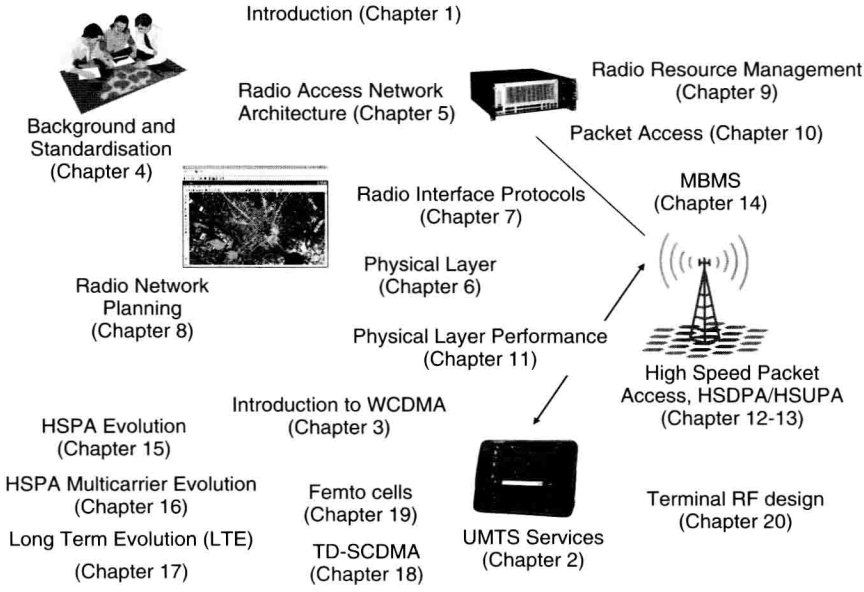

Figure 1. Contents of this book

The book is structured as follows. Chapters 1–4 provide an introduction to the technology and its standardization. Chapters 5–7 give a detailed presentation of the WCDMA standard, while Chapters 8–11 cover the utilization of the standard and its performance. Chapters 12–16 present HSPA and its evolution. TD-SCDMA is described in Chapter 18. The home base stations, also called femtocells, are explained in Chapter 19. Chapter 20 covers terminal RF design challenges.

Chapter 1 briefly introduces the background, development, status and future of WCDMA/HSPA radio. Chapter 2 presents examples of the current UMTS applications and the main uses cases. Chapter 3 introduces the principles of the WCDMA air interface, including spreading, Rake receiver, power control and handovers. Chapter 4 presents the background to WCDMA, the global harmonization process and the standardization. Chapter 5 describes the architecture of the radio access network, interfaces within the radio access network between base stations and radio network controllers (RNC), and the interface between the radio access network and the core network. Chapter 6 covers the physical layer (Layer 1), including spreading, modulation, user data and signalling transmission, and the main physical layer procedures of power control, paging, transmission diversity and handover measurements. Chapter 7 introduces the radio interface protocols, consisting of the data link layer (Layer 2) and the network layer (Layer 3). Chapter 8 presents the guidelines for radio network dimensioning, gives an example of detailed capacity and coverage planning, and covers GSM co-planning. Chapter 9 covers the radio resource management algorithms that guarantee the efficient utilization of the air interface resources and the quality of service. These algorithms are power control, handovers, admission and load control. Chapter 10 depicts packet access and presents the performance of packet protocols of WCDMA. Chapter 11 analyses the coverage and capacity of the WCDMA air interface. Chapter 12 presents the significant Release 5 feature, High Speed Downlink Packet Access, HSDPA, and Chapter 13 the corresponding uplink counterpart High Speed Uplink Packet Access, HSUPA in Release 6. Chapter 14 presents Multimedia Broadcast Multicast System, MBMS. Chapter 15 introduces HSPA evolution in Releases 7, 8 and 9. Chapter 16 describes HSPA multicarrier evolution up to four carriers. Long Term Evolution (LTE) in Releases 8 and 9 is presented in Chapter 17. The time division duplex (TDD) based TD-SCDMA (Time Division Synchronous Code Division Multiple Access) is illustrated in Chapter 18. The femtocells are presented in Chapter 19 and the challenges in the terminal RF design in Chapter 20.

The 2nd edition contained coverage of the recently introduced key features of 3GPP Release 5 specifications, such as High Speed Downlink Packet Access, HSDPA and IP Multimedia Subsystem (IMS). The 3rd edition of the book continued to deepen the coverage of several existing topics both based on the field experiences and based on more detailed simulation studies. The 3rd edition covered the main updates in 3GPP standard Release 6. The 4th edition added in detail 3GPP Release 6 features including High Speed Uplink Packet Access (HSUPA) Multimedia Broadcast Multicast System (MBMS), HSPA evolution and terminal RF design challenges.

The 5th edition of the book introduces new material in the areas of HSPA evolution including Releases 8 and 9, HSPA multicarrier solutions, GSM band refarming for HSPA, Integrated Mobile Broadcast (IMB), TD-SCDMA description, femtocells, terminal power consumption estimates, services and LTE.

This book is aimed at operators, network and terminal manufacturers, service providers, university students and frequency regulators. A deep understanding of the WCDMA/HSPA air interface, its capabilities and its optimal usage is the key to success in the UMTS business.

This book represents the views and opinions of the authors, and does not necessarily represent the views of their employers.

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Finally, we would like to acknowledge the efforts of our colleagues in the wireless industry for the great work done within the 3rd Generation Partnership Project (3GPP) to produce the global WCDMA standard in merely a year and thus to create the framework for this book. Without such an initiative this book would never have been possible.

The editors and authors welcome any comments and suggestions for improvements or changes that could be implemented in forthcoming editions of this book. The feedback is welcome to editors' email addresses harri.holma@nsn.com and antti.toskala@nsn.com.

Abbreviations

3GPP	3rd Generation partnership project (produces WCDMA standard)
3GPP2	3rd Generation partnership project 2 (produced cdma2000 standard)
AAL2	ATM Adaptation Layer type 2
AAL5	ATM Adaptation Layer type 5
ABB	Analog baseband
ACELP	Algebraic code excitation linear prediction
ACIR	Adjacent channel interference ratio, caused by the transmitter non-idealities and imperfect receiver filtering
ACK	Acknowledgement
ACL	Access control list
ACLR	Adjacent channel leakage ratio, caused by the transmitter non-idealities, the effect of receiver filtering is not included
ACTS	Advanced communication technologies and systems, EU research projects framework
ADC	Analog to digital conversion
AGC	Automatic gain control
A-GW	Access gateway
AICH	Acquisition indication channel
ALCAP	Access link control application part
AM	Acknowledged mode
AM	Amplitude modulation
AMD	Acknowledged mode data
AMR	Adaptive multirate (speech codec)
AMR-NB	Narrowband AMR
AMR-WB	Wideband AMR
ARIB	Association of radio industries and businesses (Japan)
AOL	America on-line
AP	Access point
ARP	Allocation and retention priority
ARQ	Automatic repeat request
ASC	Access service class
ASN.1	Abstract syntax notation one
ATM	Asynchronous transfer mode
AWGN	Additive white Gaussian noise
AWS	Advanced wireless services

BB	Baseband
BB SS7	Broadband signalling system #7
BCCH	Broadcast channel (logical channel)
BCFE	Broadcast control functional entity
BCH	Broadcast channel (transport channel)
BER	Bit error rate
BLER	Block error rate
BMC	Broadcast/multicast control protocol
BM-SC	Broadcast multicast service center
BO	Backoff
BoD	Bandwidth on demand
BOM	Bill of material
BPSK	Binary phase shift keying
BS	Base station
BSC	Base station controller
BSS	Base station subsystem
CA-ICH	Channel assignment indication channel
CB	Cell broadcast
CBC	Cell broadcast center
CBS	Cell broadcast service
CCCH	Common control channel (logical channel)
CCH	Common transport channel
CCH	Control channel
CDD	Cyclic Delay Diversity
CDF	Cumulative distribution function
CD-ICH	Collision detection indication channel
CDMA	Code division multiple access
CFN	Connection frame number
CIF	Common intermediate format
CIR	Carrier to interference ratio
CM	Connection management or Cubic metric
CMOS	Complementary metal oxide semiconductor
CN	Core network
C-NBAP	Common NBAP
CODIT	Code division test bed, EU research project
CPC	Continuous packet connectivity
CPCH	Common packet channel
CPE	Customer premises equipment
CPICH	Common pilot channel
CQI	Channel quality indicator
CRC	Cyclic redundancy check
CRNC	Controlling RNC
C-RNTI	Cell-RNTI, radio network temporary identity
CS	Circuit Switched
CSCF	Call state control function
CSG	Closed subscriber group
CSICH	CPCH status indication channel
CTCH	Common traffic channel
CW	Continuous wave
CWTS	China wireless telecommunications standard group

DAC	Digital to audio conversion
DARP	Downlink advanced receiver performance
DBB	Digital baseband
DC	Direct current
DCA	Dynamic channel allocation
DCCH	Dedicated control channel (logical channel)
DCFE	Dedicated control functional entity
DCH	Dedicated channel (transport channel)
DC-HSDPA	Dual cell HSDPA
DC-HSPA	Dual cell HSPA
DC-HSUPA	Dual cell HSUPA
DCR	Direct conversion receiver
DDR	Direct digital receiver
DECT	Digital enhanced cordless telephone
DF	Decision feedback
DFCA	Dynamic frequency and channel allocation
DL	Downlink
D-NBAP	Dedicated NBAP
DNS	Domain name system
DPCCH	Dedicated physical control channel
DPDCH	Dedicated physical data channel
DPI	Deep packet inspection
DRNC	Drift RNC
DRX	Discontinuous reception
DS-CDMA	Direct spread code division multiple access
DSCH	Downlink shared channel
DSL	Digital subscriber line
DTCH	Dedicated traffic channel
DTX	Discontinuous transmission
DVB-T/H	Digital video broadcast terrestrial / handheld
DwPTS	Downlink pilot time slot
E-AGCH	E-DCH absolute grant channel
E-DCH	Enhanced uplink DCH
EDGE	Enhanced data rates for GSM evolution
E-DPCCH	E-DCH dedicated physical control channel
E-DPDCH	E-DCH dedicated physical data channel
EFR	Enhance full rate
EGSM	Extended GSM
E-HICH	E-DCH acknowledgement indicator channel
EIRP	Equivalent isotropic radiated power
EP	Elementary Procedure
EPC	Evolved Packet Core
E-PUCH	E-DCH physical uplink channel
E-RGCH	E-DCH relative grant channel
E-RUCCH	E-DCH random access uplink control channel
ETSI	European Telecommunications Standards Institute
E-UCCH	The E-DCH uplink control channel
E-UTRAN	Evolved UTRAN
EVM	Error vector magnitude

FACH	Forward access channel
FBI	Feedback information
FCC	Federal communication commission
FCS	Fast cell selection
FDD	Frequency division duplex
FDMA	Frequency division multiple access
FER	Frame error ratio
FFT	Fast Fourier transform
FP	Frame protocol
FPACH	Fast physical access channel
FRAMES	Future radio wideband multiple access system, EU research project
FTP	File transfer protocol
GERAN	GSM/EDGE Radio Access Network
GGSN	Gateway GPRS support node
GMSC	Gateway MSC
GNSS	Global navigation satellite system
GP	Guard Period
GPRS	General packet radio system
GPS	Global positioning system
GSIC	Groupwise serial interference cancellation
GSM	Global system for mobile communications
GTP-U	User plane part of GPRS tunnelling protocol
GW	Gateway
HARQ	Hybrid automatic repeat request
HB	High band
HLR	Home location register
HNB	Home node B
HNBAP	Home node B application part
HP	High power
HPF	High pass filter
HSDPA	High speed downlink packet access
HS-DPCCH	Uplink high speed dedicated physical control channel
HS-DSCH	High speed downlink shared channel
HSS	Home subscriber server
HS-SCCH	High speed shared control channel
HSUPA	High speed uplink packet access
HTML	Hypertext markup language
HTTP	Hypertext transfer protocol
HUE	Home Node B UE
IC	Interference cancellation or Integrated circuit
ID	Identity
IETF	Internet engineering task force
IFFT	Inverse Fast Fourier Transform
IMB	Integrated mobile broadcast
IMD	Intermodulation
IMEISV	International Mobile Station Equipment Identity and Software Version
IMS	IP multimedia sub-system
IMSI	International mobile subscriber identity
IMT-2000	International mobile telephony, 3rd generation networks are referred as IMT-2000 within ITU
IN	Intelligent network

IP	Internet protocol
IPDL	Idle periods in downlink
IPI	Inter-path interference
IPSec	IP security
IRC	Interference rejection combining
IS-95	cdmaOne, one of the 2nd generation systems, mainly in Americas and in Korea
IS-136	US-TDMA, one of the 2nd generation systems, mainly in Americas
IS-2000	IS-95 evolution standard, (cdma2000)
ISDN	Integrated services digital network
ISI	Inter-symbol interference
ITU	International telecommunications union
ITUN	SS7 ISUP Tunnelling
Iu BC	Iu broadcast
L2	Layer 2
LAI	Location area identity
LAN	Local area network
LB	Low band
LCD	Liquid crystal display
LCS	Location services
LNA	Lower noise amplifier
LO	Local oscillator
LP	Low pass
LTE	Long term evolution
MAC	Medium access control
MAI	Multiple access interference
MAP	Maximum a posteriori
MBMS	Multimedia broadcast multicast service
MBSFN	Mobile broadcast single frequency network
MCCH	MBMS point-to-multipoint control channel
MCS	Modulation and coding scheme
MCU	Multipoint control unit
MDT	Minimization of drive test
ME	Mobile equipment
MF	Matched filter
MGCF	Media gateway control function
MGW	Media gateway
MHA	Mast head amplifier
MIMO	Multiple input multiple output
MLSD	Maximum likelihood sequence detection
MM	Mobility management
MME	Mobility management entity
MMS	Multimedia message
MMSE	Minimum mean square error
MNB	Macro Node B
MOS	Mean opinion score
MPEG	Motion picture experts group
MR-ACELP	Multirate ACELP
MRF	Media resource function
MS	Mobile station
MSCH	MBMS scheduling channel

MSC/VLR	Mobile services switching centre/visitor location register
MSN	Microsoft network
MT	Mobile termination
MTCH	MBMS point-to-multipoint control channel
MTP3b	Message transfer part (broadband)
MUD	Multiuser detection
MUE	Macro UE
NAS	Non access stratum
NBAP	Node B application part
NF	Noise figure
NITZ	Network identity and time zone
NRT	Non-real time
O&M	Operation and maintenance
OCNS	Orthogonal channel noise simulator
ODMA	Opportunity driven multiple access
OFDMA	Orthogonal frequency division multiple access
OSS	Operations support system
OTDOA	Observed time difference of arrival
OVSF	Orthogonal variable spreading factor
PA	Power amplifier
PAD	Padding
PAR	Peak to average ratio
PC	Power control
PCB	Printed circuit board
PCCC	Parallel concatenated convolutional coder
PCCCH	Physical common control channel
PCCH	Paging channel (logical channel)
PCCPCH	Primary common control physical channel
PCFICH	Physical control format indicator channel
PCH	Paging channel (transport channel)
PCI	Precoding information
PCMCIA	Personal computer memory card international association
PCPCH	Physical common packet channel
PCRF	Policy and Charging Rules Function
PCS	Personal communication systems, 2nd generation cellular systems mainly in Americas, operating partly on IMT-2000 band
PDC	Personal digital cellular, 2nd generation system in Japan
PDCP	Packet data convergence protocol
PDN	Public data network
PDP	Packet data protocol
PDSCH	Physical downlink shared channel
PDU	Protocol data unit
PEP	Performance enhancement proxy
PER	Packed encoding rules
PF	Proportional fair
P-GW	Packet Data Network Gateway
PHY	Physical layer
PI	Page indicator
PIC	Parallel interference cancellation
PICH	Paging indicator channel

PLL	Phase locked loop
PLMN	Public land mobile network
PM	Phase modulation
PNFE	Paging and notification control function entity
POC	Push-to-talk over cellular
PRACH	Physical random access channel
PS	Packet switched
PSC	Physical scrambling code
PSCH	Physical shared channel
PSTN	Public switched telephone network
P-TMSI	Packet-TMSI
PU	Payload unit
PUCCH	Physical uplink control channel
PUSCH	Physical uplink shared channel
PDCCH	Physical downlink control channel
PLCCH	Physical layer common control channel
PSD	Power spectral density
PVC	Pre-defined Virtual Connection
QAM	Quadrature amplitude modulation
QCIF	Quarter common intermediate format
QoS	Quality of service
QPSK	Quadrature phase shift keying
QVGA	Quarter video graphics array
RAB	Radio access bearer
RACH	Random access channel
RAI	Routing area identity
RAN	Radio access network
RANAP	RAN application part
RB	Radio bearer
RF	Radio frequency
RLC	Radio link control
RMC	Reference measurement channel
RN	Relay node
RNC	Radio network controller
RNS	Radio network sub-system
RNSAP	RNS application part
RNTI	Radio network temporary identity
ROHC	Robust header compression
RR	Round robin
RRC	Radio resource control
RRM	Radio resource management
RSS	Really Simple Syndication
RSSI	Received signal strength indicator
RSVP	Resource reservation protocol
RT	Real time
RTCP	Real-time transport control protocol
RTP	Real-time protocol
RTSP	Real-time streaming protocol
RU	Resource unit
RUA	RANAP user adaptation

SAAL-NNI	Signalling ATM adaptation layer for network to network interfaces
SAAL-UNI	Signalling ATM adaptation layer for user to network interfaces
SABP	Service Area Broadcast Protocol
SAE	System architecture evolution
SAIC	Single antenna interference cancellation
SAP	Service access point
SAP	Session announcement protocol
SAS	Stand alone SMLC
SAW	Surface acoustic wave
SCCP	Signalling connection control part
SCCPCH	Secondary common control physical channel
SC-FDMA	Single carrier frequency division multiple access
SCH	Synchronization channel
SCRI	Signaling connection release indication
SCTP	Simple control transmission protocol
SDD	Space division duplex
SDP	Session description protocol
SDQNR	Signal to distortion quantization noise ratio
SDU	Service data unit
SeGW	Sequrity gateway
SEQ	Sequence
SF	Spreading Factor
SFN	System frame number
SFN	Single frequency network
SGSN	Serving GPRS support node
S-GW	Serving Gateway
SHO	Soft handover
SIB	System information block
SIC	Successive interference cancellation
SID	Silence indicator
SINR	Signal-to-noise ratio where noise includes both thermal noise and interference
SIP	Session initiation protocol
SIR	Signal to interference ratio
SM	Session management
SMLC	Serving mobile location centre
SMS	Short message service
SN	Sequence number
SNR	Signal to noise ratio
SoC	System on chip
SON	Self optimized networks
SQ-PIC	Soft quantized parallel interference cancellation
SRB	Signalling radio bearer
SRNC	Serving RNC
SRNS	Serving RNS
SRS	Sounding reference symbol
SS7	Signalling System #7
SSCF	Service specific co-ordination function
SSCOP	Service specific connection oriented protocol
SSDT	Site selection diversity transmission

STD	Switched transmit diversity
STTD	Space time transmit diversity
SVOPC	Sinusoidal voice over packet coder
TCH	Traffic channel
TCP	Transport control protocol
TCTF	Target channel type field
TD/CDMA	Time division CDMA, combined TDMA and CDMA
TDD	Time division duplex
TDMA	Time division multiple access
TD-SCDMA	Time division synchronous CDMA, 1.28 Mcps TDD
TE	Terminal equipment
TF	Transport format
TFCI	Transport format combination indicator
TFCS	Transport format combination set
TFI	Transport format indicator
TFRC	Transport format and resource combination
THP	Traffic handling priority
TM	Transparent mode
TMGI	Temporary mobile group identity
TMSI	Temporary mobile subscriber identity
TPC	Transmission power control
TR	Transparent mode
TS	Technical specification
TSTD	Time switched transmit diversity
TTA	Telecommunications Technology Association (Korea)
TTC	Telecommunication Technology Commission (Japan)
TTI	Transmission time interval
TxAA	Transmit adaptive antennas
UDP	User datagram protocol
UE	User equipment
UL	Uplink
UM	Unacknowledged mode
UMD	Unacknowledged mode data
UMTS	Universal mobile telecommunication services
UpPTS	Uplink pilot time slot
URA	UTRAN registration area
URL	Universal resource locator
U-RNTI	UTRAN RNTI
USB	Universal serial bus
USCH	Uplink shared channel
USIM	UMTS subscriber identity module
US-TDMA	IS-136, one of the 2nd generation systems mainly in USA
UTRA	UMTS Terrestrial radio access (ETSI)
UTRA	Universal Terrestrial radio access (3GPP)
UTRAN	UMTS Terrestrial radio access network
VAD	Voice activation detection
VoIP	Voice over IP
VPN	Virtual private network
WAP	Wireless application protocol

WARC	World administrative radio conference
WCDMA	Wideband CDMA, Code division multiple access
WiMAX	Worldwide interoperability for microwave access
WLL	Wireless local loop
WML	Wireless markup language
WWW	World wide web
XHTML	Extensible hypertext markup language
ZF	Zero forcing