

Mobile Radio Communications

Second Edition

**Second and Third Generation Cellular and WATM
Systems**

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Preface to the Second Edition

Second generation (2G) digital cellular mobile radio systems have taken root in many countries, untethering the telephone and enabling people to conduct conversations away from the home or office and while on the move. The systems are spectrally efficient with the frequency bands assigned by the regulatory bodies being reused repeatedly over countries and even continents. At the time of writing the standardisation of three third generation (3G) systems is also well under way in Europe, the United States and in Japan. This book aims to portray the evolutionary avenue bridging the second and third generation systems.

The fixed networks have also become digital, enabling the introduction of the integrated digital service network (ISDN). No longer are communications to be restricted to voice. Instead a range of services, such as fax, video conferencing and computer data transfer is becoming increasingly available. The second generation digital cellular networks have complex radio links, connecting the mobile users to their base stations. Mobile voice and data communications are supported by elaborate network protocols that support registration and location of mobile users, handovers between base stations as the mobiles roam, call initiation and call clear-down, and so forth. In addition there are management, maintenance, and numerous other functions unseen by the user that combine to facilitate high quality mobile communications. Some of these network issues are considered in the context of the Global System of Mobile (GSM) communications in Chapter 8 and in Wireless Asynchronous Transfer Mode (WATM) systems in Chapter 11, but this book principally addresses the so-called physical layer aspects of mobile communications.

Chapter 1 is a bottom-up approach to cellular radio. Commencing with the propagation environment of a single mobile communicating with a base station, Chapter 1 progresses via multiple access methods, first generation and second generation mobile systems, to cordless telecommunications and concludes with a discussion on the teletraffic aspects of mobile radio systems. The chapter is designed to equip the reader with a range of concepts that will prepare her or him for the more focused in-depth chapters which follow.

Chapter 2 considers mobile radio propagation in a quantitative manner, establishing the background material that is the backbone of mobile radio communications. A prerequisite to digital telephony is the selection of an appropriate speech encoder, converting the analogue speech signal into a

digital format. Chapter 3 provides an in-depth discourse on analysis-by-synthesis codecs.

Having encoded the speech signal, forward error correction coding is applied together with interleaving of the coded speech bits, in order to combat the channel error bursts that occur due to the fading inflicted by the mobile radio channel. Chapter 4 addresses these issues. The interleaved data are transmitted via a suitable modulator over a mobile radio channel to a distant receiver which recovers the data. There are many different methods of modulation but we opted for describing those, which are particularly appropriate for mobile communications. In Chapter 5 we consider quaternary frequency shift keying (QFSK), which was a contending modem for the pan-European cellular network. Chapter 6 deals with a more complex family of modulation schemes, which are known as generalised phase modulation arrangements. In this chapter we consider Viterbi equalisation of wideband dispersive mobile radio channels.

Frequency hopping is an important technique in mobile radio communications, whereby a user's channel hops from one frequency carrier to another in order to avoid being in a deep fade for long periods of time. Chapter 7 is devoted to slow frequency hopping cellular systems, and an estimation of their spectral efficiency is presented. This is followed by a description of the pan-European mobile radio system in Chapter 8, which is now known as the Global System of Mobile communications, or GSM. This chapter guides the reader through the complexities of this mobile radio network, providing an overall system study and amalgamating the system components introduced in the preceding chapters.

Since the standardisation of the second generation systems, such as GSM, a decade has elapsed and the wireless community has been working towards the third generation of mobile systems. There have also been important evolutionary developments on the 2G scene, such as the definition of the half-rate Japanese Personal Digital Cellular (PDC) system's speech codec and that of the GSM half-rate speech-coding standard, the introduction of a new breed of enhanced full-rate speech codecs and the spread of advanced data, fax and email services. Further important developments have taken place in the area of high-speed wireless local area networks. Motivated by these trends and a range of other new developments in the field, **this second edition incorporates three new chapters.**

Chapter 9 presents a range of multimedia system components, which have the potential to provide attractive enhanced services in the context of both the existing 2G and the forthcoming 3G systems. Specifically, various video codecs and handwriting codecs are described, in order to support wireless video telephony and electronic 'white-board' services. Chapter 9 also provides an overview of the recent activities in the field of multi-level modulation schemes, which can be advantageously invoked in so-called intelligent multi-mode transceivers that are capable of re-configuring themselves on a burst-by-burst basis, supporting more robust transmissions in

hostile propagation environments while transmitting an increased number of bits per symbol in benign propagation scenarios.

Chapter 10 provides an overview of the recently proposed 3G wide-band Code Division Multiple Access (W-CDMA) standards. The systems considered are the so-called 'Intelligent Mobile Telecommunications in the year 2000' (IMT-2000), the 'Universal Mobile Telecommunications System' (UMTS) scheme and the pan-American cdma2000 arrangement. Despite the call for a common global standard, there are some differences in the proposed technologies, notably the chip rates and inter-cell operation. These differences are partly due to the 2G infrastructure already in use all over the world, specifically the GSM and the IS-95 systems; an issue elaborated in Chapter 10.

Our final chapter is rather different from the others in that it is concerned with network issues related to wireless asynchronous transfer mode (WATM) networks. With the aid of a WATM simulator numerous scenarios for the transport of multimedia traffic over cellular networks are addressed. The results verify the effectiveness of the WATM concept, successfully mixing real-time, non-real-time, constant bit rate, and variable bit rate services. A number of network control enhancements have been suggested. The simulations confirm that the medium access control protocols, data link control protocols, and network management schemes must be dynamic and intelligent, and should take into account the instantaneous traffic loading on each BS and in the surrounding network. Intelligent handover and call admission schemes can provide vast improvements in the Quality of Service (QoS). The rapid re-assignment of capacity over a wide area would be beneficial. It must be emphasised that, given current bandwidth availabilities, satisfying the QoS expected in the fixed ATM network is economically impractical in wireless networks. Therefore, acceptable mobile service grades should be defined, or the available radio spectrum increased.

To our original text dealing with many of the fundamentals of the physical aspects of mobile communications, we have added new chapters dealing with the exciting subjects of multimedia mobile communications, the proposed 3G CDMA systems, and WATM. It is our hope that you will find this second edition comprehensive, technically challenging, valuable and above all, enjoyable.

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Bibliography

- [1] **J. Rapeli**, "UMTS: Targets, System Concept, and Standardization in a Global Framework," *IEEE Personal Communications*, vol. 2, no. 1, pp. 20–28, February 1995.
- [2] **M.H. Callendar**, "Future Public Land Mobile Telecommunication Systems," *IEEE Personal Communications*, vol. 12, no. 4, pp. 18–22, 1994.
- [3] **A.J. Viterbi**, *CDMA-Principles of Spread Spectrum Communication*, Addison Wesley, 1995.
- [4] **S.G. Glisic** and **B. Vucetic**, *Spread Spectrum CDMA Systems for Wireless Communications*, Artech House Publishers, 1997.
- [5] **R. Prasad**, *CDMA for Wireless Personal Communications*, Artech House, 1996.
- [6] **T. Ojanperä** and **R. Prasad**, *Wideband CDMA for Third Generation Mobile Communications*, Artech House, 1998.
- [7] **A. Toskala**, **J.P. Castro**, **E. Dahlman**, **Matti Latva-aho**, and **Tero Ojanperä**, "FRAMES FMA2 Wideband-CDMA for UMTS," *European Transactions on Telecommunications*, vol. 9, no. 4, pp. 325–336, July-August 1998.
- [8] **E. Dahlman**, **B. Gudmundson**, **M. Nilsson**, and **Johan Sköld**, "UMTS/IMT-2000 Based on Wideband CDMA," *IEEE Communications Magazine*, vol. 36, no. 9, pp. 70–80, September 1998.
- [9] **T. Ojanperä**, "Overview of Research Activities for Third Generation Mobile Communication," in *Wireless Communications TDMA versus CDMA*, Savo G. Glisic and Pentti A. Leppänen, Eds., pp. 415–446. Kluwer Academic Publishers, 1997.
- [10] **ETSI/SMG/SMG2**, "The ETSI UMTS Terrestrial Radio Access (UTRA) ITU-R RTT Candidate Submission," Tech. Rep., European Telecommunications Standards Institute, June 1998.
- [11] **ARIB**, "Japan's Proposal for Candidate Radio Transmission Technology on IMT-2000 : W-CDMA," Tech. Rep., Association of Radio Industries and Businesses, June 1998.

- [12] **F. Adachi, M. Sawahashi, and H. Suda**, "Wideband DS-CDMA for Next-generation Mobile Communications Systems," *IEEE Communications Magazine*, vol. 36, no. 9, pp. 56–69, September 1998.
- [13] **F. Adachi and M. Sawahashi**, "Wideband Wireless Access Based on DS-CDMA," *IEICE Transactions on Communications*, vol. E81-B, no. 7, pp. 1305–1316, July 1998.
- [14] **A. Sasaki**, "Current Situation of IMT-2000 Radio Transmission Technology Study in Japan," *IEICE Transactions on Communications*, vol. E81-B, no. 7, pp. 1299–1304, July 1998.
- [15] **P.-G. Andermo and L.-M. Ewerbring**, "A CDMA-Based Radio Access Design for UMTS," *IEEE Personal Communications*, vol. 2, no. 1, pp. 48–53, February 1995.
- [16] **P.W. Baier, P. Jung, and A. Klein**, "Taking the Challenge of Multiple Access for Third-Generation Cellular Mobile Radio Systems - A European View," *IEEE Communications Magazine*, vol. 34, no. 2, pp. 82–89, February 1996.
- [17] **E. Berruto, M. Gudmundson, R. Menolascino, W. Mohr, and M. Pizarroso**, "Research Activities on UMTS Radio Interface, Network Architectures, and Planning," *IEEE Communications Magazine*, vol. 36, no. 2, pp. 82–95, February 1998.
- [18] **T. Ojanperä and R. Prasad**, "An Overview of Air Interface Multiple Access for IMT-2000/UMTS," *IEEE Communications Magazine*, vol. 36, no. 9, pp. 82–95, September 1998.
- [19] **A. Baier, U.-C. Fiebig, W. Granzow, Wolfgang Koch, Paul Teder, and Jörn Thielecke**, "Design Study for a CDMA-Based Third-Generation Mobile System," *IEEE Journal on Selected Areas in Communications*, vol. 12, no. 4, pp. 733–743, May 1994.
- [20] **J. Schwarz da Silva, Bernard Barani, and Bartolomé Arroyo-Fernández**, "European Mobile Communications on the Move," *IEEE Communications Magazine*, vol. 34, no. 2, pp. 60–69, February 1996.
- [21] **E. Nikula, A. Toskala, E. Dahlman, Laurent Girard, and Anja Klein**, "FRAMES Multiple Access for UMTS and IMT-2000," *IEEE Personal Communications*, vol. 5, no. 2, pp. 16–24, April 1998.
- [22] **F. Ovesjö, E. Dahlman, T. Ojanperä, Antti Toskala, and Anja Klein**, "FRAMES Multiple Access Mode 2 - Wideband CDMA," in *IEEE International Conference on Personal, Indoor and Mobile Radio Communication*, Helsinki, Finland, pp. 42–46, September 1997, PIMRC'97.
- [23] **E. L. Kuan, C. H. Wong and L. Hanzo**, "Burst-by-burst Adaptive Joint Detection CDMA," *to appear in Proc. of VTC'99*, Houston, USA, May, 1999.
- [24] **E. L. Kuan, C. H. Wong and L. Hanzo**, "Upper-bound Performance of Burst-by-burst Adaptive Joint Detection CDMA," *submitted to IEEE Communications Letters*, 1998.
- [25] **F. Adachi, K. Ohno, A. Higashi, Tomohiro Dohi, and Yukihiro Okumura**, "Coherent multicode DS-CDMA mobile Radio Access," *IEICE Transactions on Communications*, vol. E79-B, no. 9, pp. 1316–1324, September 1996.

- [26] **J.G. Proakis**, *Digital Communications*, McGraw-Hill, 1995.
- [27] **M. O. Sunay, Z. -C. Honkasalo, A. Hottinen, H. Honkasalo and L. Ma**, "A Dynamic Channel Allocation Based TDD DS CDMA Residential Indoor System," *IEEE 6th International Conference on Universal Personal Communications, ICUPC'97*, San Diego, pp. 228–234, October 1997.
- [28] **A. Fujiwara, H. Suda, and F. Adachi**, "Turbo Codes Application to DS-CDMA Mobile Radio," *IEICE Transactions on Communications*, vol. E81A, no. 11, pp. 2269–2273, November 1998.
- [29] **M. J. Juntti**, "System Concept Comparison for Multirate CDMA with Multiuser Detection," in *Proceedings of the IEEE Vehicular Technology Conference*, Ottawa, Canada, May 1998, pp. 18–21.
- [30] **S. Ramakrishna and J. M. Holtzman**, "A Comparison between Single Code and Multiple Code Transmission Schemes in a CDMA System," in *Proceedings of the IEEE Vehicular Technology Conference*, Ottawa, Canada, May 1998, pp. 791–795.
- [31] **M. B. Pursley**, "Performance Evaluation for Phase-Coded Spread-Spectrum Multiple-Access Communication-Part I: System Analysis," *IEEE Transactions on Communications*, vol. COM-25, no. 8, pp. 795–799, August 1977.
- [32] **F. Adachi, M. Sawahashi, and K. Okawa**, "Tree-structured Generation of Orthogonal Spreading Codes with Different Lengths for Forward Link of DS-CDMA Mobile Radio," *Electronic Letters*, vol. 33, no. 1, pp. 27–28, January 1997.
- [33] **R. F. Ormondroyd and J. J. Maxey**, "Performance of Low Rate Orthogonal Convolutional Codes in DS-CDMA," *IEEE Transactions on Vehicular Technology*, vol. 46, no. 2, pp. 320–328, May 1997.
- [34] **M. K. Simon, J. K. Omura, R. A. Scholtz and B. K. Levitt**, "Spread Spectrum Communications Handbook," McGraw-Hill, 1994.
- [35] **T. Kasami**, "Combinatorial Mathematics and its Applications," University of North Carolina Press, 1969.
- [36] **E. L. Kuan and L. Hanzo**, "Joint Detection CDMA Techniques for Third-generation Transceivers," *Proceedings of ACTS'98*, Rhodes, Greece, June 1998, pp. 727–732.
- [37] **A. Chockalingam, Paul Dietrich, Laurence B. Milstein, and Ramesh R. Rao**, "Performance of Closed-Loop Power Control in DS-CDMA Cellular Systems," *IEEE Transactions on Vehicular Technology*, vol. 47, no. 3, pp. 774–789, August 1998.
- [38] **K Higuchi, M Sawahashi, and F Adachi**, "Fast Cell Search Algorithm in DS-CDMA Mobile Radio using Long Spreading Codes," in *Proceedings of the IEEE Vehicular Technology Conference*, Phoenix, U.S.A., May 1997, vol. 3, pp. 1430–1434.
- [39] **R. R. Gejji**, "Forward-Link-Power Control in CDMA Cellular-Systems," *IEEE Transactions on Vehicular Technology*, vol. 41, no. 4, pp. 532–536, November 1992.
- [40] **W.C.Y. Lee**, "Overview of Cellular CDMA," *IEEE Transactions on Vehicular Technology*, vol. 40, no. 2, pp. 291–302, May 1991.

- [41] **D. Wong** and **T. J. Lim**, "Soft Handoffs in CDMA Mobile Systems," *IEEE Personal Communications*, vol. 4, no. 6, pp. 6–17, December 1997.
- [42] **C. C. Lee** and **R. Steele**, "Effects of Soft and Softer Handoffs on CDMA System Capacity," *IEEE Transactions on Vehicular Technology*, vol. 47, no. 3, pp. 830–841, August 1998.
- [43] **M Gustafsson**, **K Jamal**, and **E Dahlman**, "Compressed Mode Techniques for Inter-frequency measurements in a wide-band DS-CDMA system," in *IEEE International Conference on Personal, Indoor and Mobile Radio Communication*, Helsinki, Finland, September 1997, PIMRC'97, pp. 231–235.
- [44] **D.N. Knisely**, **S. Kumar**, **S. Laha**, and **S. Nanda**, "Evolution of Wireless Data Services : IS-95 to cdma2000," *IEEE Communications Magazine*, vol. 36, no. 10, pp. 140–149, October 1998.
- [45] **TIA**, "The cdma2000 ITU-R RTT Candidate Submission," Tech. Rep., Telecommunications Industry Association, 1998.
- [46] **D. N. Knisely**, **Q. Li**, and **N. S. Rames**, "cdma2000 : A Third Generation Radio Transmission Technology," *Bell Labs Technical Journal*, vol. 3, no. 3, pp. 63–78, July-September 1998.
- [47] **Y. Okumura** and **F. Adachi**, "Variable-Rate Data Transmission with Blind Rate Detection for Coherent DS-CDMA Mobile Radio," *IEICE Transactions on Communications*, vol. E81B, no. 7, pp. 1365–1373, July 1998.
- [48] **J. C. Liberti, Jr.** and **T. S. Rappaport**, "Analytical Results for Capacity Improvements in CDMA," *IEEE Transactions on Vehicular Technology*, vol. 43, no. 3, pp. 680–690, August 1994.
- [49] **J. H. Winters**, "Smart Antennas for Wireless Systems," *IEEE Personal Communications*, vol. 5, no. 1, pp. 23–27, February 1998.
- [50] **S. Verdu**, "Minimum Probability of Error for Asynchronous Gaussian Multiple-Access Channel," *IEEE Transactions on Communications*, vol. 32, no. 1, pp. 85–96, January 1986.
- [51] **S. Moshavi**, "Multi-User Detection for DS-CDMA Communications," *IEEE Communications Magazine*, vol. 34, no. 10, pp. 124–136, October 1996.
- [52] **T. J. Lim** and **L. K. Rasmussen**, "Adaptive Symbol and Parameter Estimation in Asynchronous Multiuser CDMA Detectors," *IEEE Transactions on Communications*, vol. 45, no. 2, pp. 213–220, February 1997.
- [53] **T. J. Lim** and **S. Roy**, "Adaptive Filters in Multiuser (MU) CDMA Detection," *Wireless Networks*, vol. 4, no. 4, pp. 307–318, June 1998.
- [54] **L. Wei**, **L. K. Rasmussen** and **R. Wyrwas**, "Near Optimum Tree-search Detection Schemes for Bit-synchronous Multiuser CDMA Systems over Gaussian and Two-path Rayleigh Fading Channels," *IEEE Transactions on Communications*, vol. 45, no. 6, pp. 691–700, June 1997.
- [55] **T. J. Lim** and **M. H. Ho**, "LMS-Based Simplifications to the Kalman Filter Multiuser CDMA Detector," *Proceedings of IEEE Asia-Pacific Conference on Communications/International Conference on Communication Systems*, Singapore, November, 1998.

- [56] **D. You** and **T. J. Lim**, "A Modified Blind Adaptive Multiuser CDMA Detector," *Proceedings of IEEE International Symposium on Spread Spectrum Techniques and Application*, Sun City, South Africa, pp. 878–882, September 1998.
- [57] **S. M. Sun**, **L. K. Rasmussen**, **T. J. Lim** and **H. Sugimoto**, "Impact of Estimation Errors on Multiuser Detection in CDMA," *Proceedings of IEEE Vehicular Technology Conference*, Ottawa, Canada, pp. 1844–1848, May 1998.
- [58] **Y. Sanada** and **Q. Wang**, "A Co-Channel Interference Cancellation Technique Using Orthogonal Convolutional Codes on Multipath Rayleigh Fading Channel," *IEEE Transactions on Vehicular Technology*, vol. 46, no. 1, pp. 114–128, February 1997.
- [59] **M.K. Varanasi** and **B. Aazhang**, "Multistage Detection in Asynchronous Code-Division Multiple-Access Communications," *IEEE Transactions on Communications*, vol. 38, no. 4, pp. 509–519, April 1990.
- [60] **P. Patel** and **J. Holtzman**, "Analysis of a Simple Successive Interference Cancellation Scheme in a DS/CDMA System," *IEEE Journal on Selected Areas in Communications*, vol. 12, no. 5, pp. 796–807, June 1994.
- [61] **P. H. Tan** and **L. K. Rasmussen**, "Subtractive Interference Cancellation for DS-CDMA Systems," *Proceedings of IEEE Asia-Pacific Conference on Communications/International Conference on Communication Systems*, Singapore, November, 1998.
- [62] **K. L. Cheah**, **H. Sugimoto**, **T. J. Lim**, **L. K. Rasmussen** and **S. M. Sun**, "Performance of Hybrid Interference Canceller with Zero-Delay Channel Estimation for CDMA," *Proceedings of IEEE Global Communications Conference '98*, Australia, pp. 265–270, November 1998.
- [63] **S. M. Sun**, **L. K. Rasmussen** and **T.J. Lim**, "A Matrix-Algebraic Approach to Hybrid Interference Cancellation in CDMA," *Proceedings of IEEE International Conference on Universal Personal Communications '98*, Florence, Italy, pp. 1319–1323, October 1998.
- [64] **A. L. Johansson** and **L. K. Rasmussen**, "Linear Group-wise Successive Interference Cancellation in CDMA," *Proceedings of IEEE International Symposium on Spread Spectrum Techniques and Application*, Sun City, South Africa, pp. 121–126, September 1998.
- [65] **S. M. Sun**, **L. K. Rasmussen**, **H. Sugimoto** and **T. J. Lim**, "A Hybrid Interference Canceller in CDMA," *Proceedings of IEEE International Symposium on Spread Spectrum Techniques and Application*, Sun City, South Africa, pp. 150–154, September 1998.
- [66] **D. Guo**, **L. K. Rasmussen**, **S. M. Sun**, **T. J. Lim** and **C. Cheah**, "MMSE-Based Linear Parallel Interference Cancellation in CDMA," *Proceedings of IEEE International Symposium on Spread Spectrum Techniques and Application*, Sun City, South Africa, pp. 917–921, September 1998.
- [67] **L. K. Rasmussen**, **D. Guo**, **Y. Ma** and **T. J. Lim**, "Aspects on Linear Parallel Interference Cancellation in CDMA," *Proceedings of IEEE International Symposium on Information Theory '98*, Cambridge, US, pp. 37, August 1998.
- [68] **L. K. Rasmussen**, **T. J. Lim**, **H. Sugimoto** and **T. Oyama**, "Mapping Functions for Successive Interference Cancellation in CDMA," *Proceedings*

- of *IEEE Vehicular Technology Conference*, Ottawa, Canada, pp. 2301–2305, May 1998.
- [69] **S. M. Sun, T. J. Lim, L. K. Rasmussen, T. Oyama, H. Sugimoto** and **Y. Matsumoto**, “Performance Comparison of Multi-stage SIC and Limited Tree-Search Detection in CDMA,” *Proceedings of IEEE Vehicular Technology Conference*, Ottawa, Canada, pp. 1854–1858, May 1998.
- [70] **Mamoru Sawahashi, Yoshinori Miki, Hidehiro Andoh,** and **Kenichi Higuchi**, “Pilot Symbol-Assisted Coherent Multistage Interference Canceller Using Recursive Channel Estimation for DS-CDMA Mobile Radio,” *IEICE Transactions on Communications*, vol. E79-B, no. 9, pp. 1262–1269, September 1996.
- [71] **A. Wittneben** and **T. Kaltenschnee**, “TX Selection Diversity with Prediction: Systematic Nonadaptive Predictor Design,” *IEEE 44th Vehicular Technology Conference, 1994*, pp. 1246–1250, June 1994.
- [72] **A. Hottinen** and **R. Wichman**, “Transmit Diversity by Antenna Selection in CDMA Downlink,” in *Proceedings of ISSSTA'98*, Sun City, South Africa, September 1998.

Glossary

2G	Second Generation
3G	Third Generation
ACL	Auto Correlation
ACTS	Advanced Communications Technology and Services
ARIB	Association of Radio Industries and Businesses
AWGN	Additive White Gaussian Noise
BCCH	Broadcast Control Channel
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BS	Base Station
CAPICH	Common Auxiliary Pilot Channel
CCCH	Common Control Channel
CCL	Cross Correlation
CDMA	Code Division Multiple Access
CPHCH	Common Physical Channel
CRC	Cyclic Redundancy Check
DAPICH	Dedicated Auxiliary Pilot Channel
DCCH	Dedicated Control Channel
DCH	Dedicated Channel
DECT	Digital Enhanced Cordless Telecommunications
DL	Downlink
DPCCH	Dedicated Physical Control Channel
DPDCH	Dedicated Physical Data Channel
DPHCH	Dedicated Physical Channel
DS-CDMA	Direct Sequence Code Division Multiple Access
EMC	Electromagnetic Compatibility

ETSI	European Telecommunications Standards Institute
EU	European Union
FACH	Forward Access Channel
FCCH	Frequency Correction Channel
FCH	Fundamental Channel
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FPLMTS	Future Public Land Mobile Telecommunication System
FRAMES	Future Radio Wideband Multiple Access System
GPS	Global Positioning System
HCS	Hierarchical Cell Structure
IMT-2000	International Mobile Telecommunications 2000
ISO/OSI	International Standardization Organization/Open Systems Interconnection
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union - Radio-communication Sector
MAI	Multiple Access Interference
MC	Multicarrier
MDM	Modulation Division Multiplexing
MPG	Multiple Processing Gain
MS	Mobile Station
OCQPSK	Orthogonal Complex Quadrature Phase Shift Keying
OVSF	Orthogonal Variable Spreading Factor
PCCPCH	Primary Common Control Physical Channel
PCH	Paging Channel
PCS	Personal Communications Services
PHCH	Physical Channel
PHS	Personal Handyphone System
PICH	Pilot Channel
PN	Pseudo Noise
PRMA	Packet Reservation Multiple Access
PSC	Primary Synchronization Code
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying

RACE	Research in Advanced Communication Equipment
RACH	Random Access Channel
RI	Rate Information
RS	Reed-Solomon
RTT	Radio Transmission Technology
SCCPCH	Secondary Common Control Physical Channel
SCH	Synchronisation Channel
SF	Spreading Factor
SIR	Signal-to-Interference Ratio
SSC	Secondary Synchronization Code
SYCH	Sync Channel
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TFI	Transport Format Indicator
TIA	Telecommunications Industry Association
TPC	Transmit Power Control
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UTRA	Universal Mobile Telecommunications System Terrestrial Radio Access
VoD	Video on Demand
W-CDMA	Wideband Code Division Multiple Access
WARC	World Administrative Radio Conference

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