Mobile Radio Communications

Second Edition

Second and Third Generation Cellular and WATM Systems

Edited and co-authored by

Raymond Steele and Lajos Hanzo

Contents

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 wideband 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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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 - Radiocommunication 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

Index

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

Z

Author Index

C

D

E

F

G

H

L

M

N

O

P

Q

R

S

T

U

V

W

X

Y

Z