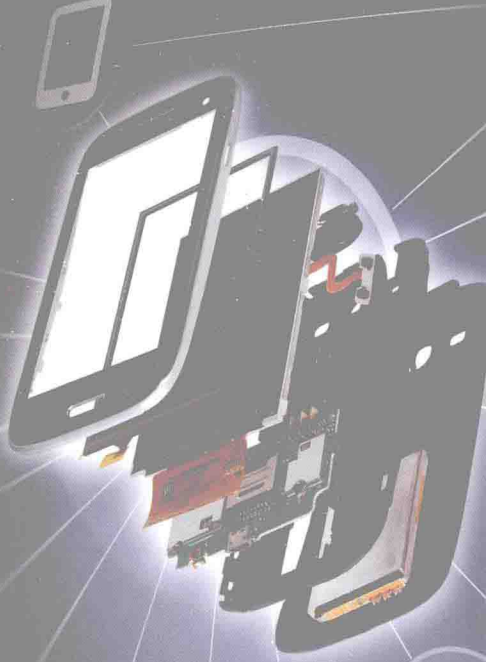
Sajal Kumar Das



MOBILE TERMINAL RECEIVER DESIGN

LTE and LTE-Advanced

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MOBILE TERMINAL RECEIVER DESIGN
LTE AND LTE-ADVANCED

Sajal Kumar Das
ERICSSON, Bangalore, India

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MOBILE TERMINAL RECEIVER DESIGN

Preface

Mobile systems have evolved over several generations, from 1G to 4G and beyond, due to an ongoing demand for higher data rates, for better quality, for more complex applications, and for seamless intersystems handover and lower latency. As a result, the mobile phone has changed from a simple telephone to a complex smartphone. Today, a smartphone encapsulates computing capabilities with cellular network access functionality in a single integrated system, with high-quality graphics, a portable size, support for complex user applications, and multimode connectivity features. The demand for supporting various complex applications, new applications, smaller form factors, lower power consumption, and multi-RAT support, has meant that the challenges in mobile phone design have been manifold. In particular, new challenges have arisen in the design of innovative mobile handset solutions, which can offer smaller sizes, low power consumption, low cost, and tremendous flexibility, while supporting more advanced features and providing an improved data rate and higher performance.

This book has been written to address these challenges. Its aim has been to equip mobile phone system designers and students with an all-in-one guide, starting from basic concepts and progressing to advanced system design, and introducing readers to various innovative solutions. It walks readers through 2G, 3G, and 4G mobile-phone system architectures and their basic building blocks, the different air-interface standards, operating principles, hardware anatomy, software and protocols, internal modules, components, and circuits for legacy and next-generation smartphones, including various research areas in 4G and 5G systems.

Mobile Terminal Receiver Design explains basic working principles, system architecture, and specification details of legacy and next-generation mobile systems. It covers in detail RF transmitter and receiver blocks, digital baseband processing blocks, receiver and transmitter signal processing, protocol stacks, AGC, AFC, ATC, the power supply, clocking, connectivity modules, and application modules with different design solutions for exploring

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various tradeoffs. It also explains the internal blocks, hardware and software components, and anatomy of legacy and LTE/LTE-Advanced smartphones, from principle to practice to product. Multi-RAT design requirements are also discussed, together with key design attributes such as low power consumption, slim form factors, seamless I-RAT handover, sensitivity, and selectivity.

This book is based on my experiences as a design engineer in the field of wireless and mobile communications and modelled from an academic course developed for electronics communication engineering students, and from a useful design handbook for practicing engineers and technicians. It is intended to help software, hardware and RF design engineers, researchers, product managers, as well as industry veterans in the areas of mobile phone system and chipset design to understand the evolution of radio access technologies and emergent trends, and also to help them make innovative and competitive next-generation mobile devices.

I express my sincere thanks to my colleagues, friends and family members for their valuable suggestions. Any constructive criticisms and suggestions for improving the book will be gratefully received and should be sent to sajal_das@yahoo.com.

Dr Sajal Kumar Das

Abbreviations

3GPP – Third-Generation Partnership Project
ACK – acknowledgment (in ARQ protocols)
ADC – analog to digital converter
AM – amplitude modulation
AMPS – advanced mobile phone service
AMR – adaptive multirate (speech codec)
APN – access point name
ARQ – automatic repeat request
AWGN – additive white Gaussian noise
BCCH – broadcast control channel
BCH – broadcast channel
BER – bit error rate
CDMA – code division multiple access
CFO – carrier frequency offset
CMOS – complementary metal oxide semiconductor
CN – core network
CPC – continuous packet connectivity
CQI – channel quality indicator
CRC – cyclic redundancy check
CS – circuit switched
DCCH – dedicated control channel
DECT – digital European cordless telephone
DFE – digital front end
DigRF – digital RF interface standard
DL – downlink
DL-SCH – downlink shared channel
DPCCH – dedicated physical control channel

DRX – discontinuous reception
DS-CDMA – direct sequence code division multiple access
DSP – digital signal processor
DTCH – dedicated traffic channel
DTX – discontinuous transmission
DwPTS – downlink pilot time slot
EDGE – enhanced data rates for GSM evolution
eNB – E-UTRAN Node B
EPC – evolved packet core
EPS – evolved packet system
ETACS – extended total access communication system
EUTRA – evolved universal terrestrial radio access
E-UTRAN – evolved UTRAN
FCC – Federal Communication Commission
FDD – frequency division duplex
FDMA – frequency division multiple access
FEC – forward error correction
FER – frame error rate
FFT – fast Fourier transform
FTP – file transfer protocol
GaAS – gallium arsenide
GERAN – GSM EDGE radio access network
GP – guard period
GPRS – general packet radio services
GSM – Global System for Mobile Communications
GSM-EFR – GSM enhanced full rate
HARQ – hybrid ARQ
HSDPA – high-speed downlink packet access
HSPA – high-speed packet access
HSUPA – high-speed uplink packet access
ICI – intercarrier interference
IFFT – inverse FFT
IMT – International Mobile Telecommunication
IP – Internet protocol
LTE – Long-Term Evolution
MAC – medium access control
MBMS – multimedia broadcast and multicast service
MCH – multicast channel
MCS – modulation and coding scheme
MIMO – multiple input multiple output
MTCH – MBMS traffic channel
NACK – negative acknowledgment (in ARQ protocols)

NAS – nonaccess stratum
OFDM – orthogonal frequency division multiplexing
OFDMA – orthogonal frequency division multiple access
PAPR – peak-to-average power ratio
PBCH – physical broadcast channel
PCCH – paging control channel
PCFICH – physical control format indicator channel
PCS – personal communication standard
PDC – personal digital cellular
PDCP – packet data convergence protocol
PDCCH – physical downlink control channel
PDC-EFR – PDC-enhanced full rate
PDCP – packet-data convergence protocol
PDSCH – physical downlink share channel
PDN – packet data network
P-GW – packet data network gateway
PHICH – physical hybrid ARQ indicator channel
PMCH – physical multicast channel
PMI – precoding matrix indicator
POCSAG – Post Office Code Standard Advisory Group
PRB – physical resource block
PSHO – packet switched handover
P-SS – primary synchronization signal
PUSCH – physical uplink shared channel
QAM – quadrature amplitude modulation
QoS – quality of service
QPSK – quadrature phase-shift keying
RB – radio bearer
RB – resource block
RF – radio frequency
RF-BB – radio frequency and baseband module
RL – radio link
RLC – radio link control
ROHC – robust header compression
RRC – radio resource control
RS – reference signal
RTT – radio transmission technology
RV – redundancy version
SAE – system architecture evolution
SC-FDMA – single carrier frequency division multiple access
SCTP/IP – stream control transmission protocol/IP
SMS – short message service

SR – scheduling request
SRB – signal radio bearer
S-SS – secondary synchronization signal
TDD – time division duplex
TDMA – time division multiple access
TDMA-EFR – TDMA enhanced full rate
TE – transverse electric
TEM – transverse electromagnetic
TM – transverse magnetic
TR – technical release
TTI – transmission time interval
UE – user equipment
UL – uplink
UL-SCH – uplink shared channel
UMTS – universal mobile telecommunications system
UTRA – universal terrestrial radio access
UTRAN – universal terrestrial radio access network
VoIP – voice over IP
WDT – watchdog timer

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1

Introduction to Mobile Terminals

1.1 Introduction to Mobile Terminals

A mobile communication device is a small, portable electronic device, with wireless communication capabilities, which is easy to carry around. There are several types of mobile communication devices, like cell phones or mobile phones, WLAN devices, and GPS navigation devices, but it is the mobile phone that has adopted the term "mobile device," and gradually its purpose has shifted from a verbal communication tool to a multimedia tool.

A mobile phone, which is also known as mobile terminal (MT), cellular phone, cell phone, hand phone, or simply a phone, is a device that can send and receive telephone calls over a radio link while being connected to a cellular base station operated by a cellular network operator. It provides user mobility around a wide geographic area. A feature phone is a low-end mobile phone with limited capabilities and it provides mainly voice calling, text messaging, multimedia, and Internet functionality. In addition to telephone calls, modern multifunctional mobile phones with more computing capabilities, which support a wide variety of other applications and services like SMS, MMS, e-mails, Internet, Web browsing, news, gaming, playing music, movies, calendar management, contact, video, photography, short-range connectivity, location-specific information, WLAN connectivity, and GPS connectivity, are considered as smartphones. Smartphones offer all these services in single device, so they are becoming increasingly important as work tools for users who rely on these services. Today, they have become universal replacements for personal digital assistant (PDA) devices. Typically, a smartphone incorporates handheld computer functionalities along with the communication capabilities of a cell phone by providing support

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