***Cellular Radio
Principles and Design***

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Cellular Radio

Principles and Design

R. C. V. Macario

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Second Edition

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Preface to the Second Edition

This book is designed to appeal to any student of the technology and operation of cellular radio, whether at advanced undergraduate or postgraduate level, or undertaking a further training course, or at practitioner level. It is assumed that the reader has a basic knowledge of electronic engineering, together with some experience in quantitative evaluation. The aims are to provide such readers with an understanding and appreciation of one of the fastest growing socially apparent artifacts in engineering today.

It has been said that there are some 30,000 subscribers being added to digital cellular networks alone every day. An operator who would have had to instal, say, a few hundred base stations for a national analog network, is now looking at having to instal a thousand and more base stations for *partial* national digital cellular coverage. The diagram below illustrates the dilemma of the author. The first edition was started at the zero digital projection point; at the time of writing one appears to be at the maximum of a take-off phase.

UK Digital Growth Projections

By having an annotated map of the world beside his desk the author can keep in view the reality of the various world cellular systems. The book is therefore carefully balanced to give equal weight to all systems; for example, AMPS/D-AMPS in the Americas, GSM/DCS 1800 in other parts of the world.

The material included is drawn from experience gained in teaching courses on cellular communications to various classes, over many years, as well as from

practical experience in designing, evaluating and operating cellular and other equipment.

Having spent much of his career in the field of radio communication, the author readily acknowledges the contribution made over the years to his teaching and research by data and information disseminated through seminars and similar events, especially those held by the leading manufacturers of test equipment, for the design and evaluation of radio equipment and cellular. In particular, he wishes to acknowledge the Hewlett Packard Company, Marconi Instruments Ltd and Rohde & Schwarz UK Ltd.

The writer has also had the advantage of being conversant with all the major UK operators, i.e. Cellnet, One-2-One, Orange and Vodafone, as well as the internationally renowned infrastructure and handset suppliers. He trusts that he has kept good faith with all concerned.

Once again I wish to thank Angela McGairl of the Engineering Faculty of the University of Wales, Swansea for preparing the drawings; Ruth Baker for preparing the text; and Malcolm Stewart of the Macmillan Press for his help and encouragement. I am also grateful to my family for accepting that the book took precedence at home and at weekends for a long time. I am especially grateful to my wife, Margaret, for her continual support and encouragement

R.C.V. Macario

Abbreviations and Acronyms Associated with Cellular Radio

A	<i>An interface</i>
A3, A5	<i>Cipher codes</i>
AB	<i>Access Burst</i>
ACCH	<i>Associated Control Channel</i>
ACS	<i>Adjacent Channel/Carrier Suppression</i>
ACI	<i>Adjacent Channel Interference</i>
ACU	<i>Antenna Combination Unit</i>
ADC	<i>American Digital Cellular</i>
ADM	<i>Adaptive Delta Modulation</i>
ADPCM	<i>Adaptive PCM</i>
AFC	<i>Automatic Frequency Control</i>
AGC	<i>Automatic Gain Control</i>
AGCH	<i>Access Grant Channel</i>
AGWN	<i>Additive White Guassian Noise</i>
AI	<i>Area Identification (field)</i>
AMPS	<i>Automatic Mobile Phone Service (USA)</i>
APC	<i>Airborne Public Correspondence</i>
ARFCH	<i>Absolute Radio Frequency Channel</i>
ARQ	<i>Automatic Request for Re-transmission</i>
ATM	<i>Asynchronous Transfer Mode</i>
AUC	<i>Authentication Centre</i>
Au	<i>Authentication</i>
BCC	<i>Base (station) Colour Code</i>
BCCH	<i>Broadcast Control Channel</i>
BCH	<i>Broadcast Channel</i>
BCH	<i>Bose-Chaudhuri-Hocquenghem code</i>
BER	<i>Bit Error Rate</i>
B_m	<i>Traffic channel for full-rate voice coder (ISDN terminology for mobile service)</i>
BP	<i>Bit periods</i>
BS	<i>Base Station</i>
BSC	<i>Base Station Controller</i>
BSCU	<i>Base Station Controller Unit</i>
BSI	<i>Base Station Interface</i>

BSIC	<i>Base Station Identity Code</i>
BSS	<i>Base Station System</i>
BSSAP	<i>Base Station Application Part</i>
BTS	<i>Base Transceiver Station</i>
CA	<i>Cell Allocation</i>
CA-CN	<i>Cell Allocation RF Channel Number</i>
CBCCH	<i>Cell Broadcast Channel</i>
CC	<i>Country Code</i>
CCCH	<i>Common Control Channel</i>
CCIR	<i>Consultative Committee for International Radiocommunications</i>
CDMA	<i>Code Division Multiple Access</i>
CDVCC	<i>Coded Digital Verificaiton Colour Code</i>
CELP	<i>Code Excited Linear Predictor</i>
CFEK	<i>Coherent Frequency Shift Keying</i>
CGI	<i>Cell Global Identity</i>
CCITT	<i>International Telegraph and Telephone Consultative Committee</i>
CI	<i>Cell Identity</i>
CPA	<i>Combined Paging Access (field)</i>
CPFSK	<i>Continuous Phase Frequency Shift Keying</i>
CRC	<i>Cyclic Redundancy Check</i>
CSPDN	<i>Circuit Switched Public Data Network</i>
CU	<i>Central Unit (of a MS)</i>
C/I	<i>Carrier-to-Interference Ratio</i>
D	<i>Downlink</i>
D/A	<i>Digital to Analog</i>
DB	<i>Dummy Burst</i>
DCC	<i>Digital Colour Code</i>
DCS	<i>Digital Cellular System</i>
DCF	<i>Data Communication Function</i>
DCCH	<i>Dedicated Control Channel</i>
DCN	<i>Data Communication Network</i>
DECT	<i>Digitally Enhanced Cordless Telecommunication</i>
DL	<i>Data Link (layer)</i>
DLD	<i>Data Link Discriminator</i>

D_m	<i>Control Channel (ISDN terminology for mobile service)</i>
DMR	<i>Digital Mobile Radio</i>
DP	<i>Dialled Pulse</i>
DRX	<i>Discontinuous Reception</i>
DSP	<i>Digital Signal Processor</i>
DTAP	<i>Direct Transfer Application Part</i>
DTE	<i>Data Terminal Equipment</i>
DTMF	<i>Dual-Tone Multi-Frequency (signalling)</i>
DTX	<i>Discontinuous Transmission (field)</i>
ECP	<i>Echo Cancellor in pool</i>
EIA	<i>Electronic Industry Association</i>
E_b/N₀	<i>Ratio of energy-per-bit to noise power spectral density</i>
EIR	<i>Equipment Identity Register</i>
END	<i>End Indication (field)</i>
ESN	<i>Electronic Serial Number</i>
E-TACS	<i>Extended TACS (more channels)</i>
ETC	<i>Exchange Terminal Circuit</i>
ETSI	<i>European Telecoms Standards Institute</i>
FB	<i>Frequency (correction) Burst</i>
FACCH	<i>Fast Associated Control Channel</i>
FCCH	<i>Frequency Correction Channel</i>
FDMA	<i>Frequency Division Multiple Access</i>
FEC	<i>Forward Error Correction</i>
FER	<i>Frame Erasure Rate</i>
FCC	<i>Forward Control Channel</i>
FN	<i>Frame Number</i>
FREG	<i>Forced Registration (field)</i>
FSK	<i>Frequency Shift Keying</i>
FVC	<i>Forward Voice Channel</i>
G	<i>Guard (bit periods)</i>
GFSK	<i>Gaussian Frequency Shift Keying</i>
GIM	<i>Group Identification Mark</i>
GMPCS	<i>Global Mobile Personal Communications by Satellite</i>

GMSC	<i>Gateway Mobile Switching Centre</i>
GMSK	<i>Gaussian Minimum Shift Keying</i>
GOS	<i>Grade of Service</i>
GSM	<i>Global System for Mobile Communications</i> <i>previously: Group Special Mobile</i>
GSM PLMN	<i>GSM Public Land Mobile Network</i>
HDLC	<i>High Level Data Link Control</i>
HLR	<i>Home Location Register</i>
HLRID	<i>Home Mobile Switching Centre</i>
HON	<i>Handover Number</i>
HPLMN	<i>Home PLMN</i>
HPU	<i>Handportable Unit</i>
ID	<i>Identification</i>
IDN	<i>Integrated Digital Network</i>
IMSI	<i>International Mobile Subscriber Identification</i>
IS-54	<i>ETL Interim Standard for U.S. Digital Cellular (USDC)</i>
IS-95	<i>ETL Interim Standard for U.S. Code Division Multiple Access</i>
IS-136	<i>ETL Interim Standard 136 - USDC with Digital Control Channels</i>
ISDN	<i>Integrated Services Digital Network</i>
ISI	<i>Intersymbol Interference</i>
ITU	<i>International Telecommunications Union</i>
IWF	<i>Inter Working Function</i>
JDC	<i>Japanese Digital Cellular</i>
JRC	<i>Joint Radio Committee</i>
J-TACS	<i>Japanese TACS system</i>
JTC	<i>Joint Technical Committee</i>
K_i K_c	<i>Cipher Keys</i>
LAC	<i>Location Area Code</i>
LAI	<i>Location Area Identity</i>
LAN	<i>Local Area Network</i>

LAR	<i>Log-area Ratio</i>
LE	<i>Local Exchange</i>
LMSI	<i>Local Mobile Station Identificaiton</i>
LOS	<i>Line of Sight</i>
LPC	<i>Linear Predictive Coding</i>
LR	<i>Location Register</i>
LTP	<i>Long Term Prediction</i>
MA	<i>Mobile Allocation</i>
MACN	<i>Mobile Allocation Channel Number</i>
MAHO	<i>Mobile Assisted Handover</i>
MAP	<i>Mobile Application Part</i>
MCC	<i>Mobile Country Code</i>
ME	<i>Mobile Equipment</i>
MIC	<i>Mobile Interface Controller</i>
MIN	<i>Mobile Identification Number</i>
MMI	<i>Man Machine Interface</i>
MNC	<i>Mobile Network Code</i>
MOS	<i>Mean Opinion Score</i>
MPE	<i>Multi-Pulse Excitation</i>
MS	<i>Mobile Station</i>
MSC	<i>Mobile Switching Centre</i>
MSCU	<i>Mobile Station Control Unit</i>
MSIN	<i>Mobile Station Identification Number</i>
MSISDN	<i>Mobile Station ISDN Number</i>
MSL	<i>Main Signalling Link</i>
MSRN	<i>Mobile Station Roaming Number</i>
MSS	<i>Mobile Satellite Services</i>
NAM	<i>Number Assignment Module</i>
N-AMPS	<i>Narrowband AMPS system</i>
NB	<i>Normal Burst</i>
NCELL	<i>Neighbouring (adjacent) Cell</i>
NDC	<i>Network Destination Code</i>
NE	<i>Network Element</i>
NMC	<i>Network Management Centre</i>
NMSI	<i>National Mobile Station Identification (number)</i>
NMT	<i>Nordic Mobile Telephone (system)</i>

NSAP	<i>Network Service Access Point</i>
N(S)N	<i>National (Significant) Number</i>
NT	<i>Network Termination</i>
OFDM	<i>Orthogonal Frequency Division Multiplexing</i>
OHD	<i>Overhead Message Type Field</i>
OMC	<i>Operations & Maintenance Centre</i>
OQPSK	<i>Offset Quadrature Phase Shift Keying</i>
OSI	<i>Open System Interconnection</i>
OSS	<i>Operator Service System</i>
P	<i>Parity Field</i>
PA	<i>Power Amplifier</i>
PCH	<i>Paging Channel</i>
PCM	<i>Pulse Code Modulator</i>
PCN	<i>Personal Communications Network</i>
PCS	<i>Personal Communication Services</i>
PDN	<i>Public Data Networks</i>
PHS	<i>Personal Handyphone System</i>
PIN	<i>Personal Identification Number</i>
PLMN	<i>Public Land Mobile Network</i>
PMR	<i>Private Mobile Radio</i>
PN	<i>Pseudo Noise (code)</i>
PSK	<i>Phase Shift Keying</i>
PSPDN	<i>Public Switched Public Data Network</i>
PSTN	<i>Public Switched Telephone Network</i>
PTO	<i>Public Telecommunications Operator</i>
QOS	<i>Quality of Service</i>
QPSK	<i>Quadrature Phase Shift Keying</i>
RACH	<i>Random Access Channel</i>
RAND	<i>Random Number</i>
RCC	<i>Reverse Control Channel</i>
REC	<i>RECommendation</i>
REGH	<i>Registration Field for Mobile</i>
REL	<i>RELease</i>
REL P	<i>Residual Excited Linear Predictive (coder)</i>

REQ	<i>REQuest</i>
RES	<i>RESponse (authentication)</i>
RFCH	<i>Radio Frequency Channel</i>
RLP	<i>Radio Link Protocol</i>
RPE	<i>Regular Pulse Excitation (Voice Coder)</i>
RPF	<i>Radio Fixed Part</i>
RR	<i>Radio Resource</i>
RSE	<i>Radio System Entity</i>
RSVD	<i>Reserved for Future Use (bits)</i>
RVC	<i>Reverse Voice Channel</i>
RX	<i>Receiver, or R_x</i>
SACCH	<i>Slow Associated Control Channel</i>
SAP	<i>Service Access Point</i>
SAPI	<i>Service Access Point Indicator</i>
SAT	<i>Supervisory Audio Tone</i>
SB	<i>Synchronization Burst</i>
SCC	<i>SAT Colour Code</i>
SCCP	<i>Signalling Connection Control Part</i>
SCH	<i>Synchronization Channel</i>
SCM	<i>Station Class Mark</i>
SCP	<i>Service Control Point</i>
SDCCH	<i>Stand-alone Dedicated Control CHannel</i>
SIDH	<i>System Identification of Home Mobile Service Area</i>
SIM	<i>Subscriber Identity Module</i>
SLTM	<i>Signalling Link Test Message</i>
SMS	<i>Short Message Service</i>
SN	<i>Subscriber Number or Serial Number</i>
SNR	<i>Signal-to-Noise Ratio</i>
SP	<i>Signalling Point</i>
SRES	<i>Signed Response</i>
SS7	<i>Signalling System No. 7</i>
ST	<i>Signalling Tone</i>
SYNC	<i>Synchronization Signal</i>
TA	<i>Terminal Adaptor</i>
TACS	<i>Total Access Communications (UK)</i>

TB	<i>Tail Bits</i>
TC	<i>Trunk Code</i>
TCH	<i>Traffic CHannel</i>
TDD	<i>Time Division Duplex</i>
TDMA	<i>Time Division Multiple Access</i>
TE	<i>Terminal Equipment</i>
TFM	<i>Tamed Frequency Modulation</i>
TFTS	<i>Terrestrial Flight Telephone System</i>
TIA	<i>Telecommunications Industry Association (USA)</i>
TMN	<i>Telecommunications Management Network</i>
TMSI	<i>Temporary Mobile Subscriber Identification</i>
TN	<i>Time slot Number</i>
TRAU	<i>Transcoder Unit</i>
TRX	<i>Transceiver</i>
TS	<i>Training Sequence; also Time Slot</i>
TSC	<i>Training Sequence Code</i>
TU	<i>Typical Urban (profile)</i>
TX	<i>Transmitter, or T_x</i>
U	<i>Uplink</i>
U_m	<i>Air Interface</i>
VAD	<i>Voice Activity Detection</i>
VCO	<i>Voltage Controlled Oscillator</i>
VLR	<i>Visitor Location Register</i>
VLSI	<i>Very Large Silicon Integrated (circuit)</i>
VMAC	<i>(Voice) Mobile Attenuation Code</i>
VSELP	<i>Vector Sim Excited Linear Predictor</i>
WAN	<i>Wide Area Network</i>
WARC	<i>World Administrative Conference</i>
WLAN	<i>Wireless Local Area Network</i>

[Note: this list is not necessarily exhaustive]