CDMA RADIO WITH REPEATERS

Information Technology: Transmission, Processing, and Storage

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CDMA Radio with Repeaters
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PREFACE

Cellular Communications is about *Service, Technology and Economy. Public awareness and safety* is considered the fourth dimension in the equation, that rolls back to impact all of the other three.

Mobile communications has become an indispensable element of modern lifestyle. The 3G cellular systems focus on high data-rate multimedia services and a host of respective applications, mostly leisure-time oriented. At the other extreme, mobile communications is a most effective driving force in boosting the economy of developing communities. These two processes may share technology momentum and the economy of scale, but their substantial differences have to be recognized, at the time when the momentum of cellular deployment moves in that direction. The introduction of mobile wireless services to developing communities is challenged by the cost of infrastructure, operations and user terminals of the advanced networks, and the mixture of older generation systems to coexist with the new deployments. Affordability considerations and priority of services inspire innovative architectural and optimization solutions to the infrastructure, choice of applications and user terminals.

Mobile communications is the art of interaction of the ingenious transmission and reception of multiple messages, with the nature of propagation that paves their way. Both the propagation channel and the distribution of the multitude of users are not known exactly, posing a major challenge to the optimization of the multiple access network. The latter aims at minimizing capital and operational costs while matching the maximal load with satisfactory performance, recognizing that the load is not evenly distributed nor is it stationary in time. The optimization of 3G systems providing multimedia services is even more challenging. Statistical propagation modeling and network simulations fall short of representing the dynamics of the network and optimizing its performance. The combination of prediction models with online measurements is needed for network performance diagnosis. Proper distribution of access nodes, both BTSs and repeaters, and duly dynamic application of coverage and diversity means by antennas and power control, in response to the diagnosed parameters, will ensure an optimized utilization of the network resources.

Each of the CDMA cellular systems, IS 95, CDMA2000 or UMTS WCDMA, is a complex adaptively controlled digital modulation and processing system. Its radio interface is governed by surprisingly simple rules, however, relating to averaging of multiple transmissions to a noise like

interference. These basically simple rules allow for an understanding of the underlying processes and trends relating to coverage, capacity, grade and quality of service, which offer the radio engineer the insight needed to guide the planning, deploying, analyzing and optimizing of the network. Furthermore, the new data-optimized systems – 1xEV-DO and HSDPA, that share the network and the air interface with the CDMA systems, bring in different radio resource management rules. A different paradigm has to be attended to in optimizing the mixed services operating on the same network.

The schematic uniform, preferably hexagonal, grid of identical cells as conceived at the introduction of the service in early 80s, does not meet the continuous coverage requirements over a diversified environment and teletraffic densities. Way over half of the service area in each major market is coverage-limited and does not fully utilize its communications resources. The optimal cell size in these areas is governed by the cost structure of its constituents: tower, shelter, radio and processing equipment. Distributed radio access by repeaters, augmenting nodal base stations, substantially reduces the cost in such a rural coverage, as they do when stacked in multi-hop chains in coverage of long roads, when illuminating shadowed areas within the regular cell coverage ("radio holes"), and when providing access indoors.

Repeaters constitute an interactive part within the cellular CDMA network. Effective deployment of the repeaters, and optimization of repeater-embedded network - requires an intimate understanding of the CDMA air interface. The purpose of this book is to enrich the cellular scientist and engineer with the understanding of the interaction between the CDMA network dynamics and its embedded repeaters - and with the propagation channel, and offer them the insight into the processes and trends.

The interrelation of the parameters involved in the radio access is too complex and site-dependent to be accurately simulated, and any attempt to heuristically typify a model does not cast comprehension on others. This book takes the approach of simple modeling of the radio access behavior, with physically based canonical scenarios. The interrelation of these propagation models with the system performance models provides a convenient tool for understanding of the system performance, parametric dependence and dynamics. These models are supported by observed experience and occasional detailed calculations.

The book is written in simple language, enriched with graphical description of the scenarios and with trending plots. Ten chapters cover the cellular scene and rational for distributed access, the relevant aspects of the cellular standards, the characteristics of the mobile propagation, the inter-relations and dynamic of the CDMA network, the application of diversity transmission and reception, and the application of repeaters to the CDMA network and their impact and optimization of the repeater-embedded network.

Costing models for the application of repeaters are elaborated upon. Supporting chapters provide detailed structure and tuning parameters for repeaters and their backhaul relay. Chapter 10 - Advances in Repeaters, then reviews emerging technologies and applications.

ABBREVIATIONS

3G	3rd Generation cellular system
3GPP	3rd Generation Partnership Project *(produced the WCDMA standard)*
3GPP2	3rd Generation Partnership Project 2 *(produced the CDMA2000 standard)*
1x	Single carrier (1.25 MHz) version of CDMA2000
3X	Multicarrier (5 MHz) version of CDMA2000
ACP	Adjacent Channel Power
ACPR	Adjacent Channel Power Ratio
AFC	Automatic Frequency Control
AFL	Automatic Frequency Locking
AFLT	Advanced FL Triangulation
AGC	Automatic Gain Control
AIN	Advanced Intelligent Network
AISG	Antenna Interface Standardization Group
AMLC	Automatic Maximum Level Control
AMC	Adaptive Modulation and Coding
AMPS	Advanced Mobile Phone Service
AP	Access Point
APD	Avalanche Photo Diode
ARQ	Automatic Repeat Request
AWGN	Additive White Gaussian Noise
BDA	Bidirectional Amplifier
BER	Bit Error Rate
BFN	Beam Forming Network
BHCA	Busy Hour Call Attempt
BPF	Band Pass Filter
BPSK	Biphase Shift Keying *modulation*
BSC	Base Station Controller
BSS	Base Station Subsystem
BSSM	Base Station Subsystem Manager
BTS	Base Transceiver Subsystem
CAPEX	Capital Expenditure
CCP	Call Control Processor
CDE	Code Domain Error
CDF	Cumulative Distribution Function
CDG	CDMA Development Group
CDMA	Code-Division Multiple Access

CDMA2000	3rd generation CDMA standard *produced by 3GPP2*
CEPT	European Conference of Postal and Telecommunication Administrations
CFR	Code of Federal Regulations *(goes with a number)*
CIS	CDMA Interconnect Subsystem
COST WI	(Commission of European Communities) Walfish Ikegami – *an urban propagation model adopted by COST*
CSCG	Circularly Symmetric Complex Gaussian
CTIA	Cellular Telecommunications Industry Association
CW	Continuous Wave
D/A	Digital to Analog
dBO	dB of Optical gain
DFB	Distributed Feedback
DG	Digital Gain
DGU	Digital Gain Unit – *In the FL power and power control*
DRC	Data Rate Control
DTOA	Differential Time of Arrival
DU	Diversity Unit
DWDM	Dense Wavelength-Division Multiplex
EAM	Electro-Absorption Modulator
EGC	Equal-Gain Combining *of diversity branches*
EIA	Electronics Industry Alliance
EIRP	Effective Isotropic Radiated Power
ETSI	European Telecommunications Standards Institute
EV-DO	Evolution to Data Optimized. *Version of CDMA2000 standard*
EV-DV	Evolution to Data and Voice. *Version of CDMA2000 standard*
EVM	Error-Vector Magnitude
F1/F1	On-frequency relay
FA	Frequency Allocation. *The same as Channel*
FCAPiCh	Forward Common Auxiliary Pilot Channel
FCC	Federal Communications Commission
FCH	Fundamental Channel. *Used in call and low data rate*
FDAPiCh	Forward Dedicated Auxiliary Pilot Channel
FDD	Frequency-Division Duplex
FDM	Frequency-Division Multiplex
FDMA	Frequency-Division Multiple Access
FEC	Forward Error-correction Code
FER	Frame Error Rate
Finger	A time-delayed branch in the RAKE receiver
FL	Forward Link

FLPC	Forward Link Power Control
FM	Fade Margin
FP	Fabry-Perot *optical filter*
FPCh	Forward Paging Channel
FPiCh	Forward Pilot Channel
FSCCh	Forward Supplemental Code Channel
FSO	Free-Space Optics
FSR	Frequency Shifted Repeater (F1/F2)
G/T	Gain to Temperature ratio
GDV	Group Delay Variations
GM	Gain Margin – *-Gain+Isolation in dB*
GoS	Grade of Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
HARQ	Hybrid ARQ
HLR	Home Location Registry
HPA	High-Power Amplifier
HSDPA	High Speed Downlink Packet Access
ICI	InterCarrier Interference
ID	Identification
iDEN	integrated Digital Enhanced Network
IF	Intermediate Frequency
i.i.d	independent identically distributed
IIP	Intermodulation Intercept Point *where the intermodulation product equals the signal power*
IM	Intermodulation
IMT2000	International Mobile Telephone standardization program by ITU
IP	Internet Protocol
IP3	Intermodulation Product of 3rd order
IR	Infrared
IS 95	cdmaOne 2nd generation standard
ITU	International Telecommunications Union
LHC	Left-Hand Circular *(polarization of electromagnetic wave)*
LNA	Low-Noise Amplifier
LO	Local Oscillator
LOS	Line of Sight
LPI	Low Probability of Intercept
LPIR	Low Probability of Intercept Radar
MIMO	Multiple In – Multiple Out *antenna arrays communications*
MMDS	Multipoint Microwave Distribution Service
MOU	Minutes of Use

MRC	Maximal Ratio Combining *of diversity branches*
MS	Mobile Station. *See ST.*
MW	Microwave *transmission conduit*
MZM	Mach-Zehnder optical Modulator
NBPF	Narrow-Band-Pass Filter
NE	Network Element
NF	Noise Figure
NLOS	Non Line of Sight
NMC	Network Management Center
NMS	Network Management System
NOC	Network Operations Center
Noise Rise	Measure of the total power received at the BTS relative to its thermal noise. *Also called RoT*
NSS	Network Switching System
OA&M	Operation, Administration and Maintenance
ODU	Out Doors Unit
OF	Optical Fiber
OFDM	Orthogonal Frequency-Division Multiplex
OFR	On-Frequency Repeater (F1/F1)
OPEX	Operational Expenditure
OQPSK	Offset Quadrature Phase Shift Keying *modulation*
OR	Optical Fiber Repeater
OTD	Orthogonal Transmit Diversity
PA	Power Amplifier
P.C.	Power Control
PC	Portable Computer
PCDE	Peak Code Domain Error
PCG	Power Control Group
PCS	Personal Communications Service. *A frequency allocation in the US (1850-1990 MHz).*
PCSCh	Power Control SubChannel
PDC	Pseudo Diversity Combining
PDF	Probability Distribution Function
PG	Path-gain. *The inverse of Path-loss*
PIN	P I N *diode*
PLL	Phase-Lock Loop
PMRM	Power Measurement Report Message
PN	Pseudo Noise. *PN code offset identifies the pilot.*
PolMatch	Polarization Matching
PSMM	Pilot Strength Measurement Message
PSTD	Phase-Sweep Transmit Diversity
PSTN	Public Switched Telephone Network