



universal personal communications

John Farserotu
Ramjee Prasad

IP/ATM

**Mobile
Satellite
Networks**

Contents

Preface	xvii
Acknowledgments	xix
Chapter 1 Introduction	1
1.1 OVERVIEW	1
1.2 IMT-2000 AND THE ROLE OF SATCOM AND LMS	2
1.2.1 Global coverage	2
1.2.2 Terrestrial alternative or gap-filling in IMT-2000	3
1.2.3 Enable IMT-2000 and the role of LMS	3
1.2.4 Communication architecture employing LMS	3
1.3 MULTIMEDIA INFORMATION SERVICES	5
1.4 IP AND ATM NETWORKS	6
1.5 PREVIEW OF THE BOOK	7
1.6 SUMMARY	9
REFERENCES	9
Chapter 2 Overview of Land Mobile Satellite Communication	11
2.1 INTRODUCTION	11
2.1.1 Characteristics and limits of LMS systems	11
2.2 GENERAL ORBITAL CONSIDERATIONS (LEO, MEO, OR GEO)	13
2.2.1 General satellite orbital model	14
2.2.2 Orbital period	15
2.2.3 Coverage, beamwidth, and range	16
2.2.4 Intersatellite crosslinks	17
2.3 FREQUENCY ALLOCATIONS AND REGULATORY ISSUES	18
2.4 INTERFERENCE CONSTRAINTS	20
2.4.1 Interference limits	20
2.4.2 MSS space-to-Earth band (2,170–2,200 MHz)	20
2.4.3 MSS Earth-to-space band (2,170–2,200 MHz)	20
2.4.4 Satellite unwanted emissions	21
2.4.5 User terminal unwanted emissions	21
2.4.6 WLANs and short-range wireless links in the ISM band	21

2.5	LINK BUDGET ANALYSIS	21
2.5.1	Power and gain	22
2.5.2	Path losses	22
2.5.3	Thermal noise	22
2.5.4	Link analysis for satellite with onboard processing	23
2.6	OVERVIEW OF EXISTING AND PLANNED SYSTEMS	23
2.6.1	Globalstar	24
2.6.2	ICO	25
2.6.3	INMARSAT-C	26
2.6.4	Iridium	26
2.6.5	Orbcomm	26
2.7	LAND MOBILE SATCOM IN THE IMT-2000	26
2.7.1	UTRA and WCDMA	27
2.7.2	S-UMTS	27
2.8	S-UMTS ITU-R RTT PROPOSALS	28
2.8.1	SAT-CDMA	29
2.8.2	ESA RTT proposals	29
2.8.3	ICO global communications RTT proposal	31
2.8.4	Other (non-ITU proposals)	31
2.8.5	Services and performance requirements	31
2.9	EVOLVING TOWARDS FOURTH-GENERATION MOBILE SYSTEMS AND BEYOND (A UNIFIED APPROACH)	33
2.9.1	Mobile broadband service	33
2.9.2	Broadband SATCOM: ATM-SATCOM systems and developments	34
2.10	SUMMARY	36
	REFERENCES	36
Chapter 3	Land Mobile Satellite Communication Channel	39
3.1	MULTIPATH FADING	40
3.1.1	Rayleigh fading and the diffuse multipath signal components	40
3.1.2	The signal	41
3.2	RAYLEIGH FADING PROCESS AND THE DIFFUSE SIGNAL COMPONENTS	42
3.3	RICIAN FADING AND THE LOS AND SPECULAR SIGNAL COMPONENTS	43
3.3.1	LOS and specular components	43
3.3.2	Rician fading	44
3.4	NAKAGAMI FADING MODEL	46
3.5	SHADOWING AND THE LOGNORMAL MODEL	46

3.6	SHADOWING AND FADING (LOO'S MODEL)	47
3.6.1	Shadowing and fading (Loo's model)	47
3.6.2	The signal phase	47
3.7	FREQUENCY, TIME, AND SPACE SELECTIVE FADING	48
3.7.1	Coherence bandwidth (f_0)	48
3.7.2	Coherence length (l_0)	48
3.7.3	Coherence time (τ_0)	48
3.7.4	Angle of arrival deviation (σ_0)	49
3.8	POWER SPECTRAL DENSITY	49
3.8.1	Case 1 (omni antenna)	50
3.8.2	Case 2 (directive antenna)	51
3.9	POWER DELAY SPECTRUM	51
3.9.1	Case 1 (omni antenna)	51
3.9.2	Case 2 (directive antenna)	52
3.10	FADING RATE	53
3.10.1	Level crossing rate	53
3.10.2	Case 1 (Rayleigh fading)	54
3.10.3	Case 2 (Rician fading)	54
3.11	RAYLEIGH FADE STATISTICS	54
3.11.1	Average fade duration	54
3.11.2	Availability in multipath fading	55
3.12	SUMMARY	56
	REFERENCES	56
	APPENDIX 3A: Useful Equations	58
Chapter 4	System Design Issues	59
4.1	INTRODUCTION	59
4.2	THE WAVEFORM AND SYSTEM DESIGN DRIVERS	60
4.2.1	LMS air interface drivers	60
4.2.2	Cost and complexity of CDMA systems	61
4.2.3	LMS architecture	61
4.3	WAVEFORM AND TECHNOLOGY CONSIDERATIONS	62
4.3.1	Multiple access techniques and issues	63
4.3.2	CDMA for LMS	63
4.3.3	Multiuser detection and interference cancellation	64
4.3.4	Interference cancellation	67
4.3.5	Channel estimation and equalization	68
4.3.6	Power control	68
4.3.7	Synchronization	70
4.3.8	Modulation	71
4.3.9	Error control and correction issues for LMS	73
4.3.10	Duplexing	74

4.3.11	Handover	74
4.3.12	Receiver implementation and equalization	75
4.3.13	Adaptive equalization	76
4.3.14	Interleaving	77
4.3.15	Adaptive "smart" antenna technology	78
4.3.16	Side information and waveform implementation	78
4.3.17	Security	79
4.4	SUMMARY AND CONCLUDING REMARKS	79
	REFERENCES	80
Chapter 5	Introduction to Multiple Access Techniques	83
5.1	INTRODUCTION	83
5.2	FDMA	83
5.2.1	FDMA capacity	86
5.2.2	ACI limitation	86
5.2.3	Frequency uncertainty and guard band	86
5.2.4	Frequency uncertainty due to drift and wander	87
5.2.5	Sensitivity to intermod products	87
5.3	TDMA	88
5.4	TIME AND FREQUENCY UNCERTAINTY OVER SATELLITE LINKS	89
5.4.1	The sources of time and frequency uncertainty	91
5.4.2	Satellite motion	92
5.4.3	Time uncertainty due to wander and drift	94
5.4.4	Short-term stability: Timing jitter between clocks	95
5.5	DS-CDMA	95
5.5.1	CDMA capacity	96
5.5.2	DS-CDMA receiver	97
5.5.3	IP/ATM over CDMA integration issues	101
5.6	HYBRID FH/DS-CDMA WAVEFORM	102
5.7	WCDMA-BASED S-UMTS AIR INTERFACE	103
5.7.1	CDMA codes for UMTS	104
5.8	SUMMARY	107
	REFERENCES	107
Chapter 6	MPSK TCM	109
6.1	INTRODUCTION	109
6.2	MODELING OF MPSK AND PRAGMATIC MPSK TCM	110
6.2.1	General MPSK performance model	111
6.2.2	Pragmatic MPSK TCM performance model and modifications	113

6.3	PRAGMATIC MPSK TCM PERFORMANCE	117
6.3.1	Performance in AWGN	117
6.3.2	Performance in Rician fading	118
6.3.3	Performance in Rayleigh fading	120
6.4	MPSK TCM WITH SYMBOL DIVERSITY	121
6.5	CONCATENATED REED-SOLOMON MPSK TCM	122
6.6	SUMMARY AND CONCLUDING REMARKS	123
	REFERENCES	124
	APPENDIX 6A: Terms at Hamming Distance 12	125
Chapter 7	Antennas	127
7.1	INTRODUCTION	127
7.2	BASICS OF ANTENNAS FOR LMS	127
7.2.1	Directivity and gain	127
7.2.2	The LMS terminal	129
7.2.3	Tracking	129
7.3	ANTENNAS AND DIVERSITY	130
7.3.1	Antenna diversity in the ground segment	130
7.3.2	Satellite diversity	131
7.3.3	Diversity combining techniques	131
7.4	SMART ANTENNAS	136
7.4.1	Phased array	136
7.4.2	Adaptive array	137
7.5	SUMMARY AND CONCLUDING REMARKS	140
	REFERENCES	140
Chapter 8	Multimedia Information Services for LMS	143
8.1	INTRODUCTION	143
8.1.1	What is multimedia?	143
8.1.2	Design goals of multimedia systems	144
8.2	MULTIMEDIA INFORMATION SERVICES	145
8.2.1	Mobile multimedia services	145
8.2.2	Multimedia over LMS issues	146
8.2.3	Content	147
8.2.4	Reuseable objects, distribution, and delivery mechanisms	147
8.2.5	Service from a SATCOM perspective	148
8.2.6	Comments on mobile broadband service	149
8.2.7	Security	149
8.3	OVERVIEW OF STANDARDS	150
8.3.1	MPEG standards for multimedia	150
8.3.2	Status of MPEG4 over mobile	151
8.3.3	Error resilient video coding	151

8.4	QUALITY OF SERVICE REQUIREMENTS	152
8.4.1	Delay	152
8.4.2	Error performance	153
8.5	A HYPOTHETICAL REFERENCE CONNECTION FOR LAND MOBILE SATELLITE	153
8.5.1	Error performance apportionment	153
8.5.2	Delay and delay equalization	154
8.5.3	Sources of delay variation	155
8.5.4	Satellite motion induced delay variation	155
8.6	NETWORK SERVICE PERSPECTIVES	156
8.6.1	IP and ATM networks	156
8.6.2	Point-to-point service	157
8.6.3	Broadcast service	157
8.6.4	Multicast service (via satellite)	157
8.7	MIDDLEWARE	158
8.7.1	What is middleware?	158
8.7.2	Resource allocation and adaptability	158
8.8	SUMMARY	159
	REFERENCES	160
Chapter 9	ATM over SATCOM	163
9.1	INTRODUCTION TO ATM	163
9.1.1	The potential benefits of ATM over SATCOM	163
9.1.2	Key issues with respect to the operation of ATM over SATCOM	165
9.2	THE ATM PROTOCOL STACK	167
9.2.1	Service classes and the B-ISDN reference model	167
9.2.2	ATM cell structure	168
9.3	IP/ATM-SATCOM	169
9.4	THE TRAFFIC PROFILE AND ITS RELATIONSHIP TO ATM-SATCOM LINKS	170
9.4.1	Sensitivity to service type and traffic intensity	170
9.4.2	SATCOM implications	171
9.5	ATM QoS PERFORMANCE MEASURES	172
9.6	ATM-SATCOM SYSTEMS AND DEVELOPMENTS	173
9.7	IMPLEMENTATION OF ATM-SATCOM NETWORKS	174
9.7.1	ATM-SATCOM relay	174
9.7.2	What are OBP, signal regeneration and OBS?	180
9.7.3	Satellite switched ATM	182
9.8	CDMA-BASED ATM-SATCOM CONNECTION ADMISSION CONTROL	185
9.8.1	Connection admission control	185

9.8.2	Capacity-based ATM-SATCOM CAC for the "switch-in-the-sky"	185
9.8.3	Capacity-based ATM-SATCOM CAC at the SGT	186
9.8.4	ATM-CDMA CAC example	186
9.9	SUMMARY	188
	REFERENCES	188
Chapter 10	TCP/IP over Satellite	191
10.1	INTRODUCTION	191
10.2	DESCRIPTION OF TCP/IP	191
10.2.1	IP datagram	192
10.2.2	TCP segment	193
10.3	KEY ISSUES AND LIMITATIONS	194
10.3.1	GEO versus LEO	195
10.3.2	Enhanced TCP	195
10.3.3	QoS awareness	196
10.3.4	IP routing and ATM switching	197
10.3.5	IP routing techniques	198
10.3.6	IP multicasting	201
10.3.7	IP security over SATCOM	201
10.3.8	Congestion control	201
10.4	TCP/IP OVER ATM-SATCOM AND THE IMPORTANCE OF ERROR CONTROL	202
10.4.1	Performance dependency on TCP window size	202
10.4.2	The combined effects of errors, delay, and window size	203
10.4.3	TCP acknowledgment mechanism	204
10.4.4	The dependency on MTU size and delay	205
10.4.5	Dependency on TCP window size and MTU size	207
10.5	SUMMARY	207
	REFERENCES	207
Chapter 11	Traffic Modeling	211
11.1	INTRODUCTION	211
11.2	POISSON ARRIVALS	212
11.2.1	Poisson distribution	213
11.2.2	Birth-death process state flow diagram	213
11.2.3	Equilibrium equation	214
11.2.4	Balance equation	214
11.3	QUEUEING MODELS	215
11.3.1	M/M/1	215
11.3.2	Queueing delay	216
11.3.3	General M/M/S/S and M/D/S/S queues	217

11.3.4	Erlangs and traffic load	218
11.3.5	Grade of service	219
11.3.6	Probability of blocking	219
11.3.7	Probability of blocking and the Erlang B formula	219
11.4	UMTS TRAFFIC CONSIDERATIONS	220
11.5	SATCOM CONSIDERATIONS	221
11.5.1	SATCOM delay variance analysis for multimedia component services	221
11.5.2	Delay variation common to all ATM VCs on an ATM-SATCOM link	221
11.5.3	Delay variation relative to the ATM VCs on an ATM-SATCOM link	222
11.6	SUMMARY	224
	REFERENCES	224
Chapter 12	MAC Layer Considerations	227
12.1	INTRODUCTION	227
12.2	MAC LAYER PROTOCOLS	227
12.2.1	FAMA protocols	229
12.2.2	DAMA protocols	229
12.2.3	Random access protocols	230
12.2.4	Hybrid random access and reservation protocols	230
12.2.5	Adaptive protocols	230
12.2.6	UMTS MAC protocol point of reference	231
12.2.7	Satellite versus terrestrial MAC	232
12.2.8	Proprietary MAC versus standard MAC for satellites	233
12.3	CONNECTION ADMISSION CONTROL, RESOURCE ALLOCATION, AND MANAGEMENT	233
12.3.1	Connection admission control	233
12.3.2	Channel allocation	234
12.3.3	Radio resource allocation and management	235
12.4	CAPACITY AND RESOURCE ESTIMATION	235
12.4.1	Capacity in Erlangs, blocking, and grade of service	235
12.4.2	Resource estimation, accuracy and limitations	237
12.4.3	ALOHA and slotted ALOHA	237
12.5	SLOTTED ALOHA FOR UMTS VOICE, DATA, AND VIDEO TRAFFIC	240
12.5.1	Offered traffic in requests per slot	240
12.5.2	Total traffic and probability of collision	240
12.5.3	Delay and the Pollaczek-Khinchin formula	242
12.6	SUMMARY AND CONCLUDING REMARKS	242
	REFERENCES	242

Chapter 13	Cost Issues	245
13.1	INTRODUCTION	245
13.2	COST MODEL	245
13.2.1	Spacecraft mass	246
13.2.2	Modeling the mass of the communication payload	247
13.2.3	Antennas	248
13.2.4	Gimballed assembly, autotrack receiver, and electronics	249
13.2.5	Receiver, baseband, and multiplexing	249
13.2.6	Power amplifier and assembly	249
13.2.7	Processor	249
13.2.8	Miscellaneous	249
13.2.9	Example SATCOM payload mass	249
13.2.10	Development cost	251
13.2.11	Propellant and ABM	251
13.2.12	Launch cost per kilogram	252
13.3	SUMMARY AND CONCLUDING REMARKS	253
	REFERENCES	253
	APPENDIX 13A: Antenna Size and Mass Data	255
	APPENDIX 13B: Satellite Mass and Power Data	256
	APPENDIX 13C: Spacecraft Cost Data in 1998 U.S. Dollar	257
	APPENDIX 13D: Launch Vehicle and Cost	258
	APPENDIX 13E: Mass of Communication Payload Components	259
	APPENDIX 13F: Power Amplifier and Assembly (PAA) Data	260
List of Acronyms		261
About the Authors		267
Index		271