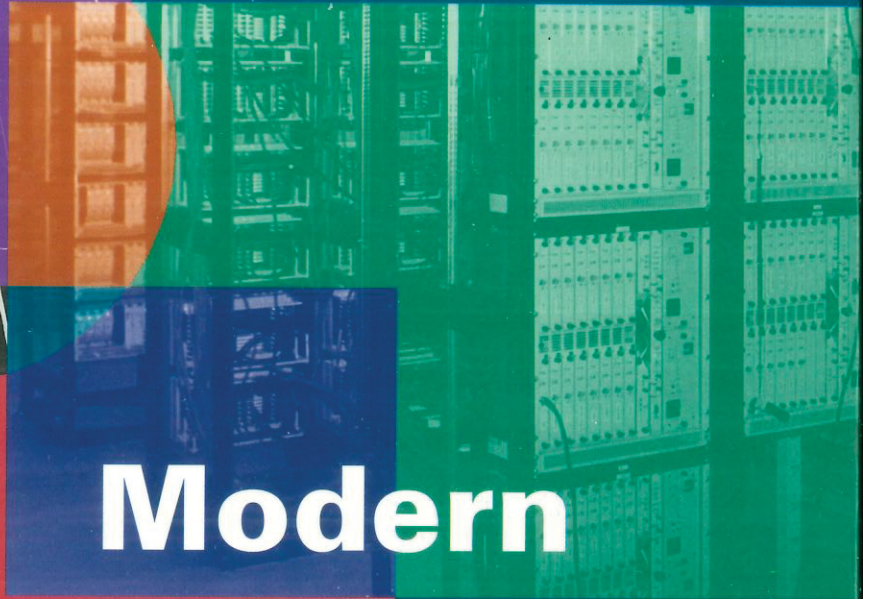
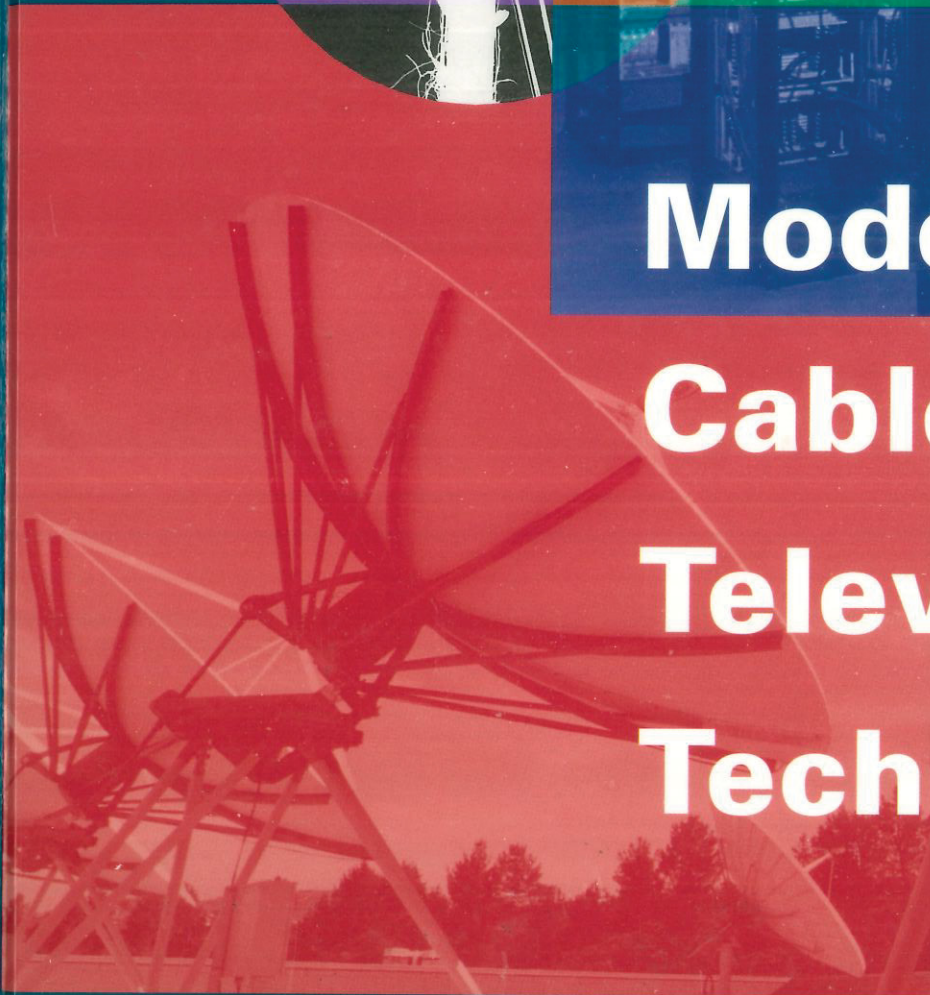


Walter Ciciora | James Farmer | David Large



Modern Cable Television Technology



Video, Voice, and Data Communications

**Ciciora
Farmer
Large**



Modern Cable Television Technology

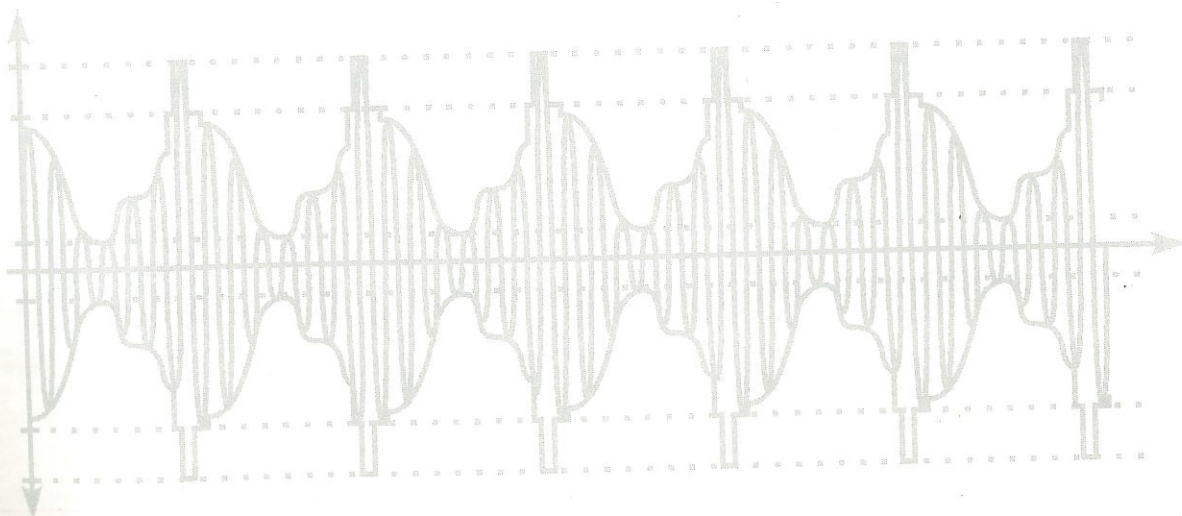
Video, Voice, and Data Communications



**Morgan
Kaufmann**

Modern Cable Television Technology

**Video, Voice, and
Data Communications**



The Morgan Kaufmann Series in Networking

Series Editor, David Clark

Modern Cable Television Technology: Video, Voice, and Data Communications
Walter Ciciora, James Farmer, and David Large

Switching in IP Networks: IP Switching, Tag Switching, and Related Technologies
Bruce S. Davie, Paul Doolan, and Yakov Rekhter

Wide Area Network Design: Concepts and Tools for Optimization
Robert S. Cahn

Optical Networks: A Practical Perspective
Rajiv Ramaswami and Kumar Sivarajan

Practical Computer Network Analysis and Design
James D. McCabe

Frame Relay Applications: Business and Technology Case Studies
James P. Cavanagh

High-Performance Communication Networks
Jean Walrand and Pravin Varaiya

Computer Networks: A Systems Approach
Larry L. Peterson and Bruce S. Davie

Modern Cable Television Technology

Video, Voice, and Data Communications

WALTER CICIORA
Consultant

JAMES FARMER
Antec Corporation

DAVID LARGE
Media Connections Group



Morgan Kaufmann Publishers, Inc.
San Francisco, California

Senior Editor Jennifer Mann
Director of Production and Manufacturing Yonie Overton
Production Editor Cheri Palmer
Editorial Assistant Karyn Johnson
Cover Design Ross Carron Design
Cover Photograph XXXXXXXX
Text Design Rebecca Evans & Associates
Copyeditor Robert Fiske
Proofreader Jennifer McClain
Composition and Illustrations Technologies 'n Typography
Indexer Steve Rath
Printer Courier Corporation

Designations used by companies to distinguish their products are often claimed as trademarks or registered trademarks. In all instances where Morgan Kaufmann Publishers, Inc. is aware of a claim, the product names appear in initial capital or all capital letters. Readers, however, should contact the appropriate companies for more complete information regarding trademarks and registration.

Morgan Kaufmann Publishers, Inc.

Editorial and Sales Office

340 Pine Street, Sixth Floor

San Francisco, CA 94104-3205

USA

Telephone 415 / 392-2665

Facsimile 415 / 982-2665

Email mkp@mkp.com

WWW <http://www.mkp.com>

Order toll free 800 / 745-7323

© 1999 by Morgan Kaufmann Publishers, Inc.

All rights reserved

Printed in the United States of America

03 02 01 00 99 5 4 3 2 1

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means—electronic, mechanical, photocopying, recording, or otherwise—without the prior written permission of the publisher.

Library of Congress Cataloging-in-Publication Data

Ciciora, Walter S.

Modern cable television technology : video, voice, and data communications / Walt Ciciora, James Farmer, David Large.

p. cm.

Includes bibliographical references and index.

ISBN 1-55860-416-2

1. Cable television. I. Farmer, James, (date) II. Large, David, (date) III. Title.

TK6675.C53 1999

621.388'57—dc21

98-35328

CIP

Contents

Foreword

vii

Preface

xxiii

Part 1 Once Over Lightly

Chapter 1	Introduction to Cable Television	3
1.1	Introduction	4
1.2	Historical Perspective	5
1.3	Spectrum Reuse	7
1.4	Cable Network Design	9
1.5	Signal Quality	13
1.6	Cable System Trade-Offs	15
1.7	Hybrid Fiber-Coax	18
1.7.1	The Hybrid Fiber-Coax Architecture	18
1.7.2	Distribution Plant Improvements	20
1.8	Signal Security Systems	21
1.8.1	Trapping Systems	21
1.8.2	Scrambling and Addressability	22
1.8.3	RF Synchronization Suppression Systems	22
1.8.4	Baseband Scrambling Systems	23
1.8.5	Off-Premises Systems	23
1.9	The Signal and the Customer's Equipment	24
1.9.1	Signal Splitting at the Customer's Premises	24
1.9.2	Consumer Electronics Compatibility	25
1.10	Digital Video Compression	28
1.11	Cable Economics	29
1.12	Summary	31
	Endnotes	32

ix

Part 2 The Signals

Chapter 2	Analog Television	35
2.1	Introduction	36
2.2	Baseband Monochrome Video and Monaural Audio	36
2.2.1	Television Briefly	37
2.2.2	Scanning	45
2.2.3	Synchronization	49
2.2.4	Spectrum of Scanned Images	52
2.2.5	Television Audio	52
2.3	Modulation	53
2.3.1	A Phenomenological Approach to Amplitude Modulation	55
2.3.2	A Mathematical Approach to Amplitude Modulation	56
2.3.3	Double Sideband Modulation	57
2.3.4	Synchronous Detection	63
2.3.5	Envelope Detection	67
2.3.6	Single Sideband Modulation	68
2.3.7	Vestigial Sideband Modulation	70
2.3.8	Video Bandwidth	72
2.3.9	Frequency Modulation	76
2.4	Modern Analog Television	77
2.4.1	Color Television	87
2.4.2	Stereo Sound	89
2.4.3	Ancillary Signals	95
2.5	Signal Quality and Customer Expectations	95
2.5.1	CableLabs Updates Early Testing	97
2.5.2	The W Curve and DPU	99
2.6	Other Television Systems	100
2.7	Summary	101
	Endnotes	
Chapter 3	Digitally Compressed Television	105
3.1	Introduction	106
3.2	Digitization of Video	106
3.2.1	Digital Signals	106
3.2.2	Digital Television	116
3.3	Digital Compression	119
3.3.1	Video Redundancies	119
3.3.2	Source Coding and Channel Coding	121
3.3.3	The Discrete Cosine Transform	122
3.3.4	Compression	127
3.3.5	Intraframe and Interframe Coding	129
3.3.6	Motion Estimation and Compensation	134
3.3.7	B Frames and Groups of Pictures	137
3.3.8	Digital Artifacts	137

3.3.9	Digital Audio	139
3.3.10	JPEG, MPEG-1, and MPEG-2	141
3.3.11	Other Approaches to Compression	142
3.4	Packetized Multiprogram Datastream Formation	143
3.4.1	Packetization and the PES	143
3.4.2	Time Division Multiplexing and the Transport Stream Packet	145
3.4.3	Statistical Multiplexing	147
3.4.4	Challenges	148
3.5	Modulation	149
3.6	Error Correction	150
3.7	Required Signal Quality	154
3.7.1	Signal Quality	154
3.7.2	Picture Quality	155
3.8	OpenCable	155
3.9	The Digital Video Standard	157
3.10	Summary	157
	Endnotes	158
Chapter 4 Cable Data Transport		161
4.1	Introduction	162
4.2	Modulation Methods	162
4.2.1	Spectral Efficiency	162
4.2.2	Frequency Shift Keying (FSK)	163
4.2.3	Baseband Spectrum of a Data Signal	166
4.2.4	Introduction to Bit Error Rate	166
4.2.5	ASK and PSK	167
4.2.6	Biphase Shift Keying (BPSK)	167
4.2.7	Some Fundamental Principles of Data Communications	169
4.2.8	Quadrature Phase Shift Keying (QPSK)	175
4.2.9	Higher-Order QAM Modulation	179
4.2.10	8- and 16-VSB Modulation	183
4.2.11	Peak-to-Average Ratio	184
4.2.12	Measuring the Level of a Digitally Modulated Signal	186
4.2.13	Bit Error Rate Versus Carrier-to-Noise Ratio	187
4.3	Forms of Spectrum Sharing	189
4.3.1	Time Division Multiple Access (TDMA)	189
4.3.2	Frequency Division Multiplexing (FDM)	190
4.3.3	Orthogonal Frequency Division Multiplexing (OFDM)	191
4.3.4	Code Division Multiple Access (CDMA)	192
4.4	Protocol Issues	194
4.4.1	The Concept of Protocols	194
4.4.2	The OSI Seven-Layer Reference Model	196
4.4.3	MAC Layer Issues of Interest in Cable Modem Applications	199
4.4.4	Connection-Oriented and Connectionless Service	200
4.5	The DOCSIS Protocol for Cable Modems	205
4.5.1	DOCSIS Reference Model	205
4.5.2	Downstream RF Characteristics	207

xii Contents

4.5.3	Upstream RF Characteristics	208
4.5.4	Data Link Layer—MAC	210
4.5.5	Security Sublayer (SSI)	211
4.5.6	Data Link Layer—LLC and Higher Layers	213
4.6	Error Detection and Correction	213
4.7	Summary	214
	Endnotes	
Chapter 5	Cable Telephony	215
5.1	Introduction	216
5.2	Modern Telephone System Architecture	216
5.2.1	The Local Exchange	218
5.2.2	Switch Architecture	220
5.2.3	Digital Loop Carrier	223
5.2.4	Backup Powering	223
5.2.5	POTS Through CLASS	225
5.2.6	The Subscriber Loop	229
5.3	The Telephone Network Digital Hierarchy	230
5.3.1	Sampling of the Voice Signal	230
5.3.2	Analog-to-Digital Conversion	232
5.3.3	Time Division Multiplexing in Telephony Systems	232
5.3.4	Asynchronous Digital Hierarchy	234
5.3.5	North American Synchronous Digital Hierarchy	235
5.4	Elements of a Cable Telephony System	235
5.4.1	The Home Interface	237
5.4.2	Powering the NID	238
5.4.3	Headend Telephony Equipment	240
5.4.4	Channel Sharing	241
5.4.5	A Sample HFC Telephony Marshaling Protocol	245
5.4.6	Implication of Diverse Routing	247
5.4.7	Alternative Transmission Methods	247
5.5	Network Engineering: Quality of Service	247
5.5.1	Call Concentration and Blockage	251
5.6	IP Telephony	253
5.7	Summary	253
	Endnotes	

Part 3 Headends

Chapter 6	Signal Reception	257
6.1	Introduction	258
6.2	Off-Air Reception	258
6.2.1	Antennas for Reception of Off-Air Signals	258
6.2.2	Propagation of Off-Air Signals	270

6.3	Satellite Reception	274
6.3.1	Antennas for Reception of Satellite Signals	275
6.3.2	Earth Station Geometry	281
6.3.3	Earth Station Performance Computations	283
6.3.4	Satellite Frequency Plans and Interference Issues	291
6.3.5	Earth Station Design Example	294
6.4	Other Methods of Receiving Programming at Headends	295
6.4.1	FM Terrestrial Microwave	295
6.4.2	Direct Feed from Television Stations	295
6.4.3	Local Origination	298
6.5	Summary	299
	Endnotes	299
Chapter 7	Headend Signal Processing	301
7.1	Introduction	302
7.2	Signal Processors	302
7.2.1	Input Section	302
7.2.2	IF Section	303
7.2.3	Output Section	305
7.2.4	Local Oscillators	305
7.2.5	Processor Frequency Response	306
7.3	Modulation	308
7.3.1	Video Switch and AGC	308
7.3.2	Sound Subcarrier Trap	310
7.3.3	DC Restoration and Peak White Clip	310
7.3.4	Modulation Process	310
7.3.5	IF Processing	311
7.3.6	Aural Modulation	312
7.3.7	Vestigial Sideband Filtering	315
7.4	Phase Locking of Carriers	317
7.4.1	Phase Locked Circuitry for Processor or Modulator	318
7.5	Demodulation	321
7.5.1	RF Input Section	321
7.5.2	IF Processing Section	321
7.5.3	Visual Carrier Demodulation	323
7.5.4	Video Output	324
7.5.5	Aural Carrier Demodulation	324
7.5.6	Nyquist Slope Filter	326
7.5.7	Synchronous Versus Envelope Detection	327
7.6	TV Stereo	332
7.6.1	BTSC Stereo Generation and Application	332
7.6.2	The NICAM Stereo System	335
7.6.3	The IRD Two-Carrier Stereo System	336
7.7	Satellite Earth Station Receiving Equipment	336
7.8	Signal Handling in Headends	339
7.8.1	Video Loop-Through	339

7.8.2	Audio Wiring	341
7.8.3	Controlling Hum in Video	343
7.9	Ad Insertion	345
7.10	Summary	347
	Endnotes	348
Chapter 8	Headend Operation	349
8.1	Introduction	350
8.2	Cable Television Band Plan	350
8.2.1	Concept of Image Response and Historical Background	350
8.2.2	Introduction to the Modern Cable Television Band Plan	352
8.2.3	The EIA-542 Band Plan	354
8.3	Headend RF Management	359
8.3.1	Downstream RF Management	360
8.3.2	Upstream RF Management	363
8.4	Headend Fiber-Optics Management	367
8.4.1	Fiber Distribution	368
8.5	Signal Quality Tests	370
8.5.1	Visual Modulation Definition	370
8.5.2	Aural Modulation	372
8.5.3	Measuring Picture and Sound Carrier Levels	378
8.6	Summary	379
	Endnotes	379

Part 4 Broadband Distribution Systems

Chapter 9	Coaxial RF Technology	383
9.1	Introduction	384
9.2	Coaxial Cable	384
9.2.1	Definition	384
9.2.2	Characteristic Impedance	385
9.2.3	Attenuation as a Function of Frequency	386
9.2.4	Attenuation as a Function of Temperature	389
9.2.5	Attenuation as a Function of Characteristic Impedance	389
9.2.6	Wavelength	390
9.2.7	Theoretical Size Limitation	391
9.2.8	Precision of Match: Structural Return Loss	392
9.2.9	Precision of Match: Time Domain Reflectometry (TDR)	393
9.2.10	Practical Factors in Cable Selection	394
9.2.11	Shielding Effectiveness in Drop Cables	397
9.3	Amplifiers	398
9.3.1	Broadband Random Noise	399
9.3.2	Amplifier Noise	400
9.3.3	Distortion	400
9.3.4	Group Delay Variation and Amplifier Stability	413

9.3.5	Hum Modulation	415
9.3.6	Frequency Response Variation and Impedance Match	417
9.3.7	Practical Amplifier Design Choices	418
9.3.8	Amplifier Operating Dynamics	420
9.3.9	Amplifier Technology Choices	425
9.4	Passive Coaxial Components	426
9.4.1	Directional Couplers	427
9.4.2	Splitters	428
9.4.3	Taps	431
9.5	Power Supplies	433
9.6	Summary	435
	Endnotes	436
<hr/> Chapter 10 Coaxial Distribution System Design		439
10.1	Introduction	440
10.2	Carrier-to-Noise Ratio	440
10.3	Carrier to Distortion	442
10.4	Noise-Distortion Trade-Off	444
10.5	System Powering	447
10.5.1	Switching Transient Effects	449
10.5.2	Hum Buildup	450
10.6	Signal Level Management	450
10.7	Signal Level Stability	452
10.8	The Service Drop	453
10.8.1	Simple Passive Architectures	453
10.8.2	Adding Amplification—The Trade-Offs	459
10.8.3	Integrated In-Home Wiring Systems	459
10.9	Summary	463
	Endnotes	464
<hr/> Chapter 11 Linear Fiber-Optic Signal Transportation		467
11.1	Introduction	468
11.2	Optical Basics	468
11.2.1	Velocity of Propagation and Wavelength	469
11.2.2	Reflection and Refraction	470
11.2.3	Light Absorption	472
11.2.4	Scattering Loss and Rayleigh Scattering	473
11.2.5	Wavelength Dispersion	473
11.3	Multimode Optical Fibers	474
11.4	Single Mode Optical Fibers	477
11.4.1	Structure	477
11.4.2	Attenuation	478
11.4.3	Chromatic (Wavelength) Dispersion	478
11.4.4	Polarization Mode Dispersion	480
11.4.5	Attenuation in Bent Fibers	482

11.4.6	Stimulated Brillouin Scattering	482
11.4.7	Self-Phase Modulation	484
11.5	Network Passives	487
11.5.1	Connectors	487
11.5.2	Signal Splitters	489
11.5.3	Wavelength Division Multiplexers	489
11.5.4	Attenuators	489
11.6	Linear Optical Transmitters	490
11.6.1	General Characteristics	491
11.6.2	Directly Modulated Fabry–Perot Laser Diodes	492
11.6.3	Directly Modulated Distributed Feedback (DFB) Laser Diodes	496
11.6.4	Externally Modulated Continuous Wave Sources	498
11.7	Optical Amplifiers	500
11.8	Optical Receivers	502
11.9	Interactions Among Transmitters, Fibers, and Receivers	502
11.9.1	Double Rayleigh Backscattering: Interferometric Intensity Noise	504
11.9.2	Phase Noise Contribution to Link Performance	505
11.10	End-to-End Fiber-Optic Link Performance	505
11.10.1	Noise Performance	507
11.10.2	Small Signal Distortions	508
11.10.3	Clipping Distortion	513
11.11	Summary	513
	Endnotes	
Chapter 12	Other Supertrunking Alternatives	517
12.1	Introduction	518
12.2	Coaxial Supertrunks	518
12.3	Broadband Amplitude Modulated Microwave Links (AMLs)	519
12.3.1	U.S. Regulation of Microwave Transmission	519
12.3.2	General Operational Principles	520
12.3.3	Path Design	521
12.3.4	Performance Calculation	529
12.4	Summary	541
	Endnotes	541
Chapter 13	End-to-End Performance	543
13.1	Introduction	544
13.2	Quality Standards and Requirements	544
13.3	Performance Allocations Among Sections of the Cable System	549
13.4	Noise and Distortion Allocations in Cable Systems	550
13.4.1	Carrier to Noise	550
13.4.2	CTB and CSO	552
13.5	Typical Network Transmission Quality Under Operation Conditions	553
13.5.1	Carrier-to-Noise Ratio	555
13.5.2	Intermodulation Products from Discrete Carriers	555

13.5.3	Composite Intermodulation Noise (CIN)	557
13.5.4	Laser Transmitter Clipping Distortion	557
13.5.5	Hum Modulation	557
13.5.6	Microreflections	558
13.5.7	Group Delay and In-Band Response Variations	558
13.5.8	Local Oscillator and Other Interfering Signals from Receivers	568
13.5.9	Antenna-Conducted Ingress from Receivers	569
13.5.10	Signal Levels and Stability	570
13.6	Summary	570
	Endnotes	572

Chapter 14	Upstream Issues	575
14.1	Introduction	576
14.2	The Two-Way Node	576
14.3	Downstream and Upstream Frequency Partitioning	577
14.4	Group Delay of Diplex Filters	578
14.4.1	Upstream Group Delay	578
14.5	Block Conversion	579
14.6	Return Signal Level Issues	581
14.6.1	Measurement of Return Signal Levels	581
14.6.2	Long Loop Automatic Level Control	584
14.6.3	Thermal Gain Control	586
14.6.4	Return Signal Levels at the Tap	586
14.7	Optional Ways to Specify Return Lasers	588
14.7.1	Data- or Video-Grade Classification	588
14.7.2	Discrete Carrier Testing and Classification	589
14.7.3	Noise Power Ratio Testing and Classification	590
14.8	Characteristics of Return Lasers	593
14.8.1	Fabry-Perot Lasers	594
14.8.2	Distributed Feedback Lasers	595
14.8.3	Return Path Combining at the Headend	597
14.9	Spurious Signals in the Return Path	598
14.9.1	Plant Unavailability Analysis Based on Undesired Signals	599
14.9.2	Discrete Interfering Signal Probability (DISP)	600
14.9.3	Plant Unavailability Analysis Based on Threshold Boundaries	600
14.10	Characteristics of the Composite Reverse Signal	603
14.11	The Reaction of Active Components to Signal Characteristics	605
14.11.1	Effect of Laser Clipping—Frequency Domain View	605
14.11.2	Effect of Laser Clipping—Time Domain View	605
14.11.3	Amplifier Characteristics	608
14.12	Common Path Distortion	608
14.13	Return Path Interference Mitigation Techniques	609
14.13.1	Option 1: Drop Filters	609
14.13.2	Option 2: Return Attenuation	610
14.13.3	Option 3: Move Diplexers and Attenuator to Midspan	612

14.13.4 Option 4: Frequency Hopping	613
14.13.5 Option 5: Error Correction	613
14.14 Examples of Signal Apportionment	613
14.14.1 Few Return Services, F-P Laser	618
14.14.2 Many Return Services, DFB Laser	620
14.15 Summary	620
Endnotes	620

Part 5 System Architecture

Chapter 15	Service-Related Architecture Requirements	625
15.1	Introduction	626
15.2	Performance Parameters	626
15.2.1	Information Capacity	626
15.2.2	Network Reliability and Availability	635
15.2.3	Signal-Processing Equipment Distribution	639
15.3	Requirements by Service Type	643
15.3.1	Broadcast Video Services	643
15.3.2	Narrowcast Video Services	645
15.3.3	On-Demand and Interactive Video Services	648
15.3.4	Packet Data Services—Internet Access	648
15.3.5	Voice-Grade Telephony Services	651
15.3.6	Utility Monitoring and Control Services	655
15.4	Summary	656
	Endnotes	656
Chapter 16	Architectural Elements and Examples	659
16.1	Introduction	660
16.2	Architectural Elements	660
16.2.1	Terminal Equipment	660
16.2.2	Coaxial Distribution Network	663
16.2.3	Fiber Node	665
16.2.4	Fiber Interconnects	668
16.2.5	Switched Video Headend Structures	673
16.3	Architectural Examples	676
16.3.1	Cable Area Network (CAN)	676
16.3.2	Evolutionary Star Networks	677
16.3.3	Double Star Networks	678
16.3.4	Star/FTTC Hybrid	679
16.3.5	Hybrid Sheath/Shared/Repeating Digital Ring	681
16.3.6	Ring/Ring/Star with WDM	682
16.3.7	Ring/Mesh/Star Regional Architecture	684
16.3.8	Hybrid Ring/Star	685
16.4	Summary	687
	Endnotes	688

Chapter 17	Network Reliability and Availability	689
17.1	Introduction	690
17.2	History and Benchmarking	690
17.2.1	Telephony	690
17.2.2	Cable Television	691
17.2.3	Cable Television Versus Telephony Reliability and Availability Definitions	692
17.3	Definitions and Basic Calculations	692
17.4	Effects of Redundant Network Connections	695
17.5	Absolute Versus User-Perceived Parameters	697
17.6	Network Analysis	699
17.6.1	Logical Subdivision of the Network for Analysis	700
17.6.2	Assigning Network Components to Subdivisions	700
17.6.3	Determining Component Failure Rates	703
17.6.4	Estimating MTTR	707
17.6.5	Special Considerations Within Headends and Hubs	708
17.6.6	Special Considerations for Two-Way Systems	709
17.6.7	Calculation of Failure Rates and Availability	710
17.7	Analysis of a Typical HFC Network	710
17.7.1	Architecture	711
17.7.2	Video Services Performance	712
17.7.3	Wired Telephony Services Performance	714
17.7.4	Effect of Improved Powering on Telephony Performance	715
17.8	Summary	717
	Endnotes	718

Part 6 Customer Interface Issues

Chapter 18	Program Denial Technologies	723
18.1	Introduction	724
18.2	Non-Set Top Resident Program Denial	724
18.2.1	Negative Traps	725
18.2.2	Positive Traps	726
18.2.3	Interdiction	728
18.2.4	Broadband Descrambling	730
18.3	Set Top Resident Program Denial	730
18.3.1	Sync Suppression Scrambling	730
18.3.2	Scrambling by Video Inversion	738
18.3.3	Phase Modulation of the Picture Carrier	739
18.3.4	Audio Scrambling	740
18.4	Other Scrambling Methods	740
18.4.1	Line Dicing	740
18.4.2	Line Rotation	741
18.4.3	Line Shuffling	742
18.4.4	Time Jitter	742

18.5	The Set Top Terminal	743
18.5.1	Set Top Terminal Classification	743
18.5.2	Elements of a Modern Set Top Terminal	746
18.6	The Back-of-Set Interface	749
18.7	Program Denial for Digital Transmission	750
18.8	Summary	751
	Endnotes	751
Chapter 19	Consumer Electronics Interface	753
19.1	Introduction	754
19.2	The Nature of the Interface	754
19.2.1	Cable Services	754
19.2.2	Relevant Cable Set Top Terminal Features	755
19.2.3	Relevant Consumer Electronics Characteristics and Features	756
19.2.4	Consumer Frustration	757
19.3	Connecting Cable, TVs, VCRs, and Set Top Terminals	757
19.3.1	Basic Cable and Trapped Premium Service Connection	757
19.3.2	A Simple Start	759
19.3.3	Two Set Top Terminal Case	760
19.3.4	Minimal Scrambled Channel Usage	762
19.3.5	Improved Simple Connection	764
19.3.6	Problematic Connection Example	765
19.3.7	Improvements	767
19.4	Consumer Electronics Interface Issues	768
19.4.1	The Importance of Compatibility	768
19.4.2	The Participants and Their Priorities	768
19.4.3	The Subscriber/Consumer	768
19.4.4	The Service Provider	768
19.4.5	The Service Provider's Equipment Manufacturer	771
19.4.6	The Consumer Electronics Industry	772
19.4.7	The Two Extremes	773
19.4.8	The Origins of the Problem	773
19.4.9	Other "Cable-Ready" Issues	774
19.5	Frustrated Product Features	775
19.5.1	Remote Control	775
19.5.2	Timers	776
19.5.3	Picture-in-Picture	776
19.6	Early Attempts	777
19.6.1	Universal Remotes	777
19.6.2	Electronic Program Guides	778
19.6.3	The TV Integrating Device	778
19.7	Management of Expectations	779
19.7.1	Complexity Overload	779
19.8	Legal Aspects of Cable-Consumer Electronics Compatibility	779
19.8.1	Compatibility Definitions	779
19.8.2	The 1992 Cable Act's Definition of Compatibility	780
19.8.3	The 1996 Telecommunications Act	782

19.9	Standards	784
19.9.1	The Need for Standards	784
19.9.2	Mandatory Standards	785
19.9.3	Official Voluntary Standards	785
19.9.4	De Facto Standards	786
19.10	OpenCable	787
19.11	National Renewable Security System	787
19.12	Summary	788
	Endnotes	788
<hr/>		
Chapter 20	Equipment Compatibility	791
20.1	Introduction	792
20.1.1	Broadcast Versus Broadband Receivers	792
20.2	Levels of Interference	793
20.3	Direct Pickup Interference	794
20.3.1	Estimate of Exposure	794
20.3.2	Estimate of Susceptibility	795
20.4	Receiver Performance	796
20.4.1	Reradiation of Cable Signals	797
20.4.2	Local Oscillator Leakage and Backfeed	798
20.4.3	A/B Switch Isolation	798
20.4.4	DPU Backfeed	799
20.4.5	VCR Through-Loss	799
20.4.6	Adjacent Channel Rejection	799
20.4.7	Image Rejection	800
20.4.8	Tuner Overload Performance	801
20.5	The Federal Communications Commission's Role	801
20.6	Summary	802
	Endnotes	803
<hr/>		
Appendix A	Channel Allocation	805
<hr/>		
Appendix B	Video Waveforms	809
<hr/>		
Glossary		815
Index		841

where

D = the inner diameter of the shield

d = the outer diameter of the center conductor

ϵ = the dielectric constant

9.2.3 Attenuation as a Function of Frequency

Signal loss (attenuation) through coaxial cable can occur through any of four principal means:

- Radiation out of the cable due to imperfect shielding
- Resistive losses in the cable conductors
- Signal absorption in the dielectric of the cable
- Signal reflection due to mismatches between the cable and terminations or along the cable due to nonuniform impedance

Even when cables have perfect shields, exact impedance matches, and uniform construction, imperfect dielectrics and resistive conductors will cause loss. The general equation for this residual cable loss is

$$\alpha = 4.344 \left(\frac{R}{Z_0} \right) + 2.774 F_p \sqrt{\epsilon} f \quad (9.2)$$

where

α = the attenuation of the cable in dB/100 feet*

R = the effective ohmic resistance of the sum of the center and outer conductors per 100 feet of cable length at f

F_p = the power factor of the dielectric used

f = the frequency in MHz

The currents in the conductors are proportional to the strength of the magnetic fields at the conductor surface. If the conductors had no resistance, the RF currents would travel only on the surface. In real conductors, however, the current extends into the conductor, decreasing exponentially with depth. This property is known as *skin effect*, and the distance from the surface to where the current has decreased to $1/e$ (36.8%) of the surface amount is known as the *skin depth* at that frequency. It is related to frequency by the formula

* In accordance with common North American practice, all attenuation values will be given in decibels per 100 feet of length. This has the advantage that signal loss becomes a linear function of length and of simple conversion to metric units of length.

$$\delta = \frac{1}{\sqrt{f}} 2.60 \sqrt{\frac{\rho}{\rho_c}} \quad (9.3)$$

where

δ = the skin depth in mils (thousands of an inch)

ρ/ρ_c = the resistivity of the conductor relative to copper

f = the frequency in MHz¹

The formula is valid only for nonferrous materials such as aluminum or copper.

Over a typical downstream frequency range of 54–750 MHz, the skin depth in copper will vary from 0.00035 to 0.00009 inch and will increase to 0.0012 inch at 5 MHz (the lower end of the upstream frequency range).

The effective resistance of the conductor is the same as if it were a tube of material whose thickness is equal to the skin depth with the current distributed equally throughout its volume. The resistance of this tube will be

$$R = 0.0996 \frac{\sqrt{f}}{d} \sqrt{\frac{\rho}{\rho_c}} \quad (9.4)$$

where

R = the resistance per 100 feet of the conductor

ρ/ρ_c = the resistivity of the conductor relative to copper

f = the frequency in MHz

d = the conductor diameter in inches

Taking into account the resistance of both center and outer conductors, Equation (9.2) can be rewritten as

$$\alpha = \frac{0.433}{Z_0} \left(\frac{\sqrt{\rho_d/\rho_c}}{d} + \frac{\sqrt{\rho_D/\rho_c}}{D} \right) \sqrt{f} + 2.774(F_p \sqrt{\epsilon})f \quad (9.5)$$

where

ρ_d/ρ_c = the resistivity of the center conductor material relative to copper

ρ_D/ρ_c = the resistivity of the shield material relative to copper

This has one term that increases as the square root of frequency and one that increases linearly with frequency. For most cable constructions (discussed later), the conductor loss will dominate the dielectric loss so that the overall cable attenuation will increase approximately as the square root of frequency. Figure 9.2 shows the specified variation in loss for several cables in comparison to an ideal

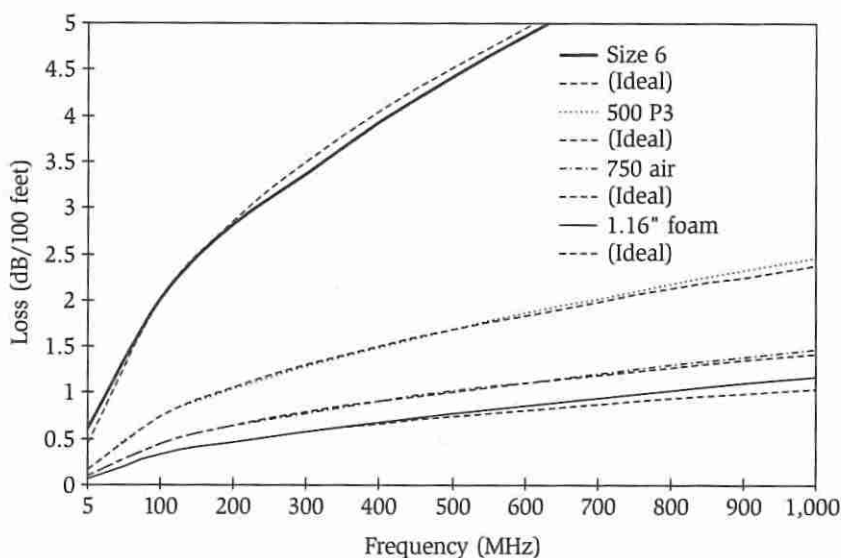


Figure 9.2 Cable loss: specified versus ideal.

square-root relationship (with the curves matched at 100 MHz). Note that the agreement is excellent for cables ranging from drop sizes to the largest trunk cables, indicating the relatively small contribution from dielectric losses.

A common cable construction, known as P3, utilizes a solid aluminum outer conductor, a foamed dielectric ($\sqrt{\epsilon} = 1.15$), and a copper-coated aluminum center conductor. It is available in a number of nominal sizes (referenced to the *outer* diameter of the aluminum shield in inches). For this family of cables, the attenuation can be approximated using

$$\alpha = \left[\frac{0.036}{D_{\text{nom}}} \right] \sqrt{f} + 0.0002f \quad (9.6)$$

where

α = the attenuation in dB/100 feet

D_{nom} = the nominal shield outer diameter in inches

f = the frequency in MHz

Other cable types using thinner shields and/or air dielectrics will have slightly lower losses for the same outer diameter, whereas solid dielectric cables will have higher losses.