# Table of Contents

**Chapter 1: Principles of Transmission**

- Metallic Media .................................................. 1-1
- Electrical Conductors ........................................... 1-2
- American Wire Gauge (AWG) ..................................... 1-6
- Insulation .......................................................... 1-6
- Balanced Twisted-Pair Cables ................................. 1-9
- Environmental Considerations ................................. 1-10
- Cable Shielding .................................................. 1-13
- Drain Wires ....................................................... 1-16
- Analog Signals .................................................. 1-17
- Telephony ......................................................... 1-23
- Digital Signals .................................................. 1-29
- Types of Transmission Circuits ............................... 1-39
- Asynchronous and Synchronous Transmission ............... 1-40
- Digital Hierarchy ............................................... 1-41
- Video Transmission ............................................. 1-46
- Transmission Line Concepts ................................... 1-48
- Balanced Twisted-Pair Performance ......................... 1-57
- Balanced Twisted-Pair Channel Performance ............... 1-58
- Balanced Twisted-Pair Permanent Link Performance ...... 1-62
- Balanced Twisted-Pair Applications ......................... 1-63
- Optical Fiber ..................................................... 1-78
- Optical Fiber Transmitters ..................................... 1-79
- Optical Fiber Receivers ........................................ 1-88
- Optical Fiber Medium .......................................... 1-89
- Bandwidth ......................................................... 1-91
- Optical Fiber Applications Support Information .......... 1-103
- Verifying Optical Fiber Performance and Electronics Compatibility ........................................ 1-105
- Selecting an Optical Fiber Core Size to Application or Original Equipment Manufacturer (OEM) Specifications ........................................ 1-116
- Synchronous Optical Network (SONET) and Synchronous Digital Hierarchy (SDH) Concepts ........................................ 1-116
- Appendix ......................................................... 1-121
Table of Contents

**Chapter 2: Electromagnetic Compatibility**
- Electromagnetic Compatibility (EMC) ........................................ 2-1
- Electromagnetic Spectrum ...................................................... 2-2
- Electromagnetics ................................................................. 2-6
- Measuring Electromagnetic Compatibility (EMC) ...................... 2-9
- Electromagnetic Interference (EMI)—A Problem ....................... 2-12
- Electromagnetic Compatibility (EMC)—The Solution ............... 2-15
- Electromagnetic Interference (EMI) and Cabling ..................... 2-18
- Electromagnetic Qualification Parameters .............................. 2-19
- Unwanted Signals ............................................................... 2-24
- Grounding (Earthing) ........................................................... 2-27
- Minimizing Electromagnetic Interference (EMI) ...................... 2-35
- Considerations for Electromagnetic Compatibility (EMC) in Cabling Systems ......................................................... 2-36
- Interference Reduction in Shielded Rooms ............................... 2-42
- Telecommunications Cabling within Joint-Use Tunnel .......... 2-44

**Chapter 3: Telecommunications Spaces**
- Telecommunications Spaces .................................................... 3-1
- Telecommunications Spaces Considerations ........................... 3-1
- Telecommunications Rooms (TRs) and Telecommunications Enclosures (TEs) ................................................................. 3-18
- Telecommunications Room (TR) and Telecommunications Enclosure (TE) Applications ................................................................. 3-19
- Telecommunications Room (TR) Design ................................ 3-21
- General Requirements for All Telecommunications Enclosures (TEs) ............................................................... 3-26
- Equipment Rooms (ERs) ......................................................... 3-28
- Equipment Room (ER) Design ............................................... 3-30
- Locating the Equipment Room (ER) .................................... 3-32
- Space Allocation and Layout ................................................ 3-37
- Cable Installation and Pathways ............................................. 3-42
- Electrical Power ................................................................. 3-45
- Heating, Ventilation, and Air-Conditioning (HVAC) Environmental Control .......................................................... 3-48
- Miscellaneous Considerations ............................................. 3-50
- Design Approval, Buildout, and Final Inspection .................... 3-50
- Entrance Facilities (EFs) ...................................................... 3-52
Chapter 4: Backbone Distribution Systems

- Backbone Distribution Systems ......................................................... 4-1
- Cabling Topologies .................................................................................. 4-3
- Hierarchical Star Campus Backbone Designs ........................................ 4-24
- Telecommunications Rooms (TRs) and Telecommunications Enclosures (TEs) ... 4-31
- Building Backbones .............................................................................. 4-32
- Choosing Media .................................................................................... 4-38
- Backbone Building Pathways (Internal) ................................................. 4-41
- Miscellaneous Support Facilities ........................................................... 4-47
- Bonding and Grounding (Earthing) ........................................................ 4-49
- Backbone Planning .............................................................................. 4-49
- Indoor Hardware ................................................................................... 4-51
- Ethernet in the First Mile (EFM) ............................................................. 4-53

Chapter 5: Horizontal Distribution Systems

- Horizontal Distribution Systems ............................................................. 5-1

SECTION 1: HORIZONTAL CABLEING SYSTEMS

- Horizontal Cabling Systems ................................................................. 5-5
- Horizontal Cabling Media ...................................................................... 5-17
- Work Areas and Open Office Cabling .................................................... 5-20
- Simultaneous Data and Power Transmission within Horizontal Cabling ... 5-37
- Centralized Optical Fiber Cabling .......................................................... 5-44
- Fiber-To-The-Outlet (FTTO) ................................................................. 5-48
- Horizontal Pathways for Fiber to the Office (FTTO) Systems ............... 5-53
- Passive Optical Networks (PONs) ......................................................... 5-56

SECTION 2: HORIZONTAL PATHWAYS

- Horizontal Pathways ............................................................................ 5-65
- Types of Horizontal Pathways ............................................................... 5-70
- Ceiling Distribution Systems ................................................................. 5-93
- Other Horizontal Pathways ................................................................... 5-110

SECTION 3: ADA REQUIREMENTS

- Americans with Disabilities Act (ADA) Requirements ....................... 5-117
- Appendix: Disabled Access and the Americans with Disabilities Act (ADA) .... 5-125
# Table of Contents

## Chapter 6: ICT Cables and Connecting Hardware
- ICT Cables and Connecting Hardware ........................................... 6-1
- Balanced Twisted-Pair Cables .................................................. 6-3
- Optical Fiber Cables .............................................................. 6-14
- Coaxial Cables ................................................................. 6-24
- Balanced Twisted-Pair Connectors ........................................... 6-33
- Balanced Twisted-Pair Connecting Hardware ......................... 6-55
- Balanced Twisted-Pair Connecting Blocks ............................... 6-61
- Optical Fiber Connectors ...................................................... 6-77
- Optical Fiber Connecting Hardware ....................................... 6-89
- Coaxial Connectors ............................................................. 6-95
- Coaxial Connecting Hardware ............................................... 6-103

## Chapter 7: Firestop Systems
- Firestop Systems ................................................................. 7-1
- Firestop and Disaster Avoidance ............................................. 7-3
- Fire-Resistance Rated Construction ........................................ 7-6
- Firestop Considerations ....................................................... 7-8
- Testing and Guidelines for Firestops ....................................... 7-11
- Types of Firestop Systems .................................................... 7-19
- Firestop for Brick, Concrete Block, and Concrete Walls .......... 7-32
- Firestop for Framed Wall Assemblies ...................................... 7-36
- Firestop for Lath and Plaster Walls ....................................... 7-42
- Firestop for Combination Walls ............................................. 7-42
- Firestop for Floor Assemblies ............................................... 7-43
- Firestop for Floor/Ceiling Assemblies .................................... 7-44
- Structural Steel Floor Units with Concrete Floor Fill without Suspended Ceiling Membranes .............................................. 7-47
- Firestop for Roof/Ceiling Assemblies .................................... 7-47
- Fire-Rated Vertical Shafts .................................................... 7-48
- Firestop for Curtain Wall Floor/Ceiling Seals ....................... 7-49
- General Firestop Considerations .......................................... 7-52
- Appendix A: Approved Firestop Methods .............................. 7-54
- Appendix B: Testing and Guidelines for Firestops ................... 7-108

## Chapter 8: Bonding and Grounding (Earthing)
- Bonding and Grounding (Earthing) ......................................... 8-1
- Alternating Current (ac) Grounding (Earthing) Electrode System .................................................. 8-5
- Equipment Grounding (Earthing) System ................................ 8-8
- Telecommunications Bonding Infrastructure ......................... 8-12
- Lightning Exposure ............................................................. 8-26
# Table of Contents

## Chapter 9: Power Distribution
- Power Distribution .................................................. 9-1
- Alternating Current (ac) Power ................................. 9-2
- American Wire Gauge (AWG) ................................. 9-15
- Alternating Current (ac) Voltage Quality Problems ............... 9-18
- Power Distribution for Information Technology Equipment (ITE) Spaces ............. 9-25
- Electrical Safety ....................................................... 9-28
- Power System Redundancy ........................................ 9-31
- Power Conditioning/Power Protection ....................... 9-36
- Direct Current (dc) Power ....................................... 9-52
- Installation of Direct Current (dc) Systems ............. 9-61
- Batteries ................................................................. 9-63
- Power System Alarms ............................................. 9-72
- Power System Monitoring and Control ...................... 9-75
- Conductor Identification ....................................... 9-77

## Chapter 10: Telecommunications Administration
- Telecommunications Administration ......................... 10-1
- Identification Methods ........................................ 10-12
- Identification Systems ......................................... 10-23
- Labeling and Recordkeeping .................................. 10-31
- Administration of Large Telecommunications Spaces .......... 10-39

## Chapter 11: Field Testing of Structured Cabling
- Field Testing of Structured Cabling .......................... 11-1
- Balanced Twisted-Pair Cabling Tests ....................... 11-2
- Balanced Twisted-Pair Cabling Acceptance Tests .............. 11-11
- Coaxial Cabling Testing ......................................... 11-18
- Optical Fiber Cabling Tests .................................. 11-19
- Optical Fiber Cabling Acceptance Tests .................. 11-22
- Optical Fiber Cabling Field Testing ......................... 11-24
- Maintenance and Troubleshooting for Optical Fiber Cabling .............. 11-27
- Additional Optical Fiber Troubleshooting Tools and Equipment ................. 11-28

## Chapter 12: Outside Plant
- Outside Plant ......................................................... 12-1
- Telecommunications Service Entrances .................. 12-6
- Underground Entrances ........................................ 12-6
- Buried Entrances .................................................. 12-9
- Aerial Entrances ................................................... 12-10
- Other Telecommunications Service Entrance Considerations ................. 12-15
- Terminating Space for Telecommunications Entrance Facilities .............. 12-20
Terminating Conduit Inside a Building ............................................. 12-22
Network Interface (NI) Locations ................................................... 12-23
Outside Building Terminals (Pedestals and Cabinets) Pedestal Hardware
Mounted on Outside Walls .............................................................. 12-25
Direct-Buried Pathways ................................................................. 12-26
Trenches ....................................................................................... 12-28
Underground Pathways ................................................................. 12-32
Conduit Guidelines ...................................................................... 12-33
Terminating Conduit at a Designated Property Line ....................... 12-38
Maintenance Hole Guidelines ...................................................... 12-39
Aerial Plant Pathways ................................................................. 12-46

Chapter 13: Audiovisual Systems

Audiovisual (AV) Systems ............................................................... 13-1
Fundamentals ............................................................................. 13-2
Types of Signals ........................................................................ 13-10
Environmental Considerations ................................................... 13-30
Visual Display Systems ............................................................... 13-38
Program Audio and Speech Reinforcement Systems ................... 13-43
Signal Distribution Systems ....................................................... 13-52
Audioconferencing Systems ....................................................... 13-54
Videoconferencing Systems ....................................................... 13-70
Control Systems ..................................................................... 13-79
Overhead Paging Systems .......................................................... 13-82
Sound Masking Systems ............................................................. 13-92
Digital Signage Systems ............................................................. 13-96
Cable Television Distribution Systems ....................................... 13-100

Chapter 14: Building Automation Systems

Building Automation Systems (BAS) ............................................. 14-1
Building Automation Systems (BAS) Interfaces with Other Systems 14-6
Building Automation Systems (BAS) Communications Networks .... 14-17
Building Automation Systems (BAS) Electrical Characteristics ........ 14-23
# Table of Contents

## Chapter 15: Data Networks
- Data Networks .................................................. 15-1
- Open Systems Interconnection (OSI) Reference Model ................ 15-4
- Network Hardware ............................................. 15-8
- Network Software .............................................. 15-14
- Network Supported Systems .................................. 15-15
- Network Design ................................................. 15-19
- Computer Rooms .............................................. 15-21
- Campus and Multisite Network Design ......................... 15-33

## Chapter 16: Wireless Networks
- Wireless Networks ............................................ 16-1
- Services and Applications .................................. 16-2
- Frequency and Wavelength .................................. 16-6
- Electromagnetic Spectrum .................................. 16-14
- Wireless System Design ..................................... 16-22
- Selection of Technology ..................................... 16-25
- Components of a Wireless System ......................... 16-28
- Distributed Antenna Systems (DAS) ...................... 16-38
- Personal Area Networks (PANs) ........................... 16-65
- Wireless LAN (WLAN) Technology ...................... 16-67
- Wireless LAN (WLAN) Components ..................... 16-69

## Chapter 17: Electronic Safety and Security
- Electronic Safety and Security (ESS) ....................... 17-1
- Electronic and Electrical Door Hardware .................. 17-8
- Video Surveillance ............................................. 17-21
- Intrusion Detection ............................................ 17-28
- Fire Detection and Alarm Systems (FDAS) ................ 17-31
- Fire Alarm (FA) Notification ................................ 17-36
- Fire Alarm Control Panels (FACP) ........................ 17-39
- Digital Alarm Communicator System (DACS) ............ 17-49
- Area of Refuge and Rescue Two-Way Communication Systems 17-56
- Mass Notification and Emergency Communications (MNEC) Systems 17-59
# Table of Contents

## Chapter 18: Data Centers
- Data Centers .................................................. 18-1
- Data Center Redundancy and Availability .......................... 18-4
- Structured Cabling Hierarchy for Data Centers ..................... 18-9
- Guidelines for Telecommunications Cabling, Cable Containment, Equipment Racks, and Cabinets .................. 18-16
- Data Center Security ............................................ 18-24
- Operation, Ownership Costs, Environmental Impact, and Efficiency ........ 18-30
- Data Center Planning Considerations ............................ 18-30

## Chapter 19: Health Care
- Health Care ...................................................... 19-1
- Space and Pathway Requirements and Considerations ............. 19-2
- Nurse Call Systems .............................................. 19-10
- Code Call Systems ................................................. 19-20
- Hospital Security .................................................. 19-21
- Wireless Networks ............................................... 19-24
- Audiovisual (AV) Systems ....................................... 19-26
- Picture Archiving and Communication System (PACS) ............ 19-28
- Patient Monitoring ................................................. 19-28
- Radio Frequency Identification (RFID)-Based Systems ............ 19-30
- Interactive Patient Entertainment and Education Systems .......... 19-33
- Wayfinding and Signage .......................................... 19-37
- Regulatory Bodies and Organizations ................................ 19-38

## Chapter 20: Residential Cabling
- Residential Cabling ............................................... 20-1
- Components ....................................................... 20-4
- Planning the Cabling System .................................... 20-19
- Rough-In Cabling .................................................. 20-20
- Finish Cabling ...................................................... 20-22

## Chapter 21: Project Administration and Execution

### SECTION 1: PROFESSIONAL DEVELOPMENT
- Professional Development ...................................... 21-1

### SECTION 2: PROJECT MANAGEMENT
- Project Management .............................................. 21-5
# Table of Contents

## SECTION 3: DISASTER RECOVERY PLANNING AND RISK MANAGEMENT
- Disaster Recovery Planning and Risk Management ........................................ 21-63
- The Disaster Recovery Plan ........................................................................... 21-67

## Chapter 22: Special Design Considerations
- Special Occupancies .................................................................................. 22-1

## SECTION 1: MICE CONSIDERATIONS
- MICE Considerations .................................................................................. 22-5

### Appendix A: Codes, Standards, Regulations, and Organizations
- Codes, Standards, Regulations, and Organizations ......................................... A-1
- International Codes and Standards ............................................................... A-6
- Regional Codes and Standards ................................................................... A-30
- National Codes and Standards ................................................................... A-42
- Enforcement of United States (U.S.) Building Codes, Standards, and Regulations .......................................................................................... A-74
- Wireless Transmission Standards ................................................................. A-77
- Approval of Electrical Products and Equipment ........................................... A-81
- Regulations and Standards for Emissions and Immunity .............................. A-86
- Commercial Products Marketed in the United States (U.S.) ...................... A-86
- Radiation Limits for Class A and Class B ..................................................... A-87
- Emission Limits for Class A and Class B ..................................................... A-88
- Commercial Products Marketed Outside the United States (U.S.) ............. A-88
- Electrostatic Discharge (ESD) ..................................................................... A-93
- Network Interfaces and Demarcation Points in the United States (U.S.) ........ A-93
- Definitions .................................................................................................... A-94
- Classifications .............................................................................................. A-94
- Groups ......................................................................................................... A-94
- Types ............................................................................................................ A-95
- Analog Voice Connectors ............................................................................. A-96
- Analog Data Connectors ............................................................................... A-116
- Network Channel Equipment Connectors .................................................. A-134

### Appendix B: Legal Considerations
- Legal Aspects of Information and Communications Technology (ICT) Design ......................... B-1

### Glossary

### Bibliography

### Index
**Figures**

**Chapter 1: Principles of Transmission**

- **Figure 1.1** Calculated attenuation values for cables insulated with FEP, ECTFE, and PVC from 1 MHz to 135 MHz at 22 °C (72 °F) .................................................. 1-11
- **Figure 1.2** Calculated and measured attenuation values for cables insulated with FEP, ECTFE, and PVC from 1 MHz to 135 MHz at 40 °C (104 °F) .......................... 1-12
- **Figure 1.3** Calculated and measured attenuation values for cables insulated with FEP, ECTFE, and PVC from 1 MHz to 135 MHz at 60 °C (140 °F) .......................... 1-12
- **Figure 1.4** Example 1 of a sinusoidal signal .......................................................... 1-17
- **Figure 1.5** Example 2 of a sinusoidal signal .......................................................... 1-19
- **Figure 1.6** IP telephony architecture .............................................................. 1-27
- **Figure 1.7** DS1 frame format  ............................................................................ 1-31
- **Figure 1.8** E1 frame format ............................................................................. 1-32
- **Figure 1.9** Polar non-return-to-zero level ......................................................... 1-36
- **Figure 1.10** Bipolar AMI ............................................................................... 1-36
- **Figure 1.11** Biphase Manchester ...................................................................... 1-36
- **Figure 1.12** Two binary bits encoded into one quaternary (2B1Q) ................. 1-36
- **Figure 1.13** MLT-3, also referred to as NRZI-3 ................................................ 1-37
- **Figure 1.14** Composite video ........................................................................ 1-46
- **Figure 1.15** Two-conductor transmission line ............................................... 1-48
- **Figure 1.16** Resistive model ........................................................................... 1-49
- **Figure 1.17** Capacitance model ....................................................................... 1-49
- **Figure 1.18** Inductive model ........................................................................... 1-50
- **Figure 1.19** Primary transmission line parameters ...................................... 1-51
- **Figure 1.20** General transmission model ....................................................... 1-52
- **Figure 1.21** Example of a channel test configuration ..................................... 1-58
- **Figure 1.22** Permanent link test configuration ............................................... 1-62
- **Figure 1.23** Typical configuration of endspan and midspan power source equipment ........................................................................................................... 1-77
- **Figure 1.24** Spectral profile comparison of laser and LED .......................... 1-80
- **Figure 1.25** Spectral width of an LED source showing full width half maximum .......................................................................................................................... 1-81
- **Figure 1.26** Numerical aperture ..................................................................... 1-82
- **Figure 1.27** System bandwidth versus distance example ................................ 1-91
- **Figure 1.28** Pulse distortion because of rise time and data rate ..................... 1-93
- **Figure 1.29** Link bandwidth at 1300 nm using 62.5/125 micrometer multimode optical fiber .................................................................................................................. 1-97
- **Figure 1.30** Core and coating ......................................................................... 1-100
- **Figure 1.31** DSX optical multiplexing design .................................................. 1-118
- **Figure 1.32** SONET multiplexing design ......................................................... 1-119
- **Figure 1.33** WDM ......................................................................................... 1-120
Chapter 2: Electromagnetic Compatibility

Figure 2.1 Electromagnetic spectrum ........................................... 2-3
Figure 2.2 Dependence of the safe distance to EMI source on its power .... 2-10
Figure 2.3 Model T for a short wire channel .................................... 2-21
Figure 2.4 Surge test voltage waveform sample ............................... 2-23
Figure 2.5 CM versus DM ...................................................... 2-25
Figure 2.6 Ground loops in shielded cabling systems ....................... 2-28
Figure 2.7 Ground loop because of stray capacitance at high frequencies ... 2-29
Figure 2.8 Common impedance coupling interference ....................... 2-30
Figure 2.9 Field-to-cable and ground loop ...................................... 2-31
Figure 2.10 Coupling reduction as function of grounding (earthing) practice ... 2-32
Figure 2.11 Higher frequency twist decrease .................................... 2-33
Figure 2.12 Typical power line filter ........................................... 2-39
Figure 2.13 Isolation transformer scheme ....................................... 2-40
Figure 2.14 Samples of ferrite toroids, beads, and sleeves ................... 2-41
Figure 2.15 Balance concept ..................................................... 2-43
Figure 2.16 EMI susceptibility of circuits and systems connected through unshielded cables ........................................ 2-45
Figure 2.17 Ground loop and EMI immunity ..................................... 2-47

Chapter 3: Telecommunications Spaces

Figure 3.1 Typical cabinet and rack mounting hole spacing arrangements .... 3-15
Figure 3.2 Rack unit ............................................................ 3-15
Figure 3.3 Space considerations when sizing a telecommunications space .... 3-17
Figure 3.4 Typical TR layout .................................................. 3-23
Figure 3.5 Typical sleeve/conduit .............................................. 3-24
Figure 3.6 Typical shallow room layout ....................................... 3-25
Figure 3.7 Typical AP ER ..................................................... 3-34
Figure 3.8 Typical ER layout .................................................. 3-38

Chapter 4: Backbone Distribution Systems

Figure 4.1 Star topology ......................................................... 4-5
Figure 4.2 Hierarchical star topology .......................................... 4-6
Figure 4.3 Ring topology (simplified) .......................................... 4-8
Figure 4.4 Buildings connected by a physical ring topology .................. 4-9
Figure 4.5 Main backbone ring and redundant backbone star combined ...... 4-10
Figure 4.6 Physical star/logical ring topology .................................. 4-11
Figure 4.7 Clustered star topology with physical star/logical ring .............. 4-12
Figure 4.8 Bus topology .......................................................... 4-13
Figure 4.9 Tree and branch topology .......................................... 4-14
Figure 4.10 Fully connected mesh topology .................................... 4-15
Figure 4.11 Partially connected mesh topology ........................................... 4-17
Figure 4.12 Point-to-multipoint optical topology ........................................ 4-18
Figure 4.13 PTP optical fiber ................................................................. 4-19
Figure 4.14 PTP balanced twisted-pair topology ........................................ 4-22
Figure 4.15 Typical backbone hierarchical star topology for multiple buildings on 
a campus (inside and outside distribution) ............................................. 4-24
Figure 4.16 Example of multiple hierarchical level campus backbone design .... 4-26
Figure 4.17 Levels of cross-connections .................................................... 4-27
Figure 4.18 Logical bus topology ............................................................. 4-28
Figure 4.19 Logical ring topology implemented using a physical star topology . 4-29
Figure 4.20 Logical tree topology implemented using a hierarchical star topology .. 4-29
Figure 4.21 Star building backbone ......................................................... 4-33
Figure 4.22 Hierarchical star building backbone ....................................... 4-34
Figure 4.23 Redundant routing for building backbone (HCS [FDs] not linked) .... 4-35
Figure 4.24 Example of combined optical fiber/balanced twisted-pair backbone 
supporting voice and data traffic ............................................................ 4-36
Figure 4.25 ERs and AP cabling system interface cabling .............................. 4-37
Figure 4.26 Typical office building pathway layout .................................... 4-44
Figure 4.27 Typical sleeve and slot installations ......................................... 4-45
Figure 4.28 EFM network boundaries ....................................................... 4-53

Chapter 5: Horizontal Distribution Systems

Figure 5.1 Typical horizontal cabling system elements .................................. 5-2
Figure 5.2 Horizontal cabling system channel ............................................. 5-7
Figure 5.3 Horizontal cabling system channel model with four connection points . 5-8
Figure 5.4 Horizontal cabling system channel model with three connection points .. 5-9
Figure 5.5 Horizontal cabling system permanent link model with three 
connection points ....................................................................................... 5-10
Figure 5.6 Example of connection by means of cross-connection ................. 5-12
Figure 5.7 Example of connection by means of interconnection ................... 5-13
Figure 5.8 Example of connection by means of cross-connection and 
interconnection ......................................................................................... 5-14
Figure 5.9 Example of connection by means of double cross-connection ........ 5-15
Figure 5.10 Total cable length in the horizontal cabling system channel .......... 5-18
Figure 5.11 Pin/pair assignments ............................................................... 5-21
Figure 5.12 Typical dimensions for furniture opening for telecommunications 
faceplate ...................................................................................................... 5-24
Figure 5.13 Example of MUTOA application ............................................. 5-26
Figure 5.14 CPs used in a combined furniture system and private office work 
area environment ...................................................................................... 5-30
Figure 5.15 CPs located on all columns ...................................................... 5-33
Figure 5.16 CPs located in a space between the columns ............................. 5-34
Figure 5.17 CPs located in checkerboard order ........................................... 5-35
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.18</td>
<td>CPs located on columns close to the building core</td>
<td>5-36</td>
</tr>
<tr>
<td>5.19</td>
<td>Temperature versus wattage for category cable types</td>
<td>5-38</td>
</tr>
<tr>
<td>5.20</td>
<td>Insertion loss versus temperature for category cable types</td>
<td>5-39</td>
</tr>
<tr>
<td>5.21</td>
<td>Centralized optical fiber cabling</td>
<td>5-45</td>
</tr>
<tr>
<td>5.22</td>
<td>Traditional structured cabling LAN design compared with FTTO LAN</td>
<td>5-49</td>
</tr>
<tr>
<td>5.23</td>
<td>Traditional active Ethernet design compared with PON-based architecture</td>
<td>5-56</td>
</tr>
<tr>
<td>5.24</td>
<td>Underfloor conduit extended to individual telecommunications outlet boxes</td>
<td>5-70</td>
</tr>
<tr>
<td>5.25</td>
<td>Typical underfloor conduit system</td>
<td>5-71</td>
</tr>
<tr>
<td>5.26</td>
<td>Conduit bodies recommended for telecommunications cables</td>
<td>5-72</td>
</tr>
<tr>
<td>5.27</td>
<td>Recommended pull box configurations</td>
<td>5-82</td>
</tr>
<tr>
<td>5.28</td>
<td>Stringered access floor system</td>
<td>5-86</td>
</tr>
<tr>
<td>5.29</td>
<td>Recommended clearance for access floor spaces</td>
<td>5-88</td>
</tr>
<tr>
<td>5.30</td>
<td>Typical zoned ceiling (plan view)</td>
<td>5-96</td>
</tr>
<tr>
<td>5.31</td>
<td>Conduit-based ceiling zone (elevation view)</td>
<td>5-97</td>
</tr>
<tr>
<td>5.32</td>
<td>Rules of installation for discrete cable support facilities</td>
<td>5-99</td>
</tr>
<tr>
<td>5.33</td>
<td>Raceways and fittings</td>
<td>5-101</td>
</tr>
<tr>
<td>5.34</td>
<td>Attaching various utility columns</td>
<td>5-103</td>
</tr>
<tr>
<td>5.35</td>
<td>Perimeter raceway</td>
<td>5-112</td>
</tr>
<tr>
<td>5.36</td>
<td>Molding raceway</td>
<td>5-113</td>
</tr>
<tr>
<td>5.37</td>
<td>Side-reach telephones</td>
<td>5-121</td>
</tr>
<tr>
<td>5.38</td>
<td>Forward-reach telephones</td>
<td>5-122</td>
</tr>
<tr>
<td>5.39</td>
<td>International teletypewriter/text telephone symbol and volume control telephone symbol</td>
<td>5-124</td>
</tr>
</tbody>
</table>

**Chapter 6: ICT Cables and Connecting Hardware**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>Balanced twisted-pair cable construction types</td>
<td>6-6</td>
</tr>
<tr>
<td>6.2</td>
<td>Examples of balanced twisted-pair cables</td>
<td>6-7</td>
</tr>
<tr>
<td>6.3</td>
<td>Multimode optical fiber</td>
<td>6-16</td>
</tr>
<tr>
<td>6.4</td>
<td>Singlemode optical fiber</td>
<td>6-17</td>
</tr>
<tr>
<td>6.5</td>
<td>Side view of a loose-tube optical fiber cable</td>
<td>6-19</td>
</tr>
<tr>
<td>6.6</td>
<td>Loose-tube furcating harness</td>
<td>6-19</td>
</tr>
<tr>
<td>6.7</td>
<td>Loose-tube optical fiber cable</td>
<td>6-20</td>
</tr>
<tr>
<td>6.8</td>
<td>Tight-buffered optical fiber cable, distribution construction</td>
<td>6-21</td>
</tr>
<tr>
<td>6.9</td>
<td>Tight-buffered optical fiber cable, breakout construction</td>
<td>6-22</td>
</tr>
<tr>
<td>6.10</td>
<td>Series-6 quad shield (screen) coaxial cable</td>
<td>6-24</td>
</tr>
<tr>
<td>6.11</td>
<td>Classification of cables and wires according to the NEC</td>
<td>6-30</td>
</tr>
<tr>
<td>6.12</td>
<td>110-style IDC connector design</td>
<td>6-34</td>
</tr>
<tr>
<td>6.13</td>
<td>Examples of 66-style connector designs</td>
<td>6-37</td>
</tr>
<tr>
<td>6.14</td>
<td>BIX-style IDC connector design</td>
<td>6-40</td>
</tr>
<tr>
<td>6.15</td>
<td>Examples of LSA-style connector designs</td>
<td>6-42</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>6.16</td>
<td>8P8C unkeyed modular plug</td>
<td>6-45</td>
</tr>
<tr>
<td>6.17</td>
<td>8P8C modular plugs for stranded and solid conductors</td>
<td>6-46</td>
</tr>
<tr>
<td>6.18</td>
<td>8P8C modular jack</td>
<td>6-48</td>
</tr>
<tr>
<td>6.19</td>
<td>Modular jack design</td>
<td>6-48</td>
</tr>
<tr>
<td>6.20</td>
<td>Eight-position jack pin/pair assignments (front view)</td>
<td>6-49</td>
</tr>
<tr>
<td>6.21</td>
<td>50-position miniature ribbon connector</td>
<td>6-51</td>
</tr>
<tr>
<td>6.22</td>
<td>50-position miniature ribbon connector design</td>
<td>6-52</td>
</tr>
<tr>
<td>6.23</td>
<td>Telecommunications outlet/connectors</td>
<td>6-55</td>
</tr>
<tr>
<td>6.24</td>
<td>Examples of work area telecommunications outlet designs</td>
<td>6-56</td>
</tr>
<tr>
<td>6.25</td>
<td>Rack-mount ≈483 mm (19 in) modular patch panel</td>
<td>6-57</td>
</tr>
<tr>
<td>6.26</td>
<td>Modular patch panel with cable management bar installed in an ≈483 mm (19 in) equipment rack</td>
<td>6-59</td>
</tr>
<tr>
<td>6.27</td>
<td>66-style block, 89-style mounting brackets, and a distribution frame with installed 66-style blocks</td>
<td>6-61</td>
</tr>
<tr>
<td>6.28</td>
<td>110-style wiring blocks</td>
<td>6-63</td>
</tr>
<tr>
<td>6.29</td>
<td>BIX-style connecting blocks mounted in a distribution frame</td>
<td>6-66</td>
</tr>
<tr>
<td>6.30</td>
<td>25-pair BIX-style connecting strip</td>
<td>6-67</td>
</tr>
<tr>
<td>6.31</td>
<td>LSA-style connecting blocks</td>
<td>6-68</td>
</tr>
<tr>
<td>6.32</td>
<td>10-pair LSA-style connecting block</td>
<td>6-69</td>
</tr>
<tr>
<td>6.33</td>
<td>Hybrid equipment cord assembly or hybrid patch cord assembly</td>
<td>6-71</td>
</tr>
<tr>
<td>6.34</td>
<td>Example of MS2 and Type 710 IDC connector splicing contacts</td>
<td>6-73</td>
</tr>
<tr>
<td>6.35</td>
<td>Example of single-pair splice connectors and modules</td>
<td>6-74</td>
</tr>
<tr>
<td>6.36</td>
<td>Example of multipair splice connectors and modules</td>
<td>6-75</td>
</tr>
<tr>
<td>6.37</td>
<td>LC-style optical fiber adapters and connectors</td>
<td>6-80</td>
</tr>
<tr>
<td>6.38</td>
<td>SC-style optical fiber adapters and connectors</td>
<td>6-81</td>
</tr>
<tr>
<td>6.39</td>
<td>ST-style optical fiber connector</td>
<td>6-83</td>
</tr>
<tr>
<td>6.40</td>
<td>Array-style optical fiber connector and adapter (example of Type-A MPO configuration)</td>
<td>6-84</td>
</tr>
<tr>
<td>6.41</td>
<td>Array-style optical fiber connector and adapter (example of Type-B MPO configuration)</td>
<td>6-84</td>
</tr>
<tr>
<td>6.42</td>
<td>Fusion splicer</td>
<td>6-85</td>
</tr>
<tr>
<td>6.43</td>
<td>Mechanical splice open position</td>
<td>6-86</td>
</tr>
<tr>
<td>6.44</td>
<td>Optical fiber pigtail splicing</td>
<td>6-87</td>
</tr>
<tr>
<td>6.45</td>
<td>Cross-connection of optical fiber cabling segments (first- and second-level backbone)</td>
<td>6-90</td>
</tr>
<tr>
<td>6.46</td>
<td>Interconnection of equipment to backbone cabling</td>
<td>6-91</td>
</tr>
<tr>
<td>6.47</td>
<td>Hybrid optical fiber patch cord assembly</td>
<td>6-92</td>
</tr>
<tr>
<td>6.48</td>
<td>BNC-style connector</td>
<td>6-95</td>
</tr>
<tr>
<td>6.49</td>
<td>BNC-style connector components</td>
<td>6-96</td>
</tr>
<tr>
<td>6.50</td>
<td>BNC-style connector plug and jack</td>
<td>6-96</td>
</tr>
<tr>
<td>6.51</td>
<td>50-ohm and 75-ohm bayonet BNC-style connectors</td>
<td>6-97</td>
</tr>
</tbody>
</table>
Figure 6.52 One-piece crimp-style F-style connector 6-99
Figure 6.53 N-style coaxial connector 6-101
Figure 6.54 Standard wall-mount multimedia and modular furniture multimedia outlets featuring F-style coaxial connectors 6-103
Figure 6.55 BNC-style bracket mount and F-style ≈483 mm (19 in) rack-mount coaxial patch panels 6-105

Chapter 7: Firestop Systems
Figure 7.1 Standard time/temperature curves up to three hours 7-10
Figure 7.2 Elastomeric modules (within frames) 7-20
Figure 7.3 Mechanical firestop system 7-21
Figure 7.4 Example of fire-rated pathway device 7-22
Figure 7.5 Typical plastic pipe device 7-24
Figure 7.6 Typical cast-in-place firestop device 7-25
Figure 7.7 Examples of poke-thru 7-26
Figure 7.8 Continuous conduit penetration through concrete 7-32
Figure 7.9 Cable penetration in concrete wall or floor 7-33
Figure 7.10 PVC innerduct penetration in concrete wall 7-33
Figure 7.11 PVC innerduct penetration in concrete floor 7-34
Figure 7.12 Qualified cable tray seal system in concrete wall 7-35
Figure 7.13 Qualified steel pipe system in framed wall 7-36
Figure 7.14 Telecommunications cable seal system for framed wall 7-37
Figure 7.15 Non-metallic innerduct penetration of framed wall 7-38
Figure 7.16 Sleeve systems for retrofit over existing cables 7-39
Figure 7.17 Sleeve system with cable tray 7-40
Figure 7.18 Sleeve system with cable support 7-40
Figure 7.19 Expansion joint or slot in a floor 7-49
Figure 7.20 Expansion joint or slot in a wall 7-50
Figure 7.21 Perimeter gap 7-50
Figure 7.22 Seal system in a curtain wall 7-51
Figure 7.23 Typical label for all firestops 7-53
Figure 7.24 Concrete floor or wall 7-55
Figure 7.25 Typical framed wall penetration 7-56
Figure 7.26 Typical concrete wall penetration 7-57
Figure 7.27 Concrete wall or floor (metallic pipes) 7-58
Figure 7.28 Concrete wall or floor (no penetrating item) 7-59
Figure 7.29 Concrete wall or floor (electrical power, telecommunications, and building signaling cables) 7-60
Figure 7.30 Concrete floor (electrical power and telecommunications cables) 7-61
Figure 7.31 Framed wall (steel pipes or conduit) 7-62
Figure 7.32 Framed wall (cable) 7-63
Figure 7.33  Framed wall (steel or aluminum cable trays) ........................................... 7-64
Figure 7.34  Concrete wall (cable) .............................................................................. 7-65
Figure 7.35  Concrete floor or wall (bus duct) ............................................................. 7-66
Figure 7.36  Concrete floor or wall (steel pipe) ........................................................... 7-67
Figure 7.37  Framed wall (cables) .............................................................................. 7-68
Figure 7.38  Framed wall (PVC pipe [closed or vented]). ............................................. 7-69
Figure 7.39  Floor or wall (PVC, CPVC, or PB pipe [closed or vented] or RNC) ......... 7-70
Figure 7.40  Wood joist floor (steel or copper pipe) .................................................... 7-72
Figure 7.41  Concrete floor or wall (electrical power, building signaling, control, and telecommunications cables) ................................................................. 7-73
Figure 7.42  Concrete floor or wall (steel or aluminum cable tray) ......................... 7-74
Figure 7.43  Framed wall (steel or aluminum cable tray) ............................................. 7-75
Figure 7.44  Floor or wall (steel or aluminum cable tray) .......................................... 7-76
Figure 7.45  Floor or wall (pipes and cable tray) ........................................................ 7-77
Figure 7.46  Head of wall joint (framed wall or concrete, fluted deck) ..................... 7-78
Figure 7.47  Head of wall joint (concrete wall or concrete fluted deck) ................. 7-79
Figure 7.48  Concrete floor or wall (telecommunications cable) ................................ 7-80
Figure 7.49  Framed wall (telecommunications cable) .............................................. 7-81
Figure 7.50  Framed wall (telecommunications cable with sleeve) ......................... 7-82
Figure 7.51  Framed wall (telecommunications cable with firestop wrap strip) ...... 7-83
Figure 7.52  Concrete floor or wall (telecommunications cable with sleeve) ......... 7-84
Figure 7.53  Concrete floor or wall (telecommunications cable with firestop collar) .. 7-85
Figure 7.54  Framed wall stud cavity (electrical outlet box) ...................................... 7-86
Figure 7.55  Concrete floor or wall (no penetrating item) .......................................... 7-87
Figure 7.56  Concrete floor or wall (PVC innerduct or ENT with optical fiber cables and firestop wrap strip) ............................................................ 7-88
Figure 7.57  Concrete floor or wall (PVC innerduct or ENT with optical fiber cables and firestop sealant) ................................................................. 7-89
Figure 7.58  Framed wall (non-metallic conduit) .......................................................... 7-90
Figure 7.59  Framed wall (electrical power, building signaling, control, or telecommunications cable steel sleeve system) ................................................. 7-91
Figure 7.60  Framed wall (electrical power, building signaling, control, or telecommunications cable split sleeve system) ................................................. 7-93
Figure 7.61  Plenum-rated wrap system for combustible pipe ................................... 7-95
Figure 7.62  Intumescent blocks ................................................................................ 7-96
Figure 7.63  Framed wall (electrical power, building signaling, control, or telecommunications cable steel sleeve system) ................................................. 7-97
Figure 7.64  Concrete floor or wall (electrical power, building signaling, control, or telecommunications cable steel sleeve system) ................................................. 7-98
Figure 7.65  Framed wall (power, building signaling, control, or telecommunications split cable pathway system) ...................................................... 7-99
Figure 7.66  Framed wall (power, building signaling, control, or telecommunications cable sleeve device system) .......................................................... 7-100
Figure 7.67 Concrete floor (power, building signaling, control, or telecommunications cable sleeve system) ........................................ 7-101
Figure 7.68 Framed wall (telecommunications cable steel sleeve membrane penetration system) ........................................ 7-102
Figure 7.69 Framed wall (telecommunications cable firestop grommet membrane penetration system) ........................................ 7-103
Figure 7.70 Framed wall (telecommunications cable firestop grommet penetration system) ........................................ 7-104
Figure 7.71 Typical perimeter fire barrier system exterior insulation glass panel curtain wall ........................................ 7-105
Figure 7.72 Typical framed wall HVAC duct ........................................ 7-106
Figure 7.73 Concrete floor (power, building signaling, control, or telecommunications cable pathway system) ........................................ 7-107

Chapter 8: Bonding and Grounding (Earthing)
Figure 8.1 Typical supplementary bonding grid ........................................ 8-11
Figure 8.2 Small systems ........................................ 8-14
Figure 8.3 Recommended large system arrangement ........................................ 8-16
Figure 8.4 Typical PBB ........................................ 8-17
Figure 8.5 Typical SBB ........................................ 8-18
Figure 8.6 Equipment rack bonding and grounding (earthing) ........................................ 8-24
Figure 8.7 Zone of protection ........................................ 8-27
Figure 8.8 Cone of protection ........................................ 8-27
Figure 8.9 Extending zone of protection ........................................ 8-28

Chapter 9: Power Distribution
Figure 9.1 Measuring amplitude ........................................ 9-2
Figure 9.2 Measuring phase difference in a three-phase system ........................................ 9-3
Figure 9.3 Delta configuration ........................................ 9-4
Figure 9.4 Wye configuration ........................................ 9-5
Figure 9.5 Center-tapped single-phase configuration ........................................ 9-5
Figure 9.6 Typical electrical power system 1 ........................................ 9-6
Figure 9.7 Typical electrical power system 2 ........................................ 9-6
Figure 9.8 Calculation chart ........................................ 9-7
Figure 9.9 Voltage and current in phase (resistive load) ........................................ 9-9
Figure 9.10 Current lags voltage (inductive circuit) ........................................ 9-9
Figure 9.11 Current leads voltage (capacitive load) ........................................ 9-10
Figure 9.12 Panelboard connection to equipment ........................................ 9-26
Figure 9.13 PDU connection to equipment ........................................ 9-27
Figure 9.14 Sample Class 1 electrical system topology ........................................ 9-32
Figure 9.15 Sample Class 2 electrical system topology ........................................ 9-33
Figure 9.16 Sample Class 3 electrical system topology ........................................ 9-34
Table of Contents

Figure 9.17  Sample Class 4 electrical system topology ................................. 9-35
Figure 9.18  UPS module with maintenance bypass .................................... 9-42
Figure 9.19  UPS system .......................................................... 9-43
Figure 9.20  Parallel redundant UPS system ........................................... 9-44
Figure 9.21  Isolated redundant UPS system .............................................. 9-45
Figure 9.22  Distributed redundant UPS system ........................................ 9-46
Figure 9.23  Communications link UPS system .......................................... 9-47
Figure 9.24  Series configured rotary UPS system ...................................... 9-48
Figure 9.25  Elevation of modular UPS system ........................................... 9-50
Figure 9.26  Typical dc power system ...................................................... 9-52
Figure 9.27  Identification by color, letter, or marking ................................. 9-78

Chapter 10: Telecommunications Administration
Figure 10.1  Telecommunications administration systems .......................... 10-1
Figure 10.2  Numbering TRs .................................................................. 10-13
Figure 10.3  Numbering cable trays ......................................................... 10-15
Figure 10.4  Patch panel labeling within a rack .......................................... 10-18
Figure 10.5  Twisted-pair patch panel labeling with six-port groupings and near- and far-end panel and port identifiers .......................................................... 10-19
Figure 10.6  Pair patch panel labeling example where available label space is limited .......................................................................................... 10-19
Figure 10.7  Optical fiber patch panel labeling using sequential port numbering identifiers .................................................................................. 10-20
Figure 10.8  Optical fiber patch panel labeling with subpanel cassette identifiers .................................................................................. 10-20
Figure 10.9  Optical fiber patch panel labeling with HDA identifiers .............. 10-21
Figure 10.10  Labeling example .................................................................. 10-27
Figure 10.11  Recordkeeping system example ............................................. 10-35
Figure 10.12  Room grid coordinate example ............................................. 10-39
Figure 10.13  Sample rack and cabinet non-grid identifiers ............................ 10-41

Chapter 11: Field Testing of Structured Cabling
Figure 11.1  Wire map testing ................................................................. 11-2
Figure 11.2  Pair electrical lengths ............................................................ 11-4
Figure 11.3  Propagation delay/delay skew ............................................... 11-4
Figure 11.4  Return loss ........................................................................... 11-5
Figure 11.5  NEXT .................................................................................. 11-6
Figure 11.6  ACR-F .................................................................................. 11-7
Figure 11.7  PSNEXT .............................................................................. 11-7
Figure 11.8  Coaxial TDR test ................................................................. 11-10
Figure 11.9  Typical work area three-connector channel ............................... 11-11
Figure 11.10  Typical work area four-connector channel ............................... 11-11
Figure 11.11  Typical data center four-connector channel ............................. 11-12
Figure 11.12 Work area three-connector permanent link .......................... 11-12
Figure 11.13 Work area four-connector permanent link .......................... 11-13
Figure 11.14 Data center four-connector permanent link .......................... 11-14
Figure 11.15 MPTL ......................................................... 11-15
Figure 11.16 OTDR display ................................................. 11-21

Chapter 12: Outside Plant
Figure 12.1 Underground pathway plan .............................................. 12-2
Figure 12.2 Direct-buried pathway plan ............................................... 12-4
Figure 12.3 Installing underground entrances ...................................... 12-8
Figure 12.4 Examples of building attachment ....................................... 12-11
Figure 12.5 Vertical conduit mast ...................................................... 12-12
Figure 12.6 Cable entrance sleeve through a wall .................................. 12-14
Figure 12.7 Typical joint trenching dimensions (section view through trench) . 12-29
Figure 12.8 Positioning conduit on poles ............................................. 12-37
Figure 12.9 Typical cable MH .......................................................... 12-39
Figure 12.10 Basic MH configurations ............................................... 12-40
Figure 12.11 MH Elements ............................................................ 12-41
Figure 12.12 Typical MH diagram ..................................................... 12-43
Figure 12.13 Typical MH on private property ....................................... 12-44

Chapter 13: Audiovisual Systems
Figure 13.1 Measuring wavelength ..................................................... 13-2
Figure 13.2 Different amplitudes of equal frequency sine waves ............... 13-3
Figure 13.3 Equal amplitudes of different frequency sine waves ............... 13-3
Figure 13.4 Two waves offset by 180 degrees ...................................... 13-4
Figure 13.5 Frequency ................................................................. 13-5
Figure 13.6 Complex waveform ....................................................... 13-6
Figure 13.7 Building complex waveforms .......................................... 13-7
Figure 13.8 Electromagnetic spectrum ................................................. 13-7
Figure 13.9 Sample rate the size of the signal frequency ......................... 13-12
Figure 13.10 Sample rate double the size of the signal frequency .............. 13-13
Figure 13.11 Video signal building blocks .......................................... 13-16
Figure 13.12 Video signal bandwidth .................................................. 13-17
Figure 13.13 Analog video signals ..................................................... 13-20
Figure 13.14 RF signal ............................................................... 13-21
Figure 13.15 Examples of DVI connectors ......................................... 13-22
Figure 13.16 Example of HDMI connector ......................................... 13-23
Figure 13.17 Example of a DisplayPort connector ............................... 13-24
Figure 13.18 Optimum and acceptable viewing areas ............................. 13-32
Figure 13.19 Sightlines ............................................................... 13-33
Table of Contents

Figure 13.20 Flat floor—seats aligned..............................................13-34
Figure 13.21 Tiered floor—seats staggered ...................................13-35
Figure 13.22 Chain of typical audio components ..............................13-43
Figure 13.23 Example of horn installation ..................................13-45
Figure 13.24 Potential versus needed acoustic gain measurements ..........13-47
Figure 13.25 Loudspeaker dispersion polar plot ................................13-49
Figure 13.26 Loudspeaker coverage formula ................................13-50
Figure 13.27 Typical audioconferencing system ..............................13-55
Figure 13.28 Conference room microphone pickup pattern ..................13-58
Figure 13.29 Two connected rooms and their acoustic echo cancellers ....13-61
Figure 13.30 Telephone hybrid ....................................................13-63
Figure 13.31 Line echo canceller ..................................................13-64
Figure 13.32 Loudspeaker coverage angle ....................................13-66
Figure 13.33 Microphone pickup and loudspeaker coverage patterns ......13-68
Figure 13.34 FOV ..................................................................13-73
Figure 13.35 Camera bright-to-dark ranges ...................................13-74
Figure 13.36 Videoconference light setup ......................................13-75
Figure 13.37 Hexagonal loudspeaker pattern ..................................13-85
Figure 13.38 Square loudspeaker pattern .....................................13-86
Figure 13.39 70 V loudspeaker line loss .......................................13-89
Figure 13.40 Distributed amplifier system ......................................13-91
Figure 13.41 Collaboration of component technology .......................13-97
Figure 13.42 Home run network design ........................................13-103
Figure 13.43 Trunk and tap design ..............................................13-104
Figure 13.44 Video over balanced twisted-pair cabling ......................13-104
Figure 13.45 Video over optical fiber cabling ................................13-105
Figure 13.46 Dividing the optical signal ........................................13-106
Figure 13.47 Signal tilt for ≈12.7 mm (0.50 in) hardline .....................13-107

Chapter 14: Building Automation Systems

Figure 14.1 Building system changes ..............................................14-3
Figure 14.2 Example of fire alarm, security, and access control interfaces with BAS ..........14-6
Figure 14.3 HVAC system in a small commercial building ..................14-9
Figure 14.4 Hierarchical configuration of processor and controller levels ..........14-18
Figure 14.5 Cabling system elements and channel ..........................14-30
Figure 14.6 Single-point and chained branch devices .......................14-31
Figure 14.7 Cabling system topologies for BAS ..............................14-37
Figure 14.8 Devices bridged at HC (FD) or HCP .............................14-38
Figure 14.9 Devices chained at the HC (FD) or HCP .......................14-39
Figure 14.10 BAS equipment cabling ...........................................14-42
Chapter 15: Data Networks

Figure 15.1 Example of a LAN ........................................ 15-2
Figure 15.2 Example of a WAN ........................................ 15-3
Figure 15.3 OSI Reference Model ....................................... 15-5
Figure 15.4 Message transfer described using the OSI Reference Model ........................................ 15-7
Figure 15.5 Multiple routers in an internetwork ........................................ 15-11
Figure 15.6 Integrated VoIP infrastructure ........................................ 15-16
Figure 15.7 Types of network video communications ........................................ 15-17
Figure 15.8 Functional (top-down) design ........................................ 15-19
Figure 15.9 Physical (bottom-up) design ........................................ 15-20
Figure 15.10 Class 1 telecommunications infrastructure ........................................ 15-22
Figure 15.11 Class 2 telecommunications infrastructure ........................................ 15-22
Figure 15.12 Class 3 telecommunications infrastructure ........................................ 15-23
Figure 15.13 Class 4 telecommunications infrastructure ........................................ 15-24
Figure 15.14 Server-to-switch connections ........................................ 15-25
Figure 15.15 Redundant server-to-switch connections ........................................ 15-26
Figure 15.16 Server-to-storage director connections ........................................ 15-27
Figure 15.17 Redundant server-to-storage director connections ........................................ 15-28
Figure 15.18 Example of Class 3 and Class 4 network and storage infrastructure ........................................ 15-29
Figure 15.19 Centralized data center topology ........................................ 15-30
Figure 15.20 End-of-row data center topology ........................................ 15-31
Figure 15.21 Top-of-rack data center topology ........................................ 15-32
Figure 15.22 Example of campus network ........................................ 15-33
Figure 15.23 Links from customer site to SP ........................................ 15-35
Figure 15.24 Example of a centralized WAN design ........................................ 15-37
Figure 15.25 Example of a partial mesh WAN design ........................................ 15-38
Figure 15.26 Partial mesh WAN after a link failure ........................................ 15-39
Figure 15.27 Example of a full mesh WAN design ........................................ 15-40

Chapter 16: Wireless Networks

Figure 16.1 Frequency, amplitude, and wavelength ........................................ 16-6
Figure 16.2 Propagation velocity through free space ........................................ 16-7
Figure 16.3 Fresnel zone ........................................ 16-8
Figure 16.4 Ground and sky waves ........................................ 16-11
Figure 16.5 Isotropic gain ........................................ 16-12
Figure 16.6 Amplitude modulation ........................................ 16-14
Table of Contents

Figure 16.7 Frequency modulation .................................................. 16-15
Figure 16.8 Phase modulation ......................................................... 16-16
Figure 16.9 Pulse modulation techniques ........................................ 16-17
Figure 16.10 Harmonic distortion .................................................... 16-19
Figure 16.11 Power injector with tower-mounted preamplifier .............. 16-35
Figure 16.12 Power injector for WLAN AP ....................................... 16-36
Figure 16.13 Typical DAS environments ........................................... 16-40
Figure 16.14 Omnidirectional antennas ........................................... 16-42
Figure 16.15 Directional antennas .................................................. 16-43
Figure 16.16 Radiating cable standoff mount .................................... 16-46
Figure 16.17 Headend and backend ............................................... 16-50
Figure 16.18 Optical to RF coupling power relationship ...................... 16-52
Figure 16.19 ESS using a wireless distribution system ......................... 16-70
Figure 16.20 ESS using a cable distribution system ........................... 16-71
Figure 16.21 PTP bridging ............................................................. 16-74
Figure 16.22 Point-to-multipoint bridging ........................................ 16-75
Figure 16.23 Repeating bridge ......................................................... 16-76

Chapter 17: Electronic Safety and Security

Figure 17.1 Elements of a security program ....................................... 17-2
Figure 17.2 Threat, risk, and vulnerability assessments ......................... 17-3
Figure 17.3 Security quandary ......................................................... 17-4
Figure 17.4 MPTL with one CP ....................................................... 17-12
Figure 17.5 Electric strikes ............................................................. 17-15
Figure 17.6 Magnetic locks ............................................................. 17-17
Figure 17.7 Electric locksets ........................................................... 17-18
Figure 17.8 Electric latch and mechanical operation ............................. 17-19
Figure 17.9 Electrified exit hardware ............................................... 17-20
Figure 17.10 Grid display layouts ..................................................... 17-25
Figure 17.11 Typical fire alarm pull station ........................................ 17-34
Figure 17.12 Example of a Class N pathway ...................................... 17-42
Figure 17.13 Redundant cables in Class N pathways ............................ 17-43
Figure 17.14 Additional pathway between Switch 1 and 2 ..................... 17-44
Figure 17.15 Endpoint servicing more than one device ........................ 17-44
Figure 17.16 Enhanced annunciator panel ........................................ 17-54
Chapter 18: Data Centers
Figure 18.1 Relationship of spaces in a data center .............................................. 18-2
Figure 18.2 Hierarchical structure of a data center from CENELEC EN 50173-5 and ISO/IEC 11801-5 ................................................................. 18-14
Figure 18.3 Example of TIA-942-B data center topology ................................... 18-15
Figure 18.4 Cabling cross-sectional area comparison ............................................. 18-16
Figure 18.5 Example of equipment cabling using overhead infrastructure .......... 18-19
Figure 18.6 Example of overhead communications cabling with power and bonding conductors beneath raised access floor ............................ 18-21
Figure 18.7 Example of communications, power, and earth conductors installed in raised access floor ......................................................... 18-22
Figure 18.8 Layering ......................................................................................... 18-26

Chapter 19: Health Care
Figure 19.1 TDR ............................................................................................. 19-5
Figure 19.2 Redundancy option 1 ................................................................. 19-6
Figure 19.3 Redundancy option 2 ................................................................. 19-7
Figure 19.4 Redundancy option 3 ................................................................. 19-8
Figure 19.5 Redundancy option 4 ................................................................. 19-9
Figure 19.6 Typical nurse call staff emergency station .................................... 19-12
Figure 19.7 Typical nurse call bedside station ................................................ 19-13
Figure 19.8 Typical nurse call code call station .............................................. 19-14
Figure 19.9 Typical nurse call staff station .................................................... 19-15
Figure 19.10 Nurse call system traditional one-line diagram ........................... 19-18
Figure 19.11 Typical physiological monitor remote wiring diagram ................ 19-29
Figure 19.12 Typical RFID tag ...................................................................... 19-31
Figure 19.13 Typical IPTS ............................................................................. 19-36

Chapter 20: Residential Cabling
Figure 20.1 Residential cabling layout ............................................................. 20-4
Figure 20.2 Media room with one balanced twisted-pair and three coaxial cable runs to a telecommunications outlet ....................................... 20-9
Figure 20.3 Example of a residential premises cabling system ....................... 20-10
Figure 20.4 Multi-dwelling unit cabling layout ................................................. 20-12
Figure 20.5 Telecommunications backbone and distribution cabling layout for an apartment building with a central backbone ..................... 20-13
Figure 20.6 Telecommunications backbone and distribution cabling layout for an apartment building with multiple backbones ..................... 20-14
Figure 20.7 Example of conduit distribution for a seven-unit townhouse ........ 20-15
Figure 20.8 Cabling distribution for a side-by-side duplex residence .............. 20-16
Figure 20.9 Example of cable distribution for frame apartment projects .......... 20-17
Figure 20.10 Example of an apartment complex with backbone cable .......... 20-18
Figure 20.11 Telecommunications outlets/connector ..................................... 20-23
Chapter 21: Project Administration and Execution
Figure 21.1 Simple OBS .......................................................... 21-17
Figure 21.2 PERT or network logic diagram using the precedence diagram method ........................................... 21-21
Figure 21.3 Milestone chart .................................................. 21-21
Figure 21.4 Gantt chart ....................................................... 21-22
Figure 21.5 Calendar of schedule .......................................... 21-22
Figure 21.6 Example of budgeted cost of work schedules ........... 21-25
Figure 21.7 Example of plotted BCWP, BCWS, and ACWP ........... 21-25
Figure 21.8 Client/supplier model ......................................... 21-27
Figure 21.9 United States National CAD Standard® layer name format .... 21-53

Chapter 22: Special Design Considerations
Figure 22.1 Industrial floor area described by MICE classification 1, 2, or 3 ........ 22-6

Appendix A: Codes, Standards, Regulations, and Organizations
Figure A.1 Conformité européenne mark ................................ A-85
Figure A.2 Emission limits at 10 m (≈33 ft) ................................... A-89
Figure A.3 IEC CISPR 22 conducted disturbance limits (main ports) ........ A-89
Figure A.4 IEC CISPR 22 conducted disturbance limits (telecommunications ports) ............................................. A-90
Figure A.5 RJ11C/RJ11W connector configuration ......................... A-97
Figure A.6 RJ15C connector configuration ................................ A-98
Figure A.7 RJ16X connector configuration ................................ A-99
Figure A.8 RJ17C connector configuration ................................ A-101
Figure A.9 RJ18C, RJ18W connector configuration ....................... A-102
Figure A.10 RJ31X connector configuration ............................... A-103
Figure A.11 RJ14C/RJ14W connector configuration ....................... A-104
Figure A.12 RJ14X connector configuration ................................ A-105
Figure A.13 RJ25C connector configuration ................................ A-106
Figure A.14 RJ61X connector configuration ................................ A-107
Figure A.15 RJ2DX connector configuration ................................ A-108
Figure A.16 RJ2EX connector configuration ................................ A-109
Figure A.17 RJ2FX connector configuration ................................ A-110
Figure A.18 RJ2GX connector configuration ................................ A-111
Figure A.19 RJ2HX connector configuration ................................ A-112
Figure A.20 RJ21X connector configuration ................................ A-113
Figure A.21 RJ2MB connector configuration ................................ A-114
Figure A.22 RJ71C connector configuration ................................ A-115
Figure A.23 RJ41S single-line data connection ............................ A-117
Figure A.24  RJ45S single-line data connection ................................. A-118
Figure A.25  RJ4MB single-line data connection ................................. A-119
Figure A.26  RJ41M single-line data connection ................................. A-121
Figure A.27  RJ45M single-line data connection ................................. A-123
Figure A.28  RJ26X single-line data connection ................................. A-124
Figure A.29  RJ27X single-line data connection ................................. A-125
Figure A.30  RJ48S connector configuration ................................. A-126
Figure A.31  RJ48T connector configuration ................................. A-127
Figure A.32  RJ48C connector configuration ................................. A-128
Figure A.33  RJ48M connector configuration ................................. A-129
Figure A.34  RJ48X connector configuration ................................. A-130
Figure A.35  RJ48H connector configuration ................................. A-131
### Tables

**Chapter 1: Principles of Transmission**

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1.1</td>
<td>Conductor descriptions</td>
<td>1-3</td>
</tr>
<tr>
<td>Table 1.2</td>
<td>Solid conductor properties</td>
<td>1-4</td>
</tr>
<tr>
<td>Table 1.3</td>
<td>Electrical characteristics of common insulation types</td>
<td>1-7</td>
</tr>
<tr>
<td>Table 1.4</td>
<td>Explanations of insulation electrical characteristics</td>
<td>1-8</td>
</tr>
<tr>
<td>Table 1.5</td>
<td>Types of cable shields</td>
<td>1-15</td>
</tr>
<tr>
<td>Table 1.6</td>
<td>Common units of frequency measurement</td>
<td>1-18</td>
</tr>
<tr>
<td>Table 1.7</td>
<td>Spectrums of standard frequency bands</td>
<td>1-20</td>
</tr>
<tr>
<td>Table 1.8</td>
<td>Power ratios from 0 to 60 dB</td>
<td>1-21</td>
</tr>
<tr>
<td>Table 1.9</td>
<td>Transmission data rates</td>
<td>1-29</td>
</tr>
<tr>
<td>Table 1.10</td>
<td>Coding methods</td>
<td>1-35</td>
</tr>
<tr>
<td>Table 1.11</td>
<td>ADSL standards</td>
<td>1-43</td>
</tr>
<tr>
<td>Table 1.12</td>
<td>ADSL performance</td>
<td>1-44</td>
</tr>
<tr>
<td>Table 1.13</td>
<td>VDSL data rate and target range</td>
<td>1-44</td>
</tr>
<tr>
<td>Table 1.14</td>
<td>Propagation delay/delay skew</td>
<td>1-55</td>
</tr>
<tr>
<td>Table 1.15</td>
<td>Balanced twisted-pair cabling channel performance</td>
<td>1-64</td>
</tr>
<tr>
<td>Table 1.16</td>
<td>Applications supported using 100-ohm balanced twisted-pair cabling</td>
<td>1-65</td>
</tr>
<tr>
<td>Table 1.17</td>
<td>Transmission, speed, distance, and pair requirements</td>
<td>1-67</td>
</tr>
<tr>
<td>Table 1.18</td>
<td>IEEE 802.3 PoE classes</td>
<td>1-76</td>
</tr>
<tr>
<td>Table 1.19</td>
<td>Characteristics of typical LED sources</td>
<td>1-83</td>
</tr>
<tr>
<td>Table 1.20</td>
<td>Characteristics of typical short wavelength laser</td>
<td>1-84</td>
</tr>
<tr>
<td>Table 1.21</td>
<td>Characteristics of typical VCSELs</td>
<td>1-85</td>
</tr>
<tr>
<td>Table 1.22</td>
<td>Characteristics of typical LD sources</td>
<td>1-86</td>
</tr>
<tr>
<td>Table 1.23</td>
<td>Comparison of transmitters</td>
<td>1-87</td>
</tr>
<tr>
<td>Table 1.24</td>
<td>Optical fiber cable performance by type</td>
<td>1-90</td>
</tr>
<tr>
<td>Table 1.25</td>
<td>Summarized comparison of core sizes of multimode and singlemode optical fiber cable</td>
<td>1-98</td>
</tr>
<tr>
<td>Table 1.26</td>
<td>Typical characteristics of multimode optical fiber</td>
<td>1-99</td>
</tr>
<tr>
<td>Table 1.27</td>
<td>Characteristics of 50/125 μm multimode optical fiber</td>
<td>1-100</td>
</tr>
<tr>
<td>Table 1.28</td>
<td>Characteristics of 62.5/125 μm multimode optical fiber</td>
<td>1-101</td>
</tr>
<tr>
<td>Table 1.29</td>
<td>Typical characteristics of singlemode optical fiber</td>
<td>1-102</td>
</tr>
<tr>
<td>Table 1.30</td>
<td>Maximum cable attenuation coefficient</td>
<td>1-104</td>
</tr>
<tr>
<td>Table 1.31</td>
<td>Mismatch of core size and power loss</td>
<td>1-106</td>
</tr>
<tr>
<td>Table 1.32</td>
<td>Calculating optical fiber performance</td>
<td>1-108</td>
</tr>
<tr>
<td>Table 1.33</td>
<td>System gain, power penalties, and link loss budget calculations</td>
<td>1-111</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1.35</td>
<td>Calculating losses</td>
<td>1-112</td>
</tr>
<tr>
<td>1.36</td>
<td>Splice loss values in decibels</td>
<td>1-113</td>
</tr>
<tr>
<td>1.37</td>
<td>Minimum system loss</td>
<td>1-114</td>
</tr>
<tr>
<td>1.38</td>
<td>Common SONET and SDH transmission rates</td>
<td>1-117</td>
</tr>
<tr>
<td>1.39</td>
<td>Levels of multiplexing and carrier transmission in North America</td>
<td>1-123</td>
</tr>
<tr>
<td>1.40</td>
<td>Levels of multiplexing and carrier transmission in Europe</td>
<td>1-125</td>
</tr>
</tbody>
</table>

**Chapter 2: Electromagnetic Compatibility**

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Factors that can affect EMI in telecommunications equipment</td>
<td>2-12</td>
</tr>
<tr>
<td>2.2</td>
<td>Factors that can affect EMI in sites</td>
<td>2-13</td>
</tr>
<tr>
<td>2.3</td>
<td>Four levels of immunity</td>
<td>2-19</td>
</tr>
<tr>
<td>2.4</td>
<td>ESD susceptibility ranges</td>
<td>2-20</td>
</tr>
<tr>
<td>2.5</td>
<td>Mutual capacitance ranges for telecommunications cables</td>
<td>2-21</td>
</tr>
<tr>
<td>2.6</td>
<td>Minimum separation distances from possible sources of EMI exceeding 5 kVA</td>
<td>2-38</td>
</tr>
<tr>
<td>2.7</td>
<td>Separation requirements between metallic cabling and specific EMI sources</td>
<td>2-38</td>
</tr>
</tbody>
</table>

**Chapter 3: Telecommunications Spaces**

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Size guidelines</td>
<td>3-11</td>
</tr>
<tr>
<td>3.2</td>
<td>Smaller buildings</td>
<td>3-11</td>
</tr>
<tr>
<td>3.3</td>
<td>Allocating termination space</td>
<td>3-12</td>
</tr>
<tr>
<td>3.4</td>
<td>Layout considerations</td>
<td>3-22</td>
</tr>
</tbody>
</table>

**Chapter 4: Backbone Distribution Systems**

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Backbone distribution system components</td>
<td>4-1</td>
</tr>
<tr>
<td>4.2</td>
<td>EFM installed singlemode optical fiber</td>
<td>4-20</td>
</tr>
<tr>
<td>4.3</td>
<td>Common conduit sizes with vernacular</td>
<td>4-41</td>
</tr>
<tr>
<td>4.4</td>
<td>Summary of EFM physical layer signaling systems</td>
<td>4-54</td>
</tr>
</tbody>
</table>

**Chapter 5: Horizontal Distribution Systems**

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Maximum allowable cable lengths with the use of multiuser telecommunications outlet assemblies</td>
<td>5-28</td>
</tr>
<tr>
<td>5.2</td>
<td>Comparison of CP locations</td>
<td>5-32</td>
</tr>
<tr>
<td>5.3</td>
<td>PoE and HDBaseT current specifications</td>
<td>5-37</td>
</tr>
<tr>
<td>5.4</td>
<td>Primary PON variations and their source standards</td>
<td>5-57</td>
</tr>
<tr>
<td>5.5</td>
<td>Maximum channel attenuation and supported distance for PON versions</td>
<td>5-60</td>
</tr>
<tr>
<td>5.6</td>
<td>EMT 40 percent conduit fill rate</td>
<td>5-74</td>
</tr>
<tr>
<td>5.7</td>
<td>Typical EMT conduit fill rate for varying cable diameters</td>
<td>5-75</td>
</tr>
<tr>
<td>5.8</td>
<td>Conduit fill with 1 bend</td>
<td>5-76</td>
</tr>
</tbody>
</table>
Table 5.9 Conduit fill with 2 bends ........................................... 5-77
Table 5.10 Bend radii guidelines ............................................. 5-80
Table 5.11 Adapting designs .................................................. 5-81
Table 5.12 Typical space requirements for pull boxes having conduit enter at opposite ends of the box ........................................... 5-83
Table 5.13 Slip sleeves and gutters ......................................... 5-84
Table 5.14 Coverings ............................................................ 5-90
Table 5.15 Load capacity ....................................................... 5-90
Table 5.16 Guidelines for recommending ceiling panels .............. 5-94
Table 5.17 Common types of cable trays ................................ 5-105
Table 5.18 Common cable tray dimensions ............................... 5-107
Table 5.19 ADA height requirements ...................................... 5-120

Chapter 6: ICT Cables and Connecting Hardware

Table 6.1 Comparison of the terms class and category within ISO/IEC and TIA standards .................................................. 6-3
Table 6.2 Balanced twisted-pair cabling channel performance .......... 6-4
Table 6.3 Balanced twisted-pair cable designations ..................... 6-4
Table 6.4 Balanced cable designs ............................................. 6-5
Table 6.5 Optical fiber cable transmission performance parameters .... 6-15
Table 6.6 Typical distances supported by optical fiber cabling .......... 6-18
Table 6.7 Examples of regional fire safety standards .................... 6-27
Table 6.8 Communications cable types .................................... 6-28
Table 6.9 Optical fiber cable types .......................................... 6-29
Table 6.10 Interclass relativity of NEC and IEC fire safety specifications ...... 6-31
Table 6.11 Comparison between NEC CM ratings and CSA FT requirements .. 6-32
Table 6.12 Connecting hardware transmission performance categories for 110-style connector-based connecting hardware .................. 6-35
Table 6.13 Connecting hardware transmission performance categories .......... 6-38
Table 6.14 Connecting hardware transmission performance categories for BIX-style connectors ........................................... 6-40
Table 6.15 Connecting hardware transmission performance categories for LSA-style connector-based connecting hardware .......... 6-43
Table 6.16 Modular plug transmission performance categories .......... 6-47
Table 6.17 Modular jack transmission performance categories ............ 6-50
Table 6.18 50-position miniature ribbon connector transmission performance categories ........................................................................ 6-53
Table 6.19 Optical fiber link transmission performance calculations worksheet .... 6-78
Table 6.20 Splice insertion loss guidelines and objectives ................ 6-86
Chapter 7: Firestop Systems
Table 7.1 Barrier standards ............................................. 7-6
Table 7.2 European test standards .................................... 7-12
Table 7.3 Rating classifications, standards, and definitions .......... 7-13
Table 7.4 Limiting temperature for each test standard ................. 7-16
Table 7.5 Pipes, conduits, sleeve systems, innerducts, cable trays, and cable penetration firestop methods (in ceilings) .................. 7-44
Table 7.6 Electrical apparatus, boxes, and access panels firestop methods (in ceilings) ........................................ 7-45
Table 7.7 Pipes, conduits, sleeve systems, innerducts, cable trays, and cable penetration firestop methods (in floors/ceilings) .............. 7-45
Table 7.8 Underfloor pipe, conduit, sleeve system, and innerduct firestop methods (in floors) ........................................ 7-46
Table 7.9 Pipe sizes and fire ratings ...................................... 7-71
Table 7.10 Sizes of pipe chokes, wrap strip layers, and fire ratings .......... 7-91
Table 7.11 United States firestop standards ......................... 7-109
Table 7.12 Canadian firestop standards ................................ 7-111
Table 7.13 International firestop standards .......................... 7-112

Chapter 8: Bonding and Grounding (Earthing)
Table 8.1 Telecommunications bonding component terms cross-reference ........ 8-2
Table 8.2 Basic guide to calculating bonding conductor resistance values .......... 8-21

Chapter 9: Power Distribution
Table 9.1 Electrical formulas ........................................... 9-14
Table 9.2 Circular mils of standard AWG conductors ................ 9-16
Table 9.3 Voltage and current fluctuations ............................ 9-18
Table 9.4 K-rating based on load makeup .............................. 9-22
Table 9.5 Calculating maximum input current .......................... 9-58
Table 9.6 Calculating voltage ............................................. 9-60
Table 9.7 Major alarms (dc) ............................................. 9-72
Table 9.8 Minor alarms (dc) ............................................. 9-73
Table 9.9 Major alarms (UPS) ........................................... 9-73
Table 9.10 Color code for conductors in the United States .............. 9-77
Table 9.11 Color code for conductors in the United Kingdom and Ireland .... 9-79

Chapter 10: Telecommunications Administration
Table 10.1 Required identifiers by class ................................ 10-6
Table 10.2 Minimum and optional administration system elements .......... 10-8
Table 10.3 Color codes .................................................. 10-22
Table 10.4 Identifying pathways .......................................... 10-32
Table 10.5 Required records by class .................................... 10-37
Chapter 11: Field Testing of Structured Cabling
Table 11.1 Determining worst-case attenuation coefficient. ....................... 11-23

Chapter 12: Outside Plant
Table 12.1 Service diversity ......................................................... 12-17
Table 12.2 Terminating space ....................................................... 12-20
Table 12.3 Vertical/horizontal separations ........................................ 12-28
Table 12.4 Metallic conduit types and sizes used in telecommunications .... 12-33
Table 12.5 Direct-bury PVC conduit types and sizes used in telecommunications ......................................................... 12-34
Table 12.6 Non-metallic conduit types and sizes used in telecommunications ... 12-35

Chapter 13: Audiovisual Systems
Table 13.1 Color temperature ranges .............................................. 13-9
Table 13.2 Typical audio signal units of measurement ................................ 13-11
Table 13.3 Common bit resolutions .................................................. 13-14
Table 13.4 Supported video formats ................................................. 13-24
Table 13.5 SDTV versus HDTV ....................................................... 13-26
Table 13.6 Front and rear projection advantages and disadvantages .......... 13-41
Table 13.7 Area covered by horns ................................................... 13-87
Table 13.8 AI speech intelligibility ................................................... 13-95
Table 13.9 Example of loss values per \(\approx 30.5 \text{ m (100 ft)}\) of the coaxial cable for the lowest and highest channels in a 60-channel system .................. 13-107

Chapter 14: Building Automation Systems
Table 14.1 Typical work and BAS coverage area sizes ......................... 14-33

Chapter 16: Wireless Networks
Table 16.1 Balanced twisted-pair cabling channel performance .............. 16-21
Table 16.2 Transceiver types and application .................................... 16-28

Chapter 18: Data Centers
Table 18.1 Comparison of the standards .......................................... 18-10

Chapter 20: Residential Cabling
Table 20.1 Recognized tenant area residential cabling by grade ............... 20-3
Table 20.2 Guidance in planning the wall space allocated for DD and associated equipment ..................................................... 20-7
Table 20.3 Telecommunications outlets/connectors for residences .......... 20-9
Table 20.4 Minimum space for a multi-dwelling unit CTR .................... 20-11

Chapter 21: Project Administration and Execution
Table 21.1 MasterFormat® 2018 numbering ................................. 21-44
Chapter 22: Special Design Considerations

Table 22.1 List of applicable IEC test procedures ........................................ 22-8
Table 22.2 IP codes ................................................................. 22-10
Table 22.3 Enclosure ratings and IP codes ............................................. 22-11
Table 22.4 Comparison of specific applications of enclosures for indoor non-hazardous locations ........................................ 22-12

Appendix A: Codes, Standards, Regulations, and Organizations

Table A.1 Schematic of the relationships between standards ...................... A-25
Table A.2 Key elements of the legal and regulatory framework of telecommunications sectors in select countries .................. A-32
Table A.3 Schematic of the relationships between CENELEC standards .... A-34
Table A.4 Sections of the *Canadian Electrical Code (CEC)* .................... A-46
Table A.5 Federal Communications Commission (FCC) documents .......... A-58
Table A.6 *National Electrical Safety Code® (NESC®)* parts, sections, and rules applicable to telecommunications distribution requirements A-60
Table A.7 *National Electrical Code® (NEC®)* articles and sections that impact telecommunications installation .................................. A-66
Table A.8 Federal Communications Commission (FCC) regulations .......... A-79
Table A.9 Class A radiation limits ..................................................... A-87
Table A.10 Class B radiation limits ..................................................... A-87
Table A.11 EN 61000-6-1 and EN 61000-6-2 generic standards ................. A-91
Table A.12 RJ11C/RJ11W connector configuration ................................. A-96
Table A.13 RJ15C connector configuration ........................................... A-98
Table A.14 RJ16X connector configuration ........................................... A-99
Table A.15 RJ17C connector configuration ........................................... A-100
Table A.16 RJ18C, RJ18W connector configuration ................................ A-102
Table A.17 RJ31X connector configuration ........................................... A-103
Table A.18 RJ14C/RJ14W connector configuration ................................ A-104
Table A.19 RJ14X connector configuration ........................................... A-105
Table A.20 RJ25C connector configuration ........................................... A-106
Table A.21 RJ61X connector configuration ........................................... A-107
Table A.22 RJ2DX connector configuration ........................................... A-108
Table A.23 RJ2EX connector configuration ........................................... A-109
Table A.24 RJ2FX connector configuration ........................................... A-110
Table A.25 RJ2GX connector configuration ........................................... A-111
Table A.26 RJ2HX connector configuration ........................................... A-112
Table A.27 RJ21X connector configuration ........................................... A-113
Table A.28 RJ2MB connector configuration .......................................... A-114
Table A.29 RJ71C connector configuration ........................................... A-115
Table A.30 RJ41S single-line data connection ....................................... A-116
Table of Contents

Table A.31 RJ45S single-line data connection .................................. A-118
Table A.32 RJ4MB single-line data connection .................................. A-119
Table A.33 RJ41M single-line data connection .................................. A-120
Table A.34 RJ45M single-line data connection .................................. A-122
Table A.35 RJ26X single-line data connection .................................. A-124
Table A.36 RJ27X single-line data connection .................................. A-125
Table A.37 RJ48S connector configuration ................................. A-126
Table A.38 RJ48T connector configuration ................................. A-127
Table A.39 RJ48C connector configuration ................................. A-128
Table A.40 RJ48M connector configuration ................................. A-129
Table A.41 RJ48X connector configuration ................................. A-130
Table A.42 RJ48H connector configuration ................................. A-131
Table A.43 Intermixable services at network-provided standard connectors ..... A-132
Table A.44 Facility interface code translator ......................... A-135

Examples

Chapter 1: Principles of Transmission
Example 1.1 Optical fiber performance calculations example ................. 1-109

Chapter 14: Building Automation Systems
Example 14.1 SoW checklist .......................................................... 14-26

Chapter 21: Project Administration and Execution
Example 21.1 WBS ................................................................. 21-19
Example 21.2 WBS in a text outline format .................................... 21-20