

**Telecommunications
Distribution
Methods**

M A N U A L

13th Edition

Volume 1



We welcome all comments about this manual. If you have any questions about BICSI and its services, please contact our office at 800.242.7405 (USA/Canada toll free); +1 813.979.1991; fax +1 813.971.4311; e-mail bicsi@bicsi.org; Website www.bicsi.org.

BICSI®, Tampa, FL 33637

© 2014 BICSI®

All rights reserved.

Thirteenth edition published 2014

First printing January 2014

Printed in the United States of America

All rights reserved

ISBN (Print) 1-928886-64-7

ISBN (Electronic) 1-928886-66-3

All brand names, trademarks, and registered trademarks are the property of their respective holders.

No part of this manual may be used, reproduced, or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without prior agreement and written permission from BICSI.

The contents of this manual are subject to revision without notice due to continued progress in information technology systems (ITS) methodology, design, and manufacturing.

THIS MANUAL IS SOLD AS IS, WITHOUT WARRANTY OF ANY KIND, RESPECTING THE CONTENTS OF THIS MANUAL, INCLUDING BUT NOT LIMITED TO IMPLIED WARRANTIES FOR THE MANUAL'S QUALITY, PERFORMANCE, MERCHANTABILITY, OR FITNESS FOR ANY PARTICULAR PURPOSE. BICSI SHALL NOT BE LIABLE TO THE PURCHASER OR ANY OTHER ENTITY WITH RESPECT TO ANY LIABILITY, LOSS, OR DAMAGE CAUSED DIRECTLY OR INDIRECTLY BY THIS MANUAL.

BICSI World Headquarters
8610 Hidden River Parkway
Tampa, FL 33637-1000 USA
Tel.: +1 813.979.1991 or
Tel.: 800.242.7405 (USA & Canada toll-free)
Fax: +1 813.971.4311
E-mail: bicsi@bicsi.org
Website: www.bicsi.org



TDMM 13th Edition Evolving With Our Industry

Welcome to the 13th edition of the *Telecommunications Distribution Methods Manual (TDMM)*. While I have worked on many earlier versions of this manual, this is the first edition that I have had the privilege of releasing as Chair of BICSI's Technical Information and Methods (TI&M) committee.

As you can imagine, there are countless people who selflessly gave of their time to help produce BICSI's flagship manual. I would like to thank the hundreds of volunteers who spent thousands of hours contributing and shaping the technical information within these pages.

Thanks also to the hard working Technical Publications & Design staff at BICSI headquarters that go above and beyond in every phase of production. They have the unenviable job of motivating those volunteers (who have plenty of responsibilities from their paying jobs) into meeting deadlines, focusing on tasks, and getting jobs done, and they do all this in a positive and professional manner: they are truly BICSI.

There were many changes to the *TDMM* 13th edition that are far too numerous to list, but here are some of the significant changes:

- **Chapter 5: Horizontal Distribution Systems**
 - 12th edition Chapter 4: Work Areas, was updated and merged into this chapter
 - A new section, Passive Optical Networks (PON), was added
 - 12th edition appendix material related to the Americans with Disabilities Act (ADA) was merged into this chapter
 - Many new figures and tables were inserted into this chapter
- **Chapter 6: ITS Cables and Connecting Hardware**
 - Significant subject matter updates were incorporated
 - Many new tables and figures were inserted
- **Chapter 10: Telecommunications Administration**
 - Much of the information was updated to reflect new codes and standards
- **Chapter 13: Audiovisual Systems**
 - 12th edition Chapter 14: Private CATV Distribution Systems and 12th edition Chapter 15: Distributed Paging Systems, were merged into this chapter
- **Chapter 15: Data Networks**
 - Stripped down by almost 50 percent due to the removal of legacy technologies
- **Chapter 16: Wireless Networks**
 - A significant amount of new material concerning distributed antenna systems (DAS) was added

- **Chapter 21: Business Development and Project Management**

- The Business Development section is new material
- 12th edition Chapter 13: Design, Construction, and Project Management, was updated and merged into this chapter as its own section

- **All Chapters**

- A significant amount of legacy technology information has been removed
- More than 90 percent of all of the metric conversions now have the approximate symbol (\approx) placed in front of the metric numbers as a result of the TI&M Committee Metric Conversion Task Force conclusions. This symbol has also been placed in more than 90 percent of the illustrations and tables that have metric conversions within them (this will be evident in all text, illustrations, and tables of all BICSI technical manuals going forward)
- The chapter order and sequence between the 12th and 13th editions has changed significantly

Each new edition of the *TDMM* reflects the evolution of our association and the work of our volunteer members. The reorganization and addition of material in this 13th edition is indicative of the next phase of this evolution, which will come into focus with our manual modularization efforts in the *TDMM* 14th edition.

Before I close this preface, I would like to give a final thank you to a special person who is my biggest supporter. I could not do what I do, be who I am, or give what I give without the constant and unselfish gifts of my loving spouse Darlene.

Sincerely,

A handwritten signature in black ink that reads "Robert Gross". The signature is written in a cursive style with a large, prominent initial "R".

Robert Gross, RCDD, OSP

Chair, Technical Information and Methods (TI&M) Committee, BICSI

Thank you for ordering the *Telecommunications Distribution Methods Manual*, 13th edition, 2014.
Please place the chapter tabs and appendix tabs in front of the title page for each chapter and appendix.

The section tabs should be inserted in front of the following pages:

Chapter 1: Principles of Transmission

1-1 Section 1: Metallic Media

1-83 Section 2: Optical Fiber

Chapter 5: Horizontal Distribution Systems

5-5 Section 1: Horizontal Cabling Systems

5-53 Section 2: Horizontal Pathways

5-103 Section 3: ADA Requirements

Chapter 21: Business Development and Project Management

21-1 Business Development

21-5 Project Management

WARNING

It is the responsibility of the user of this manual to determine the use of the applicable safety and health practices (e.g., in the United States, Occupational Safety and Health Administration [OSHA], *National Electrical Code*[®] [NEC[®]], *National Electrical Safety Code* [NESC[®]]) associated with ITS installation and design practices. BICSI shall not be liable to the purchaser or any other entity with respect to any liability, loss, or damage caused directly or indirectly by application or use of this manual. No project is so important nor any completion deadline so critical to justify nonconformance to ITS industry standards. This manual does not address safety issues associated with its use. It is the telecommunications professional's responsibility to use established and appropriate safety and health practices and to determine the applicability of all regulatory issues.

About BICSI... Advancing Information Technology Systems

BICSI Vision Statement

BICSI® is the worldwide preeminent source of information, education, and knowledge assessment for the constantly evolving information technology systems (ITS) industry.

BICSI Mission Statement

BICSI's mission is to:

- Lead the ITS industry with excellence in publications, education, and knowledge assessment.
- Advance our members' ability to deliver the highest quality products and services.
- Provide our members with opportunities for continual improvement and enhanced professional stature.

Thank you for ordering the new thirteenth edition of BICSI's *Telecommunications Distribution Methods Manual (TDMM)*. The officers of BICSI are pleased to provide an up-to-date design reference manual that offers proven telecommunications design guidelines and methods accepted by the ITS industry. Volunteers outside the United States and Canada have provided valuable input to make the newest edition of the *TDMM* a valuable tool for an international audience.

BICSI provides information, education and knowledge assessment for individuals and companies in the ITS industry. We serve more than 23,000 ITS professionals, including designers, installers and technicians. These individuals provide the fundamental infrastructure for telecommunications, audio/video, life safety and automation systems. Through courses, conferences, publications and professional registration programs, BICSI staff and volunteers assist ITS professionals in delivering critical products and services, and offer opportunities for continual improvement and enhanced professional stature. Headquartered in Tampa, Florida, USA, BICSI membership spans nearly 100 countries.

BICSI 2012-14 Board of Directors

President: Jerry L. Bowman, RCDD, NTS, RTPM, CISSP, CDCDP

President-Elect: Michael Collins, RCDD, RTPM, CCDA, NCE

Secretary: Robert "Bob" Erickson, RCDD, NTS, OSP, WD, RTPM

Treasurer: Brian Ensign, RCDD, NTS, OSP, CSI

Canadian Region Director: Peter Levoy, RCDD

European Region Director: Brendan "Greg" Sherry, RCDD, NTS, WD

U.S. North-Central Region Director: Christy Miller, RCDD, RTPM

U.S. Northeast Region Director: Carol Everett Oliver, RCDD, ESS

U.S. South Central Region Director: Jeffrey Beavers, RCDD, OSP

U. S. Southeast Region Director: Charles "Chuck" Wilson, RCDD, NTS, OSP

U.S. Western Region Director: Larry Gillen, RCDD, ESS, OSP, CTS

BICSI Executive Director & Chief Executive Officer: John D. Clark Jr., CAE

International Credentials

BICSI's professional registration programs are internationally recognized.

- RCDD® Credential
 - Registered Communications Distribution Designer (RCDD®) credential holders demonstrate expertise in the design, implementation, integration of telecommunications and data communications systems, and infrastructure components.
- RITP Credential
 - Registered Information Technology Professional (RITP) credential holders demonstrate non-design expertise in the ITS industry.
- RTPM Credential
 - Registered Telecommunications Project Management (RTPM) credential holders demonstrate proficiency in a vast collection of telecommunications project management principles, concepts, tools, and technology.
- OSP Credential
 - Outside Plant (OSP) design credential holders demonstrate proficiency in the ability to understand and apply a vast collection of OSP technology, including right-of-way, route design, media selection, cabling hardware, bonding and grounding (earthing), and electrical protection systems.
- ESS Credential
 - Electronic Safety and Security (ESS) design credential holders demonstrate the ability to understand and apply a vast collection of ESS technology, including principles of security, design process, access control, surveillance systems, intrusion detection systems, fire detection and alarm systems, notification, communication and display devices, special systems, network security, system integration, project management, and systems operation and commissioning.
- DCDC Credential
 - Data Center Design Consultant (DCDC) credential holders demonstrate proficiency in the knowledge and ability over multiple facets within data center design, including the planning, implementing and making of critical decisions regarding data centers.
- BICSI ITS Installer 1; ITS Installer 2, Copper; ITS Installer 2, Optical Fiber; and ITS Technician
 - BICSI ITS Installers and Technicians are proficient in the latest ITS industry standards and codes requirements and in various topics, including the pulling, terminating, testing, and troubleshooting of copper and optical fiber cable using BICSI global best practices as a guide.

This technical design reference manual is not a single source document but a compendium of many sources of ITS industry-related practices, processes, and procedures.

The information contained in this technical design reference manual includes, but is not limited to, national and international codes, de jure and de facto standards, and industry-accepted best practices. All source information can be found in Appendix A: Codes, Standards, Regulations, and Organizations and the Bibliography section of this manual.

Acknowledgments

BICSI's Technical Information and Methods (TI&M) Committee serves to coordinate the information within all of BICSI's technical publications. BICSI officers, membership, and Publications staff wish to thank the TI&M Committee and its many volunteer contributors who helped in the development of the thirteenth edition of BICSI's *Telecommunications Distribution Methods Manual (TDMM)*.

The following dedicated TI&M Subject Matter Expert Team Leaders (SMETLs) and Subject Matter Experts (SMEs) provided the key expertise required for the development of this manual's technical content:

TI&M Chair and TDMM 13th Edition SMETL: **Robert M. Gross**, RCDD, OSP; *GroTech*
TI&M Vice-Chair: **Robert B. Hertling**, RCDD, OSP;
Parsons Transportation Group

Chapter 1:
Principles of Transmission

Chapter SMETL: **Paul Kish**, ITS Consultant; *Belden*

SME Contributors: **Richard S. Anderson**, RCDD; *Servamatic*
Beatriz M. "Betty" Bezos, RCDD, NTS, OSP, WD,
ESS, CT; *Ross & Baruzzini*
Robert Y. Faber Jr., RCDD, NTS; *Snake Tray*
Brent J. Lehmkuhl, RCDD; *Black & Veatch*
F. Patrick Mahoney, RCDD; *Cannon Design*

Chapter 2:
**Electromagnetic
Compatibility**

Chapter SMETL: **Dr. Paulo Sérgio Marin**, EE/BSc MSc, PhD;
Paulo Marin Consulting Services

SME Contributors: **Gordon J. Ash**, RCDD, CTS; *Leidos*
Robert Y. Faber Jr., RCDD, NTS; *Snake Tray*
George M. Fewell, RCDD;
NCI Information Systems Inc.
Paul Kish, ITS Consultant; *Belden*
Ken M. Michaels, RTPM; *iGround*
Igor G. Smirnoff, RCDD;
Signamax Connectivity Systems

Acknowledgments, continued

Chapter 3: Telecommunications Spaces

Chapter SMETL: **Philip W. Janeway**, RCDD; *tw telecom*

SME Contributors: **Richard S. Anderson**, RCDD; *Servamatic*
Gordon J. Ash, RCDD, CTS; *Leidos*
George M. Fewell, RCDD;
NCI Information Systems Inc.
Shawna Irwin, RCDD, WD;
City of Overland Park, Kansas
F. Patrick Mahoney, RCDD; *Cannon Design*
Dr. Paulo Sérgio Marin, EE/BSc MSc, PhD;
Paulo Marin Consulting Services
John Romanski, OSP, WD, ESS, RTPM, DCDC;
University of Central Florida
Ronald S. Timko, PE, LEED AP; *MDA*
Engineering, Inc.
Donald T. Wright, RCDD; *CH2M Hill*

Chapter 4: Backbone Distribution Systems

Chapter SMETL: **George M. Fewell**, RCDD;
NCI Information Systems Inc.

SME Contributors: **John C. Adams**, RCDD, OSP;
Adams Telecom Systems
Richard S. Anderson, RCDD; *Servamatic*
Robert M. Gross, RCDD, OSP; *GroTech*
Robert B. Hertling, RCDD, OSP;
Parsons Transportation Group
Joseph L. Leger, RCDD; *Syska Hennessy Group*
Ken M. Michaels, RTPM; *iGround*
John Romanski, OSP, WD, ESS, RTPM, DCDC;
University of Central Florida
Scott Smith, RCDD, ITS Technician; *Teletach*
Consulting
Donald T. Wright, RCDD; *CH2M Hill*

Acknowledgments, continued

Chapter 5: Horizontal Distribution Systems

Chapter SMETL: **Robert Y. Faber Jr.**, RCDD, NTS; *Snake Tray*

SME Contributors: **John C. Adams**, RCDD, OSP; *Adams Telecom*
Richard S. Anderson, RCDD; *Servamatic*
Dustin Bateman, PON Consultant; *VT Group*
Beatriz M. “Betty” Bezos, RCDD, NTS OSP, WD,
ESS, CT; *Ross & Baruzzini*
James (Ray) Craig, RCDD, NTS, ITS Technician;
Craig Consulting Services
Dave Cunningham, RCDD, PON Consultant;
Corning Cable Systems
Robert S. “Bob” Erickson, RCDD, NTS, OSP, WD,
RTPM; *Communications Network Design*
Robert M. Gross, RCDD, OSP; *GroTech*
Robert B. Hertling, RCDD, OSP;
Parsons Transportation Group
Christopher A. Hillyer, OSP, RITP, ITS Technician;
BICSI Master Instructor
Sean Kelly, RCDD, PON Consultant;
TE Connectivity
Joseph L. Leger, RCDD; *Syska Hennessy Group*
F. Patrick Mahoney, RCDD; *Cannon Design*
Jeff Silveira, RITP, CAE, AStd;
BICSI Director of Standards
Igor G. Smirnoff, RCDD;
Signamax Connectivity Systems
Scott Smith, RCDD, ITS Technician; *Teletach
Consulting*
Loni Le Van-Etter, *3M Communications*
Michael Watts, PON Consultant;
Verizon Federal Networking Systems
Michael Wilson, RCDD, PON Consultant; *Tellabs*

Chapter 6: ITS Cables and Connecting Hardware

Chapter SMETLs: **Robert Y. Faber Jr.**, RCDD, NTS; *Snake Tray*
Igor G. Smirnoff, RCDD;
Signamax Connectivity Systems

SME Contributors: **John C. Adams**, RCDD, OSP; *Adams Telecom*
Richard S. Anderson, RCDD; *Servamatic*
Shawna Irwin, RCDD, WD;
City of Overland Park, Kansas
Philip W. Janeway, RCDD; *tw telecom*
Brent J. Lehmkuhl, RCDD; *Black & Veatch*
Jeff Silveira, RITP, CAE, AStd;
BICSI Director of Standards
Scott Smith, RCDD, ITS Technician; *Teletach
Consulting*

Acknowledgments, continued

Chapter 7: Firestop Systems

Chapter SMETL: **James P. Stahl Jr.**, CFPS, CDT, *Specified Technologies, Inc.*

SME Contributors: **Edward F. Coye**, RCDD, NTS, OSP, WD, DCDC;
Tyco AMP
Robert Y. Faber Jr., RCDD, NTS; *Snake Tray*
Philip W. Janeway, RCDD; *tw telecom*
Brent J. Lehmkuhl, RCDD; *Black & Veatch*
Julio Lopes, *Specified Technologies, Inc.*
Justin Pine, *Specified Technologies, Inc.*
John Romanski, OSP, WD, ESS, RTPM, DCDC;
University of Central Florida

Chapter 8: Bonding and Grounding (Earthing)

Chapter SMETLs: **Ken M. Michaels**, RTPM; *iGround*
Mark S. Harger, B&G Consultant;
Harger Lightning & Grounding

SME Contributors: **Richard S. Anderson**, RCDD; *Servamatic*
Edward F. Coye, RCDD, NTS, OSP, WD, DCDC;
Tyco AMP
Robert Y. Faber Jr., RCDD, NTS; *Snake Tray*
Philip W. Janeway, RCDD; *tw telecom*
Justin Pine, *Specified Technologies, Inc.*
John Romanski, OSP, WD, ESS, RTPM, DCDC;
University of Central Florida

Chapter 9: Power Distribution

Chapter SMETL: **Brent J. Lehmkuhl**, RCDD; *Black & Veatch*

SME Contributors: **Richard S. Anderson**, RCDD; *Servamatic*
John C. Adams, RCDD, OSP; *Adams Telecom*
Shawna Irwin, RCDD, WD;
City of Overland Park, Kansas
John Romanski, OSP, WD, ESS, RTPM, DCDC;
University of Central Florida
Vince Saturno, PE, LEED AP, DCEP;
Black & Veatch
Jeff Silveira, RITP, CAE, AStd;
BICSI Director of Standards
Ronald S. Timko, PE, LEED AP;
MDA Engineering, Inc.
John R. Turner, PE, LC, LEED AP; *Wiley/Wilson*

Acknowledgments, continued

Chapter 10: Telecommunications Administration

Chapter SMETL: **Jonathan L. Jew**, ITS Consultant;
J&M Consultants, Inc.

SME Contributors: **John C. Adams**, RCDD, OSP; *Adams Telecom*
Beatriz M. “Betty” Bezos, RCDD, NTS, OSP, WD,
ESS, CT; *Ross & Baruzzini*
Robert S. “Bob” Erickson, RCDD, NTS, OSP, WD,
RTPM; *Communications Network Design*
Robert Y. Faber Jr., RCDD, NTS; *Snake Tray*
Todd Fries; *Hellermann Tyton*
Steven R. Huffaker, RCDD; *JPMorgan Chase*
Alexander Jew, ITS Consultant;
J&M Consultants, Inc.
F. Patrick Mahoney, RCDD; *Cannon Design*
Gene E. Malone, RCDD; *TE Connectivity*

Chapter 11: Field Testing of Structured Cabling

Chapter SMETL: **Robert Jensen**, RCDD,
The University of Texas at Austin

SME Contributors: **Richard S. Anderson**, RCDD; *Servamatic*
Robert M. Gross, RCDD, OSP; *GroTech*
Robert B. Hertling, RCDD, OSP;
Parsons Transportation Group
Ken M. Michaels, RTPM; *iGround*

Chapter 12: Outside Plant

Chapter SMETL: **John C. Adams**, RCDD, OSP; *Adams Telecom*

SME Contributors: **Richard S. Anderson**, RCDD; *Servamatic*
Robert M. Gross, RCDD, OSP; *GroTech*
Joseph L. Leger, RCDD; *Syska Hennessy Group*
Ken M. Michaels, RTPM; *iGround*
John Romanski, OSP, WD, ESS, RTPM, DCDC;
University of Central Florida

Acknowledgments, continued

Chapter 13: Audiovisual Systems

Chapter SMETL: **Gordon J. Ash**, RCDD, CTS; *Leidos*

SME Contributors: **John C. Adams**, RCDD, OSP; *Adams Telecom*
Edward F. Coye, RCDD, NTS, OSP, WD, DCDC;
Tyco AMP
Christopher A. Hillyer, OSP, RITP, ITS Technician;
BICSI Master Instructor
Shawna Irwin, RCDD, WD;
City of Overland Park, Kansas
Philip W. Janeway, RCDD; *tw telecom*
Brent J. Lehmkuhl, RCDD; *Black & Veatch*
Dr. Paulo Sérgio Marin, EE/BSc MSc, PhD;
Paulo Marin Consulting Services
John Romanski, OSP, WD, ESS, RTPM, DCDC;
University of Central Florida

Chapter 14: Building Automation Systems

Chapter SMETL: **Dr. Paulo Sérgio Marin**, EE/BSc MSc, PhD;
Paulo Marin Consulting Services

SME Contributors: **Gordon J. Ash**, RCDD, CTS; *Leidos*
Edward F. Coye, RCDD, NTS, OSP, WD, DCDC;
Tyco AMP
Robert Y. Faber Jr., RCDD, NTS; *Snake Tray*
George M. Fewell, RCDD;
NCI Information Systems Inc.
Jeff Silveira, RITP, CAE, AStd;
BICSI Director of Standards

Chapter 15: Data Networks

Chapter SMETL: **Chris Scharrer**, RCDD, NTS, OSP, WD;
DCS Technology Design, LLC

SME Contributors: **Richard S. Anderson**, RCDD; *Servamatic*
Cory Boon, RCDD; *coryandsteve.com*
Robert M. Gross, RCDD, OSP; *GroTech*
Shawna Irwin, RCDD, WD;
City of Overland Park, Kansas
Steve Kepekci, RCDD; *coryandsteve.com*
Ken M. Michaels, RTPM; *iGround*
Jeff Silveira, RITP, CAE, AStd;
BICSI Director of Standards

Acknowledgments, continued

Chapter 16: Wireless Networks

Chapter SMETL: **Robert Y. Faber Jr.**, RCDD, NTS; *Snake Tray*

SME Contributors: **Joseph A. Concepcion**, RCDD, OSP;
Physical Layer Telecommunications Consulting, LLC
Robert S. “Bob” Erickson, RCDD, NTS, OSP, WD,
RTPM; *Communications Network Design*
Robert B. Hertling, RCDD, OSP;
Parsons Transportation Group
Shawna Irwin, RCDD, WD;
City of Overland Park, Kansas
Joseph L. Leger, RCDD; *Syska Hennessy Group*
Mike Patterson, RCDD, PE;
Physical Layer Telecommunications Consulting, LLC
Timothy V. Peters, RCDD, WD; *Tech Knowledge, Inc.*
John Romanski, OSP, WD, ESS, RTPM, DCDC;
University of Central Florida
Ward Sellars, RCDD, WD;
Hidi Rae Consulting Engineers, Inc.

Chapter 17: Electronic Safety and Security

Chapter SMETL: **Dr. Paulo Sérgio Marin**, EE/BSc MSc, PhD;
Paulo Marin Consulting Services

SME Contributors: **Richard S. Anderson**, RCDD; *Servamatic*
Edward F. Coye, RCDD, NTS, OSP, WD, DCDC;
Tyco AMP
Robert Y. Faber Jr., RCDD, NTS; *Snake Tray*
Philip W. Janeway, RCDD; *tw telecom*
Dr. Paulo Sérgio Marin, EE/BSc MSc, PhD;
Paulo Marin Consulting Services
Reese J. Miller Jr., RCDD, PE; *Miller Engineering*
John Romanski, OSP, WD, ESS, RTPM, DCDC;
University of Central Florida

Acknowledgments, continued

Chapter 18: Data Centers

Chapter SMETL: **Stephen Banks**, RCDD; *Nightlake*

SME Contributors: **Robert S. “Bob” Erickson**, RCDD, NTS, OSP, WD, RTPM; *Communications Network Design*
Robert B. Hertling, RCDD, OSP;
Parsons Transportation Group.
Steven R. Huffaker, RCDD; *JPMorgan Chase*
Alexander Jew, ITS Consultant;
J&M Consultants, Inc.
Jonathan L. Jew, ITS Consultant;
J&M Consultants, Inc.
Joseph L. Leger, RCDD; *Syska Hennessy Group*
Jeff Silveira, RITP, CAE, AStd;
BICSI Director of Standards

Chapter 19: Health Care

Chapter SMETL: **Joseph L. Leger**, RCDD; *Syska Hennessy Group*

SME Contributors: **John C. Adams**, RCDD, OSP; *Adams Telecom*
Gordon J. Ash, RCDD, CTS; *Leidos*
George M. Fewell, RCDD;
NCI Information Systems Inc.

Chapter 20: Residential Cabling

Chapter SMETL: **Robert Jensen**, RCDD;
The University of Texas at Austin

SME Contributors: **John C. Adams**, RCDD, OSP; *Adams Telecom*
Richard S. Anderson, RCDD; *Servamatic*
George M. Fewell, RCDD;
NCI Information Systems Inc.
Robert M. Gross, RCDD, OSP; *GroTech*
Ken M. Michaels, RTPM; *iGround*

Acknowledgments, continued

**Chapter 21:
Business Development and
Project Management**

Chapter SMETL: **Shawna Irwin**, RCDD, WD;
City of Overland Park, Kansas

SME Contributors: **Richard S. Anderson**, RCDD; *Servamatic*
Gordon J. Ash, RCDD, CTS; *Leidos*
Edward F. Coye, RCDD, NTS, OSP, WD, DCDC;
Tyco AMP
Robert S. “Bob” Erickson, RCDD, NTS, OSP, WD,
RTPM; *Communications Network Design*
Robert B. Hertling, RCDD, OSP;
Parsons Transportation Group
Philip W. Janeway, RCDD; *tw telecom*
Joseph L. Leger, RCDD; *Syska Hennessy Group*
F. Patrick Mahoney, RCDD; *Cannon Design*
Kevin Seeley, RCDD, RTPM, ITS Technician;
Kevin Seeley, LLC

**Appendix A:
Codes, Standards,
Regulations, and
Organizations**

Appendix SMETL: **Robert B. Hertling**, RCDD, OSP;
Parsons Transportation Group

SME Contributors: **Beatriz M. “Betty” Bezos**, RCDD, NTS, OSP,
WD, ESS, CT; *Ross & Baruzzini*
Robert Y. Faber Jr., RCDD, NTS; *Snake Tray*
Anthony Frassetta, RCDD; *A|E Works*
Jeff Silveira, RITP, CAE, AStd;
BICSI Director of Standards
Philip W. Janeway, RCDD; *tw telecom*
Robert Jensen, RCDD;
The University of Texas at Austin
Peter Olders, RCDD, NTS, OSP, ITS Technician;
Terra Communications, Inc.

Acknowledgments, continued

Appendix B: Network Interfaces and Demarcation Points in the United States

Appendix SMETL: Philip W. Janeway, RCDD; *tw telecom*

SME Contributors: John C. Adams, RCDD, OSP; *Adams Telecom*
Robert B. Hertling, RCDD, OSP;
Parsons Transportation Group
Shawna Irwin, RCDD, WD;
City of Overland Park, Kansas
Brent J. Lehmkuhl, RCDD; *Black & Veatch*
John Romanski, OSP, WD, ESS, RTPM, DCDC;
University of Central Florida

Appendix C: Regulations and Standards for Emissions and Immunity

Appendix SMETL: George M. Fewell, RCDD;
NCI Information Systems Inc.

SME Contributors: Edward F. Coye, RCDD, NTS, OSP, WD, DCDC;
Tyco AMP
Philip W. Janeway, RCDD; *tw telecom*
John Romanski, OSP, WD, ESS, RTPM, DCDC;
University of Central Florida

Appendix D: Mechanical, Ingress, Climatic/Chemical, and Electromagnetic Considerations

Appendix SMETL: Philip W. Janeway, RCDD; *tw telecom*

SME Contributors: Beatriz M. “Betty” Bezos, RCDD, NTS, OSP, WD,
ESS, CT; *Ross & Baruzzini*
Robert Y. Faber Jr., RCDD, NTS; *Snake Tray*
F. Patrick Mahoney, RCDD; *Cannon Design*

Acknowledgments, continued

**Appendix E:
Legal Considerations for
the ITS Distribution Designer**

Appendix SMETL: **M. Georgia Gibson-Henlin**, Attorney-at-Law;
Nunes Scholefield Deleon & Co.

SME Contributors: **Gordon J. Ash**, RCDD, CTS; *Leidos*
George M. Fewell, RCDD;
NCI Information Systems Inc.
Robert M. Gross, RCDD, OSP; *GroTech*
Dr. Paulo Sérgio Marin, EE/BSc MSc, PhD;
Paulo Marin Consulting Services

Bibliography:

SMETL: **Robert B. Hertling**, RCDD, OSP;
Parsons Transportation Group

SME Contributors: **TDMM 13th Edition Revision Team**

Master Glossary:

SMETL: **Robert Y. Faber Jr.**, RCDD, NTS; *Snake Tray*

SME Contributors: **Gordon J. Ash**, RCDD, CTS; *Leidos*
Joseph A. Concepcion, RCDD, OSP;
Physical Layer Telecommunications Consulting, LLC
Mike Patterson, RCDD, PE;
Physical Layer Telecommunications Consulting, LLC

Index:

Jeff Silveira, RITP, CAE, AStd;
BICSI Director of Standards

Participants, *TDMM* 13th Edition Editorial Review, Tampa, FL, December 3-7, 2012:

John C. Adams, RCDD, OSP
Richard S. Anderson, RCDD
Gordon J. Ash, RCDD, CTS
Edward F. Coye, RCDD, NTS, OSP, WD, DCDC
Robert S. “Bob” Erickson, RCDD, NTS, OSP, WD, RTPM
Robert Y. Faber Jr., RCDD, NTS
George M. Fewell, RCDD
Robert M. Gross, RCDD, OSP
Robert B. Hertling, RCDD, OSP
Shawna Irwin, RCDD, WD
Philip W. Janeway, RCDD
Joseph L. Leger, RCDD
Brent J. Lehmkuhl, RCDD
F. Patrick Mahoney, RCDD
Dr. Paulo Sérgio Marin, EE/BSc MSc, PhD
Ken M. Michaels, RTPM
John Romanski, OSP, WD, ESS, RTPM, DCDC

BICSI staff attending:

Nicole Anastasia Bryson
John Ditzel
Jeff Giarrizzo
Clarke W. Hammersley
Karen Jacob
Jeff Silveira, RITP, CAE, AStd.
Paul Weintraub, RCDD, ESS, RTPM, ITS Technician

Editorial Review Logistics:

Lois Rosa

The following BICSI Professional Development staff members produced this manual at BICSI World Headquarters, Tampa, FL:

Acting Vice President of Professional Development:

John D. Clark Jr., CAE, BICSI Executive Director & CEO

**BICSI *TDMM* 13th Edition Project Manager/
Director of Publications:**

Clarke W. Hammersley

***TDMM* 13th Edition Lead Technical Editor:**

Karen Jacob

***TDMM* 13th Edition Co-Technical Editors:**

Jeff Giarrizzo
Amy Woodland (under contract)

***TDMM* 13th Design and Production:**

John Ditzel, Senior Publications Designer
Catherine Nold, Publications Designer

In fond memory of Nicole Anastasia Bryson, Publications Designer, who skillfully formatted much of this manual shortly before her passing.



1987-2013

BICSI Policy for Numeric Representation of Units of Measurement

BICSI technical manuals primarily follow the modern metric system, known as the International System of Units (SI). The SI is intended as a basis for worldwide standardization of measurement units. With the exception of conduit measurements, units of measurement in this manual are expressed in general and approximate SI terms, followed by an equivalent imperial (U.S. customary) unit of measurement in parentheses (see exceptions listed below):

- In general, approximate (soft) conversions are used in this manual and are denoted with the approximate symbol (\approx) in front of the metric number. Approximate conversions are considered reasonable and practicable; they are not precise equivalents. In some instances, equivalents (hard conversions) may be used when it is a:
 - Manufacturer requirement for a product (e.g., conduit sizes).
 - Standard or code requirement.
 - Safety factor.
- In general, approximate SI units of measurement are converted to an imperial unit of measurement and placed in parentheses. Exception: When the reference material from which the value is pulled is provided in imperial units only, the imperial unit is the benchmark.
- For metric conversion practices, refer to SI 10-02 American Society for Testing and Materials (ASTM)/Institute of Electrical and Electronics Engineers® (IEEE®) SI 10, *American National Standard for Use of the International System of Units (SI): The Modern Metric System*.
- Trade size is approximated for both metric and nonmetric purposes. Example: \approx 100 mm (4 trade size).
- In some instances (e.g., optical fiber media specifications), the physical dimensions and operating wavelengths are designated.

Become a BICSI Member!

BICSI membership is your key to a successful career in the ITS industry. Member benefits extend into the technical, legislative, and even the financial realms of this competitive industry. Membership offers ample opportunities for professional networking and career development and advancement. Join BICSI and combine your expertise with your colleagues in the network of ITS professionals.

Corporate Connection Program

The Corporate Connection Program gives BICSI's corporate members what they are looking for in one simple package. With six levels of membership to choose from, we are sure there is something that fits your corporate needs. Whether it's training, conference, or company recognition, the Corporate Connection membership has something for your company needs. Want more information? Call our Membership and Customer Care Department at +1 813.979.1991 or e-mail us at bicsi@bicsi.org.

Member Benefits

Gain the Competitive Edge!

Combine all the benefits of BICSI membership into one complete package and you will understand why BICSI members hold a competitive advantage. BICSI keeps you ahead of your competition through a continuous flow of new information in the fast-changing field of low-voltage distribution systems. By prominently displaying your BICSI membership, you make known your professional ability to industry contacts.

Fast Access to Information

BICSI's website (www.bicsi.org) is a quick way to find a wide variety of detailed BICSI information. While on the website, find answers to industry questions and communicate with members and colleagues through BICSI's online forums or social media sites. Search for BICSI members, installers, design specialists, project managers, and RCDDs. Corporate Connection members also have the option of providing a brief company description and a link to their website.

Member Discounts

BICSI members receive substantial discounts on quality education—manuals, standards, design courses, and conferences. BICSI members also receive discounts with some of the BICSI partner organizations.

In addition, BICSI offers health, dental, vision, disability, term life, and accidental death and dismemberment insurance for individuals and companies.

Member Benefits, continued

Training

BICSI presents leading-edge technical training in all phases of ITS distribution design and installation. These vendor-neutral courses are offered at hundreds of locations across the country and around the world, including nearly 100 BICSI Authorized Training Facilities (ATFs) and several Authorized Design Training Providers (ADTPs).

In addition, BICSI can bring first-class training to your location. All BICSI courses are available for on-site training. BICSI credentialed members gain knowledge and continuing education credits (CECs) by attending BICSI courses, conferences, and classes.

BICSI CONNECT

BICSI CONNECT, BICSI's interactive learning network, offers a flexible way to earn CECs and advance your ITS knowledge. BICSI CONNECT is available 24/7, 365 days a year from the convenience of any computer, accommodating your scheduling needs, while saving you travel and hotel expenses. Visit www.bicsiconnect.org/connect.aspx to view all of the current learning opportunities.

Educational Conferences

Each year, BICSI hosts conferences in North America as well as regularly scheduled conferences held in other BICSI Districts and Regions worldwide. Conferences include presentations by leaders in the ITS industry and opportunities to network with your peers. BICSI also offers a variety of other local educational opportunities in the form of Breakfast Clubs, Lunch and Learns and Pub Clubs. Visit www.bicsi.org for more information.

Technical Publications

Become a member and you will receive substantial discounts on BICSI's highly acclaimed manuals—long considered the definitive reference source of the industry. BICSI's manuals serve as valuable reference and study tools for BICSI courses and exams. BICSI manuals are based on global best practices that follow and, in many cases, exceed the requirements of recognized international codes, standards, and regulations. Our most popular publications include the *Telecommunications Distribution Methods Manual (TDMM)*, *Electronic Safety and Security Design Reference Manual (ESSDRM)*, *Outside Plant Design Reference Manual (OSPDRM)*, and *Information Technology Systems Installation Methods Manual (ITSIMM)*. Standards include ANSI/BICSI 002-2011, *Data Center Design and Implementation Best Practices*, ANSI/BICSI 004-2012, *Information Technology Systems Design and Implementation Best Practices for Healthcare Institutions and Facilities*, and ANSI/BICSI 005-2013, *Electronic Safety And Security (ESS) System Design And Implementation Best Practices*.

Member Benefits, continued

Legislative and Standards Involvement

In the United States, the BICSI Governmental Relations Committee constantly monitors legislative, regulatory, and judicial activities and will advise you of any actions that affect BICSI and its membership. BICSI's representatives take active roles in standards-setting panels and agencies worldwide.

BICSI Community UPLINK

BICSI Community UPLINK features news about upcoming conferences, workshops, and region meetings; training and exam schedules; announcements from the Board of Directors; new publications; and other newsworthy BICSI information.

Recruiting and Job Search Engine

BICSI's ITS-jobs.com offers the ITS industry an effective tool to bring employers and job seekers together. ITS-jobs.com has an expanded number of resumes and jobs posted and offers an important service for BICSI members and the entire ITS industry.

The web-based resume posting, recruiting, and job search engine is truly an interactive tool. Using ITS-jobs.com, job seekers can post, edit, and update resumes. Areas of expertise can be identified so that employers can more easily find qualified candidates. Automatic notifications are sent when job postings match job seeker criteria.

If you are an employer seeking ITS talent, the extensive search capabilities of ITS-jobs.com help filter experience and background to search for the most qualified candidates. You also will have access to statistics such as number of views and number of applications for a job posting.

There is no cost to post and manage resumes and apply for jobs. For posting available jobs, employers pay a fee. A discounted rate applies to employers who are BICSI members.

Complete information can be found at <http://careers.its-jobs.com>.

Member Benefits, continued

Newsletters and Website

BICSI helps keep you in touch with industry news and association activities through *The Journal of Information Technology Systems*, *BICSI Community UPLINK*, ATF Insider, and targeted communications. BICSI's website (www.bicsi.org) provides immediate information about BICSI activities around the world. The site offers members and visitors the opportunity to register for courses, conferences, and exams and participate in online forum discussion topics.

BICSI members also can view a listing of more than 15,000 BICSI credential holders, including RCDDs, specialty designations, and Registered Installers and Technicians. Promote your company online as a BICSI Corporate Connection Member and include a direct link to your website. Purchase manuals and receive "members-only" access to valuable documents.

Join BICSI Today!

BICSI membership is open to individuals and corporations serving the ITS and building industries. Join BICSI, and combine your expertise with your colleagues in the network of ITS professionals. Complete BICSI information is available upon request. For a membership application or other information, contact:

Membership and Customer Care
8610 Hidden River Parkway
Tampa, FL 33637-1000 USA
Tel.: 800.242.7405 (USA/Canada toll-free)
Tel.: +1 813.979.1991
Fax: +1 813.971.4311
E-mail: bicsi@bicsi.org
Website: www.bicsi.org

We welcome your comments about the *TDMM*. To do so, simply complete the Reader's Comment Form on the last page of this Preface and return it to BICSI. Our goal is to make BICSI publications the most important design and reference tools in your office.

Comments? More Information?

For information on how to use this manual, see the following page.

To submit comments about the BICSI *Telecommunications Distribution Methods Manual (TDMM)* or for further information about BICSI, please complete the Reader's Comment Form in this section or contact:

BICSI World Headquarters

8610 Hidden River Parkway

Tampa, FL 33637-1000 USA

Tel.: 800.242.7405 (USA/Canada toll-free)

Tel.: +1 813.979.1991

Fax: +1 813.971.4311

E-mail: bicsi@bicsi.org

Web site: www.bicsi.org

HOW TO USE THIS MANUAL

Chapter number and name are indicated at the outside top of each page.

Chapter 1: Principles of Transmission

Chapters are divided into sections.

Section Heading

Topic Heading

Each chapter section is divided into multiple subheadings.

Part Heading

Part headings are used to discuss major areas of a topic.

- Bullet important terms and phrases.
 - Bullets are often followed by more detailed information.

Figures, examples, and tables are numbered sequentially in a given chapter. Each is followed by a brief descriptive title.

Figure 1.1
Title

TDMM, 13th edition

1-1

Page numbers are shown at the bottom of the page. The chapter number precedes the page number.

© 2014 BICSI®

Reader's Comment Form

Telecommunications Distribution Methods Manual (TDMM), 13th edition

You may use this form to communicate your comments about this publication, its organization, or the subject matter. Your comments will be sent to BICSI's Technical Information and Methods (TI&M) Committee for review and action, if any is deemed appropriate.

Comments (please include specific chapter and page reference; attach a marked-up page when a figure change is needed):

Please complete the following information:

last name	first name	middle initial	date
company name			
mailing address			
city	state/province	zip/postal code	country
daytime phone	fax	e-mail	

Thank you for your comments.

Send to: Attn: *TDMM* User Response
BICSI
8610 Hidden River Parkway
Tampa, FL 33637-1000 USA

or fax to: +1 813.971.4311
**or scan and
e-mail to:** chammersley@bicsi.org

Office Use Only

Response from Technical Information and Methods Committee:

Class A Class B Class C

TI&M Committee chair signature

date

TI&M SME chair signature

date

Table of Contents

Chapter 1: Principles of Transmission

SECTION 1: METALLIC MEDIA

Metallic Media	1-1
Electrical Conductors	1-2
American Wire Gauge (AWG)	1-5
Insulation.	1-5
Balanced Twisted-Pair Cables	1-8
Environmental Considerations.	1-9
Cable Shielding	1-13
Drain Wires	1-16
Analog Signals	1-17
Telephony	1-24
Digital Signals	1-30
Types of Transmission Circuits	1-42
Asynchronous and Synchronous Transmission	1-43
Digital Hierarchy	1-44
Video Transmission	1-50
Transmission Line Concepts	1-53
Balanced Twisted-Pair Performance	1-64
Balanced Twisted-Pair Channel Performance.	1-65
Balanced Twisted-Pair Permanent Link Performance	1-69
Balanced Twisted-Pair Applications	1-70

SECTION 2: OPTICAL FIBER

Optical Fiber.	1-83
Optical Fiber Transmitters	1-84
Optical Fiber Receivers	1-93
Optical Fiber Medium.	1-94
Bandwidth	1-96
Optical Fiber Applications Support Information	1-108
Verifying Optical Fiber Performance and Electronics Compatibility	1-110
Selecting an Optical Fiber Core Size to Application or Original Equipment Manufacturer (OEM) Specifications	1-121
Synchronous Optical Network (SONET) and Synchronous Digital Hierarchy (SDH) Concepts	1-122
Appendix	1-126

Chapter 2: Electromagnetic Compatibility

Electromagnetic Compatibility (EMC) 2-1

Electromagnetics 2-5

Overview of Electromagnetic Compatibility (EMC) 2-8

Electromagnetic Interference (EMI)—A Problem 2-12

Electromagnetic Compatibility (EMC)—The Solution. 2-16

Electromagnetic Interference (EMI) and Cabling 2-20

Electromagnetic Qualification Parameters. 2-21

Unwanted Signals 2-28

Grounding (Earthing). 2-31

Specific Telecommunications Electromagnetic Compatibility (EMC) Guidelines . . . 2-40

Minimizing Electromagnetic Interference (EMI). 2-40

Considerations for Electromagnetic Compatibility (EMC) in Cabling Systems. . . . 2-42

Interference Reduction in Shielded Rooms 2-49

Electromagnetic Interference (EMI) and Bandwidth of Balanced Twisted-Pair Cabling 2-49

Telecommunications Cabling Within Joint-Use Tunnel. 2-52

Chapter 3: Telecommunications Spaces

Telecommunications Spaces 3-1

Telecommunications Spaces Considerations 3-2

Telecommunications Rooms (TRs) and Telecommunications Enclosures (TEs) 3-22

Telecommunications Room (TR) and Telecommunications Enclosure (TE) Applications 3-23

Telecommunications Room (TR) Design 3-25

General Requirements for All Telecommunications Enclosures (TEs) 3-30

Equipment Rooms (ERs) 3-32

Equipment Room (ER) Design. 3-34

Locating the Equipment Room (ER). 3-37

Space Allocation and Layout. 3-43

Cable Installation and Pathways 3-49

Electrical Power 3-52

Heating, Ventilation, and Air-Conditioning (HVAC) Environmental Control 3-55

Miscellaneous Considerations 3-58

Design Approval, Buildout, and Final Inspection 3-59

Entrance Facilities (EFs). 3-61

Chapter 4: Backbone Distribution Systems

Backbone Distribution Systems. 4-1

Backbone Topologies 4-4

Hierarchical Star Campus Backbone Designs 4-5

Backbone Cable Lengths	4-12
Telecommunications Rooms (TRs) and Telecommunications Enclosures (TEs)	4-13
Building Backbones	4-16
Choosing Media	4-23
Backbone Building Pathways (Internal)	4-26
Miscellaneous Support Facilities	4-33
Bonding and Grounding (Earthing)	4-35
Backbone Planning	4-36
Indoor Hardware	4-38
Ethernet in the First Mile (EFM)	4-40
 Chapter 5: Horizontal Distribution Systems	
Horizontal Distribution Systems	5-1
 SECTION 1: HORIZONTAL CABLING SYSTEMS	
Horizontal Cabling Systems	5-5
Horizontal Cabling Media	5-18
Work Areas and Open Office Cabling	5-21
Centralized Optical Fiber Cabling	5-39
Passive Optical Networks (PONs)	5-43
 SECTION 2: HORIZONTAL PATHWAYS	
Horizontal Pathways	5-53
Types of Horizontal Pathways	5-58
Ceiling Distribution Systems	5-78
Other Horizontal Pathways	5-95
 SECTION 3: ADA REQUIREMENTS	
Americans with Disabilities Act (ADA) Requirements	5-103
Appendix: Disabled Access and the Americans with Disabilities Act (ADA)	5-111
 Chapter 6: ITS Cables and Connecting Hardware	
ITS Cables and Connecting Hardware	6-1
Balanced Twisted-Pair Cables	6-3
Optical Fiber Cables	6-15
Coaxial Cables	6-27
Balanced Twisted-Pair Connectors	6-36
Balanced Twisted-Pair Connecting Hardware	6-60
Balanced Twisted-Pair Connecting Blocks	6-66
Optical Fiber Connectors	6-82
Optical Fiber Connecting Hardware	6-95
Coaxial Connectors	6-101
Coaxial Connecting Hardware	6-110

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 7-20

Firestop for Brick, Concrete Block, and Concrete Walls 7-35

Firestop for Framed Wall Assemblies 7-38

Firestop for Lath and Plaster Walls 7-45

Firestop for Combination Walls 7-45

Firestop for Floor Assemblies 7-46

Firestop for Floor/Ceiling Assemblies 7-47

Structural Steel Floor Units with Concrete Floor Fill without Suspended Ceiling Membranes 7-51

Firestop for Roof/Ceiling Assemblies 7-51

Fire-Rated Vertical Shafts 7-52

Firestop for Curtain Wall Floor/Ceiling Seals 7-52

General Firestop Considerations 7-56

Appendix A: Approved Firestop Methods 7-58

Appendix B: Testing and Guidelines for Firestops 7-114

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 8-13

Lightning Exposure 8-29

Appendix: Bonding and Grounding (Earthing) Standards 8-33

Chapter 9: Power Distribution

Power Distribution 9-1

Alternating Current (ac) Power 9-2

American Wire Gauge (AWG) 9-16

Alternating Current (ac) Voltage Quality Problems 9-20

Power Distribution 9-29

Electrical Safety 9-33

Power System Redundancy 9-37

Power Conditioning/Power Protection 9-43

Direct Current (dc) Power 9-62

Installation of Direct Current (dc) Systems 9-73

Batteries	9-75
Power System Alarms	9-85
Power System Monitoring and Control	9-88
Conductor Identification.	9-90

Chapter 10: Telecommunications Administration

Telecommunications Administration.	10-1
Identification Methods	10-11
Identification Systems	10-24
Labeling and Recordkeeping	10-28
Administration of Large Spaces.	10-36

Chapter 11: Field Testing of Structured Cabling

Field Testing of Structured Cabling	11-1
Balanced Twisted-Pair Cabling Tests.	11-3
Balanced Twisted-Pair Cabling Acceptance Tests	11-12
Coaxial Cabling Testing	11-18
Optical Fiber Cabling Tests	11-19
Optical Fiber Cabling Acceptance Tests.	11-23
Optical Fiber Cabling Field Testing	11-25
Maintenance and Troubleshooting for Optical Fiber Cabling.	11-28
Additional Optical Fiber Troubleshooting Tools and Equipment.	11-29

Chapter 12: Outside Plant

Outside Plant	12-1
Types of Entrances	12-4
Underground Entrances	12-5
General Recommendations for Underground Entrances	12-7
Terminating Conduit at a Designated Property Line	12-8
Terminating Conduit Inside a Building	12-9
Bonding and Grounding (Earthing)	12-10
Buried Entrances.	12-10
Aerial Entrances	12-11
Aerial Cable at a Building	12-12
Other Telecommunications Service Entrance Considerations.	12-18
Terminating Space for Telecommunications Entrance Facilities	12-23
Outside Building Terminals (Pedestals and Cabinets)	12-25
Conduit Guidelines	12-36
Maintenance Hole Guidelines	12-41
Cabling Placement.	12-45
Aerial Plant Criteria	12-48

Chapter 13: Audiovisual Systems

Audiovisual (AV) Systems 13-1
Fundamentals. 13-2
Types of Signals. 13-10
Environmental Considerations. 13-34
Visual Display Systems. 13-42
Program Audio and Speech Reinforcement Systems 13-47
Signal Distribution Systems. 13-57
Audioconferencing Systems 13-59
Videoconferencing Systems 13-74
Control Systems. 13-84
Overhead Paging Systems. 13-87
Sound Masking Systems 13-97
Digital Signage Systems 13-102
Cable Television Distribution Systems 13-106

Chapter 14: Building Automation Systems

Building Automation Systems (BAS) 14-1
Building Automation Systems (BAS) Interfaces with Other Systems 14-4
Building Automation Systems (BAS) Communications Networks 14-16
Building Automation Systems (BAS) Electrical Characteristics. 14-22
Planning Building Automation Systems (BAS) Distribution Cabling 14-24

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 15-20
Computer Rooms 15-22
Campus and Multisite Network Design. 15-34

Chapter 16: Wireless Networks

Wireless Networks. 16-1
Services and Applications 16-2
Frequency and Wavelength 16-6
Electromagnetic Spectrum 16-10
Wireless System Design. 16-20
Selection of Technology 16-23

Components of a Wireless System.	16-26
Distributed Antenna Systems (DAS)	16-34
Personal Area Networks (PANs)	16-63
Wireless LAN (WLAN) Technology	16-65
Wireless LAN (WLAN) Components	16-67
Chapter 17: Electronic Safety and Security	
Electronic Safety and Security (ESS)	17-1
Locks and Electronic Access Control (EAC)	17-10
Video Surveillance.	17-24
Intrusion Detection	17-34
Fire Alarm (FA) and Detection.	17-37
Notification Appliances.	17-41
Control Units	17-44
Digital Alarm Communicator System (DACs)	17-48
Chapter 18: Data Centers	
Data Centers	18-1
Data Center Redundancy and Availability	18-4
Structured Cabling Hierarchy for Data Centers	18-10
Guidelines for Telecommunications Cabling, Cable Containment, Equipment Racks, and Cabinets	18-17
Data Center Security	18-24
Operation, Ownership Costs, Environmental Impact, and Efficiency.	18-30
Appendix: Data Center Planning Considerations	18-31
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	19-27
Picture Archiving and Communication System (PACS)	19-29
Patient Monitoring.	19-30
Radio Frequency Identification (RFID)–Based Systems	19-33
Interactive Patient Entertainment and Education Systems	19-37
Wayfinding and Signage.	19-41
Regulatory Bodies and Organizations.	19-42

Chapter 20: Residential Cabling

Residential Cabling 20-1
 Components 20-4
 Planning the Cabling System 20-21
 Rough-In Cabling 20-22
 Finish Cabling 20-24

Chapter 21: Business Development and Project Management

SECTION 1: BUSINESS DEVELOPMENT

Business Development. 21-1

SECTION 2: PROJECT MANAGEMENT

Telecommunications Project Management (TPM) 21-5
 Building Information Modeling (BIM) 21-50

Appendix A: Codes, Standards, Regulations, and Organizations

Introduction A-1
 International Codes and Standards A-6
 Regional Codes and Standards A-29
 National Codes and Standards A-40
 Enforcement of United States (U.S.) Building Codes, Standards, and
 Regulations A-69
 Regulations and Standards for Wireless Transmission A-72
 United States (U.S.) Approval of Electrical Products and Equipment A-78
 Canadian Approval of Electrical Products and Equipment A-81
 European Approval of Electrical Products and Equipment A-82

Appendix B: Network Interfaces and Demarcation Points in the United States

Network Interfaces and Demarcation Points in the United States B-1
 Definitions B-1
 Classifications. B-1
 Groups B-2
 Types B-2
 Voice Connectors B-3
 Data Connectors B-23
 Network Channel Equipment Connectors B-41
 Optical Fiber Connector Interface B-43

Appendix C: Regulations and Standards for Emissions and Immunity

Commercial Products Marketed in the United States (U.S.) C-1
Radiation Limits for Class A and Class B. C-2
Emission Limits for Class A and Class B C-3
Commercial Products Marketed Outside the United States (U.S.) C-4
Electrostatic Discharge (ESD) C-8

Appendix D: Mechanical, Ingress, Climatic/Chemical, and Electromagnetic Considerations

Introduction D-1
Environmental Classification System D-3
Compatibility with MICE Environment D-6

Appendix E: Legal Considerations for the ITS Distribution Designer

Legal Aspects of Information Technology Systems (ITS) Design E-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).	1-10
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) . .	1-11
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	Internet protocol telephony architecture	1-28
Figure 1.7	Digital signal level one frame format	1-33
Figure 1.8	E1 frame format	1-34
Figure 1.9	Polar non-return-to-zero level.	1-38
Figure 1.10	Bipolar alternate mark inversion	1-38
Figure 1.11	Biphase Manchester	1-38
Figure 1.12	Two binary bits encoded into one quaternary (2B1Q)	1-39
Figure 1.13	Multilevel transition-3 (MLT-3, also referred to as non-return-to-zero inverted [NRZI-3])	1-39
Figure 1.14	Composite video	1-51
Figure 1.15	Two-conductor transmission line	1-53
Figure 1.16	Resistive model.	1-54
Figure 1.17	Capacitance model	1-55
Figure 1.18	Inductive model	1-56
Figure 1.19	Primary transmission line parameters	1-57
Figure 1.20	General transmission model	1-58
Figure 1.21	Example of a channel test configuration.	1-65
Figure 1.22	Permanent link test configuration	1-69
Figure 1.23	Spectral profile comparison of laser and light-emitting diode	1-85
Figure 1.24	Spectral width of a light-emitting diode source showing full width half maximum	1-86
Figure 1.25	Numerical aperture	1-87
Figure 1.26	System bandwidth versus distance example.	1-96
Figure 1.27	Pulse distortion because of rise time and data rate	1-98
Figure 1.28	Link bandwidth at 1300 nanometers using 62.5/125 micrometer multimode optical fiber	1-102
Figure 1.29	Core and coating.	1-105
Figure 1.30	Digital signal cross-connect optical multiplexing design	1-123
Figure 1.31	Synchronous optical network multiplexing design	1-124
Figure 1.32	Wavelength division multiplexing	1-125

Chapter 2: Electromagnetic Compatibility

Figure 2.1	Electromagnetic spectrum	2-2
Figure 2.2	Dependence of the safe distance to electromagnetic interference source on its power.	2-9
Figure 2.3	Model T for a short wire channel	2-24
Figure 2.4	Surge test voltage waveform sample.	2-27
Figure 2.5	Common mode versus differential mode	2-29
Figure 2.6	Ground loops in shielded cabling systems	2-32
Figure 2.7	Ground loop because of stray capacitance at high frequencies	2-33
Figure 2.8	Common impedance coupling interference	2-34
Figure 2.9	Field-to-cable and ground loop	2-35
Figure 2.10	Coupling reduction as function of grounding (earthing) practice	2-37
Figure 2.11	Higher frequency twist decrease	2-38
Figure 2.12	Typical power line filter	2-46
Figure 2.13	Isolation transformer scheme	2-47
Figure 2.14	Samples of ferrite toroids, beads, and sleeves	2-48
Figure 2.15	Balance concept	2-50
Figure 2.16	Electromagnetic interference susceptibility of circuits and systems connected through unshielded cables	2-53
Figure 2.17	Ground loop and electromagnetic interference immunity	2-55

Chapter 3: Telecommunications Spaces

Figure 3.1	Typical telecommunications room layout	3-27
Figure 3.2	Typical sleeve/conduit	3-28
Figure 3.3	Typical shallow room layout	3-29
Figure 3.4	Typical access provider equipment room	3-39
Figure 3.5	Typical equipment room layout	3-44

Chapter 4: Backbone Distribution Systems

Figure 4.1	Typical backbone hierarchical star topology for multiple buildings on a campus (inside and outside distribution).	4-4
Figure 4.2	Example of a first level hierarchical star campus backbone	4-5
Figure 4.3	Example of multiple hierarchical level campus backbone design	4-7
Figure 4.4	Levels of cross-connections	4-8
Figure 4.5	Logical bus topology	4-9
Figure 4.6	Logical ring topology implemented using a physical star topology	4-10
Figure 4.7	Logical tree topology implemented using a hierarchical star topology	4-11
Figure 4.8	Buildings connected by a physical ring	4-14
Figure 4.9	Example of main backbone ring and redundant backbone star combined.	4-15
Figure 4.10	Star building backbone	4-17
Figure 4.11	Hierarchical star building backbone	4-18
Figure 4.12	Redundant routing for building backbone (HCs [FDs] not linked)	4-19

Table of Contents

Figure 4.13	Example of combined optical fiber/balanced twisted-pair backbone supporting voice and data traffic.	4-20
Figure 4.14	Equipment rooms and access provider cabling system interface cabling.	4-22
Figure 4.15	Typical office building pathway layout	4-29
Figure 4.16	Typical sleeve and slot installations	4-31
Figure 4.17	Ethernet in the first mile network boundaries	4-40
Figure 4.18	Point-to-multipoint optical topology.	4-42
Figure 4.19	Point-to-point optical fiber	4-43
Figure 4.20	Point-to-point balanced twisted-pair topology.	4-46

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	5-13
Figure 5.7	Example of connection by means of interconnection	5-14
Figure 5.8	Example of connection by means of cross-connection and interconnection.	5-15
Figure 5.9	Example of connection by means of double cross-connection	5-16
Figure 5.10	Total cable length in the horizontal cabling system channel	5-19
Figure 5.11	Pin/pair assignments.	5-22
Figure 5.12	Typical dimensions for furniture telecommunications outlet/connector	5-25
Figure 5.13	Example of multiuser telecommunications outlet assembly application	5-27
Figure 5.14	Consolidation points used in a combined furniture system and private office work area environment	5-31
Figure 5.15	Consolidation points located on all columns	5-35
Figure 5.16	Consolidation points located in a space between the columns.	5-36
Figure 5.17	Consolidation points located in checkerboard order.	5-37
Figure 5.18	Consolidation points located on columns close to the building core	5-38
Figure 5.19	Centralized optical fiber cabling	5-40
Figure 5.20	Traditional active Ethernet design compared with passive optical network-based architecture	5-43
Figure 5.21	Underfloor conduit extended to individual telecommunications outlet boxes	5-58
Figure 5.22	Typical underfloor conduit system	5-59
Figure 5.23	Conduit bodies recommended for telecommunications cables.	5-60
Figure 5.24	Recommended pull box configurations.	5-67

Figure 5.25	Stringered access floor system	5-72
Figure 5.26	Recommended clearance for access floor spaces.	5-73
Figure 5.27	Typical zoned ceiling (plan view).	5-81
Figure 5.28	Conduit-based ceiling zone (elevation view).	5-82
Figure 5.29	Rules of installation for discrete cable support facilities	5-84
Figure 5.30	Raceways and fittings	5-86
Figure 5.31	Attaching various utility columns.	5-88
Figure 5.32	Perimeter raceway	5-97
Figure 5.33	Molding raceway	5-98
Figure 5.34	Side-reach telephones.	5-107
Figure 5.35	Forward-reach telephones	5-108
Figure 5.36	International teletypewriter/text telephone symbol and volume control telephone symbol.	5-110

Chapter 6: ITS Cables and Connecting Hardware

Figure 6.1	Balanced twisted-pair cable construction types.	6-7
Figure 6.2	Examples of balanced twisted-pair cables	6-8
Figure 6.3	Multimode optical fiber	6-18
Figure 6.4	Singlemode optical fiber.	6-18
Figure 6.5	Side view of a loose-tube optical fiber cable.	6-21
Figure 6.6	Loose-tube furcating harness	6-21
Figure 6.7	Loose-tube optical fiber cable.	6-22
Figure 6.8	Tight-buffered optical fiber cable, distribution construction.	6-24
Figure 6.9	Tight-buffered optical fiber cable, breakout construction	6-24
Figure 6.10	Series-6 quad shield (screen) coaxial cable	6-27
Figure 6.11	Classification of cables and wires according to the <i>National Electrical Code</i>	6-33
Figure 6.12	110-style insulation displacement contact connector design.	6-37
Figure 6.13	Examples of 66-style connector designs.	6-40
Figure 6.14	BIX-style insulation displacement contact connector design	6-43
Figure 6.15	Examples of LSA-style connector designs.	6-46
Figure 6.16	8P8C unkeyed modular plug.	6-49
Figure 6.17	8P8C modular plugs for stranded and solid conductors	6-50
Figure 6.18	8P8C modular jack	6-52
Figure 6.19	Modular jack design	6-53
Figure 6.20	Eight-position jack pin/pair assignments (front view)	6-54
Figure 6.21	50-position miniature ribbon connector	6-56
Figure 6.22	50-position miniature ribbon connector design	6-57
Figure 6.23	Telecommunications outlet/connectors.	6-60
Figure 6.24	Examples of work area telecommunications outlet designs.	6-61
Figure 6.25	Rack-mount \approx 483 mm (19 in) modular patch panel	6-62
Figure 6.26	Modular patch panel with cable management bar installed in an \approx 483 mm (19 in) equipment rack.	6-64

Table of Contents

Figure 6.27	66-style block, 89-style mounting brackets, and a distribution frame with installed 66-style blocks	6-66
Figure 6.28	110-style wiring blocks	6-68
Figure 6.29	BIX-style connecting blocks mounted in a distribution frame	6-71
Figure 6.30	25-pair BIX-style connecting strip	6-72
Figure 6.31	LSA-style connecting blocks	6-73
Figure 6.32	10-pair LSA-style connecting block	6-74
Figure 6.33	Hybrid equipment cord assembly or hybrid patch cord assembly.	6-76
Figure 6.34	Example of MS2 and Type 710 insulation displacement connector splicing contacts	6-78
Figure 6.35	Example of single-pair splice connectors and modules	6-79
Figure 6.36	Example of multipair splice connectors and modules	6-80
Figure 6.37	LC-style optical fiber adapters and connectors	6-85
Figure 6.38	Subscriber connector-style optical fiber adapters and connectors	6-87
Figure 6.39	Straight tip-style optical fiber connector	6-88
Figure 6.40	Array-style optical fiber connector and adapter (example of Type-A multifiber push-on configuration)	6-89
Figure 6.41	Array-style optical fiber connector and adapter (example of Type-B multifiber push-on configuration)	6-90
Figure 6.42	Fusion splicer	6-91
Figure 6.43	Mechanical splice open position	6-92
Figure 6.44	Optical fiber pigtail splicing	6-94
Figure 6.45	Cross-connection of optical fiber cabling segments (first- and second-level backbone)	6-96
Figure 6.46	Interconnection of equipment to backbone cabling	6-97
Figure 6.47	Hybrid optical fiber patch cord assembly	6-98
Figure 6.48	BNC-style connector	6-102
Figure 6.49	BNC-style connector components	6-102
Figure 6.50	BNC-style connector plug and jack	6-103
Figure 6.51	50-ohm and 75-ohm bayonet BNC-style connectors	6-103
Figure 6.52	One-piece crimp-style F-style connector	6-106
Figure 6.53	N-style coaxial connector	6-108
Figure 6.54	Standard wall-mount multimedia and modular furniture multimedia outlets featuring F-style coaxial connectors	6-110
Figure 6.55	BNC-style bracket mount and F-style \approx 483 mm (19 in) rack-mount coaxial patch panels	6-112

Chapter 7: Firestop Systems

Figure 7.1	Standard time/temperature curves	7-10
Figure 7.2	Elastomeric modules (within frames).	7-21
Figure 7.3	Mechanical firestop system	7-22
Figure 7.4	Example of fire-rated pathway device	7-23

Figure 7.5	Typical plastic pipe device	7-25
Figure 7.6	Typical cast-in-place firestop device	7-26
Figure 7.7	Examples of poke-thru.	7-27
Figure 7.8	Continuous conduit penetration through concrete	7-35
Figure 7.9	Cable penetration in concrete wall or floor	7-36
Figure 7.10	Polyvinyl chloride innerduct penetration in concrete wall	7-36
Figure 7.11	Polyvinyl chloride innerduct penetration in concrete floor.	7-37
Figure 7.12	Qualified cable tray seal system in concrete wall.	7-37
Figure 7.13	Qualified steel pipe system in framed wall	7-38
Figure 7.14	Telecommunications cable seal system for framed wall	7-39
Figure 7.15	Nonmetallic innerduct penetration of framed wall	7-40
Figure 7.16	Sleeve systems for retrofit over existing cables	7-41
Figure 7.17	Sleeve system with cable tray	7-42
Figure 7.18	Sleeve system with cable support	7-43
Figure 7.19	Expansion joint or slot in a floor	7-54
Figure 7.20	Expansion joint or slot in a wall	7-54
Figure 7.21	Perimeter gap.	7-55
Figure 7.22	Seal system in a curtain wall	7-55
Figure 7.23	Typical label for all firestops	7-57
Figure 7.24	Concrete floor or wall	7-59
Figure 7.25	Typical framed wall penetration.	7-60
Figure 7.26	Typical concrete wall penetration	7-61
Figure 7.27	Concrete wall or floor (metallic pipes)	7-62
Figure 7.28	Concrete wall or floor (no penetrating item).	7-63
Figure 7.29	Concrete wall or floor (electrical power, telecommunications, and building signaling cables).	7-64
Figure 7.30	Concrete floor (electrical power and telecommunications cables)	7-65
Figure 7.31	Framed wall (steel pipes or conduit)	7-66
Figure 7.32	Framed wall (cable).	7-67
Figure 7.33	Framed wall (steel or aluminum cable trays)	7-68
Figure 7.34	Concrete wall (cable).	7-69
Figure 7.35	Concrete floor or wall (bus duct).	7-70
Figure 7.36	Concrete floor or wall (steel pipe)	7-71
Figure 7.37	Framed wall (cables).	7-72
Figure 7.38	Framed wall (polyvinyl chloride pipe [closed or vented])	7-73
Figure 7.39	Floor or wall (PVC, CPVC, or PB pipe [closed or vented] or RNC).	7-74
Figure 7.40	Wood joist floor (steel or copper pipe).	7-76
Figure 7.41	Concrete floor or wall (electrical power, building signaling, control, and telecommunications cables)	7-77
Figure 7.42	Concrete floor or wall (steel or aluminum cable tray).	7-78
Figure 7.43	Framed wall (steel or aluminum cable tray)	7-79

Table of Contents

Figure 7.44	Floor or wall (steel or aluminum cable tray)	7-80
Figure 7.45	Floor or wall (pipes and cable tray)	7-81
Figure 7.46	Head of wall joint (framed wall or concrete fluted deck).	7-82
Figure 7.47	Head of wall joint (concrete wall or concrete fluted deck).	7-83
Figure 7.48	Concrete floor or wall (telecommunications cable)	7-84
Figure 7.49	Framed wall (telecommunications cable)	7-85
Figure 7.50	Framed wall (telecommunications cable)	7-86
Figure 7.51	Framed wall (telecommunications cable)	7-87
Figure 7.52	Concrete floor or wall (telecommunications cable)	7-88
Figure 7.53	Concrete floor or wall (telecommunications cable)	7-89
Figure 7.54	Framed wall stud cavity (electrical outlet box)	7-90
Figure 7.55	Concrete floor or wall (no penetrating item).	7-91
Figure 7.56	Concrete floor or wall (PVC innerduct or ENT with optical fiber cables)	7-92
Figure 7.57	Concrete floor or wall (PVC innerduct or ENT with optical fiber cables)	7-93
Figure 7.58	Framed wall (nonmetallic conduit).	7-94
Figure 7.59	Framed wall (electrical power, building signaling, control, or telecommunications cable steel sleeve system)	7-96
Figure 7.60	Framed wall (electrical power, building signaling, control, or telecommunications cable split sleeve system)	7-98
Figure 7.61	Plenum-rated wrap system for combustible pipe	7-100
Figure 7.62	Intumescent blocks	7-101
Figure 7.63	Framed wall (electrical power, building signaling, control, or telecommunications cable steel sleeve system)	7-102
Figure 7.64	Concrete floor or wall (electrical power, building signaling, control, or telecommunications cable steel sleeve system)	7-103
Figure 7.65	Framed wall (power, building signaling, control, or telecommunications split cable pathway system)	7-104
Figure 7.66	Framed wall (power, building signaling, control, or telecommunications cable sleeve device system)	7-105
Figure 7.67	Concrete floor (power, building signaling, control, or telecommunications cable sleeve system)	7-107
Figure 7.68	Framed wall (telecommunications cable steel sleeve membrane penetration system)	7-108
Figure 7.69	Framed wall (telecommunications cable firestop grommet membrane penetration system)	7-109
Figure 7.70	Framed wall (telecommunications cable firestop grommet penetration system)	7-110
Figure 7.71	Typical perimeter fire barrier system exterior insulation glass panel curtain wall	7-111
Figure 7.72	Typical framed wall heating, ventilation, and air-conditioning duct . . .	7-112
Figure 7.73	Concrete floor (power, building signaling, control, or telecommunications cable pathway system).	7-113

Chapter 8: Bonding and Grounding (Earthing)

Figure 8.1	Typical supplementary bonding grid	8-12
Figure 8.2	Small systems	8-15
Figure 8.3	Recommended large system arrangement	8-17
Figure 8.4	Typical telecommunications main grounding busbar	8-18
Figure 8.5	Typical telecommunications grounding busbar	8-20
Figure 8.6	Equipment rack bonding and grounding (earthing)	8-27
Figure 8.7	Zone of protection.	8-30
Figure 8.8	Cone of protection.	8-31
Figure 8.9	Extending zone of protection	8-32

Chapter 9: Power Distribution

Figure 9.1	Measuring amplitude	9-2
Figure 9.2	Measuring phase difference in a three-phase system.	9-4
Figure 9.3	Delta configuration	9-5
Figure 9.4	Wye configuration	9-5
Figure 9.5	Center-tapped single-phase configuration	9-6
Figure 9.6	Typical electrical power system.	9-7
Figure 9.7	Typical electrical power system.	9-7
Figure 9.8	Calculation chart.	9-8
Figure 9.9	Voltage and current in phase (resistive load)	9-10
Figure 9.10	Current lags voltage (inductive circuit)	9-10
Figure 9.11	Current leads voltage (capacitive load)	9-11
Figure 9.12	Panelboard connection to equipment.	9-30
Figure 9.13	Power distribution unit connection to equipment.	9-31
Figure 9.14	Sample Class 1 electrical system topology	9-39
Figure 9.15	Sample Class 2 electrical system topology	9-40
Figure 9.16	Sample Class 3 electrical system topology	9-41
Figure 9.17	Class 4 electrical system topology.	9-42
Figure 9.18	Uninterruptible power supply module with maintenance bypass cabinet	9-50
Figure 9.19	Series configured rotary uninterruptible power supply system	9-51
Figure 9.20	Elevation of modular uninterruptible power supply system.	9-53
Figure 9.21	Single module uninterruptible power supply system	9-56
Figure 9.22	Parallel redundant uninterruptible power supply system	9-57
Figure 9.23	Isolated redundant uninterruptible power supply system	9-58
Figure 9.24	Distributed redundant uninterruptible power supply system	9-59
Figure 9.25	Communications link uninterruptible power supply system.	9-60
Figure 9.26	Typical direct current power system	9-63
Figure 9.27	Identification by color, letter, or marking	9-91

Chapter 10: Telecommunications Administration

Figure 10.1 Telecommunications administration systems 10-1
 Figure 10.2 Numbering telecommunications rooms 10-12
 Figure 10.3 Numbering cable trays 10-14
 Figure 10.4 Labeling example 10-18
 Figure 10.5 Example of equipment identification 10-23
 Figure 10.6 Recordkeeping system example 10-32
 Figure 10.7 Room grid coordinate example 10-37
 Figure 10.8 Sample rack and cabinet nongrid identifiers 10-38

Chapter 11: Field Testing of Structured Cabling

Figure 11.1 Wire map testing. 11-3
 Figure 11.2 Pair electrical lengths. 11-5
 Figure 11.3 Propagation delay/delay skew 11-5
 Figure 11.4 Return loss. 11-6
 Figure 11.5 Near-end crosstalk 11-7
 Figure 11.6 Attenuation-to-crosstalk ratio–far-end. 11-8
 Figure 11.7 Power sum near-end crosstalk 11-9
 Figure 11.8 Coaxial time domain reflectometer test 11-11
 Figure 11.9 Typical work area three-connector channel 11-12
 Figure 11.10 Typical work area four-connector channel 11-13
 Figure 11.11 Typical data center four-connector channel 11-13
 Figure 11.12 Work area three-connector permanent link 11-14
 Figure 11.13 Work area four-connector permanent link 11-14
 Figure 11.14 Data center four-connector permanent link 11-15
 Figure 11.15 Optical time domain reflectometer display 11-22

Chapter 12: Outside Plant

Figure 12.1 Underground pathway plan 12-3
 Figure 12.2 Installing underground entrances 12-7
 Figure 12.3 Examples of building attachment 12-13
 Figure 12.4 Vertical conduit mast. 12-16
 Figure 12.5 Cable entrance sleeve through a wall 12-17
 Figure 12.6 Direct-buried pathway plan 12-28
 Figure 12.7 Typical joint trenching dimensions (section view through trench) 12-33
 Figure 12.8 Positioning conduit on poles 12-40
 Figure 12.9 Typical maintenance hole diagram. 12-41
 Figure 12.10 Typical maintenance hole on private property. 12-42
 Figure 12.11 Basic maintenance hole configurations. 12-45
 Figure 12.12 Typical cable maintenance hole. 12-46
 Figure 12.13 Maintenance hole racking. 12-47

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	13-8
Figure 13.9	Sample rate the size of the signal frequency	13-13
Figure 13.10	Sample rate double the size of the signal frequency	13-14
Figure 13.11	Video signal building blocks	13-17
Figure 13.12	Video signal bandwidth	13-18
Figure 13.13	Analog video signals	13-22
Figure 13.14	Radio frequency (RF) signal	13-23
Figure 13.15	Examples of digital visual interface connectors	13-24
Figure 13.16	Example of high-definition multimedia interface (HDMI) connector . . .	13-25
Figure 13.17	Example of a DisplayPort connector.	13-26
Figure 13.18	Optimum and acceptable viewing areas	13-36
Figure 13.19	Sightlines.	13-37
Figure 13.20	Flat floor—seats aligned.	13-38
Figure 13.21	Tiered floor—seats staggered	13-39
Figure 13.22	Chain of typical audio components	13-47
Figure 13.23	Example of horn installation	13-49
Figure 13.24	Potential versus needed acoustic gain measurements	13-51
Figure 13.25	Loudspeaker dispersion polar plot	13-54
Figure 13.26	Loudspeaker coverage formula	13-55
Figure 13.27	Typical audioconferencing system	13-60
Figure 13.28	Conference room microphone pickup pattern	13-63
Figure 13.29	Two connected rooms and their acoustic echo cancellers	13-66
Figure 13.30	Telephone hybrid	13-68
Figure 13.31	Line echo canceller	13-68
Figure 13.32	Loudspeaker coverage angle	13-70
Figure 13.33	Microphone pickup and loudspeaker coverage patterns	13-72
Figure 13.34	Field of view.	13-77
Figure 13.35	Camera bright-to-dark ranges	13-78
Figure 13.36	Videoconference light setup	13-80
Figure 13.37	Hexagonal loudspeaker pattern.	13-90
Figure 13.38	Square loudspeaker pattern	13-91
Figure 13.39	70 Volt loudspeaker line loss	13-94
Figure 13.40	Distributed amplifier system	13-96

Table of Contents

Figure 13.41 Collaboration of component technology	13-103
Figure 13.42 Home run network design	13-109
Figure 13.43 Trunk and tap design.	13-110
Figure 13.44 Video over balanced twisted-pair cabling	13-111
Figure 13.45 Video over optical fiber cabling	13-112
Figure 13.46 Dividing the optical signal	13-112
Figure 13.47 Signal tilt for ≈ 12.7 mm (0.50 in) hardline.	13-113

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 building automation systems	14-4
Figure 14.3 Heating, ventilation, and air-conditioning system in a small commercial building	14-8
Figure 14.4 Hierarchical configuration of processor and controller levels	14-17
Figure 14.5 Cabling system elements and channel	14-29
Figure 14.6 Single-point and chained branch devices	14-31
Figure 14.7 Cabling system topologies for building automation systems	14-37
Figure 14.8 Devices bridged at horizontal cross-connect (floor distributor) or horizontal connection point.	14-38
Figure 14.9 Devices chained at the horizontal cross-connect (floor distributor) or horizontal connection point.	14-39
Figure 14.10 Building automation systems equipment cabling	14-42
Figure 14.11 Traditional distributed building automation system with multiple horizontal pathways	14-43
Figure 14.12 Integrated distributed building automation system with single horizontal pathway	14-44
Figure 14.13 Separate and consolidated cabling systems	14-46
Figure 14.14 Reducing quantity and costs of building automation systems controllers	14-48

Chapter 15: Data Networks

Figure 15.1 Example of a LAN	15-2
Figure 15.2 Example of a wide area network	15-3
Figure 15.3 Open Systems Interconnection Reference Model	15-5
Figure 15.4 Message transfer described using the Open Systems Interconnection Reference Model	15-7
Figure 15.5 Multiple routers in an internetwork	15-11
Figure 15.6 Integrated voice over Internet protocol infrastructure	15-16
Figure 15.7 Types of network video communications	15-17
Figure 15.8 Functional (top-down) design	15-20
Figure 15.9 Physical (bottom-up) design.	15-21

Figure 15.10 Class 1 telecommunications infrastructure	15-22
Figure 15.11 Class 2 telecommunications infrastructure	15-23
Figure 15.12 Class 3 telecommunications infrastructure	15-24
Figure 15.13 Class 4 telecommunications infrastructure	15-25
Figure 15.14 Server-to-switch connections	15-26
Figure 15.15 Redundant server-to-switch connections	15-27
Figure 15.16 Server-to-storage director connections	15-28
Figure 15.17 Redundant server-to-storage director connections	15-29
Figure 15.18 Example of Class 3 and Class 4 network and storage infrastructure. . .	15-30
Figure 15.19 Centralized data center topology.	15-31
Figure 15.20 End-of-row data center topology.	15-32
Figure 15.21 Top-of-rack data center topology	15-33
Figure 15.22 Example of campus network	15-34
Figure 15.23 Links from customer site to service provider	15-36
Figure 15.24 Example of a centralized wide area network design.	15-38
Figure 15.25 Example of a partial mesh wide area network design.	15-39
Figure 15.26 Partial mesh wide area network after a link failure	15-40
Figure 15.27 Example of a full mesh wide area network design	15-41

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 Electromagnetic spectrum	16-11
Figure 16.5 Amplitude modulation	16-12
Figure 16.6 Frequency modulation	16-13
Figure 16.7 Phase modulation	16-14
Figure 16.8 Pulse modulation techniques	16-15
Figure 16.9 Harmonic distortion.	16-17
Figure 16.10 Typical distributed antenna system environments	16-36
Figure 16.11 Omnidirectional antennas.	16-39
Figure 16.12 Directional antennas	16-40
Figure 16.13 Radiating cable standoff mount.	16-43
Figure 16.14 Headend and backend	16-47
Figure 16.15 Optical to radio frequency coupling power relationship	16-49
Figure 16.16 Extended service set using a wireless distribution system	16-68
Figure 16.17 Extended service set using a cable distribution system	16-69
Figure 16.18 Point-to-point bridging.	16-72
Figure 16.19 Point-to-multipoint bridging	16-73
Figure 16.20 Repeating bridge.	16-74

Chapter 17: Electronic Safety and Security

Figure 17.1 Elements of a security program 17-2

Figure 17.2 Threat, risk, and vulnerability assessments 17-4

Figure 17.3 Security quandary. 17-5

Figure 17.4 Single-connector modified permanent link with one connection point 17-15

Figure 17.5 Electric strikes 17-18

Figure 17.6 Magnetic locks 17-20

Figure 17.7 Electric locksets 17-21

Figure 17.8 Electric latch and mechanical operation 17-22

Figure 17.9 Electrified exit hardware 17-23

Figure 17.10 Grid display layouts. 17-30

Figure 17.11 Typical fire alarm pull station 17-40

Figure 17.12 Enhanced annunciator panel. 17-52

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 24764. 18-15

Figure 18.3 Example of TIA-942-A data center topology 18-16

Figure 18.4 Cabling cross-sectional area comparison 18-17

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 Technology distribution room 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 19-31

Figure 19.12 Typical radio frequency identification tag 19-34

Figure 19.13 Typical interactive patient TV infrastructure system. 19-40

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	20-10
Figure 20.3	Example of a residential premises cabling system.	20-12
Figure 20.4	Multi-dwelling unit cabling layout	20-14
Figure 20.5	Telecommunications backbone and distribution cabling layout for an apartment building with a central backbone	20-15
Figure 20.6	Telecommunications backbone and distribution cabling layout for an apartment building with multiple backbones.	20-16
Figure 20.7	Example of conduit distribution for a seven-unit townhouse.	20-17
Figure 20.8	Cabling distribution for a side-by-side duplex residence.	20-18
Figure 20.9	Example of cable distribution for frame apartment projects	20-19
Figure 20.10	Example of an apartment complex with backbone cable	20-20
Figure 20.11	Telecommunications outlets/connectors.	20-25

Chapter 21: Business Development and Project Management

Figure 21.1	Simple organizational breakdown structure	21-16
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	21-21
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.	21-28
Figure 21.9	United States National CAD Standard® layer name format	21-44

Appendix A: Codes, Standards, Regulations, and Organizations

Figure A.1	Conformité européenne (CE) mark	A-82
------------	---	------

Appendix B: Network Interfaces and Demarcation Points in the United States

Figure B.1	RJ11C/RJ11W connector configuration.	B-4
Figure B.2	RJ15C connector configuration	B-5
Figure B.3	RJ16X connector configuration	B-6
Figure B.4	RJ17C connector configuration	B-8
Figure B.5	RJ18C, RJ18W connector configuration	B-9
Figure B.6	RJ31X connector configuration	B-10
Figure B.7	RJ14C/RJ14W connector configuration.	B-11
Figure B.8	RJ14X connector configuration	B-12
Figure B.9	RJ25C connector configuration	B-13
Figure B.10	RJ61X connector configuration	B-14

Table of Contents

Figure B.11	RJ2DX connector configuration	B-15
Figure B.12	RJ2EX connector configuration	B-16
Figure B.13	RJ2FX connector configuration	B-17
Figure B.14	RJ2GX connector configuration	B-18
Figure B.15	RJ2HX connector configuration	B-19
Figure B.16	RJ21X connector configuration	B-20
Figure B.17	RJ2MB connector configuration	B-21
Figure B.18	RJ71C connector configuration	B-22
Figure B.19	RJ41S single-line data connection	B-24
Figure B.20	RJ45S single-line data connection	B-25
Figure B.21	RJ4MB single-line data connection.	B-26
Figure B.22	RJ41M single-line data connection.	B-28
Figure B.23	RJ45M single-line data connection.	B-30
Figure B.24	RJ26X single-line data connection	B-31
Figure B.25	RJ27X single-line data connection	B-32
Figure B.26	RJ48S connector configuration	B-33
Figure B.27	RJ48T connector configuration	B-34
Figure B.28	RJ48C connector configuration	B-35
Figure B.29	RJ48M connector configuration	B-36
Figure B.30	RJ48X connector configuration	B-37
Figure B.31	RJ48H connector configuration	B-38

Appendix C: Regulations and Standards for Emissions and Immunity

Figure C.1	Emission limits at 10 m (\approx 33 ft)	C-4
Figure C.2	IEC CISPR 22 conducted disturbance limits (main ports)	C-5
Figure C.3	IEC CISPR 22 conducted disturbance limits (telecommunications ports)	C-5

Appendix D: Mechanical, Ingress, Climatic/Chemical, and Electromagnetic Considerations

Figure D.1	Industrial floor area described by MICE classification 1, 2, or 3.	D-2
------------	--	-----

Tables

Chapter 1: Principles of Transmission

Table 1.1	Conductor descriptions	1-2
Table 1.2	Solid conductor properties	1-3
Table 1.3	Electrical characteristics of common insulation types	1-6
Table 1.4	Explanations of insulation electrical characteristics	1-7
Table 1.5	Types of cable shields	1-15
Table 1.6	Common units of frequency measurement	1-18
Table 1.7	Spectrums of standard frequency bands	1-21
Table 1.8	Power ratios from 0 to 60 decibels	1-22
Table 1.9	Transmission data rates	1-30
Table 1.10	Coding methods	1-37
Table 1.11	Asymmetric digital subscriber line standards	1-46
Table 1.12	Asymmetric digital subscriber line performance	1-47
Table 1.13	Very high bit-rate digital subscriber line data rate and target range . . .	1-48
Table 1.14	Propagation delay/delay skew	1-61
Table 1.15	Balanced twisted-pair cabling channel performance	1-71
Table 1.16	Applications supported using 100-ohm balanced twisted-pair cabling . .	1-72
Table 1.17	Media selection	1-74
Table 1.18	Transmission, speed, distance, and pair requirements	1-76
Table 1.19	Characteristics of typical light-emitting diode sources	1-88
Table 1.20	Characteristics of typical short wavelength laser	1-89
Table 1.21	Characteristics of typical vertical cavity surface emitting laser sources	1-90
Table 1.22	Characteristics of typical laser diode sources	1-91
Table 1.23	Comparison of transmitters	1-92
Table 1.24	Optical fiber cable performance by type	1-95
Table 1.25	Summarized comparison of core sizes of multimode and singlemode optical fiber cable	1-103
Table 1.26	Typical characteristics of multimode optical fiber	1-104
Table 1.27	Characteristics of 50/125 μm multimode optical fiber	1-105
Table 1.28	Characteristics of 62.5/125 μm multimode optical fiber	1-106
Table 1.29	Typical characteristics of singlemode optical fiber	1-107
Table 1.30	Maximum cable attenuation coefficient	1-109
Table 1.31	Mismatch of core size and power loss	1-112
Table 1.32	Calculating optical fiber performance	1-113
Table 1.33	System gain, power penalties, and link loss budget calculations	1-116
Table 1.34	Calculating losses	1-117

Table of Contents

Table 1.35	Splice loss values in decibels	1-118
Table 1.36	Minimum system loss	1-120
Table 1.37	Common synchronous optical network and synchronous digital hierarchy transmission rates.	1-122
Table 1.38	Levels of multiplexing and carrier transmission in North America	1-128
Table 1.39	Levels of multiplexing and carrier transmission in Europe	1-130

Chapter 2: Electromagnetic Compatibility

Table 2.1	Factors that can affect electromagnetic interference in telecommunications equipment.	2-12
Table 2.2	Factors that can affect electromagnetic interference in sites.	2-14
Table 2.3	Four levels of immunity	2-22
Table 2.4	Electrostatic discharge susceptibility ranges	2-23
Table 2.5	Mutual capacitance ranges for telecommunications cables	2-25
Table 2.6	Minimum separation distances from possible sources of electromagnetic interference exceeding 5 kilovolt-amperes	2-44
Table 2.7	Separation requirements between metallic cabling and specific electromagnetic interference sources	2-45

Chapter 3: Telecommunications Spaces

Table 3.1	Size guidelines	3-14
Table 3.2	Smaller buildings	3-15
Table 3.3	Allocating termination space.	3-17
Table 3.4	Layout considerations	3-26
Table 3.5	Environmental control systems standards for equipment rooms	3-56

Chapter 4: Backbone Distribution Systems

Table 4.1	Backbone distribution system components.	4-2
Table 4.2	Length and data rates for choosing optical fiber type.	4-25
Table 4.3	Common conduit sizes with vernacular	4-26
Table 4.4	Summary of Ethernet in the first mile physical layer signaling systems.	4-41
Table 4.5	Ethernet in the first mile installed singlemode optical fiber.	4-44

Chapter 5: Horizontal Distribution Systems

Table 5.1	Maximum allowable cable lengths with the use of multiuser telecommunications outlet assemblies.	5-29
Table 5.2	Comparison of consolidation point locations	5-34
Table 5.3	Primary passive optical network variations and their source standards.	5-44
Table 5.4	Maximum channel attenuation and supported distance for passive optical network versions	5-47

Table 5.5	Typical electrical metallic tubing conduit fill rate for varying cable diameters	5-62
Table 5.6	Bend radii guidelines	5-65
Table 5.7	Adapting designs	5-66
Table 5.8	Typical space requirements for pull boxes having conduit enter at opposite ends of the box	5-68
Table 5.9	Slip sleeves and gutters	5-69
Table 5.10	Coverings.	5-75
Table 5.11	Load capacity	5-75
Table 5.12	Guidelines for recommending ceiling panels	5-79
Table 5.13	Common types of cable trays	5-90
Table 5.14	Common cable tray dimensions	5-92
Table 5.15	Americans with Disabilities Act height requirements	5-106

Chapter 6: ITS 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	6-5
Table 6.4	Balanced cable designs	6-6
Table 6.5	Optical fiber cable transmission performance parameters.	6-16
Table 6.6	Typical distances supported by optical fiber cabling.	6-20
Table 6.7	Examples of regional fire safety standards	6-30
Table 6.8	Communications cable types	6-31
Table 6.9	Optical fiber cable types	6-32
Table 6.10	Interclass relativity of <i>National Electrical Code</i> and International Electrotechnical Commission fire safety specifications	6-34
Table 6.11	Comparison between <i>National Electrical Code</i> CM ratings and Canadian Standards Association FT requirements	6-35
Table 6.12	Connecting hardware transmission performance categories for 110-style connector-based connecting hardware.	6-38
Table 6.13	Connecting hardware transmission performance categories	6-41
Table 6.14	Connecting hardware transmission performance categories for BIX-style connectors	6-44
Table 6.15	Connecting hardware transmission performance categories for LSA-style connector-based connecting hardware.	6-47
Table 6.16	Modular plug transmission performance categories	6-51
Table 6.17	Modular jack transmission performance categories	6-55
Table 6.18	50-position miniature ribbon connector transmission performance categories	6-58
Table 6.19	Optical fiber link transmission performance calculations worksheet	6-83
Table 6.20	Splice insertion loss guidelines and objectives	6-93

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) 7-47

Table 7.6 Electrical apparatus, boxes, and access panels firestop methods (in ceilings) 7-48

Table 7.7 Pipes, conduits, sleeve systems, innerducts, cable trays, and cable penetration firestop methods (in floors/ceilings) 7-49

Table 7.8 Underfloor pipe, conduit, sleeve system, and innerduct firestop methods (in floors) 7-50

Table 7.9 Pipe sizes and fire ratings 7-75

Table 7.10 Sizes of pipe chokes, wrap strip layers, and fire ratings 7-95

Table 7.11 United States firestop standards 7-115

Table 7.12 Canadian firestop standards 7-117

Table 7.13 International firestop standards 7-118

Chapter 8: Bonding and Grounding (Earthing)

Table 8.1 Basic guide to calculating bonding conductor resistance values. 8-24

Chapter 9: Power Distribution

Table 9.1 Circular mils of standard American wire gauge conductors. 9-17

Table 9.2 Electrical formulas. 9-19

Table 9.3 Voltage and current fluctuations 9-20

Table 9.4 K-rating based on load makeup 9-25

Table 9.5 Calculating maximum input current. 9-70

Table 9.6 Calculating voltage 9-71

Table 9.7 Major alarms (direct current) 9-85

Table 9.8 Minor alarms (direct current) 9-86

Table 9.9 Major alarms (uninterruptible power supply) 9-86

Table 9.10 Color code for conductors in the United States 9-90

Table 9.11 Color code for conductors in the United Kingdom and Ireland 9-92

Chapter 10: Telecommunications Administration

Table 10.1 Required identifiers by class 10-5

Table 10.2 Minimum and optional administration system elements 10-7

Table 10.3 Color codes 10-16

Table 10.4 Identifying pathways 10-29

Table 10.5 Required records by class. 10-34

Chapter 11: Field Testing of Structured Cabling

Table 11.1 Determining worst-case attenuation coefficient. 11-24

Chapter 12: Outside Plant

Table 12.1	Service diversity	12-21
Table 12.2	Terminating space	12-23
Table 12.3	Vertical/horizontal separations	12-32
Table 12.4	Metallic conduit types and sizes used in telecommunications	12-37
Table 12.5	Direct-bury polyvinyl chloride (PVC) conduit types and sizes used in telecommunications	12-38
Table 12.6	Nonmetallic conduit types and sizes used in telecommunications	12-39

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	13-15
Table 13.4	Supported video formats	13-27
Table 13.5	Standard-definition TV versus high-definition TV	13-29
Table 13.6	Front and rear projection advantages and disadvantages	13-45
Table 13.7	Area covered by horns	13-92
Table 13.8	Articulation index speech intelligibility	13-100
Table 13.9	Example of loss values per ≈ 30 m (100 ft) of the coaxial cable for the lowest and highest channels in a 60-channel system	13-114

Chapter 14: Building Automation Systems

Table 14.1	Typical work and building automation systems coverage area sizes	14-33
------------	--	-------

Chapter 16: Wireless Networks

Table 16.1	Transceiver types and application	16-27
------------	---	-------

Chapter 18: Data Centers

Table 18.1	Comparison of the standards	18-11
------------	---------------------------------------	-------

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 distribution device and associated equipment	20-8
Table 20.3	Telecommunications outlets/connectors for residences	20-11
Table 20.4	Minimum space for a multi-dwelling unit common telecommunications room	20-13

Chapter 21: Business Development and Project Management

Table 21.1	MasterFormat® 2012 numbering	21-38
------------	--	-------

Appendix A: Codes, Standards, Regulations, and Organizations

Table A.1	Relationship between series EN 50174 and other design standards	A-30
Table A.2	Sections of the <i>Canadian Electrical Code</i>	A-44
Table A.3	Federal Communications Commission documents	A-52

Table of Contents

Table A.4	<i>NEESC</i> [®] parts, sections, and rules applicable to telecommunications distribution requirements	A-54
Table A.5	<i>NEC</i> [®] 2011 chapters, articles, and sections that impact telecommunications installation	A-59
Table A.6	Federal safety and health standards	A-71
Table A.7	Federal Communications Commission Regulations.	A-75

Appendix B: Network Interfaces and Demarcation Points in the United States

Table B.1	RJ11C/RJ11W connector configuration	B-3
Table B.2	RJ15C connector configuration	B-5
Table B.3	RJ16X connector configuration	B-6
Table B.4	RJ17C connector configuration	B-7
Table B.5	RJ18C, RJ18W connector configuration	B-9
Table B.6	RJ31X connector configuration	B-10
Table B.7	RJ14C/RJ14W connector configuration.	B-11
Table B.8	RJ14X connector configuration	B-12
Table B.9	RJ25C connector configuration	B-13
Table B.10	RJ61X connector configuration	B-14
Table B.11	RJ2DX connector configuration	B-15
Table B.12	RJ2EX connector configuration	B-16
Table B.13	RJ2FX connector configuration	B-17
Table B.14	RJ2GX connector configuration	B-18
Table B.15	RJ2HX connector configuration	B-19
Table B.16	RJ21X connector configuration	B-20
Table B.17	RJ2MB connector configuration	B-21
Table B.18	RJ71C connector configuration	B-22
Table B.19	RJ41S single-line data connection	B-23
Table B.20	RJ45S single-line data connection	B-25
Table B.21	RJ4MB single-line data connection.	B-26
Table B.22	RJ41M single-line data connection.	B-27
Table B.23	RJ45M single-line data connection.	B-29
Table B.24	RJ26X single-line data connection	B-31
Table B.25	RJ27X single-line data connection	B-32
Table B.26	RJ48S connector configuration	B-33
Table B.27	RJ48T connector configuration	B-34
Table B.28	RJ48C connector configuration	B-35
Table B.29	RJ48M connector configuration	B-36
Table B.30	RJ48X connector configuration	B-37
Table B.31	RJ48H connector configuration	B-38
Table B.32	Intermixable services at network-provided standard connectors	B-39
Table B.33	Facility interface code translator	B-42

Appendix C: Regulations and Standards for Emissions and Immunity

Table C.1 Class A radiation limits C-2
 Table C.2 Class B radiation limits C-2
 Table C.3 CENELEC EN 61000-6-1 and CENELEC EN 61000-6-2 generic standards . . C-6

Appendix D: Mechanical, Ingress, Climatic/Chemical, and Electromagnetic Considerations

Table D.1 List of applicable International Electrotechnical Commission test procedures. D-4
 Table D.2 Ingress protection codes D-7
 Table D.3 Enclosure ratings and ingress protection codes. D-8
 Table D.4 Comparison of specific applications of enclosures for indoor nonhazardous locations D-9

Examples

Chapter 1: Principles of Transmission

Example 1.1 Optical fiber performance calculations example 1-114

Chapter 14: Building Automation Systems

Example 14.1 Scope of work checklist 14-25

Chapter 21: Business Development and Project Management

Example 21.1 Work breakdown structure 21-19
 Example 21.2 Work breakdown structure in a text outline format. 21-20



Chapter 1

Principles of Transmission

Chapter 1 focuses on the main concepts related to signal transmission through metallic and optical fiber transmission media. Among those concepts, this chapter discusses types of signals and their properties, types of transmission, and performance of different types of transmission media. The appendix provides additional information about signals provided in North America and Europe.

This chapter has been updated to reflect current best practices, codes, standards, and technology.

Table of Contents

SECTION 1: METALLIC MEDIA

Metallic Media	1-1
Overview	1-1
Electrical Conductors	1-2
Overview	1-2
Description of Conductors	1-2
Comparison of Solid Conductors	1-3
Solid Conductors versus Stranded Conductors	1-4
Composite Conductor	1-4
American Wire Gauge (AWG)	1-5
Overview	1-5
Insulation	1-5
Overview	1-5
Electrical Characteristics of Insulation Materials	1-6
Balanced Twisted-Pair Cables	1-8
Overview	1-8
Pair Twists	1-8
Tight Twisting	1-8
Environmental Considerations	1-9
Electromagnetic Interference (EMI)	1-9
Temperature Effects	1-9
Cable Shielding	1-13
Description	1-13
Shielding Effectiveness	1-13
Types of Shields	1-14
Solid Wall Metal Tubes	1-14
Conductive Nonmetallic Materials	1-14
Selecting a Cable Shield	1-14
Comparison of Cable Shields	1-15
Drain Wires	1-16
Overview	1-16
Applications	1-16
Specifying Drain Wire Type	1-16

Analog Signals 1-17

- Overview 1-17
- Sinusoidal Signals 1-17
- Standard Frequency Bands. 1-21
- Decibel (dB) 1-22
- Echo and Delay. 1-23
- Phase and Delay 1-23

Telephony 1-24

- Overview 1-24
 - Telephone Line Impedance 1-25
 - Telephony Echo 1-25
 - Telephony Distortion. 1-26
- Trends 1-26
- Internet Protocol (IP) Telephony 1-27
 - Overview 1-27
 - Internet Protocol (IP) Telephony Devices. 1-27
 - Internet Protocol (IP) Telephony Architecture 1-27
 - Power Over Balanced Twisted-Pair 1-29
 - Mission-Critical Data Network 1-29

Digital Signals. 1-30

- Definition 1-30
- Transmission Data Rates 1-30
- Converting an Analog Signal to a Digital Signal. 1-30
 - Filtering 1-30
 - Sampling 1-31
 - Quantizing/Companding 1-31
- Pulse Code Modulation (PCM) 1-31
- Time Division Multiplexing (TDM) 1-32
- Converting Digital Data to Digital Signals 1-35
 - Encoding Techniques 1-35
- Quadrature Amplitude Modulation (QAM) 1-40
- Discrete Multitone (DMT) 1-40
- 8B/1Q4 PAM5 Encoding 1-40
- Digital versus Analog. 1-41

Types of Transmission Circuits 1-42

- Overview 1-42
- Simplex 1-42
- Half-Duplex 1-42
- Full-Duplex. 1-42

Asynchronous and Synchronous Transmission.	1-43
Overview	1-43
Asynchronous Transmission	1-43
Synchronous Transmission	1-43
Digital Hierarchy.	1-44
Overview	1-44
Integrated Services Digital Network (ISDN)	1-44
Digital Subscriber Line (DSL)	1-45
High Bit-Rate Digital Subscriber Line (HDSL)	1-45
Symmetrical Digital Subscriber Line (SDSL)	1-45
Asymmetric Digital Subscriber Line (ADSL) Technologies	1-46
Rate-Adaptive Digital Subscriber Line (RADSL)	1-47
Very High Bit-Rate Digital Subscriber Line (VDSL)	1-48
Video Transmission.	1-50
Baseband Analog	1-50
Composite Format	1-51
Component Format.	1-51
Broadband Video.	1-52
Balanced Twisted-Pair Media Implementation	1-52
Transmission Line Concepts	1-53
Overview	1-53
Characteristic Impedance.	1-59
Attenuation	1-59
Crosstalk	1-60
Nominal Velocity of Propagation (NVP).	1-60
Propagation Delay	1-60
Delay Skew	1-61
Reflection Coefficient.	1-61
Return Loss	1-62
Signal-to-Noise Ratio (SNR)	1-62
Attenuation-to-Crosstalk Ratio (ACR)	1-62
Power Sum Attenuation-to-Crosstalk Ratio (PSACR)	1-62
Power Sum Attenuation-to-Alien-Crosstalk Ratio at the Near End (PSAACRN).	1-63
Power Sum Attenuation-to-Alien-Crosstalk Ratio at the Far End (PSAACRF)	1-63
Balanced Twisted-Pair Performance.	1-64

Balanced Twisted-Pair Channel Performance 1-65

- Channel Model 1-65
- Performance Parameters 1-65
- Insertion Loss Performance Limits 1-66
- Near-End Crosstalk (NEXT) Loss Limits 1-66
- Power Sum Equal Level Far-End Crosstalk (PSELFEXT) Loss Limits 1-66
- Return Loss Limits. 1-66
- Power Sum Attenuation-to-Crosstalk Ratio (PSACR) 1-67
- Concept of Bandwidth 1-67
- Summary. 1-68

Balanced Twisted-Pair Permanent Link Performance 1-69

- Permanent Link Model 1-69
- Balanced Twisted-Pair Patch Cords and Cross-Connect Jumpers 1-69

Balanced Twisted-Pair Applications 1-70

- Design Considerations 1-70
- 100-Ohm Balanced Twisted-Pair Performance Category 1-71
- Media Selection. 1-74
- Distances and Pair Requirements 1-76
- Shared Sheath Applications and Compatibility 1-79
- Media Conversion 1-80
- Impedance-Matching Devices (Baluns) 1-80
- Signal Converters 1-80
- Media Filters. 1-81
- Transceivers 1-81
- Conclusion 1-81

SECTION 2: OPTICAL FIBER

Optical Fiber 1-83

- Overview 1-83

Optical Fiber Transmitters 1-84

- Overview 1-84
- Light-Source Characteristics that Influence Optical Fiber Selection 1-84
 - Center Wavelength. 1-84
 - Spectral Width. 1-85
 - Average Power. 1-86
 - Modulation Frequency. 1-88
- Transmitter Light Sources. 1-88
 - Light-Emitting Diode (LED) 1-88
 - Short Wavelength Lasers 1-89

Vertical Cavity Surface Emitting Laser (VCSEL)	1-90
Laser Diodes (LDs).	1-91
Comparison of transmitters	1-92
Optical Fiber Receivers	1-93
Overview	1-93
Characteristic Parameters.	1-93
Sensitivity and Bit Error Rate (BER).	1-93
Dynamic Range.	1-93
Optical Fiber Medium	1-94
Optical Fiber Core Size Selection Parameters	1-94
Active Equipment	1-94
Transmission Media	1-95
Bandwidth.	1-96
Overview	1-96
Transmitters and Rise Time	1-97
Optical Fibers	1-99
Singlemode System	1-99
Multimode System	1-99
Chromatic and Modal Dispersion in Multimode Systems	1-100
Chromatic Dispersion	1-100
Modal Dispersion	1-100
Measurement and Specification of Multimode Systems.	1-100
Calculation	1-101
Classification of Optical Fiber	1-103
Multimode Optical Fiber	1-104
Wavelength Windows.	1-106
Singlemode Optical Fiber	1-107
Optical Fiber Applications Support Information	1-108
Overview	1-108
Supportable Distances and Channel Attenuation	1-109
Verifying Optical Fiber Performance and Electronics Compatibility . .	1-110
Overview	1-110
Key Parameters	1-111
Verification Theory and Methodology	1-111
Bandwidth	1-112
Attenuation	1-113
A. Calculating the Link Loss Budget	1-115
B. Calculating the Passive Cable System Attenuation	1-117
C. Verifying Performance.	1-119

**Selecting an Optical Fiber Core Size to Application or Original
Equipment Manufacturer (OEM) Specifications 1-121**

**Synchronous Optical Network (SONET) and Synchronous Digital
Hierarchy (SDH) Concepts 1-122**

System Example 1-123

Appendix 1-126

North American Digital Signal (DS) 1-126

Digital Signal Level Zero (DS0) 1-126

Digital Signal Level One (DS1) 1-126

Digital Signal Level One C (DS1C) 1-127

Digital Signal Level Two (DS2) 1-127

Digital Signal Level Three (DS3) 1-127

Higher Levels 1-128

European E 1-129

B Channel 1-129

E1 Level 1-129

E2 Level 1-129

E3 Level 1-129

Higher Levels 1-130

Figures

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).	1-10
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) . . .	1-11
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	Internet protocol telephony architecture	1-28
Figure 1.7	Digital signal level one frame format	1-33
Figure 1.8	E1 frame format	1-34
Figure 1.9	Polar non-return-to-zero level.	1-38
Figure 1.10	Bipolar alternate mark inversion	1-38
Figure 1.11	Biphase Manchester	1-38
Figure 1.12	Two binary bits encoded into one quaternary (2B1Q)	1-39
Figure 1.13	Multilevel transition-3 (MLT-3, also referred to as non-return-to-zero inverted [NRZI-3])	1-39
Figure 1.14	Composite video	1-51
Figure 1.15	Two-conductor transmission line	1-53
Figure 1.16	Resistive model.	1-54
Figure 1.17	Capacitance model	1-55
Figure 1.18	Inductive model	1-56
Figure 1.19	Primary transmission line parameters	1-57
Figure 1.20	General transmission model	1-58
Figure 1.21	Example of a channel test configuration.	1-65
Figure 1.22	Permanent link test configuration	1-69
Figure 1.23	Spectral profile comparison of laser and light-emitting diode	1-85
Figure 1.24	Spectral width of a light-emitting diode source showing full width half maximum	1-86
Figure 1.25	Numerical aperture	1-87
Figure 1.26	System bandwidth versus distance example.	1-96
Figure 1.27	Pulse distortion because of rise time and data rate	1-98
Figure 1.28	Link bandwidth at 1300 nanometers using 62.5/125 micrometer multimode optical fiber	1-102
Figure 1.29	Core and coating.	1-105
Figure 1.30	Digital signal cross-connect optical multiplexing design	1-123
Figure 1.31	Synchronous optical network multiplexing design	1-124
Figure 1.32	Wavelength division multiplexing	1-125

Tables

Table 1.1	Conductor descriptions	1-2
Table 1.2	Solid conductor properties	1-3
Table 1.3	Electrical characteristics of common insulation types	1-6
Table 1.4	Explanations of insulation electrical characteristics	1-7
Table 1.5	Types of cable shields	1-15
Table 1.6	Common units of frequency measurement	1-18
Table 1.7	Spectrums of standard frequency bands	1-21
Table 1.8	Power ratios from 0 to 60 decibels	1-22
Table 1.9	Transmission data rates	1-30
Table 1.10	Coding methods	1-37
Table 1.11	Asymmetric digital subscriber line standards	1-46
Table 1.12	Asymmetric digital subscriber line performance	1-47
Table 1.13	Very high bit-rate digital subscriber line data rate and target range	1-48
Table 1.14	Propagation delay/delay skew	1-61
Table 1.15	Balanced twisted-pair cabling channel performance	1-71
Table 1.16	Applications supported using 100-ohm balanced twisted-pair cabling	1-72
Table 1.17	Media selection	1-74
Table 1.18	Transmission, speed, distance, and pair requirements	1-76
Table 1.19	Characteristics of typical light-emitting diode sources	1-88
Table 1.20	Characteristics of typical short wavelength laser	1-89
Table 1.21	Characteristics of typical vertical cavity surface emitting laser sources	1-90
Table 1.22	Characteristics of typical laser diode sources	1-91
Table 1.23	Comparison of transmitters	1-92
Table 1.24	Optical fiber cable performance by type	1-95
Table 1.25	Summarized comparison of core sizes of multimode and singlemode optical fiber cable	1-103
Table 1.26	Typical characteristics of multimode optical fiber	1-104
Table 1.27	Characteristics of 50/125 μm multimode optical fiber	1-105
Table 1.28	Characteristics of 62.5/125 μm multimode optical fiber	1-106
Table 1.29	Typical characteristics of singlemode optical fiber	1-107
Table 1.30	Maximum cable attenuation coefficient	1-109
Table 1.31	Mismatch of core size and power loss	1-112
Table 1.32	Calculating optical fiber performance	1-113
Table 1.33	System gain, power penalties, and link loss budget calculations	1-116
Table 1.34	Calculating losses	1-117
Table 1.35	Splice loss values in decibels	1-118

Table 1.36	Minimum system loss	1-120
Table 1.37	Common synchronous optical network and synchronous digital hierarchy transmission rates.	1-122
Table 1.38	Levels of multiplexing and carrier transmission in North America	1-128
Table 1.39	Levels of multiplexing and carrier transmission in Europe	1-130

Examples

Example 1.1	Optical fiber performance calculations example	1-114
-------------	--	-------