Telecommunications Distribution Methods

MANUAL

13th Edition

Volume 1

BICSI®

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

Thirteenth edition published 2014
First printing January 2014
Printed in the United States of America

ISBN (Print) 1-928886-64-7
ISBN (Electronic) 1-928886-66-3

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

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 (≈) 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,

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:

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

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 (≈) 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: ≈ 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** **© 2014 BICSI®**

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

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

SECTION 2: OPTICAL FIBER

Chapter 2: Electromagnetic Compatibility

Chapter 3: Telecommunications Spaces

Chapter 4: Backbone Distribution Systems

Chapter 7: Firestop Systems

Chapter 8: Bonding and Grounding (Earthing)

Chapter 9: Power Distribution

Chapter 13: Audiovisual Systems

Chapter 14: Building Automation Systems

Chapter 15: Data Networks

Chapter 16: Wireless Networks

Figures

Chapter 1: Principles of Transmission

Chapter 2: Electromagnetic Compatibility

Chapter 3: Telecommunications Spaces

Chapter 4: Backbone Distribution Systems

Chapter 6: ITS Cables and Connecting Hardware

Chapter 8: Bonding and Grounding (Earthing)

Chapter 9: Power Distribution

Chapter 10: Telecommunications Administration

Chapter 11: Field Testing of Structured Cabling

Chapter 12: Outside Plant

Chapter 13: Audiovisual Systems

Chapter 14: Building Automation Systems

Chapter 15: Data Networks

Chapter 17: Electronic Safety and Security

Chapter 18: Data Centers

Chapter 19: Health Care

Chapter 20: Residential Cabling

Chapter 21: Business Development and Project Management

Appendix A: Codes, Standards, Regulations, and Organizations

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

Appendix C: Regulations and Standards for Emissions and Immunity

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

Tables

Chapter 1: Principles of Transmission

Chapter 6: ITS Cables and Connecting Hardware

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

Appendix C: Regulations and Standards for Emissions and Immunity

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

Examples

Chapter 1: Principles of Transmission

Chapter 14: Building Automation Systems

Chapter 21: Business Development and Project Management

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

SECTION 2: OPTICAL FIBER

Figures

Tables

Examples