UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

COMMSCOPE TECHOLOGIES LLC,
Petitioner
v.
BELDEN INC,
Patent Owner

DECLARATION OF SYLVIA D. HALL-ELLIS, PHD.

I, Sylvia D. Hall-Ellis, declare as follows:

I. INTRODUCTION

1. My name is Sylvia D. Hall-Ellis. I have been retained as an expert by CommScope Technologies, LLC ("CommScope").

2. I have written this declaration at the request of CommScope to provide my expert opinion regarding the authenticity and public availability of several publications. My declaration sets forth my opinions in detail and provides the basis for my opinions regarding the authenticity and public availability of these publications.

3. I am being compensated for my time spent working on this matter at my normal consulting rate of $350 per hour, plus reimbursement for any additional reasonable expenses. My compensation is not in any way tied to the content of this declaration, the substance of my opinions, or the outcome of this proceeding. I have no other interests in this proceeding or with any of the parties.

4. All the materials that I considered and relied upon are discussed explicitly in this declaration.

II. QUALIFICATIONS

5. I am currently an Adjunct Professor in the School of Information at San José State University in San José, California. I obtained a Master of Library Science from the University of North Texas in 1972 and a Ph.D. in Library and

Information Science from the University of Pittsburgh in 1985. Over the last fifty years, I have held various positions in the field of library and information resources. I was first employed as a librarian in 1966 and have been involved in the field of library sciences since, holding numerous positions.

6. I am a member of the American Library Association (ALA) and its Association for Library Collections & Technical Services (ALCTS) Division, and I served on the Committee on Cataloging: Resource and Description (which wrote the new cataloging rules) and as the chair of the Committee for Education and Training of Catalogers and the Competencies and Education for a Career in Cataloging Interest Group. I also served as the founding Chair of the ALCTS Division's Task Force on Competencies and Education for a Career in Cataloging. Additionally, I have served as the Chair for the ALA Office of Diversity's Committee on Diversity, as a member of the REFORMA National Board of Directors, as a member of the Editorial Board for the ALCTS premier cataloging journal, *Library Resources and Technical Services,* and as a Co-Chair of the Membership Committee for the Library Research Round Table (LRRT) of the American Library Association. Currently I serve as a member of the LRRT Nominating Committee.

7. I have also given over one hundred presentations in the field, including several on library cataloging systems and Machine-Readable Cataloging

("MARC") standards. My current research interests include library cataloging systems, metadata, and organization of electronic resources.

8. I have been deposed twenty-nine times: (1) *Symantec Corp. v. Finjan, Inc.*, Petition for *Inter Partes Review* of U.S. Patent No. 7,613,926, May 26, 2016, on behalf of Symantec Corp.; (2) *Symantec Corp. v. Finjan, Inc.*, 14-cv-299-HSG (N.D. Cal.), on behalf of Symantec Corp., September 14, 2017; (3) one deposition for ten matters: *Intellectual Ventures I LLC v. AT&T Mobility LLC*; AT&T Mobility II LLC, New Cingular Wireless Services, Inc., SBC Internet Services, Inc., Wayport, Inc., and Cricket Wireless LLC, C.A. No. 12-193 (LPS); *Intellectual Ventures II LLC v. AT&T Mobility LLC*; AT&T Mobility II LLC, New Cingular Wireless Services, Inc., SBC Internet Services, Inc., Wayport, Inc., and Cricket Wireless LLC, C.A. No. 13-1631 (LPS); *Intellectual Ventures I LLC v. T-Mobile USA, Inc. and T-Mobile US, Inc.*, C.A. No. 13-1632 (LPS); *Intellectual Ventures II LLC v. T-Mobile USA, Inc. and T-Mobile US, Inc.*, C.A. No. 13-1633 (LPS); *Intellectual Ventures I LLC, v. Nextel Operations, Inc., Sprint Spectrum L.P., Boost Mobile, LLC and Virgin Mobile USA, L.P.*, C.A. No. 13-1634 (LPS); *Intellectual Ventures II LLC v. Nextel Operations, Inc., Sprint Spectrum L.P., Boost Mobile, LLC and Virgin Mobile USA, L.P.*, C.A. No. 13-1635 (LPS); *Intellectual Ventures I LLC, v. United States Cellular Corporation*, C.A. No. 13-1636 (LPS); *Intellectual Ventures I LLC v. United States Cellular Corporation*,

C.A. No. 13-1637 (LPS); *Intellectual Ventures II LLC v. AT&T Mobility LLC, AT&T Mobility II LLC, New Cingular Wireless Services, Inc.*, C.A. No. 15-799 (LPS); *Intellectual Ventures I LLC v. T-Mobile USA, Inc. and T-Mobile US, Inc.*, C.A. No. 15-800 (LPS), on behalf of AT&T Mobility LLC; AT&T Mobility II LLC, Boost Mobile, LLC Cricket Wireless LLC, Nextel Operations, Inc., New Cingular Wireless Services, Inc., SBC Internet Services, Inc., Sprint Spectrum L.P., T-Mobile USA, Inc., T-Mobile US, Inc., United States Cellular Corporation Virgin Mobile USA, L.P., and Wayport, Inc., November 15, 2016; (4) *Hitachi Maxell, LTD., v. Top Victory Electronics (Taiwan) Co. Ltd., et al.*, 2:14-cv-1121 JRG-RSP (E.D. Texas), on behalf of Top Victory Electronics (Taiwan) Co. LTD, *et. al.*, January 20, 2016; (5) *Sprint Spectrum, L.P. v. General Access Solutions, Ltd*., Petition for *Inter Partes Review* of U.S. Patent No. 7,173,916, on behalf of Sprint Spectrum L.P., July 13, 2018; (6) *Nichia Corporation v. Vizio, Inc*., 8:16-cv-00545; on behalf of Vizio, Inc., October 12, 2018; (7) *Intellectual Ventures I LLC, v. T-Mobile USA, Inc., T-Mobile US, Inc., Ericsson Inc., and Telefonaktiebolaget LM Ericsson*, 2:17-cv-00557 (JRG), on behalf of T-Mobile USA, Inc., T-Mobile US, Inc., Ericsson Inc., and Telefonaktiebolaget LM Ericsson, October 19, 2018; (8) Pfizer, Inc. v. Biogen, Inc., Petition for *Inter Partes Review* of U.S. Patent No. 8,821,873, on behalf of Pfizer, November 3, 2018; (9) Finjan, Inc. v. ESET, LLC and ESET SPOL. S.R.O., 3:17-cv-00183-

CAB-BGS, on behalf of ESET, January 15, 2019; (10) *Finjan, Inc. v. Cisco Systems, Inc.*, 5:17-cv-00072-BLF-SVK, on behalf of Cisco Systems, Inc., September 6, 2019; (11) *Facebook, Inc., Instagram, LLC and Whatsapp Inc. v. Blackberry Limited*, Petition for *Inter Partes Review* of U.S. Patent No. 9,349,120 B2, on behalf of Facebook, Inc., Instagram, LLC and Whatsapp Inc. December 20, 2019; (12) *3Shape A/S and 3Shape Inc. v. Align Technology, Inc.*, Petition for *Inter Partes Review* of U.S. Patent No. 7,156,661, IPR 2020-00222 and IPR 2020-00223, August 10, 2020, on behalf of 3Shape A/S and 3Shape Inc.; (13) *Finjan Inc. v. Rapid7, Inc. and Rapid7 LLC*, Northern District of Delaware; 1:18-cv-01519-MN, September 15, 2020; (14) *VLSI Technology LLC v. Intel Corporation*, Western District of Texas, 6:19-cv-00254, 6:19-cv-00255, 6:19-cv-00256, on behalf of Intel Corporation, September 23, 2020; (15) *Finjan Inc. v. Sonicwall, Inc.*, Northern District of California, 5:17-cv-04467-BLF-HRL, on behalf of Sonicwall, Inc., October 27, 2020; (16) *VLSI Technology, LLC v. Intel Corporation*, District of Delaware, 1:18-cv-00966-CFC-CJB, February 5, 2021, on behalf of the Intel Corporation; (17) *Unified Patents, LLC v. Good Kaisha IP Bridge 1*, Petition for *Inter Partes Review* of U. S. Patent 7,817,868, February 11, 2021, on behalf of Unified Patents; (18) *Finjan, Inc. v. Qualsys, Inc.*, Northern District of California, 4:18-cv-07229-YGR, March 1, 2021, on behalf of Qualsys, Inc.; (19) *Qualcomm, Inc. v. Monterey Research LLC*, Petition for *Inter Partes*

Review of U. S. Patent 6,534,805, May 6, 2021, on behalf of Qualcomm, Inc.; (20) *Hulu, LLC v. Sound View Innovations, LLC,* Petition for *Inter Partes Review* of U. S. Patent 5,806,062, May 14, 2021, on behalf of Hulu, LLC; (21) *VLSI Technology LLC v. Intel Corporation*, Western District of Texas, 6:19-cv-00254, 6:19-cv-00255 and 6:19-cv-00256, August 3, 2021, on behalf of Intel Corporation; (22) *Liquidia Technologies, Inc. v. United Therapeutics Corporation*, Petition for *Inter Partes Review* of U. S. Patent 10,716,793 B2, October 20, 2021, on behalf of Liquidia Technologies, Inc.; (23) *EcoFactor, Inc. v. Google, Inc.*, Western District of Texas, 6:20-cv-00075 (ADA), 6:20-0078-ADA, and 6:20-cv-00080 ADA, October 27, 2021, on behalf of Google, Inc.; (24) *Liquidia Technologies, Inc. v. United Therapeutics Corporation*, Petition for *Inter Partes Review* of U. S. Patent 10,716,793 B2, March 11, 2022, on behalf of Liquidia Technologies, Inc.; (25) *Juniper Networks, Inc. v. Swarm Technology LLC*, Petition for *Inter Partes Review* of U. S. Patent 9,852,004, May 5, 2022, on behalf of Juniper Networks, Inc.; (26) *ParkerVision, Inc. v. Intel Corporation*, Western District of Texas, 6:20-cv-108 (ADA), October 26, 2022, on behalf of the Intel Corporation; (27) *CommScope v. TQ Delta*, Petition for *Inter Partes Review* of U. S. Patents 9,094,348 and 10,833,809, February 16, 2023, on behalf of CommScope; (28) *WSOU Investments d/b/a Brazos v. Salesforce.com, Inc.* for

Western District of Texas, 6:20-cv-01164-ADA and 6:20-cv-01170-ADA, April 18, 2023, on behalf of Salesforce; and, (29) *Regents of the University of Minnesota v. Ericsson, Inc. and Nokia of America Corporation*, District of Minnesota, 14-cv-4666 JRT-TNL and 14-cv-4669 JRT-TNL, May 18, 2023, on behalf of Ericsson, Inc. and Nokia of America Corporation.

9. My full curriculum vitae is attached as an Appendix to this declaration.

III. PRELIMINARIES

A. Scope of Declaration and Legal Standards

10. I am not an attorney and will not offer opinions on the law. I am, however, rendering my expert opinion on the authenticity of the documents referenced herein and on when and how each of these documents was disseminated or otherwise made available to the extent that persons interested and ordinarily skilled in the subject matter or art, exercising ordinary diligence, could have located the documents.

11. I am informed by counsel that a printed publication qualifies as publicly accessible as of the date it was disseminated or otherwise made available such that a person interested in and ordinarily skilled in the relevant subject matter could locate it through the exercise of ordinary diligence.

12. While I understand that the determination of public accessibility under

the foregoing standard rests on a case-by-case analysis of the facts particular to an individual publication, I also understand that a printed publication is rendered "publicly accessible" if it is cataloged and indexed by a library such that a person interested in the relevant subject matter could locate it (*i.e.*, I understand that cataloging and indexing by a library is sufficient, though there are other ways that a printed publication may qualify as publicly accessible). One manner of sufficient indexing is indexing according to subject matter category. I understand that the cataloging and indexing by a single library of a single instance of a particular printed publication is sufficient, even if the single library is in a foreign country. I understand that, even if access to a library is restricted, a printed publication that has been cataloged and indexed therein is publicly accessible so long as a presumption is raised that the portion of the public concerned with the relevant subject matter would know of the printed publication. I also understand that the cataloging and indexing of information that would guide a person interested in the relevant subject matter to the printed publication, such as the cataloging and indexing of an abstract for the printed publication, is sufficient to render the printed publication publicly accessible.

13. I understand that routine business practices, such as general library cataloging and indexing practices, can be used to establish an approximate date on which a printed publication became publicly accessible.

B. Persons of Ordinary Skill in the Art

14. I am told by counsel that the subject matter of this proceeding relates to twisted pair communications cables.

15. I have been informed by counsel that a "person of ordinary skill in the art at the time of the invention" ("POSITA") is a hypothetical person who is presumed to be familiar with the relevant field and its literature at the time of the inventions. This hypothetical person is also a person of ordinary creativity, capable of understanding the scientific principles applicable to the pertinent field.

16. I am told by counsel that persons of ordinary skill in this subject matter or art would have a bachelor's degree in electrical engineering and a minimum of 3-4 years of industry experience in connection with designing, manufacturing, and testing of twisted-pair data cables. An individual with a master's degree in electrical engineering would require less industry experience (e.g., 1-2 years). I understand that additional education could compensate for less practical experience and vice versa. I have been further informed by counsel that a person of ordinary skill in the art would have been familiar with and able to understand the information known in the art relating to these fields, including the publications discussed in this declaration.

17. It is my opinion that such a person would have been engaged in research, learning, study, and practice in the field, and formal instruction so that

bibliographic resources relevant to his or her research would be familiar. Before January 19, 2001, such a person would have had access to a vast array of long-established print resources in telecommunications as well as to a rich set of online resources providing indexing information, abstracts, and full text services.

IV. LIBRARY PROFESSIONAL PRACTICES

18. In preparing this declaration, I used authoritative databases, such as the OCLC bibliographic database, the Library of Congress Online Catalog, and the Library of Congress Subject Authorities, to confirm citation details of the various publications discussed. Unless I note otherwise below in reference to a specific serial publication, it is my expert opinion that this standard protocol was followed for the serial publication discussed below.

19. *Indexing*. A researcher may discover material relevant to his or her topic in a variety of ways. One common means of discovery is to search for relevant information in an index of periodicals and other publications. Having found relevant material, the researcher will then normally obtain it online, look for it in libraries, or purchase it from the publisher, a bookstore, a document delivery service, or other provider. Sometimes, the date of a document's public accessibility will involve both indexing and library date information. However, date information for indexing entries is often unavailable. This is especially true for online indices.

20. Indexing services use a wide variety of controlled vocabularies to

provide subject access and other means of discovering the content of documents. The Library of Congress Subject Authorities includes standard forms of terms and cross references that are included in bibliographic records. Subject headings are terms that an individual seeking a document regardless of format can enter in the search bar of the online catalog. Subjects also connect an authenticated term (one included in the Library of Congress subject headings list) with related, broader, and narrower terms. The formats in which these access terms are presented vary from service to service.

21. Online indexing services commonly provide bibliographic information, abstracts, and full-text copies of the indexed publications, along with a list of the documents cited in the indexed publication. These services also often provide lists of publications that cite a given document. A citation of a document is evidence that the document was publicly available and in use by researchers no later than the publication date of the citing document. Prominent indexing services include *Scopus*, the *IEEE Xplore* database, the *ACM Digital Library*, *Google Scholar*, and the *Internet Archive*.

V. LIBRARY CATALOGING PRACTICES

22. MARC is a framework into which descriptive bibliographic data are transcribed to interact with the software in online library catalogs to provide access to books, journals, and other resources in the collection. The bibliographic data

provide points of access and can be searched by a POSITA to identify and obtain resources in the library collection. An information seeker (or POSITA) can search a local online library catalog or the holdings of a group of libraries in a state or region or in the global catalog WorldCat.

23. MARC records are not designed for public viewing. Although a significant number of libraries provide access to the MARC version of a bibliographic record, the public display is designed to show information in a succinct manner that is quickly understood and useful to the information seeker. Libraries determine the default search for the online catalog to make the entry of search terms efficient and result in a successful search. Information seekers can enter a keyword, title, author, or standard number for the item. Libraries may also provide a search capability called “Summon” that allows the information seeker to enter known information about the item to conduct a search.

24. Learning to use an online library catalog begins in elementary school and continues through high school and post-secondary studies. Undergraduate students further develop their skills to use the online catalog at the academic institution where they are studying through information literacy instruction which is provided by professional reference and user experience librarians. The skills required to search, identify, and obtain the resources identified in this declaration/report are fundamental to using the online catalogs in libraries and

information centers. Therefore, a POSITA who has attained the undergraduate and/or graduate educational levels described above (*see* paragraphs 14-17) possesses the searching and retrieval skills needed to search library catalogs.

25. Professional catalog and metadata librarians prepare and enhance MARC records to provide points of access for each item in the library collection. Using a set of internationally adopted guidelines, rules for the assignment of classification numbers, and the assignment of subject headings from standardized lists, taxonomies, folksonomies, locally developed lists. An information seeker (including POSITAs) can search the online library catalog in a number of ways to identify a specific item or resources on a defined topic.

26. The continued development of the software that supports integrated online library catalogs resulted in the potential to search by an individual creator or author, title proper or variant title, a series that contains the desired item, subjects, corporate bodies responsible in part for the creation of an item, or standard identification numbers associated with the item (e.g., International Standard Book Numbers (ISBN), International Standard Serial Numbers (ISSN), and Publisher's Numbers). Each of these data elements appears in a prescribed location within the MARC framework so that the software can parse, index, and display data elements resulting from a user-initiated search.

27. Examining the MARC records for a specific item reveals the

comprehensive data transcribed about a particular item at the time that cataloging and classification occurred. In addition to the creator, title, subjects, and standard numbers, additional information may provide additional and relevant data depending on the type of resource. Understanding the full extent of bibliographic data for an item and the points of access associated with it provides essential information that can be used to determine the indexing and public availability for documents described in this declaration.

VI. LIBRARY CATALOGING PRACTICES

28. I am fully familiar with the library cataloging standard known as the MARC standard, which is an industry-wide standard method of storing and organizing library catalog information.[1] MARC was first developed in the 1960's by the Library of Congress. A MARC-compatible library is one that has a catalog consisting of individual MARC records for each of its items. Today, MARC is the primary communications protocol for the transfer and storage of bibliographic metadata in libraries.[2]

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[1] The full text of the standard is available from the Library of Congress at http://www.loc.gov/marc/bibliographic/ (last visited May 23, 2023).

[2] Almost every major library in the world is MARC-compatible. *See, e.g.*, *MARC Frequently Asked Questions (FAQ)*, Library of Congress, https://www.loc.gov/marc/faq.html (last visited May 23, 2023) ("MARC is the acronym for Machine-Readable Cataloging. It defines a data format that emerged

29. Since at least the early 1970s and continuing to the present day, MARC has been the primary communications protocol for the transfer and storage of bibliographic metadata in libraries.[3] As explained by the Library of Congress:

> You could devise your own method of organizing the bibliographic information, but you would be isolating your library, limiting its options, and creating much more work for yourself. Using the MARC standard prevents duplication of work and allows libraries to better share bibliographic resources. Choosing to use MARC enables libraries to acquire cataloging data that is predictable and reliable. If a library were to develop a "home-grown" system that did not use MARC records, it would not be taking advantage of an industry-wide standard whose primary purpose is to foster

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from a Library of Congress-led initiative that began nearly fifty years ago. It provides the mechanism by which computers exchange, use, and interpret bibliographic information, and its data elements make up the foundation of most library catalogs used today."). MARC is the ANSI/NISO Z39.2-1994 (reaffirmed 2016) standard for Information Interchange Format.

[3] A complete history of the development of MARC can be found in *MARC: Its History and Implications* by Henrietta D. Avram (Washington, DC: Library of Congress, 1975) and available online from the Hathi Trust (https://babel.hathitrust.org/cgi/pt?id=mdp.39015034388556;view=1up;seq=1; last visited May 23, 2023).

communication of information.

> Using the MARC standard also enables libraries to make use of commercially available library automation systems to manage library operations. Many systems are available for libraries of all sizes and are designed to work with the MARC format. Systems are maintained and improved by the vendor so that libraries can benefit from the latest advances in computer technology. The MARC standard also allows libraries to replace one system with another with the assurance that their data will still be compatible.
>
> *Why Is a MARC Record Necessary?* LIBRARY OF CONGRESS.[4]

30. Thus, almost every major library in the world is MARC-compatible. *See, e.g.*, *MARC Frequently Asked Questions (FAQ)*, LIBRARY OF CONGRESS.[5] ("MARC is the acronym for MAchine-Readable Cataloging. It defines a data format that emerged from a Library of Congress-led initiative that began fifty years ago. It provides the mechanism by which computers exchange, use, and interpret bibliographic information, and its data elements make up the foundation of most library catalogs used today."). MARC is the ANSI/NISO Z39.2-1994 standard (reaffirmed in 2016) for Information Interchange Format. The full text of the

[4] http://www.loc.gov/marc/umb/um01to06.html#part2

[5] https://www.loc.gov/marc/faq.html

standard is available from the Library of Congress.[6]

31. A MARC record comprises several fields, each of which contains specific data about the work. Each field is identified by a standardized, unique, three-digit code corresponding to the type of data that follow. For example, a work's title is recorded in Field 245; the primary author of the work is transcribed in Field 100; an item's International Standard Book Number ("ISBN") consisting of ten or thirteen digits is transcribed in Field 020; an item's International Standard Serial Number ("ISSN") is transcribed in Field 022; the Library of Congress classification notation is recorded in Field 050; and the publication date is recorded in Field 260 under the subfield "c." If a work is a periodical, then its publication frequency is recorded in Field 310, and the publication dates (e.g., the first and last publication) are recorded in Field 362, which is also referred to as the enumeration/chronology field.[7]

32. The library that created the record is recorded in Field 040 in subfield "a" with a unique library code. When viewing the MARC record online via Online Computer Library Center's ("OCLC") bibliographic database, hovering over this code with the mouse reveals the full name of the library. I used this method of "mousing over" the library codes in the OCLC database to identify the originating

[6] http://www.loc.gov/marc/bibliographic/

[7] http://www.loc.gov/marc/bibliographic/bd3xx.html

library for the MARC records discussed in this declaration. Where this "mouse over" option was not available, I consulted the Directory of OCLC Libraries to identify the institution that created the MARC record.[8]

33. MARC records also include several fields that include subject matter classification information. An overview of MARC record fields is available through the Library of Congress.[9] For example, 6XX fields are termed "Subject Access Fields."[10] Among these, for example, is the 650 field; this is the "Subject Added Entry – Topical Term" field.[11] The 650 field is a "[s]ubject added entry in which the entry element is a topical term." These entries "are assigned to a bibliographic record to provide access according to generally accepted thesaurus-building rules (e.g., *Library of Congress Subject Headings* (LCSH), *Medical Subject Headings* (MeSH))." *Id.* Further, MARC records include call numbers, which themselves include a classification number. For example, the 050 field is the "Library of Congress Call Number."[12] A defined portion of the Library of Congress Call (LCC) Number is the classification number, and "source of the classification number is *Library of Congress Classification* and the *LC*

[8] https://www.oclc.org/en/contacts/libraries.html

[9] http://www.loc.gov/marc/bibliographic/

[10] http://www.loc.gov/marc/bibliographic/bd6xx.html

[11] http://www.loc.gov/marc/bibliographic/bd650.html

[12] http://www.loc.gov/marc/bibliographic/bd050.html

Classification-Additions and Changes." Thus, included in the 050 field is a subject matter classification. Further, the 082 field is the "Dewey Decimal Call Number."[13] A defined portion of the Dewey Decimal Call (DDC) Number is the classification number, and "source of the classification number is the *Dewey Decimal Classification and Relative Index*." Thus, included in the 082 field is a subject matter classification. Each item in a library has a single classification number. A library selects a classification scheme (*e.g.*, the Library of Congress classification scheme just described or a similar scheme such as the Dewey Decimal classification scheme) and uses it consistently. When the Library of Congress assigns the LCC classification number, it appears as part of the 050 field. When the Library of Congress assigns the DDC classification number, it appears as part of the 082 field. If a local library assigns the classification number, it appears in a 090 field. In either scenario, the MARC record includes a classification number that represents a subject matter classification.

34. The OCLC was created "to establish, maintain and operate a computerized library network and to promote the evolution of library use, of libraries themselves, and of librarianship, and to provide processes and products for the benefit of library users and libraries, including such objectives as increasing availability of library resources to individual library patrons and reducing the rate

[13] http://www.loc.gov/marc/bibliographic/bd082.html

of rise of library per-unit costs, all for the fundamental public purpose of furthering ease of access to and use of the ever-expanding body of worldwide scientific, literary and educational knowledge and information."[14] Among other services, OCLC and its members are responsible for maintaining the WorldCat database (http://www.worldcat.org/), used by independent and institutional libraries throughout the world.

35. OCLC also provides its members online access to MARC records through its OCLC bibliographic database. When an OCLC member institution acquires a work, it creates a MARC record for this work in its computer catalog system in the ordinary course of its business. MARC records created at the Library of Congress are tape-loaded into the OCLC database through a subscription to MARC Distribution Services daily or weekly. Once the MARC record is created by a cataloger at an OCLC member institution or is tape-loaded from the Library of Congress, the MARC record is then made available to any other OCLC members online, and therefore made available to the public. Accordingly, once the MARC record is created by a cataloger at an OCLC member institution or is tape-loaded from the Library of Congress or another library anywhere in the world, any

[14] Third Article, Amended Articles of Incorporation of OCLC Online Computer Library Center, Incorporated (available at https://www.oclc.org/content/dam/oclc/membership/articles-of-incorporation.pdf).

publication corresponding to the MARC record has been cataloged and indexed according to its subject matter such that a person interested in that subject matter could, with reasonable diligence, locate and access the publication through any library with access to the OCLC bibliographic database or through the Library of Congress.

36. When an OCLC member institution creates a new MARC record, OCLC automatically supplies the date of creation for that record. The date of creation for the MARC record appears in the fixed Field (008), characters 00 through 05. The MARC record creation date reflects the date on which, or shortly after which, the item was first acquired or cataloged. Initially, Field 005 of the MARC record is automatically populated with the date the MARC record was created in year, month, day format (YYYYMMDD) (some of the newer library catalog systems also include hour, minute, second (HHMMSS)). Thereafter, the library's computer system may automatically update the date in Field 005 every time the library updates the MARC record (*e.g.*, to reflect that an item has been moved to a different shelving location within the library). Field 005 is visible when viewing a MARC record via an appropriate computerized interface, but when a MARC record is printed to hardcopy, no "005" label appears. The initial Field 005 date (*i.e.*, the date the MARC record was created) does appear, however, next to

the label "Entered."[15] The date upon which the most recent update to Field 005 occurred also appears, next to the label "Replaced." Thus, when an item's MARC record has been printed to hardcopy—as is the case with the exhibits to this declaration—the date reflected next to the label "Entered" is necessarily on or after the date the library first cataloged and indexed the underlying item.

37. Once one library has cataloged and indexed a publication by creating a MARC record for that publication, other libraries that receive the publication do not create additional MARC records—the other libraries instead rely on the original MARC record. They may update or revise the MARC record to ensure accuracy, but they do not replace or duplicate it. This practice does more than save libraries from duplicating labor. It also enhances the accuracy of MARC records. Further, it allows librarians around the world to know that a particular MARC record is authoritative (in contrast, a hypothetical system wherein duplicative records were created would result in confusion as to which record is authoritative).

38. Catalogers can create MARC records for all types of print, online, and digital resources. The date of creation of the MARC record by a cataloger at an OCLC member institution reflects when the underlying item is accessible to the

[15] Field 005 is visible when viewing a MARC record via an appropriate computerized interface. But when a MARC record is printed directly to hardcopy from the OCLC database, the "005" label is not shown. The date in the 005 field instead appears next to the label "Replaced."

public. Upwards of two-thirds to three-quarters of book sales to libraries come from a jobber or wholesaler for online and print resources. These resellers make it their business to provide books to their customers as fast as possible, often providing turnaround times of only a single day after publication. Libraries purchase a significant portion of the balance of their books directly from publishers themselves, which provide delivery on a similarly expedited schedule. In general, libraries make these purchases throughout the year as the books are published and shelve the books as soon thereafter as possible to make the books available to their patrons. Thus, books are generally available at libraries across the country within just a few days of publication.

VII. PUBLICATION 1: *Electronic Wire & Cable: A User's Guide -- Performance and Selection* by AT & T Bell Laboratories. EXHIBIT 1016 ("AT&T")

39. Attached hereto as Exhibit 1016 is a copy of a book titled *Electronic Wire & Cable: A User's Guide -- Performance and Selection* prepared by AT & T Bell Laboratories (hereafter "AT & T") and issued by AT & T Network Systems in 1987. Exhibit 1016 is a true and correct copy of the cover, preface, table of contents, and an excerpt (Chapter 5, "Multiconductor Cables" on pages 45-54).16 obtained Exhibit 1016 from counsel. The excerpted text in Exhibit 1016 is complete; no pages are missing, and the text on each page appears to flow seamlessly from one page to the next; further, there are no visible alterations to the

document. Exhibit 1016 is a true and correct copy in a condition that creates no suspicion about its authenticity.

40. Attached hereto as Attachment 1A is a true and correct copy of the MARC record for the book titled *Electronic Wire & Cable: A User's Guide -- Performance and Selection* obtained from the OCLC bibliographic database. I personally identified and retrieved the MARC record that is Attachment 1A. As previously noted, the library that created the record is recorded in field 040 with a unique library code. For Attachment 1A, that library code is "COF," which means that the MARC record for this book was created in the Morgan Library at Colorado State University (Fort Collins, Colorado). As can be seen in the "Entered" field in the MARC record for this exhibit, a cataloger in the Morgan Library at Colorado State University created OCLC record number 26958439 on January 9, 1992, as shown in the "Entered" field ("19920109"). I personally identified and retrieved the MARC record that is Attachment 1A.

41. Attachment 1A further includes a descriptor term reading "Electronic apparatus and appliances $v Handbooks, manuals, etc." (see Attachment 1B, Library of Congress subject heading sh85042254 and Attachment 1C, Library of Congress subject heading sj96005639) in the 650 field. Thus, as of its cataloging, the publication corresponding to the MARC record attached hereto as Attachment 1A was indexed according to its subject matter by virtue of at least three

independently sufficient classifications: the field 110 entry (corporate body), the field 245 entry (title), and the field 650 entry. Further, as of January 9, 1992, the MARC record attached hereto as Attachment 1A was accessible through any library with access to the OCLC bibliographic database or the online catalog at a library that added this book to its collection, which means that the corresponding publication was publicly available on or before that same date through any library with access to the OCLC bibliographic database or through an individual library.

42. Attachment 1A indicates that the AT & T book as cataloged in the Morgan Library at Colorado State University was available from that institution until July 2, 2015, as shown in the Replaced" field. In view of above, the AT & T book was publicly available on January 9, 1992, because by that date it had been received, cataloged, and indexed in the Morgan Library at Colorado State University and made part of the OCLC bibliographic database. For these reasons, it is my opinion that Exhibit 1016 was published and accessible to the public on January 9, 1992.

VIII. PUBLICATION 2: *Subscriber Loop Signaling and Transmission Handbook* by Whitham D. Reeve. EXHIBIT 1017 ("Reeve 1995")

43. Attached hereto as Exhibit 1017 is an excerpt from a book titled *Subscriber Loop Signaling and Transmission Handbook* by Whitham D. Reeve (hereafter "Reeve 1995") and issued by the Institute of Electrical and Electronics Engineers in 1995. Exhibit 1017 is a true and correct copy of the title page,

copyright page, table of contents, and an excerpt (Chapter 7, "Loop Transmission Media, Part I-Twisted Pair-Metallic Cables" (pages 300-347) as held by the Linda Hall Library of Science, Engineering & Technology (Kansas City, Missouri). I obtained Exhibit 1017 from the Linda Hall Library of Science, Engineering & Technology. The text in Exhibit 1017 is complete; no pages are missing, and the text on each page appears to flow seamlessly from one page to the next; further, there are no visible alterations to the document. Exhibit 1017 is a true and correct copy in a condition that creates no suspicion about its authenticity.

44. Attached hereto as Attachment 2A is a true and correct copy of the MARC record for this book from the Linda Hall Library of Science, Engineering & Technology online catalog. Library ownership is indicated by the presence of the library's code (LHL) in the 049 field. The library continues to update this MARC record and enhanced the MARC record to meet current cataloging rules. The most recent enhancement to the MARC record occurred on November 23, 2020, as shown in field 005 ("20201123"). I personally identified and retrieved the library catalog record which is Attachment 2A.

45. Based on finding a print copy of the Reeve 1995 book in the Linda Hall Library of Science, Engineering & Technology and MARC record in its online library catalog attached as Attachment 2A, it is my opinion that the book titled *Subscriber Loop Signaling and Transmission Handbook* was publicly

available on July 21, 1994, as shown in field 008 ("940721"). The International Standard Book Number (ISBN) on Exhibit 1017 (0-7803-0440-3) matches the ISBN in the second field 020 of Attachment 2A. Therefore, Exhibit 1017 is the same book as the one that the cataloger at the Linda Hall Library of Science, Engineering & Technology used to create the MARC record that is Attachment 2A.

46. Attached hereto as Attachment 2B is a true and correct copy of the MARC record for the Reeve 1995 book titled *Subscriber Loop Signaling and Transmission Handbook* obtained from the OCLC bibliographic database. I personally identified and retrieved the MARC record that is Attachment 2B. As previously noted, the library that created the record is recorded in field 040 with a unique library code. For Attachment 2B, that library code is "DLC," which means that the MARC record for this book was created at the Library of Congress as part of the Cataloging in Publication program.[16] A cataloger prepares basic information about the forthcoming book which is included on the verso of the title page (also called the copyright page). The information is provided to save time needed for the cataloging process at the library after the book is purchased. The CIP data includes the author (field 100), title and subtitle (field 245), ISBN (field 022), suggested subject headings (field 650), classification numbers for the Library of Congress

[16] https://www.loc.gov/publish/cip/

classification number (field 050), and the Dewey Decimal classification number (field 082). These data elements are included in the MARC record that the Library of Congress contributes to the OCLC bibliographic database. As can be seen in the "Entered" field in the MARC record for this exhibit, a cataloger at the Library of Congress created OCLC record number 30914351 on July 21, 1994, as shown in the "Entered" field ("19940721").[17] Field 955 of the MARC record indicates that the Reeve 1995 book was publicly available on February 28, 1995 ("02-28-95"). The library continues to update and enhance this MARC record to meet current cataloging rules. The most recent enhancement to Attachment 2B occurred on January 13, 2023, as shown in the "Replaced" field ("20230113"). I personally identified and retrieved the MARC record that is Attachment 2B.

47. Attachment 2B further includes an entry in field 050 ("TK6397 $b .R443 1995")—as described above, this includes a subject matter classification number consistent with the Library of Congress classification system (analogous to the Dewey Decimal classification system). Attachment 2B further includes an entry in field 082 ("621.387/83"), a subject matter consistent with the Dewey Decimal classification system. Attachment 2B further includes three descriptor

17 https://catalog.loc.gov/vwebv/staffView?searchId=17104&recPointer=0&recCount=25&searchType=0&bibId=2069824

terms reading “Telephone switching systems, Electronic” (see Attachment 2C, Library of Congress subject heading sh85133437), “Telecommunication $x Standards” (see Attachment 2D, Library of Congress subject heading sh2001009248), and “Digital communications” (see Attachment 2E, Library of Congress subject heading sh85037972) in the 650 fields. Thus, as of its cataloging, the publication corresponding to the MARC record attached hereto as Attachment 2B was indexed according to its subject matter by virtue of at least three independently sufficient classifications: the field 050 entry, the field 082 entry, and the field 650 entries. Further, as of July 21, 1994, the MARC record attached hereto as Attachment 2B was accessible through any library with access to the OCLC bibliographic database or the online catalog at a library that added this book to its collection, which means that the corresponding publication was publicly available on or before that same date through any library with access to the OCLC bibliographic database or through an individual library.

48. Attachment 2B indicates that the Reeve 1995 book titled *Subscriber Loop Signaling and Transmission Handbook* as cataloged at the Library of Congress is currently available from 164 libraries. In view of above, the Reeve 1995 book was publicly available on February 28, 1995, because by that date it had been cataloged and indexed at the Library of Congress, made part of the OCLC bibliographic database, and received in the Linda Hall Library of Science,

Engineering & Technology. For these reasons, it is my opinion that Exhibit 1017 was published and accessible to the public on February 28, 1995.

IX. PUBLICATION 3: *Subscriber Loop Signaling and Transmission Handbook: Analog* by Whitham D. Reeve. EXHIBIT 1018 ("Reeve 1992")

49. Attached hereto as Exhibit 1018 is an excerpt from a book titled *Subscriber Loop Signaling and Transmission Handbook: Analog* by Whitham D. Reeve (hereafter "Reeve 1992") and issued by the Institute of Electrical and Electronics Engineers in 1992. Exhibit 1018 is a true and correct copy of the title page, copyright page, table of contents, and an excerpt (Chapter 3, "The Outside Plant Facility" (pages 45-62) as held by the Linda Hall Library of Science, Engineering & Technology (Kansas City, Missouri). I obtained Exhibit 1018 from the Linda Hall Library of Science, Engineering & Technology. The text in Exhibit 1018 is complete; no pages are missing, and the text on each page appears to flow seamlessly from one page to the next; further, there are no visible alterations to the document. Exhibit 1018 is a true and correct copy in a condition that creates no suspicion about its authenticity.

50. Attached hereto as Attachment 3A is a true and correct copy of the MARC record for this book from the Linda Hall Library of Science, Engineering & Technology online catalog. Library ownership is indicated by the presence of the library's code (LHL) in the 049 field. The library continues to update this

MARC record and enhanced the MARC record to meet current cataloging rules. The most recent enhancement to the MARC record occurred on October 1, 1994, as shown in field 005 ("19941001"). I personally identified and retrieved the library catalog record which is Attachment 3A.

51. Based on finding a print copy of the Reeve 1992 book in the Linda Hall Library of Science, Engineering & Technology and MARC record in its online library catalog attached as Attachment 3A, it is my opinion that the book titled *Subscriber Loop Signaling and Transmission Handbook: Analog* was publicly available on May 10, 1991, as shown in field 008 ("910510"). The International Standard Book Number (ISBN) on Exhibit 1018 (0-87942-274-2) matches the ISBN in the second field 020 of Attachment 3A. Therefore, Exhibit 1018 is the same book as the one that the cataloger at the Linda Hall Library of Science, Engineering & Technology used to create the MARC record that is Attachment 3A.

52. Attached hereto as Attachment 3B is a true and correct copy of the MARC record for the Reeve 1992 book titled *Subscriber Loop Signaling and Transmission Handbook: Analog* obtained from the OCLC bibliographic database. I personally identified and retrieved the MARC record that is Attachment 3B. As previously noted, the library that created the record is recorded in field 040 with a unique library code. For Attachment 3B, that library code is "DLC," which means

that the MARC record for this book was created at the Library of Congress as part of the Cataloging in Publication program.[18] A cataloger prepares basic information about the forthcoming book which is included on the verso of the title page (also called the copyright page). The information is provided to save time needed for the cataloging process at the library after the book is purchased. The CIP data includes the author (field 100), title and subtitle (field 245), ISBN (field 022), suggested subject headings (field 650), classification numbers for the Library of Congress classification number (field 050), and the Dewey Decimal classification number (field 082). These data elements are included in the MARC record that the Library of Congress contributes to the OCLC bibliographic database. As can be seen in the "Entered" field in the MARC record for this exhibit, a cataloger at the Library of Congress created OCLC record number 23869059 on May 10, 1991, as shown in the "Entered" field ("19910510").[19] Field 955 of the MARC record indicates that the Reeve 1995 book was publicly available on January 22, 1992 ("01-22-92"). The library continues to update and enhance this MARC record to meet current cataloging rules. The most recent enhancement to Attachment 3B occurred on May 13, 2022, as shown in the "Replaced" field ("20220513"). I personally

[18] https://www.loc.gov/publish/cip/

[19] https://catalog.loc.gov/vwebv/staffView?searchId=17132&recPointer=0&recCount=25&searchType=0&bibId=1070136

identified and retrieved the MARC record that is Attachment 3B.

53. Attachment 3B further includes an entry in field 050 ("TK6397 $b .R44 1992")—as described above, this includes a subject matter classification number consistent with the Library of Congress classification system (analogous to the Dewey Decimal classification system). Attachment 3B further includes an entry in field 082 ("621.382"), a subject matter consistent with the Dewey Decimal classification system. Attachment 3B further includes two descriptor terms reading "Telephone switching systems, Electronic" (see Attachment 2C, Library of Congress subject heading sh85133437) and "Telecommunication $x Standards" (see Attachment 2D, Library of Congress subject heading sh2001009248) in the 650 fields. Thus, as of its cataloging, the publication corresponding to the MARC record attached hereto as Attachment 3B was indexed according to its subject matter by virtue of at least three independently sufficient classifications: the field 050 entry, the field 082 entry, and the field 650 entries. Further, as of May 10, 1991, the MARC record attached hereto as Attachment 3B was accessible through any library with access to the OCLC bibliographic database or the online catalog at a library that added this book to its collection, which means that the corresponding publication was publicly available on or before that same date through any library with access to the OCLC bibliographic database or through an individual library.

54. Attachment 3B indicates that the Reeve 1992 book titled *Subscriber*

Loop Signaling and Transmission Handbook: Analog as cataloged at the Library of Congress is currently available from 141 libraries. In view of above, the Reeve 1992 book was publicly available on January 22, 1992, because by that date it had been cataloged and indexed at the Library of Congress, made part of the OCLC bibliographic database, and received in the Linda Hall Library of Science, Engineering & Technology. For these reasons, it is my opinion that Exhibit 1018 was published and accessible to the public on January 22, 1992.

X. PUBLICATION 4: *Electric Cables Handbook*, 3rd ed., edited by G. F. Moore. EXHIBIT 1029 ("Moore")

55. Attached hereto as Exhibit 1029 are excerpts from a book titled *Electric Cables Handbook,* 3rd edition, edited by G. F. Moore (hereafter "Moore") and issued by Blackwell Science in 1997. Exhibit 1029 is a true and correct copy of the cover, title page, copyright page, preface, contributors, contents, and an excerpts (Part 8, Chapter 53, "Communication Systems" (pages 773-778) and Chapter 54, "Data Communication Cables" (pages 779-792) as held by the Linda Hall Library of Science, Engineering & Technology (Kansas City, Missouri). I obtained Exhibit 1029 from the Linda Hall Library of Science, Engineering & Technology. The text in Exhibit 1029 is complete; no pages are missing, and the text on each page appears to flow seamlessly from one page to the next; further, there are no visible alterations to the document. Exhibit 1029 is a true and correct copy in a condition that creates no suspicion about its authenticity.

56. Attached hereto as Attachment 4A is a true and correct copy of the MARC record for this book from the Linda Hall Library of Science, Engineering & Technology online catalog. Library ownership is indicated by the presence of the library's code (LHL) in the 049 field. The library continues to update this MARC record and enhanced the MARC record to meet current cataloging rules. The most recent enhancement to the MARC record occurred on January 17, 2002, as shown in field 005 ("20020117"). I personally identified and retrieved the library catalog record which is Attachment 4A.

57. Based on finding a print copy of the Moore book in the Linda Hall Library of Science, Engineering & Technology and MARC record in its online library catalog attached as Attachment 4A, it is my opinion that the book titled *Electric Cables Handbook*, 3rd edition, was publicly available on June 26, 1997, as shown in field 008 ("970626"). The International Standard Book Number (ISBN) on Exhibit 1029 (0-632-04075-0) matches the ISBN in the second field 020 of Attachment 4A. Therefore, Exhibit 1029 is the same book as the one that the cataloger at the Linda Hall Library of Science, Engineering & Technology used to create the MARC record that is Attachment 4A.

58. Attached hereto as Attachment 4B is a true and correct copy of the MARC record for the Moore book titled *Electric Cables Handbook*, 3rd edition, obtained from the OCLC bibliographic database. I personally identified and

retrieved the MARC record that is Attachment 4B. As previously noted, the library that created the record is recorded in field 040 with a unique library code. For Attachment 4B, that library code is "DLC," which means that the MARC record for this book was created at the Library of Congress as part of the Cataloging in Publication program.[20] A cataloger prepares basic information about the forthcoming book which is included on the verso of the title page (also called the copyright page). The information is provided to save time needed for the cataloging process at the library after the book is purchased. The CIP data includes the author (field 100), title and subtitle (field 245), ISBN (field 022), suggested subject headings (field 650), classification numbers for the Library of Congress classification number (field 050), and the Dewey Decimal classification number (field 082). These data elements are included in the MARC record that the Library of Congress contributes to the OCLC bibliographic database. As can be seen in the "Entered" field in the MARC record for this exhibit, a cataloger at the Library of Congress created OCLC record number 37260911 on June 26, 1997, as shown in the "Entered" field ("19970626").[21] Field 955 of the MARC record indicates that the Moore book was publicly available on February 4, 1998 ("02-04-98"). The

[20] https://www.loc.gov/publish/cip/

[21] https://catalog.loc.gov/vwebv/staffView?searchId=17157&recPointer=0&recCount=25&searchType=0&bibId=1653404

library continues to update and enhance this MARC record to meet current cataloging rules. The most recent enhancement to Attachment 4B occurred on May 6, 2022, as shown in the "Replaced" field ("20220506"). I personally identified and retrieved the MARC record that is Attachment 4B.

59. Attachment 4B further includes an entry in field 050 ("TK3351 $b .E43 1997")—as described above, this includes a subject matter classification number consistent with the Library of Congress classification system (analogous to the Dewey Decimal classification system). Attachment 4B further includes an entry in field 082 ("621.319/34"), a subject matter consistent with the Dewey Decimal classification system. Attachment 4B further includes a descriptor term reading "Electric cables $v Handbooks, manuals, etc." (see Attachment 4C, Library of Congress subject heading sh85133437 and Attachment 1C, Library of Congress subject heading sj96005639) in the 650 field. Thus, as of its cataloging, the publication corresponding to the MARC record attached hereto as Attachment 4B was indexed according to its subject matter by virtue of at least three independently sufficient classifications: the field 050 entry, the field 082 entry, and the field 650 entry. Further, as of June 26, 1997, the MARC record attached hereto as Attachment 4B was accessible through any library with access to the OCLC bibliographic database or the online catalog at a library that added this book to its collection, which means that the corresponding publication was publicly available

on or before that same date through any library with access to the OCLC bibliographic database or through an individual library.

60. Attachment 4B indicates that the Moore book titled *Electric Cables Handbook*, 3rd edition, as cataloged at the Library of Congress is currently available from 99 libraries. In view of above, the Moore book was publicly available on February 4, 1998, because by that date it had been cataloged and indexed at the Library of Congress, made part of the OCLC bibliographic database, and received in the Linda Hall Library of Science, Engineering & Technology. For these reasons, it is my opinion that Exhibit 1029 was published and accessible to the public on February 4, 1998.

XI. SUMMARY OF OPINIONS

61. In view of the foregoing, it is my opinion that the publication described above were publicly available no later than the corresponding date listed in the table below:

Exhibit	Publication	Publicly Available No Later Than
1016	AT & T Bell Laboratories. *Electronic Wire & Cable: A User's Guide -- Performance and Selection*. AT&T Network Systems, 1987.	January 9, 1992
1017	Reeve, Whitham D. *Subscriber Loop Signaling and Transmission Handbook.* IEEE Telecommunications Handbook Series. New York: Institute of Electrical and Electronics Engineers, c1995.	February 28, 1995
1018	Reeve, Whitham D. *Subscriber Loop Signaling and Transmission Handbook: Analog.* IEEE	January 22, 1992

Exhibit	Publication	Publicly Available No Later Than
	Telecommunications Handbook Series. New York: Institute of Electrical and Electronics Engineers, c1992.	
1029	*Electric Cables Handbook*. Edited by G. F. Moore. 3rd ed. Oxford, England: Blackwell Science, 1997.	February 4, 1998

62. I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Date: June 12, 2023

By: Sylvia D. Hall-Ellis
Sylvia D. Hall-Ellis, Ph.D.

Appendix 1

CURRICULUM VITAE SYLVIA D. HALL-ELLIS

EDUCATION

Ph.D., University of Pittsburgh, Pittsburgh, Pennsylvania, 1985
M.P.S., University of Denver, Denver, Colorado, 2014
Post Graduate Studies, University of Texas – San Antonio, Texas, 1975-1976
M.L.S., University of North Texas, Denton, Texas, 1972
B.A., Rockford University, Rockford, Illinois, 1971

PROFESSIONAL EXPERIENCE

1981- **Consultant for higher education, non-profit organizations, and corporations.**

2002- **Adjunct Professor, School of Information, San José State University, San José, California.** Serve as part-time faculty member teaching graduate students in technical services (cataloging, bibliographic control, classification), "core courses," and special topics.

2014-2016 **Director, Grants and Resource Development, Colorado Community College System.** Provided leadership and vision to foster the continued growth of rigorous scholarship, innovative projects, and creative work for statewide system, 13 campuses, and 50 teaching sites serving 155,000 students. Responsible for leadership and ensured efficient functioning of contract and grants in compliance with state & federal requirements and successful implementation and management. Served as a subject matter expert and liaison for college Grant Directors for all issues relating to grants and subcontracts.

2010-2014 **Senior Grant Administrator, Morgridge College of Education, University of Denver (Colorado).** Provided leadership and vision to foster continued growth of rigorous scholarship, innovative research, and creative work in the Morgridge College of Education. Ensure that contract and grants processes function effectively and efficiently for 60 faculty and researchers with a focus on the successful progression and efficient management of grants totaling $13M. Worked effectively and collegially with Department Chairs and Program Coordinators on operational grant-related management activities and with a broad range of internal and external constituencies. Supported the dissemination and promotion of faculty research and scholarship to outside constituents at conferences and through publications. Assisted Principal Investigators and grant project teams by coaching, mentoring, and financial management.

2011-2013 **Interim Director & Assistant Dean, Westminster Law Library, Sturm College of Law, University of Denver.** Planned, organized, and directed all administrative activities for the library serving students, faculty, and alumni; oversaw the employment, retention, promotion, transfer and termination of library personnel; represented the library at professional conferences and public meetings; created and promoted a climate and culture of acceptance for new programs and services, a positive high-quality image of the law library, and that reflect the organization's values, encourage excellent performance, and reward high productivity and innovation; provided leadership and set strategic direction of the organization; ensured that the library provided excellent customer service through solution-oriented staff response to patron needs and by responsiveness and continuous improvement of the organization; promoted, developed, and maintained positive working relationships with colleagues and customers including key stakeholders and groups, higher education institutions, the legal community, other regional libraries and districts statewide, and national library organizations.

2007-2014 **Associate Professor, Library & Information Science, Morgridge College of Education, University of Denver (Colorado).** Served in leadership role and worked collaboratively in

program, college, campus and community environments. Advised and supervised students, taught core and specialized courses at the graduate level in an integrative, student-centered learning environment. Served on LIS, College, and University committees, and maintained working relationships with colleagues in other academic units and information professionals in the Rocky Mountain region and beyond. Served on and chair doctoral student dissertation committees. Oversaw and facilitated the College and LIS graduate student association.

2002-2007 **Assistant Professor, Library & Information Science, College of Education, University of Denver (Colorado).** Served as tenure-track faculty member teaching graduate students in "core courses," resource description and access, service learning, and independent studies. Advised graduate students, participate on LIS and College committees, and serve on doctoral student dissertation committees. Oversaw and facilitated the LIS graduate student association and alumni association.

2000-2002 **Affiliate Faculty, Library & Information Science, College of Education, University of Denver (Colorado).** Served as part-time faculty member teaching graduate students in technical services (cataloging, bibliographic control, classification), "core courses," and special topics. Oversaw and facilitated the LIS graduate student association and alumni association.

2000-2001 **Special Assistant to the Secretary's Regional Representative, U.S. Department of Education, Region VIII, Denver, Colorado.** Served as the principal advisor and representative of the U. S. Secretary of Education's Regional Representative (SRR). Ensured the implementation of major goals of the SRR and the Secretary. Provided leadership on behalf of the SRR in contacts with high-level officials in Region VIII requiring sensitive policy interpretation in communication with senior Department officials to solve problems and resolve issues raised by State and local education officials. Served as the primary contact for School-to-Work/Career, Children's Health Insurance Program, and Safe and Drug-Free Schools. Delivered technical assistance to local education agencies and institutions of higher education in technology, professional development, and school construction.

1999-2000 **Catalog Librarian, Jefferson County Public Library, Lakewood, Colorado.** Performed original, copy cataloging and classification of library materials (English and Spanish) using standard library protocols; completed original descriptive cataloging and subject analysis; enhanced brief catalog and authority records in III.

1997-1999 **Development Officer, McREL International, Aurora, Colorado.** Served as senior member of corporate management team in strategic planning, development of proposals and contracts, implementation, and evaluation of new services, products, and programs for educational agencies. Provided creative leadership to corporate committees to solicit ideas, identify goals and objectives, plan, develop, present, and evaluate professional development opportunities.

1995-1997 **Education Specialist, Education Service Center, Region One, Edinburg, Texas.** Served as member of Administrative Cabinet team in strategic planning, development of proposals and contracts, implementation, and evaluation of telecommunications capabilities, services, products, and programs for 40 school districts serving 283,000 students in 7 counties. Provided creative leadership to regional and state committees to solicit ideas, identify strategic goals and objectives, plan, develop, present, and evaluate funding opportunities and professional development for 400 librarians.

1993-1996 **Assistant Professor of Library Science, Sam Houston State University, Huntsville, Texas.** Served a faculty member teaching 400 graduate students in technical services (cataloging,

bibliographic control, classification), automation, and networking. Participated in distance education program and coordinated annual conference. Conducted university and Texas Library Association-funded field research focused on library collection development and academic achievement.

1992-1993 **Head Librarian, Rocky Mountain College of Art & Design, Denver, Colorado.** Responsible for the daily operation, selection and acquisition of materials, formulation of policies for library operations, media center, and photography/slides archives. Designed and implemented library automation and delivery of electronic resources to college community.

1981-1985 **Development Officer, PRLC, Inc., Pittsburgh, Pennsylvania.** Served as senior member of corporate management team in strategic planning, development of proposals and contracts, implementation, and evaluation of new services, products, and programs for 100 institutional member organizations. Coordinated the development of proposals and contracts totaling $4,000,000 annually. Provided creative leadership to corporate committees to solicit ideas, identify goals and objectives, plan, develop, present, and evaluate professional development opportunities.

1981 **Director of Library Development, Pennsylvania Department of Education, Harrisburg, Pennsylvania.** Responsible for statewide development, technical assistance, professional development, resource sharing, children's services, institutional library services, networking, and state aid program for all libraries throughout the Commonwealth. Functioned as liaison to Governor's Advisory Council, LSCA Advisory Council, District Administrators, private colleges, universities, consortia managers, and network directors. Supervised $14,000,000 formula-based state aid program and $3,000,000 grant awards to individual libraries, consortia, and networks.

1978-1981 **Assistant Director, Southern Tier Library System, Corning, New York.** Coordinated operation of system-wide programs (technical assistance, professional development, resource sharing, technical services, outreach) to 40 public libraries in 5 counties serving 500,000 residents. Solicited ideas, identified goals, sponsored, and evaluated professional development opportunities and technical assistance sessions.

1976-1978 **Division Librarian for Technical Services, Corpus Christi Public Libraries, Corpus Christi, Texas.** Provided leadership in acquisitions, cataloging, serials control, and processing for main library and 4 branches serving 250,000 residents. Participated as senior member of library management team. Compiled and prepared technical evaluations, reports, and statistical analyses of Division operations to measure the achievement and cost of annual goals, objectives, and staff performance.

1975-1976 **System Coordinator, San Antonio Major Resource Center, San Antonio, Texas.** Served as senior member of the management team for District X Office, charged to provide technical assistance, resource sharing, media services, and professional development to librarians and staff representing 30 public library jurisdictions in 21 counties serving 1,500,000 residents. Functioned as liaison to System Director, staff, and members of governing bodies with the System Board of Directors and the Texas State Library and Historical Commission. Prepared LSCA grant applications and monitored awards totaling $1,100,000 annually.

1973-1975 **Bilingual Branch Librarian, San Antonio Public Library, San Antonio, Texas.** Worked as librarian providing reference, information, and readers' advisory services in branch serving 50,000 Spanish-speaking residents in southwest San Antonio. Participated in collection development and resource acquisition activities, specializing in children's work, Spanish language resources, and multicultural studies.

1972-1973 **Librarian, Holding Institute, Laredo, Texas.** Worked as high school librarian serving 500 boarding students in Spanish-speaking environment of private school. Provided reference, research assistance, and library instruction to students and 35 faculty members.

1966-1971 **Rockford Public Library, Rockford, Illinois.** Worked in branches as part-time as a Library Assistant, Clerk, and Page in city library serving 150,000 residents.

PUBLICATIONS

Editor-reviewed Monographs (Completed and in Progress)

Hall-Ellis, Sylvia D., and Mary Beth Weber. *Contemporary Cataloging in an RDA Environment: A Handbook for Students and Practitioners.* Chicago, IL: American Library Association. Under contract & In development.

RDA Testing: Lessons Learned and Challenges Revealed. Sylvia D. Hall-Ellis and Robert O. Ellett, Jr., eds. Binghamton, N.Y.: Haworth, 2012. 128 p.

Hall-Ellis, Sylvia D., Stacey L. Bowers, Christopher D. Hudson, and M. Claire Williamson. *Librarian's Handbook for Seeking, Writing, and Managing Grants.* Santa Barbara, Calif.: Libraries Unlimited, 2011. 315 p.

Hall-Ellis, Sylvia D., with Ann Jerabek, and Merrie W. Valliant. *Contemporary Cataloging: A Handbook for Practitioners and Students.* Open access text. Athens, GA: University of Georgia System Regents, 2011. 767 p.

Grealy, Deborah S. and Sylvia D. Hall-Ellis. *From Research to Practice: The Scholarship of Teaching and Learning in LIS Education.* Westport, Conn.: Libraries Unlimited, 2009. 175 p.

Hall-Ellis, Sylvia D. with J. Ann Jerabek. *Grants for School Libraries.* Westport, Conn.: Libraries Unlimited, 2003. 197 p.

Hall-Ellis, Sylvia D., Doris Meyer, Frank W. Hoffmann, with J. Ann Jerabek. *Grant Writing for Small Libraries and School Library Media Centers.* Boulder, Colo.: NetLibrary, 2001. 173 p.

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Ruy Sánchez, Alberto. *Los Jardines Secretos de Mogador: Voces de Tierra.* México, D.F.: Alfaguara, S.A., 2001. 968-19-0879-1, $16.95 [*Críticas*, 2002]

Chávez, Ricardo and Celso Santajuliana. *El Final de las Nubes.* Barcelona: RBA Libros, S.A., 2001. 84-7901-760-0, $11.95 [*Críticas*, 2002]

The Power of Language / El Poder de la Palabra: Selected Papers from the Second REFORMA National Conference. Edited by Lillian Castillo-Speed and the REFORMA National Conference Publications Committee. Englewood, Colo.: Libraries Unlimited, 2001. 1-563089459, $35.00 [*Colorado Libraries*, 2001]

Martínez, Rubén. *Crossing Over: A Mexican Family on the Migrant Trail.* Metropolitan: Holt, 2001. 0-8050-4908-8, $26.00 [*Library Journal*, 2001]

Guevara, Ernesto "Che." *The African Dream: the Diaries of the Revolutionary War in the Congo.* Translated from the Spanish by Patrick Camiller. With an introduction by Richard Gott and a foreword by Aleida Guevara March. New York: Grove Press, 2001. 0-8021-3834-9, $13.00 [*Library Journal*, 2001]

Cooper, Gail and Garry Cooper. *New Virtual Field Trips.* Englewood, Colo.: Libraries Unlimited, 2001. 1-56308-887-8, $27.50 [*Colorado Libraries*, 2001]

NATIONAL SERVICE & PROFESSIONAL AFFILIATIONS

American Library Association, Life Member
Association for Library Collections & Technical Services (now CORE)
Cataloging, Classification, and Metadata Section
ALCTS Editorial Board, Member, 2015-2019
Committee on Cataloging: Description and Access, Member, 2008-2012
Test Site for RDA, Manager, 2009-2011
Nominating Committee, Member, 2007-2008
Committee for Education and Training of Catalogers, Chair, 2006-2007, Member, 2003-2007
Competencies & Education for a Career in Cataloging Interest Group, Chair, 2010-2012; Member, 2010-
President's Program Committee, 2015-2016
Education Committee, Member, 2005-2007
Task Force on Competencies and Education for a Career in Cataloging, Chair, 2007-2009
2007 Annual Meeting Pre-conference, "What They Don't Teach in Library School: Competencies, Education and Employer Expectations for a Career in Cataloging," Steering Committee Chair
Fundraising Committee, Member, 2004-2006
Office of Diversity
Committee on Diversity, Chair, 2010-2011
Diversity Research Advisory Committee, Member, 2009-2010
Spectrum Scholar Mentor, 2009
Diversity Grants Review Committee, Member, 2007, 2010, 2012
Office of Statistics and Research
Research and Statistics Committee, Member, 2005-2007; Intern, 2003-2005
Library Research Round Table
Nominating Committee, 2022-2023
Membership Committee, 2019-2021
Board of Directors, Member At-Large, 2009-2012
Office of Accreditation
Accreditation Panel Member (training completed 2004)
Accreditation Review Panel Member (training completed 2004)

REFORMA, Life Member
National Board of Directors, 2005-2013
National Fundraising Chair, 2005-2013
National Recruiting and Mentoring Committee, 2008-2010
Colorado Chapter, Secretary, 2004-2005
Colorado Chapter Liaison to National Board of Directors, 2004-2013

American Association of Law Libraries (AALL), Life Member Online Audiovisual Catalogers Association (OLAC) Colorado Association of Law Librarians (CoALL)

American Association of University Women Association for Library and Information Science Education (ALISE)
University of Denver ALISE Representative, 2003-2008; 2010-2011
Membership Advisory Committee, 2007-2010
Technical Services Education Special Interest Group, 2003-
Garfield Doctoral Dissertation Award Reviewer, 2012
Garfield Doctoral Dissertation Scholarship Reviewer, 2014
American Association of University Professors (AAUP), 2006-

American Grant Writers Association, 2014- Grant Professionals Institute, 2016- National Grants Management Association, 2014-

Grant Reviewer (National and Regional Team Leader), U.S. Department of Education, 1998- Grant Reviewer, Broadband Technologies Opportunity Program, U.S. Department of Commerce, 2009
Grant Reviewer, Institute of Museum and Library Services, 1998-2000
Grant Reviewer, Colorado Department of Education, 2014-
Grant Reviewer, Colorado State Library, 1998-
Grant Reviewer, American Association of Community Colleges *Working Connections* program, 1999
Peer Reviewer, *Journal for Library and Information Science Education*, 2005-
Peer Reviewer, *Journal of Library Metadata*, 2009
Peer Reviewer, *International Journal of Library and Information Science*, 2011
Regular Columnist, *The Bottom Line*, 2013-2016
Book Reviewer, *Library Journal*, 2001
Book Reviewer, *Críticas*, 2002-2009
Book Reviewer, *Colorado Libraries*, 2000-2012

REGIONAL SERVICE & PROFESSIONAL AFFILIATIONS

Mountain Plains Library Association

Professional Development Grants Committee, Member, 2005-2006
Professional Development Policy and Guidelines Sub-committee Chair, 2006

Colorado Association of Libraries

"Student Voices" Column Editor, *Colorado Libraries*, 2005-2006
Conference Planning Committee, Member, 2002
Technical Services and Automation Division, Chair, 2002-2003; Member, 2000-
Academic Libraries Division, Peer Review Conference Papers Committee, Member, 2007-2009
Education Committee, Member, 1988-1993
Diverse Populations Committee, Member, 2009-2013

SERVICE TO THE UNIVERSITY OF DENVER

Center for Teaching and Learning Faculty Advisory Board, 2007-2008; 2010-2012
Center for Community Engagement and Service Learning Advisory Board, 2007-2012
Faculty Senate
Executive Committee, 2008-2013
Nominations, Rules & Credentials Committee, Chair, 2008-2013; Member 2007-2013
Appointment, Promotion, and Tenure Revision Committee, 2010-2012
Grievance Policy Committee Member, 2007-2010
Law Library Director Search Committee Chair, 2012-2013
PROF Grant Review, College Representative to the University Review Team, 2006, 2008
Project Homeless Connect Evaluations, Principal Investigator, 2006-2009
University Technology Council, 2007-2009
University of Denver Hyde Interviews for Incoming Freshmen, 2003-2012

SERVICE TO THE MORGRIDGE COLLEGE OF EDUCATION

Appointment, Tenure & Review Committee
Member, voting, 2003-2005; 2007- 2009
Chair, Clinical Faculty Promotion & Tenure Policy Subcommittee, 2008-2009
Member, Community Engagement Subcommittee, 2007-2009
Member, Tenure Review Panel, 2003
Advancement and Alumni Relations Committee, Chair, 2003-2007; Member, 2002-2007
College Building Committee Member, 2004-2010

College of Education Student Association, Faculty Advisor, 2004-2007; 2009-2010
Faculty Senator, 2007-2013
Research and Scholarship Committee, Chair, 2008-2009; Member, 2002-2003, 2008-2009
Research and Grant Mentoring Committee, Chair, 2009-2010
Research Task Force Member, 2010-2012
Search Committee Member, Assistant Professor for Curriculum & Instruction, 2010-2011
Workload Task Force Member, 2010-2011

SERVICE TO THE LIBRARY & INFORMATION SCIENCE PROGRAM

Library and Information Science Student and Alumni Association, Faculty Advisor, 2002-2008
ALA Student Chapter, Faculty Advisor, 2005-2008
Beta Phi Mu Phi Chapter, Faculty Advisor, 2004-2014
Steering Committee Member, Accreditation by the American Library Association, 2001-2004
Search Committee Member, Associate Professor for LIS, 2006
Search Committee Chair, Assistant Professors for LIS, 2003, 2005, 2006, 2007
Search Committee Ex-Officio Member, Director for LIS, 2004

SERVICE TO SAM HOUSTON STATE UNIVERSITY

Rio Roundup: South Texas Literature Conference, Conference Coordinator, 1993
External Relations, Fund Raising, Grants Committee, Chair, 1993-1995
Advisory Council Committee, Chair, 1993-1995
Students, Admissions, and Advisement Committee, Chair, 1994
Institutional Effectiveness Committee, Member, 1993-1995

SERVICE TO THE COLLEGE OF EDUCATION AND APPLIED SCIENCE

Faculty Affairs Committee, Member, 1993-1995
Curriculum Committee, Member, 1993-1995
Continuing Education Committee, Member, 1993-1995

SERVICE TO THE COMMUNITY

French Teacher & Student Exchange with Laon, France, Monarch High School, Boulder Valley School District (Boulder, Colorado), 2017-
Denver/Boulder Games 2022, Board of Directors, Secretary-Treasurer, 2015-2018
United Way Campaign Committee, College of Education, 2006
Arapahoe County, Election Judge for the County Clerk and Recorder, 2000-2005
Arthritis Foundation, Rocky Mountain Chapter, Certified Educator & Trainer, 1999-2008
Bonfils Blood Center, Silver Level Donor, 2000-2016
Denver Museum of Natural History, Docent, 1992
Tech Prep of the Lower Rio Grande Valley, Inc. (Harlingen, Texas) Board of Directors, 1995-1997
Executive Committee, 1996-1997; Chair, Development Committee, 1995-1997; Chair, Fiscal Agency Committee, 1995-1996; Chair, Colleges and Universities Committee, 1996-1997
Gilpin County (Colorado) Public Library Board of Trustees, 1986-1989; Vice President, 1987-1989
City of Central (Colorado) Economic Development Committee, 1987-1989
Columbine Family Health Centers, Inc. (Nederland and Black Hawk, Colorado) Board of Directors, 1988-1989

CERTIFICATION

Permanent Public Librarian Certificate - Pennsylvania, New York, Texas
Westlaw Expert Witness, 2008-
Certified Grant Writer®, 2016-

AWARDS AND HONORS

Advanced Practitioner for Service Learning and Community Engagement, University of Denver, 2011

Platinum Star Alumnae, College of Information, Library Science & Technologies, University of North Texas, 2009
Commendation for Integration of Technologies in Teaching & Learning Environment, University of Denver, 2006
Outstanding Adjunct Faculty Member Award, College of Education, University of Denver, 2002
Beta Phi Mu, Pi, University of Pittsburgh, 1985
Alpha Lambda Sigma, University of North Texas, 1972
Albert Nelson Marquis Lifetime Achievement Award, Who's Who in America
Who's Who in American Women
Who's Who of Women Executives
Dictionary of International Biography
Who's Who in the East
Who's Who in the South and Southwest
Who's Who in the World
Who's Who of Online Professionals
Who's Who in Library and Information Science
2,000 Notable Women
Who's Who of Emerging Leaders
Who's Who in Professional and Executive Women
Who's Who in American Education
International Who's Who of Professional and Business Women
International Leaders in Achievement
International Educator of the Year
Who's Who in Finance and Industry
Who's Who in Finance and Business

Invited International and National Conference Presentations

Driscoll, Margaret, Christy Confetti Higgins, Scott Brown, and Sylvia D. Hall-Ellis. *A View from Within: Open House Tour of Three Canvas Core Courses*. Presentation to be delivered at the School of Information, San José State University Professional Development Seminar, San José, California, October 17, 2019.

Hall-Ellis, Sylvia D. *Invest in Me -- I'm Your Future: Succession Planning for Libraries.* Keynote presentation delivered at the ALCTS President's Symposium, Boston, Mass., January 8, 2016.

Seidel, Kent E. and Sylvia D. Hall-Ellis. *Making Grants Work for You: Strategies for Doctoral Students and Early Career Scholars.* Presentation delivered at the University Council for Educational Administration, Early Career Scholars Session, Indianapolis, Ind., November 9, 2013.

Hall-Ellis, Sylvia D. *So You Want to be a Manager; Leadership Skills and Competencies for Technical Services Managers and Administrators.* Presentation delivered at the 138th Annual Conference, American Library Association, Chicago, Ill., June 29, 2013.

Seidel, Kent E., Karen S. Riley, Lyndsay Agans, Susan Korach, and Sylvia D. Hall-Ellis. *Making Grants Work for You (Instead of Just Working for Grants).* A panel discussion delivered at the University Council for Educational Administration, Early Career Scholars Session, Denver, Colo., November 17, 2012.

Hall-Ellis, Sylvia D. *After the Great TS Reorganization: The Westminster Law Library.* Presentation delivered at the 137th Annual Conference, American Library Association, Anaheim, Calif., June 23, 2012.

Hall-Ellis, Sylvia D. *Conversations with Catalogers in the 21st Century.* A panel discussion sponsored by the ALCTS Competencies for a Career in Cataloging Interest Group, delivered at the 137th Annual Conference, American Library Association, Anaheim, Calif., June 22, 2012.

Hall-Ellis, Sylvia D., moderator. *Mid-Career Leaders Program.* A panel discussion sponsored by the ALA Committee on Diversity delivered at the 136th Annual Conference, American Library Association, New Orleans, La., June 26, 2011.

Hall-Ellis, Sylvia D., moderator. *Diversity Town Hall.* A community conversation sponsored by the ALA Committee on Diversity delivered at the 136th Annual Conference, American Library Association, New Orleans, La., June 24, 2011.

LaBarre, Kathryn, Sylvia D. Hall-Ellis, Karen Anderson, Rick Hasenyager, Christopher Cronin, and Penny Baker. *Briefings from RDA Test Participants.* A panel discussion delivered at the Midwinter Conference, American Library Association, San Diego, Calif., January 7, 2011.

Miksa, Shawne, Marjorie Bloss, and Sylvia D. Hall-Ellis. *Educating the Next Generation of Catalogers: Teaching RDA.* A panel discussion delivered at the 97th Annual Conference, Association for Library and Information Science Education, San Diego, Calif., January 7, 2011.

Hall-Ellis, Sylvia D., Robert Maxwell, John Hostage, and George Prager. *RDA Panel: What Cataloging Managers Need to Know.* Presentation delivered at the 103rd Annual Conference, American Association of Law Librarians, Denver, Colo., July 12, 2010.

Hall-Ellis, Sylvia D. and Stacey L. Bowers. *Catalogers in the RDA Environment: Skill Sets, Expectations and Challenges.* Presentation delivered at the 103rd Annual Conference, American Association of Law Librarians, Denver, Colo., July 11, 2010.

Hall-Ellis, Sylvia D. *Comfortable in Your Cataloging and Metadata Specialist Skin? Or, So You Want to Hire a Cataloger.* Presentation delivered to the ALCTS Research Group at the 134th Annual Conference, American Library Association, Chicago, Ill., July 11, 2009.

Perez, Megan, Sylvia D. Hall-Ellis, and Denise Anthony. *From Novice to Expert: Collaboration for Succession Planning.* A "hot topic" presentation delivered at the 14th ACRL Conference, Seattle, Wash., March 13, 2009.

Hall-Ellis, Sylvia D. *Cataloging in the RDA Environment: Skill Sets, Expectations and Challenges.* Presentation delivered to the ALCTS Research and Publications Committee at the Midwinter Conference, American Library Association, Denver, Colo., January 24, 2009.

Hall-Ellis, Sylvia D. *LIS Cataloging Education for the 21st Century: Expectations and Challenges.* A panel discussion held at the 95th Annual Conference, Association for Library and Information Science Education, Denver, Colo., January 23, 2009.

Chu, Clara, Sylvia D. Hall-Ellis, and Mark Winston. *The Doctoral Degree & Building a Career.* A panel discussion delivered at the ALA Office of Diversity Spectrum Doctoral Fellows E.J. Josey Leadership Institute, Midwinter Conference, American Library Association, Denver, Colo., January 20, 2009.

Hall-Ellis, Sylvia D. and Robert O. Ellett, Jr. *Fundamentals of Cataloging Course: An Overview of the ALCTS Online Course.* Presentation delivered to the ALCTS Big Heads Group, 133rd Annual Conference, American Library Association, Anaheim, Calif., June 30, 2008.

Hall-Ellis, Sylvia D. *Employers' Expectations for Technical Services Librarians: What We Don't Know.* Presentation delivered to the ALCTS Research and Publications Committee Program, 133rd Annual Conference, American Library Association, Anaheim, Calif., June 28, 2008.

Hall-Ellis, Sylvia D., Virginia R. Maloney, and Mary Stansbury. *Institutional Responses to Engaged Scholarship: The Carnegie Foundation Engaged University Classification at Two Universities.* Presentation delivered to the 94th Annual Conference, Association for Library and Information Science Education, Philadelphia, Pa., January 11, 2008.

Hall-Ellis, Sylvia D. *Puzzles, Problems, and Predicaments.* Presentation delivered to the ALCTS Research Discussion Group, 132nd Annual Conference, American Library Association, Washington, D.C., June 23, 2007.

Hall-Ellis, Sylvia D. *Cataloging Education: A New Emphasis for the Library and Information Science Curriculum.* Presentation delivered to the ALCTS Pre-conference, 132nd Annual Conference, American Library Association, Washington, D.C., June 22, 2007. http://www.loc.gov/catdir/cpso/careercat.html

Ellett, Jr., Robert O. and Sylvia D. Hall-Ellis. *Copy Cataloging Done Smarter*. Presentation delivered to the International Conference on Interdisciplinary Information Sciences and Technologies (InSciT2006), October 25-28, 2006.

Hall-Ellis, Sylvia D. and Robert O. Ellett, Jr. *Cooperative Cataloging: Challenges and Opportunities for Defense Libraries.* Presentation delivered to the 1st Annual Conference of Defense Libraries, Spanish Ministry of Defense, Madrid, Spain, July 7, 2006.

Hall-Ellis, Sylvia D. *Cataloger Competencies: Do the Employers Require What the Professors Teach?* Presentation delivered to the ALCTS CCS Heads of Cataloging Discussion Group, 131st Annual Conference, American Library Association, New Orleans, La., June 26, 2006.

Grealy, Deborah S. and Sylvia D. Hall-Ellis. *From Research to Practice: The Scholarship of Teaching and Learning in LIS Education.* Presentation delivered to the at the 92nd Annual Conference, Association for Library and Information Science Education, San Antonio, Tex., January 18, 2006.

Hall-Ellis, Sylvia D. *Employers' Expectations for Entry-Level Catalogers: What Position Announcement Data Indicate.* Research paper delivered to the Technical Services Special Interests Group, 91st Annual Conference, Association for Library and Information Science Education, Boston, Mass., January 12, 2005. http://dlist.sir.arizona.edu/

Hall-Ellis, Sylvia D. *Common Errors in MARC Records Prepared by LIS Students: What Does It Mean?* Research paper delivered to the ALCTS CCS Cataloging Norms Discussion Group, Mid-Winter Conference, 90th American Library Association, San Diego, Calif., January 10, 2004.

Hall-Ellis, Sylvia D. *Visual Arts as Foundation for Successful Library Automation: The Rocky Mountain College of Art & Design Experience.* Paper delivered at the 6th Annual Conference of Higher Education, Charleston, S. C., 1993.

Hall, Sylvia D. *Design Elements for Bibliographic Databases: An Overview.* Paper delivered at the 14th Online National Conference, New York, 1983.

Invited Regional Conference Presentations

Hall-Ellis, Sylvia D., Hudson, Christopher D., Brittany Cronin, and Kathryn Michaels. "The Colorado Law Project: Meeting the Public's Need for Legal Information." Panel discussion delivered at the Mountain Plains Library Association Conference, Billings, Mont., April 9, 2011.

Grealy, Deborah S. and Sylvia D. Hall-Ellis. *Education for Information Professionals in New Mexico: Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the New Mexico Library Education Summit, Las Vegas, N.M., September 26, 2005.

Hall-Ellis, Sylvia D. *Public Library-School Library Partnerships.* Presentation delivered at the 3rd Annual Colorado Association of Libraries Conference with the Mountain Plains Library Association, Denver, Colo., October 22, 2004.

Hall-Ellis, Sylvia D. *Learn All You Can – Educational Partnership Opportunities for the Lewis and Clark Bicentennial Commemoration.* Paper delivered at the 3rd Annual Lewis and Clark Bicentennial Council National Planning Conference, Bismarck, N.D., April 26, 1998.

Invited State Conference Presentations

Grealy, Deborah S. and Sylvia D. Hall-Ellis. *Academic Library Leadership Changes: Using Succession Planning and Mentoring*. Presentation delivered at the Minnesota Library Education Conference, St. Cloud, Minn., October 10, 2013.

Hall-Ellis, Sylvia D., Merrie Valliant, and Melissa Powell. *RDA: What Is It and What Do You Need To Do With It At Your Library?* Presentation delivered at the Colorado Library Consortium Spring Conference, Ft. Morgan, Colo., April 26, 2013.

Hall-Ellis, Sylvia D. *Service Learning and the Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the 4th LEADS Scholars Orientation, Denver, Colo., August 5, 2009.

Hall-Ellis, Sylvia D. *Service Learning: Enhancement to Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the 3rd LEADS Scholars Orientation, Denver, Colo., June 2008.

Hall-Ellis, Sylvia D. *Law Librarianship: A Community Conversation.* Sponsored by the Colorado Association of Law Libraries. Paper delivered at the Colorado Supreme Court Library, Denver, Colo., May 14, 2008.

Hall-Ellis, Sylvia D. *Opportunities and Challenges in Law Librarianship: A Community Conversation.* Presentation delivered at the Sturm College of Law, Denver, Colo., November 7, 2007.

Ellis, Sylvia D. *Grant Writing Resources for Nursing Professionals.* Presentation delivered at the Presbyterian / St. Luke's Health One Medical Center 1st Annual Research Symposium, Denver, Colo., October 17, 2007.

Hall-Ellis, Sylvia D. *Project Homeless Connect 4 Event Evaluation – Insights and Lessons Learned.* Presentation delivered at the Homelessness Research Symposium: What is DU Doing about Homelessness in Denver, Denver, Colo., September 14, 2007.

Hall-Ellis, Sylvia D. *Service Learning and the Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the 2nd LEADS Scholars Orientation, Denver, Colo., August 10, 2007.

Hall-Ellis, Sylvia D. *Education for Information Professionals in a Digital Environment: Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the 15th Spring Mountains and Plains Parapros Conference, Denver, Colo., February 24, 2007.

Hall-Ellis, Sylvia D. *Public Library Service to Spanish-Speaking and Latino Residents in Denver: A Case Study.* Presentation delivered at the 4th Annual Colorado Association of Libraries Conference, Denver, Colo., November 10, 2005.

Hall-Ellis, Sylvia D. *Education for Information Professionals in a Digital Environment: Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the 14th Annual Mountains and Plains Parapros Conference, Aurora, Colo., July 29, 2005.

Hall-Ellis, Sylvia D. *Educational Opportunities: Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the 13th Annual Mountains and Plains Parapros Conference, Centennial, Colo., August 6, 2004.

Hall-Ellis, Sylvia D. *Library Education & Training: Focus on the West: An LIS Faculty Member's Personal Response*. Presentation delivered at the 1st Annual Colorado Association of Libraries Conference, Keystone, Colo., October 18, 2002.

Hall-Ellis, Sylvia D. *Grant Writing for School Librarians.* Presentation delivered at the 2002 Annual Colorado Education Media Association Conference, Colorado Springs, Colo., February 15, 2002.

Hall-Ellis, Sylvia D. *Grants – Opportunities for the Future.* Paper delivered at the Southeast Regional Accountability Annual Conference, Lamar, Colo., November 12, 1998.

Hall-Ellis, Sylvia D. *The Texas Library Connection and Interlibrary Loan: An Experiment in Resource Sharing.* Paper delivered at the Texas Computer Educators' Association Annual Conference, Austin, Tex., February 6, 1997.

Hall-Ellis, Sylvia D. *Finding Grant Sources on the Internet: A Guide for Librarians.* Paper delivered at the 2nd Annual Institute for School Library Personnel, Pharr-San Juan-Alamo North High School, Pharr, Tex., July 29, 1996**.**

Hall-Ellis, Sylvia D. *Mathematical and Logical Thinking: A Critical Intelligence.* Paper delivered at the 3rd Annual Paraprofessional Conference at the University of Texas - Pan American, Edinburg, Tex., March 8, 1996.

Hall-Ellis, Sylvia D. *Cataloging Trends and Issues: Update Session.* Paper delivered at the 1st Annual Institute for School Library Personnel, South Texas Community College, McAllen, Tex., July 19, 1995.

Hall-Ellis, Sylvia D. *Grant Writing: Tips and Encouragement for School Librarians.* Paper delivered at the 1st Annual Institute for School Library Personnel, South Texas Community College, McAllen, Tex., July 18 and 19, 1995.

Hall-Ellis, Sylvia D. *How to Become an Expert Grant Writer.* Paper delivered at the 3rd Annual High School Principals' Academy, South Padre Island, Port Isabel, Tex., June 19, 1995.

Texas Library Study: Results from Regions I and II. Paper delivered at the 3rd Annual Technology Conference, Texas A&M University, College Station, Tex., November 18, 1994.

Hall-Ellis, Sylvia D. *Academic Achievement and Middle School Students.* Paper delivered at the 8th Annual Young Adult Conference, Sam Houston State University, Huntsville, Tex., November 5, 1994.

Hall-Ellis, Sylvia D. *Multimedia Resources for Library Leaders.* Paper delivered at the Institute for Librarians in A Multicultural Environment, Sam Houston State University, Huntsville, Tex., June 10, 1994.

Hall-Ellis, Sylvia D. *Finding the Resource: Empowering the User, or, the Case for Curriculum Based Subject Access to Learning Resource Center Collections.* Paper delivered at the 81st Annual Texas Library Association Conference, Corpus Christi, Tex., April 12-16, 1994.

Hall-Ellis, Sylvia D. and William H. Pichette. *Sam Houston State University Makes Use of OCLC/AMIGOS Collection Analysis CD.* Paper delivered at the 81st Annual Texas Library Association Conference, Corpus Christi, Tex., April 12-16, 1994.

Hall, Sylvia D. *Funding and Library Development in Pennsylvania: A Symbiotic Relationship.* Paper delivered at the Annual Graduate Student Colloquia, University of Pittsburgh, School of Library and Information Science, 1982.

Hall, Sylvia D. *Leadership for Public Library Trustees.* Paper delivered for the Trustees Division, Pennsylvania Library Association Annual Conference, Lancaster, Penn., 1981.

Seminar and Professional Development Presentations

Taylor, Meredith, and Sylvia D. Hall-Ellis. *Talent Management and Succession Planning.* ALCTS eForum, held March 22, 2017.

Hirsh, Sandra, Heather O'Brien, Michelle Holschuh Simmons, Michael Krasulski, and Sylvia D. Hall-Ellis. *Information Services Today: An Introduction. Part 3: Information Services: Roles in the Digital Age*. Rowan and Littlefield in partnership with Library Journal webinar, recorded February 5, 2015.

Hall-Ellis, Sylvia D. and Jennifer Sweda. *Copy Cataloging in an RDA Environment.* ALCTS eForum, held May 14 and 15, 2013.

Hall-Ellis, Sylvia D. *Law Librarianship: A Community Conversation.* Sponsored by the Colorado Association of Law Libraries, presented at the Colorado Supreme Court Library, Denver, Colo., May 14, 2008.

Hall-Ellis, Sylvia D. and Beatrice Z. Gerrish. *Reading and Libraries: Recent Research in Reading.* Presentation at the Ricks Center for Gifted Education, Denver, Colo., March 4, 2008.

Hall-Ellis, Sylvia D. *Cataloger Competencies: Do the Employers Require What the Professors Teach?* Presentation for the School of Library and Information Science, San José State University, February 12, 2008.

Hall-Ellis, Sylvia D. and Robert O. Ellett, Jr. *Cooperative Cataloging: Rules, Tools, and Conventions for Building a Multi-institutional Catalog.* Sponsored for the Spanish Ministry of Defense, Madrid, Spain, July 10, 2006.

Hall-Ellis, Sylvia D. *Cash for Kids: Grant Writing Opportunities for Youth Services Librarians.* Sponsored by the Colorado Young Adult Librarians; presented at Bemis Memorial Library, Littleton, Colo., November 13, 2002.

Hall-Ellis, Sylvia D. *MARC Records and Authority Control: Planning for Bibliographic Database Migration.* Sponsored and held at the Douglas County Public Library, Castle Rock, Colo., May 28, 2002.

Grant Writing: A Refresher for Librarians. Sponsored by Library and Information Science Program, College of Education, University of Denver; presented at University Center at Chaparral, August 12, 2000.

Hall-Ellis, Sylvia D. *Shaking the Money Tree – Basic Grant Writing for Colorado Educators.* Sponsored by the Office of Educational Telecommunications of the Colorado Department of Education.
Pikes Peak Community College, Colorado Springs, Colo., November 16, 1998.
Pueblo School District 60, Pueblo, Colo., November 12, 1998.
University of Northern Colorado, Greeley, Colo., November 10, 1998.
United Technology Educational Partnership, Grand Junction, Colo., November 9, 1998.

Hall-Ellis, Sylvia D. *Cataloging Multimedia, Kits, Globes and Map Materials in USMARC.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., April 24, 1997 and December 12, 1996.

Hall-Ellis, Sylvia D. *New Standards for School Library Media Centers.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., April 15, 1997.

Hall-Ellis, Sylvia D. *The School Library Media Specialist in the 21st Century: Visions for the Future.* Sponsored and hosted by Pharr-San Juan-Alamo Independent School District, Pharr, Tex., April 4, 1997.

Hall-Ellis, Sylvia D. *Cataloging Sound Recordings and Audio Materials in USMARC.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., March 20, 1997 and November 21, 1996.

Hall-Ellis, Sylvia D. *Evaluating and Selecting CD-ROMS for School Library Media Collections.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., March 18, 1997.

Hall-Ellis, Sylvia D. *Cataloging Audiovisual Materials in USMARC.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., February 27, 1997, November 7, 1996 and October 24, 1996.

Hall-Ellis, Sylvia D. *Introduction to Dialog: Basic Searching Strategies.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., February 14, 1997.

Hall-Ellis, Sylvia D. *Cataloging Books in USMARC.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., January 30, 1997, October 10, 1996, September 26, 1996 and August 8, 1996.

Hall-Ellis, Sylvia D. *Advanced Internet Searching Techniques for Librarians.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., January 21, 1997.

Hall-Ellis, Sylvia D. *Texas Library Connection Full-Text Searching.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., December 13, 1996 and October 25, 1996.

Hall-Ellis, Sylvia D. *Developing Evaluation Strategies for Grants and Proposals.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., December 10, 1996.

Hall-Ellis, Sylvia D. *Developing Needs Assessment for Grants and Proposals.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., November 12, 1996.

Hall-Ellis, Sylvia D. *Texas Library Connection Union Catalog Searching.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., November 8, 1996 and September 6, 1996.

Hall-Ellis, Sylvia D. *Grant Resources on the Internet.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., October 23, 1996.

Hall-Ellis, Sylvia D. *Preparing a Response to the Telecommunications Infrastructure Fund Board: Needs Assessment, Professional Development Framework, and Evaluation Strategies.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., October 16, 1996.

Hall-Ellis, Sylvia D. *Texas Library Connection: Building the Districtwide Bibliographic Database.* Sponsored and hosted by Mercedes Independent School District, Mercedes, Tex., September 13, 1996 and August 8, 1996. Sponsored and hosted by Los Fresnos Consolidated Independent School District, Los Fresnos, Tex., August 12, 1996.

Hall-Ellis, Sylvia D. *School-to-Work and Special Education: An Inclusive Partnership for Success.* Sponsored and hosted by the Office of Special Education, Region One Education Service Center, Edinburg, Tex., September 11, 1996.

Hall-Ellis, Sylvia D. *Telecommunications Infrastructure Fund Board: An Overview of Funding for Secondary Schools.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., August 31, 1996.

Hall-Ellis, Sylvia D. *Cataloging Books, Multimedia, and Realia in USMARC.* Sponsored and hosted by Edinburg Consolidated Independent School District, Edinburg, Tex., August 6, 1996.

Hall-Ellis, Sylvia D. *Internet Resources for Grant Writers.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., April 20, 1996.

Hall-Ellis, Sylvia D. *Enhanced Grant Writing Skills for Mathematics Educators: Writing Skills for Campus Teams.* Sponsored and hosted by the Office of General Education, Region One Education Service Center, Edinburg, Tex., March 22, 1996.

Hall-Ellis, Sylvia D. *Internet Resources for Grant Writers.* Sponsored and hosted by the College of Education and Applied Science, Sam Houston State University, Huntsville, Tex., March 9, 1996.

Hall-Ellis, Sylvia D. *Grant Writing for Mathematics Educators: A Development Process for Campus Teams.* Sponsored and hosted by the Office of General Education, Region One Education Service Center, Edinburg, Tex., March 4, 1996.

Hall-Ellis, Sylvia D. *Shaking the Money Tree: Preparing Successful Technology Grant Applications.* Sponsored and hosted by the Office of Technology and Media Services, Region One Education Service Center, Edinburg, Tex., February 29, 1996 and April 29, 1996.

Hall-Ellis, Sylvia D. *District-wide Technology Planning: Technical Assistance for the Texas Education Agency Initiative.* Sponsored and hosted by the Office of Technology and Media, Region One Education Service Center, Edinburg, Tex., February 2, 1996.

Hall-Ellis, Sylvia D. *Enhanced Grant Writing Skills.* Sponsored and hosted by Pharr-San Juan-Alamo Independent School District, Pharr, Tex., January 27, 1996.

Hall-Ellis, Sylvia D. *United States Copyright Act of 1976, Video Transmissions, Computer Software and the Internet.* Sponsored and hosted by the Office of Technology and Media, Region One Education Service Center, Edinburg, Tex., January 24, 1996.

Hall-Ellis, Sylvia D. *The Grant Writing Development Process.* Sponsored and hosted by Pharr-San Juan-Alamo Independent School District, Pharr, Tex., January 20, 1996.

Hall-Ellis, Sylvia D. *MARC Cataloging of Materials for Library Media Centers.* Sponsored and hosted by the Office of Media Services, Region One Education Service Center for the Donna Independent School District, Donna, Tex., August 17, 1995.

Hall-Ellis, Sylvia D. *Classification.* Sponsored by AJ Seminars, Rockville, Maryland; presented at University Hilton Hotel, Houston, Tex., May 10, 1995.

Hall-Ellis, Sylvia D. *Library Technical Services.* Sponsored by AJ Seminars, Rockville, Maryland; presented at University Hilton Hotel, Houston, Tex., April 26, 1995.

Hall-Ellis, Sylvia D. *Grant Writing: An Introduction for Public School Administrators.* Sponsored and hosted by the Office of Administrative Services, Region One Education Service Center, Edinburg, Tex., April 19, 1995.

Hall-Ellis, Sylvia D. *The School Library Media Specialist in the 21st Century: Visions for the Future.* Sponsored and hosted by the United Independent School District, Laredo, Tex., March 31, 1995.

Hall-Ellis, Sylvia D. *Using USMARC.* Sponsored by AJ Seminars, Rockville, Maryland; presented at University Hilton Hotel, Houston, Tex., March 29, 1995.

Hall-Ellis, Sylvia D. *Library Media Center Policies and Guidelines: How to Prepare for School Board Adoption.* Sponsored and hosted by the Office of Technology and Media Services, La Joya Independent School District, La Joya, Tex., March 10, 1995.

Hall-Ellis, Sylvia D. *Developing District-wide Policies and Guidelines for Library Media Centers.* Sponsored and hosted by the Office of Technology and Media Services, La Joya Independent School District, La Joya, Tex., January 10, 1995.

Hall-Ellis, Sylvia D. *MARC Cataloging of Audiovisual Materials for Library Media Centers.* Sponsored and hosted by the Office of Library Media and Technology Services, Cypress-Fairbanks Independent School District, Houston, Tex., December 1, 1994.

Hall-Ellis, Sylvia D. *The School Library Media Specialist in the 21st Century: Visions for the Future.* Sponsored and hosted by United Independent School District, Laredo, Tex., October 14, 1994.

Hall-Ellis, Sylvia D. *The School Library Media Specialist in the 21st Century: Visions for the Future.* Sponsored and hosted by the Laredo Independent School District, Laredo, Tex., October 7, 1994.

Hall-Ellis, Sylvia D. *MARC Cataloging for Library Media Centers.* Sponsored by the Office of Library Media and Technology Services, Cypress-Fairbanks Independent School District, Houston, Tex., October 5, 1994.

Hall-Ellis, Sylvia D. *Jump to the Head of the Class: Undergraduate Library Resources Available at Sam Houston State University.* Sponsored by the Office of the Associate Vice President for Student Services, Sam Houston State University, Huntsville, Tex., October 4, 1994.

Hall-Ellis, Sylvia D. *CD-ROMs - 1994's Newest and the Best for Secondary Level Media Centers.* Sponsored and hosted by Clear Lake Independent School District, Houston, Tex., June 3, 1994.

Hall-Ellis, Sylvia D. *Introduction to Classification.* Sponsored by AJ Seminars, Rockville, Maryland; presented at Holiday Inn, Market Center, Dallas, Tex., May 18, 1994.

Hall-Ellis, Sylvia D. *Basic Descriptive Cataloging.* Sponsored by AJ Seminars, Rockville, Maryland; presented at University Hilton Hotel, Houston, Tex., May 4, 1994.

Hall-Ellis, Sylvia D. *Shaking the Money Tree - Part II: Writing Successful Grant Applications.* Sponsored by Donna Independent School District, Donna, Texas, and Region One Education Service Center Edinburg, Texas; presented at South Texas Community College Library, McAllen, Tex., April 29, 1994.

Hall-Ellis, Sylvia D. *Using MARC.* Sponsored by AJ Seminars, Rockville, Maryland; presented at Holiday Inn, Market Center, Dallas, Tex., April 6, 1994.

Hall-Ellis, Sylvia D. *Automated Authority Control.* Sponsored by AJ Seminars, Rockville, Maryland; presented at University Hilton Hotel, Houston, Tex., March 23, 1994.

Hall-Ellis, Sylvia D. *Automating the District School Library Media Centers: Choices and Opportunities.* Sponsored and hosted by the Office of Technology and Library Media Services, Fort Bend Independent School District, Sugar Land, Tex., March 4, 1994.

Hall-Ellis, Sylvia D. *Shaking the Money Tree - Part I: Preparing Successful Grant Applications.* Sponsored and hosted by the Office of Library Media Services, Donna Independent School District, Donna, Tex., February 4, 1994.

GRADUATE COURSES TAUGHT

San José State University, School of Library and Information Science
INFO 249 – Advanced Cataloging and Classification (Fall 2015, 2016; Summer 2016)
INFO 287 – Special Topics in Cataloging and Classification (Spring 2017, 2018, 2019, 2020, 2021, 2022, 2023; Fall 2020, 2021, 2022, 2023)
LIBR 248 – Beginning Cataloging and Classification (Summer 2002, 2003, 2004, 2005, 2006)
LIBR 249 – Advanced Cataloging and Classification (Summer 2003; Fall 2014; Summer 2015)

University of Denver, University College
Grant Writing Certificate Seminar for Non-Profit Organizations (Fall 2020, 2021; Spring 2021)

University of Denver, Morgridge College of Education HED
5991 – Grant Writing in Higher Education (Spring 2011)
LIS 4010 – Organization of Information (Fall 2002-2009; Winter 2005; Spring 2004-2006)
LIS 4020 – Professional Principles and Ethics (Summer 2000)
LIS 4040 – Management of Libraries and Information Centers (Fall 2010; Spring 2003, 2009 (DS); Winter 2005)
LIS 4070 – Cataloging and Classification (Winter 2008, 2009, 2010, 2011, 2012; Fall 2009 (DS)) LIS 4321 – Collection Management (Spring 2005)
LIS 4326 – LIS Research (Winter 2009 (DS); Spring 2009 (DS))
LIS 4350 – Adult Materials and Services (Summer 2006, 2009)
LIS 4379 – Social Sciences Resources (Spring 2009)
LIS 4400 – Cataloging and Classification (Spring 2000, 2001; Winter 2002-2009; Summer 2005, 2006 – course renumbered LIS 4070, September 2007)
LIS 4401 – Descriptive Cataloging (Winter 2001; Spring 2002, 2003, 2006-2009; Summer 2005)
LIS 4402 – Subject Cataloging (Spring 2001, 2009; Summer 2005, 2006, 2007, 2008)
LIS 4403 – Classification Schemes (Fall 2007, 2008, 2009 (DS)) LIS
LIS 4405 – Authority Control (Winter 2009)
LIS 4510 – Materials and Services for Children (Winter 2004; Summer 2005)
LIS 4620 – Grant Writing and Fundraising (Summer 2000, 2002, 2004, 2010; Winter 2006; Fall 2006-2009)
LIS 4700 – Seminar in Technical Services (Fall 2001)
LIS 4700 – Seminar in Public Libraries (Summer 2002)
LIS 4804 – Management of Electronic Records (Spring 2004; Fall 2005)
LIS 4902 – Capstone Projects (Winter 2003, Spring 2008, 2009, 2011)
LIS 4910 – Independent Study (every quarter Winter 2000 through Spring 2011)
LIS 4920 – Service Learning (every quarter Summer 2004 through Spring 2011)
RMS 4954 – Grant Writing (Summer 2013, 2014)
RMS 4959 – Content Analysis Methodology (Spring 2015)
QRM 4978 – Grant Writing (Summer 2011, 2012)

Rutgers University, School of Communication and Information
SC&I 522 – Cataloging and Classification (Summer 2013)

University of Arizona, College of Behavioral and Social Sciences
LIS 602 – Cataloging and Classification (Summer 1995)
LIS 612 – Advanced Online Search and Retrieval (Summer 1995)

Sam Houston State University, College of Education & Applied Science
LIS 532 - Cataloging and Classification (Fall 1993, 1994, 1995)
LIS 563 - Advanced Cataloging and Classification (Summer 1994)
LIS 567 - Research Methods (Spring 1994, Spring 1995)
LIS 591 - Educational Technology (Spring 1994, 1995)
LIS 596 - Networking and Computer Technologies in Education (Fall 1993, Summer 1994, Fall 1995)

Dissertations at the University of Denver

Bowers, Stacey L. *Library Anxiety of Law School Students: A Study Utilizing the Multidimensional Library Anxiety Scale.* Chair, May 5, 2010.

Fattor, Melissa M. *Student Engagement Differences by Ethnicity and Scale for Ninth Grade Students.* Chair, November 1, 2010.

Fulton, Roseanne. *A Case Study of Culturally Responsive Teaching in Middle School Mathematics.* Kent Seidel, Chair, June 18, 2009, Outside Chair.

Grealy, Deborah S. *Tribes and Territories in Library and Information Studies Education.* Bruce Uhrmacher, Chair, June 10, 2008, Committee Member.

McCord, J. Michael. *Developing a Standard of Care for Educational Malpractice.* Chair, April 15, 2011.

Priebe, Sarah J. *Distinguishing Effects of Domain and General Knowledge on Passage Fluency and Comprehension.* Jan Keenan, Chair. July 21, 2011, Outside Chair.

Snyder-Mondragon, Sandra M. *Institutional Factors that Impact the Retention of Graduate Students of Color in Schools of Library and Information Science: A Metaregression of Accredited Library School Statistics on Student Retention and Graduation Rates.* Kathy Green, Chair, July 24, 2009, Committee Member.

Taylor, Karen Pickles. *Effective Teaching.* Elinor Katz, Chair, July 15, 2009, Outside Chair.

Thompson, Jennifer. *Distinguishing a Western Women's College: A History of the Curriculum and Student Experience at Colorado Women's College.* Edith W. King, Chair, July 16, 2010, Committee Member.

Walker, Emelda. *Influence of Organizational Factors on Job Satisfaction of Disability Service Providers at Postsecondary Institutions.* Chair, April 29, 2010.

Dissertation Proposals at the University of Denver

Bowers, Stacey L. *Library Anxiety of Law School Students: A Study Utilizing the Multidimensional Library Anxiety Scale.* Chair, November 5, 2009.

McCord, J. Michael. *Developing a Standard of Care for Educational Malpractice.* Edith W. King, Chair. April 23, 2010.

Thompson, Jennifer. *History of Colorado Women's College.* Edith W. King, Chair, October 30, 2008. Committee Member.

Walker, Emelda. *Influence of Organizational Factors on Job Satisfaction of Disability Service Providers at Postsecondary Institutions.* Chair, July 21, 2009.

Dissertations at Other Institutions

Rodríguez-Mori, Howard. *The Information Behavior of Puerto Rican Immigrants to Central Florida, 2003-2009: Grounded Analysis of Six Case Studies Use of Social Networks during the Migration Process.* Kathleen Burnett, Chair, April 10, 2009, Florida State University, Committee Member.

Schwartz, Brian *More than a Look-up Skill: Medical Information Literacy Education in Osteopathic Medical Schools.* D. Mirah Dow, Chair, July 18, 2017. Emporia State University, Committee Member.

Snow, Karen. *A Study of the Perception of Cataloging Quality among Catalogers.* Shawne D. Miksa, Chair, August 1, 2011. University of North Texas, Committee Member.

Dissertation Proposals at Other Institutions

Schwartz, Brian *More than a Look-up Skill: Medical Information Literacy Education in Osteopathic Medical Schools.* D. Mirah Dow, Chair, December 4, 2015. Emporia State University, Committee Member.

Snow, Karen. *A Study of the Perception of Cataloging Quality among Catalogers.* Shawne D. Miksa, Chair, May 11, 2010. University of North Texas, Committee Member.

Master's Thesis at the University of Denver

Hemingson, Jeff. *Recital Paper.* Lamont School of Music, February 2010, Outside Chair.

Capstones at the University of Denver

Anthony, Alisa. *Correlation of Library and Information Science Program outcomes and Vacant Position Qualifications Listed on the Colorado State Library Jobline by Employers During the Period September 1, 2000 through August 31, 2002.* Chair, Winter Quarter, 2003.

Borden, Donna M. *Improving Emergency Communications Systems: Is a Radio Communications Network the Answer?* Fall Quarter, 2014.

Bowden, Heather L.M. *Exploring Biological Models for Long-term Data Preservation.* Chair, Spring Quarter, 2008.

Casenada, Cassandra Y. *Challenges to the Recruitment, Education, and Retention of Librarians of Color.* Chair, Spring Quarter, 2008.

Chang, Jennifer C. *Legal Research Practice and Preference: A Law Firm Perspective.* Chair, Spring Quarter 2011.

Ellis, Megan S. Fitzgerald. *Design of a Public Library Adult Volunteer Recruitment Program and Training Curriculum.* Chair, Winter Quarter, 2003.

Kircher, Kathy. *Development of a Library Pathfinder for Exobiology and Posting it on the Internet.* Chair, Winter Quarter, 2003.

Melhado, Loretta. *Design of St. John's Episcopal Church Library.* Chair, Spring Quarter, 2008.

Radcliff, Kathy. *Original Cataloging of Archival materials in the HERS Collection in Penrose Library.* Chair, Winter Quarter, 2003.

Sass, Carol Ann. *ACT Periodical Index: Access to Catholic Thinking Periodical Index: Web Index to Select Catholic Periodicals.* Spring Quarter 2000.

Stone, Sergio D. *Conducting Community Analysis for the Bemis Public Library (Littleton, Colorado) Using 2002 U.S. Census Data and the Online Outcome-Based Evaluation Toolkit.* Chair, Winter Quarter, 2003.

Tureson, Tamara. *Design and Use of an Information Audit Tool for Use in a Law Library.* Chair, Winter Quarter, 2003.

Tweed, Beth. *Evaluation of Email Reference Service in a Consumer Health Library Environment.* Chair, Winter Quarter, 2003.

GRANTS AND CONTRACTS

Student Learning in Agriculture STEM through Teacher Professional Development. Research team: Stanton Gartin (PI) and Cyndi Hofmeister, Northeast Junior College; Jeff Cash, Cheryl Sánchez, Anne-Marie Crampton, Lamar Community College; Suzanna Spears, Morgan Community College; Jack Wiley, Kerry Gabrielson, Trinidad State Junior College; Michael J. Miller, Colorado State University; Michael Womochil (Co-PI), Casey Sacks, and Sylvia D. Hall-Ellis, Colorado Community College System. U.S. Department of Agriculture, Agriculture and Food Research Initiative, Food, Agriculture, Natural Resources and Human Sciences Education and Literacy Initiative, $404,460 (2017-2020)

Leading and Achieving: the Colorado Agriculture Regional Consortium. Research team: Jack Wiley (PI), Kerry Gabrielson, Trinidad State Junior College; Jeff Cash (PI), Cheryl Sánchez, Anne-Marie Crampton, Lamar Community College; Suzanna Spears, Morgan Community College; Cyndi Hofmeister, Northeast Junior College; Michael Womochil (Co-PI), Casey Sacks, and Sylvia D. Hall-Ellis, Colorado Community College System. U.S. Department of Agriculture, Hispanic Serving Institutions Education Grants Program, $504,414 (2017-2020)

Cyber Prep Program Planning Grant. Research team: Debbie Sagen (PI), Brenda Lauer, Pikes Peak Community College; Gretchen Martin, Koiosa Insights; and, Sylvia D. Hall-Ellis, Colorado Community College System. U.S. Department of Commerce, Regional Alliances and Multi-stakeholder Partnerships to Stimulate (RAMPS) Cybersecurity Education and Workforce Development, $199,681 (2016-2018)

Career and Technical Education in Colorado: Pathways to Education and Employment. Research team: Heather McKay (PI), Rutgers University; Sarah Heath, Casey Sacks, Sylvia D. Hall-Ellis, Colorado Community College System. U.S. Department of Education, Institute of Education Sciences, $1,400,000 (2017-2021)

Pre-Alliance Planning Grant Colorado Community College Alliance. Research team: Victor Vialpondo (PI) and Janel Highfill, Community College of Aurora; Heidi Loshbaugh (Co-PI), Community College of Denver; Rick Reeves, Bill McGreevy, Liz Cox, and Kristin Aslin, Red Rocks Community College; Cathy Pellish, Front Range Community College; Samuel DeVries, Arapahoe Community College; Sylvia D. Hall-Ellis, Colorado Community College System. National Science Foundation, Louis Stokes Alliance for Minority Participation (LSAMP), $86,817 (2016-2017)

Towards Scalable Differentiated Instruction Using Technology-enabled, Competency-based, Dynamic Scaffolding. Research team: Karen Wilcox (PI) and Vijay Kumar, Center for Computational Engineering, Massachusetts Institute of Technology; Flora McMartin, Broad-based Knowledge; Quinsigamond Community College; and, Casey Sacks, and Sylvia D. Hall-Ellis, Colorado Community College System. U.S. Department of Education, First in the World Developmental Grant, $2,891,882 (2015-2019)

Colorado Strategic Partnerships Emergency Grant. Research team: Elise Lowe-Vaughn (PI), Amy Hodson, Celia Hardin, Barbara McBride, James Newby, Christopher Dewhurst, Nina Holland, Kate Anderson, MaryAnn Roe, Chrystalynn Chrystalynn, Elaine Edon, Mona Barnes, Tom Morgan, Rob Hanni, and Marie Valenzuela, Colorado Department of Labor and Employment; Steve Anton, Joelle Brouner, and, Katie Griego, Colorado Department of Human Services; Rebecca Holmes, Judith Martinez, and Jennifer Jirous, Colorado Department of Education; Emily Templin Lesh, Colorado Workforce Development Council; Cory Everett, Colorado Department of Regulatory Agencies; and, Casey Sacks and Sylvia D. Hall-Ellis, Colorado Community College System. U.S. Department of Labor, Strategic Partnerships Emergency Grant, $5,000,000 (2015-2017)

CAEL Jump Start Program: Competency-Based Education. Research team: Jerry Migler (PI), Casey Sacks, Debra Cohn, Thomas Hartman, and Sylvia D. Hall-Ellis, Colorado Community College System; Matt Jamison, Front Range Community College; Mike Coste, Red Rocks Community College; Amanda Corum, Pueblo Community College; Janet Colvin, Pikes Peak Community College; and, MaryAnn Matheny, Community College of Denver. Council for Adult and Experiential Learning, $15,000 (2015)

Summit on the Redesign of Developmental Education. Research team: Jerry Migler (PI), Casey Sacks, and Sylvia D. Hall-Ellis, Colorado Community College System; Chip Nava, Pueblo Community College; Kim Moultney, Arapahoe Community College; Debbie Ulibarri, Trinidad State Junior College; and, Kris Bernard, Front Range Community College. American Association of Community Colleges, $15,000 (2015-2016)

Equity in Excellence at Colorado Community Colleges. Research team: Keith Howard (PI) and Sylvia D. Hall-Ellis, Colorado Community College System; Estela Mata Bensimon, Center for Urban Education, University of Southern California; and Kerry Gabrielson, Trinidad State Junior College. Colorado Department of Higher Education, Colorado Opportunity Scholarship Program, $150,000 (2015-2016)

MBA High School of Business in Colorado. Research team: Laurie Urich (PI) and Sylvia D. Hall-Ellis, Colorado Community College System; Rudolph Sumpter and Beatrice Gerrish, Boulder Valley Schools; Keith Curry Lance, RSL Research Group. Colorado Department of Higher Education, Colorado Opportunity Scholarship Program, $501,295 (2015-2016)

Fullbridge Program in Colorado. Research team: Keith Howard (PI) and Sylvia D. Hall-Ellis, Colorado Community College System; Suzanna Spears, Fort Morgan Community College; and, Cheryl Sánchez and Anne-Marie Compton, Lamar Community College. Colorado Department of Higher Education, Colorado Opportunity Scholarship Program, $300,000 (2015-2017)

Colorado Community College System Alternative Credit Program. Research team: Jerry Migler (PI), Keith Howard, and Sylvia D. Hall-Ellis, Colorado Community College System. American Council on Education, $13,000 (2015)

Internationalization in Higher Education. Researcher: Samuel D. Museus. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Internationalization, $8,000 (2014-2015)

International Perspectives on Bilingual Education. Researcher: Sharolyn Pollard-Durodola. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Internationalization, $3,700 (2014-2015)

Cultivating Culturally Relevant and Responsive Curriculum and Pedagogy in College. Researcher: Samuel Museus. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, iRise Grant, $5,000 (2014-2015)

Project EMERGE (Educational Model for Evaluation and Replicability in Gifted Environments). Research team: Norma Hafenstein (PI) and Bruce Uhrmacher. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Lynde and Harry Bradley Foundation, $235,000 (2014-2015)

Collecting Asian American Refugee Stories. Researcher: Samuel Museus. Technical reviewer for MCE: Sylvia D. Hall-Ellis. American Educational Research Association, Research Grant, $5,000 (2014-2015)

Developing Expertise in Teaching K-5 Mathematics. Research team: Julie Sarama (PI) and Douglas H. Clements (Co-PI), in partnership with the School of Education at the University of Michigan. Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Science Foundation, $130,344 (2013-2015)

Investigation of the Long-Term Outcomes for Special Education Students. Researcher: Antonio Olmos-Gallos. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Jefferson County School District, Office of Assessment, $40,000 (2014)

Refugee Community Collaboration. Researcher: Vicki Tomlin (PI) in partnership with the African Community Center and Jewish Family Service. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Community Engagement and Service Learning, $14,854 (2014-2015)

Access to Mathematics for All. Research team: Richard S. Kitchen (PI), Nicole M. Russell (Co-PI), and Terrence Blackman (Co-PI), Curriculum Studies and Teaching Program, Morgridge College of Education; Álvaro Árias (Co-PI, Department of Mathematics); and, James Gray (Co-PI), Department of Mathematics, Community College of Aurora. Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Science Foundation, The Robert Noyce Scholarship Program, Capacity Building Project, $349,926 (2014-2016)

Cognitive Test Battery for Intellectual Disabilities. Research team: Karen Riley (PI), Lyndsay Agans, Jessica Lerner, and Karin Dittrick-Nathan in partnership with David Hessl (PI), The MIND Institute at the University of California – Davis, and Elizabeth Berry-Kravis, Rush University Medical Center. Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Institutes of Health, Outcome Measures for Use in Treatment Trials for Individuals with Intellectual and Developmental Disabilities (R01), $2,499,996 ($588,672 at DU) (2014- 2019)

Broadening Participation in Engineering among Women and Latino/as: A Longitudinal, Multi-Site Study. Researcher: Patton Garriott (PI) in partnership with the University of North Dakota and the University of Missouri. Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Science Foundation, HER Core Research, $677,390 ($69,992 at DU) (2014-2019)

Designing a Teacher Evaluation System to Improve Teacher Effectiveness for Culturally and Linguistically Diverse Learners. Research team: María del Carmen Sálazar (PI), Jessica Lerner, and Kathy Green. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Professional Research Opportunities for Faculty, $29,988 (2014-2016)

Developing a College-Going Culture in Latina/O Families: Exploring the Influence of Funds of Knowledge on Family Outreach Programs. Researcher: Judy Marquez Kiyama. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Professional Research Opportunities for Faculty, $18,720 (2014-2016)

Assessment of Quality of Life in Neutral Implantation Surgery for the Treatment of Parkinson's Disease. Researcher: Cynthia McRae. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Internationalization, $3,967 (2014-2015)

Pura Vida: Cloud Forest, Curriculum and Cross-Cultural Study. Research team: Norma Hafenstein (PI) and Bruce Uhrmacher (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Internationalization, $8,000 (2014-2015)

Online Course Development for Curriculum and Instruction. Researcher: Ruth Chao. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Teaching and Learning, $3,000 (2014)

Online Course Development for Curriculum and Instruction. Researcher: María del Carmen Sálazar. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Teaching and Learning, $3,000 (2014)

Online Course Development for Curriculum and Instruction. Researcher: Jessica Lerner. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Teaching and Learning, $3,000 (2014)

Online Course Development for Curriculum and Instruction. Researcher: Duan Zhang. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Teaching and Learning, $3,000 (2014)

The Mathematics Education of African Americans, 1866 – 1954. Researcher: Nicole M. Russell. Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Academy of Education, Spencer Foundation Postdoctoral Fellowship, $55,000 (2014-2016)

Early Childhood Care and Education Study. Research team: Carrie Germeroth (PI), Melissa Mincic, and Douglas H. Clements. Technical reviewer for MCE: Sylvia D. Hall-Ellis. State of North Dakota, Department of Public Instruction, $73,500 (2013-2014)

Graduate Level Specialty in Addiction Counselor Training with Emphasis on Integration of Native American Specific Content. Research team: Ruth Chao (PI) and Michael J. Faragher (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. The Galena Foundation, $289,732 (2013-2016)

The Collecting Asian American and Pacific Islander Refugee Stories (CARS) Project. Researcher: Samuel Museus. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Community Engagement and Service Learning, $15,000 (2014)

Parents in Transition: A Multiple Case Study of Parent and Family Orientation Programs. Researcher: Judy Marquéz Kiyama. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Faculty Research Fund, $1,500 (2014-2015)

The Sistah Network: Black Women Graduate Students Supporting and Retaining Each Other. Researcher; Nicole M. Russell. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Faculty Research Fund, $2,708 (2014-2015)

Evaluation of the Northeast Denver Babies Ready for College Program. Research team: Carrie Germeroth (PI), Melissa Mincic, and Douglas H. Clements. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Mile High Montessori, $9,922 (2013-2014)

Developing Teaching Expertise in K-5 Mathematics. Research team: Julie Sarama (PI) and Douglas Clements (University of Denver), in partnership with Timothy Boerst (PI), Meghan Shaughnessy, Deborah Ball, Hyman Bass (School of Education at the University of Michigan). Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Science Foundation, $449,827 ($130,344 at the University of Denver (2013-2015)

Early Learning Care and Education Study Program Grant for the State of North Dakota. Research team: Carrie Germeroth (PI), Melissa Mincic, and Sheridan Green. Technical reviewer for MCE: Sylvia D. Hall-Ellis. State of North Dakota Department of Public Instruction, $73,500 (2013-2014)

Local Professional Learning Community for School Leaders. Research team: Susan Korach (PI), Kristina Hesbol, and Rebecca McClure. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Education Development Center, $10,950 (2013)

Healthy Eaters, Lifelong Movers 2: Implementing Evidence-Based School Environment, Policy, and Curricular Changes to Increase Opportunities for Healthy Eating and Physical Activity in Low Income, Rural Colorado. Research team: Elaine Berlansky, University of Colorado at Denver (PI), Nicholas Cutforth, University of Denver (Co-PI), and Allison Reeds. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Health Foundation, $3,103,108 (2013-2017)

Hughes Rare Books Library Room Renovation in the Sturm College of Law. Project team: Patti H. Marks, Sylvia D. Hall-Ellis, and Leigh Elliott. Mabel T. Hughes Charitable Trust, $34,000 (2013-2014)

The Promise Center Partnership with the Marsico Institute for Early Learning and Literacy and the City and County of Denver. Research team: Karen Riley (PI), Douglas H. Clements (Co-PI), and Sheridan Green. Technical reviewer for MCE: Sylvia D. Hall-Ellis. The Piton Foundation, $223,468 (2013-2014)

Center of Excellence for Problem Gambling. Research team: Ruth Chao (PI) and J. Mike Faragher. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Department of Behavioral Health, $68,021 (2012-2013)

United Way Implementation and Validation Review. Research team: Douglas H. Clements (PI), Amanda Moreno, and Sheridan Green. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Mile High United Way, $19,737 (2013)

Math/Science Partnership in Rural Districts. Research team: Kristen Bunn (PI, Eagle County Schools), Paul Michalec (Co-PI), and Alegra Reiber. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Department of Education, Colorado's Mathematics and Science Partnership Program, $750,000 (2013-2014)

Mathematics and Science Education of African Americans. Research team: Nicole Russell (PI), Sylvia D. Hall-Ellis, Steve Fisher (Penrose Library). Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Professional Research Opportunities for Faculty, $29,994 (2013-2015)

Online Course Development for Curriculum and Instruction. Researcher: Nicole Russell. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Teaching and Learning, $3,000 (2013)

Discourse and Opportunity: Undocumented Students and Higher Education Policy. Researcher: Ryan Gildersleeve. Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Academy of Education, Spencer Foundation Postdoctoral Fellowship, $55,000 (2012-2014)

An Anthropological Study of the Latino Graduation Ceremony. Researcher: Ryan Gildersleeve. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Spencer Foundation, $39,900 (2012-2013)

Fragile-X and Pharmaceutical Company: Clinical Trial of AFQ056. University of California – Davis Children's Hospital MIND Institute (Sacramento), Children's Hospital Denver, and Rush Children's Hospital at Rush University Medical Center (Chicago). Karen Riley, PI. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Novartis Pharmaceuticals Corporation, $394,206 (2012-2014)

Project Engage, Phase 2, a DAPRA Grant in partnership with Total Immersion Systems, Inc., and Texas A&M University. Research team: Karen Riley (PI) and Lyndsay Agans (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. U.S. Department of Defense, $60,000 (2011-2013)

International School Psychology Practicum Exchange. Researcher: Gloria L. Miller. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Community Engagement and Service Learning, $14,951 (2012-2013)

Online Course Development for Curriculum and Instruction. Research team: Bruce Uhrmacher (PI) and Norma Hafenstein (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Teaching and Learning, $18,193 (2012-2014)

Writers in the Schools. Research team: Karen Riley (PI) and Amanda Moreno (Co-PI).Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Humanities, $4,965 (2012-2013)

Learning Ecosystem Validation Grant. Research team: Karen Riley (PI), Lyndsay Agans, Kent Seidel, and Shimelis Assefa. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Bill & Melinda Gates Foundation, $315,000 (2012-2013)

Project Words of Oral Reading and Language Development (WORLD). Research team: Jorge E. Gonzalez (PI), Texas A&M University; Laura Saenz (Co-PI), University of Texas – Pan American; and, Sharolyn Pollard-Durodola (Co-PI), University of Denver. Technical reviewer for MCE: Sylvia D. Hall-Ellis. U.S. Department of Education, Institute of Education Sciences, $53,354 (2012-2015); award $640,718, transfer from Texas A&M University

Increasing the Efficacy of an Early Mathematics Curriculum with Scaffolding Designed to Promote Self-Regulation. Research team: Douglas H. Clements (PI) and Julie Sarama (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. U.S. Department of Education, Institute of Education Sciences, $1,445,315 (2008-2014); award $4,541,975, transfer from University at Buffalo, The State University of New York

Using Rule Space and Poset-based Adaptive Testing Methodologies to Identify Ability Patterns in Early Mathematics and Create a Comprehensive Mathematics Ability Test. Research team: Douglas H. Clements (PI) and Julie Sarama (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Science Foundation, $323,791 (2010-2014); award $1,194,944, transfer from University at Buffalo, The State University of New York

Comprehensive Postdoctoral Training in Scientific Education Research. Researcher: Julie Sarama (PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. U.S. Department of Education, Institute of Education Sciences, $133,458 (2010-2014); award $613,353, transfer from University at Buffalo, The State University of New York

Longitudinal Study of a Successful Scaling Up Project: Extending TRIAD. Research team: Douglas H. Clements (PI), Julie Sarama (Co-PI), and Abt Associates (Carolyn Layzer, Fatih Unlu, Laurie Bozzi, Lily Fesler, Alina Martinez, Cristofer Price, James van Orden). Technical reviewer for MCE: Sylvia D. Hall-Ellis. Institute of Education Sciences, $384,940 (2011-2015; award $1,250,286, transfer from University at Buffalo, The State University of New York

Early Childhood Education in the Context of Mathematics, Science, and Literacy. Research team: Julie Sarama (PI), Douglas H. Clements (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Science Foundation, $990,020 (2010-2014; award $2,285,228, transfer from University at Buffalo, The State University of New York

Early Childhood Clearinghouse Information Center Redesign. Research team: Karen Riley (PI) and Amanda Moreno (Co-PI).Technical reviewer for MCE: Sylvia D. Hall-Ellis. Office of the Lt. Governor of Colorado, $12,000 (2012-2013)

Morgridge Rural Educational Leadership Initiative. Research team: Lyndsay Agans (PI), Linda Brookhart (Co-PI), Susan Korach, and Rebecca McClure. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Morgridge Family Foundation, $100,000 (2012-2014)

Center of Excellence for Problem Gambling. Research team: Patrick Sherry (PI) and J. Mike Faragher. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Department of Behavioral Health, $55,000 (2012-2013)

Intermodal Transportation Institute Research Initiatives. Researcher: Patrick Sherry. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University Transportation Centers Program, Research and Innovative Technology Administration, U.S. Department of Transportation. $600,000 (2012-2014)

Mile High United Way Social Innovation Fund Early Literacy Initiative. Gloria L. Miller, PI, Amanda Moreano, Kim Hartnett-Edwards, and Sheridan Green. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Mile High United Way, $89,992 (2012-2013)

International School Psychology Practicum Exchange. Researcher: Gloria L. Miller. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Community Engagement and Service Learning, $1,000 (2012-2013)

Refugee Student Art Outreach. Researcher: Karin Dittrick-Nathan. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Faculty Research Fund, $3,000 (2012-2013)

Resistance, Resilience, and Reciprocity: Centering the Voices of Black Doctoral Women with Faculty Aspirations. Researcher: Nicole M. Russell. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Faculty Research Fund, $2,965 (2012-2013)

Assessing Learning through Student Notebooks. Research team: Keith Miller, Nancy Sasaki, and Kathy Green. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Professional Research Opportunities for Faculty, $30,000 (2012-2014)

International School Psychology Practicum Exchange. Researcher: Gloria L. Miller. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Internationalization, $2,000 (2012-2013)

ELO in Colorado. Research team: Cynthia Hazel and Duan Zhang. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Legacy Foundation, $150,000 (2012-2013)

Creating Online LIS Courses. Research team: Mary C. Stansbury (PI), Shimelis Assefa, Denise Anthony, Xiao Hu, and Krystyna Matusiak. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Teaching and Learning, $15,000 (2011-2013)

Maritime Piracy Seminar. Researcher: Ved Nanda, The Nanda Center, Sturm College of Law. Technical reviewer for Sturm College of Law: Sylvia D. Hall-Ellis. Arsenault Family Foundation, $15,000 (2012-2013).

Early Childhood Librarianship: An Interdisciplinary, Experiential Learning MLIS. Researcher: Mary C. Stansbury (PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. Laura Bush's 21st Century Librarians Program, Institute for Museums and Library Services, $249,066 (2012-2014)

Learning Ecosystem Planning Grant. Research team: Karen Riley (PI), Lyndsay Agans, Kent Seidel, and Shimelis Assefa. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Bill & Melinda Gates Foundation, $281,217 (2011-2012)

Advanced Service Learning Practitioner Faculty Grant, Sylvia D. Hall-Ellis, University of Denver, Center for Community Engagement and Service Learning, $400 (2011)

Evaluating and Enhancing the EspeciallyMe Program. Research team: Lori D. Patton and Nicole Russell. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Community Engagement and Service Learning, Public Good Fellowship Grant, $24,780 (2012)

Choosing Excellence: Let Every Child Bloom. Research team: Shimelis Assefa (PI) and Mary C. Stansbury (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Community Engagement and Service Learning, Public Good Grant, $7,657 (2012)

K-8 STEM Content Specific Professional Development to Improve Elementary Student Achievement. Research team: Kent Seidel (PI), Nicole Russell (Co-PI), Kimberly Hartnett-Edwards, Paul Michalec, Jeff Farmer, Keith Miller, Alegra Reiber, and Nancy Sasaki. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Department of Education, Improving Teacher Quality Grant, (Title II ESEA), $307,299 (2011-2012)

Building a Better Principal Pipeline to Boost Student Achievement. Researcher: Susan Korach. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Denver Public Schools; a subcontract from the Wallace Foundation Grant, $170,000 (2011-2017)

Center of Excellence for Problem Gambling. Research team: J. Mike Faragher (Co-PI) and Bobbie Vollmer (PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Department of Behavioral Health, $79,999 (2011-2012)

An Exploration of Novice Teachers' Core Competencies: Impacts on Student Achievement, and Effectiveness of Preparation. Research team: Kent Seidel (PI), Kathy Green (Co-PI), Kimberly Hartnett-Edwards, and Duan Zhang. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Institute of Education Sciences, Effective Teachers and Effective Teaching, $990,987 (2012-2015)

Project Engage, a DAPRA Grant in partnership with Total Immersion Systems, Inc., and Texas A&M University. Research team: Karen Riley (PI) and Lyndsay Agans (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. U.S. Department of Defense, $49,964 (2011-2014)

User-centered Evaluation of Music Search Engines. Researcher: Xiao Hu. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Faculty Research Fund, $2,931 (2011-2012)

Educational Practicum in Vietnam and China to Promote the Inclusion of Young Children with Disabilities. Researcher: Gloria L. Miller. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Internationalization, $5,000 (2011-2012)

Evaluation of Colorado's Enhancing Quality in Infant-Toddler (EQIT) Initiative. Research team: Virginia R. Maloney and Amanda Moreno. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Buell Foundation, $395,884 (2011-2013)

Creating Engaging Environments to Teach Pre-Algebra Mathematics to Elementary Students. Research team: Álvaro Arias, Mario López, María del Carmen Salazar, and Lyndsay Agans. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver Interdisciplinary Grant, $60,000 (2011-2012)

Morgridge Education Technology Accessible (META) Resource Project. Research team: Lyndsay Agans (PI) and Shimelis Assefa (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. Morgridge Family Foundation, $36,000 (2011)

MCE Connect: A 21st Century Framework for Faculty Development. Research team: Bruce Uhrmacher (PI), Shimelis Assefa (Co-PI), Lyndsay Agans (Co-PI), Kimberly Hartnett-Edwards, Norma Hafenstein, Xiao Hu, Paul Michalec (Co-PI), María del Carmen Salazar (Co-PI), and Sandra Snyder-Mondragon. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Teaching and Learning, $22,355 (2011-2012)

Parent Education and Parent Leadership and Advocacy. Research team: Virginia Maloney (PI) and Amanda Moreno, Marsico Institute for Early Learning and Literacy. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Health Foundation, $27,358 (2010-2011)

Intentional School Culture. Researcher: Cynthia Hazel. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Denver Public Schools, $38,040 (2010-2011)

Healthy Eaters, Lifelong Movers: Implementing Evidence-Based School Environment, Policy, and Curricular Changes to Increase Opportunities for Healthy Eating and Physical Activity in Low Income, Rural Colorado. Research team: Elaine Berlansky, University of Colorado at Denver (PI), Nicholas Cutforth, University of Denver (Co-PI), and Allison Reeds. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Health Foundation, $1,683,277 (2011-2014)

Second Life Learning Community. Research team: Don McCubbrey (PI), Sylvia D. Hall-Ellis (Co-PI), Walter LaMendola, and Paul Novak. University of Denver, Center for Teaching and Learning, $13,000 (2010-2011)

Reintroducing the Value of Law Librarians to Academic and Public Librarians in Colorado through the Identification and Use of Emerging Technologies. Research team: Sylvia D. Hall-Ellis (Co-PI), Stacey L. Bowers (PI), and Christopher Hudson, in partnership with Denver Public Library, Arapahoe Library District, and the Colorado State Supreme Court Library. University of Denver, Center for Community Engagement and Service Learning, $5,773 (2010-11)

Reintroducing the Value of Law Librarians to Public Librarians through the Identification and Use of Emerging Technologies and Resources. Research team: Stacey Bowers (PI) and Sylvia D. Hall-Ellis (Co-PI). American Association of Libraries, Wolters Kluwer Law & Business Grant Program, $2,725 (2010-2011)

Faculty Service Learning Pod. Research team: María del Carmen Salazar and Nicholas Cutforth (Curriculum and Instruction Program), Frank Tuitt (Higher Education Program), Cynthia Hazel and Gloria Miller (Child, Family, and School Psychology Program), and Sylvia D. Hall-Ellis (Library and Information Science Program). University of Denver, Center for Community Engagement and Service Learning, $8,000 (2010-2011)

Lincoln Collaborative. Research team: Antonio Esquibel (Principal, Lincoln High School), María del Carmen Salazar (Curriculum and Instruction Program), and. Sylvia D. Hall-Ellis. School Improvement Grant, Denver Public Schools, $375,000 (2010-2012)

Future LEADers of America: Leaders III. Research team: Denver Public Library (Kristen Svendson, PI), the University of Denver (Sylvia D. Hall-Ellis), the Colorado Chapter of REFORMA (Orlando Archibeque), and the Colorado Association of Libraries (Martin Garnar). Laura Bush's Recruiting Librarians for the 21st Century Program, Institute for Museums and Library Services, $988,366 (2009-2012)

Teaching for Success in the Library Environment: LIS 4030 in Library 2.0. Research team: Deborah S. Grealy (PI) and Sylvia D. Hall-Ellis (Co-PI). University of Denver, Center for Teaching and Learning, $ 9,350 (2009-10)

Writing Group Faculty Grant, Sylvia D. Hall-Ellis, University of Denver, Center for Community Engagement and Service Learning, $750 (2008-2009)

Collaborative Learning Faculty Grant, Sylvia D. Hall-Ellis, University of Denver, Center for Teaching and Learning, $1,500 (2008)

Connecting Information Literacy to Learning. Research team: Lori Micho, Merrie Valliant, Amanda Samland, and Sylvia D. Hall-Ellis. Colorado State Library, LSTA Discretionary Grant Program, $19,548 (2008-2009)

Law Librarianship Fellows Program. Research team: Sylvia D. Hall-Ellis (PI), Stacey Bowers (Co-PI), and Christopher Hudson, Westminster Law Library. Laura Bush's 21st Century Librarians Program, Institute for Museums and Library Services, $999,370 (2008-2012)

Grant Writing in a Cooperative Learning Environment. Sylvia D. Hall-Ellis. University of Denver, Center for Teaching and Learning, $2,000 (2008-2009)

Project Homeless Connect 6 Event Evaluation. Research team: Sylvia D. Hall-Ellis and Duan Zhang. University of Denver Center for Community Engagement and Service Learning, $9,785 (2008)

Project Ecuador: International Learning Service Libraries – A Faculty Development Experience in Ecuador. Sylvia D. Hall-Ellis, Office of Internationalization, University of Denver, $600 (2007)

Project Ecuador: International Learning Service Libraries – A Faculty Development Experience in Ecuador. Sylvia D. Hall-Ellis, International Service Learning Office, University of Denver, $400 (2007)

Project Homeless Connect 5 Event Evaluation. Research team: Sylvia D. Hall-Ellis and Duan Zhang. University of Denver Center for Community Engagement and Service Learning, $1,000 (2007)

Project Homeless Connect 4 Event Evaluation. Research team: Sylvia D. Hall-Ellis and Duan Zhang. University of Denver Center for Community Engagement and Service Learning, $4,595 (2007)

Future LEADers of America: Leaders II. Research team: Denver Public Library (Kristen Svendson, PI), the University of Denver (Sylvia D. Hall-Ellis), and the Colorado Chapter of REFORMA (Orlando Archibeque). Laura Bush's Recruiting Librarians for the 21st Century Program, Institute for Museums and Library Services, $988,518 (2007-2010)

Strategic Planning Assistance for the Denver Medical Library. Sylvia D. Hall-Ellis. Denver Medical Library, Inc., $30,000 (2006-2007)

Destiny Software for JMAC Student Lab. Sylvia D. Hall-Ellis, gift from the Sagebrush Corporation, Minneapolis, Minnesota, $10,000 (2006)

Libraries: Tools for Education and Development Worldwide: A Faculty Development Experience in France. Sylvia D. Hall-Ellis, Office of Internationalization, University of Denver, $800 (2005)

Denver Public Library: Opportunities for Change. Sylvia D. Hall-Ellis, Colorado Community Based Research Network, $2,000 (2005)

Future LEADers of America. Research team: Denver Public Library (Letty Icolari and Steve Taylor, PIs), Emporia State University (Jim Agee), and the University of Denver (Sylvia D. Hall-Ellis). Recruiting Librarians for the 21st Century Program, Institute for Museums and Library Services, $670,315 (2005-2008)

American Association of University Professors Summer Institute Professional Development Grant. Sylvia D. Hall-Ellis, American Association of University Professors, $300 (2005)

Beta Phi Mu Alumni Tea. Sylvia D. Hall-Ellis, gift from the Office of Alumni and Parent and Relations, University of Denver, $2,000 (2005)

Spectrum Software for LIS Student Lab. Sylvia D. Hall-Ellis, gift from the Sagebrush Corporation, Minneapolis, Minnesota, $5,000 (2005)

Developing Research Capacity in Community Organizations and Residents through Training and Technical Assistance. Nicholas J. Cutforth (PI) and Sylvia D. Hall-Ellis. Piton Foundation, $25,000 (2005-2006)

Libraries: Tools for Education and Development Worldwide: A Faculty Development Experience in Argentina. Sylvia D. Hall-Ellis, Office of Internationalization, University of Denver, $500 (2004)

Developing Research Capacity in Community Organizations and Residents through Training and Technical Assistance. Research team: Nicholas J. Cutforth (PI), Gary Lichtenstein and Sylvia D. Hall-Ellis, Piton Foundation, $25,000 (2003-2004)

Increasing Spanish-Speaking and Hispanic Diversity among Library and Information Science Students at the University of Denver: Development of a Student Recruitment Model. Researcher: Sylvia D. Hall-Ellis (PI), Office of Multicultural Excellence, University of Denver, $2,750 (2003-2004)

Collection Development Enrichment to Support the Cataloging & Classification Specialization and School Librarianship within the Library & Information Science Program at the University of Denver. Research team: Sylvia D. Hall-Ellis (PI) and Deborah S. Grealy. Women's Library Association, University of Denver, $4,000 (2003)

Collection Development Enrichment to Support the Library & Information Science Program at the University of Denver. Research team: Deborah S. Grealy (PI) and Sylvia D. Hall-Ellis. Women's Library Association, University of Denver, $4,000 (2001)

Wireless LAN for Library Education. Research team: Deborah S. Grealy (PI) and Sylvia Hall-Ellis. University of Denver, Center for Teaching and Learning, $24,000 (2001-2002)

Upward Bound – A Program for South Texas Youth. Research team: Monte Churchill, Executive Director of Community Relations; Gary R. Sauceda, Outreach Coordinator; Raymond Hernandez, (PI) Associate Dean for Student Success; and Sylvia D. Hall-Ellis, South Texas Community College (McAllen, Texas). U.S. Department of Education, Office of Postsecondary Education, $2,672,003 (1999-2003)

Write Now! Improving Elementary Students' Writing Skills. Research team: Caryl G. Thomason, Assistant Superintendent (PI); Karen Tankersley, Principal; and, Hal Anderson, Director of Technology, Cheyenne Mountain School District 12 (Colorado Springs, Colorado); and Sylvia D. Hall-Ellis. Colorado Department of Education, Educational Telecommunications Unit, $189,453 (1999-2001)

Operation Quick Start -- Distance Learning in Rural Colorado. Research team: Randal Weigum, Technology Coordinator (PI); Bonnie Barns, Director of Federal Programs and Staff Development; and, Adam "Joe" Raskop, Executive Director, Southeastern Board of Cooperative Educational Services (Lamar, Colorado); and Sylvia D. Hall-Ellis. Colorado Department of Education, Educational Telecommunications Unit, $400,000 (1999-2001)

Advanced Technological Training for Information Professionals for the 21st Century. Research team: Mario Reyna, Division of Business Director (PI) and Sylvia D. Hall-Ellis, South Texas Community College (McAllen, Texas). Phi Delta Kappa and the National Science Foundation, $250,000 (1999-2001)

Working Connections – Training Information Technologies Professionals for the 21st Century. Research team: Mario Reyna, Division of Business Director (PI) and Sylvia D. Hall-Ellis, South Texas Community College (McAllen, Texas). Microsoft Corporation and the American Association of Community Colleges, $1,147,775(1999-2001)

The ROAD (Research Oriented Amplification of Development to Literacy) Program. Research team: Deborah J. Leong (PI), Metropolitan State University; Elena Bodrova, Metropolitan State University; Dmitri Semenov, Robert J. Marzano, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). Hewlett-Packard Foundation, $25,000 (1998-1999)

Press to Literacy. Research team: Deborah J. Leong (PI), Metropolitan State University; Elena Bodrova, Metropolitan State University; Dmitri Semenov, Robert J. Marzano, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). The Denver Post and the Robert S. McCormick Foundation, $49,818 (1998-1999)

International Telementor Center. Research team: David Neils, David B. Frost (PI), and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). Hewlett-Packard Philanthropy, $100,000 (1998-1999)

America Reads: Providing Tutor Training for the America Reads Challenge. Research team: Louis F. Cicchinelli (PI) and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). U.S. Department of Education, Office of Educational Research and Improvement, $306,000 (1998-1999)

Comprehensive School Reform. Research team: Louis F. Cicchinelli (PI), J. Timothy Waters, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). U.S. Department of Education, Office of Educational Research and Improvement, $285,000 (1998-1999)

Sustainable Energy Education (SEE) Program for Grades 4-8: Preparing Today's Youth for Lifelong Learning and Responsible Actions in Energy Conservation. Research team: Mary Gromko, Colorado Department of Education; Gene McCarthy, Rocky Flats Field Office, U.S. Department of Energy; Gina Kissell, National Renewable Energy Laboratory; and Barbara L. McCombs (PI), Janet L. Bishop, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). State of Colorado Governor's Office for Energy Conservation, $499,936 (1997-1999)

Review of Kansas Curriculum Standards in Mathematics and Language Arts. Research team: Robert J. Marzano

(PI), John S. Kendall, David B. Frost, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). Submitted to the Kansas State Department of Education, $25,903 (1998)

International Telementor Center. Research team: David Neils, John Kuglin, Chris Rapp, David B. Frost (PI), and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). Hewlett-Packard Company, $54,752 (1998)

Genesis Mission: Education Public Outreach. Developed in partnership by the Jet Propulsion Laboratory, California Institute of Technology, Los Alamos National Laboratory, Lockheed Martin Astronautics, and the Mid-continent Regional Educational Laboratory (Aurora, Colorado). Research team: John T. Sutton (PI), Alice Krueger, Martha Henry, Greg Rawls, Shae Isaacs, Jeff Johnson, Deb Jordan, Arlene Mitchell, David B. Frost, Jana Caldwell, J. Timothy Waters, and Sylvia D. Hall-Ellis. National Aeronautics and Space Administration, $139,700,000; subcontract award, $4,750,000 (1997-2007)

North Dakota Mathematics Assessment Project. Developed in partnership by the North Dakota Department of Education and Mid-continent Regional Educational Laboratory (Mid-continent Regional Educational Laboratory). Research team: Ann Clapper, Clarence Bina, Greg Gallagher, North Dakota Department of Education; Don Burger (PI), Hillary Michaels, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). U.S. Office of Education, $1,618,214; subcontract award, $389,076 (1997-2001)

Pacific Resources for Education and Learning Distance Education: Project Evaluation. Developed in partnership by the Pacific Educational Community, the Pacific Resources for Education and Learning (PREL), and Mid-continent Regional Educational Laboratory (McREL). Research team: John W. Kofel (PI), Executive Director, PREL; J. Timothy Waters, Executive Director; Joan Buttram, Robert Keller, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). U.S. Office of Education, Star Schools Program, $10,000,000; subcontract award, $500,000 (1997-2002)

Identification of Bilingual Gifted and Talented Children: A Comprehensive School Grants for Bilingual Education. Developed in partnership by Hidalgo (Texas) ISD, Los Fresnos (Texas) CISD, Progreso (Texas) ISD, University of Texas – Pan American (Edinburg, Texas), and Education Service Center, Region One (Edinburg, Texas). Research team: Hilda Medrano, Dean, College of Education, University of Texas – Pan American; Linda Phemister (PI), Janie Navarro, and Sylvia D. Hall-Ellis, Education Service Center, Region One. U.S. Department of Education, Office of Bilingual Education and Minority Languages Affairs, $1,670,633 (1997-2002)

Academics 2000: First Things First -- The Texas Goals 2000. Developed for Jim Hogg (Hebbronville, Texas) County ISD, Mirando City (Texas) ISD, and San Isidro (Texas) ISD. Research team: Hilda Medrano, Dean, College of Education, University of Texas - Pan American (Edinburg, Texas); Angie Lehmann, Amy Mares, Ellen Gonzalez (PI), and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg, Texas). Texas Education Agency, $339,987 (1997-2000)

Southwestern Bell's Learning Communities Initiative. Developed for Tech Prep of the Rio Grande Valley, Inc. (Harlingen, Texas); the Center for Professional Teacher Development, University of Texas – Brownsville; Teach for America – Rio Grande Valley (McAllen, Texas); and Education Service Center, Region One (Edinburg, Texas). Research team: Patricia G. Bubb, Executive Director (PI), Tech Prep of the Rio Grande Valley; Martin Winchester, Executive Director, Teach for America – Rio Grande Valley; Aileen Johnson, Director, School of Education, University of Texas – Brownsville; and Sylvia D. Hall-Ellis. Southwestern Bell Foundation, $100,000 (1997-1998)

Texas School to Work: Regional Implementation. Developed for Tech Prep of the Rio Grande Valley, Inc. (Harlingen), South Texas Community College (McAllen), Texas State Technical College (Harlingen), Texas Southmost College (Brownsville), Empowerment Zone of the Rio Grande Valley (Mercedes), Project VIDA (Weslaco), Youth Fair Chance (McAllen), and Education Service Center, Region One (Edinburg). Research team: Patricia G. Bubb (PI), Tech Prep of the Rio Grande Valley; Stephen Vassberg, Texas State Technical College; Ellen Trevino, Youth Fair Chance; Wanda Garza, Project VIDA; Leonardo Olivares, University of

Texas – Pan American; Michael Bell, South Texas Community College; and Sylvia D. Hall-Ellis. Texas Workforce Commission, $4,250,000 (1997-2002).

Comprehensive Bilingual Education Grant for Hidalgo ISD and Roma ISD. Developed for Hidalgo (Texas) ISD, Roma (Texas) ISD, College of Education, University of Texas – Pan American (Edinburg, Texas), and Education Service Center, Region One (Edinburg, Texas). Research team: Tomas Thomas (PI), Director, Office of Bilingual Education and Sylvia D. Hall-Ellis. U.S. Department of Education, Office of Bilingual Education and Minority Languages Affairs, $1,531,361 (1997-2002)

Lopez High School, Porter High School, Rivera High School, Central Middle School, and Perkins Middle School, Brownsville (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $1,473,611 (1997-1998)

Donna High School, Todd Middle School, and Solis Middle School, Donna (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $704,052 (1997-1998)

Memorial Middle School and Nellie Schunior Middle School, La Joya Independent School District (Texas). Telecommunications Infrastructure Fund Board, $293,641 (1997-1998)

Martin High School, Christen Middle School, Cigarroa Middle School, Lamar Middle School, Laredo (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $1,200,000 (1997-1998).

Lasara Middle School, Lasara (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $246,210 (1997-1998)

Los Fresnos High School and Resaca Middle School, Los Fresnos (Texas) Consolidated Independent School District. Telecommunications Infrastructure Fund Board, $500,000 (1997-1998)

Lyford Junior High School, Lyford (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $354,997 (1997-1998)

Travis Middle School, McAllen (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $269,139 (1997-1998)

Mission High School, Mission (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $297,010 (1997-1998)

Progreso High School, Progreso (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $300,000 (1997-1998)

San Perlita High School, San Perlita (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $293,490 (1997-1998)

Myra Green Junior High School, Raymondville (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $225,000 (1997-1998)

Rio Grande City High School, Ringgold Middle School, Gruella Middle School, Rio Grande City (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $809,934 (1997-1998)

Rio Hondo Junior High School, Rio Hondo (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $297,024 (1997-1998)

Roma High School, Roma (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $333,178 (1997-1998)

San Benito High School, Miller Jordan Junior High School, San Benito (Texas) Consolidated Independent School District. Telecommunications Infrastructure Fund Board, $547,000 (1997-1998)

Santa Maria High School and Santa Maria Middle School, Santa Maria (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $400,000 (1997-1998)

Salvador High School, United Independent School District (Laredo, Texas). Telecommunications Infrastructure Fund Board, $250,879 (1997-1998)

Weslaco High School, Cabaza Middle School, Cuellar Middle School, Weslaco (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $874,242 (1997-1998)

Principals' Assessment and Training Center. Developed for Education Service Center, Region One (Edinburg, Texas). Research team: Roberto Zamora, Leonel Barrera, William H. Parry, and Sylvia D. Hall-Ellis. Texas Principals' Leadership Initiative, Texas Association of Secondary School Principals, Texas Association of Elementary School Principals, and the Sid Richardson Foundation. $461,439 (1996-1998)

The Texas Library Connection -- Integrating and Sharing Resources. Developed for Hidalgo County Library System (McAllen), Cameron County Library System (Brownsville), South Texas Community College (McAllen), the University of Texas - Pan American (Edinburg), University of Texas – Brownsville, and Education Service Center, Region One (Edinburg). Research team: William R. McGee, Coordinator, Hidalgo County Library System; Joe Garcia, Director, Cameron County Library System; Michael D. Bell, Library Director, South Texas Community College; Eleanor Folger Foster, University Library, University of Texas - Pan American; Jaime Vela (PI), Director of Instructional Technology and Media Services, Ron Pontius, Instructional Technology, and Fabiola Fuentes, Media Services, Education Service Center, Region One; and Sylvia D. Hall-Ellis. Office of Library Media Services, Technology Services, Texas Education Agency. $8,000 (1996-1997)

Developing Leadership Communities for Improving Algebra I for All Students. Developed for a partnership of the Region One Statewide Systemic Initiative Team. Research team: Noel Villarreal (PI), Eduardo Cancino, and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Statewide Systemic Initiative for Reform in Mathematics, Science and Technology Education to The Charles A. Dana Center for Mathematics and Science Education, The University of Texas at Austin. $25,000 (1996-1997)

Academics 2000: First Things First -- The Texas Goals 2000. Developed for Edinburg (Texas) CISD. Research team: Hilda Medrano, Dean, College of Education, University of Texas - Pan American (Edinburg); Helen Jones, Director (PI), Gifted and Talented Education, Edinburg CISD; and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Education Agency, $750,000 (1996-2001)

Texas Teachers Empowered for Achievement in Mathematics (TEXTEAM) Institute for Algebra I. Developed for Hidalgo ISD, Jim Hogg (Hebbronville) County ISD, La Joya ISD, La Villa ISD, Lyford ISD, Mission CISD, Pharr-San Juan-Alamo ISD, Rio Hondo ISD, San Isidro ISD, San Perlita ISD, Santa Maria ISD, Santa Rosa, Sharyland ISD, Valley View ISD, Webb (Laredo) CISD, Weslaco ISD, and Zapata County (Zapata) ISD. Research team: Noel Villarreal (PI), Chuck McInteer, Ellen M. Gonzalez, Education Service Center, Region One (Edinburg); and Sylvia D. Hall-Ellis. Charles A. Dana Center for Mathematics and Science Education, University of Texas - Austin, $15,975 (1996)

Community Learning Center for La Villa, Texas. Developed for Edcouch-Elsa Independent School District. Research team: Noe Gonzalez (PI), Assistant Superintendent, Edcouch-Elsa Independent School District, and Sylvia D. Hall-Ellis. Delta Region Subzone, Rio Grande Valley (Texas) Rural Empowerment Zone, $325,000 (1996-1997)

Monte Alto (Texas) Community Learning Center. Developed for Monte Alto Independent School District. Research team: Homero A. Diaz (PI), Superintendent, Monte Alto Independent School District, and Sylvia D. Hall-Ellis. Delta Region Subzone, Rio Grande Valley (Texas) Rural Empowerment Zone, $300,000 (1996-1997)

Community Learning Center for La Villa, Texas. Developed for La Villa Independent School District. Research team: Sam Gonzalez (PI), Assistant Superintendent, La Villa Independent School District; and Sylvia D. Hall-Ellis. Delta Region Subzone, Rio Grande Valley (Texas) Rural Empowerment Zone, $325,000 (1996-1997)

Building Project for Taylor Elementary. Developed for Mercedes (Texas) Independent School District. Research team: Mrs. Denise Rivera, Librarian, and Eduardo Infante, Principal, Taylor Elementary School; Ismael S. Cantu (PI), Federal Programs Director, Mercedes Independent School District; and Sylvia D. Hall-Ellis. Delta Region Subzone, Rio Grande Valley (Texas) Rural Empowerment Zone, $375,000 (1996-1997)

Border Education Network (BEN) - Distance Education through Cable Television. Developed for Edinburg (Texas) Consolidated Independent School District. Research team: Noe Torres (PI), Library Media Specialist, Magdalena
Rosas, Library Media and Technology Coordinator, Edinburg Consolidated Independent School District; and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Edinburg (Texas) Consolidated School District, $250,000 (1996-1997)

Multiservice One-Stop Open Enrollment Charter School. Developed for the Information Referral Resource Assistance, Inc. (McAllen, Texas). Research team: Pablo Perez and Aguie Pena (PI), Executive Director, Information Referral Resource Assistance, Inc.; Roberto Zamora and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Education Agency, $3,066,000 (1996-2001)

Project OK: A Community Youth Opportunities Grant for Summer, 1996. Developed for McAllen (Texas) Independent School District, St. Joseph the Worker Catholic Church, and the Office of Adult Education, Education Service Center, Region One. Research team: Father Bart Flatt, St. Joseph the Worker Catholic Church; Noe Calvillo (PI), Office of Adult Education; Maria Louisa Garcia, McAllen Independent School District; and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Protective and Regulatory Agency through the Office of the Mayor, City of McAllen, $350,000 (1996-2001).

Early Childhood: a Time of Discovery. Developed for a partnership of Lasara ISD, Rio Hondo ISD, San Perlita ISD, the School of Education, University of Texas - Brownsville, and Education Service Center, Region One (Edinburg). Research team: Hugo Rodriguez, Dean, School of Education, University of Texas - Pan American; Leonel Barrera and Jack Damron, Field Service Agents, Ellen M. Gonzalez (PI), Administrator for Student Instructional Services, Ruth Solis, Education Specialist in Special Education, and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Education Agency, $722,090 (1996-2001)

Innovative Gifted and Talented Programs for Early Childhood and Elementary Education Students. Developed for a partnership of Edinburg (Texas) CISD, the School of Education, University of Texas - Pan American (Edinburg), and Education Service Center, Region One (Edinburg). Research team: Hilda Medrano, Dean, School of Education, University of Texas - Pan American; Helen de la Garza (PI), Director of Elementary Curriculum and Instruction, Edinburg CISD; and Sylvia D. Hall-Ellis. Texas Education Agency, $750,000 (1996-2001)

Reading Recovery in Early Elementary Grades. Developed for a partnership of La Villa (Texas) ISD the School of Education, University of Texas - Pan American (Edinburg), and Education Service Center, Region One (Edinburg). Research team: Hilda Medrano, Dean, School of Education, University of Texas - Pan American; Marcario Salinas (PI), Supervisor of Elementary Curriculum and Instruction, La Villa ISD; and Sylvia D. Hall-Ellis, Education Service Center, Region One. Texas Education Agency, $750,000 (1996-2001)

Connected Mathematics Project for Middle and Junior High Students. Developed for a partnership of Michigan State University, The Charles A. Dana Center for Mathematics and Science Education, The University of Texas at Austin and Region One Statewide Systemic Initiative Team. Research team: Jack Damron, Chuck McInteer, Noel Villarreal (PI), and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). National Science Foundation through Michigan State University to the Charles A. Dana Center at the University of Texas - Austin, $539,610 (1996-1999)

Sharing Resources: Testing the Interlibrary Loan Potential of the Texas Library Connection -- Integrating Media Resources. Developed under the sponsorship of the Hidalgo County Library System (McAllen) and Education Service Center, Region One (Edinburg). Research team: William H. McGee, Hidalgo County System Coordinator; Fabiola Fuentes, Library Media; Ronald Pontius (PI), Instructional Technology, Education Service Center, Region One; and Sylvia D. Hall-Ellis. Library Media Services Program, Office of Technology Services, Texas Education Agency, $25,000 (1996-1997)

State and Federal Adult Education JOBS Program. Developed for Education Service Center, Region One (Edinburg). Research team: Noe Calvillo (PI), Director, Adult Education Program, and Sylvia D. Hall-Ellis. Adult Education Program, Texas Education Agency, $532,846 (1995-1996)

Creating Safe and Drug-Free Schools and Communities. Developed for a partnership of the Region One Consortium for Safe and Drug-Free Education Environments. Research team: Clara Contreras (PI), Health Specialist, and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Education Agency, $150,000 (1995-1996)

Developing Leadership Communities for Improving Mathematics Performance for All Students on Title I Campuses. Developed for a partnership of the Region One Statewide Systemic Initiative Team. Research team: Jack Damron, Chuck McInteer, Noel Villarreal (PI), and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Statewide Systemic Initiative for Reform in Mathematics, Science and Technology Education to The Charles A. Dana Center for Mathematics and Science Education, The University of Texas at Austin, $50,669 (1995-1996)

The Impact of Library Resource Centers on Academic Achievement in Selected Public Schools in South Texas. Sylvia D. Hall-Ellis (PI). Developed under the sponsorship of the Department of Library Science, College of Education and Applied Science, Sam Houston State University (Huntsville). Texas Association of School Librarians, Children's Services Round Table, and Young Adults Round Table (Austin, Texas), $2,500 (1995)

School Library Media Specialists Fellowship Program. Sylvia D. Hall-Ellis (PI). Developed under the sponsorship of the Department of Library Science, College of Education and Applied Science, Sam Houston State University (Huntsville, Texas). U.S. Department of Education, HEA Title II-B, Library Education and Human Resource Development Program, $44,000 (1995-1996)

Planning for Educational Technology. Research team: Ruth Ann Riggins (PI), Director of Library Media and Technology Services, Donna (Texas) Independent School District; Noe Torres, Education Service Center, Region One; Patricia G. Bubb, Tech Prep of the Rio Grande Calley, Inc; Michael D. Bell, South Texas Community College; and Sylvia D. Hall-Ellis, Sam Houston State University. Developed under the sponsorship of Donna (Texas) Independent School District, Education Service Center, Region One (Edinburg), Tech Prep of the Rio Grande Valley, Inc. (Harlingen), South Texas Community College (McAllen), and the Department of Library Science, Sam Houston State University (Huntsville). Funded through Infusion of Educational Technology Planning Grant Program (H.B. 18: Models). Texas Education Agency, $18,000 (1993-1994)

The Impact of Library Resource Centers on Academic Achievement in Selected Public Schools in South Texas. Sylvia D. Hall-Ellis (PI) and Mary Ann Berry. Developed under the sponsorship of the Department of Library Science, College of Education and Applied Science, Sam Houston State University (Huntsville). Sam Houston State University Research Enhancement Fund, $7,500 (1993-1994)

Electronic Mail Resource Sharing System: Management and Operation of the Iowa Computer-Assisted Network. State Library of Iowa, $294,000 (1986-1993)

The Iowa Locator: A CD-ROM Resource Sharing Tool. State Library of Iowa, $567,000 (1986-1992)

Statewide Database Development: An OCLC Tape Analysis To Determine Feasibility. State Library of South Dakota, $15,000 (1987)

The Iowa Locator: A Feasibility Study. State Library of Iowa, $50,000 (1986)

Electronic Mail Resource Sharing System: A Feasibility Study for Libraries in the State of Iowa. State Library of Iowa, $5,000 (1985)

Access Pennsylvania: A Feasibility Study. State Library of Pennsylvania, $50,000 (1984)

Automating Library Administrative and Management Tasks: Procurement and Distribution of Microcomputer Systems for District Library Centers in the Commonwealth of Pennsylvania. State Library of Pennsylvania, $495,000 (1982)

Sharing Serial Titles Resources: Procurement and Distribution of Microfiche Readers for 550 Libraries in the Commonwealth of Pennsylvania. State Library of Pennsylvania, $500,000 (1982)

Electronic Mail System: A Pilot Project for Libraries throughout the Commonwealth of Pennsylvania. State Library of Pennsylvania, $125,000 (1982)

Literacy Program for Adults in Rural Upstate New York State: Program Outreach and Evaluation - Phase 3. Appalachian Regional Commission, $50,000 (1981)

Database Building: A Cooperative Project of the Finger Lakes Library System (Ithaca), Four County Library System (Binghamton), and the Southern Tier Library System (Corning). New York State Library, $450,000 (1980-1985)

Faces of the Southern Tier: A Professional Photographer-in-Residence. New York State National Endowment for the Humanities, $25,000 (1980)

Literacy Program for Adults in Rural Upstate New York State: Program Implementation - Phase 2. Appalachian Regional Commission, $50,000 (1980)

Small Business Resources Center: A Pilot Project for Rural Public Libraries. New York State Library, $50,000 (1980)

Media Programming: A Professional Development Program for Public Librarians in Upstate New York: A Program in Allegheny, Chemung, Schuyler, Steuben, and Yates Counties. New York State Library, $35,000 (1979)

Information and Library Resources for Inmates and Prisoners in Selected Upstate New York Facilities: A Cooperative Program in Allegheny, Chemung, Schuyler, Steuben, and Yates Counties. New York State Library, $25,000 (1979)

Library Resources for Homebound Adults in Upstate New York: An Outreach Program in Allegheny, Chemung, Schuyler, Steuben, and Yates Counties. New York State Library, $40,000 (1979)

Literacy Program for Adults in Rural Upstate New York State: Program Initiation and Establishment - Phase 1. Funded by the Appalachian Regional Commission. Awarded to the Corning (New York) Public Library, $50,000 (1979)

Information Reference Services to Homebound Adults. New York State Library, $31,000 (1978)

Books-By-Mail Services to Homebound Adults. New York State Library, $31,000 (1978)

System Headquarters Services and Programs for Public Libraries in District 10. Funded through Library Services and Construction Act Title I. Texas State Library and Historical Commission, $880,000 (1976)

County Library Development Grant for Atascosita County. Funded through Library Services and Construction Act Title I. Texas State Library and Historical Commission, $15,000 (1976)

Spanish Language Materials Collection Development Program. Texas State Library and Historical Commission, $40,000 (1975)

Establishment of System Headquarters for Alamo Regional Library System (District 10) Headquartered at the San Antonio (Texas) Public Library. Texas State Library and Historical Commission, $800,000 (1975)

SELECTED CONSULTANTSHIPS

Project Strategic Planning & Funding Proposal Development

Walden University, 2015.
Pikes Peak Library District, 2014.
Douglas County Public Libraries, 2011-2012.
Denver School for Science and Technology, 2008-2011.
Johnson & Wales University, Denver Campus, 2007-2009.
Challenges, Choices, and Images K-12 Charter School, Denver Public Schools, 2007.
Denver Medical Library, Inc., 2006-2010.
Bemis Public Library (Littleton), Ergonomic Design and Facilities Enhancement Consultant, 2003.
Curtis Park Community Center (Denver), Community Technology Center Evaluation and Proposal Development Consultant, 2003.
Colorado Community Based Research Network (Denver), Funding Research Associate, 2002.
Our Lady of the Rosary Academy (Edgewater), Learning Resource Center Development Project Consultant, 2001-2003
University of Southern Colorado (Pueblo). Technology Integration and Curriculum Enhancement into Higher Education Learning Environment. Proposal Development Consultant, 2000.
Jefferson County Library System (Lakewood), 1999-2000.
Southeastern BOCES (Lamar, CO). Distance Learning Curriculum Content Development Project. Proposal Development Consultant, 1998-2004.
Cheyenne Mountain School District 12 (Colorado Springs, CO). Technology Integration into Elementary Writing Curriculum Project. Proposal Development Consultant, 1998.
Telecommunications Infrastructure Fund Board Round #2 Application, 1997. Technical assistance to the following: La Villa (Texas) Independent School District; Mirando City (Texas) Independent School District; Monte Alto (Texas) Independent School District; San Isidro (Texas) Independent School District.
Telecommunications Infrastructure Fund Board Round #1, 1996. Technical assistance to the following: Brownsville (Texas) Independent School District; Donna (Texas) Independent School District; Edinburg (Texas) Consolidated Independent School District; Harlingen (Texas) Consolidated Independent School District; Jim Hogg County Independent School District (Hebbronville, Texas); La Feria (Texas) Independent School District;

La Joya (Texas) Independent School District; La Villa (Texas) Independent School District; Los Fresnos (Texas) Consolidated Independent School District; Progreso (Texas) Independent School District; Raymondville (Texas) Independent School District; Rio Hondo (Texas) Independent School District; San Benito (Texas) Independent School District; Sharyland Independent School District (Mission, Texas); Weslaco (Texas) Independent School District; Zapata (Texas) County Independent School District.

South Texas Community College (McAllen). Strategy Development to Meet the Technology Instructional Needs for Vocational, School-To-Work and Academic Programs, 1994-2000. Development Consultant.

Donna (Texas) Independent School District. Planning for the Infusion of Technology in Middle Schools Serving High At-Risk Students, 1994-1995. Research Associate.

Pettus (Texas) Independent School District. Planning for District-wide Automation in School Library Media Centers: Preparation of Data, and CD-ROM Hardware/Software Configuration Evaluation, 1994. Principal Investigator.

Fort Bend Independent School District (Sugar Land, TX). Planning for District-wide Automation in School Library Media Centers, Preparation of Data, and CD-ROM Hardware/Software Configuration Evaluation, 1994-1995. Principal Investigator.

Northern Waters Library Services (Ashland, WI). Professional Consulting Services to Make Recommendations on the Development of System-Wide Efforts of the Northern Waters Library Service, 1988-1989. Research Associate.

State Library of Iowa (Des Moines). The Iowa Locator Compact Disc to Support Multi-Type Libraries Resource Sharing including Database Design, Building, Production, and Distribution, 1986-1991. Project Director.

State Library of Iowa (Des Moines). Iowa Computer-Assisted Network Development, Enhancement, and Operation, 1985-1992. Technical Director.

State Library of South Dakota (Pierre). Statistical Sampling and Analysis of Multi-Institutional OCLC Archive Tape for Statewide Online Database Building, 1985-1986. Research Associate.

District of Columbia Public Library (Washington, DC). Planning Document for the Retrospective Conversion of Bibliographic Records and Automation Issues in the 1990's, 1984-1985. Research Associate.

State Library of Pennsylvania (Harrisburg). Database Development for High School Libraries, 1984-1985. Research Associate.

MINITEX (Minneapolis, MN). Workshops for Retrospective Conversion, Bar Coding, Library Statistics, and OCLC Serials Format, 1985. Presenter and Research Associate.

ABC Film Consortium (Altoona, Bellefonte, Johnstown, PA). Database Building, System Design, and Implementation of Online Film Booking System, 1983-1985. Database Manager.

Library Automation -- System Design & Implementation

Douglas County Library District (Castle Rock, CO). Library Automation Technical and System Performance Specifications, 2001.

Pharr-San Juan-Alamo Independent School District (Pharr, TX). Library Automation Technical and System Performance Specifications, 1997. Project Development Consultant.

Harlingen (Texas) Independent School District. Planning for District-wide Automation in Junior High School Library Media Centers: Preparation of Data, and CD-ROM Hardware/Software Configuration Evaluation, 1996. Principal Investigator.

Sharyland (Texas) Independent School District. Design and Construction of New Elementary School Library and Technology Resources Center, 1995-1996. Principal Investigator.

South Texas Independent School District (Mercedes, TX). Design and Construction of a New High School Library and Technology Resources Center, 1995-1996. Principal Investigator.

Citizens' Library (Washington, PA). Online Community Resources Files: Design and Implementation, 1984. Research Associate.

Altoona (Pennsylvania) Hospital. Integrated Online System Upgrade Study, 1984. Research Associate.

State Library of South Dakota (Pierre). Automation Plan and State Database Development, 1982-1983. Principal Investigator.

State Library of Pennsylvania (Harrisburg). COM Production and Preparation of the Technical Specifications Document, Procurement, and Distribution of Microcomputers in the Commonwealth of Pennsylvania, 1983-1984. Research Associate.

Altoona (Pennsylvania) Area Public Library. Integrated System (Circulation/Online Catalog) Study, 1982-1983. Principal Investigator.

COPSCAULD (Council of Pennsylvania State College and University Library Directors, Edinboro, PA). Design of Online Media Catalog, 1982. Principal Investigator.

Erie (Pennsylvania) County Library System. Operations Research and Design for Automated Circulation, Hardware Upgrade and Re-Retrospective Conversion, 1982. Research Associate.
Michigan Library Consortium (Lansing, MI). Tape Management System Design and Implementation, 1982-1984. Research Associate.
State Library of Pennsylvania (Harrisburg). Preparation of the Technical Specifications Document, Procurement and Distribution of Microfiche Readers in the Commonwealth of Pennsylvania, 1982. Research Associate.
Community College of Allegheny County, Allegheny Campus (Pittsburgh, PA). Integrated Systems Study, 1981. Principal Investigator.
Community College of Allegheny County, South Campus (West Mifflin, PA). Retrospective Conversion Training Program for Handicapped Students, 1981. Technical Director.
Southern Tier Library System (Corning, NY). OCLC Acquisitions Subsystem Evaluation, 1981. Principal Investigator.
South Central Reference and Research Council (Ithaca, NY). South Central Regional Delivery System, 1980. Principal Investigator.
Southern Tier Library System (Corning, NY). Newspapers on Microfilm in the Chemung-Southern Tier Library System, 1979-1981. Principal Investigator.

Cataloging & Bibliographic Database Building

Challenges, Choices, and Images K-12 Charter School, Denver Public Schools, 2007.
Denver Medical Library, Inc., 2006-2010.
Ricks Gifted and Talented School Library, 2005-
American Humane Society (Englewood), 2004-2006.
Fisher Early Learning Center Library, 2004-
Colorado Community Based Research Network (Denver), 2004-
Boulder Valley School District (Boulder), 2002-2003.
Douglas Public Library District (Castle Rock), 2001-2002.

Bibliographic Center for Research, Inc. (Denver). Original Cataloging, 2001-2003 & 1992-1993. Professional Cataloger. Libraries include Arapahoe Library District (Centennial); Clarke College (Clarke, IA); Kaiser Permanente Center for Health Research (Portland, KS); Douglas County Library System (Carson City, NV); Grinnell College (Grinnell, IA); Kansas State University (Manhattan, KS); Kansas State Library (Topeka, KS); McPherson College (McPherson, KS); Newman University (Wichita, KS); Montana Technical University (Helena, MT); Montana State Library (Helena, MT); University of Texas Southwest Medical Center Library (Dallas, TX); Community College of Southern Nevada (Las Vegas, NV); Pikes Peak Library District (Colorado Springs); Mesa Community College (Grand Junction); Coe College (Cedar Rapids, IA); Briar Cliff College (Sioux City, IA); Tri-Care Health Systems (Aurora); The Penrose-St. Francis Healthcare System (Colorado Springs); Westminster Public Library (Westminster); Lutheran Medical Center Medical Library (Wheat Ridge); American Heritage Center, University of Wyoming (Laramie, WY); National Wildlife Research Center Library (Lakewood); University of Colorado Health Sciences Center, Denison Memorial Library (Denver); Water Resources Library, Denver District Office, Bureau of Land Management (Lakewood); Mesa State Community College Learning Resources Center (Pueblo); Front Range Community College Learning Resources Center (Westminster).

Colorado Historical Society Library (Denver). Original Cataloging of Serials for Multi-Institutional Union Listing Project, 1993. Technical Services Associate. Institutional partners: Denver Art Museum, Denver Museum of Natural History Library, and Denver Botanical Gardens Library.

Arapahoe Library District (Centennial). Original Cataloging of Major Media, 1991.

Original Cataloging Projects: Davis and Elkins College (Elkins, WV), 1989-1990; Waldorf College (Forest City, IA), 1989-1990; Kennametal Corporation (Latrobe, PA), 1984-1985; Pennsylvania Public Libraries Film Center (Harrisburg), 1982-1985.

Retrospective Conversion Projects: North Central Regional Library Service (Mason City, IA), 1987-1988; Southeastern Library Services (Davenport, IA), 1986-1987; Virginia Theological Seminary (Alexandria), 1984-1985; California University of Pennsylvania (California, PA), 1984-1985; Kennametal Corporation (Latrobe, PA), 1984-1985; West Virginia University (Morgantown), 1983-1985; Altoona Area Public Library (Altoona, PA), 1983-1984; George Washington University (Washington, DC), 1983-1984; Indiana University of Pennsylvania (Indiana, PA), 1983-1985; Health Education Center (Pittsburgh), 1983-1984; Central Pennsylvania District Library Center (Bellefonte, PA), 1982-1985; Duquesne University Law School Library (Pittsburgh), 1982-1983; Allegheny County Law Library (Pittsburgh), 1982-1984; Calgon Technical Information Center (Pittsburgh), 1982; Dow Corning Corporation, Technical Information Center (Midland, MI), 1982-1983; Tri-System Public Library Retrospective Conversion Project (Binghamton, Corning, and Ithaca, NY), 1978-1981, Technical Project Director.

Updated December 2022

Ex. 1016

ELECTRONIC WIRE & CABLE

A USER'S GUIDE: PERFORMANCE AND SELECTION

AT&T

CommScope Exhibit 1045

Preface

AT&T Network Systems has prepared this Electronic Wire and Cable manual for the express purpose of identifying the fundamental details which have established AT&T as a product leader in the industry.

Since this manual is intended to serve a variety of readers, few assumptions have been made relative to the reader's previous understanding of the subjects presented. As a foundation, the fundamental principles of electricity are reviewed to help identify cable design criteria.

The progressive stages of cable fabrication form the basic outline of this manual, tracing development from copper rod through completed multiconductor cables. Numerous drawings, charts, tables and graphs are used to enhance the reader's understanding. A collection of product photographs has been assembled to relate the concepts discussed to specific AT&T Electronic Cable and Wire (EC&W) offerings. A brief overview of transmission systems, without the complex higher mathematics, is presented to familiarize readers with the terms and concepts.

Industry standards-making organizations are identified along with appropriate standards which formulate basic cable requirements. AT&T's commitment to quality has combined these with additional in-house testing and controls to produce the finest products available. At AT&T, quality is a way of life.

AT&T Network Systems acknowledges the many staff members whose contributions have made this manual possible.

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SECTION 5

Multiconductor Cables

AT&T

Multi-conductor Cables

In much the same way as insulation improves our ability to use conductors, the grouping together of insulated conductors to form multiconductor cables makes electronic wiring more practical. Consider the alternative of having tens or hundreds of individual insulated conductors each installed separately. A wide variety of multiconductor cable types exist – the following are representative.

Parallel Conductor Cables

As the name implies, the conductors in these cables are parallel to each other. Although this construction is most often associated with flat cables, parallel (or untwisted) conductors are also made into round cables.



AT&T 902A ribbon cable has 31 conductors, each 28 gauge.

Flat Cables

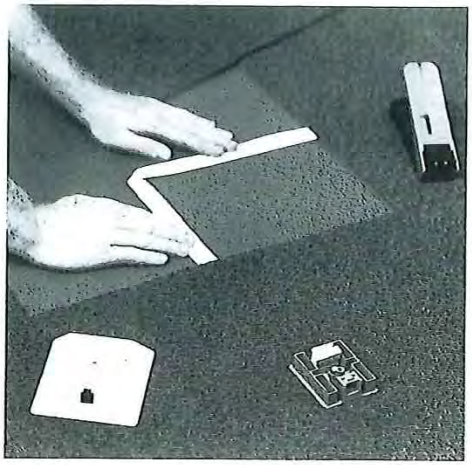
In flat-cable construction, insulated or non-insulated conductors are arranged side-by-side and encased in a common jacket, which might be laminated, extruded or woven. Examples include ribbon cables, TUCC,® Twin-Axial and antenna lead wires.

Advantages
Lower installed cost
Easier to install connectors
Good current carrying capacity
Excellent vertical flexibility
Relatively high mechanical strength due to large surface area
Excellent heat dissipation factor due to surface area
Space and weight reduction due to thin cross-section

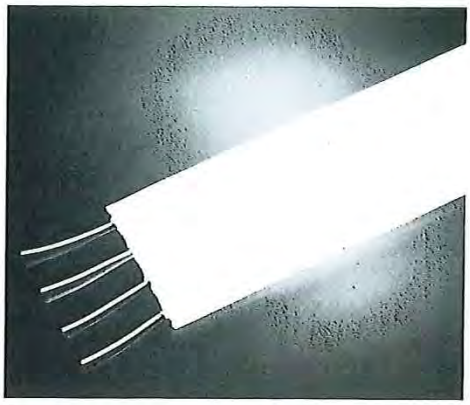
Disadvantages
Shielding limitations (see above)
Low cut-through and abrasion resistance
Limited number of conductors in a cable (see above)



Ribbon cable production machine – copper conductors are sandwiched between insulating ribbons.



1) AT&T TUCC® flat cable has four pairs of insulated conductors.



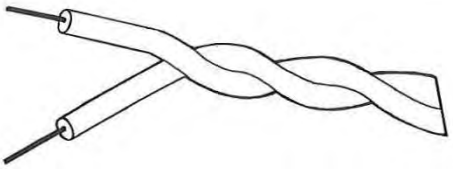
2) TUCC® installation makes it easier to place phone or data connections where they are needed.

TUCC® (**T**elephone **U**nder **C**arpet **C**able) has set the standard for under-carpet installations. Familiar applications for other ribbon cables include desktop computers, both internally and for peripheral connections, and inside computer printers and typewriters to power and control the traveling printhead or daisy wheel assembly.

Lack of shielding (to minimize interference) has been a limitation, but new braided shield sleeves provide a promising answer to that problem. The other major obstacle for flat cables is the practical width limit of about 50 conductors. Termination of flat cables is typically accomplished with self-aligning compression connectors which pierce the insulation.

Twisted Pair Cables

Most of the cables within the scope of AT&T's EC&W product line utilize the twisted pair construction. Production of small cables of this type involves twisting individual pairs and grouping of those twisted pairs to form either a cable or a unit for a larger cable.



A typical twisted pair (exaggerated for clarity).

The two main reasons for twisting pairs of conductors are to minimize or eliminate crosstalk and to decrease unbalanced mutual capacitance.

Crosstalk is signal interference between adjacent pairs, which may be caused by pickup of either unwanted signals from adjacent pairs of conductors or stray energy from nearby cables. This interference primarily results from the magnetic field which surrounds any current-carrying conductor.

Unbalanced mutual capacitance of the pairs in a cable creates a capacitive effect which transfers undesirable signals and noise between the pairs.

Both crosstalk and unbalanced capacitance are affected by the type, length and direction of twist.

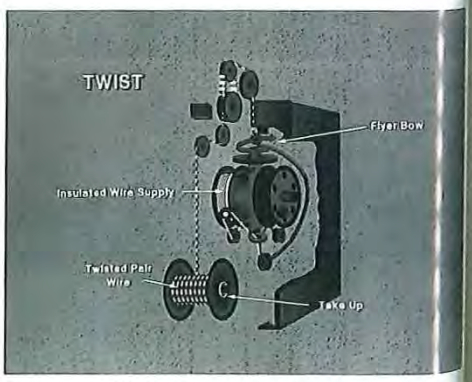
To provide maximum separations within a cable, different pairs are given different twist lengths within a standard range. Generally, a counterclockwise (left-hand) twist with twist lengths between 1.5 inches and 5.5 inches is used. Adjacent pairs are generally designed to have twist length differences of at least ½ inch.

The Pair Twisting Process

Some cable production machines both twist the individual wires into pairs and combine them to form a cable of up to 25 pairs. Primarily for larger cables, other machines combine pre-twisted pairs which are created on high speed machines called twisters.



Production line of twisters. Each is constructed as shown in the graphic.

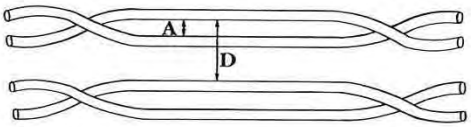


Graphic shows internal details of twister.

Tight Twisting

Tight twisting, where pair twist lengths are less than one-half inch, is an increasingly popular option, particularly in the "high tech" computer field. Tight twisting of pairs increases the separation of pairs in a cable making pair identification easier and reducing crosstalk.

Tight twisting also tends to preserve the shape of the cable better. Longer twists can become flattened and deformed as they are packed in a cable, whereas shorter, tighter twists are less likely to deform.



Two twisted pairs – exaggerated to show distances as specified below.

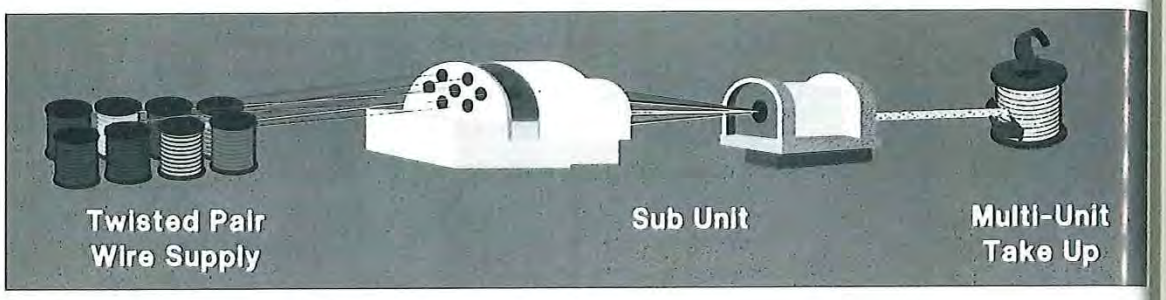
$$\text{Crosstalk} = \frac{A^2}{D^2} \times \cos(\text{twist angles})$$

Where **A** = Distance between conductors of a pair
D = Distance between pairs

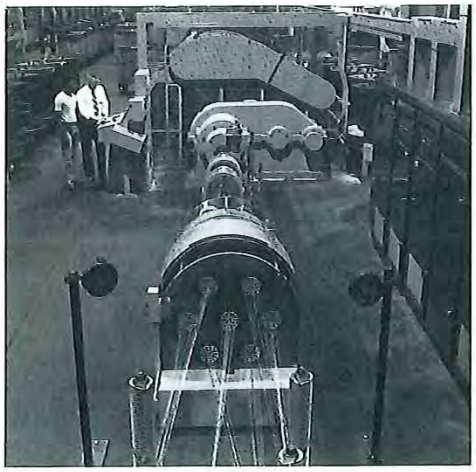
The greater the value of "D" in proportion to "A", the lower the crosstalk value. Very low, even negative crosstalk values are desirable.

Cable Core Units

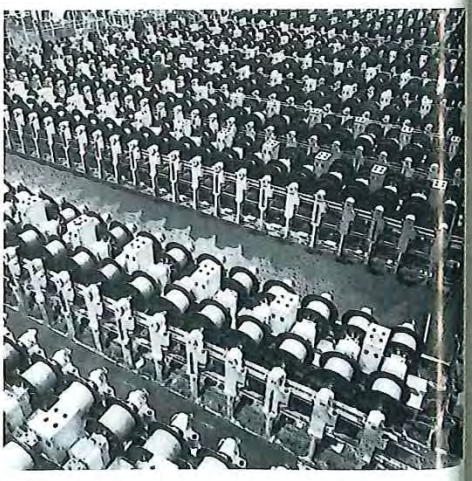
The next step in the cable making process after pair twisting is the forming of **units**, which consist of up to 25 pairs each. These **units** can comprise a relatively small cable with the addition of shielding (if desired) and a cable jacket, or they can be combined to form larger pair count cables. Those designated for use in **multi-unit** construction are wrapped with color coded binders to identify each unit.



Simplified graphic of stranded line – pairs combine into units.



25 insulated pairs enter the stranding machine which forms them into one unit.

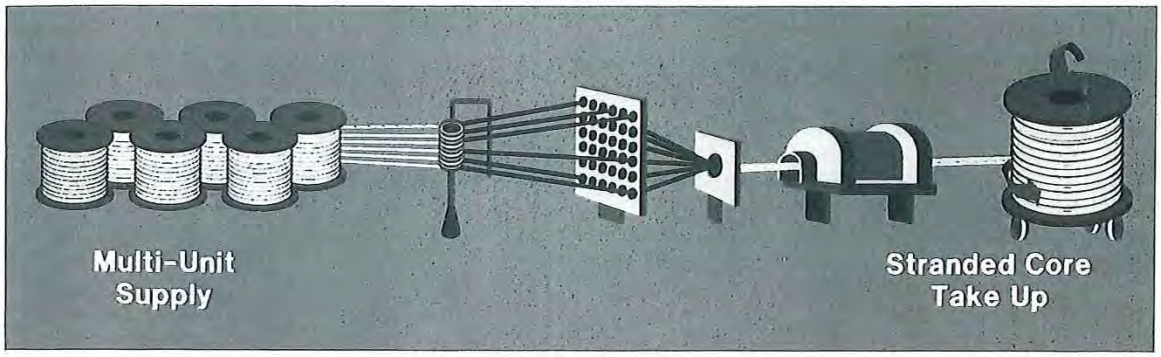


High volume production facilities – rows of tandem groups of 25 reels, each a twisted pair, feed into the stranding machines.

Multi-Unit Cable Cores

Cables with more than 25 pairs are constructed by combining **units** (25 pair each typical) to form **multi-units** (100 pair each typical). Medium size cables, from 26 to 100 pairs, are made by combining preformed **units**, which are usually 25 pairs each. For cables with larger numbers of pairs, 100 pair **multi-units** (each is 4 units) are cabled or "stranded" together by larger cabling machines. Cables of up to 600 pairs can be produced in this fashion and maintain color code identification.

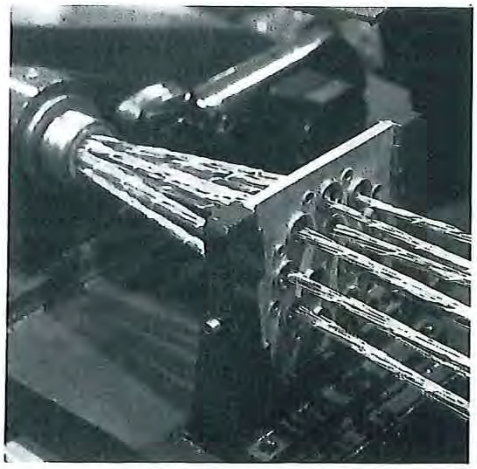
For even larger cables, 3,600 pair exchange cable, for instance, each 600 pair **super unit** is wrapped with a color coded **super binder**, and then cabled together to form one large cable core. The two construction methods used to produce a cable core, discussed on the next page, are similar to those used in producing stranded conductors.



Simplified graphic of cabling line – multi-units (100 pairs each) combine into cable or super units.



Preformed units (25 pairs each) spin off reels (left) and enter the cabling machine in the background.



Preformed units are guided into the cabling machine.

Bunched Core Cable

A bunched core cable consists of multiple units, simply collected together to form a cable. A slight twist is usually imparted to facilitate handling.

For a cable with equal number of pairs, bunched core construction produces a smaller overall cable diameter than the concentric core design does.

Because separation of pairs is reduced, electrical performance can be degraded. This bunched cores design has lower material and processing costs than the concentric core construction which follows.

Advantages
Smaller overall cable diameter
Lower material cost
Lower processing cost

Disadvantages
Electrical performance may suffer due to the reduced separation of pairs
Less uniform overall cable appearance
Pair identification can hamper splicing and termination

Concentric-Core Cable

There are two kinds of concentric-core cables:

A **true concentric-core cable** consists of a central unit with units spiraled around it, with subsequent layers wrapped in alternating directions.

A **unilay concentric-cores cable**, on the other hand consists of the same central unit with units spiraled around it, but all subsequent layers are wrapped in a single direction.

The degree of flexibility in a concentric-core cable depends on the lay (or wrap) length. A shorter lay length provides greater flexibility. The flexibility of the concentric-core design is ideal for large cable applications requiring flexibility for bending and being pulled into tight fitting locations.

The helical layering produces better separation of the twisted pairs for lower crosstalk values. Termination and splicing are also simplified because pairs can be easily identified.

Advantages
Increased flexibility
Excellent electrical performance

Disadvantages
Higher material costs
Higher processing costs

Fillers

For some cables, stringlike fillers are added between units to achieve better symmetry or to provide better conductor separation. These fillers can also act as cushions for cables subjected to flexing and impact in heavy-duty applications.

Commonly used fillers include polyethylene and twisted polyethylene monofilaments, vinyl, cotton and jute.

Core Wraps

A core wrap is an isolating layer wrapped over a core of insulated conductors. The wrap can be applied either helically (spiral wrapped) or longitudinally (lengthwise).

Core wraps are applied prior to shielding and/or jacketing a cable core.



Typical electronic cable with two twisted pairs, a longitudinal core wrap (clear plastic), drain wire, foil shield and jacket.

The following are the main reasons for applying core wraps.

Protection – Core wraps protect the cable core from both stress and heat during application of the shield and/or jacket in the manufacturing process. They also provide the finished cable an extra measure of protection from stress and heat.

Uniformity – Use of a core wrap improves roundness to give the cable a more uniform appearance. This is especially important for a smooth jacket finish in unshielded cables.

Improved Dielectric Strength – Core wraps, especially those made of PVC or polyethylene, help to isolate the cable core from electrical discharges in the environment. When used with shielding they will improve shield-to-conductor breakdown strength.

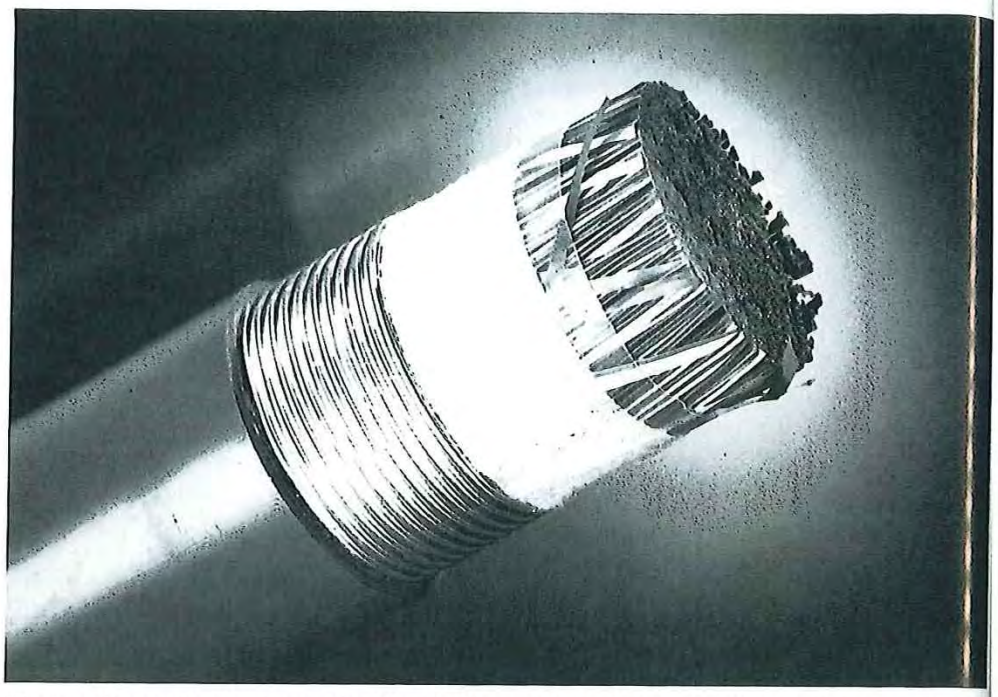
Types of Core Wraps

A variety of tape materials are used for core wraps based on the requirements of the application.

Polyester Tapes – Polyester core wraps add extra mechanical strength to the cable and aid in subsequent manufacturing steps, such as shielding and jacketing. They have high tensile strength (25,000 psi typical). Dielectric strength is 7500 volts per mil of thickness. Polyester wrap has an operating temperature of −60°C to 150°C (−76°F to 302°F).

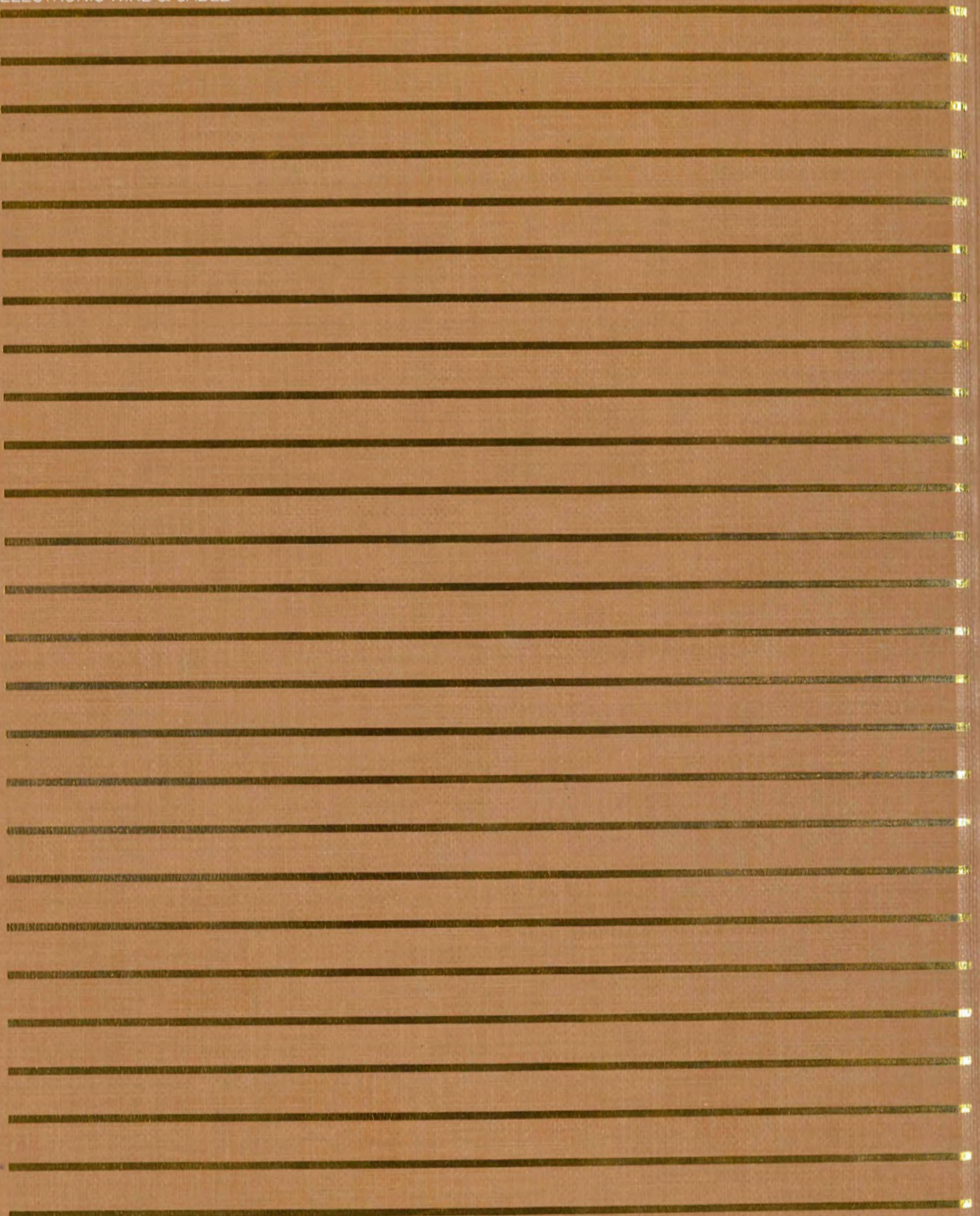
Heat Tapes – These are core wraps specifically designed to increase the heat resistance of a finished cable. They serve to retard flame and smoke generation.

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This riser cable consists of 1,800 pairs of dual insulated (expanded polyethylene with PVC skin) 24 gauge conductors. Note the cluster appearance due to the units and multi-units which form the cable core. A double core wrap is used – one clear, and one "mat wrap".

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7 Loop Transmission Media, Part I—Twisted Pair Metallic Cables

Chapter 7 Acronyms

AL	acceptance limit	ML	maintenance limit
AMI	alternate mark inversion	Neper	One Neper = 8.686 dB
AWG	American wire gauge	NESC	National Electrical Safety Code
DSL	digital subscriber line	PIC	polyolefin insulated cable
ECCS	electrolytic chrome-coated steel	PSTN	public switched telephone network
EHS	extra high strength	PVC	polyvinyl chloride
EMI	electromagnetic interference	REA	Rural Electrification Administration
FAC	facility area connector	RMS, rms	root-mean-square
FCC	Federal Communications Commission	RZ	return-to-zero
HDSL	high bit-rate digital subscriber line	SAI	serving area interface
I/O	inside/outside wire	SNR	signal-to-noise ratio
IAL	immediate action limit	UG	utilities grade
ICEA	Insulated Cable Engineers Association	XC	cross-connect
ISDN	integrated services digital network		

7.1 General Considerations

The most commonly used transmission media in present-day digital loop applications is twisted pair metallic (copper) cable, but fiber optic cables are seeing significantly more and more use. Although both media transmit electromagnetic waves, their spectra are very widely separated, and the transmission and reception of signals depend on completely different propagation mechanisms. Because of the breadth of information, the descriptions of transmission media are broken into two parts. Part I (this

chapter) covers twisted pair metallic cables and Part II (next chapter) covers fiber optic cables.

In spite of the lack of similarity between the two transmission media, the materials used in the outer (protective) layers of both cable types have many things in common and are identical in many respects. In many cases, the cables are installed under identical service conditions, and the associated loops and networks serve identical purposes.

There are cases, however, in which each cable type (twisted pair or fiber) can serve purposes the other cannot either because of economy or service requirements. For example, current use of twisted pair cable is exclusively for the final portion of the subscriber loop, commonly called "the last mile", because of its economy. On the other hand, fiber optic cable is used as a replacement for twisted pair feeder cables between the central office and remote switching terminals or digital loop carrier systems because of its economy in backbone and feeder applications. Work is under way by several large telephone companies to find economical methods to replace twisted pair cables altogether, but this is not expected to happen for many more years.

An economic trigger point is widely considered the best rationale for mass deployment of fiber optics in the loop. This point already has been reached for backbone and feeder plants. This point will be reached for the remaining portions of the loop (distribution and service drop) when the incremental cost of fiber over twisted pair is equal or close to zero, and when users demand services that can only be provided by fiber.

Economic considerations aside, the application of either twisted pair or fiber optic cables is predicated on their

- Physical characteristics
- Mechanical performance
- Electrical performance

Physical characteristics have to do with the geometry of the cable and transmission media. For example, the individual conductors of a twisted pair have a certain geometry, so they conform to a specified gauge and provide the necessary transmission characteristics. Similarly, optical fibers have a particular geometry associated with core and cladding, as well as dimensional requirements, which provide the necessary transmission characteristics.

Mechanical performance is related to the strength, abrasion resistance, and fatigue resistance of cables and the enclosed transmission media. This performance is specified in different ways for twisted pair and fiber optic cables. The same is true for electrical performance, which is due to their radically different transmission characteristics. The general physical characteristics and mechanical performance of both cable types and the specific physical and electrical characteristics of twisted pair cables are discussed in this chapter. Chapter 8 discusses the similar physical and electrical attributes of fiber optic cables.

7.2 Environment

Outside plant cables are subjected to a number of environmental hazards and conditions throughout their life. Some of these affect twisted pair cables differently than fiber optic cables. Each cable design attempts to mitigate any adverse effects over the anticipated cable life. Outside plant cables generally last at least 15 years, but in most regulated utility applications, their usefulness extends 25 to 35 years.

Environmental conditions of concern to the engineer are:

- Moisture
- Animal attack
- Electric fields
- Atmospheric disturbances (lightning)
- Temperature variations
- Absolute temperatures
- Snow and ice loading
- Wind loading
- Vibration
- Ultraviolet radiation (above ground only)

Moisture affects twisted pair and fiber optic cables through different mechanisms. Penetration and permeation of moisture into a twisted pair cable increases the attenuation by increasing the capacitance between conductors of a twisted pair. It also will corrode mechanical splices. When liquid water is present and it freezes, the expansion of the ice can crush the insulation or damage cable jackets from the inside. Such damage may not be apparent until the cable thaws and the pairs become shorted. In fiber optic cables, the crushing forces can fracture the fibers or cause microbending, both of which increase losses. Also, long-term exposure to moisture deteriorates the fiber's tensile strength.

Rodent attacks are a significant problem in some parts of the country.* The rodent's powerful jaws can easily penetrate plastic sheaths and allow moisture penetration. Also, the transmission media can be severed unless armoring is provided against the attack.

Strong electric fields from high voltage powerlines can lead to failure of the plastic sheath materials from corona discharge and arcing. Induction from powerlines can cause damaging current flow on conductive portions of the cables (armor, shields, and conductors in twisted pair cables; conductive strength members and armor in fiber optic cables).

Lightning is particularly troublesome in some parts of the country.† It can cause extremely large currents to flow on conductive portions of a cable. Also, large and

*For example, see page 246 of [1] for areas prone to gopher attack.

†See pages 3–5 of [2] or pages 2–5 of [3].

sudden currents from a lightning discharge can cause the cable to buckle as a result of mechanical forces and burn the insulation and sheaths. Rapid thermal expansion of the soil and moisture in it can exert significant forces on nearby buried cables. This damage can occur in completely dielectric fiber optic cables if they are buried near conductive material such as twisted pair or power cables.

Diurnal and seasonal temperature variations cause expansion and contraction of the materials used in cables. In some areas, the temperature can vary annually over a 90 °C range, and daily variations can easily exceed a 35 °C range. In twisted pair cables, temperature variations affect the attenuation but otherwise have no direct effect on modern cables. Older filled cables used a filling compound that flowed under high ambient temperatures; this compound would then drain out of cables used as risers. Modern filling compounds for cables have flow temperatures of 65 °C or 80 °C.

In areas of extremely cold temperatures, aerial twisted pair cables can contract enough to damage splices or supporting structures. Similarly, high temperatures increase the sag in aerial cables and allow accidental contact with vehicles or other moving objects. In fiber optic cables, the mechanical movement due to expansion and contraction can cause excessive bending loss.

Snow and ice loading can damage the cables as well as supporting structures through excessive weight. For example, one-half inch of radial ice on a one-half inch diameter cable weighs approximately 68 lb per 100 feet of length. One inch of radial ice on this same cable weighs about 200 lb per 100 feet. Snow and ice also increase the cross-sectional area of aerial cables and can amplify the adverse effects of wind.

Wind loading normally only affects aerial facilities; however, in especially windy areas, ground-mounted equipment may need special anchoring. The adverse effects of wind are manifested in four ways:

- As a transverse load on the supporting structure (for example, wooden poles)
- As a transverse load on the cable and messengers, which are coupled to the supporting structures
- Through vibration
- Through cable whipping and dancing

The transverse load, if large enough, can damage the supporting structures. Vibration, whipping, and cable dancing cause fatigue in supporting structures and in the cable itself. Even very small winds can cause large-amplitude vibrations on long sections of aerial line. Another source of vibration is road traffic, and over a long period, this source of vibration can lead to catastrophic failures of supporting structures. It is difficult to build vibration damping into cables, so external means are frequently employed, including specially made sails, spiraling the lashed cable, additional strands above the supporting strand and attached to it, and shorter spans between supports. In extreme cases of cable dancing, the only alternative is to bury the cable or change the route.

Sunlight can damage cable sheaths through breakdown of the plastic materials

from ultraviolet radiation. Any facility exposed to the sun is subject to this problem, and special materials or coatings are used to combat it.

7.3 Service Classifications

All telecommunication cables are categorized according to their service classifications, as shown in Table 7-1. These classifications are universal, but general, in nature. Most cables are not specifically made for a single service classification, so a given cable type may be used wherever it is suitable. For example, filled twisted pair cable normally is considered for direct buried applications, but it is also used in aerial and underground service. Armored cable may be used in aerial as well as direct buried service. The selection of general cable types is aided by the flow chart in Figure 7-1.

As previously noted, cables used in an outside environment normally last 25 to 35 years. Although indoor cables are manufactured for a similar life, technological advances of equipment connected to indoor cables and user requirements for more and more bandwidth may render the cables obsolete long before their physical life is exhausted. This is especially true of most existing twisted pair cables. With the widespread deployment of fiber optic cables and high-performance twisted pair cables in buildings, the threat of premature obsolescence is somewhat eased.

Table 7-1 Cable Service Classifications

CLASSIFICATION	APPLICATION
Indoor	Plenums in buildings (CMP)[a] Risers in buildings (CMR) General use in buildings (CM)
Aerial	Lashed to separate messenger or self-supporting on above-ground structures
Buried	Buried directly in earth
Underground	Installed underground in duct or raceway

[a]The designations in parentheses for indoor cable indicate classifications defined in Article 800 of the National Electrical Code.

7.4 General Cable Construction Attributes

Both twisted pair and optical fiber cables have similar external physical attributes, which are illustrated in Figure 7-2. All cables have an outer jacket, which for twisted pair and fiber optic cables is identical. This also is true of the armor (with an optional inner jacket), although fiber optic cables are equipped with armor in more applications than twisted pair cables. The buffering, strength member, and transmission media are radically different.

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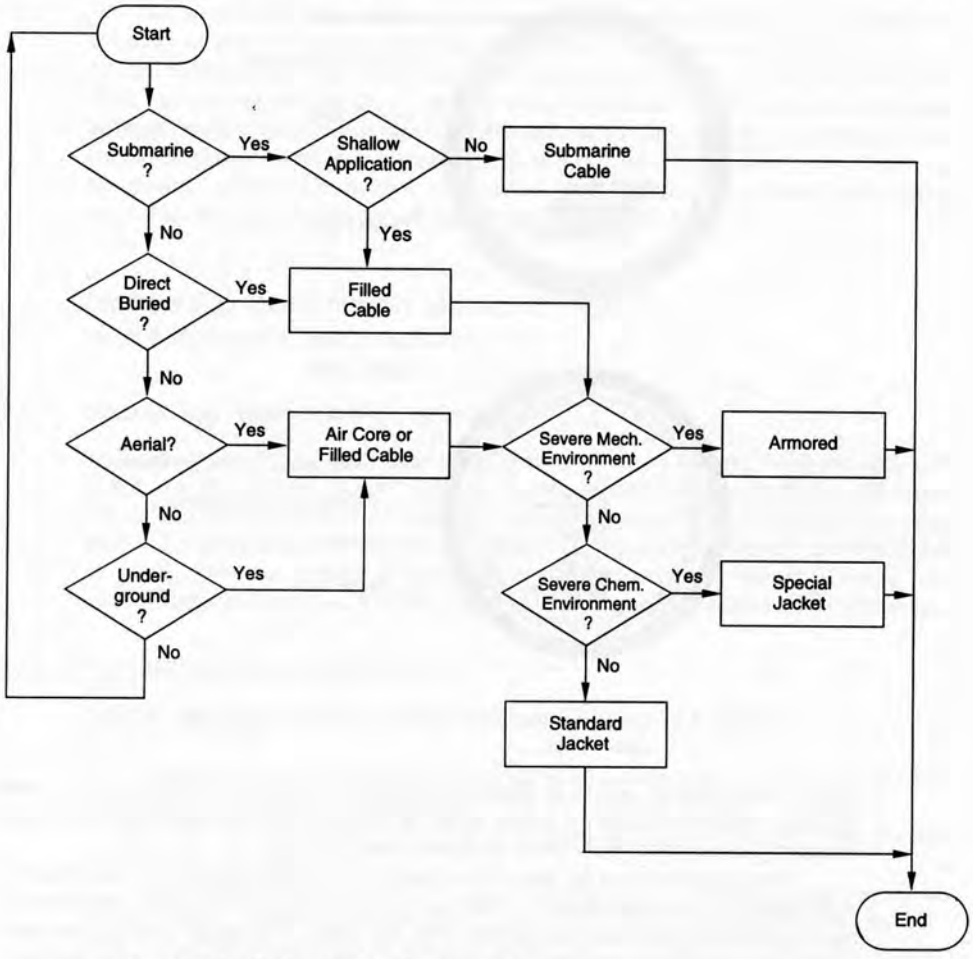


Figure 7-1 Cable selection flow chart [4]
Reeve, © 1992 Institute of Electrical and Electronics Engineers. Reprinted with permission

7.5 Other Outside Plant Equipment

Although twisted pair cables represent the highest proportion of outside plant investment, they are not the only transmission equipment found outdoors. The cables and other facilities used with digital transmission systems or digital loops are frequently shared with analog loops. Except for digital loop carrier, remote switching systems, and all present optical fiber transmission systems, digital and analog sub-

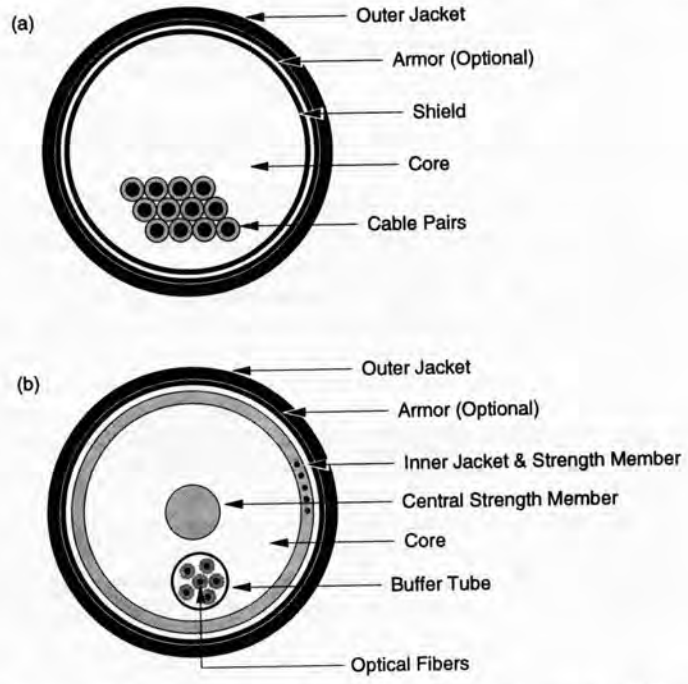


Figure 7-2 Cable construction attributes: (a) Twisted pair cable; (b) Fiber optic cable

scriber loops require access at frequent intervals. Access is typically at every pole in aerial systems installed in urban areas, or at least once in every city block (and frequently more often) for buried or underground systems.

The equipment used for access to subscriber loops depends on the type of plant. Aerial plant is accessed through "ready access" or sealed fixed-count terminals located adjacent to the pole and in-line with the cable. The aerial terminal has provisions for shield bonding and grounding, and connection of service wires to distribution pairs. In buried or underground plant, access is at pedestal or outdoor housings. The pedestals sometimes contain loop carrier equipment, loading coils, cross-connect blocks, or other devices, including protectors, for connecting distribution plant to service wires.

Digital loops frequently are used as backbone facilities to feed digital loop carrier and remote switching systems, which may be separated from the central office by several miles. Access to the digital loop in these cases is not necessary except at repeater points. Repeaters on twisted pair cables typically are about five to seven kilofeet apart for repeatered T1 systems. Fiber optic transmission systems used in digital loop applications do not require repeaters because of their relatively short lengths, so access is not required anywhere along the route except at reel-end splice points.

Repeatered T1 repeater housings used with twisted pair cables are available in a variety of sizes and forms, from one repeater to several dozen. The housings have printed wiring board connectors and mounting provisions for one or more repeater cards, grounding and bonding, and lightning protection. Some housings also may have order wire and fault location equipment, which are used for maintenance and troubleshooting. Repeater housings can be pressurized with an inert gas or with dry air through cable pressurization systems to keep out moisture. Sealed units have provisions for venting in case of excessive pressure build-up.

7.6 Twisted Pair Transmission Media: Physical and Electrical Characteristics

7.6.1 Introduction

The twisted pairs in all modern polyolefin insulated cables (PICs) are enclosed in a heavy-duty plastic sheath. Although pulp-insulated cables are still manufactured for in-kind replacements, this chapter is concerned with PIC exclusively. First, the physical aspects and non–transmission-related electrical characteristics are described in detail. Then the electrical transmission characteristics are described for a frequency range extending to 5 MHz, which covers all present digital loop applications.

7.6.2 Physical Characteristics

7.6.2.1 Twisting

Each cable pair consists of two twisted insulated conductors. The twist is used to decrease electromagnetic interference due to crosstalk between adjacent pairs in a cable. The twist also helps keep the conductors of the pair balanced with respect to the shield and other pairs.

Neighboring pairs in a given 25-pair group have a different twist length to further reduce crosstalk between them. The twist length (or pitch) is usually left-hand (counterclockwise), and it varies from two to six inches. It is optimized to reduce crosstalk at higher frequencies (hundreds of kilohertz and above), since it is in this region where crosstalk can become a problem.

The requirement for adequate crosstalk performance in all telecommunication cables is highly stressed during their design and construction. Crosstalk due to cable pair irregularities is managed by tightly controlling capacitance unbalance (pair-to-pair, pair-to-shield, and pair-to-ground) and resistance unbalance during the manufacturing process.

7.6.2.2 Feeder and Distribution Cables

Feeder cables comprise the loop from the central office to main junction points called serving area interfaces (SAIs), facility area connectors (FACs), cross-connects (XCs), or control points. The actual name depends on the company, but the function

is to provide a point at which feeder cable pairs can be administered and connected to individual distribution cable pairs.

Distribution cables comprise the loop from the main junctions to distribution terminals such as pedestals or aerial terminals. In any given geographic area, there are generally more distribution pairs than feeder pairs. This allows efficient use of larger and more expensive feeder cables through easier administration and assignment of subscribers.

The most widely used feeder and distribution cable size is 24 American wire gauge (AWG). This is due to economic tradeoffs that take into account the typical loop length. Relatively short loops in metropolitan environments are typically 26 AWG.

In the smaller cable sizes, good design practice calls for using cables that are multiples of the basic 25-pair unit (25 and 50). Pair counts of 6, 12, 18, and 37 are avoided unless other factors make their use clearly more economical than 25- or 50-pair sizes. There is very little difference between the installed cost of 6- or 12- and 25-pair cables or 37- and 50-pair cables in most applications.

The extra pairs not only give extra insurance to accommodate unforeseen growth, but also allow pairs in the field to be allocated and used more logically due to the multiple 5-pair and 25-pair color coding scheme. The long-term result, of course, is easier administration and maintenance.

With twisted pair cables, each pair may be made available at many different locations in a "preferred count" splicing scheme, or at predetermined single locations in a "dedicated count" splicing scheme. Generally, feeder cables serve a given area on an express basis, while distribution cables serve the individual subscribers in that area. Large cables cannot be provided in lengths of more than 1,000 or 2,000 feet and so must be frequently spliced along long routes. The splice, connector, and access points are required to use the facility properly. Splices and connectors add very little to the overall transmission loss in the cable route.*

7.6.2.3 Service Wires

Service wires (also called *service drops* or *service cables*) make up the final portion of the metallic loop. They are installed between the distribution terminal and network interface device. This can be at an office building or residential establishment. Beyond the network interface device are premises wiring systems, which are described in Chapter 11.

Service wires can be one pair or up to hundreds or thousands of pairs, depending on the establishment to be served. In many situations there is nothing to distinguish a service cable from a distribution cable, except for the point of termination. Exactly the same materials may be used for the cables themselves.

Service wires in the smaller sizes are not always twisted because they are usually short and do not measurably degrade transmission quality. Aerial service wires are usually 18 or 19 gauge, whereas buried service wires are usually 19, 22, or 24

*The loss of an individual twisted pair splice connector is not easily measured because it is so small; therefore, splice loss is not considered a factor in feeder and distribution design.

CommScope Exhibit 1045

gauge. Highly pure copper is the most widely used conductor material for feeder and distribution cables and underground service wires, whereas copper with special alloying (or other means for strength) is used for aerial service wires.

7.6.2.4 Current Limitations

The maximum continuous current-carrying capacity of any given conductor gauge depends on many factors, such as ambient temperature, allowable temperature rise, number of conductors in a bundle, and insulation type. Table 7-2 shows the values for various copper conductor gauges, assuming a 25 °C ambient temperature and 40 °C rise. These are provided to give an idea of current magnitudes and not as design values.

In analog applications, the maximum loop current available from an analog central office line circuit is in the range of 45 to 145 mA, although some older systems can supply at least 175 mA. Modern digital equipment limits loop current to approximately 50 mA. The current magnitude normally drops off as loop length increases beyond a certain limit. Many digital central offices use current-limiting type line circuits to limit loop current on short loops.

Digital loop circuits may be arranged to not carry any dc loop current at all, but this is to be avoided. Sealing current of 10 to 20 mA is used to keep mechanical splices and connections free of high-resistance metal oxides. Repeatered lines for digital loop carrier systems are usually loop powered with 60 to 140 mA dc. The lower value is preferred in order to reduce power consumption and dissipation in repeaters and digital line terminal equipment.

For signaling and control applications outside of the digital transmission arena, loop current normally is limited to 350 mA. In some special applications, a loop current up to 1.3 amps is sometimes allowed. This higher value coordinates with 26 AWG cable. In public switched telephone network (PSTN) applications, the local exchange carrier always will limit current to this value.

In premises wiring applications, the Federal Communications Commission (FCC) regulates the maximum allowed currents on cable pairs connected to the public telephone network. The FCC limits currents, as shown in the right-hand column of Table 7-2. The FCC does not list a value for 19 AWG conductors but does give the allowable currents of 7.5 A and 10 A for 20 AWG and 18 AWG, respectively. Also, a 45 °C rise is used for 22, 20, and 18 AWG, and de-rating is required where ambient temperatures exceed 25 °C.

Also shown in Table 7-2, for reference, is the approximate fusing current for each gauge, which is the point at which the conductor will fuse open. These are

Table 7-2 Exchange Cable Pair Current Ratings

AWG	Approx. Fusing Current (0.1 Seconds)	Max. Current Capacity (40 °C Rise)	Max. Current per FCC Rule 68.215 [5]
19	600 A	8 A	See text
22	300 A	5 A	5.0 A
24	190 A	2 A	2.1 A
26	110 A	1.3 A	1.3 A

approximations; actual values depend on many variables and published information varies widely. Fusing currents and fusing times are inversely related. For example, if the current is increased by a factor of 3, the fusing time will decrease by a factor of about 1/10.

7.6.2.5 Twisted Pair Cable Specifications

Telecommunication cables are manufactured for an intended application according to a specification prepared by the cable customer. In many cases, these specifications are generic and are in wide use throughout a segment of the telecommunications industry. Of particular interest are the telecommunication cable standards published by the Insulated Cable Engineers Association (ICEA) [6–9], Rural Electrification Administration (REA) [10–17], and BELLCORE [18–25].*

Generally, the specifications include, among other requirements, an insulation breakdown voltage, a high-voltage proof test, and insulation resistance. The insulation breakdown voltage (or dielectric strength) is the voltage at which the insulation will fail. It is usually specified in volts per mil† of insulation thickness. Typical insulation thickness is around 10 to 14 mils, but this differs among cable types and manufacturers. Cable specifications normally only show an insulation breakdown voltage, and the manufacturer then applies enough of the particular material to satisfy the requirement.‡

The high-voltage proof test is at a somewhat lower voltage than the insulation breakdown voltage. It is the voltage at which cables are tested after manufacture and before shipment to the customer. The actual values depend on such factors as cable gauge, whether filled or air core, and solid or expanded foam insulation. All proof tests are made for three seconds. The cable is not expected to withstand these voltages indefinitely.

Insulation resistance is a measure, in MΩ-miles, of the leakage between a given conductor and the other conductors and shield in the cable. By inspecting the units, it is clear that insulation resistance decreases with increasing length. For example, an air core cable five miles long will measure at least 2,000 MΩ (10,000 MΩ-miles/five miles). Insulation resistance tests are usually made at around 550 V for new cables at the factory, or 250 V for cables in the field. The higher the resistance, the better. Table 7-3 shows the ratings for typical outside plant telecommunication cables.

Unlike power cables, telecommunication cables usually do not have a specified maximum working voltage. Nevertheless, most telecommunication cables are considered to have a working voltage across the tip and ring of any given pair, and between pairs of 300 V.§

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*The listed BELLCORE documents are representative of the available outside-plant cable technical references. Additional specifications can be found in [26].

†One mil is one one-thousandth of an inch.

‡This is not an arbitrary process because the insulation thickness affects cable capacitance, which is very tightly controlled, and conductance.

§The working voltage considered here is root-mean-square (rms) or dc.

Table 7-3 Exchange Cable Voltage and Insulation Ratings

PARAMETER	RATING
Insulation breakdown voltage	300 to 1,200 volts/mil
High-voltage proof test (3 seconds)	
Conductor-to-conductor	2 to 7 kV
Conductor-to-shield	10 to 20 kV
Insulation resistance (@ 100 to 550 V)	
Air core cable	10,000 MΩ-miles
Filled cable	1,000 MΩ-miles

This does not mean the user can arbitrarily apply 300 V to the cable pairs. As expected, for equipment connected to the PSTN, FCC Part 68 has certain maximum voltage and current limitations for terminal equipment in various configurations that preclude such operation.* Basically, the terminal equipment cannot apply more than 56.5 Vdc to a loop connected to an off-premises station, or supply more than 140 mA to the loop under any circumstances. During ringing, no more than 300 V peak-to-peak can be applied to the loop.† The reasons for these limitations are obvious: safety and network harm. Some telephone company tariffs may specify more stringent voltage and current limitations.

The voltage and current limitations discussed above, as imposed by the FCC on equipment connected to the loop, do not apply to the telephone companies themselves. Although the working voltage of cable pairs is considered to be 300 V, telephone companies will use higher voltages under certain conditions. These are always associated with special equipment located outside the central office. For example, the line repeaters in long digital loop carrier span lines may be powered by up to 360 V at the central office. This voltage dwindles to much lower values along the span line due to voltage drop across the repeaters, and resistive voltage drop in the cable pairs.

Cable specifications also include requirements for resistance, capacitance, crosstalk, and loss at particular frequencies. Although the exact details of industry specifications may vary with the market segment (that is, REA, BELLCORE, AT&T, GTE, and others), the overall effect on transmission performance is not significant except in the most demanding applications (for example, at high bit rates where specially designed cables might be used).

Other basic requirements of virtually all specifications are the marking requirements for outer jackets. These include sequential marks at two-foot intervals, cable type, pair count, gauge, and manufacturer. Some cables have two sets of interval markings when shipped from the factory. Normal marking usually is white, but if this is unusable for any reason, a second interval marking is made in yellow. Also, as required in 1993 by the National Electrical Safety Code (NESC), the outer jacket must be marked with a telephone handset symbol to differentiate the communications cable from power cables (NESC Sec. 35, par. 350.6) [27].

*Par. 68.306 of [5].

†300 V peak-to-peak corresponds to about 106 V RMS, assuming a sinusoidal ringing voltage.

7.6.2.6 Splices

Copper conductors are easily spliced by a number of means. Because of requirements for long life, reliability, and fast installation, all splicing in the telecommunications industry is by specially designed insulation displacement mechanical connectors. Single-pair or bulk (25 pair at a time) splice connectors are available. All require special tools or jigs to assemble the splice properly and to ensure a long and reliable life. Twisting together of bare conductors is never used to splice exchange cables.

Of special concern in outside plant applications is the need for a weatherproof splice connector. Even when splices are enclosed in a sealed splice case, enough moisture can enter to corrode the splice connections and introduce high loss or noise. All splice connectors are available with filling compounds that prevent moisture problems. Although these type of connectors find the widest use in direct buried cable applications, they are also recommended for use with pressurized plant.

The splice connectors used in the telecommunications industry have negligible loss at all frequencies encountered in twisted pair transmission systems. Nevertheless, proper care must be taken in choosing splice connectors and the splice cases that enclose them. Without this care, the expected service reliability and availability will never be obtained over any significant period.

7.6.2.7 Summary of Twisted Pair Cable Physical Characteristics

The previously described physical characteristics are summarized in Table 7-4 for modern copper telecommunication cables. Figure 7-3 illustrates the construction of a few cable types.

Table 7-4 Outdoor Twisted Pair Cable Physical Characteristics

PARAMETER	CHARACTERISTIC
Insulation	Polyethylene Polypropylene Dual expanded polyethylene Expanded polypropylene
Conductors Pair Count	19, 22, 24, 26 AWG, copper 6, 12, 18, 25, 37, 50, 75, 100, 150, 300, 400, 600, 900, 1,200, 1,500, 1,800, 2,100, 2,400, 2,700, 3,000, 3,600, 4,200[a]
Core Shield	Air or filled Bonded aluminum (8 mils), copper (5 or 10 mils) or copper alloy (6 mils)
Armor Sheath (jacket)	Bonded steel (6 mils) when separate from the shield Polyethylene jacket Special high-temperature jacket
Special features	Compartmental core Low capacitance External wire armor

[a]Not all pair counts are available in all gauges.

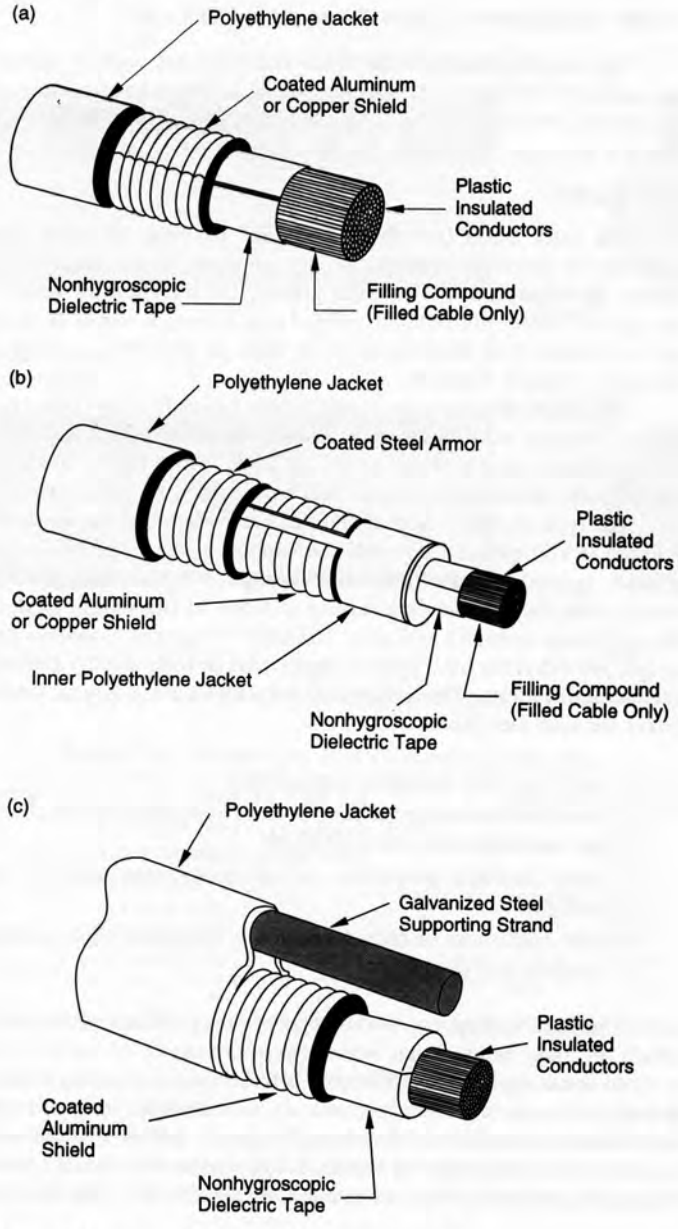


Figure 7-3 Twisted pair cable constructions, [4] Reeve, © 1992 Institute of Electrical and Electronics Engineers. Reprinted with permission

7.6.2.8 Description of Each Construction Attribute

This section describes the cable constructions used in subscriber loop applications; refer to Figure 7-3. Various coding schemes have been used in the telecommunications industry to simplify cable manufacturing and ordering. One of the more common schemes is described in Appendix A.

Outer Jacket

The outer jacket (sheath) protects and cushions the cable core. It also offers resistance to chemical deterioration and abrasion. In all modern telecommunication cables, the outer jacket is a tough plastic, the thickness of which varies with size and type of cable. For outdoor twisted pair cables, it varies from approximately 60 mils on cables with diameter of 0.75 inch, to 110 mils or more on cables with a two-inch or larger diameter.

The sheath thickness for indoor cables typically is less than comparable outdoor cables, because indoor cables are usually installed in a relatively benign environment. In those cases in which an indoor cable is installed in an abusive environment, special outer jacket constructions can be provided by cable manufacturers.

The type of plastic used in outer jackets varies with the application. A polyvinyl chloride (PVC) material that will not support a flame and has nontoxic combustion products is used for riser cables in buildings. For plenum applications in buildings, which is the most demanding service in terms of fire rating, cables typically have a fluoropolymer resin (for example, TEFLON™*) jacket. Low-density, high molecular weight polyethylene (or ethylene copolymer) or high-density polyethylene is used in outside applications. These types of polyethylene are typical choices for the outer jacket because they have:

- Relatively low humidity permeability
- Good mechanical properties, such as high resistance to abrasion, weathering, and environmental stress cracking
- Good chemical properties, including high resistance to deterioration from sunlight
- Low coefficient of friction, which is important when pulling cables through conduits and duct systems

The disadvantages of polyethylene are its stiffness and flammability, both of which preclude its use in an indoor environment.

In aerial applications, the cable is lashed to a supporting messenger (commonly called *suspension strand* or just *strand*), which varies from 3/16 inch to 7/16 inch in diameter, depending on the strength required and the material used. Lashed aerial construction is illustrated in Figure 7-4(b). Table 7-5 shows the breaking strengths for messengers used in telecommunications applications. The messenger tension never

*"Teflon" is a trademark of DuPont-Nemours, Delaware.

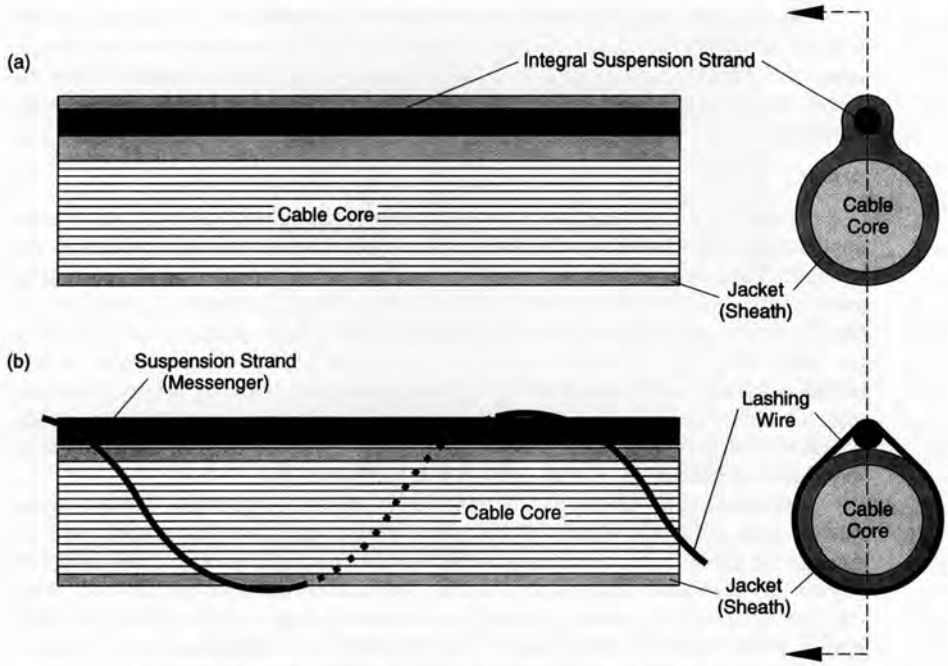


Figure 7-4 Cross-sections of aerial construction: (a) Figure 8; (b) Lashed

Table 7-5 Messenger Strand Breaking Strengths

Designation	Strand Size	Breaking Strength (lb)
6M	3/16 inch extra high strength (EHS)	6,000
6M	1/4 inch utilities grade (UG)	6,000
10M	5/16 inch EHS	10,000
10M	3/8 inch UG	10,000
16M	3/8 inch EHS	16,000
16M	7/16 inch UG	16,000

exceeds 60% of the breaking strength, under all mechanical loading conditions, in a properly designed aerial plant.*

In some aerial applications, a self-supporting cable is used, as shown in Figure 7-4(a). This cable incorporates a built-in supporting messenger along with the outer sheath. This cable is called "figure 8" because of its shape. Due to strength limitations, figure 8 cable generally is not available in cable pair counts above 300 pairs (26 AWG), 200 pairs (24 AWG), 100 pairs (22 AWG), or 50 pairs (19 AWG).

*Mechanical loading conditions and design criteria are covered in [27–29].

Many older outdoor twisted pair cables have a lead sheath, which acts as both a shield and outer covering. Because of their age and construction, few lead sheath cables are used in high-speed digital transmission service. Some modern cables use a lead sheath over a polyolefin jacket for added protection in highly corrosive environments.

Armor

A steel tape armor can be placed under the outer jacket if desired, and in some applications it is mandatory. The armor provides increased physical protection and strength. The tape is usually (but not always, especially on smaller cables) corrugated and about six mils thick. It is polymer coated on both sides to reduce corrosion. The tape material is typically an electrolytic chrome-coated steel (ECCS), although stainless steel and copper alloys also are used. In copper cables, the properties of both shield and armor can be combined in a single corrugated tape. A copper/iron alloy (six mils thick) or extra thick (ten mils) copper is used in this case. An inner jacket, which is similar in construction to the outer jacket, may be used in armored cables to reduce the chances of a kink or buckle in the cable.

Armored cables find applications in areas infested by gophers, beavers, squirrels, or other chewing rodents. The armor does not guarantee that rodents will not damage the cable, because rodents have incredibly powerful jaws; it does, however, reduce the likelihood of damage. Another application for armored cables is when they are installed in a severe physical environment, such as direct burial in sharp, broken rocks, where bedding sand is not available (or economical); or in lakes or stream crossings, where anchor or other boat-caused damage is possible.

In lakes and river crossings, a cable with a lead antimony alloy armor can be used to offset the natural buoyancy and weight the cable down. Otherwise, the cable can be installed with a submersible plow or weighted at intervals. Freshwater has a density of 62.4 $lb/feet^3$ and seawater has a density of 64 $lb/feet^3$. The volume of water displaced is that of a cylinder equal in dimensions to the cable. If the cable weight exceeds the weight of the water displaced, the cable will not float.

Specially made armored cables are available for true submarine service in oceans and deep lakes. Figure 7-5 is a photograph of heavily armored twisted pair and fiber optic cables for submarine service such as lakes and river crossings, and Figure 7-6 is a drawing of the cable components (in this case, a heavily armored fiber optic cable for water crossings). Special jacket materials can be provided for highly corrosive, potentially damaging, or chemically contaminated environments. The added protective layers are usually applied over standard cables.

Shielding

Outside plant twisted pair cables are most commonly shielded with corrugated aluminum or copper tape. Copper alloys and copper-clad stainless steel also are used. To increase corrosion resistance, the aluminum shield is bonded to a thin plastic (copolymer). This coating is not necessary with copper shields. A corrugated rather than smooth surface is used to increase shield strength and flexibility. The shield isolates the enclosed conductors from outside sources of electromagnetic interference (EMI), such as induction from powerline harmonic frequencies. The ability of a

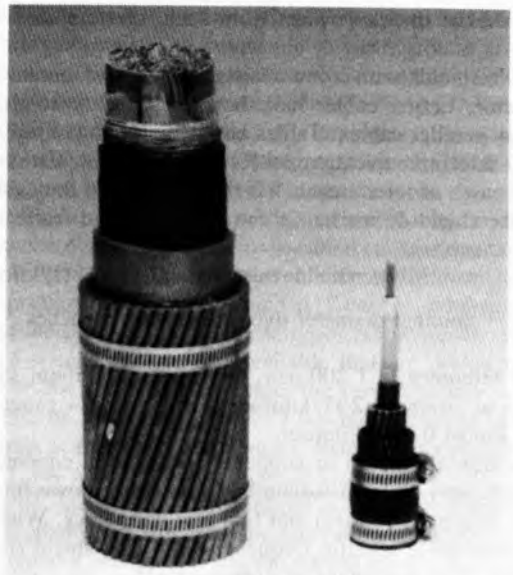


Figure 7-5 Comparison of heavily armored twisted pair and fiber optic cables
Taken from [30], with permission of AT&T Network Systems

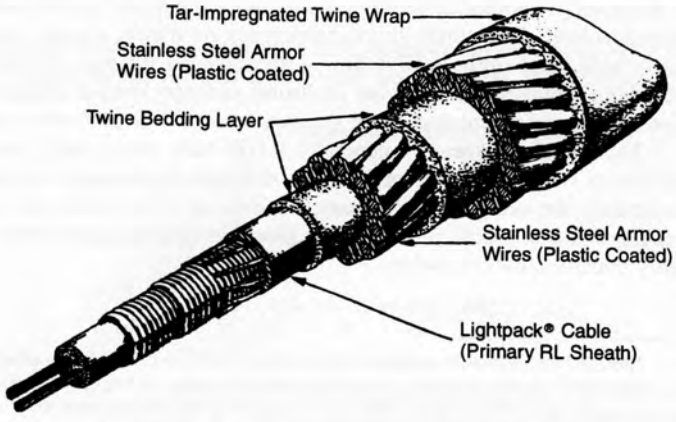


Figure 7-6 Components of heavily armored fiber optic cable
Taken from [30], with permission of AT&T Network Systems

shield to isolate the cable pairs from such interference is determined by its shield factor.

Cable shields with a low resistance and low mutual impedance have a higher shield factor. Larger cables have both these features, and so offer a better shield factor than smaller cables. Tables are available to simplify the calculation of shield factor for telecommunication cables, but these calculations are only needed in exceptional cases of interference.* If the diameter of the cable over the outer shield is known, the shield dc resistance can be determined from:

$$\text{dc shield resistance} = 0.75/D\ \Omega/\text{kilofoot}$$

where D = nominal diameter over the shield, in inches

For reference, a 1,200-pair, 24 gauge, aluminum shielded cable has a shield resistance of around 0.2 Ω/kilofoot; a 100-pair, 24 gauge cable has a shield resistance of almost 0.7 Ω/kilofoot.

The thin aluminum or copper shield used in conventional telecommunication cables does very little to isolate the pairs from powerline interference at the fundamental frequency (60 Hz) and first few harmonics. When it is necessary to shield a cable from these specific frequencies, an iron shield (for example, iron conduit) works best. The aluminum or copper shield is most effective at higher harmonic frequencies, which are annoying to the subscriber in analog service or can cause problems with digital transmission, due mostly to equipment upset. Since the telephone instrument and other terminal equipment—digital or analog—are designed to have little response at 60 Hz, induction at the fundamental powerline frequency usually is not a problem.

The shield in a given cable provides almost twice the shielding (induced voltage cut almost in half) at 540 Hz than it does at 60 Hz. Also, a cable with four times the diameter of another cable will provide twice the shielding. These low frequency-induced voltages have little direct interference on digital signals because of the relatively wide bandwidths used in digital transmission systems. If large enough, however, these voltages can upset the electronic circuitry used in digital regenerators or transmission equipment and cause the system to fail or produce excessive errors.

The shield thickness is generally 0.008 inch (eight mils) for aluminum and 0.005 inch (five mils) for copper. The different thicknesses are used to give approximately the same strength. Coated aluminum is the preferred shield because it is cheaper and is usable in all but the most demanding applications (such as some highly corrosive environments).†

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*See [31] for calculation methods. If a particular interference problem is severe enough to require these calculations, it may be easier or more economical simply to reroute the cable or use a different transmission method. For example, fiber optic transmission systems are inherently immune to all forms of EMI in the outside plant environment.

†The cost of twisted pair cables naturally varies with the costs of the materials used to make them. The biggest variables are the costs of aluminum and copper. There may be times when a copper-shielded cable is cheaper than the same cable with an aluminum shield.

The shield is made continuous through splice points, such as vaults, manholes, aerial terminals, and pedestals, and connected to earth ground at regular intervals. Aerial messengers must be grounded at least four times per mile to comply with National Electrical Safety Code requirements.*

Shield continuity and grounding are very important; otherwise, the cable pairs are susceptible not only to noise but to damaging overvoltages during lightning activity, power faults, and power system switching transients.

For digital carrier applications, an additional shield may be used that separates the cable pairs into two compartments. This is called compartmental core or screened cable. "Z-Screen," "D-Screen," or "T-Screen" are well-known trade names. The last indicates the primary application, which is T-carrier, whereas the first two indicate the shape of the core separator. These types are interchangeable in almost all applications. Some special designs are available that are optimized for the digital rate to be carried on the cable. For example, the core separator in cables designed for T1C (DS-1C rate of 3.152 Mbps) service has more overlap, and provides more immunity to crosstalk at the higher frequencies, than cables optimized for repeatered T1 (DS-1 rate of 1.544 Mbps) service.

In a given cable, the transmit pairs are put in one compartment and the receive pairs are put in the other compartment. The separation is necessary to reduce crosstalk between the transmit and receive circuits of the transmission system.

The cross-section of a compartmental core cable is illustrated in Figure 7-7. The core separator, or screen, is made electrically continuous at all splice locations, but it is not deliberately grounded or connected to the cable shield (this is an important, but often overlooked, requirement).

Wrapped between the shield and the cable core of modern cables is a nonhygroscopic dielectric tape that provides additional insulation to increase the pair-to-shield withstand voltage.

Buffering

The term *buffering*, as it is used here, is borrowed from fiber optic technology, where it describes the protective measures used in fiber optic cable constructions.

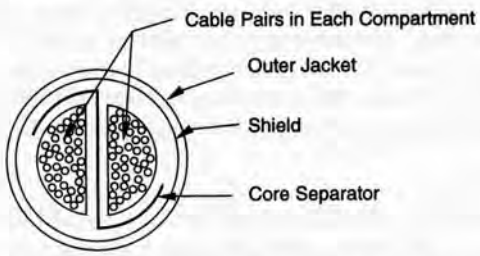


Figure 7-7 Compartmental core cable cross-section, [4]
Reeve, © 1992 Institute of Electrical and Electronics Engineers. Reprinted with permission

*See section 92C of [27].

The term is easy to envision for any cable construction, however, and it is used here for that reason. In twisted pair cables, buffering is naturally provided by the outer jacket, armor (if used), and the conductor insulation itself, and no additional specific measures are required (unlike optical fibers as explained in the next chapter).

Strength Member

Unlike fiber optic cables, twisted pair telecommunication cables normally do not employ a separate strength member (although one can be specified if needed). Instead, the strength mostly comes from the conductors themselves and the jacket/shield/armor assembly.

When calculations are made to determine the maximum pulling tension for underground copper twisted pair cables, the following formula is used:

$$\text{Tmax} = 0.008 \times \text{CM} \times \text{N} \times 80\% \text{ lb}$$

where Tmax = maximum pulling tension in lb
CM = conductor area in circular mils
N = number of conductors (N = 2 × number of cable pairs)

The maximum tension formula can be rewritten for the common cable gauges, as follows:

$$\text{Tmax}(19) = 16.5 \times \text{no. pairs}$$

$$\text{Tmax}(22) = 8.2 \times \text{no. pairs}$$

$$\text{Tmax}(24) = 5.2 \times \text{no. pairs}$$

$$\text{Tmax}(26) = 3.3 \times \text{no. pairs}$$

where Tmax(AWG) is the maximum tension in lb for the gauge indicated

The foregoing formulas assume a pulling eye is used. A pulling eye is soldered to each individual conductor to transfer the pulling strain uniformly throughout the cable cross-section. Pulling eyes are difficult to apply in the field (they are usually factory installed), so basket grips are used in a large number of installations. If a basket grip is used, the maximum pulling tension is the calculated Tmax or 1,000 lbs, whichever is less. The lesser tension takes into account that the pulling force is transferred directly to the sheath and only indirectly to the conductor itself.

Cable Pairs

Probably the most significant part of a twisted pair digital loop, in terms of investment, is the outside plant cable pair itself. An individual pair comprised of tip and ring conductors is inherently bidirectional; that is, it will work just as well for transmission or reception in either direction. In common digital loop applications, however, with the exception of basic rate integrated services digital network (ISDN) digital subscriber line (DSL), and the high bit-rate digital subscriber line (HDSL), two cable pairs (four conductors) are used to provide independent transmit and re-

ceive paths. Associated with each cable pair of either the 2-wire or 4-wire digital loop are ancillary devices for protection and termination, and repeaters for regenerating the digital signal on long loops.

Twisted pair copper telecommunication cables can be obtained in any of four gauges, as shown in Table 7-6. Aluminum conductors have seen limited use in telecommunications. Aluminum conductors provide approximately the same conductivity as copper when they are two gauge sizes larger. For example, a 20 AWG aluminum conductor provides approximately the same conductivity as a 22 AWG copper conductor.

Table 7-7 gives the dc loop resistance per unit length for the different copper cable pair gauges at different temperatures. The loop resistance at temperatures not shown in the table can be found from:

$$R_T = R_{T0}[1 + \rho_{T0}(T - T_0)]$$

where R_T = resistance at temperature T
R_{T0} = resistance at reference temperature T_0
ρ_{T0} = temperature coefficient of resistivity per °C at temperature T_0

For copper, $\rho_{T0} = 0.00401/°C$ at 15 °C and $0.00393/°C$ at 20 °C. Figure 7-8 shows the loop resistance as a function of loop length for each gauge at typical design temperatures.

For economic reasons, analog and digital signals may be carried on the same cable. When combined service is used, the cables are commonly referred to as exchange cables. When a cable is dedicated to digital service between central offices, it is sometimes referred to as a trunk cable.* Exchange cables are available in stan-

Table 7-6 Twisted Pair Copper Conductor Gauges[a]

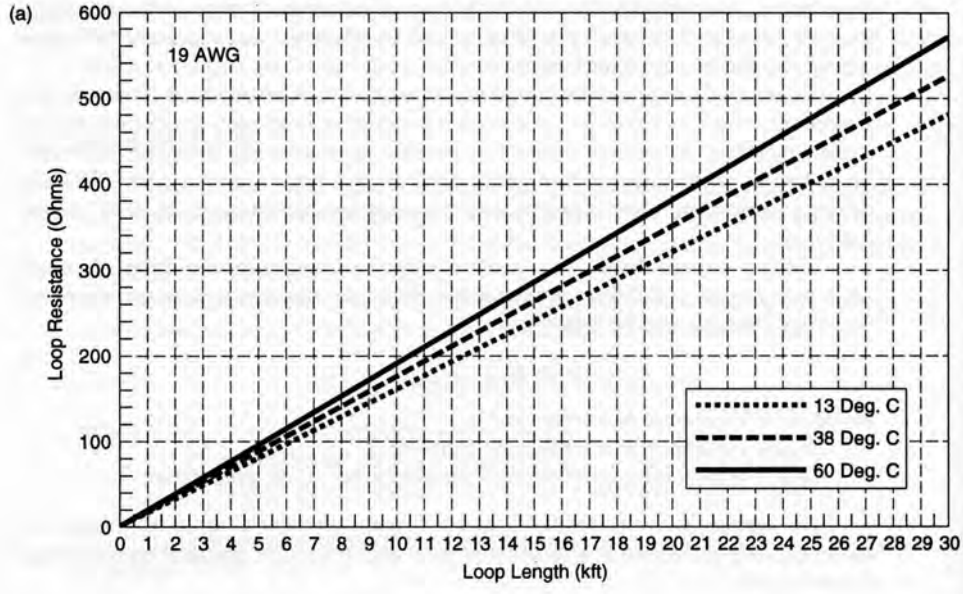
American Wire Gauge (AWG)	Diameter (inch)	Cross-Section (CM)[b]	Equivalent Diameter (mm)
19	0.03589	1,288	0.912
22	0.02535	642.4	0.643
24	0.02010	404.0	0.511
26	0.01594	254.1	0.404

[a]Source: [32]
[b]CM = circular mils = (diameter in mils)^2

Table 7-7 DC Loop Resistance of Copper Twisted Pairs (Ω/kilofoot)

Design Temperature	19 AWG	22 AWG	24 AWG	26 AWG
13 °C (55 °F)	15.9	31.7	50.3	81.1
38 °C (100 °F)	17.4	34.8	55.3	89.2
60 °C (140 °F)	18.9	37.7	59.8	96.5

*A trunk cable is more strictly defined as a cable not providing exchange service to individual subscribers, but instead providing trunk service between exchanges. In the digital transmission environment the difference becomes less clear.



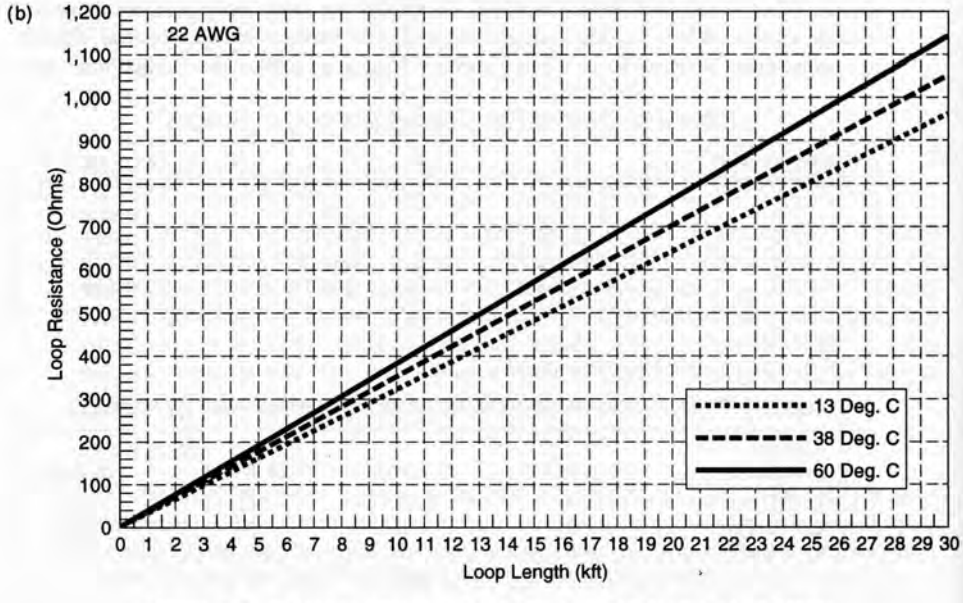
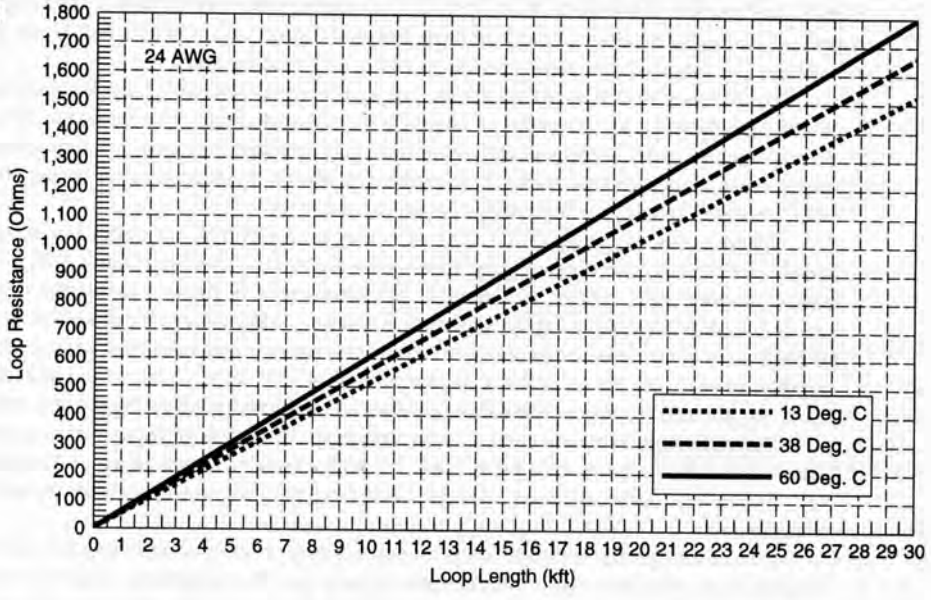


Figure 7-8 dc loop resistance vs. loop length: (a) 19 AWG; (b) 22 AWG; (c) 24 AWG; (d) 26 AWG

(c)



(d)

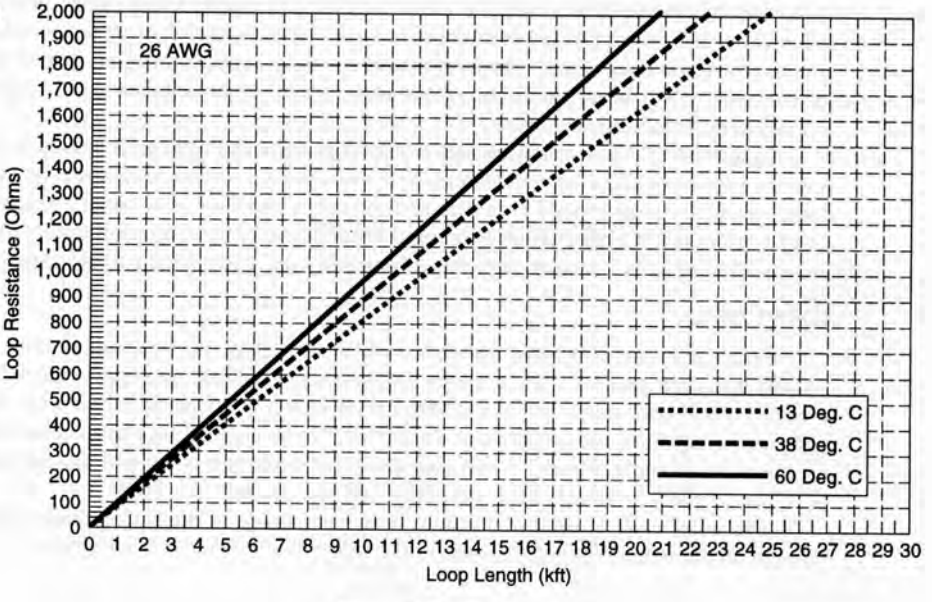


Figure 7-8 Continued

dard pair counts, from six to 4,200 pairs. The smaller sizes (up to 150 or 200 pairs) present particular problems with high-speed digital transmissions because of crosstalk between the unavoidably close-spaced transmit and receive pairs.

To alleviate the crosstalk problem, compartmental core cables are available in cables sizes from 12 to 200 pairs. In larger, noncompartmental core cables, the transmit and receive pairs are physically separated, and crosstalk reduced, by appropriate selection of binder groups for each transmission direction. If separation is not possible, repeater spacing or loop length must be reduced.

When cables up to around 1,200 pairs are manufactured for direct burial and aerial applications, the core may be filled with a polyethylene/petroleum jelly, extended thermoplastic rubber, or extended petroleum wax to prevent insulation damage and higher attenuation from moisture intrusion. Alternately, these cables may be built with an air core (absence of a filling compound) and then pressurized after installation with dry air to prevent moisture ingress. All larger cables (above 1,200 pairs) are pressurized unless the cables are specially ordered with a filling compound.

Moisture in a cable increases its capacitance. With higher capacitance comes higher attenuation, which can be as much as 40% over dry values at voice frequencies. Expanded foam cables are always filled because they are especially sensitive to moisture.

It is virtually impossible to keep moisture out of unpressurized, air core cables installed in an outdoor environment over a long period, regardless of the service classification. This applies to aerial, direct buried, and underground cables. If pressurization is not available, or if the cable is relatively small, filled cables provide much better long-term service than unpressurized, air core cables in all service classifications. Contrary to fairly common practice among some companies, unpressurized air core cables never should be placed underground or directly buried if the goal is long-term, trouble-free service.

Historically, telecommunications terminal equipment has been sensitive to the polarity of the tip and ring conductors. For switched subscriber loops, the tip conductor normally is at ground potential and the ring conductor is at battery potential (−48 V nominal). Conductors in pairs used for dedicated digital loops normally have no specified polarity, even though these frequently are designated tip and ring.

Color Coding

Many pairs are combined together to form the cable. The individual pairs are formed into units and the units are then assembled, or cabled, into cores (much like a rope). The basic unit of most modern cables contains 25 pairs, which are color coded for identification, as shown in Table 7-8.* Note also the repetitive color code for the tracer every five pairs. When necessary, the basic unit is divided into subunits of 12 or 13 pairs to attain cable roundness and the desired pair count.

The color code is used as follows. The basic color of the tip conductor insulation material is the first color shown in the table. The insulation has a striped tracer

*Appendix D provides cable core layout details for most cable types.

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Table 7-8 Telephone Pair Color Code—25-Pair Unit Binder Group

Pair No.	Color (Tip-Ring)	Pair No.	Color (Tip-Ring)	Pair No.	Color (Tip-Ring)
1	White-blue	11	Black-blue	21	Violet-blue
2	White-orange	12	Black-orange	22	Violet-orange
3	White-green	13	Black-green	23	Violet-green
4	White-brown	14	Black-brown	24	Violet-brown
5	White-slate	15	Black-slate	25	Violet-slate
6	Red-blue	16	Yellow-blue		
7	Red-orange	17	Yellow-orange		
8	Red-green	18	Yellow-green		
9	Red-brown	19	Yellow-brown		
10	Red-slate	20	Yellow-slate		

of the second color. The reverse is true of the ring conductor; that is, the basic color is the second color shown in the table and the tracer is the first color. For example, the basic color of pair 1 tip conductor is white and the tracer is blue, and the basic color of the ring conductor is blue and the tracer is white.

In cables larger than 25 pairs, the groups (or units) are wrapped with a colored tracer ribbon (unit or group binder) according to a similar color coding scheme, as shown in Table 7-9. For example, a 100-pair cable contains four groups of 25 pairs each. The first group (pairs 1 to 25) is wrapped with a white-blue binder, the second group (pairs 26 to 50) is wrapped with a white-orange binder, and so on. Since there are 25 basic colors in the color code, up to twenty-five 25-pair groups can be identified this way. Only 24 are used, however, which takes care of cables up to 600 pairs. Beyond 600 pairs, "super unit binders" are used. Each 600-pair super unit is wrapped with an appropriate binder. This color code is shown in Table 7-10. Figure 7-9 shows the unit and super unit relationships in a 3,000-pair exchange cable.

Table 7-9 Group Binder Color Code[a]

Pair Group	Group No.	Color (Tip-Ring)	Pair Group	Group No.	Color (Tip-Ring)
1–25	1	White-blue	301–325	13	Black-green
26–50	2	White-orange	326–350	14	Black-brown
51–75	3	White-green	351–375	15	Black-slate
76–100	4	White-brown	376–400	16	Yellow-blue
101–125	5	White-slate	401–425	17	Yellow-orange
126–150	6	Red-blue	426–450	18	Yellow-green
151–175	7	Red-orange	451–475	19	Yellow-brown
176–200	8	Red-green	476–500	20	Yellow-slate
201–225	9	Red-brown	501–525	21	Violet-blue
226–250	10	Red-slate	526–550	22	Violet-orange
251–275	11	Black-blue	551–575	23	Violet-green
276–300	12	Black-orange	576–600	24	Violet-brown

[a]In cables of 100 pairs (4 groups) or fewer, the white binder is optional.

Table 7-10 Super Unit Binder Color Code

Super Unit	Binder Color
Pairs 1 to 600	White
Pairs 601 to 1,200	Red
Pairs 1,201 to 1,800	Black
Pairs 1,801 to 2,400	Yellow
Pairs 2,401 to 3,000	Violet
Pairs 3,001 to 3,600	Blue
Pairs 3,601 to 4,200	Orange

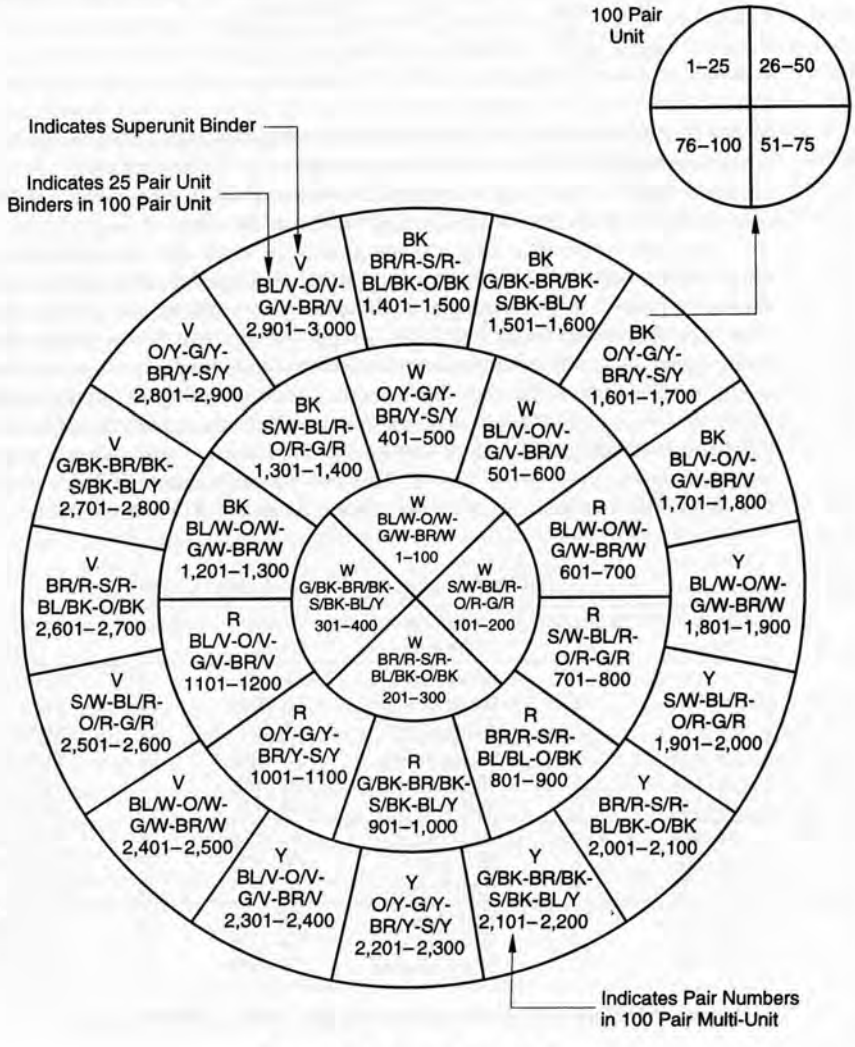


Figure 7-9 Super unit cable layout

On large exchange cables consisting of 1,200 pairs or more, the mirror-image color code and unit arrangement can be obtained, if desired. This color code is sometimes called the "Bell Design" and differs from the unit and super unit binder groups described above. For mirror-image cables, the 25-pair units are assembled into 100-pair multi-units. Each unit is identified by a standard color sequence binder: blue (pairs 1 to 25); orange (pairs 26 to 50); green (pairs 51 to 75); and brown (pairs 76 to 100).

Multi-units in a mirror-image cable are identified by a two-color binder and layering scheme. The first multi-unit in each layer has a green binder, which designates the "marker" unit. Marker units are situated radially, and a red and a blue unit are placed on each side, as shown in Figure 7-10, for a 3,000-pair mirror-image cable. The second color in the multi-unit binder indicates the layer and alternates between yellow and black. The outermost layer is yellow, second layer in is black, third layer in is yellow, and so on. Therefore, the outermost marker will have a green-yellow binder, and the marker for the "second layer in" will have a green-black binder.

With one's back to the central office, the pair counts of mirror-image cables start with the centermost marker multi-unit, with pairs 1 to 100, and continue clockwise to pairs 101 to 200 in the second multi-unit (red), and so on. The count continues through subsequent layers by following the same counting rules, always starting with the marker unit.

The most common residential type station wire (also known as "quad" or inside/outside wire, I/O) consists of four conductors, with the color code shown in Table 7-11. Quad normally is not recommended for digital service because of its limited twisting (and higher crosstalk), but it can be used on short runs (<50 feet) at subrates when nothing else is available.

Other types of multipair station wire will conform to the color code shown in Table 7-8. In addition, various other color codes are used for wiring electronic equipment, some of which may be used in telecommunication systems.

Table 7-11 Quad Station Wire Color Code[a]

Pair No.	Color (Tip-Ring)
1	Green-red
2	Black-yellow

[a]The yellow conductor (or yellow and black conductors together) is used as a ground lead, if required, by the terminal equipment.

Conductor Insulation

All modern cable conductors are insulated with a polyolefin (plastic) formed by an extrusion process. Older cables use a paper (or pulp) insulation. PIC, as defined earlier, is a general term used to describe all modern plastic insulated cables. Such cables may use solid, cellular foam, or foam skin (skinned foam) insulation. The actual insulation type may be classified as solid (polyethylene or polypropylene) or expanded foam (dual expanded polyethylene or expanded polyethylene, PVC).

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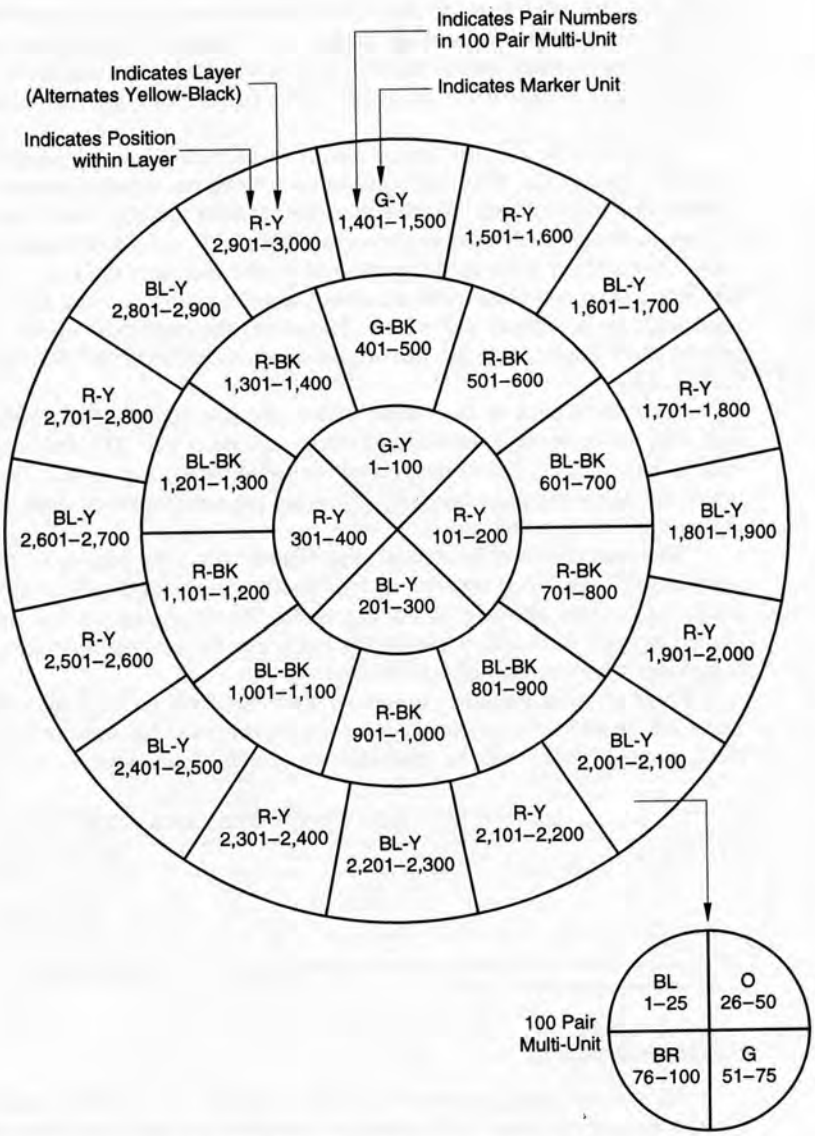


Figure 7-10 Mirror-image cable pair layout

A combination of solid and foam insulation is used in foam skin cables. In these cables, the regular foam insulation is covered by a solid plastic skin of about 2-mil thickness for added strength. Expanded foam cables have found widespread use since about 1980.

The dimensions and dielectric constant of the insulation and surrounding material determine the capacitance of twisted pair cables. The dimensions are shown in Figure 7-11 for each of the common cable gauges. The dielectric constant of solid plastic insulations used in exchange cables is about 2.3, whereas the dielectric constant of the expanded foam is about 1.6. Insulation thicknesses vary from about 10 mils for solid insulations, used in air core cables and filled foam cables, to about 14 mils for solid insulations used in filled cables. The relationship for twisted pair capacitance is

$$C = \frac{K\varepsilon}{\log\left(\frac{1.5D}{d}\right)} \text{ nF/length}$$

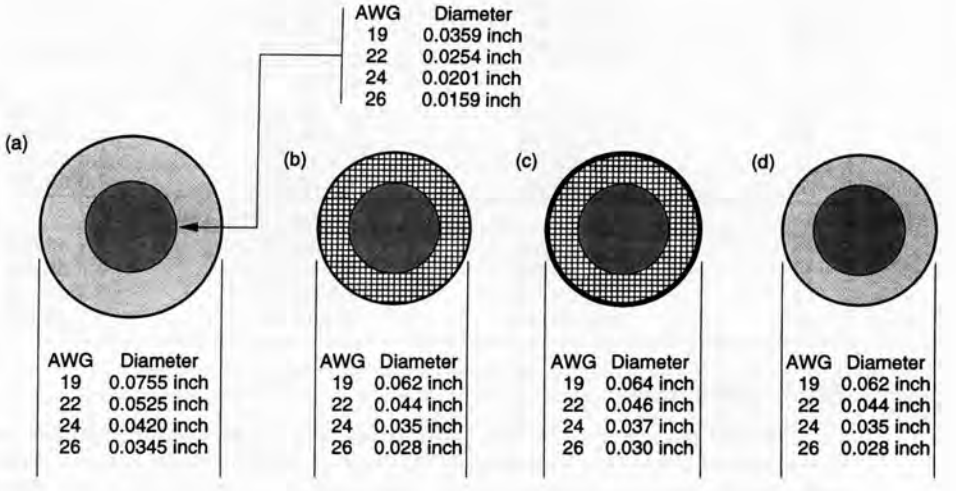


Figure 7-11 Twisted pair insulation and conductor dimensions: (a) Filled core/solid insulation; (b) Filled core/foam insulation; (c) Filled core/skinned-foam insulation; (d) Air core/solid insulation

where K = constant of proportionality, which depends on the dielectric properties of the medium surrounding the insulation (either air or filling compound)
ε = dielectric constant of the insulating material
D = diameter of the insulation
d = diameter of the conductor (units of D and d must be the same)

The transmission performance of the different conductor insulations is the same at voiceband frequencies, but this is not the case at the higher frequencies. The transmission performance of expanded foam cables at digital carrier frequencies falls between solid insulated air core and solid filled core cables at 772 kHz, which is the Nyquist frequency for repeatered T1-carrier.

A key indicator of performance is attenuation, which is given in Table 7-12 for various insulation types and frequencies. The values shown are averages for a wide variety of cables. Significant deviations exist for specific cable types at 772 kHz. A more complete list is given for this frequency in Chapter 9.

Table 7-12 Average Attenuation of PICs at 20 °C (68 °F)

AWG	1 kHz	150 kHz	772 kHz
		Solid Insulation—Filled Core	
19	0.23 dB/kft	1.3 dB/kft	2.8 dB/kft
22	0.34 dB/kft	1.8 dB/kft	4.0 dB/kft
24	0.43 dB/kft	2.4 dB/kft	5.0 dB/kft
26	0.55 dB/kft	3.5 dB/kft	6.4 dB/kft
		Foam or Foam-Skin—Filled Core	
19	0.23 dB/kft	1.4 dB/kft	3.2 dB/kft
22	0.34 dB/kft	2.0 dB/kft	4.5 dB/kft
24	0.43 dB/kft	2.7 dB/kft	5.6 dB/kft
26	0.55 dB/kft	3.7 dB/kft	7.0 dB/kft
		Solid Insulation—Air Core	
19	0.23 dB/kft	1.4 dB/kft	3.3 dB/kft
22	0.34 dB/kft	2.0 dB/kft	4.6 dB/kft
24	0.43 dB/kft	2.7 dB/kft	5.7 dB/kft
26	0.55 dB/kft	3.6 dB/kft	7.2 dB/kft

7.6.2.9 Cable Costs

Twisted pair cable costs vary considerably with gauge, construction, and the current cost of copper and aluminum (if that type of shield is used). Nineteen gauge cable can be twice as expensive as 24 gauge cable for a given pair count. Filled cable is 10 to 25% more expensive than air core cable, depending on the gauge and pair count. Expanded foam insulation cables are less expensive than comparable solid insulation cables by 7 to 20%, depending on the gauge and pair count.

Tables 7-13 and 7-14 give multipliers to find the relative material costs for various cable gauges and sizes. Multipliers for adding a compartmental core separator (screen) to exchange cables are shown in Table 7-15. The use of each cable is explained in the note below it.

Table 7-13 Relative Costs of Twisted Pair Cable Gauges and Sizes Compared to 24 AWG

	Pairs							
AWG	12	25	50	100	200	400	900	1,200
26	0.72	0.73	0.82	0.78	0.77	0.76	0.77	0.76
24	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	1.18	1.21	1.41	1.31	1.43	1.40	1.36	1.37
19	1.94	2.33	2.59	2.59	2.56	2.57	N/A	N/A

This is a vertically oriented matrix where costs are shown relative to 24 gauge, filled PIC, 8-mil aluminum shield. For example, a 26 AWG, 100-pair cable is 78% of the cost of a 24 AWG, 100-pair cable, and a 22 AWG, 400-pair cable is 140% of the cost of a 24 AWG, 400-pair cable.

Table 7-14 Relative Costs of Twisted Pair Cable Sizes for a Given Gauge

	Pairs							
AWG	12	25	50	100	200	400	900	1,200
26	0.22	0.34	0.57	1.00	1.86	3.72	8.18	10.44
24	0.23	0.35	0.54	1.00	1.91	3.71	8.31	10.73
22	0.20	0.32	0.58	1.00	2.08	3.96	8.62	11.22
19	0.17	0.31	0.54	1.00	1.88	3.68	N/A	N/A

This is a horizontally oriented matrix where costs are shown relative to a 100-pair cable of a given gauge. For example, a 26 AWG, 50-pair cable is 57% of the cost of a 26 AWG, 100-pair cable, and a 22 AWG, 400-pair cable is 396% of the cost of a 22 AWG, 100-pair cable.

Table 7-15 Multiplier for Adding Compartmental Core Separator to a Cable

	Pairs							
AWG	12	25	50	100	200	400	900	1,200
26	1.19	1.16	1.12	1.10	1.06	1.08	1.07	N/A
24	1.15	1.13	1.10	1.08	1.05	1.06	1.06	N/A
22	1.23	1.22	1.14	1.13	1.08	1.10	1.10	N/A
19	1.18	1.16	1.11	1.09	1.06	N/A	N/A	N/A

This matrix gives multipliers for adding a compartmental core separator (screen) to a cable of given size and gauge. For example, to determine the cost of adding a screen to a 26 AWG, 50-pair exchange cable, multiply its cost by 1.12, and to determine the cost of adding a screen to a 22 AWG, 200-pair exchange cable, multiply its cost by 1.08.

7.6.3 Electrical Characteristics

7.6.3.1 Bandwidth

Digital loops consist of one or two cable pairs. The cable pair is a transmission line, and it has predictable electrical characteristics. Twisted pair cables are not used presently with digital transmission systems requiring more than several megahertz of bandwidth for several reasons, as will be discussed. For comparison with voice-

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band applications, the usable bandwidth on an analog loop is considered to be limited to around 3,100 Hz (300 to 3,400 Hz) [4]. The limitation is due to the coupling transformers and other devices connected to voiceband loops.

In digital loops, a much wider bandwidth is needed for information transmission. This point is often missed in preliminary considerations of the advantages of digital transmission and cannot be overemphasized. For example, a digitally encoded voicegrade (3,100 Hz) circuit could actually require a transmission line bandwidth of as much as 64 kHz.

It is important to realize the difference between circuit bandwidth and transmission bandwidth. Figure 7-12 shows the power spectral density of a hypothetical voiceband signal that has been encoded at an 8 kHz rate into 8-bit samples (64 kbps), filtered by a first-order Butterworth lowpass filter, and transmitted using a return-to-zero (RZ), bipolar, alternate mark inversion (AMI) line code. The main lobe of the spectrum is centered at 32 kHz and extends out to at least 64 kHz.

The frequency response of a loop derived entirely from twisted pairs extends down to dc (zero frequency). Digital loop transmission systems avoid using dc for information carrying, so the loops can be transformer-coupled to regenerators. DC continuity is still required in the metallic loop circuit, however, for loop powering schemes and sealing current. When signals with frequency content approaching zero frequency are placed on the loop, the transmission is considered to be in the baseband.

A twisted pair digital loop has no precise upper frequency limit. Transmission systems using the loop are designed to accommodate its attenuation characteristics over the required bandwidth. For example, the T1C system, which operates at 3.152

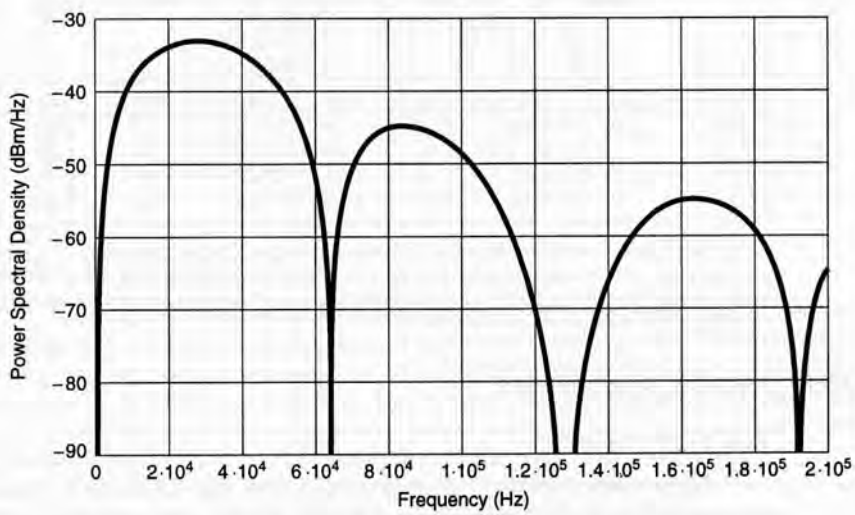


Figure 7-12 Power spectral density of a 64 kbps digitally encoded voiceband signal using bipolar AMI transmission

Mbps, has a bandwidth requirement of about 3.152 MHz. This one-for-one bit rate to bandwidth correspondence does not hold for all digital transmission systems. The T1C has the highest bandwidth requirements (and bit rate) of digital loop systems using twisted pair cable considered in this book.*

7.6.3.2 Transmission Line Primary Constants

Like all transmission lines, twisted pairs can be described by their fundamental electrical characteristics, or primary constants.† The primary constants are series inductance L, shunt capacitance C, shunt conductance G, and series resistance R. These are described in customary electrical units per unit length. Figure 7-13 shows a T-equivalent circuit commonly used to represent telecommunication transmission lines.

Inductance L of the typical cable pair depends on the geometry of the conductors and is affected by the magnetic flux distribution within and around them. It is around 0.19 mH/kilofoot at voice frequencies for air core PIC and about 7 to 10% higher for filled PIC. Due to skin effect, inductance starts to decrease at about 20 kHz and continues to decrease to at least 5 MHz.‡

Capacitance C depends on the geometry of and dielectric medium between the two conductors of the twisted pair. It is standardized during manufacture at 12.5 or 15.7 nF/kilofoot (66 or 83 nF per mile), although cables with different values are available. Cable with 15.7 nF/kilofoot capacitance is the most common in digital loop applications, but a special low-capacitance cable, with 12.5 nF/kilofoot, is preferred for higher bit-rate systems such as the 3.152 Mbps T1C system. For all practical purposes, capacitance is independent of frequency.

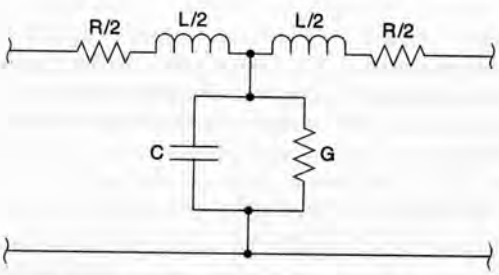


Figure 7-13 Transmission line T-equivalent circuit in terms of primary constants

*The differences between digital loop systems, digital backbones, and digital trunk transmission systems are becoming less clear as these systems become more prevalent. It is arguable whether a digital system operating at the DS-3 rate (45 MBPS) can be considered a digital loop system.

†As will be seen, the primary constants are not really constant, but the terminology is traditional and will be used here.

‡Skin effect is the tendency for higher-frequency currents to travel near the outside surface of a conductor rather than be distributed evenly throughout the entire cross-section.

Conductance G depends on the dielectric medium between the conductors and is negligible at about 0.04 microsiemen (μS) per kilofoot at 1 kHz for modern cables. It increases by a factor of ten for each decade (factor of ten) increase in frequency. The value can vary considerably from those given here, due to different insulation types and core filling compounds.

Resistance R, measured in Ω/kilofoot, depends on the resistivity of the conductors and the current distribution within them. It is constant at lower frequencies (less than a few hundred hertz) but is approximately proportional to the square root of frequency at higher frequencies (above several tens of kilohertz) where skin effect and proximity effect dominate. The resistance of each conductor gauge is different due to the different cross-sectional area.

The primary constants are affected by temperature in different ways. Some primary constants depend on whether the cable has a filled or air core. The following summarizes the temperature effects:

- Inductance varies only slightly with temperature (1.8% from −18 to +49 °C).
- Capacitance of filled cables decreases linearly at a rate of 0.016% per °C over the frequency range of 1 kHz to 3 MHz. This is attributed to a decrease in insulation density, cable expansion, and a decrease in dielectric constant with temperature increase. In air core cables, the capacitance varies only slightly with temperature over the same frequency range [38].
- Conductance varies only negligibly with temperature.
- Resistance is highly temperature dependent, increasing by about 4% for each 10 °C increase in conductor temperature at voice frequencies and 2 to 3% at frequencies higher than 10 kHz.

Tables 7-16 and 7-17 give the primary constants for typical cable pair gauges at selected frequencies [33]. A more complete listing of outside plant characteristics is given in Appendix C. Figure 7-14 shows the variation of the primary constants with frequency in graphical form (capacitance is not shown because it is frequency independent).

7.6.3.3 Secondary Parameters

The propagation constant ($\rho = \alpha + j\beta$) and characteristic impedance (Z_0) are the secondary parameters used to describe transmission line characteristics.* These parameters, which are functions of frequency, can be found from the primary constants from

$$\rho = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)}$$

where ω is the radian frequency, 2πf.

*The secondary parameters are mathematically derived from the primary constants in [4]. Simplified analyses of twisted pair cable secondary parameters when the primary constants are known, and primary constants when secondary parameters are known, are covered rather well in [34]. There are numerous other sources of information on twisted pair transmission characteristics; see [33–37].

Table 7-16 Air Core PIC, Exchange Cable Pair Primary Constants, 20 °C

FREQUENCY (kHz)	R (Ω/kft)	L (mH/kft)	C (nF/kft)	G (μS/kft)
		19 AWG		
1	16.1	0.182	15.7	0.0398
40	18.7	0.173	15.7	1.58
192	35.3	0.156	15.7	7.58
772	70.2	0.144	15.7	30.4
1,576	98.9	0.140	15.7	62.0
		22 AWG		
1	32.4	0.184	15.7	0.0398
40	34.2	0.177	15.7	1.58
192	50.4	0.167	15.7	7.58
772	100.8	0.151	15.7	30.5
1,576	141.2	0.146	15.6	62.0
		24 AWG		
1	51.3	0.181	15.7	0.0398
40	53.0	0.175	15.7	1.58
192	67.0	0.167	15.7	7.58
772	127.7	0.151	15.7	30.5
1,576	182.1	0.145	15.6	62.0
		26 AWG		
1	82.0	0.183	15.7	0.0398
40	83.6	0.177	15.7	1.58
192	94.4	0.172	15.7	7.59
772	159.8	0.159	15.7	30.5
1,576	230.3	0.152	15.7	62.0

The propagation constant is a complex number consisting of real and imaginary parts. In general, it describes the attenuation and phase characteristics of any transmission line. The real portion of the propagation constant, denoted Re(ρ), is called the attenuation constant α, and the imaginary portion, denoted Im(ρ), is called the phase constant β. The attenuation constant is expressed in Nepers per unit length and the phase constant, in radians per unit length.*

The characteristic impedance is independent of length. It, too, can be found from the primary constants:

$$Z_0 = \sqrt{\frac{(R + j\omega L)}{(G + j\omega C)}}$$

The equations for the secondary parameters can be simplified somewhat for modern outside plant PIC, as follows:

$$\rho = \sqrt{-\omega^2 LC + j\omega RC} \text{ for frequency } < 500 \text{ kHz, and}$$

*A more convenient unit than the Neper is the decibel such that 1 Neper = 8.686 dB.

Table 7-17 Filled Core PIC, Exchange Cable Pair Primary Constants, 20 °C

FREQUENCY (KHZ)	R (Ω/KFT)	L (MH/KFT)	C (NF/KFT)	G (μS/KFT)
		19 AWG		
1	16.1	0.212	15.7	0.0398
40	18.2	0.202	15.7	1.58
192	32.8	0.189	15.7	7.58
772	63.8	0.178	15.7	30.5
1,576	89.6	0.174	15.6	62.0
		22 AWG		
1	32.4	0.212	15.7	0.0398
40	33.9	0.205	15.7	1.58
192	47.7	0.196	15.7	7.59
772	93.0	0.182	15.7	30.5
1,576	129.4	0.178	15.7	62.0
		24 AWG		
1	51.3	0.212	15.7	0.0398
40	52.7	0.206	15.7	1.58
192	64.1	0.199	15.7	7.58
772	117.4	0.186	15.7	30.5
1,576	165.5	0.180	15.6	62.0
		26 AWG		
1	82.0	0.212	15.7	0.0398
40	83.3	0.205	15.7	1.58
192	92.1	0.200	15.7	7.59
772	149.4	0.190	15.7	30.5
1,576	212.7	0.183	15.7	62.0

See text for discussions of R, L, C, and G.

$$\rho = \frac{R}{2}\sqrt{\frac{C}{L}} + j\omega\sqrt{LC} \text{ at higher frequencies}$$

with

$$\alpha = \text{Re}(\rho) \text{ and } \beta = \text{Im}(\rho) \text{ as before}$$

$$Z_0 = \sqrt{\frac{L}{C} - j\frac{R}{\omega C}} \text{ for frequency } < 500 \text{ kHz}$$

$$Z_0 = \sqrt{\frac{L}{C}} \text{ at higher frequencies}$$

The characteristic impedance also is a complex number. At low frequencies (around 1 kHz), the real and imaginary parts are about equal in magnitude. At higher frequencies (above 100 kHz), the imaginary part becomes small, and the impedance is essentially constant and real at approximately 100 Ω.

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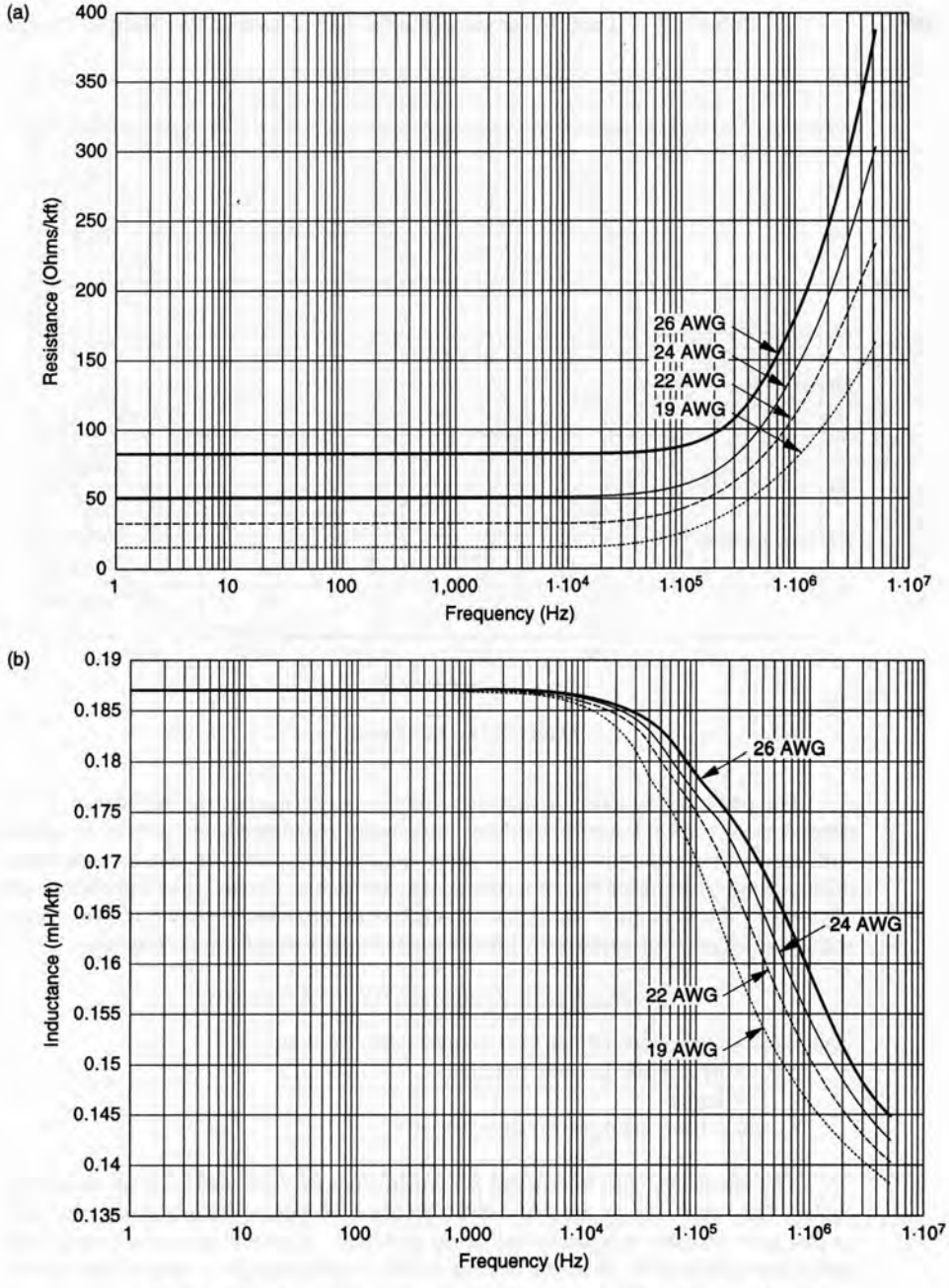


Figure 7-14 Twisted pair primary constants for typical PIC at 21 °C: (a) Resistance vs. frequency; (b) Inductance vs. frequency; (c) Conductance vs. frequency

(c)

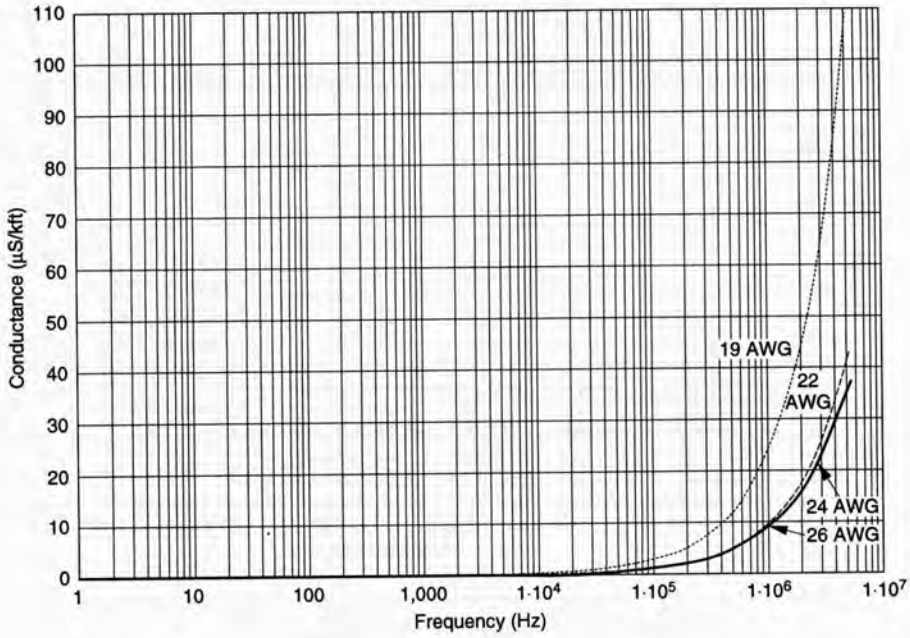


Figure 7-14 Continued

For perfectly matched transmission lines, the characteristic impedance is independent of transmission line length. A constant real impedance is easy to match with modern terminal equipment. In some applications, however, due to impedance mismatching of the loop by its terminations, the actual circuit input impedance (as opposed to the theoretical cable pair characteristic impedance shown above) varies with loop length. An expression for the input impedance of a real loop is:

$$Z_{in} = Z_0\{[Z_T + Z_0 \tanh(\rho l)]/[Z_0 + Z_T \tanh(\rho l)]\}$$

where Z_T = impedance of the load connected to the loop
tanh = hyperbolic tangent function
l = length
Z_0 and ρ have been previously defined

The secondary parameters are shown in Figures 7-15 and 7-16 for exchange cables. The values shown are sufficiently accurate for many practical situations, such as insertion loss and impedance matching problems. If greater accuracy is required, actual test data can be obtained from the cable manufacturers or actual field installations.

As with the primary constants, secondary parameters are temperature dependent. Attenuation is related to temperature such that the higher the temperature, the

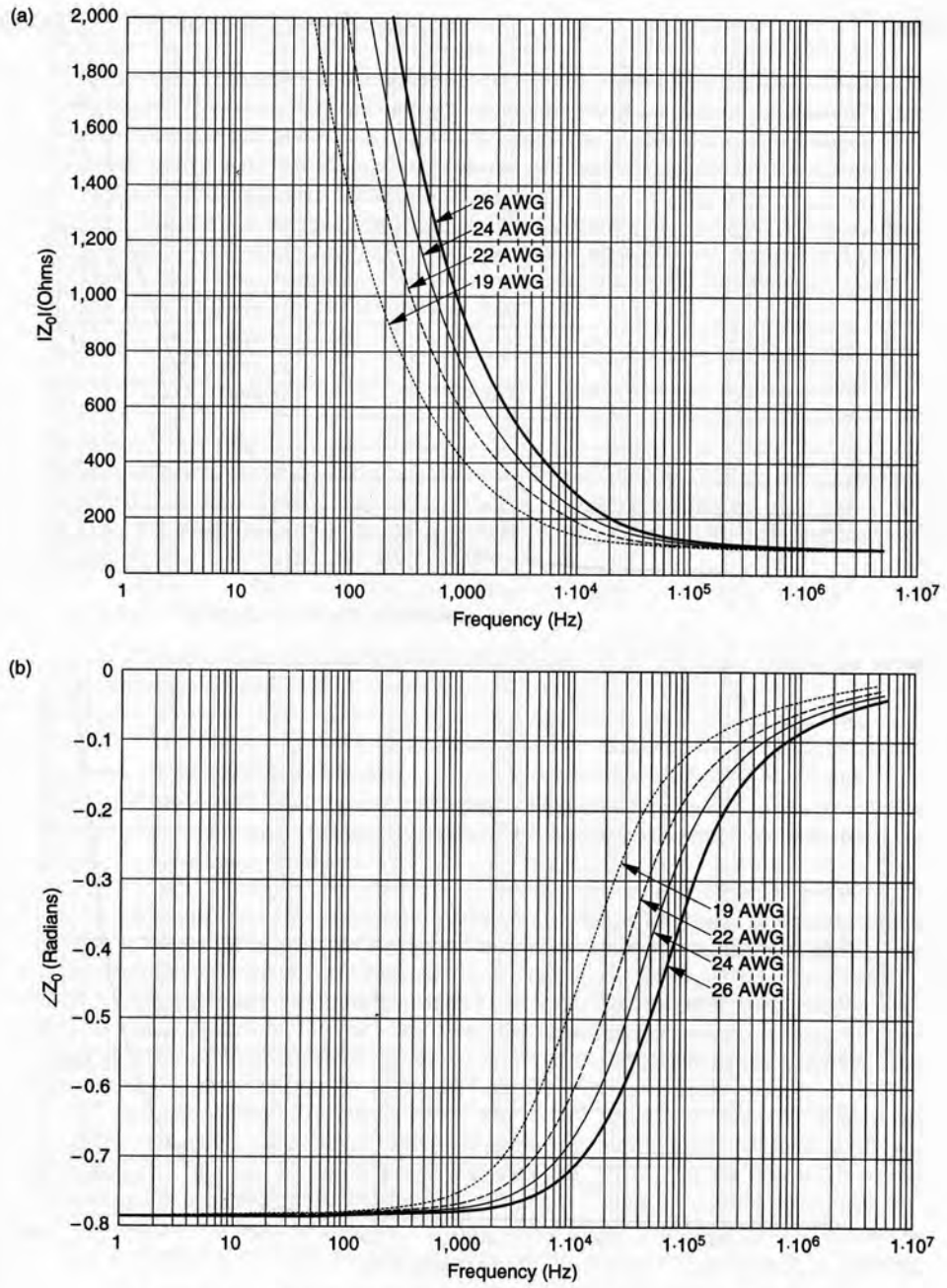


Figure 7-15 Twisted pair secondary parameters, characteristic impedance: (a) Impedance magnitude; (b) Impedance angle

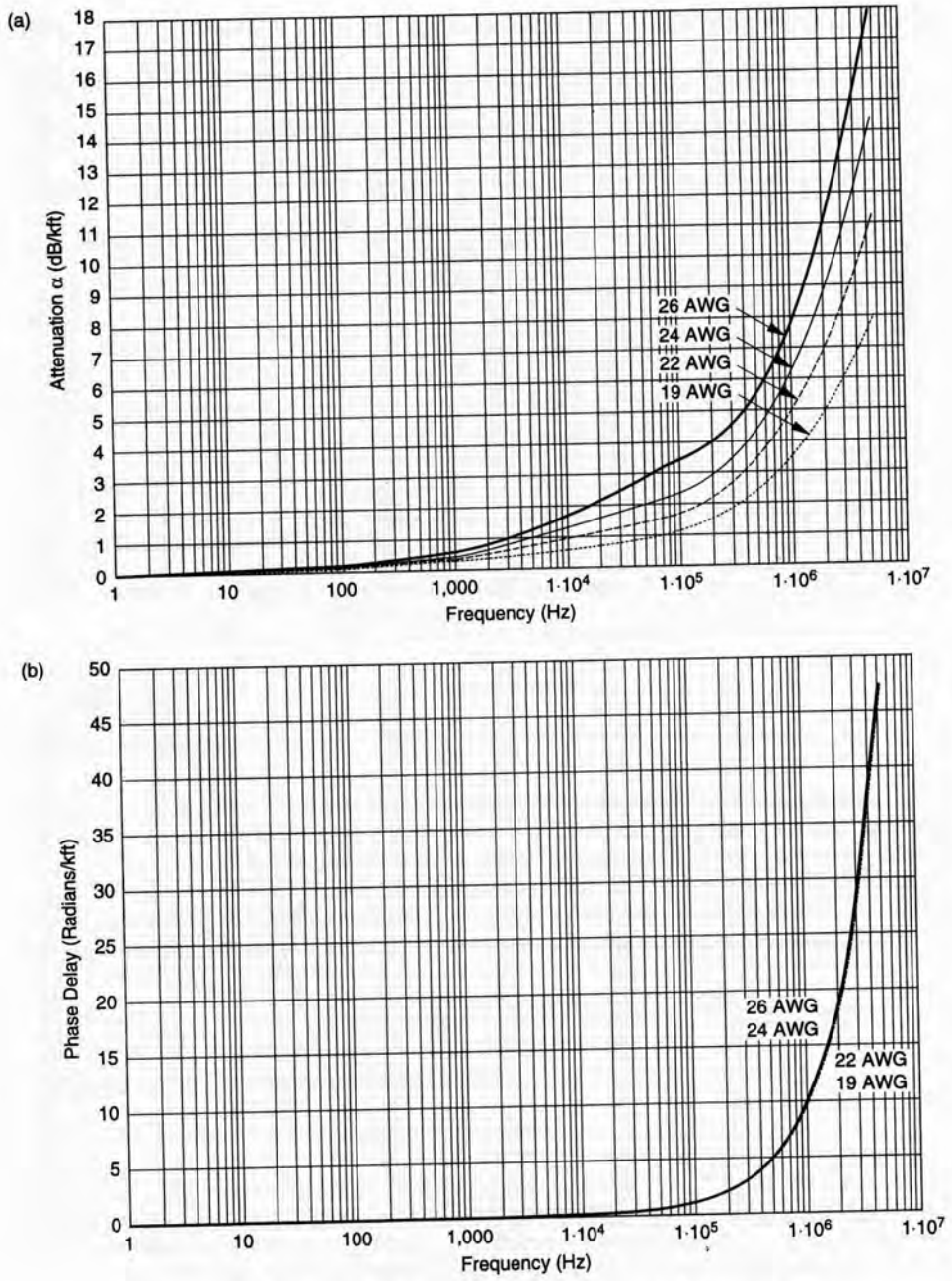


Figure 7-16 Twisted pair secondary parameters: (a) Attenuation vs. frequency; (b) Phase delay vs. frequency

higher the attenuation. The relationship is nonlinear and due primarily to changes in conductor resistance. Transmission parameters provided on cable manufacturer's data sheets usually are given at 55 °F (12.8 °C) or 68 °F (20 °C). Current digital loop design methods require the quoted values to be adjusted (corrected) to the maximum expected temperature of operation.

The attenuation characteristics of PIC frequently are modeled using a single parameter. The single-parameter model assumes attenuation is proportional to $\sqrt{f}$. Therefore, if the attenuation $\alpha(f_0)$ is known at frequency f_0, the attenuation $\alpha(f)$ at any other frequency f can be obtained from:

$$\alpha(f) = \alpha(f_0)\sqrt{\frac{f}{f_0}}$$

This model assumes that skin effect causes the predominant impact on attenuation, which is not true at low frequencies. Therefore, although fairly accurate above 200 kHz, the single-parameter model is useless in many digital loop applications, particularly the ISDN DSL and subrate digital loops.

7.6.3.4 Transmission Requirements

The fundamental transmission requirements of digital loops follow the same principles as analog loops.* On any digital loop:

- The signal must have adequate level so the presence of a signal element may be reliably detected, and
- The signal level must be sufficiently higher than the noise to ensure reliable differentiation between the signal elements and noise (high enough signal-to-noise ratio, SNR).

Adequate level is provided by controlling circuit loss for a given transmitter power output. Adequate SNR is provided by controlling crosstalk and taking care to limit the adverse effects of impulse and other noise through proper shielding.

For reference, it is informative to know what the acceptable SNRs are for various types of circuits. Digital loops operate with acceptable error performance if the SNR is above approximately 15 dB. As a rule of thumb, each dB of change in SNR will change the error rate by a factor of ten for error rates in the vicinity of 10E-6. For example, if the error rate is 10E-6 with 14 dB SNR, it will be 10E-5 at 13 dB SNR. Generally, the SNR for individual analog circuits should be at least 30 dB for voice calls (based on subscriber satisfaction) and 15 to 20 dB on data calls using analog modems (based on the specified error rate, coding, and modulation method). These figures are end-to-end. Each portion of the transmission system (loops, switching systems, terrestrial and satellite radio systems, and so on) contribute to lowering

*See [4] for analog transmission requirements.

the SNR. It follows that the SNR for any given part of the overall connection must be higher than the overall requirement.

For an analog voice circuit being transmitted on a digital loop carrier system, poor error performance of the digital loop manifests itself indirectly to the listener in terms of distortion, dropouts, and other annoyances. A degraded channel in this case may still be usable for voice transmission. Digital data circuits, on the other hand, are directly affected by error performance in that bit integrity is a requirement of digital transmission. Tolerable error levels on a digital data circuit are always much less than on a voice circuit. It should be noted there is no correlation between the attenuation of an analog signal and attenuation of the digital signal that represents it.

7.6.3.5 Loop Transmission Loss

Loop transmission loss is highly dependent on the frequency of operation. Equipment design compensates for this dependency by employing a number of equalization techniques. Digital loops have frequency components over a wide frequency range. To simplify the loop design process, a nominal frequency is chosen based on the frequency of peak energy or an upper frequency limit of significant energy for a particular loop type and the loss specified for that frequency. This nominal frequency depends on the transmission format, pulse shape, and a number of other factors.

A typical maximum loss of 32 to 42 dB at the nominal frequency is used, but the actual value depends somewhat on the technology. Also, the maximum quoted loss value may have to be reduced to counteract the adverse effects of crosstalk or other transmission impairments.

Some digital loop types require a minimum loss, which depends on the ability of the loop interface electronics to equalize the received signal automatically. For repeatered T1-carrier, the minimum loss is 7.5 dB unless the repeaters have built-in pads. If necessary, this minimum loss can be provided by external attenuators placed in the line at the receive end.

From this point forward, attenuation, as determined from the secondary parameters, is used interchangeably with insertion loss (or just loss). This is only strictly correct when the digital loop is terminated in the complex conjugate of its characteristic impedance (Z_0). In practice, this does not always happen (if ever), but for practical problems it is sufficiently accurate.

7.6.3.6 Transmission Levels

Adequate signal power at the receive end of a circuit is essential to providing satisfactory error rates in any digital transmission system. It is obvious this is not possible unless loop loss is thoroughly controlled and enough signal level is provided at the loop input.

Too much signal power, on the other hand, can overload the transmission facilities or terminal equipment and cause distortion and crosstalk. Because digital loop systems frequently share transmission facilities with other systems, such as voice and analog carrier systems, mutual interference is a potential problem. Therefore,

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the signal powers in these systems are coordinated with each other. This requires close attention to power levels at particular frequencies or particular frequency bands.

In digital systems, the signal power is not specified in the same way as with analog systems, where power levels (for example, in dBm) are referenced to a standard impedance (for example, 600 Ω). Instead, the digital levels are specified by pulse shape and maximum voltage level into a standard load impedance (typically 100 or 135 Ω). These two parameters serve to determine the spectral limits of the digital pulse train, and crosstalk considerations ensure noninterference.

7.6.3.7 Presentation of Transmission Parameters

Loss and noise directly affect regenerator and equipment error performance. The loss and noise parameters can be presented in a variety of ways. Typically, a range, variability, or other distribution of a particular parameter is specified. There should be some predetermined agreement between the design value and the measured value, but the measured value always will show some variability due to:

- Test equipment calibration
- Environmental variations that affect the circuit components as well as the measuring equipment
- Human factors associated with reading meters or displays
- Position of the test equipment or lead lengths
- Cable splicing techniques
- Cable and equipment manufacturing tolerances

These effects will influence the measurements of a large number of loops so that the results show some type of distribution. Therefore, when the transmission parameters of a digital loop are determined, they really can only be specified on a statistical basis.

For voicegrade (analog) applications, the Institute of Electrical and Electronic Engineers (IEEE) has identified three forms for the results of transmission parameter calculations or estimations [39]:

- A cumulative distribution
- A histogram
- An analytical distribution function

Although these forms are proposed by IEEE for voicegrade applications, they are generic in nature and apply just as well to digital applications.

Other forms, or variations of the above forms, can be used. The most typical, of course, is the single-value specification; for example, "The digital loop loss shall be 23.2 dB." More typically, in digital applications, the specification might read, "The equipment shall function with a digital loop loss between 7.5 and 35.0 dB." This provides a lower and upper bound only. The exact loss value for any loop does not matter as long as it falls within the specified bounds. Similarly, a cumulative

distribution would specify "95% of the loop losses shall fall between 7.5 and 33.0 dB." This specification allows some loops to have a loss outside of the boundaries, but no specification is given as to how far outside. A better specification would state "95% of the loop losses shall fall within 7.5 and 33.0 dB, and no loop shall have a loss less than 5.5 dB nor greater than 35.0 dB." If a normal distribution curve is used to specify the parameters, a mean value and a standard deviation are given. For example, "mean loop loss shall be 22.0 dB with standard deviation of 7.0 dB."

The normal distribution curve is shown in Figure 7-17. The various points labeled on the curve illustrate how transmission parameters are typically quantified. The average, or mean, value for the parameter is at the peak of the normal distribution curve. This is the value used for most field transmission calculations. At the outer edges, representing a small percentage of circuits, are the immediate action limits (IALs). If a parameter measurement gives an IAL or worse, immediate remedial action is required. Closer toward the mean are the maintenance limits (MLs). A parameter measurement falling between the ML and the IAL will receive remedial action during routine maintenance. The acceptance limits (ALs) are used when a new circuit or system is installed; these are necessarily tighter than the other limits to give allowance for equipment aging and other variations.

Because of this statistical nature, it would seem that individual parameters for several loop segments in tandem could not be combined by simple addition. This is

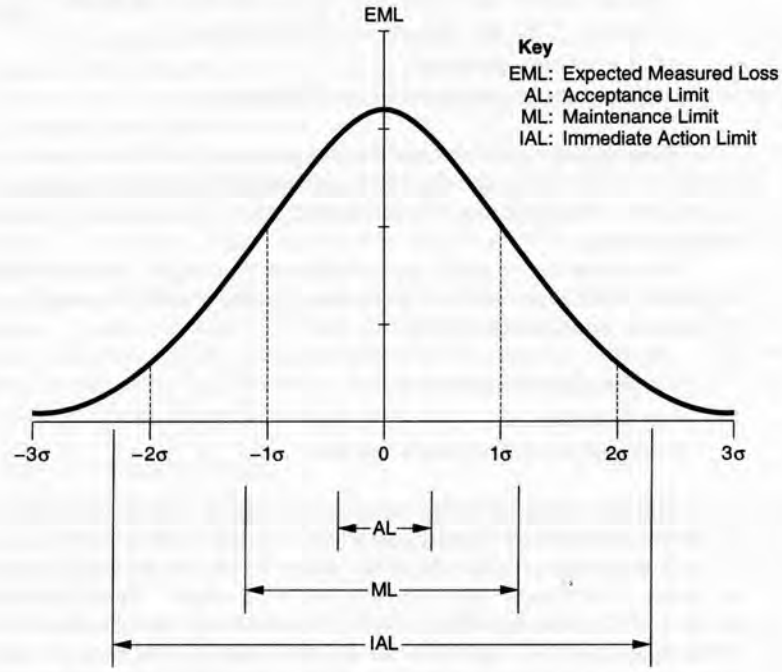


Figure 7-17 Normal distribution curve with circuit performance limits

indeed true, and various mathematical techniques are used to describe the entire connection.* For most field problems, however, parameter distributions are ignored, and simple addition is frequently used with satisfactory results.

7.6.3.8 Twisted Pair Cable Purchase Checklist

The checklist below is useful during the development of twisted pair exchange cable purchase specifications.

1. Specification? (ICEA, REA, BELLCORE) ☐
2. Deviations from the referenced specification? (specify) ☐
3. Pair gauge? (19, 22, 24, 26 AWG) ☐
4. Pair count? (not all pair counts are available with all cable gauges) ☐
5. Screened cable required? (T1, T1C, or T-Screen, D-Screen, Z-Screen) ☐
6. If screened, service pair requirements? (specify) ☐
7. Use? (direct buried, underground, aerial, riser, aerial self-supporting, service wire) ☐
8. Jacket environment? (severe, normal, submarine, rodent infested) ☐
9. Shield? (coated aluminum, copper) ☐
10. Armor? (heavy copper, steel, copper alloy) ☐
11. Factory pulling eyes required? (yes, no) ☐
12. Lengths required? (standard, custom; specify) ☐
13. Reel size or weight limitations? (specify) ☐
14. Reel requirements? (standard, wood, steel) ☐
15. Reel protection requirements? (none, wood lagging, pressboard) ☐
16. Shipping instructions? (specify) ☐

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*See, for example, Appendix B of [39].

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Analog

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Preface

The subscriber's loop continues to evolve as more and more *digital loop carrier* (DLC) and optical fibers are introduced into the *public switched telephone network* (PSTN).* But the loop's traditional use for carrying regular voice telephone calls on an analog basis over copper cable is still, by far, the most common. This will continue for a long time, perhaps until the year 2000, when optical fibers and *integrated services digital network* (ISDN) will play an equal, if not more important, role in the loop's function and use. Of course, this transition will not be instantaneous but will indeed take place as the evolution continues. Meanwhile, the loop will continue to be used much as it exists today.

The emphasis in this book is the practical application of telecommunication industry signaling and transmission practices and standards as they apply to voiceband subscriber loop design, construction and use. It tells what the loop does, how it is used and connected, and how it is designed in the sense of current applications.

Any person interested in the technical and qualitative aspects of the loop and its application—engineers, managers, construction experts, telecommunication system users and students—will find *Subscriber Loop Signaling and Transmission Handbook* informative and up to date. Some effort has been made to cover those areas over which the designer, builder or user has some control in a practical sense.

A considerable amount of diverse, but related, information appears in this book, much of which has never before been available in one volume. Chapter 1 covers the details of loop interface while Chapter 2 details loop signaling. These two chapters include practical information on terminal equipment. Unlike other, more common, discussions, this chapter goes beyond the so-called "500" set to include information on modern electronic instruments, key telephone systems and private branch exchanges.

* Listings of telecommunication terms and definitions are available [1,2].

3

The Outside Plant Facility

This chapter describes the types of physical outside plant facilities that make up the subscriber's loop. Of particular interest are the types and characteristics of cables used in subscriber loop applications. In addition, a description of the premises wiring is provided so the complete physical connection to the terminal equipment can be envisioned.

3.1 Cable Pairs

The main and most important part of a conventional two-wire loop is an outside plant cable pair (two twisted conductors), which provides a bidirectional signaling and transmission path. Some loops, in particular those associated with dedicated or private line circuits, consist of two cable pairs to provide a four-wire circuit with independent transmit and receive pairs. Associated with each cable pair of either the two-wire or four-wire loop are ancillary devices for protection and termination, which are discussed in Chapter 4.

3.2 Exchange Cables

Exchange cables are those cables used for exchange services such as regular subscriber or private line services.* Exchange cables are categorized according to their

* Many times, trunk and exchange services are combined in one cable; however, descriptions of trunk systems are beyond the scope of this book.

service classifications as shown in Table 3-1. These classifications are universal. It should be noted that it may be possible to use a given cable type in several classifications. For example, filled cable is normally considered for direct buried applications, but it is also used in aerial and underground service. Exchange cables are considered to have a life of 25 to 35 years.

Table 3-1 Exchange Cable Service Classifications

Class	Application
Indoor	Risers in the central office building
Aerial	Lashed to separate messenger or self-supporting on an above-ground structure
Buried	Buried directly in the earth
Underground	Installed underground in duct or conduit

Depending on the gauge, exchange cables are available in standard pair counts from 6 through 4,200 pairs. When cables up to around 1,200 pairs are manufactured for direct burial and aerial applications, the core may be filled with a jelly- or rubber-like substance to prevent insulation damage and higher attenuation from moisture. Alternately, these cables may be built with an air core and then pressurized after installation with dry air to prevent moisture ingress. All larger cables are pressurized. Moisture in a cable increases its capacitance; the increased capacitance can increase the attenuation as much as 40 percent over dry values.

It is virtually impossible to keep moisture out of unpressurized air-core cables installed in an outdoor environment over a long time period regardless of the service classification. If pressurization is not available, or the cable is relatively small, filled cables provide much better long-term service than unpressurized air-core cables in all service classifications. Contrary to fairly common practice among some companies, unpressurized air-core cables should never be placed underground or directly buried.

3.3 Color Coding

Many pairs are combined together to form a cable. The individual pairs are formed into units, and the units are then assembled or cabled into cores (much like a rope). The basic unit contains 25 pairs which are color coded for identification as shown in Table 3-2. Each conductor has a solid and tracer color, which is opposite to allow identification of tip and ring. For example, the tip conductor of pair 1 has a solid white color with a blue tracer. The ring conductor has a solid blue color with a white tracer. Note, also, the repetitive color code for the tracer every five pairs. When necessary, the basic unit is divided into sub-units of 12 or 13 pairs to attain cable roundness and the desired pair count.

In cables larger than 25 pairs, the units are wrapped with a colored tracer ribbon (unit binder) according to a similar color coding scheme. For example, a 100-pair cable contains 4 units of 25 pairs each. The first unit (pairs 1 through 25) would be wrapped with a binder colored white-blue, the second unit (pairs 26 through 50) would be colored white-orange, and so on. Since there are 25 basic colors in the color code, up to twenty-

five 25 pair units can be identified this way. Only 24 are used, however, which takes care of cables up to 600 pairs. Beyond 600 pairs, "super unit binders" are used. This color code is shown in Table 3-3.

The telephone color code shown in Table 3-2 is not the only one used. For example, the most common station wire, also known as *quad* or *inside/outside* (I/O) wire, consists of four conductors with the color code shown in Table 3-4. Other types of multi-pair station wire will conform to the color code shown in Table 3-2. In addition, various other color codes are used for wiring electronic equipment, some of which may be used in telecommunication systems.

Table 3-2 Telephone Color Code

Pair No.	Color (Tip-Ring)	Pair No.	Color (Tip-Ring)
1	White-Blue	14	Black-Brown
2	White-Orange	15	Black-Slate
3	White-Green		
4	White-Brown	16	Yellow-Blue
5	White-Slate	17	Yellow-Orange
		18	Yellow-Green
6	Red-Blue	19	Yellow-Brown
7	Red-Orange	20	Yellow-Slate
8	Red-Green		
9	Red-Brown	21	Violet-Blue
10	Red-Slate	22	Violet-Orange
		23	Violet-Green
11	Black-Blue	24	Violet-Brown
12	Black-Orange	25	Violet-Slate
13	Black-Green		

Table 3-3 Super Unit Binders

Super Unit	Binder Color
Pairs 1-600	White
Pairs 601-1,200	Red
Pairs 1,201-1,800	Black
Pairs 1,801-2,400	Yellow
Pairs 2,401-3,000	Violet
Pairs 3,001-3,600	Blue
Pairs 3,601-4,200	Orange

Table 3-4 Quad Station Wire Color Code

Pair. No.	Color (Tip-Ring)
1	Green-Red
2	Black-Yellow

Note: The yellow conductor (or yellow and black conductors together) is used as a ground lead when divided ringing is required.

3.4 Insulation

All modern cables use conductors insulated with a polyolefin (plastic) formed by an extrusion process. Older cables use a paper (or pulp) insulation. Polyolefin insulated cable (PIC) is a general term used to describe all modern plastic insulated cables. The actual insulation type may be classified as solid (polyethylene or polypropylene) or expanded foam (dual expanded polyethylene or expanded polyethylene – PVC). Expanded foam cables have found widespread use since about 1980. In many applications, material only costs for expanded foam are less (by about 10 to 15 percent) than solid insulation type cables. Expanded foam cables are always filled.

3.5 Crosstalk

As previously noted, each cable pair consists of two twisted insulated conductors. The twist is used to decrease electromagnetic interference (EMI) due to crosstalk between adjacent pairs in a cable. The twist also helps keep the conductors of the pair balanced with respect to the shield and other pairs. Neighboring pairs in a given 25-pair unit have a different twist length to further reduce crosstalk between them. The twist length (or pitch) is usually left-hand (counter-clockwise), and it varies from 2 to 6 inches. It is optimized to reduce crosstalk at higher frequencies (hundreds of kilohertz) since it is in this region where crosstalk can become a problem.

The requirement for adequate crosstalk performance in all exchange cables is highly stressed during their design and construction. Crosstalk due to cable pair irregularities is managed by tightly controlling capacitance unbalance (pair-to-pair, pair-to-shield and pair-to-ground) and resistance unbalance during the manufacturing process.

3.6 Shielding

All outside plant cables are shielded with corrugated aluminum or copper tape. To increase corrosion resistance, the aluminum is bonded to a thin plastic (copolymer). A corrugated rather than smooth surface is used to increase shield strength and flexibility.

The shield isolates the enclosed conductors from outside sources of electromagnetic interference, such as induction from power line harmonic frequencies. The ability of a shield to isolate the cable pairs from such interference is determined by its shield factor.

Shield factor is a function of the end-to-end shield resistance, the mutual impedance between the shield and cable pairs, frequency and the ground system impedance. Cable shields with a low resistance and low mutual impedance have a higher shield factor. Larger cables have both these features and so offer a better shield factor than smaller cables. Tables are available to simplify the calculation of shield factor for telecommunication cables [1].

The thin aluminum or copper shield used in conventional telecommunication cables does very little to isolate the pairs from power line interference at the fundamental frequency (60 Hz). Since the telephone instrument, and other terminal equipment, is designed to have little response at 60 Hz, this usually is not a problem. The shield is more effective, however, at harmonic frequencies, which are annoying to the subscriber or can cause problems with data transmission.

The shield in a given cable provides almost twice the shielding (induced voltage cut almost in half) at 540 Hz than it does at 60 Hz. Also, a cable with four times the diameter of another cable will provide twice the shielding.

Physically, the shield thickness is generally 0.008 inches (8 mil) for aluminum and 0.005 inches (5 mil) for copper.* Coated aluminum is the preferred shield because it is cheaper and usable in all but the most demanding applications (such as some highly corrosive environments). For reference purposes, a 1,200-pair, 24 gauge, aluminum shielded cable has a shield resistance of around 1 Ω per mile (Ω/mi); a 100-pair, 24 gauge cable has a shield resistance of almost 4 Ω/mi.

The shield is made continuous through splice points, which are found in vaults, manholes, aerial terminals and pedestals, and connected to earth ground at regular intervals (at least four times per mile). Shield continuity and grounding are very important; otherwise, the cable pairs are susceptible not only to noise but to damaging overvoltages during lightning activity, power faults and power system switching transients.

Wrapped between the shield and the cable core of modern exchange cables is a non-hygroscopic dielectric tape, which provides additional insulation to increase the pair-to-shield withstand voltage.

For digital carrier applications, an additional shield is used that separates the cable pairs into two compartments. This is called compartmental core cable, "Z-Screen," "D-Screen" or "T-Screen." The latter indicates the primary application for this type of cable, which is T-carrier. The separation is necessary to eliminate crosstalk between the transmit and receive pairs of the transmission system. The cross-section of a compartmental core cable is illustrated in Fig. 3-1. Compartmental cone cables are frequently installed for analog loops when it is known that the service will be upgraded to digital in the future.

3.7 Armor

In addition to the shield, a steel tape may be used as an armor for increased physical protection and strength. The tape is corrugated and usually 6 mils thick. It is polymer coated to reduce corrosion. Alternately, the properties of both shield and armor can be

* One mil = 0.001 inch or 0.0254 mm.

combined in a single corrugated tape. A copper/iron alloy (6 mils thick) or extra thick (10 mil) copper is used in this case.

Armored cables find applications in areas infested by gophers, beavers, squirrels or other chewing rodents. Another application for these cables is where they are installed in a severe physical environment such as direct burial in sharp, broken rocks and where bedding sand is not available.

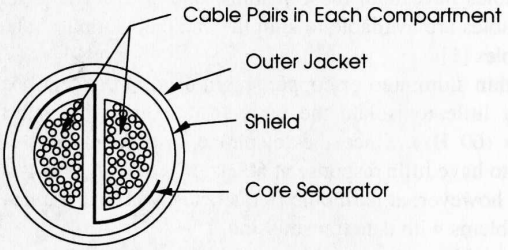


Figure 3-1 Compartmental core cable cross-section

3.8 Outer Jacket

The outer covering (jacket or sheath) on all modern cables is a tough plastic, the thickness of which varies with the size of the cable. It varies from 60 mils for a cable with diameter around 0.75 inches to 110 mils for a cable with approximately 2 inches or larger diameter. The type of plastic varies with the application. A vinyl material is used for riser cables in a central office because it will not support a flame, and its burn products are nontoxic. Low-density, high molecular weight polyethylene (or ethylene copolymer) or high-density polyethylene is used in outside applications.

In aerial applications, the cable is lashed to a supporting messenger, which varies from 3/16 inch to 7/16 inch diameter, depending on the strength required and the material used. In some aerial applications, a self-supporting cable is used. This cable incorporates a supporting messenger along with the outer sheath. Because of its shape, this cable is called *Figure 8*. Due to strength limitations, Figure 8 cable is generally not available in pair counts above 300 pairs (26 gauge), 200 pairs (24 gauge), 100 pairs (22 gauge) or 50 pairs (19 gauge).

Many older cables have a lead sheath that acts as both a shield and outer covering.

3.9 Feeder and Distribution Cables

Referring back to Fig. 1-1 in Chapter 1, feeder cables comprise the loop from the central office to main junction points called a serving area interface (SAI), facility area connector (FAC), cross-connect or control point. The actual name depends on the company, but the function is to provide a point at which feeder cable pairs can be administered and connected to individual distribution cable pairs.

Distribution cables comprise the loop from the main junctions to a distribution terminal such as a pedestal or aerial terminal. In any given area, there are generally more distribution pairs than feeder pairs. This allows efficient use of larger and more expensive feeder cables through easier administration and assignment of subscribers.

Feeder and distribution cables can contain as many as 4,200 pairs (8,400 conductors) or as few as 6 pairs, all within a single sheath. Cables are available with 19, 22, 24 or 26 American Wire Gauge (AWG) copper conductors. The most widely used feeder and distribution cable size is 24 gauge. This is due to economic tradeoffs that take into account the typical loop length.

In the smaller cable sizes, good design practice calls for using cables that are multiples of the basic 25-pair unit (25 and 50). Pair counts of 6, 12, 18 and 37 are avoided unless other factors make their use clearly more economical than 25 or 50 pair sizes. There is very little difference between the installed cost of 6 or 12 and 25 pair cables or 37 and 50 pair cables in most applications.

The extra pairs not only give extra insurance to accommodate unforeseen growth, but they also allow the allocation and use of pairs in the field to be more logical due to the 5-pair and 25-pair color coding scheme. The long-term result, of course, is easier administration and maintenance.

3.10 Service Wires

Service wires make up the final portion of the loop. They are installed between the distribution terminal and the actual serving point or network interface device (for example, at an office building or residential establishment). Beyond the network interface device are premises wiring systems, which are described at the end of this chapter.

Service wires can be one pair up to hundreds or thousands of pairs depending on the establishment to be served. Service wires in the smaller sizes are not always twisted because they are usually short and do not measurably degrade transmission quality. Aerial service wires are usually 18 or 19 gauge, while buried service wires are usually 19, 22 or 24 gauge. High-purity copper is the most widely used conductor material for underground service wires, while copper with special alloying (or other means for strength) is used for aerial service wires.

3.11 Summary of Physical Characteristics

The physical characteristics described above are summarized in Table 3-5 for modern cables. Figure 3-2 illustrates the construction of various cable types. Finally, a matrix and a flow chart are provided in Table 3-6 and Fig. 3-3 that can be used to select the cable characteristics suitable for a particular application.

3.12 Cable Costs

Cable costs vary considerably with gauge, construction and the current cost of copper (and aluminum, if that type of shield is used). Nineteen gauge cable can be twice as expensive as 24 gauge cable for a given pair count. Filled cable is 10 to 25 percent more expensive than air-core cable, depending on the gauge and pair count. Table 3-7 shows a comparison chart with relative material costs for various cable gauges and sizes.

Table 3-5 Exchange Cable Physical Characteristics

Insulation	Polyethylene Polypropylene Dual expanded polyethylene Expanded polyethylene—PVC
Gauge	19, 22, 24, 26 AWG, copper
Pair Count	6, 12, 18, 25, 37, 50, 75, 100, 150, 300, 400, 600, 900, 1,200, 1,500, 1,800, 2,100, 2,400, 2,700, 3,000, 3,600, 4,200[a]
Core	Air or filled
Shield	Bonded aluminum (8 mil), copper (5 or 10 mil) or copper alloy (6 mil)
Armor	Bonded steel (6 mil) when separate from the shield
Sheath	Vinyl, HMW polyethylene, HD polyethylene

[a] Not all pair counts are available with all gauges.

Table 3-6 Exchange Cable Selection Matrix

	Alvyn	PIC	PIC Armored	Self-Supporting	Filled	Air Core
Indoor	√					√
Aerial Normal		√		√	√*	√
Aerial Severe			√	√	√	√
Buried Normal		√			√	
Buried Severe			√		√	
Underground Normal		√			√	√
Underground Severe			√		√	√

*Filled, self-supporting cables are not available.

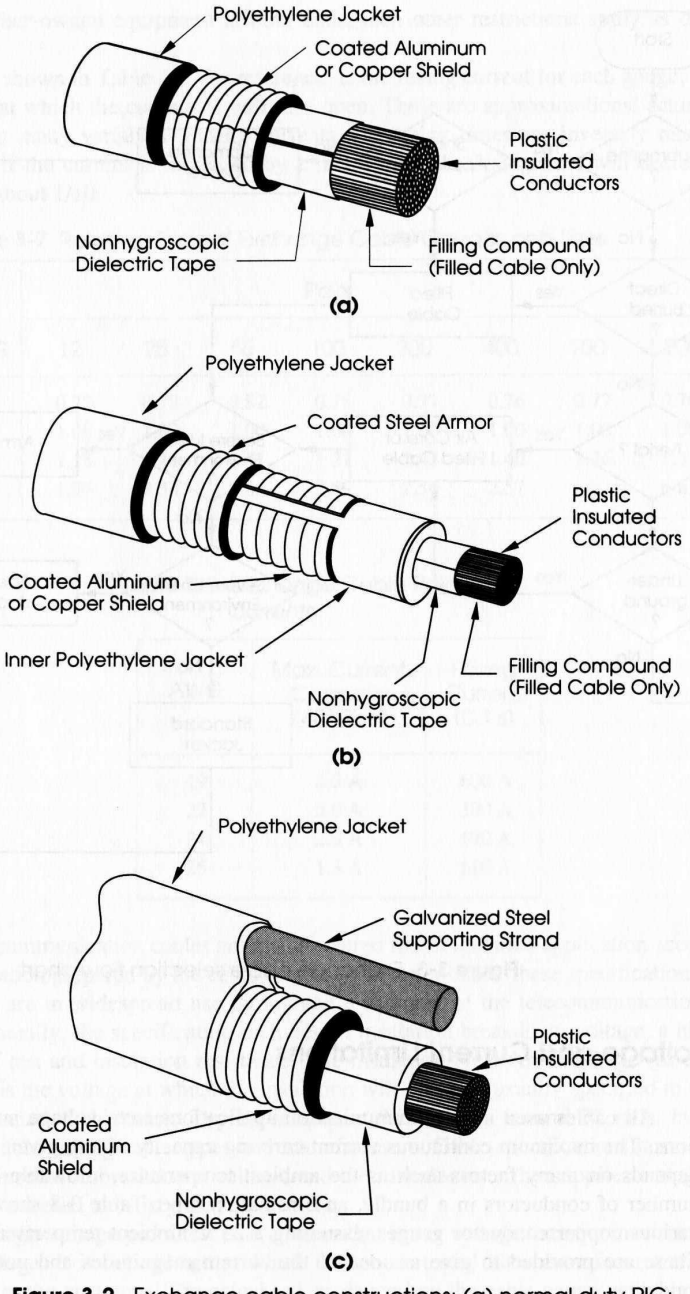


Figure 3-2 Exchange cable constructions: (a) normal duty PIC; (b) severe duty PIC (armored); (c) self-supporting ("Figure 8")

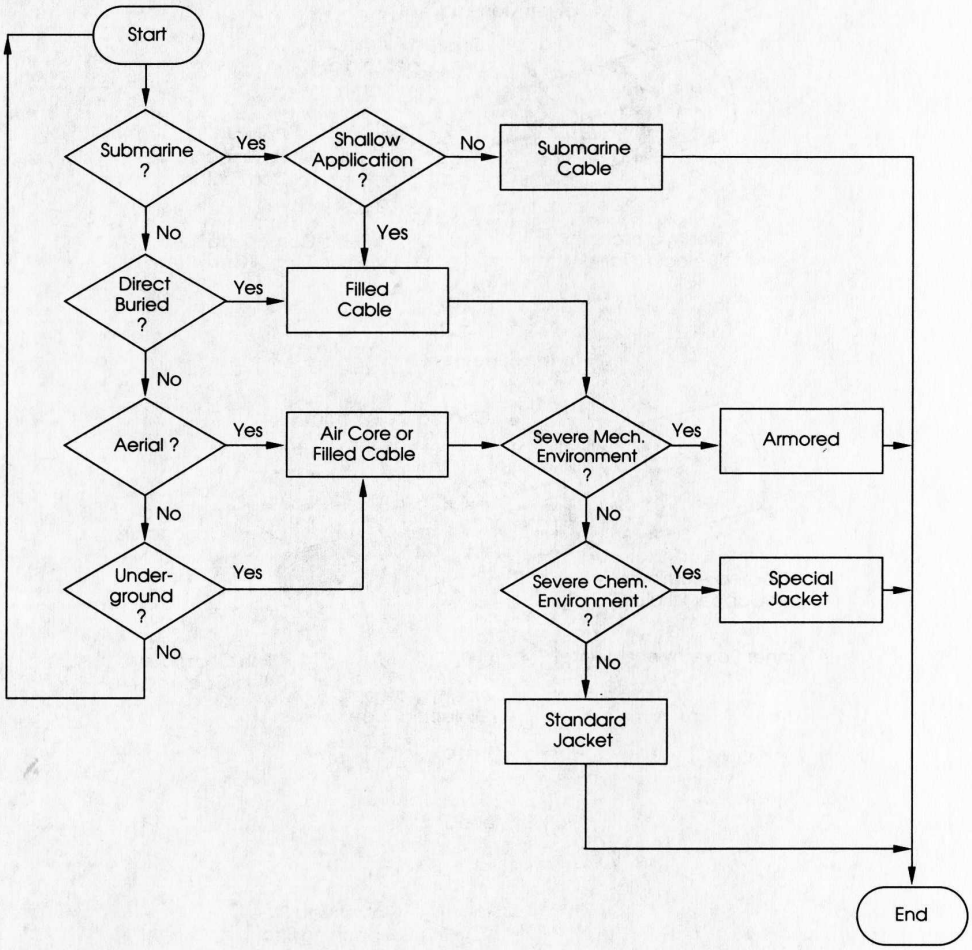


Figure 3-3 Exchange cable selection flow chart

3.13 Voltage and Current Limitations

All cables used in telecommunication applications have voltage and current limitations. The maximum continuous current-carrying capacity of any given conductor gauge depends on many factors such as the ambient temperature, allowable temperature rise, number of conductors in a bundle, and insulation type. Table 3-8 shows the values for various copper conductor gauges, assuming a 25°C ambient temperature and 40°C rise. These are provided to give an idea of the current magnitudes and not as an operating guideline.

The maximum current available from a central office line circuit on a loop is in the range of 130 to 145 mA, although some older systems can supply at least 175 mA. For other signaling and control applications, the telephone company will normally limit the current on loops to 1.3 A, which coordinates with 26 gauge cable. If the loop is connected

to subscriber-owned equipment at both ends, then other restrictions apply as discussed below.

Also shown in Table 3-8, for reference, is the fusing current for each gauge, which is the point at which the conductor will fuse open. These are approximations; actual values depend on many variables. Fusing currents and fusing times are inversely related. For example, if the current is increased by a factor of 3, the fusing time will decrease by a factor of about 1/10.

Table 3-7 Relative Costs of Exchange Cable Gauges and Sizes

	Pairs							
AWG	12	25	50	100	200	400	900	1,200
26	0.72	0.73	0.82	0.78	0.77	0.76	0.77	0.76
24	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	1.18	1.21	1.41	1.31	1.43	1.40	1.36	1.37
19	1.94	2.33	2.59	2.59	2.56	2.57	n/a	n/a

Table 3-8 Exchange Cable Pair Currents

AWG	Max. Current Capacity (40° Rise)	Fusing Current (0.1 s)
19	8.0 A	600 A
22	5.0 A	300 A
24	2.0 A	190 A
26	1.3 A	110 A

Telecommunication cables are manufactured for an intended application according to a specification prepared by the cable customer. In many cases, these specifications are generic and are in widespread use throughout a segment of the telecommunication industry.* Generally, the specification includes an insulation breakdown voltage, a high-voltage proof test and insulation resistance. The insulation breakdown voltage (or dielectric strength) is the voltage at which the insulation will fail. It is usually specified in volts per mil of insulation thickness. Typical insulation thickness is around 30 mils, but this is quite variable among cable types and manufacturers. Cable specifications normally only show an insulation breakdown voltage, and the manufacturer then applies enough of the particular material to satisfy the requirement.

The high-voltage proof test is at a somewhat lower voltage than the insulation breakdown voltage. It is the voltage at which cables are tested after manufacture and before shipment to the customer. The actual values depend on the cable gauge, whether filled or air-core, and insulation type. All proof tests are made for 3 s. The cable is not expected to withstand these voltages indefinitely.

* Examples are the REA specifications, which are used by REA and non-REA borrowers alike; and BELLCORE specifications, which are used by the Bell Operating Companies (BOCs).

Insulation resistance is a measure, in megohm-miles (MΩ-mi), of the leakage between a given conductor and the other conductors and shield in the cable. By inspecting the units, it is clear that the insulation resistance can decrease with increasing length. For example, an air core cable 5 mi long will measure at least 2,000 MΩ (10,000 MΩ-mi/5 mi). Insulation resistance tests are usually made at around 550 V for new cables at the factory, or 250 V for installed cables in the field. The higher the measured resistance, the better. Table 3-9 shows the voltage ratings for typical telecommunication cables.

Table 3-9 Exchange Cable Voltage Ratings

Insulation Breakdown Voltage	300-1,200 V/mil
High-Voltage Proof Test (3 s):	
Conductor-Conductor	2-7 kV
Conductor-Shield	10-20 kV
Insulation Resistance (100-550 V):	
Air Core	10,000 MΩ-mi
Filled	1,000 MΩ-mi

Unlike power cables, outside plant telecommunication cables usually do not have a specified maximum working voltage. Nevertheless, most telecommunication cables are considered to have a working voltage of 300 V across the tip and ring of any given pair and between pairs.*

This does not mean the user can arbitrarily apply 300 V to the loop. As expected, FCC Part 68 has certain maximum voltage and current limitations for terminal equipment in various configurations that preclude such operation.† Basically, the terminal equipment cannot apply more than 56.5 Vdc to a loop connected to an off-premises station or supply more than 140 mA to the loop under any circumstances. During ringing, no more than 300 V peak-to-peak can be applied to the loop.†† The reasons for these limitations are obvious: safety and network harm. Some telephone company tariffs may specify more stringent voltage and current limitations.

The voltage and current limitations imposed by the FCC, and discussed in the previous paragraph, on equipment connected to the loop do not apply to the telephone companies. Although the working voltage of cable pairs is considered to be 300 V, telephone companies will use higher voltages under certain conditions. These are always associated with special equipment located outside the central office. For example, the line repeaters in long T-carrier span lines may be powered by up to 360 V at the central office. This voltage dwindles to much lower values along the span line due to voltage drop across the repeaters and resistive voltage drop in the cable pairs.

* The working voltage considered here is root-mean-square (rms) or dc.

† Par. 68.306.

†† 300 V peak-to-peak corresponds to approximately 106 Vrms, assuming a sinusoidal ringing voltage.

3.14 Premises Wiring

Although not directly a part of the outside plant cabling system, and not necessarily considered a part of the subscriber's loop, premises wiring (also called *station wiring* or *inside wiring*) is a natural and necessary extension of it. Therefore, it would be worthwhile to discuss some attributes of these facilities.

Premises wiring is any wiring that interconnects telecommunications equipment on a particular premises. It is not always connected to the network interface device; however, the discussion in this section will be limited to that part of premises wiring connected to the loop through the network interface device and used in conjunction with terminal equipment.

It usually is not subjected to the same environment (electrical or physical) as outside plant cables, but the wiring inside buildings presents another set of problems to be considered by the designer, builder and users of such systems. These are noise performance and fire hazard problems.

Unlike outside plant cables, for economic reasons, premises wiring systems are not always shielded, and this can lead to problems with *electromagnetic interference* (EMI). It should be noted that premises wiring can be a noise source in addition to noise receptor. With short runs, signals on premises wiring normally have negligible effect on other systems. The reverse is also true. On longer runs, however, the lack of shielding can allow transmission degradation through noise pickup, and premises wiring also can act as a transmitting antenna.

Modern premises wiring systems are carrying a much higher percentage of digital transmission (versus analog or voice transmission), and the transmission speeds are steadily increasing. The use of unshielded twisted pair (UTP) rather than shielded twisted pair (STP) for 16 megabit per second (Mbps) data transmission in office buildings is becoming commonplace. Digital transmissions can cause and are subject to crosstalk interference because of their wide frequency spectrums. Such interference problems can be expected to increase unless the spectrums of these signals are coordinated with other uses.

In addition to the transmission problems facing the users of premises wiring systems, the uncontrolled deployment of polyolefin insulated and jacketed cables inside buildings can lead to safety problems even in minor fires or situations where the cable insulation may burn. Flame spread and burn byproducts (toxicity) are of concern in any building installation.

To reduce the safety hazard, the regulations covering premises wiring systems have become progressively tighter with the last few editions of the National Electrical Code (NEC®).* The application or location of a particular part of the premises wiring determines the type of covering required by the NEC®. The coverings are coded as shown in Table 3-10 in descending order of fire resistance rating. Multipurpose cables shown in this table can be used for communication applications as well as other applications. Communications cables and wiring systems covered by the NEC are required to have a minimum voltage rating of 300 V. A more complete discussion on the various cable types used in communications and communication-related applications in buildings was presented in [3].

* See Article 800 [2].

Table 3-10 Premises Wiring Coverings

Cable Type	Covering Type
Multipurpose plenum cable	MPP
Communications plenum cable	CMP
Multipurpose riser cable	MPR
Communications riser cable	CMR
Multipurpose cable	MP
Communications cable	CM
Limited use communications cable	CMX
Undercarpet communications cable	CMUC

The complexity of premises wiring system installations will vary with the application. In simple installations (one, two or as many as four access lines and minimal customer premises equipment), the wiring is almost always arranged in a star pattern as shown in Fig. 3-4. Here the terminal equipment is wired directly to the network interface device. Other arrangements commonly used in simple installations are the "daisy chain" where extensions are multipled (paralleled) with the terminal equipment in the chain preceding it. Standards for simple wiring, such as EIA/TIA 570, are emerging [4].

More complex systems will use a fully engineered premises wiring or premises distribution system (PDS). An example of the architecture of such a system is shown in Fig. 3-5. These are systems of fully integrated components (usually from a single manufacturer) for mechanical and electrical assembly of the wiring from the network interface device to the various terminal equipment.

Premises distribution systems are seldom used with simple installations but are commonplace with private branch exchanges (PBXs) and larger key systems (above around 25 stations), especially when interworking of these devices is required with local area networks (LANs). In this application, the PDS interconnects not only regular telecommunication terminal equipment (telephone instruments, modems, facsimile machines and the like) but also computer and other digital and analog equipment associated with the local area network.

With the integration of digital and analog signal transport for all applications, a considerable cost savings can be achieved not only in the initial installation but in daily administration of the local network.* Premises distribution systems can consist of:

1. Cables with twisted metallic pairs only (STP or UTP)
2. Cables with both twisted metallic pairs and optical fibers
3. Cables with optical fibers only

* Because premises wiring can be very labor intensive, it is imperative, from an economic standpoint, that the designer consider the total telecommunication requirement. The requirements would normally include video, data transmission, security, energy management and telecommunications. The bandwidth required could easily approach 500 MHz or more in more complex situations. It is beyond the scope of this book to discuss wiring systems that would serve these wideband requirements. Standards are being prepared that do address these systems [5,6].

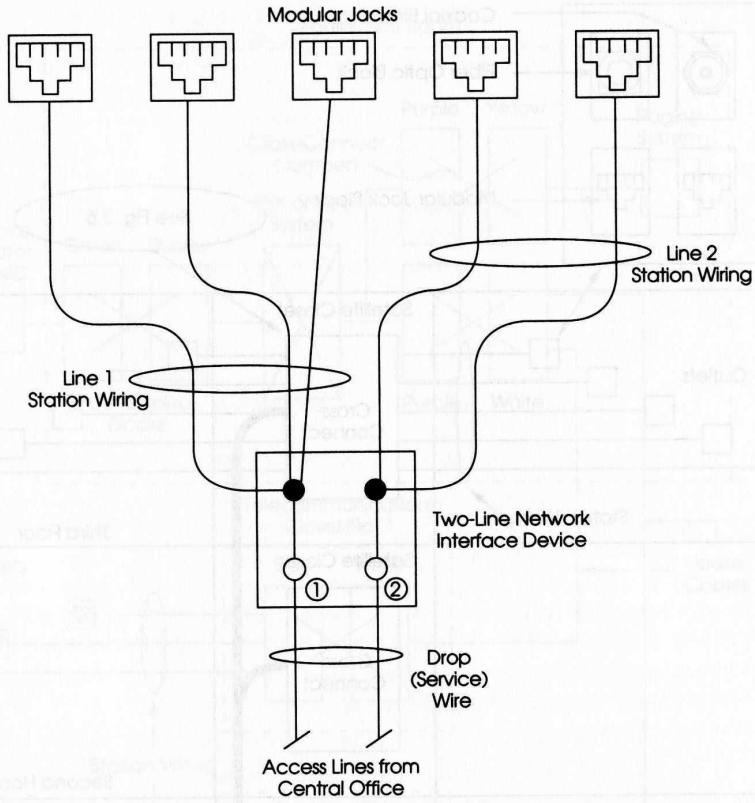


Figure 3-4 Simple premises wiring

4. Coaxial cables
5. Any combination of the above*

In those applications where the PDS interconnects terminal equipment and the loop, a color coding scheme generally is used at interconnection points to indicate the function of the wiring. The terminal blocks used for interconnection (using jumpers) have colored labels and the various cables are marked with color coded tags at each end. There is no universal acceptance of the color scheme used, but a common one is shown in Table 3-11. An explanation of the functions follows. Different PDS manufacturers may have different functions and colors in their product lines.

Central office connections (green) are the cables and terminal blocks associated with the entrance cable from the LEC. House cable terminations (white) are vertical and horizontal cables between the equipment room and telecommunications (satellite) closets or service cabinets within the building. Auxiliary connections (yellow) are cables and terminal blocks that connect to network terminating, signaling and conditioning equipment, paging systems and the like. Information outlets (blue) are cables and connections

* Some manufacturers make cable that incorporates all types into a single integral cable, commonly called Siamese cable.

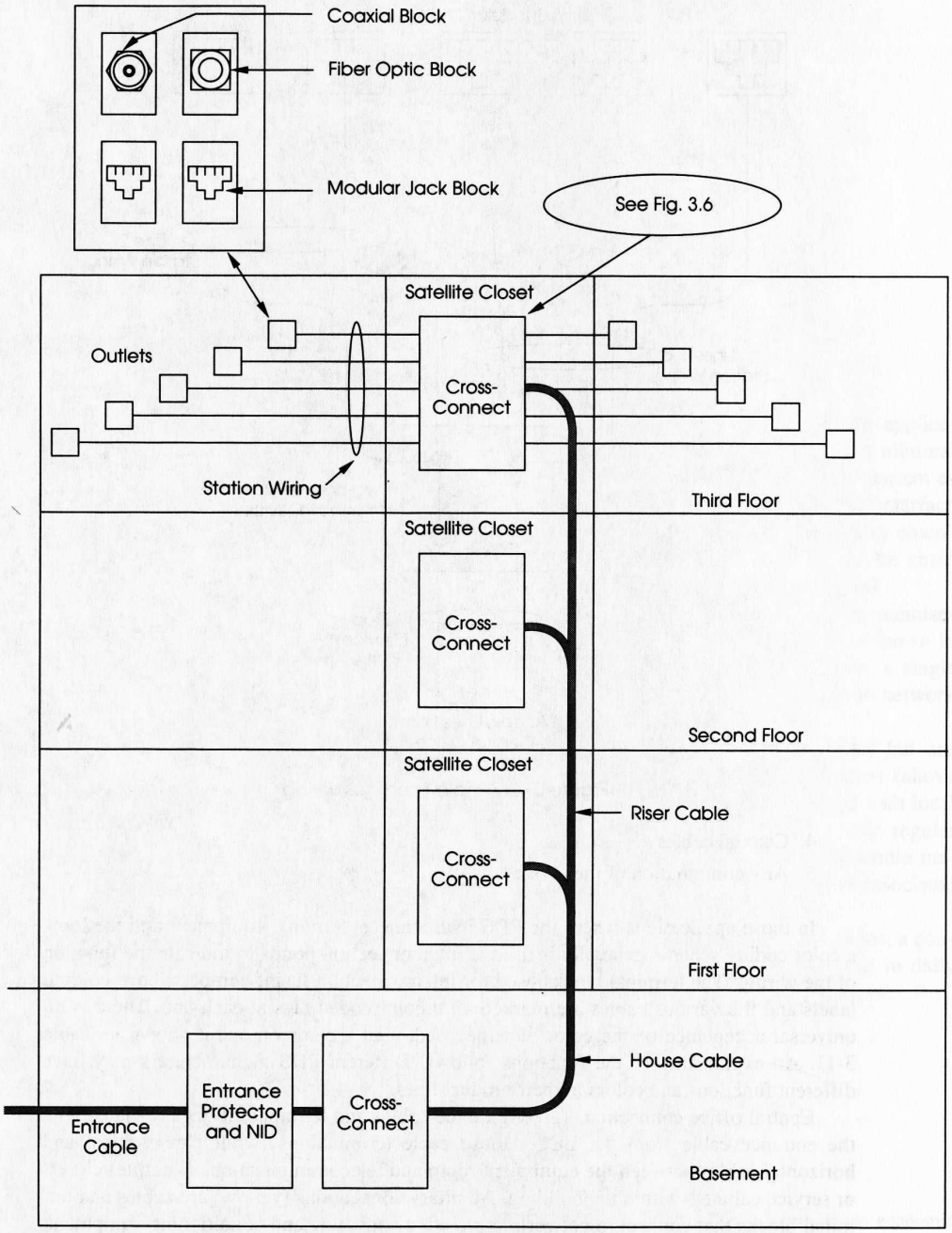


Figure 3-5 Premises distribution system

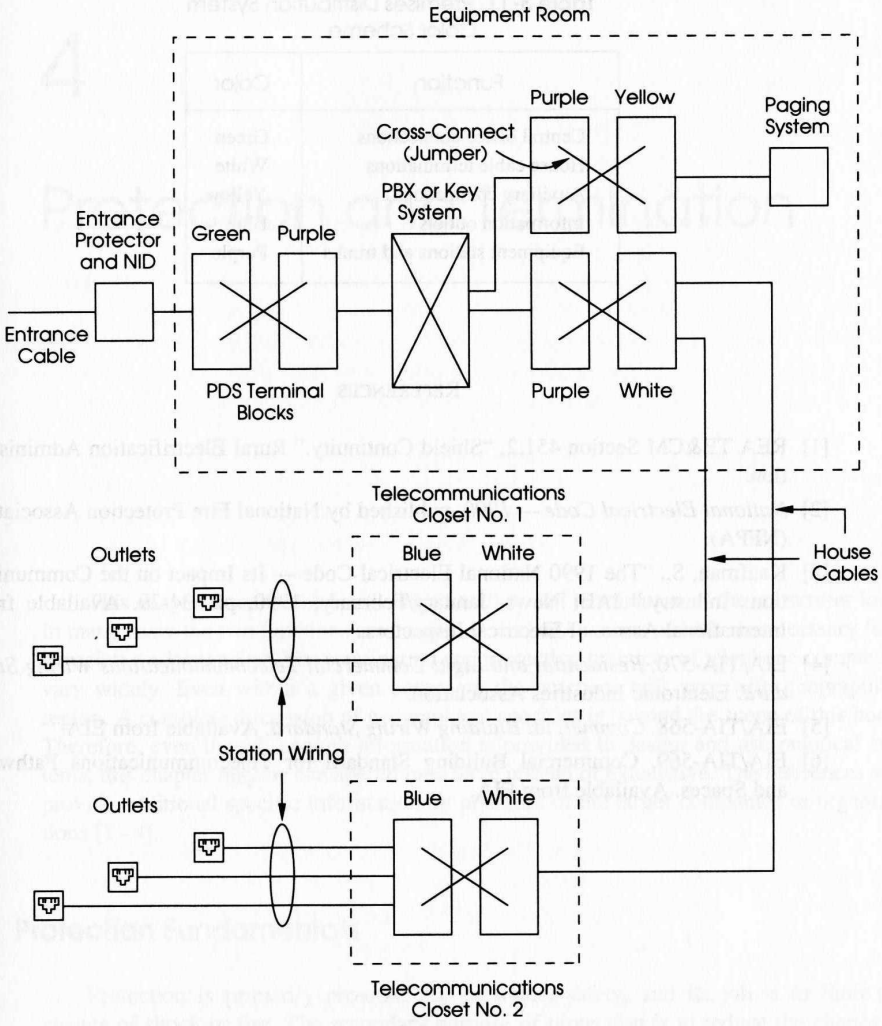


Figure 3-6 Premises distribution system application

from the telecommunications closet or cabinet to the modular connector.* Finally, equipment stations and trunks are the connections from the PBX or key system trunk, line and station circuits. Figure 3-6 shows how the above PDS color code is applied in a typical installation.

* The actual outlet may consist of multiple jacks of different designs for different functions; for example, modular jacks, coaxial connectors and special-purpose connectors.

Table 3-11 Premises Distribution System Color Scheme

Function	Color
Central office connections	Green
House cable terminations	White
Auxiliary connections	Yellow
Information outlets	Blue
Equipment stations and trunks	Purple

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Electric Cables Handbook

Third Edition

BICCCables

Edited by

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Preface to Third Edition

The first and second editions of the *Electric Cables Handbook* were well received and there were many requests for a revised edition. The third edition provides a substantial, comprehensive and up-to-date review, reflecting the changes which have occurred in the cable industry during the last seven years. The Handbook therefore continues to be a major reference book for professional engineers and electrical contractors involved in cables.

The Handbook covers all types of energy cables, from wiring and flexible cables for general use to distribution, transmission and submarine cables. It includes information on materials, design principles, installation and standards, and the many appendices contain extensive tables of data on commonly used cable types.

Once again it has been difficult to decide which older types of cable should be excluded and which new types should be included. While the Handbook has been comprehensively revised, the main aim has been to describe adequately those new energy cables which reflect the present dynamic state of the industry. The description of cables in fires has been completely rewritten; the significant developments in high performance materials, both polymeric and paper laminate, are described in detail; the application of new materials to high voltage systems is thoroughly covered; for the first time there is an extensive description of the recent developments in high temperature superconductivity, with the emphasis on potential applications in power engineering.

The Handbook has also been significantly extended to give a broad view of communication cables for the power engineer. Recognising the increasing impact of telecommunications in the power industry, a new and substantive section describes the application of optical fibres in power transmission systems. There is also an additional section on communication cables; this includes a revision of the original chapter on electronic cables.

Reflecting the extensive revision of the text, extra material has also been added to the appendices, references and bibliography. Much of the original text has been retained in the interest of providing the necessary background to the continuing technical developments in the industry.

As in previous editions, this Handbook draws on the extensive expertise and experience of the staff of BICC Cables Ltd and the editor would like to thank the many contributors for their text, their collaboration, and many helpful suggestions.

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CHAPTER 53
Communication Systems

INTRODUCTION

In part 7 we introduced the concept of optical fibres in power transmission lines, described how optical fibres are an increasingly attractive solution to the transmission of information, and gave an introduction to the principles of optical fibre transmission and optical cable design. In this part we review other cables for communication applications and in particular optical and metallic data communication cables in chapter 54 and metallic twisted pair telecommunication cables in chapter 55.

The speedy and accurate transfer of data is an essential requirement of a modern society. The behaviour of the transmission medium is of basic importance, and must produce at its distant receiving end a change of some kind which will be correctly interpreted as meaning a definite event at the transmission point. Communication systems which can use cable as the transmission medium include telephone, radio, television and data, including a whole new host of so-called multi-media services providing the user with access to services such as home banking and shopping, video on demand, and home- or tele-working. The chapters of this part of the Handbook provide an introduction to cables used for these applications. Optical cables which carry long-haul telecommunication services are not covered here as they have already been described in chapter 49.

TRANSMISSION SYSTEMS

Baseband and broadband

In a baseband system, data from different users is combined in a common path in a digital stream. Thus the cable carries only one channel, which by multiplexing in the time domain can accommodate many users. Baseband systems use cables ranging from complex coaxials to simple twisted pairs.

In a broadband system, data from different users are allocated different frequency channels and simultaneously share a common cable. A high bandwidth cable is therefore

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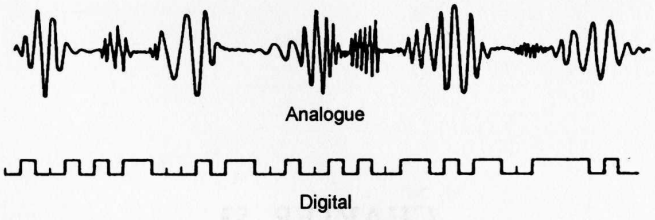


Fig. 53.1 Analogue and digital systems

required, such as the coaxials developed for cable television (CATV) systems. Broadband systems can transmit both digital and analogue signals and can accommodate multiple video, audio and data channels.

Analogue and digital

Analogue systems use a controllable smoothly varying property of electricity such as current or voltage amplitude or frequency to represent information. In digital systems information is manipulated in digital form as a stream of on–off or high–low pulses or binary digits (bits). Figure 53.1 shows an analogue and a digital signal.

With the continual need to increase data communication capacity, digital transmission is appealing because, with relatively low cost electronics, it can substantially increase the capacity of low cost cables. In analogue transmission, video and data are more demanding on the fidelity of transmission, and whenever the signal is amplified the noise is also amplified. With digital transmission, each repeater regenerates the pulses so that a pulse train can travel through a noisy medium being repeatedly reconstructed and remaining impervious to much of the noise-inducing sources.

Digital transmission, however, requires a greater frequency bandwidth than analogue, but can operate at a lower signal-to-noise ratio. The main factors in favour of digital transmission are ease of system design, the potential to increase capacity by the use of digital repeaters at frequent intervals, decreasing costs of circuitry and, last but not least, the rapidly increasing need to transmit digital data on networks.

It should be noted that, for purposes of cable design, digital pulses can be treated as the sum of a series of harmonically related sine waves, with short rise time pulses being in effect wide band radio frequency signals.

Balanced and unbalanced

For balanced systems, twisted pair cables are used and the output of the line driver is balanced to earth so that, when one terminal is positive, the other is negative by the same amount. The receiver responds to the differential voltage between the lines and rejects any signal which changes the voltage on both lines. Provided that the conductors in the pair have identical transmission characteristics, the effects of outside interference are reduced.

For unbalanced systems, one conductor of the pair is connected to earth, and although twisted pair cables can be used, multiconductor and coaxial cables are

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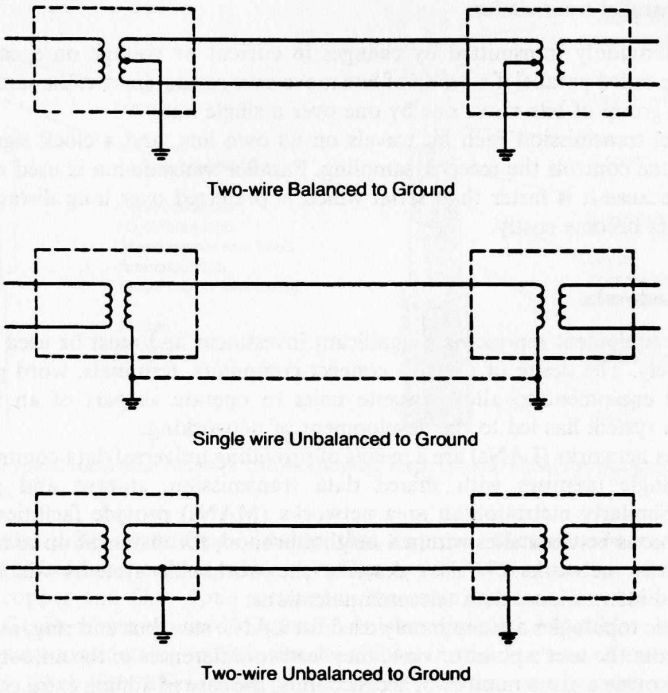


Fig. 53.2 Balanced and unbalanced systems

favoured with less expensive components when interference is not a problem. Examples of balanced and unbalanced systems are shown in fig. 53.2.

Bandwidth and data speeds

Analogue transmission is generally divided into three bands. In telephony the voice band is defined as 300–3400 Hz, and frequency bands wider than voice bands are termed wide band. A communication channel with a bandwidth less than the voice band is narrow band.

In radio engineering the bandwidth of a tuned amplifier is commonly defined as the width of the band of frequencies over which the power amplification does not drop to less than an assigned fraction of the power amplification at resonance. This fraction is usually one-half, corresponding to 3 dB loss in amplification. Transmission lines in general have an attenuation which is a function of frequency and can be constructed to have bands in the frequency spectrum where transmission is good, whilst attenuating other frequencies. In telephone carrier systems such lines or filters are used to separate the various channels.

In general, bandwidth is the frequency range between the lowest and highest frequencies that are passed through a transmission system with acceptable attenuation. For economic reasons, most data communications systems seek to maximise the amount of data that can be sent on a channel.

Serial and parallel transmission

Data are commonly transmitted by changes in current or voltage on a cable. Such transfers are called parallel if a group of bits move over several lines at the same time, or serial if the group of bits move one by one over a single line.

In parallel transmission each bit travels on its own line, and a clock signal on an additional line controls the receiver sampling. Parallel transmission is used over short distances because it is faster than serial which is preferred over long distances when multiple lines become costly.

Local area networks

Computing equipment represents a significant investment and must be used efficiently and effectively. The desire of users to connect computers, terminals, word processing and related equipment to allow discrete units to operate as part of an integrated information system has led to the development of networking.

Local area networks (LANs) are a means of providing universal data communication within a single premises with shared data transmission, storage and peripheral resources. Similarly metropolitan area networks (MANs) provide facilities for data communications between sites within a neighbourhood, for distances up to say 40 km, and wide area networks (WANs) describe the worldwide systems which provide national and international data telecommunications.

Three basic topologies are commonly used for LANs: star, bus and ring, as shown in fig. 53.3. From the user's point of view, they lead to differences in the amount of cable needed to provide a given number of access points, the ease of adding extra connections and the effect of failures. For interconnecting a scatter of points on a site, a bus will generally use the least cable, followed by a ring and then a star. It is generally easier to add connections to a bus than to a star, which may require an extra arm, or to a ring, which must be broken. A star network is least affected by failures of the devices or cables attached to it, but is likely to fail entirely if its central point, or 'hub', fails. A bus will fail if cut; but the whole network will generally not fail if one of the access points, or 'nodes', is faulty, because the node is merely a connection to the highway and can be designed to switch itself out in the event of a fault. Rings, however, are the least reliable because each node is an active repeater, and the failure of one node breaks the ring unless expensive redundancy is built into the system to overcome this.

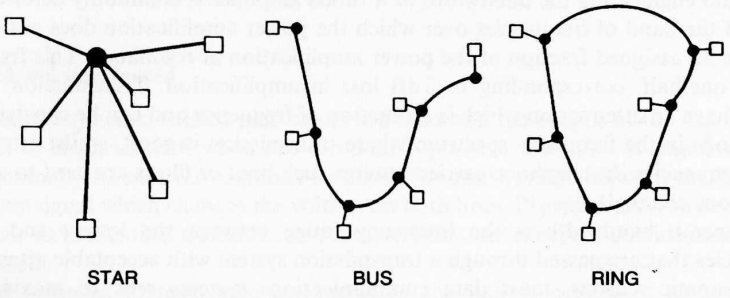


Fig. 53.3 Basic local area network topologies

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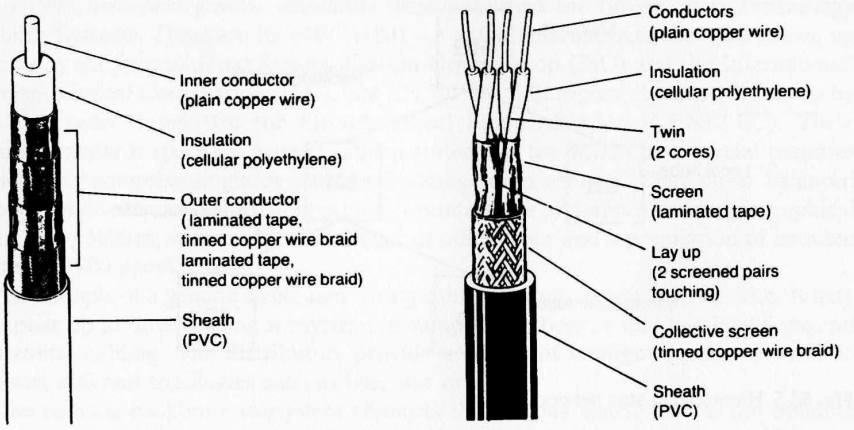


Fig. 53.4 Typical local area network cables showing large coaxial cable for bus systems (*left*) and ring system cable (*right*)

LANs also differ in the type of cables that they use. They may be implemented in coaxial or twisted pair copper cable, or in fibre optics. With some types it is possible to intermix copper and fibre optic sections in the same network, to obtain the specific benefits of each where required. Figure 53.4 shows typical LAN cables.

LANs vary considerably in their size capability, from a few tens of metres to several kilometres. They also differ in the number of devices that can be connected to them, from as few as ten up to several thousand. The rate at which they can transfer information varies widely, from 300 bits per second to 100 megabits per second or more.

OPEN SYSTEMS AND STRUCTURED WIRING

By the mid-1980s, equipment manufacturers were marketing a wide range of products covering a variety of cable types. LAN systems have proliferated, often incompatible and many using dedicated cables, so that when new computing equipment was installed, new cables were generally needed as well, leading to overcrowded cable ducts and trays, complex cable routes and difficulties in re-routing services to accommodate personnel movements.

A growing user demand for rationalisation led to the concept of an open systems interconnection whereby a system could be planned and installed without detailed knowledge of the end equipment. This freedom of choice and independence in the procurement of equipment was a significant advantage when building large multi-storey office blocks where information technology services were required at every desk. Further advantages would result from integrating voice, data, text, image and video services, and from treating these services as a utility, installed as the building is constructed, to provide access points within easy reach of any user who may change equipment and location frequently.

These requirements can be supported by a structured wiring system based on a hierarchical star network (fig. 53.5). Groups of information or telecommunication outlets, which may cover an entire floor of a high rise building, are connected via

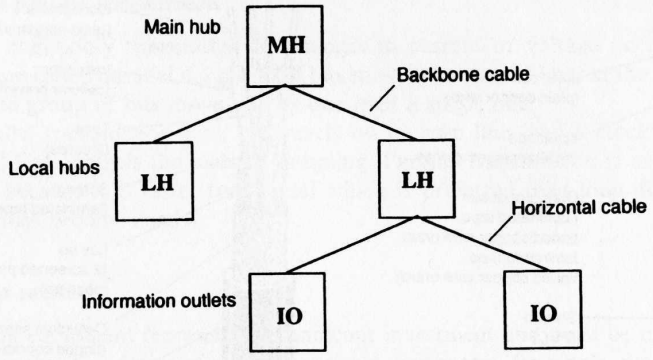


Fig. 53.5 Hierarchical star network

horizontal cabling to a local hub on the backbone cabling. The use of patch cords in the local hub allows a rapid and economic re-routeing of services to the information outlets.

Such a network could also support the interconnection of different systems using increasingly powerful personal computers for more sophisticated applications. An analysis of the requirements for these applications, many of which were the subject of international standards, together with the design and installation practices of systems in different countries, showed that the hierarchical star network could be developed into a general universal cabling system.

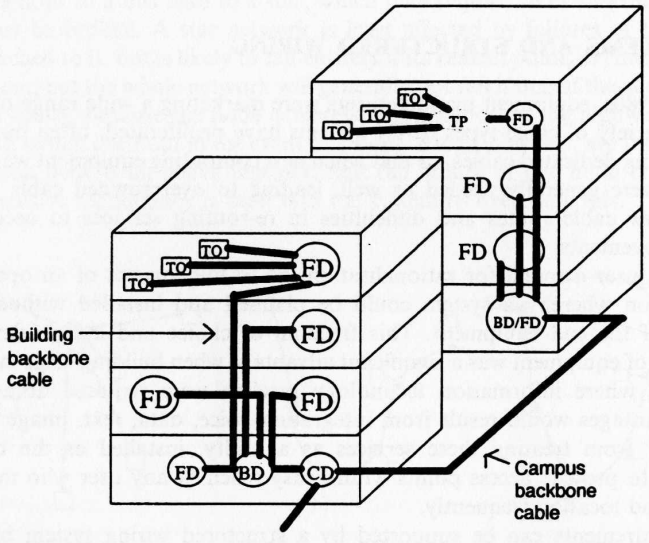


Fig. 53.6 Generic structured wiring cabling system: CD, campus distributor; BD, building distributor; FD, floor distributor; TP, transition point (optional); TO, telecommunications outlet

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In 1995, two new generic standards were published for Information Technology Cabling Systems. These are ISO/IEC 11801 – a global international standard drawn up jointly by the International Standardisation Organisation (ISO) and the International Electrotechnical Commission (IEC), and EN 50173 – a European standard drawn up by the European Committee for Elecrotechnical Standardisation (CENELEC). These similar standards specify a generic cabling system for use within commercial premises which may comprise single or multiple buildings on a campus. They cover balanced copper conductor and optical fibre cabling, optimised for premises having a geographical span up to 3000 m, with up to 1 000 000 m^2 of office space and a population of between 50 and 50 000 people.

An example of a generic structured wiring cabling system is shown in fig. 53.6. It may comprise up to three cabling subsystems, a campus backbone, a building backbone and horizontal cabling. The distributors provide a means of configuring the network to support different topologies such as bus, star or ring.

The campus backbone subsystem connects the campus distributor to the building distributor, usually located in separate buidlings. The building backbone subsystem connects the building distributor to the floor distributor and includes backbone cables, sometimes known as riser cables, terminations and cross-connects. As shown in fig. 53.7, the horizontal subsystem connects the floor distributor to the individual telecommunication outlets.

The generic system allows for typical campus backbone cable route lengths up to 1500 m, building backbone cables up to 500 m and horizontal cables up to 90 m. For the horizontal subsystem the maximum combined length of work area cable, patch cords and equipment cables is assumed to be 10 m.

Both ISO/IEC 11801 and ENN 50173 show five classes of applications and links. These are as follows.

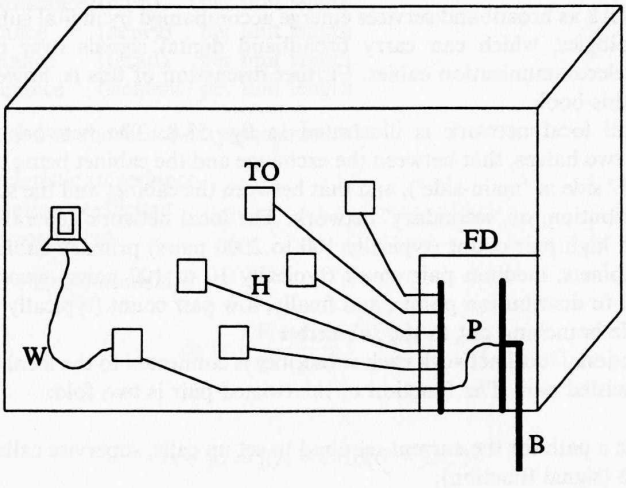


Fig. 53.7 Horizontal subsystem: B, building backbone (riser) cable; P, patch cable; H, horizontal cable; W, work area cable

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Class A: includes voice and low frequency applications, with links specified up to 100 kHz
Class B: includes medium bit rate data applications, with links specified up to 1 MHz
Class C: includes high bit rate data applications, with links specified up to 16 MHz
Class D: includes very high bit data applications, with links specified up to 100 MHz
Optical: includes high and very high bit rate data applications, with links specified to support links at 10 MHz and above. Bandwidth is generally not a limiting factor with optical links.

For structured wiring systems, a variety of cables may be used. For backbone cables, balanced copper conductor cables have impedances of 100 Ω, 120 Ω or 150 Ω, and can be constructed in pair or quad configuration with or without screening. Backbone optical cables may be used, with single mode or multimode fibres, and for the latter, 62.5/125 μm fibres are recommended. Similar cables are employed for horizontal links, except that single mode fibre cables are not specified, and 50/125 μm fibres are a permitted alternative to 62.5/125 μm. The balanced copper multipair cables have a much superior transmission performance to those used for telephone or low and medium speed data applications.

TELECOMMUNICATION NETWORKS

A telecommunication system traditionally consists of a trunk network between major conurbations, a junction network between main exchanges and local exchanges, and the local network between the local exchange and the individual customers; it includes the cable used internally within the exchanges and within customer's premises. Cable being installed in the trunk and junction networks is now almost exclusively optical, but cable for the local network, within exchanges and within customers' premises remains metallic twisted pair with the exception of large business customers who in some countries have direct fibre connections. Fibre can be expected to penetrate further into the local network as broadband services emerge accompanied by digital subscriber loop (DSL) technologies, which can carry broadband digital signals over conventional twisted pair telecommunication cables. Further discussion of this is, however, outside the scope of this book.

The external local network is illustrated in fig. 53.8. The network is generally considered in two halves, that between the exchange and the cabinet being the 'primary' network (or 'E' side or 'main-side'), and that between the cabinet and the subscriber the 'D' side, distribution, or 'secondary' network. The local network generally has a star topology with high pair count (typically 100 to 2000 pairs) primary cables branching out to the cabinets, medium pair count (typically 10 to 100 pairs) secondary cables branching out to distribution points, and finally, low pair count (typically 1 to 2 pairs) dropwire cable branching out to the subscriber.

In a conventional local network each subscriber is connected to the local exchange by a dedicated twisted pair. The function of the twisted pair is two fold:

(a) to provide a path for the current required to set up calls, supervise calls, and power the phone (signal function);
(b) to provide a transmission line for voice frequency communication (transmission function).

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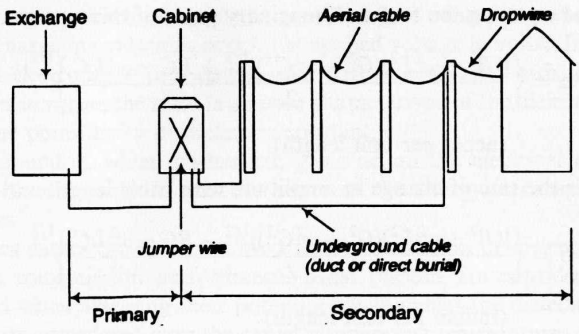


Fig. 53.8 Typical local cable network

The signal function requires that the impedance of the twisted pair be low enough so as not to reduce the current below the system limit. The transmission function requires that the transmission characteristics of the line are such that the signal is received with attenuation and interference which are within the system limits.

TRANSMISSION CHARACTERISTICS OF METALLIC COMMUNICATION CABLES

A transmission line is a network with four fundamental properties of resistance, inductance, capacitance and conductance. These are called the 'primary parameters', and they are defined by the cross-sectional geometry of the line and the materials used in the conductor and dielectric. They are denoted by:

R = loop resistance (ohm) per unit length
L = inductance (henry) per unit length
C = capacitance (farad) per unit length
G = conductance (siemens) per unit length

and are related to the 'secondary parameters'

Z_0 = characteristic impedance
α = attenuation coefficient
β = phase coefficient

by the following relationships:

$$Z_0 = \left(\frac{R + j\omega L}{G + j\omega C}\right)^{1/2} \quad (\Omega) \tag{53.1}$$

and

$$\alpha + j\beta = [(R + j\omega L)(G + j\omega C)]^{1/2} \tag{53.2}$$

where $\omega/2\pi = f$, the frequency in hertz, and the expression $\alpha + j\beta$ is often called the propagation constant.

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Expanding and equating the real and imaginary parts of this equation gives

$$\alpha = \left\{ \frac{[(R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2)]^{1/2} + RG - \omega^2 LC}{2} \right\}^{1/2} \quad (53.3)$$

(neper per unit length)

which determines the rate of change in amplitude with cable length and

$$\beta = \left\{ \frac{[(R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2)]^{1/2} - RG + \omega^2 LC}{2} \right\}^{1/2} \quad (53.4)$$

(radian per unit length)

which determines the rate of change of phase with cable length.

Primary parameters

Resistance

A wide variety of conductor materials is used in communication cables. As well as copper in solid or stranded form, copper-covered aluminium and copper-covered steel are used, the latter for small conductors where strength is required. These may also be tinned or silver plated. Aluminium conductors have also been used in the past for telephone cables but they are no longer installed in the light of corrosion problems experienced in the field.

Skin and proximity effects must be taken into account when considering resistance. The ratio that the effective a.c. resistance has to the d.c. resistance of a conductor is called the resistance ratio, which increases with frequency, with the conductor material conductivity and with the size of the conductor.

In a cylindrical plain copper wire at 20°C, when the frequency is sufficiently high, substantially all the current in the conductor is confined to a region very close to the surface, with a depth given by the relation

$$d = \frac{0.066}{f^{1/2}} \quad \text{(mm)} \quad (53.5)$$

where f is the frequency in MHz.

Inductance

Both self-inductance and mutual inductance are manifestations of the interaction of currents and fields. If the current in a circuit changes, the flux is altered and an electromotive force is induced. This effect is known as self-induction.

If part of the flux in a circuit is linked with a second circuit, there is said to be mutual inductance, and the circuits are inductively coupled. Mutual inductance is defined as the ratio of the flux linkages in the second circuit produced by current in the first to the current in the first circuit. It follows that skin and proximity effects which change the flux pattern will have an effect on inductance.

Capacitance and dielectric materials

A capacitor is formed whenever a dielectric separates two conductors between which a potential difference can exist. Capacitance is the ratio of the charge which can be stored

in a capacitor to the potential applied to it ($C = Q/V$, where C is the capacitance in farads, Q the charge in coulombs, and V the applied voltage in volts). If the capacitance between given electrodes with a certain dielectric is compared with that between the same electrodes *in vacuo*, the ratio is a figure characteristic of the dielectric material and is known as the permittivity or dielectric constant, ϵ.

A perfect capacitor, when discharged, gives up all the electrical energy that was supplied to it in charging. In practice some of the energy is dissipated, mainly as dielectric losses.

In electronics cables the materials used for the insulation or dielectric are therefore critical to the transmission performance. Most plastics are considered as electrical insulators, and when assessing their potential use in cables the dielectric constant and power factor are considered over the range of operating temperatures and frequencies. Suitable materials for high performance cable would have low dielectric constant and power factor over a wide range of temperature and frequency and these parameters should not be adversely affected by high humidity.

Molecules of a dielectric may be either polar or non-polar. In the case of polar molecules the dielectric constant is higher as a result of the rotation of the polar molecules under the influence of the applied voltage. The extent to which this polar action is effective, however, depends on the frequency and the temperature. The result is that polar dielectrics have a certain characteristic behaviour with respect to temperature and frequency. If the temperature is lowered sufficiently, polar rotations are prevented, causing the dielectric constant of the material to decrease. Similarly, if the frequency is made sufficiently high, the polar molecules are not able to follow the alternations of the applied field and the dielectric constant decreases. Hence the power factor of a polar dielectric becomes quite large for certain combinations of temperature and frequency. The variation in dielectric constant and power factor for a polar dielectric as a function of frequency for two temperatures is shown in fig. 53.9.[1]

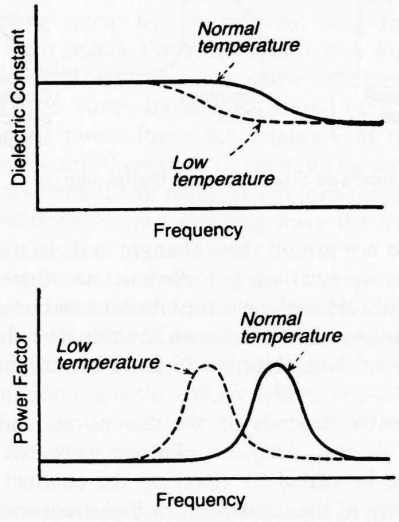


Fig. 53.9 Variation of dielectric constant and power factor of polar materials

Table 53.1 Electrical properties of insulating materials

Material	Dielectric constant		Power factor	
	50 Hz	1 MHz	50 Hz	1 MHz
Polyethylene	2.30	2.30	0.0003	0.003
Polypropylene	2.15	2.15	0.0008	0.0004
PVC	6.9	3.6	0.08	0.09
Nylon	4.0	3.4	0.014	0.04

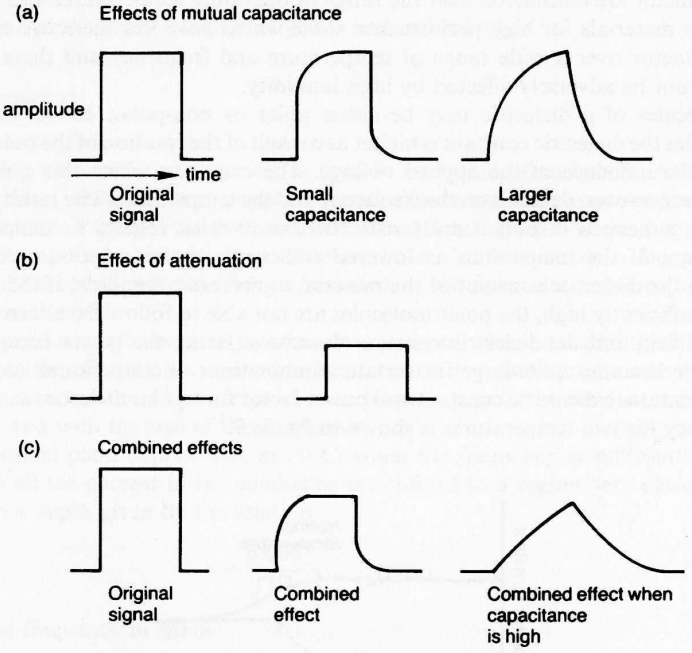


Fig. 53.10 Effects of capacitance and attenuation on digital signals

Non-polar molecules do not exhibit these changes in dielectric constant or peaks of power factor, and materials such as polyethylene are therefore used for higher performance cables. Typical values of dielectric constant and power factor for materials commonly used in electronics cables are shown in table 53.1. In these examples PVC and nylon are polar molecules exhibiting a higher dielectric constant reducing with increased frequency.

The capacitance of a cable depends on the dimensions and configuration of the conductors and screen, if any, and the effective permittivity of the dielectric. Capacitance can therefore be varied by changing the conductor size, the insulation thickness or the permittivity of the insulation. In high frequency digital transmission, capacitance rounds or distorts the pulse shape as shown in fig. 53.10(a), causing errors.

With a low capacitance, cables can cope with faster rise times, increased bit rate capacity and longer transmission distances.

Conductance

When two parallel conductors have a potential difference between them, a certain amount of current will flow because of the finite resistance of the insulation. For an air dielectric the conductance across the gap is negligible, but when other dielectrics are used, as is the case with cables, the conductance is determined by the power factor, capacitance and frequency according to the relationship

$$G = \omega C \tan \delta \tag{53.6}$$

where $\tan \delta$ is the dielectric power factor.

Secondary parameters

Impedance

If a signal is fed into an infinitely long uniform line the ratio of voltage to current at any point along the line is constant and is called the 'characteristic impedance' of the line, usually denoted Z_0. If the line is now cut to a finite length and a load impedance equal to Z_0 is connected across the far end, it behaves as if it were still infinitely long. Power fed into the line will be absorbed by the load and none will be reflected back. The line is then correctly terminated or matched.

Not all the power which is fed into the line will reach the load at the far end. In practice power losses occur in the line itself, because of resistive dissipation in the conductors and dielectric losses in the insulation. For a correctly terminated cable, the ratio of output power to input power, in decibels, is the attenuation of the cable.

The condition in a terminated line can be represented by a wave travelling forward towards the load. If the load is not a correct termination to the line a certain proportion of the forward travelling signal will be reflected back towards the input. Similar reflections can occur from points along the cable which for some reasons may differ from the mean impedance. These reflections cause increased line losses, because both the forward and backward waves are attenuated and each contributes to the overall loss. So for minimum line power losses the amplitude of the reflected wave must be reduced to zero, in other words there must be no standing waves on the line. A standing wave results from the combination of reflected and forward waves travelling in opposite directions. Under conditions of zero standing wave the load is said to be matched to the line.

The ratio of the maximum to minimum values of voltage which occur at points half a wavelength apart on a mismatched line is called the voltage standing wave ratio (VSWR). On a lossless line the VSWR is constant throughout the length and is equal to the ratio of the load impedance Z_L to the characteristic impedance of the line Z_0.

Another term in common use is the voltage reflection coefficient, which is defined as

$$\text{voltage reflection coefficient} = \frac{Z_0 - Z_L}{Z_0 + Z_L} \quad \text{or} \quad \frac{VSWR - 1}{VSWR + 1} \tag{53.7}$$

This is often expressed as a percentage, and it follows that for an open or short-circuited line the reflection coefficient is 100%; it is zero for a correctly terminated line.

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From the reflection coefficient follows another common expression, the return loss ratio, which is measured in decibels and is numerically given by

$$\text{loss ratio} = 20\log_{10}\left(\frac{1}{\text{voltage reflection coefficient}}\right) \tag{53.8}$$

In a perfect cable the dimensions and effective permittivity on which the characteristic impedance depends will be constant throughout the length. Such an ideal cable cannot be achieved in practice because of manufacturing tolerances. For example a change in the diameter of the insulation will result in a corresponding alteration of characteristic impedance at that point. Whenever an impedance change occurs, a small reflection of the forward travelling signal results. If these impedance changes happen in a random manner the effects tend to cancel out, but the manufacture of insulated core involves rotating machinery, and there is always the possibility of dimensional changes recurring at regular intervals along the cable rather than at random. The term 'structural return loss' is used as a measure of the losses which arise from internal reflections within the cable, as distinct from return losses arising from mismatched terminations.

Impedance matching is important in data communications because, as well as reducing the energy reaching the receiver, depending on their location mismatches can add to or subtract from the desired signal level and give rise to data errors.

The relationship between the characteristic impedance and the primary parameters is

$$Z_0 = \left(\frac{R + j\omega L}{G + j\omega C}\right)^{1/2} \quad (\Omega) \tag{53.9}$$

and for most cable insulations G is neglected as it is small in comparison with ωC.

At low frequencies ωL can be neglected as it is small in comparison with ωC and the relationship becomes

$$Z_0 = \left(\frac{R}{j\omega C}\right)^{1/2} \quad (\Omega) \tag{53.10}$$

At high frequencies R can be neglected as it is small in comparison with ωL, and if G can be neglected as it is small in comparison with ωC then

$$Z_0 = \left(\frac{L}{C}\right)^{1/2} \quad (\Omega) \tag{53.11}$$

Attenuation

The voltage amplitude of a signal decreases as it travels along a cable owing to the resistance of the conductor and dielectric losses, as shown in fig. 53.10(b). In the relationship between attenuation and the primary parameters, at low frequencies ωL is small compared with R and if G is small compared with ωC then

$$\alpha = \left(\frac{\omega C R}{2}\right)^{1/2} \quad \text{(neper/length)} \tag{53.12}$$

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whilst at high frequencies when R is small compared with ωL and G is small compared with ωC then

$$\alpha = \frac{R}{2Z_0} + \frac{GZ_0}{2} \qquad \text{(neper/length)} \tag{53.13}$$

In this case $R/2Z_0$ represents the attenuation due to ohmic losses in the conductors, which varies as the square root of the frequency owing to the skin effect. The term $GZ_0/2$ is the attenuation due to the dielectric losses and is directly proportional to frequency.

The relative variation of these two causes of attenuation is of significance when designing high frequency cables. The permittivity of the insulation should be kept as low as possible for low attenuation, and it should also be noted that the use of lower permittivity insulation in a cable of given impedance and overall size means that larger conductors are required to maintain the given impedance which in turn reduces the ohmic losses.

As the rise time of digital signals can be related to high frequencies, they are attenuated more than the lower frequency components, resulting in rise time degradation and the rouding of pulse edges; this effect, combined with the effects of capacitance, is illustrated in fig. 53.10(c). Excessive attenuation can prevent the signal reaching the amplitude required by the receiver, resulting in data errors.

Phase coefficient

As with other relationships with the primary parameters, phase coefficient can be simplified at low and high frequencies to

$$\beta = \left(\frac{\omega CR}{2}\right)^{1/2} \qquad \text{(radian/length)} \tag{53.14}$$

at low frequencies and

$$\beta = (\omega LC)^{1/2} \qquad \text{(radian/length)} \tag{53.15}$$

at high frequencies. Of more practical interest at high frequencies is a further relationship given by

$$v = \frac{\omega}{\beta} = \frac{1}{(LC)^{1/2}} \qquad \text{(m/s)} \tag{53.16}$$

where v is the velocity of propagation in the cable. In parallel data transmission a uniform velocity of propagation is important to ensure that bits arrive at their destination at the same time and skew errors are avoided.

The velocity ratio is the velocity of propagation in a cable compared with its free-space velocity; it is dependent on the square root of the insulation permittivity and so the lower the permittivity is the higher the velocity of propagation. For polyethylene insulation the velocity ratio is about 0.66.

Ideal balanced shielded pair model

The relationship between the electrical primary parameters and the physical properties of a twisted pair at low frequencies can be represented by the ideal balanced shielded pair model,[2,3] illustrated in fig. 53.11.

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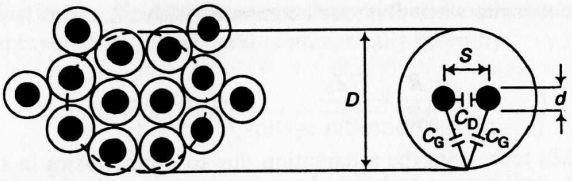


Fig. 53.11 Ideal balanced shielded pair model:
D = effective diameter of the electrostatic shield seen by the twisted pair due to the other twisted pairs in the cable (mm)
S = interaxial spacing of the two conductors (mm)
d = diameter of the conductors (mm)
C_D = direct capacitance between two conductors of the twisted pair (nF/km)
C_G = capacitance seen by each conductor between it and the effective screen, equal for a balance pair (nF/km)

Resistance

The resistance at voice frequency is simply the d.c. resistance of the conductors given by:

$$R = \frac{8 \times 10^3 \rho}{\pi d^2} \qquad (\Omega/\text{km}) \tag{53.17}$$

where ρ = resistivity of the conductor (Ω m).

Capacitance

The capacitance of the twisted pair (mutual capacitance) is the combination of the individual capacitances given by:

$$C = C_D + \frac{C_G}{2} \qquad (\text{nF/km}) \tag{53.18}$$

An approximate expression for the mutual capacitance of a twisted pair in a multipair cable[3,4] is given by:

$$C = \frac{36\epsilon}{\ln\left[1.346\left(\frac{2S}{d} - 1\right)\right]} \qquad (\text{nF/km}) \tag{53.19}$$

where ϵ = relative dielectric constant of the cable.

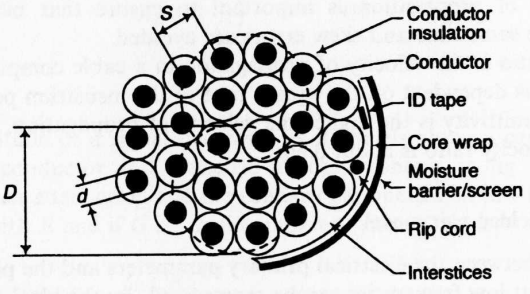


Fig. 53.12 Telephone cable dielectric insulation system

Table 53.2 Relative dielectric constants of telecommunication cables

Material (relative dielectric constant)		
Insulation	Filling compound	
	Air (1)	Petroleum jelly (2.23)
Solid polyethylene (2.3)	1.8	2.23
Cellular polyethylene (1.78)	1.45	1.9
Foam skin polyethylene (1.81)	1.5	1.92
Paper (1.95)	1.53	N/A
PVC (≈3.4)	5.5	N/A

The relative dielectric constant of the cable is an empirical value dependent on the combination of the relative dielectric constants of all the insulating materials within the cable. Figure 53.12 illustrates the various dielectrics in a multipair cable. To ensure the cable dielectric remains stable, all dielectrics should be frequency stable and have similar dielectric constants.

Typical relative dielectric constants for twisted pair telephone cables at low frequencies are illustrated in table 53.2 for various conductor insulations and interstitial filling materials.

Cable insulation

PVC insulation is used for low speed applications but for high speeds materials such as polyethylene or polypropylene are used because of their better electrical characteristics. In addition to being used in solid form, they can be applied as a cellular material with a permittivity of about 1.45. One method of producing cellular polyethylene is by mixing a chemical additive with the raw material in the extruder. At the extrusion temperature this 'blowing agent' decomposes to produce small cells of nitrogen gas which give the cellular structure, and hence the required low permittivity. There is a tendency for residual blowing agent to give a slightly higher power factor than desirable but on balance the use of cellular material offers a useful advantage. A second technique for producing cellular polyethylene is direct gas injection at extrusion, with the advantage that the reduced chemical residue results in lower dielectric losses.

Although cellular dielectrics can have low permittivities, they can be mechanically weak. A method used to strengthen them is to crosslink them by irradiation.

Screening

An important requirement for many electronic and data cables is adequate screening against various kinds of electromagnetic influences and the need to preserve the integrity of the signal from interference or noise either inside or outside the transmission line.

Many screen designs have been developed to combat the effects of interference. The ideal screen would be a homogeneous thick walled copper tube. Such screens are used on RF and CATV cables, sometimes corrugated to improve flexibility. Sometimes a lighter aluminium tube is used.

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Another form of low loss outer conductor is a copper tape applied longitudinally to the insulated core with an overlap. Because current travels longitudinally, a gap or overlap parallel to the axis of a coaxial cable does not affect the attenuation. A typical construction has a copper tape which is corrugated to give better flexibility. It is regarded as a semi-flexible cable, suitable for fixed installations.

Another cheaper version uses a much thinner copper tape. This is not corrugated but has an additional copper wire braid. It is suitable for fixed installations but is not as mechanically robust as the corrugated thick tape construction.

Copper wire braids are used extensively on many types of electronics cables. They are applied with a machine in which two sets of bobbins called spindles or carriers rotate in opposite directions round the cable core with an interweaving chain motion. Each bobbin contains a number of separate wires, referred to as the number of ends. By varying the number of spindles and ends and the lay length of the braid different degrees of coverage can be obtained.

The theoretical understanding of the a.c. resistance of braids and the way in which current flows in them is based mainly on the results of experimental measurements. It is thought that at lower frequencies the current flows mainly along the individual braid wires. The fact that there are two sets of wires spiralling in opposite directions cancels out any inductive effect that would otherwise be present. At higher frequencies the currents tend to flow parallel to the cable axis, so that the contact resistance between crossing braid wires becomes important. This can have an effect on the stability of the attenuation of the cable with time because if the contact resistance increases then the attenuation at microwave frequencies will increase. It has been found that silver-plated braid wires with an appropriate braid design give better stability of contact resistance than plain copper.

Many data cables employ screens manufactured from very thin metallic foils backed with a polyester film to provide strength. Such laminated tapes are applied longitudinally or helically and have the advantage of resulting in only small increases in cable diameter. To optimise screening efficiency, a copper wire braid can be applied over the foil screen or double-sided laminates can be used.

The efficiencies of cable screens are described by the parameter 'coupling impedance' or 'surface transfer impedance', which relates the induced current flowing on one side of a screen to the longitudinal voltage appearing on the other side. For a homogeneous tubular screen it is given by

$$Z_T = \frac{\rho}{2\pi t(ab)^{1/2}} F(u) \tag{53.20}$$

where

$$F(u) = \frac{u}{(\cosh u - \cos u)^{1/2}}$$

and

$$u^2 = \frac{2t^2\mu\omega}{\rho} \tag{53.21}$$

where ρ = screen resistivity
t = screen thickness
$(ab)^{1/2}$ = screen geometric mean diameter
μ = screen permeability
$\omega = 2\pi f$

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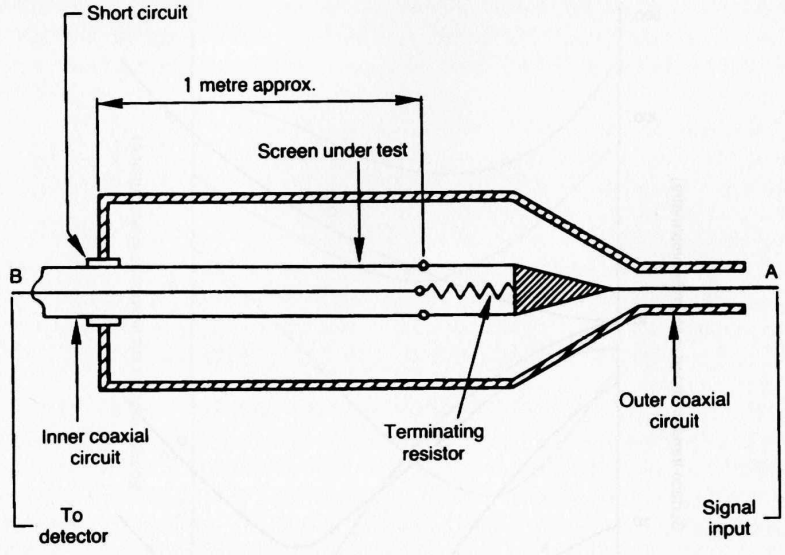


Fig. 53.13 Schematic diagram of triple coaxial apparatus

It follows that the lower the surface transfer impedance is, the better the screen is. For screens other than homogeneous tubes, the surface transfer impedance is usually measured using the triaxial arrangement shown in fig. 53.13.

Surface transfer impedances are shown in fig. 53.14 for various screen constructions at frequencies up to 30 MHz. Curves A and B show the typical drooping characteristic of the better screens. Curve C shows a popular type of screen, a single copper wire braid, which has a rising characteristic with a typical value of 200 mΩ/m at 30 MHz. To improve screening performance a second braid may be applied either directly in contact with the first (curve D) or with an intersheath (curve E).

The ratio of the resistance of a wire braid to the resistance of an equivalent tubular conductor is called the braiding factor and is given by

$$K_B = \frac{K_L}{2K_F} + \frac{\pi K_L K_F}{4} \tag{53.22}$$

where $K_L = 1 + \pi^2 D^2/L^2$ the lay factor
$K_F = mndK_L^{1/2}/2\pi D$, the filling factor
D = mean diameter of braid
m = number of spindles
n = number of wires (ends) per spindle
d = braid wire diameter
L = braid lay length

The cover provided by a braid is $100K_F(2 - K_F)\%$, and the braid angle is given by $\tan\phi = \pi D/L$.

Typical wire braid screens have a braid angle of about 40° and a cover of just over 90% which is equivalent to a filling factor of 0.7. Braids can be optimised for surface

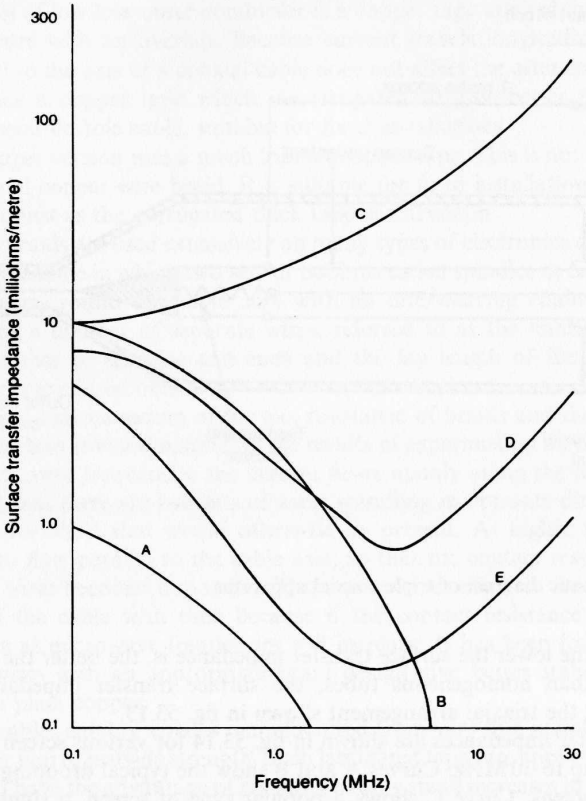


Fig. 53.14 Surface transfer impedances of various screens: curve A, seam welded copper tape 0.25 mm thick; curve B, overlapped corrugated copper tape 0.18 mm thick; curve C, single-wire braid; curve D, double-wire braids in contact; curve E, double-wire braids with intersheath

transfer impedance in terms of the numbers of spindles and ends, wire size and lay length, but generally a compromise is achieved between screening efficiency, manufacturing costs, flexibility and ease of termination.

Laminated foil tape screens provide 100% cover, and their screening efficiency is determined by the material and thickness of their metallic component. Improved efficiencies can be achieved by using double-sided foils in the form of a metal/polyester/metal sandwich, combinations of foils or combinations of foils and copper wire braids. Figure 53.15 shows the surface transfer impedance for various screens incorporating foils. Curve A is for a small coaxial cable with a single tape containing aluminium foil 0.05 mm thick. Curve B is for a multipair cable, with individual pairs screened with a single tape with an aluminium thickness of 0.025 mm, and an overall screen comprising a double-sided foil, each side 0.01 mm aluminium, and a tinned copper wire braid. Curve C shows the surface transfer impedance of the large coaxial cable illustrated in fig. 53.4 (left) which has a tape/braid/tape/braid screen, the tapes being double-sided aluminium/polyester.

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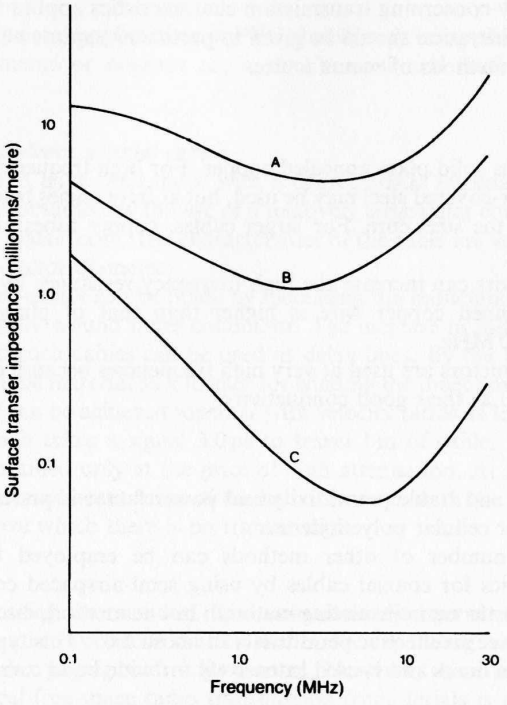


Fig. 53.15 Surface transfer impedance of cables with foil screens: curve A, single aluminium foil 0.05 mm thick; curve B, single- plus double-sided foil with copper braid; curve C, foil/braid/foil/braid

Another type of screen has been developed for applications in nuclear plant installations where very low limits are set on leakage from one control circuit to another. These 'super screened' cables have a mu-metal tape lapped between two braids and show surface transfer impedance values at 30 MHz as low as 1 $\mu\Omega$/m.

COAXIAL CABLES

In general coaxial cables perform better than their pair counterparts at higher frequencies. For a given attenuation, the size and cost of a coaxial is less than that of a twin or pair cable of comparable performance. They do not display the instability of characteristic impedance, attenuation and electrical length typical of screened twins, but at lower frequencies the screening efficiency of a balanced twisted pair can be superior.

Design features

The basic coaxial cable design is an inner conductor surrounded by a dielectric and a concentric outer conductor.

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The general theory concerning transmission characteristics applies to coaxial cables, but in addition consideration should be given to particular aspects of design related to the application and methods of manufacture.

Inner conductor

The preferred form is solid plain annealed copper. For high frequency use, because of the skin effect copper-covered steel may be used, but at frequencies below 10 MHz some current will flow in the steel core. For larger cables, copper tubes or copper-covered aluminium are used.

Stranded conductors can increase the high frequency resistance by up to 25%, and the resistance of tinned copper wire is higher than that of plain copper wire at frequencies above 10 MHz.

Silver-plated conductors are used at very high frequencies because of their smoother surface finish as well as their good conductivity.

Dielectric

Insulation with low and stable permittivity and power factor is preferred. This can be solid polyethylene or cellular polyethylene.

Alternatively, a number of other methods can be employed to fabricate low permittivity dielectrics for coaxial cables by using semi-airspaced constructions with solid polyethylene as the main insulating material. In one method, discs of polyethylene spaced at intervals give an effective permittivity of about 1.07. This type can be made to very close impedance limits and is used extensively for wide band carrier telephone and video trunk routes.

Another construction is the helical membrane type. A continuous tape of polyethylene is applied in the form of a helix along the inner conductor. This gives an effective permittivity of 1.1 which, as in the case of the disc spaced cable, is approaching the lowest practical limit.

A further type shown in fig. 53.16 uses a thread and tube construction in which a thread of polyethylene is lapped round the inner conductor and a close fitting polyethylene tube is extruded over this, giving a permittivity of about 1.3.

Outer conductor

The best form of outer conductor giving low attenuation and good screening is a solid copper tube. For flexible applications copper wire braids are used or combinations of thin tapes and copper wire braids.

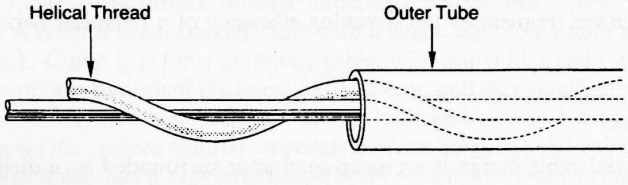


Fig. 53.16 Thread and tube dielectric construction

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Outer protection

For indoor and general applications, a PVC sheath may be applied overall. For more arduous environments or outdoor use a steel armour and further PVC sheath can be applied.

Low and high impedance coaxial cables

Some special cables have been made with a characteristic impedance as low as 14 Ω. Low impedance is obtained by the use of a relatively large inner conductor formed by a wire braid over a plastic core. The characteristics of the cable are very sensitive to small variations in conductor diameter.

High impedance cables can be made by increasing the inductance per unit length by the use of a helically wound inner conductor. The increase in inductance reduces the velocity ratio and such cables can be used as delay lines. By the use of a plastic core loaded with magnetic material as a former for winding the inner conductor, impedances as high as 4000 Ω can be achieved together with velocity ratios as low as 0.001. For this low velocity ratio it takes a signal 3.0 μs to travel 1 m of cable. The delay and high impedance are obtained only at the price of high attenuation. At high frequencies the capacitance between adjacent turns of the helix resonates with the inductance at a cut-off frequency above which there is no transmission.

Radiating cables

There is an increasing demand for rapid communication services in the interests of efficiency, safety and convenience as witnessed by the expanding use of two-way mobile radio systems, radio paging and radio control. However, there are certain situations where conventional free-space radio transmission from aerials is not practical, e.g. in mines, tunnels, power stations, industrial areas and linear situations such as railways and motorways. The range of natural radio propagation in tunnels is very poor, only a few hundred metres at the most, so that communication with a distant receiver inside a tunnel is impossible using normal techniques. One way of overcoming this problem is to use a radiating cable or leaky-feeder technique in which the required radio signals radiate from a cable rather than from a conventional aerial.

The basic principle of this technique is shown in fig. 53.17. A two-way base radio station is connected to a long radiating cable transmission line which runs throughout the area where communication is required and transfers signals to and from the mobile stations through the radiation field from the cable. The special design of cable is sometimes called a leaky feeder because when it is fed with radio signals at one end it leaks small amounts of energy all along its length to be picked up by nearby mobile aerials.

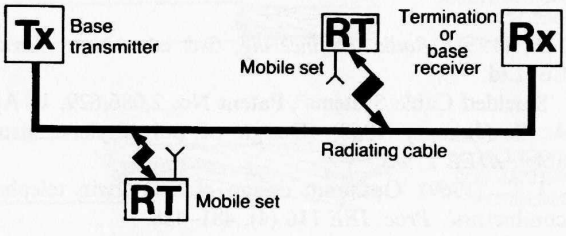


Fig. 53.17 Radiating coaxial cable system

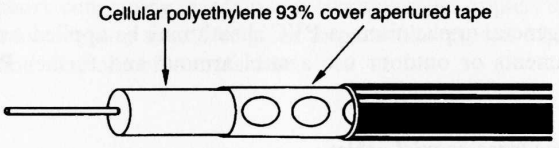


Fig. 53.18 Apertured tape screened radiating cable

The bifilar or unscreened twin cable is economic and radiates well, although the attenuation is very unstable. Even at the lower frequencies a large increase in attenuation occurs when the cable is laid on the floor or mounted close to walls. Experience in coal mines has shown that a serious increase in attenuation occurs when a layer of wet coal dust accumulates on the cable surface. However, with specially designed coaxial cables, good radiation and stable attenuation can be achieved when the cable is wet or dirty or mounted on walls. In these cables the outer screen is a corrugated copper tape perforated with a series of holes, as shown in fig. 53.18, to provide and control the radiation.

Experimental work has shown that radiation from an apertured tape cable depends on the dielectric permittivity of the insulation, and the stability of attenuation under wet and dirty conditions depends on the surface transfer impedance.

A theoretical treatment of the field leakage through a row of holes in an apertured screen has shown that at 30 MHz the surface impedance can be calculated using the formula

$$Z_T = \frac{4nd^3}{D^2} \qquad (\text{m}\Omega/\text{m}) \qquad (53.23)$$

where d = hole diameter (mm)
D = screen diameter (mm)
n = number of holes per metre

The optical coverage of apertured or braided screens is sometimes quoted as a characteristic. However, if the surface transfer impedance depends on nd^3/D^2 and the optical cover depends on nd^2/D, it can be seen that optical coverage is not a direct measure of screening efficiency.

A general purpose radiating coaxial will have a permittivity around 1.4 and a surface transfer impedance of 500 mΩ/m.

REFERENCES

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CHAPTER 54
Datacommunication Cables

TWISTED PAIR DATA CABLES

Design features

A variety of twisted pair designs is used as shown in fig. 54.1. Conductors are generally in the range 0.2–0.8 mm^2 (24–18 AWG), solid or stranded, and tinned for ease of termination. PVC insulations are used for short distances and low speed data but for higher speeds and longer distances, polyethylene and polypropylene in solid or cellular form are used. Individual pair screens to reduce crosstalk are generally laminated foils

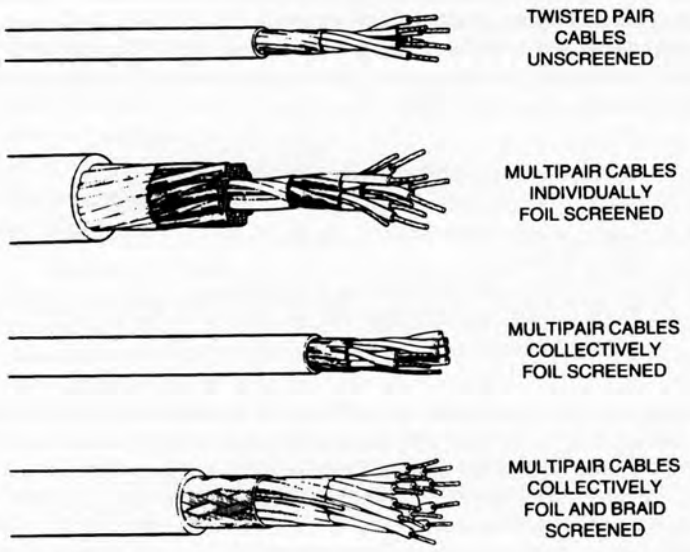


Fig. 54.1 Twisted pair cable

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and incorporate a drain wire to achieve satisfactory electrical connections. Overall screens provide protection from outside interference and can be laminated foils with or without an overall braid.

Outer sheaths are generally PVC formulated to suit the particular application, including high and low service temperatures, and to impart flame retardance. A zero halogen low smoke material is used when the emission of smoke, toxic, or acidic gases is considered a hazard in a fire.

High performance twisted pair cables

Many of the early local area network systems were introduced in the USA, and through the efforts of the American Institute of Electrical and Electronics Engineers (IEEE), and particularly Project 802, a family of standards was drawn up for local and metropolitan area networks. Having gained worldwide acceptance many of these systems standards were adopted by ISO.

The earliest standards activity for Structured Wiring was also initiated in USA in 1985 by the Electronics Industries Association (EIA) who established their Engineering Committee TR-41.8 to draw up a Commercial Building Wiring standard to provide a general purpose cabling system to accommodate all communications services. Work commenced to embrace the main features of commercially available networks and cabling schemes; particularly influential was the approval of IEEE 802.3 10 Base T, a system which promoted 10 Mbps transmission over 100 metres of a four pair unscreened cable.

After amalgamating with the Telecommunications Industries Association (TIA) the first Structured Wiring standard was published in July 1991 as EIA/TIA 568. It covered a hierarchical star network with four pair unscreened horizontal cables specified for frequencies up to 16 MHz in terms of impedance, attenuation, crosstalk, mutual capacitance, and capacitance and resistance unbalance.

As systems developed to higher data speeds, attempts were made to classify cables by performance into Levels or Categories. Five copper conductor cable categories were defined as follows.

Category 1: Basic telephone cable for voice frequencies
Category 2: Data cable for use up to 4 Mbits^{-1}
Category 3: LAN cables characterised up to 16 MHz. These cables will support Class C links
Category 4: LAN cables characterised up to 20 MHz
Category 5: LAN cables characterised up to 100 MHz. These cables will support Class D links

These categories were confirmed by the EIA/TIA in their Technical Systems Bulletin TSB-36, published in November 1991. Category 1 and 2 cables are not suitable for the higher performance Structured Wiring systems and Category 4 cables are becoming obsolete. Although ISO/IEC 11801 details Category 3, 4 and 5 cables, EN 50173 specifies Categories 3 and 5 only.

The requirements for balanced twisted pair cables in horizontal subsystems apply to materials, mechanical performance and dimensions, and electrical and transmission

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Table 54.1 Electrical characteristics of 100 Ω twisted pair cables to ISO/IEC 11801 and EN 50173

Cable characteristics			Cable category	
Electrical characteristics at 20°C	Units	MHz	3	5
Maximum d.c. loop resistance	Ω/100 m	d.c.	30	30
Maximum resistance unbalance	%	d.c.	3	3
Maximum capacitance unbalance	pF/km	0.0008 or 0.001	1600[a]	1600[a]
Maximum transfer impedance (for screened cables)	mΩ/m	10	100	100
Minimum insulation resistance	mΩ km	d.c.	150	150

[a] These values are specified in EN 50173. ISO/IEC allows up to 3400 pF/km.

characteristics. The physical requirements relate to the operating environment, installation practices and compatibility with connecting hardware, and ISO/IEC 11801 and EN 50173 lay down the permissible range of conductor diameters, the maximum diameter of the conductor insulation, the operational and installation temperature ranges, the minimum bending radius and pulling strength.

The electrical and transmission requirements for Category 3 and Category 5 100 Ω twisted pair cables in horizontal subsystems are shown in tables 54.1 and 54.2. When measuring impedance, structural return loss, attenuation and near end crosstalk, swept frequency techniques are used and it is a requirement that compliance is maintained at every measurement frequency as well as at the nominated frequencies.

The requirements for horizontal subsystem cables can be met by a four pair cable, either unscreened or collectively foil screened as shown in fig. 54.1. Typically these cables have a 0.5 mm (24 AWG) conductor with a polyolefin insulation, either solid or cellular. Because of the demanding performance requirements, control of materials and processing techniques must be at a significantly higher level than when manufacturing basic telephone pair cables.

Balanced cable transmission

The main parameters influencing the performance of a balanced transmission system are characteristic impedance, crosstalk, loop resistance, attenuation, velocity of propagation and the immunity to electromagnetic radiation. For some installations, electromagnetic radiation from the cable is also important.

Constructional features of the cable such as conductor size, variation in conductor diameter, insulation permittivity, variation in insulation diameter, twinning lays, cabling lays and screen foil thickness can have an effect on one or many of these parameters.

Crosstalk

Cables with twisted pairs are used where balanced signal transmission is required, together with low crosstalk. Crosstalk refers to interference on one channel caused by a signal in another channel and occurs between cable pairs carrying separate signals. This definition embraces both near end crosstalk and far end crosstalk.

Table 54.2 Transmission characteristics of 100 Ω twisted pair cables to ISO/IEC 11801 and EN 50173

Cable characteristics			Cable category	
Transmission characteristics at 20°C	Units	MHz	3	5
Velocity of propagation	–	10	0.6c	0.65c
		100	–	0.65c
Minimum longitudinal conversion loss[a]	dB	0.064	–	43
Minimum structural return loss[a]	dB @ 100 m	1–10	12	23
		10–16	10	23
		16–20	–	23
		20–100	–	[b]
Characteristic impedance	Ω	1–100	100 ± 15	100 ± 15
Maximum attenuation	dB/100 m	1	2.6	2.1
		4	5.6	4.3
		10	9.8	6.6
		16	13.1	8.2
		20	–	9.2
		31.25	–	11.8
		62.5	–	17.1
		100	–	22.0
Minimum near end crosstalk	dB @ 100 m	1	41	62
		4	32	53
		10	26	47
		16	23	44
		20	–	42
		31.25	–	40
		62.5	–	35
		100	–	32

[a] Values are not given in EN 50173.
[b] In accordance with the relationship $23 - 10\log(f/20)$ where f is the frequency in MHz.

Near end crosstalk is the crosstalk which is propagated in a disturbed channel in the opposite direction to the current in the disturbing channel, and far end crosstalk is propagated in a disturbed channel in the same direction as the current in the disturbing channel. Crosstalk is fundamentally the resultant of two factors, or couplings, capacitance unbalance and mutual inductance.

Capacitance unbalance gives rise to electrostatically induced potential differences between the wires of the disturbed pair; this coupling is important at all frequencies. When the capacitance of one conductor against the sheath and all of the other conductors combined is not the same as the capacitance of its mate (similarly measured) the pair is said to have a capacitance unbalance; this is measured by the difference between these two capacitances. When the capacitances are equal, the pair is said to be balanced.

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Mutual inductance gives rise to electromagnetically induced potentials along the wires of the disturbed pair. This coupling exerts little influence at audio frequencies but becomes increasingly important as the frequency increases.

Both couplings are due to departures from balance between the circuits concerned. In design and manufacture, attempts are made to ensure that the distances between the wires of one pair and the wires of another are equal, as are the distances between each wire and earth. This is done by careful choice and control of materials, insulation thicknesses, twinning lays, and tensions, but during manufacture unavoidable small differences occur which result in residual values of the couplings.

As capacitance unbalance is an electrostatic coupling, it can be reduced by enclosing either or both of the interacting pairs in a screen. The screen need only be thin, and laminated foil screens are generally used. At higher frequencies, mutual inductance becomes important and differential twinning lays in adjacent pairs are used to minimise parallel paths and reduce the effect.

Impedance

The impedance match between a cable and its terminal equipment is important in controlling signal reflections. For twisted pair cables, random structural variations along the cable length occur in addition to periodic structural variations common to manufacturing processes involving rotating machinery. It is therefore usual to specify and measure structural return loss as well as impedance. Maintenance of machinery and control of processes are essential to meet the transmission requirements for Category 5 cables.

Attenuation to crosstalk ratio

Attenuation and crosstalk are important in determining the received signal-to-noise ratio. In ISO/IEC 11801 and EN 50173, alternative limits for attenuation and crosstalk are allowed provided the required attenuation to crosstalk ratio (ACR) is maintained. The ACR of a given length of cable is calculated as:

$$ACR = a_n - a \qquad \text{(dB)} \tag{54.1}$$

where a_n = near end crosstalk in dB between any two pairs
a = attenuation in dB

Table 54.3 shows the minimum values of ACR specified in EN 50173. The introduction of this parameter allows some flexibility in cable design, for example attenuation can be reduced by increasing the conductor size, reducing the insulation permittivity, increasing pair twinning lays and for screened cables, increasing the screen metal content to reduce its resistance. Crosstalk can be improved by optimising the pair twinning lay scheme or by introducing individual pair screens. Variation in crosstalk performance is reduced by shortening pair twinning lays.

Electromagnetic compatibility

Structured wiring systems can be subject to local regulations regarding electromagnetic emission and immunity. Although the cable as a product is considered to be a passive component of the system, and therefore is not required to be tested for electromagnetic compatibility (EMC), the operational system may be required to comply with, for example, European EMC Directive 89/336/EEC. These requirements should be taken

Table 54.3 Minimum ACR for 100 Ω Category 5 twisted pair cables to EN 50173

Frequency (MHz)	ACR (dB)
1	59.9
4	48.7
10	40.4
16	35.8
20	32.8
31.25	28.2
62.5	17.9
100	10.0

into account when designing a generic cabling system, and it may be advisable to optimise the emission and immunity characteristic of the cable, by optimising the balance of the cable and by the application of screens.

In a balanced system, the receiver responds to the differential voltage between the lines and, if the pair and cable are perfectly uniform with each leg identical, electromagnetic fields generated by the two signals flowing in the twisted pair cancel with the result that the net cable radiation is zero. If the pair is not perfectly uniform, imbalances result as the two signals do not cancel; a net current flows longitudinally which produces electromagnetic radiation. Similarly, imbalances lead to a coupling with external electromagnetic fields making the cable more sensitive to interference. Discontinuities in the cable, which may be produced during installation, can cause a part of the differential mode signals to be converted to longitudinal signals.

Two types of measurements are used to characterise the balance of a cable. These are the longitudinal conversion loss (LCL) and the longitudinal conversion transfer loss (LCTL). LCL measurements are made at the near end of the cable and identify imbalances near to a transmitter which could create radiation; LCTL measurements are made at the far end of the cable and identify the effects on the received signal of imbalances throughout the cable length.

The EMC performance of a cable can be improved by applying a collective screen, and surface transfer impedance is used as a guide to its effectiveness.

Installation

For high performance twisted pair cables operating at the higher frequencies, the cable design and installation practices must ensure that adequate cable balance is maintained after installation and termination. Both ISO/IEC 11801 and EN 50173 specify the performance of cables, connecting hardware and installed links.

Manufacturers recommendations regarding bending radii, pulling tensions and cable spacing should be observed to avoid cable stress due to sharp bends, crushing, excessive tension and tightly bunched cables. When terminating cables in connecting hardware, the untwisted length of pair and the length of removed sheath should be as short as possible.

For screened cables, earthing and bonding procedures should address the EMC performance of the link as well as electrical safety. Screens intended to improve

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EMC performance are applied to both cables and connecting hardware and must be terminated in such a way that the screening effectiveness is maintained over the complete link.

OPTICAL DATA CABLES

Cable designs

Initially optical fibre cables were developed for long distance telecommunications, but as the technology advanced, numerous applications arose in data systems where the advantages of optical fibre transmission could be employed. Cables designed to meet the requirements of IEC 794 and EN 187000 will provide a satisfactory performance for the majority of data applications. The basic design principles are the same as those described in chapter 49.

For metropolitan and wide area networks where data transmission over long distances is required, cables designed for aerial, duct and buried routes on public and private telecommunications systems are used with single mode fibres (see chapter 48). For local area networks similar cable designs are used for both campus and building backbones, in some cases modified to be completely non-metallic. On the shorter route lengths, multimode fibres are often used when power budget and coupling parameters are as important as attenuation and bandwidth. IEC 793-1 (Optical Fibres) specifies a variety of step, quasi-step and graded index multimode fibres and includes a guide for fibres for short distance links, with 62.5/125 μm and 50/125 μm graded index fibres gaining popularity for local area networks.

For structured wiring, ISO/IEC 11801 and EN 50173 recommend optical fibre cables for most campus backbone cabling to overcome problems due to earth potential differences and other interfering sources as well as to provide extended route lengths up

Table 54.4 Optical fibre cable performance recommended in ISO/IEC 11801 and EN 50173

Fibre type	Multimode 50/125 or 62.5/125	Single mode
Maximum attenuation (dB/km) at:		
850 nm	3.5	–
1300 nm	1.0	–
1310–1550 nm	–	1.0
Minimum bandwidth (MHz km) at:		
850 nm	200	–
1300 nm	500	–
Maximum cut-off wavelength (nm)	–	1280

Note: Applicable standards are:
Fibre: Type A1a (50/125), A1b (62.5/125) and B1 (single mode) to IEC 793-2, EN 188201, EN 188202, EN 188100, EN 188101.
Cable: IEC 794-2, IEC 794-3, EN 187000, EN 60794-3.

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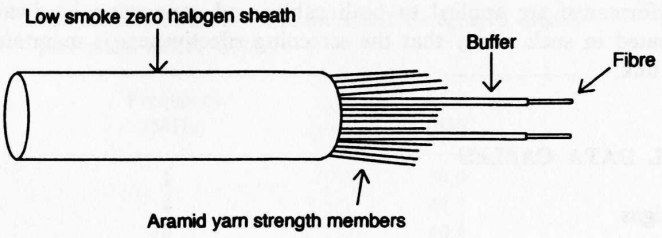


Fig. 54.2 Duplex optical cable for horizontal subsystems

to 3000 m with single mode fibres and 2000 m with multimode fibres. Optical cables are recommended for building backbones on medium to high speed data links, for horizontal data cabling with some very high bit rate systems, and where the electromagnetic environment and security considerations could cause problems with metallic conductor cables.

Table 54.4 shows the optical cable transmission requirements of ISO/IEC 11801 and EN 50173. For the horizontal cables, indoor cables are used, and preferably they should have handling characteristics similar to or better than the four pair Category 5 cables. Figure 54.2 shows a popular compact non-metallic cable featuring individually buffered fibres surrounded by a non-metallic strength member such as aramid yarn, with an overall sheath of low smoke zero halogen material.

In these tight buffered cables the fibre mechanical protection is provided by a layer of material applied directly over the coating of the fibre. This may be a dual layer, with a softer inner layer to provide a cushion against stresses which could cause an increase in attenuation, and a harder outer layer to provide mechanical protection. A typical dual layer buffer has a 140 µm thick inner layer of silicone covered by a 250 µm layer of polyamide. This form of buffer facilitates stripping, a force of only 10 N being required to strip the entire buffer over a 20 mm length.

Blown fibre systems

Of particular interest for local area networks is the development of the technique of blowing fibres into ducts or tubes. Blown fibre systems have been developed as a method of avoiding fibre overstrain for complex route installations. They allow easy upgrading and future proofing with low initial capital investment and the distribution of subsequent costs.

The network infrastructure is created by installing, using the most appropriate cabling method, one or a group of empty plastic tubes. Subsequently as and when circuit provision is required, one or more fibres can be blown by compressed air into the tubes. Individual tubes can, by means of connectors, be extended within buildings up to the fibre terminating equipment.

To enhance the blowing characteristics and to facilitate handling special coatings can be applied to the fibres. Figure 54.3 shows a typical blowable fibre construction whereby fibres can be blown singly or in groups into the same tube. Fibres with different transmission characteristics, or different types, e.g., multimode and single mode, can be blown into the same tube to accommodate particular network requirements.

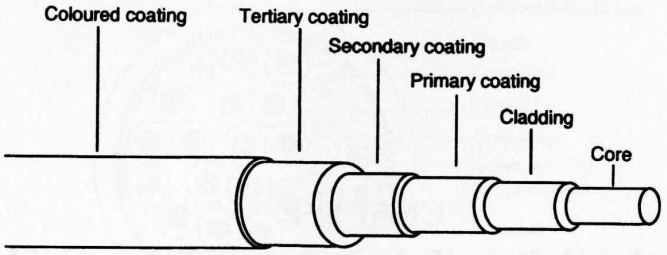


Fig. 54.3 Blowable fibre

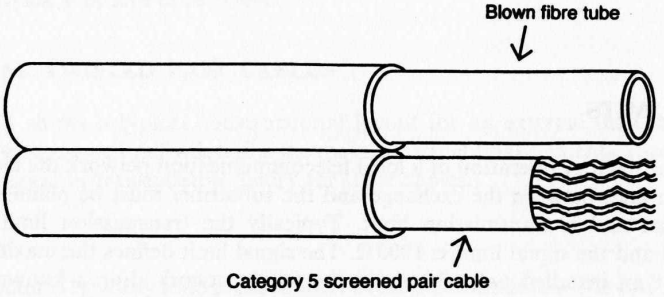


Fig. 54.4 Composite blown fibre and Category 5 pair cable

This technique can also be used to blow fibre ribbons into the tubes to take advantage of multifibre array connectors.

Another cable for local area networks combines a blown fibre tube with a Category 5 structured wiring cable, as shown in fig. 54.4. This flexible approach to the future-proofing of networks provides for immediate requirements to be met with the Category 5 four pair copper conductor cable and future optical up-grading by blowing in fibres as and when required without further cable installation costs.

Pre-connectorised cabling

To save on-site costs, loose tube, tight buffered or ribbon optical cables can be factory terminated with multifibre array connectors, and with suitable protection and end fittings, the terminated cable can be pulled-in and installed using conventional techniques.

Ex. 1032

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of the

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TECHNICAL SESSIONS

Tuesday, 18 November 1980

9:30 a.m. Session I	Tutorial - Outlook For Voluntary Standards In U.S.A.
2:00 p.m. Session II	Cable Design I
2:00 p.m. Session III	Material

Wednesday, 19 November 1980

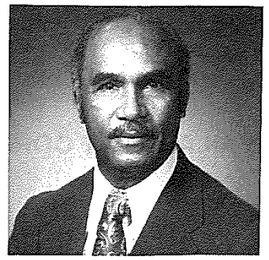
9:00 a.m. Session IV	Cable Design II
9:00 a.m. Session V	Connectors
2:00 p.m. Session VI	Fiber Optics I
2:00 p.m. Session VII	Fire Considerations

Thursday, 20 November 1980

9:00 a.m. Session VIII	Fiber Optics II
9:00 a.m. Session IX	Testing
2:00 p.m. Session X	Fiber Optics III
2:00 p.m. Session XI	Cable Applications

PAPERS

Responsibility for the contents rests upon the authors and not the symposium committee or its members. After the symposium, all the publication rights of each paper are reserved by their authors, and requests for republication of a paper should be addressed to the appropriate author. Abstracting is permitted, and it would be appreciated if the symposium is credited when abstracts or papers are republished. Requests for individual copies of papers should be addressed to the authors.



MESSAGE FROM THE DIRECTOR

On behalf of CORADCOM and the symposium committee, welcome to the 29th Annual International Wire and Cable Symposium (IWCS). It is indeed gratifying to report that the symposium continues to attract world-wide attention from scientists, consultants, manufacturers, material suppliers and end product users of cables/wires. Many favorable comments were received on the technical contents and timely relevance of the papers presented during last year's symposium. Last year's attendance of 1583 included representatives from 404 U.S. companies, 30 foreign countries and 10 U.S. government agencies.

This year, the committee is also looking forward to a very exciting and enthusiastic meeting with many excellent papers scheduled for presentation. The technical program will begin with a tutorial session, entitled "Outlook For Voluntary Standards in U.S.A.", followed by ten individual sessions. The three sessions on fiber optics should be of special interest since twelve of the eighteen papers will contrast various developments and applications of fiber optics in seven foreign countries.

Committee members, Adolf Asam, ITT Electro Optical Products Division, Ken Bow, Dow Chemical U.S.A., Marta Farago, Northern Telecom Ltd., Irv Kolodny, General Cable Company, and Frank Short, Beldon Corporation, are retiring from the committee. Each member was extremely dedicated and contributed significantly to the success of the committee's objectives. On behalf of the committee, I wish to thank each one for their valuable contributions and wish them success in their future activities.

The committee recognizes the inconveniences encountered and concern expressed by many attendees with respect to the number of hotels/motels used for housing accommodations and their location or distance from the Hyatt. However, before another location can be selected, it must be approved by CORADCOM, the symposium sponsor. CORADCOM has stipulated that any location selected for the symposium must be within a reasonable distance of Fort Monmouth, preferably less than 100 miles, which limits the number of facilities with adequate accommodations.

The symposium cannot prosper without the sustained participation and attendance of representatives of the various industrial organizations and government activities. Therefore, the committee solicits the continued support of all members of the wire and cable industry. Again, I wish to express my appreciation to each committee member for their support, dedicated effort and cooperation. A very special thanks to Ms. Conti for her sincere dedication to the symposium objectives, her support and cooperation.

ELMER F. GODWIN
Director, IWCS

AWARDS

	Outstanding Technical Paper		*Best Presentation*
	H. Lubars and J.A. Olszewski, General Cable Corp—"Analysis of Structural Return Loss in CATV Coaxial Cable"	1968	N. Dean, B.I.C.C.—"The Development of Fully Filled Cables for the Distribution Network"
	J.P. McCann, R. Sabia and B. Wargotz, Bell Laboratories—"Characterization of Filler and Insulation in Waterproof Cable"	1969	J.D. Kirk, Alberta Government Telephones—"Progress and Pitfalls of Rural Buried Cable"
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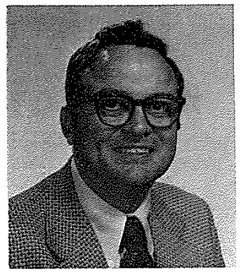
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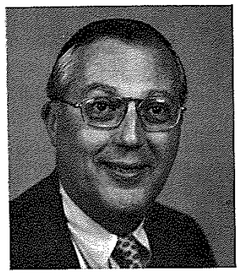
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APPLICATION OF SPACER FORMING TECHNIQUE TO COMMUNICATION CABLES

by

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Abstract

A new spacer forming technique has been developed. Flat plastic or laminated tapes are formed into V-shaped or U-shaped spacers and then stranded with each other in the stranding process. These spacers can accommodate optical fibers or star quads of insulated copper conductors, or can be used as the insulator of a coaxial core.

The technique was developed for optical cable in order that the spacers might preserve transmission characteristics and protect the optical fibers. It was then studied how to apply this technique to fabrication of coaxial cores and screened pair-type units. In coaxial cores, six V-shaped polyester spacers were used as the insulators between the inner conductor and outer conductor. A screened pair-type unit was formed by stranding five V-shaped spacers of polyester-laminated aluminum tape, and each spacer accommodated a star quad.

All of these cables which adopted the new spacer forming technique had sufficient transmission and mechanical properties, and a considerable number of spacer-type optical cables, in particular, have been put into actual use.

1. Introduction

A structure with spacers is supposed to be useful for avoiding microbending and preserving transmission characteristics of optical cables. In many reported cases, optical fibers are embeded in a groove spacer preformed by extrusion before fiber stranding.[1] The fabrication of these cables which use grooved spacers has generally two difficulties: preparation of the spacer, and synchronization between the spacer and fibers.

On the other hand, the spacer described here is constructed simultaneously with the fiber stranding process. Hence, a preformed spacer and special synchronization are not needed, and these advantages make it possible to use a conventional stranding machine. Moreover, this technique has another advantage in that arbitrary stranding pitches can be easily designed as far as the stranding machine permits.

This paper describes the principle of spacer forming, the fabrication of optical cables, and their characteristics. Applications of this technique to coaxial and screened pair-type cables are also described.

2. Manufacturing Method (2)

The manufacturing method is shown in Fig. 1. In the stranding process, flat tapes are folded into the desired V-shaped or U-shape spacers by passing the tape through spacer formers located just before the assemblage die, and are then stranded with each other. A rather thick tape is considered to be preferable as the spacer from the point of view of tape forming and mechanical strength of the cable, and the spacer formers play an important role in this technique. The formers should precisely fold the flat tapes into the designated spacer configuration, which corresponds to the slit shape of the spacer formers. That is, V-shaped spacers can be obtained by passing the tape through a narrow rectangular slit, and U-shaped spacers, through a triangular slit. These mechanisms are shown in Fig. 2. The spacer forming tension should be as small as possible and should be almost equal for all of the spacers being stranded simultaneously. Maintaining uniformity in the tension and dimensions of spacers ensures a round, firm cable core. The use of a rotary assemblage die synchronized with the cage of the stranding machine is better than that of an ordinary stationary die, for precise settlement of spacers in the cable core can thus be assured.

After stranding of the spacers, the cable core is wrapped in some tapes. These wrapping

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tapes also make the core rigid and tight in this technique. Each compartment defined by spacers can accommodate optical fibers, and also pairs or quads, and the spacers can be used as the insulator of the coaxial core.

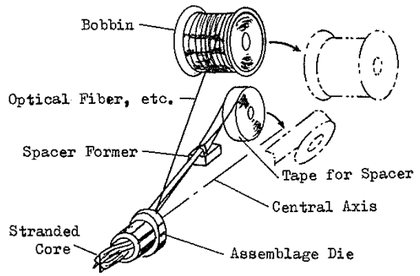


Fig. 1 Manufacturing Method

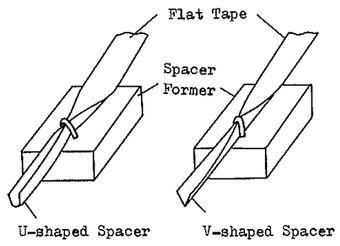


Fig. 2 Spacer Forming Mechanisms

3. Optical Cables with Spacers

3.1 Cable structure

The new spacer forming technique was first developed for optical cable. In general, lateral forces which arise due to microbending tend to increase the transmission loss of optical fibers.[3] In order to avoid microbending, it is effective to accommodate the optical fibers in the cable in a loosely fitting manner. When the V-shaped or U-shaped spacers are large enough to accommodate optical fibers, the fibers are no longer susceptible to external forces in the cabling processes and installation work.

After various investigations, it became clear that polyester tape with a thickness of 0.075mm to 0.2mm was adequate for the spacers of optical cable. Buckling load of the spacer is calculated by the following equation:

$$P = \frac{\pi^2 E t^3 B}{48 \ell^2}$$

where P : buckling load (kg)
t : thickness of spacer (mm)
E : Young's modulus of spacer (kg/mm^2)
l : height of spacer (mm)
B : length of spacer (mm)

Polyester tape possesses a large Young's modulus, about 500 kg/mm^2, compared with other plastic tapes, which contributes to increase the buckling load given by the above equation. When two spacers are in contact with each other, as illustrated in Fig. 3, buckling load of 2kg, 8 times as large as that in the case of a single spacer, is derived from the equation. The value is sufficient for the cable core to withstand any lateral force caused throughout the cable manufacturing processes.

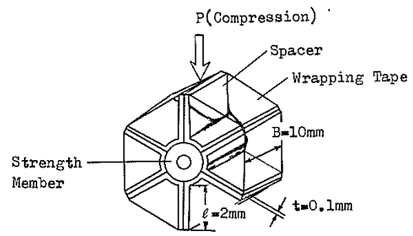


Fig. 3 Compression on Spacer

The typical structures of optical cables with spacers are shown in Fig. 4. The individual fiber can be easily identified by coloring the spacers rather than by employing colored fibers. The spacers accommodating individual fibers are stranded together around the central strength member. By adopting a larger size spacer, several fibers can be accommodated in one spacer. Use of the spacers easily leads to combining optical fibers with copper conductor pairs or quads, which are often included in optical cable, without additional loss increase.[4] Figure 5 shows the structures of various spacer-type optical cables. These cables have been put into actual use for optical communication lines at home and abroad.[5][6]

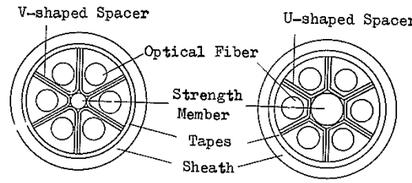


Fig. 4 Typical Structures of Spacer-Type Optical Fiber Cables

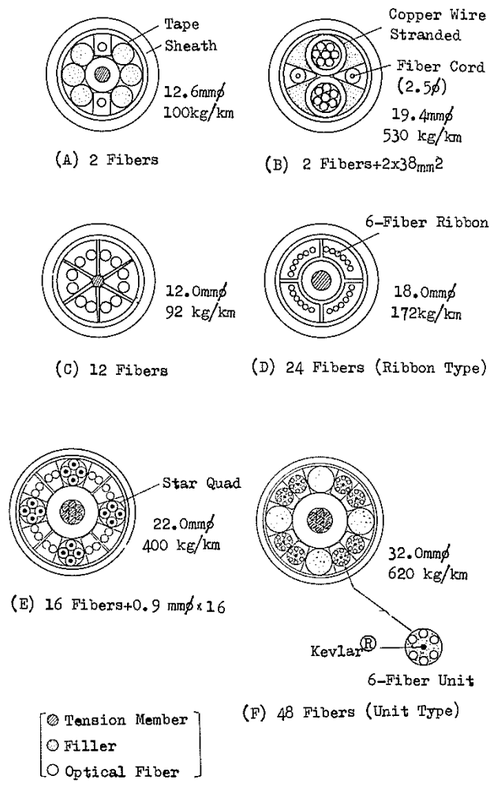


Fig. 5 Various Examples of Spacer-Type Optical Cables

3.2 General properties of spacer type optical cable

3.2.1 Transmission properties

In the cabling processes of optical cables, it is most important to conserve the inherent transmission characteristics of the optical fiber. The spacers contribute to making the optical fibers free from microbending. Figure 6 shows the average transmission loss change throughout the cabling processes for the fibers in cables(C) and (F) in Fig. 5, and almost the same results were confirmed for the other optical cables with spacers in Fig. 5. The fibers used had a core diameter of 50μm and a cladding diameter of 125μm with silica-type graded index profile, and were doubly coated with silicone and nylon.[3] The stability of transmission characteristics is primarily caused by the spacers, which isolate the optical fibers from all external forces.

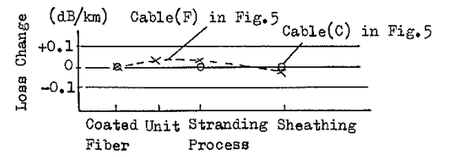


Fig. 6 Loss Change of Fibers in Cabling Processes

3.2.2 Mechanical properties

Table 1 shows the mechanical test conditions for cables (A), (C), and (F) in Fig. 5; no loss change and no fiber break were observed. The deformation of spacer-type optical cables under mechanical forces is generally less than that of non-spacer type optical cables.[7] This effect is the result of the reactional forces yielded by the spacers and of the round, tight structure produced by using spacers to sturdily combine cable elements such as the strength member, wrapping tapes, etc. The results indicate that conventional installation techniques can be satisfactorily used for these optical cables with spacers.

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Table 1 Mechanical Test Conditions

Item / Cable	Tension	Bending	Compression	Impact
(A)	150 kg	R=200mm (R: Bending Radius) 10 times	100kg / 50mm Width	Weight 0.45kg x Hight 1.0m
(C)	150 kg	R=70mm 10 times	100kg / 50mm Width	Weight 0.45kg x Hight 1.0m
(F)	1400 kg	R=100mm 10 times	500kg / 50mm Width	Weight 2.3kg x Hight 0.9m

3.2.3 Temperature property

The transmission loss of the optical fiber in the spacer also shows stability even when temperature changes. Figure 7 shows the results of transmission loss change versus temperature for cable (C) in Fig. 5. The transmission loss change is less than 0.05dB/km ranging from -40°C to 60°C. This stability depends on the central strength member and the polyester spacer, both of which have coefficients of linear expansion smaller than that of coated fiber.

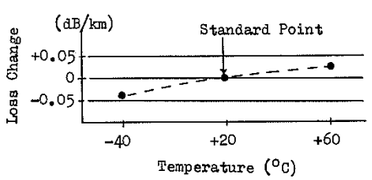


Fig. 7 Loss Change vs. Temperature for Cable (C) in Fig. 5

3.2.4 Penumatic property

It has been confirmed that the spacers, by increasing the air gaps in the cable, contribute to decreasing pneumatic resistance. Figure 8 shows the pneumatic resistances measured for fabricated spacer and non-spacer type optical cables.[8] It can be clearly seen that the pneumatic resistance of spacer type optical cable is less than that of non-spacer type even in the case of equal cross-sectional area of gaps in the cable, since the air gaps in individual elements in the spacer type is larger than that in the non-spacer type.

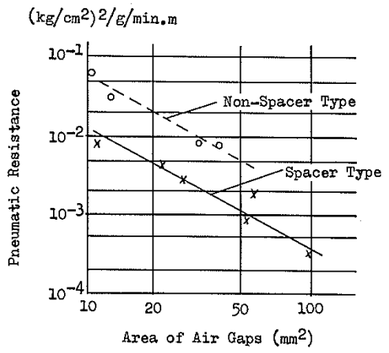


Fig. 8 Pneumatic Resistance vs. Area of Air Gaps

3.2.5 Optical fiber unit with spacers

The fiber units with spacers shown in Fig. 9 were designed and manufactured. They can be easily used for optical cables with a relatively large number of fibers. Their unit structures are summarized in Table 2. The average transmission loss change between fiber coating and unit making was 0.05dB/km and 0.0dB/km for unit (A) and unit (B), respectively.

A compression test using unit (A) was carried out as illustrated in Fig. 10. After the unit was crushed, the optical fiber was pulled out. The tension necessary to remove the fiber was measured by a spring balance; the

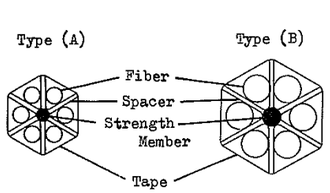


Fig. 9 6-Fiber Units with V-Spacers

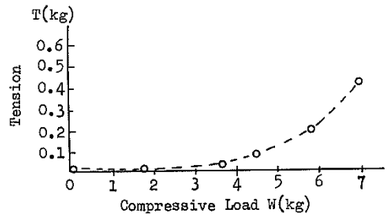


Fig. 11 Results of Compression Test

Table 2 Construction of Units

Item / Unit	(A)	(B)
Fiber	Core : 50 mφ Cladding : 125 mφ Buffer : 350 mφ Silica-Type Graded Index Profile	
Jacket of Fiber	Nylon 0.7 mmφ	Nylon 0.9 mmφ
Strength Member	0.4 mmφ steel wire	1.0 mmφ steel wire
Spacer	Polyester 0.075mm(T) x 3.5mm(W)	Polyester 0.1mm(T) x 3.5mm(W)
Unit Diameter	3.7 mmφ	4.1 mmφ

results are shown in Fig. 11. It can be clearly seen that the fiber is not subjected to any compressive stress below a load of 3kg/110mm width. There is no compressive stress left on the fiber even if wrapping tapes are strongly wound. After the unit with spacers is fabricated, it is possible to use the conventional cabling techniques for the unit without any particular need for concern.

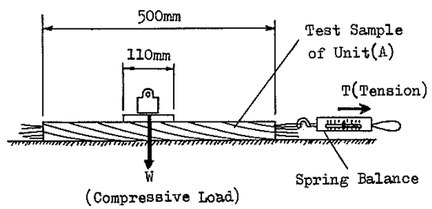


Fig. 10 Compression Test on Unit (A)

Another fiber-pulling test was done for unit (B). The relation between the maximum pulling tension of fiber removal and the length of the sample unit was investigated without lateral compressive load on the unit. From the results in Fig. 12, it can be seen that the fiber can be pulled out when the length of the unit is less than about 10m. Beyond 10m length, the fiber cannot be pulled out without damaging it. It was concluded that the fibers in the unit with spacers are sectionally free and are irremovable when they have longer lengths.

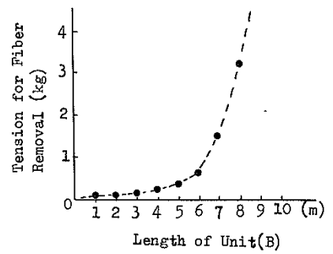


Fig. 12 Results of Fiber Pulling Test

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4. Coaxial Core with Spacers

Application of the spacer forming technique to coaxial cores was investigated. Polyester spacers were included as the insulator between the inner conductor and outer conductor. The large amount of air included with the spacers was considered to decrease the equivalent dielectric constant of the insulation. Two coaxial cores with different sizes, as shown in Fig. 13 and Table 3, were designed and fabricated. The coaxial cores were fabricated at the same time by stranding six V-shaped polyester spacers around an inner conductor, forming an outer conductor of copper tape, and wrapping in laminated tape. Polyester tape was wound under the outer conductor to make the core tight. By the selection of the spacer stranding pitch, the electrical properties of the coaxial core can be finely controlled, because the lay length affects the volume of polyester contained as the insulator.

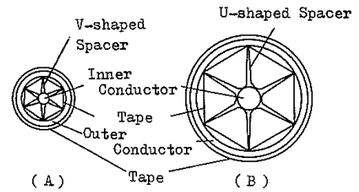


Fig. 13 Structures of Spacer Type Coaxial Cores

Electrical properties of the coaxial cores are given in Table 4. The measured values of capacitance and characteristic impedance were reasonable in view of the values of the equivalent dielectric constant derived from the construction. Attenuation constant versus frequency was measured for both coaxial cores in the range from 10 to 100MHz, as shown in Fig. 14. The structural return loss (SRL) of both coaxial cores was less than 26dB in the frequency region from 10 to 300MHz. Figure 15 shows SRL characteristics of coaxial core (A). This figure indicates good uniformity in the manufacturing process.

Various sizes of coaxial cores with spacers can be easily produced by changing spacer sizes. Moreover, it is possible to insert as many optical fibers as desired into the coaxial core with spacers.

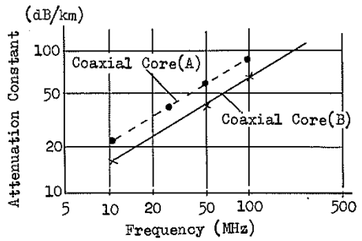


Fig. 14 Attenuation Constant vs. Frequency

Table 3 Construction of Coaxial Cores

Item \ Type	(A)	(B)
Inner Conductor	1.1 mmφ Copper Clad Steel	2.06 mmφ Copper
Spacer (Insulator)	Polyester Tape 0.125mm(T) x 3.5mm(W)	0.15mm(T) x 8mm(W)
Wrapping Tape of Spacer	0.025mm Thickness Polyester	0.025mm Thickness Polyester
Outer Conductor	Copper Tape 0.15mm(T) x 16mm(W)	Copper Tape 0.085mm(T) x 30mm(W)
Wrapping Tape of Core	Polyester (T:0.025mm) Laminated Aluminum (T:0.02mm)	Polyester (T:0.025mm) Laminated Aluminum (T:0.02mm)
Outer Diameter	5.0 mmφ	10 mmφ

Table 4 Electrical Properties of Coaxial Cores

Item \ Type		(A)	(B)
Insulation Resistance		825 kMΩ•km	1400 kMΩ•km
Dielectric Strength		Insulation capable of withstanding for 1 minute DC test potential of 2000 V	
Conductor Resistance	Inner	56.29 Ω/km	5.06 Ω/km
	Outer	7.42 Ω/km	6.18 Ω/km
Capacitance		57.68 nF/km	51.11 nF/km
Characteristic Impedance		70.8 Ω	75.5 Ω
Attenuation Constant (at 10 MHz)		22.4 dB/km	16.2 dB/km

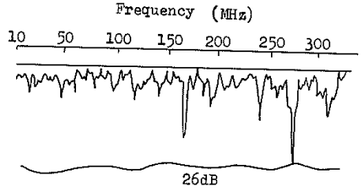


Fig. 15 Structural Return Loss of Core (A)

To clarify the improvement in crosstalk characteristics, far end crosstalk of screened units was measured in the frequency range from 100 KHz to 5 MHz together with that of non-screened units having no spacers. The results are shown in Fig. 17. The improvement of crosstalk characteristics was simply accomplished by using the spacer forming technique without any increase in the cabling process. When designed like unit (B), the unit diameter is almost equal to that of non-screened units.

5. Screened Pair-type Unit with Spacers

V-shaped or U-shaped spacers with metal can also be used as a screen of electromegnetic field. Polyester-laminated aluminum tape is suitable for this purpose. The structures of screened units with spacers are shown in Fig. 16 and Table 4. Five star quads and spacers were assembled with each other in an assemblage die, and then were wrapped in laminated tapes by a stranding machine without injuring the quads. Thus the quads were almost screened mutually regarding electromagnetic interferences.

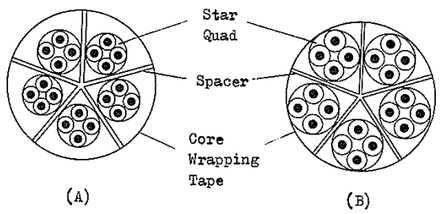


Fig. 16 Structures of Screened Units with Spacers

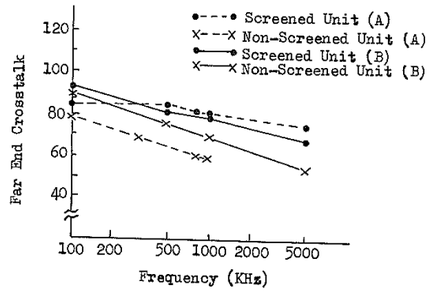


Fig. 17 Frequency Property of Far End Crosstalk within Unit

6. Complete Spacer-type Composite Cable

Optical fiber units of type (A) in Fig. 9, coaxial cores of type (A) in Fig. 13, and screened units of type (A) in Fig. 16 were assembled together by a conventional large-size stranding machine, and then were commonly sheathed as a complete spacer-type composite cable. Figure 18 shows the cross-sectional structure of the cable. Transmission loss of the fibers was almost un-

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Table 5 Construction of Screened Units

Item \ Type	(A)	(B)
Conductor Diameter	0.5mm	0.65mm
Insulation Diameter	0.74mm	1.20mm
Blowing Degree	20%	30%
Spacer	Polyester (T: 0.1 mm) Laminated Aluminum Tape (T:0.025mm)	Polyester (T: 0.1 mm) Laminated Aluminum Tape (T:0.025 mm)
Core Wrapping Tape	Polyester (T:0.025mm) Laminated Aluminum Tape (T: 0.02mm)	Polyester (T:0.025mm) Laminated Aluminum Tape (T: 0.02mm)
Unit Diameter	9mm	9mm

changed throughout the cabling processes, as shown in Fig. 19, and electrical characteristics of coaxial cores and screened units were also stable. From this, the mechanical properties of each core were considered to be strong enough to withstand the considerable mechanical loads imposed on each core by the stranding and taking up operations. A general view of the composite cable is shown in Fig. 20.

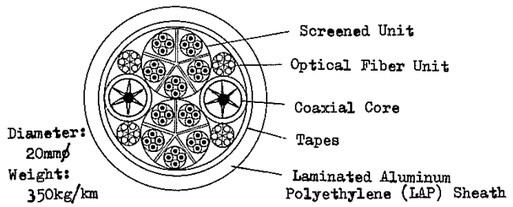


Fig. 18 Structure of Composite Cable

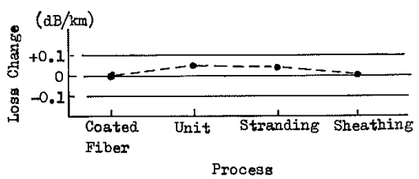


Fig. 19 Loss Change of Fibers in the Cabling Processes

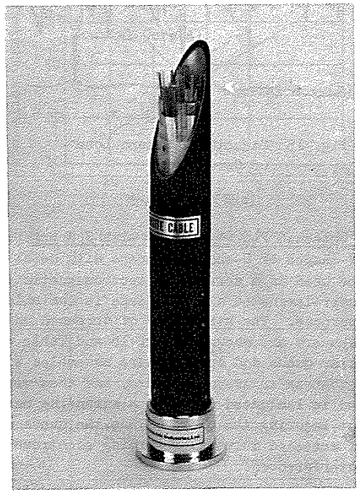


Fig. 20 General View of Composite Cable

7. Conclusion

Various kinds of optical cables utilizing the spacer forming technique were manufactured. These optical cables with spacers have excellent transmission and mechanical properties and have put into actual use at home and abroad.

By using this forming technique, it was seen that coaxial cables and screened pair-type cables could be easily manufactured and had outstanding electrical properties.

This technology will be further developed in the future to increase the range of applications.

Acknowledgements

The authors wish to thank Dr. N. Uchida of Ibaraki Electrical Communication Laboratory of N.T.T. and M. Hoshikawa and Y. Kameo of Sumitomo Electric Industries, Ltd. for their helpful comments and suggestions.

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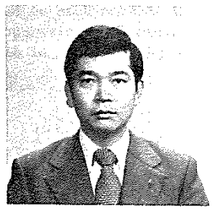
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Shigeru Tanaka was born in 1951 and received a M.S. in 1976 from Tokyo University. He joined Sumitomo Electric Industries, Ltd. in 1976, and has been engaged in research and development of optical fiber cable. He is a member of Institute of Electronics and Communication Engineers of Japan.



Hiroaki Horima

Horoaki Horima was born in 1947 and received a M.S. in 1972 from Osaka University. He joined Sumitomo Electric Industries, Ltd. in 1972, and has been engaged in research and development of multi-pair communication cable, CATV coaxial cable and optical fiber cable. He is Engineer in Optical Fiber System Department, and is a member of the Institute of Electronics and Communications Engineers of Japan.



Koushi Ishihara

Koushi Ishihara was born in 1943, received a M.S. degree from Yamanashi University in 1969, and joined the Electrical Communication Laboratory in 1969, and has been engaged in research and development of cable structure, and now designing optical fiber cable. Mr. Ishihara is Assistant Chief of Optical Transmission Line Section in Ibaraki ECL, and a member of the Institute of Electronics and Communication Engineers of Japan.

MEAN POWER SUM FAR-END CROSSTALK OF PIC CABLES AS A FUNCTION OF AVERAGE TWIST HELIX ANGLE

J. J. Refi

Bell Laboratories
Norcross, GA 30071

ABSTRACT

The mean power sum far-end crosstalk (FEXT) of the various designs of plastic insulated conductor (PIC) cables used in the Bell System (air core and waterproof, solid and expanded insulations, 19 through 26-gauge, 83 nF/mile and low capacitance) is a function of their average twist helix angle. Cables with small helix angles have stronger crosstalk coupling than cables with large helix angles. Consequently, 26-gauge solid insulation air core cable which has the smallest helix angle of any standard PIC cable also has the strongest (worst) mean FEXT coupling. At the other extreme, 19-gauge solid insulation waterproof cable which has the largest helix angle also has the weakest (best) mean FEXT coupling. The crosstalk spread between these two designs is as much as 6 dB.

Frequency scaling of mean FEXT is also a function of twist helix angle. The dependence, however, is slight—ranging from 5.7 dB per octave of frequency for 26-gauge air core to 6.2 dB per octave for 19-gauge solid insulation waterproof. This is from 0.3 dB less to 0.2 dB more than the classical 6 dB per octave rule.

Equations are presented which can be used to calculate the expected mean power sum FEXT performance of any copper PIC cable used in the Bell System. In addition, as long as pair twist schemes are judiciously chosen, these equations can also be used to predict the crosstalk performance of new cable designs.

1. INTRODUCTION

The maximum utilization of digital carrier systems on multipair cable depends to a large degree on the cable's crosstalk performance. Consequently, it has become increasingly desirable to know the crosstalk characteristics of the various cable designs. One way of obtaining this information is by actually measuring crosstalk on each cable design and, in fact, many such measurements have been made. However, knowledge of how crosstalk varies among these designs would allow predictions of not only the crosstalk performance of existing designs which have not been measured, but also of new designs which have yet to be manufactured.

A number of authors have examined the theoretical and practical aspects of modeling crosstalk in multipair cable.[1,2] Such investigations are extremely useful for examining the effect of twist length selection, manufacturing tolerances, and other parameters on crosstalk. The present paper will not attempt to delve into similar analytical detail. Instead, simple empirical data on various Bell System cable designs will be examined and their crosstalk performance related to readily identifiable cable design parameters.

2. CROSSTALK MEASUREMENTS

Over the years a number of Bell System cables have been measured for crosstalk on a Computer Operated Transmission Measurement Set (COTMS).[3] Normally, 50 consecutive pairs are connected to a pair fan-out and the 1225 pair-to-pair crosstalk combinations among those pairs measured at a number of frequencies. The power sum crosstalk of a specific pair is then calculated by summing the pair-to-pair couplings into that pair on a power basis. Statistical parameters such as means and standard deviations can then be computed and reported for both the pair-to-pair and the power sum crosstalk distributions.

3. CROSSTALK TYPE EXAMINED

The highest bit rate digital carrier systems used on multipair cable (T2[4] and T1C[5]) use power sum crosstalk rather than pair-to-pair crosstalk in the design of their repeatered lines. Consequently, *power sum* crosstalk data were examined. Power sum means were accumulated at five standard measurement frequencies—0.15, 0.772, 1.6, 3.15 and 6.3 MHz. Not all cables were measured at all five frequencies and so the number of measurements in the data base may change with frequency.

Depending on whether unidirectional or bidirectional carrier transmission is employed, either FEXT or NEXT (near end crosstalk) is important. This paper concentrates specifically on mean power sum FEXT.

As mentioned in Section 2, COTMS measurements are normally made on 50 pair groupings. All of the data presented here are therefore for 50 pair groups except for 25 pair cables. In these cases, the data are for all 25 pairs.

4. CABLE TYPES EXAMINED

Cable designs in the data base represent almost all standard 83 nF/mile copper PIC cables, i.e., air core and waterproof, solid and DEPIC (dual expanded plastic insulated conductor)[6] insulations, and 19 through 26-gauge conductors. In addition to these standard cables, data were also examined on some "special" cables such as T2 LOCAP* cable (22-gauge DEPIC, 39 nF/mile for air core, and 46 nF/mile for waterproof)[7], ICOT* cable (24-gauge DEPIC, 52 nF/mile for air core, and 60 nF/mile for waterproof)[8], MAT* cable (25-gauge DEPIC, 64 nF/mile, air core)[9], DUCTPIC* cable (26-gauge DEPIC, 83 nF/mile, air core)[10] and an experimental 28-gauge cable (28-gauge solid insulation, 83 nF/mile, air core). These cables are termed "special" because they utilize shorter twist lengths and have a basically different twist spectrum than the standard cables. In addition, T2 LOCAP, ICOT and MAT cables have lower mutual capacitances than the standard 83 nF/mile.

5. CORRELATION OF MEAN FEXT WITH DIAMETER OVER DIELECTRIC

5.1 Standard Cables

Table 1 shows the number of FEXT measurements† and the average of the power sum FEXT means of each standard cable design at 0.15 MHz.

* Trademark of Western Electric.
† The term "measurements" will be used instead of "cables" because several measurements may have been made on different units in a single cable.

Page 246

CommScope Exhibit 1045

Attachment 1A

OCLC 26958439 **No holdings in XXX - no other holdings**

Books

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090 $b
110 2 AT & T Bell Laboratories.
245 10 Electronic wire & cable : $b a user's guide : performance and selection.
260 [Place of publication not identified] : $b AT & T Network Systems, $c [1987]
300 114 pages : $b illustrations ; $c 29 cm
336 text $b txt $2 rdacontent
337 unmediated $b n $2 rdamedia
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500 Cover title.
650 0 Electronic apparatus and appliances $v Handbooks, manuals, etc.
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Attachment 1B

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360 __ |**i** subdivision |**a** Electronic equipment |**i** under types of industries and individual land vehicles and types of land vehicles, e.g. |**a** Construction industry--Electronic equipment; Automobiles--Electronic equipment

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450 __ |**a** Electronics |**x** Apparatus and appliances

550 __ |**w** g |**a** Electronics

550 __ |**w** g |**a** Physical instruments

550 __ |**w** g |**a** Scientific apparatus and instruments

550 __ |**a** Electronic instruments

906 __ |**t** 9613 |**u** te05 |**v** 0

953 __ |**a** xx00 |**b** ta25

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Attachment 1C

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952 __ |**a** ANNOTATED CARD PROGRAM SUBJECT HEADING
953 __ |**a** xx00

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Attachment 2A

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245    10$aSubscriber loop signaling and transmission handbook :
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260    ##$aPiscataway, NJ : $bIEEE Press ; $aNew York : $bInstitute
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300    ##$axv, 654 p. : $bill. ; $c27 cm.
490    1#$aTelecommunications handbook series
500    ##$a"Reviewed and endorsed by the IEEE Communications
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504    ##$aIncludes bibliographical references and index.
590    11$aTransferred from the Engineering Societies Library,
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650    #0$aTelephone switching systems, Electronic
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650    #0$aDigital communications
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Attachment 2B

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100 1 Reeve, Whitham D.
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260 Piscataway, NJ : $b IEEE Press ; $a New York : $b Institute of Electrical and Electronics Engineers, $c ©1995.
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336 text $b txt $2 rdacontent
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338 volume $b nc $2 rdacarrier
490 1 Telecommunications handbook series
500 "Reviewed and endorsed by the IEEE Communications Society."
504 Includes bibliographical references and index.
505 0 1. Subscriber loop transmission concepts and signal conversion -- 2. Digital loop applications and interfaces -- 3. Digital loop frame structures and line codes -- 4. Timing and synchronization -- 5. Loop transmission impairments -- 6. Transmission quality and performance -- 7. Loop transmission media, part I: Twisted pair metallic cables -- 8. Loop transmission media, part II: Fiber optic cables -- 9. Transmission engineering, part I: Repeatered T1-carrier -- 10. Transmission engineering, part II: Non-repeatered digital loops including fiber optics -- 11. Premises cabling systems -- Appendixes: -- A. Twisted pair cable designation cross-reference -- B. Exchange cable transmission characteristics -- C. Cable core assembly drawings -- D. Operational information for DSX-1 patch panels.
540 Current Copyright Fee: GBP32.00 $c 0. $5 Uk
650 0 Telephone switching systems, Electronic.
650 0 Telecommunication $x Standards.

650 0 Digital communications.
650 6 Téléphone $x Systèmes de commutation électronique. $0 (CaQQLa)201-0094939
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830 0 Telecommunications handbook series.

Attachment 2C

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Attachment 3B

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100 1 Reeve, Whitham D.
245 10 Subscriber loop signaling and transmission handbook : $b analog / $c Whitham D. Reeve.
260 New York : $b Institute of Electrical and Electronics Engineers ; $a Piscataway, N.J. : $b IEEE Press, $c ©1992.
300 xii, 289 pages : $b illustrations ; $c 26 cm.
336 text $b txt $2 rdacontent
337 unmediated $b n $2 rdamedia
338 volume $b nc $2 rdacarrier
490 1 Telecommunications handbook series
500 "Reviewed and endorsed by the IEEE Communications Society."
504 Includes bibliographical references and index.
530 Also issued online.
505 0 1. Loop interfaces -- 2. Loop signaling -- 3. The outside plant facility -- 4. Protection and termination -- 5. Transmission -- 6. Loop design -- 7. Transmission impairments -- 8. Transmission improvement -- 9. Pair gain devices -- 10. Coin line services -- Appendices: -- A. The decibel -- B. Transmission level point -- C. Derivation of ABCD functions for transmission line with distributed parameters -- D. Insertion loss of the subscriber loop -- E. Reflection loss caused by a bridged tap -- F. Availability information for references.
650 0 Telephone switching systems, Electronic.
650 0 Telecommunication $x Standards.
650 6 Téléphone $x Systèmes de commutation électronique. $0 (CaQQLa)201-0094939
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650 7 Telecommunication $x Standards. $2 nli
653 0 Telecommunication $a Standards
653 0 Telephone switching systems, Electronic
710 2 IEEE Communications Society.
776 08 $i Online version: $a Reeve, Whitham D. $t Subscriber loop signaling and transmission handbook. $d New York : Institute of Electrical and Electronics Engineers ; Piscataway, N.J. : IEEE Press, ©1992 $w (OCoLC)551479110
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245 00 Electric cables handbook / $c BICC Cables ; edited by G.F. Moore.
250 3rd ed.
260 Oxford ; $a Malden, Mass. : $b Blackwell Science, $c 1997.
300 xvii, 1098 pages : $b illustrations ; $c 25 cm
336 text $b txt $2 rdacontent
337 unmediated $b n $2 rdamedia
338 volume $b nc $2 rdacarrier
504 Includes bibliographical references and index.
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