Declaration of Sylvia Hall-Ellis, Ph.D. in Support of
Petition for *Inter Partes* Review

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

APPLE INC.
Petitioner

v.

ONE-E-WAY, INC.,
Patent Owner

DECLARATION OF SYLVIA HALL-ELLIS, PH.D.

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

I. INTRODUCTION

1. My name is Sylvia D. Hall-Ellis. I have been retained as an expert by Apple Inc., who I am informed is a petitioner to this IPR proceeding ("the Petitioner").

2. I have written this declaration at the request of the Petitioner to provide my expert opinion regarding the public availability of a number of publications, identified below. My Declaration sets forth my opinions in detail and provides the basis for my opinions regarding the public availability of these publications.

3. I reserve the right to supplement or amend my opinions, and bases for them, in response to any additional evidence, testimony, discovery, argument, and/or other additional information that may be provided to me after the date of this Declaration.

4. As of the preparation and signing of this declaration, many libraries across the nation (including the Library of Congress) are closed to the public due to the COVID-19 virus. However, were these libraries open, I would expect to be able to obtain paper copies of the publications for which I provide an opinion on public availability in this Declaration. Additionally, it is my common practice to obtain a paper copy of each publication for which I provide an opinion to further confirm that the publication would have been available prior to a given date (e.g., the priority date

of a patent challenged in IPR). I reserve the right to supplement my Declaration when libraries reopen to provide such information.

5. I am being compensated for my time spent working on this matter at my normal consulting rate of $300 per hour, plus reimbursement for any additional reasonable expenses. My compensation is not in any way tied to the content of this report, the substance of my opinions, or the outcome of this litigation. I have no other interests in this proceeding or with any of the parties.

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

II. QUALIFICATIONS

7. 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 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.

8. 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 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, and as a member of the Editorial Board for the ALCTS premier cataloging journal, *Library Resources and Technical Services*. Currently I serve as a Co-Chair for the Library Research Round Table of the American Library Association.

9. 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.

10. My full curriculum vitae is attached hereto as **Exhibit A**.

III. PRELIMINARIES

A. Scope of Declaration and Legal Standards

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

reasonable diligence, could have located the documents before the dates discussed below with respect to the specific documents.

12. 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.

13. 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.

14. 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

15. I am told by counsel that the subject matter of this proceeding generally relates to digital audio player systems.

16. I have been informed by counsel that a "person of ordinary skill in the art at the time of the inventions" 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.

17. I am told by counsel that a person of ordinary skill in this subject matter or art would typically be someone who would have possessed at least a bachelor's degree in electrical engineering, and two years of experience in the design or implementation of wireless communications systems (or equivalent degree or experience). 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 publication discussed in this declaration.

C. Use of Authoritative Databases

18. In preparing this report, I used authoritative databases, such as the OCLC bibliographic database and the Library of Congress Online Catalog, to confirm citation details of the publication discussed.

1. Indexing

19. 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 periodical 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.

20. Indexing services use a wide variety of controlled vocabularies to provide subject access and other means of discovering the content of documents. The formats in which these access terms are presented vary from service to service.

21. Online indexing services and digital repositories 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.

D. Summary of Opinions

22. I am informed by counsel that the earliest possible effective filing date for all three patents at issue (U.S. Patent Nos. 8,131,391, 10,129,627, and 10,468,047) is December 21, 2001.[1] As I will explain below, it is my opinion that the printed publications discussed in my Declaration were each publicly accessible more than one year before this December 21, 2001 priority date.

IV. LIBRARY CATALOGING PRACTICES

A. MARC Records and OCLC

23. 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. 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 works made available at that library.

24. Since at least the early 1970s and continuing to the present day, MARC

[1] I understand that this Declaration is being submitted in multiple IPR proceedings relating to these three patents.

has been the primary communications protocol for the transfer and storage of bibliographic metadata in libraries.[2] 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 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,

[2] 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 October 27, 2020).

http://www.loc.gov/marc/umb/um01to06.html#part2 (last visited October 27, 2020).

25. Thus, 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 October 27, 2020) ("MARC is the acronym for MAchine-Readable Cataloging. It defines a data format that emerged 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 standard (reaffirmed in 2016) for Information Interchange Format. The full text of the standard is available from the Library of Congress at http://www.loc.gov/marc/bibliographic/ (last visited October 27, 2020).

26. 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. *See, e.g.*, http://www.loc.gov/marc/umb/um07to10.html (last visited October 27, 2020); http://www.loc.gov/marc/bibliographic/ (last visited October 27, 2020). For example, a work's title is recorded in field 245, the primary author of the work is recorded in field 100, a work's International Standard Book Number ("ISBN") is

recorded in field 020, a work's International Standard Serial Number ("ISSN") is recorded in field 022, and the publication date is recorded in field 260 under the subfield "c." *Id.*[3] 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. *See* http://www.loc.gov/marc/bibliographic/bd3xx.html (last visited October 27, 2020).[4]

27. The library that initially created the MARC record is reflected in field 040 in subfield "a" with that library's unique library code. *See, e.g.*, http://www.loc.gov/marc/umb/um07to10.html (last visited October 27, 2020); http://www.loc.gov/marc/bibliographic/ (last visited October 27, 2020). Once a

[3] In some MARC records, field 264 is used rather than field 260 to record publication information. *See* http://www.loc.gov/marc/bibliographic/bd264.html (last visited October 27, 2020) ("Information in field 264 is similar to information in field 260 (Publication, Distribution, etc. (Imprint)). Field 264 is useful for cases where the content standard or institutional policies make a distinction between functions").

[4] 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 in order 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.

MARC record for a particular work is originally created by one library, other libraries can use that original MARC record to then create their own MARC records for their own copies of the same work. These other libraries may modify or add to the original MARC record as necessary to reflect data specific to their own copies of the work. However, the library that created the original MARC record would still be reflected in these modified MARC records (corresponding to other copies of the same work at other libraries) in field 040, subfield "a". The modifying library (or libraries) is reflected in field 040, subfield "d". *See* http://www.loc.gov/marc/bibliographic/bd040.html (last visited October 27, 2020).

28. I consulted the Directory of OCLC Libraries (http://www.oclc.org/contacts/libraries.en.html; last visited October 27, 2020) in order to identify the institution that created or modified the MARC record. Moreover, when viewing the MARC record online via Online Computer Library Center's ("OCLC") bibliographic database, which I discuss further below, hovering over a library code in field 040 with the mouse reveals the full name of the library. I also used this method of "mousing over" the library codes in the OCLC database to identify the originating and modifying libraries for the MARC records discussed in this report.

29. MARC records also include one or more fields that show information regarding subject matter classification. For example, 6XX fields are termed

"Subject Access Fields." *See* http://www.loc.gov/marc/bibliographic/bd6xx.html (last visited October 27, 2020). Among these, for example, is the 650 field; this is the "Subject Added Entry – Topical Term" field. *See* http://www.loc.gov/marc/bibliographic/bd650.html (last visited October 27, 2020). The 650 field is a "[s]ubject added entry in which the entry element is a topical term." *Id.* 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.*

30. Further, MARC records can include call numbers, which themselves contain a classification number. For example, a MARC record may identify a 050 field, which is the "Library of Congress Call Number." *See* http://www.loc.gov/marc/bibliographic/bd050.html (last visited October 27, 2020). A defined portion of the Library of Congress Call Number is the classification number, and "source of the classification number is *Library of Congress Classification* and the *LC Classification-Additions and Changes*." *Id.* Thus, the 050 field may be used to show information regarding subject matter classification.

31. 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

classification number, it appears as part of the 050 field, as discussed above. For MARC records created by libraries other than the Library of Congress (*e.g.*, a university library or a local public library), the classification number may appear in a 09X (e.g., 090) field. *See* http://www.loc.gov/marc/bibliographic/bd09x.html (last visited October 27, 2020).

32. When a MARC-compatible library acquires a work, it creates a MARC record for its copy of the work in its computer catalog system in the ordinary course of its business. This MARC record (for the copy of a work available at the particular library) may be later accessed by researchers in a number of ways. For example, many libraries, including the Library of Congress, make their MARC records available through their website. As an example, the MARC record for the copy of *The Unlikely Spy*, by Daniel Silva,[5] available at the Library of Congress, can be viewed through the Library of Congress website at https://catalog.loc.gov/vwebv/staffView?searchId=20265&recPointer=1&recCount=25&bibId=2579985 (last visited October 27, 2020). One could, of course, always physically visit the library at which the work is available, and request to see that library's MARC record for the work. Moreover, members of the Online Computer Library Center ("OCLC") can access the MARC records of other member

[5] *The Unlikely Spy* is a 1996 novel written by Daniel Silva, who happens to be one of my favorite authors.

institutions through OCLC's online bibliographic database, as I explain further below.

33. 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 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."[6] Among other services, OCLC and its members are responsible for maintaining the WorldCat database (http://www.worldcat.org/; last visited October 27, 2020), used by independent and institutional libraries throughout the world. All libraries that are members of OCLC are MARC-compatible. *See*, *e.g.*, https://help.oclc.org/Metadata_Services/OCLC-MARC_records/About_OCLC-MARC_records (last visited October 27, 2020) ("OCLC-MARC records describes records produced since November 1993."); https://www.oclc.org/support/services/worldcat/documentation/cataloging/electron

[6] 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; last visited October 27, 2020).

icresources.en.html (last visited October 27, 2020) ("Like the two superseded OCLC documents, this revised set of guidelines is intended to assist catalogers in creating records for electronic resources in WorldCat, the OCLC Online Union Catalog. These guidelines pertain to OCLC-MARC tagging (that is, content designation). Cataloging rules and manuals (such as AACR2) govern the content of records. You should implement these guidelines immediately.").

34. When an OCLC member institution acquires a publication, like the other MARC-compatible libraries discussed above, it creates a MARC record for this publication 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 library or is tape-loaded from the Library of Congress, the MARC record is then made available to any other OCLC members online, and thereby made available to the public. Accordingly, once the MARC record is created by a cataloger at an OCLC member library or is tape-loaded from the Library of Congress, any 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.

2. Fields 008, 005, and 955 in MARC Records as Indicators of Public Accessibility

35. When a MARC-compatible library creates an original MARC record for a work, the library records the date of creation of that MARC record in **field 008**, characters 00 through 05, in the ordinary course of its business. *See* http://www.loc.gov/marc/bibliographic/bd008a.html (last visited October 27, 2020). For OCLC member institutions that use OCLC software to create original MARC records, the date of creation in field 008 is automatically supplied by the OCLC software. The MARC record creation date in field 008 thus reflects the date on which, or shortly after which, a work was first acquired and cataloged by the library that created the original MARC record.

36. When other MARC-compatible libraries subsequently acquire their own copies of the same work, as mentioned, they create MARC records in their own computer catalog systems for their copies in the ordinary course of business.[7] They may use a MARC record previously created for that work (by another MARC-compatible library) to create their own MARC records for their own copies of that same work.[8] The previously created MARC record used by subsequently-acquiring

[7] Initial contributions to the bibliographic database for a work are called "master records."

[8] When a local library uses a master record in OCLC and produces (or downloads) it to the in-house system, the three-character symbol for the subsequent library is added to the holdings for the work.

libraries to create MARC records for their own copies may be obtained through the OCLC bibliographic database, as described above. If, when creating a MARC record to represent its own copy of the work, the subsequently-acquiring library uses the master MARC record in its original form, the subsequently-acquiring library cannot reenter data into the 008 field; therefore, the date in the 008 field will continue to reflect the date the MARC record was initially created by the originating library. On the other hand, if the subsequently-acquiring library modifies the previously created MARC record when creating its own MARC record for its own copy of the work, the subsequently-acquiring library may enter into the 008 field of its own MARC record the date its own MARC record was created.[9] But the library that created the original MARC record used by the subsequently-acquiring library would still be reflected in the MARC record of the subsequently-acquiring library in field 040, subfield "a". Thus, the work identified by any MARC record possessed by any MARC-compatible library would have been accessible to the public at least as of the date shown in the 008 field, or shortly thereafter, either from the library that possesses the MARC record itself, or from the originating library indicated in field

[9] This practice is not required by, but is nevertheless consistent with, the MARC standard. Many MARC records exist today whose 008 fields indicate when the first original MARC record for a work was created, rather than when a derivative record was created based on the original MARC record by a subsequently-acquiring library for its own computer catalog system.

040, subfield "a". As discussed, a MARC-compatible library in the ordinary course of its business creates a MARC record in its own catalog system for a work when it acquires a copy of that work.

37. Moreover, when a MARC record is created by a library for its own copy of a work, **field 005** is automatically populated with the date that MARC record was created in year, month, day format (YYYYMMDD). *See* http://www.loc.gov/marc/bibliographic/bd005.html (last visited October 27, 2020).[10] 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). *Id.*[11] Thus, the work identified by any MARC record possessed by any MARC-compatible library would have been accessible to the public at least as of the date shown in the 005 field, or shortly thereafter, from the library that possesses the MARC record itself. As noted, because the 005 field may be updated each time the library updates its MARC record, the work identified by the MARC record may, in fact, have been accessible to the public from that library much earlier than the date

[10] Some of the newer library catalog systems also include hour, minute, second (HHMMSS).

[11] 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."

indicated in the 005 field.

38. Moreover, MARC records for copies of works available at the Library of Congress can have a **955 field**. *See* http://www.loc.gov/cds/PDFdownloads/dcm/DCM_2007-03.pdf (last visited October 27, 2020). The 955 field in MARC records obtained from the Library of Congress provides Local Tracking Information, which is a record of internal steps in the cataloging process followed by the Library of Congress. *Id.* Entries in the 955 field for a particular work are generated by Library of Congress staff as the work progresses through the cataloging process. *Id.* One of the mandatory fields that library staff must enter for each step is the date (in the form of "yyyy-mm-dd" or "yy-mm-dd") the step was taken. *Id.* Thus, the work identified by a MARC record possessed by the Library of Congress would have been accessible to the public at least as of the earliest date shown in the 955 field, or shortly thereafter, from the Library of Congress.

39. Based on my personal experience as a professional librarian using the MARC and OCLC resources, it has been my experience that both of these resources were continuously operational and available since at least 1992. Indeed, in the course of my work, I have extensively used both of these resources over the past 30+ years, and I have consistently found the information contained within these resources to be complete and reliable. I have never found the date of accessibility as indicated

in fields 008, 005, or 955 to be incorrect. And in only a minute number of cases have I found any errors at all in these records—none of which affected my ability to render an accurate opinion as to accessibility, indexing, or subject headings.

V. PUBLICATIONS IN THIS PROCEEDING

A. Haartsen [Exhibit B]

40. Attached hereto as Exhibit B is a copy of the journal article "The Bluetooth Radio System," by Jaap C. Haartsen, (hereafter "Haartsen"). As indicated by the page containing the table of comments, the Haartsen article was published in Volume 7, Number 1 of the journal *IEEE Personal Communications*. As further indicated by the stamps appearing on the page containing the table of comments, the issue containing the Haartsen article was available at the Library of Congress. The Haartsen article appears beginning on page 28 of this issue dated February 2000. Exhibit B is a true and correct copy of the Haartsen article (pages 28-36) that I understand is being submitted as an exhibit in this proceeding.

41. The Haartsen article is also available through online sources such as the *IEEE Xplore* database,[12] *ResearchGate*,[13] and *Semantic Scholar*.[14] I note that the

[12] https://ieeexplore.ieee.org/document/824570
[13] https://www.researchgate.net/publication/3343921_Ericsson_radio_systems_B_V_The_bluetooth_radio_system
[14] https://www.semanticscholar.org/paper/The-Bluetooth-radio-system-Haartsen/6054e55e3038074c665afe59ee0e45a4e7386d36

bibliographic information provided by these online sources for the Haartsen article, including its original publication in *IEEE Personal Communications* in 2000, is consistent with the physical copy attached hereto as Exhibit B.

42. Attached hereto as Attachment B1 is a true and correct copy of the MARC record for the journal *IEEE Personal Communications* at the Library of Congress.[15] The library ownership is indicated by the presence of the library's code (DLC) in subfield d of field 040. The library continues to update this MARC record and enhanced the MARC record to meet current cataloging rules. The most recent enhancement to Attachment B1 occurred on March 27, 2018, as shown in field 005 ("20180327").

43. Based on the date stamps that reference the Library of Congress found in Exhibit B, and the existence of a corresponding MARC record in the Library of Congress's catalog attached as Attachment B1, it is my opinion that the Haartsen article published in the journal *IEEE Personal Communications* was available at the Library of Congress on or shortly after March 7, 2000, and in any event, more than one year before December 21, 2001, as shown on the date stamps on page 2 of Exhibit B. Attachment B1 also shows that Exhibit B was catalogued with three

15 https://catalog.loc.gov/vwebv/staffView?searchId=23384&recPointer=5&recCount=25&bibId=11440068

descriptor terms reading "Mobile communication systems $v Periodicals" (see Attachment B2, Library of Congress subject heading sh2010102188), "Wireless communication systems $v Periodicals" (see Attachment B3, Library of Congress subject heading sh2010118630), and "Local area networks (Computer networks) $v Periodicals" (see Attachment B4, Library of Congress subject heading sh2009129729) in the 650 fields.

44. Moreover, as noted in the holdings information (362 field), the Library of Congress has received the journal *IEEE Personal Communications* since 1994 and received the publication until it ceased in December 2001. In view of the MARC record for Exhibit B, the Haartsen article would have been publicly available more than one year before December 21, 2001, because before then, the serial title had been received, cataloged, and indexed at the Library of Congress and made part of its online catalog database.

45. Attached hereto as Attachment B5 is a true and correct copy of the MARC record for the journal *IEEE Personal Communications* obtained from the OCLC bibliographic database. As previously noted, the library that created the record is recorded in field 040 with a unique library code. For Attachment B5, that library code is "NSD," which means that the MARC record for this serial was cataloged as part of the National Serials Data Program at the Library of Congress. 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 28525286 on March 27, 1993, as shown in the "Entered" field ("19930327"). The library continues to update this MARC record and enhanced the MARC record to meet current cataloging rules. The most recent enhancement to Attachment B5 occurred on March 24, 2018, as shown in the "Replaced" field ("20180324"). The "BLvl" entry in Attachment B5 is "s," which indicates that the journal *IEEE Personal Communications* is a serial publication. Field 310 of Attachment B5 reads "Bimonthly, $b 1995-2001." Accordingly, the MARC record for Exhibit B corresponds to the journal *IEEE Personal Communications* from the time the serial title began using the current title and includes the date of the Haartsen article.

46. Attachment B5 includes an entry in field 050 ("TK6570.M6 $b .I215")—as described above, a subject matter classification number consistent with the Library of Congress classification system (analogous to the Dewey Decimal classification system) and an entry in field 082 ("621.3845"), a subject matter consistent with the Dewey Decimal classification system. Attachment B5 further includes three English language descriptor terms reading "Mobile communication systems $v Periodicals" (see Attachment B2, Library of Congress subject heading sh2010102188), "Wireless communication systems $v Periodicals" (see Attachment B3, Library of Congress subject heading sh2010118630), and "Local area networks (Computer networks) $v Periodicals" (see Attachment B4, Library of Congress

subject heading sh2009129729) in the 650 fields. Thus, as of its cataloging, the publication corresponding to the MARC record attached hereto as Attachment B5 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. As of March 27, 1993, the MARC record attached hereto as Attachment B5 was accessible through any library with access to the OCLC bibliographic database or the online catalog at a library that subscribed to the serial.

47. Attachment B5 indicates that the journal *IEEE Personal Communications* as cataloged at the Library of Congress is currently available from 247 libraries.

48. In view of the above, the issue of the journal *IEEE Personal Communications* corresponding to Ex. B, which includes the Haartsen article, was publicly available more than one year before December 21, 2001 because before that date it had been received, cataloged, and indexed at the Library of Congress and made part of the OCLC bibliographic database. For these reasons, it is my opinion that Exhibit B was published and accessible to the public publicly available more than one year before December 21, 2001.

49. Haartsen's public availability more than one year before December 21, 2001 is further confirmed by the bibliographic information currently maintained and

provided by the *IEEE Xplore* database,[16] attached hereto as Ex. B6. The web page for Haartsen provided by the *IEEE Xplore* database states: "**Date of Publication:** Feb. 2000." The *IEEE Xplore* database further explains: "Publication Dates[:] The Date of Publication for Journals and Standards on IEEE Xplore represents the very first instance of public dissemination of content. IEEE Xplore had previously made distinctions between physical print date, date of current version, online publication date, etc. This has been simplified with one official date of record."[17] Experts in my field would reasonably rely upon the bibliographic information for particular journal articles provided by the *IEEE Xplore* database when forming their opinions.

B. Groe and Larson [Exhibit C]

50. Exhibit C attached to my Declaration is an excerpted book, *CDMA Mobile Radio Design*, by John B. Groe and Lawrence E. Larson (hereafter "Groe") and issued by Artech House in 2000. Exhibit C is a true and correct copy of the title page, title page verso, and table of contents (which contains a listing of eleven chapters). I obtained the excerpted copy in Exhibit C from counsel, and I understand that the excerpted pages were obtained from a digitized copy of this monograph

[16] https://ieeexplore.ieee.org/document/824570
[17] https://ieeexplore.ieee.org/Xplorehelp/ieee-xplore-training/working-with-documents#publication-dates, attached hereto as Ex. B7.

available at the Internet Archive.[18]

51. Attached hereto as Exhibit C1 is a true and correct copy of the MARC record for this monograph from the Library of Congress online catalog.[19] The library ownership is indicated by the presence of the library's code (DLC) in the 040 field. The most recent enhancement to this MARC record occurred on May 2, 2016, as indicated in field 005 ("20160502").

52. Based on finding the MARC record in the online library catalog of the Library of Congress (attached hereto as Exhibit C1), it is my opinion that a physical print copy of the book *CDMA Mobile Radio Design* by Groe and Larson (hereafter. Groe and Larson"), whose contents would be materially identical to the digitized copy corresponding to Ex. C, would have been available in the Library of Congress more than one year before December 21, 2001. For example, field 955 shows a number of dates (e.g., "02-25-00," "08-02-00") that steps in the cataloging process performed by the Library of Congress, all of which occurred in 2000, ending with the last step performed on August 2, 2000 ("jf12 to BCCD 08-02-00"). Therefore, a copy of Groe and Larson would have been available at the Library of Congress on

18 https://archive.org/details/CDMAMobileRadioDesign/CDMA%20Mobile%20Radio%20Design/page/n1/mode/2up

19 https://catalog.loc.gov/vwebv/staffView?searchId=23419&recPointer=0&recCount=25&bibId=11922319

or shortly after August 2, 2000, and in any event, more than one year before December 21, 2001.

53. The International Standard Book Number (ISBN) on Exhibit C (1-580-53059-1) matches the ISBN in field 020 of Attachment C1. The Library of Congress Control Number on Exhibit C (00027455) also matches the Library of Congress Control Number field 010[20] of Attachment C1. Therefore, Exhibit C contains excerpts from the same book that a cataloger at the Library of Congress used to create the MARC record that is Attachment C1. Therefore, a copy of Groe and Larson that is materially identical to the digitized copy from which Ex. C was obtained would have been available to users in the Library of Congress more than one year before December 21, 2001.

54. Attached hereto as Ex. C2 is a true and correct copy of the MARC record for *CDMA Mobile Radio Design* by Groe and Larson obtained from the OCLC bibliographic database. As previously noted, the library that created the record is recorded in field 040 with a unique library code. For Attachment C2, that library code is "DLC," which means that the MARC record for this book was created at the Library of Congress. 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

[20] https://www.loc.gov/marc/authority/ad010.html

number 43456966 on February 25, 2000, which matches the initial date of the cataloging process reflected in field 955 of Ex. C1 ("to ASCD pb04 02-25-00") discussed above. Attachment C2 further includes an entry in field 050 ("TK5103.452 $b G76 2000")—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 C2 further includes an entry in field 082 ("621.3845"), a subject matter consistent with the Dewey Decimal classification system. Attachment C2 further includes three English language descriptor terms reading "Code division multiple access" (see Attachment C3, Library of Congress subject heading sh93009277), "Cell phone systems" (see Attachment C4, Library of Congress subject heading sh98004793), and "Mobile communication systems" (see Attachment C5, Library of Congress subject heading sh85086371) in the 650 fields. Thus, as of its cataloging, the publication corresponding to the MARC record attached hereto as Attachment C2 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 February 25, 2000, the MARC record attached hereto as Attachment C2 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.

55. Attachment C2 indicates that the book *CDMA Mobile Radio Design* by

Groe and Larson as cataloged at the Library of Congress is currently available from 194 libraries. In view of above, the Groe and Larson book was publicly available more than one year before December 21, 2001, because by then it had been received, cataloged, and indexed at the Library of Congress and made part of the OCLC bibliographic database.

56. Further supporting my opinion that Exhibit C was publicly accessible to ordinarily skilled and interested researchers in the field is the fact that the book *CDMA Mobile Radio Design* by Groe and Larson was registered with the U. S. Copyright Office as item TX0005229534 on June 15, 2000 and indicated a publication date of May 31, 2000 (see Attachment C6, U. S. Copyright Office Public Catalog). This would have provided a person of ordinary skill with keyword searching capabilities and other tools to locate this book.

C. Sklar [Exhibit D]

57. Exhibit D attached to my Declaration is an excerpted book, *Digital Communications: Fundamentals and Applications*, by Bernard Sklar (hereafter "Sklar") and issued by Prentice Hall with a 1988 copyright date. Exhibit D includes the title page, title page verso, and table of contents (which contains a listing of twelve chapters and Appendices A-F). I obtained the excerpted copy in Exhibit D from counsel, and I understand that the excerpted pages were obtained from a physical copy obtained by counsel from Amazon.

58. Attached hereto as Exhibit D1 is a true and correct copy of the MARC record for this monograph from the Library of Congress online catalog.[21] The library ownership is indicated by the presence of the library's code (DLC) in the 040 field. The most recent enhancement to this MARC record occurred on May 2, 2016, as indicated in field 005 ("20060502").

59. Based on finding the MARC record in the online library catalog of the Library of Congress (attached hereto as Exhibit D1), it is my opinion that a copy of the book *Digital Communications: Fundamentals and Applications* by Sklar, whose contents would be materially identical to the copy corresponding to Ex. D, would have been available in the Library of Congress more than one year before December 21, 2001. For example, field 008 ("870326), together with field 040, subfield "a" ("DLC") indicates that the Library of Congress created its MARC record for Sklar in 1987.

60. The International Standard Book Number (ISBN) on Exhibit D (0-132-11939-0) matches the ISBN in field 020 of Attachment D1. The Library of Congress Control Number on Exhibit D (87001316) also matches the Library of Congress Control Number field 010[22] of Attachment D1. Therefore, Exhibit D

---

21 https://catalog.loc.gov/vwebv/staffView?searchId=24194&recPointer=3&recCount=25&bibId=3366238

22 https://www.loc.gov/marc/authority/ad010.html

contains excerpts from the same book that a cataloger at the Library of Congress used to create the MARC record that is Attachment D1. Therefore, this volume (*Digital Communications: Fundamentals and Applications* by Sklar) would have been available to users in the Library of Congress more than one year before December 21, 2001.

61. Attached hereto as Attachment D2 is a true and correct copy of the MARC record for *Digital Communications: Fundamentals and Applications* by Sklar obtained from the OCLC bibliographic database. As previously noted, the library that created the record is recorded in field 040 with a unique library code. For Attachment D2, that library code is "DLC," which means that the MARC record for this book was created at the Library of Congress. 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 15518063 on March 26, 1987.

62. Attachment D2 further includes an entry in field 050 ("TK5103.7 $b .S55b 1988")—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 D2 further includes an entry in field 082 ("621.38/0413"), a subject matter consistent with the Dewey Decimal classification system. Attachment D2 further includes an English language descriptor term reading "Digital communications" (see Attachment D3, Library of

Congress subject heading sh85037972) in the 650 field. Thus, as of its cataloging, the publication corresponding to the MARC record attached hereto as Attachment C2 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 March 26, 1987, the MARC record attached hereto as Attachment D2 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.

63. Attachment D2 indicates that the book *Digital Communications: Fundamentals and Applications* by Sklar as cataloged at the Library of Congress is currently available from 348 libraries. In view of above, the Sklar book was publicly available more than one year before December 21, 2001 because before then, it would had been received, cataloged, and indexed at the Library of Congress and made part of the OCLC bibliographic database.

64. Further supporting my opinion that Exhibit D was publicly accessible to ordinarily skilled and interested researchers in the field is the fact that the book *Digital Communications: Fundamentals and Applications* by Sklar was registered with the U. S. Copyright Office as item TXu000295229 on September 8, 1987 and indicated a creation date of 1986 (see Attachment D4, U. S. Copyright Office Public Catalog). This would have provided a person of ordinary skill with keyword

searching capabilities and other tools to locate this book.

D. Walrand [Exhibit E]

65. Exhibit E attached to my Declaration is an excerpted book, *High Performance Communication Networks*, 2nd edition, by Jean Walrand and Pravin Varaiya (hereafter "Walrand") and issued by Morgan Kauffman with a 2000 copyright date. Exhibit E is a true and correct copy of the title page, title page verso, dedication page, and table of contents (which contains a listing of thirteen chapters). I obtained the excerpted copy in Exhibit E from counsel, and I understand that these excerpted pages were provided by the British Library.

66. Attached hereto as Exhibit E1 is a true and correct copy of the MARC record for this monograph from the British Library online catalog.[23] The library ownership is indicated by the presence of the library's code (Uk) in subfield d of the 040 field. Moreover, the information provided in field 852, which "[i]dentifies the organization holding the item or from which it is available,"[24] matches indicia provided by the date stamp on page 4 of Ex. E. For example, subfield "j," which identifies the "[s]helving control number that is used as the shelving scheme for an

---

23 http://primocat.bl.uk/F/?func=direct&local_base=PRIMO&doc_number=008497335&format=001&con_lng=eng

24 *See*, http://www.loc.gov/marc/bibliographic/bd852.html.

item"[25] as "99/42515," matches the control number shown on the date stamp on page 4 of Ex. E.

67. Attached hereto as Exhibit E2 is a true and correct copy of the MARC record for this monograph from the Library of Congress online catalog.[26] The library ownership is indicated by the presence of the library's code (DLC) in the 040 field. The most recent enhancement to this MARC record occurred on May 2, 2016, as indicated in field 005 ("20060502").

68. Based on finding the MARC records in the online library catalogs of the British Library (Ex. E1) and Library of Congress (Ex. E2), it is my opinion that the book *High Performance Communication Networks*, 2nd edition, by Walrand and Varaiya was available at the British Library by 1999, as indicated by the date stamp on page 4 of Ex. E, and in any event, more than one year before December 21, 2001. A copy of the same book would also have been available at the Library of Congress as early as January 11, 2000, as shown in field 955 (e.g., "01-11-00"), and in any event, more than one year before December 21, 2001.

69. The International Standard Book Number (ISBN) on Exhibit E (1-558-60574-6) matches the ISBN in field 020 of Attachment E2. The Library of

[25] *Id.*
[26] https://catalog.loc.gov/vwebv/staffView?searchId=24931&recPointer=4&recCount=25&bibId=11783143

Congress Control Number on Exhibit E (99047341) also matches the Library of Congress Control Number field 010[27] of Attachment E2. Therefore, Exhibit E contains excerpts from the same book that a cataloger at the Library of Congress used to create the MARC record that is Attachment E2.

70. Attached hereto as Attachment E3 is a true and correct copy of the MARC record for *High Performance Communication Networks*, 2nd edition, by Walrand and Varaiya obtained from the OCLC bibliographic database. As previously noted, the library that created the record is recorded in field 040 with a unique library code. For Attachment E3, that library code is "DLC," which means that the MARC record for this book was created at the Library of Congress. 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 42397851 on August 30, 1999.

71. Attachment E3 further includes an entry in field 050 ("TK5105.5 $b .W353 2000")—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 E3 further includes an entry in field 082 ("621.382/1"), a subject matter consistent with the Dewey Decimal classification system. Attachment E3 further includes five English language

[27] https://www.loc.gov/marc/authority/ad010.html

descriptor terms reading "Computer networks" (see Attachment E4, Library of Congress subject heading sh85029513), "Multimedia systems" (see Attachment E5, Library of Congress subject heading sh92002381), "High performance computing" (see Attachment E6, Library of Congress subject heading sh95008935), "Asynchronous transfer mode" (see Attachment E7, Library of Congress subject heading sh93001267), and "Wireless communication systems" (see Attachment E8, Library of Congress subject heading sh92006740) in the 650 fields. Thus, as of its cataloging, the publication corresponding to the MARC record attached hereto as Attachment E3 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 August 30, 1999, the MARC record attached hereto as Attachment E3 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.

72. Attachment E3 indicates that the book *High Performance Communication Networks*, 2nd edition, by Walrand and Varaiya as cataloged at the Library of Congress is currently available from 281 libraries. In view of above, the Walrand and Varaiya book was publicly available more than one year before December 21, 2001, because by then it had been received, cataloged, and indexed at the Library of Congress and made part of the OCLC bibliographic database.

73. Further supporting my opinion that Exhibit E was publicly accessible to ordinarily skilled and interested researchers in the field is the fact that the book *High Performance Communication Networks*, 2nd edition, by Walrand and Varaiya was registered with the U. S. Copyright Office as item TX0005207251 on April 26, 2000 and indicated October 11, 1999 as the date of publication (see Attachment E9, U. S. Copyright Office Public Catalog). As noted above, this would have provided a person of ordinary skill with keyword searching capabilities and other tools to locate this book.

E. Xia [Exhibit F]

74. Attached hereto as Exhibit F is a copy of the journal article "New Precoding for Intersymbol Interference Cancellation Using Nonmaximally Decimated Multirate Filterbanks with Ideal Fir Equalizers," by Xiang-Gen Xia, (hereafter "Xia"). As indicated by page 1 of Ex. F, the Xia article was published in Volume 45, Number 10 of the journal *IEEE Transactions on Signal Processing* and was found in the British Library. The Xia article appears beginning on page 2431 of this issue dated October 1997. Exhibit F is a true and correct copy of the Xia article (pages 2431-2441) that I understand is being submitted as an exhibit in this proceeding.

75. Xia is also available through online sources such as *IEEE Xplore* database[28] and *Semantic Scholar*.[29] I note that the bibliographic information provided by these online sources for the Xia article, including its original publication in *IEEE Transactions on Signal Processing* in 1997, is consistent with the physical copy attached hereto as Exhibit F.

76. Attached hereto as Attachment F1 is a true and correct copy of the MARC record for the journal *IEEE Transactions on Signal Processing* at the British Library.[30] The library ownership is indicated by the presence of the library's code (Uk) in field 040. The library continues to update this MARC record and enhanced the MARC record to meet current cataloging rules. The most recent enhancement to Attachment F1 occurred on July 1, 2020, as shown in field 005 ("20200701"). I personally identified and retrieved the MARC record that is Attachment F1.

77. Based on finding a print copy of Exhibit F in the Library of Congress and MARC record in its online library catalog attached as Attachment F1, it is my opinion that the Xia article published in the journal *IEEE Transactions on Signal Processing* was available at the British Library as early as 1997, as shown on the

[28] https://ieeexplore.ieee.org/document/640709
[29] https://www.semanticscholar.org/paper/New-precoding-for-intersymbol-interference-using-Xia/4c4ebf65253778cd1d8c20bbc43c54bd20df06ff
[30] http://primocat.bl.uk/F/?func=direct&local_base=PRIMO&doc_number=012102482&format=001&con_lng=eng

applied label on the cover, and in any event, more than one year before December 21, 2001. Attachment F1 also shows that Exhibit F was catalogued with two descriptor terms reading "Signal processing $v Periodicals" (see Attachment F2, Library of Congress subject heading sh2010113087) and "Speech processing systems $v Periodicals" (see Attachment F3, Library of Congress subject heading sh2010113088) in the 650 fields.

78. As noted in the holdings information (362 field), the British Library has received the journal *IEEE Transactions on Signal Processing* since 1991 and continues to receive the publication. In view of the MARC record for Exhibit F, the Xia article was publicly on or shortly after October 17, 1997, because the serial title had been received, cataloged, and indexed at the British Library and made part of its online catalog database.

79. Attached hereto as Attachment F4 is a true and correct copy of the MARC record for the journal *IEEE Transactions on Signal Processing* obtained from the OCLC bibliographic database. As previously noted, the library that created the record is recorded in field 040 with a unique library code. For Attachment F4, that library code is "NSD," which means that the MARC record for this serial was cataloged as part of the National Serials Data Program at the Library of Congress. 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 22582582 on October 25,

1990, as shown in the "Entered" field ("19901025"). The library continues to update this MARC record and enhanced the MARC record to meet current cataloging rules. The most recent enhancement to Attachment F4 occurred on March 24, 2018, as shown in the "Replaced" field ("20180324"). The "BLvl" entry in Attachment F4 is "s," which indicates that the journal *IEEE Transactions on Signal Processing* is a serial publication. Field 310 of Attachment F4 reads "Monthly." Accordingly, the MARC record for Exhibit F corresponds to the journal *IEEE Transactions on Signal Processing* from the time the serial title began and includes the date of the Xia article.

80. Attachment F4 includes an entry in field 050 ("TK5981 $b .I2")—as described above, a subject matter classification number consistent with the Library of Congress classification system (analogous to the Dewey Decimal classification system) and an entry in field 082 ("621.382/2/05"), a subject matter consistent with the Dewey Decimal classification system. Attachment F4 further includes three English language descriptor terms reading "Signal processing $v Periodicals" (see Attachment F2, Library of Congress subject heading sh2010113087), "Speech processing systems $v Periodicals" (see Attachment F3, Library of Congress subject heading sh2010113088), and "Electro-acoustics $v Periodicals" (see Attachment F5, Library of Congress subject heading sh2009124777) in the 650 fields. Thus, as of its cataloging, the publication corresponding to the MARC record attached hereto as

Attachment F4 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. As of October 25, 1990, the MARC record attached hereto as Attachment F4 was accessible through any library with access to the OCLC bibliographic database or the online catalog at a library that subscribed to the serial, 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.

81. Attachment F4 indicates that the journal *IEEE Transactions on Signal Processing* as cataloged at the Library of Congress is currently available from 426 libraries. In view of the above, this issue of the journal *IEEE Transactions on Signal Processing* was publicly available more than one year before December 21, 2001, because before then it had been cataloged and indexed at the Library of Congress, made part of the OCLC bibliographic database, and received at least at the British Library.

82. Xia's public availability more than one year before December 21, 2001 is further confirmed by the bibliographic information currently maintained and provided by the *IEEE Xplore* database,[31] attached hereto as Ex. F6. The web page

[31] https://ieeexplore.ieee.org/document/640709

for Xia provided by the *IEEE Xplore* database states: "**Date of Publication:** Oct 1997." The *IEEE Xplore* database further explains: "Publication Dates[:] The Date of Publication for Journals and Standards on IEEE Xplore represents the very first instance of public dissemination of content. IEEE Xplore had previously made distinctions between physical print date, date of current version, online publication date, etc. This has been simplified with one official date of record."[32] Experts in my field would reasonably rely upon the bibliographic information for particular journal articles provided by the *IEEE Xplore* database when forming their opinions.

VI. CONCLUSION

83. In signing this Declaration, I recognize that the Declaration will be filed as evidence in a case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

84. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful

[32] https://ieeexplore.ieee.org/Xplorehelp/ieee-xplore-training/working-with-documents#publication-dates, attached hereto as Ex. B7.

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.

Dated: December 3, 2020

Respectfully submitted,

Sylvia D. Hall-Ellis, Ph.D.

Exhibit A

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.

Hall-Ellis, Sylvia D., Doris Meyer, Frank W. Hoffmann, with J. Ann Jerabek. *Grant Writing for Small Libraries and School Library Media Centers.* Englewood, Colo: Libraries Unlimited, 2000. 173 p.

Editor-reviewed Chapters (Completed and In Progress)

Hall-Ellis, Sylvia D. "Prepared to Lead: Talent, Skills, and Competencies." In *Telling the Technical Services Story*. Chicago, IL: American Library Association, 2020. In development and review.

Hall-Ellis, Sylvia D. "Grant Writing and Sponsored Research Funding for Academic Librarians." In *The New Librarianship.* Vol. 4. Bradford Lee Eden, ed. New York: Scarecrow Press, 2015. (pp. 163-174)

Hall-Ellis, Sylvia D. "Organizing Information: Technical Services." In *Information Services Today: An Introduction.* Sandra Hirsch, ed. Lantham, Md.: Rowman and Littlefield, 2015. (pp. 139-148)

Hall-Ellis, Sylvia D. "Metadata, MARC, and More." In *Rethinking Technical Services, Considering Our Profession and Ourselves: What's the Future of Our Profession?* Mary Beth Weber, ed. Lantham, Md.: Rowman and Littlefield, 2015. (pp. 29-55)

Hall-Ellis, Sylvia D., ed. "Contingent Faculty: Non-Tenure Track Faculty Series." In the *Faculty Personnel Guidelines Relating to Appointment, Promotion, and Tenure.* November 2011. Denver, Colo.: University of Denver, 2011. 42 p.

Hall-Ellis, Sylvia D., ed. "Standard VII: Information Resources." In the *Sturm College of Law Self-Study Presentation for Accreditation by the American Bar Association.* Denver, Colo.: University of Denver, Sturm College of Law, 2011. 20 p.

Hall-Ellis, Sylvia D. "Applying for Grants from Foundations, Corporations, or Government." In *The Volunteers' Guide to Fundraising: Raise Money for Your School Team, Library or Community Group.* 1st ed. Ilona M. Bray, ed. Berkeley, Calif.: Nolo, 2011. (pp. 1-38 on accompanying disc)

Hall-Ellis, Sylvia D., ed. "Standard III: The Faculty." In the *Library and Information Science Program Self-Study Document for Accreditation by the American Library Association.* Denver, Colo.: University of Denver, Morgridge College of Education, 2010. 22 p.

Hall-Ellis, Sylvia D. "Library and Information Science Programs and Education for Catalogers and Metadata Specialists: Challenges for the Twenty-first Century." In *Conversations with Catalogers in the Twenty-First Century.* Elaine R. Sanchez, ed. Santa Barbara, Calif.: ABC-Clio, 2010. (pp. 226-254)

Hall-Ellis, Sylvia D., ed. "Standard III: The Faculty." In the *Library and Information Science Program Self-Study Document for Accreditation by the American Library Association.* Denver, Colo.: University of Denver, College of Education, 2003. 15 p.

Lesesne, Teri S. and Sylvia D. Hall-Ellis. "The Selection, Evaluation, and Integration of Culturally Authentic Texts: A Case for Making the Online Catalog Reflect Parallel Cultures." In *Literacy: Traditional, Cultural, Technological.* Pittsburgh, Pa.: International Association of School Librarianship, 1995. (pp. 110-113)

Lesesne, Teri S. and Sylvia D. Hall-Ellis. *The Selection, Evaluation, and Integration of Culturally Authentic Texts: A Case for Making the Online Catalog Reflect Parallel Cultures.* In *Conference Proceedings* of the 23rd Annual International Association of School Librarianship, Pittsburgh, Pennsylvania, July 17-22, 1994. ERIC Document ED374816. 17 p.

Hall-Ellis, Sylvia D. "Curriculum Folio for School Library Media Specialist Programs." In the *National Council for Accreditation of Teacher Education Self-Study for Sam Houston State University.* Huntsville, Tex.: Sam Houston State University, College of Education and Applied Science, 1994. 25 p.

Bruntjen, Scott and Sylvia D. Hall. "Attempting to Automate: Lessons Learned Over Five Years." In *Advances in Library Administration.* Volume 4. Weston, Conn.: JAI Press, 1985. (pp. 177-192)

Peer-Reviewed Journal Articles (Completed and In Progress)

Hall-Ellis-Sylvia D. "Job Design for Cataloging and Metadata Librarians." Submitted to *Journal of Library Administration.* In progress.

Hall-Ellis, Sylvia D. "The Relationship of Situational Leadership and the Dreyfus Model of Skill Acquisition for Supervisors in Cataloging and Metadata Services." To be submitted to *Library Resources and Technical Services.* In progress.

Hall-Ellis, Sylvia D. *The Relationship of Core Competencies on Learning Outcomes and Employers' Expectations for Catalog Librarians and Metadata Specialists.* To be submitted to the *Journal of Education for Library and Information Science.* In progress.

Hall-Ellis, Sylvia D. "Building Cataloger Competencies: The Dreyfus Model as a Prototype for the Education and Professional Development of Catalog Librarians and Metadata Specialists in Bibliographic Control." To be submitted to the *Cataloging & Classification Quarterly.* In progress.

Hall-Ellis, Sylvia D. "Descriptive Impressions of Entry-Level Cataloger and Metadata Specialists Positions, 2000-2016: Reflections and Trends." To be submitted to *Library Resources and Technical Services.* In progress.

Hall-Ellis, Sylvia D. "Competencies for Metadata and Cataloging Leaders: What Employers Expect as Reflected in Position Descriptions, 2000-2016." *Cataloging & Classification Quarterly.* In progress.

Hall-Ellis, Sylvia D. "Stackable Micro-credentials – A Framework for the Future." *The Bottom Line 29*, no. 4 (April 2016), http://www.emeraldinsight.com/doi/pdfplus/10.1108/BL-02-2016-0006

Hall-Ellis, Sylvia D. "Succession Planning and Staff Development – A Winning Combination." *The Bottom Line*, 28 no. 3 (May 2015): 95-98.

Hall-Ellis, Sylvia D. "Succession Planning and Staff Development – A Winning Combination." *The Informed Librarian Online* (September 2015), http://www.informedlibrarian.com/featuredArticle.cfm?FILE=succession_1509.pdf

Hall-Ellis, Sylvia D. "Nudges and Decision Making: A Winning Combination." *The Bottom Line 28*, no. 4 (July 2015): 133-136.

Hall-Ellis, Sylvia D. "Succession Planning and Staff Development – A Winning Combination." *The Bottom Line 28*, no. 3 (May 2015): 95-98.

Hall-Ellis, Sylvia D. "Metadata Competencies for Entry-Level Positions: What Employers Expect as Reflected in Position Descriptions, 2000-2013." *Journal of Library Metadata 15*, no. 2 (June 2015): 102-134.

Hall-Ellis, Sylvia D. "Onboarding to Improve Library Retention and Productivity." *The Bottom Line 27*, no. 4 (October 2014).

Hall-Ellis, Sylvia D. "Accept, Coach, and Inspire: A Formula for Success." *The Bottom Line 27*, no. 3 (July 2014): 103-106.

Hall-Ellis, Sylvia D. *Reward Systems for Staff in Higher Education Institutions: Case Studies of 15 Higher Education Institutions in Colorado.* Capstone Thesis. Denver, Colo.: University of Denver, University College, 2014.

Hall-Ellis, Sylvia D. "Reward Systems Promote High-Performance Work Teams Achieving Library Mission." *The Bottom Line 27*, no. 2 (April 2014): 66-69.

Hall-Ellis, Sylvia D. "Investment in Staff Development for Seeking External Grant Funds." *The Bottom Line 27*, no. 1 (January 2014): 22-25.

Hall-Ellis, Sylvia D. "Staff Investments for High Performance Teams." *The Bottom Line 26*, no. 4 (October 2013): 149-152.

Hall-Ellis, Sylvia D. and Deborah S. Grealy. "Service Learning in LIS Education: A Case for Holistic Assessment." *Catholic Library World* 82, no. 3 (March 2012): 178-187.

Hall-Ellis, Sylvia D., and Deborah S. Grealy. "The Dreyfus Model of Skill Acquisition: A Career Development Framework for Succession Planning and Management in Academic Libraries." *College and Research Libraries* (June 2012). http://crl.acrl.org/content/early/2012/06/19/crl12-349.full.pdf+html

Hall-Ellis, Sylvia D. "Cataloger Competencies…What Do Employers Require?" *Cataloging & Classification Quarterly* 46, no. 3 (2008): 305-330. http://ccq.haworthpress.com/doi:10.1080/01639370802034565

Hall-Ellis, Sylvia D. "Subject Access for Readers' Advisory Services: Their Impact on Contemporary Spanish Fiction in Selected Public Library Collections." *Public Library Quarterly* 27, no.1 (2007): 1-18. http://plq.haworthpress.com/doi:10.1080/01616840802122377

Hall-Ellis, Sylvia D. "Language Proficiencies among Catalogers and Technical Services Librarians." *Technical Services Quarterly* 25, no. 2 (2007) 31-47. http://tsq.haworthpress.com/doi:10.1300/J124v25n02_03

Hall-Ellis, Sylvia D. "Cataloging Electronic Resources & Metadata: Employers' Expectations as Reflected in *American Libraries and AutoCAT*, 2000-2005." *Journal of Education for Library and Information Science* 47, no. 1 (2006): 38-51.

Hall-Ellis, Sylvia D. "Descriptive Impressions of Managerial & Supervisory Cataloger Positions as Reflected in *American Libraries*, *AutoCAT*, and the *Colorado State Library Jobline*, 2000-2004: A Content Analysis of Education, Competencies, and Experience." *Cataloging & Classification Quarterly* 42, no. 1 (2006): 55-88.

Hall-Ellis, Sylvia D. "Descriptive Cataloging Proficiencies among Beginning Students: A Comparison among Traditional and Virtual Class Students." *Journal of Library & Information Services in Distance Education* 2, no. 2 (2005): 13-44.

Hall-Ellis, Sylvia D. "Descriptive Impressions of Entry-Level Cataloger Positions as Reflected in *American Libraries*, *AutoCAT*, and the *Colorado State Library Jobline*, 2000-2003." *Cataloging & Classification Quarterly* 40, no. 2 (2005): 33-72.

Hall-Ellis, Sylvia D. and Mary Ann Berry. "The Impact of Library Resource Centers on Academic Achievement in Selected Public Schools in South Texas: Preliminary Findings." *Texas Library Journal* 71, no. 2 (Summer 1995): 94-97.

Hall-Ellis, Sylvia D. "Visual Arts as Foundation for Successful Library Automation: The Rocky Mountain College of Art & Design Experience." *Art Reference Serials Quarterly* 4 (1994): 43-54.

Hall, Sylvia D. *High School Databases: An Examination of Bibliographic Data Elements*. Dissertation. Pittsburgh, Pa.: University of Pittsburgh, School of Library and Information Science, 1985.

Technical Reports

Hall-Ellis, Sylvia D. *Colorado Community College System Grant Handbook.* Denver, CO: Colorado Community College System, 2015.

.

Faculty Voices: Testimonials from the Frontiers of a Development Education Redesign. Elaine DeLott Baker, Marilyn Smith, and Sylvia D. Hall-Ellis, eds. Denver, CO: Colorado Community College System, 2014.

Lewis, Melanie, Jamie M. Van Leeuwen, and Sylvia D. Hall-Ellis. *Project Homeless Connect 7 Event Evaluation.* Denver, Colo.: University of Colorado Denver, 2009.

Hall-Ellis, Sylvia D. *Grant Writing Tips and Resources.* Denver, Colo.: University of Denver, 2008-2014. http://portfolio.du.edu/grants

Hall-Ellis, Sylvia D. and Duan Zhang. *Project Homeless Connect 6 Event Evaluation.* Denver, Colo.: Center for Community Engagement and Service Learning, 2008.

Hall-Ellis, Sylvia D. *Strategic Plan for Denver Medical Library System: Final Report.* Denver, Colo.: HealthONE and Denver Medical Library, 2008.

Hall-Ellis, Sylvia D. and Duan Zhang. *Project Homeless Connect 5 Event Evaluation.* Denver, Colo.: Center for Community Engagement and Service Learning, 2008.

Hall-Ellis, Sylvia D. *Strategic Plan for Denver Medical Library System: Phase Two Report.* Denver, Colo.: HealthONE and Denver Medical Library, 2007.

Hall-Ellis, Sylvia D. and Duan Zhang. *Project Homeless Connect 4 Event Evaluation.* Denver, Colo.: Center for Community Engagement and Service Learning, 2007.

Hall-Ellis, Sylvia D. *Strategic Plan for Denver Medical Library System: Phase One Report.* Denver, Colo.: HealthONE and Denver Medical Library, 2007.

Hall-Ellis, Sylvia D. *Denver Public Library: Opportunities for Change.* Denver, Colo.: University of Denver, Colorado Community-Based Research Network & Metropolitan Organization of People, 2005.

Hall-Ellis, Sylvia D. *Resources in Grant Writing for Colorado Schools and Libraries.* Sponsored by the Colorado Department of Education, Educational Telecommunications Unit, 1999. Revised September 2000.

Hall-Ellis, Sylvia D. *Lewis & Clark Fellows Concept Paper for the Bicentennial Commemoration.* Vancouver, Wash.: Lewis and Clark Bicentennial Council, 1998.

Hall-Ellis, Sylvia D. and Mary Ann Berry. *The Impact of Library Resource Centers on Academic Achievement in Public Schools in Texas: The Final Report.* Prepared under the sponsorship of the Research Enhancement Fund award from Sam Houston State University, the Texas Association of School Librarians, the Children's Services Round Table, and the Young Adults' Services Round Table. Huntsville, Tex.: Sam Houston State University, College of Education and Applied Science, 1997.

Hall-Ellis, Sylvia D. *The Impact of Library Resource Centers on Academic Achievement in Selected Public Schools in Texas.* Huntsville, Tex.: Sam Houston State University, College of Education and Applied Science, 1997.

Hall-Ellis, Sylvia D. *Planning for Educational Technology: the Distance Education Implementation Phase: An Investigation of Technology and Telecommunication Needs for Region One Education Service Center, South Texas Community College, TCI Cablevision of South Texas, Inc., Tech Prep of the Rio Grande Valley, Inc., Texas State Technical College, Centro Cultural en el Valle de Texas, McAllen Independent School District, Harlingen Consolidated Independent School District, Donna Independent School District, Edinburg Consolidated Independent School District, La Joya Independent School District, Mercedes Independent School District, Pharr-San Juan-Alamo Independent School District, Sharyland Independent School District, Easter Seal Society of the Rio Grande Valley, Inc., and McAllen Memorial Library.* Harlingen, Tex.: Tech Prep of the Rio Grande Valley, 1996.

Hall-Ellis, Sylvia D. "Barcodes for the Texas Library Connection." Prepared under the sponsorship of the Office of Technology Services, Texas Education Agency. Austin, Tex.: TENET News and Conferences, March 1995.

Hall-Ellis, Sylvia D. *[et. al.] Planning for Educational Technology: A Study of Future Technology Needs for the Donna Independent School District, Region One Education Region Service Center, Tech Prep of the Rio Grande Valley, Inc. South Texas Community College, and the Department of Library Science, Sam Houston State University.* Research team: Sylvia D. Hall-Ellis, Ruth Ann Riggins, Noe Torres, Patricia G. Bubb, and Michael D. Bell. Harlingen, Tex.: Tech Prep of the Rio Grande Valley, 1994. Funded through a grant award from the Texas Education Agency.

Hall-Ellis, Sylvia D. and Mary Ann Berry. *The Impact of Library Resource Centers on Academic Achievement in Selected Public Schools in South Texas.* Huntsville, Tex.: Sam Houston State University, College of Education and Applied Science, 1993. Funded through a grant award from the Sam Houston State University Research Enhancement Fund.

Hall-Ellis, Sylvia D., Alice Krueger, and Linda Brannan. *Thesaurus Development for National Curriculum Materials Database at the Eisenhower National Clearinghouse for Mathematics and Science Education, Columbus, Ohio.* Developed under the sponsorship of Mid-Continent Regional Educational Laboratory Corporate Library, Aurora, Colo. Washington, D.C.: National Science Foundation; Columbus, Ohio: ERIC Clearinghouse for Mathematics and Science Education, 1993.

Hall-Ellis, Sylvia D. and Clarence L. Coffindaffer. *Partners in Progress: The 1992 Montana Library Federation Study Final Report*. Helena, Mont: Montana State Library and The Blue Bear Group, Inc., 1992.

Hall-Ellis, Sylvia D. and Clarence L. Coffindaffer. *Montana Federation Study Identification Paper*. Denver, Colo.: The Blue Bear Group, Inc., 1992.

Bruntjen, Scott and Sylvia D. Hall. *Recommendations on the Development of System-Wide Efforts of the Northern Waters Library Service.* Ashland, Wisc.: Northern Waters Library Service and The Blue Bear Group, Inc., 1989.

Hall, Sylvia D. *The Iowa Union List of Serials as A Part of The Iowa Locator: Planning Document*. Des Moines, Ia.: State Library of Iowa, 1988.

Hall, Sylvia D. *Iowa Computer-Assisted Network (ICAN Users' Manual. IBM Compatible Edition: Version 7.0.* Des Moines, Ia.: State Library of Iowa, 1988.

Hall, Sylvia D. *Iowa Computer-Assisted Network (ICAN Users' Manual. IBM Compatible Edition: Version 5.0.* Des Moines, Ia.: State Library of Iowa, 1986.

Hall, Sylvia D. *Iowa Computer-Assisted Network (ICAN Users' Manual. Apple MacIntosh Edition: Version 5.0.* Des Moines, Ia.: State Library of Iowa, 1986.

Bruntjen, Scott and Sylvia D. Hall. *The District of Columbia Public Library Planning for Retrospective Conversion of Bibliographic Records and Automation Issues for the 1990's: Final Report*. Central City, Colo.: The Blue Bear Group, Inc., 1986.

Bruntjen, Scott and Sylvia D. Hall. *The Iowa Locator: Final Report.* Central City, Colo.: The Blue Bear Group, Inc., 1986.

Bruntjen, Scott and Sylvia D. Hall. *Discovering Resource Sharing Treasures: Accessing Pennsylvania's High School Library Collections*. Harrisburg, Pa.: State Library of Pennsylvania, Bureau of School Library Media Resources, 1985.

Hall, Sylvia D. *Retrospective Conversion and the Completeness of Cataloging in Pennsylvania High School Libraries.* Pittsburgh, Pa.: PRLC, Inc., 1985.

Bruntjen, Scott and Sylvia D. Hall. *The Iowa Locator*. Des Moines, Ia.: State Library of Iowa, 1985- http://www.statelibraryofiowa.org/ld/silo/locator

Bruntjen, Scott and Sylvia D. Hall. *ICAN Analysis*. Des Moines, Ia.: State Library of Iowa, 1985.

Bruntjen, Scott and Sylvia D. Hall. *Zebras: Bar Codes, Standards, and Library Automation*. Central City, Colo.: The Blue Bear Group, Inc., 1985.

Hall, Sylvia D. and Scott Bruntjen. *Access Pennsylvania.* Harrisburg, Pa.: State Library of Pennsylvania, 1984- http://www.accesspa.org

Hall, Sylvia D. *Reconfiguration of the ITAC Cataloging Data Base to Machine Readable (MARC) Format*. Classified Document. Arlington, Va.: U. S. Army Intelligence and Threat Analysis Center, 1984.

Bruntjen, Scott and Sylvia D. Hall. *South Dakota Library Automation Plan: Final Report*. Pittsburgh, Pa.: PRLC, Inc., 1982. Reprinted by the South Dakota State Library, 1983.

Bruntjen, Scott and Sylvia D. Hall. *Altoona Automation Plan: Final Report prepared for the Altoona Area Public Library and the Altoona District Library Center*. Pittsburgh, Pa.: PRLC, 1983.

Bruntjen, Scott, Sylvia D. Hall and Paul J. Pugliese. *College Space Utilization Study*. Pittsburgh, Pa.: PRLC, Inc., 1983.

Hall, Sylvia D. *Pennsylvania Public Library Film Center Union Catalog Cataloging and Technical Services Procedures Manual*. Pittsburgh, Pa.: PRLC, Inc., 1982.

Hall, Sylvia D. *History of Library Development in Pennsylvania: A Review and Content Analysis of the Plans, 1955-1980*. Pittsburgh, Pa.: PRLC, Inc., 1982.

Hall, Sylvia D. *Newspapers on Microfilm: A Listing of Newspapers in Allegheny, Chemung, Schuyler,Steuben, and Yates Counties*. Ithaca, N.Y.: South Central Reference and Research Council, 1981.

Hall, Sylvia D. *OCLC/ILL Subsystem at Southern Tier Library System.* Albany, N.Y.: SUNY/OCLC Network, 1980.

Hall, Sylvia D. *Retrospective Conversion for Major Public Libraries in South Central New York State: A Technical Report*. 2 vols. Corning, N.Y.: Southern Tier Library System, 1979-1980.

Hall, Sylvia D. *The Librarian and the Mexican-American Patron in Texas.* Austin, Tex.: Texas State Library, 1978.

Other Publications

Hall-Ellis, Sylvia D., ed. *Library and Information Science Program Self-Study Document for Accreditation by the American Library Association.* St. Paul, MN: St. Catherine University, 2017. 255 p.

Hall-Ellis, Sylvia D., and Robert O. Ellett, Jr., guest editors. *RDA Testing: Lessons Learned and Challenges Revealed: A Special Issue of Cataloging & Classification Quarterly* 49, no. 7-8 (November 2011).

Hall-Ellis, Sylvia D. and Robert O. Ellett, Jr. *Fundamentals of Cataloging I: An Online ALCTS Course.* Chicago, Ill.: American Library Association, 2009.

Hall-Ellis, Sylvia D., Angela J. Kinney and Martha Ann Bace, editors. *Best Practices in Cataloging Education Identified at the 2007 ALCTS Pre-conference: A Special Issue of the Journal for Library and Information Science Education* 49, no. 2 (Spring 2008).

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/aba/professional/

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, Louisiana, June 26, 2006. http://dlist.sir.arizona.edu/

Hall-Ellis, Sylvia D., guest editor, with Deborah S. Grealy, Clara L. Sitter, and Tassos Petrou. *Library Students' Voices in Colorado: An Issue of Colorado Libraries* 31:1 (Spring 2005).

Hall-Ellis, Sylvia D., ed. *Library and Information Science Program Self-Study Document for Accreditation by the American Library Association.* Denver, Colo.: University of Denver, College of Education, 2003. 125 p. with CD-ROM.

Hall-Ellis, Sylvia D. and Deborah S. Grealy, guest editors. *Library Education in Colorado: An Issue of Colorado Libraries* 29, no. 2 (Summer 2003).

Hall-Ellis, Sylvia D., ed. *Library and Information Science Program Self-Study Document for Accreditation by the American Library Association.* Denver, Colo.: University of Denver, College of Education, 2003.

Hall-Ellis, Sylvia D. "Adaptive Furniture for the ADA-Qualified: An Investigative Study." 2001. Unpublished manuscript.

Hall-Ellis, Sylvia D. "Cataloging Electronic Serials: A Study in User Access and Article Delivery." 2001. Unpublished manuscript.

Hall-Ellis, Sylvia D. "E-books: Acquisition and Circulation Issues in Public Libraries." 2001. Unpublished manuscript.

Hall-Ellis, Sylvia D. "Authority Control and Its Importance in School Library Media Online Catalogs." 1999. Unpublished manuscript.

Hall, Sylvia D. "Cooperation Improving Service in San Antonio System." *Texas Libraries* XXXVII (Spring 1976): 27-29.

Hall, Sylvia D. "Summer is Sea Monstrously Fun!" *Texas Library Journal* L (December 1974): 224-226.

Hall, Sylvia D. "A Brief Annotated Bibliography of Non-book Materials on the Mexican American." *Texas Library Journal* XLVIII (October 1972): 213-232.

Book Reviews

ALA Book of Library Grant Money. Ann Kepler, ed. 8th ed. Chicago, IL: American Library Association, 2011. 978-0-8389-1058-0, $175.00 [*Colorado Libraries,* June 2012]

Developing a Compensation Plan for Your Library. Paula M. Singer and Laura L. Francisco, comps. 2nd ed. Chicago, IL: American Library Association, 2009. 978-0-8389-0985-0, $57.00 [*Colorado Libraries,* March 2012]

Frugal Librarian. Carol Smallwood, ed. Chicago, IL: American Library Association, 2011. 978-0-83891-075-7, $42.00 [*Colorado Libraries,* February 2012]

Dowlin, Ken. *Getting the Money: How to Succeed in Fundraising for Public and Nonprofit Libraries.* Westport, Conn.: Libraries Unlimited, 2008. 978-1-59158-597-X, $50.00 [*Colorado Libraries,* February 2009]

Lundahl, Mats. *Bebo de Cuba; Bebo Valdés y Su Mundo*, by Mats Lundahl. Traducción de Linda Oakeshott Dragó. Barcelona: RBA Libros, 2008. 978-849-86-7259-6, $33.99 [*Críticas*, November 2008]

Bonelli, Florencia. *Marlene*, by Florencia Bonelli. Buenos Aires: Aguilar, Altea, Taurus, Alfaguara, 2008. 978-987-04-0995-3, $24.95 [*Críticas*, October 2008]

Keret, Etgar. Traducción de Ana María Bejarano. *Pizzería Kamikaze y Otras Relatos.* México, D.F.: Editorial Sexto Piso, 2008. 968-5679-29-0, no price given [*Críticas*, September 2008]

Littauer, Marita, and Florence Littauer. *Enriquece tu Comunicación. Miami, Fla.: Editorial Unilit, 2008.* 978-0-7899-1521-4, $11.99 [*Críticas*, August 2008]

Martínez, Guillermo. *La Muerte Lenta de Luciana B.* New York: Rayo Planeta, 2008. 978-0-06-156551-9, $14.95 [*Críticas*, May 2008]

Matthews, Joseph R. *The Evaluation and Measurement of Library Services.* Westport, Conn.: Libraries Unlimited, 2007. 978-1-59158-532-9, $50.00 [*Colorado Libraries,* April 2008]

Gómez-Jurado, Juan. *A Masacre de Virginia Tech: Anatomía de una Mente Torturada*. Barcelona: Ediciones El Andén, 2007. 978-84-935789-4-7, €16.50 [*Críticas*, February, 2008]

Matthews, Joseph R. *Library Assessment in Higher Education.* Westport, Conn.: Libraries Unlimited, 2007. 978-1-59158-531-2, $45.00 [*Colorado Libraries,* February 2008]

Chacón, Inma. *La Princesa India: Cuando el Viento Azul.* México: Alfaguara, 2006. 970-770398-9, $19.95 [*Críticas*, June 2006]

Vargas Llosa, Mario. *Israel/Palestina: Paz o Guerra Santa.* fotogs. by Morgana Vargas Llosa. Spain/U.S.: Aguilar: Santillana, 2006. 84-03-09691-7, paper, $19.95 [*Críticas*, May 2006]

Findlay, Diane. *Digging into Dewey.* Fort Atkinson, Wisc.: Upstart Books, 2005. 978-1-932146-18-9, $16.95 [*Colorado Libraries,* May 2006]

Pequeñas Resistencias 4: Antología del Nuevo Cuento Norteamericano y Caribeño. Menéndez, Ronaldo, Ignacio Padilla & Enrique del Risco, eds. Madrid**:** Páginas de Espuma, 2005. 84-95642-59-X, paper, $36.95 [*Críticas*, April 2006]

Rueda, André. *Vengo a Salvar a España: Biografía de Un Franco Desconocido.* Madrid**:** Nowtilus (Investigación Abierta), 2005. photogs., bibliog. 84-9763-202-8, paper, $23.95 [*Críticas*, March 2006]

Becerra, Ángela. *El Penúltimo Sueño.* 1st ed. Barcelona: Planeta, 2005. 84-08-05795-2, $25.95. [*Críticas*, January 2006]

Aguilar Camín, Héctor. *La Conspiración de la Fortuna.* 1st ed. México: Planeta, 2005. 970-37-0368-2, $19.95 [*Críticas*, October 2005]

México en Sus Libros. Enrique Florescano with Pablo Mijangos, editors & compilers. 1st ed. México, D.F.: Taurus Aguilar, 2004. 968-19-0783-3, $16.95 [*Críticas*, September 2005]

Historia Económica de México. Coordinator, Enrique Semo. México: Universidad Nacional Autónoma de México, Editorial Oceano de México, 2004. 13 vols. 970-32-0805+3 (obra completa), $9.25 each [*Críticas*, August 2005]

Czarnowsky, Christyne A. and Michael H. Williams. *Managing Your Wired Workforce: A Practical Guide.* Denver, Colo.: Bradford Pub., 2003. 1-883726-79-4, $24.95 [*Colorado Libraries,* 2004]

Abraham Lincoln. Colección Grandes Biografías. Madrid: Edimat Libros, 2003. 84-8403-858-0, €4.95 [*Críticas*, 2004]

Alponte, Juan María. *Colón: el Hombre, el Navegante, la Leyenda.* México, D.F.: Aguilar, 2003. 968-19-1260-8, $16.95 [*Críticas*, 2004]

Olcese Salvatecci, Alfieri. *Cómo Estudiar con Èxito: Téchnicas yHhábitos Para Aprender Major.* México, D.F.: Alfaomega Grupo Editor, 2002. 970-15-0764-9 [*Críticas*, 2003]

Mujeres Como Islas: Antología de Narradoras Cubanas, Dominicanas, Puertoriqueñas. Edición: Olga Marta Pérez, Thelma Jiménez, Andrés Blanco D., eds. Santo Domingo, República Dominicana: Ediciones Ferilibro, 2002. 959-209-419-5 [*Críticas*, 2003]

Tibol, Raquel. *Los Murales de Diego Rivera: Universidad Autónoma Chapingo.* México, D.F.: Editorial RM, Universidad Autónoma Chapingo, 2002. 968-5208-08-5 [*Críticas*, 2003]

Lindsay-Poland, John. *Emperors in the Jungle: the Hidden History of the U.S. in Panama.* Durham, N.C.: Duke University Press, 2003. 0-8223-3098-9, $18.95 [*Críticas*, 2003]

Kaplan, Allison G. and Ann Marlowe Riedling. *Catalog It! A Guide to Cataloging School Library Materials.* Worthington, Ohio: Linworth Pub., 2002. 1-58683-014-7, $44.95 [*Colorado Libraries,* 2002]

Bardach, Ann Louise. *Cuba Confidential: Love and Vengeance in Miami and Havana.* New York: Random, 2002. 0-375-50489-3, $25.95 [*Library Journal*, 2002]

Swan, James. *Fundraising for Libraries: 25 Proven Ways to Get More Money for Your Library.* New York: Neal Schuman, 2002. 1-55570-433-6, $69.95 [*Colorado Libraries*, 2002]

Puíg de Lange, Victoria. *Sol Con Agua.* Nashville, Tenn.: Editorial Vistazo/Ediciones Reio Negro, 2002. 0-9724506-0-2, $17.75 [*Críticas*, 2002]

The Encyclopedia of Latin American Politics. Edited by Diana Kapiszewski; assistant editor, Alexander Kazan. Westport, Conn.: Oryx Press, 2002. 1-57356-306-4, $74.95 [*Library Journal*, 2002]

Vargas Lizano, Isabel. *Y Si Quieres Saber de Mi Pasado.* Con la colaboración de J.C. Vales. Madrid: Santillana Ediciones Generales, S.L., 2002. 84-03-09278-4, $18.95 [*Críticas*, 2002]

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
Association for Library Collections & Technical Services
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
Membership Committee, 2019-2021
Board of Directors, Member At-Large, 2009-2012
Member, 2003-
Office of Accreditation
Accreditation Panel Member (training completed 2004)
Accreditation Review Panel Member (training completed 2004)

REFORMA
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

Online Audiovisual Catalogers Association (OLAC)
American Association of Law Libraries (AALL)
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.

Hall-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.

Hall-Ellis, Sylvia D. *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.

Hall-Ellis, Sylvia D. *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)
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 Seminar for Non-Profit Organizations (Spring 2020)

University of Denver, Morgridge College of Education
HED 5991 – Grant Writing in Higher Education (Spring 2011)
LIS 4010 – Organization of Information (Fall 2002, 2003, 2004, 2005, 2006, 2009; Winter 2005; Spring 2004, 2005, 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, 2003, 2004, 2005, 2006, 2007, 2008, 2009; Summer 2005, 2006 – course renumbered LIS 4070, September 2007)
LIS 4401 – Descriptive Cataloging (Winter 2001; Spring 2002, 2003, 2006, 2007, 2008, 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 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, 2007, 2008, 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-

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 September 2019

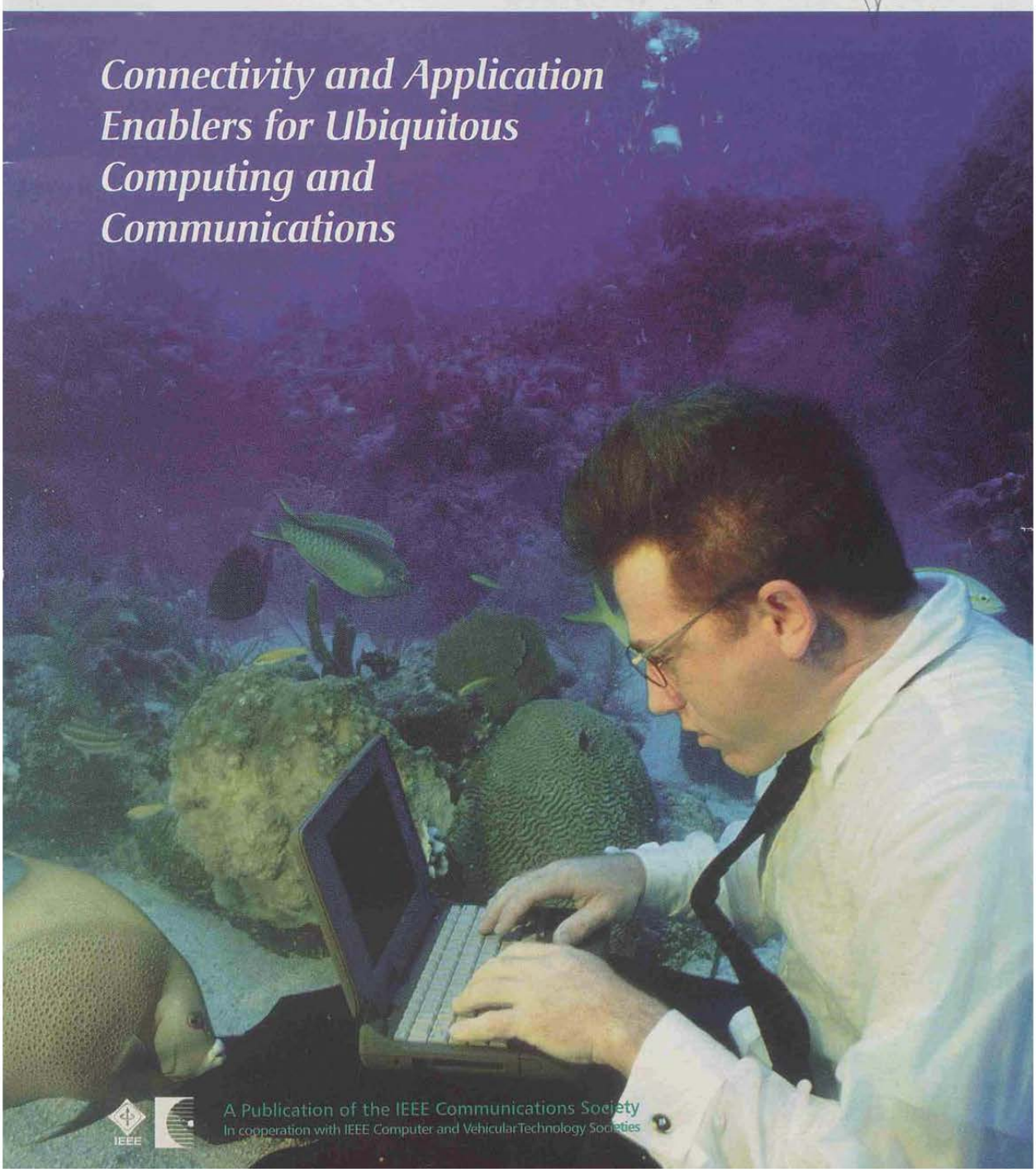
Exhibit B

IEEE Personal Communications

February 2000
Vol. 7 No. 1

THE MAGAZINE OF WIRELESS COMMUNICATIONS AND NETWORKING

Connectivity and Application Enablers for Ubiquitous Computing and Communications

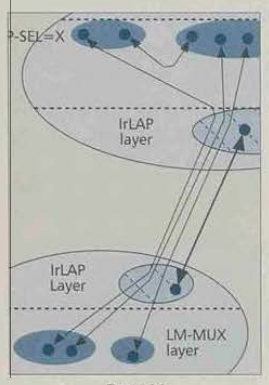


A Publication of the IEEE Communications Society
In cooperation with IEEE Computer and Vehicular Technology Societies

FEBRUARY 2000 VOL. 7 NO. 1

IEEE Personal Communications

THE MAGAZINE OF WIRELESS COMMUNICATIONS AND NETWORKING



Page 11

Page 20

Page 44

Cover illustration: The Stock Market

Features

EDITOR'S NOTE

MAHMOUD NAGHSHINEH

It is my utmost honor and privilege to serve our *IEEE Personal Communications* community starting with this issue of our magazine. At first, on behalf of our Editorial Board and the IEEE Communications Society, I would like to extend my sincere gratitude to Tom La Porta, who served as Editor-in-Chief from 1997 to 1999. Tom will continue to help and guide us as a senior advisor of the magazine. It will be hard to match the high level of leadership quality he has established, and I count on him, our founding Editor-in-Chief, Hamid Ahmadi, our Advisory Board, technical editors, and the IEEE editorial team to help me carry my responsibility as the new Editor-in-Chief.

In my view, this is the most exiting time in our area; we are starting a new millennium with tremendous anticipation of the possibilities and potentials wireless and mobile technologies will bring to us. It is expected that by 2003 the number of cellular subscribers will be equal to the number of wired phone subscribers. Obviously, new evolving architectures and standards, such as GPRS and EDGE, and third-generation systems will play a major role in this transition, enabling a high-speed, ubiquitous wireless Internet. After all, it will be a totally new world when one billion people carry a personal gateway to the Internet with integrated voice and data support. Today, wireless technologies have crossed the cost, integration, and power consumption barriers, and are a key factor in defining new directions not only in enterprise but also in consumer markets. Second-generation cellular technologies are leading this front,

IEEE Personal Communications
THE MAGAZINE OF WIRELESS COMMUNICATIONS AND NETWORKING

IEEE Personal Communications – The Magazine of Wireless Communications and Networking (ISSN 1070-9916) is published bimonthly by The Institute of Electrical and Electronics Engineers, Inc. Headquarters address: IEEE, 3 Park Avenue, 17th Floor, New York, NY 10016-5997; tel: 212-705-8900; fax: 212-705-8999; e-mail: c.kemelmacher@comsoc.org. Responsibility for the contents rests upon authors of signed articles and not the IEEE or its members. Unless otherwise specified, the IEEE neither endorses nor sanctions any positions or actions espoused in *IEEE Personal Communications*.

Annual subscription: Member subscription: $25 per year; Non-member subscription prices available on request. Single copy: $10 for members and $20 for nonmembers.

Editorial correspondence: Manuscripts for consideration may be submitted to the Editor-in-Chief: Thomas F. La Porta, Lucent Technologies, Inc., 101 Crawford Corners Road, Rm 4F-519, Holmdel, NJ 07733. Electronic submissions may be sent in postscript to: tlp@bell-labs.com.

Postmaster: Send address changes to *IEEE Personal Communications*, IEEE, 445 Hoes Lane, Piscataway, NJ 08855-1331; or email to address.change@ieee.org. Printed in USA. Periodicals postage paid at New York, NY and at additional mailing offices. Canadian GST #125634188.

Subscriptions: Send orders, address changes to: IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08855-1331; tel.: 908-981-0060.

Advertising: Advertising is accepted at the discretion of the publisher. Address correspondence to: Advertising Manager, *IEEE Personal Communications*, 305 East 47th Street, New York, NY 10017-2394.

Abstract

A few years ago it was recognized that the vision of a truly low-cost, low-power radio-based cable replacement was feasible. Such a ubiquitous link would provide the basis for portable devices to communicate together in an ad hoc fashion by creating personal area networks which have similar advantages to their office environment counterpart, the local area network. Bluetooth™ is an effort by a consortium of companies to design a royalty-free technology specification enabling this vision. This article describes the radio system behind the Bluetooth concept. Designing an ad hoc radio system for worldwide usage poses several challenges. The article describes the critical system characteristics and motivates the design choices that have been made.

The Bluetooth Radio System

JAAP C. HAARTSEN, ERICSSON RADIO SYSTEMS B.V.

In the last decades, progress in microelectronics and very large scale integration (VLSI) technology has fostered the widespread use of computing and communication devices for commercial usage. The success of consumer products like PCs, laptops, personal digital assistants (PDAs), cell phones, cordless phones, and their peripherals has been based on continuous cost and size reduction. Information transfer between these devices has been cumbersome, mainly relying on cables. Recently, a new universal radio interface has been developed enabling electronic devices to communicate wirelessly via short-range ad hoc radio connections. The Bluetooth technology — which has gained the support of leading manufacturers like Ericsson, Nokia, IBM, Toshiba, Intel, and many others — eliminates the need for wires, cables, and the corresponding connectors between cordless or mobile phones, modems, headsets, PDAs, computers, printers, projectors, and so on, and paves the way for new and completely different devices and applications. The technology enables the design of low-power, small-sized, low-cost radios that can be embedded in existing (portable) devices. Eventually, these embedded radios will lead toward ubiquitous connectivity and truly connect everything to everything. Radio technology will allow this connectivity to occur without any explicit user interaction.

This article describes the basic design and technology trade-offs which have led to the Bluetooth radio system. We describe some fundamental issues regarding ad hoc radio systems. We give an overview of the Bluetooth system itself with the emphasis on the radio architecture. It explains how the system has been optimized to support ad hoc connectivity. We also describe the Bluetooth specification effort.

Ad Hoc Radio Connectivity

The majority of radio systems in commercial use today are based on a cellular radio architecture. A mobile network established on a wired backbone infrastructure uses one or more base stations placed at strategic positions to provide local cell coverage; users apply portable phones, or more generic mobile terminals, to access the mobile network; the terminals maintain a connection to the network via a radio link to the base stations. There is a strict separation between the base stations and the terminals. Once registered to the network, the terminals remain locked to the control channels in the network, and connections can be established and released according to the control channel protocols. Channel access, channel allocation, traffic control, and interference minimization are neatly controlled by the base stations. Examples of these conventional radio systems are the public cellular phone systems like Global System for Mobile Communications (GSM), D-AMPS, and IS-95 [1–3], but also private systems like wireless local area network (WLAN) systems based on 802.11 or HIPERLAN I and HIPERLAN II [4–6], and cordless systems like Digital Enhanced Cordless Telecommunications (DECT) and Personal Handyphone System (PHS) [7, 8].

In contrast, in truly ad hoc systems, there is no difference between radio units; that is, there are no distinctive base stations or terminals. Ad hoc connectivity is based on peer communications. There is no wired infrastructure to support connectivity between portable units; there is no central controller for the units to rely on for making interconnections; nor is there support for coordination of communications. In addition, there is no intervention of operators. For the scenarios envisioned by Bluetooth, it is highly likely that a large number of ad hoc connections will coexist in the same area without any mutual coordination; that is, tens of ad hoc links must share the same medium at the same location in an uncoordinated fashion. This is different from ad hoc scenarios considered in the past, where ad hoc connectivity focused on providing a single (or very few) network(s) between the units in range [4, 5]. For the Bluetooth applications, typically many independent networks overlap in the same area. This will be indicated as a scatter ad hoc environment. Scatter ad hoc environments consist of multiple networks, each containing only a limited number of units. The difference between a conventional cellular environment, a conventional ad hoc environment, and a scatter ad hoc environment is illustrated in Fig. 1. The environmental characteristics the ad hoc radio system has to operate in have a major impact on the following fundamental issues:

- Applied radio spectrum
- Determining which units are available to connect to
- Connection establishment
- Multiple access scheme
- Channel allocation
- Medium access control
- Service prioritization (i.e., voice before data)
- (Mutual) interference
- Power consumption

Ad hoc radio system have been in use for some time, for example, walky-talky systems used by the military, police, fire departments, and rescue teams in general. However, the Bluetooth system is the first commercial ad hoc radio system envisioned to be used on a large scale and widely available to the public.

1070-9916/00/$10.00 © 2000 IEEE

Bluetooth Radio System Architecture

In this section the technical background of the Bluetooth radio system is presented. It describes the design trade-offs made in order to optimize the ad hoc functionality and addresses the issues listed above.

Radio Spectrum

The choice of radio spectrum is first determined by the lack of operator interaction. The spectrum must be open to the public without the need for licenses. Second, the spectrum must be available worldwide. The first Bluetooth applications are targeted at the traveling businessperson who connects his/her portable devices wherever he/she goes. Fortunately, there is an unlicensed radio band that is globally available. This band, the Industrial, Scientific, Medical (ISM) band, is centered around 2.45 GHz and was formerly reserved for some professional user groups but has recently been opened worldwide for commercial use. In the United States, the band ranges from 2400 to 2483.5 MHz, and the FCC Part 15 regulations apply. In most parts of Europe,[1] the same band is available under the ETS-300328 regulations. In Japan, recently the band from 2400 to 2500 MHz has been allowed for commercial applications and has been harmonized with the rest of the world. Summarizing, in most countries of the world, free spectrum is available from 2400 MHz to 2483.5 MHz, and harmonization efforts are ongoing to have this radio band available truly worldwide.

The regulations in different parts of the world differ. However, their scope is to enable fair access to the radio band by an arbitrary user. The regulations generally specify the spreading of transmitted signal energy and maximum allowable transmit power. For a system to operate globally, a radio concept has to be found that satisfies all regulations simultaneously. The result will therefore be the minimum denominator of all the requirements.

Interference Immunity

Since the radio band is free to be accessed by any radio transmitter as long as it satisfies the regulations, interference immunity is an important issue. The extent and nature of the interference in the 2.45 GHz ISM band cannot be predicted. Radio transmitters may range, for example, from 10 dBm baby monitors to 30 dBm WLAN access points. With high probability, the different systems sharing the same band will not be able to communicate. Coordination is therefore not possible. More of a problem are the high-power transmitters covered by the FCC part 18 rules which include, for example, microwave ovens and lighting devices. These devices fall outside the power and spreading regulations of part 15, but still coexist in the 2.45 GHz ISM band. In addition to interference from external sources, co-user interference must be taken into account, which results from other Bluetooth users.

Interference immunity can be obtained by interference suppression or avoidance. Suppression can be obtained by coding or direct-sequence spreading. However, the dynamic range of the interfering and intended signals in an ad hoc, uncoordinated radio environment can be huge. Taking into account the distance ratios and power differences of uncoordinated transmitters, near-far ratios in excess of 50 dB are no exception. With desired user rates on the order of 1 Mb/s and beyond, practically attained coding and processing gains are inadequate. Instead, interference avoidance is more attractive since the desired signal is transmitted at points in frequency and/or time where interference is low or absent. Avoidance in time can be an alternative if the interference concerns a pulsed jammer and the desired signal can be interrupted. Avoidance in frequency is more practical. Since the 2.45 GHz band provides about 80 MHz of bandwidth and most radio systems are band-limited, with high probability a part of the radio spectrum can be found where there is no dominant interference. Filtering in the frequency domain provides the suppression of the interferers at other parts of the radio band. The filter suppression can easily arrive at 50 dB or more.

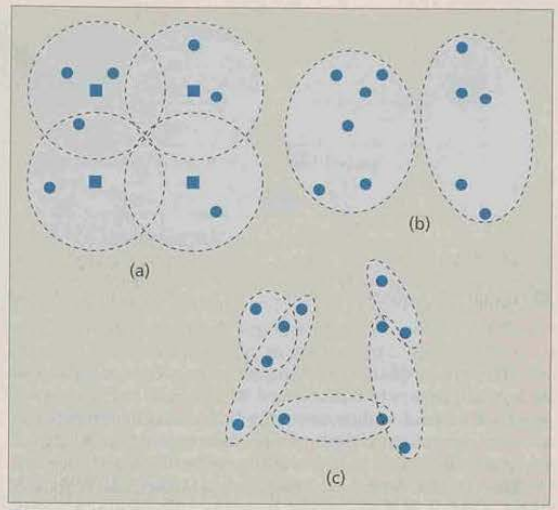
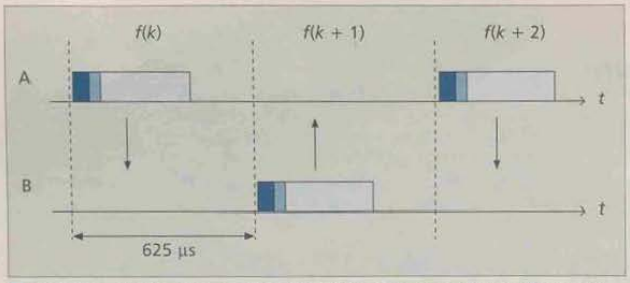


Figure 1. *Topologies for: a) cellular radio systems with squares representing stationary base stations; b) conventional ad hoc systems; and c) scatter ad hoc systems.*

Multiple Access Scheme

The selection of the multiple access scheme for ad hoc radio systems is driven by the lack of coordination and the regulations in the ISM band. Frequency-division multiple access (FDMA) is attractive for ad hoc systems since channel orthogonality only relies on the accuracy of the crystal oscillators in the radio units. Combined with an adaptive or dynamic channel allocation scheme, interference can be avoided. Unfortunately, pure FDMA does not fulfill the spreading requirements set in the ISM band. Time-division multiple access (TDMA) requires strict time synchronization for channel orthogonality. For multiple collocated ad hoc connections, maintaining a common timing reference becomes rather cumbersome. Code-division multiple access (CDMA) offers the best properties for ad hoc radio systems since it provides spreading and can deal with uncoordinated systems. Direct sequence (DS)-CDMA is less attractive because of the near-far problem which requires coordinated power control or excessive processing gain. In addition, as in TDMA, DS-CDMA channel orthogonality requires a common timing reference. Finally, for higher user rates, rather high chip rates are required, which is less attractive because of the wide bandwidth (interference immunity) and higher current consumption. Frequency-hopping (FH)-CDMA combines a number properties which make it the best choice for ad hoc radio systems. On average the signal can be spread over a large frequency range, but instantaneously only a small bandwidth is occupied, avoiding most of the potential interference in the ISM band. The hop carriers are orthogonal, and the interference on adjacent hops can effectively be suppressed by filter-

[1] *In France and Spain the exact location of the band differs, and the band is smaller.*



■ **Figure 2.** *An illustration of the FH/TDD channel applied in Bluetooth.*

ing. The hop sequences will not be orthogonal (coordination of hop sequences is not allowed by the FCC rules anyway), but narrowband and co-user interference is experienced as short interruptions in the communications, which can be overcome with measures at higher-layer protocols.

Bluetooth is based on FH-CDMA. In the 2.45 GHz ISM band, a set of 79 hop carriers have been defined at a 1 MHz spacing.[2] The channel is a hopping channel with a nominal hop dwell time of 625 µs. A large number of pseudo-random hopping sequences have been defined. The particular sequence is determined by the unit that controls the FH channel, which is called the *master*. The native clock of the master unit also defines the phase in the hopping sequence. All other participants on the hopping channel are *slaves*; they use the master identity to select the same hopping sequence and add time offsets to their respective native clocks to synchronize to the frequency hopping. In the time domain, the channel is divided into slots. The minimum dwell time of 625 µs corresponds to a single slot. To simplify implementation, full-duplex communications is achieved by applying time-division duplex (TDD). This means that a unit alternately transmits and receives. Separation of transmission and reception in time effectively prevents crosstalk between the transmit and receive operations in the radio transceiver, which is essential if a one-chip implementation is desired. Since transmission and reception take place at different time slots, transmission and reception also take place at different hop carriers. Figure 2 illustrates the FH/TDD channel applied in Bluetooth. Note that multiple ad hoc links will make use of different hopping channels with different hopping sequences and may have misaligned slot timing.

The Modulation Scheme

In the ISM band, the signal bandwidth of FH systems is limited to 1 MHz. For robustness, a binary modulation scheme was chosen. With the above-mentioned bandwidth restriction, the data rates are limited to about 1 Mb/s. For FH systems and support for bursty data traffic, a noncoherent detection scheme is most appropriate. Bluetooth uses Gaussian-shaped frequency shift keying (FSK) modulation with a nominal modulation index of $k = 0.3$. Logical ones are sent as positive frequency deviations, logical zeroes as negative frequency deviations. Demodulation can simply be accomplished by a limiting FM discriminator. This modulation scheme allows the implementation of low-cost radio units.

Medium Access Control

Bluetooth has been optimized to allow a large number of uncoordinated communications to take place in the same area. Unlike other ad hoc solutions where all units in range share the same channel, Bluetooth has been designed to allow a large number of independent channels, each channel serving only a limited number of participants. With the considered modulation scheme, a single FH channel in the ISM band only supports a gross bit rate of 1 Mb/s. This capacity has to be shared by all participants on the channel. Theoretically, the spectrum with 79 carriers can support 79 Mb/s. In the user scenarios targeted by Bluetooth, it is highly unlikely that all units in range need to share information among all of them. By using a large number of independent 1 Mb/s channels to which only the units are connected that really want to exchange information, the 80 MHz is exploited much more effectively. Due to nonorthogonality of the hop sequences, the theoretical capacity of 79 Mb/s cannot be reached, but is at least much larger than 1 Mb/s.

An FH Bluetooth channel is associated with a piconet. As mentioned earlier, the piconet channel is defined by the identity (providing the hop sequence) and system clock (providing the hop phase) of a master unit. All other units participating in the piconet are slaves. Each Bluetooth radio unit has a free-running system or native clock. There is not a common timing reference, but when a piconet is established, the slaves add offsets to their native clocks to synchronize to the master. These offsets are released again when the piconet is cancelled, but can be stored for later use. Different channels have different masters and therefore also different hopping sequences and phases. The number of units that can participate on a common channel is deliberately limited to eight (one master and seven slaves) in order to keep a high-capacity link between all the units. It also limits the overhead required for addressing. Bluetooth is based on peer communications. The master/slave role is only attributed to a unit for the duration of the piconet. When the piconet is cancelled, the master and slave roles are cancelled. Each unit can become a master or slave. By definition, the unit that establishes the piconet becomes the master.

In addition to defining the piconet, the master also controls the traffic on the piconet and takes care of access control. Access is completely contention free. The short dwell time of 625 µs only allows the transmission of a single packet. A contention-based access scheme would provide too much overhead and is not efficient in the short dwell time Bluetooth applies. In Bluetooth, the master implements centralized control; only communication between the master and one or more slaves is possible. The time slots are alternately used for master transmission and slave transmission. In the master transmission, the master includes a slave address of the unit for which the information is intended. In order to prevent collisions on the channel due to multiple slave transmissions, the master applies a polling technique: for each slave-to-master slot, the master decides which slave is allowed to transmit. This decision is performed on a per-slot basis: only the slave addressed in the master-to- slave slot directly preceding the slave-to-master slot is allowed to transmit in this slave-to-master slot. If the master has information to send to a specific slave, this slave is polled implicitly and can return information. If the master has no information to send, it has to poll the slave explicitly with a short poll packet. Since the master schedules the traffic in both the uplink and downlink, intelligent scheduling algorithms have to be used that take into account the slave characteristics. The master control effectively prevents collisions between the participants on the piconet channel. Independent collocated piconets may interfere when they occasionally use the same hop carrier. A type of ALOHA is applied: information is transmitted without checking for a clear carrier (no listen-before-talk). If the information is

[2] *Currently, for France and Spain a reduced set of 23 hop carriers has been defined at a 1 MHz carrier spacing.*

received incorrectly, it is retransmitted at the next transmission opportunity (for data only). Due to the short dwell time, collision avoidance schemes are less appropriate for FH radio. For each hop, different contenders are encountered. Backoff mechanisms are therefore less efficient.

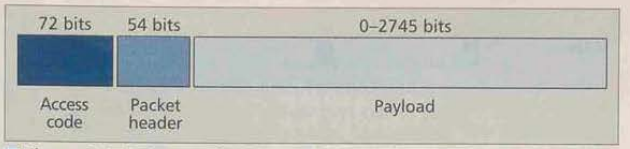


Figure 3. *The format of packets applied in Bluetooth.*

Packet-Based Communications

The Bluetooth system uses packet-based transmission: the information stream is fragmented into packets. In each slot, only a single packet can be sent. All packets have the same format, starting with an access code, followed by a packet header, and ending with the user payload (Fig. 3).

The access code has pseudo-random properties and is used as a direct-sequence code in certain access operations. The access code includes the identity of the piconet master. All packets exchanged on the channel are identified by this master identity. Only if the access code matches the access code corresponding to the piconet master will the packet be accepted by the recipient. This prevents packets sent in one piconet falsely being accepted by units of another piconet that happens to land on the same hop carrier. In the receiver, the access code is matched against the anticipated code in a sliding correlator. This correlator provides the direct-sequence processing gain. The packet header contains link control information: a 3-bit slave address to separate the slaves on the piconet, a 1-bit acknowledgment/negative acknowledgmennt (ACK/NACK) for the automatic repeat request (ARQ) scheme, a 4-bit packet type code to define 16 different payload types, and an 8-bit header error check (HEC) code which is a cyclic redundancy check (CRC) code to detect errors in the header. The packet header is limited to 18 information bits in order to restrict the overhead. The header is further protected by 1/3 rate forward error correction (FEC) coding. Bluetooth defines four control packets:

- The ID or identification packet: Only consists of the access code; used for signaling
- The NULL packet: Only has an access code and a packet header; used if link control information carried by the packet header has to be conveyed
- The POLL packet: Similar to the NULL packet; used by the master to force slaves to return a response
- The FHS packet: An FH-synchronization packet; used to exchange real-time clock and identity information between the units; contains all the information to get two units hop synchronized

The remaining 12 type codes are used to define packets for synchronous and asynchronous services. These 12 types are divided into three segments. Segment 1 specifies packets that fit into a single slot, segment 2 specifies 3-slot packets, and segment 3 specifies 5-slot packets. Multislot packets are sent on a single-hop carrier. The hop carrier which is valid in the first slot is used for the remainder of the packet; therefore, there is no frequency switch in the middle of a packet. After the packet has been sent, the hop carrier as specified by the current master clock value is used (Fig. 4). Note that only an odd number of multislot packets have been defined, which guarantees that the TX/RX timing is maintained.

On the slotted channel, synchronous and asynchronous links have been defined, as will be further explained later. The interpretation of packet type is different for synchronous and asynchronous links. Currently, asynchronous links support payloads with or without a 2/3-rate FEC coding scheme. In addition, on these links single-slot, three-slot, and five-slot packets are available. The maximum user rate that can be obtained over the asynchronous link is 723.2 kb/s. In that case, a return link of 57.6 kb/s can still be supported. Link adaptation can be applied on the asynchronous link by changing the packet length and FEC coding depending on link conditions. The payload length is variable and depends on the available user data. However, the maximum length is limited by the minimum switching time between RX and TX, which is specified at 200 μs. This switching time seems large, but allows the use of open-loop voltage controlled oscillators (VCOs) for direct modulation and provides time for packet processing between RX and TX; this is also discussed later. For synchronous links, only single-slot packets have been defined. The payload length is fixed. Payloads with 1/3-rate FEC, 2/3-rate, or no FEC are supported. The synchronous link supports a full-duplex link with a user rate of 64 kb/s in both directions.

Physical Link Definition

The Bluetooth link supports both synchronous services such as voice traffic, and asynchronous services such as bursty data traffic. Two physical link types have been defined:

- The synchronous connection-oriented (SCO) link
- The asynchronous connectionless (ACL) link

The SCO link is a point-to-point link between the master and a single slave. The link is established by reservation of duplex slots at regular intervals. The ACL link is a point-to-multipoint link between the master and all the slaves on the piconet. The ACL link can use all of the remaining slots on the channel not used for SCO links. The traffic over the ACL link is scheduled by the master. The slotted structure of the piconet channel allows effective mixing of the synchronous and asynchronous links. An example of a channel

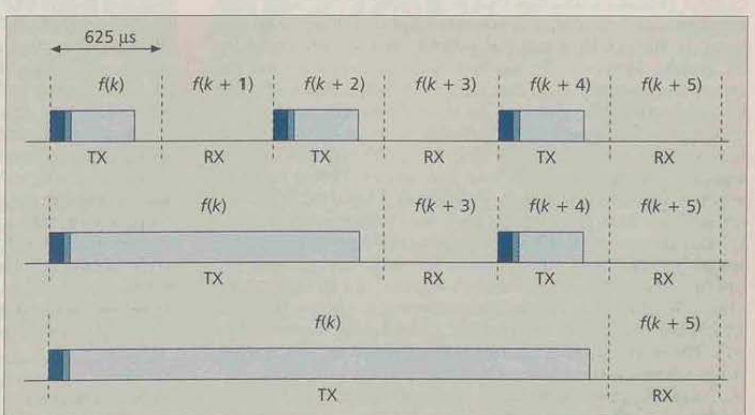


Figure 4. *The frequency and timing characteristics of single-slot, three-slot, and five-slot packets.*

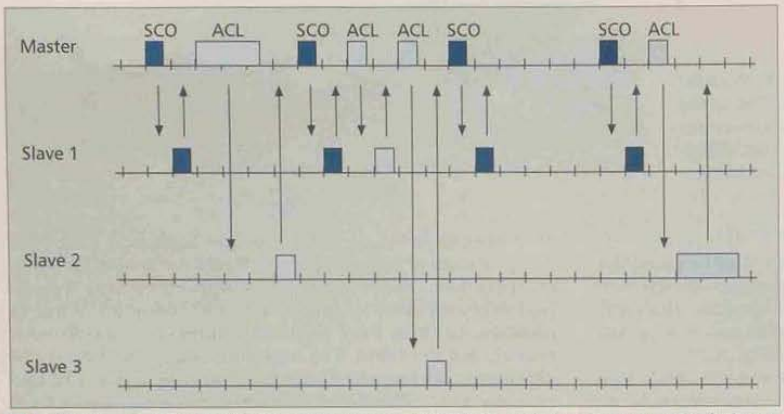


Figure 5. *An example of mixing synchronous SCO links and asynchronous ACL links on a single piconet channel.*

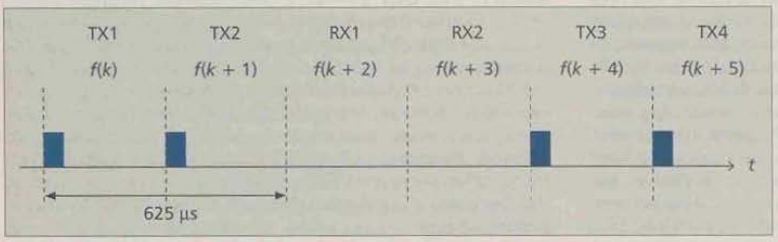


Figure 6. *Frequency and timing behavior for a Bluetooth paging unit.*

with SCO and ACL links is illustrated in Fig. 5. For the SCO link and ACL link, different packet types have been defined.

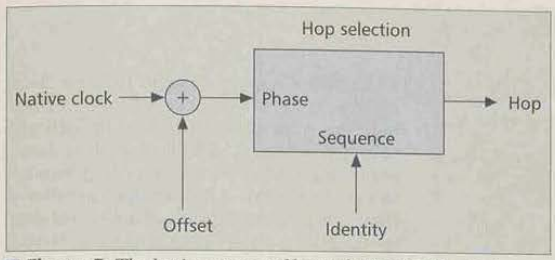
Connection Establishment

A critical design issue in ad hoc radio systems is connection establishment. How do units find each other, and how do they make connections? In Bluetooth, three elements have been defined to support connection establishment: scan, page, and inquiry. A unit in idle mode wants to sleep most of the time to save power. However, in order to allow connections to be made, the unit frequently has to listen whether other units want to connect. In truly ad hoc systems, there is no common control channel a unit can lock to in order to listen for page messages, as is common in conventional (cellular) radio systems. In Bluetooth, a unit periodically wakes up to listen for its identity. However, the explicit identity is not used, but the access code derived from this identity. When a Bluetooth unit wakes up to scan, it opens its sliding correlator which is matched to the access code derived from its own identity. The scan window is a little longer than 10 ms. Every time the unit wakes up, it scans at a different hop carrier. This is required by the regulations, which do not permit a fixed wake-up frequency, and also provides the necessary interference immunity. The Bluetooth wake-up hop sequence is only 32 hops in length and is cyclic. All 32 hops in the wake-up sequence are unique, and they span at least 64 MHz of the 80 MHz available. The sequence is pseudo-random and unique for each Bluetooth device. The sequence is derived from the unit identity. The phase in the sequence is determined by the free-running native clock in the unit. Thus, during idle mode, the native clock is used to schedule wake-up operations. It will be understood that a trade-off has to be made between idle mode power consumption and response time: increasing the sleep time will reduce power consumption, but will prolong the time before an access can be made. The unit that wants to connect has to solve the frequency-time uncertainty: it does not know when the idle unit will wake up and on which frequency. The burden of solving this uncertainty is deliberately placed at the paging unit because this will require power consumption. Since a radio unit will be in idle mode most of the time, the paging unit should take the power burden. We first assume that the paging unit knows the identity of the unit to which it wants to connect. Then it knows the wake-up sequence and can also generate the access code which serves as the page message. The paging unit then transmits the access code repeatedly at different frequencies: every 1.25 ms; the paging unit transmits two access codes and listens twice for a response (Fig. 6).

Consecutive access codes are transmitted on different hops selected from the wake-up sequence. In a 10 ms period 16 different hop carriers are visited, which represent half of the wake-up sequence. The paging unit transmits the access code on these 16 frequencies cyclically for the duration of the sleep period of the idle unit. If the idle unit wakes up in any of these 16 frequencies, it will receive the access code and a connection setup procedure follows. However, since the paging unit does not know the phase the idle unit is using, the idle unit can equally well wake up in any of the 16 remaining frequencies in the 32-hop wake-up sequence. Therefore, if the paging unit does not receive a response from the idle unit after a time corresponding to the sleep time, it will transmit the access code repeatedly on the hop carriers in the remaining half of the sequence.[3] The maximum access delay therefore amounts to twice the sleep time. When the idle unit receives the page message, it notifies the paging unit by returning a message, which again is the access code derived from the idle unit's identity. Thereafter the paging unit transmits an FHS packet which contains all of the pager's information (e.g., identity and clock). This information is then used by both the paging unit and the idle unit to establish a piconet; that is, the paging unit becomes the master using its identity and clock to define the FH channel, and the idle unit becomes the slave.

The above-described paging process assumes that the paging unit has no knowledge at all of the clock in the idle unit. However, if the units have met before, the paging unit will have an estimate of the clock in the idle unit. When units connect, they exchange their clock information, and the time offsets between their free-running native clocks are stored. This offset is only accurate during the connection; when the connection is released, the offset information becomes less reliable due to clock drifts. The reliability of the offsets is inversely proportional to the time elapsed since the last con-

[3] *In determining the hop carriers of the second half of the sequence, the paging unit takes into account that the clock in the idle unit also progresses. The remaining half will therefore have one carrier in common with the first half.*



■ **Figure 7.** *The basic concept of hop selection in Bluetooth.*

nection. However, the paging unit can exploit the offset information to estimate the phase of the idle unit. Suppose the clock estimate of the idle unit in the paging unit is k'. If $f(m)$ is the hop in the wake-up sequence at time m, the paging unit will assume that the idle unit will wake up in $f(k')$. But since in 10 ms it can cover 16 different frequencies, it will also transmit the access code a hop frequencies before and after $f(k')$ or $f(k'-8), f(k'-7), \ldots f(k'), f(k'+1), \ldots f(k'+7)$. As a result, the phase estimate in the paging unit can be off by –8 or +7 while it still covers the wake-up frequency of the unit in idle mode. With a free-running clock accuracy of ±250 ppm, the clock estimate k' is still useful at least 5 hr after the last connection. In this case, the average response time is reduced to half the sleep time.

To establish a connection, the identity of the recipient is required to determine the page message and wake-up sequence. If this information is not known, a unit that desires to make a connection may broadcast an inquiry message that induces recipients to return their address and clock information. With the inquiry procedure, the inquirer can determine which units are in range and what their characteristics are. The inquiry message is again an access code, but derived from a reserved identity (the inquiry address). Idle units also listen to the inquiry message according to a 32-hop inquiry sequence. Units that receive the inquiry message return an FHS packet which includes, among other things, their identity and clock information. For the return of the FHS packet a random backoff mechanism is used to prevent multiple recipients transmitting simultaneously.

During the page and inquiry procedures, 32 hop carriers are used. For pure hopping systems, at least 75 hop carriers must be used. However, during the page and inquiry procedures, only an access code is used for signaling. This access code is used as a direct-sequence code. The processing gain obtained from this direct-sequence code combined with the processing gain obtained from the 32-hop sequence provides sufficient processing gain to satisfy the regulations for hybrid DS/FH systems. Thus, during the page and inquiry procedures the Bluetooth system acts like a hybrid DS/FH system, whereas during the connection it acts as a pure FH system.

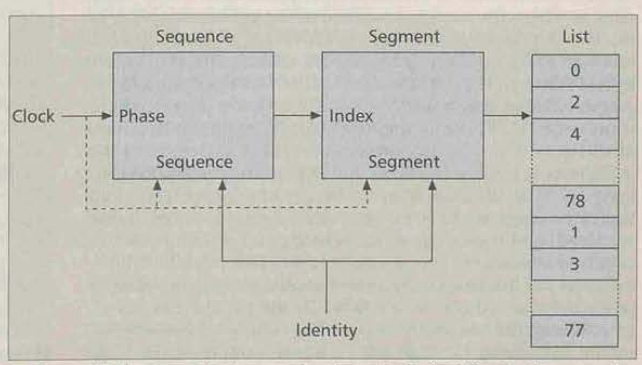
Hop Selection Mechanism

Bluetooth applies a special hop selection mechanism. The hop selection mechanism can be considered a black box with an identity and clock in, and a hop carrier out (Fig. 7). The mechanism satisfies the following requirements:

- The sequence is selected by the unit identity, the phase by the unit clock.
- The sequence cycle covers about 23 hours.
- 32 consecutive hops span about 64 MHz of spectrum.
- On average, all frequencies are visited with equal probability.
- The number of hop sequences is very large.
- By changing the clock and/or identity, the selected hop changes instantaneously.

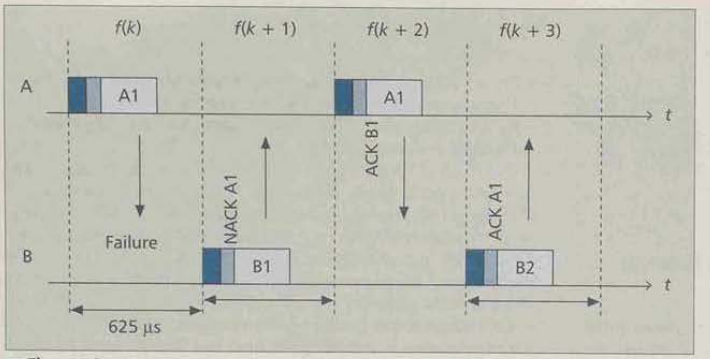
Note that no extra effort has been taken to make the sequences orthogonal. With only 79 hop carriers, the number of orthogonal sequences is rather limited. The first requirement supports the piconet concept where the master unit defines the hop channel by its identity and clock. The second requirement prevents repetitions in the interference pattern when several piconets are collocated. Repetitive interference is detrimental for synchronous services such as voice. The spanning requirement provides maximal interference immunity by spreading as much as possible over a short time interval. Again, this is most important for voice services. It also provides the desired features for the wake-up and inquiry sequences which are 32 hops in length. Over a larger interval, regulations require that all carriers are visited with equal probability. Since many piconets can coexist in the same area, many hop patterns must be available. This excludes the use of prestored sequences: the sequences are generated on the fly by logic circuitry. Finally, the last requirement provides flexibility to run backward and forward in the sequence by running the clock backward or forward, which is attractive in the page and inquiry procedures. In addition, it supports jumping between piconets: a unit can jump from one piconet to another by merely changing the master parameters (i.e., identity and clock). The latter requirement excludes the use of a memory in the algorithm: only combinatorial logic circuitry is used.

The selection mechanism is illustrated in Fig. 8.[4] In the first block, the identity selects a 32-hop subsequence with pseudo-random properties. The least significant part of the clock hops through this sequence according to the slot rate (1600 slots/s). The first block thus provides an index in a 32-hop segment. The segments are mapped on the 79-hop carrier list. The carrier list is constructed in such a fashion that even-numbered hops are listed in the first half of the list, odd-numbered hops in the second half of the list. An arbitrary segment of 32 consecutive list elements spans about 64 MHz. For the paging and inquiry procedures, the mapping of the 32-hop segment on the carrier list is fixed. When the clock runs, the same 32-hop sequence and 32 hop carriers will be used. However, different identities will map to different segments and different sequences, so the wake-up hop sequences of different units are well randomized. During the connection, the more significant part of the clock affects both sequence selection and segment mapping: after 32 hops (one segment) the sequence is altered, and the segment is shifted in the forward



■ **Figure 8.** *The hop selection mechanism; the dashed line for the more significant clock part is used in connection mode only.*

[4] *For 23-hop systems, a corresponding scheme is constructed with 16-hop segments and a 23-hop list.*



■ **Figure 9.** *An example of retransmission operation in Bluetooth.*

direction by half its size (16 hops). Segments, each 32 hops in length, are concatenated, and the random selection of the index changes for each new segment; the segments slide through the carrier list, and on average all carriers are visited with equal probability. Changing the clock and/or identity will directly change the sequence and segment mapping.

Error Correction

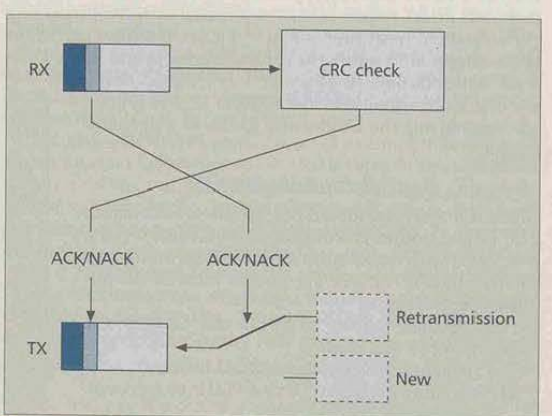
Bluetooth includes both FEC and packet retransmission schemes. For FEC, a 1/3-rate code and a 2/3-rate FEC code are supported. The 1/3-rate code merely uses a 3-bit repeat coding with majority decision at the recipient. With the repeat coding, extra gain is obtained due to the reduction of instantaneous bandwidth. As a result, intersymbol interference (ISI) introduced by the receive filtering is decreased. The 1/3-rate code is used for the packet header, and can additionally be applied on the payload of the synchronous packets on the SCO link. For the 2/3-rate FEC code, a shortened Hamming code is used. Error trapping can be applied for decoding. This code can be applied on both the payload of the synchronous packets on the SCO link and the payload of the asynchronous packets on the ACL link. The applied FEC codes are very simple and fast in encoding and decoding operations, which is a requirement because of the limited processing time between RX and TX. This will be further apparent in the next paragraph.

On the ACL link, an ARQ scheme can be applied. In this scheme, a packet retransmission is carried out if the reception of the packet is not acknowledged. Each payload contains a CRC to check for errors. Several ARQ schemes have been considered like stop-and-wait ARQ, go-back-*N* ARQ, and selective-repeat ARQ [9]. Also, hybrid schemes have been analyzed. However, to minimize complexity, overhead, and wasteful retransmissions, Bluetooth has implemented a fast-ARQ scheme where the sender is notified of the packet reception in the RX slot directly following the TX slot in which the packet was sent (Fig. 9). If the 2/3-rate FEC code is added, a type I hybrid ARQ scheme results. The ACK/NACK information is piggybacked in the packet header of the return packet. There is only the RX/TX switching time for the recipient to determine the correctness of the received packet and creating the ACK/NACK field in the header of the return packet. In addition, the ACK/NACK field in the header of the packet received indicates whether the previously sent payload was correctly received, and thus determines whether a retransmission is required or the next packet can be sent. This process is illustrated in Fig. 10. Due to the short processing time, decoding is preferably carried out on the fly while the packet is received. In addition, the simplicity of the FEC coding schemes speed up the processing. The fast-ARQ scheme is similar to the stop-and-wait ARQ scheme, but the delay has been minimized; in fact, there is no additional delay caused by the ARQ scheme. The scheme is more efficient than go- back-*N*, since only failed packets are retransmitted. This is the same efficiency obtained with selective-repeat ARQ, but with reduced overhead: only a 1-bit sequencing number suffices in the fast-ARQ scheme (in order to filter out packets that are correctly received twice due to an error in the ACK/NACK field).

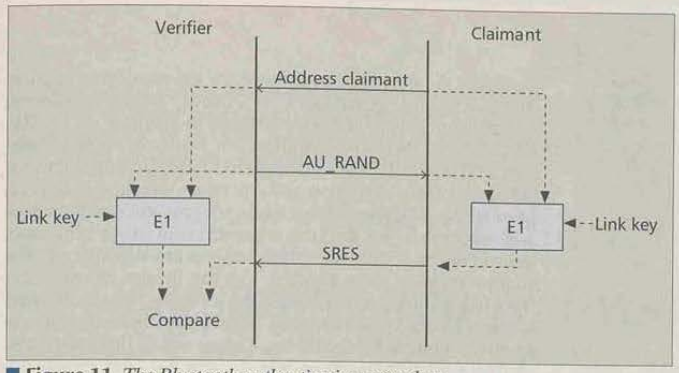
Power Management

In the Bluetooth design, special attention has been paid to reduction of current consumption. In the idle mode, the unit only scans a little over 10 ms every T s where T can range from 1.28 to 3.84 s. Thus, the duty cycle is well below 1 percent. Additionally, a PARK mode has been defined where the duty cycle can be reduced even more. However, the PARK mode can only be applied after the piconet has been established. The slave can then be parked; that is, it only listens to the channel at a very low duty cycle. The slave only has to listen to the access code and the packet header (126 µs excluding guard time to account for drift) to resynchronize its clock and decide whether it can return to sleep. Since there is no uncertainty in time and frequency (the parked slave is locked to the master, similar to how cordless and cellular phones are locked to their base stations), a much lower duty cycle is achievable. Another low-power mode during connection is the SNIFF mode, in which the slave does not scan at every master-to-slave slot, but has a larger interval between scans.

In the connection state, current consumption is minimizedand wasteful interference prevented by only transmitting when data is available. If no useful information needs to be exchanged, no transmission takes place. If only link control information needs to be transferred (e.g., ACK/NACK), a NULL packet without payload is sent. Since NACK is implicit, a NULL packet with NACK does not have to be sent. In longer periods of silence, the master once in a while needs to send a packet on the channel such that all slaves can resynchronize their clocks and compensate for drift. The accuracy of the clocks and the scan window length applied in the slave determines the period of this resynchronization. During continuous TX/RX operations, a unit starts to scan for the access



■ **Figure 10.** *ARQ mechanisms where received ACK/NAK information decides on retransmission and received payload determines transmitted ACK/NAK information.*



■ **Figure 11.** *The Bluetooth authentication procedure.*

code at the beginning of the RX slot. If in a certain window this access code is not found, the unit returns to sleep until the next TX slot (for the master) or RX slot (for the slave). If the access code is received (which means the received signal matches the expected access code), the header is decoded. If the 3-bit slave address does not match the recipient, further reception is stopped. The header indicates what type of packet it is and how long the packet will last; therefore, the nonaddressed recipients can determine how long they can sleep.

The nominal transmit power used by most Bluetooth applications for short-range connectivity is 0 dBm. This both restricts current consumption and keeps interference to other systems to a minimum. However, the Bluetooth radio specifications allow TX power up to 20 dBm. Above 0 dBm, closed-loop received signal strength indication (RSSI)-based power control is mandatory. This power control only compensates for propagation losses and slow fading. In the uncoordinated environment where ad hoc systems operate, interference-based power control is to say the least doubtful, especially since different types of systems with different power characteristics share the same band. Since power control cannot be coordinated among different systems, it cannot be prevented that certain systems always try to overpower their contenders, and the strongest transmitter will prevail.

Security

Although Bluetooth is mainly intended for short-range connectivity between personal devices, some basic security elements are included to prevent unauthorized usage and eavesdropping. At connection establishment, an authentication process is carried out to verify the identities of the units involved. The authentication process uses a conventional challenge-response routine illustrated in Fig. 11. The claimant (right) transmits its claimed 48-bit address to the verifier (left). The verifier returns a challenge in the form of a 128-bit random number (AU_RAND). The AU_RAND, the claimant address, and a 128-bit common secret link key form the inputs to a computational secure hash function *E1* based on SAFER+, which produces a 32-bit signed response (SRES). The SRES produced by the claimant is sent to the verifier, which compares this result with its own SRES. Only if the two calculated SRES numbers are the same will the challenger continue with connection establishment. The authentication can be uni- or bidirectional.

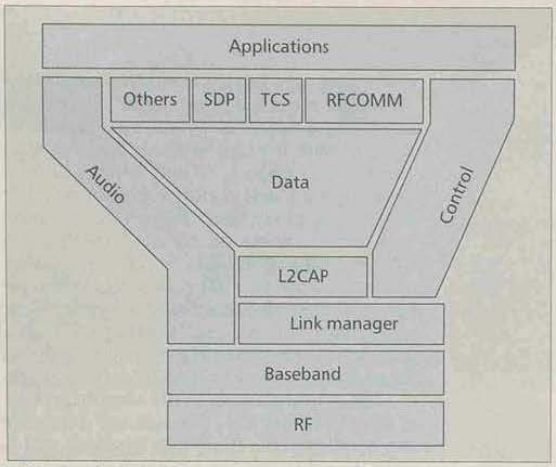
In addition to the 32-bit SRES, the *E1* algorithm produces a 96-bit authenticated cipher offset (ACO). This offset is used in the encryption procedure. To prevent eavesdropping on the link, which is a danger inherent to radio communications even if the intended recipient is only at short range, the payload of each packet is encrypted. Encryption is based on stream-ciphering; the payload bits are modulo-2 added to a binary keystream. The binary keystream is generated by a second hash function *E0* which is based on linear feedback shift registers (LFSRs). When encryption is enabled, the master sends a random number EN_RAND to the slave. Before the transmission of each packet, the LFSR is initialized by a combination of this EN_RAND, the master identity, an encryption key, and the slot number. Since the slot number changes for each new packet, the initialization is new for each packet. The encryption key is derived from the secret link key, the EN_RAND, and the ACO.

The central element in the security process is the 128-bit link key. This link key is a secret key residing in the Bluetooth hardware and is not accessible by the user. The link key is generated during an initialization phase. Two units that want to authenticate each other and establish secure links in the future have to be associated (i.e., provided with the same secret link key). An initialization phase initiated by the user is required to associate two devices. To authorize initialization, the user has to enter an identical PIN in both devices. For devices without a user interface (e.g., headsets), initialization is only possible during a short time window (e.g., after the user has pressed an initialization key). Once the initialization has been carried out, the 128-bit link keys reside in the devices and can from then on be used for automatic authentication without user interaction. In principle, the link key provides an agreement between two units. Thus, to provide security in N units, $N \times (N-1)/2$ link keys are required. Bluetooth provides methods to reduce the number of keys in certain applications. If a single unit is used by many users (e.g., a printer shared by several users), a single key is used by all users for secure communications to this single unit. In addition, methods are available to use the same encryption key for all slaves in a single piconet.

Bluetooth provides a limited number of security elements at the lowest level. More advanced security procedures (e.g., public keys, certificates) can be implemented at higher layers.

Interpiconet Communications

The Bluetooth system has been optimized to have tens of piconets operate in the same area without noticeable performance degradation. Multiple piconets in the same area are referred to as a *scatternet*. Due to the fact that Bluetooth uses packet-based communication over slotted links, it is possible to interconnect different piconets. This means that units can participate in different piconets. However, since the radio can tune to a single hop carrier only, at any instant in time a unit can communicate in one piconet only. However, the unit can jump from one piconet to another by adjusting the piconet channel parameters (i.e., the master identity and master clock). A unit can also change role when jumping from one piconet to another. For example, a unit can be the master in one piconet at one instant in time, and be a slave in a different piconet at another instant in time. A unit can also be a slave in different piconets. However, by definition, a unit cannot be the master in different piconets, since the master parameters specify the piconet FH channel. The hop selection mechanism has been designed to allow for interpiconet communications: by changing the identity and clock input to the selection mechanism, instantaneously a new hop for the new piconet is selected. In order to make jumps between different piconets feasible, guard time has to be included in the traffic scheduling to account for the slot misalignment of different piconets. In Bluetooth, a HOLD mode has been intro-



■ **Figure 12.** *The Bluetooth protocol stack.*

duced to allow a unit to temporary leave one piconet and visit another (HOLD can also be used as an additional low-power mode when no new piconet is visited during the leave). Traffic scheduling and routing in a scatternet with interpiconet communications is a challenge and still a subject for future study.

Bluetooth Standardization

In the beginning of 1998, a Bluetooth Special Interest Group (SIG) was formed to further expand and promote the Bluetooth concept and establish an industry standard. The SIG promoters are formed by leading manufacturers of the mobile communication industry, portable computer industry, and chip integration industry: Ericsson, Nokia, IBM, Toshiba, and Intel. Version 1.0 of the specification was published in July 1999. Over 1000 companies have signed as adopters of the technology. The Bluetooth technology is royalty-free. A special certification program, including logos, is under development to guarantee Bluetooth interoperability.

The specified protocol stack of Bluetooth is shown in Fig. 12. This article has dealt mainly with the three lower layers:

- The RF layer, specifying the radio parameters
- The baseband layer, specifying the lower-level operations at the bit and packet levels (FEC operations, encryption, CRC calculations, ARQ protocol)
- The link manager (LM) layer, specifying connection establishment and release, authentication, connection and release of SCO and ACL channels, traffic scheduling, link supervision, and power management tasks

The Logical Link Control and Adaptation Protocol (L2CAP) layer has been introduced to form an interface between standard data transport protocols and the Bluetooth protocol. It handles multiplexing of higher-layer protocols, and segmentation/reassembly of large packets. The data stream crosses the LM layer, where packet scheduling on the ACL channel takes place. The audio stream is directly mapped on an SCO channel and bypasses the LM layer. The LM layer, though, is involved in the establishment of the SCO link. Between the LM layer and the application, control messages are exchanged in order to configure the Bluetooth transceiver for the considered application. Above the L2CAP layer, RFCOMM, Telephone Control Specification (TCS), and other network protocols (e.g., TCP/IP, PPP, OBEX, Wireless Application Protocol) may reside. RFCOMM and TCS are also specified in Bluetooth and provide serial cable emulation and a cordless telephony protocol, respectively. SDP is a service discovery protocol which enables a Bluetooth unit to find the capabilities of other Bluetooth units in range. It discovers which services are available and the characteristics of these services. This can involve common services like printing, faxing, and so on, as well as more advanced services like teleconferencing, network bridging and access points, e-commerce facilities, and so on. SDP specifically addresses the Bluetooth environment; it does not specify the methods for accessing the service, for which other (non-Bluetooth) protocols can be used.

In addition to protocols which guarantee that two units speak the same language, profiles are defined. Profiles are associated with applications. The profiles specify which protocol elements are mandatory in certain applications. This concept prevents devices with little memory and processing power implementing the entire Bluetooth stack when they only require a small fraction of it. Simple devices like a headset or mouse can thus be implemented with a strongly reduced protocol stack. Profiles are dynamic in the sense that for new applications, new profiles can be added to the Bluetooth specification.

Conclusions

In this article the Bluetooth radio system is presented. The focus is on its capabilities to provide ad hoc radio connectivity. With the restrictions set by regulations, power consumption, lack of coordination, and interference immunity, a robust radio system has evolved which provides a universal wireless interface to a large range of low-cost, portable devices. The article has also described the motivation of the various design choices.

References

[1] M. Mouly and M.-B. Pautet, *The GSM System for Mobile Communications*, 1992.
[2]TIA/EIA/IS-136.2, "800 MHz TDMA Cellular-Radio Interface-Mobile Station-Base Station Compatibility — Traffic Channels and FSK Control Channel," Dec. 1994.
[3] TIA/EIA IS-95B, "Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular Systems," 1998.
[4] IEEE 802.11, "Wireless LAN MAC and Physical Layer Specification," June 1997.
[5] ETSI RES, "High Performance Radio Local Area Network (HIPERLAN) Type 1, Functional Specifications," ETS 300 652, 1996.
[6] ETSI BRAN, "HIPERLAN Type 2, Functional Specifications," preliminary.
[7] ETSI RES, "Digital European Cordless Telecommunications (DECT), Common interface Part 1: Overview," ETS 300 175-1, 1996.
[8] "Personal Handy Phone Standard (PHS)," CRC STD-28, 1993.
[9] S. Lin and D. J. Costello, *Error Control Coding*, Prentice-Hall, 1983.

Biography

JAAP C. HAARTSEN (jaap.haartsen@erh.ericsson.se) joined Ericsson Mobile Communications in 1991 and has since worked at sites in RTP, the United States, and Lund, Sweden in the area of wireless technology. In Sweden he worked on the foundations of the Bluetooth radio concept. Currently, he is located in Emmen, the Netherlands, where he is working with the Bluetooth system for both vcurrent and future applications. Jaap is chair of the Bluetooth air protocol group. He earned M.Sc. and Ph.D. degrees (both with honors) in electrical engineering from Delft University of Technology, the Netherlands. He holds over 25 patents.

Exhibit B1

LIBRARY | CATALOG

Search Navigation < 6 of 52 >

PERIODICAL OR NEWSPAPER

IEEE personal communications : a publication of the IEEE Communications Society ...

Full Record MARC Tags

000		03116cas a2200673 a 4500
001		11440068
005		20180327094841.0
008		930727d19942001nyubr p 0 a0eng c
010	__	|**a** 2008219021 |**z** 94648256 |**z** sn 93002833
022	0_	|**a** 1070-9916 |**l** 1070-9916 |**2** 1
030	__	|**a** IPCME7 |**z** IPECEL
035	__	|**a** (OCoLC)ocm28525286
037	__	|**b** IEEE Service Center, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331
040	__	|**a** NSD |**b** eng |**c** NSD |**d** DLC |**d** WAU |**d** COO |**d** DLC |**d** CAS |**d** EYM |**d** NSD |**d** CAS |**d** NYG |**d** NSD |**d** DLC |**d** UMC |**d** MYG |**d** CUS |**d** MYG |**d** SYS |**d** NYP |**d** NSD |**d** IEEEX |**d** HNK |**d** DLC |**d** OCLCQ |**d** ZCU |**d** NSD |**d** LVB |**d** NSD |**d** DLC |**d** OCLCQ |**d** OCLCF |**d** IUL |**d** OCLCA
042	__	|**a** nsdp |**a** pcc
050	00	|**a** TK6570.M6 |**b** I215
082	00	|**a** 621.3845 |**2** 20
210	0_	|**a** IEEE pers. commun.
222	_0	|**a** IEEE personal communications
245	00	|**a** IEEE personal communications : |**b** a publication of the IEEE Communications Society in cooperation with IEEE Computer and Vehicular Technology Societies.
246	3_	|**a** Institute of Electrical and Electronics Engineers personal communications
246	30	|**a** Personal communications
260	__	|**a** New York, NY : |**b** Institute of Electrical and Electronics Engineers, |**c** c1994-[2001]

300	__	|**a** 8 v. : |**b** ill. ; |**c** 28 cm.
310	__	|**a** Bimonthly, |**b** 1995-2001
321	__	|**a** Quarterly, |**b** 1994
362	0_	|**a** Vol. 1, no. 1 (1st quarter 1994)-v. 8, no. 6 (Dec. 2001).
500	__	|**a** Title from cover.
590	__	|**a** SERBIB/SERLOC merged record
650	_0	|**a** Mobile communication systems |**v** Periodicals.
650	_0	|**a** Wireless communication systems |**v** Periodicals.
650	_0	|**a** Local area networks (Computer networks) |**v** Periodicals.
650	_6	|**a** Télécommunications |**v** Périodiques.
650	_6	|**a** Réseaux d'ordinateurs |**v** Périodiques.
650	_6	|**a** Technologie de l'information |**v** Périodiques.
650	_6	|**a** Nouvelles technologies de l'information et de la communication |**v** Périodiques.
650	_6	|**a** Réseaux d'information |**v** Périodiques.
650	_7	|**a** Local area networks (Computer networks) |**2** fast |**0** (OCoLC)fst01001200
650	_7	|**a** Mobile communication systems. |**2** fast |**0** (OCoLC)fst01024207
650	_7	|**a** Wireless communication systems. |**2** fast |**0** (OCoLC)fst01176209
655	_7	|**a** Periodicals. |**2** fast |**0** (OCoLC)fst01411641
710	2_	|**a** Institute of Electrical and Electronics Engineers.
710	2_	|**a** IEEE Communications Society.
710	2_	|**a** IEEE Computer Society.
710	2_	|**a** Vehicular Technology Society.
776	08	|**i** Online version: |**t** IEEE personal communications (Online) |**x** 1558-0652 |**w** (DLC) 2005212467 |**w** (OCoLC)60638309
785	00	|**t** IEEE wireless communications |**x** 1536-1284 |**w** (DLC) 2001211743 |**w** (OCoLC)47362849
850	__	|**a** CPT |**a** DLC |**a** MdU |**a** MiU |**a** N |**a** NIC |**a** WaU
859	41	|**u** http://ieeexplore.ieee.org/servlet/opac?punumber=98
853	33	|**8** 1 |**a** v. |**i** (year)
863	40	|**8** 1 |**a** <1>- |**i** <1994>- |**x** provisional
890	__	|**a** IEEE personal communications. |**i** 94-648256
906	__	|**a** 7 |**b** cbc |**c** serials |**d** u |**e** ncip |**f** 19 |**g** n-oclcserc
920	__	|**a** Keep 1
955	__	|**a** dg01 2008-03-13 assigned new LCCN
984	__	|**a** srvf
985	__	|**e** eserial 200406
991	__	|**b** c-GenColl |**h** TK6570.M6 |**i** I215 |**w** SERIALS
992	__	|**b** SER |**w** SERLOC

Request this Item | LC Find It

Item Availability

CALL NUMBER	TK6570.M6 I215 Set 1
Request in	Jefferson or Adams Building Reading Rooms
Status	Not Charged
Older receipts	v.1-v.8:no.4 (1994-2001:Aug.), v.8:no.6 (2001:Dec.)

CALL NUMBER	TK6570.M6 I215 Copy 1 Unbound issues
Request in	Newspaper & Current Periodical Reading Room (Madison LM133)

Exhibit B2

LIBRARY OF CONGRESS AUTHORITIES

Library buildings are closed to the public until further notice, but LC Authorities is available. More.

LC control no.: sh2010102188
LCCN Permalink: https://lccn.loc.gov/sh2010102188
HEADING: Mobile communication systems Periodicals

000 00486cz a2200169n 450
001 8165688
005 20110729163623.0
008 100202|| anannbabn |n ana
010 __ |**a** sh2010102188
035 __ |**a** (DLC)453893
035 __ |**a** (DLC)sh2010102188
040 __ |**a** DLC |**b** eng |**c** DLC
150 __ |**a** Mobile communication systems |**v** Periodicals
667 __ |**a** Record generated for validation purposes.
670 __ |**a** Work cat.: IEEE personal communications, c1994-[2001]
906 __ |**t** 8888 |**u** tc00 |**v** 0
953 __ |**a** tc00

◀ Previous Next ▶

Save, Print or Email Records (View Help)

Select Download Format: Text (Labelled Display) Press to SAVE or PRINT

Email Text (Labelled Display) to:
Press to SEND EMAIL

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit B3

LIBRARY OF CONGRESS AUTHORITIES

LC control no.: sh2010118630
LCCN Permalink: https://lccn.loc.gov/sh2010118630
HEADING: Wireless communication systems Periodicals

000 00482cz a2200169n 450
001 8462608
005 20110729164628.0
008 101102|| anannbabn |n ana
010 __ |**a** sh2010118630
035 __ |**a** (DLC)487490
035 __ |**a** (DLC)sh2010118630
040 __ |**a** DLC |**b** eng |**c** DLC
150 __ |**a** Wireless communication systems |**v** Periodicals
667 __ |**a** Record generated for validation purposes.
670 __ |**a** Work cat.: Applied microwave & wireless, c1993-
906 __ |**t** 8888 |**u** tc00 |**v** 0
953 __ |**a** tc00

◀ Previous Next ▶

Save, Print or Email Records (View Help)

Select Download Format: Text (Labelled Display) Press to SAVE or PRINT

Email Text (Labelled Display) to: Press to SEND EMAIL

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit B4

LIBRARY OF CONGRESS AUTHORITIES

LC control no.: sh2009129729
LCCN Permalink: https://lccn.loc.gov/sh2009129729
HEADING: Local area networks (Computer networks) Periodicals

000 00494cz a2200169n 450
001 8126974
005 20110729162937.0
008 091222|| anannbabn |n ana
010 __ |**a** sh2009129729
035 __ |**a** (DLC)448952
035 __ |**a** (DLC)sh2009129729
040 __ |**a** DLC |**b** eng |**c** DLC
150 __ |**a** Local area networks (Computer networks) |**v** Periodicals
667 __ |**a** Record generated for validation purposes.
670 __ |**a** Work cat.: Campus-wide information systems, c1993-
906 __ |**t** 8888 |**u** tc00 |**v** 0
953 __ |**a** tc00

◀ Previous Next ▶

Save, Print or Email Records (View Help)

Select Download Format: Text (Labelled Display) Press to SAVE or PRINT

Email Text (Labelled Display) to: Press to SEND EMAIL

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit B5

OCLC 28525286 **No holdings in XXX - 247 other holdings**

Continuing Resources								**Rec Stat**	c	**Entered**	19930727
								Replaced	20180324184100.9		
Type	a	**ELvl**		**Srce**	c	**GPub**		**Ctrl**		**Lang**	eng
BLvl	s	**Form**		**Conf**	0	**Freq**	b	**MRec**		**Ctry**	nyu
S/L	0	**Orig**		**EntW**		**Regl**	r	**Alph**	a		
Desc	a	**SrTp**	p	**Cont**		**DtSt**	d	**Dates**	1994 ,	2001	

010 2008219021 $z 94648256 $z sn 93002833
040 NSD $b eng $c NSD $d DLC $d WAU $d COO $d DLC $d CAS $d EYM $d NSD $d CAS $d NYG $d NSD $d DLC $d UMC $d MYG $d CUS $d MYG $d SYS $d NYP $d NSD $d IEEEX $d HNK $d DLC $d OCLCQ $d ZCU $d NSD $d LVB $d NSD $d DLC $d OCLCQ $d OCLCF $d IUL $d OCLCA
012 $i 9405 $j 0 $k 1 $l 1 $m d
019 187430021 $a 987026900 $a 1001830882 $a 1013275327 $a 1029225297
022 0 1070-9916 $l 1070-9916 $2 1
030 IPCME7 $z IPECEL
037 $b IEEE Service Center, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331
042 nsdp $a pcc
050 00 TK6570.M6 $b I215
082 00 621.3845 $2 20
090 $b
210 0 IEEE pers. commun.
222 0 IEEE personal communications
245 00 IEEE personal communications : $b a publication of the IEEE Communications Society in cooperation with IEEE Computer and Vehicular Technology Societies.
246 3 Institute of Electrical and Electronics Engineers personal communications
246 30 Personal communications
260 New York, NY : $b Institute of Electrical and Electronics Engineers, $c c1994-[2001]
300 8 v. : $b ill. ; $c 28 cm.
310 Bimonthly, $b 1995-2001
321 Quarterly, $b 1994
362 0 Vol. 1, no. 1 (1st quarter 1994)-v. 8, no. 6 (Dec. 2001).
500 Title from cover.
650 0 Mobile communication systems $v Periodicals.
650 0 Wireless communication systems $v Periodicals.
650 0 Local area networks (Computer networks) $v Periodicals.
650 6 Télécommunications $v Périodiques.
650 6 Réseaux d'ordinateurs $v Périodiques.
650 6 Technologie de l'information $v Périodiques.
650 6 Nouvelles technologies de l'information et de la communication $v Périodiques.
650 6 Réseaux d'information $v Périodiques.
650 7 Local area networks (Computer networks) $2 fast $0 (OCoLC)fst01001200
650 7 Mobile communication systems. $2 fast $0 (OCoLC)fst01024207
650 7 Wireless communication systems. $2 fast $0 (OCoLC)fst01176209
655 7 Periodicals. $2 fast $0 (OCoLC)fst01411641

710 2 Institute of Electrical and Electronics Engineers.
710 2 IEEE Communications Society.
710 2 IEEE Computer Society.
710 2 Vehicular Technology Society.
776 08 $i Online version: $t IEEE personal communications (Online) $x 1558-0652 $w (DLC) 2005212467 $w (OCoLC)60638309
785 00 $t IEEE wireless communications $x 1536-1284 $w (DLC) 2001211743 $w (OCoLC)47362849
850   CPT $a DLC $a MdU $a MiU $a N $a NIC $a WaU
856 41 $u http://ieeexplore.ieee.org/servlet/opac?punumber=98

Exhibit B6

The Bluetooth radio system

Publisher: IEEE

J.C. Haartsen **All Authors**

Abstract:A few years ago it was recognized that the vision of a truly low-cost, low-power radio-based cable replacement was feasible. Such a ubiquitous link would provide the basi... **View more**

Metadata

Abstract:
A few years ago it was recognized that the vision of a truly low-cost, low-power radio-based cable replacement was feasible. Such a ubiquitous link would provide the basis for portable devices to communicate together in an ad hoc fashion by creating personal area networks which have similar advantages to their office environment counterpart, the local area network. Bluetooth/sup TM/ is an effort by a consortium of companies to design a royalty-free technology specification enabling this vision. This article describes the radio system behind the Bluetooth concept. Designing an ad hoc radio system for worldwide usage poses several challenges. The article describes the critical system characteristics and motivates the design choices that have been made.

Published in: IEEE Personal Communications (Volume: 7 , Issue: 1, Feb. 2000)

Page(s): 28 - 36

INSPEC Accession Number: 6523365

Date of Publication: Feb. 2000

DOI: 10.1109/98.824570

ISSN Information: **Publisher:** IEEE

Authors

References

Citations

Keywords

Metrics

Exhibit B7

Resources and Help

Working with Documents

Learn more about working with documents on IEEE *Xplore*.

Contents

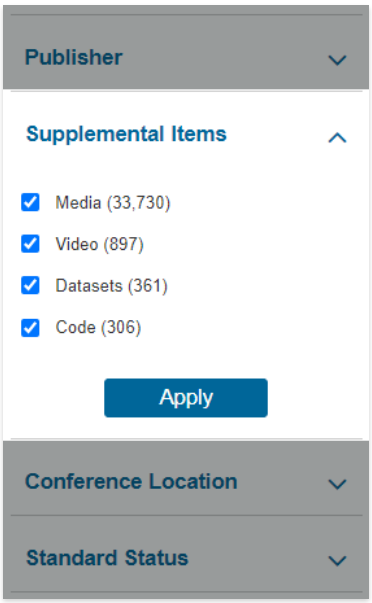
Experiencing Supplemental Items

Some documents in IEEE *Xplore* contain Media, Video, Datasets, and/or Code to illustrate concepts described by the author(s). This helps authors produce information that can be more accessible and reproducible.

Select the applicable Supplemental Items icon when on a search results or table of contents page to view the item on a document page.

If you are on a document page that has Supplemental Items, you will see a clickable tab in the left-hand and bottom navigation accordions.

You can also filter by Supplemental Items on the search results page.



Search all content with Supplemental Items

Here are the four Supplemental Item types in *IEEE* Xplore:

Media

Media assets are available in select content in IEEE *Xplore*. File types vary across documents. PDF and video file open/download behavior can most-often be changed in your browser settings.

Media

Search all content with Media

Video

Video items are embedded in document pages of participating conference proceedings. The video players can be found under the Conference metadata section on document pages.

Video

Search all content with Video

Datasets

Datasets are available outside of IEEE *Xplore* through IEEE DataPort.

Datasets

Search all content with Datasets

Code

Code is available through a Code Ocean embed on document pages that allows anyone with access to view the code. You can edit code by signing in to Code Ocean. You can also edit code in full desktop view by selecting "Open on Code Ocean" in the bottom-left of the embedded capsule on IEEE *Xplore*.

Code

Search all content with Code

Filing Documents in the File Cabinet

Users in participating institutions can file documents in the File Cabinet. To file a document in the File Cabinet, click on any PDF icon or button on any page. You can also select "+ File Cabinet" on search results. If you are eligible for access, you will be asked to continue. By selecting the continue button, the document will be added to the to the File Cabinet and the PDF will open automatically. If the document has already been filed, selecting any PDF icon or button will open the PDF.

For more information on using the File Cabinet, see Browsing File Cabinets.

ORCID Author ID

IEEE *Xplore* uses third-party ORCID ids to connect document authors with their Education, Employment, and Works history. This system ensures that authors are accurately identified by unique accounts that are created and curated by the authors themselves on the ORCID website. Authors who have created ORCID accounts will have an ORCID icon next to their name under the document title and in the Authors tab in IEEE *Xplore*.

ORCID (Open Researcher and Contributor ID) is a nonprofit helping create a world in which all who participate in research, scholarship and innovation are uniquely identified and connected to their contributions and affiliations, across disciplines, borders, and time.

Clicking on the ORCID icon will take you to an author's ORCID profile page on the ORCID website:

Publication Dates

The Date of Publication for Journals and Standards on IEEE *Xplore* represents the very first instance of public dissemination of content. IEEE *Xplore* had previously made distinctions between physical print date, date of

current version, online publication date, etc. This has been simplified with one official date of record.

Conference proceedings have Date of Conference and Date Added to IEEE *Xplore* fields denote when the conference occurred and when the conference proceeding was first published in IEEE *Xplore*.

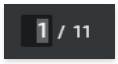
Courses show the month and year of publication. Older courses have a Reaffirmed field that shows that the course has been reevaluated to ensure that the course content is up-to-date and relevant.

Books show the Copyright Year of publication.

Viewing PDF Documents

IEEE *Xplore* uses Adobe Acrobat Reader to present complete full-page images of documents in PDF format. Click on a PDF icon or button to view the full text of the document. If you do not have access, in most cases you can purchase the document individually. Some access requires a subscription.

Here are the basic options for viewing PDFs:

- Zoom in and out using the plus and minus buttons: 
- Go to a specific page using page navigation: 

- Print by selecting the print icon: 
- Download the PDF by selecting the download icon: 

Exhibit C

CDMA Mobile Radio Design

CDMA Mobile Radio Design

John B. Groe
Lawrence E. Larson

Artech House
Boston • London
www.artechhouse.com

Library of Congress Cataloging-in-Publication Data
Groe, John B.
CDMA mobile radio design/John B. Groe, Lawrence E. Larson.
p. cm. — (Artech House mobile communications series)
Includes bibliographical references and index.
ISBN l-58053-059-1 (alk. paper)
1. Code division multiple access. 2. Cellular telephone systems. 3. Mobile communication systems. I. Larson, Lawrence E. II. Tide. III. Series.

TK5 103.452.G76 2000
621.3845-dc21

00-027455
CIP

British Library Cataloguing in Publication Data
Groe, John B.
CDMA mobile radio design. — (Artech House mobile communications series)
1. Cellular radio -- Design 2. Wireless communication systems -Design 3. Code division multiple access
I. Tide II. Larson, Lawrence E.
621.3' 845

ISBN l-58053-059-1

Cover design by Igor Valdman

685 **Canton Street**
Norwood, MA 02062

International Standard Book Number: l-58053-059-1
Library of Congress Catalog Card Number: 00-027455

10 9 8 7 6 5 4 3 2 1

Contents

Exhibit C1

LIBRARY | CATALOG

BOOK

CDMA mobile radio design

Full Record MARC Tags

000		01175cam a22003134a 4500
001		11922319
005		20160502093822.0
008		000225s2000 maua b 001 0 eng
906	__	|**a** 7 |**b** cbc |**c** orignew |**d** 1 |**e** ocip |**f** 20 |**g** y-gencatlg
925	0_	|**a** acquire |**b** 1 shelf copy |**x** policy default
925	1_	|**a** acquire |**b** 2 shelf copies |**x** policy default
955	__	|**a** to ASCD pb04 02-25-00; jf02 02-29-00; jf08 03-01-00 to SL; jf12 to Dewey 03-03-00; aa07 03-06-00; CIP ver. jf03 07-31-00; jf12 to BCCD 08-02-00
010	__	|**a** 00027455
020	__	|**a** 1580530591 (alk. paper)
040	__	|**a** DLC |**c** DLC |**d** DLC
042	__	|**a** pcc
050	00	|**a** TK5103.452. |**b** G76 2000
082	00	|**a** 621.3845 |**2** 21
100	1_	|**a** Groe, John B.
245	10	|**a** CDMA mobile radio design / |**c** John B. Groe, Lawrence E. Larson.
260	__	|**a** Boston : |**b** Artech House, |**c** c2000.
300	__	|**a** xv, 346 p. : |**b** ill. ; |**c** 23 cm.
490	1_	|**a** Mobile communications series
504	__	|**a** Includes bibliographical references and index.
650	_0	|**a** Code division multiple access.
650	_0	|**a** Cell phone systems.
650	_0	|**a** Mobile communication systems.

700 1_ |**a** Larson, Lawrence E.

830 _0 |**a** Artech House mobile communications series.

Request this Item | LC Find It

Item Availability

CALL NUMBER	TK5103.452 .G76 2000 CABIN BRANCH Copy 1
Request in	Jefferson or Adams Building Reading Rooms - STORED OFFSITE
Status	Not Charged

Exhibit C2

OCLC 43456966 **No holdings in XXX - 194 other holdings**

Books

Rec Stat		**Entered**	20002025	**Replaced**	20200728152956.5						
Type	a	**ELvl**	4	**Srce**		**Audn**		**Ctrl**		**Lang**	eng
BLvl	m	**Form**		**Conf**	0	**Biog**		**MRec**		**Ctry**	mau
		Cont	b	**GPub**		**LitF**	0	**Indx**	1		
Desc	a	**Ills**	a	**Fest**	0	**DtSt**	s	**Dates**	2000 ,		

010 00027455
040 DLC $b eng $c DLC $d UKM $d C#P $d GZM $d BTCTA $d YDXCP $d BAKER $d IG# $d DEBBG $d UKMGB $d ILU $d BDX $d OCLCF $d OCLCQ $d OCLCO $d CPO $d OCLCQ $d BGU $d OCLCQ $d OCLCA
015 GBA0Z2636 $2 bnb
016 7 009160718 $2 Uk
016 7 010757184 $2 Uk
019 49239048 $a 1022616251 $a 1173302243
020 1580530591 $q (alk. paper)
020 9781580530590 $q (alk. paper)
042 pcc
050 00 TK5103.452 $b G76 2000
082 00 621.3845 $2 21
090 $b
100 1 Groe, John B.
245 10 CDMA mobile radio design / $c John B. Groe, Lawrence E. Larson.
260 Boston : $b Artech House, $c ©2000.
300 xv, 346 pages : $b illustrations ; $c 23 cm.
336 text $b txt $2 rdacontent
337 unmediated $b n $2 rdamedia
338 volume $b nc $2 rdacarrier
490 1 Mobile communications series
504 Includes bibliographical references and index.
505 00 $g 1. $t Introduction to Wireless Communications -- $g 2. $t The CDMA Concept -- $g 3. $t The Digital System -- $g 4. $t Speech Coding -- $g 5. $t Digital Modem -- $g 6. $t Data Converters -- $g 7. $t RF System Fundamentals -- $g 8. $t RF Transmitter Circuits -- $g 9. $t RF Receiver Circuits -- $g 10. $t Next-Generation CDMA -- $g 11. $t Advanced CDMA Mobile Radios.
650 0 Code division multiple access.
650 0 Cell phone systems.
650 0 Mobile communication systems.
650 7 Cell phone systems. $2 fast $0 (OCoLC)fst01734555
650 7 Code division multiple access. $2 fast $0 (OCoLC)fst00866205
650 7 Mobile communication systems. $2 fast $0 (OCoLC)fst01024207
650 7 CDMA $2 gnd $0 (DE-588)4358900-5
650 7 Mobilfunk $2 gnd $0 (DE-588)4170280-3
650 07 CDMA. $2 swd
700 1 Larson, Lawrence E.

830 0 Artech House mobile communications series.

Exhibit C3

LC control no.: sh 93009277

LCCN Permalink: https://lccn.loc.gov/sh93009277

HEADING: Code division multiple access

000 01171cz a2200301n 450

001 4855692

005 20130906055942.0

008 931203i| anannbabn |a ana c

010 __ |**a** sh 93009277

035 __ |**a** (DLC)sh 93009277

035 __ |**a** (DLC)8111588

035 __ |**a** (DLC)sp 93009277

035 __ |**a** (DLC)447528

040 __ |**a** ViBlbV |**c** DLC |**d** DLC

053 _0 |**a** TK5103.452

150 __ |**a** Code division multiple access

450 __ |**a** CDMA (Telecommunication)

450 __ |**a** Spread spectrum multiple access

550 __ |**w** g |**a** Cell phone systems

550 __ |**w** g |**a** Multiplexing

550 __ |**w** g |**a** Spread spectrum communications

670 __ |**a** Work cat.: Li, Y. Bit error rate simulation of a CDMA system for personal communications, 1993.

670 __ |**a** Elect. engr. handbk., 1993: |**b** p. 1552-53 (CDMA; code division multiple access; CDMA sytem; CDMA scheme)

670 __ |**a** McGraw-Hill encyc. sci. tech.: |**b** v. 11, p. 481 (code-division multiple access; CDMA; spread-spectrum multiple access) v. 17, p. 281 (Code division multiple access; CDMA; CDMA systems)

906 __ |**t** 0951 |**u** tc03 |**v** 0

910 __ |**a** Proposal saved by tc03 on 06/18/2013 at 11:35:31

953 __ |**a** yz00 |**b** xh12

906 __ |**t** 1308 |**v** 0

◀ Previous Next ▶

Save, Print or Email Records (View Help)

Select Download Format: Text (Labelled Display) Press to SAVE or PRINT

Email Text (Labelled Display) to:
Press to SEND EMAIL

Help - Search - Search History - Headings List - Start Over

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit C4

LC control no.: sh 98004793

LCCN Permalink: https://lccn.loc.gov/sh98004793

HEADING: Cell phone systems

000 01777cz a2200409n 450
001 4895284
005 20120402075233.0
008 980731i| anannbabn |a ana
010 __ |**a** sh 98004793
035 __ |**a** (DLC)sh 98004793
035 __ |**a** (DLC)5937841
035 __ |**a** (DLC)sp 98004793
035 __ |**a** (DLC)299621
035 __ |**a** (DLC)6764973
035 __ |**a** (DLC)338893
035 __ |**a** (DLC)8111591
035 __ |**a** (DLC)447529
040 __ |**a** DLC |**c** DLC |**d** DLC |**d** ViU |**d** DLC
150 __ |**a** Cell phone systems
450 __ |**w** nne |**a** Cellular radio
450 __ |**a** Cellular radiotelephone systems
450 __ |**a** Cellular systems (Telecommunication)
450 __ |**w** nne |**a** Cellular telephone systems
450 __ |**a** Mobile telephony
450 __ |**a** Wireless telephone systems (Cell phone)
550 __ |**w** g |**a** Mobile communication systems
550 __ |**w** g |**a** Telephone systems
670 __ |**a** Work cat.: 98033856: IS-136 TDMA technology, economics, and services, 1998: |**b** CIP introd. (public cellular mobile radio; cellular systems)
670 __ |**a** ASTI on FirstSearch, July 31, 1998 |**b** (subject term: Cellular radiotelephone)
670 __ |**a** INSPEC on FirstSearch, July 31, 1998 |**b** (descriptor: Cellular radio)
670 __ |**a** Leclair, M.G. Wireless technology, c1998 |**b** (Cellular radio; Cellular System; Cellular telephone)
670 __ |**a** Weik, M.H. Communications standard dictionary, 1996 |**b** (Cellular telephone)
670 __ |**a** Held, G. Dict. of communications technology, 1995 |**b** (Cellular radio

communications; Cellular telephone technology)

670 __ |**a** Mobile communications: re-negotiation of the social sphere, c2005: |**b** p. viii (adoption and use of mobile telephony is being studied by a broad selection of disciplines)

906 __ |**t** 0951 |**u** tc03 |**v** 0

952 __ |**a** 330 bib. records to be changed

953 __ |**a** jg12 |**b** td13

◀ Previous Next ▶

Save, Print or Email Records (View Help)

Select Download Format: Text (Labelled Display) Press to SAVE or PRINT

Email Text (Labelled Display) to: Press to SEND EMAIL

Help - Search - Search History - Headings List - Start Over

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit C5

The Library of Congress

>> Go to Library of Congress Online Catalog

LIBRARY OF CONGRESS AUTHORITIES

Library buildings are closed to the public until further notice, but LC Authorities is available. More.

Help | New Search | Search History | Headings List | Start Over

◀ Previous Next ▶

MARC Display | Labelled Display

LC control no.: sh 85086371
LCCN Permalink: https://lccn.loc.gov/sh85086371
HEADING: Mobile communication systems

000 00558cz a2200205n 450
001 4736746
005 20120327094050.0
008 860211i| anannbabn |a ana
010 __ |**a** sh 85086371
035 __ |**a** (DLC)sh 85086371
035 __ |**a** (DLC)83431
040 __ |**a** DLC |**c** DLC |**d** DLC
053 _0 |**a** TK5103.2 |**b** TK5103.4885
150 __ |**a** Mobile communication systems
450 __ |**a** Vehicles |**x** Communication systems
450 __ |**a** Vehicular communication systems
550 __ |**w** g |**a** Radio
550 __ |**w** g |**a** Wireless communication systems
906 __ |**t** 9604 |**u** te03 |**v** 1
953 __ |**a** xx00 |**b** td04

◀ Previous Next ▶

Save, Print or Email Records (View Help)

Select Download Format: Text (Labelled Display) Press to SAVE or PRINT

Email Text (Labelled Display) to: Press to SEND EMAIL

Help - Search - Search History - Headings List - Start Over

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Washington, DC 20540

Questions, comments, error reports: Contact Us

Exhibit C6

Copyright United States Copyright Office

Library buildings are closed to the public until further notice, but the U.S. Copyright Office Catalog is available. More.

Help | Search | History | Titles | Start Over

Public Catalog

Copyright Catalog (1978 to present)
Search Request: Left Anchored Name = groe, john b
Search Results: Displaying 1 of 1 entries

previous next

Labeled View

CDMA mobile radio design / John B. Groe, Lawrence E. Larson.

Type of Work: Text
Registration Number / Date: TX0005229534 / 2000-06-15
Title: CDMA mobile radio design / John B. Groe, Lawrence E. Larson.
Imprint: Boston : Artech House, c2000.
Description: 346 p.
Series: Mobile communications series
Copyright Claimant: Artech House, Inc.
Date of Creation: 1999
Date of Publication: 2000-05-31
Names: Groe, John B.
Larson, Lawrence E.
Artech House, Inc.

previous next

Save, Print and Email (Help Page)	
Select Download Format	Full Record ▾ Format for Print/Save
Enter your email address:	Email

Help Search History Titles Start Over

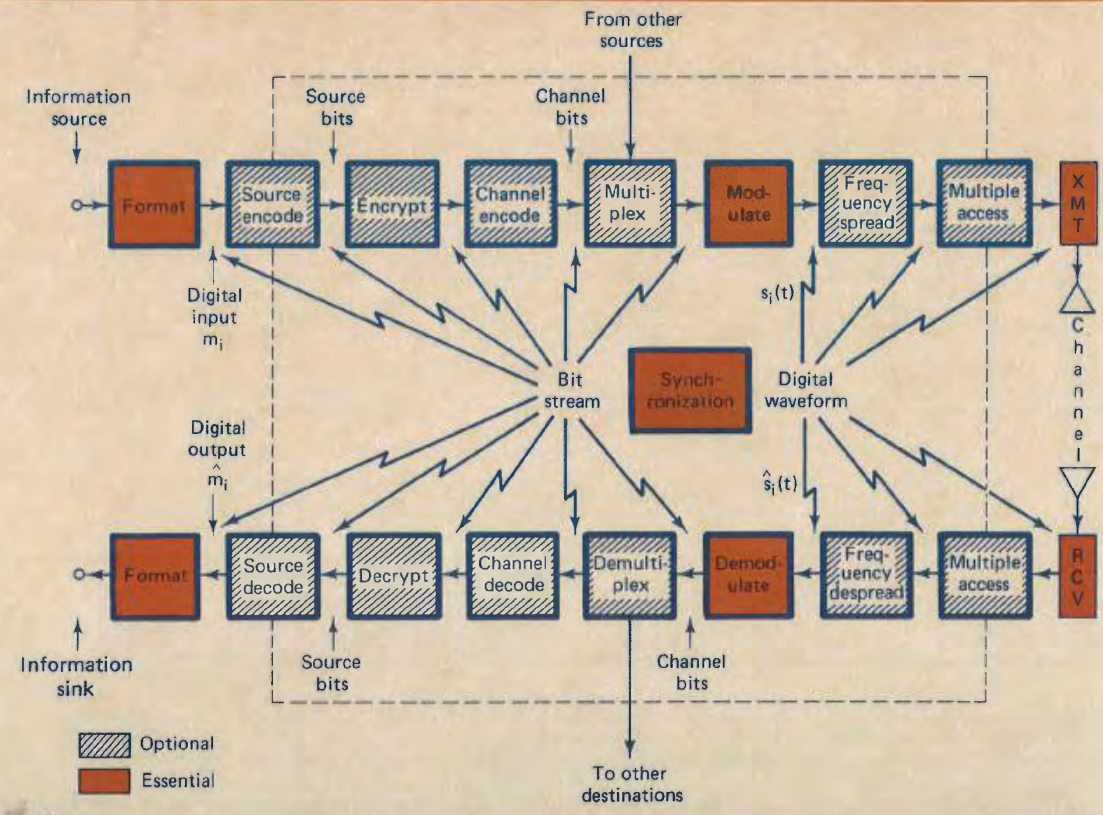
Contact Us | Request Copies | Get a Search Estimate | Frequently Asked Questions (FAQs) about Copyright | Copyright Office Home Page | Library of Congress Home Page

Exhibit D

BERNARD SKLAR

DIGITAL COMMUNICATIONS

Fundamentals and Applications



DIGITAL COMMUNICATIONS

Fundamentals and Applications

BERNARD SKLAR

The Aerospace Corporation, El Segundo, California
and
University of California, Los Angeles

P T-R Prentice Hall
Englewood Cliffs, New Jersey 07632

Library of Congress Cataloging-in-Publication Data

SKLAR, BERNARD (date)
Digital communications.

Bibliography: p.
Includes index.
1. Digital communications. I. Title.
TK5103.7.S55 1988 621.38'0413 87-1316
ISBN 0-13-211939-0

Editorial/production supervision and
interior design: Reynold Rieger
Cover design: Wanda Lubelska Design
Manufacturing buyers: Gordon Osbourne and Paula Benevento

Printed in the United States of America

20 19 18 17 16

ISBN 0-13-211939-0

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall Canada Inc., *Toronto*
Prentice-Hall Hispanoamericana, S.A., *Mexico*
Prentice-Hall of India Private Limited, *New Delhi*
Prentice-Hall of Japan, Inc., *Tokyo*
Simon & Schuster Asia Pte. Ltd., *Singapore*
Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

Contents

51

3 BANDPASS MODULATION AND DEMODULATION 117

595

Exhibit D1

LIBRARY | CATALOG

BOOK

Digital communications : fundamentals and applications

Full Record MARC Tags

000		00843pam a2200241 a 4500
001		3366238
005		20160502080503.0
008		870326s1988 njua b 001 0 eng
906	__	|**a** 7 |**b** cbc |**c** orignew |**d** 1 |**e** ocip |**f** 19 |**g** y-gencatlg
925	0_	|**a** acquire |**b** 1 shelf copy |**x** policy default
010	__	|**a** 87001316
020	__	|**a** 0132119390 : |**c** $53.33
035	__	|**9** (DLC) 87001316
040	__	|**a** DLC |**c** DLC |**d** DLC
050	00	|**a** TK5103.7 |**b** .S55 1988
082	00	|**a** 621.38/0413 |**2** 19
100	1_	|**a** Sklar, Bernard, |**d** 1927-
245	10	|**a** Digital communications : |**b** fundamentals and applications / |**c** Bernard Sklar.
260	__	|**a** Englewood Cliffs, N.J. : |**b** Prentice-Hall, |**c** c1988.
300	__	|**a** xxiv, 776 p. : |**b** ill. ; |**c** 24 cm.
504	__	|**a** Includes bibliographies and index.
650	_0	|**a** Digital communications.
991	__	|**b** c-GenColl |**h** TK5103.7 |**i** .S55 1988 |**p** 00004336124 |**t** Copy 1 |**w** BOOKS

Request this Item LC Find It

Item Availability

CALL NUMBER	TK5103.7 .S55 1988 CABIN BRANCH Copy 1
Request in	Jefferson or Adams Building Reading Rooms - STORED OFFSITE
Status	Not Charged

Exhibit D2

OCLC 15518063 **No holdings in XXX - 348 other holdings**

Books

Rec Stat		**Entered**	19870326	**Replaced**	20200908220324.2								
Type	a	**ELvl**		**Srce**		**Audn**		**Ctrl**		**Lang**	eng		
BLvl	m	**Form**		**Conf**	0	**Biog**		**MRec**		**Ctry**	nju		
		Cont	b	**GPub**		**LitF**	0	**Indx**	1				
Desc	a	**Ills**	a	**Fest**	0	**DtSt**	s	**Dates**	1988 ,				

010 87001316
040 DLC $b eng $c DLC $d BTCTA $d LVB $d YDXCP $d AU@ $d DEBBG $d GBVCP $d OCLCF $d FCC $d OCLCQ $d OCLCO $d DHA $d APUMS $d OCLCQ $d CNO $d OCLCQ $d DCHUA $d UKUOY $d UKBTH
015 GB8847280 $2 bnb
019 1191363259
020 0132119390
020 9780132119399
020 013212713X
020 9780132127134
050 00 TK5103.7 $b .S55 1988
080 0 688.2
082 00 621.38/0413 $2 19
084 53.71 $2 bcl
084 53.73 $2 bcl
084 *94-01 $2 msc
084 94A05 $2 msc
084 ZN 6040 $2 rvk
084 ZN 6120 $2 rvk
084 ELT 517f $2 stub
090 $b
100 1 Sklar, Bernard, $d 1927-
245 10 Digital communications : $b fundamentals and applications / $c Bernard Sklar.
260 Englewood Cliffs, N.J. : $b Prentice-Hall, $c ©1988.
300 xxiv, 776 pages : $b illustrations ; $c 24 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.
505 0 Signals and spectra -- Formatting and baseband transmission -- Bandpass modulation and demodulation -- Communications link analysis -- Channel coding: Part 1 -- Channel coding: Part 2 -- Modulation and coding trade-offs -- Synchronization -- Multiplexing and multiple access -- Spread-spectrum techniques -- Source coding -- Encryption and decryption -- A review of fourier techniques -- Fundamentals of statistical decision theory.
583 1 Legacy $c 2018 $5 UoY
650 0 Digital communications.
650 6 Transmission numérique.

650 7 Digital communications. $2 fast $0 (OCoLC)fst00893634
650 7 Digitale Nachrichtentechnik $2 gnd $0 (DE-588)4224275-7
650 7 Digitale Signalverarbeitung $2 gnd $0 (DE-588)4113314-6
650 07 Digitale Nachrichtentechnik. $2 swd
650 07 Digitale Signalverarbeitung. $2 swd
653 0 11030 $a communication $a digital
653 0 Digital communications
776 08 $i Online version: $a Sklar, Bernard, 1927- $t Digital communications. $d Englewood Cliffs, N.J. : Prentice-Hall, ©1988 $w (OCoLC)742270986
856 41 $3 Table of contents $u http://www.gbv.de/dms/bowker/toc/9780132119399.pdf
856 42 $3 Inhaltstext $u http://www.zentralblatt-math.org/zmath/en/search/?an=0717.94002

Exhibit D3

The Library of Congress

>> Go to Library of Congress Online Catalog

LIBRARY OF CONGRESS AUTHORITIES

Library buildings are closed to the public until further notice, but LC Authorities is available. More.

Help | New Search | Search History | Headings List | Start Over

◀ Previous Next ▶

MARC Display | Labelled Display

LC control no.: sh 85037972
LCCN Permalink: https://lccn.loc.gov/sh85037972
HEADING: Digital communications

000 00785cz a2200277n 450
001 4690005
005 20120323072233.0
008 860211i| anannbabn |b ana
010 __ |**a** sh 85037972
035 __ |**a** (DLC)sh 85037972
035 __ |**a** (DLC)36690
040 __ |**a** DLC |**c** DLC |**d** DLC
053 _0 |**a** TK5103.7 |**b** TK5103.75
150 __ |**a** Digital communications
450 __ |**a** Communications, Digital
450 __ |**a** Digital transmission
450 __ |**a** Pulse communication
550 __ |**w** g |**a** Digital electronics
550 __ |**w** g |**a** Pulse techniques (Electronics)
550 __ |**w** g |**a** Telecommunication
550 __ |**a** Digital media
550 __ |**a** Signal processing |**x** Digital techniques
670 __ |**a** UMI business vocab. |**b** (Digital transmission)
906 __ |**t** 9843 |**u** te07 |**v** 1
952 __ |**a** LC-BRF
953 __ |**a** xx00 |**b** ta25

◀ Previous Next ▶

Save, Print or Email Records (View Help)

Select Download Format: Text (Labelled Display) Press to SAVE or PRINT

Email Text (Labelled Display) to:
Press to SEND EMAIL

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit D4

Copyright United States Copyright Office

Library buildings are closed to the public until further notice, but the U.S. Copyright Office Catalog is available. More.

Help | Search | History | Titles | Start Over

Public Catalog

Copyright Catalog (1978 to present)
Search Request: Left Anchored Name = sklar, bernard
Search Results: Displaying 2 of 2 entries

previous next

Labeled View

Digital communications : fundamentals and applications / Bernard Sklar.

Type of Work: Text
Registration Number / Date: TXu000295229 / 1987-09-08
Title: Digital communications : fundamentals and applications / Bernard Sklar.
Description: 776 p.
Copyright Claimant: Prentice-Hall, Inc., a division of Simon and Schuster
Date of Creation: 1986
Variant title: Digital communications : fundamentals and applications
Names: Sklar, Bernard, 1927-
Simon and Schuster. Prentice-Hall, Inc.

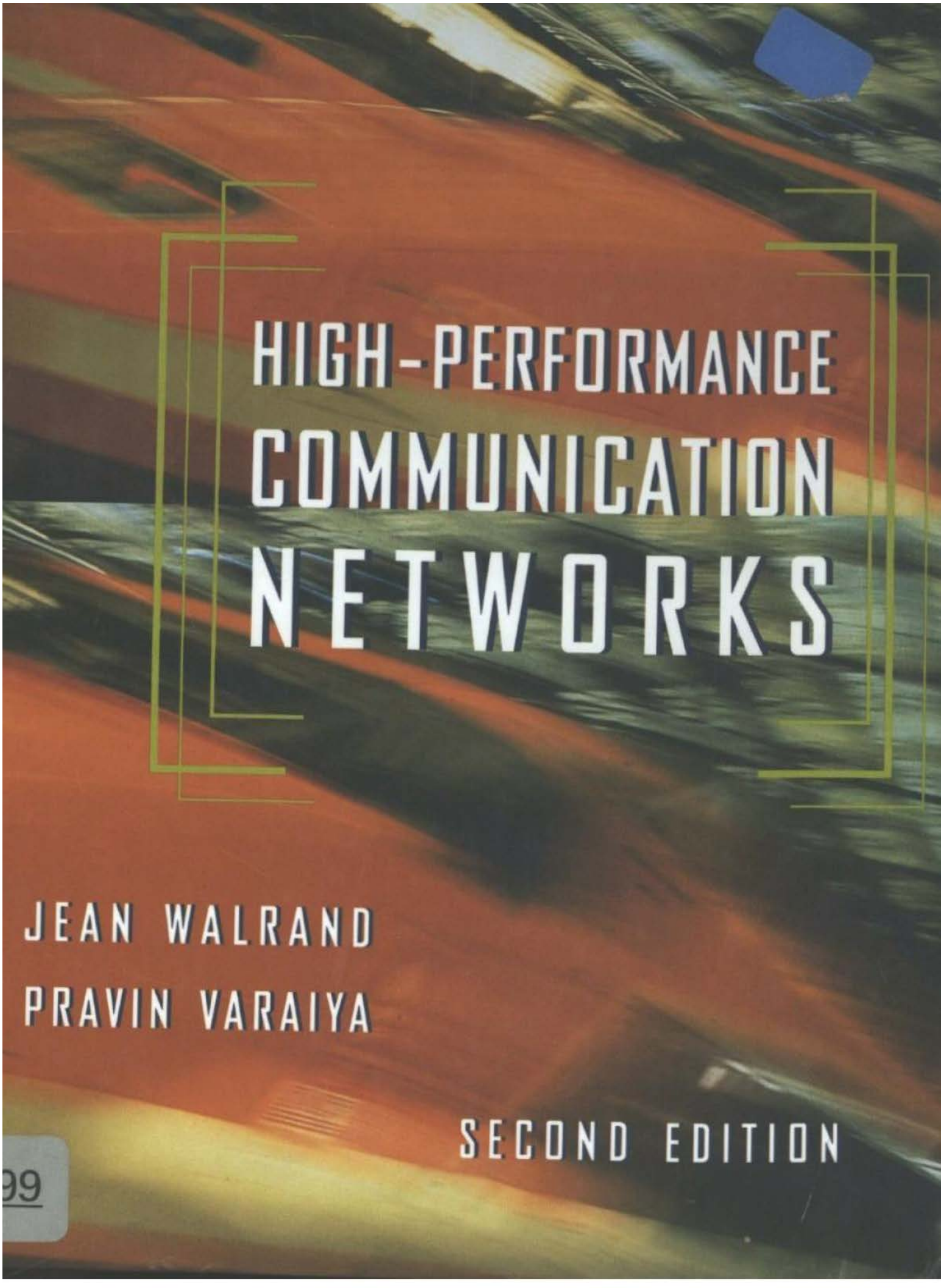
previous next

Save, Print and Email (Help Page)
Select Download Format Full Record Format for Print/Save
Enter your email address: Email

Help Search History Titles Start Over

Contact Us | Request Copies | Get a Search Estimate | Frequently Asked Questions (FAQs) about Copyright | Copyright Office Home Page | Library of Congress Home Page

Exhibit E



High-Performance Communication Networks

SECOND EDITION

The Morgan Kaufmann Series in Networking
Series Editor, David Clark

High-Performance Communication Networks, 2e
Jean Walrand and Pravin Varaiya

Computer Networks: A Systems Approach, 2e
Larry Peterson and Bruce Davie

Internetworking Multimedia
Jon Crowcroft, Mark Handley, Ian Wakeman

Understanding Networked Applications: A First Course
David G. Messerschmitt

Integrated Management of Networked Systems: Concepts, Architectures, and their Operational Application
Heinz-Gerd Hegering, Sebastian Abeck, and Bernhard Neumair

Virtual Private Networks: Making the Right Connection
Dennis Fowler

Networked Applications: A Guide to the New Computing Infrastructure
David G. Messerschmitt

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

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

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

Optical Networks: A Practical Perspective
Rajiv Ramaswami and Kumar Sivarajan

Practical Computer Network Analysis and Design
James D. McCabe

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

For a list of forthcoming titles, please visit our website at
http://www.mkp.com/publish/mann/networking.htm

High-Performance Communication Networks

SECOND EDITION

Jean Walrand
Pravin Varaiya
University of California,
Berkeley

Morgan Kaufmann Publishers
San Francisco, California

Sponsoring Editor Jennifer Mann
Director of Production and Manufacturing Yonie Overton
Production Editor Heather Collins
Editorial Assistant Karyn Johnson
Cover Design Ross Carron Design
Text Design, Composition, and Illustrations Windfall Software
Copyeditor Carol Leyba
Proofreader Erin Milnes
Indexer Ted Laux
Printer Courier Corporation
Cover credit: © Lockyer, Romilly/The Image Bank

Morgan Kaufmann Publishers
Editorial and Sales Office
340 Pine Street, Sixth Floor
San Francisco, CA 94104-3205
USA
Telephone 415 / 392-2665
Facsimile 415 / 982-2665
E-mail mkp@mkp.com
Web site *http://www.mkp.com*

03 02 01 00 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Walrand, Jean.
High-performance communication networks / Jean Walrand, Pravin Varaiya.
—2nd ed.
p. cm.—(The Morgan Kaufmann series in networking)
Includes bibliographical references.
ISBN 1-55860-574-6
1. Computer networks. 2. Multimedia systems. 3. High performance computing.
4. Asynchronous transfer mode. 5. Wireless communications systems. I. Varaiya, P.P. (Pravin Pratap) II. Title. III. Series.
TK5105.5 .W353 2000
621.382'1–dc21 99-047341
CIP

We dedicate this book

to *Annie* and *Isabelle* and *Julie,*

and to *Ruth* 

Contents

Exhibit E1

EXPLORE THE BRITISH LIBRARY

Item Details

FMT	BK
LDR	cam a22003613u 4500
001	008497335
008	000104s1999 xxu ||b 001 ||eng |
020	|a 1558605746
020	|c CIP entry
040	|a DLC |c DLC |d Uk
05000	|a TK5105.5
08204	|a 621.382/1 |2 21
1001	|a Walrand, Jean.
24510	|a High-performance communication networks / |c Jean Walrand, Pravin Varaiya.
250	|a 2nd ed.
260	|a San Francisco : |b Morgan Kaufmann, |c 2000.
300	|a p. cm.
336	|a text |2 rdacontent
337	|a unmediated |2 rdamedia
338	|a volume |2 rdacarrier
4900	|a The Morgan Kaufmann series in networking
504	|a Includes bibliographical references.
650 0	|a Computer networks.
650 0	|a Multimedia systems.
650 0	|a High performance computing.
650 0	|a Asynchronous transfer mode.
650 0	|a Wireless communication systems.
7001	|a Varaiya, P.P |q (Pravin Pratap)
85241	|a British Library |b DSC |j 99/42515
SYS	008497335

Exhibit E2

LIBRARY | CATALOG

BOOK

High-performance communication networks

Full Record MARC Tags

000		01523cam a2200349 a 4500
001		11783143
005		20160502092424.0
008		990830s2000 cau b 001 0 eng
906	__	|**a** 7 |**b** cbc |**c** orignew |**d** 1 |**e** ocip |**f** 19 |**g** y-gencatlg
925	0_	|**a** acquire |**b** 1 shelf copy |**x** policy default
925	1_	|**a** acquire |**b** 2 shelf copies |**x** policy default
955	__	|**a** to ASCD pc01 08-30-99;jf05; jf08 09-09-99 to SL; jf25 to Dewey 09-14-99; aa07 09-17-99; bk rec'd, to CIP ver. ps02 12-07-99; bk rec'd, to CIP ver. ps02 12-07-99; CIP ver. yj05 01-08-00; yj12 to BCCD 01-11-00; copy 2 added jf16 to BCCD 03-15-00
010	__	|**a** 99047341
020	__	|**a** 1558605746
040	__	|**a** DLC |**c** DLC |**d** DLC
050	00	|**a** TK5105.5 |**b** .W353 2000
082	00	|**a** 621.382/1 |**2** 21
100	1_	|**a** Walrand, Jean.
245	10	|**a** High-performance communication networks / |**c** Jean Walrand, Pravin Varaiya.
250	__	|**a** 2nd ed.
260	__	|**a** San Francisco : |**b** Morgan Kaufmann, |**c** c2000.
300	__	|**a** xxii, 693 p. ; |**c** 25 cm.
440	_4	|**a** The Morgan Kaufmann series in networking
504	__	|**a** Includes bibliographical references (p. [646]-653) and index.
650	_0	|**a** Computer networks.
650	_0	|**a** Multimedia systems.

650 _0 |**a** High performance computing.
650 _0 |**a** Asynchronous transfer mode.
650 _0 |**a** Wireless communication systems.
700 1_ |**a** Varaiya, P.P. |**q** (Pravin Pratap)
856 41 |**3** Table of contents |**u** http://www.loc.gov/catdir/toc/els033/99047341.html
856 42 |**3** Publisher description |**u** http://www.loc.gov/catdir/description/els033/99047341.html

Request this Item | LC Find It

Item Availability

CALL NUMBER	TK5105.5 .W353 2000 CABIN BRANCH Copy 1
Request in	Jefferson or Adams Building Reading Rooms - STORED OFFSITE
Status	Not Charged

Exhibit E3

OCLC 42397851 **No holdings in XXX - 281 other holdings**

Books

						Rec Stat		**Entered**	19990830	**Replaced**	20200910144000.8		
Type	a	**ELvl**		**Srce**		**Audn**		**Ctrl**		**Lang**	eng		
BLvl	m	**Form**		**Conf**	0	**Biog**		**MRec**		**Ctry**	cau		
		Cont	b	**GPub**		**LitF**	0	**Indx**	1				
Desc	a	**Ills**		**Fest**	0	**DtSt**	s	**Dates**	2000 ,				

010 99047341
040 DLC $b eng $c DLC $d UKM $d C#P $d BAKER $d BTCTA $d YDXCP $d STF $d CIT $d HEBIS $d DEBBG $d EUM $d BDX $d OCLCF $d OCLCO $d OCLCQ $d OCLCO $d I8M $d OCLCQ $d ICN $d OCLCO $d DHA $d OCLCQ $d CCH $d IPL $d OCLCO $d OCLCQ $d BGU $d OCLCO $d OCLCQ $d OCLCO $d LVT
015 GB99V4480 $2 bnb
019 228266079
020 1558605746
020 9781558605749
020 1558606548
020 9781558606548
050 00 TK5105.5 $b .W353 2000
080 621.391.W22
082 00 621.382/1 $2 21
084 ST 200 $2 rvk
084 DAT 250f $2 stub
084 ZN 6220 $0 (DE-625)157529: $2 rvk
090 $b
100 1 Walrand, Jean.
245 10 High-performance communication networks / $c Jean Walrand, Pravin Varaiya.
250 2nd ed.
260 San Francisco : $b Morgan Kaufmann, $c ©2000.
300 xxii, 693 pages ; $c 25 cm.
336 text $b txt $2 rdacontent
337 unmediated $b n $2 rdamedia
338 volume $b nc $2 rdacarrier
490 1 The Morgan Kaufmann series in networking
504 Includes bibliographical references (pages 646-653) and index.
505 0 History of communications networks -- Networking principles -- Future networks -- Network services and layered architectures -- Applications -- Traffic characterization and quality of service -- Network services -- High-performance networks -- Network elements -- Basic network mechanisms -- Layered architecture -- Open data network model -- Network architectures -- Network bottlenecks -- Packet-switched networks -- OSI and IP models -- Ethernet (IEEE 802.3) -- FDDI -- DQDB -- Frame relay -- SMDS -- Internet and TCP/IP networks -- Internet -- Overview of internet protocols -- Internet protocol -- TCP and UDP -- Internet success and limitation -- Performance of TCP/IP networks -- Circuit-switched networks -- Performance of circuit-switched networks -- SONET -- Dense wave-division multiplexing (DWDM) -- Fiber to the home -- Digital subscriber line (DSL) -- Intelligent networks -- CATV -- Asynchronous transfer mode -- Main features of ATM -- Addressing, signaling, and routing -- ATM

header structure -- ATM adaptation layer -- Management and control -- BISDN -- Internetworking with ATM -- WIreless networks -- Wireless channel -- Link level design -- Channel access -- Network design -- Wireless networks today -- Future systems and standards -- Control of networks -- Objectives and methods of control -- Circuit-switched networks -- Datagram networks -- ATM networks -- Control of networks: mathematical background -- Circuit-switched networks -- Datagam networks -- ATM networks -- Network economics -- Derived demand for network services -- Internet service providers -- Network charges: theory and practice -- Billing and provisioning system for internet connections -- Pricing a single resource -- Pricing for ATM services -- Optical networks -- WDM systems -- Optical cross-connects -- Optical LANs -- Optical paths and networks -- Switching -- Distributed buffer -- Shared buffer -- Output buffer -- Input buffer -- Toward a global multimedia network -- Attributes of the global network -- Technology areas -- Challenges.
520 Retaining the first edition's technology-centred perspective, this book gives readers a sound understanding of packed-switched, circuit-switched and ATM networks, and techniques for controlling them.
650 0 Computer networks.
650 0 Multimedia systems.
650 0 High performance computing.
650 0 Asynchronous transfer mode.
650 0 Wireless communication systems.
650 7 Asynchronous transfer mode. $2 fast $0 (OCoLC)fst00819876
650 7 Computer networks. $2 fast $0 (OCoLC)fst00872297
650 7 High performance computing. $2 fast $0 (OCoLC)fst00956032
650 7 Multimedia systems. $2 fast $0 (OCoLC)fst01028920
650 7 Wireless communication systems. $2 fast $0 (OCoLC)fst01176209
610 27 Abwassertechnik München GbR $g München $2 gnd $0 (DE-588)6095086-9
650 7 Rechnernetz $2 gnd $0 (DE-588)4070085-9
650 7 Drahtloses lokales Netz $2 gnd $0 (DE-588)4633975-9
650 7 Multimedia $2 gnd $0 (DE-588)4192358-3
650 07 Drahtloses lokales Netz. $2 swd
650 07 Rechnernetz. $2 swd
650 07 Multimedia. $2 swd
700 1 Varaiya, P. P. $q (Pravin Pratap)
776 08 $i Online version: $a Walrand, Jean. $t High-performance communication networks. $b 2nd ed. $d San Francisco : Morgan Kaufmann, ©2000 $w (OCoLC)606907487
830 0 Morgan Kaufmann series in networking.
856 41 $3 Books24x7 $u http://www.books24x7.com/marc.asp?bookid=1105
856 41 $3 Table of contents $u http://catdir.loc.gov/catdir/toc/els033/99047341.html
856 42 $3 Publisher description $u http://catdir.loc.gov/catdir/description/els033/99047341.html

Exhibit E4

LC control no.: sh 85029513
LCCN Permalink: https://lccn.loc.gov/sh85029513
HEADING: Computer networks

000 01442cz a2200409n 450
001 4681787
005 20120323071047.0
008 860211i| anannbabn |b ana
010 __ |**a** sh 85029513
035 __ |**a** (DLC)sh 85029513
035 __ |**a** (DLC)5721786
035 __ |**a** (DLC)sp 85029513
035 __ |**a** (DLC)288027
035 __ |**a** (DLC)7651246
035 __ |**a** (DLC)409258
040 __ |**a** DLC |**c** DLC |**d** DLC |**d** DGPO |**d** DLC
053 _0 |**a** TK5105.5 |**b** TK5105.9
150 __ |**a** Computer networks
360 __ |**i** subdivision |**a** Computer networks |**i** under subjects
450 __ |**a** Communication systems, Computer
450 __ |**a** Computer communication systems
450 __ |**a** Data networks, Computer
450 __ |**a** ECNs (Electronic communication networks)
450 __ |**a** Electronic communication networks
450 __ |**a** Networks, Computer
450 __ |**a** Teleprocessing networks
550 __ |**w** g |**a** Data transmission systems
550 __ |**w** g |**a** Digital communications
550 __ |**w** g |**a** Electronic systems
550 __ |**w** g |**a** Information networks
550 __ |**w** g |**a** Telecommunication
550 __ |**a** Cyberinfrastructure
550 __ |**a** Electronic data processing |**x** Distributed processing
550 __ |**a** Network computers
670 __ |**a** U.S. Cong. Senate. Comm. on banking, Housing and Urban Affairs. Subcom. on

Securities. The changing face of capital markets and the impact of electronic communications networks (ECNs), hearing ... 2000.

906 __ |**t** 0839 |**u** te04 |**v** 1

953 __ |**a** xx00 |**b** ta39

◀ Previous Next ▶

Save, Print or Email Records (View Help)

Select Download Format: Text (Labelled Display) Press to SAVE or PRINT

Email Text (Labelled Display) to: Press to SEND EMAIL

Help - Search - Search History - Headings List - Start Over

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit E5

LC control no.: sh 92002381

LCCN Permalink: https://lccn.loc.gov/sh92002381

HEADING: Multimedia systems

000 02042cz a2200373n 450

001 4843481

005 20120330075100.0

008 920429i| anannbabn |a ana

010 __ |**a** sh 92002381

035 __ |**a** (DLC)sh 92002381

035 __ |**a** (DLC)190166

040 __ |**a** DLC |**c** DLC |**d** DLC

053 _0 |**a** QA76.575

150 __ |**a** Multimedia systems

450 __ |**a** Computer-based multimedia information systems

450 __ |**a** Multimedia computing

450 __ |**a** Multimedia information systems

450 __ |**a** Multimedia knowledge systems

550 __ |**w** g |**a** Information storage and retrieval systems

670 __ |**a** Work cat.: Multimedia review, c1990.

670 __ |**a** ASTI: |**b** p. 1391 (Multimedia information systems)

670 __ |**a** Business period. index, 1990-91: |**b** p. 1134 (Multimedia computers, multimedia software)

670 __ |**a** BYTE, Feb. 1990: |**b** p. 203 ("Multimedia uses the computer to integrate and control diverse electronic media such as computer screens, videodisk players, CD-ROM disks, and speech and audio synthesizers")

670 __ |**a** Computer, Oct. 1985: |**b** p. 92 (Computer-based multimedia information system)

670 __ |**a** Computer data base thes. |**b** (Multimedia technology, multimedia software, multimedia terminals)

670 __ |**a** Computer lib. period., Sept. 1990 |**b** (Multimedia technology)

670 __ |**a** L.C. Nat. Demo. Lab. Info bull. Feb. 24, 1992: |**b** pp. 73-76.

670 __ |**a** LC data base, 4/10/92.

670 __ |**a** Lib. lit., Feb. 1992 |**b** (Multimedia systems)

675 __ |**a** Computer dict.; |**a** IAC; |**a** Legislative index, 1991; |**a** McGraw-Hill dict. sci. tech.; |**a** Stnd. gloss. of comp. terminology

680 __ |**i** Here are entered works on computer systems that integrate and present diverse media,

such as text, graphics, still and moving images, and audio. Works on media containing information that may be interactively manipulated by individual users through the use of software or microprocessing capabilities are entered under |**a** Interactive multimedia.

681 __ |**i** Note under |**a** Interactive multimedia

906 __ |**t** 9412 |**u** te05 |**v** 0

953 __ |**a** yn07 |**b** ta25

◀ Previous Next ▶

Save, Print or Email Records (View Help)

Select Download Format: Text (Labelled Display) Press to SAVE or PRINT

Email Text (Labelled Display) to: Press to SEND EMAIL

Help - Search - Search History - Headings List - Start Over

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit E6

LC control no.: sh 95008935

LCCN Permalink: https://lccn.loc.gov/sh95008935

HEADING: High performance computing

000 01654cz a2200301n 450

001 4872137

005 20120330083156.0

008 951023i| anannbabn |a ana

010 __ |**a** sh 95008935

035 __ |**a** (DLC)sh 95008935

035 __ |**a** (DLC)7651257

035 __ |**a** (DLC)sp 95008935

035 __ |**a** (DLC)409260

040 __ |**a** DLC |**c** DLC |**d** DLC

053 _0 |**a** QA76.88

150 __ |**a** High performance computing

450 __ |**a** HPC (Computer science)

550 __ |**w** g |**a** Electronic data processing

550 __ |**a** Cyberinfrastructure

550 __ |**a** Supercomputers

670 __ |**a** Work cat.: 95-214906: High performance computing, 1995: |**b** p. v (We define High Performance Computing (HPC) as an integrated computing environment that includes software, algorithms, programming tools, and visualization, and enables solving compute intensive problems) p. 3 (High Performance Computing (HPC), synonymous with Supercomputing, orginated in the late 1970s and has spread dramatically in the current decade. Initially limited to applications in defense industry and several high technology industries, HPC is now entering other sectors of business, industry and science)

670 __ |**a** ASTI, June, 1995.

670 __ |**a** SCI, 1989: |**b** v. 18.

670 __ |**a** LC database, Oct. 23, 1995.

670 __ |**a** Federal High Performance Computing Program (U.S.); High Performance Computing Act of 1991.

670 __ |**a** Freedman, A. Computer glossary, 1993: |**b** High-Performance Computing (Federal initiative to enhance U.S. computing capability that includes a T3-speed network linking agencies, private companies and schools to supercomputer centers; HPC)

906 __ |**t** 0839 |**u** te04 |**v** 1

953 __ |**a** jf11 |**b** ta39

◀ Previous Next ▶

Save, Print or Email Records (View Help)
Select Download Format: Text (Labelled Display) Press to SAVE or PRINT
Email Text (Labelled Display) to: Press to SEND EMAIL

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit E7

LC control no.: sh 93001267
LCCN Permalink: https://lccn.loc.gov/sh93001267
HEADING: Asynchronous transfer mode

000 01179cz a2200253n 450
001 4848554
005 20120330075909.0
008 930310|| anannbabn |a ana
010 __ |**a** sh 93001267
035 __ |**a** (DLC)sh 93001267
035 __ |**a** (DLC)195239
040 __ |**a** DLC |**c** DLC |**d** DLC
053 _0 |**a** TK5105.35
150 __ |**a** Asynchronous transfer mode
450 __ |**a** ATM (Data transmission)
550 __ |**w** g |**a** Broadband communication systems
550 __ |**w** g |**a** Packet switching (Data transmission)
670 __ |**a** Work cat.: 93-119183: Lane, J. Asynchronous transfer mode : bandwidth for the future, c1992: |**b** p. 1, etc. (went from obscurity to general awareness early 1992; one of the general class of packet technologies; a specific type of cell relay service)
670 __ |**a** Facts on file dict. of telecommunications, c1991 |**b** (asynchronous transfer mode; ATM; technique for packet transfer that is expected to be used on networks built with fiber optic cable; uses technique called cell relay)
670 __ |**a** LC data base, 3/8/93 |**b** (ATM; Asynchronous transfer mode)
675 __ |**a** ASTI; |**a** Web. 3
906 __ |**t** 9315 |**u** te03 |**v** 0
952 __ |**a** LC pattern: Packet switching (Data transmission)
953 __ |**a** jg12

Press to SEND EMAIL

Help - Search - Search History - Headings List - Start Over

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit E8

LC control no.: sh 92006740

LCCN Permalink: https://lccn.loc.gov/sh92006740

HEADING: Wireless communication systems

000 01349cz a2200313n 450

001 4847318

005 20120330075715.0

008 921222i| anannbabn |a ana

010 __ |**a** sh 92006740

035 __ |**a** (DLC)sh 92006740

035 __ |**a** (DLC)194003

040 __ |**a** DLC |**c** DLC

053 _0 |**a** TK5103.2

150 __ |**a** Wireless communication systems

450 __ |**a** Communication systems, Wireless

450 __ |**a** Wireless data communication systems

450 __ |**a** Wireless information networks

450 __ |**a** Wireless telecommunication systems

550 __ |**w** g |**a** Telecommunication systems

670 __ |**a** Work cat.: 92-43366: Wireless communications, c1993: |**b** CIP pref. (wireless information networks)

670 __ |**a** LC data base, 12/10/92 |**b** (wireless information networks, wireless communications, wireless data communications)

670 __ |**a** ASTI |**b** (Wireless telecommunications networks)

670 __ |**a** Engr. index: |**b** v. 89, pt. IX, p. 10249 (Wireless communication)

670 __ |**a** Web. 3 |**b** (Wireless; Wireless telephony: relating to radiotelegraphy, radiotelephony, or radio)

680 __ |**i** Here are entered works on networks for transmission of voice or data using either radio or optical (e.g. infrared) technologies.

906 __ |**t** 9304 |**u** te07 |**v** 1

952 __ |**a** 4 bib. record(s) to be changed

952 __ |**a** LC pattern: Broadband communication systems

953 __ |**a** jg12

Save, Print or Email Records (View Help)

Select Download Format: Text (Labelled Display) Press to SAVE or PRINT

Email Text (Labelled Display) to:

Press to SEND EMAIL

Help - Search - Search History - Headings List - Start Over

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit E9

Copyright United States Copyright Office

Library buildings are closed to the public until further notice, but the U.S. Copyright Office Catalog is available. More.

Help | Search | History | Titles | Start Over

Public Catalog

Copyright Catalog (1978 to present)
Search Request: Left Anchored Title = High Performance Communication Networks
Search Results: Displaying 1 of 2 entries

previous | next

Labeled View

High-performance communication networks / Jean Walrand, Pravin Varaiya.

Type of Work: Text
Registration Number / Date: TX0005207251 / 2000-04-26
Title: High-performance communication networks / Jean Walrand, Pravin Varaiya.
Edition: 2nd ed.
Imprint: San Francisco : Morgan Kaufmann Publishers, c2000.
Description: 693 p.
Copyright Claimant: Morgan Kaufmann Publishers
Date of Creation: 1999
Date of Publication: 1999-10-11
Previous Registration: Prev. reg. 1997, TX 4-678-703.
Basis of Claim: New Matter: additions and revisions.
Names: Walrand, Jean
Varaiya, Pravin
Morgan Kaufmann Publishers

previous | next

Save, Print and Email (Help Page)

Select Download Format [Full Record] Format for Print/Save

Enter your email address: [ ] Email

Help Search History Titles Start Over

Contact Us | Request Copies | Get a Search Estimate | Frequently Asked Questions (FAQs) about Copyright | Copyright Office Home Page | Library of Congress Home Page

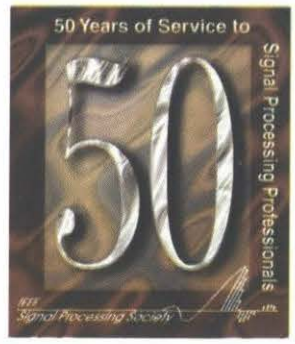
Exhibit F

IEEE TRANSACTIONS ON

SIGNAL PROCESSING

A PUBLICATION OF THE IEEE SIGNAL PROCESSING SOCIETY

OCTOBER 1997 VOLUME 45 NUMBER 10 ITPRED (ISSN 1053–587X)



(Contents Continued on Back Cover)

(Contents Continued from Front Cover)

IEEE TRANSACTIONS ON SIGNAL PROCESSING (ISSN 1053–587X) is published monthly by the Institute of Electrical and Electronics Engineers, Inc. Responsibility for the contents rests upon the authors and not upon the IEEE, the Society/Council, or its members. **IEEE Corporate Office:** 345 East 47 Street, New York, NY 10017-2394. **IEEE Operations Center:** 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331. **NJ Telephone:** (908) 981-0060. **Price/Publication Information:** Individual copies: IEEE Members $10.00 (first copy only), nonmembers $20.00 per copy. (Note: Add $4.00 postage and handling charge to any order from $1.00 to $50.00, including prepaid orders.) Member and nonmember subscription prices available upon request. Available in microfiche and microfilm.

Periodicals Postage Paid at New York, NY and at additional mailing offices. **Postmaster:** Send address changes to IEEE TRANSACTIONS ON SIGNAL PROCESSING, IEEE, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331. GST Registration No. 125634188. Printed in U.S.A.

New Precoding for Intersymbol Interference Cancellation Using Nonmaximally Decimated Multirate Filterbanks with Ideal FIR Equalizers

Xiang-Gen Xia, *Member, IEEE*

***Abstract*—In this paper, we propose a new precoding method for intersymbol interference (ISI) cancellation by using nonmaximally decimated multirate filterbanks. Unlike the existing precoding methods, such as the TH and trellis precodings, the new precoding**

- **i) may be independent of the ISI channel;**
- **ii) is linear and does not have to implement any modulo operation;**
- **iii) gives the ideal FIR equalization at the receiver for any FIR ISI channel including spectral-null channels;**
- **iv) expands the transmission bandwidth in a minimum amount.**

The precoding is built on nonmaximally decimated multirate filterbanks. Based on multirate filterbank theory, we present a necessary and sufficient condition on an FIR ISI transfer function in terms of its zero set such that there is a linear FIR $N \times K$ precoder so that an ideal FIR equalizer exists, where the integers K and N are arbitrarily fixed. The condition is easy to check. As a consequence of the condition, for any given FIR ISI transfer function (not identically 0), there always exist such linear FIR precoders. Moreover, for almost all given FIR ISI transfer functions, there exist linear FIR precoders with size $N \times (N-1)$, i.e., the bandwidth is expanded by $1/N$. In addition to the conditions on the ISI transfer functions, a method for the design of the linear FIR precoders and the ideal FIR equalizers is also given. Numerical examples are presented to illustrate the theory.

I. Introduction

INTERSYMBOL interference (ISI) is a common problem in telecommunication systems, such as terrestrial television broadcasting, digital data communication systems, and cellular mobile communication systems. The main reasons for the ISI are because of high-speed transmission and multipath fading. There have been considerable studies for these problems, such as [1]–[29] and [33]–[40]. These studies can be primarily split into three categories:

- i) post equalization, such as least-mean-squared (LMS) equalizer and decision feedback equalization (DFE), for example, [1]–[3], [18]–[29], and [36]–[39];
- ii) multicarrier modulation to increase transmission symbol length, for example, [4]–[6];
- iii) precoding techniques, such as Tomlinson–Harashima (TH) precoding [7], [8], trellis precoding by Eyuboglu and Forney [9], [10], matched spectral null precoding in partial response channels [12], and other precoding schemes, for example, [13]–[17] and [40].

The basic idea for DFE is that once an information symbol has been detected, the ISI that it causes on future symbols may be estimated and subtracted out prior to symbol detection. DFE usually consists of a feedforward filter and feedback filter. The feedback filter is driven by decisions of the output of the detector, and its coefficients are adjusted to cancel the ISI on the current symbol that results from past detected symbols. The coefficient adjustment may be done via a linear equalizer with LMS algorithms. The convergence of these iterative algorithms are dependent of the channel characteristics. When a channel is spectral null or frequency selective fading, these algorithms are very slow and, therefore, become computationally expensive. The performance of the existing linear equalizers significantly degrades over frequency selective fading channels. Although DFE has better performance than the existing linear equalizers when the frequency fading is in the middle of a passband, it does not offer much improvement in other fading cases. For more details, see, for example, [3] and [35]. In post equalization techniques, there are many research results (see, for example, [18]–[29] and [36]–[39] on blind equalizations where channel characteristics are assumed unknown. In blind equalization techniques, there are approximately three groups of results:

- i) high-order statistics techniques;
- ii) second-order cyclostationary statistics techniques with oversampling;
- iii) antenna array (smart antenna) multireceiver techniques;

where there is a considerable amount of overlaps between ii) and iii).

A block diagram for TH precoding is shown in Fig. 1, where the basic idea is to equalize the signal before transmission. With TH precoding there are two drawbacks: i) The transmitter needs to know the channel characteristics, and ii) the precoding is not reliable when the ISI channel $H(z)$ has spectral null or frequency selective fading characteristics, which is because the pre-equalizer $\mathrm{mod}[1/H(z), M]$ oscillates in a dramatic way when $H(z)$ is close to zero. The trellis precoding scheme proposed by Eyuboglu and Forney [9] whitens the noise at the equalizer output. This scheme combines precoding and trellis

Manuscript received September 2, 1995; revised April 18, 1997. The associate editor coordinating the review of this paper and approving it for publication was Prof. Roberto H. Bamberger.

The author was with Hughes Research Laboratories, Malibu, CA 90265 USA. He is currently with the Department of Electrical Engineering, University of Delaware, Newark, DE 19716 USA (e-mail: xxia@ee.udel.edu).

Publisher Item Identifier S 1053-587X(97)07357-1.

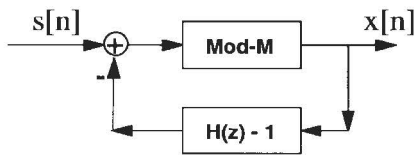


Fig. 1. TH precoder.

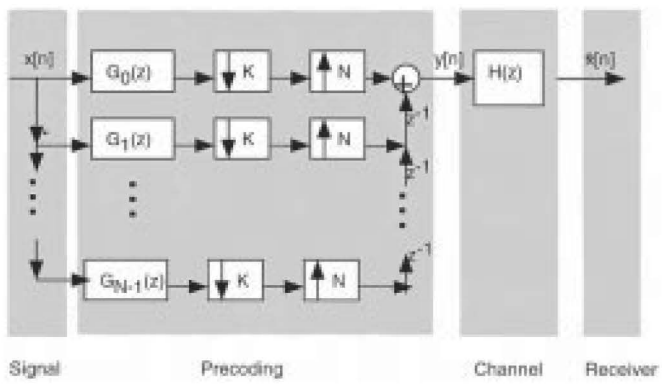


Fig. 2. Nonmaximally decimated multirate filterbank in a communication channel with ISI.

shaping. There are also similar drawbacks about this approach.

i) The transmitter also needs to know the ISI channel characteristics.
ii) The trellis shaping depends on the ISI channel.
iii) The trellis precoding technique may not be suitable for spectral-null channels either.

In the matched spectral null precoding scheme [12] in partial response channels, certain error control codes are chosen to match the spectral nulls of partial response channels in order to lose less signal information through the channel. This approach is mainly for magnetic recording systems.

We now propose a multirate filterbank as a precoder before transmission (shown in Fig. 2), where $\downarrow K$ indicates downsampling by K, and $\uparrow N$ indicates upsampling by N, i.e., inserting $N-1$ zeros between two adjacent samples, and $H(z)$ is the ISI transfer function. Later, we will see a multirate filterbank decoder for the receiver to eliminate the ISI. If input signal $x[n]$ in Fig. 2 can be completely recovered from the received signal $\hat{x}[n]$ through an FIR linear system, we call that the system in Fig. 2 has perfect reconstruction (PR) or an FIR ideal linear equalizer. In what follows, we use "precoder" and "multirate filterbank" interchangeably.

With the precoder proposed in Fig. 2, there are three questions to be answered:

i) What is the condition on $H(z)$ such that there exists a multirate filterbank with N channels and decimation by K in Fig. 2 so that $x[n]$ can be recovered from $\hat{x}[n]$ through an FIR linear system?
ii) If the condition on $H(z)$ in the first question is satisfied, how does one design a multirate filterbank in Fig. 2 to eliminate the ISI?
iii) If both of these two problems are solved, how does the receiver recover the input signal $x[n]$ from the received $\hat{x}[n]$?

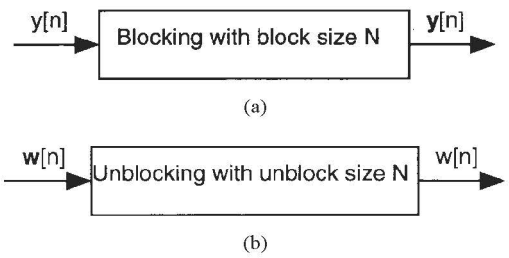


Fig. 3. Blocking and unblocking.

Next, we want to find brief solutions for these questions. When $K = 1, G_0(z) = 1, G_1(z) = \cdots = G_{N-1}(z) = 0$, the precoding scheme in Fig. 2 is equivalent to the fractionally spaced equalizer studied, for example, [36]–[39], where the receiver needs to sample a signal N times faster than the baud sampling. When $K = 1$, the precoding concept has appeared in [39] by Tsatsanis and Giannakis, where the precoder $G_l(z) = c_l, l = 0, 1, \cdots, N-1$ for N constants c_l was used. As we can see, the case of $K = 1$ is a very special case in our precoding scheme, and moreover, our new precoding scheme in Fig. 2 provides other potential precoders $G_l(z), l = 0, 1, \cdots, N-1$ rather than only constants c_l, which allows one to search the optimal one with respect to an individual channel.

When $K \geq N$ and there are N interference channels instead of a single channel $H(z)$ in Fig. 2, a detailed analysis was given by Nguyen [31]. When $K > N$, as mentioned in [31], PR is impossible, but partial alias cancellation filterbanks were proposed in [31]. The applications discussed in [31] are in wide-band radio communications, where only part of the signal frequencies is of interest to the user. In this paper, we are interested in applications in the ISI channels with PR systems in Fig. 2 and, therefore, the case of $K < N$. This also implies that unlike the existing precoding techniques, the new precoding expands the transmission bandwidth, which is what we lose for the new precoding method, and fortunately, we will show that the bandwidth expansion can be as small as possible in theory.

An intuitive way to reduce the ISI generated from a lowpass $H(z)$ is to smoothly interpolate $x[n]$ with a large enough number of interpolations between samples of $x[n]$ so that the interpolated one has the lowpass property. However, two drawbacks about this approach may occur. One is that it usually requires a large amount of increasing of data rate (number of interpolations between samples). The other is that a good frequency band structure for a nonlowpass, such as bandpass, filter $H(z)$ is required for PR. In this paper, we want to solve the above three problems systematically. Given two integers $0 < K < N$, we present a necessary and sufficient condition (see Theorem 1) on an FIR filter $H(z)$ such that there exists an FIR nonmaximally decimated multirate filterbank with N channels and decimation by K so that $x[n]$ can be recovered from $\hat{x}[n]$ in Fig. 2 with an FIR synthesis bank. The condition we found is basically very weak. In fact, it can be proved that for any given FIR filter $H(z)$ not identically 0, there always exists an FIR nonmaximally decimated multirate filterbank in Fig. 2 for recovering $x[n]$

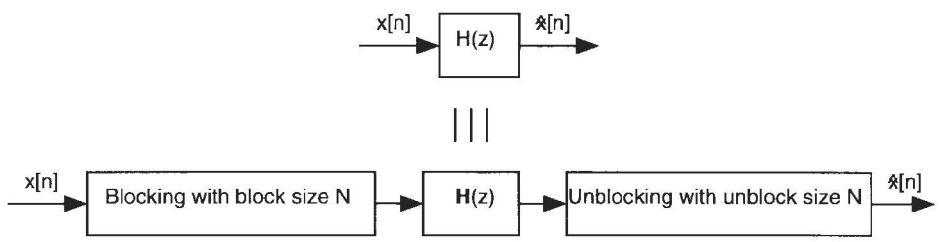


Fig. 4. Equivalence of an LTI system and its blocked version.

from $\hat{x}[n]$. A nonmaximally decimated filterbank precoder requires a higher transmission rate with the increasing amount proportional to the difference $N-K$. It is clear that the smallest $N-K$ is 1. In other words, a multirate filterbank with N channels and decimation by $N-1$ has the smallest increasing of a transmission rate, and therefore, it is usually desired. We show that a multirate filterbank with N channels and decimation by $N-1$ exists in Fig. 2 for PR if and only if any two sets of zeros of the polynomials $H(zW_N^l)$ of z^{-1} for $l=0,1,\cdots,N-1$ do not intersect, where $W_N = e^{-2\pi\sqrt{-1}/N}$. This condition is true almost surely. Various examples are presented. With the above conditions, we also derive some results on the submatrices of a pseudo-circulant polynomial matrices [32]. Constructions of FIR nonmaximally decimated multirate filterbanks and their FIR syntheses for the reconstruction for a given $H(z)$ in Fig. 2 are provided. Numerical examples are presented to illustrate the theory, which also indicates that the technique we developed for eliminating the ISI is robust.

This paper is organized as follows. In Section II, we present necessary and sufficient conditions on $H(z)$. We also discuss the construction of nonmaximally decimated multirate filterbanks for eliminating ISI. In Section III, we present examples and the reconstruction method. In Section IV, we consider applications of the ISI cancellation.

II. A Necessary and Sufficient Condition

In this section, we study necessary and sufficient conditions on the ISI transfer functions $H(z)$ in Fig. 2 such that there exists a nonmaximally decimated multirate filterbank with N channels and decimation by K and such that an ideal FIR linear equalizer exists. We also present a design method for an FIR nonmaximally decimated multirate filterbank for eliminating the ISI. Throughout this paper, boldface lowercase letters denote vector-valued sequences, capital letters denote transfer functions, and boldface capital letters denote function matrices (or polynomial matrices). We first consider the case when K and N $(0<K<N)$ are two arbitrarily fixed integers.

Before we go to the results, let us see some fundamentals on blocking and linear time invariant (LTI) systems. We then convert the system in Fig. 2 into a single multirate system. The output $\mathbf{y}[n]$ shown in Fig. 3(a) of the blocked $y[n]$ with block size N is the vector-valued signal $\mathbf{y}[n]=(y[Nn], y[Nn-1], \cdots, y[Nn-N+1])^T$, where ^{T} indicates transpose. Conversely, the output $w[n]$ shown in Fig. 3(b) of the unblocked vector-valued signal $\mathbf{w}[n]=[w_0[n], w_1[n], \cdots, w_{N-1}[n])^T$

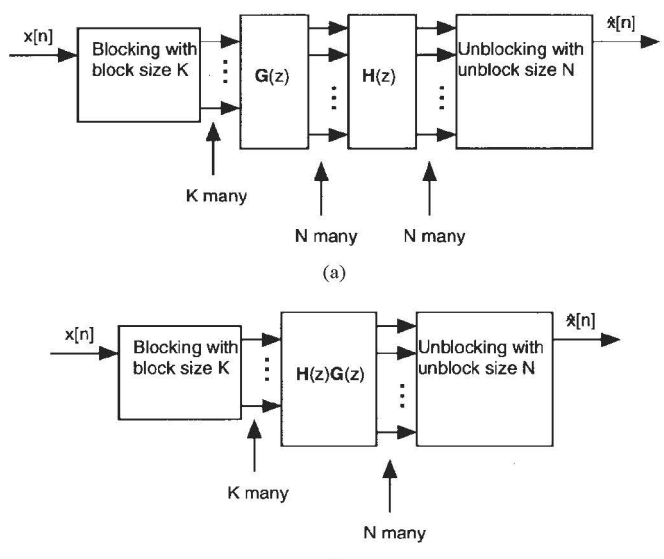


Fig. 5. Equivalent systems of the system in Fig. 2.

with unblock size N is $w[n]=w_k[l]$ when $n=Nl-k$ for $k=0,1,\cdots,N-1$. In particular, when $w[n]=(y[Nn], y[Nn-1], \cdots, y[Nn-N+1])^T$, then $w[n]=y[n]$.

Let $H(z)=\sum_n h[n]z^{-n}$ and $H_j(z)$ be its jth forward polyphase component with N channels, i.e., $H_j(z)=\sum_n h[Nn+j]z^{-n}, 0\le j\le N-1$. With $H_j(z), 0\le j\le N-1$, we form the following $N\times N$ pseudo-circulant matrix $\mathbf{H}(z)$ (see [30], [32])

$$\mathbf{H}(z)=\begin{bmatrix} H_0(z) & z^{-1}H_{N-1}(z) & \cdots & z^{-1}H_1(z) \\ H_1(z) & H_0(z) & \cdots & z^{-1}H_2(z) \\ \vdots & \vdots & \cdots & \vdots \\ H_{N-2}(z) & H_{N-3}(z) & \cdots & z^{-1}H_{N-1}(z) \\ H_{N-1}(z) & H_{N-2}(z) & \cdots & H_0(z) \end{bmatrix}. \tag{2.1}$$

Then, we have the equivalence for an LTI system and blocking process shown in Fig. 4, where $\mathbf{H}(z)$ is from (2.1) and is called the *blocked version* of $H(z)$; see [30] and [32].

For $0\le l\le N-1$, let $G_{l,j}(z)$ be the jth forward polyphase component of the lth filter $G_l(z)$ in Fig. 2 with K channels, i.e., $G_{l,j}(z)=\sum_n g_l[Kn+j]z^{-n}$, when $G_l(z)=\sum_n g_l[n]z^{-n}$, for $0\le j\le K-1$. Let $\mathbf{G}(z)$ be the polyphase matrix of the filterbank $G_0(z), G_1(z), \cdots, G_{N-1}(z)$ in Fig. 2: $\mathbf{G}(z)=[G_{l,j}(z)]_{N\times K}$. Then, the system in Fig. 2 is equivalent to the one in Fig. 5(a), which is also equivalent to the one in Fig. 5(b).

Therefore, the PR of $x[n]$ from $\hat{x}[n]$ in Fig. 2 is equivalent to the one of the linear multirate system $\mathbf{H}(z)\mathbf{G}(z)$ in Fig. 4(b). Notice that $\mathbf{H}(z)\mathbf{G}(z)$ is an $N \times K$ function matrix of z^{-1}. To analyze it, we need a property on the pseudo-circulant matrix $\mathbf{H}(z)$ in (2.1). In fact, $\mathbf{H}(z)$ can be diagonalized as follows.

Let $\mathbf{W}_N$ be the $N \times N$ DFT matrix, i.e., $\mathbf{W}_N \triangleq (W_N^{jk})_{0 \le j,k \le N-1}$, where $W_N = e^{-2\pi\sqrt{-1}/N}$. Let $\mathbf{\Lambda}(z)$ be the diagonal matrix

$$\mathbf{\Lambda}(z) \triangleq \text{diag } (1, z^{-1}, \cdots, z^{-N+1}).$$

Notice that the transpose of the matrix $\mathbf{H}(z)$ is the forward polyphase matrix of the N filters $H(z)$, $z^{-1}H(z)$, $\cdots$, $z^{-N+1}H(z)$ in N channels

$$[H(z), z^{-1}H(z), \cdots, z^{-N+1}H(z)] = (1, z^{-1}, \cdots, z^{-N+1})\mathbf{H}(z^N).$$

Replacing z by zW_N^l for $l = 0, 1, \cdots, N-1$ in the above equality, we have the following $N \times N$ matrix multiplications

$$\hat{\mathbf{H}}(z) = \mathbf{W}_N^* \mathbf{\Lambda}(z)\mathbf{H}(z^N) \tag{2.2}$$

where we have (2.3), shown at the bottom of the page. Let

$$\mathbf{V}(z) \triangleq \text{diag } [H(z), H(zW_N), \cdots, H(zW_N^{N-1})]. \tag{2.4}$$

Then, the matrix $\hat{\mathbf{H}}(z)$ in (2.3) can be rewritten as

$$\hat{\mathbf{H}}(z) = \mathbf{V}(z)\mathbf{W}_N^* \mathbf{\Lambda}(z).$$

This completes the following diagonalization of $\mathbf{H}(z^N)$ by combining (2.2)

$$\mathbf{H}(z^N) = [\mathbf{W}_N^* \mathbf{\Lambda}(z)]^\dagger \mathbf{V}(z) \mathbf{W}_N^* \mathbf{\Lambda}(z) \tag{2.5}$$

where † means the inverse.

From now on, we assume all filters in Fig. 2 are FIR, and the PR of the system in Fig. 2 means the overall system function $\mathbf{H}(z)\mathbf{G}(z)$ has an FIR inverse.

The PR of the multirate system $\mathbf{H}(z)\mathbf{G}(z)$ is equivalent to the one of the multirate system $\mathbf{H}(z^N)\mathbf{G}(z^N)$. In fact, if $\mathbf{H}(z^N)\mathbf{G}(z^N)$ has PR, then any input signal $X(z)$ can be reconstructed from $\mathbf{H}(z^N)\mathbf{G}(z^N)X(z)$. Thus, $X(z^N)$ can be reconstructed from $\mathbf{H}(z^N)\mathbf{G}(z^N)X(z^N)$ with an FIR synthesis filterbank. In other words, any $X(z)$ can be reconstructed from $\mathbf{H}(z)\mathbf{G}(z)X(z)$ with an FIR synthesis filterbank. This implies the PR of $\mathbf{H}(z)\mathbf{G}(z)$. Conversely, we assume the PR of $\mathbf{H}(z)\mathbf{G}(z)$, which is equivalent to that there exists an FIR inverse, i.e., there is an FIR $K \times N$ polynomial matrix $\mathbf{Q}(z)$ such that

$$\mathbf{Q}(z)\mathbf{H}(z)\hat{\mathbf{G}}(z) = I_K$$

where I_K is the $K \times K$ identity matrix. Thus, we also have

$$\mathbf{Q}(z^N)\mathbf{H}(z^N)\hat{\mathbf{G}}(z^N) = I_K.$$

It implies that $\mathbf{H}(z^N)\hat{\mathbf{G}}(z^N)$ has an FIR inverse (or PR).

We, thus, consider the PR of $\mathbf{H}(z^N)\mathbf{G}(z^N)$. By (2.5)

$$\mathbf{H}(z^N)\mathbf{G}(z^N) = [\mathbf{W}_N^* \mathbf{\Lambda}(z)]^\dagger \mathbf{V}(z) \mathbf{W}_N^* \mathbf{\Lambda}(z)\mathbf{G}(z^N). \tag{2.6}$$

It is clear that $[\mathbf{W}_N^* \mathbf{\Lambda}(z)]^\dagger = \mathbf{\Lambda}(z^{-1})\mathbf{W}_N$, which is paraunitary. Let

$$\hat{\mathbf{G}}(z) \triangleq \mathbf{W}_N^* \mathbf{\Lambda}(z)\mathbf{G}(z^N).$$

Then, the PR of $\mathbf{H}(z)\mathbf{G}(z)$ is equivalent to the one of $\mathbf{V}(z)\hat{\mathbf{G}}(z)$. Notice that the size of the matrix $\mathbf{V}(z)\hat{\mathbf{G}}(z)$ is $N \times K$.

On the other hand, $\mathbf{V}(z)\hat{\mathbf{G}}(z)$ has an FIR inverse equivalent to that of the greatest common divisor (gcd) of all determinants of all $K \times K$ submatrices of the $N \times K$ matrix $\mathbf{V}(z)\hat{\mathbf{G}}(z)$ that is cz^{-d} for a nonzero constant c and an integer d; see, for example, [32]. Since $\mathbf{V}(z)$ is diagonal and of the form (2.4), the above condition for the PR can be simplified further as follows.

Without loss of the generality, we assume

$$H(z) = \sum_{k=0}^{P} h[k]z^{-k}$$

where $h[0] \neq 0$, $h[P] \neq 0$, and $P \ge 1$. Let S denote the set of all zeros of the polynomial $H(z)$ of z^{-1}: $S \triangleq \{z_1, z_2, \cdots, z_P\}$ with $H(z_l) = 0$, where $z_l, 1 \le l \le P$ may not be necessarily distinct. For a constant c, let $cS \triangleq \{cz_1, cz_2, ..., cz_P\}$, which is a rotated version of S. We have the following result for the PR.

Theorem 1: There exists an FIR nonmaximally decimated multirate filterbank in Fig. 2 such that the system in Fig. 2 has an FIR ideal linear equalizer if and only if

$$\bigcap_{0 \le l_1 < l_2 < \cdots < l_K \le N-1} (S_{l_1} \cup S_{l_2} \cup \cdots \cup S_{l_K}) = \phi \tag{2.7}$$

where $S_{l_k} = W_N^{l_k} S$, $k = 1, 2, \cdots, K$.

Theorem 1 tells us that there exists a multirate filterbank in Fig. 2 for the ideal linear equalization if and only if the intersection of the unions of any K sets of all N rotated zero sets of S with angles $l2\pi/N, l = 0, 1, \cdots, N-1$ of the ISI transfer function $H(z)$ is empty. When $K = N$, the intersection in (2.7) contains at least S, which is not empty. This implies that when $K = N$, the system in Fig. 2 does not have PR in the sense of nonexistence of FIR inverses. This is not surprising because any maximally decimated multirate filterbank does not add any redundancy to the signal and, therefore, does not have any error correction capability.

$$\hat{\mathbf{H}}(z) \triangleq \begin{bmatrix} H(z) & z^{-1}H(z) & \cdots & z^{-N+1}H(z) \\ H(zW_N) & z^{-1}W_N^{-1}H(zW_N) & \cdots & z^{-N+1}W_N^{-N+1}H(zW_N) \\ \vdots & \vdots & \cdots & \vdots \\ H(zW_N^{N-1}) & z^{-1}W_N^{(-1)(N-1)}H(zW_N^{N-1}) & \cdots & z^{-N+1}W_N^{(-N+1)(N-1)}H(zW_N^{N-1}) \end{bmatrix}. \tag{2.3}$$

Proof: We first prove the "necessary part." Assume the set

$$\bigcap_{0\le l_1<l_2<\cdots<l_K\le N-1} (S_{l_1}\cup S_{l_2}\cup\cdots\cup S_{l_K})\neq\phi.$$

This implies that the polynomials $\prod_{k=1}^{K} H(W_N^{l_k}z)$ for all possible $0\le l_1<l_2<\cdots<l_K\le N-1$ has at least a common zero z_0. In other words, they have a common factor $z^{-1}-z_0^{-1}$. By the form of $\mathbf{V}(z)\hat{\mathbf{G}}(z)$ and the diagonality of $\mathbf{V}(z)$, the polynomial $\prod_{k=1}^{K} H(W_N^{l_k}z)$ is a factor of the determinant of the submatrix of $\mathbf{V}(z)\hat{\mathbf{G}}(z)$ at the rows $l_1, l_2, \cdots, l_K$. When $l_1, l_2, \cdots, l_K$ run over all possible $0\le l_1<l_2<\cdots<l_K\le N-1$, the corresponding submatrices run over all possible $K\times K$ submatrices of $\mathbf{V}(z)\hat{\mathbf{G}}(z)$. Therefore, all determinants of all $K\times K$ submatrices of $\mathbf{V}(z)\hat{\mathbf{G}}(z)$ have at least a common factor $z^{-1}-z_0^{-1}$, no matter what $\hat{\mathbf{G}}(z)$ is. This proves that $\mathbf{V}(z)\hat{\mathbf{G}}(z)$ does not have an FIR inverse.

Let us prove the "sufficient part." Assume (2.7) is true. We construct

$$\mathbf{G}(z)=\begin{bmatrix} I_K \\ \mathbf{0}_{(N-K)\times K}\end{bmatrix} \tag{2.8}$$

where $\mathbf{0}_{(N-K)\times K}$ is the all-zero $(N-K)\times K$ matrix. Then

$$\begin{aligned}\hat{\mathbf{G}}(z)&=\mathbf{W}_N^{*}\mathbf{\Lambda}(z)\mathbf{G}(z^N)=\mathbf{W}_N^{*}\text{diag }(1, z^{-1}, \cdots, z^{-K+1})\\ &=(z^{-k}W_N^{-jk})_{0\le j\le N-1,\,0\le k\le K-1}.\end{aligned}$$

It is not hard to see that the determinant of the $l_1, l_2, \cdots, l_K$ row submatrix of $\mathbf{V}(z)\hat{\mathbf{G}}(z)$ is

$$c_{l_1l_2\cdots l_K}\prod_{j=1}^{K} H(zW_N^{l_j})z^{-(1+2+\cdots+K-1)} \tag{2.9}$$

where $0\le l_1<l_2<\cdots<l_K\le N-1$, $c_{l_1l_2\cdots l_K}$ is the Vandermonde's determinant of a $K\times K$ submatrix of the following $N\times K$ matrix

$$\left(W_N^{-jk}\right)_{0\le j\le N-1,\,0\le k\le K-1}$$

which is a nonzero constant. By (2.7), the gcd of all polynomials in (2.9) is cz^{-d} for a nonzero constant c and an integer d. This proves that the matrix $\mathbf{V}(z)\hat{\mathbf{G}}(z)$ has an FIR inverse and, therefore, completes the proof. □

By the fact that

$$\bigcap_{0\le l_1<l_2<\cdots<l_{K-1}\le N-1} (S_{l_1}\cup S_{l_2}\cup\cdots\cup S_{l_{K-1}})\subset \bigcap_{0\le l_1<l_2<\cdots<l_K\le N-1} (S_{l_1}\cup S_{l_2}\cup\cdots\cup S_{l_K})$$

we have the following immediate corollary.

Corollary 1: If there exists an FIR multirate filterbank with N channels and decimation by K in Fig. 2 so that the system in Fig. 2 has an ideal FIR linear equalizer, then there also exists an FIR multirate filterbank with N channels and decimation by $K-1$ in Fig. 2 for the ideal linear equalization, where $K>1$.

Corollary 1 is not surprising. It is because that the decreasing of the decimation rate from K to $K-1$ of a nonmaximally decimated multirate filterbank means the increase of the redundancy. If a multirate filterbank with less redundancy eliminates the ISI, then the multirate filterbank with much redundancy eliminates the ISI as well.

The proof of Theorem 1 also suggests a way to construct a nonmaximally decimated multirate filterbank in Fig. 2 to eliminate the ISI of $H(z)$. When $H(z)$ satisfies the condition in Theorem 1, to have the PR, it is good enough to set the polyphase matrix of the filterbank $G_0(z)$, ..., $G_{N-1}(z)$ in Fig. 2 to be the one in (2.8), i.e.

$$\mathbf{G}(z)=\begin{bmatrix} I_K \\ \mathbf{0}_{(N-K)\times K}\end{bmatrix}.$$

This precoder basically adds $N-K$ zeros for each K symbols (or samples). It is certainly not necessary, as long as the $N\times K$ polynomial matrix $\mathbf{V}(z)\hat{\mathbf{G}}(z)$ has an FIR inverse. Put the above $\mathbf{G}(z)$ into the system in Fig. 5(b), and the overall system function becomes

$$\begin{aligned}&\hat{\mathbf{H}}(z)\mathbf{G}(z)\\ &\quad=\mathbf{F}_K(z)\\ &\quad\triangleq\begin{bmatrix} H_0(z) & z^{-1}H_{N-1}(z) & \cdots & z^{-1}H_{N-K+1}(z)\\ H_1(z) & H_0(z) & \cdots & z^{-1}H_{N-K+2}(z)\\ \vdots & \vdots & \cdots & \vdots\\ H_{K-1}(z) & H_{K-2}(z) & \cdots & H_0(z)\\ \vdots & \vdots & \cdots & \vdots\\ H_{N-1}(z) & H_{N-2}(z) & \cdots & H_{N-K}(z)\end{bmatrix}.\end{aligned} \tag{2.10}$$

By the proof of Theorem 1, when the condition (2.7) on $H(z)$ is satisfied, then $\mathbf{F}_k(z)$ in (2.10) has an FIR inverse. Conversely, if $\hat{\mathbf{H}}(z)\mathbf{G}(z)$ in (2.9) has an FIR inverse, then $x[n]$ can be recovered from $\hat{x}[n]$ in Fig. 5(b). Therefore, by Theorem 1, the condition (2.7) is satisfied. In addition, using Corollary 1, we have proved the following corollary.

Corollary 2: The $N\times K$ matrix $\mathbf{F}_K(z)$ in (2.10) with $0<K\le N$ has an FIR inverse if and only if the condition (2.7) is satisfied. The system in Fig. 2 has an ideal linear equalizer if, and only if, the matrix $\mathbf{F}_K(z)$ in (2.10) has an FIR inverse. If $\mathbf{F}_K(z)$ has an FIR inverse, then $\mathbf{F}_{K-1}(z)$ has an FIR inverse for $K>1$.

We now consider two special cases. The first case is when $K=1$. In this case, (2.7) becomes

$$\bigcap_{0\le l\le N-1} S_l=\phi. \tag{2.11}$$

By Theorem 1 and Corollary 2, we have the following result.

Corollary 3: There exists a multirate filterbank in Fig. 2 with $K=1$ for the ideal linear equalization if and only if

$$\gcd\{H(z), H(zW_N), \cdots, H(zW_N^{N-1})\}=c_1z^{-d_1}$$

if and only if

$$\gcd\{H_0(z), H_1(z), \cdots, H_{N-1}(z)\}=c_2z^{-d_2}$$

where c_1 and c_2 are two nonzero constants, and d_1 and d_2 are two integers.

The result in Corollary 3 coincides with the known result for fractionally spaced equalizers, i.e., there are no zeros of $H(z)$ equispaced on a circle with angle $2\pi/N$ separated one zero from another. From Corollary 3, we immediately have the following consequence.

Corollary 4: For any ISI transfer function $H(z)$ not identically zero, there always exists a nonmaximally decimated multirate filterbank in Fig. 2 for the ideal linear equalization of the system in Fig. 2.

The nonmaximally decimated multirate filterbank with N channels and decimation by K in Fig. 2 plays the coding role in eliminating the ISI generated from the ISI channel $H(z)$. We have already known that K has to be less than N for PR. In other words, the data rate has to be increased by $N-K>0$ for eliminating the ISI. In practice, the smallest data rate expansion is desired, which is $N-K=1$, or $K=N-1$. We next want to study this case.

Theorem 2: There exists an FIR multirate filterbank with N channels and decimation by $N-1$ in Fig. 2 such that the system in Fig. 2 has an ideal FIR linear equalizer if and only if $S_l \cap S_k = \phi$, i.e., polynomials $H(zW_N^l)$ and $H(zW_N^k)$ are coprime for $0 \le l \ne k \le N-1$.

Proof: Theorem 2 can be proved by the following set equations.

$$\bigcap_{0\le l_1<l_2<\cdots<l_{N-1}\le N-1} \left(\bigcup_{k=1}^{N-1} S_{l_k}\right) = \bigcap_{l_0=0}^{N-1} \left(\bigcup_{l\ne l_0} S_l\right) = \bigcup_{l\ne k} (S_l \cap S_k).$$

□

Let us consider the case when the ISI transfer function $H(z)=a+z^{-1}$ with $|a|=1$, i.e., the first-order case. In this case, the zero set $S=\{-1/a\}$. For a general $N, S_l = \{-W_N^l/a\}, l=0,1,\cdots,N-1$. Clearly, $S_l \cap S_k = \phi$ since $W_N^l \ne W_N^k$ when $0 \le l \ne k \le N-1$. By Theorem 2 and Corollary 1, we proved the following result.

Corollary 5: Assume the ISI transfer function $H(z) = a+z^{-1}$ in Fig. 2, where $|a|=1$. Then, the system in Fig. 2 for the multirate filterbank $\mathbf{G}(z)$ in (2.8) always has PR for any integers K and N with $0<K<N$.

Corollary 5 implies that any $\epsilon(>0)$ amount of data rate increasing in coding may eliminate the ISI generated from any first order ISI channel. This is because for any $\epsilon>0$, there exists a positive integer N such that $0<1-(N-1)/N<\epsilon$. We then use this N as the number of channels and $N-1$ as the decimation ratio in the multirate filterbank in Fig. 2.

III. Examples and Reconstruction

In this section, we study some examples and also the reconstruction of $x[n]$ from $\hat{x}[n]$ in Fig. 2, given $H(z)$ and an FIR nonmaximally decimated multirate filterbank in Fig. 2, where the system has perfect reconstruction. We first see some examples.

Example 1: $H(z)=1+z^{-1}$. By Corollary 5, one is able to recover $x[n]$ from $\hat{x}[n]$ when $\mathbf{G}(z)$ takes the form in (2.8) for any $0<K<N$. Consider $K=1$ and $N=2$. In this case, the output $\hat{x}[n]$ in Fig. 2 is

$$\hat{x}[n]: \cdots, x[0], x[0], x[1], x[1], \cdots.$$

Clearly, Fig. 6(b) gives the reconstruction.

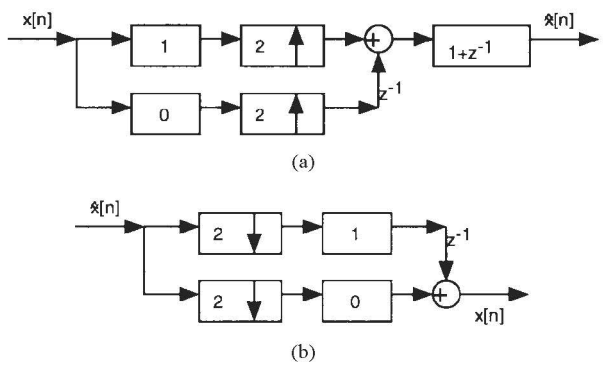


Fig. 6. (a) Transmission and channel parts. (b) Reconstruction.

Example 2: $H(z)=(1+z^{-1})(1-z^{-1})$. In this case, the zero set $S=\{1,-1\}$. When N is even, $S_0=S_{N/2}=S$. By Theorem 2, it is impossible to recover $x[n]$ from $\hat{x}[n]$ in Fig. 2 for any FIR nonmaximally decimated multirate filterbank with two channels. However, for any odd $N>2, S_l=\{W_N^l,-W_N^l\}, 0,\le l\le N-1$. Clearly, $S_l\cap S_k=\phi$ for $0\le l\ne k\le N-1$. By Theorem 2, we proved that the system in Fig. 2 with the above $H(z)$ and the multirate filterbank $\mathbf{G}(z)$ in (2.8) with $0<K<N>2$ for odd N always has an ideal FIR linear equalizer. This also implies that a little increasing of the data rate in coding may eliminate the ISI generated from the ISI channel.

Example 3: Consider a linear phase lowpass filter $H(z)$ of length 5 constructed from the Parks–McClellan algorithm of the optimal equiripple FIR filter design technique. The filter is

$$H(z)=\tfrac{1}{9}(1+2z^{-1}+2.5z^{-2}+2z^{-3}+z^{-4}). \qquad (3.1)$$

Its frequency and impulse responses are shown in Fig. 7. Its zeros and rotated zeros with angle π are shown in Fig. 8(a). Its zeros and rotated zeros with angles $2\pi/3$, $4\pi/3$ are shown in Fig. 8(b). One can see that all of them are disjoint. By Theorem 2, the multirate filterbank $\mathbf{G}(z)$ with $N=2$ or $N=3$ gives the PR of the system in Fig. 2.

Example 4: Consider a linear-phase lowpass filter $H(z)$ of length 9 also constructed from the Parks–McClellan algorithm. Its frequency and impulse response are shown in Fig. 9, and zeros and rotated versions are shown in Fig. 10. One can see that with length 9, the lowpass property is much better than the one with length 5 in Example 3, and the rotated zeros are also disjoint. The lowpass property will be useful in applications in denoising.

After we have discussed the possibility to eliminate the ISI, the next problem is the reconstruction. Suppose an FIR nonmaximally decimated multirate filterbank is designed in Fig. 2, and it is able to eliminate the ISI generated from $H(z)$. We now want to construct another multirate filterbank for the receiver to reconstruct the original signal $x[n]$ from the received one $\hat{x}[n]$.

We consider a general nonmaximally decimated multirate filterbank $\mathbf{G}(z)$ in Fig. 5. By the above assumption,

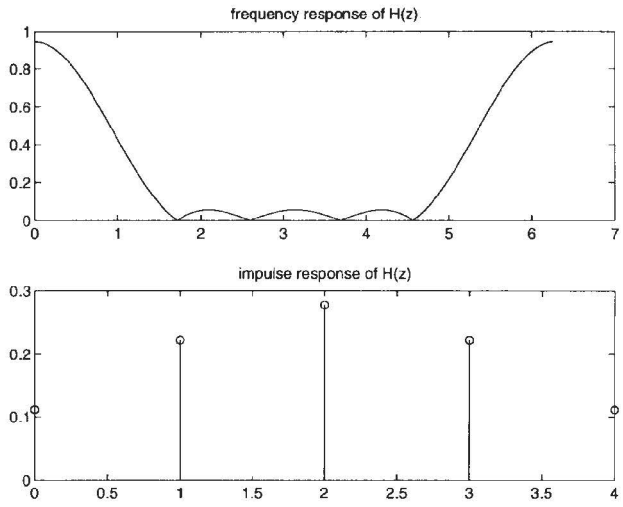


Fig. 7. Lowpass filter $H(z)$ with length 5.

we know that the overall $N \times K$ multirate system matrix $\mathbf{F}(z) \triangleq \mathbf{H}(z)\mathbf{G}(z)$ has an FIR inverse. The problem is then to find its inverse $\mathbf{F}^{-1}(z)$ in the sense that $\mathbf{F}^{-1}(z)\mathbf{F}(z) = I_K$. Then, $x[n]$ can be recovered by $\mathbf{F}^{-1}(z)\hat{x}[n]$. To find $\mathbf{F}^{-1}(z)$, we use the Smith form decomposition technique [32] as described below.

It is known [32] that any $N \times K$ polynomial matrix $\mathbf{F}(z)$, where all components are polynomials of z^{-1}, can be decomposed into a product of three polynomial matrices $\mathbf{U}(z)$, $\mathbf{\Lambda}(z)$, and $\mathbf{W}(z)$:

$$\mathbf{F}(z) = \mathbf{U}(z)\mathbf{\Lambda}(z)\mathbf{W}(z) \tag{3.2}$$

where $\mathbf{U}(z)$ and $\mathbf{W}(z)$ are $N \times N$ and $K \times K$ unimodular matrices, respectively, and $\mathbf{\Lambda}(z)$ is diagonal with the form

$$\mathbf{\Lambda}(z) = \begin{Bmatrix} \text{diag } [\lambda_1(z), \cdots, \lambda_\rho(z)] \\ 0_{(N-K)\times K} \end{Bmatrix}$$

where ρ is the normal rank of $\mathbf{F}(z)$, $\lambda_l(z)$ divides $\lambda_{l+1}(z)$ for $l = 1, 2, \cdots, \rho - 1$, $\lambda_l(z) = \Delta_{l+1}(z)/\Delta_l(z)$ with $\Delta_1(z) = 1$, and $\Delta_l(z), l > 1$, which is the gcd of all the determinants of all the $(l-1) \times (l-1)$ submatrices of $\mathbf{F}(z)$. A square polynomial matrix is *unimodular* means that its determinant is a nonzero constant.

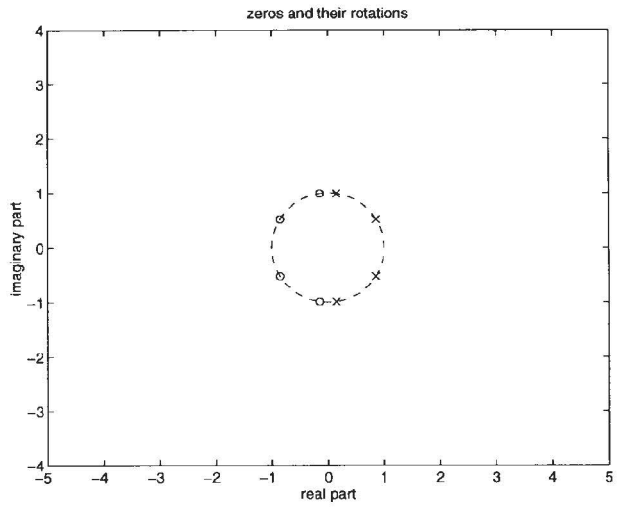
When $\mathbf{F}(z)$ has an inverse, we then have $\rho = K$ and $\Delta_{K+1}(z) = cz^{-d}$ for a nonzero constant c and an integer d. Therefore, when $\mathbf{F}(z)$ has an inverse, the diagonal matrix $\mathbf{\Lambda}(z)$ in (3.2) has the form

$$\mathbf{\Lambda}(z) = \text{diag } (z^{-d_0}, z^{-d_1}, \cdots, z^{-d_{K-1}}) \tag{3.3}$$

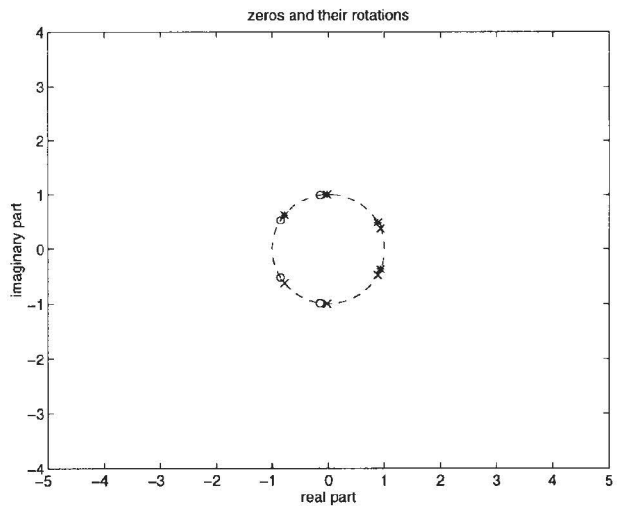
for K integers $d_0, d_1, \cdots, d_{K-1}$. Using the above analysis, we have that the overall system in Fig. 4 has the following decomposition

$$\mathbf{F}(z) = \mathbf{H}(z)\mathbf{G}(z) = \mathbf{U}(z)\mathbf{\Lambda}(z)\mathbf{W}(z) \tag{3.4}$$

where $\mathbf{U}(z)$ and $\mathbf{W}(z)$ are $N \times N$ and $K \times K$ unimodular matrices, respectively, and $\mathbf{\Lambda}(z)$ has the form in (3.3). With



(a)



(b)

Fig. 8. Length 5 filter: (a) Zeros marked by "o," their rotations with angle π marked by "x." (b) Zeros marked by "o," their rotations with angles $2\pi/3$ and $4\pi/3$ marked by "x" and "*," respectively. Dashed line: the unit circle.

the form (3.4) of $\mathbf{F}(z)$ (see Fig. 10), its inverse is

$$\mathbf{F}^{-1}(z) = \mathbf{W}^{-1}(z)[\text{diag } (z^{d_0}, z^{d_1}, \cdots, z^{d_{K-1}}) \; \mathbf{0}_{K\times(N-K)}]\mathbf{U}^{-1}(z). \tag{3.5}$$

The reconstruction can be achieved by the diagram shown in Fig. 11.

Given a polynomial matrix, there is a systematic way to find its Smith form. For more details, see [32].

IV. Applications in the ISI Cancellation

We now consider the application for the ISI cancellation. Example 3 in Section III is used as the ISI transfer function. For its frequency and impulse responses, see Fig. 7.

By the theory in Sections II and III, and the properties of its zero sets shown in Fig. 8(a), it is known that the nonmaximally decimated multirate filterbank with two channels and decimation 1 and its polyphase matrix in (2.8) is able to eliminate the ISI. This implies that when we insert 0 between each two samples $x[n], \cdots, x[0], 0, x[1], 0, \cdots$, which is the signal to

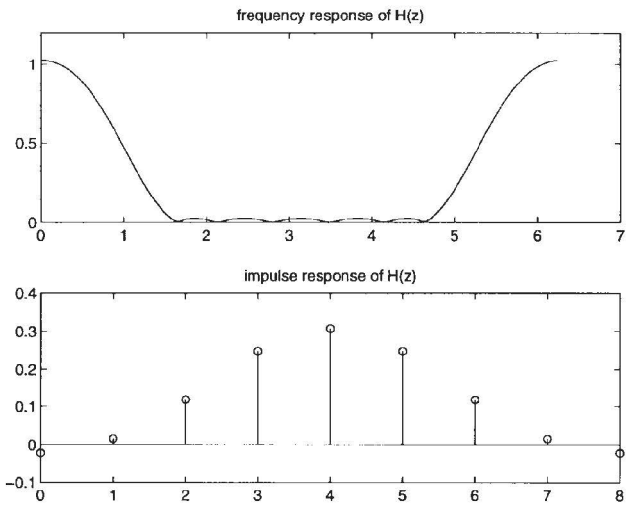


Fig. 9. Lowpass filter $H(z)$ with length 9.

be transmitted, we can reconstruct $x[n]$ from the output $\hat{x}[n]$ of the ISI transfer function $H(z)$. In this case, the overall system transfer matrix $\mathbf{F}(z)$ is

$$\mathbf{F}(z) = \frac{1}{9}\begin{bmatrix} 1 + 2.5z^{-1} + z^{-2} \\ 2 + 2z^{-1} \end{bmatrix}. \tag{4.1}$$

Its inverse can be calculated as

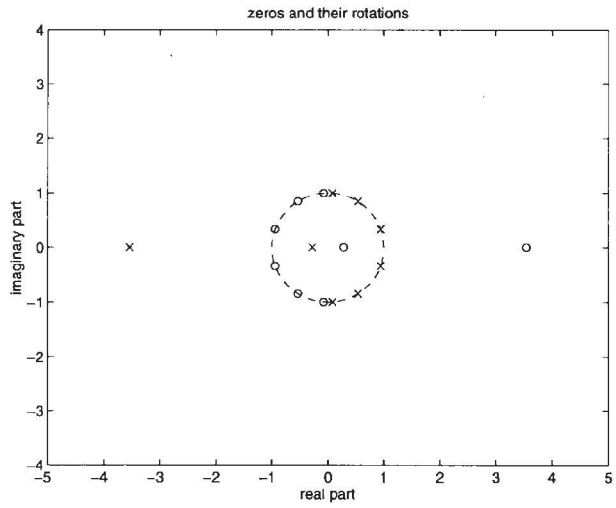
$$\mathbf{F}^{-1}(z) = 9\,(-2,\ 1.5 + z^{-1}). \tag{4.2}$$

With the above inverse, we apply the reconstruction scheme shown in Fig. 11 to the received signal. The simulation results are shown in Fig. 12 with the original signal $x[n]$, the ISI transfer function in the frequency domain, the received signal $\hat{x}[n]$ after the channel, and, finally, the reconstruction with mean square error 7.0704×10^{-7}. In addition to the ISI, if there is a random noise in transmission, the above reconstruction is robust. A numerical example is shown in Fig. 13, where the maximum magnitude of the additive channel white noise is 0.05, whereas the one for the original signal shown in Fig. 12 is 1. The mean square error for the reconstruction is 0.004.

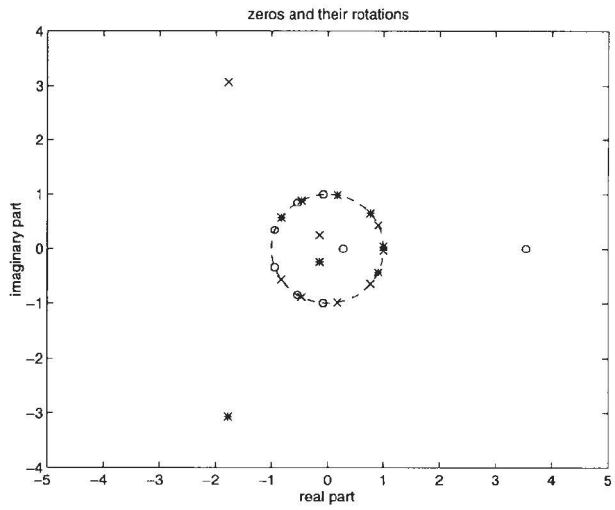
By the property of zeros and their rotations shown in Fig. 8(b), the above increasing of the transmission rate can be reduced by using the nonmaximally decimated multirate filterbank with three channels and decimation 2 in (2.8). In other words, the rate 1/2 can be reduced to 2/3. In this case, the overall system transfer matrix $\mathbf{F}(z)$ is

$$\mathbf{F}(z) = \frac{1}{9}\begin{bmatrix} 1 + 2z^{-1} & 2.5z^{-1} \\ 2 + z^{-1} & 1 + 2z^{-1} \\ 2.5 & 2 + z^{-1} \end{bmatrix}. \tag{4.3}$$

Its inverse can be calculated as shown in (4.4), shown at the bottom of the page. Numerical simulations are given in Fig. 14 without random channel noise and, in Fig. 15, with additional channel additive white noise. One can see that the reconstruction is also robust.



(a)



(b)

Fig. 10. Length 9 filter: (a) Zeros marked by "o," their rotations with angle π marked by "x." (b) Zeros marked by "o," their rotations with angle $2\pi/3$ and $4\pi/3$ marked by "x" and "*," respectively. Dashed line: the unit circle.

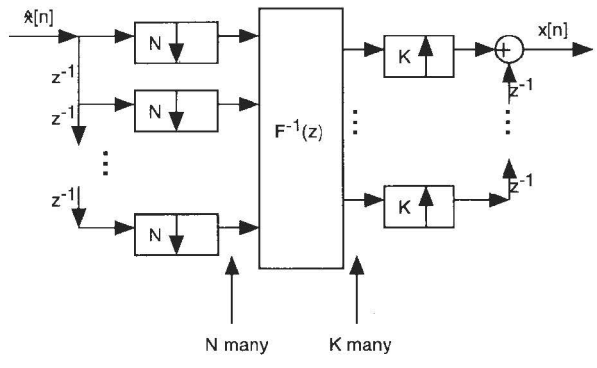


Fig. 11. Reconstruction.

$$\mathbf{F}^{-1}(z) = 9\begin{bmatrix} -\frac{16}{35} - \frac{56}{35}z^{-1} - \frac{24}{35}z^{-2} & \frac{68}{35} + \frac{130}{35}z^{-1} + \frac{48}{35}z^{-2} & -\frac{34}{35} - \frac{96}{35}z^{-1} - \frac{36}{35}z^{-2} \\ \frac{4}{7} + \frac{12}{7}z^{-1} & -\frac{17}{7} - \frac{24}{7}z^{-1} & \frac{12}{7} + \frac{18}{7}z^{-1} \end{bmatrix} \tag{4.4}$$

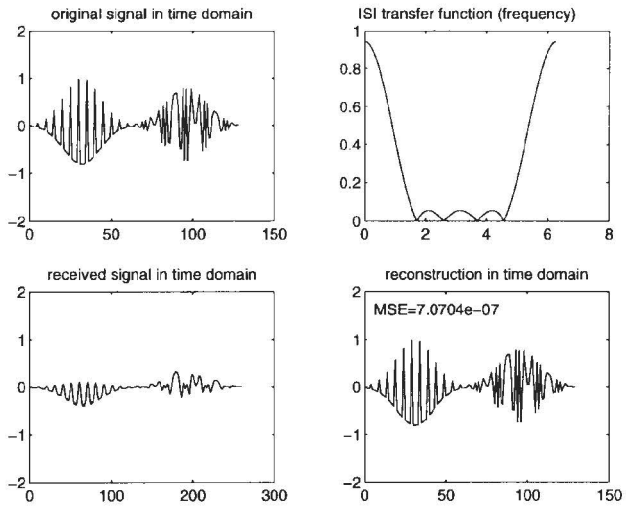


Fig. 12. Rate 1/2 multirate filterbank for the ISI cancellation without random noise in channel.

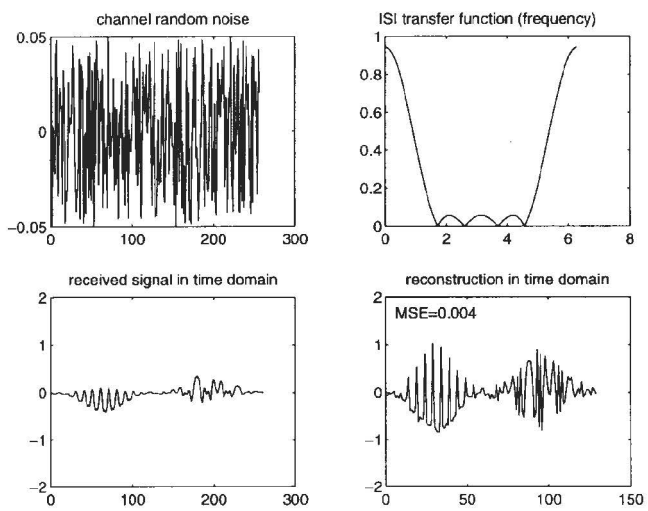


Fig. 13. Rate 1/2 multirate filterbank for the ISI cancellation with additional channel additive white noise.

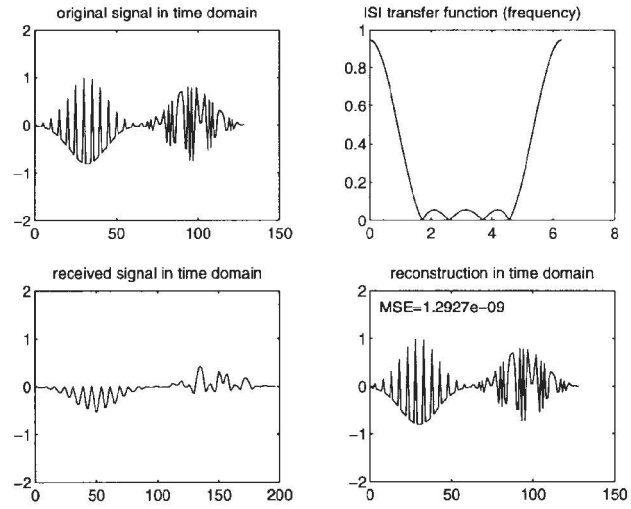


Fig. 14. Rate 2/3 multirate filterbank for the ISI cancellation without random noise in channel.

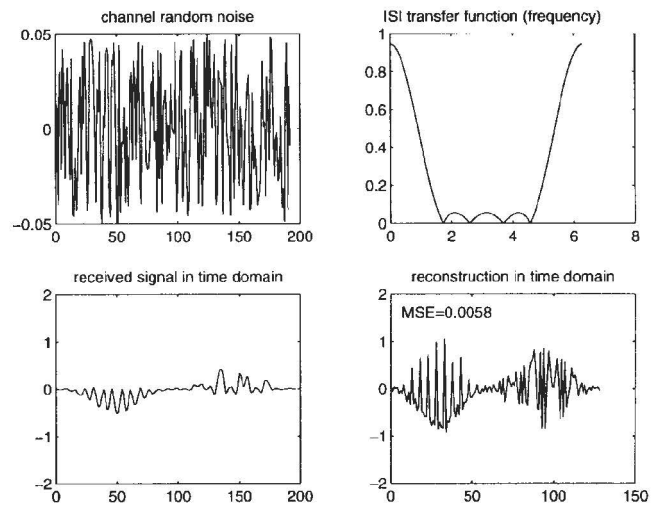


Fig. 15. Rate 2/3 multirate filterbank for the ISI cancellation with additional channel additive white noise.

Remarks: One can further reduce the data rate 2/3 by using a multirate filterbank in (2.8) with $N > 3$ and $K = N - 1$. For simplicity, we do not go to higher N's here. Another point that should be noticed is that the above ISI cancellation technique is data independent. Although we use the Smith form decomposition technique for the equalization, it is certainly possible and might be better that some existing equalization techniques, such as [23]–[29], [36], [38], are applicable.

V. Conclusions

In this paper, we have studied nonmaximally decimated multirate filterbanks as precoders for the ISI elimination, where each K samples are expanded into N samples. When $K = 1$, it is equivalent to the fractionally spaced equalizers, where the sampling rate is N times faster than the baud rate in the receiver. We have found a necessary and sufficient condition on the ISI transfer function for the existence of an FIR ideal linear equalizer. The condition coincides with the known one for the fractionally spaced equalizers when $K = 1$. The condition is not difficult to check when the ISI transfer function is known. In particular, we obtained a simplified version of the condition for an FIR nonmaximally decimated multirate filterbank precoder with N channels and the largest decimation, i.e., $K = N - 1$, which corresponds to the case of the smallest bandwidth expansion in the precoding. The condition can be stated as follows: All rotations of the zero set of the FIR transfer function $H(z)$ at angles $l2\pi/N$ for $l = 0, 1, \cdots, N - 1$ are disjoint from each other. These conditions are basically easy to satisfy. Thus, the approach in this paper suggests that the sampling rate that is N/K times faster than the baud rate for the receiver may be good enough. Moreover, the approach in this paper also suggests the possibility of other precoders besides the trivial one in (2.8) or the constants in [39].

The new precoding method proposed in this paper differs from the existing precoding methods in the following aspects.

It is reliable for any FIR ISI channel, including spectral-null channels, may be independent of the ISI channel, does not implement any modulo operations and is linear; however, it expands the transmission bandwidth with a minimum amount as a sacrifice. This paper provides a framework on the ISI cancellation using multirate filterbanks as precoders. Many practical implementation issues still remain to be investigated in the future.

As a final remark, in this paper, the receiver needs to know the ISI channel characteristics. Most recently, we have studied precoding equalizations without knowing the ISI channel characteristics for the transmitter or the receiver in [41]–[46]. Particularly, ambiguity resistant precoders have been studied in [41]–[44] to combat the ISI.

ACKNOWLEDGMENT

The author would like to thank R. Matic and B. Soffer at Hughes Research Laboratories for their support, encouragement, and various discussions on the subject. He also wishes to thank the reviewers for carefully reading this manuscript and connecting it with the existing blind equalization techniques.

REFERENCES

[1] C. A. Belfiore and J. H. Park, "Decision feedback equalization," *Proc. IEEE,* vol. 67, pp. 1143–1156, Aug. 1979.
[2] J. G. Proakis, "Adaptive equalization for TDMA digital mobile radio," *IEEE Trans. Veh. Technol.,* vol. 40, pp. 333–341, May 1991.
[3] ——, *Digital Communications.* New York: McGraw-Hill, 1989.
[4] J. Chow, J. M. Cioffi, and J. Bingham, "A discrete multitone transceiver system for HDSL applications," *IEEE J. Select. Areas Commun.,* vol. 9, pp. 895–908, Aug. 1991.
[5] M. Sablatash, "Transmission of all-digital advanced television: State of the art and future directions," *IEEE Trans. Broadcasting,* vol. 40, pp. 102–121, June 1994.
[6] W. Y. Zou and Y. Wu, "COFDM: An overview," *IEEE Trans. Broadcasting,* vol. 40, pp. 1–8, Mar. 1995.
[7] M. Tomlinson, "New automatic equalizer employing modulo arithmetic," *Electron. Lett.,* vol. 7, pp. 138–139, Mar. 1971.
[8] H. Harashima and H. Miyakawa, "Matched-transmission technique for channels with intersymbol interference," *IEEE Trans. Commun.,* vol. COMM-30, pp. 774–780, Aug. 1972.
[9] M. V. Eyuboglu and G. D. Forney, Jr., "Trellis precoding: Combined coding, precoding and shaping for intersymbol interference channels," *IEEE Trans. Inform. Theory,* vol. 38, pp. 301–314, Mar. 1992.
[10] G. D. Forney, Jr., "Trellis shaping," *IEEE Trans. Inform. Theory,* vol. 38, pp. 281–300, Mar. 1992.
[11] R. Laroia, S. A. Tretter, and N. Farvardin, "A simple and effective precoding scheme for noise whitening on intersymbol interference channels," *IEEE Trans. Commun.,* vol. 41, pp. 1460–1463, Oct. 1993.
[12] R. Karabed and P. H. Siegel, "Matched spectral-null codes for partial-response channels," *IEEE Trans. Inform. Theory,* vol. 37, pp. 818–855, May 1991.
[13] J. K. Wolf and G. Ungerboeck, "Trellis coding for partial-response channels," *IEEE Trans. Commun.,* vol. COMM-34, pp. 765–773, Aug. 1986.
[14] A. R. Calderbank, C. Heegard, and T. A. Lee, "Binary convolutional codes with application to magnetic recording," *IEEE Trans. Inform. Theory,* vol. IT-32, pp. 797–815, Nov. 1986.
[15] L.-F. Wei, "Precoding technique for partial-response channels with applications to HDTV transmission," *IEEE J. Select. Areas Commun.,* vol. 11, pp. 127–135, Jan. 1993.
[16] K. A. S. Immink, "Coding techniques for noisy magnetic recording channel: A state-of-the-art report," *IEEE Trans. Commun.,* vol. COMM-37, pp. 413–419, May 1987.
[17] S. Kasturia, J. Aslanis, and J. Cioffi, "Vector-coding for partial-response channels," *IEEE Trans. Inform. Theory,* vol. 36, pp. 741–762, July 1990.
[18] Y. Sato, "A method of self-recoving equalization for multi-level amplitude modulation," *IEEE Trans. Commun.,* vol. COMM-23, pp. 679–682, June 1975.
[19] D. N. Godard, "Self-recoving equalization and carrier tracking in two-dimensional data communication systems," *IEEE Trans. Commun.,* vol. COMM-28, pp. 1867–1875, Nov. 1980.
[20] O. Shalvi and E. Weinstein, "New criteria for blind deconvolution of nonminimum phase systems (channels)," *IEEE Trans. Inform. Theory,* vol. 36, pp. 312–321, Mar. 1990.
[21] D. Hatzinakos and C. L. Nikias, "Estimation of multipath channel response in frequency selective channels," *IEEE J. Select. Areas. Commun.,* vol. 7, pp. 12–19, Jan. 1989.
[22] G. B. Giannakis and J. M. Mendel, "Identification of nonminimum phase systems using higher order statistics," *IEEE Trans. Acoust., Speech, Signal Processing,* vol. 37, pp. 360–377, 1989.
[23] W. A. Gardner, "A new method of channel identification," *IEEE Trans. Commun.,* vol. 39, pp. 813–817, 1991.
[24] L. Tong, G. Xu, and T. Kailath, "A new approach to blind identification and equalization of multipath channels," in *Proc. IEEE 25th Asilomar Conf. Signals, Syst., Comput.,* Nov. 1991, pp. 856–860.
[25] Z. Ding and Y. Li, "Channel identification using second order cyclic statistics," in *Proc. IEEE 25th Asilomar Conf. Signals, Syst., Comput.,* Oct. 1992, pp. 334–338.
[26] G. Xu, H. Liu, L. Tong, and T. Kailath, "A least-square approach to blind channel identification," *IEEE Trans. Signal Processing,* vol. 43, pp. 2982–2993, Dec. 1995.
[27] H. Liu and G. Xu, "Closed-form blind symbol estimation in digital communications," *IEEE Trans. Signal Processing,* vol. 43, pp. 2714–2723, Nov. 1995.
[28] S. Talwar, M. Viberg, and A. Paulraj, "Blind estimation of multiple cochannel digital signals using an antenna array," *IEEE Signal Processing Lett.,* vol. 1, pp. 29–31, Feb. 1994.
[29] J. K. Tugnait, "Blind equalization and estimation of FIR communications channels using fractional sampling," *IEEE Trans. Commun.,* vol. 44, pp. 324–336, Mar. 1996.
[30] S. K. Mitra and R. Gnanasekaran, "Block implementation of recursive digital filters—New structures and properties," *IEEE Trans. Circuits Syst.,* vol. CAS-25, pp. 200–207, Apr. 1978.
[31] T. Q. Nguyen, "Partial spectrum reconstruction using digital filter bank," *IEEE Trans. Signal Processing,* vol. 41, pp. 2778–2795, Sept. 1993.
[32] P. P. Vaidyanathan, *Multirate Systems and Filter Banks.* Englewood Cliffs, NJ: Prentice-Hall, 1993.
[33] X.-G. Xia, "Applications of multirate filterbanks in error correction codes: Partial response channels," in *Proc. SPIE,* Orlando, FL, Apr. 1996.
[34] ——, "Applications of nonmaximally decimated multirate filterbanks in partial response channel ISI cancellation," in *Proc. IEEE Third Time-Frequency Time-Scale Symp.,* Paris, France, June 1996.
[35] K. Pahlavan and A. H. Levesque, *Wireless Information Networks.* New York: Wiley, 1995.
[36] D. T. M. Slock, "Blind fractionally-spaced equalization based on cyclostationarity and second-order statistics," in *Proc. ATHOS Workshop Syst. Identification Higher Order Statist.,* Sophia Antipolis, France, Sept. 1993.
[37] J. K. Tugnait, "Blind equalization and estimation of FIR communication channels using fractional sampling," *IEEE Trans. Commun.,* vol. 44, pp. 324–336, Mar. 1996.
[38] G. B. Giannakis and S. Halford, "Blind fractionally-spaced equalization of noisy FIR channels: Adaptive and optimal solutions," in *Proc. ICASSP,* Detroit, MI, May 1995.
[39] M. K. Tsatsanis and G. B. Giannakis, "Fractional spacing or channel coding for blind equalization?," in *Proc. Int. Conf. Commun. Contr.: Telecom./Signal Process. Multimedia Era,* Rithymna/Crete, Greece, June 26–30, 1995, pp. 451–462, invited paper.
[40] G. W. Wornell, "Emerging applications of multirate signal processing and wavelets in digital communications," in *Proc. IEEE,* vol. 84, pp. 586–603, Apr. 1996.
[41] H. Liu and X.-G. Xia, "Precoding techniques for undersampled multi-receiver communication systems," submitted for publication.
[42] X.-G. Xia and H. Liu, "Polynomial ambiguity resistant precoders: Theory and applications in ISI/multipath cancellation," submitted for publication.
[43] X.-G. Xia and G. Zhou, "On optimal ambiguity resistant precoders in ISI/multipath cancellation," submitted for publication.
[44] X.-G. Xia, "Modulated coding and least square decoding via coded modulation and Viterbi decoding," submitted for publication.
[45] G. B. Giannakis, "Filterbanks for blind channel identification and equalization," *IEEE Signal Processing Lett.,* to be published.
[46] E. Serpedin and G. B. Giannakis, "Blind channel identification and equalization with modulation induced cyclostationarity," in *Proc. 31st Conf. Inform. Sci. Syst.,* Johns Hopkins Univ., Baltimore, MD, Mar. 1997.

Xiang-Gen Xia (M'97) received the B.S. degree in mathematics from Nanjing Normal University, Nanjing, China, the M.S. degree in mathematics from Nankai University, Tianjin, China, and the Ph.D. degree in electrical engineering from the University of Southern California, Los Angeles, in 1983, 1986, and 1992, respectively.

He was a Lecturer at Nankai University from 1986 to 1988, a Teaching Assistant at the University of Cincinnati, Cincinnati, OH, from 1988 to 1990, a Research Assistant at the University of Southern California from 1990 to 1992, and a Research Scientist at the Air Force Institute of Technology, Wright-Patterson AFB, OH, from 1993 to 1994. He was a Senior Research Staff Member at Hughes Research Laboratories, Malibu, CA, from 1995 to 1996. In September 1996, he joined the Department of Electrical Engineering, University of Delaware, Newark, where he is currently an Assistant Professor. His current research interests include communication systems, including equalization and coding, wavelet transform and multirate filterbank theory and applications, time-frequency analysis and synthesis, and numerical analysis and inverse problems in signal/image processing.

Dr. Xia received the National Science Foundation Faculty Early Career Development (CAREER) Program Award in 1997. He is currently an Associate Editor of the IEEE TRANSACTIONS ON SIGNAL PROCESSING. He is also a member of the American Mathematical Society.

Exhibit F1

EXPLORE THE BRITISH LIBRARY

Item Details

FMT	SE
LDR	as a2200289 a 4500
001	012102482
003	Uk
005	20200701005240.0
007	ta
008	920318c19919999xxumr p 0 a0eng
0220	|a 1053-587X
040	|a Uk |c Uk |d Uk
08204	|a 621.3822 |2 21
084	|a RV 50 |2 blsrissc
084	|a RQ 81 |2 blsrissc
2100	|a IEEE trans. signal process.
222 0	|a IEEE transactions on signal processing
24500	|a IEEE transactions on signal processing.
260	|a New York, N.Y. : |b Institute of Electrical and Electronics Engineers, |c 1991-
300	|a v. : |b ill. ; |c 28 cm.
310	|a Monthly
336	|a text |2 rdacontent
337	|a unmediated |2 rdamedia
338	|a volume |2 rdacarrier
3620	|a Vol. 39, no. 1 (Jan. 1991)-
500	|a Title from cover.
5102	|a Chemical abstracts |x 0009-2258 |b Jan. 1991-
500	|a Published for the IEEE Signal Processing Society.
530	|a Also available by subscription via the World Wide Web.
595	|a FORMERLY 4363.107 UP TO VOL. 38, 1990 SEE ALSO 4363.107 FOR OTHER EXTERNAL HOLDINGS SEE ALSO SERIAL RECORDS KCS-SE.
650 0	|a Signal processing |v Periodicals.
650 0	|a Speech processing systems |v Periodicals.
7102	|a IEEE Signal Processing Society.
77608	|i Also issued online |t IEEE transactions on signal processing (Online) |x 1941-0476
78000	|t IEEE transactions on acoustics, speech, and signal processing |x 0096-3518
945	|a IEEE TRANSACTIONS ON SIGNAL PROCESSING.
LKR	|a PAR |b 009844962 |l BLL01 |r 78000 |m IEEE transactions on signal processing |n I.E.E.E. transactions on acoustics, speech, and signal processing
85241	|a British Library |b DSC |j 4363.219900
866 0	|a Vol. 39, no. 1 (1991)-v. 60, no. 12 (2012) |z UKRR Retained Title
85271	|a British Library |b STI |k (P) |h RV 50 |m -E(3) |2 blsrissc
866 0	|a Vol. 39 (1991)-v. 50 (2002)
SYS	012102482

Exhibit F2

LIBRARY OF CONGRESS AUTHORITIES

LC control no.: sh2010113087
LCCN Permalink: https://lccn.loc.gov/sh2010113087
HEADING: Signal processing Periodicals

000 00451cz a2200169n 450
001 8366007
005 20110729164255.0
008 100803|| anannbabn |n ana
010 __ |**a** sh2010113087
035 __ |**a** (DLC)478976
035 __ |**a** (DLC)sh2010113087
040 __ |**a** DLC |**b** eng |**c** DLC
150 __ |**a** Signal processing |**v** Periodicals
667 __ |**a** Record generated for validation purposes.
670 __ |**a** Work cat.: Signal processing,
906 __ |**t** 8888 |**u** tc00 |**v** 0
953 __ |**a** tc00

◀ Previous Next ▶

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit F3

The Library of Congress

>> Go to Library of Congress Online Catalog

LIBRARY OF CONGRESS AUTHORITIES

Library buildings are closed to the public until further notice, but LC Authorities is available. More.

Help | New Search | Search History | Headings List | Start Over

◀ Previous Next ▶

MARC Display | Labelled Display

LC control no.: sh2010113088
LCCN Permalink: https://lccn.loc.gov/sh2010113088
HEADING: Speech processing systems Periodicals

000 00487cz a2200169n 450
001 8366008
005 20110729164255.0
008 100803|| anannbabn |n ana
010 __ |**a** sh2010113088
035 __ |**a** (DLC)478977
035 __ |**a** (DLC)sh2010113088
040 __ |**a** DLC |**b** eng |**c** DLC
150 __ |**a** Speech processing systems |**v** Periodicals
667 __ |**a** Record generated for validation purposes.
670 __ |**a** Work cat.: IEEE transactions on signal processing, c1991-
906 __ |**t** 8888 |**u** tc00 |**v** 0
953 __ |**a** tc00

◀ Previous Next ▶

Save, Print or Email Records (View Help)

Select Download Format: Text (Labelled Display) Press to SAVE or PRINT

Email Text (Labelled Display) to: Press to SEND EMAIL

Help - Search - Search History - Headings List - Start Over

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit F4

OCLC 22582582 **No holdings in XXX - 426 other holdings**

						Rec Stat		**Entered**	19901025	**Replaced**	20180324182157.9		
Continuing Resources													
Type	a	**ELvl**		**Srce**	c	**GPub**		**Ctrl**				**Lang**	eng
BLvl	s	**Form**		**Conf**	0	**Freq**	m	**MRec**				**Ctry**	nyu
S/L	0	**Orig**		**EntW**		**Regl**	r	**Alph**	a				
Desc	a	**SrTp**	p	**Cont**		**DtSt**	c	**Dates**	1991	,	9999		

010 91642053 $z sn 90004861
040 NSD $b eng $c NSD $d WAU $d NSD $d NYG $d DLC $d COO $d DLC $d NST $d NSD $d ELM $d HUL $d NST $d DLC $d CAS $d DLC $d MYG $d IUL $d NST $d IUL $d NST $d DLC $d MYG $d CUS $d MYG $d SYS $d IEEEX $d NLM $d OCLCQ $d NLGGC $d NSD $d OCLCQ $d OCLCF $d OCLCO $d OCLCA $d IUL $d OCLCO $d OCLCA
012 $i 9104 $k 1 $l 1 $m 1
016 7 9885223 $2 DNLM
016 7 SR0070324 $2 DNLM
019 173448432 $a 1012002384 $a 1013229445 $a 1029222376
022 0 1053-587X $l 1053-587X $2 1
030 ITPRED
032 256620 $b USPS
037 $b IEEE Service Center, P.O. Box 1331, 445 Hoes Lane, Piscataway, NJ 08855-1331
042 nsdp $a pcc
050 00 TK5981 $b .I2
082 00 621.382/2/05 $2 20
090 $b
210 0 IEEE trans. signal process.
222 0 IEEE transactions on signal processing
245 00 IEEE transactions on signal processing : $b a publication of the IEEE Signal Processing Society.
246 30 Institute of Electrical and Electronics Engineers transactions on signal processing
246 30 Transactions on signal processing
246 30 Signal processing
260 New York, NY : $b Institute of Electrical and Electronics Engineers, $c c1991-
300 v. : $b ill. ; $c 28 cm.
310 Monthly
362 0 Vol. 39, no. 1 (Jan. 1991)-
500 Title from cover.
510 2 Chemical abstracts $x 0009-2258 $b Jan. 1991-
588 Latest issue consulted: Vol. 39, no. 6 (June 1991.
650 0 Electro-acoustics $v Periodicals.
650 0 Signal processing $v Periodicals.
650 0 Speech processing systems $v Periodicals.
650 17 Signaalverwerking. $2 gtt
650 7 Electro-acoustics. $2 fast $0 (OCoLC)fst00906339
650 7 Signal processing. $2 fast $0 (OCoLC)fst01118281
650 7 Speech processing systems. $2 fast $0 (OCoLC)fst01129243

655 7 Periodicals. $2 fast $0 (OCoLC)fst01411641
710 2 IEEE Signal Processing Society.
776 08 $i Online version: $t IEEE transactions on signal processing (Online) $x 1941-0476 $w (DLC) 2008212918 $w (OCoLC)44608166
776 08 $i Online version: $t IEEE transactions on signal processing $w (OCoLC)623586529
780 00 $t IEEE transactions on acoustics, speech, and signal processing $x 0096-3518 $w (DLC) 74646881 $w (OCoLC)1156938
850 AAP $a ArU $a AzTeS $a CSt $a CU-A $a CU-I $a CU-RivP $a CU-SB $a CoFS CoU $a DGW $a DLC $a DeU $a ICarbS $a IaU $a InLP $a InU $a MBU $a MCM $a MH-GM $a MdBJ $a MdU $a MiEM $a MiU $a MnU $a MoKL $a MoU $a MsSM $a NBuU $a NN $a NNC $a NNE $a NRU $a NSyU $a NcD $a NcRS $a NcU $a NjP $a NjR $a NmU $a OCP $a OCU $a OU $a OrCS $a PPD $a PPiM $a PU $a RPB-S $a TU $a TxHR $a ViBlbV
856 41 $u http://ieeexplore.ieee.org/servlet/opac?punumber=78

Exhibit F5

LIBRARY OF CONGRESS AUTHORITIES

LC control no.: sh2009124777
LCCN Permalink: https://lccn.loc.gov/sh2009124777
HEADING: Electro-acoustics Periodicals

000 00472cz a2200169n 450
001 8044974
005 20110729162630.0
008 091006|| anannbabn |n ana
010 __ |**a** sh2009124777
035 __ |**a** (DLC)440618
035 __ |**a** (DLC)sh2009124777
040 __ |**a** DLC |**b** eng |**c** DLC
150 __ |**a** Electro-acoustics |**v** Periodicals
667 __ |**a** Record generated for validation purposes.
670 __ |**a** Work cat.: IEEE signal processing magazine, c1991-
906 __ |**t** 8888 |**u** tc00 |**v** 0
953 __ |**a** tc00

◀ Previous Next ▶

Save, Print or Email Records (View Help)

Select Download Format: Text (Labelled Display) Press to SAVE or PRINT

Email Text (Labelled Display) to: Press to SEND EMAIL

Library of Congress
URL: https://www.loc.gov/

Mailing Address:
101 Independence Ave, S.E.
Washington, DC 20540

Library of Congress Authorities
URL: http://authorities.loc.gov/
Library of Congress Online Catalog
URL: https://catalog.loc.gov/

Questions, comments, error reports: Contact Us

Exhibit F6

New precoding for intersymbol interference cancellation using nonmaximally decimated multirate filterbanks with ideal FIR equalizers

Publisher: IEEE

Xiang-Gen Xia All Authors

Abstract: In this paper, we propose a new precoding method for intersymbol interference (ISI) cancellation by using non-maximally decimated multirate filterbanks. Unlike the existi... **View more**

Metadata

Abstract:
In this paper, we propose a new precoding method for intersymbol interference (ISI) cancellation by using non-maximally decimated multirate filterbanks. Unlike the existing preceding methods, such as the TH and trellis precodings, the new preceding (i) may be independent of the ISI channel; (ii) is linear and does not have to implement any modulo operation; (iii) gives the ideal FIR equalization at the receiver for any FIR ISI channel including spectral-null channels; (iv) expands the transmission bandwidth in a minimum amount. The precoding is built on non-maximally decimated multirate filterbanks. Based on multirate filterbank theory, we present a necessary and sufficient condition on an FIR ISI transfer function in terms of its zero set such that there is a linear FIR N/spl times/M precoder so that an ideal FIR equalizer exists, where the integers K and N are arbitrarily fixed. The condition is easy to check. As a consequence of the condition, for any given FIR ISI transfer function (not identically 0), there always exist such linear FIR precoders. Moreover, for almost all given FIR ISI transfer functions, there exist linear FIR precoders

with size N/spl times/(N-1), i,e., the bandwidth is expanded by 1/N. In addition to the conditions on the ISI transfer functions, a method for the design of the linear FIR precoders and the ideal FIR equalizers is also given. Numerical examples are presentec to illustrate the theory.

Published in: IEEE Transactions on Signal Processing (Volume: 45 , Issue: 10, Oct 1997)

Page(s): 2431 - 2441

INSPEC Accession Number: 5728514

Date of Publication: Oct 1997

DOI: 10.1109/78.640709

ISSN Information:

Publisher: IEEE

Authors

References

Citations

Keywords

Metrics

IEEE Personal Account

CHANGE USERNAME/PASSWORD

Purchase Details

PAYMENT OPTIONS

VIEW PURCHASED DOCUMENTS

Profile Information

COMMUNICATIONS PREFERENCES

PROFESSION AND EDUCATION

TECHNICAL INTERESTS

Need Help?

US & CANADA: +1 800 678 4333

WORLDWIDE: +1 732 981 0060

CONTACT & SUPPORT

Follow

About IEEE *Xplore* | Contact Us | Help | Accessibility | Terms of Use | Nondiscrimination Policy | Sitemap | Privacy & Opting Out of Cookies

A not-for-profit organization, IEEE is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity.

IEEE Account

» Change Username/Password

» Update Address

Purchase Details

» Payment Options

» Order History

» View Purchased Documents

Profile Information

» Communications Preferences

» Profession and Education

» Technical Interests

Need Help?

» **US & Canada:** +1 800 678 4333

» **Worldwide:** +1 732 981 0060

» Contact & Support

About IEEE *Xplore* | Contact Us | Help | Accessibility | Terms of Use | Nondiscrimination Policy | Sitemap | Privacy & Opting Out of Cookies

A not-for-profit organization, IEEE is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity.