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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/185,729	08/04/2008	John M. Cioffi	8241.P002D

CONFIRMATION NO. 9857

Adaptive Spectrum and Signal Alignment, Inc.
333 Twin Dolphin Drive
Redwood City, CA 94065-1417

POWER OF ATTORNEY NOTICE

OC000000089950945

Date Mailed: 03/16/2017

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 03/08/2017.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/dtdinh/

Charter Communications, Inc.
Exhibit 1007
Page #1

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/185,729	08/04/2008	John M. Cioffi	20145-002D

CONFIRMATION NO. 9857

146571
North Weber & Baugh LLP - ASSIA
3260 Hillview Avenue
Palo Alto, CA 94304

POA ACCEPTANCE LETTER

OC00000089950977

Date Mailed: 03/16/2017

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 03/08/2017.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/dtdinh/

Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82A (07-13)
Approved for use through 11/30/2014. OMB 0651-0051
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	12/185,729
Filing Date	4 AUG 2008
First Named Inventor	John M. Cioffi
Title	ADAPTIVE FEC CODEWORD MANAGEMENT
Art Unit	
Examiner Name	
Attorney Docket Number	20145-002D

SIGNATURE of Applicant or Patent Practitioner

Signature	/Michael V. North/	Date (Optional)	8 MAR 2017
Name	Michael V. North	Registration Number	46,963
Title (if Applicant is a juristic entity)	Attorney		
Applicant Name (if Applicant is a juristic entity)	Adaptive Spectrum and Signal Alignment, Inc.		

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ *Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Document Description: Power of Attorney

PTO/AIA/82B (07-13)
Approved for use through 11/30/2014. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

Application Number	Filing Date

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

✓ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 146571

OR

I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

✓ The address associated with the above-mentioned Customer Number

OR

The address associated with Customer Number:

OR

Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

Adaptive Spectrum and Signal Alignment, Inc.

Inventor or Joint Inventor (title not required below)

Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

✓ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature	Mary Fuller	Date (Optional)	2/24/2014
Name	Mary Fuller		
Title	General Counsel and Corporate Secretary		

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

✓ Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

PTO/AIA/96 (08-12)
Approved for use through 01/31/2013. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: ADAPTIVE SPECTRUM AND SIGNAL ALIGNMENT, INC.

Application No./Patent No.: 7,809,996 Filed/Issue Date: 10-05-2010

Titled: ADAPTIVE FEC CODEWORD MANAGEMENT

ADAPTIVE SPECTRUM AND SIGNAL ALIGNMENT, INC., a Corporation

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. ☑ The assignee of the entire right, title, and interest.

2. ☐ An assignee of less than the entire right, title, and interest (check applicable box):

   ☐ The extent (by percentage) of its ownership interest is _____%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.

   ☐ There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

3. ☐ The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

4. ☐ The recipient, via a court proceeding or the like (*e.g.*, bankruptcy, probate), of an undivided interest in the entirety (a complete transfer of ownership interest was made). The certified document(s) showing the transfer is attached.

The interest identified in option 1, 2 or 3 above (not option 4) is evidenced by either (choose **one** of options A or B below):

A. ☑ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel 021563, Frame 0172, or for which a copy thereof is attached.

B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: _____ To: _____

   The document was recorded in the United States Patent and Trademark Office at

   Reel _____, Frame _____, or for which a copy thereof is attached.

2. From: _____ To: _____

   The document was recorded in the United States Patent and Trademark Office at

   Reel _____, Frame _____, or for which a copy thereof is attached.

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/AIA/96 (08-12)
Approved for use through 01/31/2013. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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STATEMENT UNDER 37 CFR 3.73(c)

3. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

4. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

5. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

6. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☑ As required by 37 CFR 3.73(c)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Michael North/	2017-03-08
Signature	Date
Michael North	46,963
Printed or Typed Name	Title or Registration Number

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Acknowledgement Receipt	
EFS ID:	28569970
Application Number:	12185729
International Application Number:	
Confirmation Number:	9857
Title of Invention:	ADAPTIVE FEC CODEWORD MANAGEMENT
First Named Inventor/Applicant Name:	John M. Cioffi
Correspondence Address:	Adaptive Spectrum and Signal Alignment, Inc. - 333 Twin Dolphin Drive - Redwood City CA 94065-1417 US 6506543400 -
Filer:	Michael V. North
Filer Authorized By:	
Attorney Docket Number:	8241.P002D
Receipt Date:	08-MAR-2017
Filing Date:	04-AUG-2008
Time Stamp:	17:30:06
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	002D_POA.pdf	1770558 0d9356c1e0d94daf604eca1aeffd96e73096b7e8	no	2
Warnings:					
Information:					
2	Assignee showing of ownership per 37 CFR 3.73	002D_373c.pdf	117973 6b3f88832d9adce8d5893ed7de1a902931d5cdbb	no	3
Warnings:					
Information:					
		Total Files Size (in bytes):	1888531		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/123 (04-15)
Approved for use through 01/31/2018. OMB 0651-0035
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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CHANGE OF CORRESPONDENCE ADDRESS
Patent

Address to:
Mail Stop Post Issue
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Patent Number	7,809,996
Issue Date	10-05-2010
Application Number	12/185,729
Filing Date	08-04-2008
First Named Inventor	John M. Cioffi
Attorney Docket Number	8241.P002D

Please change the Correspondence Address for the above-identified patent to:

☐ The address associated with Customer Number: [ ]

OR

☒ **Firm *or* Individual Name** Adaptive Spectrum and Signal Alignment, Inc.

333 Twin Dolphin Drive

Address

City Redwood City	**State** CA	**ZIP** 94065-1417

Country

Telephone 650-654-3400	**Email**

This form cannot be used to change the data associated with a Customer Number. To change the data associated with an existing Customer Number use "Request for Customer Number Data Change" (PTO/SB/124).

This form will not affect any "fee address" provided for the above-identified patent. To change a "fee address" use the "Fee Address Indication Form" (PTO/SB/47).

I am the:

☐ Patentee.

☐ Assignee of record of the entire interest. See 37 CFR 3.71.
Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96).

☒ Attorney or agent of record. Registration Number 39,926.

Signature	/Gregory D. Caldwell/
Typed or Printed Name	Gregory D. Caldwell
Date	December 1, 2015
Telephone	503-439-8778

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

☐ *Total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Mail Stop Post Issue, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Electronic Acknowledgement Receipt

EFS ID:	24227120
Application Number:	12185729
International Application Number:	
Confirmation Number:	9857
Title of Invention:	ADAPTIVE FEC CODEWORD MANAGEMENT
First Named Inventor/Applicant Name:	John M. Cioffi
Customer Number:	8791
Filer:	Gregory D. Caldwell/Lisa Bennett
Filer Authorized By:	Gregory D. Caldwell
Attorney Docket Number:	8241.P002D
Receipt Date:	01-DEC-2015
Filing Date:	04-AUG-2008
Time Stamp:	17:05:26
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Change of Address	8241P002D_COCA.pdf	32581 767ce1a1553348ae7996f8020b8ee5ae4f652912	no	1
Warnings:					
Information:					

Total Files Size (in bytes):	32581

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/185,729	10/05/2010	7809996	8241.P002D	9857

8791 7590 09/15/2010

BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP
1279 OAKMEAD PARKWAY
SUNNYVALE, CA 94085-4040

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 205 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

John M. Cioffi, Atherton, CA;

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/185,729	08/04/2008	John M. Cioffi	8241.P002D	9857

8791 7590 08/30/2010

BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP
1279 OAKMEAD PARKWAY
SUNNYVALE, CA 94085-4040

EXAMINER	
TON, DAVID	
ART UNIT	PAPER NUMBER
2117	
MAIL DATE	DELIVERY MODE
08/30/2010	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Supplemental Notice of Allowability	**Application No.** 12/185,729	**Applicant(s)** CIOFFI, JOHN M.	
	Examiner David Ton	**Art Unit** 2117	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *IDS filed on 8/17/2010*.

2. ☒ The allowed claim(s) is/are *1-20*.

3. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☐ All b) ☐ Some* c) ☐ None of the:
      1. ☐ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 8/17/10
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☐ Examiner's Amendment/Comment
8. ☐ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

/David Ton/
Primary Examiner, Art Unit 2117

Charter Communications, Inc.
Exhibit 1007
Page #15

Substitute for form 1449A/PTO	*Complete if Known*	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT *(Use as many sheets as necessary)*	**Application Number**	12/185,729
	Filing Date	August 4, 2008
	First Named Inventor	Cioffi, John
	Group Art Unit	2611
	Examiner Name	David Ton
Sheet 1 of 1	Attorney Docket No: 8241P002D	

US PATENT DOCUMENTS					
Examiner Initial *	**Cite No [1]**	**USP Document Number**	**Publication or Issue Date MM-DD-YYYY**	**Name of Patentee or Applicant of cited Document**	**Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear**

FOREIGN PATENT DOCUMENTS						
Examiner Initials*	**Cite No [1]**	**Foreign Patent Document** Country Code/Number/Kind Code (if known)	**Publication Date MM-DD-YYYY**	**Name of Patentee or Applicant of cited Document**	**Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear**	**T [2]**

OTHER DOCUMENTS -- NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	**Cite No [1]**	**Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.**	**T [2]**
		Office Action for Application No. 10/795,593 (Attorney Docket No. 8241P002) mailed March 21, 2007; 12 pgs	
		Office Action for Application No. 10/795,593 (Attorney Docket No. 8241P002) mailed October 22, 2007; 12 pgs	
		Examiner's Report for Australian Application No. 2004298118 (Attorney Docket No. 8241P002AU) mailed January 23, 2009, 3 pgs	
		Examiner's Report for Australian Application No. 2004298118 (Attorney Docket No. 8241P002AU) mailed November 23, 2009, 2 pgs	
		Office Action for Chinese Application No. 200480040960.5 (Attorney Docket No. 8241P002CN) mailed July 24, 2009, 11 pgs	
		Office Action for European Application No. 04801294.2 (Attorney Docket No. 8241P002EP) mailed March 11, 2009, 5 pgs	

EXAMINER	/David Ton/	**DATE CONSIDERED**	08/23/2010

Based on PTO/SB/08A(09-06) - Substitute Disclosure Statement Form (PTO-1449) as modified by BSTZ 03/26/07

* EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional) 2 Applicant is to place a check mark here if English language Translation is attached

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /D.T./

Substitute for form 1449A/PTO	*Complete if Known*	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT *(Use as many sheets as necessary)*	**Application Number**	12/185,729
	Filing Date	August 4, 2008
	First Named Inventor	Cioffi, John
	Group Art Unit	2611
	Examiner Name	David Ton
Sheet 1 of 1	Attorney Docket No: 8241P002D	

US PATENT DOCUMENTS					
Examiner Initial *	**Cite No [1]**	**USP Document Number**	**Publication or Issue Date MM-DD-YYYY**	**Name of Patentee or Applicant of cited Document**	**Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear**

FOREIGN PATENT DOCUMENTS						
Examiner Initials*	**Cite No [1]**	**Foreign Patent Document** Country Code/Number/Kind Code (if known)	**Publication Date MM-DD-YYYY**	**Name of Patentee or Applicant of cited Document**	**Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear**	**T [2]**

OTHER DOCUMENTS -- NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	**Cite No [1]**	**Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.**	**T [2]**
		Office Action for Application No. 10/795,593 (Attorney Docket No. 8241P002) mailed March 21, 2007; 12 pgs	
		Office Action for Application No. 10/795,593 (Attorney Docket No. 8241P002) mailed October 22, 2007; 12 pgs	
		Examiner's Report for Australian Application No. 2004298118 (Attorney Docket No. 8241P002AU) mailed January 23, 2009, 3 pgs	
		Examiner's Report for Australian Application No. 2004298118 (Attorney Docket No. 8241P002AU) mailed November 23, 2009, 2 pgs	
		Office Action for Chinese Application No. 200480040960.5 (Attorney Docket No. 8241P002CN) mailed July 24, 2009, 11 pgs	
		Office Action for European Application No. 04801294.2 (Attorney Docket No. 8241P002EP) mailed March 11, 2009, 5 pgs	

EXAMINER **DATE CONSIDERED**

Based on PTO/SB/08A(09-06) - Substitute Disclosure Statement Form (PTO-1449) as modified by BSTZ 03/26/07

* EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1] Applicant's unique citation designation number (optional) [2] Applicant is to place a check mark here if English language Translation is attached

Electronic Patent Application Fee Transmittal

Application Number:	12185729
Filing Date:	04-Aug-2008
Title of Invention:	ADAPTIVE FEC CODEWORD MANAGEMENT
First Named Inventor/Applicant Name:	John M. Cioffi
Filer:	Gregory D. Caldwell/Merissa Anderson
Attorney Docket Number:	8241.P002D

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl issue fee	1501	1	1510	1510
Publ. Fee- early, voluntary, or normal	1504	1	300	300

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
Submission- Information Disclosure Stmt	1806	1	180	180
		Total in USD ($)		**1990**

Electronic Acknowledgement Receipt	
EFS ID:	8235703
Application Number:	12185729
International Application Number:	
Confirmation Number:	9857
Title of Invention:	ADAPTIVE FEC CODEWORD MANAGEMENT
First Named Inventor/Applicant Name:	John M. Cioffi
Customer Number:	08791
Filer:	Gregory D. Caldwell/Merissa Anderson
Filer Authorized By:	Gregory D. Caldwell
Attorney Docket Number:	8241.P002D
Receipt Date:	17-AUG-2010
Filing Date:	04-AUG-2008
Time Stamp:	17:43:40
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$1990
RAM confirmation Number	4201
Deposit Account	022666
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.16 (National application filing, search, and examination fees) Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)	

Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)	
Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)	
Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	20100817_Issue_Fee_Transmittal_8241P002D.pdf	5805416 5ef58d6cd2b83a379883385c7e708b18ce93aa1c	no	1
Warnings:					
Information:					
2	Transmittal Letter	20100817_IDS_after_Allowance_8241P002D.pdf	24489 0ece7d9f0be39ce0c83f4cf18e2c53fae793e679	no	2
Warnings:					
Information:					
3	Information Disclosure Statement (IDS) Filed (SB/08)	20100817_PTO1449_8241P002D.pdf	29296 05d84f4deaaf859e43ae843cc89719ebb482e7cf	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
4	NPL Documents	1_Office_Action_mailed_3-21-07_8241P002.pdf	745676 8f8ac66f6ad177e07198ecf7eb4a7de47f5da44d	no	12
Warnings:					
Information:					
5	NPL Documents	2_Final_Office_Action_Mailed_10-22-07_8241P002.pdf	804700 3b49981c95423d9d31497a3b340944cacbc69eff	no	12
Warnings:					
Information:					
6	NPL Documents	3_Office_Action_mailed_1-23-09_8241P002AU.pdf	1329314 9c9161334616d0b3b088da96e3bc2b565f23e7e4	no	3
Warnings:					
Information:					
7	NPL Documents	4_2nd_Office_Action_mailed_11-23-09_8241P002AU.pdf	648848 9345434ae521c22c0d5f56449727a8fcd68e6996	no	2
Warnings:					
Information:					

8	NPL Documents	5_Office_Action_7-24-09_8241P002CN.pdf	926033 d6afe023d1c3428cbb73908c01509d878490a4bb	no	11
Warnings:					
Information:					
9	NPL Documents	6_Office_action_mailed_3-11-09_8241P002EP.pdf	212625 49414bcec70a083b78c1e835fe95ffa51f5c2003	no	5
Warnings:					
Information:					
10	Fee Worksheet (PTO-875)	fee-info.pdf	33782 78071dcaf1ee06eef093a02521318591032edc2e	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	10560179	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

8791 7590 06/09/2010

BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP
1279 OAKMEAD PARKWAY
SUNNYVALE, CA 94085-4040

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

I hereby certify that this correspondence is being deposited via EFS web on August 17, 2010:

Signature: /Merissa R. Anderson/

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/185,729	08/04/2008	John M. Cioffi	8241.P002D	9857

TITLE OF INVENTION: ADAPTIVE FEC CODEWORD MANAGEMENT

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$300	$0	$1810	09/09/2010

EXAMINER	ART UNIT	CLASS-SUBCLASS
TON, DAVID	2117	711-154000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Blakely, Sokoloff, Taylor & Zafman
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Adaptive Spectrum and Signal Alignment, Inc.

(B) RESIDENCE: (CITY and STATE OR COUNTRY): Redwood City, California

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual X Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
X Issue Fee
X Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
☐ A check is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
X The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number 02-2666 (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.
☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature /Gregory D. Caldwell/ Date August 17, 2010

Typed or printed name Gregory D. Caldwell Registration No. 39,926

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Charter Communications, Inc.
Exhibit 1007
Page #23

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s):	John M. Cioffi, et al.		
Serial No.:	12/185,729	Confirmation No.: 9857	
Filed:	August 4, 2008		
For:	ADAPTIVE FEC CODEWORD MANAGEMENT	Examiner:	David Ton
Docket No.:	8241P002D	Art Unit:	2117

Mail Stop Issue Fee
Commissioner For Patents
P.O. Box 1450
Alexandria, VA 22313-1450

INFORMATION DISCLOSURE STATEMENT AFTER ALLOWANCE

In accordance with Applicant's duty of disclosure, this Information Disclosure Statement, substitutes for form 1449A/PTO (based on PTO/SB/08A), and cited reference(s) are being submitted prior to the payment of the Issue Fee. It is respectfully requested that the cited reference(s) be placed in the file and that the subject application not be withdrawn from issue.

The submission of this Information Disclosure Statement is not to be construed as a representation that a search has been made in the subject application and is not to be construed as an admission that the information cited in this statement is material to patentability.

I hereby certify that this correspondence is being deposited via EFS Web on the date below:

August 17, 2010
Date of Deposit

/Merissa Anderson/
Merissa Anderson

Charter Communications, Inc.
Exhibit 1007
Page #24

CONCLUSION

The Commissioner is authorized to charge or credit any deficiencies or overpayments in connection with this submission to Deposit Account No. 02-2666, and is requested to notify us of same.

Respectfully Submitted,
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP

/Gregory D. Caldwell/	August 17, 2010
Gregory D. Caldwell	Date
Registration No. 39,926	
Attorney for Applicants	

Blakely, Sokoloff, Taylor & Zafman LLP
1279 Oakmead Parkway
Sunnyvale, CA 94085-4040
Telephone: (503) 439-8778
Facsimile: (503) 439-6073

Charter Communications, Inc.
Exhibit 1007
Page #25

Substitute for form 1449A/PTO	Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Use as many sheets as necessary)	**Application Number**	12/185,729
	Filing Date	August 4, 2008
	First Named Inventor	Cioffi, John
	Group Art Unit	2611
ifw sent	**Examiner Name**	Unknown
Sheet 1 of 4	Attorney Docket No: 8241P002D	

TS 7/27/10

US PATENT DOCUMENTS					
Examiner Initial *	Cite No [1]	USP Document Number	Publication or Issue Date MM-DD-YYYY	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US-20030072380	04/17/2003	Huang, Gang	
		US-20030086362	05/08/2003	Hasegawa, et al.	
		US-20030086514	05/08/2003	Ginis, et al.	
		US-20030235245	12/25/2003	Erdogan, et al.	
		US-20040086064	05/06/2004	Van Acker, et al.	
		US-20040109546	06/10/2004	Fishman	
		US-20050052988	03/10/2005	Tsatsanis, et al.	
		US-20050053229	03/10/2005	Tsatsanis, et al.	
		US-20050152385	~~06/14/2005~~	Cioffi 7/2005	
		US-20050195892	09/08/2005	Ginis, et al.	
		US-2005129218	06/16/2005	Kimble, et al.	
		US-20060056305	03/16/2006	Oksman, et al.	
		US-20060109779	05/25/2006	Shah, et al.	
		US-20060133519	06/22/2006	Tsatsanis, et al.	
		US-20060146945	07/06/2006	Chow, et al.	
		US-5,181,198	01/19/1993	Lechleider	
		US-5,511,119	04/23/1996	Lechleider	
		US-5,621,768	04/15/1997	Lechleider	
		US-5,901,205	05/04/1999	Smith, et al.	
		US-6,147,963	11/14/2000	Walker, et al.	
		US-6,507,608	01/14/2003	Norrell	
		US-6,597,745	07/22/2003	Dowling	
		US-6,636,603	10/21/2003	Milbrandt	
		US-6,751,255	06/15/2004	Reuven, et al.	
		US-6,940,973	09/06/2005	Yeap, et al.	

FOREIGN PATENT DOCUMENTS						
Examiner Initials*	Cite No [1]	Foreign Patent Document Country Code/Number/Kind Code (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T [2]
		DE-4444312	02/22/1996	Siemens AG		
		GB-2315392	01/28/1998	4 Links for Techical Help		
		WO-2001/035611	05/17/2001	Voyan Technology, Inc.		
		WO-2005/094052	10/06/2005	Adaptive Spectrum & Signal Alignment, Inc.		
		WO-2004/027579	04/01/2004	Toyko Electron Ltd.		
		WO-1995/031867	11/23/1995	Bell Communications Research, Inc.		

EXAMINER **DATE CONSIDERED**

Based on PTO/SB/08A(09-06) - Substitute Disclosure Statement Form (PTO-1449) as modified by BSTZ 03/26/07

* EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional) 2 Applicant is to place a check mark here if English language Translation is attached

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /D.T./

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

8791 7590 06/09/2010

BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP
1279 OAKMEAD PARKWAY
SUNNYVALE, CA 94085-4040

EXAMINER	
TON, DAVID	
ART UNIT	PAPER NUMBER
2117	

DATE MAILED: 06/09/2010

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/185,729	08/04/2008	John M. Cioffi	8241.P002D	9857

TITLE OF INVENTION: ADAPTIVE FEC CODEWORD MANAGEMENT

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$300	$0	$1810	09/09/2010

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PTOL-85 (Rev. 08/07) Approved for use through 08/31/2010.

Charter Communications, Inc.
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Page #27

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

8791 7590 06/09/2010

BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP
1279 OAKMEAD PARKWAY
SUNNYVALE, CA 94085-4040

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/185,729	08/04/2008	John M. Cioffi	8241.P002D	9857

TITLE OF INVENTION: ADAPTIVE FEC CODEWORD MANAGEMENT

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$300	$0	$1810	09/09/2010

EXAMINER	ART UNIT	CLASS-SUBCLASS
TON, DAVID	2117	711-154000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

❑ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

❑ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

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Page #28

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/185,729	08/04/2008	John M. Cioffi	8241.P002D	9857

8791 7590 06/09/2010

BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP
1279 OAKMEAD PARKWAY
SUNNYVALE, CA 94085-4040

EXAMINER	
TON, DAVID	
ART UNIT	PAPER NUMBER
2117	

DATE MAILED: 06/09/2010

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 205 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 205 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 08/07) Approved for use through 08/31/2010.

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Notice of Allowability	Application No.	Applicant(s)	
	12/185,729	CIOFFI, JOHN M.	
	Examiner	Art Unit	
	David Ton	2117	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *Terminal Disclaimer filed on 05/07/2010*.

2. ☒ The allowed claim(s) is/are *1-20*.

3. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☐ All b) ☐ Some* c) ☐ None of the:
      1. ☐ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☐ Examiner's Amendment/Comment
8. ☒ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

/David Ton/
Primary Examiner, Art Unit 2117

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1. Applicant's amendment filed on 05/07/2010 has been entered and reviewed. The Terminal Disclaimer has been approved.

Allowance

2. Claims 1-20 are allowed.

3. The following is an Examiner's Statement of Reasons for Allowance:

The prior art of record teaches the claimed invention substantially, but it fails to teach or suggest singly or in combination a controller communicatively interfaced with a Digital Subscriber Line (DSL) modem wherein the controller comprises: a means for repeatedly acquiring Measured transmission Error Values (MEVs) representing impulse noise events detected on the channel, a means coupled with the acquiring means for analyzing the acquired MEVs relative to a Target transmission Error Value (TEV); and a means coupled with the analyzing means for generating a retransmission overhead control signal to modify the original transmission parameters during normal operation of the DSL modem ("SHOWTIME") as set forth in independent claim 1.

The prior art of record also fails to teach or suggest singly or in combination a method for generating a retransmission overhead control signal in a Digital Subscriber Line (DSL) modem comprising repeatedly acquiring Measured transmission Error Values (MEVs) representing impulse noise events detected on the channel; analyzing the acquired MEVs relative to a Target transmission Error Value (TEV); and adjusting

the retransmission overhead parameters when the MEV differs sufficiently from the TEV as set forth in independent claim 11.

Furthermore, the prior art of record also fails to teach or suggest singly or in combination a transmission system comprising transmission error value monitor communicatively interfaced with the receiver/decoder to periodically monitor for transmission error values indicative of impulse noise events on the transmission channel, and wherein the transmission error value monitor to further generate an input signal based on the transmission error values monitored; and a controller coupled with the transmitter to receive the input signal from the transmission error value monitor and to further generate a retransmission overhead control signal for the transmitter in response to the input signal as set forth in independent claim 20.

4. Any comments considered necessary by applicant must be submitted no later than the payment of the Issue Fee and, to avoid processing delays, should preferably accompany the Issue Fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance".

5. Any inquiry concerning this communication or earlier communications from the examiner should be directed to David Ton whose telephone number is (571) 272-3828. The examiner can normally be reached on M-F from 9:00 - 6:00.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Kevin Ellis can be reached on (571) 272-4205. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/David Ton/
Primary Examiner, Art Unit 2117

David Ton
Primary Examiner
Art Unit 2117

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	46487	dsl	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/06 10:01
L2	49230	(measured adj1 transmission ajd1 error adj1 value) or mev	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/06 10:02
L3	10	1 same 2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/06 10:02
L4	4306	(target adj1 transmission adj1 error adj1 value) or tev	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/06 10:03
L5	17	2 same 4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/06 10:03
L6	2	5 same modem	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/06 10:03
L7	25	adaptive adj1 codeword	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/06 10:04

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L8	113	adaptive near3 codeword	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/06 10:04
L9	22013	fec	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/06 10:04
L10	5	8 same 9	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/06 10:05
L11	5	10 and 1	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/06 10:05
S1	2	7428669[pn]	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/03/13 12:51
S2	57880	(digital adj1 subscriber adj1 line) or dsl	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:07
S3	11328	S2 adj1 modem	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:07
S4	2162672	controller	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:07

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S5	18854	(measured adj1 transmission adj1 value) or mev	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:08
S6	3461	training same initializ$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:09
S7	0	S5 same S6	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:09
S8	3	S3 same S5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:09
S9	11	S3 same S6	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:10
S10	59	overhead adj1 control adj1 signal	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:14
S11	4	S10 same retransmi$5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:15
S12	2	S11 and S3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:15

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S13	2	S11 and S2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:15
S14	4247	(target adj1 transmission adj1 error adj1 value) or tev	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:19
S15	2	S14 and S3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:19
S16	3	S14 same modem	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:19
S17	986	adaptive same fec	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:20
S18	1	S17 same S3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:20
S19	206	S6 same modem	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:21
S20	1	S19 same overhead	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:21

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S21	46	transmission adj1 error adj1 value	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:22
S22	4	S21 same modem	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:22
S23	38	S3 same fec	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:23
S24	903681	"38" same control $4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:23
S25	15	S23 same control $4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:23
S26	725	S6 same after	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:27
S27	37	S26 same controller	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:27
S28	3	S27 and S2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:27

6/6/10 10:06:48 AM
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20031207.wsp

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Page #39

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12185729	CIOFFI, JOHN M.
	Examiner	Art Unit
	David Ton	2117

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☒ Claims renumbered in the same order as presented by applicant ☐ CPA ☒ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	04/25/2010	06/06/2010							
1	1	✓	=							
2	2	✓	=							
3	3	✓	=							
4	4	✓	=							
5	5	✓	=							
6	6	✓	=							
7	7	✓	=							
8	8	✓	=							
9	9	✓	=							
10	10	✓	=							
11	11	✓	=							
12	12	✓	=							
13	13	✓	=							
14	14	✓	=							
15	15	✓	=							
16	16	✓	=							
17	17	✓	=							
18	18	✓	=							
19	19	✓	=							
20	20	✓	=							

Charter Communications, Inc.
Exhibit 1007
Page #40

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12185729	CIOFFI, JOHN M.
	Examiner	**Art Unit**
	David Ton	2117

ORIGINAL		INTERNATIONAL CLASSIFICATION														
CLASS	SUBCLASS	CLAIMED					NON-CLAIMED									
714	704	G	0	6	F	11 / 00 (2006.01.01)										

CROSS REFERENCE(S)					
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				
714	774				

☒ Claims renumbered in the same order as presented by applicant ☐ CPA ☒ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	17	17												
2	2	18	18												
3	3	19	19												
4	4	20	20												
5	5														
6	6														
7	7														
8	8														
9	9														
10	10														
11	11														
12	12														
13	13														
14	14														
15	15														
16	16														

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	20	
/David Ton/ Primary Examiner.Art Unit 2117	06/06/2010	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	5

Charter Communications, Inc.
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Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12185729	CIOFFI, JOHN M.
	Examiner	Art Unit
	David Ton	2117

SEARCHED			
Class	Subclass	Date	Examiner
375	222	4/25/10	DT
375	295	4/25/10	DT
714	704	4/25/10	DT
714	774	4/25/10	DT
714	701	4/25/10	DT
714	785	4/25/10	DT
714	704	6/6/10	DT
714	774	6/6/10	DT

SEARCH NOTES		
Search Notes	Date	Examiner
EAST, JPO, DERWENT, IEEE searches	4/25/10	DT
EAST, JPO, DERWENT, IEEE searches	6/6/10	DT

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner
714	704	6/6/10	DT
714	774	6/6/10	DT

	/David Ton/ Primary Examiner.Art Unit 2117

Application Number	Application/Control No.	Applicant(s)/Patent under Reexamination	
	12/185,729	CIOFFI, JOHN M.	

Document Code - DISQ	Internal Document – DO NOT MAIL

TERMINAL DISCLAIMER	☒ APPROVED	☐ DISAPPROVED
Date Filed : 5/07/10	This patent is subject to a Terminal Disclaimer	

Approved/Disapproved by:
j.proctor

U.S. Patent and Trademark Office

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s):	John M. Cioffi		
Serial No.:	12/185,729	Confirmation No.:	9857
Filed:	August 4, 2008		
For:	ADAPTIVE FEC CODEWORD MANAGEMENT	Examiner:	Ton, David
Docket No.:	8241P002D	Art Unit:	2117

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

AMENDMENT AND RESPONSE UNDER 37 C.F.R. § 1.111

Dear Examiner:

This amendment is submitted in response to the Office Action mailed April 27, 2010, for the above-noted patent application. Applicants respectfully request the Examiner to:

1. Please enter the amendments to the claims in section I, beginning on page 2.

2. Please consider the amendments to the claims in section I in view of the remarks in section II, beginning on page 7.

I hereby certify that this correspondence is being deposited via EFS Web on the date below:

5/7/2010
Date of Deposit

/Tina Miller/
Tina Miller

SECTION I—CLAIMS

Amendment to the Claims:

This listing of the claims will replace all prior versions and listings of claims in the application. No claims are amended. No claims are canceled. No new claims are added. Claims 1-20 remain pending in this application.

Listing of Claims:

1. (Original) A controller communicatively interfaced with a Digital Subscriber Line (DSL) modem operating in a DSL system, the DSL modem to transmit data via a channel according to original transmission parameters, wherein the controller comprises:

a means, coupled with the DSL modem, for repeatedly acquiring Measured transmission Error Values (MEVs) representing impulse noise events detected on the channel, the MEVs acquired after training and initialization on the DSL modem;

a means, coupled with the acquiring means, for analyzing the acquired MEVs relative to a Target transmission Error Value (TEV); and

a means, coupled with the analyzing means, for generating a retransmission overhead control signal to modify the original transmission parameters during normal operation of the DSL modem ("SHOWTIME") responsive to the means for analyzing, and transmitting the same to the DSL modem.

2. (Original) The controller of Claim 1, wherein the MEVs are based on at least one of:

a bit error rate;

errored seconds;

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errored minutes;

code violations over a fixed period of time;

a Signal-to-Noise Ratio (SNR) measured at the receiver; and

Transmission Control Protocol and Internet Protocol (TCP/IP) throughput.

3. (Original) The controller of Claim 1, wherein the acquiring means, the analyzing means, and the generating means are implemented as computer readable program code.

4. (Original) The controller of Claim 1, wherein the acquiring means, the analyzing means, and the generating means are implemented as hardware.

5. (Original) The controller of Claim 1, wherein the TEV is a threshold error rate limit.

6. (Original) The controller of Claim 1, further comprising:

a historical data module to store historical MEVs representing impulse noise events detected on the channel over time, wherein the historical data module is coupled with the analyzing means; and wherein

analyzing the acquired MEVs relative to the TEV comprises analyzing the historical MEVs for information about impulse noise events that occurred during prior transmissions on the channel.

7. (Original) The controller of Claim 6, wherein the historical data module comprises a database.

8. (Original) The controller of Claim 1, wherein the controller comprises a dynamic spectrum manager.

9. (Original) The controller of Claim 1, wherein:

the DSL modem is an Asymmetric Digital Subscriber Line (ADSL) modem operable in compatibility with an ADSL2 standard; and wherein

the generated retransmission overhead control signal to adjust at least one of the following

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parameters:

Impulse Noise Protection (INP), and

Codeword Composition Ratio (CCR).

10. (Original) The controller of Claim 1, wherein the means for repeatedly acquiring the MEVs comprises means for receiving an input signal representative of the MEVs.

11. (Original) A method for generating a retransmission overhead control signal in a Digital Subscriber Line (DSL) modem having a transmitter to exchange data between a transmitter and a receiver on a channel, the method comprising:

(a) transmitting a control signal from the DSL modem via the channel, wherein the control signal specifies retransmission overhead parameters for the retransmission overhead control signal;

(b) repeatedly acquiring Measured transmission Error Values (MEVs) representing impulse noise events detected on the channel, the MEVs acquired after training and initialization on the DSL modem;

(c) analyzing the acquired MEVs relative to a Target transmission Error Value (TEV); and

(d) adjusting the retransmission overhead parameters when the MEV differs sufficiently from the TEV.

12. (Original) The method of Claim 11, wherein repeatedly acquiring the MEVs comprises at least one of the following:

directly measuring a characteristic of the DSL modem;

collecting a value from an element management system; and

computing the MEVs from collected data.

13. (Original) The method of Claim 11, wherein steps (a) through (d) are repeated.

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14. (Original) The method of Claim 11, wherein the method is performed by one of:

a controller communicably interfaced with the DSL modem;

a controller embodying a dynamic spectrum manager;

a controller physically located within a Central Office (CO);

a controller physically located separate from the CO;

a controller operated by an entity which operates the DSL modem; and

a controller operated independently of the entity which operates the DSL modem.

15. (Original) The method of Claim 11, wherein analyzing the acquired MEVs relative to the TEV comprises analyzing historically acquired MEVs representing impulse noise events that occurred during prior transmissions on the channel.

16. (Original) The method of Claim 11, wherein the MEV is based on at least one of the following:

a Bit Error Rate (BER);

errored seconds;

errored minutes;

code violations over a fixed period of time;

a Signal-to-Noise Ratio (SNR) measured at the receiver; and

Transmission Control Protocol and Internet Protocol (TCP/IP) throughput.

17. (Original) The method of Claim 11, wherein repeatedly acquiring the MEVs, analyzing the acquired MEVs relative to the TEV, and adjusting the retransmission overhead parameters are implemented in computer readable program code.

18. (Original) The method of Claim 11, wherein repeatedly acquiring the MEVs, analyzing the repeated MEVs relative to the TEV, and adjusting the retransmission overhead

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parameters are implemented in hardware.

19. (Original) The method of Claim 11, wherein:

the DSL modem is an Asymmetric Digital Subscriber Line (ADSL) system operable in compatibility with an ADSL2 standard; and wherein

adjusting the retransmission overhead parameters comprises adjusting Impulse Noise Protection (INP), Codeword Composition Ratio (CCR), or both.

20. (Original) A transmission system comprising:

a transmission channel to carry data between a transmitter and a receiver/decoder, each communicatively interfaced with the transmission channel;

a transmission error value monitor communicatively interfaced with the receiver/decoder to periodically monitor for transmission error values indicative of impulse noise events on the transmission channel, wherein the transmission error values are periodically monitored after training and initialization on the receiver/decoder, the transmission error values being selected from a group comprising: a bit error rate, errored seconds, errored minutes, code violations over a fixed period of time, Signal-to-Noise Ratio (SNR) measured at the receiver/decoder, and Transmission Control Protocol and Internet Protocol (TCP/IP) throughput, and wherein the transmission error value monitor to further generate an input signal based on the transmission error values monitored; and

a controller coupled with the transmitter to receive the input signal from the transmission error value monitor and to further generate a retransmission overhead control signal for the transmitter in response to the input signal.

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SECTION II—REMARKS

Applicants respectfully request reconsideration of the above referenced patent application for the following reasons:

Double Patenting Rejection

Claims 1-20 were provisionally rejected on the ground of non-statutory obviousness-type double patenting as being unpatentable over claims 1-31 of U.S. Patent No. 7,428,669.

Applicants respectfully submit concurrently herewith a terminal disclaimer complying with 37 C.F.R. 1.321(c) to overcome the provisional rejection. Accordingly, Applicants respectfully request the Examiner to withdraw the rejection.

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CONCLUSION

Given the above remarks, all claims pending in the application are in condition for allowance. If there are any informalities or questions that can be addressed via telephone, the Examiner is encouraged to contact the undersigned attorney at (503) 439-8778.

Charge Deposit Account

Please charge our Deposit Account No. 02-2666 for any additional fee(s) that may be due in this matter, and please credit the same deposit account for any overpayment.

Respectfully Submitted,

BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP

/Gregory D. Caldwell/	May 7, 2010
Gregory D. Caldwell	Date
Registration No. 39,926	
Attorney for Applicants	

Blakely, Sokoloff, Taylor & Zafman LLP
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Facsimile: (503) 439-6073

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Page #51

TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION OVER A PRIOR PATENT	Docket Number (Optional) 8241P002D

In re the Application of: John M. Cioffi

Application No.: 12/185,729

Filed: August 04, 2008

For: **ADAPTIVE FEC CODEWORD MANAGEMENT**

The owner*, Adaptive Spectrum and Signal Alignment, Inc.
of 100 percent interest in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of **prior patent** No. 7,428,669 as the term of said prior patent is defined in 35 U.S.C. 154 and 173, and as the term of said **prior patent** is presently shortened by any terminal disclaimer. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and the **prior patent** are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of any patent granted on the instant application that would extend to the expiration date of the full statutory term as defined in 35 U.S.C. 154 and 173 of the **prior patent**, "as the term of said **prior patent** is presently shortened by any terminal disclaimer," in the event that said **prior patent** later: expires for failure to pay a maintenance fee; is held unenforceable; is found invalid by a court of competent jurisdiction; is statutorily disclaimed in whole or terminally disclaimed under 37 C.F.R. 1.321; has all claims cancelled by a reexamination certificate; is reissued; or is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.

Check either box 1 or 2 below, if appropriate.

1. ☐ For submissions on behalf of a business/organization (e.g., corporation, partnership, university, government agency, etc.), the undersigned is empowered to act on behalf of the business/organization.

   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 are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

2. ☐ The undersigned is an attorney or agent of record.

/Gregory D. Caldwell/ — Signature

May 7, 2010 — Date

Gregory D. Caldwell, Reg. No. 39,926 — Typed or printed name

☒ Terminal disclaimer fee under 37 CFR 1.20(d) included.

☒ Please charge Deposit Account No. 02-2666 for any fee deficiency that may be due.

* Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner). Form PTO/SB/96 may be used for making this statement. See MPEP § 324.

Based on PTO/SB/26 (10-07) as modified by Blakely, Sokoloff, Taylor & Zafman (iab) 3/17/2010.
Send To: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450

Electronic Patent Application Fee Transmittal

Application Number:	12185729
Filing Date:	04-Aug-2008
Title of Invention:	ADAPTIVE FEC CODEWORD MANAGEMENT
First Named Inventor/Applicant Name:	John M. Cioffi
Filer:	Gregory D. Caldwell/Heidi Yerton/Tina Miller
Attorney Docket Number:	8241.P002D

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Statutory disclaimer	1814	1	140	140
		Total in USD ($)		**140**

Electronic Acknowledgement Receipt	
EFS ID:	7574673
Application Number:	12185729
International Application Number:	
Confirmation Number:	9857
Title of Invention:	ADAPTIVE FEC CODEWORD MANAGEMENT
First Named Inventor/Applicant Name:	John M. Cioffi
Customer Number:	08791
Filer:	Gregory D. Caldwell/Heidi YertonTina Miller
Filer Authorized By:	Gregory D. Caldwell
Attorney Docket Number:	8241.P002D
Receipt Date:	07-MAY-2010
Filing Date:	04-AUG-2008
Time Stamp:	19:00:19
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$140
RAM confirmation Number	7044
Deposit Account	022666
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees) Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		8241P002D_Reply_to_OA_mailed_4-27-10.pdf	39963 7ef5a76010b3bb308388eab302c2e48c28edbfdd	yes	8

Multipart Description/PDF files in .zip description

Document Description	Start	End
Amendment/Req. Reconsideration-After Non-Final Reject	1	1
Claims	2	6
Applicant Arguments/Remarks Made in an Amendment	7	8

Warnings:

Information:

2	Terminal Disclaimer Filed	8241P002D_TerminalDisclaimer_wrt_Reply_to_OA_mailed_4-27-10.pdf	32152 04540e3ff9be86c526790e3af18a719900d58298	no	1

Warnings:

Information:

3	Fee Worksheet (PTO-875)	fee-info.pdf	30185 933a7e8b39e23b1722c512050a39f249116f60fc	no	2

Warnings:

Information:

Total Files Size (in bytes):	102300

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number	Filing Date	☐ To be Mailed
12/185,729	08/04/2008	

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY ☐ RATE ($)	SMALL ENTITY FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	05/07/2010	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X $ =		OR	X $52=	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X $ =		OR	X $220=	0
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	0

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)	OR	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/MARGARET BYARS/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number	Filing Date	☐ To be Mailed
12/185,729	08/04/2008	

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)	SMALL ENTITY ☐		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	05/07/2010	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X $ =		OR	X $52=	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X $ =		OR	X $220=	0
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	0

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)	OR	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/MARGARET BYARS/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/185,729	08/04/2008	John M. Cioffi	8241.P002D	9857

8791 7590 04/27/2010

BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP
1279 OAKMEAD PARKWAY
SUNNYVALE, CA 94085-4040

EXAMINER	
TON, DAVID	
ART UNIT	PAPER NUMBER
2117	
MAIL DATE	DELIVERY MODE
04/27/2010	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)	
	12/185,729	CIOFFI, JOHN M.	
	Examiner	Art Unit	
	David Ton	2117	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☐ Responsive to communication(s) filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-20* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-20* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *08/04/2008* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date *8/18/08&4/28/09*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

1. Claims 1-20 are presented for examination.

Double Patenting

2. The non-statutory double patenting rejection, whether of the obviousness-type or non-obviousness-type, is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent. *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969); *In re Vogel*, 422 USPQ 761 (CCPA 1982); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); and *In re Goodman*, 29 USPQ2d 2010 (Fed. Cir. 1993).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(b) and 8 may be used to overcome an actual or provisional rejection based on a non-statutory double patenting ground provided the conflicting application or patent is shown to be commonly owned with this application. See 37 CFR 1.78(d).

Effective January 1, 1994, a registered attorney or agent of record may sign a terminal disclaimer. A terminal disclaimer signed by the assignee must fully comply with 37 CFR 3.73(b).

3. Claims 1-20 are rejected under the judicially created doctrine of obviousness-type double patenting as being unpatentable over claims 1-31 of U.S. patent no. 7,428,669. Although the conflicting claims are not identical, they are not patentably

distinct from each other because the scope of the claimed subject matter in claims 1-20 of the instant application is broader than the scope of the claimed subject matter in claims 1-31 of U.S. patent no. 7,428,669. Omission of an element and its function is obvious if the function of the element is not desired. Representative independent claim 1 of the instant application will be taken as an example in view of claim 1 of U.S. patent no. 7,428,669.

4. Claims 1-20 would be allowable if a timely filed terminal disclaimer is used to overcome the double patenting rejection.

5. The prior art of record and not relied upon is considered pertinent to applicant's disclosure.

6. Any inquiry concerning this communication or earlier communications from the examiner should be directed to David Ton whose telephone number is (571) 272-3828. The examiner can normally be reached on M-F from 9:00 - 6:00.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Ellis Kevin can be reached on (571) 272-4205. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/David Ton/
Primary Examiner, Art Unit 2117

David Ton
Primary Examiner
Art Unit 2117

Notice of References Cited	Application/Control No. 12/185,729	Applicant(s)/Patent Under Reexamination CIOFFI, JOHN M.	
	Examiner David Ton	Art Unit 2117	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,704,351 B1	03-2004	Ott et al.	375/222
*	B	US-6,967,996 B1	11-2005	Cai et al.	375/222
*	C	US-7,110,467 B2	09-2006	Mitlin et al.	375/295
*	D	US-7,123,651 B2	10-2006	Altekar et al.	375/222
*	E	US-7,131,038 B2	10-2006	Mitlin et al.	714/708
*	F	US-7,386,040 B1	06-2008	Cai et al.	375/222
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Charter Communications, Inc.
Exhibit 1007
Page #64

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CONFIRMATION NO. 9857

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
12/185,729	08/04/2008 RULE	714	2117	8241.P002D

APPLICANTS

John M. Cioffi, Atherton, CA;

**** CONTINUING DATA ***************************

This application is a DIV of 10/795,593 03/08/2004 PAT 7,428,669
which claims benefit of 60/527,853 12/07/2003

**** FOREIGN APPLICATIONS ***************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****

Foreign Priority claimed	Met after Allowance	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
❑ Yes ☑ No	❑	CA	8	20	3
35 USC 119(a-d) conditions met ❑ Yes ❑ No					
Verified and Acknowledged /DAVID TON/ Examiner's Signature	Initials				

ADDRESS

BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP
1279 OAKMEAD PARKWAY
SUNNYVALE, CA 94085-4040
UNITED STATES

TITLE

ADAPTIVE FEC CODEWORD MANAGEMENT

FILING FEE RECEIVED	FEES: Authority has been given in Paper	❑ All Fees
1030	No._____ to charge/credit DEPOSIT ACCOUNT	❑ 1.16 Fees (Filing)
	No._____ for following:	❑ 1.17 Fees (Processing Ext. of time)
		❑ 1.18 Fees (Issue)
		❑ Other _____
		❑ Credit

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12185729	CIOFFI, JOHN M.
	Examiner	**Art Unit**
	David Ton	2117

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	04/25/2010								
	1	✓								
	2	✓								
	3	✓								
	4	✓								
	5	✓								
	6	✓								
	7	✓								
	8	✓								
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	13	✓								
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	16	✓								
	17	✓								
	18	✓								
	19	✓								
	20	✓								

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Page #66

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12185729	CIOFFI, JOHN M.
	Examiner	Art Unit
	David Ton	2117

SEARCHED			
Class	Subclass	Date	Examiner
375	222	4/25/10	DT
375	295	4/25/10	DT
714	704	4/25/10	DT
714	774	4/25/10	DT
714	701	4/25/10	DT
714	785	4/25/10	DT

SEARCH NOTES		
Search Notes	Date	Examiner
EAST, JPO, DERWENT, IEEE searches	4/25/10	DT

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

	/David Ton/ Primary Examiner.Art Unit 2117

Charter Communications, Inc.
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Page #67

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	57880	(digital adj1 subscriber adj1 line) or dsl	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:07
L2	11328	1 adj1 modem	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:07
L3	2162672	controller	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:07
L4	18854	(measured adj1 transmission adj1 value) or mev	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:08
L5	3461	training same initializ$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:09
L6	0	4 same 5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:09
L7	3	2 same 4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:09

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L8	11	2 same 5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:10
L9	59	overhead adj1 control adj1 signal	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:14
L10	4	9 same retransmi $5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:15
L11	2	10 and 2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:15
L12	2	10 and 1	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:15
L13	4247	(target adj1 transmission adj1 error adj1 value) or tev	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:19
L14	2	13 and 2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:19
L15	3	13 same modem	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:19

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L16	986	adaptive same fec	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:20
L17	1	16 same 2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:20
L18	206	5 same modem	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:21
L19	1	18 same overhead	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:21
L20	46	transmission adj1 error adj1 value	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:22
L21	4	20 same modem	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:22
L22	38	2 same fec	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:23
L23	903681	"38" same control $4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:23

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L24	15	22 same control $4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:23
L25	725	5 same after	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:27
L26	37	25 same controller	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:27
L27	3	26 and 1	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/04/25 13:27
S1	2	7428669[pn]	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/03/13 12:51

4/25/10 1:29:18 PM
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Page #71

Substitute for form 1449A/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Complete if Known

Application Number	12/185,729
Filing Date	August 4, 2008
First Named Inventor	Cioffi, John
Group Art Unit	2611
Examiner Name	Unknown

Sheet 1 of 4

Attorney Docket No: 8241P002D

US PATENT DOCUMENTS

Examiner Initial *	Cite No [1]	USP Document Number	Publication or Issue Date MM-DD-YYYY	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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		US-20030086362	05/08/2003	Hasegawa, et al.	
		US-20030086514	05/08/2003	Ginis, et al.	
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Examiner Initials*	Cite No [1]	Foreign Patent Document Country Code/Number/Kind Code (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T [2]
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		GB-2315392	01/28/1998	4 Links for Techical Help		
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		WO-2004/027579	04/01/2004	Toyko Electron Ltd.		
		WO-1995/031867	11/23/1995	Bell Communications Research, Inc.		

EXAMINER **DATE CONSIDERED**

Based on PTO/SB/08A(09-06) - Substitute Disclosure Statement Form (PTO-1449) as modified by BSTZ 03/26/07

* EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional) 2 Applicant is to place a check mark here if English language Translation is attached

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /D.T./

Substitute for form 1449A/PTO	Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT *(Use as many sheets as necessary)*	**Application Number**	12/185,729
	Filing Date	August 4, 2008
	First Named Inventor	Cioffi, John
	Group Art Unit	2611
	Examiner Name	Unknown
Sheet 2 of 4	Attorney Docket No: 8241P002D	

OTHER DOCUMENTS -- NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	**Cite No [1]**	**Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.**	**T[2]**
		Non-Final Office Action for U.S. Patent Application No. 11/336,113 (Attorney Docket No. 8241P018) Mailed 11/12/2008, 23 pages.	
		State Intellectual Property Office of the P.R. China, "Notification of the First Office Action" Chinese Application No. 200480040960.5, Attorney Docket No. 8241P002CN. 3/27/09.	
		"International Search Report and Written Opinion", International Application No. PCT/IB2006/000884, 13 pgs. (Atty Docket No. 8241P018PCT) mailed 9/4/2006.	
		"International Search Report and Written Opinion", International Application No. PCT/IB2006/000759, 16 pgs.(Atty Docket No. 8241P017PCT) mailed 8/16/2006.	
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Based on PTO/SB/08A(09-06) - Substitute Disclosure Statement Form (PTO-1449) as modified by BSTZ 03/26/07

* EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1] Applicant's unique citation designation number (optional) [2] Applicant is to place a check mark here if English language Translation is attached

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Substitute for form 1449A/PTO	*Complete if Known*	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT *(Use as many sheets as necessary)*	**Application Number**	12/185,729
	Filing Date	August 4, 2008
	First Named Inventor	Cioffi, John
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	Examiner Name	Unknown
Sheet 3 of 4	Attorney Docket No: 8241P002D	

OTHER DOCUMENTS -- NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	**Cite No [1]**	**Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.**	**T[2]**
		Acoustics, Speech and Signal Processing, New York, NY, US vol. 38, no. 4, (4/1/1990), pgs. 631-653.	
		CUYPERS, et al., "Combined per tone equalization and receiver windowing in DSL receivers: WiPTEQ", Elsevier Science Publishers, Amsterdam, NL, vol. 85, no. 10, (10/2005), pgs. 1921-1942.	
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		GINIS, GEORGE, et al., "A Multiuser precoding scheme achieving crosstalk cancellation with application to DSL systems", Signals, Systems, and Computers, 200. IEEE vol. 2, (10/29/2000), pgs. 1627-1631.	
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		LOUVEAUX, J. , et al., "Downstream VDSL channel tracking using limited feedback for crosstalk precompensated schemes", Acoustics, Speech and Signal Processing,	

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Substitute for form 1449A/PTO	*Complete if Known*	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT *(Use as many sheets as necessary)*	**Application Number**	12/185,729
	Filing Date	August 4, 2008
	First Named Inventor	Cioffi, John
	Group Art Unit	2611
	Examiner Name	Unknown
Sheet 4 of 4	Attorney Docket No: 8241P002D	

OTHER DOCUMENTS -- NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	**Cite No [1]**	**Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.**	**T[2]**
		2005, (3/18/2005), pgs. 337-340.	
		MAGESACHER, et al., "Exploiting the Common-Mode Signal in xDSL", Proc. 12th European Signal Processing Conference (EUSIPCO 2004), Vienna, Austria, September 7-10, 2004., (9/2004), 4 pgs.	
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EXAMINER	/David Ton/	**DATE CONSIDERED**	02/27/2010

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Sheet 1 of 2

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EXAMINER	/David Ton/	**DATE CONSIDERED**	02/27/2010

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application No.	12/185,729
Filing Date	August 4, 2008
First Inventor	John M. Cioffi
Art Unit	2611
Examiner Name	Rhonda Nichol
Attorney Docket No.	8241P002D Conf. No. 9857

DUTY OF DISCLOSURE STATEMENT

In accordance with the duty of disclosure, enclosed is a copy of an Information Disclosure Statement (IDS) Citation Form PTO/SB/08 or PTO-1449, together with copies of the documents cited on that form, except for copies not required to be submitted (e.g., copies of U.S. patents and U.S. published patent applications need not be enclosed). This IDS and IDS Citation Form are being submitted before the mailing of a first Office Action. It is respectfully requested that the cited references be considered and that the enclosed copy of PTO/SB/08 be initialed by the Examiner to indicate such consideration and a copy thereof returned to applicant(s).

The submission of this Information Disclosure Statement is not to be construed as a representation that a search has been made in the subject application and is not to be construed as an admission that the information cited in this statement is material to patentability.

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

OR

☒ None

☐ The IDS Filing Fee in the amount of $180.00 as set forth in 37 CFR 1.17(p) has been submitted herewith.

☒ It is requested that any requisite fees be debited from Deposit Account 02-2666.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of signature.

Signature	/Gregory D. Caldwell/	Date (YYYY-MM-DD)	2009- 04-28
Name/Print	Gregory D. Caldwell	Registration Number	39,926

I hereby certify that this correspondence is being submitted electronically via EFS Web on the date shown below.

Christina Rainey *Date* *04-28-09*

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Sheet 1 of 4	Attorney Docket No: 8241P002D	

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EXAMINER **DATE CONSIDERED**

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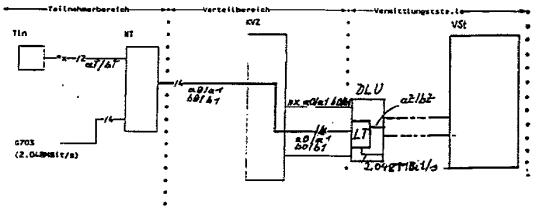
(56) Für die Beurteilung der Patentfähigkeit in Betracht gezogene Druckschriften:
DE 42 10 023 A1

(54) Fernmeldeanschlußnetz zur Übertragung von Fernmeldeinformationen zwischen teilnehmernahen Leitungsanschlußeinheiten und teilnehmerindividuellen Netzabschlußeinheiten

(57) Zwischen teilnehmernahen Leitungsanschlußeinheiten (LT) und teilnehmerindividuellen Netzabschlußeinheiten (NT) werden auf zwei Paaren (a0, b0 · a1, b1) von Kupferleitungsadern nach dem HDB3-Verfahren oder dem HDSL-Verfahren 2,048 MBit/s-Informationen übertragen. Außerdem ist mit den Leitungsaderpaaren ein Phantomkreis gebildet, an den teilnehmerseitig die a, b-Adern aT/bT der Endgerätezuleitung und vermittlungsseitig die a, b-Adern (aZ/bZ) der Teilnehmeranschlußleitung für die Übertragung von 64 kBit/s-Informationen angeschlossen sind.



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Beschreibung

Die Erfindung betrifft ein Fernmeldeanschlußnetz zur Übertragung von Fernmeldeinformationen zwischen teilnehmernahen Leitungsanschlußeinheiten und teilnehmerindividuellen Netzabschlußeinheiten.

Die Entwicklung von Fernsprechnetzen geht immer mehr in Richtung eines Universalnetzes, in dem neben der Übertragung von reinen Fernsprechinformationen in der bisherigen Übertragungsqualität höherwertige Dienste geboten werden, zu denen neben der Sprachübertragung in verbesserter Qualität die Übertragung von Informationen anderer Fernmeldedienste gehören.

Wegen der enormen Investitionen, die in dem existierenden Fernsprechnetz liegen, kann bei der Einführung neuer Dienste nur so vorgegangen werden, daß insbesondere im dezentralen, also teilnehmernahen Bereich auf existierende Einrichtungen und Leitungen zurückgegriffen wird.

Beim sogenannten ISDN (Integrated Services Digital Network) wird mit einem Basisanschluß über die normalen Teilnehmeranschlußleitungen neben zwei Basiskanälen von jeweils 64 kBit/sec Übertragungsbitrate für Sprachübertragung noch ein Kanal von 16 kBit/sec Übertragungsbitrate für die Übertragung anderweitiger Daten zur Verfügung gestellt.

Für Dienste, die eine höhere Übertragungsbitrate erfordern, wie beispielsweise Bildfernsprechen in zufriedenstellender Bildqualität, ist ein solcher Basisanschluß allerdings nicht besonders gut geeignet, da bei der zugrundeliegenden Übertragungstechnik die erforderlichen höherratigen Signale eine zu starke Dampfung erfahren würden.

Die Aufgabe der Erfindung besteht daher darin, ein Fernmeldeanschlußnetz anzugeben, das unter Beibehaltung der kostenintensiven Netzteile neben dem Fernmeldedienst Fernsprechen die Installierung höherwertiger Fernmeldedienste erlaubt, deren Übertragungsbitrate weit über den Möglichkeiten des erwähnten ISDN-Basisanschlusses liegen.

Diese Aufgabe wird durch die im Patentanspruch 1 angegebenen Merkmale gelöst.

Die Erfindung geht davon aus, daß ein sehr großer Teil sowohl der Arbeits- als auch der Materialinvestitionskosten des heutigen Fernsprechnetzes in den Leitungsverbindungen zwischen teilnehmernahen Leitungsanschlußeinheiten in der Form von Anschlußkästen bzw. Kabelverzweigern oder von aus der Vermittlungsstelle ausgelagerten digitalen Leitungseinheiten mit Konzentratorfunktion und teilnehmerindividuellen Netzabschlußeinheiten liegt, wobei es sich bei diesen Leitungsverbindungen um Kupferleitungsadernpaare handelt, von denen in vielen Fällen bisher nur ein Leitungsadernpaar ausgenutzt ist.

Die Erfindung greift auf schon existierende Übertragungstechniken zurück, mit deren Hilfe Informationen mit einer Übertragungsbitrate, die wesentlich höher ist als die für Fernsprechen benötigte Übertragungsbitrate, über Entfernungen übertragen werden können, die in der Größenordnung der Leitungslängen zwischen den erwähnten Leitungsanschlußeinheiten und den teilnehmerindividuellen Netzabschlußeinheiten liegen.

Es ist hier das sogenannten HDB3-Verfahren zu erwähnten, das Gebrauch von einer Vierdrahtleitung mit einem Kupferleitungsadernpaar für die eine Übertragungsrichtung und einem zweiten Kupferleitungsadernpaar für die andere Übertragungsrichtung Gebrauch macht. Mit diesem Verfahren sind bei einer Bitrate von

2,048 MBit/sec Entfernungen von ca. 1 km überbrückbar. Es ist hier ferner das sogenannte HDSL-Verfahren zu erwähnen, bei dem beide Kupferleitungsadernpaare sowohl für die Hin- als auch für die Rückrichtung ausgenutzt werden, wozu eine Echokompensation erforderlich ist, und bei dem der Informationsstrom in bestimmter Weise hälftig auf die beiden Leitungsadernpaare verteilt ist. Mit diesem Verfahren lassen sich bei der angegebenen Bitrate ca. 3 km überbrücken.

Die genannten Verfahren kommen bisher zur Informationsübertragung innerhalb von Fernsprechvermittlungsstellen bzw. zur Informationsübertragung zwischen Fernsprechvermittlungsstelle und vermittlungsnahen Übertragungseinheiten zur Anwendung.

Im Zusammenhang mit dem HDSL-Verfahren ist es aus der DE 42 10 023 auch schon bekannt, zum Übertragen von Datensignalen eine aus zwei symmetrischen Zweidraht-Leitungen bestehende Vierdrahtleitung nach dem sogenannten Vierdraht-Doppel-Duplexverfahren zu betreiben, was bedeutet, daß beide Zweidraht-Leitungen der Vierdrahtleitung für beide Übertragungsrichtungen ausgenutzt werden. Um hohe Dämpfungswerte bei hohen Übertragungsbitraten zu vermeiden, wird bei diesem Übertragungssystem unter Verwendung der Zweidrahtleitungen ein Phantomkreis gebildet und der gesamte Datenstrom dreigeteilt über diesen Phantomkreis und die beiden Zweidraht-Leitungen übertragen.

Da das HDB3-Verfahren und das HDSL-Verfahren schon genormt sind, liegt bei dem erfindungsgemäßen Vorschlag, eine solche Übertragungstechnik auf den Leitungen zwischen Leitungsanschlußeinheiten und teilnehmerindividueller Netzanschlußeinheit einzusetzen, die weitere Überlegung zugrunde, daß diese genormte Technik für die über den eigentlichen Fernsprechverkehr hinausgehenden Dienste unverändert beibehalten werden sollte, um solche Dienste nützende Einrichtungen unverändert einsetzen zu können und nicht diese Techniken durch weiteren Investitionsaufwand oder durch Inkaufnahme verringerter Reichweite um den Bitratenbedarf des Fernsprechens in der Größenordnung von 256 kBit/sec zu erweitern.

In den Unteransprüchen sind vorteilhafte Realisierungen des erfindungsgemäßen Fernsprechanschlußnetzes angegeben

Nachstehend wird die Erfindung anhand eines Ausführungsbeispiels unter Bezugnahme auf eine Zeichnung näher erläutert.

In der Zeichnung zeigen:

Fig. 1 eine Anordnung zur Veranschaulichung des erfindungsgemäß zur Übertragung von Informationen höherer Bitrate in Frage kommenden HDB3-Verfahrens,

Fig. 2 eine entsprechende Anordnung für das alternativ zur Anwendung in Frage kommende HDSL-Verfahren,

Fig. 3 und 4 zwei Varianten von Netzstrukturen, bei denen die Erfindung zum Einsatz gebracht worden ist,

Fig. 5 und 6 die erfindungsgemäße Ausgestaltung der teilnehmernahen Leitungsanschlußeinheiten und teilnehmerindividuellen Netzabschlußeinheiten im Hinblick auf die Zusammenführung der Fernsprechdaten und der mit demgegenüber höherer Bitrate zu übertragenden Daten.

Beim HDB3-Verfahren erfolgt die Informationsübertragung zwischen Sendeeinrichtungen S und Empfangseinrichtungen E, wie **Fig.** 1 zeigt, für Hin- und Rückrichtung über getrennte Leitungsadernpaare a0, a1 bzw. b0, b1.

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Der HDB3-Code, der bei diesem Verfahren für die Digitalsignalübertragung verwendet wird, ist ein pseudoternärer Code, bei dem die "1"-Werte eines Binärcodes abwechselnd durch Impulse mit positiver und negativer Spannung wiedergegeben werden, wogegen die Binärwerte "0" durch die Spannung Null repräsentiert werden und bei dem dafür gesorgt ist, daß, keine längeren "0"-Folgen auftreten können, da diese eine Taktrückgewinnung aus den Wechseln zwischen positiven und negativen Spannungswerten erschweren könnten. Mit dem HDB3-Verfahren lassen sich ohne Einsatz von Zwischenregeneratoren bei einer Übertragungsbitrate von 2,048 MBit/sec Reichweiten von ca. 1 km erreichen.

Beim HDSL-Verfahren (HIGH Bit-Rate Digital Subscriber Line), wie es anhand der **Fig.** 2 veranschaulicht wird, sind für die Übertragung von digitalen Informationen ebenfalls zwei Leitungsadernpaare vorgesehen, wobei jedoch auf jeden Leitungsadernpaar Signale der Hin- und Rückrichtung im Gleichlageverfahren übertragen werden. In den Empfangseinrichtungen der Sende-Empfangseinheiten SE muß daher eine Echokompensation vorgenommen werden.

Der Datenstrom ist beim HDSL-Verfahren in bestimmter Weise hälftig auf die beiden Leitungsadernpaare verteilt. Mit diesem Verfahren lassen sich bei der Übertragung von 2 MBit/sec Signalen, wie erwähnt, Leitungslängen von ca. 3 km überbrücken. Die gegenüber dem HDB3-Verfahren größere Reichweite des HDSL-Verfahrens kommt zum einen durch die erwähnte Verteilung des Datenstroms auf zwei Leitungsadernpaare zustande, wobei so vorgegangen wird, daß aufeinanderfolgende Bits eines Datenwortes abwechselnd über das eine und das andere Leitungsadernpaar übertragen werden und zum andern dadurch, daß jeweils zwei Bit zur Bildung eines quaternären Codes herangezogen werden, so daß sich die Schrittweite der übertragenen Signale, durch die der Grad der Bedämpfung auf der Übertragungsleitung bestimmt wird, insgesamt um den Faktor 4 reduziert, wogegen beim HDB3-Verfahren die Schrittweite der Übertragungsbitrate, also 2 MBit/sec gleicht.

Bei der Netzstruktur gemäß **Fig.** 3 verlaufen zwischen der von der Vermittlungsstelle VSt abgesetzten Leitungsanschlußeinheit LT einer digitalen Leitungseinheit DLU, die zwar funktionell noch zur Vermittlungsstelle zu rechnen ist, jedoch teilnehmernah in einem Abstand von weniger als 3 km angeordnet ist, und einen Kabelverzweiger KVZ, der im Nahbereich von Gebäuden angeordnet ist, ein Bündel von Leitungsadernpaaren. Eines dieser Leitungsadernpaare ist vom Kabelverzweiger KVZ zu der dargestellten Netzanschlußeinheit NT weitergeführt, die dem dargestellten Teilnehmeranschluß mit einem Teilnehmerapparat Tlna und einer Schnittstelle G703 für Daten mit einer höheren Übertragungsrate, beispielsweise 2,048 MBit/s individuell zugeordnet ist.

Auf einem solchen zwischen der Leitungsanschlußeinheit LT der digitalen Leitungseinheit DLU und der Netzanschlußeinheit NT verlaufenden Leitungsadernpaar werden sowohl Fernsprechinformationen, die für den Teilnehmerapparat TlnA bestimmt sind bzw. von diesem stammen, als auch die 2 MBit/sec-Daten von und zur Schnittstelle G703 übertragen, wobei das Multiplexen bzw. Demultiplexen dieser Daten in den Einheiten NT und LT erfolgt, worauf weiter unten noch eingegangen wird.

Schon bisher existierten zwischen den Einheiten LT und NT jeweils zwei Paare von Kupferleitungsadern, so daß das zusätzliche Heranführen von 2 MBit/sec-Informationen keinen zusätzlichen Leitungsaufwand erfordert.

Bei der Netzstruktur gemäß **Fig.** 4 verläuft zwischen der Vermittlungsstelle VSt und dem Kabelverzweiger KVZ ein Bündel von Kupferleitungsadernpaaren, das für die Übertragung von Fernsprechinformationen bestimmt ist und von denen jeweils ein Leitungsadernpaar der Verbindung mit einem bestimmten Teilnehmeranschluß dient.

Zwischen der Vermittlungsstelle VSt und dem Kabelverzweiger KVZ verläuft ferner ein Übertragungssystem ÜH für Signale höherer Übertragungsbitrate, beispielsweise ein Lichtleiterkabel, auf dem 2,048 MBit/s-Informationen übertragen werden.

Die Zusammenführung der beiden Informationsarten erfordern in der Leitungsanschlußeinheit LT, die hier Bestandteil des Kabelverzweigers KVZ ist. Von dort aus verlaufen zur teilnehmerindividuellen Netzabschlußeinheit NT zwei Paare von Leitungsadern, auf denen beide Arten von Informationen übertragen werden.

Das Zusammenführen bzw. Trennen der beiden Arten von Informationen in den Einheiten NT und LT für die Anwendungsfälle nach den **Fig.** 3 oder 4 wird nunmehr anhand der **Fig.** 5 und 6 näher erläutert, wobei in beiden Fällen die Anwendung des HDSL-Verfahrens vorausgesetzt ist.

Gemäß **Fig.** 5 sind als Bestandteil einer Netzabschlußeinheit NT und einer Leitungsanschlußeinheit LT, zwischen denen zwei Leitungsadernpaare mit den Adern a0, a1 und b0, b1 verlaufen, jeweils ein Übertrager ÜT bzw. ÜA angeordnet, die die Leitungsadernpaare abschließen. Die mit diesen Leitungsadernpaaren verbundenen ersten Wicklungen weisen jeweils eine Mittelanzapfung auf, an die im Falle des Übertragers ÜT der Netzabschlußeinheit NT die a-Ader bzw. die b-Ader der Teilnehmerendgerätezuleitung und im Falle des Übertragers ÜA der Leitungsanschlußeinheit LT die a-Ader bzw. die b-Ader der mit der Vermittlungsstelle verbindenden Teilnehmeranschlußleitung angeschlossen ist, die, wie anhand der **Fig.** 3 und 4 erläutert, Bestandteil des zwischen dem Kabelverzweiger KVZ und der abgesetzten digitalen Leitungseinheit DLU mit der Leitungsanschlußeinheit LT bzw. zwischen dem Kabelverzweiger KVZ und der Vermittlungsstelle VSt verlaufenden Leitungsbündels ist.

Es ist also ein Phantomkreis gebildet, bei dem die Adern a0 und a1 bzw. b0 und b1 jeweils gemeinsam neben ihrer Eigenschaft als Bestandteil einer Übertragungsleitung für 2 MBit/sec-Signale Bestandteil der a-Adernverbindung bzw. b-Adernverbindung zwischen Teilnehmeranschluß und Vermittlungsstelle darstellen, über die der konventionelle Fernsprechverkehr abgewickelt wird oder die Bestandteil eines ISDN-Basisanschlusses ist. Im letztgenannten Fall wäre bei den Anordnungen gemäß **Fig.** 3 und 4 zu den Netzabschlußeinheiten NT zum ISDN-Basisanschluß gehörende Netzabschlußeinheiten funktionell in Reihe geschaltet zu denken.

Durch den beschriebenen Anschluß der Teilnehmerendgerätezuleitung bzw. der Teilnehmeranschlußleitung an Mittelanzapfungen der Übertrager ist eine symmetrische Ein- und Auskopplung der auf diesen Leitungen auftretenden Ströme gewährleistet und damit die Beeinträchtigung der 2MBit/sec-Signale durch diese Ströme schon weitgehend vermieden.

Bei der Ausführungsform gemäß **Fig.** 6 ist den mit

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den Adern der Leitungsadernpaare verbundenen Wicklungen der Übertrager ÜT und ÜA jeweils die Reihenschaltung gleichgroßer Koppelglieder K parallel geschaltet, an deren Verbindungspunkt die a-Adern bzw. b-Adern der Teilnehmerendgerätezuleitung bzw. der mit der Vermittlungsstelle verbindenden Teilnehmeranschlußleitung angeschlossen sind. Zur weiteren Vermeidung gegenseitiger Störungen ist es erforderlich, daß die Adern a0 und a1 bzw. b0 und b1 der Leitungsadernpaare jeweils miteinander und in dieser Form auch von Leitungsadernpaar zu Leitungsadernpaar verdrallt sind. Diese Art von Verdrallung ist bei Leitungsadernpaaren bisher schon verlegter Leitungen, die noch nicht als Bestandteil eines Phantomkreises und demnach noch nicht für die Übertragung von 2 MBit/sec-Informationen ausgenutzt waren, schon gegeben, so daß solche Leitungen ohne weiteres in der erfindungsgemäßen Weise betrieben werden können.

Unter Umständen können zur Verbesserung der Störvermeidung auch noch einfache Filter vorgesehen sein, die verhindern, daß durch Schaltvorgänge im Bereich der a-/b-Adern des Teilnehmerendgeräts höherfrequente Anteile auftreten, die bei nicht vollkommener Symmetrie die 2 MBit/sec-Signale stören könnten.

Patentansprüche

1. Fernmeldeanschlußnetz zur Übertragung von Fernmeldeinformationen zwischen teilnehmernahen Leitungsanschlußeinheiten (LT), die mit der Fernmeldevermittlungsstelle neben einem Kupferleitungsbündel über ein Breitbandkabel, vorzugsweise Lichtleiterkabel verbunden sind, und teilnehmerindividuellen Netzabschlußeinheiten (NT) mit jeweils zwei teilnehmerindividuellen Kupferleitungsaderpaaren (a0, a1; b0, b1) zwischen Leitungsanschlußeinheit und teilnehmerindividuellem Netzabschluß (NT) zur Übertragung digitaler Informationen, deren Bitrate über der Bitrate von Fernsprechinformationen liegt, gemäß einer durch Normung für solche hohen Bitraten festgelegten Übertragungstechnik und unter Einhaltung einer ausreichend geringen Leitungslänge sowie mit Ausnutzung der Adern (a0, a1; b0, b1) der jeweils zwei teilnehmerindividuellen Kupferleitungsadernpaare zur Bildung eines Phantomkreises, in den teilnehmerseitig die a-Ader und b-Ader (aZ, bZ) der Fernsprechteilnehmerendgerätezuleitung und auf der Seite einer Leitungsanschlußeinheit die a-Ader und die b-Ader (aT, bT) einer mit der Fernsprechvermittlungsstelle verbindenden Fernsprechteilnehmeranschlußleitung mündet, wozu die auf den genannten a-Adern und b-Adern (aZ, bZ; aT, bT) auftretenden Ströme symmetrisch auf die Adern (a0, a1; b0, b1) der beiden Kupferleitungsadernpaare eingekoppelt werden und wozu die Adern (a0, b0; a1, b1) der beiden Kupferleitungsadernpaare jeweils untereinander wie auch von Leitungsadernpaar zu Leitungsadernpaar möglichst eng verkoppelt sind.

2. Fernsprechanschlußnetz nach Anspruch 1, dadurch gekennzeichnet, daß die Einkopplung der auf den a-Adern und b-Adern (aZ, bZ; aT, bT) der Fernspechteilnehmerendgerätezuleitung und der Fernsprechteilnehmeranschlußleitung auftretenden Ströme auf die Adern (a0, a1; b0, b1) der beiden Leitungsadernpaare durch Verwendung eines teilnehmerseitigen und eines auf der Seite des Anschlußverzweigers liegenden Übertragers (ÜT, ÜA) erfolgt, an deren erste Wicklung (w1) die Adern (a0, a1; b0, b1) der Leitungsadernpaare angeschlossen sind und die eine Mittelanzapfung aufweisen, an die jeweils eine der genannten a-Adern (aZ, aT) oder b-Adern (bZ, bT) angeschlossen ist und deren jeweils zweite Wicklung (w2) an Sende- bzw. Empfangseinrichtungen (S/E) für die Informationen höherer Bitrate angeschlossen sind.

3. Fernsprechanschlußnetz nach Anspruch 1, dadurch gekennzeichnet, daß zur Entkopplung der auf den a-Adern und b-Adern der Fernsprechteilnehmerendgerätezuleitung (aZ, bZ) und der Fernsprechteilnehmeranschlußleitung (aT, bT) auftretenden Ströme auf die Adern (a0, a1; b0, b1) jeweils zweier Leitungsadernpaare teilnehmerseitig die a-Ader und b-Ader (aZ, bZ) der Fernsprechteilnehmerendgerätezuleitung und auf der Seite des Anschlußverzweigers (A) die a-Ader und b-Ader (aT, bT) der Fernsprechteilnehmeranschlußleitung jeweils über zwei Identische Koppelglieder (K, K) mit den Adern eines der Leitungsadernpaare verbunden sind.

4. Fernmeldeanschlußnetz nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß zur Erzielung der möglichst engen Verkopplung die Adern (a0, b0; a1, b1) der Leitungsadernpaare miteinander verdrallt sind und in dieser Form die beiden Leitungsadernpaare miteinander verdrallt sind.

Hierzu 3 Seite(n) Zeichnungen

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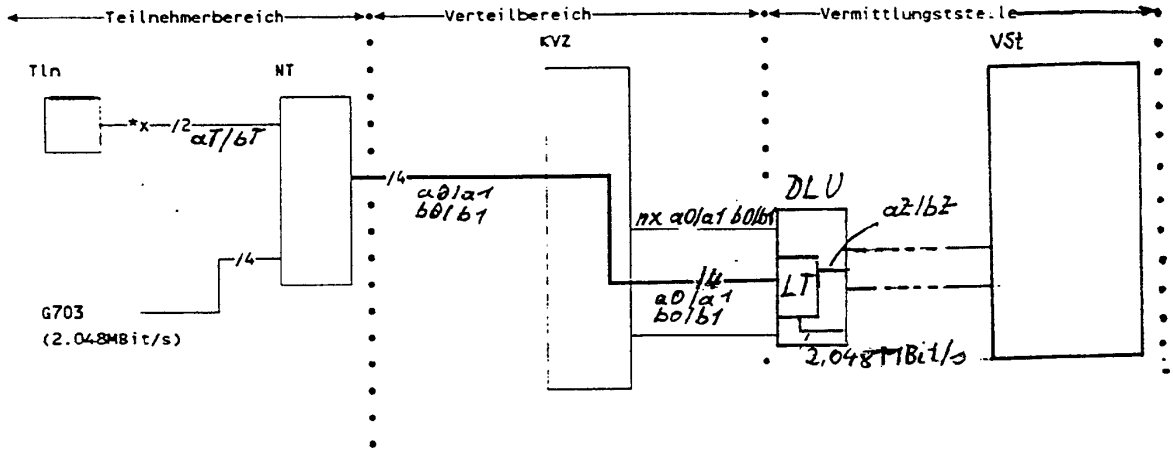

Fig. 3

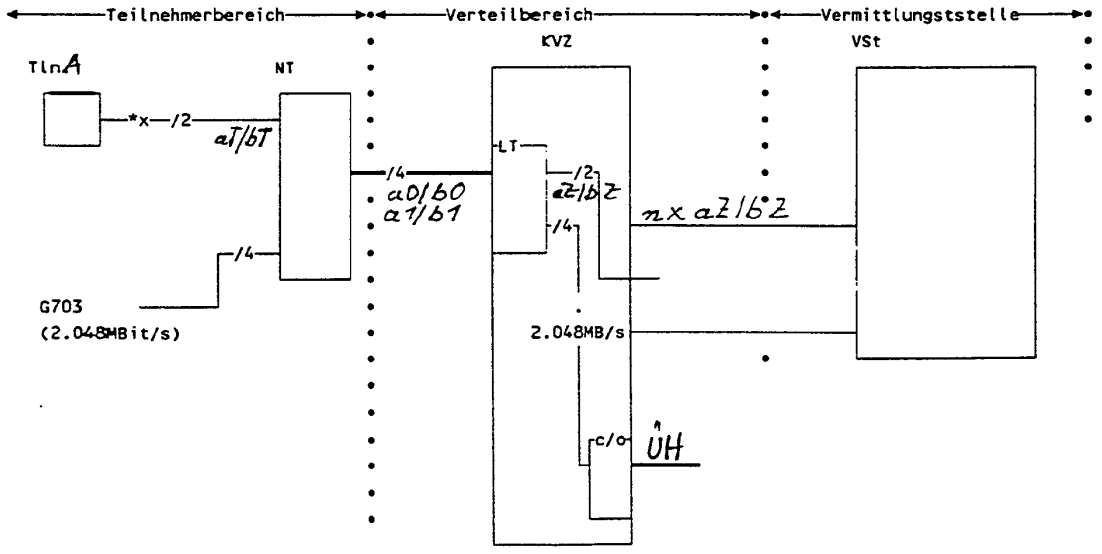

Fig. 4

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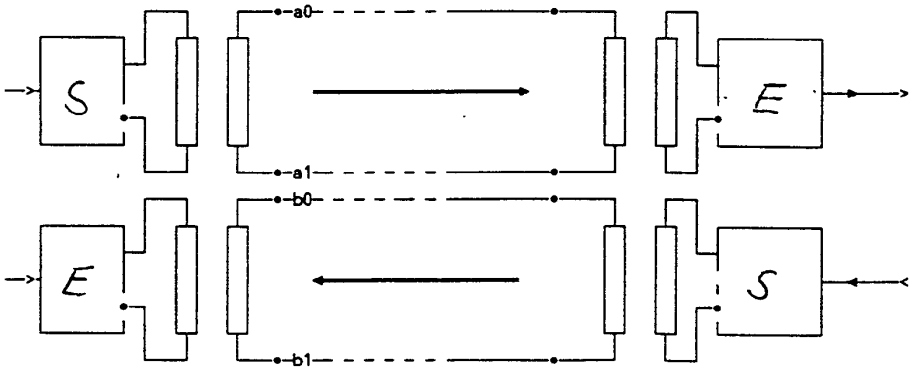

Fig. 1

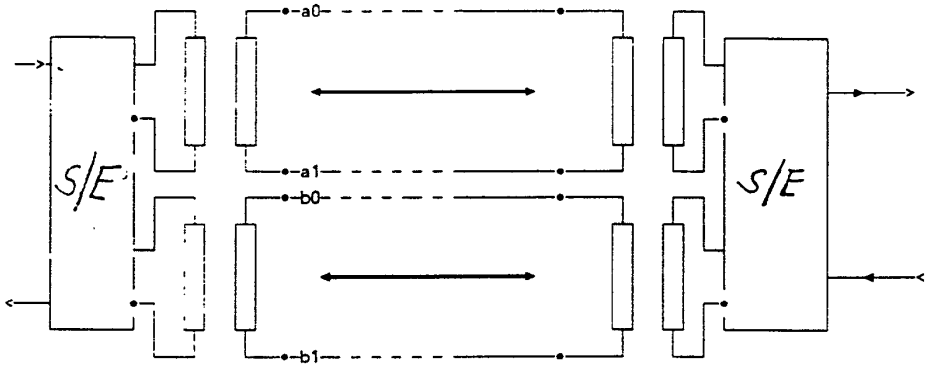

Fig. 2

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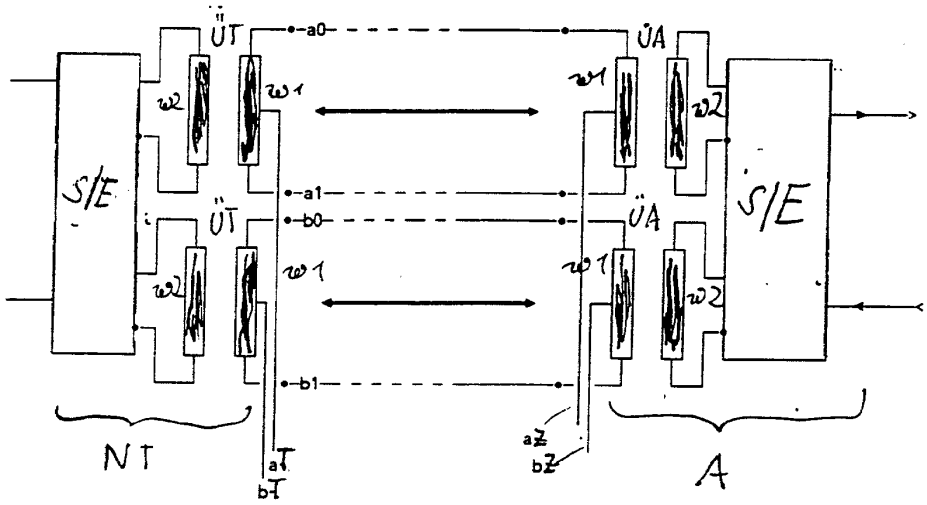

Fig. 5

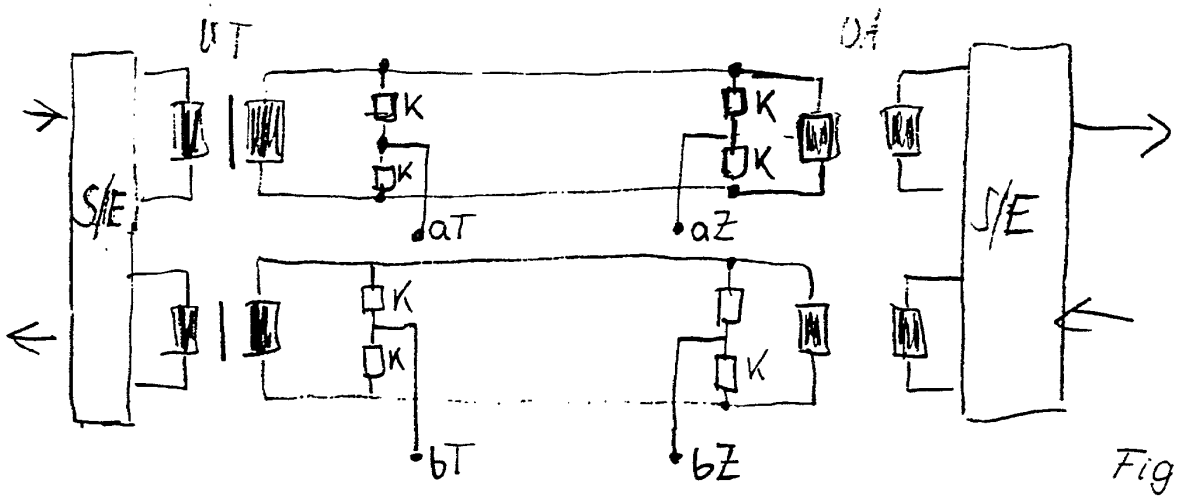

Fig. 6

508 168/359

Charter Communications, Inc.
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Page #90

(12) UK Patent Application (19) GB (11) 2 315 392 (13) A

(43) Date of A Publication 28.01.1998

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(22) Date of Filing 10.07.1997

(30) Priority Data
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(71) Applicant(s)
4 Links for Technical Help

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(51) INT CL[6]
H04L 5/20 , H03M 5/16 , H04B 1/69 , H04L 7/04 12/40 25/49

(52) UK CL (Edition P)
H4P PDCR PDCSL PDD PDT PPC

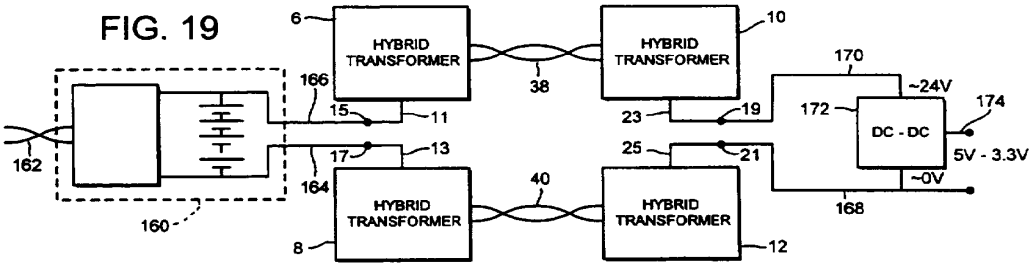
(56) Documents Cited
GB 2280826 A GB 1540414 A GB 1516751 A
EP 0404994 A1 EP 0112716 A2 US 4583214 A
US 4173714 A

(58) Field of Search
UK CL (Edition O) H4P PPC , H4R RLH RLS
INT CL[6] H04L 5/20 12/40 25/22
Online : WPI

(54) Transformer coupled communications system

(57) A communication system includes two high speed communication links 38, 40 formed by pairs of transformers 6, 8, 10, 12 at either end thereof. A low speed link comprising a "phantom circuit" formed by the pairs of transformers is used to distribute power to devices connected to the high speed links. In the transmission part of a communications system, data is transmitted under the control of a continuously variable frequency clock. Transmission is on parallel data-strobe links, and the receive part includes circuitry to identify on which parallel the data signal is preset. A method and circuitry is provided for transmitting and receiving dc balanced data-strobe signals. An 8B10B encoder and decoder are described. Also ternary encoding/decoding arrangements.

FIG. 19



GB 2 315 392 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Charter Communications, Inc.
Exhibit 1007
Page #91

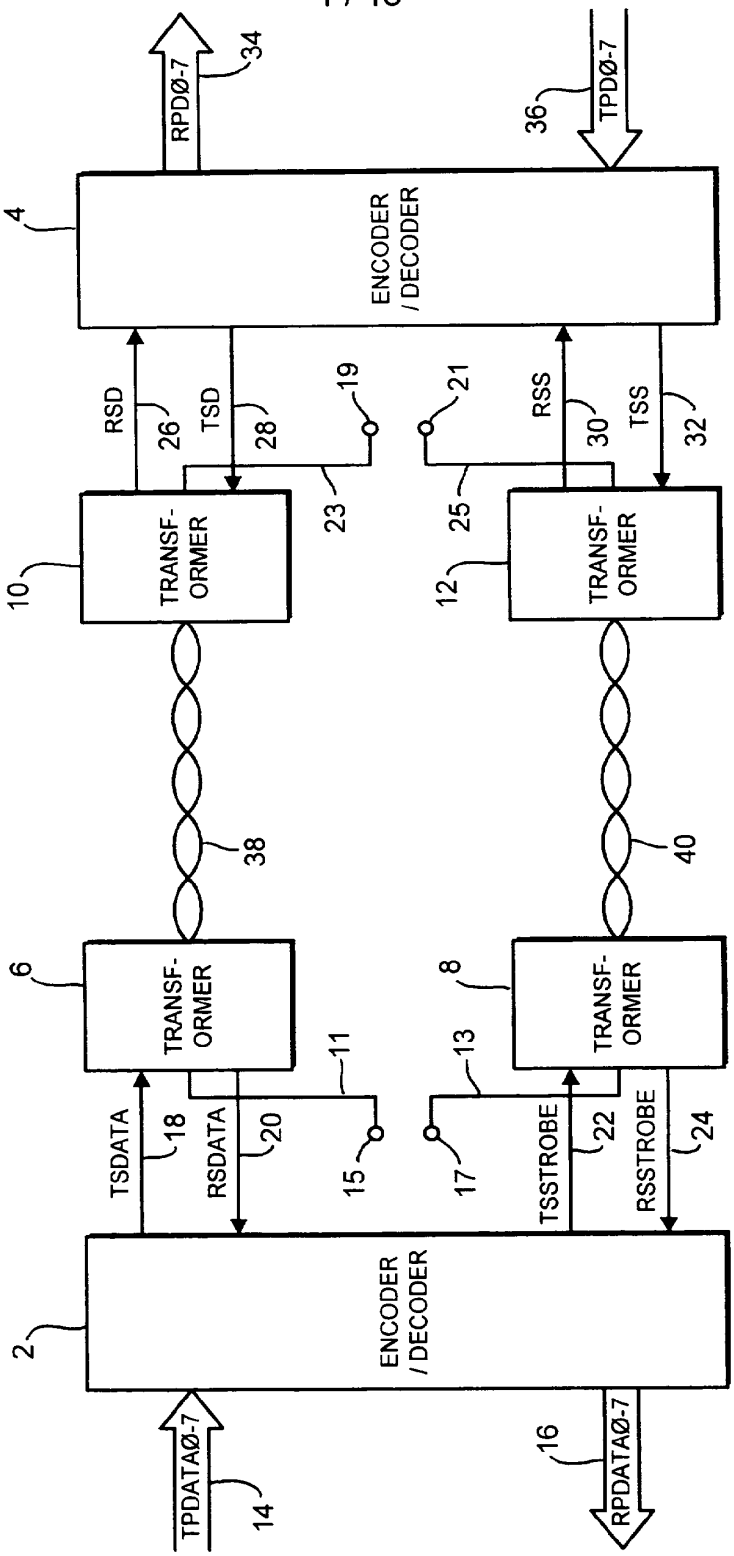

ENCODER / DECODER
4
RPDØ-7
34
TPDØ-7
36
RSD
26
TSD
28
19
21
RSS
30
TSS
32
TRANSF-ORMER
10
TRANSF-ORMER
12
23
25
38
40
TRANSF-ORMER
6
TRANSF-ORMER
8
11
13
TSDATA
18
RSDATA
20
15
17
TSSTROBE
22
RSSTROBE
24
ENCODER / DECODER
2
TPDATAØ-7
14
16
RPDATAØ-7

FIG. 1

FIG. 2

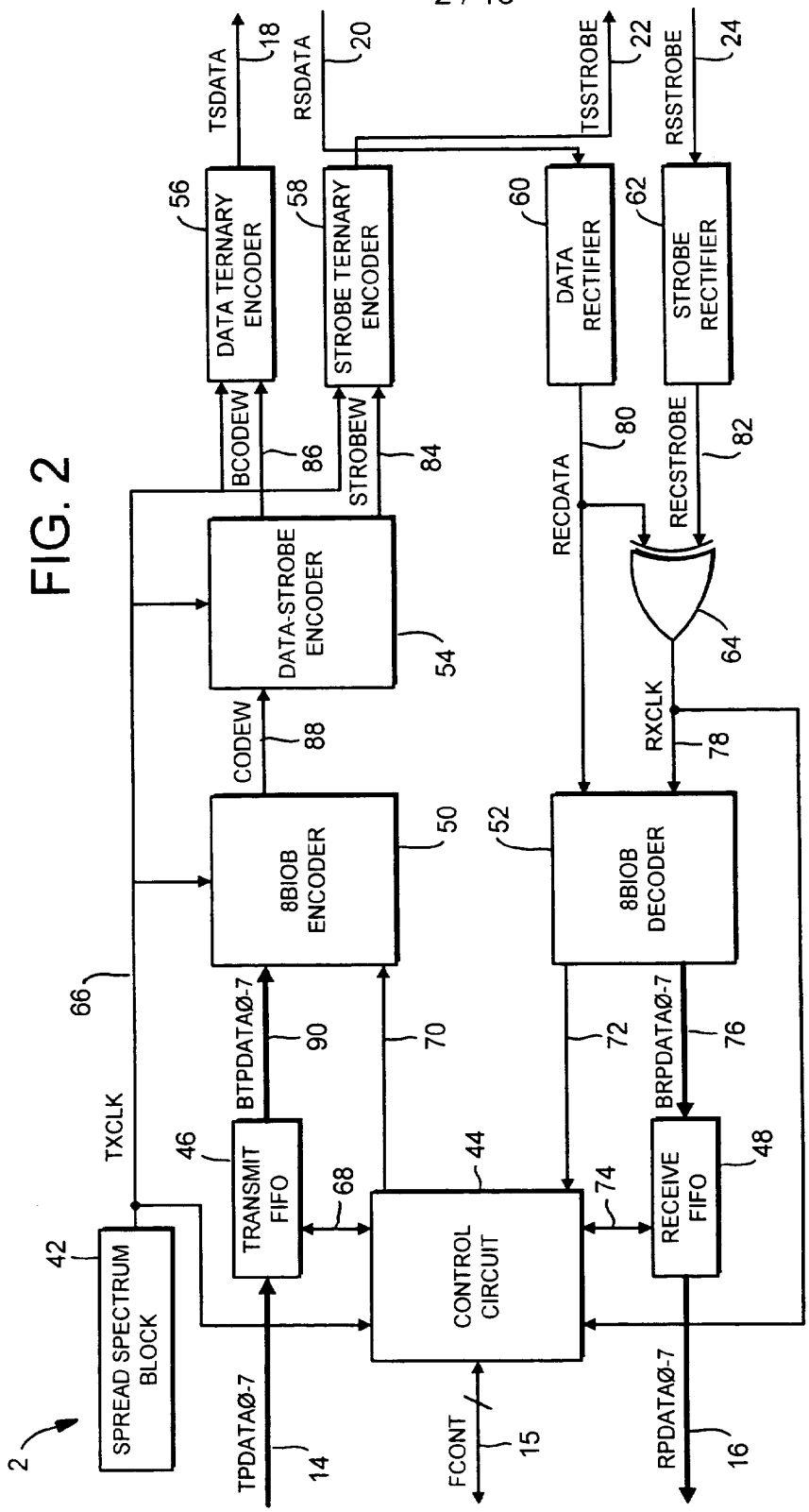

2
SPREAD SPECTRUM BLOCK
42
TXCLK
66
TRANSMIT FIFO
46
BTPDATAØ-7
90
8BIOB ENCODER
50
CODEW
88
DATA-STROBE ENCODER
54
BCODEW
86
STROBEW
84
DATA TERNARY ENCODER
56
STROBE TERNARY ENCODER
58
TSDATA
18
RSDATA
20
TPDATAØ-7
14
CONTROL CIRCUIT
44
68
70
FCONT
15
8BIOB DECODER
52
DATA RECTIFIER
60
STROBE RECTIFIER
62
TSSTROBE
22
RSSTROBE
24
RECDATA
80
RECSTROBE
82
64
RXCLK
78
72
74
BRPDATAØ-7
76
RECEIVE FIFO
48
RPDATAØ-7
16

FIG. 3

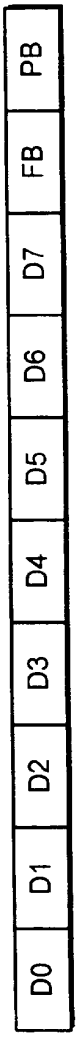

D0
D1
D2
D3
D4
D5
D6
D7
FB
PB

FIG. 4

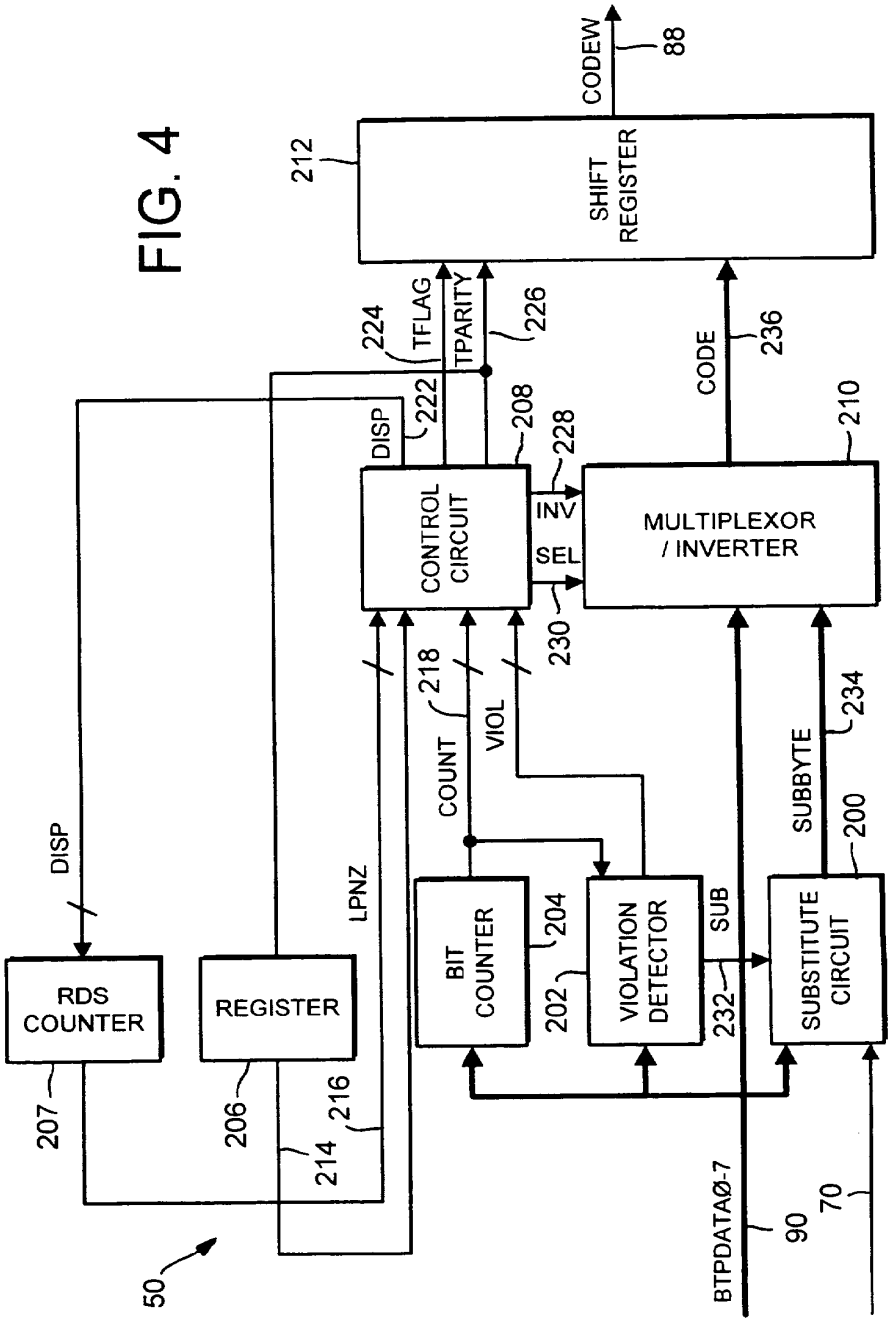

CODEW
88
212
SHIFT REGISTER
224
TFLAG
TPARITY
226
CODE
236
DISP
222
208
228
210
CONTROL CIRCUIT
INV
SEL
MULTIPLEXOR / INVERTER
230
218
COUNT
VIOL
234
SUBBYTE
200
DISP
LPNZ
RDS COUNTER
REGISTER
BIT COUNTER
204
VIOLATION DETECTOR
SUB
232
SUBSTITUTE CIRCUIT
202
207
206
214
216
50
BTPDATAØ-7
90
70

FIG. 5

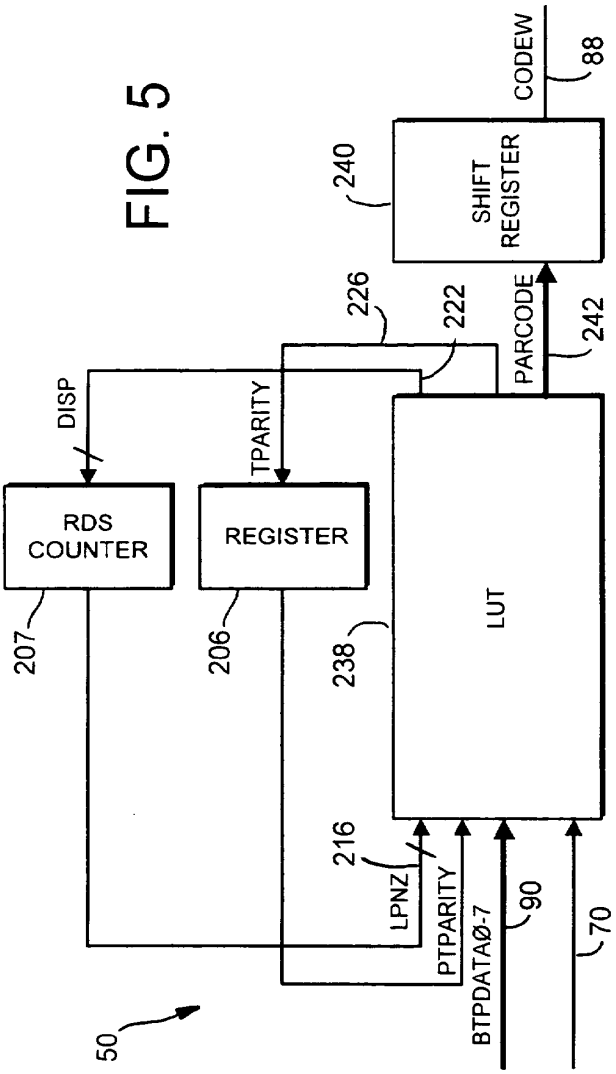
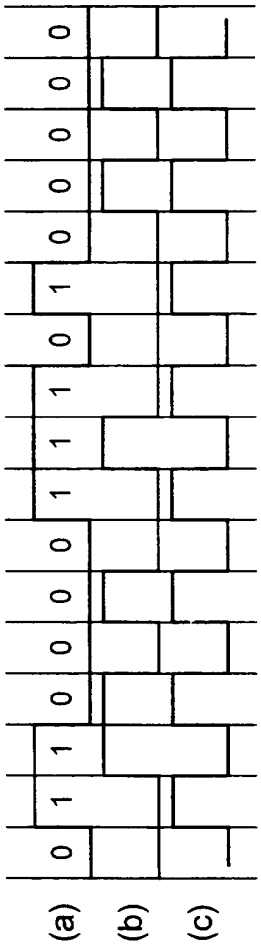

CODEW
88
240
SHIFT REGISTER
226
222
PARCODE
242
DISP
TPARITY
RDS COUNTER
REGISTER
LUT
207
206
238
216
LPNZ
PTPARITY
BTPDATAØ-7
90
70
50

FIG. 6


0 1 1 0 0 0 1 1 1 0 1 0 0 0 0 0
(a)
(b)
(c)

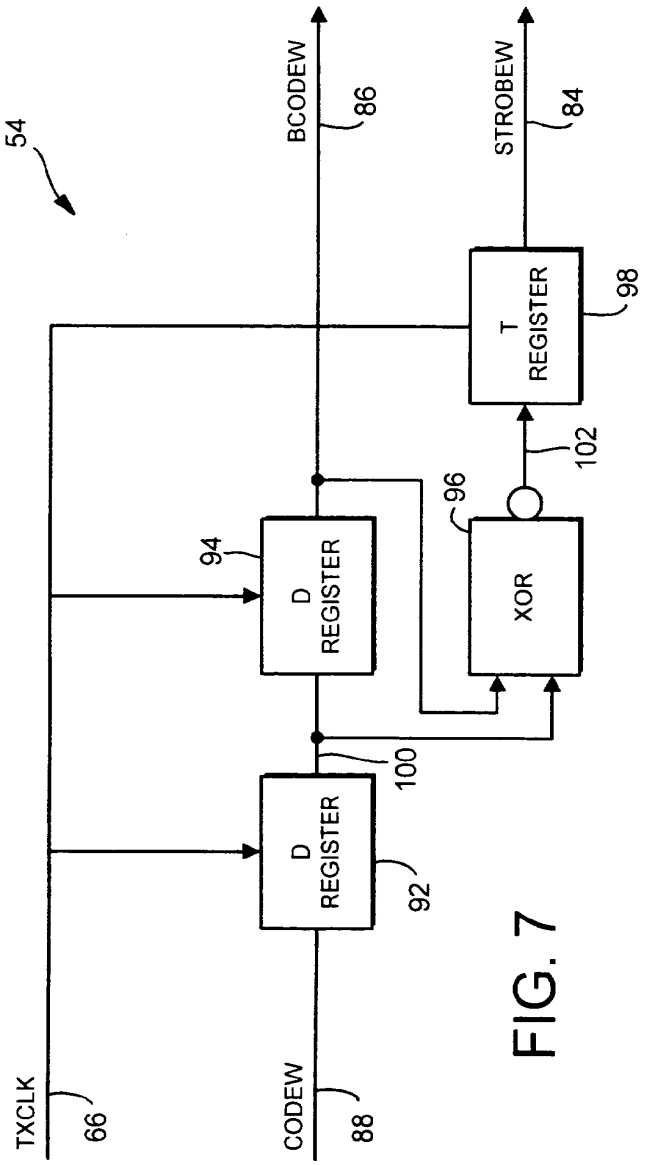

54
BCODEW
86
STROBEW
84
T
REGISTER
98
D
REGISTER
94
XOR
96
102
D
REGISTER
92
100
TXCLK
66
CODEW
88

FIG. 7

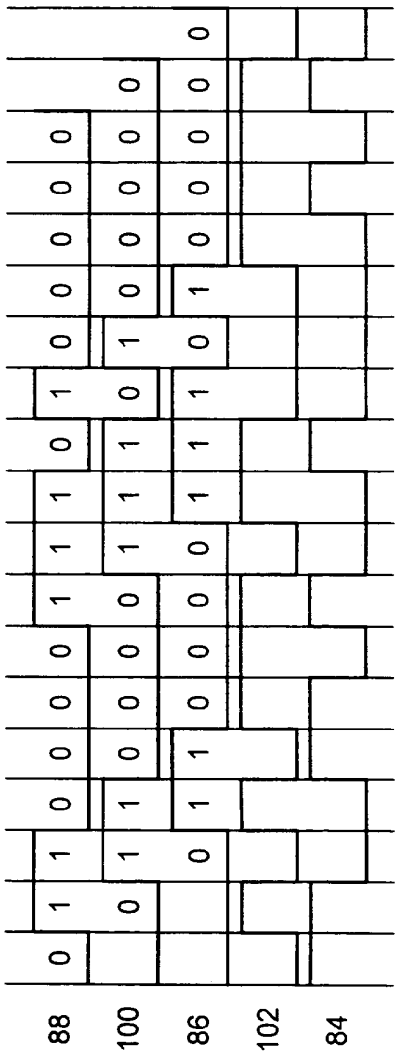

88
100
86
102
84

FIG. 8

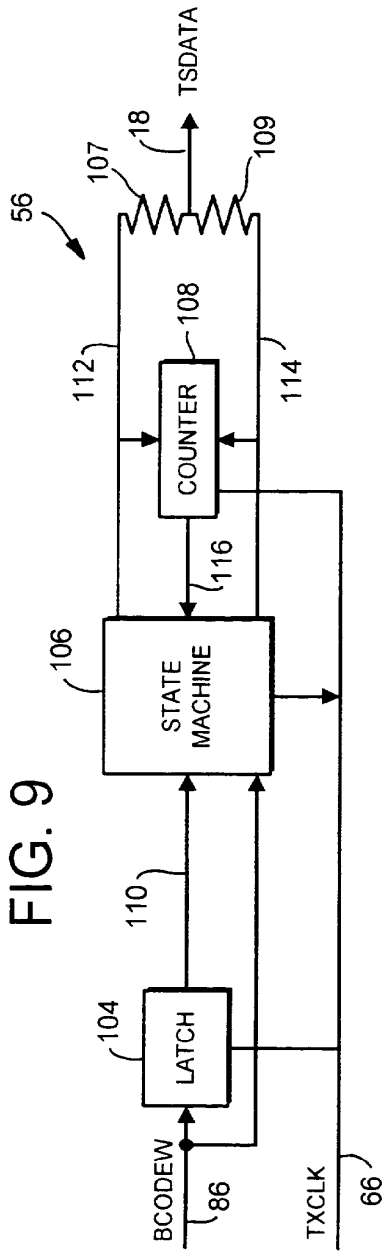

56
107
18
TSDATA
109
112
108
COUNTER
114
116
106
STATE MACHINE
110
104
LATCH
BCODEW
86
TXCLK
66

FIG. 9

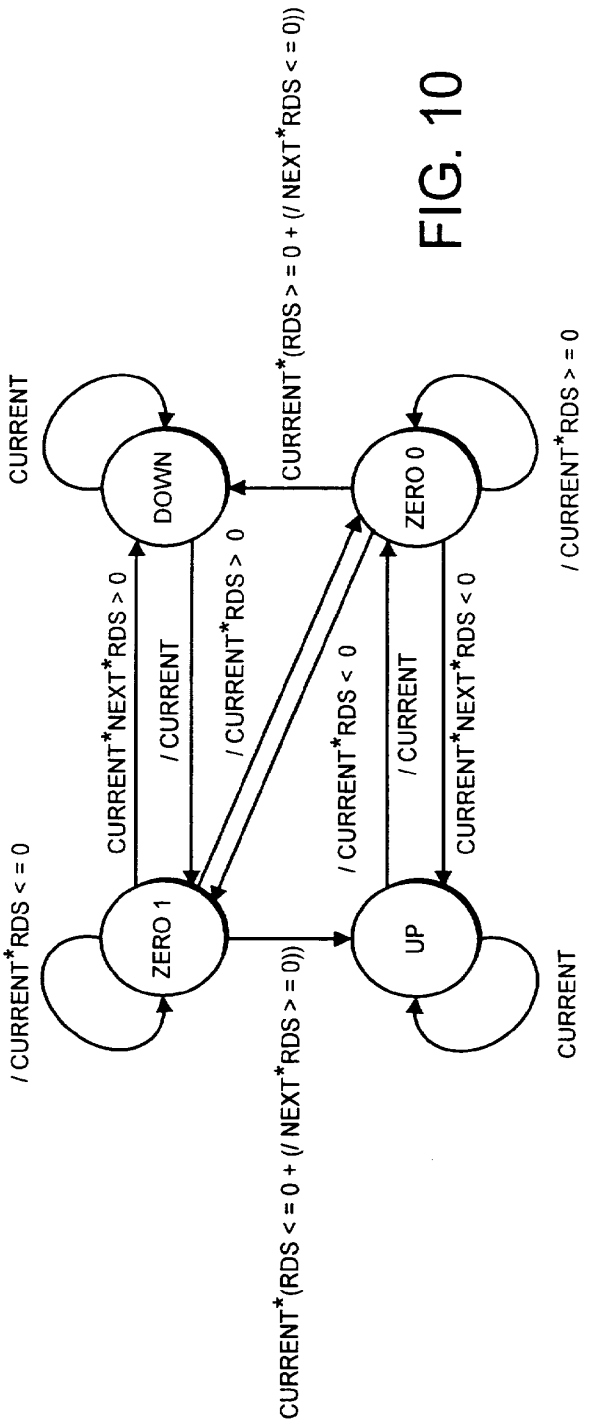

CURRENT
DOWN
CURRENT*(RDS > = 0 + (/ NEXT*RDS < = 0))
ZERO 0
/ CURRENT*RDS = 0
/ CURRENT*RDS < = 0
CURRENT*NEXT*RDS > 0
/ CURRENT
/ CURRENT*RDS > 0
/ CURRENT*RDS < 0
CURRENT*NEXT*RDS < 0
/ CURRENT
ZERO 1
UP
/ CURRENT*RDS < = 0
CURRENT*(RDS < = 0 + (/ NEXT*RDS > = 0))
CURRENT

FIG. 10

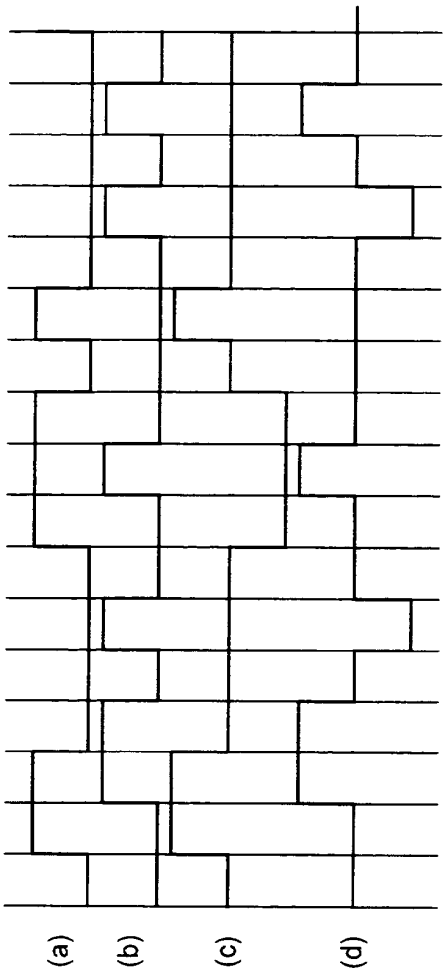

(a)
(b)
(c)
(d)

FIG. 11

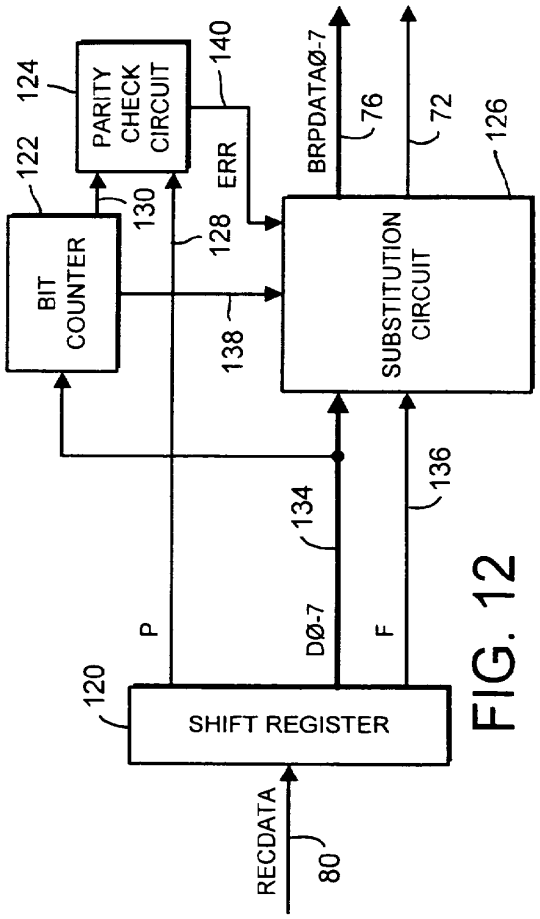

RECDATA
80
SHIFT REGISTER
120
P
DØ-7
F
134
136
BIT COUNTER
122
PARITY CHECK CIRCUIT
124
130
128
ERR
140
138
SUBSTITUTION CIRCUIT
126
BRPDATAØ-7
76
72

FIG. 12

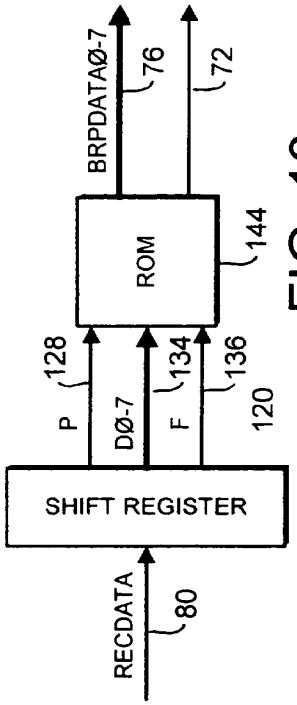

BRPDATAØ-7
76
72
ROM
144
128
134
136
120
P
DØ-7
F
SHIFT REGISTER
RECDATA
80

FIG. 13

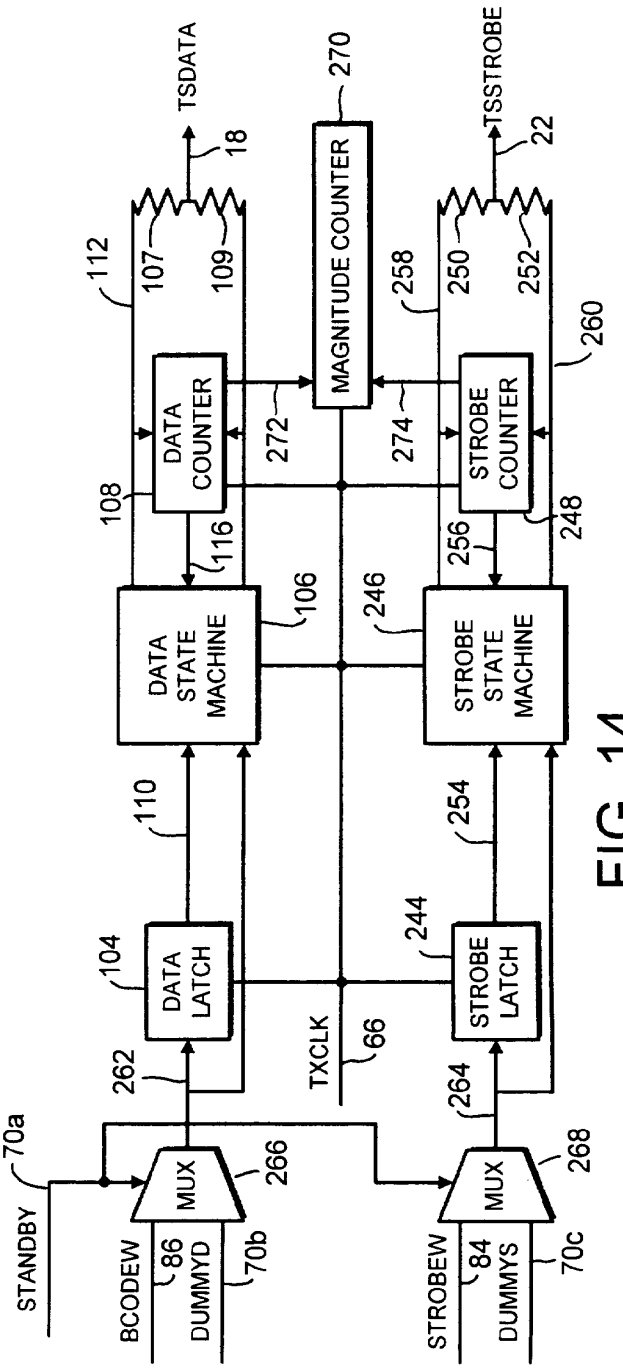

TSDATA
18
TSSTROBE
22
270
MAGNITUDE COUNTER
112
107
109
258
250
252
260
DATA COUNTER
STROBE COUNTER
272
274
108
116
256
248
DATA STATE MACHINE
STROBE STATE MACHINE
106
246
110
254
DATA LATCH
STROBE LATCH
104
244
TXCLK
66
262
264
70a
MUX
MUX
266
268
STANDBY
BCODEW
86
DUMMYD
70b
STROBEW
84
DUMMYS
70c

FIG. 14

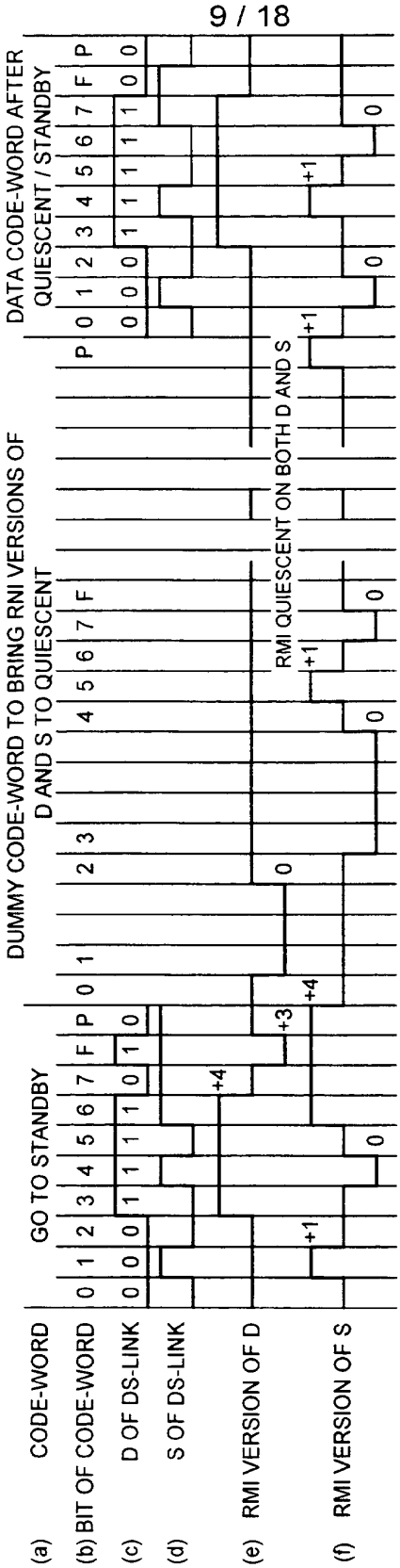

(a) CODE-WORD
(b) BIT OF CODE-WORD
(c) D OF DS-LINK
(d) S OF DS-LINK
(e) RMI VERSION OF D
(f) RMI VERSION OF S
GO TO STANDBY
DUMMY CODE-WORD TO BRING RNI VERSIONS OF D AND S TO QUIESCENT
RMI QUIESCENT ON BOTH D AND S
DATA CODE-WORD AFTER QUIESCENT / STANDBY
+1
+3
+4

FIG. 15

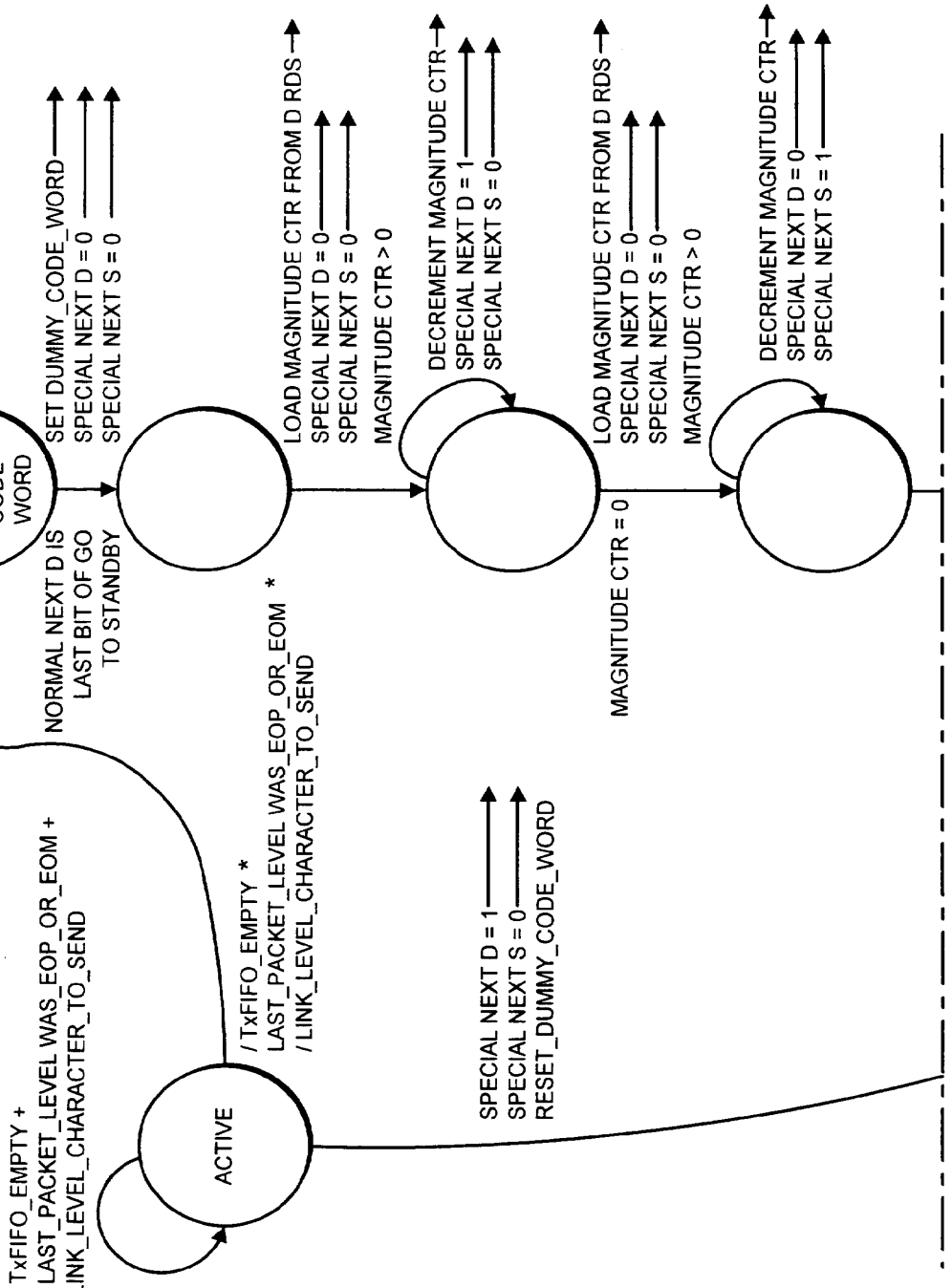

ACTIVE
SEND GO TO STANDBY CODE-WORD
/ TxFIFO_EMPTY +
/ LAST_PACKET_LEVEL WAS_EOP_OR_EOM +
LINK_LEVEL_CHARACTER_TO_SEND
NORMAL NEXT D IS
NOT LAST BIT OF
GO TO STANDBY
NORMAL NEXT D IS
LAST BIT OF GO
TO STANDBY
/ TxFIFO_EMPTY *
LAST_PACKET_LEVEL WAS_EOP_OR_EOM *
/ LINK_LEVEL_CHARACTER_TO_SEND
SET DUMMY_CODE_WORD
SPECIAL NEXT D = 0
SPECIAL NEXT S = 0
SPECIAL NEXT D = 1
SPECIAL NEXT S = 0
RESET_DUMMY_CODE_WORD
LOAD MAGNITUDE CTR FROM D RDS
SPECIAL NEXT D = 0
SPECIAL NEXT S = 0
MAGNITUDE CTR > 0
DECREMENT MAGNITUDE CTR
SPECIAL NEXT D = 1
SPECIAL NEXT S = 0
MAGNITUDE CTR = 0
LOAD MAGNITUDE CTR FROM D RDS
SPECIAL NEXT D = 0
SPECIAL NEXT S = 0
MAGNITUDE CTR > 0
DECREMENT MAGNITUDE CTR
SPECIAL NEXT D = 0
SPECIAL NEXT S = 1

FIG. 16

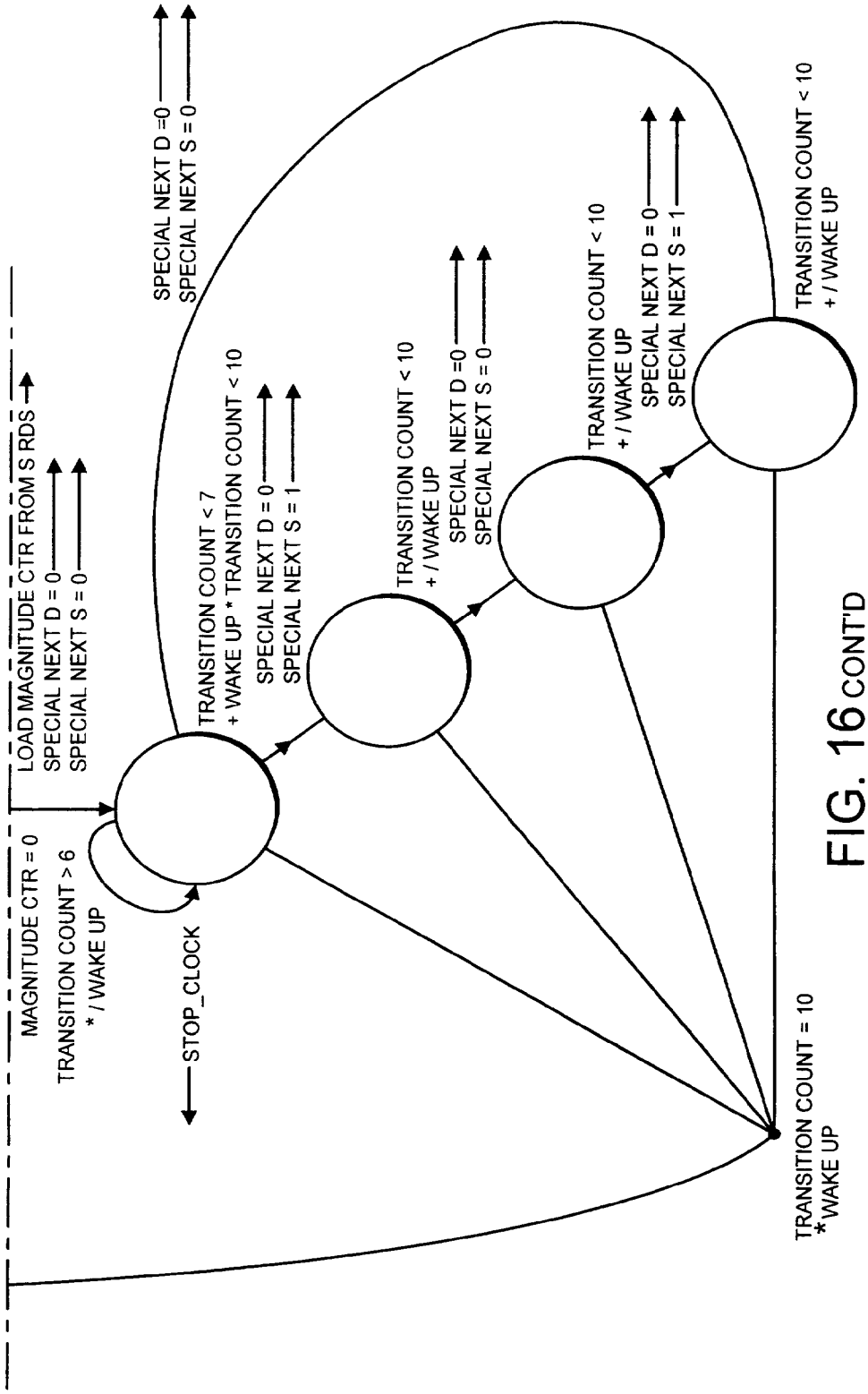

MAGNITUDE CTR = 0
TRANSITION COUNT > 6
* / WAKE UP
LOAD MAGNITUDE CTR FROM S RDS
SPECIAL NEXT D = 0
SPECIAL NEXT S = 0
STOP_CLOCK
TRANSITION COUNT < 7
+ WAKE UP * TRANSITION COUNT < 10
SPECIAL NEXT D = 0
SPECIAL NEXT S = 1
TRANSITION COUNT < 10
+ / WAKE UP
SPECIAL NEXT D =0
SPECIAL NEXT S = 0
TRANSITION COUNT < 10
+ / WAKE UP
SPECIAL NEXT D = 0
SPECIAL NEXT S = 1
TRANSITION COUNT < 10
+ / WAKE UP
SPECIAL NEXT D =0
SPECIAL NEXT S = 0
TRANSITION COUNT = 10
*WAKE UP

FIG. 16 CONT'D

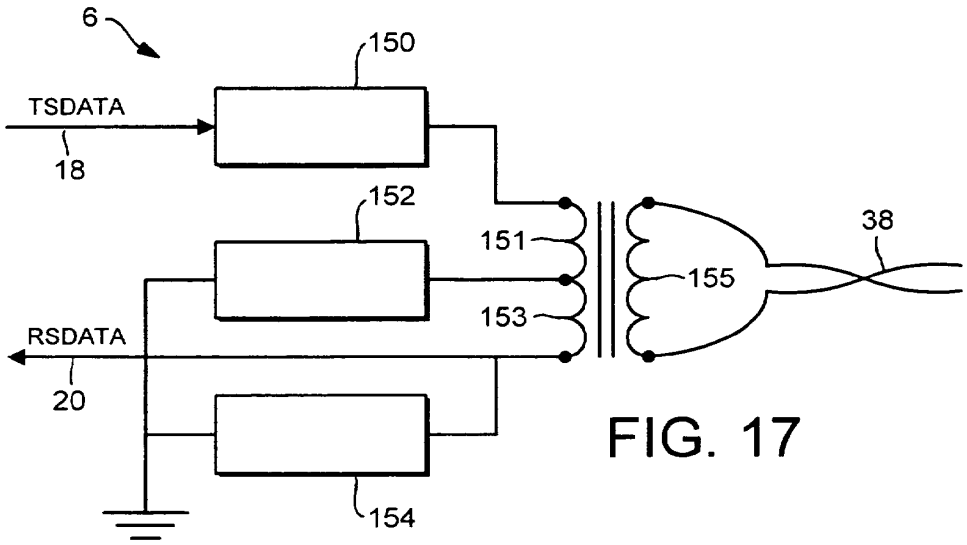

6
150
TSDATA
18
152
151
38
155
153
RSDATA
20
154

FIG. 17

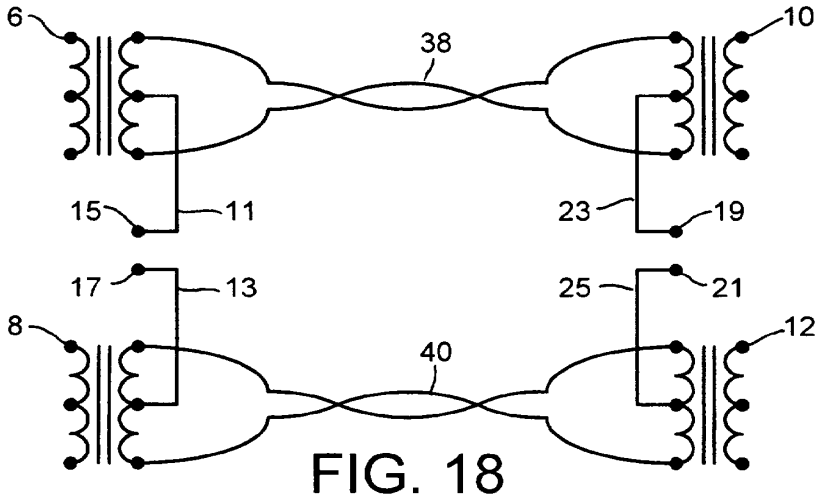

6
38
10
15
11
23
19
17
13
25
21
8
40
12

FIG. 18

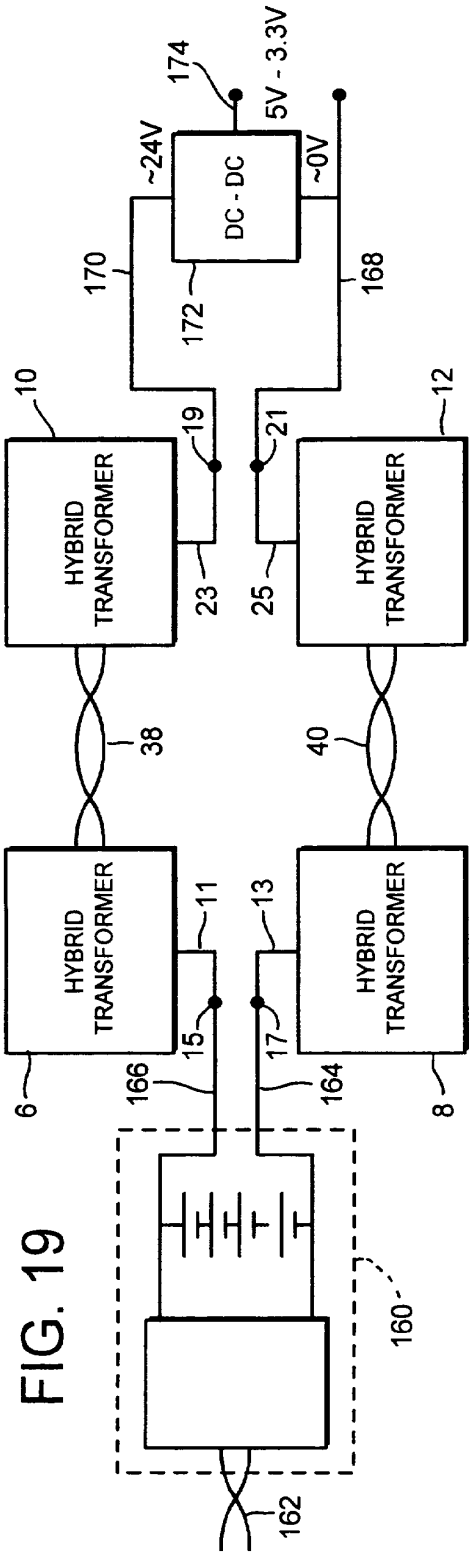

174
5V - 3.3V
~24V
DC - DC
~0V
170
172
168
10
HYBRID TRANSFORMER
19
21
12
HYBRID TRANSFORMER
23
25
38
40
HYBRID TRANSFORMER
11
13
HYBRID TRANSFORMER
6
15
17
8
166
164
160
162

FIG. 19

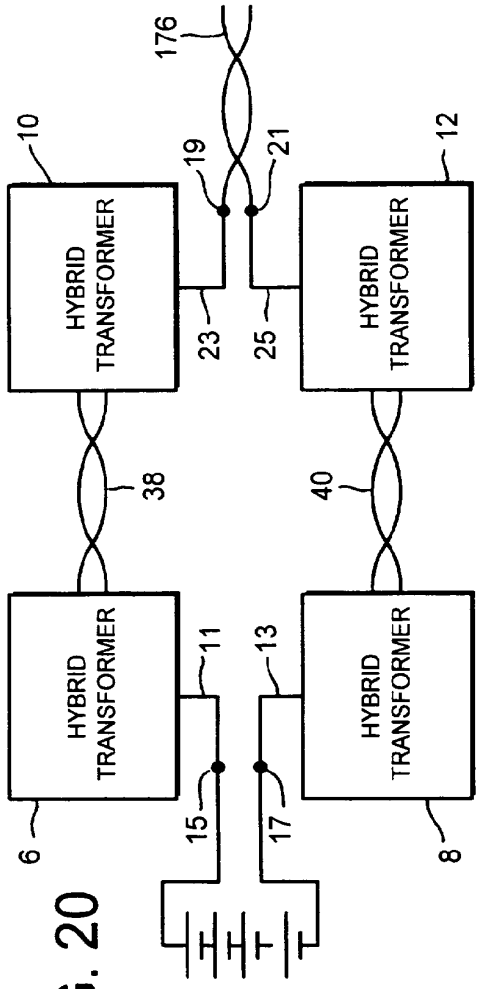

176
10
HYBRID TRANSFORMER
19
21
12
HYBRID TRANSFORMER
23
25
38
40
HYBRID TRANSFORMER
11
13
HYBRID TRANSFORMER
6
15
17
8

FIG. 20

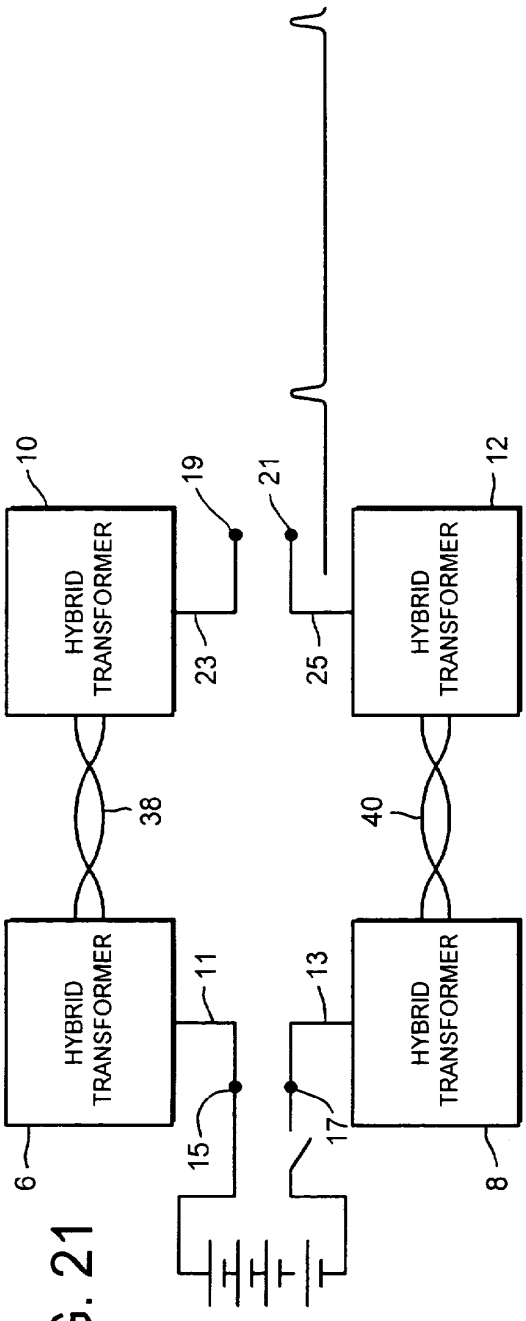

HYBRID TRANSFORMER
10
19
21
12
23
25
38
40
11
13
15
17
6
8

FIG. 21

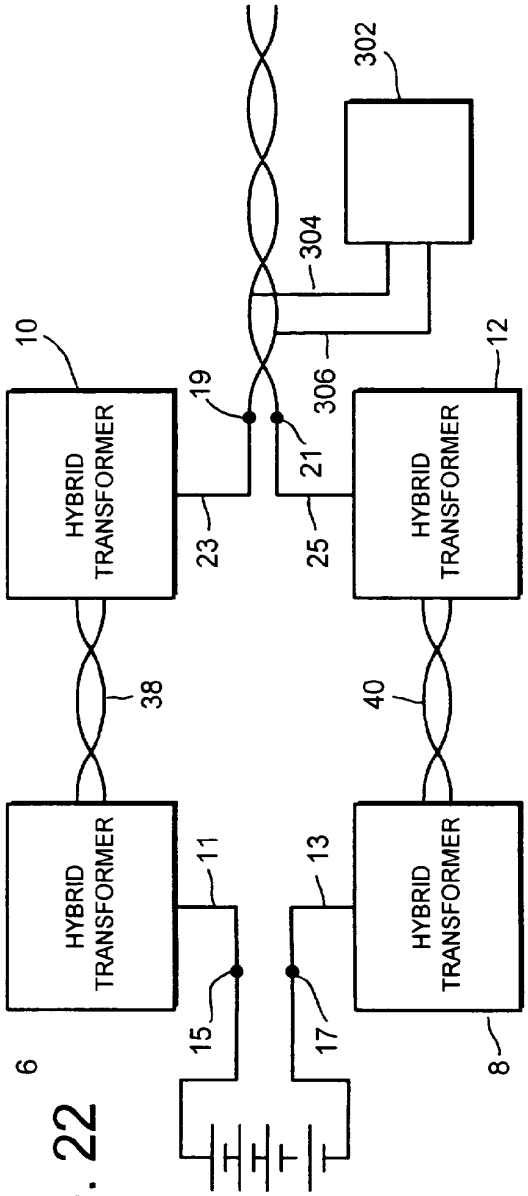

HYBRID TRANSFORMER
10
19
302
304
306
12
23
25
21
38
40
11
13
15
17
6
8

FIG. 22

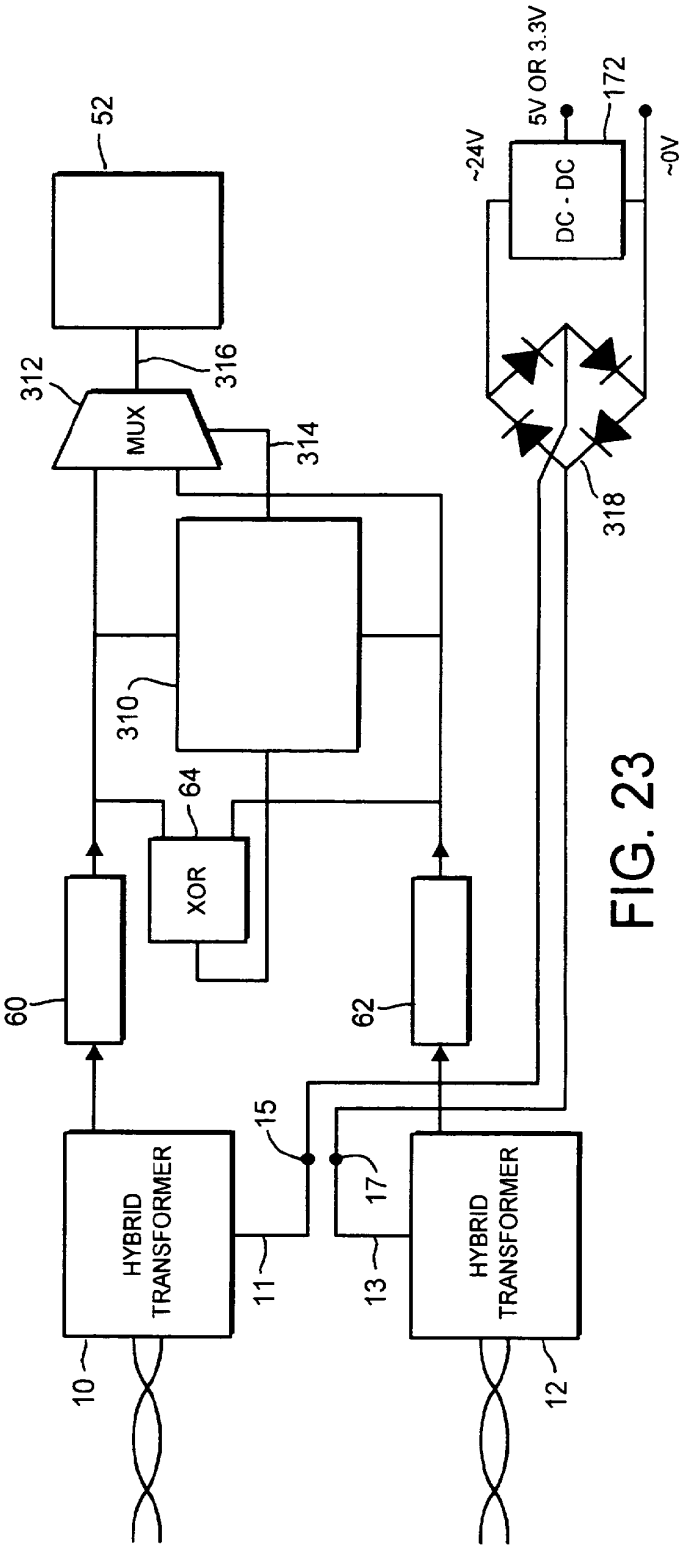

52
312
316
MUX
314
310
64
XOR
60
62
15
17
HYBRID TRANSFORMER
11
13
HYBRID TRANSFORMER
10
12
~24V
5V OR 3.3V
172
DC - DC
~0V
318

FIG. 23

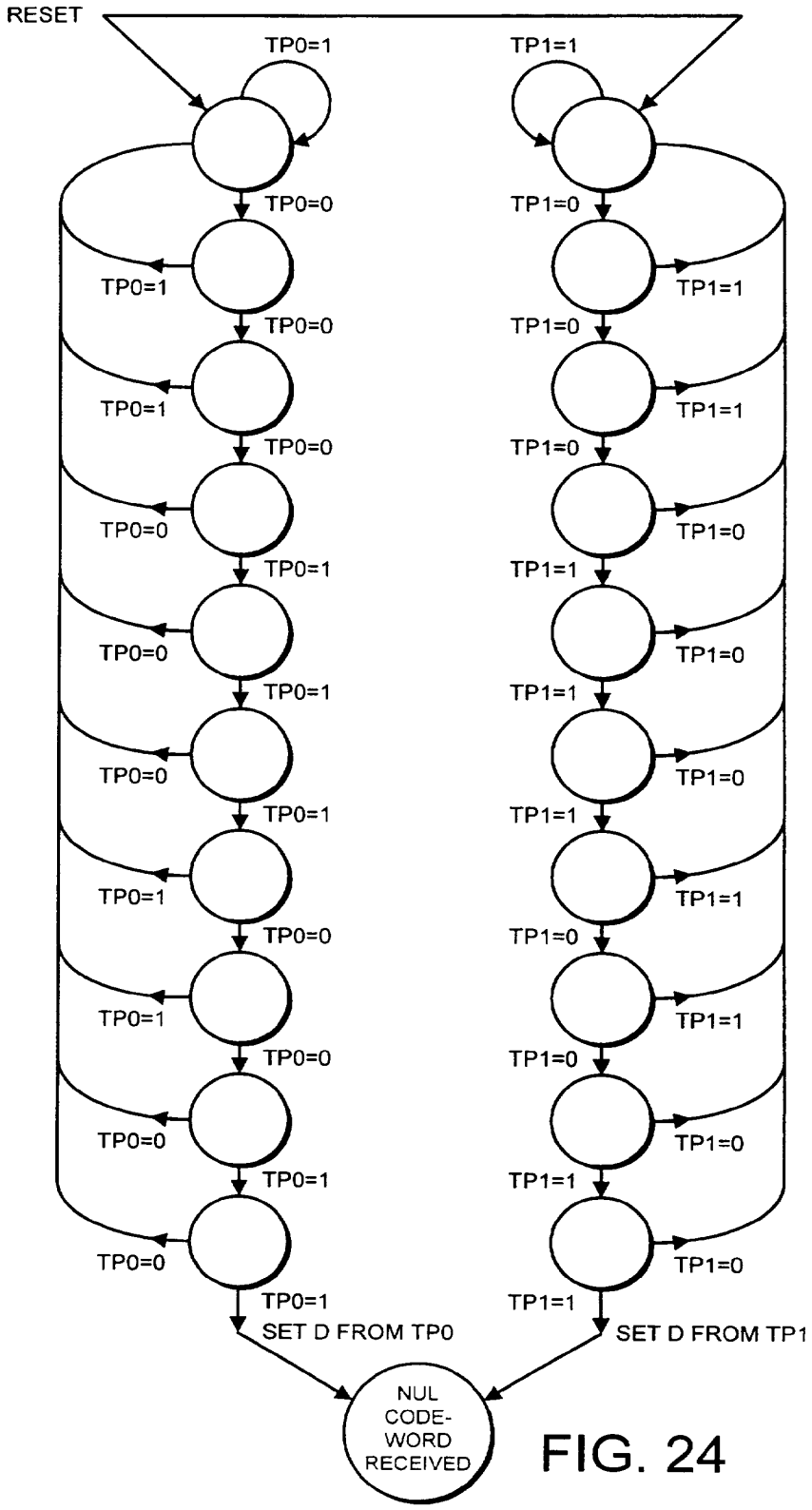

RESET
TP0=1
TP1=1
TP0=0
TP1=0
TP0=1
TP1=1
TP0=0
TP1=0
TP0=1
TP1=1
TP0=0
TP1=0
TP0=0
TP1=0
TP0=1
TP1=1
TP0=0
TP1=0
TP0=1
TP1=1
TP0=0
TP1=0
TP0=1
TP1=1
TP0=0
TP1=0
TP0=1
TP1=1
TP0=0
TP1=0
TP0=1
TP1=1
SET D FROM TP0
SET D FROM TP1
NUL CODE-WORD RECEIVED

FIG. 24

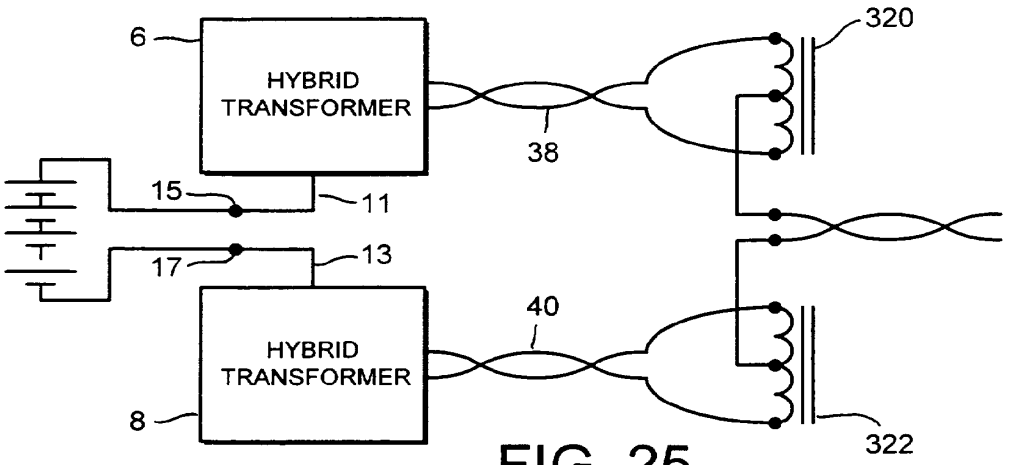


FIG. 25

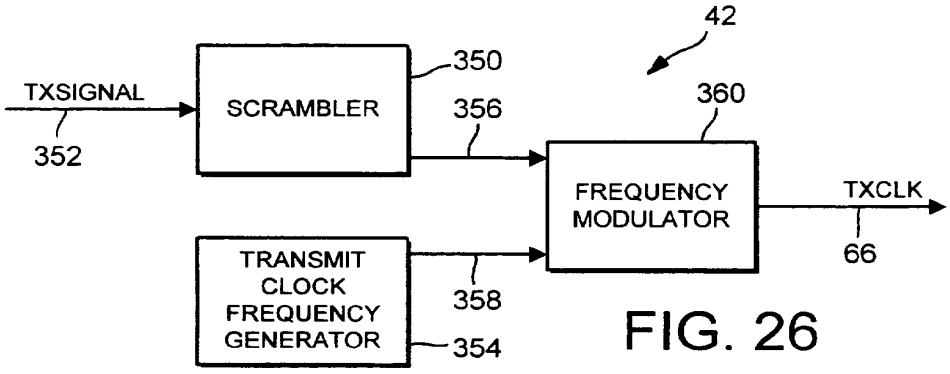


FIG. 26

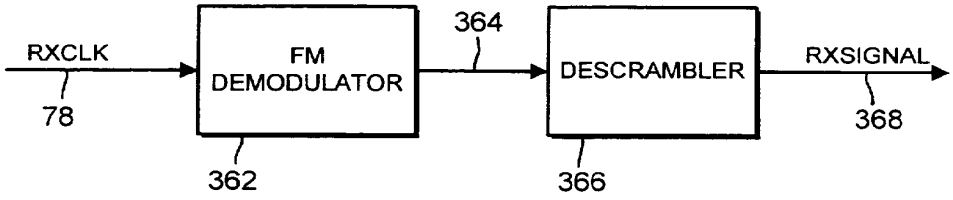


FIG. 27

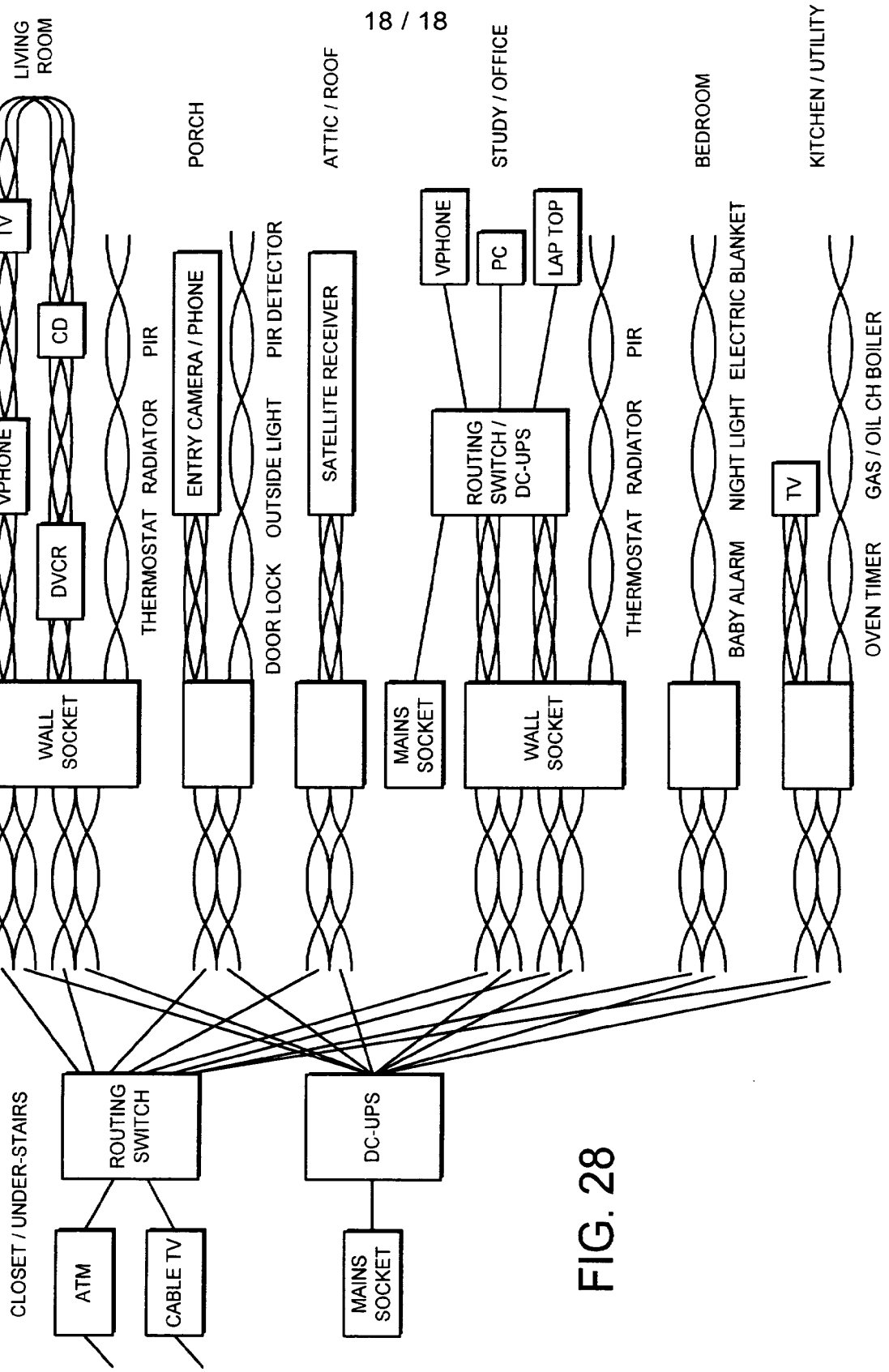

LIVING ROOM
TV
CD
VPHONE
DVCR
THERMOSTAT
RADIATOR
PIR
WALL SOCKET
PORCH
ENTRY CAMERA / PHONE
DOOR LOCK
OUTSIDE LIGHT
PIR DETECTOR
ATTIC / ROOF
SATELLITE RECEIVER
STUDY / OFFICE
VPHONE
PC
LAP TOP
ROUTING SWITCH / DC-UPS
MAINS SOCKET
WALL SOCKET
THERMOSTAT
RADIATOR
PIR
BEDROOM
BABY ALARM
NIGHT LIGHT
ELECTRIC BLANKET
KITCHEN / UTILITY
TV
OVEN TIMER
GAS / OIL CH BOILER
CLOSET / UNDER-STAIRS
ROUTING SWITCH
ATM
CABLE TV
DC-UPS
MAINS SOCKET

FIG. 28

COMMUNICATIONS SYSTEM

The present invention relates to the use of twisted pair connections as communication links driven by transformer couplings, and particularly to the use of phantom circuits formed by pairs of transformers driving pairs of twisted pairs.

A phantom circuit is formed by connections to the centre taps of a pair of transformers at a transmit end, which pair of transformers are linked by respective communication links to a pair of transformers at a receive end, connections to the centre taps of the transformers at the receive end forming the other end of the phantom circuit. The communication links between the two transformers of the transmit end and the two transformers of the receive end form two high speed communication links and the phantom circuit provides a further low speed communication link. Thus advantageously phantom circuits provide an additional communications link without the provision of additional communications link circuitry.

Typically the communication links formed by the respective pairs of transformers will transmit high speed data, typically between computers. The phantom circuit cannot support high speed communication such as that between computers, but can advantageously be used in accordance with the present invention to distribute power from a transmit end to a receive end, the phantom circuit being used to supply power to devices to which the high speed communication links are connected.

Thus according to the present invention there is provided a communication system comprising:

a first high speed link having a first transformer interface at a transmit end and a second transformer interface at a receive end;

a second high speed link having a third transformer interface at a transmit end and a fourth transformer interface at a receive end;

a low speed link comprising a phantom circuit formed by the first to fourth transformers, the transmit end of the low speed link being formed by connections to the centre taps of the first and third transformers and the receive end of the low speed link being formed by connections to the centre taps of the second and fourth transformers;

wherein the transmit end of the low speed link is connected to a power supply and at least one of the high speed links is connected to a device at the receive end for receiving signals from the respective high speed link, the receive end of the low speed link providing power to the device from the power supply.

Preferably one of the high speed links transmits a serial data signal, and the other high speed link transmits a strobe signal having transitions only at bit boundaries of the data signal where there are no transitions, thus forming a data-strobe communication link as disclosed in earlier European Patent Application Publication No. 0458648.

In addition to the distribution of power, the phantom circuit may be used to transmit low speed signals. The phantom circuit may also be used to distribute a global signalling clock. The global signalling clock may be implemented by providing a switch on the transmit side of the phantom circuit which switches the power supply for transmission in and out of the phantom circuit.

The phantom circuits may also be used to distribute power to remote destinations where there are no devices for receiving high speed communication signals.

The present invention also relates to a communication system in which a variable frequency clock is used in the transmission circuit. The invention is particularly, but not exclusively, concerned with the use of spread spectrum clocks in the transmission circuits of communications systems.

For communication networks, particularly those implemented in the

home, there is a need to minimise electromagnetic radiation. The use of spread spectrum clocks reduces the peaks of electromagnetic radiation at harmonics of the clock frequency, and thus it would be advantageous to employ a variable frequency clock such as a spread spectrum clock in any communication system utilising a high speed network, particularly in the home.

Thus according to the present invention there is provided a communications interface comprising output circuitry for providing a data signal to be transmitted under the control of a transmit clock signal, the frequency of the transmit clock signal being continuously variable.

The data-strobe link can cope very well with changing clock frequency, whereas typical PLL clock recovery circuits may have more difficulty in tracking the viable frequency clock.

When using a variable frequency clock in a transmission circuit, further problems arise in attempting to recover the clock at the receive end. European Patent Application Publication No. 0458648 describes an encoding scheme where data is transmitted on one serial link, and on a parallel serial link a strobe signal is transmitted which has transitions only at bit boundaries of the data signal where there is no transition. Such an encoding scheme advantageously allows the transmit clock to be simply recovered at the receive end, and therefore such a communication system can be advantageously used with the variable clock.

Thus according to the present invention there is additionally provided a communications interface comprising:

output circuitry for providing two parallel outputs, one in the form of a data signal and one in the form of a strobe signal and including strobe generation circuitry, wherein the data signal comprises a serial bit pattern and the strobe generation circuitry generates the strobe signal such that the strobe signal has signal transitions only at bit boundaries where there is no transition on the data signal, the strobe generation circuitry

being controlled by a clock signal such that for each clock pulse where there is no signal transition in the data signal a signal transition is generated in the strobe signal, the frequency of the clock signal being continuously variable; and

input circuitry having two inputs for receiving data and strobe signals, and including an exclusive-or circuit for receiving the data and strobe signals and generating a receive clock on the output thereof, the receive clock being generated with clock signal transitions having a timing matching that at which the strobe and data signals were transmitted.

The present invention also relates to receive circuitry for use in a communications system utilising data-strobe encoding in which the receiver is insensitive to which of the parallel signal lines the data signal is on. Data strobe encoding is described in earlier European Patent Application Publication No. 0458648.

In the data strobe encoding scheme, a data signal is transmitted on a serial data line, and a strobe signal transmitted on a serial strobe line parallel to the data line, the strobe signal having transitions only at bit boundaries of the data signal where there are no transitions. On the receive side, the transmit clock can be readily recovered by exclusive-ORing both the data and strobe signals.

According to the present invention there is provided data receiving circuitry comprising:

input circuitry having two inputs, one input for receiving a data signal and the other input for receiving a strobe signal, the strobe signal being parallel to the data signal and having signal transitions only at bit boundaries where there is no transition on the data signal;

an exclusive-or gate, having inputs connected to the two inputs, and generating a receive clock on the output thereof;

detection circuitry having two inputs coupled to the respective two inputs of the input circuitry and for detecting an expected bit sequence associated with the data signal on one

of said two inputs;

output circuitry for outputting the data signal under the control of the receive clock; and

selection circuitry for connecting the one of said inputs on which said sequence is detected to the output circuit.

The present invention further relates to a communications system code which utilises transformer couplings to communication links, and particularly to such a code employing a data strobe encoding scheme.

The data strobe encoding scheme is described in European Patent Application Publication No. 0458648. A serial data signal is transmitted on one line, and a serial strobe link signal transmitted parallel on a second line. The strobe signal has transmissions only at bit boundaries of the data signal at which there are no transitions on the data signal.

For certain applications, and particularly for high speed networks in the home, it is desirable to employ a communications system in which devices are transformer coupled to allow isolation. If transformer coupling is being used to interface to communication links, then the signals being transmitted must be dc balanced. However the data strobe communication code described in European Patent Application Publication No. 0458648 is not a dc balanced code.

Furthermore, for high speed networks and also particularly for applications of high speed networks in the home, it is desirable to use a simple encoding and decoding technique to minimise cost. It is also desirable, particularly for applications of communication systems in the home, to minimise any electromagnetic radiation associated with the coding scheme.

A number of codes are in existence which have some of the desirable properties required for a high speed network in the home. The DS link code, mentioned hereinabove, is exceptionally

simple to encode and decode, it uses two signal wires such that data is transmitted without further encoding on the data signal wire, and the strobe signal wire changes its state whenever the data signal wire does not change at bit boundaries. This also has the advantage that clock recovery is a simple exclusive ORing of the data and strobe signals at the receive end, so there is no need for a PLL or a DLL to recover the received clock. However there is nothing inherent in the DS link code which minimises electromagnetic radiation. A further major disadvantage of the DS link code is that it is not dc balanced and is therefore not suitable for transformer coupling.

There are many dc balanced codes and particularly pseudo-ternary codes which have the advantage that, in the quiescent state, there is no current flow in the coupling transformer. Regulated mark inversion, described in Electronic Letters, 9th November 1995, pp. 1996-1997, is a simple pseudo-ternary code in which a 1 is always represented as a -1 or +1, and a 0 is always represented as 0. Thus the decoded data is always a simple rectification of the received signal. The regulated mark inversion code has an improved emission spectrum over many other codes, with reduced components at both high frequencies and low frequencies, and only increased components between one tenth and one-hundredth of the bit rate. The regulated mark inversion code can be controlled to limit the run length of consecutive 1's, such that there are never more consecutive 1's than the maximum disparity permitted by the particular implementation of the regulated mark inversion code. By ensuring that transitions in the regulated mark inversion code are always between -1 and 0, 0 and -1, +1 and 0, or 0 and +1, and never between -1 and +1 or +1 and -1, then the frequency of the electromagnetic radiation can be further reduced. This also further simplifies the receiver, because it only has to see a transition, rather than discriminate between two different size of transitions of a ternary code. However, the regulated mark inversion code does not allow for simplified clock recovery at the receive end.

Neither the data strobe link code itself, nor the regulated mark inversion code, is particularly suitable for optical fibre implementation. Codes that are much more suitable include the serial HIPPI code and the HS-LINK code of IEEE 1355. These are binary codes which maintain dc balance by inverting the data if necessary to reduce the running digital sum of the code. Each code word includes an inversion flag to indicate inversion, and because the inversion has particular significance, it is normally accompanied by a parity bit which covers parity of both the data and the flag.

Thus it is an object of the present invention to provide a communication code which enables simple clock recovery at the receive end, is dc balanced, minimises electromagnetic radiation, and is suitable for transformer coupling.

Thus according to the present invention there is provided a method of establishing parallel data and strobe signal communication paths having dc balanced data and strobe signals on each path, comprising:

outputting a binary data signal;

generating and outputting a binary strobe signal, parallel to the binary data signal, having signal transitions only at bit boundaries where there is no transition on the parallel binary data signal; and

encoding the binary data signal and the binary strobe signal into respective ternary dc balanced signals for transmission.

Preferably the step of encoding the binary data signal and the binary strobe signal into respective ternary dc balanced signals encodes such signals such that only single level logic transitions are permitted between successive trits of the ternary signals.

Preferably the encoding step comprises the steps of, for each of the data and strobe signal:

calculating the running digital sum of the ternary signal;

transmitting next binary 1 as ternary -1 if the running digital sum is positive and at least two 0's have been transmitted since the last ternary +1;

transmitting the next binary 1 as ternary +1 if the running digital sum is negative and at least two 0's have been transmitted since the last ternary -1;

transmitting at least two successive binary 1's as ternary -1's if the running digital sum is positive and the at least two binary 1's follow any number of 0's;

transmitting at least two successive binary 1's as ternary +1's if the running digital sum is negative and the at least two binary 1's follow any number of 0's; and

otherwise reversing the polarity of each ternary 1 each time a run of at least one 0 occurs.

The present invention also provides data transmission circuitry comprising:

input circuitry for receiving a binary data signal;

strobe generation circuitry for generating a binary strobe signal, parallel to the binary data signal, and having signal transitions only at bit boundaries where there is no transition on the parallel binary data signal;

encoding circuitry for encoding the binary data and strobe signals into respective ternary dc balanced signals; and

output circuitry for transmitting the ternary encoded data and strobe signals.

According to another aspect of the invention there is provided a method of decoding a ternary data signal and a ternary strobe signal, the strobe signal being parallel to the data signal and having signal transitions only at trit boundaries of the data signal where there is no transition, the method comprising:

rectifying the ternary data and strobe signals to generate binary data and strobe signals;

exclusive-ORing the data and strobe signals to generate a receive clock; and

outputting the rectified data signals under the control of

the receive clock.

This aspect of the invention also provides data receiving circuitry comprising:

input circuitry for receiving a ternary data signal and a ternary strobe signal, the strobe signal being parallel to the data signal and having signal transitions only at bit boundaries where there is no transition on the data signal;

rectification circuitry for rectifying the ternary data and strobe signals and generating binary data and strobe signals;

an exclusive-OR gate for receiving the data and strobe signals and generating the receive clock at its output; and

output circuitry for outputting the binary data signal under the control of the receive clock.

For a better understanding of the present invention and to show how the same may be carried into effect, reference will now be made by way of example to the accompanying drawings, in which:

Figure 1 is a block diagram of transmitting and receiving circuits for implementing the present invention;

Figure 2 is a block diagram of an encoder/decoder such as may be used in the transmitting and receiving circuits of Figure 1;

Figure 3 is an example of a code-word encoded in accordance with the present invention;

Figure 4 is a block diagram of an implementation of an encoder according to the present invention;

Figure 5 is a block diagram of another implementation of an encoder according to the present invention;

Figure 6 is a timing diagram exemplifying a data strobe encoding technique;

Figure 7 is a block diagram of circuitry for encoding a data signal into data and strobe signals;

Figure 8 is a block diagram showing the timing signals at various points in the circuit of Figure 7;

Figure 9 is a block diagram of a ternary encoder;

Figure 10 is a state diagram of the ternary encoder of Figure 9;

Figure 11 is a timing diagram exemplifying the operation of the ternary encoder of Figure 9;

Figure 12 is a block diagram of one implementation of a decoder according to the present invention;

Figure 13 is a block diagram of another implementation of a decoder according to the present invention;

Figure 14 is a block diagram of circuitry for enabling the data and strobe signal lines to go into a quiescent state;

Figure 15 is a timing diagram exemplifying the operation of the circuit of Figure 14;

Figure 16 is a state diagram of the operation of the circuit of Figure 14;

Figure 17 is a diagram of a standard hybrid transformer;

Figure 18 is a diagram illustrating the formation of a phantom circuit employing four hybrid transformers;

Figure 19 is a block diagram illustrating the use of the phantom circuit to distribute power;

Figure 20 is a block diagram illustrating an alternative use of the phantom circuit;

Figure 21 is a block diagram illustrating use of the phantom circuit to additionally distribute a clock signal;

Figure 22 is a block diagram illustrating an alternative use of the phantom circuit;

Figure 23 is a block diagram of circuitry used for detecting, on a receive side, which of two twisted pair links carries the data signal;

Figure 24 is a state diagram of the circuitry of Figure 23;

Figure 25 is a block diagram illustrating the use of a phantom circuit to distribute power alone;

Figure 26 is a block diagram illustrating the use of a variable frequency clock to distribute a signal;

Figure 27 is a block diagram illustrating the recovery of a signal transmitted using the circuitry of Figure 26; and

Figure 28 is a block diagram illustrating the application of the present invention to a building environment.

Figure 1 shows an exemplary embodiment of a communication interface according to the present invention.

A high speed twisted pair serial link 38 communicates serial data signals bidirectionally between transformers 6 and 10 which provide a communications interface for data signals to the respective encoders/decoders 2 and 4. Similarly, a high speed serial twisted pair link 40 communicates serial strobe signals between the pair of transformers 8 and 12 which provide a communications interface for strobe signals to the respective encoders/decoders 2 and 4. The encoder/decoder 2 receive bytes of parallel data TPDATA0-7 on bus 14, encodes it in accordance with the present invention as discussed in detail hereinafter, and outputs a serial ternary data signal TSDATA on line 18 and a serial ternary strobe signal TSSTROBE on line 22 to the respective transformers 6 and 8 for transmission on the respective twisted pair signal lines 38 and 40. The respective transformers 10 and 12 receive the encoded data and strobe ternary signals on twisted pairs 38 and 40. The transformer 10 communicates the ternary data signal received RSD from twisted pair 38 to the encoder/decoder 4 on line 26. The transformer 12 communicates the ternary strobe signal RSS received from twisted pair 40 on line 30 to encoder/decoder 4. The encoder/decoder 4 decodes the received ternary data signal RSD and the received ternary strobe signal RSS into parallel bytes of binary data RPD0-7 which it outputs on bus 34.

The bytes of parallel data TPDATA0-7 on bus 14 may additionally have a control bit associated therewith. Such control bit may indicate, when set, that the byte TPDATA0-7 contains control information for use by the encoder/decoder 2. The control information may be for flow control purposes between the source of the parallel data TPDATA0-7 and the encoder/decoder 2. Similarly the encoder/decoder 2 may generate a control bit associated with the parallel data byte RPDATA0-7 for transmission therewith as a 9 bit bus.

The encoder/decoder 4 receives on bus 36 parallel bytes of data to be transmitted TPD0-7, and encodes it into a ternary serial data signal to be transmitted TSD on line 28 and a ternary serial strobe signal to be transmitted TSS on line 32. The transformer 10 communicates the signal TSD via twisted pair 38 to the transformer 6, and the transformer 12 communicates the ternary signal TSS via twisted pair 40 to the transformer 8. The transformer 6 outputs the received ternary data from twisted pair 38 as signal RSDATA on line 20, and the transformer 8 outputs the received ternary strobe signal from twisted pair line 40 as the signal RSSTROBE on line 24. The encoder/decoder 2 receives the ternary signals RSDATA and RSSTROBE and decodes them into parallel bytes RPDATA0-7 and outputs them on bus 16.

In addition to providing the bidirectional communication of signals down the high speed twisted pair links 38 and 40, the four transformers 6, 8, 10 and 12 in addition form a "phantom circuit". As will be described in greater detail hereinafter, this phantom circuit is formed by providing a connection line 11 to the centre tap of the primary winding of the transformer 6, and a connection line 13 to the centre tap of the primary winding of the transformer 8. Connections 11 and 13 have respective terminals 15 and 17 for inputting signals between the centre taps of the primary windings of transformers 6 and 8. Similarly, a connection line 23 is provided from a terminal 19 to the centre tap of the secondary winding of the transformer 10 and a connection line 25 is provided from the terminal 21 to a centre tap of the secondary winding of the transformer 12. In this way, a signal applied to the terminals 15 and 17 is transmitted down the phantom circuit and received at the terminals 19 and 21. Bidirectional communication down the phantom circuit is possible, such that a signal applied to the terminals 19 and 21 is also received at the terminals 15 and 17. The advantageous utilisation of this phantom circuit in accordance with the present invention will be discussed in greater detail hereinafter.

Referring now to Figure 2, there is shown a block diagram of the

encoder/decoder 2 of Figure 1 according to an exemplary embodiment of the present invention. The encoder/decoder 4 of Figure 1 is constructed identically to the encoder/decoder 2.

The encoder/decoder 2 comprises a control circuit 44, a transmit FIFO 46, an 8B10B encoder 50, a data-strobe encoder 54, a data ternary encoder 56, strobe ternary encoder 58, a data rectifier 60, a strobe rectifier 62, an exclusive OR gate 64, an 8B10B decoder 52, a receive FIFO 48, and a spread spectrum clock 42.

The spread spectrum clock 42 provides a transmit clock signal TXCLK on line 66 to the control circuit 44, the 8B10B encoder 50, the data-strobe encoder 54, the data ternary encoder 56 and the strobe ternary encoder 58. The parallel data bytes to be encoded TPDATA0-7 on bus 14 are input successively to the transmit FIFO 46 under the control of control signals on line 68 from the control circuit 44. The buffered data bytes BTPDATA0-7 from the transmit FIFO 46 are output on bus 90 to the 8B10B encoder 50. The transfer of the data bytes to be transmitted to the 8B10B encoder 50 from the transmit FIFO 46 is also controlled by control signals on line 68 from the control circuit 44, which not only communicates control signals to the transmit FIFO 46 on line 68 but also to the 8B10B encoder 50 on line 70. In addition, the control circuit may provide for flow control mechanisms with the device sending the data bytes to be transmitted, and in such event the transmit FIFO 46 may return control signals to the control circuit 44 on line 68 such as flags indicating the fullness of the FIFO and whether there is enough space in the transmit FIFO 46 to receive additional bytes of data. Although the signals for the flow control between the encoder/decoder 2 of Figure 2 and the device sending the data to be transmitted TPDATA0-7 on bus 14 is not shown in Figure 2, the implementation of such will be well understood by one skilled in the art.

The 8B10B encoder 50 encodes the buffered data bytes BTPDATA0-7 in accordance with the present invention as discussed in detail hereinafter, and outputs serial code-words CODEW on line 88 to

the data-strobe encoder 54. As will be discussed further in detail hereinbelow, the data-strobe encoder 54 buffers the serial data code-word CODEW on line 88 and transfers to its output on line 86 the buffered serial data code-word BCODEW. In addition, the data-strobe encoder 54 generates a serial strobe signal STROBEW on line 84 parallel to the buffered serial data code-word BCODEW. The buffered serial data code-words BCODEW on line 86 are input to the data ternary encoder 56, which in accordance with the present invention converts the binary serial data to be transmitted into ternary serial data as signals TSDATA on line 18. Similarly the strobe ternary encoder 58 receives the signal STROBEW on line 84 and converts such into a ternary strobe signal TSSTROBE for transmission on line 22.

On the receive side, the data rectifier 60 receives the ternary encoded serial data RSDATA on line 20 and the strobe rectifier 62 receives the ternary encoded strobe signal RSSTROBE on line 24. Each of the data rectifier 60 and strobe rectifier 62 rectifies the ternary signal input thereto to produce a respective binary serial signal on the respective ones of the outputs on lines 80 and 82. The rectified data serial signal RECDATA on line 80 is input to the 8B10B decoder 52. The rectified strobe serial signal RECSTROBE on line 82 forms an input, together with the rectified serial data signal RECDATA on line 80 to the exclusive OR gate 64. As will be understood from the description of the data-strobe encoder 54 given hereinafter, the output of the exclusive OR gate 64 reconstructs the transmit clock as the receive clock RXCLK on line 78, and the receive clock RXCLK is used to clock the 8B10B decoder 52 and the control circuit 44. The 8B10B decoder 52 receives the received code-word data RECDATA on line 80, and decodes it in accordance with the present invention as discussed in detail hereinafter to output decoded bytes of data BRPDATA0-7 on bus 76. The 8B10B decoder 52 transmits control signals on line 72 to the control circuit 44. The decoded data bytes BRPDATA0-7 on bus 76 are input to a receive FIFO 48 under control of the control signals 74 from the control circuit 44, and output from the receive FIFO 48 onto the

data bus 16 as signals RPDATA 0-7. The signals 74 linking the control circuit 44 to the receive FIFO 48 will preferably be bidirectional to allow the control circuit to control the flow of data to and from the receive FIFO 48 in accordance with the relative fullness of the FIFO.

The control circuit 44 receives and transmits control signals FCONT on lines 15. The control circuit 44 may receive a write signal associated with the parallel data byte TPDATA0-7 for controlling the writing of the data into the transmit FIFO 46, and may transmit a flag status signal of the transmit FIFO 46 to the source of the parallel byte of data TPDATA0-7 indicating that there is space in the transmit FIFO 46. The control circuit 44 may also receive a read signal from the destination circuit to which the parallel data byte RPDATA0-7 is to be read, the read signal for controlling the reading of data from the receive FIFO 48. The control circuit 44 may generate a signal on the signals FCONT indicating that the receive FIFO 48 is not empty and contains data bytes to be read.

In the embodiment in which the data bytes TPDATA0-7 and RPDATA0-7 have control bits associated therewith the transmit FIFO 46 and the receive FIFO 48 will each be 9 bits wide, the ninth control bit being used by the control circuit 44 to determine whether the data byte TPDATA0-7 is for control purposes or transmission on the twisted pair 38. Alternatively if the control circuit 44 is generating a control byte it will set the control bit in the FIFO 48.

In accordance with well known techniques, the control circuit 44 may encode an interface flow control mechanism into the data transmitted between the interfaces at either end of the high speed twisted pair communication links. Thus the control circuit 44 may control the 8B10B encoder via line 70 to add flow control information to the encoded data. This flow control information is then decoded by the 8B10B decoder 52 at the receive end, and the flow control information passed via line 72 to the control

circuit 44. Such techniques of flow control are well known in the art, and are not discussed in detail herein since they are not specific to the inventive code.

The 8B10B encoder 50 of the decoder/encoder 2 encodes the parallel byte of data BTPDATA0-7 on bus 90 into a serial signal CODEW on line 88 comprising 10 bit code-words. The 8B10B encoder 50 preferably adds a flag bit and a parity bit to the byte of data to form a code-word, and then converts the 10 bit code-word from parallel format into serial format as will be described in detail hereinafter with reference to Figure 4. The structure of the serial code-words CODEW output by the 8B10B encoder on line 88 is shown in Figure 3. The code-word CODEW comprises eight data bits D0-D7, a flag bit FB and a parity bit PB. Preferably the flag bit FB and the parity bit PB are added to the end of the serial code-word. Thus in Figure 3 the data bit D0 is the least significant bit and the parity bit PB is the most significant bit. By adding the flag and parity bits to the end of the serial code-word the time for any logic operations on the data byte of the serial code-word is maximised. The parity bit PB is preferably chosen to ensure that there is an odd number of 1's in the ten bit code-word. As will be described in further detail hereafter, the flag bit FB indicates whether the data bits D0-D7 in the code-word are the true data bits or the inverted data bits. The flag bit FB is set when the data byte in the serial code-word is inverted. Referring to Table I below there is shown, for all ten bit code-words having an odd number of ones, a breakdown of the code-words with 1, 3, 5, 7, 9 ones therein, showing the corresponding number of zeros in the code-word, the disparity of the code-word, and the number of possible code-words having that number of ones that number of zeros and that particular disparity.

Number of ones in code-word	Number of zeros in code-word	Disparity of the code-word	Number of code-words with this disparity
1	9	-8	10
3	7	-4	120
5	5	0	252
7	3	4	120
9	1	8	10

TABLE I

It is desirable to ensure that the magnitude of the running digital sum at code-word boundaries is minimised, and preferably maintained at zero to ensure dc balance of the code. As can be seen from Table I, code-words will have a disparity of either 0, ± 4, or ± 8. Thus, as will be described further hereafter, the magnitude of the running digital sum can be minimised by inverting the data byte in certain code-words so as to select a code-word having a positive or negative disparity rather than a negative or positive disparity respectively.

Thus, according to the preferable encoding scheme, if the code-word after having a parity bit added to it and a flag bit set at zero included therein has a disparity of zero, i.e. an equal number of ones and zeros then the code-word is transmitted true, since the disparity of zero will not affect the running digital sum at code-word boundaries.

However, if the code-word after having the parity bit added thereto and the flag bit set at zero has an unequal number of ones and zeros, then it will either be transmitted true, or else inverted with the flag bit set to one, in order to reduce or to change the sign of the running digital sum at code-word boundaries. For example, the data byte 00000111 (with the least significant bit at the left and most significant bit at the right) would be transmitted as the code-word 0000011100 if the

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running digital sum of the code, prior to the transmission of this code-word, was positive. Thus the data of the code-word would be transmitted true, the flag bit being set to zero, and the parity bit being set to zero to ensure an odd number of 1's in the code-word. This transmitted code-word has a negative disparity, which would either reduce the magnitude of the running digital sum or else make the running digital sum negative. However, in this example if the running digital sum was currently negative, then the data in the code-word would be inverted, the flag bit set at one to indicate inversion of the data, and the parity bit set to one to ensure an odd number of ones, such that the code-word transmitted would be 1111100011. Thus this would reduce the magnitude of the running digital sum or else make the running digital sum positive.

As is clear from Table I, the disparity of the non-zero disparity code-words is either ± 4 or ± 8. Thus in this exemplary embodiment of the invention a limit of ± 8 is placed on the running digital sum at code-word boundaries. Thus a rule for inversion of data in the code-word is set such that the data in the code-word is either inverted or not inverted to ensure that the running digital sum at code-word boundaries is maintained within the ± 8 limit.

If the code-word to be transmitted has an equal number of ones and zeros, then it is always transmitted with the data true. For example, the data byte 0011 0011 will be transmitted as the code-word 0011 0011 01, the flag bit being set at 0 due to indicate non-inversion, and the parity bit being set at 1 to provide an odd number of 1's, the resulting disparity of the code-word being zero. The data byte 0011 0111 having five ones would, when encoded as a code-word without inversion, result in the code-word 0011 0111 00 having zero disparity, the flag bit being set at zero to indicate non-inversion and the parity bit being set at zero to ensure an odd number of ones.

The fact that zero disparity code-words are always transmitted

true, leaves a large number of code-words unused. That is, those code-words which are the inverse of zero disparity code-words. For example, the two code-words described in the preceding paragraph having non-inverted data provide two unused code-words in which the flag bit is set to one and the code-words still have zero disparity, namely 1100 1100 10 and 1100 1000 11. These unused code-words can advantageously be used for control codes. In particular they may be used for implementing a flow control mechanism, for indicating end of messages, for indicating end of packets, for transmitting idle signals etc. Advantageously they may be used to implement the inventive "Go To Standby" control protocol as described herein later. The control codes may also be used to distribute a synchronous clock, or as part of a safety protocol for optical fibre. There may be eight or even more control codes using the unused codes.

From Table I hereinabove, it can be seen that there are 252 code-words having zero disparity, but from the above discussion it will be clear that only half of these code-words are needed to encode data. Thus there are 126 unused codes having zero disparity, and it will be clear that only a very small proportion of these unused codes need to be used for control purposes, and therefore a large number of zero disparity code-words unused are still available even after a small number have been allocated for control purposes.

By placing a constraint on the running digital sum between code-words of ± 8 and selecting the inverted or non-inverted data in the code-words to ensure that the running digital sum is maintained within these limits as discussed hereinabove it is however, still possible for the instantaneous run length of the code other than at code-word boundaries to become much larger than ± 8. For example, if prior to transmission of the next code-word the running digital sum at the code-word boundary is at -8, a code-word having a disparity of +4 is transmitted, and then a code-word having disparity of +8 is transmitted, then a possible bit sequence that could occur is 0111 1111 11 followed by 1111

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1110 00 to give a run length of 16. Such a long run length is undesirable, and in a preferable embodiment of the code long run lengths such as this are eliminated, as described in detail hereinafter.

Furthermore, encoded data is desirably transmitted as a data-strobe signal in accordance with the encoding scheme described in earlier European Patent Application Publication No. 0458648. The data-strobe encoding scheme described therein transmits a data signal on a data line, and a parallel strobe signal on the strobe line. The nature of the generation of the strobe signal is such that for every bit boundary of the data signal for which there is no transition on the data signal there is a transition on the strobe signal, and for every bit boundary of the data signal for which there is a transition on the data signal there is no transition on the strobe signal. This code advantageously allows simple clock recovery at the receiver end. Thus, in seeking to eliminate excessive run lengths on the data line, it is also necessary to consider those data sequences on the data line which will cause excessive run lengths on the strobe line.

In order to achieve the desirable aim of reducing the maximum run length that can be produced by the code on either the data or the parallel strobe signal, the unused codes having zero disparity but having their data inverted and their flag bit set to 1 which are not used for control purposes can be used to substitute code-words which contribute to extreme run lengths, whether the code-word causes an extreme run length on the data signal or causes a consequential extreme run length on the parallel strobe signal.

The code-words on the data signal line that need elimination due to their effect on the run length of the code, and to be substituted by the unused control codes are:

a) code-words having disparity of ± 8 (for example 1111 1111 10);

b) code-words having excessive leading run-length on the data signal, such as 1111 1110 00 (where the data byte is true) or 1111 1100 10 (where the data byte is inverted). These code-words are actually the worst-case run-lengths on the data signal from those codes with disparity ±4;

c) code-words having excessive trailing run-length on the data signal (which can occur only when the data byte is inverted and the flag bit consequently set at 1) such as 0001 1111 11. This code-word is the worst-case trailing run-length on the data signal from those codes with disparity ±4;

d) code-words on the data signal which cause an excessive leading run-length on the parallel strobe signal, such as 0101 0111 00 (where the data byte is true) or 0101 0100 10 (where the data byte is inverted) or 1010 1011 00 (where the resulting code-word is zero-disparity; and

e) code-words on the data signal which cause an excessive trailing run-length on the parallel strobe signal, such as 1111 0101 01 (where the data byte is true) or 0000 1010 10 (where the data byte is inverted) or 1001 0101 01 (where the resulting code-word is zero disparity).

The number of violating codes obviously depends on the run-length limit selected. For example, with a total run-length limit of 10 selected, and with consequently permitted leading and trailing run-lengths being a maximum of 5, less than 30 code-words need substitution, which is easily managed with the 126 code-words available.

If the run-length limit is chosen as 6, with leading and trailing limits of 3, there are more codes needing substitution than there are available codes. Therefore in the described preferred embodiment the trailing run-length is relaxed to a limit of 4, with the leading run-length limit at 3, to give an overall run-length limit of 7. Although there are apparently, within these

rules, more code-words needing substitution than there are code-words available, some of the violating code-words have zero-disparity, and it is possible in some of these cases to remove the violation without using one of the substitution codes.

For the run-length limit of 7, a violation is a leading run-length of 4 or more on either the data or strobe signal, or a trailing run-length of 5 or more on either the data or strobe signal. For violating code-words with non-zero disparity, then substitution by one of the unused code-words including inverted data is necessary. This is a simple matter of mapping violating code-words having non-zero disparity to unused zero disparity code-words. For violating code-words with zero disparity, the code-word is transmitted according to the following rules:

a) for zero disparity code-words with excessive leading run-length on the data signal, such as 1111 0000 01, use the inverse 0000 1111 10, which does not violate;

b) the only cases of excessive trailing run length on the data signal for zero-disparity code-words are the inverted codes with both flag-bit and parity bit set such as 1000 0011 11. It is not necessary to use these codes because the true 0111 1100 00 does not violate. For a run-length limit of seven, there is actually no code violating this criterion which does not also violate other criteria. The run-length limit of seven does include one zero-disparity code whose inverse violates the leading data signal run length, but whose true code does not violate;

c) for zero-disparity code-words on the data signal which cause excessive leading run-length on the strobe signal, such as 1010 1011 00, invert or not to make it the same as the parity bit (the last bit transmitted) of the previous code-word. For example, with the previous parity bit set to one, the example code-word would not be inverted: xxxx xxxx x1 1010 1011 00, but if the previous parity bit

had been set to zero, the code-word would be inverted: xxxx xxxx x0;

d) for zero disparity code-words on the data signal excessive trailing run-length on the strobe signal, such as 1001 0101 01 when the parity bit of the code-word is set, force the flag bit to one which in turn forces the parity bit to zero 1001 0101 10 which removes the violation. The resulting code-words are actually codes that would otherwise be code-words used for substitution, but the logic may be simpler to follow this rule than to substitute in these cases;

e) as separate rules are described above for leading and trailing violations on both the data signal itself and transitions on the data signal which cause a violation on the strobe signal, then any zero disparity code-word which violates more than one of these conditions must be substituted, for example the code-word 1010 0101 01 on the data signal, which causes a leading run length violation on the strobe signal of three and a trailing run-length on the strobe signal of five, would violate both leading and trailing run-lengths for an overall run-length limit of seven described above.

An example set of code-words to meet a run-length constraint of seven on both the data and strobe signals is given in Appendix 1. This appendix includes at least one example of each of the rules listed as (a) to (d) above, with the code-words violating more than one of those rules substituted by an unused code-word. In addition, in the example coding scheme shown in Appendix 1 the violating code-words having a non-zero disparity are substituted with unused code-words. The example code-word given in Appendix 1 as decimal 50 is an example of rule (a) above, the example code-word given in Appendix 1 as decimal 240 is an example of rule (b) above, the example code-word given as decimal 213 in Appendix 1 is an example of rule (c) above, and the example code-word given as decimal 169 in Appendix 1 is an example of rule

(d). In addition, decimal 165 given in the enclosed Appendix 1 is an example of a code-word which violates both leading and trailing edge constraints, and specifically substitution of the code-word 1010 0101 01 given as an example in rule (e) above.

Referring to Figure 4 there is shown an example implementation of an 8B10B encoder 50 according to the present invention. The 8B10B encoder 50 includes a control circuit 208, a multiplexor/inverter 210, a substitute circuit 200, a violation detector 202, a bit counter 204, a register 206, a RDS counter 207 and a shift register 212. The parallel data bytes to be encoded BTPDATA0-7 on bus 90 form inputs to the multiplexor/invertor 210, the substitute circuit 200, the violation detector 202 and the bit counter 204. The substitute circuit 200 receives the control signal 70 from the control circuit 44. The substitute circuit 200 also outputs substitution bytes SUBBYTE on bus 234 to the multiplexor/invertor 210 as will be described further hereinafter. The violation detector 202 outputs a control signal SUB on line 232 to the substitute circuit 200, and a plurality of control signals VIOL on lines 220 to the control circuit 208. The bit counter 204 outputs a count signal COUNT on lines 218 to the control circuit 208 and the violation detector 202. The multiplexor/invertor 210 outputs the data byte of the code-word CODE on bus 236, and the control circuit 208 outputs the flag bit TFLAG of the code-word on line 224 and the parity bit TPARITY on line 226. The data bus CODE, flag bit TFLAG and the parity TPARITY form inputs to the shift register 212. In addition the control circuit 208 outputs the disparity DISP of the code-word on lines 222. The disparity DISP of the code-word on lines 222 forms an input to the RDS counter 207. The RDS counter 207 calculates the running digital sum of the code at code-word boundaries using the code-word disparity DISP presented at its inputs for successive code-words. The RDS counter 207 outputs a signal LPNZ on line 216, which is set if the last non-zero running digital sum was positive, and not set if the last non-zero running digital sum was negative.

The parity bit TPARITY on line 226 forms an input to the register 206. The register 206 outputs on line 214 the previous parity bit PTPARITY which is the parity bit TPARITY on line 226 buffered by one clock cycle. Although not shown in Figure 4, each of the circuit elements shown therein receive the transmit clock TXCLK on line 66.

In operation, the violation detector 202 monitors incoming data bytes BTPDATA0-7 on bus 90 to see whether the violating conditions exist which require either the data byte in the code-word to be inverted to minimise the running digital sum at code-word boundaries, or substitution of the data byte by a substitute code-word so as to minimise the run length of the code. By looking at the data bytes BTBDATA0-7 and receiving the signal COUNT on lines 218 from the bit counter 204, which gives the number of 1's in the data byte, the violation detector itself can determine the disparity for the resulting code-word by itself calculating the parity bit, the flag bit obviously being considered as set to 0 in this calculation since the data is not yet inverted. If the violation detector 202 detects no violations, then the signals VIOL on line 220 and SUB on line 232 are not set. The bit counter 204 counts the bits in the data byte BTPDATA0-7 and provides a bit count as the signal COUNT on line 218 to the control circuit 208. When the violation detector 202 is not indicating a violation, the control circuit controls the multiplexor/inverter using the control signal SEL on line 230 to transfer the data bytes BTPDATA0-7 on bus 90 to the output thereof as the code byte CODE on bus 236. The control circuit 208 generates the parity bit TPARITY before the code-word in dependence on the signal COUNT to ensure an odd number of bits in the code-word. In addition if the signal LPNZ input to the control circuit on line 216, which effectively indicates whether the running digital sum prior to transmission of the current code-word was positive or negative if non-zero, dictates such, the control circuit 208 sets the signal INV on line 228 to invert the data at the output of the multiplexor/invertor 210. In such event the control circuit 208 also directly sets the flag signal

TFLAG on line 224. The shift register 212 merely converts the parallel code-word formed by the bus 236 and the signals on lines 226 and 224 into a serial code-word for transmission CODEW on line 88.

When the violation detector 202 detects the violation in the incoming data byte BTPDATA0-7, which violations have been summarised in the above rules, the appropriate violation is identified to the control circuit as a signal VIOL on lines 220. In accordance with the type of violation identified by the violation detector, the control circuit 208 will use the various inputs presented thereto to determine substitution of the incoming data byte in accordance with the above rules. For instance, if the violation detected is one that requires the incoming data byte to be substituted for an unused code-word having 0 disparity, then in addition to setting the signals VIOL to the control circuit 208 the violation detector also sets the signal SUB on line 232 to select the appropriate substitution data byte from the substitute circuit 200, which is output on bus 234 as the signal SUBBYTE. The control circuit 208 will then set the select signal SEL on line 230 such that the byte SUBBYTE on bus 234 is transferred to the output as the byte CODE on bus 236. The control circuit 208 will then set the flag bit TFLAG and the parity bit TPARITY accordingly. When the control circuit 208 is substituting an incoming data byte for an unused code-word having 0 disparity, then the signal LPNZ indicating whether the last non-zero running digital sum was positive or negative does not affect whether the outputs of the multiplexor/invertor are inverted.

The control circuit 208 receives as one of its inputs the previous parity bit PTPARITY of the last code-word transmitted. Thus, when a violation such as illustrated in rule c) above occurs, the control circuit 208 can invert or not invert the signals on the output of the multiplexor/inverter 210 by setting the signal INV on line 228 appropriately in dependence on the previous parity bit PTPARITY of the last code-word transmitted.

In addition the substitute circuit 200 receives the control signal 70 from the control circuit 44. In this way the control circuit 44 can select from the substitute circuit 200 those unused code-words having 0 disparity which have been reserved for control purposes.

Referring to Figure 5 there is shown an alternative implementation of the 8B10B encoder 50 which employs a look-up table. In this embodiment, the 8B10B encoder 50 includes a look-up table 238, a shift register 240, the register 206 and RDS counter 207 employed in the embodiment of Figure 4. Again the register 206 receives the parity bit TPARITY of the current code-word and the RDS counter 207 receives the disparity DISP of the current code-word, which signals in this embodiment are stored and output from, the look-up table 238. In addition the look-up table 238 outputs on a 10 bit bus 242 the code-word to be transmitted in parallel format PARCODE which forms an input to the shift register 240. It will be appreciated that the parity bit TPARITY output by the look-up table 238 on line 226 is actually one of the signals on the bus 242, but is shown separately in Figure 5 for ease of explanation. As in Figure 4, the register 206 records the parity bit PTPARITY of the previous code-word transmitted on line 214 and the signal LPNZ on line 216. In the embodiment of Figure 5 the signal PTPARITY and the signals LPNZ form inputs to the look-up table 238. The look-up table 238 also receives the binary data byte BTPDATA0-7 on bus 90 and the control signals on lines 70 from the control circuit 44. Thus the look-up table 238, which is implemented using a ROM, merely uses the information presented at its inputs to look up the appropriate outputs in its memory and output them on bus 242 and the code-word to be transmitted in parallel form. ,

Referring once again to Figure 2, it can be seen that the serial code-words CODEW on line 88 output from the 8B10B encoder 50 are input to the data strobe encoder 54 for generation of the buffered data code-words BCODEW on line 86 and the strobe signal STROBEW on line 84. As was mentioned hereinabove earlier, the

serial strobe signal STROBEW on line 84 is generated such that at the bit boundaries of the data signal where there is no transition there is a transition on the strobe signal, and at the bit boundaries of the data signal where there is a transition there is no transition on the strobe signal. Thus referring to Figures 6a and 6b there is shown a serial data stream in Figure 6a and a corresponding parallel serial strobe signal in Figure 6b. As can be seen, the strobe signal is generated such that it transits always, but only at, bit boundaries of the data signal where there is no transition.

Referring now to Figure 7, there is shown a possible implementation of a data strobe encoder 54. The data strobe encoder 54 includes two D-type registers 92 and 94, a T-type register 98, and an exclusive NOR gate 96. Each of the D-type register 92, D-type register 94, and T-type register 98 receive the transmit TXCLK on line 66. The operation of such a circuit is known from earlier European Patent Application Publication No. 0458648, and therefore will not be described in detail herein. The waveform signals at various nodes of the data strobe encoder 54 of Figure 7 are shown in Figure 8. Essentially the serial data code-word CODEW on line 88 is clocked by the transmit clock TXCLK through two successive D-type registers 92 and 94 onto the signal line 86 to form the buffered serial code-word BCODEW. The output of the D-type registers 92 and 94 form the inputs to the exclusive NOR gate 96. Thus the exclusive NOR gate will output a logic one if the outputs of the two D-type registers 92 and 94 are both the same, i.e. if there is no transition between the two successive bits of the serial code-word CODEW which are at the outputs of the two D-type registers 92 and 94. The T-type register 98 is such that its output changes state if its input is logic one when clocked. Thus a high output on the output of the exclusive NOR gate 96 on line 102 will cause a change of state on the STROBEW signal line 84 output from the T-type register when the bits on lines 100 and 86 are the same indicating no transition of the data signal.

The data signal including the code-word BCODEW on line 86 is dc balanced owing to the encoding technique employed in the 8B10B encoder 50 described herein above in which the running digital sum of the data signal and code-word boundaries is minimised. However, the strobe signal STROBEW on line 84 is not dc balanced. In the preferred embodiment of this invention the serial data and parallel strobe signal are to be transmitted over respective twisted pairs, and the interface for coupling these signals to those twisted pairs is provided by a pair of transformers. However signals can only be used to interface with the transformers if they are dc balanced. Thus it is desired to dc balance the serial strobe signal STROBEW on line 84.

The dc balancing of the STROBEW signal on line 84 is achieved by converting the signal into a ternary three-level signal, having one of three states: -1, 0, or +1.

In the preferred embodiment of this invention, both the serial data signal BCODEW on line 86 and the serial strobe signal STROBEW on line 84 are converted into ternary signals. Although the serial data signal BCODEW on line 86 is already dc balanced, encoding it into a ternary signal further improves the spectral characteristics of the serial data signal. A simple pseudo-ternary code is used to encode the binary signals CODEW and STROBEW. The encoding scheme is such that a binary zero is always represented as a ternary zero, and a binary one is always represented as either a -1 or a +1. In this way the decode of the ternary signal, as will be described in further detail hereinafter, is a simple rectification of the receive signal. The encoding from binary into ternary is such that there are never any two-level transitions, i.e. the ternary signal never transits from -1 to +1 on a trit boundary or between +1 to -1 on a trit boundary. All the transitions are single-level transitions, i.e. between a -1 and 0, 0 and -1, +1 and 0, or 0 and +1 at trit boundaries.

The simple pseudo-ternary code employed by the preferred

embodiment of the present invention is regulated mark inversion (RMI). There is a variety of RMI codes, depending on the permitted run length of the binary signal input to the RMI encoder.

The actual coding rules for the ternary encoding scheme employed in the present invention are:

a) if the running digital sum of the ternary encoded signal is positive and at least two 0s have been transmitted since the last +1, then the next 1 is transmitted as -1;

b) if the running digital sum of the ternary encoded signal is negative and at least two 0s have been transmitted since the last -1, then the next 1 is transmitted as +1;

c) if the running digital sum of the ternary encoded signal is negative and at least two 1s follow any numbers of 0s, then those 1s are transmitted as +1;

d) If the running digital sum of the ternary encoded signal is negative and at least two 1s follow any number of 0s, then those 1s are transmitted as +1.

e) otherwise the polarity of 1s is reversed each time a run of at least one 0 occurs.

An example of a circuit for implementing the ternary encoding scheme is illustrated in Figure 9. The circuit of Figure 9 is an example of the data ternary encoder 56 of Figure 2. An identical circuit would be used to implement the strobe ternary encoder 58 of Figure 2. The data ternary encoder 56 includes a latch 104, a state machine 106, a counter 108, and a pair of resistors 107 and 109. The latch 104 receives the serial data code words BCODEW on line 86 and transfers its latched output to an input of the state machine 106 via line 110. In addition the state machine 106 receives the serial data code words BCODEW on

line 86 as a second input. The state machine 106 outputs signals on lines 112 and 114, which signals form inputs to the counter 108. The counter 108 generates an output signal on line 116 to the state machine 106. The resistors 107 and 109 are connected in serial fashion, with one end of the resistor 107 being connected to the signal line 112 and one end of the resistor 109 being connected to the signal line 114, the other ends of the resistors 107 and 109 being connected together. The common point of connection between the resistors 107 and 109 forms the output signal TSDATA on line 18 of the data ternary encoder 56. In addition each of the latch 104, state machine 106 and counter 108 receive the transmit TXCLK on line 66.

The state machine 106 outputs signals on lines 112 and 114 in accordance with whether the ternary trit is to be -1, 0 or +1. The resistors 107 and 109 convert the signals on lines 112 and 114 into ternary trits on line 18. The counter 108 counts the signal on line 112 and 114 to calculate the running digital sum of the ternary encoded code-words. The running digital sum thereby calculated is outputted on line 116 to state machine 106. In addition it will be clear from the operation of the latch 104 that the state machine receives as inputs the current incoming serial bit of the code-word BCODEW on line 86, and the previous bit of the code-word BCODEW latched by the latch 104 onto line 110. Thus the state machine 106 knows the value of the current bit to be encoded, the previous bit encoded, and the running digital sum of the code-word. The state machine contains an algorithm allowing the rules (a) to (e) described hereinabove to be implemented.

Figure 10 shows the logic state diagram for the state machine 106 of Figure 9.

Figure 11 shows example waveforms of the binary data signal code-words in Figure 11a, and the binary parallel encoded strobe signal in Figure 11b. Also shown are the corresponding ternary encoded signals, with Figure 11c showing the ternary encoded

serial data signal TSDATA on line 18 and Figure 11d shows the ternary encoded serial strobe signal TSSTROBE on line 22.

The thus encoded ternary serial data code-word on line 18 and the ternary serial parallel strobe signal on line 22 are communicated to respective transformers 6 and 8 by the encoder/decoder 2 for transmission on the respective twisted pair links 38 and 40.

On the receive side, the encoder/decoder 2 receives from the respective transformers 6 and 8 the received serial ternary encoded signal RSDATA on line 20 and the received serial ternary encoded parallel strobe signal RSSTROBE on line 24 from the respective twisted pair links 38 and 40. On the receive side, the first operation which must be performed is to convert the received ternary signals into binary signals.

As mentioned hereinabove with regard to the description of the ternary encoding scheme, the conversion from ternary to binary with the advantageous ternary encoding scheme used is extremely simple, in that the incoming ternary signals merely need to be rectified to produce the binary data and strobe signals. Because on the transmit side a binary 1 is always encoded as a +1 or a -1, then rectifying the incoming ternary signal means that the +1 or -1 on the ternary signal is always decoded as a 1, and a 0 is always decoded as a 0. Thus, the decoder circuitry of the encoder/decoder 2 comprises at the input stage thereof a data rectifier 60 and a strobe rectifier 62 for receiving the respective ternary serial data signal RSDATA on line 20 and ternary serial strobe signal RSSTROBE on line 24. Data rectifier 60 outputs on line 80, the rectified receive data signal RECDATA and the strobe rectifier 62 outputs on line 82 the rectified serial strobe signal RECSTROBE on line 82. The rectified data and strobe signals on lines 80 and 82 form inputs to the exclusive OR gate 64, and as will be appreciated from the foregoing description with reference to Figure 7, the clock used to encode and transmit the data can simply be recovered from the output of this exclusive OR gate. Referring once again to Figure

6, it will be understood that if the rectified data signal is that of Figure 6a, then the rectified strobe signal is that of Figure 6b. Thus the exclusive OR gate 64 receives as its two input signals the waveforms shown in Figures 6a and 6b. Thus the output of the exclusive OR gate 64 will be the waveform shown in Figure 6c, which is the recovered transmit clock, which forms the receive clock RXCLK on line 78 of the output of the exclusive OR gate 64.

The rectified data signal RECDATA on line 80, which includes the serial 10 bit code-words received by the encoder/decoder 2, is input to the 8B10B decoder 52.

In Figure 12 there is shown a block diagram of a preferred implementation of the 8B10B decoder 52. The 8B10B decoder 52 includes a shift register 120, a substitution circuit 126, a bit counter 122, and a parity check circuit 124. Although not shown in Figure 12 the reasons of clarity, each of the shift register 120, substitution circuit 126, bit counter 122 and parity check circuit 124 receive the receive clock signal RXCLK on line 78. The shift register 120 receives the rectified data code-words RECDATA on line 80 and converts them into 10 parallel bits. The parallel received data bytes of the data code-word is output from the shift register as bits D0-7 on line 134, the parity bit P of the received code-word is output from the shift register on line 128 and the flag bit F of the received code-word is output from the shift register 120 on line 136. The received data byte D0-7 forms an input to the bit counter 122 and the substitution circuit 126. The parity bit P forms an input to the parity check circuit 124. The flag bit F forms an input to the substitution circuit 126. The bit counter 122 generates count signals on lines 130 and 138, the count signal on line 130 forming an input to the parity check circuit 124 and the count signal on line 138 forming an input to the substitution circuit 126. The substitution circuit 126 outputs the received decoded data byte RPDATA0-7 on bus 76, and also the control signals, if any, on line 72 to the control circuit 44.

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Thus, the parallel received data byte D0-7 is input to the substitution circuit 126 together with the flag bit F. The substitution circuit will, in dependence on whether the flag bit F is set or not, invert the data byte D0-7 or not. The bit counter 122 counts the number of 1s in the received data byte D0-7 and outputs this value on line 130 to the parity check circuit 124. The parity check circuit 124 checks to ensure that the number of 1s in a received code-word is an odd number. If the parity check circuit 124 detects a parity error, then an error signal ERR is generated on line 140 to the substitution circuit. Such an error may well be communicated to the control circuit 44 via control line 72. The bit counter 122 also outputs the value of the bit count of the received data byte D0-7 to the substitution circuit 126 to assist the substitution circuit 126 in identifying those received data bytes which need to be substituted. If the code-word has zero disparity and the flag bit is set, then the received data byte needs to be substituted. If the code-word has non-zero disparity and the flag bit is set then the data byte is inverted. If the code-word has non-zero disparity and the flag bit is not set the data byte is not inverted. Substitution circuit 126 will contain a small look-up table for identifying those data bytes which require substitution together with associated logic circuitry.

Referring to Figure 13 there is shown an alternative implementation of the 8B10B decoder 52. This implementation still includes the shift register 120 for receiving the rectified data code-words RECDATA on line 80 and for outputting the data byte D0-7, the parity bit P and the flag bit F. However the other blocks of the implementation shown in Figure 12 are eliminated and replaced by a single read only memory (ROM). Thus the data byte D0-7, the flag bit F and the parity bit P are used as an address to the ROM to look up the appropriate decoded data byte for output as the data byte RPDATA0-7 on bus 76. In addition the ROM will also include the necessary control information which will be accessed by the address of the data byte D0-7, flag bit F and the parity bit P if such a code-word

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is a control code-word, and output the appropriate control signals on the line 72.

The decoded data byte BRPDATA0-7 on bus 76 is then input into the received FIFO 48 under the control of the receive clock RXCLK, and subsequently output on the bus 16 as the received data RPDATA0-7 for transmission to a destination device.

The preferable embodiment of the code has been described hereinabove with a parity bit. A number of communication codes discard parity in order to improve the coding efficiency. It is possible to discard parity in this code, which would result in a code word of nine bits. Instead of disparities of each code word of 0, ± 4 and ± 8, the code-words would have disparity ± 1, ± 3 or ± 5, These disparities mean that the substitution codes have to be taken from those codes which have disparity +1, and so for the basic binary serial data code it is not possible to guarantee dc balance on the data signal line.

The rule for choosing the polarity of code-word depending on the previous parity bit, rule (c) hereinabove, would be changed to depend on the previous flag bit, which would become the last bit to be transmitted of each code-word.

The run lengths, both of consecutive ones and consecutive transitions, would in such an embodiment preferably be reduced to six between code-words. For those code-words which had the parity bit at 0, but the flag bit at 1, there are a few additional codes needing substitution, for example code 0001 1111 1 (decimal value 3 in Appendix 1), and some of the existing substitution codes also violate, such as the code used in Appendix 1 to substitute for decimal value zero. A further two code-words have a run length of seven internally, and these would need additional substitution codes (code 0111 1111 0, decimal value 254, with an internal run length of seven ones, and 0010 1010 0, decimal value 84, with an internal run length of seven transitions).

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The code table in Appendix 1 has several spare substitution codes, and a possible allocation of these spare codes to the additional violations is given in enclosed Appendix 2.

While it is not possible to guarantee dc balance of this code, it is still possible further to encode it as a data strobe signal, with the strobe signal making a transition at every bit boundary where the data signal does not make a transition. It is also possible to further ternary encode it which ensures the dc balance of the data signal, or with ternary coding of both the data and strobe signals, which gives dc balance on both the data and strobe signals, while preserving the run length constraint of six consecutive ones and six consecutive transitions given by the code.

As with the preferred embodiment described above with parity, it may not be necessary to limit the run length as much as possible. For the code without parity, the run length of six can be achieved with the rules and with the substitution codes. A run-length of seven or eight or more could be achieved with fewer substitution codes and hence with less logic, and such a code may be preferable in certain applications to the code with the run length of six.

A benefit of the simple clock recovery with an exclusive OR gate is that it is possible to take the signals to a standby state when there is nothing to transmit, and then very quickly to restart transmission when there is data. In such a standby state both the data and strobe signals go quiescent.

A preferred algorithm for going to quiescence is:

1. If the last code-word sent was an end of packet or end of message control code-word, and the transmit FIFO 46 is empty, and there is no flow control token (or other link-level token) to send, send a GoToStandby code-word.

2. After the GoToStandby code-word, insert a dummy code-word which brings the ternary versions of the data and strobe signals both to zero and their running digital sum to zero. This code-word need not follow the normal rule of a data bit of the code-word being transmitted every clock cycle, and the value of the code-word must be ignored by the receiver.

3. The dummy code-word first brings the strobe signal to zero.

4. It then brings the ternary version of the data signal to zero disparity and then to zero, without the strobe signal changing during this adjustment.

5. It then brings the ternary version of the strobe signal to zero disparity and then to zero, without the data signal changing during this adjustment.

6. If less than six transitions have occurred in the dummy code-word so far, the strobe signal is cycled through four (or eight) transitions so that no more than three transitions are needed when the transmission needs to "wake up".

7. At this point the line is quiescent with no energy stored in the transformers, and can stay in that state until there is new data to transmit.

8. When there is new data to transmit, the strobe signal is cycled through as many transitions as are necessary to complete the dummy code-word (a maximum of three transitions), and the new code-word is transmitted).

An example of circuitry for implementing the GoToStandby control technique is shown in Figure 14, and Figure 15 shows examples of the sequence of signals generated in such circuitry.

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In Figure 14 there is shown each of the data ternary encoder 56 and strobe ternary encoder 58 of the encoder/decoder 4. As will be appreciated from Figure 9 hereinabove, the data ternary encoder 56 comprises the data latch 104, the data state machine 106 and data counter 108, together with the resistors 107 and 109, interconnected identically as described hereinabove with reference to Figure 9. Similarly, the strobe ternary encoder 58 comprises a strobe latch 244, a strobe state machine 246, a strobe counter 248, and resistors 250 and 252. Each of these elements of the strobe ternary encoder 58 is connected in an identical fashion to that of the data ternary encoder 56 as described herein above with reference to Figure 9. In addition in accordance with this embodiment of the invention with the provision of the Go To Standby control protocol, the data ternary encoder 56 additionally comprises a multiplexor 266 and the strobe ternary encoder 58 additionally comprises a multiplexor 268. A magnitude comparator 270 is provided common to each of the data ternary encoder 56 and the strobe ternary encoder 58.

The multiplexor 266 receives the buffered serial data code-word BCODEW on line 86 on one input and a dummy data signal DUMMYD on line 70b on a second input. The multiplexor 266 receives a control signal STANDBY on line 70a which is one of the signal lines 70 generated by the control circuit 44. The multiplexor 268 of the strobe ternary encoder 58 receives on one input thereof the serial data strobe signal STROBEW on line 84, and on the other input thereof a dummy strobe signal DUMMYS on line 70c which is one of the control signals 70 generated by the control circuit 44. The multiplexor 268 also receives as a select control input the signal STANDBY on line 70a. In normal operation of the device, when data and/or control signals are being transmitted on a serial data signal, the STANDBY signal on line 70a is set such that the serial data code-word BCODEW on line 86 is transferred to the output of the multiplexor 266 on line 262, and ternary encoded by the data ternary encoder 56 as described hereinabove with reference to Figure 9. Similarly the STANDBY signal on line 70a controls the multiplexor 268 such that

the serial strobe signal STROBEW on line 84 is output by the multiplexor 268 onto line 264 and ternary encoded in a similar manner to that described with reference to the data ternary encoder 56 in Figure 9.

However, when the control circuit 44 determines that the transmit FIFO 46 is empty and there is no more data to be transmitted, then it sets the STANDBY signal on line 70a such that the multiplexor 266 transfers the serial dummy data signal DUMMYD on line 70b to line 262, and the multiplexor 268 transfers the dummy strobe signal DUMMYS on line 70c to line 264. Thus the dummy data and dummy strobe signals are ternary encoded by the respective ones of the data ternary encoder 56 and the strobe ternary encoder 58. The control circuit 44 then outputs signals on each of the dummy data signal line 70b and dummy strobe signal line 70c to bring the transmission line to a quiescent state.

Firstly, the control circuit 44 outputs the control code-word corresponding to the Go To Standby control. This will be one of the data code-words having 0 disparity which is reserved for control purposes. Thus, on the receive side, when the 8B10B decoder 52 decodes the Go To Standby control code-word, the control circuit 44 on the receive side will decode such control code-word.

Referring to Figure 15, there is shown example waveforms generated when there is no data to be transmitted and the system is to be brought to a quiescent state. The first 10 bits transmitted are the respective bits of the Go To Standby control word. Thus as shown in Figure 15b in this particular embodiment of the invention the code-word 0001 1110 10 is reserved as the Go To Standby control code-word. The corresponding strobe signal is generated on the dummy strobe line 70c having transitions at those bit boundaries of the dummy data signal where there are no transitions. The strobe signal is illustrated in Figure 15d. Both the Go To Standby control code-word on the dummy data signal line 70b and the parallel strobe signal on the dummy strobe line

70c are encoded by the respective ternary encoders 56 and 58 to generate the respective ternary versions thereof as illustrated in Figures 15e and 15f.

Thereafter the control circuit 44 generates signals on the dummy data signal DUMMYD and dummy strobe signal DUMMYS on lines 70b and 70c respectively in accordance with steps 2 to 6 of the algorithm described herein above. The magnitude counter 270 is used to compare the transitions on the respective data and strobe signal lines in accordance with the steps 2 to 6 of the algorithm.

When the control circuit 44 receives control information on line 68 from the transmit FIFO 46 indicating that there are now data bytes to be transmitted, the system is woken up, in accordance with step 8 of the above algorithm, by cycling through as many transitions as are necessary to complete the dummy code-word. As can be seen in Figure 15, only one transition is needed to complete the dummy code-word since 9 bits of the dummy code-word have been used to bring the data and strobe signals to a quiescent state. Thereafter a new data code-word is transmitted as normal with the standby signal on line 78 being reset.

Figure 16 shows the logic state diagram for either of the data state machine 106 or strobe state machine 246 of Figure 14.

The data strobe encoding scheme, in which a serial strobe signal is generated parallel to a serial data signal, the strobe signal only having transitions at bit boundaries of the data signal where there are no transitions, and having no transitions at bit boundaries of data signal where there are transitions, provides for advantageous simple clock recovery at a receive end of a transmission link. In particular, such data strobe encoding techniques have significant advantages over conventional phase locked loop techniques for recovering clocks from received data at the receive end of a transmission link.

The receiver depends on the sequence of transitions between the data and strobe signals, and not on their timing with respect to some fixed-frequency clock. There is a full bit-time of skew tolerance, twice the skew tolerance of the data with respect either to a clock carried in a parallel wire or to a clock recovered from the data itself using conventional phase locked loop clock recovery techniques.

Because the transmit clock does not need to be a fixed frequency, the transmit clock frequency can vary, as with "Spread Spectrum Clocks" being used as the master clocks in personal computers (PCs) to reduce their EMC emissions. This benefit is potentially of more benefit to communications between computers, via comparatively uncontrolled wiring outside the box, than it is to the computers themselves which are in a comparatively well-controlled environment inside a box.

Because the clock can change instantaneously from high speed to dc and then, maybe some time later, switch back again to high frequency, it offers the opportunity of stopping transmission when there is nothing to transmit and starting up instantaneously when data arrives to be transmitted. The ability to be active and dissipating power only when there is traffic to transport offers a great opportunity for reducing power consumption, which is increasingly important for consumer products. It is important for the telephone and cable industries in the distribution of broad-band services, where dc is distributed to all subscribers' equipments and there is a need to minimise the load on this supply. This particular advantage has been described hereinabove with reference to the "GoToStandby" mode of operation.

An alternative to completely stopping transmission would be to run the clock more slowly when there is no traffic. This alternative would require larger transformers than would otherwise be necessary in order to limit the base-line-wander of the slower signals. A simple autonomous protocol for the use of such a mechanism would be that if the transmit FIFO is more than

half full, the transmission speed doubles; if after transmitting a few more code-words, the FIFO is still more than half full, double the transmission speed again, and so on until maximum speed is reached; when the FIFO empties, transmission speed halves, and halves again if it stays empty. An even simpler protocol would be to run at full speed if there is data to transmit, and run at 1/8th speed (or some other fractional speed) when there is nothing to transmit.

In most communication systems, there is a need to distribute a clock, such as the 8kHz clock used by the telephone system. One way to distribute this clock is on the phantom circuit described hereinafter. An alternative for clock distribution from a routing switch would be to pause the transmit clock at the end of a code-word on each output port when a synch code-word is received by the switch. Then, some fixed delay after the synch code-word is received (a delay long enough for all the output ports of the switch to have become paused), the synch code-word (labelled CLK in the code-table in Appendix 1) would be forwarded to all output ports of the switch at exactly the same time.

The transformers 6, 8, 10 and 12 used to interface the twisted pair connections 38 and 40 between the respective encoders/decoders 2 and 4 of Figure 1 are preferably each a standard arrangement hybrid transformer as shown in Figure 17, but alternative bridge circuit implementations may be used. Figure 17 illustrates the transformer 6 of Figure 1, but it will be understood that each of transformers 8, 10 and 12 will be constructed identical to that of transformer 6. The transformer 6 includes three impedances 150, 152, 154 and a winding 156. The winding 156 has two primary windings 151 and 153 and a secondary winding 155. The two primary windings connect to the signals to be transmitted/received to/from the encoder/decoder 2, and the secondary winding connects to the twisted pair 38.

The connections are such that the winding connected to the encoder/decoder is split into two using a centre tap, and the

winding connected to the twisted pair has the twisted pair connected across it. The use of transformer ratios of $\sqrt{2}$:1 between each of the windings connected to the encoder/decoder and the winding connected to the twisted pair is common and may be preferred. Instead of using the hybrid transformer as a bridge to cancel out the transmitted signal, another form of bridge circuit might be used.

The two primary windings 151 and 153 is Figure 17 cancel each other out, so that the voltage on the node to which the signal line 20 is connected is a virtual earth, independent of the voltage to be transmitted on line 18. As the received signal is coupled into both primary windings, it is seen as a voltage on line 20.

A simple method by which the number of communication channels carried by a given number of wires can be increased is by use of a "phantom" circuit. Referring to Figure 18 there is shown the four transformers 6, 8, 10 and 12 of Figure 1, with the respective twisted wire links 38 and 40 therebetween. As can be seen from Figure 18, the secondary winding of transformer 6 is connected to one end of the twisted pair 38 and the primary winding of the transformer 10 is connected to the other end of the twisted pair 38. Similarly the secondary winding of the transformer 8 is connected to one end of the twisted pair 40, and the primary winding of the transformer 12 is connected to the other end of the twisted pair 40. In addition, a connection is made from the centre tap of the secondary winding of the transformer 6 and to the centre tap of the secondary winding of the transformer 8. These connections, 11 and 13 respectively, are connected to terminals 15 and 17 to which a signal may be applied. Similarly a signal may be applied to the terminals 19 and 21, which are respectively connected via connections 23 and 25 to the centre tap of the primary winding of the transformer 10 and the centre tap of the primary winding of the transformer 12.

Thus the terminals 15 and 17 form one end of the phantom circuit, and the terminals 19 and 21 form the other end of the phantom circuit. The operation of a phantom circuit is well known, working on a balancing principle.

The twisted pair 38 and the twisted pair 40 provide high speed bidirectional links between the respective transformer pairs 6 and 10, and 8 and 12 respectively. The phantom circuit provides a lower speed bidirectional link between the terminal pairs 15 and 17, and 19 and 21 respectively.

Referring to Figure 19 there is shown an implementation of the phantom circuit discussed hereinabove according to a preferred embodiment of the present invention. In Figure 19, a power supply, such as a battery charger or an ac/dc power supply 160 which receives a mains input on signal line 162, is connected across the terminals 15 and 17 via connections 164 and 166, signal lines 168 and 170 are connected to the respective terminals 21 and 19, a dc converter 172 being connected across the signal lines 168 and 170 and generating an output on signal line 174. Thus in the implementation of Figure 19 the phantom circuit is used to deliver power. The twisted pair signal lines 38 and 40 are both in use transmitting high speed communication signals, and in this particular example the transformers 10 and 12 will be connected to any peripheral device to which high speed information is being transmitted. In this example, power delivered down the phantom circuit is used to power the devices to which the high speed information is delivered. In a preferable embodiment of the invention, the twisted pair signal lines 38 and 40 communicate respective data and strobe signals.

The use of both wires of each twisted pair 38 and 40 to conduct the power supply current, via the phantom circuit, reduces the cable resistance and resulting power loss compared with a single dedicated twisted pair for supplying power. In the preferable embodiment the power supplied down the phantom circuit is a 24V power level, easily supplied by a lead-acid battery which is safe

and can supply 10 to 30 watts or more of power per pair of twisted pair high speed communication links. Preferably the dc converter 172 is inverting and does not have a failure mode where the full 24V received can be supplied on the output signal line 174. Typically for a device to which power is being supplied the output signal line 174 will have a 5V or 3.3V output. The combination of battery charger, power supply and batteries is equivalent to a normal uninterruptable power supply (UPS) except that the UPS does need the inverter back to mains voltage.

Referring to Figure 20 there is shown another implementation according to a preferred embodiment of the present invention utilising the phantom circuit. In this embodiment, the phantom circuit is used for a "power line" signalling scheme such as CEBUS or LON. These normally connect to the 120V or 240V ac mains, but would connect much more simply to the dc power supply as does the WattCAN version of the CAN standard, or as do the POTS and ISDN phone lines.

Referring to Figure 21 there is shown another preferred embodiment of the present invention in which a series switch is connected to a one of the terminals 15,17 for interrupting the power supply applied to that terminal. In Figure 21 a switch 178 is shown connected to the line 164. Such a switch in series with the power supply 160 can be used to limit the current supplied by the battery to each cable. Alternatively, or in addition, the switch could be opened periodically to provide a global signalling clock. For instance if the switch was opened for 1μs every 125μs then a 8kHz clock such as used in telephone systems would be provided.

It is possible that a single chip could integrate the power supply, transceiver, bus protocol logic, and microprocessor - a level of integration very difficult for mains connections. The SGS-THOMSON L6901 is nominally a battery charger IC, but includes a 5V power supply plus a 4Amp dc-dc converter, a microprocessor, OTP EPROM, and a small amount of RAM. It also includes EEPROM

and an 8 bit A to D converter, and is clearly very close to including all the necessary circuitry in a single chip. The communications protocol for such a bus could be implemented in software by the microprocessor, and the 4Amp output amplifier could be used as a very low impedance driver to output to the bus (a low impedance driver is needed in such circuits because the battery/power supply impedance is low). An example of how such a single chip would be connected is shown in Figure 22. A further twisted pair 300 is connected to the phantom circuit terminals 19 and 21. A single chip circuit 302 has connections 304 and 306 to the power supply on the twisted pair 300.

If, as disclosed in the data strobe encoding scheme according to European Patent Application Publication No. 0458648, there is an initialisation routine which waits for valid codes, the receiver can also be designed so that the two twisted pairs can be swapped.

The initialisation routine to allow the pairs to be swapped looks for NUL tokens on both the data and the strobe received signals, and consequently chooses which of the two decode outputs generated by the data rectifier 60 and the strobe rectifier 62 to treat as the data signal and which to treat as the strobe signal.

Referring to Figure 23 there is shown an alternative implementation of the receive side of the encoder/decoder 2 of Figure 2. There is additionally provided a state machine 310 and a multiplexor 312. The state machine 310 receives the receive clock RXCLK on line 78, and also receives the rectified serial data signal RECDATA on line 80 and the rectified serial strobe signal RECSTROBE on line 82. The state machine generates a signal on line 314 which controls the multiplexor 312. The multiplexor 312 receives as inputs the serial data signal RECDATA on line 80 and the received rectified serial strobe signal RECSTROBE on line 82. In dependence on which one of the signals RECDATA or RECSTROBE the state machine 310 identifies as carrying

the appropriate control token, the state machine sets output 314 to choose that signal as the receive data signal and inputs it on line 316 to the 8B10B decoder 52.

Figure 24 shows the logic state diagram of the state machine 310 of Figure 23.

The fact that the ternary decode is simply a rectification means that the individual wires of each twisted pair can also be swapped. Twisted pair 40 is shown in Figure 23 with a missing twist, and so the signal seen at the hybrid transformer appears to be inverted. After rectification, the signal is unchanged from the signal of the overall block diagram in Figure 2.

A bridge rectifier 318 is shown in Figure 23 between the phantom circuit and the dc-dc converter 172. It is used to make the power supplied by the phantom circuit insensitive to the polarity of the power supplied. The power supplied by the phantom circuit is still a dc supply, in spite of the bridge rectifier.

The NUL code that the state machine 318 would preferably look for is the NUL code given in the code table in Appendix 1.

It is also possible to connect the phantom circuit when there is no encoder/decoder plugged in, by using half-transformers or common-mode chokes, as shown in Figure 25. The transformers 10 and 12 are replaced by half-transformers 320,322.

A number of methods have been described above for providing additional communications or services via the phantom circuit. A further communications method is possible through the two twisted pairs 38 and 40 by the use of the spread spectrum clock. As shown in Figure 26, the spread spectrum clock 42 preferably comprises a scrambler 350 a transmit clock frequency generator 354 and a frequency modulator 360. The spread spectrum clock modulates the clock frequency over a range from a few per cent of the nominal clock frequency up to about 10 per cent of the

nominal clock frequency. The signal used to modulate the clock is generated internally inside a chip. However, as shown in Figure 26, a signal source such as the transmit signal TXSIGNAL on line 352 is used as a modulator to a scrambler 350. The frequency modulator 360 then receives as inputs the output of the scrambler 350 on line 356 and the output of the transmit clock frequency generator 354 on line 358. The output of the frequency modulator 360 is the transmit clock TXCLK on line 66.

Referring to Figure 27 there is shown circuitry for demodulating the recovered clock at the receiver, comprising an FM demodulator 362 and a descrambler 366. The FM demodulator 362 receives as an input the receive clock RXCLK on line 78 and presents its output on line 364 to a descrambler 366 for generating the receive signal RXSIGNAL on line 368 corresponding to the transmit signal TXSIGNAL on line 352. Although Figure 26 shows the use of a scrambler 350 and consequently Figure 27 shows the use of a descrambler 366, it is not essential to scramble the transmitter signal but it is preferable to do so to ensure the clock frequency is adequately spread.

Figure 28 shows the outline of a home-wiring system based on the proposed technology. The routing switch and batteries (DC-UPS) would be in a closet, and would each connect via one or more DS pairs of twisted pairs to each room. Within each room, equipments might be connected individually to a wall socket or in a ring or other network, or be themselves connected by another routing switch and maybe separate power supply and DC-UPS.

Appendix 1: Code table

Spare substitution codes available for control codes

Control signal	Code [0.....7]	F l a g [8]	P a r i t y		
NUL	00011100	1	1		199
FCT	01101100	1	0		201
EOP	00101100	1	1		203
EOM	11001100	1	0		204
GTS	01001100	1	1		205
CLK	10001100	1	1		206
	01110100	1	0		209
	10110100	1	0		210
	00110100	1	1		211
	11010100	1	0		212
	10010100	1	1		214
	11100100	1	0		216
	01100100	1	1		217
	11000100	1	1		220
	01111000	1	0		225
	10111000	1	0		226
	00111000	1	1		227
	11011000	1	0		228
	10011000	1	1		230
	11101000	1	0		232
	01101000	1	1		233
	11001000	1	1		236
	01110000	1	1		241
	10110000	1	1		242

Dec-imal	Code [0.....7]	F l a g [8]	P a r i t y		Inverse or alternative code [0.....7]	F l a g [8]	P a r i t y	Use of inverse or alternative code	
0					00010111	1	0	Substitute	23
1					00100111	1	0	Substitute	27
2					01000111	1	0	Substitute	29
3	11000000	0	1		00111111	1	0	Use true or inverse to reduce or reverse RDS	
4					10000111	1	0	Substitute	30
5					00011011	1	0	Substitute	39
6	01100000	0	1		10011111	1	0	Use true or inverse to reduce or reverse RDS	
7					00101011	1	0	Substitute	43
8					01001011	1	0	Substitute	45
9	10010000	0	1		01101111	1	0	Use true or inverse to reduce or reverse RDS	
10					10001011	1	0	Substitute	46
11					00110011	1	0	Substitute	51
12	00110000	0	1		11001111	1	0	Use true or inverse to reduce or reverse RDS	
13					10010011	1	0	Substitute	54
14					00010011	1	1	Substitute	55
15					00001111	1	0	Use inverse	
16					01100011	1	0	Substitute	57
17	10001000	0	1		01110111	1	0	Use true or inverse to reduce or reverse RDS	
18	01001000	0	1		10110111	1	0	Use true or inverse to reduce or reverse RDS	
19					00100011	1	1	Substitute	59
20	00101000	0	1		11010111	1	0	Use true or inverse to reduce or reverse RDS	
21					11000011	1	0	Substitute	60
22					01000011	1	1	Substitute	61
23	11101000	0	1						
24	00011000	0	1		11100111	1	0	Use true or inverse to reduce or reverse RDS	
25					10000011	1	1	Substitute	62
26					00010101	1	1	Substitute	87
27	11011000	0	1						
28					00100101	1	1	Substitute	91
29	10111000	0	1						
30	01111000	0	1						
31					01000101	1	1	Substitute	93
32					10000101	1	1	Substitute	94
33	10000100	0	1		01111011	1	0	Use true or inverse to reduce or reverse RDS	
34	01000100	0	1		10111011	1	0	Use true or inverse to reduce or reverse RDS	
35	11000100	0	0		00111011	1	1	Use true or inverse to reduce or reverse RDS	
36	00100100	0	1		11011011	1	0	Use true or inverse to reduce or reverse RDS	
37					00111001	1	0	Substitute	99
38	01100100	0	0		10011011	1	1	Use true or inverse to reduce or reverse RDS	
39	11100100	0	1						
40	00010100	0	1		11101011	1	0	Use true or inverse to reduce or reverse RDS	
41	10010100	0	0		01101011	1	1	Use true or inverse to reduce or reverse RDS	
42					10011001	1	0	Substitute	102
43	11010100	0	1						
44	00110100	0	0		11001011	1	1	Use true or inverse to reduce or reverse RDS	
45	10110100	0	1						
46	01110100	0	1						
47					00001011	1	1	Use inverse	
48					00011001	1	1	Substitute	103
49	10001100	0	0		01110011	1	1	Use true or inverse to reduce or reverse RDS	
50	01001100	0	0		10110011	1	1	Use true or inverse to reduce or reverse RDS	
51	11001100	0	1						
52	00101100	0	0		11010011	1	1	Use true or inverse to reduce or reverse RDS	
53	10101100	0	1		01010011	1	0	Use true or inverse for no change after previous parity bit	
54	01101100	0	1						
55	11101100	0	0						
56	00011100	0	0		11100011	1	1	Use true or inverse to reduce or reverse RDS	
57	10011100	0	1						
58	01011100	0	1		10100011	1	0	Use true or inverse for no change after previous parity bit	
59	11011100	0	0						
60	00111100	0	1						
61	10111100	0	0						
62	01111100	0	0						
63					01101001	1	0	Substitute	105

Dec-imal	Code [0.....7]	F l a g [8]	P a r i t y		Inverse or alternative code [0.....7]	F l a g [8]	P a r i t y	Use of inverse or alternative code	
64					00101001	1	1	Substitute	107
65	10000010	0	1		01111101	1	0	Use true or inverse to reduce or reverse RDS	
66	01000010	0	1		10111101	1	0	Use true or inverse to reduce or reverse RDS	
67	11000010	0	0		00111101	1	1	Use true or inverse to reduce or reverse RDS	
68	00100010	0	1		11011101	1	0	Use true or inverse to reduce or reverse RDS	
69					11001001	1	0	Substitute	108
70	01100010	0	0		10011101	1	1	Use true or inverse to reduce or reverse RDS	
71	11100010	0	1						
72	00010010	0	1		11101101	1	0	Use true or inverse to reduce or reverse RDS	
73	10010010	0	0		01101101	1	1	Use true or inverse to reduce or reverse RDS	
74					01001001	1	1	Substitute	109
75	11010010	0	1						
76	00110010	0	0		11001101	1	1	Use true or inverse to reduce or reverse RDS	
77	10110010	0	1						
78	01110010	0	1						
79					00001101	1	1	Use inverse	
80					10001001	1	1	Substitute	110
81	10001010	0	0		01110101	1	1	Use true or inverse to reduce or reverse RDS	
82	01001010	0	0		10110101	1	1	Use true or inverse to reduce or reverse RDS	
83	11001010	0	1						
84	00101010	0	0		11010101	1	1	Use true or inverse to reduce or reverse RDS	
85					01110001	1	0	Substitute	113
86	01101010	0	1						
87	11101010	0	0						
88	00011010	0	0		11100101	1	1	Use true or inverse to reduce or reverse RDS	
89	10011010	0	1						
90	01011010	0	1		10100101	1	0	Use true or inverse for no change after previous parity bit	
91	11011010	0	0						
92	00111010	0	1						
93	10111010	0	0						
94	01111010	0	0						
95					10110001	1	0	Substitute	114
96					00110001	1	1	Substitute	115
97	10000110	0	0		01111001	1	1	Use true or inverse to reduce or reverse RDS	
98	01000110	0	0		10111001	1	1	Use true or inverse to reduce or reverse RDS	
99	11000110	0	1						
100	00100110	0	0		11011001	1	1	Use true or inverse to reduce or reverse RDS	
101	10100110	0	1		01011001	1	0	Use true or inverse for no change after previous parity bit	
102	01100110	0	1						
103	11100110	0	0						
104	00010110	0	0		11101001	1	1	Use true or inverse to reduce or reverse RDS	
105	10010110	0	1						
106	01010110	0	1		10101001	1	0	Use true or inverse for no change after previous parity bit	
107	11010110	0	0						
108	00110110	0	1						
109	10110110	0	0						
110	01110110	0	0						
111					11010001	1	0	Substitute	116
112					10010001	1	1	Substitute	118
113	10001110	0	1						
114	01001110	0	1						
115	11001110	0	0						
116	00101110	0	1						
117	10101110	0	0		01010001	1	1	Use true or inverse for no change after previous parity bit	
118	01101110	0	0						
119	11101110	0	1		00010001	1	0	Use true or inverse to reduce or reverse RDS	
120	00011110	0	1						
121	10011110	0	0						
122	01011110	0	0		10100001	1	1	Use true or inverse for no change after previous parity bit	
123	11011110	0	1		00100001	1	0	Use true or inverse to reduce or reverse RDS	
124	00111110	0	0						
125	10111110	0	1		01000001	1	0	Use true or inverse to reduce or reverse RDS	
126	01111110	0	1		10000001	1	0	Use true or inverse to reduce or reverse RDS	
127					11100001	1	0	Substitute	120

Dec-imal	Code [0.....7]	F l a g [8]	P a r i t y		Inverse or alternative code [0.....7]	F l a g [8]	P a r i t y	Use of inverse or alternative code	
128					01100001	1	1	Substitute	121
129	10000001	0	1		01111110	1	0	Use true or inverse to reduce or reverse RDS	
130	01000001	0	1		10111110	1	0	Use true or inverse to reduce or reverse RDS	
131	11000001	0	0		00111110	1	1	Use true or inverse to reduce or reverse RDS	
132	00100001	0	1		11011110	1	0	Use true or inverse to reduce or reverse RDS	
133					11000001	1	1	Substitute	124
134	01100001	0	0		10011110	1	1	Use true or inverse to reduce or reverse RDS	
135	11100001	0	1						
136	00010001	0	1		11101110	1	0	Use true or inverse to reduce or reverse RDS	
137	10010001	0	0		01101110	1	1	Use true or inverse to reduce or reverse RDS	
138					00011110	1	0	Substitute	135
139	11010001	0	1						
140	00110001	0	0		11001110	1	1	Use true or inverse to reduce or reverse RDS	
141	10110001	0	1						
142	01110001	0	1						
143					00001110	1	1	Use inverse	
144					00101110	1	0	Substitute	139
145	10001001	0	0		01110110	1	1	Use true or inverse to reduce or reverse RDS	
146	01001001	0	0		10110110	1	1	Use true or inverse to reduce or reverse RDS	
147	11001001	0	1						
148	00101001	0	0		11010110	1	1	Use true or inverse to reduce or reverse RDS	
149	10101001	0	1		01010110	1	0	Use true or inverse for no change after previous parity bit	
150	01101001	0	1						
151	11101001	0	0						
152	00011001	0	0		11100110	1	1	Use true or inverse to reduce or reverse RDS	
153	10011001	0	1						
154	01011001	0	1		10100110	1	0	Use true or inverse for no change after previous parity bit	
155	11011001	0	0						
156	00111001	0	1						
157	10111001	0	0						
158	01111001	0	0						
159					01001110	1	0	Substitute	141
160					10001110	1	0	Substitute	142
161	10000101	0	0		01111010	1	1	Use true or inverse to reduce or reverse RDS	
162	01000101	0	0		10111010	1	1	Use true or inverse to reduce or reverse RDS	
163					11000101	1	0	Force flag	92
164	00100101	0	0		11011010	1	1	Use true or inverse to reduce or reverse RDS	
165					00110110	1	0	Substitute	147
166					01100101	1	0	Force flag	89
167	11100101	0	0						
168	00010101	0	0		11101010	1	1	Use true or inverse to reduce or reverse RDS	
169					10010101	1	0	Force flag	86
170					10010110	1	0	Substitute	150
171					11100000	1	1	Substitute	248
172					00110101	1	0	Force flag	83
173	10110101	0	0						
174	01110101	0	0						
175					00010110	1	1	Substitute	151
176					01100110	1	0	Substitute	153
177					10001101	1	0	Force flag	78
178					01001101	1	0	Force flag	77
179	11001101	0	0						
180					00101101	1	0	Force flag	75
181	10101101	0	0		01010010	1	1	Use true or inverse for no change after previous parity bit	
182	01101101	0	0						
183					00100110	1	1	Substitute	155
184					00011101	1	0	Force flag	71
185	10011101	0	0						
186	01011101	0	0		10100010	1	1	Use true or inverse for no change after previous parity bit	
187					11000110	1	0	Substitute	156
188	00111101	0	0						
189					01000110	1	1	Substitute	157
190					10000110	1	1	Substitute	158
191					00011010	1	1	Substitute	167

Dec-imal	Code [0.....7]	F l a g [8]	P a r i t y		Inverse or alternative code [0.....7]	F l a g [8]	P a r i t y	Use of inverse or alternative code	
192					11010000	1	1	Substitute	244
193	10000011	0	0		01111100	1	1	Use true or inverse to reduce or reverse RDS	
194	01000011	0	0		10111100	1	1	Use true or inverse to reduce or reverse RDS	
195	11000011	0	1						
196	00100011	0	0		11011100	1	1	Use true or inverse to reduce or reverse RDS	
197	10100011	0	1		01011100	1	0	Use true or inverse for no change after previous parity bit	
198	01100011	0	1						
199	11100011	0	0						
200	00010011	0	0		11101100	1	1	Use true or inverse to reduce or reverse RDS	
201	10010011	0	1						
202	01010011	0	1		10101100	1	0	Use true or inverse for no change after previous parity bit	
203	11010011	0	0						
204	00110011	0	1						
205	10110011	0	0						
206	01110011	0	0						
207					01001010	1	1	Substitute	173
208					10001010	1	1	Substitute	174
209	10001011	0	1						
210	01001011	0	1						
211	11001011	0	0						
212	00101011	0	1						
213	10101011	0	0		01010100	1	1	Use true or inverse for no change after previous parity bit	
214	01101011	0	0						
215	11101011	0	1		00010100	1	0	Use true or inverse to reduce or reverse RDS	
216	00011011	0	1						
217	10011011	0	0						
218	01011011	0	0		10100100	1	1	Use true or inverse for no change after previous parity bit	
219	11011011	0	1		00100100	1	0	Use true or inverse to reduce or reverse RDS	
220	00111011	0	0						
221	10111011	0	1		01000100	1	0	Use true or inverse to reduce or reverse RDS	
222	01111011	0	1		10000100	1	0	Use true or inverse to reduce or reverse RDS	
223					00110010	1	1	Substitute	179
224					10010010	1	1	Substitute	182
225	10000111	0	1						
226	01000111	0	1						
227	11000111	0	0						
228	00100111	0	1						
229	10100111	0	0		01011000	1	1	Use true or inverse for no change after previous parity bit	
230	01100111	0	0						
231	11100111	0	1		00011000	1	0	Use true or inverse to reduce or reverse RDS	
232	00010111	0	1						
233	10010111	0	0						
234	01010111	0	0		10101000	1	1	Use true or inverse for no change after previous parity bit	
235	11010111	0	1		00101000	1	0	Use true or inverse to reduce or reverse RDS	
236	00110111	0	0						
237	10110111	0	1		01001000	1	0	Use true or inverse to reduce or reverse RDS	
238	01110111	0	1		10001000	1	0	Use true or inverse to reduce or reverse RDS	
239					01100010	1	1	Substitute	185
240	00001111	0	1						
241	10001111	0	0						
242	01001111	0	0						
243	11001111	0	1		00110000	1	0	Use true or inverse to reduce or reverse RDS	
244	00101111	0	0						
245					11000010	1	1	Substitute	188
246	01101111	0	1		10010000	1	0	Use true or inverse to reduce or reverse RDS	
247	11101111	0	0		00010000	1	1	Use true or inverse to reduce or reverse RDS	
248	00011111	0	0						
249	10011111	0	1		01100000	1	0	Use true or inverse to reduce or reverse RDS	
250					00111100	1	0	Substitute	195
251	11011111	0	0		00100000	1	1	Use true or inverse to reduce or reverse RDS	
252	00111111	0	1		11000000	1	0	Use true or inverse to reduce or reverse RDS	
253	10111111	0	0		01000000	1	1	Use true or inverse to reduce or reverse RDS	
254	01111111	0	0		10000000	1	1	Use true or inverse to reduce or reverse RDS	
255					10011100	1	0	Substitute	198

Appendix 2: Additional substitutions for code without parity

Deci-mal	Substitution Code	F		
	[0.....7]	i		
		a		
		g		
		[8]		
	10001100	1		206
	01110100	1		209
	10110100	1		210
	00110100	1		211
0	11010100	1		212
1	10010100	1		214
2	11100100	1		216
3	01100100	1		217
4	11000100	1		220
6	01111000	1		225
9	10111000	1		226
12	00111000	1		227
15	11011000	1		228
17	10011000	1		230
18	11101000	1		232
20	01101000	1		233
24	11001000	1		236
84	01110000	1		241
254	10110000	1		242

CLAIMS:

1. A communication system comprising:

a first high speed link having a first transformer interface at a transmit end and a second transformer interface at a receive end;

a second high speed link having a third transformer interface at a transmit end and a fourth transformer interface at a receive end;

a low speed link comprising a phantom circuit formed by the first to fourth transformers, the transmit end of the low speed link being formed by connections to the centre taps of the first and third transformers and the receive end of the low speed link being formed by connections to the centre taps of the second and fourth transformers;

wherein the transmit end of the low speed link is connected to a power supply and at least one of the high speed links is connected to a device at the receive end for receiving signals from the respective high speed link, the receive end of the low speed link providing power to the device from the power supply.

2. A communications interface comprising output circuitry for providing a data signal to be transmitted under the control of a transmit clock signal, the frequency of the transmit clock signal being continuously variable.

3. The communications interface of claim 2, wherein the frequency of the transmit clock's signal is continuously modulated between upper and lower frequency values.

4. A communications interface comprising:

output circuitry for providing two parallel outputs, one in the form of a data signal and one in the form of a strobe signal and including strobe generation circuitry, wherein the data signal comprises a serial bit pattern and the strobe generation circuitry generates the strobe signal such that the strobe signal

has signal transitions only at bit boundaries where there is no transition on the data signal, the strobe generation circuitry being controlled by a clock signal such that for each clock pulse where there is no signal transition in the data signal a signal transition is generated in the strobe signal, the frequency of the clock signal being continuously variable; and

input circuitry having two inputs for receiving data and strobe signals, and including an exclusive-or circuit for receiving the data and strobe signals and generating a receive clock on the output thereof, the receive clock being generated with clock signal transitions having a timing matching that at which the strobe and data signals were transmitted.

5. The communication system of claim 1, including the communications interface of any one of claims 2 to 4.

6. Data receiving circuitry comprising:

input circuitry having two inputs, one input for receiving a data signal and the other input for receiving a strobe signal, the strobe signal being parallel to the data signal and having signal transitions only at bit boundaries where there is no transition on the data signal;

an exclusive-or gate, having inputs connected to the two inputs, and generating a receive clock on the output thereof;

detection circuitry having two inputs coupled to the respective two inputs of the input circuitry and for detecting an expected bit sequence associated with the data signal on one of said two inputs;

output circuitry for outputting the data signal under the control of the receive clock; and

selection circuitry for connecting the one of said inputs on which said sequence is detected to the output circuit.

7. The communication system of claim 1, including the data receiving circuitry of claim 6.

8. The communications interface of any one of claims 2 to 5,

including the data receiving circuitry of claim 6.

9. A method of establishing parallel data and strobe signal communication paths having dc balanced data and strobe signals on each path, comprising:

outputting a binary data signal;

generating and outputting a binary strobe signal, parallel to the binary data signal, having signal transitions only at bit boundaries where there is no transition on the parallel binary data signal; and

encoding the binary data signal and the binary strobe signal into respective ternary dc balanced signals for transmission.

10. The method of claim 9, wherein the step of encoding the binary data signal and the binary strobe signal into respective ternary dc balanced signals encodes such signals such that only single level logic transitions are permitted between successive trits of the ternary signals.

11. The method of claim 9 or claim 10, wherein the encoding step comprises the steps of, for each of the data and strobe signal:

calculating the running digital sum of the ternary signal;

transmitting next binary 1 as ternary -1 if the running digital sum is positive and at least two 0's have been transmitted since the last ternary +1;

transmitting the next binary 1 as ternary +1 if the running digital sum is negative and at least two 0's have been transmitted since the last ternary -1;

transmitting at least two successive binary 1's as ternary -1's if the running digital sum is positive and the at least two binary 1's follow any number of 0's;

transmitting at least two successive binary 1's as ternary +1's if the running digital sum is negative and the at least two binary 1's follow any number of 0's; and

otherwise reversing the polarity of each ternary 1 each time a run of at least one 0 occurs.

12. The method of any one of claims 9 to 11, wherein the step of outputting the binary data signal comprises:

receiving n binary bits to be transmitted;

adding a flag bit to the n binary bits to form a n+1 bit binary code-word;

calculating the running digital sum of successively formed binary code-words;

outputting as the binary data signal successive code-words in which the n binary bits are in an inverted or non-inverted state depending on the current running digital sum of the binary code-words, the flag bit being set to indicate inverted data.

13. The method of claim 12, wherein those code-words having non-zero disparity are inverted or not so as to reduce the magnitude of the running digital sum at code-word boundaries.

14. The method of claim 12 or claim 13, wherein said adding step includes adding a parity bit to form a n+2 bit code-word.

15. The method of claim 14, wherein the value of the parity bit is selected to ensure an odd number of 1's in the code-word.

16. The method of claim 14 or claim 15, wherein those binary code-words having zero disparity are not inverted.

17. The method of any one of claims 14 to 16, wherein for those code-words having zero disparity, the code-words containing the inverse data with the flag bit set are reserved for control purposes.

18. The method of any one of claims 14 to 17, wherein for those code-words having zero disparity, the code-words containing the inverse data thereof with the flag bit set are used to substitute code-words to limit the running digital sum at boundaries of the binary code-words.

19. The method of any one of claims 14 to 18, wherein for those

code-words having zero disparity, the code-words containing the inverse data thereof with the flag bit set are used to substitute code-words to minimise the run length on the ternary data and strobe signals.

20. The method of any one of claims 9 to 19, wherein when there is no data to transmit, the encoding step comprises generating extra ternary signals on each of the data and strobe signal communication paths until the running digital sum on each of said paths becomes zero, and then ceasing to generate further ternary signals on said paths.

21. The method of any of claim claims 12 to 19, wherein n=8.

22. Data transmission circuitry comprising:

input circuitry for receiving a binary data signal;

strobe generation circuitry for generating a binary strobe signal, parallel to the binary data signal, and having signal transitions only at bit boundaries where there is no transition on the parallel binary data signal;

encoding circuitry for encoding the binary data and strobe signals into respective ternary dc balanced signals; and

output circuitry for transmitting the ternary encoded data and strobe signals.

23. Data transmission circuitry according to claim 22, wherein the input circuitry receives n binary bits to be transmitted and further comprises:

bit generation circuitry for generating a flag bit associated with the n binary bits;

addition circuitry for adding the flag bit to the n binary bits to form a binary code-word;

calculation circuitry for calculating the running digital sum of successively formed binary code-words;

inversion circuitry for inverting the n binary bits of data in a code-word in dependence on the current running digital sum and for setting the flag bit to indicate inverted data; and

outputting as the binary data signal successive code-words.

24. Data transmission circuitry according to claim 23, further comprising calculation circuitry to calculating the disparity of a code-word, wherein the disparity of a code-word is zero the data therein is not inverted.

25. Data transmission circuitry according to any one of claims 22 to 24, wherein the bit generation circuitry further generates a parity bit and the addition circuitry further adds the parity bit to the n binary bits and the flag bit to form a n+2 bit binary code-word.

26. Data transmission circuitry according to any one of claims 22 to 25, further comprising control circuitry for controlling the inversion circuitry to invert the data in a code-word in dependence on the running digital sum at code-word boundaries.

27. Data transmission circuitry according to any one of claims 22 to 26, further comprising substitution storage means for storing those code-words having zero disparity and their flag bits set to indicate inversion of the data therein, such code-words being used to substitute for code-words which increase the running digital sum at code-word boundaries or the run length of the data signal.

28. A method of decoding a ternary data signal and a ternary strobe signal, the strobe signal being parallel to the data signal and having signal transitions only at trit boundaries of the data signal where there is no transition, the method comprising:

rectifying the ternary data and strobe signals to generate binary data and strobe signals;

exclusive-ORing the data and strobe signals to generate a receive clock; and

outputting the rectified data signals under the control of the receive clock.

29. The method of claim 28, wherein the ternary data signal comprises a plurality of code-words including a flag bit indicative of whether the data in the code-word is inverted or non-inverted, and further comprises the steps of:

inverting or not inverting the data in the received code-word in dependence on the flag bit of the code-word.

30. The method of claim 29, wherein the received code-words further include a parity bit, the parity bit being set to ensure an odd number of ones in the code-word, the method further including the step of checking that the code-word includes an odd number of 1's.

31. Data receiving circuitry comprising:

input circuitry for receiving a ternary data signal and a ternary strobe signal, the strobe signal being parallel to the data signal and having signal transitions only at bit boundaries where there is no transition on the data signal;

rectification circuitry for rectifying the ternary data and strobe signals and generating binary data and strobe signals;

an exclusive-OR gate for receiving the data and strobe signals and generating the receive clock at its output; and

output circuitry for outputting the binary data signal under the control of the receive clock.

32. Data receiving circuitry according to claim 31, wherein the received ternary data signal comprises code-words including n ternary trits and a flag trit, the data receiving circuitry further comprising control means for receiving the flag trit and in dependence thereon inverting or not inverting the n bits of data in the received code-word.

33. Data receiving circuitry according to claim 31 or claim 32, wherein the received ternary code-words include a parity trit the data receiving circuitry further comprising a parity check circuit, the parity check circuit checking the parity of the received code-word in dependence on the parity bit.

34. Data receiving circuitry according to any one of claims 31 to 33, further comprising circuitry for calculating the disparity of each received code-word, wherein if the disparity of the code-word is zero and the flag bit of the code-word is set to indicate inversion, the data receiving circuitry further comprising storage means for storing code-words for substitution of code-words having zero disparity and their flag bits set.

35. Data receiving circuitry according to any one of claims 31 to 34, further comprising inversion circuitry, wherein if the disparity of the code-word is non-zero and the flag bit is set, the inversion circuitry inverts the data contained in the code-word.

36. A communication system according to any one of claims 1, 5 or 7, or the communications interface of claim 8, including transmission circuitry according to any one of claims 22 to 27 or data receiving circuitry according to any one of claims 31 to 35.

37. Circuitry substantially as described herein with reference to any one of Figures 1 to 16 or 18 to 28.

38. A method substantially as described herein with reference to any one of Figures 1 to 16 or 18 to 28.

The Patent Office

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Claims searched: 1,5,7,36-38 **Date of search:** 3 October 1997

Patents Act 1977
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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4P (PPC); H4R (RLH, RLS)

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Other: Online WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2280826 A	Northern Telecom - see Figs.3,4	1
X	GB 1540414 A	Soc. Ital. Telecom. Siemens - see page 2, line 28 onwards	1
A	GB 1516751 A	Soc. Ital. Telecom. Siemens - page 2, line 38 onwards	1
X	EP 0404994 A1	Siemens AG - see abstract	1
A	EP 0112716 A2	General Datacomm - see abstract	1
X	US 4583214	Iwasaki Tsushinki KK - see abstract	1
X	US 4173714	TIE/Comms. - see abstract	1

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
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E Patent document published on or after, but with priority date earlier than, the filing date of this application.

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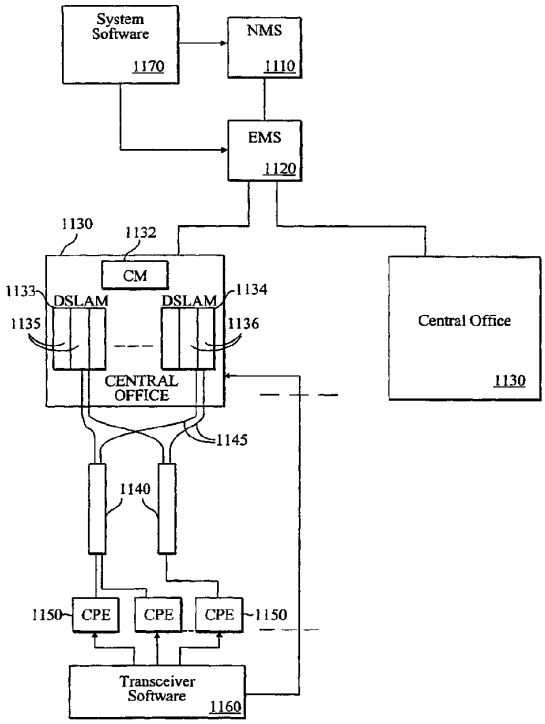
(54) Title: METHOD AND APPARATUS FOR COOPERATIVE DIAGNOSIS OF IMPAIRMENTS AND MITIGATION OF DISTURBERS IN COMMUNICATION SYSTEMS



(57) Abstract: A method that sends upstream a collection of data samples measured from a Digital Subscriber Line (401).

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DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

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Method and Apparatus for Cooperative Diagnosis of Impairments and Mitigation of Disturbers in Communication Systems

CLAIM OF PRIORITY

This application claims the benefit of the filing date of the following Provisional U.S. Patent Applications:

"SPECTRAL MANAGEMENT AND OPTIMIZATION THROUGH ACCURATE IDENTIFICATION OF CROSS-TALK CHANNELS AND UNCERTAINTY", application number 60/164,986, filed November 11, 1999;

"SPECTRAL MANAGEMENT AND OPTIMIZATION THROUGH ACCURATE IDENTIFICATION OF CROSS-TALK CHANNELS AND UNCERTAINTY", application number 60/181,125, filed on February 8, 2000;

"SPECTRAL MANAGEMENT AND OPTIMIZATION THROUGH ACCURATE IDENTIFICATION OF CROSS-TALK CHANNELS AND UNCERTAINTY", application number 60/183,675, filed on February 18, 2000;

"USE OF UNCERTAINTY IN PHYSICAL LAYER SIGNAL PROCESSING IN COMMUNICATIONS", application number 60/165,399, filed November 11, 1999;

"SHARED COMPUTATIONAL RESOURCES FOR IMPROVED PERFORMANCE OF A TRANSCEIVER" application number 60/215,159, filed on June 30, 2000; and

"SYSTEM LEVEL SUPPORT FOR TRANSCEIVER PERFORMANCE", application number 60/215,680, filed on June 30, 2000.

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FIELD OF THE INVENTION

The field of invention relates to communications generally; and more specifically, to improving the performance of a network by sharing resources or information between a network perspective and a line perspective.

BACKGROUND

Overview

In the communications arena one of the biggest challenges is to overcome crosstalk, noise, and other disturbances that interfere with signals. Whether the signals are transmitted over wires, cable, fiber optics, wireless, or other types of communication the signals suffer from some level of interference.

Interference in the signal may lead to certain limitations of the communication system. For example in wireless systems, such as cellular phones, interference may shorten the distance at which the signal can be reliably received and the clarity of the signal. As another example, in wire systems, such as digital subscriber lines (DSL), interference may shorten the distance at which the signal can be reliably received, i.e., limit loop reach. Interference may also decrease the bit rate of the data being transferred. Providers of telecommunications services recognize the need to monitor the quality of service provided to users of their networks and to identify the causes of problems reported by their customers. This task, however, is complicated significantly by several factors.

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Some of these factors include: the large number of network users, the large amount of data collected from the deployed lines, and the presence of competing providers in the same physical line plant. The coexistence of ILECs (Incumbent Local Exchange Carriers) and CLECs (Competitive Local Exchange Carriers) in the same cable binders, brought about by the federally mandated deregulation of local telecommunications markets, implies that services deployed by one carrier may be disturbing the users of another carrier, who has no information about the source of this disturbance.

It is thus highly desirable to sort through the collected data and determine whether a specific line is being disturbed by external interference, such as AM radio stations, or by internal interference, such as another DSL service, and whether that offending service belongs to the same carrier or not. Unfortunately, with today's deployed monitoring technology, carriers are extremely limited in their ability to perform such diagnoses with adequate accuracy and reliability.

The following discussion outlines in detail many of the problems of digital subscriber line (DSL) technology and potential solutions thereto. However, the discussion merely uses DSL as one example of the many communication systems (e.g., wireline, wireless, optical, cable, etc.) in which the present invention may be used. Thus the present invention should not be limited to merely DSL communication systems.

Overview with Respect to DSL

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Digital Subscriber Line (DSL) networks provide high speed networking service while preserving the investment made in traditional telephone lines. Figure 1 shows an exemplary topology of a DSL network. In the exemplary DSL network topology 100 of Figure 1, various customer premise equipment (CPE) modems 105, 106, 107 are communicatively coupled to a central office switching center 101 via ordinary telephone lines (e.g., lines 120 through 122).

Customer premise equipment 105, 106, 107 is equipment located at the customer's location (e.g., a customer's home or office). In the exemplary network topology 100 of Figure 1, the customer premise equipment 105, 106, 107 possesses at least one transceiver (e.g., transceiver 108 in CPE 105) that is responsible for: 1) controlling at the CPE the reception of information sent from the service provider; and 2) controlling at the CPE the transmission of information sent to the service provider.

Information that flows in the network 100 toward the customer (e.g., toward the direction of a CPE as seen in Figure 1) has a "downstream" direction while information that flows in the network 100 away from the customer (e.g., away from a CPE as seen in Figure 1) has an "upstream" direction. Thus it may be said that a transceiver within a CPE is responsible for controlling at the CPE the transmission of upstream information and the reception of downstream information.

Various DSL service schemes exist. For example, at a high level, DSL services are characterized according to the bandwidth allocated for a customer's

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upstream and downstream traffic. Services that reserve approximately equal amounts of bandwidth for a customer's upstream and downstream traffic are referred to as "symmetric DSL" while services that reserve approximately unequal amounts of bandwidth for a customer's upstream and downstream traffic are referred to as "asymmetric DSL".

Symmetric DSL (SDSL), High bit rate DSL (HDSL, HDSL-2) and ISDN DSL (IDSL) are versions of symmetric DSL. Asymmetric DSL (ADSL), Rate Adaptive DSL (RADSL), Very high bit rate DSL (VDSL), and G.Lite are versions of asymmetric DSL. Any of these DSL services (as well as other potential future DSL services that are not listed above) may be referred to as "DSL".

Note that the central office 101 includes a plurality of DSL Access Multiplexers 102, 103, 104 (DSLAMs). A DSLAM operates as a distributor of DSL services. That is, for example, DSLAM 102 forwards/collects downstream/upstream information sent from/to higher layers of a service provider's network to/from transceivers 108, 109, 110.. The service provider's DSL network is controlled by a Network Management Agent (NMA) 118.

An NMA 118 is one or more software routines that monitor the operation of a network (e.g., by collecting various performance monitoring statistics sent from the DSLAMs 102, 103, 104) and controls various aspects of a network (e.g., by enabling or disabling service on a particular line). The NMA 118 shown in Figure 1 monitors and controls the DSL network 100 by communicating with the DSLAMs through the Element Management Systems 116, 117 (EMSs). The NMA

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118, as an example, may be executed as part of a network's Network Management System (NMS). An EMS effectively distributes to the DSLAMs control information sent from the NMA and forwards to the NMA 118 network performance or network status indicia sent from the DSLAMs. More details on a DSL system are provided below.

Figure 2 shows an exemplary depiction of a receiver 201 within a DSL transceiver 208. That is, for example, transceiver 208 of Figure 2 may be viewed as corresponding to transceiver 108 of Figure 1 and line 220 of Figure 2 may be viewed as corresponding to line 120 of Figure 1. Recalling that the transceiver 208 is responsible for controlling both the transmission of upstream traffic and the reception of downstream traffic, note that receiver 201 assists the performance of the latter of these two functions.

The receiver 201 includes an equalizer 202 and a symbol detection unit 203 (which may also be referred to as a symbol detector 203). The equalizer 202 adjusts the transfer function of the receive channel such that the frequency components of the received waveform rx(t) 221 that are associated with the signal (i.e., the frequency components of the received waveform rx(t) 221 that are associated with the downstream information sent from the service provider to the transceiver 208) are enhanced with respect to the frequency components of the waveform rx(t) 221 that are not associated with the signal (i.e., the frequency components of the waveform's "noise"). For example, the signal components

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alone may be amplified, the noise components alone may be suppressed or a combination of both.

The symbol detection unit 203 converts the features of the equalized waveform 222 into digital 1s and 0s according to the modulation scheme employed by the particular type of DSL service being implemented. As a result of the equalizer's activity, the signal-to-noise ratio (SNR) in the receive channel is enhanced and the performance of the symbol detection unit 203 (i.e., its ability to correctly reproduce the digital information sent by the service provider) is improved.

Referring back to Figure 1, note that the ordinary telephone lines that couple the DSLAMs and the CPEs are tightly packed together in a binder such as binder 114 and binder 115. Because ordinary telephone lines were originally designed for low speed voice/telephony communications, they are typically packed in a binder without shielding. That is, a line is not protected from receiving electromagnetic interference associated with the waveforms that appear on another line; nor are the waveforms on a line prevented from radiating so as to interfere with the waveforms that appear on another line.

The interference described above, commonly referred to as cross-talk, is viewed as noise that may corrupt the operation of the symbol detection unit 203 discussed above with respect to Figure 2. Cross-talk typically increases as the frequencies of the waveforms on an ordinary telephone line increase.

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When the ordinary telephone lines were originally installed to carry voice traffic, cross-talk was insubstantial because of the lower frequencies used to transmit voice traffic. However, as DSL is designed to provide higher speed services (as compared to traditional telephony service) over these ordinary telephone lines, cross-talk from DSL waveforms is much more severe. The more severe cross-talk frequently hampers the successful deployment of a DSL service.

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SUMMARY OF INVENTION

A method that sends upstream a collection of data samples measured from a network line.

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BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example, and not limitation, in the Figures of the accompanying drawings in which:

Figure 1 shows an exemplary DSL network topology;

Figure 2 shows an exemplary DSL receiver within a DSL transceiver;

Figure 3a shows an exemplary line perspective;

Figure 3b shows an exemplary network perspective;

Figure 4 shows an improved DSL receiver having a cross-talk compensation unit;

Figure 5 shows an embodiment of a DMT- ADSL DSL receiver that conforms to the improved DSL receiver approach of Figure 4;

Figure 6 shows a methodology for developing a line perspective;

Figure 7 shows a depiction of event notification flows that may be used to develop a network perspective;

Figure 8 shows a depiction of information being shared between a line level perspective and a network level perspective;

Figure 9 shows another depiction of information being shared between a line level perspective and a network level perspective;

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Figure 10 illustrates an exemplary communication system 1005 that may benefit from the present invention; and

Figure 11 illustrates a DSL system.

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DETAILED DESCRIPTION

1.0 Overview

In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be evident, however, to one skilled in the art that the present invention may be practiced without these specific details. In some instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring the present invention. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, mechanical, electrical and other changes may be made without departing from the scope of the present invention.

Some portions of the detailed descriptions that follow are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of acts leading to a desired result. The acts are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times,

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principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

The present invention can be implemented by an apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer, selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or

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optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method. For example, any of the methods according to the present invention can be implemented in hard-wired circuitry, by programming a general purpose processor or by any combination of hardware and software. One of skill in the art will immediately appreciate that the invention can be practiced with computer system configurations other than those described below, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, and the like. The invention can also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. The required structure for a variety of these systems will appear from the description below.

The methods of the invention may be implemented using computer software. If written in a programming language conforming to a recognized standard, sequences of instructions designed to implement the methods can be compiled for execution on a variety of hardware platforms and for interface to a variety of operating systems. In addition, the present invention is not described

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with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the invention as described herein. Furthermore, it is common in the art to speak of software, in one form or another (e.g., program, procedure, application...), as taking an action or causing a result. Such expressions are merely a shorthand way of saying that execution of the software by a computer causes the processor of the computer to perform an action or produce a result.

2.0 Overview of General Communication Network

The present invention is applicable to a variety of communication systems, for example: wireline, wireless, cable, and optical. Figure 10 illustrates an exemplary communication system 1005 that may benefit from the present invention. The backbone network 1020 is generally accessed by a user through a multitude of access multiplexers 1011 such as: base stations, DSLAMs (DSL Access Mulitplexers), or switchboards. The access multiplexers 1011 communicate management data with a Network Access Management System (NAMS) 1010. The NAMS 1010 includes several management agents 1015 which are responsible for monitoring traffic patterns, transmission lines status, etc. Further, the access multiplexers 1011 communicate with the network users. The user equipment 1040 exchanges user information, such as user data and management data, with the access multiplexer 1011 in a downstream and upstream fashion. The upstream data transmission is initiated at the user equipment 1040 such that the user data is transmitted from the user equipment

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1040 to the access multiplexer 1011. Conversely, the downstream data is transmitted from the access multiplexer 1011 to the user equipment 1040. User equipment 1040 may consist of various types of receivers that contain modems such as: cable modems, DSL modems, and wireless modems.

The invention described herein provides a method and system for managing the upstream and downstream data in a communication system. As such, the present invention provides management agents that may be implemented in the NAMS 1010, the access multiplexers 1011, and/or the user equipment 1040. One example of such a management agent is a system software module 1070 that may be embedded in the NAMS 1010. Another management agent that manages the data in the communication system 1005 is a transceiver software module 1060 that may be embedded in the access multiplexer 1011 and/or the user equipment 1040. Further details of the operation of modules 1070 and 1060 are described below.

For illustration purposes and in order not to obscure the present invention, an example of a communication system that may implement the present invention is a DSL communication system. As such, the following discussion, including Figure 11, is useful to provide a general overview of the present invention and how the invention interacts with the architecture of the DSL system.

3.0 Overview of DSL Example

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The present invention may be implemented in software modules or hardware that DSL equipment manufacturers may then embed in their hardware. Thus, although Figure 11 illustrates the present invention as software, the present invention should not be limited thereto. It should also be noted that this patent application may only describe a portion or portions of the entire inventive system and that other portions are described in co-pending patent applications filed on even date herewith.

Figure 11 illustrates an exemplary embodiment of the present invention as implemented in a DSL system. The DSL system consists of a network of components starting from the Network Management System (NMS) 1110 all the way down to the Customer Premise Equipment (CPE) 1150. The following is a brief description of how these components are interconnected.

The Network Management System (NMS) 1110 is a very high level component that monitors and controls various aspects of the DSL system through an Element Management System (EMS) 1120. The NMS 1110 may be connected to several Central Offices (CO) 1111 through any number of EMSs 1120. The EMS 1120 effectively distributes the control information from the NMS 1110 to the DSL Access Multiplexers (DSLAMs) 1133 and forwards to the NMS 1110 network performance or network status indicia from the DSLAMs 1133. DSLAMs 1133 reside in a Central Office (CO) 1111, usually of a telecommunications company. Alternatively, DSLAMs 1133 may reside in remote enclosures called Digital Loop Carriers (DLC). The CO 1111 may have

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tens or hundreds of DSLAMs 1133 and control modules (CM) 1132. A DSLAM 1133 operates as a distributor of DSL service and includes line cards 1135 and 1136 that contain CO modems. The CO modems are connected to at least one line 1145, but more frequently it contains several line cards 1135 and 1136 that are connected to several lines 1145. Usually the lines 1145 are traditional phone lines that consist of twisted wire pairs and there may be multiple lines 1145 in a binder 1140 and multiple binders in a cable. The transmission cables act as packaging and protection for the lines 1145 until the lines 1145 reach the Customer Premise Equipment (CPE) 1150. It should be noted that a DSLAM 1135 does not necessarily have to be connected to lines 1145 in a single binder 1140 and may be connected to lines in multiple binders 1140. The lines 1145 terminate at the CPE 1150 in transceivers that include CPE modems. The CPE 1150 may be part of or connected to residential equipment, for example a personal computer, and/or business equipment, for example a computer system network.

As discussed in the background section, communications systems often suffer from interference and/or impairments such as crosstalk, AM radio, power ingress noise, thermal variations, and/or other "noise" disturbers. The present invention or portions of the present invention provide the user the capability to analyze, diagnose and/or compensate for these interferences and/or impairments. It also provides the ability to predict and optimize performance of the communication system in the face of impairments.

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As illustrated in Figure 11, the transceiver software of the present invention 1160, depending upon how implemented, may provide the user with the ability to analyze, diagnose, and compensate for the interference and/or impairment patterns that may affect their line.

Also as illustrated in Figure 11, the system software of the present invention 1170, depending upon how implemented, may provide the service provider with the ability to diagnose, analyze, and compensate for the interference and/or impairment patterns that may affect the service they are providing on a particular line. The diagnosis and analysis of the transceiver software also provide the ability to monitor other transmission lines that are not connected to the DSLAMs or NMS but share the same binders.

It should be noted that the system software of the present invention 1170 may be implemented in whole or in part on the NMS 1110 and/or EMS 1120 depending upon the preference of the particular service provider. Likewise, it should be noted that the transceiver software of the present invention 1160 may be implemented in whole or in part on the DSLAM 1133 and/or transceivers of CPE 1150 depending upon the preference of the particular user. Thus, the particular implementation of the present invention may vary, and depending upon how implemented, may provide a variety of different benefits to the user and/or service provider.

It should also be noted that the system software of the present invention 1170 and the transceiver software of the present invention 1160 may operate

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separately or may operate in conjunction with one another for improved benefits. As such, the transceiver software of the present invention 1160 may provide diagnostic assistance to the system software of the present invention 1170. Additionally, the system software of the present invention 1170 may provide compensation assistance to the transceiver software of the present invention 1160.

Thus, given the implementation of the present invention with respect to the DSL system example of Figure 11, one of ordinary skill in the communications art would understand how the present invention may also be implemented in other communications systems, for example: wireline, wireless, cable, optical, and other communication systems. Further details of the present invention are provided below. Additional examples of how the present invention may be implemented in a DSL system are also provided below for illustrative purposes.

4.0 Overview of a Line Perspective and a Network Perspective

Recall from the background that cross-talk between lines in a DSL network may hamper the successful deployment of the DSL network. Figures 3a and 3b relate to perspectives of a DSL network that may be developed by two different network components (e.g., a transceiver 308 as seen in Figure 3a and the NMA 318 as seen in Figure 3b) in order to understand the causes and/or effects of cross-talk within the DSL network.

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Figure 3a shows a perspective that may be developed at the line of a DSL network (e.g., by a DSL transceiver 308). A line perspective is a collection of information that characterizes the environment of a DSL line. For example, the line perspective of line 320 in Figure 3a includes a model for each source of cross-talk noise that disturbs signal reception on line 320. A source of cross-talk noise (e.g., a waveform on a proximate line) may be referred to as a disturber. Cross-talk noise may therefore also be referred to as disturber noise. The exemplary line perspective of Figure 3a indicates that the DSL transceiver 308 has identified three different disturbers d1(t), d2(t), and d3(t).

Thus, for example, disturber d1(t) may correspond to a waveform on a first line, d2(t) may correspond to a waveform on a second line, and d3(t) may correspond to a waveform on a third line. Each disturber d1(t), d2(t), d3(t) passes through and is processed by its corresponding co-channel h1(t), h2(t), and h3(t). Each co-channel h1(t), h2(t), and h3(t) represents the impulse response of the electromagnetic coupling that exists between lines that "cross-talk" with one another.

In order to improve the signal-to-noise ratio (SNR) in the transceiver's receive channel, as an example, the transceiver 308 may develop as part of its line perspective of line 320: 1) the disturber signals d1(t), d2(t), d3(t); and 2) each disturber's corresponding co-channel impulse response h1(t), h2(t), and h3(t). With this line perspective of line 320, the transceiver 380 may then at least approximate and remove disturber noise on line 320. As a result, SNR will be

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improved. More details as to how a line perspective may be developed are provided further below.

Figure 3b shows another perspective of a DSL network that may be referred to as a network perspective. A network perspective is an understanding of cross-talk (or other interference) as developed through the correlation of information obtained from events observed on the lines within a network. As seen in Figure 3b, note that a network perspective may be developed by a DSL network's NMA 318. The NMA 318 "keeps track of" events such as changes in the performance and/or configuration of each line in the DSL network that the NMA 318 exhibits control over.

By keeping track of and correlating information from these events, an understanding of the cross-talk between the network's lines (or other types of interference) may be developed. For example, if the NMA 318 observes as an event that lines 320, 321 and 323 each experienced a drop in SNR just after an increase in the service speed on line 324 was allowed, the NMA 318 can assume that line 324 presents disturber noise on lines 320, 321 and 322.

Furthermore, in light of the amount of SNR reduction that has occurred on each line, the NMA 318 can approximate the degree of cross coupling between line 324 and each of lines 320, 321 and 322. This information may be used, for example, to prevent or limit the extent of further speed increases on line 324 (so that proper operation of lines 320, 321 and 322 is ensured). More details as to how a network perspective may be developed is provided further below.

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The discussion that follows demonstrates that transferring line perspective information to a network perspective and/or transferring network perspective information to a line perspective may result in the development of more accurate line and/or network perspectives and/or increased performance of the DSL network as a whole. For example, referring to Figure 3b, if the network perspective is informed that the line perspective of line 321 includes a disturber having a frequency that corresponds to the speed of line 324, the network perspective's confidence that line 324 presents cross-talk on line 321 is increased.

As a second example, recall that a line perspective may develop an understanding of the disturbers d1(t), d2(t), d3(t) and their corresponding co-channels h1(t), h2(t), and h3(t). The computational resources available to a transceiver 308 that develops this line perspective (e.g., a microprocessor or digital signal processor (DSP) in the CPE) may be limited so that only a less detailed perspective of the disturbers and/or their corresponding co-channels can be developed.

By measuring the waveform rx(t) and/or its associated frequency spectra and then forwarding this data upstream from the transceiver 308 (e.g., to the DSLAM, EMS or NMA) more accurate models of the disturbers and/or their co-channels can be developed. Typically, the DSLAM, EMS, and NMA possess more powerful computational resources (e.g., a multi-processor processing core) than the CPE.

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By executing disturber and co-channel identification routines on these more powerful computational resources, more precise characterizations of the disturber and co-channel profiles may be developed. The more precise characterizations may then be sent downstream to the transceiver 308 resulting in an improved SNR as compared to the SNR that would have been achieved by executing disturber and/or co-channel characterization sequences at the CPE alone.

The following discussion develops a deeper understanding of how the line and network perspectives of Figures 3a and 3b may be developed. A discussion of the information that may be exchanged between these perspectives, and the benefits derived from this exchange, follows immediately afterward. Before continuing, however, it is important to emphasize that the techniques, design strategies, improvements, advantages, etc. discussed below may be applied to network technologies other tha DSL (e.g., wireless networks, fiber optic networks, etc.). As such, a line may be viewed more generally as a communication channel that exists between a service provider and customer (e.g., a wireless link, a fiber optic cable, a copper cable, etc.).

5.0 Development Of A Line Perspective

A. Improved Receiver Operation

Before discussing a methodology for developing a line perspective, the design and operation of an embodiment of a DSL receiver that is able to improve

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SNR by maintaining a line perspective will first be discussed. Figure 4 shows an embodiment 401 of a DSL receiver as described just above. The operation of the equalizer 402 and the symbol detection unit 403 of Figure 4 corresponds to the operation of the equalizer 202 and symbol detection unit 203 as described with respect to Figure 2.

Comparing the prior art DSL receiver 201 of Figure 2 with the improved DSL receiver 401 of Figure 4, note the insertion of a cross-talk compensation unit 490 between the equalizer 402 and the symbol detection unit 403. The cross-talk compensation unit 490 includes a signal removal unit 404, disturber receiver 407 and a disturber removal unit 408. The cross-talk compensation unit 490 removes disturber noise from the received waveform on line 420 prior to the symbol detection that is performed by the symbol detection unit 403. Referring to Figures 3a and 4, the signal removal unit 404 and the disturber receiver 407 together represent a channel that provides a representation (e.g., a time domain representation or a frequency domain representation) of one or more disturber signals (e.g., disturber signals d1(t), d2(t), d3(t) of Figure 3a) to the disturber removal unit 408 at a first disturber removal unit input 450.

The disturber removal unit 408 accepts the disturber signal representation(s) and effectively processes them according to: 1) their corresponding co-channel h1(t), h2(t), h3(t); and 2) the activity of the equalizer 402. This processing produces a representation of the disturber noise as it appears at the output of the equalizer 403. The disturber removal unit 408 then

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combines (e.g., subtracts) the disturber noise representation with the equalizer 402 output to produce an equalized signal having reduced disturber noise. The equalized signal having reduced disturber noise is then presented to the symbol detection unit 403 so that the signal (i.e., the downstream information sent from the service provider) may be detected.

Recall that the signal removal unit 404 and the disturber receiver 407 together represent a channel that provides a representation (e.g., a time domain representation or a frequency domain representation) of one or more disturber signals (e.g., disturber signals d1(t), d2(t), d3(t) of Figure 3a) to the disturber removal unit 408 at a first disturber removal unit input 450. The signal removal unit 404 removes those aspects of the equalizer 403 output that correspond to the signal being sent as downstream traffic from the service provider to the receiver 401.

That is, to the extent possible, the output of the signal removal unit 404 corresponds to pure "noise". The disturber receiver 407 includes a disturber equalizer 405 and a disturber symbol detection unit 406. The disturber equalizer 407 attempts to "undo" the activity of the equalizer 203. That is, recall from the discussion in the background that an equalizer (such as equalizer 203 of Figure 2 or equalizer 403 of Figure 4) suppresses a channel's noise and/or amplifies it's signal.

In so doing, the equalizer 203 attempts to "whiten" the noise so that it possesses an approximately constant power spectral density over the frequency

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range of interest. As a result, particularly strong disturber noise frequency components (e.g., a 20 - 392 KHz band for a symetric DSL service on a neighboring line) will be individually and disproportionately attenuated by the equalizer 203 (as compared to other noise frequency components). The disturber equalizer 405 attempts to reverse this disproportionate attenuation so that the pure spectral components of the disturber noise, as they appear on the line 420 prior to processing by the equalizer 402, are recaptured.

After the original disturber noise power profile is approximately recaptured by the disturber equalizer 405, the disturber symbol detection unit 406 reconstructs or otherwise deduces (to the extent possible), one or more disturber signals (e.g., disturber signals d1(t), d2(t), d3(t) shown in Figure 3a) as they appear on their respective lines. These are then forwarded to the disturber removal unit 408.

Figure 5 shows an exemplary embodiment of a Discrete Multi Tone – Asymmetric Digital Subscriber Line (DMT-ADSL) receiver 501 that conforms to the processing approach just described with respect to Figure 4. The DMT-ADSL receiver 501 of Figure 5 includes an equalizer 502 (which corresponds to the equalizer 402 of Figure 4), a DMT signal removal unit 504 (which corresponds to the signal removal unit 404 of Figure 4), a disturber receiver 507 (which corresponds to the disturber receiver 407 of Figure 4), a disturber removal unit 508 (which corresponds to the disturber removal unit 408 of Figure 4) and a

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symbol detection unit 503 (which corresponds to the symbol detection unit 403 of Figure 4).

During a sequence referred to as "line training", the equalizer 502 searches for the signal based upon the type and/or speed of service that is to be received. When the signal is found, the equalizer 502 adjusts an impulse response function profile associated with a time domain equalizer (TEQ) 509. This impulse response function, when convoluted with the received signal rx(t), produces an efficient representation of the received signal rx(t) at the TEQ output 509. Furthermore, the TEQ convolution may also provide (as an ancillary benefit) some degree of noise suppression.

An efficient representation of the received signal rx(t) may be realized by limiting the number of samples used to represent the convolution of the TEQ impulse response with the channel g(t) impulse response. An efficient representation of the received signal rx(t) reduces the processing load presented to the transceiver's processing resources (e.g., a microprocessor or digital signal processor or combination of both) for subsequent processing of the received waveform rx(t).

The fast Fourier transform (FFT) unit 517 converts the efficient representation of the received waveform rx(t) from the time domain to the frequency domain. The frequency domain equalizer (FEQ) 518 searches for and extracts an efficient frequency domain representation of the DMT signal originally transmitted by the service provider tx(t).

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The DMT signal removal unit 504 corresponds to the signal removal unit 404 of Figure 4. As such the output 510 of the DMT signal removal unit 504 corresponds to, to the extent possible, pure "noise". As seen in Figure 5, a slicer unit 521 detects (within the frequency domain) the DMT signal.

DMT is a modulation scheme that uses a plurality of quadrature amplitude modulated (QAM) sinusoids to transmit digital information. The frequency of each sinusoid is centered within a frequency "bin" (e.g., a frequency band of 4.3125 KHz reserved for its transmission. According to QAM modulation, the phase and amplitude of a sinusoid are modulated to represent the different possible states of the digital bits being transmitted. The number of bits that are transmitted on a line increases with the number of sinusoids that are transmitted and/or the number of different phase and amplitude positions (i.e., bit states) implemented per sinusoid.

The slicer unit 521 effectively determines the phase and amplitude of the received sinusoid(s) in order to extract the symbol information sent by the service provider. Remodulator 522 constructs a DMT signal (as modified by the channel g(t) and the TEQ 509) from this symbol information. The DMT signal is then converted to the time domain by the inverse Fourier transform (IFFT) unit 519. Pure noise is created by subtracting the DMT signal (as presented by the IFFT unit 519) from the equalizer output 522. Pure noise, in this case, may also be referred to as a DMT-compensated signal.

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It is important to point out that the receiver approach outlined in Figure 5 may be used for DSL signals other than a DMT-ADSL signal. That is, the receiver design of Figure 5 may be tailored for any DSL service provided the proper modulation schemes are accounted for. For example, if the received signal is a Pulse Amplitude Modulated (PAM) signal (as is the case with SDSL signals), the DMT removal unit 504 can be reconfigured as a PAM removal unit if a PAM based slicer 521 is employed. Thus, even though the particular embodiment being discussed with respect to Figure 5 is limited to a DMT-ADSL application, those of ordinary skill will recognize that the receiver approach of Figure 5 is actually applicable to DSL services other than DMT-ADSL.

After the DMT signal is removed by the DMT signal removal unit 504, disturber signals are generated by the disturber receiver 507. The disturber receiver 507 includes a disturber equalizer (DEQ) 505 (that corresponds to the disturber equalizer 405 of Figure 4) and a disturber symbol detector 506 (that corresponds to the disturber symbol detector 406 of Figure 4). In the embodiment of Figure 5, the disturber symbol detector employs Viterbi processing techniques and thus may also be referred to as a Viterbi detector 506.

As discussed with respect to the disturber equalizer 405 of Figure 4, the DEQ 505 attempts to "undo" any noise suppression provided by the equalizer 502. That is, with respect to the design approach of Figure 5, the DEQ 505 attempts to undo any noise suppression provided by the TEQ 509. Noise suppression from the TEQ may be undone by effectively inversely

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compensating for the adjustments made by the TEQ (during line training as discussed above) to the TEQ impulse response function profile.

That is, recalling that the TEQ 509 provides noise suppression, if the DEQ 505 impulse response function adjustment is opposite to that of the TEQ 509, the noise suppression provided by the TEQ 509 may be effectively eliminated. As such, at the DEQ 505 output, the disturber noise as it appears on the line has been re-captured.

In an embodiment, the DEQ 505 is designed using minimum –mean-squared-error (MMSE) techniques. The result of this DEQ design is filter coefficients that a yield a filter which effectively counteracts the noise suppression provided by the TEQ 509.

The Viterbi detector 506 of Figure 5 corresponds to the disturber symbol detector 406 of Figure 4. As such, the Viterbi detector 506 reconstructs or otherwise deduces (to the extent possible), one or more disturber signals (e.g., disturber signals d1(t), d2(t), d3(t) shown in Figure 3a) as they appear on their respective lines.

For example, if a particular portion of the disturber noise presented by the DEQ 505 is understood to be a PAM-SDSL signal that is cross coupled to the receiver's line 520, the Viterbi detector 506 reconstructs the PAM-SDSL signal on the cross coupled (e.g., nearby) PAM-SDSL line from that portion of the disturber noise. Similarly, if another particular portion of the disturber noise presented by the DEQ 505 is understood to be a second PAM-SDSL signal that is cross coupled

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to the receiver's line 520, the Viterbi detector 506 may also reconstruct the second PAM-SDSL signal on the second cross coupled (e.g., nearby) PAM-SDSL line from the other portion of the disturber noise.

Note that the association of particular portions of the disturber noise presented by the DEQ 505 with specific types of "nearby" services is an aspect of the line level perspective (discussed with respect to Figure 3a) held by the receiver 501. An exemplary embodiment of how this understanding/perspective is developed is provided in more detail below. The Viterbi detector 506 of Figure 5 employs Maximum Likelihood Sequence Estimation (MLSE) to reconstruct, from its line level perspective, the particular disturber signal on the cross coupled line.

For example, PAM signals are used to transmit two bits of information via the modulation of a pulse amplitude (e.g., a pulse amplitude of +3 may correspond to 11, a pulse amplitude of +1 may correspond to 10, a pulse amplitude of –1 may correspond to 01, and a pulse amplitude of –3 may correspond to 00). The Viterbi detector 506 employs an MLSE technique to determine whether particular portions of the disturber noise presented by the DEQ 505 (that are understood to be caused by a particular PAM disturber) correspond to a +3, +1, -1, or -3. As such, the particular sequences of +/-3 and +/-1 deduced by the Viterbi detector 506 correspond to a disturber signal on a cross coupled line.

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The deduced disturber signal is then presented to the disturber removal unit 508 at the disturber receiver output 550. Other disturber signals that the Viterbi detector 506 is designed to detect are also presented at the disturber receiver output 550. Note that the number of disturber signals that the Viterbi detector 506 is designed to detect is an aspect of the line level perspective held by the receiver 501.

For example, in an embodiment, the number of disturber signals detected by the Viterbi detector are limited (e.g., to 2 or 3 typically) by processing limitations available to the receiver 501. Thus, in such an embodiment, part of the Viterbi design process involves prioritizing which disturbers cause the strongest disturber noise.

After the disturber signals are presented to the disturber removal unit 508, the disturber remodulator 515 effectively passes each disturber signal through an estimation of its corresponding co-channel. That is, referring briefly back to Figure 3a, recall that a line level perspective may include not only an understanding of a disturber signal (e.g., disturber signals d1(t), d2(t), and d3(t)) but also an understanding of the channel (referred to as a co-channel h1(t), h2(t), h3(t)) that the cross-talk passes through in reaching the affected line 320. A discussion of how a co-channel may be estimated for each disturber signal is presented in more detail below.

The disturber remodulator 515 convolves the disturber signals d1(t), d2(t), d3(t) that are received from the disturber detector 507 with the impulse response

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function of its corresponding co-channel (e.g., h1(t) for d1(t), h2(t) for d2(t), and h3(t) for d3(t)). As a result, a representation of the disturber noise that is produced on the line 520 from these disturbers is created. This representation is then convolved with an impulse response $h_{TEQ}(t)$ that is representative of the equalization provided by the TEQ 509.

As a result, a representation of the disturber noise as it appears at the output of the TEQ 509 is created. This disturber noise representation (which corresponds to the disturber remodulator 515 output) is then converted from the time domain to the frequency domain by an FFT unit 516. The output of the FFT 516 is then multiplied by the FEQ 528 (which may be identical to the FEQ 518). This signal is, to the extent possible, identical to the disturber noise as it is presented at the output of the FEQ 518. By subtracting the output of the FEQ 528 from the FEQ 518 output, the disturbers will be approximately canceled (i.e., removed from the FEQ 518 output). As such, the SNR is enhanced before the symbols on the line 520 are detected by the symbol detection unit. It is important to point out that the receiver 501 approach outlined above should not be construed as limited to the particular frequency domain processing / time domain processing strategy that is displayed in Figure 5.

B. Development of Line Level Perspective During Line Training

Recall from the discussions above that a line level perspective may be developed that includes: 1) an understanding of the disturber signals that exist on one or more cross coupled lines (e.g., as represented by disturber signals

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d1(t), d2(t), and d3(t) in Figure 3a) and their corresponding co-channels (e.g., as represented by impulse responses h1(t), h2(t), and h3(t) in Figure 3a).

Figure 6 shows a methodology that may be used to develop the line perspective discussed just above. The development of a line perspective (and/or any disturber noise compensation that results) may be referred to as mitigation of disturbers. The development of a line perspective may occur during line training. Line training is a period of time prior to the actual use of the line to transmit a customer's information (referred to as "showtime"). During line training the CPE transceiver responsible for controlling the transmission/reception of upstream/downstream traffic "learns" about the operating environment of the line.

For example as seen in Figure 6, before showtime occurs, the equalizers (e.g., the TEQ 509 and FEQ 518 of Figure 5) undergo a training sequence in which the proper adjustments for suppressing the line's noise and/or amplifying the line's signal are established. After the equalizer adjustments are established, the disturber signals and their corresponding co-channels may be identified and/or otherwise characterized 610.

Then, based on the understanding of the disturber signals and their corresponding co-channels: 1) the disturber receiver (e.g., disturber receiver 407 of Figure 4) is tailored 620 to detect the particular disturber signals chosen for compensation. This process is completed before showtime begins.

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Referring to Figure 6, a disturber signal may be identified or otherwise characterized through its type of service 601. Said another way, with foresight of the types of services that may cause disturber noise (e.g., T1 or PAM-SDSL on a DMT-ADSL line), certain frequency ranges may be "focused upon" to see if disturber noise exists.

That is, for example, it is known that a T1 signal has a fundamental frequency of approximately 1.5 MHz. By searching across a frequency range centered at 1.5 MHz, the existence (or lack thereof) of disturber noise resulting from a cross-coupled T1 line may be confirmed and its exact frequency may be determined. Such a frequency range may be referred to as a "service specific" frequency range.

If disturber noise power (e.g., above a critical threshold to warrant further analysis) is detected for a particular service type, the corresponding frequency range may be further analyzed 602 to see how many disturber signals (i.e., how many cross coupled lines) exist for this type of service. For example, by "refocusing" in the service specific frequency range with a finer resolution bandwidth, each discovered "peak" may be assumed to be caused by a different line (owing to differences in crystal oscillator frequencies used to form the disturber signals). Note that identification of the frequency at which a particular peak occurs corresponds to a further refinement of the line level perspective. That is, not only has the service type for a source of disturbance been identified but also its particular frequency has been identified.

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Once the number of disturbers of a particular service type is determined, a model of the spectral content of an ideal disturber signal for each discovered disturber is generated. This ideal disturber signal model may be compared against what is actually observed on the line (i.e., the disturber signal's corresponding disturber noise) to generate 603 an estimation of the disturber signal's co-channel. That is, the co-channel is responsible for (and may be characterized by) the "distortion" that occurs to the disturber signal as it is converted from a disturber signal to disturber noise.

The process described just above is iterated until each of the potential (i.e., foreseen) types of service that can cause disturber noise on the line are analyzed (e.g., when all the service specific frequency ranges have been searched over). Note that the concept of service type may be extended to include any cause of disturber noise. As such the method described above should not be construed as limited only to networking services that exist on an ordinary telephone line. For example, AM radio station carrier frequencies may be searched for any resulting disturbance noise.

Note that once all of the disturber sources and their co-channels have been identified, a complete line level perspective has been developed. That is, the service type and frequency particular to each disturber signal has been identified. Furthermore, the profile particular to each corresponding co-channel has also been identified.

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The disturbers are then ranked according to disturber noise power. That is, the highest powered observed disturber noise is ranked first, the second highest powered observed disturber noise is ranked second, etc. As such, a corresponding ranking of disturber signals results. The disturber signals chosen for compensation are taken from the ranking (coextensive with the processing constraints that apply).

The line level perspective is then built 620 into the design of the transceiver. First, because the amount of disturber noise that will be removed is understood, the transceiver can estimate its expected improved SNR and determine 606 an appropriate line speed (or data rate) for the line. Second, the disturber equalizer (e.g., disturber equalizers 405, 505 of Figures 4 and 5) is configured 607 to "undo" the equalization of the equalizer (e.g., equalizer 402, 502 of Figure 4 and 5) based upon the parameters that setup the equalizer.

Third, the disturber symbol detector is configured 608 to detect the chosen disturber signals according to the particular type of service that have been identified for each disturber. The co-channel for each disturber signal and the impulse response of the equalizer is also made available to the disturber removal unit. This process is completed before showtime.

For examples of the methodologies and apparati discussed just above, see co-pending patent applications entitled "Method and Apparatus for Characterization of Disturbers in Communication Systems", "Method and Apparatus for Mitigation of Disturbers in Communication Systems", "Design &

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Architecture of an Impairment Diagnosis System for Use in Communication Systems", "Method and Apparatus for Impairment Diagnosis in Communication Systems", "Method and Apparatus for Prediction & Optimization in Impaired Communication Systems" all assigned to the present assignee and filed on an even date herewith.

6.0 Development of Network Perspective

Figure 7 shows a depiction of event notification flows that may be used to develop a network perspective. Development of a network perspective (and/or any network improvement that results) may be referred to as diagnosis of impairments. Recall from the discussion of Figure 3b that a network perspective is an understanding of cross-talk (or other interference) as developed through the correlation of events observed on the lines within a network. The cross-talk understanding may be embodied in the form of a "chart" that identifies: 1) which lines are cross coupled with one another; and 2) for each cross coupling that is identified, how strong the particular cross coupling is.

A networking perspective may be developed by designing intelligence at the line level (e.g., within a CPE transceiver) that sends notification of an event upstream to higher layers of the network (such as the NMA 718). For example, an event may be designed to correspond to: 1) an observed change in SNR on a line (or a change in bit error rate or other measurement of signal quality); 2) a change in transmitter signal power on a line as demanded or otherwise permitted by the NMA; and/or 3) a change in transmitted bit rate speed for a

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line as demanded or otherwise permitted by the NMA. The direction of the event notification flow is indicated by the arrow heads seen in Figure 7.

In an embodiment, event notifications are sent to and collected by the NMA 718. The NMA "keeps track of" these events and attempts to correlate them with other network events that the NMA is aware of. For example, if the NMA 718 collects event notifications from lines 720, 721 and 722 that each has experienced a drop in SNR just after an increase in the service speed on line 724 was allowed, the NMA 718 can assume that line 724 is the source of disturber noise on lines 720, 721 and 722.

Furthermore, in light of the amount of SNR reduction that has occurred on each line, the NMA 718 can approximate the strength of the cross coupling that exists between line 724 and each of lines 720, 721 and 722. This information may be used, for example, to prevent or limit the extent of further bit rate increases on line 724 (so that proper operation of lines 720, 721 and 722 is ensured).

When event notifications are sent upstream from a CPE transceiver to a line card, the events are collected at the line card that is responsible for communicating with the line that experiences an event. Thus, for example, if line card 706 communicates over lines 720, 721 and 722, line card 706 collects the events from these lines.

An event notification may be time stamped by a transceiver before it is sent upstream or may be time stamped by the line card that receives the event

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notification. By comparing the timestamps of the collected event notifications, the line card is able to assume that some events are correlated while other events are not correlated. Specifically, those events that occurred at approximately the same time may be deemed as related to one another (e.g., by a cause/effect relationship). For example, if a drop in SNR occurs at approximately the same time on lines 720, 721, 722, the line card may assume that each of these SNR changes had the same cause.

Each line card 706, 707, 708 reports its event notifications (and any correlation it has discovered) to a DSLAM control unit 704. The DSLAM control unit prioritizes and condenses the event information before sending them further upstream to the NMA 718. For example, insignificant events (such as a small change in SNR) may be ignored by the DSLAM control unit 704.

As another example, with respect to DSLAM 702, consider an instance where each line card 706, 707, 708 reports an event that was correlated to each of the line card's lines. If the DSLAM control unit 704 further determines that each of these reports are correlated (e.g., the timestamp of the event reported by each line card 706, 707, 708 are approximately the same), the DSLAM control unit 704 may conclude that a "significant" event has occurred that has affected every line coupled to the DSLAM 702.

The reporting of this event to the NMA may take priority over (i.e., be sent prior to) other events that have already been reported by the line cards but do not correlate to as many lines. Queuing of events at the DSLAM control unit

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704 may be employed if the flow of events to be reported exceeds the bandwidth of the communication link between the DSLAM 702 and the NMA 718. The DSLAM control unit 704 may also be configured to condense the event information (e.g., by coupling multiple events in a single message to the NMA) to enhance the efficiency of upstream event notification flow.

The NMA 718 collects the network events sent by the DSLAMS it has control over. The NMA 718 performs a higher level correlation by correlating events reported by different DSLAMs. For any change in SNR caused by an adjustment in line power or line speed within the DSL network, the NMA 718 will be able to get a full report of the lines affected and build an understanding of the cross-talk that exists in the network. Furthermore, specific verification tests may be executed to see if a particular line change is allowable.

For example, if an existing customer desires to increase the speed of his or her service, the service provider can send a higher speed test signal over the line. Depending on the SNR changes to other lines that are caused by the increase in speed, the service provider may permit or deny the increased service. Furthermore, the service provider may continuously run tests during a network's "quiet time" (e.g., in the early morning when the customer population is mostly asleep). By continually running tests (e.g., adjustments in speed and/or power to one or more lines) and continually collecting the events that follow, the NMA 718 can build upon and improve its understanding of the cross-talk that exists between the lines on its network.

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For examples of improving an understanding through continued monitoring and analysis of the lines see patent applications entitled "Design and Architecture of an Impairment Diagnosis System for Use in Communication Systems" and "Method and Apparatus for Impairment Diagnosis in Communication Systems" assigned to the present assignee and filed on an even data herewith.

That is, the aforementioned "chart" (that identifies: 1) which lines are cross coupled with one another; and 2) for each cross coupling that is identified, the strength of the particular cross coupling) is continuously refined and improved as to its accuracy. Note that so far the network perspective has been limited to "in domain" lines. In domain lines are lines that the NMA 718 has control over (in terms of being able to adjust their speed or power) and can receive event notifications from.

The NMA 718 may also be able to build an understanding of "out of domain" disturbers (i.e., disturbers that the NMA 718 does not have control over and does not receive event reports from). For example, if a local AM radio station reduces its transmitted power every day after sunset, those in-domain lines that are cross coupled with the AM radio station will report an increase in SNR every day after sunset. The NMA 718 can therefore add to the "chart" the existence of an AM radio station that affects the lines that indicate cross coupling. Various other processes may also be used to identify at least the presence of disturbers originating from lines that are controlled by other service providers.

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Other types of diagnosis and analysis reports may be generated, depending upon the application. For instance, in a DSL application, a report may include the type of activity of all diagnosed out-of-domain and in-domain disturbers disturbers and victims that are estimated to be in a given binder. Since twisted pair lines in a binder often terminate in a small geographic area of users, e.g., within several hundred feet, such a report may also provide information regarding services deployed by other carriers in that small geographical area.

7.0 Exchange of Information Between A Line Level Perspective and A Networking Level Perspective

The discussion that follows demonstrates that transferring line perspective information to a network perspective and/or transferring network perspective information to a line perspective may result in the development of a more accurate perspective and/or increased performance by a DSL network as a whole. For example, referring to Figure 8, if a description 801 of the disturber sources observed at a line are sent upstream (e.g., to an NMA 818 that also collects event notifications from lines in the network) a number of improvements may be realized.

First, the NMA 718 may develop a more accurate "chart" of lines that are cross coupled. That is, recall that the disturber information gathered during a line perspective development phase (as discussed with respect to Figure 6)

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includes: 1) description of the service that the disturber signal corresponds to; 2) the actual frequency of the disturber signal; and 3) an estimate of the co-channel between the line and the cross coupled line carrying the disturber signal.

By sending such a description of one or more disturbers upstream to the NMA 818, the NMA 818 can more readily and with more confidence develop its chart. For example, if the NMA 818 believes (as a result of the event reporting described above with respect to Figure 7) that a particular line (e.g., line 724 in Figure 7) causes disturber noise on particular lines (e.g., lines 720, 721, and 722), this belief may be "confirmed" if the victim lines (e.g., lines 720, 721, and 722) each report identical disturber information that match the configuration of the disturber line (e.g., line 724).

That is, if line 724 is configured to deliver a 784kbps PAM-SDSL service and lines 720, 721 and 722 each send a disturber profile corresponding to a 784kbps PAM-SDSL service with the same actual frequency, the NMA 818 may establish with a very high degree of confidence that line 724 is cross coupled with lines 720, 721, and 722.

Furthermore, recall that the event reporting scheme discussed above with respect to Figure 7 allowed the NMA 818 to develop an understanding of the strength of the cross coupling that exists between lines. The accuracy of the coupling strength understanding may be enhanced if the disturber information 801 sent upstream to the NMA 818 also includes a description of a disturber's co-channel. That is, the co-channel provides a thorough description of the cross

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coupling's dependency on disturber signal frequency. By the event reporting process alone, frequency dependent information is mostly gained by actually changing the operational speed of a line (e.g., via a test signal).

With this collection of information, the network may be better optimized by the service provider. That is, the service provider can predict with improved accuracy the effect that an increase in bit rate or an increase in transmitted power will have on the service provider's other lines. As such, the service provider is more able to correctly allow or deny such increases (if requested by a customer) based upon the actual understood cross coupling that exists among the service provider's lines.

Note that disturber information 801 sent upstream to the NMA may also describe "out-of domain" disturbers. Thus, whereas the event reporting scheme may be limited to realizing only the existence of an "out of domain" disturber, the sending of out of domain disturber information to the NMA 818 allows the NMA 818 to gain a deeper understanding of the out of domain disturber. Specifically, the type of service, the service speed and the co-channel of the out of domain disturber may be understood.

With this information, the NMA may be able to confidently configure networking service arrangements that will not be affected by the out of domain disturber. For example, due to regions of overlapping and non overlapping frequency usage by various DSL services, it is understood that a DMT-ADSL service will interfere (i.e., introduce disruptive disturber noise) with an SDSL

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service but not with a CAP-ADSL service. As a result, if the NMA 818 gains an understanding from the disturber information 801 (sent from the line perspective) that an out of domain disturber corresponds to a DMT-ADSL service, the NMA 818 may be configured to allow CAP-ADSL service on the victimized lines but not an SDSL service. Similar judgments may be exercised based upon the understood speed of an out of domain disturber and the speed of a desired service or service upgrade that may be offered by the NMA 818.

Furthermore, depending on the presence or absence of non volatile memory within a CPE, additional DSL network enhancement may be gained if the CPE uses the NMA 818 (or other upstream equipment such as a DSLAM or EMS) as an effective non volatile storage unit. That is, a CPE without non volatile storage will lose its line level understanding if its power is turned off. When the CPE is turned on again, the entire line level understanding will have to be re-developed.

However, if the CPE can use the NMA as its non-volatile storage, it may be able to maintain (and even improve) its line perspective. In particular, after the CPE initially builds its line perspective information, it can forward it to the NMA 818 through an upstream management data channel. In the case of DMT-ADSL, this corresponds to an Embedded Operations Channel (EOC).

The NMA 818 can store this line perspective information for later re-transmission, in addition to using it to improve its own network perspective.

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When that particular CPE is turned on after being turned off, it can request that its line perspective information be sent back to it from the NMA.

By receiving this information, the CPE does not have to devote computational resources to rebuilding its line perspective. Instead, it can use those resources to further refine its line perspective information (e.g., by collecting more data and focusing even more closely on the specific frequencies of the detected disturbers).

Also, if the NMA 818 notices a change in the disturber profile (i.e., if a significant loss in SNR is reported by various lines), the NMA 818 may request any line to "re-develop" its line level understanding. When the subsequent disturber information 801 gathered from the new line understanding is forwarded to the NMA 818, the NMA 818 can search for the cause of the change (e.g., such as a newly introduced out of domain disturber).

Figure 9 relates to another demonstration that transferring line perspective information to a network perspective and/or transferring network perspective information to a line perspective may result in the development of a more accurate perspective and/or increased performance by a DSL network as a whole. In the demonstration of Figure 9, note that data samples 901 taken from a line are sent upstream to more sophisticated equipment in the network (such as the equipment used to implement the NMA 918, an EMS or a DSLAM).

Referring back to Figure 6, recall that the transceiver observed the spectral content on its line in order to develop its understanding of the disturbers that

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affect the line. In the demonstration of Figure 9, observed spectral content of the line (i.e., data samples 901) is forwarded upstream. Upstream equipment may process these data samples with a methodology the same as, similar to or different from the line perspective development methodology 610 outlined in Figure 6.

That is, because upstream equipment tends to have more powerful computational resources, a more detailed and accurate analysis of the spectral content on the line may be performed (as compared to the analysis performed at the CPE). For example: 1) a wider service specific frequency range may be used; 2) a narrower resolution bandwidth that searches for a disturber peak may be employed; 3) the entire frequency spectrum (rather than just service specific frequency ranges) may be scanned; 4) a more robust algorithm for detecting the particular service type may be used (e.g., an algorithm that scans for the presence of higher frequency harmonics); 5) a more precise co-channel estimation may be developed, etc. The results of any these analyses will take the form of a more accurate disturber description 902 which is then forwarded back to the line's transceiver.

As an alternate cooperative enhancement, note that the NMA's development of a more detailed and accurate analysis of the spectral content of the line may be used to "pinpoint" to the CPE transceiver precisely where important disturbers are to be found. That is, for example, the disturber information 902 directed to the CPE may be used by the CPE to execute its own

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(i.e., "local") transceiver training and design routines (e.g., as discussed with respect to Figure 6). Because the NMA has informed the CPE transceiver "where to look", the CPE transceiver can immediately focus upon one or more disturbers, rather than scan a wide frequency range. More efficient use of training time results (e.g., via improved disturber and co-channel models and/or reduced time spent during training the training period).

Note also that these more advanced disturber descriptions may be made accessible to the NMA, thus at least all of the advantages and improvements discussed above with respect to Figure 8 may be realized. Furthermore, recall from Figure 6 that after the line understanding is developed 610 it is built into the design 620 of the transceiver. The more powerful computational resources of the NMA may also be used to calculate more precise design parameters for the disturber equalizer and the disturber symbol detector. The more precise design parameters 904 may be sent back to the CPE transceiver 908 so that they may be integrated into its design.

In particular, the NMA may perform an improved ranking of disturbers, not according to their power, but according to the severity of the impairment that they cause on the victimized line of the CPE. This ranking typically requires much more sophisticated and computationally expensive processing. As a result, a more suitable set of disturbers may be selected for compensation, with a corresponding increase in CPE compensation performance.

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Additionally, the NMA may employ much more sophisticated algorithms for computing the optimal filter coefficients for the DEQ. Such algorithms may include least-squares or min-max methods that require more memory than is available on a typical CPE processing resource. This optimized DEQ design results in further improvements in CPE computational performance.

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CLAIMS

What is claimed is:

1. A method, comprising:

sending upstream a collection of data samples measured from a DSL line.

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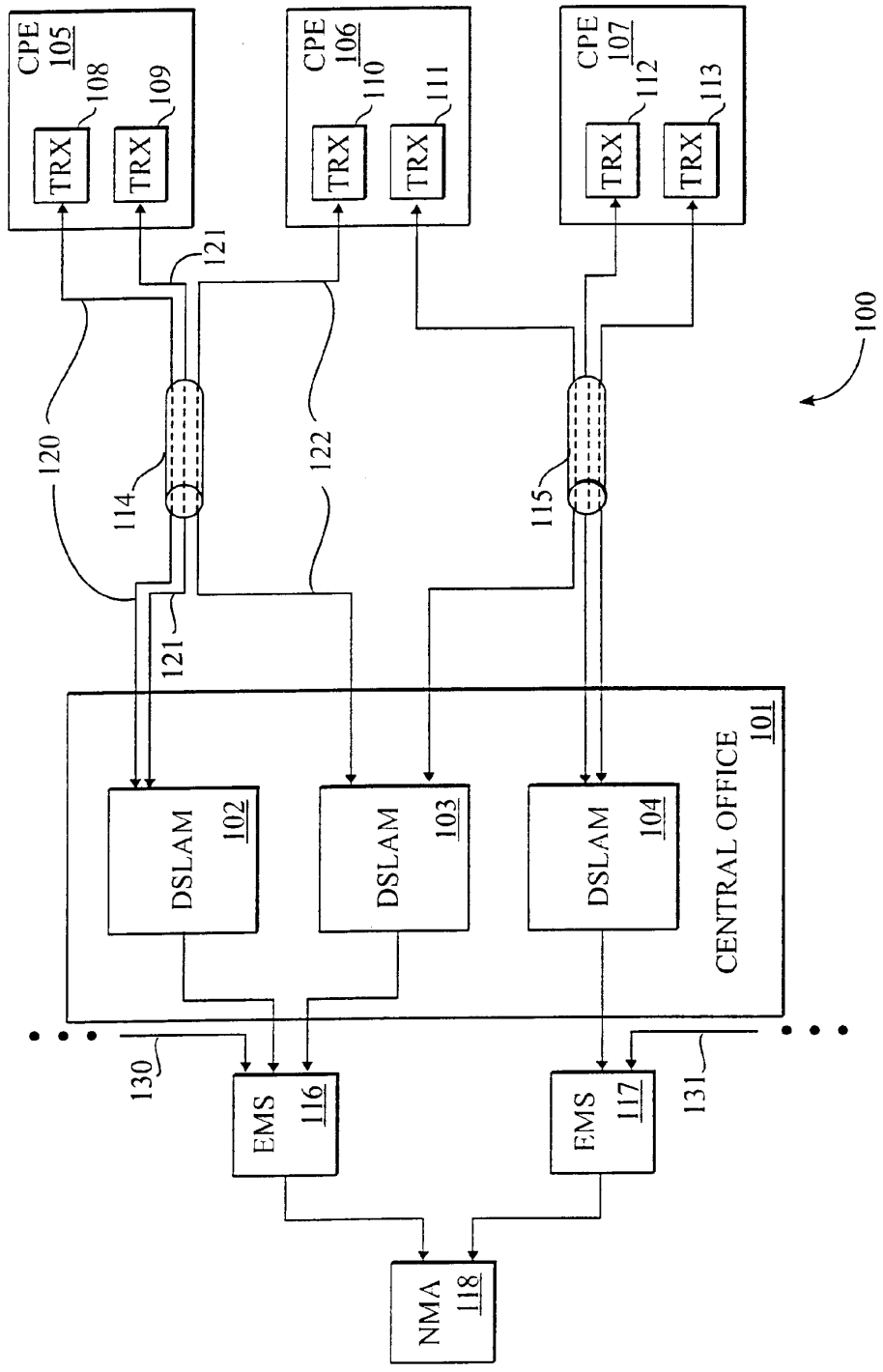

Fig. 1

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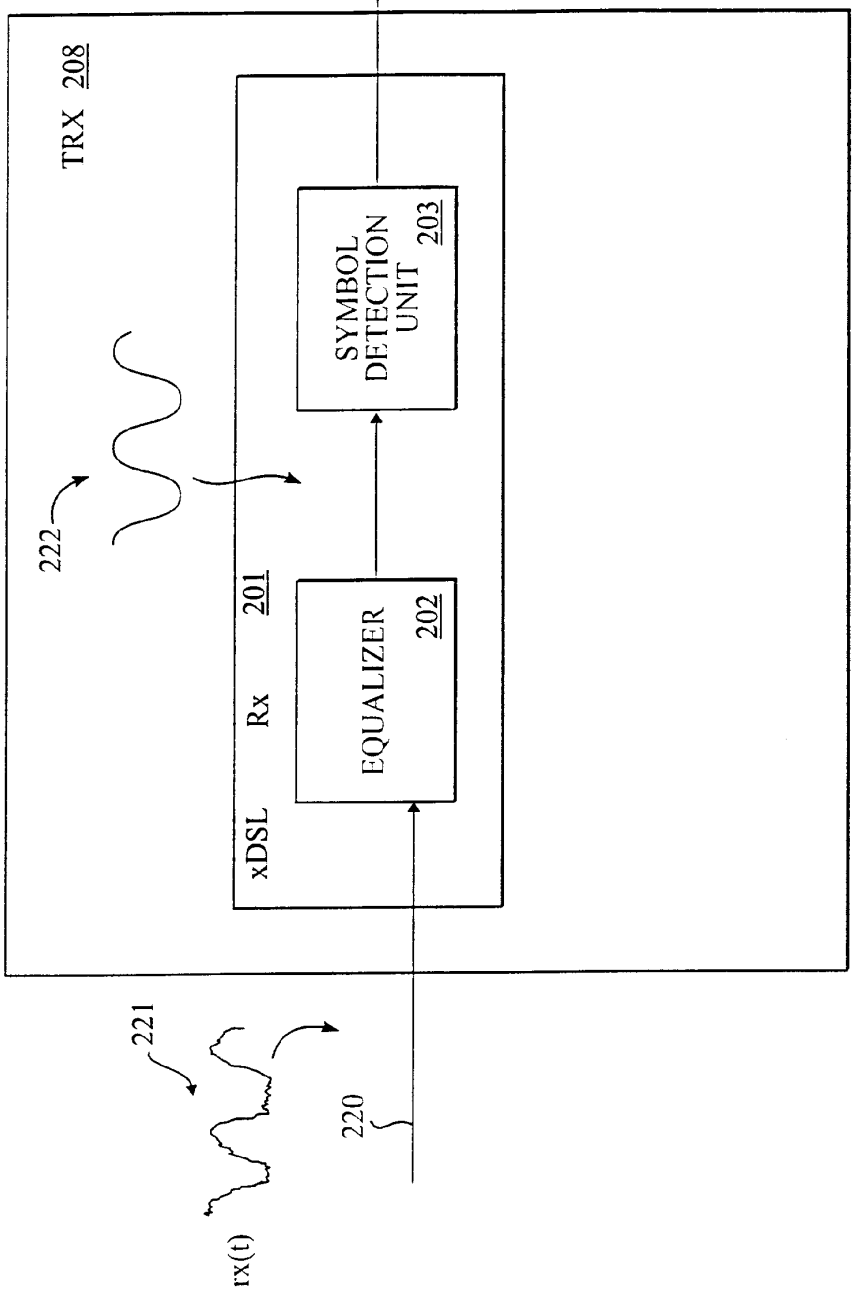

Fig. 2

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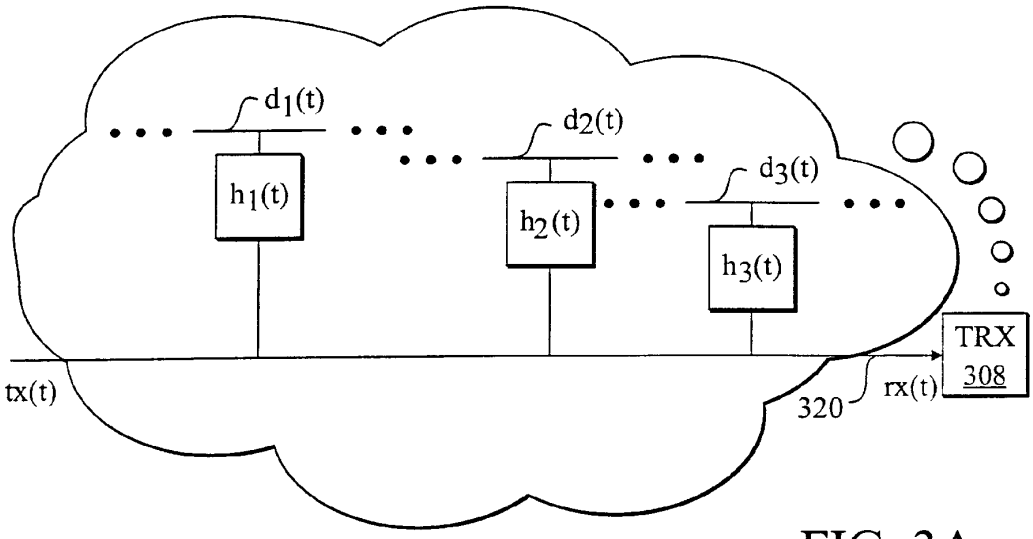

FIG. 3A

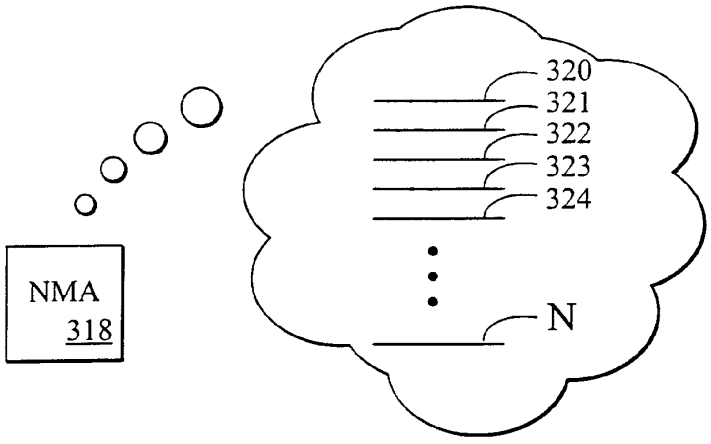

FIG. 3B

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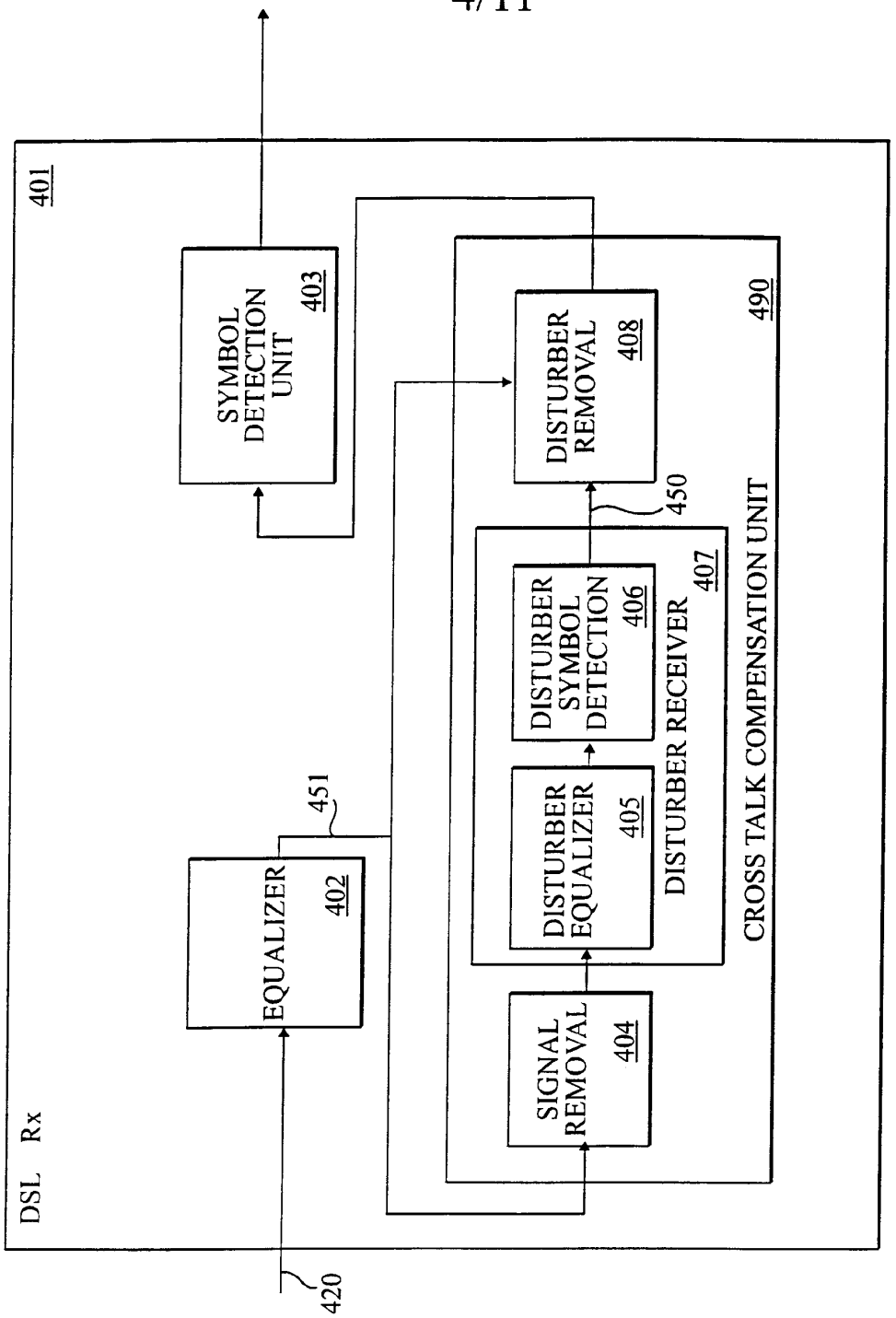

Fig. 4

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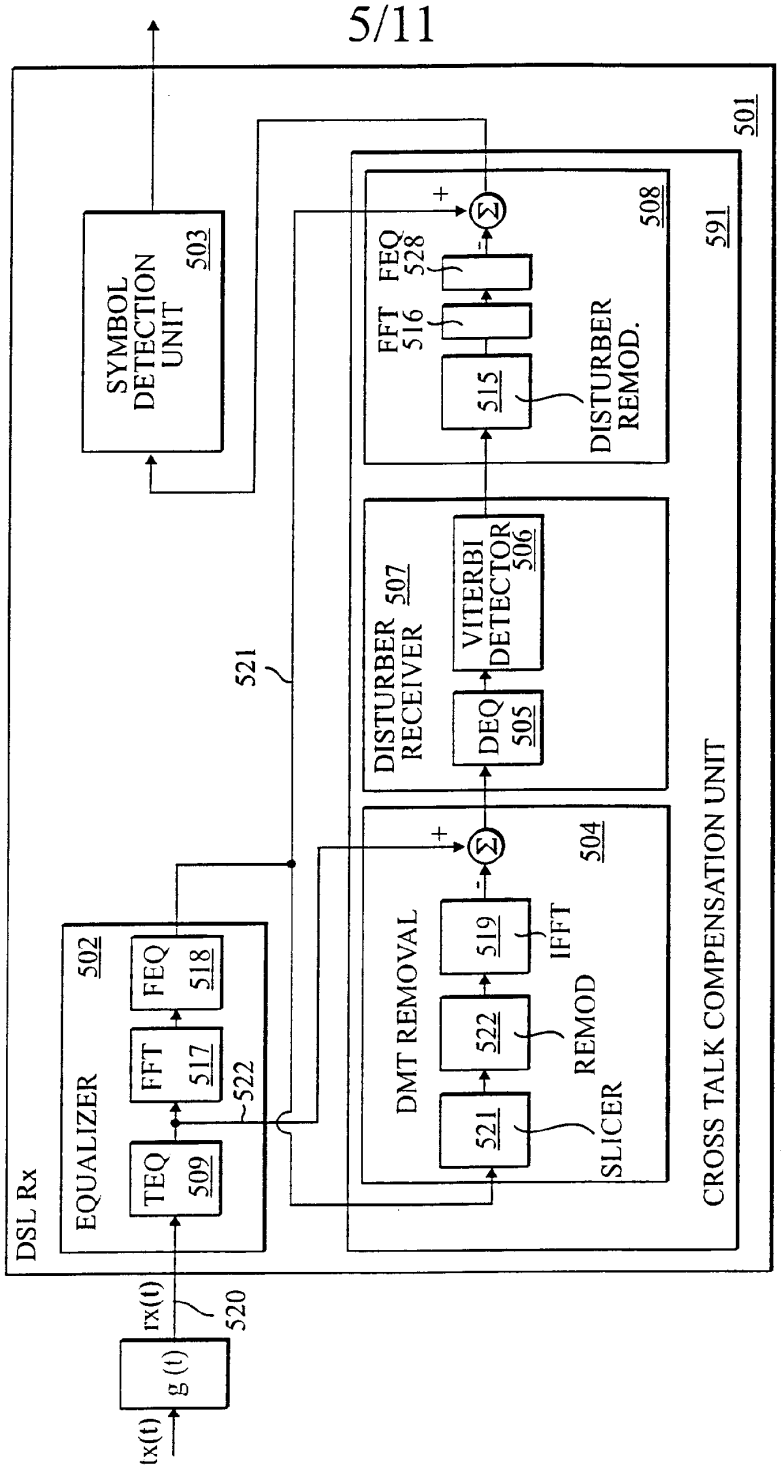

Fig. 5

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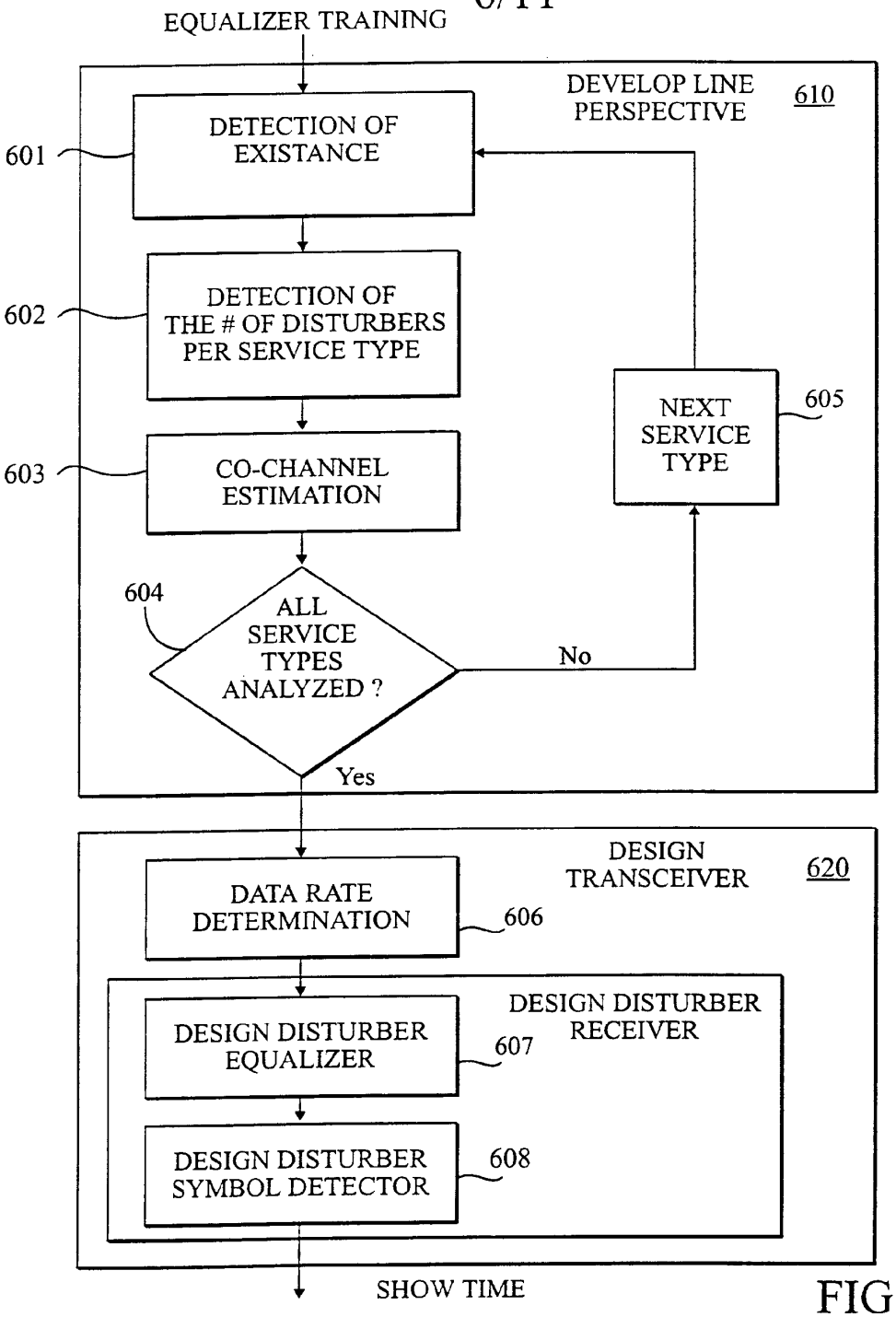

FIG. 6

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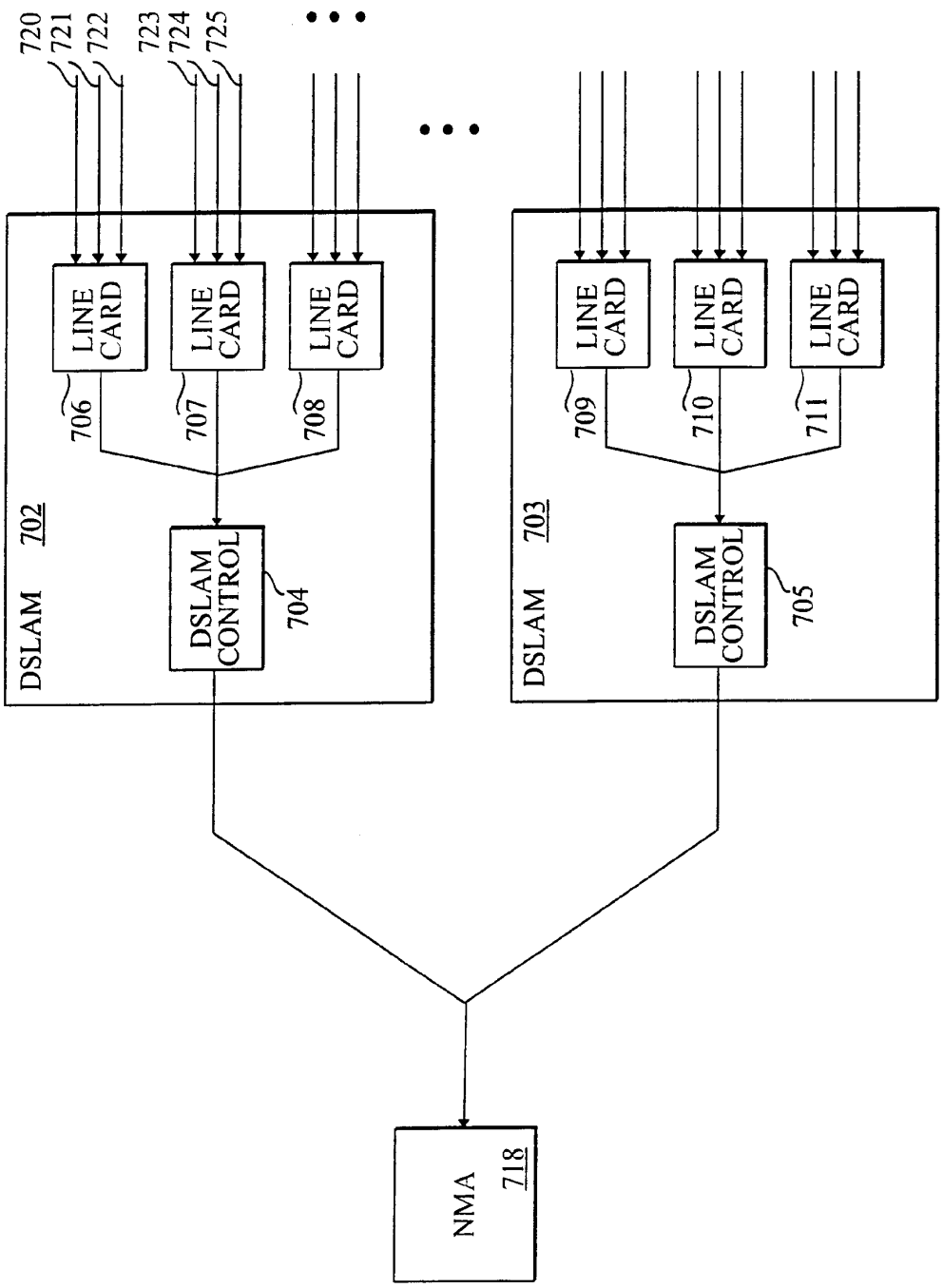

Fig. 7

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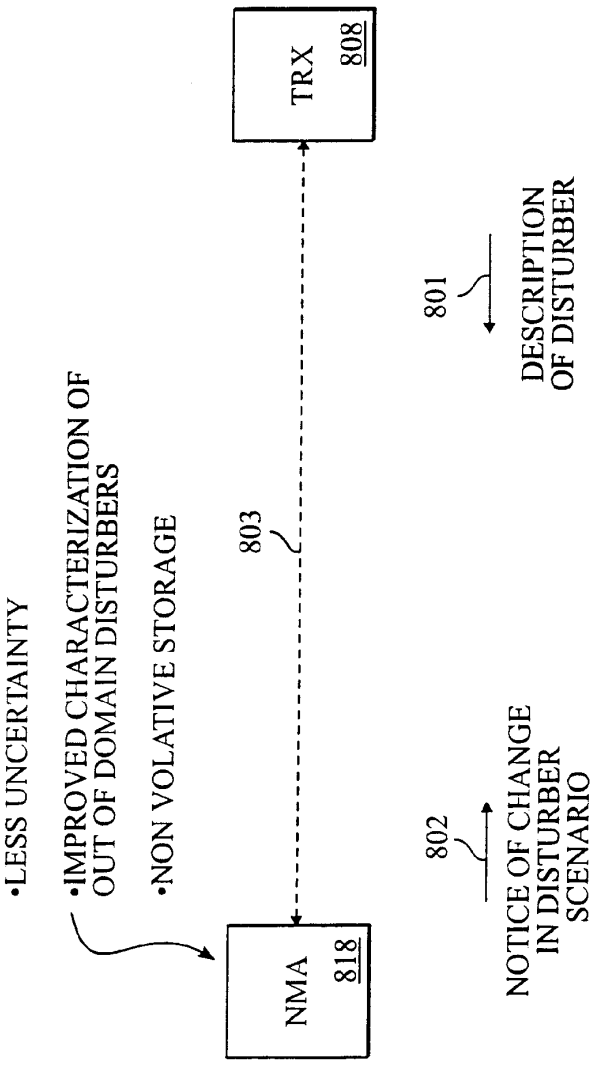

Fig. 8

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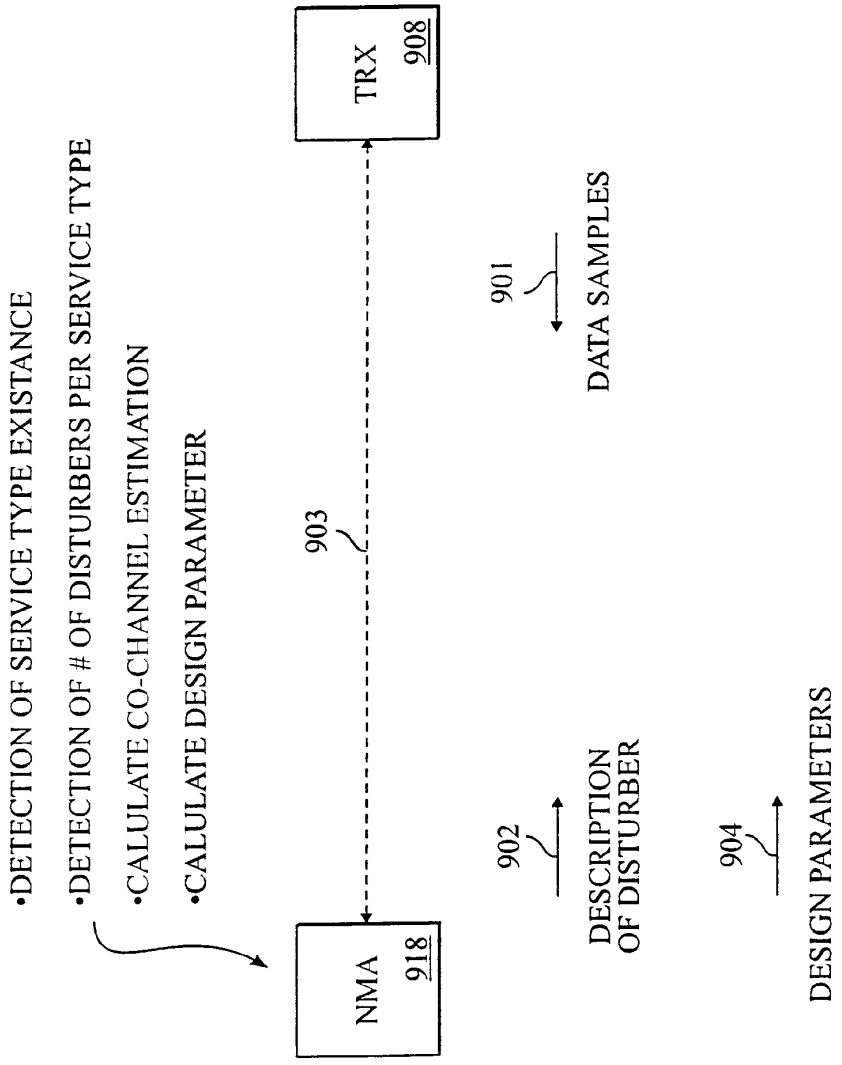
Fig. 9



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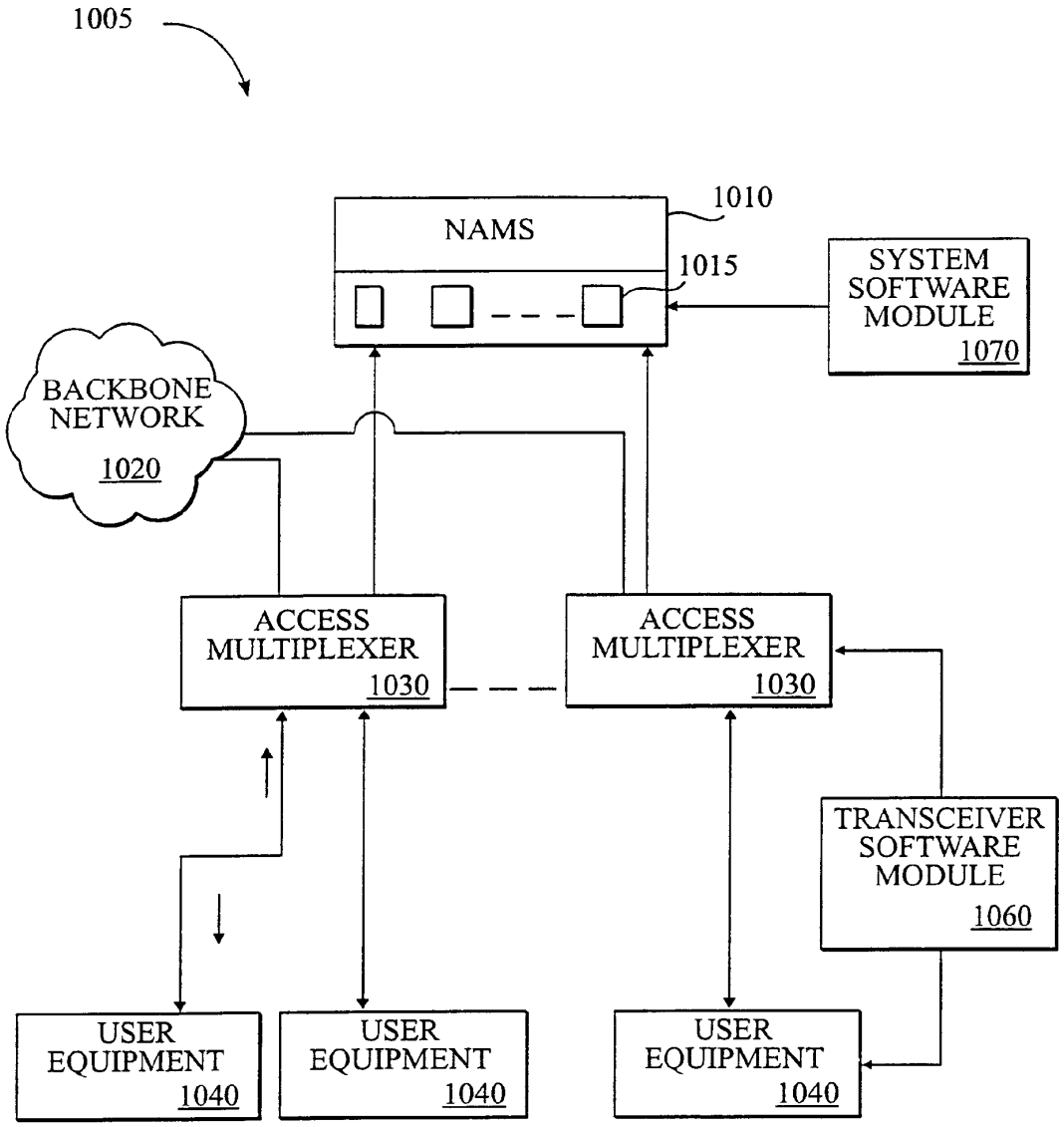

FIG. 10

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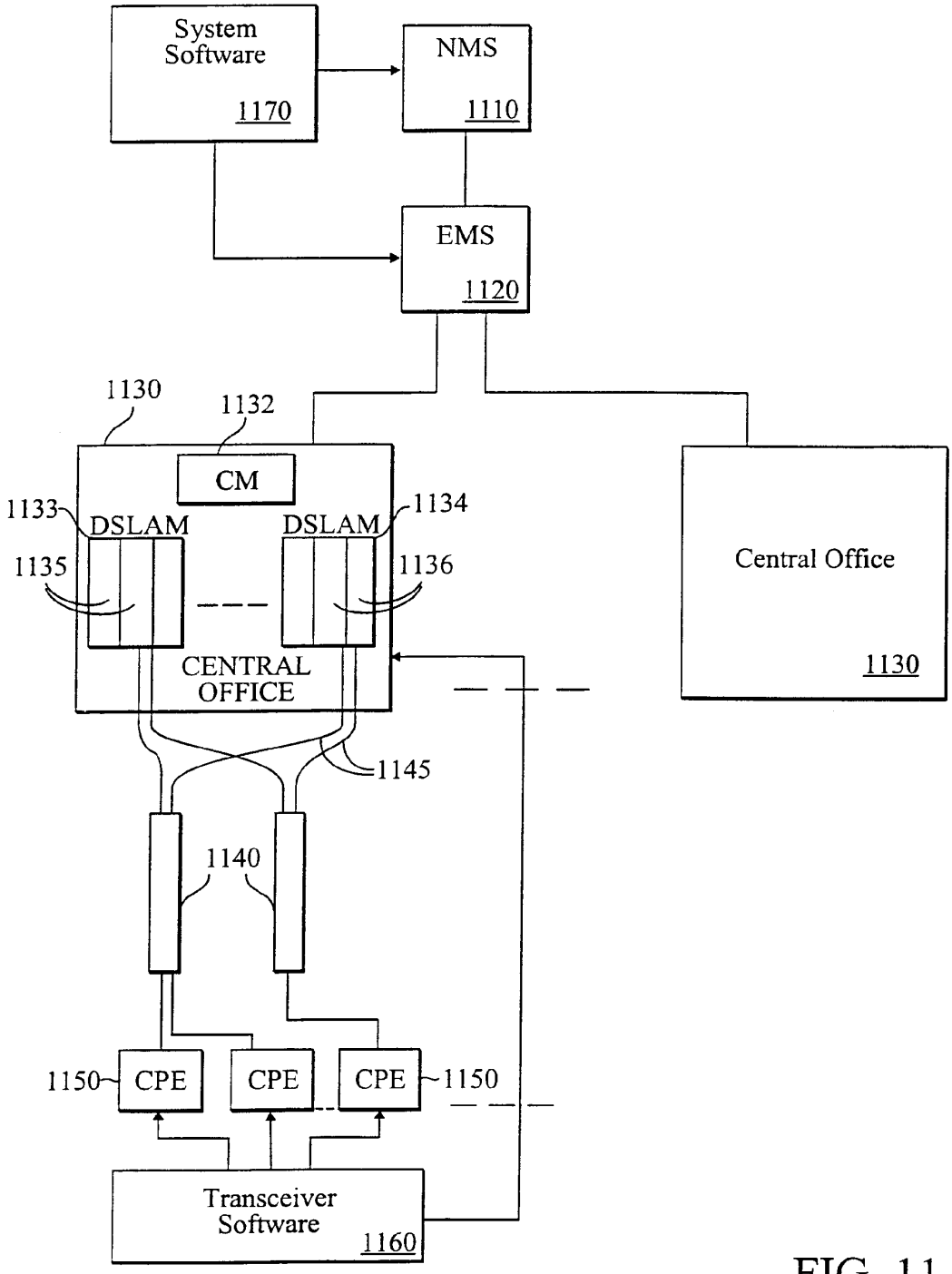

FIG. 11

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/31026

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H04M 1/24
US CL :379/1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 379/1, 10, 113, 220, 414, 416, 417

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST
SEARCH TERMS: DIAGNOSE OR ANALYSE, FAILURE OR IMPAIRMENT, INTERFERENCE OR CROSS TALK, DIGITAL SUBSCRIBER LINE, UPSTREAM

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,887,032 A (CIOFFI) 23 March 1999, Abstract, Figures 2 and 7-8, column 12, line 16-column 14, line 49.	1
X, P	US 5,995,566 A (RICKARD et al) 30 November 1999, Abstract, Figure 3, column 3, line 63-column 4, line 19.	1
A, P	US 6,055,297 A (TERRY) 25 April 2000, Abstract, column 5, line 56-column 7, line 25.	1

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 31 DECEMBER 2000	Date of mailing of the international search report 22 JAN 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer AHMAD MATAR Telephone No. (703) 305-4731

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(72) Inventor; and

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Published:
— *with international search report*
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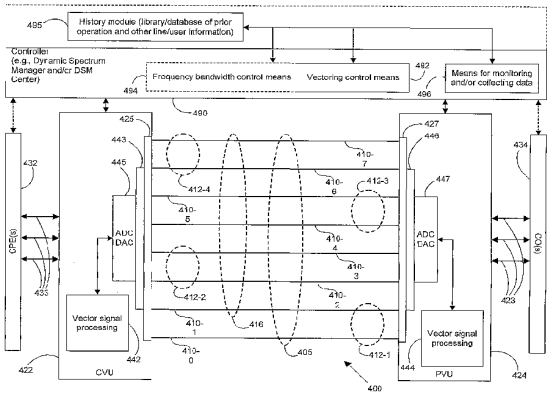
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: HIGH SPEED MULTIPLE LOOP DSL SYSTEM



(57) Abstract: A DSL system includes a multiple loop segment where K loops are bonded to provide a multiple loop segment having up to (2K-1) communication channels on which transmissions are vectored. The segment may be a drop to a customer premises, an interpedestal link, or any other suitable part of a larger DSL system. Generally the bonded loops are relatively short, being 300 meters or less. Signal vectoring is used to increase the speed and data carrying capability of the channels. In some embodiments, an expanded frequency spectrum also can be used to increase the data carrying capability of one or more of the channels. An impedance matching circuit may be coupled to each end of the segment to provided efficient transmission of data across the segment. A controller may provide control signals used to operate the segment as a vectored system and, if desired, frequency bandwidth control signals. The controller may monitor and/or collect data and information from the DSL sytem to assist in generating control signals. The controller can be a dynamic spectrum manager or DSM Center that includes a computer system and/or other hardware to assist in performing the required functions.

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HIGH SPEED MULTIPLE LOOP DSL SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority under 35 U.S.C. § 119(e) of U.S. Provisional No. 60/527,853 (Attorney Docket No. 0101-p01p) filed on December 7, 2003, entitled DYNAMIC MANAGEMENT OF COMMUNICATION SYSTEM, the disclosure of which is incorporated herein by reference in its entirety for all purposes.

BACKGROUND OF THE INVENTION

This invention relates generally to methods, systems and apparatus for managing digital communications systems. More specifically, this invention relates to a DSL system using multiple loops in a coordinated manner to provide high speed communications.

Digital subscriber line (DSL) technologies provide potentially large bandwidth for digital communication over existing telephone subscriber lines (referred to as loops and/or the copper plant). Telephone subscriber lines can provide this bandwidth despite their original design for only voice-band analog communication. In particular, asymmetric DSL (ADSL) and very-high-speed DSL (VDSL) can adapt to the characteristics of the subscriber line by using a discrete multitone (DMT) line code that assigns a number of bits to each tone (or sub-carrier), which can be adjusted to channel conditions determined during initialization and subsequent on-line training known as "bit-swapping" of the modems (typically transceivers that function as both transmitters and receivers) at each end of the subscriber line.

Currently, VDSL2 systems can achieve data rates of up to approximately 150 Mbps on short loops and ADSL2+ systems can achieve data rates of up to approximately 25 Mbps on somewhat longer loops than VDSL. "Short loops" are loops in which the component wires are preferably approximately 100 meters or less, and certainly 300 meters or less. Higher data rates are generally prohibited due to the line attenuation, but

on short loops are particularly limited by the maximum bandwidth used by the ADSL and VDSL modems and by frequency selective noises caused by crosstalk from other phone lines sharing the same cable, radio ingress, and a variety of customer-premises noises often known generically as impulse noise. These short loops are found at various points in a typical DSL plant.

Systems, methods and techniques that permit higher data rates without having to extend optical fiber and other high bandwidth materials to customer premises and the like would represent a significant advancement in the art.

BRIEF SUMMARY OF THE INVENTION

A high speed DSL system includes a multiple loop segment having K bonded loops providing up to (2K-1) communication channels. The segment may be a drop to a customer premises, an inter-pedestal link, or any other suitable part of a larger DSL system that has multiple loops that are available for bonding and vectored transmission of data. Generally the bonded loops are relatively short, being 300 meters or less.

Signal vectoring is used to increase the speed and data carrying capability of the channels. In some embodiments, an expanded frequency spectrum also can be used to increase the data carrying capability of one or more of the channels. An impedance matching circuit may be coupled to each end of the segment to provided efficient transmission of data across the segment.

Vectoring units can be connected to each end of the segment to provide vectored transmission and/or reception (that is, one-sided or two-sided vectoring). The vectoring units may house vector signal processing modules connected to the segment. The vectoring components can be hardware, software or a combination of both hardware and software, as appropriate. The vectoring units also may perform other signal processing such as filtering and digital-to-analog and analog-to-digital conversion and may include any impedance matching circuitry.

In some embodiments, a controller is configured to provide control signals used to

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operate a multiple loop segment as a vectored system. The controller also may provide frequency bandwidth control signals, in the event that an expanded frequency spectrum is used to improve data rates. The controller may monitor and/or collect data and information from the DSL system to assist in generating control signals. The controller can be a dynamic spectrum manager or DSM Center that includes a computer system and/or other hardware to assist in performing the required functions. In other embodiments, the DSL system may run independent of any controller or be pre-programmed to perform in a given vectoring mode.

The present invention can be used in ADSL, VDSL and other communication systems. The loops are bonded using an appropriate bonding protocol (for example, TDIM bonding, Ethernet bonding, ATM bonding or the G.bond protocol).

Methods of the present invention include bonding multiple DSL loops to provide a multiple loop segment having a number of communication channels, and vectoring transmissions across the bonded segment. Bonding and vectoring can be performed in various ways, as noted herein. These methods can be implemented in ADSL, VDSL and other communication systems.

Further details and advantages of the invention are provided in the following Detailed Description and the associated Figures.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The present invention will be readily understood by the following detailed description in conjunction with the accompanying drawings, wherein like reference numerals designate like structural elements, and in which:

Figure 1 is a diagram of a typical DSL plant.

Figure 2 is a schematic diagram showing a generic DSL deployment in which embodiments of the present invention can be used.

Figure 3 is a schematic block diagram showing the relevant portions of a DSL

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system implementing one or more methods, systems and/or other embodiments of the present invention.

Figure 4 is a schematic block diagram showing the relevant portions of another DSL system implementing one or more methods, systems and/or other embodiments of the present invention.

Figure 5 is a schematic block diagram of a one-sided vectoring system implementable with embodiments of the present invention.

Figure 6 is a schematic diagram illustrating the principles of a matrix impedance matching circuit implementable with one or more embodiments of the present invention.

Figure 7 are tables showing test data using multiple DSL bonded and vectored loop segments using 4096 and 8192 tones in a DMT system.

Figure 8 is a block diagram of a typical computer system suitable for implementing embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The following detailed description of the invention will refer to one or more embodiments of the invention, but is not limited to such embodiments. Rather, the detailed description is intended only to be illustrative. Those skilled in the art will readily appreciate that the detailed description given herein with respect to the Figures is provided for explanatory purposes as the invention extends beyond these limited illustrative and exemplary embodiments.

The present invention leverages the use of multiple loops in a DSL system where the loops can be bonded and are short (though the present invention is not limited solely to short loops). Bonding the loops and vectoring the data transmission on the loops allows the creation and operation of a multiple channel system that typically can achieve data rates greater than the sum of the individual loops' data rates when operated as individual DSL loops.

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The term subscriber loop or "loop" refers to the loop that is formed by the line that connects each subscriber or user to the central office (CO) of a telephone operator (or possibly a remote terminal (RT) of such an operator). A typical topology 100 of a DSL plant is presented in Figure 1. As can be seen, a CO 105 provides high bandwidth transmission via a feeder 110 (which can be a high-bandwidth link, such as fiber optic cable, or a binder with a number of copper lines running through it). The feeder 110 may connect the CO 105 to a serving area interface (SAI) 120 (which may be an optical networking unit or ONU). From interface 120, a number of copper lines 125 may then extend to a pedestal 130 near one or more customer premises equipment (CPE) locations 140. Such pedestals are not uncommon on each block of a street or neighborhood, for example. In some cases, pedestals are intermediate points between a CO, SAI and/or other pedestals. For example, in Figure 1, a inter-pedestal link 128 allows service for one CPE to be split off, while lines continue on to another pedestal and to one or more other CPEs.

Pedestals offer a cross connection point between lines going to a specific or a few customer premises (often referred to as a "drop") and the remainder of lines that may continue to other pedestals. Typically, there are 2-6 lines in the "drop" segment to each customer, providing extra copper for the contingency of one or more customers later demanding multiple phone services. The cable back to the ONU or central office usually does not have 2-6 times as many phone lines as would be needed by all the customers (because not all customers will demand that many phones). However, the pedestal drops typically have extra copper.

This extra copper is exploited in embodiments of the present invention when fiber or other high-bandwidth media passes to the pedestals and those pedestals are upgraded both to bond and vector electronically the lines in the drop segment to a customer (and thus interface that group of one customer's lines to the fiber or other high-bandwidth media passing to the pedestal). Those skilled in the art will recognize that, while the terms ONU and pedestal are used in examples discussed herein, many other equivalent names are used in the practice such as boxes, service terminals, cabinets, etc. and that

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embodiments of the present invention presented herein are equally applicable to all such locations. Furthermore, the continuing connection between pedestals could actually be in the nature of a repeater function, continuing service to other pedestals or connection points. In particular, the fiber could be a passive optical network, a multi-user sharing of a single fiber that would connect all the pedestals.

Connections to pedestals, if optical fiber, could be part of a passive optical network (PON), which would then have an Optical network terminal (ONT) at each pedestal, which functions logically as a T connection to a single fiber. In the future, an Ethernet PON (EPON) may have fiber running 10 Gbps and pedestal connections running several Gbps rates. Today, the recent EPON standard has a Gbps on the fiber and each ONT as 100 Mbps – that, too, could be used where pedestals only run at 100 Mbps.

Part of each subscriber loop may be collocated with the loops of other users within a multi-pair binder (or bundle). As seen in Figure 1, after the pedestal 130, very close to the CPE 140, one or more loops take the form of a drop segment 135 that exits the bundle. The subscriber loop can thus traverse different environments. Part of it typically is located inside a binder, where the loop is shielded from external electromagnetic interference, but is subject to crosstalk, which is interference from other subscriber loops hosted by the binder. After the pedestal 130, the drop wire(s) 135 may or may not be affected by crosstalk, depending on distance from other pairs, but transmission also can be impaired due to electromagnetic interference because drop wires typically are unshielded.

As mentioned above, in most cases, multiple loops connect a pedestal (or other location) to a single CPE. In such cases, loops operated as independent loops have at least the following drawbacks:

-- First, despite being short loops (typically 100 meters or less, and almost always less than 300 meters), each single loop is limited as to the data rate it can carry by attenuation, etc., irrespective of noise, crosstalk and/or other interference from other nearby loops;

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-- Second, when multiple loops are in the same drop, they can interfere with one another via crosstalk; and

-- Third, each of these short loops would need connection to a loop back to the ONU or CO and there may not be a sufficient number of such loops available within the cable to provided sufficient connection for all customers if they used all their drop wires.

As seen in the generic DSL deployment shown in Figure 2, two sources of data signals 210, 220 (for example, DSLAMs and the like) provide services to a number of users/CPEs 291, 292, 293 via a series of feeders and other communication lines 213, 217, 227, 250. In one case, a group of 4 loops 260 are dropped from pedestal 251 to CPE 293. The proximity of the loops 260 to one another likely gives rise to crosstalk. Also, the drop of loops 260 typically is unshielded. Embodiments of the present invention can use such a configuration, however, to not only reduce and/or virtually eliminate crosstalk problems, but also to significantly increase the data rate available to the CPE 293 and/or a group of CPEs coupled to the downstream end of the loops 260. The phrases "coupled to" and "connected to" and the like are used herein to describe a connection between two elements and/or components and are intended to mean coupled either directly together, or indirectly, for example via one or more intervening elements.

Figures 3 and 4 show examples of the system of Figure 2 using embodiments of the present invention. These Figures illustrate both structural and apparatus embodiments of the present invention, as well as method embodiments of the present invention. In the following discussion, examples using 4 loops will be presented, though embodiments of the present invention can use 2, 3, 4 or more loops in the systems, methods and techniques described herein. Moreover, the multiple loop segments discussed herein may be referred to as "drops" for ease of explanation but, again, the present invention is not limited solely to drops from pedestal to CPE. The present invention may be applied in any suitable location or site in a DSL topology. For example, connections between pedestals can be converted to "supervectored" segments using embodiments of the present invention and coordinating, for example, 8-20 loops to carry several Gbps.

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As noted above, drops from pedestals, pedestal links and the like are short loops to the CPE, typically 50-100 meters, and certainly less than 300 meters (though the present invention is not limited to short loops only). In Figure 3, system 300 includes a multiple loop segment 305 comprised of 8 wires 310-0 through 310-7, which are the 8 wires from 4 loops 312-1 through 312-4 (similar to loops 260 of Figure 2). Wires 310 are bonded using any suitable means or technique.

DSL bonding is line aggregation that combines multiple independent DSL loops into a single logical channel for high-speed transmission. There are several techniques known to those skilled in the art for implementing DSL Bonding. For example, DSL bonding can be done in conjunction with Copper Mountain's CopperEdge DSLAMs with Multilink Frame Relay technology implementation. This type of DSL bonding is also referred to as DSLAM-based DSL bonding. Another example is the industry standard Multilink PPP (MP), which is implemented in a customer's DSL router and the ISP's DSL subscriber management system or router (for example, Redback or Cisco). MP bonding creates a bonded or aggregated connection consisting of two or more independent DSL loops. DSL bonding over Multilink PPP (MP) requires the DSLAM be configured to support PPP. Using either of these DSL bonding techniques, multiple DSL loops can be aggregated to create a single logical data channel that is the sum of the individual lines' bandwidth, minus a small amount used for overhead. In addition to aggregating multiple DSL loops, both techniques perform automatic balancing of traffic across the links and actively monitor the performance of the bonded connection. Should one of the links fail for any reason, traffic is automatically forwarded to the active link. When the failed link is restored, the bonded connection is also transparently restored. From this perspective, DSL bonding not only provides increased bandwidth, but it also provides redundancy in the event of line failure.

Various protocols can be considered and implemented for bonding in embodiments of the present invention. For example, time division inverse multiplexing (TDIM bonding), Ethernet Transport for Single and Multiple Pair xDSL Systems (Ethernet bonding), and ATM-based multi-pair bonding (ATM bonding) are all well

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known to those skilled in the art and additional information regarding TDIM bonding can be found in publications from the American National Standard for Telecommunications. Moreover, the G.bond standard currently under consideration by the International Telecommunications Union also is known to those skilled in the art.

In the embodiment of the present invention shown in Figure 3, bonding means that the lines 310 function as and include a reference wire (for example, wire 310-0) and a communication link 316 having 7 available channels, where anywhere from 1 to 7 of channels may be used (thus yielding a channel matrix having dimensions up to a 7x7 matrix), where the data rate to CPE(s) 332 in Figure 3 is:

$$\text{Rate to/from CPE(s)} = \sum_{n=1}^{7} R_n \quad \text{where } R_n \text{ is the data rate on the } n\text{th wire}$$

In some embodiments of the present invention, vectoring can be used. Vectoring is a technique in which all DSL lines are synchronized in DMT symbol rate and crosstalk nominally is cancelled – in this invention, vectoring can also be used to increase the bandwidth by exploiting crosstalk between the individual wires. In effect, each of the 7 wires referenced to a common 8th wire presents an opportunity for transmission of useful data and any crosstalk between the 7 data bearing wires is cancelled via synchronized, coordinated transmission on the 7 channels created by bonding the 4 loops. Those skilled in the art will note that, in general, for a given number of loops K, the maximum number of channels available for data transmission is twice the number of loops minus one (that is, 2K-1). Further, not all channels need be excited nor all possible signals received, which can lead to a non-square channel transfer comprising from 1 to (2K-1) transmitters and from 1 to (2K-1) receivers. The number of transmitters and receivers need not be the same, but simply coordinated by vectoring since all are contributing to the overall data rate for the set of drop wires to an individual customer.

Techniques for use with the present invention are disclosed in more detail in United States Patent Application 20030086514, United States Serial No. 09/877,724, filed by Ginis, Yu, Zeng and Cioffi on June 8, 2001 and published by the USPTO on May

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8, 2003, entitled "DYNAMIC DIGITAL COMMUNICATION SYSTEM CONTROL", which is incorporated herein by reference in its entirety for all purposes. Use of vectoring with the bonded wires 310 of the system 300 of Figure 3 means that the signals transmitted on one or more of those 7 channels are coordinated to reduce and/or avoid crosstalk. Line 310-0 is the reference line and thus carries no data.

In the embodiment of the present invention shown in Figure 3, vectoring is accomplished using a pair of vectoring units (VUs) - a Customer VU (CVU) 322 and a Pedestal VU (PVU) 324. A VU may be a computer system, module, modem, etc. and may include software, hardware or a combination of both software and hardware. The VUs provide vectored transmissions across the segment 305. CVU 322 may be located in a customer premises and is coupled to one or more CPE devices 332 (for example, computers, telephones, television sets and/or other devices) in any suitable manner. As indicated by the dashed lines in Figure 3, the CVU 322 may or may not be part of or included in the CPE device(s) 332. The CVU 322 also can reside in a separate location and be coupled to the CPE device(s) 332 by one or more suitable communication links 333 (for example, wireless connections, Ethernet connections and/or other suitable connections). In some cases a single CPE device may be connected to segment 305 by CVU 322. The PVU 324 can be located within a pedestal or other device and is connected to the CO or ONU via fiber (PON or other), copper or other connection as suitably chosen by the service provider.

Substantial signal and/or data processing for the PVU 324 also can reside in a separate location (for example, a controller and/or an independent dynamic spectrum management (DSM) center, facility, location and/or entity) and be coupled to the PVU 324 by one or more suitable communication links 323. As will be appreciated by those skilled in the art, a controller such as a DSM center may also be coupled to the CVU 322 via element management (or "embedded operations) channels or over the internet itself (which may be carried through the bandwidth on the link). In the case of each VU, the VU may be coupled to some other type of user, operator, location, etc., rather than the CPE device(s) and/or service provider(s) illustrated in Figure 3. In some embodiments,

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the VUs 322, 324 and any vectoring functionality in a controller coordinate reception of data at each end of the segment 305. In other embodiments, each VU 322, 324 coordinates both transmission and reception of data across segment 305. This coordination can include distributing data across the 7 channel link 316, detecting and eliminating crosstalk and managing data using the 7 channel matrix that can be determined by either VU 322, 324 or both in combination, perhaps assisted by a controller and/or dynamic spectrum manager, as discussed. Other vectoring functions will be known and appreciated by those skilled in the art.

In cases where fewer than all available wires are used in both directions for data transmission, non-square vectoring may be employed. Figure 5 is a block diagram illustrating a zero-forcing generalized decision feedback equalizer (ZF-GDFE) for the receiver 500 of either a CVU or PVU in embodiments of the present invention, where receiver 500 receives transmissions from transmitters 540 via a channel *H* 530. This particular structure is shown for digitally duplexed DMT (used, for example, in VDSL1 and VDSL2) with the symbol clocks for all lines synchronized. Such synchronization renders the FEXT crosstalk between the lines independent. The use of such a system is well known and covered, for example, in Chapter 11 of Understanding Digital Subscriber Lines (Starr, Sorbara, Cioffi, and Silverman, Prentice Hall, 2003), referred to as "Starr et al."

This one-sided structure is preferable to the two-sided "vector-coding" special case in many situations because that equivalent-performing structure also requires coordination at the transmit side. For example, using the two-sided vector-coding may be physically impossible where upstream transmissions originate from multiple CPEs using multiple loop segments of the present invention that terminate in the same pedestal. FEXT from these customers into one another in such a situation can be eliminated via the structure of Figure 5. Nevertheless, two-sided vector-coding is may be appropriate for some embodiments of the present invention.

The (2K-1) wires of a channel/segment 530 of the present invention will

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form/produce a $k \times l$ matrix H_n, where k could be any integer 2, 3,..., 2K-1 and so could l. In the highest-data-rate case, $k = l = 2K - 1$. The tone index n is an integer $n = 1,...,8192$ for the advantageous embodiment where transmissions and in particular crosstalk are independent from tone to tone. The structure of Figure 5 can be generalized to other modulation methods, but the matrix H then represents a potentially enormous coupling structure of much higher complexity (with no gain and usually a loss in performance).

For the one-sided-case shown in Figure 5, the receiver is determined for each tone independently by a "QR" factorization of the matrix H_n so that

$$H_n = Q_n \cdot D_n \cdot R_n \qquad (1)$$

where the Q_n matrix is orthogonal, the D_n matrix is diagonal $k \times l$ with zeroed entries to make it non-square when $k \neq n$, and the R_n matrix is triangular and monic. Such a computation might well be done for each tone by a controller such as a dynamic spectrum manager in DSM center, for example. Such a decomposition need not be square. The H_n should include any noise-prewhitening factor, so this matrix is formed by multiplying the inverse of any square root of the measured noise spatial-autocorrelation matrix S_n (this noise is all the noise from sources other than the (2K-1) lines) by the channel insertion loss matrix $Hlin_n$, so that $H_n = S_n^{-0.5} \cdot Hlin_n$. The receiver processing matrices are then determined from those of the factorization as shown in Figure 5 (* denotes conjugate matrix transpose in the explanation of this illustrative example). The matrix H_n can be any dimension for this procedure. The D matrix will be zero for non-excited input components, so these zero entries are actually also zeroed on the receive side (to avoid dividing by zero) when $k > l$ or some spatial modes of transmission on any frequency are zero for any other reason. The receive matrix W_n 520 in receiver 500, where $W_n = (D_n)^{-1} Q^*_n S^{-0.5}$, will be $l \times k$, and the feedback matrix 515 of the feedback/packet detector 510 is $B_n = R_n$ and will be $l \times l$. The G_n "scalar" entries are

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the energies determined by an appropriate energy allocation scheme (for example, water-filling for each of the l excited inputs) to be used in connection with the input data $X_{l,n}$.

For the two-sided-case, both the receiver and transmitter become matrix multiplies on each tone so that coordination is then also needed on the transmit side (sometimes this configuration can work somewhat better when the spatial noise has special characteristics). The matrices for these matrix multiplies are determined for each tone independently by a "singular-value" factorization of the matrix H_n so that

$$H_n = F_n \cdot V_n \cdot M_n^* \qquad (2)$$

where the F_n matrix is $k \times k$ orthogonal, V_n is a diagonal $k \times l$ matrix with zeroed entries to make it non-square when $k \neq n$, and the M_n matrix is $l \times l$ orthogonal. Again, such a computation might be done by a controller such as a dynamic spectrum manager in a DSM center or the like. Such a decomposition need not be square. The H_n should include any prewhitening factor so this matrix is formed by multiplying the inverse of any square root of the measured noise spatial-autocorrelation matrix S_n (this noise is all the noise from sources other than the (2K-1) lines) by the channel insertion loss matrix $Hlin_n$, so that $H_n = S_n^{-0.5} \cdot Hlin_n$. The receiver processing matrix is then $W_n = F_n \cdot S_n^{-0.5}$ and $B_n = 0$ (no feedback) while the transmitter now is a matrix multiply of a vector of inputs (one each tone) by M_n^*. The energies and number of bits applied to each of the vector inputs are again determined by some appropriate procedure like water-filling. In effect for one or two-sided vectoring, the water-filling is applied using the diagonally gains determined by the diagonal elements of $|\mathbf{V}_n|^2$ for all the tones, so that effectively a water-filling procedure of up to $(2K-1)\cdot 8192$ subchannels for the K loops is executed to maximize the sum of the data rates on each of the lines (individual line power constraints as might occur in practice are handled by discrete loading procedures such as the well-known Levin-Campello procedures by maintaining a monitor for each line or wire's total power as bits are allocated to the various tones and wires in positions of least

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energy increase to see if any particular line exceeds its total power limit. When such a limit is exceeded all tones on that wire then will then have incremental energy tables updated to be very large (infinite) cost associated to putting any more bits on tones for that loop/wire.

For the one-sided case, a special precoded downstream transmitter (as in Chapter 11 of Starr et al.) can be used to remove FEXT between CPEs that are in different places but terminate on the same pedestal. However, more than k sources of NEXT and other noises cannot be eliminated, and there will likely be more than k sources if there are multiple users, because each and every wire of one customer is a potential crosstalk noise source for another customer's group of wires in that case. Such a situation might benefit from FDM rather than NEXT/echo-cancellation, as will be appreciated by those skilled in the art. NEXT and echo cancellation also can be done independently and simply for each tone in a digitally duplexed DMT system, as will be appreciated by those skilled in the art, but will not be shown in detail.

Vectoring is an especially useful tool where, as in the example of Figure 3, all lines are coterminous at both ends and all signals on any of the 7 (2K-1) lines that are used (keeping in mind that not all 7 must be used) are sent/received by a single user CPE 325. The channel transfer matrix H can be determined with great precision as can the remaining non-crosstalk-noise power spectra. Moreover, despite being unshielded in many situations (for example, a drop from a neighborhood pedestal to a residential CPE), sources of interference that typically would be troublesome (for example, radio signals, RF interference and impulses generated by lighting or household appliances) are mitigated more effectively in the vectored receiver. Vectoring when the non-crosstalk-noise spectra are known can be used to eliminate up to (2K-1) independent sources of such noise, thus further enhancing the transmission capacity of the bonded set of loops.

Data-rate capacity can be further enhanced in some embodiments of the present invention by expanding the transmission frequency bandwidth for one or more of the channels in link 316. In many VDSL1 systems, the transmission spectrum has an optional maximum-usable frequency of approximately 17.664 MHz (with the default

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being only 8.8 MHz) while even ADSL2+ systems can use no more than 2.2 MHz of bandwidth. In some embodiments of the present invention, the transmit spectrum is increased to an upper bandwidth limit of approximately 35.328 MHz, for at least some of the wires 310.

Frequency-division-multiplexing (FDM), echo/NEXT cancellation or some combination of the two can be used to separate upstream and downstream transmission. Echo/NEXT cancellation will attain the highest data rates if there are less than (2K-1) sources of independent noise (that is not generated from any of the (2K-1) coordinated wires) in the drop segment (including drop upstream-into-downstream NEXT from other customers' upstream CVU transmitters in the same drop), because the full bandwidth is used in both up and down directions. FDM can be used and is simpler to implement when there is a concern about a surplus of other customers' crosstalk in the same drop segment. Assuming symmetric transmission, the data rates attainable with FDM are approximately 50% of the data rates attainable with NEXT/echo cancellation. Wires from loops 312 that normally would be theoretically considered or deemed reference wires (most DSLs are differentially transmitted and received; therefore, calling one of the two wires in a loop the "reference wire" is convenient for theoretical purposes and often done) and therefore would not carry any data (for example, wires 310-2, 310-4, 310-6 that would be the reference wires for loops 312-2, 312-3 and 312-4, respectively, in Figure 3) can be used for data transport as well. These extra wires can be employed and combined in the bonded, vectored environment of system 300.

Those skilled in the art will note that the use of these extra wires is equivalent to the use of all the transverse electromagnetic modes of propagation in the transmission binder and, in particular, that the extra signals can sometimes be referenced between the average voltages between the two wires of a single pair with respect to the average voltages between the two wires of a different single pair, sometimes called "center to center" of the loops. These signals so referenced are called "phantoms." Actually, the use of the extra wires with the nomenclature explicitly described in embodiments of the present invention is mathematically equivalent to the phantom nomenclature, but often

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referred to as "split-pair" circuits. Split-pairs occasionally occur in DSL inadvertently (for example, a mistake made by technical field personnel), but can actually function. The fact that they do, in fact work in these unintentional implementations is an indication of their data carrying capability, fully exploited intentionally in embodiments of the present invention. While these split-pair (or "phantom") circuits may or may not be able to achieve data rates comparable to the other data-bearing wires in segment 305, they nevertheless can contribute to the link's data-rate (that is, the aggregate data-rate) for any CPE(s) on the downstream side of segment 305. As the line lengths become shorter and if the split-pair modes are intentionally well excited, the data-rates possible in these modes approach those of the normal modes. One aspect and benefit of the embodiments of the present invention is magnifying and expanding the data-carrying capability of the split-pair modes of transmission.

In the bonded environment of system 300, impedance matching at both ends of the wires 310 becomes considerably more complex as a result of the 7 channel transmission configuration and the crosstalking that exists between wires 310-1 through 310-7. While not essential to operation of the system 300, impedance matching can assist in achieving higher data rates. Consequently, a matrix impedance matching circuit (MIMC) 325 is in CVU 322 and another matching MIMC 327 is used in PVU 324. The MIMC ensures that minimal or no signal/energy is reflected at the wires' ends as a result of impedance imbalance. This impedance matching results in optimal use of available transmit power as well as eliminating potential interference by reflected data signals.

An example of an MIMC, shown in Figure 6, is a matrix matched circuit for 2 loops. Those skilled in the art will be able to extend the basic principles of this circuit to links of 3, 4, 5, etc. bonded lines. Essentially, a resistor is coupled to each pair of wires (in general, any complex impedance works, so each name can be changed to a Z; but in phone lines, it usually is a resistor). The resistance values are then computed from a matrix matched impedance as specified in T1E1.4 contribution number T1E1.4/2003-018R9 (February 24, 2004 – Dynamic Spectrum Management draft report). Further information regarding this technique may be found in Analysis of Multiconductor

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Transmission Lines (Paul, Clayton; Wiley: New York, 1994.

A $(2m-1)\times(2m-1)$ matrix resistance (for m loops bonded to provide $2m$-1 data carrying lines), which would have 6 independent values and would have the relationship

$$\mathbf{V}=\begin{bmatrix}V_3\\V_2\\V_1\end{bmatrix}=Z\cdot\mathbf{I}=\begin{bmatrix}Z_{33}&Z_{32}&Z_{31}\\Z_{32}&Z_{22}&Z_{21}\\Z_{31}&Z_{21}&Z_{11}\end{bmatrix}\cdot\begin{bmatrix}I_3\\I_2\\I_1\end{bmatrix} \qquad (3)$$

The values in the Z matrix give no clue as to the resistors in the circuit of Figure 6 upon first examination. However, maximum energy transfer occurs (when Z is real) when the matrix circuit of Figure 6 has resistor values that maintain the relations between current and voltage in Equation (3).

The solution is derived by listing the 6 resistance values and the currents between them as shown in Figure 6. In general,

$$\tilde{I}_{ij}=\frac{1}{R_{ij}}\cdot\left[V_i-V_j\right] \qquad (4)$$

for any wire $i=1,...,2m-1$ and any different $j=1,...,2m-1$ (so this extends to more than 4 wires directly). Then the matrix relationship

$$\mathbf{I}=\begin{bmatrix}1&1&1&0&0&0\\-1&0&0&1&1&0\\0&-1&0&-1&0&1\end{bmatrix}\cdot\begin{bmatrix}\tilde{I}_{32}\\\tilde{I}_{31}\\\tilde{I}_{30}\\\tilde{I}_{21}\\\tilde{I}_{20}\\\tilde{I}_{10}\end{bmatrix}=\mathbf{J}\cdot\tilde{\mathbf{I}} \qquad (5)$$

can be illustrated by a 3×6 matrix J of 1's, 0's and -1's and extends in the straightforward manner to a $(2m-1)\times2\cdot(2m-1)$ matrix. A second matrix relation derives from stacking the relations of Equation (4) into

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$$\tilde{\mathbf{I}} = \begin{bmatrix} \frac{1}{R_{32}} & -\frac{1}{R_{32}} & 0 \\ \frac{1}{R_{31}} & 0 & -\frac{1}{R_{31}} \\ \frac{1}{R_{30}} & 0 & 0 \\ 0 & \frac{1}{R_{21}} & -\frac{1}{R_{21}} \\ 0 & \frac{1}{R_{20}} & 0 \\ 0 & 0 & \frac{1}{R_{10}} \end{bmatrix} \cdot \begin{bmatrix} V_3 \\ V_2 \\ V_1 \end{bmatrix} = \tilde{\mathbf{Y}} \cdot \mathbf{V} \qquad (6)$$

and again easily extends to larger numbers of loops.

Finally, $\mathbf{I} = \mathbf{J} \cdot \tilde{\mathbf{Y}} \cdot \mathbf{V}$, so

$$\mathbf{Y} = \mathbf{J} \cdot \tilde{\mathbf{Y}} = \begin{bmatrix} \frac{1}{R_{32}} + \frac{1}{R_{31}} + \frac{1}{R_{30}} & -\frac{1}{R_{32}} & -\frac{1}{R_{31}} \\ -\frac{1}{R_{32}} & \frac{1}{R_{32}} + \frac{1}{R_{21}} + \frac{1}{R_{20}} & -\frac{1}{R_{21}} \\ -\frac{1}{R_{31}} & -\frac{1}{R_{21}} & \frac{1}{R_{31}} + \frac{1}{R_{21}} + \frac{1}{R_{10}} \end{bmatrix}.$$

This set of equations can then be easily back-solved for the resistors, given **Z**, by the set of equations:

compute: $\mathbf{Y} = \mathbf{Z}^{-1}$

compute: $R_{2m-1,i} = -1/Y_{2m-1,i} \quad i = 1,\ldots,2m-2$

$$R_{2m-1,0} = \left[Y_{2m-1,2m-1} - \sum_{i=1}^{2m-2} \frac{1}{R_{2m-1,i}} \right]^{-1}$$

compute: $R_{j,i} = -1/Y_{2m-1,i} \quad i = 1,\ldots,j-1$

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$$R_{j,0} = \left[Y_{j,j} - \sum_{i=1}^{2m-1} \frac{1}{R_{j,i}} \right]^{-1}$$

compute: $$R_{1,0} = \left[Y_{11} - \sum_{i=1}^{2m-1} \frac{1}{R_{1,i}} \right]^{-1}$$

Another embodiment of the present invention is shown in Figure 4. In Figure 4, operation of the PVU 424 and CVU 422, as well as other components, if desired, is controlled by a controller 490 that manages system 400. As seen in Figure 4, controller 490 (for example, a dynamic spectrum manager and/or DSM center utilizing a computer system) is coupled to and communicates with the VUs 422, 424. CVU 422 includes an MIMC 425 coupled to the customer end of the segment 405. Appropriate filters 443 and an analog-to-digital/digital-to-analog converter 445 can also be coupled to the MIMC 425. A vector signal processing module 442 is coupled to the customer end of the segment 405 as well. The vector signal processing module 442 can be a computer, integrated circuit (or "chip") or other suitable device for processing signals received and/or transmitted on the segment 405. In the embodiment of the present invention shown in Figure 4, module 442 is coupled to the vectoring control means 492 of controller 490, which assists in regulating (for example, one-sided and/or two-sided vectoring) transmissions across the segment and can provide control information and instructions (for example, coefficients used in signal processing for one-sided and/or two-sided vectoring).

Similarly, PVU 424 includes an MIMC 427 coupled to the pedestal end of the segment 405. Appropriate filters 446 and an analog-to-digital/digital-to-analog converter 447 can also be coupled to the MIMC 427. A vector signal processing module 444 is coupled to the pedestal end of the segment 405 as well. Module 444 can be a computer, integrated circuit, chip or other suitable device for processing signals received and/or transmitted on the segment 405. In the embodiment of the present invention shown in

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Figure 4, module 444 is coupled to the vectoring control means 492 of controller 490, which can provide control information and instructions (for example, coefficients used in signal processing for one-sided and/or two-sided vectoring). Modules 442, 444 may also be implemented as part of the controller 490 or be located somewhere other than inside their respective VUs, as will be appreciated by those skilled in the art.

In some embodiments of the present invention, the controller 490 may communicate with a remote location, such as downstream VU 422, via the link 416 rather than directly. Also, the controller 490 may be coupled to the CPE(s) 432 and/or CO(s) 434, if desired, which link may be used for communicating with the respective VUs. Those skilled in the art will appreciate that communication with the VUs can be accomplished in a variety of ways using various types of links (including, for example, the DSL system itself, email, ftp (file transfer program) over the internet, or some other "external" communication means, etc.). One practical partitioning is for a remote controller (for example a DSM center) to collect the data from initialization and operations that can be used to construct the *H* matrix describing the matrix channel, analyze noise, and then make decisions on the appropriate vectors to be used by the VUs. In this way a remote capability for such computationally intensive functions and determinations could be shared (rather than embedding this function at the VU location where power, memory, computation and cost are at a premium).

Controller 490 includes segment monitoring means 496, which collects data regarding operation of the system 400 and may provide this data to a history module 495, such as a database. Vectoring control means 492 uses this data to generate control signals sent to the vector signal processing modules 442, 444 for VUs 422, 424, respectively. These vectoring control signals provide information on the bit distributions, margins, transmission power levels and other operational information needed to operate the vectored system 400 properly (for example, at the highest aggregate data rate available within any given constraints). Again, this can include what mode of vectoring to use (for example, one-sided or two-sided, as described above) and coefficients and other data needed to process signals for segment 405.

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Controller 490 also may include a frequency bandwidth control means 494, which generates frequency bandwidth control signals used by the VUs 422, 424 to determine what frequency bandwidths will be used for communication on link 416. In generating their respective control signals, both means 492, 494 may consult or otherwise utilize historical performance and operational data in a library module 495 or the like. As noted above, module 495 might take the form a database coupled to a computer system. Means 492, 494, 496 can be implemented as software, hardware or a combination of both software and hardware (for example, one or more computer systems and/or integrated circuits), as will be appreciated by those skilled in the art.

A controller implementing one or more embodiments of the present invention can be a dynamic spectrum manager or spectrum management center and can be a computer-implemented device or combination of devices that monitors the appropriate system 400 and data relating thereto. The controller may directly or indirectly dictate/require changes in the operation of system 400 by users and/or equipment coupled to the controller or may only recommend changes. In some embodiments, upstream VUs to which the controller is coupled may all reside in the same location (for example, a DSL central office) and may or may not share other resources for their respective transmission channels. The structure, programming and other specific features of a controller usable in connection with embodiments of the present invention will be apparent to those skilled in the art after reviewing the present disclosure.

The controller can reside in one or more locations, as will be appreciated by those skilled in the art. For example, the controller may reside in the CO with to which a CPE is coupled. Moreover, in some embodiments, the controller may reside in a pedestal or other intermediate location within the DSL plant. Finally, the controller may reside in the CPE (for example, in a user-side transceiver, modem or the like).

Thus, embodiments of the present invention provide substantial improvements in data rate for short length DSL systems where multiple loops are available for bonding and vectoring, or other coordination that provides similar functionalities. In the exemplary systems of Figures 3 and 4, the 4 loops would individually be able to achieve rates of

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approximately 150 Mbps per loop, yielding an aggregate data rate to the CPE(s) of approximately 600 Mbps over the 4 loops. Using one of the 7 channel bonded and vectored configurations of Figures 3 and 4, rates of over 1,000 Mbps (1 Gbps) can be realized -- an increase of over 65%.

Figure 7 provides data from testing using line lengths varying from 50 meters to 300 meters and various combinations of frequency bandwidth and wire/channel dimensions. As can be seen from the data presented in Figure 7, none of the rates fell below 900 Mbps. As would be expected, using all available channels (the 7x7 channel instances) produces the best results, none falling below 1.38 Gbps. This data can be contrasted with high speed (1 Gbps or more) Ethernet systems using 4 loops. The 4 loops are used as four channels with NEXT cancellation, but no vectoring or handling of FEXT, with 5-level PAM transmission at 125 MHz symbol rate (250 Mbps per loop) on each of the 4 wires. Actually, this works to 1.25 Gbps, but the extra 0.25 Gbps is internal overhead (normally 4 levels is enough with no overhead). There are no bridged taps and noise is reduced by much tighter twisting of the Cat5, Cat53, Cat6 cables that abound in high speed Ethernet. The maximum range in such systems is 100 meters. Moreover, the present invention uses extra modes, more efficient adaptive DMT, synchronizing so that each tone is individual vectored system, and exploiting of the FEXT and split-pairs, and lines of 300 meters plus on much inferior grade wiring for the same number of pairs.

Generally, embodiments of the present invention employ various processes involving data stored in or transferred through one or more computer systems. Embodiments of the present invention also relate to a hardware device or other apparatus for performing these operations. This apparatus may be specially constructed for the required purposes, or it may be a general-purpose computer selectively activated or reconfigured by a computer program and/or data structure stored in the computer. The processes presented herein are not inherently related to any particular computer or other apparatus. In particular, various general-purpose machines may be used with programs written in accordance with the teachings herein, or it may be more convenient to construct a more specialized apparatus to perform the required method steps. A particular structure

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for a variety of these machines will be apparent to those of ordinary skill in the art based on the description given below.

Embodiments of the present invention as described above employ various process steps involving data stored in computer systems. These steps are those requiring physical manipulation of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared and otherwise manipulated. It is sometimes convenient, principally for reasons of common usage, to refer to these signals as bits, bitstreams, data signals, control signals, values, elements, variables, characters, data structures or the like. It should be remembered, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities.

Further, the manipulations performed are often referred to in terms such as identifying, fitting or comparing. In any of the operations described herein that form part of the present invention these operations are machine operations. Useful machines for performing the operations of embodiments of the present invention include general purpose digital computers or other similar devices. In all cases, there should be borne in mind the distinction between the method of operations in operating a computer and the method of computation itself. Embodiments of the present invention relate to method steps for operating a computer in processing electrical or other physical signals to generate other desired physical signals.

Embodiments of the present invention also relate to an apparatus for performing these operations. This apparatus may be specially constructed for the required purposes, or it may be a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. The processes presented herein are not inherently related to any particular computer or other apparatus. In particular, various general purpose machines may be used with programs written in accordance with the teachings herein, or it may be more convenient to construct a more specialized apparatus to perform the required method steps. The required structure for a variety of these

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machines will appear from the description given above.

In addition, embodiments of the present invention further relate to computer readable media that include program instructions for performing various computer-implemented operations. The media and program instructions may be those specially designed and constructed for the purposes of the present invention, or they may be of the kind well known and available to those having skill in the computer software arts. Examples of computer-readable media include, but are not limited to, magnetic media such as hard disks, floppy disks, and magnetic tape; optical media such as CD-ROM disks; magneto-optical media such as floptical disks; and hardware devices that are specially configured to store and perform program instructions, such as read-only memory devices (ROM) and random access memory (RAM). Examples of program instructions include both machine code, such as produced by a compiler, and files containing higher level code that may be executed by the computer using an interpreter.

Figure 8 illustrates a typical computer system that can be used by a user and/or controller in accordance with one or more embodiments of the present invention. The computer system 800 includes any number of processors 802 (also referred to as central processing units, or CPUs) that are coupled to storage devices including primary storage 806 (typically a random access memory, or RAM), primary storage 804 (typically a read only memory, or ROM). The CPU and some of the components of system 800 may also be implemented as an integrated circuit or chip that is a single device capable of being used in embodiments of the present invention. As is well known in the art, primary storage 804 acts to transfer data and instructions uni-directionally to the CPU and primary storage 806 is used typically to transfer data and instructions in a bi-directional manner. Both of these primary storage devices may include any suitable of the computer-readable media described above. A mass storage device 808 also is coupled bi-directionally to CPU 802 and provides additional data storage capacity and may include any of the computer-readable media described above. The mass storage device 808 may be used to store programs, data and the like and is typically a secondary storage medium such as a hard disk that is slower than primary storage. It will be appreciated that the information

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retained within the mass storage device 808, may, in appropriate cases, be incorporated in standard fashion as part of primary storage 806 as virtual memory. A specific mass storage device such as a CD-ROM 814 may also pass data uni-directionally to the CPU.

CPU 802 also is coupled to an interface 810 that includes one or more input/output devices such as such as video monitors, track balls, mice, keyboards, microphones, touch-sensitive displays, transducer card readers, magnetic or paper tape readers, tablets, styluses, voice or handwriting recognizers, or other well-known input devices such as, of course, other computers. Finally, CPU 802 optionally may be coupled to a computer or telecommunications network using a network connection as shown generally at 812. With such a network connection, it is contemplated that the CPU might receive information from the network, or might output information to the network in the course of performing the above-described method steps. The above-described devices and materials will be familiar to those of skill in the computer hardware and software arts. The hardware elements described above may define multiple software modules for performing the operations of this invention. For example, instructions for running a codeword composition controller may be stored on mass storage device 808 or 814 and executed on CPU 802 in conjunction with primary memory 806. In a preferred embodiment, the controller is divided into software submodules.

Examples have been provided herein using 4096 and/or 8192 tones in the frequency bandwidth of a DMT system. As will be appreciated by those skilled in the art, other frequency bandwidth spectra may be used, including wider bands of frequencies. Moreover, in some systems NEXT/echo cancellation may be used, while in other exemplary systems FDM is used. Again, as those skilled in the art will appreciate, one technique may be more advantageous than the another and/or have drawbacks relative to the other (for example, FDM's lower data rate relative to NEXT/echo cancellation techniques).

The many features and advantages of the present invention are apparent from the written description, and thus, the appended claims are intended to cover all such features and advantages of the invention. Further, since numerous modifications and changes will

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readily occur to those skilled in the art, the present invention is not limited to the exact construction and operation as illustrated and described. Therefore, the described embodiments should be taken as illustrative and not restrictive, and the invention should not be limited to the details given herein but should be defined by the following claims and their full scope of equivalents, whether foreseeable or unforeseeable now or in the future.

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CLAIMS

1. A DSL system comprising:

a multiple loop segment, comprising K bonded loops providing up to (2K-1) communication channels; and

a controller coupled to the segment and configured to provide control signals used to operate the segment as a vectored system.

2. The DSL system of Claim 1 wherein the controller comprises vectoring control means and further wherein a customer vectoring unit (CVU) is coupled to a first end of the segment and to the vectoring means and further wherein a pedestal VU (PVU) is coupled to a second end of the segment and to the vectoring means.

3. The DSL system of Claim 2 wherein the PVU is in a pedestal and further wherein the CVU is in a customer premises.

4. The DSL system of Claim 2 wherein the PVU is in a first pedestal and further wherein the CVU is in a second pedestal.

5. The DSL system of Claim 2 wherein the PVU comprises a vector signal processing module coupled to the controller and further wherein the CVU comprises a vector signal processing module coupled to the controller.

6. The DSL system of Claim 1 wherein at least one of the communication channels is operated using an expanded frequency spectrum.

7. The DSL system of Claim 1 wherein the controller comprises means for controlling the frequency bandwidth used in transmitting data across the segment.

8. The DSL system of Claim 1 wherein the controller is a dynamic spectrum manager comprising vectoring control means comprising a computer system.

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9. The DSL system of Claim 1 wherein the controller comprises a computer system.

10. The DSL system of Claim 1 further comprising a first impedance matching circuit coupled to a first end of the segment and a second impedance matching circuit coupled to a second end of the segment.

11. The DSL system of Claim 1 wherein the DSL system is an ADSL system.

12. The DSL system of Claim 1 wherein the DSL system is a VDSL system.

13. The DSL system of Claim 1 wherein the loops are bonded using one of the following bonding protocols: TDIM bonding; Ethernet bonding; ATM bonding; or the G.bond protocol.

14. A DSL system comprising:

a multiple loop segment, comprising K bonded loops providing up to (2K-1) communication channels on (2K-1) wires;

a first vectoring unit coupled to a first end of the segment and comprising a first vector signal processing module;

a second vectoring unit coupled to a second end of the segment and comprising a second vector signal processing module; and

wherein the first and second vectoring units provide vectored transmissions across the segment.

15. The DSL system of Claim 14 further comprising a controller coupled to the first and second vectoring units, wherein the controller comprises vectoring control means, wherein the vectoring control means assists in regulating transmissions across the segment.

16. The DSL system of Claim 14 wherein the first vectoring unit is in a first pedestal and further wherein the second vectoring unit is in a second pedestal.

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17. The DSL system of Claim 14 wherein the first vectoring unit is in a customer premises and further wherein the second vectoring unit is in a pedestal.

18. The DSL system of Claim 14 wherein the controller is a dynamic spectrum manager.

19. The DSL system of Claim 14 wherein the controller further comprises frequency bandwidth control means for regulating the frequency bandwidth used in transmissions across the segment.

20. The DSL system of Claim 14 further comprising a first impedance matching circuit coupled to the first end of the segment and a second impedance matching circuit coupled to the second end of the segment.

21. A DSL system comprising:

a multiple loop segment, comprising K bonded loops providing up to (2K-1) communication channels on (2K-1) wires;

a first impedance matching circuit coupled to a first end of the segment;

a first vector signal processing module coupled to the first impedance matching circuit;

a second impedance matching circuit coupled to a second end of the segment;

a second vector signal processing module coupled to the second impedance matching circuit; and

a controller coupled to the first and second vector signal processing modules comprising:

means for collecting data regarding transmissions across the segment; and

means for controlling vectoring of transmissions across the segment;

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wherein the first and second vector signal processing modules process transmissions across the segment.

22. The DSL system of Claim 21 wherein the first and second vector signal processing modules provide two-sided vectoring of transmissions across the segment.

23. The DSL system of Claim 21 wherein the first and second vector signal processing modules provide one-sided vectoring of transmissions across the segment.

24. The DSL system of Claim 21 wherein the segment couples customer premises equipment to a pedestal.

25. The system of Claim 21 wherein the segment couples a first pedestal to a second pedestal.

26. A method of providing high speed DSL service, the method comprising:

bonding K loops to provide a multiple loop segment having up to (2K-1) communication channels; and

vectoring transmissions across the segment.

27. The method of Claim 26 wherein the segment has a first end coupled to a first vectoring unit and a second end coupled to a second vectoring unit.

28. The method of Claim 26 wherein vectoring transmissions across the segment comprises one-sided vectoring.

29. The method of Claim 26 wherein vectoring transmissions across the segment comprises two-sided vectoring.

30. The method of Claim 26 wherein the vectored transmissions across the segment utilize an expanded frequency spectrum on at least one channel.

31. The method of Claim 26 wherein a controller provides vectoring control signals to the segment.

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32. The method of Claim 31 wherein the controller is a dynamic spectrum manager.

33. The method of Claim 31 wherein the controller is a DSM center.

34. The method of Claim 31 wherein the controller is a computer system.

35. The method of Claim 26 further comprising providing impedance matching circuits at each end of the segment.

36. The method of Claim 26 wherein bonding the loops comprises using one of the following bonding protocols: TDIM bonding; Ethernet bonding; ATM bonding; or the G.bond protocol.

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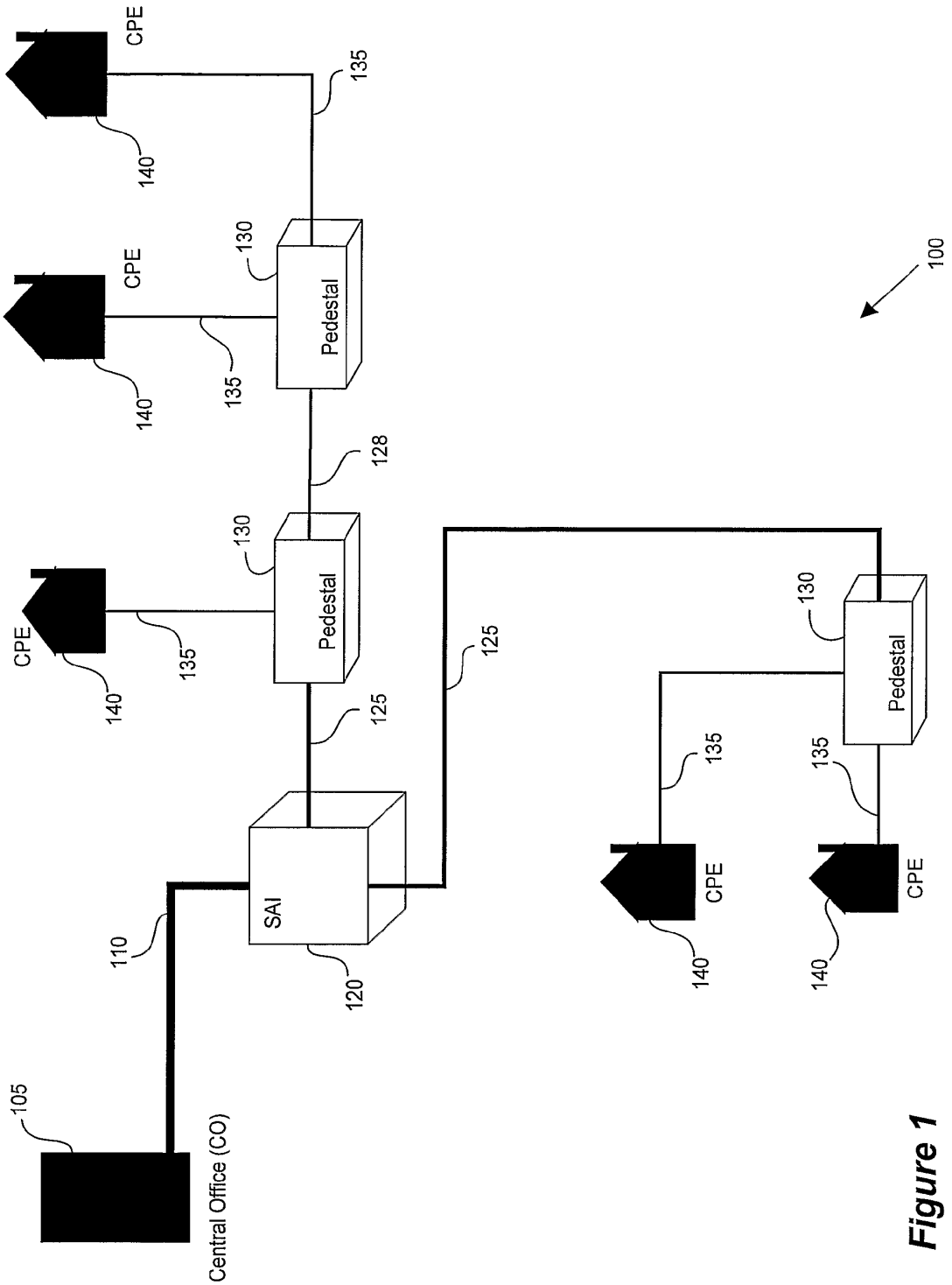
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Pedestal
CPE
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CPE
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Central Office (CO)
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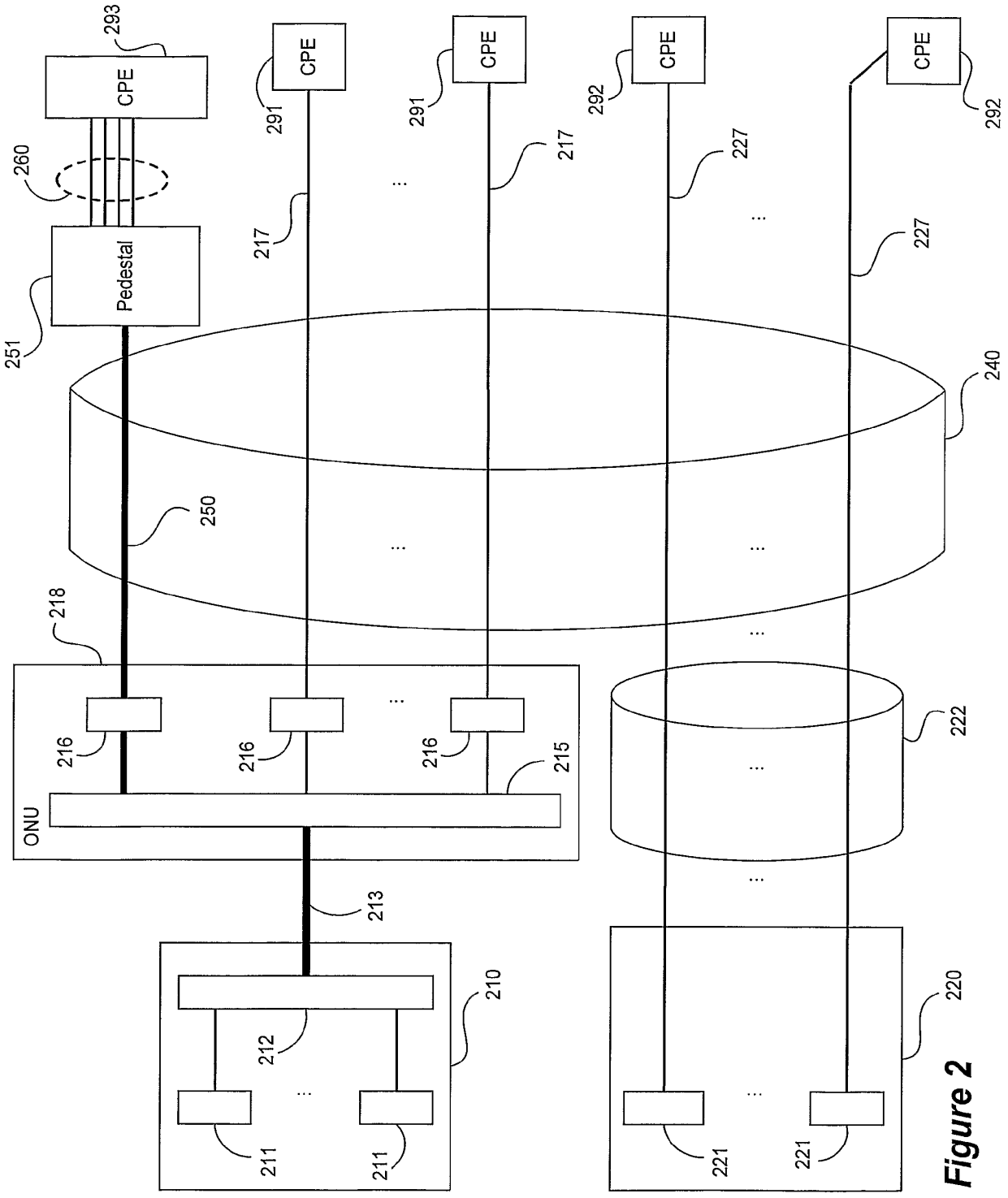
130
Pedestal
135
CPE
140
135
CPE
140
100

Figure 1


CPE
293
260
Pedestal
251
CPE
291
CPE
291
CPE
292
CPE
292
217
217
227
227
240
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218
ONU
216
216
216
215
222
213
210
212
211
211
220
221
221

Figure 2

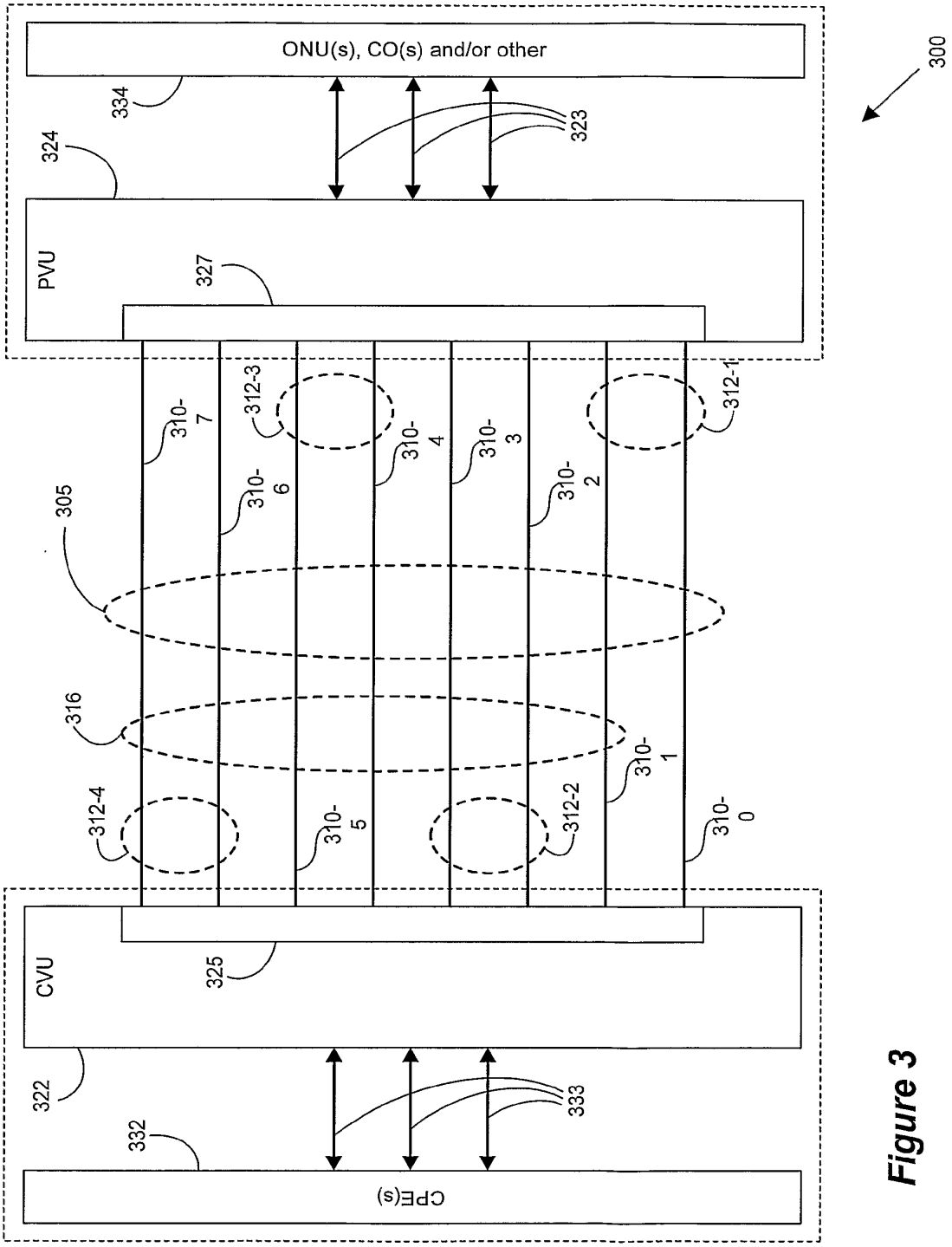
ONU(s), CO(s) and/or other
334
323
324
PVU
327
300
310-7
312-3
310-4
310-3
312-1
310-6
310-2
305
316
310-1
312-4
310-5
312-2
310-0
CVU
325
322
333
332
CPE(s)

Figure 3

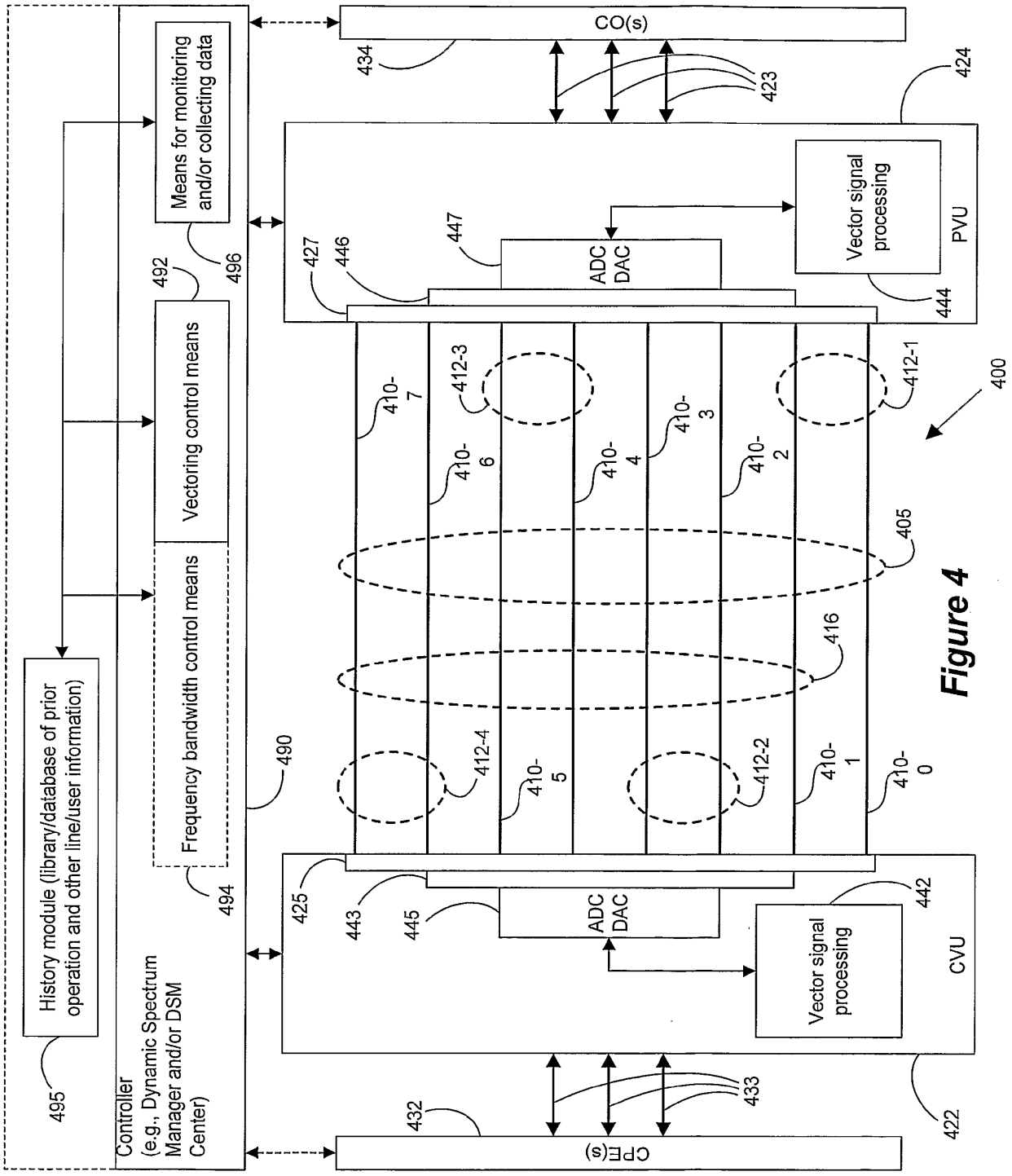
CO(s)
434
423
424
PVU
Vector signal processing
444
ADC
DAC
447
427
446
Means for monitoring and/or collecting data
496
492
Vectoring control means
Frequency bandwidth control means
494
490
History module (library/database of prior operation and other line/user information)
495
Controller
(e.g., Dynamic Spectrum Manager and/or DSM Center)
410-7
410-6
410-5
410-4
410-3
410-2
410-1
410-0
412-3
412-4
412-2
412-1
400
405
416
425
443
445
ADC
DAC
Vector signal processing
442
CVU
422
433
432
CPE(s)

Figure 4

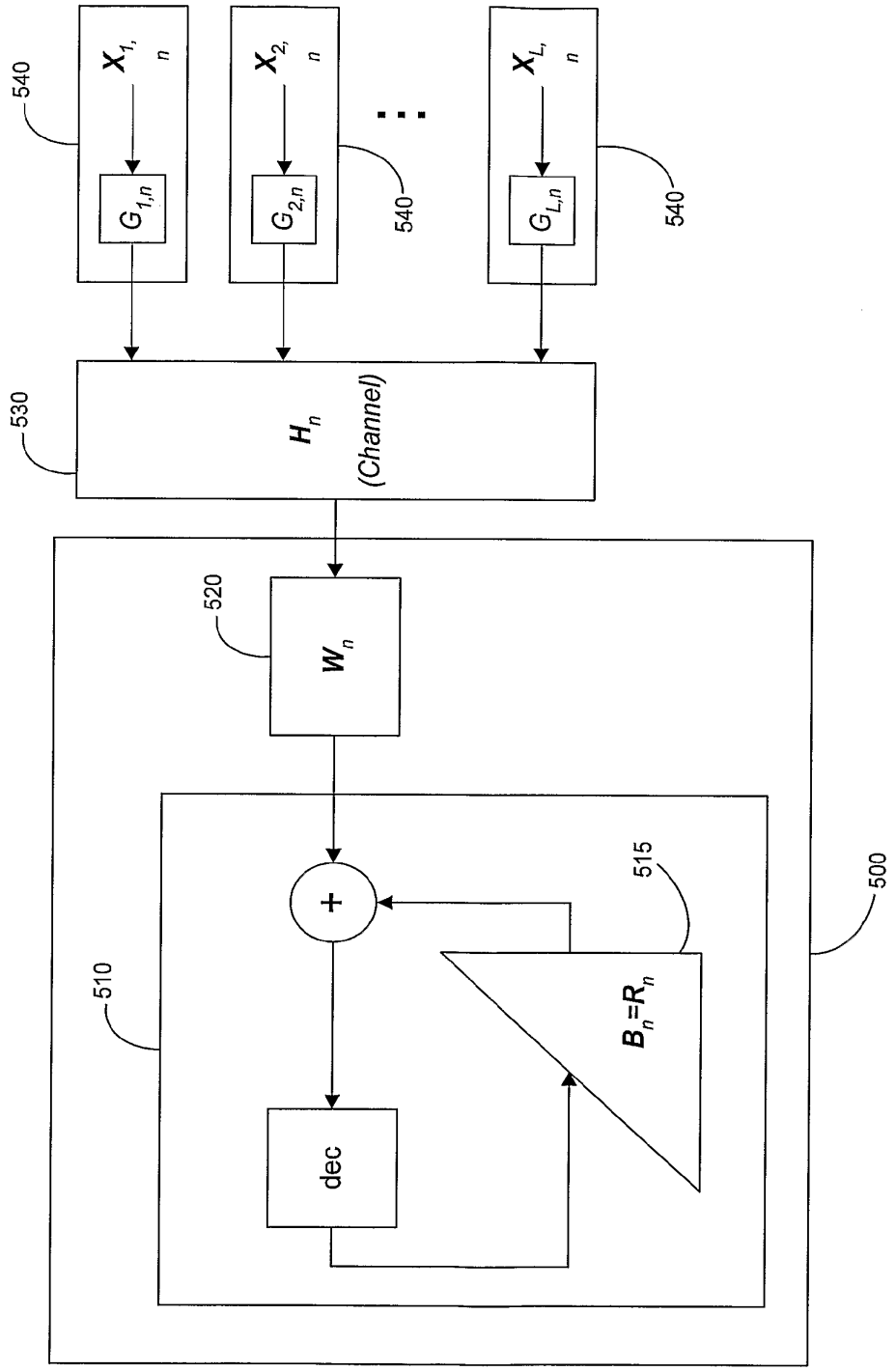
540
$X_{1,n}$
$G_{1,n}$
$X_{2,n}$
$G_{2,n}$
540
$X_{L,n}$
$G_{L,n}$
540
530
H_n
(Channel)
520
W_n
515
+
$B_n=R_n$
510
dec
500

Figure 5

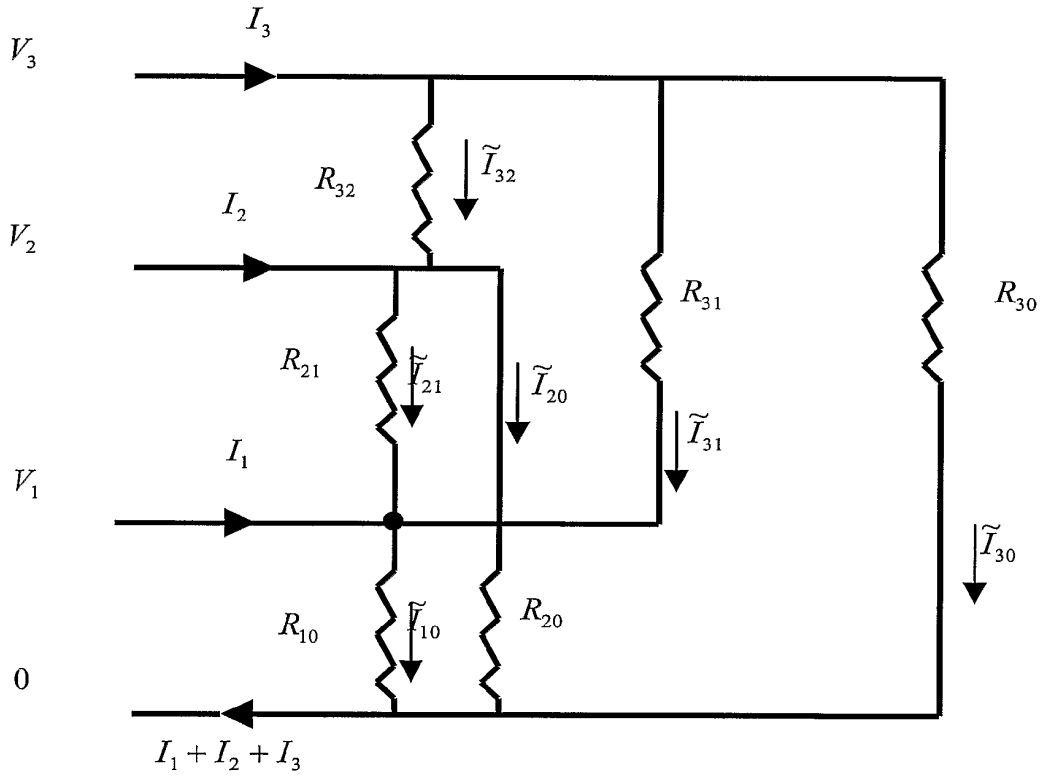
I_3
V_3
R_{32}
$\tilde{I}_{32}$
I_2
V_2
R_{31}
R_{30}
R_{21}
$\tilde{I}_{21}$
$\tilde{I}_{20}$
$\tilde{I}_{31}$
I_1
V_1
$\tilde{I}_{30}$
R_{10}
$\tilde{I}_{10}$
R_{20}
0
$I_1 + I_2 + I_3$

Figure 6

Using 8192 tones

7x7 Channel

Line length	Speed
50 m	3379.456 Mbps
100 m	3292.700 Mbps
150 m	3086.508 Mbps
200 m	2860.460 Mbps
250 m	2622.604 Mbps
300 m	2430.580 Mbps

4x4 Channel

Line length	Speed
50 m	1835.644 Mbps
100 m	1851.464 Mbps
150 m	1831.016 Mbps
200 m	1714.832 Mbps
250 m	1555.568 Mbps
300 m	1389.960 Mbps

Using 4096 tones

7x7 Channel

Line length	Speed
50 m	1694.620 Mbps
100 m	1693.324 Mbps
150 m	1684.680 Mbps
200 m	1626.964 Mbps
250 m	1556.748 Mbps
300 m	1481.112 Mbps

4x4 Channel

Line length	Speed
50 m	927.272 Mbps
100 m	934.376 Mbps
150 m	939.040 Mbps
200 m	938.220 Mbps
250 m	934.188 Mbps
300 m	901.836 Mbps

Figure 7

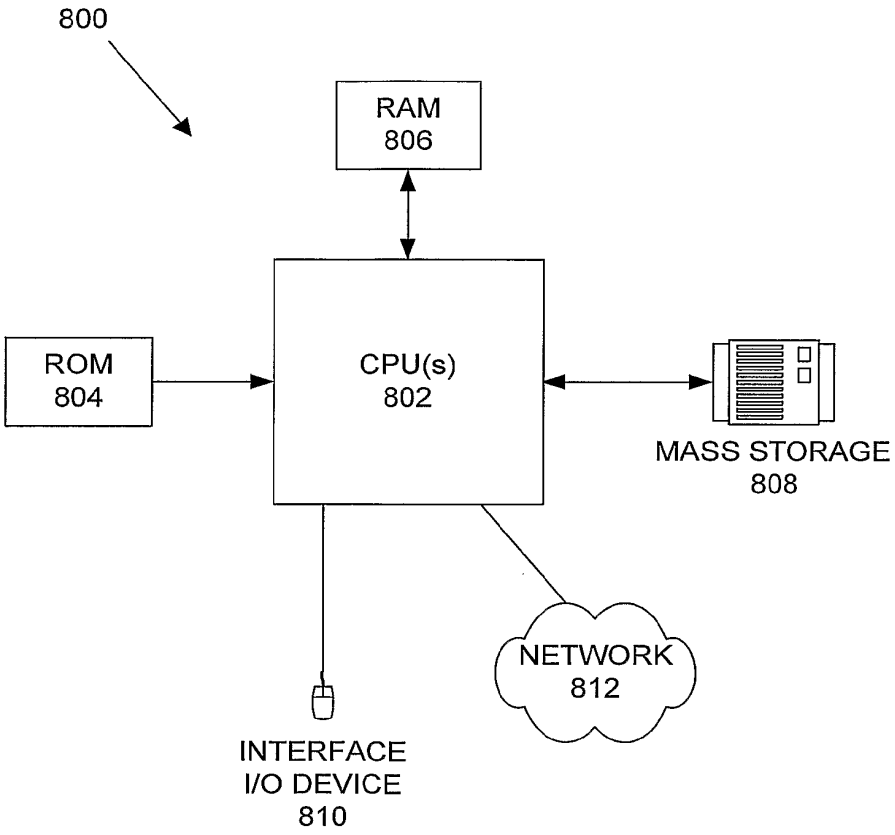
800
RAM
806
ROM
804
CPU(s)
802
MASS STORAGE
808
NETWORK
812
INTERFACE
I/O DEVICE
810

Figure 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB2005/000714

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04M11/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 03/105339 A (TOKYO ELECTRON LIMITED; TSATSANIS, MICHAIL; ERICKSON, MARK, A; SHAH, S) 18 December 2003 (2003-12-18) abstract; figures 2,5,6,11 paragraph '0014! - paragraph '0016! paragraph '0042! - paragraph '0061!	1-36
X	EP 1 009 154 A (LUCENT TECHNOLOGIES INC) 14 June 2000 (2000-06-14) abstract; figure 5 paragraphs '0020!, '0024!, '0025! paragraphs '0033! - '0036!	1-36

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 August 2005	08/08/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	DE LA PENA ALVAREZ

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB2005/000714

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 03105339 A	18-12-2003	AU 2003237502 A1	22-12-2003
		AU 2003237504 A1	22-12-2003
		AU 2003247506 A1	22-12-2003
		AU 2003251417 A1	22-12-2003
		WO 03105352 A2	18-12-2003
		WO 03105339 A1	18-12-2003
		WO 03105369 A1	18-12-2003
		WO 03105431 A1	18-12-2003
EP 1009154 A	14-06-2000	CA 2287690 A1	07-06-2000
		EP 1009154 A2	14-06-2000
		JP 2000232664 A	22-08-2000
		TW 445736 B	11-07-2001

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19 September 2003 (19.09.2003)

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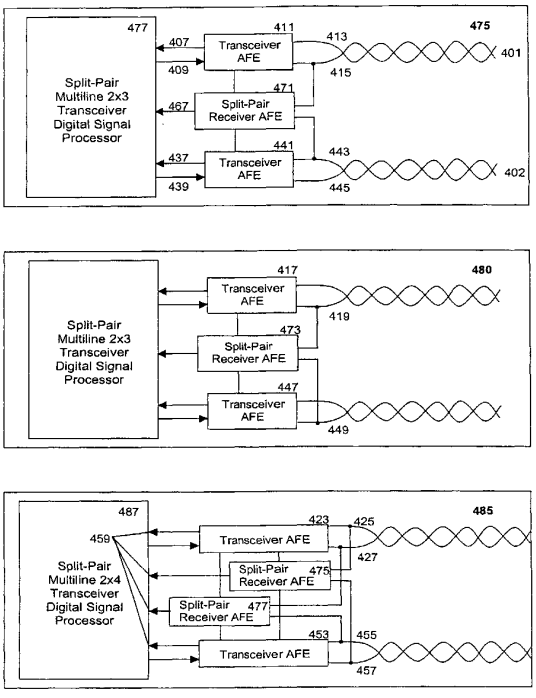
(74) Agent: **DUTTA, Sanjeet, K.**; 12400 Wilshire Boulevard, Seventh Floor, Los Angeles, CA 90025 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: METHOD AND SYSTEM FOR SPLIT-PAIR RECEPTION IN TWISTED-PAIR COMMUNICATION SYSTEMS



(57) Abstract: A method and system are disclosed for improving the performance of a multiline transmission system by using one or more split-pair receivers in a multiline communications system to identify crosstalk on a pair of transceivers coupled to the split pair receivers, wherein each split pair receiver receives a signal including the crosstalk from each transceiver and provides a corresponding signal vector to a post processing unit, and performing MIMO post-processing on signal vectors received at a receiver from each transceiver and each split-pair receiver while minimizing crosstalk on pairs of lines in the multiline communications system with a frequency equalizer.

WO 2004/027579 A2

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Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHOD AND SYSTEM FOR SPLIT-PAIR RECEPTION IN TWISTED-PAIR COMMUNICATION SYSTEMS

[0001] This application claims the benefit of the filing date of the following Provisional U.S. Patent Application:

Split-Pair Signals in Communications Systems, U.S. Provisional Application Serial No. 60/412,160, filed on September 19, 2002.

Field of the Invention

[0002] The present invention relates generally to copper-based communication systems and, in particular to, multiple line transmission in copper-based communication systems.

Background of the Invention

[0003] The explosive popularity of the Internet has ushered in a new era for telecommunications. The expanding use of applications such as e-mail, online services, secure electronic transactions, media file sharing, video conferencing, remote collaboration, and telecommuting, to name but a few, is causing a significant increase in the bandwidth needs and demands of telecommunications users.

[0004] As a result, service providers around the world are continuously searching for economically attractive ways of deploying new high-bandwidth, high-revenue services. Over the last few years, telephone, cable, and wireless operators have been upgrading their equipment in order to utilize their existing infrastructures for higher-bitrate services. The result has been the widespread availability of high-speed data connectivity through Digital Subscriber Line (DSL) service, high-speed digital cable, and, more recently, Third Generation (3G) wireless networks.

[0005] Copper telephone lines are generally viewed as the most widely available access medium that is suitable for high-speed data connectivity. In an impressive display of technological progress, the lines that until a few years ago carried only low-speed voice services, are now used to deliver services running at speeds up to several Mbps (Mega-bits per second). This progress has caused the existing copper infrastructure to be viewed as a significant capital asset that telephone carriers can utilize to meet the increasing bandwidth demands of their customers.

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[0006] Over the last two decades, several technologies for data transmission over copper lines have been developed, including, but not limited to these technologies: T1/E1, ISDN (integrated services digital network), HDSL (High Speed DSL), SDSL (Symmetric DSL), ADSL (Asymmetric DSL), VDSL (Very High Speed DSL) and ADSL2. These technologies have continued to increase the data throughput that can be delivered over copper, but that progress is now being slowed by the shortcomings of the existing copper infrastructure.

[0007] Typically, a copper line consists of two copper wires that are twisted together to produce a "twisted copper pair." Multiple twisted pairs are then twisted together into bundles called "binders." Twisting of pairs was not used in the early days of voice telephony. It was introduced later in an effort to reduce the effect of interference noise on the received signal. The logic behind this noise reduction is as follows: Interference noise on each copper pair is caused by sources outside the copper pair, such as services operating on other copper pairs in the same binder or in adjacent binders, radio towers, power wires, electrical appliances at the customer's premises, etc. Those sources transmit signals whose electromagnetic fields generate noise voltage signals on each copper wire. If the two wires were not twisted together, the electromagnetic fields from the noise sources could potentially have very different values on each of the two wires, and thus they could generate very different noise voltage signals on each of the two wires. By twisting the two wires together in a copper pair, the electromagnetic fields from the noise sources have roughly the same value on both wires, and therefore they generate noise voltage signals that are approximately equal on both wires. Therefore, when these approximately equal noise signals are subtracted at the differential receiver of the copper pair, the resulting differential noise voltage signal is much smaller than it would have been had the two wires not been twisted. On the other hand, the main communications signal, which is transmitted as the voltage difference between the two wires of the copper pair, is not affected by the twisting of the wires and is received by the differential receiver in full strength. Therefore, the use of twisted copper pairs and differential receivers reduces the effect of the noise only, and does not have a similar reduction effect on the main signal. As a result, the SNR (Signal-to-Noise Ratio), and thus also the communications capacity, that can be achieved on a twisted copper pair with a differential transmitter and receiver is substantially higher than the SNR of an untwisted copper pair of the same gauge and length with a common-mode (i.e., non-differential) transmitter and receiver.

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[0008] When telephone carriers began setting the specifications for the copper pairs used in their cables, including the gauge and twisting of the wires, they considered only POTS (Plain-Old Telephone Service) voice services, which typically occupy only a small frequency band at the low end of the spectrum, approximately from 0 to 4 kHz. As a result, they decided to use relatively thin wires, mostly 26AWG and 24AWG, and to twist them once every few feet or so. At the time, these choices of gauge and twist length represented an excellent tradeoff between performance and cost. Wires of larger gauges that are twisted more tightly cost more to produce and are heavier, larger, and less flexible; therefore, they also cost more to transport and to install. Moreover, having enough copper pairs to serve all the current and future customers in a given area means that, as the wires become larger and heavier, the underground conduits that carry them have to be larger, and the poles that support them have to be sturdier. Since POTS service utilizes frequencies below 4 kHz, these choices of gauge and twist length were perfectly adequate for ensuring high-quality POTS service with very low crosstalk noise. Crosstalk originally denoted the noise that was generated when the voice of one telephone subscriber talking on his line "crossed" into another subscriber's line and could be heard as low-volume background speech.

[0009] Unfortunately, these choices do not guarantee the same performance when the copper pairs are used to deliver high-speed data services, which typically operate at frequencies that are more than 100 times higher than POTS frequencies. The small gauge of the wires results in high attenuation of high-frequency signals; as a result, the data capacity of a copper pair decreases rapidly as the length of the pair increases. Even worse, the long twisting of existing copper pairs is much less effective at reducing crosstalk noise at higher frequencies. As the frequencies used for transmission and reception of signals rise, the wavelengths of those signals are reduced. Therefore, pairs with long twisting appear more and more as untwisted pairs to the corresponding short-wavelength electromagnetic fields. Since the cost of replacing existing copper pairs with new ones that have much shorter twisting would be prohibitively high, the only economically viable option is to use existing pairs for the transmission of high-speed data services. As a result, high-speed data services are much more sensitive to crosstalk noise from outside sources. This is especially detrimental on longer lines, since the main signal on those lines is already significantly attenuated; as a result, the increased crosstalk noise often reduces the SNR to levels that are not suitable for high-speed data transmission.

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[00010] The realization that crosstalk is one of the primary causes of performance degradation in high-speed data transmission over copper pairs has resulted in substantial attention to the problem of mitigating crosstalk. Transmission technologies designed for operation over a single copper pair attempt to mitigate crosstalk through the use advanced coding schemes and adaptive filters that aim to maximize SNR in a given crosstalk environment. Such mitigation techniques have evolved steadily over the last decade, and have reached a level of maturity where small additional SNR gains come at the cost of significant increases in complexity.

[00011] The most recent advance in the effort to mitigate crosstalk on copper pairs is the use of "vectoring" in multiline transmission schemes. In such schemes, multiple copper pairs are used to deliver high-speed services; but instead of simply using each copper pair as a separate communications channel and "bonding" the corresponding data streams at the digital layer, vectoring techniques coordinate the transmission and/or reception of signals at the physical layer, in order to increase the overall capacity of the multiline communications channel. One such vectoring scheme, disclosed in a recent application PCT/US 03/18004, which is incorporated herein by reference, exploits the correlation of crosstalk noise across its associated multiple copper pairs. In particular, that scheme treats the transmitters and receivers on multiple copper pairs as inputs and outputs of a MIMO (Multiple Input Multiple Output) communications channel. Operating in the signal space defined by these multiple inputs and outputs, the scheme identifies the subspace that contains the crosstalk noise, and then uses MIMO pre-processing at the transmitter and MIMO post-processing at the receiver to transmit most of its main signal in the subspace that is orthogonal to the crosstalk noise. For DMT (Discrete-Multi-Tone) systems, these operations are simply matrix multiplications in the frequency domain. The MIMO post-processing at the receiver consists of multiplying the received symbol vector in each bin by a matrix that combines the operations of noise pre-whitening and frequency equalization. The MIMO pre-processing at the transmitter consists of multiplying the transmitted symbol vector in each bin with a matrix that compensates for the distortion caused by the noise pre-whitening matrix at the receiver. As a result, the main signal is received without distortion, while the crosstalk noise, which is not multiplied by the MIMO pre-processing matrix, is restricted to a small subspace of the received signal space.

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[00012] Another way of interpreting the vectoring effect of that MIMO scheme is that it identifies the crosstalk noise on some of its receivers and then removes it from the remaining receivers, thereby significantly reducing its overall effect. As a rule of thumb, the effectiveness of this type of crosstalk mitigation is reduced as the number of strong independent crosstalk sources increases beyond the number of receivers available in the multiline system. This is due to the fact that each independent crosstalk source increases the dimension of the crosstalk subspace by one. As the number of such crosstalk sources increases beyond the number of receivers available, the dimension of the crosstalk subspace becomes equal to the dimension of the signal space of the multiline system, thereby eliminating the orthogonal subspace where the main signal can be received free of crosstalk noise.

[00013] Therefore, it would be desirable to find a way to increase the dimension of the signal space in a multiline system for a given number of copper pairs used.

Summary Of The Invention

[00014] A method and system are disclosed for improving the performance of a multiline transmission system by adding "split-pair" receivers to measure and process additional signals across copper pairs. These additional "split-pair" receivers increase the dimension of the signal space and therefore enhance the crosstalk mitigation abilities of the multiline system.

Brief Description Of The Drawings

[00015] Features and advantages of the present invention will be apparent to one skilled in the art in light of the following detailed description in which:

[00016] **Figure 1** illustrates an exemplary communication system that may benefit from the present method and system;

[00017] **Figure 2** illustrates an exemplary embodiment of a communication system, wherein the present method and system may be implemented;

[00018] **Figure 3** illustrates an exemplary two-pair multiline transmission system for reducing crosstalk noise utilizing one AFE (Analog Front End) circuit for each copper pair, for a total of two AFE circuits;

[00019] **Figure 4A** illustrates various two-pair multiline transmission systems corresponding to several exemplary embodiments of the present invention as applied to two-pair multiline transmission systems;

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[00020] **Figure 4B** illustrates a split-pair receiver circuit according to one embodiment of the present invention;

[00021] **Figure 5** illustrates an exemplary functional block diagram of split-pair MIMO processing according to one embodiment of the present invention;

[00022] **Figure 6** illustrates an exemplary split-pair MIMO transmission process 600 once a processing architecture is computed according to one embodiment of the present invention; and

[00023] **Figure 7** illustrates an exemplary block diagram of a computer system 2000 representing an integrated multi- processor, in which elements of the present invention may be implemented.

Detailed Description

[00024] A method and system are described for improving the performance of a multiline transmission system by receiving additional signals across copper pairs. For purposes of discussing and illustrating the invention, an example of a multiline system using two copper pairs will be described. However, one skilled in the art will recognize and appreciate that the same methodology can be applied to multiline systems with more than two copper pairs.

[00025] In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be evident, however, to one skilled in the art that the present invention may be practiced without these specific details. In some instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring the present invention. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, mechanical, electrical, and other changes may be made without departing from the scope of the present invention.

[00026] Some portions of the detailed descriptions that follow are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of acts leading to a desired result. The acts

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are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

[00027] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[00028] In varying embodiments, the present invention can be implemented by an apparatus for performing the disclosed method. The apparatus may be specially constructed or may comprise a general-purpose computer such that when configured by a computer program executes the disclosed method. Such a computer program may be stored in a computer readable storage medium, such as, but not limited to, floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), magnetic or optical cards, or any type of media suitable for storing electronic instructions.

[00029] The methods of the invention may be implemented using computer software. If written in a programming language conforming to a recognized standard, sequences of instructions designed to implement the methods can be compiled for execution on a variety of hardware platforms and for interface to a variety of operating systems. In addition, the present invention is not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the invention as described herein. Furthermore, it is common in the art to speak of software, in one form or another (e.g., program, procedure, application...), as taking an action or causing a result. Such expressions are merely a shorthand way of saying that execution of the software by a

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computer causes the processor of the computer to perform an action or produce a result.

[00030] The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general-purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct a more specialized apparatus to perform the required method. For example, any of the methods according to the present invention can be implemented in hard-wired circuitry, by programming a general-purpose processor or by any combination of hardware and software. One of skill in the art will appreciate that the invention can be practiced with computer system configurations other than those described below, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, DSP devices, network PCs, minicomputers, mainframe computers, and the like. The invention can also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. The required structure for a variety of these systems will appear from the description below.

[00031] It is to be understood that various terms and techniques are used by those knowledgeable in the art to describe communications, protocols, applications, implementations, mechanisms, etc. One such technique is the description of an implementation of a technique in terms of an algorithm or mathematical expression. That is, while the technique may be, for example, implemented as executing code on a computer, the expression of that technique may be more aptly and succinctly conveyed and communicated as a formula, algorithm, or mathematical expression. Thus, one skilled in the art would recognize a block denoting A+B=C as an additive function whose implementation in hardware and/or software would take two inputs (A and B) and produce a summation output (C). Thus, the use of formula, algorithm, or mathematical expression as descriptions is to be understood as having a physical embodiment in at least hardware and/or software (such as a computer system in which the techniques of the present invention may be practiced as well as implemented as an embodiment).

Overview of a General Communication Network

[00032] **Figure 1** illustrates an exemplary communication system 105 that may benefit from the present method and system. The backbone network 120 is generally accessed by a user through a multitude of access multiplexers 130 such as: base

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stations, DSLAMs (DSL Access Mulitplexers), or switchboards. The access multiplexers 130 communicate with the network users. The user equipment 140 exchanges user information, such as user data and management data, with the access multiplexer 130 in a downstream and upstream fashion. The upstream data transmission is initiated at the user equipment 140 such that the user data is transmitted from the user equipment 140 to the access multiplexer 130. Conversely, the downstream data is transmitted from the access multiplexer 130 to the user equipment 140. User equipment 140 may consist of various types of receivers that contain modems such as: cable modems, DSL modems, and wireless modems. In this network access system the current method and system may be practiced to identify sources of interference in the access channels.

Overview of Exemplary DSL System

[00033] "DSL" is to be understood to refer to a variety of Digital Subscriber Line (DSL) standards that, even now, are evolving. Each DSL standard will be referred to as a DSL service type. At the present time, DSL service types include, but are not limited to, ADSL, SDSL, HDSL, and VDSL (Asymmetrical, Symmetrical, High speed, and Very high speed DSL, respectively).

[00034] **Figure 2** illustrates an exemplary embodiment of a communication system wherein the present invention may be implemented. A central office 202 has a series of DSL modems 204-1 through 204-N, including transceivers 214-1 through 214-N, connected via twisted pairs 206-1 through 206-N as a bundle 208 connected to customers DSL 210-1 through 210-N, including transceivers 216-1 through 216-N, which is connected respectively to customer's premise equipment (CPE) 212, such as a local area network or computer. One skilled in the art recognizes that twisted pair bundle 208 may experience crosstalk between the twisted pairs 206-1 through 206-N and depending upon the services carried by the pairs, data rates, and other factors, such as proximity of the pairs to each other, etc., there may be varying types of crosstalk on each pair, such as alien or out of domain crosstalk.

Split-Pair Receiver AFE

[00035] The present invention discloses a method for improving the crosstalk mitigation capabilities of a multiline system by increasing the dimension of the signal space without increasing the number of copper pairs. By inserting additional receiver circuitry between the wires of adjacent copper pairs and modifying the multiline

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transmission scheme to incorporate the additional receiver measurements, it is possible to increase the dimension of signal space within the multiline system while maintaining the existing quantity of copper pairs. This effectively "splits" the copper pairs of the multiline system, and is therefore called a "split-pair" receiver.

[00036] **Figure 3** illustrates an exemplary two-pair multiline transmission system for reducing crosstalk noise utilizing one AFE (Analog Front End) circuit for each copper pair, for a total of two AFE circuits. The multiline system 301 includes two separate but essentially identical AFE circuits 311 and 341, each devoted to one of the two copper pairs connected to the multiline system 301 at Tip1 313, Ring1 315, Tip2 343, and Ring2 345, respectively. Differential receiver lines 302 and 306 are connected to the multiline 2x2 transceiver 303 for receiving signals from their associated twisted copper pairs 313, 315, and 343, 345, respectively. Differential transmission lines 304 and 308 are connected to the multiline 2x2 transceiver 303 for transmitting signals through to their associated twisted copper pairs 313, 315, and 343, 345, respectively.

[00037] The multiline 2x2 transceiver 303 includes a digital signal processor wherein MIMO processing can be performed in either the time domain or the frequency domain as further discussed below in reference to **Figures 5, 6, and 7**. The 2x2 designation refers to the number of differential transmitter lines, in this case two, 304 and 308, and the number of differential receiver lines, again two, 302 and 306. Further, 2x2 defines the size of the matrix associated with the MIMO processing scheme.

[00038] Transceiver AFEs 310 and 340 illustrate in more detail the transceivers 311 and 341 of multiline transmission system 301. Drive1P 316, Drive1N 318, Drive2P 346 and Drive2N 348 further illustrate differential transmission lines 304 and 308. Recvr1P 320, Recvr1N 322, Recvr2P 350 and Recvr2N 352 further illustrate differential receiver lines 302 and 306. Tip1 312 and Ring1 314 illustrate twisted pair 313 and 315, respectively, of multiline transmission system 301 in AFE 310. Tip2 342, and Ring2 344 illustrate twisted pair 343 and 345, respectively, of multiline transmission system 301 in AFE 340.

[00039] The addition of split-pair receivers enhances the crosstalk mitigation capability of the multiline system over the two-pair multiline transmission system. The addition of split-pair circuitry increases the number of receivers that can be used to identify independent sources of crosstalk noise, and therefore increase the number of receivers from which the crosstalk noise can be effectively removed. This increases the dimension of the crosstalk-free subspace of the multiline system, and therefore

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increases the total bitrate that can be supported by the multiline system in a given crosstalk noise environment.

[00040] **Figure 4A** illustrates various two-pair multiline transmission systems corresponding to several exemplary embodiments of the present invention as applied to two-pair multiline transmission systems. Multiline transmission system 475 has transceiver AFEs 411 and 441 as similarly described in reference to **Figure 3** but with an additional split pair receiver 471. AFE 411 connects to twisted pair 401 through inputs Tip1 413 and Ring1 415. AFE 441 connects to twisted pair 402 through inputs Tip2 443 and Ring2 445. The split pair receiver 471 has two inputs that connect to Ring1 415 and Tip2 443. Additionally, multiline 2x3 transceiver 477 transmits signals to AFE 411 and 441 through differential lines 409 and 439, respectively. Multiline 2x3 transceiver 477 also receives signals from AFE 411, 441, and split pair receiver 471 through differential lines 407, 437,and 467, respectively. In this case, the 2x3 refers to the two differential transmitter lines, 409 and 439, and the three differential receiver lines, 407, 437, and 467. Further, 2x3 defines the size of the matrix associated with the MIMO processing discussed below with reference to **Figures 5** through **7**.

[00041] In another embodiment of the present invention, multiline transmission system 481 has transceiver AFEs 417 and 447, and split pair receiver 473, similarly described above with reference to the multiline transmission system 475. In this embodiment, however, the two inputs of split pair receiver 471 are connected to Ring1 419 and Ring2 449.

[00042] In yet another embodiment of the present invention, multiline transmission system 485 has transceiver AFEs 423 and 453, and split pair receivers 475 and 477. The two inputs of split pair receiver 475 are connected to Tip1 425 and Ring2 457 and the two inputs of split pair receiver 477 are connected to Ring1 427 and Tip2 455. The multiline 2x4 transceiver 487 receives differential input 459 from transceiver AFEs 423 and 453, and split pair receivers 475 and 477. The additional split pair receiver 477 adds an additional dimension (a fourth receiver input) to the matrix associated with the MIMO processing discussed below with reference to **Figures 5** through **7**.

[00043] **Figure 4B** illustrates a split-pair receiver circuit 400, according to one embodiment of the present invention. There are two separate but essentially identical AFE circuits 410 and 440, each devoted to one of the two copper pairs connected to the multiline system at Tip1 412, Ring1 414, Tip2 442, and Ring2 444, respectively. The

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differential lines Drive1P 416, Drive1N 418, Drive2P 446 and Drive2N 448 are connected to multiline transceiver circuitry (not shown) for transmitting signals through to their associated twisted copper pairs. The differential lines Recvr1P 420, Recvr1N 422, Recvr2P 450, Recvr2N 452 are connected to multiline transceiver circuitry for receiving signals through their associated twisted copper pairs. Additionally, a split pair receiver 470 is connected between AFEs 410 and 440. The split pair receiver 470 is a passive circuit coupled to AFE 410 by a connection at Ring1 414 and another connection at Tip2 442. Differential lines, Recvr12P 476 and Recvr12N 478, are also connected to the multiline transceiver circuitry.

[00044] One of ordinary skill in the art will recognize the additional circuit 470 as a passive receiver-only circuit. There is no driver for the split-pair receiver circuit 470 because it does not transmit any signals. The standard transceivers of AFEs 410 and 440 continue to transmit and receive signals in accordance with standard operations. The circuit 470 is balanced with respect to circuits 410 and 440, so that it neither affects nor is affected by their transmitted signals.

[00045] Further, it should be recognized by one of ordinary skill in the art, that the same concept is applicable to multiline systems that use more than two copper pairs. In particular, in a multiline system that uses N copper pairs, one can add up to N-1 split-pair receivers and process a total of 2N-1 received signals. These split-pair receivers can be added in many different configurations; for example, in a multiline system that uses three copper pairs, up to two split-pair receivers can be added between Ring1-Tip2 and Ring2-Tip3, or Tip1-Ring2 and Tip2-Ring3, or Ring1-Tip3 and Ring3-Tip2, or Tip1-Ring3 and Tip3-Ring2, or Ring1-Ring2 and Tip2-Tip3, and so on.

[00046] The reasoning behind limiting to N-1 the number of split-pair receivers in a multiline system that uses N copper pairs is that the total number of wires is 2N, and one of the wires is considered a reference ground for the differential receiver scheme, so that the total number of independent measurements that can be made on 2N wires is 2N-1. Since there are already N standard-pair receivers in the multiline system, adding more than N-1 split-pair receivers would produce measurements that are not independent. Nevertheless, one can use more than N-1 split-pair receivers to obtain repeated measurements of the main signal and the crosstalk noise. For example, the embodiment 485 illustrated in **Figure 4A** shows a two-pair multiline system with two split-pair receivers 475 connected to Tip1 425 and Ring2 457, and 477 connected to Ring1 427 and Tip2 455. In general, in a multiline system that uses two copper pairs,

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one could add up to four split-pair receivers: Ring1-Tip2, Ring2-Tip1, Ring1-Ring2, and Tip1-Tip2. This addition would reduce the effect of the thermal background noise, which is independent on each receiver, and would therefore result in improved measurements of the main signal and the crosstalk noise. However, since additional receivers come at an additional component cost, it would be up to the system designer to decide whether the small increases in performance that can be obtained by adding more than N-1 split-pair receivers are enough to justify the extra cost.

[00047] The next step in the effort to enhance the performance of multiline systems would be to consider each wire in a copper pair as independent, and use it to transmit a separate signal. This scheme would result in the transmission of up to 2N-1 independent main signals over a multiline system that uses N copper pairs, and would further increase the data capacity of such a multiline system. However, the implementation of such a split-pair transmission scheme is not practical in the public telephone network, since there are strict regulations that severely limit the transmission of common-mode signals over copper pairs, in order to prevent excessive interference to the installed base of services using differential receivers. On the other hand, the addition of split-pair receivers, as disclosed in the present invention, is a passive receiver-only enhancement, and as such it is not limited by public telephone network regulations.

Split-Pair MIMO Processing

[00048] As is the case with MIMO processing schemes that use only standard receivers across copper pairs, the claimed method and system for split-pair receivers in the present invention is applicable to both frequency-domain transmission schemes, such as the Discrete Multi-Tone (DMT) scheme defined in the G.dmt and G.lite standards of the International Telecommunications Union (ITU), and time-domain transmission schemes, such as the 2B1Q scheme defined in the HDSL standard of the American National Standards Institute (ANSI). The preferred embodiment is with frequency-domain schemes, because the split-pair MIMO processing can be performed much more efficiently in the frequency domain, where it reduces to a simple matrix multiplication in each of the independent frequency bins. Frequency bins are the small frequency bands surrounding each individual "tone" or frequency carrier in a DMT system.

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[00049] **Figure 5** illustrates an exemplary functional block diagram 500 of split-pair MIMO (Multiple Input Multiple Output) processing according to one embodiment of the present invention. Referring to the block diagram of **Figure 5**, we use the following notations:

k denotes the kth DMT symbol;

n_s denotes the number of elements in the transmitted signal vector, which is equal to the number of transmitters used in the multiline system;

n_r denotes the number of elements in the received signal vector, which is equal to the total number of receivers used in the multiline system, including standard receivers and split-pair receivers;

n_d denotes the number of independent crosstalk noise sources that affect the multiline system;

$\underline{w}(k)$ 505 is a vector of symbols for a single frequency bin, which has n_s elements;

$\underline{x}(k)$ 525 is a vector of signals to be transmitted in a single frequency bin after MIMO transmitter pre-processing, which has n_s elements;

$\underline{y}(k)$ 535 is a vector of received signals in a single frequency bin before MIMO receiver post-processing, which has n_r elements;

$\underline{z}(k)$ 545 is a vector of symbols to be decoded in a single frequency bin after MIMO receiver post-processing, which has n_s elements;

$\underline{d}(k)$ 515 is the vector of interference signals, which has n_d elements;

H_m 520 is the main channel matrix for a single frequency bin, which is of dimension $n_r \times n_s$;

H_d 530 is the interference matrix for a single frequency bin, which is of dimension $n_r \times n_d$;

B 510 is the transmitter MIMO pre-processing matrix for a single frequency bin, which is of dimension $n_s \times n_s$; and

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$\mathcal{A}$ 550 is the receiver MIMO post-processing matrix for a single frequency bin, which is of dimension $n_s \times n_r$.

[00050] The present invention assumes that the prefix is long enough and the time equalizer (TEQ) is designed well enough that there is no Inter-Block Interference (IBI), that H_m is a full-rank matrix (this is always true if the multiline system uses exactly one transmitter per copper pair and at least one receiver per copper pair), and that the elements of $\underline{d}(k)$ 515 are random variables with $E\left[\underline{d}(i)\underline{d}^H(j)\right] = \mathrm{R}_d$ for $i = j$ and *0* otherwise, implying that the interference noise is uncorrelated between different symbols; one skilled in the art will recognize that this is only approximately true in practice, but that this approximation is a very good one for all practical purposes.

[00051] The pair of matrices $\mathcal{A}$ 550 and B 510 are computed with the following properties:

1. B 510 is Hermitian, so that the transmitted signal power is preserved across pairs by the pre-processing operation;

2. $\mathcal{A}H_m B = I$, so that the symbol vector component of the received signal is the same as the transmitted symbol vector, this allows the received signal to be sliced correctly after receiver post-processing; and

3. the sum of the SNRs (expressed in dB) of the independent received signals, i.e., the elements of the received symbol vector $\underline{z}(k)$, is maximized.

[00052] The algorithm that solves this problem is as follows:

Step 1: C is computed by solving the equation $CH_d \mathrm{R}_d H_d^H C^H = I$. This implies that that $\mathrm{E}\left[CH_d \underline{d}\underline{d}^H H_d^H C^H\right] = I$. The resulting matrix C is a square matrix of dimension $n_r \times n_r$.

Step 2: The $n_r \times n_s$ matrix U and the $n_s \times n_s$ matrices Σ and V are computed as the solutions of the SVD (Singular Value Decomposition) equation $U\Sigma V^H = CH_m$.

Step 3: Then $B = V$ and $\mathcal{A} = \Sigma^{-1}U^H C$.

[00053] This solution has the following properties:

Property 1 is satisfied by Step 3, since the matrix V is unitary.

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Property 2 can be verified by substituting the equalities in Step 2 and Step 3 into the expression of the property:

$$\mathcal{A}H_m B = \left(\Sigma^{-1}U^H C\right)H_m V = V^H\left(V\Sigma^{-1}U^H\right)\left(CH_m\right)V = V^H\left(CH_m\right)^H\left(CH_m\right)V = I.$$

As for Property 3, it can be verified as follows. Using the expression in Step 1, the noise covariance after MIMO post-processing at the receiver of the multiline system is

$$E\left[\mathcal{A}H_d \underline{d}\underline{d}^H H_d^H \mathcal{A}^H\right] = E\left[\Sigma^{-1}U^H CH_d \underline{d}\underline{d}^H H_d^H C^H U\Sigma^{-1}\right] =$$

$$= \Sigma^{-1}U^H E\left[CH_d \underline{d}\underline{d}^H H_d^H C^H\right]U\Sigma^{-1} = \Sigma^{-1}U^H CH_d R_d H_d^H C^H U\Sigma^{-1} = \Sigma^{-2}.$$

Consider now a tall matrix $\mathcal{W}$ of the same dimensions as U such that $U^H\mathcal{W} = 0$. We can define a modified MIMO post-processing matrix $\tilde{\mathcal{A}}$ as follows: $\tilde{\mathcal{A}} = \Sigma^{-1}\left(U + \mathcal{W}\right)^H C$. This implies that $\tilde{\mathcal{A}}H_m B = I$. The noise covariance after MIMO post-processing at the receiver of the multiline system with the modified MIMO post-processing matrix $\tilde{\mathcal{A}}$ is

$$E\left[\tilde{\mathcal{A}}H_d \underline{d}\underline{d}^H H_d^H \tilde{\mathcal{A}}^H\right] = E\left[\Sigma^{-1}\left(U + \mathcal{W}\right)^H CH_d \underline{d}\underline{d}^H H_d^H C^H\left(U + \mathcal{W}\right)\Sigma^{-1}\right] =$$

$$= \Sigma^{-1}\left(U + \mathcal{W}\right)^H E\left[CH_d \underline{d}\underline{d}^H H_d^H C^H\right]\left(U + \mathcal{W}\right)\Sigma^{-1}$$

$$= \Sigma^{-1}\left(U + \mathcal{W}\right)^H CH_d R_d H_d^H C^H\left(U + \mathcal{W}\right)\Sigma^{-1}$$

$$= \Sigma^{-1}\left(U + \mathcal{W}\right)^H\left(U + \mathcal{W}\right)\Sigma^{-1}$$

$$= \Sigma^{-2} + \Sigma^{-1}\mathcal{W}^H\mathcal{W}\Sigma^{-1}$$

Clearly, the covariance of the noise in this system is minimized with $\mathcal{W} = 0$, which means that the MIMO post-processing matrix $\mathcal{A}$ satisfies Property 1.

[00054] The split-pair MIMO processing architecture of **Figure 5** uses the pre-processing matrix B 510 at the transmitter and the post-processing matrix $\mathcal{A}$ 550 at the receiver to coordinate the transmitted and received signals in a fashion that preserves the integrity of the transmitted signal $\underline{w}(k)$ 550, while simultaneously pre-whitening the crosstalk noise to create a set of directions in the symbol vector space, namely a subspace, that is free of crosstalk noise.

[00055] In particular, the interference noise after receiver post-processing is given by $\mathcal{A}H_d \underline{d}(k)$. As shown above, the covariance of the noise after post-processing is equal to Σ^{-2}, which implies that this received noise has been diagonalized. This in turn

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means that the subspace that is orthogonal to the range space of the interference noise vector, namely the nullspace of the interference noise, now contains some of the channels of the multiline system. Moreover, due to the addition of the split-pair receivers, the dimension of the subspace that is free of crosstalk noise has been increased.

[00056] Hence, compared to a multiline system without split-pair receivers, more channels are now free of noise and can carry significantly higher bitrates than the channels that are in the range space of the interference noise, which continue to be impaired. In other words, the split-pair MIMO processing of **Figure 5** increases the total number of available channels and then restricts the effect of the interference noise to the minimum possible number of channels, and therefore is optimal with respect to the criterion of maximizing the overall capacity of the multiline transmission system.

[00057] **Figure 6** illustrates exemplary MIMO post-processing process 600 once a processing architecture is computed according to one embodiment of the present invention. Process 600 commences at block 601. At processing block 610, each transceiver in the split-pair multiline transmission system receives differential signal vectors including crosstalk. The crosstalk received is not limited in origin and may be alien crosstalk or crosstalk from sources outside or external to the split-pair multiline transmission system. The split-pair receiver receives a signal vector including crosstalk from each transceiver at processing block 620. The MIMO post-processing unit receives signals including interference signals and vector signals from each transceiver and each split-pair receiver at processing block 630. At processing block 640, a MIMO post-processor with a receiver converts each of the received signal vectors into received symbol vectors. The received symbols are decoded at processing block 650. The process completes at block 699.

[00058] **Figure 7** illustrates an exemplary block diagram of a computer system 700 representing an integrated multi- processor, in which elements of the present invention may be implemented. Computer system 700 can be used to perform the method 600 as referenced in **Figure 6**. One embodiment of computer system 700 comprises a system bus 716 for communicating information, and a processor 718 coupled to bus 716 for processing information. Computer system 700 further comprises a random access memory (RAM) or other dynamic storage device 710 (referred to herein as main memory), coupled to bus 716 for storing information and instructions to be executed by processor 718. Main memory 710 also may be used for storing

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temporary variables or other intermediate information during execution of instructions by processor 718. Computer system 700 also may include a read only memory (ROM) and/or other static storage device 712 coupled to bus 716 for storing static information and instructions used by processor 718.

[00059] A data storage device 714 such as a magnetic disk or optical disc and its corresponding drive may also be coupled to computer system 700 for storing information and instructions. Computer system 700 can also be coupled to a second I/O bus 722 via an I/O interface 720. A plurality of I/O devices may be coupled to I/O bus 722, including a display device 708, an input device (e.g., an alphanumeric input device 706 and/or a cursor control device 704). For example, video news clips and related information may be presented to the user on the display device 708.

[00060] The communication device 702 is for accessing other computers (servers or clients) via a network. The communication device 702 may comprise a modem, a network interface card, or other well-known interface device, such as those used for coupling to Ethernet, token ring, or other types of networks.

[00061] In the foregoing specification, the invention has been described with reference to specific embodiments. It will, however, be evident that various modifications and changes can be made without departing from the broader spirit and scope of the invention as set forth in the claims. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

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CLAIMS

What is claimed is:

1. A method reducing signal distortion in a multiple line transmission system, the method comprising:

using one or more split-pair receivers in a multiline communications system to identify crosstalk on a pair of transceivers coupled to the split pair receivers, wherein each split pair receiver receives a signal including the crosstalk from each transceiver and provides a corresponding signal vector to a post processing unit; and

performing MIMO post-processing on signal vectors received at a receiver from each transceiver and each split-pair receiver while minimizing crosstalk on pairs of lines in the multiline communications system with a frequency equalizer.

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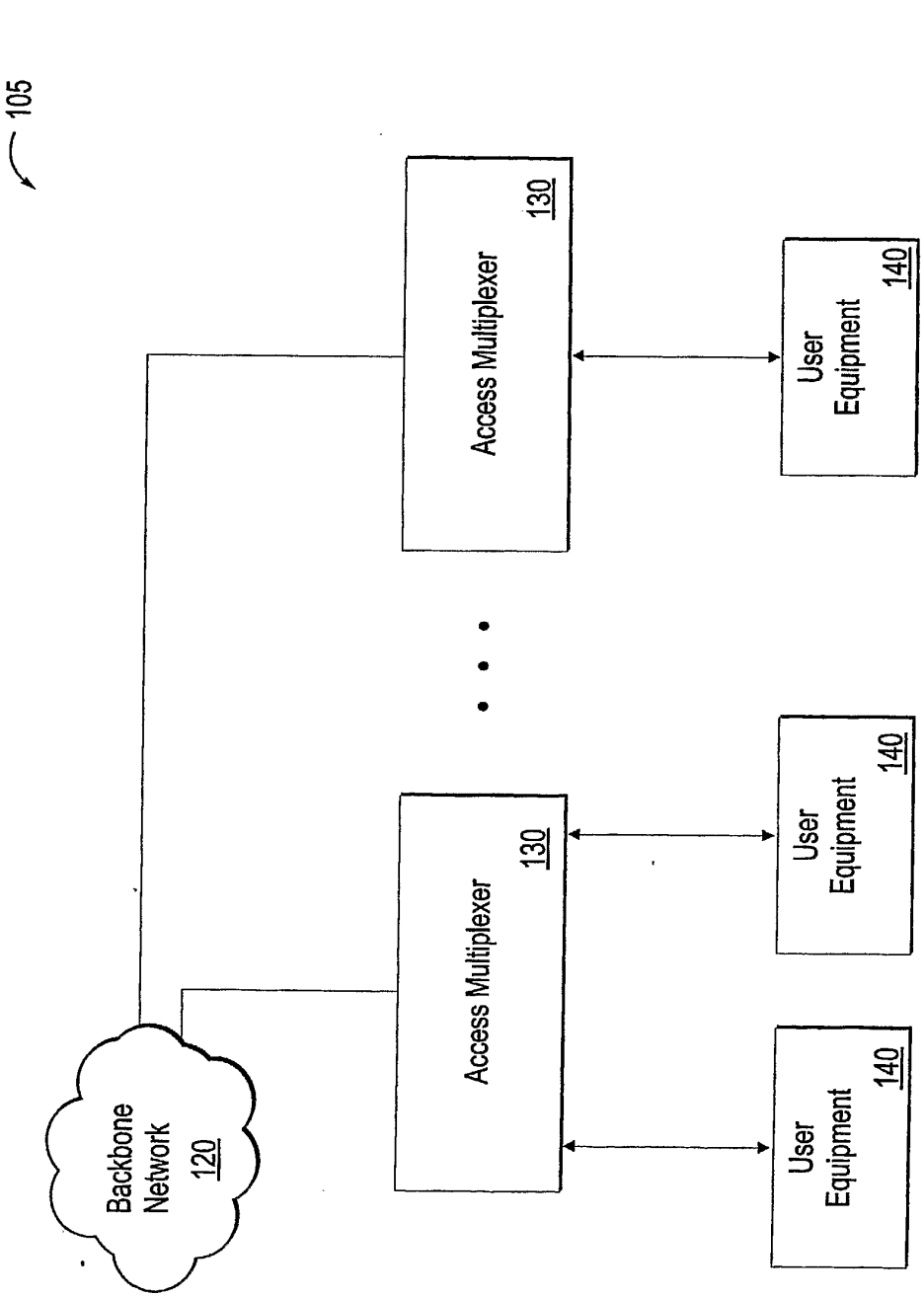
105
Backbone Network 120
Access Multiplexer 130
Access Multiplexer 130
User Equipment 140
User Equipment 140
User Equipment 140

FIG. 1

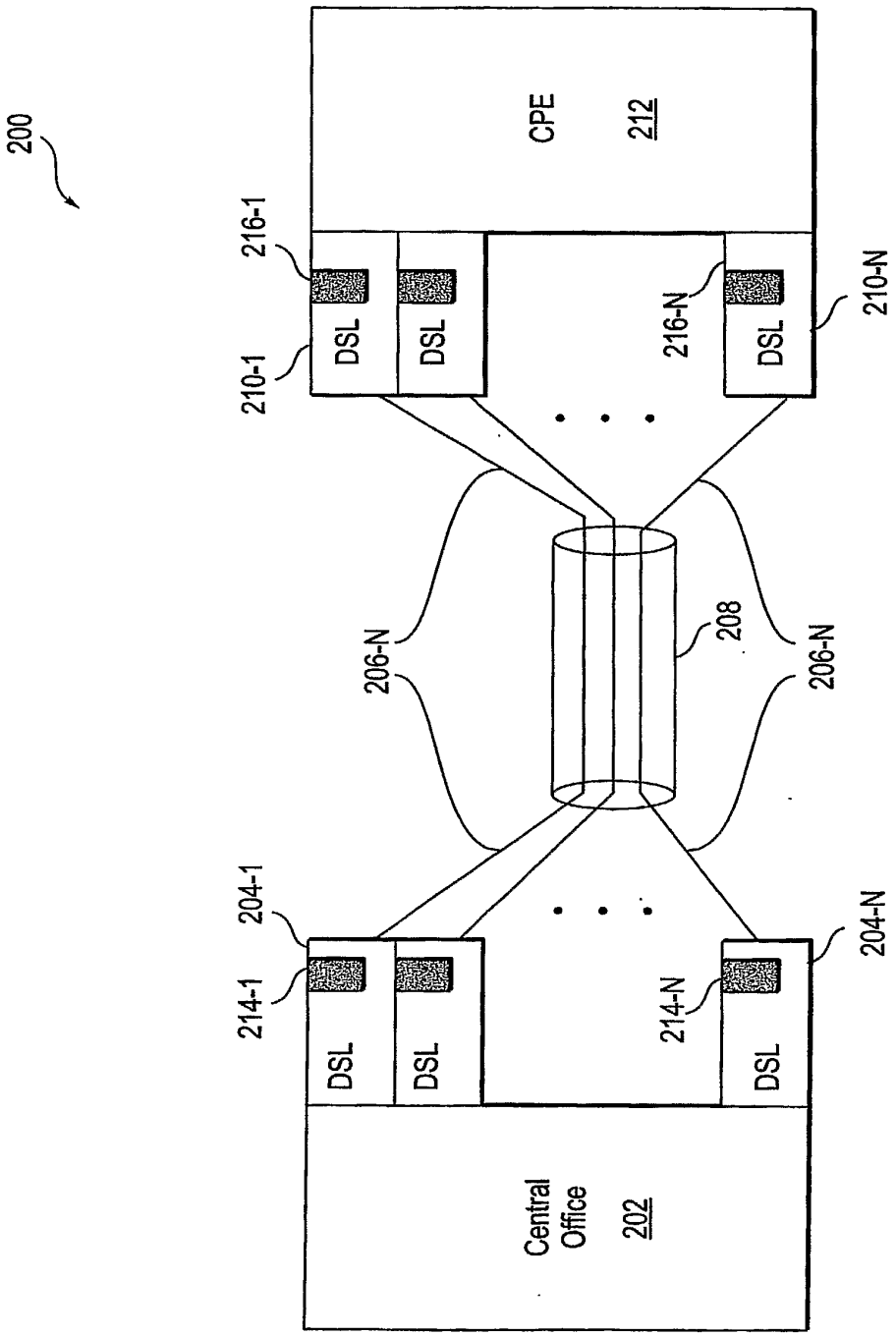
200
CPE
212
216-1
210-1
DSL
DSL
216-N
210-N
DSL
206-N
208
206-N
204-1
214-1
DSL
DSL
214-N
204-N
DSL
Central Office
202

FIG. 2

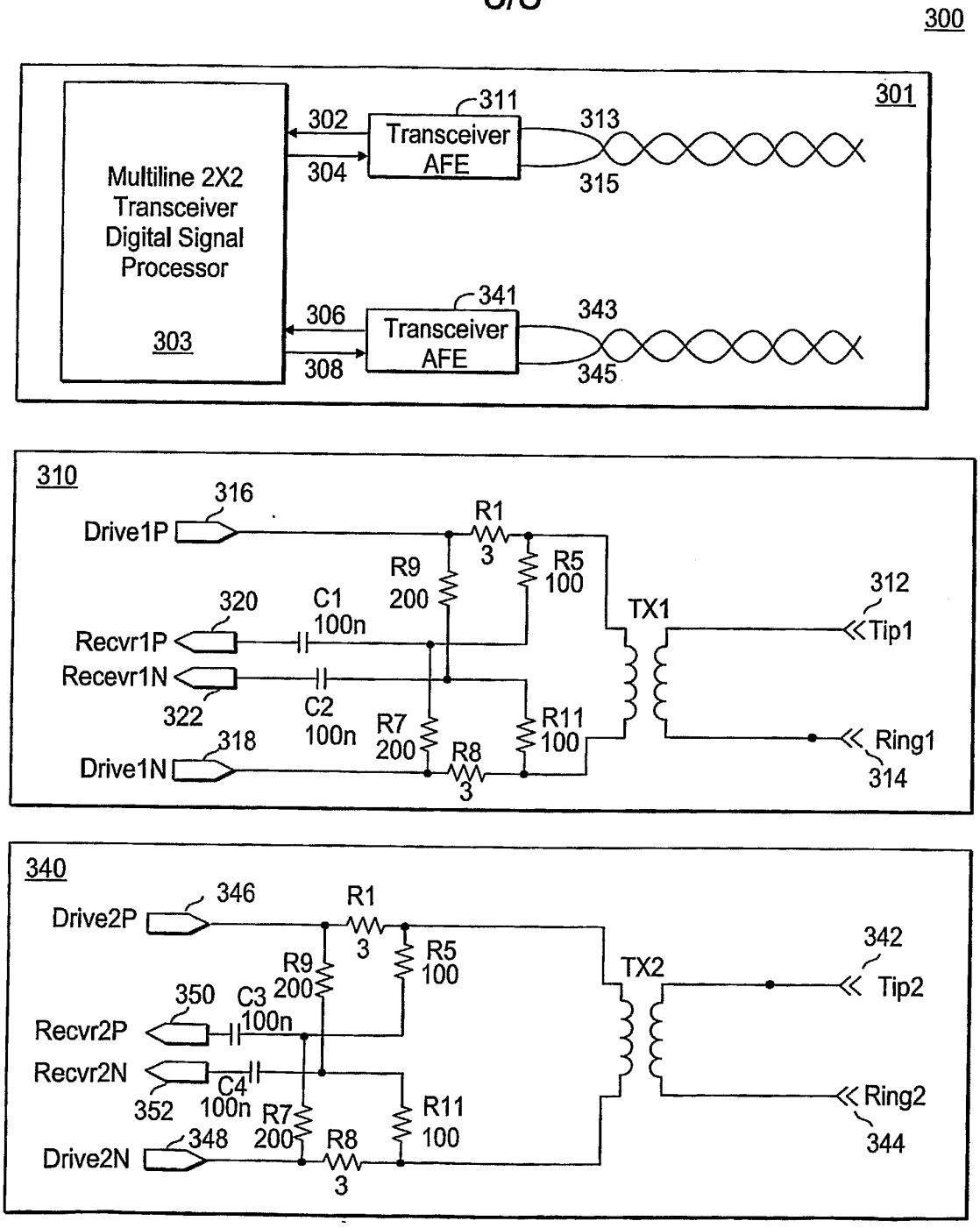
300
301
Multiline 2X2
Transceiver
Digital Signal
Processor
303
302
304
311
Transceiver
AFE
313
315
306
308
341
Transceiver
AFE
343
345
310
316
Drive1P
R1
3
R9
200
R5
100
320
C1
100n
Recvr1P
Recevr1N
322
C2
100n
R7
200
R8
3
318
Drive1N
R11
100
TX1
312
Tip1
Ring1
314
340
346
Drive2P
R1
3
R9
200
R5
100
350
C3
100n
Recvr2P
Recvr2N
C4
100n
352
R7
200
348
Drive2N
R8
3
R11
100
TX2
342
Tip2
Ring2
344

FIG. 3

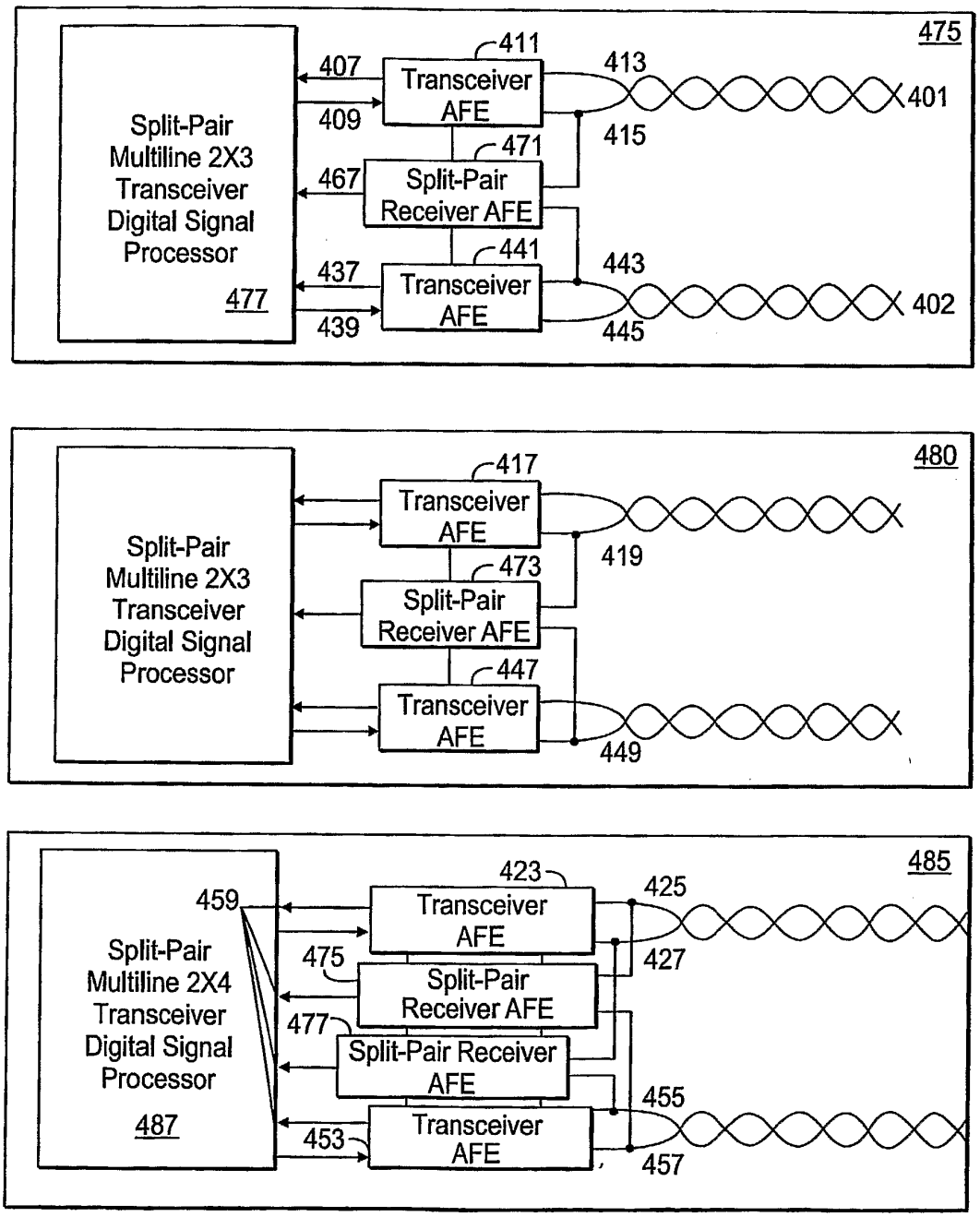
475
Split-Pair Multiline 2X3 Transceiver Digital Signal Processor
477
411
Transceiver AFE
407
409
413
401
415
471
Split-Pair Receiver AFE
467
441
Transceiver AFE
437
439
443
402
445
480
Split-Pair Multiline 2X3 Transceiver Digital Signal Processor
417
Transceiver AFE
419
473
Split-Pair Receiver AFE
447
Transceiver AFE
449
485
Split-Pair Multiline 2X4 Transceiver Digital Signal Processor
487
459
423
Transceiver AFE
425
427
475
Split-Pair Receiver AFE
477
Split-Pair Receiver AFE
455
453
Transceiver AFE
457

FIG. 4A

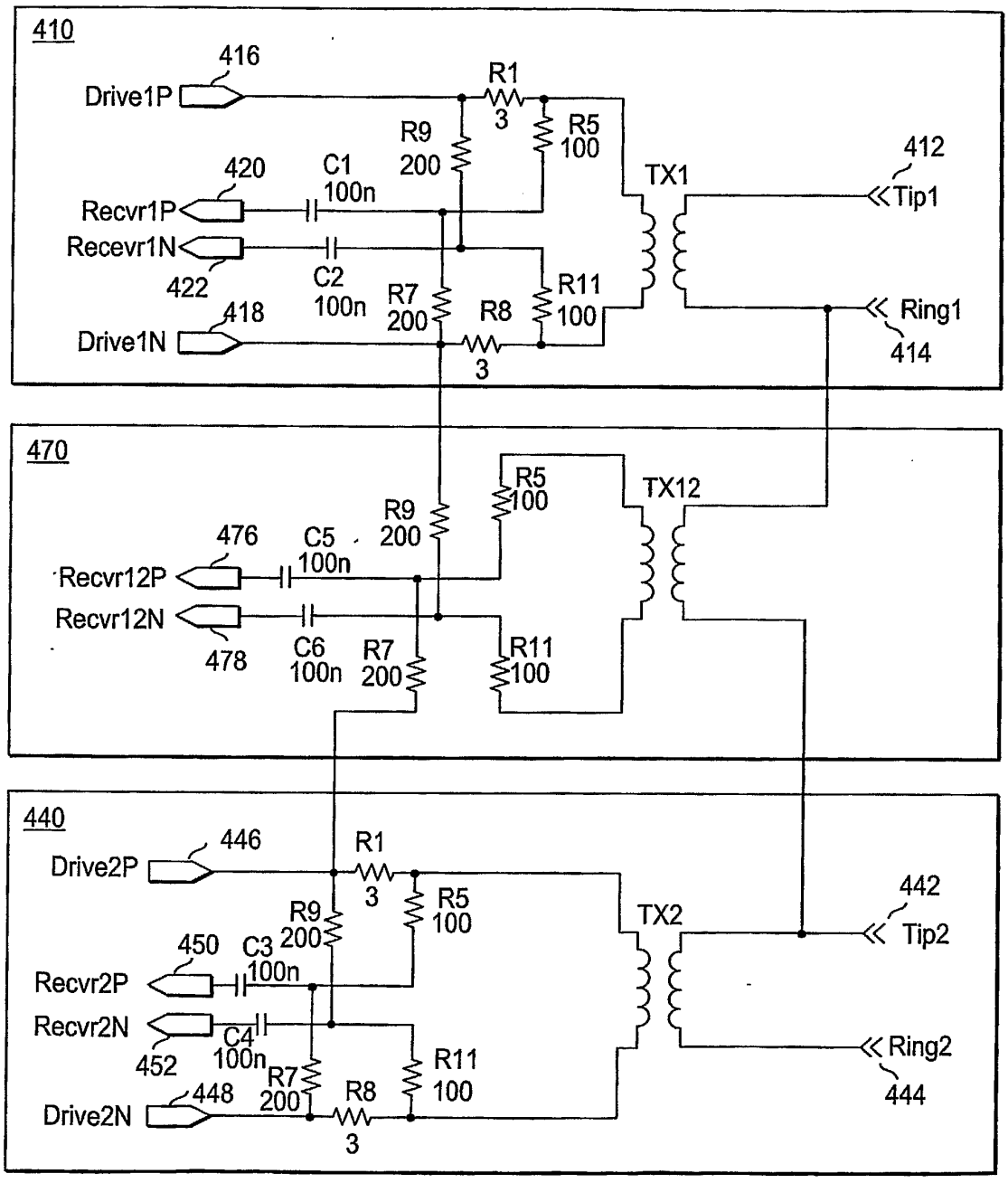
410
416
Drive1P
R1
3
R5
100
R9
200
420
C1
100n
Recvr1P
Recevr1N
422
C2
100n
R7
200
R8
3
R11
100
418
Drive1N
TX1
412
Tip1
Ring1
414
470
R5
100
TX12
R9
200
476
C5
100n
Recvr12P
Recvr12N
478
C6
100n
R7
200
R11
100
440
446
Drive2P
R1
3
R5
100
R9
200
450
C3
100n
Recvr2P
Recvr2N
452
C4
100n
R7
200
R8
3
R11
100
448
Drive2N
TX2
442
Tip2
Ring2
444

FIG. 4B

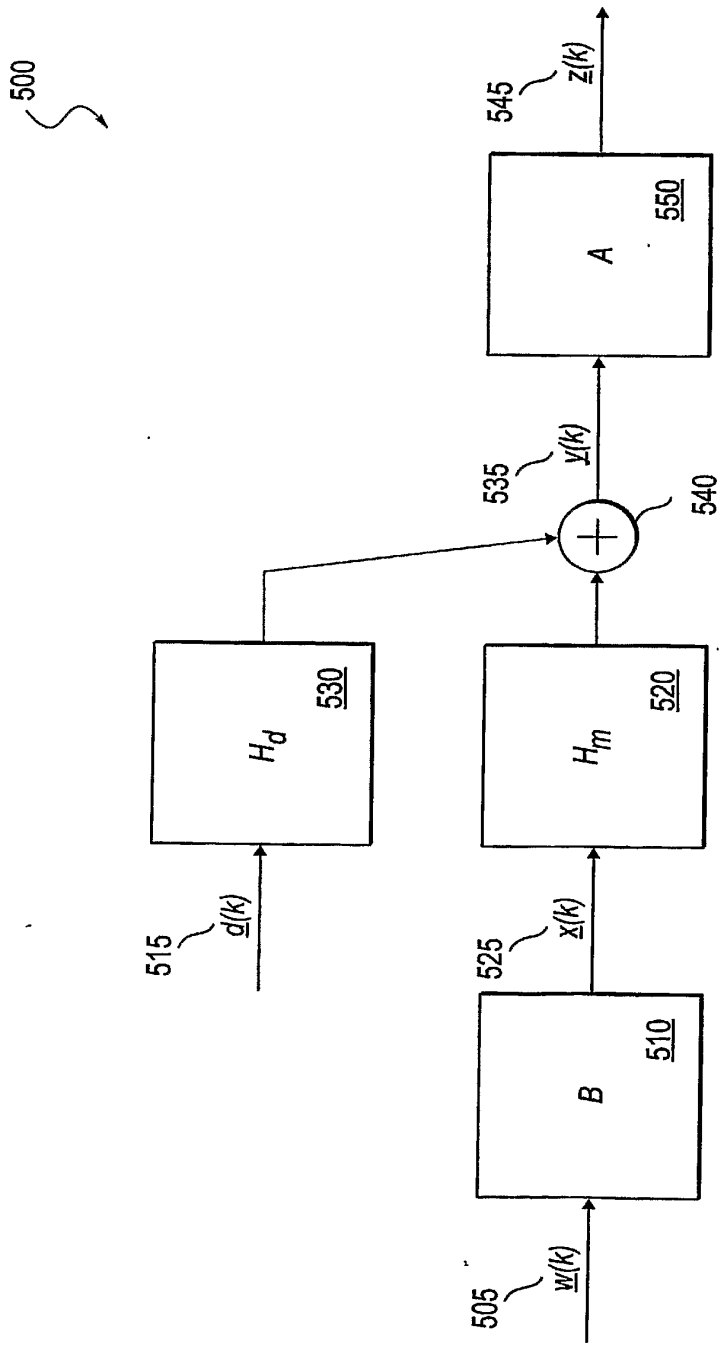

FIG. 5

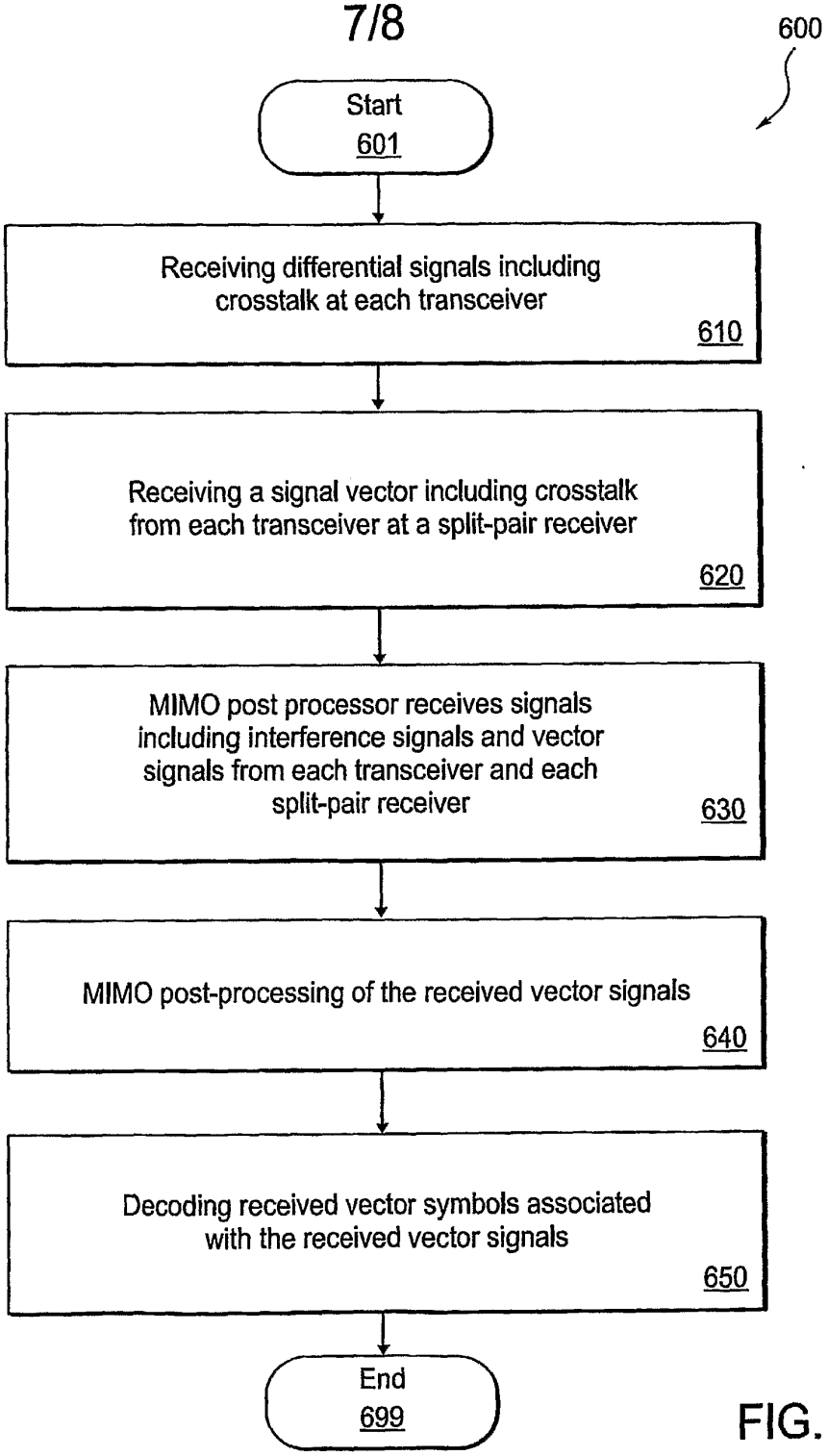
600
Start
601
Receiving differential signals including crosstalk at each transceiver
610
Receiving a signal vector including crosstalk from each transceiver at a split-pair receiver
620
MIMO post processor receives signals including interference signals and vector signals from each transceiver and each split-pair receiver
630
MIMO post-processing of the received vector signals
640
Decoding received vector symbols associated with the received vector signals
650
End
699

FIG. 6

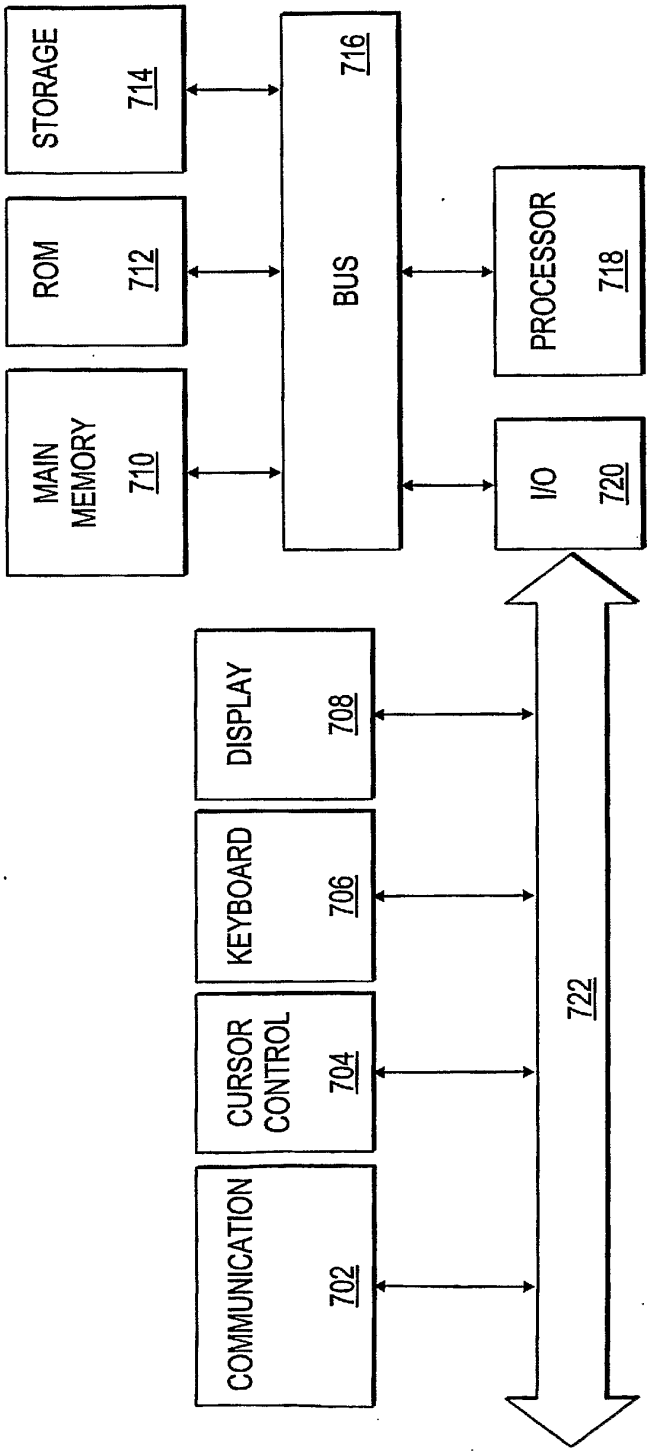
STORAGE
714
ROM
712
MAIN MEMORY
710
BUS
716
PROCESSOR
718
I/O
720
DISPLAY
708
KEYBOARD
706
CURSOR CONTROL
704
COMMUNICATION
702
722

FIG. 7

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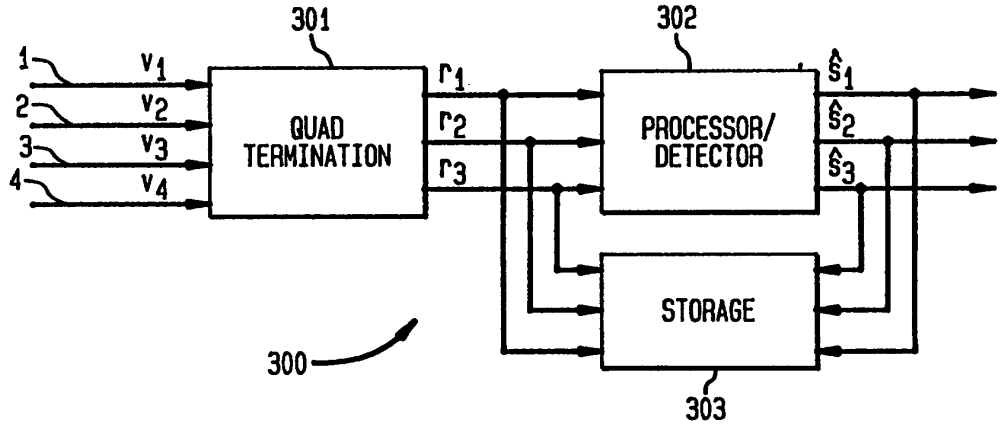

(57) Abstract

Coupling between two side circuits and a phantom circuit in a quaded cable (200) is compensated for at the receiving end of a transmission system. Known signals are separately transmitted on each circuit and coupling between each circuit is estimated based on a measured signal received at the receiving end of the quaded cable for initialization. During data transmission, received data signals are modified in accordance with the initially determined coupling to produce estimated transmitted data signals. Reestimation of the coupling between each circuit is performed during data transmission by storing (303) N received data signals and N estimated transmitted data signals on each circuit. The coupling between circuits is determined as a function of the covariance of the N received signals and covariance of the N estimated transmitted signals on each circuit. The reestimated coupling is used to modify (302) subsequent received data signals on each circuit.

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GA	Gabon				

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METHOD AND SYSTEM FOR COMPENSATING FOR COUPLING BETWEEN CIRCUITS OF QUADED CABLE IN A TELECOMMUNICATION TRANSMISSION SYSTEM

TECHNICAL FIELD

This invention relates to methods and systems for compensating for coupling between circuits of quaded cable and, in particular, to methods and systems for compensating for coupling between such circuits in a telecommunication transmission system.

BACKGROUND OF THE INVENTION

Almost all North American telephone loop wire pair cable is multipair cable. These transmission circuits are formed by individually twisted pairs of copper wires that are stranded together. In contrast, much of the European and Asian cable plant is constituted of quaded cable or circuits. Some building cables in North America are also quaded. The elemental units in these cables are quads which are four insulated conductors or wires twisted together. The advantage of quading is that more circuits can be packed into a given cross-sectional area of cable. The disadvantage comes from the fact that the quad is geometrically unstable and the capacitances between the conductors in the quad are difficult to control. These factors lead to poorer crosstalk performance between circuits in the same quad.

Quaded cable can be made in two different configurations. In multiple twin quad, the two pairs that constitute the quad are individually twisted and then stranded together to effectively form a two-pair sub-unit. In star-quaded cable, the four conductors are twisted together. Most quaded cable is star-quaded. The cross-section of a typical star-quad is illustrated in FIG. 1A, which shows the four conductors, 1-4, surrounded by insulating sheathings 5-8, respectively. The natural modes of propagation of a perfectly constructed star-quad are obvious from the symmetry of the quad, and are illustrated in FIGS. 1B, 1C, 1D and 1E, where in each of these figures the insulating sheathings are not shown for improved clarity.

In an ideal star-quad, the two balanced pair modes, illustrated in FIGS. 1B and 1C, do not couple to each other because of the symmetry and opposite polarities of two opposite conductors of the quad. The balanced pair modes are frequently referred to as "side circuits," a terminology descended from the use of multiple twin quad. In side circuit one, a first signal is impressed positively and negatively between conductors 1 and 3, respectively, and in side circuit two, a second signal is impressed positively and negatively between conductors 4 and 2, respectively. Besides the balanced pair modes, one could use the phantom circuit of the balanced pair modes as shown in FIG. 1D to

transmit a third signal. In the phantom circuit, the third signal is impressed "on-top" of the signals on side circuits one and two, positively and negatively between conductors 1 and 3 together, and conductors 2 and 4 together, respectively. An additional mode of transmission, the ground mode, is shown in FIG. 1E. In this mode a signal is positively impressed on top of all other signals between all four conductors together and an external ground. This mode is not used for transmission because of strong coupling to ground modes in other conductors within the same cable.

The polarities of the voltages on the four conductors guarantees that there would be no coupling between the phantom mode and the side circuits in a perfectly constructed star-quad. Thus, in such a quad, one would get three transmission circuits with four conductors. As far as coupling between quads is concerned, coupling between side circuits in different quads would be like dipole-dipole coupling as it is in multipair cables. Coupling between phantom circuits would be quadripole-quadripole coupling, which is generally looser than dipole-dipole coupling.

Unfortunately, it is essentially impossible to achieve the precision and stability of the quad structure to take advantage of the mode structure. The mechanical instability of the quad structure leads to coupling between circuits in the same quad. At high frequencies the coupling or cross-talk between conductors can be at unacceptable levels. The far end coupling, the coupling at the receive end of the cable, generated by the signal induced at the transmitted end, increases by 20 dB per decade. Further, the near end coupling induced on the transmitter by the transmitted signals increases by 15 dB per decade.

Consequently, phantom circuits are never used and side circuits in quaded cable have a shorter range than twisted pairs at the higher frequencies used in modern services, such as Basic Rate ISDN.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a method and system for compensating for coupling between the circuits of a quad, such as a star-quad, so that all three circuits on such a quad can be used with essentially no noticeable coupling between them.

In accordance with the present invention the coupling between circuits in a quad is initially determined in a training period by transmitting sets of known signals on the quaded cable and measuring the signals received by a receiver at the opposite end of the cable. By transmitting signals on one circuit one at a time during the training period, the coupling from one circuit to another is measured at the receiver and a coupling matrix between transmitting and receiving end circuits is calculated. The inverse of this coupling matrix is then used as an operator on the received signals, to estimate the

transmitted signals once actual data transmission begins. During data transmission, the coupling matrix is updated using the actual statistical data. Specifically, after plural sets of data signals from the three circuits are received and the transmitted signals are estimated using the initial estimate of the coupling matrix, the covariance matrices of these plural sets of received signals and estimated transmitted signals are calculated and used to determine a new estimate of the coupling matrix. The new coupling matrix is then used to estimate the next set of transmitted signals on the three circuits. Depending upon whether the transmission channel is rapidly changing, or moderately or slowly changing, the coupling matrix is updated either after each set of signals on these circuits is received, or periodically after plural sets of signals on these circuits are received.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1A is a cross-sectional view of a typical star-quad;

FIG. 1B is a cross-sectional view of side circuit one in such a star-quad wherein conductors 2 and 4 are at ground and conductors 1 and 3 are at +1 and -1 volts, respectively;

FIG. 1C is a cross-sectional view of side circuit two wherein conductors 1 and 3 are at ground and conductors 2 and 4 are at -1 and +1 volts, respectively;

FIG. 1D is a cross-sectional view of a phantom circuit of such a cable wherein conductors 1, 2, 3 and 4 are at +1, -1, +1 and -1 volts, respectively;

FIG. 1E is a cross-sectional view of a ground mode circuit wherein conductors 1-4 are all at +1 volts;

FIG. 2 is a diagram that illustrates a mechanism at the transmitting end of the quad for coupling signals to the first and second side circuits and to the phantom circuit; FIG. 2 also illustrates this same mechanism at the receiving end of the quad for coupling signals from the first and second side circuits and from the phantom circuit; and

FIG. 3 is a block diagram of an adaptive quad receiver in accordance with the present invention which processes the signals coupled from the quad by compensating for the coupling between circuits as that coupling is determined first by sending test signals over the quad and then by adaptively tracking coupling variations in response to statistical data.

DETAILED DESCRIPTION

With reference to FIG. 2, one end of a quad 200 shows the four conductors 1, 2, 3 and 4. At the transmitting end of the quad, three signals, $\{S_i\}$, $i=1-3$, are shown coupled through the primary and secondary windings of a coil to the two side circuits and to the phantom circuit. Thus, the first signal, S_1, is coupled through coil 201 to side circuit one across conductors 1 and 3; the second signal, S_2, is coupled through coil 202 to side circuit two across conductors 2 and 4; and the third signal, S_3, is coupled through coil 203 to the center taps of the secondary windings of coils 201 and 202 to the phantom circuit between conductors 1 and 3, together, and 2 and 4, together. By coupling the secondary winding of 203 to the center taps of the secondary windings of coils 201 and 202, the effects of the side circuit voltages are filtered, thus impressing S_3 "on top" of the signals on each of the side circuits.

At the receiving end, a configuration identical to that shown in FIG. 2 is used to couple the transmitted signals from the quad to a receiver (not shown). Thus, at the receiving end, three signals, $\{r_i\}$, $i=1-3$, are coupled from the quad from the first side circuit, the second side circuit and the phantom circuit, respectively, as shown in FIG. 2. Because of the coupling between circuits, the received signals, $\{r_i\}$, are not equal to the transmitted signals, $\{S_i\}$. By measuring the coupling between circuits in accordance with the method and apparatus of the present invention, however, it is possible to compensate for the effects of this coupling between circuits. Thus, by "operating" on the received signal, $\{r_i\}$, so as to remove the effects of cross-coupling between circuits, estimates of the transmitted signals, $\{S_i\}$, can be calculated that are close to the actual transmitted signals, $\{S_i\}$. All three circuits can therefore be used for transmission.

In the following sections the characteristic of nominal star quads are described as well as the mathematical derivation of the method of the present invention for adapting quad terminations to minimize coupling. The method of the present invention for startup using a transmitted training sequence and for then tracking coupling over time using statistical data are then presented.

Characteristics of Nominal Star Quads

Since a star-quad has four conductors, the voltage transfer matrix from one end of the quad (x=0) to the other (x=1) is a four by four matrix:

$$\begin{bmatrix} v_1(1) \\ v_2(1) \\ v_3(1) \\ v_4(1) \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} v_1(0) \\ v_2(0) \\ v_3(0) \\ v_4(0) \end{bmatrix} \quad (1)$$

The voltages in (1) are with respect to a putative remote ground at voltage zero.

In a nominal quad configuration, there is perfect geometrical symmetry within the quad and with respect to ground. Consequently, the coefficients in the transfer matrix satisfy the following symmetry:

$$a_{i,(i+n)\bmod(4)} = a_{k,(k+n)\bmod(4)}; \quad \text{all } k \tag{2}$$

Consequently, equation (1) may be written in the form:

$$\begin{bmatrix} v_1(1) \\ v_2(1) \\ v_3(1) \\ v_4(1) \end{bmatrix} = \begin{bmatrix} a & b & c & b \\ b & a & b & c \\ c & b & a & b \\ b & c & b & a \end{bmatrix} \begin{bmatrix} v_1(0) \\ v_2(0) \\ v_3(0) \\ v_4(0) \end{bmatrix} \tag{3}$$

The natural modes or eigenvectors, of any uniform transmission line are those distributions of voltages among the conductors that are unaffected by transmission except that all voltages are multiplied by the same number that depends on the distance transmitted. These distributions are proportional to the eigenvectors of the transmission matrix of the transmission line. The natural modes or eigenvectors of the nominal quad are easy to identify because of the form of the matrix on the right in equation (3). They are:

- The ground return mode, with all conductors at the same voltage, with an eigenvalue of $a+2b+c$.
- Two side circuits. One circuit has conductors two and four at ground, with conductors one and three at +1 and -1 volts, respectively. The other circuit has conductors one and three at ground, with conductors two and four at +1 and -1 volts, respectively. The eigenvalues of both of the side circuit modes is $a-c$.
- The phantom circuit. This mode has the four conductor voltages equal to +1, -1, +1, -1, respectively. The eigenvalue for this mode is $a-2b+c$.

The phantom circuit is usually the lossiest mode, and the ground return the least lossy. Since ground return modes in separate quads couple strongly to each other, they are never used for transmission, but are important to the theory of crosstalk coupling and inductive interference and impulse noise.

Adapting Quad Terminations To Minimize Coupling

Real quads are never nominal, but differ slightly from the nominal configurations as mentioned above. Thus, the side and phantom circuits of the quad will all be coupled loosely. The method and system of the present invention can be used to minimize the coupling between the modes.

For example, the normalized eigenvectors (mode vectors) of the nominal quad may be called $\{\mathbf{e}_i\}$. Then, the transmitted voltage vector, i.e. the array of conductor voltages at the transmitter can be written in the form:

$$\mathbf{v4} = \sum_{i=1}^{4} \mathbf{S}_i \mathbf{e}_i \tag{4}$$

where the $\{\mathbf{S}_i\}$ are the information voltages transmitted on the separate modes; e.g., $\mathbf{S}_1$ is the information transmitted on side circuit 1, etc. If transmission effects are equalized, equation (4) also represents the received voltage vector except for the delay in transmission, which we may ignore for the purposes of our discussion. The ground mode is never used because ground modes in the same cable strongly couple to each other. Consequently, $\mathbf{S}_4 = \mathbf{0}$. Of course, if the ground mode is not used, one of the $\mathbf{S}_i$ would be zero. It is assumed, in writing equation (4), that the transmission effects have been equalized.

To extract the $\mathbf{i}^{th}$ data value ($\mathbf{S}_i$) from the received vector, one can use the orthogonality of the normalized eigenvectors:

$$\mathbf{S}_i = \mathbf{e}_i^T \mathbf{v} \tag{5}$$

where

$$\mathbf{e}_i^T \tag{6}$$

is the transpose of $\mathbf{e}_i$

Of course, when the quad is not nominal, what is received is not $\mathbf{S}_i$, but $\mathbf{r}_i$, given by

$$\mathbf{r}_i = \sum_{j=1}^{4} \mathbf{C}_{ij} \mathbf{S}_j \tag{7}$$

where the $\mathbf{C}_{ij}$ are unknown coupling constants. Since the ground mode is never transmitted, we may assume that $\mathbf{S}_4 = \mathbf{0}$ as indicated above. Also, the ground mode output ($\mathbf{r}_4$), will not be measured. This converts equation (7) into a set of three

equations in three unknowns, the $\{S_i\}$ for $i = 1,2,3$, which may be written in matrix form as follows:

$$\mathbf{r} = \mathbf{CS} \tag{8}$$

with obvious definitions for **r**, **C** and **S**. Of course, **r** and **S** are now 3-vectors and **C** is a three by three matrix. One of the problems of an adaptive receiver for a quad is estimating the matrix **C** from measurements of **r** and a knowledge of the properties of **S**.

When the coupling is relatively loose, which is almost always the case, the diagonal elements in the coupling matrix, i.e., the C_{ii}, are close to one and the off-diagonal elements are (C_{ij} for $i \neq j$) close to zero. In this case, one may advantageously write equation (7) in the form:

$$\mathbf{r} = (\mathbf{E} + \mathbf{B})\ \mathbf{S} \tag{9}$$

where **E** is a unit matrix (each diagonal element is equal to one and each off-diagonal element is equal to zero) and **B** is a small matrix in the sense that it substantially reduces the magnitude of any vector that it operates on.

If one knew the cross-covariance of **r** and **S**, one could determine **B** and use this knowledge to cancel intermodal coupling. To see this, take the outer product of both sides of equation (8) with $\mathbf{S}^T$ and take expected values to get:

$$<\mathbf{r}\ \mathbf{S}^T> = (\mathbf{E} + \mathbf{B})\ <\mathbf{S}\ \mathbf{S}^T> \tag{10}$$

which could be solved for **B** if ,$<\mathbf{r}\ \mathbf{S}^T>$ were known (where the brackets "<>" indicate expected value or statistical expectation so that $<\mathbf{r}\ \mathbf{S}^T>$ is the cross-covariance matrix of **r** and **S**). However, **S** is never known at the receiver unless a known sequence is being transmitted for training purposes so that $<\mathbf{r}\ \mathbf{S}^T>$ cannot be obtained. However, one can write $<\mathbf{r}\ \mathbf{S}^T>$ in terms of what is known at a receiver. To do this, take the outer product of both sides of equation (8) with $\mathbf{r}^T$ and take expectations to get :

$$<\mathbf{r}\ \mathbf{r}^T> = (\mathbf{E} + \mathbf{B})\ <\mathbf{S}\ \mathbf{r}^T> \tag{11}$$

or equivalently,

$$<\mathbf{r}\ \mathbf{r}^T> = <\mathbf{r}\ \mathbf{S}^T>\ (\mathbf{E} + \mathbf{B}^T)(12 \tag{12}$$

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Combining equations (9) and (11) then yields:

$$\langle \mathbf{r}\,\mathbf{r}^T\rangle = (\mathbf{E}+\mathbf{B})\,\langle \mathbf{S}\,\mathbf{S}^T\rangle\,(\mathbf{E}+\mathbf{B}^T) \qquad (13)$$

This equation may be written in the form:

$$\langle \mathbf{r}\,\mathbf{r}^T\rangle - \langle \mathbf{S}\,\mathbf{S}^T\rangle = \mathbf{B}\,\langle \mathbf{S}\,\mathbf{S}^T\rangle + \langle \mathbf{S}\,\mathbf{S}^T\rangle\,\mathbf{B}^T + \mathbf{B}\,\langle \mathbf{S}\,\mathbf{S}^T\rangle\,\mathbf{B}^T \qquad (14)$$

If this equation could be solved for **B** one would know the cable matrix **C** and would be able to make error free determination of the transmitted signal vectors. An approximate solution for equation (13) is easy to obtain. The clue to this is to note that, since **B** is small, the last term on the right in equation (13) is of second order in small quantities and may be neglected in obtaining an approximation, $\mathbf{B}_0$ for **B**. Thus, $\mathbf{B}_0$ is a solution of:

$$\langle \mathbf{r}\,\mathbf{r}^T\rangle - \langle \mathbf{S}\,\mathbf{S}^T\rangle = \mathbf{B}_0\,\langle \mathbf{S}\,\mathbf{S}^T\rangle + \langle \mathbf{S}\,\mathbf{S}^T\rangle\,\mathbf{B}_0^T \qquad (15)$$

and may hence be solved by standard methods.

The error, $(\mathbf{B}-\mathbf{B}_0)$, between **B** and its approximant, $\mathbf{B}_0$, is of second order in small quantities. To see this, equation (4) is subtracted from equation (13) to obtain:

$$(\mathbf{B}_0-\mathbf{B})\,\langle \mathbf{S}\,\mathbf{S}^T\rangle + \langle \mathbf{S}\,\mathbf{S}^T\rangle(\mathbf{B}_0^T-\mathbf{B}^T) = \mathbf{B}\,\langle \mathbf{S}\,\mathbf{S}^T\rangle\,\mathbf{B}^T \qquad (16)$$

Since $\langle \mathbf{S}\,\mathbf{S}^T\rangle$ is not small or singular and the right side of equation (15) is of second order in small quantities, so is $(\mathbf{B}_0-\mathbf{B})$. Hence, $\mathbf{B}_0$ is a good approximation to B.

If we use $\mathbf{B}_0$ to obtain an estimate, $\hat{\mathbf{S}}$, of the transmitted signal vector, one has:

$$\mathbf{r} = (\mathbf{E}+\mathbf{B}_0)\hat{\mathbf{S}} \qquad (16A)$$

or, since $\mathbf{B}_0$ is small,

$$\hat{\mathbf{S}} \approx (\mathbf{E}-\mathbf{B}_0)\mathbf{r} \qquad (17)$$

which is good to first order as a solution of equation (16). In a similar way, one could write:

$$\mathbf{S} \approx (\mathbf{E}-\mathbf{B})\mathbf{r} \qquad (18)$$

Subtracting equation (17) from equation (18) one gets:

$$\mathbf{S} - \hat{\mathbf{S}} = (\mathbf{B}_0 - \mathbf{B})\mathbf{r} \tag{19}$$

Since it has been shown that $(\mathbf{B}_0 - \mathbf{B})$ is of second order in small quantities, equation (19) shows that the error in $\hat{\mathbf{S}}$ is of the second order in small quantities.

If the first order estimate $\mathbf{B}_0$ needs to be improved, successively better approximation can be obtained by converting equation (13) into an iteration equation, which uses an earlier estimate for $\mathbf{B}$ in the second order term on the extreme right in equation (13) to obtain a closer approximation. Thus, one may write:

$$\langle \mathbf{r}\,\mathbf{r}^T \rangle - \langle \mathbf{S}\,\mathbf{S}^T \rangle - \mathbf{B}_{n-1}\langle \mathbf{S}\,\mathbf{S}^T \rangle\,\mathbf{B}_{n-1}^T = \mathbf{B}_n \langle \mathbf{S}\,\mathbf{S}^T \rangle + \langle \mathbf{S}\,\mathbf{S}^T \rangle\,\mathbf{B}_n \tag{20}$$

If one sets $\mathbf{B}_{-1} = \mathbf{0}$, setting n=0 in equation (20) yields equation (14).

Startup and Tracking With a Training Sequence

One way to startup and adapt the receiver to changing quad characteristics is by use of known transmitted sequences, i.e. by transmitting prescribed sequences of vectors **S** and then measuring the resulting received vectors **r** at the receiver. This will be effective on quads because the rate of change of the quad's characteristics will be low compared to the data rate of the information being transmitted. The purpose of using the known sequences is so that the coupling matrix, **C**, can be determined at the receiver, which can then invert the coupling matrix and apply the inverse to equation (16) when the transmitted signal vector, **S**, is data rather than a known training vector. This would convert equation (8) to:

$$\mathbf{S} = \mathbf{C}^{-1}\mathbf{r} \tag{21}$$

Since the coupling matrix is a three by three matrix, it is theoretically only necessary to transmit a known sequence of three linearly independent signal vectors. In practice, longer sequences may be used to overcome uncertainties in received data caused by transmission noise and equipment imprecision.

A particularly convenient set of three known signal vectors to use are the three mode vectors, which we will call $\{\mathbf{S}^j\}$. The components of any signal vector are the values of the voltages transmitted on each of the three quad modes that are used to communicate, i.e., $\{\mathbf{S}_i\}$. The training vectors $\{\mathbf{S}^j\}$ have components $\mathbf{S}_j = \mathbf{1}$ and the other components equal to zero, $\mathbf{S}_k = \mathbf{0}$, $\mathbf{k} \neq \mathbf{j}$. Consequently the components of the

corresponding received vectors are the columns of the coupling matrix. E.g., when $\mathbf{S^1}$ is sent, the components of the received vector, $\mathbf{r^1}$, are $\{\mathbf{C_{j1}}\}$. Since the coupling matrix is a three by three matrix, it is easily inverted using standard formulas in a processing chip.

A known transmitted sequence can be used at startup before any data is transmitted. It may also be used to track the changing coupling matrix during communication by inserting short known training sequences into the transmitted sequence at prearranged intervals. The procedure outlined above for adapting the receiver during startup or in tracking quad transmission characteristic changes is formalized in the following algorithm:

- 1. At the transmitter, set $\mathbf{S_1 = 1}$ and $\mathbf{S_2 = S_3 = 0}$. At the receiver, measure the output vector $\mathbf{r} = (\mathbf{C_{11}, C_{21}, C_{31}})^{\mathbf{T}}$. Store this data at the receiver.
- 2. At the transmitter, set $\mathbf{S_2 = 1}$ and $\mathbf{S_1 = S_3 = 0}$. At the receiver, measure the output vector $\mathbf{r} = (\mathbf{C_{12}, C_{22}, C_{32}})^{\mathbf{T}}$. Store this data at the receiver
- 3. At the transmitter, set $\mathbf{S_3 = 1}$ and $\mathbf{S_1 = S_2 = 0}$. At the receiver, measure the output vector $\mathbf{r} = (\mathbf{C_{13}, C_{23}, C_{33}})^{\mathbf{T}}$. Store this data at the receiver
- It may be necessary to repeat steps 1, 2 and 3 several times in a noisy environment to mitigate against the effects of the noise.
- 4. At the receiver, invert the matrix of $\mathbf{C_{ij}}$'s.
- 5. Start data transmission. Apply the inverse of the coupling matrix, $\mathbf{C^{-1}}$, to the received mode amplitude vectors, $\mathbf{r}$, to eliminate coupling between the modes.
- For tracking changes in the coupling characteristics, it is necessary to inject training periods in the data stream. This can be done in intervals where steps 1-5 are repeated, or it can be done by transmitting known signal vectors at prescribed intervals, as indicated in the following steps.
- 6. After $\mathbf{N}$ data symbols are transmitted, transmit $\mathbf{S^1}$ and then resume data transmission. Upon reception of the resultant received vector, replace the oldest received data stored in the receiver corresponding to the transmission of $\mathbf{S^1}$. Using the new stored data, update the value of $\mathbf{C^{-1}}$ and resume data reception.
- 7. After $\mathbf{N}$ additional data symbols are transmitted, repeat the procedure in step 6, but with $\mathbf{S^2}$ transmitted instead of $\mathbf{S^1}$. Then, after transmitting another N data symbols, repeat step 6 with $\mathbf{S^3}$ transmitted instead of $\mathbf{S^1}$.

- 8. Return to step 6.

- In this way, by a judicious choice of **N**, which depends on line conditions, changes in coupling between modes can be tracked.

Tracking Using Statistical Data

In some situations it may be undesirable to track coupling variations by using known transmitted sequences. In these cases, it is still preferable to startup using known training sequences. However, after data transmission is started, the receiver is adapted using the methods described hereinabove in the section entitled "Adapting Quad Terminations To Minimize Coupling". This sections details an algorithm for using those methods.

- 1. Startup using the procedure outlined in the above algorithm using a training sequence to determine an initial coupling matrix and its inverse.

- 2. Start data transmission. For the first **N** received data vectors, use the initial estimate of the coupling matrix to determine estimates of the transmitted data. Store the sequence of received vectors (called $\mathbf{r(n)}$, where n indicates the position sequence). Also store the values of the corresponding data vector estimates, $\hat{\mathbf{S}}\mathbf{(n)}$, as determined by using the inverse of the coupling matrix calculated in step 1.

- 3. Form the products $\mathbf{r(n)\,r^T(n)}$ and $\mathbf{S(n)\,S^T(n)}$ and store them.

- 4. After **N** data symbols have been received estimate the covariance matrices of received and transmitted data vectors as follows:

$$<\mathbf{rr^T}> \approx \frac{\mathbf{1}}{\mathbf{N}} \sum_{\mathbf{n=1}}^{\mathbf{N}} \mathbf{r(n)\,r^T(n)} \tag{22}$$

$$<\mathbf{SS^T}> \approx \frac{\mathbf{1}}{\mathbf{N}} \sum_{\mathbf{n=1}}^{\mathbf{N}} \hat{\mathbf{S}}\mathbf{(n)}\hat{\mathbf{S}}^{\mathbf{T}}\mathbf{(n)} \tag{23}$$

- 5. After step 4 is complete, use equation (15) and the results of equations (22) and (23) to make an estimate, $\mathbf{B_0^N}$, of the matrix $\mathbf{B_0}$. $\mathbf{B_0^N}$ is a three by three matrix with nine unknowns. Nine separate equations can be derived from the matrix equation (15), one equation per each element in the three by three matrix on each side of the "=" sign. The nine unknowns can be readily determined from these nine equations.

- 6. Use equation (17) to calculate the estimate of the $(\mathbf{N+1})$st transmitted data vector.

- 7. As each new received vector arrives, replace the oldest data in the storage with the newest data and repeat steps 3 through 6 for the updated data, thus continuously updating the estimate of $\mathbf{B_0}$. As the estimate of $\mathbf{B_0}$ is continuously update, the mathematical mechanism for estimating the transmitted data vector from the received data vector is updated.

The process described above is particularly useful on a rapidly changing channel. On a moderately changing channel, which is the more likely typical quad situation, step 7 may be replaced with step 7A:

- 7A. Use the estimate of $\mathbf{B_0}$, $\mathbf{B_0^N}$, and equation (17) to estimate the next N transmitted data vectors, storing $\mathbf{r(N+1)}$ through $\mathbf{r(2N)}$, and $\hat{\mathbf{S}}\mathbf{(N+1)}$ through $\hat{\mathbf{S}}\mathbf{(2N)}$. Then use equations (22) and (23), summing from $\mathbf{n=N+1}$ to $\mathbf{n=2N}$, and equation (15) to make a new estimate, $\mathbf{B_0^{2N}}$, of the matrix $\mathbf{B_0}$, which is then used to estimate the next **N** transmitted data vectors. This step is then repeated every **N** received data vectors.

On an even more slowly varying channel the estimate of $\mathbf{B_0}$ can be used to estimate **P** transmitted data vectors, where **P** is greater than **N**. The last **N** of each **P** received vectors and corresponding estimated transmitted data vectors are then stored and used to estimate a new $\mathbf{B_0}$, which is then used to estimate the next **P** transmitted data vectors. In all variations of this method, **N** itself depends on how fast the channel changes and the general conditions of the system, including thermal noise.

FIG. 3 shows a block diagram of an adaptive quad receiver 300 used for estimating transmitted data vectors from received vectors to compensate for cross-coupling between circuits. The quad conductors, 1-4, having voltages $\mathbf{v_1}$ - $\mathbf{v_4}$ thereon, respectively, terminate in a quad termination 301. Quad termination 301, shown in FIG. 2, transforms the received voltages into received signals, $\mathbf{r_1}$, $\mathbf{r_2}$, and $\mathbf{r_3}$, from the first, second, and phantom circuits of the quad, respectively. These received signals are input to a processor/detector 302, which detects these signals and processes them in accordance with the procedures described hereinabove to calculate estimates of the transmitted signals, $\hat{\mathbf{S}}_1$, $\hat{\mathbf{S}}_2$, and $\hat{\mathbf{S}}_3$. Both the received signals and the estimated transmitted signals are input to a storage device 303, which stores the **N** last received and estimated signals and passes them to the processor for calculation of the covariance matrices (22) and (23). During the startup procedure, processor/detector 302 detects the received vectors for each of the three known transmitted vectors, as described in the startup procedure detailed above. The initial coupling matrix **C** and its inverse $\mathbf{C^{-1}}$ are calculated and stored in storage 303. Receiver 300 then enters the adaptive stage and actual data is transmitted over the quad. Processor/detector 302 uses the initial estimate

of the inverse of the coupling matrix, $\mathbf{C}^{-1}$, to estimate the transmitted data from the received data. Then, as detailed in the tracking section above, the **N** received sets of signals and the **N** corresponding estimates of the transmitted signals in storage 303 are used by processor 302 to calculate the covariance matrices (22) and (23). Processor 302 then estimates $\mathbf{B}_0^{\mathbf{N}}$, which is then used to estimate the next transmitted signals from the received signals. As described in the section hereinabove, processor 302 updates its estimate of $\mathbf{B}_0$ based on the last **N** received and estimated transmitted signals after each set of received signals, after every **N** sets of received signals, or after every **P** sets of received signals, depending upon whether the channel is rapidly changing, moderately changing, or slowly changing, respectively.

A relatively simple method and system has been described above for compensating for coupling between conductors in star-quaded cable. The method and system adaptively terminate star-quaded cable to substantially suppress coupling between nominal quad modes when there is loose coupling between them. An approximation method is described for estimating the transmitted signal using only information that is available at the receiver and is good to second order in small quantities when the coupling is of first order. Thus, for example, if the coupling between modes is down, say, 20 dB, the adaptive termination would suppress it so that it was down about 40 dB.

Obviously more elaborate adaptation procedures that require the transmission of information about received signal levels back to the transmitter, or the use of known training sequences, could reduce this error further.

While the best mode for carrying out the invention has been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments for practicing the invention as defined by the following claims.

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What is claimed is:

1. In a telecommunications transmission system including a cable having at least one quad, a method for compensating for coupling between circuits of the quad, the method comprising the steps of:

during a startup period, separately and successively transmitting at a transmitting end of the cable known signals on each of the circuits of the quad;

measuring at an opposite receiving end of the cable the signals received on each of the circuits of the quad in response to the separate successive known signals;

estimating the coupling between circuits of the quad between the transmitting end and the receiving end of the cable from the measured received signals;

during transmission of data signals from the transmitting end on the circuits following the startup period, modifying received data signals on the circuits at the receiving end in accordance with the estimated coupling between circuits to produce estimated transmitted data signals;

storing at least one previous received data signal on each circuit and at least one previous corresponding estimated transmitted data signal on each circuit;

reestimating the coupling between circuits during transmission of data signals as a function of the stored at least one previous received data signal on each circuit and the stored at least one previous corresponding estimated transmitted data signal on each circuit; and

modifying the data signals received at the receiving end after reestimating the coupling in accordance with the reestimated coupling between circuits.

2. The method of claim 1 wherein the step of storing stores **N** previous received data signals and **N** previous corresponding estimated transmitted data signals on each circuit, and the step of reestimating the coupling between circuits includes the steps of estimating a covariance of received data signals from the stored **N** previous received data signals on each circuit, and estimating a covariance of transmitted data signals from the stored **N** previous estimated transmitted data signals on each circuit.

3. The method of claim 1 wherein the step of storing stores **N** previous received data signals on each circuit and **N** previous corresponding estimated transmitted data signals on each circuit, and the step of reestimating the coupling between circuits reestimates the coupling as a function of the stored **N** previous received data signals on each circuit and the stored **N** corresponding estimated transmitted data signals on each circuit.

4. The method of claim 3 wherein the step of reestimating the coupling between circuits is continuously performed after receiving a new data signal on each circuit.

5. The method of claim 3 wherein the step of reestimating the coupling between circuits is periodically performed after each new **N** data signals are received on each circuit.

6. The method of claim 3 wherein the step of reestimating the coupling between circuits is periodically performed after each new **P** data signals are received on each circuit, where **P** is greater than **N**.

7. In a telecommunications transmission system including a cable having at least one quad, a receiver at a receiving end of the cable for compensating for coupling between circuits of the quad, the receiver comprising:

means for receiving and measuring signals on each of the circuits of the quad in response to signals transmitted on each of the circuits from a transmitting end of the cable to the receiving end;

means for estimating the coupling between circuits of the quad between the transmitting end and the receiving end of the cable from signals received and measured in response to separately and successively transmitted known signals on each of the circuits of the quad during a startup period;

means for modifying received data signals on the circuits in accordance with the estimated coupling between circuits to produce estimated transmitted data signals;

storage means for storing at least one previous received data signal on each circuit and at least one previous corresponding estimated transmitted data signal on each circuit; and

means for reestimating the coupling between circuits during transmission of data signals as a function of the stored at least one previous received data signal on each circuit and the stored at least one previous corresponding estimated transmitted data signal on each circuit.

8. The receiver in accordance with claim 7 wherein said storage means stores **N** previous received data signals on each circuit and **N** previous corresponding estimated transmitted data signals on each circuit, and said means for reestimating the coupling between circuits comprises means for estimating a covariance of received data signals from the stored **N** previous received data signals on each circuit and for estimating a covariance of transmitted data signals from the stored **N** previous estimated transmitted data signals on each circuit.

9. The receiver in accordance with claim 7 wherein said storage means stores **N** previous received data signals on each circuit and **N** previous corresponding estimated transmitted data signals on each circuit, and said means for reestimating the coupling between circuits reestimates the coupling as a function of the stored **N** previous received data signals on each circuit and the stored **N** corresponding estimated transmitted data

signals on each circuit.

10. The receiver in accordance with claim 9 wherein said means for reestimating the coupling between circuits continuously reestimates the coupling after receiving a new data signal on each circuit.

11. The receiver in accordance with claim 9 wherein said means for reestimating the coupling periodically reestimates the coupling after each new **N** data signals are received on each circuit.

12. The receiver in accordance with claim 9 wherein said means for reestimating the coupling periodically reestimates the coupling after each new **P** data signals are received on each circuit, where **P** is greater than **N**.

AMENDED CLAIMS

[received by the International Bureau on 11 September 1995 (11.09.95); original claims 1-12 amended; (3 pages)]

What is claimed is:

1. In a telecommunications transmission system including a cable providing communications channels and having at least one quad having two side modes and one phantom mode, a method for compensating for coupling between said modes of the quad, the method comprising the steps of:

during a startup period, separately and successively transmitting at a transmitting end of the cable known signals on each of said modes of the quad;

measuring at an opposite receiving end of the cable the signals received on each of said modes of the quad in response to the separate successive known signals;

estimating the coupling between said modes of the quad between the transmitting end and the receiving end of the cable from the measured received signals;

during transmission of data signals from the transmitting end on the channels following the startup period, modifying received data signals on the channels at the receiving end of the cable in accordance with the estimated coupling between said modes to produce estimated transmitted data signals;

storing at least one received data signal on each channel and at least one corresponding estimated transmitted data signal on each channel;

reestimating the coupling between said modes during transmission of data signals as a function of the stored at least one received data signal on each channel and the stored at least one corresponding estimated transmitted data signal on each channel; and

modifying the data signals received at the receiving end after reestimating the coupling in accordance with the reestimated coupling between said modes.

2. The method of claim 1 wherein the step of storing stores a plurality **N** received data signals and **N** corresponding estimated transmitted data signals on each channel, and the step of reestimating the coupling between said modes includes the steps of estimating a covariance of received data signals from the stored **N** received data signals on each channel, and estimating a covariance of transmitted data signals from the stored **N** estimated transmitted data signals on each channel.

3. The method of claim 1 wherein the step of storing a plurality **N** received data signals on each channel and **N** corresponding estimated transmitted data signals on each channel, and the step of reestimating the coupling between said modes reestimates the coupling as a function of the stored **N** received data signals on each channel and the stored **N** corresponding estimated transmitted data signals on each channel.

4. The method of claim 3 wherein the step of reestimating the coupling between said modes is performed after receiving (a) each new data signal on each channel.

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5. The method of claim 3 wherein the step of reestimating the coupling between said modes is periodically performed after each new **N** data signals are received on each channel.

6. The method of claim 3 wherein the step of reestimating the coupling between said modes is performed after each new plurality **P** data signals are received on each channel, where **P** is greater than **N**.

7. In a telecommunications transmission system including a cable providing communication channels and having at least one quad having two side modes and one phantom mode, a compensating system at a receiving end of the cable for compensating for coupling between said modes of the quad, the compensating system comprising:

means for receiving and measuring signals on each of said modes of the quad in response to signals transmitted on each of the channels from a transmitting end of the cable to the receiving end;

means for estimating the coupling between said modes of the quad between the transmitting end and the receiving end of the cable from signals received and measured in response to separately and successively transmitted known signals on each of said modes of the quad during a startup period;

means for modifying received data signals on the channels in accordance with the estimated coupling between said modes to produce estimated transmitted data signals;

storage means for storing at least one received data signal on each channel and at least one corresponding estimated transmitted data signal on each channel;

means for reestimating the coupling between said modes during transmission of data signals as a function of the stored at least one received data signal on each channel and the stored at least one corresponding estimated transmitted data signal on each channel, and

means for modifying receival data signals on the channels in accordance with the reestimated coupling between said modes.

8. The system in accordance with claim 7 wherein said storage means stores a plurality **N** received data signals on each channel and **N** corresponding estimated transmitted data signals on each channel, and said means for reestimating the coupling between said modes comprises means for estimating a covariance of received data signals from the stored **N** estimated transmitted data signals on each channel.

9. The system in accordance with claim 7 wherein said storage means stores **N** received data signals on each channel and **N** corresponding estimated transmitted data signals on each channel, and said means for reestimating the coupling between said modes reestimates the coupling as a function of the stored **N** received data signals on

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each channel and the stored **N** corresponding estimated transmitted data signals on each channel.

10. The system in accordance with claim 9 wherein said means for reestimating the coupling between said modes continuously reestimates the coupling after receiving a new data signal on each channel.

11. The system in accordance with claim 9 wherein said means for reestimating the coupling reestimates the coupling after each new **N** data signals are received on each channel.

12. The system in accordance with claim 9 wherein said means for reestimating the coupling reestimates the coupling after each new plurality **P** data signals are received on each channel, where **P** is greater than **N**.

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STATEMENT UNDER ARTICLE 19

The amendments being made to claims 1 through 12 as originally filed clarify the language of the claims and improve their form. The amendments have no impact on the description and drawing of the application.

FIG. 1A

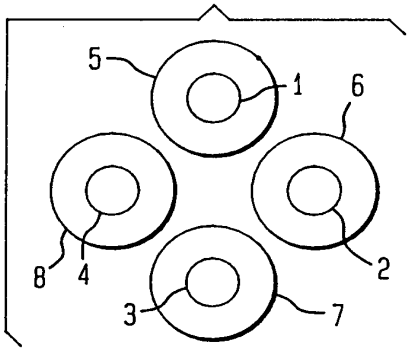

FIG. 1B

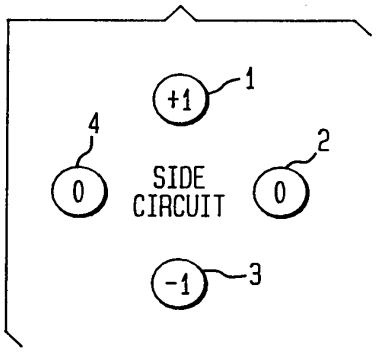

FIG. 1C

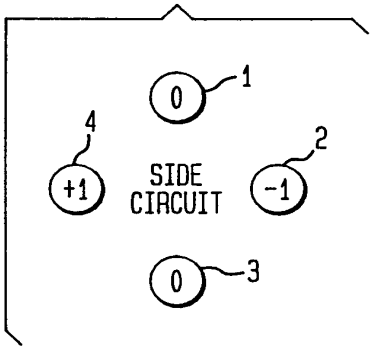

FIG. 1D

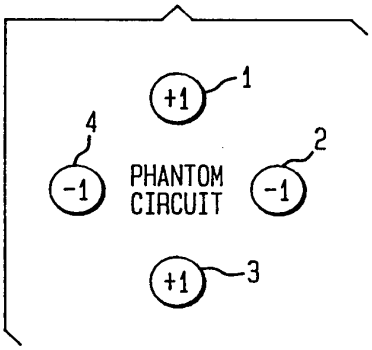

FIG. 1E

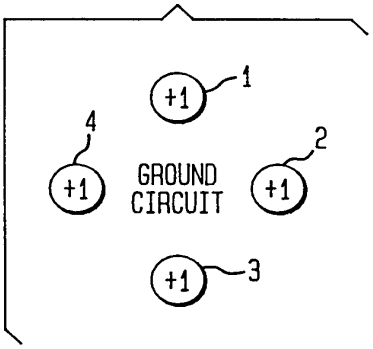

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FIG. 2

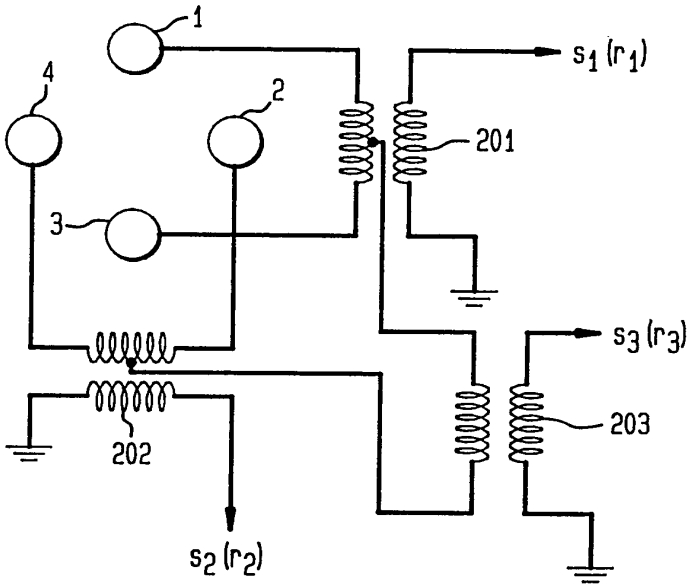
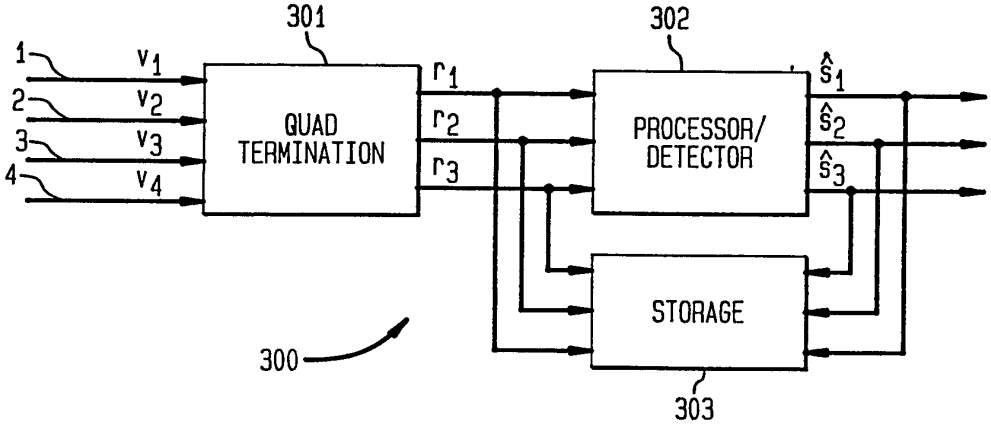


FIG. 3



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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/05061

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04M 1/24, 1/76, 3/34, 7/00; H04B 1/12, 17/00; H03H 7/30
US CL :379/1, 6, 24, 414, 415, 416, 417; 375/12, 13, 14; 364/724.2; 455/41, 63, 67.1, 67.3, 67.4
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 379/1, 6, 24, 414, 415, 416, 417; 375/12, 13, 14; 364/724.2; 455/41, 63, 67.1, 67.3, 67.4

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS
Search Terms: EQUALIZER, QUADED CABLE, TEST, MONITOR, COMPENSATE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,295,159 (KERPEZ) 15 March 1994, claims 16-20, col.10-col.11.	1-12
Y	US, A, 3,659,229 (MILTON) 25 April 1972, col.1,ln.50-col.2,ln.27, col.3,ln.1-25.	1, 3-7, 9-12
A	US, A, 5,181,198 (LECHLEIDER) 19 January 1993, col.10,ln.25-col.11,ln.39.	1-12
Y	US, A, 4,995,104 (GITLIN) 19 February 1991, abstract, col.1,ln.1-45, col.3,ln.41-66.	1, 7
A	US, A, 4,715,064 (CLAESSEN) 22 December 1987, col.1,ln.61-col.2,ln.35, col.6,ln.10-col.7,ln.6.	1, 7

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
01 JUNE 1995	26 JUL 1995

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	SCOTT L. WEAVER
Facsimile No. (703) 305-3230	Telephone No. (703) 308-6974

Form PCT/ISA/210 (second sheet)(July 1992)*

Charter Communications, Inc.
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/05061

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,634,964 (CHATTLER) 06 January 1987, col.1, col.4, ln.30-68.	1, 7
A	US, A, 4,053,723 (ARRAS ET AL.) 11 October 1977, col.1,ln.29-col.3,ln10, col.3,ln.34-col.6,ln.53.	1, 7

Form PCT/ISA/210 (continuation of second sheet)(July 1992)*

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Page #335

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

To:
URQUHART-DYKES & LORD LLP
Attn. Alton, Andrew
Tower North Central, Merrion Way
Leeds
LS2 8PA
GRANDE BRETAGNE

RECEIVED
- 4 SEP 2006
URQUHART-DYKES & LORD LLP
LEEDS

Applicant's or agent's file reference: AA/P205602WO	Date of mailing (day/month/year): 04/09/2006
International application No.: PCT/IB2006/000884	FOR FURTHER ACTION See paragraphs 1 and 4 below
Applicant: ADAPTIVE SPECTRUM AND SIGNAL ALIGNMENT, INC.	International filing date (day/month/year): 17/03/2006

1. [x] The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the International Search Report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Fascimile No.: (41-22) 338.82.70

   For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   [ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   [ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

   In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

   See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the International Searching Authority European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Hans Pettersson

Form PCT/ISA/220 (October 2005) *(See notes on accompanying sheet)*

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the *PCT Applicant's Guide*, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report and the written opinion of the International Searching Authority, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims,description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only (see *PCT Applicant's Guide*, Volume I/A, Annexes B1 and B2).

The attention of the applicant is drawn to the fact that amendments to the claims under Article 19 are not allowed where the International Searching Authority has declared, under Article 17(2), that no international search report would be established (see *PCT Applicant's Guide*, Volume I/A, paragraph 296).

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When?

Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How?

Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

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Page #337

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
AA/P205602WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/IB2006/000884	17/03/2006	02/06/2005

Applicant

ADAPTIVE SPECTRUM AND SIGNAL ALIGNMENT, INC.

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of:
      [X] the international application in the language in which it was filed
      [ ] a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. [ ] With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. [ ] **Certain claims were found unsearchable** (See Box No. II)

3. [ ] **Unity of invention is lacking** (see Box No III)

4. With regard to the **title**,
   [X] the text is approved as submitted by the applicant
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   [ ] the text is approved as submitted by the applicant
   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings**,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 4
      [ ] as suggested by the applicant
      [X] as selected by this Authority, because the applicant failed to suggest a figure
      [ ] as selected by this Authority, because this figure better characterizes the invention
   b. [ ] none of the figures is to be published with the abstract

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Page #338

Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

Adaptive generalized decision feedback equalization (GDFE) allows variations in one or more channels and noise of a multi-line/multi-channel communication system to be tracked. Such tracking can be used in vector upstream (one-sided) situations in communication systems such as ADSL and VDSL, among others. The GDFE may be separated into adaptive and static portions and/or components. Either a feedforward section or a feedback section (or both) can be separated to create a static component and an adaptive component. The adaptive components adjust to the instantaneous channel and nosie changes (for example, using the intantaneous errors and simple LMS algorithms). When the channel and noise do not exhibit any time-variation, the adaptive filters can zero themselves.

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2006/000884

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L25/03 H04L5/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/235245 A1 (ERDOGAN ALPER TUNGA ET AL) 25 December 2003 (2003-12-25) paragraphs [0003], [0004] paragraph [0009] - paragraph [0012] paragraph [0064] - paragraph [0073] figure 3 ----- -/--	1-64

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 August 2006	04/09/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Chave, J

3

Form PCT/ISA/210 (second sheet) (April 2005)

Charter Communications, Inc.
Exhibit 1007
Page #340

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GINIS G ET AL: "Blind adaptive MIMO decision feedback equalization using givens rotations" ICC 2002. 2002 IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS. CONFERENCE PROCEEDINGS. NEW YORK, NY, APRIL 28 - MAY 2, 2002, IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS, NEW YORK, NY : IEEE, US, vol. VOL. 1 OF 5, 28 April 2002 (2002-04-28), pages 59-63, XP010589458 ISBN: 0-7803-7400-2 the whole document	9-13,15, 17-20, 41-44, 58,60-63
A	GINIS G ET AL: "VECTORED TRANSMISSION FOR DIGITAL SUBSCRIBER LINE SYSTEMS" IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 20, no. 5, June 2002 (2002-06), pages 1085-1104, XP001143167 ISSN: 0733-8716 Section III. Crosstalk cancellation via QR decomposition. In particular sub-section III.C	1,9,15, 30,31, 34,35, 41,45, 58,63
A	CIOFFI J M ET AL: "Canonical packet transmission on the ISI channel with Gaussian noise" GLOBAL TELECOMMUNICATIONS CONFERENCE, 1996. GLOBECOM '96. 'COMMUNICATIONS: THE KEY TO GLOBAL PROSPERITY LONDON, UK 18-22 NOV. 1996, NEW YORK, NY, USA,IEEE, US, vol. 2, 18 November 1996 (1996-11-18), pages 1405-1410, XP010220148 ISBN: 0-7803-3336-5 the whole document	1,9,15, 30,31, 34,35, 41,45, 58,63

Charter Communications, Inc.
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Page #341

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2006/000884

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003235245 A1	25-12-2003	NONE	

Charter Communications, Inc.
Exhibit 1007
Page #342

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:

see form PCT/ISA/220

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference
see form PCT/ISA/220

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IB2006/000884	17.03.2006	02.06.2005

International Patent Classification (IPC) or both national classification and IPC
INV. H04L25/03 H04L5/02

Applicant
ADAPTIVE SPECTRUM AND SIGNAL ALIGNMENT, INC.

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☒ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notifed the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA	Date of completion of this opinion	Authorized Officer
European Patent Office - Gitschiner Str. 103 D-10958 Berlin Tel. +49 30 25901 - 0 Fax: +49 30 25901 - 840	see form PCT/ISA/210	Chave, J Telephone No. +49 30 25901-476

Form (PCT/ISA/237) (Cover Sheet) (April 2005)

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b)).

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

      ☐ a sequence listing

      ☐ table(s) related to the sequence listing

   b. format of material:

      ☐ on paper

      ☐ in electronic form

   c. time of filing/furnishing:

      ☐ contained in the international application as filed.

      ☐ filed together with the international application in electronic form.

      ☐ furnished subsequently to this Authority for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Charter Communications, Inc.
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Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-64
	No:	Claims	
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-64
Industrial applicability (IA)	Yes:	Claims	1-64
	No:	Claims	

2. Citations and explanations

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Charter Communications, Inc.
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Page #345

Re Item V.

1 Reference is made to the following documents:

D1 : US 2003/235245 A1 (ERDOGAN ALPER TUNGA ET AL) 25 December 2003 (2003-12-25)

D2 : GINIS G ET AL: "Blind adaptive MIMO decision feedback equalization using givens rotations" ICC 2002. 2002 IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS. CONFERENCE PROCEEDINGS. NEW YORK, NY, APRIL 28 - MAY 2, 2002, IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS, NEW YORK, NY : IEEE, US, vol. VOL. 1 OF 5, 28 April 2002 (2002-04-28), pages 59-63, XP010589458 ISBN: 0-7803-7400-2

D3: GINIS G ET AL: "VECTORED TRANSMISSION FOR DIGITAL SUBSCRIBER LINE SYSTEMS" IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 20, no. 5, June 2002 (2002-06), pages 1085-1104, XP001143167 ISSN: 0733-8716

2 INDEPENDENT CLAIMS 1, 9, 15, 30, 31, 34, 35, 41, 45, 58 and 63:

2.1 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of claim 1 does not involve an inventive step in the sense of Article 33(3) PCT.

Document D1, which is considered as the closest prior art, discloses (the references in parentheses applying to this document):

A method of operating an adaptive ~~generalized~~ decision feedback equalizer, the method comprising:

receiving ~~multi-~~user data;

applying a static ~~GDFE function~~ feedforward filter (pre-equalizer block on figure 3 and paragraph 65) to the received data; and

applying an adaptive ~~GDFE function~~ DFE function to the received data (equalizer blocks 318 to 324 on figure 3 and paragraphs 72-73).

D1 and claim 1 therefore both solve the subjective problem of tracking rapid time

Charter Communications, Inc.
Exhibit 1007
Page #346

variation of the channel (page 14 lines 25-29) through the use of a static equalizer for the time-invariant part of the channel and an adaptive equalizer for the time-varying channel conditions.

The subject-matter of claim 1 differs from the disclosure of D1 in that:
Multi-user data is received, and therefore as a result of joint processing a Generalized Decision Feedback Equalizer is used instead of a standard DFE.

However in the field of DSL transmission, it is well-known to the skilled person that joint processing of the multi-users can be performed through a vectored transmission (see document D3) in order to enhance the capacity. Therefore the skilled person would also apply the solution of D1 to a MIMO approach of DSL as disclosed in D3 and therefore arrives to the solution of claim 1.

2.2 D1 further discloses that the static equalizer (pre equalizer 316) is a static feedforward filter, whereas the adaptive equalizer (blocks 318 to 324) comprises an adaptive feedforward filter and an adaptive feedback filter. Adding a static feedback filter to the pre equalizer block lies within the ability of the skilled person facing such static channel conditions requiring a feedback filter. The further features or steps of the independent claims are either disclosed by D1 or by D3. Therefore the subject-matter of claims 9, 15, 30, 31, 34, 35, 41, 45, 58 and 63 does not involve an inventive step (Article 33(3) PCT).

2.3 Since the independent claims 9, 15, 41 and 58 and 63 fail to mention a static GDFE function, the subject-matter of these claims at least does not involve an inventive step over the disclosure of D2, which discloses a vectored DSL transmission using adaptive GDFE at the receiver.

3. DEPENDENT CLAIMS 2-8, 10-14, 16-29, 32, 33, 36-40, 42-44, 46-57, 59-62, 64
Dependent claims 2-8, 10-14, 16-29, 32, 33, 36-40, 42-44, 46-57, 59-62, 64 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive

Charter Communications, Inc.
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step (Article 33(2) and (3) PCT).

Re Item VIII.

1. Claims 1, 9, 15, 30, 31, 34, 35, 41, 45, 58 and 63 have been drafted as separate independent claims. The aforementioned claims therefore lack conciseness as such and do not meet the requirements of Article 6 PCT for the following reasons: claim 1, 9, 30 appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for which protection is sought and/or in respect of the terminology used for the features of that subject-matter. The same applies to claims 15, 35 on one hand and claims 31, 34 on the other hand and to claims 45, 58, 63 also.

2. The terms "GDFE function" used in claims 1 and 45 are vague and unclear and should be clarified.

Charter Communications, Inc.
Exhibit 1007
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PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

To:
URQUHART-DYKES & LORD LLP
Attn. Alton, Andrew
Tower North Central, Merrion Way
Leeds
LS2 8PA
GRANDE BRETAGNE

RECEIVED
18 AUG 2006
URQUHART-DYKES & LORD LLP
LEEDS

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing *(day/month/year)* 16/08/2006
Applicant's or agent's file reference AA/P205601WO	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/IB2006/000759	International filing date *(day/month/year)* 16/03/2006
Applicant ADAPTIVE SPECTRUM AND SIGNAL ALIGNMENT, INC.	

1. [X] The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the International Search Report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Fascimile No.: (41-22) 338.82.70

   For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   [ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   [ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

   In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

   See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Audrey Rummery

Charter Communications, Inc.
Exhibit 1007
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NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the *PCT Applicant's Guide*, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report and the written opinion of the International Searching Authority, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims,description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only (see *PCT Applicant's Guide*, Volume I/A, Annexes B1 and B2).

The attention of the applicant is drawn to the fact that amendments to the claims under Article 19 are not allowed where the International Searching Authority has declared, under Article 17(2), that no international search report would be established (see *PCT Applicant's Guide*, Volume I/A, paragraph 296).

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

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NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped),whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international application is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments and any accompanying statement, under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the time of filing the amendments (and any statement) with the International Bureau, also file with the International Preliminary Examining Authority a copy of such amendments (and of any statement) and, where required, a translation of such amendments for the procedure before that Authority (see Rules 55.3(a) and 62.2, first sentence). For further information, see the Notes to the demand form (PCT/IPEA/401).

If a demand for international preliminary examination is made, the written opinion of the International Searching Authority will, except in certain cases where the International Preliminary Examining Authority did not act as International Searching Authority and where it has notified the International Bureau under Rule 66.1*bis*(b), be considered to be a written opinion of the International Preliminary Examining Authority. If a demand is made, the applicant may submit to the International Preliminary Examining Authority a reply to the written opinion together, where appropriate, with amendments before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later (Rule 43*bis*.1(c)).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see the *PCT Applicant's Guide*, Volume II.

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PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
AA/P205601WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/IB2006/000759	16/03/2006	02/06/2005
Applicant		
ADAPTIVE SPECTRUM AND SIGNAL ALIGNMENT, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 6 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language,** the international search was carried out on the basis of:
      [X] the international application in the language in which it was filed
      [ ] a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. [ ] With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. [ ] **Certain claims were found unsearchable** (See Box No. II)

3. [X] **Unity of invention is lacking** (see Box No III)

4. With regard to the **title,**
   [ ] the text is approved as submitted by the applicant
   [X] the text has been established by this Authority to read as follows:

   TONAL PRECODING IN MULTI-USER VECTORED DSL TRANSMISSION

5. With regard to the **abstract,**
   [ ] the text is approved as submitted by the applicant
   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings,**
   a. the figure of the **drawings** to be published with the abstract is Figure No. 3A
      [ ] as suggested by the applicant
      [X] as selected by this Authority, because the applicant failed to suggest a figure
      [ ] as selected by this Authority, because this figure better characterizes the invention
   b. [ ] none of the figures is to be published with the abstract

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2006/000759

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-10,11-26,32-36,52-61,74,81-83

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

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Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

Precoding mitigates or removes interference signals (especially crosstalk) among multiple users with interconnected transmitters in vectored DSL systems and the like. Efficient implementation is provided of the R matrix in RQ factorization that characterizes multi-user downstream vector channels (such as DMT VDSL one-sided or two-sided transmission channels). A set of precoder coefficients can vary with each tone used by each user and depend upon the encoding order of users selected for each tone. In adaptive operation, the coefficients of the R and Q matrices can be updated when changes occur to the transmission environment. Variable modulo arithmetic mitigates the power-enhancement problem, and the base of the modular arithmetic also can vary with each user within a single tone.

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FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-10,11-26,32-36,52-61,74,81-83

   Adaptive precoding: The precoding is adjusted to channel/noise variations.

   ---

2. claims: 30,31,39,62-66,77

   A dither signal is added to the transmitted signal. This dither signal may vary with user and constellation in order to uniform the energy's distribution.

   ---

3. claims: 38,75

   dynamic precoding: substraction, modulo operation and dither are selected dynamically to accomodate power constraints.

   ---

4. claims: 27-29,40-50, 67-72,85-88

   Variation of the modulo arithmetic depending on the constellation size.

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2006/000759

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L25/03 H04L27/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GINIS G ET AL: "A multi-user precoding scheme achieving crosstalk cancellation with application to DSL systems*" SIGNALS, SYSTEMS AND COMPUTERS, 2000. CONFERENCE RECORD OF THE THIRTY-FOURTH ASILOMAR CONFERENCE ON OCT. 29 - NOV. 1, 2000, PISCATAWAY, NJ, USA,IEEE, vol. 2, 29 October 2000 (2000-10-29), pages 1627-1631, XP010535274 ISBN: 0-7803-6514-3 Section 2. Precoding for Crosstalk cancellationfigure 2 ----- -/--	37,51, 73,76, 78-80,84

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 May 2006	16 8 06
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Chave, J

4

Form PCT/ISA/210 (second sheet) (April 2005)

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(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LOUVEAUX J ET AL: "Downstream VDSL channel tracking using limited feedback for crosstalk precompensated schemes" ACOUSTICS, SPEECH, AND SIGNAL PROCESSING, 2005. PROCEEDINGS. (ICASSP '05). IEEE INTERNATIONAL CONFERENCE ON PHILADELPHIA, PENNSYLVANIA, USA MARCH 18-23, 2005, PISCATAWAY, NJ, USA,IEEE, 18 March 2005 (2005-03-18), pages 337-340, XP010792243 ISBN: 0-7803-8874-7 Sections 2. 3. and 4.	1-26, 32-36, 52-61, 74,81-83
A	CENDRILLON R ET AL: "Improved linear crosstalk precompensation for DSL" ACOUSTICS, SPEECH, AND SIGNAL PROCESSING, 2004. PROCEEDINGS. (ICASSP '04). IEEE INTERNATIONAL CONFERENCE ON MONTREAL, QUEBEC, CANADA 17-21 MAY 2004, PISCATAWAY, NJ, USA,IEEE, vol. 4, 17 May 2004 (2004-05-17), pages 1053-1056, XP010718770 ISBN: 0-7803-8484-9 Section 3.figure 3	1,11,16, 52,81

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PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:

see form PCT/ISA/220

RECEIVED
18 AUG 2006
URQUHART-DYKES & LORD LLP
LEEDS

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY
(PCT Rule 43*bis*.1)

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference
see form PCT/ISA/220

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IB2006/000759	16.03.2006	02.06.2005

International Patent Classification (IPC) or both national classification and IPC
INV. H04L25/03 H04L27/34

Applicant
ADAPTIVE SPECTRUM AND SIGNAL ALIGNMENT, INC.

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☒ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☒ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notifed the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA:	Date of completion of this opinion	Authorized Officer
European Patent Office - Gitschiner Str. 103 D-10958 Berlin Tel. +49 30 25901 - 0 Fax: +49 30 25901 - 840	see form PCT/ISA/210	Chave, J Telephone No. +49 30 25901-476

Form (PCT/ISA/237) (Cover Sheet) (April 2005)

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b)).

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

      ☐ a sequence listing

      ☐ table(s) related to the sequence listing

   b. format of material:

      ☐ on paper

      ☐ in electronic form

   c. time of filing/furnishing:

      ☐ contained in the international application as filed.

      ☐ filed together with the international application in electronic form.

      ☐ furnished subsequently to this Authority for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

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Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non obvious), or to be industrially applicable have not been examined in respect of

☐ the entire international application

☒ claims Nos. 27-31, 38-50, 62-72, 75, 77, 85-88

because:

☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international search *(specify)*:

☐ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. are so unclear that no meaningful opinion could be formed *(specify)*:

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed *(specify)*:

☒ no international search report has been established for the whole application or for said claims Nos. 27-31, 38-50, 62-72, 75, 77, 85-88

☐ a meaningful opinion could not be formed without the sequence listing; the applicant did not, within the prescribed time limit:

- ☐ furnish a sequence listing on paper complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.
- ☐ furnish a sequence listing in electronic form complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.
- ☐ pay the required late furnishing fee for the furnishing of a sequence listing in response to an invitation under Rules 13*ter*.1(a) or (b).

☐ a meaningful opinion could not be formed without the tables related to the sequence listings; the applicant did not, within the prescribed time limit, furnish such tables in electronic form complying with the technical requirements provided for in Annex C-*bis* of the Administrative Instructions, and such tables were not available to the International Searching Authority in a form and manner acceptable to it.

☐ the tables related to the nucleotide and/or amino acid sequence listing, if in electronic form only, do not comply with the technical requirements provided for in Annex C-*bis* of the Administrative Instructions.

☐ See Supplemental Box for further details

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Box No. IV Lack of unity of invention

1. ☒ In response to the invitation (Form PCT/ISA/206) to pay additional fees, the applicant has, within the applicable time limit:

   ☐ paid additional fees

   ☐ paid additional fees under protest and, where applicable, the protest fee

   ☐ paid additional fees under protest but the applicable protest fee was not paid

   ☒ not paid additional fees

2. ☐ This Authority found that the requirement of unity of invention is not complied with and chose not to invite the applicant to pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rule 13.1, 13.2 and 13.3 is

   ☐ complied with

   ☒ not complied with for the following reasons:

   see separate sheet

4. Consequently, this report has been established in respect of the following parts of the international application:

   ☐ all parts.

   ☒ the parts relating to claims Nos. 1-10,11-26,32-36,52-61,74,81-83

Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	3-10,12-15,17-26,32-36,53-61,74,81-83
	No:	Claims	1,2,11,16,37,51,52,73,76,78-80,84
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-26,32-36,51-61,73,74,76,78-84
Industrial applicability (IA)	Yes:	Claims	1-26,32-36,51-61,73,74,76,78-84
	No:	Claims	

2. Citations and explanations

   see separate sheet

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Re Item IV.

1 Reference is made to the following document:

D1: GINIS G ET AL: "A multi-user precoding scheme achieving crosstalk cancellation with application to DSL systems" SIGNALS, SYSTEMS AND COMPUTERS, 2000. CONFERENCE RECORD OF THE THIRTY-FOURTH ASILOMAR CONFERENCE ON OCT. 29 - NOV. 1, 2000, PISCATAWAY, NJ, USA,IEEE, vol. 2, 29 October 2000 (2000-10-29), pages 1627-1631, XP010535274 ISBN: 0-7803-6514-3

2. Document D1 discloses a multi-user DSL system where precoding is performed at the transmitter (see figure 2 with feedback filter and modulo operation). D1 therefore discloses the subject-matter of claims 37, 51, 73, 76, 78-80 and 84 which are consequently not novel (Article 33(2) PCT).

3. Document D1 ("A Multi-user precoding scheme achieving Crosstalk cancellation with Application to DSL systems" from Cioffi) is considered as the most relevant prior art.

4 Groups of claims or potential inventions have been delimited and present the following potential special technical feature over D1:

- Group of claims 1-10,11-26,32-36,52-61,74,81-83:
The precoding is made adaptive in order to cope with channel and noise variations.

- Group of claims 30,31,39,62-66,77:
A dither signal is added to the transmitted signal. This dither signal may vary with user and constellation in order to uniform the energy's distribution.

- Group of claims 38,75:
dynamic precoding: substraction, modulo operation and dither are selected dynamically to accommodate power constraints.

- Group of claims 27-29,40-50, 67-72,85-88:
Variation of the modulo arithmetic depending on the constellation size in order to

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enable the joint precoding of users having different constellations.

These potential special technical features are clearly not the same or do not correspond, therefore unity is lacking (Rule 13(2) PCT).

Re Item V.

1 Reference is made to the following document:

D2 : LOUVEAUX J ET AL: "Downstream VDSL channel tracking using limited feedback for crosstalk precompensated schemes" ACOUSTICS, SPEECH, AND SIGNAL PROCESSING, 2005. PROCEEDINGS. (ICASSP '05). IEEE INTERNATIONAL CONFERENCE ON PHILADELPHIA, PENNSYLVANIA, USA MARCH 18-23, 2005, PISCATAWAY, NJ, USA,IEEE, 18 March 2005 (2005-03-18), pages 337-340, XP010792243 ISBN: 0-7803-8874-7

D3: CENDRILLON R ET AL: "Improved linear crosstalk precompensation for DSL" ACOUSTICS, SPEECH, AND SIGNAL PROCESSING, 2004. PROCEEDINGS. (ICASSP '04). IEEE INTERNATIONAL CONFERENCE ON MONTREAL, QUEBEC, CANADA 17-21 MAY 2004, PISCATAWAY, NJ, USA,IEEE, vol. 4, 17 May 2004 (2004-05-17), pages 1053-1056, XP010718770 ISBN: 0-7803-8484-9

2 INDEPENDENT CLAIMS 1, 11, 16, 52, 81:

D2 like D1 also discloses a multi-user DSL system where precoding is performed at the transmitter. The precoding involves a feedback filter (the precoder used by D2 is depicted on figure 3 of D3) and a modulo arithmetic. Furthermore the precoding is made adaptive in order to cope with channel variations. The precoder is regularly recomputed based on received feedback from the receiver.

Therefore the subject-matter of claims 1, 11, 16 and 52 is not novel (Article 33(2) PCT).

Concerning claim 81, the method implemented by the computer program is disclosed

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by D2, therefore a computer program product implementing a known method can not be considered as inventive (Article 33(3) PCT).

7 DEPENDENT CLAIMS 2-10, 12-15, 17-26, 32-36, 53-61, 74, 82, 83
Dependent claims 2-10, 12-15, 17-26, 32-36, 53-61, 74, 82, 83 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step (Article 33(2) and (3) PCT).

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PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

To:
URQUHART-DYKES & LORD LLP
Attn. Alton, Andrew
Tower North Central
Merrion Way
Leeds LS2 8PA
UNITED KINGDOM

Date of mailing *(day/month/year)* 09/06/2006	
Applicant's or agent's file reference AA/P205592WO	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/IB2006/000499	International filing date *(day/month/year)* 28/02/2006
Applicant ADAPTIVE SIGNAL AND SPECTRUM ALIGNMENT, INC	

1. [x] The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the International Search Report.

Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Fascimile No.: (41-22) 338.82.70

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the International Searching Authority European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Audrey Rummery

Form PCT/ISA/220 (October 2005) *(See notes on accompanying sheet)*

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the *PCT Applicant's Guide*, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report and the written opinion of the International Searching Authority, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims,description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only (see *PCT Applicant's Guide*, Volume I/A, Annexes B1 and B2).

The attention of the applicant is drawn to the fact that amendments to the claims under Article 19 are not allowed where the International Searching Authority has declared, under Article 17(2), that no international search report would be established (see *PCT Applicant's Guide*, Volume I/A, paragraph 296).

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When?

Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How?

Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

Charter Communications, Inc.
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Page #366

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
AA/P205592WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/IB2006/000499	28/02/2006	10/05/2005
Applicant		
ADAPTIVE SIGNAL AND SPECTRUM ALIGNMENT, INC		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of:
      [X] the international application in the language in which it was filed
      [ ] a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. [ ] With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. [ ] **Certain claims were found unsearchable** (See Box No. II)

3. [ ] **Unity of invention is lacking** (see Box No III)

4. With regard to the **title**,
   [ ] the text is approved as submitted by the applicant
   [X] the text has been established by this Authority to read as follows:
   QR DECOMPOSITION IN DSL EQUALIZERS USING REAL GIVENS ROTATIONS

5. With regard to the **abstract**,
   [ ] the text is approved as submitted by the applicant
   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings**,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 3
      [ ] as suggested by the applicant
      [ ] as selected by this Authority, because the applicant failed to suggest a figure
      [X] as selected by this Authority, because this figure better characterizes the invention
   b. [ ] none of the figures is to be published with the abstract

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Page #367

Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

The invention assists in the efficient implementation of any unitary "Q" matrix in a QR or other sophisticated matrix factorization. A complex form of the so-called "Givens" implementation of the Q matrix is characterized in terms of a sequence of complex rotations that can implemented using a complex rotor computational unit that accepts a minimum of two real angles and a pair of integer indices for each of a set of successive complex rotor calculations and then implements the complex rotation as a series of a minimum of three real rotations with one real angle used twice and the other real angle used once, providing two complex outputs (that is, two rotated data entries from a data vector comprising indexed communication data) for two complex inputs (two original data entries from a data vector comprising indexed communication data). The index-angle sets for each successive rotation can be provided by a complex rotor calculation unit, which may be collocated with the complex rotor computational unit, located in a controller such as a DSL optimizer, or located in any other suitable device or apparatus that has performed the QR factorization upon supplied matrix MIMO transfer functions for the vectored channel.

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2006/000499

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F17/16 H04L25/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GINIS G ET AL: "VECTORED TRANSMISSION FOR DIGITAL SUBSCRIBER LINE SYSTEMS" IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 20, no. 5, June 2002 (2002-06), pages 1085-1104, XP001143167 ISSN: 0733-8716 Section III.: Crosstalk Cancellation via QR decomposition ----- -/--	1-19

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 May 2006	09/06/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Chave, J

Form PCT/ISA/210 (second sheet) (April 2005)

Charter Communications, Inc.
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Page #369

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	CUYPERS ET AL: "Combined per tone equalization and receiver windowing in DSL receivers: WiPTEQ" SIGNAL PROCESSING, ELSEVIER SCIENCE PUBLISHERS B.V. AMSTERDAM, NL, vol. 85, no. 10, October 2005 (2005-10), pages 1921-1942, XP005016634 ISSN: 0165-1684 Section 3.2.1. Trapezoidal window	1-19
A	OTTE M ET AL: "Complex CORDIC-like algorithms for linearly constrained MVDR beamforming" BROADBAND COMMUNICATIONS, 2000. PROCEEDINGS. 2000 INTERNATIONAL ZURICH SEMINAR ON ZURICH, SWITZERLAND 15-17 FEB. 2000, PISCATAWAY, NJ, USA,IEEE, US, 15 February 2000 (2000-02-15), pages 97-104, XP010376445 ISBN: 0-7803-5977-1 Section 4. Complex CORDIC-like Algorithms	1-3,9, 10,17
A	CIOFFI J M: "THE FAST ADAPTIVE ROTOR'S RLS ALGORITHM" IEEE TRANSACTIONS ON ACOUSTICS, SPEECH AND SIGNAL PROCESSING, IEEE INC. NEW YORK, US, vol. 38, no. 4, 1 April 1990 (1990-04-01), pages 631-653, XP000128135 ISSN: 0096-3518 figure 3 Section II.D: Computational Units.	1,5-7,9

1

Charter Communications, Inc.
Exhibit 1007
Page #370

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:

see form PCT/ISA/220

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY
(PCT Rule 43*bis*.1)

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference
see form PCT/ISA/220

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IB2006/000499	28.02.2006	10.05.2005

International Patent Classification (IPC) or both national classification and IPC
INV. G06F17/16 H04L25/02

Applicant
ADAPTIVE SIGNAL AND SPECTRUM ALIGNMENT, INC

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☒ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☒ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notifed the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA:	Date of completion of this opinion	Authorized Officer
European Patent Office - Gitschiner Str. 103 D-10958 Berlin Tel. +49 30 25901 - 0 Fax: +49 30 25901 - 840	see form PCT/ISA/210	Chave, J Telephone No. +49 30 25901-476

Form (PCT/ISA/237) (Cover Sheet) (April 2005)

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b)).

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

      ☐ a sequence listing

      ☐ table(s) related to the sequence listing

   b. format of material:

      ☐ on paper

      ☐ in electronic form

   c. time of filing/furnishing:

      ☐ contained in the international application as filed.

      ☐ filed together with the international application in electronic form.

      ☐ furnished subsequently to this Authority for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

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Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-19
	No:	Claims	
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-19
Industrial applicability (IA)	Yes:	Claims	1-19
	No:	Claims	

2. Citations and explanations

see separate sheet

Box No. VI Certain documents cited

1. Certain published documents (Rules 43*bis*.1 and 70.10)

and / or

2. Non-written disclosures (Rules 43*bis*.1 and 70.9)

see form 210

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

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Re Item V.

1 Reference is made to the following document:

D1 : GINIS G ET AL: "VECTORED TRANSMISSION FOR DIGITAL SUBSCRIBER LINE SYSTEMS" IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 20, no. 5, June 2002 (2002-06), pages 1085-1104, XP001143167 ISSN: 0733-8716

D2: OTTE M ET AL: "Complex CORDIC-like algorithms for linearly constrained MVDR beamforming" BROADBAND COMMUNICATIONS, 2000. PROCEEDINGS. 2000 INTERNATIONAL ZURICH SEMINAR ON ZURICH, SWITZERLAND 15-17 FEB. 2000, PISCATAWAY, NJ, USA,IEEE, US, 15 February 2000 (2000-02-15), pages 97-104, XP010376445 ISBN: 0-7803-5977-1

D3: CIOFFI J M: "THE FAST ADAPTIVE ROTOR'S RLS ALGORITHM" IEEE TRANSACTIONS ON ACOUSTICS, SPEECH AND SIGNAL PROCESSING, IEEE INC. NEW YORK, US, vol. 38, no. 4, 1 April 1990 (1990-04-01), pages 631-653, XP000128135 ISSN: 0096-3518

2 INDEPENDENT CLAIMS 1, 9 and 17:

2.1 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of claim 1 does not involve an inventive step in the sense of Article 33(3) PCT.
Document D1 which is considered as the closest prior art, discloses (the references in parentheses applying to this document):

A method of processing indexed DSL data samples in order to triangularize the channel matrix H using a so-called QR decomposition. The Q matrix may be calculated based on a series of Givens rotations (Section III).

Since D1 does not specify how the Q matrix is calculated using Givens rotations, the skilled person would use its common general technical knowledge to which document

Charter Communications, Inc.
Exhibit 1007
Page #374

D3 belongs, in order to compute the Q matrix. D3 discloses a QR decomposition based on modular units implementing the repeated Givens rotations. In particular the CISORs and ROTORs depicted on figure 3 and their controller implement the further steps of:

providing a first angle, a second angle, a first index and a second index;
obtaining a first original data entry from the indexed DSL data samples using the first index;
obtaining a second original data entry from the indexed DSL data samples using the second index;
performing a complex rotation of the first original data entry and the second original data entry using the first angle and the second angle to generate a first rotated data entry and a second rotated data entry;
replacing the first original data entry with the first rotated data entry in the indexed ~~DSL~~ data samples; and
replacing the second original data entry with the second rotated data entry in the indexed communication data.

Therefore the skilled person would arrive to the implementation of the computation of the Q matrix in a DSL system as disclosed in claim 1.

2.2 Concerning claim 9 which is the corresponding apparatus claim in another category, the features used are obvious features that the skilled person would envisage in order to implement the method of claim 1. Therefore the subject-matter of claim 9 does not involve an inventive step (Article 33(3) PCT).

2.3 Concerning now claim 17, its additional step of decomposing the complex Givens rotations into real rotations is obvious and disclosed for instance by document D2, that also belongs to the common general technical knowledge (numerous articles trying to reduce the computational burden of the Givens rotations by decomposing them into real rotations). Therefore the subject-matter of claim 17 does not involve an inventive step (Article 33(3) PCT).

Charter Communications, Inc.
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Page #375

4 DEPENDENT CLAIMS 2-8, 10-16, 18, 19
Dependent claims 2-8, 10-16, 18, 19 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of inventive step (Article 33(3) PCT). In particular the steps or features of claims 2,3 and 10 are disclosed by D2, and the steps of claims 5-7 are disclosed by D3.

Re Item VIII.

1. The terms Q matrix in claim 2 and H matrix in claim 5 are not clear since they have not been defined. A definition like in claim 9 is recommended.

2. It is not clear how to calculate the Q matrix in claim 2 since the terms in the formula have not been defined, and since it is defined as a result to be achieved.

Charter Communications, Inc.
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PATENT COOPERATION TREATY

RECEIVED
JAN 11 2008
BEAVERTON

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

To:
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP
Attn. Caldwell, Gregory D.
1279 Oakmead Parkway
Sunnyvale, California 94085-4040
ETATS-UNIS D'AMERIQUE

RECEIVED
JAN 10 2008
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN

(PCT Rule 44.1)

Applicant's or agent's file reference 008241.P030	Date of mailing *(day/month/year)* 04/01/2008 **FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US2007/013393	International filing date *(day/month/year)* 06/06/2007
Applicant ADAPTIVE SPECTRUM AND SIGNAL ALIGMENT, INC.	

1. [X] The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the International Search Report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Fascimile No.: (41-22) 338.82.70

   For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   [ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   [ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

   In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

   See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the International Searching Authority European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Carina Bergström Date in to SV FF: 1/10/08 Docketed by: WLA Reviewed by: _____ Sent Out by SV FF on: 1/10/08

Form PCT/ISA/220 (October 2005) *(See notes on accompanying sheet)*

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the *PCT Applicant's Guide*, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report and the written opinion of the International Searching Authority, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims,description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only (see *PCT Applicant's Guide*, Volume I/A, Annexes B1 and B2).

The attention of the applicant is drawn to the fact that amendments to the claims under Article 19 are not allowed where the International Searching Authority has declared, under Article 17(2), that no international search report would be established (see *PCT Applicant's Guide*, Volume I/A, paragraph 296).

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When?

Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How?

Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

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PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
008241.P030		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US2007/013393	06/06/2007	06/06/2006
Applicant		
ADAPTIVE SPECTRUM AND SIGNAL ALIGMENT, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 5 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language,** the international search was carried out on the basis of:

[X] the international application in the language in which it was filed

[ ] a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

b. [ ] This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. [ ] With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. [ ] **Certain claims were found unsearchable** (See Box No. II)

3. [ ] **Unity of invention is lacking** (see Box No III)

4. With regard to the **title,**

[ ] the text is approved as submitted by the applicant

[X] the text has been established by this Authority to read as follows:

VECTORED DSL SYSTEM

5. With regard to the **abstract,**

[ ] the text is approved as submitted by the applicant

[X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings,**

a. the figure of the **drawings** to be published with the abstract is Figure No. 15

[ ] as suggested by the applicant

[ ] as selected by this Authority, because the applicant failed to suggest a figure

[X] as selected by this Authority, because this figure better characterizes the invention

b. [ ] none of the figures is to be published with the abstract

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2007/013393

Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

An apparatus comprises at least one vectoring engine (1511; 1512) and a cross-connect (1520) coupled to the vectoring engine (1511; 1512). The cross-connect (1520) is to couple with each of a plurality of customer premises equipment (CPE) devices (1541; 1592; 1543; 1544) via a respective DSL loop (1531; 1532; 1533; 1534). An interface is to receive instructions for the cross-connect (1520) to couple the vectoring engine (1511) to a nonoverlapping subset of the CPE devices (1541; 1543) via the respective DSL loops (1532; 1533). The interface is further to receive instructions for the vectoring engine (1511) to apply vectoring to the DSL loop via which to couple one of the CPE devices to the cross-connect.

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2007/013393

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04Q3/00 H04B3/32 H04M11/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04Q H04B H04M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, IBM-TDB, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/129218 A1 (KIMBLE BRUCE [US] ET AL) 16 June 2005 (2005-06-16) paragraph [0012] paragraphs [0075] - [0078] paragraphs [0089] - [0096]	1-25
A	WO 2005/094052 A (ADAPTIVE SPECTRUM AND SIGNAL ALIGNMENT, INC) 6 October 2005 (2005-10-06) page 2, line 10 - page 3, line 16 page 10, line 6 - page 11, line 8 page 19, line 4 - page 22, line 4	1-25

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 December 2007	04/01/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Vercauteren, Steven

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Form PCT/ISA/210 (second sheet) (April 2005)

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Page #381

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2007/013393

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GEORGE GINIS ET AL: "Vectored Transmission for DigitalSubscriber Line Systems" IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONSS, vol. 20, no. 5, June 2002 (2002-06), pages 1085-1104, XP011065493 ISSN: 0733-8716 the whole document	1-25

3

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2007/013393

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005129218 A1	16-06-2005	NONE	
WO 2005094052 A	06-10-2005	AU 2005226164 A1	06-10-2005
		CA 2561009 A1	06-10-2005
		CN 1954586 A	25-04-2007
		EP 1733550 A1	20-12-2006

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PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:

see form PCT/ISA/220

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY
(PCT Rule 43*bis*.1)

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference
see form PCT/ISA/220

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2007/013393	06.06.2007	06.06.2006

International Patent Classification (IPC) or both national classification and IPC
INV. H04Q3/00 H04B3/32 H04M11/06

Applicant
ADAPTIVE SPECTRUM AND SIGNAL ALIGMENT, INC.

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☒ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☒ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notifed the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA:	Date of completion of this opinion	Authorized Officer
European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	see form PCT/ISA/210	Vercauteren, Steven Telephone No. +31 70 340-1045

Form (PCT/ISA/237) (Cover Sheet) (April 2005)

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43bis.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

      ☐ a sequence listing

      ☐ table(s) related to the sequence listing

   b. format of material:

      ☐ on paper

      ☐ in electronic form

   c. time of filing/furnishing:

      ☐ contained in the international application as filed.

      ☐ filed together with the international application in electronic form.

      ☐ furnished subsequently to this Authority for the purposes of search.

4. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

Box No. II Priority

1. ☒ The validity of the priority claim has not been considered because the International Searching Authority does not have in its possession a copy of the earlier application whose priority has been claimed or, where required, a translation of that earlier application. This opinion has nevertheless been established on the assumption that the relevant date (Rules 43*bis*.1 and 64.1) is the claimed priority date.

2. ☐ This opinion has been established as if no priority had been claimed due to the fact that the priority claim has been found invalid (Rules 43*bis*.1 and 64.1). Thus for the purposes of this opinion, the international filing date indicated above is considered to be the relevant date.

3. Additional observations, if necessary:

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Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	3-6,8,11-25
	No:	Claims	1,2,7,9,10
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-25
Industrial applicability (IA)	Yes:	Claims	1-25
	No:	Claims	

2. Citations and explanations

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

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Re Item VIII.

1. The application does not meet the requirements of Article 6 PCT, because claims 1-25 are not clear.

1.1 The vague and imprecise statement "*the invention should ... be defined by the following claims and their full scope of equivalents, whether foreseeable or unforeseeable now or in the future*" in the last sentence of the description implies that the subject-matter for which protection is sought may be different to that defined by the claims, thereby resulting in lack of clarity (Article 6 PCT) when used to interpret them.

1.2 Although claims 1 and 7 have been drafted as separate independent claims, it appears that claim 7 contains all the features resp. the apparatus of claim 1. Claim 7 should therefore have been formulated as a claim dependent on claim 1.
The aforementioned claims therefore lack conciseness. Moreover, lack of clarity of the claims as a whole arises, since the plurality of independent claims makes it difficult, if not impossible, to determine the subject-matter for which protection is sought, and places undue burden on others seeking to establish the extent of protection. Hence claims 1-25 do not meet the requirements of Article 6 PCT.

1.3 The term "*vectored CPE device*" used in claim 7 is vague and unclear and leaves the reader in doubt as to the meaning of the technical features to which it refers, thereby rendering the definition of the subject-matter of said claim unclear, Article 6 PCT.

1.4 The formulation of claim 9, i.e. "*In an apparatus including a vectoring engine, ... , a method comprising ...*", leaves the reader in doubt as to whether it concerns an apparatus claim or a method claim, thereby rendering the definition of the subject-matter of said claim unclear (Article 6 PCT). A better formulation would have been "*A method for managing an apparatus including a vectoring engine, ... , the method comprising ...*".

Re Item V.

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Reference is made to the following document:

D1 : US 2005/129218 A1 (KIMBLE BRUCE [US] ET AL) 16 June 2005 (2005-06-16)

2. Furthermore, the above-mentioned lack of clarity notwithstanding, the subject-matter of claims 1, 7, and 9 is not new in the sense of Article 33(2) PCT, and therefore the criteria of Article 33(1) PCT are not met.

2.1 Document D1 discloses (the references in parentheses applying to this document) *an apparatus* (cf. Fig. 9), *comprising:*
at least one vectoring engine (cf. the component resp. MIMO transceiver 910)*;*
a cross-connect (cf. the local interconnect 945 + the dedicated interconnect 920) *coupled to the at least one vectoring engine* (cf. Fig. 9), *the cross-connect to couple with each of a plurality of customer premises equipment device* (cf. subscriber equipment 960), *hereafter referred to as CPE devices, via a respective DSL loop* (cf. the subscriber line 972)*;*
an interface to receive instructions from a source external to the apparatus (implicitly disclosed) *for the cross-connect to couple the at least one vectoring engine* (cf. the component resp. MIMO transceiver 910) *to a nonoverlapping subset of the CPE devices via the respective DSL loops* (cf. the subscriber lines 978, 976, 974, 972) *and receive instructions for the at least one vectoring engine to apply vectoring* (cf. paragraph [0006]) *to the DSL loop via which one of the CPE devices is to couple to the cross-connect.*

The subject-matter of claim 1 is therefore not new (Article 33(2) PCT).

Further, it should be noted that, even if novelty could be argued based on the fact resp. difference that D1 does not explicitly disclose said interface to receive instructions, such difference would not contribute to an inventive step in the sense of Article 33(3) PCT. The cross-connections shown in Fig. 9 should be made resp. programmed somehow. Providing an interface to receive instructions therefor is then obvious design measure that the skilled person would take to solve the problem posed.

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2.2 As far as claim 7 can be understood, see points 1.2 and 1.3 above, it appears that the system of claim 7 includes a CPE device as well as the apparatus of claim 1, where it is further said that said apparatus is a Digital Subscriber Line Access Multiplexer (DSLAM). In figures 5 and 8 of D1, a DSLAM 415 is depicted. It follows that the subject-matter of claim 7 is also new (Article 33(2) PCT).

2.3 As far as claim 9 can be understood, see point 1.4 above, claim 9 appears to contain essentially the same features, in terms of method steps, as claim 1. A similar objection (Article 33(2) PCT) therefore applies.

3. Dependent claims 2-6, 8 and 10-25 do not contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty (Article 33(2) PCT) and/or inventive step (Article 33(3) PCT), since these additional features concern routine design measures and/or are already known from document D1.

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Possible steps after receipt of the international search report (ISR) and written opinion of the International Searching Authority (WO-ISA)

General information	For all international applications filed on or after 01/01/2004 the competent ISA will establish an ISR. It is accompanied by the WO-ISA. Unlike the former written opinion of the IPEA (Rule 66.2 PCT), the WO-ISA is not meant to be responded to, but to be taken into consideration for further procedural steps. This document explains about the possibilities.
Amending claims under Art. 19 PCT	Within 2 months after the date of mailing of the ISR and the WO-ISA the applicant may file amended claims under Art. 19 PCT directly with the International Bureau of WIPO. The PCT reform of 2004 did not change this procedure. For further information please see Rule 46 PCT as well as form PCT/ISA/220 and the corresponding Notes to form PCT/ISA/220.
Filing a demand for international preliminary examination	In principle, the WO-ISA will be considered as the written opinion of the IPEA. This should, in many cases, make it unnecessary to file a demand for international preliminary examination. If the applicant nevertheless wishes to file a demand this must be done before expiry of 3 months after the date of mailing of the ISR/WO-ISA or 22 months after priority date, whichever expires later (Rule 54bis PCT). Amendments under Art. 34 PCT can be filed with the IPEA as before, normally at the same time as filing the demand (Rule 66.1 (b) PCT). If a demand for international preliminary examination is filed and no comments/amendments have been received the WO-ISA will be transformed by the IPEA into an IPRP (International Preliminary Report on Patentability) which would merely reflect the content of the WO-ISA. The demand can still be withdrawn (Art. 37 PCT).
Filing informal comments	After receipt of the ISR/WO-ISA the applicant may file informal comments on the WO-ISA directly with the International Bureau of WIPO. These will be communicated to the designated Offices together with the IPRP (International Preliminary Report on Patentability) at 30 months from the priority date. Please also refer to the next box.
End of the international phase	At the end of the international phase the International Bureau of WIPO will transform the WO-ISA or, if a demand was filed, the written opinion of the IPEA into the IPRP, which will then be transmitted together with possible informal comments to the designated Offices. The IPRP replaces the former IPER (international preliminary examination report).
Relevant PCT Rules and more information	Rule 43 PCT, Rule 43bis PCT, Rule 44 PCT, Rule 44bis PCT, PCT Newsletter 12/2003, OJ 11/2003, OJ 12/2003

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XS CPRTENFRDE

BNSDOCID: <XS ...2006100103CF I >

Electronic Acknowledgement Receipt

EFS ID:	5235199
Application Number:	12185729
International Application Number:	
Confirmation Number:	9857
Title of Invention:	ADAPTIVE FEC CODEWORD MANAGEMENT
First Named Inventor/Applicant Name:	John M. Cioffi
Customer Number:	08791
Filer:	Gregory D. Caldwell/Christina Rainey
Filer Authorized By:	Gregory D. Caldwell
Attorney Docket Number:	8241.P002D
Receipt Date:	28-APR-2009
Filing Date:	04-AUG-2008
Time Stamp:	17:37:13
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Filed (SB/08)	8241P002D_IDS_4-28-09.pdf	326433 f90d50bbf32880b07ab8f864e2cf1f619c74a15b	no	5
Warnings:					
Information:					

This is not an USPTO supplied IDS fillable form					
2	Foreign Reference	1_DE4444312.pdf	454174 8a80d936b1e78d104af157ad4612e002b63144ef	no	8
Warnings:					
Information:					
3	NPL Documents	1_DE4444312_English_Abstract.pdf	27755 6ce5fec4ee36fae748bc24118632f527c54d6c05	no	1
Warnings:					
Information:					
4	Foreign Reference	2_GB2315392.pdf	3408659 2b2a8c606ffbf965c4af86ef242f4dc570e840c1	no	82
Warnings:					
Information:					
5	Foreign Reference	3_WO01035611A1.pdf	2117638 7c9ef204c81ef3a2f7696823d5be25a039270040	no	66
Warnings:					
Information:					
6	Foreign Reference	4_WO2005094052.pdf	1811543 a74ab7c37a0903913b0cbcb4c360812e13d615a4	no	42
Warnings:					
Information:					
7	Foreign Reference	5_WO04027579.pdf	1246480 1f3e7e5e1e44fd4febc5034feece21cb95ad4ee0	no	29
Warnings:					
Information:					
8	Foreign Reference	6_WO95031867.pdf	1088554 932a3044ec7116de22e2cf390ab1fa70f249e3c8	no	26
Warnings:					
Information:					
9	NPL Documents	7_P018_OA_11-12-08.pdf	1598568 fc97f3be51e3ecc6f332b8d1270fc0a54c65220b	no	23
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Information:					
10	NPL Documents	8_P002CN_OA_3-27-09.pdf	1067909 b79d4dac43c40c2413a3eeae21ad18b80974594c	no	12

Warnings:					
Information:					
11	NPL Documents	9_P018PCT_ISR_WO.PDF	519966 d7c27903d31c78387a09154f01c020d8181b10b0	no	13
Warnings:					
Information:					
12	NPL Documents	10_P017PCT_ISR_WO.PDF	684862 15c1fabbcda567055fc38fb0f3c5c2f88f777d9e	no	16
Warnings:					
Information:					
13	NPL Documents	11_P016PCT_ISR_WO.PDF	511562 ddf31300bedf247a7568d4151238c720eaa663ac	no	12
Warnings:					
Information:					
14	NPL Documents	12_P030PCT_ISR_WO.pdf	1260550 2515e0138f92b306e547a2eb43e71742f7c7e1a9	no	15
Warnings:					
Information:					
15	NPL Documents	13_Cendrillon_Improved_Linear_Crosstalk_Precompensation_for_DSL_5-2004.pdf	122569 2407f2f686d70d6a05b560e5c3b5216c71aa710e	no	4
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16	NPL Documents	14_Cendrillon_Partial_Crosstalk_Cancellation_Exploiting_Line_and_tone_selection_in_VDSL_9-2003.pdf	138730 db914effe1c68a80adff655892a699d884c7f72f	no	6
Warnings:					
Information:					
17	NPL Documents	15_Cendrillon_Partial_Crosstalk_Cancellation_for_Upstream_VDSL_10-2004.pdf	841179 e9cae4c07e43f08d4bf1f42505fd543e948ccf8d	no	16
Warnings:					
Information:					
18	NPL Documents	16_Cendrillon_Partial_crosstalk_precompensation_in_downstream_VDSL_11-2004.pdf	324627 424494decbb10a840fc3dae2b0a90a5d5c6b0760	no	15
Warnings:					
Information:					
19	NPL Documents	17_Cendrillon_The_Linear_Zero-Forcing_Crosstalk_Canceler_is_Near-Optimal_12-2004.pdf	106068 65559364ba061c73ec138614e994adf6609a3ab8	no	5

Warnings:					
Information:					
20	NPL Documents	18_Cheong_Computationally_Efficient_Cancellation_of_Partially_Overlapped_11-2005.pdf	296964 2755c6727445abd6ef3047c1142bf70ee28a64a0	no	5
Warnings:					
Information:					
21	NPL Documents	19_Cioffi_Canonical_packet_transmission_on_the_ISI_channel_with_Gaussian_noise_5-1996.PDF	351409 9ea493850c3843348c67045c8c1cb11592cadf1b	no	6
Warnings:					
Information:					
22	NPL Documents	20_Cioffi_Dynamic_Spectrum_Management_A_Methodology_for_providing_significantly.pdf	221031 3d9c586485b07326ff435f85d61c6ce4f72cab4b	no	12
Warnings:					
Information:					
23	NPL Documents	21_Cioffi_Dynamic_Spectrum_Management_Report_2-21-05.pdf	22548 543a27a771bf76ae6236255ca937103423af4243	no	1
Warnings:					
Information:					
24	NPL Documents	22_Cioffi_MIMO_Channel_Measurement_Test_Plan_2-17-03.pdf	309009 348172d1e933561cb1b751bfcc754c8a1339516b	no	8
Warnings:					
Information:					
25	NPL Documents	23_Cioffi_The_Fast_Adaptive_Rotors_RLS_Algorithm_4-1-90.pdf	1243958 bb306bc33c023d9b09673261fe71dd84f975b1f7	no	23
Warnings:					
Information:					
26	NPL Documents	24_Cuypers_Combined_Per_Tone_equalization_and_receiver_windowing_in_DSL_receivers.pdf	871122 29b7f6358a915df1ebe3fe1a64d96fc3e9b774ea	no	22
Warnings:					
Information:					
27	NPL Documents	25_Cuypers_combining_per_tone_equaliztn_windowing_dmt_receivers.pdf	451733 9952fe66e8d444e732879358f4c69335ece554cd	no	4
Warnings:					
Information:					
28	NPL Documents	26_P002EP_OA_6-27-08.pdf	778966 be294fc2bb9f0dd0a8d36dcfb440e2a84031c073	no	6

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Information:					
29	NPL Documents	27_Fang_Modeling_and_Characterization_of_Copper_Access_Systems_5-31-02.pdf	410212 d068288ca9e35d3f783401e7b9d50297830411a5	no	53
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30	NPL Documents	28_Fischer_appendixe.pdf	556757 2c715d2cd6a3187b08b3b19b11d26dd234666b64	no	11
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31	NPL Documents	29_Forouzan_Generalized_Iterative_Spectrum_Balancing_and_Grouped_12-2-05.pdf	246072 44d26b7bec738166f2f74f26496c182f27a8125e	no	5
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32	NPL Documents	30_Ginis_A_Multiuser_Precoding_Scheme_achieving_Crosstalk_Cancellation.pdf	213439 d1cf3e626f92b53df13e1adb3b64e20632704780	no	5
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Information:					
33	NPL Documents	31_Ginis_Alien_Crosstalk_Cancellation_for_Multi-pair_Digital_Subscriber_Line_Systems_2006.pdf	820381 394b5eb684f593cc826984a950d125b991bce31f	no	12
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Information:					
34	NPL Documents	32_Ginis_Blind_Adaptive_MIMO_Decision_Feedback_Equalization.pdf	272902 9ae3a5b9f331121ee44cb24e5049372773d92a47	no	5
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Information:					
35	NPL Documents	33_Ginis_Vectored_Transmission_for_Digital_Subscriber_Line_systems_6-2002.pdf	2998864 0ca2d5a913df72d32ff02578e8cbe087e4d5e16f	no	20
Warnings:					
Information:					
36	NPL Documents	34_Harashima_Matched_Transmission_technique_for_channels_with_intersymbol_interference_8-1972.pdf	476123 4c14039e067c0e1d6292c6ce429278ab5df7ca33	no	7
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Information:					
37	NPL Documents	35_Gi-Hong_Im_FEXT_Cancellation_for_Multi-Carrier_Transmission_system_4-11-02.pdf	275060 2eec73a2744f6129b91741afe53ae0a243f80a05	no	8

Warnings:					
Information:					
38	NPL Documents	36_Laroia_A_Simple_and_Effective_Precoding_Scheme_for_Noise_Whitening.pdf	282518 9fca5dcb7288caed9acf6873869b527b9ded15aa	no	4
Warnings:					
Information:					
39	NPL Documents	38_Louveaux_Downstream_VDSL_Channel_Tracking_3-2005.pdf	325728 45199ac77d3ebca17c2b5d68c4f32f5d720c74f1	no	4
Warnings:					
Information:					
40	NPL Documents	39_Magesacher_Exploiting_the_Common-Mode_Signal_in_xDSL_9-2004.pdf	411209 b00f35e3fa76d7a1fde00f583c4f7fe4b2a998bb	no	4
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Information:					
41	NPL Documents	40_Otte_Complex_CORDIC-like_algorithms_for_linearly_constrained_MVDR_Beamforming_2-2000.pdf	774393 7e906ec8c6da38b18767176a017a68411de9d67a	no	21
Warnings:					
Information:					
42	NPL Documents	41_P015PCT_ISR_and_WO_mailed-5-18-06.pdf	495021 c7e820cdcad6c02237a732f6a1cd404b3cc653d8	no	9
Warnings:					
Information:					
43	NPL Documents	42_Paul_Anaylsis_of_Multiconductor_Transmission_Lines.pdf	31009 4a19cec2b295b2c442afafa30a12432304b72fee	no	1
Warnings:					
Information:					
44	NPL Documents	43_Song_Dynamic_Spectrum_Managment_for_Next-Generation_DSL_Systems_10-2002.pdf	460637 ef32537d686a43a7d013a81d061ac3bde141c7b8	no	9
Warnings:					
Information:					
45	NPL Documents	44_Tomlinson_New_Automatic_Equaliser_Employing_Modulo_Arithmetic_3-1971.pdf	170438 4fd944651cb9e6f4f76bd6ec3c626b69ee243156	no	2
Warnings:					
Information:					
46	NPL Documents	45_Vectoring_Techniques_for_Multi-line_10MDSL_Systems_8-2002.pdf	368070 0ff6e425674449ea9eafca4d6b3cdac12d854f42	no	11

Warnings:					
Information:					
47	NPL Documents	46_Wei_Generalized_Square_and_Hexagonal_Constellations_for.pdf	616392 056bc2655fa66dc87c0064611bfae872bfc5fac7	no	9
Warnings:					
Information:					
48	NPL Documents	37_Lee_Binder_MIMO_Channels.pdf	1456482 7d16c17ee04aad63bdd5f3849ed94083b1079200	no	31
Warnings:					
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		Total Files Size (in bytes):	33866273		

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New International Application Filed with the USPTO as a Receiving Office
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/185,729	08/04/2008	John M. Cioffi	8241.P002D

CONFIRMATION NO. 9857

8791
BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP
1279 OAKMEAD PARKWAY
SUNNYVALE, CA 94085-4040

PUBLICATION NOTICE

OC000000035299025

Title:ADAPTIVE FEC CODEWORD MANAGEMENT

Publication No.US-2009-0086800-A1
Publication Date:04/02/2009

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/185,729	08/04/2008	John M. Cioffi	8241.P002D

CONFIRMATION NO. 9857

8791
BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP
1279 OAKMEAD PARKWAY
SUNNYVALE, CA 94085-4040

NEW OR REVISED PPD NOTICE

OC00000033807405

NOTICE OF NEW OR REVISED PROJECTED PUBLICATION DATE

The above-identified application has a new or revised projected publication date. The current projected publication date for this application is 04/02/2009. If this is a new projected publication date (there was no previous projected publication date), the application has been cleared by Licensing & Review or a secrecy order has been rescinded and the application is now in the publication queue.

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
12/185,729	08/04/2008	2611	1030	8241.P002D	20	3

CONFIRMATION NO. 9857

8791
BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP
1279 OAKMEAD PARKWAY
SUNNYVALE, CA 94085-4040

FILING RECEIPT

OC000000032534190

Date Mailed: 10/14/2008

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

John M. Cioffi, Atherton, CA;

Power of Attorney: The patent practitioners associated with Customer Number 08791

Domestic Priority data as claimed by applicant

This application is a DIV of 10/795,593 03/08/2004 PAT 7,428,669
which claims benefit of 60/527,853 12/07/2003

Foreign Applications

Projected Publication Date: To Be Determined - pending completion of Security Review
Non-Publication Request: No
Early Publication Request: No
Title

ADAPTIVE FEC CODEWORD MANAGEMENT

Preliminary Class

375

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re the Application of:	
JOHN M. CIOFFI	Art Group: 2611
Application No.: 12/185,729	Examiner:
Filed: August 4, 2008	
For: **ADAPTIVE FEC CODEWORD MANAGEMENT**	Confirmation No.: 9857

INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §1.97

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In accordance with the duty of disclosure, enclosed is a copy of an Information Disclosure Statement (IDS) Citation Form PTO/SB/08 or PTO-1449, together with copies of the documents cited on that form, except for copies not required to be submitted (e.g., copies of U.S. patents and U.S. published patent applications need not be enclosed). This IDS and IDS Citation Form are being submitted within three (3) months of filing of the application. It is respectfully requested that the cited references be considered and that the enclosed copy of PTO/SB/08 be initialed by the Examiner to indicate such consideration and a copy thereof returned to applicant(s).

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Please charge any fees due to Deposit Account 02-2666.

Respectfully submitted,

BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP

Date: August 18, 2008

/Gregory D. Caldwell/

Gregory D. Caldwell, Reg. No. 39,926

1279 Oakmead Parkway
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I hereby certify that this correspondence is being submitted electronically via EFS Web on the date shown below.

Gigi Hoover 08-18-08

Gigi Hoover *Date*

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Substitute for form 1449A/PTO	Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT *(Use as many sheets as necessary)*	**Application Number**	12/185,729
	Filing Date	August 4, 2008
	First Named Inventor	Cioffi, John
	Group Art Unit	2611
	Examiner Name	
Sheet 1 of 2	Attorney Docket No: 8241P002D	

US PATENT DOCUMENTS					
Examiner Initial *	**Cite No [1]**	**USP Document Number**	**Publication or Issue Date MM-DD-YYYY**	**Name of Patentee or Applicant of cited Document**	**Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear**
		US-4,733,395	03/22/1988	Gelbrich, Hans-Joachim , et al.	
		US-4,901,319	02/13/1990	Daniel, Ross	
		US-5,023,872	06/11/1991	Annamalai, Kadiresan	
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		US-6,067,646	05/23/2000	Starr, Thomas J.	
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		US-6,310,909	10/30/2001	Jones, David	
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		US-6,546,509	04/08/2003	Starr, Thomas J.	
		US-6,598,188	07/22/2003	Locke, Michael , et al.	
		US-6,629,249	09/30/2003	Gonzalez, Julio A.	

OTHER DOCUMENTS -- NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	**Cite No [1]**	**Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.**	**T [2]**
		International Search Report from International Application No. PCT/IB2004003961, Attorney Docket No. 8241P002PCT, mailed 7/4/2005, pgs. 1-4.	
		ITU-T Recommendation G.992.1, Asymmetric digital subscriber line (ADSL) transceivers, Series G, as provided by International Searching Authority, Reference No. XP-002321806, 6/1999, 14 pgs.	
		Written Opinion of the International Search Authority, International Application No. PCT/IB2004003961, Attorney Docket No. 8241P002PCT, 1/2004, pgs. 1-6.	
		CIOFFI, JOHN, "Dynamic Spectrum Management", Alcatel DSL Forum presentation; Paris, France, (11/11/2003), pgs. 1-47.	
		CIOFFI, JOHN, "Dynamic Spectrum Management", Deutsche Telecom DSL	

EXAMINER **DATE CONSIDERED**

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Substitute for form 1449A/PTO	Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT *(Use as many sheets as necessary)*	**Application Number**	12/185,729
	Filing Date	August 4, 2008
	First Named Inventor	Cioffi, John
	Group Art Unit	2611
	Examiner Name	
Sheet 2 of 2	Attorney Docket No: 8241P002D	

OTHER DOCUMENTS -- NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	**Cite No [1]**	**Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.**	**T[2]**
		presentation; Darmstadt, Germany, (10/6/2003), pgs. 1-37.	
		CIOFFI, JOHN, "Dynamic Spectrum Management", IEEE Globalcom presentation; San Francisco, California, (12/3/2003), pgs. 1-30.	
		CIOFFI, JOHN, "Dynamic Spectrum Management", Telecom Italia presentation; Turin, Italy, (11/19/2003), pgs. 1-32.	
		CIOFFI, JOHN, "Dynamic Spectrum Management", Korea Telecom DSL presentation; Seoul, Korea, (9/24/2003), pgs. 1-38.	
		CIOFFI, JOHN M., "Dynamic Spectrum Management Report", Broadband World Forum; London, England, (9/10/2003), pgs. 1-17.	
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		MOULIN, F., et al., "Discrete-multitone-based ADSL and VDSL systems performance analysis in an impulse noise environment", IEEE Proceedings: Sci Meas. Technol. Vol. 150 No. 6, Reference No. XP-006024286, (11/3/2003), pgs. 273-78.	
		NEDEV, N., et al., "Comparison between Interleaving and Multiple DMT Symbols per RESPECTFULLY SUBMITS Codeword in ADSL Systems", Globalcom 2002 - IEEE Global Telecommunications Conference; Taipei, Taiwan, Reference No. XP-010636152, (11/17/2002), pgs. 2265-69.	
		STARR, et al., "DSL Advances", Chapters 3, 7, and 11; Prentice- Hall, (2003), Ch. 3 (pgs. 41-98); Ch. 7 (pgs. 184-244); Ch. 11 (pgs. 1-53).	
		STARR, et al., "Information comment solicitation on ITU FEC INP submission for ADSL2", Committee T1, Working group T1E1.4 (DSL Access); Vancouver, BC, (2/23/2004), Paper (pgs. 1-7); PowerPoint Slides (pgs. 1-9).	
		STARR, et al., "Proposed revisions to G.992.4 and G.992.3&5 regarding impulse noise protection", Study group 15, ITU - Telecommunication Standardization Sector; San Francisco, California, (3/8/2004), pgs. 1-6.	
		VEITHEN, D., et al., "A 70Mb/s Variable-Rate DMT-Based Modem for VDSL", 1999 IEEE International Solid-State Circuits Conference; ISSCC99/Session 14/Paper TP 14.6., Reference No. XP-002184687, (2/15/1999), pgs. 248-49.	
		Office Action; European Patent Application No. 04801294.2; Attorney Docket No. 8241P002EP, received via facsimile August 1, 2008, pgs. 1-2.	

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EFS ID:	3779843
Application Number:	12185729
International Application Number:	
Confirmation Number:	9857
Title of Invention:	ADAPTIVE FEC CODEWORD MANAGEMENT
First Named Inventor/Applicant Name:	John M. Cioffi
Customer Number:	8791
Filer:	Gregory D. Caldwell/Gigi Hoover
Filer Authorized By:	Gregory D. Caldwell
Attorney Docket Number:	8241.P002D
Receipt Date:	18-AUG-2008
Filing Date:	
Time Stamp:	18:19:02
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Foreign Reference	1_8241P002PCT_ISR.pdf	144015 8c9773d409c5b897da6c0f90d5ddf94cc6ef2b48	no	4

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2	NPL Documents	2_ITU_Reccommendation_G_9921.pdf	549238 18d6af047919c7c0c805b3f46249bf54b027068e	no	14
Warnings:					
Information:					
3	Foreign Reference	3_8241P002PCT_WO.pdf	225025 03c786e0c8b9bdd9507045ad128fb6aa1d03c664	no	6
Warnings:					
Information:					
4	NPL Documents	4_DSM_Paris.pdf	3627825 2218a5eea300757c1c89a49d414cf010592868f3	no	47
Warnings:					
Information:					
5	NPL Documents	5_DSM_Germany.pdf	4308525 95efb404f87fd3cfb0722a8f222f6da278c2bc41	no	37
Warnings:					
Information:					
6	NPL Documents	6_DSM_San_Francisco.pdf	1862095 80d28df0409322bf8c2bb2a58595826d1b100ade	no	30
Warnings:					
Information:					
7	NPL Documents	7_DSM_Italy.pdf	2251915 edaa04e1e8200848fd4ec488171fd97c787330b9	no	32
Warnings:					
Information:					
8	NPL Documents	8_DSM_Korea.pdf	3384408 e39f4eb9d7b4ffbb2a134e33d0593814de11c7a9	no	38
Warnings:					
Information:					
9	NPL Documents	9_DSM_London.pdf	3182914 bfc391141c529b96cc5267a84a7808f5f34a080a	no	59
Warnings:					
Information:					
10	NPL Documents	10_Low_Latency_Impulse.pdf	1600784 17c83ad022f71fefb6bb2c9680dcc66af57dad5d	no	13
Warnings:					
Information:					

11	NPL Documents	11_Discrete_multitone_based_ADSL.pdf	500339 f3a9a02d883203e6f53802c098a9dd306107e440	no	6
Warnings:					
Information:					
12	NPL Documents	12_Comparison_between_Interleaving.pdf	340271 52d71574cb55e2d28189bfdd700a2c874449d37e	no	5
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13	NPL Documents	13_Starr_DSL_Advances_Ch_3_7_11.pdf	16019478 d816b1ebdd7ff478b4cefbd3c3b61663a785cbff	no	173
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Information:					
14	NPL Documents	14_Starr_Information.pdf	2398396 340ee1661e23c47e0d3499114952224629dd517e	no	33
Warnings:					
Information:					
15	NPL Documents	15_Proposed_revisions.pdf	316685 482152182911cc17e6d437da08163deed1900993	no	6
Warnings:					
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16	NPL Documents	16_A_70Mbs_Variable_Rate.pdf	158598 84b0bbeac8d44c5c2d19bcdb7255fb8ffb69a235	no	2
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17	Foreign Reference	17_8241P002EP_OA.pdf	1000237 e2dc5bbba1a580a2e985a71353e5f13213a5d204	no	10
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18		8241P002D_IDS_081808.PDF	140240 c274c1a108e387d03ca15a9585d52c37fbdd92e4	yes	4

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
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Attorney Docket No.8241.P002D

PATENT APPLICATION

TITLE OF THE INVENTION

ADAPTIVE FEC CODEWORD MANAGEMENT

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ADAPTIVE FEC CODEWORD MANAGEMENT

John M. Cioffi

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional of U.S. Patent Application No. 10/795,593, filed March 8, 2004, which claims the benefit of priority under 35 U.S.C. § 119(e) of U.S. Provisional No. 60/527,853 (Attorney Docket No. 0101-p01p) filed on December 7, 2003, entitled DYNAMIC MANAGEMENT OF COMMUNICATION SYSTEM, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates generally to methods, systems and apparatus for managing digital communications systems. More specifically, this invention relates to dynamically controlling system parameters that affect performance in communication systems such as DSL systems.

Description of Related Art

Digital subscriber line (DSL) technologies provide potentially large bandwidth for digital communication over existing telephone subscriber lines (referred to as loops and/or the copper plant). Telephone subscriber lines can provide this bandwidth despite their original design for only voice band analog communication. In particular, asymmetric DSL (ADSL) can adjust to the characteristics of the subscriber line by using a discrete multitone (DMT) line code that assigns a number of bits to each tone (or sub-carrier), which can be adjusted to channel conditions as determined during training and initialization of the modems (typically transceivers that function as both transmitters and receivers) at each end of the subscriber line.

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Impulse noise, other noise and other sources of error can substantially impact the accuracy of data transmitted by ADSL and other communications systems. Various techniques have been developed for reducing, avoiding and/or repairing the damage done to data during transmission by such error. These error reduction/avoidance/repair techniques have performance costs for a communication system in which they are used. As is well known in the art, interleaving can reduce and/or eliminate adverse error effects by distributing errors generated by noise and other sources during transmission. Interleaving is a coding technique commonly used to increase the performance of transmission systems by decreasing errors in the system. Prior to transmission, interleaving rearranges transmission data to improve the error-correction performance of redundancy coding techniques by spreading errors out over more bytes of data.

The interleave "depth" is preferably defined conceptually and most generally as the distance between bits that originally were adjacent to one another. The interleave depth is altered by varying the distance between originally adjacent bits. Increasing the interleave depth improves the error correction capability of a given system. However, as discussed in more detail below, interleaving increases the transmission latency (that is, the time required for data to traverse the end-to-end transmission path) of the system. The interleave depth also may be a numerical value D that will be explained in more detail below.

One redundancy coding technique used in connection with interleaving is forward error correction (FEC) employing Reed-Solomon encoding, which is well known to those skilled in the art. FEC takes data to be transmitted by a user (referred to as "payload" data) and generates codewords that contain the "payload" data bytes and parity bytes (which also may be referred to as "redundancy" bytes in ADSL standards and various other publications), which assist a system receiver in checking for errors in transmitted data. These FEC codewords are inputs to a programmed transmitter interleaver.

Reed-Solomon codewords are made up of K data or information bytes (the user's payload data) and R parity bytes, totaling N bytes in each codeword (that is, K+R=N).

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Typically N must be 255 or less and DSL systems use only even numbers. The ADSL1 standard describes the methods used in FEC coding for that type of system and explains the use of FEC encoding and interleaving in detail. As noted in the ADSL1 standard, the FEC coder takes in S mux data frames of K_{mux} bytes of payload data and appends R FEC redundancy bytes to produce the FEC codeword of length $N_{FEC}=SxK_{mux}+R$ bytes. The FEC output data frames contain N_{FEC}/S bytes, which is an integer.

In communication systems such as ADSL that use DMT techniques, each codeword may contain all or part of one or more DMT symbols. The variable S is used to refer to the number of DMT symbols present in each FEC codeword. Typically S=1 for fast transmission (low delay mode), since spanning more than one symbol introduces extra delay. In DSL, S can be a rational fraction as low as 1/3 (or effectively even lower in VDSL standards) and can be greater than 1. In some embodiments of the present invention, a modem may compute its S value based on other parameters.

The N, K, S and D parameters are directly specified by modem pairs in ADSL. In ADSL1 (or G.992.1/2), the downstream FEC settings for N, R, S, and D are determined by the transmitter (or ATU-C), while in ADSL2 (or G.992.3/4/5) the downstream FEC settings N, R, S and D and related parameters are determined by the downstream receiver (ATU-R) during loading. Upstream FEC settings are set by the ATU-C in both ADSL1 and ADSL2. The setting of S allows a modem the flexibility to match a the requested data rate with whatever internal overhead it determines it should use. If the modem also is told S, the modem might be put into a quandary of incompatible or otherwise conflicting requirements. Earlier systems have not used adaptive programming of the N, K and D parameters. While one system implemented by Alcatel currently allows 3 choices for D only, disadvantageously, the 2 choices useful for addressing impulse noise and the like have excessive delays and cause higher layer protocols to be less efficient.

Interleaving FEC codewords introduces a transmission delay (or "latency"), which can be a significant drawback in DSL systems. The latency associated with interleaving can constitute a significant portion of a system's overall latency. High latency can have a

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substantial negative impact on system performance, especially when the system is operating at high data transmission rates. The impact is especially pronounced for systems where many end-to-end transmissions are required to accomplish a task (for example, systems utilizing TCP/IP to send a large file). Accordingly, providers generally strive to minimize latency through their systems, though still tolerate it to gain the benefits of interleaving and offset adverse error effects. Therefore, it is desirable to minimize the interleaving necessary to achieve desired performance.

Some prior art systems use "adaptive" interleaving, which allows different interleaving depths to be applied to different transmissions. Adaptive interleavers are known to those skilled in the art. U.S. Pat. Nos. 4,901,319 and 6,546,509 describe adaptive interleaving systems, which adjust for various channel problems, noise and other sources of error. However, they require changes to the interleaving depths (denoted by the variable D) to be applied to different transmissions, which in turn alters the latency of the system.

Where the interleave depth is adaptively increased to reduce the error rate in earlier systems, the latency of the system increases, adversely affecting system performance and possibly leading to other performance-related problems. In addition, increasing interleave depth (and thus latency) may violate standards relating to prescribed latencies that are permitted for operation of a transceiver in an ADSL system. In some cases, increasing interleave depth even a small amount may compel large increases in latency due to the fact that some standards have discrete latency values. Therefore, a small, adaptive "bump up" in interleave depth by an adaptive interleaver may lead to a disproportionately large increase in latency, again a highly undesirable consequence of error correction.

ADSL standards prescribe some latencies. For example, in most implementations of ADSL1, the available latency delays typically are 4 ms and 24 ms (though occasionally a third option of 16 ms might be available) and are set by the DSLAM manufacturer's default for both upstream and downstream. In ADSL2 and ADSL2+ (G.992.5), the

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available latencies are set by the operator between 2 ms and 20 ms using the element management system (a data acquisition system, described in detail in G.997.1, that allows a service provider to implement control parameters such as the INP value and maximum interleaving delay), which conveys the preference to the line's modems, including the downstream receiver (ATU-R). That receiver selects the N, R and D parameters using a minimum impulse noise protection value or impulse strength indicator (called INP in G.992.3/4/5 and the related G.997.1), depending on vendor-imposed default options (sometimes referred to as "profiles"). The maximum interleaving delay and INP values in the G.992.3/4/5 and G.997.1 standards (which are incorporated herein in their entireties by reference for all purposes) however must be supplied upon initialization of the modem and there is no way to know any error measurements before data transmission. Emerging VDSL standards also use Reed Solomon codes and may have INP/Delay and/or N, R and D specification capability, depending on their evolution. Also, SHDSL standards may use bonding and Reed Solomon codes also and the same basic methods apply there to the setting of the N, R and D parameters or their equivalents like INP/Maximum Interleaving Delay. However, as can be seen from the available latency values in these systems, having to go to a higher latency as a result of adaptive interleaving and the like can mean a substantial increase in transmission delay.

Systems, methods and techniques that permit adjustment of a communications system to compensate for changing channel and other conditions, including noise effects, while minimizing and/or preserving the latency characteristics of the system would represent a significant advancement in the art. Moreover, maintaining a fixed latency delay for interleaving of data in an ADSL system, while adaptively adjusting the system to meet one or more error rate requirements would likewise constitute a significant advancement in the art.

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BRIEF SUMMARY OF THE INVENTION

Adaptive FEC coding is used to adjust the codeword composition of FEC codewords in a communication system. A codeword composition ratio may be adjusted in response to variance of a measured transmission error value from a target transmission error value in the system. The codeword composition ratio may be any quantity or value that represents the relation between the payload and parity bytes in the applicable FEC coding scheme. Adjustment of the codeword composition ratio may be adjusting parameters such as the N, K and/or R values in ADSL1 systems or the INP and/or maximum interleaving delay values in ADSL2 systems. A controller may be used to monitor, analyze and adjust the various values used in adaptively managing FEC coding. The present invention may be implemented in a transmission system in which a transmitter transmits data to a receiver via a transmission channel, such as a DSL system.

In some embodiments of the present invention, a controller for an adaptive FEC coder uses a codeword composition ratio (CCR) that is a quantity or value that represents the relation between the payload and parity bytes in the applicable FEC coding scheme. The FEC coder is used in a communication system in which a transmitter sends data to a receiver via a channel using FEC coding, interleaving and an original transmission latency. The controller includes means, such as a transmission error value monitor, coupled to the communication system for acquiring a measured transmission error value (MEV). Coupled to this monitor is means for analyzing the MEV relative to a target transmission error value (TEV). Means for generating one or more control signals is coupled to the analyzing means and generates appropriate output control signals that are used to adjust the CCR and/or the interleave depth in the transmission system.

A method according to one or more embodiments of the present invention includes selecting a CCR and transmitting data using that codeword composition and the FEC coding scheme. An MEV is acquired and analyzed relative to a TEV. If the MEV differs sufficiently from the TEV, the CCR can be adjusted to compensate for the

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difference. Adjusting the CCR can be accomplished by changing one or more of the codeword composition parameters (such as the N, K and/or R values in an ADSL1 system, or the INP and/or maximum interleaving delay values in an ADSL2 system). If desired, the acquisition, analysis and adjustment steps can be repeated one or more times to permit updating of the communication system performance to address changing conditions and operational behavior.

A transmission system can implement the controller and/or utilize one or more of the methods of the present invention, as will be appreciated by those skilled in the art. The controller can be coupled to an FEC coder in a transmitter and to another system components, such as a receiver and/or decoder. Data acquired by the controller can be used to generate control signals that instruct the transmitter and/or receiver coding-related components to adjust their operation.

The controller in these embodiments may be a dynamic spectrum manager or similar entity residing within or outside a central office. The transmission error value(s) used in embodiments of the present invention can be based upon or be computed from the bit error rate, errored seconds, errored minutes, the number of code violations over a fixed period of time, the signal-to-noise ratio measured at the receiver, the TCP/IP or other protocol throughput at a higher level and/or other quantities obvious to those skilled in the art that represent the amount or level of error detectable in a given system.

Further details and advantages of the invention are provided in the following Detailed Description and the associated Figures.

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BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The present invention will be readily understood by the following detailed description in conjunction with the accompanying drawings, wherein like reference numerals designate like structural elements, and in which:

Figure 1 is a schematic block diagram of an ADSL reference model system from the ADSL1 standard.

Figure 2 is a schematic block diagram showing the relevant portions of the transmitter reference models from the ADSL1 standard for ATU-R and ATU-C transmitters using synchronous and asynchronous data transport.

Figure 3 is a schematic block diagram showing the relevant portions of a receiver usable with one or more embodiments of the present invention.

Figure 4 is a process flow diagram of a method representing one embodiment of the present invention.

Figure 5 is a block diagram of one embodiment of a controller.

Figure 6 is a block schematic diagram of communication system implementing one embodiment of the present invention.

Figure 7 is a block schematic diagram of a DSL communication system implementing one embodiment of the present invention.

Figure 8 is a block diagram of a typical computer system suitable for implementing an embodiment of the present invention.

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DETAILED DESCRIPTION OF THE INVENTION

The following detailed description of the invention will refer to one or more embodiments of the invention, but is not limited to such embodiments. Rather, the detailed description is intended only to be illustrative. Those skilled in the art will readily appreciate that the detailed description given herein with respect to the Figures is provided for explanatory purposes as the invention extends beyond these limited embodiments.

The present invention allows for adjustments to the transmission error rate of a communications system using data codewords, without affecting the latency of data transmission through the system between a transmitter and a receiver. This transmission error rate adjustment is accomplished using changes to a codeword composition ratio (for example, by changing at least one codeword length parameter) when a measured transmission error value (or MEV) differs sufficiently from a target transmission error value (or TEV). For example, when the measured bit error rate (BER) of transmissions in a communication system differs sufficiently from a target BER (for example, where the measured BER is sufficiently above a threshold maximum error rate), the composition of codewords used in FEC/interleaving is adjusted to meet the target BER, while leaving the latency unaffected (or possibly reduced).

The transmission error value(s) used in the present invention can be one or more of the following (or can be based upon one or more of the following) -- the bit error rate, errored seconds, errored minutes, the number of code violations over a fixed period of time, the signal-to-noise ratio measured at the receiver, the TCP/IP or other protocol throughput at a higher level and/or other quantities obvious to those skilled in the art that represent the amount or level of error detectable in a given system. The codeword parameters are adaptively adjusted (for example, by a signal sent by a computer-implemented controller), resulting in an increase or decrease in data rate, until an acceptable error rate is achieved (while also, in some embodiments of the present

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invention, meeting power, margin and/or other system operating requirements and/or goals).

As described in more detail below, a controller implementing one or more embodiments of the present invention can be a dynamic spectrum manager or spectrum management center and can be a computer-implemented device or combination of devices that monitors the appropriate transmission error value(s). The controller may directly or indirectly dictate/require changes in codeword composition by users coupled to the controller or may only recommend changes to those users. (The phrases "coupled with" and "coupled to" and the like are used herein to describe a connection between two elements and/or components and are intended to mean coupled either directly together, or indirectly, for example via one or more intervening elements.) In some embodiments, transmitters to which the controller is coupled all reside in the same location (for example, a DSL central office) and may or may not share a common binder for their respective transmission channels. The structure, programming and other specific features of a controller usable in connection with embodiments of the present invention will be apparent to those skilled in the art after reviewing the present disclosure.

The present invention changes the structure of the codewords provided for interleaving of data to protect against the adverse effects of errors without increasing the transmission latency. The following values and/or variables are used in the ADSL1 standard:

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Value/variable	Description
K	Number of payload data bytes in each mux data frame, which is a DMT symbol (Figure 2, Point A)
S	Number of DMT symbols per codeword
(S x K)	Number of payload data bytes per codeword
R	Number of parity (or redundancy) bytes per codeword
$N_{FEC} = (S \times K) + R$	Total number of bytes (combined payload data and parity/redundancy) per codeword
$N_I = N/S$	Number of bytes per FEC output data frame (Figure 2, Point B)
D	Interleaving depth in codewords

The following examples of embodiments of the present invention may use ADSL systems as exemplary communications systems. Within these ADSL systems, Reed-Solomon coding is used for FEC. However, as will be appreciated by those skilled in the art, embodiments of the present invention may be applied to various communications and coding systems and the invention is not limited to any particular system. The present invention can be used in any data transmission system that uses codeword-type data structures.

Figure 1 shows an ADSL reference model system from the ADSL1 standard (G.dmt or G.992.1), which is incorporated herein in its entirety by reference for all purposes. Similar figures could be composed based on one or more DSL standards that may or may not include splitters, such as ADSL-Lite (G.992.2), ADSL2 (G.992.3), ADSL2-Lite (G.992.4), ADSL2+ (G.992.5) and the G.993.x emerging VDSL standards, as well as the G.991.1 and G.991.2 SHDSL standards, all with and without bonding. In particular, when splitters are not used, the types of intermittent noise for which the invention disclosed herein provides protection may be more prevalent. Figure 2 shows

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the relevant portions of the transmitter reference models from the ADSL1 standard for ATU-R and ATU-C transmitters using synchronous and asynchronous data transport. These models are well known to those skilled in the art.

The ADSL1 standard does not specify receiver operation in as much detail as the transmitter, permitting a great deal of flexibility. The relevant portions of a typical design of a receiver that can be used in connection with the transmitter of Figure 2 are illustrated in Figure 3. The functional blocks depicted in both Figures 1-3 may be physically performed by specialized circuitry or be programmed into a digital signal processor or other processor or by a combination of such elements. For example, combinations of blocks may be housed and operate within a single modem/transceiver.

Many of the receiver functions (for example, the demodulator, decoder, descrambler and de-interleaver) perform the inverse of their related transmitter functions. Some components may be unique to the receiver (for example, a time domain equalizer, a frequency domain equalizer, and an automatic gain control). The job of some of the receiver functions in an ADSL modem is to recover and process the transmitted signal for presentation to the demodulator. The demodulator's task is to retrieve the digital bits that form the payload data of the transmitted message.

In Figure 2 the payload data 210 provided to the transmitter 200 is supplied to a framer (multiplexer and sync control) 212. Data that is to be handled in a "fast" data path 204 in an ADSL1 system (without interleaving) is sent for assignment of a fast cyclic redundancy code prefix (crc_f) at 214 and then on to a scrambler and FEC coder 224. Data to be interleaved is sent through an interleave path 208 for assignment of an interleaving cyclic redundancy code prefix (crc_i) at 218 and then on to a scrambler and FEC coder 228. The crc_i prefix and payload data are configured into Reed-Solomon codewords in coder 228 and sent to the interleaver 238 for interleaving. ADSL employs FEC coding based on Reed-Solomon codes using GF(256); the use of GF(256) permits the Galois field elements to be represented by bytes, and codewords may have up to 255 bytes. The bits of a codeword are allocated among the sub-carriers (during tone ordering at 240 in

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Figure 2) and, after constellation encoding in encoder 250, are presented for modulation (for example, using an inverse discrete Fourier transform, for example, at 260 in Figure 2) to form an ADSL symbol for transmission as transmitted data 280. As noted in the ADSL1 standard, the FEC coder 228 takes in S mux data frames from Point A and appends R FEC redundancy bytes to produce the FEC codeword of length $N_{FEC}=(SxK+R)$ bytes. The FEC output data frames at Point B thus contain $N_I=N_{FEC}/S$ bytes, which is an integer.

It should be noted that N_{FEC} and N_I contain different numbers of bytes whenever $S\neq1$ in ADSL1. However, the ratio of total bytes to payload bytes for each of these different N values is the same, though notation in the ADSL1 standard is confusing since K is not the total number of payload bytes per codeword when $S\neq1$. SxK is instead. Those skilled in the art will recognize the applicability of the present invention and general principles pertaining to the present invention when discussed in connection with the codeword values K, N and R and their relative proportions. For ease of notation in the following discussion, K will refer generally to the number of payload bytes in each FEC codeword, R will refer generally to the number of redundancy bytes in each FEC codeword, and N will refer generally to the total number of bytes in each FEC codeword.

As noted in the ADSL1 standard, because of the addition of FEC redundancy bytes and data interleaving, the data frames (that is, bit level data prior to constellation encoding) have different structural appearances at the three reference points through the transmitter 200. As shown in Figure 2, the data framing reference points are Point A (multiplexed, synchronized data after the appropriate CRC has been inserted), Point B (data frames generated at the output of the FEC encoder at the DMT symbol rate, where an FEC block may span more than one DMT symbol period), and Point C (data frames presented to the constellation encoder 250).

The present invention focuses on adjusting one or more codeword parameters outside of the interleaver in a typical communication system. Earlier systems have ignored adaptive codeword generation and adjustment and, instead, have focused only on

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programming the D parameter alone in the interleaver (and, of these systems, most allow only 2 or 3 choices). Codeword parameters such as the N parameter can be far more important, and have been missed by earlier systems. There has been no interface to program/adapt codewords and these parameters have been fixed in firmware in delivered products (even though some standards allow two modems to tell each other what choices they have in firmware, nothing has been developed in this regard). As will be appreciated by those skilled in the art, embodiments of the present invention typically allow finer tuning of error correction in the communication system in which the present invention is implemented and allow system operators and users to maintain critical performance parameters such as latency, while providing an adaptable operational environment. While changes to the codeword structure produce changes in data rates, latency problems can be reduced or eliminated.

Per the ADSL1 standard, the following coding capability values may be used for R, S and D (the interleaver depth D is measured in codewords, not bytes) in the ATU-C (per the ADSL1 standard) and the ATU-R (per the ADSL1 standard):

Value	ATU-C	ATU-R
R	0, 2, 4, 6, 8, 10, 12, 14, 16	0, 2, 4, 6, 8, 10, 12, 14, 16
S	1, 2, 4, 8, 16	1, 2, 4, 8, 16
D	1, 2, 4, 8, 16, 32, 64	1, 2, 4, 8

Generally, FEC coding uses parity bits/bytes to permit receiver correction of errors caused by noise and other error-generating phenomena. In an ADSL1 system, a transmitter takes S mux data frames available at Point A of Figure 2, each mux data frame having K bytes of payload data, and creates FEC output data frames that are presented to the interleaver at Point B. The FEC coder takes the original (SxK) payload data bytes and adds R parity bytes to form a codeword having N total bytes. FEC output data frames having N/S bytes are then output from the FEC coder. The ADSL1 standard provides a detailed description of the framing of data according to that standard.

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G.997.1 and the ADSL1 standard define the maximum ADSL latency (line delay) when data is interleaved. This ADSL line delay parameter is the requested transmission delay introduced by interleaving and the FEC process. The delay is defined based on the number of DMT symbols per codeword (S) and interleaving depth (D). In prior practice, the ATU-C and ATU-R chose their S and D parameters so that they were equal to or as close as possible to the requested delay. In the ADSL1 standard, the delay is defined as (4 + (S-1)/4 + S*D/4) ms. The minimum delay occurs when S=1 and D=1 (those values' minimums) and is a function of the DMT transmission system and not the interleaving or FEC structure. ADSL2 uses a similar, though not identical formula for the delay.

Using embodiments of the present invention, a desired error rate can be achieved by adjusting one or more of FEC codeword composition parameters, while optimizing DSL use (for example, maximizing the transmission data rate and not increasing latency) within that constraint. In one embodiment of the present invention, shown in Figure 4, a method 400 commences with communications system transmitting data via a transmission channel between a transmitter and a receiver at step 405. These transmissions use an original codeword composition ratio (CCR), which in the following illustrative discussion is defined as either:

$$CCR = \frac{\text{Payload data bytes}}{\text{Total data bytes}} \quad \text{OR} \quad \text{(Payload bytes):(Total bytes)}$$

However, as will be apparent to those skilled in the art, any quantity or value can be used as the CCR as long as it represents the relation between the payload and parity bytes in the applicable FEC coding scheme.

In an ADSL1 system, for example, the CCR could be the ratio of (SxK) to N_{FEC}. Adjusting any of the parameters/variables contributing to the relative difference between these quantities will increase or decrease the CCR, which measures the linear reduction in

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the data rate as the ratio increases or decreases.

One or more transmission error values that represent the error rate in transmissions between the transmitter and receiver are then acquired at step 410 (for example, by a controller). Acquiring the MEV(s) could include, for example, directly measuring a characteristic of the communication system, collecting a value from an element management system, or computing the MEV from collected data.

The measured transmission error value(s), or MEV(s), may be selected from, include and/or be based upon one or more of the following: the BER, errored seconds, errored minutes, the number of code violations over a fixed period of time, the signal-to-noise ratio measured at the receiver, the TCP/IP (or other protocol) throughput at a higher level, and/or a combination of these values. Other values representative of the error rate of the transmission system may also be apparent to those skilled in the art.

Each MEV is then analyzed relative to (for example, compared to) a corresponding target transmission error value, or TEV, at step 420. If the MEV and TEV are equal at decision step 430 (or, perhaps, at least approximately equal within a given tolerance), then the method continues to transmit data at step 405 using the existing CCR. This means that FEC coding in the transmitter/receiver pair is maintaining a desired threshold error rate (or acceptable range of rates), while sending the maximum number of payload data bytes per codeword within this constraint.

If, however, a given MEV is sufficiently different from its corresponding TEV, then appropriate adjustment of the current CCR is decided at decision step 440. Historical performance data may be consulted, for example in the form of a history or library module or database 445, in deciding whether to take any action in adjusting the CCR.

When the measured transmission error value is "sufficiently" below the target transmission error value at decision step 440, the CCR is increased at step 450. "Sufficiency" of difference between the measured transmission error value and the target

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transmission error value may include considerations beyond the numerical values alone. Changes to the CCR may be triggered according to various preferences (for example, the length of time an MEV remains above/below a TEV). For instance, the MEV may have to remain sufficiently low over a span of days, weeks or longer before triggering a change allowing the CCR to be increased. This would guard against intermittent noise that may not occur often, but is limiting when it does occur.

As noted above, maximum interleaving delay and INP values in G.992.3/4/5 are supplied upon initialization of the modem and there is no way before data transmission to know the error measurement. Some embodiments of the present invention can record and/or maintain a history of performance from previous line initializations and adapt the maximum interleaving delay and INP values set by the operator in ADSL2 (or the N, R and D values set by the transmitter default profile choice in ADSL1).

Changes to the CCR can be determined and implemented in various ways apparent to those skilled in the art. In ADSL1 systems, the CCR may be dependent upon and can be adjusted by changing N, K and/or R. In ADSL2 systems, the CCR may be dependent upon and can be adjusted by changing INP and/or the maximum interleaving delay in the system.

In one embodiment of the present invention, the INP and maximum interleaving delay values passed in the "handshake" between transmitter and receiver can be converted into the usual FEC parameters using the following approximate formulas (where, if erasures are used, t=R, the number of parity bytes, and if erasures are not used and rate includes information and synch/control bits, t=R/2):

$$D' = \text{depth in bytes} = \frac{(INP/4)\times\left(\frac{\text{rate in kbps}}{8}\right)}{t}$$

$$N = \frac{(\text{delay in ms})\times\left(\frac{\text{rate in kbps}}{8}\right)}{(D'-1)} + 1 \approx \frac{\text{delay}}{\text{burst length}} \cdot t$$

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The ratio of the INP parameter to the interleaving depth determines the codeword block size, which is supplied to the transmitter by the receiver by one or more messages implemented in ADSL2. A higher upper limit for the INP value can be used when intermittent noise (not an isolated impulse) is present and a greater fraction of parity bytes per codeword is desired and/or advisable. Other, more refined versions of these parameters that are specific to vendors' implementations could be used with the proper interpretation of INP observed. Further, the parameters M, T, L, etc. can be computed and S inferred for all latency paths as well as the values of B for each frame bearer and latency path. Also, once N is known, then $D = ND'$. Even approximate adherence to the above mathematical rules should allow reduction of strong intermittent noise on chronic DSL lines. Service providers may well train the modem several times, each time increasing the INP value until zero or small numbers of code violations and/or errored seconds are observed over a time period determined by the service provider.

In another version of adjusting the CCR in an ADSL2 system, FEC codeword composition can be altered during SHOWTIME using an adjustment to the INP value to force a change to the CCR. For example, an ATU-C could send a message to its ATU-R providing a new INP value. The ATU-R uses the new INP value to generate a new CCR (or merely to generate the FEC coding parameters) and sends that to the ATU-C. The modems then implement the new CCR at some mutually agreed to point in time. This type of adjustment to the CCR only modifies the number of payload data bytes and parity data bytes in a codeword, leaving the total codeword size and interleave depth at their current values. A reduction in K, however, will reduce the data rate, but the line rate and S are left as is.

In practical systems, changing the CCR may often lead to a reset so that the modems can reset the FEC parameters. Typically such a reset would occur at the next interval in which data traffic is measured to be zero (typically indicated by low or zero ATM cell counts that are measured and reported in ADSL1 and ADSL2 to the element management system and thus can be forwarded to the controller).

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It should be noted that implementation of the present invention when traffic on a system is low or zero may or may not be appropriate, as will be appreciated by those skilled in the art. Moreover, embodiments of the present invention may observe the history of performance of one or more lines over a given period of time and respond to noise/errors in different ways. For example, in one case, if high code violations are observed only once a week, the CCR might not be changed, allowing performance to suffer for only a brief period each week while maintaining higher performance (higher data rates) the rest of the week. On the other hand, in another case, the CCR might be kept at a level to accommodate the "once a week" code violation instigator/generator, thus providing a worst case setting since it might not be possible to know when the line/system will be "hit" by the unusual, error-generating noise. The interval of one week could also be longer or shorter and is used as an example here. One method of setting and/or adjusting the CCR follows:

> To compute FEC parameters that affect the CCR, the controller looks at the level of code violations in a given time interval. The formula for non-erasure ADSL1 modems (so this is worst case, since many modems do not use erasures or do not use them properly) may require that the ratio of parity bytes to total codeword bytes (denoted for this example as R/N) exceeds twice the ratio of (0.017 x CV)/[15(60)].
>
> That is, looking at 15 minutes of 60 seconds each, code violations are measured on 0.017 second intervals in ADSL1 – the code violation count is computed every 17 ms (0.017), so the controller computes the fraction by which to multiply the code violation count in 15 minutes to compute the ratio of erroneous bytes to correct bytes received – since 2 parity bytes correct one errored byte (without erasures), then the controller can upper bound the fraction of parity bytes to total bytes necessary to correct all errors this way. That is, R/N > (0.000038) x (# of CVs). So, if a line has 10,000 code violations in 15 minutes, the system would need R/N > (0.000038) x (10,000) = 0.38. In this case, for example, R=16, N=40 (so that R/N=0.40)

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would work (instead of R=16 and N=240, for instance, as is commonly used in ADSL modems and which yields R/N=0.07).

In exchange for eliminating the errors, the data rate on this line would be reduced by 1-[24/40 x 240/224] = 35.7% of the line's data rate when operated with 10,000 code violations per 15 minutes.

Even in this extreme case of 10,000 violations per quarter hour, approximately 2/3 of the data rate can still be achieved with no errors if the N and R values are changed in the profile according to one or more embodiments of the present invention. Moreover, the latency of the system does not have to be affected by the added error correction capability at the new data rate.

In another example, a controller could measure throughput at the link or network level and adjust the CCR if the throughput is low and code violations are high (or vice versa).

In one embodiment of the present invention, changes to one or more FEC codeword parameters may have to comply with an applicable communications standard. In many cases of impulsive or more generally time-varying intermittent noises, a proportional change to the existing CCR will cause a generally equal proportional change in the transmission error rate. Again, if an intermittent noise is observed once, the CCR might be held for a very long period of time, anticipating that the increased code-violation count will be seen again whenever the offending source is energized again in the future (for example, a vacuum cleaner). Therefore, in another embodiment of the present invention, the proportional increase in the CCR at step 450 may be generally equal to the proportional different between the TEV and the MEV. If the length of codewords sent to an interleaver is changed as a result of the CCR adjustment, then, to preserve the existing latency of the system, the interleave depth D can be adjusted to compensate for a larger or smaller codeword size (for example, D would be reduced at step 455, since when the total number of bytes per interleaved codeword is increased, fewer codewords will be needed to achieve the same latency, and vice versa.

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If the error rate as represented by the MEV on this line is too high after comparison at step 440, then the CCR is reduced at step 460. Again, the amount and nature of codeword composition adjustment can be made as appropriate (for example, in keeping with one of the embodiments described above). Moreover, adjustment to the interleaving depth can be made as described above as well (for example, increasing D at step 465).

A specific example follows using aspects of the ADSL1 standard. The number of total bytes in each FEC output data frame to be interleaved is ((SxK+R)/S), where R must always be an integer multiple of S, which may be 1, 2, 4, 8 or 16. In this illustrative example:

delay = 4 ms
S = 2
R = 8 (thus able to correct 4 bytes of error per codeword)
K = 188
then each FEC output data frame is (2x188+8)/2=192 (K/R=23.5)

If the MEV is sufficiently above the TEV, then K might be cut in half to K´=94, while holding R=16, thus making each FEC output data frame 94 bytes long and yielding K´/R=94/8=11.75. The interleave depth D is increased (by approximately a factor of 2) to maintain the established latency delay of 4 ms. Although the delay will remain constant at 4 ms in this example, the data rate drops due to the fact that each data transmission sent from the transmitter in a given time period will contain fewer payload data bytes per codeword. However, the error rate problem is addressed effectively without having to increase the delay, as would happen pursuant to the '509 Patent and other prior methodologies that deepen interleaving.

An alternate solution is to leave K=188 and to increase the number of parity bytes so that R´=16. The FEC output data frame length is 196 bytes and K/R´=188/16=11.75. In this case, the interleave depth probably does not need to be changed, since the codeword length has not changed significantly.

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The method 400 of Figure 4 can be implemented in a communications system, using a controller (for example, a dynamic spectrum manager or spectrum management center), one embodiment of which is shown in Figure 5. Referring to Figure 5, a controller 500 used in implementing one or more embodiments of the present invention is shown. The controller 500 preferably comprises means 510 for acquiring (and possibly monitoring) one or more MEVs, means 520 for analyzing any MEV(s) relative to corresponding TEV(s), and means 530 for generating a CCR adjustment control signal 545. This control signal generator 530 may also include means 535 for generating an interleave depth adjustment control signal 545, for cases where the changes to an existing CCR would require a change in the interleave depth D as well.

The means 510 for acquiring the MEV(s) preferably comprises a transmission error value monitor for acquiring a transmission error value and generating a signal representative of that MEV, as is known to those skilled in the art. Means 510 might receive an MEV by receiving an input signal 505 that is representative of the value being sought. Acquiring the MEV(s) could include, for example, directly measuring a characteristic of the communication system, collecting a value from an element management system, or computing the MEV from collected data. The MEV(s) might be acquired using code violation or errored-second counts (both are available) from the element management system that periodically acquires the number of CRC violations that have occurred (for example, during 15 minute intervals in ADSL). Code violations and/or errored seconds also could be obtained by interface to an ATU-R modem through a vendor database or "email" message to the controller (which thus circumvents the element management system).

As noted above the transmission error values are preferably chosen from (or are based upon one or more members of) the group consisting of the communications system's BER, errored seconds, errored minutes, the number of code violations over a fixed period of time, the signal-to-noise ratio measured at the receiver, the TCP/IP or other protocol throughput at a higher level and/or a combination of these values. This can be done by monitoring and/or measuring the bit error rate, errored minutes, code

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violations and/or the signal-to-noise ratio at the receiver. These measurements may be made directly by the controller 500 or may be sent by the receiver to controller 500 by any suitable alternative means (for example, sending the data to a DSL central office via the transmitter-receiver pair's communication).

The means 520 for analyzing one or more MEV(s) relative to the corresponding TEV(s) can comprise software, hardware or a combination of the two. In some embodiments of the present invention, the controller 500 is a computer or computer system attached to an ADSL element management system interface (directly or indirectly through service provider intermediate entities). Monitoring, measuring, analysis, comparing, processing, evaluation, and N, R, D or INP/Maximum Interleaving Delay recommendations can be implemented via this interface. The controller 500 also can maintain a history module 540 (for example, a library or database of events) that helps makes better recommendations over time and assists in analyzing the MEV(s) relative to the TEV(s) by means 520. Other various structures implementable in connection with embodiments of the present invention will be apparent to those skilled in the art. For example, as suggested by the dashed line in Figure 5, module 540 may be an external module that is accessed as necessary by controller 500. Finally, means 530 and 535 for generating appropriate control signals 545 likewise can be implemented using software, hardware and/or a combination thereof. The analyzing means 520 and generating means 530, 535 may be a single unit or module or be separate units.

As illustrated in the following embodiments, the system preferably measures the desired transmission error value. This MEV of the system is analyzed, which may include comparing the MEV to a TEV. The CCR can then be adjusted in response to the MEV's deviation from the TEV. Alternatively, MEVs may be measured and compared, either alone or in combination, to any appropriate TEV(s). While such a system is of particular importance with regard to digital subscriber lines, those skilled in the art will appreciate that it is applicable to any system that incorporates codeword-type data structures and interleaving, especially where it is desirable to avoid increasing latency when improving error correction.

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By way of example, Figure 6 shows a transmission system 600 comprising a transmitter 610, a transmission channel 620, a receiver 630 and a controller 640. The transmitter includes an FEC coder 612 coupled to an interleaver 614 (the transmitter may and likely does include more components). The FEC coder 612 generates FEC codewords having a given codeword composition ratio designed to meet error correction requirements and the FEC coding scheme of the system 600. The interleaver 614 may be any suitable interleaver used to interleave data to be transmitted by the transmitter 600 over the transmission channel 620. In an ADSL1 system, the FEC coder 612 and interleaver 614 would be part of the "interleaved data path" as opposed to the "fast data path" available without interleaving.

The receiver 630 receives and decodes the transmitted data. Data that has been interleaved in the transmitter is de-interleaved by a de-interleaver 634 and then decoded by FEC decoder 632. In so doing, the receiver 630 is able to generate information (for example, in the form of an input signal 641) relating to the bit error rate of the system 600 and other information pertaining to errors generated in the transmission of data through channel 620. As will be appreciated by those skilled in the art, embodiments of the present invention may also be used where no interleaving is implemented (for example, where S=1 for ADSL systems). As also will be appreciated by those skilled in the art, Figure 6 tacitly assumes that the means for generating CCR adjustment control talks to the transmitter . However, it should be kept in mind that INP/Maximum Interleaving Delay parameters might be sent to a receiver that uses them to set its N, R and D as part of a loading algorithm. Such variations are contemplated by and embodied in the Figures and the present disclosure.

The controller 640 measures error rate performance of the system 600 at the receiver 630 in an effort to determine whether adjustment of the CCR is beneficial and how best to implement such an adjustment. The controller 640 generates a CCR adjustment control signal 648 in response to the MEV(s) and the controller's analysis of the MEV(s) relative to the TEV(s). The FEC coder 612 adjusts the CCR in response to the CCR adjustment control signal 648. In cases where the system's original

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transmission latency is being maintained and interleaving is used, the controller 640 also may generate an interleave depth control signal 649 to adjust the interleave depth to compensate for adjustments to the CCR to maintain the original transmission latency that might otherwise be changed by signal 648 and the FEC coder 612 in transmitter 610. Finally, as noted above, a receiver-bound control signal 647 may be sent to the receiver as required in some cases where the INP and maximum interleaving delay parameters are used by a receiver to set the CCR.

The FEC coder 612 preferably comprises means for receiving a multiple bit CCR adjustment control signal and means for adjusting the CCR in response to the CCR adjustment control signal, as will be known to those skilled in the art. The FEC coder 612 preferably further comprises means for adjusting the composition of codewords produced in the coder 612, as known to those skilled in the art. The FEC coder 612 is preferably coupled with the transmitter 610 and the controller 640.

Similarly, the interleaver 614 preferably comprises means for receiving a multiple bit interleave depth adjustment control signal and means for adjusting the depth of interleaving in response to the interleave depth adjustment control signal, as will be known to those skilled in the art. The interleaver 614 preferably further comprises means for adjustably interleaving data at different interleave depths as known to those skilled in the art. The interleaver 614 is preferably coupled with the transmitter 610 and the controller 640.

The FEC coder 612 preferably receives data and generates codewords by adding parity bytes to the payload data bytes, preferably in a manner similar to those discussed above. One example of such a technique is Reed-Solomon coding, as described in the ADSL1 standard. An original CCR is provided to and/or determined by the FEC coder 612 in any suitable manner, as is known to those skilled in the art. One example of FEC coding usable in connection with the present invention is described in the ADSL1 standard.

The codewords are sent to the interleaver 614, which interleaves the data by

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rearranging the order in which the bits that comprise the data are transmitted. Any suitable adjustable interleaver that is responsive to a multiple bit interleave depth adjustment control signal, as known to those skilled in the art, can be configured for use in the present embodiments. One example of convolutional interleaving usable in connection with the present invention is described in the ADSL1 standard.

The transmitter 610 preferably comprises an ADSL transmitter known to those skilled in the art. Alternatively, the transmitter 610 can comprise a digital transmitter for use with any form of transmission media as known to those skilled in the art. Alternatively, the transmitter 610 can comprise any transmitter for use with any form of transmission media as known to those skilled in the art. The transmitter 610 is preferably coupled with the FEC coder 612, the interleaver 614, the controller 640 and the transmission channel 620.

The transmitter 610 may modulate data (for example, using an inverse Fourier transform technique) for transmission to the receiver 630 via the transmission channel 620 as known to those skilled in the art. The transmitter 610 can preferably transmit data at different data rates as known to those skilled in the art. The capacity of the transmission channel 620 typically depends on factors including the following: the distance a transmission has to travel; the wire gauge of the transmission channel; the number of bridged-taps on the transmission channel; the temperature of the transmission channel, splice loss of the transmission channel; noise present in the transmission channel; and the precision of the transmitter and receiver. While many of these factors are not directly measurable, their cumulative effect may be monitored by measuring one or more of the transmission error values mentioned above (for example, the BER). Thus, the CCR, interleave depth and data rate can be adapted in response to the MEV(s).

The FEC coder 612 can adjust the CCR in a number of ways. For example, the CCR can be altered by changing the number of payload data bytes per codeword (K), while leaving the number of parity bytes R unchanged. In ADSL2 systems, the INP value could be increased while the maximum interleaving delay is held constant.

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The CCR could be adjusted by resetting the modem and in ADSL1 then setting the N, R, and D through the element management system MIB to the ATU-C. These values would correspond to those computed as best (or to be tried next) on the next reset of the DSL line that causes exchange of N, R, D and the equipment vendor's choice of S during initialization. The CCR could be adjusted in ADSL2 by providing N, R and D for upstream and the INP/ Maximum Interleaving Delay for downstream through the element management system MIB to the ATU-C. The INP/Maximum Interleaving Delay values would be communicated during initialization to the ATU-R, which would then compute the corresponding N, R, S and D parameters that best approximate the desired INP and Maximum Interleaving Delay settings.

Accordingly, a greater or lesser number of payload bytes can be transmitted within a given time interval, depending on any adjustments made to the original CCR. Alternatively, the CCR can be adjusted by altering the number of parity bytes per codeword, while holding the number of payload data bytes unchanged. Changes to the CCR might be implemented only when the cell count is low or zero, meaning the user is not active and thus will not even notice retraining of the system to improve their service.

The transmission channel 620 preferably comprises twisted-pair conductive wire as known to those skilled in the art. Alternatively, the transmission channel can comprise coaxial cable, optical fiber, free-space laser, radio or any other type of transmission media as known to those skilled in the art. The transmission channel 620 preferably couples the transmitter 610 and the receiver 630.

The receiver 630 preferably comprises an ADSL receiver having an adjustable de-interleaver 634 and an adjustable decoder 632, as known to those skilled in the art. Alternatively, the receiver 630 can comprise a digital receiver for use with any type of transmission media as known to those skilled in the art. Alternatively, the receiver 630 can comprise any type of receiver for use with any type of transmission media as known to those skilled in the art. For example, the decoder 632 of receiver 630 can employ a Reed-Solomon decoder or any other suitable error correcting decoder as known to those

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skilled in the art. In the exemplary system 600 of Figure 6, the receiver 630 is preferably coupled to the transmission channel 620 and to the transmission error value measuring means 642 of the controller 640.

The receiver 630 receives and demodulates the data from the transmitter 610. After demodulation, the de-interleaver 634 of receiver 630 de-interleaves the data. The decoder 632 utilizes decoding techniques known to those skilled in the art to detect and correct errors in the transmitted data. In particular, the decoder 632 analyzes the transmitted data using the redundant bytes that are generated by FEC coder 612 prior to transmission to determine whether any data was corrupted and thus requires correction. Reed-Solomon error correction coding can correct R/2 bytes if the codeword has R parity bytes; for example, in ADSL a codeword composition selection may be N=204, K=188, and R=16 which can correct 8 erroneous bytes per 204-byte codeword. ADSL constrains R to be an even integer between 0 and 16 plus N is limited to 255 by use of the field GF(256).

The controller 640 preferably comprises means 642 for collecting and/or calculating one or more MEVs, means 644 for analyzing the MEV(s) (for example, by comparing the MEV(s) to the TEV(s)), and means 646 for providing CCR adjustment and interleave depth adjustment control signals. The means 642 preferably comprises a monitor for measuring, collecting and/or calculating one or more of the transmission error values mentioned above, as is known to those skilled in the art. The transmission error value(s) monitor 642 preferably is coupled to the decoder 632 and the controller 640 in the exemplary system 600 of Figure 6. As mentioned above, any appropriate transmission error values can be used that provide a representation of the error rate of the system 600. Various values can be used and various ways of measuring those values are known to those skilled in the art. Therefore, the transmission error value(s) can be determined through a variety of techniques, and any suitable method of selecting, measuring and determining the transmission error value(s) can be adapted for use in the presently preferred system. Averaging many measurements of the transmission error value(s) can be performed to improve the accuracy of the current transmission error value

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measurement, as is known to those skilled in the art.

Means 642 preferably generates an input signal 643 that varies as a function of the MEV(s). Alternatively, the input signal 643 can take many forms and can be based in whole or in part on the BER, errored seconds, etc. The input signal 643 can be analog or digital and linear or non-linear, as will be appreciated by those skilled in the art. Alternatively, the input signal 643 can be binary such that the input signal 643 is greater than or less than one or more threshold values based upon the MEV(s). Means 642 may continuously generate the input signal 643, if desired. Alternatively, means 642 can generate the input signal 643 in a sampled or periodic fashion, on a random or non-random basis.

The means 644 for analyzing input signal 643 preferably comprises means for analyzing the MEV(s) relative to the TEV(s), such as a threshold value, based upon an analysis of the input signal 643. This can be accomplished by comparing the input signal 643 to one or more TEV(s), possibly allowing for slight variations and tolerances. Alternatively, the means 644 for analyzing the MEV(s) input signal 643 can analyze multiple input signals that correspond to MEVs. The means 644 for analyzing input signals is preferably implemented in computer readable program code written in any suitable programming language and implemented on an analog or digital computer utilizing any suitable operating system. The analyzing means 644 also can be implemented through the use of hardware in the form of a hardwired computer, an integrated circuit, or a combination of hardware and computer readable program code.

The CCR adjustment and interleave depth control signals 647, 648, 649 can take many forms. Control signals 647, 648, 649 can be based in whole or in part on one or more input signals, such as input signal 643. The control signals 647, 648, 649 can be analog or digital and linear or non-linear, as appreciated by those skilled in the art. Alternatively, the control signals 647, 648, 649 can be binary. The means 646 for providing one or more control signals is preferably implemented in computer readable program code written in any suitable programming language and implemented on an

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analog or a digital computer utilizing any suitable operating system. The means 646 for providing the control signals 647, 648, 649 also can be implemented through the use of hardware in the form of a hardwired computer, an integrated circuit, or a combination of hardware and computer readable program code.

A second embodiment of a communication system implementing the present invention is shown in Figure 7, which illustrates an example using a common scenario in the implementation of DSL systems. System 700 has a central office 710 and a number of remote locations 704 downstream of the CO 710. The system 700 shown in Figure 7 may be an ADSL1 system, so that each remote location 704 is a transceiver that functions both as a transmitter and a receiver. These remote locations 704 are ATU-R units, according to the ADSL1 standard. There are counterpart transceivers 712 in the CO 710. Again, these are ATU-C transceivers according to the ADSL1 standard and function as both transmitters and receivers. A DSL access module (DSLAM) 714 coordinates signals to and from the CO 710 through loops 722. A number of loops 722 may share a common binder 724, giving rise to crosstalk and/or other interference, and typically are exposed to various sources of noise and other error-generating phenomenon.

A controller 730 according to one embodiment of the present invention is coupled to the transceivers 712 in the CO 710 and/or the DSLAM 714. As suggested by the dashed line extending from the CO 710, controller 730 may be in the CO 710 or may be external to the CO 710. In some cases, the controller 730 may be operated by an entity independent of the CO 710 and any users or service providers using transceivers 712 in the CO 710 or at any remote locations 714. The controller 730 functions in generally the same manner as described above. However, instead of being directly connected to each remote location 704, the controller 730 monitors error rate information via a single transceiver 712 in each ATU-C/ATU-R pair.

Instead of measuring transmission error values in each receiving unit 704, 712, the controller 730 collects this information from the transceivers 712 in the CO 710 only. This can be done by having the remote transceivers 704 send their error rate data to the

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controller 730 directly or by having each ATU-R 704 provide that information to its ATU-C 712 counterpart, which in turn supply that data to the controller 730. In some embodiments, the information can be collected from the DSLAM 714 through the element management system (per G.997.1 or DSL forum document WT-87/82). However, information can also be extracted from the system 700 through the "email" method in which each transceiver 704, 712 sends its information to the controller 730 via a communication route outside the DSL lines' operating system. There is an EOC (embedded operations channel) that the user does not see in the payload data where the ATU-R and ATU-C exchange messages about performance with one another. This performance information is then available through the element management system (for example, an MIB if SNMP, simple network management protocol, is used). In all other respects, the exemplary system of Figure 7 functions analogously to those embodiments of the present invention described above.

In some embodiments of the present invention, implementations include communication system equipment providing more profile options for different (though not necessarily all) values of N. This allows a controller to select/recommend the appropriate profile that provides the highest data rate available with little or no errors within the remaining constraints of the communication system.

Generally, embodiments of the present invention employ various processes involving data stored in or transferred through one or more computer systems. Embodiments of the present invention also relate to a hardware device or other apparatus for performing these operations. This apparatus may be specially constructed for the required purposes, or it may be a general-purpose computer selectively activated or reconfigured by a computer program and/or data structure stored in the computer. The processes presented herein are not inherently related to any particular computer or other apparatus. In particular, various general-purpose machines may be used with programs written in accordance with the teachings herein, or it may be more convenient to construct a more specialized apparatus to perform the required method steps. A particular structure for a variety of these machines will be apparent to those of ordinary skill in the art based

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on the description given below.

Embodiments of the present invention as described above employ various process steps involving data stored in computer systems. These steps are those requiring physical manipulation of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared and otherwise manipulated. It is sometimes convenient, principally for reasons of common usage, to refer to these signals as bits, bitstreams, data signals, control signals, values, elements, variables, characters, data structures or the like. It should be remembered, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities.

Further, the manipulations performed are often referred to in terms such as identifying, fitting or comparing. In any of the operations described herein that form part of the present invention these operations are machine operations. Useful machines for performing the operations of embodiments of the present invention include general purpose digital computers or other similar devices. In all cases, there should be borne in mind the distinction between the method of operations in operating a computer and the method of computation itself. Embodiments of the present invention relate to method steps for operating a computer in processing electrical or other physical signals to generate other desired physical signals.

Embodiments of the present invention also relate to an apparatus for performing these operations. This apparatus may be specially constructed for the required purposes, or it may be a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. The processes presented herein are not inherently related to any particular computer or other apparatus. In particular, various general purpose machines may be used with programs written in accordance with the teachings herein, or it may be more convenient to construct a more specialized apparatus to perform the required method steps. The required structure for a variety of these

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machines will appear from the description given above.

In addition, embodiments of the present invention further relate to computer readable media that include program instructions for performing various computer-implemented operations. The media and program instructions may be those specially designed and constructed for the purposes of the present invention, or they may be of the kind well known and available to those having skill in the computer software arts. Examples of computer-readable media include, but are not limited to, magnetic media such as hard disks, floppy disks, and magnetic tape; optical media such as CD-ROM disks; magneto-optical media such as floptical disks; and hardware devices that are specially configured to store and perform program instructions, such as read-only memory devices (ROM) and random access memory (RAM). Examples of program instructions include both machine code, such as produced by a compiler, and files containing higher level code that may be executed by the computer using an interpreter.

Figure 8 illustrates a typical computer system that can be used by a user and/or controller in accordance with one or more embodiments of the present invention. The computer system 800 includes any number of processors 802 (also referred to as central processing units, or CPUs) that are coupled to storage devices including primary storage 806 (typically a random access memory, or RAM), primary storage 804 (typically a read only memory, or ROM). As is well known in the art, primary storage 804 acts to transfer data and instructions uni-directionally to the CPU and primary storage 806 is used typically to transfer data and instructions in a bi-directional manner. Both of these primary storage devices may include any suitable of the computer-readable media described above. A mass storage device 808 also is coupled bi-directionally to CPU 802 and provides additional data storage capacity and may include any of the computer-readable media described above. The mass storage device 808 may be used to store programs, data and the like and is typically a secondary storage medium such as a hard disk that is slower than primary storage. It will be appreciated that the information retained within the mass storage device 808, may, in appropriate cases, be incorporated in standard fashion as part of primary storage 806 as virtual memory. A specific mass

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storage device such as a CD-ROM 814 may also pass data uni-directionally to the CPU.

CPU 802 also is coupled to an interface 810 that includes one or more input/output devices such as such as video monitors, track balls, mice, keyboards, microphones, touch-sensitive displays, transducer card readers, magnetic or paper tape readers, tablets, styluses, voice or handwriting recognizers, or other well-known input devices such as, of course, other computers. Finally, CPU 802 optionally may be coupled to a computer or telecommunications network using a network connection as shown generally at 812. With such a network connection, it is contemplated that the CPU might receive information from the network, or might output information to the network in the course of performing the above-described method steps. The above-described devices and materials will be familiar to those of skill in the computer hardware and software arts. The hardware elements described above may define multiple software modules for performing the operations of this invention. For example, instructions for running a codeword composition controller may be stored on mass storage device 808 or 814 and executed on CPU 802 in conjunction with primary memory 806. In a preferred embodiment, the controller is divided into software submodules.

The many features and advantages of the present invention are apparent from the written description, and thus, the appended claims are intended to cover all such features and advantages of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, the present invention is not limited to the exact construction and operation as illustrated and described. Therefore, the described embodiments should be taken as illustrative and not restrictive, and the invention should not be limited to the details given herein but should be defined by the following claims and their full scope of equivalents, whether foreseeable or unforeseeable now or in the future.

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CLAIMS

What is claimed is:

1. A controller communicatively interfaced with a Digital Subscriber Line (DSL) modem operating in a DSL system, the DSL modem to transmit data via a channel according to original transmission parameters, wherein the controller comprises:

a means, coupled with the DSL modem, for repeatedly acquiring Measured transmission Error Values (MEVs) representing impulse noise events detected on the channel, the MEVs acquired after training and initialization on the DSL modem;

a means, coupled with the acquiring means, for analyzing the acquired MEVs relative to a Target transmission Error Value (TEV); and

a means, coupled with the analyzing means, for generating a retransmission overhead control signal to modify the original transmission parameters during normal operation of the DSL modem ("SHOWTIME") responsive to the means for analyzing, and transmitting the same to the DSL modem.

2. The controller of Claim 1, wherein the MEVs are based on at least one of:

a bit error rate;

errored seconds;

errored minutes;

code violations over a fixed period of time;

a Signal-to-Noise Ratio (SNR) measured at the receiver; and

Transmission Control Protocol and Internet Protocol (TCP/IP) throughput.

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3. The controller of Claim 1, wherein the acquiring means, the analyzing means, and the generating means are implemented as computer readable program code.

4. The controller of Claim 1, wherein the acquiring means, the analyzing means, and the generating means are implemented as hardware.

5. The controller of Claim 1, wherein the TEV is a threshold error rate limit.

6. The controller of Claim 1, further comprising:

a historical data module to store historical MEVs representing impulse noise events detected on the channel over time, wherein the historical data module is coupled with the analyzing means; and wherein

analyzing the acquired MEVs relative to the TEV comprises analyzing the historical MEVs for information about impulse noise events that occurred during prior transmissions on the channel.

7. The controller of Claim 6, wherein the historical data module comprises a database.

8. The controller of Claim 1, wherein the controller comprises a dynamic spectrum manager.

9. The controller of Claim 1, wherein:

the DSL modem is an Asymmetric Digital Subscriber Line (ADSL) modem operable in compatibility with an ADSL2 standard; and wherein

the generated retransmission overhead control signal to adjust at least one of the following parameters:

Impulse Noise Protection (INP), and

Codeword Composition Ratio (CCR).

10. The controller of Claim 1, wherein the means for repeatedly acquiring the MEVs

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comprises means for receiving an input signal representative of the MEVs.

11. A method for generating a retransmission overhead control signal in a Digital Subscriber Line (DSL) modem having a transmitter to exchange data between a transmitter and a receiver on a channel, the method comprising:

(a) transmitting a control signal from the DSL modem via the channel, wherein the control signal specifies retransmission overhead parameters for the retransmission overhead control signal;

(b) repeatedly acquiring Measured transmission Error Values (MEVs) representing impulse noise events detected on the channel, the MEVs acquired after training and initialization on the DSL modem;

(c) analyzing the acquired MEVs relative to a Target transmission Error Value (TEV); and

(d) adjusting the retransmission overhead parameters when the MEV differs sufficiently from the TEV.

12. The method of Claim 11, wherein repeatedly acquiring the MEVs comprises at least one of the following:

directly measuring a characteristic of the DSL modem;

collecting a value from an element management system; and

computing the MEVs from collected data.

13. The method of Claim 11, wherein steps (a) through (d) are repeated.

14. The method of Claim 11, wherein the method is performed by one of:

a controller communicably interfaced with the DSL modem;

a controller embodying a dynamic spectrum manager;

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a controller physically located within a Central Office (CO);

a controller physically located separate from the CO;

a controller operated by an entity which operates the DSL modem; and

a controller operated independently of the entity which operates the DSL modem.

15. The method of Claim 11, wherein analyzing the acquired MEVs relative to the TEV comprises analyzing historically acquired MEVs representing impulse noise events that occurred during prior transmissions on the channel.

16. The method of Claim 11, wherein the MEV is based on at least one of the following:

a Bit Error Rate (BER);

errored seconds;

errored minutes;

code violations over a fixed period of time;

a Signal-to-Noise Ratio (SNR) measured at the receiver; and

Transmission Control Protocol and Internet Protocol (TCP/IP) throughput.

17. The method of Claim 11, wherein repeatedly acquiring the MEVs, analyzing the acquired MEVs relative to the TEV, and adjusting the retransmission overhead parameters are implemented in computer readable program code.

18. The method of Claim 11, wherein repeatedly acquiring the MEVs, analyzing the repeated MEVs relative to the TEV, and adjusting the retransmission overhead parameters are implemented in hardware.

19. The method of Claim 11, wherein:

the DSL modem is an Asymmetric Digital Subscriber Line (ADSL) system operable in compatibility with an ADSL2 standard; and wherein

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adjusting the retransmission overhead parameters comprises adjusting Impulse Noise Protection (INP), Codeword Composition Ratio (CCR), or both.

20. A transmission system comprising:

a transmission channel to carry data between a transmitter and a receiver/decoder, each communicatively interfaced with the transmission channel;

a transmission error value monitor communicatively interfaced with the receiver/decoder to periodically monitor for transmission error values indicative of impulse noise events on the transmission channel, wherein the transmission error values are periodically monitored after training and initialization on the receiver/decoder, the transmission error values being selected from a group comprising: a bit error rate, errored seconds, errored minutes, code violations over a fixed period of time, Signal-to-Noise Ratio (SNR) measured at the receiver/decoder, and Transmission Control Protocol and Internet Protocol (TCP/IP) throughput, and wherein the transmission error value monitor to further generate an input signal based on the transmission error values monitored; and

a controller coupled with the transmitter to receive the input signal from the transmission error value monitor and to further generate a retransmission overhead control signal for the transmitter in response to the input signal.

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ABSTRACT

Adaptive FEC coding is used to adjust the codeword composition of FEC codewords in a communication system. A codeword composition ratio may be adjusted in response to variance of a measured transmission error value from a target transmission error value in the system. The codeword composition ratio may be any quantity or value that represents the relation between the payload and parity bytes in the applicable FEC coding scheme. Adjustment of the codeword composition ratio may be adjusting parameters such as the N, K and/or R values in ADSL1 systems or the INP and/or maximum interleaving delay values in ADSL2 systems. A controller may be used to monitor, analyze and adjust the various values used in adaptively managing FEC coding. The present invention may be implemented in a transmission system in which a transmitter transmits data to a receiver via a transmission channel, such as a DSL system.

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DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION (37 CFR 1.63)		
☐ Declaration Submitted with Initial Filing	OR ☒	Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16(e)) required)

Attorney Docket Number	8241P002
First Named Inventor	John M. Cioffi
COMPLETE IF KNOWN	
Application Number	10/795,593
Filing Date	March 8, 2004
Art Unit	2112
Examiner Name	Mujtaba M. Chaudry

As a below named inventor, I hereby declare that:

My residence, mailing address, and citizenship are as stated below, next to my name.

I believe the inventor(s) named below to be the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Adaptive FEC Codeword Management

(Title of the Invention)

the specification of which

☐ is attached hereto.

OR

☒ was filed on (if applicable):

or **03/08/2004** as United States Application Number **10/795,593**

as PCT International Application Number

and was amended on (if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment specifically referred to above.

I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application. I do not know and do not believe that the claimed invention was in public use or on sale in the United States of America more than one year prior to this application, nor do I know or believe that the invention has been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

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I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent, or inventor's or plant breeder's rights certificate(s), or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent, inventor's or plant breeder's rights certificate(s), or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s):

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached?
			☐	☐ Yes ☐ No
			☐	☐ Yes ☐ No
			☐	☐ Yes ☐ No
			☐	☐ Yes ☐ No
			☐	☐ Yes ☐ No

Appointment of Practitioners:

I hereby appoint the practitioners associated with Customer Number: **08791** as my respective patent attorneys and patent agents, with full power of substitution and revocation, to prosecute this application and to transact all business in the U.S. Patent and Trademark Office connected herewith.

If this patent application is assigned, then the undersigned hereby authorizes the patent attorneys and patent agents named herein to accept and follow instructions from the assignee(s) as to any action to be taken in the United States Patent and Trademark Office regarding this application without direct communication between the patent attorneys and patent agents and the undersigned. In the event of a change in the persons from whom instructions may be taken, at least one patent attorney or patent agent named herein will be so notified by the undersigned.

Correspondence:

Direct all correspondence to Customer Number **08791**,

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 false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR: ☐ A petition has been filed for this undersigned inventor

Full Name: **John M. Cioffi**
(First, Middle [if any], Family Name (or Surname), and Suffix [if any])

Inventor's Signature _____ Date 8/30/2007

Residence Atherton, California United States Citizenship USA
(City, State, Country) *(Country)*

Mailing Address 323 Stockbridge Avenue
Atherton, California 94027 United States

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Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	ADAPTIVE FEC CODEWORD MANAGEMENT
First Named Inventor/Applicant Name:	John M. Cioffi
Filer:	Gregory D. Caldwell/Gigi Hoover
Attorney Docket Number:	8241.P002D
Filed as Large Entity	

Utility Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility application filing	1011	1	310	310
Utility Search Fee	1111	1	510	510
Utility Examination Fee	1311	1	210	210
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1030**

Electronic Acknowledgement Receipt

EFS ID:	3726970
Application Number:	12185729
International Application Number:	
Confirmation Number:	9857
Title of Invention:	ADAPTIVE FEC CODEWORD MANAGEMENT
First Named Inventor/Applicant Name:	John M. Cioffi
Customer Number:	08791
Filer:	Gregory D. Caldwell/Vivian Lee
Filer Authorized By:	Gregory D. Caldwell
Attorney Docket Number:	8241.P002D
Receipt Date:	04-AUG-2008
Filing Date:	
Time Stamp:	19:41:30
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$1030
RAM confirmation Number	4164
Deposit Account	022666
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 C.F.R. Section 1.16 (National application filing, search, and examination fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)
1		8241P002D_Application_080408.PDF	1631472 836912377a03813b7f2a03a5387d47457206c4a7	yes	49

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	35
Claims	36	40
Abstract	41	41
Drawings-only black and white line drawings	42	49

Warnings:

Information:

2	Oath or Declaration filed	8241P002D_Declaration_080408.pdf	95096 651f450d032470a2a14ebe359c1ba8d723fef187	no	2

Warnings:

Information:

3	Fee Worksheet (PTO-06)	fee-info.pdf	8359 c8d508dba3e7b64b6565f33aed347ec6608d3dae	no	2

Warnings:

Information:

Total Files Size (in bytes):	1734927

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Electronic Acknowledgement Receipt

EFS ID:	3726970
Application Number:	12185729
International Application Number:	
Confirmation Number:	9857
Title of Invention:	ADAPTIVE FEC CODEWORD MANAGEMENT
First Named Inventor/Applicant Name:	John M. Cioffi
Customer Number:	08791
Filer:	Gregory D. Caldwell/Vivian Lee
Filer Authorized By:	Gregory D. Caldwell
Attorney Docket Number:	8241.P002D
Receipt Date:	04-AUG-2008
Filing Date:	
Time Stamp:	19:41:30
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$1030
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Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

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Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)
1		8241P002D_Application_080408.PDF	1631472 836912377a03813b7f2a03a5387d47457206c4a7	yes	49

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Specification	1	35
	Claims	36	40
	Abstract	41	41
	Drawings-only black and white line drawings	42	49

Warnings:					
Information:					
2	Oath or Declaration filed	8241P002D_Declaration_080408.pdf	95096 651f450d032470a2a14ebe359c1ba8d723fef187	no	2
Warnings:					
Information:					
3	Fee Worksheet (PTO-06)	fee-info.pdf	8359 c8d508dba3e7b64b6565f33aed347ec6608d3dae	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	1734927		

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National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

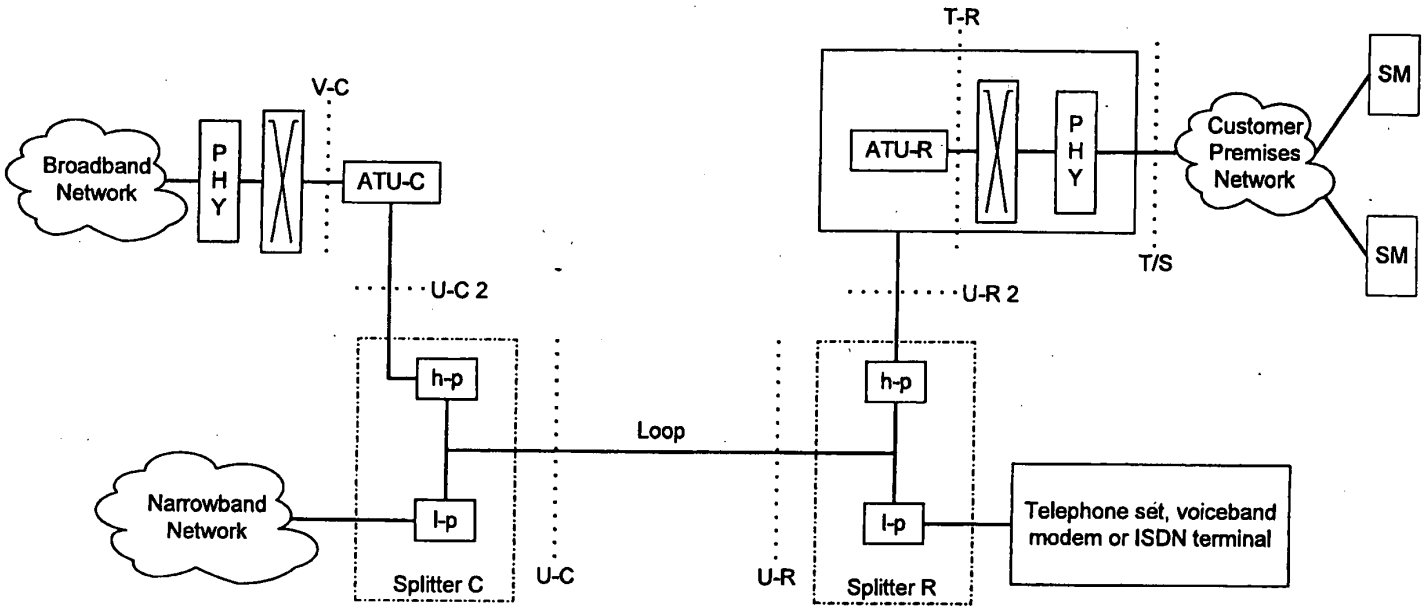

Figure 1 – Prior Art

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Page #463

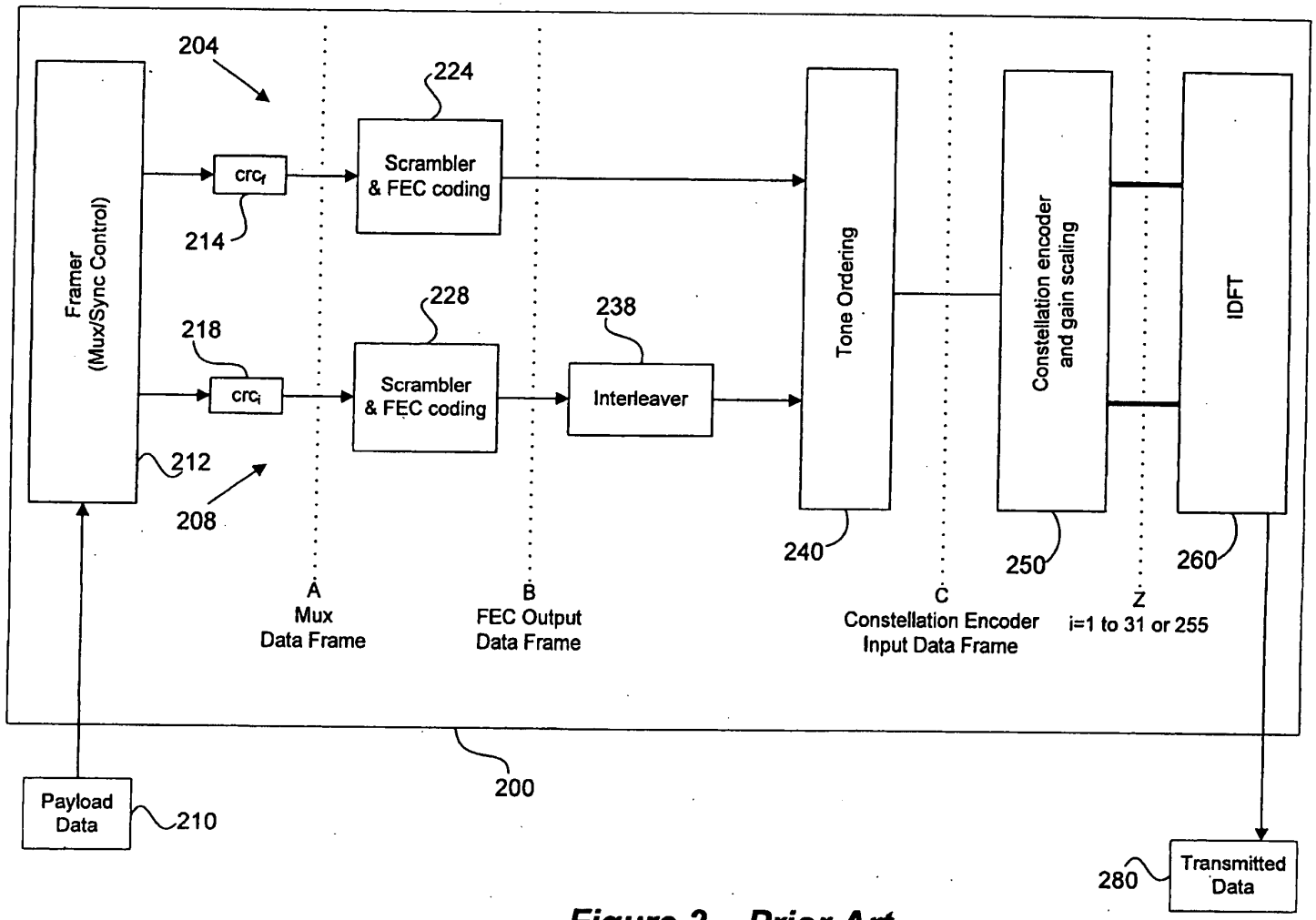

Figure 2 – Prior Art

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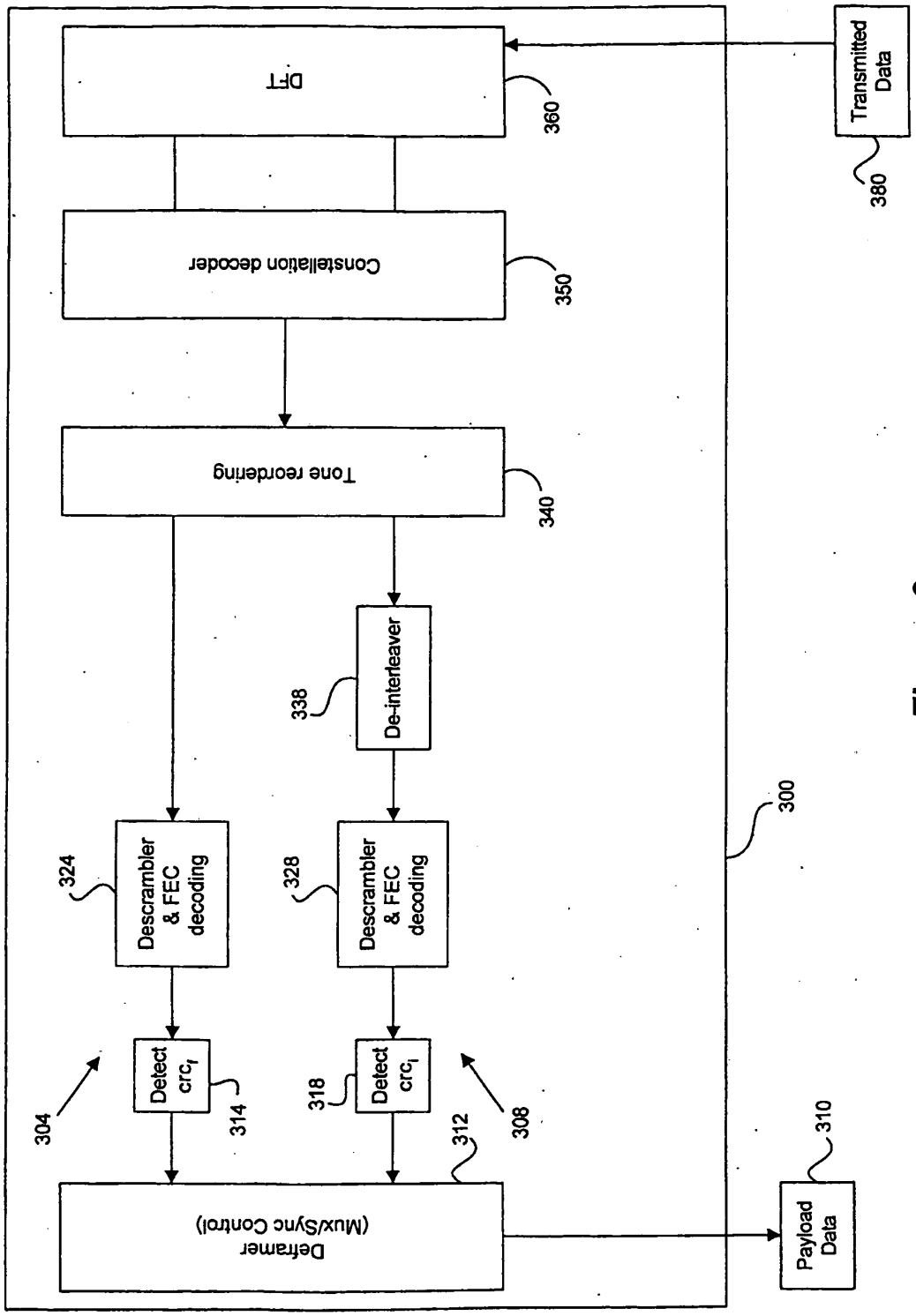
DFT
360
Transmitted Data
380
Constellation decoder
350
Tone reordering
340
De-interleaver
338
300
324
Descrambler & FEC decoding
328
Descrambler & FEC decoding
Detect crc_I
314
318
Detect crc_I
304
308
312
Deframer (Mux/Sync Control)
310
Payload Data

Figure 3

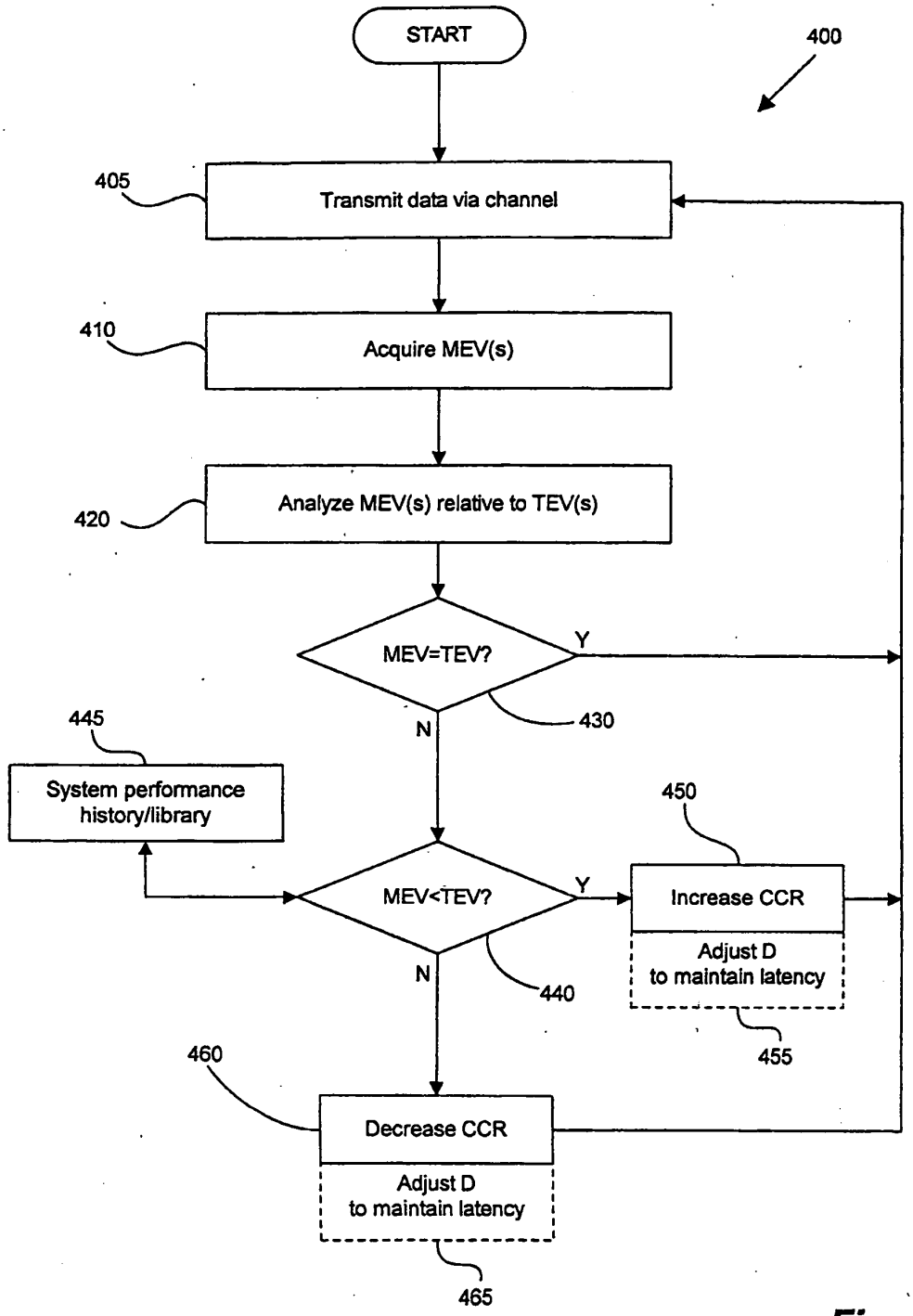
START
400
405
Transmit data via channel
410
Acquire MEV(s)
420
Analyze MEV(s) relative to TEV(s)
MEV=TEV?
Y
N
430
445
System performance history/library
450
MEV<TEV?
Y
Increase CCR
Adjust D to maintain latency
N
440
455
460
Decrease CCR
Adjust D to maintain latency
465

Figure 4

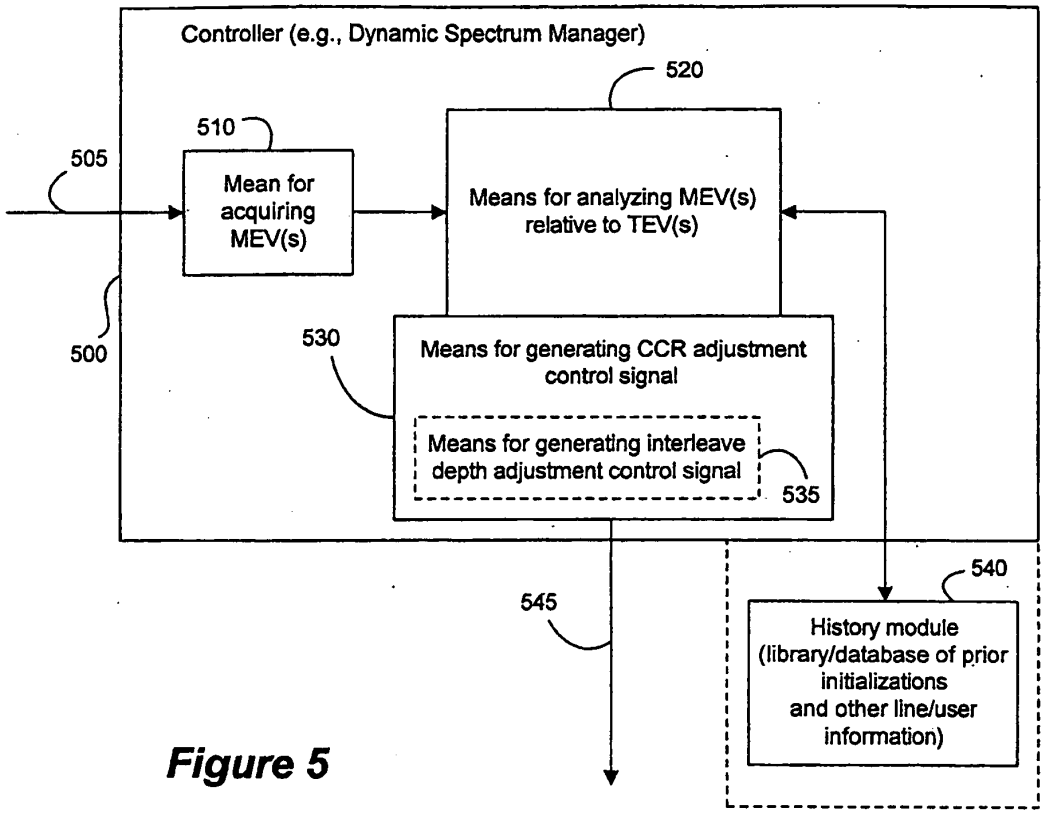
Controller (e.g., Dynamic Spectrum Manager)
520
510
505
Mean for acquiring MEV(s)
Means for analyzing MEV(s) relative to TEV(s)
500
530
Means for generating CCR adjustment control signal
Means for generating interleave depth adjustment control signal
535
540
545
History module (library/database of prior initializations and other line/user information)

Figure 5

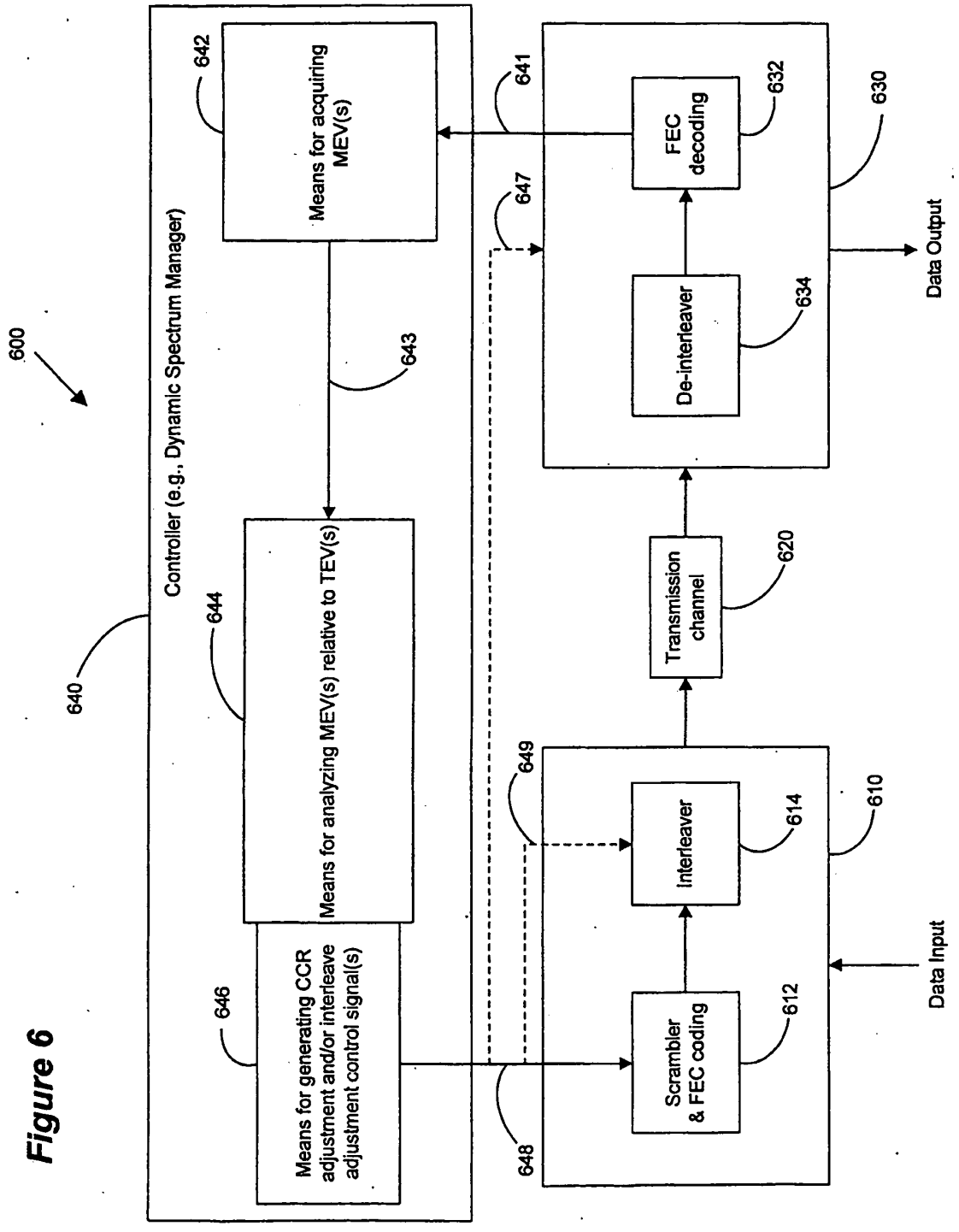
600
640
Controller (e.g., Dynamic Spectrum Manager)
642
Means for acquiring MEV(s)
643
644
Means for analyzing MEV(s) relative to TEV(s)
646
Means for generating CCR adjustment and/or interleave adjustment control signal(s)
641
647
649
648
630
FEC decoding
632
De-interleaver
634
Data Output
Transmission channel
620
610
Interleaver
614
Scrambler & FEC coding
612
Data Input

Figure 6

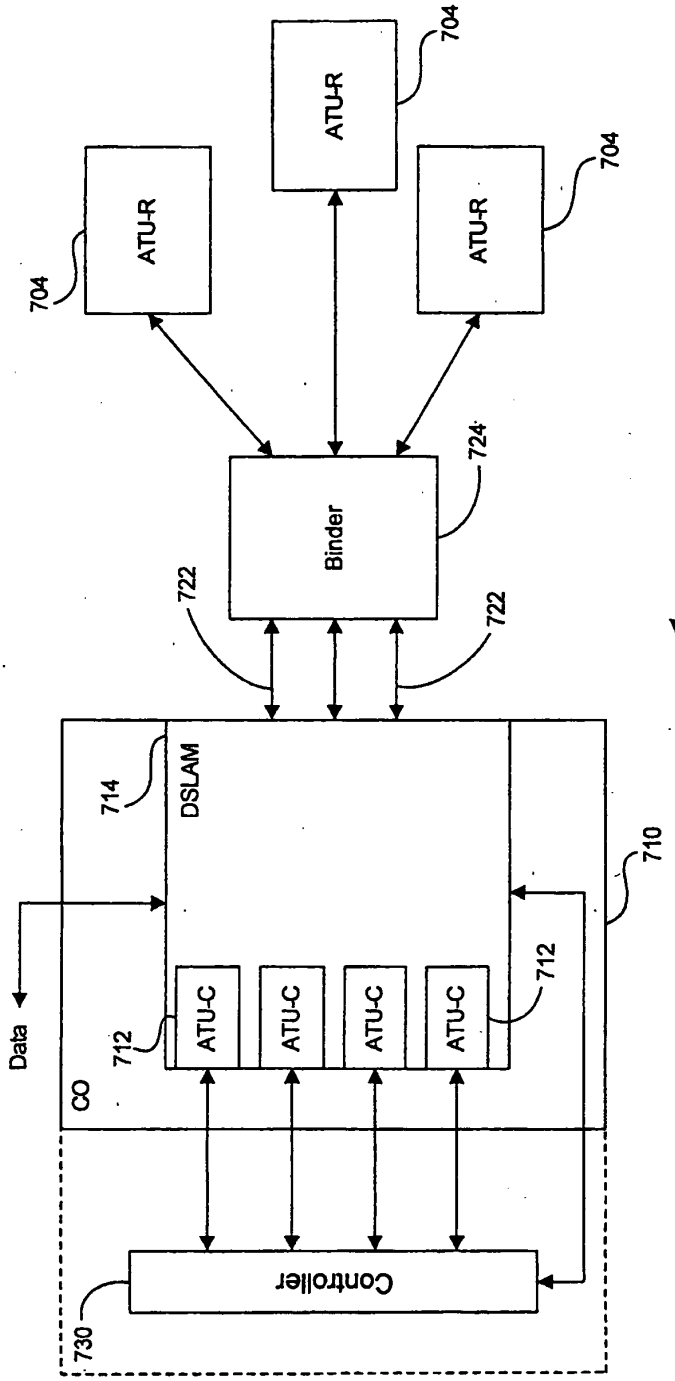
ATU-R
704
ATU-R
704
ATU-R
704
Binder
724
722
722
700
714
DSLAM
710
Data
CO
712
ATU-C
ATU-C
ATU-C
ATU-C
712
Controller
730

Figure 7

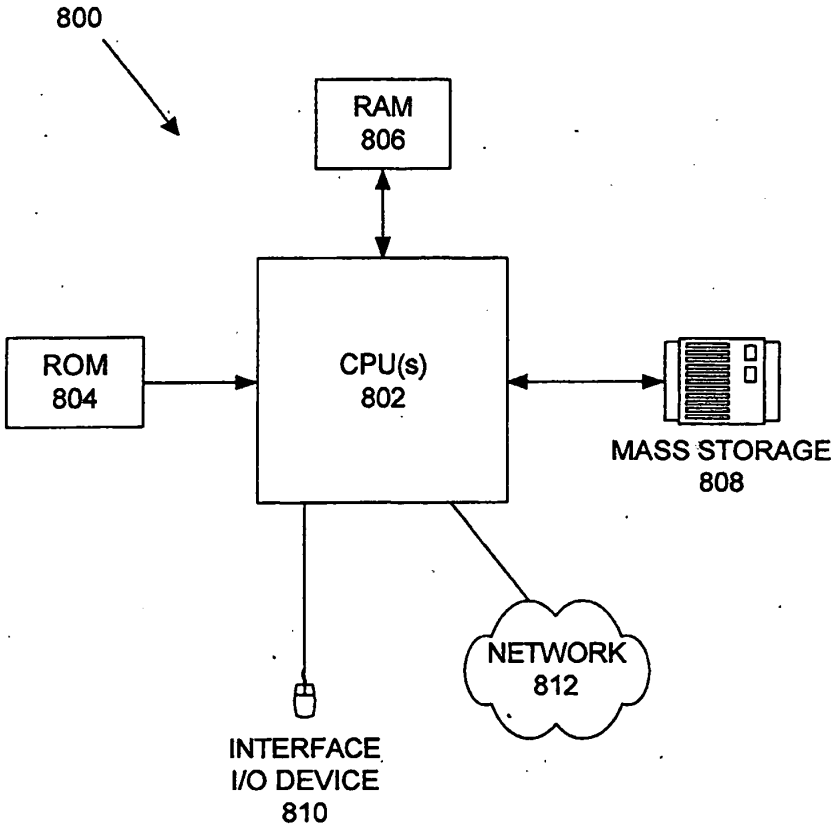
800
RAM
806
ROM
804
CPU(s)
802
MASS STORAGE
808
NETWORK
812
INTERFACE
I/O DEVICE
810

Figure 8

PTO/SB/06 (12-04)

08/04/08

Approved for use through 7/31/2006. OMB 0651-0032
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 12/185,729

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	310
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	510
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	210
TOTAL CLAIMS (37 CFR 1.16(i))	20 minus 20 =	*	X 25=		OR	X 50=	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*	X 105=			X 210=	
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $260 ($130 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR						
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))			N/A			N/A	
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	1030

APPLICATION AS AMENDED – PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	X =		OR	X =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X =		OR	X =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
						TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	X =		OR	X =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X =		OR	X =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
						TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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