IN THE UNITED STATES DISTRICT COURT

FOR THE DISTRICT OF DELAWARE

MOTOROLA, INC., CISCO SYSTEMS, INC., SCIENTIFIC-ATLANTA, INC., ARRIS GROUP, INC., THOMSON, INC., AMBIT MICROSYSTEMS, INC., and NETGEAR, INC.,	)	
Plaintiffs,	)	
v.	)	C.A. No. _____
REMBRANDT TECHNOLOGIES, LP,	)	**JURY TRIAL DEMANDED**
Defendant.	)	

COMPLAINT FOR DECLARATORY JUDGMENT

Plaintiffs Motorola, Inc. ("Motorola"), Cisco Systems, Inc. ("Cisco"), Scientific-Atlanta, Inc. ("Scientific-Atlanta"), ARRIS Group, Inc. ("ARRIS"), Thomson, Inc. ("Thomson"), Ambit Microsystems, Inc. ("Ambit") and NETGEAR, Inc. ("NETGEAR") (collectively "Plaintiffs") are manufacturers of cable equipment that defendant Rembrandt Technologies, LP ("Rembrandt") has accused of infringing eight patents in multiple different lawsuits Rembrandt has brought against Plaintiffs' customers, cable Multiple System Operators ("MSOs"). Specifically, Rembrandt claims to own patents that read on cable equipment complying with "DOCSIS" (the Data Over Cable Service Interface Specification), and alleges that any cable operator who uses certain DOCSIS-certified equipment infringes Rembrandt's alleged patents. Rather than suing the cable equipment manufacturers, however, Rembrandt has instead filed several lawsuits against Plaintiffs' customers, the cable MSO's who purchase Plaintiffs' products and offer cable services to subscribers. Those customer lawsuits were filed in Delaware, Texas, and New York,

and all of those lawsuits are now before this Court by Order of the Judicial Panel on Multidistrict Litigation.

Accordingly, Rembrandt has accused Plaintiffs' equipment of infringing its patents and several of Plaintiffs' customers have sought indemnification from Plaintiffs in relation to the pending customer lawsuits. Plaintiffs thus bring this action in this Court to seek a declaration that their products do not infringe any of Rembrandt's alleged patents and that Rembrandt's alleged patents are invalid. Accordingly, for their Complaint against Rembrandt, Plaintiffs hereby demand a jury trial and allege as follows:

PARTIES

1. Plaintiff Ambit is a California corporation with its principal place of business at 9570 La Costa Lane, Lone Tree, CO 80124.

2. Plaintiff ARRIS is a Delaware corporation with its principal place of business at 3871 Lakefield Drive, Suwanee, GA, 30024.

3. Plaintiff Cisco is a California corporation with its principal place of business at 170 West Tasman Drive, San Jose, CA 95134.

4. Plaintiff Motorola is a Delaware corporation with its principal place of business at 1303 E. Algonquin Road, Schaumburg, IL 60196.

5. Plaintiff NETGEAR is a Delaware corporation with its principal place of business at 4500 Great America Parkway, Santa Clara, CA 95054.

6. Plaintiff Scientific-Atlanta is a wholly owned subsidiary of Plaintiff Cisco and is a Georgia corporation with its principal place of business at 5030 Sugarloaf Parkway, Lawrenceville, GA 30044-2869.

7. Plaintiff Thomson is a Delaware corporation with its principal place of business at 101 W. 103rd Street, INH 3340, Indianapolis, IN 46290.

8. On information and belief, defendant Rembrandt is a limited partnership organized and existing under the laws of New Jersey, with a principal place of business at 401 City Avenue, Suite 528, Bala Cynwyd, PA 19004. Rembrandt asserts that its business is enforcing and licensing patents. In carrying out its business of patent enforcement, Rembrandt has instituted patent litigation in this forum against Cablevision Systems Corporation and CSC Holdings Inc., in C.A. No. 06-635-GMS. In that action, Rembrandt has asserted that "DOCSIS is a specification that describes the operational parameters of equipment that is used for cable networks. Rembrandt alleges that DOCSIS-compliant equipment infringes the '631, '858, '819, and '903 patents." Rembrandt purports to have obtained patents at-issue in this action through a sale agreement with Paradyne Corp., a Delaware corporation. Rembrandt has also filed patent infringement law suits on another patent in this forum, suing ABC Inc., CBS Corporation, NBC Universal, Fox Entertainment Group Inc. and Fox Broadcasting Company. Those actions can be found as C.A. No. 06-727-GMS, C.A. No. 06-729-GMS, C.A. No. 06-730-GMS and C.A. No. 06-731-GMS. Rembrandt has also caused to be formed in Delaware a number of limited liability corporations, limited partnerships, limited liability limited partnerships and/or corporations. On information and belief, Rembrandt has caused those entities to be formed to assist with its business of patent enforcement and licensing.

NATURE OF THE ACTION

9. In this action, Plaintiffs seek a declaratory judgment of patent noninfringement and invalidity of eight United States Patents pursuant to the Declaratory Judgment Act, 28 U.S.C. §§ 2201-02, and the Patent Laws of the United States, 35 U.S.C. § 100 *et seq.*, and such other relief as the Court deems just and proper.

JURISDICTION AND VENUE

10. This Court has jurisdiction over this action under, and without limitation, 28 U.S.C. §§ 1331,1338(a), 1367, 2201, and 2202, and the Patent Laws of the United States, 35 U.S.C. § 1 *et seq.*

11. Venue is proper in this judicial district under 28 U.S.C. §§ 1391 and 1400(b).

RELATED ACTIONS

12. Pursuant to D. Del. LR 3.1(b), Plaintiffs state that this declaratory judgment action is related to the following actions (the "Related Actions"):

- *Rembrandt Technologies, LP v. Cablevision et al.*, C.A. No. 06-635-GMS;
- *Coxcom v. Rembrandt Technologies, LP*, C.A. No. 06-721-GMS;
- *Rembrandt Technologies, LP v. Adelphia Comm'n Corp., et al.*, C.A. No. 07-396-GMS;
- *Rembrandt Technologies, LP v. Adelphia Comm'n Corp., et al.*, C.A. No. 07-397-GMS;
- *Rembrandt Technologies, LP v. Comcast Corp. et al.*, C.A. No. 07-398-GMS;
- *Rembrandt Technologies, LP v. Charter Comm'n, Inc., et al.*, C.A. No. 07-400-GMS;
- *Rembrandt Technologies, LP v. Time Warner Cable, et al.*, C.A. No. 07-401-GMS;
- *Rembrandt Technologies, LP v. Time Warner Cable, et al.*, C.A. No. 07-402-GMS;
- *Rembrandt Technologies, LP v. Comcast Corp. et al.*, C.A. No. 07-403-GMS;

- *Rembrandt Technologies, LP v. Charter Comm'n, Inc., et al.*, C.A. No. 07-404-GMS;

- *In re Rembrandt Technologies, LP Patent Litigation*, C.A. No. 07-1848-GMS.

THE PATENTS

13. U.S. Patent No. 4,937,819 ("the '819 patent") entitled "Time Orthogonal Multiple Virtual DCE for Use in Analog and Digital Networks" reports that it was filed on September 26, 1988 and issued on June 26, 1990. The inventor named on the '819 patent is Joseph B. King. A copy of the '819 patent is attached hereto as Exhibit A. As alleged herein, Plaintiffs deny that the patent duly and legally issued.

14. U.S. Patent No. 5,008,903 ("the '903 patent") entitled "Adaptive Transmit Pre-Emphasis for Digital Modem Computed from Noise Spectrum" reports that it was filed on May 25, 1989 and issued on April 16, 1991. The inventors named on the '903 patent are William L. Betts and James J. DesRosiers. A copy of the '903 patent is attached hereto as Exhibit B. As alleged herein, Plaintiffs deny that the patent duly and legally issued.

15. U.S. Patent No. 5,710,761 ("the '761 patent") entitled "Error Control Negotiation Based on Modulation" reports that it was filed on May 31, 1995 and issued on January 20, 1998. The inventor named on the '761 patent is Robert Earl Scott. A copy of the '761 patent is attached hereto as Exhibit C. As alleged herein, Plaintiffs deny that the patent duly and legally issued.

16. U.S. Patent No. 5,719,858 ("the '858 patent") entitled "Time-Division Multiple-Access Method for Packet Transmission on Shared Synchronous Serial Buses" reports that it was filed on July 31, 1995 and issued on February 17, 1998. The inventor named on the '858 patent is Wayne T. Moore. A copy of the '858 patent is attached hereto as Exhibit D. As alleged herein, Plaintiffs deny that the patent duly and legally issued.

17. U.S. Patent No. 5,778,234 ("the '234 patent") entitled "Method for Downloading Programs" reports that it was filed on July 24, 1997 and issued on July 7, 1998. The inventors named on the '234 patent are Gideon Hecht, Kurt Ervin Holmquist, and Donald C. Snoll. A copy of the '234 patent is attached hereto as Exhibit E. As alleged herein, Plaintiffs deny that the patent duly and legally issued.

18. U.S. Patent No. 5,852,631 ("the '631 patent") entitled "System and Method for Establishing Link Layer Parameters Based on Physical Layer Modulation" reports that it was filed on January 8, 1997 and issued on December 22, 1998. The inventor named on the '631 patent is Robert Earl Scott. A copy of the '631 patent is attached hereto as Exhibit F.

19. U.S. Patent No. 6,131,159 ("the '159 patent") entitled "System for Downloading Programs" reports that it was filed on May 8, 1992 and issued on October 10, 2000. The inventors named on the '159 patent are Gideon Hecht, Kurt Ervin Holmquist, and Donald C. Snoll. A copy of the '159 patent is attached as Exhibit G. As alleged herein, Plaintiffs deny that the patent duly and legally issued.

20. U.S. Patent No. 6,950,444 ("the '444 patent") entitled "System and Method for a Robust Preamble and Transmission Delimiting in a Switched-Carrier Transceiver" reports that it was filed on August 11, 2000 and issued on September 27, 2005. The inventors named on the '444 patent are Kurt Holmquist and Joseph Chapman. A copy of the '444 patent is attached as Exhibit H. As alleged herein, Plaintiffs deny that the patent duly and legally issued.

21. Rembrandt asserts (but Plaintiffs do not admit) that Rembrandt is the owner of all rights, title, and interest in and to the '819, '903, '761, '858, '234, '631, '159, and '444 patents (collectively, the "Patents"). Rembrandt did not invent the technology in the Patents. Rembrandt also did not invent DOCSIS or contribute to the development of DOCSIS.

Rembrandt purports to have obtained the Patents through an agreement with Paradyne Corporation. Paradyne Corporation did not invent DOCSIS. Paradyne Corporation did not participate in the creation of DOCSIS. Paradyne did not sell cable modems or cable modem termination systems. Rembrandt has contended in discovery responses in one or more of the MSO actions that Paradyne sold products in the United States that Rembrandt alleges to practice the Patents. Rembrandt has also admitted that Paradyne products sold in the United States were not marked with the Patents. Rembrandt is presently aware that Paradyne sold products in the United States that were not marked with the Patents and Rembrandt believes that those products practiced claims of the Patents.

COUNT I
(Declaratory Judgment Action for a Declaration of Noninfringement and Invalidity of U.S. Patent No. 4,937,819)

22. Paragraphs 1 through 21 are incorporated by reference as if stated fully herein.

23. Rembrandt has accused Cablevision Systems Corporation, Charter Communications Operating, LLC, Charter Communications, Inc., Comcast Cable Communications, LLC, Comcast Corporation, Comcast of Plano, LP, Coxcom, Inc., CSC Holdings, Inc., Time Warner Cable Inc., Time Warner Cable LLC, Time Warner Entertainment-Advance/Newhouse Partnership, Time Warner Entertainment Company, L.P. and Time Warner New York Cable LLC of infringing the '819 patent because of the operational parameters of the cable equipment that they purchase for their cable systems. Specifically, Rembrandt has alleged that DOCSIS is a specification that describes operational parameters of equipment that is used for cable networks. Rembrandt further asserts that DOCSIS-compliant cable modem ("CM") and cable modem termination system ("CMTS") equipment allegedly infringe the '819 patent. Plaintiffs manufacture and sell accused CM and/or CMTS equipment, and each of Plaintiffs has

supplied accused CM and/or CMTS equipment to one or more of the cable MSOs that Rembrandt has accused of infringement.

24. An actual and justiciable controversy exists between Plaintiffs and Rembrandt regarding the infringement and validity of the '819 patent.

25. Plaintiffs have not infringed (directly or indirectly) any valid, enforceable claim of the '819 patent, either literally or under the doctrine of equivalents.

26. The '819 patent is invalid because of its failure to meet the conditions of patentability and/or otherwise comply with the requirements of 35 U.S.C. §§ 101, 102, 103, and/or 112.

27. A judicial declaration of noninfringement and invalidity is necessary and appropriate in order to resolve this controversy.

COUNT II
(Declaratory Judgment Action for a Declaration of Noninfringement and Invalidity of U.S. Patent No. 5,008,903)

28. Paragraphs 1 through 21 are incorporated by reference as if stated fully herein.

29. Rembrandt has accused Cablevision Systems Corporation, Charter Communications Operating, LLC, Charter Communications, Inc., Comcast Cable Communications, LLC, Comcast Corporation, Comcast of Plano, LP, Coxcom, Inc., CSC Holdings, Inc., Time Warner Cable Inc., Time Warner Cable LLC, Time Warner Entertainment-Advance/Newhouse Partnership, Time Warner Entertainment Company, L.P. and Time Warner New York Cable LLC of infringing the '903 patent because of the operational parameters of the cable equipment that they purchase for their cable systems. Specifically, Rembrandt has alleged that DOCSIS is a specification that describes operational parameters of equipment that is used for cable networks. Rembrandt further asserts that DOCSIS-compliant cable modem ("CM")

and cable modem termination system ("CMTS") equipment allegedly infringe the '903 patent. Plaintiffs manufacture and sell accused CM and/or CMTS equipment, and each of Plaintiffs has supplied accused CM and/or CMTS equipment to one or more of the cable MSOs that Rembrandt has accused of infringement.

30. An actual and justiciable controversy exists between Plaintiffs and Rembrandt regarding the infringement and validity of the '903 patent.

31. Plaintiffs have not infringed (directly or indirectly) any valid, enforceable claim of the '903 patent, either literally or under the doctrine of equivalents.

32. The '903 patent is invalid because of its failure to meet the conditions of patentability and/or otherwise comply with the requirements of 35 U.S.C. §§ 101, 102, 103, and/or 112.

33. A judicial declaration of noninfringement and invalidity is necessary and appropriate in order to resolve this controversy.

COUNT III
(Declaratory Judgment Action for a Declaration of Noninfringement and Invalidity of U.S. Patent No. 5,710,761)

34. Paragraphs 1 through 21 are incorporated by reference as if stated fully herein.

35. Rembrandt has accused Adelphia Communications Corporation, Century-TCI Distribution Company, LLC, Century-TCI California, LP, Century-TCI California Communications, LP, Century-TCI Holdings, LLC, Charter Communications Operating, LLC, Charter Communications, Inc., Comcast Cable Communications, LLC, Comcast Corporation, Comcast of Plano, LP, Coxcom, Inc., Parnassos Communications, LP, Parnassos Distribution Company I, LLC, Parnassos Distribution Company II, LLC, Parnassos Holdings, LLC, Parnassos, LP, Time Warner Cable Inc., Time Warner Cable LLC, Time Warner Entertainment-

Advance/Newhouse Partnership, Time Warner Entertainment Company, L.P., Time Warner New York Cable LLC and Western NY Cablevision, LP of infringing the '761 patent because of the operational parameters of the cable equipment that they purchase for their cable systems. Specifically, Rembrandt has alleged that DOCSIS is a specification that describes operational parameters of equipment that is used for cable networks. Rembrandt further asserts that DOCSIS-compliant cable modem ("CM") and cable modem termination system ("CMTS") equipment allegedly infringe the '761 patent. Plaintiffs manufacture and sell accused CM and/or CMTS equipment, and each of Plaintiffs has supplied accused CM and/or CMTS equipment to one or more of the cable MSOs that Rembrandt has accused of infringement.

36. An actual and justiciable controversy exists between Plaintiffs and Rembrandt regarding the infringement and validity of the '761 patent.

37. Plaintiffs have not infringed (directly or indirectly) any valid, enforceable claim of the '761 patent, either literally or under the doctrine of equivalents.

38. The '761 patent is invalid because of its failure to meet the conditions of patentability and/or otherwise comply with the requirements of 35 U.S.C. §§ 101, 102, 103, and/or 112.

39. A judicial declaration of noninfringement and invalidity is necessary and appropriate in order to resolve this controversy.

COUNT IV
(Declaratory Judgment Action for a Declaration of Noninfringement and Invalidity of U.S. Patent No. 5,719,858)

40. Paragraphs 1 through 21 are incorporated by reference as if stated fully herein.

41. Rembrandt has accused Cablevision Systems Corporation, Charter Communications Operating, LLC, Charter Communications, Inc., Comcast Cable

Communications, LLC, Comcast Corporation, Comcast of Plano, LP, Coxcom, Inc., CSC Holdings, Inc., Time Warner Cable Inc., Time Warner Cable LLC, Time Warner Entertainment-Advance/Newhouse Partnership, Time Warner Entertainment Company, L.P. and Time Warner New York Cable LLC of infringing the '858 patent because of the operational parameters of the cable equipment that they purchase for their cable systems. Specifically, Rembrandt has alleged that DOCSIS is a specification that describes operational parameters of equipment that is used for cable networks. Rembrandt further asserts that DOCSIS-compliant cable modem ("CM") and cable modem termination system ("CMTS") equipment allegedly infringe the '858 patent. Plaintiffs manufacture and sell accused CM and/or CMTS equipment, and each of Plaintiffs has supplied accused CM and/or CMTS equipment to one or more of the cable MSOs that Rembrandt has accused of infringement.

42. An actual and justiciable controversy exists between Plaintiffs and Rembrandt regarding the infringement and validity of the '858 patent.

43. Plaintiffs have not infringed (directly or indirectly) any valid, enforceable claim of the '858 patent, either literally or under the doctrine of equivalents.

44. The '858 patent is invalid because of its failure to meet the conditions of patentability and/or otherwise comply with the requirements of 35 U.S.C. §§ 101, 102, 103, and/or 112.

45. A judicial declaration of noninfringement and invalidity is necessary and appropriate in order to resolve this controversy.

COUNT V
(Declaratory Judgment Action for a Declaration of Noninfringement and Invalidity of U.S. Patent No. 5,778,234)

46. Paragraphs 1 through 21 are incorporated by reference as if stated fully herein.

47. Rembrandt has accused Adelphia Communications Corporation, Century-TCI Distribution Company, LLC, Century-TCI California, LP, Century-TCI California Communications, LP, Century-TCI Holdings, LLC, Charter Communications Operating, LLC, Charter Communications, Inc., Comcast Cable Communications, LLC, Comcast Corporation, Comcast of Plano, LP, Coxcom, Inc., Parnassos Communications, LP, Parnassos Distribution Company I, LLC, Parnassos Distribution Company II, LLC, Parnassos Holdings, LLC, Parnassos, LP, Time Warner Cable Inc., Time Warner Cable LLC, Time Warner Entertainment-Advance/Newhouse Partnership, Time Warner Entertainment Company, L.P., Time Warner New York Cable LLC and Western NY Cablevision, LP of infringing the '234 patent because of the operational parameters of the cable equipment that they purchase for their cable systems. Specifically, Rembrandt has alleged that DOCSIS is a specification that describes operational parameters of equipment that is used for cable networks. Rembrandt further asserts that DOCSIS-compliant cable modem ("CM") and cable modem termination system ("CMTS") equipment allegedly infringe the '234 patent. Plaintiffs manufacture and sell accused CM and/or CMTS equipment, and each of Plaintiffs has supplied accused CM and/or CMTS equipment to one or more of the cable MSOs that Rembrandt has accused of infringement.

48. An actual and justiciable controversy exists between Plaintiffs and Rembrandt regarding the infringement and validity of the '234 patent.

49. Plaintiffs have not infringed (directly or indirectly) any valid, enforceable claim of the '234 patent, either literally or under the doctrine of equivalents.

50. The '234 patent is invalid because of its failure to meet the conditions of patentability and/or otherwise comply with the requirements of 35 U.S.C. §§ 101, 102, 103, and/or 112.

51. A judicial declaration of noninfringement and invalidity is necessary and appropriate in order to resolve this controversy.

COUNT VI
(Declaratory Judgment Action for a Declaration of Noninfringement and Invalidity of U.S. Patent No. 5,852,631)

52. Paragraphs 1 through 21 are incorporated by reference as if stated fully herein.

53. Rembrandt has accused Cablevision Systems Corporation, Charter Communications Operating, LLC, Charter Communications, Inc., Comcast Cable Communications, LLC, Comcast Corporation, Comcast of Plano, LP, Coxcom, Inc., CSC Holdings, Inc., Time Warner Cable Inc., Time Warner Cable LLC, Time Warner Entertainment-Advance/Newhouse Partnership, Time Warner Entertainment Company, L.P. and Time Warner New York Cable LLC of infringing the '631 patent because of the operational parameters of the cable equipment that they purchase for their cable systems. Specifically, Rembrandt has alleged that DOCSIS is a specification that describes operational parameters of equipment that is used for cable networks. Rembrandt further asserts that DOCSIS-compliant cable modem ("CM") and cable modem termination system ("CMTS") equipment allegedly infringe the '631 patent. Plaintiffs manufacture and sell accused CM and/or CMTS equipment, and each of the Plaintiffs has supplied accused CM and/or CMTS equipment to one or more of the cable MSOs that Rembrandt has accused of infringement.

54. An actual and justiciable controversy exists between Plaintiffs and Rembrandt regarding the infringement and validity of the '631 patent.

55. Plaintiffs have not infringed (directly or indirectly) any valid, enforceable claim of the '631 patent, either literally or under the doctrine of equivalents.

56. The '631 patent is invalid because of its failure to meet the conditions of patentability and/or otherwise comply with the requirements of 35 U.S.C. §§ 101, 102, 103, and/or 112.

57. A judicial declaration of noninfringement and invalidity is necessary and appropriate in order to resolve this controversy.

COUNT VII
(Declaratory Judgment Action for a Declaration of Noninfringement and Invalidity of U.S. Patent No. 6,131,159)

58. Paragraphs 1 through 21 are incorporated by reference as if stated fully herein.

59. Rembrandt has accused Adelphia Communications Corporation, Century-TCI Distribution Company, LLC, Century-TCI California, LP, Century-TCI California Communications, LP, Century-TCI Holdings, LLC, Charter Communications Operating, LLC, Charter Communications, Inc., Comcast Cable Communications, LLC, Comcast Corporation, Comcast of Plano, LP, Coxcom, Inc., Parnassos Communications, LP, Parnassos Distribution Company I, LLC, Parnassos Distribution Company II, LLC, Parnassos Holdings, LLC, Parnassos, LP, Time Warner Cable Inc., Time Warner Cable LLC, Time Warner Entertainment-Advance/Newhouse Partnership, Time Warner Entertainment Company, L.P., Time Warner New York Cable LLC and Western NY Cablevision, LP of infringing the '159 patent because of the operational parameters of the cable equipment that they purchase for their cable systems. Specifically, Rembrandt has alleged that DOCSIS is a specification that describes operational parameters of equipment that is used for cable networks. Rembrandt further asserts that DOCSIS-compliant cable modem ("CM") and cable modem termination system ("CMTS") equipment allegedly infringe the '159 patent. Plaintiffs manufacture and sell accused CM and/or

CMTS equipment, and each of Plaintiffs has supplied accused CM and/or CMTS equipment to one or more of the cable MSOs that Rembrandt has accused of infringement.

60. An actual and justiciable controversy exists between Plaintiffs and Rembrandt regarding the infringement of the '159 patent.

61. Plaintiffs have not infringed (directly or indirectly) any valid, enforceable claim of the '159 patent, either literally or under the doctrine of equivalents.

62. The '159 patent is invalid because of its failure to meet the conditions of patentability and/or otherwise comply with the requirements of 35 U.S.C. §§ 101, 102, 103, and/or 112.

63. A judicial declaration of noninfringement and invalidity is necessary and appropriate in order to resolve this controversy.

COUNT VIII
(Declaratory Judgment Action for a Declaration of Noninfringement and Invalidity of U.S. Patent No. 6,950,444)

64. Paragraphs 1 through 21 are incorporated by reference as if stated fully herein.

65. Rembrandt has accused Adelphia Communications Corporation, Century-TCI Distribution Company, LLC, Century-TCI California, LP, Century-TCI California Communications, LP, Century-TCI Holdings, LLC, Charter Communications Operating, LLC, Charter Communications, Inc., Comcast Cable Communications, LLC, Comcast Corporation, Comcast of Plano, LP, Coxcom, Inc., Parnassos Communications, LP, Parnassos Distribution Company I, LLC, Parnassos Distribution Company II, LLC, Parnassos Holdings, LLC, Parnassos, LP, Time Warner Cable Inc., Time Warner Cable LLC, Time Warner Entertainment-Advance/Newhouse Partnership, Time Warner Entertainment Company, L.P., Time Warner New York Cable LLC and Western NY Cablevision, LP of infringing the '444 patent because of the

operational parameters of the cable equipment that they purchase for their cable systems. Specifically, Rembrandt has alleged that DOCSIS is a specification that describes operational parameters of equipment that is used for cable networks. Rembrandt further asserts that DOCSIS-compliant cable modem ("CM") and cable modem termination system ("CMTS") equipment allegedly infringe the '444 patent. Plaintiffs manufacture and sell accused CM and/or CMTS equipment, and each of Plaintiffs has supplied accused CM and/or CMTS equipment to one or more of the cable MSOs that Rembrandt has accused of infringement.

66. An actual and justiciable controversy exists between Plaintiffs and Rembrandt regarding the infringement and validity of the '444 patent.

67. Plaintiffs have not infringed (directly or indirectly) any valid, enforceable claim of the '444 patent, either literally or under the doctrine of equivalents.

68. The '444 patent is invalid because of its failure to meet the conditions of patentability and/or otherwise comply with the requirements of 35 U.S.C. §§ 101, 102, 103, and/or 112.

69. A judicial declaration of noninfringement and invalidity is necessary and appropriate in order to resolve this controversy.

PRAYER FOR RELIEF

WHEREFORE, Plaintiffs ask that this Court enter judgment in Plaintiffs' favor and grant the following relief:

A. A declaration that Plaintiffs have not infringed any of the claims of U.S. Patent Nos. 4,937,819; 5,008,903; 5,710,761; 5,719,858; 5,778,234; 5,852,631; 6,131,159 or 6,950,444;

B. A declaration that U.S. Patent Nos. 4,937,819; 5,008,903; 5,710,761; 5,719,858; 5,778,234; 5,852,631; 6,131,159 or 6,950,444 are invalid for failure to meet the conditions of

patentability and/or otherwise comply with the requirements of 35 U.S.C. §§ 101, 102, 103, and/or 112;

C. An injunction against Rembrandt and its affiliates, subsidiaries, assigns, employees, agents or anyone acting in privity or concert with Rembrandt from charging infringement or instituting or continuing any legal action for infringement of U.S. Patent Nos. 4,937,819; 5,008,903; 5,710,761; 5,719,858; 5,778,234; 5,852,631; 6,131,159 or 6,950,444 against Plaintiffs, their customers, or anyone acting in privity with Plaintiffs.

D. An order declaring that Plaintiffs are prevailing parties and that this is an exceptional case, awarding Plaintiffs their costs, expenses, disbursements and reasonable attorney fees under 35 U.S.C. § 285 and all other applicable statutes, rules and common law; and

E. Any such other and further relief as the Court deems just and proper.

DEMAND FOR JURY TRIAL

Pursuant to Rule 38 of the Federal Rules of Civil Procedure, Plaintiffs hereby demand a jury trial on all issues so triable.

Respectfully submitted,

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Dated: November 21, 2007

EXHIBIT A

United States Patent [19]

King

[11] **Patent Number: 4,937,819**

[45] **Date of Patent: Jun. 26, 1990**

[54] **TIME ORTHOGONAL MULTIPLE VIRTUAL DCE FOR USE IN ANALOG AND DIGITAL NETWORKS**

[75] Inventor: **Joseph B. King**, St. Petersburg, Fla.

[73] Assignee: **A.T. & T. Paradyne**, Largo, Fla.

[21] Appl. No.: **249,450**

[22] Filed: **Sep. 26, 1988**

[51] **Int. Cl.**[5] **H04J 3/16**

[52] **U.S. Cl.** **370/95.3**; 370/95.1; 370/85.7; 370/104.1

[58] **Field of Search** 370/96, 90, 85, 86, 370/95, 79, 82, 94, 104, 95.1, 95.2, 95.3, 85.7, 104.1, 94.1; 375/12, 13, 14; 340/825.5, 825.51

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Primary Examiner—Douglas W. Olms

Assistant Examiner—Alpus H. Hsu

Attorney, Agent, or Firm—Kane, Dalsimer, Sullivan, Kurucz, Levy, Eisele and Richard

[57] **ABSTRACT**

Apparatus and method for time division multiple access in a multidrop system with multiple host applications Employing half-duplex polled protocols is disclosed. Ranging with respect to time is used so as to reduce guard time between successive transmissions thereby increasing system efficiency. Host applications can request extra time slots for long messages via a request bit within the message format.

15 Claims, 9 Drawing Sheets

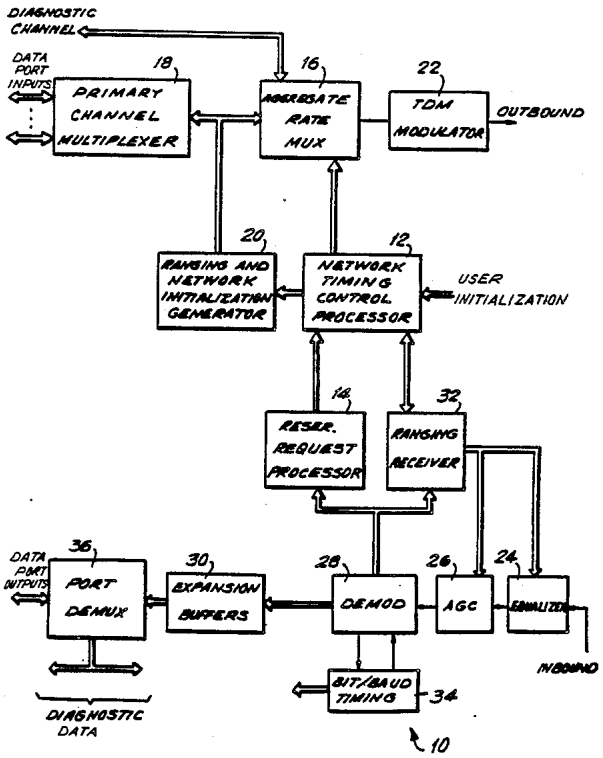
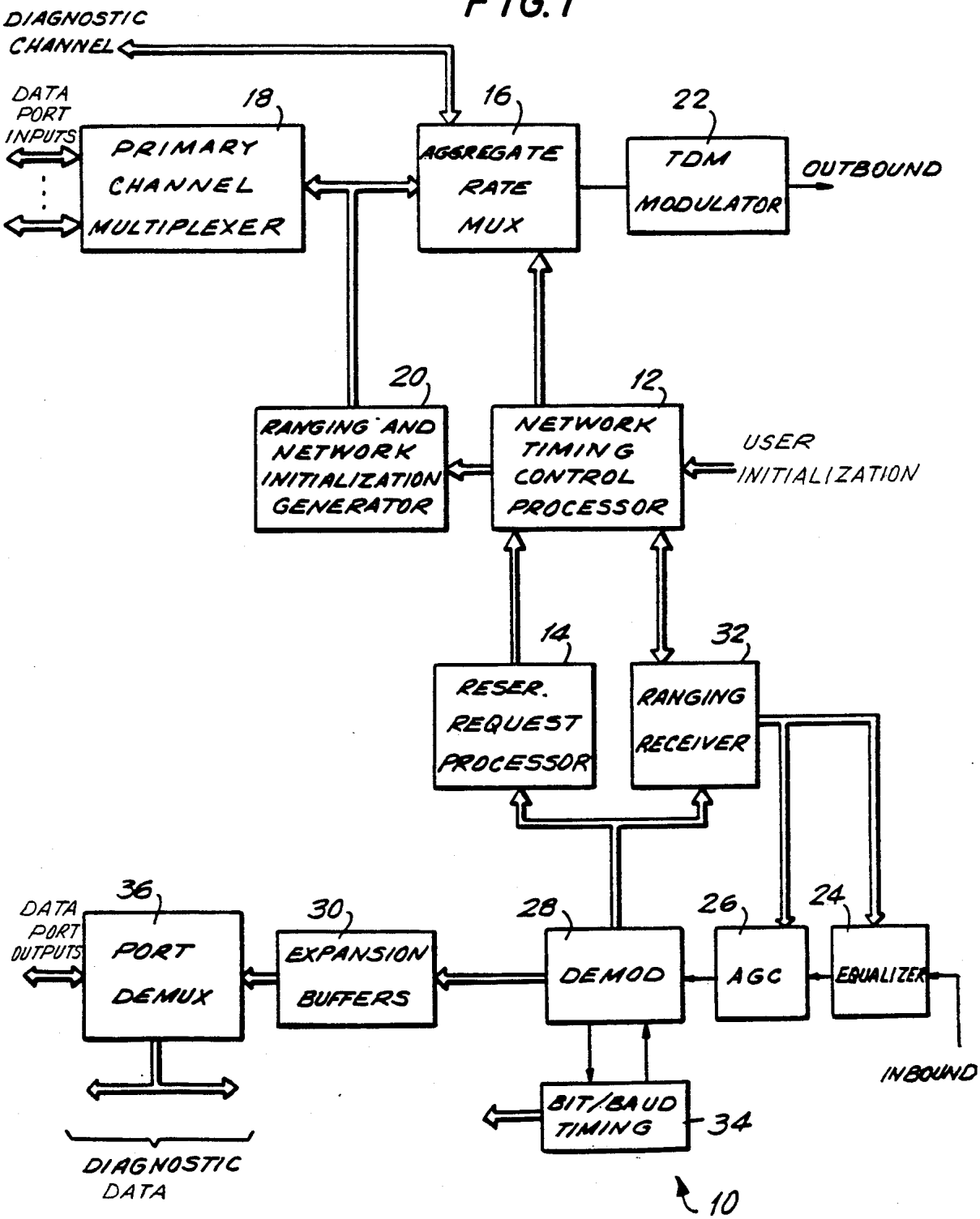


FIG. 1


DIAGNOSTIC CHANNEL
DATA PORT INPUTS
18
PRIMARY CHANNEL MULTIPLEXER
16
AGGREGATE RATE MUX
22
TDM MODULATOR
OUTBOUND
20
RANGING AND NETWORK INITIALIZATION GENERATOR
12
NETWORK TIMING CONTROL PROCESSOR
USER INITIALIZATION
14
RESER. REQUEST PROCESSOR
32
RANGING RECEIVER
36
DATA PORT OUTPUTS
PORT DEMUX
30
EXPANSION BUFFERS
28
DEMOD
26
AGC
24
EQUALIZER
INBOUND
BIT/BAUD TIMING
34
DIAGNOSTIC DATA
10

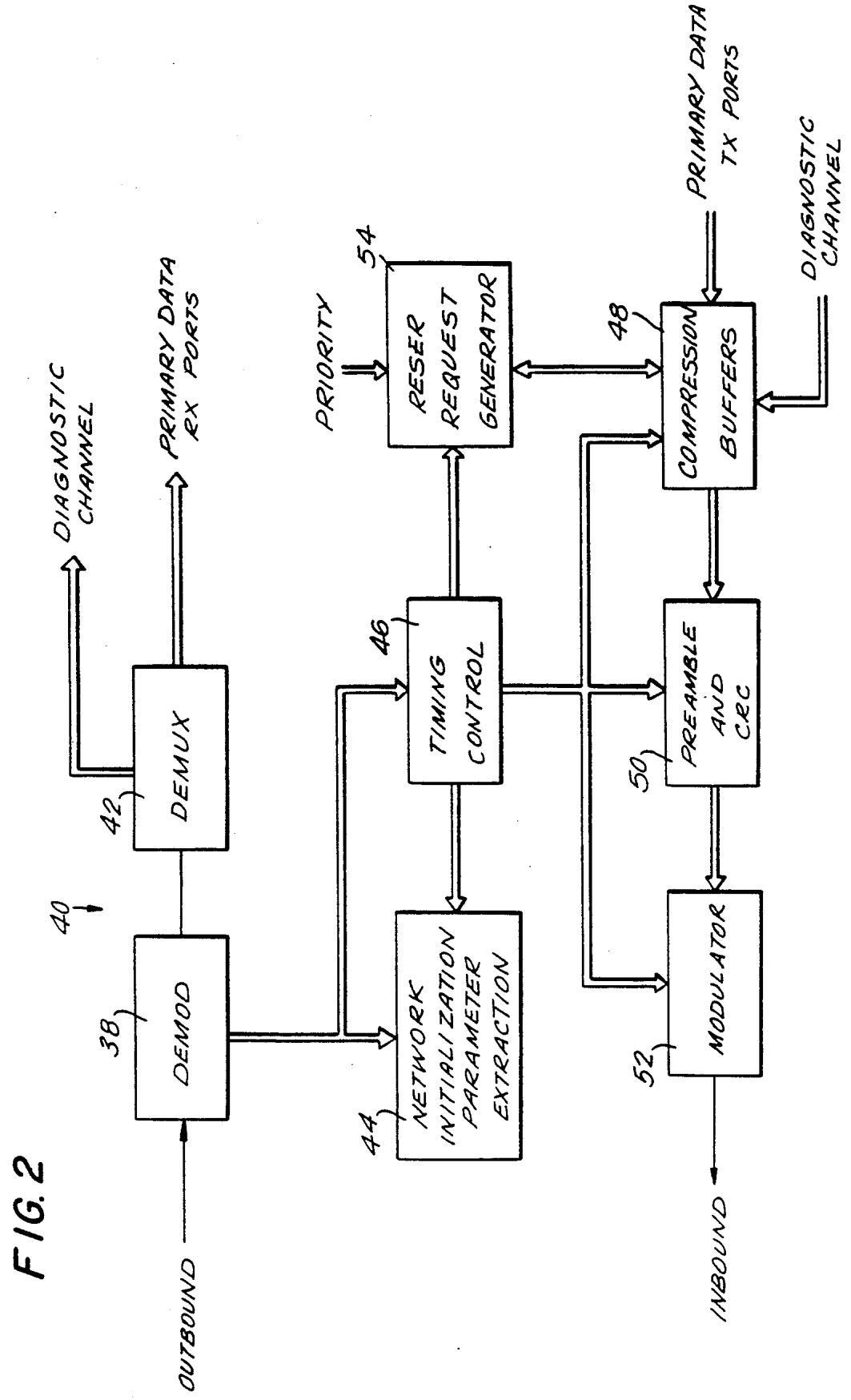
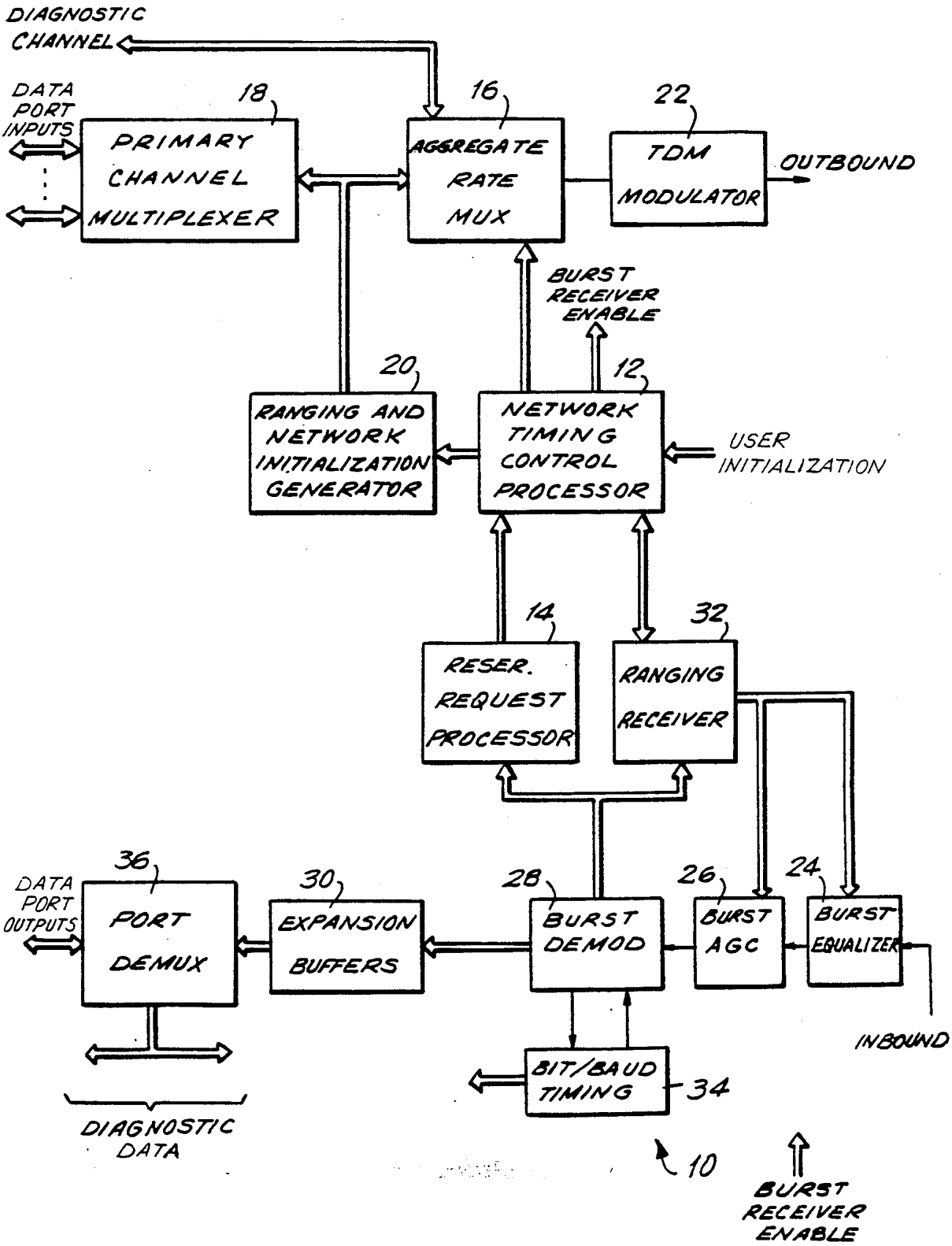

OUTBOUND
DEMOD
38
DEMUX
42
40
DIAGNOSTIC CHANNEL
PRIMARY DATA RX PORTS
NETWORK INITIALIZATION PARAMETER EXTRACTION
44
TIMING CONTROL
46
RESER REQUEST GENERATOR
54
PRIORITY
COMPRESSION BUFFERS
48
PREAMBLE AND CRC
50
MODULATOR
52
INBOUND
PRIMARY DATA TX PORTS
DIAGNOSTIC CHANNEL

FIG. 2

FIG. 3


DIAGNOSTIC CHANNEL
DATA PORT INPUTS
18
PRIMARY CHANNEL MULTIPLEXER
16
AGGREGATE RATE MUX
22
TDM MODULATOR
OUTBOUND
BURST RECEIVER ENABLE
20
RANGING AND NETWORK INITIALIZATION GENERATOR
12
NETWORK TIMING CONTROL PROCESSOR
USER INITIALIZATION
14
RESER. REQUEST PROCESSOR
32
RANGING RECEIVER
36
DATA PORT OUTPUTS
PORT DEMUX
30
EXPANSION BUFFERS
28
BURST DEMOD
26
BURST AGC
24
BURST EQUALIZER
INBOUND
BIT/BAUD TIMING
34
DIAGNOSTIC DATA
10
BURST RECEIVER ENABLE

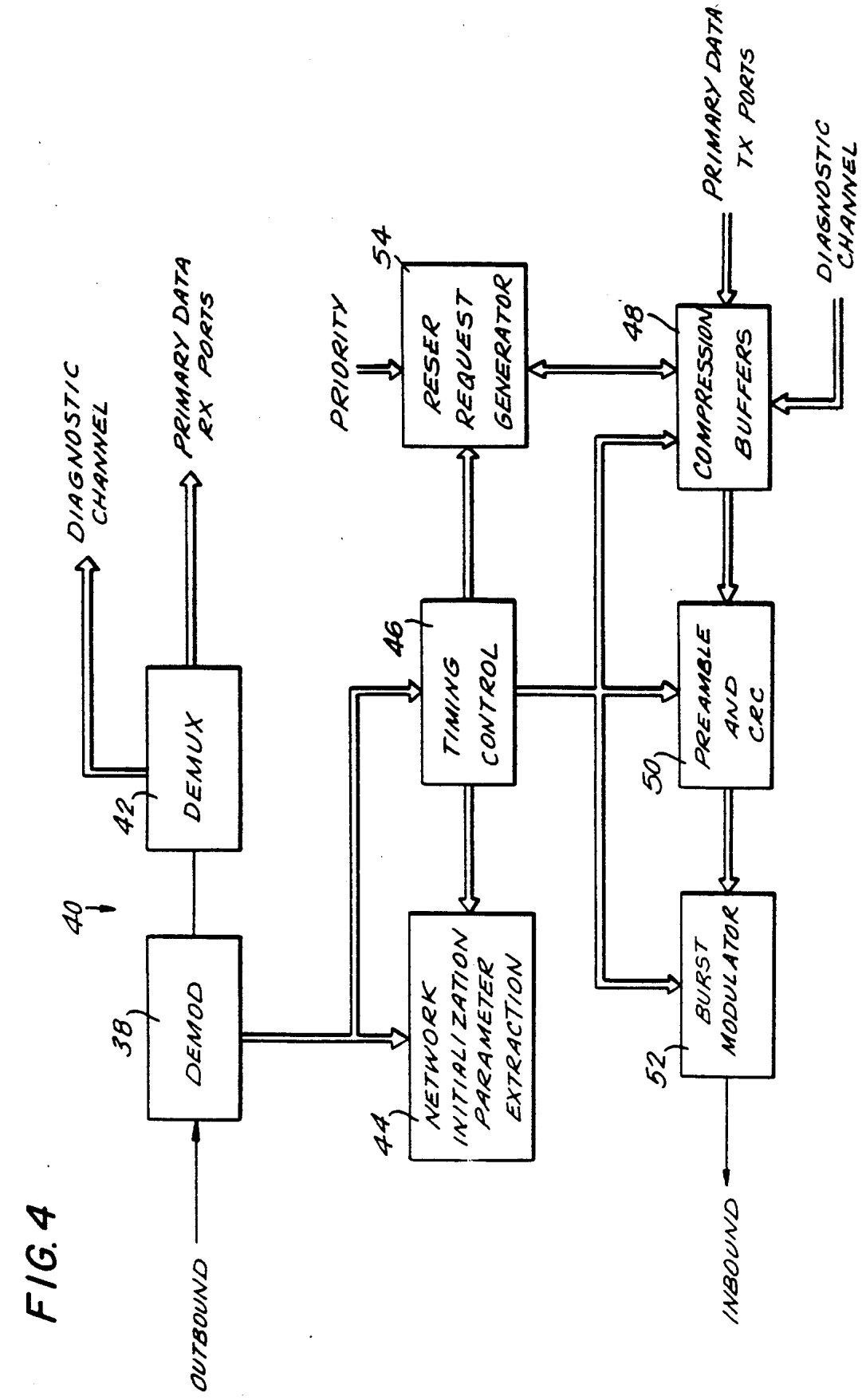

OUTBOUND
DEMOD
38
DEMUX
42
40
DIAGNOSTIC CHANNEL
PRIMARY DATA RX PORTS
NETWORK INITIALIZATION PARAMETER EXTRACTION
44
TIMING CONTROL
46
RESER REQUEST GENERATOR
54
PRIORITY
COMPRESSION BUFFERS
48
PREAMBLE AND CRC
50
BURST MODULATOR
52
PRIMARY DATA TX PORTS
DIAGNOSTIC CHANNEL
INBOUND

FIG. 4

FIG. 5

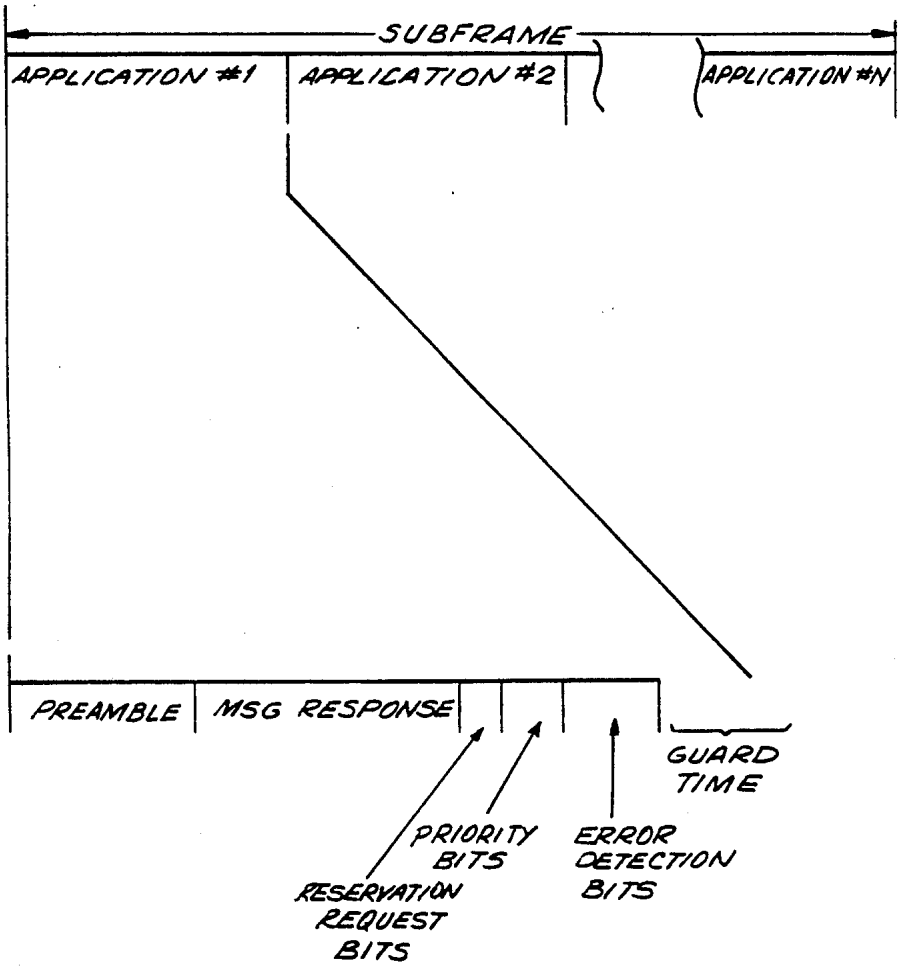

SUBFRAME
APPLICATION #1
APPLICATION #2
APPLICATION #N
PREAMBLE
MSG RESPONSE
GUARD TIME
RESERVATION REQUEST BITS
PRIORITY BITS
ERROR DETECTION BITS

FIG. 6

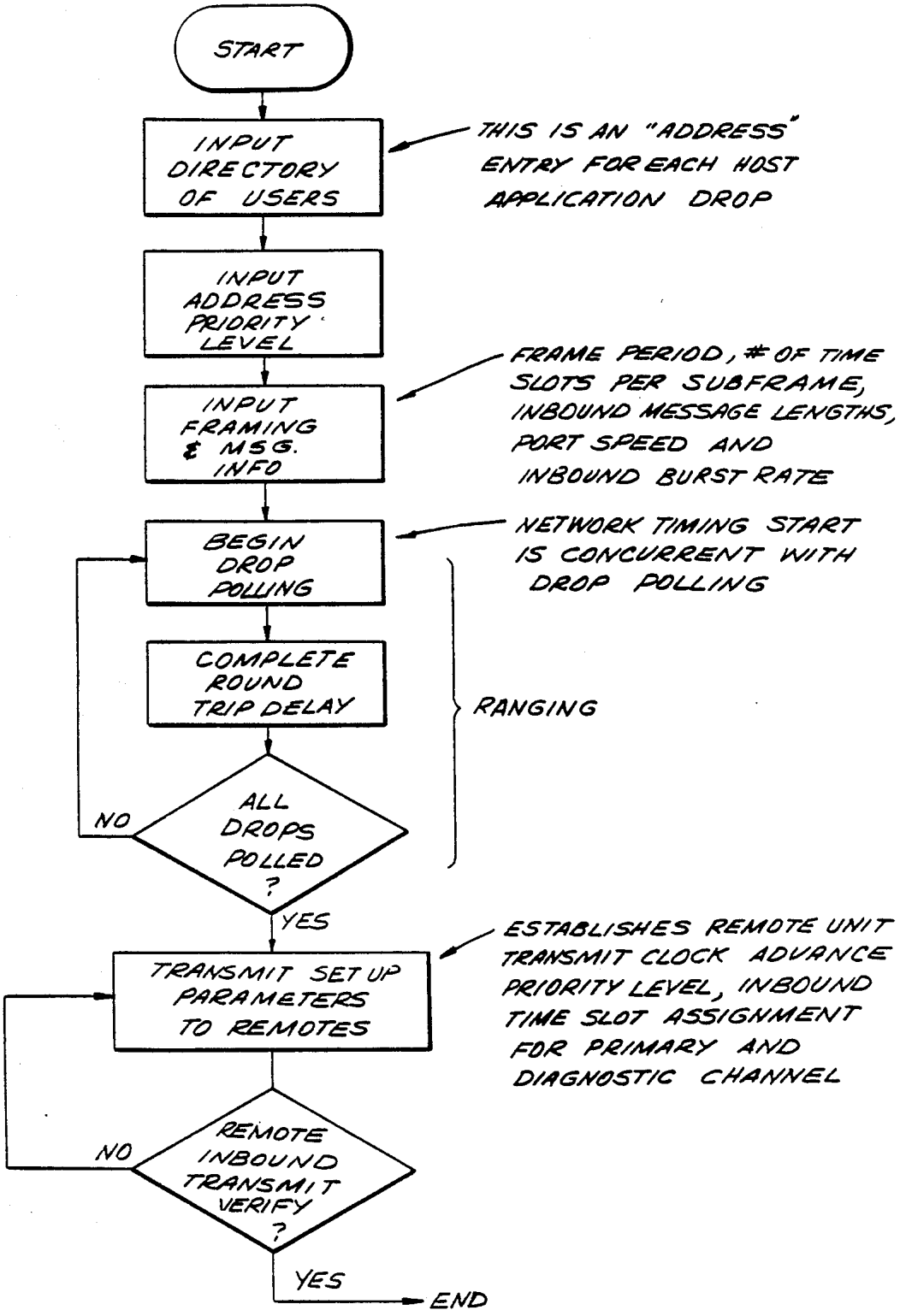

START
INPUT DIRECTORY OF USERS
THIS IS AN "ADDRESS" ENTRY FOR EACH HOST APPLICATION DROP
INPUT ADDRESS PRIORITY LEVEL
INPUT FRAMING & MSG. INFO
FRAME PERIOD, # OF TIME SLOTS PER SUBFRAME, INBOUND MESSAGE LENGTHS, PORT SPEED AND INBOUND BURST RATE
BEGIN DROP POLLING
NETWORK TIMING START IS CONCURRENT WITH DROP POLLING
COMPLETE ROUND TRIP DELAY
RANGING
ALL DROPS POLLED ?
NO
YES
TRANSMIT SET UP PARAMETERS TO REMOTES
ESTABLISHES REMOTE UNIT TRANSMIT CLOCK ADVANCE PRIORITY LEVEL, INBOUND TIME SLOT ASSIGNMENT FOR PRIMARY AND DIAGNOSTIC CHANNEL
REMOTE INBOUND TRANSMIT VERIFY ?
NO
YES
END

FIG. 7

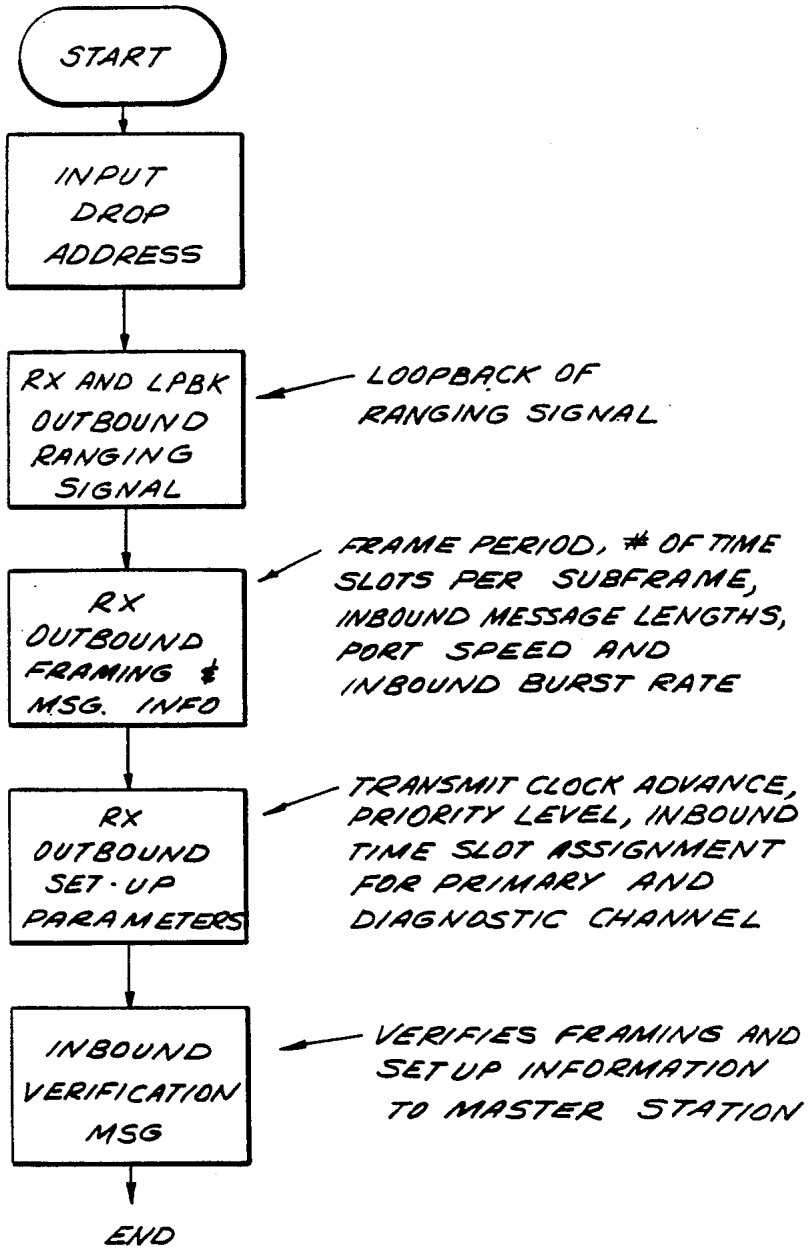

START
INPUT DROP ADDRESS
RX AND LPBK OUTBOUND RANGING SIGNAL
LOOPBACK OF RANGING SIGNAL
RX OUTBOUND FRAMING & MSG. INFO
FRAME PERIOD, # OF TIME SLOTS PER SUBFRAME, INBOUND MESSAGE LENGTHS, PORT SPEED AND INBOUND BURST RATE
RX OUTBOUND SET-UP PARAMETERS
TRANSMIT CLOCK ADVANCE, PRIORITY LEVEL, INBOUND TIME SLOT ASSIGNMENT FOR PRIMARY AND DIAGNOSTIC CHANNEL
INBOUND VERIFICATION MSG
VERIFIES FRAMING AND SETUP INFORMATION TO MASTER STATION
END

FIG. 8

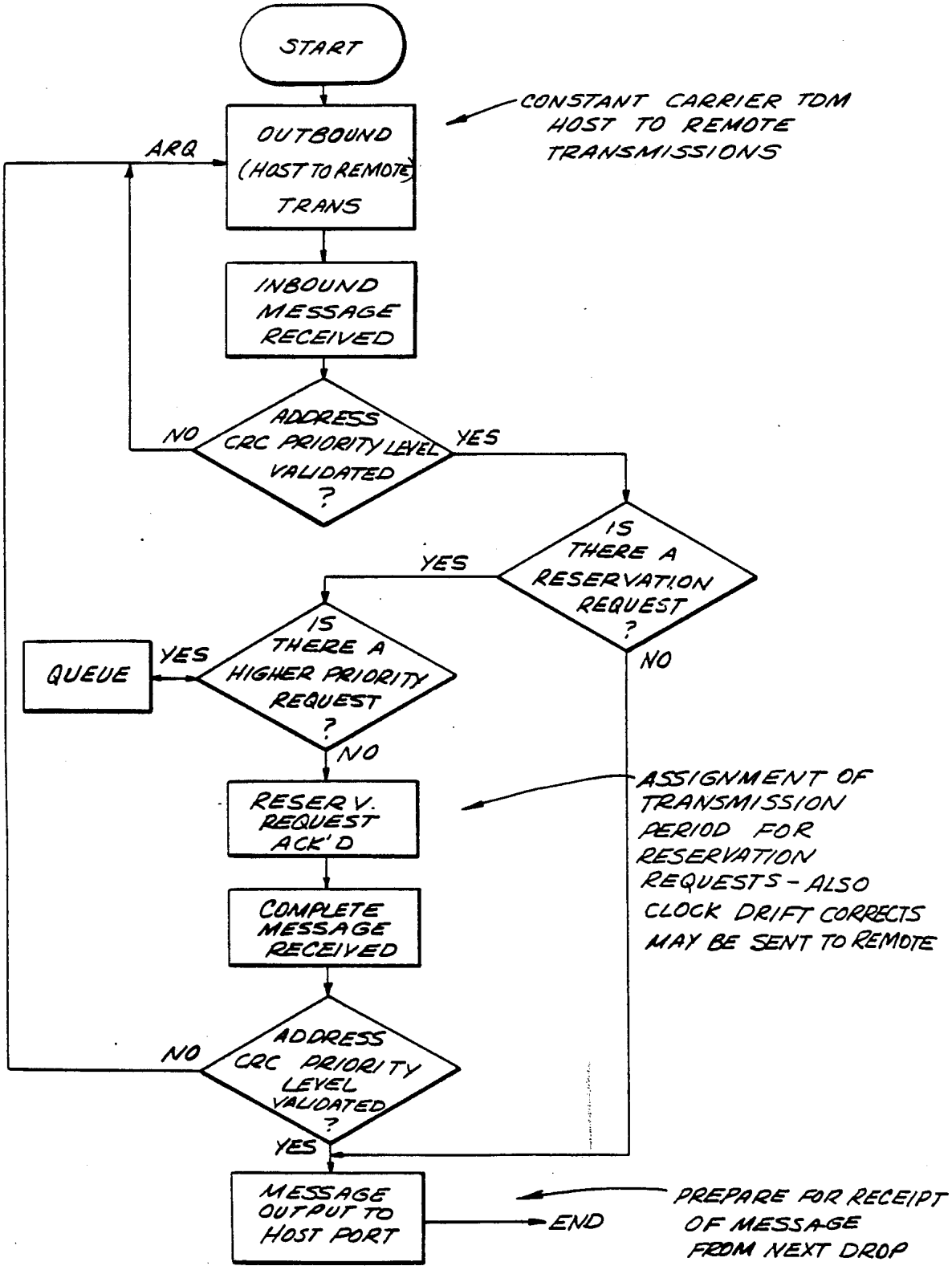
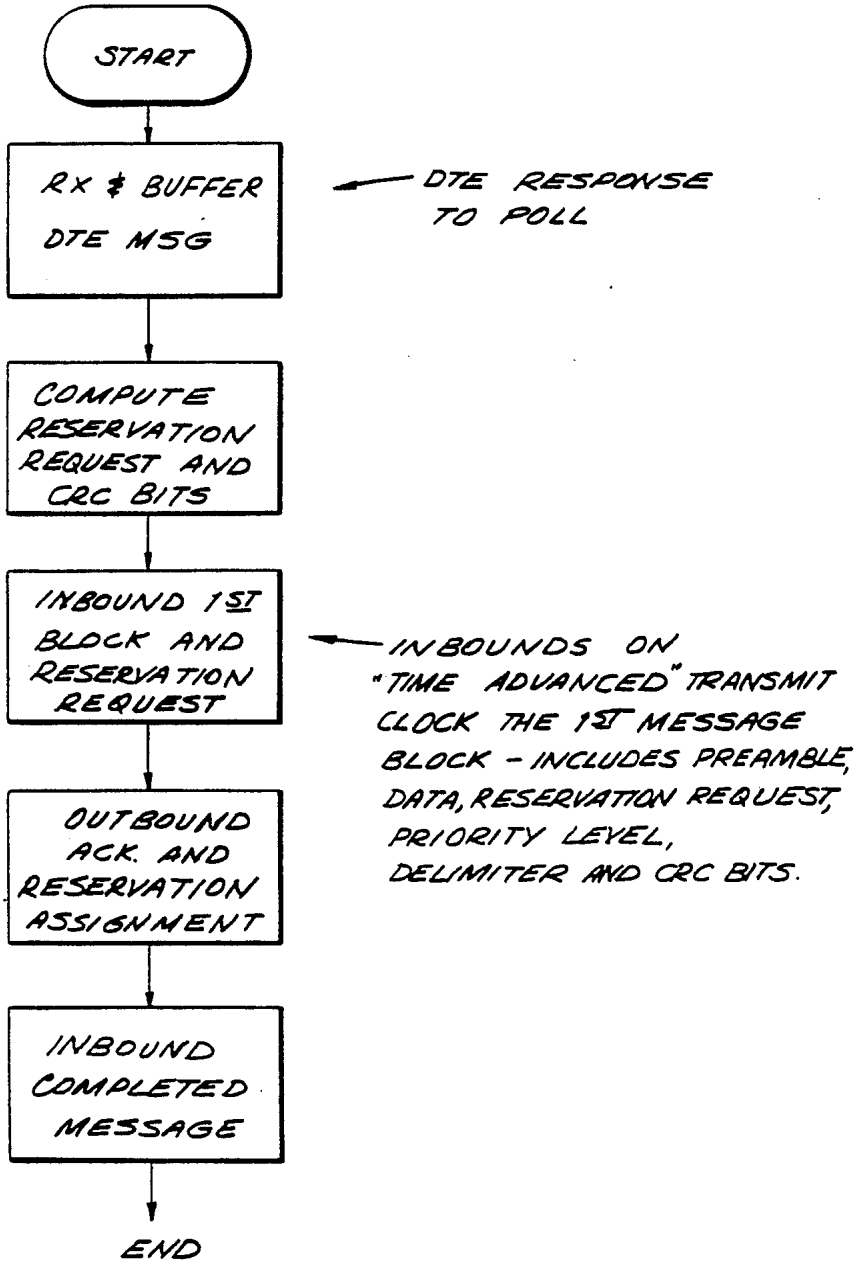

START
OUTBOUND (HOST TO REMOTE) TRANS
CONSTANT CARRIER TDM HOST TO REMOTE TRANSMISSIONS
ARQ
INBOUND MESSAGE RECEIVED
ADDRESS CRC PRIORITY LEVEL VALIDATED ?
NO
YES
IS THERE A RESERVATION REQUEST ?
YES
NO
IS THERE A HIGHER PRIORITY REQUEST ?
QUEUE
YES
NO
RESERV. REQUEST ACK'D
ASSIGNMENT OF TRANSMISSION PERIOD FOR RESERVATION REQUESTS - ALSO CLOCK DRIFT CORRECTS MAY BE SENT TO REMOTE
COMPLETE MESSAGE RECEIVED
ADDRESS CRC PRIORITY LEVEL VALIDATED ?
NO
YES
MESSAGE OUTPUT TO HOST PORT
END
PREPARE FOR RECEIPT OF MESSAGE FROM NEXT DROP

FIG. 9


START
RX # BUFFER DTE MSG
DTE RESPONSE TO POLL
COMPUTE RESERVATION REQUEST AND CRC BITS
INBOUND 1ST BLOCK AND RESERVATION REQUEST
INBOUNDS ON "TIME ADVANCED" TRANSMIT CLOCK THE 1ST MESSAGE BLOCK - INCLUDES PREAMBLE, DATA, RESERVATION REQUEST, PRIORITY LEVEL, DELIMITER AND CRC BITS.
OUTBOUND ACK. AND RESERVATION ASSIGNMENT
INBOUND COMPLETED MESSAGE
END

TIME ORTHOGONAL MULTIPLE VIRTUAL DCE FOR USE IN ANALOG AND DIGITAL NETWORKS

BACKGROUND OF INVENTION

1. Field of Invention

This invention relates to an apparatus and method for a master unit in a multidrop network to communicate to and from a plurality of remote units, using a plurality of host applications using half duplex polled protocols, through the use of time division multiple access techniques.

2. Scope of the Prior Art

In the prior art, in order to run multiple host applications to multiple modems in a multidrop network, it is common to use a single network channel for each application, thereby effectively resulting in a number of networks rather than a single network. Further, such an arrangement is clearly an inefficient use of leased lines and other equipment.

A common solution to this deficiency of the prior art is to use a single line with frequency division multiplexing. That is, a number of orthogonal carrier frequencies, one for each application, are transmitted over a single line to a plurality of remote units in a multidrop network. However, with such apparatus, the non-linearities of the communications line (most frequently, a telephone line), interfere with the co-existence of multiple carrier frequencies. This interference includes intermodulation, cross-modulation and spillover between and among channels. Furthermore, a strong signal on one carrier frequency could suppress a weak signal on another carrier frequency.

Due to this interference, time-consuming engineering adjustment is required to install and maintain such a system. Such interference increases with an increasing number of co-existing carrier frequencies, thereby limiting the number of carrier frequencies which could be practically carried on a single line. For practical applications, no more than three carrier frequencies can be carried simultaneously on a telephone line.

OBJECTS AND SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide a method and apparatus for allowing a single multidrop network to run multiple applications to multiple remote units.

It is therefore a further object of this invention to provide such a method and apparatus without a fundamental limitation on the number of applications which can be implemented.

It is therefore a further object of this invention to reduce the amount of engineering adjustment needed to install and maintain such a method and apparatus.

The present method and apparatus permits multiple multidrop networks (such as Dataphone Digital Service for digital applications or conventional telephone company lines for analog applications), each serving a distinct half-duplex host polled application, to be replaced by a single multidrop network serving each of said host applications.

The basic features of this method and apparatus are time division multiplexed outbound transmissions from the master to the remote units for data and control; time division multiple access transmissions inbound from the remote units to the master unit; master to remote ranging with respect to transmission time; and priority assigned reservation request for long poll responses. A channel rate exceeding the aggregate port rate is required in order to transmit effectively all of the information from the remote units and allow for control format messages. All remote units (or "drops") receive messages outbound from the control unit and respond in a unique time period assigned to each host application. Contention between applications is thereby avoided due to the fact that each application is assigned such a unique time period. By ranging or measuring the round-trip transmission or delay time between the master unit and each remote unit, and storing these times in a table so as to accurately synchronize the transmissions in a time division multiple access mode, the "guard time" separating inbound transmissions from interfering with each other can be minimized thereby increasing system efficiency.

In order to accommodate longer message lengths from a remote unit to the master unit, a remote unit can append a request for additional time onto its message to the master unit. The master unit will then compare the priority of the requesting remote unit to the priority of subsequent units and make a decision as to whether to allow the requesting remote unit to use the time division multiple access slots of subsequent units.

By the use of the foregoing, a user can install several host applications employing half duplex polling on a single multidrop network, without a fundamental limit on the number of applications and without the need for extensive engineering adjustment during the installation and maintenance of the system. This allows an end user to have fewer modems or data service units/channel service units (DSU/CSU) on the customer premises.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. I shows a block diagram of the master unit in the digital application of this invention.

FIG. II shows a block diagram of the remote unit in the digital application of this invention.

FIG. III shows a block diagram of the master unit in the analog application of this invention.

FIG. IV shows a block diagram of the remote unit in the analog application of this invention.

FIG. V shows a schematic of a subframe format.

FIG. VI shows a flow diagram of the initialization of the master unit.

FIG. VII shows a flow diagram of the initialization of the remote unit.

FIG. VIII shows a flow diagram of the normal operation of the master unit.

FIG. IX shows a flow diagram of the normal operation of the remote unit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in detail wherein like numerals refer to like elements throughout the several views, master unit **10** for digital applications is shown FIG. I. Master unit **10** includes a network timing and control processor **12**. Network timing and control processor **12** uses firmware or software to implement clock drift reset functions, guard time predict functions, burst receiver control functions, reservation assignment functions, cyclic redundancy check (crc) "checksum" calculations, arq functions, remote transmit control functions and user library update functions such as activity rate and frame parameters. Additionally, network timing

and control processor **12** stores user-input initialization parameters including network clock framing periods, slot and subframe assignments, inbound and outbound burst length for each "drop" or remote unit, priority assignments, drop addressing, and port speed assignments.

Reservation request processor **14** allows a drop or remote unit to request more than a single time slot for longer messages. Reservation request processor **14** communicates such a granted request to the network timing and control processor **12**.

The aggregate rate multiplexing module **16**, in response to commands from the network timing and control processor **12**, sets up the timing and bit interleaving of the various application inputs from the various input ports of the primary channel multiplexer **18** and of the overhead and control bits required for outbound control of the remote units from the ranging and network initialization generator **20**. The output of the aggregate rate multiplexer **16** is input to the time division multiplexed modulator **22** which transmits the data to the various drops or remote units (see FIG. II). The time division multiplexed modulator **22** is typically a baseband modulator for digital applications.

The master unit **10** also provides, in addition to primary traffic flow over the channel outbound to remote units, a diagnostic channel which can be inband, and any control information necessary to update clock drifts, perform new ranging, etc.

The input in the form of noncontending packets or bursts of information from the various drops or remote units is received via a single data channel by equalizer **24**. The input stream has its gain automatically adjusted **26** and is demodulated by demodulator **28**.

Demodulator **28** provides digital data to the expansion buffers **30**, the ranging receiver **32**, the reservation request processor **14** and the bit/baud timing processor **34**.

The expansion buffers **30** output digital data to the data port outputs of the various applications and a diagnostic channel via the port demultiplexer **36**.

The ranging receiver **32** receives data from the demodulator **28** during an initial training period (to be described later) so as to store round trip transmission times to each remote unit. This allows an optimization in synchronization of the time division multiple access process, thereby reducing "guard time" between the reception of data from the various remote units thereby increasing the total data transfer rate of the system.

Referring now to FIG. II, data outbound from the time division multiplexed modulator **22** of FIG. I is received by the demodulator **38** of remote unit **40**. The output of demodulator **38** is demultiplexed by demultiplexer **42** which, in turn, feeds the primary data receiver ports and any diagnostic or secondary channel required by the particular application. The demodulator **38** also provides bits to the network initialization parameter extraction module **44** and the timing and control block **46**. Network initialization parameter extraction module **44** and timing and control block **46** provide the user with network timing extraction information, the slot assignment in which the user is allowed to operate and any control information such as transmit inhibit, transmit enable, reservation grants and other network control provided by the master unit (see FIG. I). Additionally, the ranging calculations, that is, the master unit calculation of the time a signal takes to go from the master unit to any remote unit and vice versa, is stored in the timing and control block **46** where it is used for time advancing the transmit clock.

The timing and control block **46** supplies control bits to compression buffers **48**. The timing and control block **46** also feeds the preamble and cyclic redundancy check ("checksum") module **50** and the modulator **52**. Additionally, the timing and control block **46** sets up the reservation request generator **54**. Reservation request generator **54** monitors the compression buffer for fields exceeding a preset parameter limit which is stored in the initialization parameter table. If a field length exceeding the parameter is sensed, then reservation request generator **54** automatically sets the reservation bits in the outgoing message. The format of the outgoing message, including reservation bits, crc bits, message traffic and preambles are described later herein.

Modulator **52** outputs messages via the communication lines to equalizer **24** of the master unit (see FIG. I).

FIG. III discloses the analog version of the master unit. FIG. I is identical to FIG. III except for the addition of the automatic gain control/equalizer tap store function which is added to ranging receiver **32** so as to provide operating parameters to the burst equalizer **24** and the burst automatic gain control **26** dependent upon the particular remote unit which is transmitting to the master unit. Furthermore, as data is transmitted in "bursts" from the remote unit in the analog mode, such elements as the demodulator, agc, and equalizer in the master unit are entitled "burst demodulators", "burst agc", and "burst equalizer" respectively in the master unit. Similarly, the analog modulator in the remote unit is entitled "burst modulator" (FIG. IV).

This is due to the fact that, in the preferred embodiment, the analog mode requires a true burst mode of operation whereas in the digital case, the burst mode requirement is eliminated due to the presence of a constant envelope baseband which includes idle codes when data is not being transmitted.

It should be noted here that the digital application, for instance, one using Dataphone Digital Service, has an inherent advantage over the analog counterpart, and is therefore a slightly preferred embodiment, in that the inbound traffic received at the master unit is a continuous transmission. That is, either information or idle codes are always being transmitted. There are no periods when the signal is not present. As a result, the number of overhead bits required in each remote transmission in the digital application is considerably reduced. This combined with the high channel to port speed ratio permits lower delay penalties. This results in a greater efficiency in the digital system as compared with the analog system.

The time division multiple access sequence is established by the user. An epoch period or frame is defined by the user. The frame is divided with respect to time into a number of subframes. The subframe is further subdivided into slots, one for each application. Therefore, an application has a preassigned time period (or slot) within a subframe to transmit from the remote unit to the master unit, with the possibility of a reservation request for longer messages.

FIG. V discloses a typical subframe. A subframe is divided into N time slots, each separated by a guard time. Each slot contains a preamble, message bits, reservation request bits, priority bits, and error detection bits. The reservation and priority bits may be replaced by address bits. For example, five bits would permit up to 32 drops. The address bits would be an identifier to

the master. The master could then monitor remote clock accuracy, monitor drop transmission events, perform ranging, etc.

Due to the number of total bits exceeding the number of message bits, the aggregate burst (in the case of analog) or transmission (in the case of digital) rate must be higher than the sum of the independent port rates.

As part of the installation of this device, both the master and remote units must be initialized.

As is disclosed in FIG. VI, the first step in the initialization of the master unit is to input the directory of users. This is an address entry for each host application drop.

The next step is to input the address priority level. This is followed by an initialization of such system parameters as frame period, number of time slots per subframe, inbound message lengths, inbound and outbound transmission rates (notice that aggregate burst rate must be higher than the sum of the independent port rates so as to accommodate individual ports along with associated overhead), priority assignments, drop addressing and, port speed assignments. This information is stored in the network timing and control processor.

The initialization phase of operation also includes a ranging calculation for each combination of remote unit (or "drop") and application. The master unit sends a message which makes a round-trip between the master unit and the individual remote unit. The delay period is stored in a library table in the network timing and control processor **12** so that the remote to master unit communication is synchronized, thereby reducing guard time required between successive transmissions and increasing the efficiency of the system.

Additionally, in the case of analog apparatus, the signals received by the master unit during the ranging calculation are used to train the automatic gain control **26** and the equalizer **24**, thereby generating an automatic gain control/equalizer tap store function.

Finally, "set-up" parameters are transmitted from the master unit to the remote units so as to establish remote unit transmit clock advances, priority level, and inbound time slot assignments for the primary and diagnostic channels. The remote unit verifies receipt to the master unit.

Initialization of the remote drops is disclosed in FIG. VII. The user inputs the address of the drop or remote unit. The remote unit returns or "loops-back" the ranging signal from the master unit. The remote unit receives the frame period, the number of time slots per subframe, inbound message lengths, port speed and inbound burst (digital) or transmission (analog) rate.

The remote unit receives set-up parameters such as clock advance, priority level and inbound time slot assignment for the primary and diagnostic framing and set-up information to the master unit.

A flow diagram of the normal operation of the master unit is shown in FIG. VIII.

The master unit sends a message to one of the remote units. An inbound message is received from one of the remote units. The address, cyclic redundancy calculation (i.e. checksum) and priority level are checked. If any of these values are invalid, the master unit retransmits to the remote unit. If these values are valid and there is no reservation request, the message is output to the appropriate application host port at the master end. This process is continually repeated for each application in each remote unit.

If the aforementioned values are valid but there is a reservation request, then the message is queued in the event that there is a higher priority request or acknowledged and completely received in the event that there is no higher priority request. After the complete message is received, its address, checksum and priority are validated. If these values are valid, the message is output to the host port. If the values are not valid, the initial step of an outbound transmission from the master to the remote is returned.

FIG. IX discloses the normal operation of a drop or remote unit. The remote unit receives and buffers a DTE poll response message. The remote unit computes the reservation request and the CRC (cyclic redundancy check or checksum) bits. The CRC bits provide error detection for both overhead and transmit port primary data bits. The remote unit transmits the first block of data, and possibly a reservation request on the inbound channel at a predetermined time in accordance with the "time advanced" (to allow for transmission time and synchronize so as to reduce guard time) transmit clock. This block of data includes preamble data, reservation request, priority level, delimiter and CRC bits.

From the foregoing, it is seen that this system includes the following features:

1. The master to remote (outbound) transmission is a constant carrier time division multiplexed bit stream in which multiple Host/FEP poll and data traffic is bit interleaved along with master to remote network timing control and diagnostic information.

2. The master unit periodically transmits a network clock reading to all remotes and performs a roundtrip delay transmission calculation ("ranging") to each remote unit. The master unit informs each remote unit of its precise round trip value.

3. The period of the master network clock transmission establishes a "frame". This frame is further segmented into subframes at the remote.

4. The remote establishes a receive clock reference (a delayed version of the Master Network Clock) and a transmit clock reference.

5. For analog applications, the remote sends a long train to the master and the master trains and stores equalization taps and automatic gain control settings unique to the drop. This is unnecessary for digital networks due to the continuous presence of traffic (either idle codes or data).

6. The master unit preassigns time slots within the subframes, one for each of the independent host applications.

7. Upon receiving a poll at the remote DTE, RTS/CTS toggles and the DTE response bits are loaded into a buffer. The remote then transmits these bits in the assigned time slot using the transmit clock reference. Therefore, contention due to inbound poll responses from other remotes is precluded. All inbound transmissions contain a preamble, poll response data bits, reservation request bits, at least one priority bit and error detection bits. In the case of analog networks, the preamble is unique to the remote and enables the master to rapidly set the equalization taps and automatic gain control.

8. All inbound transmissions are at burst rates exceeding the remote port rate.

9. The subframe time slot is sized for the dominant poll response message length for the application. For longer transmissions, the remote unit sets the reserva-

tion bits to identify the required number of additional time slots. The priority bit or bits define the remote's relative importance in reducing poll-response delays. The master unit clocks the received message bits to the expansion buffer **30** and checks the reservation and priority bits for error. If no errors are detected, the master responds to the remote with an "authorization to transmit" command and transmits a "transmit inhibit" command to all of the other remote units. Each of these outbound transmissions are error protected so that remote transmission contention is extremely unlikely. The authorized remote commences transmission on the next available time slot and continues until the message transmission has been completed. During this period the expansion buffer clocks data bits to the host.

10. The master unit can recognize whether a remote clock is drifting and so inform the remote with a fast or slow correction value. Such information can be extracted from the actual time of arrival compared with the expected time of arrival at the master unit and the preamble which identifies the transmitted remote.

11. Analysis diagnostic related information is bit interleaved onto the outbound transmission. Because of the relatively slow poll rate of the Analysis system, the inbound response may be assigned to time slot in every Nth subframe. Thus, the aforementioned goals are achieved.

What is claimed is:

1. A communications network comprising:

a master unit;

a plurality of remote units communicating with said master unit in a multidrop configuration;

wherein each of said remote units execute at least one application program, at least one of said remote units executing at least two application programs, said remote units receiving messages outbound from said master unit and responding in a time slot assigned to each of said application programs;

said master unit including a master network timing means with a period which is divided into a plurality of subframes, wherein each subframe is divided into said time slots, and each of said time slots is used as an interval in which one of said application programs in said one of said remote units is assigned to transmit to said master unit in a time division multiple access fashion; and

said master unit including ranging means communicating with said master network timing means wherein a transmission time between said master unit and each of said respective remote units is calculated and transmitted from said master unit to each of said respective remote units, each of said respective remote units using said transmission time to adjust initiation of said time slots.

2. The network of claim **1** wherein said remote units include a reservation request generator which activates a reservation request bit for requesting an additional time interval inbound to said master unit, and wherein said master unit includes a reservation request processor communicating to said master network timing means, said reservation request processor being responsive to said reservation request bit.

3. The network of claim **2** wherein said master unit initiates communication with said remotes using half duplex polled protocols.

4. The network of claim **3** wherein communication from said remote units to said master unit is in the form of modulated bursts on an analog carrier frequency.

5. The network of claim **4** wherein communication from said remote units is received by a burst equalizer in series with a burst automatic gain control in said master unit, said burst equalizer and said burst automatic gain control being responsive to operating parameters which are dependent upon which of said remote units is scheduled to transmit.

6. The network of claim **5** wherein said operating parameters are calculated in an initial training period and stored in said master unit.

7. The network of claim **6** wherein said operating parameters are indexed in said master unit and advanced from said master unit to said burst equalizer and said automatic gain control in response to a preamble unique to each of said remote units which is communicated from said remote units to said master unit.

8. The network of claim **3** wherein communication from said remote units to said master units is in digital form.

9. The network of claim **8** wherein communication between said remote units and said master unit is encoded using baseband modulation.

10. The network of claim **3** wherein said master unit includes a master network clock with a period which is divided into a plurality of subframes, each corresponding to transmission time for one of said remote units, and wherein each subframe is divided into said time slots, and each of said time slots is used as an interval in which one of said applications programs in said one of said remote units transmits to said master unit.

11. The network of claim **2** wherein said time slot comprises a format so as to include a preamble, a poll response data bit, said reservation request bits, at least one priority bit and error detection bit.

12. The network of claim **1** wherein the master unit includes means for calculating clock drifts of the remote units and issuing reset commands to correct the same whereby each remote unit determines its transmit epoch accurately, thereby minimizing guard time while maintaining contention-free transmission to said master unit, said means for calculating clock drifts and issuing reset commands being in communication with said master network timing means.

13. The network of claim **4** wherein said bursts occur at a burst rate which is greater than an aggregate port rate of said remote units.

14. A method for a plurality of remote units to operate a plurality of application programs in communication with a master unit in a multidrop configuration, comprising the steps of:

calculating and storing in said master unit inbound and outbound transmission times between the master unit and said remote units;

dividing a period of a clock in said master unit into a number of subframes, dividing each subframe into a number of slots, each corresponding to transmission times for one of said remote units, and assigning a slot to each of said application programs in said one of said remote units;

transmitting from said master unit to each of said respective remote units the transmission time between said master unit and said respective remote unit, each of said respective remote units using said transmission time to adjust initiation of said slots; and

transmitting data from each of said remote units to said master unit in a time division multiple access configuration wherein each application in each remote unit transmits during said assigned subframe.

15. The method of claim **14** further comprising the step of initiating communication between said master unit and said remote units by using half-duplex polled protocols.

* * * * *

EXHIBIT B

United States Patent [19]

Betts et al.

[11] **Patent Number: 5,008,903**

[45] **Date of Patent: Apr. 16, 1991**

[54] **ADAPTIVE TRANSMIT PRE-EMPHASIS FOR DIGITAL MODEM COMPUTED FROM NOISE SPECTRUM**

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[73] Assignee: **A.T. & T. Paradyne**, Largo, Fla.

[21] Appl. No.: **357,056**

[22] Filed: **May 25, 1989**

[51] **Int. Cl.**[5] **H04L 7/00**

[52] **U.S. Cl.** **375/60**; 375/14

[58] **Field of Search** ..... 375/7, 8, 12, 13, 14, 375/15, 60, 109; 333/18, 28 R; 364/724; 371/64, 34; 455/24

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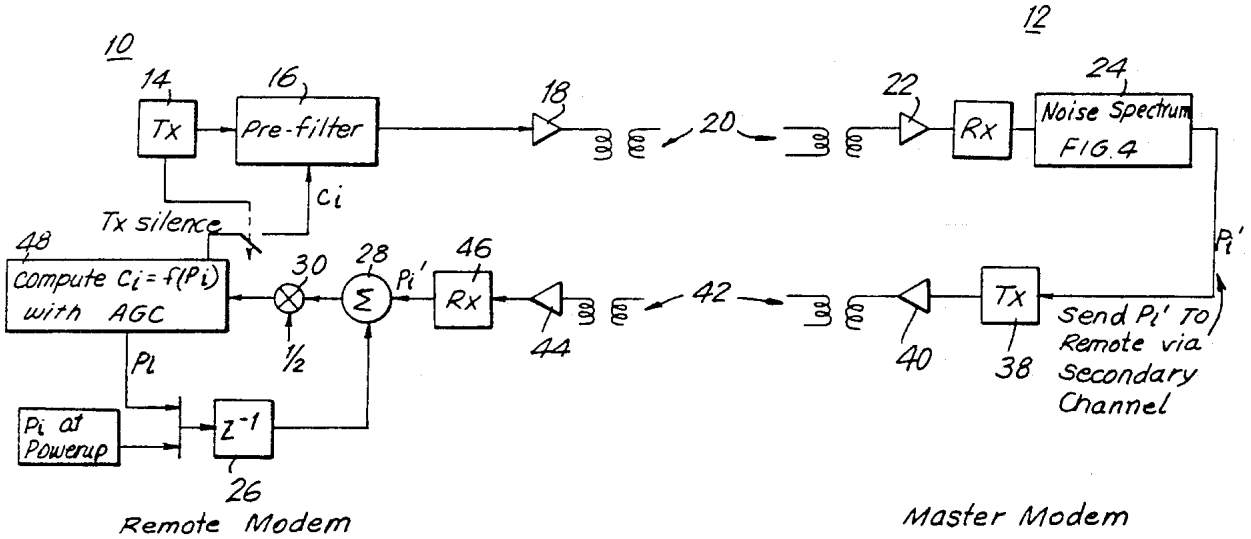
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Primary Examiner—Douglas W. Olms
Assistant Examiner—Stephen Chin
Attorney, Agent, or Firm—Kane, Dalsimer, Sullivan, Kurucz, Levy, Eisele & Richard

[57] **ABSTRACT**

An apparatus and method calculates pre-emphasis coefficients for a transmitting modem based upon the noise spectrum as it is received at the receiving modem. A noise spectrum analysis circuit calculates a difference between the best-fit transmitted data and the actually received data. This difference is used to compute a discrete Fourier transform of the noise spectrum, which is transmitted back to the transmitting modem on the secondary channel. This data is used to calculate filter coefficients for the transmitting modem.

21 Claims, 4 Drawing Sheets



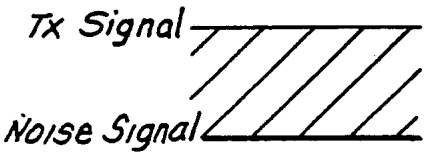


FIG. 1a

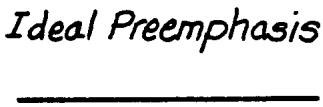


FIG. 1b

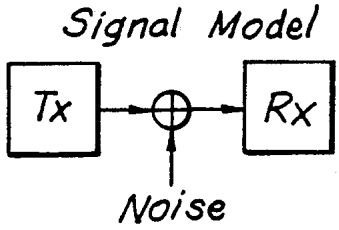


FIG. 1c

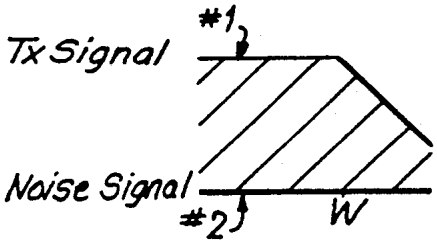


FIG. 2a

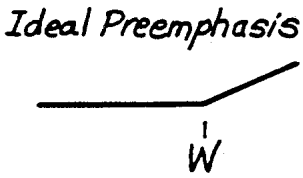


FIG. 2b

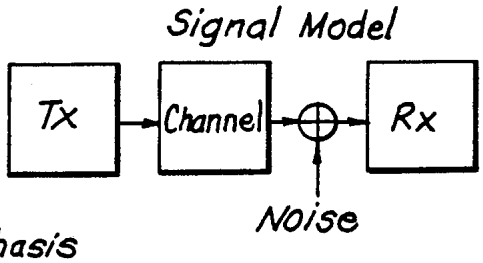


FIG. 2c

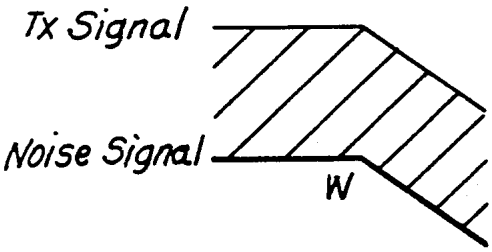


FIG. 3a

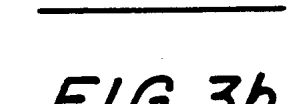


FIG. 3b

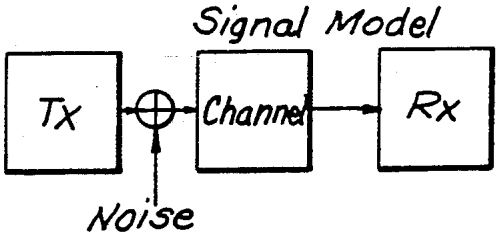


FIG. 3c

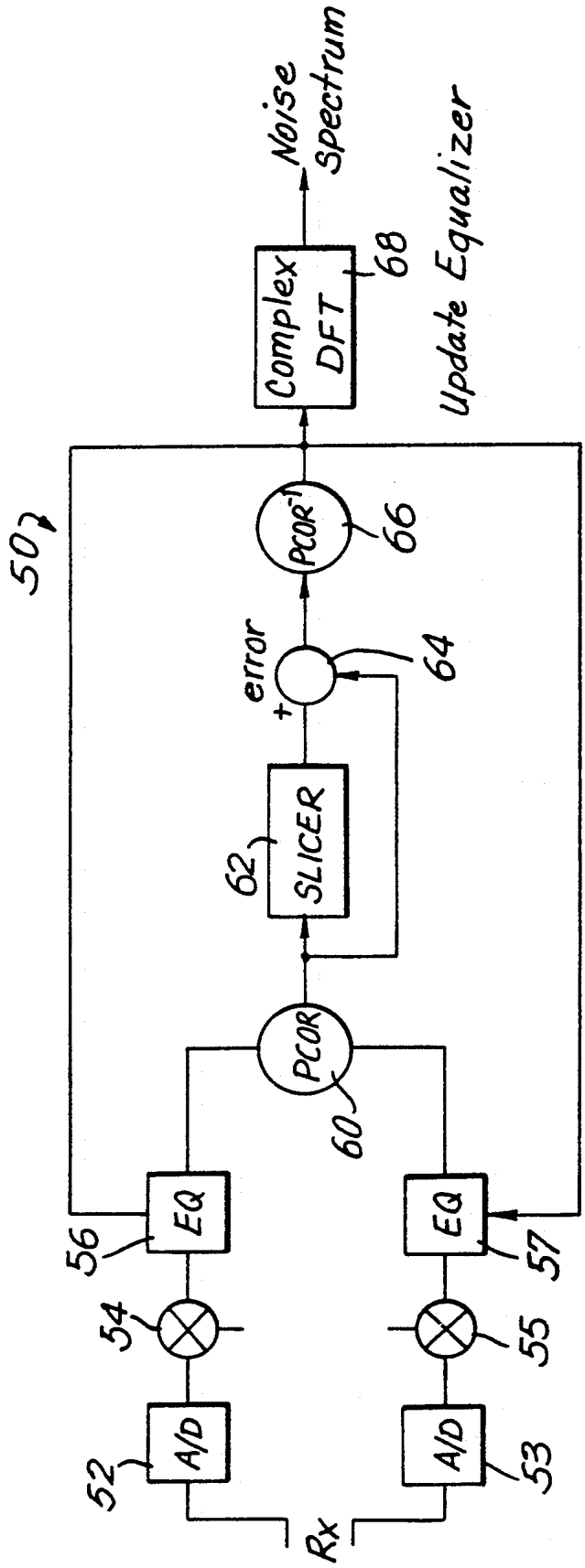

Noise Spectrum
Complex DFT
68
Update Equalizer
50
PCOR^{-1}
66
error
+
64
62
SLICER
PCOR
60
EQ
56
EQ
57
54
55
A/D
52
A/D
53
Rx

FIG. 4

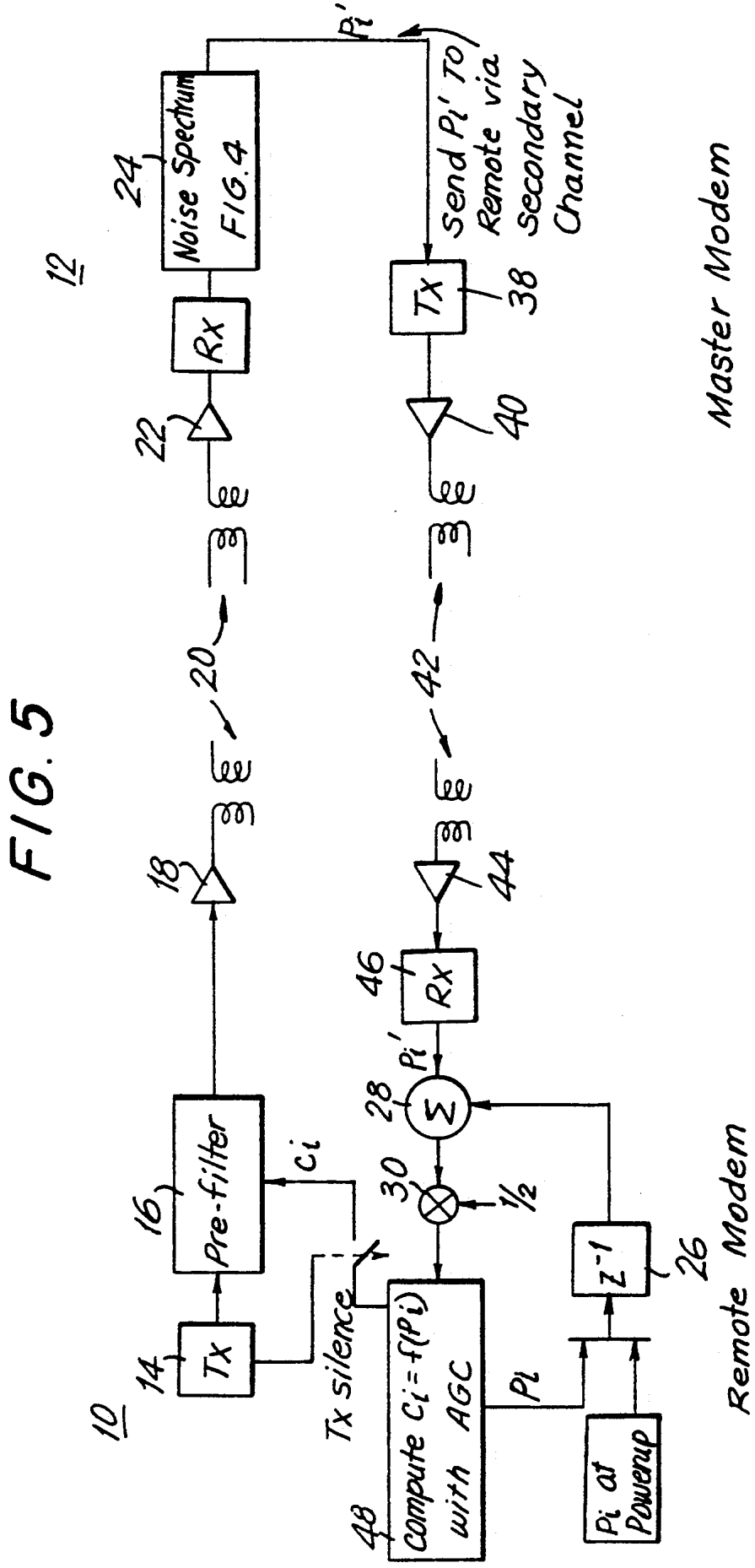

Master Modem
Remote Modem
Noise Spectrum
FIG.4
Send Pi' To Remote via Secondary Channel
Rx
Tx
Pre-filter
Tx silence
Compute Ci=f(Pi) with AGC
Pi at Powerup
Z-1
1/2
Pi'
Ci
Pi
12
10
16
14
18
20
22
24
26
28
30
38
40
42
44
46
48

FIG. 5

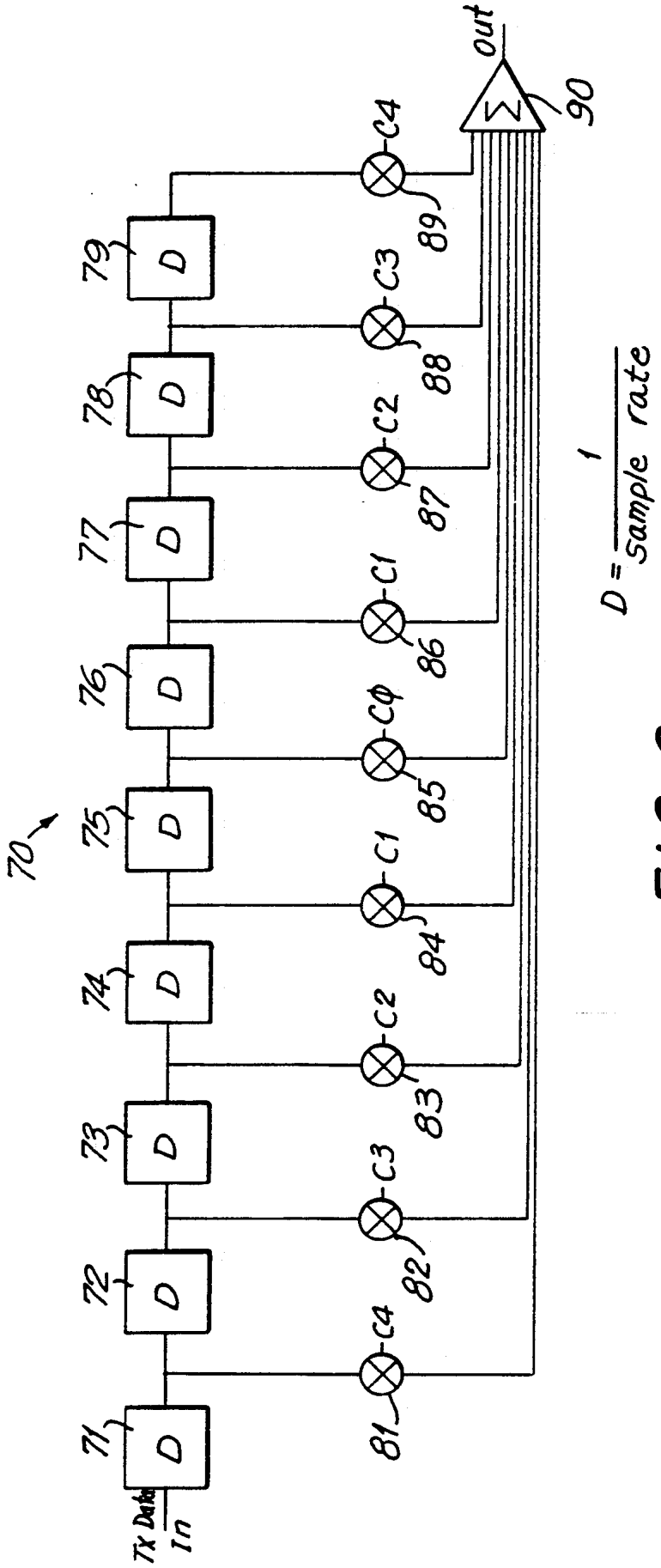

out
90
C4
C3
C2
C1
C0
C1
C2
C3
C4
89
88
87
86
85
84
83
82
81
79
78
77
76
75
74
73
72
71
D
70
Tx Data In
D = 1 / sample rate

FIG. 6

ADAPTIVE TRANSMIT PRE-EMPHASIS FOR DIGITAL MODEM COMPUTED FROM NOISE SPECTRUM

BACKGROUND OF INVENTION

1. Field of Invention

This invention relates to an apparatus for determining a frequency-dependent signal-to-noise ratio in a communications network so as to allow proper equalization in a transmit pre-emphasis mode.

2. Description of the Prior Art

It is well-known in the prior art that a transmitter in a communications network, particularly a multipoint network, should emphasize or amplify certain frequencies so as to compensate for frequency-dependent losses in the communications process. For example, with the use of a telephone line as a communications line, losses are more pronounced at higher frequencies. These losses are typically modelled as a constant negative slope above a given break frequency on a decibels versus frequency plot.

When noise is injected into a communications line subsequent to the high-frequency roll-off of the communications line and the signal rolls off above a break frequency while the noise signal remains constant (thereby resulting in a signal-to-noise ratio which progressively decreases above the break frequency), prior art methods of frequency-dependent analysis of total energy received is adequate as an equalization technique. These methods include fixed pre-emphasis wherein a fixed frequency-dependent boost is included in the communication apparatus, or adaptive pre-emphasis wherein the required frequency-dependent boost is calculated on-line during a periodic training sequence.

However, when noise is injected into a communications line prior to the high frequency roll-off of the communications line and the noise rolls off in parallel to the roll-off of the signals (resulting in a constant signal-to-noise ratio as a function of frequency), prior art methods of frequency-dependent analysis of total energy received are inadequate as an equalization technique.

This inadequacy is due to the fact that a positive gain is applied to higher frequency portions of the total signal. However, in order to keep the total signal energy constant as is required by telephone and other communications line applications, this positive gain in the upper frequency spectrum must be compensated for by a negative gain in the lower frequency spectrum thereby reducing the signal-to-noise ratio in the lower frequencies and resulting in a degradation in performance. This principle is illustrated in more detail by the several drawings of FIGS. **1**, **2** and **3**.

FIG. **1***a* illustrates the received transmitter signal and the received noise signal being "flat" across the entire band. The signal model for this spectrum is shown in FIG. **1***b* wherein the communications line includes no roll-off or other frequency-dependent characteristics and noise is added between the transmitter and the receiver. Such a system requires no frequency-dependent pre-emphasis as is shown by the ideal flat pre-emphasis of FIG. **1***c*.

FIG. **2***a* illustrates the received transmitter signal rolling off above a break frequency w_o while the received noise spectrum is "flat" across the entire band. The signal included for this spectrum is shown in FIG. **2***b* wherein the transmitter signal passes through a channel or communications line thereby being rolled-off before having frequency-independent noise added thereto. The ideal pre-emphasis, whether manually set or periodically calculated on-line, is illustrated in FIG. **2***c* wherein an increasing gain is applied above the frequency w_o. This frequency-dependent pre-emphasis flattens the transmitter signal as received without affecting the noise signal, thereby increasing the signal-to-noise ratio at the frequencies above w_o and improving overall system performance. A slight negative gain may be applied in the lower frequencies so as to keep the total incoming energy constant. This ideal pre-emphasis is accurately calculated by prior art methods.

FIG. **3***a* illustrates the received transmitter signal and the received noise both rolling off in parallel above break frequency w_o. The signal model for this spectrum is shown in FIG. **3***c* wherein the noise is added to the transmitter signal at the transmitter end and both the transmitter signal and the noise are passed through the channels or communication line thereby having substantially identical attenuation characteristics applied thereto. Therefore, the signal-to-noise ratio remains constant throughout the entire band as is illustrated by the constant vertical distance between the received transmitter signal and the noise. As the signal-to-noise ratio is constant, the ideal signal pre-emphasis is flat or shown in FIG. **3***c* (or **1***c*). However, prior art methods of pre-emphasis, either manual or automated, would look to the frequency-dependent energy spectrum of the entire received signal (received transmitter signal plus received noise) and calculate a pre-emphasis similar to that shown in FIG. **2***c*. This would result in a lowering of the transmitter signal power and the signal-to-noise ratio at frequencies below break frequency w_o and an overall degradation in system performance.

OBJECTS AND SUMMARY OF THE INVENTION

It is therefore the object of this invention to provide a method and apparatus for automated transmit pre-emphasis calculation which properly accounts for frequency-dependent signal-to-noise ratios.

This apparatus and method uses a noise spectrum generator circuit to calculate a frequency-dependent noise spectrum. This spectrum is transmitted from the receiver to the transmitter (or from the master to the remote in a multipoint system) via the secondary channel. The transmitter uses this information to compute the new pre-emphasis coefficients from its own transmitted spectrum as seen by the receiver and uses the result on its subsequent transmission.

Thus, this and other objects are effectively achieved.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1***a*, **1***b* and **1***c* are illustrative of a communications system with no frequency-dependent attenuation or roll-off.

FIGS. **2***a*, **2***b* and **2***c* are illustrative of a communications system with noise injected subsequent to frequency-dependent attenuation or roll-off.

FIGS. **3***a*, **3***b* and **3***c* are illustrative of a communications system with noise injected prior to frequency-dependent attenuation or roll-off.

FIG. **4** is a schematic of the noise spectrum generator circuit of the present invention.

FIG. 5 is a schematic of the transmitter and receiver of the present invention.

FIG. 6 is a schematic of the nine-tap filter of the pre-filter of FIG. 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in detail wherein like numerals indicate like elements throughout the several views, noise spectrum generator circuit **50** is illustrated in FIG. **4**. As will be described herein, noise spectrum generator circuit **50** is incorporated into the circuitry of the modem receiver circuit **12** of FIG. **5**.

Noise spectrum generator circuit **50** includes analog-to-digital converters **52, 53** and sinusoidal mixers **54, 55** for demodulation. The demodulated signal from mixers **54, 55** is equalized by linear equalizers **56, 57**. Linear equalizers **56, 57** are transversal filters which are from the prior art and are not to be confused with the equalization used for pre-emphasis in the transmitter circuitry. The resulting signals are phase corrected by phase corrector **60** which results in an x-y signal representative of the complex plane to slicer **62**. Slicer **62** includes the constellation or eye pattern data which is used in the quadrature amplitude modulation scheme of the signal received by analog-to-digital convertors **52, 53**. Slicer **62** outputs the constellation point which is closest to the input of slicer **62**. Therefore, the actual received point is input to slicer **62** and the presumed actual transmitted point is output from slicer **62**. Comparator **64** subtracts the actual received point from the actual transmitted point so as to calculate an error signal which is representative of the noise signal at the given frequency. This error or noise signal is inversely related to the distance between the signal line and the noise line of FIGS, **1***a*, **2***a* and **3***a* at the given frequency.

The resulting error signal is phase corrected by inverse phase corrector **66**. The output of inverse phase corrector **66** is used to update the characteristics of linear equalizers **56, 57** and as an input to complex DFT (discrete Fourier transform) block **68**. Complex DFT block **68** converts the phase corrected noise signals in the time domain (i.e. successive values corresponding to successive frequencies) into the noise spectrum in the frequency domain.

FIG. **5** discloses the entire modem transmitter circuit **10** and modem receiver circuit **12** of the present invention. Modem transmitter circuit **10** includes a conventional modem transmitter **14** which outputs digital signals to be transmitted to pre-filter **16**. Pre-filter **16** pre-emphasizes the digital signals prior to their conversion to analog signals. Pre-filter **16**, as will be described herein, includes nine-tap filter **70** as shown in FIG. **7**. The output of the pre-filter **16** is converted to analog format by digital-to-analog converter **18** for transmission across communications line **20**, which may be a telephone line, to modem receiver circuit **12**.

Analog-to-digital converter **22** (which corresponds to analog-to-digital converters **42, 43** of FIG. **4**) converts the analog signal from communications line **20** into digital format for input into noise spectrum analysis block **24**. The remainder of the noise spectrum generator circuit of FIG. **4** is included in noise spectrum analysis block **24** from which a frequency domain plot of the noise signal (P'_i, i=1,5) is output, said frequency domain plot being derived by discrete Fourier transform techniques as previously described.

Secondary channel transmitter **38** transmits communications network control parameters, including the spectrum (P_i, i=1,5) from block **24**, on a sideband of the primary channel at a low transmission rate through line **42** via digital-to-analog converter **40** to analog-to-digital converter **44** of modem transmitter circuitry **10**.

Modem transmitter circuitry **10** includes analog-to-digital converter **44** and secondary channel receiver **46** which receives the spectrum sent from secondary channel transmitter **38** through line **42**. Secondary channel receiver **46** transmits the spectrum (P'_i, i=1,5) data to comparator **28**. In order to account for existing pre-emphasis, the frequency domain plot of the noise signal has subtracted from it the previous frequency domain plot as stored in shift register **26**. This subtraction is performed by comparator **28**. The reference spectrum outputs from comparator **28** is multiplied by one half by multiplier **30**. This division is done as the current state-of-the-art is to have the transmitter provide by pre-emphasis one half of the signal compensation required while the receiver provides the other half. The portion provided by the receiver of, course, is done by apparatus separate from the invention as herein described. This division by two is optional and not crucial to the invention. The reference spectrum may be divided by other values, or not divided at all, in other embodiments of the invention.

Shift register **26** includes a power-up line which initializes the contents of shift register **26** with values representative of a flat spectrum as stored in block **29**.

The output of multiplier **30** is input to compute block **48** which calculates and transmits the pre-filter coefficients (C_i, i=0,4) for pre-filter **16** as will be described hereinafter.

Pre-filter **16** includes nine-tap filter **70** as shown in FIG. **6**. Nine-tap filter **70** receives its input from the output from modem transmitter **14**. The input is transmitted through a series of **9** delay blocks **71–79**, the outputs of each of these delay blocks is sent through multipliers **81–89**. Multipliers **81–89** receive their second multiplicands (C_0–C_4) from compute block **48** and send their respective products to adder **90**. The output of adder **90** is the output of pre-filter **16**.

Compute block **48** includes a power-up line which initializes the pre-filter coefficients (C_i, i=0,4) for a flat spectrum for the first transmission of the transmitting circuit **10**. Subsequent initialization could be provided by the previously calculated C_i, i=0,4 stored in non-volatile memory.

The functional description of this invention is as follows.

The transmitting modem **10** sends QAM modulated data signals to the receiving modem **12**.

The noise spectrum generator circuit **50**, including the complex DFT block **68**, calculates a frequency spectrum (P_i, i=1,5) of the noise at 5 frequencies—709, 1145, 1800, 2455 and 2891 Hertz. These frequencies are chosen from a 22 point discrete Fourier transform calculation so as to span the usable frequency of a telephone line. The spectrum is transmitted back to the transmitting modem **10** over the secondary channel. The previous frequency spectrum is subtracted from the new frequency spectrum, and the result is divided in half. This result is stored as the "previous value" for the next calculation.

The frequency spectrum (P_i, i=1,4) of the noise expressed in a logarithm scale are converted to a linear scale (F_i, i=0,4) in compute block **48**.

The linear scale frequency spectrum is converted to filter coefficients through the following transformation:

$$C'_0 = (F_0 - 2F_1 + 2F_2 - 2F_3 + F_4)/8$$
$$C'_1 = (F_0 - 2F_1 + 2F_3 - F_4)/8$$
$$C'_2 = (F_0 - 2F_2 + F_4)/8$$
$$C'_3 = (F_0 + 2F_1 + 2F_3 - F_4)/8$$
$$C'_4 = (F_0 + 2F_1 + 2F_2 + 2F_3 + F_4)/8$$

C_i, i=0,4, is then transformed by computer block **48** into C'_i, i=0,4 in order to adjust the pre-emphasis coefficients to be appropriate for the resonators of the resonating filters. These resonators are located at 0, 600, 1200 and 2400 Hertz. An iterative calculation is done to adjust the pre-emphasis coefficients, C'_i, i=0,4 (i.e. scalars) into appropriate filter coefficients, C_i, i=0,4.

Finally, these filter coefficients, C_i, i=0,4, are adjusted via an AGC circuit in compute block **48**, so as to assure a constant power output from transmitting modem **10**.

These appropriate filter coefficients C_i, i=0,4 are transmitted to pre-filter **16**. However, pre-filter **16** implements these coefficients only whenever data is not being transmitted through pre-filter **16**, such as just before a remote modem responds to a poll. This implementation precludes changing the transmission characteristics in the middle of a transmission.

Obviously, many modifications and variations of the invention are possible in light of the above description. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is claimed is:

1. An apparatus for calculating pre-emphasis coefficients for a transmitting modem in a communications system, including:

first transmitting means in the transmitting modem, including adjusting means responsive to the pre-emphasis coefficients for adjusting frequency-dependent characteristics of an output of said first transmitting means;

receiving means for receiving said output from said first transmitting means;

generating means for generating parameters responsive to a noise spectrum of said output including means for calculating said noise spectrum of said output;

second transmitting means for transmitting said parameters to the transmitting modem, and

computing means for computing the pre-emphasis coefficients from said parameters.

2. The apparatus of claim **1** wherein said adjusting means includes a filter with several taps.

3. The apparatus of claim **2** wherein said filter includes at least nine taps.

4. The apparatus of claim **1** wherein said generating means includes a noise spectrum generator circuit.

5. The apparatus of claim **4** wherein said noise spectrum generator circuit includes:

determining means for determining best-fit transmitted data points from said output of said first transmitting means as received by said receiving means;

comparing means for determining a difference between said best-fit transmitted data points and said output as received by said receiving means thereby calculating said noise spectrum of said output.

6. An apparatus for calculating pre-emphasis coefficients for a transmitting modem in a communications systems, including:

first transmitting means in the transmitting modem, including adjusting means responsive to the pre-emphasis coefficients for adjusting frequency-dependent characteristics of an output of said first transmitting means;

receiving means for receiving said output from said first transmitting means;

generating means, including a noise spectrum generator circuit, for generating parameters responsive to a noise spectrum of said output;

second transmitting means for transmitting said parameters to the transmitting modem; and

computing means for computing the pre-emphasis coefficients from said parameters;

wherein said noise spectrum generator circuit includes determining means for determining best-fit transmitted data points from said output of said first transmitting means as received by said receiving means; and comparing means for determining a difference between said best-fit transmitted data points and said output as received by said receiving means;

wherein said receiving means includes analog-to-digital conversion means and demodulating means which generates a complex signal; and wherein said noise spectrum generator circuit includes a phase corrector responsive to said complex signal; a slicer which determines, from said complex signal, best-fit transmitted data points from said first transmitted means; subtracting means for determining a difference between said best-fit transmitted data points and said complex signal; an inverse phase corrector responsive to said difference; and a complex discrete Fourier transform block responsive to said inverse phase corrector.

7. The apparatus of claim **6** wherein said phase corrector is responsive to equalization means and wherein said equalization means is responsive to said inverse phase corrector.

8. An apparatus for calculating pre-emphasis coefficients for a transmitting modem in a communications systems, including:

first transmitting means in the transmitting modem, including adjusting means responsive to the pre-emphasis coefficients for adjusting frequency-dependent characteristics of an output of said first transmitting means;

receiving means for receiving said output from said first transmitting means;

generating means, including a noise spectrum generator circuit, for generating parameters responsive to a noise spectrum of said output;

second transmitting means for transmitting said parameters to the transmitting modem; and

computing means for computing the pre-emphasis coefficients from said parameters;

wherein said noise spectrum generator circuit includes determining means for determining best-fit transmitted data points from said output of said first transmitting means as received by said receiving means; and comparing means for determining a difference between said best-fit transmitted data points and said output as received by said receiving means; and

wherein said determining means includes eye pattern data.

9. An apparatus for calculating pre-emphasis coefficients for a transmitting modem in a communications systems, including:

first transmitting means in the transmitting modem, including adjusting means responsive to the pre-emphasis coefficients for adjusting frequency-dependent characteristics of an output of said first transmitting means;

receiving means for receiving said output from said first transmitting means;

generating means, including a noise spectrum generator circuit, for generating parameters responsive to a noise spectrum of said output;

second transmitting means for transmitting said parameters to the transmitting modem; and

computing means for computing the pre-emphasis coefficients from said parameters;

wherein said noise spectrum generator circuit includes determining means for determining best-fit transmitted data points from said output of said first transmitting means as received by said receiving means; and comparing means for determining a difference between said best-fit transmitted data points and said output as received by said receiving means; and

wherein said generating means includes discrete Fourier transform means responsive to said difference, thereby calculating a frequency domain representation of said noise spectrum of said output.

10. The apparatus of claim 8 wherein said generating means further includes discrete Fourier transform means responsive to said difference, thereby calculating a frequency domain representation and storing the values of the frequency domain representation of a noise spectrum of said output.

11. The apparatus of claim 10, wherein said computing means includes subtracting means for subtracting previously stored values from said frequency domain representation thereby calculating second differences.

12. The apparatus of claim 11 wherein said computing means further includes dividing means for dividing said second differences.

13. The apparatus of claim 12 wherein said dividing means divides by two.

14. The apparatus of claim 11 wherein said second differences replace said previously stored values.

15. The apparatus of claim 1 wherein said second transmitting means transmits over a secondary channel.

16. The apparatus of claim 15 wherein said secondary channel is a sideband of a channel of said first transmitting means.

17. The apparatus of claim 16 wherein said receiving means and said second transmitting means are incorporated into a single circuit.

18. The apparatus of claim 1 wherein said computing means converts said parameters from logarithmic to linear scale.

19. The apparatus of claim 1 wherein said computing means adjusts said parameters iteratively to adjust for resonator frequencies of said first transmitting means.

20. The apparatus of claim 1 wherein said computing means adjusts said parameters to assure a constant power output of said first transmitting means.

21. A method for calculating pre-emphasis coefficients for a transmitting modem in a communications systems, including the steps of:

transmitting from the transmitting modem;

adjusting frequency characteristics of output from said transmitting step responsive to the pre-emphasis coefficients;

receiving said output from said first transmitting means;

calculating a noise spectrum of said output;

generating parameters responsive to said noise spectrum of said output;

sending said parameters to the transmitting modem; and

computing the pre-emphasis coefficients from said parameters.

* * * * *

EXHIBIT C

US005710761A

United States Patent [19]

Scott

[11] Patent Number: 5,710,761

[45] Date of Patent: Jan. 20, 1998

[54] **ERROR CONTROL NEGOTIATION BASED ON MODULATION**

[75] Inventor: **Robert Earl Scott**, Indian Rocks Beach, Fla.

[73] Assignee: **Paradyne Corporation**, Largo, Fla.

[21] Appl. No.: **458,048**

[22] Filed: **May 31, 1995**

[51] **Int. Cl.**[6] **H04L 1/00**

[52] **U.S. Cl.** **370/252**; 375/222; 379/93.08

[58] **Field of Search** 370/252, 465, 370/466, 467, 469; 375/222; 379/93

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Primary Examiner—Melvin Marcelo

Attorney, Agent, or Firm—Thomas, Kayden, Horstemeyer & Risley

[57] **ABSTRACT**

A modem dynamically selects the type of error-control negotiation sequence as a function of a negotiated parameter of the physical layer. In one embodiment of the invention, a modem selects between error-control negotiation sequences as a function of the type of modulation negotiated in the physical layer. In particular, the modem has at least two type of error-control negotiation sequences to select from: "LAPM or Disconnect," and "LAPM, MNP or Buffer." When the modem negotiates a V.32 or higher modulation, the modem uses the "LAPM or Disconnect" error control negotiation sequence. However, when the modem negotiates a V.22 bis or lower modulation, the modem uses the "LAPM, MNP or Buffer" error control sequence.

16 Claims, 1 Drawing Sheet

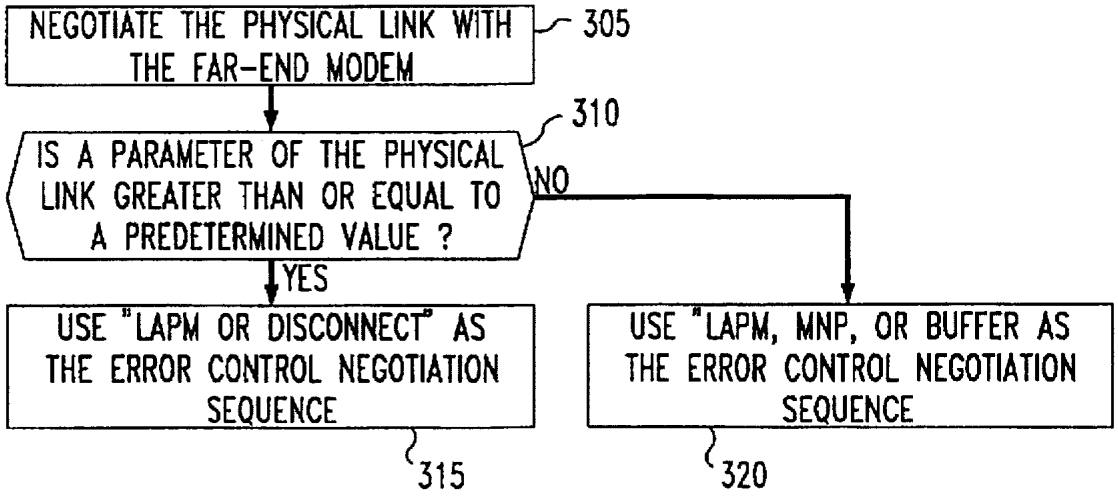


FIG. 1

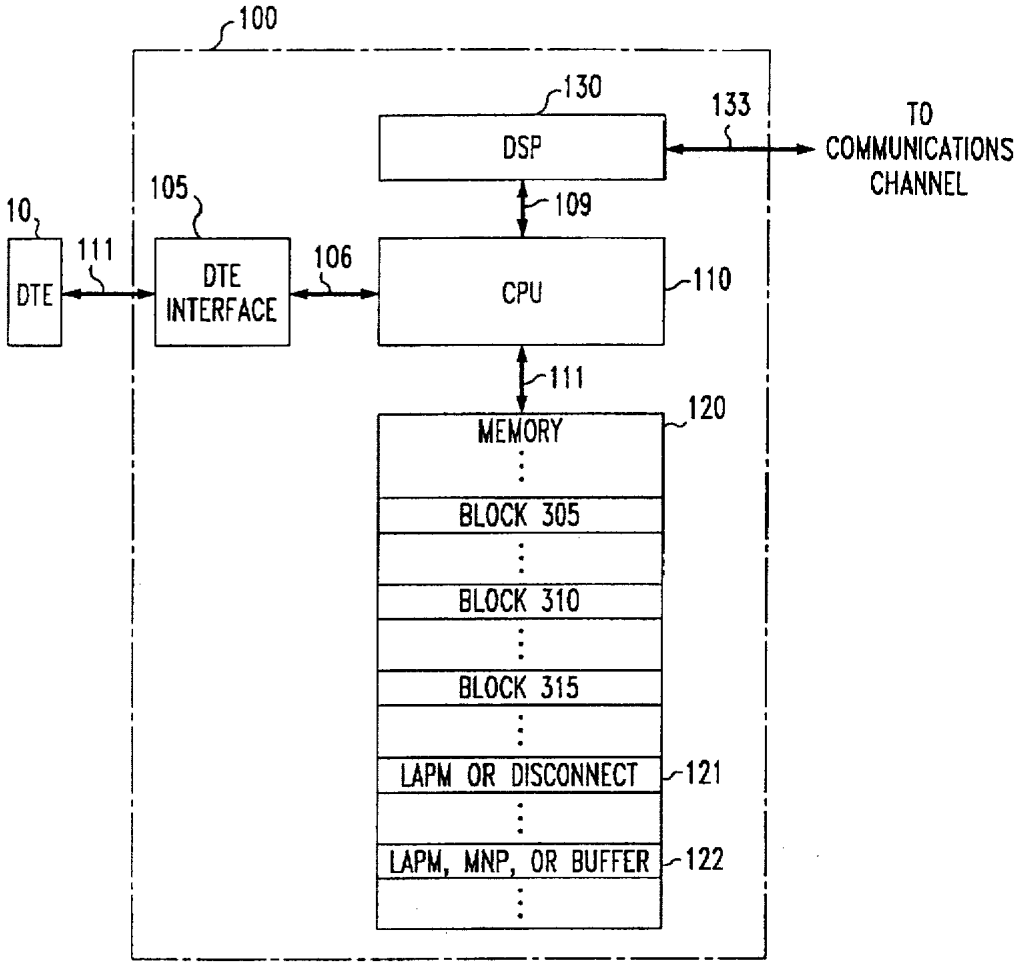
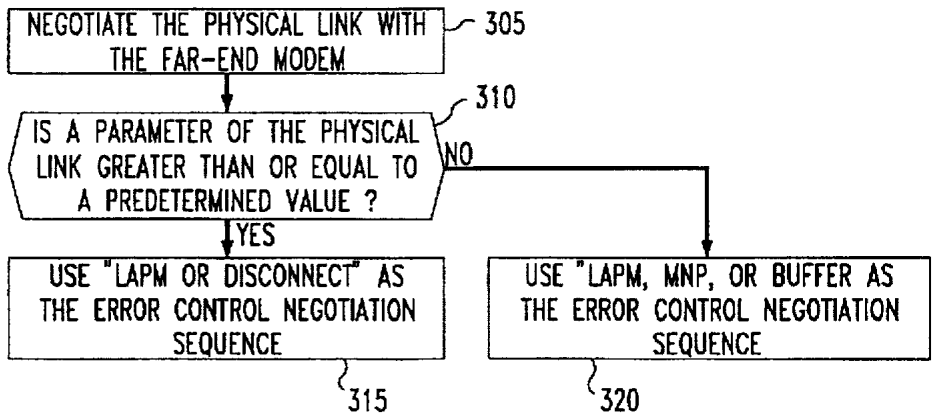

100
130
DSP
133
TO COMMUNICATIONS CHANNEL
105
10
109
111
DTE
DTE INTERFACE
106
CPU
110
111
120
MEMORY
BLOCK 305
BLOCK 310
BLOCK 315
LAPM OR DISCONNECT
121
LAPM, MNP, OR BUFFER
122

FIG. 2


NEGOTIATE THE PHYSICAL LINK WITH THE FAR-END MODEM
305
IS A PARAMETER OF THE PHYSICAL LINK GREATER THAN OR EQUAL TO A PREDETERMINED VALUE ?
310
NO
YES
USE "LAPM OR DISCONNECT" AS THE ERROR CONTROL NEGOTIATION SEQUENCE
315
USE "LAPM, MNP, OR BUFFER AS THE ERROR CONTROL NEGOTIATION SEQUENCE
320

ERROR CONTROL NEGOTIATION BASED ON MODULATION

BACKGROUND OF THE INVENTION

The present invention relates to data communications equipment, e.g., modems, and, more particularly, to the error control negotiation phase of establishing a data connection.

In establishing a data connection between two modems, the modems perform a "handshaking" sequence to negotiate various parameters about the data connection, e.g., the type of modulation (which relates to line speed), and the type of error control protocol. The type of modulation is representative of the "physical" layer of a data connection, while the type of error control protocol is representative of the "link" layer of the data connection. The negotiation of the physical layer is always negotiated before the link layer.

The types of error control protocols used today are: "Link Access Protocol Modem" (LAPM), "Microcom Networking Protocol" (MNP), or "Buffer" (which in reality is no error control). Typically, in negotiating the type of error control protocol a modem tries each type of error control protocol in turn. In particular, the modem uses a negotiation sequence defined herein as "LAPM, MNP, or Buffer." In this negotiation sequence, the modem attempts to connect with the far-end modem for several seconds, e.g., 2 seconds, using an "LAPM" protocol like International Telecommunication Union (ITU) standard V.42. If the far-end modem does not appropriately respond, the modem then tries to connect with the far-end modem for several seconds, e.g., 6 seconds, using the "MNP" protocol. If this too is unsuccessful, the modem then falls back to a non-error control mode, i.e., the "Buffer" mode of operation. This type of negotiation sequence typically allows a modem to connect to the widest range of industry-available modems.

Unfortunately with higher modulation speeds available, like those in ITU standards V.34 and, to a lesser degree, V.32bis, the above error control negotiation sequence can present a problem. In particular, as noted above, the negotiation of the line speed (modulation) occurs before the negotiation of the type of error control. In order to determine the appropriate line speed, a modem uses a technique called "line probing." Unfortunately, the accuracy of current line probing techniques is not perfect. As a result, a modem may erroneously connect at too high a line speed. In other words, even though the line speed was successfully negotiated, the error rate at that line speed is high. This affects the time it takes to perform the subsequent error control negotiation. In particular, with an increase in the error rate, the LAPM type of error control may not be negotiated within the 2 seconds, mentioned above. Further, in severe cases, the time delay in negotiating the error control protocol will be so long that neither LAPM nor MNP is negotiated, causing the modem to fallback to buffer mode. The latter presents a problem, since users typically want V.42 error control and V.42bis data compression for their data calls, however in buffer mode neither V.42 error control nor V.42bis data compression are available.

One way to solve the above-mentioned problem is to have a different negotiation sequence for error control negotiation—"LAPM or Disconnect" for example. With this negotiation setting, the modem tries for an extended length of time, e.g., 30 seconds, to negotiate a LAPM data connection. Even if the modem has trouble at the start of the call, LAPM may still be negotiated because of the longer time delay. However, this negotiation sequence presents a problem when connecting to modems that do not support

LAPM, i.e., MNP-only or non-error-control modems. In order to connect to MNP-only or non-error-control modems, the user must switch the modem back to using the "LAPM, MNP, or Buffer" error control negotiation sequence, described above. Typically, the user switches between error control negotiation sequences via an respective AT command. This is not user-friendly. In today's marketplace, the configuration of the modem itself, e.g., what type of error control negotiation sequence to use, should be transparent to the user.

SUMMARY OF THE INVENTION

However, I have realized a solution that solves all of the above problems and is user-friendly. I have observed that almost every high-speed modem (V.34, V.32bis, V.32) has a LAPM mode, and that the LAPM mode is enabled. Further, only the low-speed modems (V.22bis or below) are MNP-only or non-error control. And, finally, the modulation (physical layer) is always negotiated before the error control protocol (link layer). Therefore, and in accordance with the invention, a modem dynamically selects the type of link layer negotiation sequence as a function of a negotiated parameter of the physical layer.

In one embodiment of the invention, a modem selects between error control negotiation sequences as a function of the type of modulation negotiated in the physical layer. In particular, the modem has at least two type of error control negotiation sequences to select from: "LAPM or Disconnect," and "LAPM, MNP or Buffer." When the modem negotiates a V.32 or higher modulation, the modem uses the "LAPM or Disconnect" error control negotiation sequence. However, when the modem negotiates a V.22bis or lower modulation, the modem uses the "LAPM, MNP or Buffer" error control sequence.

In another embodiment of the invention, a modem uses the data rate negotiated at the physical layer, rather than the modulation, to select the type of error control sequence. For example, if the modem connects at 2400 bits per second (bps) or below, the modem uses the "LAPM, MNP or Buffer" error control sequence. However, if the modem connects at a rate higher than 2400 bps, the modem uses the "LAPM or Disconnect" error control negotiation sequence. It should be noted that even though V.34 supports 2400 bps, I have observed that this data rate is unlikely to be used, i.e., a data rate of 2400 bps or less can be used to infer there is no high-speed modem in the data connection.

The above-described inventive concept provides a number of advantages. The user does not have to administer the modem to select a particular type of error control negotiation sequence via an AT command or other type of strap setting. Further, a modem incorporating the inventive concept still maintains compatibility with a large part of the currently installed-base of modems. Finally, this approach allows a high-speed modem to connect at the highest feasible rate and still negotiate the use of the LAPM protocol.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a block diagram of a data communications equipment embodying the principles of the invention; and

FIG. 2 is a flow diagram of an illustrative method embodying the principles of the invention for use in the modem of FIG. 1.

DETAILED DESCRIPTION

FIG. 1 shows an illustrative high-level block diagram of a modem embodying the principles of the invention. As

shown, modem **100** couples to a communications channel (not shown) via line **133**, which is, e.g., a local loop that couples modem **100** to a local central office (not shown). Modem **100** is also coupled to respective data terminal equipment (DTE) **10** via line **11**. Other than the inventive concept, the components of modem **100** are well-known and will not be described in detail. Modem **100** includes DTE interface **105**, microprocessor-based central processing unit (CPU) **110**, memory **120** and digital signal processing circuitry (DSP) **130**. Since FIG. **1** is a high-level block diagram, other parts of modem **100** not important to the inventive concept are assumed to be included within these representative components. For example, DSP **130** is representative of not only a digital signal processing chip, but also includes the "data access arrangement" (DAA) circuitry that couples any transmitted and received data signals to, and from, line **133**. Further, although shown as single lines in FIG. **1**, lines **11**, **106**, **111**,**109**, and **133**, are representative of a plurality of signals as known in the art to interconnect the various components. For example, line **11** is representative of any one of a number of ways for coupling data communications equipment to data terminal equipment, e.g., a serial interface like that specified in Electronic Industry Association (EIA) standard RS-232.

As known in the art, CPU **110** provides a controlling function for modem **100**, e.g., CPU **110** controls, via line **109**, DSP **130** for establishing, maintaining, and disconnecting, from a data connection to a far-end modem (not shown), via line **109**. In performing this controlling function, CPU **110** operates on, or executes, program data stored in memory **120** via line **111**, which is representative of control, address, and data signals (not shown).

In accordance with the inventive concept, modem **100** dynamically selects the type of error control negotiation sequence as a function of the type of physical layer negotiated. Turning now to FIG. **2**, an illustrative method embodying the principles of the invention will be described. The steps shown in FIG. **2** are illustratively stored in memory **120** as program data as represented by blocks **305**, block **310**, block **315**, etc., of FIG. **1**, respectively. For the purposes of this description, it is assumed that modem **100** has already initiated a data call to a far-end modem (not shown) and a handshaking sequence has begun. As known in the art, CPU **110** first negotiates with the far-end modem the physical layer of the data connection, as shown in step **305**. (It should be realized that since this is a negotiation process, whether modem **100** is the originating, or answering, modem is irrelevant to the inventive concept). During the physical layer negotiation, modem **100** negotiates the type of modulation, e.g., V.22, V.22bis, V.32, V.32bis, and V.34 industry standards. After negotiation of the physical layer, CPU **110** evaluates a negotiated parameter of the physical layer in step **310**. In particular, CPU **110** compares a value of the negotiated parameter to a predefined value. If the value of the negotiated parameter is greater than or equal to the predefined value, CPU **110** uses an "LAPM or Disconnect" error control negotiation sequence in step **315** as part of the link layer negotiation. The software instructions for executing the "LAPM or Disconnect" error control negotiation sequence are illustratively stored in memory **120** at location **121**. With this negotiation setting, modem **100** tries for an extended length of time to negotiate a LAPM link layer on the data connection. If a LAPM link layer cannot be negotiated, modem **100** disconnects.

On the other hand, if the value of the negotiated parameter is less than the predefined value, CPU **110** uses an "LAPM, MNP or Buffer" error control negotiation sequence in step **320** as part of the link layer negotiation. The software instructions for executing the "LAPM, MNP, or Buffer" error control negotiation sequence are illustratively stored in memory **120** at location **122**. As described earlier, in this negotiation sequence modem **100** attempts to connect with the far-end modem for several seconds using an "LAPM" protocol like International Telecommunication Union (ITU) standard V.42. If the far-end modem does not appropriately respond, modem **100** then tries to connect with the far-end modem for several seconds using the "MNP" protocol. If this too is unsuccessful, modem **100** then falls back to a non-error control mode, i.e., the "Buffer" mode of operation.

In one embodiment of the invention, the negotiated parameter from the physical layer is the type of modulation negotiated in the physical layer. In particular, when modem **100** negotiates a V.32 or higher modulation, modem **100** performs step **315**, described above. However, when modem **100** negotiates a V.22bis or lower modulation, modem **100** performs step **320**, described above.

In another embodiment of the invention, the negotiated parameter from the physical layer is the negotiated data rate. For example, if modem connects below **4800** bps, modem **100** performs step **320**, described above. However, when modem **100** connects at a rate equal to or higher than 4800 bps, modem **100** performs step **315**, described above. It should be noted that even though high-speed modulations, like V.**34**, support rates below 4800, I have observed that these data rates are unlikely to be used. As a result, a data rate less than 4800 bps can be used to infer there is no high-speed modem in the data connection.

The above-described inventive concept provides a number of advantages. The user does not have to administer the modem to select a particular type of error control negotiation sequence for use during the link layer negotiation. Further, a modem incorporating the inventive concept still maintains compatibility with a large part of the currently installed-base of modems. Finally, this approach allows a high-speed modem to connect at the highest feasible rate and still negotiate the use of the LAPM protocol.

The foregoing merely illustrates the principles of the invention and it will thus be appreciated that those skilled in the art will be able to devise numerous alternative arrangements which, although not explicitly described herein, embody the principles of the invention and are within its spirit and scope.

For example, although the invention is illustrated herein as being implemented with discrete functional building blocks, e.g. a memory, CPU, etc., the functions of any one or more of those building blocks can be carded out using one or more appropriate integrated circuits, e.g., a microprocessor that includes memory.

In addition, although described in the context of a modem external to the data terminal equipment, the inventive concept applies to any other forms of coupling a modem to data terminal equipment, e.g., a modem that is internal to a personal computer or a modem that is part of a mobile phone transceiver. Finally, the selection of a link layer negotiation sequence can be a function of other data rates, types of modulations, and/or other parameters of the physical layer.

What is claimed:

1. A method for use in data communications equipment, the method comprising the steps of:

negotiating a physical layer of a data connection with a far-end data communications equipment to determine a set of parameters for the physical layer of the data connection with the far-end data communications equipment; and

selecting one of a number of error control negotiation sequences as a function of a value of at least one parameter from the set of parameters for the physical layer.

2. The method of claim 1, further including the step of negotiating error control of the data connection with the far-end data communications equipment in accordance with the selected one of the number of error control negotiation sequences.

3. The method of claim 1, wherein the at least one parameter is the type of modulation negotiated with the far-end data communications equipment.

4. The method of claim 3, wherein the number of error control negotiation sequences include a Link Access Protocol Modem, Microcom Networking Protocol, or Buffer sequence and a Link Access Protocol Modem or Disconnect sequence.

5. The method of claim 4, wherein the Link Access Protocol Modem, Microcom Networking Protocol, or Buffer sequence is selected when the type of modulation negotiated is less than V.32, and wherein the Link Access Protocol Modem or Disconnect sequence is selected when the type of modulation negotiated is greater than or equal to V.32.

6. The method of claim 1, wherein the at least one parameter is the data rate negotiated with the far-end data communications equipment.

7. The method of claim 6, wherein the number of error control negotiation sequences include a Link Access Protocol Modem, Microcom Networking Protocol, or Buffer sequence and a Link Access Protocol Modem or Disconnect sequence.

8. The method of claim 7, wherein the Link Access Protocol Modem, Microcom Networking Protocol, or Buffer sequence is selected when the data rate is less than 4800 bits per second, and wherein the Link Access Protocol Modem or Disconnect sequence is selected the data rate is greater than or equal to 4800 bits per second.

9. Data communications apparatus comprising:

a memory that stores a number of error control negotiation sequences; and

processor circuitry that negotiates a physical layer of a data connection with a far-end data communications equipment to determine a set of parameters for the physical layer of the data connection with the far-end data communications equipment, and then selects from memory one of a number of error control negotiation sequences as a function of a value of at least one parameter from the set of parameters for the physical layer.

10. The apparatus of claim 9, wherein the processor negotiates error control of the data connection with the far-end data communications equipment in accordance with the selected one of the number of error control negotiation sequences.

11. The apparatus of claim 9, wherein the at least one parameter is the type of modulation negotiated with the far-end data communications equipment.

12. The apparatus of claim 11, wherein the number of error control negotiation sequences include a Link Access Protocol Modem, Microcom Networking Protocol, or Buffer sequence and a Link Access Protocol Modem or Disconnect sequence.

13. The apparatus of claim 12, wherein the processor selects the Link Access Protocol Modem, Microcom Networking Protocol, or Buffer sequence when the type of modulation negotiated is less than V.32, and wherein the processor selects the Link Access Protocol Modem or Disconnect sequence when the type of modulation negotiated is greater than or equal to V.32.

14. The apparatus of claim 9, wherein the at least one parameter is data rate negotiated with the far-end data communications equipment.

15. The apparatus of claim 9, wherein the number of error control negotiation sequences include a Link Access Protocol Modem, Microcom Networking Protocol, or Buffer sequence and a Link Access Protocol Modem or Disconnect sequence.

16. The apparatus of claim 15, wherein the processor selects the Link Access Protocol Modem, Microcom Networking Protocol, or Buffer sequence when the data rate is less than 4800 bits per second, and wherein the processor selects the Link Access Protocol Modem or Disconnect sequence when the data rate is greater than or equal to 4800 bits per second.

* * * * *

EXHIBIT D

US005719858A

United States Patent [19]

Moore

[11] Patent Number: 5,719,858

[45] Date of Patent: Feb. 17, 1998

[54] **TIME-DIVISION MULTIPLE-ACCESS METHOD FOR PACKET TRANSMISSION ON SHARED SYNCHRONOUS SERIAL BUSES**

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[73] Assignee: **Paradyne Corporation**, Largo, Fla.

[21] Appl. No.: **509,309**

[22] Filed: **Jul. 31, 1995**

[51] **Int. Cl.**[6] **H04B 7/212**

[52] **U.S. Cl.** **370/347**; 370/349; 370/442; 370/458; 370/468; 340/825.5

[58] **Field of Search** 370/349, 331, 370/335, 355, 442, 462, 461, 460, 463, 352, 353, 468, 447, 405, 458, 347; 340/825.5

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Primary Examiner—Wellington Chin
Assistant Examiner—Melissa Kay Carman
Attorney, Agent, or Firm—Thomas, Kayden, Horstemeyer & Risley

[57] **ABSTRACT**

A plurality of packet data sources, e.g., packet application modules, and synchronous data sources, e.g., synchronous application modules, are coupled to the same TDM bus for communicating data to a network access module. A portion of the bandwidth, or time-slots, of the TDM bus is allocated as a multiple-access packet channel that is shared among the packet application modules. As a result, the network access module receives a single, continuously multiplexed, packet stream for transmission to an opposite endpoint. Packet application modules on the TDM bus contend for this multiple access packet channel when transmitting to the opposite endpoint. In the receiving direction, each packet application module accepts the entire received packet stream from the network access module and may either filter the packets using their address field or may transparently forward the data to a packet service.

32 Claims, 4 Drawing Sheets

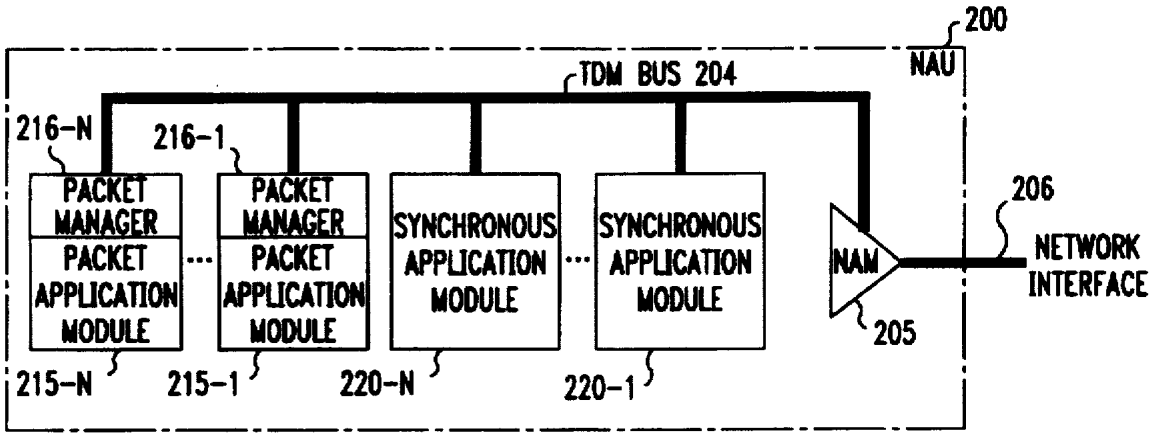


FIG. 1
PRIOR ART

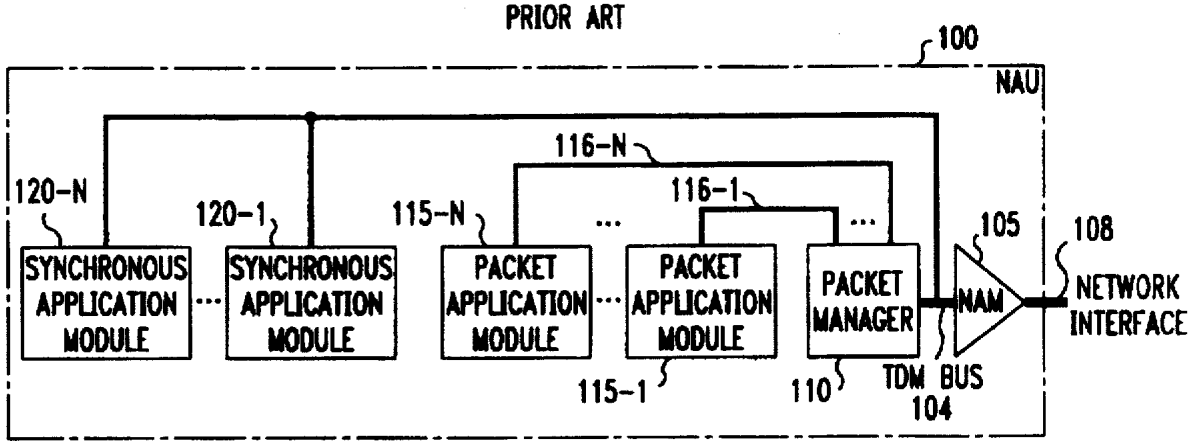


FIG. 2
PRIOR ART

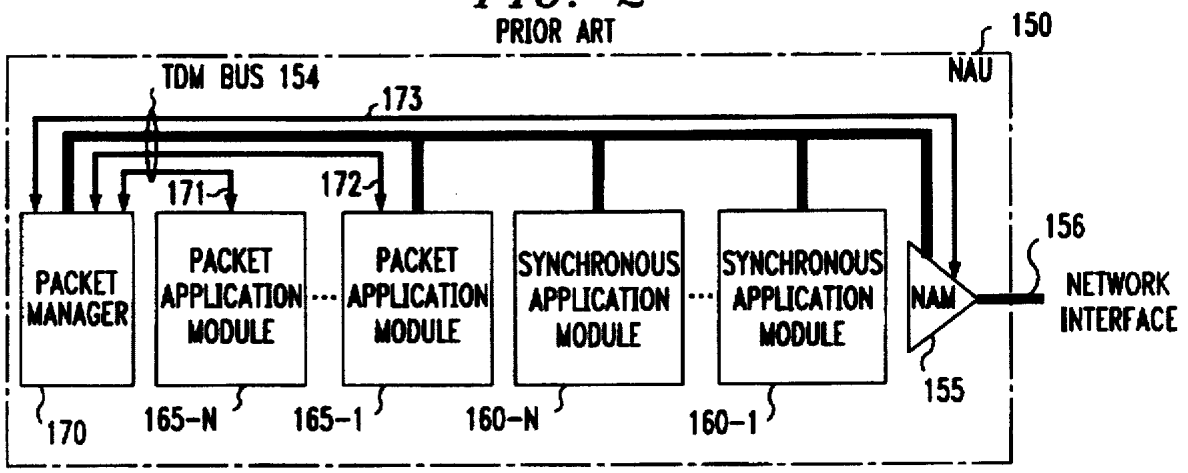


FIG. 3

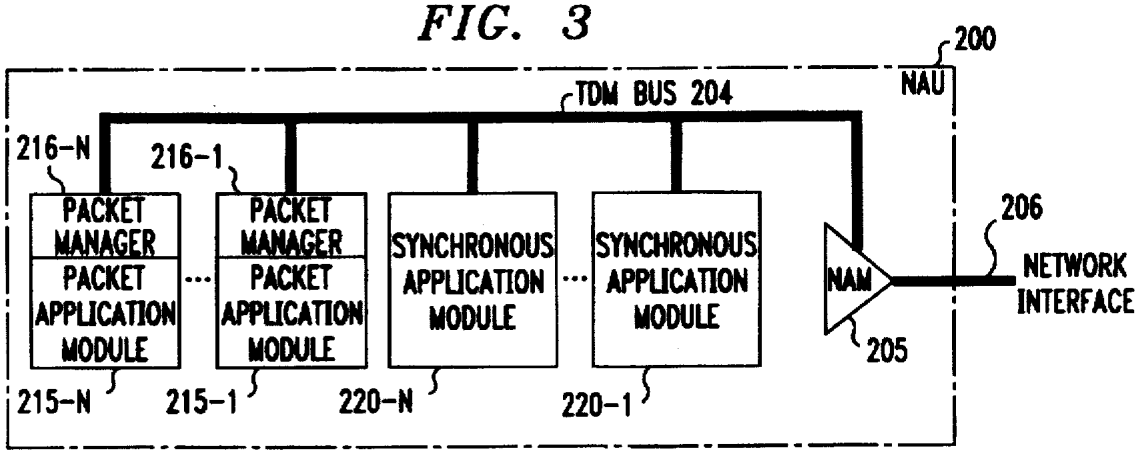


FIG. 4

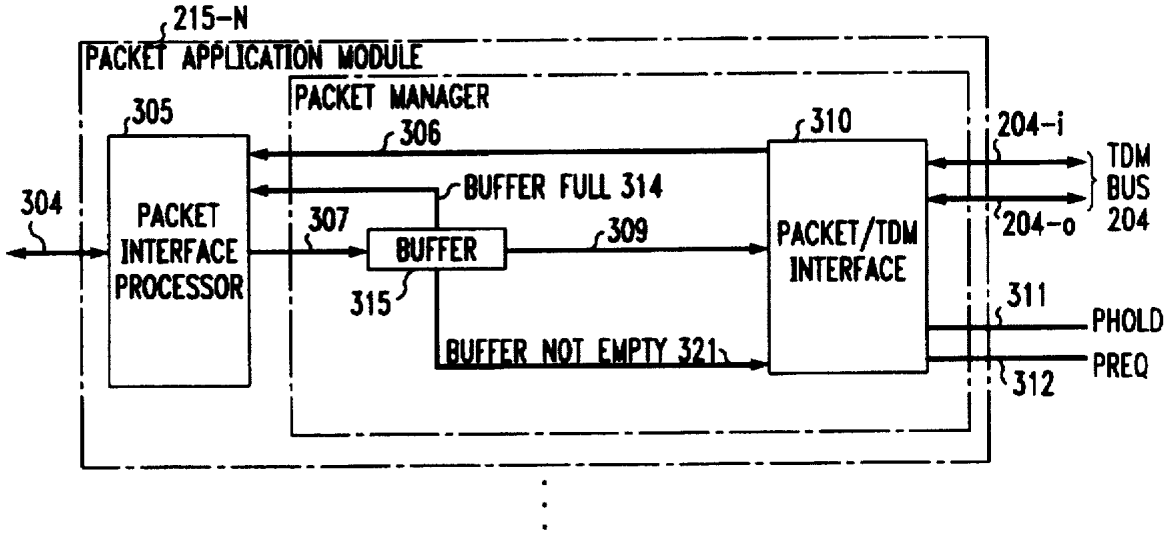

215-N
PACKET APPLICATION MODULE
PACKET MANAGER
305
306
310
204-i
TDM BUS 204
304
PACKET INTERFACE PROCESSOR
BUFFER FULL 314
307
BUFFER
309
PACKET/TDM INTERFACE
204-o
315
311
PHOLD
BUFFER NOT EMPTY 321
PREQ
312

FIG. 5

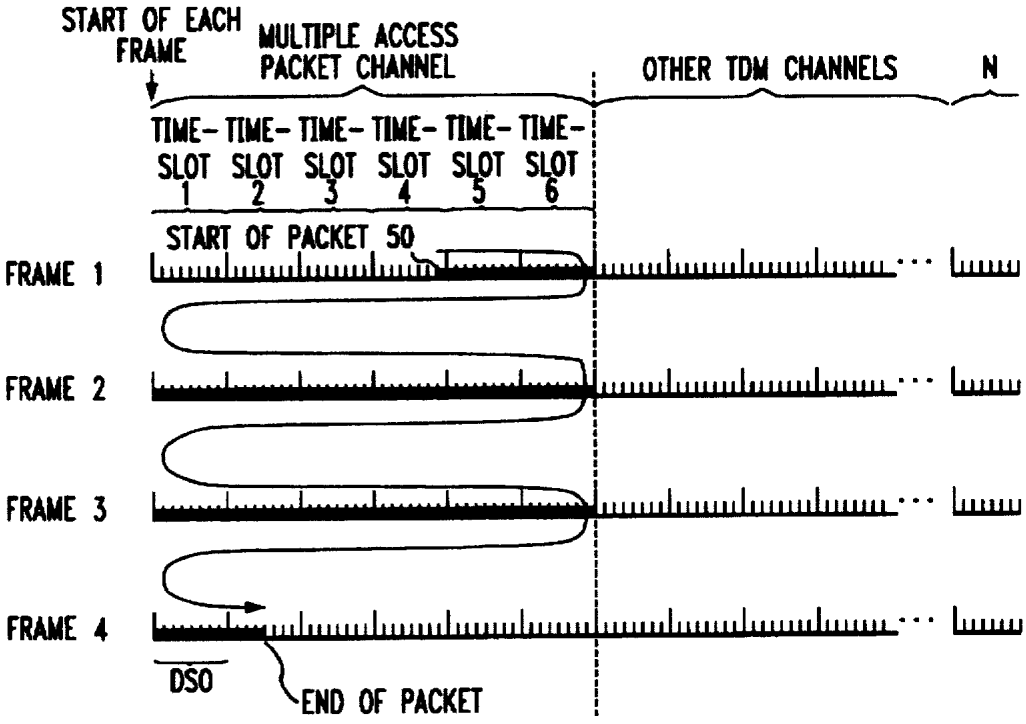

START OF EACH FRAME
MULTIPLE ACCESS PACKET CHANNEL
OTHER TDM CHANNELS
N
TIME-SLOT 1
TIME-SLOT 2
TIME-SLOT 3
TIME-SLOT 4
TIME-SLOT 5
TIME-SLOT 6
START OF PACKET 50
FRAME 1
FRAME 2
FRAME 3
FRAME 4
DSO
END OF PACKET

FIG. 6

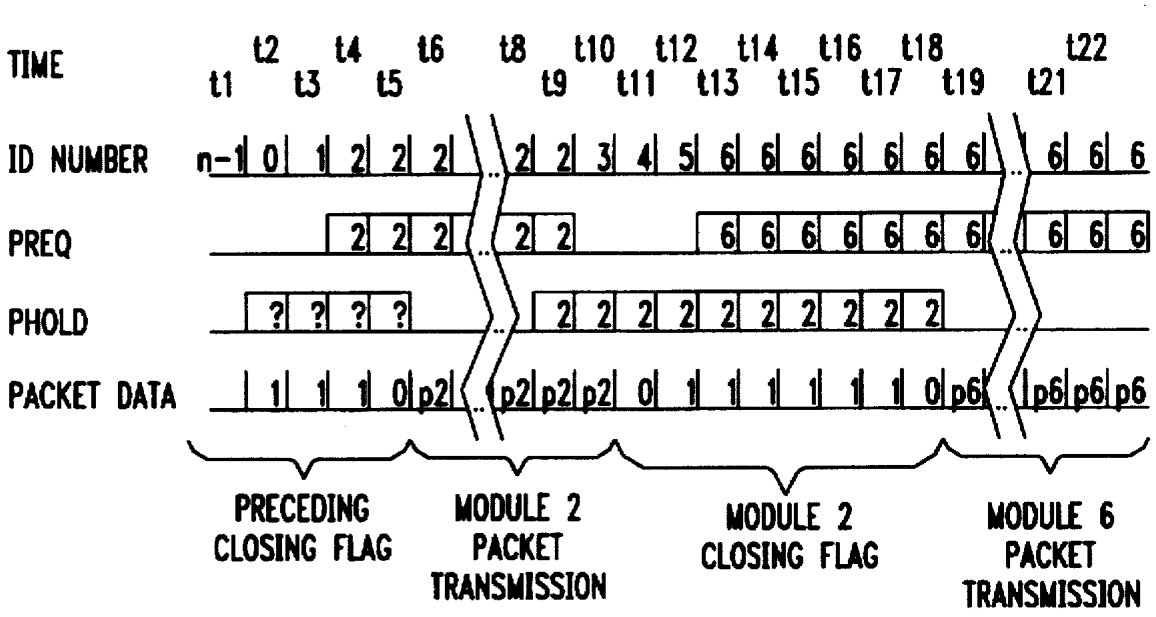

TIME
t1 t2 t3 t4 t5 t6 t8 t9 t10 t11 t12 t13 t14 t15 t16 t17 t18 t19 t21 t22
ID NUMBER
PREQ
PHOLD
PACKET DATA
PRECEDING CLOSING FLAG
MODULE 2 PACKET TRANSMISSION
MODULE 2 CLOSING FLAG
MODULE 6 PACKET TRANSMISSION

FIG. 7

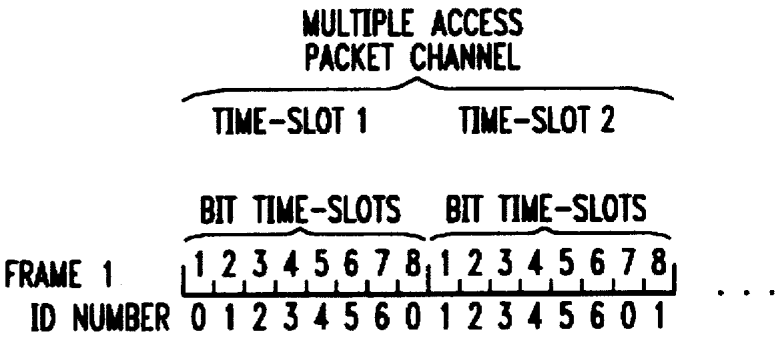

MULTIPLE ACCESS PACKET CHANNEL
TIME-SLOT 1
TIME-SLOT 2
BIT TIME-SLOTS
BIT TIME-SLOTS
FRAME 1
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8
ID NUMBER 0 1 2 3 4 5 6 0 1 2 3 4 5 6 0 1

FIG. 8A

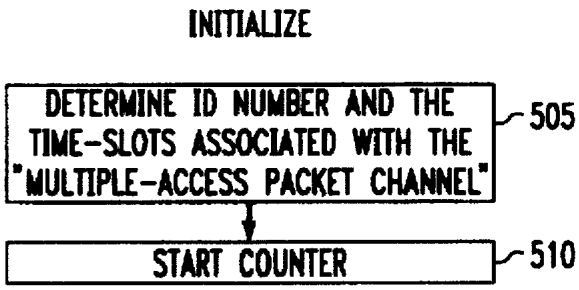


FIG. 8B

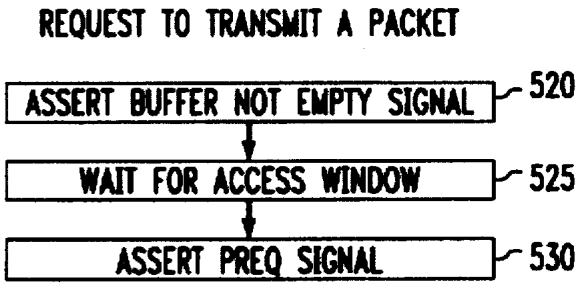
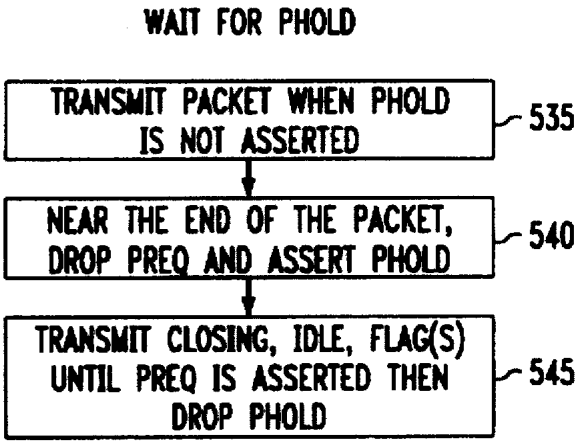


FIG. 8C



TIME-DIVISION MULTIPLE-ACCESS METHOD FOR PACKET TRANSMISSION ON SHARED SYNCHRONOUS SERIAL BUSES

BACKGROUND OF THE INVENTION

The present invention relates to data communications, and more particularly, to communications systems that have channelized network access, and may transport both synchronous data and variable-bit-rate data such as frame relay (hereafter referred to as packet data), in a time-division multiplexed format.

Communications equipment horn as a "network access unit" (NAU) typically provides frame-relay-type services between a local communications network and a network facility, like a T1 facility. The NAU messages the flow of data between the local communications network and the network facility in both directions. To provide the most flexibility, it is preferable that the NAU support two types of data: synchronous data and packet data. For example, the support of synchronous data provides the ability to make telephone, i.e., voice, calls, while the support of packet data provides the ability to interwork with public network packet services. However, the asynchronous nature of packet data at the logical level combined with the requirements of synchronous data causes design tradeoffs in both the complexity and cost of an NAU.

One prior art approach of designing an NAU to support both synchronous data and packet data is shown in FIG. **1**. NAU **100** includes network access module **115-1** **105**, synchronous application modules **120-1** to **120**-n, packet application modules **115-1** to **115**-n, and packet manager **110**. NAM **105** provides the interface between time-division-multiplexing (TDM) bus **104** and network facility **106**, which is representative of a T1 facility. The synchronous application modules couple synchronous data equipment (not shown), e.g., telephone equipment, to NAM **105** via TDM bus **104**. The packet application modules couple packet data equipment (not shown), e.g., a data terminal, to packet manager **110**. The later is a common resource module that performs internal aggregation in one direction, and distribution in the other direction, of packet streams between NAM **105** and each packet application module, via TDM bus **104** and wideband packet buses **116-1** to **116**-n, respectively. In this context, each wideband packet bus is transmitting packet data in parallel, e.g., a "byte" at a time, in contrast to TDM bus **104**, which is a serial bus, i.e., it transmits data a bit at a time. As a reset of coupling the packet data to the TDM bus, packet manager **110** provides a single multiplexed packet stream to NAM **105** for transmission across the network interface. It should be understood that the network interface bandwidth is "channelized" and, in the context of packet data, expects a single multiplexed packet stream.

NAU **100** is representative of a mixed TDM and packet NAU architecture. In this approach, NAU **100** provides a TDM bus in conjunction with one or more packet buses which taken together provide more bandwidth than is required to support the network interface. This additional bandwidth is used to support multiple point-to-point packet connections. Packet manager **110** not only aggregates the packet data, as mentioned above, but also allocates a fixed amount of the TDM bandwidth to the packet application modules.

Unfortunately, the instantaneous, or peak, data rate of all outbound packet streams taken together may be greater than the "fixed amount of TDM bandwidth" allocated for packet

data on the network interface. These peak data rates create a large demand on both the overall packet bus capacity and on the packet handling requirements of packet manager **110**. For example, once the packet application modules exceed their allocated network interface bandwidth, packet manager **110** must take steps to prevent the loss of any packet data. These steps include buffering the packet data, which may require a buffer of considerable size to support all of the packet application modules, and, perhaps, flow control to throttle the packet traffic. As a result, the complexity of packet manager **110** increases not only with the number of packet application modules that packet manager **110** must support but also with the respective data rate requirements of these packet application modules.

Another prior art approach is illustrated in FIG. **2**, which is similar to FIG. **1** except that separate point-to-point wideband packet buses have been replaced with separate TDM channels between each packet application module and the packet manager. In particular, packet application modules **165-1** to **165**-n are coupled to TDM bus **154**, along with packet manager **170**. Each packet application module communicates data to, and from, packet manager **170** in a separate TDM channel as represented by lines **171** and **172**. Like the description above for FIG. **1**, packet manager **170** aggregates the packet traffic to NAM **155** via a TDM channel, as represented by line **173**, to create a single multiplexed packet stream.

Unfortunately, this approach has the above-mentioned problems with respect to the packet manager and, in addition, drives up the bandwidth requirement of the TDM bus. For example, the TDM bus must now support the peak rate of each packet application module on each TDM channel in addition to a TDM channel for the aggregate packet data stream provided by packet manager **170**. Conversely, if the TDM channels are limited to a fixed fraction of the allocated network interface bandwidth, a single packet application module would never be able to peak near the full rate when other packet application modules have little or no traffic.

SUMMARY OF THE INVENTION

I have realized an alternative approach to the design of TDM-based equipment that supports both synchronous data and packet data and, in addition, provides an efficient substrate for packet handling. In particular, multiple packet data sources share a single TDM channel. As a result, no central packet manager is required to aggregate the packet data.

In an embodiment of the invention, a plurality of packet data sources, e.g., packet application modules, and synchronous data sources, e.g., synchronous application modules, are coupled to the same TDM bus for communicating data to a network access module. In particular, a portion of the TDM bandwidth allocated to packet data is treated as a "multiple-access packet channel." This allows packet application modules on the TDM bus to share, and contend for, the entire TDM bandwidth allocated to packet data. Each packet application module includes its own TDM bus interface and the network access module receives a single, continuously multiplexed, packet stream for transmission to an opposite endpoint. In the receiving direction, each packet application module accepts the entire received packet stream from the network access module and either filters the packets using their address field or transparently forwards the packet data to a packet service.

In a feature of the invention, a contention scheme for accessing the "multiple-access packet channel" is described

that avoids packet collisions, maximizes bandwidth efficiency, and provides for interframe High-level Data Link Control (HDLC) flags.

This invention provides the following advantages: no central packet manager is required to synchronize packet data to the TDM bus; packet sources share all of the TDM bandwidth allocated to packet data resulting in maximum efficiency; there is no additional overhead required for packet addressing on the bus; packet buffering is distributed across the bus, rather than being fixed in a central location; and the system has "modularity" and can quickly grow simply by adding additional packet application modules.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** shows a block diagram of a prior art mixed TDM and packet network access unit;

FIG. **2** shows a block diagram of another prior art time-division-multiplexing-only network access unit;

FIG. **3** shows an illustrative block diagram of a time-division-multiplexing-only network access unit in accordance with the principles of the invention;

FIG. **4** shows a block diagram of a packet application module in accordance with the principles of the invention;

FIG. **5** shows a representation of a sequence of time-division-multiplexing frames in accordance with the principles of the invention;

FIG. **6** is an illustration of a packet arbitration scheme for use in the network access unit of FIG. **2** in accordance with the principles of the invention;

FIG. **7** is an illustration of counting bit time-slots in the "multiple-access packet channel;" and

FIGS. **8A–8C** are illustrative flow diagram of a method in accordance with the principles of the invention for use in the packet application module of FIG. **4**.

DETAILED DESCRIPTION

An illustrative block diagram of an NAU embodying the principles of this invention is shown in FIG. **3**. NAU **200** provides access to a T1 facility for frame relay services as well as synchronous data transport. For simplicity, data endpoints, synchronous or packet, are not shown. NAU **200** includes network access module (NAM) **205**, synchronous application modules **220-1** to **220-n**, and packet application modules **215-1** to **215-n**. NAM **205** provides the interface between TDM bus **204** and network facility **206**, which is representative of a T1 facility. The synchronous application modules couple synchronous data equipment (not shown), e.g., telephone equipment, to NAM **205** via TDM bus **204**, as is known in the art. In accordance with the inventive concept, multiple packet application modules now share a single TDM channel (described below). Each of the plurality of packet application modules couple packet data equipment (not shown), e.g., a data terminal, to TDM bus **204**, and the packet manager is eliminated. Indeed, the function of the packet manager is now distributed among the various packet application modules that created the need for it in the first place. This distribution of the packet manager is represented by the inclusion of packet managers **216-1** through **216-n** in the respective packet application modules.

A block diagram of illustrative packet application module **215-n** is shown in FIG. **4**. Other than the inventive concept, the components of packet application module **215-n** are well-known and will not be described in detail. Packet application module **215-n** includes packet interface processor **305**, buffer **315**, and packet/TDM interface **310**. The latter is an "application specific integrated circuit" (ASIC), which is a programmable large-scale integrated circuit device that is dedicated to performing a specific function, or application, which in this case is described below. Packet interface processor **305** communicates packet data between packet/TDM interface **310** and line **304**. The latter is representative of any one of a number of facilities for coupling packet application module **215-n** to a packet system. For example, line **304** could be a local area network, or a dedicated facility to a "router" or a packet data terminal. Packet interface processor **305** performs packet handling, e.g., it provides the physical and link layer connections for packet transmission as known in the art, e.g., it checks for addresses, errors, etc., on the packets. Packet data transmitted to a far-end packet endpoint is provided from packet interface processor **305** to packet/TDM interface **310** via line **307**, buffer **315**, and line **309**. It is assumed that lines **307** and **309** are representative of wideband data buses as known in the art. In the other direction, packet data from a far-end packet endpoint is received by packet interface processor **305** from packet/TDM interface **310** via line **306**. Packet interface processor **305** receives a BUFFER FULL signal via line **314** from buffer **315**, which provides a BUFFER NOT EMPTY signal via line **321** to packet/TDM interface **310**. In accordance with the principles of the invention, packet/TDM interface **310** synchronizes packet data retrieved from buffer **315** for insertion into an appropriate time slot on TDM bus **204**. The latter is shown as actually comprising two TDM buses. TDM bus **204**-o is used for "outbound" traffic through NAM **205** to network interface **206**. Conversely, TDM bus **204**-i is used for "inbound" traffic from the network. Typically, in the art, TDM bus **204**-i and **204**-o are symmetrical, e.g., if time-slot **0** is used for status and control information on the "inbound" TDM bus, time-slot **0** of the "outbound" TDM is similarly used for status and control information.

The storage size of buffer **315** is determined empirically and is a function of the type of packet equipment and its data rate. For example, if a packet application module is interfacing to a router, as known in the art, a router may communicate packet data on the order of 128 Kb/sec. Consequently if the packet application module cannot, for the moment, transmit a packet from the router to the TDM bus, the packet application module can perform flow control with the router with a concomitant minimal amount of buffering required on the packet application module because of the low data rate from the router. Conversely, if a packet application module is interfacing to a LAN, which typically communicates data at a higher speed, e.g., 10 Mb/sec., a larger amount of buffering may be required on the packet application module. Thus, depending on the packet equipment, each packet application module may have different buffering requirements—but each packet application module has less buffer requirements than the packet manager module of the prior art.

In accordance with the invention, a portion of the bandwidth of TDM bus **204** is pre-assigned to all the packet data. In particular, this packet-dedicated portion of the bandwidth is referred to herein as a "multiple-access packet channel," which is shared among at least two of the packet application modules. This is in contrast to allocating a fixed fraction of the TDM bandwidth to each packet application module. The "multiple-access packet channel" provides a single channel for communicating all packet data to, or from, NAM **205**. In effect, this "multiple-access packet channel" resembles a packet "local area network" (LAN) in many respects, except that the bandwidth of the "multiple-access packet channel"

is closely matched (or equal) to that allocated for packet traffic across network facility **206**. In this case, each packet application module must contend for the bandwidth of the "multiple-access packet channel" with the other packet application modules. (Although, the nature of a TDM bus prevents any packet application module from using more bandwidth than is available from the network, this approach makes the entire network bandwidth allocated to packet data dynamically available to each packet application module as a channel for the transport of packet data.)

NAM **205** communicates to all application modules and controls time-slot allocation among the synchronous modules and the packet modules. The control of time-slot allocation can be performed either over TDM bus **204** or another bus (not shown). In this example, it is assumed that a portion of the TDM bus bandwidth is allocated to control and status information, as known in the art. In accordance with the principles of the invention, the time-slots allocated by NAM **205** to the packet application modules are the "multiple-access packet channel."

In this example, it is assumed that every time-frame is comprised of a plurality of 64 Kbit (DS**0**) channels, and it is assumed that the "multiple-access packet channel" is any grouping of these DS**0** channels. Although not a requirement, it is also assumed that the "multiple-access packet channel" is composed of a subset of contiguous DS**0** channels available on the bus. In this case, this corresponds to time-slots **1**, **2**, **3**, **4**, **5**, and **6**, of every frame. The remaining time-slots are allocated to synchronous data and control/status information. The allocation of the above-mentioned six time-slots yields a "multiple-access packet channel" with a bandwidth of 384 Khz. The number of DS**0** channels allocated on the inbound and outbound data highways are assumed to the be same, so that equal bandwidth is assured in both directions. (As described above, it is assumed that TDM bus **204**-i and TDM bus **204**-o are symmetrical, i.e., time-slots **1** through **6** are used for the "multiple-access packet channel" for inbound and outbound traffic.) Finally, it is assumed that this 384 Khz bandwidth is equal to the bandwidth allocated over the network facility for the same packet traffic, i.e., NAM **205** is not required to buffer the packet data.

In accordance with a feature of the invention, it is assumed that packet transmission is utilizing HDLC, which is a bit-oriented layer **2** protocol that produces variable bit length packets. This allows a packet to be spread across time-slots and multiple TDM frames. The "multiple-access packet channel" in this case can be considered a continuous sequence of bits with no framing boundaries other than those of the protocol. As such, the starting point of a packet may lie anywhere in the "multiple-access packet channel." An illustrative sequence of frames is shown in FIG. **5**. Frame **1** includes time slots **1** through N, where, as mentioned above, each time-slot represents a 64 Kbit DS**0** channel. In this example, it is assumed that N is equal to 64 time-slots. Each frame repeats every 125 micro-seconds and each time-slot is further broken down into a sequence of 8 bits as shown in FIG. **5**. Each bit is hereafter referred to as a "bit time-slot." It should be noted that the term "time-slot" refers to a collection of "bit time-slots." Time-slots **1–6** represent the "multiple-access packet channel." As described above, since HDLC is a bit-oriented layer **2** protocol, this allows the packet data to begin and end anywhere in a time-slot. Consequently, each packet is mapped into a plurality of "bit time-slots" within time-slots **1** through **6** on TDM bus **204**, rather than the DS**0** channels representing each time-slot as a whole. This is illustrated in FIG. **5**, where packet **50** begins with "bit time-slot" **7** in time-slot **4**, of frame **1**, and ends with "bit time-slot **3**" in time-slot **2** of frame **4**. As illustrated by the starting and ending time of packet **50**, of FIG. **5**, these bit intervals do not have to conform to time slot boundaries into which the packets are mapped and inserted.

As described above, each packet application module must contend for the "multiple-access packet channel." If a packet application module "grabs" the "multiple-access packet channel" that packet application module then transmits using the full 384 Khz of bandwidth. However, if a packet application module cannot "grab" the "multiple-access packet channel," then that packet application module must queue, or buffer, the packet. As a result, the flow control is now distributed among the packet application modules.

The properties desired for packet transport on the "multiple-access packet channel" are high bandwidth efficiency and deterministic fairness. Bandwidth efficiency is a measure of how closely the packet utilization oft he available (fixed) TDM bandwidth matches the offered packet load. It also measures efficiency of the channel as the offered packet load exceeds the available bandwidth. Fairness describes how a chosen priority scheme affects the comparative delay of packets through the system under bandwidth contention with multiple packet sources.

Any method used for implementing a "multiple-access packet channel" should be designed to achieve as close to 100% bandwidth efficiency as possible with no negative throughput effects due to congestion. The method should also have no inherent priority bias among the packet sources so that priorities may be enforced selectively if needed, preferably in software on the packet application modules. These properties are only applicable to the outbound (toward the network) direction, where multiple packet sources are contending for a fixed network pipe. Inbound packet data is already multiplexed as a single packet stream within the network channel. Since the TDM bus **204** is full duplex, as represented by separate data highways TDM bus **204**-i and TDM bus **204**-o, NAU **200** may have an asymmetric access protocol. That is, the access protocol for the inbound direction can be different from the access protocol described below for the outbound direction. In the context of this invention, it is assumed that all modules are continually listening to the TDM in-bound bus to pull off data addressed to them. In the case of the packet application modules, it is assumed that each packet application module is monitoring, or listening to, the "multiple-access packet channel" for packets that have addresses associated with that packet application module. A packet application module listens for its header, e.g., virtual address, if it is not their packet, it is just dropped. The remainder of this description will focus on outbound packet traffic.

In accordance with the invention, a Time-division Multiple Access with Collision Avoidance (TDMA/CA) scheme is used for the outbound direction to regulate access to the "multiple-access packet channel." In particular, the synchronous property of TDM bus **204** provides the means to implement a slotted-access method to avoid collisions. This slotted-access method enables each packet application module to contend for the "multiple-access packet channel," and avoid packet collisions, in a fair and efficient manner. In this embodiment, the slotted-access method is implemented by packet/TDM interface **310** of each packet application module.

Before describing it in detail, an overview of this slotted-access method is described. In the slotted-access method, each packet application module, in rotation order, is given an

"access window" of time, corresponding to a "bit time-slot" on the TDM bus, to either capture the "multiple-access packet channel" for transmission, or defer and allow the "access window" to advance to the next packet application module in order. Once granted access, that packet application module has sole access to the "multiple-access packet channel" for a period of time, referred to herein as the "access period." During this "access period," a packet application module sends at least one HDLC frame of queued packet traffic toward the network, and the "access window" is frozen at the current packet application module and does not advance until that packet application module releases the "multiple-access packet channel." Under some conditions however, a packet application module may not begin transmitting packet data as soon as it has captured the "multiple-access packet channel." In particular, whenever the previously transmitting packet application module is still transmitting a packet or closing flag, the next packet application module must wait until completion before transmitting its first packet. Since a rotational arbitration scheme on the bus may take several "bit time-slots," or clock, intervals, this mechanism allows the arbitration to overlap an active packet transmission, avoiding idle time on the bus and increasing bandwidth utilization.

FIG. **6** shows an illustrative slotted-access method. There is an implied numbering of the packet application modules and "bit time-slots." This implied numbering is hereafter referred to as an "ID number." Generally speaking, a packet application module can attempt to access TDM bus **204**-o only when the ID number of the "bit time-slot" matches the ID number of the packet application module. In a system with N packet application modules, each "bit time-slot" of the "multiple-access packet channel" is counted in a repeating sequence from 0 to N–1 starting at some arbitrary "bit time-slot" by each packet application module. In other words, each packet application module only counts those "bit time-slots" assigned to the "multiple-access packet channel." The value of the count is the ID number for the "bit time-slot." All packet application modules are synchronized with this counting sequence and are aware of the ID number of each "bit time-slot" at all times. As a result, the ID number need not be present on the bus. As noted earlier, each packet application module knows, a priori, the time-slots associated with the "multiple-access packet channel." In combination with this, each packet application module is configured with an unique ID number, which can be determined in any number of ways. For example, each module, or circuit board, can have an address associated either via a "software-controlled" configuration, e.g., a system administer literally assigns addresses to the various modules; or by a hardware setting that specifically associates a particular address with a particular position in the system, e.g., what slot the circuit board is plugged into. Note, this counting of "bit time-slots" may span more than one frame. Since N may be any integer there is no relationship between this ID numbering and the position of bits in the TDM frame.

For example, if there are seven packet application modules, and assuming for the moment that none of the seven packet application modules wanted access to the TDM bus, this counting would look like that shown in FIG. **7**. FIG. **7** is similar to FIG. **5**, except packet **50** has been removed, i.e., there is no transmission of a packet and only time-slots **1** and **2** of frame **1** are shown. It is assumed that each packet application module counts "bit time-slots" of the "multiple-access packet channel" beginning with "bit time-slot" **1** of frame **1**, which is associated with the count value of 0. Each packet application module waits for its ID number to equal the count, or ID number, of the "bit time-slot" to attempt to access TDM bus **204**-o. For example, the packet application module associated with ID **0**, can attempt access only upon the value of the count equaling 0, which, in this example, occurs in "bit time-slot" **1** of time-slot **1** of frame **1**, "bit time-slot" **8** of time-slot **1** of frame **1**, "bit time-slot" **7** of time-slot **2** of frame **1** etc.

To implement this slotted-access method two additional signals are bussed between packet application modules. These signals are "packet request" (PREQ) and "packet hold" (PHOLD). It is assumed these signals are bussed among the packet application modules as simply "open collector" as known in the art which allows them to be logically "OR"ed. Referring back to FIG. **6**, a sequence of "bit time-slots" is shown. This sequence of bit time-slots only represents those "bit time-slots" assigned to the "multiple-access packet channel." The top row of FIG. **6** is simply a sequence of bit time reference points. The second row of FIG. **6** is the ID number of the "bit time-slot" of the "multiple-access packet channel," i.e., the value of the count. The next two rows represent the state of the PREQ and PHOLD busses. The final row simply represents packet data.

Beginning at time **t2**, the "bit time-slot" ID number is equal to 0. In order for a packet application module to transmit a packet on TDM bus **204**-o, the packet application module must assert the PREQ signal whenever the ID numbers of the "bit time-slot" and the packet application module match. Upon receiving the PREQ signal, each packet application module halts the counting. The packet application module that asserted the PREQ signal becomes the next in line to begin transmission. For example, when the packet application module associated with the ID number of 2 wants to transmit, it must wait until time **t4**, when the ID numbers of the "bit time-slot" and the packet application module match, to assert the PREQ signal. However, the presence of a PHOLD signal driven by the currently transmitting packet application module delays the access of packet application module **2** to TDM bus **204**-o until PHOLD is withdrawn at time **t5**. (The question marks illustrated in FIG. **6** simply represent that another, unidentified packet application module is currently transmitting.) At the next "bit time-slot," **t6**, packet application module **2** concatenates its packet stream with that of the previous transmission.

Although it could occur at any point, it is assumed that packet application module **2** drops the PREQ signal at the end of its packet transmission (described below) to allow the counting of time-slots by all packet application modules to again advance. At the same time, packet application module **2** asserts the PHOLD signal, which prevents the next packet application module from beginning its transmission until packet application module **2** has completed its closing flag sequence. These events occur at time **t9**. Subsequently, packet application module **6** raises it PREQ signal at time **t13**, signaling its readiness to send at least one packet, while packet application module **2** is still transmitting its closing flag. At time **t18**, packet application module **2** completes its packet transmission and drops PHOLD. At time **t19**, packet application module **6** begins sending its packet data.

It should be noted that the HDLC flags are a byte in length. Consequently, transmission of an HDLC inter-frame flag must end first before another packet application module can get the TDM bus **204**-o to insert data. In addition, and in accordance with HDLC, the last packet application module may continue inserting the inter-frame flags, and asserting the PHOLD signal until the PREQ signal is asserted, by

itself or another module. Once the PREQ signal is asserted, TDM/packet interface **310** drops the PHOLD signal only when the insertion of the current flag is finished.

As mentioned above, the point at which an actively transmitting packet application module asserts the PHOLD signal and lowers the PREQ signal is arbitrary. The earlier this occurs, the higher the probability that the next packet application module will be found by the time the first closing flag sequence is sent. This increases the efficiency of the "multiple-access packet channel" because there is no waiting for data transmission to finish to start arbitration again, i.e., no time is lost for contention (a packet application module is always ready to go). On the other hand, waiting until near the end of the transmission allows more timely packet queue information to be used in the arbitration. A balance between these two extremes could be implemented.

A method illustrating this slotted-access technique for use in the packet application module of FIG. **4** is shown in FIG. **8**. The steps shown in FIG. **8** have been divided into different "subroutines" for simplicity, i.e., an "initialize subroutine" (FIG. **8**A), "request to transmit a packet subroutine" (FIG. **8**B), and a "wait for PHOLD" subroutine (FIG. **8**C). In step **505**, packet application module **215**-n is initialized, e.g., via a power-up sequence, and determines its ID number, e.g., via a hardware strap or software configuration. During this initialization, NAM **205** of FIG. **3** allocates the time-slots associated with the "multiple-access packet channel." Packet/TDM interface **310** uses the assignment information from NAM **205** as the synchronizing signal to begin counting "bit time-slots" of the "multiple access packet channel" in step **510** (provided that the PREQ signal is not asserted). In this example, it is assumed that packet/TDM interface **310** includes a counter to count each "bit time-slot" of TDM bus **204**-o that is associated with the "multiple-access packet channel." The counter included within packet/TDM interface **310** rims continuously and is controlled by the PREQ signal, i.e., if PREQ is asserted—no counting takes place and the count holds at the last value.

When there is a packet to transmit, packet interface processor **305** begins to fill buffer **315** provided buffer **315** is not full. In particular, referring briefly back to FIG. **4**, it can be seen that a BUFFER FULL signal is provided by buffer **315** to packet interface processor **305**. This signal alerts packet interface processor **305** if buffer **315** is full. As a result, packet interface processor **305** fills buffer **315** when packet data is available to transmit only if the BUFFER FULL signal is not active. Once the BUFFER FULL signal is active, packet interface processor **305** could, if necessary, perform flow-control, if possible, with the associated packet endpoint like a router, or simply begin dropping packets. Assuming buffer **315** is initially empty, as packet interface processor **305** begins to fill up buffer **315**, the BUFFER NOT EMPTY signal is asserted for TDM/packet interface **310** in step **520**, via line **321**.

Upon receiving the BUFFER NOT EMPTY signal, TDM/packet interface **310** waits for the "access window" in step **525**. Once the "access window" matches, i.e., the ID number of packet application module **215**-n matches the current value of the counter, i.e., the "bit time-slot" ID number, TDM/packet interface **310** asserts the PREQ signal in step **530**.

In step **535**, TDM/packet interface **310** waits until PHOLD is no longer asserted before transmitting the packet from buffer **315** onto TDM bus **204**-o. Upon nearing the end of the packet transmission (which can be determined simply by knowing the length of the packet from the packet header information), TDM/packet interface **310** drops the PREQ signal and asserts the PHOLD signal in step **540**. As mentioned above, the last packet application module to grab the "multiple-access packet channel" continues inserting flags and asserting PHOLD until PREQ is asserted, by itself or another module. Once PREQ is again asserted, TDM/packet interface **310** drops PHOLD only when the insertion of an flag is finished. At this point the next packet application module then has access to the "multiple-access packet channel."

Within this general method, different approaches may be taken to offset the arbitration fairness. In general, each time a packet application module gains transmission access to the "multiple-access packet channel," it may send any prescribed number of packets. The access method may be designed to limit this number to one, or it may allow the application to empty its packet transmit buffer. If the hardware imposes no limit on the size or number of packets sent during one access period, the application software is then able to implement rules for sending varying amounts of packet traffic across the bus. There is no reason why those rules must be applied the same for every packet application module, and in fact could be different for each port.

For example, the packet application module may send as many packets as can be transmitted within a fixed amount of time. Another possibility is that the amount of packet data transmitted may be a function of the number of packets queued or the time they have been queued. The size of the packets, always known to the software, may also be a factor in determining when to terminate the access period.

The only hardware function required to support such strategies is the combination of the PREQ signal and PHOLD signal. Once the active packet application module is about to fulfill its prescribed transmission requirement, the corresponding packet interface processor either informs the respective TDM/packet interface via a control line (not shown) or the TDM/packet interface continues transmitting until a corresponding BUFFER EMPTY signal (not shown) is received by the TDM/packet interface. Whatever the signal, the TDM/packet interface then stops asserting PREQ to allow another packet application module to gain access to the TDM bus.

As noted above, the above description assumed that the packet/TDM interface was incorporated in a single ASIC bus interface chip. This is feasible if bus speeds and capacities are modest, say 10–20 Mbps maximum throughput, and only one packet channel is required. As a result, the use of an ASIC to implement a bus interface chip to integrate these functions should result in minimal additional cost (in quantity). Further, adding support for a second packet channel may be a similar incremental cost. However, boosting the TDM bus capacity to T3 rates or higher will pose the greatest potential cost increase due to higher bus clock rates and the number of 64K channels. At this level, an ASIC having a much larger gate-count may be needed to provide a large number of timeslot registers, increased buffering, and higher speed DMA channels.

The foregoing merely illustrates the principles of the invention and it will thus be appreciated that those skilled in the art will be able to devise numerous alternative arrangements which, although not explicitly described herein, embody the principles of the invention and are within its spirit and scope.

For example, although the invention is illustrated herein as being implemented with functional building blocks, e.g., a packet interface processor, etc., the functions of any one or

more of those building blocks can be carded out using one or more appropriate integrated circuits.

In addition, although illustrated in the context of a T1 network facility, the inventive concept applies to other network facilities as well, e.g., fractional T1, digital data service (DDS), T3, etc. Further, more than one "multiple-access packet channel," can exist. For example, a first plurality of packet application modules may be assigned to a first group of time-slots, e.g., time-slots 1–6, for transmitting packet data, while a second plurality of packet application modules is assigned to a second group of time-slots, e.g., time-slots 7–12, for transmitting packet data. Also, because the bandwidth of a TDM bus may be divided into many separate logical channels, data with different formats and access methods, such as isochronous and packet data, may be combined in the system. Mother variation is to use the time-slots to control contention access, as opposed to the "bit-time slots," described above.

It should also be noted that the inventive concept is applicable to Asynchronous Transfer Mode (ATM) transmission. In particular, ATM cells are handled in a similar manner, although not on the same "multiple-access packet channel" carrying bit-oriented protocols. In the case of ATM cells, the octets which form the cells need to be aligned within DS0 channels. This places an additional constraint on the packet/TDM interface to recognize those boundaries and transmit within them. The "bit time-slots" may still be used in the same manner as describe above for arbitration however. Another property of ATM cells is that they are not delimited by flags. Idle time between cells transporting user data must be filled with null cells. Responsibility for filling voids in the cell stream may be assigned to the packet application modules to perform in a fashion similar to adding flag fills for HDLC protocols described earlier. Alternatively, this could be the responsibility of the NAM on the outbound trunk, especially if the NAM is required to buffer cells in order to map them onto the network link.

What is claimed:

1. Data communications apparatus comprising:

a time division multiplexed bus having a bandwidth, where a portion of the bandwidth is allotted to packet data;

a plurality of packet data sources coupled to the time-division multiplexed bus that share the allotted bandwidth for transmitting packet data; and

a distributed packet manager within each of said packet data sources configured to allocate access to the allotted bandwidth among said packet data sources.

2. The apparatus of claim 1 including a packet arbitration bus comprising a packet request signal and a packet hold signal.

3. The apparatus of claim 2 wherein each packet data source comprises:

interface circuitry that inserts packets to the allocated bandwidth of the time-division multiplexed bus and is coupled to the packet arbitration bus; and

a packet data processor for providing the packets from a packet endpoint to the interface circuitry.

4. Data communications apparatus comprising:

a time-division multiplexed bus having a bandwidth, where a portion of the bandwidth is allocated to packet data;

a plurality of packet data sources coupled to the time-division multiplexed bus that share the allocated bandwidth for transmitting packet data;

a packet arbitration bus comprising a packet request signal and a packet hold signal;

interface circuitry coupled to the packet arbitration bus, said interface circuitry inserting packets to the allocated bandwidth of the time-division multiplexed bus, and performing a counting function by counting time-slots of the allocated bandwidth so long as the packet request signal is not asserted; and

a packet data processor for providing the packets from a packet endpoint to the interface circuitry.

5. The apparatus of claim 4 wherein the time-slots are bit time-slots.

6. The apparatus of claim 4 wherein the interface circuitry inserts the packets into the allocated bandwidth when a value of the counter is equal to a predetermined identification number of the respective packet data source and the packet hold signal is not asserted.

7. Communications apparatus comprising:

a time-division multiplexed bus having a predefined bandwidth;

a plurality of synchronous data sources coupled to the time-division multiplexed bus for communicating synchronous data in a first portion of the predefined bandwidth;

a plurality of packet data sources coupled to the time-division multiplexed bus for communicating packet data in a second portion of the predefined bandwidth, where the plurality of packet data sources share the second portion of the predefined bandwidth for transmitting packet data; and

a distributed packet manager within each of said packet data sources configured to allocate access to the second portion of the predefined bandwidth among said packet data sources.

8. The apparatus of claim 7 further including a network access manager coupled to the time-division-multiplexed bus for communicating the synchronous data and the packet data to at least one network facility.

9. Communications apparatus comprising:

a time-division multiplexed bus having a predefined bandwidth;

a plurality of synchronous data sources coupled to the time-division multiplexed bus for communicating synchronous data in a first portion of the predefined bandwidth; and

a plurality of packet data sources coupled to the time-division multiplexed bus for communicating packet data in a second portion of the predefined bandwidth, where the plurality of packet data sources share the second portion of the predefined bandwidth for transmitting packet data, the second portion of the predefined bandwidth being shared in such a way that only one of the plurality of packet data sources accesses the second portion of the predefined bandwidth at a time.

10. The apparatus of claim 7 wherein each one of the plurality of packet data sources includes interface circuitry to the time-division multiplexed bus for synchronizing packet data to the time-division multiplexed bus.

11. Communications apparatus comprising:

a time-division multiplexed bus having a predefined bandwidth;

a plurality of synchronous data sources coupled to the time-division multiplexed bus for communicating synchronous data in a first portion of the predefined bandwidth;

a plurality of packet data sources coupled to the time-division multiplexed bus for communicating packet

data in a second portion of the predefined bandwidth, where the plurality of packet data sources share the second portion of the predefined bandwidth for transmitting packet data, wherein each one of the plurality of packet data sources includes interface circuitry to the time-division multiplexed bus for synchronizing packet data to the time-division multiplexed bus, and the interface circuitry includes a counter for counting time-slots representing the second portion of the predefined bandwidth.

12. The apparatus of claim **11** wherein the time-slots are bit time-slots.

13. The apparatus of claim **11** wherein the interface circuitry inserts packets into the second portion of the predefined bandwidth when a value of the counter equals a predetermined identification number of a respective packet data source and a hold signal is not being asserted by the interface circuitry of the remaining packet data sources.

14. The apparatus of claim **11** wherein the counter is inhibited from counting when a packet request signal is asserted by interface circuitry from any packet data source.

15. A method for use in a data communications apparatus for transmitting packet data on a time-division multiplexed bus, the method comprising the steps of:

coupling a plurality of packet data sources to the time-division multiplexed bus;

allocating a portion of the bandwidth of the time-division multiplexed bus to the plurality of packet data sources in such a way that the allocated portion is shared among the plurality of packet data sources;

transmitting packet data from the plurality of packet data sources on the allocated portion of the bandwidth; and

controlling access by said packet data sources to the allocated portion of the bandwidth via a distributed packet manager within each of said packet data sources.

16. A method for use in a data communications apparatus for transmitting packet data on a time-division multiplexed bus, the method comprising the steps of:

coupling a plurality of packet data sources to the time-division multiplexed bus;

allocating a portion of the bandwidth of the time-division multiplexed bus to the plurality of packet data sources in such a way that the allocated portion is shared among the plurality of packet data sources;

assigning to each one of the plurality of packet data sources an identification number;

counting, in each one of the plurality of packet data sources, a sequence of time-slots representing the allocated portion of the bandwidth; and

transmitting packet data from one of the plurality of packet data sources on the allocated portion of the bandwidth only when the value of the count matches the respective identification number assigned to that packet data source.

17. The method of claim **16**, wherein said step of counting a sequence of time-slots representing the allocated portion of the bandwidth is enabled only when none of the plurality of packet data sources assert a packet request signal.

18. The method of claim **16**, wherein said step of transmitting packet data from one of the plurality of packet data sources is enabled only if a packet hold signal is not asserted by any other one of the plurality of packet data sources.

19. The method of claim **16**, wherein said step of counting a sequence of time-slots representing the allocated portion of the bandwidth further comprises counting bit time-slots.

20. A method for transmitting packet data on a time-division multiplexed bus in data communications equipment, the method comprising the steps of:

allocating a portion of the bandwidth of the time-division multiplexed bus as a multiple-access packet channel;

coupling a plurality of packet data sources to the time-division multiplexed bus;

controlling the access by said packet data sources to the allocated portion of the bandwidth via a distributed packet manager within each of said packet data sources;

transmitting packet data from the one of the plurality of packet data sources having access to the multiple-access packet channel.

21. A method for transmitting packet data on a time-division multiplexed bus in data communications equipment, the method comprising the steps of:

allocating a portion of the bandwidth of the time-division multiplexed bus as a multiple-access packet channel;

coupling a plurality of packet data sources to the time-division multiplexed bus;

assigning a unique identification number to each one of the plurality of packet data sources;

counting, in each one of the plurality of packet data sources, a sequence of time-slots representing the multiple-access packet channel;

granting access to the multiple-access packet channel to that one of the plurality of packet data sources that requests access when the value of the count matches the respective identification number of that packet data source; and

transmitting packet data from the one of the plurality of packet data sources having access to the multiple-access packet channel.

22. The method of claim **21** wherein the counting step is enabled only when none of the plurality of packet data sources assert a packet request signal.

23. The method of claim **21** wherein the granting step further includes the step of asserting a packet request signal by the packet data source granted access.

24. The method of claim **21** wherein the counting step counts a sequence of bit time-slots.

25. A method for transmitting packet data on a time-division multiplexed bus for use in data communications equipment, the method comprising the steps of:

allocating a portion of the bandwidth of the time-division multiplexed bus as a multiple-access packet channel;

coupling a plurality of packet data sources to the time-division multiplexed bus;

arbitrating between the plurality of packet data sources to grant access to the multiple-access packet channel to one of the plurality of packet data sources at a time; and

transmitting packet data from the one of the plurality of packet data sources having access in the arbitrating step only if a packet hold signal is not asserted by another one of the plurality of packet data sources.

26. The method of claim **20** further comprising the step of coupling a network access module to the time-division multiplexed bus for receiving the packet data for transmission over a network facility.

27. A data communications apparatus, comprising;

a time-division multiplexed bus with a bandwidth which is split into at least two portions, one of the portions being allocated for packet data;

a plurality of packet data sources coupled to said time-division multiplexed bus, the packet data sources transmitting packet data on said portion allocated for packet data; and

means for arbitrating access to the portion of the time-division multiplexed bus allocated for packet data among the plurality of packet data sources.

28. The apparatus of claim **27**, wherein said means for arbitrating access to the portion of the time-division multiplexed bus allocated for packet data further comprises a packet arbitration bus having a packet request signal and a packet hold signal, the arbitration bus being coupled to each of the packet data sources, and the packet data sources including means for generating the packet request signal and the packet hold signal.

29. The apparatus of claim **28**, wherein said means for arbitrating access to the portion of the time-division multiplexed bus allocated for packet data further comprises a means within each packet data source for counting the time-slots of the portion of the time-division multiplexed bus.

30. The apparatus of claim **29**, wherein said means for arbitrating access to the portion of the time-division multiplexed bus allocated for packet data further comprises the communication of packet data by one of the packet data sources when the packet hold signal is not asserted and the value of said counting means is equal to a predetermined identification number assigned to said packet data source.

31. The apparatus of claim **29**, wherein said means for arbitrating access to the portion of the time-division multiplexed bus allocated for packet data further comprises means for generating the packet request signal by a packet data source wishing to gain access to the time-division multiplexed bus when the value of said counting means is equal to a predetermined identification number assigned to said packet data source, said counting means being stopped by said packet request signal.

32. The apparatus of claim **29**, wherein said means for arbitrating access to the portion of the time-division multiplexed bus allocated for packet data further comprises means for releasing said packet request signal and for asserting said packet hold signal by a packet data source while said packet data source is transmitting packet data.

* * * * *

EXHIBIT E

US005778234A

United States Patent [19]

Hecht et al.

[11] **Patent Number: 5,778,234**

[45] **Date of Patent: Jul. 7, 1998**

[54] **METHOD FOR DOWNLOADING PROGRAMS**

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[73] Assignee: **Paradyne Corporation**, Largo, Fla.

[21] Appl. No.: **899,834**

[22] Filed: **Jul. 24, 1997**

Related U.S. Application Data

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[51] **Int. Cl.**[6] **G06F 9/44**

[52] **U.S. Cl.** **395/712**; 395/652

[58] **Field of Search** 395/712, 651, 395/652

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Primary Examiner—Emanuel Todd Voeltz
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Attorney, Agent, or Firm—Thomas, Kayden, Horstemeyer & Risley LLP

[57] **ABSTRACT**

A modified version of the operating communication program of a stored program controlled apparatus is downloaded by first downloading a segment of the new package of programs which contains the essential portion of the new programs. Control of the apparatus is then transferred to the new program segment. Thereafter, utilizing the downloaded essential portion of the new package of programs, the remainder of the new package of programs is downloaded.

8 Claims, 1 Drawing Sheet

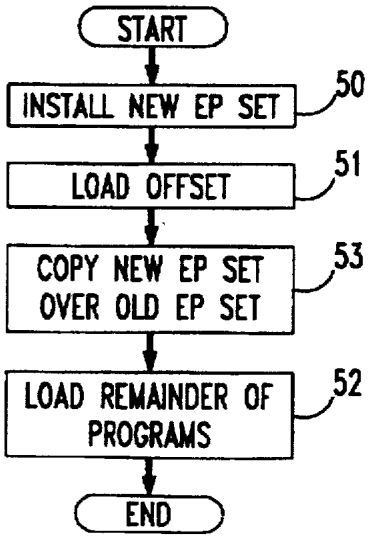


FIG. 1

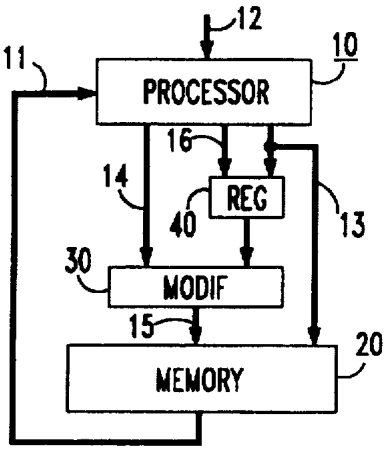


FIG. 2

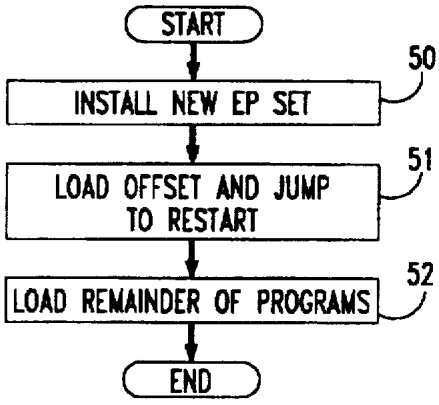
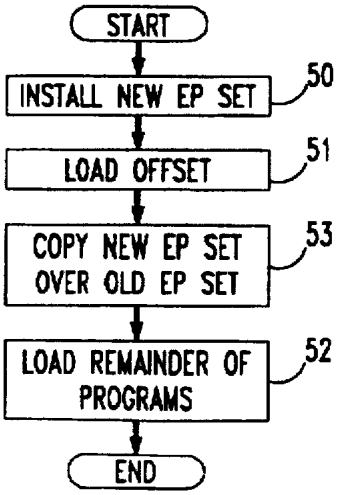


FIG. 3



METHOD FOR DOWNLOADING PROGRAMS

This application is a division of U.S. patent application having Ser. No. 07/880,257 of Hecht,et al., filed May 8,1992.

BACKGROUND OF THE INVENTION

This invention relates to stored program controlled apparatus and, in particular, to apparatus with a capability for remote updating of its entire set of programs.

Stored program controlled apparatus can conveniently be divided into two types; one where the stored programs are completely unalterable under normal operating circumstances, and the other where the stored programs are alterable, at least at times, during normal operation. In apparatus of the first type, the program is often executed automatically and the user does not even know that the controlled apparatus is "stored program controlled". This is typically the case in equipment that is designed for people who are not knowledgeable in computers and for whom the equipment is just a tool of the trade. "Point of sale" terminals, such as check-out terminals at a supermarket, are a good example. Modems are another example. People who use this equipment desire fail-safe operation and they do not want to be bothered with loading programs, fixing program bugs, installing updated versions of software, etc.

One approach to programming such equipment is to imprint the program into read-only-memory integrated circuits and physically install the circuits into the equipment. The problem with this approach is that updated versions of the program require the creation of new sets of read-only memories and new installations.

When a communication link is present, "downloading" the programs to the equipment from a remote processor, through the communication link, forms another approach for programming the equipment. It has been known in the art for some time that it is feasible to download limited types of control information from a remote processor. It is also known to download entire machine language application programs. Often such equipment does not include writable non-volatile store, such as a hard disk, so the programs are stored in battery protected read/write memories.

This is an unattractive solution because it leaves a substantial portion of program memory to be at risk. To mitigate this problem, U.S. Pat. No. 4,724,521, suggests storing within read-only memories of the local equipment a number of general purpose routines which comprise instructions to be executed by the central processing unit to accomplish a particular program task. These, in effect, form a set of macro-instructions. The downloaded machine language program utilizes these macro-instructions to the extent possible, and thereby achieves flexibility without the need to download substantial amounts of program code.

In all of the known approaches, however, there is a program portion in the local equipment that is resident in a read-only memory, and its contents is not changed. That resident portion contains "boot-up" segments and program segments that are necessary to maintain the communication between the remote processor and the local equipment (so that the process of downloading the programs can continue). This set of programs is the "essential programs" (EP) set. This set of programs should, of course, be a non-volatile store because there is always a possibility of power loss.

The fact that the EP set is needed to maintain communications presents a problem when the EP set itself needs to be modified or updated. Indeed, that is often the case with modems, where essentially the sole function of the modem software is to support communication.

SUMMARY OF THE INVENTION

The problem of downloading a modified version of the operating communication program, and the problem of effectively updating the entire set of programs in a stored program controlled apparatus, such as a modem, is solved with a downloadable start address specification means and, optionally, with an EEPROM memory. The start address specification means stores information that is downloaded through the communication link, and that information is used in defining the address from where the communication link programs are initiated.

In accordance with the method of this invention, downloading comprises what may be considered two communication segments. In the first segment the essential portion of the new package (EP set) of programs is downloaded to some chosen location in the local apparatus and the downloadable start address specification means is loaded with the appropriate new start address. Utilizing the most recently downloaded EP set of the new communication package, the second segment downloads the remainder of the new package.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** presents a block diagram of an arrangement for carrying out this invention;

FIG. **2** is a flow diagram of a downloading process in accordance with this invention; and

FIG. **3** is a flow diagram of an augmented downloading process in accordance with this invention.

DETAILED DESCRIPTION

A modem's primary function is to enable communications between a customer's digital equipment and a remote apparatus over a transmission medium. In a modem with a stored programmed controlled architecture this communication is effected with a set of programs, which includes call establishment programs, link layer protocols with flow control and error recovery functions, and programs that handle and store the communicated data, as well as the modulation and demodulation programs used by the modem. These programs occupy a significant portion of the modem's program memory. In accordance with this invention, all programs—including the EP set of programs that carry out the elemental communications—are downloadable. That is, the apparatus employing the principles of this invention does not need to have a non-volatile "boot-up" read-only-memory. All programs (including the boot-up programs) can be stored in a single memory arrangement which, for some applications, can consist of just two memory devices.

FIG. **1** depicts one structure that, in conformance with the principles of this invention, enables the downloading of programs to the modem's program memory. FIG. **1** includes a processor element **10** with a port for receiving signals from, and sending signals to, line **12**. Processor **10** is also responsive to line **11** data from program memory **20**, and it supplies address and data to memory **20** via bus **13** and bus **14**, respectively. In a conventional processor structure, bus **14** is connected to an address port of memory **20**. In FIG. **1**, address modifier **30** is interposed between processor **10** and program memory **20**, with bus **15** supplying the address information to memory **20**. Modifier **30** is responsive to

register **40**, which is loaded with bus **13** data when the register is enabled by bus **16**. Modifier **30** is a modulo M adder, where M is the size of memory **20**. A typical stored program controlled modem also includes a read/write data memory, means for interfacing with the transmission medium, means for interfacing with the local digital equipment, and perhaps other data and control ports. For purposes of this invention, however, these other elements are irrelevant, so they are not included in the drawing.

It should be understood that line **12** in the FIG. **1** architecture effectively offers a "remote execution" capability to processor **10**, in that the programs which are executed by processor **10** are affected by data supplied by line **12**. For example, data supplied by line **12** can effect branching to programs that are normally dormant. One such normally dormant program is a program that downloads information to the program memory. It should also be understood, and noted, that although this invention is described in connection with modems, its principles are applicable to all stored program apparatus. In particular, the principles of this invention are applicable to all situations where it is desirable to download an entire set of new programs, including the EP set. For example, this invention is useful in PCs, "point of sale" terminals, etc.

The operation of the FIG. **1** apparatus is quite simple. The processes carried out by the FIG. **1** apparatus are effected by executing a sequence of instructions that the processor receives from program memory **20** via bus **11**. In turn, processor **10** determines which instructions are delivered to it by controlling the addresses applied to memory **20** (typically by controlling a "program counter" within processor **10**, which is not shown in the FIG.). The primary difference between a conventional microprocessor arrangement and the FIG. **1** arrangement is that the addresses supplied on bus **14** are not the actual addresses that are applied to program memory **20**, because of the interposed circuit **30**. One might call these addresses "virtual addresses", which are translated into the real addresses by the additive constant applied by register **40** to modifier circuit **30**.

The exact structure and organization of the programs executed by the FIG. **1** arrangement is not really relevant to this invention, but it is to be understood that a protocol exists for sending information out on line **12** and for receiving information from line **12**. This protocol provides a mechanism for intelligent communication with processor **10**, which includes, for example, knowing when the received data is commands or data, and whether to store the received data in memory **20** or elsewhere.

The programs that can be executed by the FIG. **1** arrangement reside throughout memory **20**, but the set of programs that is essential to the maintenance of communication with line **12** (the EP set) may, advantageously, occupy a contiguous segment of memory **20** addresses in the range 0 to N. Within that range of addresses there is a subroutine for installing a new EP set

In accordance with the principles of this invention, the entire set of programs contained in memory **20** can be over-written with a new set of programs (in a process initiated by the apparatus itself or by the party connected to the apparatus via line **12**) by following the procedure outlined in FIG. **2**. In step **50** of FIG. **2**, a command is received on line **12** to branch to the subroutine in the EP set that installs new EP sets (that command may simply be a data word that is installed in a particular read/write memory location). After supplying the branch instruction, the new EP set of programs are downloaded via line **12**. Optionally, an offset address that is the starting address of the new EP set (the address corresponding to 0 in the existing EP set) is also downloaded. Alternatively, the offset address may be predefined, in which case it does not need to be supplied by line **12**. In any event, the offset address is greater than N and less than M–N. It may be noted that N must be less than M/2, because two EP sets must temporarily coexist in memory **20**.

After the new EP set is installed in memory locations X through X+N, where X is the offset address (X=M/2, for example), memory locations that serve as software-defined registers in the new EP set are populated with data that is found in the corresponding software-defined addresses in the active EP set. Thereafter, according to step **51**, register **40** is loaded with the offset address.

The immediate effect of loading the offset address into register **40** is to transfer control to the newly installed EP set. That means that the program in the new EP set to which control is transferred, must be at a predetermined logic point so that the communication can continue seamlessly. This minor requirement can be easily accommodated by proper planning of the new EP set. Once operation proceeds under control of the new EP set of programs, according to FIG. **2**, step **52** conditions processor **10** to account for the offset present in register **40** and loads the remainder of programs destined for memory **20** in addresses higher than X+N (modulo M).

It is obviously important to protect the information loaded into memory **20** from loss. At the very least, that means that memory **20** must be non-volatile. Memory **20** must also be relatively fast because it directly affects the processing speed that can be attained with the FIG. **1** arrangement. Currently, we use an electrically bulk erasable, programmable, read-only memory (FLASH EEPROM) to form memory **20**. This memory must be erased in bulk before new information can be written in it. To install a new EP in such a memory, it is recalled that the EP set must occupy less than half of memory **20**, and that makes it convenient to construct memory **20** from at least two distinct chips (distinct in the sense of being able to erase one and not the other). Each segment of the downloading process begins with a bulk erasure of one of the memory **20** halves.

To summarize the downloading process of this invention,

1. Bulk erase the that half of memory **20** which does NOT contain the EP set of programs;
2. download a new EP set of programs to the erased half of memory **20**;
3. download the offset address to pass control to the new EP set of programs;
4. bulk erase the other half of memory **20**;
5. download the remainder of programs into memory **20**.

If register **40** is to contain the offset address for a substantial time after downloading is accomplished, then its contents must be protected in a manner not unlike that of memory **20**. Of course, register **40** can manufactured together with memory **20** and be an EEPROM. However, that is not absolutely necessary, and manufacturing costs could benefit if register **40** were constructed as part of the read/write memory or as part of processor **10**.

Register **40** may be a volatile memory if the downloading process is carried out as depicted in FIG. **3**. Specifically, by including a copy subroutine in the EP set of programs, the downloading process can be modified to the following (assuming the EP set is in the first half of memory **20**):

1. Bulk erase the second half of memory **20**;

2. download a new EP set of programs to the second half of memory **20**;

4. download the offset address to pass control to the new EP set of programs;

5. bulk erase the first half of memory **20**;

6. copy the contents of the second half of memory **20** into the first half of memory **20**;

7. reset the offset address to 0; and

8. download the remainder of programs into memory **20**.

Admittedly, during the copy sequence (which may also be a "move" sequence) the arrangement is vulnerable to power failures. Since the time of copying or moving is very small, this is a very unlikely event. Still, to protect against this unlikely event, the power source can be designed to have sufficient reserve to complete the copy operation, or to protect the starting address. A capacitor at the output of the power supply may supply the necessary power reserve.

In the arrangement described above where memory **20** consists of two FLASH EEPROM chips, register **40** needs to have only one bit of memory, and modifier circuit **30** can be merely an Exclusive OR gate which, with the aid of the one bit memory of register **40**, selects the bank of memory that is active.

We claim:

1. A method for installing a new set of communication programs P_{new} into a stored program controlled apparatus that includes a communication port and a memory by transmitting said set of programs P_{new} to said apparatus via said port, with the aid of a set of communications programs P_{old} already resident in said memory, where said set of programs P_{old} contains a subset of programs EP_{old} that occupy less than half of the memory and said set of programs P_{new} also contains a subset of programs EP_{new} that, when installed, occupy less than half of the memory, comprising the steps of:

installing the EP_{new} programs in a first area of said memory that contains programs other than the EP_{old} programs, thereby overwriting at least a portion of one program in said P_{old} set of programs;

altering operation of said apparatus to execute the EP_{new} programs instead of the EP_{old} programs; and

installing the remaining programs of said P_{new} set of programs in a second area of said memory, said second area constituting memory locations not occupied by the EP_{new} programs.

2. The method of claim **1** further comprising

a step of moving, interposed between said step of altering operation of the apparatus and said step of installing the remaining programs, that installs said EP_{new} programs into memory locations starting at a location that corresponds to a starting location of the EP_{old} programs, and

a second step of altering operation of said apparatus to execute the EP_{new} programs in the installed locations by said step of moving.

wherein said installing the remaining programs of said P_{new} set of programs stores the programs in memory locations not occupied with the EP_{new} programs installed by said step of moving.

3. The method of claim **1**, further comprising the steps of:

erasing said first area of said memory, said erasing step to be performed prior to said step of installing the EP_{new} programs into said first area of said memory; and

erasing said second area of said memory, said erasing step to be performed after said step of altering operation of the apparatus and prior to said step of installing the remaining programs of said P_{new} set of programs.

4. The method of claim **1**, wherein said step of altering operation of said apparatus to execute said EP_{new} programs is accomplished by installing an offset address to pass control of said apparatus to said EP_{new} programs.

5. A method for installing a new set of communication programs P_{new} into a stored program controlled apparatus that includes a communication port and a memory by transmitting said set of programs P_{new} to said apparatus via said port, with the aid of a set of communications programs P_{old} already resident in said memory, where said set of programs P_{old} contains a subset of programs EP_{old} that occupy less than half of the memory and said set of programs P_{new} also contains a subset of programs EP_{new} that, when installed, occupy less than half of the memory, comprising the steps of:

installing the EP_{new} programs in a first area of said memory that contains programs other than the EP_{old} programs, thereby overwriting at least a portion of one program in said P_{old} set of programs;

altering operation of said apparatus to execute the EP_{new} programs instead of the EP_{old} programs;

moving the EP_{new} programs from said first area of memory to a second area of said memory; and

installing the remaining programs of said P_{new} set of programs in said first area of memory.

6. The method of claim **5**, further comprising the step of:

erasing said first area of said memory, said erasing step to be performed prior to said step of installing the EP_{new} programs into said first area of said memory.

7. The method of claim **5**, wherein said moving step further comprises the steps of:

copying the EP_{new} programs from said first area of memory to said second area of memory; and

erasing said first area of memory.

8. The method of claim **5**, wherein said step of altering operation of said apparatus to execute said EP_{new} programs is accomplished by installing an offset address to pass control of said apparatus to said EP_{new} programs.

* * * * *

EXHIBIT F

US005852631A

United States Patent [19]

Scott

[11] Patent Number: 5,852,631

[45] Date of Patent: *Dec. 22, 1998

[54] **SYSTEM AND METHOD FOR ESTABLISHING LINK LAYER PARAMETERS BASED ON PHYSICAL LAYER MODULATION**

[75] Inventor: **Robert Earl Scott**, Indian Rocks Beach, Fla.

[73] Assignee: **Paradyne Corporation**, Largo, Fla.

[*] Notice: The term of this patent shall not extend beyond the expiration date of Pat. No. 5,710,761.

[21] Appl. No.: **780,762**

[22] Filed: **Jan. 8, 1997**

Related U.S. Application Data

[60] Provisional application No. 60/026,970, Sep. 20, 1996, and provisional application No. 60/022,474, Jun. 21, 1996.

[51] **Int. Cl.**[6] **H04L 29/10**

[52] **U.S. Cl.** **375/222**; 379/93.32

[58] **Field of Search** 375/222, 223; 379/93.29, 93.31, 93.32, 93.33, 120; 370/252

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FOREIGN PATENT DOCUMENTS

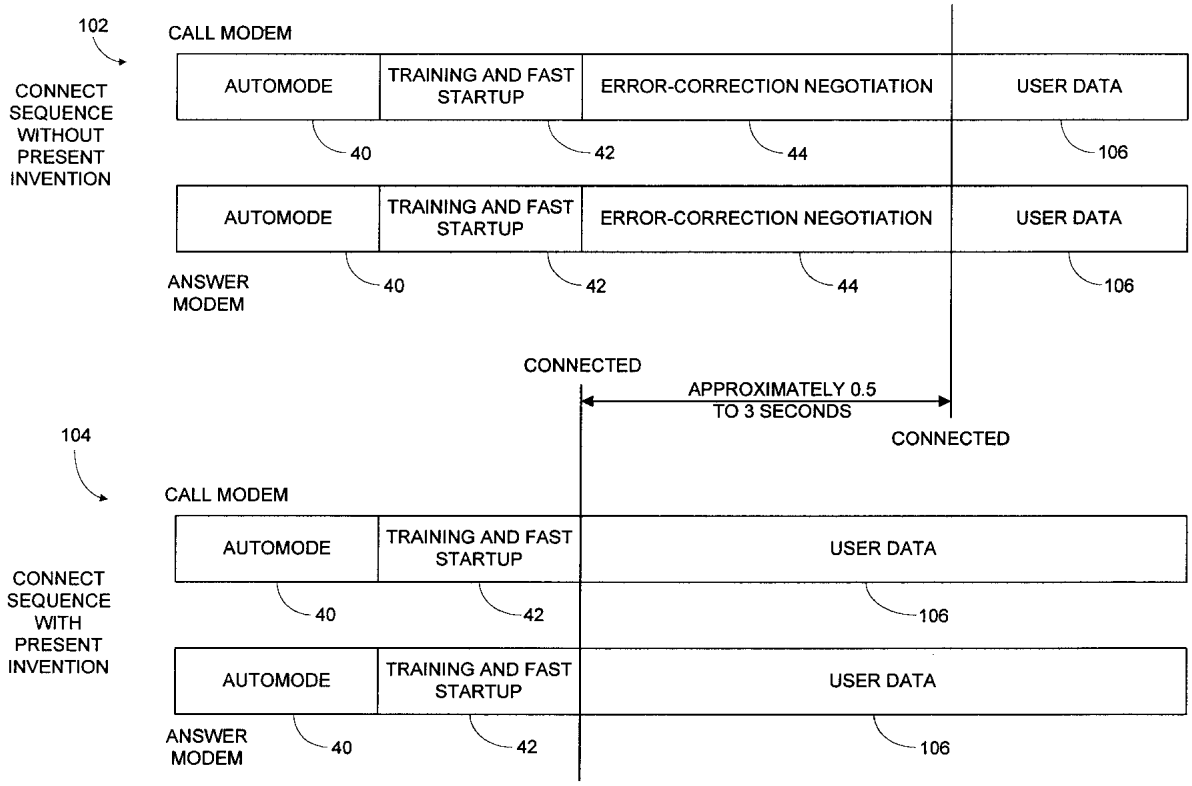
0 418 165	3/1991	European Pat. Off.	375/222

Primary Examiner—Stephen Chin
Assistant Examiner—Jeffrey W. Gluck
Attorney, Agent, or Firm—Thomas, Kayden, Horstemeyer & Risley, L.L.P.

[57] **ABSTRACT**

A system and method for establishing a link layer connection between a calling modem having a plurality of possible first physical layer modulations and one or more possible link layer connections and an answering modem having a plurality of possible second physical layer modulations and one or more possible link layer connections comprising the steps of establishing a physical layer connection between the calling and the answering modems, wherein the physical layer connection is based on a negotiated physical layer modulation chosen from the first and second physical layer modulations, and establishing link layer connection based upon said negotiated physical layer modulation. The link layer connection includes parameters that are preset to default values based upon the negotiated physical layer connection. Thus, the modems are able to avoid the link layer negotiation, thereby providing a faster and more robust connection.

10 Claims, 8 Drawing Sheets



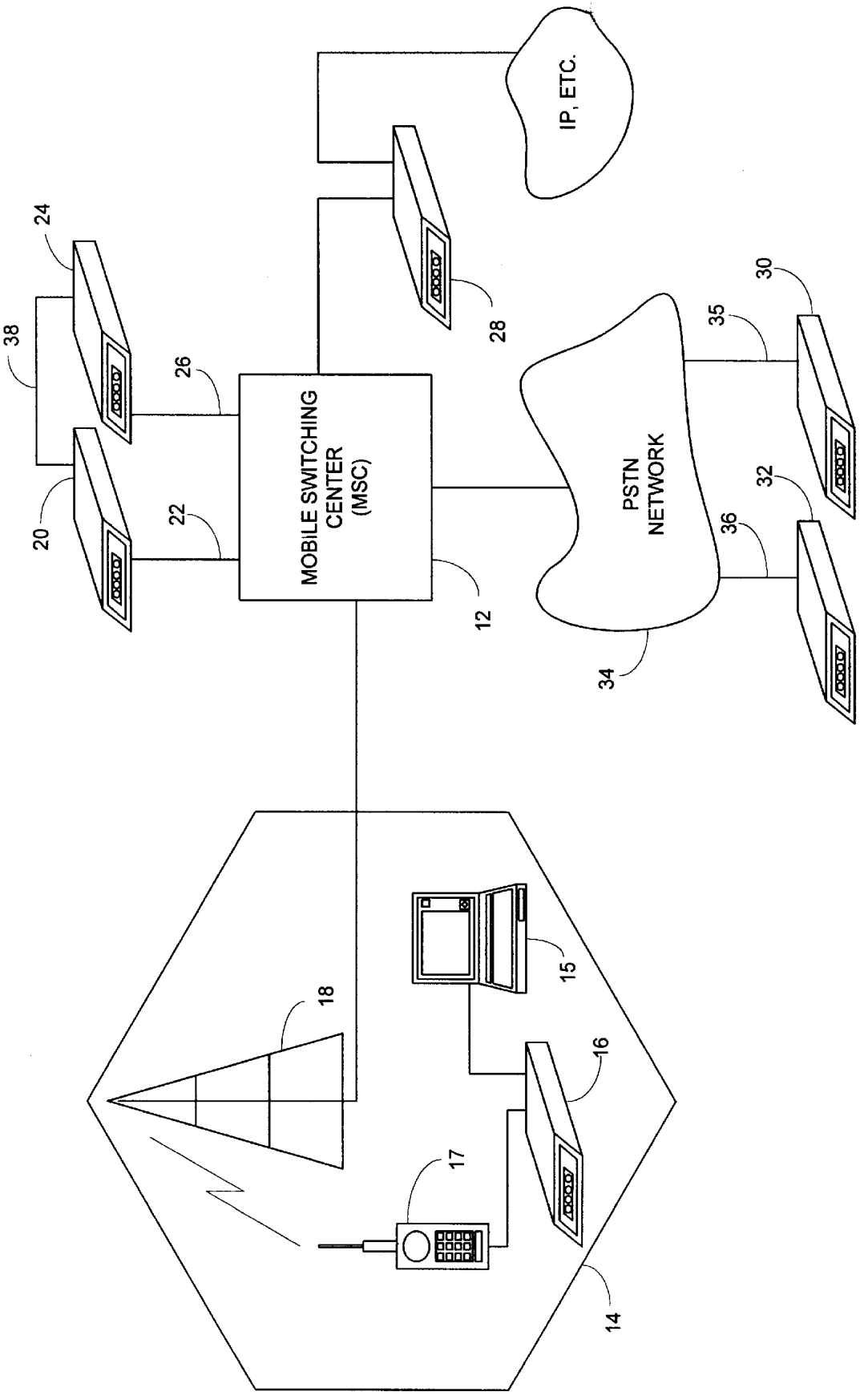

IP, ETC.
28
24
38
26
MOBILE SWITCHING CENTER (MSC)
22
20
12
PSTN NETWORK
34
35
30
32
36
18
15
16
17
14

FIG. 1

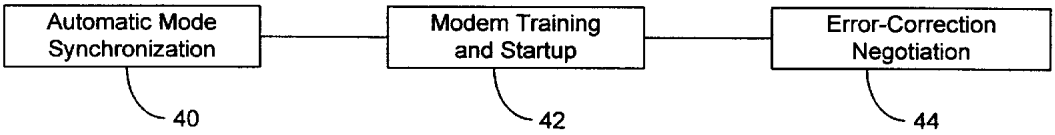

Automatic Mode Synchronization
Modem Training and Startup
Error-Correction Negotiation
40
42
44

FIG. 2

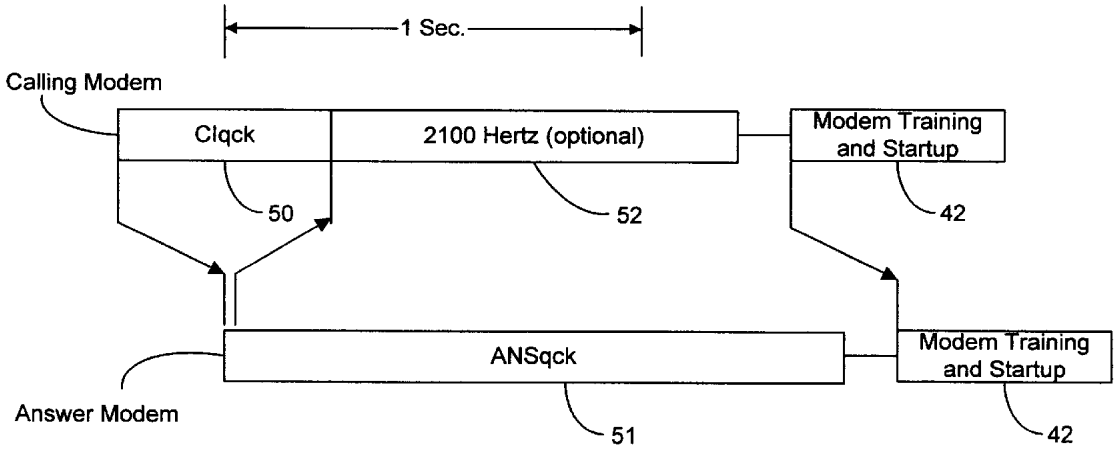
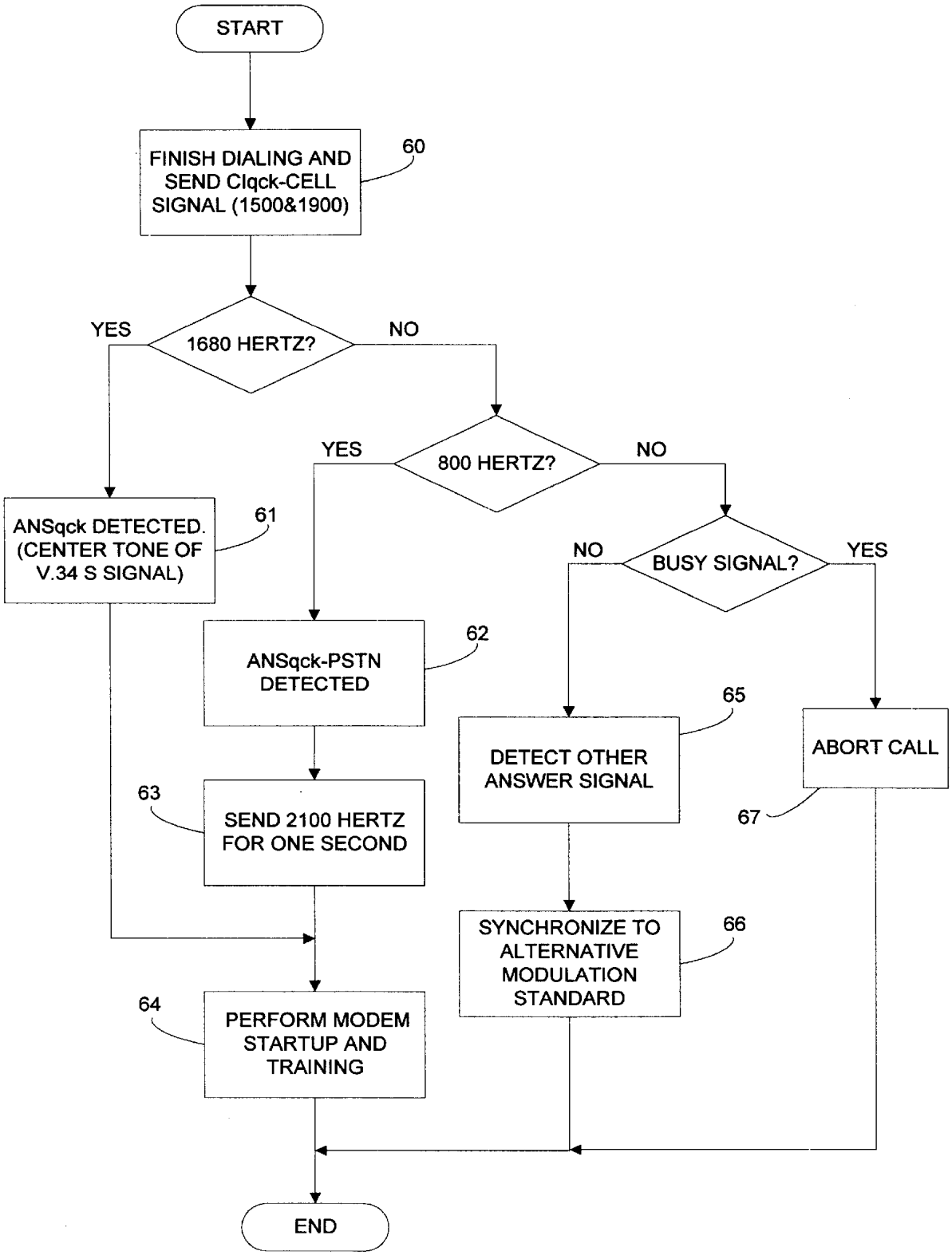
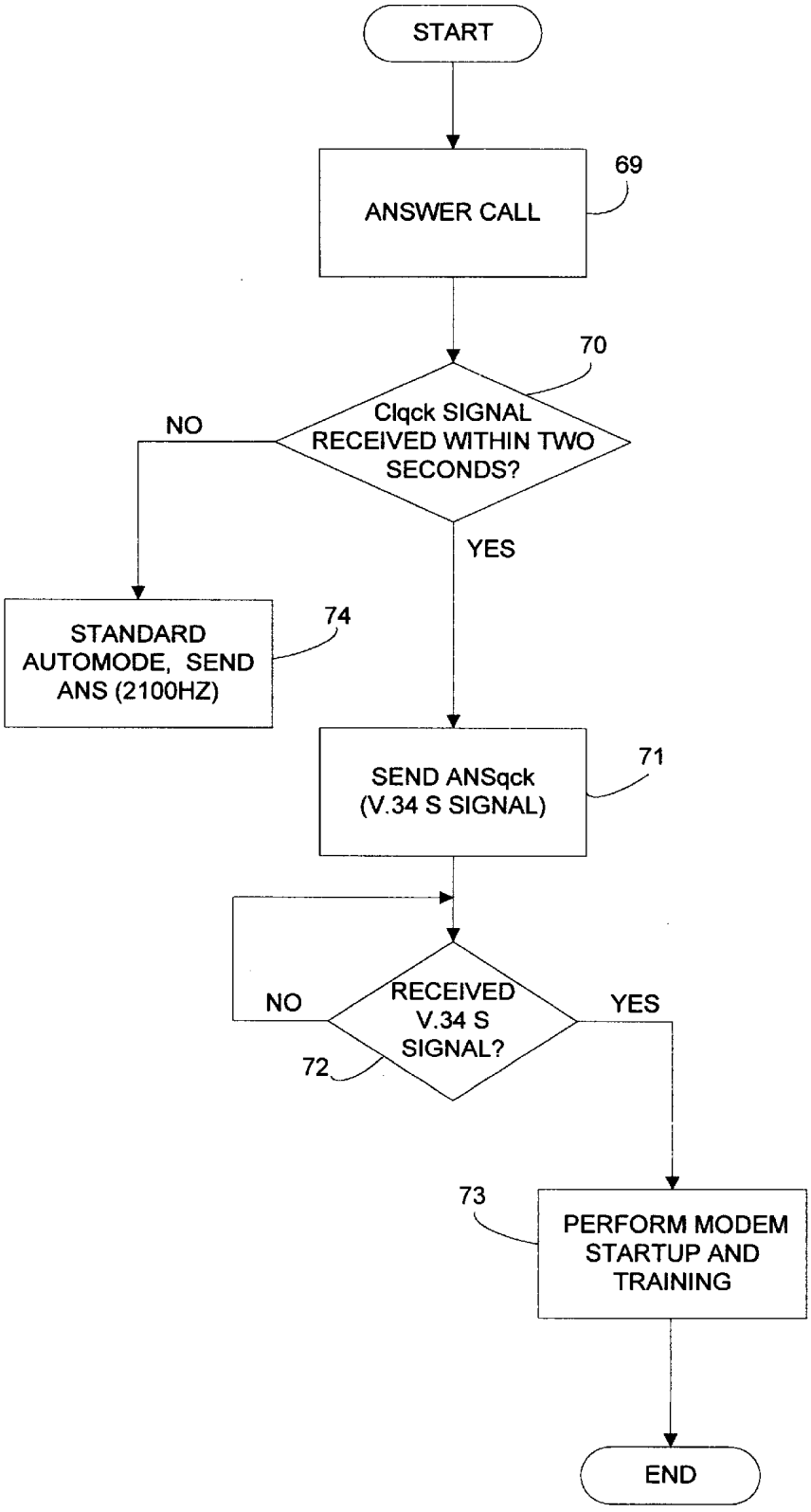

1 Sec.
Calling Modem
Clqck
2100 Hertz (optional)
Modem Training and Startup
50
52
42
ANSqck
Modem Training and Startup
Answer Modem
51
42

FIG. 3



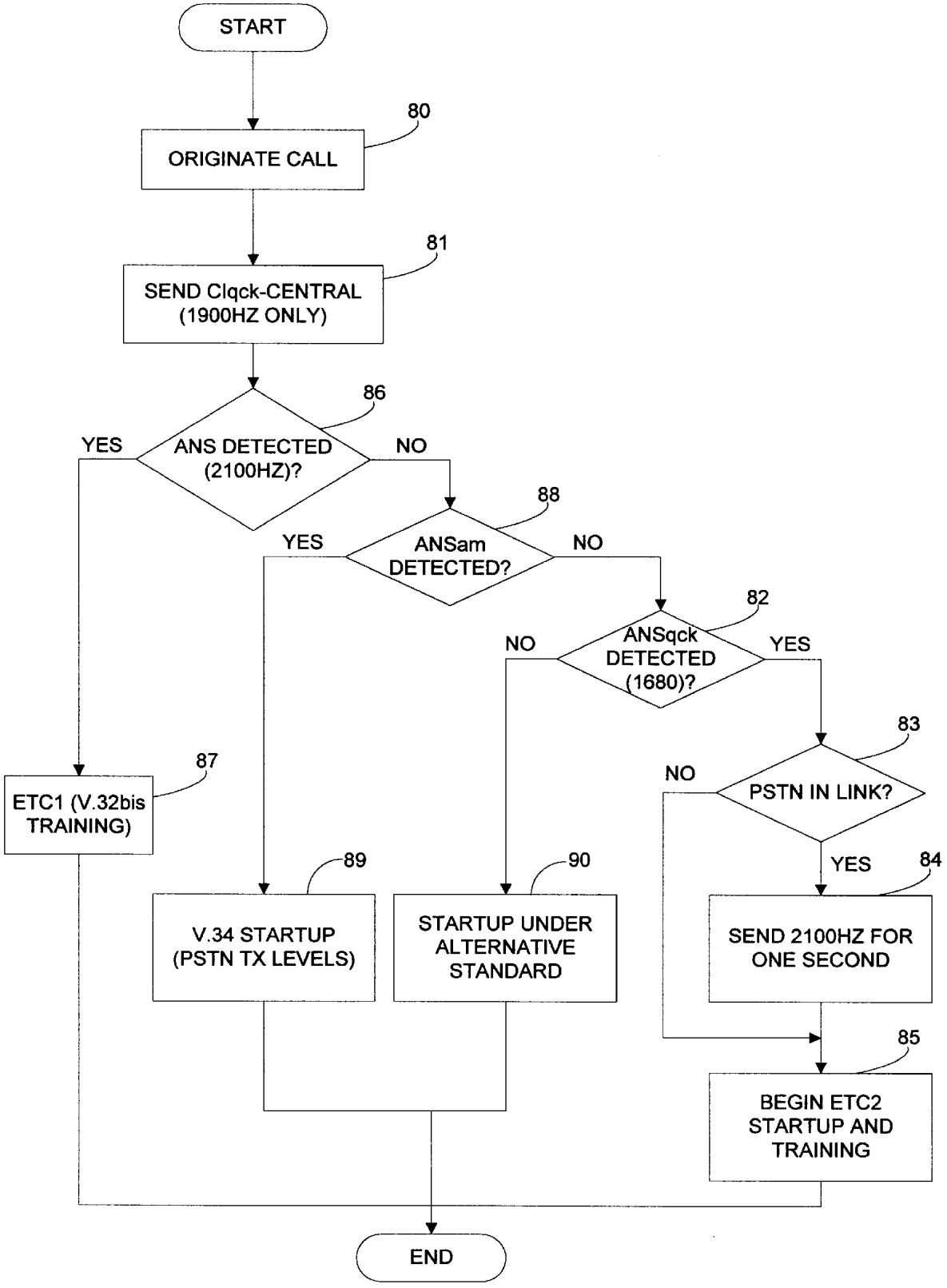
Calling Modem -- Cellular

FIG. 4



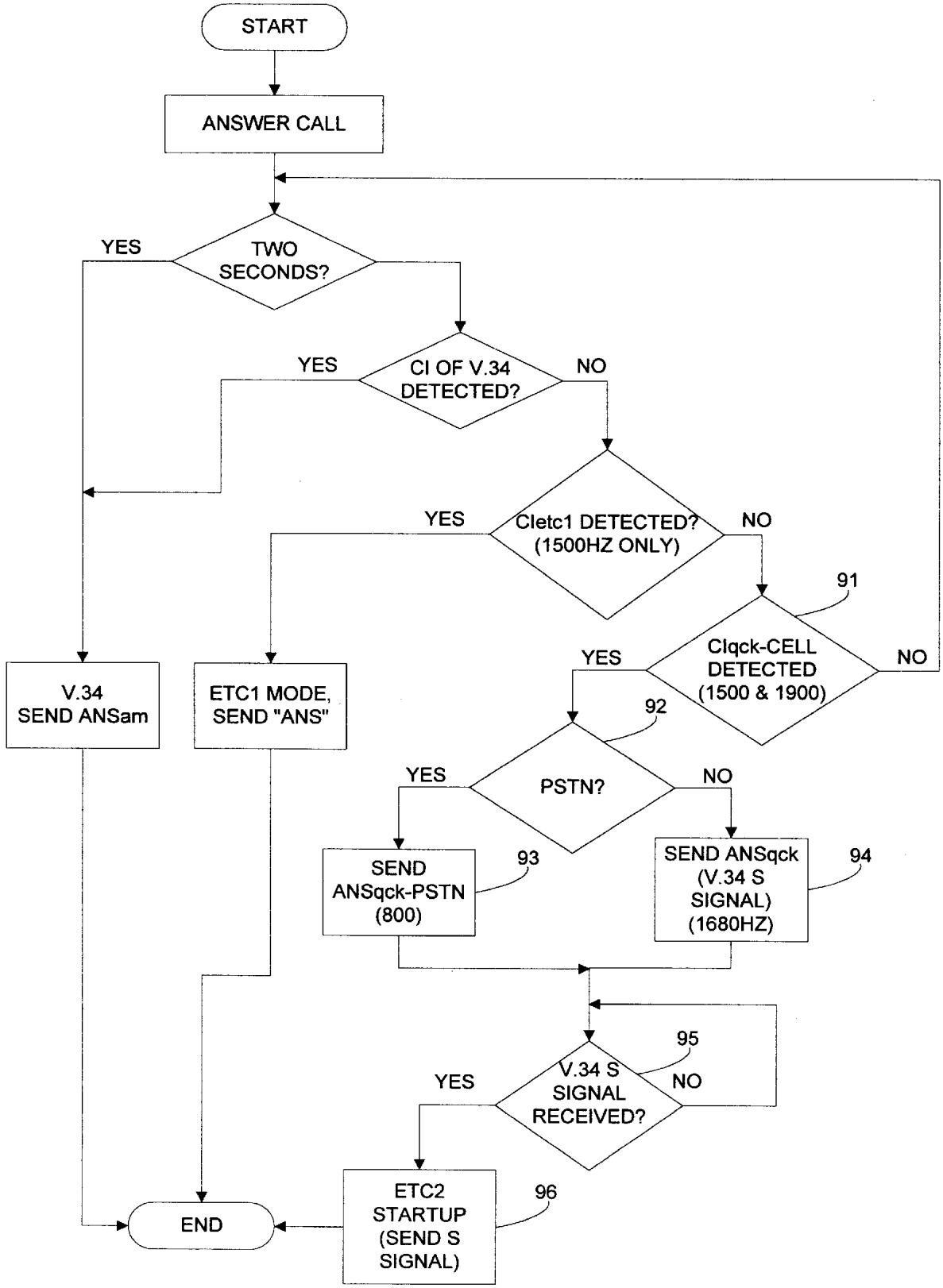
Answer Modem -- Cellular

FIG. 5



Calling Modem -- Central Site

FIG. 6



Answer Modem -- Central Site

FIG. 7

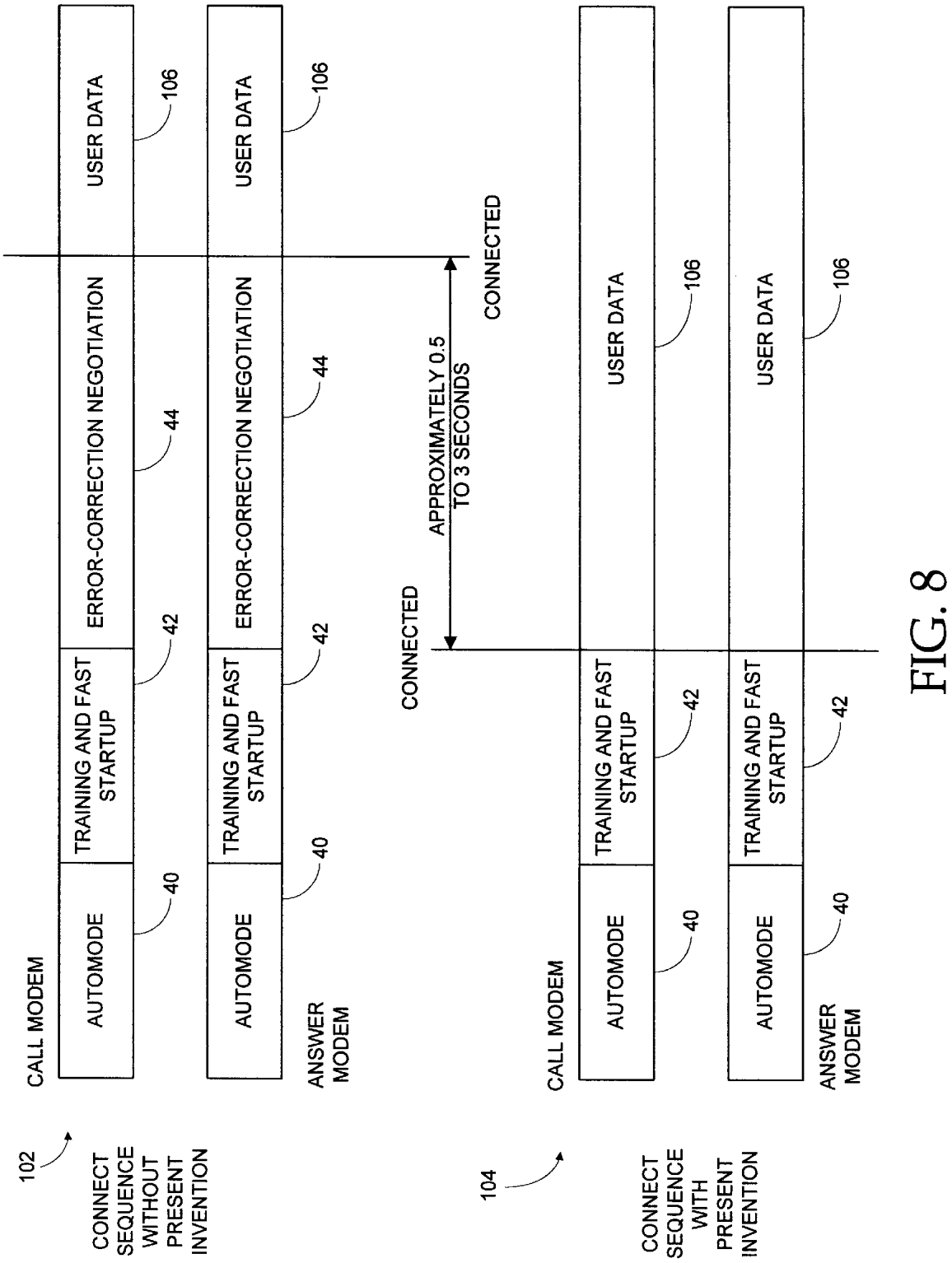

CALL MODEM
AUTOMODE
TRAINING AND FAST STARTUP
ERROR-CORRECTION NEGOTIATION
USER DATA
40
42
44
106
ANSWER MODEM
AUTOMODE
TRAINING AND FAST STARTUP
ERROR-CORRECTION NEGOTIATION
USER DATA
40
42
44
106
CONNECTED
APPROXIMATELY 0.5 TO 3 SECONDS
CONNECTED
102
CONNECT SEQUENCE WITHOUT PRESENT INVENTION
CALL MODEM
AUTOMODE
TRAINING AND FAST STARTUP
USER DATA
40
42
106
ANSWER MODEM
AUTOMODE
TRAINING AND FAST STARTUP
USER DATA
40
42
106
104
CONNECT SEQUENCE WITH PRESENT INVENTION

FIG. 8

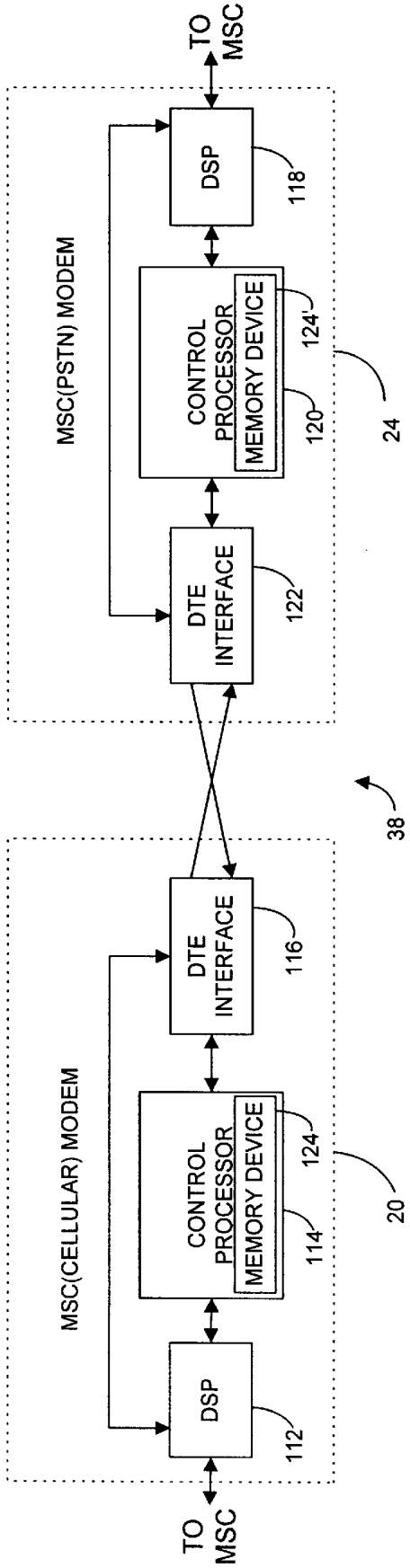

TO MSC
DSP
118
MSC(PSTN) MODEM
CONTROL PROCESSOR
MEMORY DEVICE
124
120
24
DTE INTERFACE
122
38
DTE INTERFACE
116
MSC(CELLULAR) MODEM
CONTROL PROCESSOR
MEMORY DEVICE
124
114
20
DSP
112
TO MSC

FIG. 9

SYSTEM AND METHOD FOR ESTABLISHING LINK LAYER PARAMETERS BASED ON PHYSICAL LAYER MODULATION

This application claims priority to and the benefit of the filing date of copending and commonly assigned provisional application entitled CELLULAR DATA PROTOCOL FOR QUICK CONNECTION, assigned Ser. No. 60/026,970, and filed Sep. 20, 1996; and copending and commonly assigned provisional application entitled A RAPID START UP PROTOCOL FOR COMMUNICATION BETWEEN A PLURALITY OF MODEMS, assigned Ser. No. 60/022,474, and filed Jun. 21, 1996.

FIELD OF THE INVENTION

The present invention generally relates to data communication protocols, and more particularly, to presetting the link layer parameters per the physical layer modulation in a protocol stack for modems.

BACKGROUND OF THE INVENTION

In an effort to facilitate more reliable and platform independent communication links between remotely located computers, communication protocols are typically organized into individual layers or levels comprising a protocol stack. The lowest layer is designed to establish host-to-host communication between the hardware of different hosts. The highest layer, on the other hand, comprises user application programs which pass customer data back and forth across the communication link. Each layer is configured to use the layer beneath it and to provide services to the layer above it.

Examples of two protocol stacks are the Opened Systems Interconnect (OSI) seven layer model and the Transmission Control Protocol/Internet Protocol (TCP/IP) five layer model. The OSI seven layer model comprises the following layers from lowest to highest: a physical layer, a data link layer, a network layer, a transport layer, a session layer, a presentation layer, and an application layer. When combined, the seven layers form a protocol stack that is designed to provide a heterogeneous computer network architecture. The TCP/IP five layer model comprises the following layers from lowest to highest: a physical layer, a data link layer, a network layer, a transport layer, and an application layer. Of particular relevance to the present invention is the implementation of the physical layer and data link layer in these systems.

The physical layer of the OSI model is the lowest layer and is concerned with establishing the electrical and mechanical connection between two modems. The data link layer is the second lowest layer of the OSI seven layer model and is provided to perform error checking functions as well as retransmitting frames that are not received correctly.

As is well known, a variety of standards exist which govern the protocols for communication between modems. For example, V.21, V.22, V.32, V.32bis, V.34, V.42, and V.42bis, are identifiers of differing communication standards recommended by the International Telecommunications Union (ITU). Each one of these is directed to an aspect of either the physical layer or data link layer of the OSI model.

The ITU Standard V.34 (hereafter referred to as V.34) is intended for use in establishing a physical layer connection between two remotely located computers over the Public Switch Telecommunications Network (PSTN). The V.34 standard includes the following primary characteristics: (1) full and half-duplex modes of operation; (2) echo cancellation techniques for channel separation; (3) quadrature amplitude modulation for each channel with synchronous line transmission at selectable symbol rates; (4) synchronous primary channel data signaling rates ranging from 2,400 bits per second to 33,600 bits per second, in 2,400 bit-per-second increments; (5) trellis coding for all data signaling rates; and (6) exchange of rate sequences during start-up to establish the data signaling rate. The features of V.34 are documented in the publicly-available ITU Standard V.34 Specification and are well known by those skilled in the art, and will not be described in detail herein.

Another significant feature of V.34, as it relates to the present invention, is the ability to automode to other V.-series modems that are supported by the ITU Standard V.32bis automode procedures. In this regard, V.34 defines signal handshaking that two connecting modems exchange at startup in order to learn the capabilities of the other modem to most efficiently exchange information.

While V.34 achieves efficient and generally high speed communication between two communicating modems, it nevertheless possesses several shortcomings that impede even more efficient operation. One significant shortcoming is the lengthy startup sequence which takes approximately 10–15 seconds. Particularly, for cellular customers, the ability to provide faster connections and faster data rates is particularly desirable since the cellular customer typically pays a charge for each cellular call based primarily on the length of the call and several other factors such as day of the week, time of day, roaming, etc. As a result, new fast connect protocols are being developed that provide for faster and more efficient startup operation based upon the system configuration and the path of the established communication link. An example of one such fast connect protocol is Paradyne Corporation's Enhanced Throughput Cellular 2 Quick Connect™ (ETC2-QC™). In essence, the ETC2-QC™ protocol uses techniques in the physical layer to reduce the physical layer startup time delay to about 1 second.

Of particular relevance to the present invention is the ITU Standard V.42 (hereinafter referred to as V.42). The V.42 standard is intended for use in establishing the error-correcting protocol of the data link layer connection. The V.42 standard includes a detection phase which determines whether both modems are capable of a an error-corrected connection, an exchanging identification phase for determining error-correcting parameter values and a link establishment phase for establishing the error-corrected connection. Under normal circumstances, V.42 requires approximately 1–3 seconds to establish an error-corrected connection. While this is relatively small in comparison to the establishment of a physical layer connection under V.34, it can essentially double the connection time when used in conjunction with fast connect modems.

Therefore, a heretofore unaddressed need exists in the industry for a system and method that reduces or eliminates the time required to establish a link layer connection so as to minimize the amount of time for establishing a connection between two modems.

SUMMARY OF THE INVENTION

The present invention overcomes the inadequacies an inefficiencies of the prior art as discussed hereinbefore and well known in the industry. The present invention provides a system and method for establishing a link layer connection between a calling modem having a plurality of possible first physical layer modulations and a plurality of possible link

layer connections and an answering modem having a plurality of possible second physical layer modulations and a plurality of possible second link layer connections that comprises the following steps. One step includes establishing a physical layer connection between the calling and the answering modems, wherein the physical layer connection is based on a negotiated physical layer modulation chosen from the first and second physical layer modulations. Another step includes establishing a link layer connection based upon the negotiated physical layer modulation. This link layer connection includes parameters that are preset to default values based upon the negotiated physical layer connection. Thus, the modems are able to avoid the link layer negotiation that essentially all other modems perform, thereby providing a faster and more robust connection.

Other features and advantages of the present invention will become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional features and advantages be included herein within the scope of the present invention, as defined by the claims.

DESCRIPTION OF THE DRAWINGS

The present invention can be better understood with reference to the following drawings. The elements of the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Furthermore, like referenced numerals designate corresponding parts throughout the several views.

FIG. **1** is a system diagram, illustrating a multi-modem system, wherein a plurality of modems are interconnected among a plurality of communication links;

FIG. **2** is a diagram illustrating the primary handshaking and data exchange sequences between a calling and an answer modem;

FIG. **3** is a timing diagram similar to FIG. **2**, illustrating the signal exchange during the automatic mode synchronization sequence of FIG. **2**;

FIG. **4** is a software flowchart illustrating the operation of the present invention when the calling modem is a cellular modem;

FIG. **5** is a software flowchart illustrating the operation of the present invention when the answer modem is a cellular modem;

FIG. **6** is a software flowchart illustrating the operation of the present invention when the calling modem is a Central-site modem;

FIG. **7** is a software flowchart illustrating the operation of the present invention when the answer modem is a Central-site modem;

FIG. **8** is a schematic diagram comparing a first connect sequence of two fast connect modems with a conventional link layer connection and a second connect sequence of two fast connect modems with a link layer connection based on the physical layer negotiation in accordance with the present invention; and

FIG. **9** is a block diagram of the modems comprising a data gateway connected to the mobile switching center of FIG. **1**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The following description is of the best presently contemplated mode of carrying out the present invention. This description is not to be taken in a limiting sense, but is made merely for the purpose of describing the general principles of the invention. Consequently, the scope of the invention should be determined by referencing the appended claims.

The following description is divided into two parts. The first part discloses an example of a fast connect protocol for use in a modem system that is suitable for operating in conjunction with the present invention. It should be noted that the modem system disclosed in the first part is merely illustrative of a system that can benefit from the present invention, as will be evident to those of ordinary skill in the art upon reading the following disclosure. The second part discloses the present invention in the context of the fast connect modem system described in the first part. However, the present invention is equally well suited for application outside the context of the fast connect modem system described herein, for example, with modems that connect slowly.

I. Physical Layer Connection

Turning now to the drawings, FIG. **1** shows a system diagram of a system illustrating multiple modems intercommunicating through a variety of mediums, including cellular and PSTN. Indeed, as previously mentioned, a driving factor in the development of the present invention was to design a system that provided improved reliability in data communication over a data communication link. This goal has been achieved by removing the necessity to perform error-correction negotiation during the connect sequence in modem communication so as to reduce the overall connection time.

As illustrated, a cellular modem system may be disposed for communication with a mobile switching center (MSC) **12**. More specifically, a cell **14** includes a portable computer **15** that is connected via a cellular modem **16** to a cellular phone **17**, which in turn communicates (wirelessly) with a cell tower **18** that communicates with the MSC **12**. It is appreciated that the modem **16** recognizes that it is on the cellular side via a strap or configuration setting, or alternatively by a direct connect sensing of the cellular phone. Therefore, and as will be discussed in more detail below, the modem **16** will know that it is capable of communicating in accordance with a modulation standard capable of performing a fast connect sequence as described below.

The MSC **12** is also connected to a data gateway comprising modems **20** and **24**. The modems **20** and **24** are illustrated as connected in a back-to-back configuration and communicating to the MSC **12** over links **22** and **26**. As will be appreciated and discussed below, the links **22** and **26** will support different communication protocols, or different modulation standards. The modem pool provides a data gateway for interfacing data calls originating from the modem **16**, and thereby, allows cellular specific protocols to be used over the wireless connection between modems **16** and **20**, as described below.

By way of definition, a "Central-site" modem is one that is capable of supporting the modulation standard of the present invention, and is not connected to a cellular phone. In this regard, all central-site modems are connected via four-wire connections. Examples which are illustrated in FIG. **1** include a mobile switching center MSC(Cellular) modem **20**, an MSC(PSTN) modem **24**, an MSC(Single-ended) modem **28**, and a PSTN(ETC2-QC™) modem **30**—where an MSC modem is one that is connected at the mobile switching center **12**. A significant distinction among these various types of modems relates to the startup sequence, which will differ slightly depending upon the type

of central-site modem. Preferably, a hardware identifier, such as a DIP switch or a firmware option configurable at modem installation, defines the type of modem for purposes of the startup sequence.

In keeping with the description of FIG. **1**, modem **20** is illustrated as an MSC(Cellular) modem that is connected in a back-to-back mode with modem **24**, an MSC(PSTN) modem. Modem **20**, therefore, is designed to support the ETC2-QC™ modulation protocol and simulate a cellular modem during the initial modem startup routine. Modem **28** is an MSC(Single-ended) modem that, although it may communicate with modems on the PSTN **34**, will typically communicate only with cellular modems. Indeed, when communicating with cellular modems, the 2100 Hertz tone, which is typically inserted to disable echo cancellers, is preferably omitted. Advantageously, elimination of this tone achieves a faster and more desirable modem startup.

A PSTN(ETC2-QC™) modem **30** and a standard PSTN modem **32** are connected via PSTN **34** to the MSC **12**. The modem **30** is connected to the PSTN **34** via a four-wire connection **35**, and modem **32** via a two-wire connection **36**. Consistent with the concepts and teachings of the present invention, the four-wire connection **35** facilitates the communication of modem **30** with the cellular modem **16**, for example, in the ETC2-QC™ modulation standard. However, as will be appreciated by those of ordinary skill in the art, merely ensuring a four-wire connection **35** alone will not ensure proper system operation in accordance with the present invention. In this regard, such a four-wire connection **35** may nevertheless pass through a two-wire connection, and thus a hybrid converter circuit, at the central office. In this event, echo will be injected into the signal and the abbreviated modulation standard of the present invention may be compromised. There are, however, steps that may be taken to ensure proper operation of the invention. These include, (1) ordering a Direct Inward Dial connection and instructing the phone company to avoid a two-wire connection for that setup; (2) obtaining a direct T1 connection to the Interexchange Carrier (for example, a "1-800" number); and obtaining an ISDN PRI connection, as it will always support four-wire for both call origination and call answer.

By way of illustration, consider a call originated by the computer **15** and cellular modem **16** to the standard PSTN modem **32**. The established communication link will pass through the cellular phone **17** to the cell tower **18**, through the MSC **12**, across link **22** to the MSC(Cellular) modem **20** and to the connected modem **24** via RS-232 connection **38**, across link **26** and back through the MSC **12** to the PSTN **34**, and ultimately across the two-wire link **36** to modem **32**. As will become clear from the description that follows, the cellular modem **16** and the MSC(Cellular) modem **20** will connect and startup in accordance with the fast connect communication protocol described herein. However, since the established communication link that passes from modem **24** to modem **32** passes through a PSTN **34** and a hybrid converter, then the communication protocol of the present invention will not be adequately supported. Accordingly, the modems **24** and **32** will identify this situation and will connect and communicate using an alternative communication protocol supported by both modems and capable of effective transmission across the established link. In this regard, the overall communication link does not realize the fast connection.

Indeed, an aspect of the fast connect protocol described herein is the determination of whether both modems are compatible, in terms of communication protocol, and whether they are connected through a line that passes through a PSTN. If the modems are compatible and the established communication link is outside a PSTN (e.g., cellular to MSC) or is to a PSTN modem with a 4-wire connection that has been configured for supporting a fast connect protocol, then the modems may connect and begin their startup sequence. In this regard, the fast connect communication protocol is designed to be fast as well as robust, and is accomplished by the use of simple tones. The use of such simple tones facilitates the implementation of the automatic mode select to be in the modem's control processor rather than the digital signal processor (DSP) chip.

In addition to the fast connect protocol discussed in below, the fast connect protocol also includes several "fall-back" modulations. More particularly, the modem of the present invention will preferably include Paradyne Corporation's Enhanced Throughput Cellular 1™ (ETC1™), V.34, V.32bis, V.32, and V.22bis modulations. Thus, in the previous example, modems **24** and **32** may communicate using one of these communication protocols. These modulation protocols are documented and will be understood by persons of ordinary skill in the art, and will not be discussed herein. It suffices to say that supporting the above-listed modulation standards greatly enhances the flexibility and versatility of a fast connect modem.

To more particularly describe the initial startup sequence in accordance with the modulation standard of the fast connect modem, reference is made to FIGS. **2** and **3**. FIG. **2** illustrates the three principal components of modem exchange or communication. After the cellular modem initiates the call, such that a communication link is established, the modems enter a mode select sequence, referred to herein as automatic mode synchronization **40**. During this period, the modems exchange parameters that identify the modems, and thus, their communication protocol. This sequence **40**, thus, synchronizes the modems for communication in accordance with the same standard or protocol, such as V.34, V.22, V.22bis, etc.

Once the modems have synchronized their communication protocol, or modulation standard, then they enter a training and startup sequence **42**. In a manner known in the art, during this sequence the modems may test the established communication link for noise, bandwidth, etc., in order to determine an appropriate rate for communication. The modems may also operate during this period to train their internal echo cancellers by, for example, ranging the established link of communication. In accordance with a related aspect of the fast connect modems, under certain circumstances the modem training and startup sequence may also be significantly shortened to provide a more robust (both time-shortened and reliable) startup sequence. More particularly, the "circumstances" which provide such a robust startup include communicating modems constructed in accordance with the invention detecting an established link of communication that does not pass through any two-wire connections. The completion of this sequence signifies the establishment of a physical layer connection between two modems.

After the physical layer has been established, the communicating modems enter the information exchange/communication sequence, referred to herein as error-correction negotiation **44**, in order to establish the link layer connection. This is of particular relevance to the present invention in that it includes negotiation of a error-correcting protocol such as V.42. During this sequence **44**, the modems detect whether they are error-correcting modems and, if so, they negotiate the error-correcting parameters.

Referring now to FIG. **3**, the initial automatic mode synchronization **40** is illustrated. As shown, this sequence is

executed by exchanging signals between the calling modem and the answer modem. After the calling modem instructs the cellular phone to establish the communication link with the answer modem, it transmits the calling signal CIqck **50**. As will be described in more detail in connection with the flowcharts of FIGS. **4–7**, this signal may comprise a 1900 hertz tone, or alternatively may comprise a 1500 hertz tone modulated with a 1900 hertz tone. If only a 1900 hertz tone is transmitted as Ciqck signal **50**, then the answer modem knows that the calling modem is configured as a Central Site, four-wire modem (see FIG. **6**). Alternatively, if the CIqck signal includes both 1500 and 1900 hertz components, then the answer modem knows that the calling modem is configured as a cellular modem.

As will be appreciated by those of ordinary skill in the art, other calling signals may be transmitted by the calling modem. For example, calling signals consistent with that of a facsimile transmission, or calling signals consistent with other modem modulation standards, such as V.34, V.32, V.32bis, etc., may be transmitted. Since automatic connection and synchronization to facsimile, and these other modulation standards, are well known it will not be discussed herein. Indeed, the significance of the fast connect protocol is achieved when both the calling modem and the answer modem are capable of communicating in accordance with the fast connect modulation protocol herein described so that through the exchange of tones, the modems are made aware of the possible shortcuts in the fast startup and training sequence **42**, and more particularly, in the error-correction negotiation **44**.

Once the CIqck signal **50** is received by the answer modem, then the answer modem transmits its response back to the calling modem. The purpose of this answer signal is not only to signal receipt of the calling signal, but also to uniquely identify the answer modem. Again, as is known in the art, this answer signal may comprise ANS or ANSam signals as are known by the V.34 and V.32bis communication protocols. If so, the calling modem will then startup and train **42** and perform error-correction negotiation **44**. Significant to the present invention, however, is when the answer signal is ANSqck, which is defined by either a 1680 hertz tone or an 800 hertz tone.

As illustrated in FIG. **4** (assuming the calling modem is a cellular modem), if ANSqck is an 800 hertz tone, then the calling modem knows that the answer modem is configured as a four-wire connection, and can communicate with the calling modem in accordance with the fast connect communication protocol and, in accordance with the present invention, set the error-correction parameters to preset values so as to avoid the necessity of negotiating the parameters. In addition, the 800 hertz ANSqck signals the calling modem that the answer modem is connected to a PSTN **34** (see FIG. **1**). Therefore, the calling modem transmits a 2100 hertz tone for approximately one second. This, as is known, serves to pad the initial two second connect period, as required by the FCC for billing purposes. Furthermore, it serves to disable the echo cancellers within the PSTN **34**.

If ANSqck is a 1680 hertz tone, which is the center tone of V.34 S signal, then the calling modem knows that the answer modem is configured as a four-wire connection, and can again communicate with the calling modem in accordance with the fast connect communication protocol and, in accordance with the present invention, set the error-correction parameters to preset values so as to avoid the necessity of negotiating the parameters. More significantly, it tells the cellular calling modem that the answer modem is not connected to the PSTN **34**. Therefore, both the calling modem and the answer modem can determine that the established communication link is entirely outside the PSTN **34**. Accordingly, the Federal Communications Commission (FCC) billing delay need not be inserted. Furthermore, certain assumptions may be made in regard to bandwidth, or transmission quality. For example, the established communication link will not pass through echo cancellers, and as a result, the calling modem need not transmit the 2100 hertz tone. Instead, upon receiving the ANSqck answer signal, the calling modem may immediately enter the modem training and startup sequence **42**.

As will be further appreciated by those of ordinary skill in the art, by making certain assumptions regarding the line quality of the established link, the modem training and startup sequence **42** may be shortened. For example, in the preferred embodiment, the system initiates communication by assuming a 9600 baud rate. It has been found that most cellular connections may transmit at this rate, and certain front-end savings may be realized by defaulting to this initial startup rate. Of course, this rate may be increased, or autorated upwardly, in accordance with methods known in the prior art, after the initial startup and training sequence **42** has been completed.

Referring back to FIG. **4**, a top-level flowchart is shown, illustrating the automatic mode synchronization of a cellular calling modem constructed in accordance with the fast connect protocol disclosed herein. Once the calling modem has completed transmitting the dialing sequence, it transmits the CIqck signal, which for a cellular calling modem includes modulated 1500 and 1900 hz tones, as indicated in block **60**. Once the calling signal has been transmitted, the calling modem will wait to receive the answer signal from the answer modem. In order to exchange data using the modified modulation standard of the present invention, the calling modem looks to receive one of two answer signals. The first valid answer signal as in 1680 hz tone, which is the center tone of the V.34 S signal, as indicated in block **61**. This tone signals to the calling modem that the answer modem is not only compatible to transmit in the fast connect modified modulation standard, but further indicates that the answer modem is connected via four wire connections, and does not interconnect to a PSTN. Accordingly, since the calling modem is a cellular modem, then the established communication link does not pass through a PSTN and the initial two second FCC-required delay need not be inserted into the start-up sequence. Moreover, since the entire communication link is four wire, then the modems need not transmit the 2100 hz signal to disable echo cancellors.

A second valid answer signal is an 800 hz tone, as shown by block **62**, which also indicates that the answer modem is connected via four wire, and therefore, can communicate in accordance with the fast connect modulation protocol. In addition, the 800 hz tone indicates that the answer modem is connected to a PSTN. Assuming, as previously discussed, that the requisite steps have been taken to ensure that the established communication link does not pass through a two wire connection, then certain savings or efficiencies can be gained during the modem start-up and training sequences (e.g., eliminate echo training since no hybrid circuits are present in the communication link). Nevertheless, the FCC-required delay must be inserted and, therefore, a 2100 hz tone is transmitted at block **63** by the calling modem for a duration of approximately one second. The amount of the 2100 hz tone will "pad" the total modem automode and startup time to two seconds. This ensures that no customer data is transferred in the first two seconds (which meets FCC requirements). Thereafter, calling modem proceeds with the modem training and start-up sequence at block **64**.

If neither of the foregoing answer signals are received, then the system operates to determine whether another valid answer signal has been transmitted from the answer modem. The step of block **65** broadly designates this function. It should be appreciated that well known answer signals such as ANS or ANSam may be transmitted by the answer modem and, if received, the calling modem may synchronize to the appropriate modulation standard, as indicated in block **66**. Although not separately designated in the figure, it should be further appreciate that if no valid answer signal is received by the calling modem within a given period of time, the calling modem will time out and abort the attempted communication. Also, and as illustrated at block **67**, the calling modem will abort the attempted communication if a busy signal is received.

FIG. **5** shows a top-level flowchart illustrating the operation of a cellular answer modem constructed in accordance with the fast connect communication protocol described herein. Once the communication link has been established and the call answered at block **69**, the answer modem looks to detect the CIqck calling signal, as indicated by block **70**. In the presently described fast connect protocol, cellular to cellular modem communications are not supported. Therefore, a cellular answer modem will assume that a calling modem transmitted a CIqck signal will transmit only a 1900 hz tone rather than the modulated 1500 and 1900 hz tones. Having said this, it should be appreciated that cellular-to-cellular communications could be supported.

In keeping with the description of FIG. **5**, once the answer modem has received the CIqck calling signal, it transmits the ANSqck answer signal at block **71**. It then waits for the calling modem to enter the modem start-up and training sequence. This sequence is identified by receiving the S signal as assigned by the V.34 modulation standard, as indicated by the decision block **72**. Once this signal is received, then the answer modem will transmit back to the calling modem the appropriate S signal, so as to initiate the startup and training sequence **42**.

Alternatively, if the answer modem, within a period of two seconds, has not received CIqck calling signal, then it will proceed with the start-up sequence in accordance with an alternative modulation standard. This, therefore, assumes that the modified communication protocol of the present invention is not supported by the calling modem, and the answer modem will typically respond to the calling signal of an alternative communication signal by transmitting a 2100 hz tone, as indicated in block **74**.

Referring now to FIG. **6**, a software flowchart illustrating the top-level operation of a central site calling modem is shown. As depicted, the calling modem originates the call and establishes a communication link at block **80**. Once the communication link is established, the calling modem transmits the CIqck calling signal at block **81**, which in the case of a central site calling modem comprises a 1900 hz signal tone. If the 1680 hz ANSqck answer signal is detected at block **82**, then the calling modem recognizes the answer modem as one capable of transmitting pursuant to the fast connect communication protocol. Thereafter, the calling modem must determine the network configuration of the established communication link, as indicated in block **83**. That is, the central site calling modem will determine whether the established communication link passes through a PSTN or not. If it is determined that the established link passes through a PSTN, then, as in the case of the cellular calling modem, the calling modem transmits a 2100 hz signal for approximately one second at block **84**. Thereafter, the calling modem enters the modem start-up and training sequence, as indicated in block **85**.

Alternatively, if the calling modem detects the ANS answer signal (2100 hz) at block **86**, then it communicates with the answer modem using the ETC1™ communication protocol and the V.32bis training, as indicated by block **87**. If the ANSam answer signal is detected at block **88**, then the modem will startup in standard V.34 mode at block **89**, which is well known in the art and therefore not described herein. The modem will also monitor for ANSqck at block **82**, which in this example is a 1680 Hz tone. If this is not detected, then the modem will startup under an alternate low speed standard at block **90**, which is well known in the art and therefore not described herein. If ANSqck is detected, then the modem will operate differently depending on whether it is connected to the PSTN network or not, as indicated by block **83**. The modem will know whether it is connected to the PSTN via a configuration option which was set at installation. If connected to the PSTN, then the modem will transmit a 2100 Hz tone for one second at block **84** then proceed to the ETC2™ training sequence at block **85**. If the modem is not connected to the PSTN at block **83**, then it can proceed directly to the ETC2™ training sequence at block **85**, avoiding the additional one second of startup shown at block **84**.

Reference is now made to FIG. **7**, which is a software flowchart illustrating the top-level operation of a central site answer modem. As illustrated in the flowchart, and in accordance with the presently disclosed fast connect protocol, when the answer modem is a central-site modem, it assumes that any transmissions made in accordance with the modulation standard with the present invention will be via a communication link with a cellular calling modem. Therefore, block **91** indicates detection the CIqck calling signal in the form of a modulated 1500 and 1900 hz tones, as transmitted by cellular calling modem. If the CIqck calling signal is detected, then the answer modem determines the network configuration at block **92**. More specifically, the answer modem determines whether the established communication link passes through a PSTN or not. In the event that the established link does in fact pass through a PSTN, then the answer modem will transmit an 800 hz ANSqck answer signal at block **93**. As illustrated in FIG. **4**, this instructs the calling modem to transmit the 2100 hz tone. Alternatively, the answer modem will transmit the 1680 hz tone, which instructs the calling modem to proceed directly with the modem start-up and training sequence at block **94**. Thereafter, the answer modem will await transmission of the S signal in accordance with the V.34 start-up sequence, as indicated by block **95**. Thereafter, the answer modem will respond by transmitting the S of the V.34 start-up, as indicated by block **96**. Since the V.34 start-up sequence is well-known in the art, it would not be described herein.

The remainder of the flowchart depicted in FIG. **7** illustrates the central-answer modem operation and connects sequence in accordance with alternative standards that are well-known in the prior art and need not be discussed herein.

Accordingly, at the completion of the automatic mode synchronization sequence **40** (FIG. **2**), the modems enter into a training and start-up sequence **42**. As mentioned above, in the training and startup sequence **42** the modems test the established communication link for noise, bandwidth, etc., in order to determine the appropriate rate for communication. This is performed using the modulation scheme determined in the automatic mode synchronization sequence **40** as illustrated in FIGS. **4**, **5**, **6**, and **7**. For purposes of the following discussion, it is assumed that the call and the answer modems are capable of communicating

with one another using a fast connect protocol. Consequently, since the call modem knows what type of modem it is and what type of modem the answer modem is, certain shortcuts can be taken during the training and startup sequence **42** so as to reduce the overall connection time. Specifically, the modems can default to preset values that eliminate the need for probing, ranging and half-duplex training. Thus, the modems merely perform a special full-duplex training mode during the training and start-up sequence **42** which results in a much faster connection.

Particularly, the probing and ranging sequences are bypassed and the file parameters are assumed in ITU Standard V.8, INFO0, and INFO1. As an example, in ITU Standard V.8, the data call, the LAPM and the full-duplex training parameters are preset to default values if the tones exchanged during automode sequence indicate that both modems are capable of fast connect operation. Further, in the INFO sequences, the 4 point train, 2800 L symbol rate, the power level drop, and preemphasis filter can also be preset to default values. Thus, the ITU Standard V.8 and INFO sequences are eliminated.

At the completion of the training and start-up sequence **42**, the modems have established a physical layer connection and are ready to establish the second layer connection, referred to as the link layer connection, via an error-correction negotiation sequence **44** in accordance with the present invention, as disclosed below.

II. Link Layer Connection

The link layer is the second layer of the ISO model protocol stack and includes negotiating and establishing an error-correcting connection such as with ITU Standard V.42 or Microcom Networking Protocol (MNP). The link layer connection follows the physical layer connection and uses the physical layer in establishing the error-corrected connection. It is noted, however, that conventional wisdom to date has maintained the link layer connection be independent of the physical layer connection when establishing a connection between two modems. In contrast, the present invention establishes the link layer connection based upon the modulation chosen in the physical layer connection during the automatic mode synchronization sequence **40** (FIG. **2**). Thus, the steps for establishing an error-correcting protocol are eliminated and the link layer connection is established substantially instantaneously upon the completion of the physical layer negotiation. This not only reduces the amount of time required to establish a connection between two modems, it makes the connection more robust by removing the necessity of performing additional handshaking that, if corrupted for whatever reason, will result in a disconnect or call connect failure.

By way of example, the ITU Standard V.42 (hereafter referred to as V.42) comprises a detection phase, and exchange identification (XID) phase, and a link establishment phase, all of which are briefly discussed below. A more detailed explanation of V.42 can be found in the publicly-available ITU (CCITT) Recommended Standard V.42 documentation.

The detection phase is provided to determine whether the answer modem supports an error-correcting protocol. This phase is designed to avoid the potential disruptions to the answer DTE that could occur if the calling modem immediately enters the XID phase and the answering modem was not capable of an error-correcting communication. However, the detection phase is optional and may be disabled. If the call modem determines that the answering modem does not support a V.42 error-correcting protocol, there are often times fall-back error protocols provided by the calling modem, such as in the case of V.42, where MNP is provided as a fall-back error-correcting protocol. Alternatively, if the answer modem does not support V.42 nor MNP, then no error-correcting protocol is established and a connect message is issued by the modems to their respective digital terminal equipment so that user data can be transmitted between the two modems.

The XID phase is provided for the negotiation of the error-correcting parameter values. These parameters essentially govern the error-correcting operation of the modems once the connection is established. As with the detection phase, the XID phase may be omitted if default parameter values are acceptable. For example, the following are provided as the default parameters values in the V.42 standard: Standard Reject, 16 bit FCS (Frame Check Sequence), V.42bis compression disabled, Frame Length (N401) of 128 octets, and Window Size (k) of 15 frames. However, the default settings are more often than not undesirable because, for example, most modems wish to negotiate Selective Reject, V.42bis data compression, and longer Frame Lengths and Window Sizes.

Lastly, the link establishment phase is provided for actually making the error-corrected connection between the two modems. In V.42, this is implemented via a set asynchronous balanced mode extended (SABME) command. The SABME command is used to place the addressed error-corrected entity (i.e., the answering modem) into the connected state. The error-correcting entity then confirms acceptance of the SABME command by the transmission of an unnumbered acknowledgment (UA) response. By acceptance of this command, the error-corrected connection is essentially established and the modems then send a connect message to their respective data terminal equipment, such as computer **15** (FIG. **1**).

Unlike the detection phase and the XID phase, the link establishment phase is not optional and must be performed under V.42. Thus, in a best case scenario, only the link establishment phase is performed, which takes approximately 0.5 seconds. If all three phases are performed, then the link layer connection may take three or more seconds.

Therefore, establishing an error-corrected connection with V.42 can take up to three seconds, depending on what defaults are set in the system. While this amount of time does not seem significant relative to the time required for establishing a physical layer connection via V.34 modulation (e.g., approximately 10–15 seconds), it is considerably more noticeable when a fast connect protocol is utilized that can establish a physical layer connection in about 1 second. Thus, when using a fast connect protocol, the error-correction negotiation can easily double the connect time, not to mention introduce a greater opportunity for failure by requiring additional handshaking.

Accordingly, the present invention enables an error-corrected connection without having to perform the steps described above with regard to V.42, or those steps associated with other error-correcting protocols as known in the art. The present invention achieves this by presetting the XID phase parameters to default values that are based upon the negotiated physical layer connection. Therefore, when two multi-mode modems negotiate a physical layer connection, the link layer connection can be immediately established based upon the negotiated physical layer modulation. For example, in the embodiment described above in Section I, the exchange of tones in the mode synchronization sequence **40** indicates to each modem the type of modem it

is communicating with, and therefore, certain assumptions can then be made regarding the error-correction negotiation sequence **44** so as to eliminate the steps normally performed to establish an error-corrected connection. In the preferred embodiment of the present invention with the V.42 standard, the following parameters are set to the indicated default values when the two modems are capable of the fast connect sequence described above: Selective Reject, 16 bit FCS, 64 bit Maximum Frame Size (transmit and receive directions), 8 Frame Window Size (transmit and receive directions), V.42bis enabled, and 1,024 bit dictionary (transmit and receive directions). It should be noted, however, that one of ordinary skill in the art would recognize that these default values are merely illustrative settings and that different default values can be used. Moreover, each different type of connect sequence would preferably have its own set of default values. If it is determined by the modems in the mode synchronization sequence **40** that one or the other is not capable of a fast connect as described above, then the modems essentially fallback and perform an alternative error-correction sequence such as the recommended ITU Standard V.42 error-correction sequence.

With reference to FIG. **8**, a graphical illustration is provided of two fast connect modems in a first connect sequence **102** where error-correction negotiation is performed without the present invention and a second connect sequence **104** where the error-correction negotiation is performed with the present invention. As shown, following the mode synchronization sequence (also referred to as automode) **40** and the training and start-up sequence **42**, the connect sequence **102** performs error-correction negotiation **44** which essentially doubles the time required for a connection to be established so as to allow user data **106** to be exchanged. In comparison, the connect sequence **104** in accordance with the present invention is able to establish a connection in essentially half the time by eliminating the error-correction negotiation **44**. Thus, by establishing the error-correction parameters to default values in accordance with the type of physical error-connection determined by the automode sequence **40**, a faster and more reliable connection is established.

Regarding the implementation of the present invention, FIG. **9** generally illustrates the components of MSC (cellular) modem **20** and MSC(PSTN) modem **24** which implement the data gateway. The MSC(cellular) modem **20** comprises a digital signal processor (DSP) **112**, a control processor **114**, and a DTE interface **116**. Likewise, the MSC(PSTN) modem **24** comprises a DSP **118**, a control processor **120**, and a DTE interface **122**. The DTE interface **116** of the MSC(cellular) modem **20** interfaces with the DTE interface **122** of the MSC(PSTN) modem **24** via the connection **38**, which can be implemented by any suitable interconnecting device such as, but not limited to, an Electronic Industry Association (EIA) standard RS-232 crossover or a backplane bus between the modems. As shown in FIG. **9**, each modem **20**, **24** is configured essentially the same, and thus, they operate in essentially the same manner. However, each modem is provided with operating code which is stored in a memory device **124**, **124'** provided with the central processor **114**, **120**, respectively, though additional memory can also be provided and connected to the control processor **114**, **120**, if necessary. In the context of the present disclosure, a memory device is a computer readable medium that is embodied in an electronic, magnetic, optical or other physical device or means that can contain or store a computer program, such as the operating code for the modem **20**, **24**, for use by or in connection with a computer related system or method. The operating code includes control logic that controls, among other things, the type of modulation and error correction techniques utilized which is dependent upon whether the modem is used for cellular or land-line connections. Accordingly, the control processor **114**, **120** operates on, or executes, the operating code that is in memory device **124**, **124'** and configured for implementing the present invention so as to control the operation of modem **20**, **24**.

The foregoing description has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obvious modifications or variations are possible in light of the above teachings. The embodiment or embodiments discussed were chosen and described to provide the best illustration of the principles of the invention and its practical application to thereby enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly and legally entitled.

Wherefore, the following is claimed:

1. A method for establishing a link layer connection between a calling modem having a plurality of possible first physical layer modulations and a plurality of possible link layer connections and an answering modem having a plurality of possible second physical layer modulations and a plurality of possible second link layer connections, comprising the steps of:

establishing a physical layer connection between said calling and said answering modems, wherein said physical layer connection is based on a negotiated physical layer modulation chosen from said first and second physical layer modulations; and

establishing said link layer connection based upon said negotiated physical layer modulation.

2. The method of claim **1**, wherein said negotiated physical layer modulation is a fast connect modem modulation.

3. The method of claim **1**, wherein said link layer connection is an error-correcting protocol.

4. The method of claim **1**, further comprising the step of presetting link layer parameters of said link layer connection to default settings based on said negotiated physical layer modulation.

5. The method of claim **3**, wherein said error-correcting protocol includes parameters that are set to pre-defined settings based on said negotiated physical layer modulation.

6. A system for establishing a link layer connection between a calling modem having a plurality of possible first physical layer modulations and a plurality of possible link layer connections and a answering modem having a plurality of possible second physical layer modulations and a plurality of possible second link layer connections, comprising:

means for establishing a physical layer connection between said calling and said answering modems, wherein said physical layer connection is based on a negotiated physical layer modulation chosen from said first and second physical layer modulations; and

means for establishing said link layer connection based upon said negotiated physical layer modulation.

7. The system of claim **6**, wherein said negotiated physical layer modulation is a fast connect modem modulation.

8. The system of claim **6**, wherein said link layer connection is an error-correcting protocol.

9. The system of claim **6**, further comprising means for presetting link layer parameters of said link layer connection to pre-defined settings based on said negotiated physical layer modulation.

10. A computer program product having a computer readable medium including computer program logic recorded thereon for use in a calling modem for establishing a link layer convention between said calling modem having a plurality of possible first physical layer modulations and a plurality of possible link layer connections and an answering modem having a plurality of possible second physical layer modulations and a plurality of possible second link layer connections, comprising:

logic for establishing a physical layer connection between said calling and said answering modems, wherein said physical layer connection is based on a negotiated physical layer modulation chosen from said first and second physical layer modulations; and

logic for establishing link layer connection based upon said negotiated physical layer modulation.

* * * * *

EXHIBIT G

US006131159A

United States Patent [19]

Hecht et al.

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[45] **Date of Patent: Oct. 10, 2000**

[54] **SYSTEM FOR DOWNLOADING PROGRAMS**

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[73] Assignee: **Paradyne Corporation**, Largo, Fla.

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[51] **Int. Cl.**[7] **G06F 9/445**

[52] **U.S. Cl.** **713/1**; 713/100; 711/1

[58] **Field of Search** ..... 395/700, 651, 395/652, 653, 712; 364/DIG. 1, DIG. 2; 713/1, 2, 100; 711/114, 1, 145, 202–206; 710/23, 104

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[57] **ABSTRACT**

A modified version of the operating communication program of a stored program controlled apparatus is installed with the aid of a downloadable start address specification means, optionally realized with an EEPROM memory. The start address specification means stores information that is downloaded through a communication port in the apparatus, and that information is used in defining the address from where the communication programs are initiated. In accordance with the method of this invention, downloading of the entire new set of programs is effected by first downloading a segment of the essential portion of the new package of programs. Control is then transferred to the new segment by downloading appropriate information into the start address specification means. Thereafter, utilizing the downloaded essential portion of the new package of programs, the remainder of the new package is downloaded.

21 Claims, 1 Drawing Sheet

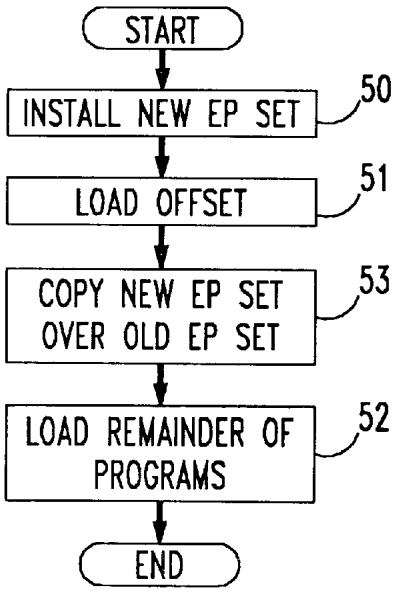


FIG. 1

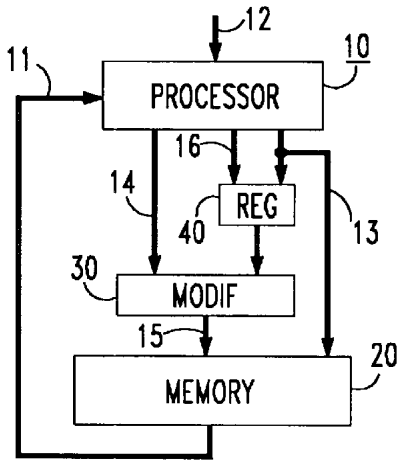


FIG. 2

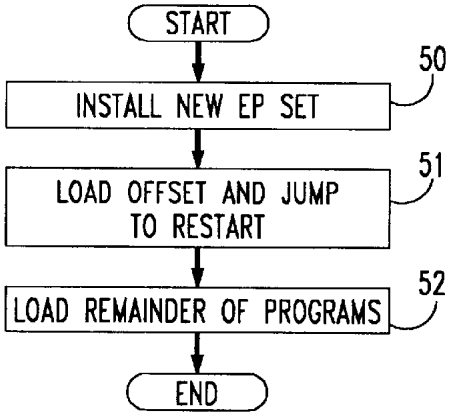
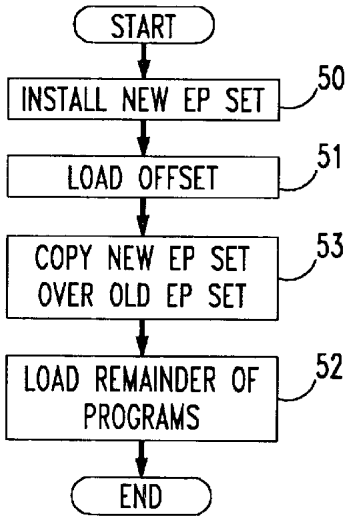


FIG. 3



SYSTEM FOR DOWNLOADING PROGRAMS

BACKGROUND OF THE INVENTION

This invention relates to stored program controlled apparatus and, in particular, to apparatus with a capability for remote updating of its entire set of programs.

Stored program controlled apparatus can conveniently be divided into two types; one where the stored programs are completely unalterable under normal operating circumstances, and the other where the stored programs are alterable, at least at times, during normal operation. In apparatus of the first type, the program is often executed automatically and the user does not even know that the controlled apparatus is "stored program controlled". This is typically the case in equipment that is designed for people who are not knowledgeable in computers and for whom the equipment is just a tool of the trade. "Point of sale" terminals, such as check-out terminals at a supermarket, are a good example. Modems are another example. People who use this equipment desire fail-safe operation and they do not want to be bothered with loading programs, fixing program bugs, installing updated versions of software, etc.

One approach to programming such equipment is to imprint the program into read-only-memory integrated circuits and physically install the circuits into the equipment. The problem with this approach is that updated versions of the program require the creation of new sets of read-only memories and new installations.

When a communication link is present, "downloading" the programs to the equipment from a remote processor, through the communication link, forms another approach for programming the equipment. It has been known in the art for some time that it is feasible to download limited types of control information from a remote processor. It is also known to download entire machine language application programs. Often such equipment does not include writable non-volatile store, such as a hard disk, so the programs are stored in battery protected read/write memories. This is an unattractive solution because it leaves a substantial portion of program memory to be at risk. To mitigate this problem, U.S. Pat. No. 4,724,521, suggests storing within read-only memories of the local equipment a number of general purpose routines which comprise instructions to be executed by the central processing unit to accomplish a particular program task. These, in effect, form a set of macro-instructions. The downloaded machine language program utilizes these macro-instructions to the extent possible, and thereby achieves flexibility without the need to download substantial amounts of program code.

In all of the known approaches, however, there is a program portion in the local equipment that is resident in a read-only memory, and its contents are not changed. That resident portion contains "boot-up" segments and program segments that are necessary to maintain the communication between the remote processor and the local equipment (so that the process of downloading the programs can continue). This set of programs is the "essential programs" (EP) set. This set of programs should, of course, be a non-volatile store because there is always a possibility of power loss.

The fact that the EP set is needed to maintain communications presents a problem when the EP set itself needs to be modified or updated. Indeed, that is often the case with modems, where essentially the sole function of the modem software is to support communication.

SUMMARY OF THE INVENTION

The problem of downloading a modified version of the operating communication program, and the problem of

effectively updating the entire set of programs in a stored program controlled apparatus, such as a modem, is solved with a downloadable start address specification means and, optionally, with an EEPROM memory. The start address specification means stores information that is downloaded through the communication link, and that information is used in defining the address from where the communication link programs are initiated.

In accordance with the method of this invention, downloading comprises what may be considered two communication segments. In the first segment the essential portion of the new package (EP set) of programs is downloaded to some chosen location in the local apparatus and the downloadable start address specification means is loaded with the appropriate new start address. Utilizing the most recently downloaded EP set of the new communication package, the second segment downloads the remainder of the new package.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** presents a block diagram of an arrangement for carrying out this invention;

FIG. **2** is a flow diagram of a downloading process in accordance with this invention; and

FIG. **3** is a flow diagram of an augmented downloading process in accordance with this invention.

DETAILED DESCRIPTION

A modem's primary function is to enable communications between a customer's digital equipment and a remote apparatus over a transmission medium. In a modem with a stored programmed controlled architecture this communication is effected with a set of programs, which includes call establishment programs, link layer protocols with flow control and error recovery functions, and programs that handle and store the communicated data, as well as the modulation and demodulation programs used by the modem. These programs occupy a significant portion of the modem's program memory. In accordance with this invention, all programs—including the EP set of programs that carry out the elemental communications—are downloadable. That is, the apparatus employing the principles of this invention does not need to have a non-volatile "boot-up" read-only-memory. All programs (including the boot-up programs) can be stored in a single memory arrangement which, for some applications, can consist of just two memory blocks.

FIG. **1** depicts one structure that, in conformance with the principles of this invention, enables the downloading of programs to the modem's program memory. FIG. **1** includes a processor element **10** with a port for receiving signals from, and sending signals to, line **12**. Processor **10** is also responsive to line **11** data from program memory **20**, and it supplies address and data to memory **20** via bus **13** and bus **14**, respectively. In a conventional processor structure, bus **14** is connected to an address port of memory **20**. In FIG. **1**, address modifier **30** is interposed between processor **10** and program memory **20**, with bus **15** supplying the address information to memory **20**. Modifier **30** is responsive to register **40**, which is loaded with bus **13** data when the register is enabled by bus **16**. Modifier **30** is a modulo M adder, where M is the size of memory **20**. A typical stored program controlled modem also includes a read/write data memory, means for interfacing with the transmission medium, means for interfacing with the local digital equipment, and perhaps other data and control ports. For purposes of this invention, however, these other elements are irrelevant, so they are not included in the drawing.

It should be understood that line **12** in the FIG. **1** architecture effectively offers a "remote execution" capability to processor **10**, in that the programs which are executed by processor **10** are affected by data supplied by line **12**. For example, data supplied by line **12** can effect branching to programs that are normally dormant. One such normally dormant program is a program that downloads information to the program memory. It should also be understood, and noted, that although this invention is described in connection with modems, its principles are applicable to all stored program apparatus. In particular, the principles of this invention are applicable to all situations where it is desirable to download an entire set of new programs, including the EP set. For example, this invention is useful in PCs, "point of sale" terminals, etc.

The operation of the FIG. **1** apparatus is quite simple. The processes carried out by the FIG. **1** apparatus are effected by executing a sequence of instructions that the processor receives from program memory **20** via bus **11**. In turn, processor **10** determines which instructions are delivered to it by controlling the addresses applied to memory **20** (typically by controlling a "program counter" within processor **10**, which is not shown in the FIG.). The primary difference between a conventional microprocessor arrangement and the FIG. **1** arrangement is that the addresses supplied on bus **14** are not the actual addresses that are applied to program memory **20**, because of the interposed circuit **30**. One might call these addresses "virtual addresses", which are translated into the real addresses by the additive constant applied by register **40** to modifier circuit **30**.

The exact structure and organization of the programs executed by the FIG. **1** arrangement is not really relevant to this invention, but it is to be understood that a protocol exists for sending information out on line **12** and for receiving information from line **12**. This protocol provides a mechanism for intelligent communication with processor **10**, which includes, for example, knowing when the received data is commands or data, and whether to store the received data in memory **20** or elsewhere.

The programs that can be executed by the FIG. **1** arrangement reside throughout memory **20**, but the set of programs that is essential to the maintenance of communication with line **12** (the EP set) may, advantageously, occupy a contiguous segment of memory **20** addresses in the range 0 to N. Within that range of addresses there is a subroutine for installing a new EP set.

In accordance with the principles of this invention, the entire set of programs contained in memory **20** can be over-written with a new set of programs (in a process initiated by the apparatus itself or by the party connected to the apparatus via line **12**) by following the procedure outlined in FIG. **2**. In step **50** of FIG. **2**, a command is received on line **12** to branch to the subroutine in the EP set that installs new EP sets (that command may simply be a data word that is installed in a particular read/write memory location). After supplying the branch instruction, the new EP set of programs are downloaded via line **12**. Optionally, an offset address that is the starting address of the new EP set (the address corresponding to 0 in the existing EP set) is also downloaded. Alternatively, the offset address may be predefined, in which case it does not need to be supplied by line **12**. In any event, the offset address is greater than N and less than M−N. It may be noted that N must be less than M/2, because two EP sets must temporarily coexist in memory **20**.

After the new EP set is installed in memory locations X through X+N, where X is the offset address (X=M/2, for example), memory locations that serve as software-defined registers in the new EP set are populated with data that is found in the corresponding software-defined addresses in the active EP set. Thereafter, according to step **51**, register **40** is loaded with the offset address.

The immediate effect of loading the offset address into register **40** is to transfer control to the newly installed EP set. That means that the program in the new EP set to which control is transferred, must be at a predetermined logic point so that the communication can continue seamlessly. This minor requirement can be easily accommodated by proper planning of the new EP set. Once operation proceeds under control of the new EP set of programs, according to FIG. **2**, step **52** conditions processor **10** to account for the offset present in register **40** and loads the remainder of programs destined for memory **20** in addresses higher than X+N (modulo M).

It is obviously important to protect the information loaded into memory **20** from loss. At the very least, that means that memory **20** must be non-volatile. Currently, we use an electrically bulk erasable, programmable, read-only memory (FLASH EEPROM) to form memory **20**. This memory must be erased in bulk before new information can be written in it. To install a new EP in such a memory, it is recalled that the EP set must occupy less than half of memory **20**, and that makes it convenient to construct memory **20** from at least two distinct erasable memory blocks (distinct in the sense of being able to erase one and not the other). Each segment of the downloading process begins with a bulk erasure of one of the memory **20** halves.

To summarize the downloading process of this invention,

1. Bulk erase the that half of memory **20** which does NOT contain the EP set of programs;
2. download a new EP set of programs to the erased half of memory **20**;
3. download the offset address to pass control to the new EP set of programs;
4. bulk erase the other half of memory **20**;
5. download the remainder of programs into memory **20**.

If register **40** is to contain the offset address for a substantial time after downloading is accomplished, then its contents must be protected in a manner not unlike that of memory **20**. Of course, register **40** can manufactured together with memory **20** and be an EEPROM. However, that is not absolutely necessary, and manufacturing costs could benefit if register **40** were constructed as part of the read/write memory or as part of processor **10**.

Register **40** may be a volatile memory if the downloading process is carried out as depicted in FIG. **3**. Specifically, by including a copy subroutine in the EP set of programs, the downloading process can be modified to the following (assuming the EP set is in the first half of memory **20**):

1. Bulk erase the second half of memory **20**;
2. download a new EP set of programs to the second half of memory **20**;
4. download the offset address to pass control to the new EP set of programs;
5. bulk erase the first half of memory **20**;
6. copy the contents of the second half of memory **20** into the first half of memory **20**;
7. reset the offset address to 0; and
8. download the remainder of programs into memory **20**.

Admittedly, during the copy sequence (which may also be a "move" sequence) the arrangement is vulnerable to power failures. Since the time of copying or moving is very small, this is a very unlikely event. Still, to protect against this unlikely event, the power source can be designed to have sufficient reserve to complete the copy operation, or to protect the starting address. A capacitor at the output of the power supply may supply the necessary power reserve.

In the arrangement described above where memory **20** consists of two FLASH EEPROM chips, register **40** needs to have only one bit of memory, and modifier circuit **30** can be merely an Exclusive OR gate which, with the aid of the one bit memory of register **40**, selects the bank of memory that is active.

What is claimed is:

1. A system comprising:

(a) a processor;

(b) a memory, and a set of programs stored in said memory that are executed when the system needs to be initialized, said memory being of a type which may be completely updated in its entirety but which is not volatile, said memory being the only program memory in said system; and

(c) alterable storage means for holding a displacement multi-bit memory address that is used to point to the starting address accessed by the processor when initializing.

2. The system of claim **1** wherein said memory is an EEPROM memory.

3. The system of claim **1** wherein said memory consists of 2-FLASH EEPROM devices.

4. The system of claim **1** wherein said alterable storage means is an EEPROM memory.

5. The system of claim **1** further comprising translation means interposed between said alterable storage means and said memory, wherein said alterable storage means holds an address that translates between addresses directed to the memory via said translation means and addresses actually applied to the memory by said translation means.

6. A system comprising:

(a) a processor;

(b) a memory coupled to said processor, said memory being the only program memory in the system, said memory being completely updatable in its entirety but non-volatile, there being a set of programs stored in said memory that are executed when the system needs to be initialized; and

(c) alterable memory means for storing a multi-bit memory address that controls the starting address accessed by the processor when initializing.

7. The system of claim **6** further comprising means for receiving a trigger signal at a telecommunications input port of the system to begin execution of said programs.

8. A system comprising;

(a) a processor;

(b) a memory and a communications port coupled to said processor, said communications port being adapted to communicate with devices which are external to said system, said memory being completely updatable in its entirety but non-volatile;

(c) a program module in said memory that, when activated by said processor, effects communication with said port; and

(d) operationally alterable means for setting the starting address of said program, which address is supplied to said system via said communication port.

9. The system of claim **8** wherein:

(a) said memory contains a first set of programs and a second set of programs;

(b) said memory is at least twice the size of the size of the first set of programs; and

(c) said operationally alterable means sets the starting position of the program executed by said processor in connection with communication with said port at a second specified location that is M removed from the first location, M being half the size of said memory.

10. A system comprising:

(a) a processor;

(b) a communication port coupled to said processor, said communication port being adapted to communicate with devices which are external to said system;

(c) a memory coupled to said processor, said memory being non-volatile and capable of being completely updated in its entirety, said memory containing programs, including a set of programs that are executed when the system needs to be initialized and a program for controlling communication through said communication port; and

(d) means for activating said program for controlling communication and receiving information through said communication port to modify the programs in said memory, said information including the program for controlling communication through said communication port and a command that is executed by said processor effectively when it is received.

11. The system of claim **10** wherein the communication port is a telecommunication port.

12. The system of claim **10** wherein the communication port is a telecommunication port and the programs execute the functions of a modem.

13. The system of claim **10** where the communication port receives commands to be executed by the processor and data to be stored in the memory.

14. The system of claim **10** wherein said means for receiving includes means for altering the program according to the information obtained by the means for receiving.

15. The system of claim **10** wherein said means for receiving modifies the programs by altering a portion of the memory contents pursuant to data received via said communication port.

16. The system of claim **10** wherein said means for receiving modifies the programs by replacing them with program data received via said communication port.

17. The system of claim **10** where the means for altering alters all of the programs in the system in a single communication session with said communication port.

18. A system comprising:

(a) a processor;

(b) a memory coupled to said processor, said memory being of a type, which is completely updatable in its entirety but non-volatile;

(c) a set of program means stored in said memory that are activated when said system needs to be updated wit a new set of programs, and

(d) alterable storage means for holding an offset memory address that is used to point to a starting address accessed by said processor when initializing.

19. The system of claim **18** wherein said memory is an EEPROM memory.

20. The system of claim **18** wherein said memory consists of 2 FLASH EEPROM devices.

21. The system of claim **18** wherein said alterable storage means is an EEPROM memory.

* * * * *

EXHIBIT H

US006950444B1

(12) **United States Patent**
Holmquist et al.

(10) **Patent No.: US 6,950,444 B1**
(45) **Date of Patent: Sep. 27, 2005**

(54) **SYSTEM AND METHOD FOR A ROBUST PREAMBLE AND TRANSMISSION DELIMITING IN A SWITCHED-CARRIER TRANSCEIVER**

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(73) Assignee: **Paradyne Corporation**, Largo, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 812 days.

(21) Appl. No.: **09/637,185**

(22) Filed: **Aug. 11, 2000**

Related U.S. Application Data

(60) Provisional application No. 60/150,436, filed on Aug. 24, 1999.

(51) **Int. Cl.**[7] **H04L 12/56**
(52) **U.S. Cl.** **370/476**; 370/477
(58) **Field of Search** 370/476, 471, 370/472, 474, 477, 389

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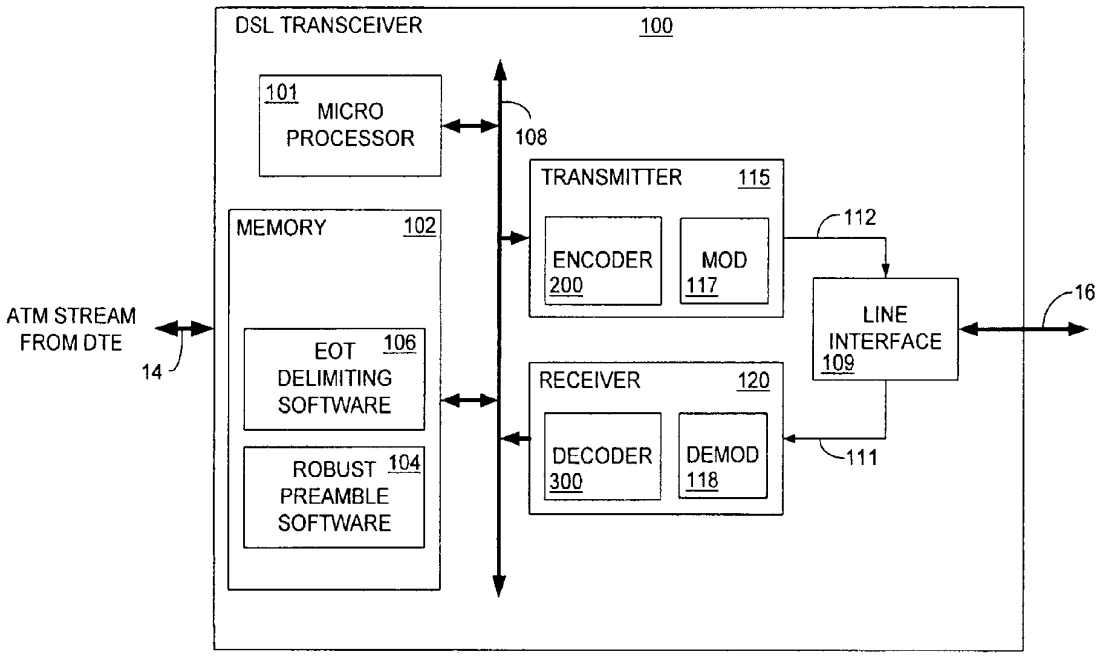
* cited by examiner

Primary Examiner—Kenneth Vanderpuye
(74) *Attorney, Agent, or Firm*—Thomas, Kayden, Horstemeyer & Risley LLP

(57) **ABSTRACT**

A method and system for robust delimiting of transmitted messages in switched-carrier operation in which a preamble precedes each communication message with the preamble comprising symbols transmitted at a rate lower than that of the following data. The lower rate symbols of the preamble significantly increase the probability that the decoder will decode the preamble symbols error free. Communication line control information can be included in the robust preamble, thereby ensuring that line control information is reliably transferred over the communication channel. The first symbol of the preamble can be transmitted at the lower symbol rate and at an increased power level, thereby clearly and reliably delimiting the beginning of a transmission. The end of the communication message can be reliably delimited by sending the first symbol containing only bits from a next cell of information at a lower symbol rate and including an extra bit in that symbol. The extra bit can be set to indicate to a receiver whether the last cell of information has just begun.

55 Claims, 10 Drawing Sheets



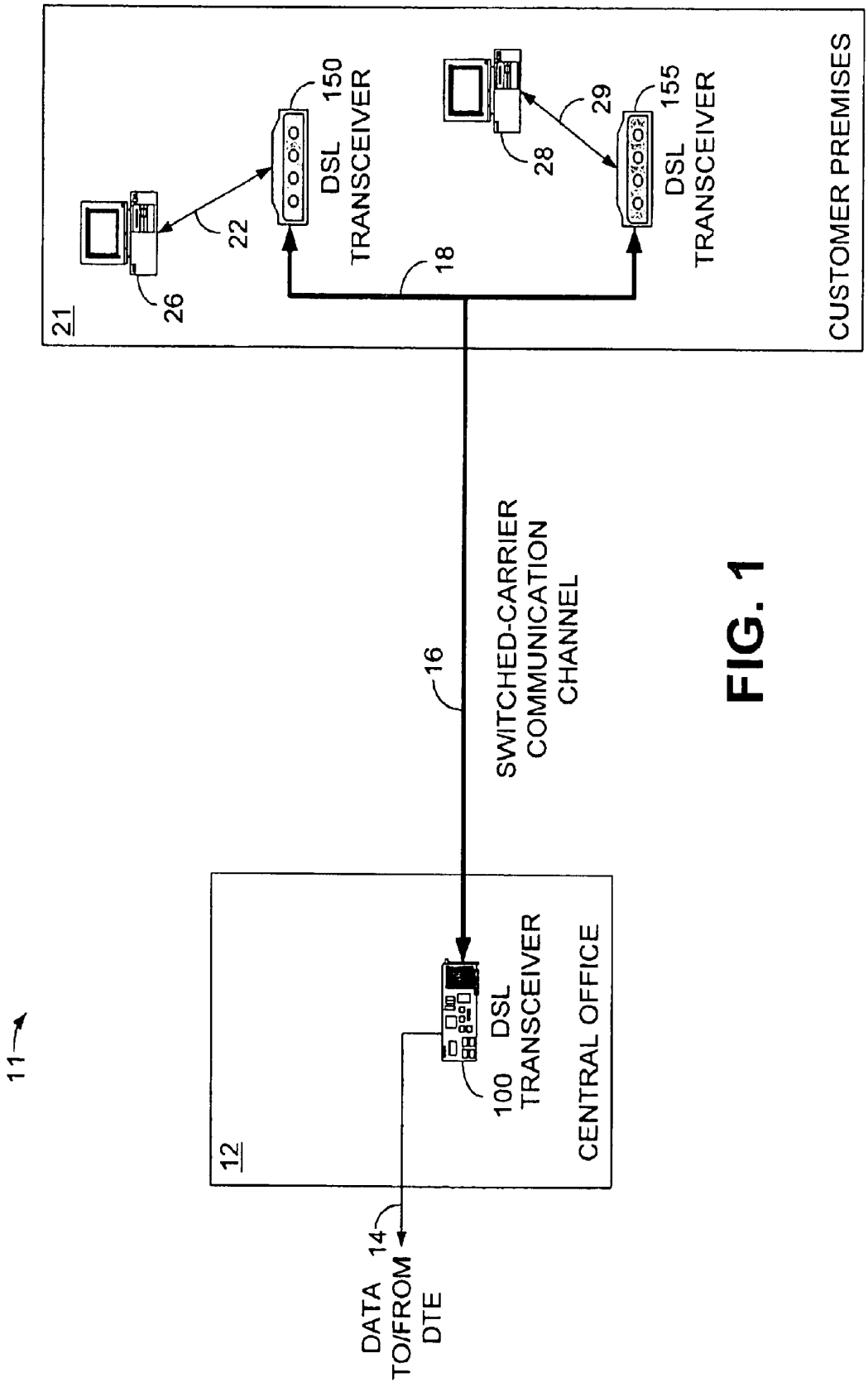

11
21
CUSTOMER PREMISES
DSL TRANSCEIVER
150
22
26
18
28
29
DSL TRANSCEIVER
155
16
SWITCHED-CARRIER COMMUNICATION CHANNEL
12
CENTRAL OFFICE
100 DSL TRANSCEIVER
DATA TO/FROM DTE
14

FIG. 1

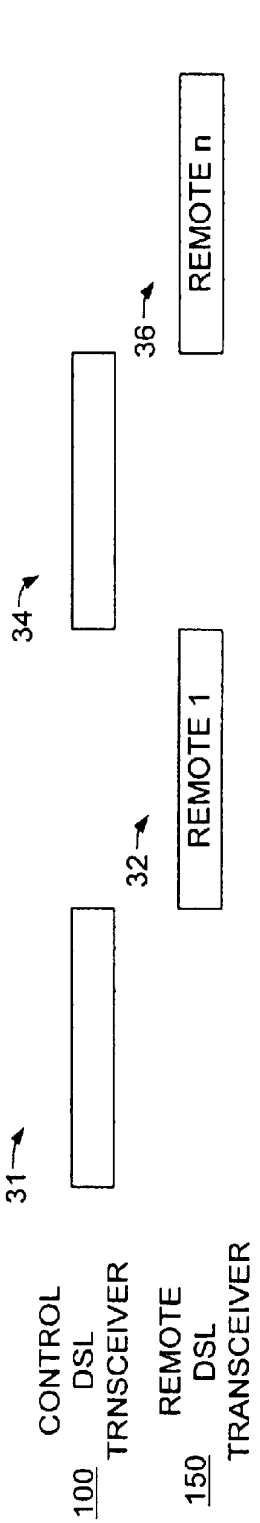

CONTROL DSL TRNSCEIVER
100
REMOTE DSL TRANSCEIVER
150
31
34
32
REMOTE 1
36
REMOTE n

FIG. 2A

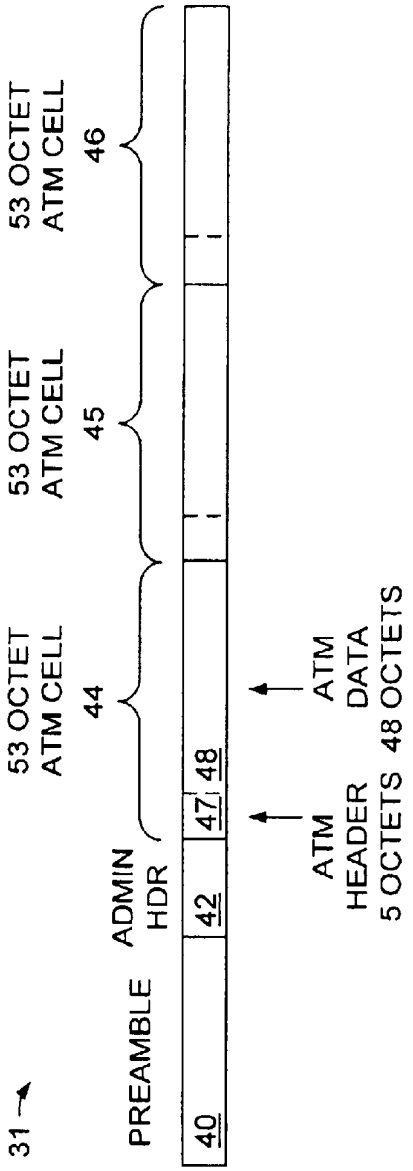

31
PREAMBLE
ADMIN HDR
40
42
47
48
53 OCTET ATM CELL
44
53 OCTET ATM CELL
45
53 OCTET ATM CELL
46
ATM HEADER 5 OCTETS
ATM DATA 48 OCTETS

FIG. 2B

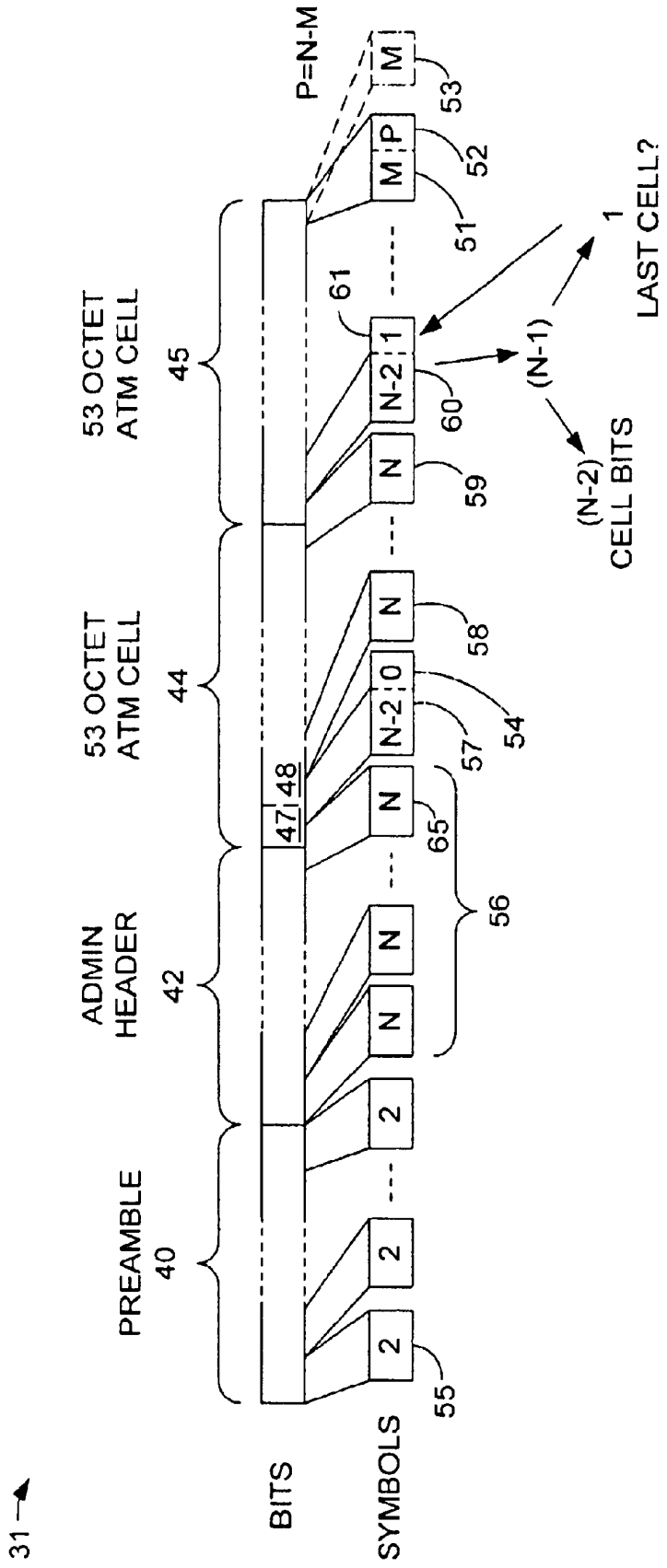

31
PREAMBLE
40
ADMIN HEADER
42
53 OCTET ATM CELL
44
53 OCTET ATM CELL
45
BITS
SYMBOLS
47
48
2
N
N-2
1
0
M
P
P=N-M
53
52
51
61
60
59
58
54
57
65
56
55
(N-1)
1
LAST CELL?
(N-2)
CELL BITS

FIG. 3A

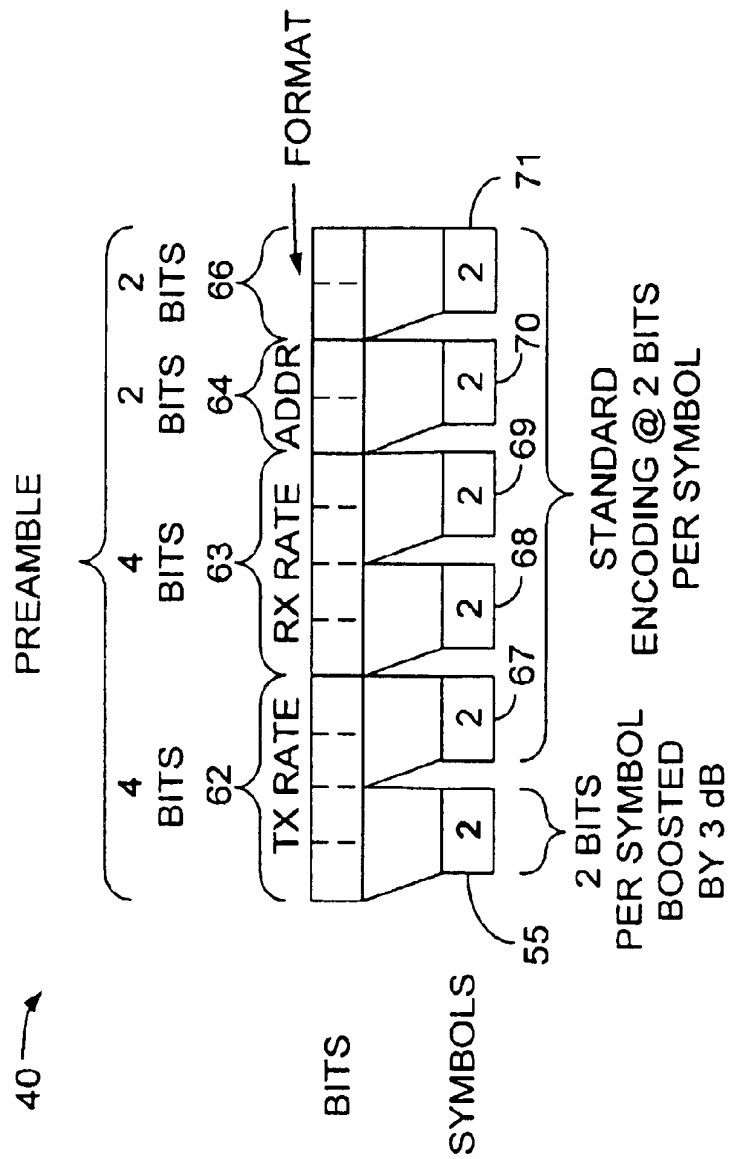

40
PREAMBLE
4 BITS
62
TX RATE
4 BITS
63
RX RATE
2 BITS
64
ADDR
2 BITS
66
FORMAT
BITS
SYMBOLS
2
55
2 BITS PER SYMBOL BOOSTED BY 3 dB
2
67
2
68
2
69
2
70
2
71
STANDARD ENCODING @ 2 BITS PER SYMBOL

FIG. 3B

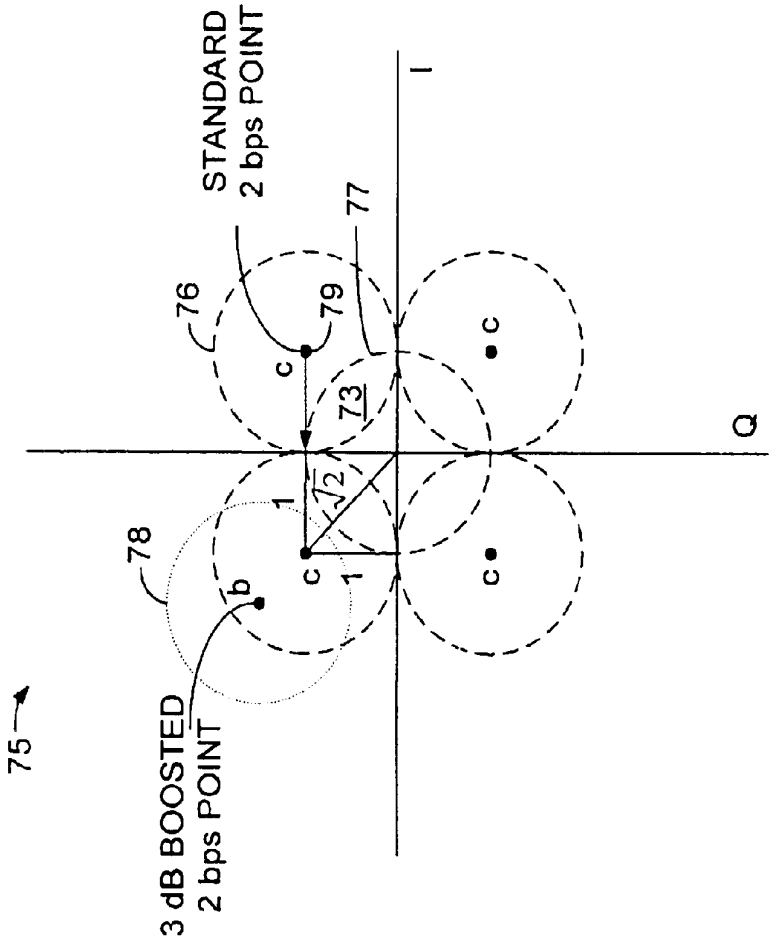

STANDARD
2 bps POINT
77
76
79
I
Q
c
73
1
√2
78
b
3 dB BOOSTED
2 bps POINT
75

FIG. 4A

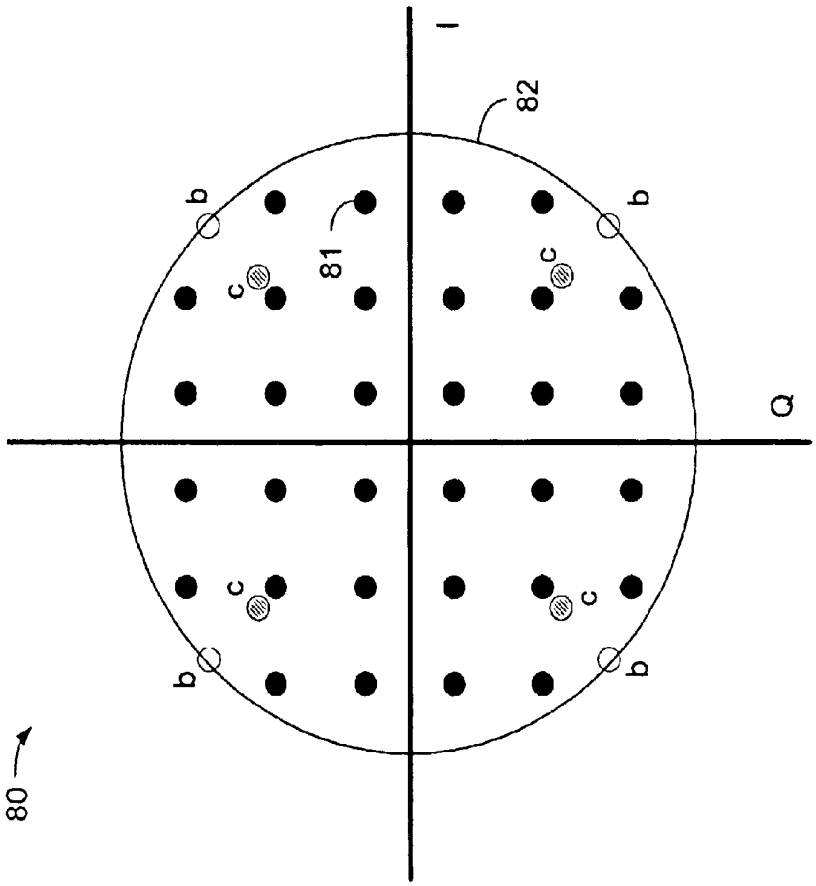


FIG. 4B

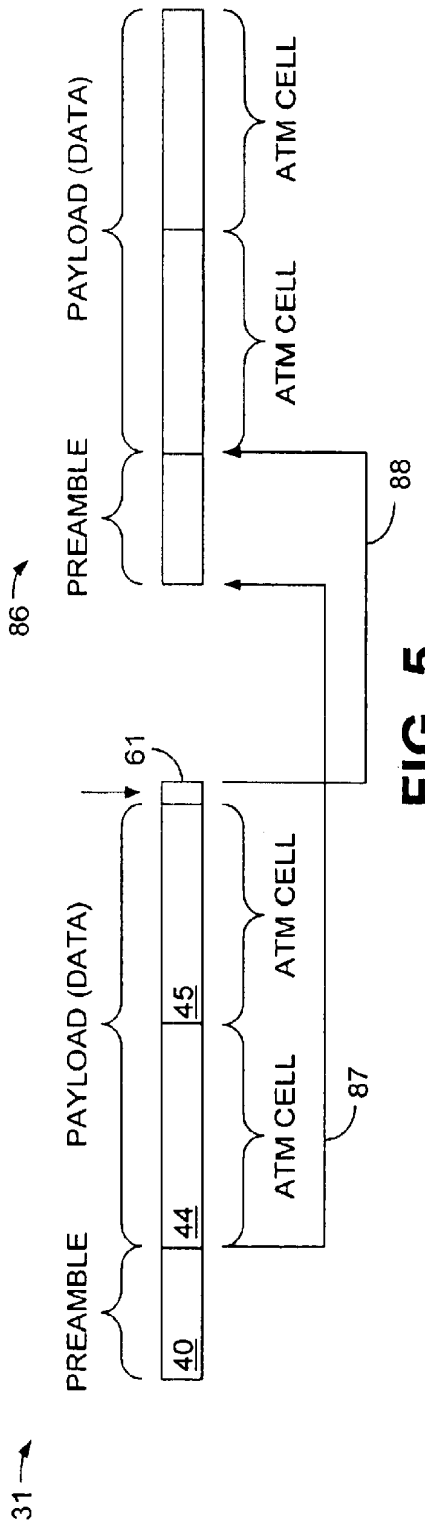

31
PREAMBLE
PAYLOAD (DATA)
40
44
45
61
ATM CELL
ATM CELL
87
86
PREAMBLE
PAYLOAD (DATA)
ATM CELL
ATM CELL
88

FIG. 5

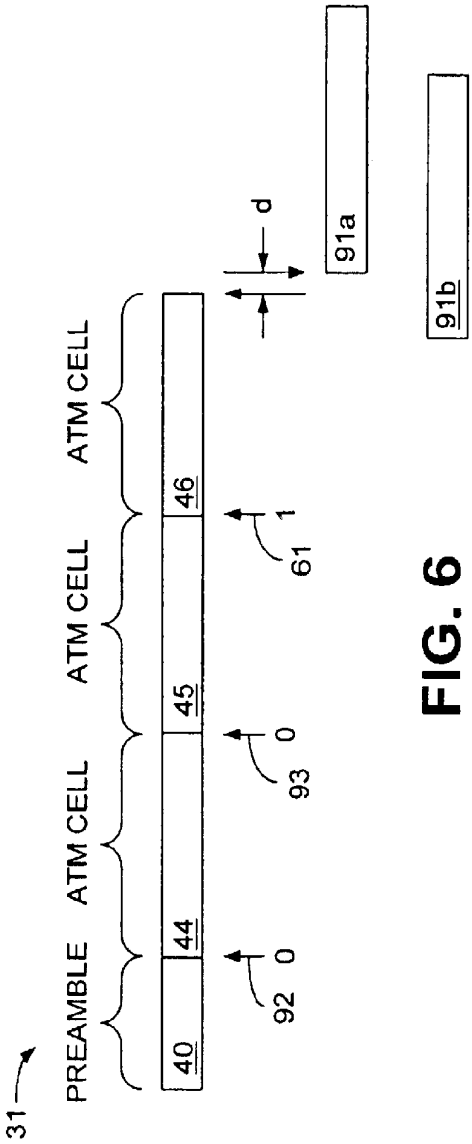

31
PREAMBLE
ATM CELL
ATM CELL
ATM CELL
40
44
45
46
92 0
93 0
61 1
d
91a
91b

FIG. 6

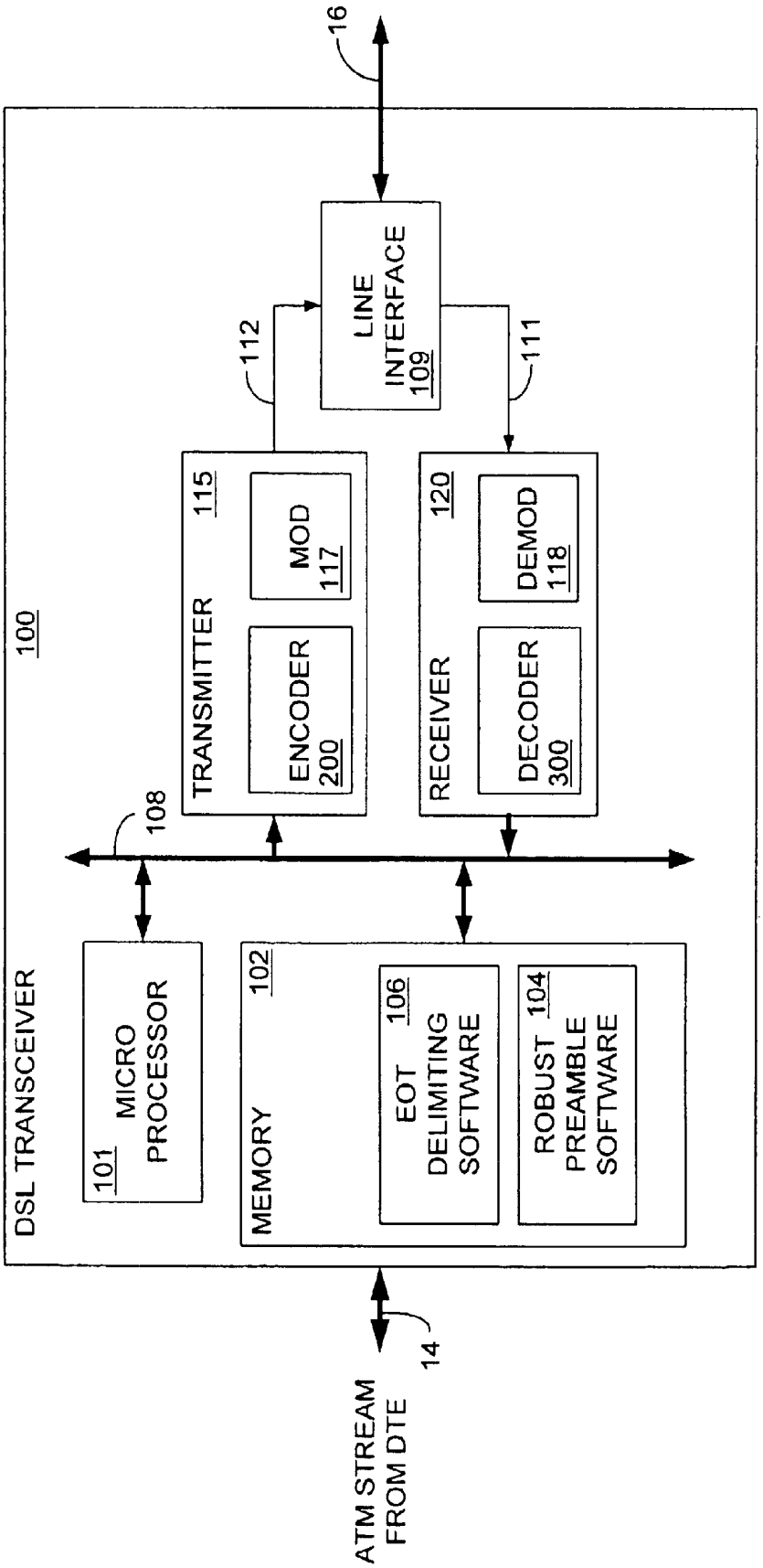

16
LINE INTERFACE 109
112
111
DSL TRANSCEIVER
100
TRANSMITTER 115
MOD 117
ENCODER 200
RECEIVER 120
DEMOD 118
DECODER 300
108
101 MICRO PROCESSOR
MEMORY 102
EOT DELIMITING SOFTWARE 106
ROBUST PREAMBLE SOFTWARE 104
14
ATM STREAM FROM DTE

FIG. 7

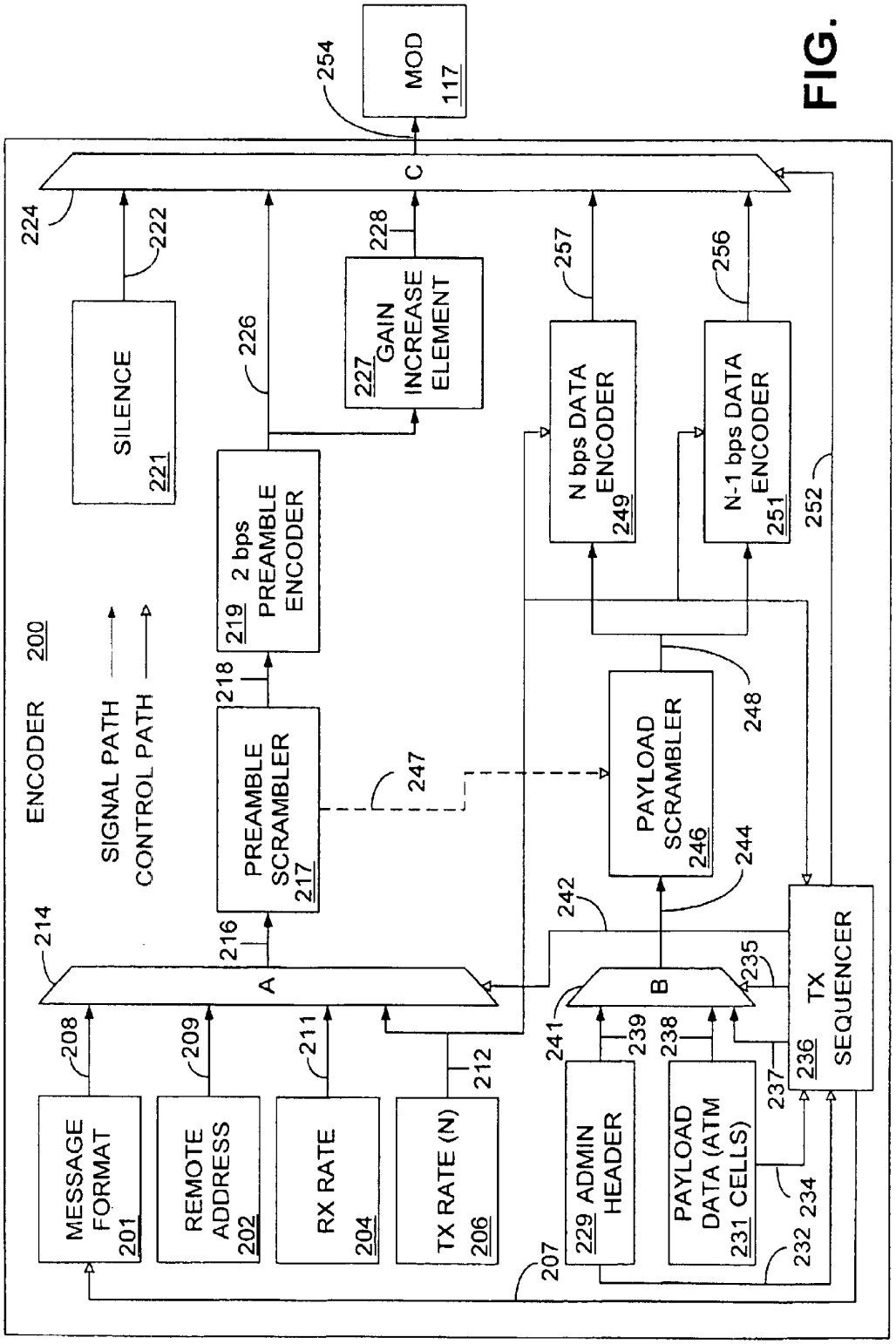

ENCODER 200
SIGNAL PATH
CONTROL PATH
MESSAGE FORMAT 201
REMOTE ADDRESS 202
RX RATE 204
TX RATE (N) 206
PREAMBLE SCRAMBLER 217
219 2 bps PREAMBLE ENCODER
SILENCE 221
227 GAIN INCREASE ELEMENT
N bps DATA ENCODER 249
N-1 bps DATA ENCODER 251
PAYLOAD SCRAMBLER 246
229 ADMIN HEADER
PAYLOAD DATA (ATM 231 CELLS)
236 TX SEQUENCER
MOD 117
A
B
C

FIG. 8

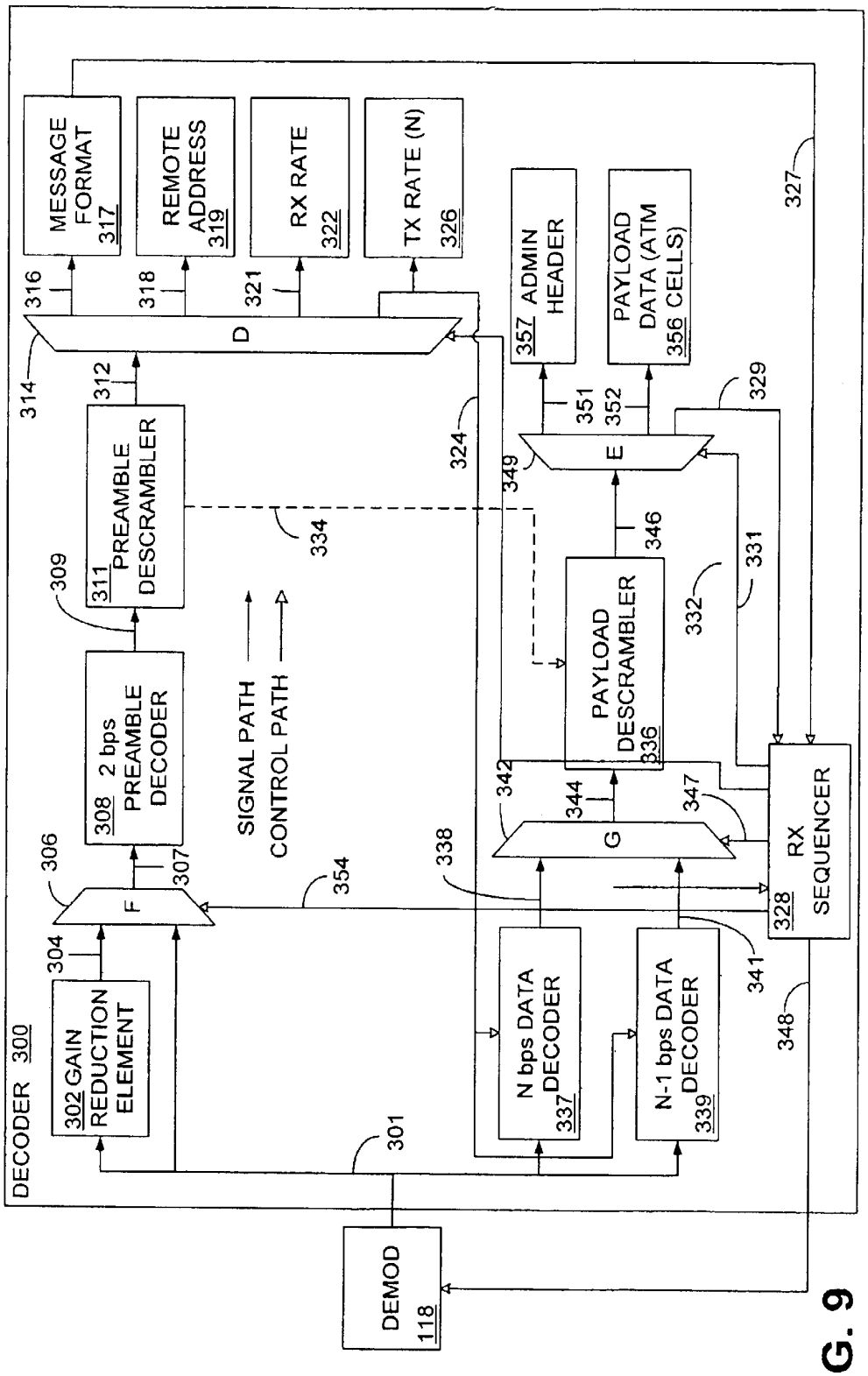

DECODER 300
MESSAGE FORMAT 317
REMOTE ADDRESS 319
RX RATE 322
TX RATE (N) 326
316
318
321
D
314
312
PREAMBLE DESCRAMBLER 311
309
PREAMBLE DECODER 308 2 bps
306
307
F
304
GAIN REDUCTION ELEMENT 302
SIGNAL PATH
CONTROL PATH
334
324
349
357 ADMIN HEADER
PAYLOAD DATA (ATM 356 CELLS)
351
352
E
329
346
PAYLOAD DESCRAMBLER 336
332
331
342
344
G
347
338
354
RX SEQUENCER 328
341
348
N bps DATA DECODER 337
N-1 bps DATA DECODER 339
301
DEMOD 118
327

FIG. 9

SYSTEM AND METHOD FOR A ROBUST PREAMBLE AND TRANSMISSION DELIMITING IN A SWITCHED-CARRIER TRANSCEIVER

CROSS-REFERENCE TO RELATED APPLICATIONS

This document claims priority to, and the benefit of, the filing date of Provisional Application Ser. No. 60/150,436 entitled "A TECHNIQUE FOR ROBUST SIGNAL DELIMITING AND ENCODING OF CRITICAL LINK CONTROL SIGNALS APPLIED TO TRANSMISSION OF ATM CELLS OVER A DSL USING ADAPTIVE TIME DOMAIN DUPLEX (ATDD)," filed on Aug. 24, 1999, which is hereby incorporated by reference.

TECHNICAL FIELD

The present invention relates generally to communications systems, and more particularly, to a system and method for a robust preamble and transmission delimiting in a switched-carrier transceiver.

BACKGROUND OF THE INVENTION

Data communication typically occurs as the transfer of information from one communication device to another. This is typically accomplished by the use of a modem located at each communication endpoint. In the past, the term modem denoted a piece of communication apparatus that performed a modulation and demodulation function, hence the term "modem". Today, the term modem is typically used to denote any piece of communication apparatus that enables the transfer of data and voice information from one location to another. For example, modem communication systems use many different technologies to perform the transfer of information from one location to another. Digital subscriber line (DSL) technology is one vehicle for such transfer of information. DSL technology uses the widely available subscriber loop, the copper wire pair that extends from a telephone company central office to a residential location, over which communication services, including the exchange of voice and data, may be provisioned. DSL devices can be referred to as modems, or, more accurately, transceivers, which connect the telephone company central office to the user, or remote location typically, referred to as the customer premises. DSL communication devices utilize different types of modulation schemes and achieve widely varying communication rates. However, even the slowest DSL communications devices achieve data rates far in excess of conventional point-to-point modems.

DSL transceivers can be used to provision a variety of communication services using, for example, asynchronous transfer mode (ATM). ATM defines a communication protocol in which 53 octet (byte) cells are used to carry information over the DSL communication channel. The first five octets of the ATM cell are typically used for overhead and the remaining 48 octets are used to carry payload data. When using a switched-carrier transmission methodology, a control transceiver may be connected via the DSL to one or more remote transceivers. In such a communication scheme, the transmission is commonly referred to as "half-duplex," which is defined as two way electronic communication that takes place in only one direction at a time. With only a single remote transceiver on a line, switched-carrier transmission may instead be employed in full-duplex mode (i.e., allowing transmission in both directions simultaneously). In this case, full-duplex operation is typically enabled by employing

either echo cancellation or frequency division multiplexing. Hybrid techniques are possible such as one in which there are multiple remote transceivers and communication takes place between the control transceiver and only one remote transceiver in full-duplex fashion. As it relates to the present invention, the common characteristic of these communication techniques is the use of a switched-carrier modulation in which transmitters are deliberately silent for some interval between signal transmissions. For simplicity, the following discussions assume the simplest case of using switch carrier modulation with a half-duplex (also sometimes referred to as "time domain duplex") line usage discipline.

Before the transmission of ATM cells, a preamble containing channel, transmission, address and administrative information may be transmitted by the transceiver. The application of this preamble is sometimes referred to as "framing" the data to be transmitted. Due to the switched-carrier nature of the transmission, silence precedes this preamble and it is of course important for all symbols in this preamble to be received error free. It is also desirable to have the ability to precisely delimit the beginning and end of a transmission to within one transmitted symbol interval. Robustly delimiting the beginning of a message enables a receiving transceiver to reliably begin immediately decoding the message at the correct symbol. Likewise, robustly delimiting the end of a message enables a receiving transceiver to reliably decode the entire message through the final symbol and then stopping so as to prevent data loss and to prevent the inclusion of any false data. Furthermore, by communicating the end of message indicator to a receiving transceiver prior to the actual end of the message, line turnaround time (i.e., idle time on the line between transmissions) can be reduced, thereby increasing the effective use of the available line bandwidth.

Because the most efficient signal constellation encoding cannot allocate signal space to silence, it is impractical to reliably discriminate silence from a signal when analyzing only a single symbol encoding an arbitrary data value.

To improve message delimiting, existing techniques use special marker symbols whose symbol indices are greater than those used to encode data. At N bits per symbol (bps) data is encoded using symbol indices **0** through $\mathbf{2}^N$–1. The special symbols use indices $\mathbf{2}^N$ and above. While these special marker symbols are useful for marking the beginning and end of a transmission, their placement at the outer edges of a constellation raises the peak signal, thus increasing the peak to average ratio (PAR) across all data rates by as much as 4 dB. Unfortunately, discrimination of special symbols has the same error threshold as does decoding of data.

Thus, it would be desirable to have a robust manner in which to detect the beginning and end of a transmission so that line bandwidth can be most efficiently allocated. Furthermore, it would be desirable to robustly transmit a message preamble including control information thereby greatly improving the probability that the preamble is received error free.

SUMMARY OF THE INVENTION

The present invention provides an improved system and method for robustly delimiting a message transmission in switched-carrier communication systems. The invention provides a method and system for transmission of a message preamble in which transmission of the preamble is more robust than the data. In this manner, the beginning and end of a transmission can be robustly delimited and channel control information can be reliably conveyed to a receiving transceiver.

The system of the present invention uses a novel header application, which enables the transport of ATM, or any other data, efficiently and economically over a communications channel, such as a DSL communications channel.

Briefly described, in architecture, the system for robust transmission delimiting comprises a communication message including a preamble including a plurality of bits representing communication link control information, and an encoder configured to encode the preamble bits into a plurality of symbol indices. The symbol indices are encoded at a lower bit per symbol rate relative to the maximum rate capable of being supported over a communication channel.

In another aspect, the invention is a system for delimiting the end of a transmission. The system takes a communication message segmented into a plurality of fixed size units, each fixed size unit including a plurality of bits, and includes an encoder configured to encode the plurality of bits into a plurality of symbol indices at a first data rate. The encoder is also configured to encode the first symbol index containing only bits from each fixed size unit at a data rate lower than that of the first data rate.

The present invention can also be viewed as a method for robust transmission delimiting comprising the steps of applying a preamble to a communication message, the preamble including a plurality of bits representing communication link control information, and encoding the preamble bits into a plurality of symbol indices. The symbol indices are encoded at a lower bit per symbol rate relative to the maximum rate capable of being transmitted over a communication channel.

In another aspect, the invention is a method for delimiting the end of a transmission comprising the steps of segmenting a communication message into a plurality of fixed size units, each unit including a plurality of bits, encoding a plurality of the bits in the cells into a plurality of symbol indices, the symbol indices being encoded at a first rate, and encoding the first symbol index containing only bits from each fixed size unit at a rate lower than that of the first rate.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a schematic view illustrating a switched-carrier half-duplex communication environment, in which DSL transceivers containing the present invention reside;

FIB **2**A is an illustration of the time-domain duplex communication methodology employed by the DSL transceivers of FIG. **1**;

FIG. **2**B is a schematic view illustrating, in further detail, a communication message of FIG. **2**A;

FIG. **3**A is a schematic view illustrating the bit to symbol relationship of the communication message of FIG. **2**B;

FIG. **3**B is a schematic view illustrating, in further detail, the preamble of FIG. **3**A;

FIG. **4**A is a graphical illustration representing a two (2) bit per symbol signal space constellation and the increased energy symbol of FIG. **3**B;

FIG. **4**B is a graphical illustration showing an exemplar grouping of constellation points representing different bit per symbol rates in accordance with an aspect of the invention;

FIG. **5** is a schematic view illustrating the communication message of FIG. **3**A and a technique for scrambling that further improves reliable transmission of the message preamble;

FIG. **6** is a schematic view illustrating the communication message of FIG. **3**A and the reduced line turn around delay made possible by an aspect of the invention;

FIG. **7** is a block diagram illustrating the control DSL transceiver of FIG. **1**;

FIG. **8** is a block diagram illustrating the encoder of FIG. **7**; and

FIG. **9** is a block diagram illustrating the decoder of FIG. **7**.

DETAILED DESCRIPTION OF THE INVENTION

Although, described with particular reference to the transmission of ATM cells over a DSL communication channel, the system and method for a robust preamble and transmission delimiting can be implemented to transmit all forms of data in any switched-carrier transmission system in which it is desirable to send a robust preamble and to robustly delimit the beginning and end of each communication message.

Furthermore, the system and method for a robust preamble and transmission delimiting can be implemented in software, hardware, or a combination thereof. In a preferred embodiment(s), selected portions of the system and method for a robust preamble and transmission delimiting are implemented in hardware and software. The hardware portion of the invention can be implemented using specialized hardware logic. The software portion can be stored in a memory and be executed by a suitable instruction execution system (microprocessor). The hardware implementation of the system and method for a robust preamble and transmission delimiting can include any or a combination of the following technologies, which are all well known in the art: an discrete logic circuit(s) having logic gates for implementing logic functions upon data signals, an application specific integrated circuit having appropriate logic gates, a programmable gate array(s) (PGA), a field programmable gate array (FPGA), etc

Furthermore, the robust preamble and transmission delimiting software, which comprises an ordered listing of executable instructions for implementing logical functions, can be embodied in any computer-readable medium. Moreover, use by or in connection with an instruction execution system, apparatus, or device, such as a computer-based system, processor-containing system, or other system that can fetch the instructions from the instruction execution system, apparatus, or device and execute the instructions.

In the context of this document, a "computer-readable medium" can be any means that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The computer readable medium can be, for example but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, device, or propagation medium. More specific examples (a non-exhaustive list) of the computer-readable medium would include the following: a electrical connection (electronic) having one or more wires, a portable computer diskette (magnetic), a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory) (magnetic), an optical fiber (optical), and a portable compact disc read-only memory (CDROM) (optical). Note that the computer-

readable medium could even be paper or another suitable medium upon which the program is printed. As the program can be electronically captured, via for instance optical scanning of the paper or other medium, then compiled, interpreted or otherwise processed in a suitable manner if necessary, and then stored in a computer memory.

Turning now to the drawings, FIG. **1** is a schematic view illustrating a switched-carrier half-duplex communication environment **1**, in which DSL transceivers containing the present invention reside. Although the invention will be described below in a half-duplex communication environment, the DSL transceivers containing the invention may be used in a switched-carrier full-duplex environment as well. In such a case, full-duplex operation may be enabled using technologies such as echo cancellation or frequency division multiplexing. Communication environment **11**, includes central office **12** connected via communication channel **16** to customer premises **21**. Communication channel **16** can be any physical medium over which communications signals can be exchanged, and in the preferred embodiment, is the copper wire pair that extends from a telephone company central office to an end-user location, such as a home or office. Central office **12** includes DSL transceiver **100** connected to communication channel **16**. DSL transceiver **100** processes data via connection **14**. DSL transceiver **100** exchanges data via connection **14** with any data terminal equipment (DTE), such as a computer or data terminal.

Customer premises **21** includes one or more DSL transceivers **150** connected via internal infrastructure wiring **18** to communication channel **16**. The infrastructure wiring **18** can be, for example but not limited to, the telephone wiring within a private residence or within an office. DSL transceivers **150** can be connected to a variety of telecommunication devices located at customer premises **21**. For example, DSL transceiver **150** connects via connection **22** to a personal computer **26**. Although additional DSL transceivers can be located at customer premises **21**, an exemplar one of which is indicated using reference numeral **155**, the aspects of the invention to be discussed below are also applicable if only one DSL transceiver **150** is located at customer premises **21**. In the example given in FIG. **1**, DSL transceiver **155** connects to computer **28** via connection **29**.

The DSL transceiver **100** located at central office **12** is considered a "control device" and the DSL transceiver **150** located at customer premises **21** is considered a "remote device." This is so because the control DSL transceiver **100** controls the communication sessions by periodically polling each remote DSL transceiver **150** to determine whether the remote device has information to transmit. Regardless of the number of DSL transceivers located at customer premises **21**, the method of communication between DSL transceiver **100** located at central office **12** and DSL transceiver **150** located at customer premises **21** is half-duplex in nature, sometimes referred to as adaptive time-domain duplex, or data driven half-duplex, unless the above-mentioned technologies such as echo cancellation or frequency division multiplexing allow full-duplex operation between the control transceiver **100** and one remote transceiver **150**. This means that during any time period only one DSL transceiver may transmit at any time. In the situation in which there are multiple DSL transceivers located at customer premises **21**, the DSL transceiver **100** located at central office **12** periodically polls each DSL transceiver located at customer premises **21** at an appropriate time to determine whether any of the remotely located DSL transceivers have any information to transmit to central office **12**. If only one DSL transceiver **150** is located at customer premises **21**, the communication method may be half-duplex in nature or conventional full-duplex techniques may be used (e.g., using either frequency division multiplexing or echo cancellation).

FIG. **2**A is a schematic view illustrating the time-domain duplex communication methodology between a control DSL transceiver **100** and a remote DSL transceiver **150**. When a control DSL transceiver **100** desires to send a message to a remote DSL transceiver **150** the control DSL transceiver **100** sends a communication message **31** including a preamble and any information that is to be transmitted. There are times when the communication message may include only a preamble. After the transmission of communication message **31**, the remote DSL transceiver to which communication message **31** is addressed (in this example remote DSL transceiver **150**) responds with communication message **32**. After the remote DSL transceiver **150** completes the transmission of communication message **32**, the control DSL transceiver **100** is now free to send another communication message **34** to either the same remote DSL transceiver **150** or, if present, a different remote DSL transceiver, such as DSL transceiver **155** (remote "n") of FIG. **1**. As illustrated in FIG. **2**A, remote DSL transceiver "n" responds with communication message **36**. In this manner, the communication methodology between control DSL transceiver **100** and all remote DSL transceivers **150**, **155**. . . n, is switched-carrier and time-domain duplexed.

FIG. **2**B is a schematic view illustrating, in further detail, the communication message **31** of FIG. **2**A. Communication message **31** begins with preamble **40** followed by optional administrative header **42**. In accordance with an aspect of the invention, all communication messages, regardless of the content, begin with preamble **40**. Administrative header **42** is optional and can be used to send information that is neither part of the preamble **40** or of any data to follow. For example, the administrative header **42** could convey a description of noise level conditions at one end so the other end may opt to increase or reduce the power level of its transmission as necessary. Likewise, the administrative header **42** sent by a remote transceiver could contain information regarding the amount of payload information that the remote transceiver is ready to transmit and its relative priorities so that the control transceiver could alter the amount of time that this remote transceiver is given to transmit its data (relative to any other transceivers connected to the line). When the payload data comprises ATM cells, the control transceiver could use messages conveyed by the administrative header **42** to direct remote devices to activate or deactivate various ATM virtual circuits.

If data is included in communication message **31**, one or more ATM cells follow the optional administrative header **42**. Although illustrated using three ATM cells, **44**, **45** and **46**, there are situations in which no ATM cells, or for that matter, no information of any kind, follows preamble **40**. In the case in which information does follow preamble **40**, and for purposes of illustration only, ATM cells **44**, **45** and **46** are each standard 53 octet ATM cells. For example, ATM cell **44** includes 5 octet ATM header **47** and **48** octets of ATM data **48**. ATM cells **45** and **46** are identical in structure to ATM cell **44**. ATM cells **44**, **45** and **46** adhere to the conventional ATM cell structure as defined in standardized ATM literature. It should be noted that optional administrative header **42** does not follow the standard ATM cell format and that administrative header **42** can be any number of octets in length. As known to those having ordinary skill in the art, an octet comprises 8 bits of information. Although described with particular reference to the transportation of ATM cells

over a DSL communication channel, the principles of the invention are applicable to all fixed length communication messages.

FIG. **3**A is a schematic view illustrating the bit to symbol relationship of the communication message **31** of FIG. **2**B. In accordance with an aspect of the invention, preamble **40** is placed at the beginning of every transmission (i.e., each communication message **31**). Preamble **40** is followed by optional administrative header **42**, which is then followed, if there is data to transmit, by one or more 53 octet ATM cell **44** and **45**. Although illustrated using only two ATM cells, any number of ATM cells may follow preamble **40** and, if included, optional administrative header **42**. The ATM cells are a stream of data information represented as a series of bits that are placed into each ATM cell.

The preamble **40** is also a series of bits, which are encoded into a number of communication symbols. Symbols are the representation of the bits to be transmitted, and are represented as signal points in a signal space constellation (to be described below with respect to FIGS. **4**A and **4**B). In accordance with one aspect of the invention, each of the bits in preamble **40** are encoded into symbols, an exemplar one of which is illustrated using reference numeral **55**, at the lowest available bit rate that can be transmitted over the communication channel **16**. For purposes of illustration only, the symbols that encode the bits in the preamble **40** shown in FIG. **3**A are encoded at a rate of two (2) bits per symbol. However, any number of bits per symbol lower than that of the normally transmitted data rate can be used so long as the symbol rate allows a receiving device to more reliably decode those symbols. For example, if the normal data rate is five (5) bits per symbol, then a symbol rate of two (2) bits per symbol has a significantly (approximately 9 dB) higher noise margin than the five (5) bit per symbol data rate, thereby allowing the symbols that are encoded at the lower rate of two (2) bits per symbol to be very robustly and reliably decoded by a receiving device. In this manner, the preamble **40**, which is sent at the beginning of every communication message **31**, can be made sufficiently robust so that the chance that it will always be received error free is greatly increased. Although very robust, there are still situations in which the symbols into which the preamble bits are encoded can be corrupted. However, in accordance with another aspect of the invention, because the preamble **40** is sent at the beginning of every communication message **31**, even if the preamble **40** is corrupted, only data following that preamble may be affected, i.e., lost due to corruption, if certain bits of the preamble are corrupted.

In accordance with another aspect of the invention, the first symbol **55** representing the first bits in the preamble **40** can be sent using an increased power level, thereby clearly and robustly delimiting the beginning of the communication message **31**. The effect of this increased power level symbol **55** will be explained in greater detail below with respect to FIGS. **4**A and **4**B.

Still referring to FIG. **3**A, if an administrative header **42** is present in communication message **31**, then the bits that are contained in administrative header **42** will be encoded at a symbol rate of "N" bits per symbol, where N is the normal data rate. The normal data rate can be any data rate, for example, but not limited to, a value between 2 and 12 (inclusive) bits per symbol. For purposes of illustration, and for simplicity of explanation, the normal symbol rate can be five bits per symbol. This is represented by the group of symbols **56** into which all the bits of administrative header **42** and a portion of the bits of header **47** of ATM cell **44** are encoded.

In accordance with another aspect of the invention, the first symbol used to encode bits from a particular cell that contains bits only from that cell will be encoded at a data rate lower than that of the standard data rate used for all other bits of each cell. For example, symbol **57** is the first symbol that contains bits only from ATM cell **44**. The last symbol **65** of symbol group **56** contains bits from both administrative header **42** and ATM cell **44**. Likewise, symbol **60** is the first symbol containing only bits from ATM cell **45**. In accordance with this aspect of the invention, the symbols **57** and **60** will be encoded at a data rate that is two (2) bits per symbol lower than that of the preceding symbol (represented by N−2 where N is the number of bits per symbol used for encoding all other bits of the administrative header and ATM cells.) In this manner, because of the fixed length 53 octet ATM cells, by simple bit counting, the receiver will always know the first symbol encoding bits from a cell that contains only bits from this cell, and therefore has the special encoding described herein. These N−2 bits of the cell data are grouped for transmission and an additional bit (bit **54** for cell **44** or bit **61** for cell **45**) is added for a total of N−1 bits encoded into symbol **57** or **60**, respectively. This group of N−1 bits, represented by symbol **57** or **60**, is encoded into a symbol and scaled for transmission with the scaling normally applied when encoding at N−1 bits per symbol. The extra bit **54** or **61** indicates whether or not the cell just started (ATM cell **44** or **45**, respectively) is the last cell of the transmission. The extra bit **61** in symbol **60** is set to logic one to indicate that ATM cell **45** is the last cell of the transmission so that the receiver will know at the beginning of the receipt of ATM cell **45** that ATM cell **45** is the last cell in the transmission. For the same reason, bit **54** in symbol **57** set to zero so that the receiver will know that at least one more cell follows cell **44**.

If N=2, then no bits are taken from the cell to encode the next symbol (since N−2=0). Since N−1=1, the next symbol contains just one bit, which is the last cell indicator. This effectively inserts an entire extra symbol in each cell. Nevertheless, the same encoding/decoding logic for this special symbol applies for any value of $N \leqq 2$.

Once the receiver knows that a particular cell is the last cell in the message, by simple counting it can readily identify the symbol that contains the last bits of the last cell. This is represented in FIG. **3**A as symbol **51** or optionally symbol **53**. Since the number of bits remaining to be transmitted in the last symbol (M) can be less than N, a modified encoding technique is preferable for this symbol. One option is to add one or more padding bits (P) **52** so that M+P=N. Another option is to encode the last group of bits at M bits per symbol as represented by symbol **53**. This has the advantage of increased robustness for the transmission of these bits.

For simplicity, the following discussion does not address this second technique. Having recognized the last symbol of the transmission, the receiver does not attempt to demodulate and decode the signal on the line following this symbol since the transmitting station must now be sending silence.

It should be noted that although described as being encoded at N−1 bits per symbol, the symbols **57** and **60** containing the additional last cell indicator bit can be encoded at any symbol rate lower than that of the standard transmission rate (N bits per symbol). For example, if N is five (5), the specially encoded symbols could also be encoded at N−2 or three (3) bits per symbol so that they contain two (2) bits of cell data plus the last cell indicator bit. In this manner, the receiver can clearly and reliably decode the symbol **60**, thereby providing a robust and reliable end of message delimiter.

In accordance with this aspect of the invention, and to be described in further detail with respect to FIG. **3**B, it is also desirable to have the ability to indicate that a message contains only an administrative header **42**. In order to accomplish this, the first symbol containing data from the administrative header **42** can also be encoded using the higher noise margin N−1 bit per symbol encoding technique described above. For example, the first N−2 bits of the administrative header **42** can be combined with a last cell bit (such as bit **61** of symbol **60**) and be encoded at the N−1 bit per symbol rate. This can provide the extra bit to indicate whether or not one or more ATM cells follow administrative header **42**. An alternative technique is to simply include a bit in the preamble **40** that indicates whether an administrative header **40** follows the preamble. For simplicity, it has been assumed that this alternative technique is used with respect to FIG. **3**A and in the following discussion.

Because each ATM cell is the smallest unit of a payload of ATM cells, and because all ATM cells have the same length, the first symbol of each cell that carries only bits of that cell can readily be identified. Because these bits are transmitted using the specially encoded symbol carrying two fewer bits than normal (as described above), the length of each cell is effectively increased by two bits. In some cases this can result in one extra symbol being needed to transmit the cell. In other cases an additional cell is not needed because the spare bits are available anyway (and would have ended up as the padding bits (P) **52** in FIG. **3**A). Because the cells may be transmitted contiguously as a bit stream, the addition of one extra symbol may provide sufficient extra bits to cover the opening symbol of multiple following cells. For example, at eight (8) bits per symbol, in one (1) extra symbol is needed to cover the end of frame signaling overhead to transmit up to four (4) cells.

FIG. **3**B is a schematic view illustrating, in further detail, the exemplar preamble **40** of FIG. **3**A. The bit stream of preamble **40** comprises four (4) bits **62** that include information regarding the transmit rate (in bits per symbol) used to encode data following preamble **40** (the data comprising the optional administrative header and optional ATM cells), four (4) bits **63** that include information regarding the rate (also in bits per symbol) that the receiver is capable of receiving, two (2) bits **64** that identify the address of a remote DSL transceiver if the control DSL transceiver is transmitting (if a remote DSL transceiver is transmitting, then these two (2) bits **64** can represent the address of that remote DSL transceiver) and two (2) bits **66**, which can be used to communicate the format of the message to follow. For example, the two (2) bits **66** can be used to advise a receiving device whether an administrative header **42** follows the preamble **40**, whether ATM cells follow the preamble, whether both follow or whether only the preamble is being transmitted. The four (4) bits provided by symbols **55** and **67** and by symbols **68** and **69** can each encode as many as sixteen data encoding rates.

As mentioned above, the preamble **40** is sent at the beginning of each transmission. The twelve (12) bits that comprise the preamble **40** are encoded into symbols **55**, **67**, **68**, **69**, **70** and **71** in accordance with that described above. In accordance with an aspect of the invention, all of the symbols in preamble, **40** are encoded at a low bit per symbol rate. In this example, all of the symbols are encoded at a rate of two (2) bits per symbol, however, any other low bit per symbol rate can be used with similar results. The low bit per symbol rate ensures a high signal-to-noise ratio for these symbols, thereby significantly decreasing the probability that these preamble symbols will be corrupted by noise on the communication channel. The payload data (administrative header and ATM cells) would typically be encoded at N bits per symbol only if transmission at this N bit per symbol rate has an acceptably low rate of errors (based on line length, signal strength, noise, distortion and other impairments that may be present). Otherwise, data transmission efficiency would suffer. Therefore, encoding the preamble at less than N bits per symbol allows a corresponding improvement in the reliability of transmitting this information such that it is highly unlikely to be corrupted. Since very few bits are needed to convey the information carried in the preamble, a very low rate can be used without seriously reducing the overall transmission efficiency.

In accordance with another aspect of the invention, the first symbol **55** is encoded at a rate of two (2) bits per symbol and has its energy increased to a point at which noise on the communication channel is unlikely to cause a receiver to erroneously interpret the first symbol **55** as silence. Likewise the increased energy makes it unlikely that noise on the communication channel will cause the receiver to erroneously interpret an interval of the silence that precedes each message as the starting symbol of a message. It has been found that an energy increase of **3**dB is sufficient. This aspect of the invention will be described in greater detail below with respect to FIGS. **4**A and **4**B. In this manner, the beginning of each transmission can be clearly and robustly delimited. The remainder of the symbols **67**, **68**, **69**, **70** and **71** that represent the bits in preamble **40** are all encoded at two (2) bits per symbol, but do not have their energy increased.

The four (4) transmit rate bits **62** inform a receiving DSL transceiver of the transmit rate of the information to follow the preamble **40**. Sending this information in every message has significant benefits. It provides the transmitting transceiver the option of changing the encoding rate for the payload from one message to the next. Messages containing information that has been determined to be of high priority can be transmitted using a lower number of bits per symbol to improve the chances of its being received without errors. If the communications system intermittently has a reduced throughput demand, the transceivers may instantly reduce their data rates to improve robustness without adversely affecting real throughput. Finally, if a severe noise condition (such as an impulse caused by plain old telephone service (POTS) ringing signals on a subscriber line **16**) happens to corrupt one or both of the symbols **55** and **67** that encode the transmit rate, only the payload data in this message will be improperly decoded. The receiver's memory of a corrupted rate value lasts only until the next transmission begins. This allows the transmit rate to potentially be changed for every message while at the same time avoiding the complexities of providing fail-safe communication of the rate, such as through use of an automatic repeat request (ARQ) protocol, that would be needed if the rate is sent only when it is changed.

The receive rate bits **63** allow the transmitting device to communicate to the receiving device the maximum receive rate at which the transmitting device can receive. Inherently included in these receive rate bits **63** are commands that instruct the opposite device to either increase or decrease its transmit rate. This allows the responding transceiver to instantly modify the rate it uses for its next transmission to accommodate changes in the signal quality that have been detected at the opposite end of the line.

In accordance with an aspect of the invention, the address bits **64** need only be used when the control DSL transceiver

100 is communicating with a plurality of remote DSL transceivers in what is commonly referred to as "multi-point" mode. When communicating in "multi-point," mode the address bits **64** include either the address of the remote DSL transceiver **150** that is to transmit next (if the transmission is sent by the control DSL transceiver **100**) or the address of the responding remote DSL transceiver **150** (if the transmission is sent by the remote DSL transceiver **150**). Sending these bits **64** at the lower bit rate of the preamble reduces the likelihood of a remote transceiver **150** not responding or of the incorrect remote transceiver **150** responding to a message from the control transceiver **100**. Frequent occurrence of either of these two types of errors could adversely affect the overall data transmission efficiency of the line.

The format bits **66** indicate whether the optional administrative header **42** is being sent, whether one or more ATM cells are being sent, or whether both or neither are being sent. As described previously, the receiver uses this information in conjunction with the transmit rate from bits **62** to identify the special symbols at the start of each ATM cell and to determine the symbol that is the last in the message. Robust transmission of this information at the start of each message allows the transmitter to dynamically modify the message format as needed from one message to the next. Should one of the format bits be corrupted by an abnormally severe noise event, the "damage" is restricted to the current message only. To operate reliably, the receiver could have a "back up" method of recognizing the end of a message such as through detecting loss of signal energy for an extended duration.

FIG. **4**A is a graphical illustration representing a two (2) bit per symbol signal space constellation and the increased energy symbol of FIG. **3**B. The constellation points labeled "c" represent the points in a standard 2 bit per symbol constellation. For each constellation point "c" transmitted, the effect of noise can make the point appear to a receiver to have been moved with respect to where it was when it was transmitted. The dashed circle **76** surrounding constellation point **79** represents the space within which noise may move the point and still have the point reliably decoded by the receiver. The point **79** appears in a different place at the decoder due to noise induced in the communications channel **16**. Each of the points "c" have a space about which they can move and still be reliably decoded by the receiver.

The circle **77** encloses the area surrounding the origin of the in-phase-(horizontal) and quadrature (vertical) axes of FIG. **4**A about which an interval of silence (no constellation point) can be moved by the same additive noise that can affect signal points. This additive noise could cause the silence to be interpreted by the decoder as one of the constellation points in a two (2) bit per symbol constellation due to the overlap of the decoding discrimination threshold circles **76** and **77**. As shown, the circle **76** and the circle **77** have sufficient overlap in region **73** so that silence can easily be interpreted as one of the signal points "c". Conversely, one of the signal points "c" could also be interpreted by the decoder as silence.

For efficient operation, it is desirable that the beginning and end of each transmission be robustly and precisely identified (to within one (1) symbol interval). The beginning and end of each transmission are preceded and followed by silence on the line. Because the most efficient constellation encoding cannot allocate signal space to silence, it is impractical to reliably discriminate silence from signal when analyzing only a single symbol. In other words, it would be undesirable for silence that occurs before a message or after a message to be interpreted as a constellation point "c", and it would be undesirable for a constellation point "c" to be interpreted as silence. As mentioned above, this is possible due to the effect of noise altering the position of the constellation signal points "c" or the position of silence.

In accordance with an aspect of the invention, the first symbol (symbol **55** of FIG. **3**B) in the preamble **40** is transmitted with increased energy, thereby increasing the probability that it will be reliably detected by the decoder of the receiving device. In this manner, the beginning of each transmission is clearly and robustly delimited. The signal point "b" in FIG. **4**A is an exemplar one of four (4) two (2) bit per symbol constellation points that are transmitted at an increased energy level. While other increases may provide useful, a 3 dB increase is typically sufficient and does not increase the ratio of peak power to average power (PAR) of the transmitted signal. As illustrated, the signal point "b" is enclosed by dotted circle **78**, within which the point "b" may move due to noise on the communication channel **16** and still be reliably decoded by the receiver. As shown, there is no overlap between circle **78** and circle **77**. Accordingly, by boosting the energy of the first symbol (symbol **55** of FIG. **3**B) transmitted in a communication message (**31** of FIG. **3**A), there is a significantly higher probability that the boosted symbol will be reliably decoded and not be mistaken for silence. Nor will silence be mistaken for this boosted energy first symbol. Preferably, the receiver places the threshold to discriminate signal from noise at one unit from the origin as shown by circle **77** in FIG. **4**A.

FIG. **4**B is a graphical illustration showing an exemplar grouping of constellation points representing different bit per symbol rates in accordance with an aspect of the invention. For example purposes only, assuming that normal data is encoded at five (5) bits per symbol, the black constellation points, an exemplar of one of which is illustrated using reference numeral **81**, represent data encoded at five (5) bits per symbol. In accordance with an aspect of the invention, all the symbols in the preamble **40** are encoded at a rate of two (2) bits per symbol and are illustrated by the four (4) constellation points labeled "c" in FIG. **4**B. These two (2) bit per symbol constellation points provide a higher signal-to-noise ratio (high margin) than do the normal data encoded at five (5) bits per symbol. This increased margin increases the probability that the receiver will reliably decode all the symbols in the preamble.

In accordance with another aspect of the invention, the four constellation points labeled "b" in FIG. **4**B represent the first symbol (symbol **55** of FIGS. **3**A and **3**B), which energy is boosted by 3 dB. In this manner, the constellation points "b" representing the boosted symbol **55** of FIG. **3**A and **3**B will robustly and reliably communicate the beginning of a transmission. Circle **82** represents the maximum signal level of any symbols as the number of bits per symbol becomes arbitrarily large, but the average power of the transmitted signal is the same as it is for either the five (5) bits per symbol (**81**) or the two (2) bits per symbol (points "c") constellations shown. Therefore, as illustrated by circle **82**, the instantaneous power required by the boosted symbol points "b" is not any higher than that used to send the normal data at any bits per symbol value. In this manner, the boosted symbol represented by constellation points "b" can be used to reliably indicate the start of a message without requiring a higher transmit level capability than that needed for normal data transmission. The non-boosted two (2) bit per symbol constellation points indicated as "c" (having a significantly higher signal-to-noise ratio than that of the normal five (5) bit per symbol data) are used to transmit all symbols of the preamble after the first symbol.

FIG. **5** is a schematic view illustrating the communication message **31** of FIG. **3**A and another aspect of the invention. Typically, it is desirable to scramble all the data bits in a communications message using a self-synchronizing scrambler so that all points in the signal constellation can be used. Unfortunately, the self-synchronizing capability of the scrambler carries the inherent disadvantage of error propagation and extension. A single bit in error in the received data stream is typically transformed by the self-synchronizing descrambling process into at least 3 erroneous bits that are separated by several bits that are not in error.

Typically, in switched-carrier operation, the scrambler setting (state) at the end of one transmission is preserved and used to begin scrambling the next message. (This enables full randomization of the encoding process so as to make full use of the available channel bandwidth.) Similarly, in a receiving device, when descrambling, the state of the descrambler that exists at the end of the previously received message is used to begin the descrambling process for the next received message. This means that the last state of the scrambler saved after scrambling the data portion of the message would then be used to begin scrambling the preamble bits of the next message.

Unfortunately, using this technique with the robust preamble **40** of the invention can lead to error propagation from the data portion of the communication message to the preamble **40**. Allowing errors, which are more likely due to the larger number of bits per symbol, in the payload data to corrupt the data in the preamble due to the inherent error extension of the descrambling process significantly reduces the robustness of the preamble **40**. In accordance with another aspect of the invention, a first scrambler can be used to scramble the information contained in the preamble **40** and a second scrambler can be used to scramble the data (i.e., the information in the ATM cells **44**, **45**, etc.)

As shown in FIG. **5**, line **87** indicates that a first scrambler is used to scramble the preamble **40** of communication message **31** and also used to scramble the preamble of communication message **86**. Similarly, line **88** indicates that a second scrambler is used to scramble the data portion of communication message **31** and the data portion of communication message **86**. The message to message randomizing desirable for full usage of the available channel bandwidth can be maintained if the setting of the preamble scrambler (to be described with respect to FIG. **8**) at the end of one preamble is used to begin the scrambling of the preamble of the next communication message **86**. Because errors in the preamble are considered unlikely to occur, and because the bits received at the end of a previous preamble define the descrambler state used to descramble the next preamble, error extension from one message preamble into the preamble is also much less likely than in the single scrambler case.

An alternative to this that avoids the use of two scramblers is to save the state of the preamble scrambler after scrambling the preamble as the state to use to begin scrambling of the next preamble. This cab be done instead of the conventional approach of using the state of the scrambler at the end of the message. This technique can also prevent errors at the end of one message from corrupting the preamble of the next transmission.

FIG. **6** is a schematic view illustrating the communication message **31** and the reduced line turn around delay made possible by an aspect of the invention. In time-domain duplex operation any periods during which no transceiver is transmitting represent loss of available bandwidth. To make most efficient usage of a communication line, it is desirable to minimize these periods. Some intervals of silence necessarily occur between transmissions because the transition from silence to the first symbol of the preamble is the manner in which the beginning of the next transmission is delimited. The process by which a transceiver makes the transition from receiving to transmitting is referred to as "line turn-around" and the time required may determine the minimum amount of silence that can occur between messages. Various aspects of the design and implementation of a time-domain duplex transceiver may result in increased delays in the line turn-around process. For example, transmitter filters and receiver equalizers have inherent delays. The analog-to-digital and digital-to-analog conversion process as well as the process of transferring digital samples between the signal processor and converters may have some inherent delays. If the signal processing is implemented in firmware there may be delays between the arrival of received signal samples and the time the processing can be performed. All of these factors may extend the line turn-around time to the point that transmission efficiency is significantly reduced.

As described above with respect to FIG. **3**A, communication message **31** includes a specially encoded symbol **60** transmitted at a lower bit per symbol rate than that of the normal data encoding rate. The symbol encodes an additional bit **61** that indicates whether or not the ATM cell is the last cell in the communication message **31**. If it is indicated to the receiver at the beginning of the last ATM cell **46** that the ATM cell **46** is the last cell in the communication message, (instead of waiting to the end of the ATM cell **46**) line turn around delay can be reduced. As illustrated, if a receiving device must wait until the end of the last message to learn that the message is complete, there will be a delay "d" between the time that the communication message **31** is received and the time at which the transmission of communication message **91***a* can begin. By having advance notification that the communication message is about to be complete, a remote DSL transceiver **150** can begin transmission of the next message before reception of the current message has been completed. By knowing the delay contributed by the factors such as those mentioned previously, the transceiver can begin the transmission process, indicated by communication message **91***b*, so as to reduce delay "d" as much as possible, potentially reducing it to the minimum value needed for the receiver to reliably detect the transition-from silence to signal at the beginning of the next message.

FIG. **7** is a block diagram illustrating the control DSL transceiver **100** of FIG. **1**. Although, described with respect to control DSL transceiver **100**, the following description is equally applicable to a remote DSL transceiver **150**. Control DSL transceiver **100** includes microprocessor **101**, memory **102**, transmitter **115** and receiver **120** in communication via logical interface **108**. A bi-directional stream of ATM cells from a DTE is communicated via line **14** to the control DSL transceiver **100**. Memory **102** includes end of transmission delimiting software **106** and robust preamble software **104**. This software resides in memory **102** and executes in microprocessor **101** in order to achieve and perform the benefits of the present invention. Transmitter **115** communicates with line interface **109** via connection **112** in order to gain access to communication channel **16**. Information received on communication channel **16** is processed by line interface **109** and sent via connection **111** to receiver **120**.

Transmitter **115** includes, among other elements that are known to those having ordinary skill in the art, encoder **200** and modulator **117**. Similarly, receiver **120** includes, among

other elements that have been omitted for clarity, decoder **300** and demodulator **118**.

FIG. **8** is a block diagram illustrating the encoder **200** of FIG. **7**. The transmit sequencer **236** commands the multiplexer **214** via connection **242** to select the first two (2) bits of the four (4) bits (**62** of FIG. **3**B) that define the current transmit rate from transmit rate element **206**, via connection **212**. This symbol is then forwarded to preamble scrambler **217**, via connection **216** for scrambling, and is then forwarded via connection **218** to two (2) bit per symbol preamble encoder **219**. This encoded symbol is then forwarded via connection **226** to gain increase element **227** where its energy is increased by approximately 3 dB and is then sent via connection **228** to multiplexer **224** and over connection **254** to modulator **117**.

The next two (2) bits of the transmit rate (**62** of FIG. **3**B) are then scrambled and encoded in the same way. Next, the transmit sequencer **236** commands the multiplexer **214** via connection **242** to select the four (4) bits representing the requested received rate from receive rate element **204**, which bits are forwarded to multiplexer **214** via connection **211**. These four (4) bits are then forwarded to preamble scrambler **217** where they are scrambled, and then forwarded via connection **218** to two (2) bit per symbol preamble encoder **219** where they are encoded into a pair of symbols. These encoded symbols, are forwarded directly via connection **226** to multiplexer **224** and then forwarded via connection **254** to modulator **117**.

If there are multiple remote DSL transceivers **150** and **155**, then the transmit sequencer **236** commands the multiplexer **214** via connection **242** to select the two (2) bits representing the remote address from remote address element **202**, which bits are then forwarded via connection **209** to multiplexer **214**. These two (2) bits are then forwarded via connection **216** to preamble scrambler **217**, which scrambles the bits and forwards them via connection **218** to the two (2) bit per symbol preamble encoder **219**. The two (2) bit per symbol preamble encoder **219** encodes the bits and transfers the encoded symbol via connection **226** through multiplexer **224** and then via connection **254** to modulator **117**.

Transmit sequencer **236** senses if an administrative header **42** and/or ATM cells **44**, **45**, **46** are available for transmission via connections **232** and **234**, respectively, and uses this information to prepare the message format indicator which is loaded by the transmit sequencer **236** via connection **207**. The transmit sequencer **236** commands the multiplexer **214** via connection **242** to select the two (2) bits representing the message format from element **201**, which bits are then forwarded via connection **208** to multiplexer **214**. These two (2) bits are then forwarded via connection **216** to preamble scrambler **217**, which scrambles the bits and forwards them via connection **218** to the two (2) bit per symbol preamble encoder **219**. The two (2) bit per symbol preamble encoder **219** encodes the bits and transfers the encoded symbol via connection **226** through multiplexer **224** and then via connection **254** to modulator **117**.

Next, transmission of either the administrative header **42** or the ATM cell payload begins by transmit sequencer **236** sending a command via connection **235** to multiplexer **241** to select either the administrative header **42** via element **229** or payload data via element **231**. These bits are supplied through multiplexer **241** via connections **239** and **238** and are then forwarded via connection **244** to payload scrambler **246**. Payload scrambler **246** scrambles the bits and forwards them via connection **248** to N bit per symbol data encoder **249** and N−1 bit per symbol data encoder **251**. As mentioned above with respect to FIG. **5**, payload scrambler **246** may use as its initial state either the state that exists at the end of scrambling the preamble (supplied via connection **247**) or the state that exists after completion of scrambling the payload portion of the previous message. As mentioned above with respect to FIG. **3**A, all the data bits are encoded at an N bit per symbol data rate by data encoder **249** and forwarded via connection **257** to multiplexer **224** until the first symbol containing only bits from a new ATM cell is detected. This symbol is encoded at a rate of N−1 bits per symbol by N−1 bit per symbol data encoder **251** and forwarded via connection **256** to multiplexer **224**. The index for this symbol as delivered to payload scrambler **246** is formed by selecting the first N−2 bits of the first octet of the cell and adding an additional bit (i.e., bit **54** or bit **61** of FIG. **3**A) representing the state of the last cell signal **237** as selected via multiplexer **241**. When instructed by transmit sequencer **236** via connection **252**, the multiplexer **224** selects the symbols from either N bit per symbol data encoder **249** or from N−1 bit per symbol data encoder **251** and forwards these symbols via connection **254** to modulator **117**.

Transmit sequencer **236** uses the payload bits per symbol value N received via connection **212** to determine the number of symbols to encode for each cell and to determine which symbol is to be encoded at the N−1 bits per symbol rate and contain the last cell indicator bit. After completing transmission of the message, transmit sequencer **236** commands multiplexer **224** via connection **252** to select silence **221** via connection **222** as the input to the modulator **117**.

FIG. **9** is a block diagram illustrating the decoder **300** of FIG. **7**. A received transmission stream is received in demodulator **118**, where it is demodulated in accordance with techniques known those having ordinary skill in the art. The first symbol is forwarded via connection **301** to gain reduction element **302**. Gain reduction element **302** reduces the gain of the first symbol and supplies that reduced energy symbol via connection **304** to multiplexer **306**. Receive sequencer **328** sends a signal to multiplexer **306** via connection **354** instructing multiplexer **306** to select that reduced gain symbol and transfer it via connection **307** to two (2) bit per symbol preamble decoder **308**. The decoded bits from the first symbol are then sent via connection **309** to preamble descrambler **311**. Preamble descrambler **311** descrambles the first bits in the transmission and forwards them via connection **312** to the multiplexer **314**. When instructed by receive sequencer **328** via connection **332**, the multiplexer **314** forwards these bits via connection **324** to transmit rate element **236**.

The following preamble symbols are all forwarded via connection **301** directly to multiplexer **306**, which forwards these symbols via connection **307** for decoding by two (2) bit per symbol preamble decoder **308**. The decoded bits are forwarded via connection **309** to preamble descrambler **311** as mentioned above. These bits are then forwarded in order via connections **324**, **321**, **318** and **316** to transmit rate element **326**, receive rate element **322**, remote address element **319** and message format element **317**, respectively.

Next, the administrative header symbols and ATM cell data symbols that have been encoded at N bits per symbol are forwarded via connection **301** to N bit per symbol data decoder **337** and the ATM cell data symbols that have been encoded at N−1 bits per symbol are forwarded via connection **301** to N−1 bit per symbol data decoder **339**. These symbols are decoded and the decoded bits are transferred via connections **338** and **341** to multiplexer **342**. Similarly, as mentioned above with respect to FIG. **8**, receive sequencer

328 insures that the symbols encoded at the rate of N−1 bits per symbol are forwarded via connection 301 to N−1 bit per symbol data decoder 339, which forwards the decoded bits via connection 341 to multiplexer 342. As shown, the value of N, which is the bits per symbol value used for the N bits per symbol, or N−1 bits per symbol decoding is controlled by the just received transmit rate bits that have been stored in transmit rate element 326.

At the appropriate time, receive sequencer 328 commands the multiplexer 342 via connection 347 to forward the bits via connection 344 to payload descrambler 336. In accordance with an aspect of the invention, the preamble descrambler 311 operates only on the preamble bits and the payload descrambler 336 operates only on the payload bits. As mentioned above with respect to FIG. 5, the payload descrambler may use as its initial state either the state of the preamble descrambler at the end of descrambling the preamble as supplied via connection 334 or the state of the payload descrambler at the end of descrambling the payload bits of the previous message. The descrambled payload bits are then forwarded via connection 346 to multiplexer 349. When ordered by receive sequencer 328 via connection 331, the multiplexer 349 forwards the administrative header bits via connection 351 and the payload data bits via connection 352. These bits are then forwarded via logical interface 108 to microprocessor 101 for processing (FIG. 7). Receive sequencer 328 determines the presence or absence of the administrative header and ATM cells via the just received message format bits that have been stored in element 317 and provided to receive sequencer 328 via connection 327. When the bits for each symbol containing the last message bit are available at multiplexer 349, receive sequencer 328 directs the N−2 bits of payload data to the payload data element 356 via connection 352 and receives the last cell bit via connection 329. Receive sequencer 328 uses the current bits per symbol value for payload data received via connection 324 to determine the beginning and end of each cell. Based on the message format and the value of the last cell indicator bit, receive sequencer 328 determines when the last symbol of the message has been decoded and instructs demodulator 118 (FIG. 7) to stop delivering demodulated symbols.

In an alternative embodiment, the special encoding of the last cell as described above in FIG. 3A can be omitted and an "eye pattern closure test" can be used to detect the end of the message. In such a situation where it is acceptable to lose the advanced notification of the end of the transmission, beneficial alternative uses for the special encoding of the first bits of each cell are possible. For example, this special encoding as described above with respect to FIG. 3A wherein N−2 bits are encoded for the first full bytes of each cell, can be used to indicate whether or not the ATM cell header (e.g., ATM header 47 of FIG. 2B) is present. This can be useful in the situation in which a string of ATM cells have exactly the same header. This can happen, for example, for ATM adaptation layer 5 (AAL5) cells that carry data from a single protocol data unit (PDU) if no other cells have been interleaved. The single extra bit (bit 61 of FIG. 3A) provided by the encoding described above with respect to FIG. 3A, can be used to indicate whether or not the following cell contains a header. If the bit 61 indicates that there is no header, the receiver copies the last header received ahead of the payload octets of this next cell before forwarding it to the ATM layer. Advantageously, this reduces the approximate 10 percent overhead imposed by the five (5) octet header (47 of FIG. 2B).

It should be emphasized that the above-described embodiments of the present invention, particularly any "preferred" embodiments, are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the invention. Many variations and modifications may be made to the above-described embodiment(s) of the invention without departing substantially from the spirit and principles of the invention. For example, the robust preamble and transmission delimiting system and method are applicable to all switched-carrier transmission methodologies in which it is desirable to reliably convey channel establishment information and reliably delimit the beginning and end of each communication message. All such modifications and variations are intended to be included herein within the scope of the present invention.

Therefore, having thus described the invention, at least the following is claimed:

1. A system for robust transmission delimiting, comprising:

a communication message including a preamble, the preamble operating to frame the message and to delimit the message from silence, the preamble including a plurality of bits representing communication link control information; and

an encoder configured to encode the preamble bits into a plurality of symbol indices, the symbol indices encoded at a lower bit per symbol rate relative to the maximum rate capable of being supported over a communication channel.

2. A system for robust transmission delimiting, comprising:

a communication message including a preamble, the preamble including a plurality of bits representing communication link control information; and

an encoder configured to encode the preamble bits into a plurality of symbol indices, the symbol indices encoded at a lower bit per symbol rate relative to the maximum rate capable of being supported over a communication channel,

wherein the preamble includes information that defines a rate at which data following the preamble has been encoded for transmission.

3. The system as defined in claim 2, further comprising a gain boost element configured to increase the energy of the first symbol index to reliably indicate the beginning of the communication message.

4. The system as defined in claim 2, wherein the preamble includes information defining a maximum rate at which a first transceiver that is sending the preamble is able to receive transmissions from a second transceiver that is receiving the preamble.

5. The system as defined in claim 2, wherein the preamble indicates whether a data portion follows the preamble and, if so, the format and type of data that follows the preamble.

6. The system as defined in claim 2, wherein the preamble indicates whether administrative information follows the preamble.

7. The system as defined in claim 5, further comprising:

a first scrambler configured to scramble the preamble; and

a second scrambler configured to scramble the data,

wherein a state of the scrambler used to scramble the bits that comprise the preamble is the state that existed when scrambling of a previous preamble was completed.

8. The system as defined in claim 5, wherein the data portion of the communication message comprises fixed size units, the fixed size units comprising a plurality of bits and

wherein the bits are encoded into symbol indices such that, for each of the fixed size units, one symbol index is encoded differently from the other symbols.

9. The system as defined in claim **8**, wherein the differently encoded symbol index further comprises an extra bit that indicates whether the fixed size unit from which the other bits of the differently encoded symbol indices are obtained is the last one transmitted in a message.

10. The system as defined in claim **8**, wherein the differently encoded symbol index is encoded at a data rate lower than that of the other symbols carrying message data.

11. A system for delimiting the end of a transmission, comprising:

a communication message segmented into a plurality of fixed size units, each fixed size unit including a plurality of bits; and

an encoder configured to encode the plurality of bits into a plurality of symbol indices at a first data rate, the encoder also configured to encode at a second rate when producing the first symbol index in the plurality of symbol indices that contains only bits from each fixed size unit, where the second rate is lower than the first rate.

12. A method for robust transmission delimiting, the method comprising the steps of:

applying a preamble to a communication message, the preamble operating to frame the message and to delimit the message from silence, the preamble including a plurality of bits representing communication link control information; and

encoding the preamble bits into a plurality of symbol indices, the symbol indices encoded at a lower bit per symbol rate relative to the maximum rate capable of being transmitted over a communication channel.

13. A method for robust transmission delimiting, the method comprising the steps of:

applying a preamble to a communication message, the preamble including a plurality of bits representing communication link control information;

encoding the preamble bits into a plurality of symbol indices, the symbol indices encoded at a lower bit per symbol rate relative to the maximum rate capable of being transmitted over a communication channel; and

including information in the preamble defining a rate at which data following the preamble has been encoded for transmission.

14. The method as defined in claim **13**, further comprising the step of increasing the energy of the first symbol index to reliably indicate the beginning of the communication message.

15. The method as defined in claim **13**, further comprising the step of including information in the preamble defining a maximum rate at which a transceiver that is sending the preamble is able to receive transmissions from a transceiver that is receiving the preamble.

16. The method as defined in claim **13**, further comprising the step of using the preamble to indicate whether a data portion follows the preamble and, if so, the format and type of data that follows the preamble.

17. The method as defined in claim **13**, further comprising the step of using the preamble to indicate whether administrative information follows the preamble.

18. The method as defined in claim **16**, further comprising the steps of:

scrambling the preamble using a first scrambler;

scrambling the data using a second scrambler; and

scrambling the bits in the preamble using the state of the scrambler that existed when scrambling of the previous preamble was complete.

19. The method as defined in claim **16**, wherein the data portion of the communication message comprises fixed size units, the fixed size units comprising a plurality of bits, and wherein the bits that comprise each of the fixed size units are encoded into symbol indices such that for each of the fixed size units, one symbol index is encoded differently from the other symbols.

20. The method as defined in claim **19**, further comprising the step of including in said differently encoded symbol index an extra bit that indicates whether the fixed size unit from which the other bits of said differently encoded symbol indices are obtained is the last one transmitted in a message.

21. The method as defined in claim **19**, further comprising the step of encoding the differently encoded symbol index at a data rate lower than that of the other symbols carrying message data.

22. A method for delimiting the end of a transmission, the method comprising the steps of:

segmenting a communication message into a plurality of units, each unit including a plurality of bits and having a fixed size;

encoding a plurality of the bits in the plurality of units into a plurality of symbol indices, the symbol indices being encoded at a first rate; and

encoding one symbol index of the plurality of symbol indices at a rate lower than the first rate, the one symbol index containing bits from only one of the plurality of units.

23. A system for robust transmission delimiting, comprising:

means for applying a preamble to a communication message, the preamble operating to frame the message and to delimit the message from silence, the preamble including a plurality of bits representing communication link control information; and

means for encoding the preamble bits into a plurality of symbol indices, the symbol indices encoded at a lower bit per symbol rate relative to the maximum rate capable of being transmitted over a communication channel.

24. The system as defined in claim **23**, further comprising means for increasing the energy of the first symbol index to reliably indicate the beginning of the communication message.

25. A system for robust transmission delimiting, comprising:

means for applying a preamble to a communication message, the preamble including a plurality of bits representing communication link control information;

means for encoding the preamble bits into a plurality of symbol indices, the symbol indices encoded at a lower bit per symbol rate relative to the maximum rate capable of being transmitted over a communication channel; and

means for including information in the preamble defining a rate at which data following the preamble has been encoded for transmission.

26. The system as defined in claim **25**, further comprising means for including information in the preamble defining a maximum rate at which a transceiver that is sending the preamble is able to receive transmissions from a transceiver that is receiving the preamble.

27. The system as defined in claim **25**, further comprising means for using the preamble to indicate whether a data

portion follows the preamble and, if so, the format and type of data that follows the preamble.

28. The system as defined in claim **25**, further comprising means for using the preamble to indicate whether administrative information follows the preamble.

29. The system as defined in claim **27**, further comprising:

means for scrambling the preamble using a first scrambler;

means for scrambling the data using a second scrambler; and

means for scrambling the bits in the preamble using the state of the scrambler that existed when scrambling of the previous preamble was complete.

30. The system as defined in claim **27**, wherein the data portion of the communication message comprises fixed size units, the fixed size units comprising a plurality of bits; and

means for encoding the bits that comprise each of the fixed size units into symbol indices such that for each of the fixed size units, one symbol index is encoded differently from the other symbols.

31. The system as defined in claim **30**, further comprising means for including in said differently encoded symbol index an extra bit that indicates whether the fixed size unit from which the other bits of said differently encoded symbol indices are obtained is the last one transmitted in a message.

32. The system as defined in claim **30**, further comprising means for encoding the differently encoded symbol index at a data rate lower than that of the other symbols carrying message data.

33. A system for delimiting the end of a transmission, comprising:

means for segmenting a communication message into a plurality of fixed size units, each unit including a plurality of bits;

means for encoding a plurality of the bits in the units into a plurality of symbol indices, the symbol indices being encoded at a first rate; and

means for encoding at a second rate when producing the first symbol index in the plurality of symbol indices that contains only bits from each fixed size unit, where the second rate is lower than the first rate.

34. A computer readable medium having a program for robust transmission delimiting, the program comprising logic for performing the steps of:

applying a preamble to a communication message, the preamble operating to frame the message and to delimit the message from silence, the preamble including a plurality of bits representing communication link control information; and

encoding the preamble bits into a plurality of symbol indices, the symbol indices encoded at a lower bit per symbol rate relative to the maximum rate capable of being transmitted over a communication channel.

35. The program as defined in claim **34**, further comprising logic for performing the step of increasing the energy of the first symbol index to reliably indicate the beginning of the communication message.

36. A computer readable medium having a program for robust transmission delimiting, the program comprising logic for performing the steps of:

applying a preamble to a communication message, the preamble including a plurality of bits representing communication link control information;

encoding the preamble bits into a plurality of symbol indices, the symbol indices encoded at a lower bit per symbol rate relative to the maximum rate capable of being transmitted over a communication channel; and

including information in the preamble defining a rate at which data following the preamble has been encoded for transmission.

37. The program as defined in claim **36**, further comprising logic for performing the step of including information in the preamble defining a maximum rate at which a transceiver that is sending the preamble is able to receive transmissions from a transceiver that is receiving the preamble.

38. The program as defined in claim **36**, further comprising logic for performing the step of using the preamble to indicate whether a data portion follows the preamble and, if so, the format and type of data that follows the preamble.

39. The program as defined in claim **36**, further comprising logic for performing the step of using the preamble to indicate whether administrative information follows the preamble.

40. The program as defined in claim **38**, further comprising logic for performing the steps of:

scrambling the preamble using a first scrambler;

scrambling the data using a second scrambler; and

scrambling the bits in the preamble using the state of the scrambler that existed when scrambling of the previous preamble was complete.

41. The program as defined in claim **38**, wherein the data portion of the communication message comprises fixed size units, the fixed size units comprising a plurality of bits; and

wherein the bits that comprise each of the fixed size units are encoded into symbol indices such that for each of the fixed size units, one symbol index is encoded differently from the other symbols.

42. The program as defined in claim **41**, further comprising logic for performing the step of including in said differently encoded symbol index an extra bit that indicates whether the fixed size unit from which the other bits of said differently encoded symbol indices are obtained is the last one transmitted in a message.

43. The program as defined in claim **41**, further comprising logic for performing the step of encoding the differently encoded symbol index at a data rate lower than that of the other symbols carrying message data.

44. A computer readable medium having a program for delimiting the end of a transmission, the program comprising logic to perform the steps of:

segmenting a communication message into a plurality of fixed size units, each unit including a plurality of bits;

encoding a plurality of the bits in the fixed sized units into a plurality of symbol indices, the symbol indices being encoded at a first rate; and

encoding at a second rate when producing the first symbol index in the plurality of symbol indices that contains only bits from each fixed size unit, where the second rate is lower than the first rate.

45. A method for delimiting the end of a transmission, the method comprising the steps of:

segmenting a communication message into a plurality of fixed size units, each unit including a plurality of bits;

encoding the first N bits in a unit into a first symbol index, the first symbol index being encoded at a first rate, N being less than the fixed size; and

encoding the remaining bits in the plurality of units into a plurality of symbol indices at a rate greater than the first rate.

46. The system as defined in claim **11**, further comprising a gain boost element configured to increase the energy of the first symbol index to reliably indicate the beginning of the communication message.

47. The system as defined in claim **11**, wherein the preamble indicates whether a data portion follows the preamble and, if so, the format and type of data that follows the preamble.

48. The method as defined in claim **22**, further comprising the step of increasing the energy of the first symbol index to reliably indicate the beginning of the communication message.

49. The method as defined in claim **22**, further comprising the step of using the preamble to indicate whether a data portion follows the preamble and, if so, the format and type of data that follows the preamble.

50. The system as defined in claims **33**, further comprising means for increasing the energy of the first symbol index to reliably indicate the beginning of the communication message.

51. The system as defined in claim **33**, further comprising means for using the preamble to indicate whether a data portion follows the preamble and, if so, the format and type of data that follows the preamble.

52. The program as defined in claim **44**, further comprising logic for performing the step of increasing the energy of the first symbol index to reliably indicate the beginning of the communication message.

53. The program as defined in claim **44**, further comprising logic for performing the step of using the preamble to indicate whether a data portion follows the preamble and, if so, the format and type of data that follows the preamble.

54. The method as defined in claim **45**, further comprising the step of increasing the energy of the first symbol index to reliably indicate the beginning of the communication message.

55. The method as defined in claim **45**, further comprising the step of using the preamble to indicate whether a data portion follows the preamble and, if so, the format and type of data that follows the preamble.

* * * * *

JS 44 (Rev. 3/99)

CIVIL COVER SHEET

The JS 44 civil cover sheet and the information contained herein neither replace nor supplement the filing and service of pleadings or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. (SEE INSTRUCTIONS ON THE REVERSE OF THE FORM.)

I. (a) PLAINTIFFS

MOTOROLA, INC., CISCO SYSTEMS, INC., SCIENTIFIC-ATLANTA, INC., ARRIS GROUP, INC., THOMSON, INC., AMBIT MICROSYSTEMS, INC., and NETGEAR, INC.,

(b) County Of Residence Of First Listed Plaintiff: (Except In U.S. Plaintiff Cases)

DEFENDANT

REMBRANDT TECHNOLOGIES, LP

County Of Residence Of First Listed Defendant: (IN U.S. PLAINTIFF CASES ONLY)
NOTE: IN LAND CONDEMNATION CASES, USE THE LOCATION OF THE TRACT OF LAND INVOLVED

(c) Attorneys (Firm Name, Address, And Telephone Number)

Attorneys (If Known)

II. BASIS OF JURISDICTION (PLACE AN X IN ONE BOX ONLY)

- ☐ 1 U.S. Government Plaintiff
- ☒ 3 Federal Question (U.S. Government Not a Party)
- ☐ 2 U.S. Government Defendant
- ☐ 4 Diversity (Indicate Citizenship of Parties in Item III)

III. CITIZENSHIP OF PRINCIPAL PARTIES (Place An X In One Box For Plaintiff And One Box For Defendant) (For Diversity Cases Only)

	PTF	DEF		PTF	DEF
Citizen of This State	1	○ 1	Incorporated or Principal Place of Business in This State	○ 4	○ 4
Citizen of Another State	○ 2	○ 2	Incorporated and Principal Place of Business in This State	○ 5	○ 5
Citizen or Subject of a Foreign Country	○ 3	○ 3	Foreign Nation	○ 6	○ 6

V. NATURE OF SUIT (Place An X In One Box Only)

CONTRACT
- ☐ 110 Insurance
- ☐ 120 Marine
- ☐ 130 Miller Act
- ☐ 140 Negotiable Instrument
- ☐ 150 Recovery of Overpayment & Enforcement of Judgment
- ☐ 151 Medicare Act
- ☐ 152 Recovery of Defaulted (Excl. Veterans)
- ☐ 153 Recovery of Overpayment of Veteran's Benefits
- ☐ 160 Stockholders' Suits
- ☐ 190 Other Contract
- ☐ 195 Contract Product Liability

REAL PROPERTY
- ☐ 210 Land Condemnation
- ☐ 220 Foreclosure
- ☐ 230 Rent Lease & Ejectment
- ☐ 240 Torts to Land
- ☐ 245 Tort Product Liability
- ☐ 290 All Other Real Property

TORTS

PERSONAL INJURY
- ☐ 310 Airplane
- ☐ 315 Airplane Product Liability
- ☐ 320 Assault, Libel & Slander
- ☐ 330 Federal Employers Liability
- ☐ 340 Marine
- ☐ 345 Marine Product Liability
- ☐ 350 Motor Vehicle
- ☐ 355 Motor Vehicle Product Liability
- ☐ 360 Other Personal Injury

PERSONAL INJURY
- ☐ 362 Personal Injury - Med Malpractice
- ☐ 365 Personal Injury - Product Liability
- ☐ 368 Asbestos Personal Injury Product Liability

PERSONAL ROPERTY
- ☐ 370 Other Fraud
- ☐ 371 Truth in Lending
- ☐ 380 Other Personal Property Damage
- ☐ 385 Property Damage Product Liability

CIVIL RIGHTS
- ☐ 441 Voting
- ☐ 442 Employment
- ☐ 443 Housing/ Accommodations
- ☐ 444 Welfare
- ☐ 440 Other Civil Rights

PRISONER PETITIONS
- ☐ 510 Motions to Vacate Sentence Habeas Corpus
- ☐ 530 General
- ☐ 535 Death Penalty
- ☐ 540 Mandamus & Other
- ☐ 550 Civil Rights
- ☐ 555 Prison Condition

FORFEITURE/PENALTY
- ☐ 610 Agriculture
- ☐ 620 Other Food & Drug
- ☐ 625 Drug Related Seizure of Property 21 U.S.C. 881
- ☐ 630 Liquor Laws
- ☐ 640 R.R. & Truck
- ☐ 650 Airline Regs
- ☐ 660 Occupational Safety/Health
- ☐ 690 Other

LABOR
- ☐ 710 Fair Labor Standards Act
- ☐ 720 Labor/Mgmt Relations
- ☐ 730 Labor/Mgmt. Reporting & Disclosure Act
- ☐ 740 Railway Labor Act
- ☐ 790 Other Labor Litigation
- ☐ 791 Empl Ret Inc Security Act

BANKRUPTCY
- ☐ 422 Appeal 28 U.S.C. 158
- ☐ 423 Withdrawal 28 U.S.C. 157

PROPERTY RIGHTS
- ☐ 820 Copyrights
- ☒ 830 Patent
- ☐ 840 Trademark

SOCIAL SECURITY
- ☐ 861 HIA (1395ff)
- ☐ 862 Black Lung (923)
- ☐ 863 DIWC/DIWW (405(g))
- ☐ 864 SSID Title XVI
- ☐ 865 RSI (405(g))

FEDERAL TAX SUITS
- ☐ 870 Taxes (U.S. Plaintiff or Defendant)
- ☐ 871 IRS - Third Party 26 U.S.C. 7609

OTHER STATUTES
- ☐ 400 State Reapportionment
- ☐ 410 Antitrust
- ☐ 430 Banks and Banking
- ☐ 450 Commerce/ICC Rates, etc.
- ☐ 460 Deportation
- ☐ 470 Racketeer Influenced and Corrupt Organizations
- ☐ 810 Selective Service
- ☐ 850 Securities/Commodities/ Exchange
- ☐ 875 Customer Challenge 12 U.S.C. 3410
- ☐ 891 Agricultural Acts
- ☐ 892 Economic Stabilization Act
- ☐ 893 Environmental Matters
- ☐ 894 Energy Allocation Act
- ☐ 895 Freedom of Information Act
- ☐ 900 Appeal of Fee Determination Under Equal Access to Justice
- ☐ 950 Constitutionality of State Statutes
- ☐ 890 Other Statutory Actions

IV. ORIGIN (PLACE AN "X" IN ONE BOX ONLY)

☒ 1 Original Proceeding ☐ 2 Removed from Court ☐ 3 Remanded from Appellate Court ☐ 4 Reinstated or Reopened ☐ 5 Transferred from another district (specify) ☐ 6 Multidistrict Litigation ☐ 7 Appeal to District Judge from Magistrate Judgment

VI. CAUSE OF ACTION

(CITE THE U.S. CIVIL STATUTE UNDER WHICH YOU ARE FILING AND WRITE BRIEF STATEMENT OF CAUSE DO NOT CITE JURISDICTIONAL STATUTES UNLESS DIVERSITY.)
35 U.S.C. § 1 et seq.

Brief description of cause:
Declaratory judgment action for patent noninfringement.

VII. REQUESTED IN COMPLAINT: CHECK IF THIS IS A UNDER F.R.C.P. 23 **CLASS ACTION** YES NO **DEMAND** $

Check YES only if demanded in complaint
JURY DEMAND: ☒ YES NO

VIII. RELATED CASE(S) (See instructions) **IF ANY**

JUDGE: DOCKET NUMBER:
SEE ATTACHED LIST OF RELATED CASES

DATE 11/21/07 SIGNATURE OF ATTORNEY OF RECORD

FOR OFFICE USE ONLY

RECEIPT # _____ AMOUNT _____ APPLYING IFP _____ JUDGE _____ MAG. JUDGE _____

JS 44 Reverse
(Rev. 3/99)

INSTRUCTIONS FOR ATTORNEYS COMPLETING CIVIL COVER SHEET FORM JS-44

Authority For Civil Cover Sheet

The JS-44 civil cover sheet and the information contained herein neither replaces nor supplements the filings and service of pleading or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. Consequently a civil cover sheet is submitted to the Clerk of Court for each civil complaint filed. The attorney filing a case should complete the form as follows:

I. (a) **Plaintiffs - Defendants.** Enter names (last, first, middle initial) of plaintiff and defendant. If the plaintiff or defendant is a government agency, use only the full name or standard abbreviations. If the plaintiff or defendant is an official within a government agency, identify first the agency and then the official, giving both name and title.

(b) **County of Residence.** For each civil case filed, except U.S. plaintiff cases, enter the name of the county where the first listed plaintiff resides at the time of filing. In U.S. plaintiff cases, enter the name of the county in which the first listed defendant resides at the time of filing. (NOTE: In land condemnation cases, the county of residence of the "defendant" is the location of the tract of land involved).

(c) **Attorneys.** Enter firm name, address, telephone number, and attorney of record. If there are several attorneys, list them on an attachment, noting in this section "(see attachment)."

II. Jurisdiction. The basis of jurisdiction is set forth under Rule 8(a), F.R.C.P., which requires that jurisdictions be shown in pleadings. Place an "X" in one of the boxes. If there is more than one basis of jurisdiction, precedence is given in the order shown below.

United States plaintiff. (1) Jurisdiction is based on 28 U.S.C. 1345 and 1348. Suits by agencies and officers of the United States are included here.

United States defendant. (2) When the plaintiff is suing the United States, its officers or agencies, place an "X" in this box.

Federal question. (3) This refers to suits under 28 U.S.C. 1331, where jurisdiction arises under the Constitution of the United States, an amendment to the Constitution, an act of Congress or a treaty of the United States. In cases where the U.S. is a party, the U.S. plaintiff or defendant code takes precedence, and box 1 or 2 should be marked.

Diversity of citizenship. (4) This refers to suits under 28 U.S.C. 1332, where parties are citizens of different states. When Box 4 is checked, the citizenship of the different parties must be checked. (See Section III below; federal question actions take precedence over diversity cases.)

III. Residence (citizenship) of Principal Parties. This section of the JS-44 is to be completed if diversity of citizenship was indicated above. Mark this section for each principal party.

IV. Cause of Action. Report the civil statute directly related to the cause of action and give a brief description of the cause.

V. Nature of Suit. Place an "X" in the appropriate box. If the nature of suit cannot be determined, be sure the cause of action, in Section IV above, is sufficient to enable the deputy clerk or the statistical clerks in the Administrative Office to determine the nature of suit. If the cause fits more than one nature of suit, select the most definitive.

VI. Origin. Place an "X" in one of the seven boxes.

Original Proceedings. (1) Cases which originate in the United States district courts.

Removed from State Court. (2) Proceedings initiated in state courts may be removed to the district courts under Title 28 U.S.C. Section 1441. When the petition for removal is granted, check this box.

Remanded from Appellate Court. (3) Check this box for cases remanded to the district court for further action. Use the date of remand as the filing date.

Reinstated or Reopened. (4) Check this box for cases reinstated or reopened in the district court. Use the reopening date as the filing date.

Transferred from Another District. (5) For cases transferred under Title 28 U.S.C. Section 1404(a). Do not use this for within district transfers or multidistrict litigation transfers.

Multidistrict Litigation. (6) Check this box when a multidistrict case is transferred into the district under authority of title 28 U.S.C. Section 1407. When this box is checked, do not check (5) above.

Appeal to District Judge from Magistrate Judgment. (7) Check this box for an appeal from a magistrate's decision.

VII. Requested in Complaint. Class Action. Place an "X" in this box if you are filing a class action under Rule 23, F.R.Cv.P.

Demand. In this space enter the dollar amount (in thousands of dollars) being demanded or indicate other demand such as a preliminary injunction.

Jury Demand. Check the appropriate box to indicate whether or not a jury is being demanded.

VIII. Related Cases. This section of the JS-44 is used to reference relating pending cases if any. If there are related pending cases, insert the docket numbers and the corresponding judge names for such cases.

Date and Attorney Signature. Date and sign the civil cover sheet.

Related Cases

- *Rembrandt Technologies, LP v. Cablevision et al.*, C.A. No. 06-635-GMS;
- *Coxcom v. Rembrandt Technologies, LP*, C.A. No. 06-721-GMS;
- *Rembrandt Technologies, LP v. Adelphia Comm'n Corp., et al.*, C.A. No. 07-396-GMS;
- *Rembrandt Technologies, LP v. Adelphia Comm'n Corp., et al.*, C.A. No. 07-397-GMS;
- *Rembrandt Technologies, LP v. Comcast Corp. et al.*, C.A. No. 07-398-GMS;
- *Rembrandt Technologies, LP v. Charter Comm'n, Inc., et al.*, C.A. No. 07-400-GMS;
- *Rembrandt Technologies, LP v. Time Warner Cable, et al.*, C.A. No. 07-401-GMS;
- *Rembrandt Technologies, LP v. Time Warner Cable, et al.*, C.A. No. 07-402-GMS;
- *Rembrandt Technologies, LP v. Comcast Corp. et al.*, C.A. No. 07-403-GMS;
- *Rembrandt Technologies, LP v. Charter Comm'n, Inc., et al.*, C.A. No. 07-404-GMS;
- *In re Rembrandt Technologies, LP Patent Litigation*, C.A. No. 07-1848-GMS.

AO FORM 85 RECEIPT (REV. 9/04)

United States District Court for the District of Delaware

Civil Action No. -07-752-

ACKNOWLEDGMENT OF RECEIPT FOR AO FORM 85

NOTICE OF AVAILABILITY OF A UNITED STATES MAGISTRATE JUDGE TO EXERCISE JURISDICTION

I HEREBY ACKNOWLEDGE RECEIPT OF 1 COPIES OF AO FORM 85.

11/21/2007
(Date forms issued)

(Signature of Party or their Representative)

James Higgins
(Printed name of Party or their Representative)

Note: Completed receipt will be filed in the Civil Action