IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

INTELLECTUAL VENTURES I LLC and INTELLECTUAL VENTURES II LLC, Plaintiffs, v. CANON INC., CANON U.S.A., INC. and CANON SOLUTIONS AMERICA, INC. Defendants.	C.A. No. 13-cv-473-SLR JURY TRIAL DEMANDED

SECOND AMENDED COMPLAINT

Plaintiffs Intellectual Ventures I LLC ("Intellectual Ventures I") and Intellectual Ventures II LLC ("Intellectual Ventures II") (collectively, "Intellectual Ventures I and II"), by and through its attorneys, for its Complaint for Patent Infringement against Defendants Canon Inc., Canon U.S.A., Inc., and Canon Solutions America, Inc. (individually and collectively, "Canon") allege as follows, upon personal knowledge with respect to its own acts, and upon information and belief with respect to the circumstances and fact of others:

PARTIES

1. Intellectual Ventures I is a Delaware limited liability company with its principal place of business located in Bellevue, Washington.

2. Intellectual Ventures II is a Delaware limited liability company with its principal place of business located in Bellevue, Washington.

3. On information and belief, defendant Canon Inc., also known as Canon Kabushiki Kaisha, is a corporation organized under the laws of Japan having a principal place of business at 30-2, Shimomaruko 3-chome, Ohta-ku, Tokyo 146-8501, Japan.

4. On information and belief, Canon U.S.A., Inc. is a wholly-owned and controlled subsidiary of Canon Inc. and is a corporation organized and existing under the laws of the State of New York, with its principal place of business at One Canon Plaza, Lake Success, New York, 11042-1113.

5. On information and belief, Canon Solutions America, Inc. is a wholly-owned and controlled subsidiary of Canon U.S.A., Inc. and is a corporation organized and existing under the laws of the State of New York, with its principal place of business at One Canon Plaza, Lake Success, New York, 11042-1113.

6. On information and belief, Canon Inc., Canon U.S.A., Inc., and Canon Solutions America, Inc. have been and are acting individually, collectively, and jointly or in concert with regard to all Canon activities referenced and alleged in this Complaint.

JURISDICTION AND VENUE

7. This is a civil action for the infringement of United States Patent Nos. 5,444,728, 6,130,761, 6,650,432, RE43,086, 7,315,406, 5,712,870, 6,754,195, 6,977,944, 7,817,914, 8,300,285, and RE44,528 (collectively, the "Patents-in-Suit") under the patent laws of the United States, 35 U.S.C. § 100 *et seq.*, including in particular under 35 U.S.C. § 271. Intellectual Ventures I owns United States Patent Nos. 5,444,728, 6,130,761, 6,650,432, RE43,086, 7,315,406, 5,712,870, 6,754,195, 6,977,944, 8,300,285, and RE44,528 and holds the right to sue and recover damages for infringement thereof, including past infringement. Intellectual Ventures II owns United States Patent No. 7,817,914 and holds the right to sue and recover

damages for infringement thereof, including past infringement. This Court has subject matter jurisdiction pursuant to 28 U.S.C. §§ 1331 and 1338(a).

8. Canon is subject to personal jurisdiction in this Court because, upon information and belief, Canon does and has done substantial business in this District, including both independently and through and with its subsidiaries and various commercial arrangements by placing its products, including those that infringe Intellectual Venture I and II's patents, into the stream of commerce, which stream is directed at the State of Delaware and this District, with the knowledge and/or understanding that such products would be sold in the State of Delaware and this District. These acts have caused and continue to cause injury to Intellectual Ventures I and II within this District. Canon derives substantial revenue from the sale of infringing products distributed within the District, and/or expect or should reasonably expect their actions to have consequences within the District, and derive substantial revenue from interstate and international commerce. In addition, Canon has induced and continues to knowingly induce infringement within this District by contracting with others to market and sell infringing products with the knowledge and intent to facilitate infringing sales of the products by others within this District and by creating and/or disseminating instructions and other materials for the products with like mind and intent.

9. On information and belief, Canon has sufficient minimum contacts with the District that an exercise of personal jurisdiction over Canon would not offend traditional notions of fair play and substantial justice and would be appropriate under Delaware Code Title 10, Section 3104.

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

COUNT I: INFRINGEMENT OF U.S. PATENT NO. 5,444,728

11. Paragraphs 1 through 10 are incorporated as if fully set forth herein.

12. United States Patent No. 5,444,728 ("the '728 patent"), entitled "Laser Driver Circuit," issued on August 22, 1995, to inventor Marc T. Thompson. A true and correct copy of the '728 patent is attached to this Complaint as Exhibit A. The '728 patent is owned by Intellectual Ventures I.

13. Canon will have knowledge and notice of the '728 patent and its infringement at least through the filing and/or service of this Complaint.

14. Upon information and belief, Canon has infringed and continues to infringe one or more claims of the '728 patent in violation of 35 U.S.C. § 271(a), literally or under the doctrine of equivalents, by making, using, offering for sale, and selling in the United States and by importing into the United States Canon printers, multifunction devices, and copiers that include a laser driver circuit with a bypass switch ("the '728 Accused Instrumentalities"). Upon information and belief, the '728 Accused Instrumentalities include, for example and without limitation, the Canon imageRUNNER ADVANCE Series (*e.g.*, imageRUNNER ADVANCE C2020).

15. Upon information and belief, Canon has induced and continues to induce infringement of the '728 patent pursuant to 35 U.S.C. § 271(b) by encouraging its subsidiaries, customers and resellers, and other third parties to make, use, offer for sale, and sell the '728 Accused Instrumentalities. Such making, using, offering for sale, and selling of the '728 Accused Instrumentalities constitutes infringement, literally or under the doctrine of equivalents, of one or more claims of the '728 patent by such subsidiaries, customers, resellers, or third parties. Canon's acts of encouragement include: intending its subsidiaries, resellers, customers,

and other third parties to make, sell, offer to sell, and use the ’728 Accused Instrumentalities; providing other components of and accessories for the ’728 Accused Instrumentalities; advertising the ’728 Accused Instrumentalities through its own and third-party websites; and providing instruction manuals and maintenance manuals for the ’728 Accused Instrumentalities.

16. Canon has proceeded in this manner despite its actual knowledge of the ’728 patent and knowledge and specific intent that the actions it actively induced on the part of its subsidiaries, customers and resellers, and other third parties constitute infringement of the ’728 patent. At the very least, because Canon is on notice of the ’728 patent and the accused infringement, it has been and remains willfully blind regarding the infringement it has induced and continues to induce.

17. Upon information and belief, Canon has contributed and continues to contribute to the infringement of the ’728 patent pursuant to 35 U.S.C. § 271(c) by selling and offering to sell within the United States, and/or importing into the United States the ’728 Accused Instrumentalities and components thereof to its subsidiaries, customers and resellers, and other third parties. For example, upon information and belief, Canon contributed and continues to contribute to the infringement of the ’728 Accused Instrumentalities by selling, offering to sell, and/or importing a laser driver circuit with a bypass switch for use in the ’728 Accused Instrumentalities. Canon also contributed and continues to contribute to the infringement of the ’728 Accused Instrumentalities by selling, offering to sell, and/or importing the ’728 Accused Instrumentalities, which include a laser driver circuit with a bypass switch, that are used in practicing the claimed methods of the ’728 patent. When the ’728 Accused Instrumentality is made, used, sold, or offered for sale by Canon’s subsidiaries, customers and resellers, or other third parties, those subsidiaries, customers, resellers, or other third parties are thereby infringing,

literally or under the doctrine of equivalents, one or more claims of the ’728 patent. The laser driver circuit with a bypass switch supplied by Canon constitute material parts of the claimed inventions of the ’728 patent.

18. Upon information and belief, Canon knows, for the reasons described above, that the laser driver circuits with a bypass switch are especially made and/or especially adapted for use in infringing the ’728 patent. Moreover, these components and apparatuses are not staple articles of commerce suitable for substantial non-infringing use, at least because the components and apparatuses have no use apart from making and/or using a laser driver circuit with a bypass switch as claimed in the ’728 patent. For example and without limitation, laser driver circuit in the imageRUNNER ADVANCE C2020 is used only in conjunction with or as part of the claimed apparatuses and methods.

COUNT II: INFRINGEMENT OF U.S. PATENT NO. 6,130,761

19. Paragraphs 1 through 10 are incorporated as if fully set forth herein.

20. U.S. Patent No. 6,130,761 (“the ’761 patent”), entitled “Image Scanning Method,” issued on October 10, 2000, to inventors Pao-Yuan Yeh and Yu-Ting Wu. A true and correct copy of the ’761 patent is attached to this Complaint as Exhibit B. The ’761 patent is owned by Intellectual Ventures I.

21. Canon will have knowledge and notice of the ’761 patent and its infringement at least through the filing and/or service of this Complaint.

22. Upon information and belief, Canon has infringed and continues to infringe one or more claims of the ’761 patent in violation of 35 U.S.C. § 271(a), literally or under the doctrine of equivalents, by making, using, offering for sale, and selling in the United States and by importing into the United States Canon scanners, multifunction devices, and copiers that

perform an image scanning method that determines a number of rotation steps for a driving motor ("the '761 Accused Instrumentalities"). Upon information and belief, the '761 Accused Instrumentalities include, for example and without limitation, the Canon imageCLASS Series (*e.g.*, imageCLASS MF4890dw).

23. Upon information and belief, Canon has induced and continues to induce infringement of the '761 patent pursuant to 35 U.S.C. § 271(b) by encouraging its subsidiaries, customers and resellers, and other third parties to make, use, offer for sale, and sell the '761 Accused Instrumentalities. Such making, using, offering for sale, and selling of these '761 Accused Instrumentalities constitutes infringement, literally or under the doctrine of equivalents, of one or more claims of the '761 patent by such subsidiaries, customers, resellers, or third parties. Canon's acts of encouragement include: intending its subsidiaries, resellers, customers, and other third parties to make, sell, offer to sell, and use the '761 Accused Instrumentalities; providing other components of and accessories for the '761 Accused Instrumentalities; advertising the '761 Accused Instrumentalities through its own and third-party websites; and providing instruction manuals and maintenance manuals for the '761 Accused Instrumentalities.

24. Canon has proceeded in this manner despite its actual knowledge of the '761 patent and knowledge and specific intent that the actions it actively induced on the part of its subsidiaries, customers and resellers, and other third parties constitute infringement of the '761 patent. At the very least, because Canon is on notice of the '761 patent and the accused infringement, it has been and remains willfully blind regarding the infringement it has induced and continues to induce.

25. Upon information and belief, Canon has contributed and continues to contribute to the infringement of the '761 patent pursuant to 35 U.S.C. § 271(c) by selling and offering to

sell within the United States, and/or importing into the United States the ’761 Accused Instrumentalities to its subsidiaries, customers and resellers, and other third parties. For example, upon information and belief, Canon contributed and continues to contribute to the infringement of the ’761 Accused Instrumentalities by selling, offering to sell, and/or importing an apparatus that includes a motor that performs an image scanning method by determining a number of rotation steps as claimed in the ’761 patent. When the ’761 Accused Instrumentality is used by Canon’s subsidiaries, customers, resellers, or other third parties, those subsidiaries, customers, resellers, or other third parties are thereby infringing, literally or under the doctrine of equivalents, one or more claims of the ’761 patent. The apparatus supplied by Canon constitutes a material part of the claimed inventions of the ’761 patent.

26. Upon information and belief, Canon knows, for the reasons described above, that the apparatus supplied by Canon is especially made and/or especially adapted for use in infringing the ’761 patent. Moreover, the apparatus is not a staple articles of commerce suitable for substantial non-infringing use at least because the apparatus has no use apart from performing scanning functionality as claimed in the ’761 patent. For example and without limitation, the stepper motor in Canon’s imageCLASS MF4890dw is used only for performing an image scanning method that determines a number of rotation steps for a driving motor as claimed in the ’761 patent.

COUNT III: INFRINGEMENT OF U.S. PATENT NO. 6,650,432

27. Paragraphs 1 through 10 are incorporated as if fully set forth herein.

28. U.S. Patent No. 6,650,432 (“the ’432 patent”), entitled “Method and User Interface for Performing an Automatic Scan Operation For a Scanner Coupled to a Computer System,” issued on November 18, 2003, to inventors Chuan-Yu Hsu, Jay Liu, and T.J. Hsu. A

true and correct copy of the ’432 patent is attached to this Complaint as Exhibit C. The ’432 patent is owned by Intellectual Ventures I.

29. Canon will have knowledge and notice of the ’432 patent and its infringement at least through the filing and/or service of this Complaint.

30. Upon information and belief, Canon has infringed and continues to infringe one or more claims of the ’432 patent in violation of 35 U.S.C. § 271(a), literally or under the doctrine of equivalents, by making, using, offering for sale, and selling in the United States and by importing into the United States Canon printers, scanners, multifunction devices, and copiers with software that provides a user interface for use on a computer system coupled with a scanner for performing a scan operation on an original document, including performing a set of image processing routines (“the ’432 Accused Instrumentalities”). Upon information and belief, the ’432 Accused Instrumentalities include, for example and without limitation, the Canon PIXMA Series (*e.g.*, PIXMA MG6220).

31. Upon information and belief, Canon has induced and continues to induce infringement of the ’432 patent pursuant to 35 U.S.C. § 271(b) by encouraging its subsidiaries, customers and resellers, and other third parties to make, use, offer for sale, and sell the ’432 Accused Instrumentalities. Such making, using, offering for sale, and selling of the ’432 Accused Instrumentalities constitutes infringement, literally or under the doctrine of equivalents, of one or more claims of the ’432 patent by such subsidiaries, customers, resellers, or third parties. Canon’s acts of encouragement include: intending its subsidiaries, resellers, customers, and other third parties to make, sell, offer to sell, and use the ’432 Accused Instrumentalities; providing other components of and accessories for the ’432 Accused Instrumentalities;

advertising the ’432 Accused Instrumentalities through its own and third-party websites; and providing instruction manuals and maintenance manuals for the ’432 Accused Instrumentalities.

32. Canon has proceeded in this manner despite its actual knowledge of the ’432 patent and knowledge and specific intent that the actions it actively induced on the part of its subsidiaries, customers and resellers, and other third parties constitute infringement of the ’432 patent. At the very least, because Canon is on notice of the ’432 patent and the accused infringement, it has been and remains willfully blind regarding the infringement it has induced and continues to induce.

33. Upon information and belief, Canon has contributed and continues to contribute to the infringement of the ’432 patent pursuant to 35 U.S.C. § 271(c) by selling and offering to sell within the United States, and/or importing into the United States the ’432 Accused Instrumentalities to its subsidiaries, customers and resellers, and other third parties. For example, upon information and belief, Canon contributed and continues to contribute to the infringement of the ’432 Accused Instrumentalities by selling, offering to sell, and/or importing software that provides a user interface for use on a computer system coupled with a scanner for performing a scan operation on an original document, including performing a set of image processing routines. When the ’432 Accused Instrumentality is made, used, sold, or offered for sale by Canon’s subsidiaries, customers and resellers, or other third parties, those subsidiaries, customers, resellers, or other third parties are thereby infringing, literally or under the doctrine of equivalents, one or more claims of the ’432 patent. The software supplied by Canon constitutes material parts of the claimed inventions of the ’432 patent.

34. Upon information and belief, Canon knows, for the reasons described above, that the accused functionality of the software is especially made and/or especially adapted for use in

infringing the ’432 patent. Moreover, the accused functionality of the software is not a staple article of commerce suitable for substantial non-infringing use at least because it has no use apart from providing a user interface for use on a computer system coupled with a scanner for performing a scan operation on an original document as claimed in the ’432 patent. For example and without limitation, at least the PIXMA MG6220 includes software functions that provide a user interface that is used only in conjunction with or as part of the claimed systems.

COUNT IV: INFRINGEMENT OF U.S. PATENT NO. RE43,086

35. Paragraphs 1 through 10 are incorporated as if fully set forth herein.

36. U.S. Patent No. RE43,086 (“the ’086 patent”), entitled “Method and User Interface For Performing a Scan Operation For a Scanner Coupled to a Computer System,” issued on January 10, 2012, to inventors Chuan-Yu Hsu, Jay Liu, and T.J. Hsu. A true and correct copy of the ’086 patent is attached to this Complaint as Exhibit D. The ’086 patent is owned by Intellectual Ventures I.

37. Canon will have knowledge and notice of the ’086 patent and its infringement at least through the filing and/or service of this Complaint.

38. Upon information and belief, Canon has infringed and continues to infringe one or more claims of the ’086 patent in violation of 35 U.S.C. § 271(a), literally or under the doctrine of equivalents, by making, using, offering for sale, and selling in the United States and by importing into the United States Canon printers, scanners, multifunction devices, and copiers that include a memory device with instructions stored thereon and software that provide a user interface for use on a computer system coupled with a scanner for performing a scan operation with an image-enhancement process (“the ’086 Accused Instrumentalities”). Upon information

and belief, the ’086 Accused Instrumentalities include, for example and without limitation, the Canon PIXMA Series (*e.g.*, PIXMA MG6220).

39. Upon information and belief, Canon has induced and continues to induce infringement of the ’086 patent pursuant to 35 U.S.C. § 271(b) by encouraging its subsidiaries, customers and resellers, and other third parties to make, use, offer for sale, and sell the ’086 Accused Instrumentalities. Such making, using, offering for sale, and selling of the ’086 Accused Instrumentalities constitutes infringement, literally or under the doctrine of equivalents, of one or more claims of the ’086 patent by such subsidiaries, customers, resellers, or third parties. Canon’s acts of encouragement include: intending its subsidiaries, resellers, customers, and other third parties to make, sell, offer to sell, and use the ’086 Accused Instrumentalities; providing other components of and accessories for the ’086 Accused Instrumentalities; advertising the ’086 Accused Instrumentalities through its own and third-party websites; and providing instruction manuals and maintenance manuals for the ’086 Accused Instrumentalities.

40. Canon has proceeded in this manner despite its actual knowledge of the ’086 patent and knowledge and specific intent that the actions it actively induced on the part of its subsidiaries, customers and resellers, and other third parties constitute infringement of the ’086 patent. At the very least, because Canon is on notice of the ’086 patent and the accused infringement, it has been and remains willfully blind regarding the infringement it has induced and continues to induce.

41. Upon information and belief, Canon has contributed and continues to contribute to the infringement of the ’086 patent pursuant to 35 U.S.C. § 271(c) by selling and offering to sell within the United States, and/or importing into the United States the ’086 Accused Instrumentalities to its subsidiaries, customers and resellers, and other third parties. For

example, upon information and belief, Canon contributed and continues to contribute to the infringement of the ’086 Accused Instrumentalities by selling, offering to sell, and/or importing a memory device with instructions stored thereon and software that provide a user interface for use on a computer system coupled with a scanner for performing a scan operation with an image-enhancement process for use in practicing the claimed methods of the ’086 patent. When the ’086 Accused Instrumentality is made, used, sold, or offered for sale by Canon’s subsidiaries, customers and resellers, or other third parties, those subsidiaries, customers, resellers, or other third parties are thereby infringing, literally or under the doctrine of equivalents, one or more claims of the ’086 patent. The memory device and software supplied by Canon constitute material parts of the claimed inventions of the ’086 patent.

42. Upon information and belief, Canon knows, for the reasons described above, that accused functionality of the memory device with instructions stored thereon and the software are especially made and/or especially adapted for use in infringing the ’086 patent. Moreover, these memory devices with instructions stored thereon and the software are not staple articles of commerce suitable for substantial non-infringing use at least because they have no use apart from a user interface for use on a computer system coupled with a scanner for performing a scan operation with an image-enhancement process as claimed in the ’086 patent. For example and without limitation, at least the PIXMA MG6220 includes software that provides a user interface that is used only in conjunction with or as part of the claimed inventions.

<u>COUNT V: INFRINGEMENT OF U.S. PATENT NO. 7,315,406</u>

43. Paragraphs 1 through 10 are incorporated as if fully set forth herein.

44. U.S. Patent No. 7,315,406 (“the ’406 patent”), entitled “Scanning Circuit Structure,” issued on January 1, 2008, to inventors Kaun-Yu Lee and Chen-Ho Lee. A true and

correct copy of the ’406 patent is attached to this Complaint as Exhibit E. The ’406 patent is owned by Intellectual Ventures I.

45. Canon will have knowledge and notice of the ’406 patent and its infringement at least through the filing and/or service of this Complaint.

46. Upon information and belief, Canon has infringed and continues to infringe one or more claims of the ’406 patent in violation of 35 U.S.C. § 271(a), literally or under the doctrine of equivalents, by making, using, offering for sale, and selling in the United States and by importing into the United States certain Canon printers, scanners, multifunction devices, and copiers that include a scanning circuit that converts scan control signals to timing control signals (“the ’406 Accused Instrumentalities”). Upon information and belief, the ’406 Accused Instrumentalities include, for example and without limitation, the Canon CanoScan Series (*e.g.*, CanoScan 9000F).

47. Upon information and belief, Canon has induced and continues to induce infringement of the ’406 patent pursuant to 35 U.S.C. § 271(b) by encouraging its subsidiaries, customers and resellers, and other third parties to make, use, offer for sale, and sell the ’406 Accused Instrumentalities. Such making, using, offering for sale, and selling of the ’406 Accused Instrumentalities constitutes infringement, literally or under the doctrine of equivalents, of one or more claims of the ’406 patent by such subsidiaries, customers, resellers, or third parties. Canon’s acts of encouragement include: intending its subsidiaries, resellers, customers, and other third parties to make, sell, offer to sell, and use the ’406 Accused Instrumentalities; providing other components of and accessories for the ’406 Accused Instrumentalities; advertising the ’406 Accused Instrumentalities through its own and third-party websites; and providing instruction manuals and maintenance manuals for the ’406 Accused Instrumentalities.

48. Canon has proceeded in this manner despite its actual knowledge of the ’406 patent and knowledge and specific intent that the actions it actively induced on the part of its subsidiaries, customers and resellers, and other third parties constitute infringement of the ’406 patent. At the very least, because Canon is on notice of the ’406 patent and the accused infringement, it has been and remains willfully blind regarding the infringement it has induced and continues to induce.

49. Upon information and belief, Canon has contributed and continues to contribute to the infringement of the ’406 patent pursuant to 35 U.S.C. § 271(c) by selling and offering to sell within the United States, and/or importing into the United States components and apparatuses of the ’406 Accused Instrumentalities to its subsidiaries, customers and resellers, and other third parties. For example, upon information and belief, Canon contributed and continues to contribute to the infringement of the ’406 Accused Instrumentalities by selling, offering to sell, and/or importing a scanning circuit that converts scan control signals to timing control signals for use in the ’406 Accused Instrumentalities and for use in practicing the claimed methods of the ’406 patent. When the ’406 Accused Instrumentality is made, used, sold, or offered for sale by Canon’s subsidiaries, customers and resellers, or other third parties, those subsidiaries, customers, resellers, or other third parties are thereby infringing, literally or under the doctrine of equivalents, one or more claims of the ’406 patent. These scanning circuits supplied by Canon constitute material parts of the claimed inventions of the ’406 patent.

50. Upon information and belief, Canon knows, for the reasons described above, that the scanning circuits are especially made and/or especially adapted for use in infringing the ’406 patent. Moreover, scanning circuits are not staple articles of commerce suitable for substantial non-infringing use, at least because they have no use apart from converting scan control signals

to timing control signals, as claimed in the ’406 patent. For example and without limitation, at least the CanoScan 9000F includes a scanning circuit that converts scan control signals to timing control signals that is used only in conjunction with or as part of the claimed apparatuses and methods.

COUNT VI: INFRINGEMENT OF U.S. PATENT NO. 5,712,870

51. Paragraphs 1 through 10 are incorporated as if fully set forth herein.

52. U.S. Patent No. 5,712,870 (“the ’870 patent”), entitled “Packet Header Generation and Detection Circuitry,” issued on January 27, 1998, to inventor Al Petrick. A true and correct copy of the ’870 patent is attached to this Complaint as Exhibit F. This ’870 patent is owned by Intellectual Ventures I.

53. Canon will have knowledge and notice of the ’870 patent and its infringement at least through the filing and/or service of this Complaint.

54. Upon information and belief, has infringed since at least the filing of this Complaint and continues to infringe one or more claims of the ’870 patent in violation of 35 U.S.C. § 271(a), literally or under the doctrine of equivalents, by making, using, offering for sale, and selling in the United States and by importing into the United States Canon printers, scanners, multifunction devices, copiers and cameras that include the wireless local area network (“Wi-Fi”) functionality claimed in the ’870 patent (“the ’870 Accused Instrumentalities”). Upon information and belief, the ’870 Accused Instrumentalities include, for example and without limitation, the Canon PIXMA Series (*e.g.*, PIXMA MX882 and PIXMA MX870).

55. Upon information and belief, Canon has induced and continues to induce infringement of the ’870 patent pursuant to 35 U.S.C. § 271(b) by encouraging its subsidiaries, customers and resellers, and other third parties to make, use, offer for sale, and sell the ’870

Accused Instrumentalities. Such making, using, offering for sale, and selling of these ’870 Accused Instrumentalities constitutes infringement, literally or under the doctrine of equivalents, of one or more claims of the ’870 patent by such subsidiaries, customers, resellers, or third parties. Canon’s acts of encouragement include: intending its subsidiaries, resellers, customers, and other third parties to make, sell, offer to sell, and use the ’870 Accused Instrumentalities; providing other components of and accessories for the ’870 Accused Instrumentalities; advertising the ’870 Accused Instrumentalities through its own and third-party websites; and providing instruction manuals and maintenance manuals for the ’870 Accused Instrumentalities.

56. Canon has proceeded in this manner despite its actual knowledge of the ’870 patent and knowledge and specific intent that the actions it actively induced on the part of its subsidiaries, customers, resellers, and other third parties constitute infringement of the ’870 patent. At the very least, because Canon is on notice of the ’870 patent and the accused infringement, it has been and remains willfully blind regarding the infringement it has induced and continues to induce.

57. Upon information and belief, Canon has contributed and continues to contribute to the infringement of the ’870 patent pursuant to 35 U.S.C. § 271(c) by selling and offering to sell within the United States, and/or importing into the United States, materials and components of the ’870 Accused Instrumentalities to its subsidiaries, customers and resellers, and other third parties. For example, upon information and belief, Canon contributed and continues to contribute to the infringement of the ’870 Accused Instrumentalities by selling, offering to sell, and/or importing materials and components that provide Wi-Fi functionality for use in the ’870 Accused Instrumentalities. When the resulting ’870 Accused Instrumentality is made, used, sold, or offered for sale by Canon’s subsidiaries, customers, resellers, or other third parties, those

subsidiaries, customers, resellers, or other third parties are thereby infringing, literally or under the doctrine of equivalents, one or more claims of the ’870 patent. These materials and components supplied by Canon constitute material parts of the claimed inventions of the ’870 patent.

58. Upon information and belief, Canon knows, for the reasons described above, that the materials and components that provide Wi-Fi functionality in the ’870 Accused Instrumentalities are especially made and/or especially adapted for use in infringing the ’870 patent. Moreover, the materials and components are not staple articles of commerce suitable for substantial non-infringing use at least because they have no use apart from providing Wi-Fi functionality as claimed in the ’870 patent. For example and without limitation, the accused Wi-Fi functionalities of the PIXMA MX882 is used only in conjunction with or as part of the claimed systems.

COUNT VII: INFRINGEMENT OF U.S. PATENT NO. 6,754,195

59. Paragraphs 1 through 10 are incorporated as if fully set forth herein.

60. U.S. Patent No. 6,754,195 (“the ’195 patent”), entitled “Wireless Communication System Configured to Communicate Using a Mixed Waveform Configuration,” issued on June 22, 2004, to inventor Mark A. Webster and Michael J. Seals. A true and correct copy of the ’195 patent is attached to this Complaint as Exhibit G. The ’195 patent is owned by Intellectual Ventures I.

61. Canon will have knowledge and notice of the ’195 patent and its infringement at least through the filing and/or service of this Complaint.

62. Upon information and belief, Canon has infringed and continues to infringe one or more claims of the ’195 patent in violation of 35 U.S.C. § 271(a), literally or under the

doctrine of equivalents, by making, using, offering for sale, and selling in the United States and by importing into the United States Canon printers, multifunction devices, copiers, and cameras that include the Wi-Fi functionality claimed in the ’195 patent (“the ’195 Accused Instrumentalities”). Upon information and belief, the ’195 Accused Instrumentalities include, for example and without limitation, the Canon PIXMA Series (*e.g.*, PIXMA MX882 and PIXMA MX870).

63. Upon information and belief, Canon has induced and continues to induce infringement of the ’195 patent pursuant to 35 U.S.C. § 271(b) by encouraging its subsidiaries, customers and resellers, and other third parties to make, use, offer for sale, and sell the ’195 Accused Instrumentalities. Such making, using, offering for sale, and selling of the ’195 Accused Instrumentalities constitutes infringement, literally or under the doctrine of equivalents, of one or more claims of the ’195 patent by such subsidiaries, customers, resellers, or third parties. Canon’s acts of encouragement include: intending its subsidiaries, resellers, customers, and other third parties to make, sell, offer to sell, and use the ’195 Accused Instrumentalities; providing other components of and accessories for the ’195 Accused Instrumentalities; advertising the ’195 Accused Instrumentalities through its own and third-party websites; and providing instruction manuals and maintenance manuals for the ’195 Accused Instrumentalities.

64. Canon has proceeded in this manner despite its actual knowledge of the ’195 patent and knowledge and specific intent that the actions it actively induced on the part of its subsidiaries, customers and resellers, and other third parties constitute infringement of the ’195 patent. At the very least, because Canon is on notice of the ’195 patent and the accused infringement, it has been and remains willfully blind regarding the infringement it has induced and continues to induce.

65. Upon information and belief, Canon has contributed and continues to contribute to the infringement of the ’195 patent pursuant to 35 U.S.C. § 271(c) by selling and offering to sell within the United States, and/or importing into the United States components of the ’195 Accused Instrumentalities to its subsidiaries, customers and resellers, and other third parties. For example, upon information and belief, Canon contributed and continues to contribute to the infringement of the ’195 Accused Instrumentalities by selling, offering to sell, and/or importing parts that provide Wi-Fi functionality for use in the ’195 Accused Instrumentalities. When the ’195 Accused Instrumentality is made, used, sold, or offered for sale by Canon’s subsidiaries, customers and resellers, or other third parties, those subsidiaries, customers, resellers, or other third parties are thereby infringing, literally or under the doctrine of equivalents, one or more claims of the ’195 patent. These components supplied by Canon constitute material parts of the claimed inventions of the ’195 patent.

66. Upon information and belief, Canon knows, for the reasons described above, that these components of the ’195 Accused Instrumentalities are especially made and/or especially adapted for use in infringing the ’195 patent. Moreover, these components are not staple articles of commerce suitable for substantial non-infringing use at least because the accused Wi-Fi functionalities have no use apart from providing Wi-Fi functionality as claimed in the ’195 patent. For example and without limitation, the accused Wi-Fi functionality of the PIXMA MX882 is used only in conjunction with or as part of the claimed systems.

COUNT VIII: INFRINGEMENT OF U.S. PATENT NO. 6,977,944

67. Paragraphs 1 through 10 are incorporated as if fully set forth herein.

68. U.S. Patent No. 6,977,944 (“the ’944 patent”), entitled “Transmission Protection For Communications Networks Having Stations Operating With Different Modulation Formats,”

issued on December 20, 2005, to inventors Ronald A. Brockmann, Maarten Hoeben and Maarten Menzo Wentink. A true and correct copy of the ’944 patent is attached to this Complaint as Exhibit H. The ’944 patent is owned by Intellectual Ventures I.

69. Canon will have knowledge and notice of the ’944 patent and its infringement at least through the filing and/or service of this Complaint.

70. Upon information and belief, Canon has infringed and continues to infringe one or more claims of the ’944 patent in violation of 35 U.S.C. § 271(a), literally or under the doctrine of equivalents, by making, using, offering for sale, and selling in the United States and by importing into the United States Canon printers, multifunction devices, copiers, and cameras that include Wi-Fi functionality as claimed in the ’944 patent (“the ’944 Accused Instrumentalities”). Upon information and belief, the ’944 Accused Instrumentalities include, for example and without limitation, the Canon PIXMA Series (*e.g.*, PIXMA MX882 and PIXMA MX870).

71. Upon information and belief, Canon has induced and continues to induce infringement of the ’944 patent pursuant to 35 U.S.C. § 271(b) by encouraging its subsidiaries, customers and resellers, and other third parties to make, use, offer for sale, and sell the ’944 Accused Instrumentalities. Such making, using, offering for sale, and selling of the ’944 Accused Instrumentalities constitutes infringement, literally or under the doctrine of equivalents, of one or more claims of the ’944 patent by such subsidiaries, customers, resellers, or third parties. Canon’s acts of encouragement include: intending its subsidiaries, resellers, customers, and other third parties to make, sell, offer to sell, and use the ’944 Accused Instrumentalities; providing other components of and accessories for the ’944 Accused Instrumentalities;

advertising the ’944 Accused Instrumentalities through its own and third-party websites; and providing instruction manuals and maintenance manuals for the ’944 Accused Instrumentalities.

72. Canon has proceeded in this manner despite its actual knowledge of the ’944 patent and knowledge and specific intent that the actions it actively induced on the part of its subsidiaries, customers and resellers, and other third parties constitute infringement of the ’944 patent. At the very least, because Canon is on notice of the ’944 patent and the accused infringement, it has been and remains willfully blind regarding the infringement it has induced and continues to induce.

73. Upon information and belief, Canon has contributed and continues to contribute to the infringement of the ’944 patent pursuant to 35 U.S.C. § 271(c) by selling and offering to sell within the United States, and/or importing into the United States the ’944 Accused Instrumentalities and components thereof to its subsidiaries, customers and resellers, and other third parties. For example, upon information and belief, Canon contributed and continues to contribute to the infringement of the ’944 Accused Instrumentalities by selling, offering to sell, and/or importing components that provide the accused Wi-Fi functionality for use in the ’944 Accused Instrumentalities, including for practicing the claimed methods of the ’944 patent. When the ’944 Accused Instrumentality is made, used, sold, or offered for sale by Canon’s subsidiaries, customers and resellers, or other third parties, those subsidiaries, customers, resellers, or other third parties are thereby infringing, literally or under the doctrine of equivalents, one or more claims of the ’944 patent. These components or apparatuses supplied by Canon constitute material parts of the claimed inventions of the ’944 patent.

74. Upon information and belief, Canon knows, for the reasons described above, that these components and apparatuses of the ’944 Accused Instrumentalities are especially made

and/or especially adapted for use in infringing the ’944 patent. Moreover, these components and apparatuses are not staple articles of commerce suitable for substantial non-infringing use at least because the accused Wi-Fi functionalities have no use apart from providing Wi-Fi functionality as claimed in the ’944 patent. For example and without limitation, the accused Wi-Fi functionality of the PIXMA MX882 is used only in conjunction with or as part of the claimed systems.

COUNT IX: INFRINGEMENT OF U.S. PATENT NO. 7,817,914

75. Paragraphs 1 through 10 are incorporated as if fully set forth herein.

76. United States Patent No. 7,817,914 (“the ’914 patent”), entitled “Camera Configurable For Autonomous Operation,” issued on October 19, 2010, to inventors Cheryl J. Kuberka, David C. Barnum, Frances C. Williams, John N. Border, and Kenneth A. Johnson. A true and correct copy of the ’914 patent is attached to this Complaint as Exhibit I. The ’914 patent is owned by Intellectual Ventures II.

77. Canon will have knowledge and notice of the ’914 patent and its infringement at least through the filing and/or service of this Complaint.

78. Upon information and belief, Canon has infringed and continues to infringe one or more claims of the ’914 patent in violation of 35 U.S.C. § 271(a), literally or under the doctrine of equivalents, by making, using, offering for sale, and selling in the United States and by importing into the United States Canon cameras that capture a digital image upon the automatic detection of an image trigger condition meeting a threshold level (“the ’914 Accused Instrumentalities”). Upon information and belief, the ’914 Accused Instrumentalities include, for example and without limitation, cameras that have Canon’s Smart Shutter and Face Detection Self-Timer features (*e.g.*, PowerShot S110).

79. Upon information and belief, Canon has induced and continues to induce infringement of the ’914 patent pursuant to 35 U.S.C. § 271(b) by encouraging its subsidiaries, customers and resellers, and other third parties to make, use, offer for sale, and sell the ’914 Accused Instrumentalities. Such making, using, offering for sale, and selling of these ’914 Accused Instrumentalities constitutes infringement, literally or under the doctrine of equivalents, of one or more claims of the ’914 patent by such subsidiaries, customers, resellers, or third parties. Canon’s acts of encouragement include: intending its subsidiaries, resellers, customers, and other third parties to make, sell, offer to sell, and use the ’914 Accused Instrumentalities; providing other components of and accessories for the ’914 Accused Instrumentalities; advertising the ’914 Accused Instrumentalities through its own and third-party websites; and providing instruction manuals and maintenance manuals for the ’914 Accused Instrumentalities.

80. Canon has proceeded in this manner despite its actual knowledge of the ’914 patent and knowledge and specific intent that the actions it actively induced on the part of its subsidiaries, customers and resellers, and other third parties constitute infringement of the ’914 patent. At the very least, because Canon is on notice of the ’914 patent and the accused infringement, it has been and remains willfully blind regarding the infringement it has induced and continues to induce.

81. Upon information and belief, Canon has contributed and continues to contribute to the infringement of the ’914 patent pursuant to 35 U.S.C. § 271(c) by selling and offering to sell within the United States, and/or importing into the United States the ’914 Accused Instrumentalities and components thereof to its subsidiaries, customers and resellers, and other third parties. For example, upon information and belief, Canon contributed and continues to contribute to the infringement of the ’914 Accused Instrumentalities by selling, offering to sell,

and/or importing materials and apparatuses that allow a camera to capture a digital image upon the automatic detection of an image trigger condition meeting a threshold level (*e.g.*, the Smart Shutter and Face Detection Self-Timer features) as claimed in the ’914 patent. When the ’914 Accused Instrumentality is used by Canon’s subsidiaries, customers, resellers, or other third parties, those subsidiaries, customers, resellers, or other third parties are thereby infringing, literally or under the doctrine of equivalents, one or more claims of the ’914 patent. The materials and apparatuses supplied by Canon constitute material parts of the claimed inventions of the ’914 patent.

82. Upon information and belief, Canon knows, for the reasons described above, that these materials and apparatuses supplied by Canon are especially made and/or especially adapted for use in infringing the ’914 patent. Moreover, these materials and apparatuses are not staple articles of commerce suitable for substantial non-infringing use at least because the materials and apparatuses have no use apart from allowing a camera to capture a digital image upon the automatic detection of an image trigger condition meeting a threshold level (*e.g.*, the Smart Shutter and Face Detection Self-Timer features) as claimed in the ’914 patent. For example and without limitation, the accused portions of the PowerShot S110 that automatically detects an image trigger condition is used only in conjunction with or as part of the claimed methods of the ’914 patent.

COUNT X: INFRINGEMENT OF U.S. PATENT NO. 8,300,285

83. Paragraphs 1 through 10 are incorporated as if fully set forth herein.

84. U.S. Patent No. 8,300,285 (“the ’285 patent”), entitled “Scanning Circuit Structure,” issued on October 30, 2012 to inventors Kaun-Yu Lee and Chen-Ho Lee. A true and

correct copy of the ’285 patent is attached to this Complaint as Exhibit J. The ’285 patent is owned by Intellectual Ventures I.

85. Canon will have knowledge and notice of the ’285 patent and its infringement at least through the filing and/or service of this Complaint.

86. Upon information and belief, Canon has infringed and continues to infringe one or more claims of the ’285 patent in violation of 35 U.S.C. § 271(a), literally or under the doctrine of equivalents, by making, using, offering for sale, and selling in the United States and by importing into the United States certain Canon printers, scanners, multifunction devices, and copiers that include a scanning circuit that converts scan control signals to timing control signals (“the ’285 Accused Instrumentalities”). Upon information and belief, the ’285 Accused Instrumentalities include, for example and without limitation, the Canon CanoScan Series (*e.g.*, CanoScan 9000F).

87. Upon information and belief, Canon has induced and continues to induce infringement of the ’285 patent pursuant to 35 U.S.C. § 271(b) by encouraging its subsidiaries, customers and resellers, and other third parties to make, use, offer for sale, and sell the ’285 Accused Instrumentalities. Such making, using, offering for sale, and selling of the ’285 Accused Instrumentalities constitutes infringement, literally or under the doctrine of equivalents, of one or more claims of the ’285 patent by such subsidiaries, customers, resellers, or third parties. Canon’s acts of encouragement include: intending its subsidiaries, resellers, customers, and other third parties to make, sell, offer to sell, and use the ’285 Accused Instrumentalities; providing other components of and accessories for the ’285 Accused Instrumentalities; advertising the ’285 Accused Instrumentalities through its own and third-party websites; and providing instruction manuals and maintenance manuals for the ’285 Accused Instrumentalities.

88. Canon has proceeded in this manner despite its actual knowledge of the ’285 patent and knowledge and specific intent that the actions it actively induced on the part of its subsidiaries, customers and resellers, and other third parties constitute infringement of the ’285 patent. At the very least, because Canon is on notice of the ’285 patent and the accused infringement, it has been and remains willfully blind regarding the infringement it has induced and continues to induce.

89. Upon information and belief, Canon has contributed and continues to contribute to the infringement of the ’285 patent pursuant to 35 U.S.C. § 271(c) by selling and offering to sell within the United States, and/or importing into the United States components and apparatuses of the ’285 Accused Instrumentalities to its subsidiaries, customers and resellers, and other third parties. For example, upon information and belief, Canon contributed and continues to contribute to the infringement of the ’285 patent by selling, offering to sell, and/or importing a scanning circuit that converts scan control signals to timing control signals for use in the ’285 Accused Instrumentalities. When the ’285 Accused Instrumentality is made, used, sold, or offered for sale by Canon’s subsidiaries, customers and resellers, or other third parties, those subsidiaries, customers, resellers, or other third parties are thereby infringing, literally or under the doctrine of equivalents, one or more claims of the ’285 patent. These components and apparatuses supplied by Canon constitute material parts of the claimed inventions of the ’285 patent.

90. Upon information and belief, Canon knows, for the reasons described above, that the scanning circuits are especially made and/or especially adapted for use in infringing the ’285 patent. Moreover, these components and apparatuses are not staple articles of commerce suitable for substantial non-infringing use, at least because they have no use apart from converting scan

control signals to timing control signals, as claimed in the ’285 patent. For example and without limitation, at least the CanoScan 9000F includes a scanning circuit that converts scan control signals to timing control signals that is used only in conjunction with or as part of the claimed apparatuses.

COUNT XI: INFRINGEMENT OF U.S. PATENT NO. RE44,528

91. Paragraphs 1 through 10 are incorporated as if fully set forth herein.

92. U.S. Patent No. RE44,528 (“the ’528 patent”), entitled “Method and User Interface For Performing a Scan Operation For a Scanner Coupled to a Computer System,” issued on October 8, 2013, to inventors Chuan-Yu Hsu, Jay Liu, and T.J. Hsu. A true and correct copy of the ’528 patent is attached to this Complaint as Exhibit K. The ’528 patent is owned by Intellectual Ventures I.

93. Canon will have knowledge and notice of the ’528 patent and its infringement at least through the filing and/or service of this Complaint.

94. Upon information and belief, Canon has infringed and continues to infringe one or more claims of the ’528 patent in violation of 35 U.S.C. § 271(a), literally or under the doctrine of equivalents, by making, using, offering for sale, and selling in the United States and by importing into the United States Canon printers, scanners, multifunction devices, and copiers that include a memory device with instructions stored thereon and software that provide a user interface for use on a computer system coupled with a scanner for performing a scan operation with an image-enhancement process (“the ’528 Accused Instrumentalities”). Upon information and belief, the ’528 Accused Instrumentalities include, for example and without limitation, the Canon PIXMA Series (*e.g.*, PIXMA MG6220).

95. Upon information and belief, Canon has induced and continues to induce infringement of the ’528 patent pursuant to 35 U.S.C. § 271(b) by encouraging its subsidiaries, customers and resellers, and other third parties to make, use, offer for sale, and sell the ’528 Accused Instrumentalities. Such making, using, offering for sale, and selling of the ’528 Accused Instrumentalities constitutes infringement, literally or under the doctrine of equivalents, of one or more claims of the ’528 patent by such subsidiaries, customers, resellers, or third parties. Canon’s acts of encouragement include: intending its subsidiaries, resellers, customers, and other third parties to make, sell, offer to sell, and use the ’528 Accused Instrumentalities; providing other components of and accessories for the ’528 Accused Instrumentalities; advertising the ’528 Accused Instrumentalities through its own and third-party websites; and providing instruction manuals and maintenance manuals for the ’528 Accused Instrumentalities.

96. Canon has proceeded in this manner despite its actual knowledge of the ’528 patent and knowledge and specific intent that the actions it actively induced on the part of its subsidiaries, customers and resellers, and other third parties constitute infringement of the ’528 patent. At the very least, because Canon is on notice of the ’528 patent and the accused infringement, it has been and remains willfully blind regarding the infringement it has induced and continues to induce.

97. Upon information and belief, Canon has contributed and continues to contribute to the infringement of the ’528 patent pursuant to 35 U.S.C. § 271(c) by selling and offering to sell within the United States, and/or importing into the United States the ’528 Accused Instrumentalities to its subsidiaries, customers and resellers, and other third parties. For example, upon information and belief, Canon contributed and continues to contribute to the infringement of the ’528 patent by selling, offering to sell, and/or importing an apparatus that

includes a memory device with instructions stored thereon and software that provide a user interface for use on a computer system coupled with a scanner for performing a scan operation with an image-enhancement process for use in practicing the claimed methods of the ’528 patent. When the ’528 Accused Instrumentality is made, used, sold, or offered for sale by Canon’s subsidiaries, customers and resellers, or other third parties, those subsidiaries, customers, resellers, or other third parties are thereby infringing, literally or under the doctrine of equivalents, one or more claims of the ’528 patent. The components and apparatuses supplied by Canon constitute material parts of the claimed inventions of the ’528 patent.

98. Upon information and belief, Canon knows, for the reasons described above, that accused functionality of the memory device with instructions stored thereon and the software are especially made and/or especially adapted for use in infringing the ’528 patent. Moreover, these components and apparatuses are not staple articles of commerce suitable for substantial non-infringing use at least because they have no use apart from a user interface for use on a computer system coupled with a scanner for performing a scan operation with an image-enhancement process as claimed in the ’528 patent. For example and without limitation, at least the PIXMA MG6220 includes software that provides a user interface that is used only in conjunction with or as part of the claimed inventions.

DEMAND FOR JURY TRIAL

Pursuant to Federal Rules and Civil Procedure 38(b), Intellectual Ventures I and II demand a trial by jury.

PRAYER FOR RELIEF

WHEREFORE, Intellectual Ventures I and II respectfully pray that this Court enter judgment in its favor as follows:

a) declaring that Canon has directly infringed, induced infringement of, and/or contributed to the infringement of one or more claims of the Asserted Patents;

b) awarding Intellectual Ventures I and II all damages adequate to compensate for Canon's infringement, and in no event less than a reasonably royalty for Canon's acts of infringement, including all pre-judgment and post-judgment interest at the maximum rate allowed by law;

c) awarding Intellectual Ventures I and II attorney fees, costs, and expenses that it incurs in prosecuting this action; and

d) awarding Intellectual Ventures I and II any further and additional relief as the Court may deem just and equitable.

Dated: January 10, 2014

OF COUNSEL:
TENSEGRITY LAW GROUP LLP
Matthew D. Powers
Steven S. Cherensky
Monica M. Eno
Stefani C. Smith
Sam Kim
Palani R. Rathinasamy
555 Twin Dolphin Drive, Suite 360
Redwood Shores, CA 94065
Telephone: (650) 802-6000
Fax: (650) 802-6001

FARNAN LLP
/s/ Brian E. Farnan
Brian E. Farnan (Bar No. 4089)
919 North Market Street, 12th Floor
Wilmington, DE 19801
(302) 777-0300
(302) 777-0301
bfarnan@farnanlaw.com

Attorneys for Plaintiffs

EXHIBIT A

US005444728A

United States Patent [19]

Thompson

[11] **Patent Number: 5,444,728**

[45] **Date of Patent: Aug. 22, 1995**

[54] **LASER DRIVER CIRCUIT**

[75] Inventor: **Marc T. Thompson**, Watertown, Mass.

[73] Assignee: **Polaroid Corporation**, Cambridge, Mass.

[21] Appl. No.: **172,834**

[22] Filed: **Dec. 23, 1993**

[51] **Int. Cl.**[6] **H01S 3/00**

[52] **U.S. Cl.** **372/38**; 372/29; 372/26

[58] **Field of Search** 372/38, 29, 25, 26

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,081,670	3/1978	Albanese	250/199
4,237,427	12/1980	Holland	331/94.5 S
4,347,610	8/1982	Meuleman	372/29
4,412,331	10/1983	Chapman	372/29
4,492,970	1/1985	Lee et al.	346/160
4,504,951	3/1985	McMahan et al.	372/38
4,539,686	9/1985	Bosch et al.	372/26
4,677,632	6/1987	Lisco et al.	372/38
4,698,817	10/1987	Burley	372/31
4,709,370	11/1987	Bednarz et al.	372/38
4,713,672	12/1987	Horihata et al.	346/108
4,725,854	2/1988	Ohtsuka et al.	346/108
4,748,633	5/1988	Negishi	372/38
4,771,431	9/1988	Nakazawa et al.	372/38
4,791,632	12/1988	Anderson et al.	372/31
4,878,066	10/1989	Shiraishi	346/108
4,886,963	12/1989	Ohmori	250/235
4,912,714	3/1990	Hatanaka et al.	372/31
4,916,706	4/1990	Ohashi	372/31
4,945,541	7/1990	Nakayama	372/31
5,123,023	6/1992	Santarelli et al.	372/38
5,170,403	12/1992	Mayer	372/26
5,177,755	1/1993	Johnson	372/38
5,182,756	1/1993	Waki et al.	372/38
5,191,589	3/1993	Amano et al.	372/38
5,199,038	3/1993	Vahala et al.	372/33
5,224,112	6/1993	Uesaka	372/38
5,253,267	10/1993	Johnson	372/38

OTHER PUBLICATIONS

An Integrated Circuit for Multiplexing and Driving Injection Lasers, R. G. Swartz et al., Journal of Solid State Circuits, vol. SC-17, No. 4, Aug. 1982, pp. 753–760.

Direct Modulation of Double–Hetero–Structure Lasers at Rates up to 1 Gbit/s, M. Chown et al., Electronics Letters, Jan. 25, 1973, vol. 9, No. 2.

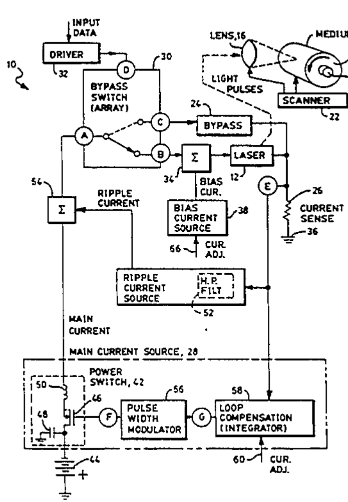
Primary Examiner—Léon Scott, Jr.

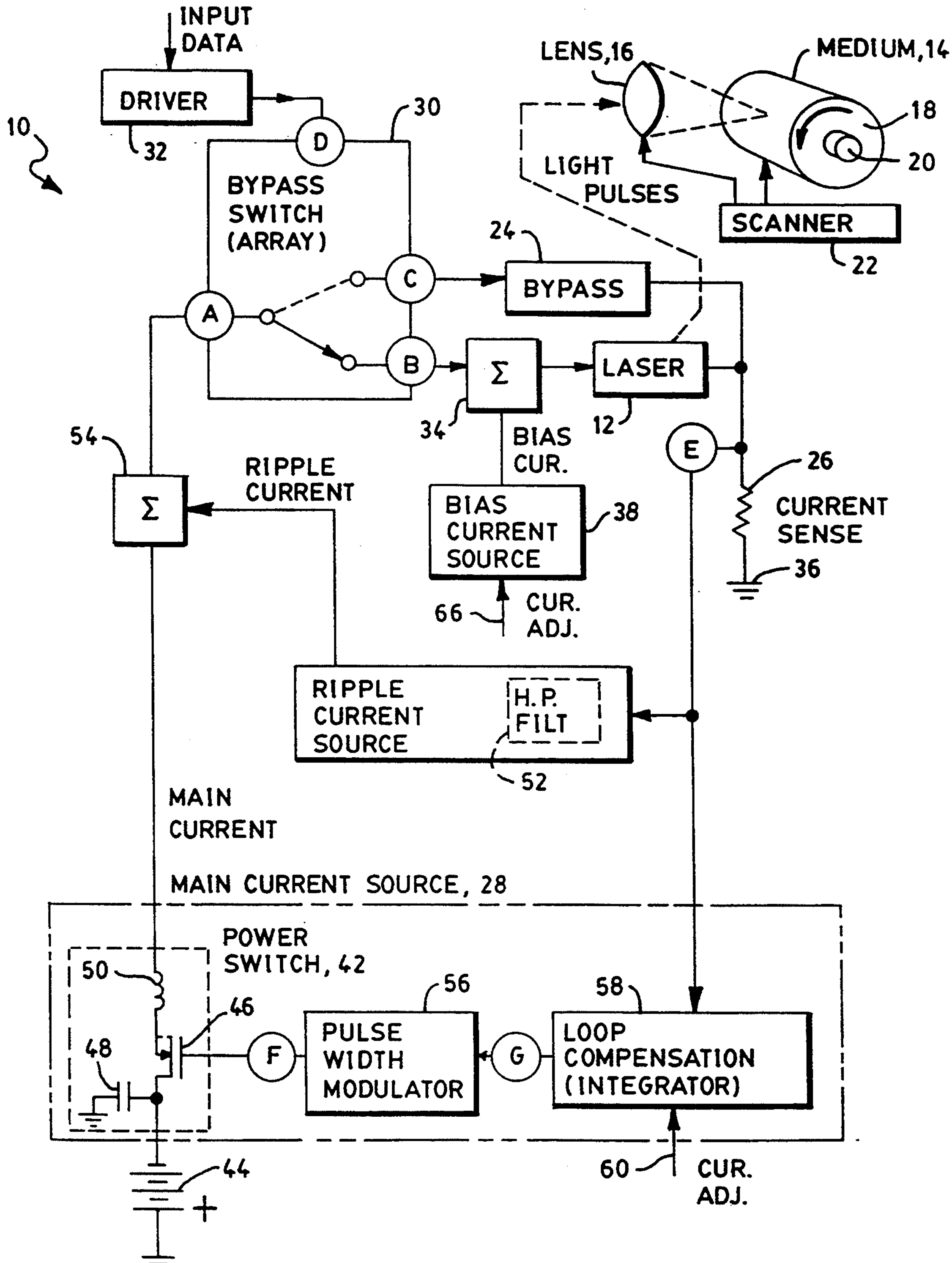
Attorney, Agent, or Firm—Francis J. Caufield

[57] **ABSTRACT**

A driver circuit applies electric current to a semiconductor laser for emission of light suitable for use in a laser printer wherein a photosensitive medium is exposed by the light for imprinting an image of marks or pixels upon the medium. The current is the sum of bias current plus signal current, the latter being a sequence of pulses providing image data. The circuit includes a bypass around the laser, and the signal current is pulsed by using a switching circuit which applies a steady input current alternately to the laser and the bypass under control of a digital data signal. The switching circuit is an array of emitter-coupled logic elements operating in parallel for reduced inductance and higher switching speed. The steady input current is provided by a switching current regulator wherein a power transistor, driven by a pulse width modulator, alternately connects and disconnects current from a DC power supply in conjunction with a smoothing filter comprising an inductor and a capacitor. A current sensing resistor connects in series with the parallel circuit of laser and bypass to output a sense signal representing the amplitude of the steady input current. The sensor signal drives the pulse width modulator via a loop compensation element to establish an average value of laser current. An additional ripple current source, responsive to a high frequency component of the sensor signal, is added to the input current to counteract any ripple from the regulator.

20 Claims, 5 Drawing Sheets





INPUT DATA
DRIVER
32
10
30
D
BYPASS SWITCH (ARRAY)
LENS,16
MEDIUM,14
18
20
LIGHT PULSES
SCANNER
22
24
BYPASS
C
A
B
Σ
LASER
34
12
BIAS CUR.
E
26
CURRENT SENSE
36
54
RIPPLE CURRENT
Σ
BIAS CURRENT SOURCE
38
66
CUR. ADJ.
RIPPLE CURRENT SOURCE
H.P. FILT
52
MAIN CURRENT
MAIN CURRENT SOURCE, 28
POWER SWITCH, 42
50
46
48
56
58
F
PULSE WIDTH MODULATOR
G
LOOP COMPENSATION (INTEGRATOR)
44
60
CUR. ADJ.

FIG. 1

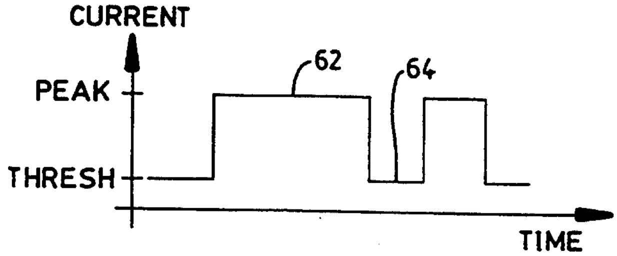

CURRENT
PEAK
THRESH
62
64
TIME

FIG. 2

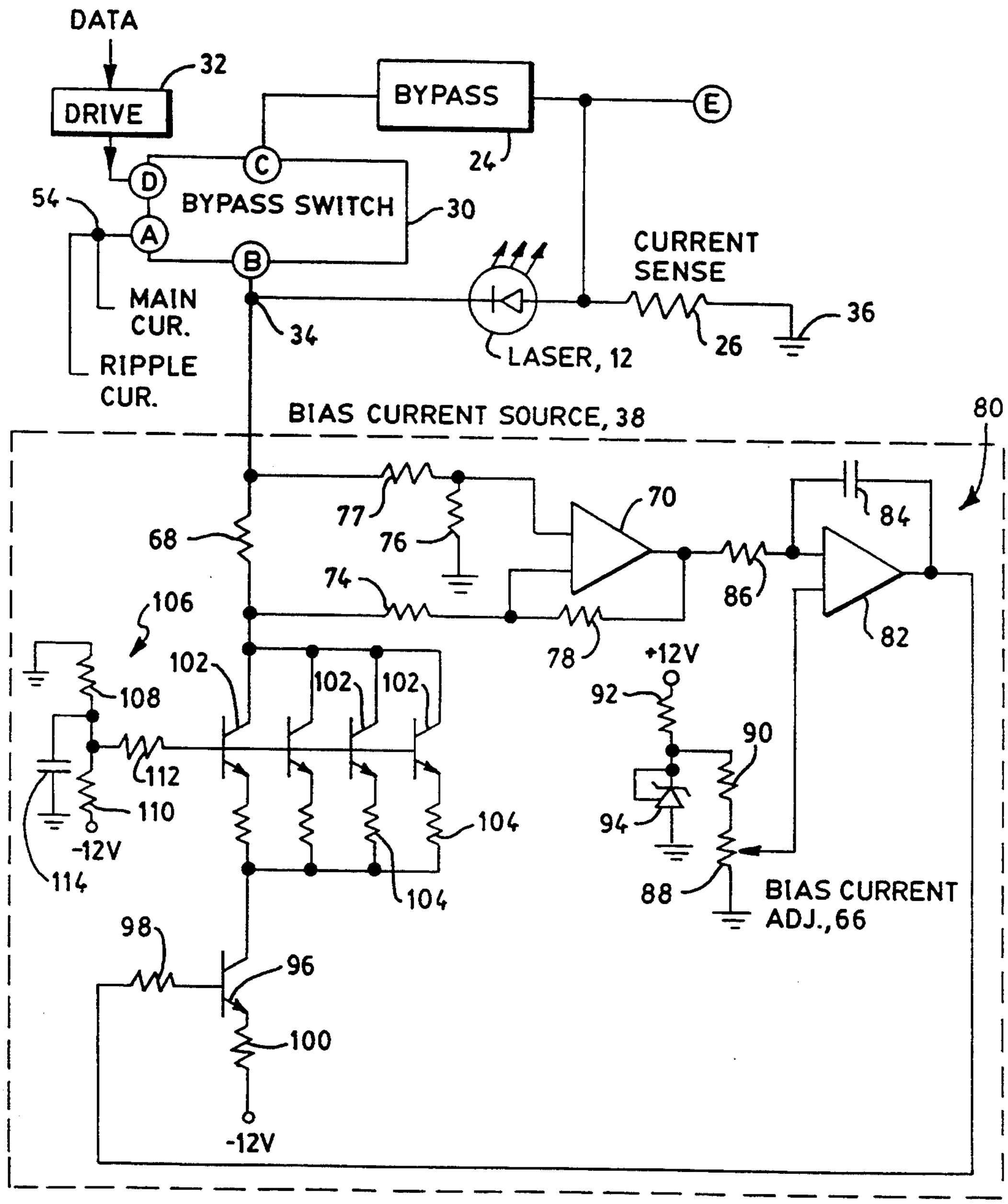
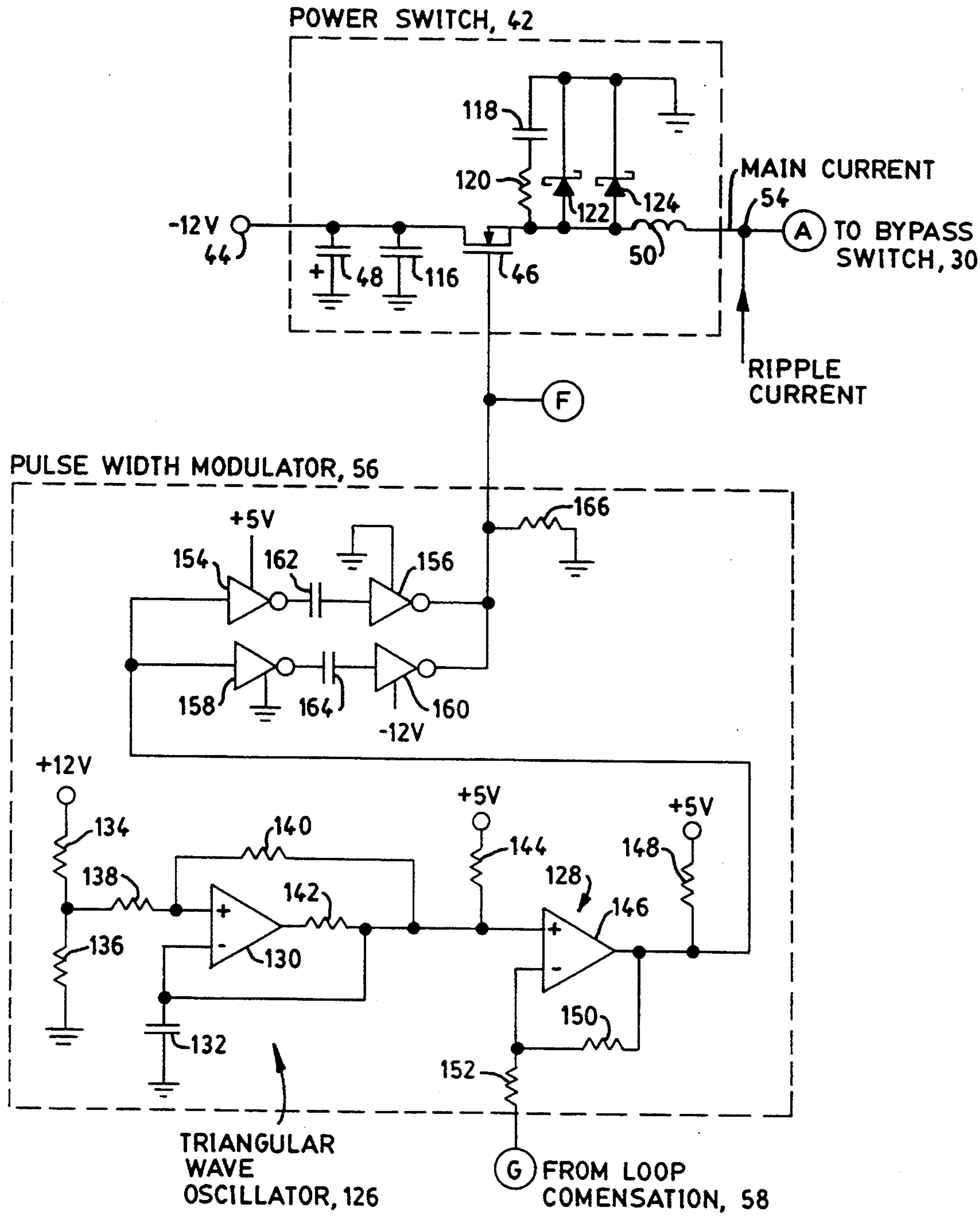
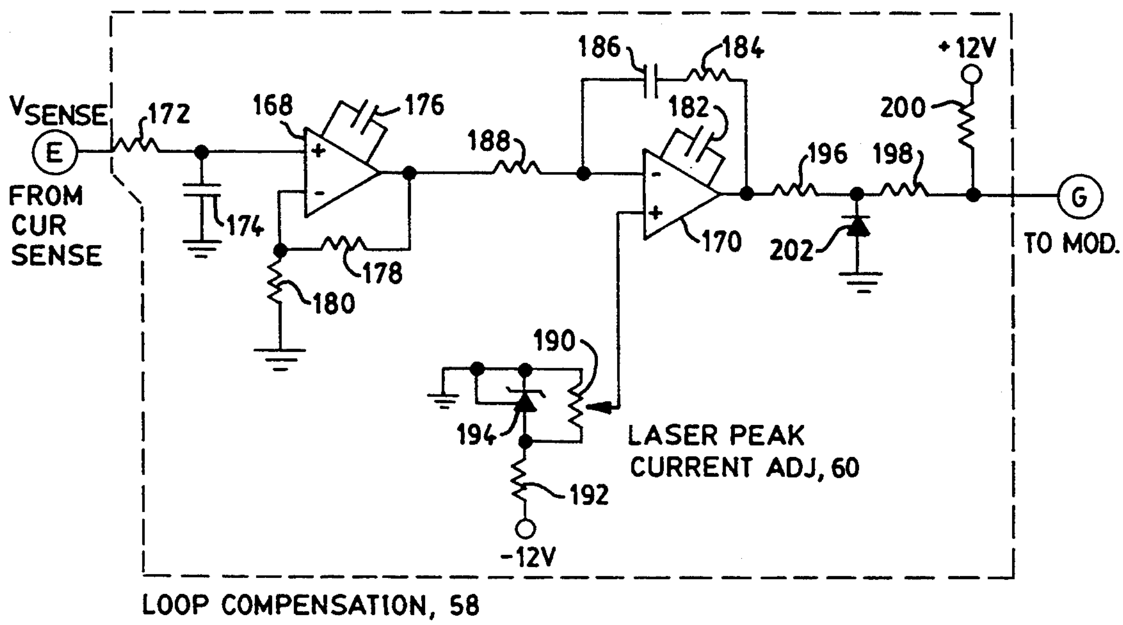

DATA
32
DRIVE
BYPASS
24
E
C
D
BYPASS SWITCH
30
54
A
B
MAIN CUR.
RIPPLE CUR.
34
LASER, 12
CURRENT SENSE
26
36
BIAS CURRENT SOURCE, 38
80
77
76
70
84
68
74
86
82
78
+12V
106
102
102
102
108
92
90
112
110
-12V
114
104
104
94
88
BIAS CURRENT ADJ.,66
98
96
100
-12V

FIG. 3



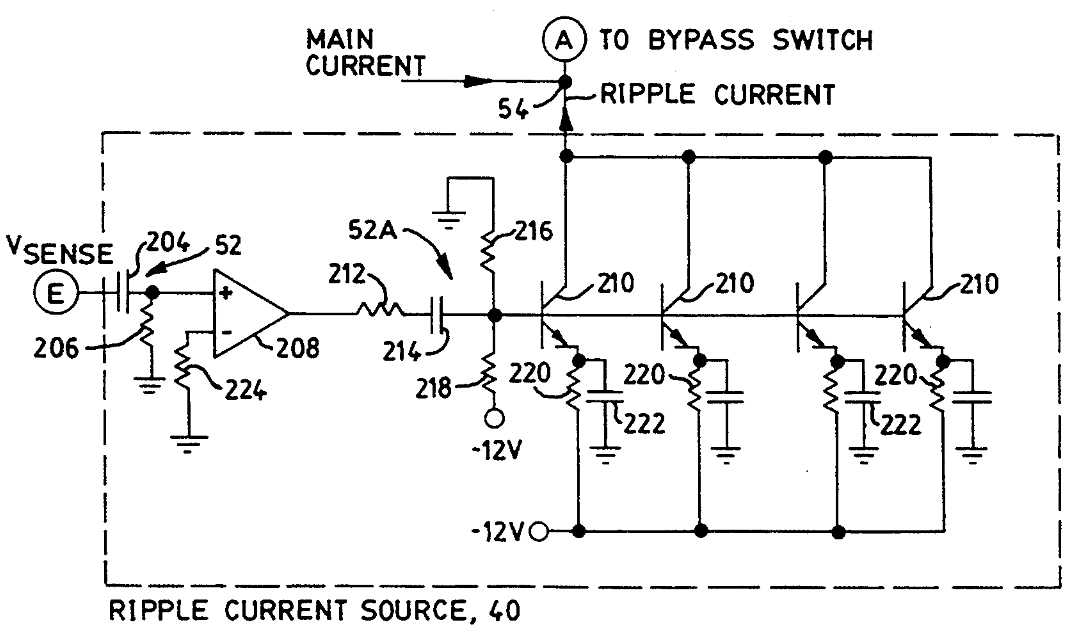
POWER SWITCH, 42
118
120
122
124
-12V
44
+
48
116
46
50
MAIN CURRENT
54
A
TO BYPASS SWITCH, 30
RIPPLE CURRENT
F
PULSE WIDTH MODULATOR, 56
166
+5V
154
162
156
158
164
160
-12V
+12V
134
138
136
140
142
130
132
+5V
144
128
146
+5V
148
150
152
TRIANGULAR WAVE OSCILLATOR, 126
G
FROM LOOP COMENSATION, 58

FIG. 4



VSENSE
E
FROM
CUR
SENSE
172
174
168
176
178
180
188
186
184
182
170
190
194
192
-12V
LASER PEAK
CURRENT ADJ, 60
196
198
200
+12V
202
G
TO MOD.
LOOP COMPENSATION, 58

FIG. 5



MAIN
CURRENT
A
TO BYPASS SWITCH
54
RIPPLE CURRENT
VSENSE
E
204
52
206
208
224
52A
212
214
216
218
-12V
210
220
222
-12V
RIPPLE CURRENT SOURCE, 40

FIG. 6

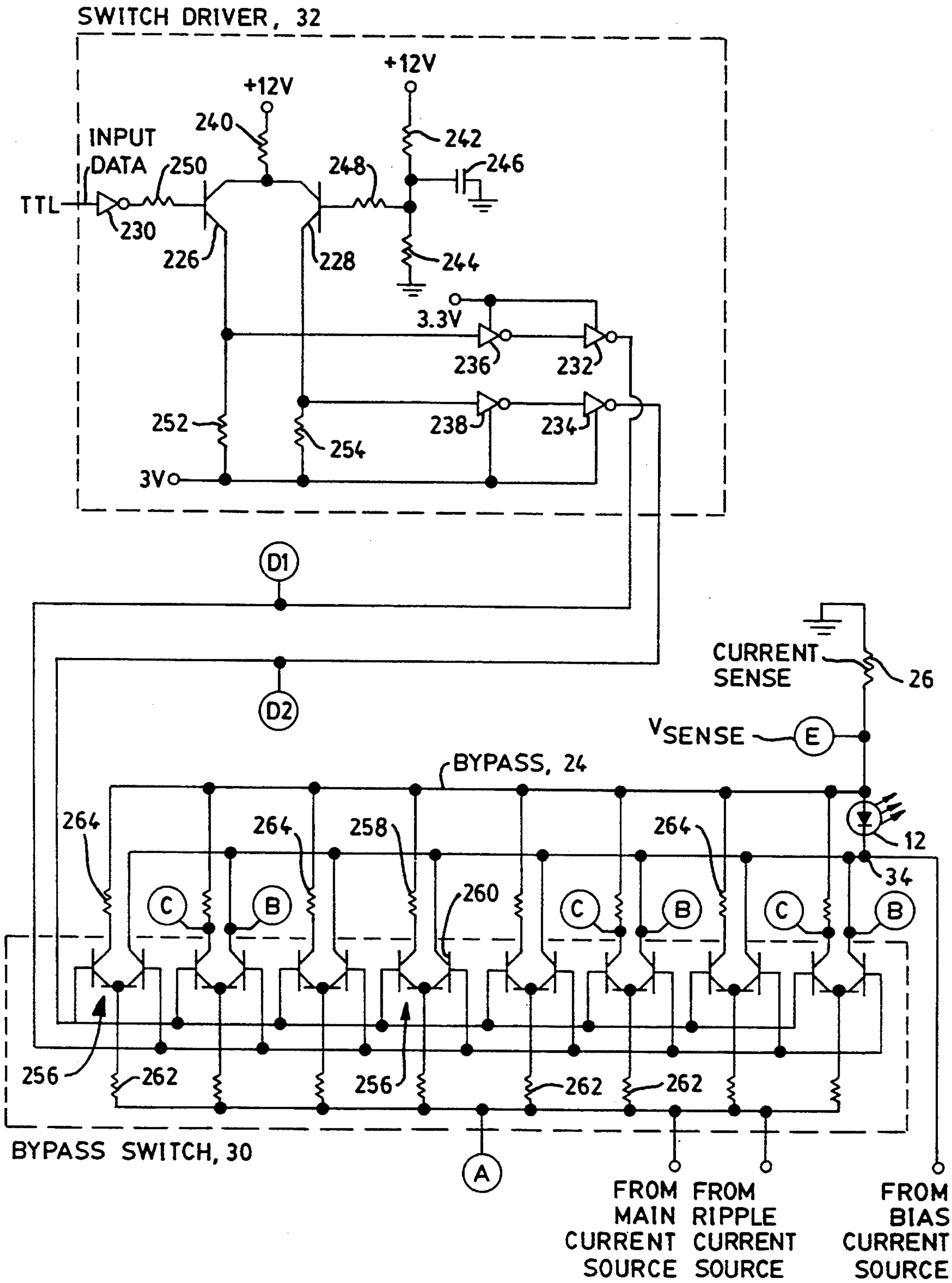

SWITCH DRIVER, 32
+12V
+12V
240
242
246
INPUT
DATA
250
248
TTL
230
226
228
244
3.3V
236
232
252
254
238
234
3V
D1
D2
CURRENT
SENSE
26
VSENSE
E
BYPASS, 24
264
264
258
264
12
34
C
B
260
C
B
C
B
256
262
256
262
262
BYPASS SWITCH, 30
A
FROM
MAIN
CURRENT
SOURCE
FROM
RIPPLE
CURRENT
SOURCE
FROM
BIAS
CURRENT
SOURCE

FIG. 7

LASER DRIVER CIRCUIT

BACKGROUND OF THE INVENTION

This invention relates to a laser driver circuit, suitable for use in a laser printing system and, more particularly, to the implementation of a pulse modulation of the laser current by diverting laser current around the laser in a bypass during interpulse intervals, the invention including also features of parallel bypass switching stages of emitter-coupled logic (ECL) for reduced inductance and increased bandwidth, as well as use of a pulse-width modulated current-switching regulator to produce the main current for energizing the laser in conjunction with a feedback anti-ripple current source for cancellation of current ripple associated with operation of the current-switching regulator.

The use of a laser, in the form of a diode, has found wide use as a source of light in laser printing systems wherein pulses of the light illuminate a photosensitive material of a recording medium. By scanning the light across the medium, and by imparting imaging data to a train of pulses of the light, an image is constructed on the medium. By way of example, the image may be a message composed of alphanumeric characters, or the image may be in a pictorial format constructed of gray scale.

In the construction of a gray-scale image, pixels of dark and light image are imprinted with a sufficiently high density to appear to the human eye as a continuum wherein a high density of dark marks gives the appearance of a relatively dark region of the image while a low density of dark marks gives the appearance of a relatively light portion of the image. By way of example, such an imaging process is most useful for imprinting medical data, such as copies of x-rays, sonograms, and pictorial data from magnetic resonance imaging.

Protection of a high density of pixels on the recording medium is useful, not only in the production of high quality medical images, but also in the production of the printing of high quality alphanumeric characters, particularly in the case of very fine writing. In order to accomplish the small pixels, it is necessary to focus the laser beam to a small point on the medium, which point is to be illuminated by the laser beam, or is to be left blank by a termination of the laser beam. As a practical matter in the construction of such images, it is important to print the images quickly. This requires a rapid scanning of the laser beam relative to the medium, and a capacity for generating the pulses of light at a high rate, the latter requiring a high frequency operating capability to the electric circuitry which energizes the laser with pulses of current. In addition, in order to expose a pixel of the recording medium with sufficient optical energy to produce a mark in a short interval of time, there is a need for increased optical power output from a laser as well as increased power from the circuitry which drives the laser.

A problem arises in that presently available circuitry does not have both adequate power and adequate speed for rapid generation of high intensity pulses of laser light as would be desired for high resolution in the imaging of pictorial data. Attempts to overcome the problem of increased power with present circuit topologies generally entails utilization of larger heat sinks for dissipation of heat produced by the higher power circuits. However, such a requirement for enlarged heat sinks is incompatible with the relatively small spaces available in modern laser printers for replacement of electrical components as well as for the cooling of the components. As an example of the difficulties entailed in use of present laser circuit topologies, a linear feedback amplifier with a power transistor in the feedback loop has been used generally in the construction of circuits for driving pulses of current through a laser to excite the laser to emit light. However, an increase in the size of the power transistor for increased power handling capacity results in a reduction of the switching speed of the transistor. Furthermore, the enlarged power transistor is wasteful of energy due to the large amount of heat dissipated at the transistor, the heat in itself creating a need for additional heat sinking.

SUMMARY OF THE INVENTION

The aforementioned problem is overcome and other advantages are provided by a driver circuit for applying pulses of current to a semiconductor laser to energize the laser to emit pulses of light. As used herein, the term light is understood to include radiation in the visible spectrum as well as radiation lying outside of the visible spectrum such as infrared radiation and ultraviolet radiation. The invention is ideally suited for the driving of a laser in a printing system wherein light of the laser is scanned relative to a photosensitive recording medium, and wherein the pulses of light correspond to pulses of a digital data signal, each pulse providing data of a pixel of an image being printed on the medium.

In order to accommodate a higher input data rate and higher laser drive current, the drive circuit of the invention includes a bypass for conducting electric current in a path around the laser, in conjunction with a bypass switch which is operative to select an electrical path for the current to flow either through the laser or through the bypass. By directing the flow of current, to be referred to as the main current, through the laser, the laser is energized to emit light. In the alternate position of the bypass switch, the main current is directed to flow via the bypass so as to terminate emission of light by the laser. Thereby, by operation of the bypass switch in synchronism with the pulses of an input digital data signal, the laser emits a train of light pulses identical in format to the train of electrical pulses of the input digital signal. A bias current is provided by a bias current source directly to the laser for maintaining a minimum laser current having a value just below the lasing threshold of the laser. The main current is provided by a separate main current source connected with an input terminal of the bypass switch. An advantage in the use of the bypass switch for energizing and deenergizing the laser is the fact that the main current is able to flow continuously at a steady value even though the laser is being pulsed. The bypass switch simply redirects the flow of current through alternate current paths, namely the laser or the bypass. Preferably, the bypass path includes a resistor having a resistance approximately equal to the resistance of the laser so as to minimize the power dissipated in the current switch. The two current paths rejoin at a current sensing device, such as a current-sensing resistor. A voltage drop across the current sensing resistor serves as a current sense signal indicating the magnitude of the total laser current which is the sum of the main current plus the bias current.

The main current source is in the nature of a power converter which is connected to an external electrical power supply, such as a battery, and which includes a transistor connected as a gate or switch. The transistor is operated in pulsating fashion to alternately connect and disconnect a path of the main current flow from the external power source to the bypass switch. Included with the transistor switch are energy storage elements, particularly a capacitor connected to an input terminal of the transistor switch and an inductor connected to an output terminal of the transistor switch, for storing electrical energy of the pulses and for outputting the electrical energy as a steady value of the main current. The main current source further comprises a pulse-width modulator connected to a control terminal of the transistor switch for alternately placing the transistor switch in states of conduction and nonconduction with a duty cycle which is variable in accordance with the amount of the main current to be supplied. The modulator increases the conduction time of the transistor switch for an increased value of main current, and decreases the conduction time of the transistor switch to decrease the value of the main current. This enables the main current source to provide the peak values of current to the laser at a desired fixed amplitude for a uniform printing of an image on a recording medium. A feedback amplifier with a loop compensation filter connects between the current sensor signal and an input terminal of the pulse-width modulator to provide for closed-loop operation of the main current source in maintaining a desired amplitude of the main current.

It is noted that the switching operation of the main current source provides a ripple component in addition to the DC component of the main current. For improved uniformity in the illumination of the recording medium by the laser light, it may be desirable to reduce the tipple component of the main current. While such reduction can be attained by use of larger energy storage elements, a large physical size to the energy storage elements may be undesirable in situations wherein laser printing equipment is to have a small physical size. Accordingly, in accordance with a further feature of the invention, there is provided a ripple current source responsive to the current sense signal for generating a ripple current which is substantially equal and opposite to that of the tipple component of the main current. The ripple current is summed with the main current at the input terminal of the bypass switch to essentially cancel the ripple component of the main current. This ensures a substantially constant amplitude to the main current.

As a further feature of the invention, it is desirable to increase the obtainable speed and frequency of operation of the bypass switch. This is accomplished by constructing the bypass switch as a set of parallel stages of emitter-coupled logic (ECL) wherein a first output terminal of each stage is connected to the laser, a second output terminal of each stage is connected to the bypass, and a common emitter terminal of each stage is connected to the input terminal of the bypass switch. A driver circuit responsive to the input digital data signal provides a pair of complementary output signals for driving the pair of differential input signals of each of the ECL stages. The parallel interconnection of the plural stages provides for a substantial reduction of the total inductance of the bypass switch, this allowing for an improved frequency response of the switch. The driver circuit has adequate power to overcome the total input capacitance of the plural ECL stages. Thereby, the bypass switch is operable to attain a high frequency pulsing of the laser current.

BRIEF DESCRIPTION OF THE DRAWINGS

The aforementioned aspects and other features of the invention are explained in the following description, taken in connection with the accompanying drawing wherein:

FIG. **1** is a simplified diagrammatic view of the driver circuit of the invention showing utilization of light outputted by a laser for printing an image on a photosensitive medium;

FIG. **2** is a timing diagram showing pulses of current applied to a laser in FIG. **1** for energizing the laser to emit pulses of light to expose a photosensitive recording medium of FIG. **1**;

FIG. **3** is a schematic of a portion of the circuit of FIG. **1**, namely a laser bias current source, and connection of the bias current source with other components of FIG. **1**;

FIGS. **4** and **5** together constitute a schematic drawing of a main current source of the circuit of FIG. **1**, wherein FIG. **4** shows a current switching regulator and a pulse-width modulator driving a transistor of the regulator, and

FIG. **5** shows an amplifier with filter for loop compensation responsive to sensed current of the laser and the bypass for driving the pulse-width modulator of FIG.

FIG. **6** is a schematic diagram of a ripple reduction current source for canceling ripple in output current of the main current source of FIG. **4**; and

FIG. **7** is a schematic diagram of an array of parallel stages of emitter-coupled logic stages employed in construction of a bypass switch of FIG. **1**, and a driver circuit responsive to an input data signal for driving the switch.

DETAILED DESCRIPTION

FIG. **1** shows a laser printer system **10** wherein a semiconductor laser **12** emits light for exposing a photosensitive recording medium **14** for imprinting an image thereon. An optical system, represented by a lens **16**, focuses the light upon the medium **14**. By way of example, the medium **14** may be carried along the outer surface of a drum **18** rotatable about an axle **20**. Well-known scanning apparatus **22** positions the lens **16** to focus the laser beam in synchronism with rotation of the drum **18** to provide for a scanning of a beam of the laser light along the medium **14** to produce the image. The image is composed of a set of light and dark regions, or pixels, resulting from a sequence of pulses of the laser light. It is to be understood that the drum **18** represents one form of carrier of the medium **14** and that other forms of carrier, such as a planar film tray (not shown) may be used in carrying the medium **14** for producing the image. While FIG. **1** shows the use of the light pulses in the operation of a printing system to print an image, it is to be understood that, in accordance with the invention, the light pulses may be used also for purposes other than printing.

The circuitry of the invention comprises a bypass **24**, a sensor of laser current such as a current-sensing resistor **26**, a main current source **28** in the form of a power converter, and a bypass switch **30**. Current from the main source **28** is applied to the laser **12** via the switch **30**, the switch **30** being operative, in accordance with an important feature of the invention, to direct the main current alternately through the laser **12** and via a bypass path around the laser **12**, the alternate bypass path being indicated in FIG. 1 as the bypass 24. Details in the construction of the bypass 24 and the switch 30 will be described hereinafter. To facilitate the description, it is convenient to identify various terminals of the circuitry. The main current enters the switch 30 via terminal A, and exits the switch 30 via either terminal B or terminal C. Terminal B provides for the direction of current through the laser 12, and terminal C provides for the direction of current through the bypass 24.

The switch 30 is operated via a driver 32 connected to terminal D of the switch 30, the driver 32 being responsive to an input digital data signal. In response to an input data signal having a logic-1 state, the driver 32 drives the switch 30 to apply the main current via the laser 12, and in response to an input data signal having a state of logic-0, the driver 32 drives the switch 30 to the alternate position for applying the main current to flow through the bypass 24. A first terminal of the laser 12 is connected via the summer 34 to terminal B of the switch 30, and a second terminal of the laser 12 is connected to terminal E of the current-sensing resistor 26. A first terminal of the bypass 24 connects with terminal C of the switch 30, and a second terminal of the bypass 24 connects also with terminal E of the resistor 26. Thereby, both the current of the laser 12 and the current of the bypass 24 pass through the current-sensing resistor 26. A voltage drop across the resistor 26, measured between terminal E and ground 36, serves as a measure of the current flowing through the laser 12 and of the current flowing through tile bypass 24.

The circuitry of FIG. 1 also includes a bias current source 38 and a ripple current source 40. The bias current source 38 applies bias current to the laser 12, the bias current being summed with the main current by the summer 34 for application of the sum of both main and bias currents to the laser 12. The main current source 28 includes a power switch 42 which is operative as a converter, in a manner to be described, by pulsing current from an external source of electrical power, shown as a battery 44 , to convert the current and voltage of the battery 44 to a current of suitable value and a voltage of suitable value for operation of the laser 12. The power switch 42 includes a field-effect transistor (FET) 46 for switching current of the battery 44 to provide pulses of the current, and electrical-storage elements shown as a capacitor 48 and an inductor 50 for smoothing the train of current pulses to output a main current from the source 28 having a substantially constant amplitude. However, in view of the converter operation and the generation of pulses by the transistor 46, the main current has both a steady DC component plus a relatively small AC ripple component. In order to insure uniformity in the generation of the image of the medium 14, with respect to the difference between a light pixel and a dark pixel, it is desirable to minimize the ripple component of the main current. As will be described hereinafter, the ripple current source 40 includes a high-pass filter 52 for sensing the AC ripple component, tile ripple current source 40 generating a ripple current which is substantially equal and opposite to the ripple component of the main current so as to effectively cancel the ripple component of the main current. The cancellation is accomplished by summing the ripple current with the main current by a summer 54 prior to application of the main current to terminal A of the bypass switch 30. Thus, the current flowing in the laser 12 is the sum of the main current from the source 28, the ripple current from the source 40, and the bias current from the source 38.

The main current source 28 further comprises a pulse width modulator 56 and a loop compensation unit 58 which will be described in detail hereinafter. Briefly, the modulator 56 includes an oscillator for providing a pulse train wherein the duty cycle of pulses of the pulse train are varied in accordance with a control signal provided by the compensation unit 58. The control signal of the compensation unit 58 is coupled via terminal G to the modulator 56. The pulse train outputted by the modulator 56 is coupled via terminal F to a gate terminal of the transistor 46 wherein pulses of the modulator 56 place the transistor 46 alternately in states of conduction and nonconduction. The average value of the main current increases with increased duty cycle of the modulator 56 providing for increased intervals of conduction of the transistor 46, a corresponding decrease in average value of the main current occurring upon a decrease in the duty cycle provided by the modulator 56. The compensation unit 58 operates in response to the magnitude of the current sensing signal at terminal E so as to maintain an average value of the main current to a desired level designated at a manual current adjustment 60.

FIG. 2 shows a graph of current applied to the laser 12. The peak value of the current, at 62, is the same for all pulses of the current, and the minimum value of the current at 64, is the same for all interpulse intervals. The peak value is obtained with the bypass switch 30 coupling current between terminals A and B, as shown in FIG. 1, and the minimum value of current is obtained upon placing the bypass switch 30 in the alternate position for connecting current between terminals A and C for operation of the bypass 24. During application of the peak current to the laser 12, the sum of the currents of all three of the aforementioned sources 28, 40, and 38 is applied to the laser 12. However, during operation of the bypass 24, only the current of the bias current source 38 is applied to the laser 12. Adjustment of the bias current at the source 38 is provided by a manual current adjustment at 66. Thereby, as shown in FIG. 2, the laser current is modulated between two preset values of current. The minimum or bias current is set at a threshold value which biases the laser 12 to an operational state just below lasing threshold. The peak current is the current necessary to generate a desired optical power output by the laser 12.

The circuitry of the system 10 is operable to switch current to a semiconductor laser diode at various duty cycles with a maximum pulse repetition rate of 5 megahertz (MHz), and with a minimum pulse width of approximately 100 nanoseconds. Laser optical power output is to have a maximum value of approximately 1200 milliwatts, the laser threshold current provided by the bias source 38 is to be adjustable within a range of approximately 200 milliamperes (mA) to 500 mA, and the peak value of a current provided by the main source 28 is adjustable up to a maximum value of approximately 2.5 amperes.

As shown in FIG. 2, the pulses of the laser current, and accordingly of the optical pulses emitted by the laser, vary in their time duration. For example, if it is desired to produce a totally white or totally black line across the image of the medium 14, then a pulse of current applied to the laser 12 may be held continuously at the threshold value or at the peak value during the entire duration of a scan line across the medium 134. In contrast, during the generation of a portion of an image having line detail, the pulse repetition frequency may be at or near to the aforementioned maximum repetition rate of 5 MHz. The pulsing frequency of the pulse-width modulator **56** (FIG. **1**) has a relatively high value, approximately 1 MHz so as to facilitate a filtering of the ripple component by the energy storage elements, namely the capacitor **48** and the inductor **50**. The ripple current source **40** produces sufficient cancellation of the ripple component of the main current for image fidelity so that there is no need to provide any specific relationship between the operating frequency of the modulator **56** and an operating frequency of the scanning apparatus **22**. Thus, the oscillation of the modulator **56** is allowed to proceed in a free-running manner independent of the operation of the scanning apparatus **22**.

In accordance with yet another feature of the invention, the bypass switch is constructed of a plurality of emitter-logic (ECL) stages to facilitate handling of relatively large amounts of laser current and to increase the switching speed so as to accomplish the high pulse repetition rate for the switching current in the laser **12**. The use of the parallel ECL stages decreases the total inductance of the switch **30** so as to allow for a higher rate of signal pulses outputted by the switch **30**. The increased input capacitance presented to the driver **32** by the parallel connection of the plural switching stages is met by providing the driver **32** with sufficient power to overcome the additional capacitance, and thereby attain the high switching speed for the switch **30**.

FIG. **3** shows details in the construction of the bias current source **38**, and interconnection of the current source **38** with other components of the system **10** of FIG. **1**. The function of the summer **34**, namely the summing of the bias current with the main current, is accomplished by connection of the electrical conductors from terminal B and from the bias source **38** at a current-summing node, as indicated at **34** in FIG. **3**. Similarly, the function of the summer **54**, namely the summing of the ripple current with the main current, is accomplished by connecting the electrical conductors from the ripple current source **40** and the main current source **28** at a current-summing node, as indicated at **54** in FIG. **3**.

The bias current source **38** comprises a current sensing resistor **68** and a differential amplifier **70** having a non-inverting input terminal connected by a resistor **72** to one terminal of the resistor **68**, and an inverting input terminal connected via a resistor **74** to the second terminal of the resistor **68**. A resistor **76** connects between the noninverting input terminal of the amplifier **70** and ground, and a resistor **78** is connected in a feedback path between the inverting input terminal and the output terminal of the amplifier **70**. In the preferred embodiment of the invention, the current sensing resistor **26** has a value of 0.1 ohm, the resistor **68** has a value of 1 ohm, each of the resistors **72**, **74**, **76**, and **78** have a value of 10 kilohm. The amplifier **70** has a voltage gain of unity so that the output terminal thereof provides a voltage equal to the voltage dropped across the resistor **68**. Preferably, the resistors **26** and **68** are precision resistors so as to provide accurate measures of the total current flowing through the resistor **26**, and the bias current flowing through the resistor **68** to the laser **12**.

The bias current source **38** further comprises an integrator **80** having a differential amplifier **82** with a capacitor **84** connected between an inverting input terminal and an output terminal of the amplifier **82**. The inverting input terminal of the amplifier **82** is connected via resistor **86** to the output terminal of the amplifier **70**. The bias current adjustment **66** comprises a potentiometer **88** having a tap connected to the noninverting input terminal of the amplifier **82**. One terminal of the potentiometer **88** is grounded, and the second terminal of the potentiometer **88** is connected serially via resistors **90** and **92** to a positive terminal of a voltage source, a 12 volt source being used in the preferred embodiment of the invention. Also, a semiconductor voltage reference element **94** is connected between ground and the junction of resistor **90** and resistor **92** to provide a stable voltage reference for the potentiometer **88**. In the preferred embodiment of the invention, the resistor **86** has a value of 10 kilohm, the capacitor **84** has a value of 0.01 microfarad, the resistor **92** has a value of 1 kilohm, the resistor **90** has a value of 22 kilohm, and the potentiometer **88** has a resistance of 5 kilohm.

The bias current source **38** further comprises a transistor **96** which serves as a current source, and has a base terminal connected via a resistor **98** to an output terminal of the integrator **80**. An emitter terminal of the transistor **96** is connected via a resistor **100** to the negative terminal of a voltage source, a 12 volt source being employed in the preferred embodiment of the invention. A set of four transistors **102** each of which has an external emitter resistor **104**, are connected in parallel with their respective collector terminals being connected together and to the junction of the resistors **68** and **74**, and wherein the base terminals of the transistors **102** are connected together. Each of the transistors **102** is connected via its emitter resistor **104** to the collector terminal of the transistor **96**. A bias current supply **106** provides base current to the transistors **102**, and comprises two resistors **108** and **110** connected serially between ground and a negative voltage terminal (−12 volts). The bias current supply **106** includes a resistor **112** connecting between a junction of the resistors **108** and **110** to feed current to the base terminals of the transistors **102**, and a capacitor **114** connected between ground and the junction of the resistors **108** and **110**.

The set of transistors **102** serves as an isolation unit for isolating the transistor **96** from any transient voltages resulting from the switching of current to the laser **12** and appearing at terminal B, thereby preventing such transient voltages from being coupled via capacitance of the transistor **96** throughout the bias current source **38**. In addition, the set of transistors **102** serves to reduce the amount of voltage appearing across the transistor **96** by absorbing power of the bias current passing from the transistor **96** to the resistor **68**. The power dissipated in the transistors **102** is regarded as a relatively small power loss because of the relatively small size of the bias current, as compared to the size of the main current. In the preferred embodiment of the invention, each of the transistors **102** is type 2N2222, and each of the resistors **104** has a value of 10 ohms. The transistor **96** is type 2SC3072, the resistor **98** has a value of 1 kilohm and the resistor **100** has a value of 6.8 kilohm. In the preferred embodiment of the invention, the resistor **108** has a value of 1 kilohm, the resistor **110** has a value of 2 kilohm, the resistor **112** has a value of 470 ohms, and the capacitor **114** has a value of 0.1 microfarad.

In the operation of the bias current source **38**, the amplifier **70** in conjunction with the sense resistor **68** outputs a signal to the integrator **80** indicating the amplitude of the bias current. The signal is integrated by the integrator **80** and applied as an input signal to the transistor **96**. The differential amplifier **82** of the integrator **80** drives the transistor **96** to produce a bias current which drives the overall loop of the bias source **38** to induce equality between the signals at the two input terminals of the differential amplifier **82**. Thereby, the bias current flowing through the resistor **68** is made to be equal to the selected value of current at the bias current adjust **66**.

FIG. **4** shows details in the construction of the power switch **42** and the pulse-width modulator **56** of the main current source **28** of FIG. **1**. In FIG. **4**, the power switch **42** comprises additional capacitors **116** and **118**, a resistor **120**, and two Schottky diodes **122** and **124**. The capacitor **116** is connected in parallel with the capacitor **48**. The diodes **122** and **124** are connected in parallel, their anode terminals being connected to a junction of the transistor **46** and the inductor **50**. The resistor **120** and the capacitor **118** are connected in series between ground and the junction of the transistor **46** with the inductor **50**. In the preferred embodiment of the invention, the capacitor **48** has a capacitance of 22 microfarads and the capacitor **116** has a value of 0.1 microfarads for operation at both low and high frequencies of the current flowing between the negative terminal of the battery **44** and the switch terminal A. The diodes **122** and **124** provide for a current path allowing current in the inductor **50** to continue to flow after a termination of a state of conduction within the transistor **46**. The resistor **120** and the capacitor **118** serve as a filter for smoothing the switching transients in the switching of the main current. The capacitors **48** and **116** serve as both a source and a sink of current for smoothing switching transients as the transistor **46** passes between successive stages of conduction and nonconduction. Upon a termination of a state of conduction of the transistor **46**, energy stored within the magnetic field of the inductor **50** provides for a continuation of the flow of current to terminal A of the bypass switch **30**. In the preferred embodiment of the invention, the Schottky diodes **122** and **124** are type 6CWQ03F, specified for a maximum DC current of 6.6 amperes and a maximum reverse voltage of **30** volts, and the transistor **46** is a N-channel MOSFET type IRFR014. The inductor **50** has a value of 47 microhenries.

The modulator **56** includes a triangular wave oscillator **126** and a comparator **128**. The oscillator **126** includes a differential amplifier **130**, a capacitor **132**, and five resistors **134**, **136**, **138**, **140**, and **142**. The resistors **134** and **136** are connected in series between a positive voltage (such as 12 volts) and ground. A junction of the two resistors **134** and **136** is connected by the resistor **138** to a noninverting input terminal of the amplifier **130**. The resistor **142** is connected at a first terminal thereof to the output terminal of the amplifier **130**, a second terminal of the resistor **142** being connected to the inverting input terminal of the amplifier **130**. The resistor **140** is connected between the noninverting input terminal of the amplifier **130** to the second terminal of the resistor **142**. A further resistor **144** connects a source of positive voltage (such as 5 volts) to the junction of the resistors **140** and **142**. The comparator **128** comprises a differential amplifier **146** and three resistors **148**, **150**, and **152**. The inverting input terminal of the differential amplifier **146** connects with the junction of the resistors **140**, **142**, and **144**. The resistor **150** connects between an output terminal of the amplifier **146** and the noninverting input terminal of the amplifier **146**. The resistor **148** connects between a source of positive voltage (such as 5 volts) and the output terminal of the amplifier **146**. The resistor **152** connects between the noninverting input terminal of the amplifier **146** and terminal G for connection to an output terminal of the loop compensation unit (FIGS. **1** and **5**).

With reference to FIG. **4**, and in reference to the operation of the oscillator **126**, the resistors **140** and **142** provide positive feedback and the resistor **142** provides negative feedback. The amplifier **130** provides current which serves to charge the capacitor **132** during a portion of each cycle and to discharge the capacitor **132** during the balance of each cycle of the oscillation waveform. The resistors **134**, **136**, and **138** provide an input operating point to the amplifier **130**. In addition, these resistors in combination with the resistor **140** serve to provide a gain factor for the amplifier **130**. The resistor **144**, in view of its connection between the capacitor **132** and the source of positive voltage, aids in the charging of the capacitor **132**. With respect to the operation of the comparator **128**, the resistor **150** serves as a feedback resistor for establishing gain of the comparator. A signal from the loop compensation unit **58** at terminal G is applied via the resistor **152** to the amplifier **146**, and a signal of the oscillator **126** is coupled via the resistor **152** to the amplifier **146**. The two signals are compared at the two input terminals of the amplifier **146** to provide an output signal having either a high or a low value depending on the relative magnitudes of the two input signals to the amplifier **146**.

A set of four output driver units **154**, **156**, **158** and **160** couple the output terminal of the comparator **128** via terminal F to the power switch **42**. The resistor **148** serves to provide an output load to the comparator **128** as well as an input bias to the driver units **154** and **158**. The driver units **156** and **160** are gate drivers having sufficient power to drive input capacitance of the transistor **146** so as to accomplish the 1 MHz pulse repetition switching rate of the transistor **46**. The driver units **154** and **158** may be buffer amplifiers. The driver units **154** and **156** are coupled via a capacitor **162**, and the driver units **158** and **160** are coupled via a capacitor **164**. A resistor **166** is connected between terminal F and ground to provide an operating point to the gate terminal of the transistor **46** as well as to establish a load for the driver units **156** and **160**. The series parallel arrangement of the driver units **154**–**160** provides for the application of power to the output signal of the comparator **128** during both positive and negative swings of the output signal of the comparator **128**.

In the preferred embodiment of the invention, the resistors **134**, **138**, **140** and **150** each have a value of 100 kilohm. The resistor **136** has a value of 39 kilohm, the resistor **142** has a value of 680 ohms, and the capacitor **132** has a capacitance of 1000 picofarads. Each of the resistors **144**, **148**, and **152** have a value of 1 kilohm. Each of the capacitors **162** and **164** have a value of 0.1 microfarad. The driver units **154** and **158** are buffer amplifiers, type 74F14, and the driver units **156** and **160** are gate drivers, type DS0026. The resistor **166** has a value of 100 kilohm.

FIG. **5** shows circuitry of the loop compensation unit **58**. The compensation unit **58** comprises two differential amplifiers **168** and **170**, and an input low-pass filter comprising a resistor **172** connected between a noninverting input of the amplifier **168** and terminal E and a capacitor **174** connected between ground and the junction of the resistor **172** with the amplifier **168**. The amplifier **168** includes an externally connected capacitor **176** for controlling stability and bandwidth of the amplifier **168**, a resistor **178** connected in a feedback path between an output terminal of the amplifier **168** and an inverting input terminal of the amplifier **168**, and a resistor **180** connecting between ground and the inverting input terminal of the amplifier **168**. The amplifier **170** includes an externally connected capacitor **182** for controlling stability and bandwidth of the amplifier **170**, and a feedback path comprising a resistor **184** serially connected with a capacitor **186** between an output terminal of the amplifier **170** and an inverting input terminal of the amplifier **170**. A resistor **188** interconnects an output terminal of the amplifier **168** with the inverting input terminal of the amplifier **170**.

A voltage reference circuit of the laser peak current adjustment **60** includes a potentiometer **190** with a tap connected to the noninverting input terminal of the amplifier **170**. One terminal of the potentiometer **190** is grounded and the other terminal is connected via a resistor **192** to a source of negative voltage (such as −12 volts). A voltage reference element **194** is connected across the terminals of the potentiometer **190** to establish a precise value of voltage to serve as a reference for the peak current adjustment **60**. A diode clamp circuit interconnects an output terminal of the amplifier **170** with terminal G, the clamp circuit comprising three resistors **196, 198**, and **200**, and a diode **202**. The resistors **196** and **198** are connected serially between terminal G and the output terminal of the amplifier **170**, with the diode **202** being connected between ground and a junction of the resistors **196** and **198**. The resistor **202** is connected between terminal G and a positive source of voltage (such as 12 volts).

In operation, the current sense signal at terminal E is applied to the low-pass filter of the resistor **172** and the capacitor **174** to form an average value of the current in the sense resistor **26** (shown in FIG. **1**), the average value being applied to the amplifier **168**. It is noted that the value of the current in the resistor **26** of FIG. **1** is essentially constant because the bias current from the bias source **38** flows steadily through the laser **12** into the resistor **26**, and the sum of the main and the ripple currents flows steadily either via the laser **12** or via the bypass **24** into the resistor **26**. Thus, except for possible differences in resistance of the electrical paths through the laser **12** and the bypass **24**, and with the exception of possible switching transients, the sense voltage at terminal E is constant, and the low-pass filter of the resistor **172** and the capacitor **174** serves to smooth out the foregoing perturbations. The filtered signal is amplified by the amplifier **168**, and applied to the amplifier **170** which performs an integration function. The integration is accomplished by the feedback loop comprising the resistor **184** and the capacitor **186**. In addition, the amplifier **170** forms the difference between the desired current as set by the current adjustment **60**, and the actual current measurement, as inputted via resistor **188** to the amplifier **170**. The compensation unit **58** outputs a signal to terminal G to provide a magnitude of main current which minimizes the difference between the current commanded at the current adjustment **60** and the current as measured from terminal E.

In the construction of the preferred embodiment of the invention, the resistor **172** has a value of 270 ohms, and the capacitor **174** has a value of 330 picofarads. The capacitor **176** has a value of 3 picofarads, the resistor **178** has a value of 2.7 kilohms, and the resistor **180** has a value of 300 ohms. The resistor **188** has a value of 680 ohms, and the resistors **184** and **198** each have a value of 4.7 kilohm. The resistors **192** and **196** each have a value of 2.2 kilohms. The capacitor **186** has a value of 0.01 microfarads, and the capacitor **182** has a value of 3 picofarads. The potentiometer **190** has a value of 10 kilohms, and the resistor **200** has a value of 100 kilohm.

FIG. **6** shows details in the construction of the ripple current source **40**. In the ripple source **40**, the high-pass filter **52** comprises a capacitor **204** and a resistor **206**. The capacitor **204** connects the noninverting input terminal of the amplifier **208** to terminal E, and the resistor **206** grounds the noninverting input terminal. The ripple source **40** further comprises a differential amplifier **208** and a set of four transistors **210** having their collector terminal connected together and to the terminal A, and having their base terminals connected together. The base terminals of the transistors **210** are driven by an output signal of the amplifier **208** via a high-pass filter **52A**. The filter **52A** comprises a resistor **212** and a capacitor **214** serially connected between the output terminal of the amplifier **208** and the base terminals of the transistors **210**. The filter **52A** further comprises two resistors **216** and **218** serially connected between ground and a negative source of voltage (such as −12 volts), wherein a junction of the resistors **216** and **218** connects with a junction of the capacitor **214** and the base terminals of the transistors **210**. Each of the transistors **210** is coupled via a resistor **220** to a source of negative voltage (such as −12 volts), and by a capacitor **222** to ground. The serial connection of the resistors **216** and **218** serves to provide bias base current to the transistors **210**. An inverting input terminal of the amplifier **208** is connected by a resistor **224** to ground.

In the operation of the ripple current source **40**, the voltage sense signal at terminal E, representing the current flowing through the resistor **26**, is filtered by the high-pass filter **52** preceding the amplifier **208**, and via the high-pass filter **52A** following the amplifier **208**. This filtering of the signal at terminal E extracts any AC ripple component which may be present, and applies the signal to activate the transistors **210** to draw a current via terminal A. The current has a sense opposite to that of the detected ripple, and a magnitude equal to that of the detected ripple. Thereby, the current produced by the transistors **210** is a ripple current equal and opposite to that sensed at terminal E, and which is suitable for cancellation of the ripple component of the main current by summation with the main current at the summer **54**. The resistors **220** serve to provide quiescent bias currents in the respective transistors **210**, and the capacitors **222** serve to provide bypass paths past the resistors **220** for the AC current. In the construction of the preferred embodiment of the invention, each of the capacitors **204, 214**, and **222** has a value of 0.1 microfarads. The resistors **206, 224**, and **218** each have a value of 1 kilohm, and the resistor **216** has a value of 3.3 kilohm. The resistor **206, 212** has a value of 47 ohms, and each of the resistors **220** has a value of 33 ohms. Each of the transistors **210** is type 2N2222.

FIG. **7** shows details in the construction of the bypass switch **30** and its driver **32**, including interconnections of the units with other units of the circuit of the system **10** of FIG. **1**. The switch driver **32** comprises two PNP transistors **226** and **228**, an input buffer amplifier **230**, two gate drivers **232** and **234** having sufficient power to drive the capacitance of an array of transistors, and two buffer amplifiers **236** and **238** which drive the drivers **232** and **234**, respectively. In the preferred embodiment of the invention, the transistors **226** and **228** are type 2N3906, and are connected in an emitter-coupled configuration via a common emitter resistor **240** connecting with a positive supply of voltage (such as 12 volts). A bias reference current is provided by two resistors **242** and **244** connected serially between the source of positive voltage (such as 12 volts) and ground. A junction of the two resistors **242** and **244** is grounded incrementally via a capacitor **246**, and connects via a resistor **248** to the base terminal of the transistor **228**. An output terminal of the amplifier **230** connects via a resistor **250** to the base terminal of the transistor **226**. Collector terminals of the transistors **226** and **228** are connected via resistors **252** and **254**, respectively, to a source of negative voltage (such as −8.3 volts), thereby to provide the function of a voltage level shift suitable for driving the amplifiers **236** and **238**. The collector terminals of the transistors **226** and **228** are further connected to input terminals of the amplifiers **236** and **238**, respectively. In the preferred embodiment of the invention, the amplifiers **230**, **236**, and **238** are type 74F14, and the gate drivers **232** and **234** are type DS0056.

In the operation of the switch driver **32**, the input data, which is in the form of a TTL (transistor transistor logic) digital signal is applied via the input buffer amplifier **230** to drive the transistor **226**. Due to the differential configuration of the circuitry of the two transistors **226** and **228**, an increase of current in the transistor **226** in response to the input data signal is accompanied by a decrease in current in the transistor **228**. This produces a pair of oppositely phased output voltages generated across the resistors **252** and **254** for application to the amplifiers **236** and **238**, respectively. The gate drivers **232** and **234** thereby output a pair of opposed or complementary drive signals wherein the gate driver **232** outputs a signal at terminal D1 having a waveform equal to that of the input data, and the gate driver **234** outputs a signal at terminal D2 having a waveform complementary to that of the input data signal. It is noted that in the simplified view of FIG. **1**, the connection of the driver **32** to the bypass switch **30** is indicated by a single terminal identified as terminal D. In the detailed schematic of FIG. **7**, the two terminals **D1** and D2 correspond to the single terminal D of FIG. **1**. In the preferred embodiment of the invention, each of the resistors **248** and **250** have values of 100 ohms, and each of the resistors **252** and **254** have values of 220 ohms. Each of the resistors **240** and **244** have values of 1 kilohm. The resistor **242** has a value of 4.7 kilohms, and the capacitor **246** has a value of 0.01 microfarad.

The bypass switch **30** comprises eight stages **256** of transistors wherein each of the stages **256** comprises two transistors **258** and **260** connected together in an emitter-coupled configuration (ECL) sharing a common emitter resistor **262** connecting with terminal A. In each of the stages **256**, the base terminal of the transistor **258** connects with terminal D2, and the base terminal of transistor **260** connects with the terminal D1. Thereby, all of the transistors **258** are driven in parallel via terminal D2 by the driver **234**, and all of the transistors **260** are driven in parallel via the terminal D1 by the driver **232**. In each of the stages **256**, the collector terminal of the transistor **258** connects with terminal C and is further connected via a resistor **264** to terminal E. In each of the stages **256** the collector terminal of the transistor **260** connects via terminal B and the summer **34** to the laser **12**. Also, as shown in FIG. **7**, the semiconductor laser **12** is in the form of a diode having its cathode connected to the summer **34**, and having its anode connected to terminal E.

Upon comparing FIGS. **1** and **7**, it is noted that the single bypass **24** of FIG. **1** is accomplished by use of the eight parallel stages in FIG. **7** wherein there are provided eight separate ones of the resistors **264** for the bypass **24**. The combined resistance of the resistors **264**, taken in parallel, is approximately equal to that of the diode of the laser **12** during conduction of laser current in the forward direction of the diode. As has been noted hereinabove, the use of the eight stages in parallel reduces the inductance presented by the bypass switch **30** to the gate drivers **232** and **234** enabling the switch driver **32** to switch the laser current at the desired high rate. Also, as has been noted hereinabove, the use of eight transistors in parallel greatly increases the capacitive loading to the switch driver **32**. However, the gate drivers **232** and **234** have been selected because of their ability to handle the additional capacitance and provide for the desired high-switching rate of the bypass switch **30**. In the preferred embodiment of the invention, each of the transistors **258** and **260** is type 2N2222. Each of the resistors **262** has a value of 2.2 ohms. Each of the resistors **264** has a value of 9.1 ohms.

In response to a logic-1 signal applied in the input data to the amplifier **230**, the transistor **260** in each of the stages **256** is placed in a state of conduction and the transistor **258** in each of the stages **256** is placed in a state of nonconduction. Therefore current is drawn through the laser **12** activating the laser to emit light, and no current is drawn through the bypass **24**. In view of the polarity of the battery **44** (shown in FIG. **1**), the positive direction of current flow through the laser **12** is from ground through the sense resistor **26** to the laser **12**, and then continuing through the transistors **260** and the emitter resistors **262** in each of the stages **256**, and then via terminal A through the power switch **42** (shown in FIGS. **1** and **4**) to the battery **44**. In the presence of a logic-0 signal in the input data to the amplifier **230**, the states of conduction of the transistors **260** and **258** in each of the stages **256** are interchanged with the result that the current of terminal A now flows from the sense resistor **26** through the resistors **264** of the bypass **24** instead of flowing through the laser **12**. Thereby, each of the stages **256** acts as a switch for directing current from the sense resistor to the terminal A via either the laser **12** or the bypass **24**.

By way of alternative embodiments of the invention, it is noted that, if desired, the resistors **264** in each of the stages **256** could be replaced by a single additional laser having substantially matched characteristics to the laser **12** to provide impedance loading for the bypass equal to the impedance loading provided by the laser **12**. The optical output of the additional laser would simply be absorbed and the resultant heat dissipated. It is noted also that, by way of alternative embodiments of the invention, that the current levels outputted by the gate drivers **232** and **234** can be reduced so as to place transistors **258** and **260** in each of the stages **256** in states of only partial conduction and partial nonconduction in which case the light of the laser **12** would not be fully extinguished between pulses of the light. While such a utilization of the bypass switch **30** may be detrimental in the operation of a laser printer, it is noted that the circuitry of the invention has use in areas outside of the laser printing field, in which case such partial switching of current through a laser diode or other load may be useful.

In view of the foregoing circuitry, it is apparent that the components of the laser printer system are able to switch the laser current at a high rate by use of the bypass, this arrangement permitting the main current and the bias current to be maintained at a constant value. This also increases the efficiency of the circuitry over that which has been available heretofore, this benefit being attained by virtue of the use of the bypass and the bypass switch to maintain the constant flow of the main current.

It is to be understood that the above described embodiment of the invention is illustrative only, and that modifications thereof may occur to those skilled in the art. Accordingly, this invention is not to be regarded as limited to the embodiment disclosed herein, but is to be limited only as defined by the appended claims.

What is claimed is:

1. A laser current drive circuit comprising;

a laser having a first terminal and a second terminal, and a current bypass having a first terminal and a second terminal;

a current sensor having a terminal connecting to the second terminal of said laser and to the second terminal of said bypass to provide a signal indicating the amplitude of current flowing through said laser and said bypass;

a main source of current for energizing said laser to emit light, said main current source further comprising feedback means responsive to the signal of said current sensor to output a main current at a desired amplitude;

a bypass switch connecting an output terminal of said regulator to the first terminal of said laser and to the first terminal of said bypass; and

drive means responsive to pulses of an input data signal for operating said bypass switch to direct the main current alternately to said laser and to said bypass, pulsations of said data signal resulting in pulsations of the main current to said laser with corresponding emission of light pulses from said laser.

2. A circuit according to claim **1** further comprising a bias current source connected to the first terminal of said laser for applying a bias current to said laser in addition to said main current, wherein said laser is a semiconductor laser, and said bias current has an amplitude below a lasing threshold amplitude of the semiconductor laser.

3. A circuit according to claim **2** wherein said main source of current includes a current switching regulator operative by said feedback means to output the main current.

4. A circuit according to claim **3** wherein the main current outputted by said regulator has a DC component and a ripple component, said circuit further comprising a ripple current source responsive to the signal of said current sensor for generating a ripple current substantially equal and opposite to said ripple component, said ripple current source being connected to an input terminal of said bypass switch for summing the ripple current with said main current to cancel the ripple component.

5. A circuit according to claim **4** wherein the said current sensor is a resistor.

6. A circuit according to claim **4** wherein said ripple current source includes a high-pass filter connected to the terminal of said current sensor for receiving a ripple component of the sensor signal while excluding a DC component of the sensor signal.

7. A circuit according to claim **2** wherein said bias current source includes a current sensing resistor to develop a feedback signal, and a transistor current source responsive to the feedback signal for providing a desired magnitude of bias current.

8. A circuit according to claim **1** wherein said main source of current includes a current switching regulator operative by said feedback means to output the main current and wherein, in said main source of current, said feedback means includes a pulse-width modulator for driving said regulator.

9. A circuit according to claim **8** wherein, in said main source of current, said regulator has a transistor connected as a gate on an electrical conductor from an external source of electrical power, said transistor being placed alternately in states of conduction and nonconduction by said pulse-width modulator.

10. A circuit according to claim **9** wherein said main source of current further comprises electrical-energy storage elements including an inductor and a capacitor connected to terminals of said transistor of said regulator for converting pulsations of current in said transistor of said regulator to a substantially steady flow of current.

11. A circuit according to claim **1** wherein said bypass switch comprises a plurality of emitter-coupled logic (ECL) stages, said ECL stages being connected in parallel to reduce inductance and provide an increased speed of operation, each of the ECL stages having one output terminal connected to said laser and a second output terminal connected to said bypass and a common emitter terminal connected via an input terminal of the bypass switch to said main source of current.

12. A circuit according to claim **11** further comprising a bias current source connected to the first terminal of said laser for applying a bias current to said laser in addition to said main current, wherein said laser is a semiconductor laser, and said bias current has an amplitude below a lasing threshold amplitude of the semiconductor laser;

wherein said main source of current includes a current switching regulator operative by said feedback means to output the main current; and

wherein the main current outputted by said regulator has a DC component and a ripple component, said circuit further comprising a ripple current source responsive to the signal of said current sensor for generating a ripple current substantially equal and opposite to said ripple component, said ripple current source being connected to the input terminal of said bypass switch for summing the ripple current with said main current to cancel the ripple component.

13. A circuit according to claim **11** wherein said main source of current includes a current switching regulator operative by said feedback means to output the main current;

wherein the main current outputted by said regulator has a DC component and a ripple component, said circuit further comprising a ripple current source responsive to the signal of said current sensor for generating a ripple current substantially equal and opposite to said ripple component, said ripple current source being connected to the input terminal of said bypass switch for summing the ripple current with said main current to cancel the ripple component;

wherein said ripple current source includes a high-pass filter connected to the terminal of said current sensor for receiving a ripple component of the sensor signal while excluding a DC component of the sensor signal; and

wherein in said main source of current, said feedback means includes a pulse-width modulator for driving said regulator.

14. A laser current drive circuit comprising;

a semiconductor laser having a first terminal and a second terminal, and a current bypass having a first terminal and a second terminal;

a current sensor having a terminal connecting to the second terminal of said laser and to the second terminal of said bypass to provide a signal indicating the amplitude of current flowing through said laser and through said bypass;

a main source of current, including a current switching regulator, for energizing said laser to emit light, said main current source further comprising feedback means responsive to the signal of said current sensor for operating said regulator to output a main current at a desired amplitude;

a bypass switch connecting an output terminal of said regulator to the first terminal of said laser and to the first terminal of said bypass alternately in response to pulses of an input data signal to direct the main current alternately to said laser and to said bypass, pulsations of said data signal resulting in pulsations of the main current to said laser with corresponding emission of light pulses from said laser; and

wherein the bypass has an electrical resistance approximating an electrical resistance of said laser to maintain a substantially constant power dissipation of said main current independent of a position of said bypass switch.

15. A current drive circuit comprising;

a semiconductor device having a first terminal and a second terminal, and a current bypass having a first terminal and a second terminal;

a current sensor having a terminal connecting to the second terminal of said device and to the second terminal of said bypass to provide a signal indicating amplitude of current flowing through said device and through said bypass;

a main source of current, including a current switching regulator, for energizing said device to emit light, said main current source further comprising feedback means responsive to the signal of said current sensor for operating said regulator to output a main current at a desired amplitude;

a bypass switch connecting an output terminal of said regulator to the first terminal of said device and to the first terminal of said bypass alternately in response to pulses of an input data signal to direct the main current alternately to said device and to said bypass, pulsations of said data signal resulting in pulsations of the main current to said device with corresponding emission of light pulses from said device; and

a bias current source connected to the first terminal of said device for applying a bias current to said device in addition to said main current, wherein said bias current source is connected between said bypass switch and said device to maintain a substantially constant amplitude of said bias current independent of a position of said bypass switch.

16. A current drive circuit comprising;

a semiconductor device having a first terminal and a second terminal;

a current sensor having a terminal connecting to the second terminal of said device to provide a signal indicating amplitude of current flowing through said device and through said bypass;

a main source of current, including a current switching regulator, for energizing said device to emit light, said main current source further comprising feedback means responsive to the signal of said current sensor for operating said regulator to output a main current at a desired amplitude;

a bypass switch connecting an output terminal of said regulator to the first terminal of said device for alternately directing the main current to said device and diverting the main current from said device in accordance with an input data signal, pulsations of said data signal resulting in pulsations of the main current to said device with corresponding emission of light pulses from said device; and

a bias current source connected to the first terminal of said device for applying a bias current to said device in addition to said main current, wherein said bias current source is connected between said bypass switch and said device to maintain a substantially constant amplitude of said bias current independent of a position of said bypass switch.

17. A method of applying current to a laser comprising steps of:

providing a current bypass around the laser;

selectively switching a main current from a source of the main current alternately between said laser and said bypass to provide pulses of the main current of said laser;

monitoring a flow of current in said laser and in said bypass to provide a measure of current; and

controlling a magnitude of said main current in response to said current measure.

18. A method according to claim 17 further comprising steps of feeding a bias current to said laser, and holding the magnitude of the bias current constant during a pulsation of the main current in said laser.

19. A method according to claim 18 further comprising steps of: providing said main current source; providing a pulse-width modulation control of the main current in said main current source; and wherein said controlling step is accomplished by altering a duty cycle of said modulation.

20. A method according to claim 19 further comprising steps of: sensing a ripple component of the main current due to said modulation; producing a ripple current; and summing the ripple current with the main current to cancel said ripple component.

* * * * *

EXHIBIT B

US006130761A

United States Patent [19]

Yeh et al.

[11] Patent Number: 6,130,761

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

[54] **IMAGE SCANNING METHOD**

[75] Inventors: **Pao-Yuan Yeh**; **Yu-Ting Wu**, both of Taipei, Taiwan

[73] Assignee: **Primax Electronics Ltd.**, Taipei Hsien, Taiwan

[21] Appl. No.: **09/073,512**

[22] Filed: **May 6, 1998**

[51] **Int. Cl.**[7] **H04N 1/04**

[52] **U.S. Cl.** **358/474**; 358/409; 358/408

[58] **Field of Search** 358/474, 408, 358/318, 319, 312; 382/408, 574, 581, 443

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,574,291 3/1986 Wimmer 348/75

4,622,596 11/1986 Suga et al. 358/335

Primary Examiner—Jerome Grant, II

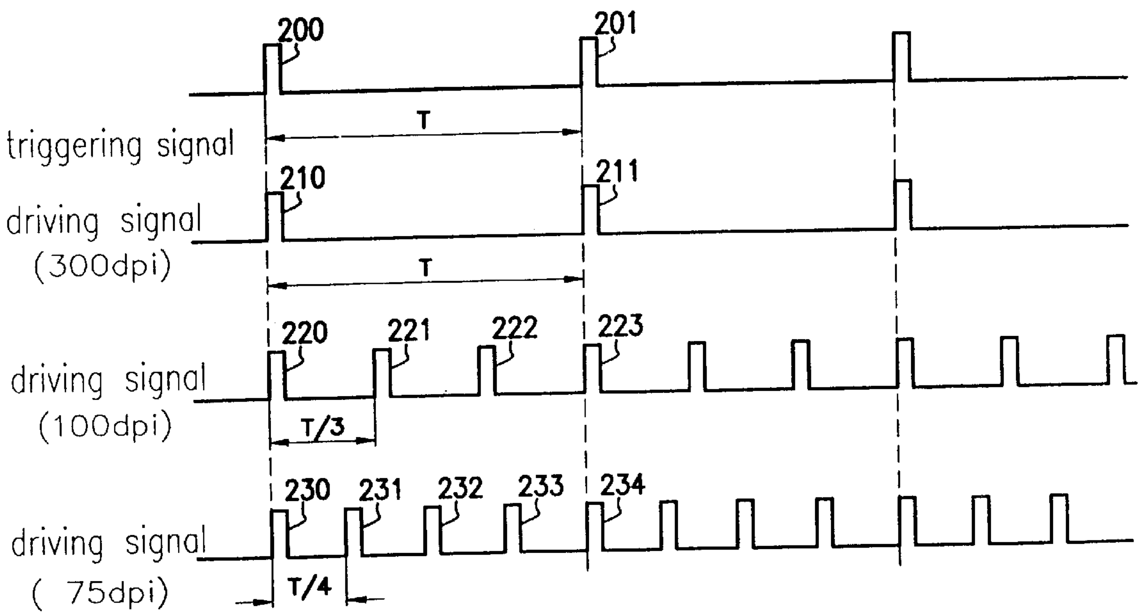
Assistant Examiner—Negussie Worku

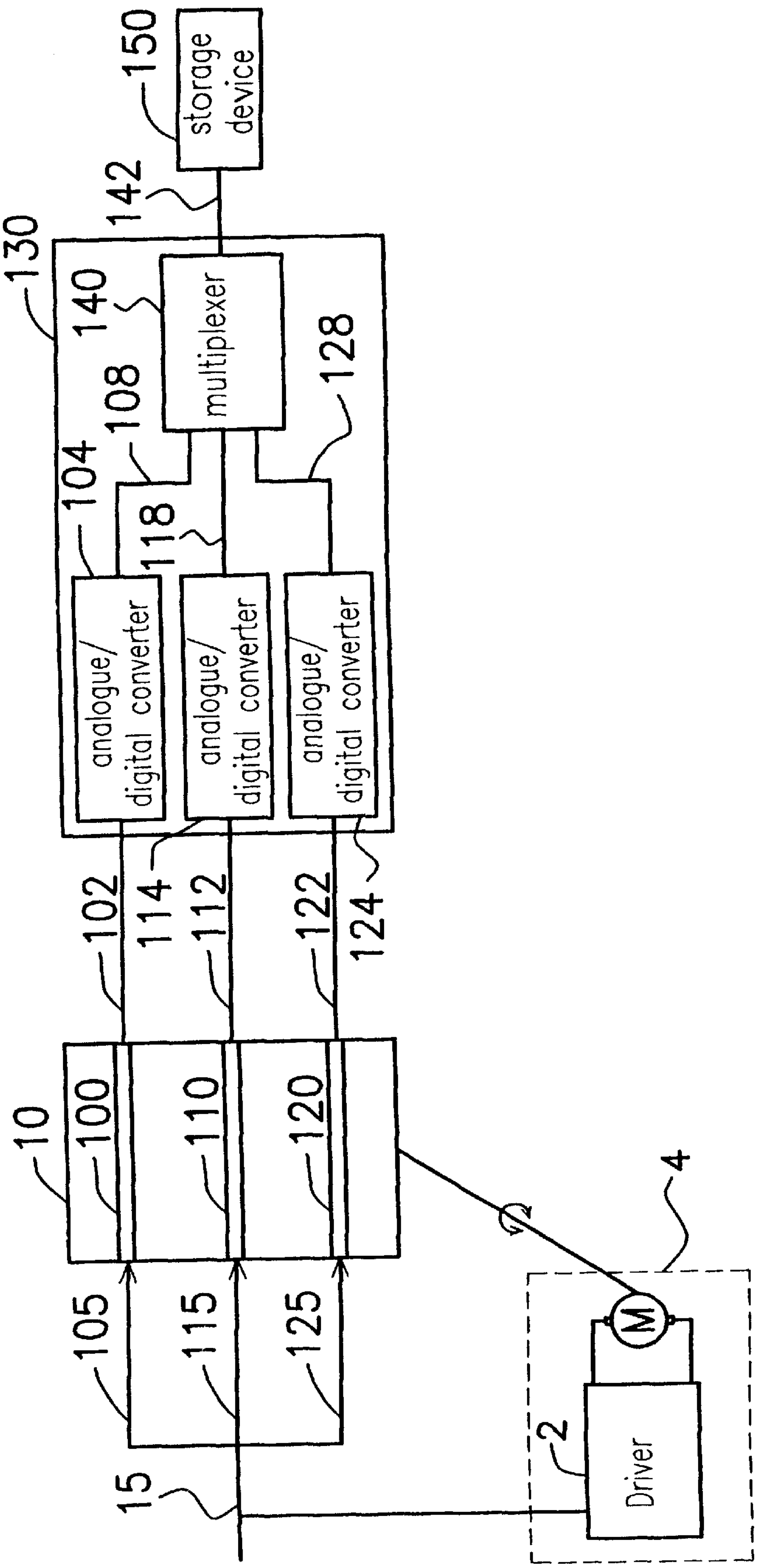
Attorney, Agent, or Firm—Thomas, Kayden, Horstemeyer & Risley

[57] **ABSTRACT**

An image scanning method for a scanner that can simultaneously sense image signals corresponding to the three primary colors or a monochromic color, and store the signals in a storage device within one exposition process. The scanning method can further determine a period of the driving signal and a number of rotation steps for the driving motor to calculate the period of the triggering signal for a light-sensitive device. The scanning method according to the invention can therefore reduce the time needed for a scanning process and improve efficiency. Furthermore, the signal-to-noise ratio of a CCD module can be improved, and the requirement for the brightness of the light source is lowered as well.

13 Claims, 2 Drawing Sheets





150
storage device
142
130
140
multiplexer
108
128
104
118
analogue/ digital converter
analogue/ digital converter
analogue/ digital converter
102
114
112
122
124
10
100
110
120
4
105
115
125
M
2
Driver
15

FIG. 1A

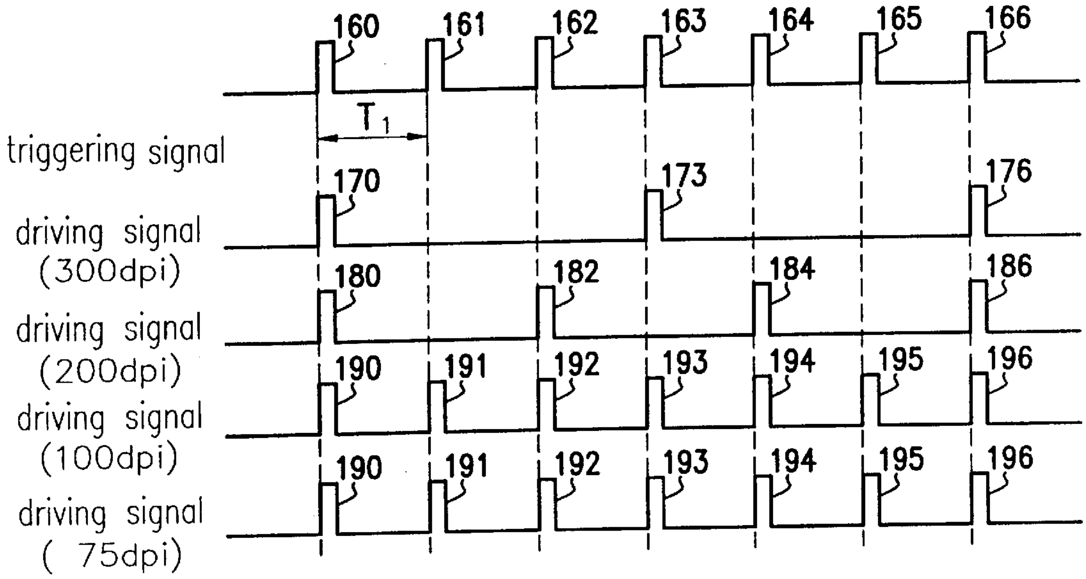

160
161
162
163
164
165
166
T_1
triggering signal
170
173
176
driving signal
(300dpi)
180
182
184
186
driving signal
(200dpi)
190
191
192
193
194
195
196
driving signal
(100dpi)
190
191
192
193
194
195
196
driving signal
(75dpi)

FIG. 1B

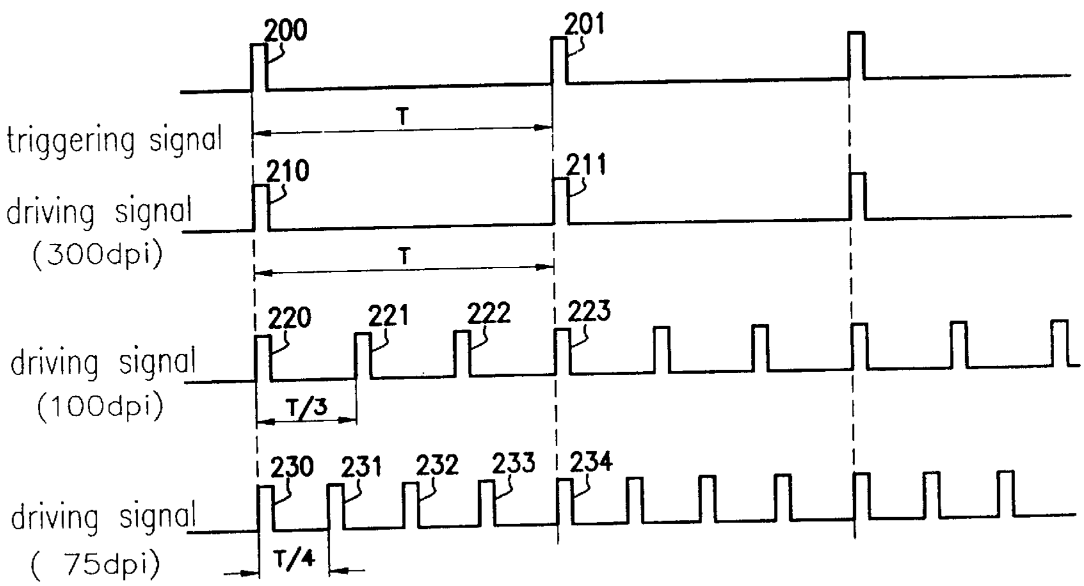

200
201
T
triggering signal
210
211
driving signal
(300dpi)
T
220
221
222
223
driving signal
(100dpi)
T/3
230
231
232
233
234
driving signal
(75dpi)
T/4

FIG. 2

IMAGE SCANNING METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority benefit of Taiwan application serial no. 87104240, filed Mar. 21, 1998, the full disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an image scanning method for a scanner. More particularly, this invention relates to an image scanning method that can improve the image scanning rate by determining the period of the driving signal and the number of rotating steps of the driving motor, and calculating the period of triggering signal for the light-sensitive devices according to a predetermined resolution.

2. Description of Related Art

In an early scanner design, the period of the triggering signal for a light-sensitive device is conventionally used as the timing pulse because the minimum period of triggering signal for the light-sensitive device is limited by the exposure time and the time needed for storing a pixel. Hence the period of the triggering signal for the driving motor is an integral multiple of the period of the triggering signal for the light-sensitive device. As a result, the scanning rate is limited as well.

In FIG. **1**A, a charge coupled device (CCD) module **10** includes three CCD sensors, which are respectively used to detect and receive the three primary colors of light. The colors of light are red, green, and blue owing to different wavelengths. The sensors include a red light sensor **100**, a green light sensor **110** and a blue light sensor **120**. The red, green, and blue light signals received by the light sensors are then combined to duplicate the original image. It is also practical to employ a single light sensor to receive and display a monochromic image. Conventionally, a light-sensitive device receives a signal of exposition generated corresponding to an image illuminated by a light source. Then the light-sensitive device sends a triggering signal **15** to activate the red light sensor **100**, the green light sensor **110** and the blue light sensor **120** simultaneously for extracting the image signals of red, green, and blue lights respectively. Normally, the signal lines **105**, **115**, and **125** are shorted together at one end so that the triggering signal **15** can be fed into the red light sensor **100**, green light sensor **110** and the blue light sensor **120** simultaneously. These three sensors **110**, **110**, and **120** receive the same triggering signal **15** because the signal lines **105**, **115**, and **125** are connected to each other.

The signal lines **102**, **112**, and **122** are used to feed received image signals of the three primary colors into the converting module **130**. The converting module **130** includes a number of independent analogue/digital converters and a multiplexer **140**. The red image signal, green image signal and blue image signal are converted into a red digital signal, a green digital signal, and a blue digital signal by analogue/digital converters **104**, **114**, and **124** respectively. Then the converted red, green, and blue digital signals are fed into the multiplexer **140** through signal lines **108**, **118**, and **128**. The multiplexer **140** picks one signal from the group consisting of red, green, and blue digital signals according to the actual application, and stores it in storage device **150** through signal line **142**.

The multiplexer **140** doesn't switch between signal lines **108**, **118**, and **128** during the time between two triggering

signals **15** in a conventional method, that is, only one corresponding converted digital signal is stored in the storage device **150** within a triggering period. In another conventional method, the multiplexer **140** is switched three times within a triggering period and a pixel period to extract three converted digital signals and store them into the storage device **150**.

Generally, a CCD module **10** driven by a motor **4** is used as an example for describing a conventional scanning device. Another functional design employs a motor to drive the document scanner but not the CCD module. A user can predetermine a scanning resolution and start the scanning job according to the predetermined scanning resolution. Normally, the higher the scanning resolution, the more digital data from the three primary colors is needed, which requires a longer scanning time as well, so the processing rate of a CCD module **10** is closely related to the predetermined resolution, As a result, the rotating speed of the motor **4** is determined according to the predetermined resolution. Since the triggering signal of a light-sensitive device is used as a basic timing pulse in a conventional method, the triggering signal **15** is fed into a driver **2** as a basic driving pulse for driving the driving motor **4** to drive the CCD module **10** to scan images. The relationship between the triggering signal **15** and the driving signal is shown in FIG. **1**B.

Referring to FIG. **1**B, the rotation of the motor **4** is controlled by the driving signal, wherein the driving signal is related to the predetermined resolution of the scanner and the triggering signal **15**. For example, for a predetermined resolution of 300 dots per inch (dpi), a corresponding triggering signal **15** has pulses **160** to **166**, and the driving signal has pulses **170**, **173**, and **176**. In other words, every three times the CCD module **10** is triggered, the motor **4** rotates one step. Since the CCD module **10** is triggered three times during the time between the rotating steps of the motor **4**, and the multiplexer **140** is not switched within every triggering period, three sets of digital data are stored by using the circuit shown in FIG. **1**A. The three sets of digital data correspond to the three primary colors, and each one of the digital data is stored within a triggering period. On the other hand, the multiplexer **140** can be switched three times within one triggering period when this conventional method is applied to extract the data of a pixel, that is, all digital data from the three primary colors can be stored within one triggering period. In order to keep the motor **4** rotating at a constant speed and save the space in the buffer memory, which has a limited capacity, there is no data stored within the other two triggering periods.

The following examples are used for describing a different scanning process according to different predetermined resolutions, wherein the multiplexer **140** is not switched within one triggering period.

In the case of a predetermined resolution of 200 dpi, a corresponding driving signal has pulses **180–186** (**180**, **182**, **184**, **186**) to the triggering signal **15**, that is, the motor **4** rotates one step after every two times the CCD module **10** is triggered as shown in FIG. **1**B. By utilizing the circuit shown in FIG. **1**A, there are two sets of digital data stored within the time needed for motor **4** to rotate one step.

In the case of a predetermined resolution of 100 dpi and 75 dpi, a corresponding driving signal has pulses **190–196** (**100**, **191**, **192**, **193**, **194**, **195**, **196**) to the triggering signal **15**. That is to say, the motor **4** rotates one step after every time the CCD module **10** is triggered, as shown in FIG. **1**B. By utilizing the circuit shown in FIG. **1**A, there is one set of digital data stored within the time needed for motor **4** to rotate one step.

According to the foregoing, the triggering signal **15** has pulses **160–166** for triggering CCD module **10**. Every time the CCD module **10** is triggered, there is one set of digital data selected from the digital data from the three primary colors stored. Since the digital data of the three primary colors are needed in combination in order to duplicate an image, the amount of required digital data is directly related to the predetermined resolution. The higher the resolution, the more color data are required. Generally, the data needed for displaying an image at a resolution of 300 dpi is about three times the data needed for displaying an image at a resolution of 100 dpi. Since the method for extracting colors is not related to the invention, there is no further discussion about it.

If there is only one set of data from which a color can be extracted within one triggering period, the motor **4** has to wait for at least three triggering periods for the CCD module **10** to extract three sets of digital data for the three primary colors at one position before the motor can move to the next position. Furthermore, even though the CCD module **10** only extracts one set of digital data for a monochrome image, the motor **10** still has to wait for one triggering period before it can move the CCD module **10** to the next position for extracting the next set of color data. As a result, the motor speed is limited by the frequency of the triggering signal **15**.

Even though the CCD module **10** is able to extract and store three sets of digital color data within one triggering period, that is, the multiplexer **140** is switched three times within one triggering period, but the triggering signal is still used as a basic driving pulse for the motor **4**, the rotation speed of motor **4** is still limited by the frequency of the triggering signal **15**. Furthermore, since the other two triggering periods are not used for extracting or storing data, it wastes the system's resources.

According to the foregoing, a conventional image scanning method for a scanner has at least the following drawbacks:

1. The CCD module can only store one set of digital data for the three primary colors within one triggering period, which makes the scanning rate low and limited.
2. Because the triggering signal is used as a basic driving pulse, the frequency of the driving signal cannot exceed the frequency of the triggering signal, which limits the scanning rate.

SUMMARY OF THE INVENTION

It is therefore objective of the present invention to provide an image scanning method that can release the driving signal from the limitation of the triggering signal to improve the rotation rate of the driving motor.

It is another objective of the present invention to provide an image scanning method to let the light-sensitive device extract digital data for all the three primary colors, or any one of the three primary colors, at once within one triggering period to improve the scanning rate.

In accordance with the foregoing and other objectives of the present invention, the method according to the present invention provides an image scanning method that includes the following steps.

Firstly, a predetermined resolution is set according to an actual application to determine the frequency of the driving signal and the number of rotation steps of the motor. Furthermore, the period of the triggering signal is determined by the product of the period of the driving signal and the number of rotation steps of the driving motor.

Then, in the presence of the pulse of the triggering signal, a light-sensitive device, such as a CCD module, extracts the three primary colors at the same time. The extracted image signals are then output by the light-sensitive device in an output frequency and converted into digital signals through an analogue/digital converting process. The converted digital signals are stored in a storage device.

A frequency of the triggering signal can be obtained according to the predetermined resolution and the period of the driving signal; the needed number of rotation steps of the motor within one triggering period varies with the predetermined resolution as well. The frequency of the triggering signal T_G, the frequency of the driving signal T_M, and the number of rotation steps of the motor within one triggering period N have a following relationship.

$T_G=T_M*$ N, or

$T_M=T_G/N$.

Hence, the lower the resolution, the larger the number of rotation steps of the motor within one triggering period, and the faster the scanning rate.

BRIEF DESCRIPTION OF DRAWINGS

The invention can be more fully understood by reading the following detailed description of the preferred embodiments, with reference made to the accompanying drawings, wherein:

FIG. **1A** is a schematic block diagram showing a conventional image scanning method of a CCD module;

FIG. **1B** is a schematic diagram showing the relationship between the triggering signal and the driving signals in a conventional image scanning method; and

FIG. **2** is a schematic diagram showing the relationship between the triggering signal and the driving signals in the image scanning method in a preferred embodiment according to the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

As in the constructed circuit shown in FIG. **1A**, a CCD module is able to extract signals of the three primary colors from an exposition signal. The functions of the circuit are mostly similar to the conventional method except that the extracted digital signals of the three primary colors are fed into the multiplexer **140** through signal lines **108**, **118**, and **128**. The multiplexer **140** can selectively store either three sets of digital signals or just one of them into a storage device **150**. In the case of storing three sets of digital signals into the storage device **150**, the multiplexer **140** is working with a timing signal frequency three times faster than the frequencies of the three digital signals. Thus, the multiplexer **140** is switched three times within one period of the digital signals, so that three sets of digital signals can be stored into the storage device **150**. One of ordinary skills in the art can still store three sets of digital signals respectively for achieving the purpose of storing three sets of digital signals at the same time by dividing the stored signals and using the raising edge, dropping edge, and the signal voltage level.

Referring to FIG. **2**, the triggering signals includes pulses **200** and **201**, wherein the interval T between pulses is the period of the triggering signal. In the case of a predetermined resolution of 300 dpi, the driving signal of the driving motor in a scanner has pulses **210** and **211**, wherein the pulses **210** and **211** are in phase with the triggering signals. Thus, the CCD module extracts the exposition signal once within one driving step of the driving motor. In fact, the frequency of the driving signal and the number of rotation steps of the motor are determined by a predetermined resolution, and the period of the triggering signal is determined by the product of the period of the driving signal and the number of rotation steps of the driving motor.

In the case of a resolution of 100 dpi, a driving signal of the motor includes pulses **220**, **221**, **222**, and **223**, wherein the period of the triggering signal T is three times the period of the driving signal. Thus, the CCD module extracts the exposition signal once every time the driving motor moves three steps. The resolution is one third of the resolution of 300 dpi.

In the case of a resolution of 75 dpi, a driving signal of the motor includes pulses **230**, **231**, **232**, **233**, and **234**, wherein the period of the triggering signal T is four times the period of the driving signal. Thus, the CCD module extracts the exposition signal once every time the driving motor moves four steps. The resolution is one forth of the resolution of 300 dpi.

The periods of driving signals for different resolutions are related to the actual applications and designs, that is, it is not necessary that they be the same, and not necessary that they be different, either. The point of the method according to the invention is that the period of the triggering signal is no longer used as a basic timing pulse. The triggering signal and driving signal are two totally independent signals. Normally, the period of the triggering signal is an integral multiple of the period of the driving signal. In fact, since the period of the triggering signal is larger than or equal to the product of the period of the driving signal and the number of the rotation steps of the driving motor within one period of the triggering signal, the period of the driving signal is always smaller than or equal to the period of the triggering signal. As a result, the rotation rate of the driving motor is not limited by the period of the triggering signal, so that the rotation rate can be improved, especially in the cases of low resolutions. It is an important technical characteristic of the invention.

Furthermore, even though the method in this embodiment according to the invention stores three sets of signals of the three primary colors at once, one of ordinary skills in the art can still apply the same principle on a monochromic application. Such an application would not go against the spirit of the invention.

In order to make the differences between the method according to the invention and the conventional method more obvious, the differences are listed in the table below:

TABLE 1

Resolution	300 dpi	100 dpi	75 dpi
Number of needed periods of the triggering signal	3 ms	3 ms	3 ms
Number of triggering periods	3	1	1
Rotation time	9 ms	3 ms	3 ms

TABLE 2

Resolution	300 dpi	100 dpi	75 dpi
Number of needed periods of the triggering signal	6 ms	6 ms	6 ms
Number of triggering periods	1	3	4
Rotation time	6 ms	2 ms	1.5 ms

Table 1 is a conventional image scanning method for storing a set of color data within one period of the triggering signal at the resolutions of 300 dpi, 100 dpi, and 75 dpi. The second row represents the needed number of periods of the triggering signal, wherein the triggering signal is used to trigger the CCD module for outputting extracted image signals of the three primary colors within the needed periods of triggering signals. Since an operating time is needed by the CCD module to process the received and outputted image signals, the triggering period has to match the operating time in order to be efficient. That is to say, the triggering period cannot be shorter than the operating time or else the extracted data will be lost because of the interruption of the next triggering signal. Inversely, if the period of triggering signal is longer than the operating time, the system is in an idle state after storing data and before the next triggering signal, which will decrease the scanning rate.

The third row represents the number of triggering signals needed to drive the driving motor to rotate one step. Because the CCD module can only store one set of data at once, the CCD module needs to extract more data at one position when the resolution is getting higher, so that a higher number of triggering periods are needed.

The fourth row represents the rotation time, which is the time needed for the motor to rotate one step.

Table 2 represents the results of scanning images at the resolution s of 300 dpi, 100 dpi, and 75 dpi by a method used in a preferred embodiment according to the invention.

The second row represents the periods of the triggering signals, and is described below.

The third row represents the numbers of rotation steps of the driving motor, that is, the steps the driving motor needs to relocate the CCD module within a period of the triggering signal at different required resolutions. As the required resolution is high, the number of steps is less because more image data are needed. For instance, at the resolution of 300 dpi, the driving motor only move the CCD module one step away from the position where the CCD module extracts signals of the three primary colors within one triggering period before the CCD module extracts another set of signals. At the resolution of 100 dpi, the driving motor only moves the CCD module three steps away from the position where the CCD module extracts signals from the three primary colors within one triggering period before the CCD module extracts another set of signals. And at the resolution of 75 dpi, the driving motor only moves the CCD module four steps away from the position where the CCD module extracts signals of the three primary colors within one triggering period before the CCD module extracts another set of signals. As a result, the scanning rate is faster while the required resolution is lower. In practice, the required resolutions and the corresponding numbers of rotation steps of the driving motor are listed in a table such as Table 2 for checking the needed number of rotation steps of the driving motor before a scanning process.

In the foregoing description, the image scanning method according to the invention simultaneously stores three sets of image data in one exposition process by using a multiplexer **140** to store three sets of data in sequence or just one set of monochromic data. Because a CCD module with a shorter operating time is more expensive, the period of the triggering signal has a minimum in reality due to the consideration of manufacturing cost. However, theoretically, the period of the triggering signal can be reduced proportionally according to a predetermined resolution.

The fourth row represents the time needed for the driving motor to move the CCD module one step away, that is, the period of the driving signal. The lower the resolution, the shorter the rotation time, and the faster the scanning rate.

According to the foregoing, since the driving signal for the driving motor is dependent on the triggering signal, the rotation time of the driving motor cannot be shorter than the period of the triggering signal. The period of the driving signal of the driving motor in the invention is found by dividing the period of the triggering signal according to the required resolution, so it is always shorter than the period of the triggering signal, and the rotation time needed for the driving motor can be reduced, especially in the case of low resolutions. Furthermore, the invention has a longer triggering period, so the signal-to-noise ratio increases, and the requirement on the brightness of light source decreases as well.

According to the foregoing, the invention includes at least the following advantages:

1. Three sets of image data are stored within one triggering period for improving the scanning rate;
2. The driving signal is not limited by the triggering period, so that the rotation rate of the motor can be improved, especially in the cases of low resolutions; and
3. The invention has a longer triggering period, so that the signal-to-noise ratio is increased, and the requirement on the brightness of the light source is decreased as well.

Even though a CCD module is used in the foregoing embodiment according to the invention, one of ordinary skill in the art can understand that a light-sensitive device of any kind can be used in place of the CCD module.

The invention has been described using exemplary preferred embodiments. However, it is to be understood that the scope of the invention is not limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and similar arrangements. The scope of the claims, therefore, should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

What is claimed is:

1. An image scanning method for a scanner, the method comprising the steps of:

determining a driving signal, a triggering signal, and a number of rotation steps according to a predetermined resolution, wherein a period T_G of the triggering signal equals a period T_M of the driving signal multiplied by the number of rotation steps N within the period T_G;

driving a motor by the driving signal;

outputting an image signal by the triggering signal; and

storing the image signal within the period of the triggering signal.

2. The method of claim **1**, wherein the period of the driving signal is obtained by checking a table referring to the predetermined resolution.

3. The method of claim **1**, wherein the number of rotation steps is obtained by checking a table referring to the predetermined resolution.

4. The method of claim **1**, wherein the period of the driving signal is obtained by checking a table referring to the predetermined resolution.

5. The method of claim **1**, wherein the step of storing the image signal further comprises the steps of:

converting the image signal into a digital signal; and

storing the digital signal within the period of the triggering signal.

6. An image scanning method comprising the steps of:

obtaining a number of rotation steps for a motor and a period of a driving signal by checking a table and referring to a predetermined resolution, and obtaining a period of a triggering signal by means of the period of the driving signal and the number of rotation steps for the motor, wherein the period T_G of the triggering signal equals the period of the driving signal T_M multiplied by the number of rotation steps for the motor N within the period T_G;

driving the motor by means of the driving signal;

outputting a first image signal, a second image signal, and a third image signal by means of the triggering signal; and

storing the first image signal, the second image signal, and the third image signal within the period of the triggering signal.

7. The method of claim **6**, wherein the step of storing the first image signal, the second image signal, and the third image signal further comprises:

converting the first image signal into a first digital signal;

converting the second image signal into a second digital signal;

converting the third image signal into a third digital signal; and

storing the first image signal, the second image signal, and the third image signal within the period of the triggering signal.

8. An image scanning method comprising the steps of:

obtaining a number of rotation steps for a motor and a period of a triggering signal by checking a table and referring to a predetermined resolution, and obtaining a period of a driving signal by means of the period of the triggering signal and the number of rotation steps for the motor, wherein the period of the driving signal T_M equals the period T_G of the triggering signal divided by the number of rotation steps for the motor N within the period T_G;

driving the motor by the driving signal;

outputting a first image signal, a second image signal, and a third image signal of the triggering signal; and

storing the first image signal, the second image signal, and the third image signal within the period of the triggering signal.

9. The method of claim **8**, wherein the step of storing the first image signal, the second image signal, and the third image signal further comprises:

converting the first image signal into a first digital signal;

converting the second image signal into a second digital signal;

converting the third image signal into a third digital signal; and

storing the first image signal, the second image signal, and the third image signal within the period of the triggering signal.

10. An image scanning method comprising:

obtaining a number of rotation steps for a motor and a period of a driving signal by checking a table and referring to a predetermined resolution, and obtaining a period of a triggering signal by means of the period of the driving signal and the number of rotation steps for the motor, wherein the period T_G of the triggering signal equals the period of the driving signal T_M multiplied by the number of rotation steps for the motor N within the period T_G;

driving the motor by means of the driving signal;

outputting a first image signal, a second image signal, and a third image signal by means of the triggering signal; and storing one of the first image signal, the second image signal, or the third image signal within the period of the triggering signal.

11. The method of claim **10**, wherein the step of storing the first image signal, the second image signal, and the third image signal further comprises:

converting the first image signal into a first digital signal;

converting the second image signal into a second digital signal;

converting the third image signal into a third digital signal; and

storing one of the first image signal, the second image signal, or the third image signal within the period of the triggering signal.

12. An image scanning method comprising:

obtaining a number of rotation steps for a motor and a period of a triggering signal by checking a table and referring to a predetermined resolution, and obtaining a period of a driving signal by means of the period of the triggering signal and the number of rotation steps for the motor, wherein the period of the driving signal T_M equals the period T_G of the triggering signal divided by the number of rotation steps for the motor N within the period T_G;

driving the motor by means of the driving signal;

outputting a first image signal, a second image signal, and a third image signal by means of the triggering signal; and

storing one of the first image signal, the second image signal, or the third image signal within the period of the triggering signal.

13. The method of claim **12**, wherein the step of storing the first image signal, the second image signal, and the third image signal further comprises:

converting the first image signal into a first digital signal;

converting the second image signal into a second digital signal;

converting the third image signal into a third digital signal; and

storing one of the first image signal, the second image signal, or the third image signal within the period of the triggering signal.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,130,761
APPLICATION NO. : 09/073512
DATED : October 10, 2000
INVENTOR(S) : Pao-Yuan Yeh and Yu-Ting Wu

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page, please insert:

Item --**[30]** **Foreign Application Priority Data**
March 21, 1998 [TW] Taiwan..........................87104240--

Signed and Sealed this
Twelfth Day of July, 2011

David J. Kappos
Director of the United States Patent and Trademark Office

EXHIBIT C

US006650432B1

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

(10) **Patent No.: US 6,650,432 B1**
(45) **Date of Patent: Nov. 18, 2003**

(54) **METHOD AND USER INTERFACE FOR PERFORMING AN AUTOMATIC SCAN OPERATION FOR A SCANNER COUPLED TO A COMPUTER SYSTEM**

(75) Inventors: **Chuan-Yu Hsu**, Hsinchu (TW); **Jay Liu**, Hsinchu Hsien (TW); **T. J. Hsu**, Tainan Hsien (TW)

(73) Assignee: **Umax Data Systems, Inc.**, Hsinch (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/417,497**

(22) Filed: **Oct. 13, 1999**

(30) **Foreign Application Priority Data**

Aug. 18, 1999 (TW) .... 88114079 A

(51) **Int. Cl.**[7] **G06K 15/00**
(52) **U.S. Cl.** **358/1.15**; 382/187; 382/167
(58) **Field of Search** 358/1.15, 474, 358/476; 709/208, 326; 382/167, 176

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,140,414 A * 8/1992 Mowry 358/81
5,812,125 A * 9/1998 Wilkinson 345/330
5,845,076 A * 12/1998 Arakawa 395/200.33
6,137,591 A * 10/2000 Kikinis 358/1.6
6,256,662 B1 * 7/2001 Lo et al. 709/203

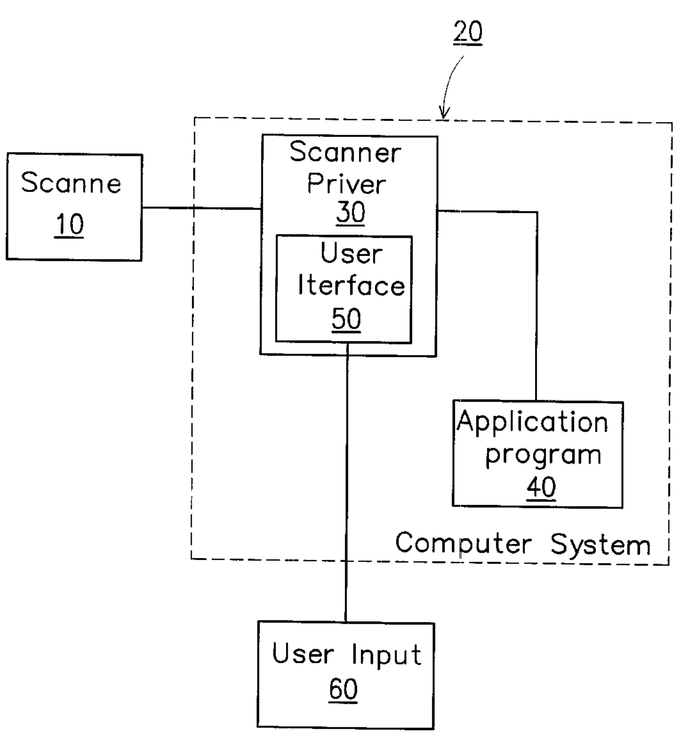
* cited by examiner

Primary Examiner—Jerome Grant, II
(74) *Attorney, Agent, or Firm*—J. C. Patents

(57) **ABSTRACT**

A method and user interface is provided for use on a computer system coupled with a scanner for performing an automatic scan operation on an original document, with the computer system running a scanner driver and an application program. By the method and user interface, the scanner is first activated to perform a primitive scan operation on the original document based on the default image processing settings to thereby obtain a primitive scanned image. Next, the scanner driver is activated to perform a set of image processing routines on the primitive scanned image to thereby obtain the image qualities of the original document; and based on the image qualities of the original document, a set of suited image processing settings are specified for optimal scan of the original document. The suited image processing settings are then used to replace the default image processing settings, and the scanner is again activated to perform a final scan operation on the original document based on the suited image processing settings to thereby obtain a final scanned image which is transferred to the application program for use by the application program.

8 Claims, 2 Drawing Sheets



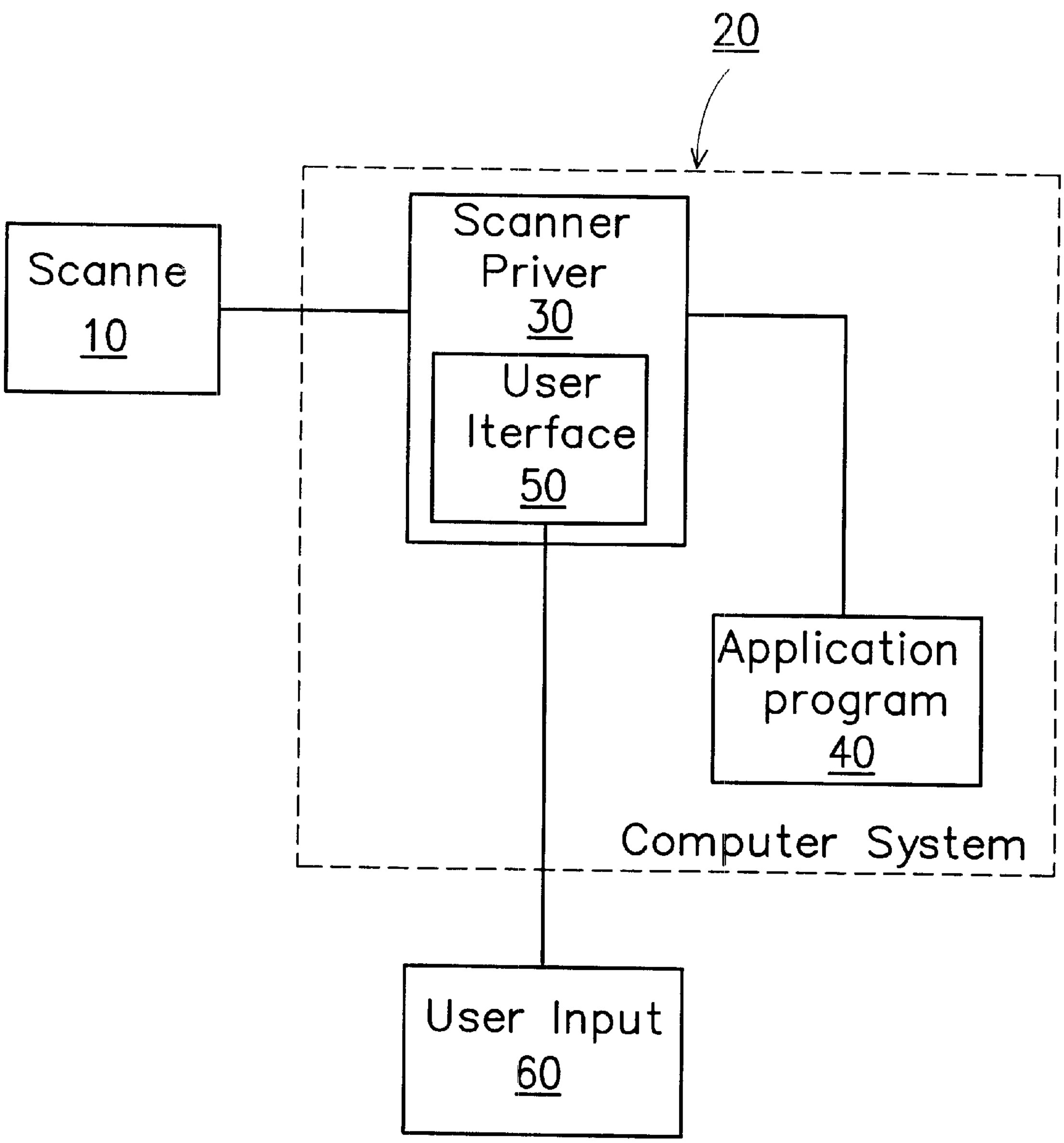

20
Scanne
10
Scanner
Priver
30
User
Iterface
50
Application
program
40
Computer System
User Input
60

FIG. 1

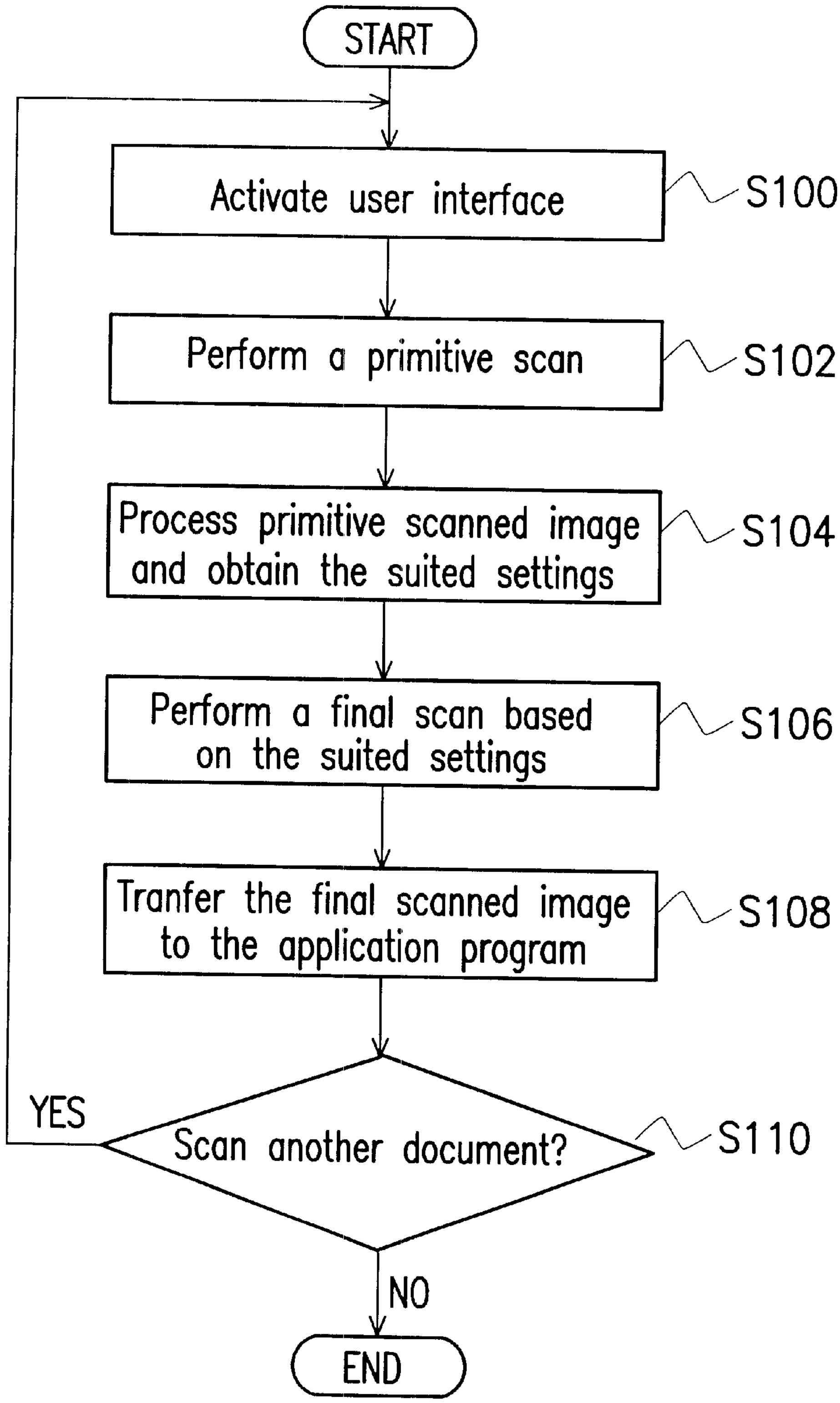

START
Activate user interface
S100
Perform a primitive scan
S102
Process primitive scanned image and obtain the suited settings
S104
Perform a final scan based on the suited settings
S106
Tranfer the final scanned image to the application program
S108
Scan another document?
S110
YES
NO
END

FIG. 2

METHOD AND USER INTERFACE FOR PERFORMING AN AUTOMATIC SCAN OPERATION FOR A SCANNER COUPLED TO A COMPUTER SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to scanner technology, and more particularly, to a method and user interface for performing an automatic scan operation for a scanner coupled to a computer system, which allows the user to acquire scanned images in a more user-friendlier manner.

2. Description of Related Art

A scanner allows a user to convert the printed matter on a document into a digital image for further processing by a computer. In the use of a scanner, however, it requires highly-experienced users to do the image processing tasks properly. For inexperienced users, it usually requires a long period to learn, typically in a trial-and-error manner, which would make the training quite cost-ineffective since additional electricity and paper cost may be required.

The U.S. Pat. No. 4,837,635 discloses a method that allows the user to first obtain a primitive scanned image from the scanner, and then specify suited image processing settings such as size and scan area for the scanner to perform a second scan operation on the original document to thereby obtain a final scanned image. By this method, the final scanned image is closed in image qualities to the original document. One drawback to this patent, however, is that it is quite laborious to use due to the reason that it requires the user to specify the settings. Moreover, it is still insufficient in functionality to meet user demands in high-end image processing.

In the use of many conventional image scan programs, it requires the user to specify various image processing settings to the scan operation. To specify these settings properly, however, the user is required to have learned knowledge background in the science of image processing. Therefore, for unlearned and inexperienced users, it would be highly difficult for them to specify these settings properly, which would make the use of the scanner very user-unfriendly.

In summary, conventional user interfaces for scanner operation have the following drawbacks.

First, they require the user to have learned knowledge background in the science of image processing in order to properly specify the image processing settings, which makes the use of the scanner quite difficult and user-unfriendly.

Second, if a user has no such knowledge background, the user needs to spend much time to learn the image scan operation, typically in a trial-and-error manner, which would make the use of the scanner quite cost-ineffective.

Third, the U.S. Pat. No. 4,837,635 provides only limited functionality to the image processing, which would not meet user demands in high-end image processing.

SUMMARY OF THE INVENTION

It is therefore an objective of this invention to provide a method and user interface for use on a computer system coupled with a scanner for performing an automatic scan operation, which allows the user to operate the scanner without requiring the user to specify image processing settings, so that the user operation can be made very easy.

In accordance with the foregoing and other objectives, the invention proposes a new user interface for scanner.

Fundamentally, the invention allows the user to scan an original document without requiring the user to specify image processing settings to the scan operation. The suited image processing settings can be automatically specified based on the image qualities of the primitive scanned image, and which are specified to such values that would make the image qualities of the final scanned image as close to the image qualities of the original document as possible. This feature allows users of any skill levels to perform the scan operation without having to specify any image processing settings to the scan operation, making the use of the scanner easier and more user-friendly than the prior art.

The invention is designed for use with a user interface incorporated in a computer system coupled with a scanner for performing an automatic scan operation on an original document. The computer system runs a scanner driver and an application program. The scanner driver is used to drive the scanner, and the application program can process the scanned image as an image file.

The method of the invention includes the following procedural steps: (1) reading a set of default image processing settings into the user interface; (2) activating the scanner to perform a primitive scan operation on the original document based on the default image processing settings to thereby obtain a primitive scanned image which is then transferred to the scanner driver; (3) activating the scanner driver to perform a set of image processing routines on the primitive scanned image to thereby obtain the image qualities of the original document; and based on the image qualities of the original document, specifying a set of suited image processing settings for optimal scan of the original document; and (4) activating the scanner to perform a final scan operation on the original document based on the suited image processing settings to thereby obtain a final scanned image which is transferred to the application program for use by the application program. The application program can be either an image editing program or a word processor that can accept the final scanned image as an image file.

In the foregoing method, the image processing routines include automatic cutting, distortion correction, color calibration, and automatic character recognition. Further, the scanner driver will specify the suited image processing settings to such values that will make the image qualities of the final scanned image as close to the image qualities of the original document as possible. These suited image processing settings are then used in the final scan operation to obtain the final scanned image whose image qualities would be close to the original document. The final scanned image is then transferred to the scanner driver in the computer system, and then transferred via the scanner driver to the application program specified by the user through the user interface. The application program can be either an image editing program or a word processor that can accept the final scanned image as an image file.

By the invention, the user first needs to place the original document on the scanner, and then press a scan button to activate the scan operation. After this, all the user needs to do is simply wait until the final scanned image is produced. The user needs not to specify any image processing settings. These will be automatically specified by the user interface based on the image qualities of the primitive scanned image. This feature allows users of any skill levels to perform the scan operation without having to specify any image processing settings to the scan operation, making the use of the scanner easier and more user-friendly than the prior art. Moreover, since the user needs not to spend time and material on learning the operation of the scanner, it also makes the use of the scanner more economical.

BRIEF DESCRIPTION OF DRAWINGS

The invention can be more fully understood by reading the following detailed description of the preferred embodiments, with reference made to the accompanying drawings, wherein:

FIG. **1** is a schematic block diagram of the incorporation of the user interface of the invention in a computer system coupled with a scanner; and

FIG. **2** is a flow diagram showing the procedural steps involved in the method of the invention for performing an automatic scan operation on an original document.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **1** is a schematic block diagram of the incorporation of the user interface of the invention, as the block designated by the reference numeral **50**, in a computer system **20** coupled with a scanner **10**. The computer system **20** runs a scanner driver **30**, which is a software program, for driving the scanner **10**. Further, the computer system **20** runs an application program **40** which can process the scanned image from the scanner **10** as an image file. The user interface **50** contains a set of default image processing settings, including, for example, color setting, DPI setting, and image size setting. The block designated by the reference numeral **60** is used to represent the input from user operation.

When the user wants to obtain a scanned image from an original document (not shown), the user first needs to place the original document (not shown) on the scanner **10**. Next, the user simply needs to press a scan button (not shown) to cause the user interface **50** to activate the scanner **10** to perform a primitive scan operation on the original document (not shown) based on the default image processing settings in the user interface **50** to thereby obtain a primitive scanned image. The primitive scanned image is then transferred to the scanner driver **30** in the computer system **20**.

Next, the scanner driver **30** performs an image-enhancement process on the primitive scanned image. The image-enhancement process includes several image processing routines, including automatic cutting, distortion correction, color calibration, and automatic character recognition.

Based the results from the foregoing image processing routines, the scanner driver **30** can recognize the image qualities of the original document and thereby automatically specify a set of suited image processing settings for optimal scan of the original document. These suited image processing settings also include color rendition, DPI, and image size, which will then override the default settings in the user interface **50**, and also include the optimal settings for automatic cutting, distortion correction, color calibration, and automatic character recognition.

The scanner driver **30** will then use these suited image processing settings to perform a final scan operation on the same original document to thereby obtain a final scanned image. The final scanned image is then transferred to the scanner driver **30** in the computer system **20**, and then transferred via the scanner driver **30** to the application program **40** specified by the user through the user interface **50**. The application program **40** can be either an image editing program or a word processor that can process the final scanned image as an image file.

FIG. **2** is a flow diagram showing the procedural steps involved in the method of the invention for performing an

automatic scan operation on the original document. This method is used with the computer system **20** and the scanner **10** shown in FIG. **1** and is performed by the user interface **50**.

In the first step **S100**, the user interface **50** is activated. This user interface **50** is preset with a set of default image processing settings, including, for example, color setting, DPI setting, and image size setting.

In the next step **S102**, the user interface **50** commands the scanner **10** to perform a primitive scan operation on the original document based on the default image processing settings in the user interface **50** to thereby obtain a primitive scanned image. The primitive scanned image is then transferred to the scanner driver **30**.

In the next step **S104**, the scanner driver **30** is activated to perform an image-enhancement process on the primitive scanned image. The image-enhancement process includes automatic cutting, distortion correction, color calibration, and automatic character recognition.

Based the results from the foregoing image processing routines, the scanner driver **30** can recognize the image qualities of the original document and thereby automatically specify a set of suited image processing settings for optimal scan of the original document. These suited image processing settings also include color rendition, DPI, and image size, which will then override the default settings in the user interface **50**, and also include the optimal settings for automatic cutting, distortion correction, color calibration, and automatic character recognition.

For example, if the default image processing settings are such that the color setting is COLOR and the DPI setting is 600 dpi; while the original document is a low-resolution B/W (black and white) document. In this case, the original document can be scanned with B/W setting and a low resolution setting. Through the image processing routines on the primitive scanned image, the image qualities of the original document can be recognized, allowing the scanner driver **30** to change the image processing settings from the default settings (COLOR, 600 dip) to the suited settings (B/W, 300 dpi). Fundamentally, the scanner driver **30** will specify the suited image processing settings as close to the image qualities of the original document as possible.

In the next step **S106**, the user interface **50** activates the scanner **10** to perform a final scan operation on the original document based on the suited image processing settings to thereby obtain a final scanned image.

In the next step **S108**, the final scanned image is transferred via the scanner driver **30** to the application program **40** so that the final scanned image can be used by the application program **40**. The application program **40** can be either an image editing program or a word processor that can process the final scanned image as an image file.

In the next step **S110**, the user interface **50** displays a message asking whether the user wants to scan another document. If the user responds with YES, the procedure returns to the step **S100**; otherwise, the procedure is ended.

In conclusion, the invention provides a method and user interface for performing an automatic scan operation for a scanner coupled to a computer system, which allows the user to scan an original document without requiring the user to specify image processing settings to the scan operation. The suited image processing settings can be automatically obtained based on the image qualities of the primitive scanned image. This feature allows users of any skill levels to perform the scan operation without having to specify any image processing settings to the scan operation, making the use of the scanner easier and more user-friendly than the prior art.

The invention has been described using exemplary preferred embodiments. However, it is to be understood that the scope of the invention is not limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and similar arrangements. The scope of the claims, therefore, should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

What is claimed is:

1. A method implemented on a user interface incorporated in a computer system coupled with a scanner for performing an automatic scan operation on an original document, the computer system running a scanner driver and an application program; the method comprising the steps of:

reading a set of default image processing settings into the user interface;

activating the scanner to perform a primitive scan operation on the original document based on the default image processing settings to thereby obtain a primitive scanned image which is then transferred to the scanner driver;

activating the scanner driver to perform a set of image processing routines on the primitive scanned image to thereby obtain the image qualities of the original document, wherein the set of image processing routines include automatic cutting; and based on the image qualities of the original document, specifying a set of suited image processing settings for optimal scan of the original document; and

activating the scanner to perform a final scan operation on the original document based on the suited image processing settings to thereby obtain a final scanned image which is transferred to the application program for use by the application program.

2. A method implemented on a user interface incorporated in a computer system coupled with a scanner for performing an automatic scan operation on an original document, the computer system running a scanner driver and an application program; the method comprising the steps of:

reading a set of default image processing settings into the user interface;

activating the scanner to perform a primitive scan operation on the original document based on the default image processing settings to thereby obtain a primitive scanned image which is then transferred to the scanner driver;

activating the scanner driver to perform a set of image processing routines on the primitive scanned image to thereby obtain the image qualities of the original document, wherein the set of image processing routines include distortion correction; and based on the image qualities of the original document, specifying a set of suited image processing settings for optimal scan of the original document; and

activating the scanner to perform a final scan operation on the original document based on the suited image processing settings to thereby obtain a final scanned image which is transferred to the application program for use by the application program.

3. A method implemented on a user interface incorporated in a computer system coupled with a scanner for performing an automatic scan operation on an original document, the computer system running a scanner driver and an application program; the method comprising the steps of:

reading a set of default image processing settings into the user interface;

activating the scanner to perform a primitive scan operation on the original document based on the default image processing settings to thereby obtain a primitive scanned image which is then transferred to the scanner driver;

activating the scanner driver to perform a set of image processing routines on the primitive scanned image to thereby obtain the image qualities of the original document, wherein the set of image processing routines include color calibration; and based on the image qualities of the original document, specifying a set of suited image processing settings for optimal scan of the original document; and

activating the scanner to perform a final scan operation on the original document based on the suited image processing settings to thereby obtain a final scanned image which is transferred to the application program for use by the application program.

4. A method implemented on a user interface incorporated in a computer system coupled with a scanner for performing an automatic scan operation on an original document, the computer system running a scanner driver and an application program; the method comprising the steps of:

reading a set of default image processing settings into the user interface;

activating the scanner to perform a primitive scan operation on the original document based on the default image processing settings to thereby obtain a primitive scanned image which is then transferred to the scanner driver;

activating the scanner driver to perform a set of image processing routines on the primitive scanned image to thereby obtain the image qualities of the original document, wherein the set of image processing routines include automatic character recognition; and based on the image qualities of the original document, specifying a set of suited image processing settings for optimal scan of the original document; and

activating the scanner to perform a final scan operation on the original document based on the suited image processing settings to thereby obtain a final scanned image which is transferred to the application program for use by the application program.

5. A user interface for use on a computer system coupled with a scanner for performing an automatic scan operation on an original document, the computer system running a scanner driver and an application program;

the user interface comprising:

means for reading a set of default image processing settings;

means for activating the scanner to perform a primitive scan operation on the original document based on the default image processing settings to thereby obtain a primitive scanned image which is then transferred to the scanner driver;

means for activating the scanner driver to perform a set of image processing routines on the primitive scanned image to thereby obtain the image qualities of the original document, wherein the set of image processing routines include automatic cutting; and based on the image qualities of the original document, obtaining a set of suited image processing settings for optimal scan of the original document; and

means for activating the scanner to perform a final scan operation on the original document based on the suited image processing settings to thereby obtain a final scanned image which is transferred to the application program for use by the application program.

6. A user interface for use on a computer system coupled with a scanner for performing an automatic scan operation on an original document, the computer system running a scanner driver and an application program;

the user interface comprising:

means for reading a set of default image processing settings;

means for activating the scanner to perform a primitive scan operation on the original document based on the default image processing settings to thereby obtain a primitive scanned image which is then transferred to the scanner driver;

means for activating the scanner driver to perform a set of image processing routines on the primitive scanned image to thereby obtain the image qualities of the original document, wherein the set of image processing routines include distortion correction; and based on the image qualities of the original document, obtaining a set of suited image processing settings for optimal scan of the original document; and

means for activating the scanner to perform a final scan operation on the original document based on the suited image processing settings to thereby obtain a final scanned image which is transferred to the application program for use by the application program.

7. A user interface for use on a computer system coupled with a scanner for performing an automatic scan operation on an original document, the computer system running a scanner driver and an application program;

the user interface comprising:

means for reading a set of default image processing settings;

means for activating the scanner to perform a primitive scan operation on the original document based on the default image processing settings to thereby obtain a primitive scanned image which is then transferred to the scanner driver;

means for activating the scanner driver to perform a set of image processing routines on the primitive scanned image to thereby obtain the image qualities of the original document, wherein the set of image processing routines include color calibration; and based on the image qualities of the original document, obtaining a set of suited image processing settings for optimal scan of the original document; and

means for activating the scanner to perform a final scan operation on the original document based on the suited image processing settings to thereby obtain a final scanned image which is transferred to the application program for use by the application program.

8. A user interface for use on a computer system coupled with a scanner for performing an automatic scan operation on an original document, the computer system running a scanner driver and an application program;

the user interface comprising:

means for reading a set of default image processing settings;

means for activating the scanner to perform a primitive scan operation on the original document based on the default image processing settings to thereby obtain a primitive scanned image which is then transferred to the scanner driver;

means for activating the scanner driver to perform a set of image processing routines on the primitive scanned image to thereby obtain the image qualities of the original document, wherein the set of image processing routines include automatic character recognition; and based on the image qualities of the original document, obtaining a set of suited image processing settings for optimal scan of the original document; and

means for activating the scanner to perform a final scan operation on the original document based on the suited image processing settings to thereby obtain a final scanned image which is transferred to the application program for use by the application program.

* * * * *

EXHIBIT D

US00RE43086E

(19) **United States**
(12) **Reissued Patent**
Hsu et al.

(10) **Patent Number: US RE43,086 E**
(45) **Date of Reissued Patent: Jan. 10, 2012**

(54) **METHOD AND USER INTERFACE FOR PERFORMING A SCAN OPERATION FOR A SCANNER COUPLED TO A COMPUTER SYSTEM**

(75) Inventors: **Chuan-Yu Hsu**, Hsinchu (TW); **Jay Liu**, Hsinchu (TW); **T. J. Hsu**, Hsinchu (TW)

(73) Assignee: **Transpacific Systems, LLC**, Wilmington, DE (US)

(21) Appl. No.: **11/237,579**

(22) Filed: **Sep. 27, 2005**

Related U.S. Patent Documents

Reissue of:
(64) Patent No.: **6,628,416**
Issued: **Sep. 30, 2003**
Appl. No.: **09/417,985**
Filed: **Oct. 13, 1999**

(51) **Int. Cl.**
G06K 15/00 (2006.01)
H04N 1/00 (2006.01)
G06K 9/00 (2006.01)
G06K 9/34 (2006.01)

(52) **U.S. Cl.** **358/1.15**; 382/167; 382/176

(58) **Field of Classification Search** 358/1.15, 358/442, 444, 473, 1.6, 1.1, 474; 382/167, 382/176
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,826,035 A * 10/1998 Hamada et al. 709/247
5,974,173 A * 10/1999 Kimura 382/167
5,996,029 A * 11/1999 Sugiyama et al. 710/15
6,137,591 A * 10/2000 Kikinis 358/1.6
6,370,277 B1 4/2002 Borrey et al.
6,480,304 B1 11/2002 Os et al.
6,751,780 B1 6/2004 Neff et al.
2002/0012453 A1* 1/2002 Hashimoto et al. 382/112

* cited by examiner

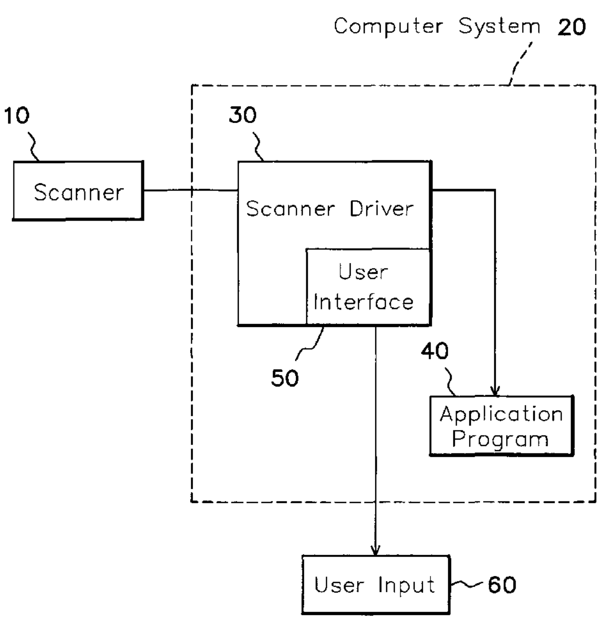
Primary Examiner — Jerome Grant, II

(74) *Attorney, Agent, or Firm* — Stolowitz Ford Cowger LLP

(57) **ABSTRACT**

A method and user interface is provided for use on a computer system coupled with a scanner for performing a scan operation on an original document, which allows the user to acquire scanned images in an easier and more user-friendly manner. The method allows the user to scan an original document without requiring the user to have [learned knowledge] *a* background in the science of image processing, and also allows the scanner to perform only one scan operation on the original document. These features allow the use of the scanner to be easier and more user-friendly than the prior art. [By the, method, the first step is to determine] *In the method, first a scanner driver program suited for optimizing the scan of the original document determines* a set of image processing settings [by a scanner driving program that are suited for optimal scan of the original document; and then]. *Then* the scanner is activated to perform a scan operation on the original document based on the image processing settings to thereby obtain a primitive scanned image. Next, an image-enhancement process is performed on the primitive scanned image to thereby obtain a quality-enhanced image; and finally, the quality-enhanced image is transferred to the application program for use by [the] *an* application program.

25 Claims, 3 Drawing Sheets



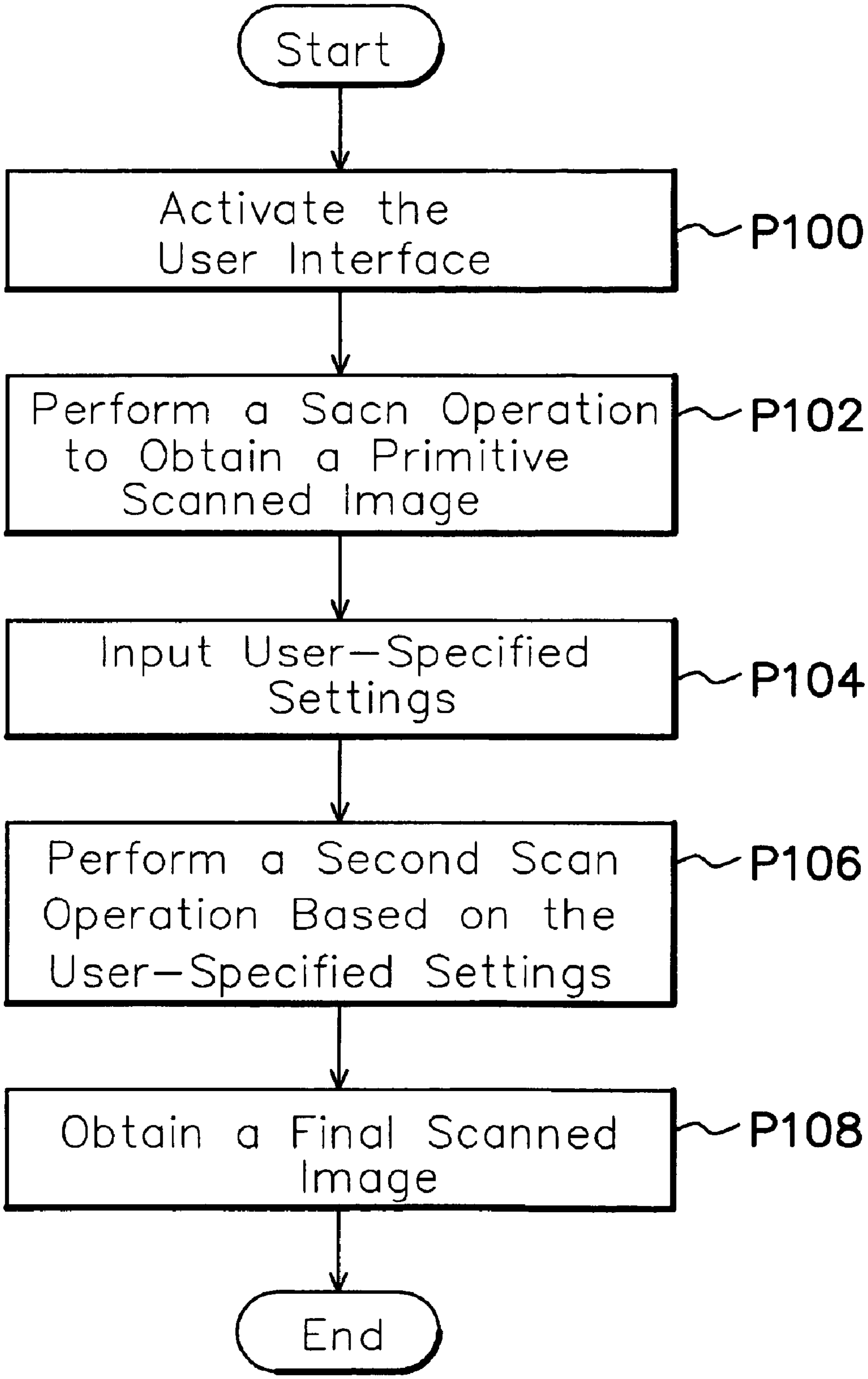


FIG. 1 (PRIOR ART)

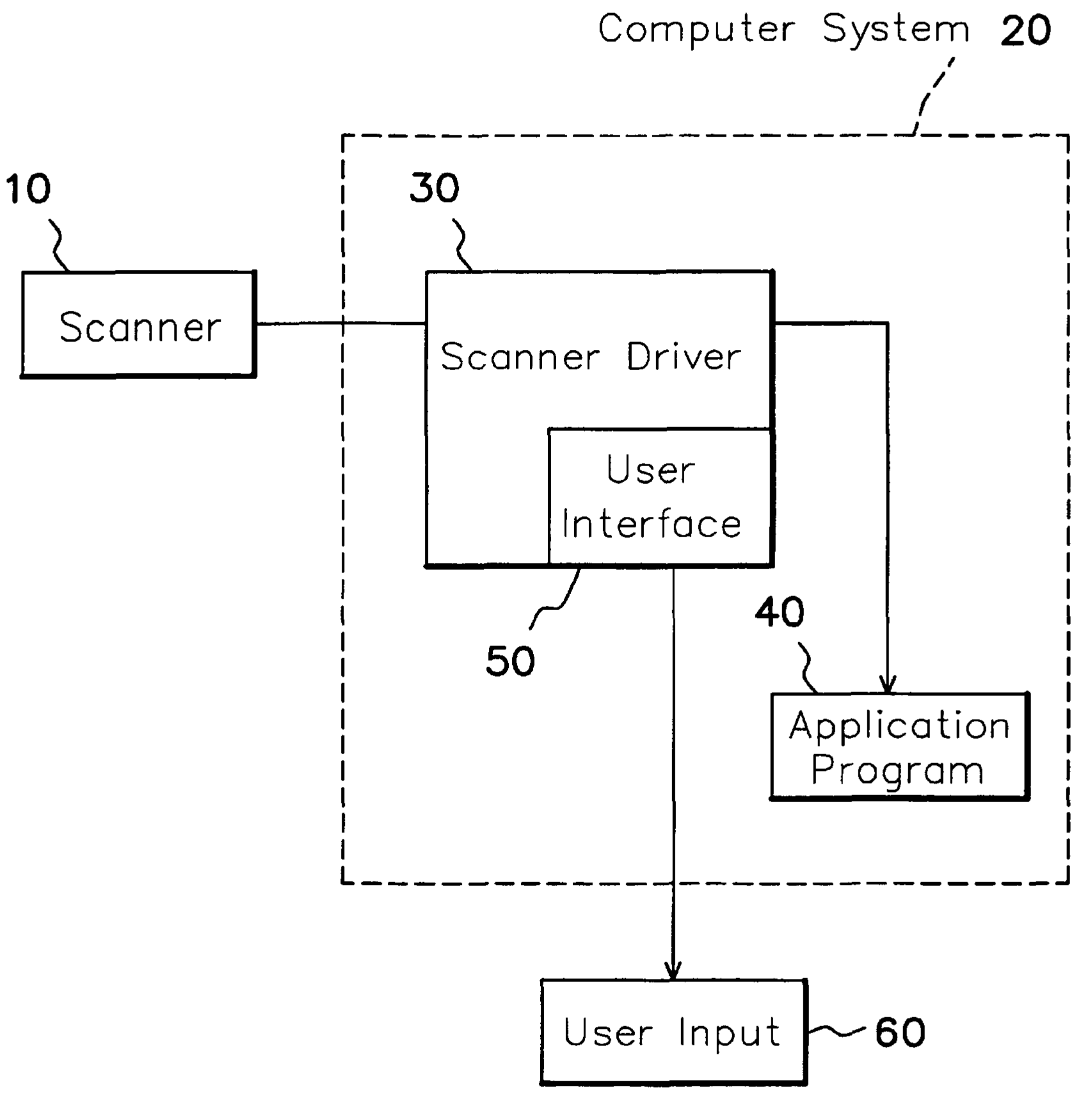

Computer System 20
10
Scanner
30
Scanner Driver
User
Interface
50
40
Application
Program
User Input
60

FIG. 2

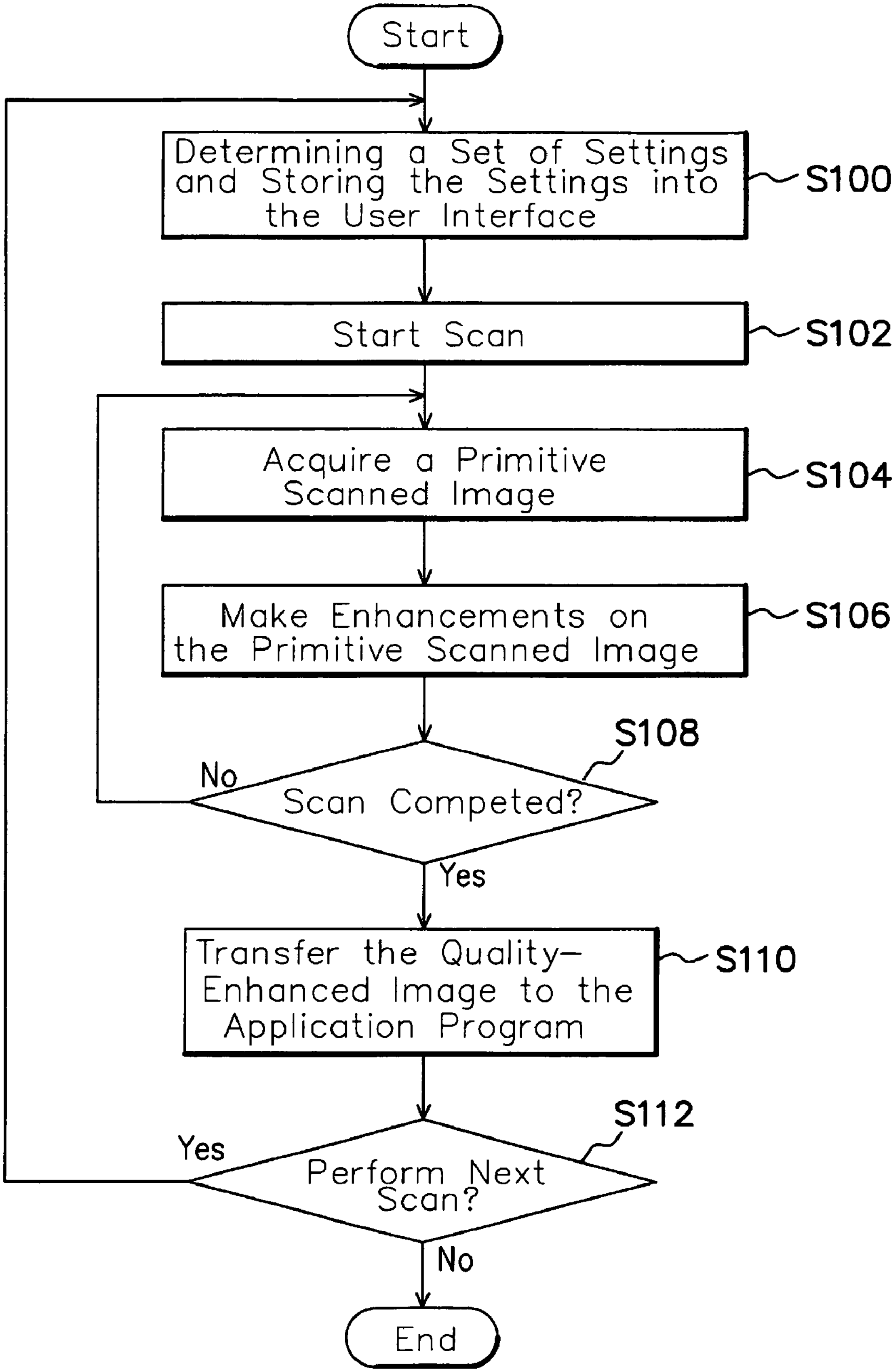

Start
Determining a Set of Settings and Storing the Settings into the User Interface
S100
Start Scan
S102
Acquire a Primitive Scanned Image
S104
Make Enhancements on the Primitive Scanned Image
S106
S108
No
Scan Competed?
Yes
Transfer the Quality-Enhanced Image to the Application Program
S110
S112
Yes
Perform Next Scan?
No
End

FIG. 3

METHOD AND USER INTERFACE FOR PERFORMING A SCAN OPERATION FOR A SCANNER COUPLED TO A COMPUTER SYSTEM

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to scanner technology, and more particularly, to a method and user interface for performing a scan operation for a scanner coupled to a computer system, which allows the user to acquire scanned images in an easier and more user-friendly manner.

2. Description of Related Art

A scanner allows a user to convert the printed matter on a document into a digital image for further processing by a computer. In the use of a scanner, however, it requires well-learned and highly-experienced users to do the image processing tasks properly. For inexperienced users, it usually requires a long period to learn, typically in a trial-and-error manner, which would make the training quite cost-ineffective since additional electricity and paper cost may be required in the training course.

The U.S. Pat. No. 4,837,635 discloses a method that allows the user to acquire a scanned image by first obtaining a primitive scanned image from the scanner, and then specify suited image processing settings such as size and scan area for the scanner to perform a second scan operation on the original document to thereby obtain a final scanned image. By this method, the final scanned image can approach closely to the image qualities of the original document. One drawback to this patent, however, is that it is quite inefficient to use since it requires the scanner to perform two scan operations on the same document.

FIG. **1** is a flow diagram showing the procedural steps involved in a conventional method to obtain a scanned image from an original document.

In the first step P**100**, the user interface for the scanner is activated. In the next step P**102**, the user interface commands the scanner to perform a primitive scan operation on the original document. The primitive scanned image is then displayed by the user interface for the user to make enhancements thereon.

In the next step P**104**, the user interface asks the user to specify suited image processing settings for the enhancement of the primitive scanned image, such as size setting and the desired scan area of the original document.

In the next step P**106**, the user interface activates the scanner to perform a second scan operation on the original document based on the image processing settings to thereby obtain a final scanned image. In the next step P**108**, the final scanned image is transferred to an application program for use by the application program.

It is apparent that the foregoing procedure has the drawback of requiring the scanner to perform two scan operations on the same document to obtain the final scanned image, which makes the image acquisition quite inefficient.

Moreover, the U.S. Pat. No. 4,837,635 is still [quire] *quite* insufficient in functionality to meet user demands in image processing.

In the use of many conventional image scan programs, it requires the user to have [learned knowledge] *a* background in the science of image processing. [Therefore, for unlearned and inexperienced users, it would be highly difficult for them to use these programs rightly, and requires the user to spend much time and material on training.] *Consequently, inexperienced users have a difficult time using the programs correctly without spending time, and other resources, on obtaining the proper training.*

In summary, conventional user interfaces for scanner operation have the following drawbacks.

First, they require the user to have [learned knowledge] *a* background in the science of image processing in order to properly carry out the image acquisition, which makes the use of the scanner quite difficult and user-unfriendly.

Second, if a user has no such knowledge background, the user needs to spend much time and material on training, typically in a trial-and-error manner, which would make the use of the scanner quite cost-ineffective.

Third, the U.S. Pat. No. 4,837,635 provides only limited functionality to the image processing, which would not meet user demands in high-end image processing.

Fourth, the prior art requires the scanner to perform two scan operations on the same document to acquire the final scanned image to be used by the application program, which makes the use of the scanner quite inefficient. It is desired that only one scan operation is needed.

SUMMARY OF THE INVENTION

It is therefore an objective of this invention to provide a method and user interface for use on a computer system coupled with a scanner for performing a scan operation, which allows the user to operate the scanner in an easy and user-friendly manner.

It is therefore an objective of this invention to provide a method and user interface for use on a computer system coupled with a scanner for performing a scan operation, which allows the scanner to perform only one scan operation on the original document.

In accordance with the foregoing and other objectives, the invention proposes a new method and user interface for use on a computer system coupled with a scanner for performing a scan operation.

Fundamentally, the invention allows the user to scan an original document without requiring the user to have learned knowledge background in the science of image processing, and also allows the scanner to perform only one scan operation on the original document. These features allow the use of the scanner to be easier and more user-friendly than the prior art.

The invention is designed for use with a user interface incorporated in a computer system coupled with a scanner for performing an automatic scan operation on an original document. The computer system runs a scanner driver and an application program. The scanner driver is used to drive the scanner, and the application program can process the scanned image as an image file.

The method of the invention includes the following procedural steps: (1) determining a set of image processing settings by a scanner driving program that are suited for optimal scan of the original document; (2) activating the scanner to perform a scan operation on the original document based on the image processing settings to thereby obtain a primitive scanned image which is then transferred to the scanner driver; (3) activating the scanner driver to perform an image-enhancement process on the primitive scanned image to thereby obtain a quality-enhanced image; and (4) transferring the quality-enhanced image to the application program for use by the application program.

In the foregoing method, the image-enhancement process includes a comprehensive set of image processing routines, such as automatic cutting, distortion correction, color calibration, and automatic character recognition. The quality-enhanced image is then transferred to the scanner driver in the computer system, and then transferred via the scanner driver to the application program specified by the user through the user interface. The application program can be either an image editing program or a word processor that can accept the quality-enhanced image as an image file.

By the invention, the scanner needs just to perform one scan operation on the original document rather than two scan operations required by the prior art (the U.S. Pat. No. 4,837,635). The invention is therefore more efficient than the prior art. After this, the invention will automatically perform an image-enhancement process on the primitive scanned image to thereby obtain the quality-enhanced image, without requiring the user to have learned knowledge background in the science of image processing in order to perform the image enhancement, and therefore no training is required. Since the user needs not to spend time and material on learning the operation of the scanner, it makes the use of the scanner more cost-effective and user-friendly. Furthermore, the invention provides an image-enhancement process that includes a comprehensive set of image processing routines which would meets most user's demands in image processing.

BRIEF DESCRIPTION OF DRAWINGS

The invention can be more fully understood by reading the following detailed description of the preferred embodiments, with reference made to the accompanying drawings, wherein:

FIG. **1** (PRIOR ART) is a flow diagram showing the procedural steps involved in a conventional method to obtain a scanned image from an original document;

FIG. **2** is a schematic block diagram of the incorporation of the user interface of the invention in a computer system coupled with a scanner; and

FIG. **3** is a flow diagram showing the procedural steps involved in the method of the invention for performing a scan operation on an original document.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **2** is a schematic block diagram of the incorporation of the user interface of the invention, as the block designated by the reference numeral **50**, in a computer system **20** coupled with a scanner **10**. The computer system **20** runs a scanner driver **30**, which is a software program, for driving the scanner **10**. Further, the computer system **20** runs an application program **40** which can process the scanned image from the scanner **10** as an image file. The block designated by the reference numeral **60** is used to represent the input from user operation. The user can specify a set of proper image processing settings into the user interface **50**.

When the user wants to acquire a scanned image from an original document (not shown), the user first needs to place the original document (not shown) on the scanner **10**, and then specify a set of image processing settings that are suited for optimal scan of the original document (not shown). Next, the user interface **50** activates the scanner **10** to perform a scan operation on the original document (not shown) based on the image processing settings in the user interface **50** to thereby obtain a primitive scanned image. The primitive scanned image is then transferred to the scanner driver **30** in the computer system **20**.

Next, the scanner driver **30** performs an image-enhancement process on the primitive scanned image to thereby obtain a quality-enhanced image. The image-enhancement process includes a comprehensive set of image processing routines, including automatic cutting, distortion correction, color calibration, and automatic character recognition.

After this, the scanner driver **30** checks whether there is still another document waiting to be scanned. If YES, the scanner driver **30** will perform another scan operation. The quality-enhanced image is then transferred to the application program **40** for use by the application program **40**.

FIG. **3** is a flow diagram showing the procedural steps involved in the method of the invention for performing a scan operation on the original document. This method is used with the computer system **20** and the scanner **10** shown in FIG. **2** and is performed by the user interface **50**.

In the first step S**100**, a set of image processing settings that are suited for optimal scan of the original document is determined by a scanner driving program, and then stores these settings into the user interface **50**.

In the next step S**102**, the user interface **50** issues a scan request to the scanner **10**. In response, in the next step S**104**, the scanner **10** is activated to perform a scan operation on the original document based on the image processing settings in the user interface **50** to thereby obtain a primitive scanned image. The primitive scanned image is then transferred to the scanner driver **30**.

In the next step S**106**, the scanner driver **30** is activated to perform an image-enhancement process on the primitive scanned image to thereby obtain a quality-enhanced image. The image-enhancement process includes a comprehensive set of image processing routines, including automatic cutting, distortion correction, color calibration, and automatic character recognition.

In the next step S**108**, the user interface **50** checks whether there is still another document waiting to be scanned. If YES, the procedure returns to the step S**104**; otherwise, the procedure goes to the step S**110**.

In the step S**110**, the quality-enhanced image **[**resulted**]** *resulting* from the image-enhancement process is transferred to the application program **40** for use by the application program **40**. The application program **40** can be either an image editing program or a word processor that can accept the quality-enhanced image as an image file.

In the next step S**112**, the user interface **50** displays a message asking whether the user wants to scan another document. If the user responds with YES, the procedure returns to the step S**100**; otherwise, the procedure is ended.

In conclusion, the invention has the following advantages over the prior art.

First, it requires the scanner to perform only one scan operation on the original document rather than two scan operations required by the prior art (the U.S. Pat. No. 4,837,635). The invention is therefore more efficient to use than the prior art.

Second, the invention allows the image-enhancement process to be entirely carried out automatically without requiring the user to have knowledge background in the science of image processing, so that the use of the scanner is easier and more user-friendly.

Third, since the invention allows the user to carry out the scan operation without having to spend time and material on training, the use of the scanner is more cost-effective than the prior art.

Fourth, the invention provides an image-enhancement process that includes a comprehensive set of image processing routines which would meet most user's demands in image processing.

Fifth, the invention allows the image acquisition to be mostly performed automatically, allowing the operation of the scanner to be more simplified and user-friendly.

The invention has been described using exemplary preferred embodiments. However, it is to be understood that the scope of the invention is not limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and similar arrangements. The scope of the claims, therefore, should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

What is claimed is:

1. A method implemented on a user interface incorporated in a computer system coupled with a scanner for performing a scan operation on an original document, the computer system running a scanner driver and an application program**[**;**]**, the method comprising the steps of:

determining a set of image processing settings required for the original document by a scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses *the* image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes an automatic cutting routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to the application program.

2. A method implemented on a user interface incorporated in a computer system coupled with a scanner for performing a scan operation on an original document, the computer system running a scanner driver and an application program**[**;**]**, the method comprising the steps of:

determining a set of image processing settings required for the original document by a scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses *the* image processing settings through the scanner driving program;

performing an image-enhancement**[**,**]** process on the primitive scanned image, wherein the image-enhancement process includes a distortion correction routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to the application program.

3. A method implemented on a user interface incorporated in a computer system coupled with a scanner for performing a scan operation on an original document, the computer system running a scanner driver and an application program**[**;**]**, the method comprising the steps of:

determining a set of image processing settings required for the original document by a scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses *the* image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes a color calibration routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to the application program.

4. A method implemented on a user interface incorporated in a computer system coupled with a scanner for performing a scan operation on an original document, the computer system running a scanner driver and an application program**[**;**]**, the method comprising the steps of:

determining a set of image processing settings required for the original document by a scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses *the* image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes an automatic character recognition routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to the application program.

5. A user interface for a scanner, comprising:

[a**]** *the* scanner, for scanning an original document to **[**an**]** image data;

a computer system, for storing and processing the image data from the scanner;

a scanner driving program, for driving the scanner and then performing an image-enhancement process on the image data stored in the computer system; *and*

an application program, for receiving a final image processed by the image-enhancement process, wherein a method implemented on the user interface **[**comprising**]** *comprises* the steps of:

determining a set of image processing settings required for the original document by **[**a**]** *the* scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses *the* image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes an automatic cutting routine; and

obtaining **[**a**]** *the* final image by the image-enhancement process *on the primitive scanned image,* wherein the final image is transferred to the application program.

6. A user interface for a scanner, comprising:

[a**]** *the* scanner, for scanning an original document to **[**an**]** image data;

a computer system, for storing and processing the image data from the scanner;

a scanner driving program, for driving the scanner and then performing an image-enhancement process on the image data stored in the computer system; *and*

an application program, for receiving a final image processed by the image-enhancement process, wherein a method implemented on the user interface **[**comprising**]** *comprises* the steps of:

determining a set of image processing settings required for the original document by **[**a**]** *the* scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses *the* image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes a distortion correction routine; and

obtaining **[**a**]** *the* final image by the image-enhancement process *on the primitive scanned image,* wherein the final image is transferred to the application program.

7. A user interface for a scanner, comprising:

[a] *the* scanner, for scanning an original document to [an] image data;

a computer system, for storing and processing the image data from the scanner;

a scanner driving program, for driving the scanner and then performing an image-enhancement process on the image data stored in the computer system; *and*

an application program, for receiving a final image processed by the image-enhancement process, wherein a method implemented on the user interface [comprising] *comprises* the steps of:

determining a set of image processing settings required for the original document by [a] *the* scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses *the* image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes a color calibration routine; and

obtaining [a] *the* final image by the image-enhancement process *on the primitive scanned image,* wherein the final image is transferred to the application program.

8. A user interface for a scanner, comprising:

[a] *the* scanner, for scanning an original document to [an] image data;

a computer system, for storing and processing the image data from the scanner;

a scanner driving program, for driving the scanner and then performing an image-enhancement process on the image data stored in the computer system; *and*

an application program, for receiving a final image processed by the image-enhancement process, wherein a method implemented on the user interface [comprising] *comprises* the steps of:

determining a set of image processing settings required for the original document by [a] *the* scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses *the* image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes an automatic character recognition routine; and

obtaining [a] *the* final image by the image-enhancement process *on the primitive scanned image,* wherein the final image is transferred to the application program.

9. A method, comprising:

obtaining an image processing setting for a target of a scan;

obtaining a primitive scanned image of the scan target using the obtained image processing setting through a scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes at least one of an automatic cutting routine, a distortion correction routine, a color calibration routine, or an automatic character recognition routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to an application program.

10. The method of claim 9, further comprising:

checking for another scan target to be scanned, the checking based on an input from a user interface;

if the checking indicates no additional scanning, then transferring the final image to the application program; and

if the checking indicates another scan target to be scanned, then causing the scanner to scan a second time before transferring the final image to the application program.

11. The method of claim 9, further comprising obtaining the image processing setting for the scan target based on an input from a user interface.

12. The method of claim 9, wherein the final image is obtained using only a single scanning of the scan target.

13. The method of claim 9, wherein the application program is an image editing program or a word processor.

14. The method of claim 9, further comprising:

selecting, using the scanner driving program, a subset of available image processing settings, the subset selected based on the scan target; and

issuing a scan request that includes at least the obtained image processing setting, wherein the obtained image processing setting is one of the settings from the subset.

15. A memory device having instructions stored thereon that, in response to execution by a computing device, cause the computing device to perform operations comprising:

obtaining a primitive scanned image using an image processing setting through a scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes at least one of an automatic cutting routine, a distortion correction routine, a color calibration routine, or an automatic character recognition routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to an application program.

16. The memory device of claim 15, wherein the operations further comprise:

checking for another scan job, the checking based on an input from a user interface;

if the checking indicates no additional scanning, then transferring the final image to the application program; and

if the checking indicates another scan job, then causing the scanner to scan a second time before transferring the final image to the application program.

17. The memory device of claim 15, wherein the operations further comprise obtaining the image processing setting for a scan target based on an input from a user interface.

18. The memory device of claim 15, wherein the final image is obtained using only a single scanning of a scan target.

19. The memory device of claim 15, wherein the application program is an image editing program or a word processor.

20. The memory device of claim 15, wherein the operations further comprise:

selecting, using the scanner driving program, a subset of available image processing settings, the subset selected based on a scan target; and

issuing a scan request that includes at least the obtained image processing setting, wherein the obtained image processing setting is one of the settings from the subset.

21. An apparatus, comprising:

means for obtaining a primitive scanned image using an image processing setting through a scanner driving program;

means for performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes at least one of an automatic cutting routine, a distortion correction routine, a color calibration routine, or an automatic character recognition routine; and

means for obtaining a final image by the image-enhancement process, wherein the final image is transferred to an application program.

22. The apparatus of claim 21, further comprising:

means for checking if there is another scan job; and

means for transferring the final image to the application program based on a result of the checking.

23. The apparatus of claim 21, further comprising means for determining the image processing setting based on a scan target associated with the primitive scanned image.

24. The apparatus of claim 21, wherein the final image is obtained using only a single scanning of a scan target.

25. The apparatus of claim 21, wherein the application program is an image editing program or a word processor.

* * * * *

EXHIBIT E

US007315406B2

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

(10) **Patent No.: US 7,315,406 B2**
(45) **Date of Patent: Jan. 1, 2008**

(54) **SCANNING CIRCUIT STRUCTURE**

(75) Inventors: **Kuan-Yu Lee**, Taichung (TW); **Chen-Ho Lee**, Hsinchu (TW)

(73) Assignee: **Transpacific IP, Ltd.**, Taipei (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 957 days.

(21) Appl. No.: **10/064,265**

(22) Filed: **Jun. 27, 2002**

(65) **Prior Publication Data**

US 2004/0001236 A1 Jan. 1, 2004

(51) **Int. Cl.**
H04N 1/04 (2006.01)
H04N 1/32 (2006.01)

(52) **U.S. Cl.** **358/482**; 358/474; 358/483; 358/442; 358/468

(58) **Field of Classification Search** 358/482, 358/483, 468, 442, 434, 474, 484, 497, 494, 358/445, 409, 412, 505, 506, 512–514; 250/208.1, 250/234–236, 208.2, 312, 318, 319; 382/312, 382/318, 319; 359/212; 399/211, 212
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,627,603 A * 5/1997 Sakai 348/708
6,002,508 A * 12/1999 Mai 359/212
6,084,691 A * 7/2000 Tsai et al. 358/474
6,801,254 B1 * 10/2004 Nishio 348/241

FOREIGN PATENT DOCUMENTS

JP 2002218185 A * 8/2002
JP 2003110798 A * 4/2003

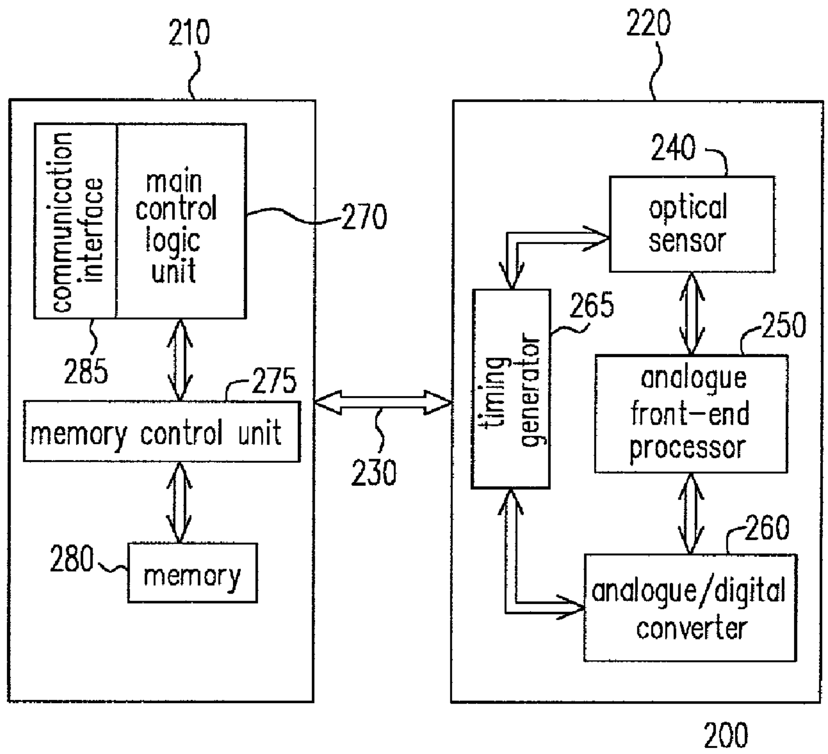
* cited by examiner

Primary Examiner—Cheukfan Lee
(74) *Attorney, Agent, or Firm*—Stolowitz Ford Cowger LLP

(57) **ABSTRACT**

A scanning circuit having rearranged circuit modules at each end of a flat cable. After the rearrangement, the flat cable carries scanning control signals produced by a conventional IC communication interface instead of timing signals and carries digital image data instead of easily distorted and interfered analog image signals.

31 Claims, 1 Drawing Sheet



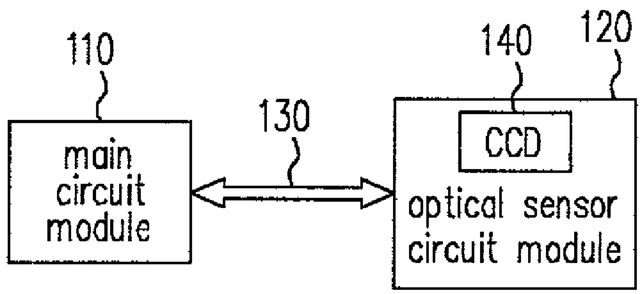


FIG. 1 (PRIOR ART)

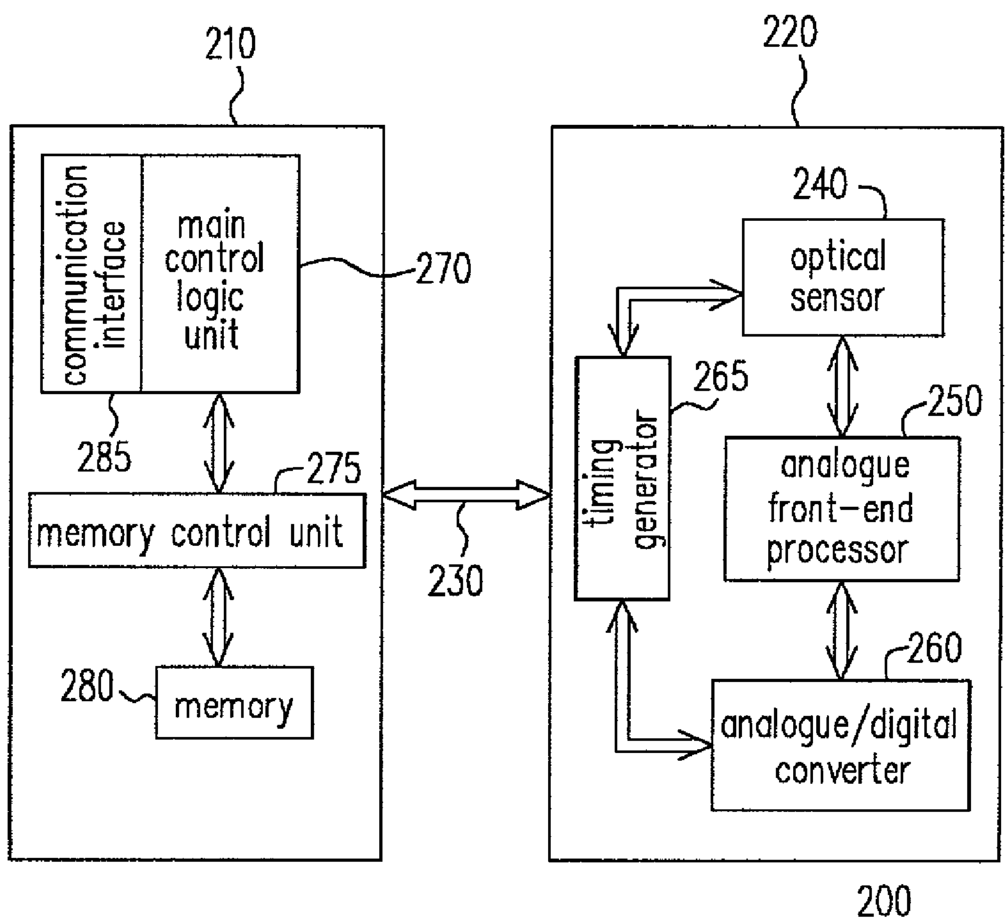


FIG. 2

SCANNING CIRCUIT STRUCTURE

BACKGROUND OF INVENTION

1. Field of Invention

The present invention relates to a scanner. More particularly, the present invention relates to scanning circuit structure.

2. Description of Related Art

In recent years, rapid progress in digital technologies has lead to the development of Internet and multimedia systems. Accompanying this trend, a large number of analog images are routinely converted into a digital format to facilitate processing. A digital camera (DC) is used to extract an image from an actual scene. Similarly, an optical scanner is used to extract textual data from a document or image data from a picture. The extracted data is converted into a digital format so that a computer or electronic equipment may display an image, carry out an optical character recognition, edit the data, store up the data or simply output to some devices.

According to the method of inputting document image, optical scanners may be classified as a palmtop scanner, a sheet feed scanner, a drum scanner or a flatbed scanner. FIG. **1** is a diagram showing the circuit structure of a conventional scanner. As shown in FIG. **1**, the circuit includes an optical sensor circuit module **120** and a main circuit module **110**. Each circuit module is fabricated on a printed circuit board. The circuit modules **110** and **120** communicate with each other through a flat cable **130**. In general, the main circuit module **110** is fixed inside the lower casing of a scanner while the optical sensor circuit module **120** is attached to a scanning module capable of moving longitudinally. The optical sensor circuit module **120** has a charge-coupled device **140** therein. The charge-coupled device **140** can sense the light reflected from the image within a scan document to produce analog image signals. The analog image signals are transmitted to the main circuit module **120** by a form of analog voltage signals through the flat cable **130**. The main circuit module **120** processes the analog image signals and converts the analog image signals into digital image data, so as to provide a user to retrieve the digital image data file to carry out various operations including image display, optical character recognition, editing, data archiving or data transfer through a computer or other electronic device. In addition, to capture the image produced by the reflected light while scanning the document, the charge-coupled device **140** must receive timing control signals from the main circuit module **120** as well. Hence, the flat cable **130** must carry both timing control signals and analog image signals.

When demand for image quality is low, a flat cable is adequate because the quantity of image data that needs to be transferred is small. However, due to rapid expansion of computer power, the production of a high-quality scan image at a shorter scan period is always in demand. Eventually, to meet these demands, the flat cable has to carry greater quantities of analog image signals and timing control signals. In other words, the flat cable not only has to transmit signal at a higher rate, but also has to increase the number of transmission lines for transmitting timing control signals. The additional transmission lines for carrying control signals may cause electromagnetic interference (EMI) of analog image signals. Ultimately, image data may be distorted.

SUMMARY OF INVENTION

Accordingly, one object of the present invention is to provide a scanning circuit structure for a scanner capable of reducing distortion during high-speed image signal transmission so that electromagnetic interference is minimized and quality of transmitted image is improved.

To achieve these and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, the invention provides a scanning circuit structure for a document scanner. The scanning circuit includes a main circuit module and an optical sensor circuit module. The main circuit module receives a scanning instruction from a communication interface and converts the scanning instruction into scan control signals. The scan control signals are passed to a connection cable. In the meantime, the main circuit module also receives digital image data of a scan document from the connection cable. The optical sensor circuit module is connected to the main circuit module via the connection cable. The optical sensor circuit module receives the scan control signals and converts the scan control signal into timing control signals. Hence, operations including the scanning of a document, the extraction of an analog image signal and the conversion of the analog image signal into a digital image data are executed in sequence.

In one embodiment of this invention, the main circuit module includes a main control logic unit, a memory unit and a memory control logic unit. The optical sensor circuit module includes an optical sensor, an analog front-end processor, an analog/digital converter and a timing signal generator. The main control logic unit in the main control module receives scanning instructions and converts the instructions into scanning control signals. The main control logic also receives digital image data scanned from a document. The memory unit stores digital image data. The memory control logic unit is coupled to the main control logic unit and the memory unit for controlling the access of digital image data. The optical sensor inside the optical sensor circuit module is used to sense an analog image signal that is formed by the light reflected from the document. The analog front-end processor is coupled to the optical sensor for pre-processing the analog image. The analog/digital converter is coupled to the front-end processor for converting the pre-processed analog image signal into digital image data. The timing signal generator is coupled to the optical sensor and the analog/digital converter for producing timing control signals, so as to control the scanning process on the document, produce the analog image signal of the document, and convert the analog image signal into the digital image data.

The main control logic unit in this invention also includes an image front-end processor for compensating and adjusting the captured digital image data so that the scanned image has a better quality. In general, the memory unit contains dynamic random access memory and the optical sensor is a charge-coupled device (CCD) or a CMOS image sensor. The connection cable linking the main circuit module and the optical sensor circuit module include a flat cable and the scanning circuit interfaces with a computer through a universal serial bus (USB). The scanning control signals are transmitted through an IIC or 3-wire IC communication interface.

In this invention, digital image data are transmitted instead of analog image signals. Furthermore, the scanning control signals are transmitted through a common IC communication interface instead of timing control signals transmitted through a connection cable. Through this arrangement, image data distortion due to high-speed transmission is greatly minimized. Hence, electromagnetic interference is minimized and quality of image transmitted by the scanner is improved.

It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF DRAWINGS

The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention. In the drawings,

FIG. **1** is a diagram showing the circuit structure of a conventional scanner; and

FIG. **2** is a diagram showing the circuit structure of a scanner according to one preferred embodiment of this invention.

DETAILED DESCRIPTION

Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

FIG. **2** is a diagram showing the circuit structure of a scanner according to one preferred embodiment of this invention. As shown in FIG. **2**, the scanning circuit **200** is responsible for controlling the entire process of scanning a document. The scanning circuit **200** includes a main circuit module **210** and an optical sensor circuit module **220**. The main circuit module **210** and the optical sensor circuit module **220** are linked together through a connection cable **230** such as a flat cable. The flat cable carries both scan control signals and digital image data. The main circuit module **210** further includes a main control logic unit **270**, a memory unit **280** and a memory control logic unit **275**. The optical sensor circuit module **220** further includes an optical sensor **240**, an analog front-end processor (AFE) **250**, an analog/digital converter **260** and a timing signal generator **265**.

The main control logic unit **270** in the main circuit module **210** connects with the human/machine interface of a personal computer (not shown) through a communication interface **285**. Here, the communication interface **285** can be a universal serial bus (USB) interface or an enhanced parallel port (EPP) interface, for example. The communication interface **285** receives important scanning instructions regarding image resolution, brightness level and scanning range and converts the scanning instructions into scanning control signals that pass along the connection cable **230**.

When the optical sensor circuit module **220** receives scanning control signals from the main circuit module **210**, the timing generator **265** produces the required timing control signals for extracting an analog image signal from the optical sensor **240**. The optical sensor **240** is a charge-coupled device (CCD) or a CMOS image sensor, for example. The captured analog image signal is preprocessed by the analog front-end preprocessor **250**. Thereafter, the pre-processed analog image is transmitted to the analog/digital converter **260** and converted to digital image data. The digital image data is subsequently transmitted to the main circuit module **210** through the connection cable **230**. At this moment, the data transmitted on the connection cable **230** is no longer the analog signal that easily has the distortion but is the digital image data that can be easily transmitted in a fast speed. As a result, it can effectively solve the issue about difficulty on maintaining the scanning quality when the scanning process is operated in the fast speed.

On receiving the digital image data, the main circuit module **210** transfers the data to the memory unit **280** via the memory controller **275**. The memory unit **280** may contain conventional types of memory such as synchronous or non-synchronous dynamic random access memory (DRAM) or static random access memory (SRAM). Obviously, the main control logic unit **270** may incorporate an image preprocessor (not shown) for compensating and adjusting the captured digital image data so that the scanned image can have better quality. In addition, timing signals may have to be adjusted due to the change in connection between the communication interface of various integrated circuits (ICs).

In conclusion, major advantages of this invention include:

1. Since the flat cable transmits digital data instead of easily distorted analog image signals, a clearer image can be obtained at a higher scanning speed.

2. Since the flat cable transmits scanning control signals between conventional IC communication interfaces instead of timing control signals, the effect due to electromagnetic interference is greatly minimized.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

The invention claimed is:

1. A scanning circuit for a document scanner, comprising:

a main circuit module capable of receiving a scanning instruction from a communication interface, converting the scanning instruction into scan control signals, passing the scan control signals to a connection cable as well as receiving a digital image data captured in a document scanning operation through the connection cable; and

an optical sensor circuit module connected to the main circuit module through the connection cable capable of receiving the scan control signals and converting the scan control signals to timing control signals that control document scanning, extraction of an analog image signal from the document and conversion of the analog image signal into the digital image data.

2. The scanning circuit of claim **1**, wherein the main circuit module further includes: a main control logic unit capable of receiving the scanning instruction and converting the scanning instruction into scan control signals and receiving digital image data; a memory unit capable of holding the digital image data; and a memory control logic unit coupled to the main control logic unit and the memory unit capable of controlling the access of digital image data.

3. The scanning circuit of claim **2**, wherein the main control logic unit further includes an image preprocessor capable of compensating and adjusting the digital image data.

4. The scanning circuit of claim **2**, wherein the memory comprises a dynamic random access memory.

5. The scanning circuit of claim **1**, wherein the optical sensor circuit module further includes: an optical sensor capable of detecting and producing the analog image signal; an analog front-end processor coupled to the optical sensor capable of preprocessing the analog image signal; an analog/digital converter coupled to the analog front-end processor capable of converting the pre-processed analog image signal into the digital image data; and a timing generator coupled to the optical sensor and the analog/digital converter capable of generating the timing control signals that control a generation of the analog image signal and a conversion of the analog image signal into the digital image data.

6. The scanning circuit of claim **5**, wherein the optical sensor includes a charge-coupled device.

7. The scanning circuit of claim **5**, wherein the optical sensor includes a complementary metal-oxide-semiconductor (CMOS) image sensor.

8. The scanning circuit of claim **1**, wherein the connection cable includes a flat cable.

9. The scanning circuit of claim **1**, wherein the communication interface includes a universal serial bus interface.

10. The scanning circuit of claim **1**, wherein the scan control signals are capable of being transmitted through an integrated circuit (IC) communication interface.

11. A scanning method, comprising:

receiving scan control signals at an optical sensor circuit module via a connection cable; and

converting the scan control signals to timing control signals to control document scanning.

12. The method of claim **11**, further comprising:

receiving a scanning instruction from a communication interface via a main circuit module;

converting the scanning instruction into scan control signals; and

passing the scan control signals to the connection cable.

13. The method of claim **12**, further comprising:

extracting an analog image signal captured in a document scanning operation from a document at said optical sensor circuit module;

converting the analog image signal into a digital image data at said optical sensor circuit module; and

receiving the digital image data at said main circuit module through the connection cable.

14. The method of claim **13**, further comprising:

receiving the scanning instruction and converting the scanning instruction into scan control signals and receiving digital image data at the main circuit module via a main control logic unit;

holding the digital image data at the main circuit module via a memory unit; and

controlling the access of digital image data at the main circuit module via a memory control logic unit coupled to the main control logic unit and the memory unit.

15. The method of claim **14**, further comprising compensating and adjusting the digital image data at the main control logic unit via an image preprocessor.

16. The method of claim **13**, further comprising:

detecting and producing the analog image signal at the optical sensor circuit module via an optical sensor;

preprocessing the analog image signal at the optical sensor circuit module via an analog front-end processor coupled to the optical sensor;

converting the pre-processed analog image signal into the digital image data at the optical sensor circuit module via an analog/digital converter coupled to the analog front-end processor; and

generating the timing control signals that control a generation of the analog image signal and a conversion of the analog image signal into the digital image data at the optical sensor circuit module via a timing generator coupled to the optical sensor and the analog/digital converter.

17. A scanning method, comprising:

extracting an analog image signal captured in a document scanning operation from a document at an optical sensor circuit module including an optical sensor;

converting the analog image signal into a digital image data at said optical sensor circuit module;

receiving the digital image data from said optical sensor circuit module at a main circuit module through a connection cable; and

generating timing control signals that control a generation of the analog image signal and a conversion of the analog image signal into the digital image data at the optical sensor circuit module via a timing generator coupled to the optical sensor and an analog/digital converter.

18. The method of claim **17**, further comprising:

holding the digital image data at the main circuit module via a memory unit; and

controlling the access of digital image data at the main circuit module via a memory control logic unit coupled to a main control logic unit and the memory unit.

19. The method of claim **18**, further comprising compensating and adjusting the digital image data at the main control logic unit via an image preprocessor.

20. The method of claim **17**, further comprising:

detecting and producing the analog image signal at the optical sensor circuit module via an optical sensor;

preprocessing the analog image signal at the optical sensor circuit module via an analog front-end processor coupled to the optical sensor; and

converting the pre-processed analog image signal into the digital image data at the optical sensor circuit module via an analog/digital converter coupled to the analog front-end processor.

21. A scanning apparatus, comprising:

means for extracting an analog image signal captured in a document scanning operation from a document at an optical sensor circuit module;

means for converting the analog image signal into a digital image data at said optical sensor circuit module;

means for receiving the digital image data from said optical sensor circuit module at a main circuit module through a connection cable; and

means for generating timing control signals that control a generation of the analog image signal and a conversion of the analog image signal into the digital image data at the optical sensor circuit module.

22. The apparatus of claim **21**, further comprising:

means for receiving a scanning instruction from a communication interface at said main circuit module;

means for converting the scanning instruction into scan control signals;

means for passing the scan control signals to said connection cable;

means for receiving the scan control signals at said optical sensor circuit module via the connection cable; and

means for converting the scan control signals to timing control signals to control document scanning.

23. The apparatus of claim **22**, further comprising:

means for holding the digital image data at the main circuit module; and means for controlling the access of the digital image data at the main circuit module.

24. The apparatus of claim **21**, further comprising means for compensating and adjusting the digital image data at the main circuit module.

25. The apparatus of claim **21**, further comprising:

means for preprocessing the analog image signal a the optical sensor circuit module; and

means to converting the pre-processed analog image signal into the digital image data at the optical sensor circuit module.

26. A scanner, comprising:

a scanning module, the scanning module including a main circuit module and an optical sensor circuit module;

the main circuit module capable of receiving a scanning instruction from a communication interface, converting the scanning instruction into scan control signals, passing the scan control signals to a connection cable as well as receiving a digital image data captured in a document scanning operation through the connection cable; and

the optical sensor circuit module connected to the main circuit module through the connection cable capable of receiving the scan control signals and converting the scan control signals to timing control signals that control document scanning, extraction of an analog image signal from the document and conversion of the analog image signal into the digital image data.

27. The scanner of claim **26**, wherein the main circuit module further includes: a main control logic unit capable of receiving the scanning instruction and converting the scanning instruction into scan control signals and receiving digital image data; a memory unit capable of holding the digital image data; and a memory control logic unit coupled to the main control logic unit and the memory unit capable of controlling the access of digital image data.

28. The scanner of claim **27**, wherein the main control logic unit further includes an image preprocessor capable of compensating and adjusting the digital image data.

29. The scanner of claim **26**, wherein the optical sensor circuit module further includes: an optical sensor capable of detecting and producing the analog image signal; an analog front-end processor coupled to the optical sensor capable of preprocessing the analog image signal; an analog/digital converter coupled to the analog front-end processor capable of converting the pre-processed analog image signal into the digital image data; and a timing generator coupled to the optical sensor and the analog/digital converter capable of generating the timing control signals that control a generation of the analog image signal and a conversion of the analog image signal into the digital image data.

30. An apparatus, comprising:

an optical sensor circuit module capable of being connected to a main circuit module through a connection cable,

wherein the optical sensor circuit module is capable of receiving scan control signals from the main circuit module and converting the scan control signals to timing control signals that control document scanning, and

wherein the optical sensor circuit module is capable of extraction of an analog image signal from the document and conversion of the analog image signal into digital image data.

31. The apparatus of claim **30**, wherein the optical sensor circuit module further includes: an optical sensor capable of detecting and producing the analog image signal; an analog front-end processor coupled to the optical sensor capable of preprocessing the analog image signal; an analog/digital converter coupled to the analog front-end processor capable of converting the pre-processed analog image signal into the digital image data; and a timing generator coupled to the optical sensor and the analog/digital converter capable of generating the timing control signals that control a generation of the analog image signal and a conversion of the analog image signal into the digital image data.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,315,406 B2
APPLICATION NO. : 10/064265
DATED : January 1, 2008
INVENTOR(S) : Lee et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

At column 7, line 3, please replace “and means” with --and¶means--.
At column 7, line 4, please replace “the digital” with --digital--.
At column 7, line 9, please replace “signal a the” with --signal at the--.
At column 7, line 11, please replace “means to” with --means for--.

Signed and Sealed this

First Day of June, 2010

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office

EXHIBIT F

US005712870A

United States Patent [19]

Petrick

[11] Patent Number: 5,712,870

[45] Date of Patent: Jan. 27, 1998

[54] **PACKET HEADER GENERATION AND DETECTION CIRCUITRY**

[75] Inventor: **Al Petrick**, Orlando, Fla.

[73] Assignee: **Harris Corporation**, Melbourne, Fla.

[21] Appl. No.: **509,462**

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

[51] **Int. Cl.**[6] **H04B 15/00**

[52] **U.S. Cl.** **375/206**; 375/200; 375/279; 375/308; 370/206; 370/320

[58] **Field of Search** 375/200, 206, 375/207, 208, 219, 220, 261, 298, 279, 280, 308, 329, 364, 367, 332; 370/206, 207, 320, 335, 342, 349, 350, 465, 466, 474

[56] **References Cited**

U.S. PATENT DOCUMENTS

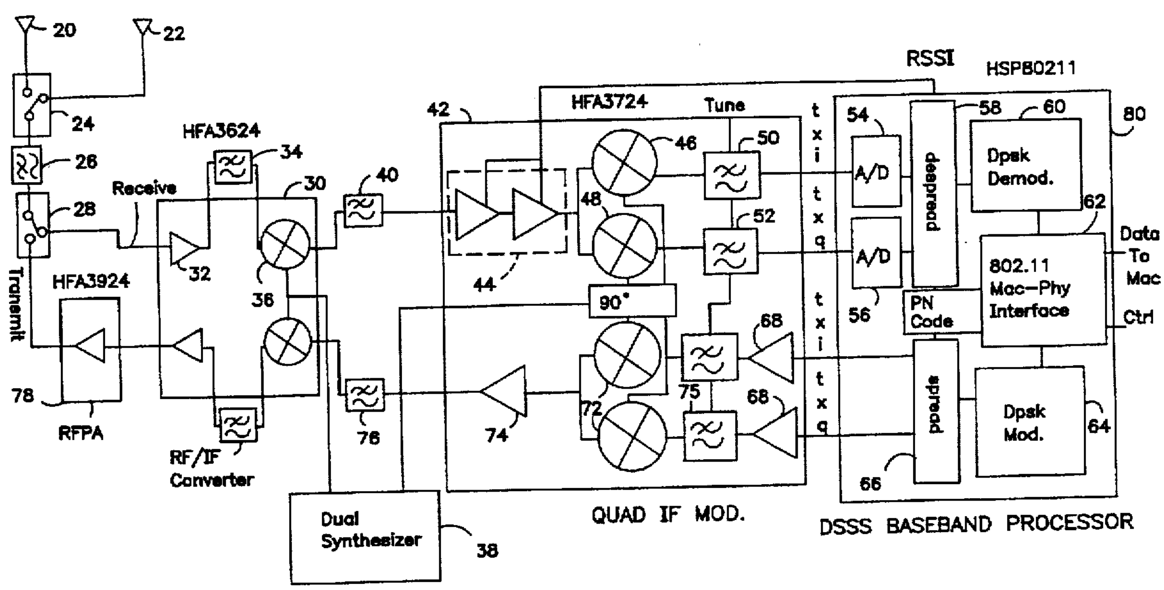
5,179,574 1/1993 Watanabe et al. 375/200
5,371,734 12/1994 Fischer 370/331
5,377,232 12/1994 Davidov et al. 375/206
5,553,095 9/1996 Engdahl et al. 375/222
5,596,600 1/1997 Dimos et al. 375/206

Primary Examiner—Wellington Chin
Assistant Examiner—Congvan Tran
Attorney, Agent, or Firm—Rogers & Killeen

[57] **ABSTRACT**

A method and apparatus for receiving and transmitting direct sequence spread spectrum signals uses a single integrated device for converting and demodulating an RF signal into a serial data signal. Critical timing relationships during the acquisition and demodulation of the received signal are satisfied by the use of an integrated circuit specially designed to perform all operations needed to convert the physical signal to an media access circuit level data signal.

20 Claims, 3 Drawing Sheets



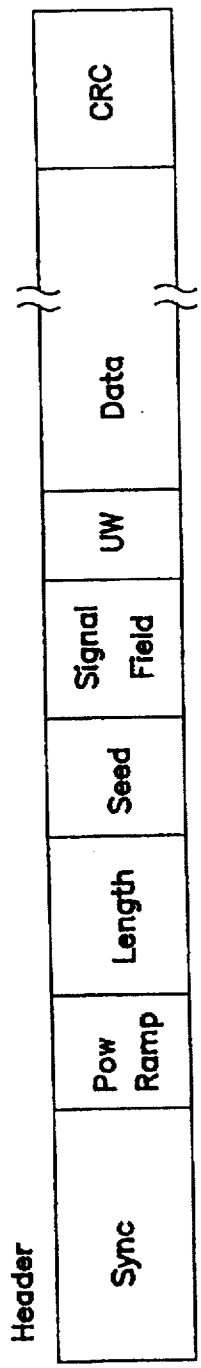
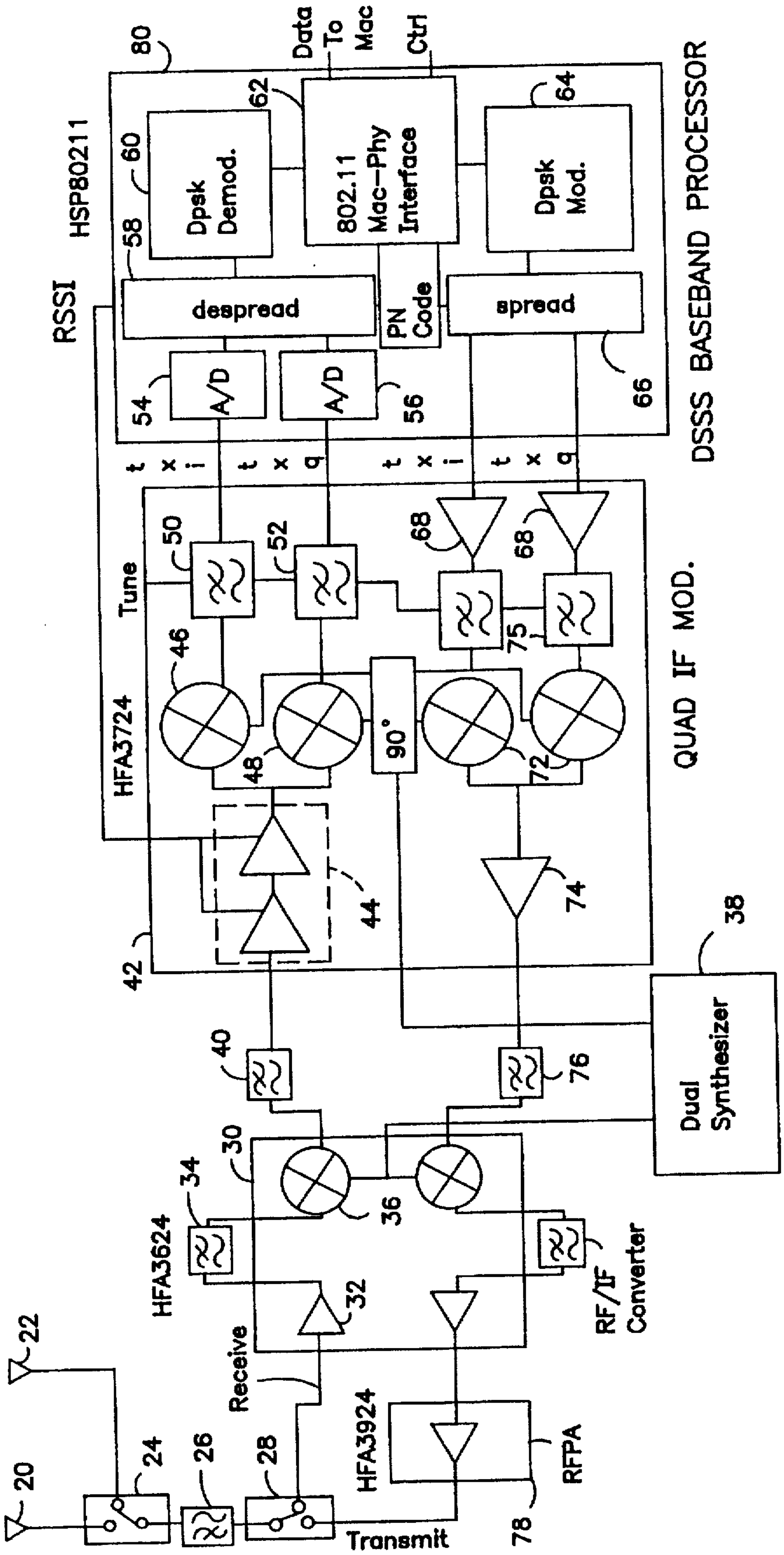
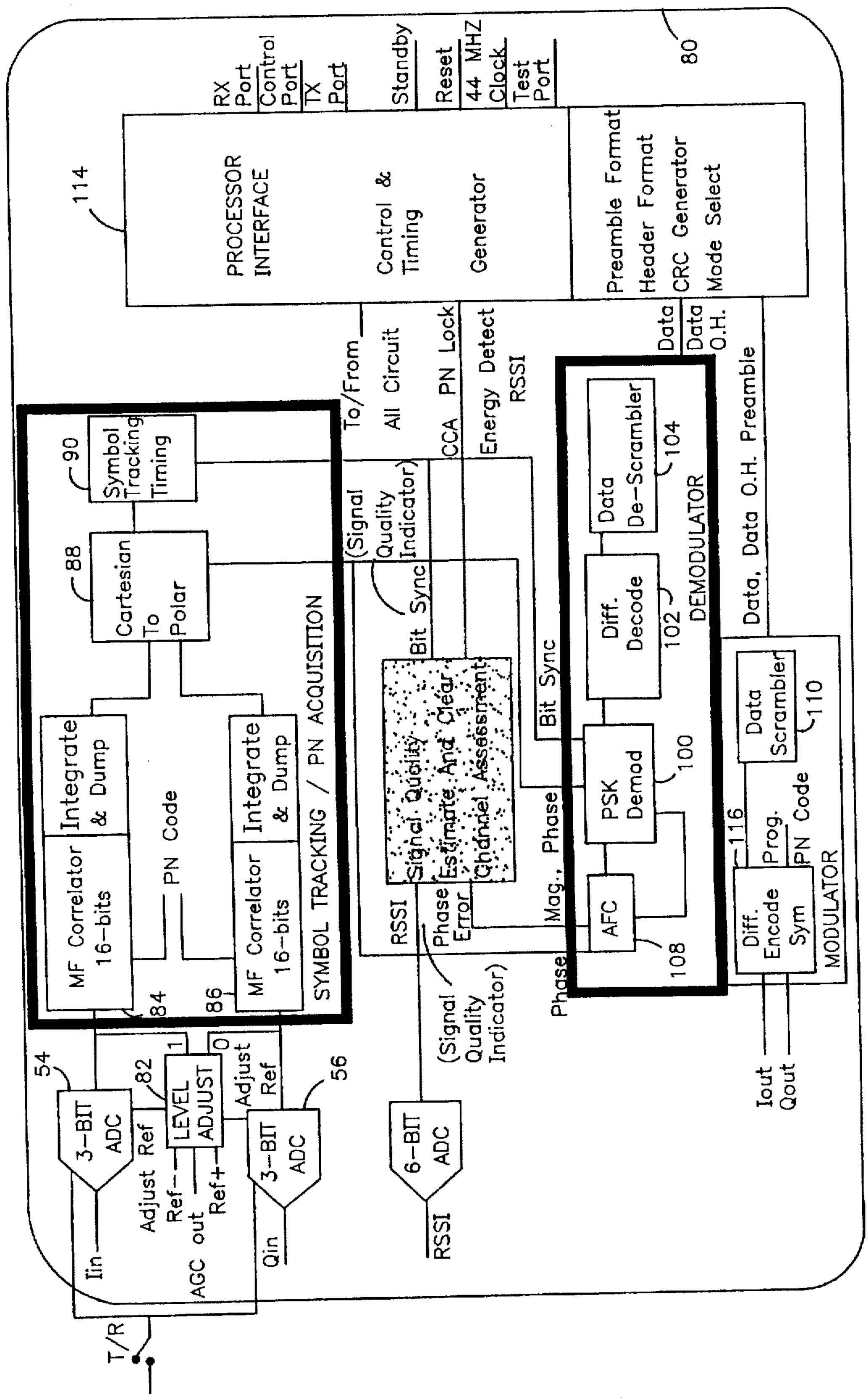


FIG. 1



Data To Mac
Ctrl
80
62
64
HSP80211
60
Dpsk Demod.
802.11 Mac-Phy Interface
Dpsk Mod.
DSSS BASEBAND PROCESSOR
58
RSSI
despread
PN Code
spread
54
A/D
A/D
56
66
t x i
t x q
t x i
t x q
50
52
68
68
Tune
46
75
HFA3724
48
90°
72
QUAD IF MOD.
44
74
42
38
40
76
Dual Synthesizer
30
34
36
HFA3624
32
RF/IF Converter
22
Receive
20
24
26
28
HFA3924
RFPA
Transmit
78

FIG. 2



80
114
RX Port
Control Port
TX Port
Standby
Reset
44 MHZ Clock
Test Port
PROCESSOR INTERFACE
Control & Timing Generator
Preamble Format
Header Format
CRC Generator
Mode Select
To/From All Circuit
CCA PN Lock
Energy Detect RSSI
Data
Data O.H.
Data, Data O.H. Preamble
90
Symbol Tracking Timing
88
Cartesian To Polar
(Signal Quality Indicator)
Bit Sync
Integrate & Dump
MF Correlator 16-bits
PN Code
84
86
SYMBOL TRACKING / PN ACQUISITION
Signal Quality Estimate And Clear Channel Assessment
RSSI
Phase Error
Mag., Phase
Phase
Bit Sync
Data De-Scrambler
104
Diff. Decode
102
DEMODULATOR
PSK Demod
100
AFC
108
Data Scrambler
110
116
Prog. PN Code
Diff. Encode Sym
MODULATOR
Iout
Qout
54
3-BIT ADC
82
LEVEL ADJUST
1
0
Adjust Ref
56
Adjust Ref
Ref−
Ref+
AGC out
Iin
Qin
6-BIT ADC
RSSI
T/R

FIG. 3

PACKET HEADER GENERATION AND DETECTION CIRCUITRY

BACKGROUND OF THE INVENTION

The present invention is related generally to receivers for acquiring radio-frequency signals and, particularly, to receivers for acquiring data from signals which may have been transmitted in a spread spectrum system.

Wireless systems have been developed and proposed in the prior art in which plural radio frequency ("RF") transmitters send bursts of messages to a receiver which must acquire the signal from each transmitter and decode the data contained therein. For example, in a wireless Local Area Network ("LAN") plural nodes which are not necessarily geolocated together may each communicate with a base station (or even with each other) and transmit data to and from the base station for the use by applications located at the nodes. Because the system is wireless, the transmissions are made using the ether. In simple systems, a base station may be able to communicate with only a single remote node during any given time period. Obviously, such an arrangement limits the amount of data which can be passed between the nodes and the base station in a given period of time. To increase the amount of data which may be transmitted, it is known for a wireless system to use plural distinct frequencies the use of which is arbitrated or determined by the system. In this way, several remote nodes may be transmitting to or receiving data from the base station simultaneously. Such systems tend to use a relatively large bandwidth of the available spectrum and are relatively expensive in forcing the base station to have plural transceivers and for the nodes to be capable of communicating on plural frequencies. In addition, in such prior art systems, the allocation of frequencies for communications may consume a relatively large portion of the available processing resources and degrade the ability of the system to communicate data. In still other prior art systems, the various nodes and the base station may use a time-division multiplex protocol in which a base unit allots periods of time to nodes requiring data communications and controls the communication by the nodes during the assigned time periods. Again, the overhead in processing resources needed to manage the system and the consumption of communication resources by control messages may be relatively high for such systems.

Another means by which plural remote nodes may communicate with a base station or other nodes is the use of PN-encoded spread spectrum technology. In a typical spread spectrum signal, the signal to be transmitted is modulated with a pseudorandom noise ("PN") code. Demodulating such a signal generally involves the demodulating of a received signal by the same PN code as was used to modulate the signal. Once the signal is demodulated, it may be correlated to ensure that an actual signal was present, and subsequently demodulated/decoded to extract the data. One of the benefits of such spread spectrum systems is that multiple nodes may be simultaneously transmitting without necessarily destroying each other's signals. Thus, some of the inter-nodal timing problems of other prior art systems are reduced. The use of such spread spectrum systems is also often beneficial to the ability of the receiver to acquire and decode the signal in high noisy environments.

In spread spectrum signal communications, as in many wireless communications systems, it is often desirable to communicate between nodes and the base station in short, bursty packets of data. Bursty communications generally permits many nodes (which often have bursty communications needs) to be joined in a system without significant degradation at any one node, i.e., each node receives an opportunity to communicate within a desired latency period. Thus, in some communications systems, it is desirable to have messages be relatively short to ensure that each node has an opportunity to communicate within an acceptable latency period.

Typical spread spectrum messages generally include a data portion containing the data to be transmitted preceded by a preamble or header portion used for synchronization of the receiver to the signal being transmitted and a check portion (often a Cyclical Redundancy Check, CRC) which provides signals whereby the correctness of the decoded message may be determined. Particularly when data messages are desired to be bursty, and thus short, the length of the preamble may be significant in determining the data bandwidth of the system or the amount of data which can be communicated within a particular period of time. Generally, the smaller the preamble for a system having a particular speed, the greater is the available data bandwidth. Short preambles, however, generally provide the receiver with less information on which to synchronize.

In a typical wireless LAN using bursty communications, the system can be characterized as having multiple bursts from various transmitters, each of which must be acquired and decoded by the receiver. The problems of acquiring such signals is made all the more difficult if, as is sometimes the case, the plural nodes provide communication signals having varying signal strengths and signal to noise ratios and if the start of the communications from the various nodes is not synchronous. Often in such wireless LAN systems, the receiver has no apriori knowledge of the time of the start of a communication, or the particular off-nominal characteristics of the sending node. Each sending node, for example, may have a different frequency offset or frequency drift which affects how its signal must be acquired and/or decoded.

In prior art systems, baseband processors were typically used to extract data from PN modulated spread spectrum signals (and to modulate a signal to be transmitted with PN modulation). Typical prior art baseband processors used a symbol length matched filter correlator, with the output acquired by a phase locked loop, to remove the offset frequency of the carrier. In such systems, the matched filter is set to match the PN code sequence used for the spread spectrum link. Generally, in such prior arts systems, acquisition of the signal is declared based on the amplitude of the correlation output peaks from the matched filter. The disadvantage of this typical prior art approach is that the phase locked loop is relatively slow and may have large amounts of jitter if the signal is near the noise level. If the presence of the signal is falsely declared on the basis of the noise, the desired signal may be rejected. In addition, the slow acquisition may preclude the use of a diversity of antennas, particularly where the message preamble is relatively short in duration. In some prior art systems, plural parallel receive paths are used for the diverse antennae so that each antenna may be evaluated in parallel. Obviously, such duplication of elements is relatively expensive in terms of cost, power and area.

Another aspect which influences the design and operation of prior art baseband processors involves the A/D sampling of the baseband signal. A low cost direct sequence baseband demodulator utilizes as few bits as possible in the A/D sampling converter used to sample the I and Q signals while maintaining acceptable system performance. Each bit of an additional A/D flash converter approximately doubles the number of comparators needed. Additionally, in the light of the fact that the A/D converter will experience several dB of variation at the Rf and IF chain because of variances in manufacturing tolerances and temperature effects, unless means are taken to eliminate the effects of these variances, up to one-half the dynamic range of a prior art A/D device may become unavailable.

One prior art solution to the problems of dynamic range in a direct sequence spread spectrum system is to increase the number of bits in the A/D converter until acceptable performance is achieved by the demodulator. The nominal signal level may then be set such that at the minimum signal level into the A/D converter, the required number of effective bits is met, and at the maximum signal level, saturation of the A/D converter is held to an acceptable level. The disadvantages of such an approach are generally seen in the additional size and corresponding cost of the A/D converter which would not be required for operation at nominal signal levels. Additionally, such approaches are generally disadvantageous in that the circuits following the A/D converter must also be designed to carry these additional bits, substantially increasing the amount of hardware and operational power requirements.

During signal acquisition and synchronization in direct sequence spread spectrum systems, it is usually necessary to adjust the timing of the receiving system to the bit timing of the received signal. By adjusting the timing, the receiving system can increase the probability that it is correctly acquiring and demodulating the correct signal. Many prior art systems used a voltage controlled oscillator ("VCO") to adjust the A/D sampling phase. This solution has the advantage of obtaining very fine sampling phase resolution but generally requires costly analog components. Another prior art solution has been to oversample the A/D input and use the closest samples. This solution, however, generally requires very fast and high power consumption A/D converters.

It is known in the prior art to demodulate a received direct sequence spread spectrum signal by using the in phase (I) and quadrature (Q) components from the correlator in the demodulator system and to use the bit synch amplitude to determine the signal quality. In such prior art systems, carrier frequency offset may be compensated for by the use of differential demodulation or by phase locked loop tracking of the carrier. Independent processing of both the I and Q components, however, generally requires twice the hardware through most of the signal processing path (one complete set of hardware for each signal component). In addition, in prior art systems, the phase locked loops can be relatively hardware intensive ad complex in order to achieve the speed necessary to acquire the short preambles of bursty communications.

Within the environment of a wireless LAN or other plural node system, it is desirable to be able to decode the communicated signals reliably: not permitting false data to be accepted as true and capturing with a high degree of probability the data which is transmitted. In addition, it is desirable to obtain such high performance while keeping relatively low the costs, sizes and power consumption of the hardware used in such systems.

Accordingly, it is an object of the present invention to provide a novel method and apparatus of acquiring a spread spectrum signal reliably and without false alarms.

It is another object of the present invention to provide a novel method and apparatus of acquiring a spread spectrum signal from one of plural transmitting nodes without prior knowledge of the time of the start of the signal.

It is yet another object of the present invention to provide a novel method and apparatus of acquiring a spread spectrum signal with a relatively small preamble in comparison to prior art systems.

It is still another object of the present invention to provide a novel method and apparatus of acquiring a spread spectrum signal from one or more of plural transmitters, having independent frequency and/or phase offsets.

It is a further object of the present invention to provide a novel method and apparatus of acquiring a spread spectrum signal in an environment having a relatively low signal to noise ratio and/or having a rapidly changing noise characteristic.

It is yet a further object of the present invention to provide a novel method and apparatus of acquiring a signal transmitted in accordance with the IEEE 802.11 standard.

It is still a further object of the present invention to provide a novel method and apparatus to acquire spread spectrum signals whether or not transmitted using the IEEE 802.11 standard.

These and many other objects and advantages of the present invention will be readily apparent to one skilled in the art to which the invention pertains from a perusal of the claims, the appended drawings, and the following detailed description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a representational diagram of the format of a type of signal which can be communicated in one embodiment of the present invention;

FIG. 2 is a functional block diagram of a communications transceiver which may be used in accordance with the present invention; and

FIG. 3 is a functional block diagram of a baseband processor which may be used in the transceiver of FIG. 2.

DESCRIPTION OF PREFERRED EMBODIMENTS

Standards have been proposed and are being developed for the communication of signals in a wireless LAN system. These standards include IEEE 802.11 typically utilize a short, bursty message format. As shown in FIG. 1, a typical message may consist of a fixed length preamble having the fields for power ramping, synchronization, a signal field, a descrambling seed, and a unique word. Immediately upon the end of the preamble, the data starts followed by a CRC field. As specified in IEEE 802.11, the preamble may be modulated onto the carrier signal using digital Binary Phase Shift Keyed ("BPSK") modulation. The data and CRC signals may be modulated using either BPSK or Quarternary Phase Shift Keyed modulation ("QPSK"). A transceiver in accordance with the present invention may readily acquire and decode the preamble, data and CRC portions of a standard message packet. However, the present invention is in no way limited to this one packet format and may be used in many other formats.

With reference to FIG. 2, a transceiver using one aspect of the present invention may include dual antennae **20**, **22** which can be operatively connected to the remainder of the transceiver through a selector switch **24** and a conventional antenna coupler **26** which matches the impedance of the signal to/from the antennae **20**, **22** to the transceiver. A second selector switch **28** connects the antenna coupler **26** to either a transmit circuit or a receive circuit of the transceiver. In the receive circuit, the second selector switch **28** is connected to an RF/IF converter 30 which amplifies the incoming signal through an amplifier 32, a bandpass filter 34 and a down conversion mixer 36. The down conversion mixer 36 also receives a clock signal from a synthesizer 38.

With continued reference to FIG. 2, the received signal exiting the RF/IF converter 30 may again be filtered to remove higher frequency signals therefrom in a second filter 40 and provided to a quadrature IF modulator/demodulator 42. Within the modulator/demodulator 42, the received signal may be passed through a two stage integrating limiting amplifier 44 which amplifies the received signal and provides a signal indicating the Received Signal Strength (RSSI) of the incoming signal. The amplified incoming signal may be split into I and Q (in-phase (real) and quadrature (imaginary)) components and mixed in dual mixers 46, 48 with a demodulating signal and a signal 90 degrees out of phase with the demodulating signal. Each of the mixed signals may be filtered by conventional antialiasing and shaping filters 50, 52 to provide two baseband signals, one of which is the I component and the other is the Q component of the intermediate frequency demodulated signal (RXI RXQ). (note that at this time, the received signal contains data which has been PN modulated (i.e., spread) and PSK modulated). The I and Q component signals may be provided to a baseband processor which converts the analog signals to digital signals at A/D converters and which despreads the spread spectrum signal through a despreader 58. The despread signal may be demodulated by a demodulator to provide a digital data signal which may be passed to an application system through an interface circuit 62.

With continued reference to FIG. 2, data to be transmitted may be received by the interface circuit 62 and then used to generate a spread spectrum modulated signal through a modulator 64 and a data spreader 66. The spread signal from the spreader 66, in the form of its I and Q components, may be amplified, filtered and modulated within the modulator/demodulator 42 by amplifiers 68, filters 70 and mixers 72. The modulated signal output from the mixers 72 may be amplified by an amplifier 74, filtered by a filter 76 and upconverted to RF by the RF/IF converter 30. The transmit signal output from the converter 30 may be power amplified by power amplifier 78 and then provided to one of the antennae, as selected by the switch 24.

In operation, a signal received at the antennae 20, 22 may be passed through the coupler 26. In one aspect of the present invention, each antennae may be used for a portion of the preamble of a message and the antenna receiving the better signal can be utilized to receive the data signal. Additional details regarding the antenna selection method and apparatus may be obtained from U.S. Pat. No. 5,694,417, entitled "Short Burst Acquisition Circuit for Direct Sequence Spread Spectrum Links" assigned to the same assignee as the present application and filed on even date herewith, which is incorporated herein by reference.

The signal received at the antennae may be provided to the receive portion of the RF/IF converter 30 and there be amplified by the amplifier 32, which may be a low noise amplifier. The amplified signal may be filtered by a bandpass filter, such as a filter centered at 2.5 GHz and having a 1 GHz RF frequency range. The filtered signal may be mixed in the mixer 36 with a downconversion signal to develop an Intermediate Frequency ("IF") signal. In an embodiment of the present invention, the downconversion signal may be a sinusoidal signal generated by a local synthesizer and may have a frequency in the range of 2.1 to 2.49 GHz. Thus, in one embodiment, the IF signal may have a range of from 10 to 400 MHz.

The RF/IF converter 30 may have independent enable and power circuits for each of the receive and transmit portions. By powering down the portions of the circuit not in use, the RF/IF converter 30 reduces the power consumption of the device and, significantly, provides isolation between the receive and transmit portions of the circuit. Such isolation may be particularly significant in time division multiplexed systems.

The receive signal output from the RF/IF converter 30 may be filtered through a bandpass filter 40 and provided to the quadrature IF modulator/demodulator 42 in which the signal is amplified in the two stage integrating limiting amplifier 44. The limiting amplifier 44 may include circuits to provide baseband antialiasing and shaping to the received signal. The limiting amplifier 44 may also provide a Receive Signal Strength Indicator (RSSI) signal to receive-downstream elements.

With continued reference to FIG. 2, after the receive signal has been amplified by the limiting amplifier 44, the signal may be split and each form of the resulting signal provided to the input the mixers 46, 48. One mixer mixes the receive signal by a locally synthesized periodic signal and the other mixer mixes the receive signal by a signal which is ninety degrees out of phase with the first periodic signal, as is well known in quadrature demodulation. The result of the signal mixing are two signals, one the I (in-phase or real) component of the demodulated receive signal and the other the Q (quadrature or imaginary) component of the demodulated receive signal. Note that if the receive signal is a spread spectrum PSK signal, the I and Q components signals are spread spectrum PSK modulated signals at the output of the mixers 46, 48. The I and Q component signals may each be filtered in tunable filters 50, 52.

In one embodiment of the present invention, the quadrature IF modulator/demodulator 42 may have a frequency range of between 10 to 400 MHz and the limiting amplifier 44 may provide in excess of 80 dB of gain.

In similar (but opposite) manner to the receive side of the quadrature IF modulator/demodulator 44, the transmit portion may amplify, filter and quadrature mix I and Q signals received from the baseband processor for transmission as a transmit signal. The transmit signal output from the transmit mixers 72 may be amplified, upconverted (by the RF/IF converter 30) and further amplified (by the power amplifier 78) to radiating power levels. The amplified transmit signal may thereafter be provided to one of the antennae 20, 22 after being impedance matched in the impedance matching circuit 26.

With reference to FIG. 3, a baseband processor in accordance with the present invention may provide all of the functions necessary for spreading and despreading, modulating and demodulating, differential phase shift keyed signals ("DPSK") for full duplex data packet transmission. While the present invention is not necessarily limited to a single device, the performance of all of these functions on a single device provides substantial advantages over other designs in which these functions or portions of these functions are handled by plural hardware or software driven devices. These advantages include lower power requirements, better signal timing and synchronization, reduced device area and reduced cost.

With continued reference to FIG. 3, in which like reference numerals are used for like elements to those of FIG. 2, the baseband processor receives the I and Q signals from the modulator/demodulator 42 via the A/D converters 54, 56. The A/D converters are maintained in tolerance over a variety of conditions through a level adjust circuit **82**. The A/D converters may be three bit converters which each provide their digital outputs to correlator circuits **84**, **86** which acquire the signal of interest by detecting the pseudorandom noise ("PN") code in use for the particular spread spectrum link. The correlators **84**, **86** may be matched filter correlators which (1) despread the wideband direct sequence spread spectrum ("DSSS") signal information to convert it back to the original data rate; and (2) spread unwanted interfering signals and noise to separate them spectrally from the data.

The correlators **84**, **86** may receive a PN code of variable length, programmable up to 16 bits. The correlators **84**, **86** are each dedicated to one of the component channels (I and Q) and have a common correlation reference which can be varied in both length and sequence to permit the system to be used to demodulate a wide variety of signal types. As is explained in more detail in the copending application entitled "SHORT BURST ACQUISITION CIRCUIT FOR DIRECT SEQUENCE SPREAD SPECTRUM LINES" filed on even date herewith, and incorporated herein by reference, the received signal may be sampled at twice the chip rate and the correlators have taps on every other stage. The output signal from the correlators are converted from I and Q form to polar form by a cartesian to polar converter **88**. The polar form of the signal is used in the remainder of the demodulator processing, reducing the need for duplicate hardware for the independent I and Q channels.

A symbol tracking and timing circuit **90** is used to track the peak correlation magnitude and to control chip timing resolution to plus/minus one-quarter chip. The symbol tracking and timing circuit **90** can be a circuit such as described in more detail in "FAST ACQUISITION BIT TIMING LOOP METHOD AND APPARATUS", filed on even date herewith and incorporated herein by reference. The symbol tracking and timing circuit **90** averages the individual correlator samples over a desired period, such as the dwell period of the system on one of the antennae during the preamble. By averaging the samples, the effect of noise is reduced, permitting an improved ability to resolve a small early or late bias.

In the tracking and timing circuit **90**, the magnitude of the correlator output ample are accumulated modulo the number of samples in a symbol. In this way, a sum of the correlator magnitudes is formed at each one sample phase of symbol timing. The best sample phase will produce a discernible peak with smaller samples on either side. All other samples will generally consist of accumulated noise and will be smaller in the sum of magnitudes. If the received signal is strong, the magnitudes provided by the correlator will be large and, in conventional designs, would have required an accumulator and other downstream equipment to maintain extra bits to prevent overflow. In contrast, in the present invention, overflow is prevented in large signals while maintaining accuracy on poor signals by barrel shifting the accumulations of magnitude when the largest value gets above one-half full scale. In one embodiment of the present invention, this value can be readily trapped by tracking the most significant bit ("MSB") of the accumulation. When the MSB of an accumulation is set to 1 (all numbers from the correlator are magnitudes and therefor positive), all of the accumulations and the subsequent outputs of the correlator are right shifted by one bit. The number of shifts may be counted and is similar in fashion to an exponent. Thus, the sample having the largest sum of magnitudes may be identified without adding extra bits to the accumulators and downstream equipment while maintaining, with the accumulator and exponent, and absolute indication of the strength of the received signal.

With continued reference to FIG. **3**, the polar signal produced by the cartesian to polar converter **88** is provided to a PSK demodulator **100**, and in turn to a differential decoder **102** and to a data descrambler **104**. The PSK demodulator can demodulate both BPSK and QPSK signalling. In one aspect of the present invention, the preamble of a received signal may be in BPSK format and the data of the received signal may be in either BPSK or QPSK format. Because QPSK and BPSK signals are modulated differentially, the symbol information is based upon the state of the previous symbol. Phase errors introduced by multipath and oscillator offset drifts are compensated by a phase locked carrier tracking loop **108**. In one embodiment, the loop uses an NCO providing eight bits of phase output to the PSK demodulator **100**, and may be variously set to track and adjust for phase offset errors by rotation of the signal phase. The phase and frequency information developed during the preamble of a message is used to preset the loop **100** for minimum loop settling time.

With continued reference to FIG. **3**, in one embodiment of the present invention, signal quality (SQ) and signal frequency (SF) measurements are made simultaneously with symbol timing measurements. When the bit synch level, signal quality (SG) and the Received Signal Strength Indicator (RSSI) are all above their respective thresholds, the received signal is declared present. As explained in detail in co-pending U.S. application Ser. No. 509,586, entitled "A METHOD OF ESTIMATING SIGNAL QUANTITY FOR A DIRECT SEQUENCE SPREAD SPECTRUM RECEIVER", filed on even date herewith and incorporated herein by reference, decisions as to which of two antennae would be used to receive data can be made after taking measurements during the dwell period for each antenna. Once a particular antenna is selected, the measured symbol timing and carrier frequency offset for the selected antenna is jammed into the symbol timing and into the phase-locked-loop of the NCO tracking the carrier to begin carrier de-rotation. In this way, the demodulating circuitry gets a "head start" in reacquiring and demodulating the incoming preamble data within the brief period desired for bursty communications.

The data descrambler **104** may be a self synchronizing circuit having programmable (or user settable) taps comprising 7 bit shift registers. For data to be transmitted, a similar data scrambler **110** is used. The data scrambler **110** can be selectively disabled for measuring RF carrier suppression, during which an alternating 1/0 pattern is transmitted. Likewise, the data descrambler may be selectively disabled to permit data to pass without change from the differential decoder **102** to the processor interface **114**.

Data to be transmitted may be received from an external device by the processor interface **114**. The processor interface **114** may generate a preamble, CRC and other protocols to be sent along with the data and to provide the data and other protocol signals to the data scrambler **110** and to a differential encoder **116** to develop PN modulated I and Q signals which can be provided to a quadrature IF modulator such as the modulator **42** of FIG. **2** for eventual transmission on an antenna.

Descrambled data may be provided to a processor interface **114** which may control the passage of the data to another device such as a media access control ("MAC") circuit.

With continued reference to FIG. **3**, it has been found that placing the entire baseband processor onto a single chip can provide considerable benefit to accurate and timely demodulation of received signals and the extraction of data therefrom, particularly for bursty, brief data packets. As contrasted with the known prior art in which various of the portions of circuits similar to the circuits of the baseband processor of FIG. 3 have been provided by separate hardware devices and/or by separate complex programmable devices, the present invention is particularly suited to integration into a single device.

The baseband processor of FIG. 3 may be used to transfer packetized data received in the form of serial data in a physical layer to a media access control ("MAC") layer imbedded in the packetized data are header information used to control the physical layer. The header information may include fields of preamble/sync, unique word, signal field, service field, length field and a CRC field. The signal field is used to specify the signalling type used to modulate the data: either DPSK or QPSK. In one embodiment, the processor may receive data in which the header is in BPSK but the data is in QPSK. In such situations, the timing of switching the receiver from one signalling format to another is time critical. In another aspect of the present invention, the number of fields in the header may be user selectable.

It is known in the prior art that interfaces between the physical layer and the MAC level may be either serial or parallel. Most prior art implementations are parallel because the of the severe timing restrictions in which parallel circuits permit quicker timing but at the considerable additional expense of parallel hardware. Often the physical layer tasks of header generation and detection are done at the MAC layer, usually by separate devices. In contrast, in the present invention, all of the header detection and similar physical layer tasks may be imbedded into a single device.

In prior art devices where the header and similar physical layer tasks are handled by separate circuits/devices, there passes some period of time between when the circuit detects and demodulates an acceptable header and the transmission of that state to the circuit demodulating the data. In the preset invention, where the number of bits in the header is held to a minimum and may be used to determine which of plural antennae are to be used in addition to the other customary header functions, the slip of a single bit may mean the difference between successfully decoding a message and missing the message.

During demodulation of the header, the present invention monitors and uses the header data to both identify the type of signalling to be used for the data but to select between plural antennae. By using the data developed in the preamble for immediate data decoding, the number of lost bits is minimized. In receiving the header, the baseband processor converts the serial data from the data descrambler **104** into a 16 but parallel word which is compared with the preselected vales for the unique word and the signalling fields. The unique word is searched for a fixed amount of time and if it is not found, the modulator/demodulator is reset and acquisition of the RF signal is restarted. Once the unique word is found, a field counter searches through the incoming bits in a parallel fashion for the fields making up the header. As each fields is detected, the received data is stored into internal registers for access through the serial control bus the signalling field, when detected, is used to switch the receiver modulator/demodulator between BPSK and QPSK at the correct time with respect to the data portion of the packet. When the length field is detected, this value is loaded into a counter and is used to track the incoming bits of the data packet and to signal the MAC layer when the last bit of the packet is received. The processor interface **114** may also compute the CRC on the fly and compare the computed CRC to the CRC received within the message. If the CRCs do not match the receive data packet may be terminated and the receiver reset into reacquisition.

While preferred embodiments of the present invention have been described, it is to be understood that the embodiments described are illustrative only and the scope of the invention is to be defined solely by the appended claims when accorded a full range of equivalence, many variations and modifications naturally occurring to those of skill in the art from a perusal hereof.

What is claimed is:

1. A circuit for detecting a message header in a signal which has been transmitted using direct sequence spread spectrum modulation, comprising a single device having:

means for receiving an analog signal having modulated thereon in a spread spectrum format a message having a header portion and a data portion;

means for converting said analog signal into a digital signal;

means for demodulating the header of the digital signal using digital binary phase shift keyed (BPSK) demodulation and for demodulating the data portion of the same message using quarterary phase shift keyed demodulation (QPSK);

means contained on said single device for timing a transition from BPSK mosulation to QPSK modulation; and,

means for providing the demodulated data signal to a media access control (MAC) layer.

2. The circuit of claim **1** further comprising means for adjusting said means for timing to account for headers of variable length.

3. The circuit of claim **2** wherein said means for adjusting is contained within said single device and wherein said means for adjusting is responsive to a data field within said message header.

4. The circuit of claim **1** wherein said single device is a single monolithic device.

5. The circuit of claim **1** wherein said analog signal is in the form of in-phase and quadrature components.

6. The circuit of claim **5** wherein the data within said signal is modulated using PN modulation and phase shift keyed modulation.

7. The circuit of claim **5** further comprising means to evaluate during the header portion of the message the signals received from plural antennae and to select one of said antennae for use during the receipt of the data portion of the same message.

8. The circuit of claim **7** wherein the circuit is contained on a single monolithic device.

9. The circuit of claim **8** wherein said circuit acquires a unique word within a message header and if no unique word is acquired within a predetermined period of time resets the circuit.

10. In a communication system capable of receiving RF direct sequence spread spectrum signals, said system having a message header detection circuit comprising a single device having:

an analog receiver for receiving a spread spectrum modulated signal having a header portion and a data portion;

an analog-to-digital converter operable on said modulated signal;

a digital demodulator for binary phase shift keyed (BPSK) demodulation of said header portion and quaternary phase shift keyed (QPSK) demodulation of said data portion;

a timer for transitioning between the BPSK demodulation and the QPSK demodulation; and,

an interface for providing the demodulated data signal to a media access control (MAC) layer.

11. The circuit of claim **10** wherein said timer is adjustable to account for headers of variable length.

12. The circuit of claim **11** wherein the adjustability of said timer is based on information contained within a data field of said header portion.

13. The circuit of claim **10** further comprising antenna selection circuitry for selecting, upon evaluation of said header portion obtained from a plurality of antennae, one of said plurality for receipt of the associated data portion of said header portion.

14. The circuit of claim **13** wherein the circuit is contained on a single monolithic device.

15. The circuit of claim **14** wherein said circuit acquires a unique word within said header portion and if no unique word is acquired within a predetermined period of time the circuit resets.

16. The circuit of claim **10** wherein the analog signal received is in the form of in-phase and quadrature components and the data within the signal is modulated using PN modulation and phase shift keyed modulation.

17. A direct sequence spread spectrum receiver, said receiver having a physical layer associated with the receiving of RF signals and a media access control (MAC) layer associated with the using of data within said RF signals, said physical layer comprising a single device having:

an analog receiver for receiving a spread spectrum modulated signal having a header portion and a data portion;

an analog-to-digital converter operable on said modulated signal;

a digital demodulator for binary phase shift keyed (BPSK) demodulation of said header portion and quaternary phase shift keyed (QPSK) demodulation of said data portion;

a timer for transitioning between the BPSK demodulation and the QPSK demodulation; and,

an interface for providing the demodulated data signal to said MAC layer.

18. The receiver of claim **17** wherein the single device transmits the data from said physical layer to said MAC layer in a serial data stream.

19. The receiver of claim **18** wherein the single device is a single monolithic device.

20. The receiver of claim **17** wherein the data is modulated within the signals by both PN and phase shift keyed modulation.

* * * * *

EXHIBIT G

US006754195B2

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

(10) **Patent No.: US 6,754,195 B2**
(45) **Date of Patent: Jun. 22, 2004**

(54) **WIRELESS COMMUNICATION SYSTEM CONFIGURED TO COMMUNICATE USING A MIXED WAVEFORM CONFIGURATION**

(75) Inventors: **Mark A. Webster**, Indian Harbour Beach, FL (US); **Michael J. Seals**, Melbourne, FL (US)

(73) Assignee: **Intersil Americas Inc.**, Milpitas, CA (US)

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

(21) Appl. No.: **10/143,134**

(22) Filed: **May 10, 2002**

(65) **Prior Publication Data**

US 2003/0012160 A1 Jan. 16, 2003

Related U.S. Application Data

(60) Provisional application No. 60/306,438, filed on Jul. 6, 2001.

(51) **Int. Cl.**[7] **H04B 7/216**; H04Q 7/24
(52) **U.S. Cl.** **370/335**; 370/338; 370/342
(58) **Field of Search** 370/204, 205, 370/206, 208, 480, 482, 486, 487, 503; 375/260, 340

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,241,545	A	8/1993	Kazecki et al.	
5,425,050	A	6/1995	Schreiber et al.	
6,067,391	A	5/2000	Land	
6,128,276	A	10/2000	Agee	
6,298,035	B1	* 10/2001	Heiskala	370/206
6,344,807	B1	2/2002	Hassner et al.	
6,434,119	B1	8/2002	Wiese et al.	

FOREIGN PATENT DOCUMENTS

JP	2000 101623 A	4/2000
WO	WO 03 005652 A	1/2003

OTHER PUBLICATIONS

Webster, Mark and Halford, Steve, "Reuse of 802.11 Preambles with HRb OFDM," IEEE 802.11–00/390, Nov. 1, 2000, pp. 1–36, XP002217331.
Lambrette U., et al., "OFDM Burst Frequency Synchronization by Single Carrier Training Data," IEEE Communications Letters, IEEE Service Center, Piscataway, U.S., vol. 1, No. 2, Mar. 1, 1997, pp. 46–48, XP000687090.
Nee Van R., et al, "New High–Rate Wireless Lan Standards," IEEE Communications Magazine, IEEE Service Center, Piscataway, N.J., U.S., vol. 37, No. 12, Dec. 1999, pp. 82–88, XP000908328.

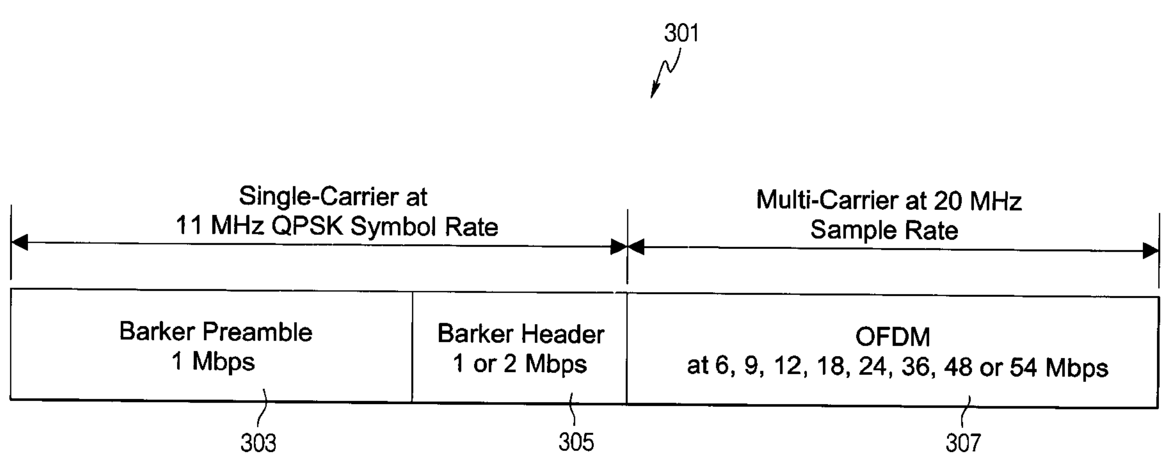
(List continued on next page.)

Primary Examiner—Wellington Chin
Assistant Examiner—William Schultz
(74) *Attorney, Agent, or Firm*—Gary R Stanford

(57) **ABSTRACT**

A wireless communication system configured to communicate using a mixed waveform configuration. The mixed waveform includes a first portion modulated according to a single-carrier scheme with a preamble and header and a second portion modulated according to a multi-carrier scheme. The waveform is specified so that a CIR estimate obtainable from the first portion is reusable for acquisition of the second portion by the receiver. The transmitter may include first and second kernels and a switch, where switch selects the first kernel for the first portion and the second kernel for the second portion to develop a transmit waveform. The receiver may include a single-carrier receiver, a multi-carrier receiver, and a switch that provides a first portion of a signal being received to the single-carrier receiver and a second portion of the signal being received to the multi-carrier receiver.

23 Claims, 18 Drawing Sheets



OTHER PUBLICATIONS

"Supplement to IEEE standard for Information technology—telecommunications and information exchange between systems—local and metropolitan area networks—specific requirements. Part 11: wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: high–speed physical layer in the 5 GHZ Band," IEEE STD 802.11A–1999, Dec. 30, 1999, pp. 1–90, XP0021899725.

PCT Notification of Transmittal of the International Search Report or the Declaration, dated Nov. 12, 2002, 4 pages.

"Draft Supplement to Standard [for]Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific Requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High Speed Physical Layer in the 5 GHz Band", *IEEE P802.11a/D7.0* (*Supplement to IEEE Std 802.11–1999*), Jul. 1999, 90 pages.

"Draft Supplement to Standard [for] Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher speed Physical Layer (PHY) extension in the 2.4 GHz band", *IEEE Std 802.11b/D7.0,* (*Draft Supplement to IEEE Std 802.11 1999 Edition*), Jul. 1999, 94 pages.

"Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks,—Specific requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications", *ISO/IEC 8802–11:1999*(*E*) *ANSI/IEEE Std 802.11, 1999 Edition,* Aug. 1999, 531 pages.

Written Opinion, dated Aug. 13, 2002, 4 pages.

Steve Halford et al: "IEEE P802.11 Wireless LANs, CCK–OFDM Proposed Normative Text," Jul. 10, 2001, XP002242971, Retrieved from the Internat: <URL: http://grouper.ieee.org/groups/802/11/Documents/D1T401–450.html>, pp. 52–66.

Crochiere R E et al: "Interpolation and Decimation of Digital Signals —A Tutorial Review,"Proceeding of the IEEE, IEEE, New York, US, vol. 69, No. 3, Mar. 1, 1981, pp. 300–331, XP000615159, ISSN: 0018–9219, p. 301, left–hand column, last paragraph –right–hand column, paragraph 5, figures 15, 18 and 20A, section ll–B, section lll–C.

Adams R: "Asynchronous Conversion Thwarts Incompatibility in Sampling A/D Systems" EDN Electrical Design News. Cahners Publishing Co. Newton, Massachusetts, US, vol. 39, No. 15, Jul. 21, 1994, pp. 83–88, XP000491530, ISSN: 0012–7515, section "Synchronous rate–conversion theory".

PCT Notification of Transmittal of the International Search Report or the Declaration, dated Jun. 30, 2003, 5 pages.

PCT Notification of Transmittal of International Preliminary Examination Report, 7 pages.

* cited by examiner

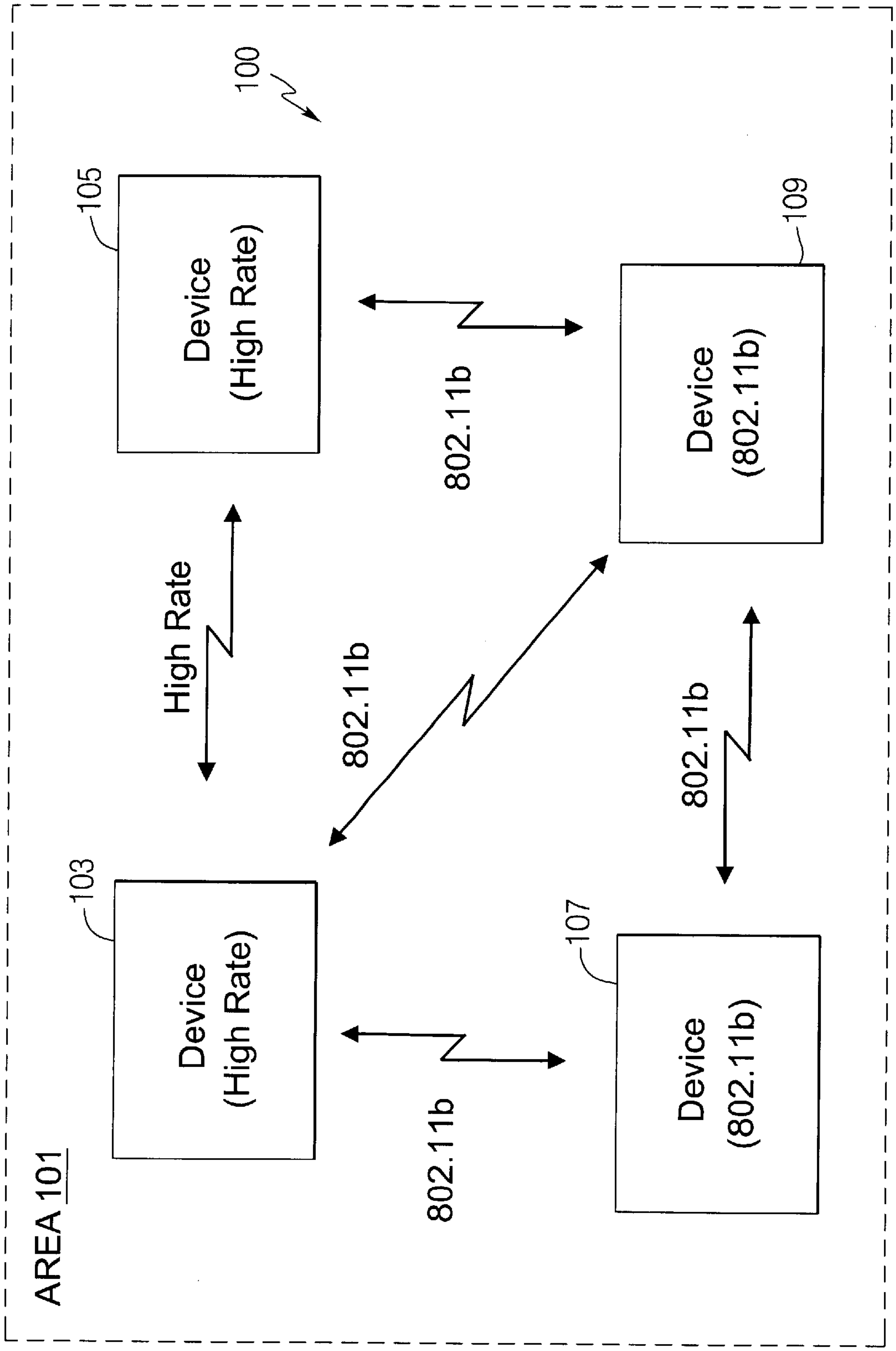

100
AREA 101
103
Device
(High Rate)
105
Device
(High Rate)
107
Device
(802.11b)
109
Device
(802.11b)
High Rate
802.11b
802.11b
802.11b
802.11b

FIG. 1

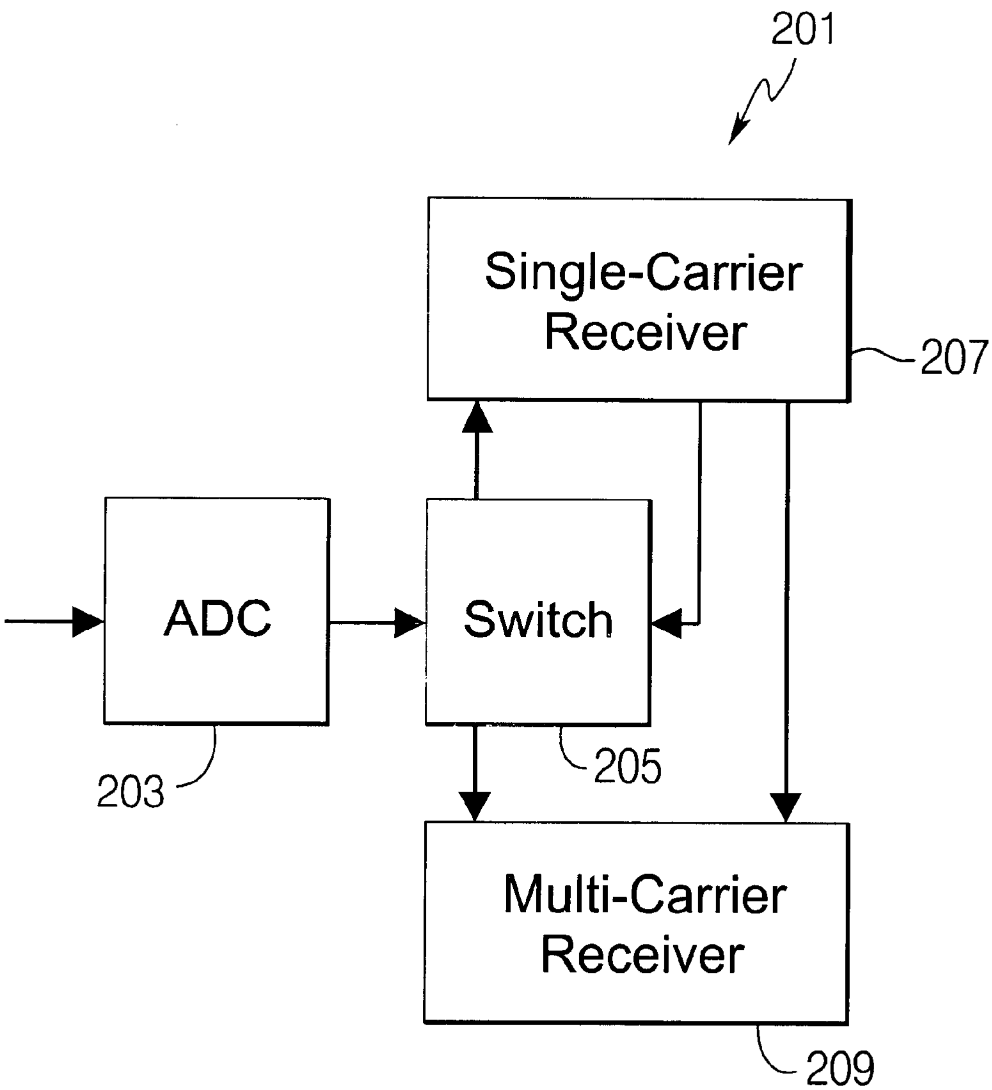

201
Single-Carrier Receiver
207
ADC
Switch
203
205
Multi-Carrier Receiver
209

FIG. 2

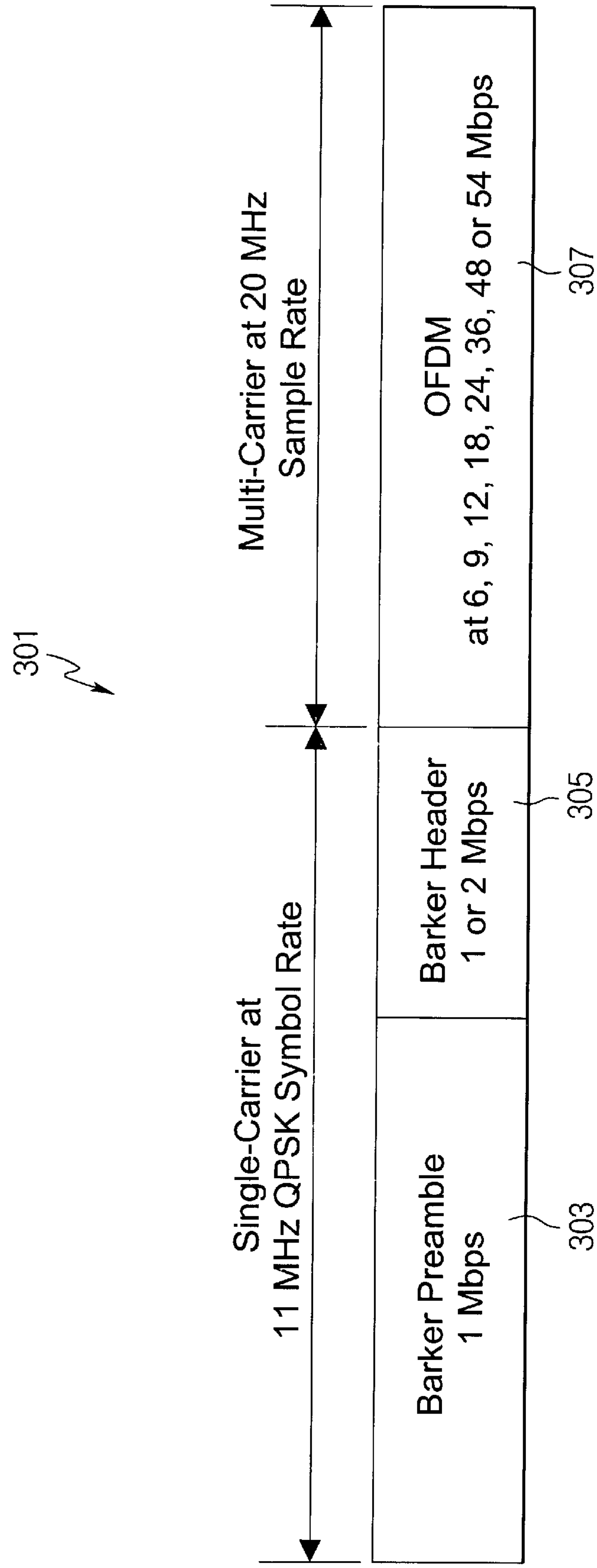

301
Single-Carrier at
11 MHz QPSK Symbol Rate
Multi-Carrier at 20 MHz
Sample Rate
Barker Preamble
1 Mbps
303
Barker Header
1 or 2 Mbps
305
OFDM
at 6, 9, 12, 18, 24, 36, 48 or 54 Mbps
307

FIG. 3

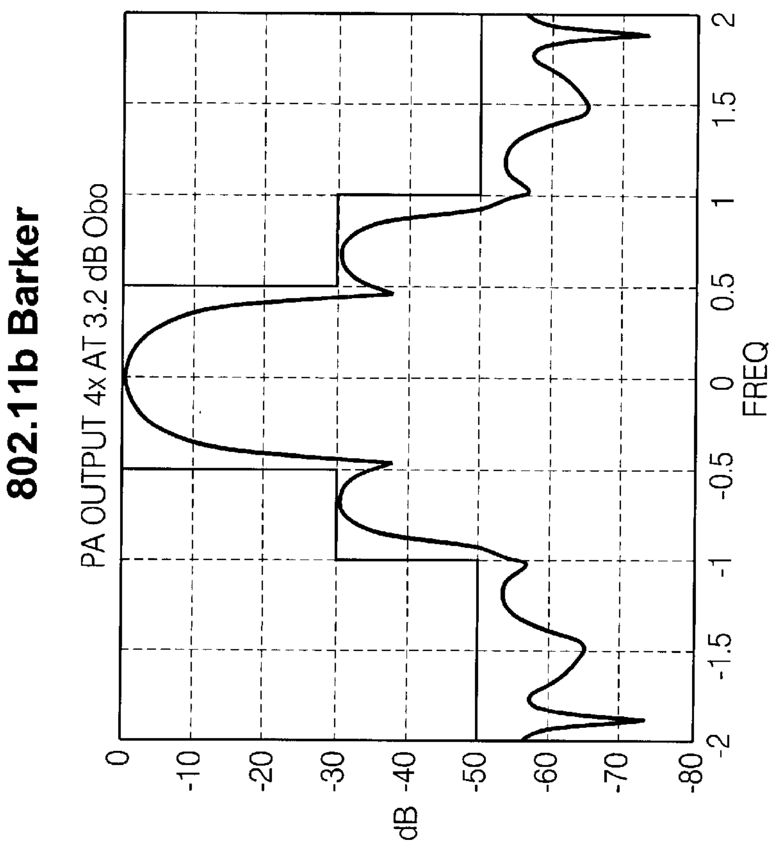

802.11b Barker
PA OUTPUT 4x AT 3.2 dB Obo
dB
0
-10
-20
-30
-40
-50
-60
-70
-80
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
FREQ

FIG. 4A

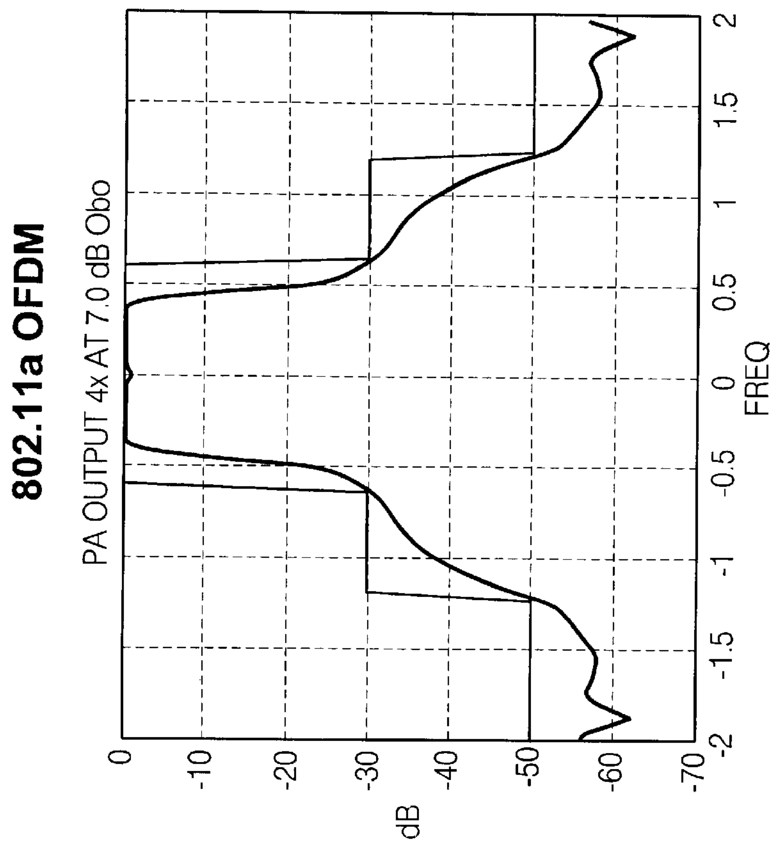

802.11a OFDM
PA OUTPUT 4x AT 7.0 dB Obo
dB
0
-10
-20
-30
-40
-50
-60
-70
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
FREQ

FIG. 4B

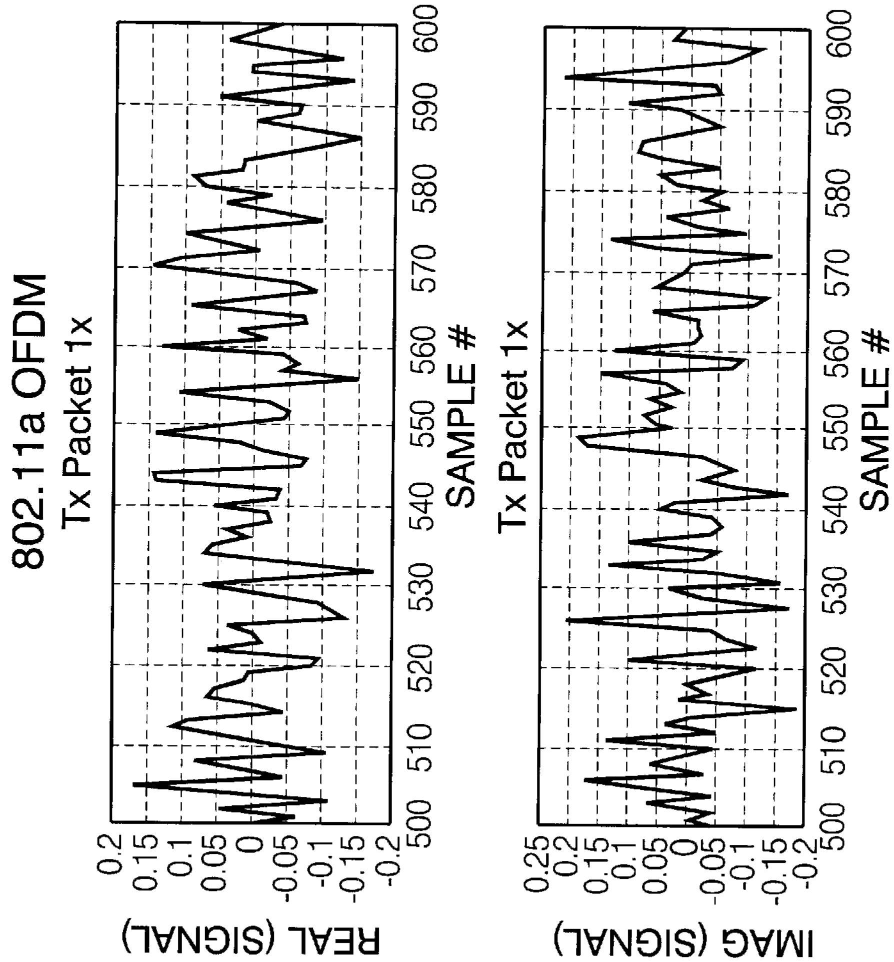

802.11a OFDM
Tx Packet 1x
REAL (SIGNAL)
SAMPLE #
Tx Packet 1x
IMAG (SIGNAL)
SAMPLE #

FIG. 5B

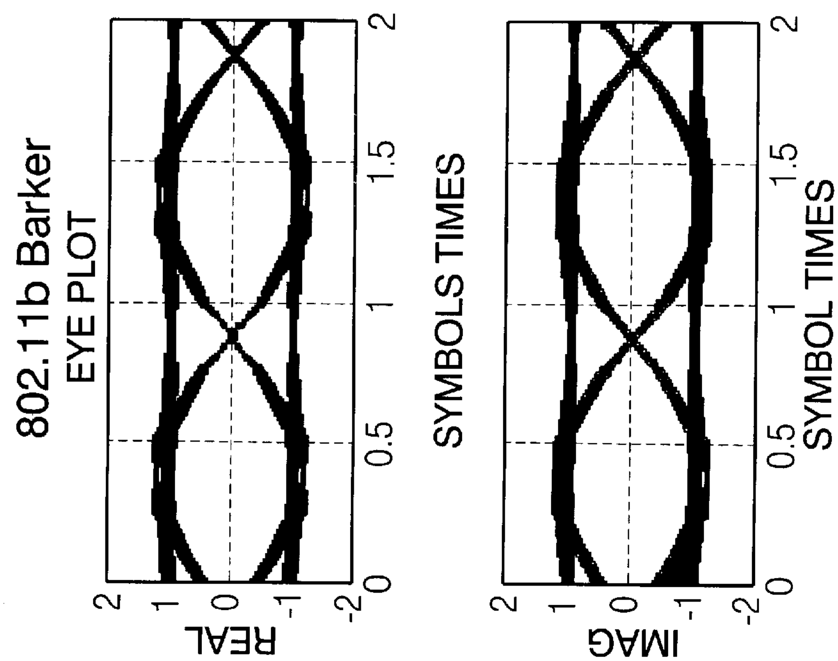

802.11b Barker
EYE PLOT
REAL
SYMBOLS TIMES
IMAG
SYMBOL TIMES

FIG. 5A

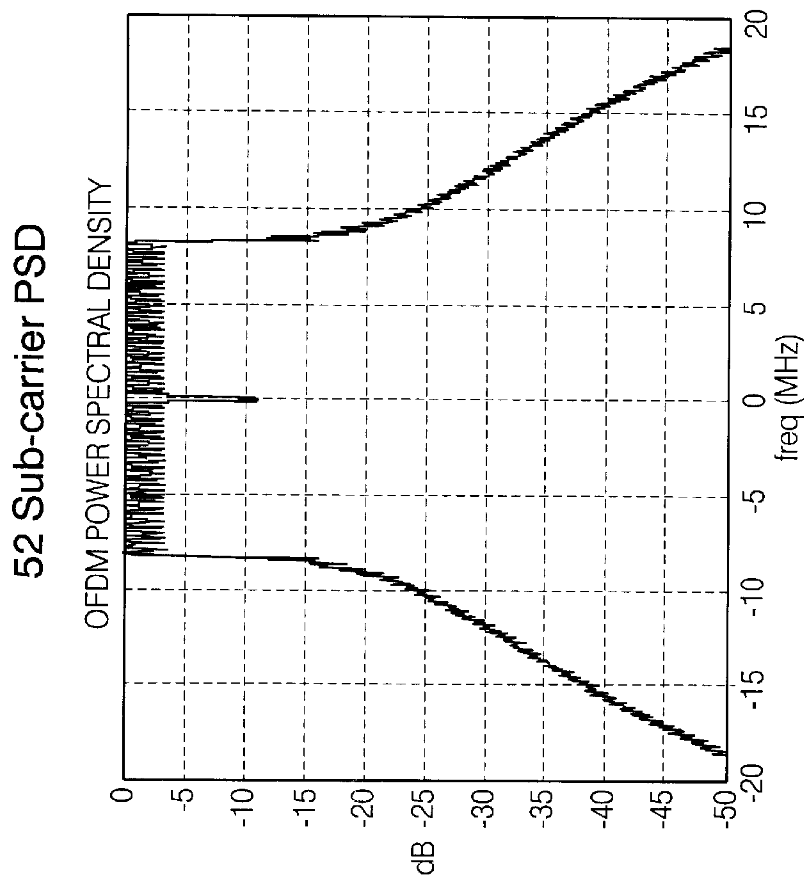

52 Sub-carrier PSD
OFDM POWER SPECTRAL DENSITY
dB
0 -5 -10 -15 -20 -25 -30 -35 -40 -45 -50
freq (MHz)
-20 -15 -10 -5 0 5 10 15 20

FIG. 6B

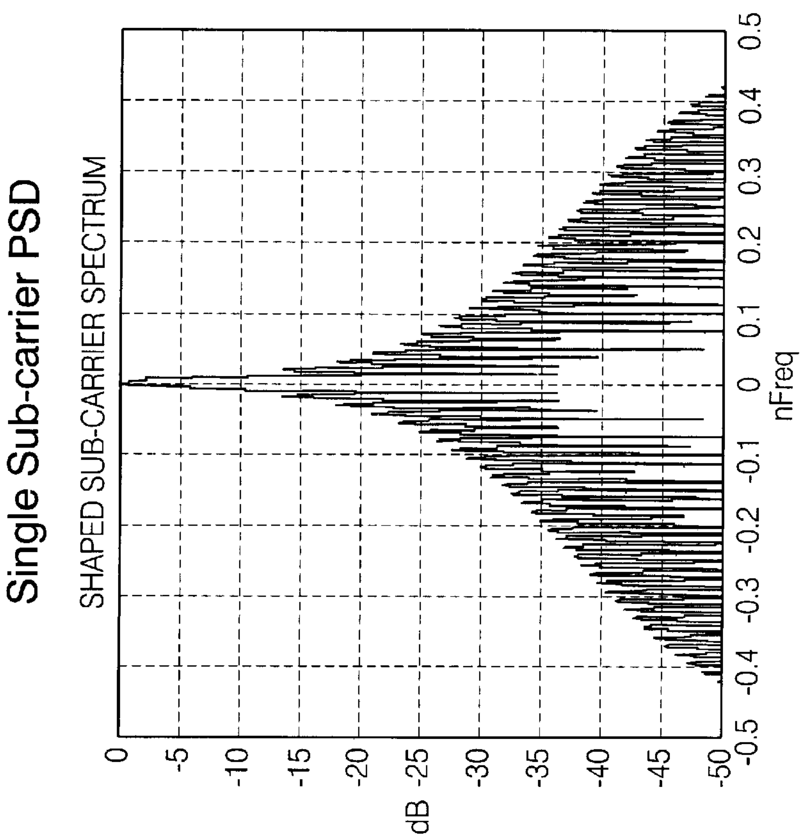
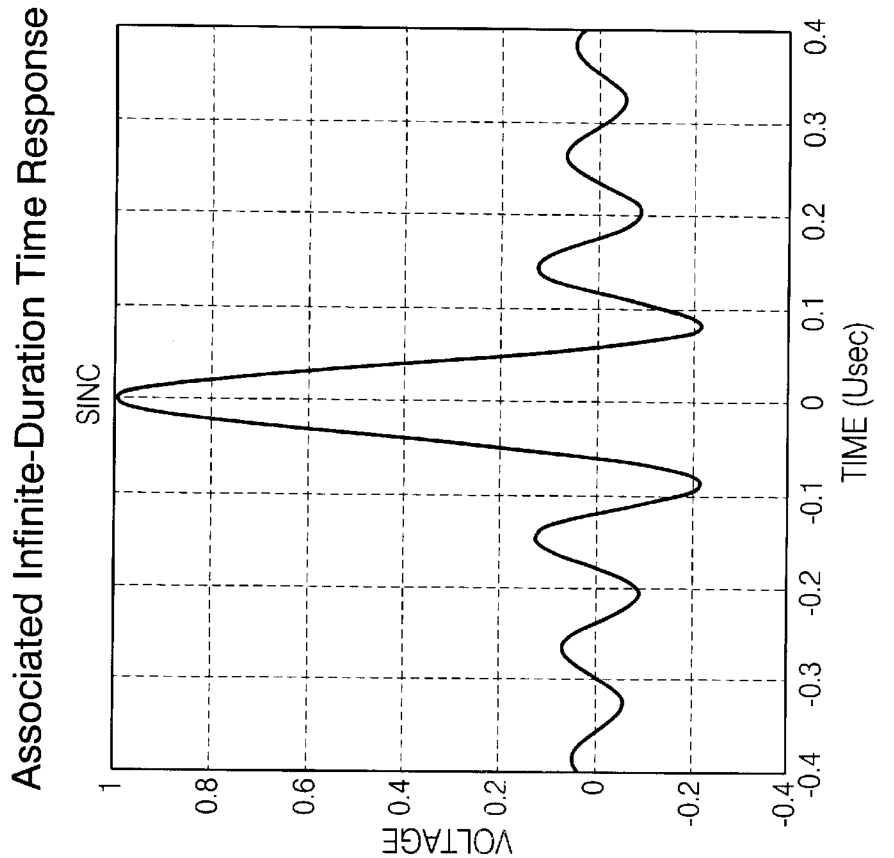

Single Sub-carrier PSD
SHAPED SUB-CARRIER SPECTRUM
dB
0 -5 -10 -15 -20 -25 -30 -35 -40 -45 -50
nFreq
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5

FIG. 6A



$$h_{IdealBW}(t) = f_W \frac{\sin(\pi f_W t)}{\pi f_W t} = f_W \operatorname{sinc}(f_W t),$$

$$\text{where } f_W = 52(20/64)\text{MHz}$$

FIG. 7B

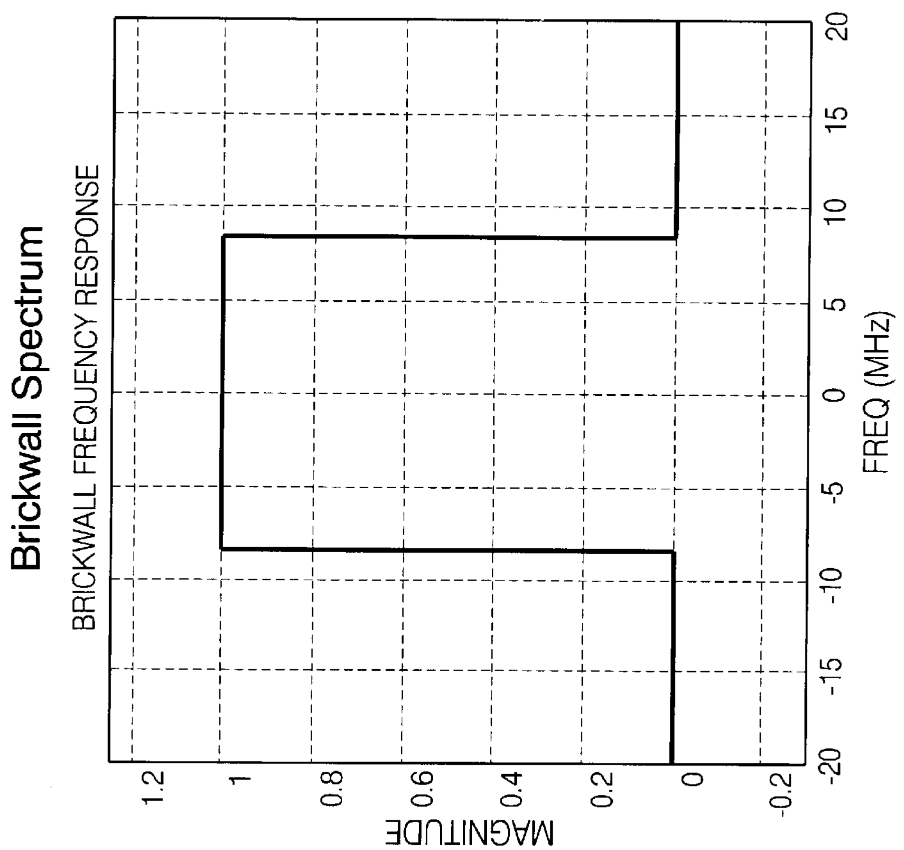
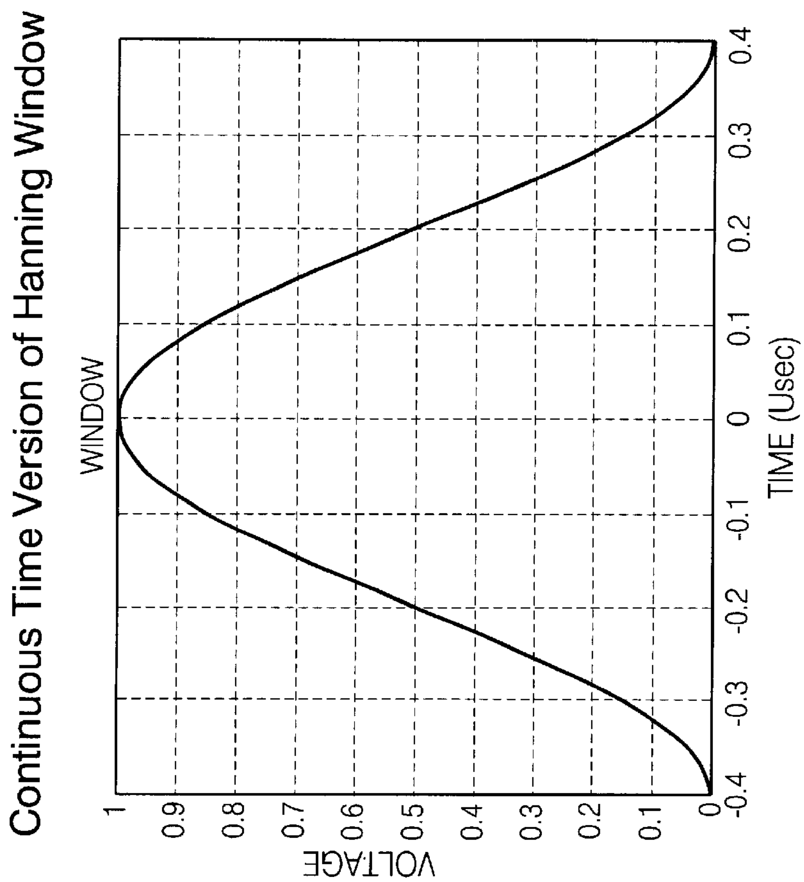


FIG. 7A



$$h_{Window}(t) = 0.5\left[1 + \cos\left(2\pi \frac{t}{T_{SPAN}}\right)\right],$$

where $T_{SPAN} = 0.8$ *usecs*

FIG. 8

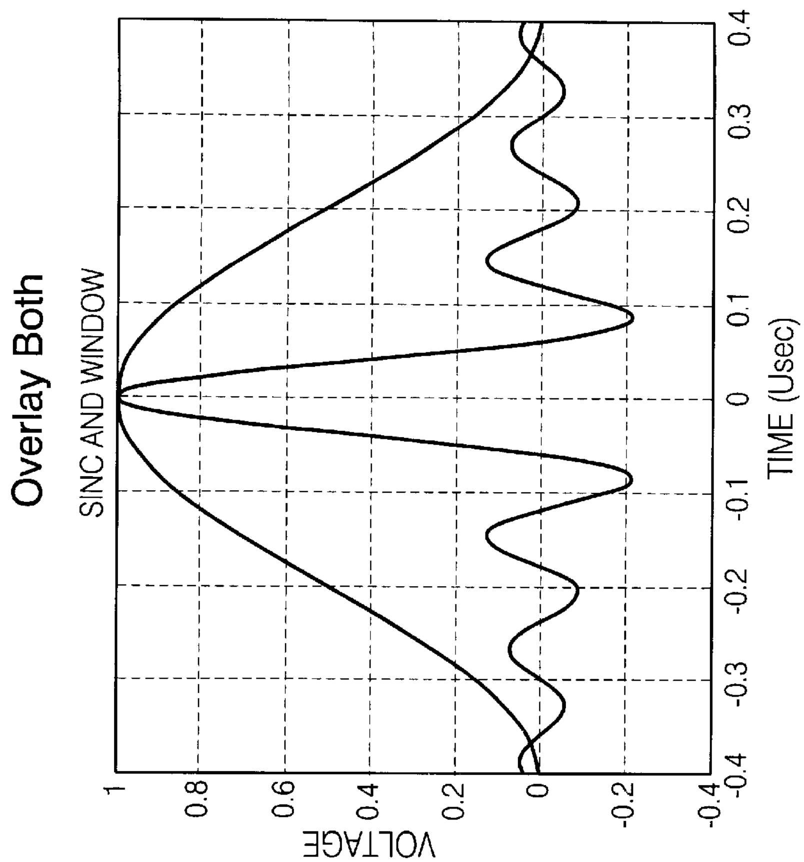


FIG. 9

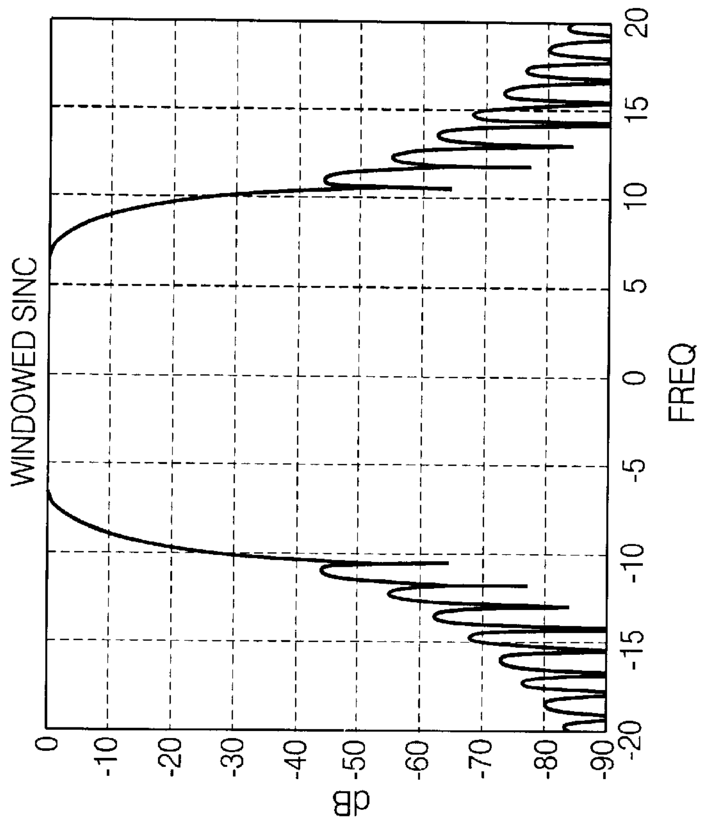
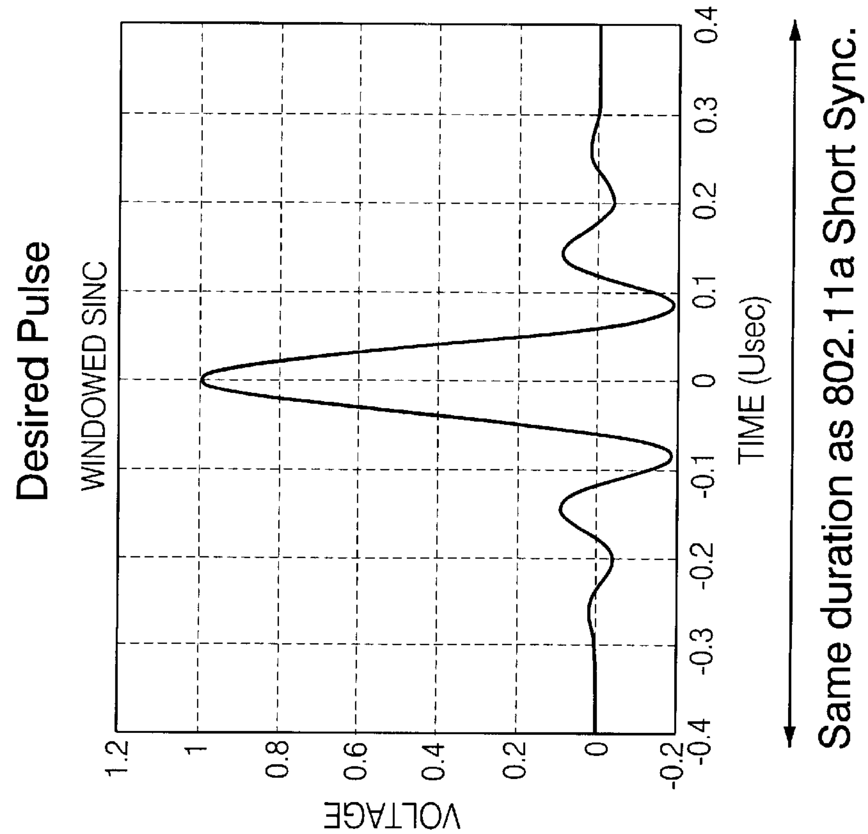


FIG. 11



$$p(t) = h_{Window}(t)\, h_{IdealBW}(t)$$

FIG. 10

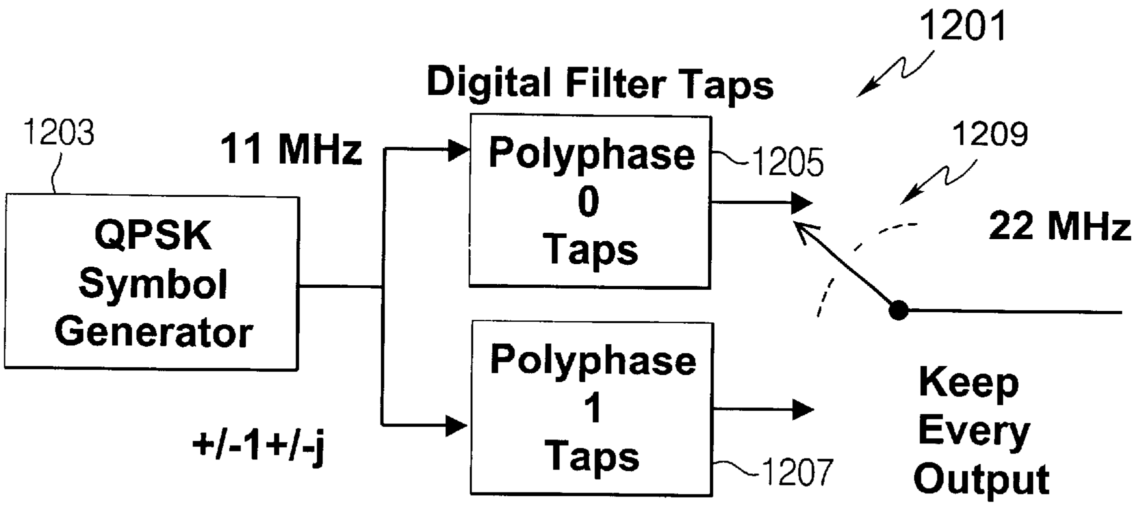

1201
Digital Filter Taps
1203
11 MHz
QPSK
Symbol
Generator
Polyphase
0
Taps
1205
1209
22 MHz
Polyphase
1
Taps
+/-1+/-j
1207
Keep
Every
Output

FIG. 12

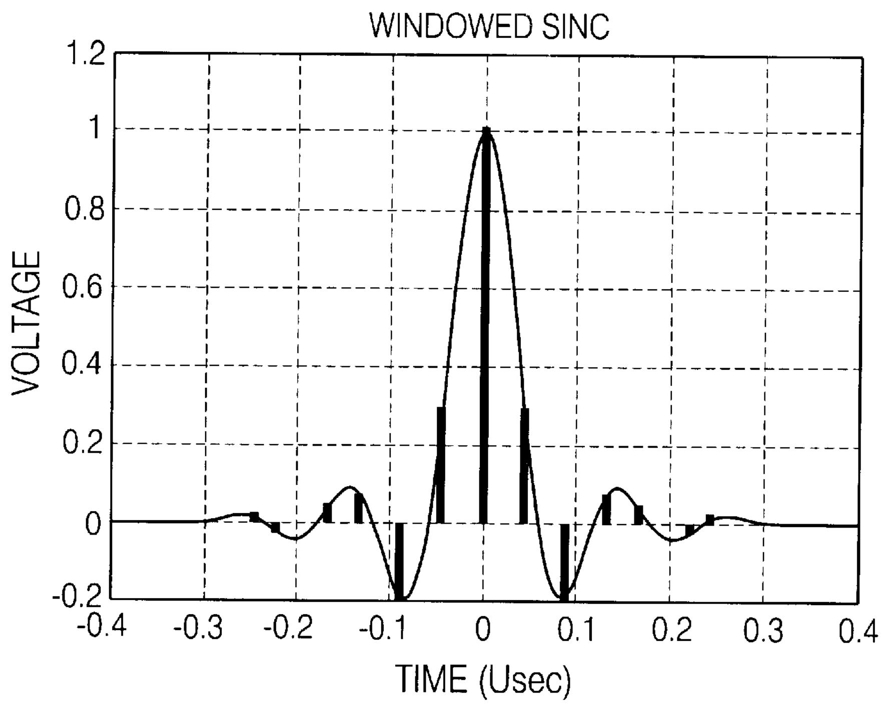
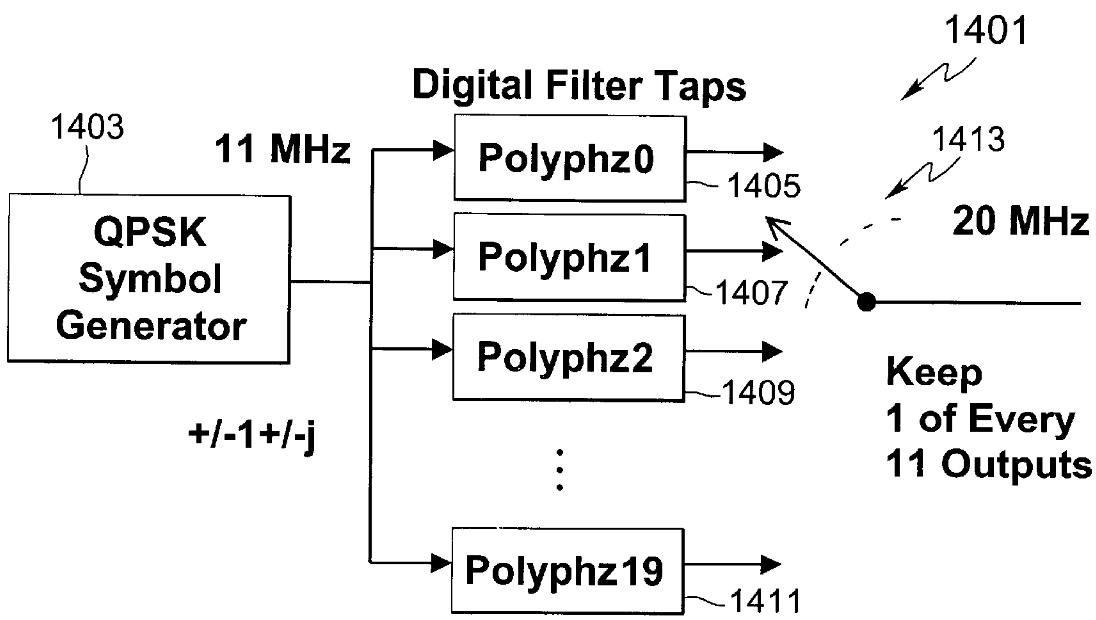
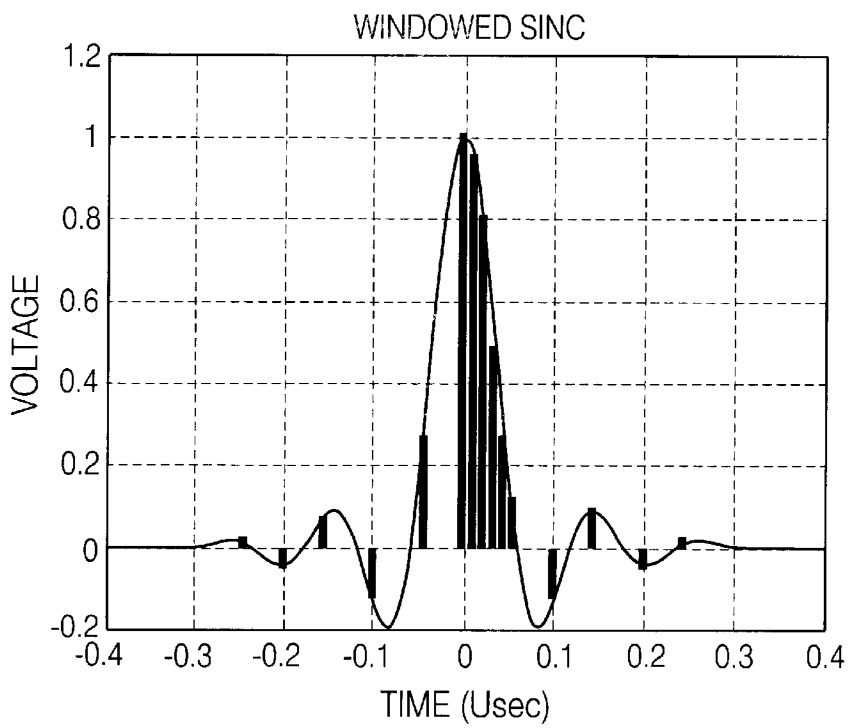

WINDOWED SINC
VOLTAGE
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
TIME (Usec)

FIG. 13



1401
Digital Filter Taps
1403
11 MHz
QPSK Symbol Generator
Polyphz0
1405
Polyphz1
1407
Polyphz2
1409
Polyphz19
1411
1413
20 MHz
Keep 1 of Every 11 Outputs
+/-1+/-j

FIG. 14



WINDOWED SINC
VOLTAGE
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
TIME (Usec)

FIG. 15

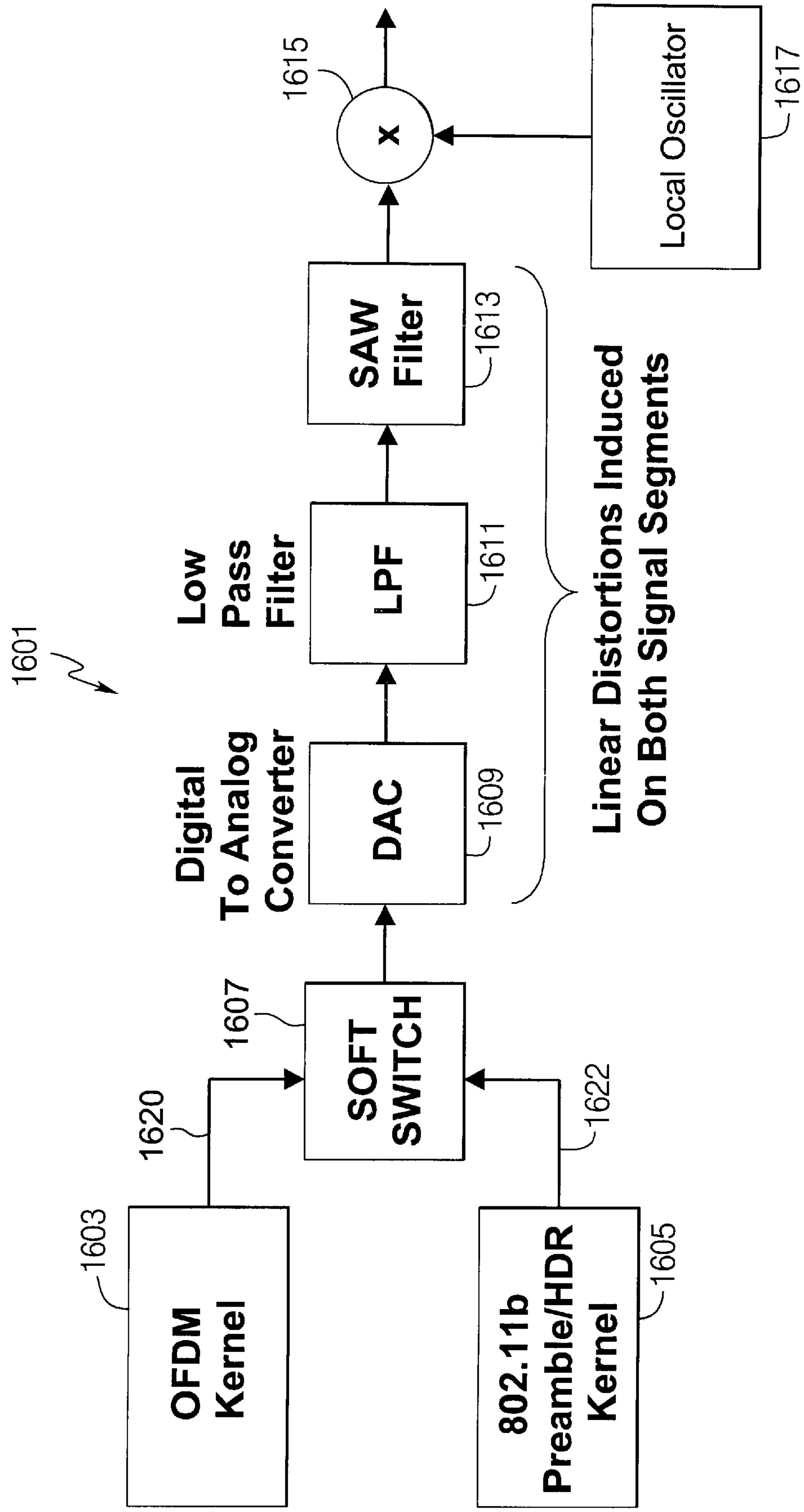

1601
OFDM Kernel
1603
802.11b Preamble/HDR Kernel
1605
1620
1622
SOFT SWITCH
1607
Digital To Analog Converter
DAC
1609
Low Pass Filter
LPF
1611
SAW Filter
1613
x
1615
Local Oscillator
1617
Linear Distortions Induced On Both Signal Segments

FIG. 16

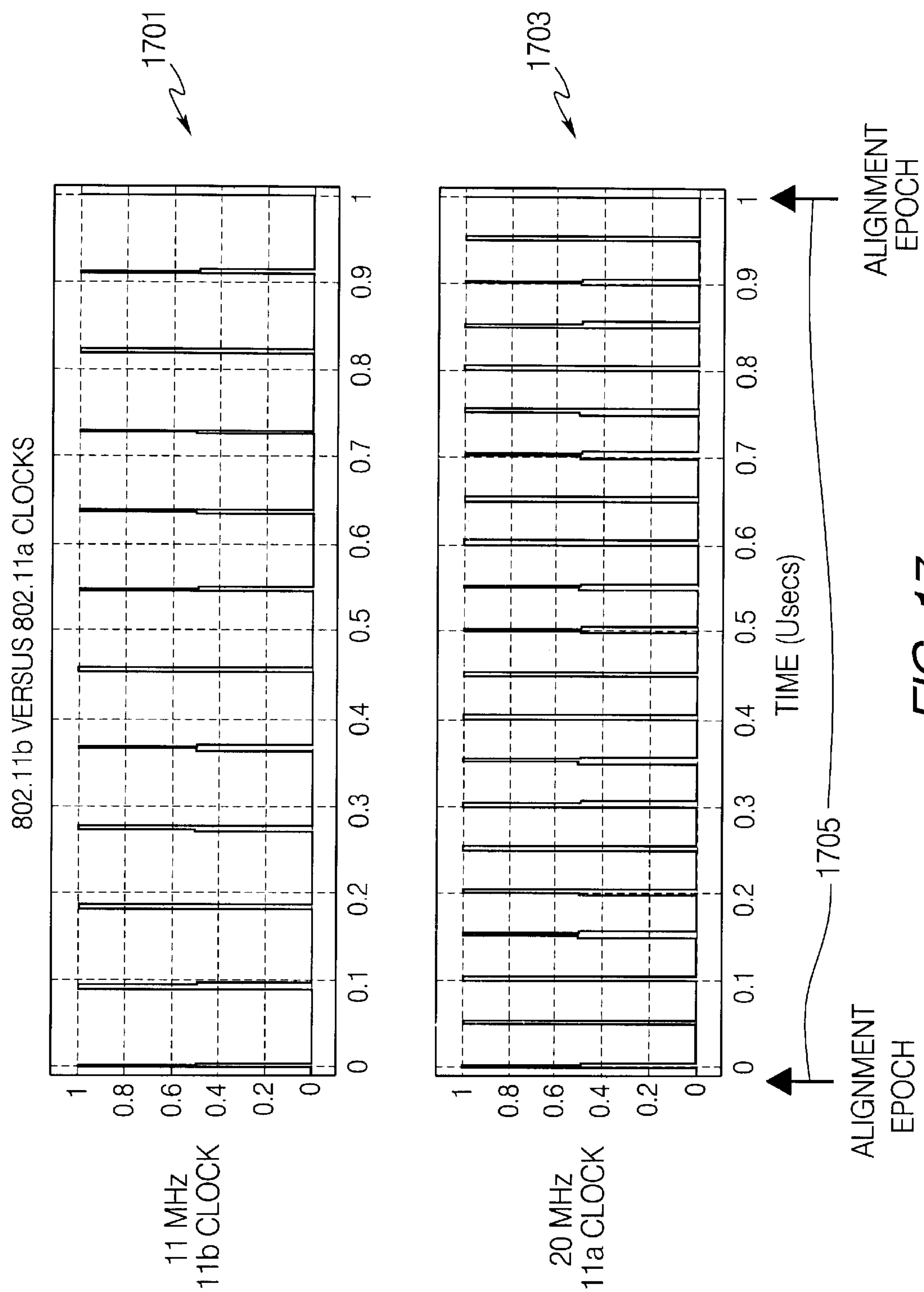
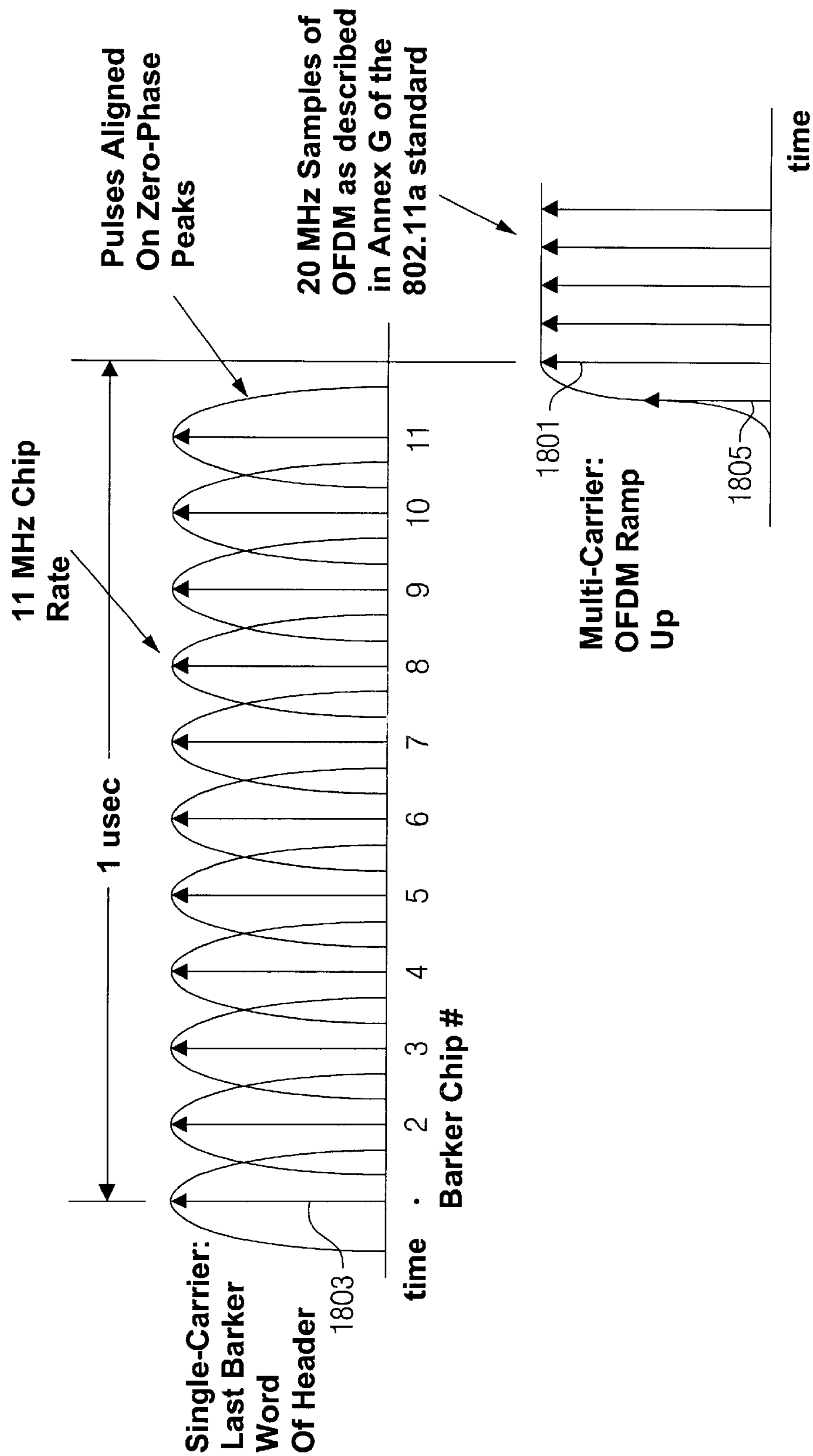

802.11b VERSUS 802.11a CLOCKS
1701
1703
11 MHz
11b CLOCK
20 MHz
11a CLOCK
1
0.8
0.6
0.4
0.2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
TIME (Usecs)
1705
ALIGNMENT EPOCH
ALIGNMENT EPOCH

FIG. 17



Pulses Aligned On Zero-Phase Peaks
20 MHz Samples of OFDM as described in Annex G of the 802.11a standard
time
11 MHz Chip Rate
1 usec
1801
1805
Multi-Carrier: OFDM Ramp Up
1 2 3 4 5 6 7 8 9 10 11
Barker Chip #
time
1803
Single-Carrier: Last Barker Word Of Header

FIG. 18

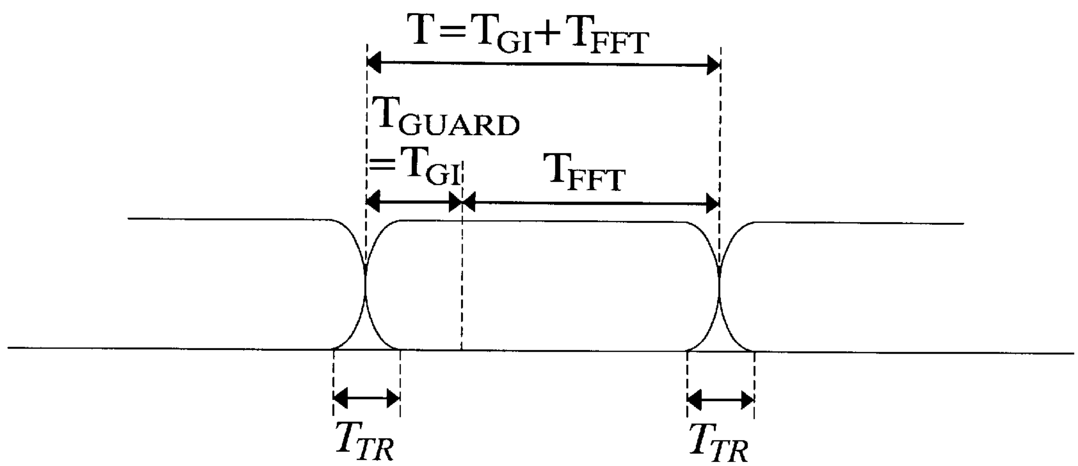

$T=T_{GI}+T_{FFT}$
T_{GUARD}
$=T_{GI}$
T_{FFT}
T_{TR}
T_{TR}

FIG. 19

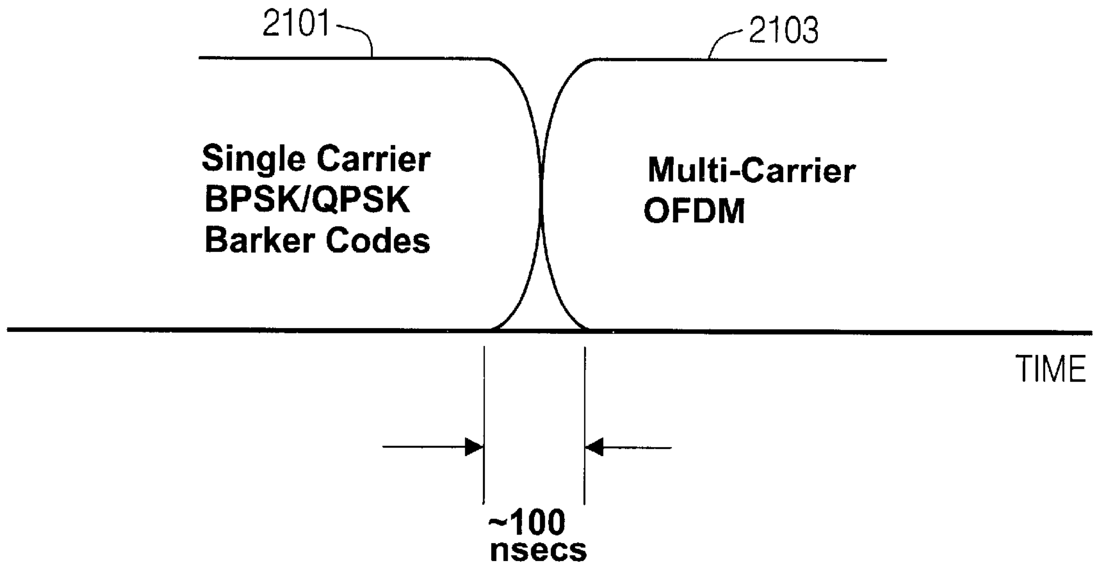

2101
2103
Single Carrier
BPSK/QPSK
Barker Codes
Multi-Carrier
OFDM
TIME
~100
nsecs

FIG. 21

$$w_T(t) = \sin^2\left[\frac{\pi}{2}\left(0.5 + \frac{t}{T_{TR}}\right)\right] \quad \text{for} \quad \left(-\frac{T_{TR}}{2} < t < \frac{T_{TR}}{2}\right)$$

$$w_T(t) = 1 \quad \text{for} \quad \left(\frac{T_{TR}}{2} < t < T - \frac{T_{TR}}{2}\right)$$

$$w_T(t) = \sin^2\left[\frac{\pi}{2}\left(0.5 - \frac{(t-T)}{T_{TR}}\right)\right] \quad \text{for} \quad \left(T - \frac{T_{TR}}{2} < t < T + \frac{T_{TR}}{2}\right)$$

where TTR is the Transition Duration

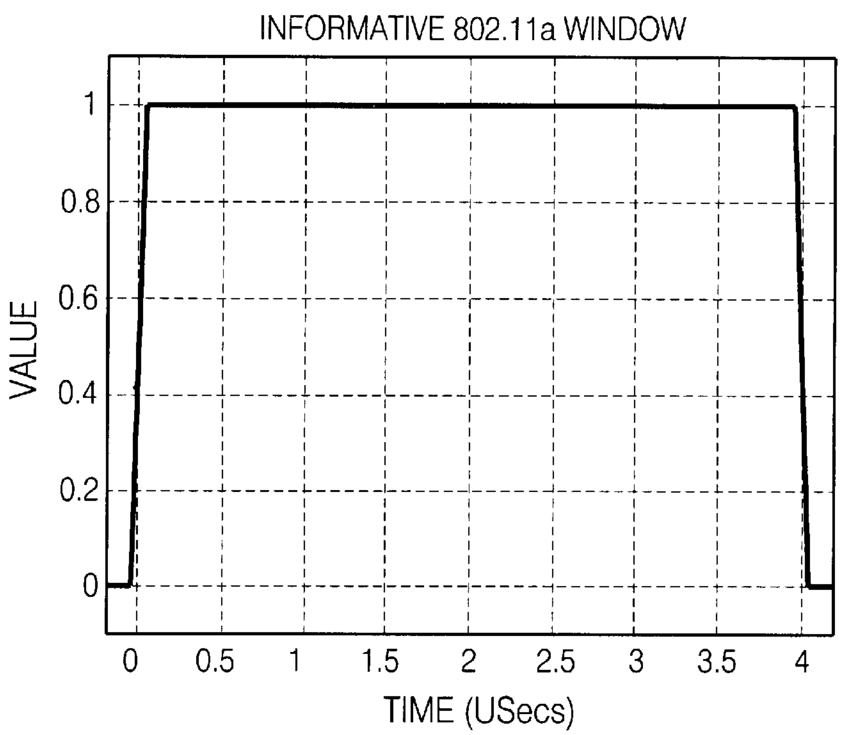


FIG. 20

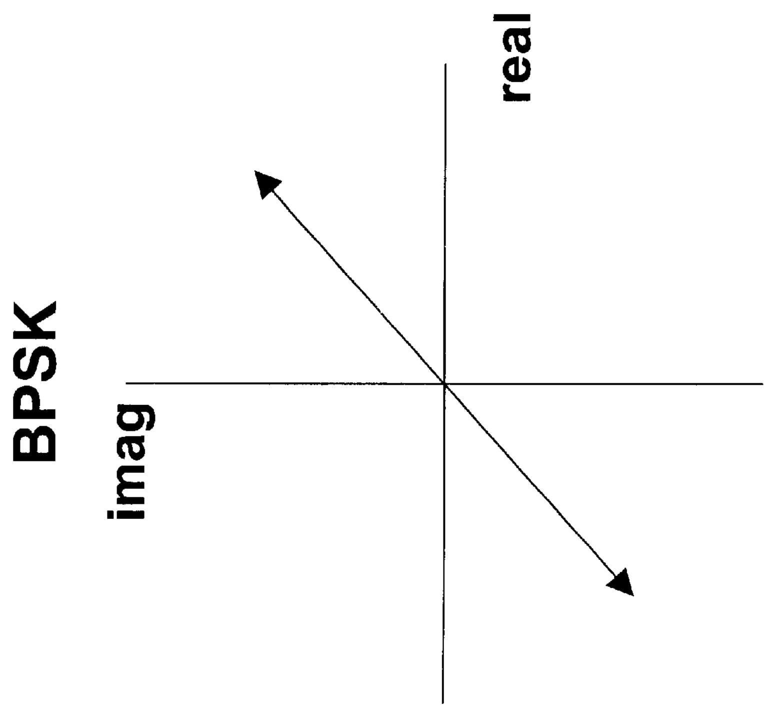


FIG. 22A

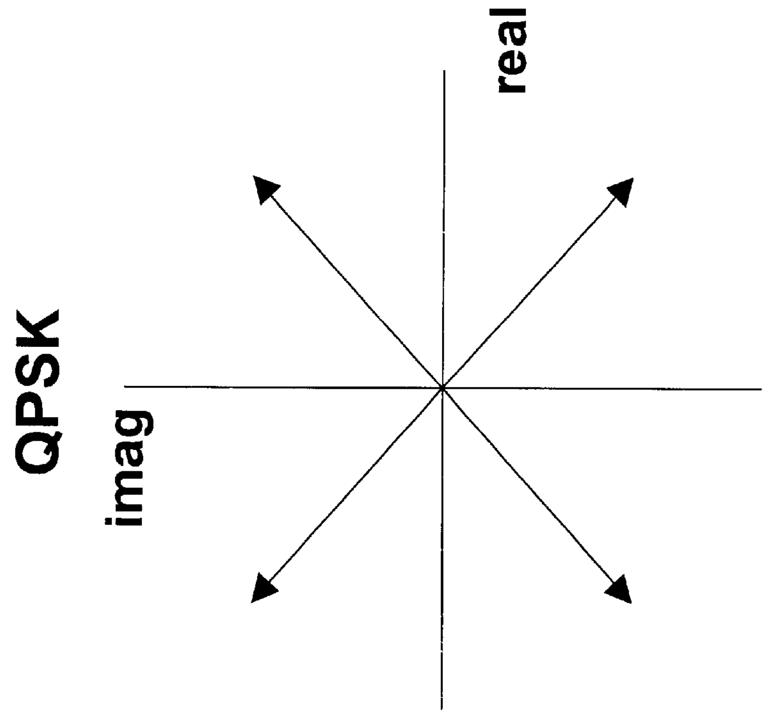


FIG. 22B

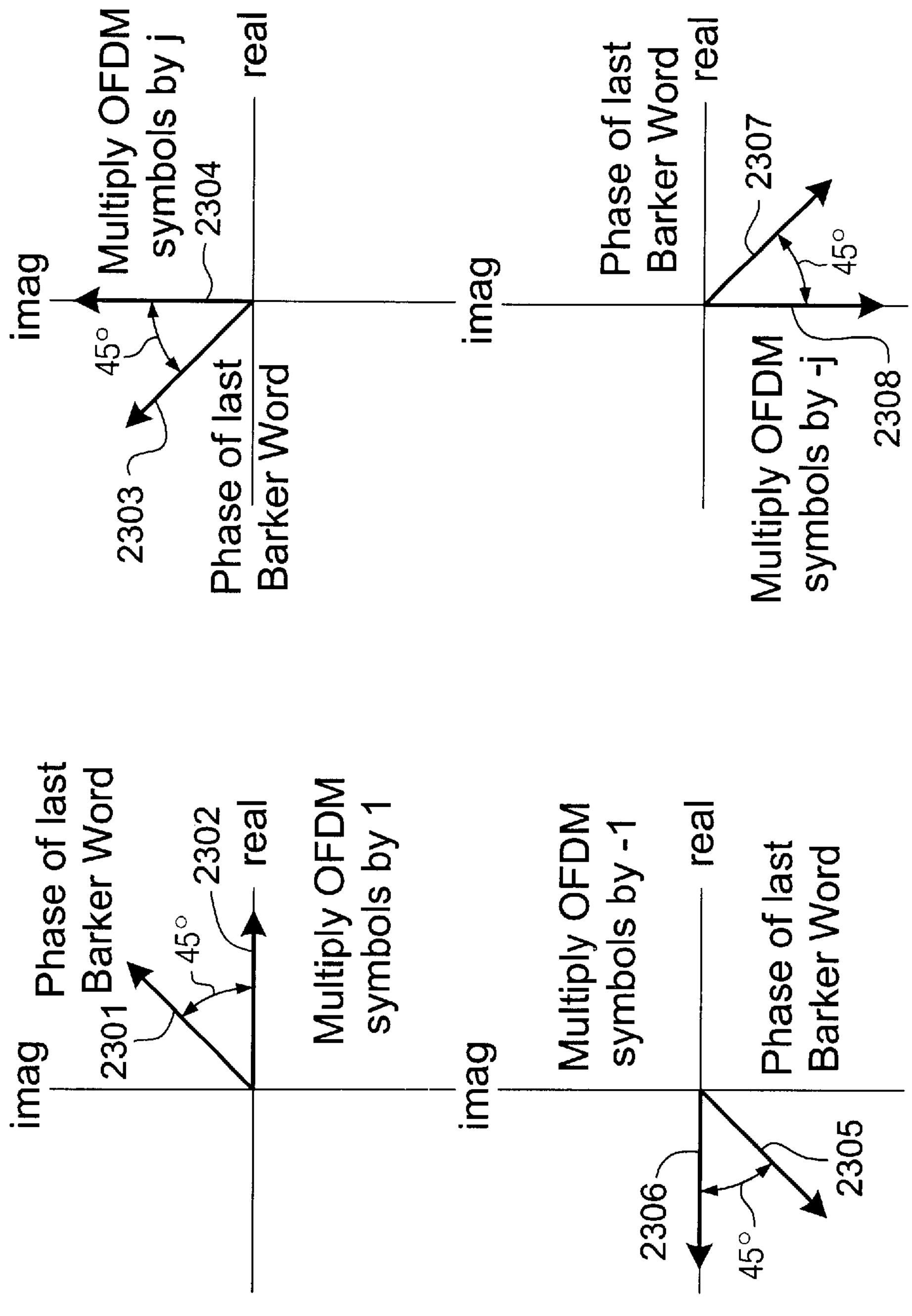

imag
real
Phase of last Barker Word
45°
2301
2302
Multiply OFDM symbols by 1
imag
real
Multiply OFDM symbols by j
2304
45°
2303
Phase of last Barker Word
imag
real
Multiply OFDM symbols by -1
Phase of last Barker Word
2305
2306
45°
imag
real
Phase of last Barker Word
2307
45°
2308
Multiply OFDM symbols by -j

FIG. 23

WIRELESS COMMUNICATION SYSTEM CONFIGURED TO COMMUNICATE USING A MIXED WAVEFORM CONFIGURATION

CROSS-REFERENCE TO RELATED APPLICATION(S)

The present application is based on U.S. Provisional Patent Application entitled "Wireless Communication System Configured to Communicate Using a Mixed Waveform Configuration", Serial No. 60/306,438, filed Jul. 6, 2001, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates to wireless communications, and more particularly to a wireless communication system configured to communicate using a single-carrier to multi-carrier mixed waveform configuration.

BACKGROUND OF THE INVENTION

The Institute of Electrical and Electronics Engineers, Inc. (IEEE) 802.11 standard is a family of standards for wireless local area networks (WLAN) in the unlicensed 2.4 and 5 Gigahertz (GHz) bands. The current 802.11 b standard defines various data rates in the 2.4 GHz band, including data rates of 1, 2, 5.5 and 11 Megabits per second (Mbps). The 802.11b standard uses direct sequence spread spectrum (DSSS) with a chip rate of 11 Megahertz (MHz), which is a serial modulation technique. The 802.11a standard defines different and higher data rates of 6, 12, 18, 24, 36 and 54 Mbps in the 5 GHz band. It is noted that systems implemented according to the 802.11 a and 802.11b standards are incompatible and will not work together.

A new standard is being proposed, referred to as 802.11 g (the "802.11 g proposal"), which is a high data rate extension of the 802.11b standard at 2.4 GHz. It is noted that, at the present time, the 802.11 g proposal is only a proposal and is not yet a completely defined standard. Several significant technical challenges are presented for the new 802.11 g proposal. It is desired that the 802.11 g devices be able to communicate at data rates higher than the standard 802.11b rates in the 2.4 GHz band. In some configurations, it is desired that the 802.11b and 802.11 g devices be able to coexist in the same WLAN environment or area without significant interference or interruption from each other, regardless of whether the 802.11b and 802.1 g devices are able to communicate with each other. It may further be desired that the 802.11 g and 802.11b devices be able to communicate with each other, such as at any of the standard 802.11b rates.

A dual packet configuration for wireless communications has been previously disclosed in U.S. patent application entitled, "A Dual Packet Configuration for Wireless Communications", Ser. No. 09/586,571 filed on Jun. 2, 2000, which is hereby incorporated by reference in its entirety. This previous system allowed a single-carrier portion and an orthogonal frequency division multiplexing (OFDM) portion to be loosely coupled. Loosely coupled meant that strict control of the transition was not made to make implementations simple by allowing both an existing single-carrier modem and an OFDM modem together with a simple switch between them with a minor conveyance of information between them (e.g., data rate and packet length). In particular, it was not necessary to maintain strict phase, frequency, timing, spectrum (frequency response) and power continuity at the point of transition (although the power step would be reasonably bounded). Consequently, the OFDM system needed to perform an acquisition of its own, separate from the single-carrier acquisition, including re-acquisition of phase, frequency, timing, spectrum (including multi-path) and power (Automatic Gain Control [AGC]). A short OFDM preamble following the single carrier was used in one embodiment to provide reacquisition.

An impairment to wireless communications, including WLANs, is multi-path distortion where multiple echoes (reflections) of a signal arrive at the receiver. Both the single-carrier systems and OFDM systems must include equalizers that are designed to combat this distortion. The single-carrier system designs the equalizer on its preamble and header. In the dual packet configuration, this equalizer information was not reused by the OFDM receiver. Thus, the OFDM portion employed a preamble or header so that the OFDM receiver could reacquire the signal. In particular, the OFDM receiver had to reacquire the power (AGC), carrier frequency, carrier phase, equalizer and timing parameters of the signal.

Interference is a serious problem with WLANs. Many different signal types are starting to proliferate. Systems implemented according to the Bluetooth standard present a major source of interference for 802.11-based systems. The Bluetooth standard defines a low-cost, short-range, frequency-hopping WLAN. Preambles are important for good receiver acquisition. Hence, losing all information when transitioning from single-carrier to multi-carrier is not desirable in the presence of interference.

There are several potential problems with the signal transition, particularly with legacy equipment. The transmitter may experience analog transients (e.g., power, phase, filter delta), power amplifier back-off (e.g. power delta) and power amplifier power feedback change. The receiver may experience AGC perturbation due to power change, AGC perturbation due to spectral change, AGC perturbation due to multi-path effects, loss of channel impulse response (CIR) (multi-path) estimate, loss of carrier phase, loss of carrier frequency, and loss of timing alignment.

SUMMARY OF THE INVENTION

A wireless communication system configured to communicate using a mixed waveform configuration is disclosed and includes a transmitter configured to transmit according to a mixed waveform configuration and a receiver configured to acquire and receive packets with a mixed waveform configuration. The mixed waveform includes a first portion modulated according to a single-carrier scheme with a preamble and header and a second portion modulated according to a multi-carrier scheme. The waveform is specified so that a channel impulse response (CIR) estimate obtainable from the first portion is reusable for acquisition of the second portion.

In one configuration, the transmitter maintains power, carrier phase, carrier frequency, timing, and multi-path spectrum between the first and second portions of the waveform. The transmitter may include first and second kernels and a switch. The first kernel modulates the first portion according to the single-carrier modulation scheme and the second kernel generates the second portion according to the multi-carrier modulation scheme. The switch selects the first kernel for the first portion and the second kernel for the second portion to develop a transmit waveform. In one embodiment, the first kernel operates at a first sample rate and the second kernel operates at a second sample rate. The first kernel may employ a single-carrier spectrum that resembles a multi-carrier spectrum of the multi-carrier modulation scheme.

The first kernel may employ a time shaping pulse that is specified in continuous time. The time shaping pulse may be derived by employing an infinite impulse response of a brick wall approximation that is truncated using a continuous-time window that is sufficiently long to achieve desired spectral characteristics and sufficiently short to minimize complexity. The first kernel may sample the time shaping pulse according to a Nyquist criterion. The average output signal power of the first kernel and the average output signal power of the second kernel may be maintained substantially equal. The first kernel may employ a first sample rate clock while the second kernel employs a second sample rate clock. In this latter case, the first and second sample rate clocks are aligned at predetermined timing intervals. Also, a first full sample of the multi-carrier modulation scheme begins one timing interval after the beginning of a last sample of the single-carrier modulation scheme.

The single-carrier signal from the first kernel may be terminated according to a windowing function specified for OFDM signal shaping defined in the 802.11a standard. The carrier frequency may be coherent between the first and second kernels. The carrier phase may be coherent between the first and second kernels. In one embodiment to achieve coherent phase, carrier phase of the second kernel multi-carrier signal is determined by carrier phase of a last portion of the second kernel single-carrier signal. The carrier phase of the second kernel multi-carrier signal may further be rotated by a corresponding one of a plurality of rotation multiples, each rotation multiple corresponding to one of a plurality of predetermined phases of the last portion of the second kernel single-carrier signal. In a particular embodiment, the first kernel single-carrier modulation scheme is according to 802.11b Barkers in which each Barker word is one of first, second, third and fourth possible phases and the second kernel multi-carrier modulation scheme is according to OFDM as defined in Annex G of the 802.11a standard. In this case, the OFDM symbols are rotated by the second kernel by zero if the last Barker word has the first phase, by 90 degrees if the last Barker word has the second phase, by 180 degrees if the last Barker word has the third phase, and by −90 degrees if the last Barker word has the fourth phase.

The requisite fidelity of the entire mixed waveform configuration may be specified by a requisite fidelity specified for the multi-carrier scheme. In one embodiment, the requisite fidelity is a function of data rate of the second portion and is determined by mean-squared-error normalized by signal power as specified for OFDM in the 802.11a standard.

The symbol rate clock and carrier frequency of the waveform may be derived from the same reference clock. The part per million (PPM) error of a clock fundamental for symbol rate and PPM error of a clock fundamental for carrier frequency may be substantially equal.

The receiver may include a single-carrier receiver, a multi-carrier receiver, and a switch that provides a first portion of a signal being received to the single-carrier receiver and that provides a second portion of the signal being received to the multi-carrier receiver. The single-carrier receiver acquires a first portion of an incoming signal including the preamble and header and determines a CIR estimate, and the multi-carrier receiver uses the CIR estimate for a second portion of the incoming signal. In a specific configuration, the single-carrier receiver programs taps of the first equalizer based on the CIR estimate, the multi-carrier receiver includes a second equalizer, and the multi-carrier receiver modifies taps of the second equalizer based on the CIR estimate determined by the first equalizer.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the present invention can be obtained when the following detailed description of the preferred embodiment is considered in conjunction with the following drawings, in which:

FIG. **1** is a block diagram of a WLAN system including four devices operating within the same room or area, where two of the devices are implemented according to the 802.11b standard and the other two are implemented according to the 802.11 g proposal.

FIG. **2** is a block diagram of a mixed signal receiver implemented according to an embodiment of the present invention that may be used in either or both of the high rate devices of FIG. **1**.

FIG. **3** is a conceptual diagram of a mixed signal packet implemented according to an embodiment of the present invention.

FIGS. **4**A and **4**B are graph diagrams of plots of the spectrum of the 802.11b Barker chips and the 802.11a OFDM, respectively.

FIGS. **5**A and **5**B are graph diagrams of time domain plots of the 802.11b QPSK Barker chips and the 802.11a OFDM, respectively, illustrating that the waveforms are radically different.

FIG. **6**A is a graph diagram of a plot of the power spectral density (PSD) of a single sub-carrier out of the possible 64 possible sub-carriers defined in the 802.11a standard.

FIG. **6**B is a graph diagram of a plot of the composite PSD of the 52 non-zero sub-carriers used in 802.11a.

FIG. **7**A is a graph diagram of a plot of an exemplary "brickwall" double-sided spectrum centered at 0 MHz.

FIG. **7**B is a graph diagram of a portion of the associated infinite-duration time response corresponding to the brickwall spectrum of FIG. **7**A.

FIG. **8** is a graph diagram of a plot of an exemplary continuous-time window, which is a continuous time version of a Hanning window.

FIG. **9** is a graph diagram of a plot of the Hanning window of FIG. **8** overlayed with the portion of the infinite-duration time response corresponding to the brickwall spectrum of FIG. **7**A.

FIG. **10** is a graph diagram of a plot of the exemplary pulse p(t) resulting from the overlaying illustrated in FIG. **9** and truncated to approximately 0.8 μs.

FIG. **11** is a graph diagram of a plot of the spectral characteristics of the pulse p(t) illustrating that it is a close match to the OFDM spectrum.

FIG. **12** is a block diagram of an exemplary digital filter employed to architect a digital 22 MHz output sample rate using the continuous time pulse p(t).

FIG. **13** is a graph diagram illustrating the sampling and polyphase decomposition of the continuous time pulse p(t) using the sampling scheme of FIG. **12**.

FIG. **14** is a block diagram of another exemplary digital filter employed to architect a digital 20 MHz output sample rate using the pulse p(t).

FIG. **15** is a graph diagram illustrating the sampling and polyphase decomposition of the continuous time pulse p(t) using the sampling scheme of FIG. **14**.

FIG. **16** is a block diagram of a transmitter implemented according to an embodiment of the present invention.

FIG. **17** is a graph diagram comparing the 11 MHz Barker chip clock versus the 20 MHz OFDM sample clock.

FIG. **18** is a conceptual graph diagram illustrating alignment of the OFDM signal portion with the last Barker word of the header of the single-carrier portion.

FIG. **19** is a graph diagram illustrating normal OFDM symbol overlap.

FIG. **20** is a graph diagram illustrating exemplary 802.11a OFDM symbol onset and termination.

FIG. **21** is a graph diagram illustrating exemplary single-carrier termination, shaped consistent with 802.11a, and OFDM onset shaped identical to 802.11 a.

FIG. **22**A is a simplified graph diagram of a BPSK plot illustrating that BPSK incorporates both real and imaginary portions in two quadrants (1 of 2 phases).

FIG. **22**B is a simplified graph diagram of a QPSK plot illustrating that QPSK incorporates both real and imaginary portions in all four quadrants (1 of 4 phases).

FIG. **23** is a graph diagram of a plot illustrating the phase of the last Barker word in the 802.11 g header and the relative phase of the OFDM symbol in accordance with that described in Annex G of the 802.11a standard.

DETAILED DESCRIPTION OF EMBODIMENT (S) OF THE INVENTION

A configuration according to the present invention reuses the equalizer information obtained during acquisition of the single-carrier portion of the signal. In this manner, no OFDM preamble is required, although it still may be present for both convenience and fine tuning. The present disclosure describes a technique for providing complete continuity between the single-carrier and OFDM (multi-carrier) segments. This continuity is provided by specifying the transmit waveform completely for both the single-carrier and OFDM segments and specifying the transition. This enables complete continuity between the two signal segments, including AGC (power), carrier phase, carrier frequency, timing and spectrum (multi-path). In this manner, the signal does not have to be reacquired by the multi-path portion of the receiver since the information developed during the single-carrier portion (preamble/header) is valid and used to initiate capture of the multi-carrier portion. Maintaining and accumulating information makes the signal much more robust in the face of common interferences experience in wireless communications.

FIG. **1** is a block diagram of a wireless local area network (WLAN) system **100** operating within a particular room or area **101**, including four WLAN devices **103**, **105**, **107** and **109** (**103**–**109**) are located within the area **101**. The devices **103** and **105** are implemented according to at least one of several embodiments of the present invention with the 802.11 g proposal in mind, whereas the devices **107** and **109** are implemented according to the 802.11b standard. All of the devices **103**–**109** operate in the 2.4 GHz band. The devices **103**–**109** may be any type of wireless communication device, such as any type of computer (desktop, portable, laptop, etc.), any type of compatible telecommunication device, any type of personal digital assistant (PDA), or any other type of network device, such as printers, fax machines, scanners, hubs, switches, routers, etc. It is noted that the present invention is not limited to the 802.11 g proposal, the 802.11b standard, the 802.11a standard or the 2.4 GHz frequency band, although these standards and frequencies may be utilized in certain embodiments.

The devices **107** and **109** communicate with each other at any of the standard 802.11b rates, including 1, 2, 5.5 and 11 Mbps. The devices **103** and **105** are mixed signal mode devices that communicate with each other at different or higher data rates using a mixed signal configuration according to any one of several embodiments, such as the standard 802.11a data rates of 6, 9, 12, 18, 24, 36, 48 or 54 Mbps. Alternative data rate groups are considered herein. The second group is advantageous as including two of the 802.11b standard data rates, namely 5.5 and 11 Mbps.

In one or more first embodiments, the mixed signal devices **103**–**109**may operate or coexist in the same area **101** without significant interference from each other, where the devices **103**, **105** communicate with each other at different or higher data rates than the 802.11b devices **107**, **109**. In the first embodiments, the devices **103**, **105** may communicate with each other while the devices **107**, **109** may communicate with each other, but the devices **103**, **105** do not communicate with the devices **107**, **109**. In one or more second embodiments, at least one of the mixed signal devices **103**, **105** is configured with a standard mode to be able to communicate with either of the devices **107**, **109** at any one or more of the standard 802.11b data rates. In at least one third embodiment, the mixed signal devices **103**, **105** communicate at different or higher data rates and are incompatible with the devices **107** and **109**, so that the devices **103**–**109** are not able to coexist within the same area **101**. The mixed signal devices **103**, **105** may be implemented to operate in the 2.4 GHz band, although other frequency bands are contemplated.

In the first or second embodiments, it is desired that the devices **103** and **105** be able to communicate with each other without interruption or interference from either of the devices **107** and **109**. This presents a significant technical challenge since the devices **103**, **105** operate at different data rates when communicating with each other. The present invention solves this problem by enabling the devices **103** and **105** to be implemented to be able to communicate with each other at different or at higher data rates while residing in a same area **101** as the 802.11b devices **107**, **109**. Further, in the second embodiments the devices **103**, **105** may also communicate with either of the devices **107**, **109** at the 802.11b data rates.

FIG. **2** is a block diagram of a mixed signal receiver **201** implemented according to an embodiment of the present invention that may be used in either or both of the devices **103**, **105**. The incoming signal is received by an automatic gain control (AGC) **203** that adjusts receive power and provides a corresponding signal to a switch **205**. The switch **205** initially provides the received signal to a single-carrier receiver **207**. The single-carrier receiver **207** includes an equalizer and other circuitry that analyzes the predetermined preamble of the received signal compared to known data and "learns" the parameters associated with the multi-path medium through which the signal was propagated. The single-carrier receiver **207** also examines the header to determine if the packet is intended for the mixed signal receiver **201** and if the packet is a mixed packet, and if so, causes the switch **205** to provide the remaining portion of the incoming signal to a multi-carrier receiver **209**. It is noted that the header includes a mixed mode identifier (not shown), such as a mode bit or the like, that identifies the packet as a mixed mode packet. Thus, in one embodiment, the single-carrier receiver **207** determines that the packet is intended for the mixed signal receiver **201** from a destination address or the like, and determines that the packet is a mixed mode packet from the mode identifier. If the packet is intended for the mixed signal receiver **201** but is not a mixed mode packet (e.g., a standard 802.11b packet), then the single-carrier receiver **207** continues to process the packet. A length field is also provided in the header which includes a length value that identifies the total length of the mixed mode packet. Thus, any device, including mixed mode or legacy devices (e.g. 802.11b devices), may determine that the packet is not intended for it, and backs-off by an amount of time corresponding to the length value.

The multi-carrier receiver **209** is configured to receive the signal, which is transmitted according to OFDM or the like. The multi-carrier receiver **209** is coupled to the single-carrier receiver **207** so that the multi-path information determined by the single-carrier receiver **207** is re-used to enable a smooth transition between the packet portions of the incoming signal. In particular, the AGC (power), carrier frequency, carrier phase, equalizer, and timing parameters from the single-carrier receiver **207** are used by the multi-carrier receiver **209** to receive the incoming signal. The OFDM multi-carrier receiver **209** need not re-acquire the signal, since the information used by the single-carrier receiver **207** is obtained and used.

FIG. **3** is a conceptual diagram of a mixed signal packet **301** implemented according to an embodiment of the present invention. The packet **301** includes a Barker Preamble **303**, which is transmitted at 1 megabits per second (Mbps), followed by a Barker Header **305**, which is transmitted at 1 or 2 Mbps, followed by one or more OFDM symbols **307** incorporating payload data, which is transmitted at any selected data rate from among typical data rates of 6, 9, 12, 18, 24, 36, 48 or 54 Mbps with a selected sample rate of 20 megahertz (MHz). The preamble **303** and header **305** are transmitted with a single carrier at the 11 MHz Quadrature Phase Shift Keying (QPSK) symbol rate (and Binary Phase Shift Keying [BPSK] is also contemplated). Different OFDM sample rates are contemplated, such as 18.333 megahertz (MHz), 22 MHz, etc., in which the same principles apply. The transmit signal is specified for complementary code keying OFDM, or CCK-OFDM (802.11b preamble and header using Barkers [single carrier] followed by OFDM [multi-carrier]). The OFDM portion of the waveform can optionally be one of several effective sample rates (e.g., 22, 20, or 18.33 MHz). The packet **301** is shown employing the 802.11a sample rate of 20 MHz. The goal is to specify the signal so that the channel impulse response (CIR) estimate obtained on the preamble and header is reusable on the OFDM. Hence, the transition is completely specified, with no free variables, which allows important equalizer information to be retained at switch-over. Also, it is desirable to eliminate receiver power changes due to the signal transition. A power step may cause legacy equipment to enter an undefined state, since they do not have knowledge of the OFDM, nor the capability to receive it.

FIGS. **4**A and **4**B are graph diagrams of plots of the spectrum of the 802.11b Barker chips and the 802.11a OFDM, respectively, in decibels (dB) versus normalized frequency (freq). Spectrum refers to center frequency, power spectral density, and frequency response. The 802.11b Barker chip spectrum has a round "top" whereas the 802.11a OFDM spectrum has a flat top. The 3 dB bandwidths are also different. FIGS. **5**A and **5**B are graph diagrams of time domain plots of the 802.11b QPSK Barker chips and the 802.11a OFDM, respectively, illustrating that the waveforms are radically different. It is desired to create a smooth transition between the preamble/header single-carrier portion **303**, **305** and the OFDM symbol portion **307** even though the waveforms are different. One solution is to make

the 802.11b Barker preamble and header look like OFDM with approximately the same transmit spectrum and approximately the same power.

FIG. **6**A is a graph diagram of a plot of the power spectral density (PSD) of a single sub-carrier out of the possible 64 possible sub-carriers defined in the 802.11a standard, in dB versus frequency. FIG. **6**B is a graph diagram of a plot of the composite PSD of the 52 non-zero sub-carriers used in 802.11a. The curves are plotted versus normalized frequency (nfreq) and frequency in MHz, respectively. It is desired to design a spectrum/time shaping pulse, which makes the spectrum of the single-carrier portion of the signal resemble OFDM. This pulse is made known so that the receiver is able to compensate the CIR for the OFDM portion of the packet. The pulse is specified in continuous time, so that it is implementation independent. For digital implementations, the pulse may be sampled at any desired appropriate implementation rate. The signal should provide a nearly flat spectrum in the pass-band with sufficiently steep roll-off on the band edges. It is desired that the transmit pulse be easily handled by 802.11b legacy receivers. It should have a dominant peak, therefore, with a small amount of spread in the impulse response. This allows the 802.11b receiver to lock on to this impulse response component. It is desired that the signal have a short duration to minimize complexity.

FIG. **7**A is a graph diagram of a plot of an exemplary "brickwall" double-sided spectrum centered at 0 MHz, having a magnitude of 1 at a selected bandwidth of approximately 2(8.5)=17 MHz and 0 otherwise. A brickwall spectrum is essentially an idealized low-pass filter. The exemplary frequency range is selected as (2)(27)(20 MHz/64)=16.875 MHz in the embodiment shown. FIG. **7**B is a graph diagram of a portion of the associated infinite-duration time response corresponding to the brickwall spectrum. In general, a target spectrum is chosen for the single carrier system. This is done by specifying a brickwall approximation to the desired spectrum. A brickwall spectrum has an infinite impulse response in the time domain (i.e., spans from +/−infinity). The pulse is then truncated using a continuous-time window. A long enough window is chosen to give the desired spectral characteristics while a short enough window is chosen to minimize complexity, each generally employing engineering judgment.

FIG. **8** is a graph diagram of a plot of an exemplary continuous-time window, which is a continuous time version of a Hanning window. It is appreciated that this is only one of many different window configurations that may be successfully employed to achieve desirable results. FIG. **9** is a graph diagram of a plot of the Hanning window overlayed with the portion of the infinite-duration time response corresponding to the brickwall spectrum. FIG. **10** is a graph diagram of a plot of the resulting exemplary pulse p(t) truncated to approximately 0.8 μs so that it is zero outside +/−0.4 μs. The short duration of the pulse p(t) provides low complexity. FIG. **11** is a graph diagram of a plot of the spectral characteristics of the pulse p(t) illustrating that it is a close match to the OFDM spectrum. The spectral characteristics of the pulse p(t) include a nearly flat spectrum where OFDM is flat and a fast roll-off where OFDM rolls off. The continuous time pulse can be used to construct any digital filter unambiguously and is independent of particular implementations. The Nyquist criteria (sampling of the continuous time pulse) should be satisfied at the level of the target fidelity. The pulse p(t) is "digitized" or sampled according to the Nyquist criterion. In some embodiments, the samples are then decomposed as described further below.

FIG. **12** is a block diagram of an exemplary digital filter **1201** employed to architect a digital 22 MHz output sample rate using the continuous time pulse p(t). In this case, an exemplary QPSK symbol generator **1203** provides an 11 MHz signal to respective inputs of each of a pair of polyphase digital filters **1205** and **1207**. The QPSK symbol generator **1203**, used as an exemplary transmitter for illustration, passes each symbol (a complex number) to both of the digital filters **1205** and **1207** at a rate of 11 MHz each. Each digital filter **1205** and **1207** samples the input waveform and generates an output at 11 MHz. The digital filter taps **1205** are composed of even numbered samples and the digital filter taps **1207** are composed of odd numbered samples of the pulse p(t). Select logic **1209**, such as multiplexor (MUX) circuitry or the like, selects every output of the polyphase digital filter taps **1205** and **1207** to achieve a 2(11)=22 MHz sample rate signal. FIG. **13** is a graph diagram illustrating the sampling and polyphase decomposition of the continuous time pulse p(t) (plotted versus time in microseconds, "μs"). Since every output of every filter is used, the effective sampling rate is 22 MHz.

FIG. **14** is a block diagram of another exemplary digital filter **1401** employed to architect a digital 20 MHz output sample rate using the pulse p(t). In this case, an exemplary QPSK symbol generator **1403**, similar to the generator **1203**, provides an 11 MHz signal to respective inputs of twenty polyphase digital filters **1405**, **1407**, **1409**, . . . **1411**. Each digital filter **1405**–**1411** generates an output at 11 MHz, so that the sampling rate is increased from 11 MHz to 220 MHz. Each filter consists of the samples spaced 20 samples apart. Select logic **1413**, such as multiplexor (MUX) circuitry or the like, selects one of every 11 outputs of the polyphase digital filters **1405**–**1411** to achieve a 20 MHz sample signal. For example, for the first QPSK symbol, the respective outputs of filters **1** and **11** are used and for the second QPSK symbol, the respective outputs of filters **19** and **10** are used, etc. Also, one out of every eleven input symbols will generate **1** output sample, whereas the remaining input samples each generate two output samples. FIG. **15** is a graph diagram illustrating the sampling and polyphase decomposition of the continuous time pulse p(t) plotted versus time. Since one out of every 11 outputs is used of the 220 MHz combined output of the filters **1405**–**1411**, the effective sampling rate is 20 MHz.

FIG. **16** is a block diagram of a transmitter **1601** implemented according to an embodiment of the present invention. The transmitter **1601** includes an OFDM Kernel block **1603** supplying the OFDM portion of the signal to a soft switch block **1607**, which receives the 802.11b preamble and header portion from an 802.11b preamble/header Kernel block **1605**. The soft switch block **1607** provides the 802.11 g signal to a digital to analog converter (DAC) **1609**, which provides a resulting analog signal to a low-pass filter (LPF) **1611**. The filtered signal is provided to a SAW filter **1613**, illustrating that linear distortions are induced on both signal segments. The output of the SAW filter **1613** is provided to one input of a mixer **1615**, having another input which receives a local oscillator (LO) signal from a local oscillator **1617**. The mixer **1615** asserts a mixed or combined signal at its output.

Distortions can be induced in the transmitter, multi-path channel and receiver. An obvious linear distortion in the transmitter is a SAW filter, such as the SAW filter **1613**. In communications systems, it is frequently assumed that linear distortions are common and (essentially) time-invariant across waveform symbols. For example, linear distortions are assumed common between the preamble/header and payload portions for both 802.11a and 802.11b communications. In a similar manner, linear distortions of the transmit radio are assumed to be common to both the single-carrier segment and the multi-carrier segment. In this manner, a spectral binding requirement is imposed to allow the equalizer information and the AGC to carry over from single- to multi-carrier.

The transmitter **1601** further illustrates a sample-power matching scheme to enable the AGC information to carry over from single-carrier to multi-carrier portions of the signal. In particular, it is desired that the average signal power output from the OFDM Kernel block **1603**, as shown at **1620**, be approximately the same as the average signal power output from the 802.11b preamble/header Kernel block **1605**, as shown at **1622**.

FIG. **17** is a graph diagram comparing the 11 MHz Barker chip clock shown at **1701** versus the 20 MHz OFDM sample clock shown at **1703**, both plotted versus time in μs. The 802.11b communication scheme uses a chip rate of 11 MHz. The 802.11b preamble/header uses 11 chip Barker words, so that there are 11 chips/μs. The 802.11a OFDM uses a 20 MHz sample rate. In the embodiment shown, in order to achieve transition time alignment, the 802.11b (11 MHz) and 802.11a (20 MHz) signal segments are aligned at the 1 MHz boundary, every 1 μs interval, illustrated by alignment epochs **1705** at each 1 μs interval. FIG. **18** is a conceptual graph diagram illustrating alignment of the OFDM signal portion with the last Barker word of the header of the single-carrier portion. The first chip of each Barker word, shown at **1803**, is centered on the 1 μs alignment. The first full 20 MHz sample of the OFDM signal, shown at **1801**, occurs 1 μs after the zero-phase peak of first chip of the last Barker word in the header. Effectively, one half-scale OFDM sample, shown at **1805**, occurs before the full scale sample (for smoothing). Such transition time alignment allows the equalizer information and the timing information to carry over between the single- and multi-phase portions of the signal.

FIG. **19** is a graph diagram illustrating normal OFDM symbol overlap. FIG. **20** is a graph diagram illustrating exemplary 802.11a OFDM symbol onset and termination. FIG. **21** is a graph diagram illustrating exemplary single-carrier termination, shaped consistent with 802.11a as shown at **2101**, and OFDM onset shaped identical to 802.11a, as shown at **2103**. As illustrated in these graph diagrams, the single-carrier is terminated in a controlled fashion when transitioning from single-carrier to multi-carrier. This single-carrier termination maintains the AGC at the point of transition, minimizes the signal power gap, which in turn minimizes the corruption of one signal by the other. The single-carrier termination of the 802.11b segment is similar to that used for 802.11a OFDM shaping. 802.11a specifies a windowing function for OFDM symbols, which is employed to define termination of single-carrier segment. The single-carrier signal is terminated in a predetermined window of time, such as nominally 100 nanoseconds (ns). It is not necessary to completely flush the single-carrier pulse-shaping filter. The resulting distortion to the last Barker word in the header is trivial compared to the 11 chips processing gain, thermal noise and multi-path distortion. The termination may be accomplished either explicitly in the digital signal processing or by analog filtering.

It is further desired that the carrier frequency be coherent for both waveform segments, achieved by using a single LO signal via the local oscillator **1617**. This allows the equalizer information to carry over. Carrier frequency lock may be maintained with a phase-lock loop (PLL) circuit or the like.

It is further desired that the carrier phase be aligned, which allows the equalizer information to carry over. FIG.

22A is a simplified graph diagram of a BPSK plot illustrating that BPSK incorporates both real and imaginary portions in two quadrants (1 of 2 phases). FIG. **22**B is a simplified graph diagram of a QPSK plot illustrating that QPSK incorporates both real and imaginary portions in all four quadrants (1 of 4 phases). The single-carrier signals, employing Direct Sequence Spread Spectrum (DSSS), are fundamentally different as compared to the OFDM signal format and modulation schemes. For 802.11 g CCK-ODFM, either of these formats are re-used for the header.

FIG. **23** is a series of graph diagrams illustrating the phase relationship between the last Barker word, rather than the last chip, in the 802.11 g header and subsequent OFDM symbol samples. Annex G of the 802.11a standard describes how to transmit an OFDM symbol including real and imaginary components. The arrows shown at **2301**, **2303**, **2305** and **2307** illustrate the four possible phases of the last Barker word. The phase of the OFDM symbol is determined by the phase of the last Barker word, in that each OFDM sample is either not rotated or rotated by the same, predetermined amount based on the phase of the last Barker word. The arrows shown at **2302**, **2304**, **2306** and **2308** represent the corresponding four relative phase shifts applied to the OFDM symbol corresponding to the Barker phase illustrated by arrows **2301**, **2303**, **2305** and **2307**, respectively. For example, if the phase of the last Barker word is in the first quadrant, then the phase of the OFDM symbols will be rotated by zero degrees (not rotated, or multiplied by 1) relative to the OFDM phase as described in Annex G of the 802.11a standard. Furthermore, if the phase of the last Barker word is in the second quadrant (135 degree phase rotation), then the phase of the OFDM symbols will be rotated by 90 degrees relative to the phase of the samples in 802.11a Annex G (i.e., multiplied by "j"); if the phase of the last Barker word is in the third quadrant (−135 degree phase rotation), then the phase of the OFDM symbols will be rotated by 180 degrees relative to the phase of the samples in 802.11a Annex G (i.e., multiplied by "−1"); and if the phase of the last Barker word is in the fourth quadrant (−45 degree phase rotation), then the phase of the OFDM symbols will be rotated by −90 degrees relative to the phase of the samples in 802.11a Annex G (i.e., multiplied by "−j").

In many design implementations, it is often desired to know the relative accuracy and fidelity requirements to maintain signal integrity and compatibility among different transceivers. In this manner, designers are able to reduce costs and maximize efficiency while maintaining parameters and characteristics within specification. The accuracy characteristic constrains the short-cuts the transmit designer may make which may otherwise significantly harm receiver performance. In one embodiment, the requisite fidelity of the entire waveform behavior is established using a metric based on the fidelity requirements of the OFDM signal of the 802.11a standard. Thus, the requisite fidelity of the single-carrier portion is the same as the multi-carrier portion even though the single-carrier portion is typically at a reduced data rate. As described in the 802.11a specification, the requisite fidelity for OFDM is set by the error vector magnitude (EVM) specification, as illustrated in the following Data Rate versus EVM Table 1:

TABLE 1

Data Rate versus EVM specification

Data Rate Mbps	EVM Spec
6	−5
9	−8
12	−10
18	−13
24	−16
36	−19
48	−22
54	−25

where data rate is specified in Mbps and EVM is specified in dB. As illustrated in Table 1, the OFDM accuracy is a function of the data rate. The higher the data rate, the more complex and intricate the transmit waveform, and the greater the accuracy necessary. This requisite fidelity is applied to the entire waveform. EVM is the same thing as mean-squared-error (MSE) normalize by the signal power. MSE may be measured after best-fit time alignment, best-fit gain alignment, and best-fit phase alignment. Also, linear distortion common to OFDM and the single-carrier Barker chips may be backed-out, if desired. If and when the 802.11b accuracy specification becomes more stringent, it may be used for the single-carrier portion.

Portions of 802.11b specification and all of the 802.11a specification employ a locked-oscillator requirement. A locked oscillator characteristic allows timing tracking information to be derived from carrier frequency and phase. There are two fundamental clocks in a transmit waveform: a symbol rate clock and a carrier frequency. In at least one embodiment of the transmitter, all of the 802.11 g signals have a symbol rate clock and carrier frequency derived from the same clock reference. It is further desired that the part-per-million (PPM) error on these two clock signals be equal. The receiver is allowed to track symbol rate timing from carrier frequency error.

The multi-carrier receiver **209** portion of the mixed signal receiver **201** obtains the behavior of the transition from the single-carrier receiver **207** of the waveform as described herein to receive the ODFM portion of the signal. The carrier frequency and phase is coherent. Furthermore, the time alignment, the signal level (AGC), and the channel impulse response (CIR) are each coherent. The single-carrier receiver **207** determines the CIR estimate during the single-carrier portion. The multi-carrier receiver **209** modifies the CIR estimate for the OFDM using the known pulse shape used by the single-carrier segment. In particular, the equalizer taps of the multi-carrier receiver **209** are modified using the known pulse shape used by the transmitter during the single-carrier preamble and header. In this manner, the multi-carrier receiver **209** does not have to reacquire the OFDM portion of the signal, but uses the information obtained by the single-carrier receiver **207** along with predetermined or known information for a smooth single-carrier to multi-carrier signal transition. Also, a separate OFDM preamble/header is not necessary, although it may be employed for both convenience and fine tuning, if desired.

Although a system and method according to the present invention has been described in connection with the preferred embodiment, it is not intended to be limited to the specific form set forth herein, but on the contrary, it is intended to cover such alternatives, modifications, and equivalents, as can be reasonably included within the spirit and scope of the invention.

What is claimed is:

1. A wireless communication system that is configured to communicate using a mixed waveform configuration, comprising:

a transmitter configured to transmit according to a mixed waveform configuration including a first portion modulated according to a single-carrier scheme with a preamble and header and a second portion modulated according to a multi-carrier scheme;

the waveform being specified so that a channel impulse response estimate obtainable from the first portion is reusable for acquisition of the second portion; and

a receiver configured to acquire and receive packets with a mixed waveform configuration.

2. The wireless communication system of claim **1**, wherein the transmitter maintains power, carrier phase, carrier frequency, timing, and multi-path spectrum between the first and second portions of the waveform.

3. The wireless communication system of claim **2**, wherein the transmitter comprises:

a first kernel that modulates the first portion according to the single-carrier modulation scheme;

a second kernel that generates the second portion according to the multi-carrier modulation scheme; and

a switch, coupled to the first and second kernels, that selects the first kernel for the first portion and the second kernel for the second portion to develop a transmit waveform.

4. The wireless communication system of claim **3**, wherein the first kernel operates at a first sample rate and wherein the second kernel operates at a second sample rate.

5. The wireless communication system of claim **3**, wherein the first kernel employs a single-carrier spectrum that resembles a multi-carrier spectrum of the multi-carrier modulation scheme.

6. The wireless communication system of claim **5**, wherein the first kernel employs a time shaping pulse that is specified in continuous time.

7. The wireless communication system of claim **6**, wherein the time shaping pulse is derived employing an infinite impulse response of a brick wall approximation that is truncated using a continuous-time window that is sufficiently long to achieve desired spectral characteristics and sufficiently short to minimize complexity.

8. The wireless communication system of claim **6**, wherein the first kernel samples the time shaping pulse according to a Nyquist criterion.

9. The wireless communication system of claim **3**, wherein the average output signal power of the first kernel and the average output signal power of the second kernel are maintained substantially equal.

10. The wireless communication system of claim **3**, wherein the single-carrier modulation scheme is according to 802.11b Barkers and wherein the multi-carrier modulation scheme is according to the 802.11a standard employing orthogonal frequency division multiplexing (OFDM).

11. The wireless communication system of claim **3**, wherein the first kernel employs a first sample rate clock, wherein the second kernel employs a second sample rate clock, wherein the first and second sample rate clocks are aligned at predetermined timing intervals, and wherein a first full sample of the multi-carrier modulation scheme begins one timing interval after the beginning of a last sample of the single-carrier modulation scheme.

12. The wireless communication system of claim **3**, wherein the single-carrier signal from the first kernel is terminated according to a windowing function specified for OFDM signal shaping defined in the 802.11a standard.

13. The wireless communication system of claim **3**, wherein carrier frequency is coherent between the first and second kernels.

14. The wireless communication system of claim **3**, wherein carrier phase is coherent between the first and second kernels.

15. The wireless communication system of claim **14**, wherein carrier phase of the second kernel multi-carrier signal is determined by carrier phase of a last portion of the second kernel single-carrier signal.

16. The wireless communication system of claim **15**, wherein carrier phase of the second kernel multi-carrier signal is rotated by a corresponding one of a plurality of rotation multiples, each rotation multiple corresponding to one of a plurality of predetermined phases of the last portion of the second kernel single-carrier signal.

17. The wireless communication system of claim **16**, wherein the first kernel single-carrier modulation scheme is according to 802.11b Barkers in which each Barker word is one of first, second, third and fourth possible phases, wherein the second kernel multi-carrier modulation scheme is according to OFDM as defined in Annex G of the 802.11a standard, and wherein OFDM symbol are rotated by the second kernel by zero if the last Barker word has the first phase, by 90 degrees if the last Barker word has the second phase, by 180 degrees if the last Barker word has the third phase, and by −90 degrees if the last Barker word has the fourth phase.

18. The wireless communication system of claim **3**, wherein a requisite fidelity of the entire mixed waveform configuration is specified by a requisite fidelity specified for the multi-carrier scheme.

19. The wireless communication system of claim **18**, wherein the requisite fidelity is a function of data rate of the second portion and is determined by mean-squared-error normalized by signal power as specified for OFDM in the 802.11a standard.

20. The wireless communication system of claim **2**, wherein a symbol rate clock and a carrier frequency of the waveform are derived from the same reference clock.

21. The wireless communication system of claim **20**, wherein part per million (PPM) error of a clock fundamental for symbol rate and PPM error of a clock fundamental for carrier frequency are substantially equal.

22. The wireless communication system of claim **2**, wherein the receiver comprises:

a single-carrier receiver;

a multi-carrier receiver, coupled to the single-carrier receiver; and

a switch, coupled to the single-carrier receiver and the multi-carrier receiver, that provides a first portion of a signal being received to the single-carrier receiver and that provides a second portion of the signal being received to the multi-carrier receiver;

wherein the single-carrier receiver acquires a first portion of an incoming signal including the preamble and header and determines a channel impulse response (CIR) estimate, and wherein the multi-carrier receiver uses the CIR estimate for a second portion of the incoming signal.

23. The wireless communication system of claim **22**, further comprising:

the single-carrier receiver including a first equalizer, wherein the single-carrier receiver programs taps of the first equalizer based on the CIR estimate; and

the multi-carrier receiver including a second equalizer, and wherein the multi-carrier receiver modifies taps of the second equalizer based on the CIR estimate determined by the first equalizer.

* * * * *

EXHIBIT H

US006977944B2

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

(10) **Patent No.: US 6,977,944 B2**
(45) **Date of Patent: Dec. 20, 2005**

(54) **TRANSMISSION PROTECTION FOR COMMUNICATIONS NETWORKS HAVING STATIONS OPERATING WITH DIFFERENT MODULATION FORMATS**

(75) Inventors: **Ronald A. Brockmann**, Utrecht (NL); **Maarten Hoeben**, Amersfoort (NL); **Maarten Menzo Wentink**, Utrecht (NL)

(73) Assignee: **Conexant, Inc.**, Newport Beach, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 268 days.

(21) Appl. No.: **10/295,596**

(22) Filed: **Nov. 15, 2002**

(65) **Prior Publication Data**

US 2003/0133469 A1 Jul. 17, 2003

Related U.S. Application Data

(60) Provisional application No. 60/347,412, filed on Jan. 12, 2002.

(51) **Int. Cl.**[7] **H04L 12/43**
(52) **U.S. Cl.** **370/461**; 370/445
(58) **Field of Search** 370/431, 433, 370/437, 445, 450, 456, 461, 462, 464, 471, 370/483, 487, 341, 329, 322, 348, 349, 373, 370/377, 384, 389, 392, 439, 443, 447, 454, 370/203, 310, 235, 229, 236, 455, 459

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,719,620	A *	1/1988	Machino et al.	370/445
5,231,634	A	7/1993	Giles et al.	
5,502,724	A	3/1996	Chen	
5,706,428	A	1/1998	Boer	
5,844,905	A	12/1998	McKay	
5,940,399	A	8/1999	Weizman	
6,078,588	A *	6/2000	Dove et al.	370/412
6,195,334	B1	2/2001	Kadambi et al.	
6,240,083	B1	5/2001	Wright	
6,404,756	B1	6/2002	Whitehill	
6,469,997	B1	10/2002	Dorenbosch et al.	

FOREIGN PATENT DOCUMENTS

EP 1 178 630 A1 2/2002

OTHER PUBLICATIONS

Joa-Ng M et al: "Spread spectrum medium access protocol with collision avoidance in mobile ad-hoc wireless network" INFOCOM '99. Mar. 21, 1999, pp. 776-783, IEEE, Piscataway, NJ.

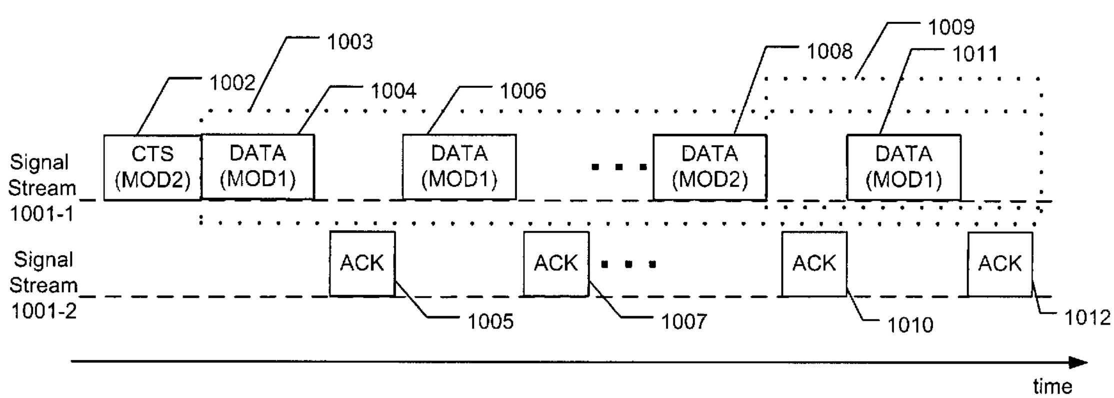
(Continued)

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

(57) **ABSTRACT**

A technique to allow enhanced stations and legacy stations to work with each other without the inefficiencies of signaling overhead in the prior art is disclosed. An enhanced station transmits an initial, short frame using a modulation compatible with legacy stations. The frame sets the duration for a frame exchange—consisting of a data frame, followed by acknowledgement frame—in which the data frame is transmitted using an enhanced modulation format. The duration specified in the transmitted initial frame covers the time interval of the subsequent frame exchange. All stations, including legacy stations, listen in on the frame exchange and refrain subsequently from transmitting spontaneously for the time interval covered by the duration. Alternatively, the frame exchange can comprise multiple data frames with corresponding acknowledgement frames. The enhanced station can also transmit, during the remaining frame exchange, one or more intermediate frames that indicate duration.

24 Claims, 11 Drawing Sheets



OTHER PUBLICATIONS

Halford S et al: "CCK-OFDM Normative Text Summary" IEEE Standard Submission, Online—Jul. 2001 pp. 1-42, <URL: http://grouper.ieee.org/groups/802/11/Documents/DocumentHolder/1-4.

Halford S et al: "OFDM as a High Rate Extension to the CCK-based 802.11b Standard" IEEE Standard Submission, Mar. 2001 pp. 1-35.

Halford S et al: "Proposed Draft Text:B+A=G High Rate Extension to the 802.11b Standard" IEEE Proposed Standard, Nov. 2001 pp. 1-68.

IEEE: "Draft Supplement to IEEE Std 802.11, 1999 Edition" IEEE Standard Draft, Jul. 2001 pp. 1-29, Retrieved from the Internet.

* cited by examiner

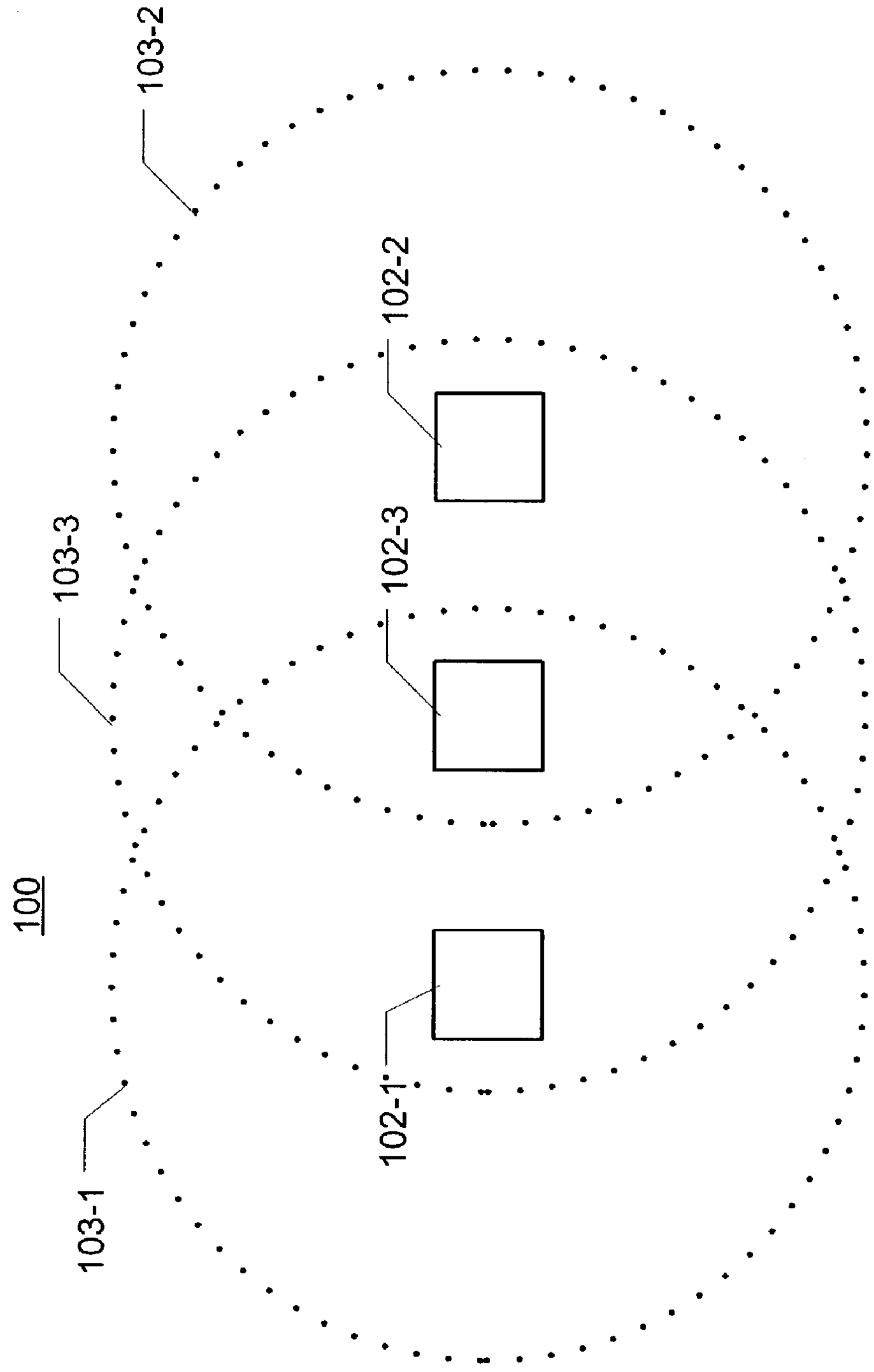


FIG. 1 (Prior Art)

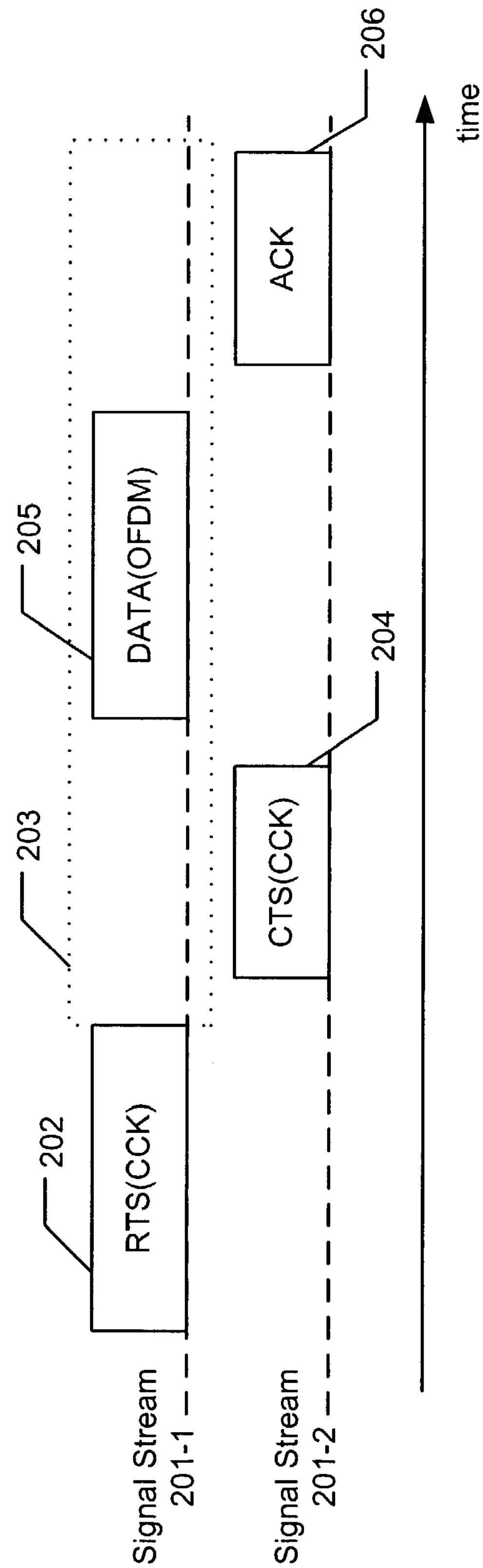


FIG. 2 (Prior Art)

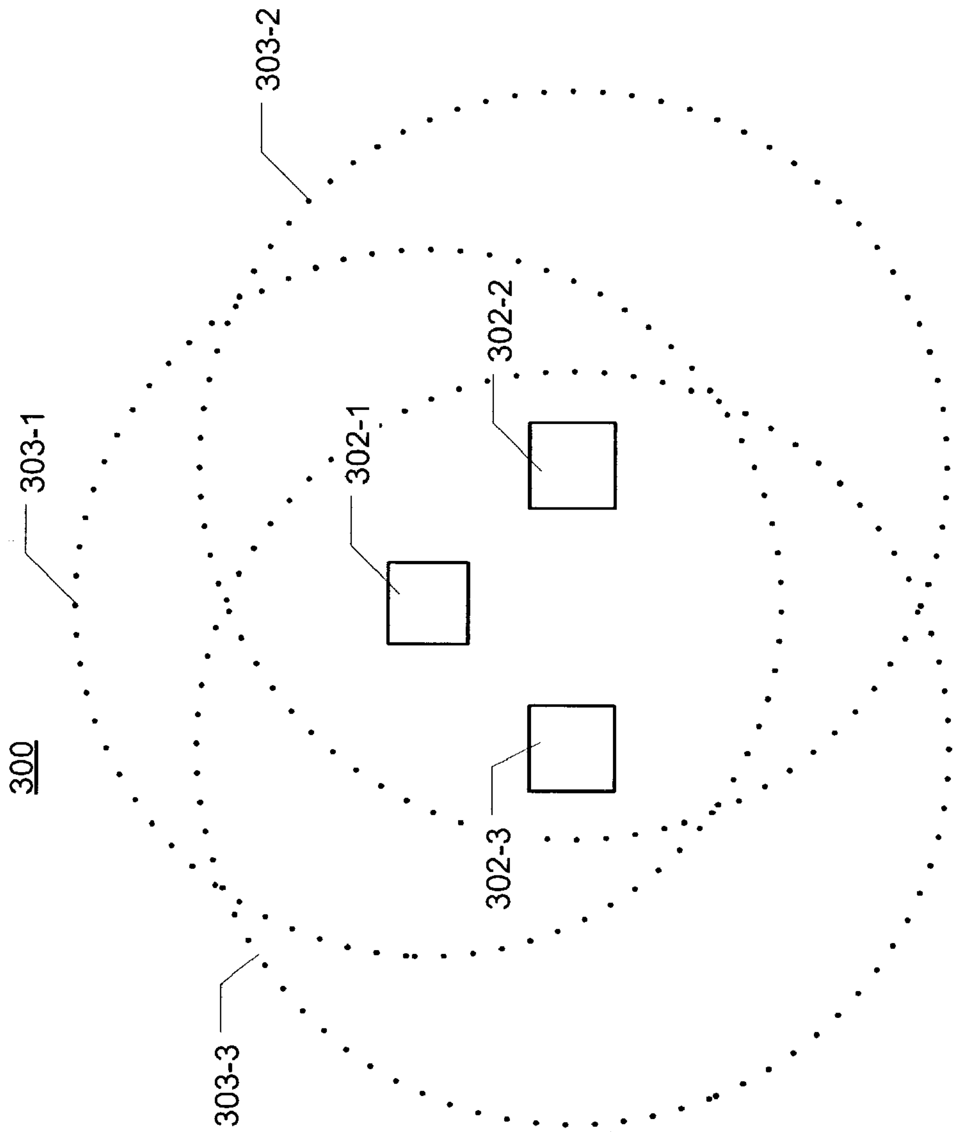
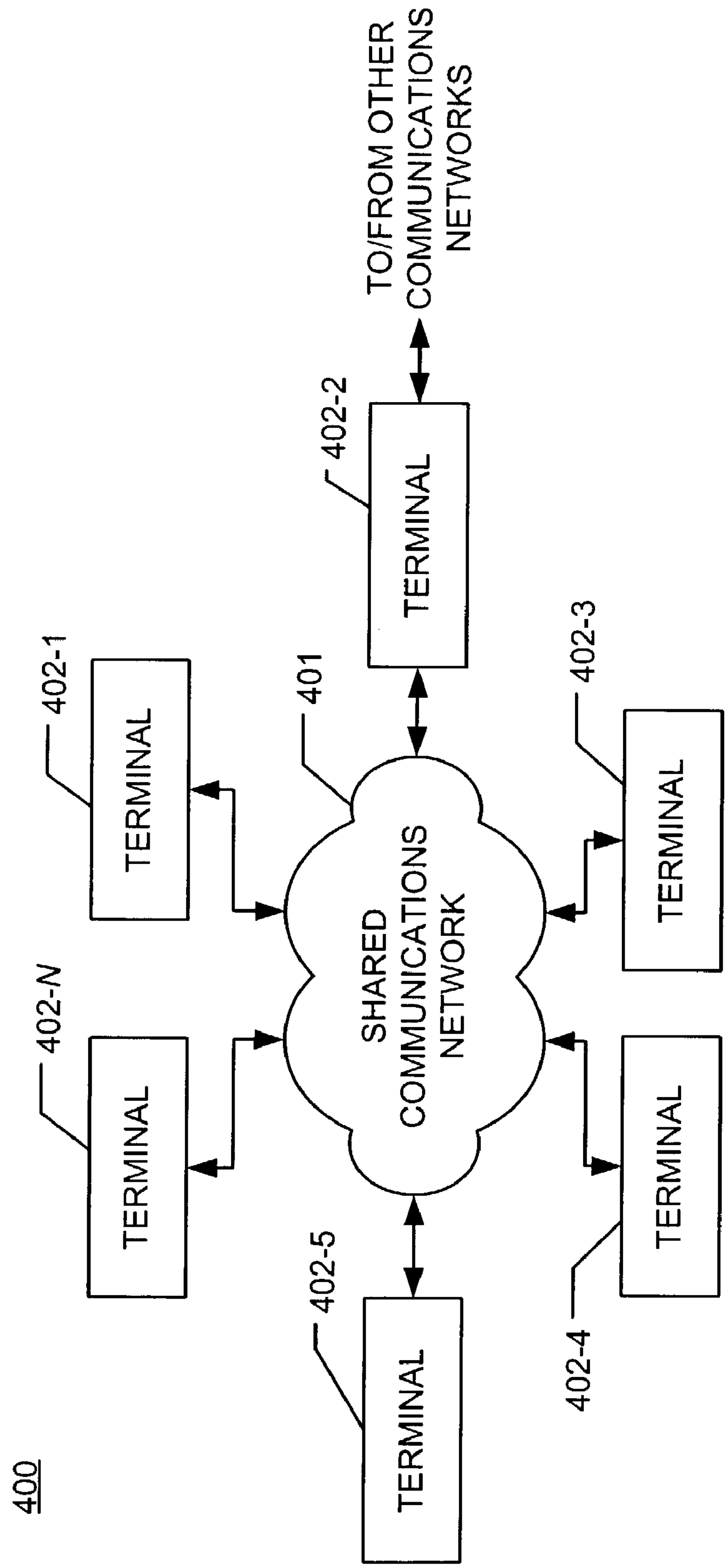


FIG. 3 (Prior Art)



TO/FROM OTHER COMMUNICATIONS NETWORKS
402-2
TERMINAL
402-1
TERMINAL
401
SHARED COMMUNICATIONS NETWORK
402-3
TERMINAL
402-N
TERMINAL
TERMINAL
402-5
TERMINAL
402-4
400

FIG. 4

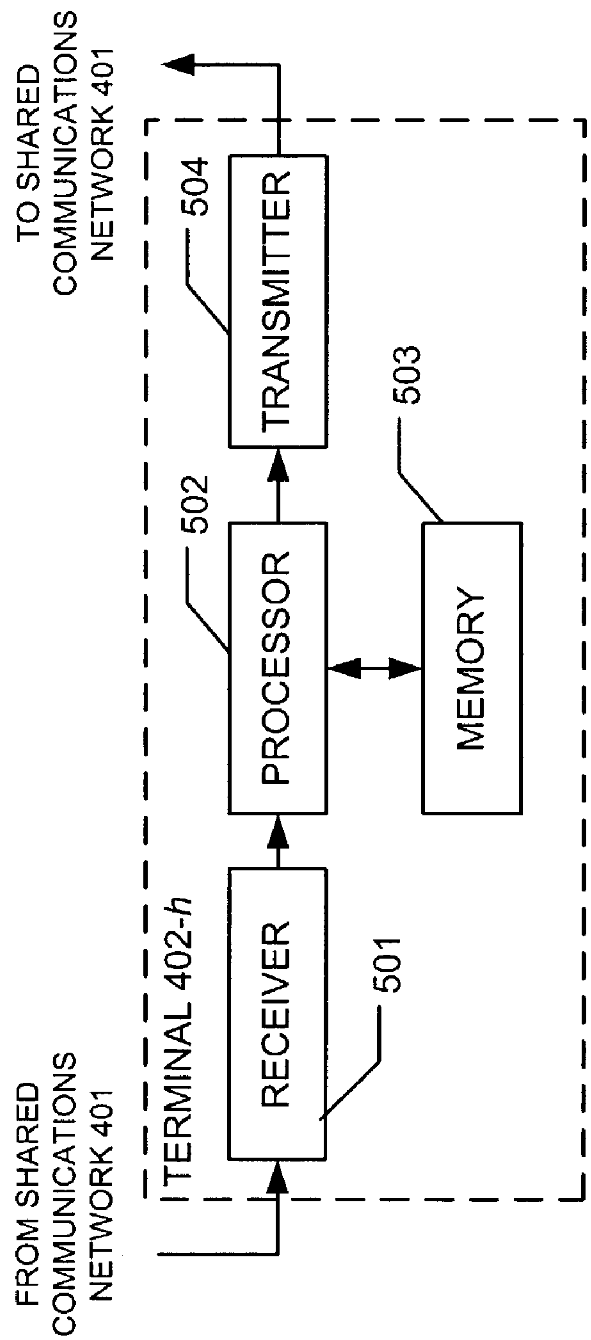

FROM SHARED COMMUNICATIONS NETWORK 401
TERMINAL 402-*h*
RECEIVER
501
PROCESSOR
502
MEMORY
503
TRANSMITTER
504
TO SHARED COMMUNICATIONS NETWORK 401

FIG. 5

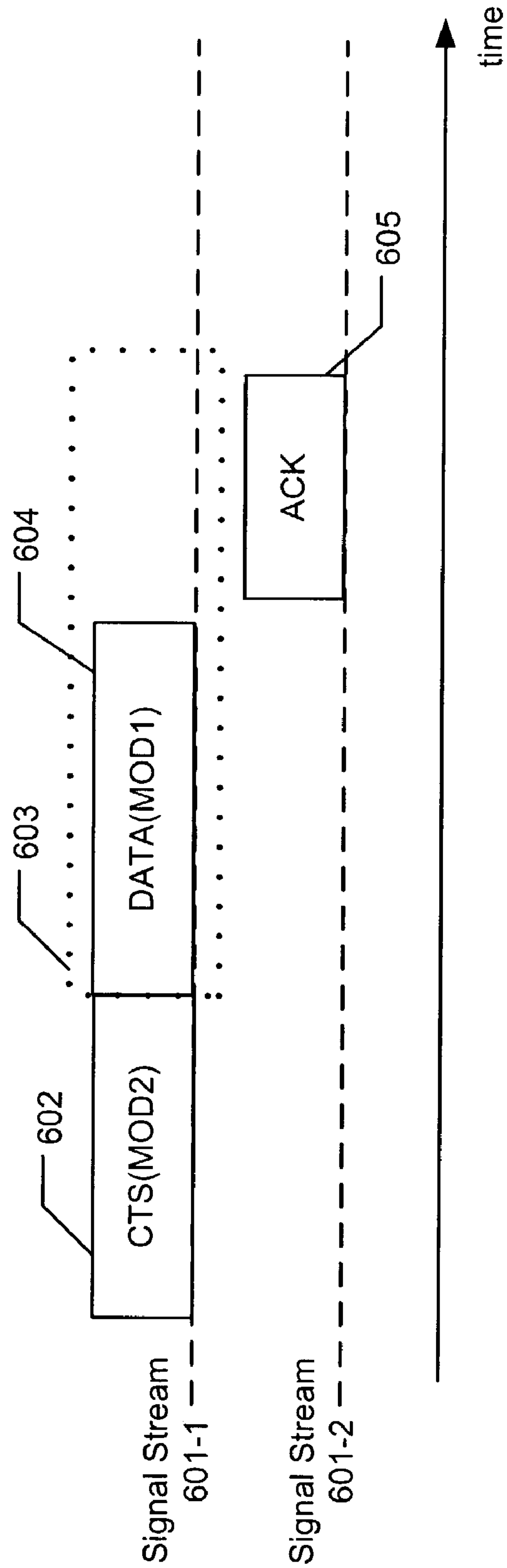
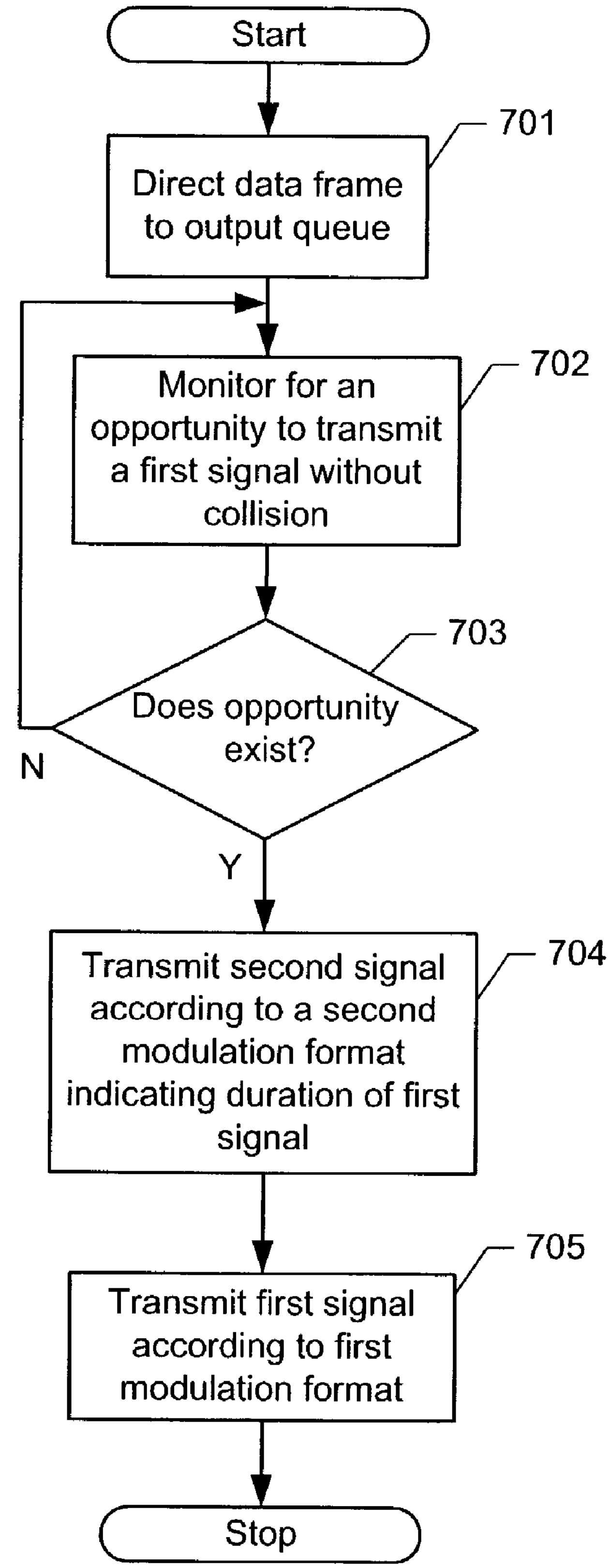

time
605
604
603
602
ACK
DATA(MOD1)
CTS(MOD2)
Signal Stream 601-1
Signal Stream 601-2

FIG. 6

FIG.7


Start
701
Direct data frame to output queue
702
Monitor for an opportunity to transmit a first signal without collision
703
Does opportunity exist?
N
Y
704
Transmit second signal according to a second modulation format indicating duration of first signal
705
Transmit first signal according to first modulation format
Stop

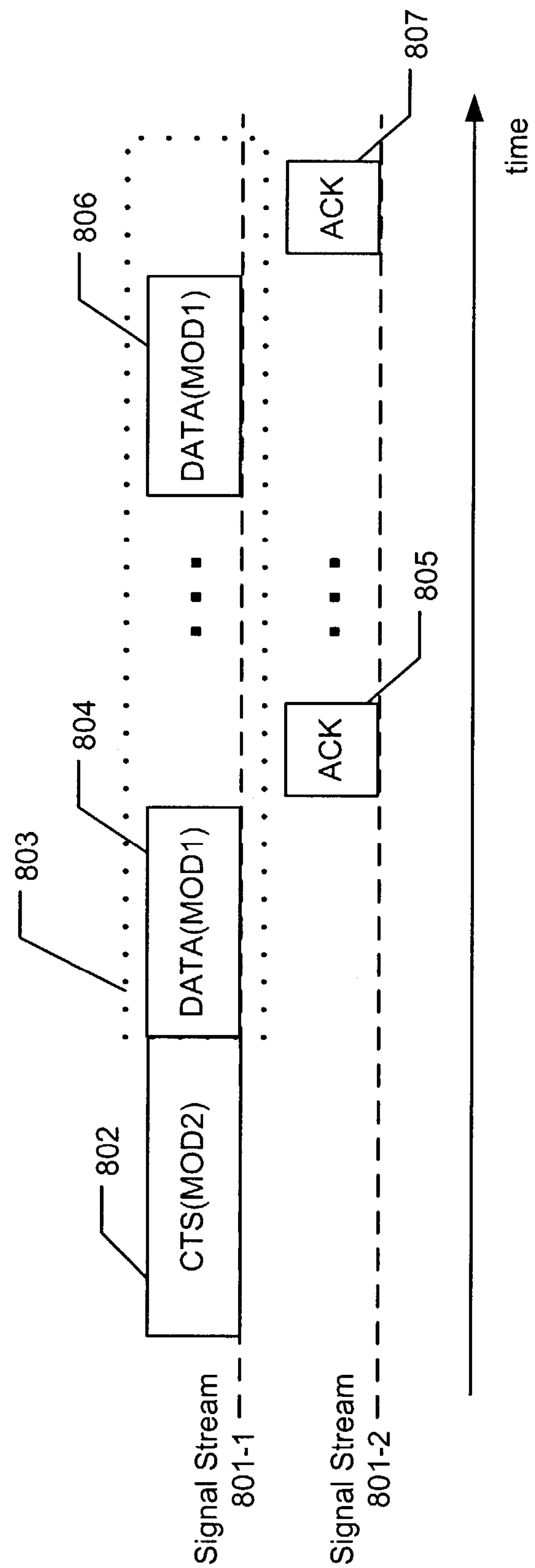

807
time
ACK
806
DATA(MOD1)
805
ACK
804
803
DATA(MOD1)
802
CTS(MOD2)
Signal Stream 801-1
Signal Stream 801-2

FIG. 8

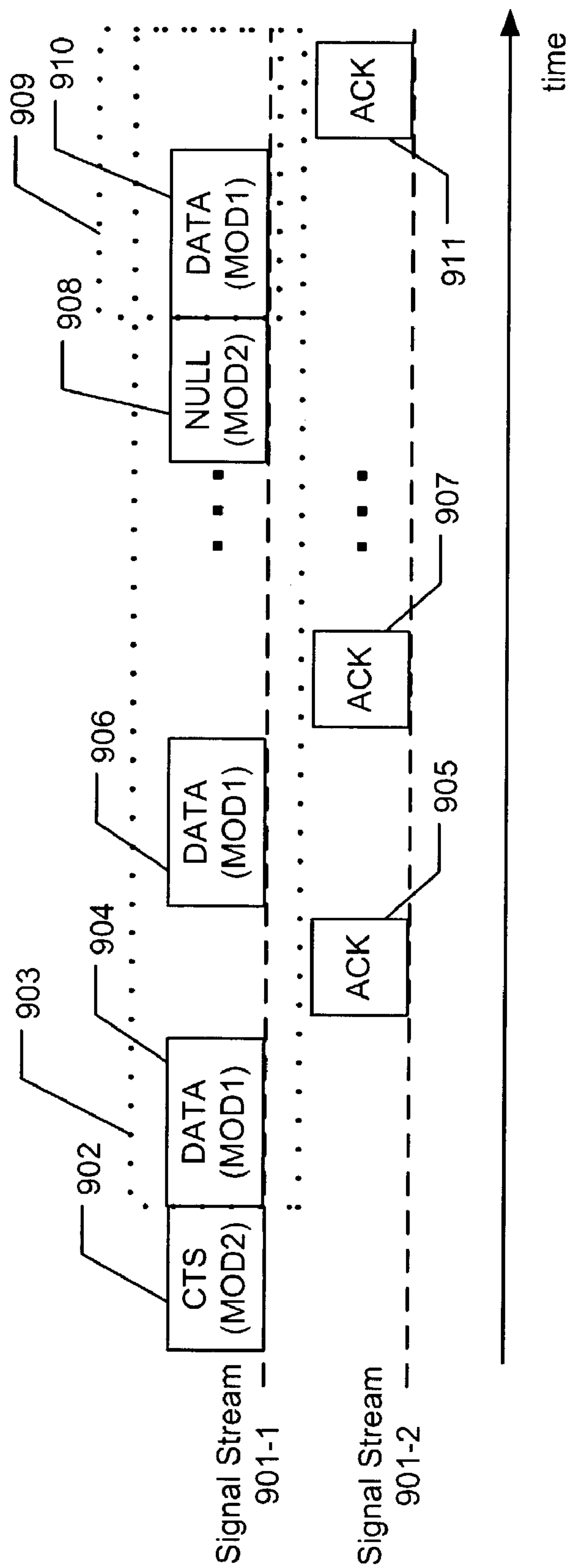

CTS (MOD2)
DATA (MOD1)
DATA (MOD1)
NULL (MOD2)
DATA (MOD1)
ACK
ACK
ACK
902
903
904
905
906
907
908
909
910
911
Signal Stream 901-1
Signal Stream 901-2
time

FIG. 9

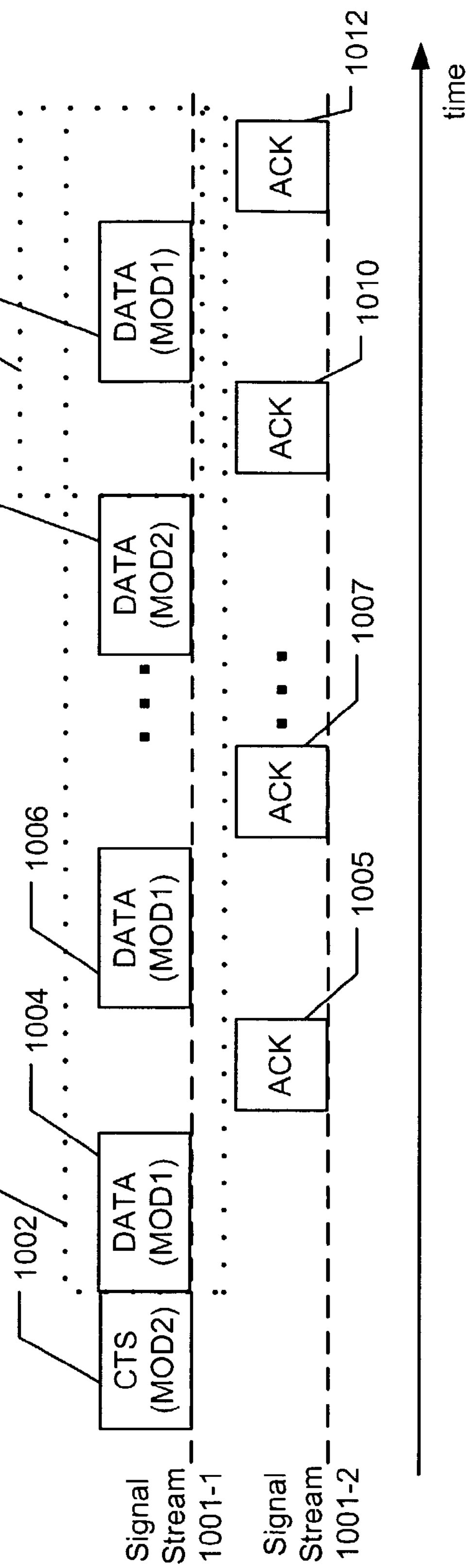
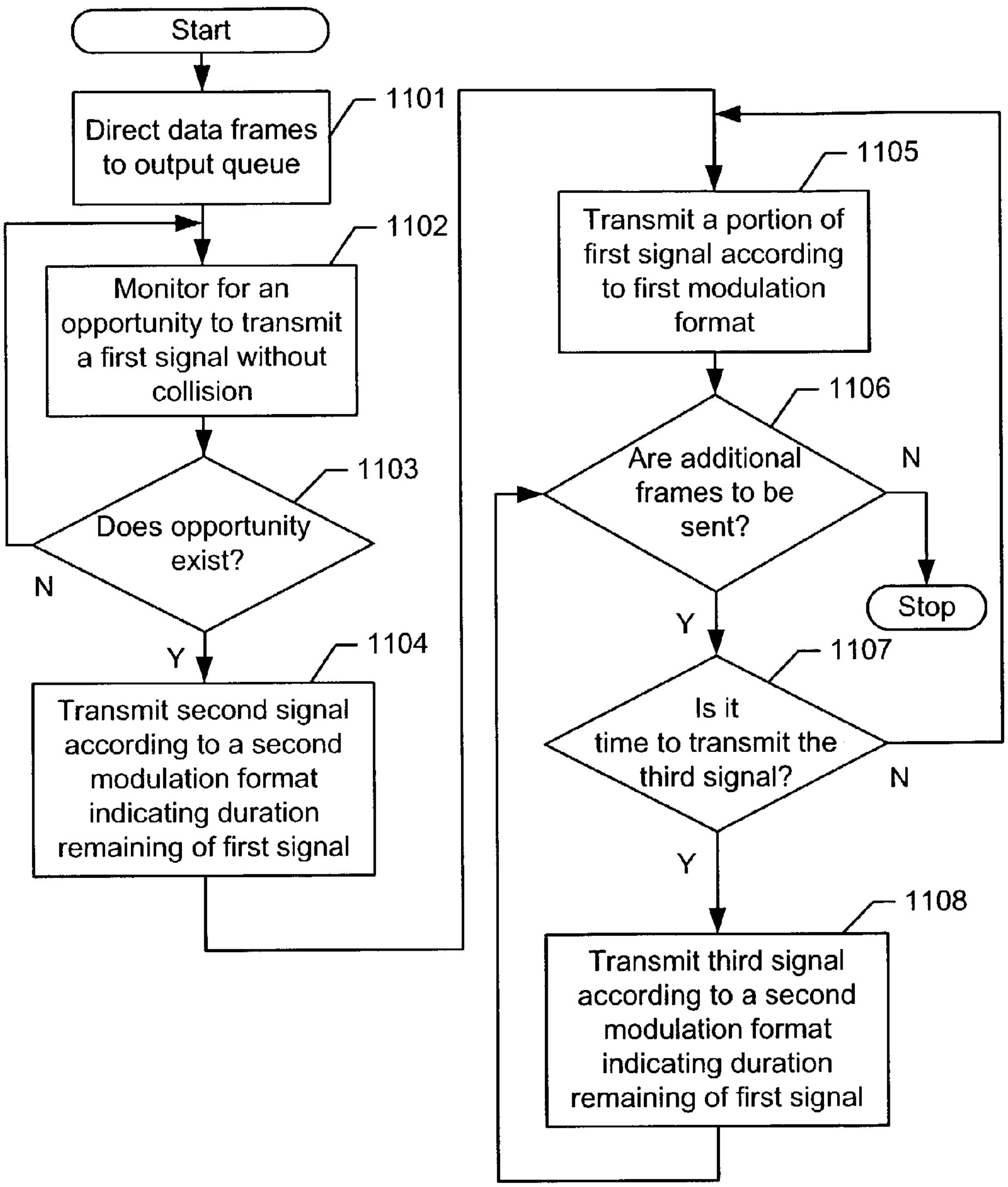

CTS (MOD2)
DATA (MOD1)
DATA (MOD1)
DATA (MOD2)
DATA (MOD1)
ACK
ACK
ACK
ACK
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
Signal Stream 1001-1
Signal Stream 1001-2
time

FIG. 10

FIG.11



Start
Direct data frames to output queue
1101
Monitor for an opportunity to transmit a first signal without collision
1102
Does opportunity exist?
1103
N
Y
Transmit second signal according to a second modulation format indicating duration remaining of first signal
1104
Transmit a portion of first signal according to first modulation format
1105
Are additional frames to be sent?
1106
N
Stop
Y
Is it time to transmit the third signal?
1107
N
Y
Transmit third signal according to a second modulation format indicating duration remaining of first signal
1108

TRANSMISSION PROTECTION FOR COMMUNICATIONS NETWORKS HAVING STATIONS OPERATING WITH DIFFERENT MODULATION FORMATS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application Ser. No.: 60/347,412, entitled "Transmission Protection For Wireless LAN Stations Operating With Different Modulation Formats," filed on Jan. 12, 2002 and incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to communications protocols in general, and, more particularly, to techniques for reducing the likelihood of collisions between data packets in wireless communications channels.

BACKGROUND OF THE INVENTION

The IEEE 802.11 set of protocols includes 802.11(b) and 802.11(a). Also known as 802.11 High Rate or Wi-Fi (i.e., "wireless fidelity"), the 802.11(b) approach was approved by the IEEE in 1999 and is currently the mainstream technology adopted by wireless device manufacturers. Essentially using a Direct-Sequence Spread Spectrum (DSSS) technique, 802.11(b) uses a modulation scheme known as Complementary Code Keying (CCK) to transmit data signals at 11 megabits per second (Mbps) over an unlicensed portion of the radio frequency spectrum at around 2.4 GHz. IEEE 802.11(b) enabled a new generation of products to communicate wirelessly with an Ethernet-like connection. Unfortunately, however, the speed of 802.11(b) is only one-tenth that of its wired counterpart, IEEE 802.3.

The IEEE 802.11(a) standard was approved concurrently with 802.11(b), but utilizes Orthogonal Frequency Division Multiplexing (OFDM) as the modulation technique for signal transmission. OFDM is not compatible with 802.11 (b) devices because they use CCK modulation. IEEE 802.11 (a) technology can transmit data signals at up to 54 Mbps and operates in the 5 GHz frequency spectrum.

It would be desirable to extend the benefits of higher bit rate OFDM transmission to the 2.4 GHz band, which, between the two modulations, is the exclusive domain of the CCK scheme of 802.11(b). The IEEE 802.11(g) standard attempts to merge these operational characteristics together. IEEE 802.11(g) OFDM transmissions, however, are hidden from the legacy 802.11(b) nodes, because the 802.11(b) "physical carrier sense mechanism," explained shortly, does not detect the OFDM carrier.

In the prior art, 802.11(g) nodes can fall back to the "virtual carrier sense mechanism" to protect OFDM transmissions from colliding (i.e., experiencing collisions) with transmissions using other modulations. The 802.11 medium access control (MAC) is based around a collision avoidance mechanism, meaning that nodes defer to an active transmission because they see that the shared channel (or "medium") is busy. Their clear channel assessment is a mechanism that senses a physical carrier on the medium.

Furthermore, the MAC protocol defines a virtual carrier sense mechanism, in addition to the traditional physical carrier sense mechanism. To implement the virtual carrier sense mechanism, each node maintains a network allocation vector (NAV) counter that indicates whether the medium

must be considered busy or not. After each frame reception at a node (whether the frame has been directed to the node or not), the node initializes its NAV counter with a duration value that is obtained from the duration field in the frame header of the received frame. Over time, this duration value decrements down until it reaches zero, indicating that it is presumptively safe to transmit. Conversely, a non-zero NAV value indicates that the virtual carrier sense (and the share channel) is busy.

An acknowledgement (ACK) frame acknowledges receipt of each transmitted data frame. The ACK frame is NAV protected by the preceding data frame, in which the duration field in the data frame specifies a duration value that reserves the medium until the end of the ACK transmission. Alternatively, the first frame transmitted in a signal stream can carry a value in the duration field that covers the entire remaining frames exchanged, possibly comprising multiple data frames and ACK frames. In other words, the duration value covers the subsequent frame exchange, in which each frame exchange is typically one or more pairs of a data frame responded to with an ACK frame.

The virtual carrier sense mechanism, a familiar part of the 802.11 standard, has been previously used to solve a different problem unique to wireless networks. First and second nodes can potentially be separated by a distance greater than their respectively transmitted signals (carriers) can reach, while an intermediate third node can be close enough to each of the first and second nodes to hear both signals.

FIG. **1** depicts telecommunications system **100** of the prior art, comprising nodes **102-1**, **102-2**, and **102-3**. Rings **103-1**, **103-2**, and **103-3** represent the respective limits of signal coverage for nodes **102-1**, **102-2**, and **102-3**. As depicted, ring **103-1** does not encompass node **102-2**, and ring **103-2** does not encompass node **102-1**, meaning that the signals from each of the two nodes does not reach the other node. In the example, the intermediate third node (i.e., node **102-3**) is already receiving from the first node (i.e., node **102-1**), and the second node (i.e., node **102-2**) has data packets to transmit. The situation can arise that the second node will not defer its transmission, but instead will also try to transmit and, in the process, potentially corrupt the active transmission from the first node. In the example, nodes **102-1** and **102-2** are essentially hidden from each other.

If a hidden node case is suspected, then 802.11 nodes can invoke an RTS/CTS mechanism of the prior art before any data transmission, depicted in FIG. **2**. This means that prior to sending a data frame, a node transmits, as part of its signal stream **201-1**, Request to Send (RTS) frame **202**, which contains a duration value that covers interval **203** needed for the pending data transmission, including data frame **205** and ACK frame **206**. RTS frame **202** will set the NAV locally around the sender using this duration value. If the medium is free around the receiver, it responds, as part of its signal stream **201-2**, with Clear to Send (CTS) frame **204**, which sets the NAV for all other nodes in the vicinity of the receiver. After the RTS/CTS exchange, other nodes in the areas around the sending and receiving nodes defer their transmission through the virtual carrier sense mechanism.

Although the RTS/CTS mechanism provides interoperability with legacy stations, it is suboptimal because it requires the transmission of two CCK frames (RTS and CTS) prior to the OFDM transmission. The RTS/CTS mechanism is targeted specifically at hidden node situations, in which the area at both the sender and the receiver must be NAV protected, each by a different frame. NAV protection, however, does not necessarily have to be imposed in all

OFDM transmissions, especially where it is known that no hidden nodes exist, as shown in the configuration of FIG. **3**.

Telecommunications system **300** of the prior art comprises nodes **302-1**, **302-2**, and **302-3**, each with a limit of signal coverage represented by rings **303-1**, **303-2**, and **303-3**, respectively. Note that all three nodes are in each of the three areas of signal coverage, signifying that no hidden nodes exist in the configuration. In such a situation where no hidden nodes exist—a property that can be readily determined—it is disadvantageous to use the additional overhead of the RTS/CTS mechanism.

The need exists for a technique to allow enhanced stations and legacy stations to work with each other without the inefficiencies of signaling overhead in the prior art.

SUMMARY OF THE INVENTION

The present invention provides a technique to allow enhanced stations and legacy stations to work with each other without the inefficiencies of signaling overhead in the prior art.

In accordance with the illustrative embodiment of the present invention, an enhanced station transmits an initial, short frame using a modulation compatible with legacy stations. The frame sets the duration for a frame exchange—consisting of a data frame, followed by acknowledgement frame—in which the data frame is transmitted using an enhanced modulation format. The duration specified in the transmitted initial frame covers the time interval of the subsequent frame exchange. All stations, including legacy stations, listen in on the frame exchange and refrain subsequently from transmitting spontaneously for the time interval covered by the duration. This protects the frame exchange, even where legacy stations are incapable of listening in on the enhanced modulation. Alternatively, the frame exchange can comprise multiple data frames with corresponding acknowledgement frames.

An additional means of providing protection of the frame exchange, in accordance with another illustrative embodiment of the present invention, is by the enhanced station transmitting, during the remaining frame exchange, one or more intermediate frames that indicate duration. The enhanced station transmits the intermediate protection frame or frames using the legacy-compatible modulation. In accordance with a variation of the illustrative embodiment, each intermediate frame can also carry actual data.

The illustrative embodiment of the present invention comprises: directing to an output queue at a station a data frame to be transmitted over a shared communications network; monitoring at the station for an opportunity to transmit a first signal without colliding with signals present on the shared communications network wherein the first signal, when transmitted, is modulated according to a first modulation format and conveys the data frame; and responsive to identifying an opportunity to transmit without colliding with signals present on the shared communications network, transmitting during the opportunity a second signal modulated according to a second modulation format prior to transmitting the first signal, wherein the second signal indicates the duration of the frame exchange of the first signal and corresponding acknowledgement.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a schematic diagram of the respective coverage areas of three communication nodes, hidden nodes present, in the prior art.

FIG. **2** depicts a message flow diagram of transmissions between two communication nodes in the prior art.

FIG. **3** depicts a schematic diagram of the respective coverage areas of three communication nodes, no hidden nodes present, in the prior art.

FIG. **4** depicts a schematic diagram of the illustrative embodiment of the present invention.

FIG. **5** depicts a block diagram of the salient components of station **402**-x, for x=1 through N, in accordance with the illustrative embodiment of the present invention.

FIG. **6** depicts a message flow diagram of the first variation of the first embodiment of the present invention.

FIG. **7** depicts a flowchart of the tasks performed by an enhanced station in transmitting a frame in the first embodiment of the present invention.

FIG. **8** depicts a message flow diagram of the second variation of the first embodiment of the present invention.

FIG. **9** depicts a message flow diagram of the first variation of the second embodiment of the present invention.

FIG. **10** depicts a message flow diagram of the second variation of the second embodiment of the present invention.

FIG. **11** depicts a flowchart of the tasks performed by an enhanced station in transmitting a frame in the second embodiment of the present invention.

DETAILED DESCRIPTION

FIG. **4** depicts a schematic diagram of the illustrative embodiment of the present invention, telecommunications system **400**, which transmits signals between stations (i.e., nodes) **402-1** through **402**-N, wherein N is a positive integer, over shared communications network **401**. Each of stations **402-1** through **402**-N can be a stationary, portable, or mobile type with different types in the mix.

In accordance with the illustrative embodiment, telecommunications system **400** is a packet-switched network, in contrast to a circuit-switched network, as is well known to those skilled in the art. In other words, a macro data structure (e.g., a text file, a portion of a voice conversation, etc.) of indefinite size is not necessarily transmitted across shared communications network **401** intact, but rather might be transmitted in small pieces.

Each of these small pieces is encapsulated into a data structure called a "data frame," and each data frame traverses shared communications network **401** independently of the other data frames. The intended receiver of the macro data structure collects all of the data frames as they are received, recovers the small pieces of data from each, and reassembles them into the macro data structure. This process is described in more detail below.

Shared communications network **401** can be a wireless or wireline or hybrid wireless and wireline network. A salient characteristic of shared communications network **401** is that every data frame transmitted on shared communications network **401** by any station is received or "seen" by every station on shared communications network **401**, regardless of whether the data frame was intended for it or not. In other words, shared communications network **401** is effectively a broadcast medium.

If shared communications network **401** is wireless, in whole or in part, embodiments of the present invention can use a variety of radio or optical frequencies and transmission methods. Possible radio frequency spectrum, if used, includes the Industrial, Scientific, and Medical (ISM) frequency band in the range of 2.4 GHz. Shared communications network **401** could be a wireless local area network.

It will be clear to those skilled in the art how to make and use shared communications network **401**. It will also be clear to those skilled in the art that the shared communications network depicted in FIG. **4** is illustrative only and that other types of communications networks are within the scope of the present invention.

Stations **402-1** through **402**-N receive or generate the macro data structure and prepare it for transmission over shared communications network **401**. The macro data structure can represent, for example, telemetry, text, audio, video, etc. Alternatively, one or more of stations **402-1** through **402**-N (e.g., station **402-2**, etc.) can function as gateways between shared communications network **401** and other communications networks. In functioning as a gateway, a station receives the macro data structure from another communications network.

FIG. **5** depicts a block diagram of the salient components of station **402**-x, for x=1 through N, in accordance with the illustrative embodiment of the present invention. Receiver **501** comprises the wireless or wireline or hybrid wireless and wireline interface circuitry that enables station **402**-x to receive data frames from communications network **401**. When receiver **501** receives a data frame from shared communications network **401**, it passes the data frame to processor **502** for processing. It will be clear to those skilled in the art how to make and use receiver **501**.

Processor **502** is a general-purpose or special-purpose processor that is capable of performing the functionality described below and with respect to FIG. **6** through **10**. In particular, processor **502** is capable of storing data into memory **503**, retrieving data from memory **503**, and of executing programs stored in memory **503**. Memory **503** accommodates input queues and output queues for incoming data and outgoing messages (including data frames), respectively. It will be clear to those skilled in the art how to make and use processor **502** and memory **503**.

Transmitter **504** comprises the wireless or wireline or hybrid wireless and wireline interface circuitry that enables station **502**-x to transmit data frames onto shared communications network **401**. It will be clear to those skilled in the art how to make and use transmitter **504**.

In accordance with the illustrative embodiment of the present invention, not all of stations **402-1** through **402**-N are of identical capability. Situations involving stations with heterogeneous capabilities can occur, for example, where modern stations are added to a telecommunication system that comprises only legacy stations. Additionally, the situation can result where some, but not all, of the stations in a telecommunications system are upgraded with additional capabilities. Whatever the reason, it will be clear to those skilled in the art why telecommunications systems exist that comprise stations with heterogeneous capabilities.

In accordance with the illustrative embodiment of the present invention, some of stations **402-1** through **402**-N are capable of transmission using an older modulation format, but not a newer modulation format. For the purposes of this specification, these stations are hereinafter called "legacy stations." The example of a legacy station in the illustrative embodiment is an 802.11(b)-capable station using CCK modulation only. In contrast, others of stations **402-1** through **402**-N are capable of transmission using the newer modulation format, in addition to the older modulation format. For the purposes of this specification, these stations are hereinafter called "upgraded stations." The example of a legacy station in the illustrative embodiment is an 802.11 (g)-capable station using both OFDM modulation and CCK modulation. In accordance with the illustrative embodiment of the present invention, legacy stations and upgraded stations are capable of communicating with each other because the upgraded stations transmit data frames that are intended for legacy stations in the modulation format that is used by the legacy stations.

FIG. **6** depicts a message flow diagram of the first variation of the first illustrative embodiment of the present invention. Signal stream **601-1** represents the sequence of messages transmitted by a first station on shared communications network **401**, in which at least some of the messages are intended for a second station. Signal stream **601-2** represents the sequence of messages transmitted by the second station on shared communications network **401**, in which at least some of the messages are intended for the first station. Both stations are of the upgraded type.

Prior to sending a data frame, the first station transmits, as part of its signal stream **601-1**, a frame indicating clear to send, CTS frame **602**. CTS frame **602** contains a duration field with a value that covers time interval **603** associated with the frame exchange of pending data transmission and corresponding acknowledgement. Time interval **603** comprises the transmission times for data frame **604** and ACK frame **605**. The value of the duration field representing time interval **603** can be calculated, for example, by adding up the anticipated transmission times of the relevant signals to be subsequently transmitted. The value can be determined empirically, it can be estimated, or it can be determined in another way. It can comprise a margin of variation in transmission, or it can comprise no extra margin. It will be clear to those skilled in the art how to calculate and set the value of the duration field in CTS frame **602**.

It will be clear to those skilled in the art that a different frame can be used in place of CTS frame **602**, such as a null frame, a data frame with an empty payload, etc., to achieve the same purpose of indicating duration.

As part of the illustrative embodiment, although the first station is capable of transmitting in an enhanced first modulation format (i.e., "MOD1"), the first station transmits CTS frame **602** using a legacy-compatible second modulation format (i.e., "MOD2"). This allows legacy stations to listen in and set their NAV counters to the value of the transmitted duration field in CTS frame **602**, causing those stations to refrain from transmitting spontaneously during the duration of the frame exchange. An example of the first modulation format is orthogonal frequency division multiplexing (OFDM). An example of the second modulation format is complementary code keying (CCK). As part of the illustrative embodiment, the first station transmits CTS frame **602** (or equivalent) to itself, consequently not requiring a second station to respond. Furthermore, the first station does not have to acknowledge CTS frame **602**, since the node sent the frame to itself, minimizing message overhead.

The first station then immediately transmits data frame **604** using the enhanced first modulation format. The second station, upon receiving data frame **604**, responds by transmitting ACK frame **605**. ACK frame **605** can be sent using either the first modulation format or second modulation format, since the first station can understand either format. If ACK frame **605** is sent in the legacy second modulation format, then additional protection is added against legacy stations newly arriving into shared communications network **401** that were previously unavailable to set their NAV counters. Both data frame **604** and ACK frame **605** are protected by the NAV counter running in nearby legacy stations.

Throughout the time interval occupied by signal streams **601-1** and **601-2**, other stations present on shared communications network **401**, comprising legacy stations (if present) and other enhanced stations (if present), are presumably monitoring for an opportunity to transmit signals without colliding with signals already present. The legacy stations sense shared communications network **401** for signals modulated according to the second modulation format. The stations refrain from transmitting spontaneously if a signal is present. Furthermore, the stations refrain from transmitting during the time interval specified by the value in the transmitted duration field.

It will be clear to those skilled in the art how to format, encode, transmit, receive, and decode CTS frame **602** (or equivalent, as discussed), data frame **604**, and ACK frame **605**.

FIG. **7** depicts a flowchart of the tasks constituting the first illustrative embodiment and performed by an upgraded station in queuing and transmitting a data frame in the presence of legacy stations on shared communications network **401**. It will be clear to those skilled in the art which of the tasks depicted in FIG. **7** can be performed simultaneously or in a different order than that depicted.

At task **701**, the upgraded station directs a formed data frame to an output queue. It will be clear to those skilled in the art how to form the data frame and how to make and use the output queue.

At task **702**, the upgraded station monitors for an opportunity to transmit a first signal that conveys the queued data frame, without collision and by using a first modulation format. The first modulation format can be, for example, the OFDM format existing within an 802.11(g)-based wireless local area network. It will be clear to those skilled in the art how to recognize when it is improper to transmit and how to recognize when it is appropriate to transmit. If it is determined at task **703** that an opportunity exists, control proceeds to task **704**.

At task **704**, the upgraded station transmits onto shared communications network **401** a second signal that is modulated according to a second modulation format. As part of the illustrative embodiment, the second modulation format is the legacy format understood by all the stations. For example, this can be CCK format, as opposed to the enhanced OFDM format also existing within an 802.11(g)-based wireless local area network. As part of the illustrative embodiment, the information conveyed by the second signal indicates the allotted duration of subsequently transmitted signals, in this case, the first signal transmitted by the transmitting station and the corresponding acknowledgement from the receiving station. The value of the duration field can be calculated, for example, by adding up the anticipated transmission times of the relevant signals to be subsequently transmitted. The value can be determined empirically, it can be estimated, or it can be determined in another way. It can comprise a margin of variation in transmission, or it can comprise no extra margin. It will be clear to those skilled in the art how to calculate and set the duration.

The second signal (e.g., conveying a clear to send indication, etc.) is transmitted by the transmitting station to itself (e.g., by the station specifying its own address as the destination, etc.). It will be clear to those skilled in the art how a station can transmit a signal to itself.

At task **705**, the upgraded station transmits onto shared communications network **401** the first signal. The first signal can convey a data frame or it can convey other information. The upgraded station transmits the first signal (and can receive a signal indicating an acknowledgement) while under NAV protection as specified in the duration field sent previously in the second signal.

It will be clear to those skilled in the art how to perform each of tasks **701** through **705**.

FIG. **8** depicts a message flow diagram of the second variation of the first illustrative embodiment of the present invention. Signal stream **801-1** represents the sequence of messages transmitted by a first station on shared communications network **401**, in which at least some of the messages are intended for a second station. Signal stream **801-2** represents the sequence of messages transmitted by the second station on shared communications network **401**, in which at least some of the messages are intended for the first station. Both stations are of the upgraded type.

Prior to sending a data frame, the first station transmits, as part of its signal stream **801-1**, a frame indicating clear to send, CTS frame **802**, which contains a duration field with a value that covers time interval **803** associated with the frame exchange of pending data transmissions and acknowledgements. Time interval **803** comprises the transmission times for multiple data frames (e.g., data frames **804** and **806**, etc.) and corresponding ACK frames (e.g., ACK frames **805** and **806**, etc.). The value of the duration field representing time interval **803** can be calculated, for example, by adding up the anticipated transmission times of the relevant signals to be subsequently transmitted. The value can be determined empirically, it can be estimated, or it can be determined in another way. It can comprise a margin of variation in transmission, or it can comprise no extra margin. It will be clear to those skilled in the art how to calculate and set the value of the duration field in CTS frame **802**.

It will be clear to those skilled in the art that a different frame can be used in place of CTS frame **802**, such as a null frame, a data frame with an empty payload, etc., to achieve the same purpose of indicating duration. As part of the illustrative embodiment, although the first station is capable of transmitting in an enhanced first modulation format (i.e., "MOD1"), the first station transmits CTS frame **802** in similar fashion as is CTS frame **602** and for similar reasons.

The first station then immediately transmits first data frame **804** using the enhanced first modulation format. The second station, upon receiving first data frame **804**, responds by transmitting ACK frame **805**. ACK frame **805** can be sent using either the first modulation format or second modulation format, since the first station can understand either format. If ACK frame **805** is sent in the legacy second modulation format, then additional protection is added against legacy stations newly arriving into shared communications network **401** that were previously unavailable to set their NAV counters. Both first data frame **804** and ACK frame **805** are protected by the NAV counter running in nearby legacy stations.

The first station can then subsequently transmit additional data frames, paired with additional ACK frames sent by the second station. Finally, the first station transmits last data frame **806** using the enhanced first modulation format. The second station, upon receiving last data frame **806**, responds by transmitting ACK frame **807**. ACK frame **807** is sent in similar fashion as ACK frame **805**. Both last data frame **806** and ACK frame **807** are protected by the NAV counter running in nearby legacy stations.

Throughout the time interval occupied by signal streams **801-1** and **801-2**, other stations present on shared communications network **401**, comprising legacy stations (if present) and other enhanced stations (if present), are presumably monitoring for an opportunity to transmit signals without colliding with signals already present. The legacy stations sense shared communications network **401** for signals modulated according to the second modulation format. The stations refrain from transmitting spontaneously if a signal is present. Furthermore, the stations refrain from transmitting during the time interval specified by the value in the transmitted duration field.

It will be clear to those skilled in the art how to format, encode, transmit, receive, and decode CTS frame **802** (or equivalent, as discussed), first data frame **804**, last data frame **806**, and ACK frames **805** and **807**.

FIG. **9** depicts a message flow diagram of the first variation of the second illustrative embodiment of the present invention. Signal stream **901-1** represents the sequence of messages transmitted by a first station on shared communications network **401**, in which at least some of the messages are intended for a second station. Signal stream **901-2** represents the sequence of messages transmitted by the second station on shared communications network **401**, in which at least some of the messages are intended for the first station. Both stations are of the upgraded type.

Prior to sending a data frame, the first station transmits, as part of its signal stream **901-1**, a frame indicating clear to send, CTS frame **902**. CTS frame **902** contains a duration field with a value that covers time interval **903** associated with the frame exchange of pending data transmissions and acknowledgements. Time interval **903** comprises the transmission times for multiple data frames (e.g., data frames **904**, **906**, and **910**; etc.) and corresponding ACK frames (e.g., ACK frames **905**, **907**, and **911**; etc.). The value of the duration field representing time interval **903** can be calculated, for example, by adding up the anticipated transmission times of the relevant signals to be subsequently transmitted. The value can be determined empirically, it can be estimated, or it can be determined in another way. It can comprise a margin of variation in transmission, or it can comprise no extra margin. It will be clear to those skilled in the art how to calculate and set the value of the duration field in CTS frame **902**.

It will be clear to those skilled in the art that a different frame can be used in place of CTS frame **902**, such as a null frame, a data frame with an empty payload, etc., to achieve the same purpose of indicating duration. As part of the illustrative embodiment, although the first station is capable of transmitting in an enhanced first modulation format (i.e., "MOD1"), the first station transmits CTS frame **902** in similar fashion as CTS frame **602** and for similar reasons.

The first station can then immediately transmit first data frame **904** using the enhanced first modulation format. The second station, upon receiving first data frame **904**, responds by transmitting ACK frame **905**. ACK frame **905** can be sent using either the first modulation format or second modulation format, since the first station can understand either format. If ACK frame **905** is sent in the legacy second modulation format, then additional protection is added against legacy stations newly arriving into shared communications network **401** that were previously unavailable to set their NAV counters. Both first data frame **904** and ACK frame **905** are protected by the NAV counter running in nearby legacy stations.

The first station can then subsequently transmit additional data frames (e.g., data frame **906**, etc.), paired with additional ACK frames (e.g., ACK frame **907**, etc.) sent by the second station.

At some point interposed in the series of data frame transmissions, the first station can choose to transmit an intermediate, reinforcing protection frame. Specifically, the first station transmits, as part of its signal stream **901-1**, null frame **908**, which contains a duration field with a value that covers time interval **909** associated with the frame exchange of pending data transmissions and acknowledgements that remain. Time interval **909** comprises the transmission times for multiple data frames (e.g., data frame **910**, etc.) and corresponding ACK frames (e.g., ACK frame **911**, etc.). It will be clear to those skilled in the art how to calculate and set the value of the duration field in null frame **908**.

It will be clear to those skilled in the art that a different frame can be used in place of null frame **908** to achieve the same purpose of indicating duration. As part of the illustrative embodiment, although the first station is capable of transmitting in an enhanced first modulation format (i.e., "MOD1"), the first station transmits null frame **908** in similar fashion as CTS frame **602** and for similar reasons. The first station can transmit null frame **908** intermittently whenever it is determined to do so. The transmission can be based upon time, new stations arriving into shared communications network **401**, etc. If based upon time, the transmission can be periodic or aperiodic. It will be clear to those skilled in the art how to determine when null frame **908** (or equivalent, as discussed) is transmitted.

The first station transmits data frame **910** using the enhanced first modulation format. The second station, upon receiving data frame **910**, responds by transmitting ACK frame **911**. ACK frame **911** is sent in similar fashion as ACK frame **905**. The NAV counter running in nearby legacy stations protects both data frame **910** and ACK frame **911**, in addition to any additional data frame/ACK frame pairs transmitted during the duration period.

Throughout the time interval occupied by signal streams **901-1** and **901-2**, other stations present on shared communications network **401**, comprising legacy stations (if present) and other enhanced stations (if present), are presumably monitoring for an opportunity to transmit signals without colliding with signals already present. The legacy stations sense shared communications network **401** for signals modulated according to the second modulation format. The stations refrain from transmitting spontaneously if a signal is present. Furthermore, the stations refrain from transmitting during the time interval specified by the value in the transmitted duration field.

It will be clear to those skilled in the art how to format, encode, transmit, receive, and decode CTS frame **902** (or equivalent, as discussed); null frame **908** (or equivalent, as discussed); data frames **904**, **906**, and **910**; and ACK frames **905**, **907**, and **911**. Finally, it will be clear to those skilled in the art that multiple intermediate frames (e.g., null frame **908**, etc.) can be transmitted to reinforce the NAV protection.

FIG. **10** depicts the second variation of the second illustrative of the present invention. Signal stream **1001-1** as transmitted by a first station comprises CTS frame **1002**, and data frames **1004**, **1006**, **1008**, and **1011**. Signal stream **1001** as transmitted by a second station comprises ACK frames **1005**, **1007**, **1010**, and **1012**. The variation depicted is similar to that depicted in FIG. **9**, except that a data frame (i.e., data frame **1008**) is used to reinforce the NAV protection, instead of a null frame.

Specifically, the first station transmits, as part of its signal stream **1001-1** and at an intermediate point, data frame **1008**, which contains a duration field with a value that covers time interval **1009** associated with the frame exchange of pending data transmissions and acknowledgements that remain. Time interval **1009** comprises the transmission times for multiple data frames (e.g., data frame **1011**, etc.) and corresponding

ACK frames (e.g., ACK frames **1010** and **1012**, etc.). It will be clear to those skilled in the art how to calculate and set the value of the duration field in data frame **1008**.

As part of the illustrative embodiment, although the first station is capable of transmitting in an enhanced first modulation format (i.e., "MOD1"), the first station transmits data frame **1008** using a legacy-compatible second modulation format (i.e., "MOD2"). This allows legacy stations to listen in and set their NAV counters to the value of the transmitted duration field in data frame **1008**, causing those stations to refrain from transmitting spontaneously during the duration of the frame exchange. Note that data frame **1008** also contains valid data that had to be transmitted in some data frame.

Throughout the time interval occupied by signal streams **1001-1** and **1001-2**, other stations present on shared communications network **401**, comprising legacy stations (if present) and other enhanced stations (if present), are presumably monitoring for an opportunity to transmit signals without colliding with signals already present. The legacy stations sense shared communications network **401** for signals modulated according to the second modulation format. The stations refrain from transmitting spontaneously if a signal is present. Furthermore, the stations refrain from transmitting during the time interval specified by the value in the transmitted duration field.

It will be clear to those skilled in the art how to format, encode, transmit, receive, and decode CTS frame **1002** (or equivalent, as discussed); data frames **1004**, **1006**, **1008**, and **1011**; and ACK frames **1005**, **1007**, **1010**, and **1012**. Finally, it will be clear to those skilled in the art that multiple intermediate frames (e.g., data frame **1008**, etc.) can be transmitted to reinforce the NAV protection.

FIG. **11** depicts a flowchart of the tasks constituting the second illustrative embodiment and performed by an upgraded station in queuing and transmitting a data frame in the presence of legacy stations on shared communications network **401**. It will be clear to those skilled in the art which of the tasks depicted in FIG. **11** can be performed simultaneously or in a different order than that depicted.

At task **1101**, the upgraded station directs formed data frames to an output queue. It will be clear to those skilled in the art how to form data frames and how to make and use the output queue.

At task **1102**, the upgraded station monitors for an opportunity to transmit a first signal that conveys the queued data frames, without collision and by using a first modulation format. The first modulation format can be, for example, the OFDM format existing within an 802.11(g)-based wireless local area network. It will be clear to those skilled in the art how to recognize when it is improper to transmit and how to recognize when it is appropriate to transmit. If it is determined at task **1103** that an opportunity exists, control proceeds to task **1104**.

At task **1104**, the upgraded station transmits onto shared communications network **401** a second signal that is modulated according to a second modulation format. As part of the illustrative embodiment, the second modulation format is the legacy format understood by all the stations. For example, this can be CCK format, as opposed to the enhanced OFDM format also existing within an 802.11(g)-based wireless local area network. As part of the illustrative embodiment, the information conveyed by the second signal indicates the allotted duration of subsequently transmitted signals, in this case, the first signal comprising a plurality of data frames, the third signal comprising intermediate protection frames, and the corresponding acknowledgements from the receiving station. The value of the duration field can be calculated, for example, by adding up the anticipated transmission times of the relevant signals to be subsequently transmitted. The value can be determined empirically, it can be estimated, or it can be determined in another way. It can comprise a margin of variation in transmission, or it can comprise no extra margin. It will be clear to those skilled in the art how to calculate and set the duration.

The second signal (e.g., conveying a clear to send indication, etc.) is transmitted by the transmitting station to itself (e.g., by the station specifying its own address as the destination, etc.). It will be clear to those skilled in the art how a station can transmit a signal to itself.

At task **1105**, the upgraded station transmits onto shared communications network **401** a portion of the first signal. The portion of the first signal can convey a single data frame or it can convey other information. The upgraded station transmits the portion of the first signal (and can receive a signal indicating an acknowledgement) while under NAV protection as specified in the duration field sent previously in the second signal.

At task **1106**, if additional frames of any kind are to be transmitted, control proceeds to task **1107**. If not, execution of the tasks depicted in FIG. **11** stops.

At task **1107**, if it is time to transmit a third signal, control proceeds to task **1108**. If not, control proceeds to task **1105**.

At task **1108**, the upgraded station transmits onto shared communications network **401** a third signal that is modulated according to the second modulation format, which, as explained earlier, is the legacy format understood by all the stations. For example, this can be CCK format, as opposed to the enhanced OFDM format also existing within an 802.11(g)-based wireless local area network. As part of the illustrative embodiment, the information conveyed by the third signal indicates the allotted duration of subsequently transmitted signals, in this case, the remaining portions of the first signal comprising one or more data frames, any remaining third signals comprising intermediate protection frames, and the corresponding one or more acknowledgements from the receiving station. The duration represented in the third signal can be calculated by adding up the anticipated transmission times of the relevant signals to be subsequently transmitted. It will be clear to those skilled in the art how to calculate and set the duration.

The third signal, if conveying a null frame or similar non-data frame message, is transmitted by the transmitting station to itself (e.g., by the station specifying its own address as the destination, etc.). It will be clear to those skilled in the art how a station can transmit a signal to itself. Alternatively, the third signal can convey a data frame carrying underlying data that would had to have been transmitted to another station, anyway. In this alternative case, the third signal is actually intended for a receiving station, although all stations are able to listen to it (since it is transmitted in the second modulation format) and read the duration field information.

The first station can transmit the third signal intermittently whenever it is determined to do so. The transmission can be based upon time, new stations arriving into shared communications network **401**, etc. If based upon time, the transmission can be periodic or aperiodic. It will be clear to those skilled in the art how to determine when the third signal is transmitted.

It will be clear to those skilled in the art how to perform each of tasks **1101** through **1108**.

It is to be understood that the above-described embodiments are merely illustrative of the present invention and that many variations of the above-described embodiments can be devised by those skilled in the art without departing from the scope of the invention. It is therefore intended that such variations be included within the scope of the following claims and their equivalents.

What is claimed is:

1. A method comprising:

(a) monitoring a shared-communications medium for an opportunity to transmit a first signal and a second signal;

(b) transmitting said second signal in accordance with a second modulation scheme on said shared-communications medium, wherein:

(i) said second signal conveys a frame indicating clear to send that is addressed to the sender of said frame indicating clear to send; and

(ii) said frame indicating clear to send comprises a duration field that has a value based on the expected length of time required to transmit at least one data frame; and

(c) transmitting said first signal in accordance with a first modulation scheme on said shared-communications medium after said second signal, wherein said first signal conveys said at least one data frame;

wherein said frame indicating clear to send and said at least one data frame are addressed to different stations.

2. The method of claim **1**, wherein said second modulation scheme is different than said first modulation scheme.

3. The method of claim **1**, wherein said first modulation scheme comprises orthogonal frequency division multiplexing and said second modulation scheme comprises complementary code keying.

4. The method of claim **1**, wherein said frame indicating clear to send is at least one of a clear-to-send frame and a frame with an empty payload.

5. The method of claim **1**, further comprising transmitting a third signal on said shared-communications medium, wherein said third signal conveys a data frame in accordance with said second modulation scheme.

6. The method of claim **1**, wherein said shared-communications medium is operative in the 2.4 GHz Industrial, Scientific, Medical band of the radio frequency spectrum.

7. A station comprising:

(a) a receiver for monitoring a shared-communications medium for an opportunity to transmit a first signal and a second signal; and

(b) a transmitter for:

(1) transmitting said second signal in accordance with a second modulation scheme on said shared-communications medium, wherein:

(i) said second signal conveys a frame indicating clear to send that is addressed to the sender of said frame indicating clear to send; and

(ii) said frame indicating clear to send comprises a duration field that has a value based on the expected length of time required to transmit at least one data frame; and

(2) transmitting said first signal in accordance with a first modulation scheme on said shared-communications medium after said second signal, wherein said first signal conveys said at least one data frame;

wherein said frame indicating clear to send and said at least one data frame are addressed to different stations.

8. The station of claim **7**, wherein said second modulation scheme is different than said first modulation scheme.

9. The station of claim **7**, wherein said first modulation scheme comprises orthogonal frequency division multiplexing and said second modulation scheme comprises complementary code keying.

10. The station of claim **7**, wherein said frame indicating clear to send is at least one of a clear-to-send frame and a frame with an empty payload.

11. The station of claim **7**, wherein said transmitter also transmits a third signal on said shared-communications medium, conveying a data frame in accordance with said second modulation scheme.

12. The station of claim **7**, wherein said shared-communications medium is operative in the 2.4 GHz Industrial, Scientific, Medical band of the radio frequency spectrum.

13. A method comprising:

(a) monitoring a shared-communications medium for an opportunity to transmit a first signal, a second signal, and a third signal;

(b) transmitting said second signal in accordance with a second modulation scheme on said shared-communications medium, wherein:

(i) said second signal conveys a frame indicating clear to send that is addressed to the sender of said frame indicating clear to send; and

(ii) said frame indicating clear to send comprises a duration field that has a value based on the expected length of time required to transmit at least one data frame;

(c) transmitting said first signal in accordance with a first modulation scheme on said shared-communications medium after said second signal, wherein said first signal conveys said at least one data frame; and

(d) transmitting said third signal in accordance with said second modulation scheme on said shared-communications medium after said first signal, wherein said third signal conveys a data frame;

wherein said frame indicating clear to send and said at least one data frame are addressed to different stations.

14. The method of claim **13**, wherein said second modulation scheme is different than said first modulation scheme.

15. The method of claim **13**, wherein said first modulation scheme comprises orthogonal frequency division multiplexing and said second modulation scheme comprises complementary code keying.

16. The method of claim **13**, wherein said frame indicating clear to send is at least one of a clear-to-send frame and a frame with an empty payload.

17. The method of claim **13**, wherein said frame indicating clear to send and said data frame are addressed to different stations.

18. The method of claim **13**, wherein said shared-communications medium is operative in the 2.4 GHz Industrial, Scientific, Medical band of the radio frequency spectrum.

19. A station comprising:

(a) a receiver for monitoring a shared-communications medium for an opportunity to transmit a first signal, a second signal, and a third signal; and

(b) a transmitter for:

(1) transmitting said second signal in accordance with a second modulation scheme on said shared-communications medium, wherein:

(i) said second signal conveys a frame indicating clear to send that is addressed to the sender of said frame indicating clear to send; and

(ii) said frame indicating clear to send comprises a duration field that has a value based on the expected length of time required to transmit the subsequent data frames conveyed by said first signal and said third signal;

(2) transmitting said first signal in accordance with a first modulation scheme on said shared-communications medium after said second signal, wherein said first signal conveys said at least one data frame; and

(3) transmitting said third signal in accordance with said second modulation scheme on said shared-communications medium after said first signal, wherein said third signal conveys a data frame;

wherein said frame indicating clear to send and said at least one data frame are addressed to different stations.

20. The station of claim **19**, wherein said second modulation scheme is different than said first modulation scheme.

21. The station of claim **19**, wherein said first modulation scheme comprises orthogonal frequency division multiplexing and said second modulation scheme comprises complementary code keying.

22. The station of claim **19**, wherein said frame indicating clear to send is at least one of a clear-to-send frame and a frame with an empty payload.

23. The station of claim **19**, wherein said transmitter also transmits the third signal on said shared-communications medium, conveying a data frame in accordance with said second modulation scheme.

24. The station of claim **19**, wherein said shared-communications medium is operative in the 2.4 GHz Industrial, Scientific, Medical band of the radio frequency spectrum.

* * * * *

EXHIBIT I

US007817914B2

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

(10) **Patent No.: US 7,817,914 B2**
(45) **Date of Patent: Oct. 19, 2010**

(54) **CAMERA CONFIGURABLE FOR AUTONOMOUS OPERATION**

(75) Inventors: **Cheryl J. Kuberka**, Penfield, NY (US); **David C. Barnum**, Rochester, NY (US); **Frances C. Williams**, Rochester, NY (US); **John N. Border**, Walworth, NY (US); **Kenneth A. Johnson**, Rochester, NY (US)

(73) Assignee: **Eastman Kodak Company**, Rochester, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 753 days.

(21) Appl. No.: **11/755,203**

(22) Filed: **May 30, 2007**

(65) **Prior Publication Data**

US 2008/0298796 A1 Dec. 4, 2008

(51) **Int. Cl.**

G03B 17/00	(2006.01)
G03B 17/18	(2006.01)
G03B 7/02	(2006.01)
H04N 5/225	(2006.01)

(52) **U.S. Cl.** **396/263**; 396/153; 396/281; 396/287; 348/169

(58) **Field of Classification Search** 396/263, 396/52, 281, 287, 153; 348/208.1, 208.15, 348/169

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,654,506	B1	11/2003	Luo et al.	
6,654,507	B2	11/2003	Luo	
7,046,924	B2	5/2006	Miller et al.	
7,164,490	B2	1/2007	Manico et al.	
2004/0080618	A1	4/2004	Norris et al.	
2005/0012830	A1	1/2005	Pilu	
2005/0134719	A1 *	6/2005	Beck	348/333.11
2005/0228849	A1	10/2005	Zhang	

FOREIGN PATENT DOCUMENTS

EP	1571634	A	9/2005
GB	2250156	A	5/1992
WO	WO2004/111971		12/2004
WO	WO 2006040761	A	4/2006

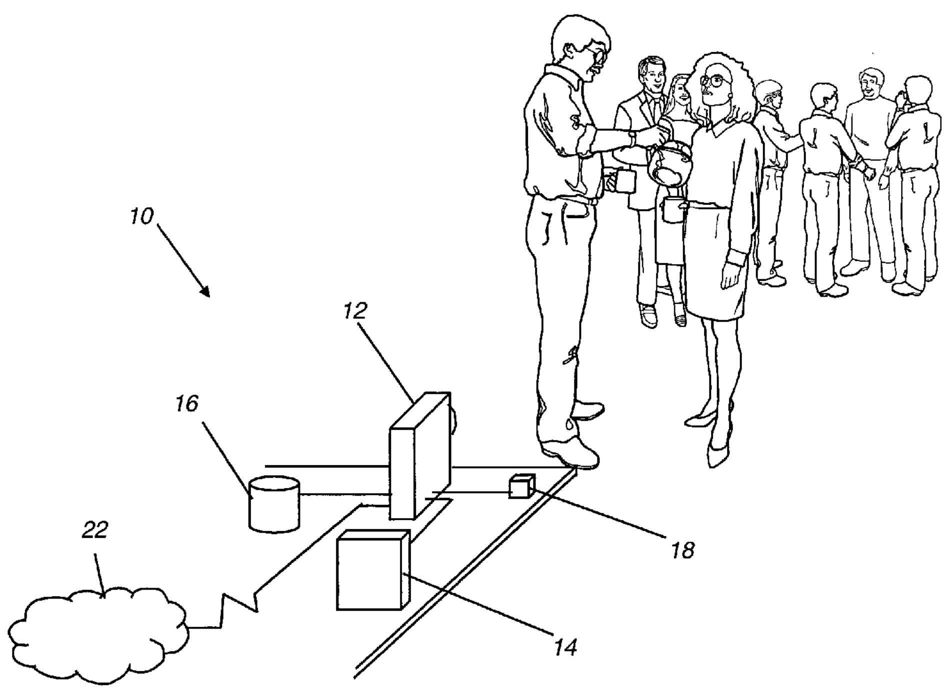
* cited by examiner

Primary Examiner—Rochelle-Ann J Blackman
(74) *Attorney, Agent, or Firm*—Thomas J. Strouse; Raymond L. Owens

(57) **ABSTRACT**

The present disclosure relates to an image capture device and a technique for capturing an image. The technique includes selecting at least one subject displayed on an image capture device as an image trigger condition and entering a threshold level corresponding to the at least one image trigger condition. The technique further provides monitoring a signal from at least one sensor detecting the at least one image trigger condition and obtaining at least one digital image upon detecting the sensed image trigger condition meeting the threshold level.

24 Claims, 8 Drawing Sheets



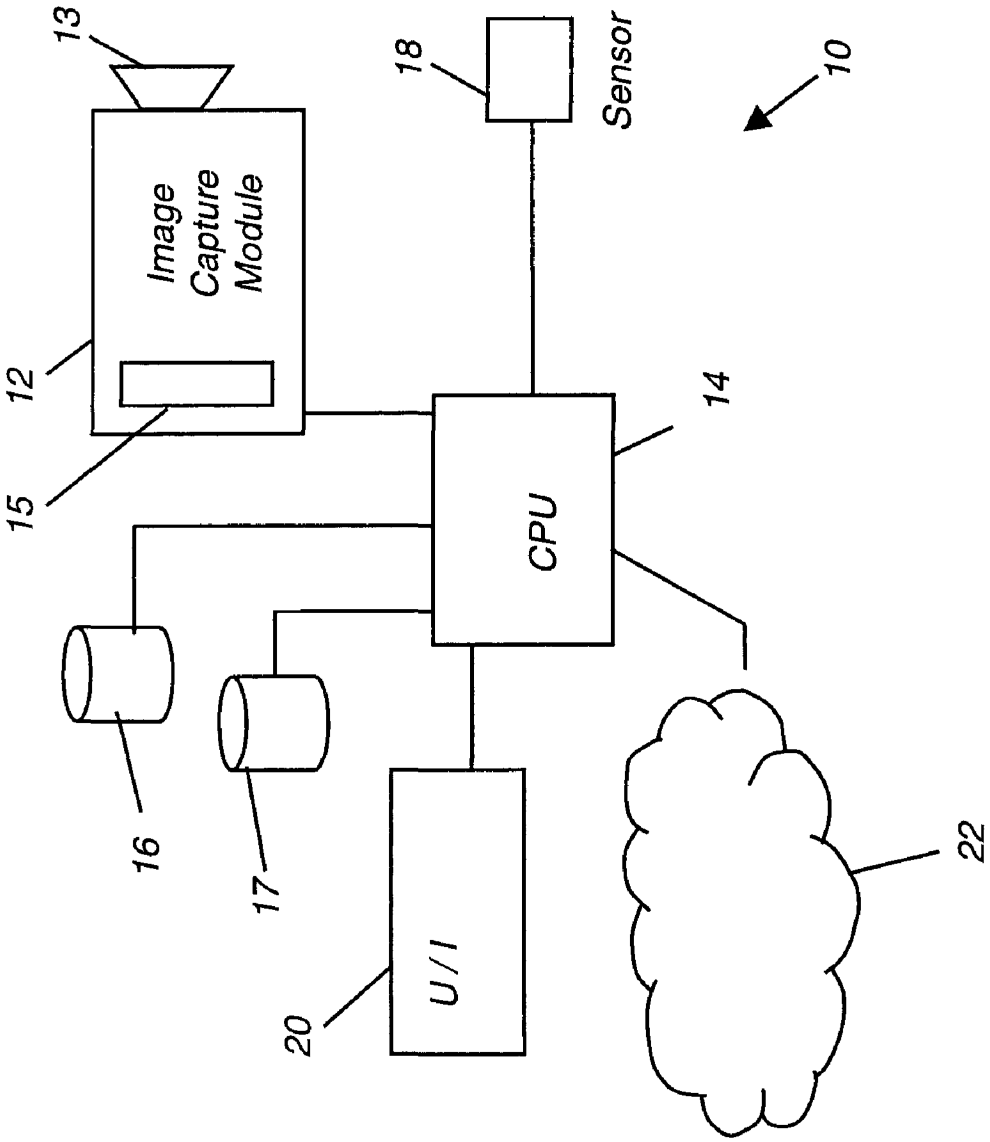


FIG. 1

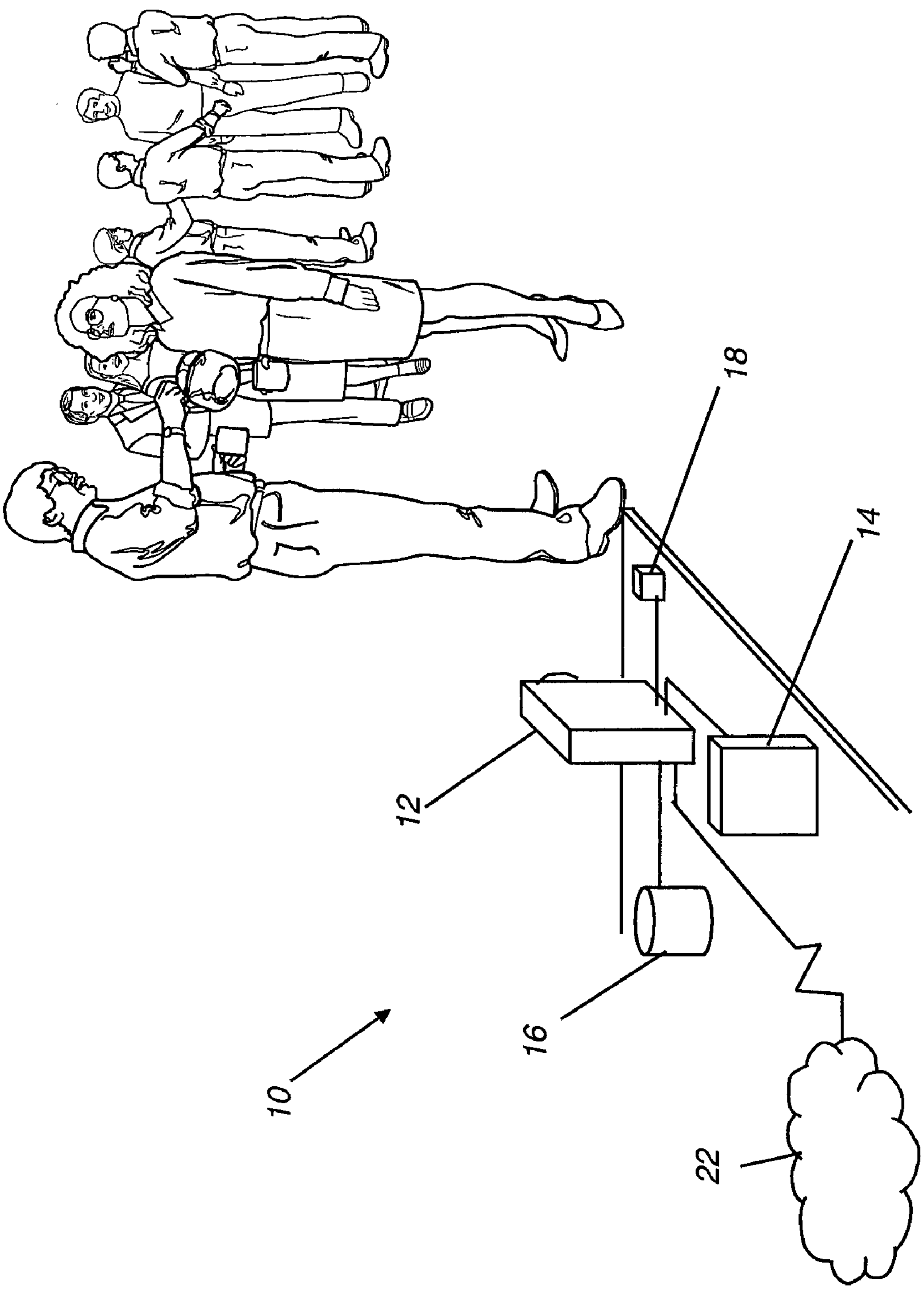


FIG. 2

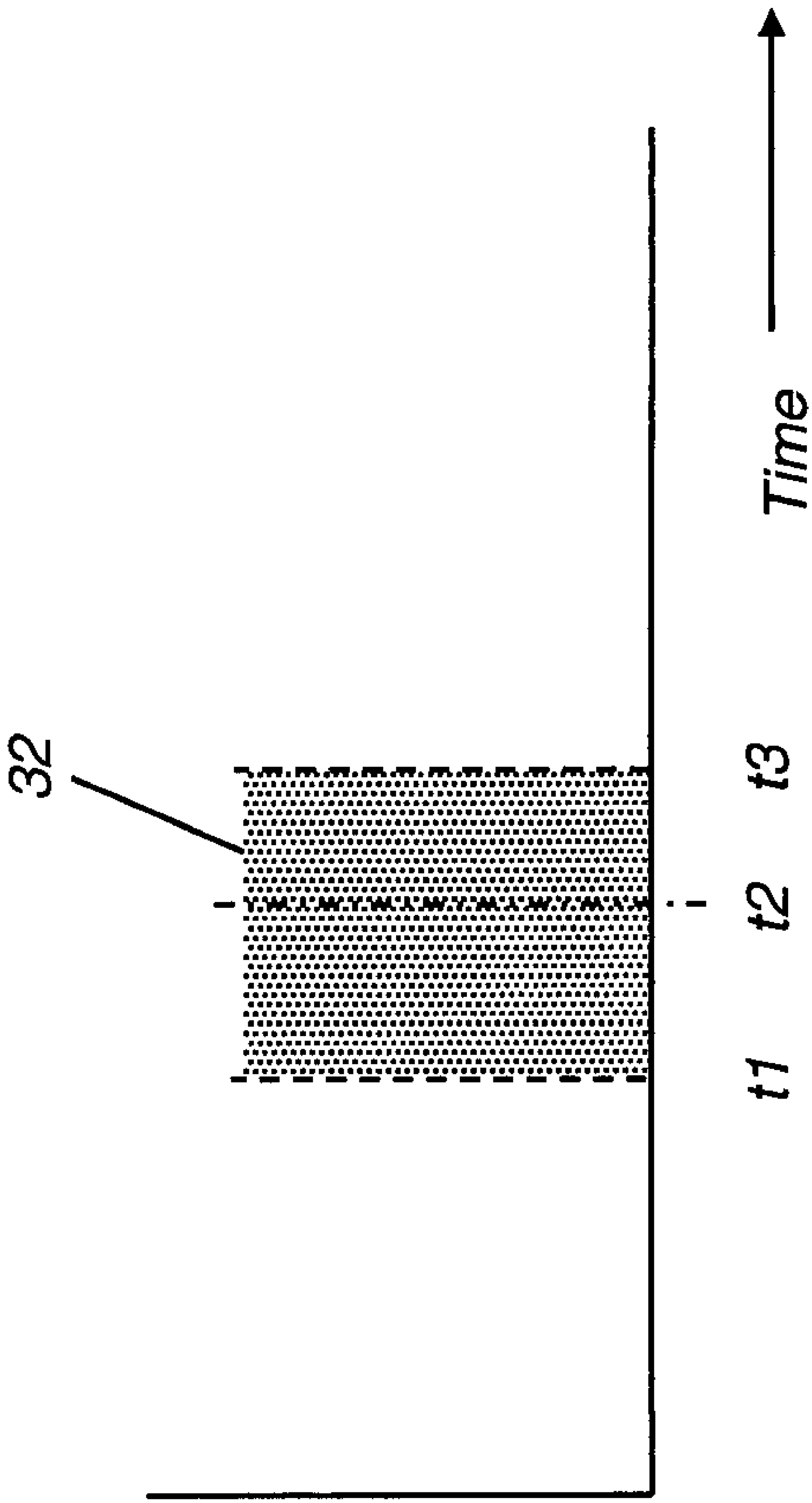


FIG. 3

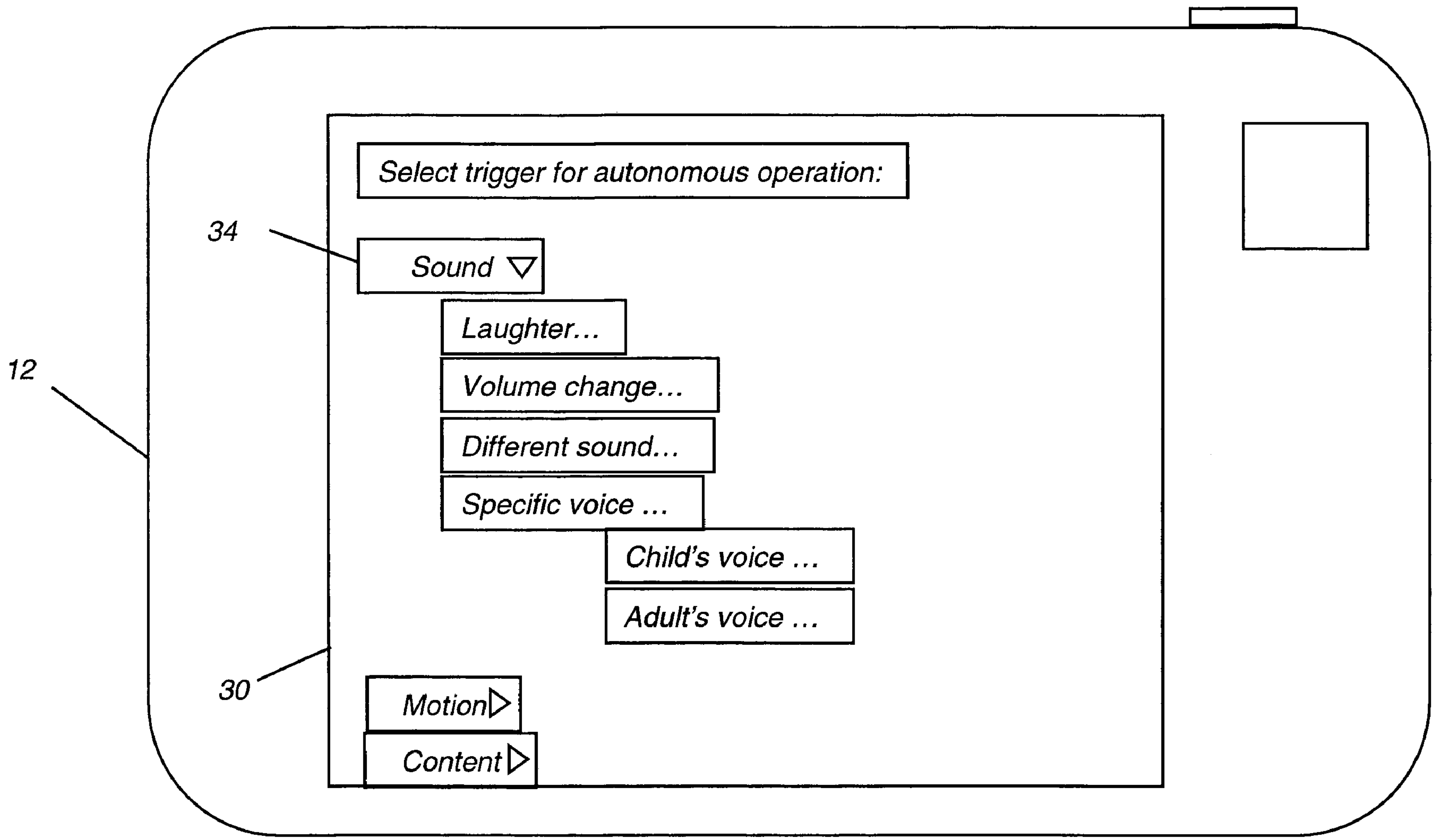

Select trigger for autonomous operation:
34
Sound
Laughter…
Volume change…
Different sound…
Specific voice …
Child's voice …
Adult's voice …
12
30
Motion
Content

FIG. 4

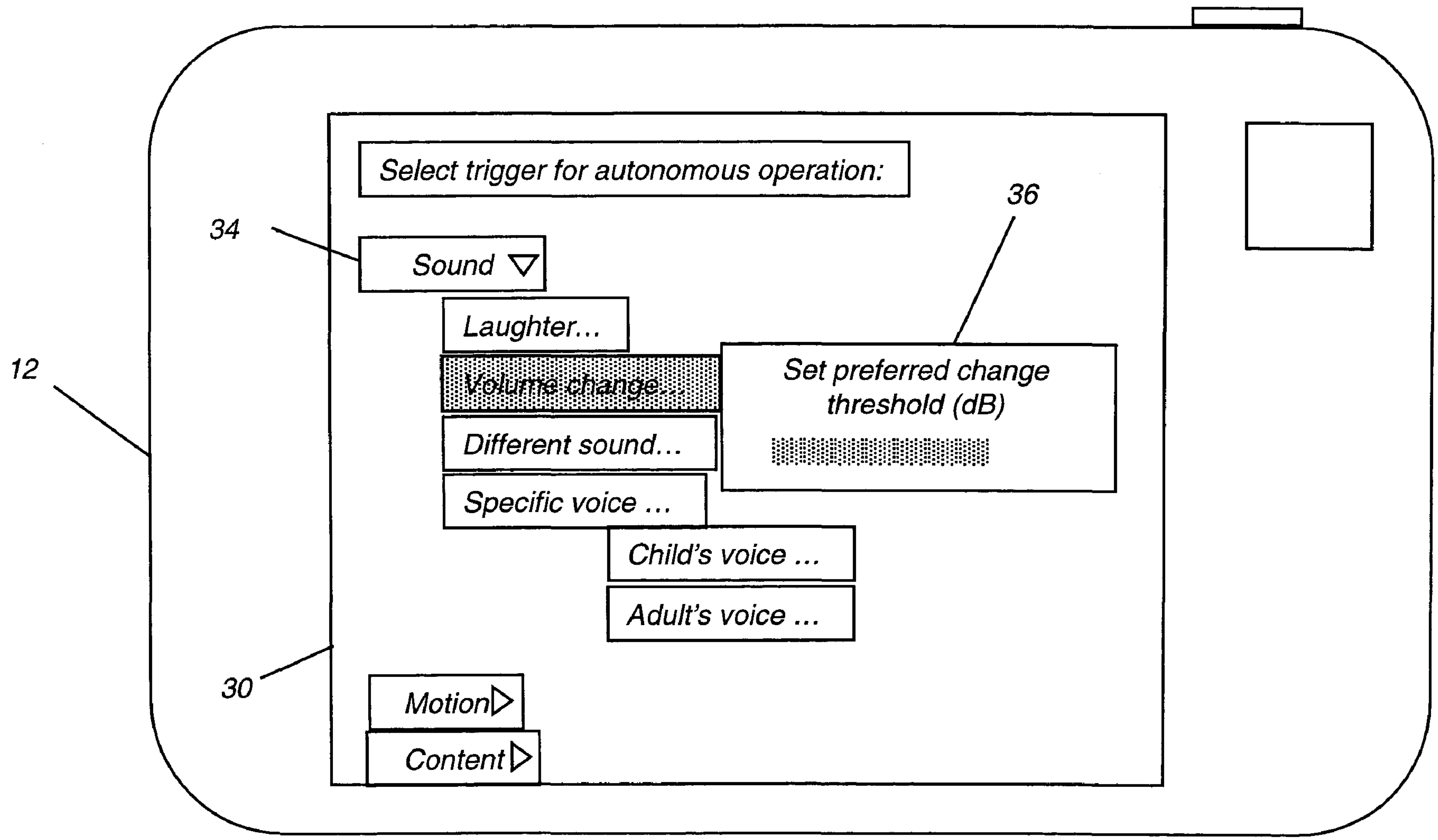

Select trigger for autonomous operation:
34
Sound
Laughter…
Volume change…
Different sound…
Specific voice …
Child's voice …
Adult's voice …
36
Set preferred change threshold (dB)
12
30
Motion
Content

FIG. 5

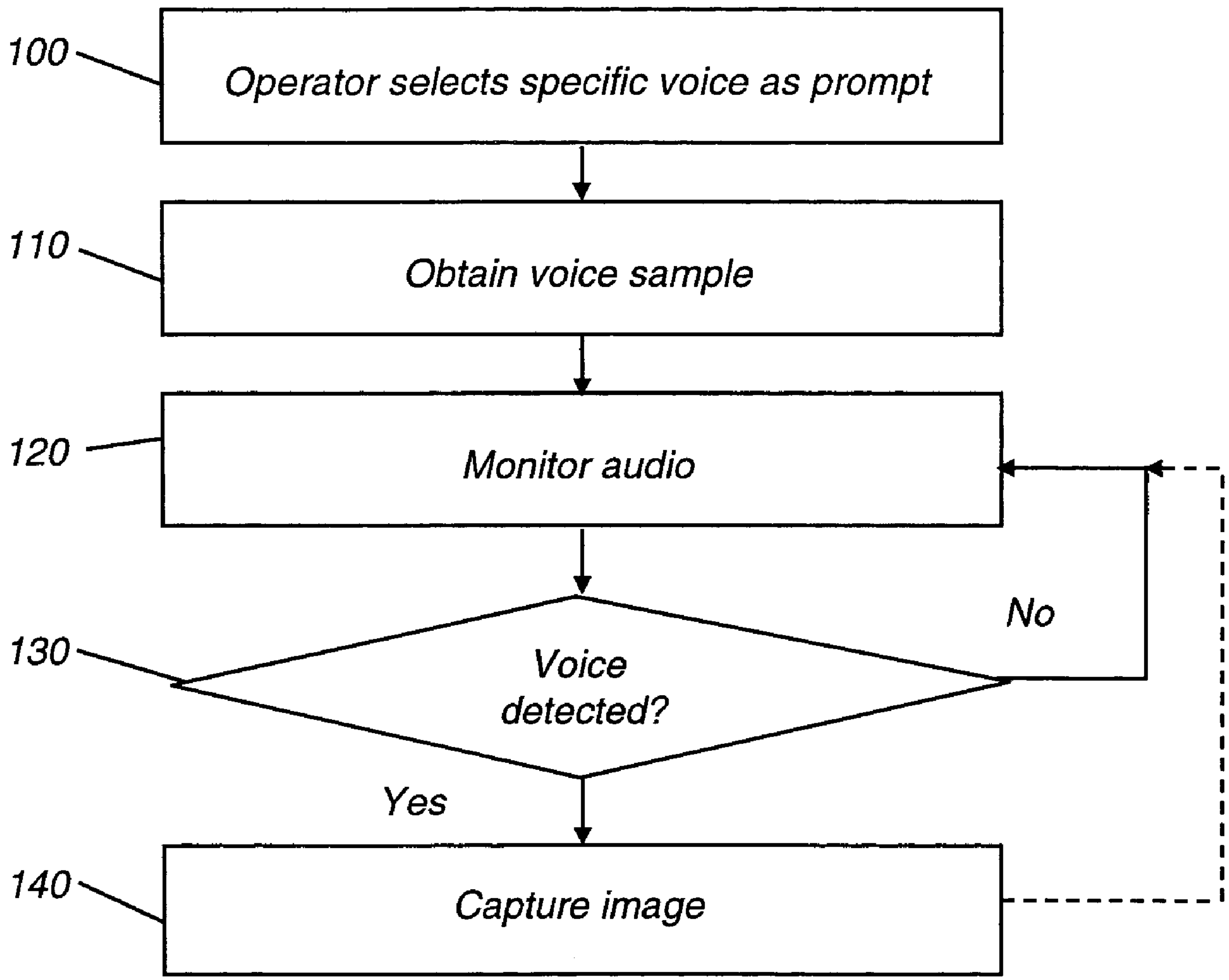

100
Operator selects specific voice as prompt
110
Obtain voice sample
120
Monitor audio
130
Voice detected?
No
Yes
140
Capture image

FIG. 6

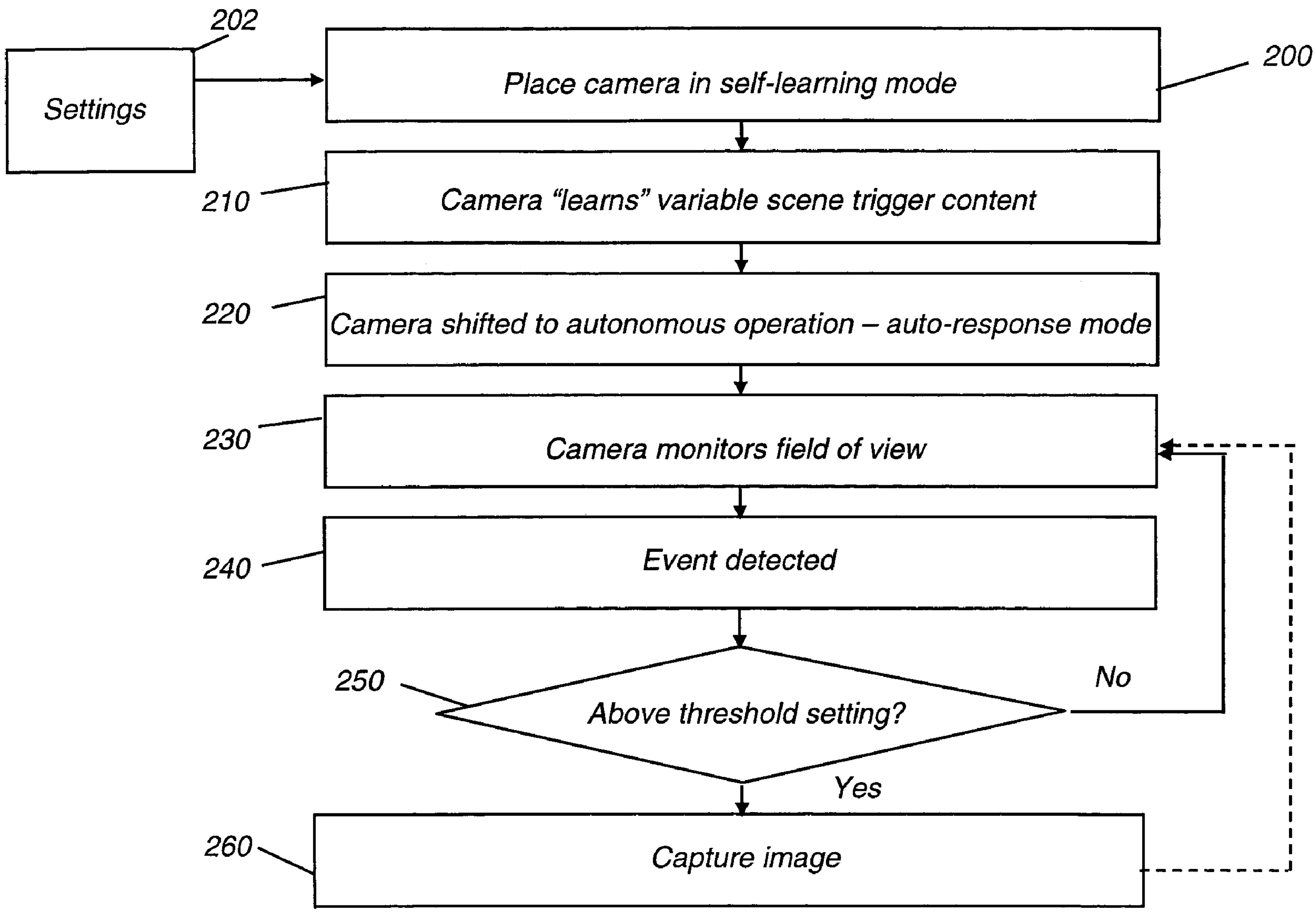

202
Settings
200
Place camera in self-learning mode
210
Camera "learns" variable scene trigger content
220
Camera shifted to autonomous operation – auto-response mode
230
Camera monitors field of view
240
Event detected
250
Above threshold setting?
No
Yes
260
Capture image

FIG. 7

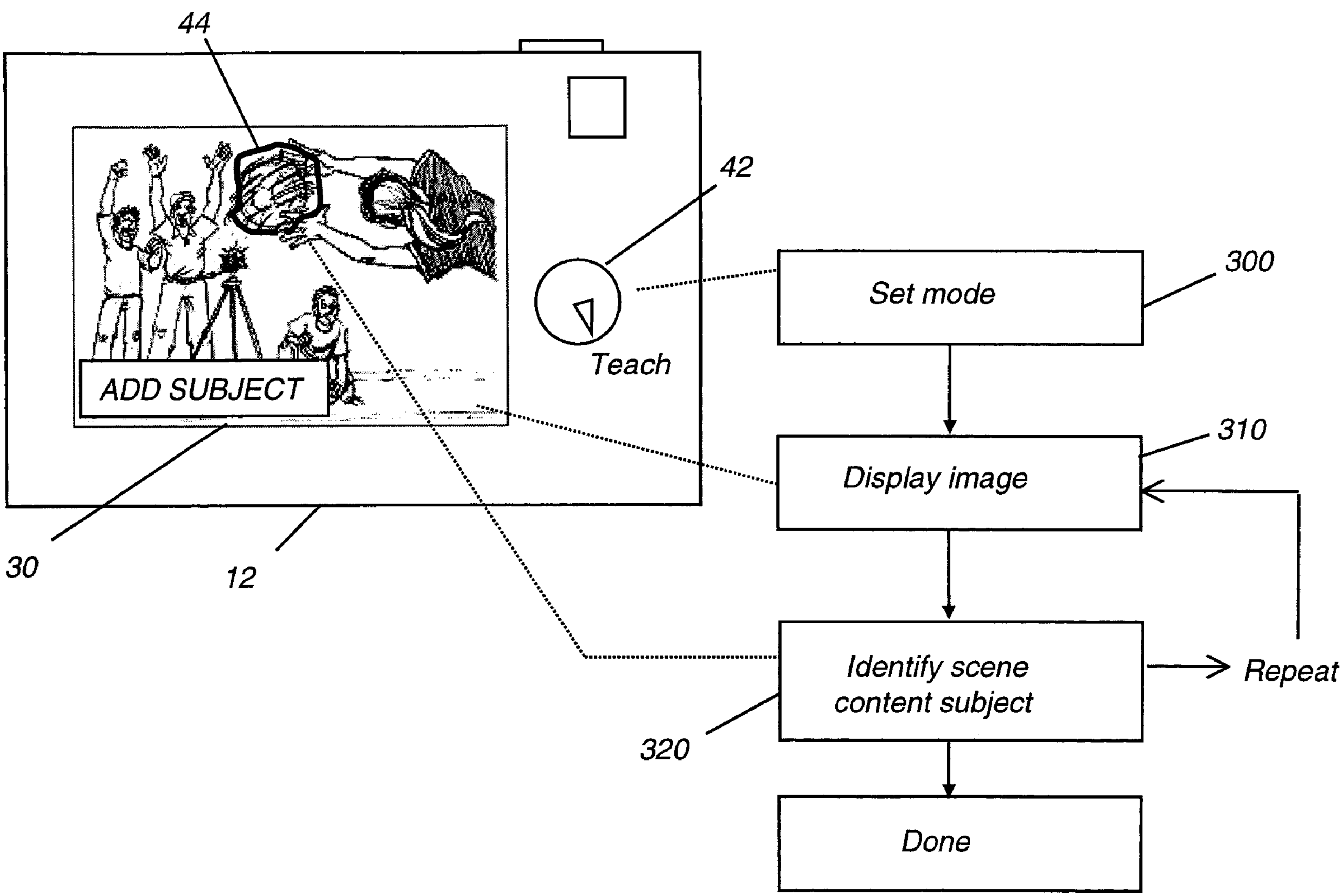

44
42
Teach
ADD SUBJECT
30
12
300
Set mode
310
Display image
320
Identify scene content subject
Repeat
Done

FIG. 8

CAMERA CONFIGURABLE FOR AUTONOMOUS OPERATION

CROSS REFERENCE TO RELATED APPLICATIONS

Reference is made to co-pending application Ser. No. 11/755,156 filed May 30, 2007 entitled "Camera Configurable for Autonomous Self-Learning Operation" to Cheryl Kuberka et al., the disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

This invention generally relates to image capture and more particularly relates to a camera apparatus that responds to a set of environmental cues without direct operator intervention.

BACKGROUND OF THE INVENTION

In spite of advances that have made today's digital cameras easy to use and relatively trouble-free, there are still drawbacks that can impede enjoyment of the picture-taking experience. Even with the most intuitive "point-and-shoot" digital cameras, the photographer is often more involved in the task of picture taking, rather than in enjoying an event as a participant. To a large degree, this has been the accepted norm; the picture-taker has a job to do and is, therefore, somewhat less involved in the action than are other participants. Another disadvantage of this arrangement relates to the response of participants at an event, who know that their picture is being taken and may respond less than naturally during the picture-taking session.

There have been a number of solutions proposed for freeing the picture taker, allowing the photographer to get out from behind the camera and become a part of the scene. The most familiar solutions range from delay timers that enable the photographer to hustle out from behind the camera once all settings and adjustments are made, to remotely controlled shutters and other devices. While solutions such as these can provide some measure of freedom to the photographer, a significant amount of attention and setup is still required for obtaining images at an event.

Remote camera activation has been used for applications such as industrial monitoring, espionage, and building security. Sound- or motion-actuated systems for image capture enable various types of events to be recorded, such as the entry or exit of personnel, movement of a person, animal, or object, etc. Webcam devices for remote monitoring may also capture images upon sensing noise, light, sound, or motion, such as from an infrared (IR) motion detector. Cameras for such systems are typically located in fixed positions and obtain image content in a known format. Event detection camera devices are described, for example, in U.S. Patent Application Publication No. 2004/0080618 entitled "Smart Camera System" by Norris et al.

While remote camera activation for event picture-taking can utilize solutions that were developed for security and monitoring, however, there are a number of significant differences between the picture-taking environment for consumer imaging, capturing moments with family and friends, and the more mundane work of monitoring events at remote locations. Certainly, image quality, choice of subject, and timing are of key interest for consumer event photography and are relatively less important for remote monitoring. Mere camera activation with detection of movement or sound, although

sufficient for remote industrial imaging, would not be likely to obtain pleasing images at a family event such as a birthday party or a holiday gathering with friends, for example.

Attempts to provide a more natural picture-taking experience include those outlined in U.S. Patent Application Publication No. 2005/0012830 entitled "Autonomous Camera Having Exchangeable Behaviors" by Pilu. The '830 Pilu disclosure describes wearable cameras having a behavior memory, where the cameras are capable of detecting events or situations of interest by analyzing data from the object field. Similarly, a group at Hewlett-Packard Corp. has proposed an "always on camera" that records continuously and is supplemented with algorithms to sort through the huge volume of images obtained in order to help select the few good ones that might be worth preserving. One version, for example, fastens to the side of a pair of eyeglasses, which makes it usable to at least some portion of the population. While it may feel natural to have a camera obtruding from the side of one's head, however, it can be questioned whether or not one is likely to elicit natural and spontaneous behavior from those in the object field, whose images are being continuously captured. Moreover, wearable solutions do not bring the photographer into the picture, but simply change how the user aims the camera. Certainly, for many types of consumer imaging situations, the idea of attaching the camera to the photographer hardly seems consonant with the idea of "freeing" the photographer.

Thus, while the value of obtaining images automatically in a more natural and spontaneous manner is acknowledged, existing solutions fall short of what is needed, on one hand, to free the photographer from the image capture function and, on the other hand, to free the subject(s) from the psychological constraint of "having one's picture taken". Existing solutions for continuous "bulk" imaging with a subsequent sorting-out process miss elements of excitement, spontaneity, and social interaction that characterize key moments that people want to capture and preserve.

Existing solutions involve the capture of either a still image or a video image when capturing a key moment. The ability to capture the entire moment including video before and after a moment as well as the still image would greatly increase context of the moment as well as increase the photographer's experience. Whereas, combined capture of video and still images has been described in International patent application WO2004/111971 A2 "Automatic Traffic Violation Monitoring and Reporting System with Combined Video and Still-Image Data" it is limited to use as evidence in traffic violations and furthermore requires the use of multiple video and still capture devices and multiple captured images. A single device capable of capturing the entire key moment that is usable by a consumer is needed to free the photographer from the image capture function.

Among problems not addressed or solved in existing solutions is the need to provide improved imaging where motion is involved. For example, it is difficult for the consumer photographer to capture an image of a soccer ball in motion, just before it is caught or missed by a goalie. For fast-moving action, consumer pictures tend to be delayed, due both to delay by the camera operator and inherent delay in the image capture timing itself, so that more interesting images can be missed, sometimes by a small fraction of a second. Subsequent editing of a video stream is one solution conventionally used to address this problem. However, it would be advantageous to have a method that allows high-speed event imaging and allows the photographer a greater degree of freedom and ease of use for obtaining an image.

Thus, it can be seen that innovative approaches are needed in order to provide a more satisfying picture-taking experience that is likely to obtain good pictures without constraining the photographer to the picture-taking task and without keeping the photographer out of the picture. For some situations, a workable autonomous camera solution should even be able to provide a workable substitute for a dedicated photographer at a group event. It would be advantageous to provide apparatus and methods for automatic or "autonomous" camera operation, well suited to the needs of the picture-taking consumer.

SUMMARY OF THE INVENTION

In general terms, the present disclosure relates to improving the versatility of digital imaging devices to include autonomous operation. With this goal in mind, the present invention provides a method of image capture including selecting at least one image trigger condition, entering a threshold level corresponding to the at least one image trigger condition, monitoring a signal from at least one sensor detecting the at least one image trigger condition, and obtaining at least one digital image upon detecting the sensed image trigger condition meeting the threshold level.

One aspect of the present invention is an apparatus for capturing an image. The apparatus includes an image capture device for selecting at least one image trigger condition and for setting a threshold level corresponding to the at least one image trigger condition, at least one sensor coupled to the image capture device for detecting the at least one image trigger condition, and a memory coupled to the image capture device for storing at least one digital image captured upon detecting the at least one image trigger condition meeting the threshold level.

Another aspect of the present invention is a method for obtaining an image capture set, composed of a still image and the previous few seconds of video, following an image capture triggered by the detection of at least one image trigger condition or the combination of the still image and the few seconds of video following the detection of the image trigger condition or combinations thereof. The method includes obtaining a video image, continuously storing at least the most current portion of the video image, responding to an instruction to obtain a still image and storing both the still image and the most current portion of the video image.

These and other objects, features, and advantages of the present invention will become apparent to those skilled in the art upon a reading of the following detailed description when taken in conjunction with the drawings wherein there is shown and described an illustrative embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter of the present invention, it is believed that the invention will be better understood from the following description when taken in conjunction with the accompanying drawings, wherein:

FIG. **1** is a schematic block diagram of a digital image capture device according to an embodiment of the present invention;

FIG. **2** is a block diagram illustrating a digital image capture device used at an event according to the present invention;

FIG. **3** is a timing diagram for an image capture set obtained according to the present invention;

FIG. **4** illustrates one example of an interface screen for setup of the imaging system according to one embodiment of the present invention;

FIG. **5** is a plan view of the user interface screen used for image trigger setup;

FIG. **6** is a logic flow diagram that shows steps used for automatic triggering of image capture;

FIG. **7** illustrates how an automatic response mode works according to one embodiment of the present invention; and

FIG. **8** illustrates a procedure an operator will follow for training the camera to use various image subjects as image capture triggers.

DETAILED DESCRIPTION OF THE INVENTION

Various embodiments of the present invention will be described in detail with reference to the drawings, wherein like reference numerals represent like parts and assemblies throughout the several views. Reference to various embodiments does not limit the scope of the invention, which is limited only by the scope of the claims attached hereto. Additionally, any examples set forth in this specification are not intended to be limiting and merely set forth some of the many possible embodiments for the claimed invention.

The present invention provides an autonomous image capture device, such as a camera, providing a solution that is well-suited to the needs of consumers for taking pictures of family, friends, and group events. The autonomous image capture device captures digital images automatically, in response to prompts sensed by the device, according to instructions entered by a user, training provided by the user, or environmental events detected as suitable image trigger conditions by the device. The device is flexible, allowing image capture to be triggered by, in addition to, the image capture button being pushed by the user, any of a number of programmable events. For embodiments of the present invention, it should be noted that the image captured using the image capture device can be either a video image or a still image, or some combination of video and still images.

The image capture device of the embodiments described subsequently can be a digital still camera, a video camera, or a camera that is capable of obtaining both still and video images. An image capture set is obtained by the image capture device and can contain one or more of either or both still and video images captured by the device, based on the capabilities of the device and on the setup parameters specified by the operator or by device control logic. In one embodiment, the image capture set is composed of the combination of a still image and a predetermined number of seconds of video preceding the detection of the image trigger condition, the combination of the still image and the predetermined number of seconds of video following the detection of the image trigger condition, and/or combinations thereof.

FIG. **1** is a schematic block diagram of a digital image capture device **10** according to an embodiment of the present invention. An image capture module **12** containing at least a lens **13** and an image sensor **15** connects to a central processing unit **14** that executes a logic program for automatically obtaining pictures. At least one sensor **18** is in communication with the central processing unit **14**, enabling the central processing unit **14** to respond to a sensed condition by activating image capture module **12** to capture an image. Image data of the captured image can be stored locally at optional storage **16** or can be transmitted to remote storage over network **22**, such as an Ethernet network or other network type. A user interface **20** enables operator instructions to be entered and acted upon by the central processing unit **14**, allowing flexible operation and response of image capture device **10**.

As would be apparent to one skilled in the image capture arts, the basic arrangement of FIG. **1** allows a number of different embodiments. For example, digital image capture device **10** can have sensor **18** integrally built-in, along with any of the central processing unit **14**, user interface **20**, or storage **16**. One or more environmental sensors **18** can be provided, including sensors that detect sound, light (visible, ultraviolet or infrared), vibration, heat, electric fields, magnetic fields, radiation and other environmental variables that can act as cues or prompts, as will be described subsequently. Central processing unit **14** can alternately be an on-board microprocessor or a separate personal computer, such as a laptop computer or workstation, for example. User interface **20** can be built-in or can be separable from apparatus **10**. The central processing unit **14** and storage **16** components can be located remotely, at some other location along network **22**. Connections between components can be wireless or wired, depending on the flexibility needed. Therefore, for the purpose of subsequent description, the arrangement of FIG. **1** can serve as a useful model, subject to any number of variants.

FIG. **2** is a block diagram illustrating a digital image capture device **10** used at an event according to the present invention. Digital image capture device **10** is positioned at a convenient location for image capture, such as on a shelf or high table for an indoor event, for example. Alternately, the digital image capture device **10** could be handheld or attached to the body or other method wherein the digital image capture device **10** is vaguely pointed in the direction where an image capture is desired. One or more sensors **18** can be built into digital image capture device **10** or located at any suitable distance from digital image capture device **10**, as permitted by the interconnecting communication channel between them. This interconnecting communication channel can be wired or wireless. One or more of sensors **18** could be concealed, disguised as or in an object in the scene, or worn by someone who is in the vicinity of the scene or of digital image capture device **10**.

Sensor Types and Arrangements

Sensor **18** can be any of a number of types of sensor device and can detect any of a number of conditions, particularly using the processing capabilities of the central processing unit **14**. Multiple sensors **18** can be used. Sensor **18** can be, for example, an audio sensor. In one embodiment, noise above a predetermined threshold level can indicate a suitable time for image capture. However, there can be subtler cues that are appropriate for image capture. A type of sound can also indicate a time that is advantageous for image capture. This can include a cue from one or more participants, such as a key word, a sound obtained from a type of prompt device, whether or not audible to the human ear, the sound of laughter, a sudden transition in volume, either from high to lower or from low to higher, applause, transition to silence, etc. A voice profile of one or more participants can also be obtained and the central processing unit **14** programmed to respond to the voice of any particular person or to intonations in sound from one or more persons. Also, sound from animals or objects, such as a bell, can trigger image capture.

Alternately, sensor **18** can be any type of environmental sensor such as a type of heat sensor or infrared sensor. Heat detected from event participants can be used to initiate image capture. Changes in a detected heat profile for the image field can also be used, such as changes that indicate motion. Sensor **18** could also sense changes in light, including brightness or spectral changes. Spectral changes could be sensed beyond the visible spectrum into the ultraviolet region or the infrared region by sensor **18**. This type of change could be used, for example, to indicate movement suitable for initiating image capture. Vibration or airflow could alternately be sensed by sensor **18** or by multiple sensors **18**. Electric fields, magnetic fields or radiation could be sensed by sensor **18** as well to sense changes in the image field that initiate image capture. These factors can indicate proximity of one or more participants, for example.

In other embodiments, the role of sensor **18** can be performed by image processing software that executes on image data that is continuously obtained by image capture module **12**. By continually monitoring the video signal that is obtained by image capture module **12**, this software can detect events such as sudden motion, motion starting or motion stopping, change in brightness, and other conditions that can serve as image trigger conditions to initiate image capture.

Capturing Content

In another operating mode of digital image capture device **10**, an image capture set is obtained. The image capture set is composed of the combination of a still image and a predetermined number of seconds of video prior to the detection of the image trigger condition, the combination of the still image and a predetermined number of seconds of video following the detection of the image trigger condition, or combinations thereof. In this embodiment, image capture module **12** can capture both still images and a series of images as in video or alternately the video can be captured from the preview stream provided to the display.

One problem noted earlier, relates to the response time of a camera operator. In this operating mode, temporary buffer **17** is used as a temporary buffer, to store the most current portion of the video image that is continuously being obtained by image capture module **12**. The resolution of the video is lower than the resolution of the still image to enable fast frame rate video, to reduce the data rate of the video stream and also to reduce the required size of the temporary buffer **17**. This provides a method for obtaining video images from a few seconds prior to detection of the image trigger condition to show the events leading up to the still image capture. In addition, this few seconds of video can provide context to the still image capture when in an image capture set.

FIG. **3** is a simplified timing diagram that shows how an image capture set can be obtained according to the present invention. In FIG. **3**, window **32** illustrates a time window **32**. In time window **32**, time t**1** is a predetermined period of time earlier than t**2** for which the video data can be stored in the temporary buffer **17**. For example, time t**1** could be 10 seconds prior to time t**2**. Time t**3** is a predetermined period of time after t**2** for which the video data can be stored in the temporary buffer **17**. For example, time t**3** could be 5 seconds after t**2**. The trigger event occurs at time t**2**, as shown in the diagram of FIG. **3**. Since time t**3** is a period of time later than t**2**, the video data from the period t**2** to t**3** can be stored directly in storage **16**. The image capture set can be composed of any combination of the video image from time t**1** to t**2**, the still image captured at t**2**, and the video image from t**2** to t**3** as discussed in more detail below. Following capture of the image capture set, the image capture set is moved into storage **16**.

In one embodiment, video taken for a predetermined period of time preceding the still image capture can be included in an image capture set. This period of time is illustrated by window **32** in FIG. **3** as the times between t**1** and t**2**. For this period, the video is continuously being stored in temporary buffer **17** (FIG. **1**). In addition, video from a predetermined period of time following the still image capture, shown in FIG. **3** as time t**2** to time t**3**, can also be included in the image capture set. The time between t**1** and t**2** and the time between t**2** and t**3** are established by: user preference, temporary buffer **17** size, a default setting or a combination thereof. The video is continuously stored in temporary buffer **17** when the device is ready to capture, such as when the digital capture device **10** is placed in a mode in which image capture sets are enabled when the digital capture device **10** is picked up by the user, or when the user contacts the image capture button.

User Interface Example

FIG. **4** illustrates one example of an interface screen **30** for setup of the imaging system according to one embodiment of the present invention. In one embodiment, the image capture system is programmed to respond to subtle cues in the event environment. For example, laughter can have particular audio signal characteristics that can be quantified and used to initiate image capture. Some amount of training can also be used, by which the central processing unit **14** is programmed to achieve better and better results for distinguishing between one type of sound and another (or, more generally, one type of sensed condition and another).

In FIG. **4**, interface screen **30** appears on the camera display and uses touchscreen menu selections. Expandable menu selections **34** are provided to enable selection of basic cues or prompts for autonomous image capture. In the example of FIG. **5**, a volume change condition is selected as a prompt to initiate image capture. The camera operator makes a setting **36** for a volume change threshold that will cause an image or an image capture set to be obtained. A control knob on the camera can be re-mapped in order to set the setting level. Optionally, a touchscreen or other type of operator input mechanism can be used to obtain a preferred setting level.

Transitions can be effectively used as image capture triggers and can be more useful than static conditions. For example, digital image capture device **10** could be set up to obtain images when noise above a certain threshold is sensed. However, in a relatively noisy environment, this could cause digital image capture device **10** to activate and capture images more often than is desired. Instead, transitions between noise levels, of a certain number of dB within a given time interval, for example, would be more likely to initiate image capture during an event that interests the camera user.

Other prompt selections can be more complex than shown in the simple example of FIG. **5**. For example, prompt selection can specify a type of voice (Adult or Child, for example) or can specify a particular person's voice. Voice recognition software running on the central processing unit **14** (FIG. **1**) would be used to detect the voice of one or more individuals as a cue, as described subsequently in a more detailed example.

Still other selectable events that could be used as image capture triggers including but are not limited to: changes in color, brightness, or other image characteristics. Motion can be detected by a number of characteristics, including sudden motion, stopped motion, motion above or below a specified threshold speed, or having other characteristics that can be programmable selected. Content can also be used as an image capture trigger, so that various image subjects can be detected and act as image capture triggers. For example, variables such as a number of faces in the image field could serve as image capture triggers; changes in complexion or color, such as those that might indicate exertion or blushing, might also be sensed by digital image capture device **10** and used as image trigger conditions for image capture.

Still other defined content conditions can include detection of a person, animal, face, or other distinguishable subject or object. Digital image capture device **10** can be provided with logic tools for periodically analyzing images and determining if the image is that of a person, pet or other animal, or object of interest. Digital image capture device **10** can also have the capability to "learn" specific people or objects, as described subsequently.

A number of optional sensors could be employed to detect conditions other than those normally associated with light or sound. Infrared detectors could be selected to identify certain people, pets, or situations where body heat or other changes in the measured heat profile in the field of view are suitable image capture triggers. Sensors for body temperature, EKG, vibration, or other detectable parameters could be used.

As noted earlier, both still and video images can be obtained as part of an image capture set. The operator interface for digital image capture device **10** can offer the operator an option to set up image trigger conditions specifically for either type of image capture or for capture of both types in some combination.

Example Using Specified Voice or Other Audio Signal

FIG. **6** is a flow chart illustrating voice and/or audio detection logic according to the present invention. For voice or other audio detection, the logic flow of FIG. **6** or similar logic can be used. The following example and steps are given for a voice example. It should be noted that any type of sound, such as that of a particular pet, musical instrument, door opening, phone, bell, or other sound could be a similar stimulus for image capture with digital image capture device **10** in autonomous image capture mode.

In a selection step **100**, the operator specifies voice or sound recognition for one or more voices (or other sounds) using interface screen **30** commands. In a sample acquisition step **110**, the operator has the identified person or persons speaking into a microphone. The microphone can be on the camera itself, or attached to the camera or to the central processing unit **14**. Depending on the sophistication required, voice sampling can be relatively simple, merely requiring the speaker to talk for a period of a few seconds, long enough for a basic audio profile to be generated. In a more complex setting, the identified person can be required to say specific phrases that help to characterize tone and speech patterns of a particular person so that they can be distinguished from those of others.

A monitor step **120** is executed once the camera is activated for autonomous operation. During monitor step **120**, the central processing unit **14** on digital image capture device **10** continually monitors the audio stream detected from a microphone input signal. An event detection looping step **130** occurs periodically, as control logic determines whether or not the voice(s) of the specified person(s) has been detected. If so, an image capture step **140** is executed. Imaging can then be stopped until the next operator command is received. Optionally, continuous image capture can be initiated with each detected audio "event" indicating that the specified person(s) or participants have spoken.

Automatic Response to Environmental Variables

FIG. **7** illustrates how an automatic response mode works according to one embodiment of the present invention. A digital image capture device **10** can be put into an automatic response mode, in which it responds to changes in an “expected” or “normal” setting. In this mode, digital image capture device **10** can adapt to changes in its field of view and capture images when it detects a sufficient amount of change in its environment. In this way, for example, digital image capture device **10** can be left by itself in a room that is initially empty. As a person enters, the detected activity can be of sufficient energy to activate digital image capture device **10** for image capture.

In FIG. **7**, a mode initialization step **200** is first carried out, during which the digital image capture device **10** is placed in a mode for adapting to its particular field of view. One or more sets of preset threshold settings **202** can be provided to help set sensitivity thresholds for “energy levels” at which digital image capture device **10** performs image capture. A self-learning step **210** for training the digital image capture device **10** to learn about the scene in order to develop image trigger condition thresholds follows. During step **210**, digital image capture device **10** senses one or more variables from its environment. These variables can include, for example, activity in its field of view, ambient noise level, relative brightness, color, and other detectable cues. While in this mode, digital image capture device **10** integrates this sensed activity over time, so that it obtains a characteristic “profile” of what its “world” looks like. Digital image capture device **10** will then be able to respond to transitions in the scene once it has sensed the relative activity or energy level in the scene over time. After some learning time period, digital image capture device **10** is then ready for an autonomous operation step **220**. This can be after a preset time period, for example. Alternately, some instruction from the operator can be used to end self-learning step **210** and to begin autonomous operation step **220**.

A monitoring step **230** is executed as part of autonomous operation step **220**. During monitoring step **230**, digital image capture device **10** monitors its field of view and its selected set of environmental variables. An event detection step **240** occurs when some measured variable exceeds a given threshold value. For example, noise of a passing car outside can be detectable, but below the threshold value that has been “learned” by digital image capture device **10**. This can occur where digital image capture device **10** has been placed in a relatively noisy environment, so that false triggering from expected environment noise is not used to trigger image capture. A decision step **250** is executed when a stimulus of some type has been sensed. If the sensed signal exceeds a given threshold value or meets other necessary conditions that can be influenced both by preset settings **202** and by learned characteristics obtained in self-learning step **210**, an image capture step **260** can be initiated. This can terminate autonomous operation, or can simply cause the control logic to loop back to monitoring step **230** as shown.

As yet another part of autonomous operation step **220**, digital image capture device **10** can also continually “re-learn” its environment based on what is sensed while in operation. For example, a meeting room can initially be empty during self-learning step **210**. As participants begin to enter the room, digital image capture device **10** will begin to obtain images, advancing to image capture step **260** as just described. For example, an image will be captured for each new person entering the room or periodically. However, once the room is full or no one else will enter, the camera’s response should change accordingly. In another embodiment, by continuing to integrate sensed data, digital image capture device **10** can thus obtain a history that is updated, so that its sensitivity threshold changes once a meeting has begun. A

type of redefined, recalculated or “rolling” normal state would then be used, allowing digital image capture device **10** to adjust its threshold sensitivity in response to a changing environment or new conditions, using recent “history” of sensed conditions. With respect to the logic shown in FIG. **7**, self-learning step **210** can thus be invoked periodically in order to adjust the threshold setting used in decision step **250**. By obtaining this history, only a dramatic change in volume or motion might then trigger subsequent image capture. False triggering could be effectively prevented to minimize the capture of uninteresting or repetitive images.

It should also be observed that digital image capture device **10** can automatically enter automatic response mode, carrying out mode initialization step **200** immediately upon power-up or according to a timer. Additionally, monitoring step **230** can have different levels of sensitivity that change with time. This feature would allow digital image capture device **10** to enter a “power save” mode, reducing battery or other power consumption if there are no detected events within a predetermined time period. For example, where a user neglects to turn the digital image capture device **10** off and the device is kept in a meeting room over the weekend, a lower level of monitoring sensitivity can be most appropriate for a power save feature.

Overall, a various configurations are available to the operator of digital image capture device **10** for use in an automatic response mode. In one embodiment, no configuration of the camera is needed. The camera automatically enters the automatic response mode as soon as power is applied unless otherwise instructed by the operator. Alternately, configuration tools can be provided to select from various sensed conditions or to provide initialization thresholds.

As noted earlier, the image capture set that is obtained in automatic response mode can be still images or video images or some combination of both image types. A short video sequence can be obtained in image capture step **260** under certain conditions, such as for some types of events or for different threshold settings.

Learned Response to Subjects or Events

FIG. **8** illustrates a procedure for teaching the digital image capture device **10** to use various identifiable portions of an image as subjects of interest that act as image capture triggers. In one embodiment, the digital image capture device **10** continuously analyzes a field of view and when a subject of interest is detected, image capture is initiated. As such, the subject of interest represents the variable to be detected and the presence of the subject of interest within the field of view indicates that the image trigger condition threshold level has been exceeded. Alternately, the image trigger condition can be a change in the presence of the subject of interest wherein the threshold is exceeded when the subject of interest leaves the field of view.

The digital image capture device **10** learns or is trained to respond to specific subjects of interest or specific types of events that can be sensed or that occur within its field of view. In one embodiment, as shown in the example of FIG. **8**, the operator follows a procedure for educating or training the camera to use various subjects of interest as image capture triggers. More specifically, in a setup step **300**, the operator instructs digital image capture device **10** to enter a teach mode. This instruction can be entered using a control **42** on the camera or by some other command entry device provided for this purpose, such as a pull-down menu or specified control sequence.

In a display step **310**, an image containing the subject or event of interest appears on camera display **30**. This can be a newly captured image or a previously stored image that is accessible to the camera. With the image displayed, an identification step **320** is next performed. In identification step **320**, the operator explicitly indicates the subject of interest that should be used as an image capture trigger. In the example of FIG. **8**, the operator would like an image captured when digital image capture device **10** has a soccer ball in its field of view. The operator displays an appropriate image with that subject of interest and then highlights the subject of interest in some way such as with a touchscreen. However, the invention is not limited to highlighting, and any suitably technique to select a subject can be used, such as those techniques described in U.S. Pat. No. 7,164,490 "Custom Cut Image Products" issued to Manico et al. The displayed image can be an image previously captured and stored in digital image capture device **10**, or an image that is accessible to digital image capture device **10**, such as through a network **22**. Optionally, the displayed image could be simply the live image display that is continuously obtained during digital image capture device **10** operation.

In FIG. **8**, an outline **44** is drawn around the soccer ball shown in the camera display **30**. Outline **44** could be sketched on a touchscreen display or could be generated in some other way. Optionally, a finger press on a touchscreen can identify the subject of interest. Image analysis software on the central processing unit **14** (FIG. **1**) would then be able to bound and identify the object nearest the finger press.

The setup steps for teaching digital image capture device **10** shown in FIG. **8** can be repeated as many times as is necessary in order to generate a "library" of subjects of interest. This same sequence could be used, for example to introduce people as subjects of interest to the digital image capture device **10**. This would allow digital image capture device **10** to identify it's people "of interest" and to work on obtaining images of this set of people. A library of subjects of interest could then include both objects, such as the soccer ball of the example of FIG. **8**, and any number of people.

A similar sequence could be used to identify particular colors or sounds and store these similarly in the library of learned response subjects and events. In this way, the soccer team uniform or team cheer could be stored as image trigger conditions, for example.

Part of the teaching sequence can require feedback and correction of camera errors in obtaining images of people or objects that are similar, but not the preferred choices. For example, a mother could effectively teach digital image capture device **10** to distinguish her child from other children on the team or in the school play.

By combining multiple subjects of interest, the user can teach the digital image capture device **10** to capture images when the subjects of interest are all present in an image together. An example of using multiple subjects of interest would be to teach the digital image capture device **10** to initiate an image capture when a soccer player with a specific jersey number is in the field of view along with the soccer ball and the soccer goal. In this case, the jersey number, the soccer ball and the soccer goal would each be identified as subjects of interest and the image trigger condition threshold would be the simultaneous presence of all 3 subjects of interest in the field of view.

In another embodiment, digital image capture device **10** can be configured to use a library of images to determine the preferred subjects of interest that a particular user tends to have based on the content of the library. This library of images may be located on the digital image capture device **10** or be located at a remote site that is accessed via the network **22**. For example, repeated images of a certain child, pet, or other subject would indicate that this particular subject is of significant value to the user. Image analysis software can be used to track the number of images obtained of various subjects and use this data as input to a learning process to determine the preferred subjects of interest. Similarly, digital image capture device **10** can assign an image value to each image in a library of images according to its perceived value to the user. This has been termed an Image Value Index (IVI). For example, data can be obtained on how long a user looked at certain images and the content of those images. Areas of importance in an image can be detected in a number of ways, such as that described in commonly assigned U.S. Pat. No. 7,046,924 entitled "Method and Computer Program Product for Determining an Area of Importance in an Image using Eye Monitoring Information" issued to Miller et al. Other useful indicators of the effective value of various image content can include the number of email transactions using an image and identifiable content for images captured from this device. Metadata provided with images transferred and detected by digital image capture device **10** can also be scanned and used to indicate subjects that appear to be of particular interest to a user.

Once one or more subjects of interest have been stored, digital image capture device **10** can employ these subjects of interest as image capture triggers whenever it is placed in automatic response mode. These image capture triggers can then be sensed as "instructions" to digital image capture device **10** to capture an image (or capture an image capture set) when the subject or subjects of interest are present in the field of view and a corresponding threshold has been satisfied. Additional user procedures are provided for managing the library of subjects of interest and other learned image capture triggers, eliminating image capture triggers that no longer have value to the user, prioritizing image capture triggers, or coordinating the use of multiple image capture triggers in combination.

Image Processing

Conventional photography approaches often required considerable care and attention to the exact setup of the camera device and supporting lighting components, in order to optimize image quality as much as possible. In contrast, the present invention takes advantage of various benefits of digital imaging for automating the image processing that is needed in order to obtain pleasing images when using digital image capture device **10**.

In one embodiment, a wide-angle camera is used for obtaining the original digital image. Then, this original image is centered and cropped using any of a number of well-known techniques for identifying the significant image content from an image and cropping to remove content of less interest for forming a conditioned digital image. It can be observed that ongoing and anticipated future improvements in imaging resolution would enable a cropped image to have a pleasing appearance and very good image quality.

Key frame extraction methods can be used in order to detect and distinguish key image frames that are most likely to be of value to the user. Key frame extraction methods are described, for example, in commonly assigned pending U.S. patent application Ser. No. 11/346,708, filed Feb. 3, 2006 entitled "Extracting Key Frame Candidates from Video Clip" to Luo et al., and pending U.S. patent application Ser. No. 11/347,679, filed Feb. 3, 2006 entitled "Analyzing Camera Captured Video for Key Frames." to Luo et al. Other key frame extraction methods are described in U.S. Patent Application No. 2005/0228849 entitled "Intelligent Key Frame Extraction From a Video" by Zhang.

Automatic zoom and crop techniques are also of value for selecting that portion of a wide-field image that is of particular interest. Examples of patents that describe automatic zoom and crop techniques that could be used include commonly assigned U.S. Pat. No. 6,654,507 entitled "Automatically Producing an Image of a Portion of a Photographic Image" to Luo and commonly assigned U.S. Pat. No. 6,654,506 entitled "Method for Automatically Creating Cropped and Zoomed Versions of Photographic Images" to Luo et al. The video in the image capture set can be used to further improve the automatic zoom and crop process as applied to the content of the still image of the image capture set. Also, the image capture trigger information can be used to further improve the image content of the automatically zoomed and cropped images by providing input to the automatic zoom and crop process.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the scope of the invention as described above, and as noted in the appended claims, by a person of ordinary skill in the art without departing from the scope of the invention. For example, the invention could be used with a number of types of digital camera, by making the appropriate connections between components and using control program logic that executes on a standard workstation or laptop computer platform. Or, the apparatus of the present invention could be packaged as a product, with sensor, control logic, interface, and other functions integral to the device. Various types of image processing could be employed, depending on the application. Multiple cameras could be used, at different locations, and obtaining images based on the same sensed condition. Different arrangements of sensors could be used, with different behavior programmed based on various combinations of conditions sensed.

Thus, what is provided is an apparatus and method for providing a camera apparatus that responds to a set of environmental cues to obtain an image capture set without direct operator intervention.

PARTS LIST

10 digital image capture device
12 image capture module
13 lens
14 processing unit
15 image sensor
16 storage
17 temporary buffer
18 sensor
20 user interface
22 network
30 screen
32 window
34 menu selections
36 setting
42 control
44 outline
100 selection step
110 sample acquisition step
120 monitor step
130 event detection looping step
140 image capture step
200 mode initialization step
202 threshold settings
210 self-learning step
220 autonomous operation step
230 monitoring step
240 event detection step
250 decision step
260 image capture step
300 setup step
310 display step
320 identification step

The invention claimed is:

1. A method of automatically capturing an image with an image capture device comprising:

selecting an automatic image trigger condition;

entering a threshold level corresponding to the automatic image trigger condition, wherein reaching the threshold level of the automatic trigger condition indicates that a suitable image can be captured;

monitoring of a signal for detecting the automatic image trigger condition; and

automatically operating the image capture device to capture at least one digital image upon the automatic detection of the automatic image trigger condition meeting the threshold level.

2. The method of claim **1**, wherein selecting the automatic image trigger condition further comprises selecting the presence of predetermined image content in the field of view of the image capture device.

3. The method of claim **2**, wherein selecting the presence of predetermined image content comprises selecting the predetermined image content from a portion of an image previously captured and stored in the image capture device.

4. The method of claim **3**, wherein selecting the predetermined image content from a portion of an image previously captured and stored in the image capture device further comprises indicating the predetermined image content by using a touchscreen.

5. The method of claim **3**, wherein selecting the predetermined image content from a portion of an image previously captured and stored in the image captured device further comprises outlining the predetermined image content from a group consisting of an object, animal and person from the previously captured and stored image displayed on the image capture device.

6. The method of claim **2**, wherein selecting the predetermined image content further comprises selecting the predetermined image content from a portion of digital image that is accessible to the image capture device.

7. The method of claim **6** further comprising accessing the digital images via a network.

8. The method of claim **2** further comprising analyzing an image collection to select the predetermined image content.

9. The method of claim **8**, wherein analyzing the image collection to select the predetermined image content further comprises analyzing image metadata.

10. The method of claim **8**, wherein analyzing the image collection to select the predetermined image content further comprises using an Image Value Index.

11. The method of claim **8**, wherein analyzing the image collection to select the predetermined image content further comprises analyzing the image content.

12. The method of claim **1** further comprising:

detecting a region of interest in the obtained at least one digital image; and

cropping the at least one digital image automatically according to the region of interest in the image, and forming a conditioned digital image.

13. The method of claim **1**, wherein selecting the at least one automatic image trigger further comprises selecting the automatic image trigger from the group consisting of laughter, applause, transition in volume level over a predefined threshold, a spoken term or phrase, a sound made by a prompt device, a certain person's voice, presence of a preferred subject in the field of view of the image capture device, a change in temperature, a change in vibration, a change in spectrum, a change in infrared, a change in ultraviolet, a change in electric field, a change in magnetic field, a change in radiation, and a change in air flow.

14. The method of claim **1**, wherein the step of monitoring a signal further comprises using a sensor to produce a signal and monitoring the signal from the sensor, wherein the sensor is selected from the group consisting of an audio sensor, a heat sensor, a vibration sensor, a spectral sensor, an ultraviolet sensor, an infrared sensor, an electric field sensor, a magnetic field sensor, a radiation sensor, an air flow sensor, a motion sensor or an image sensor.

15. The method of claim **1**, wherein obtaining the at least one digital image further comprises obtaining an image capture set having both at least one still image and a predetermined number of seconds of video preceeding the detection of the automatic image trigger condition.

16. A method of claim **15**, wherein obtaining an image capture set further comprises obtaining a combination of at least one still image, a predetermined number of seconds of video preceding the detection of the automatic image trigger condition and a predetermined number of seconds of video following the detection of the automatic image trigger condition.

17. The method of claim **15**, wherein the still image is automatically cropped using information from the video.

18. The method of claim **15**, wherein the still image is automatically cropped using information from the automatic image trigger condition.

19. The method of claim **1**, wherein the step of monitoring the signal is provided by analyzing images from an image sensor.

20. The method of claim **19** further comprising detecting motion using the image sensor.

21. The method of claim **1**, wherein monitoring the signal further comprises detecting changes in light level in excess of a predetermined threshold value.

22. The method of claim **1**, wherein selecting the automatic image trigger condition further comprises selecting more than one automatic image trigger condition, with corresponding thresholds and obtaining at least one digital image upon detecting that all of the more than one automatic image trigger conditions thresholds have been met.

23. The method of claim **1**, wherein selecting the automatic image trigger condition comprises accepting predetermined default conditions for the image capture device.

24. The method of claim **1**, wherein the automatic image trigger condition for obtaining the at least one digital image further comprises detecting motion starting or motion stopping in the field of view of the image capture device.

* * * * *

EXHIBIT J

US008300285B2

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

(10) **Patent No.: US 8,300,285 B2**
(45) **Date of Patent: *Oct. 30, 2012**

(54) **SCANNING CIRCUIT STRUCTURE**

(75) Inventors: **Kuan-Yu Lee**, Taichung (TW); **Chen-Ho Lee**, Hsinchu (TW)

(73) Assignee: **Transpacific Systems, LLC**, Wilmington, DE (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1235 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/694,472**

(22) Filed: **Mar. 30, 2007**

(65) **Prior Publication Data**

US 2008/0030799 A1 Feb. 7, 2008

Related U.S. Application Data

(63) Continuation of application No. 10/064,265, filed on Jun. 27, 2002, now Pat. No. 7,315,406.

(51) **Int. Cl.**
H04N 1/04 (2006.01)
H04N 1/32 (2006.01)

(52) **U.S. Cl.** **358/482**; 358/483; 358/445; 358/474; 358/468; 358/442

(58) **Field of Classification Search** 358/482, 358/483, 445, 442, 468, 434, 505, 512–514, 358/409, 412; 250/208.1, 234–236, 216, 250/208.2; 382/312, 318, 319; 399/211, 399/212; 716/108

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,920,429	A	4/1990	Jaffe et al.	
5,040,079	A	8/1991	Shimizu	
5,239,387	A	8/1993	Stein et al.	
5,483,357	A *	1/1996	Nagano	358/483
5,594,468	A	1/1997	Marshall et al.	
5,627,603	A	5/1997	Sakai	
5,778,109	A	7/1998	Morigami	
6,002,508	A	12/1999	Mai	
6,084,691	A	7/2000	Tsai et al.	
6,422,682	B1	7/2002	Kaneko et al.	
6,631,507	B2 *	10/2003	Shih et al.	716/108
6,801,254	B1	10/2004	Nishio	
6,958,830	B2 *	10/2005	Kono	358/443
7,315,406	B2 *	1/2008	Lee et al.	358/482
7,336,402	B2	2/2008	Moritaka	
7,375,754	B2 *	5/2008	Miyazaki	348/308
RE40,644	E	3/2009	Omi	
7,697,172	B2 *	4/2010	Ikeno et al.	358/474
8,149,468	B2 *	4/2012	Okamoto	358/409
2004/0196504	A1 *	10/2004	Kono	358/300
2006/0176525	A1 *	8/2006	Mizuta et al.	358/474
2007/0146821	A1 *	6/2007	Joh	358/482
2008/0204826	A1 *	8/2008	Kimura	358/497

FOREIGN PATENT DOCUMENTS

EP	0568080		11/1993
JP	2002218185	A	8/2002
JP	2003110798	A	4/2003

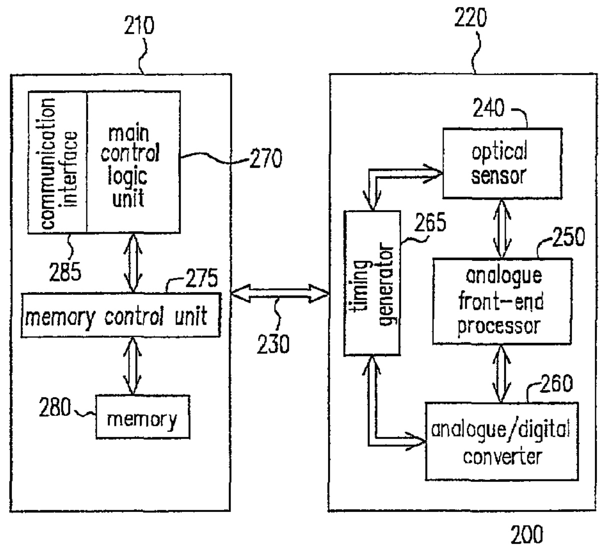
* cited by examiner

Primary Examiner — Cheukfan Lee
(74) *Attorney, Agent, or Firm* — Stolowitz Ford Cowger LLP

(57) **ABSTRACT**

A scanning circuit having rearranged circuit modules at each end of a flat cable. After the rearrangement, the flat cable carries scanning control signals produced by a conventional IC communication interface instead of timing signals and carries digital image data instead of easily distorted and interfered analog image signals.

20 Claims, 1 Drawing Sheet



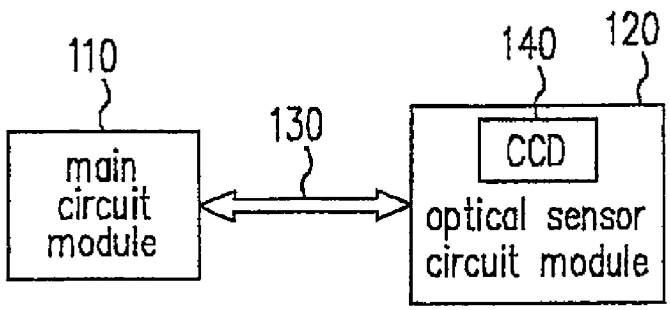


FIG. 1 (PRIOR ART)

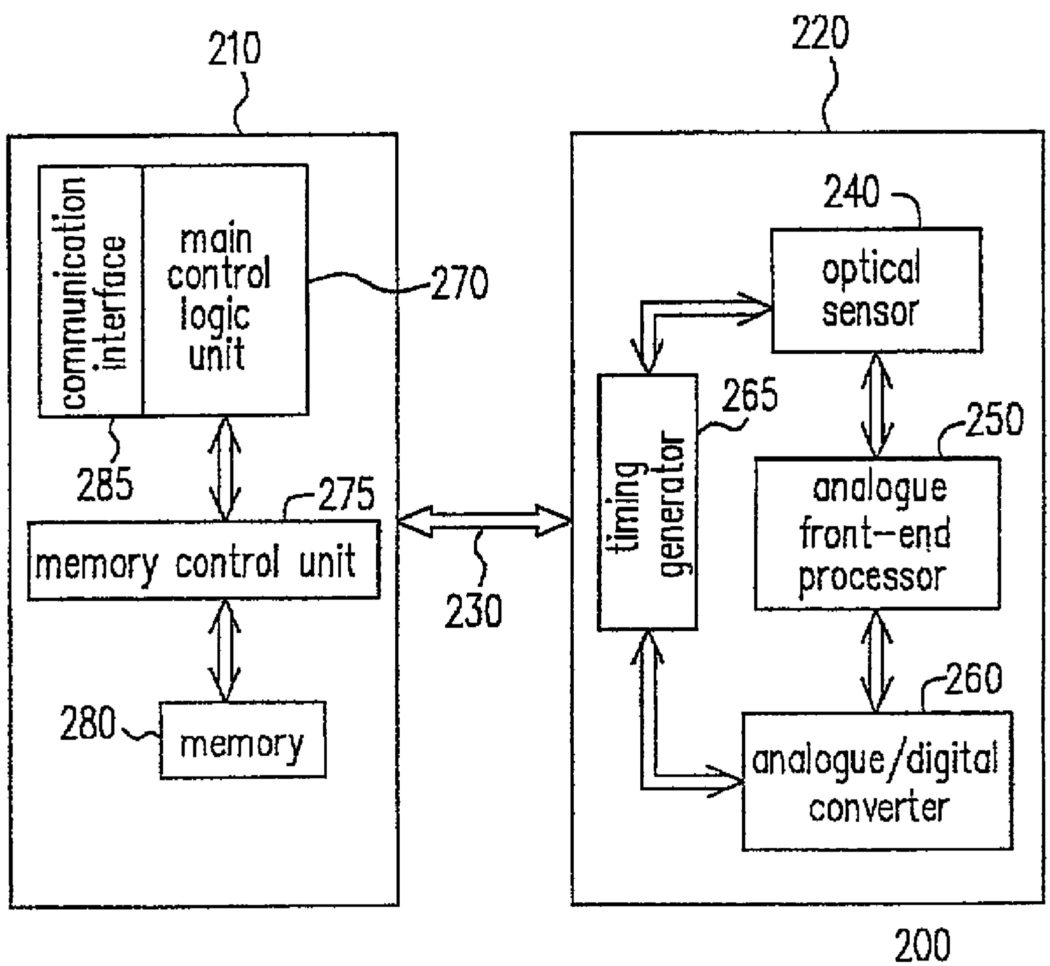


FIG. 2

SCANNING CIRCUIT STRUCTURE

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation application of U.S. application Ser. No. 10/064,265, filed Jun. 27, 2002, and since issued as U.S. Pat. No. 7,315,406. The entire disclosure of U.S. application Ser. No. 10/064,265 is considered as being part of the disclosure of the present application and is hereby incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

1. Field of Invention

The present invention relates to a scanner. More particularly, the present invention relates to scanning circuit structure.

2. Description of Related Art

In recent years, rapid progress in digital technologies has lead to the development of Internet and multimedia systems. Accompanying this trend, a large number of analog images are routinely converted into a digital format to facilitate processing. A digital camera (DC) is used to extract an image from an actual scene. Similarly, an optical scanner is used to extract textual data from a document or image data from a picture. The extracted data is converted into a digital format so that a computer or electronic equipment may display an image, carry out an optical character recognition, edit the data, store up the data or simply output to some devices.

According to the method of inputting document image, optical scanners may be classified as a palmtop scanner, a sheet feed scanner, a drum scanner or a flatbed scanner. FIG. **1** is a diagram showing the circuit structure of a conventional scanner. As shown in FIG. **1**, the circuit includes an optical sensor circuit module **120** and a main circuit module **110**. Each circuit module is fabricated on a printed circuit board. The circuit modules **110** and **120** communicate with each other through a flat cable **130**. In general, the main circuit module **110** is fixed inside the lower casing of a scanner while the optical sensor circuit module **120** is attached to a scanning module capable of moving longitudinally. The optical sensor circuit module **120** has a charge-coupled device **140** therein. The charge-coupled device **140** can sense the light reflected from the image within a scan document to produce analog image signals. The analog image signals are transmitted to the main circuit module **110** by a form of analog voltage signals through the flat cable **130**. The main circuit module **110** processes the analog image signals and converts the analog image signals into digital image data, so as to provide a user to retrieve the digital image data file to carry out various operations including image display, optical character recognition, editing, data archiving or data transfer through a computer or other electronic device. In addition, to capture the image produced by the reflected light while scanning the document, the charge-coupled device **140** must receive timing control signals from the main circuit module **110** as well. Hence, the flat cable **130** must carry both timing control signals and analog image signals.

When demand for image quality is low, a flat cable is adequate because the quantity of image data that needs to be transferred is small. However, due to rapid expansion of computer power, the production of a high-quality scan image at a shorter scan period is always in demand. Eventually, to meet these demands, the flat cable has to carry greater quantities of analog image signals and timing control signals. In other words, the flat cable not only has to transmit signal at a higher

rate, but also has to increase the number of transmission lines for transmitting timing control signals. The additional transmission lines for carrying control signals may cause electromagnetic interference (EMI) of analog image signals. Ultimately, image data may be distorted.

SUMMARY OF INVENTION

Accordingly, one object of the present invention is to provide a scanning circuit structure for a scanner capable of reducing distortion during high-speed image signal transmission so that electromagnetic interference is minimized and quality of transmitted image is improved.

To achieve these and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, the invention provides a scanning circuit structure for a document scanner. The scanning circuit includes a main circuit module and an optical sensor circuit module. The main circuit module receives a scanning instruction from a communication interface and converts the scanning instruction into scan control signals. The scan control signals are passed to a connection cable. In the meantime, the main circuit module also receives digital image data of a scan document from the connection cable. The optical sensor circuit module is connected to the main circuit module via the connection cable. The optical sensor circuit module receives the scan control signals and converts the scan control signal into timing control signals. Hence, operations including the scanning of a document, the extraction of an analog image signal and the conversion of the analog image signal into a digital image data are executed in sequence.

In one embodiment of this invention, the main circuit module includes a main control logic unit, a memory unit and a memory control logic unit. The optical sensor circuit module includes an optical sensor, an analog front-end processor, an analog/digital converter and a timing signal generator. The main control logic unit in the main control module receives scanning instructions and converts the instructions into scanning control signals. The main control logic also receives digital image data scanned from a document. The memory unit stores digital image data. The memory control logic unit is coupled to the main control logic unit and the memory unit for controlling the access of digital image data. The optical sensor inside the optical sensor circuit module is used to sense an analog image signal that is formed by the light reflected from the document. The analog front-end processor is coupled to the optical sensor for pre-processing the analog image. The analog/digital converter is coupled to the front-end processor for converting the pre-processed analog image signal into digital image data. The timing signal generator is coupled to the optical sensor and the analog/digital converter for producing timing control signals, so as to control the scanning process on the document, produce the analog image signal of the document, and convert the analog image signal into the digital image data.

The main control logic unit in this invention also includes an image front-end processor for compensating and adjusting the captured digital image data so that the scanned image has a better quality. In general, the memory unit contains dynamic random access memory and the optical sensor is a charge-coupled device (CCD) or a CMOS image sensor. The connection cable linking the main circuit module and the optical sensor circuit module include a flat cable and the scanning circuit interfaces with a computer through a universal serial bus (USB). The scanning control signals are transmitted through an IIC or 3-wire IC communication interface.

In this invention, digital image data are transmitted instead of analog image signals. Furthermore, the scanning control signals are transmitted through a common IC communication interface instead of timing control signals transmitted through a connection cable. Through this arrangement, image data distortion due to high-speed transmission is greatly minimized. Hence, electromagnetic interference is minimized and quality of image transmitted by the scanner is improved.

It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF DRAWINGS

The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention. In the drawings,

FIG. **1** is a diagram showing the circuit structure of a conventional scanner; and

FIG. **2** is a diagram showing the circuit structure of a scanner according to one preferred embodiment of this invention.

DETAILED DESCRIPTION

Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

FIG. **2** is a diagram showing the circuit structure of a scanner according to one preferred embodiment of this invention. As shown in FIG. **2**, the scanning circuit **200** is responsible for controlling the entire process of scanning a document. The scanning circuit **200** includes a main circuit module **210** and an optical sensor circuit module **220**. The main circuit module **210** and the optical sensor circuit module **220** are linked together through a connection cable **230** such as a flat cable. The flat cable carries both scan control signals and digital image data. The main circuit module **210** further includes a main control logic unit **270**, a memory unit **280** and a memory control logic unit **275**. The optical sensor circuit module **220** further includes an optical sensor **240**, an analog front-end processor (AFE) **250**, an analog/digital converter **260** and a timing signal generator **265**.

The main control logic unit **270** in the main circuit module **210** connects with the human/machine interface of a personal computer (not shown) through a communication interface **285**. Here, the communication interface **285** can be a universal serial bus (USB) interface or an enhanced parallel port (EPP) interface, for example. The communication interface **285** receives important scanning instructions regarding image resolution, brightness level and scanning range and converts the scanning instructions into scanning control signals that pass along the connection cable **230**.

When the optical sensor circuit module **220** receives scanning control signals from the main circuit module **210**, the timing generator **265** produces the required timing control signals for extracting an analog image signal from the optical sensor **240**. The optical sensor **240** is a charge-coupled device (CCD) or a CMOS image sensor, for example. The captured analog image signal is preprocessed by the analog front-end preprocessor **250**. Thereafter, the pre-processed analog image

is transmitted to the analog/digital converter **260** and converted to digital image data. The digital image data is subsequently transmitted to the main circuit module **210** through the connection cable **230**. At this moment, the data transmitted on the connection cable **230** is no longer the analog signal that easily has the distortion but is the digital image data that can be easily transmitted in a fast speed. As a result, it can effectively solve the issue about difficulty on maintaining the scanning quality when the scanning process is operated in the fast speed.

On receiving the digital image data, the main circuit module **210** transfers the data to the memory unit **280** via the memory controller **275**. The memory unit **280** may contain conventional types of memory such as synchronous or non-synchronous dynamic random access memory (DRAM) or static random access memory (SRAM). Obviously, the main control logic unit **270** may incorporate an image preprocessor (not shown) for compensating and adjusting the captured digital image data so that the scanned image can have better quality. In addition, timing signals may have to be adjusted due to the change in connection between the communication interface of various integrated circuits (ICs).

In conclusion, major advantages of this invention include:

1. Since the flat cable transmits digital data instead of easily distorted analog image signals, a clearer image can be obtained at a higher scanning speed.

2. Since the flat cable transmits scanning control signals between conventional IC communication interfaces instead of timing control signals, the effect due to electromagnetic interference is greatly minimized.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

The invention claimed is:

1. An optical scanning apparatus, comprising:

communication means for receiving scan control signals from a main circuit module; and

means for generating timing control signals for extracting an analog image signal in response to the received scan control signals, wherein the timing control signals are generated at an optical sensor circuit coupled to the main circuit module via the communication means, and wherein the received scan control signals do not comprise any timing control signals.

2. The apparatus of claim **1**, further comprising:

means for receiving a scanning instruction from a communication interface; and

means for producing the scan control signals in response to the received Scanning instructions.

3. The apparatus of claim **2**, wherein the scan control signals are produced at the main circuit module.

4. The apparatus of claim **3**, further comprising means for converting the analog image signal into digital image data, wherein the scan control signals are transmitted to the sensor circuit module, and wherein the digital image is transmitted to the main circuit module.

5. The apparatus of claim **1**, further comprising:

means for extracting the analog image signal; and

means for converting the analog image signal into a digital, wherein the digital image data is transmitted to the main circuit module via the communication means.

6. The apparatus of claim **5**, further comprising:

means for generating the analog image signal at the optical sensor circuit module;

means for pre-processing the analog image signal at an optical sensor circuit module; and

means for converting the pre-processed analog image signal into the digital image data at the optical sensor circuit module, wherein the timing control signals that control a generation of the analog image signal and a conversion of the analog image signal into the digital image data at the optical sensor circuit module.

7. An apparatus, comprising:

a main circuit module;

a connection cable; and

an optical sensor circuit module coupled to the main circuit module through the connection cable, wherein the optical sensor circuit module is configured to:

receive scan control signals from the main circuit module; and

generate timing control signals for extracting an analog image signal in response to the received scan control signals, wherein the received scan control signals do not comprise any timing control signals.

8. The apparatus of claim **7**, wherein the main circuit module is configured to:

receive scanning instruction associated with an image resolution, a brightness level, or a scanning range;

produce the scan control signals in response to the received scanning instruction; and

transmit the scan control signals through the connection cable.

9. The apparatus of claim **8** wherein the main circuit module comprises:

a main control logic unit configured to produce the scan control signals; and

a memory control logic unit coupled to the main control logic unit and configured to transfer digital image data to a memory unit.

10. The apparatus of claim **9** wherein the main control logic unit comprises an image pre-processor capable of compensating and adjusting the digital image data.

11. The apparatus of claim **7** wherein the optical sensor circuit module is further configured to:

extract an analog image signal captured in a document scanning operation from a document; and

convert the analog image signal into a digital image data, wherein the digital image data is transmitted through the connection cable.

12. The apparatus of claim **11** wherein the optical sensor circuit module comprises:

an optical sensor configured to generate the analog image signal;

an analog front-end processor coupled to the optical sensor and configured to pre-process the analog image signal;

an analog/digital converter coupled to the analog front-end processor and configured to convert the pre-processed analog image signal into the digital image data; and

a timing generator couples to the optical sensor and the analog/digital converter, wherein the timing generator configured to generate the timing control signals that control a generation of the analog image signal and a conversion of the analog image signal into the digital image data.

13. Scanning circuitry comprising an optical sensor circuit module operatively coupled to a main circuit module vie a connection cable, wherein the scanning circuitry is configured to:

receive scan control signals transmitted over the connection cable;

generate timing control signals in response to receiving the scan control signals, wherein the scan signals do not comprise any timing control signals; and

extract an analog image signal using the generated timing control signals.

14. The scanning circuitry of claim **13**, further configured to:

receive a scanning instruction from a communication interface; and

produce the scan control signals in response to receiving the scanning instructions.

15. The scanning circuitry of claim **14**, wherein the scanning instruction comprise an image resolution, a brightness level, or a scanning range, and wherein the scan control signals are produced in the main circuit module.

16. The scanning circuitry of claim **14**, further configured to convert the analog image signal into digital image data, wherein the scan control signals are transmitted to the optical sensor circuit module, and wherein the digital image data is transmitted to the main circuit module.

17. The scanning circuitry of claim **13**, further configured to:

extract the analog image signal;

convert the analog image signal into a digital image data; and

transmit the digital image data via the communication cable.

18. The scanning circuitry of claim **17**, further configured to:

pre-process the analog image signal; and

convert the pre-processed analog image signal into the digital image data prior to the transmission of the digital image data via the communication cable.

19. The scanning of circuitry of claim **17**, further configured to generate timing control signals that control a generation of the analog image signal and the conversion of the analog image signal into the digital image data.

20. The scanning circuitry of claim **13**, further configured to:

generate the analog image signal;

pre-process the analog image signal; and

convert the pre-processed analog image signal into the digital image data, wherein the generated timing control signals control a generation of the analog image signal and a conversion of the analog image signal into the digital image data.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,300,285 B2
APPLICATION NO. : 11/694472
DATED : October 30, 2012
INVENTOR(S) : Lee et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In Column 4, Line 55, in Claim 2, delete “Scanning instructions.” and insert -- scanning instruction. --, therefor.

In Column 4, Line 60, in Claim 4, delete “sensor” and insert -- optical sensor --, therefor.

In Column 4, Line 61, in Claim 4, delete “image” and insert -- image data --, therefor.

In Column 4, Line 65, in Claim 5, delete “into a digital,” and insert -- into digital image data, --, therefor.

In Column 5, Line 4, in Claim 6, delete “at an” and insert -- at the --, therefor.

In Column 5, Line 8, in Claim 6, delete “that control” and insert -- control --, therefor.

In Column 5, Line 46, in Claim 11, delete “an” and insert -- the --, therefor.

In Column 5, Line 48, in Claim 11, delete “a digital” and insert -- digital --, therefor.

In Column 5, Line 51, in Claim 12, delete “11” and insert -- 11, --, therefor.

In Column 6, Line 1, in Claim 12, delete “couples” and insert -- coupled --, therefor.

In Column 6, Line 3, in Claim 12, delete “configured” and insert -- is configured --, therefor.

In Column 6, Line 8, in Claim 13, delete “vie” and insert -- via --, therefor.

In Column 6, Line 13, in Claim 13, delete “scan” and insert -- scan control --, therefor.

Signed and Sealed this
Second Day of April, 2013

Teresa Stanek Rea
Acting Director of the United States Patent and Trademark Office

In Column 6, Line 19, in Claim 14, delete “receive a scanning instruction” and insert -- receive scanning instructions --, therefor.

In Column 6, Line 24, in Claim 15, delete “instruction” and insert -- instructions --, therefor.

In Column 6, Line 35, in Claim 17, delete “into a” and insert -- into --, therefor.

In Column 6, Line 37, in Claim 17, delete “via the” and insert -- via a --, therefor.

In Column 6, Line 45, in Claim 19, delete “of circuitry” and insert -- circuitry --, therefor.

In Column 6, Line 46, in Claim 19, delete “generate” and insert -- generate the --, therefor.

In Column 6, Line 53, in Claim 20, delete “into the” and insert -- into --, therefor.

EXHIBIT K

US00RE44528E

(19) **United States**
(12) **Reissued Patent**
Hsu et al.

(10) **Patent Number: US RE44,528 E**
(45) **Date of Reissued Patent: *Oct. 8, 2013**

(54) **METHOD AND USER INTERFACE FOR PERFORMING A SCAN OPERATION FOR A SCANNER COUPLED TO A COMPUTER SYSTEM**

(75) Inventors: **Chuan-Yu Hsu**, Hsinchu (TW); **Jay Liu**, Hsinchu Hsien (TW); **T. J. Hsu**, Tainan Hsien (TW)

(73) Assignee: **Intellectual Ventures I LLC**, Wilmington, DE (US)

(*) Notice: This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/290,951**

(22) Filed: **Nov. 7, 2011**
(Under 37 CFR 1.47)

Related U.S. Patent Documents

Reissue of:
(64) Patent No.: **6,628,416**
Issued: **Sep. 30, 2003**
Appl. No.: **09/417,985**
Filed: **Oct. 13, 1999**

U.S. Applications:
(63) Continuation of application No. 11/237,579, filed on Sep. 27, 2005, now Pat. No. Re. 43,086.

(51) **Int. Cl.**
G06K 15/00 (2006.01)
G06F 3/12 (2006.01)

(52) **U.S. Cl.**
USPC **358/1.15**; 382/167; 382/176

(58) **Field of Classification Search**
USPC 358/1.13, 400, 401, 451, 452, 1.16, 358/1.15, 442, 444, 473, 1.6, 1.1; 382/298, 382/176, 167
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,826,035	A *	10/1998	Hamada	....	395/200.77
5,974,173	A *	10/1999	Kimura	....	382/167
5,996,029	A *	11/1999	Sugiyama	....	710/15
6,137,591	A *	10/2000	Kikinis	....	358/1.6
6,370,277	B1 *	4/2002	Borrey et al.	....	382/260
6,480,304	B1 *	11/2002	Os et al.	....	358/474
6,628,416	B1 *	9/2003	Hsu et al.	....	358/1.15
6,751,780	B1 *	6/2004	Neff et al.	....	715/247
2002/0012453	A1 *	1/2002	Hashimoto	....	382/112

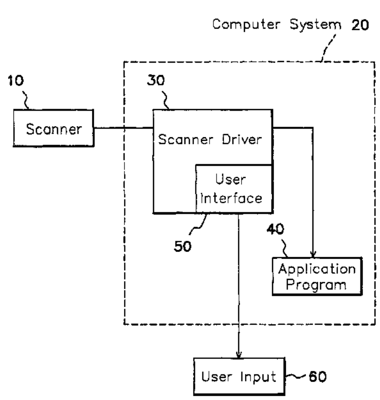
* cited by examiner

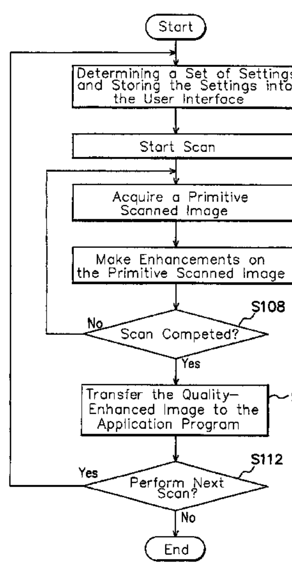
Primary Examiner — Jerome Grant, II
(74) *Attorney, Agent, or Firm* — Stolowitz Ford Cowger LLP

(57) **ABSTRACT**

A method and user interface is provided for use on a computer system coupled with a scanner for performing a scan operation on an original document, which allows the user to acquire scanned images in an easier and more user-friendly manner. The method allows the user to scan an original document without requiring the user to have learned knowledge background in the science of image processing, and also allows the scanner to perform only one scan operation on the original document. These features allow the use of the scanner to be easier and more user-friendly than the prior art. By the, method, the first step is to determine a set of image processing settings by a scanner driving program that are suited for optimal scan of the original document; and then the scanner is activated to perform a scan operation on the original document based on the image processing settings to thereby obtain a primitive scanned image. Next, an image-enhancement process is performed on the primitive scanned image to thereby obtain a quality-enhanced image; and finally, the quality-enhanced image is transferred to the application program for use by the application program.

17 Claims, 3 Drawing Sheets





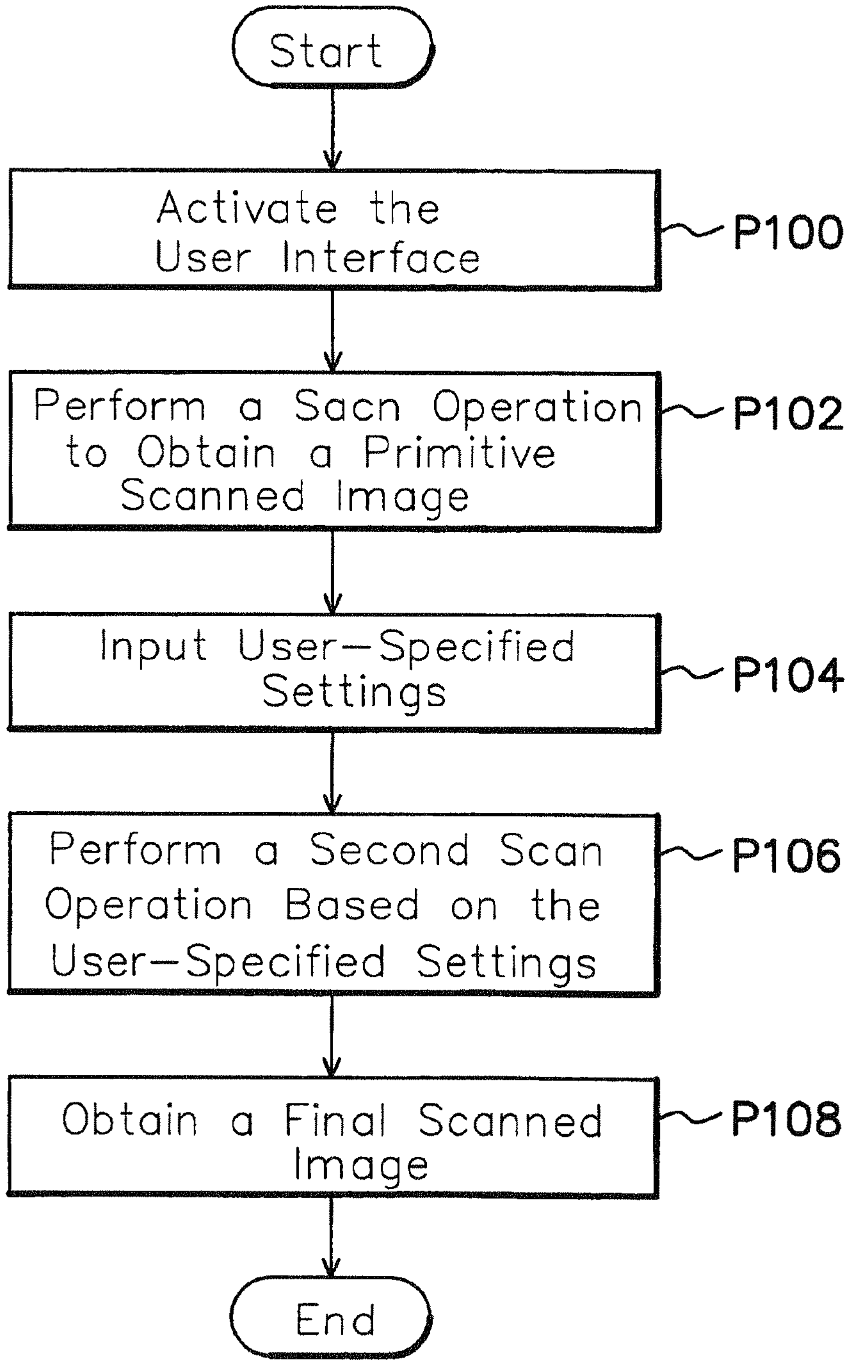


FIG. 1 (PRIOR ART)

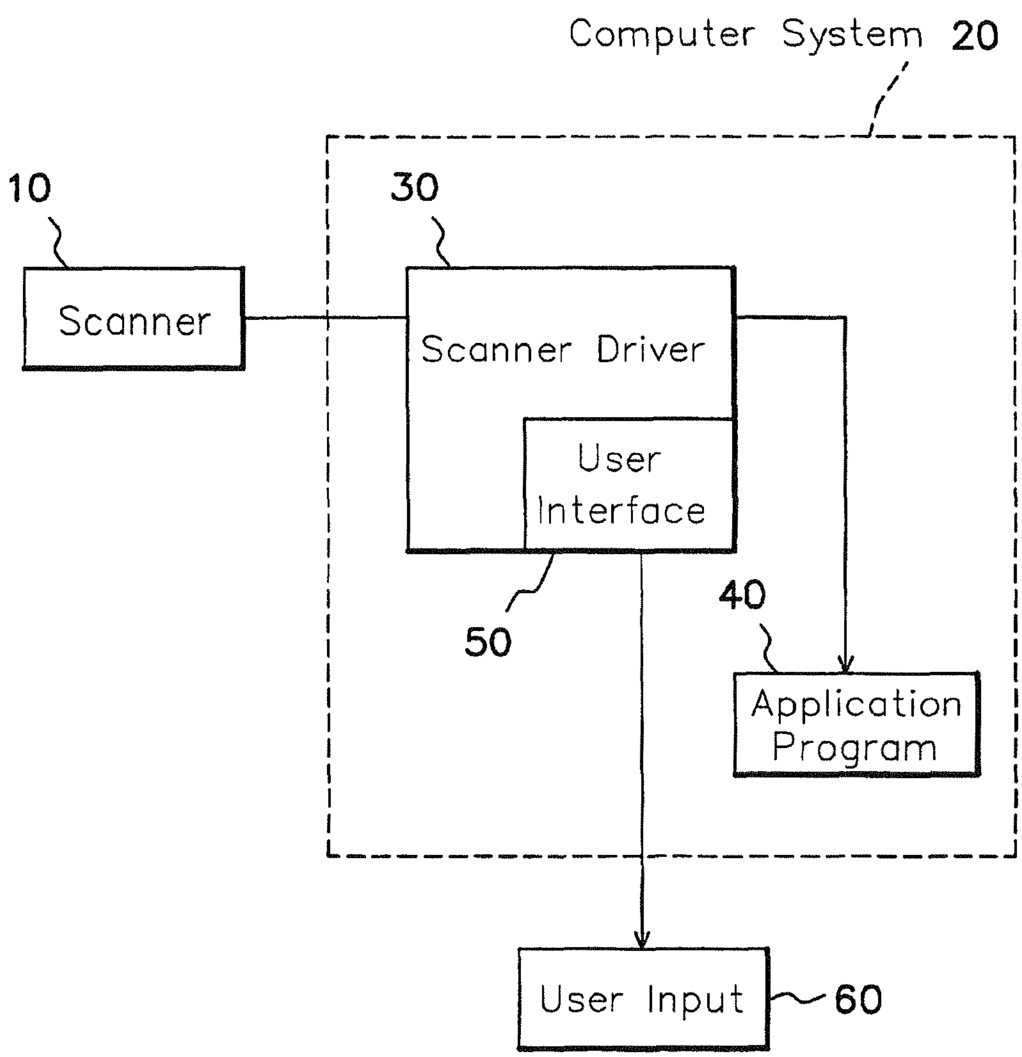

Computer System 20
10
Scanner
30
Scanner Driver
User Interface
50
40
Application Program
User Input
60

FIG. 2

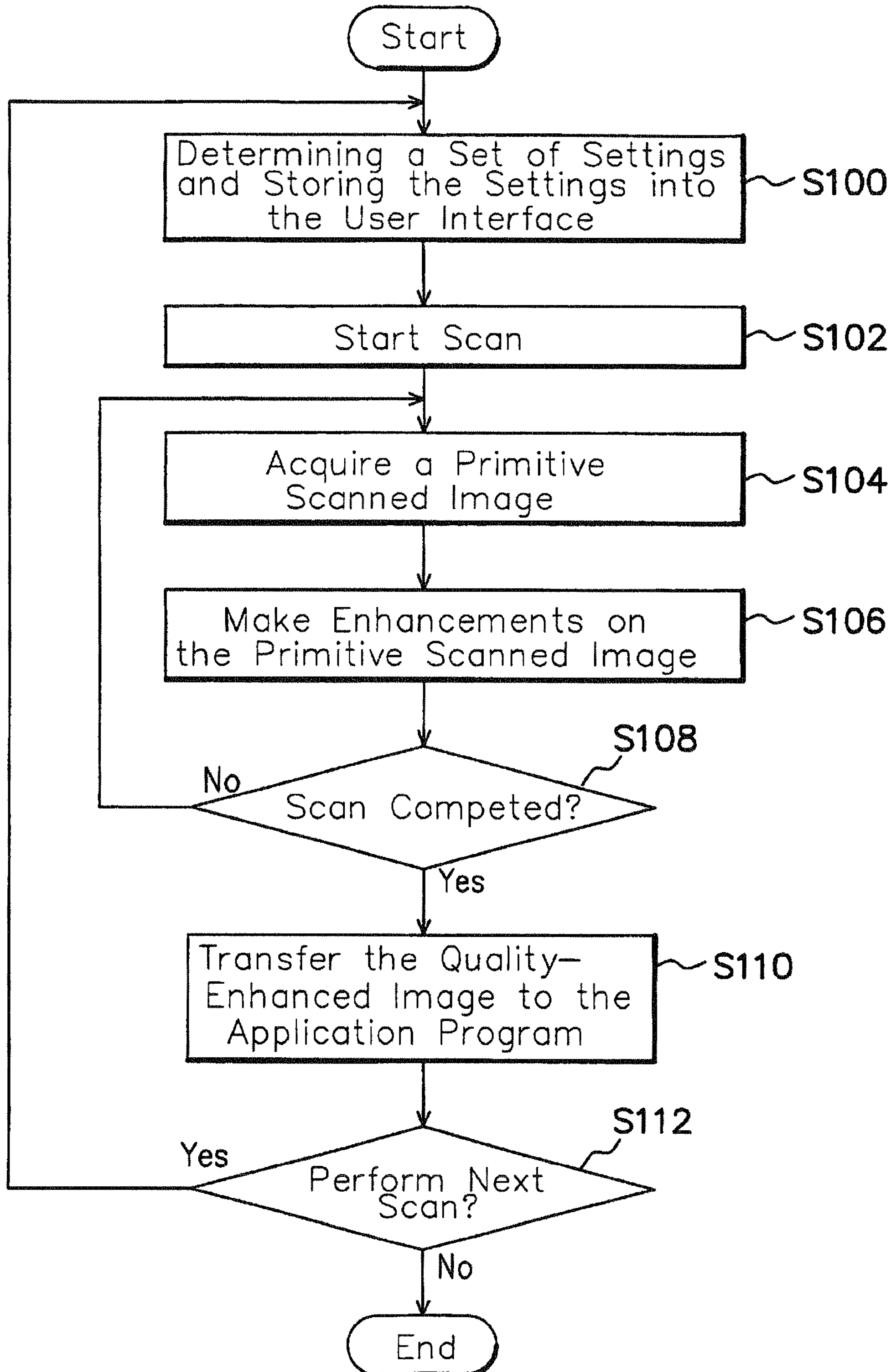

Start
Determining a Set of Settings and Storing the Settings into the User Interface
S100
Start Scan
S102
Acquire a Primitive Scanned Image
S104
Make Enhancements on the Primitive Scanned Image
S106
S108
No
Scan Competed?
Yes
Transfer the Quality-Enhanced Image to the Application Program
S110
S112
Yes
Perform Next Scan?
No
End

FIG. 3

METHOD AND USER INTERFACE FOR PERFORMING A SCAN OPERATION FOR A SCANNER COUPLED TO A COMPUTER SYSTEM

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

Notice: More than one reissue application has been filed for the reissue of U.S. Pat. No. 6,628,416 filed as application Ser. No. 09/417,985 on Oct. 13, 1999.

The present application is a continuation of U.S. patent application Ser. No. 11/237,579, filed on Sep. 27, 2005, which is a reissue of U.S. patent application Ser. No. 09/417,985, filed on Oct. 13, 1999, now U.S. Pat. No. 6,628,416, each of which is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to scanner technology, and more particularly, to a method and user interface for performing a scan operation for a scanner coupled to a computer system, which allows the user to acquire scanned images in an easier and more user-friendly manner.

2. Description of Related Art

A scanner allows a user to convert the printed matter on a document into a digital image for further processing by a computer. In the use of a scanner, however, it requires well-learned and highly-experienced users to do the image processing tasks properly. For inexperienced users, it usually requires a long period to learn, typically in a trial-and-error manner, which would make the training quite cost-ineffective since additional electricity and paper cost may be required in the training course.

The U.S. Pat. No. 4,837,635 discloses a method that allows the user to acquire a scanned image by first obtaining a primitive scanned image from the scanner, and then specify suited image processing settings such as size and scan area for the scanner to perform a second scan operation on the original document to thereby obtain a final scanned image. By this method, the final scanned image can approach closely to the image qualities of the original document. One drawback to this patent, however, is that it is quite inefficient to use since it requires the scanner to perform two scan operations on the same document.

FIG. **1** is a flow diagram showing the procedural steps involved in a conventional method to obtain a scanned image from an original document.

In the first step P**100**, the user interface for the scanner is activated. In the next step P**102**, the user interface commands the scanner to perform a primitive scan operation on the original document. The primitive scanned image is then displayed by the user interface for the user to make enhancements thereon.

In the next step P**104**, the user interface asks the user to specify suited image processing settings for the enhancement of the primitive scanned image, such as size setting and the desired scan area of the original document.

In the next step P**106**, the user interface activates the scanner to perform a second scan operation on the original document based on the image processing settings to thereby obtain a final scanned image. In the next step P**108**, the final scanned image is transferred to an application program for use by the application program.

It is apparent that the foregoing procedure has the drawback of requiring the scanner to perform two scan operations on the same document to obtain the final scanned image, which makes the image acquisition quite inefficient.

Moreover, the U.S. Pat. No. 4,837,635 is still [quire] *quite* insufficient in functionality to meet user demands in image processing.

In the use of many conventional image scan programs, it requires the user to have [learned knowledge] *a* background in the science of image processing. [Therefore, for unlearned and inexperienced users, it would be highly difficult for them to use these programs rightly, and requires the user to spend much time and material on training.] *Consequently, inexperienced users have a difficult time using the programs correctly without spending time, and other resources, on obtaining the proper training.*

In summary, conventional user interfaces for scanner operation have the following drawbacks.

First, they require the user to have [learned knowledge] *a* background in the science of image processing in order to properly carry out the image acquisition, which makes the use of the scanner quite difficult and user-unfriendly.

Second, if a user has no such knowledge background, the user needs to spend much time and material on training, typically in a trial-and-error manner, which would make the use of the scanner quite cost-ineffective.

Third, the U.S. Pat. No. 4,837,635 provides only limited functionality to the image processing, which would not meet user demands in high-end image processing.

Fourth, the prior art requires the scanner to perform two scan operations on the same document to acquire the final scanned image to be used by the application program, which makes the use of the scanner quite inefficient. It is desired that only one scan operation is needed.

SUMMARY OF THE INVENTION

It is therefore an objective of this invention to provide a method and user interface for use on a computer system coupled with a scanner for performing a scan operation, which allows the user to operate the scanner in an easy and user-friendly manner.

It is therefore an objective of this invention to provide a method and user interface for use on a computer system coupled with a scanner for performing a scan operation, which allows the scanner to perform only one scan operation on the original document.

In accordance with the foregoing and other objectives, the invention proposes a new method and user interface for use on a computer system coupled with a scanner for performing a scan operation.

Fundamentally, the invention allows the user to scan an original document without requiring the user to have learned knowledge background in the science of image processing, and also allows the scanner to perform only one scan operation on the original document. These features allow the use of the scanner to be easier and more user-friendly than the prior art.

The invention is designed for use with a user interface incorporated in a computer system coupled with a scanner for performing an automatic scan operation on an original document. The computer system mm a scanner driver and an application program. The scanner driver is used to drive the scanner, and the application program can process the scanned image as an image file.

The method of the invention includes the following procedural steps: (1) determining a set of image processing settings by a scanner driving program that are suited for optimal scan of the original document; (2) activating the scanner to perform a scan operation on the original document based on the image processing settings to thereby obtain a primitive scanned image which is then transferred to the scanner driver; (3) activating the scanner driver to perform an image-enhancement process on the primitive scanned image to thereby obtain a quality-enhanced image; and (4) transferring the quality-enhanced image to the application program for use by the application program.

In the foregoing method, the image-enhancement process includes a comprehensive set of image processing routines, such as automatic cutting, distortion correction, color calibration, and automatic character recognition. The quality-enhanced image is then transferred to the scanner driver in the computer system, and then transferred via the scanner driver to the application program specified by the user through the user interface. The application program can be either an image editing program or a word processor that can accept the quality-enhanced image as an image file.

By the invention, the scanner needs just to perform one scan operation on the original document rather than two scan operations required by the prior art (the U.S. Pat. No. 4,837,635). The invention is therefore more efficient than the prior art. After this, the invention will automatically perform an image-enhancement process on the primitive scanned image to thereby obtain the quality-enhanced image, without requiring the user to have learned knowledge background in the science of image processing in order to perform the image enhancement, and therefore no training is required. Since the user needs not to spend time and material on learning the operation of the scanner, it makes the use of the scanner more cost-effective and user-friendly. Furthermore, the invention provides an image-enhancement process that includes a comprehensive set of image processing routines which would meets most user's demands in image processing.

BRIEF DESCRIPTION OF DRAWINGS

The invention can be more fully understood by reading the following detailed description of the preferred embodiments, with reference made to the accompanying drawings, wherein:

FIG. **1** (PRIOR ART) is a flow diagram showing the procedural steps involved in a conventional method to obtain a scanned image from an original document;

FIG. **2** is a schematic block diagram of the incorporation of the user interface of the invention in a computer system coupled with a scanner; and

FIG. **3** is a flow diagram showing the procedural steps involved in the method of the invention for performing a scan operation on an original document.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **2** is a schematic block diagram of the incorporation of the user interface of the invention, as the block designated by the reference numeral **50**, in a computer system **20** coupled with a scanner **10**. The computer system **20** runs a scanner driver **30**, which is a software program, for driving the scanner **10**. Further, the computer system **20** runs an application program **40** which can process the scanned image from the scanner **10** as an image file. The block designated by the reference numeral **60** is used to represent the input from user operation. The user can specify a set of proper image processing settings into the user interface **50**.

When the user wants to acquire a scanned image from an original document (not shown), the user first needs to place the original document (not shown) on the scanner **10**, and then specify a set of image processing settings that are suited for optimal scan of the original document (not shown). Next, the user interface **50** activates the scanner **10** to perform a scan operation on the original document (not shown) based on the image processing settings in the user interface **50** to thereby obtain a primitive scanned image. The primitive scanned image is then transferred to the scanner driver **30** in the computer system **20**.

Next, the scanner driver **30** performs an image-enhancement process on the primitive scanned image to thereby obtain a quality-enhanced image. The image-enhancement process includes a comprehensive set of image processing routines, including automatic cutting, distortion correction, color calibration, and automatic character recognition.

After this, the scanner driver **30** checks whether there is still another document waiting to be scanned. If YES, the scanner driver **30** will perform another scan operation. The quality-enhanced image is then transferred to the application program **40** for use by the application program **40**.

FIG. **3** is a flow diagram showing the procedural steps involved in the method of the invention for performing a scan operation on the original document. This method is used with the computer system **20** and the scanner **10** shown in FIG. **2** and is performed by the user interface **50**.

In the first step S**100**, a set of image processing settings that are suited for optimal scan of the original document is determined by a scanner driving program, and then stores these settings into the user interface **50**.

In the next step S**102**, the user interface **50** issues a scan request to the scanner **10**. In response, in the next step S**104**, the scanner **10** is activated to perform a scan operation on the original document based on the image processing settings in the user interface **50** to thereby obtain a primitive scanned image. The primitive scanned image is then transferred to the scanner driver **30**.

In the next step S**106**, the scanner driver **30** is activated to perform an image-enhancement process on the primitive scanned image to thereby obtain a quality-enhanced image. The image-enhancement process includes a comprehensive set of image processing routines, including automatic cutting, distortion correction, color calibration, and automatic character recognition.

In the next step S**108**, the user interface **50** checks whether there is still another document waiting to be scanned. If YES, the procedure returns to the step S**104**; otherwise, the procedure goes to the step S**110**.

In the step S**110**, the quality-enhanced image **[**resulted**]** *resulting* from the image-enhancement process is transferred to the application program **40** for use by the application program **40**. The application program **40** can be either an image editing program or a word processor that can accept the quality-enhanced image as an image file.

In the next step S**112**, the user interface **50** displays a message asking whether the user wants to scan another document. If the user responds with YES, the procedure returns to the step S**100**; otherwise, the procedure is ended.

In conclusion, the invention has the following advantages over the prior art.

First, it requires the scanner to perform only one scan operation on the original document rather than two scan operations required by the prior art (the U.S. Pat. No. 4,837,635). The invention is therefore more efficient to use than the prior art.

Second, the invention allows the image-enhancement process to be entirely carried out automatically without requiring the user to have knowledge background in the science of image processing, so that the use of the scanner is easier and more user-friendly.

Third, since the invention allows the user to carry out the scan operation without having to spend time and material on training, the use of the scanner is more cost-effective than the prior art.

Fourth, the invention provides an image-enhancement process that includes a comprehensive set of image processing routines which would meet most user's demands in image processing.

Fifth, the invention allows the image acquisition to be mostly performed automatically, allowing the operation of the scanner to be more simplified and user-friendly.

The invention has been described using exemplary preferred embodiments. However, it is to be understood that the scope of the invention is not limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and similar arrangements. The scope of the claims, therefore, should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

What is claimed is:

[**1**. A method implemented on a user interface incorporated in a computer system coupled with a scanner for performing a scan operation on an original document, the computer system running a scanner driver and an application program; the method comprising the steps of:

determining a set of image processing settings required for the original document by a scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes an automatic cutting routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to the application program.]

[**2**. A method implemented on a user interface incorporated in a computer system coupled with a scanner for performing a scan operation on an original document, the computer system running a scanner driver and an application program; the method comprising the steps of:

determining a set of image processing settings required for the original document by a scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses image processing settings through the scanner driving program;

performing an image-enhancement, process on the primitive scanned image, wherein the image-enhancement process includes a distortion correction routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to the application program.]

[**3**. A method implemented on a user interface incorporated in a computer system coupled with a scanner for performing a scan operation on an original document, the computer system running a scanner driver and an application program; the method comprising the steps of:

determining a set of image processing settings required for the original document by a scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes a color calibration routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to the application program.]

[**4**. A method implemented on a user interface incorporated in a computer system coupled with a scanner for performing a scan operation on an original document, the computer system running a scanner driver and an application program; the method comprising the steps of:

determining a set of image processing settings required for the original document by a scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes an automatic character recognition routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to the application program.]

[**5**. A user interface for a scanner, comprising:

a scanner, for scanning an original document to an image data;

a computer system, for storing and processing the image data from the scanner;

a scanner driving program, for driving the scanner and then performing an image-enhancement process on the image data stored in the computer system;

an application program, for receiving a final image processed by the image-enhancement process, wherein a method implemented on the user interface comprising the steps of:

determining a set of image processing settings required for the original document by a scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes an automatic cutting routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to the application program.]

[**6**. A user interface for a scanner, comprising:

a scanner, for scanning an original document to an image data;

a computer system, for storing and processing the image data from the scanner;

a scanner driving program, for driving the scanner and then performing an image-enhancement process on the image data stored in the computer system;

an application program, for receiving a final image processed by the image-enhancement process, wherein a method implemented on the user interface comprising the steps of:

determining a set of image processing settings required for the original document by a scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes a distortion correction routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to the application program.]

[7. A user interface for a scanner, comprising:

a scanner, for scanning an original document to an image data;

a computer system, for storing and processing the image data from the scanner;

a scanner driving program, for driving the scanner and then performing an image-enhancement process on the image data stored in the computer system;

an application program, for receiving a final image processed by the image-enhancement process, wherein a method implemented on the user interface comprising the steps of:

determining a set of image processing settings required for the original document by a scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes a color calibration routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to the application program.]

[8. A user interface for a scanner, comprising:

a scanner, for scanning an original document to an image data;

a computer system, for storing and processing the image data from the scanner;

a scanner driving program, for driving the scanner and then performing an image-enhancement process on the image data stored in the computer system;

an application program, for receiving a final image processed by the image-enhancement process, wherein a method implemented on the user interface comprising the steps of:

determining a set of image processing settings required for the original document by a scanner driving program;

obtaining a primitive scanned image in a manner that the scanner uses image processing settings through the scanner driving program;

performing an image-enhancement process on the primitive scanned image, wherein the image-enhancement process includes an automatic character recognition routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to the application program.]

9. A memory device having instructions stored thereon that, in response to execution by a computing device, cause the computing device to perform operations comprising:

obtaining an original scanned image using an image processing setting through a scanner driving program;

performing an image-enhancement process on the original scanned image, wherein the image-enhancement process includes at least one of an automatic cutting routine, a distortion correction routine, a color calibration routine, or an automatic character recognition routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to an application program.

10. The memory device of claim 9, wherein the operations further comprise:

checking for another scan job, the checking based on an input from a user interface;

if the checking indicates no additional scanning, then transferring the final image to the application program; and

if the checking indicates another scan job, then causing the scanner to scan a second time before transferring the final image to the application program.

11. The memory device of claim 9, wherein the operations further comprise obtaining the image processing setting for a scan target based on an input from a user interface.

12. The memory device of claim 9, wherein the final image is obtained using only a single scanning of a scan target.

13. The memory device of claim 9, wherein the application program is an image editing program or a word processor.

14. The memory device of claim 9, wherein the operations further comprise:

selecting, using the scanner driving program, a subset of available image processing settings, the subset selected based on a scan target; and

issuing a scan request that includes at least the obtained image processing setting, wherein the obtained image processing setting is one of the settings from the subset.

15. An apparatus, comprising:

a processing device configured to:

obtain an original scanned image using an image processing setting through a scanner driving program;

perform an image-enhancement process on the original scanned image, wherein the image-enhancement process includes at least one of an automatic cutting routine, a distortion correction routine, a color calibration routine, or an automatic character recognition routine; and

obtain a final image by the image-enhancement process, wherein the final image is transferred to an application program.

16. The apparatus of claim 15, wherein the processing device is further configured to:

check if there is another scan job; and

transfer the final image to the application program based on a result of the checking.

17. The apparatus of claim 15, wherein the processing device is further configured to determine the image processing setting based on a scan target associated with the original scanned image.

18. The apparatus of claim 15, wherein the final image is obtained using only a single scanning of a scan target.

19. The apparatus of claim 15, wherein the application program is an image editing program or a word processor.

20. A method, comprising:

obtaining an image processing setting for a target of a scan;

obtaining an original scanned image of the scan target using the obtained image processing setting through a scanner driving program;

performing an image-enhancement process on the original scanned image, wherein the image-enhancement process includes at least one of an automatic cutting rou-

tine, a distortion correction routine, a color calibration routine, or an automatic character recognition routine; and

obtaining a final image by the image-enhancement process, wherein the final image is transferred to an application program.

21. The method of claim 20, further comprising:

checking for another scan target to be scanned, the checking based on an input from a user interface;

if the checking indicates no additional scanning, then transferring the final image to the application program; and

if the checking indicates another scan target to be scanned, then causing the scanner to scan a second time before transferring the final image to the application program.

22. The method of claim 20, further comprising obtaining the image processing setting for the scan target based on an input from a user interface.

23. The method of claim 20, wherein the final image is obtained using only a single scanning of the scan target.

24. The method of claim 20, wherein the application program is an image editing program or a word processor.

25. The method of claim 20, further comprising:

selecting, using the scanner driving program, a subset of available image processing settings, the subset selected based on the scan target; and

issuing a scan request that includes at least the obtained image processing setting, wherein the obtained image processing setting is one of the settings from the subset.

* * * * *